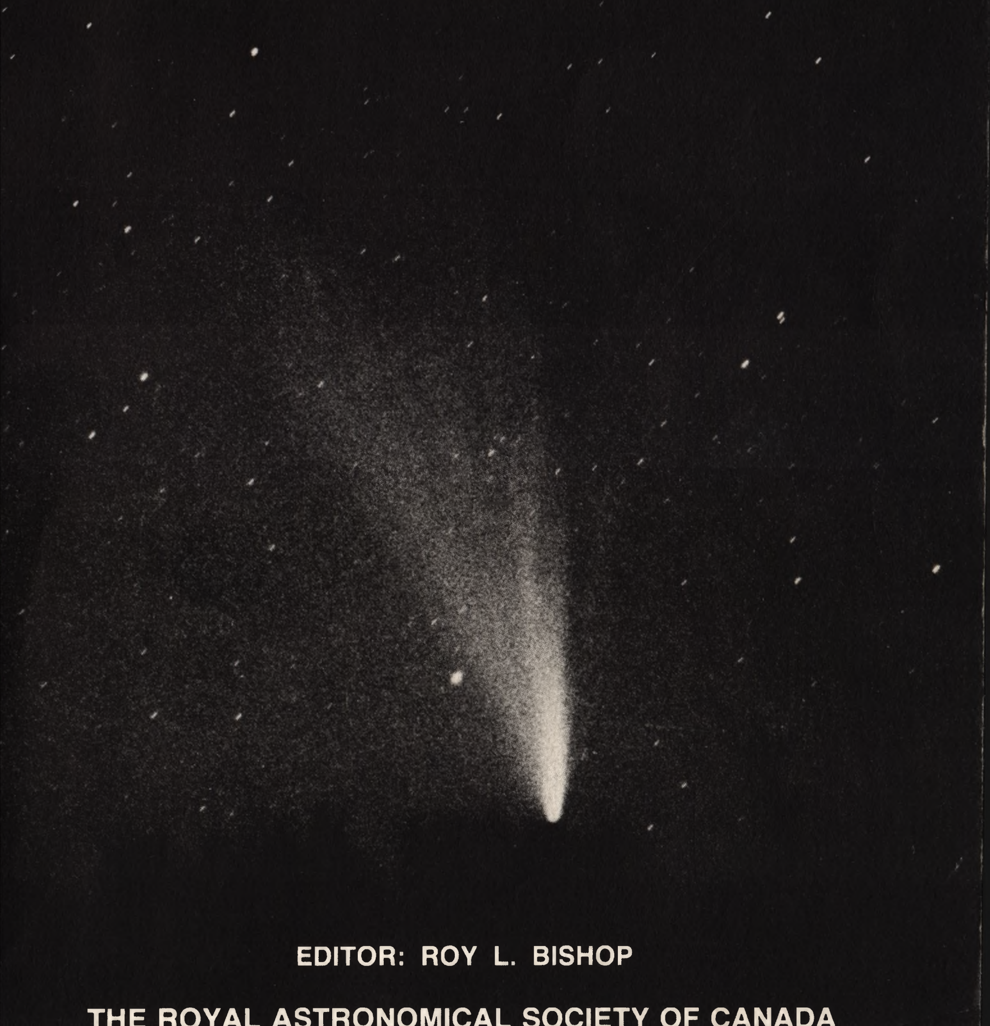
OBSERVER'S HANDBOOK 1986



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PRINTED IN CANADA
BY THE UNIVERSITY OF TORONTO PRESS

OBSERVER'S HANDBOOK 1986

EDITOR
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SEVENTY-EIGHTH YEAR OF PUBLICATION

136 DUPONT STREET, TORONTO, ONTARIO M5R 1V2

ISSN 0080-4193

HALLEY'S COMET - A TRILOGY

In my browsings I have come across three items which have specially intrigued me about this, the most famous comet. I am succumbing to the urge to bring them to the attention of as many readers as possible.

The first is a superb new volume: *Halley's Comet, A Bibliography*, compiled by Ruth S. Freitag, Senior Science Specialist, Science and Technology Division, Library of Congress, Washington, 1984. Of course this volume will be reviewed in many publications including the *Journal of the Royal Astronomical Society of Canada*, but it merits extra mention. The massive information on the 580 pages includes 3235 numbered references arranged in alphabetical order from (1) Ångström, Anders at Uppsala in 1862 on light variation in the comet, through Ziolkowski, Krzysztof in *Urania* (Krakow) 1983, on the International Halley Watch. Other information includes computed perihelion dates for the comet from 1986 February 9 back to 1464 B.C. October 15, and bibliographical sources, library location symbols, and two indices, one by name, the other by topic. Long after the comet has faded from our skies on its 1986 return, workers will be blessing Ruth Freitag for her tremendous efforts in placing references only a finger's touch away from us.

My second item pertains to a comment by the American humorist Mark Twain on this comet. Frequently I have been asked if it is true that Twain said that he had come in with the comet and would go out with it. It *is* true, but the precise reference is rarely mentioned. It cannot be found in Ruth Freitag's work. Obviously she could not index everything that anybody ever *said* about the comet. In 1909 Mark Twain (Samuel Clemens, 1835–1910) remarked: "I came in with Halley's Comet in 1835. It is coming again next year, and I expect to go out with it .... The Almighty has said, no doubt: now here are these two unaccountable freaks: they came together, they must go out together." This statement is recorded by Twain's biographer, Albert Bigelow Paine, in Volume III of *Mark Twain*, page 1511, 1912. Twain died on April 21 before the comet became a bright object.

My third item is a poem about Halley's Comet which appeared in the delightful column "From an Oxford Notebook" by Professor H. H. Turner in the periodical *The Observatory*, volume 33, page 150, 1910. David Hughes drew attention to this poem in *Nature*, volume 304, page 119, 1983, and more recently so did Peter Broughton in *The Observatory*, volume 104, page 273, 1984, adding a related verse of his own.

The first verse of this poem has been fairly well known for decades, with various users improving on the word "meteors" in the first line by substituting "objects" or "comets". This verse has a real significance by explaining in a nutshell that Comet Halley is the brightest periodic comet and has naked eye visibility; that the proper pronunciation of Halley's name rhymes with "periodically"; that Halley was not the discoverer, but was the first to predict the return of this comet. (However, you cannot deduce from the rhyme that Halley was the first to predict the return of *any* comet.)

In his *Notebook* Professor Turner writes: "With so many comets about, it is perhaps not surprising that the MS. of another comet song has been put into my hands by the gifted author. It originally contained four verses, but as the last one mentions names in a manner which might be deemed invidious, I have ventured to suppress it".

The poem is without a title, so with help from a professor of English, I am contributing one.

LINES ON HALLEY'S COMET
(Air: "Sally in our Alley")

Of all the meteors in the sky
   There's none like Comet Halley;
We see it with the naked eye
   And periodically.
The first to see it was not he,
   But still we call it Halley;
The notion that it would return
   Was his originally.

Of all the years we've lately seen
   There's none to rival this year,
Because though busy we have been
   We're likely to be busier.
When five-and-seventy years are sped,
   Then back comes Comet Halley;
He told us that it would return,
   And mathematically.

Some probe the secrets of the Sun,
   And most effectually;
There's much good honest work been done
   Selenographically.
Whatever quest may prove the best
   We all admire bold Halley,
Who said his comet would return,
   Perhaps perpetually.

by Sir Frank Dyson,
later ninth Astronomer Royal

All these years the name of the author has remained a mystery. Now it has been revealed by Ruth Freitag in her *Bibliography*, Reference 2920, along with the publication in which the missing fourth verse may be found. With the help of her volume, readers may now complete the story of the Halley's Comet poem.

HELEN SAWYER HOGG

COVER PHOTOGRAPH

Comet West (1975n), the brightest comet of the past 15 years, in the dawn twilight on March 6, 1976. Moving across the southwestern corner of Pegasus, Comet West was near 1st magnitude and displayed a tail spanning 20° to the unaided eye. This is a 20-second, unguided exposure with a standard 50mm, f/1.4 lens, and Tri-X film. In this instance, initiative and timing were more important than elaborate equipment. Photograph by Sherman Williams of Avonport, Nova Scotia.

EDITOR'S COMMENTS

On behalf of The Royal Astronomical Society of Canada I wish to thank the twenty-four contributors, listed on the inside front cover, without whose support this Handbook would not exist. I particularly wish to acknowledge the many years that Gordon Taylor of the Royal Greenwich Observatory has provided predictions of occultations by asteroids and planets, and to welcome Dr. Robert Millis of Lowell Observatory who has taken over this section.

Due to several changes and additions, the 1986 edition has grown by 24 pages. The introduction to the section on time has been revised and expanded in response to suggestions from Dr. G. A. Wilkins, Superintendent of Her Majesty's Nautical Almanac Office of The Royal Greenwich Observatory. Dr. John Percy has revised the left-hand pages of the section "The Sky Month By Month" to provide more information, and in a form that we hope will be more convenient to users of this Handbook. In the section "Planets, Satellites, and Asteroids" will be found several new items: a diagram providing a quick reference to planetary phenomena throughout the year; information on the 1986 transit of Mercury, by Fred Espenak; a description of an important, but not widely-appreciated relation between telescope optical design and planetary observations, by Terry Dickinson; a diagram showing the orbital geometry of several oppositions of Mars; additional information on the ring system of Saturn; and a set of diagrams giving the configuration of Saturn's brightest satellites, by a new contributor to this Handbook, Dr. Larry Bogan of Acadia University. There are six pages on Halley's Comet, including four diagrams. The highly-regarded section "The Brightest Stars" has been completely revised, and is now the best such compilation in existence (users of this Handbook are indebted to Dr. Garrison for the many weeks of effort required for this revision). In response to requests, a section "Variable Galaxies" has been reintroduced (it last appeared in 1982), along with new finder charts for the quasar 3C 273.

As in past years, The Royal Astronomical Society of Canada is indebted to the Nautical Almanac Office (U.S. Naval Observatory) and its Director, Dr. P. K. Seidelmann, for essential, pre-publication material from *The Astronomical Almanac*. Also, I wish to thank Randall Brooks (St. Mary's University, Halifax, N.S.) for preparing the base map for the chart of Pluto's path. Rosemary Freeman, the Society's capable Executive-Secretary, looks after the advertising and sales of the *Observer's Handbook*. Finally, special acknowledgement is due to Acadia University and its Department of Physics for providing support in the form of some three months of the Editor's time.

Although I hope this edition is error-free, I know from experience what a difficult goal this is, and accept responsibility for any flaws in the following pages. Please send comments and suggestions for improvements to the undersigned. Good observing *quo ducit Urania* in this year of the Voyager 2 encounter with Uranus, and of the passage of Halley's Comet.

ROY L. BISHOP, EDITOR
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REPORTING OF SIGNIFICANT ASTRONOMICAL DISCOVERIES

Professional and amateur astronomers who wish to report a possible discovery (e.g. a new comet, nova, or supernova) should send their report to Dr. Brian Marsden of the International Astronomical Union Central Bureau for Astronomical Telegrams, 60 Garden St., Cambridge, MA 02138, U.S.A. TWX/telex/telegraphic communication is preferred (TWX number: 710-320-6842 ASTROGRAM CAM). Inexperienced observers are advised to have their observation checked, if at all possible, before contacting the Central Bureau. For an account of the history of the Bureau and its work today, see "Life in the Hot Seat", *Sky and Telescope*, August 1980, p. 92.

AN INVITATION FOR MEMBERSHIP IN THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

The history of The Royal Astronomical Society of Canada goes back to the middle of the nineteenth century. The Society was incorporated within the province of Ontario in 1890, received its Royal Charter in 1903, and was federally incorporated in 1968. The National Office of the Society is located at 136 Dupont Street, Toronto, Ontario M5R 1V2, telephone (416) 924 7973. The business office and library are housed there.

The Society is devoted to the advancement of astronomy and allied sciences, and has members in many countries and from all walks of life. Any serious user of this HANDBOOK would benefit from membership. An applicant may affiliate with one of the twenty Centres across Canada, or may join the Society directly as an unattached member. Centres are located in Newfoundland (St. John's), Nova Scotia (Halifax), Quebec (Montreal (2), and Quebec), Ontario (Ottawa, Kingston, Toronto, Hamilton, Niagara Falls, Kitchener-Waterloo, London, Windsor, and Sarnia), Manitoba (Winnipeg), Saskatchewan (Saskatoon), Alberta (Edmonton and Calgary), and British Columbia (Vancouver and Victoria). Contact the National Office for the address of any of the Centres.

Members receive the publications of the Society free of charge: the OBSERVER'S HANDBOOK (published annually in November), and the bimonthly JOURNAL and NATIONAL NEWSLETTER which contain articles on many aspects of astronomy. The membership year begins October 1, and members receive the publications of the Society for the following calendar year. Annual fees are currently $20, and $12.50 for persons under 18 years. Life membership is $300. (To cover higher mailing costs, these fees are to be read as U.S. dollars for members outside of Canada. Also, persons wishing to affiliate with one of the Centres are advised that some Centres levy a small surcharge.)

SUGGESTIONS FOR FURTHER READING

Burnham, Robert. *Burnham's Celestial Handbook, Volumes 1, 2 and 3*. Dover Publications, Inc., New York, 1978. A detailed, well-presented, observer's guide to the universe beyond the solar system.

Dickinson, Terence. *Nightwatch.* Camden House Publishing Ltd., Camden East, Ontario, 1983. An attractive, comprehensive, introductory guide to observing the sky.

Harrison, E. R. *Cosmology*. Cambridge University Press, Cambridge, 1981. An elegant, stimulating introduction to the structure of the universe.

Hogg, Helen S. *The Stars Belong To Everyone.* Doubleday Canada Ltd., Toronto, 1976. Superb introduction to the sky.

Newton, Jack, and Teece, Philip. *The Cambridge Deep Sky Album*. Cambridge University Press, Cambridge, 1983. A photographic introduction to the Universe beyond the Solar System through a small telescope.

Norton, A. P. *Norton's Star Atlas.* Sky Publishing Corp., 49 Bay State Road, Cambridge, MA 02238-1290. A classic. Contains 8700 stars to magnitude 6.3.

Rükl, A. *Moon, Mars and Venus*. Hamlyn Publishing Group Ltd., Toronto and New York, 1976. A compact, detailed, lunar atlas.

Sherrod, P. C. *A Complete Manual of Amateur Astronomy.* Prentice-Hall, New Jersey, 1981. A comprehensive guide to observational astronomy for amateurs.

Sky and Telescope. Sky Publishing Corp., 49 Bay State Road, Cambridge, MA 02238. A monthly magazine containing articles on all aspects of astronomy.

Texereau, J. *How To Make A Telescope*. Doubleday and Co., New York, 1963. The best guide to making a Newtonian telescope.

Tirion, W. *Sky Atlas 2000.0*. Sky Publishing Corp., 49 Bay State Road, Cambridge, MA 02238-1290. A large format, modern, detailed atlas. Contains 43 000 stars to magnitude 8.0.

VISITING HOURS AT SOME CANADIAN OBSERVATORIES AND PLANETARIA

Compiled By Marie Fidler

OBSERVATORIES

Algonquin Radio Observatory, Lake Traverse, Ontario K0A 2L0.

Group tours by appointment only. Small groups welcome any day; notice helpful but not essential. Telephone (613) 735–0141 and ask for Ross Austin or Richard Murowinski.

Burke-Gaffney Observatory, Saint Mary's University, Halifax, Nova Scotia B3H 3C3.

October-April: Saturday evenings, 7:00 p.m.
May-September: Saturday evenings, 9:00 p.m.
Monday evening or daytime tours by arrangement. Phone 429-9780, ext. 2184.

Canada-France-Hawaii Telescope, Mauna Kea, Hawaii, U.S.A. 96743.

R.A.S.C. members visiting the "Big Island" are welcome to day-time visits to the CFHT installations. Arrangements should be made in advance either by writing to Canada-France-Hawaii Telescope Corporation, P.O. Box 1597, Kamuela, HI 96743, U.S.A., or by telephone (808) 885-7944.

David Dunlap Observatory, Richmond Hill, Ontario L4C 4Y6.

Tuesday mornings throughout the year, 10:00 a.m.
Saturday evenings, April through October, by reservation. Telephone (416) 884-2112.

Dominion Astrophysical Observatory, 5071 West Saanich Road, Victoria, B.C. V8X 4M6.

May-August: Daily, 9:15 a.m.–4:15 p.m.
September-April: Monday to Friday, 9:15 a.m.–4:15 p.m.
Public observing, Saturday evenings, April-October inclusive.

Dominion Radio Astrophysical Observatory, Penticton, B.C. V2A 6K3.

Conducted Tours: Sundays, July and August only, 2:00–5:00 p.m.
Visitors' Centre: Open year round during daylight hours.
For information please phone (604) 497-5321.

Hume Cronyn Observatory, University of Western Ontario, London, ON, N6A 3K7.

For tour and program information please phone (519) 679-3184.

National Museum of Science and Technology, 1867 St. Laurent Blvd., Ottawa, Ontario. K1A 0M8.

Evening tours, by appointment only. Telephone (613) 998-4566.
October-June: Group tours: Mon. through Thurs. Public visits, Fri. (2nd Fri. French)
July-August: Public visits: Tues.(French), Wed. and Thurs. (English).

Observatoire astronomique du mont Mégantic, Notre-Dame-des-Bois, P.Q. J0B 2E0.

Telephone (819) 888-2822 for information on summer programs.

Gordon MacMillan Southam Observatory, 1100 Chestnut St., Vancouver, BC, V6J 3J9.

Open clear weekends and holidays (noon through 10:30 p.m.), and open 6 days per week during July and August (closed on non-holiday Mondays). Free admission. For information call (604) 738-2855.

University of British Columbia Observatory, 2219 Main Mall, Vancouver, B.C. V6T 1W5.

Free public observing, clear Saturday evenings: telephone (604) 228-6186.
Tours: telephone (604) 228-2802.

PLANETARIA

Alberta's Mobile Astronomy Project, Provincial Museum of Alberta, 12845-102 Avenue, Edmonton, Alberta T5N 0M6.

This planetarium travels throughout Alberta from September to June, with school group shows given daily and public shows given Monday, Tuesday and Thursday evenings. For locations and times, telephone (403) 427-1766.

Calgary Centennial Planetarium, 701–11 Street S.W., P.O. Box 2100, Calgary, Alberta T2P 2M5.

For program information, telephone (403) 264-4060 or 264-2030.

Doran Planetarium, Laurentian University, Ramsey Lake Road, Sudbury, Ontario P3E 2C6.

Telephone (705) 675-1151, ext. 528 or 517 for information.

Dow Planetarium, 1000 St. Jacques Street W., Montreal, P.Q. H3C 1G7.

Live shows in French and in English every open day. Closed three weeks in September after Labour Day. For general information telephone (514) 872-4530.

Edmonton Space Sciences Centre, Coronation Park, 11211-142 Street, Edmonton, Alberta T5M 4A1.

Features planetarium Star Theatre, IMAX film theatre, and exhibit galleries. Public shows daily in both theatres. Telephone 451-7722 for program information. Also contains Science Bookstore: telephone 451-6516.

The Halifax Planetarium, The Education Section of Nova Scotia Museum, Summer Street, Halifax, N.S. B3H 3A6.

Free public shows take place on some evenings at 8:00 p.m. and group shows can be arranged. For information, telephone (902) 429-4610.

The Lockhart Planetarium, 394 University College, 500 Dysart Road, The University of Manitoba, Winnipeg, Manitoba R3T 2M8.

For group reservations, telephone (204) 474-9785.

H.R. MacMillan Planetarium, 1100 Chestnut Street, Vancouver, B.C. V6J 3J9.

Public shows daily except Monday.
For show information telephone (604) 736-3656.

Manitoba Planetarium, 190 Rupert Avenue at Main Street, Winnipeg, Manitoba R3B 0N2.

Shows daily except some Mondays. "Touch the Universe" interactive science gallery opens May 1986. Museum shop includes telescopes and science books. Show times (204) 943-3142. Offices (204) 956-2830.

McLaughlin Planetarium, 100 Queen's Park, Toronto, Ontario M5S 2C6.

Public shows Tues.–Fri. 3:00 and 7:45. Additional shows on weekends and during summer. School shows and evening courses. Sky information (416) 978-5399. For show times and information call (416) 978-8550.

Ontario Science Centre, 770 Don Mills Road, Don Mills, Ontario M3C 1T3.

Open daily except Christmas Day from 10:00 a.m. to 6:00 p.m. Telephone (416) 429-4100.

University of Prince Edward Island Planetarium, Charlottetown, P.E.I. C1A 4P3

For show information telephone (902) 566-0410.

SYMBOLS

SUN, MOON, AND PLANETS

☉	The Sun	☾	The Moon generally	♃	Jupiter
🌑	New Moon	☿	Mercury	♄	Saturn
🌕	Full Moon	♀	Venus	♅	Uranus
🌓	First Quarter	⊕	Earth	♆	Neptune
🌗	Last Quarter	♂	Mars	♇	Pluto

SIGNS OF THE ZODIAC

♈	Aries	0°	♌	Leo	120°	♐	Sagittarius	240°
♉	Taurus	30°	♍	Virgo	150°	♑	Capricornus	270°
♊	Gemini	60°	♎	Libra	180°	♒	Aquarius	300°
♋	Cancer	90°	♏	Scorpius	210°	♓	Pisces	330°

THE GREEK ALPHABET

Α, α	Alpha	Ι, ι	Iota	Ρ, ρ	Rho
Β, β	Beta	Κ, κ	Kappa	Σ, σ	Sigma
Γ, γ	Gamma	Λ, λ	Lambda	Τ, τ	Tau
Δ, δ	Delta	Μ, μ	Mu	Υ, υ	Upsilon
Ε, ϵ	Epsilon	Ν, ν	Nu	Φ, ϕ	Phi
Ζ, ζ	Zeta	Ξ, ξ	Xi	Χ, χ	Chi
Η, η	Eta	Ο, ο	Omicron	Ψ, ψ	Psi
Θ, θ, ϑ	Theta	Π, π	Pi	Ω, ω	Omega

CO-ORDINATE SYSTEMS AND TERMINOLOGY

Astronomical positions are usually measured in a system based on the *celestial poles* and *celestial equator*, the intersections of Earth's rotation axis and equatorial plane, respectively, and the infinite sphere of the sky. *Right ascension* (R.A. or α) is measured in hours (h), minutes (m) and seconds (s) of time, eastward along the celestial equator from the *vernal equinox. Declination* (Dec. or δ) is measured in degrees (°), minutes (′) and seconds (″) of arc, northward (N or +) or southward (S or −) from the celestial equator toward the N or S celestial pole.

Positions can also be measured in a system based on the *ecliptic*, the intersection of Earth's orbit plane and the infinite sphere of the sky. The Sun appears to move eastward along the ecliptic during the year. *Longitude* is measured eastward along the ecliptic from the vernal equinox; *latitude* is measured at right angles to the ecliptic, northward or southward toward the N or S ecliptic pole. The *vernal equinox* is one of the two intersections of the ecliptic and the celestial equator; it is the one at which the Sun crosses the celestial equator moving from south to north.

Objects are *in conjunction* if they have the same longitude or R.A., and are *in opposition* if they have longitudes or R.A.'s which differ by 180°. If the second object is not specified, it is assumed to be the Sun. For instance, if a planet is "in conjunction", it has the same longitude as the Sun. At *superior conjunction*, the planet is more distant than the Sun; at *inferior conjunction*, it is nearer. (See the diagram on page 96.)

If an object crosses the ecliptic moving northward, it is at the *ascending node* of its orbit; if it crosses the ecliptic moving southward, it is at the *descending node*.

Elongation is the difference in longitude between an object and a second object (usually the Sun). At conjunction, the elongation of a planet is thus zero.

BASIC DATA

PRINCIPAL ELEMENTS OF THE SOLAR SYSTEM

MEAN ORBITAL ELEMENTS

Planet	Mean Distance from Sun		Period of Revolution		Eccentricity (e)	Inclination (i)	Long. of Node (☊)	Long. of Perihelion (π)	Mean Long. at Epoch (L)
	A	millions of km	Sidereal (P)	Synodic					
				days		°	°	°	°
Mercury	0.387	57.9	87.97d	116	0.206	7.0	47.9	76.8	222.6
Venus	0.723	108.2	224.70	584	0.007	3.4	76.3	131.0	174.3
Earth	1.000	149.6	365.26	. . .	0.017	0.0	0.0	102.3	100.2
Mars	1.524	227.9	686.98	780	0.093	1.8	49.2	335.3	258.8
Jupiter	5.203	778.3	11.86a	399	0.048	1.3	100.0	13.7	259.8
Saturn	9.539	1427.0	29.46	378	0.056	2.5	113.3	92.3	280.7
Uranus	19.182	2869.6	84.01	370	0.047	0.8	73.8	170.0	141.3
Neptune	30.058	4496.6	164.79	367	0.009	1.8	131.3	44.3	216.9
Pluto	39.439	5899.9	247.69	367	0.250	17.2	109.9	224.2	181.6

These elements, for epoch 1960 Jan. 1.5 E.T., are taken from the *Explanatory Supplement to the American Ephemeris and Nautical Almanac.*

PHYSICAL ELEMENTS

Object	Equat. Diam. km	Oblateness	Mass $\oplus = 1$	Density g/cm^3	Gravity $\oplus = 1$	Esc. Speed km/s	Rotn. Period d	Incl. °	Albedo
☉ Sun	1 392 000	0	332 946.0	1.41	27.9	617.5	25–35*		—
☾ Moon	3 476	0	0.012300	3.34	0.17	2.4	27.3217	6.7	0.12
☿ Mercury	4 878	0	0.055274	5.43	0.38	4.3	58.646	0.0	0.106
♀ Venus	12 104	0	0.815005	5.24	0.91	10.4	243.017	177.3	0.65
⊕ Earth	12 756	1/298	1.000000	5.52	1.00	11.2	0.9973	23.4	0.37
♂ Mars	6 787	1/193	0.107447	3.94	0.38	5.0	1.0260	25.2	0.15
♃ Jupiter	142 800	1/15	317.833	1.33	2.54	59.6	0.4101†	3.1	0.52
♄ Saturn	120 000	1/9	95.159	0.70	1.08	35.6	0.4440	26.7	0.47
⛢ Uranus	50 800	1/30	14.500	1.30	0.91	21.3	0.65	97.9	0.51
♆ Neptune	48 600	1/40	17.204	1.76	1.19	23.8	0.768	29.6	0.41
♇ Pluto	3 000?	0?	0.0026?	1.1?	0.05?	1.2?	6.3867	118?	0.5?

The table gives the *mean* density, the gravity and escape speed *at the pole* and the inclination of equator *to orbit.*

*Depending on latitude

†For the most rapidly rotating part of Jupiter, the equatorial region.

SATELLITES OF THE SOLAR SYSTEM

BY JOSEPH VEVERKA

Name	Diam. (km)	Mass (10^{20} kg)	Mean Dist. from Planet (10^3 km/″)	Eccentricity	Vis. Mag.	Discovery
		Density (t/m^3)	Rev. Period (d)	Orbit Incl (°)	Vis. Albedo	
SATELLITE OF EARTH						
Moon	3476	734.9 ± 0.7	384.5/ —	0.0549	−12.7	
		3.34	27.322	18–29	0.11	
SATELLITES OF MARS						
I Phobos	21	(1.3 ± 0.2) × 10^{-4}	9.4/ 25	0.015	11.6	A. Hall, 1877
		~2	0.319	1.1	0.07	
II Deimos	12	(1.8 ± 0.2) × 10^{-5}	23.5/ 63	0.0005	12.7	A. Hall, 1877
		~2	1.263	1.8v	0.07	
SATELLITES OF JUPITER						
XVI Metis	(40)	—	128/ 42	0	17.5	S. Synnott, 1979
		—	0.294	—	(0.05)	
XV Adrastea	(25)	—	129/ 42	0	18.7	Jewitt, Danielson, Synnott, 1979
		—	0.297	—	(0.05)	
V Amalthea	170	—	180/ 59	0.003	14.1	E. Barnard, 1892
		—	0.498	0.4	0.05	
XIV Thebe	(100)	—	222/ 73	0.013	16.0	S. Synnott, 1979
		—	0.674	—	(0.05)	
I Io	3630	892 ± 4	422/138	0.004	5.0	Galileo, 1610
		3.55	1.769	0	0.6	
II Europa	3140	487 ± 5	671/220	0.010	5.3	Galileo, 1610
		3.04	3.551	0.5	0.6	
III Ganymede	5260	1 490 ± 6	1 070/351	0.001	4.6	Galileo, 1610
		1.93	7.155	0.2	0.4	

Apparent magnitude and mean distance from planet are at mean opposition distance. The inclination of the orbit is referred to the planet's equator; a value greater than 90° indicates retrograde motion.

Names in brackets are provisional, pending decision by the I.A.U.

Values in parentheses are uncertain.

Note: Pronunciations of the names of the planetary satellites are given on p. 97.

Name	Diam. (km)	Mass (10^{20} kg)	Mean Dist. from Planet (10^3 km/″)	Eccen-tricity	Vis. Mag.	Discovery
		Density (t/m^3)	Rev. Period (d)	Orbit Incl (°)	Vis. Albedo	
IV Callisto	4800	1075 ± 4	1 885/ 618	0.007	5.6	Galileo, 1610
		1.83	16.689	0.2	0.2	
XIII Leda	(15)	—	11 110/3640	0.147	20	C. Kowal, 1974
		—	240	26.7	—	
VI Himalia	185	—	11 470/3760	0.158	14.8	C. Perrine, 1904
		—	251	27.6	0.03	
X Lysithea	(35)	—	11 710/3840	0.130	18.4	S. Nicholson, 1938
		—	260	29.0	—	
VII Elara	75	—	11 740/3850	0.207	16.8	C. Perrine, 1905
		—	260	24.8	0.03	
XII Ananke	(30)	—	20 700/6790	0.17	18.9	S. Nicholson, 1951
		—	617	147	—	
XI Carme	(40)	—	22 350/7330	0.21	18.0	S. Nicholson, 1938
		—	692	164	—	
VIII Pasiphae	(50)	—	23 330/7650	0.38	17.1	P. Melotte, 1908
		—	735	145	—	
IX Sinope	(35)	—	23 370/7660	0.28	18.3	S. Nicholson, 1914
		—	758	153	—	
SATELLITES OF SATURN						
XV Atlas	30	—	137/ 23	0.002	(18)	R. Terrile, 1980
		—	0.601	0.3	0.4	
1980S27	100	—	139/ 23	0.004	(15)	S. Collins,
[Prometheus]		—	0.613	0.0	0.6	D. Carlson, 1980
1980S26	90	—	142/ 24	0.004	(16)	S. Collins,
[Pandora]		—	0.628	0.1	0.5	D. Carlson, 1980
X Janus	190	—	151/ 25	0.009	(14)	A. Dollfus, 1966
		—	0.695*	0.3	0.6	
XI Epimetheus	120	—	151/ 25	0.007	(15)	J. Fountain,
		—	0.695*	0.1	0.5	S. Larson, 1966
I Mimas	390	0.38 ± 0.01	187/ 30	0.020	12.5	W. Herschel, 1789
		1.2	0.942	1.5	0.8	
II Enceladus	500	0.8 ± 0.3	238/ 38	0.004	11.8	W. Herschel, 1789
		1.1	1.370	0.02	1.0	

*Co-orbital satellites.

Name	Diam. (km)	Mass (10^{20} kg) Density (t/m^3)	Mean Dist. from Planet (10^3 km/″) Rev. Period (d)	Eccentricity Orbit Incl (°)	Vis. Mag. Vis. Albedo	Discovery
III Tethys	1060	7.6 ± 0.9 1.2	295/ 48 1.888	0.000 1.1	10.3 0.8	G. Cassini, 1684
XIII Telesto	25	— —	295/ 48 1.888[a]	— —	(18) 0.7	Smith, Larson, Reitsema, 1980
XIV Calypso	25	— —	295/ 48 1.888[b]	— —	(18) 1.0	Pascu, Seidelmann, Baum, Currie, 1980
IV Dione	1120	10.5 ± 0.3 1.4	378/ 61 2.737	0.002 0.02	10.4 0.6	G. Cassini, 1684
XII 1980S6	30	— —	378/ 61 2.737[c]	0.005 —	(18) 0.6	P. Laques, J. Lecacheux, 1980
V Rhea	1530	24.9 ± 1.5 1.3	526/ 85 4.517	0.001 0.4	9.7 0.6	G. Cassini, 1672
VI Titan	5550†	1345.7 ± 0.3 1.88	1 221/ 197 15.945	0.029 0.3	8.4 0.2	C. Huygens, 1655
VII Hyperion	255	— —	1 481/ 239 21.276	0.104 0.4	14.2 0.3	W. Bond, G. Bond, W. Lassell, 1848
VIII Iapetus	1460	18.8 ± 1.2 1.2	3 561/ 575 79.331	0.028 14.7	11.0v 0.08 −0.4	G. Cassini, 1671
IX Phoebe	220	— —	12 960/2096 550.46	0.163 186	16.5 0.05	W. Pickering, 1898
SATELLITES OF URANUS						
V Miranda	(300)	— —	130/ 9 1.414	0.017 3.4	16.5 —	G. Kuiper, 1948
I Ariel	1350	(17) (1.3 ± 0.5)	192/ 14 2.520	0.0028 0	14.0 0.3	W. Lassell, 1851
II Umbriel	1100	(10) (1.4 ± 0.5)	267/ 20 4.144	0.0035 0	14.9 0.2	W. Lassell, 1851

[a] Librates about trailing (L_5) Lagrangian point of Tethys' orbit.

[b] Librates about leading (L_4) Lagrangian point of Tethys' orbit.

[c] Librates about leading (L_4) Lagrangian point of Dione's orbit with a period of ~790 d.

†Cloud-top diameter. Solid-body diameter equals 5150 km.

Name	Diam. (km)	Mass (10^{20} kg) Density (t/m^3)	Mean Dist. from Planet (10^3 km/″) Rev. Period (d)	Eccen-tricity Orbit Incl (°)	Vis. Mag. Vis. Albedo	Discovery
III Titania	1600	(58) (2.7 ± 0.6)	438/ 33 8.706	0.0024 0	13.9 0.2	W. Herschel, 1787
IV Oberon	1650	(61) (2.6 ± 0.6)	587/ 44 13.463	0.0007 0	14.1 0.2	W. Herschel, 1787
SATELLITES OF NEPTUNE						
I Triton	(3500)	1300? ?	354/ 17 5.877	<0.0005 160.0	13.6 (0.4)	W. Lassell, 1846
II Nereid	(300)	— —	5 600/264 365.21	0.75 27.6	18.7 —	G. Kuiper, 1949
SATELLITE OF PLUTO						
[Charon]	(1300)	— —	20.0/ 0.9 6.387	0 0	17 —	J. Christy, 1978

TELESCOPE PARAMETERS

(where D = diameter of aperture in millimetres)

Light Grasp (LG) is the ratio of the light flux intercepted by a telescope's objective lens or mirror to that intercepted by a human eye having a 7 mm diameter entrance pupil.

Limiting Visual Magnitude $m_l \simeq 2.7 + 5 \log D$, assuming transparent, dark-sky conditions and magnification $\geqslant$ 1D. (See article by R. Sinnott, *Sky and Telescope*, *45*, 401, 1973)

Smallest Resolvable Angle $\theta \simeq 120/D$ seconds of arc. However, atmospheric conditions seldom permit values less than 0″.5.

Useful Magnification Range ≃ 0.2D to 2D. The lower limit may be a little less, but depends upon the maximum diameter of the entrance pupil of the individual observer's eye. Also, 0.2D provides better contrast than a lower value. The upper limit is determined by the wave nature of light and the optical limitations of the eye, although atmospheric turbulence usually limits the maximum magnification to 500× or less. For examination of double stars, magnifications up to 4D are sometimes useful. Note that the reciprocal of the coefficient to D is the diameter (in mm) of the telescope's exit pupil.

Values for some common apertures are:

D (mm)	60	75	100	125	150	200	350	440
LG	73	110	200	320	460	820	2500	4000
m_l	11.6	12.1	12.7	13.2	13.6	14.2	15.4	15.9
θ (″)	2.0	1.6	1.2	1.0	0.80	0.60	0.34	0.27
0.2D	12x	15x	20x	25x	30x	40x	70x	88x
2D	120x	150x	200x	250x	300x	400x	700x	880x

D

SOME ASTRONOMICAL AND PHYSICAL DATA

Many of the numbers listed below are determined by measurement. Exceptions include defined quantities (indicated by three lines in the equal sign ≡), quantities calculated from defined quantities (e.g. m/ly, A/pc), and numbers of mathematical origin such as π and conversion factors in angular measure. Of the measured quantities, some are known to only approximate precision. For these the equal sign is reduced to ≈. Many others are known to quite high precision. In these cases all digits shown are significant, with the uncertainties occurring after the last digit. The units, symbols, and nomenclature are based on recommendations of the *International Astronomical Union*, the *International Union of Pure and Applied Physics*, and the *Metric Commission Canada*.

LENGTH

1 astronomical unit (A)	$= 1.495\,978\,70 \times 10^{11}$ m = 499.004 782 light seconds
1 light year (ly)	$= 9.460\,536 \times 10^{15}$ m (based on average Gregorian year) = 63 239.8 A
1 parsec (pc)	$= 3.085\,678 \times 10^{16}$ m = 206 264.8 A = 3.261 631 light years
1 mile*	≡ 1.609 344 km
1 Angstrom*	≡ 0.1 nm

TIME

Day:	Mean sidereal (equinox to equinox)	= 86 164.094 s
	Mean rotation (fixed star to fixed star)	= 86 164.102 s
	Day (d)	≡ 86 400. s
	Mean solar	= 86 400.003 s
Month:	Draconic (node to node)	= 27.212 22 d
	Tropical (equinox to equinox)	= 27.321 58 d
	Sidereal (fixed star to fixed star)	= 27.321 66 d
	Anomalistic (perigee to perigee)	= 27.554 55 d
	Synodic (New Moon to New Moon)	= 29.530 59 d
Year:	Eclipse (lunar node to lunar node)	= 346.6201 d
	Tropical (equinox to equinox) (a)	= 365.2422 d
	Average Gregorian	≡ 365.2425 d
	Average Julian	≡ 365.2500 d
	Sidereal (fixed star to fixed star)	= 365.2564 d
	Anomalistic (perihelion to perihelion)	= 365.2596 d

EARTH

Mass = 5.974×10^{24} kg

Radius: Equatorial, a = 6378.140 km; Polar, b = 6356.755 km;
Mean, $\sqrt[3]{a^2b}$ = 6371.004 km

1° of latitude = $111.133 - 0.559 \cos 2\phi$ km (at latitude ϕ)

1° of longitude = $111.413 \cos \phi - 0.094 \cos 3\phi$ km

Distance of sea horizon for eye h metres above sea-level $\approx 3.9\sqrt{h}$ km (refraction inc.)

Standard atmospheric pressure = 101.325 kPa (≈1 kg above 1 cm^2)

Speed of sound in standard atmosphere = 331 m s^{-1}

Magnetic field at surface $\approx 5 \times 10^{-5}$ T

Magnetic poles: 76°N, 101°W; 66°S, 140°E

Surface gravity at latitude 45°, g = 9.806 m s^{-2}

Age ≈4.6 Ga

Meteoric flux $\approx 1 \times 10^{-15}\,\text{kg m}^{-2}\,\text{s}^{-1}$

Escape speed from Earth = 11.2 km s^{-1}

Solar parallax = $8''.794\,148$ (Earth equatorial radius ÷ 1 A)

Constant of aberration = $20''.495\,52$

*Obsolete units

Obliquity of ecliptic = 23°.4411 (1986.0)
Annual general precession = 50″.26; Precession period = 25 800 a
Orbital speed = 29.8 km s^{-1}
Escape speed at 1 A from Sun = 42.1 km s^{-1}

SUN

Mass ≡ 1S = 1.9891 × 10^{30} kg; Radius = 696 265 km; Eff. temperature = 5770 K
Output: Power = 3.83 × 10^{26} W; M_{bol} = 4.75
Luminous intensity = 2.84 × 10^{27} cd; M_V = 4.84
At 1 A, outside Earth's atmosphere:
Energy flux = 1.36 kW m^{-2}; m_{bol} = −26.82
Illuminance = 1.27 × 10^5 lx; m_V = −26.73
Inclination of the solar equator on the ecliptic of date = 7°.25
Longitude of the ascending node of the solar equator on the ecliptic of date = 76°
Period of rotation at equator = 25.38 d (sidereal), 27.275 d (mean synodic)
Solar wind speed near Earth ≈ 450 km s^{-1} (travel time, Sun to Earth ≈ 5 d)
Solar velocity = 19.75 km s^{-1} toward α = 18.07 h, δ = +30° (solar apex)

MILKY WAY GALAXY

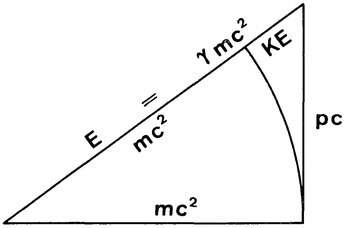
Mass ≈ 10^{12} solar masses
Centre: α = 17 h 42.5 min, δ = −28° 59′ (1950)
Distance to centre ≈9 kpc, diameter ≈100 kpc
North pole: α = 12 h 49 min, δ = 27° 24′ (1950)
Rotational speed (at Sun) ≈250 km s^{-1}
Rotational period (at Sun) ≈220 Ma
Velocity relative to the 3 K background ≈600 km s^{-1} toward α ≈ 10 h, δ ≈ −20°

SOME CONSTANTS

Speed of light, c ≡ 299 792 458. m s^{-1} (This, in effect, defines the metre.)
Planck's constant, h = 6.6262 × 10^{-34} J s
Gravitational constant, G = 6.672 × 10^{-11} N m^2 kg^{-2}
Elementary charge, e = 1.6022 × 10^{-19} C
Avogadro constant, N_A = 6.022 × 10^{26} $kmol^{-1}$
Boltzmann constant, k = 1.381 × 10^{-23} J K^{-1} = 8.62 × 10^{-5} eV K^{-1} ≈1 eV/10^4 K
Stefan-Boltzmann constant, σ = 5.67 × 10^{-8} W m^{-2} K^{-4}
Wien's law, $\lambda_m T$ = 2.898 × 10^{-3} m K (per dλ)
Hubble constant, H ≈ 50 to 75 km s^{-1} Mpc^{-1} (depending on method of determination)
Volume of ideal gas at 0°C, 101.325 kPa = 22.41 m^3 $kmol^{-1}$

MASS AND ENERGY

Atomic mass unit (u) = 1.6606 × 10^{-27} kg = N_A^{-1} = 931.50 MeV
Electron rest mass = 9.1095 × 10^{-31} kg = 548.580 μu = 0.51100 MeV
Proton rest mass = 1.007 276 u = 938.28 MeV
Neutron rest mass = 1.008 665 u = 939.57 MeV
Some atomic masses:
^{1}H = 1.007 825 u
^{2}H = 2.014 102 u
^{4}He = 4.002 603 u
^{5}Li = 5.012 5 u
^{8}Be = 8.005 305 u
^{12}C ≡ 12.000 000 u
^{16}O = 15.994 915 u
^{56}Fe = 55.934 940 u
^{235}U = 235.043 928 u
Electron-volt (eV) = 1.6022 × 10^{-19} J
1 eV per event = 23 060 cal mol^{-1}
Thermochemical calorie (cal) ≡ 4.184 J
1 erg s^{-1} ≡ 10^{-7} W
$C + O_2 \rightarrow CO_2$ + 4.1 eV
$4\,{}^1H \rightarrow {}^4He$ + 26.73 MeV
1 kg TNT releases 4.20 MJ (≈1 kWh)
Relation between rest mass (m), linear momentum (p), total energy (E), kinetic energy (KE), and $\gamma \equiv (1 - v^2/c^2)^{-0.5}$:



MAGNITUDE RELATIONS

Log of light intensity ratio ≡ 0.4 times magnitude difference

Distance Modulus (D) ≡ apparent magnitude (m) − absolute magnitude (M)

Log of distance in ly = 0.2 D + 1.513 435 (neglecting absorption)

OPTICAL WAVELENGTH DATA

Bright-adapted (photopic) visible range ≈ 400 − 750 nm

Dark-adapted (scotopic) visible range ≈ 400 − 620 nm

Wavelength of peak sensitivity of human eye ≈ 555 nm (photopic)
≈ 510 nm (scotopic)

Mechanical equivalent of light: 1 lm ≡ 1/683 W at 540 THz ($\lambda \approx 555$ nm)

Colours (representative wavelength, nm): violet (420), blue (470), green (530), yellow (590), orange (610), red (660).

Some useful wavelengths (element, spectral designation or colour and/or (Fraunhofer line), nm):

H Lyman α	122	Hγ (g solar)	434	Hg yellow	579
Ca (K solar)	393	Hg deep blue	436	Na (D_2 solar)	589.0
Ca (H solar)	397	Hβ (F solar)	486	Na (D_1 solar)	589.6
Hg violet	405	Hg green	546	He-Ne laser	633
Hδ (h solar)	410	Hg yellow	577	Hα (C solar)	656

DOPPLER RELATIONS FOR LIGHT

α ≡ angle between velocity of source and line from source to observer.

$\beta \equiv v/c$

$\gamma \equiv (1 - \beta^2)^{-0.5}$

Frequency: $\nu = \nu_0 \gamma^{-1}(1 - \beta \operatorname{Cos} \alpha)^{-1}$

$z \equiv (\lambda - \lambda_0)/\lambda_0 = \gamma(1 - \beta \operatorname{Cos} \alpha) - 1$

$$\text{For } \alpha = \pi \begin{cases} z = (1 + \beta)^{0.5}(1 - \beta)^{-0.5} - 1 \ \ (\approx \beta \text{ if } \beta \ll 1) \\ \beta = [(1 + z)^2 - 1][(1 + z)^2 + 1]^{-1} \end{cases}$$

ANGULAR RELATIONS

$\pi = 3.141\,592\,654 \approx (113 \div 355)^{-1}$

$1'' = 4.8481 \times 10^{-6}$ rad

Number of square degrees on a sphere = 41 253.

For 360° = 24 h, 15° = 1 h, 15′ = 1 min, 15″ = 1 s

Relations between sidereal time t, right ascension α, hour angle h, declination δ, azimuth A (measured east of north), altitude a, and latitude ϕ:

$h = t - \alpha$

$\sin a = \sin \delta \sin \phi + \cos h \cos \delta \cos \phi$

$\cos \delta \sin h = -\cos a \sin A$

$\sin \delta = \sin a \sin \phi + \cos a \cos A \cos \phi$

Annual precession in $\alpha = 3.0730 + 1.3362 \sin \alpha \tan \delta$ seconds

Annual precession in $\delta = 20''.043 \cos \alpha$

SOME SI SYMBOLS AND PREFIXES

m	metre	N	newton (kg m s^{-2})	f	femto	10^{-15}
kg	kilogram	J	joule (N m)	p	pico	10^{-12}
s	second	W	watt (J s^{-1})	n	nano	10^{-9}
min	minute	Pa	pascal (N m^{-2})	μ	micro	10^{-6}
h	hour	t	tonne (10^3 kg)	m	milli	10^{-3}
d	day	Hz	hertz (s^{-1})	c	centi	10^{-2}
a	year	C	coulomb (A s)	k	kilo	10^3
A	ampere	T	tesla (Wb m^{-2})	M	mega	10^6
rad	radian	cd	candela (lm sr^{-1})	G	giga	10^9
sr	steradian	lx	lux (lm m^{-2})	T	tera	10^{12}

TABLE OF PRECESSION FOR ADVANCING 50 YEARS

If declination is positive, use inner R.A. scale; if declination is *negative*, use *outer* R.A. scale, and *reverse the sign of the precession in declination*

R.A. for Dec. −	R.A. for Dec. +	Prec. in Dec.	Precession in right ascension											Prec. in Dec.	R.A. for Dec. +	R.A. for Dec. −
			δ = 85°	80°	75°	70°	60°	50°	40°	30°	20°	10°	0°			
h m	h m	′	m	m	m	m	m	m	m	m	m	m	m		h m	h m
12 00	0 00	+16.7	+ 2.56	+2.56	+2.56	+2.56	+2.56	+2.56	+2.56	+2.56	+2.56	+2.56	+2.56	−16.7	12 00	*24 00*
12 30	0 30	+16.6	4.22	3.39	3.10	2.96	2.81	2.73	2.68	2.64	2.61	2.59	2.56	−16.6	11 30	*23 30*
13 00	1 00	+16.1	5.85	4.20	3.64	3.35	3.06	2.90	2.80	2.73	2.67	2.61	2.56	−16.1	11 00	*23 00*
13 30	1 30	+15.4	7.43	4.98	4.15	3.73	3.30	3.07	2.92	2.81	2.72	2.64	2.56	−15.4	10 30	*22 30*
14 00	2 00	+14.5	8.92	5.72	4.64	4.09	3.53	3.22	3.03	2.88	2.76	2.66	2.56	−14.5	10 00	*22 00*
14 30	2 30	+13.3	10.31	6.41	5.09	4.42	3.73	3.37	3.13	2.95	2.81	2.68	2.56	−13.3	9 30	*21 30*
15 00	3 00	+11.8	11.56	7.03	5.50	4.72	3.92	3.50	3.22	3.02	2.85	2.70	2.56	−11.8	9 00	*21 00*
15 30	3 30	+10.2	12.66	7.57	5.86	4.99	4.09	3.61	3.30	3.07	2.88	2.72	2.56	−10.2	8 30	*20 30*
16 00	4 00	+ 8.4	13.58	8.03	6.16	5.21	4.23	3.71	3.37	3.12	2.91	2.73	2.56	− 8.4	8 00	*20 00*
16 30	4 30	+ 6.4	14.32	8.40	6.40	5.39	4.34	3.79	3.42	3.15	2.94	2.74	2.56	− 6.4	7 30	*19 30*
17 00	5 00	+ 4.3	14.85	8.66	6.57	5.52	4.42	3.84	3.46	3.18	2.95	2.75	2.56	− 4.3	7 00	*19 00*
17 30	5 30	+ 2.2	15.18	8.82	6.68	5.59	4.47	3.88	3.49	3.20	2.96	2.76	2.56	− 2.2	6 30	*18 30*
18 00	6 00	0.0	15.29	8.88	6.72	5.62	4.49	3.89	3.50	3.20	2.97	2.76	2.56	0.0	6 00	*18 00*
0 00	12 00	−16.7	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	+16.7	24 00	*12 00*
0 30	12 30	−16.6	+ 0.90	1.74	2.02	2.16	2.31	2.39	2.44	2.48	2.51	2.54	2.56	+16.6	23 30	*11 30*
1 00	13 00	−16.1	− 0.73	0.93	1.49	1.77	2.06	2.22	2.32	2.39	2.46	2.51	2.56	+16.1	23 00	*11 00*
1 30	13 30	−15.4	− 2.31	+0.14	0.97	1.39	1.82	2.05	2.20	2.31	2.41	2.49	2.56	+15.4	22 30	*10 30*
2 00	14 00	−14.5	− 3.80	−0.60	0.48	1.03	1.60	1.90	2.09	2.24	2.36	2.46	2.56	+14.5	22 00	*10 00*
2 30	14 30	−13.3	− 5.19	−1.28	+0.03	0.70	1.39	1.75	1.99	2.17	2.31	2.44	2.56	+13.3	21 30	*9 30*
3 00	15 00	−11.8	− 6.44	−1.90	−0.38	0.40	1.20	1.62	1.90	2.11	2.27	2.42	2.56	+11.8	21 00	*9 00*
3 30	15 30	−10.2	− 7.54	−2.45	−0.74	+0.13	1.03	1.51	1.82	2.05	2.24	2.41	2.56	+10.2	20 30	*8 30*
4 00	16 00	− 8.4	− 8.46	−2.91	−1.04	−0.09	0.89	1.41	1.75	2.00	2.21	2.39	2.56	+ 8.4	20 00	*8 00*
4 30	16 30	− 6.4	− 9.20	−3.27	−1.28	−0.27	0.78	1.33	1.70	1.97	2.19	2.38	2.56	+ 6.4	19 30	*7 30*
5 00	17 00	− 4.3	− 9.73	−3.54	−1.45	−0.39	0.70	1.28	1.66	1.94	2.17	2.37	2.56	+ 4.3	19 00	*7 00*
5 30	17 30	− 2.2	−10.06	−3.70	−1.56	−0.47	0.65	1.25	1.63	1.92	2.16	2.37	2.56	+ 2.2	18 30	*6 30*
6 00	18 00	0.0	−10.17	−3.75	−1.59	−0.50	0.63	1.23	1.63	1.92	2.16	2.36	2.56	0.0	18 00	*6 00*

To avoid interpolation in this table, which becomes increasingly inaccurate for large |δ|, precession formulae may be used (see p. 16).

TIME

Time has been said to be nature's way of keeping everything from happening at once. For astronomical purposes the concern is not with defining time, but with its measurement. For this, units of time and time scales must be established and clocks devised.

There are three obvious, natural, periodic time intervals on Earth: the seasonal cycle (year); the cycle of lunar phases (month); and the day-night cycle (day). The problem of accurately subdividing these natural intervals to make time locally available at any moment was satisfactorily solved in 1657 by Christiaan Huygens who invented the first practical pendulum clock. Through successive refinements the pendulum clock reigned supreme for nearly three centuries, until it was surpassed in precision by the quartz oscillator in the 1940's. Within another 20 years the quartz clock was, in turn, superseded by the cesium atomic clock which today has a precision near one part in 10^{13} (one second in 300 000 years).

The cycle of the seasons is called the *tropical year* and contains 365.2422 days. The cycle of lunar phases is known as the *synodic month* and equals 29.53059 days. The average day-night (diurnal) cycle is the *mean solar day* and contains approximately 86 400.003 s. Other types of year, month and day have been defined and are listed along with brief definitions and durations on p. 14.

Today the second is the basic unit of time. For many years a second meant 1/86400 of the mean solar day. However, Earth's rotation on its axis is not perfectly uniform: there are (i) long, (ii) medium, and (iii) short-term accelerations. (i) Over many centuries there is a *secular* slowing due to tidal friction of about 5 parts in 10^{13} per day (i.e. the day becomes one second longer about every 60 000 years). (ii) Over a few decades there are *random* accelerations (positive and negative), apparently due to core-mantle interactions. These are about ten times larger than the tidal acceleration and thus completely obscure the latter effect over time intervals of less than a century or so. (iii) The largest accelerations in Earth's rotation rate are short-term ones: they are *periodic* and appear to be associated with seasonal meteorological factors. They are typically one or two orders of magnitude larger again than the random, decade fluctuations on which they are superimposed. Also, although not actually a variation in Earth's rotation rate, shifts of Earth's crust relative to the axis of rotation (*polar wobble*) also affect astronomical time determinations through the resulting east-west shift in the meridian at latitudes away from the equator. Like the seasonal accelerations, these are short-term and periodic, but of smaller amplitude.

Atoms display a permanence and stability that planets cannot, thus, since 1967, the second has had an atomic definition: 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom. This is known as the SI (for Système International) second (abbreviation s).

Although Earth's axial rotation is not sufficiently predictable to serve as a precise clock, the orbital motions of the planets and of our Moon are predictable to high accuracy. Through the dynamical equations describing these motions, a uniform time scale can be derived. This scale, known as *Ephemeris Time* (ET), was for many years the basis of astronomical ephemerides. Also, the definition of the SI second, mentioned above, was chosen so that it was identical to the ephemeris second to within the precision of measurement. Because atomic clocks are readily available and because of their proven precision, at the beginning of 1984 Ephemeris Time was abandoned in favor of *Terrestrial Dynamical Time* (TDT). The unit of TDT is the SI second and its scale was chosen to agree with the 1984 ET scale.

Other time scales are in use. *International Atomic Time* (TAI), like TDT, runs at the SI rate but, for historical reasons, lags TDT by exactly 32.184 seconds. Another is *Universal Time* (UT1, or often simply UT) which is mean solar time at the

Greenwich (England) meridian, corrected for polar wobble. In practice UT1 is defined in terms of *Greenwich Mean Sidereal Time* (GMST), the latter being defined in terms of Earth's rotation relative to the mean vernal equinox of date (see p. 8). The adjective *mean* is used here to denote that small, periodic variations due to the nutation of Earth's axis have been averaged out, the mean equinox being affected only by the precession of the axis. GMST is the hour angle of this equinox, i.e. GMST equals the right ascension of a star (corrected for nutation) at the Greenwich meridian. In short, UT1 follows Earth's rotation relative to the mean Sun, and includes the associated seasonal (periodic), decade (random), and secular (tidal slowing) accelerations.

Early in the 20th century the UT1 and ET scales coincided, but since Earth's rotation rate has been generally slower than the SI (ET) rate, by 1970 UT1 was 40 seconds behind ET and was losing more than one second per year. During the next 15 years, Earth's rotation rate increased (part of the random decade fluctuations) so that UT1 now loses only about half a second per year relative to TDT.

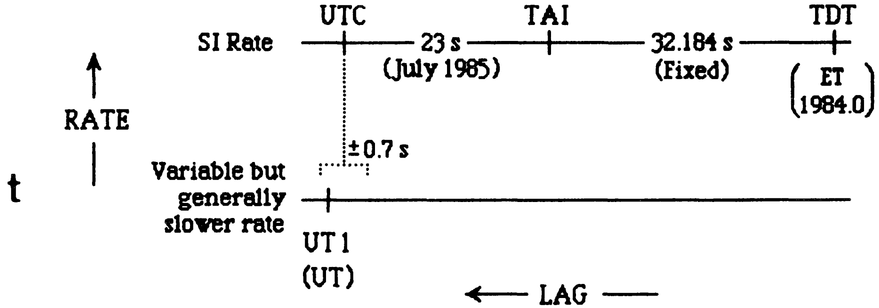
Closely related to UT1 is *Coordinated Universal Time* (UTC). UTC runs at the SI rate and is offset an integral number of seconds from TAI so that it approximates UT1. When required (at the end of June 30 or December 31), "leap seconds" are inserted into (or, if necessary, deleted from) UTC so that the difference UT1 − UTC ≡ ΔUT1 does not exceed ±0.7 s. UTC now lags TAI, and as of July 1, 1985 (when a leap second was inserted) TAI − UTC ≡ ΔAT = 23 s. Thus when this edition of the *Observer's Handbook* appears, TDT − UTC = 23 s + 32.184 s = 55.184 s exactly).

The world system of civil time is based on UTC. To keep clocks at various longitudes reasonably in phase with the day-night cycle and yet to avoid the inconvenience to travellers of a local time that varies continuously with longitude, a century ago Earth was divided into about 24 *standard time* zones, adjacent zones generally differing by one hour and each ideally 15 degrees wide (see the maps on pages 20 and 21). The zero zone is centred on the Greenwich meridian. All clocks within the same time zone read the same time. Some countries observe "daylight saving time" during the summer months. In Canada and the United States, clocks are generally set one hour ahead of standard time on the last Sunday in April and return to standard time on the last Sunday in October ("spring ahead, fall back").

A sundial indicates *apparent solar time* at the observer's meridian. Not only is this, in general, different from standard time, but it is far from uniform because of Earth's elliptical orbit and the inclination of the ecliptic to the celestial equator. If the Sun is replaced by a fictitious mean sun moving uniformly along the equator, this defines *Local Mean (Solar) Time* (LMT). Apparent solar time can differ by up to 16 minutes from LMT depending upon the time of year (see p. 52). Also, depending upon the observer's location within his standard time zone, his standard time may differ by up to an hour or so from LMT (see p. 56).

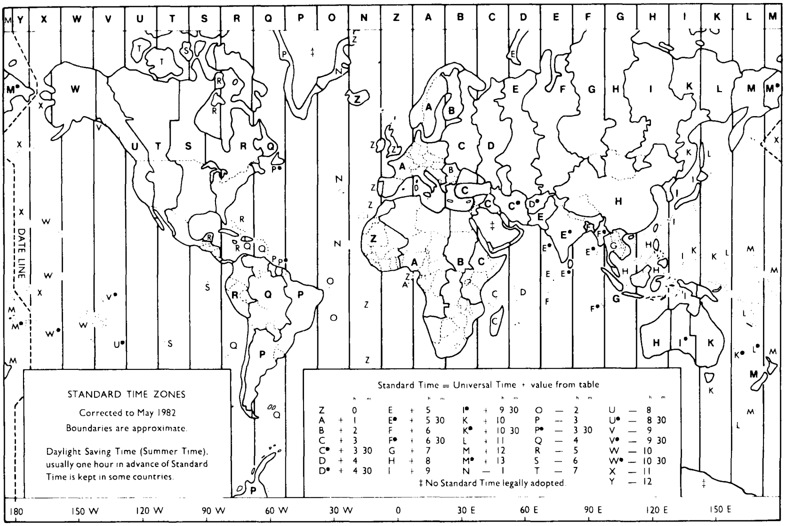
In the same manner that GMST is defined, a *Local Mean Sidereal Time* (LMST) is defined for each observer's meridian. Because Earth makes one more rotation with respect to the other stars than it does with respect to the Sun during a year, sidereal time gains relative to standard time, LMT, UT1, TAI or TDT by about $3^{m}56^{s}$ per day or 2^{h} per month. Also, because of precession, the mean sidereal day is about 8 ms shorter than Earth's period of rotation (see p. 14). LMST may be used to set a telescope on an object of known right ascension. The hour angle of the object equals the sidereal time less the right ascension. LMST may be available from a sidereal clock, or it can be calculated as explained on p. 22.

The diagram at the top of the next page displays the rate and scale relations between the time scales which run at or near the SI rate and which are not longitude dependent.



WORLD MAP OF TIME ZONES

Taken from *Astronomical Phenomena for the Year* 1985 (Washington: U.S. Government Printing Office, and London: Her Majesty's Stationery Office)



STANDARD TIME ZONES

Corrected to May 1982

Boundaries are approximate.

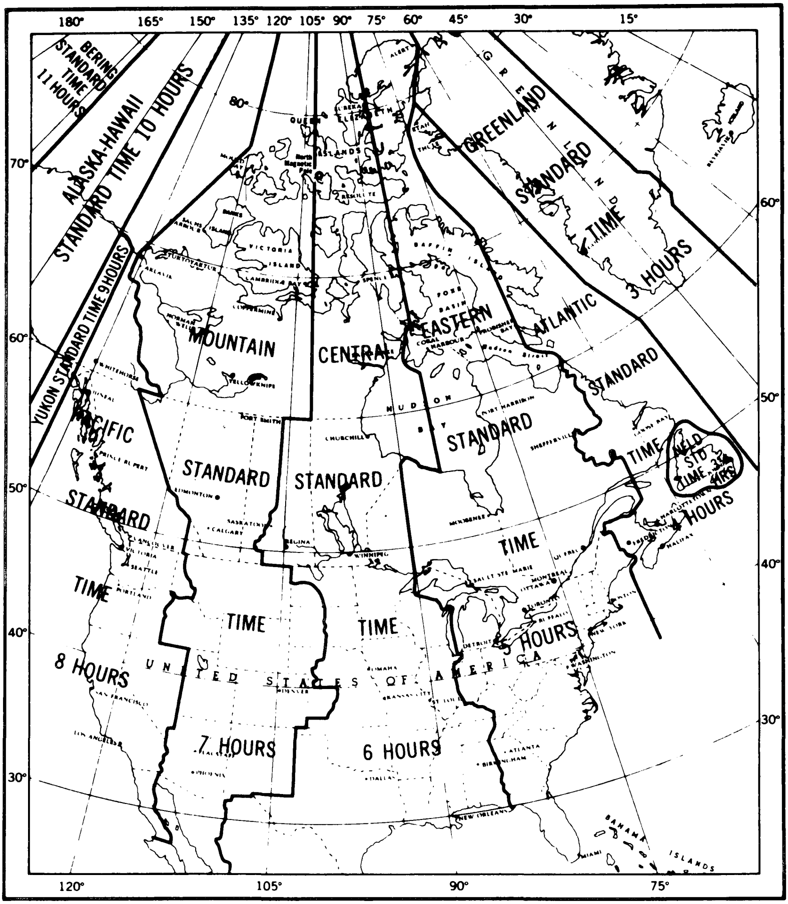
Daylight Saving Time (Summer Time), usually one hour in advance of Standard Time is kept in some countries.

Standard Time = Universal Time + value from table

		h	m			h	m			h	m			h	m			h	m
Z		0		E	+	5		I•	+	9	30	O	—	2		U	—	8	
A	+	1		E•	+	5	30	K	+	10		P	—	3		U•	—	8	30
B	+	2		F	+	6		K•	+	10	30	P•	—	3	30	V	—	9	
C	+	3		F•	+	6	30	L	+	11		Q	—	4		V•	—	9	30
C•	+	3	30	G	+	7		M	+	12		R	—	5		W	—	10	
D	+	4		H	+	8		M•	+	13		S	—	6		W•	—	10	30
D•	+	4	30	I	+	9		N	—	1		T	—	7		X	—	11	
																Y	—	12	

‡ No Standard Time legally adopted.

MAP OF STANDARD TIME ZONES



REPRODUCED BY THE SURVEYS AND MAPPING BRANCH, DEPARTMENT OF ENERGY, MINES AND RESOURCES, OTTAWA, CANADA, 1973.

MAP OF STANDARD TIME ZONES

The map shows the number of hours by which each time zone is *slower* than Greenwich, that is, the number of hours which must be *added* to the zone's standard time to give Universal Time.

Note: Since the preparation of the above map, the standard time zones have been changed so that all parts of the Yukon Territory now observe Pacific Standard Time. The Yukon, Alaska-Hawaii, and Bering Standard Time Zones have disappeared, and all of Alaska is now on Alaska Standard Time, −9 hours. Also, the part of Texas west of longitude 105° is in the Mountain Time Zone.

RADIO TIME SIGNALS

National time services distribute Coordinated Universal Time (UTC). UTC is coordinated through the Bureau International de l'Heure in Paris so that most time services are synchronized to a tenth of a millisecond. Radio time signals available in North America include:

CHU Ottawa, Ontario	3.330, 7.335, 14.670 MHz
WWV Fort Collins, Colorado	2.5, 5, 10, 15, 20 MHz

The difference ΔUT1 = UT1 − UTC to the nearest tenth of a second is coded in the signals. If UT1 is ahead of UTC, second markers beginning at the 1 second mark of each minute are doubled, the number of doubled markers indicating the number of tenths of a second UT1 is ahead of UTC. If UT1 is behind UTC, the doubled markers begin at the 9 second point.

MEAN SIDEREAL TIME 1986

The following is the Greenwich Mean Sidereal Time (GMST) on day 0 at 0^{h} UT of each month:

Jan. 0	06.6245^{h}	Apr. 0	12.5384^{h}	July 0	18.5180^{h}	Oct. 0	00.5633^{h}
Feb. 0	08.6615^{h}	May 0	14.5097^{h}	Aug. 0	20.5550^{h}	Nov. 0	02.6003^{h}
Mar. 0	10.5014^{h}	June 0	16.5467^{h}	Sep. 0	22.5920^{h}	Dec. 0	04.5716^{h}

GMST at hour t UT on day d of the month

$$= \text{GMST at } 0^{\mathrm{h}}\text{UT on day } 0 + 0^{\mathrm{h}}\!.065710d + 1^{\mathrm{h}}\!.002738t$$

Local Mean Sidereal Time (LMST) = GMST − west longitude
(or + east longitude)

LMST calculated by this method will be accurate to ±0.2s provided t is stated to ±0.1s or better and the observer's longitude is known to ± 1″. (Note that t must be expressed in decimal hours UT. Also, to achieve ±0.1s accuracy in t, the correction ΔUT1 must be applied to UTC. See the above section on radio time signals.)

JULIAN DATE, 1986

The Julian date is commonly used by astronomers to refer to the time of astronomical events, because it avoids some of the annoying complexities of the civil calendar. The Julian day corresponding to a given date is the number of days which have elapsed since January 1, 4713 B.C. For an account of the origin of the Julian system see: "The Julian Period", by C. H. Cleminshaw in the *Griffith Observer*, April 1975; "The Origin of the Julian Day System", by G. Moyer in *Sky and Telescope*, April 1981.

The Julian day commences at noon (12^{h}) UT. To find the Julian date at any time during 1986, determine the day of the month and time at the Greenwich meridian, convert this to a decimal day, and add it to one of the following numbers according to the month. (These numbers are the Julian dates for 0^{h}UT on the "0th" day of each month.):

Jan.	244 6430.5	Apr.	244 6520.5	July	244 6611.5	Oct.	244 6703.5
Feb.	244 6461.5	May	244 6550.5	Aug.	244 6642.5	Nov.	244 6734.5
Mar.	244 6489.5	June	244 6581.5	Sep.	244 6673.5	Dec.	244 6764.5

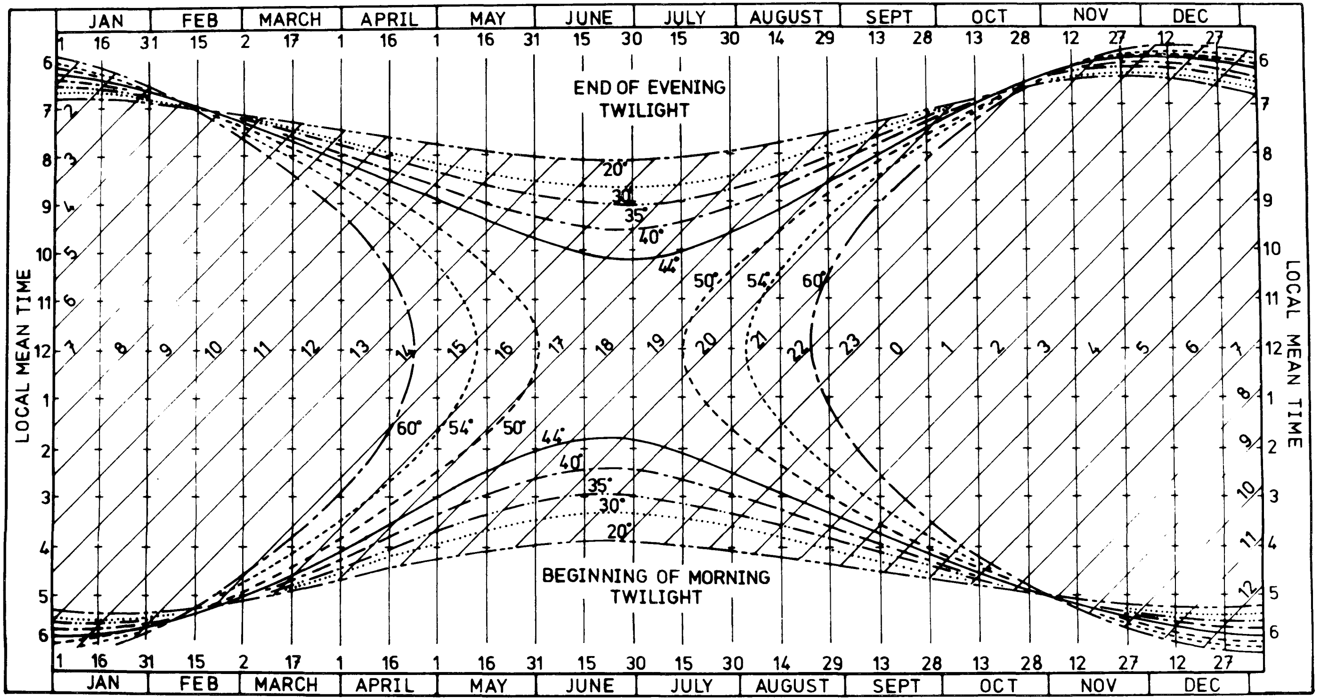
e.g. 21:36 EDT on May 18 = 01:36 UT on May 19 = May 19.07 UT = 244 6550.5 + 19.07 = JD 244 6569.57

The Julian dates for 0 UT January 0 for several previous years are 244 0000.5 plus (for years indicated): 951(1971), 1316(1972), 1682(1973), 2047(1974), 2412(1975), 2777(1976), 3143(1977), 3508(1978), 3873(1979), 4238(1980), 4604(1981), 4969(1982), 5334(1983), 5699(1984), 6065(1985).

Note: Anniversary and festival dates for 1986 appear on p. 25.

ASTRONOMICAL TWILIGHT AND SIDEREAL TIME

The diagram gives (i) the local mean time (LMT) of the beginning and end of astronomical twilight (curved lines) at a given latitude on a given date and (ii) the local mean sidereal time (LMST, diagonal lines) at a given LMT on a given date. The LMST is also the right ascension of an object on the observer's celestial meridian. To use the diagram, draw a line downward from the given date; the line cuts the curved lines at the LMT of beginning and end of twilight, and cuts each diagonal line at the LMT corresponding to the LMST marked on the line. See pages 18 and 60 for definitions of LMT, LMST and astronomical twilight. (Diagram prepared by Randall Brooks.)



THE SKY MONTH BY MONTH

BY JOHN R. PERCY

Introduction—In the monthly descriptions of the sky on the following pages, the right ascension (RA), declination (Dec) (both at 0^h UT), time of transit at the Greenwich meridian (Tran), and magnitude (Mag) have been tabulated for seven planets for the 1st, 11th, and 21st day of each month. A more modern scale of visual magnitudes of the planets (approximating the photoelectric V system) has been introduced. Unless noted otherwise, the descriptive comments about the planets apply to the middle of the month. Estimates of altitude are for an observer in latitude 45°N. We hope that users of these pages find the new format useful and convenient.

The Sun—Data concerning the position, transit, orientation, rotation, activity, rise, and set of the Sun appear in the section beginning on page 50. For detailed information on solar eclipses during the year, see the section beginning on page 78.

The Moon—Its phases, perigee and apogee times and distances, and its conjunctions with the planets are given in the monthly tables. The perigee and apogee distances are taken from *Astronomical Tables of the Sun, Moon, and Planets* by Jean Meeus (Willmann-Bell, 1983). For times of moonrise and moonset, see p. 64.

Elongation, Age and Phase of the Moon—The *elongation* is the angular distance of the Moon from the Sun in degrees, counted eastward around the sky. Thus, elongations of 0°, 90°, 180°, and 270° correspond to new, first quarter, full, and last quarter moon. The *age* of the Moon is the time since the new moon phase. Because the Moon's orbital motion is not uniform, the age of the Moon does not accurately specify its phase. The Moon's elongation increases on the average by 12.2° per day, first quarter, full and last quarter phases corresponding approximately to 7.4, 14.8 and 22.1 days respectively.

The Sun's selenographic colongitude is essentially a convenient way of indicating the position of the sunrise terminator as it moves across the face of the Moon. It provides an accurate method of recording the exact conditions of illumination (angle of illumination), and makes it possible to observe the Moon under exactly the same lighting conditions at a later date. The Sun's selenographic colongitude is numerically equal to the selenographic longitude of the sunrise terminator reckoned eastward from the mean centre of the disk. Its value increases at the rate of nearly 12.2° per day or about ½° per hour; it is approximately 270°, 0°, 90° and 180° at New Moon, First Quarter, Full Moon and Last Quarter respectively. Values of the Sun's selenographic colongitude are given on the following pages for the first day of each month.

Sunrise will occur at a given point *east* of the central meridian of the Moon when the Sun's selenographic colongitude is equal to the eastern selenographic longitude of the point; at a point *west* of the central meridian when the Sun's selenographic colongitude is equal to 360° minus the western selenographic longitude of the point. The longitude of the sunset terminator differs by 180° from that of the sunrise terminator.

Libration is the shifting, or rather apparent shifting, of the visible disk of the Moon. Sometimes the observer sees features farther around the eastern or the western limb (libration in longitude), or the northern or southern limb (libration in latitude). When the libration in longitude is positive, the mean central point of the disk of the Moon is displaced eastward on the celestial sphere, exposing to view a region on the west limb. When the libration in latitude is positive, the mean central point of the disk of the Moon is displaced towards the south, and a region on the north limb is exposed to view.

The dates of the greatest positive and negative values of the libration in longitude and latitude are given in the following pages, as are the dates of greatest positive and negative declination.

The Moon's Orbit. In 1986, the ascending node of the Moon's orbit regresses from longitude 36° to 16° (Aries to Pisces).

The Planets—Further information in regard to the planets, including Pluto, is found on pp. 95–120. For the configurations of Jupiter's four Galilean satellites, see the monthly tables. In these diagrams, the central vertical band represents the equatorial diameter of the disk of Jupiter. Time is shown by the vertical scale, each horizontal line denoting 0^h Universal Time. (Be sure to convert to U.T. before using these diagrams.) The relative positions of the satellites at any time with respect to the disk of Jupiter are given by the four labelled curves (I, II, III, IV) (see p. 10 for the key to these Roman numerals). In constructing these diagrams, the positions of the satellites in the direction perpendicular to the equator of Jupiter are necessarily neglected. Note that the orientation is for an inverting telescope. Similar diagrams for the four brightest satellites of Saturn appear on pages 135–140. For the various transits, occultations, and eclipses of Jupiter's satellites, see p. 121.

Minima of Algol—The times of mid-eclipse are given in the monthly tables and are calculated from the ephemeris

$$\text{heliocentric minimum} = 2440953.4657 + 2.8673075\ E$$

and are expressed as geocentric times, for comparison with observations. (The first number in the equation is the Julian date corresponding to 1971 Jan. 1.9657, an Algol minimum. The second number is the period of Algol in days, and E is an integer.) We thank Roger W. Sinnott of *Sky and Telescope* for providing these times.

Occultations of Stars and Planets—For information about occultations of stars and planets visible in North America, see pp. 86–94 and 144.

ANNIVERSARIES AND FESTIVALS 1986

New Year's Day	Wed.	Jan.	1
Epiphany	Mon.	Jan.	6
Lincoln's Birthday (U.S.)	Wed.	Feb.	12
Ash Wednesday		Feb.	12
Valentine's Day	Fri.	Feb.	14
Washington's Birthday (U.S.)	Mon.	Feb.	17
St. David (Wales)	Sat.	Mar.	1
St. Patrick (Ireland)	Mon.	Mar.	17
Palm Sunday		Mar.	23
Good Friday		Mar.	28
Easter Sunday		Mar.	30
Astronomy Day	Sat.	Apr.	19
Birthday of Queen Elizabeth II (1926)	Mon.	Apr.	21
St. George (England)	Wed.	Apr.	23
First Day of Passover	Thur.	Apr.	24
Ascension Day	Thur.	May	8
First Day of Ramadân	Sat.	May	10
Mother's Day	Sun.	May	11
Whit Sunday – Pentecost		May	18
Victoria Day (Canada)	Mon.	May	19
Trinity Sunday		May	25

Memorial Day (U.S.)	Mon.	May	26
Feast of Weeks	Fri.	June	13
Father's Day	Sun.	June	15
Canada Day	Tues.	July	1
Independence Day (U.S.)	Fri.	July	4
Civic Holiday (Canada)	Mon.	Aug.	4
Labour Day	Mon.	Sept.	1
Islamic New Year	Sat.	Sept.	6
Jewish New Year	Sat.	Oct.	4
Thanksgiving Day (Canada)	Mon.	Oct.	13
Columbus Day (U.S.)	Mon.	Oct.	13
Day of Atonement	Mon.	Oct.	13
First Day of Tabernacles	Sat.	Oct.	18
Halloween	Fri.	Oct.	31
General Election Day (U.S.)	Tues.	Nov.	4
Remembrance Day (Canada)	Tues.	Nov.	11
Veterans' Day (U.S.)	Tues.	Nov.	11
Thanksgiving Day (U.S.)	Thur.	Nov.	27
St. Andrew (Scotland)	Sun.	Nov.	30
First Sunday in Advent		Nov.	30
Christmas Day	Thur.	Dec.	25

1986 and 1987 calendars are on the inside back cover.

THE SKY FOR JANUARY 1986

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	$17^{h}29^{m}$	$18^{h}25^{m}$	$14^{h}34^{m}$	$21^{h}24^{m}$	$16^{h}14^{m}$	$17^{h}14^{m}$	$18^{h}16^{m}$
	11	$18^{h}34^{m}$	$19^{h}20^{m}$	$14^{h}58^{m}$	$21^{h}32^{m}$	$16^{h}18^{m}$	$17^{h}17^{m}$	$18^{h}17^{m}$
	21	$19^{h}42^{m}$	$20^{h}14^{m}$	$15^{h}22^{m}$	$21^{h}41^{m}$	$16^{h}22^{m}$	$17^{h}19^{m}$	$18^{h}19^{m}$
Dec	1	-22°58'	-23°39'	-14°01'	-16°07'	-19°23'	-23°05'	-22°20'
	11	-24°06'	-22°53'	-15°53'	-15°26'	-19°33'	-23°08'	-22°19'
	21	-23°07'	-20°56'	-17°34'	-14°42'	-19°41'	-23°10'	-22°19'
Tran	1	$10^{h}49^{m}$	$11^{h}45^{m}$	$7^{h}52^{m}$	$14^{h}41^{m}$	$9^{h}31^{m}$	$10^{h}31^{m}$	$11^{h}32^{m}$
	11	$11^{h}14^{m}$	$12^{h}00^{m}$	$7^{h}37^{m}$	$14^{h}10^{m}$	$8^{h}56^{m}$	$9^{h}54^{m}$	$10^{h}55^{m}$
	21	$11^{h}44^{m}$	$12^{h}14^{m}$	$7^{h}21^{m}$	$13^{h}39^{m}$	$8^{h}21^{m}$	$9^{h}17^{m}$	$10^{h}17^{m}$
Mag	1	-0.4	-3.9	+1.4	-2.0	+0.5	+5.7	+8.0
	11	-0.5	-3.9	+1.4	-2.0	+0.5	+5.7	+8.0
	21	-0.8	-3.9	+1.3	-2.0	+0.6	+5.7	+8.0

The Moon—On Jan. 1.0 UT, the age of the Moon is 20.0 d. The Sun's selenographic colongitude is 150.44° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Jan. 14 (7°) and minimum (east limb exposed) on Jan. 27 (5°). The libration in latitude is maximum (north limb exposed) on Jan. 11 (7°) and minimum (south limb exposed) on Jan. 25 (7°). The Moon reaches its greatest northern declination on Jan. 23 (+28°) and its greatest southern declination on Jan. 9 (−28°).

Mercury was visible last month at dawn, very low in the southeast. This month, it moves progressively closer to the Sun and is therefore not visible (except with great difficulty early in the month). It is in superior conjunction on Feb. 1.

Venus is not visible this month. It is in superior conjunction on Jan. 19.

Mars, in Libra, rises about 5 h before the Sun, and is due south at sunrise. During 1986, this planet will be a source of constant interest to observers – as the following pages will demonstrate.

Jupiter, in Capricornus, is best seen early in the month, when it stands about 30° above the southwestern horizon at sunset. By the end of the month, it is too low to be easily seen.

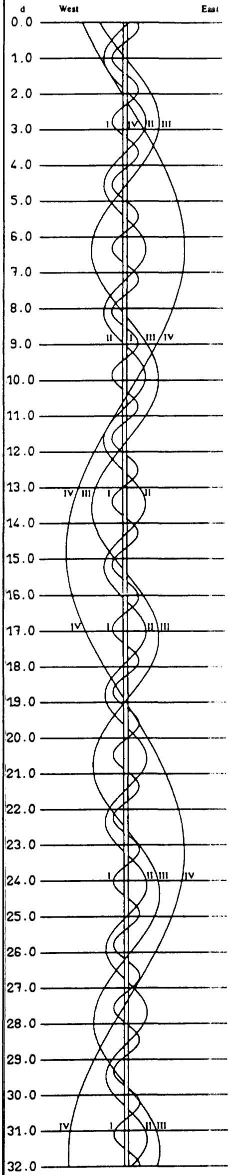
Saturn moves from Scorpius into Ophiuchus in mid-month. It rises about 3 h before the Sun, and is low in the southeast at sunrise. Throughout 1986, it remains about 7° north of Antares, which is redder and slightly fainter than the planet. During the first week of the month, watch the waning crescent moon as it passes Mars and Saturn as it closes in on the Sun.

Uranus is in Ophiuchus throughout 1986. Although there are many fainter stars in this region of the sky, the planet is easily visible in binoculars (if one knows where to look) and is actually visible to the unaided eye under good viewing conditions.

Neptune is in Sagittarius throughout 1986. Neptune is considerably more difficult to locate than Uranus, because it is much fainter and is in an even more densely populated part of the sky.

1986	d	h m	JANUARY UNIVERSAL TIME	Min. of Algol h m
Wed.	1			
Thu.	2	05	Earth at perihelion (147 096 400 km)	09 17
Fri.	3	19	Quadrantid meteors	
		19 47	☾ Last Quarter	
			Mercury at descending node	
Sat.	4			
Sun.	5			06 06
Mon.	6	01	Mars 1.7° N. of Moon	
Tue.	7	14	Saturn 4° N. of Moon	
Wed.	8	07	Moon at perigee (363 304 km)	02 55
		10	Mercury 1.7° S. of Neptune	
		12	Uranus 3° N. of Moon	
Thu.	9			
Fri.	10	12 22	● New Moon	23 45
Sat.	11			
Sun.	12	14	Jupiter 4° N. of Moon	
Mon.	13		Mercury at aphelion	20 34
Tue.	14			
Wed.	15			
Thu.	16	12	Vesta in conjunction with Sun	17 23
Fri.	17	22 13	☽ First Quarter	
Sat.	18			
Sun.	19	16	Venus in superior conjunction	14 12
		19	Ceres stationary	
Mon.	20	01	Moon at apogee (404 718 km)	
Tue.	21			
Wed.	22			11 02
Thu.	23			
Fri.	24			
Sat.	25			07 51
Sun.	26	00 31	○ Full Moon	
Mon.	27		Venus at aphelion	
Tue.	28			04 40
Wed.	29			
Thu.	30			
Fri.	31			01 29

Config. of Jupiter's Satellites



THE SKY FOR FEBRUARY 1986

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	20^h59^m	21^h11^m	15^h49^m	21^h51^m	16^h26^m	17^h21^m	18^h20^m
	11	22^h09^m	22^h00^m	16^h13^m	22^h01^m	16^h29^m	17^h23^m	18^h22^m
	21	23^h14^m	22^h48^m	16^h38^m	22^h10^m	16^h31^m	17^h25^m	18^h23^m
Dec	1	-19°15'	-17°38'	-19°12'	-13°51'	-19°49'	-23°12'	-22°18'
	11	-13°09'	-13°44'	-20°27'	-13°03'	-19°54'	-23°14'	-22°17'
	21	-5°10'	-9°13'	-21°30'	-12°13'	-19°57'	-23°16'	-22°16'
Tran	1	12^h17^m	12^h28^m	7^h05^m	13^h06^m	7^h41^m	8^h36^m	9^h35^m
	11	12^h48^m	12^h38^m	6^h50^m	12^h36^m	7^h05^m	7^h59^m	8^h57^m
	21	13^h12^m	12^h46^m	6^h35^m	12^h06^m	6^h27^m	7^h21^m	8^h19^m
Mag	1	-1.4	-3.9	+1.1	-2.0	+0.5	+5.7	+8.0
	11	-1.3	-3.9	+1.0	-2.0	+0.5	+5.7	+8.0
	21	-1.0	-3.9	+0.9	-2.0	+0.5	+5.7	+8.0

The Moon—On Feb. 1.0 UT, the age of the Moon is 21.5 d. The Sun's selenographic colongitude is 167.33° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Feb. 10 (5°) and minimum (east limb exposed) on Feb. 22 (5°). The libration in latitude is maximum (north limb exposed) on Feb. 7 (7°) and minimum (south limb exposed) on Feb. 22 (7°). The Moon reaches its greatest northern declination on Feb. 19 (+28°) and its greatest southern declination on Feb. 5 (−28°).

Mercury moves from superior conjunction on Feb. 1 to greatest elongation east (18°) on Feb. 28, at which time it stands about 15° above the southwestern horizon at sunset. This would be a more favourable elongation if it were not for the fact that the planet is at perihelion on Feb. 26, and is only 18° from the Sun. Note that, in these pages, references to favourable and unfavourable elongations apply to Northern Hemisphere observers only.

Venus is not visible this month.

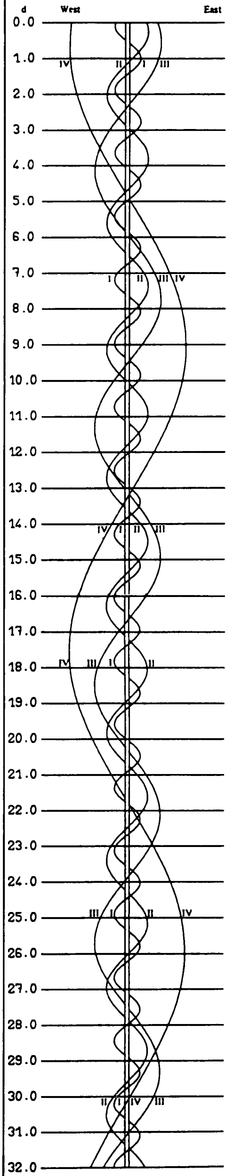
Mars spends an eventful month, moving from Libra through Scorpius into Ophiuchus. It passes between δ and β Sco (very close to the latter) on Feb. 6–7; these, along with Saturn and the waning crescent moon, make an impressive display in the pre-dawn sky. Then on Feb. 17–18, Mars passes 5° north of Antares and 1.3° south of Saturn. The three objects are comparable in brightness; Mars and Antares are slightly fainter and much redder. Mars continues to rise about 5 h before the Sun (see next month) and is due south at sunrise.

Jupiter, in Capricornus, may be visible with great difficulty early in the month, very low in the southwest at sunset. It is in conjunction with the Sun on Feb. 18.

Saturn, in Ophiuchus, rises about 5 h before the Sun, and is low in the south at sunrise. It passes 7° north of Antares on Feb. 10. (The separation of the two stars in the end of the bowl of the Big Dipper is 5°.) See also *Mars* above.

1986			FEBRUARY UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Sat.	1	01	Mercury in superior conjunction	
		18	Pallas stationary	
Sun.	2	04 41	☾ Last Quarter	22 19
			Mercury at greatest hel. lat. S.	
Mon.	3	12	Mars 3° N. of Moon	
Tue.	4	01	Saturn 5° N. of Moon	
		16	Moon at perigee (368 820 km)	
		22	Uranus 4° N. of Moon	
Wed.	5	20	Neptune 5° N. of Moon	19 08
			Comet Halley in conjunction with Sun	
Thu.	6			
Fri.	7			
Sat.	8			15 57
Sun.	9	00 55	● New Moon	
			Comet Halley at perihelion (0.59 A)	
Mon.	10	03	Saturn 7° N. of Antares	
Tue.	11			12 46
Wed.	12			
Thu.	13	21	Pluto stationary	
Fri.	14			09 36
Sat.	15			
Sun.	16	19 55	☽ First Quarter	
		22	Moon at apogee (404 256 km)	
Mon.	17	06	Mars 5° N. of Antares	06 25
Tue.	18	00	Mars 1.3° S. of Saturn	
		10	Jupiter in conjunction with Sun	
			Venus at greatest hel. lat. S.	
Wed.	19			
Thu.	20			03 15
Fri.	21		Mercury at ascending node	
Sat.	22			
Sun.	23			00 04
Mon.	24	15 02	○ Full Moon	
Tue.	25			20 53
Wed.	26		Mercury at perihelion	
Thu.	27	18	Ceres at opposition	
Fri.	28	16	Mercury at greatest elong. E. (18°)	17 42

Config. of Jupiter's Satellites



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THE SKY FOR MARCH 1986

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	23^h51^m	23^h25^m	16^h57^m	22^h17^m	16^h32^m	17^h25^m	18^h23^m
	11	23^h56^m	0^h10^m	17^h21^m	22^h26^m	16^h33^m	17^h26^m	18^h24^m
	21	23^h27^m	0^h56^m	17^h44^m	22^h35^m	16^h33^m	17^h27^m	18^h25^m
Dec	1	+0°48'	-5°19'	-22°10'	-11°33'	-19°59'	-23°16'	-22°16'
	11	+3°23'	-0°14'	-22°49'	-10°42'	-19°59'	-23°17'	-22°15'
	21	-0°36'	+4°54'	-23°16'	-9°52'	-19°58'	-23°18'	-22°14'
Tran	1	13^h16^m	12^h51^m	6^h23^m	11^h42^m	5^h57^m	6^h50^m	7^h48^m
	11	12^h39^m	12^h57^m	6^h07^m	11^h11^m	5^h19^m	6^h12^m	7^h10^m
	21	11^h31^m	13^h03^m	5^h51^m	10^h41^m	4^h40^m	5^h33^m	6^h31^m
Mag	1	-0.3	-3.9	+0.7	-2.0	+0.5	+5.7	+8.0
	11	+2.5	-3.9	+0.5	-2.0	+0.4	+5.6	+8.0
	21	+3.7	-3.9	+0.4	-2.0	+0.4	+5.6	+7.9

The Moon—On Mar. 1.0 UT, the age of the Moon is 20.0 d. The Sun's selenographic colongitude is 148.01° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Mar. 9 (5°) and minimum (east limb exposed) on Mar. 22 (6°). The libration in latitude is maximum (north limb exposed) on Mar. 7 (7°) and minimum (south limb exposed) on Mar. 21 (7°). The Moon reaches its greatest northern declination on Mar. 19 (+28°) and its greatest southern declination on Mar. 5 (−28°). There is an occultation of Antares by the Moon on Mar. 30, visible in northwest North America. This is the first of a series of such occultations in 1986, as the Moon's shifting orbit passes in front of this star.

Mercury is visible early in the month, very low in the southwest at sunset, but by mid-month, it is in inferior conjunction with the Sun. On Mar. 8, Mercury and Venus are in conjunction, but they are too close to the Sun to be seen at that time.

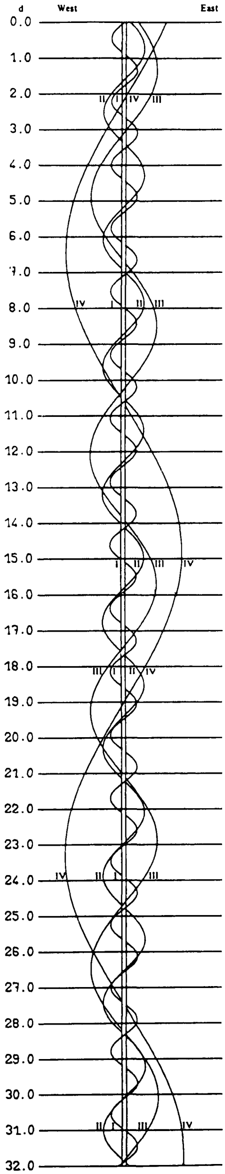
Venus moves progressively further from the Sun, and by the end of the month, it is visible very low in the west, just after sunset.

Mars moves from Ophiuchus into Sagittarius later in the month. It passes 0.3° north of Uranus on Mar. 13, providing an excellent opportunity for observers to locate the fainter planet. At the end of the month, Mars passes between the Lagoon and Trifid nebulae. It continues to rise about 5 h before the Sun, as it will for another three months. This situation arises because, although the Sun moves eastward more rapidly than Mars, it also moves northward, and so rises earlier each month.

Jupiter, in Aquarius, reappears in the morning sky and may be visible with great difficulty at the end of the month, very low in the southeast at sunrise.

Saturn, in Ophiuchus, rises at about midnight and is west of south by sunrise. On Mar. 30, the Moon passes between Saturn and Antares, and an occultation of the latter is visible in the northwest of North America. You can use Antares as a marker to follow Saturn's retrograde loop in the spring and early summer.

Uranus is 0.3° south of Mars on Mar. 13, and should be easy to locate at that time.

1986	d	h m	MARCH UNIVERSAL TIME	Min. of Algol h m	Config. of Jupiter's Satellites
Sat.	1	10	Moon at perigee (369 173 km)		
Sun.	2				
Mon.	3	08	Saturn 5° N. of Moon	14 32	
		12 17	☾ Last Quarter		
		20	Mars 4° N. of Moon		
Tue.	4	05	Uranus 4° N. of Moon		
Wed.	5	03	Neptune 6° N. of Moon		
Thu.	6	23	Mercury stationary	11 21	
Fri.	7				
Sat.	8	13	Mercury 5° N. of Venus		
			Mercury at greatest hel. lat. N.		
Sun.	9			08 10	
Mon.	10	14 52	● New Moon		
			Comet Halley at its descending node		
Tue.	11	15	Venus 1.3° N. of Moon		
Wed.	12			04 59	
Thu.	13	09	Mars 0.3° N. of Uranus		
Fri.	14				
Sat.	15			01 49	
Sun.	16	19	Moon at apogee (404 610 km)		
		20	Mercury in inferior conjunction		
Mon.	17			22 38	
Tue.	18	16 39	☽ First Quarter		
Wed.	19	14	Saturn stationary		
Thu.	20	22 03	Vernal equinox; spring begins	19 27	
Fri.	21				
Sat.	22				
Sun.	23			16 16	
Mon.	24				
Tue.	25				
Wed.	26	03 02	○ Full Moon	13 06	
			Mars at descending node		
Thu.	27	14	Uranus stationary		
Fri.	28	14	Moon at perigee (363 957 km)		
Sat.	29	06	Mercury stationary	09 55	
Sun.	30	13	Antares 1.2° S. of Moon; occultation[1]		
		15	Saturn 5° N. of Moon		
Mon.	31	11	Uranus 4° N. of Moon		

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[1]Visible in the N.W. of N. America

THE SKY FOR APRIL 1986

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	$23^{h}16^{m}$	$1^{h}46^{m}$	$18^{h}08^{m}$	$22^{h}44^{m}$	$16^{h}33^{m}$	$17^{h}27^{m}$	$18^{h}25^{m}$
	11	$23^{h}39^{m}$	$2^{h}33^{m}$	$18^{h}29^{m}$	$22^{h}53^{m}$	$16^{h}32^{m}$	$17^{h}26^{m}$	$18^{h}25^{m}$
	21	$0^{h}20^{m}$	$3^{h}22^{m}$	$18^{h}49^{m}$	$23^{h}00^{m}$	$16^{h}30^{m}$	$17^{h}26^{m}$	$18^{h}25^{m}$
Dec	1	-4°41'	+10°19'	-23°34'	-8°57'	-19°56'	-23°18'	-22°14'
	11	-4°18'	+14°49'	-23°41'	-8°09'	-19°52'	-23°18'	-22°13'
	21	-0°47'	+18°44'	-23°43'	-7°23'	-19°47'	-23°17'	-22°13'
Tran	1	$10^{h}38^{m}$	$13^{h}10^{m}$	$5^{h}32^{m}$	$10^{h}07^{m}$	$3^{h}56^{m}$	$4^{h}50^{m}$	$5^{h}48^{m}$
	11	$10^{h}23^{m}$	$13^{h}18^{m}$	$5^{h}13^{m}$	$9^{h}36^{m}$	$3^{h}15^{m}$	$4^{h}10^{m}$	$5^{h}09^{m}$
	21	$10^{h}25^{m}$	$13^{h}27^{m}$	$4^{h}53^{m}$	$9^{h}04^{m}$	$2^{h}34^{m}$	$3^{h}30^{m}$	$4^{h}29^{m}$
Mag	1	+1.2	-3.9	+0.1	-2.0	+0.3	+5.6	+7.9
	11	+0.5	-3.9	-0.1	-2.1	+0.3	+5.6	+7.9
	21	+0.2	-3.9	-0.3	-2.1	+0.2	+5.6	+7.9

The Moon—On Apr. 1.0 UT, the age of the Moon is 21.4 d. The Sun's selenographic colongitude is 165.59° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Apr. 5 (6°) and minimum (east limb exposed) on Apr. 19 (7°). The libration in latitude is maximum (north limb exposed) on Apr. 3 (7°) and Apr. 30 (7°) and minimum (south limb exposed) on Apr. 17 (7°). The Moon reaches its greatest northern declination on Apr. 15 (+28°) and its greatest southern declination on Apr. 1 (−28°) and Apr. 28 (−28°). A total eclipse of the Moon, visible in western North America, occurs on Apr. 24.

Mercury is at greatest elongation west (28°) on Apr. 13. It is at almost the maximum possible elongation from the Sun, because the planet was at aphelion on Apr. 11. Because of the shallow inclination of the ecliptic to the eastern horizon in spring, however, the planet is only 10° above the southeastern horizon at sunrise, and is visible only with the greatest difficulty.

Venus stands about 20° above the western horizon at sunset, and sets about 2 h later. Late in the month, it appears level with and to the right (north) of Aldebaran.

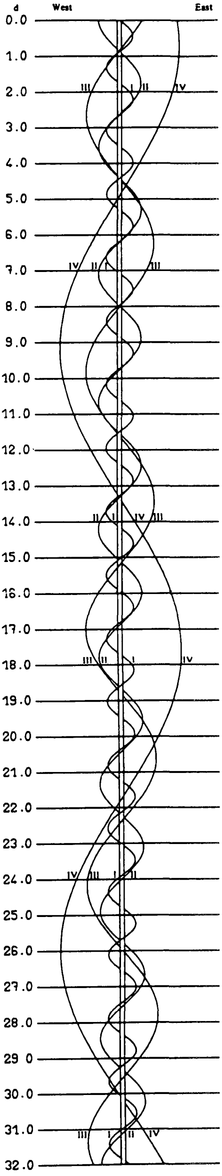
Mars, in Sagittarius, again provides a useful pointer to an outer planet: it passes 1.4° south of Neptune on Apr. 8. See also *Mars* in March.

Jupiter, in Aquarius, gradually moves higher in the southeastern sky at sunrise: from 12° at the beginning of the month to 20° at the end. It passes about 0.5° south of λ Aqr on Apr. 10.

Saturn, in Ophiuchus, rises about 3.5 h after sunset, and is low in the southwest by sunrise. It passes 7° north of Antares (in retrograde motion) on Apr. 26.

Neptune is 1.4° north of Mars on Apr. 8. This provides a useful opportunity to try to locate the planet.

Pluto is at opposition on Apr. 26.

1986			APRIL UNIVERSAL TIME	Min. of Algol	Config. of Jupiter's Satellites
	d	h m		h m	
Tue.	1	03	Mars 5° N. of Moon	06 44	
		09	Neptune 6° N. of Moon		
		19 30	☾ Last Quarter		
			Mercury at descending node		
Wed.	2				
Thu.	3				
Fri.	4			03 33	
Sat.	5				
Sun.	6	02	Jupiter 3° N. of Moon		
		08	Juno stationary		
		21	Mercury 2° N. of Moon		
Mon.	7	12	Neptune stationary	00 23	
Tue.	8	22	Mars 1.4° S. of Neptune		
Wed.	9	06 08	● New Moon; eclipse of Sun, pg. 78	21 12	
Thu.	10		Comet Halley at greatest dec. S. (−48°)		
Fri.	11	02	Venus 1.3° S. of Moon		
			Mercury at aphelion		
			Comet Halley closest to Earth (0.42 A)		
Sat.	12			18 01	
Sun.	13	12	Moon at apogee (405 519 km)		
		15	Mercury at greatest elong. W. (28°)		
Mon.	14				
Tue.	15		Venus at ascending node	14 50	
Wed.	16				
Thu.	17	10 35	☽ First Quarter		
			Comet Halley at opposition		
Fri.	18			11 39	
Sat.	19	23	Ceres stationary		
Sun.	20				
Mon.	21			08 28	
Tue.	22	15	Lyrid meteors		
Wed.	23				
Thu.	24	12 46	○ Full Moon; eclipse of Moon, pg. 78	05 17	
Fri.	25	18	Moon at perigee (359 352 km)		
Sat.	26	13	Pluto at opposition		
		21	Saturn 5° N. of Moon		
		21	Antares 1.1° S. of Moon; occultation[1]		
		22	Saturn 7° N. of Antares		
Sun.	27	18	Uranus 4° N. of Moon	02 06	
Mon.	28	16	Neptune 6° N. of Moon		
Tue.	29	06	Mars 4° N. of Moon	22 55	
Wed.	30				

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[1] Visible in N. and Central Asia

THE SKY FOR MAY 1986

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	1^h13^m	4^h12^m	19^h06^m	23^h08^m	16^h28^m	17^h25^m	18^h24^m
	11	2^h19^m	5^h04^m	19^h21^m	23^h14^m	16^h25^m	17^h23^m	18^h24^m
	21	3^h39^m	5^h57^m	19^h32^m	23^h20^m	16^h22^m	17^h22^m	18^h23^m
Dec	1	$+4^\circ59'$	$+21^\circ49'$	$-23^\circ44'$	$-6^\circ40'$	$-19^\circ41'$	$-23^\circ17'$	$-22^\circ13'$
	11	$+12^\circ10'$	$+23^\circ56'$	$-23^\circ46'$	$-6^\circ01'$	$-19^\circ35'$	$-23^\circ16'$	$-22^\circ14'$
	21	$+19^\circ33'$	$+24^\circ55'$	$-23^\circ56'$	$-5^\circ26'$	$-19^\circ28'$	$-23^\circ14'$	$-22^\circ14'$
Tran	1	10^h40^m	13^h38^m	4^h31^m	8^h32^m	1^h53^m	2^h50^m	3^h49^m
	11	11^h06^m	13^h51^m	4^h06^m	7^h59^m	1^h11^m	2^h09^m	3^h09^m
	21	11^h48^m	14^h04^m	3^h38^m	7^h26^m	0^h28^m	1^h28^m	2^h29^m
Mag	1	-0.2	-3.9	-0.6	-2.2	+0.1	+5.5	+7.9
	11	-0.9	-3.9	-0.9	-2.2	+0.1	+5.5	+7.9
	21	-2.0	-3.9	-1.2	-2.3	0.0	+5.5	+7.9

The Moon—On May 1.0 UT, the age of the Moon is 21.7 d. The Sun's selenographic colongitude is 171.52° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on May 2 (7°) and May 30 (8°) and minimum (east limb exposed) on May 18 (8°). The libration in latitude is maximum (north limb exposed) on May 27 (7°) and minimum (south limb exposed) on May 14 (7°). The Moon reaches its greatest northern declination on May 12 (+28°) and its greatest southern declination on May 26 (−28°). There is an occultation of Antares by the Moon on May 24, visible from western and central North America.

Mercury is not visible this month. It is in superior conjunction with the Sun on May 23.

Venus stands about 20° above the western horizon at sunset, and sets about 2 h later. It passes 6° north of Aldebaran on May 5.

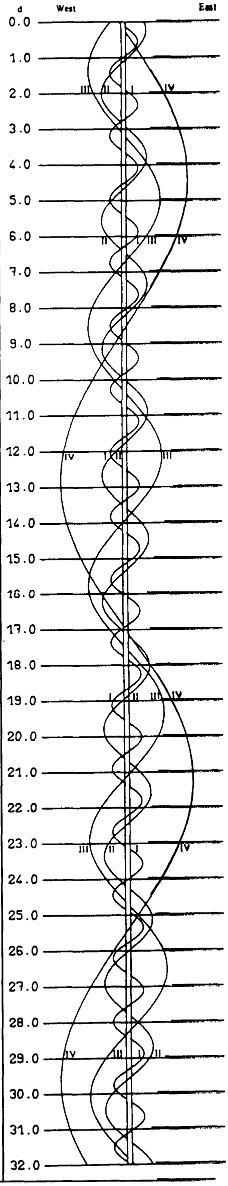
Mars, in Sagittarius, continues to rise about 5 h before the Sun, and is due south by sunrise.

Jupiter, in Aquarius, continues to move higher in the southeastern sky at sunrise: from 20° at the beginning of the month to 31° at the end. This improvement is due to the increasing elongation of Jupiter from the Sun, and the increasing angle between the ecliptic and the eastern horizon at sunrise.

Saturn moves from Ophiuchus into Scorpius late in the month. It is at opposition on May 28, at which time it rises at about sunset and is visible throughout the night.

1986			MAY UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Thu.	1	03 22	☾ Last Quarter	
			Mercury at greatest hel. lat. S.	
Fri.	2			19 44
Sat.	3	18	Jupiter 3° N. of Moon	
Sun.	4	03	Vesta 0.9° S. of Moon; occultation	
		19	Eta Aquarid meteors	
Mon.	5	11	Venus 6° N. of Aldebaran	16 33
Tue.	6			
Wed.	7	11	Mercury 2° S. of Moon	
Thu.	8	22 10	● New Moon	13 22
Fri.	9			
Sat.	10	23	Moon at apogee (406 328 km)	
Sun.	11	11	Venus 3° S. of Moon	10 11
Mon.	12			
Tue.	13			
Wed.	14			07 00
Thu.	15			
Fri.	16			
Sat.	17	01 00	☽ First Quarter	03 49
Sun.	18			
Mon.	19		Venus at perihelion	
Tue.	20		Mercury at ascending node	00 38
Wed.	21			
Thu.	22			21 27
Fri.	23	01	Mercury in superior conjunction	
		20 45	○ Full Moon	
Sat.	24	03	Moon at perigee (357 096 km)	
		05	Saturn 5° N. of Moon	
		08	Antares 1.2° S. of Moon; occultation[1]	
Sun.	25	03	Uranus 4° N. of Moon	18 16
			Mercury at perihelion	
Mon.	26	00	Neptune 6° N. of Moon	
Tue.	27	03	Mars 3° N. of Moon	
Wed.	28	01	Saturn at opposition	15 05
Thu.	29			
Fri.	30	12 55	☾ Last Quarter	
		16	Juno at opposition	
Sat.	31	08	Jupiter 2° N. of Moon	11 54

Config. of Jupiter's Satellites



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[1] Visible in W. and Central N. America

THE SKY FOR JUNE 1986

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	5^h20^m	6^h55^m	19^h40^m	23^h26^m	16^h18^m	17^h20^m	18^h22^m
	11	6^h43^m	7^h47^m	19^h42^m	23^h30^m	16^h15^m	17^h18^m	18^h21^m
	21	7^h45^m	8^h36^m	19^h39^m	23^h33^m	16^h13^m	17^h16^m	18^h20^m
Dec	1	+24°48'	+24°37'	-24°21'	-4°54'	-19°20'	-23°13'	-22°14'
	11	+25°09'	+23°09'	-25°00'	-4°30'	-19°14'	-23°11'	-22°15'
	21	+22°31'	+20°38'	-25°52'	-4°13'	-19°08'	-23°09'	-22°15'
Tran	1	12^h46^m	14^h19^m	3^h03^m	6^h48^m	23^h38^m	0^h43^m	1^h45^m
	11	13^h28^m	14^h31^m	2^h26^m	6^h13^m	22^h55^m	0^h02^m	1^h05^m
	21	13^h50^m	14^h41^m	1^h43^m	5^h36^m	22^h13^m	23^h17^m	0^h24^m
Mag	1	-1.3	-4.0	-1.5	-2.3	0.0	+5.5	+7.9
	11	-0.4	-4.0	-1.9	-2.4	+0.1	+5.5	+7.9
	21	+0.3	-4.0	-2.2	-2.4	+0.1	+5.5	+7.9

The Moon—On June 1.0 UT, the age of the Moon is 23.1 d. The Sun's selenographic colongitude is 190.11° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on June 27 (8°) and minimum (east limb exposed) on June 15 (7°). The libration in latitude is maximum (north limb exposed) on June 23 (7°) and minimum (south limb exposed) on June 11 (7°). The Moon reaches its greatest northern declination on June 9 (+28°) and its greatest southern declination on June 22 (−28°).

Mercury is visible late in the month, low in the west at sunset. It is at greatest elongation east (25°) on June 25. At that time, Mercury and Venus make a striking display with Castor and Pollux at sunset. The two stars are about 23° above the horizon (Pollux to the south), Venus is a few degrees further south, and Mercury is a few degrees closer to the horizon.

Venus stands about 23° above the western horizon at sunset, and sets about 2.5 h later. See also *Mercury* above.

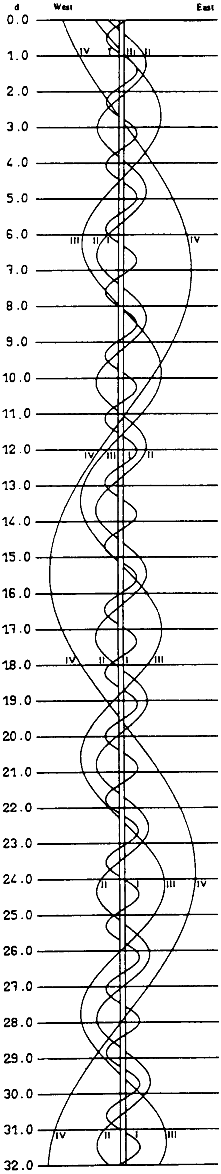
Mars, in Sagittarius, now rises about 2 h after sunset, and is low in the southwest by sunrise. Throughout the summer, you can follow its retrograde loop in the constellation Sagittarius. As it begins its retrograde motion and approaches opposition in early July, it becomes rapidly brighter and more conspicuous.

Jupiter, nearing the border of Aquarius and Pisces, rises at about midnight and is due south by sunrise.

Saturn, in Scorpius (near β Sco), is rising in the southeast at sunset and is visible low in the south for most of the night.

Uranus is at opposition on June 11.

Neptune is at opposition on June 26.

1986			JUNE UNIVERSAL TIME	Min. of Algol	Config. of Jupiter's Satellites
	d	h m		h m	
Sun.	1				
Mon.	2				
Tue.	3			08 42	
Wed.	4		Mercury at greatest hel. lat. N.		
Thu.	5				
Fri.	6			05 31	
Sat.	7	02	Moon at apogee (406 562 km)		
		14 00	● New Moon		
Sun.	8				
Mon.	9	06	Mercury 3° S. of Moon	02 20	
Tue.	10	00	Mars stationary		
			Venus at greatest hel. lat. N.		
		14	Venus 5° S. of Pollux		
		16	Venus 3° S. of Moon		
Wed.	11	15	Uranus at opposition	23 09	
Thu.	12				
Fri.	13				
Sat.	14			19 58	
Sun.	15	12 00	☽ First Quarter		
Mon.	16				
Tue.	17			16 46	
Wed.	18				
Thu.	19				
Fri.	20	13	Saturn 5° N. of Moon	13 35	
		19	Antares 1.1° S. of Moon; occultation[1]		
		23	Mercury 6° S. of Pollux		
Sat.	21	12	Uranus 4° N. of Moon		
		13	Moon at perigee (357 668 km)		
		16 30	Summer solstice; summer begins		
Sun.	22	03 42	○ Full Moon		
		10	Neptune 6° N. of Moon		
Mon.	23	13	Mars 0.5° N. of Moon; occultation[2]	10 24	
Tue.	24				
Wed.	25	20	Mercury at greatest elong. E. (25°)		
Thu.	26	08	Neptune at opposition	07 13	
Fri.	27	20	Jupiter 1.9° N. of Moon		
Sat.	28		Mercury at descending node		
Sun.	29	00 53	☾ Last Quarter	04 01	
Mon.	30				

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[1] Visible in N. and Central Asia

[2] Visible in S.W. Australia, Tasmania, S. New Zealand and Antarctica

THE SKY FOR JULY 1986

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	8^h22^m	9^h23^m	19^h31^m	23^h35^m	16^h10^m	17^h15^m	18^h19^m
	11	8^h32^m	10^h08^m	19^h19^m	23^h36^m	16^h08^m	17^h13^m	18^h17^m
	21	8^h13^m	10^h50^m	19^h06^m	23^h35^m	16^h07^m	17^h12^m	18^h16^m
Dec	1	+18°47'	+17°14'	-26°52'	-4°04'	-19°03'	-23°08'	-22°16'
	11	+15°43'	+13°10'	-27°48'	-4°01'	-19°00'	-23°06'	-22°17'
	21	+14°58'	+8°36'	-28°27'	-4°06'	-18°58'	-23°05'	-22°17'
Tran	1	13^h47^m	14^h48^m	0^h56^m	4^h59^m	21^h31^m	22^h36^m	23^h40^m
	11	13^h15^m	14^h53^m	0^h04^m	4^h21^m	20^h50^m	21^h55^m	22^h59^m
	21	12^h15^m	14^h56^m	23^h08^m	3^h41^m	20^h09^m	21^h14^m	22^h19^m
Mag	1	+0.9	-4.0	-2.5	-2.5	+0.2	+5.5	+7.9
	11	+2.1	-4.1	-2.6	-2.6	+0.3	+5.5	+7.9
	21	+4.5	-4.1	-2.6	-2.7	+0.3	+5.5	+7.9

The Moon—On July 1.0 UT, the age of the Moon is 23.4 d. The Sun's selenographic colongitude is 196.73° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on July 25 (7°) and minimum (east limb exposed) on July 13 (6°). The libration in latitude is maximum (north limb exposed) on July 21 (7°) and minimum (south limb exposed) on July 8 (7°). The Moon reaches its greatest northern declination on July 6 (+28°) and its greatest southern declination on July 19 (−28°). There is an occultation of Antares by the Moon on July 18, visible in North America.

Mercury is visible early in the month, very low in the west at sunset. By the end of the month, it has passed through inferior conjunction (July 23) and is no longer visible.

Venus stands about 20° above the western horizon at sunset, and sets about 2 h later. It passes 1.1° north of Regulus on July 11.

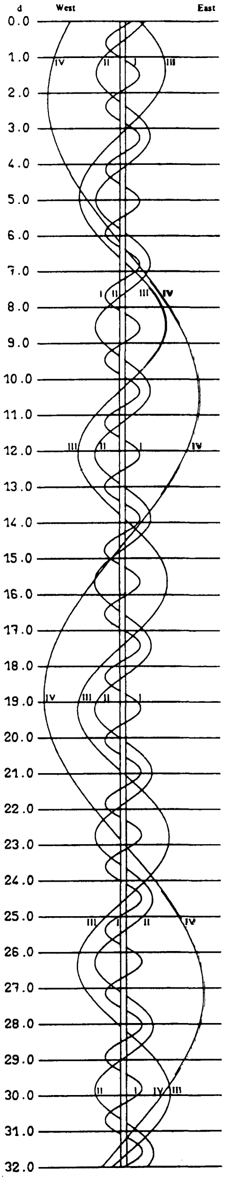
Mars is a brilliant (−2.6) object in Sagittarius, rising at sunset and setting at sunrise. It is at opposition on July 10 and is at its closest to Earth (0.404 A) on July 16. This is close to the minimum possible separation of Earth and Mars (0.375 A), so this is a favourable opposition.

Jupiter, in Aquarius, rises in the east in the early evening and is west of south by sunrise. It is stationary on July 13; you can use the great square of Pegasus as a marker to follow the planet's retrograde loop in the late summer and fall.

Saturn, in Scorpius (near β Sco), is east of south at sunset and sets about 5 h later.

1986			JULY UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Tue.	1			
Wed.	2			00 50
Thu.	3			
Fri.	4	08	Moon at apogee (406 103 km)	21 38
Sat.	5	10	Earth at aphelion (152 102 800 km)	
Sun.	6			
Mon.	7	04 55	● New Moon	18 27
Tue.	8	20	Mercury 8° S. of Moon	
			Mercury at aphelion	
Wed.	9	01	Mercury stationary	
Thu.	10	05	Mars at opposition	15 16
		17	Venus 3° S. of Moon	
Fri.	11	01	Venus 1.1° N. of Regulus	
Sat.	12			
Sun.	13	09	Jupiter stationary	12 04
Mon.	14	20 10	☽ First Quarter	
Tue.	15			
Wed.	16	11	Mars closest approach (60 370 000 km)	08 53
Thu.	17	20	Saturn 5° N. of Moon	
Fri.	18	04	Antares 1.0° S. of Moon; occultation[1]	
		20	Uranus 4° N. of Moon	
Sat.	19	19	Neptune 6° N. of Moon	05 42
		20	Moon at perigee (360 847 km)	
Sun.	20	13	Mars 0.9° S. of Moon; occultation[2]	
Mon.	21	10	Pluto stationary	
		10 40	○ Full Moon	
Tue.	22			02 30
Wed.	23	11	Mercury in inferior conjunction	
Thu.	24			23 19
Fri.	25	06	Jupiter 1.5° N. of Moon	
Sat.	26			
Sun.	27			20 07
Mon.	28	15 34	☾ Last Quarter	
		21	S. Delta Aquarid meteors	
			Mercury at greatest hel. lat. S.	
Tue.	29	18	Juno stationary	
Wed.	30			16 56
Thu.	31	21	Moon at apogee (405 165 km)	

Config. of Jupiter's Satellites



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[1] Visible in N. America

[2] Visible in E. Asia

THE SKY FOR AUGUST 1986

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	$7^{h}49^{m}$	$11^{h}33^{m}$	$18^{h}56^{m}$	$23^{h}34^{m}$	$16^{h}06^{m}$	$17^{h}11^{m}$	$18^{h}15^{m}$
	11	$8^{h}04^{m}$	$12^{h}11^{m}$	$18^{h}52^{m}$	$23^{h}31^{m}$	$16^{h}06^{m}$	$17^{h}10^{m}$	$18^{h}14^{m}$
	21	$9^{h}01^{m}$	$12^{h}48^{m}$	$18^{h}54^{m}$	$23^{h}27^{m}$	$16^{h}06^{m}$	$17^{h}09^{m}$	$18^{h}14^{m}$
Dec	1	+16°59'	+3°14'	-28°43'	-4°21'	-18°58'	-23°03'	-22°18'
	11	+18°53'	-1°45'	-28°35'	-4°41'	-19°00'	-23°02'	-22°19'
	21	+17°49'	-6°40'	-28°12'	-5°07'	-19°04'	-23°02'	-22°19'
Tran	1	$11^{h}09^{m}$	$14^{h}56^{m}$	$22^{h}14^{m}$	$2^{h}56^{m}$	$19^{h}25^{m}$	$20^{h}30^{m}$	$21^{h}34^{m}$
	11	$10^{h}47^{m}$	$14^{h}55^{m}$	$21^{h}32^{m}$	$2^{h}14^{m}$	$18^{h}46^{m}$	$19^{h}50^{m}$	$20^{h}54^{m}$
	21	$11^{h}07^{m}$	$14^{h}51^{m}$	$20^{h}55^{m}$	$1^{h}31^{m}$	$18^{h}07^{m}$	$19^{h}10^{m}$	$20^{h}14^{m}$
Mag	1	+2.5	-4.2	-2.3	-2.8	+0.4	+5.6	+7.9
	11	+0.2	-4.2	-2.2	-2.8	+0.4	+5.6	+7.9
	21	-1.0	-4.3	-1.9	-2.9	+0.5	+5.6	+7.9

The Moon—On Aug. 1.0 UT, the age of the Moon is 24.8 d. The Sun's selenographic colongitude is 215.61° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Aug. 22 (6°) and minimum (east limb exposed) on Aug. 9 (5°). The libration in latitude is maximum (north limb exposed) on Aug. 17 (7°) and minimum (south limb exposed) on Aug. 4 (7°) and Aug. 31 (7°). The Moon reaches its greatest northern declination on Aug. 2 (+28°) and Aug. 29 (+28°) and its greatest southern declination on Aug. 16 (−28°).

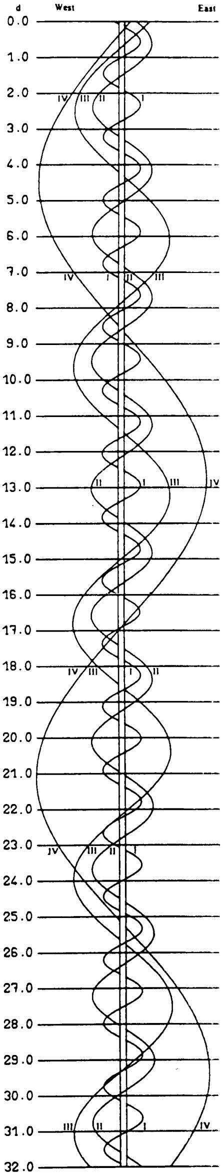
Mercury is visible around the middle of the month, very low in the east at sunrise. It is at greatest elongation west (19°) on Aug. 11. The greatest elongation is rather smaller than average, because the planet is close to perihelion, but this is partially offset by the favourable geometry of the ecliptic and horizon.

Venus is at greatest elongation east (46°) on Aug. 27, but the geometry is distinctly *unfavourable*, and the planet is only about 17° above the southwestern horizon at sunset; it sets about 2 h later. It passes 0.5° south of Spica on Aug. 31.

Mars, in Sagittarius, is east of south at sunset, and sets about 6 h later. This situation will persist through December because, although Mars moves eastward more slowly than the Sun, sunset occurs earlier every month.

Jupiter, in Aquarius, rises in the east shortly after sunset, and is visible throughout the rest of the night.

Saturn, in Scorpius (near β Sco), is to the west of south at sunset, and sets about 4 h later. As a result of the shallow angle between the ecliptic and the western horizon, the planet is rather low in the sky.

1986			AUGUST UNIVERSAL TIME	Min. of Algol	Config. of Jupiter's Satellites
	d	h m		h m	
Fri.	1				
Sat.	2	15	Mercury stationary	13 45	
Sun.	3				
Mon.	4	06	Mercury 8° S. of Moon		
Tue.	5	18 36	● New Moon	10 33	
			Venus at descending node		
Wed.	6				
Thu.	7	16	Saturn stationary		
Fri.	8			07 22	
Sat.	9	11	Venus 2° S. of Moon		
Sun.	10				
Mon.	11	16	Mercury at greatest elong. W. (19°)	04 10	
Tue.	12	12	Mars stationary		
		12	Perseid meteors		
Wed.	13	02 21	☽ First Quarter		
Thu.	14	02	Saturn 5° N. of Moon	00 59	
		11	Antares 0.8° S. of Moon; occultation[1]		
Fri.	15	03	Uranus 4° N. of Moon		
Sat.	16	03	Neptune 6° N. of Moon	21 47	
		16	Mars 0.5° S. of Moon; occultation[2]		
		17	Moon at perigee (365 720 km)		
			Mercury at ascending node		
Sun.	17				
Mon.	18				
Tue.	19	18 54	○ Full Moon	18 36	
		22	Vesta stationary		
Wed.	20				
Thu.	21	11	Jupiter 1.4° N. of Moon		
			Mercury at perihelion		
Fri.	22			15 24	
Sat.	23				
Sun.	24				
Mon.	25			12 13	
Tue.	26				
Wed.	27	08 38	☾ Last Quarter		
		09	Venus at greatest elong. E. (46°)		
		21	Uranus stationary		
Thu.	28	15	Moon at apogee (404 380 km)	09 02	
Fri.	29				
Sat.	30		Mars at greatest hel. lat. S.		
Sun.	31	15	Venus 0.5° S. of Spica	05 50	
			Mercury at greatest hel. lat. N.		

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[1] Visible in E. Europe, Asia, Philippines

[2] Visible in N.E. and Central Africa, S. Asia

THE SKY FOR SEPTEMBER 1986

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	$10^{h}25^{m}$	$13^{h}26^{m}$	$19^{h}03^{m}$	$23^{h}23^{m}$	$16^{h}08^{m}$	$17^{h}09^{m}$	$18^{h}13^{m}$
	11	$11^{h}35^{m}$	$13^{h}58^{m}$	$19^{h}16^{m}$	$23^{h}18^{m}$	$16^{h}09^{m}$	$17^{h}10^{m}$	$18^{h}13^{m}$
	21	$12^{h}37^{m}$	$14^{h}27^{m}$	$19^{h}34^{m}$	$23^{h}13^{m}$	$16^{h}12^{m}$	$17^{h}10^{m}$	$18^{h}13^{m}$
Dec	1	+11°49'	-11°47'	-27°32'	-5°40'	-19°10'	-23°02'	-22°20'
	11	+4°10'	-16°00'	-26°43'	-6°12'	-19°18'	-23°02'	-22°20'
	21	-3°37'	-19°37'	-25°41'	-6°43'	-19°26'	-23°03'	-22°21'
Tran	1	$11^{h}47^{m}$	$14^{h}46^{m}$	$20^{h}21^{m}$	$0^{h}43^{m}$	$17^{h}25^{m}$	$18^{h}27^{m}$	$19^{h}31^{m}$
	11	$12^{h}18^{m}$	$14^{h}39^{m}$	$19^{h}56^{m}$	$23^{h}54^{m}$	$16^{h}48^{m}$	$17^{h}48^{m}$	$18^{h}51^{m}$
	21	$12^{h}40^{m}$	$14^{h}28^{m}$	$19^{h}34^{m}$	$23^{h}10^{m}$	$16^{h}11^{m}$	$17^{h}09^{m}$	$18^{h}12^{m}$
Mag	1	-1.6	-4.4	-1.7	-2.9	+0.5	+5.6	+7.9
	11	-1.3	-4.5	-1.4	-2.9	+0.5	+5.6	+7.9
	21	-0.6	-4.5	-1.2	-2.9	+0.6	+5.6	+7.9

The Moon—On Sept. 1.0 UT, the age of the Moon is 26.2 d. The Sun's selenographic colongitude is 234.28° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Sept. 18 (5°) and minimum (east limb exposed) on Sept. 4 (5°). The libration in latitude is maximum (north limb exposed) on Sept. 13 (7°) and minimum (south limb exposed) on Sept. 27 (7°). The Moon reaches its greatest northern declination on Sept. 26 (+28°) and its greatest southern declination on Sept. 12 (−28°).

Mercury is not visible this month. It is in superior conjunction on Sept. 5. It passes 1.5° north of Spica on Sept. 29.

Venus is visible very low in the southwest at sunset, and sets about 1.5 h later. It approaches greatest brilliancy (−4.6) at the end of the month. Early in the month, the waxing crescent moon moves eastward past Venus (Sept. 7), Saturn and Antares (Sept. 10).

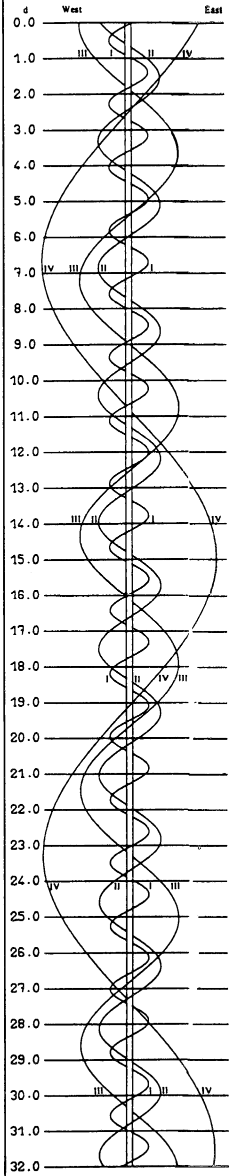
Mars, in Saggittarius, is east of south at sunset, and sets about 6 h later. It passes perihelion on Sept. 25. It becomes rapidly fainter during the fall.

Jupiter, in Aquarius, is at opposition on Sept. 10. It rises at about sunset and is visible throughout the night.

Saturn, in Scorpius, stands about 25° above the southwestern horizon at sunset, and sets about 3 h later.

1986			SEPTEMBER UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Mon.	1			
Tue.	2			
Wed.	3			02 39
Thu.	4	07 10	● New Moon	
Fri.	5	18	Mercury in superior conjunction	23 27
Sat.	6			
Sun.	7	20	Venus 3° S. of Moon	
Mon.	8		Venus at aphelion	20 16
Tue.	9			
Wed.	10	09	Saturn 5° N. of Moon	
		17	Antares 0.7° S. of Moon; occultation[1]	
		21	Jupiter at opposition	
Thu.	11	07 41	☽ First Quarter	17 04
		09	Uranus 4° N. of Moon	
Fri.	12	00	Moon at perigee (369 753 km)	
		08	Neptune 6° N. of Moon	
Sat.	13	10	Mars 0.9° N. of Moon; occultation[2]	
Sun.	14	19	Neptune stationary	13 53
Mon.	15			
Tue.	16			
Wed.	17	14	Jupiter 1.6° N. of Moon	10 41
			Comet Halley in conjunction with Sun	
Thu.	18	05 34	○ Full Moon; Harvest Moon	
Fri.	19			
Sat.	20			07 30
Sun.	21			
Mon.	22			
Tue.	23	07 59	Autumnal equinox; autumn begins	04 19
		15	Pallas in conjunction with the Sun	
Wed.	24		Mercury at descending node	
Thu.	25	10	Moon at apogee (404 333 km)	
			Mars at perihelion	
Fri.	26	03 17	☾ Last Quarter	01 07
Sat.	27			
Sun.	28			21 56
Mon.	29	08	Mercury 1.5° N. of Spica	
Tue.	30			

Config. of Jupiter's Satellites



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[1] Visible in S.W. and W. Europe, N. and Central Africa, S.W. Asia

[2] Visible in Antarctica

THE SKY FOR OCTOBER 1986

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	13^h34^m	14^h49^m	19^h54^m	23^h08^m	16^h15^m	17^h11^m	18^h13^m
	11	14^h26^m	15^h02^m	20^h16^m	23^h04^m	16^h19^m	17^h13^m	18^h14^m
	21	15^h13^m	15^h01^m	20^h40^m	23^h02^m	16^h23^m	17^h15^m	18^h15^m
Dec	1	-10°40'	-22°26'	-24°25'	-7°10'	-19°36'	-23°05'	-22°21'
	11	-16°36'	-24°09'	-22°55'	-7°33'	-19°47'	-23°06'	-22°21'
	21	-20°55'	-24°19'	-21°08'	-7°49'	-19°58'	-23°08'	-22°22'
Tran	1	12^h57^m	14^h10^m	19^h15^m	22^h27^m	15^h35^m	16^h31^m	17^h33^m
	11	13^h10^m	13^h43^m	18^h58^m	21^h43^m	14^h59^m	15^h53^m	16^h54^m
	21	13^h17^m	13^h02^m	18^h42^m	21^h01^m	14^h24^m	15^h16^m	16^h15^m
Mag	1	-0.3	-4.6	-0.9	-2.9	+0.6	+5.7	+7.9
	11	-0.1	-4.6	-0.8	-2.8	+0.6	+5.7	+7.9
	21	-0.1	-4.4	-0.5	-2.8	+0.6	+5.7	+8.0

The Moon—On Oct. 1.0 UT, the age of the Moon is 26.7 d. The Sun's selenographic colongitude is 240.34° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Oct. 15 (6°) and minimum (east limb exposed) on Oct. 1 (5°) and Oct. 29 (6°). The libration in latitude is maximum (north limb exposed) on Oct. 10 (7°) and minimum (south limb exposed) on Oct. 24 (7°). The Moon reaches its greatest northern declination on Oct. 23 (+28°) and its greatest southern declination on Oct. 9 (−28°). There is an occultation of Antares by the Moon on Oct. 7, visible from western North America (among other places). There is also a total eclipse of the Moon on Oct. 17, but it is not visible from North America.

Mercury is at greatest elongation east (24°) on Oct. 21, but even at that time, it is only a few degrees above the southwestern horizon at sunset, and is effectively not visible.

Venus is at greatest brilliancy (−4.6) on Oct. 1, but is too close to the horizon at sunset to be easily visible. The unfavourable geometry of the ecliptic and the western horizon at sunset is accentuated by the fact that on Oct. 1, Venus is at its greatest heliocentric latitude south and, as seen from Earth, is a full 8° south of the ecliptic!

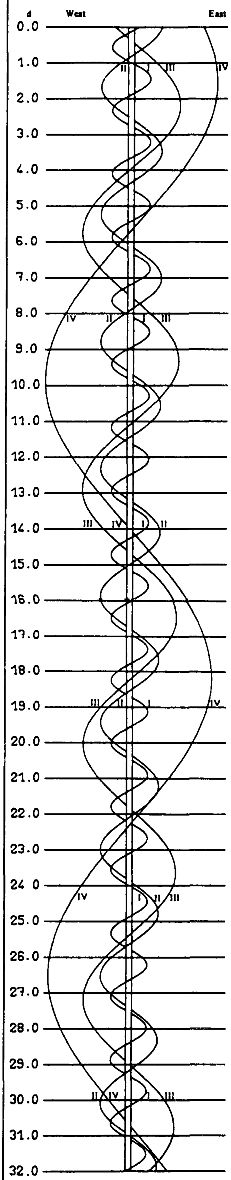
Mars moves from Sagittarius into Capricornus early in the month. It is east of south at sunset, and sets about 6 h later.

Jupiter, in Aquarius, is rising in the east at sunset, and is visible throughout most of the rest of the night.

Saturn moves from Scorpius into Ophiuchus in mid-month. It may be visible with great difficulty, low in the southwest at sunset.

1986	d	h m	OCTOBER UNIVERSAL TIME	Min. of Algol h m
Wed.	1	10	Venus at greatest brilliancy (−4.6)	18 44
			Venus at greatest hel. lat. S.	
Thu.	2			
Fri.	3	06	Vesta at opposition	
		18 55	● New Moon; eclipse of Sun, pg. 78	
Sat.	4		Mercury at aphelion	15 33
Sun.	5	07	Mercury 0.4° S. of Moon; occultation[1]	
Mon.	6	10	Venus 4° S. of Moon	
Tue.	7	10	Moon at perigee (367 199 km)	12 22
		18	Saturn 5° N. of Moon	
		23	Antares 0.6° S. of Moon; occultation[2]	
Wed.	8	15	Uranus 4° N. of Moon	
Thu.	9	14	Neptune 6° N. of Moon	
Fri.	10	13 28	☽ First Quarter	09 11
Sat.	11	13	Mars 2° N. of Moon	
Sun.	12			
Mon.	13			05 59
Tue.	14	16	Jupiter 1.9° N. of Moon	
Wed.	15	12	Venus stationary	
Thu.	16			02 48
Fri.	17	19 22	○ Full Moon; Hunters' Moon	
			Eclipse of Moon, pg 78	
Sat.	18	14	Mercury 4° N. of Venus	23 37
Sun.	19			
Mon.	20			
Tue.	21	17	Orionid meteors	20 25
		22	Mercury at greatest elong. E. (24°)	
Wed.	22			
Thu.	23	06	Moon at apogee (405 073 km)	
Fri.	24		Mercury at greatest hel. lat. S.	17 14
Sat.	25	22 26	☾ Last Quarter	
Sun.	26			
Mon.	27			14 03
Tue.	28			
Wed.	29			
Thu.	30			10 52
Fri.	31	01	Pluto in conjunction with Sun	

Config. of Jupiter's Satellites



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[1]Visible in E. Europe, S.W. Asia, Indonesia, N. Australia

[2]Visible in W. of N. America, Central America, N.W. of S. America

THE SKY FOR NOVEMBER 1986

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	15^h45^m	14^h44^m	21^h07^m	23^h00^m	16^h27^m	17^h17^m	18^h16^m
	11	15^h23^m	14^h23^m	21^h32^m	22^h59^m	16^h32^m	17^h19^m	18^h17^m
	21	14^h46^m	14^h11^m	21^h57^m	23^h00^m	16^h37^m	17^h21^m	18^h18^m
Dec	1	-22°41'	-22°04'	-18°54'	-7°58'	-20°10'	-23°11'	-22°22'
	11	-19°13'	-18°13'	-16°37'	-7°58'	-20°22'	-23°13'	-22°22'
	21	-13°45'	-14°31'	-14°08'	-7°50'	-20°33'	-23°15'	-22°21'
Tran	1	13^h03^m	12^h01^m	18^h26^m	20^h16^m	13^h45^m	14^h35^m	15^h33^m
	11	11^h59^m	11^h01^m	18^h12^m	19^h37^m	13^h11^m	13^h57^m	14^h55^m
	21	10^h45^m	10^h10^m	17^h58^m	18^h59^m	12^h36^m	13^h21^m	14^h17^m
Mag	1	+0.4	-4.1	-0.3	-2.7	+0.5	+5.7	+8.0
	11	+4.0	-4.1	-0.2	-2.6	+0.5	+5.7	+8.0
	21	+0.7	-4.5	0.0	-2.5	+0.5	+5.7	+8.0

The Moon—On Nov. 1.0 UT, the age of the Moon is 28.2 d. The Sun's selenographic colongitude is 258.11° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Nov. 10 (7°) and minimum (east limb exposed) on Nov. 26 (7°). The libration in latitude is maximum (north limb exposed) on Nov. 7 (7°) and minimum (south limb exposed) on Nov. 21 (7°). The Moon reaches its greatest northern declination on Nov. 19 (+28°) and its greatest southern declination on Nov. 5 (−28°).

Mercury passes through inferior conjunction on Nov. 13. At that time, a transit of Mercury across the disk of the Sun is visible from some parts of Earth. By Nov. 30, Mercury is at greatest elongation west (20°), at which time it stands about 16° above the southeastern horizon at sunrise.

Venus also passes through inferior conjunction this month (Nov. 5) and moves into the morning sky. By the end of the month, it is visible low in the southeast at sunrise.

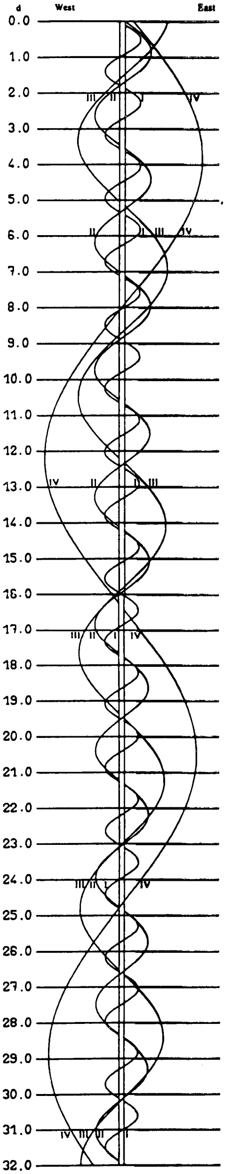
Mars moves from Capricornus into Aquarius late in the month. It is east of south at sunset, and sets about 6 h later.

Jupiter, in Aquarius, is well up in the southeast at sunset, and is visible throughout most of the night. It appears approximately level with Mars, but further east.

Saturn, in Ophiuchus, is no longer visible, as it approaches conjunction on Dec. 4.

1986	d	h m	NOVEMBER UNIVERSAL TIME	Min. of Algol h m
Sat.	1			
Sun.	2	06 02	● New Moon	07 41
		10	Ceres in conjunction with Sun	
		12	Mercury stationary	
Mon.	3	14	Saturn 6° N. of Antares	
		14	Mercury 0.8° N. of Moon; occultation[1]	
			S. Taurid meteors	
Tue.	4	02	Moon at perigee (361 815 km)	
		07	Saturn 6° N. of Moon	
		07	Antares 0.6° S. of Moon; occultation[2]	
Wed.	5	01	Uranus 4° N. of Moon	04 29
		10	Venus in inferior conjunction	
		22	Neptune 6° N. of Moon	
Thu.	6			
Fri.	7			
Sat.	8	20	Jupiter stationary	01 18
		21 11	☽ First Quarter	
Sun.	9	00	Mars 3° N. of Moon	
Mon.	10	19	Jupiter 2° N. of Moon	22 07
Tue.	11			
Wed.	12		Mercury at ascending node	
Thu.	13	04	Mercury in inferior conjunction; Transit across disc of Sun, pg. 99[3]	18 56
Fri.	14			
Sat.	15			
Sun.	16	12 12	○ Full Moon	15 45
Mon.	17		Mercury at perihelion	
Tue.	18	00	Leonid meteors	
Wed.	19	22	Moon at apogee (406 028 km)	12 34
Thu.	20			
Fri.	21			
Sat.	22	03	Vesta stationary	09 23
		05	Mercury stationary	
Sun.	23			
Mon.	24	04	Venus stationary	
		16 50	☾ Last Quarter	
Tue.	25			06 12
Wed.	26		Venus at ascending node	
Thu.	27		Mercury at greatest hel. lat. N.	
Fri.	28			03 01
Sat.	29	11	Venus 2° N. of Moon	
Sun.	30	03	Mercury greatest elong. W. (20°)	23 50
		09	Mercury 5° N. of Moon	

Config. of Jupiter's Satellites



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[1] Visible in Antarctica, S. of S. America

[2] Visible in S.W. and Central Asia, Philippines

[3] Visible in Australasia, Asia, part of Antarctica, Africa except N.W., E. Europe.

THE SKY FOR DECEMBER 1986

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	$15^{h}07^{m}$	$14^{h}14^{m}$	$22^{h}23^{m}$	$23^{h}02^{m}$	$16^{h}42^{m}$	$17^{h}24^{m}$	$18^{h}20^{m}$
	11	$15^{h}58^{m}$	$14^{h}29^{m}$	$22^{h}48^{m}$	$23^{h}06^{m}$	$16^{h}47^{m}$	$17^{h}27^{m}$	$18^{h}21^{m}$
	21	$17^{h}00^{m}$	$14^{h}55^{m}$	$23^{h}14^{m}$	$23^{h}10^{m}$	$16^{h}52^{m}$	$17^{h}29^{m}$	$18^{h}23^{m}$
Dec	1	-15°06'	-12°29'	-11°28'	-7°34'	-20°43'	-23°18'	-22°21'
	11	-19°13'	-12°14'	-8°40'	-7°11'	-20°53'	-23°20'	-22°20'
	21	-22°43'	-13°16'	-5°46'	-6°42'	-21°01'	-23°22'	-22°20'
Tran	1	$10^{h}28^{m}$	$9^{h}34^{m}$	$17^{h}44^{m}$	$18^{h}21^{m}$	$12^{h}02^{m}$	$12^{h}44^{m}$	$13^{h}39^{m}$
	11	$10^{h}41^{m}$	$9^{h}11^{m}$	$17^{h}30^{m}$	$17^{h}45^{m}$	$11^{h}28^{m}$	$12^{h}07^{m}$	$13^{h}01^{m}$
	21	$11^{h}04^{m}$	$8^{h}57^{m}$	$17^{h}16^{m}$	$17^{h}11^{m}$	$10^{h}53^{m}$	$11^{h}30^{m}$	$12^{h}24^{m}$
Mag	1	-0.5	-4.6	+0.1	-2.5	+0.4	+5.7	+8.0
	11	-0.6	-4.7	+0.3	-2.4	+0.4	+5.7	+8.0
	21	-0.6	-4.6	+0.4	-2.3	+0.5	+5.7	+8.0

The Moon—On Dec. 1.0 UT, the age of the Moon is 28.7 d. The Sun's selenographic colongitude is 263.22° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Dec. 8 (8°) and minimum (east limb exposed) on Dec. 25 (8°). The libration in latitude is maximum (north limb exposed) on Dec. 4 (7°) and Dec. 31 (7°) and minimum (south limb exposed) on Dec. 18 (7°). The Moon reaches its greatest northern declination on Dec. 17 (+28°) and its greatest southern declination on Dec. 3 (−28°) and Dec. 30 (−28°). There is an occultation of Antares by the Moon on Dec. 1, visible in North America.

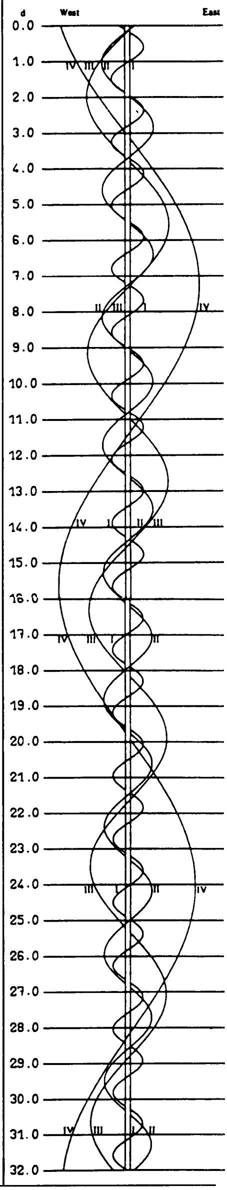
Mercury is visible throughout the month, very low in the southeast at dawn. It passes 1.3° south of Saturn on Dec. 19, and 0.4° south of Uranus on Dec. 25.

Venus becomes progressively easier to see during the month. By month's end, it rises about 3 h before the Sun, and stands about 25° above the southeastern horizon at sunrise. It is at greatest brilliancy (−4.7) on Dec. 11.

Mars, in Aquarius, is east of south at sunset, and sets about 6 h later. It passes about 0.5° south of the fourth-magnitude red star λ Aqr on Dec. 12, and 0.5° north of Jupiter (from west to east) on Dec. 19. Mars is redder and much fainter than Jupiter. Early in the month, the waxing crescent moon moves eastward past the two planets. At the very end of the month, Mars moves from Aquarius into Pisces.

Jupiter, in Aquarius, is well up in the southeast at sunset, and sets in the early morning. By the end of the month, Mars and Jupiter are high in the south at sunset, with Mars now to the east – and much redder and fainter. See also *Mars* above.

Saturn, in Ophiuchus, is not visible this month (it is in conjunction with the Sun on Dec. 4). By early January, it emerges into the morning sky, and can be seen very low in the southeast at sunrise. See also *Mercury* above.

1986			DECEMBER UNIVERSAL TIME	Min. of Algol	Config. of Jupiter's Satellites
	d	h m		h m	
Mon.	1	16 43	● New Moon		
		17	Antares 0.6° S. of Moon; occultation[1]		
Tue.	2	11	Moon at perigee (357 736 km)		
Wed.	3	08	Neptune 6° N. of Moon	20 39	
Thu.	4	16	Saturn in conjunction with Sun		
Fri.	5				
Sat.	6			17 28	
Sun.	7	16	Mars 3° N. of Moon		
Mon.	8	04	Jupiter 1.8° N. of Moon		
		08 01	☽ First Quarter		
Tue.	9			14 17	
Wed.	10				
Thu.	11	20	Venus at greatest brilliancy (−4.7)		
Fri.	12			11 06	
Sat.	13				
Sun.	14	12	Geminid meteors		
		21	Uranus in conjunction with Sun		
Mon.	15			07 55	
Tue.	16	01	Mercury 5° N. of Antares		
		07 04	○ Full Moon		
Wed.	17	05	Moon at apogee (406 507 km)		
Thu.	18			04 44	
Fri.	19	07	Mars 0.5° N. of Jupiter		
		15	Mercury 1.3° S. of Saturn		
Sat.	20				
Sun.	21		Mercury at descending node	01 33	
Mon.	22	04 02	Winter solstice; winter begins		
		18	Ursid meteors		
Tue.	23			22 22	
Wed.	24	09 17	☾ Last Quarter		
Thu.	25	14	Mercury 0.4° S. of Uranus		
Fri.	26			19 12	
Sat.	27	14	Neptune in conjunction with Sun		
Sun.	28	01	Venus 7° N. of Moon		
Mon.	29	05	Antares 0.6° S. of Moon; occultation[2]	16 01	
		15	Saturn 6° N. of Moon		
Tue.	30	23	Moon at perigee (356 615 km)		
			Venus at perihelion		
Wed.	31	03 10	● New Moon		
			Mercury at aphelion		

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[1] Visible in N. America, N. of S. America

[2] Visible in E. Europe, S. Asia, Philippines

SUN

EPHEMERIS

Date	Apparent		UT Transit at	Orientation		
0^h UT	α (1986)	δ	Greenwich	P	B_0	L_0
Jan. 1	$18^h44.7^m$	-23°03'	$12^h03^m30^s$	+2.1°	-2.9°	173.6°
6	$19^h06.7^m$	-22°33'	$12^h05^m47^s$	-0.3°	-3.5°	107.8°
11	$19^h28.5^m$	-21°53'	$12^h07^m53^s$	-2.7°	-4.0°	41.9°
16	$19^h50.1^m$	-21°02'	$12^h09^m45^s$	-5.1°	-4.6°	336.1°
21	$20^h11.4^m$	-20°01'	$12^h11^m18^s$	-7.4°	-5.0°	270.2°
26	$20^h32.4^m$	-18°51'	$12^h12^m32^s$	-9.6°	-5.4°	204.4°
31	$20^h53.0^m$	-17°32'	$12^h13^m27^s$	-11.7°	-5.8°	138.6°
Feb. 5	$21^h13.4^m$	-16°05'	$12^h14^m01^s$	-13.7°	-6.2°	72.7°
10	$21^h33.4^m$	-14°31'	$12^h14^m16^s$	-15.6°	-6.5°	6.9°
15	$21^h53.0^m$	-12°51'	$12^h14^m11^s$	-17.3°	-6.7°	301.1°
20	$22^h12.4^m$	-11°06'	$12^h13^m47^s$	-18.9°	-6.9°	235.2°
25	$22^h31.4^m$	-9°17'	$12^h13^m07^s$	-20.4°	-7.0°	169.4°
Mar. 2	$22^h50.3^m$	-7°24'	$12^h12^m13^s$	-21.7°	-7.1°	103.5°
7	$23^h08.9^m$	-5°29'	$12^h11^m06^s$	-22.9°	-7.2°	37.6°
12	$23^h27.4^m$	-3°31'	$12^h09^m50^s$	-23.8°	-7.1°	331.8°
17	$23^h45.7^m$	-1°33'	$12^h08^m27^s$	-24.7°	-7.0°	265.8°
22	$0^h03.9^m$	+0°26'	$12^h06^m59^s$	-25.3°	-6.9°	199.9°
27	$0^h22.1^m$	+2°24'	$12^h05^m27^s$	-25.8°	-6.7°	134.0°
Apr. 1	$0^h40.3^m$	+4°20'	$12^h03^m57^s$	-26.1°	-6.5°	68.0°
6	$0^h58.6^m$	+6°15'	$12^h02^m29^s$	-26.2°	-6.2°	2.1°
11	$1^h16.9^m$	+8°08'	$12^h01^m07^s$	-26.2°	-5.9°	296.1°
16	$1^h35.4^m$	+9°56'	$11^h59^m51^s$	-25.9°	-5.5°	230.1°
21	$1^h53.9^m$	+11°41'	$11^h58^m45^s$	-25.5°	-5.1°	164.0°
26	$2^h12.7^m$	+13°21'	$11^h57^m49^s$	-24.9°	-4.6°	98.0°
May 1	$2^h31.7^m$	+14°55'	$11^h57^m05^s$	-24.1°	-4.2°	31.9°
6	$2^h50.9^m$	+16°23'	$11^h56^m36^s$	-23.2°	-3.6°	325.8°
11	$3^h10.3^m$	+17°45'	$11^h56^m20^s$	-22.0°	-3.1°	259.7°
16	$3^h30.0^m$	+18°59'	$11^h56^m19^s$	-20.7°	-2.6°	193.6°
21	$3^h49.9^m$	+20°05'	$11^h56^m31^s$	-19.2°	-2.0°	127.5°
26	$4^h10.0^m$	+21°02'	$11^h56^m57^s$	-17.6°	-1.4°	61.3°
31	$4^h30.3^m$	+21°51'	$11^h57^m34^s$	-15.8°	-0.8°	355.2°
June 5	$4^h50.8^m$	+22°29'	$11^h58^m23^s$	-13.9°	-0.2°	289.0°
10	$5^h11.4^m$	+22°58'	$11^h59^m20^s$	-11.9°	+0.4°	222.8°
15	$5^h32.2^m$	+23°17'	$12^h00^m22^s$	-9.8°	+1.0°	156.6°
20	$5^h53.0^m$	+23°26'	$12^h01^m27^s$	-7.7°	+1.5°	90.4°
25	$6^h13.8^m$	+23°24'	$12^h02^m31^s$	-5.5°	+2.1°	24.3°
30	$6^h34.5^m$	+23°12'	$12^h03^m33^s$	-3.2°	+2.7°	318.1°

Date	Apparent		UT Transit at	Orientation		
0^h UT	α (1986)	δ	Greenwich	P	B_0	L_0
July 5	$6^h55.2^m$	+22°50'	$12^h04^m29^s$	-0.9°	+3.2°	251.9°
10	$7^h15.7^m$	+22°18'	$12^h05^m17^s$	+1.3°	+3.7°	185.7°
15	$7^h36.1^m$	+21°37'	$12^h05^m54^s$	+3.6°	+4.2°	119.6°
20	$7^h56.2^m$	+20°46'	$12^h06^m18^s$	+5.7°	+4.7°	53.4°
25	$8^h16.1^m$	+19°46'	$12^h06^m28^s$	+7.9°	+5.1°	347.2°
30	$8^h35.8^m$	+18°38'	$12^h06^m23^s$	+9.9°	+5.5°	281.1°
Aug. 4	$8^h55.2^m$	+17°23'	$12^h06^m04^s$	+11.9°	+5.9°	215.0°
9	$9^h14.3^m$	+16°00'	$12^h05^m30^s$	+13.8°	+6.2°	148.9°
14	$9^h33.3^m$	+14°31'	$12^h04^m41^s$	+15.6°	+6.5°	82.8°
19	$9^h52.0^m$	+12°57'	$12^h03^m38^s$	+17.2°	+6.7°	16.7°
24	$10^h10.4^m$	+11°17'	$12^h02^m23^s$	+18.8°	+6.9°	310.6°
29	$10^h28.7^m$	+9°33'	$12^h00^m58^s$	+20.2°	+7.0°	244.5°
Sept. 3	$10^h46.9^m$	+7°45'	$11^h59^m25^s$	+21.5°	+7.1°	178.5°
8	$11^h05.0^m$	+5°53'	$11^h57^m45^s$	+22.6°	+7.2°	112.4°
13	$11^h22.9^m$	+4°00'	$11^h56^m00^s$	+23.6°	+7.1°	46.4°
18	$11^h40.9^m$	+2°04'	$11^h54^m13^s$	+24.5°	+7.1°	340.4°
23	$11^h58.8^m$	+0°08'	$11^h52^m26^s$	+25.2°	+6.9°	274.4°
28	$12^h16.8^m$	-1°49'	$11^h50^m43^s$	+25.7°	+6.8°	208.4°
Oct. 3	$12^h34.9^m$	-3°46'	$11^h49^m06^s$	+26.0°	+6.6°	142.4°
8	$12^h53.1^m$	-5°41'	$11^h47^m37^s$	+26.2°	+6.3°	76.5°
13	$13^h11.5^m$	-7°35'	$11^h46^m19^s$	+26.2°	+6.0°	10.5°
18	$13^h30.1^m$	-9°26'	$11^h45^m13^s$	+26.0°	+5.6°	304.6°
23	$13^h48.9^m$	-11°13'	$11^h44^m22^s$	+25.6°	+5.2°	238.6°
28	$14^h08.0^m$	-12°57'	$11^h43^m49^s$	+25.1°	+4.7°	172.7°
Nov. 2	$14^h27.5^m$	-14°35'	$11^h43^m35^s$	+24.3°	+4.3°	106.7°
7	$14^h47.3^m$	-16°08'	$11^h43^m41^s$	+23.3°	+3.7°	40.8°
12	$15^h07.4^m$	-17°33'	$11^h44^m08^s$	+22.2°	+3.2°	334.9°
17	$15^h27.9^m$	-18°51'	$11^h44^m56^s$	+20.8°	+2.6°	269.0°
22	$15^h48.7^m$	-20°01'	$11^h46^m04^s$	+19.3°	+2.0°	203.1°
27	$16^h09.8^m$	-21°02'	$11^h47^m33^s$	+17.6°	+1.4°	137.2°
Dec. 2	$16^h31.3^m$	-21°53'	$11^h49^m20^s$	+15.7°	+0.8°	71.3°
7	$16^h53.0^m$	-22°33'	$11^h51^m23^s$	+13.7°	+0.2°	5.4°
12	$17^h15.0^m$	-23°02'	$11^h53^m37^s$	+11.6°	-0.5°	299.5°
17	$17^h37.1^m$	-23°20'	$11^h56^m00^s$	+ 9.3°	-1.1°	233.6°
22	$17^h59.3^m$	-23°27'	$11^h58^m28^s$	+ 7.0°	-1.7°	167.8°
27	$18^h21.4^m$	-23°21'	$12^h00^m57^s$	+ 4.6°	-2.3°	101.9°
32	$18^h43.6^m$	-23°04'	$12^h03^m23^s$	+ 2.2°	-2.9°	36.0°

SUNDIAL CORRECTION

The "Transit at Greenwich" time on the previous two pages may be used to calculate the sundial correction at the observer's position. e.g. To find the correction at Winnipeg on August 15, 1986: At Greenwich the Sun transits at $12^h04^m41^s$ on August 14 and at $12^h03^m38^s$ on August 19. Thus, to the nearest minute, on August 15 at both Greenwich and Winnipeg the Sun will transit at 12^h04^m mean solar time, or 12^h33^m CST, since Winnipeg has a longitude correction of $+29^m$ (see page 56). Thus a 4^m correction must be added to the reading of a simple sundial to obtain mean solar time.

A figure accurate to a second or two can be obtained by interpolating for longitude. The interpolated transit time at Greenwich for August 15 is $12^h04^m28^s$, the daily change in the time being $-12\overset{s}{.}6$. Adjusting this for the longitude of Winnipeg: $12^h04^m28^s - (12\overset{s}{.}6 \times 6^h29^m \div 24^h) = 12^h04^m25^s$. Thus the sundial correction is 4^m25^s. To find the standard time of the Sun's transit to the nearest second or two, the observer's longitude must be known to 10″ or better. e.g. Suppose an observer in Winnipeg is at longitude 97°13′50″ W, or $6^h28^m55^s$ W of Greenwich. The time of transit will be $12^h04^m25^s + 28^m55^s = 12^h33^m20^s$ CST ($13^h33^m20^s$ CDT).

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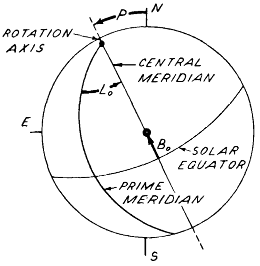
ORIENTATION OF THE SUN

The tables on the previous two pages give three angles which specify the orientation of the Sun. *P* is the position angle of the axis of rotation, measured eastward from the north point on the disk. B_0 is the heliographic latitude of the centre of the disk, and L_0 is the heliographic longitude of the centre of the disk, from Carrington's solar meridian, measured in the direction of rotation (see diagram, and also note the table below). The rotation period of the Sun depends on latitude. The *sidereal* period of rotation at the equator is 25.38d.



SOLAR ROTATION (SYNODIC)

DATES OF COMMENCEMENT (UT, $L_0 = 0°$)
OF NUMBERED SYNODIC ROTATIONS

No.	Commences	No.	Commences	No.	Commences
1770	1985 Dec. 17.84	1775	May 3.40	1780	Sept. 16.51
1771	1986 Jan. 14.17	1776	May 30.62	1781	Oct. 13.79
1772	Feb. 10.51	1777	June 26.82	1782	Nov. 10.08
1773	Mar. 9.85	1778	July 24.02	1783	Dec. 7.40
1774	Apr. 6.15	1779	Aug. 20.25	1784	1987 Jan. 3.73

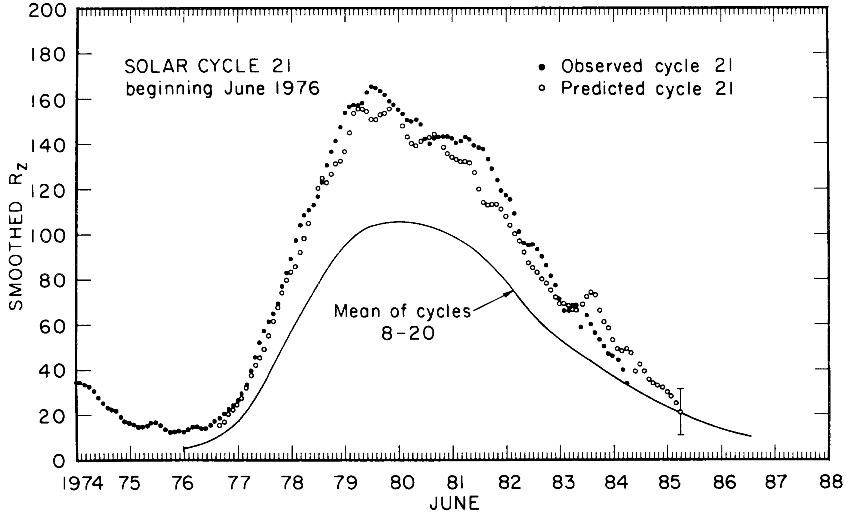
SOLAR ACTIVITY

SUNSPOTS, FLARES, AND AURORAE

By V. Gaizauskas

The present sunspot cycle (21) is compared with the mean of cycles 8 to 20 in the diagram adapted from "Solar-Geophysical Data" (U.S. Dept. of Commerce, Boulder, Colorado). The data plotted in the graph are monthly smoothed International sunspot numbers. The vertical bar defines the interval in which the most recent value in the graph can be predicted with a confidence of 90%. These *smoothed* data indicate that the maximum of the cycle occurred in the interval December 1979–January 1980. Another measure of solar activity is the 10 cm microwave flux which has been monitored daily since 1947 by the National Research Council of Canada (Covington, A.E. 1967, *J. Roy. Astron. Soc. Can.*, *61*, 314). The 10 cm flux correlates closely with sunspot number and has the advantage of being reproducible without subjective bias by an observer.

OBSERVED AND ONE-YEAR-AHEAD PREDICTED SMOOTHED SUNSPOT NUMBERS



The continuing decline of activity towards solar minimum in 1987 does not proceed as smoothly as one would infer from this diagram. Prolonged quiet intervals in which the 10 cm flux approaches its minimum value, as happened from September 1984 to March 1985, alternate sporadically with outbreaks of intense activity confined to just a few active regions, as in April and again in May 1985. Spasmodic sunspot activity can be expected throughout 1985–86, but chances for the eruptions of any major solar flares are rapidly dwindling. At this phase of the solar cycle, active regions form close to the solar equator; the majority are now found within a belt of latitudes 15° wide to the north and to the south. When Cycle 21 began, activity favoured the northern over the southern hemisphere for about a year. But from the beginning of 1983, more active regions formed in the southern than in the northern

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Editor's Note: Some of the hazards in viewing the Sun and some effective safety precautions are discussed by B. Ralph Chou (*J. Roy. Astron. Soc. Can.*, *75*, 36, 1981; *Sky and Telescope*, *62*, 119, 1981).

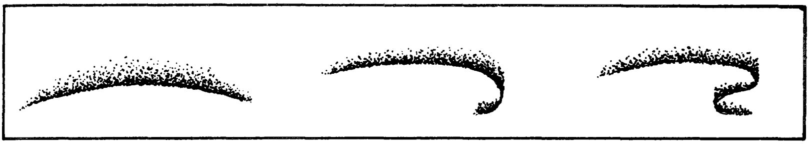
hemisphere. This reversed trend during the declining phase of the cycle ended around September 1984 when global activity dropped to very low levels.

Successive eleven-year peaks of sunspot activity follow long-term trends which can in extreme cases result in prolonged periods of very low activity (Eddy, J.A. 1976, *Science, 192*, 1189; 1977, *Scientific Am.*, *236*, 80). We are at an opposite extreme; Cycle 21 has the second highest peak of this century, exceeded only by Cycle 19 (maximum at 1957.9).

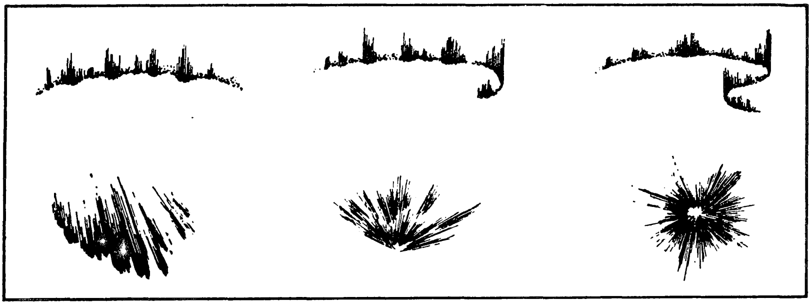
Some auroral displays may yet be observed in 1986 in the southern, populous parts of Canada. Aurorae ("Northern Lights") are caused by the precipitation into the ionosphere of energetic charged particles from a vast reservoir enveloping Earth, the *magnetosphere*. Seen from above (e.g. from the Canadian ISIS satellites) aurorae are concentrated in elliptical bands called *auroral ovals* that ring Earth's magnetic poles. When the Sun is calm, the ovals shrink to nearly circular rings centred close to the geomagnetic poles. As the Sun grows more active, the ovals advance towards lower latitudes (e.g. in Canada to Churchill, Man. and to Yellowknife, N.W.T.) and become more eccentric with respect to the geomagnetic poles. During periods of very intense solar activity, the ovals shift closer still towards the Equator (e.g. down to the southern United States for the northern oval). For an observer at the ground, the shifting patterns of the aurora over the night sky reflect the changes in the magnetic and electric fields along the paths of electrons streaming toward Earth.

☉ The magnetospheric reservoir of particles is created by a complicated interaction between Earth's magnetic field and the *solar wind*, a magnetized plasma that flows continuously from the Sun even in the absence of solar activity. The solar wind has considerable structure; the highest speed streams originate in *coronal holes*, extended regions of low density and temperature in the solar corona. Near sunspot maximum, coronal holes are nearly absent except in small areas near the Sun's poles. But during the declining phase of the cycle, holes form rapidly and live longer (e.g. up to 10 solar rotations). They were most prominent just before 1984 when long-lived holes extended from either of the Sun's poles to its equator and into the adjacent hemisphere. While coronal holes are still expected to be prominent at the polar caps in 1986, mid-latitude holes shrank rapidly during 1984–85 and are expected to be small and weak when present in 1986. They are firmly associated with recurrent 27-day geomagnetic disturbances. The normal balance between the solar wind and the magnetosphere can be suddenly upset (e.g. by changes in the magnitude and direction of the magnetic field 'blown' towards Earth by the solar wind, by changes in the wind's speed, or by a major solar flare) and can lead to an *auroral sub-storm*. But universal agreement is still lacking on the exact mechanism which triggers sub-storms.

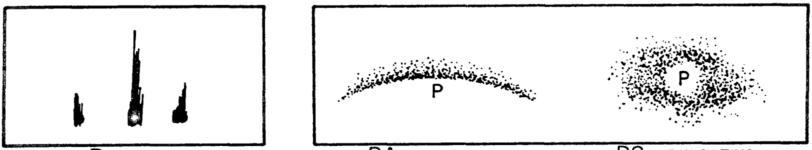
The atoms and molecules, mostly those of oxygen and nitrogen, that radiate the shimmering light of the aurora are terrestrial in origin. They become luminous at heights between 100 and 400 km through collisions with energetic particles that have leaked out of the magnetosphere during a sub-storm. A faint auroral display may not exceed the brightness threshold of colour perception for the eye; it will be sensed as white. Most aurorae appear green or blue-green with occasional faint patches of pink or red. The green colour is due to excited atoms of oxygen radiating at a wavelength of 558 nm; the blue is produced by ionized nitrogen molecules radiating in a group of spectral bands between 391 and 470 nm. The green and blue emissions are concentrated near an altitude of 110 km. Rare, all-red auroras have been measured to occur between 200 and 400 km; the red colour is due to the 630 and 636 nm lines of atomic oxygen, and is normally faint (because of the low concentration of oxygen at that altitude) unless the influx of particles is very great. Red emission also occurs at lower altitudes, near 90 km, where the spectrum can be dominated by emission in a series of bands between 650 and 680 nm.



HA (HOMOGENEOUS ARC)



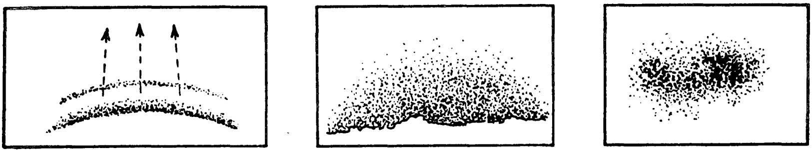
RA (RAYED ARC)



R (RAYS)

PA (PULSATING ARC)

PS (PULSATING SPOT)



F (FLAMES)

G (GLOW)

S (SPOT OR PATCH)

Illustrative sketches of standard auroral forms. This simplified classification was devised for visual observers during the International Geophysical Year (IGY), nearly three decades ago. The sketches emphasize the fundamental features of auroral patterns and minimize variations which depend on the location of the observer.

TIMES OF SUNRISE AND SUNSET

The tables on the next three pages give the times of sunrise and sunset at four day intervals for places ranging from 20° to 60° north latitude. "Rise" and "set" correspond to the upper limb of the Sun appearing at the horizon for an observer at sea level. The values are in UT and are for the Greenwich meridian, although for North American observers the stated values may be read as standard time at the standard meridians (60°, 75°, *etc.*) without significant error. The values may be interpolated linearly for both non-tabular latitudes and dates. Also, it is possible to extrapolate the table beyond the 20° and 60° latitude limits a few degrees without significant loss of accuracy.

The standard time of an event at a particular location must take account of the observer's longitude relative to his or her standard meridian. The table below lists the latitude and the longitude correction (in minutes of time) for a number of cities and towns. e.g. To find the time of sunrise at Toronto on February 17, 1986: The latitude is 44°, and from the table the time of sunrise at 0° longitude is 06:57 UT. Thus at the Eastern time zone (E) meridian (75° west), the time of sunrise will be approximately 06:57 EST. The correction for Toronto is + 18 minutes, so sunrise will occur at 07:15 EST on that date. Corrections for places not listed below may be found by converting the difference between the longitude of the place and that of its standard meridian to time (15° = 1 h), the correction being positive if the place is west of its standard meridian, negative if east. Finally, *it should be emphasized* that the observed time will often differ up to several minutes from the predicted time because of a difference in height between the observer and the actual horizon.

CANADIAN CITIES AND TOWNS						AMERICAN CITIES		
	Lat.	Corr.		Lat.	Corr.		Lat.	Corr.
Baker Lake	64°	+24C	Peterborough	44°	+13E	Atlanta	34°	+37E
Brandon	50	+40C	Prince Albert	53	+63C	Baltimore	39	+06E
Calgary	51	+36M	Prince George	54	+11P	Birmingham	33	−13C
Charlottetown	46	+12A	Prince Rupert	54	+41P	Boston	42	−16E
Chicoutimi	48	−16E	Quebec	47	−15E	Buffalo	43	+15E
Churchill	59	+17C	Regina	50	+58C	Chicago	42	−10C
Corner Brook	49	+22N	Resolute	75	+20C	Cincinnati	39	+38E
Cornwall	45	−01E	Rimouski	48	−26E	Cleveland	42	+26E
Edmonton	54	+34M	St. Catharines	43	+17E	Dallas	33	+27C
Fredericton	46	+27A	St. Hyacinthe	46	−08E	Denver	40	00M
Gander	49	+08N	St. John, N.B.	45	+24A	Fairbanks	65	−10A
Goose Bay	53	+02A	St. John's, Nfld.	48	+01N	Flagstaff	35	+27M
Granby	45	−09E	Sarnia	43	+29E	Indianapolis	40	−15C
Halifax	45	+14A	Saskatoon	52	+67C	Juneau	58	+58P
Hamilton	43	+20E	Sault Ste. Marie	47	+37E	Kansas City	39	+18C
Kapuskasing	49	+30E	Sept Iles	50	−35E	Los Angeles	34	−07P
Kenora	50	+18C	Sherbrooke	45	−12E	Louisville	38	−17C
Kingston	44	+06E	Sudbury	47	+24E	Memphis	35	00C
Kitchener	43	+22E	Sydney	46	+01A	Miami	26	+21E
Lethbridge	50	+31M	The Pas	54	+45C	Milwaukee	43	−09C
London	43	+25E	Thunder Bay	48	+57E	Minneapolis	45	+13C
Medicine Hat	50	+23M	Timmins	48	+26E	New Orleans	30	00C
Moncton	46	+19A	Toronto	44	+18E	New York	41	−04E
Montreal	46	−06E	Trail	49	−09P	Omaha	41	+24C
Moosonee	51	+23E	Trois Rivieres	46	−10E	Philadelphia	40	+01E
Moose Jaw	50	+62C	Vancouver	49	+12P	Phoenix	33	+28M
Niagara Falls	43	+16E	Victoria	48	+13P	Pittsburgh	40	+20E
North Bay	46	+18E	Whitehorse	61	00Y	St. Louis	39	+01C
Ottawa	45	+03E	Windsor, Ont.	42	+32E	San Francisco	38	+10P
Owen Sound	45	+24E	Winnipeg	50	+29C	Seattle	48	+09P
Pangnirtung	66	+23A	Yarmouth	44	+24A	Tucson	32	+24M
Penticton	49	−02P	Yellowknife	62	+38M	Washington	39	+08E

LAT.		+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
EVENT		RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET
		h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
Jan.	−2	6 34	17 30	6 55	17 09	7 07	16 57	7 21	16 43	7 34	16 30	7 59	16 06	8 19	15 45	9 03	15 01
	2	6 35	17 33	6 56	17 12	7 08	17 00	7 22	16 46	7 35	16 33	7 59	16 10	8 19	15 49	9 02	15 06
	6	6 37	17 35	6 57	17 15	7 09	17 03	7 22	16 50	7 35	16 37	7 58	16 14	8 18	15 54	8 59	15 13
	10	6 37	17 38	6 57	17 18	7 09	17 07	7 22	16 54	7 34	16 41	7 56	16 19	8 15	16 00	8 55	15 20
	14	6 38	17 40	6 57	17 21	7 08	17 10	7 21	16 58	7 32	16 46	7 54	16 25	8 12	16 07	8 50	15 29
	18	6 38	17 43	6 56	17 25	7 07	17 14	7 19	17 02	7 30	16 51	7 51	16 31	8 08	16 13	8 43	15 38
	22	6 38	17 46	6 55	17 28	7 05	17 18	7 17	17 07	7 27	16 56	7 47	16 37	8 03	16 21	8 36	15 48
	26	6 37	17 48	6 54	17 32	7 03	17 22	7 14	17 12	7 24	17 02	7 42	16 44	7 57	16 28	8 28	15 58
	30	6 36	17 51	6 52	17 35	7 01	17 26	7 11	17 16	7 20	17 07	7 37	16 50	7 51	16 36	8 19	16 08
Feb.	3	6 35	17 53	6 49	17 39	6 58	17 30	7 07	17 21	7 16	17 13	7 31	16 57	7 44	16 44	8 10	16 19
	7	6 33	17 55	6 47	17 42	6 54	17 34	7 03	17 26	7 11	17 18	7 25	17 04	7 37	16 52	8 00	16 29
	11	6 32	17 57	6 44	17 45	6 51	17 38	6 58	17 31	7 06	17 24	7 18	17 11	7 29	17 00	7 50	16 40
	15	6 29	17 59	6 40	17 48	6 46	17 42	6 53	17 35	7 00	17 29	7 11	17 18	7 21	17 08	7 39	16 50
	19	6 27	18 01	6 37	17 52	6 42	17 46	6 48	17 40	6 54	17 35	7 04	17 25	7 12	17 17	7 28	17 01
	23	6 24	18 03	6 33	17 55	6 37	17 50	6 43	17 45	6 48	17 40	6 56	17 31	7 03	17 25	7 17	17 11
	27	6 22	18 04	6 29	17 57	6 33	17 54	6 37	17 49	6 41	17 45	6 48	17 38	6 54	17 32	7 05	17 21
Mar.	3	6 19	18 06	6 24	18 00	6 27	17 57	6 31	17 54	6 34	17 50	6 40	17 45	6 45	17 40	6 54	17 31
	7	6 15	18 07	6 20	18 03	6 22	18 01	6 25	17 58	6 27	17 56	6 32	17 51	6 35	17 48	6 42	17 42
	11	6 12	18 08	6 15	18 06	6 17	18 04	6 19	18 02	6 20	18 01	6 23	17 58	6 26	17 56	6 30	17 51
	15	6 09	18 10	6 10	18 08	6 11	18 07	6 12	18 06	6 13	18 06	6 15	18 04	6 16	18 03	6 18	18 01
	19	6 05	18 11	6 06	18 11	6 06	18 11	6 06	18 11	6 06	18 11	6 06	18 11	6 06	18 11	6 06	18 11
	23	6 02	18 12	6 01	18 13	6 00	18 14	5 59	18 15	5 59	18 16	5 57	18 17	5 56	18 18	5 54	18 21
	27	5 58	18 13	5 56	18 15	5 55	18 17	5 53	18 19	5 51	18 20	5 49	18 23	5 46	18 26	5 42	18 31
	31	5 55	18 14	5 51	18 18	5 49	18 20	5 46	18 23	5 44	18 25	5 40	18 30	5 36	18 33	5 30	18 40
Apr.	4	5 51	18 15	5 46	18 20	5 43	18 23	5 40	18 27	5 37	18 30	5 31	18 36	5 27	18 41	5 17	18 50
	8	5 48	18 16	5 42	18 23	5 38	18 27	5 34	18 31	5 30	18 35	5 23	18 42	5 17	18 48	5 05	19 00
	12	5 45	18 17	5 37	18 25	5 33	18 30	5 27	18 35	5 23	18 40	5 14	18 48	5 07	18 56	4 54	19 10
	16	5 42	18 18	5 33	18 28	5 27	18 33	5 21	18 39	5 16	18 45	5 06	18 55	4 58	19 03	4 42	19 20
	20	5 39	18 20	5 28	18 30	5 22	18 36	5 16	18 43	5 09	18 49	4 58	19 01	4 49	19 11	4 30	19 30
	24	5 36	18 21	5 24	18 33	5 18	18 39	5 10	18 47	5 03	18 54	4 50	19 07	4 40	19 18	4 19	19 40
	28	5 33	18 22	5 20	18 35	5 13	18 43	5 04	18 51	4 57	18 59	4 43	19 13	4 31	19 25	4 07	19 49

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LAT.		+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
EVENT		RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET
		h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
May	2	5 30	18 24	5 17	18 38	5 09	18 46	4 59	18 55	4 51	19 04	4 35	19 20	4 22	19 33	3 56	19 59
	6	5 28	18 25	5 13	18 40	5 05	18 49	4 55	18 59	4 45	19 09	4 29	19 26	4 14	19 40	3 46	20 09
	10	5 26	18 27	5 10	18 43	5 01	18 52	4 50	19 03	4 40	19 13	4 22	19 32	4 07	19 47	3 35	20 19
	14	5 24	18 28	5 07	18 45	4 58	18 56	4 46	19 07	4 36	19 18	4 16	19 37	4 00	19 54	3 26	20 29
	18	5 23	18 30	5 05	18 48	4 55	18 59	4 42	19 11	4 31	19 22	4 11	19 43	3 53	20 01	3 16	20 38
	22	5 22	18 32	5 03	18 50	4 52	19 02	4 39	19 14	4 27	19 26	4 06	19 48	3 47	20 07	3 08	20 47
	26	5 21	18 33	5 01	18 53	4 50	19 04	4 37	19 18	4 24	19 30	4 01	19 53	3 42	20 13	3 00	20 55
	30	5 20	18 35	5 00	18 55	4 48	19 07	4 34	19 21	4 21	19 34	3 58	19 58	3 37	20 19	2 53	21 03
June	3	5 20	18 36	4 59	18 57	4 47	19 10	4 33	19 24	4 19	19 37	3 55	20 02	3 33	20 23	2 47	21 10
	7	5 20	18 38	4 58	18 59	4 46	19 12	4 31	19 26	4 18	19 40	3 52	20 05	3 30	20 28	2 42	21 16
	11	5 20	18 39	4 58	19 01	4 45	19 14	4 31	19 29	4 17	19 42	3 51	20 08	3 28	20 31	2 38	21 21
	15	5 20	18 40	4 58	19 02	4 45	19 15	4 30	19 30	4 16	19 44	3 50	20 11	3 27	20 34	2 36	21 25
	19	5 21	18 41	4 59	19 04	4 46	19 17	4 31	19 32	4 17	19 46	3 50	20 12	3 27	20 36	2 35	21 27
	23	5 22	18 42	5 00	19 04	4 47	19 17	4 32	19 33	4 17	19 47	3 51	20 13	3 28	20 36	2 36	21 28
	27	5 23	18 43	5 01	19 05	4 48	19 18	4 33	19 33	4 19	19 47	3 52	20 13	3 29	20 36	2 38	21 27
July	1	5 24	18 43	5 02	19 05	4 49	19 18	4 35	19 33	4 21	19 47	3 55	20 13	3 32	20 35	2 42	21 25
	5	5 25	18 44	5 04	19 05	4 51	19 18	4 37	19 32	4 23	19 46	3 57	20 11	3 35	20 33	2 46	21 22
	9	5 27	18 43	5 06	19 04	4 53	19 17	4 39	19 31	4 26	19 44	4 01	20 09	3 39	20 30	2 52	21 17
	13	5 28	18 43	5 08	19 03	4 56	19 15	4 42	19 29	4 29	19 42	4 05	20 06	3 44	20 27	2 59	21 11
	17	5 30	18 42	5 10	19 02	4 58	19 14	4 45	19 27	4 32	19 39	4 09	20 02	3 49	20 22	3 07	21 04
	21	5 31	18 41	5 12	19 00	5 01	19 11	4 48	19 24	4 36	19 36	4 14	19 58	3 55	20 17	3 15	20 56
	25	5 33	18 40	5 14	18 58	5 04	19 09	4 52	19 21	4 40	19 32	4 19	19 53	4 01	20 11	3 24	20 48
	29	5 34	18 39	5 17	18 56	5 07	19 06	4 55	19 17	4 44	19 28	4 24	19 48	4 08	20 04	3 33	20 39
Aug.	2	5 36	18 37	5 19	18 53	5 10	19 02	4 59	19 13	4 49	19 23	4 30	19 42	4 14	19 57	3 42	20 29
	6	5 37	18 35	5 22	18 50	5 13	18 58	5 03	19 09	4 53	19 18	4 36	19 35	4 21	19 49	3 51	20 19
	10	5 38	18 32	5 24	18 46	5 16	18 54	5 06	19 04	4 58	19 12	4 42	19 28	4 28	19 41	4 01	20 08
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	18	5 41	18 27	5 29	18 39	5 22	18 45	5 14	18 53	5 07	19 00	4 53	19 13	4 42	19 24	4 20	19 46
	22	5 42	18 24	5 31	18 34	5 25	18 40	5 18	18 47	5 11	18 54	4 59	19 05	4 49	19 15	4 30	19 34
	26	5 43	18 21	5 33	18 30	5 28	18 35	5 22	18 41	5 16	18 47	5 05	18 57	4 57	19 06	4 40	19 23
	30	5 44	18 17	5 36	18 25	5 31	18 30	5 25	18 35	5 20	18 40	5 11	18 49	5 04	18 56	4 49	19 11

LAT.		+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
EVENT		RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET
		h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
Sep.	3	5 45	18 14	5 38	18 21	5 34	18 25	5 29	18 29	5 25	18 33	5 17	18 41	5 11	18 47	4 59	18 59
	7	5 46	18 10	5 40	18 16	5 37	18 19	5 33	18 23	5 29	18 26	5 23	18 32	5 18	18 37	5 08	18 47
	11	5 46	18 07	5 42	18 11	5 40	18 13	5 37	18 16	5 34	18 19	5 29	18 23	5 25	18 27	5 17	18 35
	15	5 47	18 03	5 44	18 06	5 42	18 08	5 40	18 09	5 39	18 11	5 35	18 14	5 32	18 17	5 27	18 22
	19	5 48	17 59	5 46	18 01	5 45	18 02	5 44	18 03	5 43	18 04	5 41	18 06	5 39	18 07	5 36	18 10
	23	5 49	17 56	5 49	17 56	5 48	17 56	5 48	17 56	5 48	17 56	5 47	17 57	5 47	17 57	5 46	17 58
	27	5 50	17 52	5 51	17 51	5 51	17 50	5 52	17 50	5 52	17 49	5 53	17 48	5 54	17 47	5 55	17 46
Oct.	1	5 51	17 48	5 53	17 46	5 54	17 45	5 56	17 43	5 57	17 42	5 59	17 39	6 01	17 37	6 04	17 34
	5	5 52	17 45	5 55	17 41	5 57	17 39	6 00	17 37	6 02	17 34	6 05	17 31	6 08	17 28	6 14	17 22
	9	5 53	17 42	5 58	17 36	6 01	17 34	6 04	17 30	6 07	17 27	6 12	17 22	6 16	17 18	6 24	17 10
	13	5 54	17 38	6 00	17 32	6 04	17 28	6 08	17 24	6 12	17 20	6 18	17 14	6 23	17 08	6 33	16 58
	17	5 55	17 35	6 03	17 28	6 07	17 23	6 12	17 18	6 16	17 14	6 24	17 06	6 31	16 59	6 43	16 46
	21	5 57	17 32	6 06	17 23	6 11	17 18	6 16	17 12	6 22	17 07	6 31	16 58	6 38	16 50	6 53	16 35
	25	5 58	17 30	6 08	17 19	6 14	17 14	6 21	17 07	6 27	17 01	6 37	16 50	6 46	16 41	7 03	16 24
	29	6 00	17 27	6 11	17 16	6 18	17 09	6 25	17 02	6 32	16 55	6 44	16 43	6 54	16 33	7 14	16 13
Nov.	2	6 02	17 25	6 14	17 13	6 22	17 05	6 30	16 57	6 37	16 49	6 51	16 36	7 02	16 25	7 24	16 02
	6	6 04	17 23	6 17	17 10	6 25	17 02	6 34	16 53	6 42	16 44	6 57	16 29	7 10	16 17	7 34	15 52
	10	6 06	17 22	6 21	17 07	6 29	16 58	6 39	16 48	6 48	16 40	7 04	16 23	7 17	16 10	7 44	15 43
	14	6 08	17 21	6 24	17 05	6 33	16 55	6 44	16 45	6 53	16 35	7 11	16 18	7 25	16 03	7 55	15 34
	18	6 10	17 20	6 27	17 03	6 37	16 53	6 48	16 42	6 58	16 32	7 17	16 13	7 33	15 57	8 05	15 25
	22	6 13	17 19	6 31	17 01	6 41	16 51	6 53	16 39	7 03	16 28	7 23	16 08	7 40	15 52	8 14	15 17
	26	6 15	17 19	6 34	17 00	6 45	16 50	6 57	16 37	7 08	16 26	7 29	16 05	7 47	15 47	8 24	15 10
	30	6 18	17 19	6 37	17 00	6 48	16 49	7 01	16 36	7 13	16 24	7 35	16 02	7 53	15 43	8 32	15 05
Dec.	4	6 20	17 20	6 40	17 00	6 52	16 48	7 05	16 35	7 17	16 23	7 40	16 00	7 59	15 40	8 40	15 00
	8	6 23	17 21	6 43	17 00	6 55	16 48	7 09	16 35	7 22	16 22	7 45	15 59	8 05	15 38	8 47	14 56
	12	6 25	17 22	6 46	17 01	6 58	16 49	7 12	16 35	7 25	16 22	7 49	15 58	8 10	15 38	8 53	14 54
	16	6 28	17 23	6 49	17 02	7 01	16 50	7 15	16 36	7 28	16 23	7 52	15 58	8 13	15 38	8 58	14 53
	20	6 30	17 25	6 51	17 04	7 03	16 52	7 18	16 37	7 31	16 24	7 55	16 00	8 16	15 39	9 01	14 54
	24	6 32	17 27	6 53	17 06	7 05	16 54	7 20	16 39	7 33	16 26	7 57	16 02	8 18	15 41	9 03	14 56
	28	6 34	17 29	6 55	17 08	7 07	16 56	7 21	16 42	7 34	16 29	7 58	16 05	8 19	15 44	9 04	14 59
	32	6 35	17 32	6 56	17 11	7 08	16 59	7 22	16 45	7 35	16 32	7 59	16 08	8 19	15 48	9 03	15 04

TWILIGHT

This table gives the beginning of morning and ending of evening astronomical twilight (Sun 18° below the horizon) in UT at the Greenwich meridian. For observers in North America, the times may be treated in the same way as those of sunrise and sunset (see p. 56).

LAT.	+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
M-E	MORN.	EVE.	MORN.	EVE.	MORN.	EVE.	MORN.	EVE.	MORN.	EVE.	MORN.	EVE.	MORN.	EVE.	MORN.	EVE.
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
Jan. 0	5 15	18 50	5 30	18 35	5 37	18 29	5 45	18 21	5 50	18 15	6 00	18 07	6 06	18 00	6 18	17 48
10	5 19	18 56	5 32	18 43	5 39	18 37	5 46	18 30	5 52	18 24	6 00	18 16	6 05	18 10	6 15	18 00
20	5 21	19 01	5 32	18 50	5 38	18 44	5 44	18 39	5 48	18 34	5 55	18 29	6 00	18 24	6 07	18 17
30	5 21	19 07	5 30	18 57	5 34	18 53	5 39	18 49	5 41	18 46	5 47	18 42	5 49	18 40	5 53	18 36
Feb. 9	5 18	19 11	5 25	19 05	5 27	19 02	5 30	19 00	5 32	18 59	5 34	18 57	5 34	18 57	5 34	18 57
19	5 14	19 15	5 18	19 12	5 18	19 11	5 19	19 11	5 19	19 11	5 18	19 12	5 16	19 15	5 11	19 20
Mar. 1	5 08	19 18	5 08	19 19	5 08	19 19	5 06	19 21	5 04	19 24	4 59	19 29	4 54	19 34	4 44	19 45
11	5 00	19 21	4 58	19 24	4 54	19 28	4 50	19 32	4 46	19 37	4 38	19 46	4 29	19 54	4 12	20 12
21	4 52	19 24	4 45	19 32	4 39	19 37	4 33	19 44	4 27	19 50	4 14	20 04	4 03	20 16	3 37	20 43
31	4 42	19 28	4 32	19 39	4 24	19 46	4 16	19 56	4 06	20 06	3 49	20 24	3 33	20 40	2 57	21 18
Apr. 10	4 32	19 32	4 19	19 46	4 09	19 56	3 57	20 08	3 45	20 20	3 22	20 44	3 01	21 07	2 08	22 03
20	4 23	19 36	4 05	19 54	3 54	20 06	3 39	20 22	3 23	20 37	2 54	21 08	2 24	21 39	0 52	23 23
30	4 14	19 41	3 54	20 03	3 39	20 18	3 20	20 36	3 02	20 56	2 24	21 34	1 42	22 19	.. ..	.. ..
May 10	4 08	19 46	3 42	20 12	3 25	20 29	3 04	20 51	2 41	21 15	1 52	22 05	0 39	23 26	.. ..	.. ..
20	4 02	19 52	3 33	20 21	3 14	20 41	2 49	21 05	2 22	21 33	1 16	22 42	.. ..	.. ..	.. ..	.. ..
30	3 58	19 58	3 26	20 29	3 04	20 51	2 37	21 19	2 06	21 51	0 29	23 35	.. ..	.. ..	.. ..	.. ..
June 9	3 56	20 03	3 22	20 36	3 00	20 59	2 30	21 29	1 54	22 06	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
19	3 57	20 05	3 22	20 40	2 59	21 04	2 28	21 35	1 50	22 13	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
29	3 59	20 07	3 25	20 41	3 01	21 05	2 30	21 36	1 52	22 14	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
July 9	4 03	20 06	3 30	20 39	3 08	21 02	2 38	21 31	2 04	22 05	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
19	4 08	20 04	3 37	20 34	3 17	20 55	2 50	21 21	2 20	21 51	1 00	23 07	.. ..	.. ..	.. ..	.. ..
29	4 14	19 59	3 45	20 26	3 27	20 44	3 03	21 07	2 37	21 33	1 40	22 29	.. ..	.. ..	.. ..	.. ..
Aug. 8	4 18	19 51	3 54	20 16	3 38	20 32	3 17	20 51	2 55	21 13	2 12	21 56	1 16	22 49	.. ..	.. ..
18	4 23	19 44	4 03	20 04	3 49	20 18	3 32	20 33	3 14	20 51	2 40	21 25	2 02	22 00	.. ..	.. ..
28	4 28	19 34	4 11	19 51	3 59	20 02	3 45	20 16	3 31	20 29	3 04	20 55	2 37	21 21	1 25	22 29
Sep. 7	4 31	19 24	4 18	19 37	4 09	19 46	3 58	19 57	3 47	20 07	3 26	20 28	3 05	20 47	2 18	21 32
17	4 33	19 14	4 25	19 24	4 18	19 30	4 09	19 38	4 01	19 46	3 44	20 01	3 30	20 16	2 57	20 48
27	4 37	19 05	4 30	19 11	4 27	19 14	4 21	19 20	4 15	19 26	4 03	19 37	3 52	19 48	3 28	20 09
Oct. 7	4 39	18 56	4 37	18 58	4 34	19 00	4 31	19 04	4 27	19 06	4 20	19 14	4 12	19 21	3 56	19 35
17	4 41	18 49	4 42	18 48	4 42	18 47	4 41	18 48	4 39	18 50	4 36	18 53	4 31	18 57	4 22	19 06
27	4 45	18 43	4 49	18 38	4 50	18 37	4 51	18 36	4 51	18 35	4 51	18 36	4 49	18 36	4 46	18 40
Nov. 6	4 48	18 38	4 56	18 32	4 58	18 28	5 01	18 25	5 03	18 23	5 05	18 20	5 06	18 19	5 07	18 18
16	4 53	18 36	5 02	18 27	5 07	18 22	5 11	18 17	5 14	18 14	5 19	18 08	5 23	18 05	5 28	17 59
26	4 58	18 36	5 09	18 24	5 15	18 19	5 21	18 12	5 25	18 08	5 33	18 01	5 37	17 55	5 45	17 47
Dec. 6	5 03	18 38	5 16	18 25	5 23	18 18	5 29	18 12	5 35	18 06	5 43	17 57	5 50	17 50	6 01	17 40
16	5 08	18 42	5 23	18 27	5 29	18 21	5 37	18 14	5 43	18 08	5 53	17 57	5 59	17 51	6 12	17 39
26	5 13	18 47	5 27	18 32	5 35	18 26	5 42	18 18	5 48	18 12	5 58	18 02	6 05	17 55	6 17	17 43
Jan. 5	5 18	18 52	5 32	18 39	5 38	18 32	5 45	18 25	5 51	18 19	6 00	18 11	6 07	18 05	6 18	17 53

MOON

KEY TO THE MAP OF THE MOON

CRATERS

21—Albategnius
22—Alphonsus
23—Arago
24—Archimedes
25—Aristarchus
26—Aristillus
27—Aristoteles
28—Arzachel
29—Atlas
31—Autolycus
32—Bessel
33—Bullialdus
34—Cassini
35—Catharina
36—Clavius
37—Cleomedes
38—Cook
39—Copernicus
41—Cyrillus
42—Delambre
43—Endymion
44—Eratosthenes
45—Eudoxus
46—Fracastorius
47—Furnerius
48—Gassendi
49—Grimaldi
51—Halley
52—Hercules
53—Herschel
54—Hevelius
55—Hipparchus
56—Julius Caesar
57—Kepler
58—Langrenus
59—Lansberg
61—Longomontanus
62—Macrobius
63—Maginus
64—Manilius
65—Maskelyne
66—Maurolycus
67—Mersenius
68—Newcomb
69—Petavius
71—Piccolomini
72—Plato
73—Plinius
74—Posidonius
75—Ptolemaeus
76—Reinhold
77—Ross
78—Schickard
79—Schiller
81—Snellius
82—Stevinus
83—Taruntius
84—Theophilus
85—Timocharis
86—Tycho
87—Wilhelm

MOUNTAINS

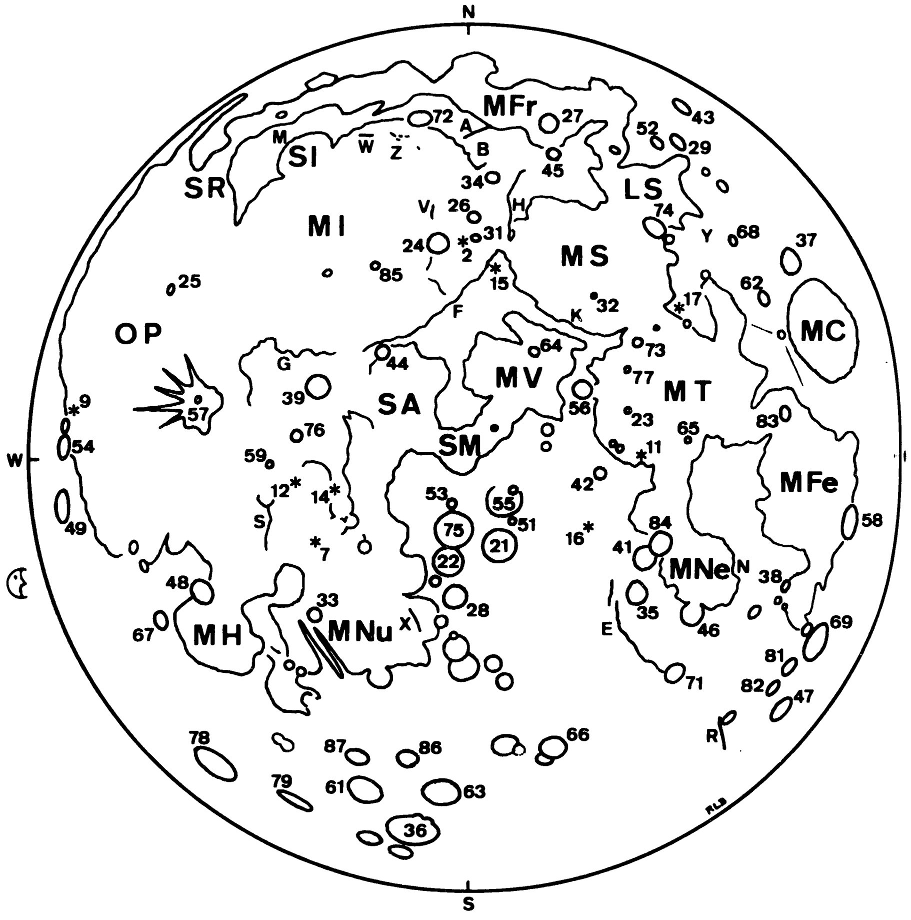
A —Alpine Valley
B —Alps Mts.
E —Altai Mts.
F —Apennine Mts.
G —Carpathian Mts.
H —Caucasus Mts.
K —Haemus Mts.
M—Jura Mts.
N —Pyrenees Mts.
R —Rheita Valley
S —Riphaeus Mts.
V —Spitzbergen
W—Straight Range
X —Straight Wall
Y —Taurus Mts.
Z —Teneriffe Mts.

MARIA

LS —Lacus Somniorum (Lake of Dreams)
MC —Mare Crisium (Sea of Crises)
MFe —Mare Fecunditatis (Sea of Fertility)
MFr —Mare Frigoris (Sea of Cold)
MH —Mare Humorum (Sea of Moisture)
MI —Mare Imbrium (Sea of Rains)
MNe—Mare Nectaris (Sea of Nectar)
MNu—Mare Nubium (Sea of Clouds)
MS —Mare Serenitatis (Sea of Serenity)
MT —Mare Tranquillitatis (Sea of Tranquillity)
MV —Mare Vaporum (Sea of Vapors)
OP —Oceanus Procellarum (Ocean of Storms)
SA —Sinus Aestuum (Seething Bay)
SI —Sinus Iridum (Bay of Rainbows)
SM —Sinus Medii (Central Bay)
SR —Sinus Roris (Bay of Dew)

LUNAR PROBES

2—Luna 2, First to reach Moon (1959·9·13)
7—Ranger 7, First close pictures (1964·7·31)
9—Luna 9, First soft landing (1966·2·3)
11—Apollo 11, First men on Moon (1969·7·20)
12—Apollo 12 (1969·11·19)
14—Apollo 14 (1971·2·5)
15—Apollo 15 (1971·7·30)
16—Apollo 16 (1972·4·21)
17—Apollo 17 (1972·12·11)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MC
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73
G
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MV
MT
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SA
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54
W
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SM
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MFe
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MH
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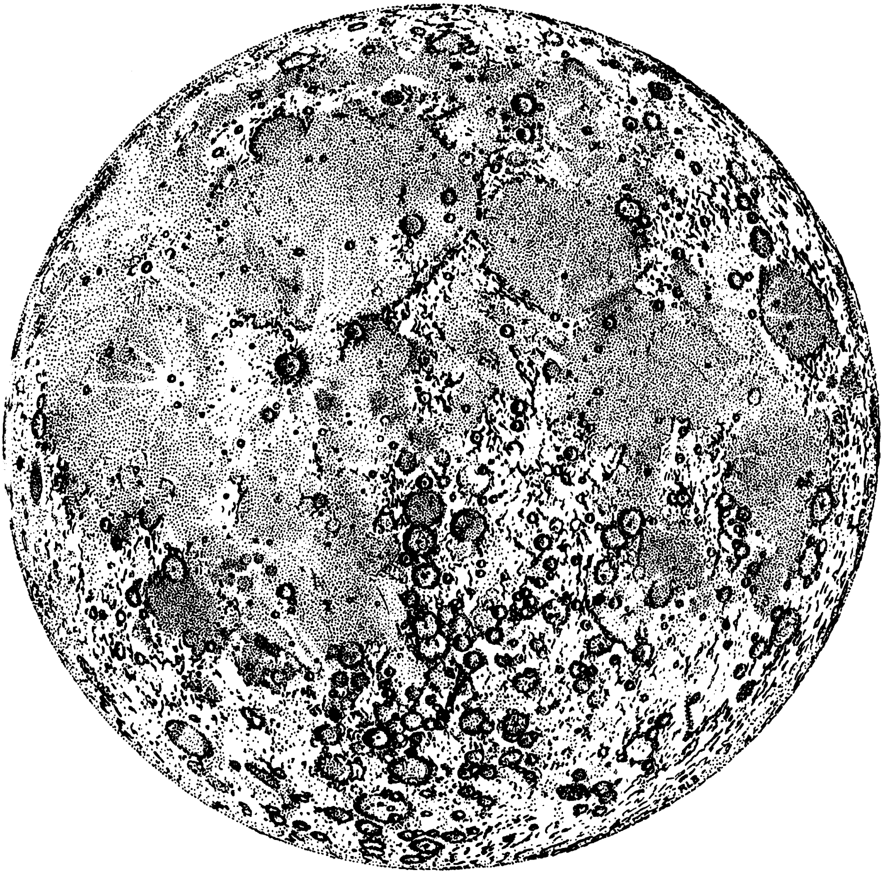
RLB

MAP OF



THE MOON

FULL MOON DATES

(UT)

1986		1987	
Jan. 26	**July 21**	**Jan. 15**	**July 11**
Feb. 24	**Aug. 19**	**Feb. 13**	**Aug. 9**
Mar. 26	**Sept. 18**	**Mar. 15**	**Sept. 7**
Apr. 24	**Oct. 17**	**Apr. 14**	**Oct. 7**
May 23	**Nov. 16**	**May 13**	**Nov. 5**
June 22	**Dec. 16**	**June 11**	**Dec. 5**

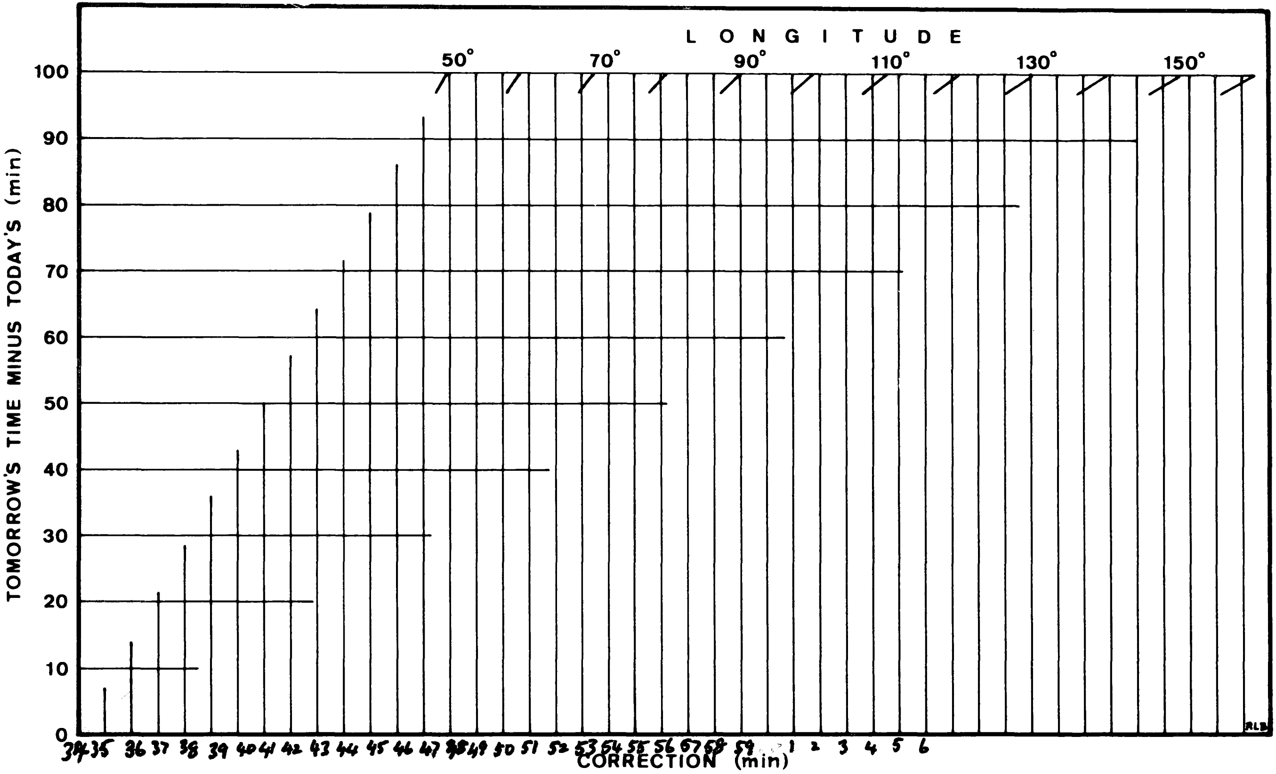
TIMES OF MOONRISE AND MOONSET

The tables on pages 66 to 77 give the times of moonrise and moonset for each day of the year for places ranging from 20° to 60° north latitude. The tables may be interpolated linearly for non-tabular latitudes, and can be extrapolated beyond the 20° and 60° latitude limits a few degrees without significant loss of accuracy. "Rise" and "set" correspond to the upper limb of the Moon appearing at the horizon for an observer at sea level. The times are in UT and are for the Greenwich meridian. Because of the relatively rapid eastward motion of the Moon, unlike the sunrise and sunset tables, the times *cannot* be read directly as standard times at the various standard meridians in North America. The table must be interpolated according to the observer's longitude. Also, the observer's longitude correction relative to his standard meridian must, of course, be applied (see p. 56). The graph on the opposite page enables the sum of these two corrections to be determined easily in one step. However, the graph must be set for your longitude.

To prepare the Moon Rise/Set Correction graph, first locate your longitude on the longitude scale. Using a straight-edge, draw a line from the origin (0,0 point) to your position on the longitude scale (a *red* pen is recommended to make this line stand out). Next, the CORRECTION axis must be labeled. As a guide, the first three divisions have been tentatively labeled 0, 1, 2; *but*, to these numbers must be added your longitude correction relative to your standard meridian (p. 56). e.g. For Toronto the correction is +18 minutes, thus an observer in Toronto would label this axis: 18, 19, 20, 21, ... 62, 63. An observer in Rimouski (longitude correction: −26) would label the axis: −26, −25, −24, ... 18, 19.

The graph is now ready for use on any day from your position. From the table obtain tomorrow's time and today's time for the event (moonrise, or moonset), enter the difference on the ordinate, and run horizontally across to meet the diagonal line. The correction, to the nearest minute, can then be read directly below off the abscissa. This correction is applied to "today's time" in the table. (*Note* that, due to a difference in height between the observer and the actual horizon, the observed time may differ by up to several minutes from the predicted time.)

MOON RISE/SET CORRECTION



LAT.		+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
EVENT		RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET
		h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
Jan.	1	22 23	10 29	22 15	10 39	22 11	10 45	22 06	10 51	22 01	10 57	21 53	11 08	21 46	11 16	21 33	11 33
	2	23 18	11 05	23 16	11 10	23 15	11 13	23 14	11 16	23 13	11 18	23 11	11 23	23 10	11 27	23 07	11 34
☾	3	.. ..	11 42	.. ..	11 40	.. ..	11 40	.. ..	11 39	.. ..	11 38	.. ..	11 37	.. ..	11 36	.. ..	11 35
	4	0 15	12 19	0 19	12 12	0 21	12 08	0 24	12 04	0 26	12 00	0 31	11 52	0 34	11 46	0 42	11 35
	5	1 13	12 59	1 23	12 46	1 29	12 39	1 36	12 31	1 42	12 23	1 53	12 09	2 03	11 58	2 21	11 37
	6	2 15	13 43	2 31	13 25	2 40	13 14	2 51	13 02	3 01	12 51	3 19	12 31	3 35	12 14	4 07	11 39
	7	3 20	14 34	3 42	14 11	3 54	13 57	4 09	13 42	4 23	13 27	4 48	13 00	5 10	12 37	5 59	11 46
	8	4 28	15 32	4 54	15 05	5 09	14 49	5 27	14 31	5 43	14 14	6 15	13 41	6 44	13 12	7 52	12 03
	9	5 36	16 35	6 04	16 08	6 20	15 51	6 39	15 32	6 57	15 14	7 32	14 39	8 04	14 07	9 25	12 46
●	10	6 40	17 42	7 07	17 16	7 23	17 00	7 41	16 42	7 59	16 25	8 32	15 53	9 02	15 23	10 14	14 12
	11	7 37	18 48	8 01	18 25	8 15	18 12	8 31	17 57	8 46	17 43	9 14	17 16	9 39	16 52	10 33	16 00
	12	8 27	19 50	8 46	19 33	8 58	19 23	9 10	19 11	9 22	19 00	9 44	18 40	10 03	18 23	10 40	17 48
	13	9 10	20 49	9 24	20 37	9 32	20 30	9 42	20 22	9 50	20 15	10 06	20 01	10 18	19 50	10 43	19 28
	14	9 48	21 43	9 57	21 37	10 02	21 33	10 08	21 29	10 13	21 25	10 22	21 18	10 30	21 12	10 45	21 00
	15	10 22	22 34	10 26	22 33	10 28	22 33	10 30	22 32	10 32	22 31	10 36	22 30	10 39	22 29	10 45	22 27
	16	10 55	23 24	10 53	23 28	10 52	23 31	10 51	23 33	10 50	23 36	10 49	23 41	10 47	23 44	10 45	23 52
☽	17	11 27	.. ..	11 20	.. ..	11 16	.. ..	11 12	.. ..	11 08	.. ..	11 01	.. ..	10 56	.. ..	10 45	.. ..
	18	11 59	0 13	11 48	0 23	11 41	0 28	11 34	0 34	11 27	0 40	11 15	0 50	11 05	0 58	10 45	1 15
	19	12 34	1 03	12 18	1 17	12 09	1 25	11 58	1 35	11 48	1 44	11 31	1 59	11 16	2 13	10 47	2 40
	20	13 12	1 54	12 51	2 13	12 40	2 24	12 26	2 36	12 13	2 48	11 50	3 10	11 31	3 28	10 50	4 07
	21	13 54	2 47	13 30	3 09	13 16	3 23	12 59	3 38	12 44	3 53	12 16	4 20	11 52	4 44	10 57	5 37
	22	14 40	3 41	14 14	4 07	13 58	4 22	13 40	4 39	13 23	4 56	12 51	5 28	12 22	5 56	11 13	7 04
	23	15 32	4 35	15 04	5 03	14 48	5 19	14 29	5 37	14 11	5 55	13 37	6 29	13 06	7 00	11 48	8 18
	24	16 27	5 29	16 01	5 56	15 45	6 12	15 27	6 30	15 09	6 48	14 37	7 21	14 07	7 51	12 54	9 04
	25	17 25	6 19	17 01	6 44	16 47	6 59	16 31	7 16	16 15	7 32	15 47	8 01	15 21	8 28	14 23	9 27
○	26	18 23	7 06	18 04	7 27	17 52	7 40	17 39	7 54	17 26	8 08	17 03	8 32	16 44	8 53	16 02	9 37
	27	19 21	7 49	19 07	8 06	18 58	8 16	18 48	8 27	18 39	8 37	18 23	8 55	18 09	9 11	17 40	9 42
	28	20 18	8 29	20 09	8 40	20 04	8 47	19 58	8 55	19 52	9 02	19 42	9 14	19 34	9 24	19 17	9 44
	29	21 14	9 06	21 11	9 12	21 09	9 16	21 07	9 20	21 05	9 23	21 01	9 30	20 58	9 35	20 52	9 45
	30	22 10	9 43	22 13	9 43	22 14	9 43	22 16	9 44	22 18	9 44	22 20	9 44	22 23	9 45	22 27	9 45
	31	23 08	10 19	23 16	10 14	23 21	10 11	23 27	10 07	23 32	10 04	23 41	9 59	23 49	9 54	.. ..	9 46

LAT.		+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
EVENT		RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET
		h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
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MOON

LAT.	+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
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MOON

LAT.	+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
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MOON

LAT.		+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
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11	14 23	1 39	14 28	1 32	14 30	1 27	14 33	1 22	14 36	1 17	14 41	1 09	14 45	1 02	14 52	0 48
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13	15 29	3 24	15 23	3 28	15 20	3 30	15 16	3 32	15 12	3 35	15 05	3 38	15 00	3 42	14 50	3 48
14	16 03	4 16	15 52	4 25	15 45	4 30	15 38	4 36	15 31	4 42	15 19	4 52	15 09	5 00	14 49	5 16
15	16 39	5 08	16 22	5 22	16 13	5 30	16 02	5 40	15 52	5 49	15 34	6 05	15 19	6 19	14 50	6 46
○ 16	17 17	6 01	16 57	6 20	16 44	6 31	16 30	6 44	16 18	6 56	15 54	7 19	15 34	7 38	14 51	8 18
17	18 00	6 55	17 35	7 18	17 21	7 32	17 04	7 48	16 48	8 03	16 19	8 31	15 54	8 56	14 56	9 53
18	18 46	7 50	18 19	8 16	18 03	8 32	17 44	8 50	17 27	9 07	16 53	9 40	16 23	10 10	15 08	11 24
19	19 36	8 43	19 08	9 11	18 51	9 28	18 32	9 47	18 13	10 06	17 38	10 41	17 05	11 14	15 39	12 40
20	20 29	9 34	20 02	10 02	19 45	10 19	19 26	10 38	19 08	10 56	18 34	11 31	18 03	12 03	16 42	13 24
21	21 23	10 22	20 58	10 48	20 43	11 04	20 26	11 21	20 10	11 38	19 40	12 09	19 12	12 37	18 08	13 42
22	22 17	11 06	21 56	11 29	21 43	11 42	21 29	11 57	21 15	12 11	20 50	12 38	20 29	13 00	19 42	13 49
23	23 10	11 46	22 54	12 05	22 44	12 15	22 33	12 28	22 23	12 39	22 04	12 59	21 48	13 17	21 15	13 52
◑ 24	.. ..	12 23	23 52	12 37	23 45	12 45	23 37	12 54	23 30	13 02	23 18	13 16	23 07	13 29	22 46	13 52
25	0 03	12 58	.. ..	13 07	.. ..	13 11	.. ..	13 17	.. ..	13 22	.. ..	13 31	.. ..	13 38	.. ..	13 52
26	0 56	13 32	0 50	13 35	0 46	13 37	0 42	13 39	0 39	13 41	0 32	13 44	0 27	13 46	0 16	13 51
27	1 50	14 07	1 49	14 04	1 49	14 03	1 49	14 01	1 49	14 00	1 49	13 57	1 49	13 55	1 48	13 50
28	2 46	14 44	2 51	14 36	2 55	14 31	2 58	14 25	3 02	14 20	3 08	14 11	3 13	14 04	3 24	13 50
29	3 45	15 25	3 57	15 11	4 04	15 02	4 12	14 53	4 19	14 44	4 32	14 28	4 44	14 15	5 06	13 50
30	4 49	16 12	5 07	15 52	5 17	15 40	5 30	15 26	5 41	15 14	6 02	14 51	6 20	14 31	6 58	13 51

LAT.		+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
EVENT		RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET
		h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
Dec. 🌑	1	5 57	17 06	6 21	16 41	6 35	16 26	6 51	16 09	7 06	15 53	7 35	15 23	8 00	14 57	8 58	13 57
	2	7 08	18 08	7 36	17 40	7 52	17 23	8 11	17 04	8 29	16 46	9 04	16 10	9 36	15 38	10 57	14 15
	3	8 18	19 16	8 47	18 48	9 04	18 31	9 24	18 11	9 42	17 53	10 19	17 17	10 52	16 44	12 21	15 15
	4	9 22	20 26	9 49	20 00	10 05	19 45	10 23	19 27	10 40	19 11	11 13	18 39	11 42	18 11	12 52	17 02
	5	10 18	21 33	10 41	21 12	10 54	21 00	11 09	20 46	11 24	20 33	11 50	20 08	12 12	19 46	13 01	19 00
	6	11 06	22 36	11 24	22 21	11 34	22 12	11 45	22 02	11 56	21 52	12 15	21 35	12 31	21 20	13 04	20 51
	7	11 47	23 34	11 59	23 25	12 06	23 19	12 14	23 13	12 21	23 07	12 34	22 57	12 44	22 49	13 04	22 32
🌓	8	12 24	.. ..	12 30	.. ..	12 34	.. ..	12 38	.. ..	12 42	.. ..	12 48	.. ..	12 54	.. ..	13 04	.. ..
	9	12 58	0 29	12 59	0 25	12 59	0 23	13 00	0 21	13 00	0 19	13 01	0 15	13 02	0 11	13 03	0 05
	10	13 31	1 21	13 27	1 23	13 24	1 24	13 21	1 26	13 18	1 27	13 13	1 29	13 09	1 31	13 02	1 34
	11	14 05	2 12	13 55	2 20	13 49	2 24	13 43	2 29	13 37	2 34	13 26	2 42	13 18	2 49	13 01	3 02
	12	14 39	3 04	14 24	3 17	14 16	3 24	14 06	3 32	13 57	3 40	13 41	3 55	13 28	4 06	13 01	4 30
	13	15 17	3 56	14 57	4 14	14 46	4 24	14 33	4 36	14 21	4 47	13 59	5 07	13 40	5 25	13 02	6 01
	14	15 58	4 49	15 34	5 12	15 20	5 25	15 04	5 40	14 50	5 54	14 22	6 20	13 58	6 43	13 06	7 34
	15	16 43	5 44	16 16	6 09	16 01	6 24	15 42	6 42	15 25	6 58	14 53	7 30	14 24	7 58	13 16	9 06
🌕	16	17 32	6 38	17 04	7 05	16 47	7 22	16 28	7 41	16 09	7 59	15 34	8 34	15 02	9 05	13 40	10 28
	17	18 24	7 30	17 56	7 58	17 39	8 14	17 20	8 34	17 02	8 52	16 27	9 27	15 55	9 59	14 32	11 22
	18	19 17	8 19	18 52	8 45	18 36	9 01	18 19	9 19	18 02	9 36	17 30	10 09	17 02	10 38	15 53	11 47
	19	20 11	9 04	19 49	9 27	19 36	9 41	19 20	9 57	19 06	10 12	18 40	10 40	18 16	11 04	17 25	11 57
	20	21 04	9 45	20 46	10 05	20 36	10 16	20 24	10 29	20 12	10 41	19 52	11 04	19 34	11 22	18 57	12 01
	21	21 57	10 22	21 44	10 37	21 36	10 46	21 27	10 56	21 19	11 05	21 04	11 22	20 52	11 36	20 28	12 03
	22	22 48	10 57	22 40	11 07	22 36	11 13	22 31	11 20	22 26	11 26	22 17	11 37	22 10	11 46	21 56	12 03
	23	23 40	11 30	23 37	11 35	23 36	11 38	23 34	11 42	23 33	11 45	23 30	11 50	23 28	11 54	23 24	12 02
🌗	24	.. ..	12 04	.. ..	12 03	.. ..	12 03	.. ..	12 03	.. ..	12 03	.. ..	12 02	.. ..	12 02	.. ..	12 01
	25	0 33	12 38	0 36	12 32	0 38	12 29	0 40	12 25	0 42	12 21	0 46	12 15	0 49	12 10	0 54	12 00
	26	1 28	13 16	1 37	13 04	1 43	12 57	1 49	12 50	1 54	12 43	2 04	12 30	2 13	12 20	2 29	12 00
	27	2 28	13 58	2 43	13 41	2 52	13 30	3 02	13 19	3 11	13 08	3 28	12 49	3 43	12 33	4 13	12 01
	28	3 32	14 47	3 53	14 24	4 05	14 11	4 19	13 56	4 33	13 42	4 57	13 15	5 19	12 52	6 06	12 04
	29	4 41	15 45	5 07	15 18	5 22	15 02	5 39	14 43	5 56	14 26	6 28	13 53	6 57	13 24	8 06	12 14
	30	5 52	16 50	6 20	16 21	6 37	16 04	6 57	15 45	7 15	15 26	7 51	14 50	8 24	14 16	9 53	12 47
🌑	31	7 00	18 01	7 28	17 33	7 45	17 17	8 04	16 58	8 22	16 40	8 57	16 06	9 29	15 35	10 50	14 15

ECLIPSES DURING 1986

BY FRED ESPENAK

Four eclipses will occur during 1986. Two of these are solar eclipses (one partial and one annular/total) and two are lunar eclipses (both total).

1. *April 9: Partial Eclipse of the Sun*
The first solar eclipse of 1986 will be partial as the Moon's umbral shadow sweeps 525 kilometres above Earth's surface. Confined entirely to the Southern Hemisphere, the event will be visible from Australia, New Guinea, New Zealand, Antarctica and the Indian Ocean. Greatest eclipse occurs at 6:20.5 UT, when the magnitude will reach 0.822 from a point 1000 kilometres north of Antarctica. The magnitudes and times of maximum eclipse for several cities of interest follow: Canberra – 0.652 (7:10 UT); Darwin – 0.223 (7:40 UT); Melbourne – 0.680 (7:03 UT); Perth – 0.440 (6:47 UT); Sidney – 0.632 (7:13 UT); Hobart – 0.735 (6:53 UT).

2. *April 24: Total Eclipse of the Moon*
Some 29 hours before reaching perigee, the Moon will swing through Earth's dark umbral shadow. As a result of this geometry, the Moon will appear quite large and will exhibit a high angular velocity as it passes though the umbra. At maximum eclipse (12:42.6 UT), the umbral magnitude will peak at 1.2078 as the Moon's southern limb passes within 6 arc-minutes of the shadow's central axis. Unfortunately, the eclipse will not be visible from eastern Canada since moonset occurs before the initial penumbral contact. Central Canada and the U.S. will have the opportunity of witnessing the early stages of the partial umbral phase. Western North America will experience totality shortly before moonset. Observers in Hawaii, Australia and the Pacific Ocean will see all stages of the eclipse. At mid-totality, the Moon will appear in the zenith from near the New Hebrides in the South Pacific. This eclipse will offer the unusual opportunity of observing Comet Halley some 74 days after perihelion. The comet will be 40 degrees southeast of the Moon and will have a declination of −26°. According to John Bortle (*Sky and Telescope*, January 1984), the comet should have a visual magnitude of 3.5 and a tail 10 or 15 degrees long.

3. *October 3: Annular/Total Eclipse of the Sun*
The annular/total eclipse is a rather unusual event because of some interesting geometry. During a total eclipse, the Moon's umbral shadow extends beyond Earth's geocenter while at an annular eclipse, the umbra falls short of the planet's surface. The annular/total eclipse forms the intermediate case: the umbra extends beyond Earth's surface but does not reach the geocenter. The path of such an eclipse exhibits a dual nature. It is annular at the extremes but becomes total along the middle section of the shadow's path. The annular/total eclipse of 1986 is just such an event. Beginning at sunset off the western coast of Iceland, the path of annularity is 59 km wide. It travels southwest and quickly narrows to a mathematical point where the umbral shadow cone first reaches Earth. For the next 160 km, the path of totality rushes due south as it broadens to a maximum of 2.4 km. Continuing another 160 km south, the umbra leaves Earth and the eclipse once again becomes annular. The path curves east and ends at sunset about 1100 km south of Iceland. This entire sequence of events transpires in 21 minutes, but the umbra actually touches our planet for only 6 minutes. Theoretically, the maximum duration of totality is a scant 1/3 second. However, this prediction does not take into account the irregularities along the Moon's limb. A detailed analysis reveals that four deep lunar valleys will result in a false or beaded totality at greatest eclipse. Nevertheless, the

chromosphere will be visible for 20 or 30 seconds and observations of the solar corona should be possible for several minutes if the bright crescent is artificially occulted. The North Atlantic in mid-autumn is probably not the most ideal place to observe a total eclipse of the Sun. If the weather prospects are not too bleak and a sea rendezvous is attempted, the expedition must deal with the unique navigational problems associated with such a narrow path of totality. Even if a ship can be positioned within the path, small perturbations in the Moon's orbit may shift the path several kilometres. It would be rather embarrassing to find that the northern end of the ship was in the path of totality while the southern end was outside the path! In any case, observers can still enjoy a partial eclipse from most of North America (except for the west coast). The magnitude and times of contacts and maximum eclipse for many cities in Canada and the U.S. are presented in a table (page 81).

4. *October 17: Total Eclipse of the Moon*
   The second lunar eclipse of the year occurs with the Moon in Pisces. The umbral magnitude attains a maximum value of 1.2501 at 19:17.9 UT, when the Moon's southern limb will pass a scant 3 arc-minutes from the shadow's central axis. Unfortunately, the visibility of this event will be confined primarily to the Eastern Hemisphere. However, observers in Labrador and Newfoundland will see the partial phase end shortly after moonrise.

SOLAR ECLIPSE MAPS

For each solar eclipse, an orthographic projection map of Earth shows the path of partial and total (or annular) eclipse. The map for the partial eclipse is oriented with its origin at the sub-solar longitude at greatest eclipse and latitude equal to the Sun's declination minus 45 degrees. The map for the annular/total eclipse is oriented with the point of greatest eclipse at the origin. Greatest eclipse is defined as the instant when the axis of the Moon's shadow passes closest to Earth's center. The point on Earth's surface which is at or is nearest to the axis at this instant is marked by an '*'. Although greatest eclipse differs slightly from the instants of greatest magnitude and greatest duration, the differences are usually negligible. The position of the Moon's umbral shadow at each hour (UT) is labeled along the path of totality. The much larger outline of the penumbral shadow is also shown at each hour (UT) and appears as a dotted curve. The limits of the penumbra delineate the region of visibility of the partial solar eclipse. Loops at the western and eastern extremes of the penumbra's path identify the areas where the eclipse is in progress at sunrise and sunset, respectively.

Data pertinent to the eclipse appear with each map. In the upper left corner are the times of greatest eclipse and conjunction of the Moon and Sun in right ascension, the minimum distance of the Moon's shadow axis from Earth's center in Earth radii (Gamma) and the geocentric ratio of diameters of the Moon and the Sun. For the partial eclipse, the geocentric ratio is replaced by the magnitude at greatest eclipse. To the upper right are contact times of the Moon's shadow with Earth. P1 and P4 are the first and last contacts of the penumbra; they mark the start and end of the partial eclipse. U1 and U4 are the first and last contacts of the umbra; they denote the start and end of the total eclipse. Below each map are the geocentric coordinates of the Sun and Moon at the instant of greatest eclipse. They consist of the right ascension (RA), declination (DEC), apparent semi-diameter (SD) and horizontal parallax (HP). The Saros series for the eclipse is listed along with the Julian Date at greatest eclipse and delta T, the difference between Dynamical and Universal Time. Finally, the geodetic coordinates of the point of greatest eclipse are given, as well as the local circumstances there. In particular, the Sun's altitude (ALT) and azimuth (AZ) are listed along with the duration of totality and the width of the path.

LUNAR ECLIPSE MAPS

Each lunar eclipse has two diagrams associated with it. The top one shows the path of the Moon with respect to Earth's penumbral and umbral shadows. To the left is the time of maximum eclipse, the angle subtended between the Moon and the shadow axis at that instant, followed by the penumbral (PMAG) and umbral (UMAG) magnitudes of the eclipse. The penumbral (or umbral) magnitude is the fraction of the Moon's disk obscured by the penumbra (or umbra) at maximum eclipse as measured along a common diameter. To the right are the contact times of the eclipse. P1 and P4 are the first and last contacts of the Moon with the penumbra; they mark the start and end of the penumbral eclipse. U1 and U4 denote the first and last contacts of the Moon with the umbra; they are the instants when the partial umbral eclipse begins and ends. U2 and U3 are the instants of internal tangency between the Moon and the umbral shadow; they identify the start and end of total umbral eclipse. In a left corner are the Julian Date at maximum eclipse and delta T, the difference between Dynamical and Universal Time. The Moon's geocentric coordinates at maximum eclipse are given on the right. They consist of the right ascension (RA), declination (DEC), apparent semi-diameter (SD), and horizontal parallax (HP).

The bottom map is a cylindrical equidistant projection of Earth which shows the regions of visibility for each stage of the eclipse. In particular, the moonrise/moonset terminator is plotted for each contact and is labeled accordingly. The point where the Moon is in the zenith at maximum eclipse is indicated by an '*'. The region which is completely unshaded will observe the entire eclipse while the area marked by solid diagonal lines will not witness any of the event. The remaining shaded areas will experience moonrise or moonset while the eclipse is in progress. The shaded zones east of '*' will witness moonset before the eclipse ends while the shaded zones west of '*' will witness moonrise after the eclipse has begun.

Additional information about eclipses is published annually in the *Astronomical Almanac*. Special circulars on up-coming solar eclipses are usually published twelve months in advance of an event. They contain many pages of detailed predictions and are highly recommended. They can be obtained by writing to the Almanac Office, U.S. Naval Observatory, Washington, DC 20390, U.S.A.

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Newcomb, S., 1895, *Tables of the Motion of the Earth on its Axis Around the Sun*, Astron. Papers Amer. Eph., Vol. 6, Part 1.

LOCAL CIRCUMSTANCES FOR THE ANNULAR/TOTAL SOLAR ECLIPSE OF 3 OCT 1986

GEOGRAPHIC LOCATION	ECLIPSE BEGINS	MAXIMUM ECLIPSE	ECLIPSE ENDS	SUN'S ALTITUDE	ECLIPSE MAGNITUDE
CHARLOTTETOWN, PEI	18:03	19:17	20:26	24°	0.845
CALGARY, ALTA.	17:17	18:12	19:07	33°	0.301
EDMONTON, ALTA.	17:13	18:11	19:09	30°	0.356
FREDERICTON, N.B.	17:59	19:14	20:24	26°	0.815
HALIFAX, N.S.	18:05	19:19	20:29	25°	0.830
MONTREAL, QUEBEC	17:53	19:08	20:19	31°	0.747
OTTAWA, ONT.	17:50	19:06	20:17	32°	0.724
QUEBEC, QUEBEC	17:53	19:08	20:19	29°	0.781
REGINA, SASK.	17:21	18:24	19:27	35°	0.414
ST. JOHN'S, NFD.	18:11	19:22	20:28	16°	0.916
SASKATOON, SASK.	17:18	18:20	19:22	33°	0.414
TORONTO, ONT.	17:50	19:05	20:16	35°	0.665
VANCOUVER, B.C.	17:22	18:02	18:43	31°	0.152
VICTORIA, B.C.	17:25	18:02	18:40	31°	0.130
WINNIPEG, MAN.	17:25	18:33	19:41	36°	0.504
ATLANTA, GA	18:07	19:18	20:25	44°	0.477
BISMARK, ND	17:29	18:33	19:37	39°	0.409
BOISE, IDAHO	17:38	18:16	18:54	39°	0.119
BILLINGS, MONT.	17:29	18:24	19:19	39°	0.279
BOSTON, MA	18:01	19:17	20:27	31°	0.743
CHICAGO, IL	17:46	18:58	20:08	41°	0.535
CLEVELAND, OH	17:51	19:06	20:17	38°	0.613
DENVER, CO	17:45	18:37	19:29	46°	0.226
DES MOINES, IOWA	17:42	18:50	19:57	43°	0.442
DETROIT, MI	17:48	19:03	20:14	38°	0.603
HOUSTON, TX	18:15	19:10	20:04	53°	0.233
MIAMI, FL	18:31	19:39	20:42	43°	0.424
NEW ORLEANS, LA	18:14	19:17	20:18	50°	0.331
NEW YORK, NY	18:01	19:17	20:28	33°	0.697
PHILADELPHIA, PA	18:01	19:17	20:27	35°	0.676
PORTLAND, OR	17:38	18:04	18:30	34°	0.058
SEATTLE, WA	17:27	18:04	18:41	33°	0.124
ST. LOUIS, MO	17:51	19:00	20:07	44°	0.454
SALT LAKE CITY	17:45	18:25	19:06	44°	0.129
WASHINGTON, D.C.	18:01	19:17	20:27	36°	0.643

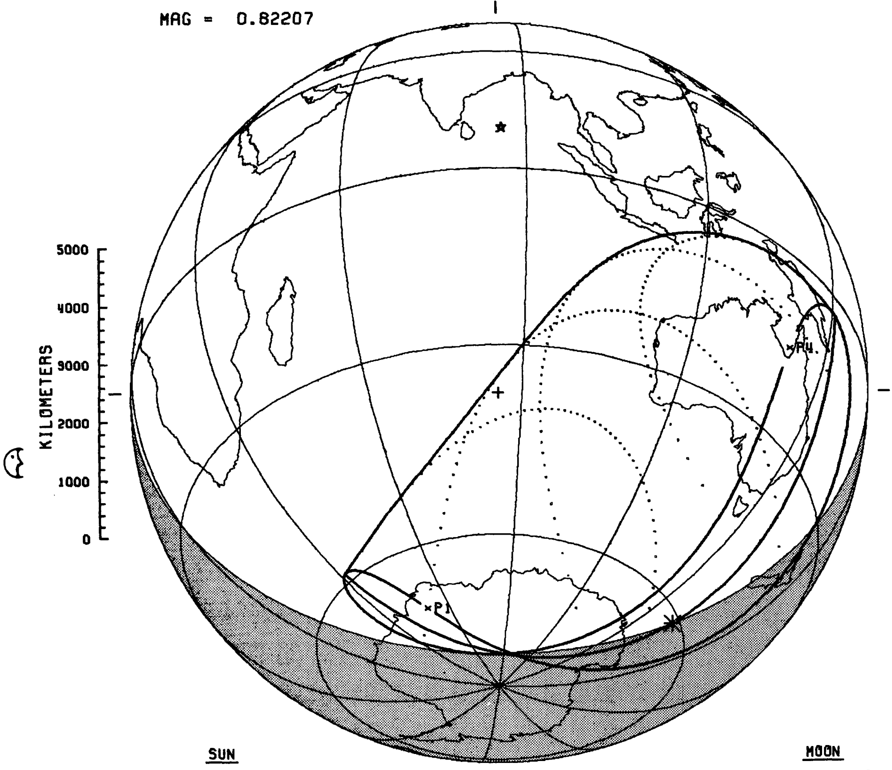
NOTE : All times are in Universal Time.
Sun's altitude is for instant of Maximum Eclipse.

PARTIAL SOLAR ECLIPSE - 9 APR 1986

GREATEST = 6:20:25.9 UT
CONJUNCTION = 5:13:53.0 UT
GAMMA = -1.08233
MAG = 0.82207

CONTACTS

P1 = 4: 9:41.4 UT
P4 = 8:31:41.1 UT



SUN

RA = $1^{h}10^{m}32^{s}.0$
DEC = $7^{\circ}29'0''.6$
SD = $15'58''.1$
HP = $0^{\circ}0'8''.8$

MOON

RA = $1^{h}12^{m}23^{s}.8$
DEC = $6^{\circ}36'30''.2$
SD = $14'59''.5$
HP = $0^{\circ}55'1''.4$

SAROS 119

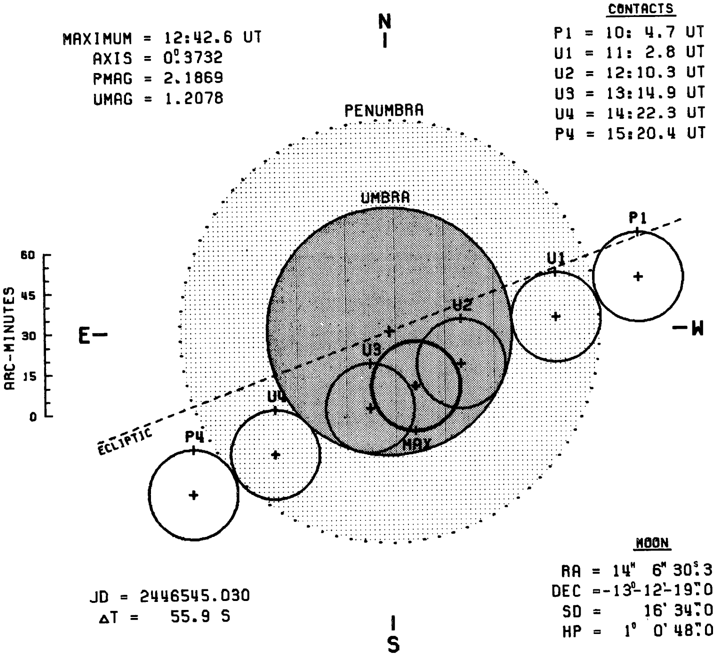
JD = 2446529.765

ΔT = 55.8 S

TOTAL LUNAR ECLIPSE - 24 APR 1986

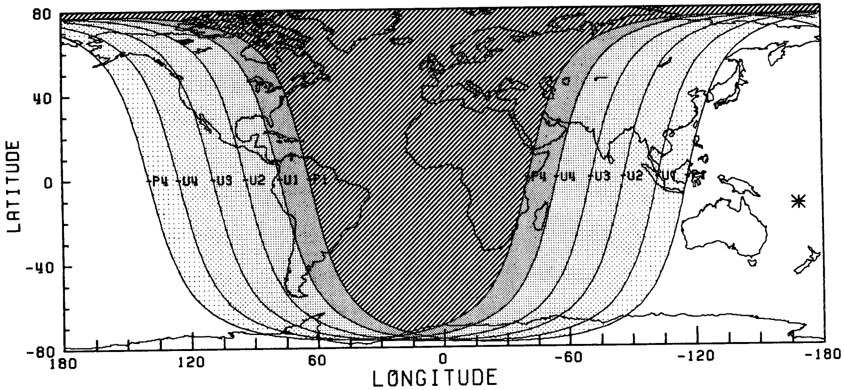
MAXIMUM = 12:42.6 UT
AXIS = 0°.3732
PMAG = 2.1869
UMAG = 1.2078

CONTACTS
P1 = 10: 4.7 UT
U1 = 11: 2.8 UT
U2 = 12:10.3 UT
U3 = 13:14.9 UT
U4 = 14:22.3 UT
P4 = 15:20.4 UT



JD = 2446545.030
ΔT = 55.9 S

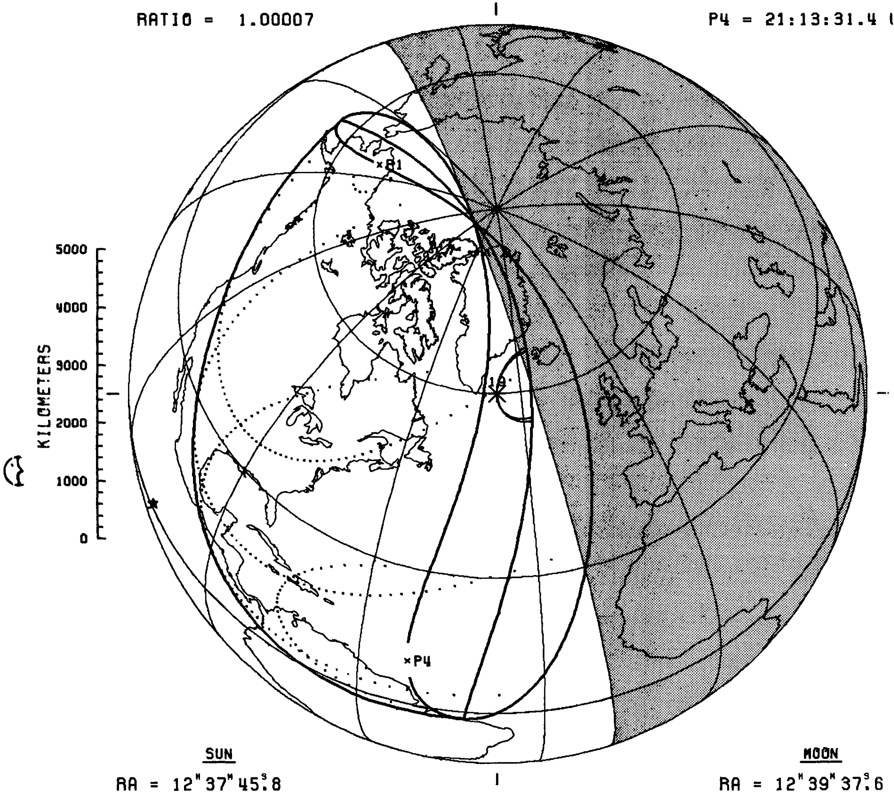
MOON
RA = 14h 6m 30s.3
DEC = -13°-12'-19".0
SD = 16' 34".0
HP = 1° 0' 48".0



ANN/TOT SOLAR ECLIPSE - 3 OCT 1986

GREATEST = 19: 5:17.6 UT
CONJUNCTION = 18: 6:25.7 UT
GAMMA = 0.99280
RATIO = 1.00007

CONTACTS
P1 = 16:57:22.3 UT
U1 = 18:54:41.2 UT
U4 = 19:16:27.8 UT
P4 = 21:13:31.4 UT



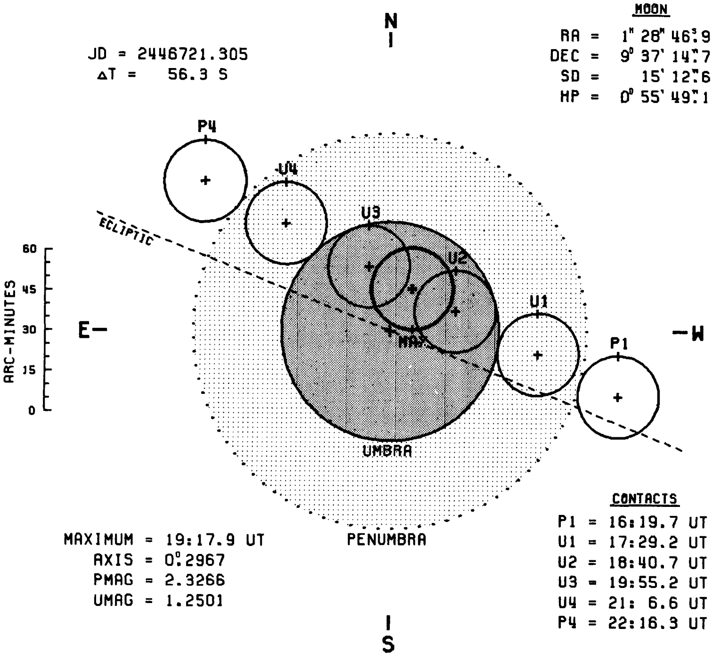
SUN
RA = $12^{h}37^{m}45^{s}.8$
DEC = $-4^{\circ}-4'-6''.4$
SD = $15'59''.2$
HP = $0^{\circ}\ 0'\ 8''.8$

MOON
RA = $12^{h}39^{m}37^{s}.6$
DEC = $-3^{\circ}-13'-11''.3$
SD = $15'58''.3$
HP = $0^{\circ}58'36''.8$

SAROS 124 JD = 2446707.296 ΔT = 56.3 S

GREATEST ECLIPSE : LAT = $59^{\circ}54'.1$N LONG = $37^{\circ}25'.4$W ALT = $5^{\circ}.6$ AZ = $252^{\circ}.2$ DURATION = 0.3 S WIDTH = 2.4 KM

TOTAL LUNAR ECLIPSE - 17 OCT 1986

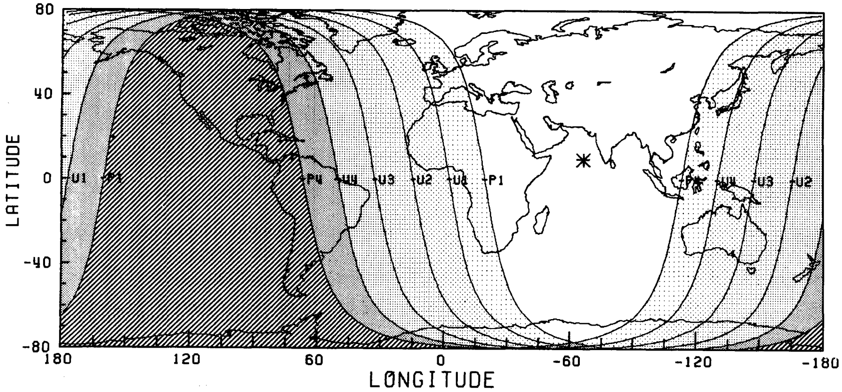


JD = 2446721.305
ΔT = 56.3 S

MOON
RA = $1^{h}\,28^{m}\,46^{s}.9$
DEC = $9^{\circ}\,37'\,14''.7$
SD = $15'\,12''.6$
HP = $0^{\circ}\,55'\,49''.1$

MAXIMUM = 19:17.9 UT
AXIS = $0^{\circ}.2967$
PMAG = 2.3266
UMAG = 1.2501

CONTACTS
P1 = 16:19.7 UT
U1 = 17:29.2 UT
U2 = 18:40.7 UT
U3 = 19:55.2 UT
U4 = 21: 6.6 UT
P4 = 22:16.3 UT



OCCULTATIONS BY THE MOON

PREDICTIONS BY THE
INTERNATIONAL LUNAR OCCULTATION CENTRE
TOKYO, JAPAN

The Moon often passes between Earth and a star, an event called an occultation. During an occultation a star suddenly disappears as the east limb of the Moon crosses the line between the star and observer. The star reappears from behind the west limb some time later. Because the Moon moves through an angle about equal to its own diameter every hour, the longest time for an occultation is about an hour. The time is shorter if the occultation is not central. Occultations are equivalent to total solar eclipses, except they are eclipses of stars other than the Sun.

Since observing occultations is rather easy, amateur astronomers are encouraged to try this activity. The slow, majestic drift of the Moon in its orbit is an interesting part of such observations, and the disappearance or reappearance of a star at the Moon's limb is a remarkable sight, particularly when it occurs as a *graze* near the Moon's northern or southern edge. In the latter case the star may disappear and reappear several times in succession as mountains and valleys in the Moon's polar regions pass by it. On rarer occasions the moon occults a planet.

Lunar occultation and graze observations are used to refine our knowledge of the Moon's orbit, the shape of the lunar profile, and the fundamental star coordinate system. These observations complement those made by other techniques, such as laser-ranging and photographs. Improved knowledge of the lunar profile is useful in determinations of the Sun's diameter from solar eclipse records. Occultation observations are also useful for detecting double stars and measuring their separations. Binaries with separations as small as 0″.01 have been discovered visually during grazes. Doubles with separations in this range are useful for filling the gap between doubles which can be directly resolved visually and those whose duplicity has been discovered spectroscopically.

Analysis of lunar occultation observations is currently being done at the U.S. Naval Observatory and the International Lunar Occultation Centre (ILOC). The latter organization is the world clearing house for such observations. Readers who are interested in pursuing a systematic program of lunar occultation observations should write to the ILOC (address on the inside front cover under "Senda") for their booklet: *Guide to Lunar Occultation Observations*.

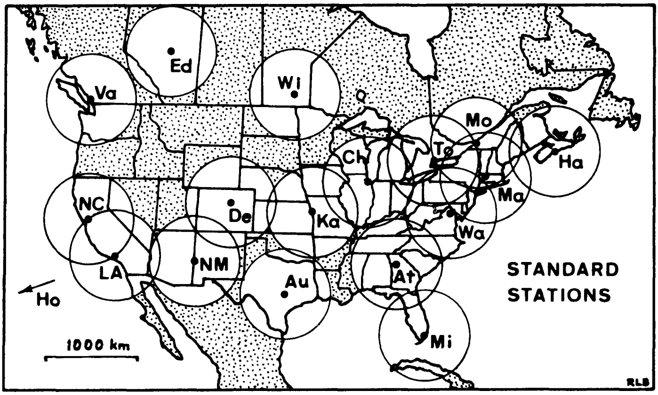
Observers in North America should also contact the International Occultation Timing Association (IOTA), P.O. Box 3392, Columbus, OH 43210-0392, U.S.A. IOTA provides predictions and coordination services for occultation observers. Detailed predictions for any grazing occultation are available ($1.50 U.S. each); instructions concerning the use of predictions are also available ($2.50 U.S.). Annual membership in IOTA is $11.00 U.S. in North America, $16.00 U.S. overseas. Membership includes free graze predictions, descriptive materials, and a subscription to *Occultation Newsletter* (available separately for $5.50 U.S.).

The main information required in a lunar occultation observation is the time of the event and the observer's location. Supplementary information includes the seeing conditions, size of telescope used, timing method used, estimate of the observer's reaction time and the accuracy of the timing, and whether or not the reaction time correction has been applied. The timing should be as accurate as possible, preferably to 0.5 s or better. (A shortwave radio time signal and cassette tape recorder provide a simple, permanent time record). The observer's geodetic latitude, longitude, and altitude should be known to at least the nearest second of arc and 20 metres respectively. These can be determined from a suitable topographical map. For Canada these are available from the Canada Map Office, 615 Booth Street, Ottawa, ON, K1A 0E9. In the United States east of the Mississippi write to: U.S. Geological Survey, 1200 S. Eads St., Arlington, VA 22202; west of the Mississippi the address is: U.S. Geological Survey, Denver Federal Centre, Bldg. 41, Denver, CO 80225.

The following pages give tables of predictions, and a table and maps of northern or southern limits for many cases where grazing occultations may be seen.

1. TOTAL OCCULTATION PREDICTIONS

The total occultation predictions are for the 18 standard stations identified on the map below; the coordinates of these stations are given in the table headings.



The tables (see pages 89–91) are generally limited to stars of magnitude 5.0 or brighter. The first five columns give for each occultation the date, the Zodiacal Catalogue number of the star, its magnitude, the phenomenon (D.D. or D.B. = disappearance at dark limb or bright limb, respectively; R.D. or R.B. = reappearance at dark limb or bright limb, respectively), and the elongation of the Moon from the Sun in degrees (see page 24). Under each station are given the universal time of the event, factors A and B (see below), and the position angle (from the north point, eastward around the Moon's limb to the point of occurrence of the phenomenon). In several cases, predictions have been replaced by the cryptic notations: GBG (after moonset); GSM (before moonrise); NB2 (Sun's altitude greater than −6°); NSG (after sunrise); NBM (before sunset). If A and B are insignificant, they are omitted.

The terms A and B are for determining corrections to the times of the phenomena for stations within 500 km of the standard stations. Thus if λ_o, ϕ_o, be the longitude and latitude of the standard station and λ, ϕ, the longitude and latitude of the observer, then for the observer we have: UT of phenomenon = UT of phenomenon at the standard station + $A(\lambda - \lambda_o) + B(\phi - \phi_o)$ where $\lambda - \lambda_o$ and $\phi - \phi_o$ are expressed in degrees and A and B are in minutes of time per degree. Due regard must be paid to the algebraic signs of the terms. Also, to convert UT to the standard time of the observer, see page 19.

As an example, consider the occultation of ZC 2172 on Jan. 6, 1986 as seen from Ottawa. For Ottawa, $\lambda = 75.72°$ and $\phi = 45.40°$. The nearest standard station is Montreal, for which $\lambda_o = 73.60°$ and $\phi_o = 45.50°$. Therefore, the UT of the reappearance at the dark limb ("R.D.") is $11^{\mathrm{h}}5\overset{\mathrm{m}}{.}0 - 0\overset{\mathrm{m}}{.}9(75.72 - 73.60) - 0\overset{\mathrm{m}}{.}1(45.40 - 45.50) = 11^{\mathrm{h}}3\overset{\mathrm{m}}{.}1$. Note that almost the same result is obtained by using Toronto as the standard station. The elongation of the Moon is 305° which means that the Moon is in the waning crescent phase (between last quarter and new). The position angle of disappearance is about 310°.

The total lunar occultation predictions on the next three pages, being limited to stars of magnitude 5.0 or brighter, are only the more spectacular events and are presented in order to introduce observers to this type of work. The number of events observable at any location increases *rapidly* as predictions are extended to fainter and fainter stars. Observers who wish to pursue this work can obtain more extensive lists from Walter V. Morgan, 10961 Morgan Territory Rd., Livermore, CA 94550, U.S.A., by providing accurate geographical coordinates and a long, self-addressed envelope (with postage). Experienced observers who regularly measure 60 or more events per year may obtain even more detailed predictions computed for their location by contacting: Occultation Project, Nautical Almanac Office, U.S. Naval Observatory, 34th and Massachusetts Ave., NW, Washington, D.C. 20390, U.S.A.

2. GRAZE PREDICTIONS

The table on page 92 lists lunar graze predictions for much of North America for 1986. The events are limited to stars of magnitude 7.5 or brighter which will graze the limb of the Moon when it is at a favourable elongation from the Sun and at least 10° above the observer's horizon (5° in the case of stars brighter than $5^{\mathrm{m}}.5$ and 2° for those brighter than $3^{\mathrm{m}}.5$). For each is given: a chronological sequential number, the Zodiacal Catalogue number and magnitude of the star, the time of the beginning of each graze track (the west end of the track), the percent of the Moon sunlit (a minus sign indicates a waning Moon), and whether the track is the northern (N) or southern (S) limit of the occultation.

The maps show the predicted graze tracks. Each track is keyed to the sequential number in the table. Several tracks begin and/or end with a letter *A*, *B*, or *S* indicated. *A* denotes that the Moon is at a low altitude, *B* that the bright limb interferes, and *S* that daylight interferes. The tick marks along the tracks indicate multiples of 5 minutes of every hour. e.g. If the time for the west end of a track is $3^{\mathrm{h}}16^{\mathrm{m}}11^{\mathrm{s}}$, the tick marks proceeding eastward correspond to $3^{\mathrm{h}}20^{\mathrm{m}}00^{\mathrm{s}}$, $3^{\mathrm{h}}25^{\mathrm{m}}00^{\mathrm{s}}$, *etc*. Also, the tick marks are located on the side of each line that the star is occulted. The locations of the North American *standard stations* for lunar total occultation predictions are indicated by dots on the graze maps (as on the map on page 87, where the names are indicated by symbols).

Detailed predictions for any graze are available from the International Occultation Timing Association (see page 86).

NAMES OF OCCULTED STARS

The stars which are occulted by the Moon are stars which lie along the zodiac; hence they are known by their number in the *Zodiacal Catalogue* (ZC) compiled by James Robertson and published in the *Astronomical Papers Prepared for the Use of the American Ephemeris and Nautical Almanac*, vol. 10, pt. 2 (U.S. Government Printing Office, Washington, 1940). Since stars are not usually recognized by their ZC numbers, the equivalent Bayer designations (and, in one instance, the Flamsteed number) of twelve of the brightest stars occulted during the year are given in the following table:

ZC	Name	ZC	Name	ZC	Name
465	**δ Ari**	**1772**	**η Vir**	**3164**	**ε Cap**
890	**136 Tau**	**2172**	**ι Lib**	**3175**	**κ Cap**
1149	**υ Gem**	**2349**	**σ Sco**	**3419**	**ψ^1 Aqr**
1484	**η Leo**	**2366**	**α Sco**	**3425**	**ψ^2 Aqr**

					HALIFAX, N.S. W 63.6 , N 44.6				MONTREAL, Q.P. W 73.6 , N 45.5				TORONTO, ONT. W 79.4 , N 43.7			
DATE M D	ZC	MAG.	PH.	ELG. °	TIME H M	A	B	P °	TIME H M	A	B	P °	TIME H M	A	B	P °
JAN. 6	2172	4.7	R.D.	305	NB2				11 5.0	-0.9	-0.1	310	10 59.4	-1.0	0.3	297
JAN. 30	1772	4.0	D.D.	235	10 36.3	...	...	212	.. ..				.. ..			
JAN. 30	1772	4.0	R.D.	235	10 41.4	...	...	220	.. ..				.. ..			
MAR. 30	2349	3.1	R.D.	239	NB2				NB2				10 27.0	-1.6	-1.1	310
APR. 15	890	4.5	D.D.	64	2 16.8	-0.9	-0.0	43	2 7.7	-0.9	-0.5	58	2 3.7	-0.9	-0.9	71
MAY 24	2366	1.2	D.B.	188	.. ..				8 31.5	...	...	174	8 25.5	...	...	171
MAY 24	2366	1.2	R.B.	188	.. ..				GBG				8 47.2	...	...	208
JULY 18	2349	3.1	D.D.	132	0 20.8	...	...	49	NBM				NBM			
JULY 18	2366	1.2	D.D.	134	GBG				4 22.1	-1.4	-1.5	128	4 16.2	-1.5	-1.4	128
JULY 18	2366	1.2	R.B.	135	GBG				GBG				5 18.8	-0.9	-0.9	251
AUG. 21	3419	4.5	R.D.	199	R.B.				5 13.0	-0.4	2.1	187	5 6.2	-0.7	2.0	195
AUG. 26	465	4.5	R.D.	258	6 4.5	-0.7	2.1	236	5 59.3	-0.7	1.8	251	5 52.7	-0.5	1.7	256
AUG. 29	890	4.5	R.D.	292	NB2				NB2				9 42.6	-0.5	3.0	222
OCT. 23	890	4.5	R.D.	239	1 27.0	0.4	1.5	253	1 32.1	0.4	1.2	265	GSM			
NOV. 19	890	4.5	D.D.	212	D.B.				10 26.2	...	...	180	.. ..			
NOV. 19	890	4.5	R.D.	212	NB2				10 33.9	...	...	192	.. ..			
DEC. 33	3175	4.8	D.D.	40	.. ..				23 25.6	-1.6	-2.6	114	23 20.4	-1.7	-2.1	108

					KANSAS CITY,MO. W 94.5 , N 39.0				DENVER,COLORADO W105.0 , N 39.8				NEW MEX._ARIZONA W109.0 , N 34.0			
DATE M D	ZC	MAG.	PH.	ELG. °	TIME H M	A	B	P °	TIME H M	A	B	P °	TIME H M	A	B	P °
JAN. 6	2172	4.7	R.D.	304	10 38.7	-1.2	1.7	258	GSM				.. ..			
MAR. 30	2349	3.1	R.D.	238	10 5.1	-1.8	-0.4	294	9 46.3	-1.8	0.2	282	9 35.8	-2.2	0.8	264
APR. 15	890	4.5	D.D.	64	1 54.6	-1.1	-1.7	104	NSG				NSG			
MAY 24	2366	1.2	D.B.	188	8 16.1	...	...	185	.. ..				.. ..			
MAY 24	2366	1.2	R.B.	188	8 26.4	...	...	201	.. ..				.. ..			
MAY 27	2912	4.6	R.D.	230	NB2				10 19.9	-1.3	1.8	199	9 59.1	...	...	184
JUN. 16	1772	4.0	D.D.	100	GBG				GBG				7 25.3	-0.3	-1.0	80
JUN. 27	3419	4.5	R.D.	251	NB2				10 19.9	-2.2	0.8	269	10 5.6	-2.2	1.0	265
JUN. 27	3425	4.6	R.D.	251	.. ..				NB2				10 41.4	...	...	169
JULY 18	2366	1.2	D.D.	134	3 57.0	-1.7	-1.2	136	3 39.8	-1.4	-1.0	144	3 42.9	-0.9	-1.9	163
JULY 18	2366	1.2	R.B.	135	5 2.7	-1.7	-0.4	251	4 42.8	-2.1	-0.0	250	4 31.0	-2.8	1.0	235
AUG. 21	3419	4.5	R.D.	199	4 43.8	-0.9	2.2	208	4 36.3	-0.8	2.1	217	4 20.6	-0.7	2.3	210
AUG. 26	465	4.5	R.D.	258	5 39.9	-0.2	1.4	268	5 40.0	0.0	1.1	280	GSM			
AUG. 29	890	4.5	R.D.	292	9 25.1	-0.2	2.3	232	9 24.9	-0.2	1.7	250	9 14.8	0.1	1.7	243
OCT. 7	2366	1.2	D.D.	55	.. ..				.. ..				21 57.1	-3.5	2.0	52
OCT. 7	2366	1.2	R.B.	55	.. ..				.. ..				22 40.5	-0.9	-2.5	349
NOV. 9	3164	4.7	D.D.	94	4 55.3	-0.5	-0.7	72	4 49.1	-0.6	-0.1	54	4 47.0	-0.9	-0.2	63

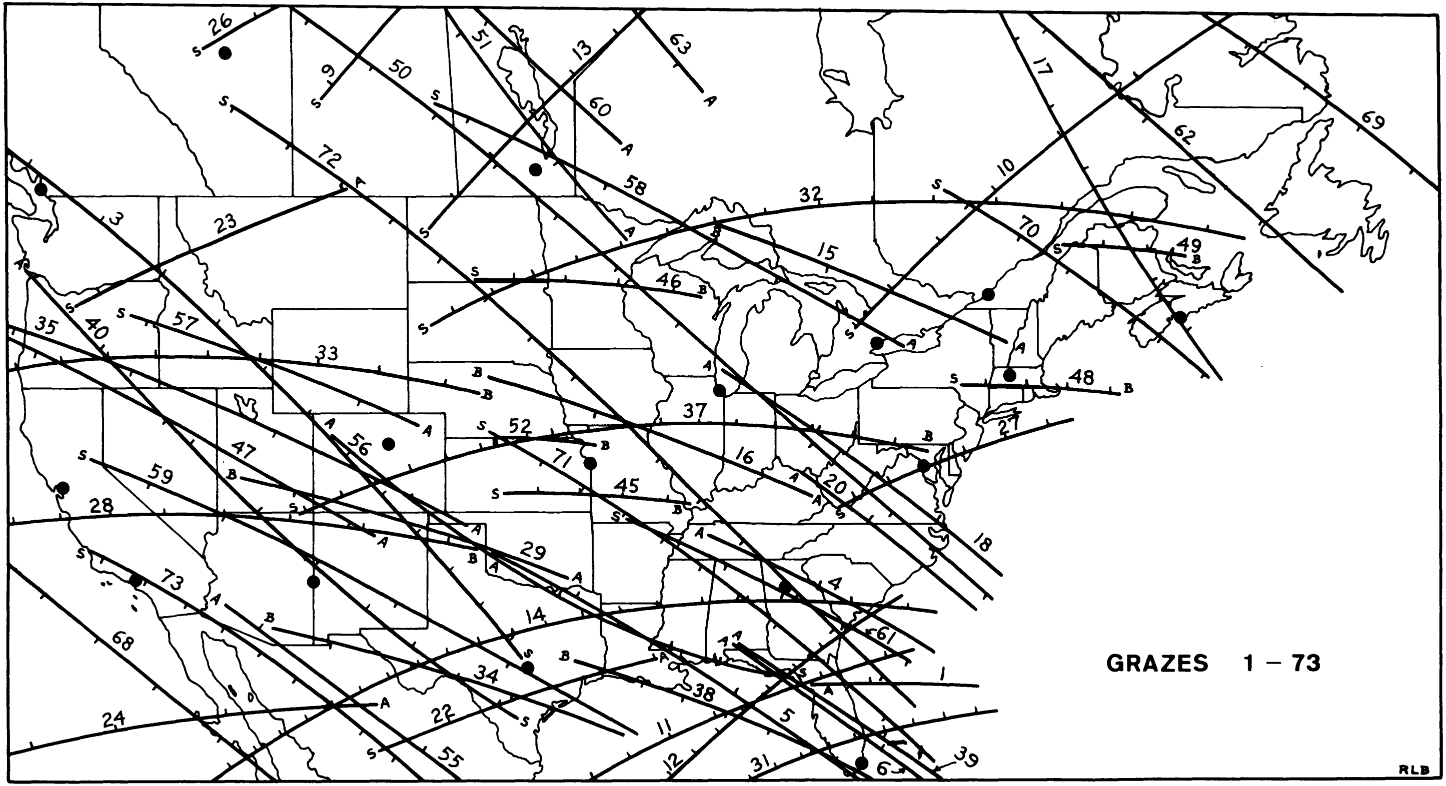
					WINNIPEG,MAN				EDMONTON,ALTA.				VANCOUVER,B.C.			
					W 97.2 , N 49.9				W113.4 , N 53.6				W123.1 , N 49.2			
DATE M D	ZC	MAG.	PH.	ELG. °	TIME H M	A	B	P °	TIME H M	A	B	P °	TIME H M	A	B	P °
FEB. 11	3425	4.6	D.D.	25	.. ..				1 17.0	-0.9	-2.1	100	NSG			
MAR. 30	2349	3.1	R.D.	238	9 57.4	-1.2	-0.2	305	9 39.9	-1.0	0.5	292	9 26.4	-1.1	1.0	273
MAR. 30	2366	1.2	D.B.	240	GBG				13 5.6	-1.2	-1.2	160	13 0.5	...	...	170
MAR. 30	2366	1.2	R.D.	240	GBG				GBG				13 32.5	...	...	220
APR. 15	890	4.5	D.D.	64	1 38.1	-1.4	-0.6	73	NSG				NSG			
MAY 24	2366	1.2	D.B.	187	7 47.9	-1.1	-1.1	158	7 32.0	...	...	171	.. ..			
MAY 24	2366	1.2	R.D.	188	8 29.6	-1.4	-0.3	230	8 2.5	...	...	224	.. ..			
MAY 27	2912	4.6	R.D.	230	NB2				NB2				10 5.5	-1.5	1.3	220
JUN. 16	1772	4.0	D.D.	100	GBG				7 7.0	...	...	39	7 0.1	...	...	61
JUN. 27	3419	4.5	D.D.	251	D.B.				D.B.				9 38.8	...	...	332
JUN. 27	3419	4.5	R.D.	251	NB2				NB2				9 41.6	...	...	327
JUN. 27	3425	4.6	R.D.	251	NB2				NB2				11 6.1	-1.0	1.6	219
JULY 18	2366	1.2	D.D.	134	3 43.8	-1.4	-0.5	125	3 24.2	-0.9	0.0	135	3 17.6	-0.5	-0.3	154
JULY 18	2366	1.2	R.B.	135	4 52.0	-1.4	-0.7	264	4 26.9	-1.5	0.0	260	4 9.0	-1.9	0.8	246
AUG. 21	3419	4.5	R.D.	199	5 2.2	-0.9	1.7	222	4 56.5	-0.6	1.8	233	GSM			
AUG. 26	465	4.5	R.D.	258	5 54.2	-0.4	1.4	286	5 54.3	...	...	309	GSM			
AUG. 29	890	4.5	R.D.	292	9 45.5	-0.6	1.7	262	9 42.7	-0.4	1.3	288	9 34.1	-0.2	1.1	292
OCT. 7	2366	1.2	D.D.	55	.. ..				.. ..				21 48.3	...	...	36
OCT. 7	2366	1.2	R.B.	55	.. ..				.. ..				22 6.8	...	...	5
NOV. 9	3164	4.7	D.D.	94	GBG				4 56.2	...	...	354	4 56.5	...	...	345
NOV. 11	3419	4.5	D.D.	118	.. ..				2 44.8	...	...	124	2 19.4	-2.2	0.6	109
NOV. 19	890	4.5	R.D.	212	.. ..				9 37.8	...	...	203	.. ..			

					MASSA~~K~~CHUSETTS				WASHINGTON,D.C.				CHICAGO,ILLINOIS			
					W 72.5 , N 42.5				W 77.0 , N 38.9				W 87.7 , N 41.9			
DATE M D	ZC	MAG.	PH.	ELG. °	TIME H M	A	B	P °	TIME H M	A	B	P °	TIME H M	A	B	P °
JAN. 6	2172	4.7	R.D.	305	11 6.3	-1.0	-0.1	306	11 0.6	-1.3	0.3	290	10 50.0	-1.0	0.9	279
MAR. 30	2349	3.1	R.D.	238	NB2				NB2				10 15.2	-1.7	-0.8	304
APR. 15	890	4.5	D.D.	64	2 10.4	-0.8	-0.7	65	2 10.3	-0.7	-1.0	81	1 57.6	-1.0	-1.2	87
MAY 24	2366	1.2	D.B.	188	.. ..				.. ..				8 15.6	...	...	171
MAY 24	2366	1.2	R.B.	188	.. ..				.. ..				8 41.0	...	...	212
JULY 18	2366	1.2	D.D.	134	4 28.5	-1.5	-1.7	132	4 27.7	-1.7	-1.8	136	4 5.1	-1.7	-1.2	130
JULY 18	2366	1.2	R.B.	135	GBG				5 24.2	-0.8	-0.5	241	5 11.1	-1.3	-0.7	254
AUG. 21	3419	4.5	R.D.	199	5 6.3	-0.0	2.6	178	4 56.2	-0.2	2.7	181	4 56.0	-0.9	2.0	205
AUG. 26	465	4.5	R.D.	258	5 54.5	-0.6	1.9	245	5 45.5	-0.5	1.8	246	5 46.0	-0.4	1.5	264
AUG. 29	890	4.5	R.D.	292	NB2				9 25.4	0.4	4.8	198	9 33.9	-0.4	2.5	230
OCT. 23	890	4.5	R.D.	239	1 27.8	0.5	1.3	259	GSM				GSM			
NOV. 21	1149	4.2	R.D.	232	.. ..				7 14.3	...	...	341	.. ..			
DEC. 33	3175	4.8	D.D.	40	23 42.9	...	...	146	.. ..				23 9.3	-1.7	-1.3	96
DEC. 33	3175	4.8	R.D.	40	23 46.2	...	...	152	.. ..				R.B.			

					MIAMI,FLORIDA W 80.3 , N 25.8				ATLANTA,GEORGIA W 84.3 , N 33.8				AUSTIN,TEXAS W 97.8 , N 30.2			
DATE	ZC	MAG.	PH.	ELG.	TIME	A	B	P	TIME	A	B	P	TIME	A	B	P
M D				°	H M			°	H M			°	H M			°
JAN. 6	2172	4.7	D.D.	304	10 15.9	...	...	195	D.B.				.. ..			
JAN. 6	2172	4.7	R.D.	304	10 37.1	...	...	232	10 45.7	-1.8	1.4	260	.. ..			
FEB. 11	3419	4.5	D.D.	25	.. ..				GBG				0 55.8	...	...	124
MAR. 30	2349	3.1	R.D.	239	10 44.5	-2.3	-0.8	281	10 28.6	-2.1	-0.9	294	10 0.4	-2.4	0.0	274
APR. 15	890	4.5	D.D.	64	2 28.1	-0.1	-2.0	123	2 12.2	-0.6	-1.7	106	2 12.6	-0.5	-3.3	139
JUN. 27	3419	4.5	R.D.	251	NB2				NB2				10 24.9	-2.0	1.4	239
JULY 18	2366	1.2	D.D.	134	.. ..				4 24.0	-2.0	-2.0	144	4 5.8	-1.7	-2.3	157
JULY 18	2366	1.2	R.B.	135	.. ..				5 18.8	-1.1	-0.0	236	4 56.1	-2.2	0.8	232
AUG. 21	3419	4.5	R.D.	198	.. ..				4 39.2	-0.5	2.9	185	4 19.8	-0.8	2.7	196
AUG. 26	465	4.5	R.D.	258	5 20.8	0.0	1.9	227	5 34.2	-0.2	1.6	247	5 28.3	0.1	1.3	256
AUG. 29	890	4.5	R.D.	292	.. ..				9 6.5	...	...	192	9 3.6	0.5	2.8	212
OCT. 7	2366	1.2	D.D.	56	23 6.0	-1.7	0.8	52	.. ..				22 29.8	...	...	41
OCT. 7	2366	1.2	R.B.	56	23 59.8	-2.1	-2.7	325	.. ..				23 6.0	...	...	351
NOV. 9	3164	4.7	D.D.	94	.. ..				GBG				5 1.2	-1.2	-1.4	97
NOV. 21	1149	4.2	R.D.	233	7 29.7	-2.8	-0.2	282	7 12.4	-2.4	-1.8	315	6 46.0	-2.1	-1.1	311

					LOS ANGELES,CAL. W118.3 , N 34.1				N. CALIFORNIA W122.0 , N 38.0				HONOLULU,HAWAII W157.9 , N 21.3			
DATE	ZC	MAG.	PH.	ELG.	TIME	A	B	P	TIME	A	B	P	TIME	A	B	P
M D				°	H M			°	H M			°	H M			°
JAN. 0	1484	3.6	R.D.	228	.. ..				.. ..				9 25.3	-1.0	-0.4	300
FEB. 5	2617	4.7	R.D.	315	14 14.7	-1.5	0.8	273	14 13.0	-1.2	0.9	276	.. ..			
FEB. 16	465	4.5	D.D.	84	.. ..				.. ..				5 36.0	-2.1	2.5	36
FEB. 19	890	4.5	D.D.	118	.. ..				.. ..				10 15.3	-1.3	-0.7	89
MAR. 30	2349	3.1	R.D.	238	9 14.0	-2.6	2.1	242	9 13.1	-2.1	1.9	247	.. ..			
APR. 22	1772	4.0	D.D.	153	GBG				GBG				13 24.8	-0.3	-2.4	158
MAY 27	2912	4.6	R.D.	230	9 42.4	...	...	188	9 47.4	...	...	201	.. ..			
JUN. 16	1772	4.0	D.D.	100	7 20.8	-0.7	-1.1	83	7 13.6	-0.9	-1.1	79	6 59.1	-0.8	-2.7	162
JUN. 27	3419	4.5	R.D.	251	9 46.9	-1.8	0.9	279	9 43.5	-1.7	0.7	291	GSM			
JUN. 27	3425	4.6	R.D.	251	10 39.3	-0.7	2.7	191	10 45.7	-1.0	2.3	204	GSM			
JULY 18	2366	1.2	D.B.	134	3 44.5	...	...	193	3 32.6	...	...	185	.. ..			
JULY 18	2366	1.2	R.B.	134	3 56.2	...	...	210	3 54.9	...	...	219	.. ..			
AUG. 14	2349	3.1	D.D.	107	GBG				GBG				9 2.7	...	...	33
AUG. 21	3419	4.5	R.D.	198	4 14.9	-0.5	2.2	212	GSM				.. ..			
AUG. 29	890	4.5	R.D.	292	9 16.3	0.2	1.3	256	9 21.6	0.1	1.2	269	GSM			
SEP. 27	1149	4.2	R.D.	287	NB2				NB2				15 47.8	-2.4	2.4	241
OCT. 7	2366	1.2	D.D.	55	21 30.0	-2.4	1.2	74	21 26.7	-2.2	1.4	71	.. ..			
OCT. 7	2366	1.2	R.B.	55	22 31.0	-1.1	-1.3	332	22 22.9	-0.8	-1.1	334	.. ..			
NOV. 9	3164	4.7	D.D.	94	4 38.5	-0.9	0.5	46	4 38.5	-0.5	0.9	28	NSG			
NOV. 9	3175	4.8	D.D.	95	GBG				GBG				7 2.9	-1.6	0.5	61
DEC. 24	1772	4.0	R.D.	272	.. ..				.. ..				12 27.2	-0.4	-1.9	338

No.	ZC	m_v	UT at Start of Track in West			%	L
1	1684	7.0	Jan.	2	$4^h53^m37^s$	-67	S
3	1808	7.0		3	$12^h03^m32^s$	-53	S
4	2034	7.2		5	$8^h41^m56^s$	-32	S
5	2172	4.7		6	$10^h13^m34^s$	-21	S
6	2328	6.4		7	$10^h54^m44^s$	-12	S
9	3478	6.5		15	$0^h09^m08^s$	23	S
10	36	7.2		15	$22^h41^m00^s$	31	S
11	155	6.8		17	$1^h49^m24^s$	41	S
12	374	6.1		19	$0^h04^m09^s$	60	S
13	480	7.3		20	$0^h06^m26^s$	69	S
14	489	7.2		20	$2^h46^m07^s$	70	S
15	500	7.0		20	$6^h37^m06^s$	71	N
16	503	7.2		20	$7^h06^m28^s$	71	N
17	1772	4.0		30	$10^h13^m00^s$	-79	S
18	2120	6.8	Feb.	2	$8^h07^m17^s$	-48	S
20	2262	7.4		3	$8^h53^m06^s$	-36	S
22	3419	4.5		11	$1^h02^m04^s$	4	S
23	3425	4.6		11	$1^h39^m12^s$	5	S
24	109	6.5		13	$3^h28^m18^s$	17	S
26	226	6.6		14	$1^h21^m19^s$	24	S
27	442	6.9		15	$23^h32^m25^s$	42	S
28	457	6.5		16	$4^h14^m16^s$	43	S
29	460	7.0		16	$5^h43^m05^s$	44	N
31	566	5.9		17	$0^h14^m27^s$	52	S
32	573	6.8		17	$0^h51^m39^s$	52	S
33	582	5.8		17	$4^h03^m43^s$	53	S
34	584	6.0		17	$5^h11^m12^s$	53	N
35	594	6.9		17	$6^h59^m35^s$	54	N
37	844	5.7		19	$1^h28^m50^s$	71	S
38	1008	5.0		20	$3^h56^m25^s$	80	N
39	2216	7.0	Mar.	2	$6^h30^m12^s$	-63	S
40	2404	6.9		3	$11^h52^m12^s$	-50	S
45	649	7.2		17	$1^h10^m29^s$	34	S
46	652	6.4		17	$1^h20^m18^s$	34	S
47	683	7.3		17	$6^h08^m38^s$	36	N
48	780	6.8		17	$23^h36^m48^s$	43	S
49	1067	7.2		19	$23^h20^m31^s$	62	S
50	1093	6.4		20	$5^h08^m23^s$	64	N
51	1108	6.9		20	$8^h28^m53^s$	65	N
52	1206	5.9		21	$1^h16^m25^s$	73	S
55	2505	5.4		31	$8^h14^m27^s$	-66	S
56	2688	6.9	Apr.	1	$10^h25^m33^s$	-54	S
57	485	6.9		12	$3^h04^m28^s$	7	N
58	611	7.0		13	$2^h18^m36^s$	13	N
59	750	6.9		14	$3^h05^m42^s$	20	N
60	762	6.6		14	$4^h54^m32^s$	20	N
61	885	5.6		15	$1^h10^m45^s$	27	N
62	890	4.5		15	$2^h18^m57^s$	28	N
63	909	6.1		15	$5^h43^m33^s$	29	N
68	1181	6.8		17	$6^h05^m50^s$	48	N
69	1274	5.7		17	$23^h56^m17^s$	56	N
70	1279	6.4		18	$0^h32^m43^s$	56	N
71	1283	6.8		18	$1^h48^m41^s$	56	N
72	1290	6.8		18	$3^h09^m50^s$	57	N
73	1408	7.4		19	$3^h03^m42^s$	67	N
78	1373	6.1	May	16	$3^h12^m26^s$	41	N
79	1578	6.8		18	$1^h58^m39^s$	61	N
80	1596	7.0	May	18	$7^h14^m06^s$	63	N
81	3202	6.1		29	$8^h37^m55^s$	-62	N
82	1093	6.4	June	10	$2^h45^m17^s$	6	N
84	1334	7.0		12	$2^h01^m37^s$	18	N
85	1772	4.0		16	$7^h09^m19^s$	58	N
86	3419	4.5		27	$9^h36^m23^s$	-66	N
87	3535	5.2		28	$8^h47^m40^s$	-56	N
88	3537	6.8		28	$9^h43^m29^s$	-56	N
90	563	6.9	July	3	$9^h02^m52^s$	-12	N
92	703	6.3		4	$9^h07^m46^s$	-7	N
93	1732	7.0		13	$3^h01^m48^s$	32	N
94	1945	5.4		15	$1^h17^m41^s$	52	N
96	2349	3.1		18	$0^h32^m37^s$	84	N
97	184	6.2		27	$8^h04^m51^s$	-62	N
98	290	6.1		28	$7^h59^m26^s$	-53	N
99	1093	6.4	Aug.	3	$12^h29^m19^s$	-5	N
100	1911	7.1		11	$0^h10^m42^s$	27	N
101	2299	6.4		14	$1^h15^m16^s$	61	N
102	486	5.2		26	$10^h33^m51^s$	-58	N
103	598	5.7		27	$6^h58^m17^s$	-50	N
104	750	6.9		28	$9^h51^m51^s$	-40	N
105	885	5.6		29	$7^h42^m44^s$	-31	N
106	1035	6.8		30	$8^h21^m56^s$	-23	N
107	1181	6.8		31	$12^h38^m24^s$	-14	N
109	1290	6.8	Sept.	1	$10^h36^m47^s$	-8	N
110	2788	6.2		13	$5^h12^m27^s$	71	S
111	556	5.5		23	$8^h14^m56^s$	-75	N
112	996	6.8		26	$9^h36^m17^s$	-47	N
114	1373	6.1		29	$11^h31^m56^s$	-19	N
115	2349	3.1	Oct.	7	$17^h55^m39^s$	20	N
116	2366	1.2		7	$21^h57^m59^s$	22	N
117	2898	7.2		11	$2^h11^m43^s$	56	S
118	2912	4.6		11	$5^h18^m25^s$	57	S
119	3052	6.2		12	$3^h09^m19^s$	67	S
120	1181	6.8		25	$5^h11^m17^s$	-56	N
121	1206	5.9		25	$11^h12^m33^s$	-54	S
122	1334	7.0		26	$14^h02^m58^s$	-43	S
123	1645	6.6		29	$12^h51^m28^s$	-16	S
125	1746	7.1		30	$11^h57^m01^s$	-9	S
127	2855	7.4	Nov.	7	$1^h19^m38^s$	30	S
128	2998	6.2		8	$1^h18^m33^s$	40	S
129	3160	7.0		9	$3^h00^m17^s$	52	S
130	3158	5.8		9	$3^h18^m32^s$	52	S
132	3419	4.5		11	$2^h21^m00^s$	73	S
133	3535	5.2		12	$1^h44^m28^s$	82	S
134	1149	4.2		21	$5^h57^m03^s$	-80	N
135	1169	5.4		21	$11^h56^m25^s$	-79	S
136	1274	5.7		22	$8^h07^m10^s$	-71	N
138	1393	6.7		23	$10^h23^m10^s$	-62	S
139	1479	6.3		24	$6^h39^m19^s$	-53	S
140	1485	7.2		24	$8^h06^m01^s$	-53	S
141	1576	5.3		25	$5^h20^m01^s$	-44	S
144	3243	7.4	Dec.	7	$0^h57^m39^s$	36	S
145	3265	6.6		7	$4^h29^m29^s$	37	S
146	3356	5.9		7	$21^h38^m25^s$	45	S
148	1986	7.0		26	$11^h07^m18^s$	-28	S
149	2115	7.1		27	$13^h08^m13^s$	-18	S



GRAZES 1 – 73

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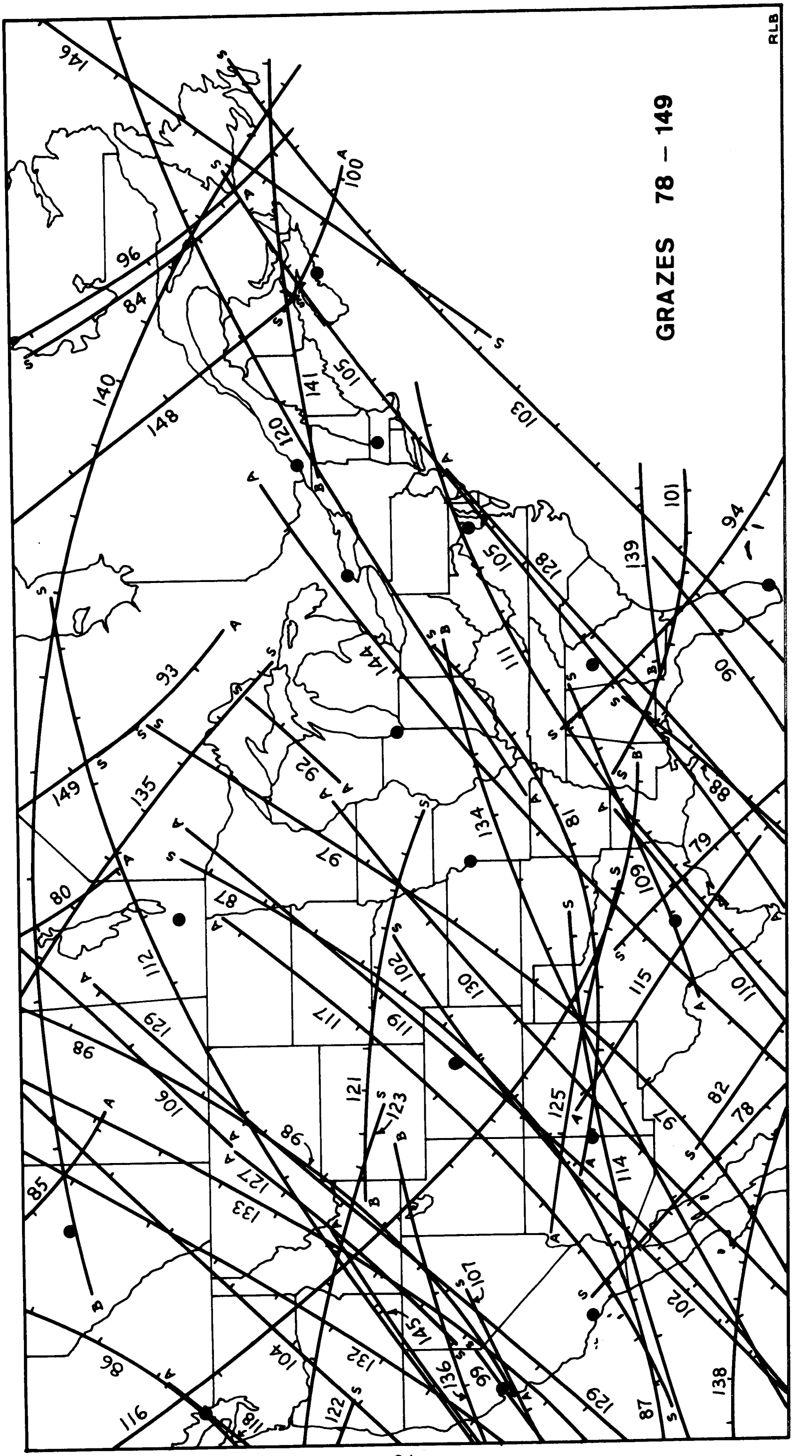
GRAZES 78 – 149
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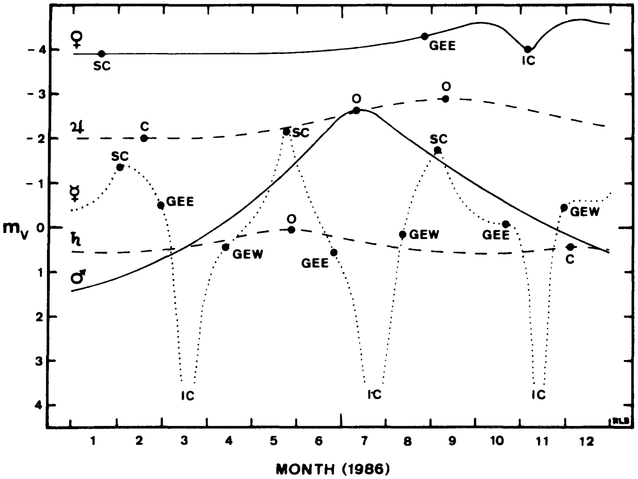
PLANETS, SATELLITES, AND ASTEROIDS

PLANETARY HELIOCENTRIC LONGITUDES 1986

The heliocentric longitude of a planet is the angle between the vernal equinox and the planet, as seen from the Sun. It is measured in the ecliptic plane, in the direction of the orbital motion of the planet (counterclockwise as viewed from the north side of the ecliptic plane). Knowing the heliocentric longitudes, and the approximate distances of the planets from the Sun (see page 9), one can construct a diagram or model showing the orientation of the Sun and planets on any date.

UT	☿	♀	⊕	♂	♃	♄	♅	♆	♇
Jan. 1.0	222°	270°	100°	189°	325°	242°	258°	273°	215°
Feb. 1.0	312	319	132	204	328	243	259	274	215
Mar. 1.0	93	3	160	217	330	244	259	274	216
Apr. 1.0	228	53	191	232	333	245	260	274	216
May 1.0	315	101	220	248	336	246	260	274	216
June 1.0	117	151	250	265	339	247	260	274	216
July 1.0	236	200	279	282	341	247	261	274	216
Aug. 1.0	330	250	308	301	344	248	261	275	217
Sept. 1.0	140	299	338	320	347	249	261	275	217
Oct. 1.0	248	346	8	339	350	250	262	275	217
Nov. 1.0	347	36	38	359	353	251	262	275	217
Dec. 1.0	155	84	68	17	355	252	262	275	218
Jan. 1.0	259	134	100	36	358	253	263	276	218

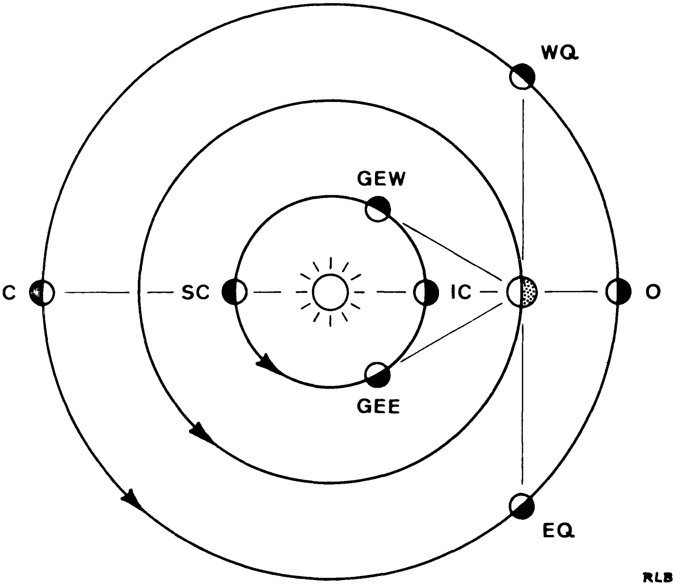


The magnitudes of the five, classical (naked eye) planets in 1986. Oppositions (O), conjunctions (C), inferior and superior conjunctions (IC, SC), and greatest elongations east and west (GEE, GEW) are indicated. (Note the diagram explaining these terms on page 96. For planetary symbols see page 8.)

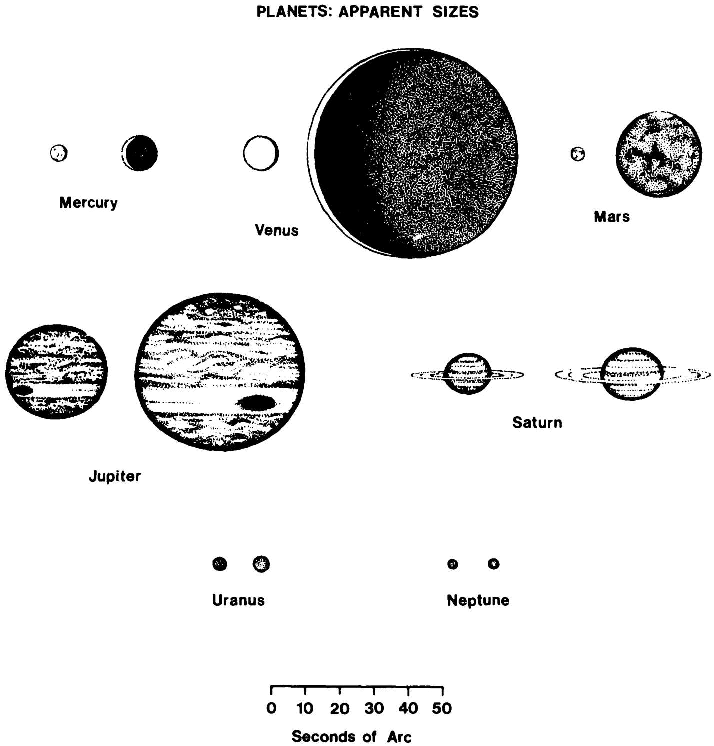
PRONUNCIATION OF PLANET NAMES

Mercury	mûr′kū-rē
Venus	vē′nŭs
Earth	ûrth
Mars	mȧrs
Jupiter	jo͞o′pĭ-tēr
Saturn	sȧt′ûrn
Uranus	yoor′ȧ-nŭs
Neptune	nĕp′tyo͞on
Pluto	plo͞o′tō

ā dāte; ă tăp; â câre; ȧ ȧsk; ē wē; ĕ mĕt; ē makēr; ī īce; ĭ bĭt; ō gō; ŏ hŏt; ô ôrb; oo book; o͞o mo͞on; ū ūnite; ŭ ŭp; û ûrn.



This diagram is a simplified view of the Solar System, from the north side. Earth is shown (middle orbit) together with an "inferior" planet (e.g. Venus) and a "superior" planet (e.g. Mars). Four special configurations of the inferior planet relative to Earth are shown (in counterclockwise chronological sequence): inferior conjunction (IC), greatest elongation west (GEW), superior conjunction (SC), greatest elongation east (GEE). Four special configurations of the superior planet relative to Earth are also shown (in clockwise chronological sequence): opposition (O), eastern quadrature (EQ), conjunction (C), western quadrature (WQ).

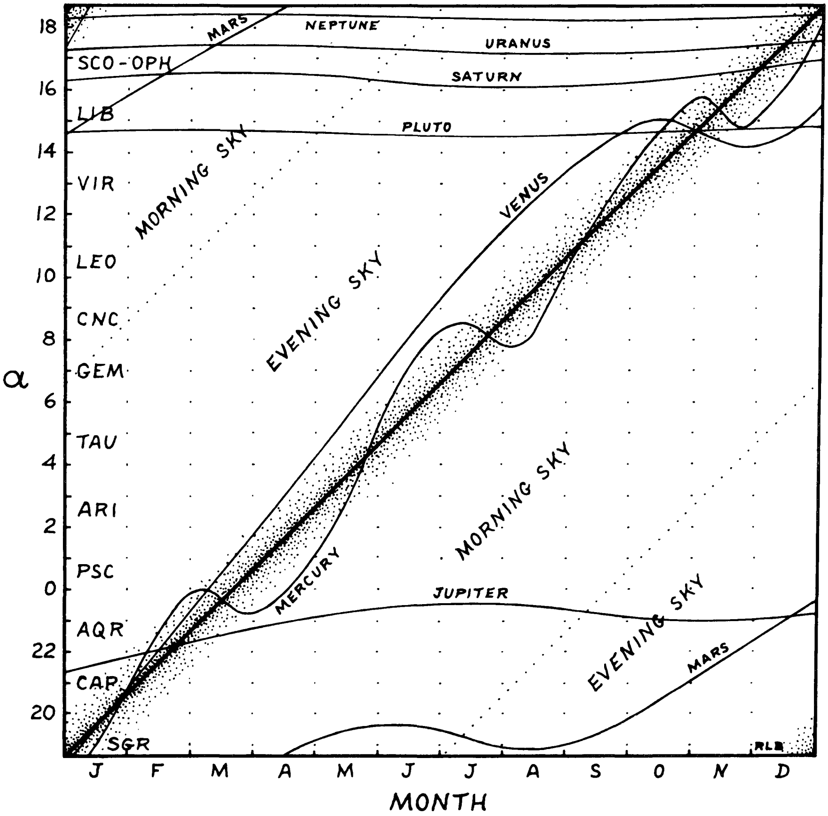


The apparent maximum and minimum observable size of seven planets is illustrated along with characteristic telescopic appearance. The large satellites of Jupiter (not shown) appear smaller than Neptune.

PRONUNCIATION OF SATELLITE NAMES

Adrastea	ȧ-drăs′tē-ȧ	Europa	yoo-rō′pȧ	Oberon	ō′bȧ-rŏn′
Amalthea	ăm′′l-thē′ȧ	Ganymede	găn′ĕ-mēd′	Pandora	păn-dôr′ȧ
Ananke	ȧ′năn-kē	Himalia	hĭm′ȧ-lĭ-ȧ	Pasiphae	pȧ-sĭf′ȧ ē′
Ariel	âr′ē-ĕl	Hyperion	hī-pēr′ĭ-ĕn	Phobos	fō′bŏs
Atlas	ăt′lăs	Iapetus	ī-ăp′ŭ-tŭs	Phoebe	fē′bē
Callisto	kȧ-lĭs′tō	Io	ī′ō	Prometheus	prŏ-mē′thē-ŭs
Calypso	kȧ-lĭp′sō	Janus	jā′nŭs	Rhea	rē′ȧ
Carme	kȧr′mē	Leda	lē′dȧ	Sinope	sĭ-nō′pē
Charon	kâr′ĕn	Lysithea	lĭs′ĭ-thē′-ȧ	Telesto	tȧ-lĕs′tō
Deimos	dī′mŏs	Metis	mē′tĭs	Tethys	tē′thĭs
Dione	dī-ŏ′nē	Mimas	mī′măs	Thebe	thē′bē
Elara	ē′lȧr-ȧ	Miranda	mĭ-răn′dȧ	Titan	tī′t’n
Enceladus	ĕn-sĕl′ȧ-dŭs	Moon	m$\overline{\text{oo}}$n	Titania	tī-tā′nē-ȧ
Epimetheus	ĕp′ȧ-mē′thē-ŭs	Nereid	nēr′ē-ĭd	Triton	trī′t’n
				Umbriel	ŭm′brē-ĕl′

ā dāte; ă tăp; â câre; ȧ ȧsk; ē wē; ĕ mĕt; ẽ makẽr; ī īce; ĭ bĭt; ō gō; ŏ hŏt; ô ôrb; oo book; $\overline{\text{oo}}$ m$\overline{\text{oo}}$n; ū ūnite; ŭ ŭp; û ûrn.



This diagram shows the variation during the year in the right ascension (α) of the Sun and the planets. The diagram is simplified in that the heavy diagonal line for the Sun (which should be slightly curved) is straight, and the months are assumed to be of equal duration. The stippling in the vicinity of the line for the Sun indicates the region of the night sky affected by twilight. The rectangular grid of dots is an aid to reading the two axes. The two dotted diagonal lines represent the boundary between the evening sky and the morning sky.

The diagram may be used as a quick reference to determine: in what part of the sky a planet may be found (including in which constellation – note the names along the vertical axis); when a superior planet is in conjunction with the Sun or at opposition (opposition is approximately where its curve intersects the dotted diagonal line, and note that, due to retrograde motion, this point is also where the planet's curve has its maximum negative slope); when Mercury and Venus have their various greatest elongations and conjunctions; and when there are conjunctions of planets (e.g. note the conjunction of Jupiter and Mars in the evening sky in Aquarius in mid-December when they are about 80° east of the Sun). For more detailed information on all these events, see the following pages and the "The Sky Month By Month" section.

I am indebted to Victor Estremadoyro Robles of Lima, Peru for suggesting that a diagram of this type would be a useful addition to the Observer's Handbook. (RLB)

TRANSIT OF MERCURY – 13 NOVEMBER 1986

By Fred Espenak

The transit or passage of a planet across the disk of the Sun is a relatively rare occurence. As seen from Earth, only transits of Mercury and Venus are possible. On the average, there are 13 transits of Mercury each century. In comparison, transits of Venus occur in pairs with more than a century separating each pair.

The principal events occuring during a transit are conveniently characterized by contacts, analogous to the contacts of an annular solar eclipse. The transit begins with contact I which is the instant when the planet's disk is externally tangent with the Sun. Shortly after contact I, the planet can be seen as a small notch along the solar limb. The entire disk of the planet is first seen at contact II when the planet is internally tangent with the Sun. During the next several hours, the silhouetted planet slowly traverses the brilliant solar disk. At contact III, the planet reaches the opposite limb and once again is internally tangent with the Sun. Finally, the transit ends at contact IV when the planet's limb is externally tangent to the Sun. Contacts I and II define the phase called ingress while contacts III and IV are known as egress.

On 13 November 1986, Mercury will transit the Sun for the first time since 1973. Unfortunately, the event will not be observable from any of the Americas with the exception of southwestern Alaska. Geocentric ingress begins at 1:42.4 UT when a tiny notch will appear along the Sun's eastern limb. Two minutes later (1:44.3 UT), ingress is complete with contact II. For the next 4.75 hours, the tiny 10 arc-second disk of Mercury will be seen against the Sun's photosphere. Maximum transit (least distance between centers of Mercury and Sun) occurs at 4:06.4 UT when Mercury passes 470 arc-seconds northeast of the Sun's center. At that time, the Sun will be near the zenith for observers in Broome, Australia. Egress commences with contact III at 6:28.6 UT and the transit ends with contact IV at 6:30.5 UT. The transit, in its entirety, will be visible from India, Southeast Asia, China, Japan, Indonesia, Australia and New Zealand. Observers from most of Africa, eastern Europe, the Middle East and western Siberia will miss ingress since the transit will already be in progress at sunrise. On the other hand, observers in the Pacific, eastern Siberia and southwestern Alaska will witness ingress but the Sun will set before the transit ends.

It should be noted that all times are for an observer at Earth's center. The actual contact times for any given observer may differ by as much as two minutes. Since Mercury is only 1/194 the Sun's diameter, a telescope with a magnification of 50x to 100x is recommended to watch this event. Naturally, the telescope must be suitably equipped with adequate filtration to ensure safe solar viewing (see the footnote on p. 53). The visual and photographic requirements for observing a transit are identical to those for sunspots. However, the most valuable scientific contribution the amateur can make is to time the four contacts at ingress and egress. Observing techniques and equipment are similar to those used for lunar occultations. Since poor seeing often increases the uncertainty in contact timings, you should make an estimate of the possible error associated with each timing. Your observations and your geographic coordinates (measured from a topographic map) should be sent to: Almanac Office, U.S. Naval Observatory, Washington, D.C. 20390, U.S.A.

Actually, direct white light observations of contacts I and IV are not technically possible since the transiting planet is only visible *after* contact I and *before* contact IV. Observations of contacts II and III also require amplification. They are often mistaken for the instant when the planet appears internally tangent to the Sun. However, just before contact II, the so-called black drop effect is seen. At that time, the transiting planet seems to be attached to the Sun's limb by a thin column or thread. When the thread breaks and the planet is completely surrounded by sunlight, this marks the true instant of contact II. Contact III occurs in exactly the reverse order.

TRANSIT DIAGRAMS

Two diagrams have been prepared to illustrate the 13 November 1986 transit of Mercury (see the next page). The top diagram shows Mercury's predicted path across the solar disk and includes the planet's position at each hour Universal Time. The '*' along this path is Mercury's position at maximum transit (4:06.4 UT) when Mercury will lie 470 arc-seconds from the center of the Sun. To the upper right are listed the four geocentric contact times. In the lower right corner are Mercury's right ascension (RA), declination (DEC), semi-diameter (SD) and horizontal parallax (HP) at the instant of maximum transit. Finally, the Julian Date (JD) and ΔT (the difference between Dynamical and Universal Time) are listed to the lower left.

The bottom map is a cylindrical equidistant projection of Earth which depicts the regions of visibility for each stage of the transit. The map shows the position of the day/night terminator at ingress (IN) and at egress (EG). These curves divide Earth into four zones. Zone 1 identifies the region where the transit will be seen in its entirety. From zone 2, observers will miss ingress since it will occur before sunrise. Observers in zone 3 will not see egress because it occurs after sunset. Finally, observers in zone 4 will not witness any of the transit since the sun will be below the horizon for the entire event. The '*' northwest of Australia marks the place where the Sun appears in the zenith at maximum transit.

Since short period planetary perturbations were not used in the calculation of Mercury's ephemeris, the geocentric contact times presented here may be in error by as much as two minutes. Additional information about this event will appear in the 1986 *Astronomical Almanac*. The next transit of Mercury occurs on 6 November 1993 and will only be visible from the Eastern Hemisphere.

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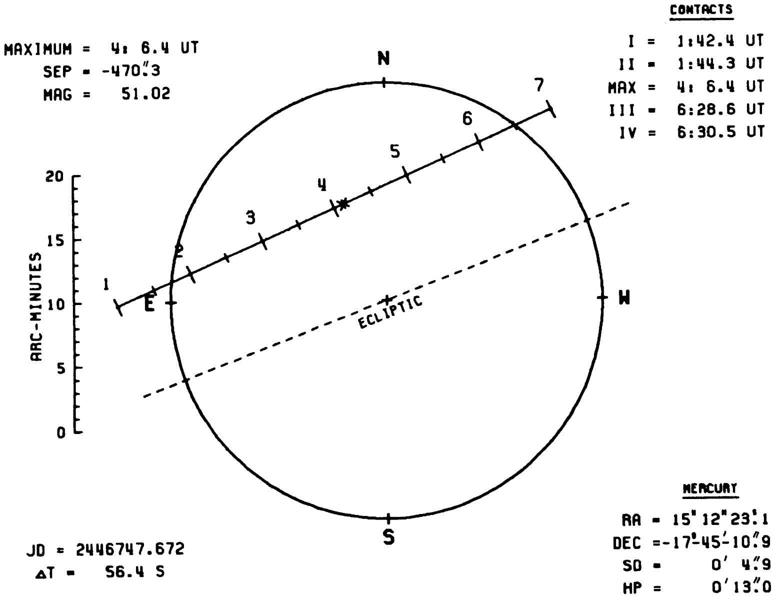
P

SOLAR TRANSIT OF MERCURY - 13 NOV 1986

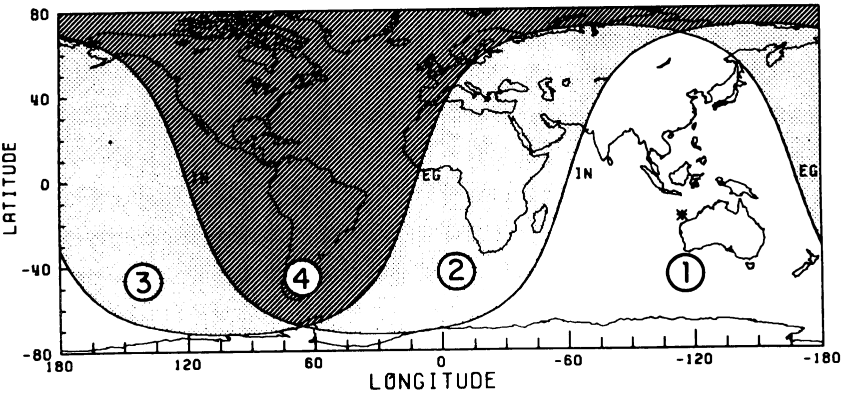


MAXIMUM = 4: 6.4 UT
SEP = -470".3
MAG = 51.02

CONTACTS
I = 1:42.4 UT
II = 1:44.3 UT
MAX = 4: 6.4 UT
III = 6:28.6 UT
IV = 6:30.5 UT

JD = 2446747.672
ΔT = 56.4 S

MERCURY
RA = $15^h 12^m 23^s.1$
DEC = $-17^\circ 45' 10''.9$
SD = 0' 4".9
HP = 0' 13".0



TELESCOPIC PLANETARY OBSERVING

By Terence Dickinson

Systematic telescopic observation of the planets by amateur astronomers has been in decline since the Mariner 4 flyby of Mars in 1965, which returned the first, crude, close-up images of its cratered surface. Then came more Mariners and the Vikings and Voyagers, which seemed to make scientifically valuable planetary observations by amateur astronomers largely a thing of the past. But since the planets are among the sky's most impressive telescopic objects, the fact that they are so seldom the targets of backyard astronomers – other than the occasional quick look, or as showpieces for visitors – suggests that there is a deeper reason for these bodies not being more frequently and more rigorously observed in the 1980's. It may be due more to a change in instrumentation than in observing philosophy.

Typical amateur equipment of the 50's and 60's was almost always limited to refractors and medium to long-focus Newtonians in apertures of 200 mm or less. By contrast, today's equipment is mainly Schmidt-Cassegrains and short-focus Newtonians (often Dobsonians) emphasizing large, short-focal-ratio primary mirrors. But these instruments, with their relatively large central obstructions and greater susceptibility to atmospheric and instrument-induced seeing effects, are the least suited to planetary observation (apart from detection of faint satellites). Planetary images in such instruments are brighter but seldom, if ever, as sharp and contrasty as images in unobstructed systems of substantially smaller aperture. Thus it may be that the planets are being ignored as subjects for extended observation more by the unsuitability of the most prevalent telescope designs than for the often-reported reason that modern space probe missions have eliminated the mystery of our neighbour worlds. This seems to be borne out in the systematic planetary observations reported to the *Association of Lunar and Planetary Observers*. For example, of the observations reported during the 1980–84 period, 70% were made with medium or long-focus Newtonians, 22% with refractors, and 8% with Schmidt-Cassegrains or Maksutov-Cassegrains.

The ability of a telescope to deliver high contrast is far more important than light collecting ability when viewing bright, extended surfaces of varying intensity and hue, such as the surfaces of the Sun, Moon, and planets. For a given aperture, maximum contrast ensures the clearest discrimination of detail such as festoons in the belts of Jupiter, subtle mottling on the surface of Mars, structures on the lunar surface, etc. Contrast is only partially related to telescopic resolution, yet a telescope's resolving ability is widely regarded as the only important performance criterion for planetary observation.

The wave nature of light causes an optical system having a circular aperture to image a point of light as a small, spurious blur, known as the Airy disk, surrounded by a few faint rings (Airy, 1835). Resolving ability is usually quoted in the form of Dawes' limit which is approximately the angular radius of the Airy disk formed by an optical system. Regardless of a telescope's optical configuration, the smallness of the Airy disk, and consequently the theoretical resolution, varies directly with aperture (e.g. a telescope of 200 mm aperture has twice the resolution of a 100 mm instrument). Being able to cleanly split two 6th-magnitude stars of equal brightness separated by the radius of their Airy disks is usually cited as the practical observational test to determine if a particular telescope reaches its theoretical resolution limit.

In any optical system the light from every object point entering the telescope is distributed between its Airy disk and tne suroun ding diffraction rings. When the optical system contains obstructions, such as the secondary mirror and supporting vanes of a Newtonian or a Schmidt-Cassegrain secondary mirror, significant *additional* light is spilled from the Airy disk into the surrounding rings. In practice, this can make the splitting of close double stars easier by slightly reducing the brightness and diameter of the individual Airy disks. Since this double star method of testing resolution is widely regarded among amateur astronomers as the standard for telescope performance on all celestial objects, it is incorrectly assumed that resolution of fine lunar and planetary detail is determined solely by aperture. But such is not the case. It is based on contrast in combination with resolution.

Imagine the disk of a planet, say Jupiter, divided into a grid of adjacent Airy disks. In a 150 mm telescope that resolves to the theoretical limit, the image of Jupiter would be approximately 60 of these resolution elements wide. An analogy that is useful here is a television screen. Its picture elements, which are visible from close range, have differing intensities and each is a tiny piece of the mosaic which constitutes the picture. However, each picture element spills a small amount of light into surrounding elements. The best television images are achieved with sets that have minimized this spillover.

In an *unobstructed* telescope system, the "picture elements" – a multitude of overlapping Airy disks – spill 16% of their light into adjacent elements. Thus each element has 84% of the "pure" light intensity and hue from the planetary surface, but is contaminated by 16% from adjacent areas.

Perhaps the most common *obstructed* system is the 200 mm Schmidt-Cassegrain. The 70 mm secondary mirror blocks about 12% of the area (35% of the diameter) of the main mirror. In these systems the diffraction effect is substantially elevated so that only 63% of the light is in the Airy disk and 37% is spread into the rings. The contrast in this case is *less than half* that of the unobstructed system because more than twice as much light from each resolution element in the image is diffused into the surrounding region. In such telescopes, a planetary image, even under excellent seeing, has a gauzy appearance, as if it were being observed through a fine ground-glass screen. The difference is instantly noticeable in side-by-side telescope comparisons.

The apochromatic refractor is an unobstructed, nearly aberration-free design. The achromatic refractor, by far the dominant form of unobstructed telescope, is only slightly less contrast efficient. Secondary chromatic aberration, noticeable in short focal-ratio achromatic refractors or in long-focus achromatic refractors over 90 mm aperture, affects contrast by diffusing unfocussed blue and (to a lesser extent) red light over the image. However, this can be largely neutralized with a yellow-green eyepiece filter (#11) that suppresses the red and blue ends of the visible spectrum and enhances image contrast.

Newtonians of f/7 or longer focal ratio can be optimized for planetary work by equipping them with small diagonals obstructing less than 5% of the incoming light (Peters and Pike, 1977), producing refractor-like planetary images. In performance per dollar, these telescopes are superior to refractors although they are more subject to temperature effects. The secondary supports for the diagonal mirror in a Newtonian also slightly degrade the contrast (Everhart and Kantorski, 1959). Schmidt-Cassegrains and short-focus Newtonians over 200 mm aperture can easily be converted to refractor-like performance by using a circular, off-axis aperture stop over the front of the tube, covering all but an unobstructed one-third (approximately) of the aperture.

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THE PLANETS FOR 1986

BY TERENCE DICKINSON

MERCURY

At just over one-third Earth's distance from the Sun, Mercury is the solar system's innermost planet and the only one known to be almost entirely without an atmosphere. Mercury is a small world only 6% as large as Earth by volume—barely larger than our Moon.

Until the advent of interplanetary probes, virtually nothing was known about the surface of Mercury. Only the vaguest smudges have been seen through Earth-based telescopes. In 1974 the U.S. spacecraft Mariner 10 photographed one hemisphere of Mercury revealing it to be extremely heavily cratered, in many respects identical in appearance to the far side of Earth's Moon. There is no interplanetary mission planned to photograph the other hemisphere.

Mercury's orbit is the most elliptical of any planet except Pluto's. Once each orbit Mercury approaches to within 0.31 A of the Sun and then half an orbit (44 days) later it is out to 0.47 A. This amounts to a 24 million km range in distance from the Sun, making the Sun in Mercury's sky vary from about four times the area we see it to more than ten times its apparent area from Earth. Mercury's sidereal rotation period of 59 days combines with the 88 day orbital period of the planet to produce a solar day (one sunrise to the next) of 176 days—the longest of any planet.

Of the five planets visible to the unaided eye, Mercury is by far the most difficult to observe and is seldom conveniently located for either unaided eye or telescopic observation. The problem for observers is Mercury's tight orbit which constrains the planet to a small zone on either side of the Sun as viewed from Earth. When Mercury is east of the Sun we may see it as an evening star low in the west just after sunset. When it is west of the Sun we might view Mercury as a morning star in the east before sunrise. But due to celestial geometry involving the tilt of Earth's axis and Mercury's orbit we get much better views of Mercury at certain times of the year.

The best time to see the planet in the evening is in the spring, and in the morning in the fall (from the northern hemisphere). Binoculars are of great assistance in searching for the planet about 40 minutes to an hour after sunset or before sunrise during the periods when it is visible. Mercury generally appears about the same colour and brightness as the planet Saturn. Telescopic observers will find the rapidly changing phases of Mercury of interest. The planet appears to zip from gibbous to crescent phase in about three weeks during each of its elongations.

MERCURY
TELESCOPIC OBSERVING DATA FOR FAVOURABLE EASTERN (EVENING) ELONGATION 1986

Date 0^h UT	Mag.	Angular Diameter	% of Disk Illuminated	Distance From Sun	α (1986)	δ
Feb. 19	-1.1	5.7"	84%	14°	23^h02^m	-6°49'
23	-0.9	6.2"	72%	16°	23^h25^m	-3°31'
27	-0.6	6.9"	55%	18°	23^h44^m	-0°30'
Mar. 3	0.0	7.8"	37%	17°	23^h56^m	+1°52'
7	+1.0	8.8"	20%	15°	00^h00^m	+3°15'

Mercury's phases have been glimpsed with telescopes of 75 mm aperture or less, but generally a 100 mm or larger telescope is required to distinguish them. In larger instruments under conditions of excellent seeing (usually when Mercury is viewed in the daytime) dusky features have been glimpsed by experienced observers. Thorough analysis has shown only a fair correlation between these visually observed features and the surface of the planet as photographed by Mariner 10.

VENUS

Venus is the only world in the solar system that closely resembles Earth in size and mass. It also comes nearer to Earth than to any other planet, at times approaching as close as 0.27 A. Despite the fundamental similarity, surface conditions on Earth and Venus differ greatly, according to findings of spacecraft missions to the planet during the past decade. The chief disparity is that Venus' surface temperature varies only a few degrees from a mean of 455°C on both day and night sides of the planet. The high temperature is due to the dense carbon dioxide atmosphere of Venus which, when combined with small quantities of water vapour and other gases known to be present, has the special property of allowing sunlight to penetrate to the planet's surface but does not permit the resulting heat to escape. This process is commonly known as the greenhouse effect.

Venus' atmosphere has a surface pressure 91 times Earth's sea-level atmospheric pressure. A haze layer extends down from about 65 km above the surface to about 50 km, where a dense 3-km-thick cloud deck occurs. The haze continues to within about 30 km from the surface, where the atmosphere clears. Several Soviet Venera spacecraft have landed on Venus since 1975 and have photographed the planet's surface, revealing daytime lighting conditions similar to those on Earth on a heavily overcast day. Winds at the surface range from 2 to 10 km/h. The clouds and haze that cloak the planet, consisting chiefly of droplets of sulphuric acid, are highly reflective, making Venus brilliant in the nighttime sky. However, telescopically, the planet is virtually a featureless orb.

Extensive radar data returned from the U.S. Pioneer Orbiter since 1978, a Soviet Orbiter and ground-based radar have yielded crude maps of the cloud-shrouded globe. Sixty percent of Venus' surface is rolling plains varying in height by only about 1 km between high and low points. Only 16 percent of the surface could be described as lowlands (perhaps comparable to ocean basins on Earth). Just 8 percent is true highland, ranging to a maximum altitude of 10.6 km above the rolling plains. Venus' crust appears to be thicker than Earth's—possibly thick enough to choke off plate tectonics. However, a substantial amount of tectonic activity, in the form of volcanoes, is reworking sectors of Venus' crust.

In 1983, readings from the still-functioning Pioneer Orbiter revealed that sulphur dioxide levels in the upper atmosphere had declined by 90 percent since the spacecraft arrived at Venus in 1978. This is interpreted as the after effect of a massive volcanic eruption that occurred shortly before Pioneer reached Venus. Furthermore, almost continuous lightning detected by Pioneer in the lower atmosphere has been traced to the major highlands, which are now believed to be giant active shield volcanoes larger than, but similar to, Hawaii's Mauna Loa. Lightning is known to be caused by electric-charge differentials near the plumes of active volcanoes. This suggestion of a volcanically active Venus could mean that the planet's atmosphere is not static but is substantially modified, perhaps over short time periods, by gaseous and particulate injection from volcanoes. Other evidence from analyses of the Pioneer readings indicates that about four billion years ago, Venus probably had a global ocean of water almost identical to Earth's for several hundred million years. At that time, the Sun was only two-thirds of its present brightness, but as solar radiation slowly increased toward present levels, the Venus ocean was doomed.

Evaporation of the oceans may have been the first step toward the greenhouse situation seen today.

Venus is the brightest natural celestial object in the nighttime sky apart from the Moon, and whenever visible, it is readily recognized. Because its orbit is within that of Earth's, Venus is never separated from the Sun by an angle greater than 47 degrees. However, this is more than sufficient for the dazzling object to dominate the morning or evening sky.

Like Mercury, Venus exhibits phases, although they are much more easily detected in small telescopes because of Venus' greater size. When it is far from us (near the other side of its orbit), we see the planet nearly fully illuminated, but because of its distance, it appears small—about 10 seconds of arc in diameter. As Venus moves closer to Earth, the phase decreases (we see less of the illuminated portion of the planet), but the diameter increases until it is a thin slice nearly a minute of arc in diameter. It takes Venus several months to move from one of these extremes to the other, compared to just a few weeks for Mercury.

When Venus is about a 20% crescent even rigidly-held, good quality binoculars can be used to distinguish that the planet is not spherical or a point source. A 60 mm refractor should be capable of revealing all but the gibbous and full phases of Venus. Experienced observers prefer to observe Venus during the daytime, and indeed the planet is bright enough to be seen with the unaided eye if one knows where to look.

Venus appears to most observers to be featureless no matter what type of telescope is used or what the planet's phase. However, over the past century some observers using medium or large size telescopes have reported dusky, patchy markings usually described as slightly less brilliant than the dazzling white of the rest of the planet. We now know that there are many subtle variations in the intensity of the clouds of Venus as photographed in ultraviolet by spacecraft and Earth-based telescopes. But when the ultraviolet photos are compared to drawings of the patchy markings seen by visual observers the correlation is fair at best.

When Venus is less than 10% illuminated the cusps (the points at the ends of the crescent) can sometimes be seen to extend into the night side of the planet. This is an actual observation of solar illumination being scattered by the atmosphere of Venus. When Venus is a thin sliver of a crescent the extended cusps may be seen to ring the entire planet.

P As 1986 opens, Venus is immersed in solar glare having just retreated from the morning sky where it was prominent for most of the previous year. Superior conjunction occurs January 19 after which the planet slowly swings to the east of the Sun, becoming visible in early March low in the west after sunset. An interesting conjunction with Mercury on March 8 places Venus in the role of guidepost to the inner planet, then at magnitude +1.4 and difficult to locate otherwise. For the next few months, as Venus climbs higher in the evening sky, it slowly almost doubles in brightness from magnitude −3.9 in March and April to a maximum of −4.6 in late September.

During October Venus rapidly retreats from the evening sky on its way to inferior conjunction on November 5. By mid-November it is seen in the morning sky and remains a prominent morning object for the rest of the year. The accompanying table supplies telescopic observing data for the period near inferior conjunction when parameters are rapidly changing. In mid-March the planet is a 97% illuminated disk, 10.1″ in diameter. By the end of May these values will be 83% and 12.4″, and by August 1, 61% and 18.8″.

VENUS NEAR INFERIOR CONJUNCTION 1986

Date 0^h UT	Mag.	Apparent Diameter	% of Disk Illuminated	Distance From Sun	α (1986)	δ
Aug. 2	-4.2	18.9"	61	44°E	11^h37^m	+ 2°44'
Sep. 3	-4.4	26.5"	45	46°	13^h32^m	-12°40'
Oct. 1	-4.6	39.7"	26	40°	14^h49^m	-22°26'
9	-4.6	45.2"	19	34°	15^h01^m	-23°55'
17	-4.5	51.4"	12	28°	15^h04^m	-24°28'
21	-4.4	54.5"	8.2	23°	15^h01^m	-24°19'
25	-4.3	57.4"	5.0	18°	14^h57^m	-23°48'
29	-4.2	59.7"	2.5	13°	14^h50^m	-22°56'
Nov. 2	-4.1	61.3"	0.9	8°E	14^h42^m	-21°44'
6	-4.0	61.9"	0.4	5°W	14^h33^m	-20°16'
10	-4.1	61.4"	1.0	9°	14^h25^m	-18°38'
14	-4.3	59.9"	2.7	14°	14^h18^m	-17°00'
18	-4.4	57.7"	5.4	20°	14^h13^m	-15°30'
22	-4.5	54.9"	8.6	24°	14^h10^m	-14°14'
Dec. 4	-4.6	45.6"	20	35°	14^h17^m	-12°14'
24	-4.6	33.3"	36	45°	15^h04^m	-13°45'

MARS

Mars is the planet that has long captivated the imagination of mankind as a possible abode of life. One of the major objectives of the Viking spacecraft which landed on Mars in 1976 was the quest for Martian microorganisms. The Viking biology experiments completed the search in 1977 and, although the results are somewhat ambiguous, there is no convincing evidence of life we are familiar with.

The landscapes photographed by the Viking landers were basically desert vistas strewn with rocks ranging up to several metres wide. Judging by their texture and colour, and chemistry analysis by Viking, the rocks are fragments of lava flows. The soil composition resembles that of basaltic lavas on Earth and our Moon. About 1% of the soil is water, chemically bound in the crystal structure of the rock and soil particles. Some planetary scientists speculate that water in the form of permafrost exists a few metres below the surface. However, Viking and its predecessors have shown that water was once abundant enough on Mars to leave major structures on the planet resembling riverbeds. Analysis of high resolution Viking Orbiter photographs of these structures has led most investigators to conclude that they were likely carved during the planet's early history.

The red planet's thin atmosphere has an average surface pressure only 0.7% of Earth's and consists of 95% carbon dioxide, 2.7% nitrogen, 1.6% argon, 0.6% carbon monoxide, 0.15% oxygen and 0.03% water vapour. Winds in the Martian atmosphere reach speeds exceeding 300 km/h and in so doing raise vast amounts of dust that can envelop the planet for weeks at a time. The dust storms were thought to occur with seasonal regularity shortly after Mars passed the perihelion point of its elliptical orbit, but the Viking observations revealed more complex weather patterns.

In many ways Mars is the most interesting planet to observe with the unaided eye. It moves rapidly among the stars—its motion can usually be detected after an interval of less than a week—and it varies in brightness over a far greater range than any other planet. Mars may be distinguished by its orange-red colour, a hue that originates with rust-coloured dust that covers much of the planet.

Telescopically Mars is usually a disappointingly small featureless ochre disk except within a few months of opposition when its distance from Earth is then near minimum. If Mars is at perihelion at these times the separation can be as little as 56 million km. Such close approaches occur at intervals of 15 to 17 years; the most recent was in 1971. At a perihelion opposition the telescopic disk of Mars is 25 seconds of arc in diameter and much detail on the planet can be distinguished with telescopes of 100 mm aperture or greater. At oppositions other than when Mars is at perihelion, the disk is correspondingly smaller.

This year Mars makes its closest approach to Earth since 1971, becoming a brilliant luminary in the south throughout the summer months. At its brightest, around opposition on July 10, it will exceed Jupiter (seen in the late evening some 60° to the east of Mars). This is a near-perihelion opposition and Mars will attain an apparent diameter of 23.2″ on July 16, the date of actual minimum separation, when its distance from Earth is 0.404 A (60 million km).

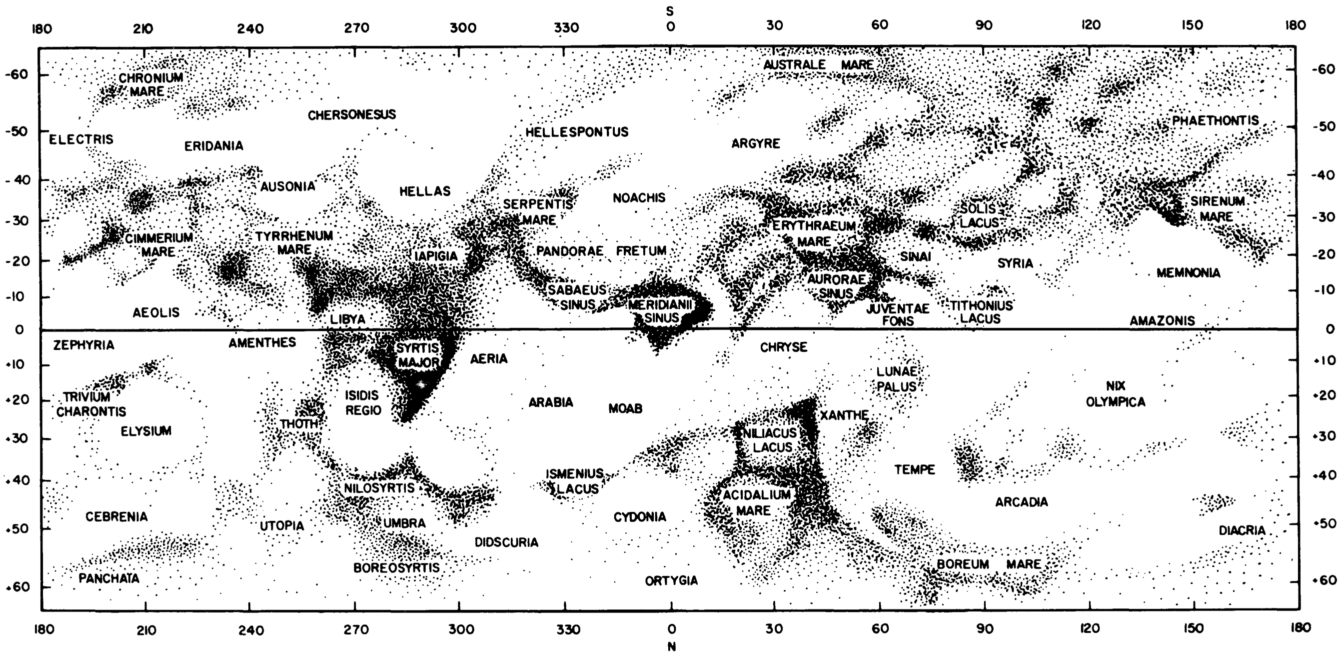
Despite the planet's large apparent size, this is not a favourable apparition for observers in Canada and most of the U.S.A. because Mars will be at its maximum southern declination. During the prime observing window, from mid-May to the end of September, the planet's declination ranges from −23° to −28½°. Declination during the weeks around closest approach to Earth averages −28°, clearly most unfavourable. When viewed from latitude 45°N, for example, Mars will then be climbing to only 17° above the horizon when on the meridian. Experienced planetary observers seldom report suitable seeing conditions for telescopic work at such low elevations. However, observers at mid-northern latitudes should be able to recognize some of the major Martian features despite the inevitable mediocre seeing.

Spring begins in Mars' southern hemisphere on June 1, so the south polar cap should be quite prominent, especially prior to opposition. On June 1, Mars' south pole is tipped 10° toward Earth. This figure reduces to 3° in early August, but increases to 11° by October 1. Martian summer in the southern hemisphere begins on October 25. For other telescopic data, see the accompanying table.

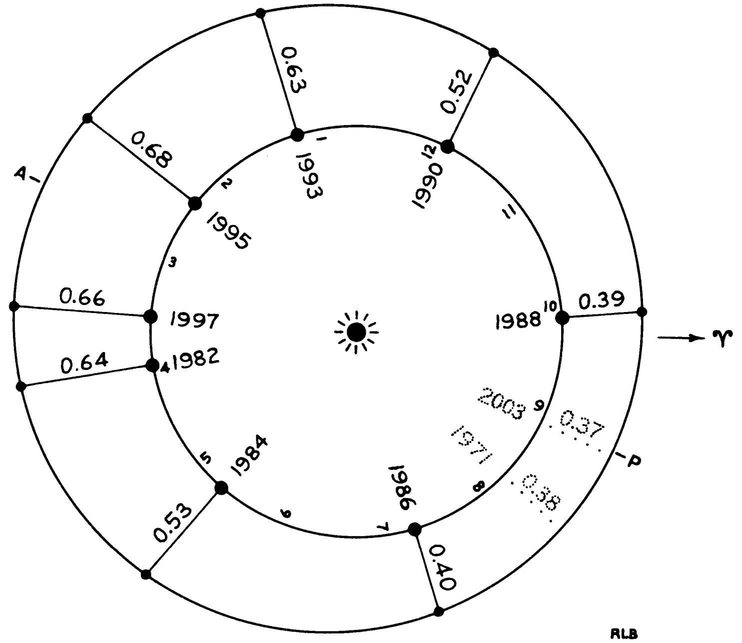
P

To the unaided eye, Mars will be an exceptionally rewarding subject to follow during a good portion of 1986. It opens the year as a morning object in Libra, but quickly moves eastward passing 5° north of Antares February 17. Mars then plants itself in Sagittarius from April through September during its retrograde loop. When at its brightest in July, Mars will be a striking sight, its reddish glow set against the backdrop of the densest sectors of the Milky Way. In October Mars moves through Capricornus, on into Aquarius in November, and Pisces in late December. The planet is conveniently seen in the evening sky throughout the last half of the year.

MAP OF MARS



Latitude is plotted on the vertical axis (south at the top); longitude is plotted on the horizontal axis



P

The above diagram represents the orbits of Earth and Mars as viewed from the north ecliptic pole. Conjugate positions of Earth and Mars (linked by straight lines) are shown for eight successive oppositions of Mars, beginning with that of the year 1982. In addition to this sequence, the 1971 and 2003 perihelic oppositions are indicated with dotted lines. The various years are marked just inside of Earth's orbit, together with small numbers which indicate the approximate position of Earth at the beginning of each month of any year, where 1 = January, 2 = February, etc. Thus from the diagram the approximate date of each opposition can be inferred. The separation of the two planets (in astronomical units) at the various oppositions is marked beside each of the connecting lines. The two tick marks labeled A and P indicate the aphelion point and the perihelion point, respectively, of the orbit of Mars. The direction of the vernal equinox ♈ is shown.

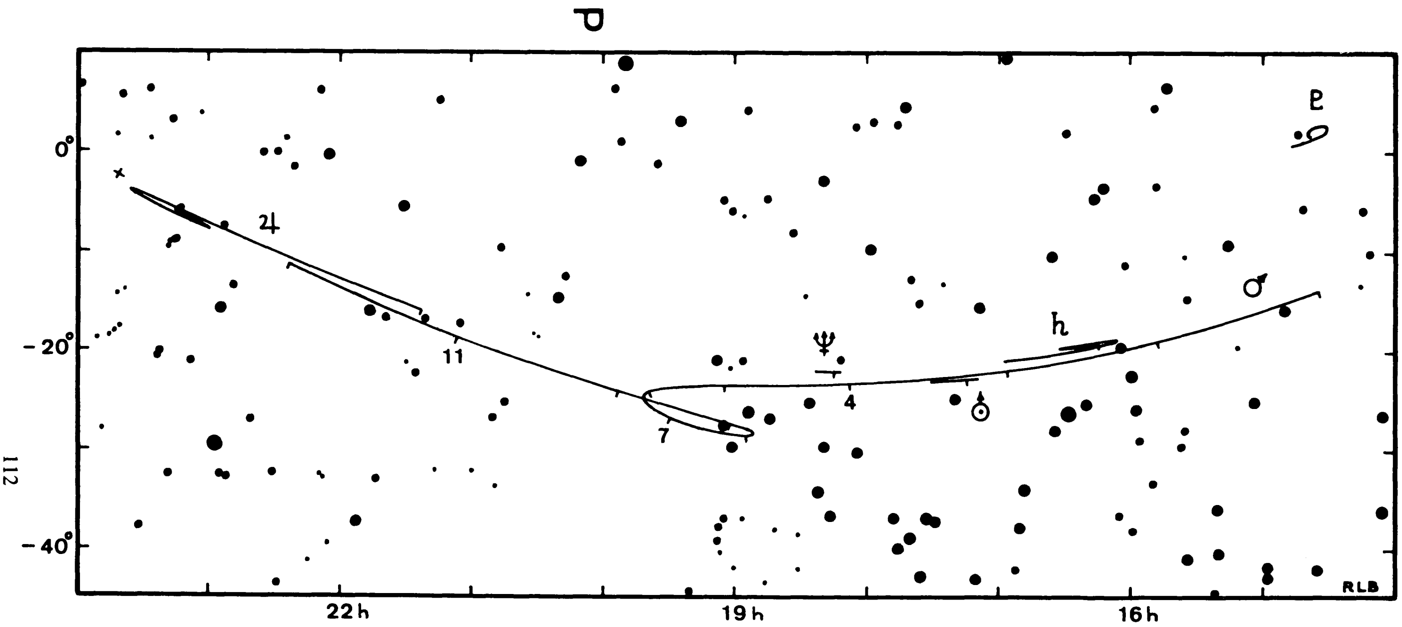
Although Mars is at opposition on July 10 in 1986, it will not be closest to Earth until six days later (see p. 39). The reason for this is apparent from the diagram if one keeps the orbital velocities of the two planets in mind: On July 10 (the position shown in the diagram) the Sun, Earth, and Mars lie in a single plane perpendicular to the ecliptic (the latter being the plane of the diagram). Because Mars has not yet reached perihelion, its velocity relative to Earth has a component directed toward Earth. It is not until Earth has moved a significant distance ahead of Mars (by July 16) that this velocity component is reduced to zero, marking the point of closest approach. (The distances indicated on the diagram are actually those of closest approach, although to the two-figure precision given, these are either the same as the opposition distances or, in one or two cases, 0.01 A smaller.)

Because the 1986 opposition occurs so close to Earth's Northern Hemisphere summer solstice, Mars will appear low in the south for observers in Canada and the United States. However, for these observers, the 1988 opposition will be much better (even better than that of 2003) with Mars near the celestial equator. (RLB)

MARS — EPHEMERIS FOR PHYSICAL OBSERVATIONS 1986

Date 0ʰ UT	Dist. A	Mag.	Equat. Diam.	Illum. %	Pos. Angle	Incl.	L(1)	Δ
Jan. 2	1.888	+1.4	5.0"	93	39°	17°	115.66°	9.66°
30	1.623	+1.1	5.8"	91	37°	10°	205.08°	9.62°
Feb. 27	1.348	+0.7	6.9"	89	33°	3°	295.72°	9.58°
Mar. 27	1.078	+0.2	8.7"	88	27°	-3°	27.51°	9.52°
Apr. 24	0.826	-0.4	11.3"	89	20°	-8°	120.91°	9.40°
May 22	0.612	-1.2	15.3"	92	15°	-10°	217.63°	9.27°
30	0.561	-1.5	16.7"	94	14°	-10°	143.45°	9.19°
June 7	0.515	-1.7	18.2"	95	13°	-10°	69.91°	9.10°
15	0.476	-2.0	19.7"	97	13°	-10°	357.08°	9.02°
23	0.444	-2.3	21.1"	98	14°	-9°	284.96°	8.94°
July 1	0.421	-2.5	22.2"	99	15°	-7°	213.48°	8.88°
9	0.408	-2.6	23.0"	100	16°	-6°	142.46°	8.86°
17	0.404	-2.6	23.2"	100	18°	-5°	71.58°	8.88°
25	0.409	-2.5	22.9"	99	19°	-4°	0.53°	8.94°
Aug. 2	0.422	-2.3	22.2"	97	20°	-3°	289.00°	9.03°
10	0.443	-2.2	21.1"	95	20°	-3°	216.80°	9.12°
18	0.470	-2.0	19.9"	93	20°	-4°	143.82°	9.22°
26	0.502	-1.8	18.6"	92	19°	-4°	70.08	9.31°
Sept. 3	0.539	-1.6	17.4"	90	18°	-5°	355.62°	9.39°
11	0.578	-1.4	16.2"	89	17°	-7°	280.52°	9.53°
Oct. 9	0.737	-0.8	12.7"	86	9°	-13°	13.63°	9.70°
Nov. 6	0.921	-0.3	10.2"	85	359°	-20°	102.11°	9.82°
Dec. 4	1.126	+0.2	8.3"	86	347°	-24°	187.29°	9.89°
32	1.346	+0.6	7.0"	88	336°	-26°		RLB

The above table gives information concerning observations of Mars during 1986. The data are given at 28-day intervals, except around opposition (July 10) when the intervals are 8-day. The columns give (1) the date; (2) the distance of Mars from Earth in astronomical units; (3) the visual magnitude of Mars; (4) its apparent equatorial angular diameter; (5) the percent of its disk illuminated; (6) the position angle of its rotation axis, measured counterclockwise from north; (7) the inclination of its rotation axis to the plane of the sky, positive if its north pole is tipped toward Earth; and two quantities, (8) L(1) and (9) Δ, which can be used to calculate the longitude L of the central meridian of Mars at any moment during 1986. For a given date and time (UT) of observation, L is equal to L(1) for the nearest preceding date in the table less Δ times the number of complete days elapsed since that date. To the result, add 14.6° multiplied by the time in hours elapsed since 0ʰ UT. If the result is less than 0°, add 360°; if the result is greater than 360°, subtract 360°. The answer is accurate to better than 1°, provided the time of observation is accurate to ± 2 or 3 minutes. This value of L can then be used to orient the map on page 109 to the view of Mars seen in a telescope. (RLB)



The paths of Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto during 1986. (For planetary symbols see page 8.) The coordinates are for 1986. For Mars, tick marks along the path indicate the position of the planet at the beginning of each month, beginning at the west (right) end (To aid identification, the marks for the beginning of April, July, and November are numbered 4, 7, and 11 respectively). To avoid confusion with Jupiter's path, the path of Mars during December has not been drawn in, but a small cross has been placed to indicate the position of Mars at the end of the year. For the other planets, excluding Pluto, the single tick mark on each path indicates the position of the planet at the beginning of the year. With the exception of Jupiter, each planet is at the east (left) end of its path at year's end. Mars begins its retrograde loop on June 10, is at opposition on July 10, and ends retrograde motion on August 12. The corresponding dates for Jupiter are July 13, September 10, and November 8; and for Saturn: March 19, May 28, and August 7. Mars passes 16′ S of the star β Scorpii on the morning of February 7, 5° N of Antares on February 17, 1.3° S of Saturn on February 18, 0.3° N of Uranus on March 13, 1.4° S of Neptune on April 8, across the northern edge of the large globular cluster M22 on the evening of April 13, and 21′ N of the star τ Sagittarii on September 3. Larger scale maps for Uranus, Neptune and Pluto appear a few pages ahead. (RLB)

JUPITER — EPHEMERIS FOR PHYSICAL OBSERVATIONS — 1986

Date UT	Mag.	App. Equat. Diam.	System I		System II	
			L(1)	Δ	L(1)	Δ
Jan. 1.0	-2.0	34.1"	316.5°	157.64°	69.0°	150.01°
Feb. 1.0	-2.0	32.9"	163.3°	157.66°	39.3°	150.03°
Mar. 1.0	-2.0	32.8"	257.8°	157.69°	280.1°	150.06°
Apr. 1.0	-2.0	33.8"	106.3°	157.75°	252.1°	150.12°
May 1.0	-2.2	35.7"	158.8°	157.82°	75.6°	150.19°
June 1.0	-2.3	38.8"	11.1°	157.90°	51.4°	150.27°
July 1.0	-2.5	42.7"	68.0°	157.98°	239.4°	150.35°
Aug. 1.0	-2.8	46.8"	285.3°	158.04°	220.2°	150.41°
Sept. 1.0	-2.9	49.4"	144.5°	158.02°	202.8°	150.39°
Oct. 1.0	-2.9	48.8"	205.0°	157.92°	34.5°	150.29°
Nov. 1.0	-2.7	45.4"	60.7°	157.80°	13.6°	150.17°
Dec. 1.0	-2.5	41.2"	114.7°	157.70°	198.7°	150.07°
Jan. 1.0	-2.3	37.5"				

RLB

JUPITER

Jupiter, the solar system's largest planet, is a colossal ball of hydrogen and helium without any solid surface comparable to land masses on Earth. In many respects Jupiter is more like a star than a planet. Jupiter likely has a small rocky core encased in a thick mantle of metallic hydrogen which is enveloped by a massive atmospheric cloak topped by a quilt of multi-coloured clouds.

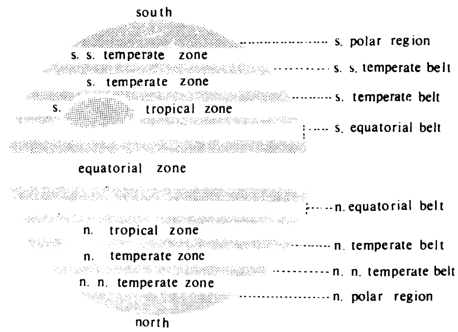
The windswept visible surface of Jupiter is constantly changing. Vast dark belts merge with one another or sometimes fade to insignificance. Brighter zones—actually smeared bands of ammonia clouds—vary in intensity and frequently are carved up with dark rifts or loops called festoons. The equatorial region of Jupiter's clouds rotates five minutes faster than the rest of the planet: 9 hours 50 minutes compared to 9 hours 55 minutes. This means constant interaction as one region slips by the other at about 400 km/h. It also means that there are basically two rotational systems from the viewpoint of week-to-week telescopic observation.

In the table above, the two quantities L(1) and Δ can be used to calculate the longitude L of the central meridian of the illuminated disk of Jupiter. System I is the most rapidly rotating region between the middle of the North Equatorial Belt and the middle of the South Equatorial Belt. System II applies to the rest of the planet. For a given date and time (U.T.) of observation, L is equal to L(1) for the month in question *plus* Δ times the number of complete days elapsed since 0 h U.T. on the first of the month *plus* either 36.58° (for system I) or 36.26° (for system II) times the number of hours elapsed since 0 h U.T. The result will usually exceed 360°; if so, divide the result by 360 and then multiply the decimal portion of the quotient by 360°. This procedure, which is accurate to 1°, is readily computed using a modest calculator.

Jupiter's rapid rotation also makes the great globe markedly oval so that it appears about 7% "squashed" at the poles. Jupiter's apparent equatorial diameter ranges from a minimum of 33″ at conjunction on February 18 to 50″ at opposition on September 10.

JUPITER'S BELTS AND ZONES

Viewed through a telescope of 150 mm aperture or greater, Jupiter exhibits a variety of changing detail and colour in its cloudy atmosphere. Some features are of long duration, others are short-lived. The standard nomenclature of the belts and zones is given in the figure.



The Great Red Spot, a salmon-coloured oval vortex whose hue may possibly be due to organic-like compounds that are constantly spewed from some heated atmospheric source below, is the longest-lived structure on the visible surface of Jupiter. The spot and the changing cloud structures that stripe the planet can be easily observed in small telescopes because the apparent size of the visible surface of Jupiter is far greater than that of any other planet. Occasionally (1981–85 for example) the Red Spot loses its prominence, becoming difficult to detect in smaller telescopes, only to return to its normal state a few years later.

Two Voyager spacecraft swung through the Jovian system in 1979 and transmitted to Earth superbly detailed photographs of the planet and its five inner moons. Among the most surprising finds was a ring of dust-size particles around the giant planet's equator. The ring apparently extends from the Jovian clouds out to 59 000 km.

The smallest of telescopes will reveal Jupiter's four large moons, each of which is equal to or larger than Earth's satellite. The moons provide a never-ending fascination for amateur astronomers. Sometimes the satellites are paired on either side of the belted planet; frequently one is missing—either behind Jupiter or in the planet's shadow. Even more interesting are the occasions when one of the moons casts its shadow on the disk of the planet. The tiny black shadow of one of the moons can be particularly evident if it is cast on one of the bright zones of Jupiter. According to some observers this phenomenon is evident in a good 60 mm refractor. Both the satellite positions and the times of their interaction with the Jovian disk are given elsewhere in the HANDBOOK. Jupiter's other satellites are photographic objects for large instruments.

As 1986 opens, Jupiter is seen low in the southwest after sunset, but by late January it is too close to the Sun for observation. Jupiter enters the morning sky in February and by mid-March is a dawn object in Aquarius, where it remains for the rest of the year. In July it rises not long after midnight, beginning a five-month period when the giant planet is well placed for telescopic viewing.

After a three-year span during which Jupiter was riding low on the ecliptic, 1986 offers the planet at relatively favourable declinations. Furthermore, Jupiter is nearing perihelion (July 10, 1987) and its apparent opposition diameter is greater than at any time since 1975. For example, at the aphelion opposition of 1981 Jupiter's disk was 44.2″ compared to this year's 49.6″ at opposition September 10. Opposition distance is 3.972 A (594 million km) from Earth. Minimum possible distance between the two planets is 3.948 A (591 million km).

Near opposition this year a telescope magnifying only 36 times will yield an image of Jupiter equal in size to the full moon seen with the naked eye. A telescope at 190x will make the Great Red Spot's major axis the same apparent diameter as the moon to the unaided eye.

SATURN

Saturn is the telescopic showpiece of the night sky. The chilling beauty of the small pale orb floating in a field of velvet is something no photographs or descriptions can adequately duplicate. According to recent Voyager spacecraft findings, the rings consist of billions of particles that range in size from microscopic specks to flying mountains kilometres across. The reason "rings" is plural and not singular is that gaps and brightness differences define hundreds of distinct rings. However, from Earth only the three most prominent components—known simply as rings A, B, and C—can be distinguished visually. (See the diagram on p. 116.)

Cassini's Division, a gap between rings A and B discovered in 1675, is visible in small telescopes when the ring system is well inclined to our view. The Voyager spacecraft revealed Cassini's Division as a region less densely populated with ring particles than adjacent rings. Ring B, the brightest, overpowers ring C to such an extent that ring C, also known as the crepe ring, is seen only with difficulty in small telescopes.

In addition to the rings, Saturn has a family of at least twenty satellites. Titan, the largest, is easily seen in any telescope as an eighth-magnitude object orbiting Saturn in about 16 days. At east and west elongation Titan appears about five ring diameters from the planet. Titan is the only satellite in the solar system with a substantial atmosphere, now known to be primarily nitrogen and 4.6 times as massive as Earth's, with a surface pressure of 1.6 Earth atmospheres.

Telescopes over 60 mm aperture should reveal Rhea at 10th magnitude less than two ring-diameters from Saturn. The satellite Iapetus has the peculiar property of being five times brighter at western elongation ($10\overset{\mathrm{m}}{.}1$) than at eastern elongation ($11\overset{\mathrm{m}}{.}9$). One side of the moon has the reflectivity of snow while the other resembles dark rock. The reason for this is unknown. When brightest, Iapetus is located about 12 ring-diameters west of its parent planet. Of the remaining moons Tethys and Dione may be glimpsed in a 150 mm telescope but the others require larger apertures or photographic techniques. (See pages 134–140 for the configurations of Saturn's four brightest satellites during 1986.)

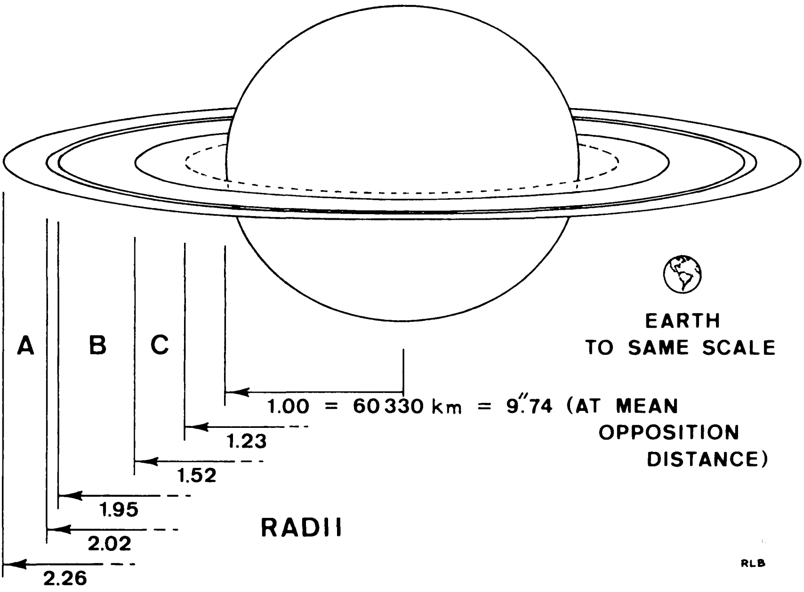
The disk of Saturn appears about 1/6 the area Jupiter appears through the same telescope with the same magnification. In telescopes less than 100 mm aperture probably no features will ever be seen on the surface of the planet other than the shadow cast by the rings. As the size of the telescope is increased the pale equatorial region, a dusky equatorial band, and the darker polar regions become evident. Basically, Saturn has a belt system like Jupiter's but it is much less active and the contrast is reduced. Seldom in telescopes less than 200 mm aperture do more than one or two belts come into view. In 1980, the planet's rotation period was established at 10 hours, 40 minutes, four percent longer than previous estimates. Very rarely a spot among the Saturnian clouds will appear unexpectedly, but less than a dozen notable spots have been recorded since telescopic observation of Saturn commenced in the 17th century.

From year to year the rings of Saturn take on different appearances. The planet's orbit is an immense 29.5 year circuit about the Sun, so in the course of an observing season the planet moves relatively little in its orbit (and thus appears to remain in about the same general area of the sky) and maintains an essentially static orientation toward Earth. In 1973 the rings were presented to their fullest extent (27°) as viewed from Earth, with the southern face being visible. The north face will be seen similarly displayed in 1987. In apparent width the rings are equal to the equatorial diameter of Jupiter.

Saturn is in Scorpius as 1986 opens and is visible in the east before sunrise. The sixth planet moves into Ophiuchus in mid-January, passes Antares on February 10, and is itself passed by Mars a week later. From then until early November when it becomes lost in the sunset glow, Saturn is not far from the Scorpius–Ophiuchus border north of Antares. Opposition is on May 28 when the planet is

SATURN

MAIN RING FEATURES VISIBLE FROM EARTH



P

SATURN'S RING SYSTEM
MAIN STRUCTURAL REGIONS

Ring	Radius[1]	Discoverer
D	1.11 - 1.23	Voyager 1 (1980)
C*	1.23 - 1.52	W. C. & G. P. Bond, W. R. Dawes (1850)
B*	1.52 - 1.95	Galileo (1610), C. Huygens (1659), G. D. Cassini (1675)
A*	2.02 - 2.26	
F	2.33	Pioneer 11 (1979)
G	2.8	Voyager 1 (1980)
E	3 - 8	W. A. Feibelman (1966)

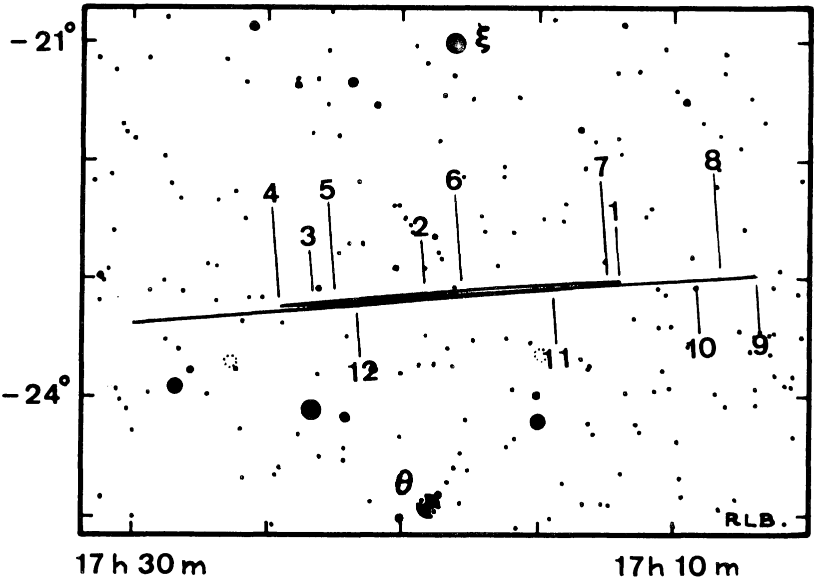
[1] In units of Saturn's equatorial radius (60 330 km).

RLB

* Visible from Earth. Also, the "E" ring can be detected when Saturn's ring system appears edge-on.

8.979 A (1.343 billion km) from Earth. At that time Saturn's equatorial diameter is 18.4″, and the rings are 41.8″ in width. Throughout the prime telescopic observing window, from April to September, the rings are tilted between 25.0° and 25.6° with respect to Earth, with the north face being visible.

URANUS



The path of Uranus in southern Ophiuchus, 1986. The position of Uranus is indicated for the beginning of each month, where 1 = January, 2 = February, etc. The faintest stars shown are of magnitude 9. The coordinates are for 1950.0. The magnitude of Uranus is about 5.6. Its pale, greenish disk is about 3.8″ in diameter when it is on the retrograde portion of its path. Opposition is on June 11. The small dotted circle by the number "11" is the 12th magnitude globular cluster NGC 6325. The small dotted circle south of the mid-December position of Uranus is the 14th magnitude planetary nebula NGC 6369. The position of the path of Uranus on a wide-field chart of the night sky is shown on page 112. (RLB)

Although Uranus can be seen with the unaided eye under a clear, dark sky, it was apparently unknown until 1781 when it was accidentally discovered by William Herschel with a 150 mm reflecting telescope. It can be easily seen with binoculars, and a telescope will reveal its small, greenish, featureless disk.

Jupiter, Saturn, Uranus and Neptune are rather similar in the sense that their interiors consist mainly of hydrogen and helium and their atmospheres consist of these same elements and simple compounds of hydrogen. Unlike the three other giant planets, the axis of Uranus is tipped almost parallel to the plane of the solar system. This means that we can view Uranus nearly pole-on at certain points in its 84-year orbit of the Sun. The northern hemisphere of Uranus is now directed toward Earth and we will be viewing the planet almost exactly toward its north pole in 1986. Uranus has five satellites, all smaller than Earth's moon, none of which can be detected in small or moderate sized telescopes.

The 1977 discovery of at least five rings encircling Uranus is regarded as one of the major planetary finds in recent years. Follow-up studies have provided evidence for a total of nine rings relatively evenly spaced from 16 000 to 24 000 km above the cloudy surface of Uranus. The outer ring is about 100 km wide but curiously eccentric. The others are estimated to be between 5 and 10 km across. These dimensions are markedly different from Saturn's three major rings, each of which is thousands of kilometres wide. The rings are not as dense as Saturn's major ring since the occulted star did not completely disappear during passage behind them. Also, the albedo of the individual particles is believed to be low suggesting a dark substance compared to Saturn's brilliantly reflective ring material. The Uranian rings are invisible by direct visual observation from Earth because of their small dimensions and the enormous distance that separates us from Uranus. Much is expected to be learned about Uranus and its rings when Voyager 2 passes within 106 000 km of the planet on January 22, 1986.

Uranus is in Ophiuchus all year with opposition on June 11, when the planet is 18.13 A (2.71 billion km) from Earth. At this time its magnitude is +5.5 and its apparent diameter is 3.9 seconds of arc.

NEPTUNE

The discovery of Neptune in 1846, after its existence in the sky had been predicted from independent calculations by Leverrier in France and Adams in England, was regarded as the crowning achievement of Newton's theory of universal gravitation. Actually Neptune had been seen—but mistaken for a star—several times before its "discovery".

Telescopically, the planet appears as a very small, featureless, bluish-green disk. Neptune's large moon Triton can be seen by an experienced observer using a 300 mm telescope. Recent measurements from NASA's Infrared Facility on Mauna Kea (Hawaii) suggest that Triton is smaller than Earth's Moon, thus effectively eliminating the possibility that it is the largest satellite in the solar system. Spectral studies in 1982 indicate that the surface of Triton may be rocky, with methane glaciers and a shallow sea of liquid nitrogen. However, these results are tentative. Triton varies from 8 to 17 seconds of arc from Neptune during its 5.9-day orbit. An unconfirmed third moon of Neptune was reported in 1981. This object may prove to be one of a large number of smaller as-yet-undetected bodies in orbit around the planet.

P

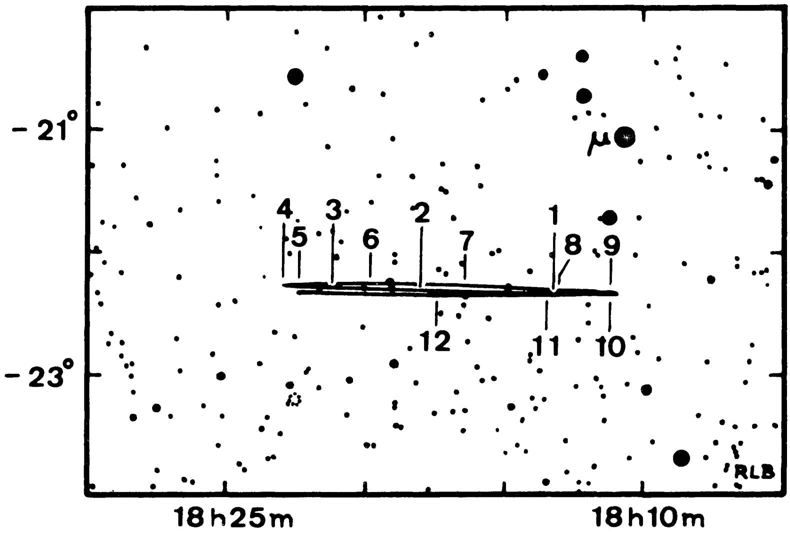
Since the discovery of Uranus' rings in 1977, numerous searches for a Neptunian ring system have failed to reveal one. Neptune's diameter was determined with high precision from occultation observations in 1969. Uncertainties in the rotation period of Neptune have narrowed in recent years with current values in the 18 to 19 hour range.

In 1986 Neptune is buried in the Milky Way in western Sagittarius a few degrees from the Lagoon Nebula (M8) (see the chart). At opposition on June 26 Neptune is magnitude +7.9, 29.23 A (4.37 billion km) distant from Earth, and 2″.3 in diameter.

PLUTO

Pluto, the most distant known planet, was discovered at the Lowell Observatory in 1930 as a result of an extensive search started two decades earlier by Percival Lowell. The faint star-like image was first detected by Clyde Tombaugh by comparing photographs taken on different dates.

The most important advance in our knowledge of Pluto since its discovery came in 1978 as a result of routine examinations of photographs of the planet taken at the U.S. Naval Observatory, Flagstaff, Arizona. James W. Christy detected an elongation of Pluto's image on some of the photos which has been confirmed as a large satellite



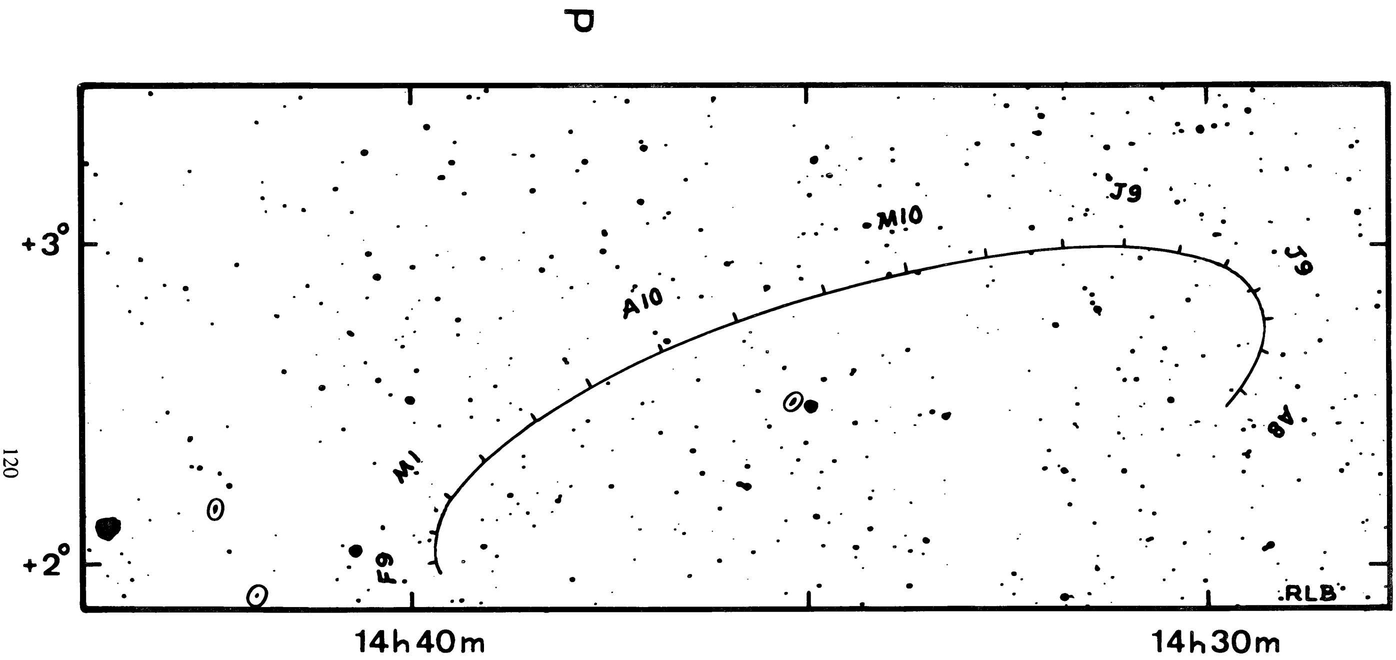
The path of Neptune in Sagittarius, 1986. Its position is indicated for the beginning of each month, where 1 = January, 2 = February, etc. The faintest stars shown are of magnitude 9. The coordinates are for 1950.0. The magnitude of Neptune is about 7.9 and its diameter 2″.3 when it is on the retrograde portion of its path. Opposition is on June 26 when Neptune is 29.2 A (4.05 light-hours) from Earth, the most distant planet at the present time. Neptune reaches its most southerly declination (−22°21′37″) since the early 19th century on October 29. Thus, for observers in the Northern Hemisphere, this is the worst year since the discovery of Neptune to study this remote world! The small dotted circle about 1° S of the April position of Neptune is the 12th magnitude planetary nebula NGC 6629. The position of the path of Neptune on a wide-field chart of the night sky is shown on page 112. (RLB)

revolving once every 6.3867 days—identical to the planet's rotation period. This means that the moon is visible only from one hemisphere of Pluto. Calculations made some years ago suggest that this is the only stable orbit a satellite could have with Pluto's slow rotation rate. The moon too would likely have one side constantly turned to Pluto forming a unique double-planet system. The name Charon has been proposed for the new-found object.

Pluto and Charon are almost certainly balls of ice, most likely water, methane, and ammonia. This conclusion is supported by recent observations of a tenuous methane atmosphere on Pluto. However, since Pluto's surface gravity is too feeble to retain a primordial methane atmosphere it is probable that as the planet nears perihelion, the Sun is evaporating its frosty surface.

Besides being the solar system's smallest planet, Pluto is different from the other eight in almost every respect. Its unique characteristics include its orbit which is relatively higher inclined and so elliptical that the planet will be closer to the Sun than Neptune from 1980 to 1999. Just where such a freak fits into the solar system's origin and evolution is unknown. Perhaps Pluto is the largest member of a group of small, icy, comet-like structures beyond Neptune.

At opposition on April 26, Pluto is located in eastern Virgo (see chart) and its distance from Earth will be 28.76 A (4.30 billion km). With an apparent magnitude of +13.7, Pluto is a difficult target in moderate-sized amateur telescopes.



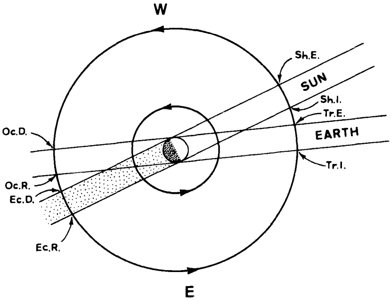
The path of Pluto in eastern Virgo, 1986. Its position is marked at 10-day intervals, beginning at February 9 (F9). The bright star (magnitude 3.7) near the left edge of the chart, 109 Vir, may be used to quickly locate the star field shown here (109 Vir appears at α = 14h 44m and just above the celestial equator on the "MAY" map of the night sky at the end of this Handbook. Note also the wide-field chart on page 112). Pluto reaches opposition on April 26 at magnitude 13.7 and 3.99 light-hours from Earth. The faintest stars shown on the chart are about magnitude 13. Note that an aperture of at least 200 mm will be needed to see Pluto. On the above chart, three objects have been enclosed in ellipses. These are spiral galaxies, and in order of increasing right ascension they are: NGC 5690, a 13th magnitude, edge-on system; NGC 5740, 12th magnitude; and NGC 5746, an 11th magnitude, nearly edge-on galaxy. The chart is based on Vehrenberg's Atlas Stellarum *1950.0, and the coordinates are for that epoch. (RLB)*

JUPITER

PHENOMENA OF THE GALILEAN SATELLITES

The following tables give the various transits, occultations, and eclipses of the four great satellites of Jupiter. Since the phenomena are not instantaneous but require up to several minutes, the predicted times are for the middle of each event. The abbreviations are: I = Io, II = Europa, III = Ganymede, IV = Callisto; Ec = eclipse, Oc = occultation, Tr = transit of the satellite, Sh = transit of the shadow, I = ingress, E = egress, D = disappearance, R = reappearance.

The general motions of the satellites, and the successive phenomena are shown in the diagram at right. Satellites move from east to west across the face of the planet, and from west to east behind it. Before opposition, shadows fall to the west, and after opposition, to the east (as in the diagram). The sequence of phenomena in the diagram, beginning at the lower right, is: transit ingress (Tr.I.), transit egress (Tr.E.), shadow ingress (Sh.I.), shadow egress (Sh.E.), occultation disappearance (Oc.D.), occultation reappearance (Oc.R.), eclipse disappearance (Ec.D.) and eclipse reappearance (Ec.R.), but this sequence will depend on the actual Sun-Jupiter-Earth angle.



Over half the phenomena listed will not be visible from any one locality because they occur when Jupiter is below the horizon or when daylight interferes. To determine which phenomena are visible from a given locality (latitude ϕ) on a certain date, note the local time that Jupiter transits and its declination δ (see The Sky Month By Month section). Jupiter will be above the horizon for a time of $(1/15)\cos^{-1}(-\tan\phi\tan\delta)$ hours on either side of the time of transit. A second time interval corresponding to nighttime can be determined from the Twilight table. The region of overlap of these two time intervals will correspond to Jupiter being both above the horizon and in a dark sky. Those phenomena in the table which fall within this time "window" will be visible.

In practice, the observer usually knows when Jupiter will be conveniently placed in the night sky, and the table can simply be scanned to select those events which occur near these times. For example, an active observer in Victoria, British Columbia, on September 20 would know that Jupiter is well placed in the late evening sky. If he planned to observe from 10 pm to 2 am PDT (7 h behind UT), he could scan the table for events in the interval September 21, 5 h to 9 h UT. He would find four events, at 2229, 2245, 0045 and 0102 PDT, all involving the satellite Io.

SATELLITES OF JUPITER, 1986

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

JANUARY

d	h	m	
0	0	40	II. Tr.I.
	2	19	II. Sh.I.
	3	33	II. Tr.E.
	5	12	II. Sh.E.
	12	03	I. Tr.I.
	12	52	I. Sh.I.
	14	20	I. Tr.E.
	15	09	I. Sh.E.
	21	40	III. Oc.D.
1	4	37	III. Ec.R.
	9	11	I. Oc.D.
	12	17	I. Ec.R.
	19	51	II. Oc.D.
2	0	21	II. Ec.R.
	0	33	IV. Oc.D.
	5	25	IV. Oc.R.
	6	33	I. Tr.I.
	7	21	I. Sh.I.
	8	04	IV. Ec.D.
	8	51	I. Tr.E.
	9	38	I. Sh.E.
	12	47	IV. Ec.R.
3	3	41	I. Oc.D.
	6	46	I. Ec.R.
	14	05	II. Tr.I.
	15	38	II. Sh.I.
	16	58	II. Tr.E.
	18	31	II. Sh.E.
4	1	04	I. Tr.I.
	1	49	I. Sh.I.
	3	21	I. Tr.E.
	4	07	I. Sh.E.
	12	06	III. Tr.I.
	15	11	III. Sh.I.
	15	45	III. Tr.E.
	18	48	III. Sh.E.
	22	12	I. Oc.D.
5	1	15	I. Ec.R.
	9	16	II. Oc.D.
	13	40	II. Ec.R.
	19	34	I. Tr.I.
	20	18	I. Sh.I.
	21	52	I. Tr.E.
	22	35	I. Sh.E.
6	16	42	I. Oc.D.
	19	44	I. Ec.R.
7	3	30	II. Tr.I.
	4	56	II. Sh.I.
	6	23	II. Tr.E.
	7	49	II. Sh.E.
	14	04	I. Tr.I.
	14	47	I. Sh.I.
7	16	22	I. Tr.E.
	17	04	I. Sh.E.
8	2	08	III. Oc.D.
	8	39	III. Ec.R.
	11	12	I. Oc.D.
	14	13	I. Ec.R.
	22	41	II. Oc.D.
9	2	58	II. Ec.R.
	8	35	I. TR.I.
	9	16	I. Sh.I.
	10	52	I. Tr.E.
	11	33	I. Sh.E.
10	5	43	I. Oc.D.
	8	41	I. Ec.R.
	10	04	IV. Tr.I.
	14	57	IV. Tr.E.
	16	34	IV. Sh.I.
	16	55	II. Tr.I.
	18	15	II. Sh.I.
	19	49	II. Tr.E.
	21	08	II. Sh.E.
	21	17	IV. Sh.E.
11	3	05	I. Tr.I.
	3	44	I. Sh.I.
	5	23	I. Tr.E.
	6	02	I. Sh.E.
	16	34	III. Tr.I.
	19	12	III. Sh.I.
	20	13	III. Tr.E.
	22	49	III. Sh.E.
12	0	13	I. Oc.D.
	3	10	I. Ec.R.
	12	06	II. Oc.D.
	16	16	II. Ec.R.
	21	36	I. Tr.I.
	22	13	I. Sh.I.
	23	53	I. Tr.E.
13	0	31	I. Sh.E.
	18	44	I. Oc.D.
	21	39	I. Ec.R.
14	6	20	II. Tr.I.
	7	33	II. Sh.I.
	9	14	II. Tr.E.
	10	27	II. Sh.E.
	16	06	I. Tr.I.
	16	42	I. Sh.I.
	18	24	I. Tr.E.
	18	59	I. Sh.E.
15	6	37	III. Oc.D
	12	40	III. Ec.R.
	13	14	I. Oc.D.
15	16	08	I. Ec.R.
16	1	31	II. Oc.D.
	5	34	II. Ec.R.
	10	37	I. Tr.I.
	11	11	I. Sh.I.
	12	54	I. Tr.E.
	13	28	I. Sh.E.
17	7	45	I. Oc.D.
	10	37	I. EC.R.
	19	46	II. Tr.I.
	20	52	II. Sh.I.
	22	40	II. Tr.E.
	23	46	II. Sh.E.
18	5	07	I. Tr.I.
	5	40	I. Sh.I.
	7	25	I. Tr.E.
	7	57	I. Sh.E.
	21	03	III. Tr.I.
	21	14	IV. Oc.D.
	23	13	III. Sh.I.
19	0	42	III. Tr.E.
	2	04	IV. Oc.R.
	2	15	I. Oc.D.
	2	16	IV. Ec.D.
	2	50	III. Sh.E.
	5	05	I. Ec.R.
	6	56	IV. Ec.R.
	14	57	II. Oc.D.
	18	52	II. Ec.R.
	23	38	I. Tr.I.
20	0	08	I. Sh.I.
	1	55	I. Tr.E.
	2	26	I. Sh.E.
	20	46	I. Oc.D.
	23	34	I. Ec.R.
21	9	11	II. Tr.I.
	10	11	II. Sh.I.
	12	05	II. Tr.E.
	13	04	II. Sh.E.
	18	08	I. Tr.I.
	18	37	I. Sh.I.
	20	26	I. Tr.E.
	20	54	I. Sh.E.
22	11	07	III. Oc.D.
	15	17	I. Oc.D.
	16	41	III. Ec.R.
	18	03	I. Ec.R.
23	4	22	II. Oc.D
	8	10	II. Ec.R.
	12	39	I. Tr.I.
	13	06	I. Sh.I.
23	14	56	I. Tr.E.
	15	23	I. Sh.E.
24	9	47	I. Oc.D.
	12	32	I. Ec.R.
	22	37	II. Tr.I.
	23	29	II. Sh.I.
25	1	31	II. TR.E.
	2	23	II. Sh.E.
	7	09	I. Tr.I.
	7	34	I. Sh.I.
	9	27	I. Tr.E.
	9	52	I. Sh.E.
26	1	33	III. Tr.I.
	3	14	III. Sh.I.
	4	18	I. Oc.D.
	5	13	III. Tr.E.
	6	51	III. Sh.E.
	7	01	I. Ec.R.
	17	47	II. Oc.D.
	21	28	II. Ec.R.
27	1	40	I. Tr.I.
	2	03	I. Sh.I.
	3	57	I. Tr.E.
	4	20	I. Sh.E.
	7	00	IV. Tr.I.
	10	49	IV. Sh.I.
	11	52	IV. Tr.E.
	15	30	IV. Sh.E.
	22	48	I. Oc.D.
28	1	29	I. Ec.R.
	12	03	II. Tr.I.
	12	48	II. Sh.I.
	14	57	II. Tr.E.
	15	42	II. Sh.E.
	20	10	I. Tr.I.
	20	32	I. Sh.I.
	22	28	I. Tr.E.
	22	49	I. Sh.E.
29	15	39	III. Oc.D.
	17	19	I. Oc.D.
	19	58	I. Ec.R.
	20	43	III. Ec.R.
30	7	13	II. Oc.D.
	10	46	II. Ec.R.
	14	41	I. Tr.I.
	15	01	I. Sh.I.
	16	58	I. Tr.E.
	17	18	I. Sh.E.
31	11	50	I. Oc.D.
	14	27	I. Ec.R.

SATELLITES OF JUPITER, 1986

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

FEBRUARY

d	h	m	
1	1	29	II. Tr.I.
	2	07	II. Sh.I.
	4	24	II. Tr.E.
	5	01	II. Sh.E.
	9	11	I. Tr.I.
	9	29	I. Sh.I.
	11	29	I. Tr.E.
	11	47	I. Sh.E.
2	6	04	III. Tr.I.
	6	20	I. Oc.D.
	7	15	III. Sh.I.
	8	56	I. Ec.R.
	9	43	III. Tr.E.
	10	52	III. Sh.E.
	20	38	II. Oc.D.
3	0	03	II. Ec.R.
	3	42	I. Tr.I.
	3	58	I. Sh.I.
	5	59	I. Tr.E.
	6	15	I. Sh.E.
4	0	51	I. Oc.D.
	3	24	I. Ec.R.
	14	55	II. Tr.I.
	15	25	II. Sh.I.
	17	50	II. Tr.E.
	18	09	IV. Oc.D.
	18	19	II. Sh.E.
	22	12	I. Tr.I.
	22	27	I. Sh.I.
5	0	30	I. Tr.E.
	0	44	I. Sh.E.
	1	05	IV. Ec.R.
	19	21	I. Oc.D.
	20	11	III. Oc.D.
	21	53	I. Ec.R.
6	0	43	III. Ec.R.
	10	03	II. Oc.D.
	13	21	II. Ec.R.
	16	43	I. Tr.I.
	16	55	I. Sh.I.
	19	00	I. Tr.E.
	19	13	I. Sh.E.
7	13	52	I. Oc.D.
	16	22	I. Ec.R.
8	4	22	II. Tr.I.
	4	44	II. Sh.I.
	7	16	II. Tr.E.
	7	38	II. Sh.E.
	11	13	I. Tr.I.
	11	24	I. Sh.I.
	13	31	I. Tr.E.
	13	41	I. Sh.E.
9	8	23	I. Oc.D.
	10	36	III. Tr.I.
	10	51	I. Ec.R.
	11	16	III. Sh.I.
	14	15	III. Tr.E.
	14	53	III. Sh.E.
	23	29	II. Oc.D.
10	2	39	II. Ec.R.
	5	44	I. Tr.I.
	5	53	I. Sh.I.
	8	01	I. Tr.E.
	8	10	I. Sh.E.
11	2	53	I. Oc.D
	5	19	I. Ec.R.
	17	48	II. Tr.I.
	18	03	II. Sh.I.
	20	42	II. Tr.E.
	20	57	II. Sh.E.
12	0	14	I. Tr.I.
	0	21	I. Sh.I.
	2	32	I. Tr.E.
	2	38	I. Sh.E.
	21	24	I. Oc.D.
	23	48	I. Ec.R.
13	0	42	III. Oc.D.
	4	06	IV. Tr.I.
	4	44	III. Ec.R.
	5	04	IV. Sh.I.
	8	54	IV. Tr.E.
	9	42	IV. Sh.E.
	12	54	II. Oc.D.
	15	57	II. Ec.R.
	18	45	I. Tr.I.
	18	50	I. Sh.I.
	21	02	I. Tr.E.
	21	07	I. Sh.E.
14	15	55	I. Oc.D.
14	18	17	I. Ec.R.
15	7	15	II. Tr.I.
	7	22	II. Sh.I.
	10	09	II. Tr.E.
	10	16	II. Sh.E.
	13	15	I. Tr.I.
	13	18	I. Sh.I.
	15	33	I. Tr.E.
	15	36	I. Sh.E.
16	10	25	I. Oc.D.
	12	46	I. Ec.R.
	15	09	III. Tr.I.
	15	17	III. Sh.I.
	18	47	III. Tr.E.
	18	54	III. Sh.E.
17	2	19	II. Oc.D.
	5	14	II. Ec.R.
	7	46	I. Tr.I.
	7	47	I. Sh.I.
	10	03	I. Tr.E.
	10	04	I. Sh.E.
18	4	56	I. Oc.D.
	7	14	I. Ec.R.
	20	40	II. Sh.I.
	20	41	II. Tr.I.
	23	34	II. Sh.E.
	23	35	II. Tr.E.
19	2	16	I. Sh.I.
	2	16	I. Tr.I.
	4	33	I. Sh.E.
	4	34	I. Tr.E.
	23	25	I. Ec.D.
20	1	45	I. Oc.R.
	5	07	III. Ec.D.
	8	54	III. Oc.R.
	15	40	II. Ec.D.
	18	37	II. Oc.R.
	20	44	I. Sh.I.
	20	47	I. Tr.I.
	23	02	I. Sh.E.
	23	04	I. Tr.E.
21	14	41	IV. Ec.D.
	17	54	I. Ec.D.
	19	52	IV. Oc.R.
21	20	16	I. Oc.R.
22	9	59	II. Sh.I.
	10	08	II. Tr.I.
	12	53	II. Sh.E.
	13	02	II. Tr.E.
	15	13	I. Sh.I.
	15	17	I. Tr.I.
	17	30	I. Sh.E.
	17	35	I. Tr.E.
23	12	22	I. Ec.D.
	14	46	I. Oc.R.
	19	18	III. Sh.I.
	19	41	III. Tr.I.
	22	54	III. Sh.E.
	23	19	III. Tr.E.
24	4	57	II. Ec.D.
	8	02	II. Oc.R.
	9	42	I. Sh.I.
	9	48	I. Tr.I.
	11	59	I. Sh.E.
	12	05	I. Tr.E.
25	6	51	I. Ec.D.
	9	17	I. Oc.R.
	23	18	II. Sh.I.
	23	34	II. Tr.I.
26	2	11	II. Sh.E.
	2	28	II. Tr.E.
	4	10	I. Sh.I.
	4	18	I. Tr.I.
	6	27	I. Sh.E.
	6	36	I. Tr.E.
27	1	20	I. Ec.D.
	3	48	I. Oc.R.
	9	08	III. Ec.D.
	13	25	III. Oc.R.
	18	15	II. Ec.D.
	21	27	II. Oc.R.
	22	39	I. Sh.I.
	22	49	I. Tr.I.
28	0	56	I. Sh.E.
	1	06	I. Tr.E.
	19	49	I. Ec.D.
	22	18	I. Oc.R.

SATELLITES OF JUPITER, 1986

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

MARCH

d	h	m		d	h	m		d	h	m		d	h	m	
1	12	37	II. Sh.I.	**8**	19	21	I. Tr.I.	**17**	7	19	III. Sh.I.	**24**	17	19	I. Sh.I.
	13	01	II. Tr.I.		21	19	I. Sh.E.		9	14	III. Tr.I.		17	54	I. Tr.I.
	15	31	II. Sh.E.		21	38	I. Tr.E.		10	54	III. Sh.E.		19	18	II. Oc.R.
	15	55	II. Tr.E.						12	42	II. Ec.D.		19	35	I. Sh.E.
	17	07	I. Sh.I.	**9**	16	12	I. Ec.D.		12	49	III. Tr.E.		20	10	I. Tr.E.
	17	19	I. Tr.I.		18	51	I. Oc.R.		15	24	I. Sh.I.				
	19	24	I. Sh.E.						15	53	I. Tr.I.	**25**	14	30	I. Ec.D.
	19	36	I. Tr.E.	**10**	3	19	III. Sh.I.		16	30	II. Oc.R.		17	25	I. Oc.R.
	23	19	IV. Sh.I.		4	43	III. Tr.I.		17	41	I. Sh.E.				
					6	55	III. Sh.E		18	09	I. Tr.E.	**26**	9	48	II. Sh.I.
2	1	16	IV. Tr.I.		8	20	III. Tr.E.						11	04	II. Tr.I.
	3	52	IV. Sh.E.		8	53	IV. Ec.D.	**18**	12	35	I. Ec.D.		11	47	I. Sh.I.
	5	56	IV. Tr.E.		10	08	II. Ec.D.		15	23	I. Oc.R.		12	24	I. Tr.I.
	14	17	I. Ec.D.		13	30	I. Sh.I.		17	35	IV. Sh.I.		12	41	II. Sh.E.
	16	49	I. Oc.R.		13	41	II. Oc.R.		22	04	IV. Sh.E.		13	57	II. Tr.E.
	23	19	III. Sh.I.		13	51	I. Tr.I.		22	22	IV. Tr.I.		14	04	I. Sh.E.
					15	47	I. Sh.E.						14	40	I. Tr.E.
3	0	12	III. Tr.I.		16	08	I. Tr.E.	**19**	2	53	IV. Tr.E.				
	2	55	III. Sh.E.		16	44	IV. Oc.R.		7	10	II. Sh.I.	**27**	3	05	IV. Ec.D.
	3	50	III. Tr.E.						8	12	II. Tr.I.		7	30	IV. Ec.R.
	7	33	II. Ec.D.	**11**	10	41	I. Ec.D.		9	53	I. Sh.I.		8	59	I. Ec.D.
	10	52	II. Oc.R.		13	21	I. Oc.R.		10	04	II. Sh.E.		9	03	IV. Oc.D.
	11	36	I. Sh.I.						10	23	I. Tr.I.		11	56	I. Oc.R.
	11	50	I. Tr.I.	**12**	4	33	II. Sh.I.		11	06	II. Tr.E.		13	27	IV. Oc.R.
	13	53	I. Sh.E.		5	20	II. Tr.I.		12	10	I. Sh.E.				
	14	07	I. Tr.E.		7	26	II. Sh.E.		12	40	I. Tr.E.	**28**	1	13	III. Ec.D.
					7	59	I. Sh.I.						4	34	II. Ec.D.
4	8	46	I. Ec.D.		8	14	II. Tr.E.	**20**	7	04	I. Ec.D.		6	16	I. Sh.I.
	11	19	I. Oc.R.		8	22	I. Tr.I.		9	54	I. Oc.R.		6	54	I. Tr.I.
					10	16	I. Sh.E.		21	12	III. Ec.D.		7	27	III. Oc.R.
5	1	55	II. Sh.I.		10	39	I. Tr.E.						8	32	I. Sh.E.
	2	27	II. Tr.I.					**21**	2	00	II. Ec.D.		8	42	II. Oc.R.
	4	49	II. Sh.E.	**13**	5	10	I. Ec.D.		2	58	III. Oc.R.		9	11	I. Tr.E.
	5	21	II. Tr.E.		7	52	I. Oc.R.		4	22	I. Sh.I.				
	6	04	I. Sh.I.		17	11	III. Ec.D.		4	53	I. Tr.I.	**29**	3	27	I. Ec.D.
	6	20	I. Tr.I.		22	28	III. Oc.R.		5	54	II. Oc.R.		6	26	I. Oc.R.
	8	21	I. Sh.E.		23	25	II. Ec.D.		6	38	I. Sh.E.		23	07	II. Sh.I.
	8	37	I. Tr.E.						7	10	I. Tr.E.				
				14	2	27	I. Sh.I.					**30**	0	31	II. Tr.I.
6	3	15	I. Ec.D.		2	52	I. Tr.I.	**22**	1	33	I. Ec.D.		0	44	I. Sh.I.
	5	50	I. Oc.R.		3	06	II. Oc.R.		4	24	I. Oc.R.		1	24	I. Tr.I.
	13	10	III. Ec.D.		4	44	I. Sh.E.		20	30	II. Sh.I.		2	01	II. Sh.E.
	17	57	III. Oc.R.		5	09	I. Tr.E.		21	39	II. Tr.I.		3	01	I. Sh.E.
	20	50	II. Ec.D.		23	38	I. Ec.D.		22	50	I. Sh.I.		3	23	II. Tr.E.
									23	23	II. Sh.E.		3	41	I. Tr.E.
7	0	16	II. Oc.R.	**15**	2	23	I. Oc.R.		23	23	I. Tr.I.		21	56	I. Ec.D.
	0	33	I. Sh.I.		17	52	II. Sh.I.								
	0	50	I. Tr.I.		18	46	II. Tr.I.	**23**	0	32	II. Tr.E.	**31**	0	56	I. Oc.R.
	2	50	I. Sh.E.		20	46	II. Sh.E.		1	07	I. Sh.E.		15	21	III. Sh.I.
	3	08	I. Tr.E.		20	56	I. Sh.I.		1	40	I. Tr.E.		17	52	II. Ec.D.
	21	43	I. Ec.D.		21	22	I. Tr.I.		20	02	I. Ec.D.		18	12	III. Tr.I.
					21	40	II. Tr.E.		22	55	I. Oc.R.		18	55	III. Sh.E.
8	0	20	I. Oc.R.		23	13	I. Sh.E.						19	13	I. Sh.I.
	15	14	II. Sh.I.		23	39	I. Tr.E.	**24**	11	20	III. Sh.I.		19	54	I. Tr.I.
	15	54	II. Tr.I.						13	43	III. Tr.I.		21	29	I. Sh.E.
	18	08	II. Sh.E.	**16**	18	07	I. Ec.D.		14	54	III. Sh.E.		21	46	III. Tr.E.
	18	48	II. Tr.E.		20	53	I. Oc.R.		15	17	II. Ec.D.		22	06	II. Oc.R.
	19	02	I. Sh.I.						17	18	III. Tr.E.		22	11	I. Tr.E.

SATELLITES OF JUPITER, 1986

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

APRIL

d	h	m	
1	16	25	I. Ec.D.
	19	27	I. Oc.R.
2	12	26	II. Sh.I.
	13	41	I. Sh.I.
	13	56	II. Tr.I.
	14	24	I. Tr.I.
	15	19	II. Sh.E.
	15	57	I. Sh.E.
	16	41	I. Tr.E.
	16	48	II. Tr.E.
3	10	53	I. Ec.D.
	13	57	I. Oc.R.
4	5	13	III. Ec.D.
	7	09	II. Ec.D.
	8	10	I. Sh.I.
	8	55	I. Tr.I.
	10	26	I. Sh.E.
	11	11	I. Tr.E.
	11	29	II. Oc.R.
	11	50	IV. Sh.I.
	11	54	III. Oc.R.
	16	13	IV. Sh.E.
	19	16	IV. Tr.I.
	23	34	IV. Tr.E.
5	5	22	I. Ec.D.
	8	27	I. Oc.R.
6	1	45	II. Sh.I.
	2	38	I. Sh.I.
	3	22	II. Tr.I.
	3	25	I. Tr.I.
	4	38	II. Sh.E.
	4	54	I. Sh.E.
	5	41	I. Tr.E.
	6	14	II. Tr.E.
	23	51	I. Ec.D.
7	2	57	I. Oc.R.
	19	22	III. Sh.I.
	20	26	II. Ec.D.
	21	07	I. Sh.I.
	21	55	I. Tr.I.
	22	40	III. Tr.I.
	22	55	III. Sh.E.
	23	23	I. Sh.E.
8	0	11	I. Tr.E.
	0	53	II. Oc.R.
	2	12	III. Tr.E.
	18	19	I. Ec.D.
	21	27	I. Oc.R.
9	15	04	II. Sh.I.
	15	35	I. Sh.I.
	16	25	I. Tr.I.
	16	47	II. Tr.I.
	17	51	I. Sh.E.
	17	56	II. Sh.E.
	18	41	I. Tr.E.
	19	39	II. Tr.E.
10	12	48	I. Ec.D.
	15	58	I. Oc.R.
11	9	14	III. Ec.D.
	9	43	II. Ec.D.
	10	04	I. Sh.I.
	10	55	I. Tr.I.
	12	20	I. Sh.E.
	13	11	I. Tr.E.
	14	16	II. Oc.R.
	16	20	III. Oc.R.
12	7	17	I. Ec.D.
	10	28	I. Oc.R.
	21	17	IV. Ec.D.
13	1	37	IV. Ec.R.
	4	23	II. Sh.I.
	4	32	I. Sh.I.
	5	25	I. Tr.I.
	5	42	IV. Oc.D.
	6	12	II. Tr.I.
	6	48	I. Sh.E.
	7	15	II. Sh.E.
	7	41	I. Tr.E.
	9	04	II. Tr.E.
	9	53	IV. Oc.R.
14	1	45	I. Ec.D.
	4	58	I. Oc.R.
	23	00	II. Ec.D.
	23	01	I. Sh.I.
	23	23	III. Sh.I.
	23	55	I. Tr.I.
15	1	17	I. Sh.E.
	2	11	I. Tr.E.
	2	55	III. Sh.E.
	3	05	III. Tr.I.
	3	39	II. Oc.R.
	6	37	III. Tr.E.
	20	14	I. Ec.D.
	23	28	I. Oc.R.
16	17	29	I. Sh.I.
	17	41	II. Sh.I.
	18	25	I. Tr.I.
16	19	37	II. Tr.I.
	19	45	I. Sh.E.
	20	34	II. Sh.E.
	20	40	I. Tr.E.
	22	28	II. Tr.E.
17	14	42	I. Ec.D.
	17	58	I. Oc.R.
18	11	58	I. Sh.I.
	12	17	II. Ec.D.
	12	54	I. Tr.I.
	13	14	III. Ec.D.
	14	13	I. Sh.E.
	15	10	I. Tr.E.
	16	49	III. Ec.R.
	17	02	II. Oc.R.
	17	11	III. Oc.D.
	20	44	III. Oc.R.
19	9	11	I. Ec.D.
	12	28	I. Oc.R.
20	6	26	I. Sh.I.
	7	00	II. Sh.I.
	7	24	I. Tr.I.
	8	42	I. Sh.E.
	9	02	II. Tr.I.
	9	40	I. Tr.E.
	9	53	II. Sh.E.
	11	52	II. Tr.E.
21	3	40	I. Ec.D.
	6	06	IV. Sh.I.
	6	58	I. Oc.R.
	10	23	IV. Sh.E.
	15	53	IV. Tr.I.
	19	55	IV. Tr.E.
22	0	54	I. Sh.I.
	1	35	II. Ec.D.
	1	54	I. Tr.I.
	3	10	I. Sh.E.
	3	23	III. Sh.I.
	4	10	I. Tr.E.
	6	24	II. Oc.R.
	6	55	III. Sh.E.
	7	29	III. Tr.I.
	10	59	III. Tr.E.
	22	08	I. Ec.D.
23	1	28	I. Oc.R.
	19	23	I. Sh.I.
	20	19	II. Sh.I.
	20	24	I. Tr.I.
	21	39	I. Sh.E.
23	22	26	II. Tr.I.
	22	39	I. Tr.E.
	23	11	II. Sh.E.
24	1	16	II. Tr.E.
	16	37	I. Ec.D.
	19	58	I. Oc.R.
25	13	51	I. Sh.I.
	14	52	II. Ec.D.
	14	54	I. Tr.I.
	16	07	I. Sh.E.
	17	09	I. Tr.E.
	17	15	III. Ec.D.
	19	46	II. Oc.R.
	20	50	III. Ec.R.
	21	35	III. Oc.D.
26	1	06	III. Oc.R.
	11	05	I. Ec.D.
	14	28	I. Oc.R.
27	8	20	I. Sh.I.
	9	23	I. Tr.I.
	9	38	II. Sh.I.
	10	36	I. Sh.E.
	11	39	I. Tr.E.
	11	50	II. Tr.I.
	12	30	II. Sh.E.
	14	40	II. Tr.E.
28	5	34	I. Ec.D.
	8	58	I. Oc.R.
29	2	48	I. Sh.I.
	3	53	I. Tr.I.
	4	09	II. Ec.D.
	5	04	I. Sh.E.
	6	08	I. Tr.E.
	7	23	III. Sh.I.
	9	08	II. Oc.R.
	10	54	III. Sh.E.
	11	50	III. Tr.I.
	15	18	III. Tr.E.
	15	29	IV. Ec.D.
	19	43	IV. Ec.R.
30	0	03	I. Ec.D.
	2	00	IV. Oc.D.
	3	27	I. Oc.R.
	5	54	IV. Oc.R.
	21	17	I. Sh.I.
	22	23	I. Tr.I.
	22	56	II. Sh.I.
	23	32	I. Sh.E.

SATELLITES OF JUPITER, 1986

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

MAY

d	h	m	
1	0	38	I. Tr.E.
	1	13	II. Tr.I.
	1	48	II. Sh.E.
	4	03	II. Tr.E.
	18	31	I. Ec.D.
	21	57	I. Oc.R.
2	15	45	I. Sh.I.
	16	52	I. Tr.I.
	17	26	II. Ec.D.
	18	01	I. Sh.E.
	19	07	I. Tr.E.
	21	16	III. Ec.D.
	22	30	II. Oc.R
3	0	50	III. Ec.R.
	1	56	III. Oc.D.
	5	26	III. Oc.R.
	13	00	I. Ec.D.
	16	27	I. Oc.R.
4	10	14	I. Sh.I.
	11	22	I. Tr.I.
	12	16	II. Sh.I.
	12	29	I. Sh.E.
	13	37	I. Tr.E.
	14	37	II. Tr.I.
	15	07	II. Sh.E.
	17	26	II. Tr.E.
5	7	28	I. Ec.D.
	10	56	I. Oc.R.
6	4	42	I. Sh.I.
	5	51	I. Tr.I.
	6	43	II. Ec.D.
	6	58	I. Sh.E.
	8	06	I. Tr.E.
	11	23	III. Sh.I.
	11	52	II. Oc.R.
	14	54	III. Sh.E.
	16	10	III. Tr.I.
	19	36	III. Tr.E.
7	1	57	I. Ec.D.
	5	26	I. Oc.R.
	23	10	I. Sh.I.
8	0	21	I. Tr.I.
	0	22	IV. Sh.I.
	1	26	I. Sh.E.
	1	34	II. Sh.I.
	2	36	I. Tr.E.
	4	00	II. Tr.I.
	4	25	II. Sh.E.
	4	32	IV. Sh.E.
	6	49	II. Tr.E.
	12	05	IV. Tr.I.
	15	47	IV. Tr.E.

d	h	m	
8	20	26	I. Ec.D.
	23	56	I. Oc.R.
9	17	39	I. Sh.I.
	18	50	I. Tr.I.
	19	54	I. Sh.E.
	20	00	II. Ec.D.
	21	05	I. Tr.E.
10	1	13	II. Oc.R.
	1	17	III. Ec.D.
	4	50	III. Ec.R.
	6	15	III. Oc.D.
	9	44	III. Oc.R.
	14	54	I. Ec.D.
	18	25	I. Oc.R.
11	12	07	I. Sh.I.
	13	20	I. Tr.I.
	14	23	I. Sh.E.
	14	53	II. Sh.I.
	15	34	I. Tr.E.
	17	23	II. Tr.I.
	17	44	II. Sh.E.
	20	11	II. Tr.E.
12	9	23	I. Ec.D.
	12	55	I. Oc.R.
13	6	36	I. Sh.I
	7	49	I. Tr.I.
	8	51	I. Sh.E.
	9	17	II. Ec.D.
	10	04	I. Tr.E.
	14	34	II. Oc.R.
	15	23	III. Sh.I.
	18	53	III. Sh.E.
	20	26	III. Tr.I.
	23	51	III. Tr.E.
14	3	51	I. Ec.D.
	7	24	I. Oc.R.
15	1	04	I. Sh.I.
	2	18	I. Tr.I.
	3	20	I. Sh.E.
	4	11	II. Sh.I.
	4	33	I. Tr.E.
	6	45	II. Tr.I.
	7	02	II. Sh.E.
	9	33	II. Tr.E.
	22	20	I. Ec.D.
16	1	53	I. Oc.R.
	9	41	IV. Ec.D.
	13	49	IV. Ec.R.
	19	33	I. Sh.I.
	20	47	I. Tr.I.
	21	48	I. Sh.E.

d	h	m	
16	21	50	IV. Oc.D.
	22	35	II. Ec.D.
	23	02	I. Tr.E.
17	1	24	IV. Oc.R.
	3	54	II. Oc.R.
	5	17	III. Ec.D.
	8	50	III. Ec.R.
	10	31	III. Oc.D.
	13	58	III. Oc.R.
	16	48	I. Ec.D.
	20	23	I. Oc.R.
18	14	01	I. Sh.I.
	15	17	I. Tr.I.
	16	16	I. Sh.E.
	17	30	II. Sh.I.
	17	31	I. Tr.E.
	20	07	II. Tr.I.
	20	21	II. Sh.E.
	22	55	II. Tr.E.
19	11	17	I. Ec.D.
	14	52	I. Oc.R.
20	8	29	I. Sh.I.
	9	46	I. Tr.I.
	10	45	I. Sh.E.
	11	52	II. Ec.D.
	12	00	I. Tr.E.
	17	14	II. Oc.R.
	19	24	III. Sh.I.
	22	54	III. Sh.E.
21	0	41	III. Tr.I.
	4	04	III. Tr.E.
	5	45	I. Ec.D.
	9	21	I. Oc.R.
22	2	58	I. Sh.I.
	4	15	I. Tr.I.
	5	13	I. Sh.E.
	6	30	I. Tr.E.
	6	48	II. Sh.I.
	9	29	II. Tr.I.
	9	39	II. Sh.E.
	12	15	II. Tr.E.
23	0	14	I. Ec.D.
	3	51	I. Oc.R.
	21	26	I. Sh.I.
	22	44	I. Tr.I.
	23	42	I. Sh.E.
24	0	59	I. Tr.E.
	1	09	II. Ec.D.
	6	34	II. Oc.R.
	9	18	III. Ec.D.
	12	50	III. Ec.R.

d	h	m	
24	14	43	III. Oc.D.
	18	09	III. Oc.R.
	18	37	IV. Sh.I
	18	42	I. Ec.D.
	22	20	I. Oc.R.
	22	41	IV. Sh.E.
25	7	43	IV. Tr.I.
	11	03	IV. Tr.E.
	15	55	I. Sh.I.
	17	13	I. Tr.I.
	18	10	I. Sh.E.
	19	28	I. Tr.E.
	20	07	II. Sh.I.
	22	50	II. Tr.I.
	22	57	II. Sh.E.
26	1	36	II. Tr.E.
	13	11	I. Ec.D.
	16	49	I. Oc.R.
27	10	23	I. Sh.I.
	11	42	I. Tr.I.
	12	38	I. Sh.E.
	13	56	I. Tr.E.
	14	26	II. Ec.D.
	19	53	II. Oc.R.
	23	24	III. Sh.I.
28	2	53	III. Sh.E.
	4	52	III. Tr.I.
	7	40	I. Ec.D.
	8	13	III. Tr.E.
	11	18	I. Oc.R.
29	4	52	I. Sh.I.
	6	11	I. Tr.I.
	7	07	I. Sh.E.
	8	25	I. Tr.E.
	9	26	II. Sh.I.
	12	10	II. Tr.I.
	12	15	II. Sh.E.
	14	56	II. Tr.E.
30	2	08	I. Ec.D.
	5	47	I. Oc.R.
	23	20	I. Sh.I.
31	0	40	I. Tr.I.
	1	35	I. Sh.E.
	2	54	I. Tr.E.
	3	43	II. Ec.D.
	9	12	II. Oc.R.
	13	18	III. Ec.D.
	16	50	III. Ec.R.
	18	53	III. Oc.D.
	20	37	I. Ec.D.
	22	16	III. Oc.R.

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SATELLITES OF JUPITER, 1986

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

JUNE

d	h	m	
1	0	16	I. Oc.R.
	17	48	I. Sh.I.
	19	09	I. Tr.I.
	20	03	I. Sh.E.
	21	23	I. Tr.E.
	22	44	II. Sh.I.
2	1	31	II. Tr.I.
	1	34	II. Sh.E.
	3	54	IV. Ec.D.
	4	16	II. Tr.E.
	7	56	IV. Ec.R.
	15	05	I. Ec.D.
	17	03	IV. Oc.D.
	18	45	I. Oc.R.
	20	15	IV. Oc.R.
3	12	17	I. Sh.I.
	13	37	I. Tr.I.
	14	32	I. Sh.E.
	15	52	I. Tr.E.
	17	01	II. Ec.D.
	22	31	II. Oc.R.
4	3	25	III. Sh.I.
	6	53	III. Sh.E.
	9	00	III. Tr.I.
	9	34	I. Ec.D.
	12	19	III. Tr.E.
	13	13	I. Oc.R.
5	6	45	I. Sh.I.
	8	06	I. Tr.I.
	9	00	I. Sh.E.
	10	20	I. Tr.E.
	12	03	II. Sh.I.
	14	50	II. Tr.I.
	14	52	II. Sh.E.
	17	35	II. Tr.E.
6	4	02	I. Ec.D.
	7	42	I. Oc.R.
7	1	14	I. Sh.I.
	2	35	I. Tr.I.
	3	29	I. Sh.E.
	4	49	I. Tr.E.
	6	18	II. Ec.D.
	11	49	II. Oc.R.
	17	18	III. Ec.D.
	20	49	III. Ec.R.
	22	31	I. Ec.D.
	22	59	III. Oc.D.
8	2	11	I. Oc.R.
	2	20	III. Oc.R.
	19	42	I. Sh.I.
	21	03	I. Tr.I.

d	h	m	
8	21	57	I. Sh.E.
	23	18	I. Tr.E.
9	1	21	II. Sh.I.
	4	10	II. Tr.I.
	4	10	II. Sh.E.
	6	54	II. Tr.E.
	16	59	I. Ec.D.
	20	39	I. Oc.R.
10	12	53	IV. Sh.I.
	14	10	I. Sh.I.
	15	32	I. Tr.I.
	16	25	I. Sh.E.
	16	49	IV. Sh.E.
	17	46	I. Tr.E.
	19	35	II. Ec.D.
11	1	07	II. Oc.R.
	2	39	IV. Tr.I.
	5	34	IV. Tr.E.
	7	25	III. Sh.I.
	10	53	III. Sh.E.
	11	28	I. Ec.D.
	13	03	III. Tr.I.
	15	08	I. Oc.R.
	16	21	III. Tr.E.
12	8	39	I. Sh.I.
	10	00	I. Tr.I.
	10	54	I. Sh.E.
	12	15	I. Tr.E.
	14	39	II. Sh.I.
	17	28	II. Tr.I.
	17	28	II. Sh.E.
	20	12	II. Tr.E.
13	5	56	I. Ec.D.
	9	36	I. Oc.R.
14	3	07	I. Sh.I.
	4	29	I. Tr.I.
	5	22	I. Sh.E.
	6	43	I. Tr.E.
	8	52	II. Ec.D.
	14	25	II. Oc.R.
	21	19	III. Ec.D.
15	0	25	I. Ec.D.
	0	50	III. Ec.R.
	3	01	III. Oc.D.
	4	05	I. Oc.R.
	6	21	III. Oc.R.
	21	36	I. Sh.I.
	22	57	I. Tr.I.
	23	51	I. Sh.E.
16	1	11	I. Tr.E.

d	h	m	
16	3	58	II. Sh.I.
	6	47	II. Tr.I.
	6	47	II. Sh.E.
	9	30	II. Tr.E.
	18	53	I. Ec.D.
	22	33	I. Oc.R.
17	16	04	I. Sh.I.
	17	26	I. Tr.I.
	18	19	I. Sh.E.
	19	40	I. Tr.E.
	22	10	II. Ec.D.
18	3	41	II. Oc.R.
	11	25	III. Sh.I.
	13	22	I. Ec.D.
	14	52	III. Sh.E.
	17	01	I. Oc.R.
	17	02	III. Tr.I.
	20	19	III. Tr.E.
	22	06	IV. Ec.D.
19	2	01	IV. Ec.R.
	10	32	I. Sh.I.
	11	30	IV. Oc.D.
	11	54	I. Tr.I.
	12	47	I. Sh.E.
	14	08	I. Tr.E.
	14	18	IV. Oc.R.
	17	16	II. Sh.I.
	20	04	II. Tr.I.
	20	05	II. Sh.E.
	22	47	II. Tr.E.
20	7	50	I. Ec.D.
	11	30	I. Oc.R.
21	5	01	I. Sh.I.
	6	22	I. Tr.I.
	7	16	I. Sh.E.
	8	36	I. Tr.E.
	11	27	II. Ec.D.
	16	58	II. Oc.R.
22	1	20	III. Ec.D.
	2	19	I. Ec.D.
	4	50	III. Ec.R.
	5	58	I. Oc.R.
	6	59	III. Oc.D.
	10	18	III. Oc.R.
	23	29	I. Sh.I.
23	0	50	I. Tr.I.
	1	44	I. Sh.E.
	3	04	I. Tr.E.
	6	35	II. Sh.I.
	9	21	II. Tr.I.
	9	23	II. Sh.E.

d	h	m	
23	12	04	II. Tr.E.
	20	47	I. Ec.D.
24	0	26	I. Oc.R.
	17	58	I. Sh.I.
	19	18	I. Tr.I.
	20	13	I. Sh.E.
	21	32	I. Tr.E.
25	0	45	II. Ec.D.
	6	14	II. Oc.R.
	15	16	I. Ec.D.
	15	25	III. Sh.I.
	18	51	III. Sh.E.
	18	54	I. Oc.R.
	20	58	III. Tr.I.
26	0	13	III. Tr.E.
	12	26	I. Sh.I.
	13	46	I. Tr.I.
	14	41	I. Sh.E.
	16	00	I. Tr.E.
	19	53	II. Sh.I.
	22	37	II. Tr.I.
	22	41	II. Sh.E.
27	1	20	II. Tr.E.
	7	09	IV. Sh.I.
	9	44	I. Ec.D.
	10	58	IV. Sh.E.
	13	22	I. Oc.R.
	20	45	IV. Tr.I.
	23	13	IV. Tr.E.
28	6	54	I. Sh.I.
	8	14	I. Tr.I.
	9	10	I. Sh.E.
	10	28	I. Tr.E.
	14	02	II. Ec.D.
	19	29	II. Oc.R.
29	4	13	I. Ec.D.
	5	21	III. Ec.D.
	7	50	I. Oc.R.
	8	50	III. Ec.R.
	10	53	III. Oc.D.
	14	10	III. Oc.R.
30	1	23	I. Sh.I.
	2	42	I. Tr.I.
	3	38	I. Sh.E.
	4	56	I. Tr.E.
	9	11	II. Sh.I.
	11	53	II. Tr.I.
	11	59	II. Sh.E.
	14	36	II. Tr.E.
	22	41	I. Ec.D.

SATELLITES OF JUPITER, 1986

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

JULY

d	h	m	
1	2	18	I. Oc.R.
	19	51	I. Sh. I.
	21	10	I. Tr.I.
	22	06	I. Sh.E.
	23	24	I. Tr.E.
2	3	20	II. Ec.D.
	8	44	II. Oc.R.
	17	10	I. Ec.D
	19	25	III. Sh.I.
	20	46	I. Oc.R.
	22	51	III. Sh.E.
3	0	49	III. Tr.I.
	4	02	III. Tr.E.
	14	20	I. Sh.I.
	15	38	I. Tr.I.
	16	35	I. Sh.E.
	17	51	I. Tr.E.
	22	29	II. Sh.I.
4	1	09	II. Tr.I.
	1	17	II. Sh.E.
	3	51	II. Tr.E.
	11	39	I. Ec.D.
	15	13	I. Oc.R.
5	8	48	I. Sh.I.
	10	05	I. Tr.I.
	11	03	I. Sh.E.
	12	19	I. Tr.E.
	16	19	IV. Ec.D.
	16	37	II. Ec.D.
	20	07	IV. Ec.R.
	21	59	II. Oc.R.
6	5	04	IV. Oc.D.
	6	07	I. Ec.D.
	7	28	IV. Oc.R.
	9	21	III. Ec.D.
	9	41	I. Oc.R.
	12	50	III. Ec.R.
	14	41	III. Oc.D.
	17	57	III. Oc.R.
7	3	17	I. Sh.I.
	4	33	I. Tr.I.
	5	32	I. Sh.E.
	6	47	I. Tr.E.
	11	47	II. Sh.I.
	14	23	II. Tr.I.
	14	35	II. Sh.E.
	17	05	II. Tr.E.
8	0	36	I. Ec.D.
	4	08	I. Oc.R.
	21	45	I. Sh.I.
	23	00	I. Tr.I.
9	0	00	I. Sh.E.
9	1	14	I. Tr.E.
	5	55	II. Ec.D.
	11	13	II. Oc.R.
	19	04	I. Ec.D.
	22	36	I. Oc.R.
	23	26	III. Sh.I.
10	2	52	III. Sh.E.
	4	35	III. Tr.I.
	7	48	III. Tr.E.
	16	13	I. Sh.I.
	17	28	I. Tr.I.
	18	29	I. Sh.E.
	19	42	I. Tr.E.
11	1	05	II. Sh.I.
	3	37	II. Tr.I.
	3	53	II. Sh.E.
	6	19	II. Tr.E.
	13	33	I. Ec.D.
	17	03	I. Oc.R.
12	10	42	I. Sh.I.
	11	55	I. Tr.I.
	12	57	I. Sh.E.
	14	09	I. Tr.E.
	19	12	II. Ec.D.
13	0	26	II. Oc.R.
	8	01	I. Ec.D.
	11	31	I. Oc.R.
	13	21	III. Ec.D.
	16	49	III. Ec.R.
	18	25	III. Oc.D.
	21	39	III. Oc.R.
14	1	25	IV. Sh.I.
	5	06	IV. Sh.E.
	5	10	I. Sh.I.
	6	23	I. Tr.I.
	7	26	I. Sh.E.
	8	36	I. Tr.E.
	13	51	IV. Tr.I.
	14	23	II. Sh.I.
	15	53	IV. Tr.E.
	16	51	II. Tr.I.
	17	11	II. Sh.E.
	19	32	II. Tr.E.
15	2	30	I. Ec.D.
	5	58	I. Oc.R.
	23	39	I. Sh.I.
16	0	50	I. Tr.I.
	1	54	I. Sh.E.
	3	04	I. Tr.E.
	8	30	II. Ec.D.
	13	39	II. Oc.R.
	20	58	I. Ec.D.
17	0	25	I. Oc.R.
	3	26	III. Sh.I.
	6	51	III. Sh.E.
	8	17	III. Tr.I.
	11	28	III. Tr.E.
	18	07	I. Sh.I.
	19	17	I. Tr.I.
	20	23	I. Sh.E.
	21	31	I. Tr.E.
18	3	41	II. Sh.I.
	6	03	II. Tr.I.
	6	29	II. Sh.E.
	8	45	II. Tr.E.
	15	27	I. Ec.D.
	18	52	I. Oc.R.
19	12	36	I. Sh.I.
	13	44	I. Tr.I.
	14	51	I. Sh.E.
	15	58	I. Tr.E.
	21	48	II. Ec.D.
20	2	51	II. Oc.R
	9	55	I. Ec.D.
	13	19	I. Oc.R.
	17	22	III. Ec.D.
	20	49	III. Ec.R.
	22	04	III. Oc.D.
21	1	17	III. Oc.R.
	7	04	I. Sh.I.
	8	11	I. Tr.I.
	9	19	I. Sh.E.
	10	25	I. Tr.E.
	16	59	II. Sh.I.
	19	16	II. Tr.I.
	19	47	II. Sh.E.
	21	57	II. Tr.E.
22	4	24	I. Ec.D.
	7	46	I. Oc.R.
	10	33	IV. Ec.D.
	14	13	IV. Ec.R.
	21	39	IV. Oc.D.
	23	41	IV. Oc.R.
23	1	32	I. Sh.I.
	2	38	I. Tr.I.
	3	48	I. Sh.E.
	4	52	I. Tr.E.
	11	06	II. Ec.D.
	16	03	II. Oc.R.
	22	52	I. Ec.D.
24	2	13	I. Oc.R.
	7	27	III. Sh.I.
	10	52	III. Sh.E.
	11	54	III. Tr.I.
	15	05	III. Tr.E.
24	20	01	I. Sh.I.
	21	05	I. Tr.I.
	22	16	I. Sh.E.
	23	19	I. Tr.E.
25	6	17	II. Sh.I.
	8	27	II. Tr.I
	9	04	II. Sh.E.
	11	08	II. Tr.E.
	17	21	I. Ec.D.
	20	40	I. Oc.R.
26	14	29	I. Sh.I.
	15	32	I. Tr.I.
	16	45	I. Sh.E.
	17	46	I. Tr.E.
27	0	24	II. Ec.D.
	5	14	II. Oc.R.
	11	49	I. Ec.D.
	15	07	I. Oc.R.
	21	22	III. Ec.D.
28	0	49	III. Ec.R.
	1	38	III. Oc.D.
	4	50	III. Oc.R.
	8	58	I. Sh.I.
	9	59	I. Tr.I.
	11	14	I. Sh.E.
	12	13	I. Tr.E.
	19	35	II. Sh.I.
	21	38	II. Tr.I.
	22	22	II. Sh.E.
29	0	19	II. Tr.E.
	6	18	I. Ec.D.
	9	34	I. Oc.R.
30	3	26	I. Sh.I.
	4	26	I. Tr.I.
	5	42	I. Sh.E.
	6	40	I. Tr.E.
	13	42	II. Ec.D.
	18	25	II. Oc.R.
	19	42	IV. Sh.I.
	23	14	IV. Sh.E.
31	0	46	I. Ec.D.
	4	00	I. Oc.R.
	5	55	IV. Tr.I.
	7	35	IV. Tr.E.
	11	27	III. Sh.I.
	14	51	III. Sh.E.
	15	26	III. Tr.I.
	18	36	III. Tr.E.
	21	55	I. Sh.I.
	22	52	I. Tr.I.

P

SATELLITES OF JUPITER, 1986

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

AUGUST

d	h	m	
1	0	11	I. Sh.E.
	1	06	I. Tr.E.
	8	53	II. Sh.I.
	10	49	II. Tr.I.
	11	40	II. Sh.E.
	13	30	II. Tr.E.
	19	15	I. Ec.D.
	22	27	I. Oc.R.
2	16	23	I. Sh.I.
	17	19	I. Tr.I.
	18	39	I. Sh.E.
	19	33	I. Tr.E.
3	3	00	II. Ec.D.
	7	36	II. Oc.R.
	13	43	I. Ec.D.
	16	53	I. Oc.R.
4	1	24	III. Ec.D.
	4	50	III. Ec.R.
	5	08	III. Oc.D.
	8	20	III. Oc.R.
	10	52	I. Sh.I.
	11	45	I. Tr.I.
	13	08	I. Sh.E.
	14	00	I. Tr.E.
	22	11	II. Sh.I.
	23	59	II. Tr.I.
5	0	58	II. Sh.E.
	2	40	II. Tr.E.
	8	12	I. Ec.D.
	11	20	I. Oc.R.
6	5	20	I. Sh.I.
	6	12	I. Tr.I.
	7	36	I. Sh.E.
	8	26	I. Tr.E.
	16	18	II. Ec.D.
	20	45	II. Oc.R.
7	2	41	I. Ec.D.
	5	46	I. Oc.R.
	15	27	III. Sh.I.
	18	51	III. Sh.E.
	18	53	III. Tr.I.
	22	03	III. Tr.E.
	23	49	I. Sh.I.
8	0	38	I. Tr.I.
	2	05	I. Sh.E.
	2	53	I. Tr.E.
	4	48	IV. Ec.D.
	8	18	IV. Ec.R.
	11	29	II. Sh.I.
	13	08	II. Tr.I.
8	13	12	IV. Oc.D.
	14	15	II. Sh.E.
	15	00	IV. Oc.R.
	15	49	II. Tr.E.
	21	09	I. Ec.D.
9	0	13	I. Oc.R.
	18	17	I. Sh.I.
	19	05	I. Tr.I.
	20	33	I. Sh.E.
	21	19	I. Tr.E.
10	5	36	II. Ec.D.
	9	55	II. Oc.R.
	15	38	I. Ec.D.
	18	39	I. Oc.R.
11	5	24	III. Ec.D.
	11	45	III. Oc.R.
	12	46	I. Sh.I.
	13	31	I. Tr.I.
	15	02	I. Sh.E.
	15	46	I. Tr.E.
12	0	47	II. Sh.I.
	2	17	II. Tr.I.
	3	33	II. Sh.E.
	4	58	II. Tr.E.
	10	06	I. Ec.D.
	13	05	I. Oc.R.
13	7	14	I. Sh.I.
	7	57	I. Tr.I.
	9	30	I. Sh.E.
	10	12	I. Tr.E.
	18	54	II. Ec.D.
	23	04	II. Oc.R.
14	4	35	I. Ec.D.
	7	32	I. Oc.R.
	19	27	III. Sh.I.
	22	17	III. Tr.I.
	22	51	III. Sh.E.
15	1	27	III. Tr.E.
	1	43	I. Sh.I.
	2	24	I. Tr.I.
	3	59	I. Sh.E.
	4	38	I. Tr.E.
	14	05	II. Sh.I.
	15	25	II. Tr.I.
	16	51	II. Sh.E.
	18	06	II. Tr.E.
	23	03	I. Ec.D.
16	1	58	I. Oc.R.
	14	00	IV. Sh.I.
16	17	23	IV. Sh.E.
	20	12	I. Sh.I.
	20	50	I. Tr.I.
	20	58	IV. Tr.I.
	22	28	I. Sh.E.
	22	29	IV. Tr.E.
	23	04	I. Tr.E.
17	8	12	II. Ec.D.
	12	12	II. Oc.R.
	17	32	I. Ec.D.
	20	24	I. Oc.R.
18	9	26	III. Ec.D.
	14	40	I. Sh.I.
	15	07	III. Oc.R.
	15	16	I. Tr.I.
	16	56	I. Sh.E.
	17	31	I. Tr.E.
19	3	22	II. Sh.I.
	4	33	II. Tr.I.
	6	09	II. Sh.E.
	7	14	II. Tr.E.
	12	01	I. Ec.D.
	14	50	I. Oc.R.
20	9	09	I. Sh.I.
	9	42	I. Tr.I.
	11	25	I. Sh.E.
	11	57	I. Tr.E.
	21	31	II. Ec.D.
21	1	20	II. Oc.R.
	6	29	I. Ec.D.
	9	16	I. Oc.R.
	23	28	III. Sh.I.
22	1	37	III. Tr.I.
	2	52	III. Sh.E.
	3	37	I. Sh.I.
	4	08	I. Tr.I.
	4	47	III. Tr.E.
	5	54	I. Sh.E.
	6	23	I. Tr.E.
	16	40	II. Sh.I.
	17	41	II. Tr.I.
	19	26	II. Sh.E.
	20	22	II. Tr.E.
23	0	58	I. Ec.D.
	3	42	I. Oc.R.
	22	06	I. Sh.I.
	22	34	I. Tr.I.
24	0	22	I. Sh.E.
	0	49	I. Tr.E.
24	10	49	II. Ec.D.
	14	29	II. Oc.R.
	19	26	I. Ec.D.
	22	08	I. Oc.R.
	23	04	IV. Ec.D.
25	2	24	IV. Ec.R.
	3	51	IV. Oc.D.
	5	39	IV. Oc.R.
	13	27	III. Ec.D.
	16	35	I. Sh.I.
	17	00	I. Tr.I.
	18	26	III. Oc.R.
	18	51	I. Sh.E.
	19	15	I. Tr.E.
26	5	58	II. Sh.I.
	6	48	II. Tr.I.
	8	44	II. Sh.E.
	9	30	II. Tr.E.
	13	55	I. Ec.D.
	16	34	I. Oc.R.
27	11	03	I. Sh.I.
	11	26	I. Tr.I.
	13	19	I. Sh.E.
	13	41	I. Tr.E.
28	0	07	II. Ec.D.
	3	36	II. Oc.R.
	8	24	I. Ec.D.
	11	00	I. Oc.R.
29	3	30	III. Sh.I.
	4	56	III. Tr.I.
	5	32	I. Sh.I.
	5	52	I. Tr.I.
	6	53	III. Sh.E.
	7	48	I. Sh.E.
	8	06	III. Tr.E.
	8	07	I. Tr.E.
	19	16	II. Sh.I.
	19	55	II. Tr.I.
	22	02	II. Sh.E.
	22	37	II. Tr.E.
30	2	52	I. Ec.D.
	5	26	I. Oc.R.
31	0	01	I. Sh.I.
	0	18	I. Tr.I.
	2	17	I. Sh.E.
	2	33	I. Tr.E.
	13	26	II. Ec.D.
	16	44	II. Oc.R.
	21	21	I. Ec.D.
	23	52	I. Oc.R.

SATELLITES OF JUPITER, 1986

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

SEPTEMBER

d	h	m	
1	17	27	III. Ec.D.
	18	29	I. Sh.I.
	18	44	I. Tr.I.
	20	46	I. Sh.E.
	20	59	I. Tr.E.
	21	43	III. Oc.R.
2	8	19	IV. Sh.I.
	8	34	II. Sh.I.
	9	02	II. Tr.I.
	11	11	IV. Tr.I.
	11	20	II. Sh.E.
	11	32	IV. Sh.E.
	11	44	II. Tr.E.
	12	53	IV. Tr.E.
	15	49	I. Ec.D.
	18	18	I. Oc.R.
3	12	58	I. Sh.I.
	13	10	I. Tr.I.
	15	14	I. Sh.E.
	15	25	I. Tr.E.
4	2	45	II. Ec.D.
	5	51	II. Oc.R.
	10	18	I. Ec.D.
	12	43	I. Oc.R.
5	7	27	I. Sh.I.
	7	31	III. Sh.I.
	7	36	I. Tr.I.
	8	11	III. Tr.I.
	9	43	I. Sh.E.
	9	51	I. Tr.E.
	10	54	III. Sh.E.
	11	23	III. Tr.E.
	21	52	II. Sh.I.
	22	09	II. Tr.I.
6	0	37	II. Sh.E.
	0	51	II. Tr.E.
	4	47	I. Ec.D.
	7	09	I. Oc.R.
7	1	55	I. Sh.I.
	2	02	I. Tr.I.
	4	12	I. Sh.E.
	4	17	I. Tr.E.
	16	04	II. Ec.D.
	18	59	II. Oc.R.
	23	15	I. Ec.D.
8	1	35	I. Oc.R.
	20	24	I. Sh.I.
	20	28	I. Tr.I.
	21	29	III. Ec.D.
8	22	40	I. Sh.E.
	22	43	I. Tr.E.
9	0	58	III. Oc.R.
	11	10	II. Sh.I.
	11	16	II. Tr.I.
	13	55	II. Sh.E.
	13	57	II. Tr.E.
	17	44	I. Ec.D.
	20	01	I. Oc.R.
10	14	53	I. Sh.I.
	14	54	I. Tr.I.
	17	09	I. Tr.E.
	17	09	I. Sh.E.
	17	21	IV. Ec.D.
	20	31	IV. Ec.R.
11	5	22	II. Ec.D.
	8	09	II. Ec.R.
	12	12	I. Oc.D.
	14	28	I. Ec.R.
12	9	20	I. Tr.I.
	9	22	I. Sh.I.
	11	27	III. Tr.I.
	11	33	III. Sh.I.
	11	35	I. Tr.E.
	11	38	I. Sh.E.
	14	39	III. Tr.E.
	14	55	III. Sh.E.
13	0	22	II. Tr.I.
	0	28	II. Sh.I.
	3	04	II. Tr.E.
	3	13	II. Sh.E.
	6	38	I. Oc.D.
	8	57	I. Ec.R.
14	3	45	I. Tr.I.
	3	50	I. Sh.I.
	6	01	I. Tr.E.
	6	07	I. Sh.E.
	18	30	II. Oc.D.
	21	28	II. Ec.R.
15	1	04	I. Oc.D.
	3	26	I. Ec.R.
	22	11	I. Tr.I.
	22	19	I. Sh.I.
16	0	27	I. Tr.E.
	0	35	I. Sh.E.
	1	01	III. Oc.D.
	4	52	III. Ec.R.
	13	29	II. Tr.I.
16	13	46	II. Sh.I.
	16	11	II. Tr.E.
	16	30	II. Sh.E.
	19	30	I. Oc.D.
	21	54	I. Ec.R.
17	16	37	I. Tr.I.
	16	48	I. Sh.I.
	18	53	I. Tr.E.
	19	04	I. Sh.E.
18	7	37	II. Oc.D.
	10	47	II. Ec.R.
	13	56	I. Oc.D.
	16	23	I. Ec.R.
19	1	05	IV. Tr.I.
	2	40	IV. Sh.I.
	3	07	IV. Tr.E.
	5	41	IV. Sh.E.
	11	03	I. Tr.I.
	11	17	I. Sh.I.
	13	19	I. Tr.E.
	13	33	I. Sh.E.
	14	42	III. Tr.I.
	15	34	III. Sh.I.
	17	55	III. Tr.E.
	18	55	III. Sh.E.
20	2	36	II. Tr.I.
	3	04	II. Sh.I.
	5	18	II. Tr.E.
	5	48	II. Sh.E.
	8	22	I. Oc.D.
	10	52	I. Ec.R.
21	5	29	I. Tr.I.
	5	45	I. Sh.I.
	7	45	I. Tr.E.
	8	02	I. Sh.E.
	20	45	II. Oc.D.
22	0	06	II. Ec.R.
	2	48	I. Oc.D.
	5	20	I. Ec.R.
	23	56	I. Tr.I.
23	0	14	I. Sh.I.
	2	11	I. Tr.E.
	2	30	I. Sh.E.
	4	17	III. Oc.D.
	8	53	III. Ec.R.
	15	43	II. Tr.I.
	16	21	II. Sh.I.
	18	25	II. Tr.E.
	19	06	II. Sh.E.
23	21	13	I. Oc.D.
	23	49	I. Ec.R.
24	18	22	I. Tr.I.
	18	43	I. Sh.I.
	20	37	I. Tr.E.
	20	59	I. Sh.E.
25	9	52	II. Oc.D.
	13	25	II. Ec.R.
	15	39	I. Oc.D.
	18	18	I. Ec.R.
26	12	48	I. Tr.I.
	13	12	I. Sh.I.
	15	03	I. Tr.E.
	15	28	I. Sh.E.
	17	59	III. Tr.I.
	19	36	III. Sh.I.
	21	13	III. Tr.E.
	22	56	III. Sh.E.
27	4	50	II. Tr.I.
	5	39	II. Sh.I.
	7	32	II. Tr.E.
	7	58	IV. Oc.D.
	8	23	II. Sh.E.
	10	06	I. Oc.D.
	10	22	IV. Oc.R.
	11	39	IV. Ec.D.
	12	46	I. Ec.R.
	14	38	IV. Ec.R.
28	7	14	I. Tr.I.
	7	41	I. Sh.I.
	9	29	I. Tr.E.
	9	57	I. Sh.E.
	23	01	II. Oc.D.
29	2	44	II. Ec.R.
	4	32	I. Oc.D.
	7	15	I. Ec.R.
30	1	40	I. Tr.I.
	2	10	I. Sh.I.
	3	56	I. Tr.E.
	4	26	I. Sh.E.
	7	35	III. Oc.D.
	12	54	III. Ec.R.
	17	58	II. Tr.I.
	18	57	II. Sh.I.
	20	40	II. Tr.E.
	21	41	II. Sh.E.
	22	58	I. Oc.D.

SATELLITES OF JUPITER, 1986

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

OCTOBER

d	h	m	
1	1	44	I. Ec.R.
	20	07	I. Tr.I.
	20	38	I. Sh.I.
	22	22	I. Tr.E.
	22	54	I. Sh.E.
2	12	09	II. Oc.D.
	16	03	II. Ec.R.
	17	24	I. Oc.D.
	20	12	I. Ec.R.
3	14	33	I. Tr.I.
	15	07	I. Sh.I.
	16	48	I. Tr.E.
	17	23	I. Sh.E.
	21	18	III. Tr.I.
	23	38	III. Sh.I.
4	0	33	III. Tr.E.
	2	57	III. Sh.E.
	7	05	II. Tr.I.
	8	15	II. Sh.I.
	9	48	II. Tr.E.
	10	59	II. Sh.E.
	11	50	I. Oc.D.
	14	41	I. Ec.R.
5	8	59	I. Tr.I.
	9	36	I. Sh.I.
	11	15	I. Tr.E.
	11	52	I. Sh.E.
	15	13	IV. Tr.I.
	17	39	IV. Tr.E.
	21	03	IV. Sh.I.
	23	50	IV. Sh.E.
6	1	18	II. Oc.D.
	5	22	II. Ec.R.
	6	17	I. Oc.D.
	9	10	I. Ec.R.
7	3	26	I. Tr.I.
	4	05	I. Sh.I.
	5	41	I. Tr.E.
	6	21	I. Sh.E.
	10	55	III. Oc.D.
	16	56	III. Ec.R.
	20	14	II. Tr.I.
	21	33	II. Sh.I.
	22	57	II. Tr.E.
8	0	16	II. Sh.E.
	0	43	I. Oc.D.
	3	39	I. Ec.R.
	21	52	I. Tr.I.
	22	34	I. Sh.I.
9	0	08	I. Tr.E.

d	h	m	
9	0	50	I. Sh.E.
	14	27	II. Oc.D.
	18	41	II. Ec.R.
	19	09	I. Oc.D.
	22	07	I. Ec.R.
10	16	19	I. Tr.I.
	17	03	I. Sh.I.
	18	34	I. Tr.E.
	19	19	I. Sh.E.
11	0	40	III. Tr.I.
	3	40	III. Sh.I.
	3	57	III. Tr.E.
	6	58	III. Sh.E.
	9	23	II. Tr.I.
	10	51	II. Sh.I.
	12	05	II. Tr.E.
	13	34	II. Sh.E.
	13	36	I. Oc.D.
	16	36	I. Ec.R.
12	10	45	I. Tr.I.
	11	32	I. Sh.I.
	13	01	I. Tr.E.
	13	47	I. Sh.E.
13	3	38	II. Oc.D.
	8	00	II. Ec.R.
	8	02	I. Oc.D.
	11	05	I. Ec.R.
	22	29	IV. Oc.D.
14	1	13	IV. Oc.R.
	5	12	I. Tr.I.
	5	58	IV. Ec.D.
	6	01	I. Sh.I.
	7	28	I. Tr.E.
	8	16	I. Sh.E.
	8	45	IV. Ec.R.
	14	19	III. Oc.D.
	17	37	III. Oc.R.
	17	38	III. Ec.D.
	20	56	III. Ec.R.
	22	32	II. Tr.I.
15	0	09	II. Sh.I.
	1	15	II. Tr.E.
	2	29	I. Oc.D.
	2	52	II. Sh.E.
	5	34	I. Ec.R.
	23	39	I. Tr.I.
16	0	30	I. Sh.I.
	1	54	I. Tr.E.
	2	45	I. Sh.E.
	16	48	II. Oc.D.
	20	56	I. Oc.D.

d	h	m	
16	21	19	II. Ec.R.
17	0	02	I. Ec.R.
	18	06	I. Tr.I.
	18	59	I. Sh.I.
	20	21	I. Tr.E.
	21	14	I. Sh.E.
18	4	08	III. Tr.I.
	7	25	III. Tr.E.
	7	43	III. Sh.I.
	11	00	III. Sh.E.
	11	42	II. Tr.I.
	13	27	II. Sh.I.
	14	25	II. Tr.E.
	15	22	I. Oc.D.
	16	09	II. Sh.E.
	18	31	I. Ec.R.
19	12	33	I. Tr.I.
	13	27	I. Sh.I.
	14	48	I. Tr.E.
	15	43	I. Sh.E.
20	5	59	II. Oc.D.
	9	49	I. Oc.D.
	10	39	II. Ec.R.
	13	00	I. Ec.R.
21	7	00	I. Tr.I.
	7	56	I. Sh.I.
	9	15	I. Tr.E.
	10	12	I. Sh.E.
	17	47	III. Oc.D.
	21	06	III. Oc.R.
	21	39	III. Ec.D.
22	0	52	II. Tr.I.
	0	57	III. Ec.R.
	2	45	II. Sh.I.
	3	35	II. Tr.E.
	4	16	I. Oc.D.
	5	27	II. Sh.E.
	6	05	IV. Tr.I.
	7	29	I. Ec.R.
	8	52	IV. Tr.E.
	15	26	IV. Sh.I.
	17	59	IV. Sh.E.
23	1	27	I. Tr.I.
	2	25	I. Sh.I.
	3	42	I. Tr.E.
	4	41	I. Sh.E.
	19	10	II. Oc.D.
	22	43	I. Oc.D.
	23	58	II. Ec.R.
24	1	57	I. Ec.R.

d	h	m	
24	19	54	I. Tr.I.
	20	54	I. Sh.I.
	22	10	I. Tr.E.
	23	10	I. Sh.E.
25	7	39	III. Tr.I.
	10	57	III. Tr.E.
	11	45	III. Sh.I.
	14	03	II. Tr.I.
	15	01	III. Sh.E.
	16	03	II. Sh.I.
	16	46	II. Tr.E.
	17	10	I. Oc.D.
	18	45	II. Sh.E.
	20	26	I. Ec.R.
26	14	21	I. Tr.I.
	15	23	I. Sh.I.
	16	37	I. Tr.E.
	17	38	I. Sh.E.
27	8	23	II. Oc.D.
	11	37	I. Oc.D.
	13	18	II. Ec.R.
	14	55	I. Ec.R.
28	8	49	I. Tr.I.
	9	52	I. Sh.I.
	11	04	I. Tr.E.
	12	07	I. Sh.E.
	21	20	III. Oc.D.
29	0	40	III. Oc.R.
	1	41	III. Ec.D.
	3	14	II. Tr.I.
	4	58	III. Ec.R.
	5	21	II. Sh.I.
	5	57	II. Tr.E.
	6	04	I. Oc.D.
	8	02	II. Sh.E.
	9	24	I. Ec.R.
30	3	16	I. Tr.I.
	4	21	I. Sh.I.
	5	31	I. Tr.E.
	6	36	I. Sh.E.
	13	53	IV. Oc.D.
	16	53	IV. Oc.R.
	21	35	II. Oc.D.
31	0	20	IV. Ec.D.
	0	32	I. Oc.D.
	2	36	II. Ec.R.
	2	52	IV. Ec.R.
	3	52	I. Ec.R.
	21	44	I. Tr.I.
	22	50	I. Sh.I.
	23	59	I. Tr.E.

SATELLITES OF JUPITER, 1986

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

NOVEMBER

d	h	m	
1	1	05	I. Sh.E.
	11	15	III. Tr.I.
	14	34	III. Tr.E.
	15	48	III. Sh.I.
	16	26	II. Tr.I.
	18	39	II. Sh.I.
	18	59	I. Oc.D.
	19	03	III. Sh.E.
	19	10	II. Tr.E.
	21	20	II. Sh.E.
	22	21	I. Ec.R.
2	16	11	I. Tr.I
	17	19	I. Sh.I.
	18	26	I. Tr.E.
	19	34	I. Sh.E.
3	10	49	II. Oc.D.
	13	27	I. Oc.D.
	15	56	II. Ec.R.
	16	50	I. Ec.R.
4	10	39	I. Tr.I.
	11	48	I. Sh.I.
	12	54	I. Tr.E.
	14	03	I. Sh.E.
5	0	57	III. Oc.D.
	4	19	III. Oc.R.
	5	39	II. Tr.I.
	5	43	III. Ec.D.
	7	54	I. Oc.D.
	7	57	II. Sh.I.
	8	22	II. Tr.E.
	9	00	III. Ec.R.
	10	38	II. Sh.E.
	11	19	I. Ec.R.
6	5	07	I. Tr.I.
	6	17	I. Sh.I.
	7	22	I. Tr.E.
	8	32	I. Sh.E.
7	0	03	II. Oc.D.
	2	22	I. Oc.D.
	5	15	II. Ec.R.
	5	48	I. Ec.R.
	21	58	IV. Tr.I.
	23	34	I. Tr.I.
8	0	46	I. Sh.I.
	0	59	IV. Tr.E.
	1	50	I. Tr.E.
	3	01	I. Sh.E.
	9	52	IV. Sh.I.
	12	08	IV. Sh.E.
	14	56	III. Tr.I.
	18	15	III. Tr.E.
8	18	52	II. Tr.I.
	19	50	III. Sh.I.
	20	49	I. Oc.D.
	21	15	II. Sh.I.
	21	35	II. Tr.E.
	23	04	III. Sh.E.
	23	56	II. Sh.E.
9	0	16	I. Ec.R.
	18	02	I. Tr.I.
	19	15	I. Sh.I.
	20	17	I. Tr.E.
	21	30	I. Sh.E.
10	13	18	II. Oc.D.
	15	17	I. Oc.D.
	18	35	II. Ec.R.
	18	45	I. Ec.R.
11	12	30	I. Tr.I.
	13	44	I. Sh.I.
	14	45	I. Tr.E.
	15	59	I. Sh.E.
12	4	41	III. Oc.D.
	8	03	III. Oc.R.
	8	06	II. Tr.I.
	9	45	I. Oc.D.
	9	46	III. Ec.D.
	10	33	II. Sh.I.
	10	49	II. Tr.E.
	13	02	III. Ec.R.
	13	13	II. Sh.E.
	13	14	I. Ec.R.
13	6	58	I. Tr.I.
	8	13	I. Sh.I.
	9	13	I. Tr.E.
	10	28	I. Sh.E.
14	2	33	II. Oc.D.
	4	13	I. Oc.D.
	7	43	I. Ec.R.
	7	54	II. Ec.R.
15	1	26	I. Tr.I.
	2	42	I. Sh.I.
	3	42	I. Tr.E.
	4	57	I. Sh.E.
	18	42	III. Tr.I.
	21	20	II. Tr.I.
	22	02	III. Tr.E.
	22	41	I. Oc.D.
	23	51	II. Sh.I.
	23	53	III. Sh.I.
16	0	04	II. Tr.E.
	2	12	I. Ec.R.
16	2	31	II. Sh.E.
	3	05	III. Sh.E.
	6	20	IV. Oc.D.
	9	32	IV. Oc.R.
	18	42	IV. Ec.D.
	19	55	I. Tr.I.
	20	58	IV. Ec.R.
	21	11	I. Sh.I.
	22	10	I. Tr.E.
	23	26	I. Sh.E.
17	15	50	II. Oc.D.
	17	09	I. Oc.D.
	20	41	I. Ec.R.
	21	14	II. Ec.R.
18	14	23	I. Tr.I.
	15	40	I. Sh.I.
	16	38	I. Tr.E.
	17	55	I. Sh.E.
19	8	29	III. Oc.D.
	10	36	II. Tr.I.
	11	37	I. Oc.D.
	11	52	III. Oc.R.
	13	09	II. Sh.I.
	13	19	II. Tr.E.
	13	49	III. Ec.D.
	15	09	I. Ec.R.
	15	49	II. Sh.E.
	17	03	III. Ec.R.
20	8	51	I. Tr.I.
	10	09	I. Sh.I.
	11	06	I. Tr.E.
	12	24	I. Sh.E.
21	5	06	II. Oc.D.
	6	05	I. Oc.D.
	9	38	I. Ec.R.
	10	33	II. Ec.R.
22	3	20	I. Tr.I.
	4	38	I. Sh.I.
	5	35	I. Tr.E.
	6	53	I. Sh.E.
	22	33	III. Tr.I.
	23	51	II. Tr.I.
23	0	33	I. Oc.D.
	1	53	III. Tr.E.
	2	27	II. Sh.I.
	2	35	II. Tr.E.
	3	55	III. Sh.I.
	4	07	I. Ec.R.
	5	07	II. Sh.E.
	7	07	III. Sh.E.
	21	48	I. Tr.I.
23	23	07	I. Sh.I.
24	0	03	I. Tr.E.
	1	22	I. Sh.E.
	14	59	IV. Tr.I.
	18	09	IV. Tr.E.
	18	24	II. Oc.D.
	19	02	I. Oc.D.
	22	36	I. Ec.R.
	23	53	II. Ec.R.
25	4	19	IV. Sh.I.
	6	16	IV. Sh.E.
	16	17	I. Tr.I.
	17	36	I. Sh.I.
	18	32	I. Tr.E.
	19	51	I. Sh.E.
26	12	23	III. Oc.D.
	13	07	II. Tr.I.
	13	30	I. Oc.D.
	15	46	II. Sh.I.
	15	46	III. Oc.R.
	15	51	II. Tr.E.
	17	05	I. Ec.R.
	17	51	III. Ec.D.
	18	25	II. Sh.E.
	21	05	III. Ec.R.
27	10	45	I. Tr.I.
	12	05	I. Sh.I.
	13	01	I. Tr.E.
	14	20	I. Sh.E.
28	7	41	II. Oc.D.
	7	59	I. Oc.D.
	11	34	I. Ec.R.
	13	12	II. Ec.R.
29	5	14	I. Tr.I.
	6	34	I. Sh.I.
	7	29	I. Tr.E.
	8	49	I. Sh.E.
30	2	24	II. Tr.I.
	2	27	I. Oc.D.
	2	28	III. Tr.I.
	5	04	II. Sh.I.
	5	08	II. Tr.E.
	5	49	III. Tr.E.
	6	02	I. Ec.R.
	7	43	II. Sh.E.
	7	58	III. Sh.I.
	11	09	III. Sh.E.
	23	43	I. Tr.I.

SATELLITES OF JUPITER, 1986

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

DECEMBER

d	h	m	
1	1	03	I. Sh.I.
	1	58	I. Tr.E.
	3	18	I. Sh.E.
	20	56	I. Oc.D.
	21	00	II. Oc.D.
2	0	31	I. Ec.R.
	2	32	II. Ec.R
	18	12	I. Tr.I.
	19	32	I. Sh.I.
	20	27	I. Tr.E.
	21	47	I. Sh.E.
	23	52	IV. Oc.D.
3	3	09	IV. Oc.R.
	13	05	IV. Ec.D.
	15	04	IV. Ec.R.
	15	25	I. Oc.D.
	15	42	II. Tr.I.
	16	20	III. Oc.D.
	18	22	II. Sh.I.
	18	25	II. Tr.E.
	19	00	I. Ec.R.
	19	44	III. Oc.R.
	21	01	II. Sh.E.
	21	53	III. Ec.D.
4	1	06	III. Ec.R.
	12	41	I. Tr.I.
	14	01	I. Sh.I.
	14	56	I. Tr.E.
	16	16	I. Sh.E.
5	9	53	I. Oc.D.
	10	19	II. Oc.D.
	13	29	I. Ec.R
	15	51	II. Ec.R.
6	7	10	I. Tr.I.
	8	30	I. Sh.I.
	9	25	I. Tr.E.
	10	45	I. Sh.E.
7	4	22	I. Oc.D.
	4	59	II. Tr.I.
	6	30	III. Tr.I.
	7	40	II. Sh.I.
	7	43	II. Tr.E.
	7	58	I. Ec.R.
	9	51	III. Tr.E.
	10	19	II. Sh.E.
	12	02	III. Sh.I.
	15	11	III. Sh.E.
8	1	39	I. Tr.I.
	2	59	I. Sh.I.
	3	54	I. Tr.E.
	5	14	I. Sh.E.
	22	51	I. Oc.D.
	23	39	II. Oc.D.
9	2	27	I. Ec.R.

d	h	m	
9	5	10	II. Ec.R.
	20	08	I. Tr.I.
	21	29	I. Sh.I.
	22	23	I. Tr.E.
	23	43	I. Sh.E
10	17	20	I. Oc.D.
	18	18	II. Tr.I.
	20	22	III. Oc.D.
	20	55	I. Ec.R.
	20	58	II. Sh.I.
	21	01	II. Tr.E.
	23	37	II. Sh.E.
	23	46	III. Oc.R.
11	1	55	III. Ec.D.
	5	07	III. Ec.R.
	9	04	IV. Tr.I
	12	17	IV. Tr.E.
	14	37	I. Tr.I.
	15	58	I. Sh.I.
	16	52	I. Tr.E.
	18	12	I. Sh.E.
	22	48	IV. Sh.I.
12	0	22	IV. Sh.E.
	11	49	I. Oc.D.
	12	59	II. Oc.D.
	15	24	I. Ec.R.
	18	29	II. Ec.R.
13	9	06	I. Tr.I.
	10	27	I. Sh.I.
	11	21	I. Tr.E
	12	41	I. Sh.E.
14	6	18	I. Oc.D.
	7	37	II. Tr.I.
	9	53	I. Ec.R.
	10	16	II. Sh.I
	10	20	II. Tr.E.
	10	35	III. Tr.I.
	12	55	II. Sh.E.
	13	56	III. Tr.E.
	16	04	III. Sh.I.
	19	13	III. Sh.E.
15	3	35	I. Tr.I.
	4	56	I. Sh.I.
	5	51	I. Tr.E.
	7	10	I. Sh.E.
16	0	47	I. Oc.D.
	2	20	II. Oc.D.
	4	22	I. Ec.R.
	7	49	II. Ec.R.
	22	05	I. Tr.I.
	23	25	I. Sh.I.
17	0	20	I. Tr.E.
	1	39	I. Sh.E.
	19	17	I. Oc.D.

d	h	m	
17	20	56	II. Tr.I.
	22	51	I. Ec.R.
	23	34	II. Sh.I.
	23	40	II. Tr.E.
18	0	29	III. Oc.D.
	2	13	II. Sh.E.
	3	53	III. Oc.R
	5	58	III. Ec.D.
	9	09	III. Ec.R.
	16	34	I. Tr.I.
	17	54	I. Sh.I.
	18	49	I. Tr.E.
	20	08	I. Sh.E.
19	13	46	I. Oc.D.
	15	41	II. Oc.D.
	17	20	I. Ec.R.
	18	23	IV. Oc.D.
	21	08	II. Ec.R.
	21	40	IV. Oc.R.
20	7	31	IV. Ec.D.
	9	08	IV. Ec.R.
	11	04	I. Tr.I.
	12	23	I. Sh.I.
	13	19	I. Tr.E.
	14	37	I. Sh.E.
21	8	15	I. Oc.D.
	10	16	II. Tr.I.
	11	48	I. Ec.R.
	12	52	II. Sh.I.
	12	59	II. Tr.E.
	14	44	III. Tr.I.
	15	31	II. Sh.E.
	18	05	III. Tr.E.
	20	07	III. Sh.I.
	23	16	III. Sh.E.
22	5	33	I. Tr.I.
	6	52	I. Sh.I.
	7	48	I. Tr.E.
	9	06	I. Sh.E.
23	2	45	I. Oc.D.
	5	03	II. Oc.D.
	6	17	I. Ec.R.
	10	28	II. Ec.R.
24	0	03	I. Tr.I.
	1	21	I. Sh.I.
	2	18	I. Tr.E.
	3	35	I. Sh.E.
	21	14	I. Oc.D.
	23	36	II. Tr.I.
25	0	46	I. Ec.R.
	2	11	II. Sh.I.
	2	20	II. Tr.E.
	4	40	III. Oc.D.
	4	49	II. Sh.E.

d	h	m	
25	8	03	III. Oc.R.
	10	00	III. Ec.D.
	13	10	III. Ec.R.
	18	32	I. Tr.I.
	19	50	I. Sh.I.
	20	48	I. Tr.E.
	22	04	I. Sh.E.
26	15	44	I. Oc.D.
	18	25	II. Oc.D.
	19	15	I. Ec.R.
	23	47	II. Ec.R.
27	13	02	I. Tr.I.
	14	19	I. Sh.I.
	15	17	I. Tr.E.
	16	33	I. Sh.E.
28	4	06	IV. Tr.I.
	7	15	IV. Tr.E.
	10	13	I. Oc.D.
	12	57	II. Tr.I.
	13	44	I. Ec.R.
	15	29	II. Sh.I.
	15	40	II. Tr.E.
	17	21	IV. Sh.I.
	18	07	II. Sh.E.
	18	25	IV. Sh.E.
	18	57	III. Tr.I.
	22	18	III. Tr.E.
29	0	10	III. Sh.I.
	3	17	III. Sh.E.
	7	32	I. Tr.I.
	8	48	I. Sh.I.
	9	47	I. Tr.E.
	11	02	I. Sh.E.
30	4	43	I. Oc.D.
	7	48	II. Oc.D.
	8	13	I. Ec.R.
	13	06	II. Ec.R.
31	2	02	I. Tr.I.
	3	17	I. Sh.I.
	4	17	I. Tr.E.
	5	31	I. Sh.E.
	23	12	I. Oc.D.
32	2	18	II. Tr.I.
	2	42	I. Ec.R.
	4	47	II. Sh.I.
	5	02	II. Tr.E.
	7	25	II. Sh.E.
	8	55	III. Oc.D.
	12	18	III. Oc.R.
	14	03	III. Ec.D.
	17	13	III. Ec.R.
	20	31	I. Tr.I.
	21	46	I. Sh.I.
	22	47	I. Tr.E.

CONFIGURATIONS OF SATURN'S BRIGHTEST SATELLITES

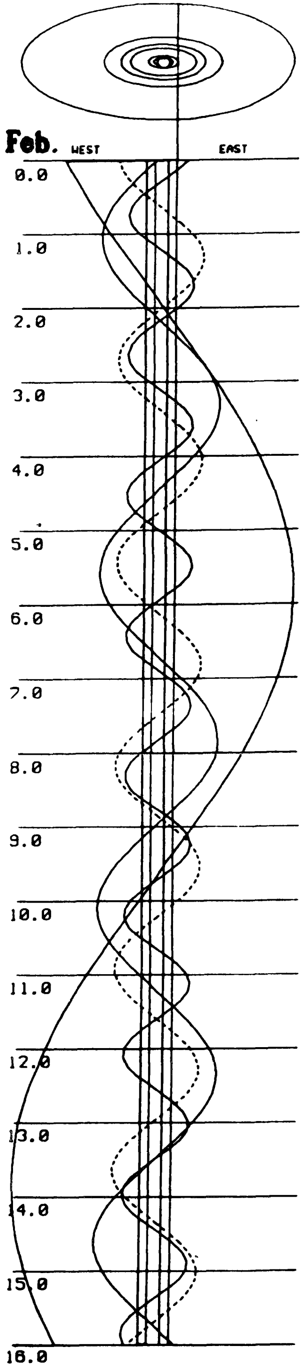
By Larry D. Bogan

The curves on the following pages enable one to determine the appearance of Saturn and its brightest satellites during the period January 31 to November 1, 1986. The names and magnitudes of these satellites, in order outward from Saturn, are: *Tethys*, 10.3, *Dione*, 10.4, *Rhea*, 9.7, and *Titan*, 8.4.

The diagrams show the elongations of the satellites from Saturn as they change with time. The horizontal lines mark 0^h UT on the days indicated. The narrower, central, vertical band represents the disk of Saturn, while the wider vertical band represents the outer edge of the "A" ring of Saturn. All four orbits have essentially zero inclination and thus lie nearly in the plane of Saturn's rings. During 1986 there are no eclipses or occultations due to the tilt of Saturn's axis; hence the curves are not shown occulted by the bands representing Saturn's disk and rings. The curve of Dione, the second out from Saturn, is dashed so that it is easy to distinguish from those of Tethys and Rhea. Titan's orbit is not as circular as the others and is the only satellite of the four that has been treated as having an elliptical orbit.

At the beginning of each month is a scale drawing of Saturn with the orbits of the four satellites tilted as seen through an inverting telescope (in the Northern Hemisphere). South is up. The axis of Saturn is now tipped toward Earth so that we see the northern side of the rings and satellite orbits. The directions of motion of the satellites are counterclockwise.

Constructing the configuration from the diagrams is very similar to that for Jupiter's satellites. The main difference is that the orbits of the satellites are not seen edge-on, and the satellites move above and below Saturn. By projecting the elongations for the date and time of interest onto the drawing at the beginning of each month, and locating the satellites on the proper side (north or south) of the orbits, the complete configuration can be developed. A millimetre scale, or better, a pair of dividers, enables one to do this both quickly and accurately. For this purpose, the vertical line representing the east edge of Saturn's "A" ring has been extended upward across the scale drawing. Use this as a fiducial line to transfer the various satellite positions at a given moment in time to the scale drawing (It is convenient first to draw a horizontal line across the lower diagram at the time (UT!) of interest). Since the satellites revolve around Saturn counterclockwise, a satellite moving toward the *right* (east) will be *below* (north of) Saturn in the diagram, and a satellite moving toward the *left* (west) will be *above* (south of) Saturn in the diagram. Hence the mnemonic statement: *right-below*, *left-above*.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WEST
EAST
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1.0
2.0
3.0
4.0
5.0
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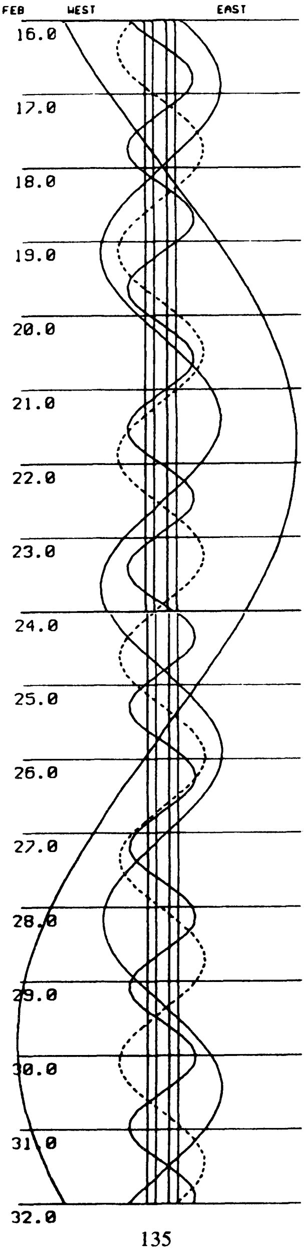
13.0
14.0
15.0
16.0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WEST
EAST
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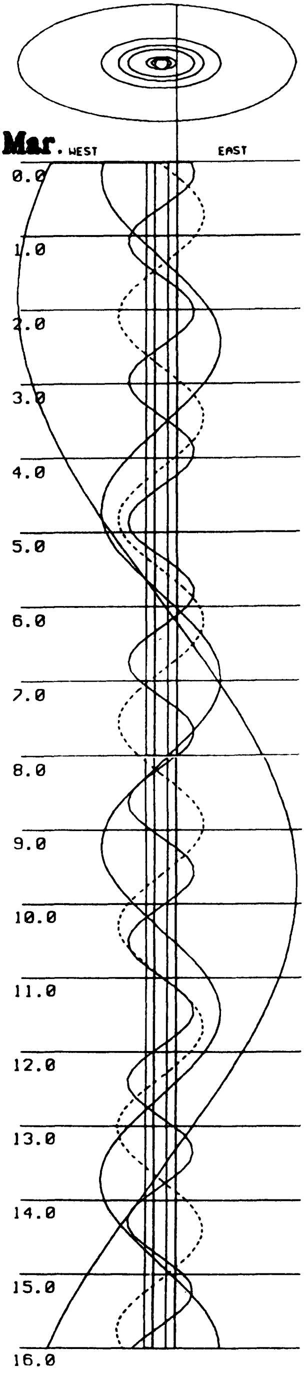
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WEST
EAST
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3.0
4.0
5.0
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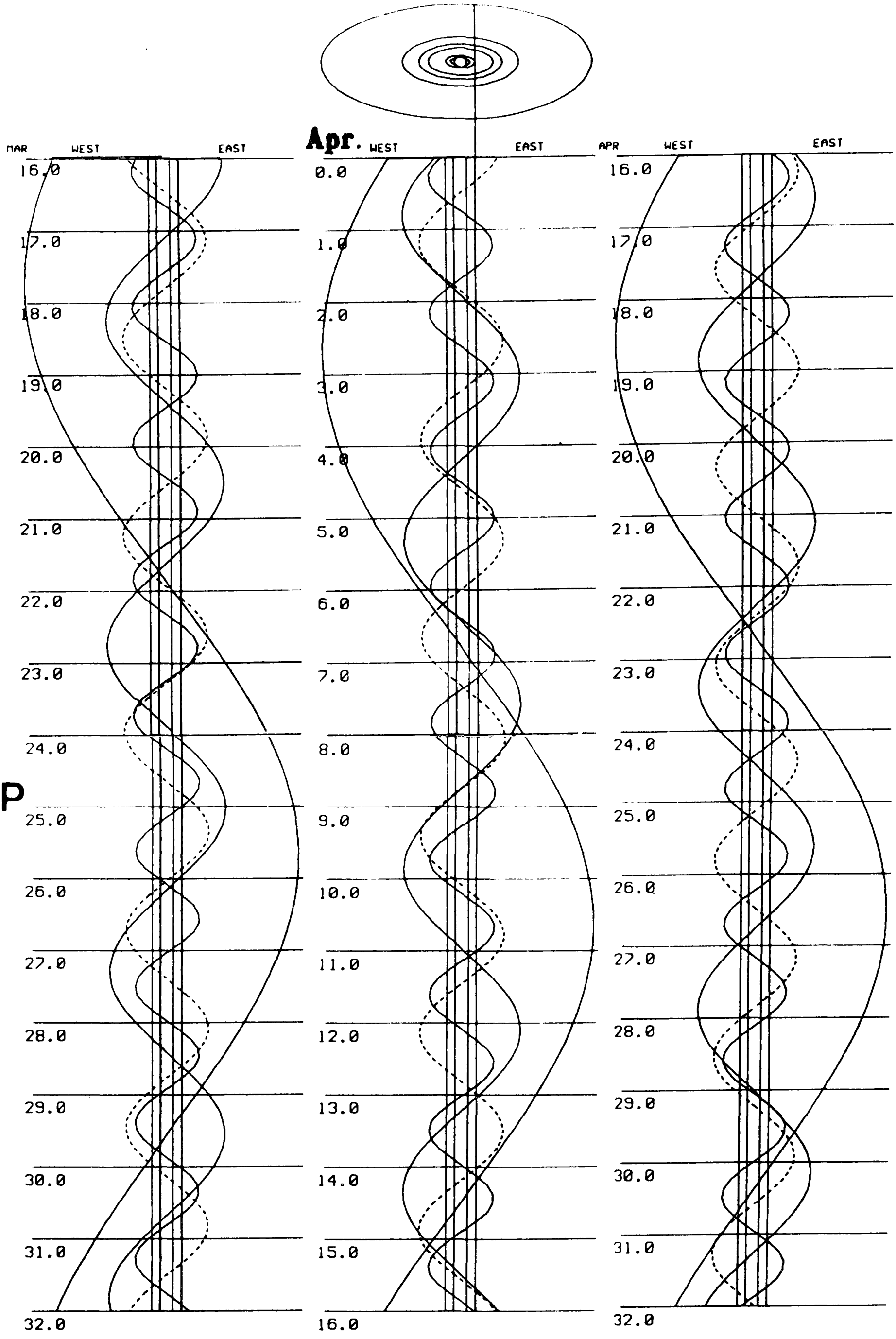
15.0
16.0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WEST
EAST
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20.0
21.0
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25.0
26.0
27.0
28.0
29.0
30.0
31.0
32.0
Apr.
WEST
EAST
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7.0
8.0
9.0
10.0
11.0
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14.0
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16.0
APR
WEST
EAST
16.0
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18.0
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20.0
21.0
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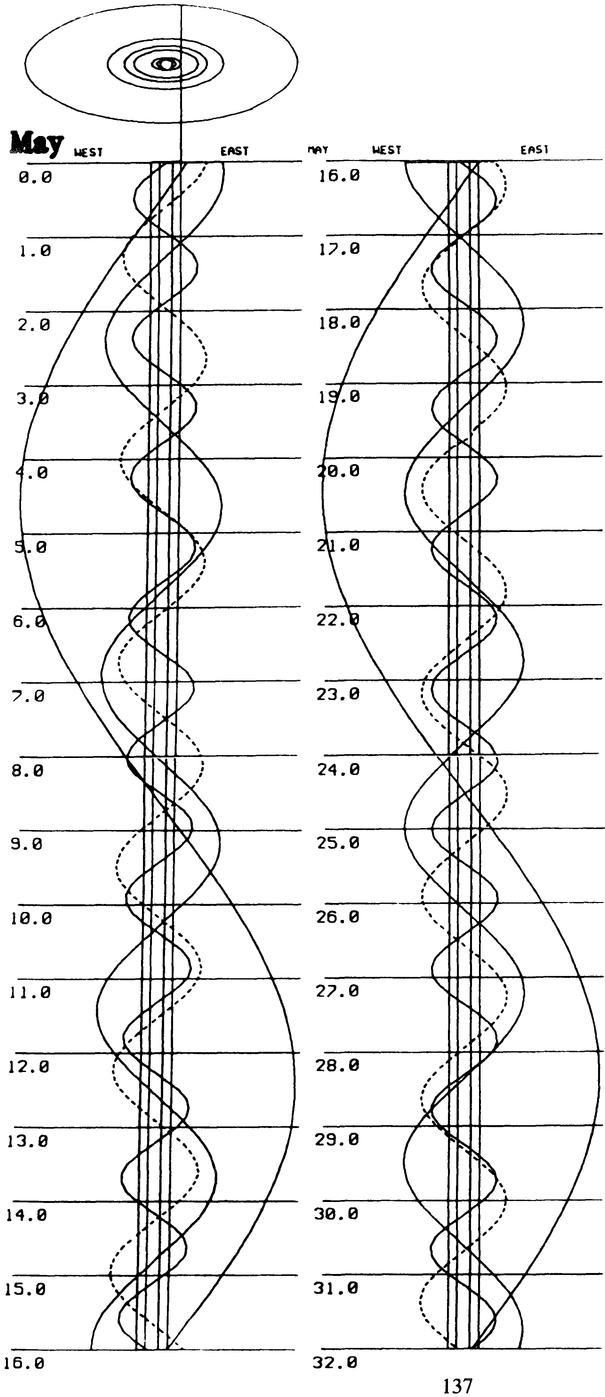
P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EAST
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5.0
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10.0
11.0
12.0
13.0
14.0
15.0
16.0
MAY
WEST
EAST
16.0
17.0
18.0
19.0
20.0
21.0
22.0
23.0
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25.0
26.0
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29.0
30.0
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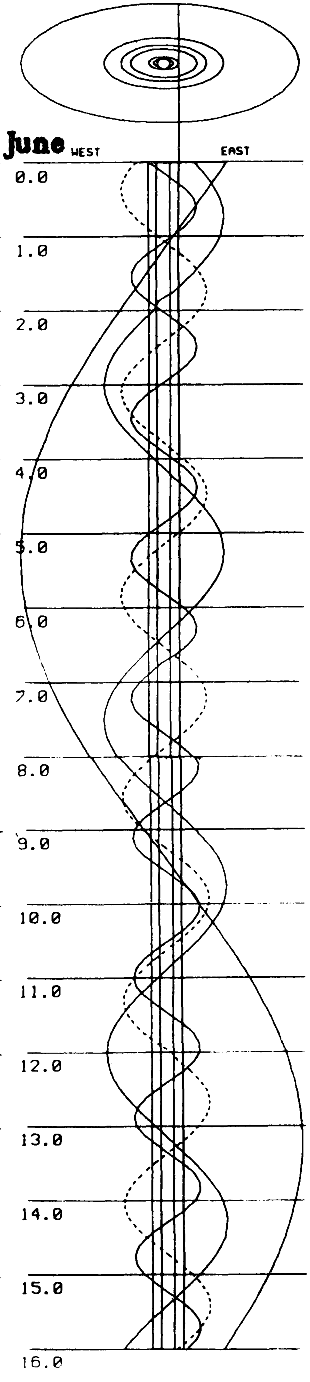
32.0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WEST
EAST
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3.0
4.0
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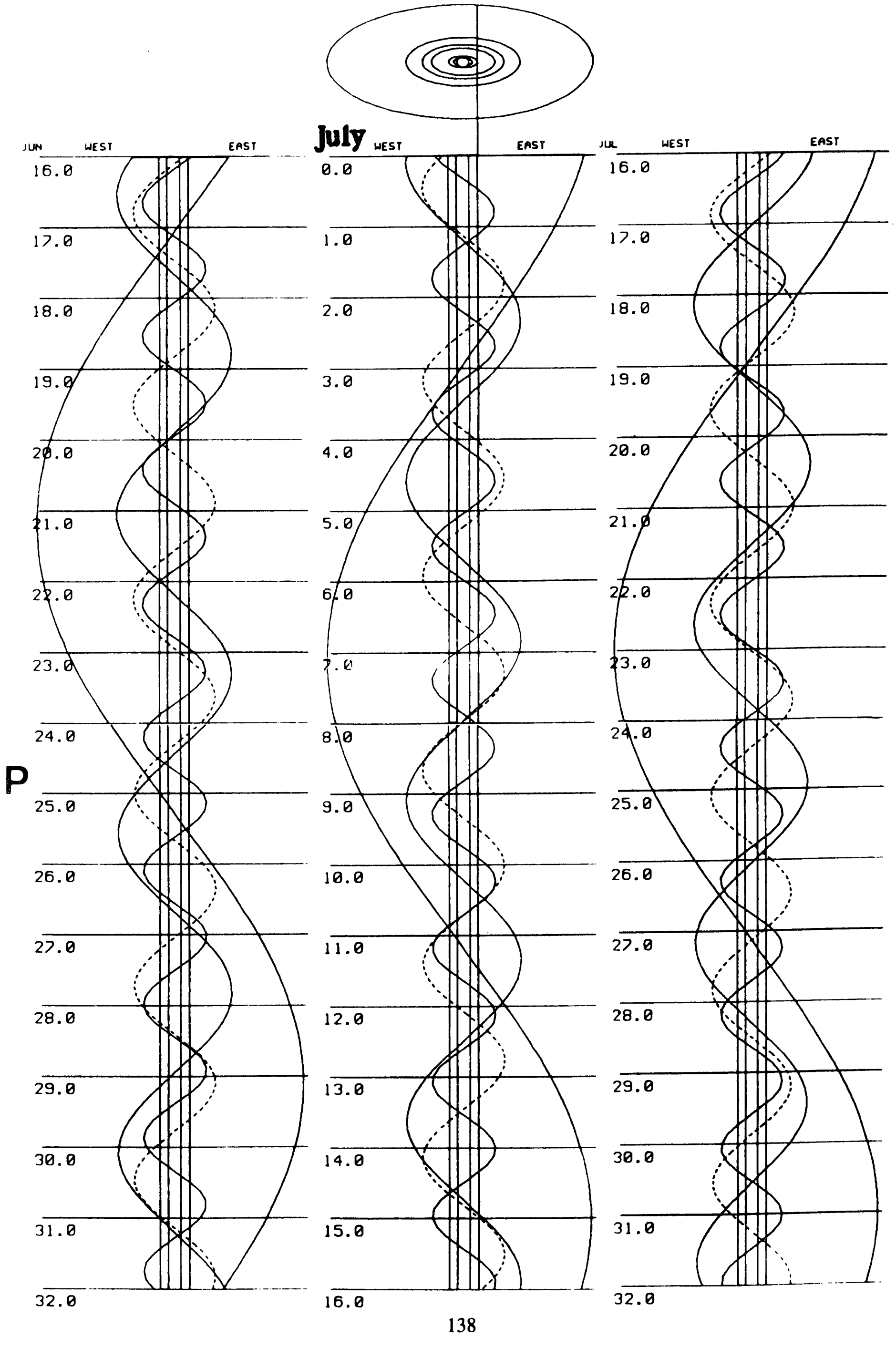
July
P
JUN
WEST
EAST
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17.0
18.0
19.0
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21.0
22.0
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27.0
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WEST
EAST
0.0
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JUL
WEST
EAST
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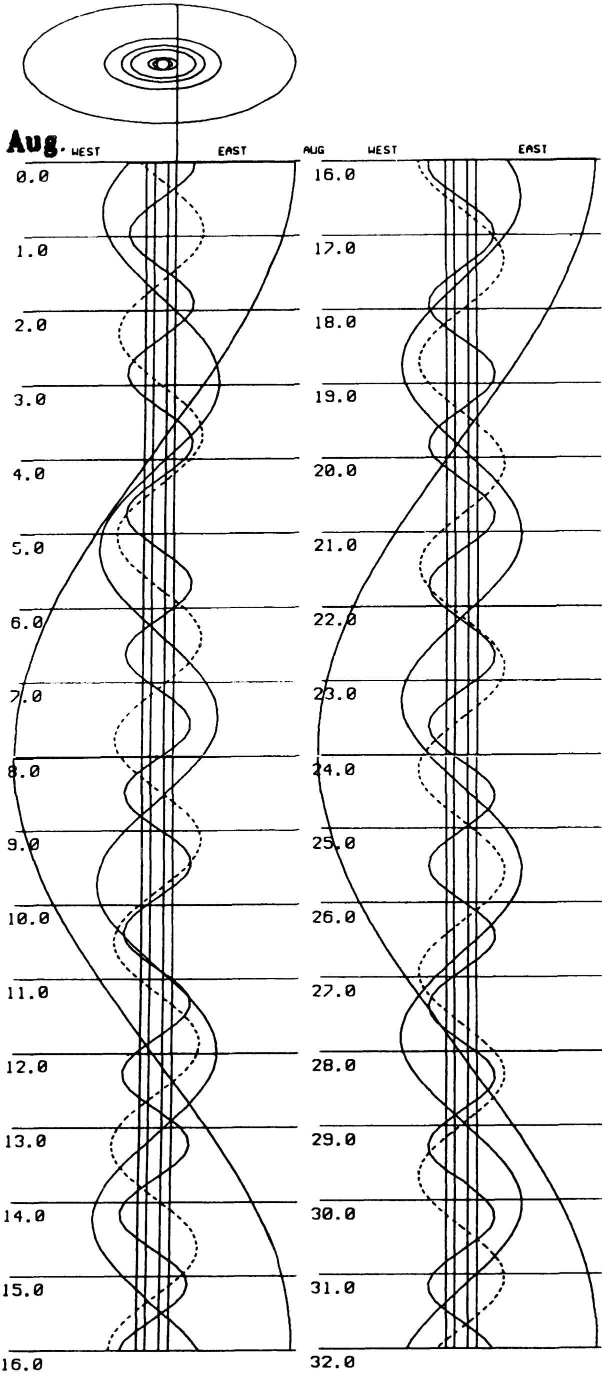
Aug.
WEST
EAST
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4.0
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15.0
16.0
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WEST
EAST
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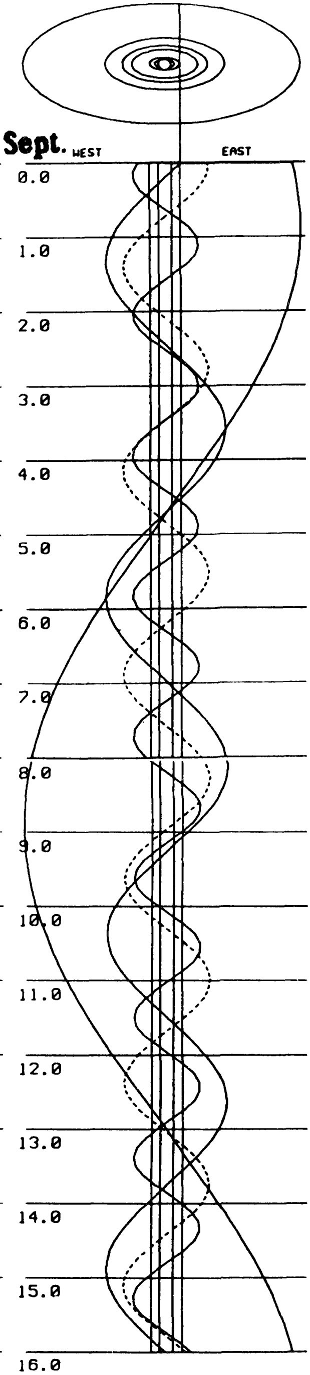
Sept.
WEST
EAST
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
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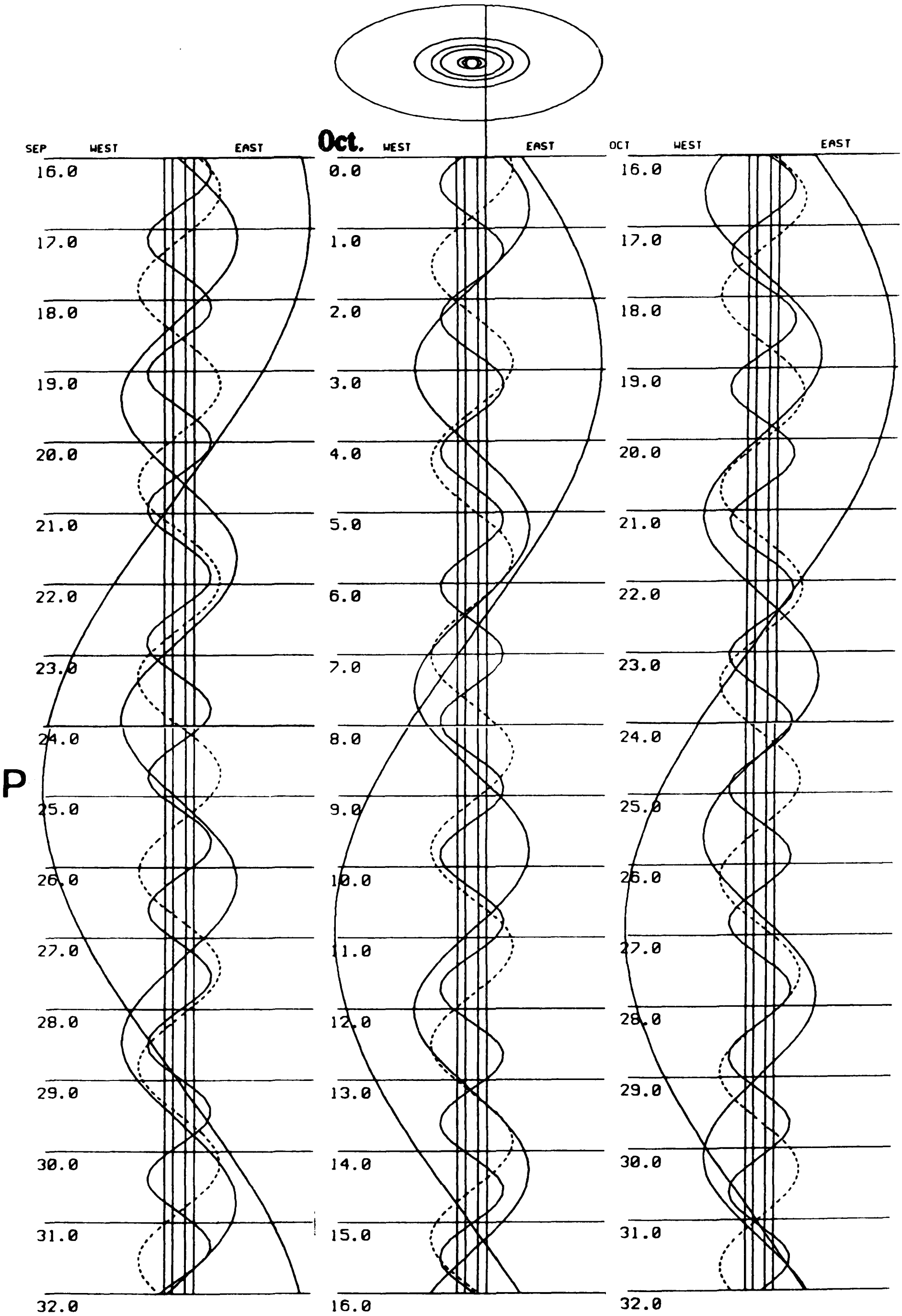
13.0
14.0
15.0
16.0



SEP
WEST
EAST
16.0
17.0
18.0
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20.0
21.0
22.0
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26.0
27.0
28.0
29.0
30.0
31.0
32.0
Oct.
WEST
EAST
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3.0
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7.0
8.0
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OCT
WEST
EAST
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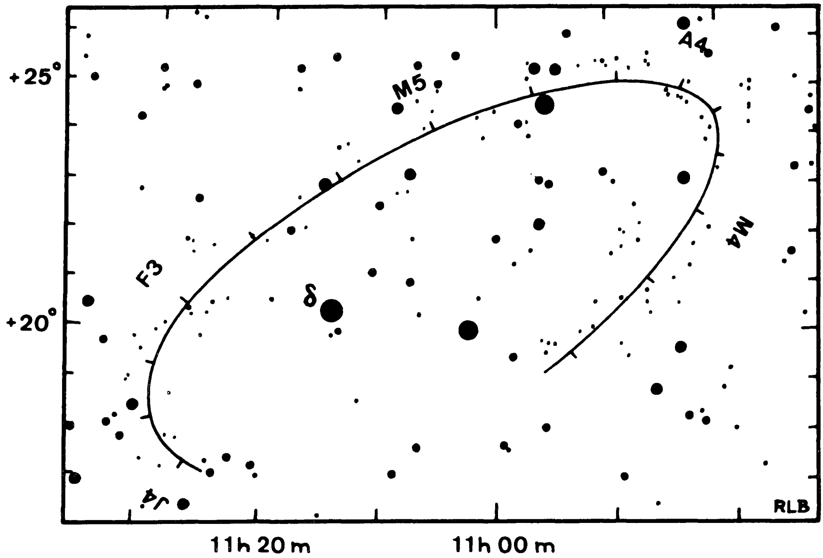
P

EPHEMERIDES FOR THE BRIGHTEST ASTEROIDS 1986

PROVIDED BY BRIAN G. MARSDEN

The following are the ephemerides for the brightest asteroids in 1986: those asteroids which will be brighter than photographic magnitude 11.0 and more than 90° from the Sun. The tables give the number and name of the asteroid, the date at 0^h E.T. (which differs only slightly from U.T.), the right ascension and declination for the epoch 1950 (for convenience in plotting on commonly-used star charts) and the *photographic* magnitude (which is normally about $0^m.7$ *fainter* than the visual magnitude). These data were derived from current osculating elements, and were generously calculated and provided by Dr. Brian G. Marsden of the Smithsonian Astrophysical Observatory.

A map is provided for Ceres, the second-brightest asteroid during 1986. Readers can make maps for other asteroids by using the ephemerides on the next two pages and an appropriate star atlas (Remember to allow for precession if your atlas does not use the same epoch as the tables: 1950.0. See page 17.)



The path of Ceres in Leo during the first 5 months of 1986. The star, δ Leo, is the northernmost bright star in the hindquarters of the lion (see the "MARCH" map of the night sky at the end of this handbook). Ceres' position is marked at 10-day intervals, beginning with January 4 (J4). The chart magnitude limit is 8.0, except in the vicinity of the track where stars to magnitude 9.5 have been shown. Ceres is at magnitude 8.3 as the year opens, and brightens to 7.6 when at opposition on March 5, 1.59 A from Earth. By late May it has faded to 9th magnitude. The coordinates are for 2000.0. In 1986 Ceres is north of Earth's equatorial plane (its orbit is inclined at 11° to the ecliptic), which is the reason for the broad, northward retrograde loop as we draw near to it this winter. It is curious that Ceres is minor planet number 1 (it was the 1st to be discovered – on the 1st day of the 1st month of the 1st year of the last century), is 1st in order of size among the minor planets, and has a diameter of 1 Mm.

(1) Ceres

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Jan. 10	$11^h25^m.3$	+18°09′	8.3
20	11 26.7	+19 07	
30	11 25.2	+20 19	8.0
Feb. 9	11 20.9	+21 38	
19	11 14.3	+22 58	7.7
Mar. 1	11 06.0	+24 07	
11	10 57.2	+24 58	7.7
21	10 49.1	+25 24	
31	10 42.7	+25 25	8.0
Apr. 10	10 38.7	+25 01	
20	10 37.4	+24 17	8.4
30	10 38.7	+23 17	
May 10	10 42.4	+22 03	8.7
20	10 48.3	+20 38	
30	10 55.9	+19 06	9.0
June 9	11 05.1	+17 27	

(2) Pallas

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Jan. 10	$5^h45^m.5$	−31°13′	8.1
20	5 40.0	−29 01	
30	5 37.4	−26 10	8.1
Feb. 9	5 38.1	−22 52	
19	5 42.1	−19 19	8.3
Mar. 1	5 49.1	−15 42	
11	5 58.8	−12 08	8.5
21	6 10.9	− 8 46	

(4) Vesta

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
July 9	$0^h55^m.9$	− 1°56′	8.3
19	1 04.7	− 1 42	
29	1 11.5	− 1 42	8.0
Aug. 8	1 16.1	− 1 59	
18	1 18.0	− 2 33	7.7
28	1 17.1	− 3 23	
Sept. 7	1 13.4	− 4 26	7.4
17	1 07.0	− 5 35	
27	0 58.8	− 6 45	7.1
Oct. 7	0 49.5	− 7 45	
17	0 40.4	− 8 29	7.3
27	0 32.6	− 8 51	
Nov. 6	0 27.0	− 8 51	7.7
16	0 24.0	− 8 28	
26	0 23.7	− 7 46	8.1
Dec. 6	0 25.9	− 6 49	
16	0 30.5	− 5 39	8.4
26	0 37.2	− 4 18	

(5) Astraea

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Dec. 16	$9^h11^m.6$	+12°21′	10.9
26	9 13.0	+12 29	

(6) Hebe

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Mar. 31	$13^h21^m.7$	+11°07′	10.9
Apr. 10	13 13.2	+12 26	
20	13 04.8	+13 25	11.0
30	12 57.2	+14 02	

(7) Iris

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Mar. 11	$14^h04^m.2$	−19°28′	11.0
21	13 59.0	−19 11	
31	13 51.7	−18 38	10.7
Apr. 10	13 42.9	−17 49	
20	13 33.5	−16 49	10.4
30	13 24.5	−15 43	
May 10	13 16.7	−14 37	10.8
20	13 10.9	−13 38	

(8) Flora

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Mar. 11	$13^h27^m.5$	+ 0°33′	11.0
21	13 20.2	+ 1 43	
31	13 11.1	+ 2 54	10.7
Apr. 10	13 01.2	+ 3 58	
20	12 51.8	+ 4 48	10.9
30	12 43.8	+ 5 20	

(9) Metis

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Sept. 27	$4^h36^m.4$	+18°50′	10.9
Oct. 7	4 41.8	+19 15	
17	4 44.0	+19 36	10.5
27	4 42.5	+19 56	
Nov. 6	4 37.3	+20 14	10.1
16	4 29.0	+20 29	
26	4 18.5	+20 42	9.5
Dec. 6	4 07.4	+20 52	
16	3 57.6	+21 02	9.9
26	3 50.5	+21 15	

(10) Hygiea

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Dec. 16	$5^h40^m.0$	+25°03′	10.9
26	5 31.1	+24 50	

(15) Eunomia

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Jan. 10	$1^h25^m.4$	+22°05′	10.0
20	1 39.4	+22 08	
Dec. 16	10 54.3	− 0 35	11.0
26	10 57.2	− 1 46	

(18) Melpomene

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Jan. 10	$6^h42^m.2$	+ 9°50′	9.9
20	6 32.8	+11 06	
30	6 26.1	+12 26	10.4
Feb. 9	6 22.7	+13 46	
19	6 22.7	+15 00	10.9
Mar. 1	6 26.0	+16 06	

(19) Fortuna

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Oct. 17	$4^h08^m.9$	+20°19′	10.8
27	4 05.2	+19 56	
Nov. 6	3 58.2	+19 24	10.4
16	3 49.0	+18 44	
26	3 39.2	+18 03	10.2
Dec. 6	3 30.4	+17 25	
16	3 23.9	+16 58	10.7
26	3 20.7	+16 44	

(20) Massalia

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
July 29	$20^{h}03^{m}.5$	-19°17′	11.0
Aug. 8	19 54.0	-19 45	

(22) Kalliope

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Nov. 6	$5^{h}01^{m}.0$	+22°11′	10.9
16	4 53.6	+22 53	
26	4 44.2	+23 33	10.5
Dec. 6	4 33.7	+24 08	
16	4 23.4	+24 39	10.6
26	4 14.7	+25 06	

(27) Euterpe

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Sept.27	$3^{h}02^{m}.0$	+14°41′	11.0
Oct. 7	2 59.9	+14 27	
17	2 54.4	+14 00	10.5
27	2 46.2	+13 25	
Nov. 6	2 36.5	+12 44	9.9
16	2 26.8	+12 06	
26	2 18.6	+11 38	10.4
Dec. 6	2 13.4	+11 26	
16	2 11.6	+11 32	10.8
26	2 13.4	+11 57	

(29) Amphitrite

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
July 9	$23^{h}05^{m}.2$	-10°45′	10.9
19	23 05.1	-10 42	
29	23 02.4	-10 51	10.6
Aug. 8	22 57.1	-11 11	
18	22 49.6	-11 40	10.2
28	22 40.6	-12 11	
Sept. 7	22 31.0	-12 39	10.0
17	22 22.2	-12 59	
27	22 15.0	-13 08	10.4
Oct. 7	22 10.2	-13 02	
17	22 08.2	-12 43	10.7
27	22 09.1	-12 11	
Nov. 6	22 12.6	-11 27	11.0
16	22 18.5	-10 31	

(40) Harmonia

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
May 10	$15^{h}27^{m}.9$	-13°37′	10.7
20	15 17.4	-13 14	
30	15 07.7	-12 57	11.0
June 9	14 59.7	-12 50	

(42) Isis

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
June 19	$21^{h}34^{m}.6$	-22°11′	11.0
29	21 40.0	-23 19	
July 9	21 42.0	-24 46	10.6
19	21 40.5	-26 28	
29	21 35.8	-28 14	10.2
Aug. 8	21 28.9	-29 50	
18	21 21.1	-31 04	10.2
28	21 14.3	-31 46	
Sept. 7	21 09.9	-31 53	10.6
17	21 08.9	-31 30	
27	21 11.6	-30 41	11.0
Oct. 7	21 17.7	-29 31	

(88) Thisbe

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Aug. 18	$22^{h}28^{m}.2$	- 1°32′	10.7
28	22 20.0	- 1 59	
Sept. 7	22 11.9	- 2 36	10.7
17	22 05.1	- 3 16	

(129) Antigone

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
June 19	$20^{h}10^{m}.3$	-10°26′	10.9
29	20 05.3	-11 15	
July 9	19 58.3	-12 20	10.6
19	19 50.3	-13 37	
29	19 42.3	-14 59	10.6
Aug. 8	19 35.5	-16 22	

(194) Prokne

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Sept. 7	$0^{h}29^{m}.3$	- 7°07′	10.8
17	0 24.5	-10 07	
27	0 18.5	-12 55	10.7
Oct. 7	0 12.5	-15 13	

(349) Dembowska

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
July 29	$22^{h}04^{m}.0$	-25°00′	10.9
Aug. 8	21 56.3	-25 44	
18	21 47.5	-26 20	10.7
28	21 38.7	-26 42	
Sept. 7	21 30.8	-26 47	10.9
17	21 24.8	-26 35	

(387) Aquitania

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
July 29	$22^{h}22^{m}.0$	-17°10′	10.8
Aug. 8	22 17.3	-19 47	
18	22 10.8	-22 21	10.6
28	22 03.8	-24 39	
Sept. 7	21 57.4	-26 30	10.9
17	21 52.8	-27 47	

(393) Lampetia

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
July 9	$19^{h}52^{m}.5$	+10°07′	10.9
19	19 46.5	+10 41	
29	19 40.6	+10 28	10.8
Aug. 8	19 36.0	+ 9 31	
18	19 33.8	+ 8 02	11.0
28	19 34.8	+ 6 11	

(471) Papagena

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Nov. 26	$6^{h}43^{m}.6$	+23°44′	10.9
Dec. 6	6 37.0	+25 04	
16	6 27.9	+26 27	10.6
26	6 17.3	+27 44	

PLANETARY APPULSES AND OCCULTATIONS

PROVIDED BY ROBERT L. MILLIS

A *planetary appulse* is a close approach of a star and a planet, minor planet (asteroid), or satellite (moon) as seen from Earth. At certain locations on Earth the appulse may be seen as an *occultation*, a "solar eclipse", but usually of a star other than our Sun. Careful observations of these events can provide valuable information on the position, size, and shape of the occulting body, and indicate the possible presence of satellites and/or atmosphere surrounding the body. In the case of asteroids, information of this sort is not currently obtainable in any other way. In addition, through a stepwise drop in the light of the occulted star or a gradual dimming, an occultation can reveal the binary nature of some stars or their diameter.

L.H. Wasserman, E. Bowell, and R.L. Millis of Lowell Observatory have prepared a list of 74 possible occultations of stars by asteroids for 1986. Their work is scheduled to appear in the October 1985 issue of *The Astronomical Journal*. The table on the next page lists the better occultations which may be observable from North America (including Hawaii), and is taken from the above paper. It was prepared by Robert L. Millis and is presented here courtesy of the Editor of *The Astronomical Journal*. The successive columns in the table list (1) the date; (2) the number and name of the occulting asteroid; (3) the apparent magnitude of the asteroid (visual values, unless there is an asterisk); (4) the AGK3 or SAO number of the occulted star; (5) the apparent magnitude of the star; the (6) right ascension and (7) declination of the star; (8) a measure of the loss of brightness when the occultation occurs (ΔI is the ratio of the star's intensity to the combined intensity of the star plus asteroid. Hence a large value of ΔI means a substantial decrease in brightness); (9) the predicted maximum duration of the occultation in seconds; (10) the approximate area across which the asteroid's shadow will pass.

The areas mentioned in the last column of the table are very uncertain. Only through astrometric observations of the highest accuracy, usually within a few days prior to the occultation, can the predictions be improved sufficiently to provide the basis for elaborate observational efforts. Observers wishing to obtain improved predictions within a few days of each event may obtain recorded telephone messages at 312-259-2376 (Chicago, Ill.), 713-488-6871 (Houston, Tex.), or 301-585-0989 (Silver Spring, Md.), or may contact Dr. Millis (see the inside front cover).

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Serious observers of occultations pay careful attention to: the determination of their geographical latitude, longitude, and altitude (which should be known to the nearest second of arc and 20 m, respectively); identification of the star; accurate timing of the events (considerable care is needed to attain an accuracy of 0.5 s or better: a shortwave radio time signal and cassette tape recorder are recommended); monitoring the star for several minutes surrounding the time of closest approach in order to time the possible occultation and/or any secondary extinctions of the star; the provision of independent observers a kilometre or more apart for both confirmation and improved "resolution" of the eclipse shadow. High speed photoelectric recordings are very desirable when possible. When reporting timings, state the aperture of the telescope used, describe the timing method, estimate your reaction time and the accuracy of the timing, and state whether or not the reaction time correction has been applied. Reaction times vary from about 0.2 s to 1.0 s or more depending on the observer and the magnitude of the star.

Observations of these events are coordinated in North America by the International Occultation Timing Association (IOTA). Dr. Dunham of the IOTA intends to publish an article on planetary occultations for 1986 in the January issue of *Sky and Telescope*. Observations of planetary occultations, *including* negative observations, should be sent to Dr. Dunham at P.O. Box 7488, Silver Spring, MD 20907, U.S.A. for publication by the IOTA. (Note that observations of *lunar* occultations should be sent to Japan. See page 86.)

U.T. Date (1986)	Asteroid	m_{AST} (mag.)	Star	m_{ST}	α (1950)	δ	ΔI	Max. Dur. (s)	Approximate Area of Visibility
17.46 Jan	511 Davida	10.8*	+20°0615	4.5*	$6^h01^m00^s.0$	+20°08'29"	1.00	33.1	Hawaii
1.01 Feb	2 Pallas	7.8	170643	8.4	5 37 14.6	-25°32'01"	0.37	39.5	Newfoundland
4.44 Feb	511 Davida	11.2*	+22°0610	10.0*	5 53 01.1	+22°08'01"	0.75	53.3	Alaska, Hawaii
8.21 Feb	444 Gyptis	12.6	137517	7.5	10 19 29.9	-0°29'56"	0.99	12.1	Canada, NE USA
11.04 Feb	216 Kleopatra	12.1*	+08°0430	9.9*	4 05 41.0	+8°11'56"	0.88	15.7	Eastern USA
21.33 Feb	48 Doris	12.2*	+11°0985	8.4*	8 25 17.7	+11°52'21"	0.97	15.0	Eastern Canada, NE USA
21.33 Mar	2 Pallas	8.3	132993	8.7	6 11 18.4	-8°39'17"	0.40	23.0	Hawaii
31.18 Jul	52 Europa	11.6	146840	9.2	23 37 57.1	-7°51'02"	0.90	47.5	Newfoundland
4.43 Oct	38 Leda	13.2*	+25°0220	9.3*	2 23 10.3	+25°31'09"	0.97	17.1	Southern USA
4.33 Nov	94 Aurora	13.5*	+29°0943	11.0*	8 07 25.0	+29°36'35"	0.91	19.6	Central USA
13.14 Nov	9 Metis	9.8*	+20°0417	10.7*	4 31 19.4	+20°24'05"	0.31	22.8	Alaska, Greenland
16.17 Nov	27 Euterpe	10.0*	+12°0266	11.0*	2 26 11.9	+12°03'48"	0.29	16.1	SE USA
28.25 Dec	87 Sylvia	12.6*	+28°0601	9.4*	6 01 06.5	+28°18'15"	0.95	16.8	N. Canada, Alaska

*Blue magnitude

METEORS, COMETS, AND DUST

METEORS, FIREBALLS, AND METEORITES

BY PETER M. MILLMAN

Meteoroids are small solid particles moving in orbits about the Sun. On entering Earth's atmosphere they become luminous and appear as meteors or fireballs, and in rare cases, if large enough to avoid complete fragmentation and vaporization, they may fall to Earth as meteorites.

Meteors are visible on any night of the year. At certain times of the year Earth encounters larger numbers of meteoroids all moving together along the same orbit. Such a group is known as a meteor stream and the visible phenomenon is called a meteor shower. The orbits followed by these meteor streams are very similar to those of short-period comets, and in many cases can be identified with the orbits of specific comets.

The radiant is the position among the stars from which the meteors of a given shower seem to radiate. This is an effect of perspective commonly observed for any group of parallel lines. Some showers, notably the Quadrantids, Perseids, and Geminids, are very regular in their return each year and do not vary greatly in the numbers of meteors seen at the time of maximum. Other showers, like the Leonids, are very unpredictable and may arrive in great numbers or fail to appear at all in any given year. The δ Aquarids and the Taurids are spread out over a fairly extended period of time without a sharp maximum.

For more information concerning meteor showers, see the paper by A. F. Cook in "Evolutionary and Physical Properties of Meteoroids", NASA SP-319, pp. 183–191, 1973.

The light of meteors is produced by a mixture of atoms and molecules, originating from both the meteoroid and Earth's atmosphere. i.e. The light of a meteor is primarily from a glowing gas, and not from the solid meteoroid itself. The collision, at a very high speed, of the material from the meteoroid with Earth's atmosphere

MAJOR VISUAL METEOR SHOWERS FOR 1986

Shower	Shower Maximum			Radiant				Single Observer Hourly Rate	Speed of Encounter with Earth	Normal Duration to ¼ Strength of Max.
				Position at Max.		Daily Motion				
	Date	U.T.	Moon	R.A.	Dec.	R.A.	Dec.			
		h		h m	°	m	°		km/s	days
Quadrantids	Jan. 3	19	LQ	15 28	+50	—	—	40	41	1.1
Lyrids	Apr. 22	15	FM	18 16	+34	+4.4	0.0	15	48	2
η Aquarids	May 4	19	LQ	22 24	00	+3.6	+0.4	20	65	3
S. δ Aquarids	July 28	21	LQ	22 36	−17	+3.4	+0.17	20	41	7
Perseids	Aug. 12	12	FQ	03 04	+58	+5.4	+0.12	50	60	4.6
Orionids	Oct. 21	17	FM	06 20	+15	+4.9	+0.13	25	66	2
S. Taurids	Nov. 3	—	NM	03 32	+14	+2.7	+0.13	15	28	—
Leonids	Nov. 18	00	FM	10 08	+22	+2.8	−0.42	15	71	—
Geminids	Dec. 14	12	FM	07 32	+32	+4.2	−0.07	50	35	2.6
Ursids	Dec. 22	18	LQ	14 28	+76	—	—	15	34	2
Quadrantids	(1987) Jan. 4	00	FQ	15 28	+50	—	—	40	41	1.1

excites the involved atoms and molecules to shine, each with its own characteristic wavelength (colour). In addition to the light of oxygen and nitrogen, prominent in the luminosity of meteors, we find the orange-yellow of sodium, the brilliant green of magnesium, and various other wavelengths of light produced by iron, calcium, and some dozen, less-common elements. For a general survey of the light of meteors see *Smithsonian Contributions to Astrophysics*, *7*, pp. 119–127, 1963.

An observer located away from city lights, and with perfect sky conditions on a moonless night, will see an overall average of seven sporadic meteors per hour apart from the shower meteors. These sporadic meteors have been included in the hourly rates listed in the table. Slight haze or nearby lighting will greatly reduce the number of meteors seen. More meteors appear in the early morning hours than in the evening, and more during the last half of the year than during the first half.

When a meteor has a luminosity greater than the brightest stars and planets it is generally termed a fireball. The visible trails of most meteors occur high in the atmosphere from 60 to 110 kilometres altitude. Only the rare, very bright fireballs survive down to the lower levels of Earth's atmosphere, and, in general, these are not associated with meteor showers. The occurrence of such an object should be reported immediately to the nearest astronomical group or other organization concerned with the collection of such information. Where no local organization exists, reports should be sent to Meteor Centre, Herzberg Institute of Astrophysics, National Research Council of Canada, Ottawa, Ontario, K1A 0R6.* Special "Fireball Report" forms and related instructions are available from the Meteor Centre without charge. If sounds are heard accompanying a bright fireball there is a possibility that a meteorite may have fallen. Astronomers must rely on observations made by the general public to track down such an object.

The two showers associated with Halley's Comet, due in 1986, are the η Aquarids and the Orionids and these showers should be given priority in meteor observations for 1986.

**Editor's Note*: Fireball reports within the United States should be mailed to the Scientific Event Alert Network (SEAN), Mail Stop 129, Natural History Building, Smithsonian Institution, Washington, DC 20560.

A SELECTION OF MINOR VISUAL METEOR SHOWERS

Shower	Dates	Date of Max.	Speed
			km/s
δ Leonids	Feb. 5–Mar. 19	Feb. 26	23
σ Leonids	Mar. 21–May 13	Apr. 17	20
τ Herculids	May 19–June 14	June 3	15
N. δ Aquarids	July 14–Aug. 25	Aug. 12	42
α Capricornids	July 15–Aug. 10	July 30	23
S. ι Aquarids	July 15–Aug. 25	Aug. 5	34
N. ι Aquarids	July 15–Sept. 20	Aug. 20	31
κ Cygnids	Aug. 9–Oct. 6	Aug. 18	25
S. Piscids	Aug. 31–Nov. 2	Sept. 20	26
N. Piscids	Sept. 25–Oct. 19	Oct. 12	29
N. Taurids	Sept. 19–Dec. 1	Nov. 13	29
Annual Andromedids	Sept. 25–Nov. 12	Oct. 3	18–23
Coma Berenicids	Dec. 12–Jan. 23	—	65

NORTH AMERICAN METEORITE IMPACT SITES

BY P. BLYTH ROBERTSON

The realization that our Earth is truly part of the solar system, and not a planet in isolation, has been dramatically demonstrated by the past two decades of space exploration. Bodies such as Phobos, Callisto, Mimas, which were once solely part of the astronomer's realm, are now familiar terrain to planetary geologists, and an insight into the age and history of their surfaces can be derived from a knowledge of, and comparison with geological processes on Earth. In particular, as the only common feature apparent on all bodies from Mercury outward to the moons of Saturn is the abundance of meteorite craters, studies of the terrestrial equivalents may lead to better understanding of the evolution of planetary crusts.

Although all the planets are heavily cratered, the source of the impacting bodies is not the same throughout the solar system, nor has the rate been constant with time. The densely-cratered lunar highlands reveal a period of intense bombardment between 4.6 and 3.9 billion years ago, whereas the crater populations on the younger mare surfaces indicate a subsequent, considerably reduced rate that may have fluctuated somewhat over the past 3 billion years. It is believed that the cratering history of Earth is like that of the Moon, but all vestiges of the early bombardment, and a large percentage of the craters from the later period have been obliterated by various geologic processes on the 'active' Earth. A significant number of the larger, younger craters have been preserved, however, and their ages determined through radiometric age-dating techniques, to permit a calculation of the recent cratering rate. This rate, for the past 120 million years, is 5.4×10^{-15} per square kilometre of Earth per year, for craters 20 kilometres or larger in diameter. In other words, an event of this magnitude may occur every 7.6 million years in North America.

An impact crater results from a combination of excavation of the shattered target rocks and further expansion of the cavity by outward and downward movements of highly fractured material. Craters larger than 4 or 5 km undergo further modification through rebound and uplift of the crater floor, and downward faulting and displacement of large blocks in a broad annulus surrounding the crater. These movements result in a comparatively shallow impact structure whose outer dimension is approximately 40% larger than that of the initial crater.

The magnitude of the impact event is proportional to the kinetic energy of the meteorite, and therefore depends on its size, composition and speed. A 20 km impact structure on Earth would result from an impact yielding the equivalent of approximately 64 000 megatons of TNT, and could be produced by a stony meteorite (density 3.4 g/cm^3), 900 m in diameter, travelling at a typical speed of 20 km/s. Thus the diameter of the impact structure is many times that of the impacting body. (The kinetic energy of a typical meteor is about 100 times the explosive energy of the same mass of TNT.—Ed.)

In impacts, where craters greater than approximately 1.5 km are created, extreme shock pressures and temperatures vaporize and melt the meteorite. It subsequently becomes thoroughly mixed with the melted target rocks and is no longer recognizable in its original form, although chemical traces have been discovered. Of the 38 North American impact structures listed, which account for roughly 40% of the world's recognized total, meteorite fragments are preserved at only 3. The remainder are identified by the presence of characteristic deformation features in the target rocks; features that are uniquely produced by extreme shock pressures generated in nature only by hypervelocity, meteorite impact. In addition to these sites there are twenty or more structures in Canada and the United States whose impact origin seems highly probable, but where distinctive shock deformation has not been found.

In the table, sites accessible by road or boat are marked "A" or "B" respectively and those sites where data have been obtained through diamond-drilling or geophysical surveys are signified by "D" and "G", respectively.

Name	Lat. °	'	Long. °	'	Diam. (km)	Age ($\times 10^6$ a)	Surface Expression	Visible Geologic Features			
Barringer, Meteor Crater, Ariz.	35	02	111	01	1.2	.05	rimmed polygonal crater	fragments of meteorite, highly shocked sandstone	A	D	G
Bee Bluff, Texas	29	02	099	51	2.4	40±10	shallow circ. depress'n.; rim remnants	breccia	A		
Brent, Ont.	46	05	078	29	3.8	450±30	sediment-filled shallow depression	fracturing	A	D	G
Carswell, Sask.	58	27	109	30	37	485±50	discontinuous circular ridge	shatter cones, breccia			G
Charlevoix, Que.	47	32	070	18	46	360±25	semi-circular trough, central elevation	breccia, shatter cones, impact melt	A		G
Clearwater Lake East, Que.	56	05	074	07	22	290±20	circular lake	sedimentary float		D	G
Clearwater Lake West, Que.	56	13	074	30	32	290±20	island ring in circular lake	impact melt		D	G
Crooked Creek, Missouri	37	50	091	23	5.6	320±80	oval area of disturbed rocks, shallow marginal depression	breccia, shatter cones	A		
Decaturville, Missouri	37	54	092	43	6	<300	slight oval depression	breccia, shatter cones	A	D	
Deep Bay, Sask.	56	24	102	59	12	100±50	circular bay	sedimentary float		D	G
Flynn Creek, Tenn.	36	16	085	37	3.8	360±20	sediment-filled shallow depression with slight central elevation	breccia, shatter cones, disturbed rocks	A	D	G
Glover Bluff, Wis.	43	58	089	32	0.4	?	disturbed dolomite exposed in 3 quarries	shatter cones	A		G
Gow Lake, Sask.	56	27	104	29	5	<250	lake and central island	breccia			G
Haviland, Kansas	37	35	099	10	0.0011	<0.001	excavated depression	fragments of meteorite	A		
Haughton, NWT	75	22	089	40	20	<20	shallow circular depression	shatter cones, breccia			G
Holleford, Ont.	44	28	076	38	2	550±100	sediment-filled shallow depression	sedimentary fill	A	D	G
Ile Rouleau, Que.	50	41	073	53	4	<300	island is central uplift of submerged structure	shatter cones, breccia dikes			
Kentland, Ind.	40	45	087	24	13	300	central uplift exposed in quarries, rest buried	breccia, shatter cones, disturbed rocks	A		
Lac Couture, Que.	60	08	075	18	8	430	circular lake	breccia float			
Lac la Moinerie, Que.	57	26	066	36	8	400	lake-filled, partly circular	breccia float			G
Lake St. Martin, Man.	51	47	098	33	23	225±40	none, buried and eroded	impact melt	A	D	G
Lake Wanapitei, Ont.	46	44	080	44	8.5	37±2	lake-filled, partly circular	breccia float	A		G
Manicouagan, Que.	51	23	068	42	100	210±4	circumferal lake, central elevation	impact melt, breccia	B		G
Manson, Iowa	42	35	094	31	32	<100	none, central elevation buried to 30 m	none	A	D	G
Middlesboro, Ky.	36	37	083	44	6	300	circular depression	disturbed rocks	A		
Mistastin Lake, Labr.	55	53	063	18	28	38±4	elliptical lake and central island	breccia, impact melt			
New Quebec Crater, Que.	61	17	073	40	3.2	<5	rimmed, circular lake	raised rim			G
Nicholson Lake, NWT	62	40	102	41	12.5	<400	irregular lake with islands	breccia			G
Odessa, Tex.	31	48	102	30	0.17	0.03	sediment-filled depression with very slight rim, 4 others buried and smaller	fragments of meteorite	A	D	G
Pilot Lake, NWT	60	17	111	01	6	<440	circular lake	fracturing, breccia float			
Redwing Creek, N. Dak.	47	40	102	30	9	200	none, buried	none	A	D	G
Serpent Mound, Ohio	39	02	083	24	6.4	300	circular area of disturbed rock, slight central elevation	breccia, shatter cones	A		G
Sierra Madera, Tex.	30	36	102	55	13	100	central hills, annular depression, outer ring of hills	breccia, shatter cones	A	D	G
Slate Islands, Ont.	48	40	087	00	30	350	islands are central uplift of submerged structure	shatter cones, breccia dikes	B		G
Steen River, Alta.	59	31	117	38	25	95±7	none, buried to 200 metres	none		D	G
Sudbury, Ont.	46	36	081	11	140	1840±150	elliptical basin	breccia, impact melt, shatter cones	A	D	G
Wells Creek, Tenn.	36	23	087	40	14	200±100	basin with cenral hill, inner and outer annular, valleys and ridges	breccia, shatter cones	A	D	G
West Hawk Lake, Man.	49	46	095	11	2.7	100±50	circular lake	none	A	D	G

COMETS IN 1986

By Brian G. Marsden

The following periodic comets are expected at perihelion during 1986:

Comet	Perihelion Date	Perihelion Dist.	Period
		A	a
Boethin	Jan. 19	1.11	11.2
Ashbrook-Jackson	Jan. 24	2.31	7.5
Halley	Feb. 9	0.59	76.0
Holmes	Mar. 14	2.17	7.1
Wirtanen	Mar. 19	1.08	5.5
Kojima	Apr. 4	2.41	7.9
Shajn-Schaldach	May 27	2.33	7.5
Whipple	June 25	3.08	8.5
Wild 1	Oct. 1	1.98	13.3

The only comet expected to be bright enough for observation with small telescopes during 1986 is P/Halley, 1982i, and an ephemeris is appended. The comet should in fact be visible in binoculars, perhaps also faintly with the naked eye, after sunset during much of January. It should be brighter during March and most of April and then have a longer tail, but it will be quite far south, for a while even too far south, for observation from Canada.

P/Boethin, making its first predicted return, is well placed for observation and might be moderately bright. P/Ashbrook-Jackson, a comet of relatively large perihelion distance, was recovered early in 1985 and will be observable in the latter part of 1986 but not around its perihelion passage. P/Holmes and P/Shajn-Schaldach, also comets of relatively large perihelion distance, will likewise be badly placed for observation at perihelion but observable later. As in 1980, P/Wirtanen will again be difficult to observe at this return, particularly after perihelion passage. A close approach to Jupiter has substantially increased the perihelion distances of both P/Kojima and P/Whipple since their last perihelion passages, so future observations will be difficult. P/Wild 1 will be badly placed before and at perihelion, but should be recovered at the end of the year or early in 1987.

COMET HALLEY

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Jan. 5	$22^{h}05^{m}.8$	$-3°28'$	
10	21 55.8	- 4 28	4.7
15	21 46.6	- 5 24	
20	21 37.8	- 6 17	3.8
Mar. 1	20 26.5	-16 20	2.4
6	20 17.5	-18 14	
11	20 07.4	-20 28	3.1
16	19 55.1	-23 13	
21	19 38.4	-26 44	3.5
26	19 13.5	-31 22	
31	18 32.4	-37 25	3.7

COMET HALLEY

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Apr. 5	$17^{h}19^{m}.5$	$-44°12'$	
10	15 21.6	-47 24	3.9
15	13 20.3	-42 03	
20	12 03.8	-32 47	5.1
25	11 21.9	-24 54	
30	10 58.1	-19 13	6.6
May 5	10 43.8	-15 14	
10	10 35.0	-12 24	7.9
15	10 29.5	-10 21	
20	10 26.2	- 8 49	9.0
25	10 24.5	- 7 41	
30	10 23.9	- 6 50	9.9
June 4	10 24.1	- 6 12	
9	10 24.9	- 5 44	10.7
14	10 26.2	- 5 24	
19	10 27.9	- 5 11	11.4

Editor's Note: The astronomical high point for 1986 will, without doubt, be the current return of Halley's Comet. Since its period of about 76 years approximates a full human lifetime, few people are privileged to see this comet more than once.

Ground-based observations of Halley's Comet are being coordinated by the *International Halley Watch* (IHW). The IHW Western Hemisphere Lead Centre is at the Jet Propulsion Laboratory in Pasadena, California. Stephen J. Edberg of the IHW is Coordinator for Amateur Observations, and has produced the highly-recommended *International Halley Watch Amateur Observers' Manual for Scientific Comet Studies*. This is available from Sky Publishing Corporation, 49 Bay State Road, Cambridge, MA 02238-1290, U.S.A. (Order: 46409 IHW Guide, $9.95 US plus 10% for orders from outside the U.S.A.).

Additional information is contained in *The Comet Halley Handbook* by Donald Yeomans, available from the U.S. Government Printing Office, Washington, DC 20402. See also *The Journal of the Royal Astronomical Society of Canada, 77,* 63, 1983, and several articles in recent issues of the periodical *Sky and Telescope*. A flood of popular material on the comet is now appearing. One of the better books is *The Return of Halley's Comet* by Patrick Moore and John Mason (Patrick Stephens, Cambridge, 1984).

The diagram on page 153 shows the path of Halley's Comet in the vicinity of Earth's orbit, 1985–1986, as viewed from the north ecliptic pole. The planes of the two orbits are inclined at 18°, thus in the diagram the path of the comet is slightly distorted since it is projected on the plane of the ecliptic. The dashed line represents the intersection of the orbital planes, and the comet's path is shown as a heavy line where it is north of the ecliptic plane. The positions of the comet and Earth are indicated by tick marks at 15-day intervals beginning at October 3, 1985 and ending at June 15, 1986. The tick marks along the comet's path have dates beside them. Conjugate positions of the comet and Earth are linked by dotted lines beginning at November 2 and ending at May 1 (for clarity, dotted lines were omitted for the first two and last three pairs of tick marks). Arrow heads showing the directions of motion are located on each path in the "early October" positions. The arrow near Earth's September position indicates the direction of the vernal equinox (♈).

Several positions along the comet's path are worth special note:

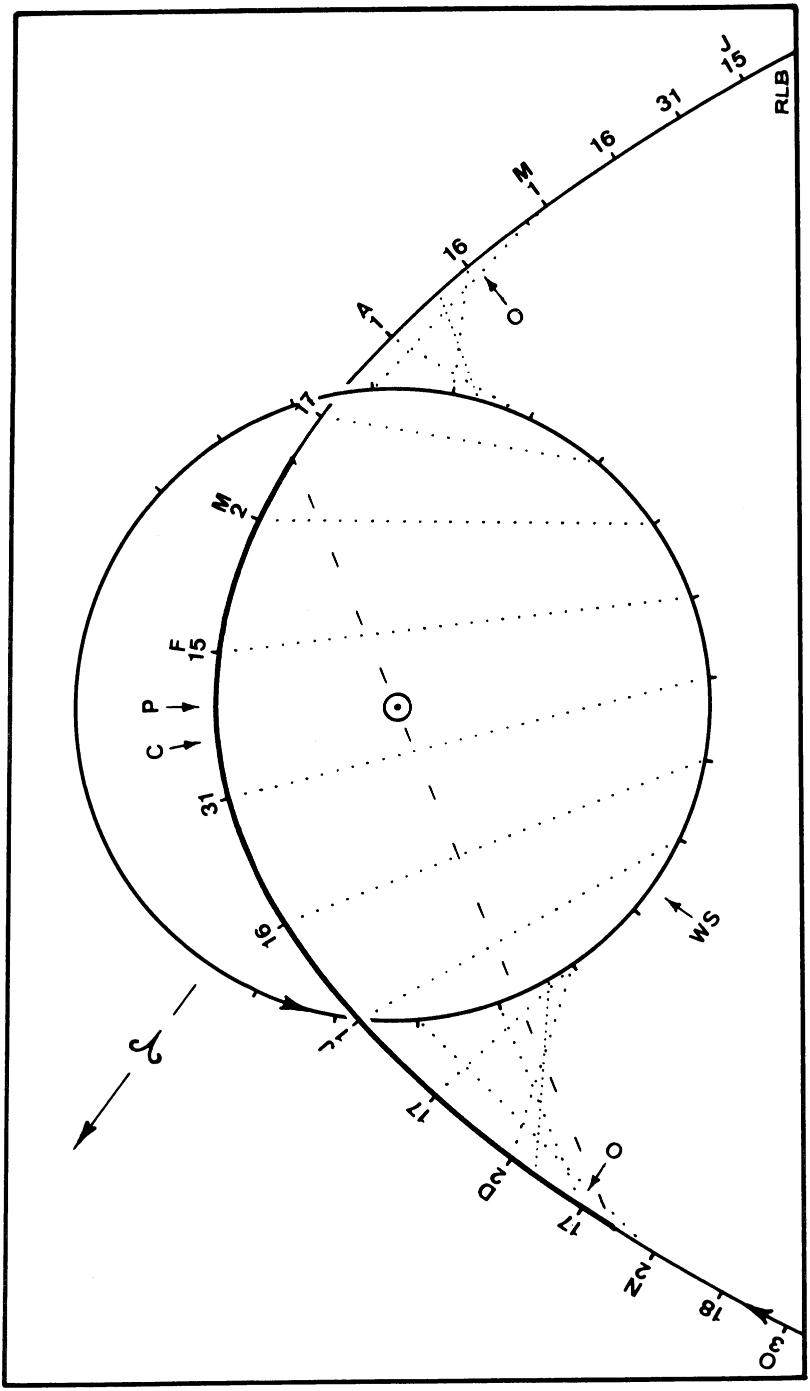
Nov. 9: Passes the ascending node.
Nov. 18: At opposition (O).
Nov. 27: Nearest to Earth in 1985 (0.62 A) (note the line with many dots).
Jan. 1: Passes within 1 A of Sun.
Feb. 5: Conjunction (C).
Feb. 9: Perihelion (P), 0.587 A from Sun.
Mar. 10: Passes descending node. (To minimize fuel requirements, it is near this point that spacecraft will intercept the comet.)
Mar. 20: Passes beyond 1 A from Sun.
Apr. 11: Nearest to Earth (0.42 A) (note the line with many dots).
Apr. 17: At opposition (O).

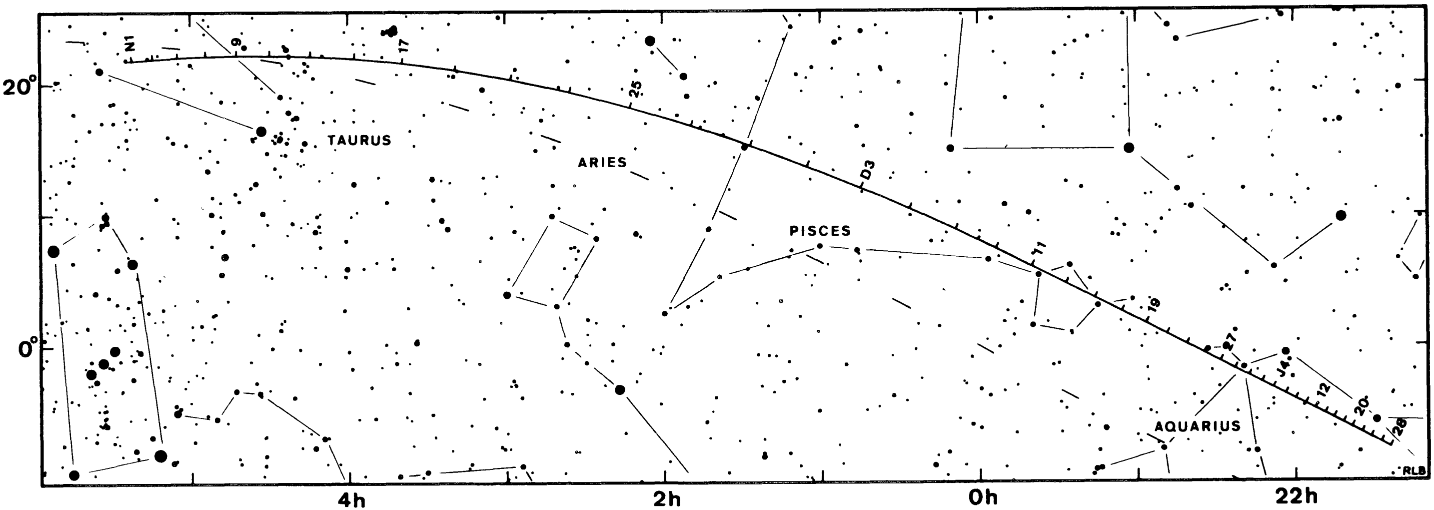
By inspection of the diagram, an appreciation of the location of the comet in the observer's sky may be obtained. In addition to the 18° tilt described above, Earth's equator is inclined at 23° to the ecliptic, the north pole of Earth being tilted toward a direction 90° counterclockwise from the vernal equinox arrow (note the position of Earth at the winter solstice: WS). Thus as Earth and Halley's Comet approach during the fall of 1985, the comet is well-placed in the night sky for observers in the Northern Hemisphere. However, as 1986 opens, the relative positions shift so that Earth begins to present its Southern Hemisphere toward the comet. Thus as the comet enters the evening twilight and approaches conjunction with the Sun, it is dropping into the southern sky.

This southern motion is accentuated as the comet reappears in the morning sky through February and March since the contribution from Earth's inclination is augmented by the comet itself as it plunges back to the southern side of the ecliptic. Thus observers in the Southern Hemisphere are favoured as Earth has its closest approach to the comet. The best views will occur as new moon approaches during the first week in April, provided the observer is south of the Tropic of Cancer.

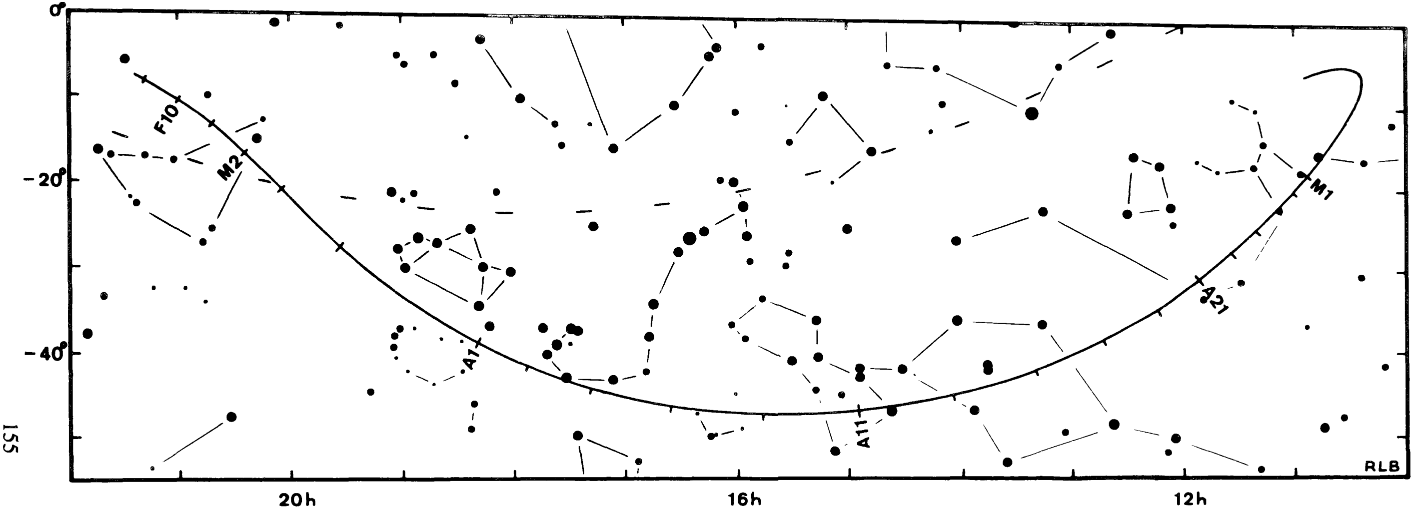
During the remainder of the spring of 1986, the relative positions shift so that Earth's 23° tilt causes the comet to move northward once again in our skies, but by then the comet is fading rapidly as it recedes from both Earth and the Sun. It will reach its aphelion in the year 2024, and will again be visible from Earth in 2061.

In some respects, the 1985–86 apparition of Halley's Comet is one of the worst on record. The comet will be brightest when it is near perihelion, but, as can be seen from the diagram, we are then as far as we could possibly be from it, and the comet is unobservable from Earth due to the solar glare. One unusual, favorable feature is that we will have *two* moderately-close encounters with the comet: in the late fall of 1985 when the comet is on its inbound leg, and again in the spring of 1986 during its outbound leg. Also, Earth-based observations, measurements from Earth-orbiting satellites, and fly-bys by several space missions will provide more information on Halley's Comet than has been obtained at *all* the previous 28 recorded apparitions since 240 BC. Nevertheless, due both to the unfavorable orbital geometry and to light pollution (a problem that did not exist at the last apparition in 1910), the comet will not be visible to the unaided eye from urban areas. Thus most of the waiting public will not see it. From temperate northern latitudes, Halley's Comet will not disappoint those observers who are familiar with the stars, who use binoculars, and who avail themselves of dark, country skies. For those who are in the tropics or further south during early April, the view will be particularly memorable.

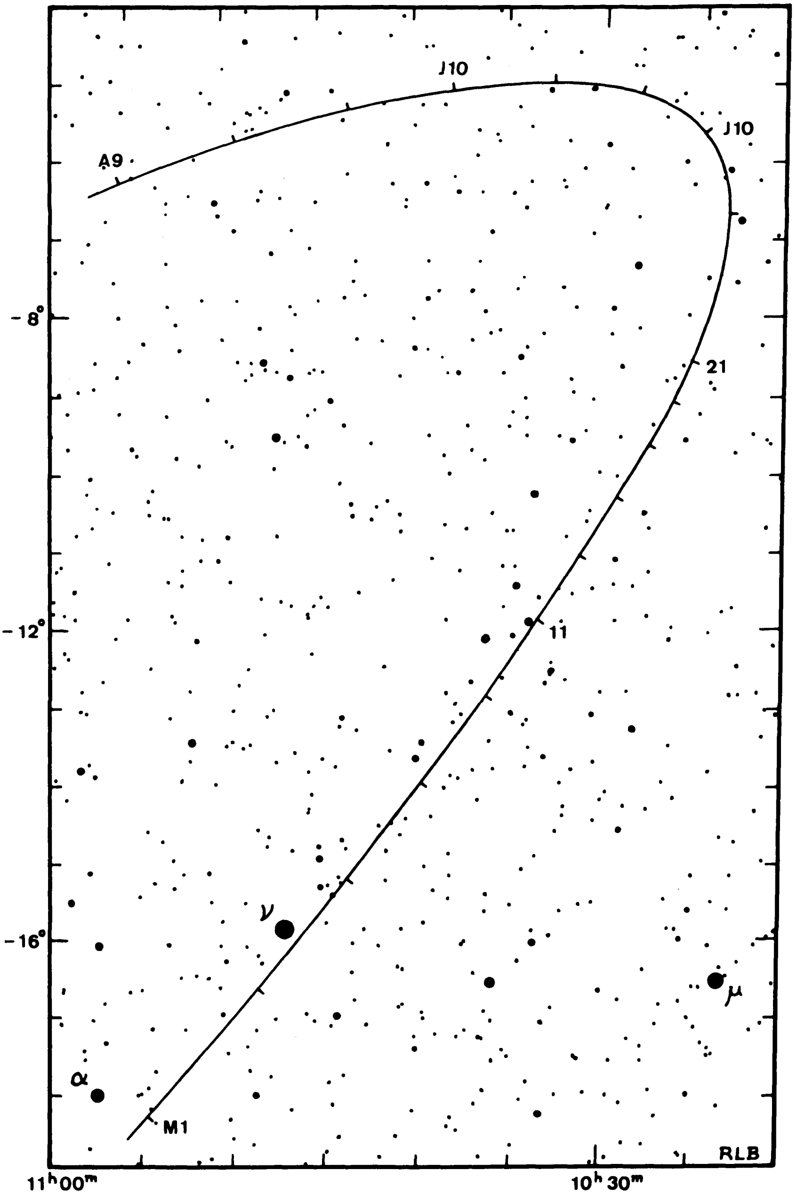

RLB
J
15
31
16
M
1
16
A
1
O
17
M
2
F
15
P
C
31
16
WS
J
17
D
2
O
17
N
2
18
O
30



The path of Halley's Comet during the last part of 1985 and early 1986. During this period it comes within reach of binoculars and the naked eye as it brightens and moves rapidly westward toward conjunction with the Sun (and perihelion) in February 1986 The path is marked (for 0 h UT) at 2-day intervals beginning at November 1 (N1) with 8-day intervals being labelled. The path ends in late January when the comet becomes lost in the evening twilight. As an aid to orientation, stars forming the usual constellation patterns are linked by straight lines (For an all-sky view see the NOVEMBER star chart on p. 206). The comet passes N of the ecliptic (the dashed line) and reaches its greatest N declination on November 9, 1985. It passes 2° S of the Pleiades on November 16, is at opposition on November 18, and is closest to Earth (during 1985) on November 27 (at 0.62 A). Note how the apparent angular speed of the comet peaks when it is closest to us and with Earth and the comet moving in opposite directions, and then slows as we recede from it and begin moving in the same direction as 1986 opens (see the diagram on page 153). Of course, relative to the Sun, the comet is still speeding up as it approaches perihelion on the far side of the Sun on February 9. Moon-free viewing periods include mid-November, and the first halves of December and January. The predicted magnitudes of the comet during these periods are approximately 7, 6, and 5, respectively. The faintest stars shown are of magnitude 6, and the constellations through which the comet passes are named. The coordinates are for 1950.0. (RLB)



The path of Halley's Comet from January 28 (the end of the path on the previous diagram) to August 9, 1986. Double-sided tick marks are placed along the path for 0 h UT at 10-day intervals from January 31 to May 1 (M1), with additional, single-sided tick marks inserted at 2-day intervals during the month of April. Note that four of these tick marks (for January 31, March 2, April 1, and May 1) coincide with four of the conjugate Earth-comet positions shown in the diagram two pages back. The ecliptic is shown as a dashed line, and stars forming the usual constellation patterns are linked by straight lines. The coordinates are for 1925.0. Note that the comet travels nearly eight hours in right ascension, a third of the way around the sky, during the month following the spring equinox. The reason for this rapid motion will be apparent if one studies the diagram two pages back. With conjunction with the Sun on February 5 and interference from moonlight toward the end of that month, the comet will not be visible during most of February. During March the comet will rapidly become a spectacular binocular object for observers in the tropics and further south. With dark, transparent skies and a low south-east horizon, observers as far north as perhaps latitude 45° should be able to view the comet before dawn during the week leading up to the spring equinox. After this, moonlight interferes and the comet moves further into the southern sky. Halley will be seen at its best from tropical and (especially) southern latitudes during the first week of April (although the Moon will still interfere on April Fools' Day). By the end of April, the comet will once again be reasonably well-placed for Northern Hemisphere observers, but it will probably have faded below naked eye visibility. The unmarked May 1 to August 9 portion of the path is shown on a larger scale on the next page. (RLB)



The path of Halley's Comet as it recedes beyond the orbit of Mars and approaches its second conjunction with the Sun during 1986 (on September 17). This diagram shows on a larger scale the western end of the path on the previous page. Tick marks are placed along the path for 0 h UT at 2-day intervals from May 1 (M1)

INTERPLANETARY DUST

Outside of the astronomical community it is not generally realized that the inner solar system contains a vast cloud of dust. The particles in this cloud are concentrated near the plane of the ecliptic and toward the Sun, their spatial particle density in the ecliptic falling off somewhat more rapidly than the reciprocal of their distance from the Sun. Measurements from spacecraft indicate that the cloud extends well beyond the orbit of Mars, but that it is negligible in the vicinity of Jupiter's orbit and beyond. In 1983, *IRAS*, the pioneering Infrared Astronomical Satellite, discovered that there is an extra concentration of dust in the asteroid region, in the form of a ring or torus centred on the Sun. Aside from this overall structure, the cloud is quite uniform both spatially and temporally.

The particles composing the cloud have a continuum of sizes, from pebble-sized clumps down to specks with diameters comparable to the wavelength of visible light and smaller. The smaller particles are the more numerous, although the mass distribution appears to peak near 10^{-8} kg, corresponding to a particle diameter of a few tenths of a millimetre. The total mass of the cloud is small, amounting to perhaps 10^{-14} of the mass of the solar system. It is as if the moons of Mars had been pulverized and spread throughout the inner solar system.

Like the planetary system, the interplanetary dust cloud is not static. Its particles generally move in orbits about the Sun. In addition, the particles undergo continual fragmentation due to collisions, sputtering associated with bombardment by the solar wind, electrostatic bursting, and sublimation. This progression toward smaller and smaller sizes is of crucial significance for the cloud, since particles with diameters appreciably less than a tenth of a millimetre have a sufficiently large surface-to-volume ratio that the pressure of the Sun's radiation has a significant effect upon their motion. Their orbits become non-Keplerian and many particles are lost as they spiral inward toward the Sun (the Poynting–Robertson effect). During a total solar eclipse in 1983, instruments carried by a balloon detected a ring-like concentration of dust only a couple of solar diameters from the Sun. Its inner edge apparently marks the point at which the Sun's heat vaporizes the infalling particles. The resulting tiny gas molecules, like the smallest particles of dust, are blown out of the solar system by the dominant radiation pressure and interactions with the solar wind.

Because of the above-mentioned influences on the sizes and motions of the dust particles, the estimated mean life of a cloud particle is about 10^5 years. Since this is much less than the age of the solar system, it is obvious that the cloud must be in a dynamic equilibrium. Part of the tail of a bright comet is due to significant quantities of dust ejected from its nucleus, and it is generally assumed that comets provide the main supply of new dust to the cloud. Since comet nuclei are believed to consist of the undifferentiated matter from which the solar system formed, the dust of the interplanetary cloud is most likely composed of this same low-density, fragile, primitive material. Collisions of asteroids may also provide dust, but the extent of this possible contribution is unknown.

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to May 21 (M21), and then at 10-day intervals through August 9 (A9). The faintest stars shown are of 9th magnitude. The comet fades from 6th magnitude at the beginning of the path, to 11th or 12th magnitude as it becomes lost in the evening twilight by mid-summer. For most observers with small telescopes in the Northern Hemisphere, the moon-free evenings in late May will be their last chance to see this famous comet (then near 10th magniude). Observers in the Southern Hemisphere should be able to follow it for a month or more longer. The three labelled stars are α Crateris, ν Hydrae, and μ Hydrae. The coordinates are for 1950.0 (RLB)

To an observer on Earth the most noticeable aspect of the dust cloud is meteors – larger particles of the cloud which encounter Earth and vaporize in its upper atmosphere. In addition, sunlight scattered by the dust cloud appears as a faint glow in the vicinity of the ecliptic. This glow is brightest toward the Sun, is due primarily to particles having diameters between a few micrometres and a millimetre, and is referred to as the *zodiacal light.* A slight brightening in the sky opposite the Sun, called the *Gegenschein* (German for "counter-glow"), is due to a phase effect (analogous to the full moon), and also possibly to a concentration of dust at the L3 Lagrangian point of the Earth-Sun system. As astronomical objects, the zodiacal light and Gegenschein are unusual in that they can be seen only with the unaided eye. Both are invisible in binoculars or a telescope.

The Zodiacal Light

Nearly a millenium ago the Persian astronomer-poet Omar Khayyam referred to the zodiacal light in the second quatrain of his *Rubaiyat.* As translated by the poet Edward FitzGerald, we have the haunting lines: "Dreaming when Dawn's Left Hand was in the Sky", and "Before the phantom of False morning died".

When conditions are favorable, the zodiacal light is indeed a mysterious and beautiful sight. It is best seen after the end of evening twilight and before the beginning of morning twilight (see page 60). Because the zodiacal light is brightest nearest the Sun, it is best seen when the ecliptic is at a steep angle relative to the horizon. In the tropics this is always the case and the short duration of twilight is an added advantage. At mid-northern latitudes the optimum geometry occurs in the evening western sky in February and March, and in the morning eastern sky in October. The zodiacal light appears as a huge, softly radiant pyramid of white light with its base near the horizon and its axis centered on the zodiac. In its brightest parts it exceeds the luminance of the central Milky Way.

Despite its brightness, many people have not seen the zodiacal light. As mentioned above, certain times of night and times of year are more favorable than others. In addition, moonlight, haze, or light pollution rule out any chance of seeing this phenomenon. Even with a dark, transparent sky the inexperienced observer may confuse the zodiacal light with twilight and thus ignore it, or he may not notice it because he is expecting a much smaller object.

The Gegenschein

Photometric measurements indicate that the zodiacal light extends all around the zodiac with a shallow minimum in brightness some 120° to 150° from the Sun; nevertheless, this "zodiacal band" or "light bridge" is exceedingly faint and hence rarely visible. However, the slight brightening in the vicinity of the anti-solar point can be seen under the right conditions.

The Gegenschein is very faint. The slightest haze, moonlight, bright nearby stars, planets, or light pollution will hide it completely. Most observers, including experienced ones, have not seen it. It is a ghostly apparition best seen near midnight and, in mid-northern latitudes, in the fall or winter when the anti-solar point is nearest the zenith. To avoid interference from bright stars or the Milky Way, observations should be restricted to the periods late September to early November, and late January to early February when the Gegenschein is in Pisces and Cancer respectively. It appears as a faint yet distinct, somewhat elliptical glow perhaps 10° in diameter. The luminance of the Gegenschein is about 10^{-4} cd/m^2, some ten orders of magnitude dimmer than the brightest light the human eye can tolerate.

STARS

CONSTELLATIONS

Nominative & Pronunciation	Genitive	Abbr.	Meaning
Andromeda, ăn-drŏm'ē-dȧ	Andromedae	And	Daughter of Cassiopeia
Antlia, ănt'lĭ-ȧ	Antliae	Ant	The Air Pump
Apus, ā'pŭs	Apodis	Aps	Bird of Paradise
Aquarius, ȧ-kwâr'ĭ-ŭs	Aquarii	Aqr	The Water-bearer
Aquila, ăk'wĭ-lȧ	Aquilae	Aql	The Eagle
Ara, ā'rȧ	Arae	Ara	The Altar
Aries, ā'rĭ-ēz	Arietis	Ari	The Ram
Auriga, ô-rī'gȧ	Aurigae	Aur	The Charioteer
Bootes, bō-ō'tēz	Bootis	Boo	The Herdsman
Caelum, sē'lŭm	Caeli	Cae	The Chisel
Camelopardalis kȧ-mĕl'ō-pȧr'dȧ-lĭs	Camelopardalis	Cam	The Giraffe
Cancer, kăn'sẽr	Cancri	Cnc	The Crab
Canes Venatici kā'nēz vē-năt'ĭ-sī	Canum Venaticorum	CVn	The Hunting Dogs
Canis Major, kā'nĭs mā'jẽr	Canis Majoris	CMa	The Big Dog
Canis Minor, kā'nĭs mī'nẽr	Canis Minoris	CMi	The Little Dog
Capricornus, kăp'rĭ-kôr'nŭs	Capricorni	Cap	The Horned Goat
Carina, kȧ-rī'nȧ	Carinae	Car	The Keel
Cassiopeia, kăs'ĭ-ō-pē'yȧ	Cassiopeiae	Cas	The Queen
Centaurus, sĕn-tô'rŭs	Centauri	Cen	The Centaur
Cepheus, sē'fūs	Cephei	Cep	The King
Cetus, sē'tŭs	Ceti	Cet	The Whale
Chamaeleon, kȧ-mē'lē-ŭn	Chamaeleontis	Cha	The Chameleon
Circinus, sûr'sĭ-nŭs	Circini	Cir	The Compasses
Columba, kō-lŭm'bȧ	Columbae	Col	The Dove
Coma Berenices kō'mȧ bĕr'ē-nī'sēz	Comae Berenices	Com	Berenice's Hair
Corona Australis kō-rō'nȧ ôs-trā'lĭs	Coronae Australis	CrA	The Southern Crown
Corona Borealis kō-rō'nȧ bō'rē-ā'lĭs	Coronae Borealis	CrB	The Northern Crown
Corvus, kôr'vŭs	Corvi	Crv	The Crow
Crater, krā'tẽr	Crateris	Crt	The Cup
Crux, krŭks	Crucis	Cru	The Cross
Cygnus, sĭg'nŭs	Cygni	Cyg	The Swan
Delphinus, dĕl-fī'nŭs	Delphini	Del	The Dolphin
Dorado, dō-rȧ'dō	Doradus	Dor	The Goldfish
Draco, drā'kō	Draconis	Dra	The Dragon
Equuleus, ē-kwo͞o'lē-ŭs	Equulei	Equ	The Little Horse
Eridanus, ē-rĭd'ȧ-nŭs	Eridani	Eri	A River
Fornax, fôr'năks	Fornacis	For	The Furnace
Gemini, jĕm'ĭ-nī	Geminorum	Gem	The Twins
Grus, grŭs	Gruis	Gru	The Crane (bird)
Hercules, hûr'kū-lēz	Herculis	Her	The Son of Zeus
Horologium, hŏr'ō-lō'jĭ-ŭm	Horologii	Hor	The Clock
Hydra, hī'drȧ	Hydrae	Hya	The Water Snake (♀)
Hydrus, hī'drŭs	Hydri	Hyi	The Water Snake (♂)

Nominative & Pronunciation	Genitive	Abbr.	Meaning
Indus, ĭn'dŭs	Indi	Ind	The Indian
Lacerta, lȧ-sûr'tȧ	Lacertae	Lac	The Lizard
Leo, lē'ō	Leonis	Leo	The Lion
Leo Minor, lē'ō mī'nẽr	Leonis Minoris	LMi	The Little Lion
Lepus, lē'pŭs	Leporis	Lep	The Hare
Libra, lī'brȧ	Librae	Lib	The Balance
Lupus, lū'pŭs	Lupi	Lup	The Wolf
Lynx, lĭnks	Lyncis	Lyn	The Lynx
Lyra, lī'rȧ	Lyrae	Lyr	The Lyre
Mensa, mĕn'sȧ	Mensae	Men	Table Mountain
Microscopium mī'krō-skō'pĭ-ŭm	Microscopii	Mic	The Microscope
Monoceros, mō-nŏs'ẽr-ŏs	Monocerotis	Mon	The Unicorn
Musca, mŭs'kȧ	Muscae	Mus	The Fly
Norma, nôr'mȧ	Normae	Nor	The Square
Octans, ŏk'tănz	Octantis	Oct	The Octant
Ophiuchus, ŏf'ĭ-ū'kŭs	Ophiuchi	Oph	The Serpent-bearer
Orion, ō-rī'ŏn	Orionis	Ori	The Hunter
Pavo, pā'vō	Pavonis	Pav	The Peacock
Pegasus, pĕg'ȧ-sŭs	Pegasi	Peg	The Winged Horse
Perseus, pûr'sūs	Persei	Per	Rescuer of Andromeda
Phoenix, fē'nĭks	Phoenicis	Phe	The Phoenix
Pictor, pĭk'tẽr	Pictoris	Pic	The Painter
Pisces, pĭs'ēz	Piscium	Psc	The Fishes
Piscis Austrinus pĭs'ĭs ôs-trī'nŭs	Piscis Austrini	PsA	The Southern Fish
Puppis, pŭp'ĭs	Puppis	Pup	The Stern
Pyxis, pĭk'sĭs	Pyxidis	Pyx	The Compass
Reticulum, rē-tĭk'ū-lŭm	Reticuli	Ret	The Reticle
Sagitta, sȧ-jĭt'ȧ	Sagittae	Sge	The Arrow
Sagittarius, săj'ĭ-tā'rĭ-ŭs	Sagittarii	Sgr	The Archer
Scorpius, skôr'pĭ-ŭs	Scorpii	Sco	The Scorpion
Sculptor, skŭlp'tẽr	Sculptoris	Scl	The Sculptor
Scutum, skū'tŭm	Scuti	Sct	The Shield
Serpens, sûr'pĕnz	Serpentis	Ser	The Serpent
Sextans, sĕks'tănz	Sextantis	Sex	The Sextant
Taurus, tô'rŭs	Tauri	Tau	The Bull
Telescopium tĕl'ē-skō'pĭ-ŭm	Telescopii	Tel	The Telescope
Triangulum, trī-ăng'gū-lŭm	Trianguli	Tri	The Triangle
Triangulum Australe trī-ăng'gū-lŭm ôs-trā'lē	Trianguli Australis	TrA	The Southern Triangle
Tucana, tū-kā'nȧ	Tucanae	Tuc	The Toucan
Ursa Major, ûr'sȧ mā'jẽr	Ursae Majoris	UMa	The Great Bear
Ursa Minor, ûr'sȧ mī'nẽr	Ursae Minoris	UMi	The Little Bear
Vela, vē'lȧ	Velorum	Vel	The Sails
Virgo, vûr'gō	Virginis	Vir	The Maiden
Volans, vō'lănz	Volantis	Vol	The Flying Fish
Vulpecula, vŭl-pĕk'ū-lȧ	Vulpeculae	Vul	The Fox

ā dāte; ă tăp; â câre; ȧ ȧsk; ē wē; ĕ mĕt; ẽ makẽr; ī īce; ĭ bĭt; ō gō; ŏ hŏt; ô ôrb; o͞o mo͞on; ū ūnite; ŭ ŭp; û ûrn.

FINDING LIST OF SOME NAMED STARS

Name	Con.	R.A.
Acamar, ā′kȧ-mȧr	θ Eri	02
Achernar, ā′kēr-nȧr	α Eri	01
Acrux, ā′krŭks	α Cru	12
Adara, ȧ-dā′rȧ	ϵ CMa	06
Al Na’ir, ăl-nâr′	α Gru	22
Albireo, ăl-bĭr′ē-ō	β Cyg	19
Alcor, ăl-kôr′	80 UMa	13
Alcyone, ăl-sī′ō-nē	η Tau	03
Aldebaran, ăl-dĕb′ȧ-rȧn	α Tau	04
Alderamin, ăl-dĕr′ȧ-mĭn	α Cep	21
Algeiba, ăl-jē′bȧ	γ Leo	10
Algenib, ăl-jē′nĭb	γ Peg	00
Algol, ăl′gŏl	β Per	03
Alioth, ăl′ĭ-ŏth	ϵ UMa	12
Alkaid, ăl-kād′	η UMa	13
Almach, ăl′măk	γ And	02
Alnilam, ăl-nī′lăm	ϵ Ori	05
Alphard, ăl′fȧrd	α Hya	09
Alphecca, ăl-fĕk′ȧ	α CrB	15
Alpheratz, ăl-fē′răts	α And	00
Altair, ăl-târ′	α Aql	19
Ankaa, ăn′kȧ	α Phe	00
Antares, ăn-tā′rēs	α Sco	16
Arcturus, ȧrk-tū′rŭs	α Boo	14
Atria, ā′trĭ-ȧ	α TrA	16
Avior, ă-vĭ-ôr′	ϵ Car	08
Bellatrix, bĕ-lā′trĭks	γ Ori	05
Betelgeuse, bĕt′ĕl-jūz	α Ori	05
Canopus, kȧ-nō′pŭs	αCar	06
Capella, kȧ-pĕl′ȧ	α Aur	05
Caph, kăf	β Cas	00
Castor, kȧs′tēr	α Gem	07
Cor Caroli, kôr kăr′ŏ-lī	α CVn	12
Deneb, dĕn′ĕb	α Cyg	20
Denebola, dĕ-nĕb′ō-lȧ	β Leo	11
Diphda, dĭf′dȧ	β Cet	00
Dubhe, dŭb′ē	α UMa	11
Elnath, ĕl′năth	β Tau	05
Eltanin, ĕl-tā′nĭn	γ Dra	17
Enif, ĕn′ĭf	ϵ Peg	21
Fomalhaut, fō′măl-ôt	α PsA	22
Gacrux, gȧ′krŭks	γ Cru	12
Gemma, jĕm′ȧ	α CrB	15
Gienah, jē′nȧ	γ Crv	12
Hadar, hăd′ȧr	β Cen	14
Hamal, hăm′ăl	α Ari	02
Kaus Australis, kôs ôs-trā′lĭs	ϵ Sgr	18
Kochab, kō′kăb	β UMi	14
Markab, mȧr′kăb	α Peg	23
Megrez, mē′grĕz	δ UMa	12
Menkar, mĕn′kȧr	α Cet	03
Menkent, mĕn′kĕnt	θ Cen	14
Merak, mē′răk	β UMa	11
Merope, mĕr′ō-pē	23 Tau	03
Miaplacidus, mī′ȧ-plăs′ĭ-dŭs	β Car	09
Mintaka, mĭn-tȧ′kȧ	δ Ori	05
Mira, mī′rȧ	o Cet	02
Mirach, mī′răk	β And	01
Mirfak, mĭr′făk	α Per	03
Mizar, mī′zȧr	ζ UMa	13
Nunki, nŭn′kē	σ Sgr	18
Peacock, pē′kŏk′	α Pav	20
Phecda, fĕk′dȧ	γ UMa	11
Polaris, pō-lâr′ĭs	α UMi	02
Pollux, pŏl′ŭks	β Gem	07
Procyon, prō′sĭ-ŏn	α CMi	07
Pulcherrima, pŭl-kĕr′ĭmȧ	ϵ Boo	14
Ras-Algethi, rȧs′ăl-jē′thē	α Her	17
Rasalhague, rȧs′ăl-hā′gwē	α Oph	17
Regulus, rĕg′ū-lŭs	α Leo	10
Rigel, rī′jĕl	β Ori	05
Rigil Kentaurus, rī′jĭl kĕn-tô′rŭs	α Cen	14
Sabik, sā′bĭk	η Oph	17
Scheat, shē′ăt	β Peg	23
Schedar, shĕd′ȧr	α Cas	00
Shaula, shô′lȧ	λ Sco	17
Sirius, sĭr′ĭ-ŭs	α CMa	06
Spica, spī′kȧ	α Vir	13
Suhail, sŭ-hāl′	λ Vel	09
Thuban, tho͞o′bȧn	α Dra	14
Vega, vē′gȧ	α Lyr	18
Zubenelgenubi, zo͞o-bĕn′ĕl-jĕ-nū′bē	α Lib	14

Key to pronunciation on p. 160.

THE BRIGHTEST STARS

BY ROBERT F. GARRISON

The 314 stars brighter than apparent magnitude 3.55

The table has been completely revised for this year. Every entry has been examined and most have been changed. The table has been created using Lotus 123 with an IBM-PC and has been printed camera-ready, so updates can be made yearly. The spectral classification column, especially, will therefore be a valuable resource for both professionals and amateurs.

Star. If the star is a visual double the letter A indicates that the data are for the brighter component. The brightness and separation of the second component B are given in the last column. Sometimes the double is too close to be conveniently resolved and the data refer to the combined light, AB; in interpreting such data the magnitudes of the two components must be considered.

Visual Magnitude (V). These magnitudes are based on photoelectric observations. The V filter is yellow and corresponds roughly to the response of the eye. The photometric system is that of Johnson and Morgan in *Ap. J.*, vol. 117, p. 313, 1953. It is as likely as not that the true magnitude is within 0.03 mag. of the quoted figure, on the average. Variable stars are indicated with a "v". The type of variability, range and period are given in the remarks.

Colour index (B–V). The blue magnitude, B, is the brightness of a star as observed photoelectrically through a blue filter. The difference B–V is therefore a measure of the colour of a star. There is a close relation between B–V and the spectral type, but some of the stars are reddened by interstellar dust. The probable error of a value of B–V is about 0.02 mag. at most.

Spectral Classification. A "temperature" type (O, B, A, F, G, K, M) is given first, followed by a finer subtype (0–9) and a "luminosity" class (Roman numerals I–V, with an "a" or "b" added occasionally to indicate slightly brighter or fainter). The sequences are in the sense that the O stars are hottest, M stars are coolest, Ia stars are the most luminous supergiants, III stars are giants and V stars are the most numerous; the V's are known as dwarfs or main-sequence stars. Other symbols used in this column are: "p" for peculiar; "e" for hydrogen emission; "m" for strong metallic lines; "f" for broad, non-hydrogen emission in hot stars; and "n" or "nn" for unusually broad lines (= rotation). The table now contains the best types available, either from the literature or from my own plates.

Parallax and Proper Motion. From "The Bright Star Catalogue" by Dorrit Hoffleit and Carlos Jaschek, *Yale University Observatory*, 1982. Parallaxes in which the decimal point is preceded by the letter "D" are "dynamical parallaxes" (i.e. determined through Kepler's laws rather than by trigonometric measurement). Proper motions given are the absolute value of the vector resultant from the individual-coordinate proper motions given in "The Bright Star Catalogue".

Absolute Visual Magnitude and Distance in Light Years. If the parallax is greater than 0″.1 the distance and absolute magnitude correspond to this trigonometric parallax. Otherwise a generally more accurate absolute magnitude and distance were obtained from a new (by the author, unpublished) calibration of the spectral classification; distances determined in this way are called "spectroscopic parallaxes." The effect of the absorption of light was corrected by comparing the spectral classification and the B–V, using an intrinsic-colour calibration by the author (unpublished).

Radial Velocity. From "The Bright Star Catalogue" referenced above. The symbol "V" indicates variable velocity and an orbit is usually not known. On the other hand, "SB" indicates a spectroscopic binary, which is an unresolved system whose duplicity is revealed by periodic oscillations of the lines in its spectrum and an orbit is generally known. If the lines of both stars are detectable, the symbol "SB2" is used.

Remarks. These contain data on companions and variability as well as notes on the spectra. Traditional names have been selected from "The Bright Star Catalogue" and there are more than in previous editions.

	Right Ascension (Hours, Minutes)	Declination (Degrees, Minutes)	Visual Magnitude	Colour Index	Spectral Classification	Parallax	Absolute Magnitude	Distance (Light Years)	Proper Motion	Radial Velocity		
Star Name	R.A. 1986	Dec	V	B - V	MK Type	PI(")	M(V)	D(ly)	MU(")	RV(km/s)	Remarks	
Sun			-26.73	0.63	G2 V	-----	+4.8	8 lm	-----	varies		Sun
α And	00 07.6	+29 01	2.1v	-0.11	B8.5p IV:(HgMn)	0.032	-0.4	103	0.209	-12 SB	Manganese star	Alpheratz
β Cas	00 08.5	+59 05	2.3v	0.34	F2 III-IV	0.072	2.0	37	0.555	+11 SB	var:2.25-3.31,0.10d	Caph
γ Peg	00 12.5	+15 07	2.8v	-0.23	B2 IV	0.000	-3.1	493	0.008	+ 4 SB	var:2.80-2.87,0.15d	Algenib
β Hyi	00 25.1	-77 20	2.80	0.62	G1 IV	0.159	3.8	20	2.255	+23		
α Phe	00 25.6	-42 23	2.39	1.09	K0 IIIb	0.039	0.7	62	0.442	+75 SB		Ankaa
δ And A	00 38.6	+30 47	3.27	1.28	K3 III	0.028	-0.3	166	0.161	- 7 SB		
α Cas	00 39.7	+56 28	2.23	1.17	K0 IIIa	0.016	-0.8	107	0.058	- 4 V?		Shedir
β Cet	00 42.9	-18 04	2.04	1.02	G9.5 III	0.061	0.3	70	0.234	+13		Diphda
η Cas A	00 48.3	+57 45	3.44	0.57	G0 V	0.176	4.7	18	1.218	+ 9 SB	B: 7.51, K4 Ve, 12"	
γ Cas	00 55.9	+60 39	2.5v	-0.15	B0 IVnpe(shell)	0.016	-4.7	730	0.026	- 7 SB	var: 1.6-3.0; B: 8.8,2"	
β Phe AB	01 05.5	-46 47	3.31	0.89	G8 III	0.021	0.3	130	0.030	- 1	AB similar in light, spectrum, 1"	
η Cet	01 07.9	-10 15	3.45	1.16	K1.5 III CN1	0.041	0.1	144	0.250	+12		
β And	01 09.0	+35 33	2.06	1.58	M0 IIIa	0.049	-1.6	173	0.210	+ 3 V		Mirach
δ Cas	01 24.9	+60 10	2.7v	0.13	A5 IV	0.037	1.4	59	0.303	+ 7 SB	ecl.? 2.68-2.76, 759d	Ruchbah

Star Name	R.A. 1986	Dec	V	B - V	MK Type	PI(")	M(V)	D(ly)	MU(")	RV(km/s)	Remarks
γ Phe	01 27.8	-43 23	3.4v	1.57	K7 IIIa	0.000	-1.4	285	0.204	+26 SB	var: 3.39-3.49
α Eri	01 37.2	-57 18	0.46	-0.16	B3 Vnp (shell)	0.026	-1.3	69	0.108	+16 V	Achernar
τ Cet	01 43.4	-16 01	3.50	0.72	G8 V	0.287	5.8	11	1.921	-16	
α Tri	01 52.3	+29 31	3.41	0.49	F6 IV	0.057	2.6	46	0.230	-13 SB	Metallah
ε Cas	01 53.4	+63 36	3.38	-0.15	B3 IV:p(shell)	0.010	-2.4	436	0.036	- 8 V	Segin
β Ari	01 53.9	+20 45	2.64	0.13	A5 V	0.074	1.8	48	0.145	- 2 SB	Sharatan
α Hyi	01 58.3	-61 38	2.86	0.28	A9 III-IVn	0.048	1.7	55	0.271	+ 1 V	
γ And A	02 03.1	+42 16	2.26	1.37	K3 IIb	0.013	1.8	42	0.066	-12 SB	B:5.4,B9V,10";C:6.2,A0V;BC1" Almaak
α Ari	02 06.4	+23 24	2.00	1.15	K2 IIIab	0.049	0.1	78	0.238	-14 SB	Calcium weak? Hamal
β Tri	02 08.7	+34 55	3.00	0.14	A5 IV	0.022	1.3	71	0.153	+10 SB2	
α UMi A	02 17.8	+89 12	2.0v	0.60	F5-8 Ib	0.007	-5.1	823	0.046	-17 SB	Cep1.9-2.1,4d;B:8.2,F3V,18" Polaris
o Cet A	02 18.7	- 3 02	2-10v	1.42	M5.5-9 IIIe	0.024	-0.5	196	0.232	+64 V	LPV,2-10;B:VZ Cet,9.5v,Bpe,1" Mira
γ Cet AB	02 42.6	+ 3 11	3.47	0.09	A2 V	0.052	1.4	82	0.203	- 5 V	A:3.57; B:6.23, 3" Kaffaljidhma
θ Eri A	02 57.8	-40 22	3.24	0.14	A5 IV	0.035	1.3	93	0.065	+12 SB2	B: 4.35, A1 V, 8" Acamar
α Cet	03 01.6	+ 4 02	2.53	1.64	M1.5 IIIa	0.009	-1.5	197	0.075	-26	Menkar
γ Per	03 03.8	+53 27	2.93	0.70	G8 III + A2 V	0.016	0.3	105	0.002	+ 3 SB	composite spectrum
ρ Per	03 04.3	+38 47	3.4v	1.65	M4 II	0.011	-2.6	496	0.165	+28	semi-regular var: 3.3-4.0
β Per	03 07.3	+40 54	2.1v	-0.05	B8 V + F:	0.045	0.1	75	0.004	+ 4 SB	ecl:2.12-3.4,2.87d;composite Algol
α Per	03 23.4	+49 49	1.79	0.48	F5 Ib	0.016	-5.1	633	0.033	- 2 V	in cluster Mirphak
δ Per	03 42.0	+47 45	3.01	-0.13	B5 IIIn	0.016	-2.2	340	0.042	+ 4 SB	
δ Eri	03 42.6	- 9 49	3.54	0.92	K0 IV	0.113	3.8	29	0.752	- 6	
η Tau	03 46.7	+24 04	2.87	-0.09	B7 IIIn	0.008	-1.5	231	0.048	+10 V?	in Pleiades Alcyone
γ Hyi	03 47.4	-74 17	3.24	1.62	M2 III	0.005	-1.1	234	0.128	+16	
ζ Per A	03 53.3	+31 51	2.85	0.12	B1 Ib	0.010	-5.8	1125	0.011	+20 SB	B: 9.16, B8 V, 13"
ε Per A	03 56.9	+39 58	2.89	-0.18	B0.5 IV	0.009	-4.2	743	0.029	+ 1 SB2	B: 7.39, B9.5 V, 9"
γ Eri	03 57.4	-13 33	2.95	1.59	M0.5 III-IIIb	0.010	-0.7	168	0.124	+62	Calcium, Chromium weak Zaurak
λ Tau A	03 59.9	+12 27	3.5v	-0.12	B3 V	0.002	-1.3	266	0.011	+18 SB2	ecl: 3.3-3.8, 3.95d; B:A4 IV
α Ret A	04 14.3	-62 30	3.35	0.91	G8 II-III	0.013	-0.9	231	0.068	+36 SB?	
ε Tau	04 27.8	+19 09	3.53	1.01	K1 III	0.020	0.2	149	0.114	+39	in Hyades Ain
θ^2 Tau	04 27.9	+15 51	3.40	0.18	A7 III	0.029	1.1	94	0.105	+40 SB	in Hyades

Star Name	R.A. 1986	Dec	V	B − V	MK Type	PI(")	M(V)	D(ly)	MU(")	RV(km/s)	Remarks
α Dor AB	04 33.7	-55 04	3.27	-0.10	A0p III:(Si)	0.018	0.0	188	0.051	+26	A: 3.8; B: 4.3, B9 IV, 0.2"
α Tau A	04 35.1	+16.29	0.85	1.54	K5 III	0.054	-0.3	52	0.200	+54 SB	var:0.75-0.95;in Hyades Aldebaran
π^3 Ori	04 49.1	+ 6 56	3.19	0.45	F6 V	0.137	3.9	24	0.463	+24 SB2	
ι Aur	04 56.1	+33 09	2.69	1.53	K3 II	0.021	-2.0	236	0.018	+18	Hassaleh var?
ε Aur A	05 01.0	+43 48	3.04	0.54	A9 Iae + B	0.007	-7.8	2762	0.004	- 3 SB	ecl:2.94-3.83,9892d Al Anz
ε Lep	05 04.9	-22 23	3.19	1.46	K5 III	0.011	-0.3	163	0.073	+ 1	
η Aur	05 05.6	+41 13	3.17	-0.18	B3 V	0.022	-1.3	248	0.073	+ 7 V?	Hoedus II
β Eri	05 07.2	- 5 06	2.79	0.13	A3 IIIn	0.050	0.5	89	0.128	- 9	Kursa
μ Lep	05 12.3	-16 13	3.1v	-0.11	B9p IV:(HgMn)	0.023	-0.2	149	0.043	+28	var:2.97-3.36, 2d
β Ori A	05 13.9	- 8 13	0.12	-0.03	B8 Iae	0.013	-7.1	906	0.004	+21 SB	B:7.6,B5 V,9";C:7.6,BC:0.1" Rigel
α Aur AB	05 15.6	+45 59	0.08	0.80	G6:III + G2:III	0.080	0.4	36	0.430	+30 SB	composite;A:0.6;B:1.1,0.04"Capella
η Ori AB	05 23.8	- 2 25	3.3v	-0.17	B1 IV + B	0.007	-3.8	853	0.003	+20 SB2	ecl:3.14-3.35,8d; A:3.6;B:5.0,1.6"
γ Ori	05 24.4	+ 6 20	1.64	-0.22	B2 III	0.029	-3.9	407	0.018	+18 SB?	Bellatrix
β Tau	05 25.4	+28 36	1.65	-0.13	B7 III	0.028	-1.5	139	0.178	+ 9 V	Alnath
β Lep A	05 27.7	-20 46	2.84	0.82	G5 II	0.020	-2.1	320	0.090	-14	B:7.4, 2.6"
δ Ori A	05 31.3	- 0 19	2.23	-0.22	09.5 II	0.014	-5.8	1178	0.002	+16 SB	ecl:1.94-2.13,5.7d Mintaka
α Lep	05 32.1	-17 50	2.58	0.21	F0 Ib	0.007	-5.1	1090	0.006	+24	Arneb
β Dor	05 33.5	-62 30	3.4v	0.82	F7-G2 Ib	0.012	-5.1	819	0.007	+ 7 V	Cepheid: 3.46-4.08, 9.8d
λ Ori A	05 34.4	+ 9 56	3.54	-0.18	08 III	0.007	-5.8	2184	0.006	+34	B: 5.61, B0 V, 4" Meissa
ι Ori A	05 34.8	- 5 55	2.77	-0.24	09 III	0.025	-5.6	1410	0.005	+22 SB2	B:7.3,B7IIIp(Hewk),11"Nair al Saif
ε Ori	05 35.5	- 1 13	1.70	-0.19	B0 Ia	0.000	-7.0	1685	0.004	+26 SB	Alnilam
ζ Tau	05 36.8	+21 08	3.0v	-0.19	B2 IIIpe(shell)	0.008	-4.0	826	0.023	+20 SB	var:2.90-3.03; B:5.0,0.0007"
α Col A	05 39.2	-34 05	2.64	-0.12	B7 IV	0.001	-1.1	178	0.026	+25 V?	Phaet
ζ Ori A	05 40.1	- 1 57	2.05	-0.21	09.5 Ib	0.024	-6.2	1463	0.002	+18 SB	B: 4.2, B0 III, 2.4" Alnitak
ζ Lep	05 46.3	-14 50	3.55	0.10	A2 IVn	0.049	1.0	97	0.023	+20 SB?	
κ Ori	05 47.1	- 9 40	2.06	-0.17	B0.5 Ia	0.015	-7.0	2001	0.006	+21 V?	Saiph
β Col	05 50.5	-35 46	3.12	1.16	K1.5 III	0.028	0.1	122	0.405	+89 V	Wezn
α Ori	05 54.4	+ 7 24	0.4v	1.85	M2 Iab	0.005	-5.2	354	0.028	+21 SB	var: 0.4-1.3 Betelgeuse
β Aur	05 58.5	+44 57	1.90	0.03	A1 IV	0.041	0.7	55	0.055	-18 SB2	ecl:1.93-2.02,4d(=mags) Menkalinan
θ Aur AB	05 58.8	+37 13	2.62	-0.08	A0p III:(Si)	0.022	0.0	110	0.097	+30 SB	B: 7.2, G2 V, 4"

Star Name	R.A. 1986	Dec	V	B - V	MK Type	PI(")	M(V)	D(1y)	MU(")	RV(km/s)	Remarks	
η Gem	06 14.1	+22 31	3.3v	1.60	M3 III	0.014	-0.7	206	0.068	+19 SB	var: 3.3-3.9; B: 8.8, 1.6"	Propus
ζ CMa	06 19.8	-30 03	3.02	-0.19	B2.5 V	0.004	-1.6	263	0.006	+32 SB		Phurud
μ Gem	06 22.1	+22 31	2.8v	1.64	M3 IIIab	0.020	-1.1	188	0.125	+55	var:2.76-3.02	Tejat Posterior
β CMa	06 22.1	-17 57	2.0v	-0.23	B1 II-III	0.019	-4.9	750	0.014	+34 SB	var:1.93-2.00, 0.25d	Murzim
α Car	06 23.7	-52 41	-0.72	0.15	A9 II	0.028	-2.5	74	0.034	+21		Canopus
γ Gem	06 36.9	+16 25	1.93	0.00	A1 IVs	0.037	0.7	57	0.061	-13 SB		Alhena
ν Pup	06 37.3	-43 11	3.17	-0.11	B8 IIIn	-----	-1.2	244	0.010	+28 SB		
ε Gem	06 43.1	+25 09	2.98	1.40	G8 Ib	0.017	-1.2	156	0.016	+10 SB		Mebsuta
ξ Gem	06 44.5	+12 55	3.36	0.43	F5 IV	0.055	-4.0	940	0.224	+25 V?		Alzirr
α CMa A	06 44.6	-16 42	-1.46	0.01	A0mA1 Va	0.378	1.4	9	1.324	- 8 SB	B:8.5, WDA, 50y, 10"(1980)	Sirius
α Pic	06 48.1	-61 56	3.27	0.21	A6 Vn	0.052	2.1	53	0.275	+21		
τ Pup	06 49.6	-50 36	2.93	1.20	K1 III	-----	0.1	100	0.079	+36 SB		
ε CMa A	06 58.1	-28 57	1.50	-0.21	B2 II	D.001	-4.8	569	0.002	+27		Adara
σ CMa	07 01.2	-27 55	3.4v	1.73	K7 Ib	0.024	-4.0	834	0.008	+22	var:3.43-3.49	
o^2 CMa	07 02.5	-23 49	3.02	-0.08	B3 Iab	-----	-6.3	2224	0.007	+48 SB		
δ CMa	07 07.8	-26 22	1.84	0.68	F8 Ia	0.000	-8.0	2566	0.008	+34 SB		Wezen
L_2 Pup	07 13.1	-44 37	2.6v	1.56	M5 IIIe	0.022	-1.3	196	0.346	+53 V?	Long Period Var: 2.6-6.2	HR2748
π Pup	07 16.7	-37 04	2.70	1.62	K3 Ib	0.032	-4.0	572	0.012	+16		
δ Gem AB	07 19.3	+22 00	3.53	0.34	F0 IV	0.061	2.2	57	0.029	+ 4 SB	B: 8.2, K3 V, 0.2"	Wasat
η CMa	07 23.6	-26 17	2.45	-0.08	B5 Ia	-----	-7.0	2531	0.008	+41		Aludra
β CMi	07 26.4	+ 8 19	2.90	-0.09	B8 V	0.019	0.1	115	0.065	+22 SB		Gomeisa
σ Pup A	07 28.8	-43 16	3.25	1.51	K5 III	0.020	-0.3	165	0.195	+88 SB	B: 8.6, G5: V, 22"	
α Gem A	07 33.7	+31 55	1.94	0.03	A1 V	0.067	1.2	55	0.199	+ 6 SB	AB: 2" separation	Castor
α Gem B	07 33.7	+31 55	2.92	0.04	A2mA5	0.067	1.4	55	0.199	- 1 SB	BA: 2" separation	Castor
α CMi A	07 38.6	+ 5 16	0.38	0.42	F5 IV-V	0.292	2.7	11	1.248	- 3 SB	B: 10.3, 4"	Procyon
β Gem	07 44.5	+28 04	1.14	1.00	K0 IIIb	0.094	0.7	40	0.629	+ 3 V		Pollux
ξ Pup	07 48.7	-24 50	3.34	1.24	G6 Ib	0.003	-4.2	797	0.033	+ 3 SB		
χ Car	07 56.4	-52 57	3.47	-0.18	B3 IVp(note)	0.004	-2.4	473	0.042	+19 V	Si II strong	
ζ Pup	08 03.1	-29 58	2.25	-0.26	O5 Iafn	-----	-6.8	1964	0.033	-24 V?		Naos
ρ Pup	08 07.0	-24 16	2.7v	0.43	F6 IIp(var.)	0.035	-2.0	284	0.100	+46 SB	delta Del spec;var:2.68-2.78,0.14d	

Star Name	R.A. 1986	Dec	V	B - V	MK Type	PI(")	M(V)	D(1y)	MU(")	RV(km/s)	Remarks
γ^2 Vel	08 09.1	-47 18	1.7v	-0.22	WC8 + 09 I:	0.017	-6.7	1539	0.007	+35 SB2	var:1.6-1.8, 154s Suhail al Muhlif
β Cnc	08 15.8	+ 9 14	3.52	1.48	K4 III	0.012	-0.2	162	0.068	+22	Altarf
ε Car	08 22.2	-59 28	1.86	1.28	K3:III + B2:V	-----	-0.1	79	0.030	+ 2	ecl? 3.1-3.4, 785d Avior
ο UMa A	08 29.2	+60 46	3.4v	0.84	G5 III	0.009	0.5	124	0.171	+20	var:3.3-3.8, 358d
δ Vel AB	08 44.3	-54 40	1.96	0.04	A1 IV	0.051	0.7	59	0.082	+ 2 V?	B: 5.0, 2"
ε Hya ABC	08 46.1	+ 6 28	3.38	0.68	G5:III + A:	0.027	0.5	147	0.198	+36 SB	compositeA:3.8;B:4.7,0.2";C:7.8,3"
ζ Hya	08 54.7	+ 6 00	3.11	1.00	G9 II-III	0.035	-1.0	216	0.101	+23	
ι UMa A	08 58.3	+48 06	3.14	0.19	A7 IVn	0.075	1.7	63	0.501	+ 9 SB	BC: 10.8, M1 V, 4" Talitha
λ Vel	09 07.5	-43 22	2.21	1.66	K4 Ib-IIa	0.022	-3.3	330	0.026	+18	var: 2.14-2.22 Suhail
a Car	09 10.6	-58 55	3.44	-0.19	B2 IV-V	-----	-2.6	498	0.028	+23 SB2	ecl: 3.2-3.6, 6.7d HR3659
β Car	09 13.1	-69 40	1.68	0.00	A1 III	0.021	0.2	64	0.183	- 5 V?	Miaplacidus
ι Car	09 16.7	-59 13	2.2v	0.18	A8 II	0.017	-2.6	304	0.019	+13	var: 2.2-2.5 Turais
α Lyn	09 20.2	+34 27	3.13	1.55	K7 IIIab	0.025	-0.5	169	0.223	+38	
κ Vel	09 21.7	-54 57	2.50	-0.18	B2 IV-V	0.013	-3.3	434	0.012	+22 SB	
α Hya	09 26.9	- 8 36	1.98	1.44	K3 II-III	0.022	-1.0	112	0.034	- 4 V?	Alphard
N Vel	09 30.8	-56 58	3.13	1.55	K5 III	0.022	-0.3	148	0.034	-14	HR3803
θ UMa	09 32.0	+51 44	3.17	0.46	F6 IV	0.068	2.6	42	1.094	+15 SB	
ο Leo AB	09 40.4	+ 9 57	3.52	0.49	F5 II + A5?	0.034	-2.3	593	0.149	+27 SB	A:occ.bin.(=mags) Subra
ε Car	09 44.9	-62 26	3.4v	1.22	F9-G5 Ib	0.027	-5.1	754	0.016	+ 3 V	Cepheid var:3.38-4.10, 35d HR3884
1 Leo	09 45.1	+23 50	2.98	0.80	G1 II	0.010	-2.3	351	0.048	+ 4 V?	Ras Elased Australis
υ Car AB	09 46.8	-65 01	3.01	0.28	A5 Ib	0.027	-5.1	1074	0.012	+14	B:6.26,B7 III, 5"
φ Vel	09 56.4	-54 30	3.54	-0.08	B5 Ib	-----	-5.4	1946	0.013	+14	
η Leo	10 06.6	+16 50	3.52	-0.03	B9 Ib	0.003	-5.2	1808	0.006		B: 4.5, 0.1"
α Leo A	10 07.7	+12 02	1.35	-0.11	B7 Vn	0.045	-0.3	69	0.248	+ 6 SB	Regulus
ω Car	10 13.4	-69 58	3.32	-0.08	B8 IIIn	-----	-1.2	251	0.032	+ 7 V	
ζ Leo	10 15.9	+23 29	3.44	0.31	F0 III	0.017	1.5	77	0.023	-16 SB	Adhafera
λ UMa	10 16.3	+42 59	3.45	0.03	A1mA2 IV-V	0.030	1.0	101	0.170	+18 V	Tania Borealis
q Car	10 16.6	-61 16	3.4v	1.54	K3 IIa	0.027	3.0	35	0.027	+ 8	var: 3.36-3.42 HR4050
γ Leo A	10 19.2	+19 55	2.61	1.15	K1 IIIb Fe-0.5	0.022	0.7	76	0.342	-37 SB	AB: 5" separation Algieba
γ Leo B	10 19.2	+19 55	3.47	1.10	G7 III Fe-1	0.022	0.8	76	0.358	-36 V	BA: 5" separation Algieba

Star Name	R.A. 1986	Dec	V	B - V	MK Type	PI(")	M(V)	D(ly)	MU(")	RV(km/s)	Remarks
μ UMa	10 21.5	+41 34	3.05	1.59	M0 IIIp	0.035	-0.7	173	0.088	-21 SB	Ca II emission Tania Australis
p Car	10 31.5	-61 37	3.3v	-0.09	B4 Vne	-----	-1.1	218	0.021	+26	var: 3.27-3.37 HR4140
θ Car	10 42.5	-64 19	2.76	-0.22	B0.5 Vp	-----	-3.5	536	0.022	+24 SB	Nitrogen enhanced
μ Vel AB	10 46.2	-49 21	2.69	0.90	G5 III + F8:V	D.022	0.8	75	0.085	+ 6 SB	B: 6.4, 2"
ν Hya	10 49.0	-16 07	3.11	1.25	K2 III	0.028	0.1	115	0.215	- 1	
β UMa	11 01.0	+56 27	2.37	-0.02	A0mA1 IV-V	0.053	0.7	70	0.087	-12 SB	Merak
α UMa AB	11 02.9	+61 49	1.79	1.07	K0 IIIa	0.038	-0.8	104	0.138	- 9 SB	A: 1.86, B: 4.8, A8 V, <1" Dubhe
ψ UMa	11 08.9	+44 34	3.01	1.14	K1 III	-----	0.2	108	0.075	- 4	
δ Leo	11 13.4	+20 36	2.56	0.12	A4 V	0.048	1.6	51	0.197	-20 V	Zosma
θ Leo	11 13.5	+15 30	3.34	-0.01	A2 Vs	0.026	1.4	80	0.104	+ 8 V	Chort
ν UMa	11 17.8	+33 10	3.48	1.40	K3 III Ba0.3	0.020	0.0	135	0.036	- 9 SB	B: 9.5, 7" Alula Borealis
ξ Hya	11 32.3	-31 47	3.54	0.94	G7 III	0.027	0.4	131	0.211	- 5 V	
λ Cen	11 35.2	-62 57	3.13	-0.04	B9 III	-----	-0.6	174	0.039	- 1 V	
β Leo	11 48.4	+14 39	2.14	0.09	A3 V	0.082	1.5	44	0.511	- 0 V	Denebola
γ UMa	11 53.1	+53 46	2.44	0.00	A0 IV-Vn	0.028	0.5	80	0.094	-13 SB	Phad
δ Cen	12 07.7	-50 39	2.5v	-0.12	B2 IVne	0.026	-3.1	369	0.034	+11 V	var: 2.51-2.65
ε Crv	12 09.4	-22 32	3.00	1.33	K3 IIIa	0.027	-0.8	180	0.073	+ 5	Minkar
δ Cru	12 14.4	-58 40	2.80	-0.23	B2 IV	0.003	-3.1	493	0.039	+22 V?	var: 2.25-2.31, 3.7h
δ UMa	12 14.8	+57 06	3.31	0.08	A2 IV-Vn	0.061	1.2	82	0.102	-13 V	Megrez
γ Crv	12 15.1	-17 28	2.59	-0.11	B8p III:(HgMn)	-----	-1.2	187	0.163	- 4 SB	Gienah Ghurab
α Cru A	12 25.8	-63 01	1.33	-0.24	B0.5 IV	D.008	-4.2	510	0.030	-11 SB	AB: 5" Acrux
α Cru B	12 25.9	-63 02	1.73	-0.26	B1 Vn	D.008	-3.2	510	0.031	- 1	BA: 5" Acrux
δ Crv A	12 29.2	-16 26	2.95	-0.05	B9.5 III	0.024	-0.3	146	0.255	+ 9 V	B: 8.26, K2 V, 24" Algorab
γ Cru	12 30.4	-57 02	1.63	1.59	M3.5 III	-----	-1.2	117	0.269	+21	var: 1.6-1.9 Gacrux
β Crv	12 33.7	-23 19	2.65	0.89	G5 II	0.034	-2.3	306	0.059	- 8	Kraz
α Mus	12 36.4	-69 04	2.69	-0.20	B2 IV-V	-----	-2.5	341	0.043	+13	var: 2.17-2.24, 2h
γ Cen A	12 40.8	-48 53	2.87	-0.03	B9.5 III	0.016	-0.3	188	0.190	- 6 SB	AB: 5"
γ Cen B	12 40.7	-48 53	2.96	0.01	A0 III	0.016	0.0	188	0.190	- 6 SB	BA: 5"
γ Vir AB	12 41.0	- 1 23	2.76	0.36	F1 V + F1 V	0.099	2.6	68	0.567	-20 SB	A: 3.48, B: 3.50, 4" Porrima
β Mus AB	12 45.4	-68 02	3.05	-0.18	B2 V + B2.5 V	D.015	-1.9	517	0.041	+42 V	A:3.58; B:4.10; 1"

Star Name	R.A. 1986	Dec	V	B - V	MK Type	PI(")	M(V)	D(ly)	MU(")	RV(km/s)	Remarks
β Cru	12 46.9	-59 37	1.2v	-0.23	B0.5 III	-----	-4.7	460	0.042	+16 SB	var:1.23-1.31,0.7d? Becrux, Mimosa
ε UMa	12 53.4	+56 02	1.8v	-0.02	A0p IV:(CrEu)	0.009	0.3	65	0.109	- 9 SB?	var: 1.76-1.79, 5.1d Alioth
δ Vir	12 54.9	+ 3 28	3.38	1.58	M3 III	0.022	-1.2	269	0.474	-18 V?	Auva
α^2 CVn A	12 55.4	+38 23	2.9v	-0.12	A0pIII:(SiEuSr)	0.027	0.0	130	0.242	- 3 V	B: 5.6, F0 V, 20m Cor Caroli
ε Vir	13 01.5	+11 02	2.83	0.94	G9 IIIab	0.043	0.3	104	0.274	-14	Vindamiatrix
γ Hya	13 18.2	-23 06	3.00	0.92	G8 IIIa	0.027	-0.8	188	0.081	- 5 V?	
ι Cen	13 19.8	-36 38	2.75	0.04	A2 V	0.062	1.4	61	0.351	0	
ζ UMa A	13 23.4	+55 00	2.27	0.02	A1p IV:(Si)	0.047	0.7	74	0.122	- 6 SB2	B: 3.94, A1mA7, 14" Mizar
α Vir	13 24.5	-11 05	1.0v	-0.23	B1 V	0.023	-3.2	216	0.054	+ 1 SB2	var0.97-1.04;mult3.1,4.5,7.5 Spica
ζ Vir	13 34.0	- 0 32	3.37	0.11	A3 IV-Vn	0.044	1.4	79	0.287	-13	Heze
ε Cen	13 39.0	-53 24	2.3v	-0.22	B1 III	-----	-4.4	675	0.028	+ 3	
η UMa	13 47.0	+49 23	1.86	-0.19	B3 V	0.035	-1.3	138	0.127	-11 SB?	Alkaid
ν Cen	13 48.7	-41 37	3.41	-0.22	B2 IV	-----	-3.1	644	0.035	+ 9 SB	
μ Cen	13 48.8	-42 24	3.0v	-0.17	B2 IV-V pne	-----	-2.5	378	0.034	+ 9 SB	variable shell: 2.92-3.43
η Boo	13 54.0	+18 28	2.68	0.58	G0 IV	0.108	2.8	31	0.370	- 0 SB	Mufrid
ζ Cen	13 54.7	-47 13	2.55	-0.22	B2.5 IV	-----	-2.7	366	0.072	+ 7 SB2	
β Cen AB	14 02.9	-60 19	0.6v	-0.23	B1 III	0.009	-4.4	320	0.030	+ 6 SB	var: 0.61-0.68; B: 3.9, 1" Hadar
π Hya	14 05.6	-26 37	3.27	1.12	K2 IIIb	0.049	0.7	104	0.049	+27	
θ Cen	14 05.9	-36 18	2.06	1.01	K0 IIIb	0.065	0.7	56	0.738	+1	Menkent
α Boo	14 15.0	+19 15	-0.04	1.23	K1.5 III Fe-0.5	0.097	0.2	25	2.281	- 5 V?	high space velocity Arcturus
ι Lup	14 18.5	-46 00	3.55	-0.18	B2.5 IVn	-----	-2.7	549	0.014	+22	
γ Boo	14 31.5	+38 22	3.03	0.19	A7 III-IV	0.025	1.9	53	0.189	-37 V	Seginus
η Cen	14 34.6	-42 06	2.4v	-0.19	B1.5 IV pne	-----	-3.5	454	0.049	- 0 SB	variable shell
α Cen A	14 38.7	-60 47	-0.01	0.71	G2 V	0.750	4.4	4	3.678	-25 SB	AB: 21" Rigil Kentaurus
α Cen B	14 38.7	-60 47	1.33	0.88	K4 V	0.750	5.7	4	3.678	-21 V?	BA:21"; C:Proxima, 12.4, M5e, 2deg
α Lup	14 41.0	-47 20	2.3v	-0.20	B1.5 III	-----	-4.1	580	0.026	+ 5 SB	var: 2.28-2.31, 0.26d
α Cir	14 41.4	-64 55	3.19	0.24	A7p (Sr)	0.056	2.0	55	0.302	+ 7 SB?	B: 8.6, K5 V, 16"
ε Boo AB	14 44.4	+27 08	2.37	0.97	K0 II-III+A0 V	0.016	-1.0	162	0.054	-17 V	A: 2.70; B: 5.12, 3" Izar
α Lib A	14 50.1	-50 59	2.75	0.15	A3 IV	0.058	1.2	61	0.130	-10 SB	Zuben Elgenubi
β UMi	14 50.7	+74 13	2.08	1.47	K4 III	0.039	-0.2	83	0.036	+17 V	Kocab

Star Name	R.A. 1986	Dec	V	B - V	MK Type	PI(")	M(V)	D(ly)	MU(")	RV(km/s)	Remarks
β Lup	14 57.6	-43 05	2.68	-0.22	B2 IV	-----	-3.1	460	0.057	+ 0 SB	
κ Cen	14 58.3	-42 03	3.13	-0.20	B2 V	-----	-1.9	317	0.033	+ 8 SB	
β Boo	15 01.4	+40 27	3.50	0.97	G8 IIIa(note)	0.037	-0.8	230	0.056	-20	Ba 0.4, Fe -0.5. Nekkar
σ Lib	15 03.3	-25 14	3.3v	1.70	M4 III	0.064	-1.0	211	0.087	- 4	var: 3.20-3.36 Brachium
ζ Lup	15 11.3	-52 03	3.41	0.92	G8 III	0.043	0.3	133	0.128	-10	
δ Boo	15 15.0	+33 22	3.47	0.95	G8 III Fe-1	0.030	0.3	138	0.143	-12 SB	
β Lib	15 16.3	- 9 20	2.61	-0.11	B8 Vn	0.000	0.1	104	0.101	-35 SB	Zuben Elschemali
γ TrA	15 17.6	-68 38	2.89	0.00	A1 IIIn	0.010	0.2	112	0.067	- 3 V	
δ Lup	15 20.5	-40 36	3.2v	-0.22	B1.5 IVn	-----	-3.4	653	0.036	+ 0 V?	
γ UMi	15 20.7	+71 53	3.05	0.05	A2.5 III	0.003	0.4	110	0.031	- 4 V	Pherkad
ε Lup AB	15 21.8	-44 39	3.37	-0.18	B2 IV-V	D.009	-2.5	510	0.024	+ 8 SB2	A: 3.5; B: 5.0, <1"
ι Dra	15 24.6	+59 01	3.29	1.16	K2 III	0.040	0.1	142	0.020	-11	Ed Asich
γ CrB	15 34.1	+26 46	2.2v	-0.02	A0 IV	0.045	0.3	78	0.151	+ 2 SB	ecl: 2.21-2.32, 17.4d Alphekka
α Lup AB	15 34.2	-41 07	2.78	-0.20	B2 IVn	D.008	-3.1	653	0.035	+ 2 V	A:3.5; B:3.6, <1"; similar spectra
α Ser	15 43.6	+ 6 28	2.65	1.17	K2 IIIb CN1	0.053	0.7	73	0.143	+ 3 V?	var? Unukalhai
μ Ser	15 48.9	-3 23	3.53	-0.04	A0 III	0.007	0.0	166	0.094	- 9 SB	
β TrA	15 53.9	-63 23	2.85	0.29	F0 IV	0.083	2.2	44	0.438	+ 0	
π Sco A	15 58.0	-26 05	2.89	-0.19	B1 V + B2 V	0.010	-3.2	569	0.028	- 3 SB2	A:occ.bin:3.4 + 4.5, 0.0003" sep.
T CrB	15 58.9	+25 57	2.0v	0.01	gM3: + Bep	-----	-1.0	8189	0.013	-29 SB	recurrent nova 1866,1946;now V=11
η Lup A	15 59.2	-38 22	3.41	-0.22	B2.5 IVn	D.008	-2.7	551	0.040	+ 8 V	A: 3.47, B: 7.70, 15"
δ Sco AB	15 59.5	-22 35	2.32	-0.12	B0.3 IV	-----	-4.4	819	0.027	- 7 SB	AB:mult<1";C:4.9,B2IV-V,8"Dschubba
β Sco AB	16 04.7	-19 46	2.62	-0.07	B0.5 V	0.009	-3.5	436	0.022	- 1 SB	A:2.78;B:5.04,1";C4.93,14"Graffias
δ Oph	16 13.6	- 3 40	2.74	1.58	M0.5 III	0.034	-0.8	164	0.153	-20 V	Yed Prior
ε Oph	16 17.6	- 4 340	3.24	0.96	G9.5 IIIbFe-0.5	0.043	0.2	130	0.089	-10 V	Yed Posterior
σ Sco A	16 20.4	-25 34	2.9v	0.13	B1 III	-----	-4.4	549	0.025	+ 3 SB	var:2.94-3.06,0.25d;B:8.3,B9 V,20" Alniyat
η Dra A	16 23.8	+61 33	2.74	0.91	G8 IIIab	0.051	0.3	100	0.064	-14 SB?	B: 8.7, 6"
α Sco A	16 28.6	-26 24	0.9v	1.83	M1.5 Iab	0.024	-5.2	388	0.024	- 3 SB	B: 5.37, B2.5 V, 3" Antares
β Her	16 29.6	+21 31	2.77	0.94	G7 IIIa	0.024	-0.8	169	0.100	-26 SB	Kornephoros
τ Sco	16 35.0	-28 11	2.82	-0.25	B0 V	0.020	-4.0	703	0.026	+ 2 V	
ζ Oph	16 36.4	-10 32	2.56	0.02	O9.5 Vn	0.003	-4.2	471	0.026	-15 V	

Star Name	R.A. 1986	Dec	V	B - V	MK Type	PI(")	M(V)	D(ly)	MU(")	RV(km/s)	Remarks
ζ Her AB	16 40.8	+31 38	2.81	0.65	G1 IV	0.102	3.0	31	0.614	-70 SB	A: 2.90; B:5.53, G7 V, 1.1"
η Her	16 42.4	+38 57	3.53	0.92	G7.5 IIIb Fe-1	0.034	0.7	117	0.089	+ 8 V?	
α TrA	16 47.2	-69 00	1.92	1.44	K2 IIb-IIIa	0.031	-1.0	107	0.044	- 3	Atria
ε Sco	16 49.3	-34 16	2.29	1.15	K2 III	0.022	0.1	89	0.661	- 3	
μ^1 Sco	16 51.0	-38 02	3.0v	-0.20	B1.5 IVn	-----	-3.5	607	0.031	-25 SB2	ecl: 2.80-3.08, 1.4d
κ Oph	16 57.0	+ 9 24	3.20	1.15	K2 III	0.031	0.1	136	0.293	-56	
ζ Ara	16 57.5	-55 58	3.13	1.60	K4 III	0.044	-0.2	113	0.037	- 6	
ζ Dra	17 08.7	+65 44	3.17	-0.12	B6 III	0.023	-1.8	308	0.033	-17 V	Aldhibah
η Oph AB	17 09.6	-15 43	2.43	0.06	A2 Vs	0.052	1.4	65	0.102	- 1 SB	A: 3.0; B: 3.5, A3 V, 1" Sabik
η Sco	17 11.2	-43 13	3.33	0.41	F2p V:(Cr)	0.062	2.7	42	0.286	-27	
α Her AB	17 14.0	+14 24	3.1v	1.44	M5 Ib-II	0.000	-3.2	627	0.035	-33 V	var:3.0-4.0;B:5.4, 5" Ras Algethi
δ Her	17 14.5	+24 51	3.14	0.08	A1 IVn	0.044	0.7	94	0.159	-40 SB	B: 8.8, 9" Sarin
π Her	17 14.6	+36 49	3.16	1.44	K3 IIab	0.025	-2.0	332	0.029	-26	
θ Oph	17 21.2	-24 59	3.3v	-0.22	B2 IV	-----	-3.1	613	0.021	- 2 SB	occbin:3.4,5.4;var:3.25-3.29,0.14d
β Ara	17 24.2	-55 31	2.85	1.46	K3 Ib-IIa	0.034	-3.5	582	0.024	- 0	
γ Ara A	17 24.3	-56.22	3.34	-0.13	B1 Ib	-----	-5.8	1992	0.011	- 3 V	broad lines for Ib; B:10.0, 18"
υ Sco	17 29.8	-37 17	2.69	-0.22	B2 IV	0.000	-3.1	463	0.032	-36	
β Dra A	17 30.1	+52 19	2.79	0.98	G2 Ib-IIa	0.013	-3.5	487	0.026	-20 V	B: 11.5, 4" Restaban
α Ara	17 30.8	-49 52	2.95	-0.17	B2 Vne	0.007	-1.9	280	0.075	+ 0 SB	
λ Sco	17 32.7	-37 06	1.6v	-0.22	B1.5 IV	-----	-3.5	328	0.029	- 3 SB2	var: 1.59-1.65, 0.21d Shaula
α Oph	17 34.3	+12 34	2.08	0.15	A5 IIIn	0.067	0.7	62	0.255	+13 SB?	Rasalhague
θ Sco	17 36.3	-42 59	1.87	0.40	F1 II	0.027	-2.4	197	0.016	+ 1	Sargas
ξ Ser	17 36.8	-15 23	3.54	0.26	F0 IIIb	0.030	1.8	73	0.076	-43 SB	
κ Sco	17 41.6	-39 01	2.4v	-0.22	B1.5 III	----	-4.2	653	0.030	-14 SB	var: 2.39-2.42, 0.2d
β Oph	17 42.8	+ 4 34	2.77	1.16	K2 III	0.033	0.1	111	0.164	-12 V	Cebalrai
μ Her A	17 45.9	+27 44	3.42	0.75	G5 IV	0.133	4.0	25	0.808	-16 V	BC: 9.78, 33"
ι^1 Sco	17 46.6	-40 07	3.03	0.51	F2 Ia	0.019	-8.0	3509	0.006	-28 SB	
G Sco	17 48.9	-37 02	3.21	1.17	K2 III	0.040	0.1	135	0.064	+25	HR6630
γ Dra	17 56.3	+51 29	2.23	1.52	K5 III	0.025	-0.3	102	0.025	-28	Etamin
ν Oph	17 58.3	- 9 46	3.34	0.99	K0 III	0.021	0.2	138	0.118	+13	

Star Name	R.A. 1986	Dec	V	B - V	MK Type	PI(")	M(V)	D(ly)	MU(")	RV(km/s)	Remarks
γ^2 Sgr	18 04.9	-30 26	2.99	1.00	K0 III	0.025	0.2	118	0.192	+22 SB	Nash
η Sgr A	18 16.7	-36 46	3.05	1.60	M3.5 IIIab	0.045	-1.0	210	0.210	+ 1 V?	var:3.08,3.12; B:8.33, G8:IV:, 4"
δ Sgr	18 20.1	-29 50	2.70	1.38	K2.5 IIIa	0.047	-0.8	142	0.050	-20	Kaus Meridionalis
η Ser	18 20.6	- 2 54	3.26	0.94	K0 III-IV	0.058	1.8	64	0.890	+ 9 V?	
ε Sgr	18 23.3	-34 24	1.85	-0.03	A0 IIInp(shell)	0.023	0.0	76	0.129	-15	Kaus Australis
α Tel	18 26.0	-45 59	3.51	-0.17	B3 IV	-----	-2.4	476	0.048	- 0 V?	
λ Sgr	18 27.1	-25 26	2.81	1.04	K1 IIIb	0.053	0.7	84	0.190	-43	Kaus Borealis
α Lyr	18 36.5	+38 46	0.03	0.00	A0 Va	0.133	0.6	25	0.348	-14 V	Vega
φ Sgr	18 44.8	-27 00	3.17	-0.11	B8.5 III	-----	-1.0	222	0.052	+22 SB	similar companion, 0.1"
β Lyr	18 49.6	+33 21	3.4v	0.00	B7 Vpe (shell)	0.000	-0.3	148	0.002	-19 SB	ecl: 3.34-4.34, 12.9d Sheliak
σ Sgr	18 54.4	-26 19	2.02	-0.22	B2.5 V	-----	-1.6	173	0.056	-11 V	Nunki
ξ^2 Sgr	18 56.9	-21 08	3.51	1.18	K1 III	0.011	0.1	135	0.035	-20	
γ Lyr	18 58.4	+32 40	3.24	-0.05	B9 III	0.021	-0.6	186	0.007	-21 V	Sulaphat
ζ Sgr AB	19 01.8	-29 54	2.60	0.08	A2.5 V + A4:V:	0.025	1.4	74	0.014	+22 SB	A: 3.2; B: 3.5, <1" Ascella
ζ Aql A	19 04.8	+13 51	2.99	0.01	A0 IVnn	0.045	0.3	112	0.095	-25 SB	
λ Aql	19 05.5	- 4 54	3.44	-0.09	B9 V	0.032	0.6	121	0.090	-12 V	
τ Sgr	19 06.1	-27 41	3.32	1.19	K1.5 IIIb	0.044	0.7	92	0.255	+45 SB	
π Sgr ABC	19 09.0	-21 03	2.89	0.35	F2 II	0.025	-2.4	484	0.035	-10	A:3.7; B:3.8; C:6.0, <1" Albaldah
δ Dra	19 12.6	+67 38	3.07	1.00	G9 III	0.032	0.3	112	0.130	+25	Nodus Secundus
δ Aql	19 24.8	+ 3 05	3.36	0.32	F2 IV-V	0.072	2.2	53	0.267	-30 SB	
β Cyg A	19 30.2	+27 56	3.08	1.13	K3 II + B9.5 V	0.017	-2.2	380	0.002	-24 V	B: 5.11, 35" Albireo
δ Cyg AB	19 44.6	+45 06	2.87	-0.03	B9.5 III	0.030	-0.3	140	0.069	-20 SB	B: 6.4, F1 V, 2"
γ Aql	19 45.6	+10 35	2.72	1.52	K3 II	0.016	-2.2	266	0.016	- 2 V	Tarazed
α Aql	19 50.1	+ 8 50	0.77	0.22	A7 Vn	0.202	2.3	16	0.662	-26	Altair
η Aql	19 51.8	+ 0 58	3.5v	0.90	F6-G1 Ib	0.010	-5.1	857	0.009	-15 SB	Cepheid var: 3.50-4.30, 7.2d
γ Sge	19 58.2	+19 27	3.47	1.57	M0 III	0.013	-0.7	219	0.070	-33	
θ Aql	20 10.6	- 0 52	3.23	-0.07	B9.5 III	0.012	-0.3	166	0.037	-27 SB2	
β Cap A	20 20.3	-14 49	3.08	0.79	K0 II + A5 V:n	0.010	-2.2	561	0.039	-19 SB	A:mult:4.0+4.3+4.8+6.7,<1" Dabih
γ Cyg	20 21.7	+40 13	2.20	0.68	F8 Ib	0.003	-5.1	797	0.001	- 8	Sadr
α Pav	20 24.6	-56 47	1.94	-0.20	B2.5 V	-----	-1.6	155	0.087	+ 2 SB	Peacock

Star Name	R.A. 1986	Dec	V	B - V	MK Type	PI(")	M(V)	D(ly)	MU(")	RV(km/s)	Remarks
α Ind	20 36.6	-47 20	3.11	1.00	K0 III Cn-1	0.046	0.2	124	0.090	- 1	
α Cyg	20 41.0	+45 14	1.25	0.09	A2 Ia	0.000	-7.2	1470	0.005	- 5 V	Deneb
β Pav	20 43.8	-66 15	3.42	0.16	A6 IV	0.035	1.5	79	0.041	+10	
η Cep	20 45.0	+61 47	3.43	0.92	K0 IV	0.076	3.1	37	0.827	-87	
ε Cyg	20 45.7	+33 55	2.46	1.03	K0 III	0.057	0.2	89	0.484	-11 SB	
ζ Cyg	21 12.4	+30 10	3.20	0.99	G8 IIIa Ba 0.6	0.027	-0.8	197	0.052	+17 SB	
α Cep	21 18.3	+62 32	2.44	0.22	A7 IV-V	0.068	2.0	39	0.159	-10	Alderamin
β Cep	21 28.5	+70 30	3.2v	-0.22	B1 III	0.014	-4.4	1021	0.016	- 8 SB	var3.16-3.27,0.2d;B:7.8,13"Alphirk
β Aqr	21 30.8	- 5 38	2.91	0.83	G0 Ib	0.006	-4.0	713	0.020	+ 7	Sadalsuud
ε Peg	21 43.5	+ 9 49	2.4v	1.53	K2 Ib	0.006	-4.0	471	0.030	+ 5 V	var: 0.7-3.5 (flare in 1972) Enif
δ Cap	21 46.3	-16 11	2.9v	0.29	A3mF2 V:	0.087	1.5	47	0.394	- 6 SB	var:2.83-3.05,1d;occ.bin:3.2 + 5.2
γ Gru	21 53.1	-37 26	3.01	-0.12	B8 III	0.013	-1.2	227	0.104	- 2 V?	
α Aqr	22 05.1	- 0 23	2.96	0.98	G2 Ib	0.012	-4.0	681	0.016	+ 8 V?	Sadalmelik
α Gru	22 07.4	-47 02	1.74	-0.13	B7 IV	0.057	-1.1	119	0.198	+12	Al Nair
θ Peg	22 09.5	+ 6 08	3.53	0.08	A2 V	0.049	1.4	82	0.277	- 6 SB2	Baham
ζ Cep	22 10.4	+58 08	3.35	1.57	K1.5 Ib	0.017	-4.0	750	0.015	-18 SB	
α Tuc	22 17.6	-60 20	2.86	1.39	K3 III	0.026	0.0	103	0.071	+42 SB	
δ Cep A	22 28.7	+58 21	3.5v	0.60	F5-G2 Ib	0.011	-5.1	1178	0.012	-15 SB	Cepheid variable:3.48-4.34, 5.4d
ζ Peg	22 40.8	+10 46	3.40	-0.09	B8 V	0.023	0.1	145	0.080	+ 7 V?	Homam
β Gru	22 41.9	-46 57	2.1v	1.60	M5 III	0.008	-1.0	136	0.138	+ 2	var: 2.0-2.3
η Peg	22 42.4	+30 09	2.94	0.86	G8 II + F0 V	0.017	-2.1	332	0.025	+ 4 SB	Matar
ε Gru	22 47.7	-51 23	3.49	0.08	A2 IVn	0.044	1.0	97	0.126	+ 0 V	
ι Cep	22 49.2	+66 08	3.52	1.05	K0 III	0.041	0.2	140	0.137	-12	
μ Peg	22 49.4	+24 32	3.48	0.93	G8 III	0.040	0.3	141	0.152	+14	
δ Aqr	22 53.9	-15 54	3.27	0.05	A3 IV	0.038	1.2	85	0.047	+18 V	Skat
α PsA	22 56.9	-29 42	1.16	0.09	A3 V	0.149	2.0	22	0.373	+ 7	Fomalhaut
β Peg	23 03.1	+28 01	2.4v	1.67	M2 II-III	0.022	-2.0	224	0.236	+ 9 V	var: 2.31-2.74 Scheat
α Peg	23 04.1	+15 08	2.49	-0.04	B9.5 V	0.038	0.7	74	0.073	- 4 SB	Markab
γ Cep	23 38.8	+77 33	3.21	1.03	K1 III-IV	0.068	1.5	71	0.168	-42	Alrai

THE NEAREST STARS

BY ALAN H. BATTEN

The accompanying table lists all the stars known to be within a distance of just over 5 parsecs (17 light-years) from the Sun. The table is based on one published in Volume 8 of the *Landolt-Bornstein* tabulations, by Professor W. Gliese. It contains, however, an additional object whose existence has been drawn to my attention by Professor Gliese. Readers who compare this table with its counterpart in the 1984 HANDBOOK will notice several differences, particularly in the order of stars. All the parallaxes given here are uncertain by several units in the last decimal; some are uncertain in the second decimal. It is thus inevitable that the order of stars of nearly equal parallaxes will change, either because of new results or because different compilers evaluate differently the quality of individual determinations of parallax that make up the means recorded here. All stars included in the 1984 list are to be found in this one, except the two components of B.D. 44°2051 and of Stein 2051, now considered to be beyond the limit of this compilation. Even close to home, astronomical distance estimates are still uncertain!

The table gives the name of each star, its coordinates for 2000, its parallax π, its distance in light-years, its spectral type, proper motion (seconds of arc per year), position angle of the proper motion (measured from north through east), total space velocity relative to the Sun (km s^{-1}, where known, with the sign of the radial velocity), apparent (V) and absolute (M_V) visual magnitudes. The revision of the table has provided an opportunity to improve the presentation of the spectral types. Recently, Dr. R. F. Wing classified all the stars in the old table on the MK system, except the white dwarfs, the stars of type K3 or earlier (whose spectral types are given in the *Bright Star Catalogue*), the Sun, and those whose parallaxes are less than 0″.2. He kindly provided his data in advance of publication and I have adopted his classifications, except that I have retained the e, indicating the presence of emission lines in the spectrum. Classifications given for the white dwarfs (indicated by D) are taken from Gliese's table. I know of no spectral type for the newcomer LP 731-58, but its colour corresponds to an early M-type. In general, I have used the same names for stars as in earlier versions of the table. I have, however, given the two components of Σ2398 their B.D. number, and changed the designation of α Centauri C to Proxima. This latter change emphasizes that Proxima is indeed somewhat closer to us than α Centauri itself. Some readers may enjoy working out the true spatial separation between Proxima and its brighter companions.

Measuring the distances of stars is one of the most difficult and important jobs of the observational astronomer. As Earth travels round the Sun each year, the apparent positions of nearby stars—against the background of more distant ones—change very slightly. This change is the *annual parallax*. Even for Proxima Centauri it is only about three-quarters of an arc-second: that is, the apparent size of a penny viewed from rather more than 5 km distance. A graphic way of conveying the distances to stars is to speak of a *light-year*, the distance (about ten million million km) that light travels in a year. The first astronomers to measure parallax spoke in this way, but modern astronomers prefer to speak of a *parsec*—the distance at which a star would have a parallax of exactly one arc-second. One parsec is equal to about 3.26 light-years. The distance of a star in parsecs is simply the reciprocal of its parallax expressed (as in the table) in arc-seconds.

The table contains 65 stars. Of these, 35 are single (including the Sun, whose planets are not counted), 24 are found in 12 double systems, and six in the two triple systems o^2 Eridani and α Centauri (with Proxima). There is some evidence for unseen companions of low mass associated with seven of the stars. The list gives an idea of the frequencies of different kinds of stars in our part of the Galaxy. Only four of the stars are brighter than the Sun; most are very much fainter and cooler. No giants or very hot massive stars are found in the solar neighbourhood.

	2000											
Name	α		δ		π	*D*	Sp.	μ	θ	*W*	*V*	M_v
	h	m	°	′	″	l.y.		″/a	°	km/s		
Sun							G2V				−26.72	4.85
Proxima	14	30	−62	41	0.772	4.2	M5.5Ve	3.85	282	−29	11.05	15.49
α Cen A	14	40	−60	50	.750	4.3	G2V	3.68	281	−32	−0.01	4.37
B							K1V				1.33	5.71
Barnard's*	17	58	+04	34	.545	6.0	M3.8V	10.31	356	−140	9.54	13.22
Wolf 359	10	56	+07	01	.421	7.7	M5.8Ve	4.70	235	+54	13.53	16.65
BD+36°2147*	11	03	+35	58	.397	8.2	M2.1Ve	4.78	187	−102	7.50	10.50
L-726-8A	01	39	−17	57	.387	8.4	M5.6Ve	3.36	80	+50	12.52	15.46
B										+52	13.02	15.96
Sirius A	06	45	−16	43	.377	8.6	A1Vm	1.33	204	−19	−1.46	1.42
B							DA				8.3:	11.2:
Ross 154	18	50	−23	50	.345	9.4	M3.6Ve	0.72	104	−11	10.45	13.14
Ross 248	23	42	+44	10	.314	10.4	M4.9Ve	1.60	176	−85	12.29	14.78
ϵ Eri	03	33	−09	28	.303	10.8	K2Ve	0.98	271	+22	3.73	6.14
Ross 128	11	48	+00	48	.298	10.9	M4.1V	1.38	152	−26	11.10	13.47
61 Cyg A	21	07	+38	45	.294	11.1	K3.5Ve	5.22	52	−106	5.22	7.56
B*							K4.7Ve				6.03	8.37
ϵ Ind	22	03	−56	47	.291	11.2	K3Ve	4.70	123	−86	4.68	7.00
BD+43°44A	00	18	+44	01	.290	11.2	M1.3Ve	2.90	82	+49	8.08	10.39
B							M3.8Ve			+51	11.06	13.37
L789-6	22	39	−15	19	.290	11.2		3.26	46	−80	12.18	14.49
Procyon A	07	39	+05	13	.285	11.4	F5IV-V	1.25	214	−21	0.37	2.64
B							DF				10.7	13.0
BD+59°1915A	18	43	+59	38	.282	11.6	M3.0V	2.29	325	38†	8.90	11.15
B							M3.5V	2.27	323	+39	9.69	11.94
CD−36°15693	23	06	−35	52	.279	11.7	M1.3Ve	6.90	79	+117	7.35	9.58
G51-15	08	30	+26	47	.278	11.7	M6.6V	1.27	242		14.81	17.03
τCet	01	44	−15	56	.277	11.8	G8V	1.92	297	−37	3.50	5.72
BD5°1668*	07	26	05	14	.266	12.3	M3.7V	3.77	171	+72	9.82	11.94
L725−32	01	12	−17	00	.261	12.5	M4.5Ve	1.32	62	+37	12.04	14.12
CD−39°14192	21	17	−38	52	.260	12.5	K5.5Ve	3.46	251	+66	6.66	8.74
Kapteyn's	05	12	−45	01	.256	12.7	M0.0V	8.72	131	+293	8.84	10.88
Krüger 60A	22	28	+57	42	.253	12.9	M3.3Ve	0.86	246	−31	9.85	11.87
B											11.3	13.3
BD−12°4253	16	30	−12	39	.247	13.2	M3.5V	1.18	183	−26	10.11	12.07
Ross 614A	06	29	−02	49	.246	13.3	M4.5Ve	1.00	133	+31	11.10	13.12
B											14.	16.
van Maanen's	00	49	+05	23	.232	14.1	DG	2.99	155	+82	12.37	14.20
Wolf 424A	12	33	+09	01	.230	14.2	M5.3Ve	1.76	279	−37	13.16	14.97
B											13.4	15.2
CD−37°15492	00	06	−37	21	.225	14.5	M2.0V	6.11	112	+131	8.56	10.32
L1159-16	02	00	+13	03	.224	14.6	M4.5Ve	2.09	149		12.26	14.01
BD+50°1725	10	11	+49	27	.222	14.7	K5.0Ve	1.45	250	−40	6.59	8.32
LP731-58	10	48	−11	20	.219	14.9		1.64	160		15.60	17.30
CD−46°11540	17	29	−46	54	.216	15.1	M2.7V	1.06	147		9.37	11.04
G158−27	00	07	−07	33	.214	15.2	M5.5:	2.04	204		13.74	15.39
CD−49°13515	21	34	−49	00	.214	15.2	M1.8V	0.81	184	+20	8.67	10.32
CD−44°11909*	17	37	−44	20	.213	15.3	M3.9V	1.16	217		10.96	12.60
BD+68°946	17	36	+68	21	.213	15.3	M3.3V	1.31	196	−37	9.15	10.79
G208−44 A	19	54	+44	25	.211	15.5		0.74	143		13.41	15.03
45 B							M5:				13.99	15.61
BD−15°6290	22	53	−14	16	.209	15.6	M3.9V	1.14	124	+27	10.17	11.77
o² Eri A	04	15	−07	39	.207	15.7	K1V	4.08	213	−102	4.43	6.01
B							DA	4.07	212	−96	9.52	11.10
C							M4.3Ve			(−45)‡	11.17	12.75
BD+20°2465*	10	20	+19	52	.206	15.8	M3.3Ve	0.49	264	+16	9.43	11.00
L145−141	11	46	−64	50	.206	15.8	DC	2.68	97		11.50	13.07
70 Oph A	18	05	+02	30	.203	16.1	K0Ve	1.12	167	−27	4.22	5.76
B							K4Ve				6.00	7.54
BD+43°4305*	22	47	+44	20	.200	16.3	M5e:	0.83	236	−20	10.2	11.7
Altair	19	51	+08	52	.198	16.5	A7V	0.66	54	−30	0.76	2.24
AC+79°3888	11	48	+78	42	.193	16.9	M4:	0.89	57	−121	10.80	12.23
G9−38A	08	58	+19	45	.192	17.0		0.89	267		14.06	15.48
B											14.92	16.34
BD+15°2620	13	46	+14	54	.192	17.0	M1.7Ve	2.30	129	+59	8.49	9.91

*Suspected unseen companion.
†Radial velocity is zero.
‡Radial velocity only.

DOUBLE AND MULTIPLE STARS

BY CHARLES E. WORLEY

Many stars can be separated into two or more components by use of a telescope. The larger the aperture of the telescope, the closer the stars which can be separated under good seeing conditions. With telescopes of moderate size and good optical quality, and for stars which are not unduly faint or of large magnitude difference, the minimum angular separation in seconds of arc is given by 120/D, where D is the diameter of the telescope's objective in millimetres.

The following lists contain some interesting examples of double stars. The first list presents pairs whose orbital motions are very slow. Consequently, their angular separations remain relatively fixed and these pairs are suitable for testing the performance of small telescopes. In the second list are pairs of more general interest, including a number of binaries of short period for which the position angles and separations are changing rapidly.

In both lists the columns give, successively: the star designation in two forms; its right ascension and declination for 1980; the combined visual magnitude of the pair and the individual magnitudes; the apparent separation and position angle for 1986.0; and the period, if known. (The position angle is the angular direction of the fainter star from the brighter, measured counterclockwise from north.)

Many of the components are themselves very close visual or spectroscopic binaries. (Other double stars appear in the tables of Nearest Stars and Brightest Stars. For more information about observing these stars, see the articles by: J. Ashbrook in *Sky and Telescope*, **60**, 379 (1980); J. Meeus in *Sky and Telescope*, **41**, 21 and 89 (1971); and by C. E. Worley in *Sky and Telescope*, **22**, 73, 140 and 261 (1961). The latter two articles have been reprinted by Sky Publishing Corp., 49 Bay State Road, Cambridge, Mass. 02238 under the titles *Some Bright Visual Binary Stars* and *Visual Observing of Double Stars*, each $1.95 U.S.—Ed.)

Star	A.D.S.	R.A. 1980.0 h	m	Dec. 1980.0 °	′	Magnitudes comb.	A	B	P.A. 1986.0 °	Sep. 1986.0 ″	P (app.) years
λ Cas	434	00	30.7	+54	26	4.9	5.5	5.8	185	0.6	640
α Psc	1615	02	01.0	+02	40	4.0	4.3	5.3	281	1.9	930
33 Ori	4123	05	30.2	+03	16	5.7	6.0	7.3	28	1.9	—
OΣ 156	5447	06	46.3	+18	13	6.1	6.8	7.0	237	0.5	1100
Σ 1338	7307	09	19.7	+38	17	5.8	6.5	6.7	264	1.1	400
35 Com	8695	12	52.3	+21	21	5.1*	5.2	7.4	169	1.1	500
Σ 2054	10052	16	23.6	+61	44	5.6	6.0	7.2	353	1.1	—
ϵ^1 Lyr†	11635	18	43.7	+39	38	5.1	5.4	6.5	354	2.7	1200
ϵ^2 Lyr†	11635	18	43.7	+39	38	4.4	5.1	5.3	88	2.3	600
π Aql	12962	19	47.7	+11	45	5.6	6.0	6.8	108	1.4	—
61 Cyg	14636	21	05.5	+38	34	4.8	5.2	6.0	147	29.7	722
OΣ 500	16877	23	36.5	+44	20	5.9	6.4	7.1	0	0.5	—
η Cas	671	00	47.7	+57	44	3.5*	3.5	7.2	310	12.3	480
Σ 186	1538	01	54.8	+01	45	6.0	6.8	6.8	56	1.3	170
γ And AB	1630	02	02.4	+42	16	2.1*	2.1	5.1	63	9.7	—
γ And BC	1630	02	02.4	+42	16	5.1	5.5	6.3	107	0.6	61
OΣ 65	2799	03	49.2	+25	32	5.2	5.8	6.2	209	0.5	62
α CMa	5423	06	44.3	−16	40	−1.4	−1.4	8.5	31	7.6	50
α Gem	6175	07	33.3	+31	55	1.6	2.0	2.8	85	2.8	500
ζ Cnc AB	6650	08	11.1	+17	43	5.0	5.6	5.9	229	0.6	60
ζ Cnc AC	6650	08	11.1	+17	43	5.2	5.4	7.3	78	5.9	1150
σ^2 UMa	7203	09	08.6	+67	13	4.8*	4.8	8.2	359	3.4	1100
γ Leo	7724	10	18.9	+19	57	1.8	2.1	3.4	124	4.3	620
ξ UMa	8119	11	17.1	+31	39	3.8	4.3	4.8	87	2.1	60
γ Vir	8630	12	40.7	−01	21	2.8	3.5	3.5	292	3.4	170
ζ Boo	9343	14	40.1	+13	49	3.8	4.5	4.5	304	1.0	125
ξ Boo	9413	14	50.4	+19	12	4.5	4.7	6.8	329	7.1	150
ζ Her	10157	16	40.6	+31	38	2.8	2.9	5.5	105	1.5	35
τ Oph	11005	18	01.9	−08	11	4.7	5.2	5.9	279	1.8	280
70 Oph	11046	18	04.5	+02	32	4.0	4.2	6.0	278	2.0	88
δ Cyg	12880	19	44.4	+45	04	2.9*	2.9	6.3	230	2.4	830
4 Aqr	14360	20	50.4	−05	53	6.0	6.4	7.2	14	1.0	190
τ Cyg	14787	21	13.9	+37	57	3.7	3.8	6.4	88	0.5	50
μ Cyg	15270	21	43.2	+28	39	4.5	4.8	6.1	303	1.7	500
ζ Aqr	15971	22	27.8	−00	08	3.6	4.3	4.5	214	1.8	850
Σ 3050	17149	23	58.5	+33	37	5.8	6.5	6.7	317	1.6	350

*There is a marked colour difference between the components.

†The separation of the two pairs of ε Lyr is 208″.

VARIABLE STARS

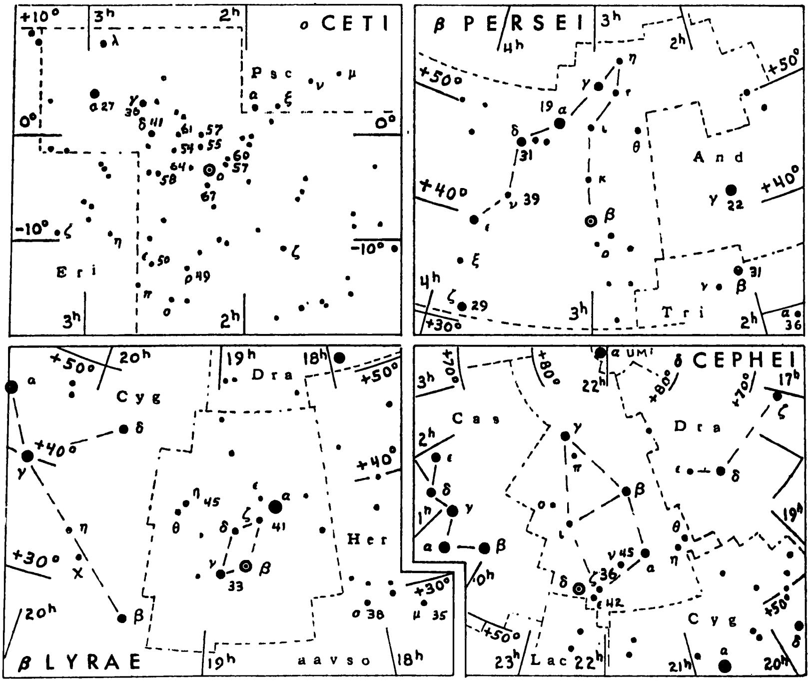
By Janet A. Mattei

Variable stars provide information about many stellar properties. Depending upon their type, variables can tell the mass, radius, temperature, luminosity, internal and external structure, composition, and evolution of stars. The systematic observation of variable stars is an area in which an amateur astronomer can make a valuable contribution to astronomy.

For beginning observers, charts of the fields of four different types of bright variable stars are printed below. On each chart, the magnitudes (with decimal point omitted) of several suitable comparison stars are shown. A brightness estimate of the variable is made using two comparison stars, one brighter, one fainter than the variable. The magnitude, date, and time of each observation are recorded. When a number of observations have been made, a graph of magnitude versus date may be plotted. The shape of this "light curve" depends on the type of variable. Further information about variable star observing may be obtained from the American Association of Variable Star Observers, 187 Concord Ave., Cambridge, Massachusetts 02138, U.S.A.

The first table on the next page is a list of long-period variables, brighter than magnitude 8.0 at maximum, and north of −20°. The first column (the Harvard designation of the star) gives the position for the year 1900: the first four figures give the hours and minutes of right ascension, the last two figures the declination in degrees (italicised for southern declinations). The column headed "Max." gives the mean maximum magnitude. The "Period" is in days. The "Epoch" gives the predicted date of the earliest maximum occurring this year; by adding multiples of the period to this epoch the dates of subsequent maxima may be found. These variables may reach maximum two or three weeks before or after the epoch and may remain at maximum for several weeks. This table is prepared using the observations of the American Association of Variable Star Observers.

The second table contains stars which are representative of some other types of variables. The data for the preparation of the predicted epoch of maximum and minimum are taken from *The General Catalog of Variable Stars*, 4th ed., and its *Second Supplement*; for the eclipsing binaries and RR Lyrae variables from *Rocznik Astronomiczny Obserwatorium Krakowskiego 1985, International Supplement*; and also for β Lyr from *Acta Astronomica 29*, 393, 1979.



LONG-PERIOD VARIABLE STARS

Variable	Max. m_v	Per d	Epoch 1986	Variable	Max. m_v	Per d	Epoch 1986
001755 T Cas	7.8	445	—	142539 V Boo	7.9	258	July 13
001838 R And	7.0	409	Feb. 7	143227 R Boo	7.2	223	Apr. 7
021143 W And	7.4	397	Aug. 29	151731 S CrB	7.3	361	Dec. 18
0214*03* o Cet	3.4	332	Mar. 14	154639 V CrB	7.5	358	Aug. 1
0228*13* U Cet	7.5	235	June 18	154615 R Ser	6.9	357	May 31
023133 R Tri	6.2	266	May 7	160625 RU Her	8.0	484	—
043065 T Cam	8.0	374	Dec. 31	162119 U Her	7.5	406	July 15
0455*14* R Lep	6.8	432	—	1621*12* V Oph	7.5	298	June 3
050953 R Aur	7.7	459	Dec. 3	163266 R Dra	7.6	245	Mar. 12
054920 U Ori	6.3	372	Nov. 22	164715 S Her	7.6	307	June 14
0617*02* V Mon	7.0	335	Aug. 4	1702*15* R Oph	7.9	302	Jan. 5
065355 R Lyn	7.9	379	Sep. 9	171723 RS Her	7.9	219	Mar. 15
070122aR Gem	7.1	370	Aug. 18	180531 T Her	8.0	165	Jan. 29
070310 R CMi	8.0	338	Nov. 1	181136 W Lyr	7.9	196	Feb. 10
072708 S CMi	7.5	332	May 13	183308 X Oph	6.8	334	Nov. 3
081112 R Cnc	6.8	362	Nov. 27	190108 R Aql	6.1	300	May 22
081617 V Cnc	7.9	272	Jan. 23	1910*17* T Sgr	8.0	392	Jan. 5
084803 S Hya	7.8	257	June 30	1910*19* R Sgr	7.3	269	June 4
0850*08* T Hya	7.8	288	Aug. 15	193449 R Cyg	7.5	426	Nov. 18
093934 R LMi	7.1	372	June 4	194048 RT Cyg	7.3	190	Feb. 20
094211 R Leo	5.8	313	Sep. 13	194632 χ Cyg	5.2	407	Aug. 21
103769 R UMa	7.5	302	Mar. 4	201647 U Cyg	7.2	465	—
1214*18* R Crv	7.5	317	June 6	2044*05* T Aqr	7.7	202	May 27
122001 SS Vir	6.8	355	Jan. 4	210868 T Cep	6.0	390	Apr. 17
123160 T UMa	7.7	257	Aug. 3	213753 RU Cyg	8.0	234	May 29
123307 R Vir	6.9	146	Jan. 25	230110 R Peg	7.8	378	Apr. 25
123961 S UMa	7.8	226	Jan. 20	230759 V Cas	7.9	228	Jan. 4
131546 V CVn	6.8	192	Jan. 4	231508 S Peg	8.0	319	June 6
1327*06* S Vir	7.0	378	May 25	2338*15* R Aqr	6.5	387	July 28
134440 R CVn	7.7	328	Apr. 5	235350 R Cas	7.0	431	July 6
142584 R Cam	7.9	270	July 28	2357*15* W Cet	7.6	351	Sept. 11

OTHER TYPES OF VARIABLE STARS

Variable		Max. m_v	Min. m_v	Type	Sp. Cl.	Period d	Epoch 1986 U.T.
005381	U Cep	6.7	9.8	Ecl.	B8+gG2	2.49307	Jan. 3.34*
025838	ρ Per	3.3	4.0	Semi R	M4	33–55, 1100	—
030140	β Per	2.1	3.3	Ecl.	B8+G	2.86731	—
035512	λ Tau	3.5	4.0	Ecl.	B3	3.952952	Jan. 3.66*
✸ 060822	η Gem	3.1	3.9	Semi R	M3	233.4	—
061907	T Mon	5.6	6.6	δ Cep	F7–K1	27.0205	Jan. 27.42
065820	ζ Gem	3.6	4.2	δ Cep	F7–G3	10.15082	Jan. 3.70
154428	R Cr B	5.8	14.8	R Cr B	cFpep		—
171014	α Her	3.0	4.0	Semi R	M5	50–130, 6 yrs.	—
1842*05*	R Sct	5.0	7.0	RVTau	G0e-K0p	144	—
184633	β Lyr	3.4	4.3	Ecl.	B8	12.93619†	Jan. 11.45*
192242	RR Lyr	6.9	8.0	RR Lyr	A2–F1	0.566867	Jan. 1.26
194700	η Aql	3.5	4.3	δ Cep	F6–G4	7.176641	Jan. 9.05
222557	δ Cep	3.5	4.4	δ Cep	F5–G2	5.366341	Jan. 6.35

*Minimum.
†Changing period.

BRIEF DESCRIPTION OF VARIABLE TYPES

Variable stars are divided into four main classes: Pulsating and eruptive variables where variability is intrinsic due to physical changes in the star or stellar system; eclipsing binary and rotating stars where variability is extrinsic due to an eclipse of one star by another or the effect of stellar rotation. A brief and general description about the major types in each class is given below.

I. *Pulsating Variables*

Cepheids: Variables that pulsate with periods from 1 to 70 days. They have high luminosity and the amplitude of light variation ranges from 0.1 to 2 magnitudes. The prototypes of the group are located in open clusters and obey the well known period-luminosity relation. They are of F spectral class at maximum and G to K at minimum. The later the spectral class of a Cepheid the longer is its period. Typical representative: δ Cephei.

RR Lyrae Type: Pulsating, giant variables with periods ranging from 0.05 to 1.2 days with amplitude of light variation between 1 and 2 magnitudes. They are usually of A spectral class. Typical representative: RR Lyrae.

RV Tauri Type: Supergiant variables with characteristic light curve of alternating deep and shallow minima. The periods, defined as the interval between two deep minima, range from 30 to 150 days. The amplitude of light variation may be as much as 3 magnitudes. Many show long term cyclic variation of 500 to 9000 days. Generally the spectral classes range from G to K. Typical representative: R Scuti.

Long period—Mira Ceti variables: Giant variables that vary with amplitudes from 2.5 to 5 magnitudes or more. They have well defined periodicity, ranging from 80 to 1000 days. They show characteristic emission spectra of late spectral classes of M, C, and S. Typical representative: o Ceti (Mira).

Semiregular Variables: Giants and supergiants showing appreciable periodicity accompanied by intervals of irregularities of light variation.The periods range from 30 to 1000 days with amplitudes not more than 1 to 2 magnitudes in general. Typical representative: R Ursae Minoris.

Irregular Variables: Stars that at times show only a trace of periodicity or none at all. Typical representative: RX Leporis.

II. *Eruptive Variables*

Novae: Close binary systems consisting of a normal star and a white dwarf that increase 7 to 16 magnitudes in brightness in a matter of 1 to several hundreds of days. After the outburst, the star fades slowly until the initial brightness is reached in several years or decades. Near maximum brightness, the spectrum is generally similar to A or F giants. Typical representative: CP Puppis (Nova 1942).

Supernovae: Brightness increases 20 or more magnitudes due to a gigantic stellar explosion. The general appearance of the light curve is similar to novae. Typical representative: CM Tauri (Supernova of A.D. 1054 and the central star of the Crab Nebula).

R Coronae Borealis Type: Highly luminous variables that have non-periodic drops in brightness from 1 to 9 magnitudes, due to the formation of "carbon soot" in the stars' atmosphere. The duration of minima varies from a few months to years. Members of this group have F to K and R spectral class. Typical representative: R Coronae Borealis.

U Geminorum Type: Dwarf novae that have long intervals of quiescence at minimum with sudden rises to maximum. Depending upon the star, the amplitude of eruptions range from 2 to 6 magnitudes, and the duration between outbursts ten to thousands of days. Most of these stars are spectroscopic binaries with periods of few hours. Typical representative: SS Cygni.

Z Camelopardalis Type: Variables similar to U Gem stars in their physical and spectroscopic properties. They show cyclic variations interrupted by intervals of constant brightness (stillstands) lasting for several cycles, approximately one third of the way from maximum to minimum. Typical representative: Z Camelopardalis.

III. *Eclipsing Binaries*

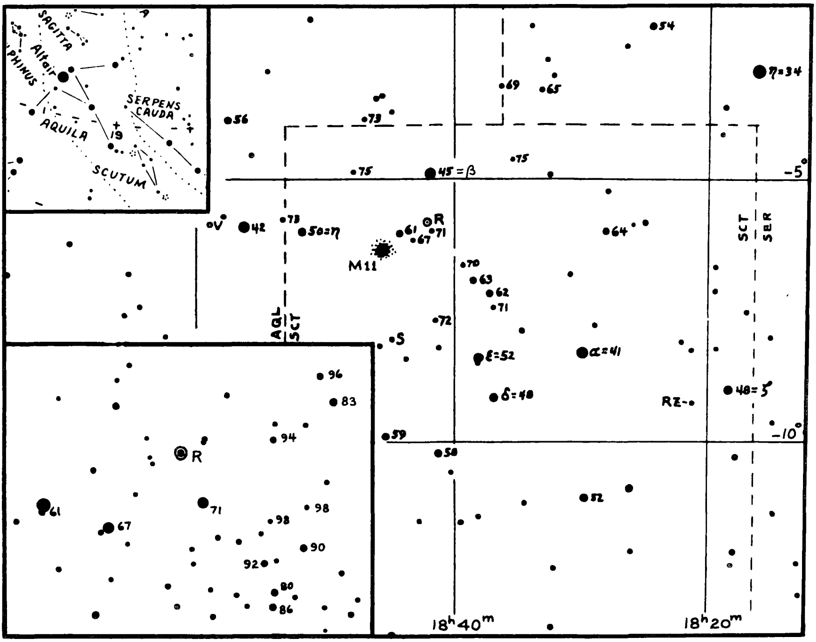
Binary system of stars with the orbital plane lying near the line of sight of the observer. The components periodically eclipse each other, causing decrease in light in the apparent brightness of the system, as is seen and recorded by the observer. The period of the eclipses coincides with the period of the orbital motion of the components. Typical representative: β Persei (Algol).

IV. *Rotating Variables*

Rapidly rotating stars, usually close binary systems, which undergo small amplitude changes in light that may be due to dark or bright spots on their stellar surface. Eclipses may also be present in such systems. Typical representative: R Canum Venaticorum.

Editor's Note: In cooperation with the A.A.V.S.O., we introduce our newer readers to R Scuti, a particularly interesting variable star that was featured in the 1977 edition of this Handbook. R Scuti is a semi-regular, pulsating star of the RV Tauri class. It was one of the earliest variables known, having been discovered by the Englishman E. Pigott in 1795. R Scuti peaks near magnitude 5 and drops to magnitude 6 to 8 at minimum, thus it is easy to observe with binoculars. Its irregular period is nearly 5 months.

The upper left portion of the diagram is a wide field view taken from the JULY map of the night sky. The cluster of dots at the northeast edge of Scutum is the spectacular open star cluster, M11. R Scuti is about 1° northwest of M11. The main portion of the diagram is on a scale approximately 10 times larger. The numbers beside several of the stars are magnitudes with decimal points omitted, and the coordinates are for 1900.0. The lower left diagram is on a scale 5 times larger again, and shows faint stars within less than 1° from R Scuti. All three charts are oriented with north upward.



STAR CLUSTERS

By Anthony Moffat

The study of star clusters is crucial for the understanding of stellar structure and evolution. For most purposes, it can be assumed that the stars seen in a given cluster formed nearly simultaneously from the same parent cloud of gas and dust; thus, the basic factor which distinguishes one star from another is the quantity of matter each contains. Comparing one cluster with another, it is essentially only the age and the chemical composition of their stars that differ. But what makes one cluster *appear* different from another in the sky is mainly the degree of concentration and regularity, the spread in magnitude and colour of the member stars, all of which vary mainly with age, and the total number of stars. Extremely young clusters are often irregular in shape with clumps of newly formed stars, pervaded by lanes of obscuring dust and bright nebulosity (e.g. the Orion Nebula around the Trapezium Cluster), while the oldest clusters, if they were fortunate enough not to have already dissipated or been torn apart by external forces, tend to be symmetric in shape, with only the slower-burning, low-mass stars remaining visible; the massive stars will have spent their nuclear fuel and passed to the degenerate graveyard of white dwarfs, neutron stars, or black holes depending on their original mass.

The star clusters in the lists below were selected as the most conspicuous. Two types can be recognized: *open* and *globular*. Open clusters often appear as irregular aggregates of tens to thousands of stars, sometimes barely distinguishable from random fluctuations of the general field; they are concentrated toward the Galactic disk and generally contain stars of chemical abundance like the Sun. They range in age from very young to very old.

Sometimes we observe loose, extended groups of very young stars. When precise methods of photometry, spectroscopy and kinematics are applied, we see that these stars often have a common, but not necessarily strictly coeval, origin. Such loose concentrations of stars are referred to as *associations*. Dynamically, they are generally unbound over time scales of the order of ten million years, being subject to the strong tidal forces of passing clouds and the background Galaxy. Often, they contain sub-concentrations of young open clusters (e.g. the double cluster h and χ Persei of slightly different ages despite their proximity, in the association Per OB1, which stretches over some 6° on the sky), with a strong gradient in age as the star formation process rips through them from one edge to another. In view of their sparse nature, we do not consider it appropriate here to list any of the over 100-odd catalogued associations in the Galaxy.

Globular clusters on the other hand are highly symmetric, extremely old and rich agglomerations of up to several million stars, distributed throughout the Galactic halo but concentrated toward the centre of the Galaxy. Compared to the Sun and other disk stars, they tend to be much less abundant in elements heavier than hydrogen and helium.

The first table includes all well-defined Galactic open clusters with diameters greater than 40′ and/or integrated magnitudes brighter than 5.0, as well as the richest clusters and some of special interest. The apparent integrated photographic magnitude is from Collinder, the angular diameter is generally from Trumpler, and the photographic magnitude of the fifth-brightest star, m_5, is from Shapley, except where in italics, which are new data. The distance is mainly from Becker and Fenkart (*Astr. Astrophys. Suppl.* **4**, 241 (1971)). The earliest spectral type of cluster stars, Sp, is a measure of the age as follows: expressed in millions of years, 05 = 2, B0 = 8, B5 = 70, A0 = 400, A5 = 1000, F0 = 3000 and F5 = 10000.

OPEN CLUSTERS

NGC or other†	R.A. 1980 h m	Dec. 1980 ° ′	Int. m_{pg}	Diam. ′	m_5	Dist. 1000 l.y.	Sp	Remarks
188	00 42.0	+85 14	9.3	14	14.6	5.0	F2	Oldest known
752	01 56.6	+37 35	6.6	45	9.6	1.2	A5	
869	02 17.6	+57 04	4.3	30	9.5	7.0	B1	h Per
884	02 21.0	+57 02	4.4	30	9.5	8.1	B0	χ Per, M supergiants
Perseus	03 21	+48 32	2.3	240	5	0.6	B1	Moving cl.; α Per
Pleiades	03 45.9	+24 04	1.6	120	4.2	0.41	B6	M45, best known
Hyades	04 19	+15 35	0.8	400	*1.5*	0.13	A2	Moving cl.**, in Taurus
1912	05 27.3	+35 49	7.0	18	9.7	4.6	B5	M38
1976/80	05 34.4	−05 24	2.5	50	*5.5*	1.3	O5	Trapezium, very young
2099	05 51.1	+32 32	6.2	24	9.7	4.2	B8	M37
2168	06 07.6	+24 21	5.6	29	9.0	2.8	B5	M35
2232	06 25.5	−04 44	4.1	*20*	*7*	1.6	B1	
2244	06 31.3	+04 53	5.2	27	*8.0*	5.3	O5	Rosette, very young
2264	06 39.9	+09 54	4.1	30	*8.0*	2.4	O8	S Mon
2287	06 46.2	−20 43	5.0	32	*8.8*	2.2	B4	M41
2362	07 18.0	−24 54	3.8	7	9.4	5.4	O9	τ CMa
2422	07 34.7	−14 27	4.3	30	9.8	1.6	B3	
2437	07 40.9	−14 46	6.6	27	10.8	5.4	B8	M46
2451	07 44.7	−37 55	3.7	37	6	1.0	B5	
2516	07 58.0	−60 51	3.3	50	10.1	1.2	B8	
2546	08 11.8	−37 35	5.0	45	7	2.7	B0	
2632	08 39.0	+20 04	3.9	90	7.5	0.59	A0	Praesepe, M44
IC2391	08 39.7	−52 59	2.6	45	3.5	0.5	B4	
IC2395	08 40.4	−48 07	4.6	20	10.1	2.9	B2	
2682	08 49.3	+11 54	7.4	18	10.8	2.7	F2	M67, very old
3114	10 02.0	−60 01	4.5	37	7	2.8	B5	
IC2602	10 42.6	−64 17	1.6	65	6	0.5	B1	θ Car
Tr 16	10 44.4	−59 36	6.7	10	10	9.6	O3	η Car and Nebula
3532	11 05.5	−58 33	3.4	55	8.1	1.4	B8	
3766	11 35.2	−61 30	4.4	12	8.1	5.8	B1	
Coma	12 24.1	+26 13	2.9	300	5.5	0.3	A1	Very sparse
4755	12 52.4	−60 13	5.2	12	7	6.8	B3	κ Cru, "jewel box"
6067	16 11.7	−54 10	6.5	16	10.9	4.7	B3	G, K supergiants
6231	16 52.6	−41 46	8.5	16	7.5	5.8	O9	O supergiants, WR stars
Tr 24	16 55.6	−40 38	8.5	60	*7.3*	5.2	O5	
6405	17 38.8	−32 12	4.6	26	8.3	1.5	B4	M6
IC4665	17 45.7	+05 44	5.4	50	7	1.1	B8	
6475	17 52.6	−34 48	3.3	50	7.4	0.8	B5	M7
6494	17 55.7	−19 01	5.9	27	10.2	1.4	B8	M23
6523	18 01.9	−24 23	5.2	45	*7*	5.1	O5	M8, Lagoon Neb.
6611	18 17.8	−13 48	6.6	8	10.6	5.5	O7	M16, nebula
IC4725	18 30.5	−19 16	6.2	35	9.3	2.0	B3	M25, Cepheid U Sgr
IC4756	18 38.3	+05 26	5.4	50	8.5	1.4	A3	
6705	18 50.0	−06 18	6.8	12.5	12	5.6	B8	M11, very rich
Mel 227	20 08.2	−79 23	5.2	60	*9*	0.8	B9	
IC1396	21 38.3	+57 25	5.1	60	*8.5*	2.3	O6	Tr 37
7790	23 57.4	+61 06	7.1	4.5	11.7	10.3	B1	Cepheids CEa, CEb and CF Cas

†IC = Index Catalogue; Tr = Trumpler; Mel = Melotte.
**Basic for distance determination.

The table below includes all globular clusters with a total apparent photographic magnitude brighter than about 7.5. The data are taken from a compilation by Arp (*Galactic Structure*, ed. Blaauw and Schmidt, U. Chicago 1965), supplemented by H. S. Hogg's Bibliography (*Publ. David Dunlap Obs.* **2**, No. 12, 1963). The apparent diameter given contains 90% of the stars, except values in italics which are from miscellaneous sources. The concentration class is such that I is the most compact, XII is least. The integrated spectral type varies mainly with the abundances, and m(25) refers to the mean blue magnitude of the 25 brightest stars excluding the 5 brightest, which are liable to fluctuate more. The number of variables known in the cluster is also given. A more detailed, recent catalogue of fundamental data for galactic globular clusters can be found in a review by Harris and Racine (*Annual Review of Astronomy and Astrophysics, 17*, 241, 1979).

GLOBULAR CLUSTERS

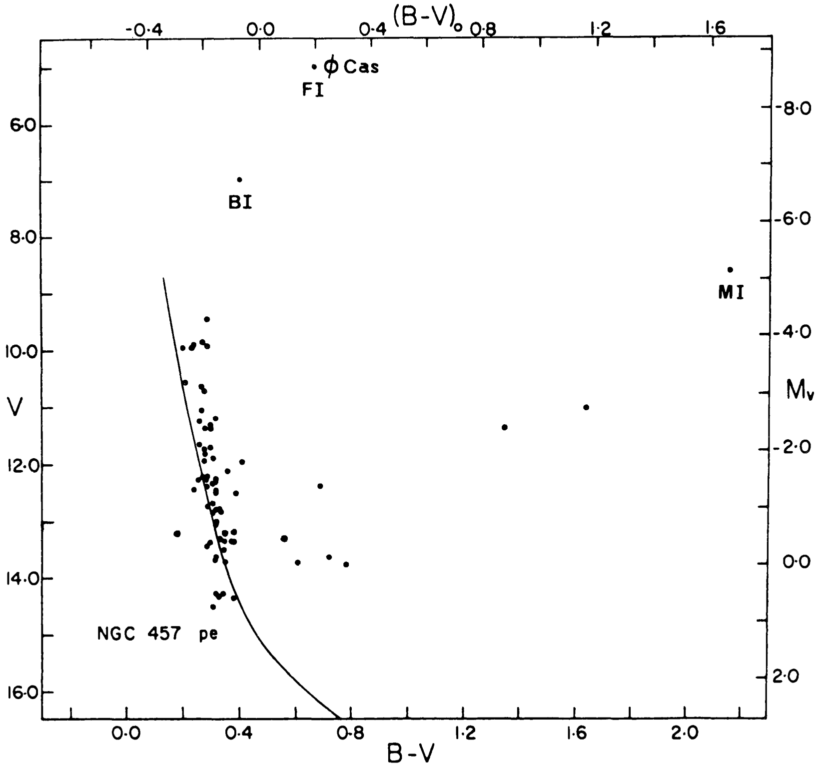
NGC	M or other	R.A. 1980 h m	Dec. 1980 ° ′	Int. m_{pg}	Diam. ′	Conc.	Int. Sp. T.	m(25)	No. Var.	Dist. 1000 l.y.
104 †	47 Tuc	00 23.1	−72 11	4.35	*44*	III	G3	13.54	11	16
1851*		05 13.3	−40 02	7.72	*11.5*	II	F7		3	46
2808		09 11.5	−64 42	7.4	*18.8*	I	F8	15.09	4	30
5139†	ω Cen	13 25.6	−47 12	4.5	*65.4*	VIII	F7	13.01	165	17
5272†	3	13 41.3	+28 29	6.86	9.3	VI	F7	14.35	189	35
5904	5	15 17.5	+02 10	6.69	10.7	V	F6	14.07	97	26
6121	4	16 22.4	−26 28	7.05	22.6	IX	*G0*	13.21	43	14
6205	13	16 41.0	+36 30	6.43	12.9	V	F6	13.85	10	21
6218	12	16 46.1	−01 55	7.58	21.5	IX	F8	14.07	1	24
6254	10	16 56.0	−04 05	7.26	16.2	VII	G1	14.17	3	20
6341	92	17 16.5	+43 10	6.94	12.3	IV	F1	13.96	16	26
6397		17 39.2	−53 40	6.9	*19*	IX	F5	12.71	3	9
6541†		18 06.5	−43 45	7.5	*23.2*	III	F6	13.45	1	13
6656†	22	18 35.1	−23 56	6.15	26.2	VII	F7	13.73	24	10
6723		18 58.3	−36 39	7.37	11.7	VII	G4	14.32	19	24
6752		19 09.1	−60 01	6.8	*41.9*	VI	F6	13.36	1	17
6809	55	19 38.8	−30 59	6.72	21.1	XI	F5	13.68	6	20
7078*	15	21 29.1	+12 05	6.96	9.4	IV	F2	14.44	103	34
7089	2	21 32.4	−00 55	6.94	6.8	II	F4	14.77	22	40

*Bright, compact X-ray sources were discovered in these clusters in 1975.
†These clusters contain dim X-ray sources.

TWO EXAMPLES OF YOUNG STAR CLUSTERS

Although globular clusters are extremely useful cosmic tracers and are equally beautiful to look at, *individual* stars in them are usually faint and crowded. It is therefore perhaps simpler and more instructive to demonstrate some effects of stellar evolution with the aid of a young open cluster. An excellent case is the "jewel box" cluster NGC 4755, visible mainly from the southern hemisphere. Within its obvious boundary, NGC 4755 contains some three blue (B-type) and one red (M-type) supergiants, which stand out like jewels on a background of fainter, blue main sequence stars. One of the blue supergiants is the sixth magnitude star κ Cru. A photograph of this cluster appears on p. 439 of the May 1984 issue of *Sky and Telescope*.

A similar case in the north is the young open cluster NGC 457 (not listed in the table). It is about 18′ across and is located at R.A. $01^{h}17^{m}.8$, Dec. +58°13′ (1980), almost diametrically opposite to NGC 4755 in the sky, and nearly 4° SE of γ Cas (the central star in the "W" of Cassiopeia). NGC 457 contains the 5th magnitude F-type supergiant φ Cas at its SE edge, accompanied by a 7th magnitude B-type supergiant just SW of ϕ Cas. Nearer to the centre of the cluster is a bright (8.6 magnitude) red (M-type) supergiant. All three stars are superposed on a background of fainter main sequence stars of type BO and later (cooler). NGC 457 is about 10 000 ly distant. Below is a colour-magnitude diagram for NGC 457, based on broadband B and V photoelectric observations.The most rapidly evolving (and thus most massive) stars, the three supergiants, have truly outstanding luminosities. The brightest of the three, ϕ Cas, has an absolute magnitude of about −8.8, making it about 260 000 times as luminous as our Sun!



A colour-magnitude diagram for NGC 457. The axes are labelled with V (apparent visual magnitude), M_V (estimated absolute visual magnitude), and B − V (blue magnitude minus visual magnitude, the "colour index"). The three supergiants have been labeled with their spectral and luminosity classes (e.g. ϕ Cas is "FI", i.e. spectral class F, luminosity class I (supergiant)). Selective absorption by inter-stellar dust has shifted the B − V values of all stars in the cluster toward the red (right). The curved line indicates the location of the "zero-age main sequence" (also shifted to the right). The four or five unlabeled points far to the right of the curved line are not members of the cluster. (From: Hagen, Publ. D. Dunlap Obs., 4, *1, 1970.)*

NEBULAE

GALACTIC NEBULAE

By William Herbst

The following objects were selected from the brightest and largest of the various classes to illustrate the different types of interactions between stars and interstellar matter in our galaxy. *Emission regions* (HII) are excited by the strong ultraviolet flux of young, hot stars and are characterized by the lines of hydrogen in their spectra. *Reflection nebulae* (Ref) result from the diffusion of starlight by clouds of interstellar dust. At certain stages of their evolution stars become unstable and explode, shedding their outer layers into what becomes a *planetary nebula* (Pl) or a *supernova remnant* (SN). Protostellar nebulae (PrS) are objects still poorly understood; they are somewhat similar to the reflection nebulae, but their associated stars, often variable, are very luminous infrared stars which may be in the earliest stages of stellar evolution. Also included in the selection are three *extended complexes* (Comp) of special interest for their rich population of dark and bright nebulosities of various types. In the table S is the optical surface brightness in magnitude per square second of arc of representative regions of the nebula, and m* is the magnitude of the associated star.

NGC	M	Con	α 1980 δ		Type	Size	S mag.	m	Dist. 10^3	Remarks
			h m	° ′		′	sq″	*	l.y.	
1435		Tau	03 46.3	+24 01	Ref	15	20	4	0.4	Merope nebula
1535		Eri	04 13.3	−12 48	Pl	0.5	17	12		
1952	1	Tau	05 33.3	+22 05	SN	5	19	16v	4	"Crab" + pulsar
1976	42	Ori	05 34.3	−05 25	HII	30	18	4	1.5	Orion nebula
2070		Dor	05 38.7	−69 06	HII	20	—	13	200	Tarantula Neb.
ζOri		Ori	05 39.8	−01 57	Comp	2°			1.5	Incl. "Horsehead"
2068	78	Ori	05 45.8	+00 02	Ref	5	20		1.5	
IC443		Gem	06 16.4	+22 36	SN	40			2	
2244		Mon	06 31.3	+04 53	HII	50	21	7	3	Rosette neb.
2261		Mon	06 38.0	+08 44	PrS	2		12v	4	Hubble's var. neb.
2392		Gem	07 28.0	+20 57	Pl	0.3	18	10	10	Clown face neb.
2626		Vel	08 34.9	−40 34	Ref	2	—	10	3	
3132		Vel	10 06.2	−40 19	Pl	1	17	10	—	Eight-Burst
3324		Car	10 36.7	−58 32	HII	15	—	8	9	
3372		Car	10 44.3	−59 35	HII	80	—	6v	9	Carina Neb.
3503		Car	11 00.5	−60 37	Ref	3	—	11	9	
3587	97	UMa	11 13.6	+55 08	Pl	3	21	13	12	Owl nebula
—		Cru	12 50	−63	Dark	6°	—	—	0.5	Coal Sack
5189		Mus	13 32.4	−65 54	HII	150	—	10	—	
ρOph		Oph	16 24.4	−23 24	Comp	4°			0.5	Bright + dark neb.
6514	20	Sgr	18 01.2	−23 02	HII	15	19		3.5	Trifid nebula
6523	8	Sgr	18 02.4	−24 23	HII	40	18		4.5	Lagoon nebula
6543		Dra	17 58.6	+66 37	Pl	0.4	15	11	3.5	
6618	17	Sgr	18 19.7	−16 12	HII	20	19		3	Horseshoe neb.
6720	57	Lyr	18 52.9	+33 01	Pl	1.2	18	15	5	Ring nebula
6726		CrA	19 00.4	−36 56	PrS	5	—	7	0.5	
6853	27	Vul	19 58.6	+22 40	Pl	7	20	13	3.5	Dumb-bell neb.
6888		Cyg	20 11.6	+38 21	HII	15				
γCyg		Cyg	20 21.5	+40 12	Comp	6°				HII + dark neb.
6960/95		Cyg	20 44.8	+30 38	SN	150			2.5	Cygnus loop
7000		Cyg	20 58.2	+44 14	HII	100	22		3.5	N. America neb.
7009		Aqr	21 03.0	−11 28	Pl	0.5	16	12	3	Saturn nebula
7027		Cyg	21 06.4	+42 09	Pl	0.2	15	13		
7129		Cep	21 42.5	+65 00	Ref	3	21	10	2.5	Small cluster
7293		Aqr	22 28.5	−20 54	Pl	13	22	13		Helix nebula

THE MESSIER CATALOGUE

BY ALAN DYER

The Messier Catalogue, with its modern additions, represents a listing of many of the brightest and best deep-sky wonders. The following table lists the Messier objects by season for the *evening observer*, grouping the objects within their respective constellations, with the constellations themselves listed roughly in order of increasing right ascension, i.e., constellations further to the east and which rise later in the night are further down the list.

The columns contain: Messier's number (M); the constellation; the object's New General Catalogue (NGC) number; the type of object (OC = open cluster, GC = globular cluster, PN = planetary nebula, EN = emission nebula, RN = reflection nebula, SNR = supernova remnant, G = galaxy (with the type of galaxy also listed); the 1980 co-ordinates; the visual magnitude (unless marked with a "p" which indicates a photographic magnitude). The "Remarks" column contains comments on the object's appearance and observability. The final column, marked "Seen", is for the observer to use in checking off those objects which he or she has located. An asterisk in the "Type" column indicates that additional information about the object may be found elsewhere in the HANDBOOK, in the appropriate table. Most data are from the Skalnate Pleso *Atlas of the Heavens* catalogue; occasionally from other sources.

All these objects can be seen in a small telescope (60 mm refractor, for instance), with M74 and M83 generally considered to be the most difficult. The most southerly M-objects are M6 and M7 in Scorpius, with M54, M55, M69, and M70 in Sagittarius almost as far south. Notice how different classes of objects dominate the skies of the various seasons: open clusters dominate the winter sky; galaxies by the hundreds abound in the spring sky; the summer sky contains many globular clusters and nebulae; while the autumn sky is a mixture of clusters and galaxies. This effect is due to the presence (or absence) of the Milky Way in any particular season, and whether or not we are looking toward the centre of the Galaxy (as in summer) or away from the centre (as in winter).

M	Con	NGC	Type	R.A. (1980) Dec.	m_v	Remarks	Seen
The Winter Sky				h m ° ′			
1	Tau	1952	SNR*	5 33.3 +22 01	8.4	Crab Neb.; supernova remnant	
45	Tau	—	OC*	3 46.3 +24 03	1.4	Pleiades; RFT object	
36	Aur	1960	OC	5 35.0 +34 05	6.3	best at low magnification	
37	Aur	2099	OC*	5 51.5 +32 33	6.2	finest of 3 Aur. clusters	
38	Aur	1912	OC	5 27.3 +35 48	7.4	large, scattered group	
42	Ori	1976	EN*	5 34.4 −05 24	—	Orion Nebula	
43	Ori	1982	EN	5 34.6 −05 18	—	detached part of Orion Neb.	
78	Ori	2068	RN	5 45.8 +00 02	—	featureless reflection neb.	
79	Lep	1904	GC	5 23.3 −24 32	8.4	20 cm scope needed to resolve	
35	Gem	2168	OC*	6 07.6 +24 21	5.3	superb open cluster	
41	CMa	2287	OC*	6 46.2 −20 43	5.0	4°S. of Sirius; use low mag.	
50	Mon	2323	OC	7 02.0 −08 19	6.9	between Sirius and Procyon	
46	Pup	2437	OC*	7 40.9 −14 46	6.0	rich cl.; contains PN NGC 2438	
47	Pup	2422	OC	7 35.6 −14 27	4.5	coarse cl.; 1.5°W. of M46	
93	Pup	2447	OC	7 43.6 −23 49	6.0	smaller, brighter than M46	
48	Hya	2548	OC	8 12.5 −05 43	5.3	former "lost" Messier object	
The Spring Sky							
44	Cnc	2632	OC*	8 38.8 +20 04	3.7	Beehive Cl.; RFT object	
67	Cnc	2682	OC*	8 50.0 +11 54	6.1	"ancient" star cluster	
40	UMa	—	—	12 34.4 +58 20	9.0	two stars; sep. 50″	
81	UMa	3031	G-Sb*	9 54.2 +69 09	7.9	very bright spiral	
82	UMa	3034	G-Pec*	9 54.4 +69 47	8.8	the "exploding" galaxy	
97	UMa	3587	PN*	11 13.7 +55 08	12.0	Owl Nebula	

M	Con	NGC	Type	R.A. (1980) Dec.	m_v	Remarks	Seen
101	UMa	5457	G-Sc*	14 02.5 +54 27	9.6	large, faint, face-on spiral	
108	UMa	3556	G-Sc	11 10.5 +55 47	10.7	nearly edge-on; near M97	
109	UMa	3992	G-Sb	11 56.6 +53 29	10.8	barred spiral; near γ UMa	
65	Leo	3623	G-Sb	11 17.8 +13 13	9.3	bright elongated spiral	
66	Leo	3627	G-Sb	11 19.1 +13 07	8.4	M65 in same field	
95	Leo	3351	G-SBb	10 42.8 +11 49	10.4	bright barred spiral	
96	Leo	3368	G-Sbp	10 45.6 +11 56	9.1	M95 in same field	
105	Leo	3379	G-E1	10 46.8 +12 42	9.2	very near M95 and M96	
53	Com	5024	GC	13 12.0 +18 17	7.6	15 cm scope needed to resolve	
64	Com	4826	G-Sb*	12 55.7 +21 48	8.8	Black Eye Galaxy	
85	Com	4382	G-SO	12 24.3 +18 18	9.3	bright elliptical shape	
88	Com	4501	G-Sb	12 30.9 +14 32	10.2	bright multiple-arm spiral	
91	Com	4548	G-SBb	12 34.4 +14 36	10.8	not the same as M58	
98	Com	4192	G-Sb	12 12.7 +15 01	10.7	nearly edge-on spiral	
99	Com	4254	G-Sc	12 17.8 +14 32	10.1	nearly face-on spiral	
100	Com	4321	G-Sc	12 21.9 +15 56	10.6	face-on spiral; star-like nuc.	
49	Vir	4472	G-E4*	12 28.8 +08 07	8.6	very bright elliptical	
58	Vir	4579	G-SB	12 36.7 +11 56	9.2	bright barred spiral	
59	Vir	4621	G-E3	12 41.0 +11 47	9.6	bright elliptical near M58	
60	Vir	4649	G-E1	12 42.6 +11 41	8.9	bright elliptical near M59	
61	Vir	4303	G-Sc	12 20.8 +04 36	10.1	face-on barred spiral	
84	Vir	4374	G-E1	12 24.1 +13 00	9.3	bright elliptical	
86	Vir	4406	G-E3	12 25.1 +13 03	9.7	M84 in same field	
87	Vir	4486	G-E1	12 29.7 +12 30	9.2	nearly spherical galaxy	
89	Vir	4552	G-E0	12 34.6 +12 40	9.5	resembles M87; smaller	
90	Vir	4569	G-Sb	12 35.8 +13 16	10.0	bright spiral; near M89	
104	Vir	4594	G-Sb*	12 38.8 −11 31	8.7	Sombrero Galaxy	
3	CVn	5272	GC*	13 41.3 +28 29	6.4	contains many variables	
51	CVn	5194	G-Sc*	13 29.0 +47 18	8.1	Whirlpool Galaxy	
63	CVn	5055	G-Sb*	13 14.8 +42 08	9.5	Sunflower Galaxy	
94	CVn	4736	G-Sbp*	12 50.1 +41 14	7.9	very bright and comet-like	
106	CVn	4258	G-Sbp*	12 18.0 +47 25	8.6	large, bright spiral	
68	Hya	4590	GC	12 38.3 −26 38	8.2	15 cm scope needed to resolve	
83	Hya	5236	G-Sc*	13 35.9 −29 46	10.1	very faint and diffuse	
102	Dra	5866	G-E6p	15 05.9 +55 50	10.8	small, edge-on galaxy	
5	Ser	5904	GC*	15 17.5 +02 11	6.2	one of the finest globulars	
The Summer Sky							
13	Her	6205	GC*	16 41.0 +36 30	5.7	spectacular globular cl.	
92	Her	6341	GC*	17 16.5 +43 10	6.1	9°NE. of M13; bright	
9	Oph	6333	GC	17 18.1 −18 30	7.3	smallest of Oph. globulars	
10	Oph	6254	GC*	16 56.0 −04 05	6.7	rich cl.; M12 3.4° away	
12	Oph	6218	GC*	16 46.1 −01 55	6.6	loose globular	
14	Oph	6402	GC	17 36.5 −03 14	7.7	20 cm scope needed to resolve	
19	Oph	6273	GC	17 01.3 −26 14	6.6	oblate globular	
62	Oph	6266	GC	16 59.9 −30 05	6.6	unsymmetrical; in rich field	
107	Oph	6171	GC	16 31.3 −13 02	9.2	small, faint globular	
4	Sco	6121	GC*	16 22.4 −26 27	6.4	bright globular near Antares	
6	Sco	6405	OC*	17 38.9 −32 11	5.3	best at low magnification	
7	Sco	6475	OC*	17 52.6 −34 48	3.2	excellent in binoculars	
80	Sco	6093	GC	16 15.8 −22 56	7.7	very compressed globular	
16	Ser	6611	EN*	18 17.8 −13 48	—	Star-Queen Neb. w/ open cl.	
8	Sgr	6523	EN*	18 02.4 −24 23	—	Lagoon Neb. w/cl. NGC 6530	
17	Sgr	6618	EN*	18 19.7 −16 12	—	Swan or Omega Nebula	
18	Sgr	6613	OC	18 18.8 −17 09	7.5	sparse cluster; 1°S. of M17	
20	Sgr	6514	EN*	18 01.2 −23 02	—	Trifid Nebula	
21	Sgr	6531	OC	18 03.4 −22 30	6.5	0.7°NE. of M20	
22	Sgr	6656	GC*	18 35.2 −23 55	5.9	low altitude dims beauty	
23	Sgr	6494	OC*	17 55.7 −19 00	6.9	bright, loose cluster	
24	Sgr	—	—	18 17 −18 27	4.6	Milky Way patch; binoc. obj.	
25	Sgr	I4725	OC*	18 30.5 −19 16	6.5	bright but sparse cluster	
28	Sgr	6626	GC	18 23.2 −24 52	7.3	compact globular near M22	
54	Sgr	6715	GC	18 53.8 −30 30	8.7p	not easily resolved	

M	Con	NGC	Type	R.A. (1980) Dec.	m_v	Remarks	Seen
55	Sgr	6809	GC*	19 38.7 −31 00	7.1p	bright, loose globular	
69	Sgr	6637	GC	18 30.1 −32 23	8.9	small, poor globular	
70	Sgr	6681	GC	18 42.0 −32 18	9.6	small globular; 2°E. of M69	
75	Sgr	6864	GC	20 04.9 −21 59	8.0	small, remote globular	
11	Sct	6705	OC*	18 50.0 −06 18	6.3	superb open cluster	
26	Sct	6694	OC	18 44.1 −09 25	9.3	bright, coarse cluster	
56	Lyr	6779	GC	19 15.8 +30 08	8.2	within rich field	
57	Lyr	6720	PN*	18 52.9 +33 01	9.3	Ring Nebula	
71	Sge	6838	GC	19 52.8 +18 44	9.0	loose globular cl.	
27	Vul	6853	PN*	19 58.8 +22 40	7.6	Dumbbell Nebula	
29	Cyg	6913	OC	20 23.3 +38 27	7.1	small, poor open cl.	
39	Cyg	7092	OC	21 31.5 +48 21	5.2	very sparse cluster	
The Autumn Sky							
2	Aqr	7089	GC*	21 32.4 −00 54	6.3	20 cm scope needed to resolve	
72	Aqr	6981	GC	20 52.3 −12 39	9.8	near NGC 7009 (Saturn Neb.)	
73	Aqr	6994	OC	20 57.8 −12 44	11.0	group of 4 stars only	
15	Peg	7078	GC*	21 29.1 +12 05	6.0	rich, compact globular	
30	Cap	7099	GC	21 39.2 −23 15	8.4	noticeable elliptical shape	
52	Cas	7654	OC	23 23.3 +61 29	7.3	young, rich cluster	
103	Cas	581	OC	01 31.9 +60 35	7.4	3 NGC clusters nearby	
31	And	224	G-Sb*	00 41.6 +41 09	4.8	Andromeda Gal.; large	
32	And	221	G-E2*	00 41.6 +40 45	8.7	companion gal. to M31	
110	And	205	G-E6*	00 39.1 +41 35	9.4	companion gal. to M31	
33	Tri	598	G-Sc*	01 32.8 +30 33	6.7	large, diffuse spiral	
74	Psc	628	G-Sc	01 35.6 +15 41	10.2	faint, elusive spiral	
77	Cet	1068	G-Sbp	02 41.6 +00 04	8.9	Seyfert gal.; star-like nuc.	
34	Per	1039	OC	02 40.7 +42 43	5.5	best at very low mag.	
76	Per	650	PN*	01 40.9 +51 28	12.2	Little Dumbbell Neb.	

NUMERICAL LISTING OF MESSIER OBJECTS

M	Sky	Con	M	Sky	Con	M	Sky	Con	M	Sky	Con	M	Sky	Con
1	Wi	Tau	23	Su	Sgr	45	Wi	Tau	67	Sp	Cnc	89	Sp	Vir
2	Au	Aqr	24	Su	Sgr	46	Wi	Pup	68	Sp	Hya	90	Sp	Vir
3	Sp	CVn	25	Su	Sgr	47	Wi	Pup	69	Su	Sgr	91	Sp	Com
4	Su	Sco	26	Su	Sct	48	Wi	Hya	70	Su	Sgr	92	Su	Her
5	Sp	Ser	27	Su	Vul	49	Sp	Vir	71	Su	Sge	93	Wi	Pup
6	Su	Sco	28	Su	Sgr	50	Wi	Mon	72	Au	Aqr	94	Sp	CVn
7	Su	Sco	29	Su	Cyg	51	Sp	CVn	73	Au	Aqr	95	Sp	Leo
8	Su	Sgr	30	Au	Cap	52	Au	Cas	74	Au	Psc	96	Sp	Leo
9	Su	Oph	31	Au	And	53	Sp	Com	75	Su	Sgr	97	Sp	UMa
10	Su	Oph	32	Au	And	54	Su	Sgr	76	Au	Per	98	Sp	Com
11	Su	Sct	33	Au	Tri	55	Su	Sgr	77	Au	Cet	99	Sp	Com
12	Su	Oph	34	Au	Per	56	Su	Lyr	78	Wi	Ori	100	Sp	Com
13	Su	Her	35	Wi	Gem	57	Su	Lyr	79	Wi	Lep	101	Sp	UMa
14	Su	Oph	36	Wi	Aur	58	Sp	Vir	80	Su	Sco	102	Sp	Dra
15	Au	Peg	37	Wi	Aur	59	Sp	Vir	81	Sp	UMa	103	Au	Cas
16	Su	Ser	38	Wi	Aur	60	Sp	Vir	82	Sp	UMa	104	Sp	Vir
17	Su	Sgr	39	Su	Cyg	61	Sp	Vir	83	Sp	Hya	105	Sp	Leo
18	Su	Sgr	40	Sp	UMa	62	Su	Oph	84	Sp	Vir	106	Sp	CVn
19	Su	Oph	41	Wi	CMa	63	Sp	CVn	85	Sp	Com	107	Su	Oph
20	Su	Sgr	42	Wi	Ori	64	Sp	Com	86	Sp	Vir	108	Sp	UMa
21	Su	Sgr	43	Wi	Ori	65	Sp	Leo	87	Sp	Vir	109	Sp	UMa
22	Su	Sgr	44	Sp	Cnc	66	Sp	Leo	88	Sp	Com	110	Au	And

The abbreviations are: Wi, winter; Sp, spring; Su, summer; Au, autumn.

Footnote to Messier Catalogue: The identifications of M91 and M102 are controversial; some believe that these two objects are duplicate observations of M58 and M101 respectively. Also, objects M104 to M110 are not always included in the standard version of the Messier Catalogue. Like many other objects in the catalogue, they were discovered by Mechain and reported to Messier for verification and inclusion in the catalogue.

THE FINEST N.G.C. OBJECTS + 20

By Alan Dyer

The New General Catalogue of deep-sky objects was originally published by J. L. E. Dreyer in 1888. Supplementary Index Catalogues were published in 1895 and 1908. Together, they contain descriptions and positions of 13,226 galaxies, clusters and nebulae. Many of these are well within reach of amateur telescopes. Indeed, the brightness and size of many NGC objects rival those of the better known deep-sky targets of the Messier Catalogue (almost all of which are also in the NGC catalogue). However, most NGC objects are more challenging to locate and observe than the Messiers.

The first four sections of the following list contain 110 of the finest NGC objects that are visible from mid-northern latitudes. The arrangement is similar to that used in the preceding Messier Catalogue. A telescope of at least 15 cm aperture will likely be required to locate all these objects. The last section is for those wishing to begin to extend their deep-sky observing program beyond the basic catalogue of Charles Messier or the brightest objects of the New General Catalogue. It is a selected list of 20 "challenging" objects, and is arranged in order of right ascension.

The *Wil Tirion Sky Atlas 2000.0*, the sets of index card finder charts called *AstroCards*, or the *AAVSO Variable Star Atlas* will be indispensible in locating the objects on this list. For more information about them, and many other deep-sky objects, see *Burnham's Celestial Handbook* (Vol. 1, 2, 3), and the *Webb Society Deep-Sky Observer's Handbooks*.

Abbreviations used: OC = open cluster, GC = globular cluster, PN = planetary nebula, EN = emission nebula, RN = reflection nebula, E/RN = combination emission and reflection nebula, DN = dark nebula, SNR = supernova remnant, G = galaxy (the Hubble classification is also listed with each galaxy). Magnitudes are visual; exceptions are marked with a "p" indicating a photographic magnitude. Sizes of each object are in minutes of arc, with the exception of planetary nebulae which are given in seconds of arc. The number of stars (*) and, where space permits, the Shapley classification is also given for star clusters in the Remarks column.

No.	NGC	Con	Type	R.A. (1950)	Dec.	m_v	Size	Remarks
The Autumn Sky				h m	° ′			
1	7009	Aqr	PN	21 01.4	−11 34	9.1	44″ × 26″	Saturn Nebula; bright oval planetary
2	7293	Aqr	PN	22 27.0	−21 06	6.5	900″ × 720″	Helix Nebula; very large and diffuse
3	7331	Peg	G-Sb	22 34.8	+34 10	9.7	10.0 × 2.3	large, very bright spiral galaxy
4	7789	Cas	OC	23 54.5	+56 26	9.6	30	200*; faint but very rich cluster
5	185	Cas	G-EO	00 36.1	+48 04	11.7	2.2 × 2.2	companion to M31; quite bright
6	281	Cas	EN	00 50.4	+56 19	—	22 × 27	large, faint nebulosity near γ Cas.
7	457	Cas	OC	01 15.9	+58 04	7.5	10	100*; Type e—intermediate rich
8	663	Cas	OC	01 42.6	+61 01	7.1	11	80*; NGC 654 and 659 nearby
9	7662	And	PN	23 23.5	+42 14	9.2	32″ × 28″	star-like at low mag.; annular, bluish
10	891	And	G-Sb	02 19.3	+42 07	10.9p	11.8 × 1.1	faint, classic edge-on with dust lane
11	253	Scl	G-Scp	00 45.1	−25 34	8.9	24.6 × 4.5	very large and bright but at low alt.
12	772	Ari	G-Sb	01 56.6	+18 46	10.9	5.0 × 3.0	diffuse spiral galaxy
13	936	Cet	G-SBa	02 25.1	−01 22	10.7	3.3 × 2.5	near M77; NGC 941 in same field
14a	869	Per	OC	02 15.5	+56 55	4.4	36	Double Cluster; superb!
14b	884	Per	OC	02 18.9	+56 53	4.7	36	Double Cluster; superb!
15	1023	Per	G-E7p	02 37.2	+38 52	10.5p	4.0 × 1.2	bright, lens-shaped galaxy; near M34
16	1491	Per	EN	03 59.5	+51 10	—	3 × 3	small, fairly bright emission nebula
17	1501	Cam	PN	04 02.6	+60 47	12.0	56″ × 58″	faint, distinctive oval; darker centre
18	1232	Eri	G-Sc	03 07.5	−20 46	10.7	7.0 × 5.5	fairly bright, large face-on spiral
19	1300	Eri	G-SBb	03 17.5	−19 35	11.3	5.7 × 3.5	large barred spiral near NGC 1232
20	1535	Eri	PN	04 12.1	−12 52	10.4	20″ × 17″	blue-grey disk

No.	NGC	Con	Type	R.A. (1950) Dec.		m_v	Size	Remarks
The Winter Sky				h m	° ′			
21	1907	Aur	OC	05 24.7	+35 17	9.9	5	40*; nice contrast with nearby M38
22	1931	Aur	EN	05 28.1	+34 13	—	3 × 3	haze surrounding 4 stars
23	1788	Ori	E/RN	05 04.5	−03 24	—	8 × 5	fairly bright but diffuse E/R neb.
24	1973+	Ori	E/RN	05 32.9	−04 48	—	40 × 25	near M42 and M43; often neglected
25	2022	Ori	PN	05 39.3	+09 03	12.4	28″ × 27″	small, faint but distinct; annular
26	2194	Ori	OC	06 11.0	+12 50	9.2	8	100*; Type e; faint but rich
27	2158	Gem	OC	06 04.3	+24 06	12.5	4	40*; same field as M35; nice contrast
28	2392	Gem	PN	07 26.2	+21 01	8.3	47″ × 43″	Clown-Face Nebula; very bright
29	2244	Mon	OC	06 29.7	+04 54	6.2	40	16*; in centre of Rosette Nebula
30	2261	Mon	E/RN	06 36.4	+08 46	var.	5 × 3	Hubble's Variable Nebula
31	2359	CMa	EN	07 15.4	−13 07	—	8 × 6	fairly bright; NGC's 2360 & 2362 nearby
32	2438	Pup	PN	07 39.6	−14 36	11.8	68″	within M46 open cluster
33	2440	Pup	PN	07 39.9	−18 05	10.3	54″ × 20″	almost starlike; irregular at high mag.
34	2539	Pup	OC	08 08.4	−12 41	8.2	21	150*; Type f—fairly rich
35	2403	Cam	G-Sc	07 32.0	+65 43	8.9	17 × 10	bright, very large; visible in binocs.
36	2655	Cam	G-S	08 49.4	+78 25	10.7	5.0 × 2.4	bright ellipse w/ star-like nucleus
The Spring Sky								
37	2683	Lyn	G-Sb	08 49.6	+33 38	9.6	8.0 × 1.3	nearly edge-on spiral; very bright
38	2841	UMa	G-Sb	09 18.6	+51 12	9.3	6.4 × 2.4	classic elongated spiral; very bright
39	2985	UMa	G-Sb	09 46.0	+72 31	10.6	5.5 × 5.0	near M81 and M82
40	3077	UMa	G-E2p	09 59.4	+68 58	10.9	2.3 × 1.9	small elliptical; companion to M81/82
41	3079	UMa	G-Sb	09 58.6	+55 57	11.2	8.0 × 1.0	edge-on spiral, NGC 2950 nearby
42	3184	UMa	G-Sc	10 15.2	+41 40	9.6	5.6 × 5.6	large, diffuse face-on spiral
43	3675	UMa	G-Sb	11 23.5	+43 52	10.6	4.0 × 1.7	elongated spiral; same field as 56 UMa
44	3877	UMa	G-Sb	11 43.5	+47 46	10.9	4.4 × 0.8	edge-on; same field as Chi UMa
45	3941	UMa	G-Sa	11 50.3	+37 16	9.8	1.8 × 1.2	small, bright, elliptical shape
46	4026	UMa	G-E8	11 56.9	+51 12	10.7	3.6 × 0.7	lens-shaped edge-on; near γ UMa
47	4088	UMa	G-Sc	12 03.0	+50 49	10.9	4.5 × 1.4	nearly edge-on; 4085 in same field
48	4111	UMa	G-S0	12 04.5	+43 21	9.7	3.3 × 0.6	bright, lens-shaped, edge-on spiral
49	4157	UMa	G-Sb	12 08.6	+50 46	11.9	6.5 × 0.8	edge-on, a thin sliver; 4026+4088 nearby
50	4605	UMa	G-Scp	12 37.8	+61 53	9.6	5.0 × 1.2	bright, distinct, edge-on spiral
51	3115	Sex	G-E6	10 02.8	−07 28	9.3	4.0 × 1.2	"Spindle Galaxy"; bright, elongated
52	3242	Hya	PN	10 22.4	−18 23	9.1	40″ × 35″	"Ghost of Jupiter" planetary
53	3344	LMi	G-Sc	10 40.7	+25 11	10.4	7.6 × 6.2	diffuse, face-on spiral
54	3432	LMi	G-Sc	10 49.7	+36 54	11.4	5.8 × 0.8	nearly edge-on; faint flat streak
55	2903	Leo	G-Sb	09 29.3	+21 44	9.1	11.0 × 4.6	very bright, large elongated spiral
56	3384	Leo	G-E7	10 45.7	+12 54	10.2	4.4 × 1.4	same field as M105 and NGC 3389
57	3521	Leo	G-Sc	11 03.2	+00 14	9.5	7.0 × 4.0	very bright, large spiral
58	3607	Leo	G-E1	11 14.3	+18 20	9.6	1.7 × 1.5	NGC 3605 and 3608 in same field
59	3628	Leo	G-Sb	11 17.7	+13 53	10.9	12.0 × 1.5	large, edge-on; same field as M65/M66
60	4214	CVn	G-irr	12 13.1	+36 36	10.3	6.6 × 5.8	large irregular galaxy
61	4244	CVn	G-S	12 15.0	+38 05	11.9	14.5 × 1.0	large, distinct, edge-on spiral
62	4449	CVn	G-irr	12 25.8	+44 22	9.2	4.1 × 3.4	bright rectangular shape
63	4490	CVn	G-Sc	12 28.3	+41 55	9.7	5.6 × 2.1	bright spiral; 4485 in same field
64	4631	CVn	G-Sc	12 39.8	+32 49	9.3	12.6 × 1.4	very large, bright, edge-on; no dust lane
65	4656	CVn	G-Sc	12 41.6	+32 26	11.2	19.5 × 2.0	same field as 4631; fainter, smaller
66	5005	CVn	G-Sb	13 08.5	+37 19	9.8	4.4 × 1.7	bright elongated spiral; near α CVn
67	5033	CVn	G-Sb	13 11.2	+36 51	10.3	9.9 × 4.8	large, bright spiral near NGC 5005
68	4274	Com	G-Sb	12 17.4	+29 53	10.8	6.7 × 1.3	NGC 4278 in same field
69	4494	Com	G-E1	12 28.9	+26 03	9.6	1.3 × 1.2	small, bright elliptical
70	4414	Com	G-Sc	12 24.0	+31 30	9.7	3.2 × 1.5	bright spiral; star-like nucleus
71	4559	Com	G-Sc	12 33.5	+28 14	10.6	11.0 × 4.5	large spiral; coarse structure
72	4565	Com	G-Sb	12 33.9	+26 16	10.2	14.4 × 1.2	superb edge-on spiral with dust lane
73	4725	Com	G-Sb	12 48.1	+25 46	8.9	10.0 × 5.5	very bright, large spiral
74	4361	Crv	PN	12 21.9	−18 29	11.4	18″	$12^{m}.8$ central star

No.	NGC	Con	Type	R.A. (1950)	Dec.	m_v	Size	Remarks
75	4216	Vir	G-Sb	12 13.4	+13 25	10.4	7.4 × 0.9	nearly edge-on; two others in field
76	4388	Vir	G-Sb	12 23.3	+12 56	11.7p	5.0 × 0.9	edge-on; near M84 and M86
77	4438	Vir	G-S	12 25.3	+13 17	10.8	8.0 × 3.0	paired with NGC 4435
78	4473	Vir	G-E4	12 27.3	+13 42	10.1	1.6 × 0.9	NGC 4477 in same field
79	4517	Vir	G-Sc	12 29.0	+00 21	12.0	8.9 × 0.8	faint edge-on spiral
80	4526	Vir	G-E7	12 31.6	+07 58	10.9	3.3 × 1.0	between two 7$^{\mathrm{m}}$0 stars
81	4535	Vir	G-Sc	12 31.8	+08 28	10.4p	6.0 × 4.0	near M49
82	4697	Vir	G-E4	12 46.0	−05 32	9.6	2.2 × 1.4	small, bright elliptical
83	4699	Vir	G-Sa	12 46.5	−08 24	9.3	3.0 × 2.0	small, bright elliptical shape
84	4762	Vir	G-Sa	12 50.4	+11 31	11.0	3.7 × 0.4	flattest galaxy; 4754 in same field
85	5746	Vir	G-Sb	14 42.3	+02 10	10.1	6.3 × 0.8	fine, edge-on spiral near 109 Virginis
86	5907	Dra	G-Sb	15 14.6	+56 31	11.3	11.1 × 0.7	fine, edge-on spiral with dust lane
87	6503	Dra	G-Sb	17 49.9	+70 10	9.6	4.5 × 1.0	bright spiral
88	6543	Dra	PN	17 58.8	+66 38	8.7	22″	luminous blue-green disk
The Summer Sky								
89	6207	Her	G-Sc	16 41.3	+36 56	11.3	2.0 × 1.1	same field as M13 cluster
90	6210	Her	PN	16 42.5	+23 53	9.2	20″ × 13″	very star-like blue planetary
91	6369	Oph	PN	17 26.3	−23 44	9.9	28″	greenish, annular, and circular
92	6572	Oph	PN	18 09.7	+06 50	8.9	16″ × 13″	tiny oval; bright blue
93	6633	Oph	OC	18 25.1	+06 32	4.9	20	wide-field cluster; IC4756 nearby
94	6712	Sct	GC	18 50.3	−08 47	8.9	2.1	small globular near M26
95	6819	Cyg	OC	19 39.6	+40 06	10.1	6	150*; faint but rich cluster
96	6826	Cyg	PN	19 43.4	+50 24	9.4	27″ × 24″	Blinking Planetary Nebula
97	6960	Cyg	SNR	20 43.6	+30 32	—	70 × 6	Veil Nebula (west component)
98	6992–5	Cyg	SNR	20 54.3	+31 30	—	78 × 8	Veil Nebula (east component)
99	7000	Cyg	EN	20 57.0	+44 08	—	120 × 100	North America Neb.; binoc. obj.
100	7027	Cyg	EN	21 05.1	+42 02	10.4	18″ × 11″	very star-like H II region
101	6445	Sgr	PN	17 47.8	−20 00	11.8	38″ × 29″	small, bright and annular; near M23
102	6818	Sgr	PN	19 41.1	−14 17	9.9	22″ × 15″	"Little Gem"; annular; 6822 nearby
103	6802	Vul	OC	19 28.4	+20 10	11.0	3.5	60*; small, faint but rich
104	6940	Vul	OC	20 32.5	+28 08	8.2	20	100*; Type e; rich cluster
105	6939	Cep	OC	20 30.4	+60 28	10.0	5	80*; very rich; 6946 in same field
106	6946	Cep	G-Sc	20 33.9	+59 58	9.7p	9.0 × 7.5	faint, diffuse, face-on spiral
107	7129	Cep	RN	21 42.0	+65 52	—	7 × 7	small faint RN; several stars inv.
108	40	Cep	PN	00 10.2	+72 15	10.5	60″ × 38″	small circular glow; 11$^{\mathrm{m}}$5 central star
109	7209	Lac	OC	22 03.2	+46 15	7.6	20	50*; Type d; within Milky Way
110	7243	Lac	OC	22 13.2	+49 38	7.4	20	40*; Type d; within Milky Way
Challenge Objects								
1	246	Cet	PN	00 44.6	−12 09	8.5	240″ × 210″	large and diffuse; deceptively difficult
2	1275	Per	G	03 16.4	+41 20	12.7	0.7 × 0.6	small and faint; exploding gal.; Perseus A
3	1432/35	Tau	RN	03 43.3	+23 42	—	30 × 30	Pleiades nebl'y; brightest around Merope
4	1499	Per	EN	04 00.1	+36 17	—	145 × 40	California Neb.; very large and faint
5	IC434/35/ B33/2023	Ori	E/R/DN	05 38.6	−02 26	—	60/3/10	complex of nebl'y S. of zeta Ori., B33 is famous dark Horsehead Neb.; difficult
6	IC431/32/ NGC 2024	Ori	E/RN	05 39.4	−01 52	—	4/6/30	complex of nebl'y N. of zeta Ori., NGC2024 is easy but masked by glow from zeta.
7	IC 443	Gem	SNR	06 13.9	+22 48	—	27 × 5	v. faint supernova remnant NE. of η Gem.
8	J 900	Gem	PN	06 23.0	+17 49	12.2	12″ × 10″	bright but starlike; oval at high mag.
9	2237/46	Mon	EN	06 29.6	+04 40	—	60	Rosette Neb.; very large; incl. NGC2244
10	2419	Lyn	GC	07 34.8	+39 00	11.5	1.7	most distant known Milky Way GC (2 × 10^5 l.y.)
11	5897	Lib	GC	15 14.5	−20 50	10.9	7.3	large, but faint and loose globular cl.
12	B 72	Oph	DN	17 21.0	−23 35	—	30	Barnard's dark S-Nebula; RFT needed
13	6781	Aql	PN	19 16.0	+06 26	11.8	106″	pale version of M97; large, fairly bright
14	6791	Lyr	OC	19 19.0	+37 40	11	13	large, faint but very rich cl.; 100+*
15	M1-92	Cyg	RN	19 34.3	+29 27	11	0.2 × 0.1	Footprint Neb.; bright but starlike; double
16	6822	Sgr	G-irr	19 42.1	−14 53	11.0	16.2 × 11.2	Barnard's Gal.; member Local Grp.; faint
17	6888	Cyg	SNR?	20 10.7	+38 16	—	18 × 12	Crescent Neb.; small faint arc near γ Cyg.
18	IC 5146	Cyg	RN	21 51.3	+47 02	—	12 × 12	Cocoon Neb.; faint; at end of long dark neb.
19	7317–20	Peg	G's	22 33.7	+33 42	14–15	—	Stephan's Quintet; $\frac{1}{2}$°SSW. of NGC 7331
20	7635	Cas	EN	23 18.5	+60 54	—	4 × 3	Bubble Neb.; v. faint; $\frac{1}{2}$°SW. of M52

GALAXIES

BY BARRY F. MADORE

External galaxies are generally of such low surface brightness that they often prove disappointing objects for the amateur observer. However it must be remembered that many of these galaxies were discovered with very small telescopes and that the enjoyment of their discovery can be recaptured. In addition the central concentration of light varies from galaxy to galaxy making a visual classification of the types possible at the telescope. Indeed the type of galaxy as listed in the first table is in part based on the fraction of light coming from the central bulge of the galaxy as compared to the contribution from a disk component. Disk galaxies with dominant bulges are classified as Sa; as the nuclear contribution declines, types of Sb, Sc, and Sd are assigned until the nucleus is absent at type Sm. Often the disks of these galaxies show spiral symmetry, the coherence and strength of which is denoted by Roman numerals I through V, smaller numbers indicating well-formed global spiral patterns. Those spirals with central bars are designated SB while those with only a hint of a disk embedded in the bulge are called S0. A separate class of galaxies which possess no disk component are called ellipticals and can only be further classified numerically by their apparent flattening: E0 being apparently round, E7 being the most flattened.

Environment appears to play an important role in the determining of the types of galaxies we see at the present epoch. Rich clusters of galaxies such as the system in Coma are dominated by ellipticals and gas-free S0 galaxies. The less dense clusters and groups tend to be dominated by the spiral, disk galaxies. Remarkably, in pairs of galaxies the two types are much more frequently of the same Hubble type than random selection would predict. Encounters between disk galaxies may in some cases result in the instabilities necessary to form the spiral structure we often see. M51, the Whirlpool and its companion NGC 519S are an often-cited example of this type of interaction. In the past when the Universe was much more densely packed, interactions and collisions may have been sufficiently frequent that entire galaxies merged to form a single large new system; it has been suggested that some elliptical galaxies formed in this way.

The following table presents the 40 brightest galaxies taken from the Revised Shapley-Ames Catalog. As well as their designations, positions, and types, the table lists the total blue magnitudes, major and minor axis lengths (to the nearest minute of arc), one modern estimate of their distances in thousands of parsecs, and finally their radial velocities corrected for the motion of our Sun about the galactic centre.

THE 40 OPTICALLY BRIGHTEST SHAPLEY-AMES GALAXIES

NGC/IC (Other)	α/δ (1983)	Type	B_T ma × mi	Distance Corrected Radial Vel.
55	$00^h14^m04^s$ $-39°17.1'$	Sc	8.22 mag 25 × 3 arc min	3 100 kpc +115 km/s
205 M110	00 39 27 +41 35.7	S0/E5pec	8.83 8 × 3	730 +49
221 M32	00 41 49 +40 46.3	E2	9.01 3 × 3	730 +86
224 M31	00 41 49 +41 10.5	Sb I–II	4.38 160 × 40	730 −10
247	00 46 19 −20 51.2	Sc III–IV	9.51 18 × 5	3 100 +604
253	00 46 46 −25 23.0	Sc	8.13 22 × 6	4 200 +504
SMC	00 52 10 −72 55.3	Im IV–V	2.79 216 × 216	60 +359
300	00 54.05 −37 46.7	Sc III	8.70 20 × 10	2 400 +625
598 M33	01 32 55 +30 34.0	Sc II–III	6.26 60 × 40	900 +506
628 M74	01 35 49 +15 41.6	Sc I	9.77 8 × 8	17 000 +507
1068 M77	02 41 49 −00 05.2	Sb II	9.55 3 × 2	25 000 +510
1291	03 16 42 −41 11.3	SBa	9.42 5 × 2	15 000 +512
1313	03 18 04 −66 33.6	SBc III–IV	9.37 5 × 3	5 200 +261
1316 Fornax A	03 22 03 −37 16.1	Sa (pec)	9.60 4 × 3	30 000 +1713
LMC	05 23 45 −69 46.3	SBm III	0.63 432 × 432	50 +34
2403	07 35 13 +65 38.2	Sc III	8.89 16 × 10	3 600 +299
2903	09 31 02 +21 34.4	Sc I–III	9.50 11 × 5	9 400 +472
3031 M81	09 54 11 +69 08.9	Sb I–II	7.86 16 × 10	3 600 +124
3034 M82	09 54 24 +69 45.5	Amorphous	9.28 7 × 2	3 600 +409
3521	11 04 57 +00 03.5	Sb II–III	9.64 7 × 2	13 000 +627

NGC/IC (Other)	α/δ (1983)	Type	B_T ma × mi	Distance Corrected Radial Vel.
3627 M66	11 19 22 +13 05.0	Sb II	9.74 8 × 3	12 000 +593
4258 M106	12 18 07 +47 24.1	Sb II	8.95 20 × 6	10 000 +520
4449	12 27 24 +44 11.4	Sm IV	9.85 5 × 3	5 000 +250
4472 M49	12 28 55 +08 05.8	E1/S0	9.32 5 × 4	22 000 +822
4486 M87	12 29 58 +12 29.2	E0	9.62 3 × 3	22 000 +1136
4594 M104	12 39 07 −11 31.8	Sa/b	9.28 7 × 2	17 000 +873
4631	12 41 18 +32 38.0	Sc	9.84 12 × 1	12 000 +606
4649 M60	12 42 49 +11 38.7	S0	9.83 4 × 3	22 000 +1142
4736 M94	12 50 06 +41 12.9	Sab	8.92 5 × 4	6 900 +345
4826 M64	12 55 55 +21 46.5	Sab II	9.37 8 × 4	7 000 +350
4945	13 04 28 −49 22.5	Sc	9.60 12 × 2	7 000 +275
5055 M63	13 15 04 +42 07.4	Sbc II–III	9.33 8 × 3	11 000 +550
5128 Cen A	13 24 29 −42 35.7	S0 (pec)	7.89 10 × 3	6 900 +251
5194 M51	13 29 10 +47 17.2	Sbc I–II	8.57 12 × 6	11 000 +541
5236 M83	13 36 02 −29 46.8	SBc II	8.51 10 × 8	6 900 +275
5457 M101	14 02 39 +54 26.4	Sc I	8.18 22 × 22	7 600 +372
6744	19 08 09 −63 53.0	Sbc II	9.24 9 × 9	13 000 +663
6822	19 43 59 −14 50.8	Im IV–V	9.35 20 × 10	680 +15
6946	20 34 30 +60 05.9	Sc II	9.68 13 × 9	6 700 +336
7793	23 56 57 −32 41.1	Sd IV	9.65 6 × 4	4 200 +241

The following table contains the positions and catalogue designations of all those galaxies known to have proper names which usually honour the discoverer (Object McLeish), identify the constellation in which the galaxy is found (Fornax A) or describe the galaxy in some easily remembered way (Whirlpool galaxy).

GALAXIES WITH PROPER NAMES

Name/Other	α/δ (1950)	Name/Other	α/δ (1950)
Andromeda Galaxy = M31 = NGC 224	$00^{h}40^{m}.0$ $+41^{\circ}00'$	Holmberg III	$09^{h}09^{m}.6$ $+74^{\circ}26'$
Andromeda I	00 43.0 +37 44	Holmberg IV = DDO 185	13 52.8 +54 09
Andromeda II	01 13.5 +33 09	Holmberg V	13 38.8 +54 35
Andromeda III	00 32.6 +36 14	Holmberg VI = NGC 1325 A	03 22.6 −21 31
Andromeda IV	00 39.8 +40 18	Holmberg VII = DDO 137	12 33.2 +06 35
Antennae = NGC 4038/39	11 59.3 −18 35	Holmberg VIII = DDO 166	13 11.0 +36 29
Barnard's Galaxy = NGC 6822	19 42.1 −14 53	Holmberg IX = DDO 66	09 53.5 +69 17
BL Lac	22 01.9 +42 11	Hydra A	09 15.7 −11 53
Capricorn Dwarf = Pal 13	21 44.0 −21 29	Keenan's System = NGC 5216/18 = Arp 104	13 31.1 +62 52
Caraffe Galaxy	04 26.6 −48 01	Large Magellanic Cloud	05 24.0 −69 48
Carina Dwarf	06 45.1 −51 00	Leo I = Harrington-Wilson #1 = Regulus Dwarf = DDO 74	10 05.8 +12 33
Cartwheel Galaxy	00 35.0 −34 01	Leo II = Harrington-Wilson #2 = Leo B = DDO 93	11 10.8 +22 26
Centaurus A = NGC 5128 = Arp 153	13 22.5 −42 46	Leo A = Leo III = DDO 69	09 56.5 +30 59
Circinus Galaxy	14 09.3 −65 06	Lindsay-Shapley Ring	06 44.4 −74 11
Copeland Septet = NGC 3745/54 = Arp 370	11 35.1 +22 18	McLeish's Object	20 05.0 −66 22
Cygnus A	19 57.7 +40 36	Maffei I	02 32.6 +59 26
Draco Dwarf = DDO 208	17 19.2 +57 58	Maffei II	02 38.1 +59 23
Fath 703	15 11.0 −15 17	Mayall's Object = Arp 148 = VV32	11 01.1 +41 07
Fornax A = NGC 1316	03 20.8 −37 23	Mice = NGC 4676 = Arp 242	12 44.7 +30 54
Fornax Dwarf	02 37.8 −34 44	Pegasus Dwarf = DDO 216	23 26.0 +14 28
Fourçade-Figueroa Object	13 32.4 −33 38	Perseus A = NGC 1275	03 16.5 +41 20
GR8 (Gibson Reaves) = DDO 155	12 56.2 +14 29	Pinwheel Galaxy = M101 = NGC 5457	14 01.5 +54 36
Hardcastle Nebula	13 10.2 −32 26	Regulus Dwarf = Leo I = DDO 74	10 05.8 +12 33
Hercules A	16 48.7 +05 06	Reticulum Dwarf	04 35.4 −58 56
Holmberg I = DDO 63	09 36.0 +71 25	Reinmuth 80 = NGC 4517 A	00 57.6 −33 58
Holmberg II = DDO 50 = Arp 268	08 13.7 +70 52	Seashell Galaxy	13 44.5 −30 10

Name/Other	α/δ (1950)	Name/Other	α/δ (1950)
Serpens Dwarf	$15^{h}13^{m}.5$ +00°03′	Triangulum Galaxy = M33 = NGC 598	$01^{h}31^{m}.0$ +30°24′
Seyfert's Sextet = NGC 6027 A–D	15 57.0 +20 54	Ursa Minor Dwarf = DDO 199	15 08.2 +67 23
Sextans A = DDO 75	10 08.6 −04 28	Virgo A = M87 = NGC 4486 = Arp 152	12 28.3 +12 40
Sextans B = DDO 70	09 57.4 +05 34	Whirlpool Galaxy = M51 = NGC 5194	13 27.8 +47 27
Sextans C	10 03.0 +00 19	Wild's Triplet = Arp 248	11 44.2 −03 33
Small Magellanic Cloud	00 51.0 −73 06	Wolf-Lundmark-Melotte = DDO 221	23 59.4 −15 44
Sombrero Galaxy = M104 = NGC 4594	12 37.6 −11 21	Zwicky No. 2 = DDO 105	11 55.9 +38 21
Spindle Galaxy = NGC 3115	10 02.8 −07 28	Zwicky's Triplet = Arp 103	16 48.0 +45 33
Stephans Quintet = NGC 7317-20 = Arp 319	22 33.7 +33 42		

The nearest galaxies listed below form what is known as our Local Group of Galaxies. Many of the distances are still quite uncertain.

THE NEAR-BY GALAXIES: OUR LOCAL GROUP

Name	α (1983.0)	δ	B_T	Type	Distance (kpc)
M31 = NGC 224	$00^{h}41^{m}.8$	+41°11′	4.38	Sb I–II	730
Galaxy	—	—	—	Sb/c	—
M33 = NGC 598	01 32.9	+30 34	6.26	Sc II–III	900
LMC	05 23.8	−69 46	0.63	SBm III	50
SMC	00 52.2	−72 55	2.79	Im IV–V	60
NGC 6822	19 44.0	−14 51	9.35	Im IV–V	520
IC 1613	01 03.9	+02 02	10.00	Im V	740
M110 = NGC 205	00 39.5	+41 36	8.83	S0/E5 pec	730
M32 = NGC 221	00 41.8	+40 46	9.01	E2	730
NGC 185	00 38.0	+48 15	10.13	dE3 pec	730
NGC 147	00 32.3	+48 25	10.36	dE5	730
Fornax	02 39.2	−34 36	9.1	dE	130
Sculptor	00 59.0	−33 47	10.5	dE	85
Leo I	10 07.6	+12 24	11.27	dE	230
Leo II	11 12.6	+22 15	12.85	dE	230
Draco	17 19.8	+57 56	—	dE	80
Ursa Minor	15 08.6	+67 16	—	dE	75
Carina	06 47.2	−50 59	—	dE	170
And I	00 44.6	+37 57	13.5	dE	730
And II	01 15.5	+33 21	13.5	dE	730
And III	00 34.5	+36 25	13.5	dE	730
LGS 3	01 02.9	+21 48	—	?	730

RADIO SOURCES

By Ken Tapping

This list gives examples of the various classes of radio sources to be found among the several thousand objects that have been catalogued. In addition, sources lying within the reach of small (amateur-built) radio telescopes are included. Where possible, the flux densities (S) at the frequencies 100, 500, and 1000 MHz are given. The flux unit equals 10^{-26} W m^{-2} Hz^{-1}.

For information on radio astronomy, see *Radio Astronomy*, by J. D. Kraus, (McGraw Hill, 1966). Radio maps of the sky can be found in *Sky and Telescope, 63*, 230 (1982). Amateur radio astronomy is discussed in *Astronomy, 5*, no. 12, 50 (1977), in a series of articles in *J. Roy. Ast. Soc. Canada, 72*, L5, L22, L38, ... (1978), and in *Sky and Telescope, 55*, 385 and 475, and *56*, 28 and 114 (1978).

Source	α(2000)δ	S (at 100, 500, 1000 MHz) Remarks
3C10	$00^{h}25^{m}.3$ +64°08′	180, 85, 56 Remnant of Tycho's Supernova of 1572
W3	02 25.4 +62 06	—, 80, 150 IC1795; Multiple HII region; OH source
Algol	03 07.9 +40 56	* Eclipsing binary star
3C84	03 19.8 +41 32	70, 25, 17 NGC 1275; Seyfert galaxy; m = 12.7, z = 0.018
Fornax-A	03 20.4 −37 22	900, 160, 110 NGC 1316; Galaxy; m = 10.1, z = 0.006
Pictor-A	05 19.9 −45 47	440, 140, 100 Galaxy; m = 15.8, z = 0.034
V371 Orionis	05 33.7 +01 55	* Red dwarf, flare star
Taurus-A	05 34.5 +22 01	1450, 1250, 1000 Crab Nebula; Remnant of 1054 Supernova
NP0532	05 34.4 +22 01	15, 0.5, 1 Crab Pulsar; Period = 0.0331 s
Orion-A	05 35.3 −05 25	90, 200, 360 Orion Neb.; HII region; OH, IR source
3C157	06 17.6 +22 42	360, 195, 180 IC443; Supernova remnant
VY CMa	07 23.1 −20 44	* Optical var.; IR, OH, H_2O source
Puppis-A	08 20.3 −42 48	650, 300, 100
Hydra-A	09 18.1 −12 05	390, 110, 65 Galaxy; m = 14.8, z = 0.052
3C273	12 29.1 +02 03	150, 57, 49 Strongest quasar; m = 13.0, z = 0.158

*Important but weak or sporadic radio source. Mean flux density ≤1 flux unit.

Source	α(2000)δ	S (at 100, 500, 1000 MHz) Remarks
Virgo-A	$12^h30\overset{m}{.}8$ $+12°23'$	1950, 450, 300 M 87; Elliptical galaxy with jet
Centaurus-A	13 25.4 −43 02	8500, 2500, 1400 NGC 5128; Galaxy; m = 7.5, z = 0.002
3C295	14 11.4 +52 12	95, 60, 28 Galaxy; m = 20.5, z = 0.461
OQ172	14 45.3 +09 59	10, 4, 2 Quasar; m = 18.4, z = 3.53
Scorpius X1	16 19.9 −15 38	* X-ray, radio, and optical variable
Hercules-A	16 51.2 +05 01	800, 120, 65 Galaxy; m = 18.5, z = 0.154
Gal. Cen. Region	17 42.0 −28 50	4400, 2900, 1800 Strong, diffuse emission
Sagittarius-A	17 42.5 −28 55	100, 250, 200 Associated with Galactic Centre
Sagittarius-B2	17 47.3 −28 24	—, 10, 70 Contains many molecules
SS433	19 11.9 +04 58	* Compact object with high velocity jets
CP1919	19 21.6 +21 52	0.08, 0.03, 0.005(?) First pulsar discovered; P = 1.3375 s
PSR 1937+21	19 39.6 +21 35	5, 0.2(?), 0.04(?) millisecond pulsar; P = 0.001558 s
Cygnus-A	19 59.5 +40 44	15 500, 4000, 2100 Strong radio galaxy
Cygnus-X	20 22.6 +40 23	400, 150, 30 Complex region
BL-Lacertae	22 02.7 +42 17	—, 5, 4 Radio galaxy; m = 14.0, z = 0.07
Cassiopeia-A	23 23.4 +58 49	25 000, 4500, 2800 Supernova remnant
Jupiter		Bursts at metre wavelengths
Moon		Thermal source (~220K)
Sun		20 000, 300 000, 900 000 Also intense bursts and strong, varying emissions.

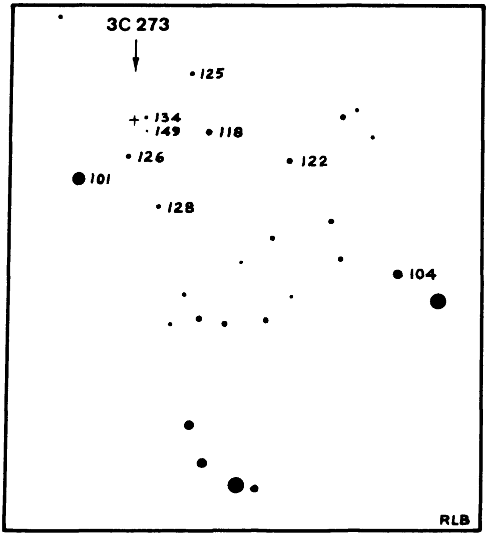
*Important but weak or sporadic radio source. Mean flux density ≲1 flux unit.

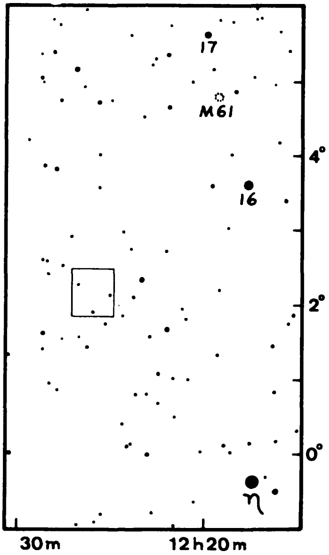
VARIABLE GALAXIES

Some peculiar galaxies (Seyfert galaxies, BL Lacertae objects, and quasars) have bright, star-like nuclei which vary in brightness by up to several magnitudes on a time scale of months to years. These variations can be studied by amateurs and students, especially using photographic techniques. The following table lists the brightest variable galaxies. For more information, see *Sky and Telescope* **55**, 372 (1978), which gives finder charts and comparison stars for the four brightest Seyfert galaxies (indicated with asterisks in the table).

Charts for finding the brightest quasar, 3C 273, are at the bottom of the page. Start with the right-hand chart which shows a "binocular size" field of view down to nearly 10th magnitude. The stars η Vir (Mag 3.9), 16 Vir (mag 5.0), and 17 Vir (mag 6.5) are labelled (η Vir is the star immediately east of the autumnal equinox on the MARCH or MAY star chart in the back of this Handbook). The two "bright" stars about 0.5 ° west of the small rectangle are of 7.6 magnitude (the small rectangle shows the area covered by the left-hand chart). On the left-hand chart, nine stars have their visual magnitudes indicated (on their west sides) to the nearest tenth of a magnitude, with the decimal point omitted. The position of 3C 273 is indicated by a small cross. With a red shift z = 0.158, 3C 273 is receding from us at 47 000 km/s, and is probably 2 or 3 billion light years from Earth, making it, by far, the intrinsically-brightest (output ≈10^{39} W), most-distant object that can be seen in a small telescope. (RLB)

Name	Type	R.A. 1950 Dec.				Mag.
		h	m	°	′	
NGC 1275*	Seyfert?	3	16.5	+41	20	11–13
3C 120	Seyfert	4	30.5	+05	15	14–16
OJ 287	BL Lac	8	52.0	+20	18	12–16
NGC 4151*	Seyfert	12	08.0	+39	41	10–12
3C 273	Quasar	12	26.6	+02	20	12–13
3C 345	Quasar	16	41.3	+39	54	14–17
Mkn. 509*	Seyfert	20	41.5	−10	54	12–13
BL Lac	BL Lac	22	00.7	+42	02	14–17
NGC 7469*	Seyfert	23	00.7	+08	36	12–13





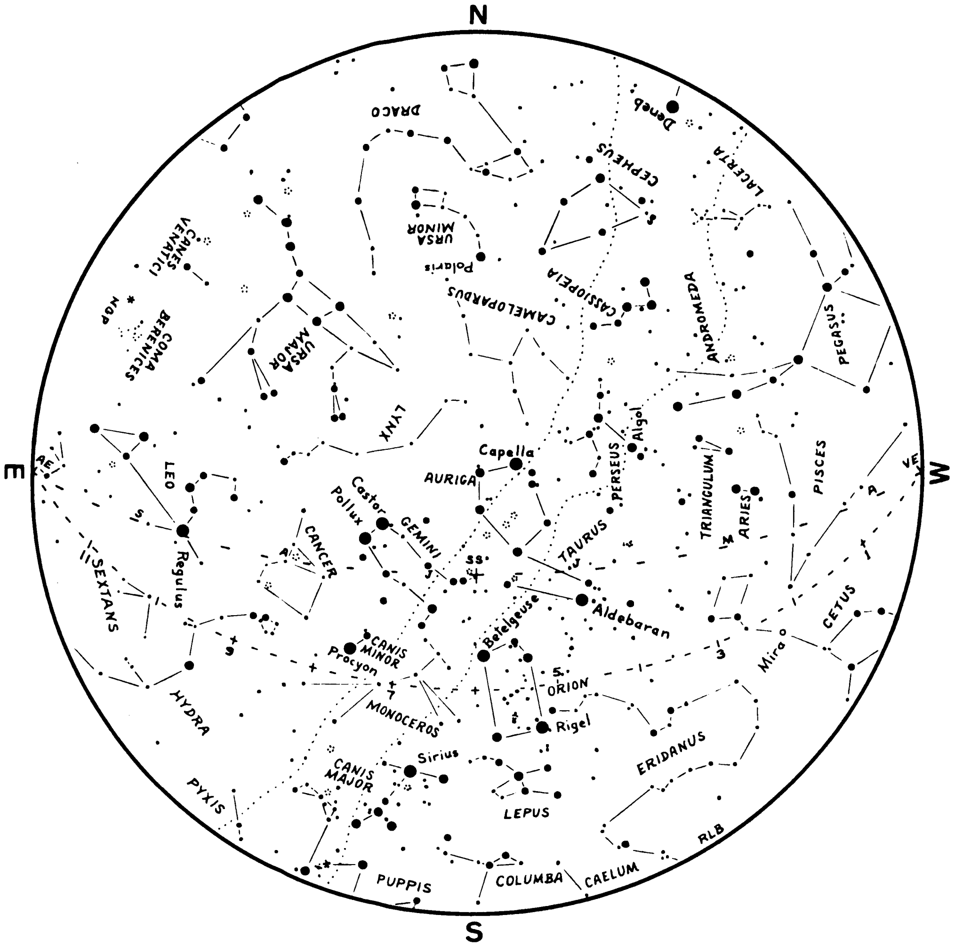
MAPS OF THE NIGHT SKY

The maps on the next seven pages cover the entire sky. Stars are shown down to a magnitude of 4.5 or 5, i.e. those which are readily apparent to the unaided eye on a reasonably dark night.

The first six maps are drawn for 45° N latitude, but are useful for latitudes several degrees north or south of this. They show the hemisphere of sky visible to an observer at various times of year. Because the aspect of the night sky changes continuously with both longitude and time, while time zones change discontinuously with both longitude and time of year, it is not possible to state simply when, in general, a particular observer will find that his or her sky fits exactly one of the six maps. The month indicated below each map is the time of year when the map will match the "late evening" sky. On any particular night, successive maps will represent the sky as it appears every four hours later. For example, at 2 or 3 am on a March night, the May map should be used. Just after dinner on a January night, the November map will be appropriate. The center of each map is the zenith, the point directly overhead; the circumference is the horizon. To identify the stars, hold the map in front of you so that the part of the horizon which you are facing (west, for instance) is downward. (The four letters around the periphery of each map indicate compass directions.)

The southern sky map is centred on the south celestial pole, and extends to 20° S declination at its periphery. There is thus considerable overlap with the southern areas of the other maps. Note that the orientation of the various names is generally inverted compared to that on the first six maps. This was done in recognition that most users of this Handbook will be residents of the Northern Hemisphere, and will make use of the southern sky map when they go on infrequent trips to the tropics. Thus in "normal" use this map will be read in an area above its centre, unlike the first six maps which are normally read below their centres. The months indicated around the edge of the map may be used to orient it to each of the preceding six maps, and have the same "late evening" significance as explained above. Tick marks around the edge of the map indicate hours of right ascension, with hours 0, 3, 6, etc. labelled. Starting at the centre of the map, the series of small crosses along 0 h right ascension indicates southern declinations 90°, 80°, 70°, ... , 20°. With the aid of a drawing compass, an observer in the Northern Hemisphere can quickly locate a circle, centred on the south celestial pole, which represents the southern limit of his or her sky.

On all seven maps, stars forming the usual constellation patterns are linked by straight lines, constellation names being given in upper case letters. Three constellations (Horologium, Mensa, and Microscopium) consist of faint stars; hence no patterns are indicated and the names are placed in parentheses. The names in lower case are those of first magnitude stars, except Algol and Mira which are famous variable stars, and Polaris which is near the north celestial pole. Small clusters of dots indicate the positions of bright star clusters, nebulae, or galaxies. Although a few of these are just visible to the naked eye, and most can be located in binoculars, a telescope is needed for good views of these objects. The pair of wavy, dotted lines indicates roughly the borders of the Milky Way. Small asterisks locate the directions of the galactic centre (GC), the north galactic pole (NGP), and the south galactic pole (SGP). LMC, SMC, and CS signify, respectively, the Large Magellanic Cloud, the Small Magellanic Cloud, and the Coal Sack. Two dashed lines appear on each of the first six maps. The one with more dashes is the celestial equator. Tick marks along this indicate hours of right ascension, the odd hours being labelled. The line with fewer dashes is the ecliptic, the apparent annual path of the Sun across the heavens. Letters along this line indicate the approximate position of the Sun at the beginning of each month. Also located along the ecliptic are the vernal equinox (VE), summer solstice (SS), autumnal equinox (AE), and winter solstice (WS). The Moon and the other eight planets are found near the ecliptic, but since their motions are not related in a simple way to our year, it is not feasible to show them on a general set of star maps.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PEGASUS
NGP
COMA BERENICES
URSA MAJOR
LYNX
Algol
Capella
PERSEUS
TRIANGULUM
PISCES
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AE
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Regulus
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CETUS
Betelgeuse
CANIS MINOR
Procyon
Mira
ORION
HYDRA
MONOCEROS
Rigel
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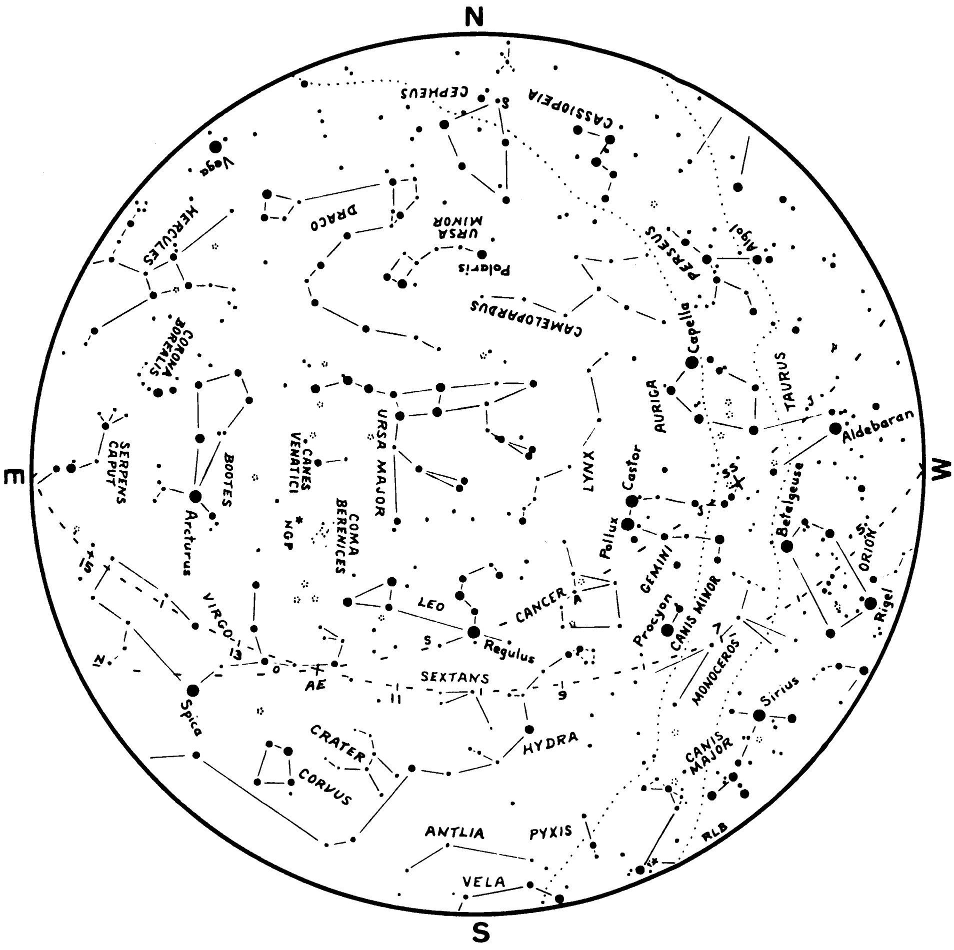
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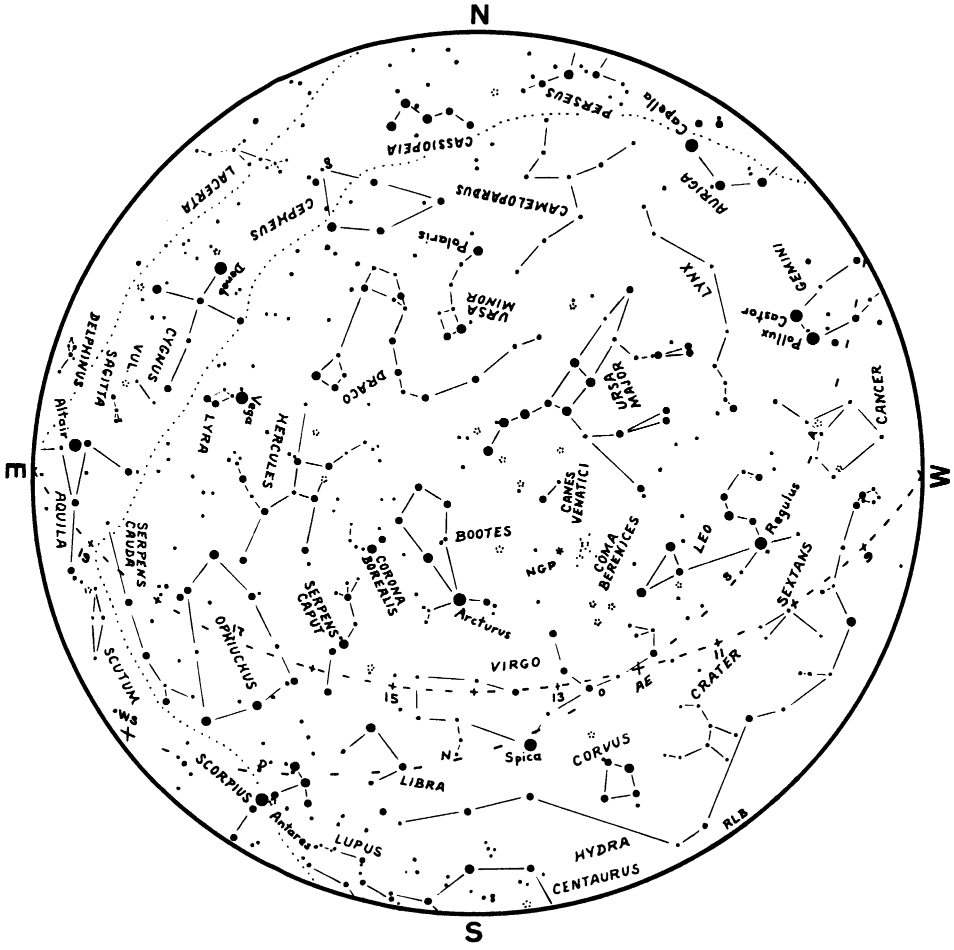
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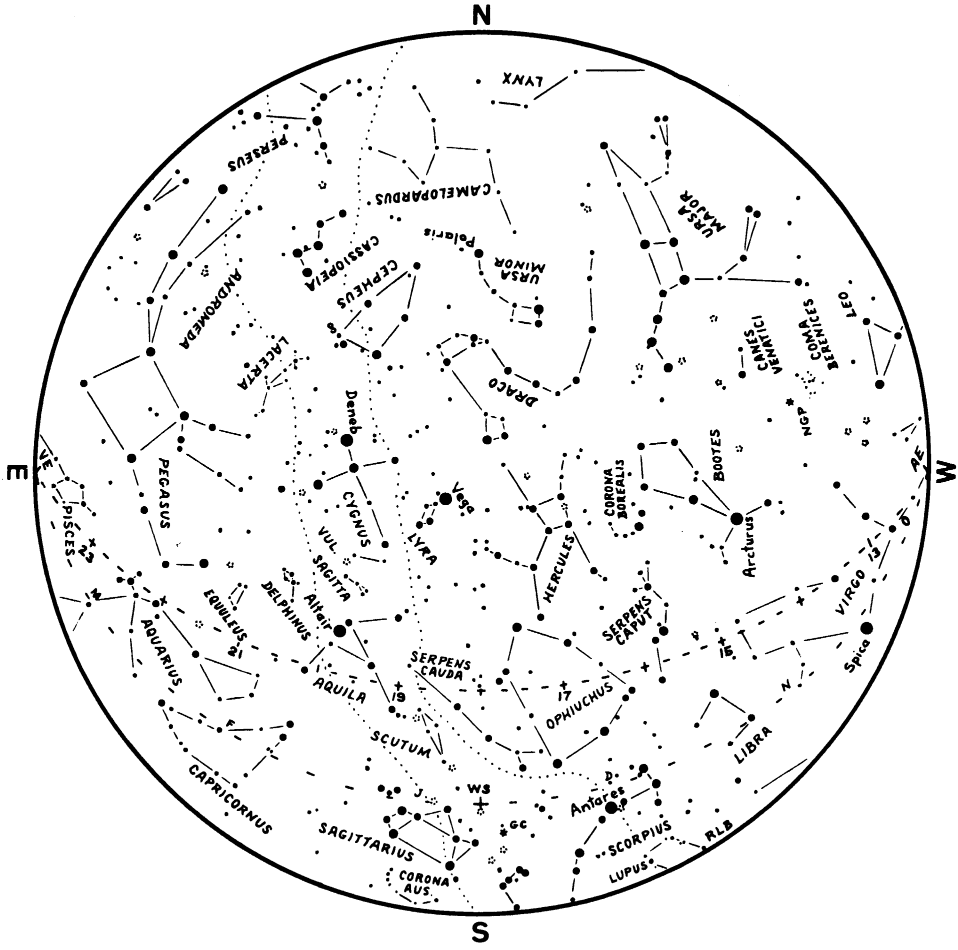
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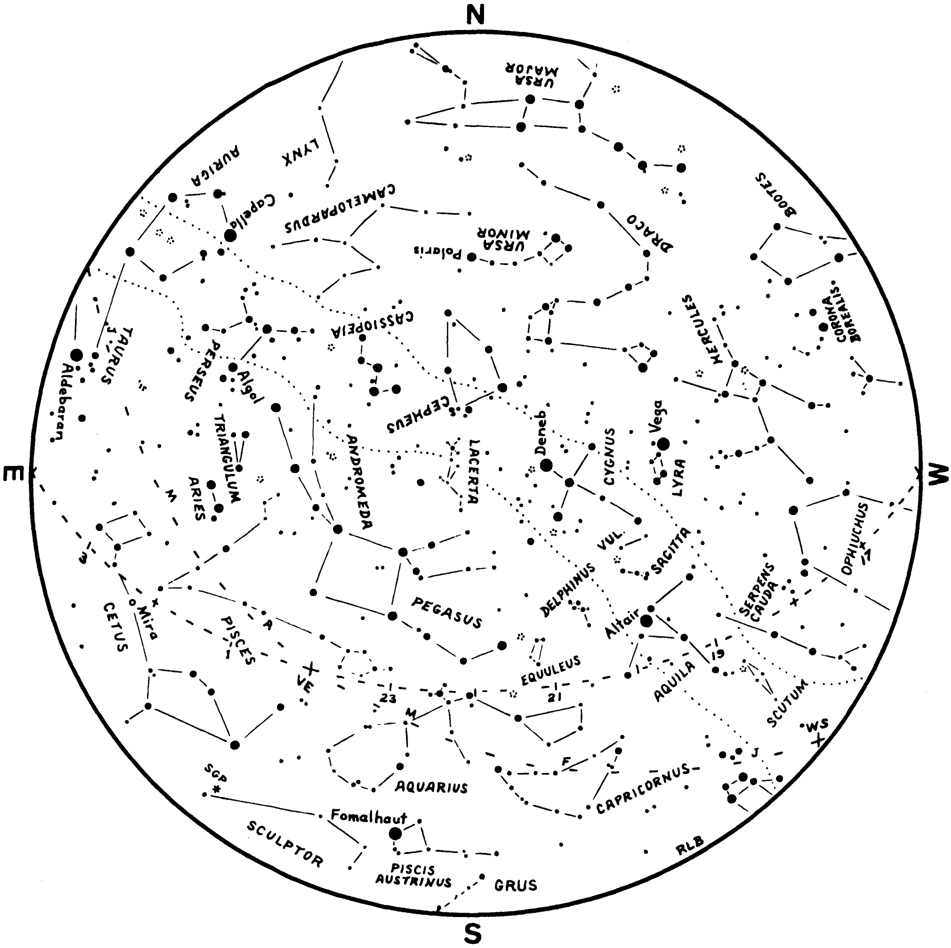
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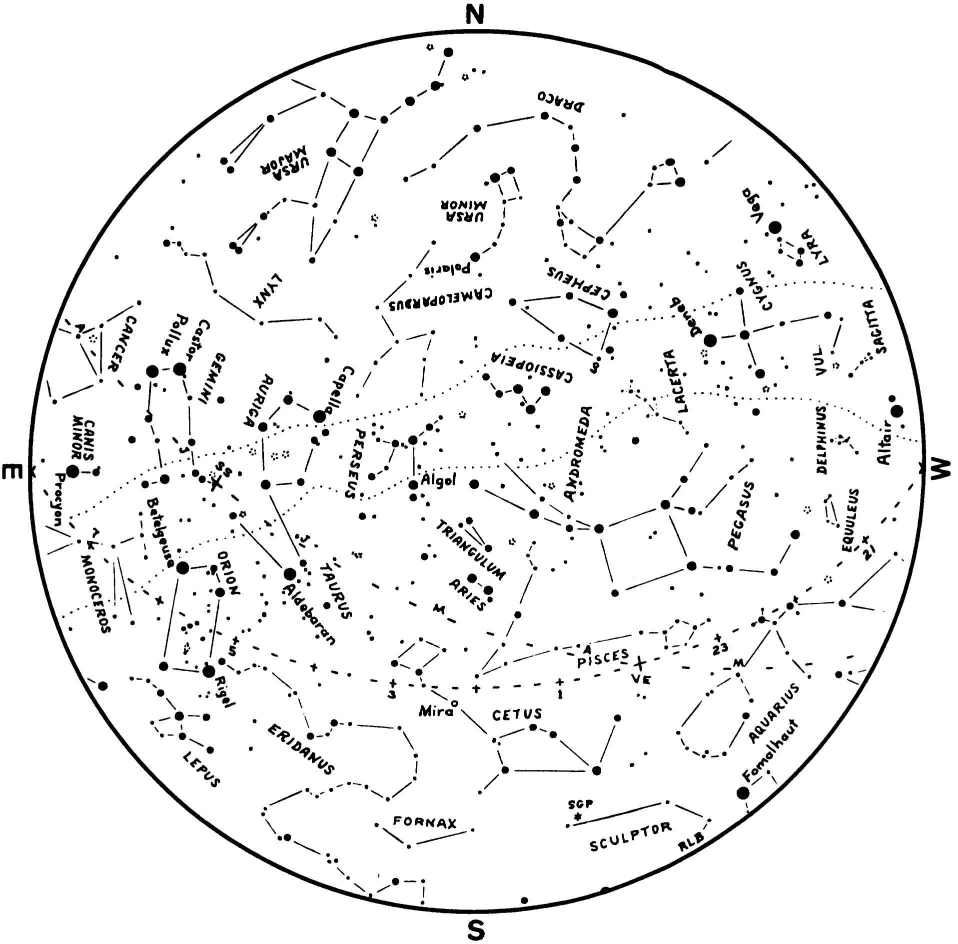
SEPTEMBER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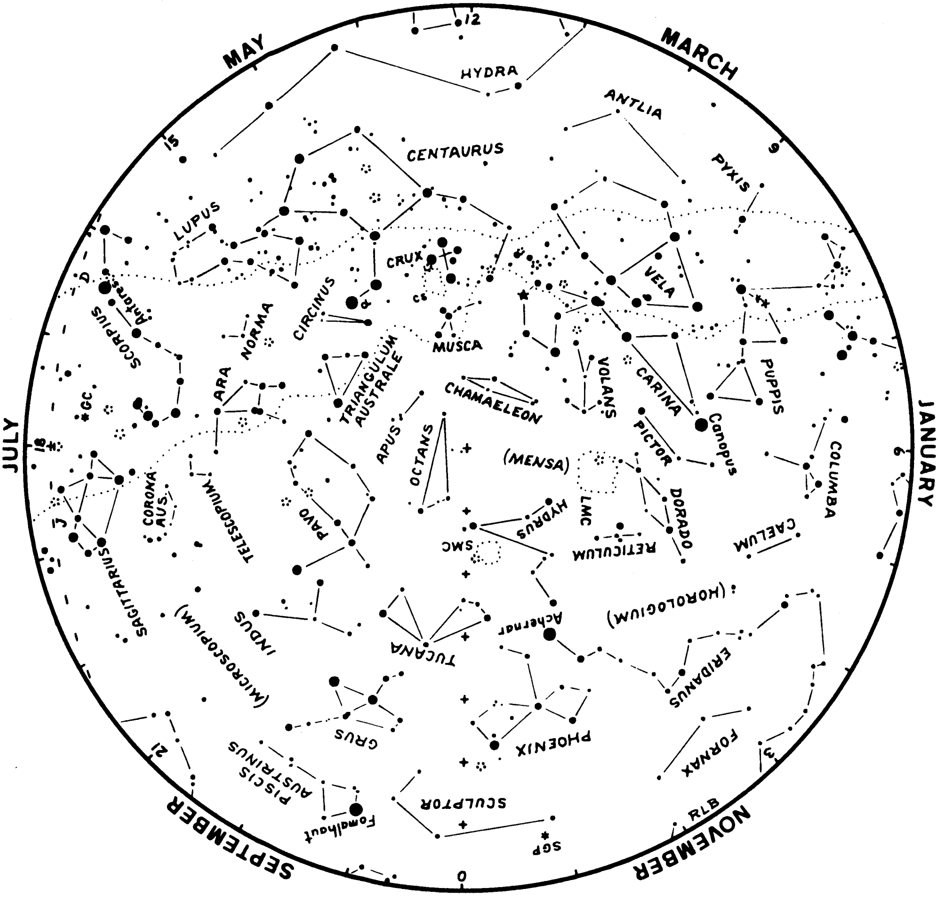

THE
SOUTHERN
SKY

KEY TO LEFT-HAND MARGIN SYMBOLS

D BASIC DATA
t TIME
M THE SKY MONTH BY MONTH
⊙ SUN
☾ MOON
P PLANETS, SATELLITES, AND ASTEROIDS
⟍ METEORS, COMETS, AND DUST
✸ STARS
⁙ NEBULAE

INDEX

CALENDAR 1986

January

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February

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CALENDAR 1987

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February

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March

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April

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July

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August

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September

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