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Journal

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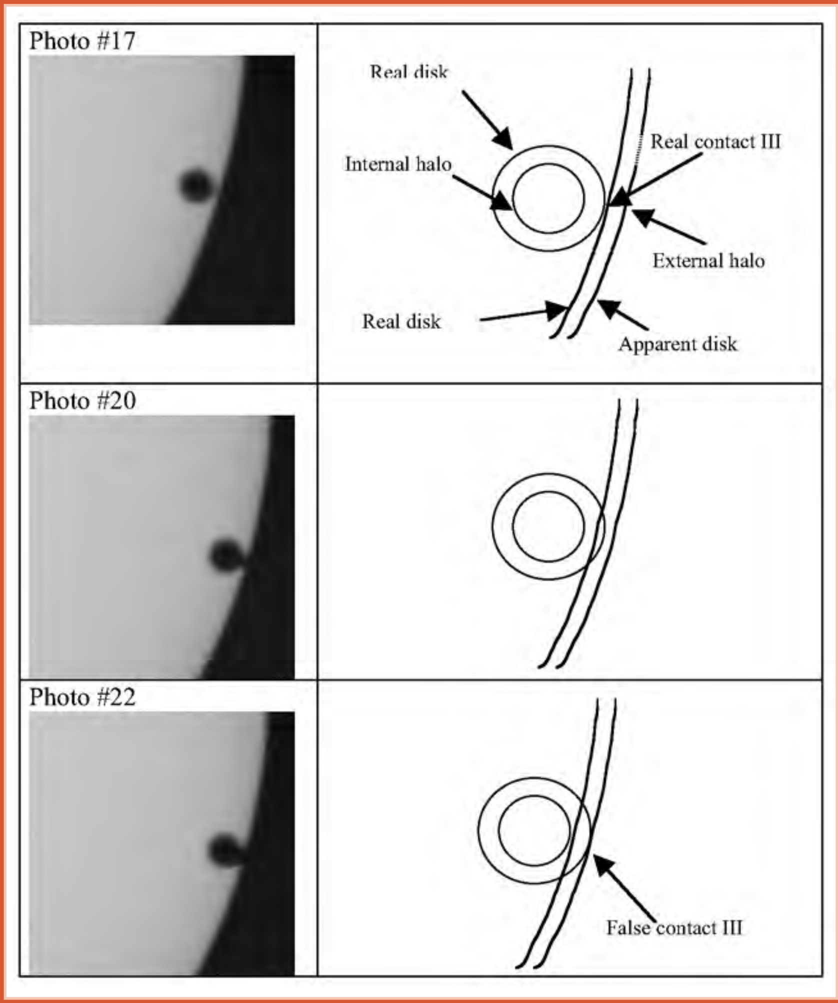

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October / octobre 2005

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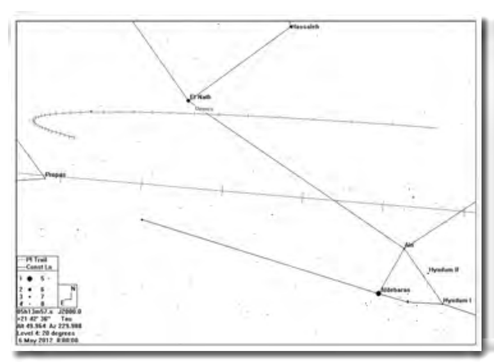

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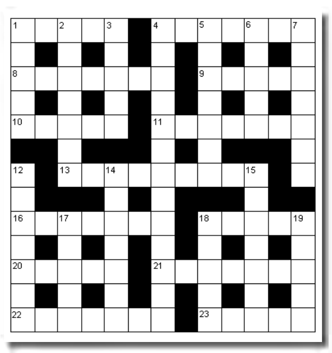

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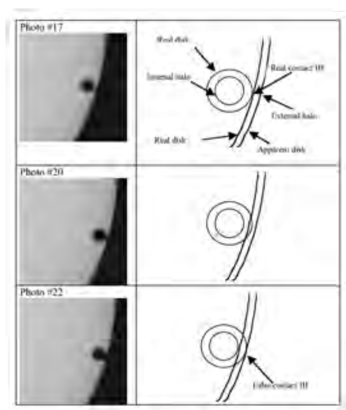

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Editorial

by Jay Anderson (jander@cc.umanitoba.ca)

With this issue, Wayne Barkhouse ends his tenure as Editor-In-Chief. As incoming Editor, I've been delighted and pleasantly surprised to find out how well the *Journal* production team works. The process is mostly invisible until you become a part of it and a large part of the credit is due to Wayne's organizational skills. We owe him a large "Thank you!" and an equally large thanks to the editorial and production staff listed on this page. Thank you all. I'm especially appreciative that most of the editorial board is staying with us.

So how will your new Editor begin?

It's a bit scary to take over after Wayne. The *Journal* is an impressive publication that is matched by no other North American astronomy society, and by only a few in Europe. It is unique in blending a mixture of amateur and professional articles, even if some of you don't read the more challenging ones. The *Journal* is the heart and soul of the RASC, the one item in our suite of products that traces our history, measures the pace of astronomy, and defines our personality as a Society. In the pages of the *Journal* you can trace the evolution of amateur and professional discovery for nearly all of the past century.

Amateur astronomy seems to be at a crossroad right now, or perhaps even a dead-end if you're on the pessimistic side. Each month the magazines we read bring us news of another professional project — new detectors, new observing programs, new spacecraft. Our Universe is being mapped and probed and autopsied so much that there sometimes seems little for the amateur to discover. Spacecraft find most comets now-a-days, along with novae, supernovae, and asteroids. Beginners with digital cameras and autoguiders can now take pictures that hugely surpass those that we struggled to obtain using Tri-X and hypersensitizing in the 1980s. Fortunately, astronomy is also deeply satisfying from a personal level: dark night skies, sudden meteors, aurorae, faint galaxies, eclipses, and the spreading Milky Way. Like a secret society, we welcome the Orion Nebula every fall and say goodbye every spring.

There are many opportunities and we'll try to explore them. Some will be technical: what is the best way of processing one-shot digital colour images? Others will subscribe to the personal thrill — observing, drawing, discovering. I'll press our professionals to tell us what they are doing — the CFHT is almost invisible on the street and it shouldn't be. I'm going to ask around to find people who will tell us about the latest discoveries they've made. Some of them will be you.

I won't promise much change at the start; I'm joining a team that's been winning. We have some challenges to develop an electronic version of the *Journal* and help sort out RASC finances. I'll see what the others on this team are thinking about the future. Above all we'll continue to make the *Journal* the diary of the RASC. Check us out in fifty years!

Journal

The *Journal* is a bi-monthly publication of the Royal Astronomical Society of Canada and is devoted to the advancement of astronomy and allied sciences. It contains articles on Canadian astronomers and current activities of the RASC and its Centres, research and review papers by professional and amateur astronomers, and articles of a historical, biographical, or educational nature of general interest to the astronomical community. All contributions are welcome, but the editors reserve the right to edit material prior to publication. Research papers are reviewed prior to publication, and professional astronomers with institutional affiliations are asked to pay publication charges of $100 per page. Such charges are waived for RASC members who do not have access to professional funds as well as for solicited articles. Manuscripts and other submitted material may be in English or French, and should be sent to the Editor-in-Chief.

The *Journal of The Royal Astronomical Society of Canada* is published at an annual subscription rate of $80.00 by The Royal Astronomical Society of Canada. Membership, which includes the publications (for personal use), is open to anyone interested in astronomy. Annual fees for 2005: Youth, $32,25; Ordinary, $80.00; Life Membership, $1,100. Applications for subscriptions to the *Journal* or membership in the RASC, and information on how to acquire back issues of the *Journal* can be obtained from:

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President's Corner

by Peter Jedicke (PJedicke@fanshawec.ca)

Not only is every article in every issue since the very beginning of the Society's *Journal* available online, but the past few issues were even posted on our Web site many weeks before the paper copy arrived in your mailbox. Are you one of the members who accessed your *Journal* "hot off the presses" there? If so, you are part of what I think is the biggest single step in the evolution of our 100-year publishing tradition.

When C.A. Chant penned the introduction to volume 1, number 1, early in 1907, I wonder if he thought of the 99 volumes to come. As Chant intended, the *Journal* has been "a bond uniting workers in this field of knowledge in all parts of the land, whether professionals or amateurs." I am particularly impressed that he realized then that "There are few technical articles on astronomy, which, if clearly written, have not a real value to the amateur." These sentiments have anchored generations of the *Journal's* proponents, and I'm sure that those who have defended our *Journal* against a variety of criticisms in the past quarter century were motivated by just such ideals.

But Chant also wrote that "...great interest and mental stimulus come from the *timely* announcement of discoveries such as are continually being made in Astronomy." In contrast to the astounding progress in so many areas of 21st-century life, the standard process of printing and distributing the *Journal* through the postal mail still goes at much the same pace. Canadians have whipped the postal service with endless abuse at least since I learned to lick a stamp, but like the proverbial weather, it seems no one ever does anything about it.

Until now. By clicking on the "Members-Only" link on our home page (`www.rasc.ca`) and entering the appropriate username and password, every one of you can take a huge leap forward in receiving your *Journal* in a timely fashion. For now at least, you still need to refer to the paper copy of the previous number of the *Journal,* which arrived in the postal mail, because that's where the appropriate username and password are found. Soon your membership identification code will suffice to unlock the gateway to the current *Journal,* or you will receive the key in an email.

There's a critical new wrinkle to add to this opportunity to see the latest *Journal,* and that relates to our Society's finances. As you have surely heard — in this very column! — we have faced significant deficits in the last year or two. One immediate consequence of this has been the two largest increases in our membership fees that the Society has ever seen.

A few influential Society leaders have expressed the view that the budget can be balanced by tweaking a few accounts here and there. But I am convinced that something much more serious is absolutely necessary, and the other members of your Executive Committee agree with me. As the Kingston Trio so musically told us, "these are the times that try men's souls." If you refer to your 2004 *Annual Report,* you can compare the expenses and the revenues related to each of our Society's publications. Only the *Journal* operates at a loss.

So we've come up with a way to balance our budget pretty much for the foreseeable future in one swoop. All that's needed is for every one of you to decide how you want to receive your *Journal*. If you want to continue to have it delivered to your mailbox by an agent of the Canadian government, that's fine. But perhaps you'd prefer — or at least be willing to accept — printing your own copy from our Web site. I've been asking Centres, when I visit, how many of you would take this option, and the response has been overwhelming: around 90% are happy to read the *Journal* online or print it off yourselves. Of those of you who prefer to get a paper copy by mail, most say you'd be willing to pay an extra fee — something around $20 per year — for that.

Your National Council recognized this trend at the recent General Assembly in Kelowna. A motion was passed to allow you to choose not to receive the *Journal* by postal mail. All you have to do is inform the *Journal* distribution team, through the National Office. Then, as soon as the procedures are in place, we will print fewer *Journals*. If you have your own reasons for preferring the traditional mode of delivery, I appeal to you to donate an extra $20, when you renew your membership or once a year if you are a Life Member, to cover the cost of printing and distribution.

If every member of the Society either gets their *Journal* online or donates $20 for the *Journal,* the drop in expenses and the increase in revenue will approximately wipe out the deficit. Then I can stop worrying about the Society's budget and get back to writing about astronomical topics like I wanted to do all along.

News Notes
En Manchettes

ALTITUDE, ELEVATION, AND SEEING

Where do you go to get the best seeing? In other words, where on Earth does the atmosphere allow your telescope to resolve the finest detail celestial objects have to offer? For centuries astronomers have believed that the best seeing is found on the top of the tallest peaks. Now, a Canadian astronomer has suggested that it is also very important to put your scope on the top of the tallest observatory.

While calibrating a simple seeing model, René Racine of the Université de Montréal discovered that the greatest impact on the quality of seeing appears to come from the relatively thin layer of atmosphere nearest the surface (*Publications of the Astronomical Society of the Pacific,* April 2005). As a result, the greatest improvement in seeing appears to come from raising the telescope's elevation a few metres above the ground rather than putting it on a mountain top thousands of metres above sea level. However, when asked to comment on his results Racine added, "it still remains that, at a given elevation, seeing is better at higher altitudes."

To calibrate his new seeing model Racine needed only the site's altitude and elevation as input. Racine tested his model against previously published data from 41 observing campaigns taken at 23 sites, including such famous observatories as those at Mauna Kea and Kitt Peak. The altitudes of the sites ranged from 1130 metres (Siding Springs, Australia) to 5150 metres (Cerro Chico, Chile) above sea level and the elevations ranged from 1 to 30 metres above the ground. The median seeing, traditionally defined as the full width of the stellar image at half-maximum intensity, was measured from 0.23 arcseconds at Dome-C in the Antarctic to 1.70 arcseconds at the South Pole.

The model not only proved to be effective in predicting seeing conditions but it appeared to suggest "that raising a telescope at an altitude of 1000 m from an elevation of 4 m to 10 m is equivalent, seeing wise, to moving it to an altitude of 4200 m." This effectively pokes the instrument through the most egregious turbulence, which is usually found only a few metres above the ground. If this result is correct, to achieve good seeing it can be far cheaper and easier to mount your telescope on a tall structure than build the infrastructure necessary to access the world's mountain-tops.

MAJDEN MAGIC! NEW ASTEROID DISCOVERED

Well-known amateur astronomer Ed Majden of Courtenay, B.C. has recently discovered his second fast-moving object (FMO) in the Spacewatch FMO Project. Ed, who is more typically known for his meteor spectroscopy work and all-sky camera observations, discovered his first FMO (asteroid 2004 MV2) on June 19, 2004. His latest discovery has been provisionally labeled 2005 NX55. The orbit of the newly discovered object (see Figure 1) passes well inside that of the Earth's and may be viewed at `neo.jpl.nasa.gov/cgi-bin/db_shm?sstr=2005+NX55&group=all&search=Search`. Ed's home page may be accessed via `members.shaw.ca/epmajden`.

FMOs are near-Earth asteroids (NEAs) that pass particularly close to the Earth and consequently leave "detection streaks" rather than "star-like" points on survey images. The Spacewatch group has found that the best way to detect FMOs is for an observer to inspect individual survey images. This time-intensive task can, in fact, be performed by any interested individual, and further details can be found at: `fmo.lpl.arizona.edu/FMO-home/index.cfm`.

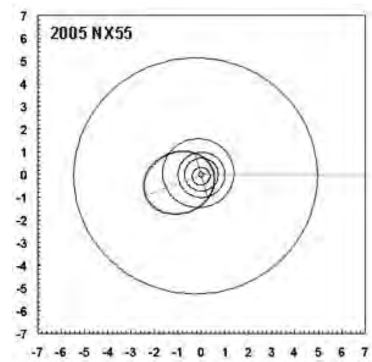

Figure 1 – The orbit of asteroid 2005 NX55. The scale is in astronomical units and the outermost circle represents the orbit of Jupiter. Plot courtesy of Marco Langbroek of the Dutch Meteor Society.

SPECTACULAR IMAGES OF THE COMET TEMPEL 1

The Canada-France-Hawaii telescope with MegaCam was recently used to observe comet Tempel 1, two days prior to the Deep Impact encounter (Figure 2). The comet images were obtained by stacking together several exposures obtained through two different filters. The elongation of the comet's "core" in the image is due to the slow proper motion of the comet against the fixed background of stars from our own galaxy and distant galaxies, on which the telescope was tracking during the set of exposures. The images were taken over a period of 15 minutes (on June 29, 2005 at 20:10 HST). Further images and details are available at: `www.cfht.hawaii.edu/News/Tempel1`.

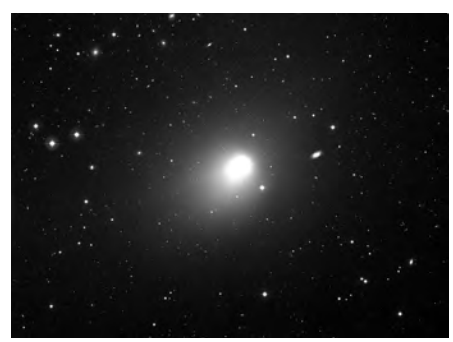

Figure 2 – The coma of comet Tempel 1 is clearly visible in this image. Notice the distant background stars and galaxies. Image courtesy of the Canada-France-Hawaii Telescope/2005.

Customized Calculation of Navigational and Astronomical Ephemerides: Applied Spherical Astronomy

by Robert A. Egler (robert_egler@ncsu.edu)

Introduction

There are many sources of astronomical data available; the *Astronomical Almanac* and the *Observer's Handbook* are two of the most common annual publications. However, each of these contains much more data than I actually use. Professionally I use both publications, but one of my astronomical hobbies is celestial navigation, the good old-fashioned use of a sextant and calculations or tables to determine my position on the surface of the Earth. While I have developed my own equations and methods for using the *Astronomical Almanac* in celestial navigation rather than the *Nautical Almanac,* the *Astronomical Almanac* is large enough to be annoying when trying to fit everything into a small duffel bag for easy transport. Unfortunately, the *Observer's Handbook* does not contain all of the ephemeris data I need for the sight reduction methods I like to use.

The calculation of ephemerides is an exercise in applied spherical astronomy. Navigational ephemerides differ from astronomical ephemerides chiefly in the manner of presenting the data and the choice of which data to include. While today we may think of astronomy primarily as a "pure" science, that is to say one without major commercial or practical applications, the U.S. Naval Observatory was in fact established in 1830 with a major focus on applied astronomy, including the calculation of ephemerides for use in navigation.

The precise calculation of the ephemeris data presented in the *Astronomical Almanac* or the *Nautical Almanac* is a very complicated and highly mathematical subject. It is possible, however, with the use of desktop computers to calculate the basic data to a degree of accuracy suitable for most uses with a telescope not requiring high precision, and quite suitable for small boat navigation.

Thus I decided to develop a customized ephemeris, one that included only the data that I wanted to use, in the format and organization that I most prefer. While my personal ephemeris is chiefly concerned with positions of the Sun and the vernal equinox (and hence the sidereal time), the usefulness of these data is not restricted to navigation, and, with some fairly minor modifications, the computer application I use can provide whatever ephemeris data I want.

The ephemeris data I choose to calculate in my personal ephemeris are the Universal Time (UT) of Greenwich transit of the mean equinox, the declination of the Sun at 00:00h UT, and the UT of the Greenwich transit of the Sun for each day of a particular year. Using these data it is possible to calculate the Greenwich Hour Angle (GHA) of the Sun, the GHA of the mean equinox, and the solar declination at any specific time of interest.

The calculation of one day's data is not too complicated, but it is not trivial either. To calculate the data for an entire year by hand would be a lengthy and tedious task. Of course, I could write a specific program in a standard programming language, however using an *Excel*[1] spreadsheet has several advantages. Chief among those advantages is the "fill down" and "fill right" functions, which allow me to enter the formulae for one day, and then "fill down" the formulae for 365 days, while *Excel* updates the references in each cell. Setting up grouped columns for the day number and the data values for each day allows me to set those columns as the print area and print the information I need, and not all of the formulae. This method is much simpler than writing a dedicated program, and very portable, as I can use the spreadsheet on any computer that runs *Excel*.

Calculation of the Ephemeris Data

The calculation of the data of interest is usually done in a series of steps, so the spreadsheet first calculates intermediate values based on the numerical day of the year, using the equations (Duffett-Smith 1989, Meeus 1988):

$$M = \left(\frac{360}{365.2422}\right)D + e_g - \omega, \qquad (1)$$

$$E - e\sin E = M, \qquad (2)$$

$$\nu = 2\arctan\left(\sqrt{\frac{1+e}{1-e}}\tan\left(\frac{E}{2}\right)\right), \qquad (3)$$

$$L = \nu + \omega, \qquad (4)$$

where D is the number of days from 2005.0

[1] Excel is a registered trademark of the Microsoft Corporation.

to the date in question (epoch 2005.0 was chosen out of convenience), M is the mean anomaly using epoch 2005.0, 360 is a complete circle in degrees, 365.2422 is a tropical year in days, e_g is the ecliptic longitude for epoch 2005.0 (e_g = 279.6543110°), ω is ecliptic longitude at perigee (ω = 283.02280°), e is the eccentricity of the Earth's orbit (e = 0.0166840), and L is the Sun's geocentric ecliptic longitude on the date in question[2]. The variable ν is the true anomaly, which is the angle through which the true Sun has moved since the time of perigee, or in this case since epoch 2005.0. The calculation of the true anomaly requires the use of Kepler's equation (equation 2), which yields E, the eccentric anomaly. Equations 2 and 3 use radian measure, but converting ν to degrees for use in equation 4 will allow equation 4 to yield the result in degrees.

Since Kepler's equation cannot be solved algebraically, an iterative approach is used. I wrote a separate spreadsheet program to which the value of M is transferred as a seed value, E originally being set as equal to M, and then the resulting value of E used as a start for the next iteration. I find that the iteration converges to the sixth decimal place within five to seven steps, and so the secondary spreadsheet is set to return the value of E after the tenth iteration. It may be necessary to check certain values in the secondary spreadsheet to be sure that they are within the proper range, for example, that time is not negative. If the values are out of range, adding or subtracting 12 hours will bring the values back in range.

It should be noted that the equations listed here use angular values in degrees, while *Excel's* trigonometric functions use radians. A conversion factor is therefore needed for equations 1 and 4 when entering the formulas into the spreadsheet cells.

The first calculation of interest, the UT of the Greenwich transit of the mean equinox (T_g), is the simplest to calculate, as it is nothing more than a conversion of Greenwich sidereal time (GST) to Universal Time, done with the GST set to 00:00h. This conversion is expressed in decimal hours as:

$$T_g = 0.9972696\ (0.0657098\ P - B), \quad (5)$$

where P is the numerical day of the year of interest, B is 24h – GST at 00:00h UT on January 0 of the same year, and 0.9972696 is the ratio of a sidereal day to a mean solar day. The constant B can be obtained from the *Astronomical Almanac;* it is the difference of 24 minus the GST (in decimal hours) at 00:00h UT of January 0 for the year in question. The values of the constant B for the years 2003 through 2006 are shown below. To approximate the value of B for up to four subsequent years to a reasonable accuracy, take the B value for the year listed that is an even multiple of 4 years from the year of interest, and subtract 0.002052 from the values of B for every 4 years difference.[3] This approximation should not be extended too far into the future. The best method of finding B is to use the *Astronomical Almanac,* although it can be calculated directly if you wish (Duffett-Smith, 1989).

2003, B = 17.383486
2004, B = 17.399159
2005, B = 17.349467
2006, B = 17.365292

The second calculation of interest is the declination of the Sun at 0:00h UT. The declination of the Sun (δ, in decimal degrees) is given most generally by:

$$\sin\delta = (\sin\beta\cos\varepsilon) + (\cos\beta\sin\varepsilon\sin L) \quad (6)$$

where β is the ecliptic latitude (for practical purposes, β is zero for the Sun), ε is the obliquity of the ecliptic (ε = 23.438631° for epoch 2005.0), and L is the Sun's geocentric ecliptic longitude on the date in question. Since we are interested in the declination at 00:00h UT, therefore the variable D in equation 1 must be an integer corresponding to the number of days since epoch 2005.0 (D is 1 for January 1, 2005). Equation 6 thus reduces to the expression for the Sun's declination:

$$\delta = \arcsin(0.3978187\ \sin L). \quad (7)$$

The third calculation of interest is for the time of Greenwich transit of the Sun. For this data, it is necessary to first calculate the solar right ascension. To calculate the solar right ascension (RA), the numerical day of the year at noon is needed, so D will have a half integer value. The RA is then given by:

$$\tan \mathrm{RA} = \frac{(\sin L\cos e) - (\tan\beta\sin e)}{\cos L}, \quad (8)$$

where again β is equal to 0. Equation 8 becomes:

$$\mathrm{RA} = \arctan\ (0.91746406\ \tan L), \quad (9)$$

which will give us the RA of the Sun at 12:00h UT. Care must be taken to adjust the value of the tangent to lie in the proper quadrant by adding 180° or 360°. The RA of the Sun is the GST at solar transit, so the time must be converted from GST to UT by:

$$\text{UT of transit} = 0.9972696(\mathrm{RA} - (0.0657098\ P - B)), \quad (10)$$

as was done to find the UT of the Greenwich transit of the mean equinox. Actually, the astute reader will note that the RA at 12:00h UT will not be exactly equal to the RA at transit unless the time of transit is also 12:00h UT, since the Sun changes in RA by 3m 55.913s (equivalent to 0.06553h) on average per day. This small difference will not substantially change the result, as the UT of transit will not vary from 12:00h UT by more than 16 minutes, thus the maximum change in RA from 12:00h UT to the actual time of transit should not exceed approximately 2.6 seconds of angle.

A bonus of the process is that a plot of the UT of the Sun's Greenwich transit as a function of the day of the year reveals the shape of the equation of time, although upside down. Plotting 12h minus the transit time will yield a correct plot of the equation of time, as seen in Figure 1.

[2] All values are from the 2005 edition of *The Astronomical Almanac*.

[3] All values of B were calculated using the Astronomical Almanac for the year in question.

To find the GHA and declination (DEC) of the Sun at a specific UT from the UT of solar transit, we use two relations. The first is:

$$\mathrm{GHA} = \frac{360°(\mathrm{UT} - Tg_1)}{24^{\mathrm{h}} + (Tg_2 - Tg_1)} \qquad (11)$$

where Tg_1 is the Greenwich transit on the date of UT, Tg_2 is the Greenwich transit on the next date, and UT is the time of interest. If GHA is negative then add 360°, or if GHA > 360 then subtract 360°.
The second relation is:

$$\mathrm{DEC} = \delta_1 + \frac{(\delta_2 - \delta_1)\mathrm{UT}}{24^{\mathrm{h}}}, \qquad (12)$$

where δ_1 is the declination on date of UT, δ_2 is the declination on the next date, and UT is the time of interest. Negative declination is south. For use with standard sight reduction tables, ignore the sign.

Accuracy of the Results

Of course, all of the preceding material is just an interesting exercise in using a spreadsheet, and is rather useless if the results are not sufficiently accurate for your purposes.

To examine the accuracy of this method, I set the spreadsheet to produce values for the years 1984, 1987, 1994, and 1995 and compared the data thus calculated to the data presented in the *Astronomical Almanac* for those years.[4] The initial comparisons used a random selection of 24 dates per year, about 2 per month throughout each of the years, resulting in 96 random comparison dates. In order to have a better understanding of how the errors varied over the course of one year, a more detailed comparison was made for an additional 190 dates in 1984 concentrating on dates near the maximum errors, resulting in a total of 214 comparison dates in that year, and 286 total comparison dates.

Based on this analysis, the calculated value of the Greenwich transit of the mean equinox (Tg) is the most accurate, with an error not exceeding 0.7 seconds from the values tabulated in the *Astronomical Almanac*. The value of the Sun's declination has a maximum error of 30 arcseconds, and an average error of 14 arcseconds. Both of these are accurate enough for most of my uses at the telescope, and are acceptable values for small boat celestial navigation where the errors in the sextant readings easily may result in position errors exceeding these calculation errors.

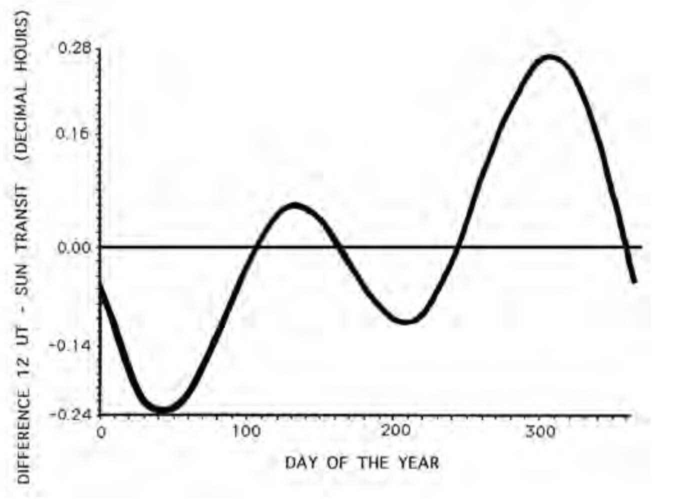

Figure 1

The calculation of the UT of solar transit at Greenwich shows the largest error to be approximately 2 seconds in time, and the average error to be approximately 1 second. The detailed comparison of the errors made for the 1984 data show that the error exceeds 1 second in transit time on approximately 86 days, or 23.6% of the year, and never exceeded 1.9 seconds.

Conclusion

When considering the accuracy of the data, we need to keep in mind that the *Nautical Almanac,* which is more widely used for celestial navigation than the *Astronomical Almanac,* only tabulates data to the nearest 0.1 arcminute. In addition, the data for the Greenwich Hour Angle of the Sun, which is tabulated in the *Nautical Almanac* rather than the time of transit as in the *Astronomical Almanac,* may be in error by as much as 0.25 arcminutes (Maloney 1985), corresponding to an error of 1 second in RA. Given these facts, these data compare well with the accuracy of the *Nautical Almanac* and is satisfactory for small boat navigation.

I found developing a personal ephemeris an interesting and enjoyable project in spherical astronomy, one that also provides me with a useful product and the data I need presented in exactly the format I want, at a level of accuracy sufficient for my needs.

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Robert Egler is an Unattached Member of the RASC. He is Senior Lecturer in Astronomy at North Carolina State University, and developed an interest in old-fashioned celestial navigation while working on the Global Positioning System in the 1980s.

[4] This comparison was done with parameters set to epoch 1980 to avoid having negative year values. The years chosen for comparison were determined by what old copies of the *Astronomical Almanac* I happen to have kept.

Naked Quasars

by Leslie J. Sage (l.sage@naturedc.com)

When I was a child, the song "Everything old is new again" was popular. This story brought that song to mind. Pierre Magain of the University of Liege, in Belgium, and his colleagues have found a bright quasar that appears not to have a surrounding galaxy (see the September 15, 2005 issue of *Nature*). A similar claim was made back in 1994 (see Bahcall *et al.* 1994 *Astrophysical Journal* 435, L11).

Quasar is the name we give to the bright optical (and sometimes radio) emission that is associated with the infall of gas into a supermassive black hole at the centre of a galaxy. As far as we can tell, all large galaxies have these black holes at their centres (dwarf galaxies might not), but only a small fraction — those that are actively feeding gas into the black hole — appear as quasars. The light from a quasar can exceed easily the luminosity of all of the stars in the rest of the galaxy put together, making it difficult observationally to see the surrounding galaxy. But, over the last 20 years or so, as astronomers' understanding of "active galactic nuclei" (of which quasars are the most luminous component) has deepened, the "standard model" of gas feeding black holes has come to be widely accepted.

It was therefore quite startling when John Bahcall, a prominent theorist at the Institute for Advanced Study in Princeton, and his colleagues, claimed to have found a population of quasars without host galaxies, using the *Hubble Space Telescope*. This would of course have gone against the prevailing view at the time, but Bahcall proposed the physically reasonable idea that quasars represent a very early stage of galaxy formation, before many stars had formed.

At that time, the *HST* had just been repaired and adaptive optics was for most ground-based telescopes just a dream. Disentangling the faint light from the stars of a surrounding galaxy from the bright point of the central quasar was therefore a difficult problem to which the *HST* was expected to make an important contribution, so Bahcall's claim attracted a lot of attention.

A year later, Mike Disney of the University of Cardiff and his colleagues used the *HST* to study quasars and found host galaxies around all of them. John Hutchings wrote in an accompanying article that "I consider there is no reasonable doubt whatever over the existence of host galaxies" (see the July 13, 1995 issue of *Nature*). Although the controversy rumbled on for another few months, it became clear that Bahcall had made an error in reducing his data, and that quasars — even his — do have host galaxies.

In the late 1990s Laura Ferrarese (then of Rutgers University, and now at the Dominion Astrophysical Observatory in Victoria) found that there is a clear relation between the mass of the central black hole and the mass of the host galaxy: the black hole is typically ~0.1 percent of the galaxy's mass.

Fast forward to now, where Magain and his colleages are again claiming to have seen a naked quasar. Is this a rerun of the earlier controversy? Probably not, for several reasons. First of all, they had clear knowledge of what happened previously, and they were armed with Ferrarese's relationship between the mass of the black hole and the mass of the expected galaxy. They were therefore careful to achieve a limit on the host galaxy's surface brightness that is a factor of six lower than would be expected, using Ferrarese's relation. In addition, it is part of a group of objects that includes a galaxy and an as-yet unidentified "blob" of gas about a tenth of an arcsecond away from the quasar. The blob is about the size of a small galaxy, yet does not appear to have any stars. The gas itself is glowing because it is illuminated by the quasar. The peculiar nature of the quasar is probably related to its presence in this group.

The nearby (about 1.5 arcsec away) galaxy is an ultra-luminous infrared galaxy — one of a class that is always associated with interactions with other galaxies. Magain proposes that the galaxy and quasar are interacting, with the quasar accreting gas from the galaxy — remember, the quasar has to get gas from somewhere to power itself.

Magain lists three possible explanations for this peculiar quasar: 1) the host galaxy was disrupted by the interaction with the companion; 2) an isolated black hole is accreting gas from the companion; 3) it lies inside a galaxy that — for some reason — doesn't have many stars. The first two explanations seem quite unlikely, while the third would imply that the host galaxy has a large "dark halo." While this could explain parts of the observations, normally a galaxy with a large dark halo and lots of gas would be expected to have formed stars. Personally, though this is not in the paper, Magain thinks that his quasar may well tell us something about the formation of some fraction of quasars.

Bahcall may well have been partially right, in that young galaxies might show quasar activity before the bulk of their stars form. But the bulk of galaxy formation was over by a redshift of 1, far earlier in the history of the Universe than the redshift of z=0.285 of Magain's quasar, so it is not clear to me that this explanation works for this particular quasar.

It is hard at this stage to see Magain's result as any kind of challenge to the "standard model" (and he makes no such claim), but it does point out that as we probe deeper into the Universe, we will continue to find strange phenomena that do not fit into the simple pictures that are commonly accepted. But that's how science progresses!

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FROM THE PAST | AU FIL DES ANS

A NEST OF BRIGHT METEORS

There appeared in a Toronto newspaper of February 24 a statement that a bright meteor had been seen on the previous evening by persons in Toronto and near London; and a request for further reports, courteously inserted next day and copied by other papers, brought to the present writer thirty responses by letter and telephone. This was very encouraging and showed the widespread interest in celestial phenomena, and it also revealed the remarkable fact that not one but four meteors had been seen.

by C.A. Chant
from *Journal,* Vol. 24, p. 146, March 1930.

WEB ACCESS TO OCTOBER 2005 ISSUE

The December 2005 issue of the *Journal* can be accessed from the RASC Web site at `www.rasc.ca/currentjrasc`. This issue will be posted immediately after the final production version is complete (approximately December 6, 2005) and removed from the Web once the issue begins arriving by mail.

THE BLACK-DROP EFFECT DURING THE TRANSIT OF VENUS ON JUNE 8, 2004

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ABSTRACT. The black-drop effect during the 2004 transit of Venus against the Sun has been observed and photographed by amateur astronomers in Montreal, Canada. It is shown in this report that the black drop can be explained by the contact then the disappearance of the halos surrounding Venus and the Sun at contact point. The black drop thus appears to be a real part of the disk of Venus and not an illusion of optical perception.

RÉSUMÉ. Le phénomène de la goutte noire pendant le transit de Vénus devant le Soleil a été observé et photographié par des astronomes amateurs à Montréal (Canada). On a pu ainsi expliquer la formation de la goutte noire par le contact puis la disparition des halos autour de Vénus et du Soleil au point de contact. La goutte noire apparaît ainsi comme étant une partie réelle du disque de Vénus et non pas une illusion de perception optique.

1. Introduction

The transit of Venus against the Sun on June 8, 2004, was a long-awaited event, observed by thousands of amateur and professional astronomers around the world. Many of them reported having seen the "black-drop effect," while others did not see it and still consider it is an optical illusion related to the turbulence of air and the quality of instruments. Others have also mistakenly thought that the black-drop effect comes from Venus' atmosphere. The existence of the black-drop effect as real and not resulting from Venus' atmosphere has been shown, however, by such authors as Pasachoff, Schneider, & Golub (2004), with spacecraft observations of a transit of Mercury.

This paper reports on the observations and photographs taken by members of the amateur astronomy clubs of Dorval and Montreal during the transit of Venus at contact III (the only one visible in Montreal), and proposes an original and detailed interpretation of the black-drop effect.

2. Instrumentation and Image Treatment

Several amateur telescopes were used in Montreal to visually observe the transit of Venus or take photographs of it (three Schmidt-Cassegrains of 5-, 8-, and 11-inch, two refractors of 3- and 4-inch, and two Maksutovs of 5- and 6-inch in diameter). The photographs reproduced in this report were taken by André Gendron and Gilles Guignier. Photographs taken from NASA's *TRACE (Transition Region and Coronal Explorer)* satellite with a telescope of 12-inch in diameter, and available from the Web site of Pasachoff *et al.* (`www.transitofvenus.info`), were also examined for comparison, with permission of the authors.

A. Gendron's telescope was an 11-inch *Celestron* C11 Schmidt-

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Cassegrain equipped with a *Thousand Oaks* solar filter, *Feather Touch* micro-focuser, *Vixen* camera with T-ring adapter, Varigami, and EQ-6 mount with Model MTS-3 Bodoefer-Elextronix system. Photographs were taken at primary focus with *Kodak* ISO 200 photographic film at 1/8 to 1/15 sec.

G. Guignier's telescope was an 8-inch *Celestron* C8 Schmidt-Cassegrain equipped with a *Baader AstroSolar* filter, *VestaPro* PCVC680K Webcam camera and *Astronomik* IR-Block filter. The images were taken at f/10 primary focus and processed using Christian Buil's *Iris* software. Typical processing consisted in extracting series of 30 to 100 black-and-white images from 180-sec AVI videos recorded at 10 frames per second. Then the images were then corrected by subtracting a reference offset image and divided by a reference flat image. Finally, selected frames were registered, accumulated, and enhanced with an un-sharp mask. Images were then exported in FITS or JPEG formats.

The size of the disks and halos around Venus and the Sun in the photographs was deduced from the magnification factor of the telescope and the dimensions of the photographic film or camera pixels used. To detect precisely the edges of Venus and the Sun, Richard Berry's *AIP W4* software, Frei & Chen's algorithm, and the Pixel Radius Tool were used by A. Gendron and G. St-Onge. The uncertainty of the spatial dimension measurements was ±1 pixel, which corresponds to ±1.4, ±0.4, and ±0.3 arcseconds in the photographs by A. Gendron, G. Guignier, and *TRACE,* respectively. The actual diameter of Venus on June 8 (58.2 arcseconds) was obtained from the *Observer's Handbook 2004*.

A likely cause for the halos is the "blurring" of the images by the telescopes, also described by Pasachoff & Schneider (2004) as the "point spread function (PSF)" of the telescopes, or the "contrast resolution" of the telescopes described by the "modulation transfer function (MTF)" or "phase transfer function (PTF)" in other publications. The frequency cutoff of the telescopes was measured by A. Gendron, using a "target" developed by M. Koren and available on the Web (see References). The target consists of a series of parallel, vertical black and white bars or lines of widths decreasing logarithmically from 2 to 200 lines per millimetre and further divided into 6 zones of different contrasts.

The target was printed by A. Gendron at a size of 25.1 cm, mounted on a foam board and placed at a distance of 51 times the focal length of the 11-in and 8-in telescopes, *i.e.* 142.5 and 103.6 metres, respectively. Photographs of the target were taken with the telescopes under conditions similar to those used during the transit of Venus. Details of the calculations can be found on the Dorval Web site. Plots of line intensity vs. line frequency (lines per mm) and of frequency modulation vs. linear frequency allowed us to determine the frequency loss and the angular resolution, which can be used to quantitatively describe the resolution of the telescopes, in arcseconds. Results are indicated in Table 1.

Table 1. Resolution of the 11-in and 8-in telescopes.

Telescope Size (inches)	Authors	Frequency Loss (lines per mm)	Angular Resolution (arcseconds)
11	A. Gendron	9	8.2
8	G. Guignier	53	1.9

In addition, it can be shown that the resolution of the 8-inch telescope was limited mainly by the size and arrangement of the camera pixels. The poor resolution of the 11-inch telescope was due to a collimation problem.

The PSF of the 8-in telescope was also measured by G. St-Onge, using images of the Epsilon Lyrae "double-double" star with the telescope, and the *MIPS* and *PRISM* software. Details of the calculations are available on the Dorval Web site. The PSF was thus found as 1.75 arcseconds, which is in good agreement with the angular resolution measurement of Table 1. We note that strictly speaking PSF and MTF are different, with PFS related to the spread of images and MTF to contrast resolution. However, since the measured PSF and angular resolution values are both quite similar to the sizes of the observed halos, this suggests that the halos are probably mainly related to the blurring or contrast resolution of the telescopes used.

To reveal more subtle differences in light densities in the photographs, *PRISM98* software was used by G. St-Onge. Using this image treatment, different light densities are attributed different colours. When looking at colour-treated photographs, one should not forget, however, that:

- these are false arbitrary colours
- the small differences revealed by the colours are not visible in general in the untreated photographs or by visually looking through the telescopes
- colours can be compared only in sets of photographs that have been subjected to the same image and colour treatment and exposure time (*e.g.* see Figure 4). Colours in photographs taken from different instruments (*e.g.* Figure 4 and 5), or taken by the same instrument and exposure time but treated differently (*e.g.* Figure 3 and 6), *correspond to different light densities and should not be compared directly.*

The photographs by G. Guignier and colour-treated by G. St-Onge were separated into 256 levels (8-bits) of light intensity to measure the relative intensities at various locations of the photographs, on a scale of 0 to 255 (see Table 2).

3. Results and discussion

3.1. The main halos around Venus and the Sun

The untreated photographs taken by A. Gendron and G. Guignier can be found on the Dorval Club Web site. The untreated photographs 17, 20, and 22 of A. Gendron, and 3, 4, 6, and 9 of G. Guignier are reproduced in Figures 1-2. A photograph taken from *TRACE* satellite, extracted from the Web site `www.transitofvenus.info` (Pasachoff 2004) with permission, and colour-treated by G. St-Onge, is presented in Figure 3.

In these photographs, halos can be observed around Venus and the Sun. These halos are represented by the drawings of Figures 1-3, alongside the photos. These drawings are a schematic but accurate reproduction of the photographs. The characteristic features of these halos are indicated in Table 2.

It can be seen that the width of the halos corresponds very closely to the resolution of the 11-inch and 8-inch telescopes deduced from MTF and PSF measurements in Table 1 (8.2 and 1.9 arcseconds, respectively). It thus appears reasonable to think that the observed halos are mainly due to the optical resolution of the telescopes under the conditions used. Even narrower halos are observed when using

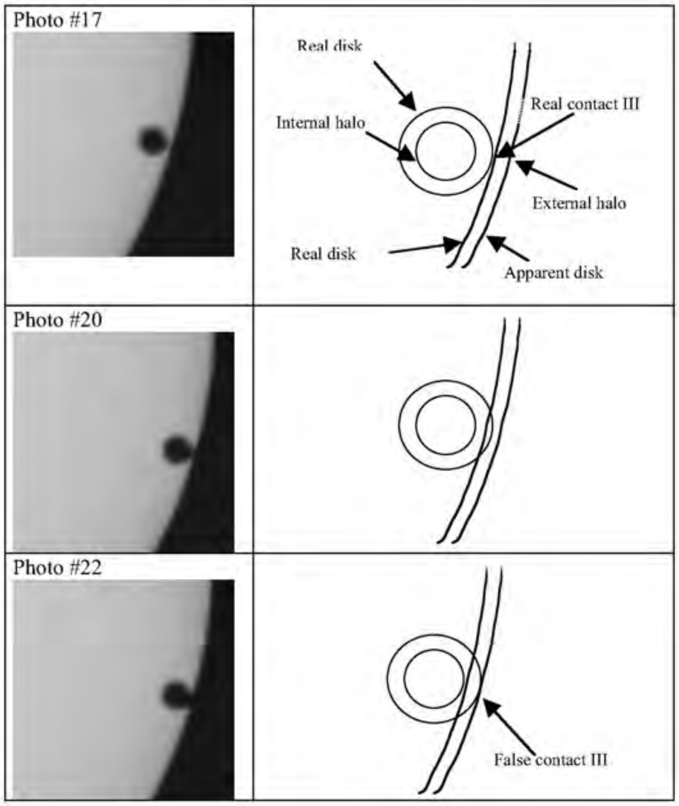


Figure 1 – Photographs 17, 20, and 22 by A. Gendron (using an 11-inch Schmidt-Cassegrain and *Kodak* photographic film), and schematic representation by M. Duval of the halos around the Sun and Venus.

Colour code: the halos around Venus and the Sun, which are red in the original colour photographs, appear as dark grey in this black and white version of Figure 1. The disk of the Sun, which is orange in the original colour photographs, appears as light grey in Figure 1. The original coloured version of this paper is available upon request from any of the authors by email, or on the Dorval Web site indicated in the references of this paper.

a telescope of very high optical resolution and a CCD camera located outside Earth's atmosphere, therefore without any seeing effects *(TRACE)*.

Table 2. The main halos around Venus and the Sun.

Authors	Telescope (inches)	Photo	True or False Colour of the halos	Width of the halo around Venus (arcseconds.)
A. Gendron	11	film	red (true)	7
G. Guignier	8	Webcam	grey (true)	2
TRACE	12	CCD	blue (false)	<1

These halos occur at the interface between the intense light of the Sun and the very dark regions of Venus and the sky. The first point to clarify was whether they are located above the bright disk of the Sun or above the dark regions of Venus and the surrounding sky, or in between.

The definitive demonstration of their location was obtained by measuring the diameter of Venus in the photographs, with and without the halo, using the methods indicated in Section 2. The internal diameter of the red halo of Venus in the untreated photographs of A. Gendron (surrounding the internal black disk) was thus evaluated at 43 arcseconds, and the external diameter of the halo (internal black disk + the red halo) at 57.6 arcseconds.

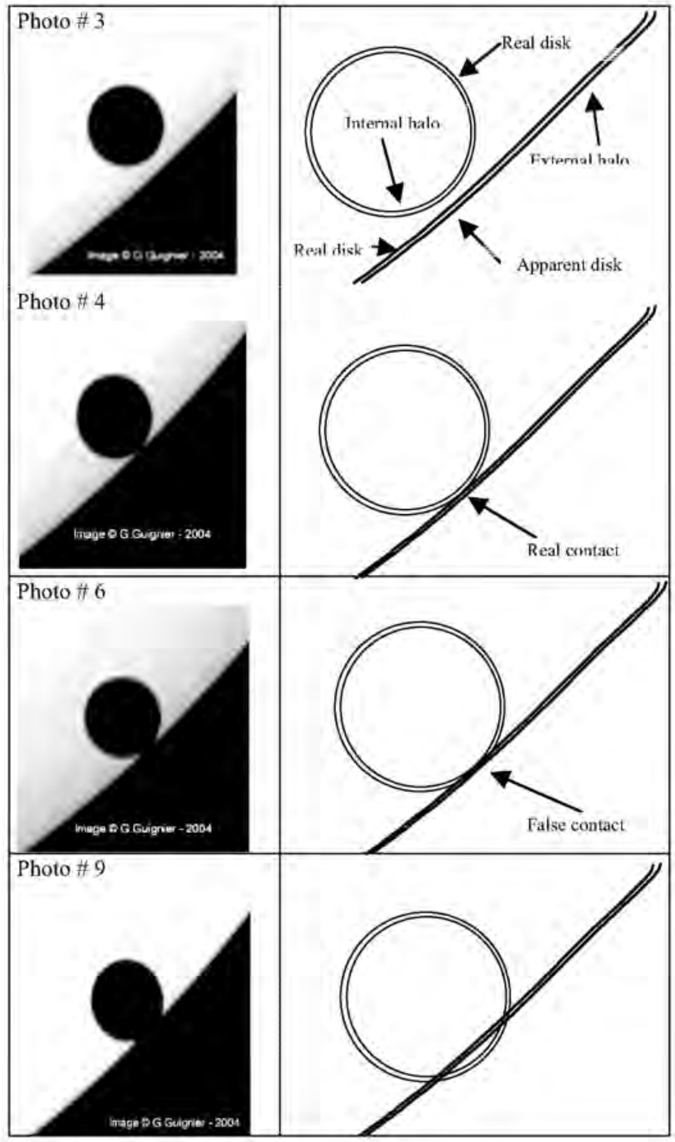


Figure 2 – Photographs 3, 4, 6, and 9 by G. Guinier (using an 8-inch Schmidt-Cassegrain and a Webcam), and schematic representation by M. Duval of the halos around the Sun and Venus.

A similar calculation was performed by G. St-Onge for the untreated photographs of G. Guignier. The internal diameter of the grey halo of Venus (surrounding the internal black disk) and its external diameter (internal black disk + the grey halo) were thus evaluated at 55 arcseconds and 58 arcseconds (100 pixels), respectively. He also evaluated the external diameter of Venus in the photograph taken from *TRACE* at 58 arcseconds for 121 pixels (in 8-bit format) and 116 pixels (in FITS format).

Since the actual diameter of the disk of Venus on June 8, 2004, was 58.2 arcseconds, the halos of Venus in these photographs are located within the real disk of Venus and not silhouetted against the Sun outside Venus' actual disk. By extension, the same conclusion most probably applies to the halos around the disk of the Sun, which must be located silhouetted against the dark surrounding sky, not on the real bright disk of the Sun.

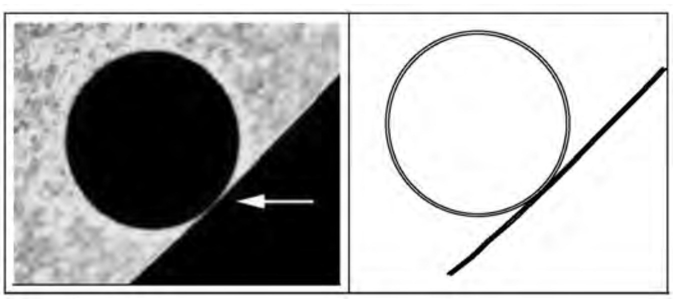
As indicated previously, these halos are generated by the optical resolution of the telescopes used. They are characterized by a loss of contrast (MTF) and a reduction in the tone of black at the interface between bright and dark regions. The edges of Venus and of the Sun thus do not become dark immediately at the interfaces but only gradually.

In summary, the main halo of Venus in the untreated photographs is located within the real disk of Venus, and the main halo of the Sun is located silhouetted against the sky. As indicated in the schematic drawings of Figures 1-2, the result is that:

- the real disk of Venus in the untreated photographs is larger than its apparent (interior) black disk (more precisely, it is the apparent black disk of Venus *plus* its internal halo).
- the real disk of the Sun in the untreated photographs is smaller than its apparent bright disk (more precisely, it is the apparent disk of the Sun *minus* its external halo).

3.2. The secondary halos around Venus and the Sun

As mentioned above, in the untreated photographs of A. Gendron, only one (red) halo is visible, which is located within the disk of Venus. After colour treatment by G. St-Onge (Figure 4), three halos of different colours (blue, green, and yellow, all colour) can be seen around Venus. The diameters of these halos have been evaluated by A. Gendron. The external diameter of the green halo is 57.6 arcseconds and the internal diameter of the blue halo 43 arcseconds. The blue-green halo therefore corresponds to the red halo in the untreated photographs of Figure 1, and it is located within the real disk of Venus. The external diameter of the yellow halo is about 66 arcseconds. The yellow halo is therefore a secondary halo located outside the real disk of Venus, silhouetted against the Sun, and not visible in the untreated photographs. Three similar halos can be seen around the Sun in Figure 4. By analogy with those around Venus, the blue-green halo around the Sun is probably located silhouetted against the sky, while the yellow halo is a secondary halo located within the disk of the Sun.



Courtesy of Jay M. Pasachoff and Glenn Schneider.

Figure 3 – Photograph taken from the *TRACE* satellite and schematic representation by M. Duval of the halos around the Sun and Venus.

Colour code: the halos at the contact point between Venus and the Sun, which are blue in the original colour photograph, appear as dark grey in this black and white version of Figure 3. The halos are indicated as blue in Table 2. The original coloured version of this paper is available upon request from any of the authors by email, or on the Dorval Web site indicated in the references of this paper.

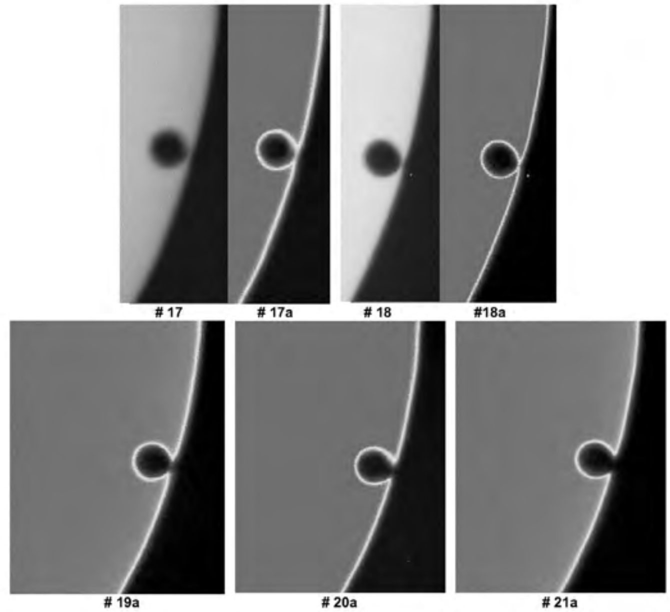


Figure 4 – Photographs by A. Gendron after colour treatment by G. St-Onge (# 17a, 18a, 19a, 20a and 21a). Photographs # 17 and 18 are without colour treatment. Colour code: the halos around Venus and the sun in the untreated photographs # 17 and 18 are as in Figure 1.

In photographs # 17a to 21a, the halos close to the black sky and the inner black disk of Venus, which are in blue in the original colour photographs, appear as dark grey in this black and white version of Figure 4. The yellow/green halos close to the bright disk of the sun appear as white grey. The red disk of the sun appears as medium grey. The original coloured version of this paper is available upon request from any of the authors by email, or on the Dorval website indicated in the references of this paper.

On the colour-treated photographs 17 and 18 of Figure 4, at the contact point between Venus and the Sun, a small deformation of the green-blue halos of Venus and the Sun can be seen, as if the halos were "attracted" by one another.

In the photographs of G. Guignier, submitted to a first colour treatment by G. St-Onge (Figure 5), a secondary halo, shown in green false colour, can also be seen around Venus, with an external diameter of 58 arcseconds. The external diameters of the blue halo and of the black disk of Venus are 55 and 50 arcseconds, respectively. The actual disk of Venus therefore is located close to the outer part of the green halo. By analogy, the actual disk of the Sun is probably smaller than the blue halo around the Sun, and located in the first green halo around the Sun. This means that in photograph E of Figure 5, a small part of the actual disk of Venus is already within the sky. In photographs C to G, a small deformation of the blue halos of Venus and the Sun can be seen as in photographs 17 and 18 of Figure 4.

A second, more extensive image treatment of the photographs of G. Guignier has been applied by G. St-Onge. With that treatment, four different halos appear around Venus instead of two, and four different halos around the Sun instead of one. The light intensities and widths of these supplementary halos are indicated in Table 3. Light intensities are in arbitrary units on a scale of 255 to 0 (248 at the centre of the Sun; 200 for the Sun close to Venus but far from the halos; 50 for the sky far from the Sun; 60 for the sky close to the halos; 58 for the internal black disk of Venus far from the halos; 60 to 65 for the internal black disk of Venus close to the blue halo). Table 3 confirms further the great similarity between the (inverse) halos around Venus and around the Sun.

Table 3. Supplementary halos around Venus and the Sun in the photographs by G. Guignier after a second, more extensive colour treatment by G. St-Onge.

Halos False Colour	Around Venus Intensity	Width (arcsec)	Around the Sun Intensity	Width (arcsec)
Blue	70-81	1.2	63-79	1.2
Green	89-104	1.2	86-114	1.2
Yellow	123	0.6	123-138	0.6
Red	147-177	1.2	>144	1.7

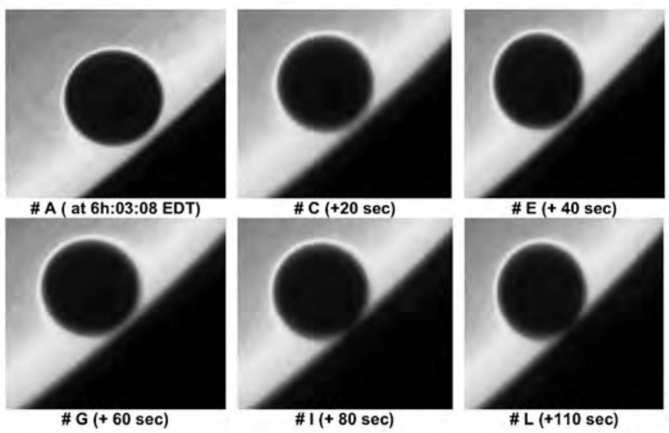


Figure 5 – Photographs # A, C, E, G, I and L by G. Guignier, treated by G. St-Onge Colour code: the halos close to the black sky and the inner black disk of Venus, which are blue in the original colour photographs appear as dark grey in this black and white version of Figure 5. The yellow halos around Venus close to the bright disk of the sun appear as white grey. The green halos in-between the blue and yellow halos of Venus and around the sun cannot be clearly distinguished in this B&W version of Figure 5 . The original coloured version of this paper is available upon request from any of the authors by email, or on the Dorval website indicated in the references of this paper.

It is to be noted that the number of halos depends on the way the computer assigns the colour table and the narrowness of the division, and is not a real quantity.

In the photograph by *TRACE*, colour treated by G. St-Onge (Figure 6A), the diameter of the red internal disk of Venus is 121 pixels or 58 arcseconds and therefore corresponds to the real disk of Venus. The external diameter of the yellow/green halo in Figure 6A (around the red disk of Venus) is 122.5 pixels or 59 arcseconds, and therefore it is located outside the real disk of Venus. Its intensity is between 59 and 179 (on a scale of 200 for the Sun and 0 for the sky).

In the photograph treated for edge detection by Pasachoff & Schneider (Figure 6B), the external and internal diameters of the white edge circle of Venus are 124 and 122 pixels, respectively, meaning that it is outside the yellow halo of Venus of Figure 6A.

3.3. The black drop formation

The formation of a "black drop" is quite obvious in the untreated photographs (Figures 1-2) and colour-treated photographs (Figures 4-5) of A. Gendron and G. Guignier. Taking into account the actual location of the halos in Figures 1-2 and 4-5, the black drop appears to start forming when the main apparent halo of Venus has contacted the main halo of the Sun, which corresponds to the contact between the real disk of Venus and the real disk of the Sun ("real" contact III, as indicated in the schematic drawings of Figures 1-2).

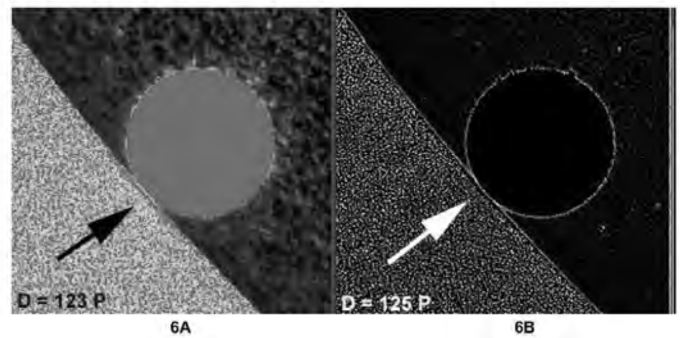


Figure 6 - Photographs taken from satellite TRACE (Courtesy of Jay M. Pasachoff and Glenn Schneider), treated by G. St-Onge.
Colour code: the halos around Venus and the sun, which are yellow in the original colour photograph 6A, appear as white grey in this black and white version of Figure 6A. The red disk of Venus appear as dark grey. The original coloured version of this paper is available upon request from any of the authors by email, or on the Dorval website indicated in the references of this paper.

We note that in the colour-treated photographs 17 and 18 of A. Gendron in Figure 4, a deformation of the blue-green halos appears to form around real contact III. A similar deformation of the blue halos also occurs in the colour-treated photographs C to G of G. Guignier in Figure 5.

A more precise examination of the photographs in Figure 5 indicates that the real contact III corresponds approximately to photograph C, and that the deformations of the halos start forming just after real contact III. This is confirmed by the deformation of the light isophotes measured by G. St-Onge in these photographs. A very faint "bridging" or "black-drop" effect thus appears in the photographs as soon as real contact III is reached and these deformations start forming. Visually, the black-drop effect becomes more visible a bit later (20 to 30 seconds later) in the photographs and in the telescopes on-site.

The black drop is more obvious and easier to observe in all photographs when the real disk of Venus comes in contact with the apparent disk of the Sun, and beyond (the apparent disk of the Sun is the bright disk plus its main halo in contact with the "black sky"), but these are "false" contacts III, the real contact having already been crossed, and the black-drop effect having already started. The black drop being easier to observe at these false contacts III may explain why it is often mistakenly mentioned that the black drop forms *before* (apparent) contact III. Actually, it forms *after* real contact III.

The black drop is also easier to observe when the halos are larger (for instance, in Figure 1 than in Figure 2). With instruments of very high resolution and low diffraction, such as those aboard the *TRACE* satellite (Figure 3A and 6A), a darkening (shown in blue or yellow false colour), or bridging of the region between Venus and the Sun can be observed, which may also be interpreted as a faint black-drop effect. The darkening appears to be related to the interaction of the darker halos around Venus and the Sun.

3.4. Proposed explanation for the black-drop effect

From the above observations, the following tentative explanation can be proposed for the black-drop effect observed visually or on untreated photographs:

When the real disk of Venus comes in contact with the real disk of the Sun (real contact III), the two halos around Venus and the Sun also come in contact. At that point, there is a loss of contrast between the two halos, which cannot be distinguished from one another anymore. That results in the formation of an apparent darker bridge between Venus and the sky. The limb darkening of the Sun probably participates in the bridging effect, especially in the high-resolution images. Then, when the real disk of Venus starts crossing the real disk of the Sun, the external halo of the Sun and the internal halo of Venus around the contact point are partially, then totally, eliminated. The external halo of the Sun disappears because the real disk of the Sun is no longer in direct contact (interface) with the sky, and the internal halo of Venus disappears because that part of the real disk of Venus is no longer above the real disk of the Sun but above the sky. These parts of the halos of Venus and the Sun having disappeared around the contact point, the underlying part of the real disk of Venus becomes very black again, giving a strong impression of a black drop.

4. Conclusions

Several observers in Montreal have visually seen the black-drop effect during the transit of Venus. The photographs taken confirm these observations and indicate that the "black drop" results from the contact then the disappearance of the halos that appear as artefacts in the scanning of Venus and the Sun. The black drop therefore is not merely an illusion of visual perception but essentially a part of the real disk of Venus (as identified by its actual diameter of 58 arcseconds in the photographs).

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Appendix

The following phenomena, which might have interfered with the interpretation of the main halos and the black-drop effect, have been examined and eliminated:

A1: Loss of Luminosity of the Sun's Limb:

In Figures 1, 2, and 5, it can be seen that the limb of the Sun becomes progressively darker towards the edge of the Sun, an effect known as "limb darkening." This loss of luminosity is related to the lower temperature of gases in the upper layers of the Sun's photosphere (T ~ 4500 K) as compared to the lower layers (T ~ 5800 K).

Starting from 10,000 at the centre of the Sun, the loss of luminosity along the limb is progressive (from 9000 to 3000 in relative intensity), and widely spread (over more than 1.5 times the diameter of Venus or 100 arcseconds in Figures 1, 2, and 5). By comparison, the halos around the Sun are located at the extreme exterior edge of the Sun, they are narrow (1.5 to 7 arcseconds), corresponding to the resolution of the telescopes, and are of more uniform luminosity. Therefore, it seems unlikely that the halos around the Sun in Figures 1, 2, and 5 are due only to the limb darkening. They are more likely related to the optical resolution of the amateur telescopes used here, as indicated in Section 3.1. Limb darkening, however, probably contributes more significantly to the halos in very high-resolution telescopes, as indicated by Schneider *et al.* 2004, who have shown that in the images of *TRACE* the falloff at the extreme edge of the Sun is so rapid that the limb darkening does, in fact, contribute to the black-drop effect.

A2: The Atmosphere of Venus:

High-resolution photographs taken by the Swedish Solar Telescope on La Palma, Canary Islands (Royal Swedish Academy of Sciences) in 2004 show the atmosphere of Venus when the planet exits the disk of the Sun. From these photographs, the thickness of the atmosphere of Venus has been calculated as 0.4 arcseconds, which is consistent with the dimension reported elsewhere (Westfall 2004) of 60 km or 0.3 arcseconds. The atmosphere of Venus therefore is smaller than the halos around Venus and cannot interfere with the interpretation of the halos of Venus (this was also ruled out by Schneider *et al.* 2004 in the images by *TRACE*).

A3. The Chromosphere of the Sun:

Photographs taken during the transit of Venus with an Hα filter (at 653.3 nm, and therefore in visible light) are available (Dantowitz 2004; Serp 2004). No halos can be seen in these photographs, while the chromosphere of the Sun is clearly visible, allowing one to estimate its thickness as between four and eight arcseconds. In the photographs by G. Guinier and *TRACE,* the chromosphere is therefore larger than the observed halos (one to two arcseconds), but since it cannot be seen at all in these photographs taken in visible light, it most probably does not interfere with the interpretation of the halos and the black drop (the limb darkening is different and the brightness difference between the Sun and the sky is much lower in Hα).

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Tracking a Fireball from Eyewitness Accounts — II

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ABSTRACT. A summary is given of the data that are required from field investigators in order that the atmospheric trajectory of a fireball can be calculated, and an outline is given of the method of computation of the trajectory.

RÉSUMÉ. Un abrégé des données requises par les investigateurs sur le terrain en sorte que la trajectoire atmosphérique d'une boule de feu soit calculée fait suite. Un croquis des méthodes de computation de la trajectoire est également fourni.

1. Introduction

Following the appearance of a major fireball, newspapers, radio and television stations, observatories, amateur astronomy clubs, and others will typically be flooded with dozens or even hundreds of reports from eyewitnesses. In the area of southwestern British Columbia where I live, most of these observations sooner or later land on my desk, from where I may try to calculate the atmospheric trajectory and any likely impact area. The basic method for doing this is as follows. From one witness you record the directions to two points on the sky track as seen by that witness. These two directions combined with the position of the witness define a *plane* that includes the atmospheric trajectory of the fireball. Similar data from a second witness at another geographic location define a second plane. The atmospheric trajectory of the fireball is, then, at the intersection of these two planes. In an earlier article of the same title in this *Journal* (Tatum 1998) I described and illustrated with a numerical example the detailed geometry of this Intersecting Planes Method, and I do not repeat that here. Instead I describe the several other considerations that go into the analysis of eyewitness observations. In particular it is my hope that this may help those who often go to considerable trouble to collect such observations in gathering the data that are necessary for the calculation. It perhaps needs to be said that, more often than not, among the dozens of eyewitness accounts that are painstakingly gathered and sent to me, nearly all, or perhaps literally all, are not really of use for carrying out the calculations, and in such cases I cannot even attempt a solution or start to do so.

2. Data Required from Eyewitness Accounts

I am discussing in this article *visual observations from untrained eyewitnesses*. I am not dealing here with *photographic records*. Photographic records of meteors from multiple stations can be measured with great precision. The analysis of photographic measurements is quite demanding mathematically, for many details have to be taken into consideration, but the reward is high precision in the eventual solution. See, for example, Tatum & Bishop (2005). Eyewitness observations, on the other hand, have a very high degree of uncertainty associated with them. Errors of angular estimates can easily be ten degrees or more. The high degree of uncertainty of such observations does have one small advantage, namely that the geometric model can be quite simple. There is rarely justification for taking the curvature of Earth into account, or the height of the witness above sea-level. (An exception could be made for a March 13, 2005 fireball that was seen along the West Coast from British Columbia to California.) To ignore the curvature of Earth and the height of the witness is tantamount to assuming that, within the (considerable) errors of estimation, the height of the fireball is negligible compared with the radius of Earth, and the height of the witness is negligible compared with the height of the fireball. The downside to the large errors inherent in eyewitness accounts is that it may be questioned whether there is any point in trying to do the calculation in the first place. I believe that, if there are witnesses scattered over a large enough area, there is value in making the attempt — but only if it is done correctly and not by compounding the errors of observation with additional errors of measurement and analysis.

With this in mind I am very particular indeed about the sort of observations that I will use before attempting a calculation. As we shall see later in this article, the analysis is long and tedious; it is by no means as simple as merely putting the observations into a computer program and getting the "answer" in a few microseconds. Before I undertake any analysis I insist that *all* of the following conditions be satisfied:

1. Witnesses are available *on both sides* of the fireball, so that some see it moving from left to right, and others see it moving from right to left.
2. Witnesses are to be interviewed by a *trained* interviewer.
3. Each witness is to be interviewed *in situ*.
4. The angles indicated by the witness are to be *measured* by the interviewer.
5. The measurements are to be done with *instruments* (such as compass and clinometer.)
6. The interview must be carried out *within a week* of the event.
7. The witness should have been stationary — *i.e.* not driving a car, sailing a boat, or flying in an aircraft.

Not all investigators will insist on adhering strictly to all of these criteria and in the judgement of some, such rigid adherence may be unnecessary. That may be so, and individual investigators may wish to make their own judgement. However, a full and thorough investigation of a fireball is a long and difficult process and my own practice is to insist upon these criteria. I am reluctant to embark upon a lengthy analysis unless I am assured of reliable data. As was pointed out by Holmes, (quoted by Watson in Doyle 1891), "It is a capital mistake to theorise before one has data."

Let us look at condition 1 to start with. There, you will see reference to moving from "left to right" or from "right to left." These words are chosen deliberately. Very often someone will report to me that the fireball moved "towards the west." It is, however, a geometric fact that in general it is *not possible, even in the roughest approximation,* to determine the direction of motion of a fireball from observations from a single station. For example, many assume that, if a witness sees a fireball in the south moving from left to right, it must have been travelling west. This is not so at all; it might equally well be travelling almost due north or almost due south, with only a very small westward component. (The caveat "in general" above is to cover some special exceptions. For example, it *is* possible to deduce the direction from a single station if observations are made by *radar,* or photographically with a *rotating shutter.* But it is not possible from eyewitness observations.)

I still have not explained why I insist that there must be observations from *both sides* of the fireball. To see this, imagine that a witness sees a fireball to his south, and that he says that it was travelling horizontally at an altitude of 50°. Another observer, 60 nautical miles (*i.e.* one degree) to the south, sees the fireball, also in the south, travelling horizontally at an altitude of 46°. Before crying "Impossible!", recall that eyewitness angular measurements typically involve an uncertainty of 10° or more, and fireball investigators will often encounter situations just like this. Let us then uncritically put these observations into the computer and run the Intersecting Planes program. We recognize that, because the estimates are prone to error, the answer will not be of the highest precision but will nevertheless be approximately right. Well, will it, indeed? What *is* the geometric implication of these two observations? Simple geometry gives the answer that the fireball is 398 km to the north of *(i.e. behind!)* the first witness and is burrowing underground at a depth of 474 km. I have given this example (which is by no means an unlikely, concocted situation) to discourage the idea that a solution, while not exact, may nevertheless be an acceptable approximation. The result obtained is meaningless, and forms the basis for my insistence that, in order to attempt a solution, witnesses must be situated on both sides of the fireball.

This example will also make it clear, I hope, why I ask for *instrumental* measurements of angles from *in situ* interviews. I don't use any observation in which angles are obtained by instructing witnesses over the telephone to "estimate" angles using "fist-widths at arm's length."

It is also important that the interview be conducted by a trained interviewer — that is, one who knows what measurements are required and who knows how to use and to read the compass and clinometer. I need to know, for example, that the appropriate correction has been made for the magnetic declination and whether azimuths are measured from true north or from magnetic north. (The angle between the two is known in geophysics as the "declination" — obviously a totally different meaning of the same word as used in astronomy.) Where I live, magnetic declination amounts to about 20°, and, if it has been applied in the wrong sense (all too easy to do), that introduces a mistake of 40° right there.

Extensive experience in interviewing witnesses has also convinced me that directions indicated by witnesses who were in a car, boat, or aircraft are usually so unreliable that I generally do not use them in a calculation, and indeed I rarely even conduct *in situ* interviews with them. I have found that it is impossible to determine where they were or in what direction they were facing when they saw the fireball. Recreational sailors and aircraft pilots in particular often take great pride in their navigational abilities, and such pride is doubtless in most cases more than justified; but it is very difficult for them to tell exactly where they were and in what direction they were facing at a particular second in time several days ago, nor is there any practical way in which an *in situ* interview can be conducted.

It might be concluded that my insistence on all of the criteria described is so restrictive that it would result in most cases in no observations at all of a given fireball satisfying them all, and hence no point at even attempting a calculation. It is unfortunate, but in many cases this conclusion is correct, and often the data received are indeed too inadequate to attempt a solution.

So — how can we attempt to gather the requisite data? There are perhaps three stages in the gathering of data, which I can describe as Immediate, Preliminary, and Detailed.

The Immediate Stage. Immediately following a fireball, newspaper, radio and television stations, observatories, astronomy clubs, and so on are inundated with telephone calls, and the person who handles these calls may not be trained in or even particularly interested in meteors, but will take down the information given and will eventually pass them on to an interested investigator. The question I ask and answer at this stage is: What information should the person handling the calls record from the witness who calls in? I can answer this definitively and simply – the information that must be recorded at that stage is:

The name and telephone number or email address of the witness.

Indeed at this stage that is really the *only* information that is absolutely essential. If this is not recorded, no use whatever can be made of that particular witness's observation. Obvious though this may appear, my experience has all too often been that some organization will call me to say that they have received dozens of telephone calls, but they have not recorded contact information for a single witness.

The Preliminary Stage. Usually after an investigator has been given a list of telephone numbers or email addresses he or she (for brevity hereafter "he") will want to know which witnesses he will want to question in more detail. He will then telephone or email (for brevity hereafter "telephone") the witnesses and ask some *Preliminary Questions.* These preliminary questions might also be asked by the original person or institute who took the calls. The following are the questions that I normally ask at this stage. I ask all of them, and at that stage I do not need to know anything else, but I **do need to know** the answers to these questions in order to decide whether to investigate that particular witness further.

(a) What city or town were you in or near when you saw the meteor?
(b) Was it to the north of you, south of you, east of you, or west of you?
(c) Did it move from left to right, or from right to left?
(d) What time was it?
(e) For how long was it in the sky — a second, a minute, or an hour?

(f) Did you hear any sound, either at the time of the meteor or later?
(g) Were you driving a car when you saw it?

I ask about the time just to be sure that the witness is talking about the same fireball I am investigating. I ask about the duration because, if the witness says anything other than "just a few seconds," then we know that he has not seen the meteor.

If there is any sound, this increases the likelihood that the meteoroid was relatively close to the witness, or that a meteorite might be deposited. The investigator will probably want to interview that witness in more depth.

If the witness was driving a car, he will probably not be interviewed further or *in situ*.

The preliminary questions determine which witnesses will be selected by an investigator for detailed interview. It is then time for:

The Detailed Stage. A trained interviewer will go and interview a witness within a week of the event, and will measure with instruments some angles indicated by the witness. Before describing these further, I would like to discuss and define some *nomenclature,* so that it is universally clear what angles are being measured. For example, all too often, I am told where the "end point" of the object was — but what is meant by the "end point?" Does it mean where the meteor disappeared in the sky? Does it mean where the meteorite landed?

I have proposed (Tatum & Stumpf 2000) and recommend the following nomenclature:

1. The *sky track* is the apparent path of the fireball on the celestial sphere as seen by a witness.
2. The *atmospheric trajectory* is the path of the fireball through the atmosphere, in three-dimensional space.
3. The *ground track* is the vertical projection of the atmospheric trajectory on the ground below.
4. A witness typically points to two points on the sky track, usually the first and last points where the witness had a clear view of the fireball or where he could relate its position to convenient objects in the landscape. I refer to these as the *first point* and the *second point* for that witness.
5. The *endpoint* is the last point on the sky track where the meteor was seen before it either cooled down to a nonluminous temperature or detonated in a terminal burst.
6. If the atmospheric trajectory is extrapolated linearly beyond the endpoint to where it intersects the ground, that point of intersection is the *extrapolated ground-level point*.
7. If there is an actual impact, that point is the *impact point*.
8. The *altitude* (or *elevation*) is the angular height above the horizon in degrees, and *height* is the vertical distance above the ground in metres.
9. The *azimuth* (or *bearing*) is the angle measured around the horizon. It must always be clearly stated what the starting point for azimuth is (*e.g.* the north point of the horizon) and whether it is measured clockwise or counterclockwise. It must also be made clear whether the azimuth is measured from magnetic north or from true geographic north. Do not assume that there is some universal convention that everyone uses and understands. If you do not make it clear, it is inevitable that you will not be understood or that you will be misunderstood.

The trained interviewer asks the witness to go to the exact spot where he was when he saw the fireball and to re-enact what he was doing in the minute or so before he saw it. This, of course, jogs the memory. The interviewer then asks the witness to indicate where he first had a clear view and where he last had a clear view of the fireball (*i.e.* the *first point* and *second point* for that witness), and the interviewer measures the altitude and azimuth of the first point and of the second point. These angles will be recorded to the nearest degree, although the actual error in memory of the witness may well be ten degrees or even more. He must also determine the geographical latitude and longitude of the witness. This need not be done to a precision of better than an arcminute, and it is usually not necessary to record the height of the witness above sea-level, unless he happens to be at the top of a very high mountain. These six angles, then, the altitude and azimuth of the first and second points, and the latitude and longitude of the witness are what are required. Additional information may be of anecdotal interest, but is not part of the subsequent calculation. If any of these six angles are not clearly given, however, the calculation cannot be done.

These six data enable the investigator to calculate a plane containing the path of the fireball. Similar data obtained from another witness *on the other side of the ground track* will enable the calculation of a second plane, and the atmospheric trajectory of the fireball is then at the intersection of these two planes. The detailed geometry, with a numerical example, was described in Tatum (1998), and is not repeated here.

Additional information may well be given to an interviewer from a witness, and, while this additional information may be of interest and worth recording, it is not used in the calculation. I discuss some of this additional information now.

The interviewer should certainly ask the witness about the time of the event. This is certainly important information, although, for eyewitness observations, it is not actually used in the calculation of the atmospheric trajectory. (For *photographic* observations, the exact time is very important.) In reporting the time, do not forget to specify the *time zone* referred to, and whether daylight-saving time was in effect. If you use military jargon such as "thirteen hundred hours" or "Zulu" I will probably not know, or I may misunderstand, what is intended, and that observation will not be used. The unambiguous and astronomically standard way of expressing time would be, for example, "2005 April 05^d 15^h 23^m 07^s UT. You may also use "UTC" if you have recorded the time to a precision of a tenth of a second; if you have not, be honest, and leave it as UT.

The witness will often tell the interviewer (or the interviewer may ask) about the *duration* of the event, or the *speed* of the fireball. The speed and direction of motion (*i.e.* the *velocity*) are absolutely essential before the pre-encounter *orbit* can be calculated — but these need to be known with high precision. The most that an eyewitness could report on, of course, would be the *angular speed* across the sky, and not its linear speed in m s^{-1}. This can be calculated by dividing the length of the sky track by the time taken for the fireball to cover it. This, of course, would be just the *average* angular speed. The angular speed across the sky is not expected to be constant, partly because of the real linear deceleration of the meteoroid, and also because of geometric effects that would result in a varying angular speed even if the linear speed were constant. It has been my experience, however, that estimates of the duration of the fireball vary wildly from one witness to another, one witness saying perhaps five seconds and the next saying about a minute! Usually the times are vastly overestimated. If a witness says "About ten seconds," I shall then tell the witness that I am going to keep silent for ten seconds. Usually after about two seconds, the witness will say "Oh! Not as long as that!" In other words, my experience is that eyewitness accounts of the duration and (angular) speed of the fireball are unreliable by a large factor, and are not to be relied upon in any subsequent numerical calculation. In particular, orbital data on meteoroids calculated from eyewitness estimates (rather than measurements) of speed fall into the realm of science fiction.

Witnesses will often describe at length the colour (or colours) of the fireball, and it is curious that many fireballs (by no means all) are described as predominantly green. What is the cause of the various colours that we see? There are many factors that can affect the perceived colour of a fireball. Examples that come quickly to mind include its temperature, its chemical composition, the fluorescence of gases in the atmosphere, atmospheric absorption and dispersion, the colour perception of the human eye. Indeed there are so many factors that it is really not possible, in the absence of a spectrum, to deduce very much at all about the fireball from the reported colour. The reported colour may be of anecdotal interest, but any attempt to explain the origin of the reported colours is largely speculative. One thing that can be said with certainty is that the oft-reported *green* colour of a fireball is *certainly not copper!* Photographically-recorded colours are much more objective, and it then becomes reasonable to attempt a physical interpretation (see, for example, Evans 2003 and Tatum & Bishop 2005), although a spectrum is really necessary before much can be said with any great certainty.

Sound is often reported in connection with a fireball, although more often there is nothing but majestic silence. Although the presence or absence of sound is not of immediate importance to an investigator who is computing the atmospheric trajectory, witnesses should certainly be asked what, if anything, they heard. Sound may be *simultaneous* or *delayed,* the former often described as "swishing" or "crackling," the latter as "thunderous" or "booming." Opinion is divided on the reality or otherwise of simultaneous sound. Unlikely though simultaneous sound may at first appear to be, there is in fact a formidable body of evidence for its reality, and literature on the subject, as well as plausible physical "electrophonic" mechanisms. See, for example, a recent article in this *Journal* (Beech 2004). In any case the interviewer, whether a believer or a nonbeliever, should certainly ask the witness to describe what he or she heard and should include this in his report. Delayed sound usually follows the visual fireball by several minutes, perhaps even as long as fifteen minutes. It can come from a hypersonic shock front as the meteoroid travels through the atmosphere at Mach 10 or more, or from a terminal burst, or even from an actual ground impact. These sonic booms can be recorded on seismograms and it is possible in principle (see, for example Tatum 1999) to compute the atmospheric trajectory and location of a terminal burst from these seismic records.

In addition to these qualitative descriptions of the phenomena, a witness may sometimes seem to a tired and exhausted interviewer to prattle on aimlessly and inaccurately about what may seem to be irrelevant details, or even to meander on about flying saucers and UFOs (although I have found that surprisingly few witnesses talk about UFOs, and most are genuinely interested in a scientific explanation of what they unquestionably saw). Regardless of how uninformed or ignorant or inaccurate a witness may appear to be to an interviewer, the interviewer, however impatient he is to gather usable data, must never lose sight of what is by far the most important part of an interview, and that is at all times to maintain the greatest courtesy towards the witness, who has gone to great trouble to explain to you what he saw and is genuinely interested to know what it was. There can never be any excuse for deviating from this important principle.

In any case, these qualitative details, interesting though they may be, are not used in the trajectory calculation. The absolutely essential data are the latitude and longitude of each witness and the measured altitude and azimuth of two points on the sky track. If these essential data have been received for witnesses on both sides of the trajectory — but not otherwise — the calculation can proceed. It is not merely a matter, however, of entering the data into an intersecting planes computer program and uncritically accepting an instant solution. There is a lot of preliminary work to be done, which will be described in the next section.

3. The Calculation

Typically the distribution of witnesses is into groups of several witnesses within a few kilometres of each other, plus a few single, isolated witnesses far from any groups. The groups, of course, are from the larger cities and population centres, or are witnesses who live within a few kilometres of an interviewer who is prepared to seek them out. A schematic typical witness distribution is shown in Figure 1.

The witnesses in a given group will all have reported the position of the fireball in slightly different positions on the sky. This is not because of the small parallactic effect of the slightly different positions of the witnesses within each group, but because of the errors inherent in the memories of the witnesses. Because of this, I do not treat separately each witness within a group. The procedure is to determine an average sky track for the witnesses in that group. The geographic position of the group is calculated as the centroid of the positions of the several individual members. I have indicated the centroid of each group by means of an asterisk in figure 1.

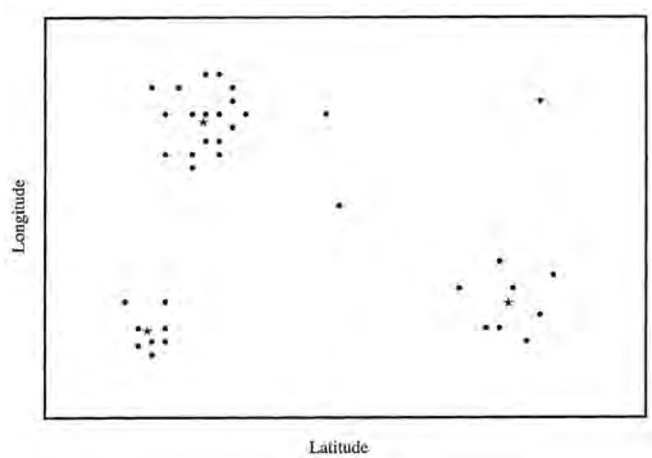

Figure 1 – Schematic distribution of witnesses. There are three groups, and three isolated witnesses. The centroid of each group is indicated with an asterisk.

A good question is: Over how large an area should a number of witnesses be scattered in order that they should be treated as a single group? This question does not require a precise answer, but it certainly requires a reasoned order-of-magnitude estimate. A reasonable criterion is as follows. Suppose that eyewitnesses can typically estimate the position of a fireball to within an angle φ. Suppose also that the angular diameter of a group of observers subtended at the position of the fireball is θ — that is, θ is the parallactic displacement of the asteroid as seen by witnesses at opposite extremes of a group. Witnesses should be considered as belonging to a single group if $\varphi > \theta$. The size of a group as so defined is going to depend on how precisely eyewitnesses can estimate the position on the sky of the fireball as well as on its height. For good witnesses and a low fireball, a group must be very compact; for poor witnesses and a distant fireball, a group would be scattered over a wide area. For a fireball that is *overhead,* the diameter d of a group should be less than $2h\tan\frac{1}{2}\phi$ where h is the height of the fireball above the ground. Of course we don't know h (one of our objectives is to find it!) and the precision, φ, with which witnesses recall angles is also unknown. However, heights are typically of order tens of km, and on average eyewitnesses probably don't do very much better or very much worse than ten degrees. I have therefore drawn in Figure 2, according to the criterion $\varphi > \theta$, the diameter of a group versus fireball height for a number of precision estimates. For example, if you believe that a fireball is 10 km above the ground and that witnesses are typically giving you angles that may be in error by about 5 degrees, any observers within a circle of diameter 20tan2.°5 = 0.9 km should be considered as belonging to a single group. If you think that the fireball is 40 km high, and witnesses are making errors of about 10 degrees, the diameter of a group should be 80tan5° = 7 km

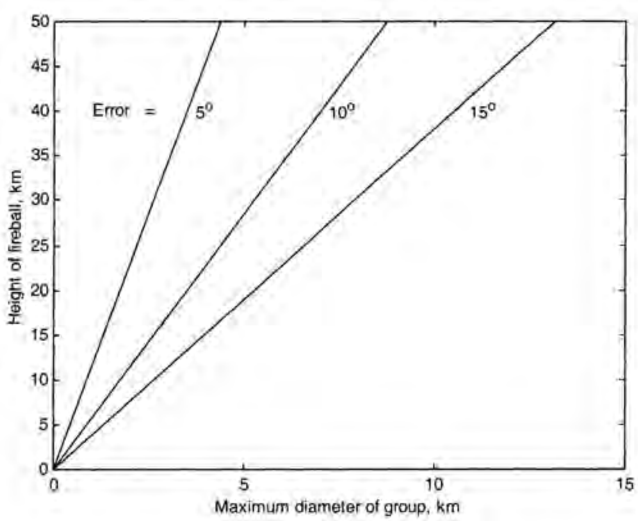

Figure 2 – Diameter of a group versus height of fireball for different eyewitness errors. The horizontal and vertical distances are not drawn to the same scale.

In Figure 3 I illustrate schematically the typical sky tracks that might be indicated by the several witnesses in a given group. Most are in broad general agreement, except for two that are wildly out and will be excluded from subsequent calculations. For each group, the investigator has to draw a figure similar to Figure 3 and has to make a decision as to which observations are so wildly out that they should be discarded. From the remaining sky tracks, he has to calculate the average sky track, shown by the dashed line in Figure 3. This requires a considerable amount of time, care, and judgement. Once that is done, the plane defined by the least-squares sky track for that group and the centroid of the group constitutes one plane that is going to be used in the intersecting planes method.

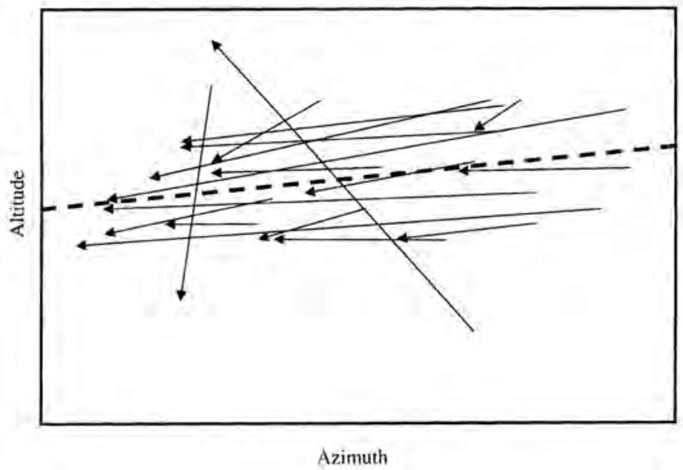

Figure 3 – Typical sky tracks from witnesses within a group. The average sky track is indicated with a dashed line.

In the previous paragraph I have referred to (and drawn in Figure 3) the "average" sky track, and there is a question as to how best to do this. One possibility is to calculate the centroid of all the first points of the several witnesses within the group, and the centroid of all the second points, and join them with a straight line. This might be all right if one can guarantee that all witnesses within the group refer to the *same* point when they indicate their first point, and similarly for their second point. My experience is that this cannot be guaranteed, nor is it required for the intersecting planes method, and therefore this is probably not the best way to calculate an "average" sky track. Another possibility might be to express each sky track in the form $y = mx + c$ and then calculate an average m and an average c — but I can see no formal mathematical justification for this, and I do not recommend it. I think the best way is simply to calculate the least-squares sky track through all the points (first and second points) for all witnesses within the group. After all, each point, whether a first or a second point, is a point that a witness believes to have been on the sky track. If, However, we assume that the witnesses are likely to make errors of comparable size in altitude and in azimuth, the least-squares sky track should not be either the regression of y upon x or of x upon y, but should be such as to minimize the sum of the perpendicular distances of each point from the final track. (It is sometimes thought that witnesses typically make larger errors in their estimates of altitude rather than azimuth, but unless this bias can be quantitatively assessed, it is the sum of the perpendicular distances that should be minimized.)

A question that often goes through my mind is whether all individual witnesses should be given equal weight, or whether some witnesses should be considered more reliable than others and should accordingly be given greater weight at this stage of the calculation. I find myself being influenced by the personality of each witness into believing that one seems to be a thoroughly reliable sort of person while another is scarcely to be believed. When all is said and done, however, I have come to believe that there is no scientific basis for this, and in general I give every witness equal weight regardless of age or apparent level of education. A sudden spectacular fireball is beyond the experience of almost everyone, and I think every report has equal weight. I make a few exceptions. One is that I give zero weight to (*i.e.* I reject) any observations made from a moving vehicle. Another is that, if an observation is made from a seated position, or lying in bed, and if the witness is able to indicate where the fireball entered on one side and departed on the other side of a window-frame, I feel that the angles so obtained are more reliable, and I may give them double weight. In such circumstances there is usually no doubt as to the exact position of the witness's head. Some delicate diplomacy is needed in asking the witness: "Madam, do you mind if I go into your bedroom, lie down on your bed, and place my head in the exact position where yours was when you saw the fireball?" I have done that on more than one occasion — though it will be appreciated that it requires much skill and courage to do so! I might also give high weight if the witness were an astronomer who was able to estimate right ascensions and declinations relative to background stars, though so far I have not been lucky enough to have had such a witness. On the three occasions when I have been lucky enough to see a bright fireball myself, I have been so taken aback that I could scarcely trust myself to supply any useful data at all!

Now, from each group, and each isolated individual, we have a plane in which the atmospheric trajectory lies. Let us suppose that we have M groups or isolated individuals on one side of the fireball (*i.e.* they saw it move from left to right) and N groups or isolated individuals on the other side of the fireball (*i.e.* they saw it move from right to left), so I have calculated a total of $M + N$ planes. I pair each of the M planes from one side of the fireball in turn with each of the N planes from the other, for a total of MN lines of intersection. Alas, each pair of planes does not intersect in the same line, so I have somehow to average the MN lines so calculated. Before I do so, I assign a weight to each intersection line according to the total number of witnesses in each of the two groups of witnesses from which that line has been calculated. The weight I generally give is $\sqrt{mn}$, where m and n are the number of witnesses in each group respectively. This weighting may be appropriate where there is a large number of witnesses in each group and if errors are normally distributed. Neither of these conditions is often satisfied, but some weighting must be given to recognize that larger groups will result in greater precision than smaller groups. There is a danger, however, in the case of an isolated witness. If the isolated witness has given an observation that is wildly wrong, this may not be evident when one is plotting out his individual sky track, but his observation will cause utter chaos when paired with other witnesses or groups. This must be guarded against, and the observation of that isolated witness may have to be disregarded, however tempting it may be to include him because of, for example, his unique geographical location.

I do not describe here how a plane containing the trajectory is calculated for each witness or group of witnesses, neither do I show how the atmospheric trajectory is calculated from the line of intersection of two planes, since that calculation is described in detail in Tatum (1998). Suffice it to say that each line of intersection is represented by a pair of equations of the form

$$ax + by + cz + d = 0 \tag{1}$$

These two equations represent a line in three-dimensional space. By eliminating in turn x, y, and z from the two equations, I obtain the projection of the line on the yz-, zx-, and xy-planes respectively. I do this for each paired group of witnesses, and, in each of the fundamental planes, I calculate the weighted (weight $= \sqrt{mn}$) least-squares straight line, and from these I reconstruct the least-squares lines of intersection in three-space — *i.e.* the atmospheric trajectory. From this the ground track and the extrapolated ground-level point are calculated as indicated in Tatum (1998).

4. Conclusion

It is hoped that this article may serve three purposes. It may help the mathematical investigator to see how the calculation is done. It may help the field investigators, interviewers, and witnesses to understand exactly what numerical data is needed and what anecdotal information is not actually used, and to understand why I have such a rigorous and unyielding insistence on the conditions under which usable data are obtained. I also hope that it will explain to everyone the complexity of the calculations, and, in particular, why it is not merely a matter of entering the raw data into a computer and uncritically accepting a solution in a fraction of a second, but it involves many hours of careful and critical work by the investigator, and an "instant solution" is not to be expected.

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Jeremy Tatum is a lecturer in physics at the University of Victoria. He has served as Treasurer of the Canadian Astronomical Society, as Editor of the Journal *of the RASC, and on the Meteorites and Impacts Advisory Committee to the Canadian Space Agency. Asteroid (3748) is named Tatum.*

THE "NEW OBSERVERS TO VISUAL ASTRONOMY" (NOVA) PROGRAM

by Brian Battersby, Prince George Centre (blbattersby@shaw.ca)

When I first joined the Prince George Centre I had no idea what a "Cassegrain," "Newtonian," or "Dobsonian" was. I had no idea about RA/Dec or even what was meant by "magnitude." I sat in the corner at our club meetings and listened quietly as most of the conversation flew high over my head.

Getting started in amateur astronomy can be a frustratingly hard undertaking. So when a friend of mine, Gil Self, asked me at the Prince George Centre's annual Christmas party to get our "New Observers to Visual Astronomy" (NOVA) program up and running I found myself saying "sure."

The club had tried the program a couple of times in the past but the stumbling block was always the weather. The classes were based around observing, but the weather in Prince George does not lend itself to designated observing times. Previous attempts at NOVA had ended in failure and a few upset people. This time around I decided to base NOVA around classroom sessions, but what should I use to teach it? In the end I decided to build the course around the *Beginner's Observing Guide, Skyways,* and the Explore the Universe certificate. This would allow me to purchase the books cheaply through the Centre as well as promote the RASC's publications.

The first order of business in designing the course was to decide what I was trying to accomplish. To that end I wrote the following statement:

> *"The purpose of this program is to provide new members of the RASC: Prince George Centre with basic astronomy knowledge and skills to enable them to become proficient amateur astronomers and to foster an environment wherein new members may quickly become active, participating members of the Centre."*

Next, I started writing down what I was going to teach in each session. The NOVA course now consists of nine sessions, which are broken into two groupings. The first four sessions deal strictly with observing:

1. How to Observe
2. Motions of the Sky and Seasons
3. Maps, North, Distance, Position, and Brightness
4. Telescope Types and Using Them.

Lessons five through eight deal with what the students are observing:

5. Star Designations, Right Ascension / Declination, Deep-Sky Objects
6. Moon and Eclipses

Figure 1 – The first NOVA lesson! January 22, 2005.

7. Solar System
8. Stars
9. Prince George Astronomical Observatory Operation.

During each lesson demonstrations and activities are given from the RASC publication *Skyways*. In between each lesson there are observing assignments encouraging the students to work on their Explore the Universe certificates.

Once the course was designed we offered it to the public. To my shock our first class ended up with twenty-three people registered. Sixteen were new members. The average age of the group was approximately 45 years, almost half of the group was women, and there was a wide range of educational backgrounds. NOVA is for anyone interested in astronomy!

From the feedback I received both during and after the course the students thoroughly enjoyed their experience. Three students finished their Explore the Universe certificates during the time allotted. Several more are continuing to work on it so I am hopeful I will be handing out more certificates soon.

The next step in the evolution of NOVA is to try to bring it to the RASC at large for use at all the Centres. The Education Committee is currently working on this aspect and I hope an instruction binder will be ready for distribution within the year. In the meantime all of the information currently available about the course can be downloaded[1] from the Prince George Centre's Web site at `www.vts.bc.ca/pgrasc/nova/nova.html`. If you have questions or comments about the NOVA program you can contact me at `blbattersby@shaw.ca`.

Brian Battersby is President of the Prince George Centre and a member of the Education Committee. He has been an avid skywatcher since attending a tour of the Prince George Astronomical Observatory with his daughter's Brownie troop eight years ago.

[1] The NOVA Program Teaching Guide is available from the members section of the RASC Web site www.rasc.ca/private.

Society News/Nouvelles de la société

by Stan Runge (stanrunge@hotmail.com)

Welcome

The National Executive is pleased to announce the hiring of Jo Taylor as the new Membership/Publications Clerk. She started on August 10th and will work closely with Bonnie to process memberships and orders at the RASC National Office. To Jo, a hearty welcome from all of us in the RASC.

Bonnie and Jo will be glad to assist you with any of your membership needs, orders, and general inquiries. They can be contacted by phone at (416) 924-7973 or toll free (888) 924-7272 (in Canada), or by email at nationaloffice@rasc.ca (Bonnie) or mempub@rasc.ca (Jo).

Also a special welcome to Jay Anderson who has been selected as the new *Journal* Editor, starting with this issue. Jay will be taking the position that has been so successfully managed by Wayne Barkhouse since 2000. The RASC is very grateful for all of Wayne's efforts and contributions.

Congratulations

Congratulations to two of our RASC members, Paul Gray and Dave Lane (our 2nd VP), on their winning the North York Astronomical Association's Starfest "Bring Home the Bacon" Award. The two had co-discovered their second Supernova, named SN2005B in UGC11066 in the constellation of Draco. The images were taken from Dave's Abbey Ridge Observatory (located at Stillwater Lake, Nova Scotia).

This award is presented to the first Canadian amateur astronomer or group

Paul Gray (left) and Dave Lane (right) receive their award at Starfest.

of Canadian amateur astronomers to make an astronomical discovery, such as a near-Earth asteroid, comet, nova, or supernova in the Starfest year (usually August to July). This discovery must be announced by and authenticated by a recognized authority such as the International Astronomical Union.

The award was inspired by a comment made by Brian Marsden several years ago at a joint meeting of the Royal Canadian Institute and Royal Astronomical Society of Canada, Toronto Centre. At that meeting, Brian indicated that Canadian amateurs were not keeping pace with other amateurs around the world in the discovery of asteroids and other things that go bump in the night.

The intent of this award is to stimulate observational activity among Canadian Amateurs by providing a cash prize for the next person who makes an astronomical discovery. Complete details about the award can be found at www.nyaa-starfest.com.

The two happy winners walked away with a special plaque, 500 Loonies, a pound of back bacon, and a toque.

Canada Wide Science Fair

Every year, the RASC sponsors awards at the Canada-Wide Science Fair for "Excellence in Astronomy," one each in the Junior, Intermediate, and Senior categories.

This year, the CWSF 2005 was held at UBC in Vancouver from May 15 to 22. Only two prizes were awarded by the Education Committee this year.

The Junior category award was given to Shelby Mielhausen for her well-researched and documented project, "Twinkle, Twinkle Little Star." It dealt with the effects of light pollution at different sites and its deleterious effect on observing.

The Senior category award was given to Vancouver resident Jennifer Loong for her "Oh-Dee: Orbit Determination." For determining the orbit of Asteroid (88) Thisbe, she wrote a computer program using IDL (Interactive Data Language), an array-oriented language for mathematical analyses.

The award was a $200 cash prize along with a certificate and a year's membership in the Society.

The Education Committee provides a more detailed report on their projects on the RASC Web site.

National Web Site

Next time you are surfing for astronomical items, might I suggest you try the RASC's Observing Resources pages. There are two links I wanted to mention.

The first is the Isabel Williamson Lunar Certificate, recently launched by our Observing Committee. This link will allow you to download a PDF file, so you can print out the observing list.

The second is the "Terry Adrian's Messier Chart/log system." I really wish this "system" were available before I did my Messier Certificate. It provides a log page plus basic star charts showing the position of the 110 Messier object list, with *Telrad* finder circles drawn on. The system makes it easy to determine all the Messier objects within a portion of the sky, and to observe them sequentially. I still use this method today and hope that Terry comes up with charts for the Herschel 400 list.

National Council Meeting in October

The upcoming meeting of your National Council (NC054) will be held on October 29, 2005. On this occasion, the meeting will be hosted by the Hamilton Centre and held at the Tim Horton Onondaga Farms, outside of Brantford, Ontario. National Council will be continuing with their efforts to try to contain our expenses and to help Treasurer Dave Clark bring the budget back into balance. After the meeting is held, I encourage all members to ask their Centre Representatives to advise them on the latest activities happening within the National Office.

Astronomical Society of the Pacific Award Goes to RASC Member

The Astronomical Society of the Pacific has awarded its 2005 Las Cumbres Amateur Outreach Award to Mary Lou Whitehorne of the Halifax Centre. The award honours outstanding educational outreach by an amateur astronomer to schoolchildren and the interested lay public. The Astronomical Society of the Pacific, a non-profit scientific and educational society founded in 1889, is one of the largest general astronomical organizations in the world and is a recognized leader in the field of astronomy education.

Mary Lou has devoted over 20 years to increasing awareness, understanding, and appreciation of astronomy by people of all ages — almost always as a volunteer. She has given dozens of presentations to groups of students, teachers, and lifelong learners of all ages as well as given numerous radio, TV, and newspaper interviews. Her work is widely known; she has published many articles on astronomy and astronomy education, and has given presentations at provincial, national, and international conferences.

While a board member of The Atlantic Space Sciences Foundation (TASSF), Mary Lou was instrumental in raising the funds to purchase a portable planetarium for Nova Scotia schools. TASSF had a policy that a school could not rent the *Starlab* unless it had at least one teacher who had attended a training session that covered not only the basics of how to properly unpack and repack the equipment, but also the astronomical content that could be explained to students with the *Starlab*. Mary Lou conducted these training sessions, as well as multi-day summer astronomy institutes that allowed teachers to add to their knowledge of astronomy. That base of trained teachers now numbers in the hundreds.

Astronomy has recently become a compulsory part of the school science curriculum in most parts of Canada. To provide support for teachers, Mary Lou built on the material that she had developed for the *Starlab,* to produce *Skyways,* an astronomy handbook for teachers. *Skyways* was published in 2003 by the RASC and is currently being translated into French.

In addition to working as an educator, she has been actively involved in the RASC both locally in the Halifax Centre and nationally, where she is presently the chair of the Education Committee.

She is a remarkable example of the contributions "amateur" (*i.e.* someone who does it for the love of the subject) astronomers can make to science and to education.

Venus Vignette

by Bruce McCurdy, Edmonton Centre (bmccurdy@telusplanet.net)

goodnight venus
it's hard to see you go
one more night comes between us
and my desire grows stronger

— Libby Kirkpatrick, *Goodnight Venus*

Without a doubt, the most-thumbed pages of my *Observer's Handbook* each year are those in the invaluable Sky Month by Month section. In addition to current sky happenings, I'm always looking for repetitions, patterns, and one-off coincidences of unrelated events.

In the latter category, this mid-autumn features a cluster of favourable alignments in the inner solar system. Highlighted events from the *Observer's Handbook* 2005 (Gupta 2004) include:

Oct. 30 3h
Mars closest approach
Nov. 3 16h
Mercury at greatest elongation E. (24°)
Nov. 3 19h
Venus at greatest elongation E. (47°)
Nov. 6
Venus at extreme declination –27° 05´
Nov. 7 8h
Mars at opposition

In theory all three of our terrestrial neighbours are favourably disposed for observation. In practice Mars at elongation of 180° is almost halfway around the sky from our inner neighbours, and is the only one well-placed for northern observers. While it won't appear quite as large and bright as during its "record" close approach of 2003, Mars will crest more than 30° higher in 2005 and so should permit much higher magnifications. Not to mention more relaxed observation in general: my observing experience last time was of sneaking peeks while "centring" and "focusing" Mars for the relentless nightly crush of thousands of curious public. I for one am greatly looking forward to observing the Red Planet in increments of more than five seconds at a time.

The apparitions of Venus and Mercury, meanwhile, are deep in the south and are therefore of more theoretical interest this time. But interesting they are.

The near-simultaneous eastern elongations of the two are a rarity, doubly so because a similar coincidence took place on March 29, 2004, just one synodic period of Venus ago. Such "markers" help to define the Mercury-Venus-Earth relationship, which will be the subject of a future column.

For now let's focus on the extreme southern declination of Venus of November 6, 2005. This marks the most southerly point of any planet so far this century, marginally south of the position of Mars during its unfavourable 2001 apparition. According to Meeus (1983-95), the previous extreme south declination of Venus occurred on November 6, 1997, the next on November 6, 2013. The maximum southern declination of the 21st century will occur on November 6, 2093, and an extreme value of –28°11´ will be achieved on November 6, 2125. The previous extreme of –28°05´ had occurred on November 6, 1874.

The repetition of the "magic" date of November 6 is most instructive. We have come to expect that events involving Venus — elongations, conjunctions, and the like — repeat in cycles of eight years with a small correction of minus ~2.4 days. In the case of extreme declinations, however, the period is much closer to eight years exactly. What's going on?

The key point is that the nature of the "event" in question is primarily an Earth-based observation. Declination is merely a coordinate on the celestial grid that is defined by the tilt of Earth. In mid-autumn, Venus near maximum evening elongation lies fairly close to the winter solstice point on the ecliptic. In essence, Earth's South Pole is tilted toward the direction of Venus' approaching orbit.

As Venus "turns the corner" at its maximum eastern elongation it is roughly 45° ahead of the Sun. The elongation of Venus stays within three or so degrees of its maximum value for two months:

2005	
Sep 30	44.1°
Oct 05	44.8°
Oct 10	45.4°
Oct 15	46.0°
Oct 20	46.5°
Oct 25	46.8°
Oct 30	47.0°
Nov 04	**47.1°**
Nov 09	47.0°
Nov 14	46.7°
Nov 19	46.1°
Nov 24	45.3°
Nov 29	44.1°

Eight years from now on the same date Earth will be in the same spot in its orbit, and Venus will be incrementally closer to Earth but at virtually the same elongation.

In subsequent episodes, however, Venus continues to sink in declination even as its elongation decreases, and it gradually withdraws from 18h00 on the magic date; I conclude that as Venus incrementally draws closer to Earth, the effect of foreshortening more than compensates for the slightly more moderate declination of the ecliptic. The inclination of Venus appears more exaggerated as its distance to Earth is reduced.

Because the 8-year cycle (almost) always includes exactly two leap days, a usual cause of jitter in the data has been eliminated; the date of November 6 holds for every maximum in the 21st century.

There exists a complementary magic date around May 6 for extreme northern declinations. You may recall the situation a year and a half ago, with Venus cruising past the Pleiades in early April near maximum elongation, cresting near El Nath (beta Tauri at the bottom of the pentagram of Auriga) while near greatest brilliancy in early May, and famously transiting the Sun a month later. It was a spectacular apparition that will virtually be repeated in 2012. Southern observers are currently enjoying a similar extremely favourable apparition (minus the transit and the famous stars).

In both cases, the extremes always seem to occur when Venus is in the evening sky closing in on inferior conjunction. Of course, Venus does so every 1.6 years; however, the two extremes of declination in each 8-year cycle are always separated by very close to 1.5 years (see Table 1).

Therefore the two series are out of phase to one another by roughly 0.1 year relative to Venus' synodic period, which is manifest in the series peaking at their extreme values over a century apart. But the two series run in parallel for a surprising period of time.

The orbit of Venus appears strongly asymmetric to us Earthlings viewing it from the outside. The elongation points are biased to the Earthward side; it takes only about 142 days for Venus to swoop from evening to morning elongation, more than three times as long to return via the far side of the Sun. Greatest declination series are similarly asymmetric, slowly building by 3-5´ every 8 years for centuries, then decaying much more rapidly after the peak.

I studied the northern declination extreme in some detail while it was happening last spring. Meeus (2004, private communication) advised the current series exceeded +27° for the first time on May 6, 1908, more than a century before the maximum in 2012, but will take only half as long to recede back to that threshold, with the last event on April 26, 2068. Note also how the last date has receded well away from the optimal "magic" one (see Figure 1).

Applying the more moderate threshold of 26° to the northern series, I found (using *Guide 7.0*) the series dates way back to May 9, 1756, and expires on April 20, 2100. That lengthened the list by 19 additional events (>26° but <27°) before the maximum (1756-1764-...1892-1900), but only four more after (2076-2084-2092-2100). Indeed, there are only two further events above +25°, on April 19, 2108 and April 16, 2116 as the series decays *rapidly*.

It is interesting that the most extreme declinations within our current data set — 1874, 2012, 2125 — all occur just weeks before a Transit of Venus. This is a temporary coincidence which can occur only when the slowly rotating nodes (which govern the transits) are at a certain distance from the equinoctial points (which rule the high declinations and anchor the calendar). Note that 1874 is the first of a transit pair, 2125 the second; the difference of 251 years, 0 days suggests that a cycle slightly different than the well-established transit periodicity of 243 years plus ~2 days is at play.

Meeus (2004) confirms that the 251-year periodicity applies to extreme declinations over longer terms. The next northern maximum occurs on May 6, 2263, which misses by 8 years the transit pair of 2247-2255. Presumably there follows an extended period of zero such coincidences.

Over the very long term even the magic dates are not sacrosanct. There is a second hypothetical "sweet spot" after the solstices around February 6 and August 6, where Earth's poles are favourably tilted towards the direction of Venus' *receding* orbit. In the present era, the circumstance of Venus' inclination to the ecliptic is

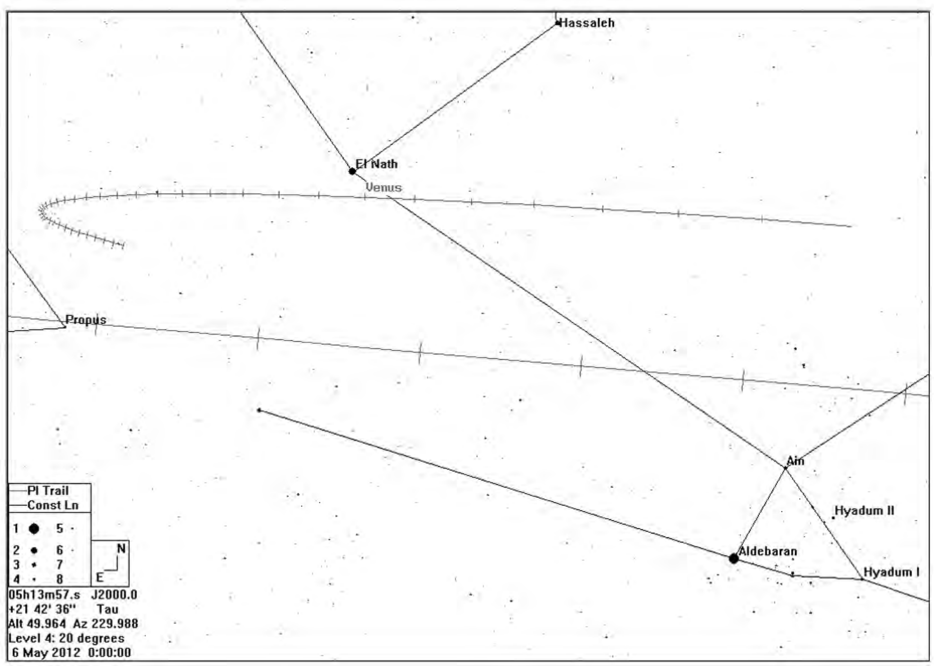

Figure 1 – The positions of Venus at 0h UT on the "magic" date of May 6, at 8-year intervals from 1756 (lower left) to 2068. The resultant curve mimics the orbit of Venus as seen against a "fixed" Sun. The shape of the curve graphically demonstrates the reason for the series' slow build-up and rapid decay. Venus is plotted as of 2012 when the extreme maximum northern declination of the current series will be reached just below El Nath (beta Tauri).

much less favourable at those times, indeed subtractive. In the long term, the inexorable rotation of the nodes ensures there will be periods when extreme declinations will be seen in the morning, rather than evening, sky.

The most extreme declinations of all, however, will not occur on any of the "magic dates." Venus' observed inclination from the ecliptic maxes out at over 8° around certain inferior conjunctions, which occur far from the nodes. A true maximum declination would occur in the situation of ascending node at vernal equinox (like that the Moon is now approaching), with inferior conjunction occurring right at either solstice. Add those 8+ degrees to the 23.5° tilt of the Earth (or, if you prefer, of the ecliptic), and it would seem a declination of 32° is possible.

To calculate an idealized maximum one must include many additional factors, and assume the following all occur simultaneously: Venus and Earth in conjunction 90° from the nodes; Venus' ascending node on the vernal equinox; obliquity of the ecliptic (which varies) at the maximum possible value; inclination of Venus' orbit (which varies) at the maximum possible value; Earth at perihelion; Earth's eccentricity (which varies) at maximum possible value; Venus at aphelion; Venus' eccentricity (which varies) at maximum possible value; Full Moon; favourable position of Jupiter; *etc.* In a mathematical equation — which I don't actually do — these would all be terms. Because they are typically in a rapidly diminishing order of importance, one can get a good feel for the range of possibilities by understanding only the first handful of ground rules for a given situation.

In reality, the likelihood of all these maxima occurring at once during the life cycle of the (stable) solar system, let alone that of the observer, are zero to the googoleth power, but in theory one must idealize, then prioritize, then predict. Then figure out why you were wrong. Repeat as necessary. Not so much magic, as logic.

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Bruce McCurdy is a Past President of the RASC Edmonton Centre who enjoys the logic puzzles of positional astronomy.

North Max	Dec.	I.C.	Days	South Max	Dec.	I.C.	Days
1964 May 6	+27°33′	1964 Jun 19	44	1965 Nov 7	−26°45′	1966 Jan 26	80
1972 May 6	+27°37′	1972 Jun 17	42	1973 Nov 7	−26°48′	1974 Jan 23	77
1980 May 6	+27°41′	1980 Jun 15	40	1981 Nov 7	−26°52′	1982 Jan 21	75
1988 May 6	+27°44′	1988 Jun 12	37	1989 Nov 7	−26°57′	1990 Jan 18	72
1996 May 5	+27°47′	1996 Jun 10	36	1997 Nov 6	−27°01′	1998 Jan 16	71
2004 May 5	+27°48′50″	2004 Jun 8	34	2005 Nov 6	−27°05′	2006 Jan 13	68
2012 May 4	**+27°49′27″**	2012 Jun 6	33	2013 Nov 6	−27°10′	2014 Jan 11	66
2020 May 4	+27°49′01″	2020 Jun 3	30	...			
				2093 Nov 6	−28°00′	2093 Dec 17	41
				...			
				2125 Nov 6	**−28°11′**	2125 Dec 8	32

Table 1. Extreme declinations of Venus > 26° for the period 1960-2020, adapted from Meeus (1983-95). Additional entries at bottom right show the maximum southerly declination of this and the next century as members of the same 8.0-year series, which peaks (**bold** type) in 2125. The northern series in the left columns will peak at its next iteration in 2012, having previously produced the most northerly declination of any planet in the 20th century in 1996.

While the maxima consistently occur within a day or so of a "magic date," the related inferior conjunction (third column) is gradually advancing forward through the calendar. Therefore the interval between the two events (shown in whole days in the fourth column) is gradually dwindling. In the current epoch, the optimal such interval is ~32 days, roughly midway between greatest eastern elongation and inferior conjunction.

Not shown are the maxima of 2007 May 10 (26°00") and 2015 May 10 (26°03") which are very early members of the next northern series which will peak at +27°57′on 2263 May 6.

Dr. Jayanne English

by Philip Mozel, Toronto Centre (phil.mozel@sympatico.ca)

Many people perceive a great divide between art and science. This is a rather narrow view as one often informs the other. A case in point is Dr. Jayanne English, whose career encompasses both.

As many people living in southern Ontario have done for years, the English family made the regular trek northward to cottage country "where we had a mesmerizing view of the sky." Like many astronomers, amateur or professional, she cannot remember when she wasn't held spellbound by the heavens. An interest in "hard" science fiction (including such authors as Robert Heinlein, Stanislaw Lem, and Isaac Asimov) also dates from a young age. On the flip side of the coin, her interest in art goes back at least as far: by the age of seven she was painting in oils, aided by her father, himself an artist.

After high school Dr. English studied part-time at many schools and worked in retail before settling on the Ontario College of Art where she completed the General Studies program. But she had already been studying math elsewhere and eventually obtained an undergraduate degree in Physics and Astronomy from the University of Toronto. The Ph.D. in Astronomy and Astrophysics was obtained at the Australian National University's Mount Stromlo and Siding Spring Observatories. Next, at Queen's University in Kingston, Ontario, she began her work with the Canadian Galactic Plane Survey (CGPS) and then moved on for a stint at the Space Telescope Science Institute. It was at CGPS that she encountered "the mushroom."

As outlined on the CGPS Web site:

Dr. Jayanne English

"Understanding our origins, ultimately from diffuse gas and dust in the interstellar medium (ISM) of our Galaxy, represents one of the most compelling challenges in natural science…The centerpiece of the CGPS, [is] an international collaboration to map all of the major interstellar components of the Milky Way at a common resolution: neutral atomic gas, molecular gas, ionized gas, dust grains, and relativistic plasma."

The CGPS has indeed gone international (I/CGPS), and the list of institutional participants is a veritable Who's Who. It includes universities and research groups from coast to coast across Canada as well as partners such as the National Astronomical Observatories, China; Max Planck Institut für Radioastronomie, Germany; and the Jet Propulsion Laboratory, USA. The main workhorse for the Canadian component of the project is the radio-telescope array at the Dominion Radio Astrophysical Observatory in Penticton, British Columbia.

Astoundingly, radio-telescope data from the I/CGPS shows a giant mushroom-shaped cloud growing from the Milky Way. The cloud, some one thousand light years tall, and an estimated three million years old, is rising from the plane of the galaxy. Since Dr. English is interested in how mass and energy are exchanged between a galaxy's spiral disk and its halo, the mushroom is coming under close scrutiny. Computer modeling by her team reveals a possible scenario in which "after a single star detonates as a supernova, a bubble of hydrogen could form inside the blast and rise buoyantly." Similar to a hydrogen bomb going off in Earth's atmosphere, the gas rises, creates a vacuum, and sucks in debris. The mushroom seems to be connecting the disk to the halo and may be a piece in the puzzle explaining why the gaseous halo surrounding the galaxy is hot.

Now, we all know that there is no "up" in space, so how can something rise? The gravity associated with the great mass of the Milky Way itself defines "down" much as the Earth does on a more modest scale.

Dr. English's interest in gas extends far beyond the Milky Way as well. For example, where do globular clusters come from? The answer may lie in the way gas flows between and among galaxies, especially those that are interacting or even colliding. Could globular clusters form from this gas? It seems so. Observations of the merging galaxy pair NGC 3256, made by a team including Dr. English, have shown a surrounding population of more than one thousand bright, blue objects. A number of these have been identified as newly born globular clusters with ages as low as a few million years.

She notes that closer to home there may be a globular-in-the-making: R136, found in the Large Magellanic Cloud's Tarantula Nebula. The cluster, containing thousands of giant, hot, blue stars, is generally described now as an open, or galactic, cluster but it may evolve to globular status in a few billion years.

Dr. English has also found a gas cloud with the mass of an entire galaxy. She asks, "Is it a primordial gas cloud or a once-normal galaxy that has been shredded by gravitational forces? And will it eventually evolve into a new galaxy?" Only time, and further study, will tell.

During all this probing of the Universe, Dr. English was still involved in art, to the extent that she was able to apply the lessons learned there to astronomy. For example, based on previous experience, she coordinated the Hubble Heritage Project while at the Space Telescope Science Institute. Using her knowledge of colour theory and composition, she would "attempt to art direct" during the creation of images from *HST* data. Different ways of presenting the information were tried so that the results would be both aesthetic and scientifically useful. She became lead image-maker for a number of the *HST* images.

Dr. English is most proud of this type of approach with I/CGPS data, becoming the first to make compellingly realistic radio *images* instead of just presenting the information as lines of equal radio intensity.

Dr. English is currently an Associate Professor in the Department of Physics and Astronomy at the University of Manitoba and is quite happy to be working in Canada. In large part this is because "Canadians are known for their collaboration," resulting in a productive, and enjoyable, working environment. The cooperative teamwork involved in the International/Canadian Galactic Plane Survey is a classic example.

At the time Dr. English was studying for her Ph.D., males greatly outnumbered females. Even today, "women are an anomaly" in some areas of the university but Dr. English, and her colleague Dr. Samar Safi-Harb, are pleased to be role models and are attracting female students to the department. Perhaps there will be an artist or two among them who, like Dr. English, will use the synergy of art and science to see the invisible and, having seen, increase our understanding.

Philip Mozel is a past Librarian of the Society and was the Producer/Educator at the McLaughlin Planetarium. He is currently an Educator at the Ontario Science Centre.

The Skies Over Canada
Observing Committee News

by Christopher Fleming (chrisfleming1@sympatico.ca)

The most active observers are, in most cases, those who have taken on a specific observing project or a series of projects aimed at their favourite observing category or categories. Many of these observers started out by completing an observing list such as the Messier Program, which provides a good foundation in observational astronomy. After completing such a list, observers have an important decision to make, and that is, what do I do now? The right choice is to get involved in another observing project, and although there are many great ones to choose from, some observers have difficulty with the transition from a skills development program, like an observing list, to a productive regular observing program focused on either recreation or science.

Of course one could simply move on to another observing list, and that is in fact a good choice if the observer wants to see all of the great objects that the night sky has to offer. An observing project, for example, to see all the thousands of Herschel objects could keep one active for many years and perhaps even for a lifetime. For others though, a new observing list may not be a suitable choice, and they could face a challenge to find themselves something interesting to do. It is for those folks that we need to provide encouragement and the necessary opportunities, and ideas, so they can progress to a new and exciting observing or imaging program.

The RASC Observing Committee has been working toward the goal of providing observers with an overview of all the possible observing projects that astronomy has to offer. There are basically four approaches to the various observing categories that exist, and all four are valid and worthwhile activities to pursue:

- The first type is traditional observing through the eyepiece (usually while doing an observing list) where the expanse of the Universe is enjoyed and appreciated, in real time, with little or no pressure to achieve any scientific results.
- The second type is also through the eyepiece, but with serious observations in mind, such as variable-star estimates, comet magnitude estimates, nova search programs, and so on.
- The third type is similar to the first type except that it involves enjoying the night sky through digital or film imaging with little or no pressure to achieve scientific results. This type could also follow an observing list such as the Finest NGC.
- The fourth type is again similar to the second type except that the serious observations are done through digital or film imaging and not through the eyepiece of a telescope.

Since most RASC members are hobbyists, and having fun is the main goal, any of the above categories would be an excellent choice. The important thing is to get involved and make the most out of your hobby by pursuing an organized project of your choosing. Without a structured program, an observer, or imager, will risk losing interest in one of the most fascinating and respected hobbies in the world.

The Explore the Universe Certificate Program (available in PDF format in the Observing Certificates area of the RASC Web site) provides new observers with a complete introduction to the night sky, including Constellations and Bright Stars, the Moon, the Solar System, Deep-Sky Objects, Double Stars, and an optional Variable Star List. The Solar System portion requires that the observer identify and record observations of five of the ten following options listed: The planets Mercury, Venus, Mars, Jupiter, Saturn, Uranus, Neptune, the Orbital Motion of a Planet, Meteors and Satellites, and Sunspots.

In addition, a comprehensive list of optional Solar System observations and activities are listed including, including Pluto, Eclipses (both lunar and solar), Conjunctions, Meteor Showers, Aurorae, Comets, Asteroids, and the Zodiacal Light. If all of the features of the Solar System portion of the Explore the Universe Program are utilized, the observer will gain a thorough knowledge of the mechanisms of our home-star system. You can download the program at `www.rasc/observing/page2.html`.

There have been three Explore the Universe Certificates awarded since our last report, and they can be found in Table 1. The recipients from the Prince George Centre were graduates of the new NOVA (New Observers to Observational Astronomy) course created by Brian Battersby and members of the Prince George Centre (see *Education Note* in this issue). The complete NOVA program course is now available for download in PDF format in the Members' Only area of the RASC Web site. It is an excellent program, and we highly recommend it.

There have also been four Messier Certificates awarded since our last report, and those talented observers are listed in Table 2.

In addition, there have been two

Table 1. Explore the Universe Certificate Recipients

Name	Centre	Date Awarded
Glen Harris	Prince George, B.C.	June 2005
Hugh Kennedy	Prince George, B.C.	June 2005
Jim Arnold	Prince George, B.C.	June 2005

Table 2. Messier Certificate Recipients

Name	Centre	Date Awarded
John Brooks	California, USA	June 2005
Michael McAllister	Toronto, Ont.	June 2005
David Player	Okanagan, B.C.	July 2005
Denis Grey	Toronto, Ont.	July2005

Table 3. Finest NGC Certificate Recipients

Name	Centre	Date Awarded
Charles Doucet	Moncton, N.B.	June 2005
Alden Foraie	Regina, Sask.	July 2005

Finest NGC Certificates awarded since our last report. A list of those skilled FNGC Certificate recipients can be found in Table 3.

Congratulations to all!

The Observing Committee has an Observing Sections Web page available at `www.rasc.ca/observing/sections.html` that features links to four observing categories as described here. The Asteroids Section features charts containing the orbital position of several bright asteroids that will be visible in 2005, and during November and December you will be able to print charts for the asteroids (3) Juno, (4) Vesta, (11) Parthenope, (16) Psyche, (19) Fortuna, and (89) Julia. Those asteroids will all be brighter than tenth magnitude at that time, and the charts will display nearby stars to tenth magnitude on a five-degree or greater vertical field layout. Dates for the position of each asteroid will be listed at three-day or longer intervals, and nearby bright "finder stars" will be highlighted. In many cases the finder stars are bright enough to be seen visually, and therefore a *Telrad* or similar pointing device can be used to target the field printed on the charts. Otherwise a typical finder-scope or binoculars will be sufficient to find the brightest star in the field.

The Variable Stars Section on the RASC Web site features direct links to genuine American Association of Variable Stars Observers (AAVSO) magnitude estimate charts for Mira-type Long Period Variables that will reach maxima in 2005, and that will be brighter than magnitude 8.0. For November and December 2005, you will be able to print charts for R Geminorum, R Leonis Minoris, R Serpentis, RU Herculis, T Cephei, and R Pegasi. We also have direct links to charts for several other variable-star types, and you will find them on the *Sample Charts 2* page. Many of the most interesting variable stars in the night sky are listed there as well as the positions of possible nova outbursts. The classic three-volume set of *Burnham's Celestial Handbook*, by Robert Burnham Jr. has detailed information about several of the variables featured on our *Sample Charts 2* page. Reading about these interesting stars before, or during, an observing session adds a great deal of depth to the experience.

The Comets Section on the RASC Web site has provided accurate finder charts for several comets over the past year, including Comet 9P/Tempel that was hit by the *Deep Impact* probe on July 4, 2005. We will continue to post charts for currently visible comets, some to as faint as fifteenth magnitude, that will challenge even the most demanding observers with large telescopes.

The Special Projects Section continues to be upgraded and now features significantly more resources. The complete upgrade is being gradually phased in, so you may want to return to this section occasionally to see the latest content. We are attempting to tap into key Web pages from Centres and individuals across Canada so that visitors to the national Web site will be more likely to find the information they are looking for. We will do our best to keep it current, and tips from members about new and interesting Web resources will be appreciated.

The night sky is truly awesome, and although we cannot yet travel to those far-off places physically, we certainly can in our imaginations, and that is what makes observing and imaging the cosmos so special.

Clear Skies.

Christopher Fleming is Chair of the RASC Observing Committee and Observers' Chair in the London Centre. He enjoys all types of observing, especially deep-sky, lunar, double stars, and variable stars.

Facelift for National Office

by James Edgar, Regina Centre (jamesedgar@sasktel.net)

A few months ago, after the February National Council meeting in Toronto, Patrice Scattolin of the Centre Francophone de Montréal was driving me to my billet in Scarborough and I was ruminating with him how obtaining a new sign for the National Office would be a great project. He suggested I make it myself.

Patrice knew I operate a small business from my home called "jameswood," making clocks, signs, small items of furniture, and such. It seemed natural that I would make the new sign and I declared right there that I would. It took a few months of picking out the right wood, routing the letters, applying a waterproof finish, shipping the sign to Toronto, and now it's done! The result is the new oak sign now installed at the National Office (see Figure 1).

Not far from where I live in Melville, Saskatchewan is a shop that does screen-print signs and embroidery. I got this Yorkton firm to make a 12-inch diameter version of our new Seal on a waterproof, sticky-backed appliqué, which they placed on a weatherproof backing — aluminum-and-plastic laminate that will last indefinitely. That part of the new sign is installed on the front door of National Office; with the office business hours on it as well (Figure 2).

Denis Grey of the Toronto Centre kindly agreed to be the installer, using his "designer's touch" to dress up the front of National Office.

Thanks to all who helped with this project. Photo credits — Bonnie Bird.

James Edgar is an RASC Life Member, attached to the Regina Centre. His serious love affair with astronomy began in Vancouver, B.C. in the early 1970s. His home in Melville, Saskatchewan provides many dark-sky nights.

Reviews of Publications
Critiques d'ouvrages

Frontiers of X-Ray Astronomy, edited by A.C. Fabian, K.A. Pounds, and R.D. Blandford, pages 246 + x, 17 cm × 25 cm, Cambridge University Press, 2004. Price $55 US softcover (ISBN 0-521-53487-9).

Optical astronomy began in prehistoric times when an unknown ancestor looked up and a puzzled expression appeared on his/her face. Radio astronomy was born approximately 70 years ago with Karl Jansky's detection of radio emission from the Milky Way. The discovery of Scorpius X-1 by Giacconi and collaborators in 1962 marked the birth of X-ray astronomy, although X-radiation from the solar corona had been detected as early as 1948. *Frontiers of X-Ray Astronomy* includes fourteen papers that are based on presentations to a Royal Society Discussion Meeting held in 2002 to mark the 40th anniversary of the detection of Scorpius X-1. The first paper is an historical review written by Ken Pounds, one of the pioneers in the field. The final paper, by Roger Blandford, looks ahead to new X-ray observatories in space and prospects for research in the next few years. Between the two are papers that address most of the principal areas of research in cosmic X-radiation.

Of the several ways in which to illustrate the importance of X-ray astronomy to an understanding of the structure of the Universe, one of the simplest is to note (p. 150) that, within some clusters of galaxies, 80% of the baryonic (*i.e.* "normal") matter is contained within hot, intergalactic, X-ray emitting gas; X-rays provide the only means for "seeing" a very significant fraction of all the normal matter in the Universe. Optical and radio telescopes alone give an incomplete and sometimes misleading picture of the true nature of the Universe. Each set of observational and analytical tools is complementary to the others: we require observations through all spectral windows in order to obtain a complete and unbiased picture of the physical Universe.

Naively one might have supposed that X-radiation would be emitted only by the most extreme — in luminosity and temperature — objects in the Universe. In fact, X-rays have been detected from Nature's more pedestrian astronomical objects, including the Sun and other "ordinary" stars (from their coronae or shocks in stellar winds), planets (usually, but not exclusively, those with strong magnetic fields), the Moon (from solar irradiation), and brown dwarfs. It is the more exotic X-ray sources, however, that have attracted the greatest attention and posed some of the most challenging problems for astrophysicists. Those sources include mass-accreting white dwarfs, neutron stars, black holes (stellar and galactic-scale), and supernova remnants...and, quite possibly, new classes of objects still to be identified. Each of these classes of sources and others, such as clusters of galaxies, is the subject of at least one of the papers.

X-ray astronomy is still in its infancy. The rapid growth of the field can be attributed to results obtained from several very productive space observatories, especially *Chandra* and *XXM-Newton*. Those missions, and others, are able to achieve very high angular resolution, permitting the unambiguous (in many instances) identification of X-ray sources with optical and radio sources. They also achieve relatively good spectral resolution. Both high-spatial resolution and high-spectral resolution are critical to constructing models and identifying the physical processes underlying cosmic X-ray emitters. Blandford's closing paper includes a discussion of the many difficulties faced when trying to identify the underlying physical processes from the observed structural and spectral characteristics of an X-ray source. Such difficulties arise for many reasons, including the non-thermal nature of many of the sources and the fact that cosmic X-ray emitters are often surrounded by matter whose physical characteristics and effects on the X-radiation remain largely unknown.

While intended for experts working in the field of X-ray astronomy and closely allied fields, the book can be profitably (if selectively) read by anyone, professional or amateur, with an interest in modern studies of stellar structure and evolution — especially star formation and the end products of stellar evolution — or an interest in the large-scale evolution of the Universe.

The book has been carefully edited and is free of all but a few inconsequential typographical errors. The fourteen papers are all well-written and well-illustrated. The discussions that must have occupied much of the time during the meeting in 2002 are not included; I assume that the papers as presented orally in 2002 have been modified to reflect those discussions before being published in print here. Each chapter includes an extensive bibliography that will direct those interested in more details to the relevant original sources. *Frontiers of X-Ray Astronomy* is strongly recommended to anyone interested in a balanced overview of what is one of today's most exciting fields of research in astrophysics.

Those, including many readers of this *Journal,* who will not have easy access to the book but who may be curious about recent developments in, and future prospects for, X-ray astronomy, can find much of that information on the Internet. All of the past (*e.g. ROSAT*), present (*e.g. Chandra* and *XMM-Newton*) and proposed (*e.g. XEUS* and *Constellation-X*) project offices host informative Web sites.

Douglas P. Hube

Doug Hube conducted research and taught astronomy and physics in the Department of Physics, University of Alberta, Edmonton, for more than thirty years. He joined the RASC in 1960 and served as National President from 1994 to 1996.

Introduction to Comets, by John C. Brandt and Robert D. Chapman, 2nd Edition, pages 441 + vii, 17.5 cm × 24.5 cm, Cambridge University Press, 2004. Price $110 US hardcover (ISBN 0-521-80863-54), $60 US softcover (ISBN 0-521-00466-7).

Midway through this book I found myself asking, "What is an introduction?" If someone were browsing an on-line bookstore for a primer on comets and took no clue from the price, this "introductory" text could wind up being returned or abandoned after a few chapters. If you are cowed by formulae, beware: *Introduction to Comets* averages 0.3 per page. *Caveat emptor* aside, I had read comet primers previously and was looking for something more substantial. Brandt and Chapman have provided all I wanted and more.

When the first edition of *Introduction to Comets* was published in 1981, comet science was not high on the list of exciting research topics. The authors predicted that would change with the planned missions to Halley's Comet. They could not predict the opportunities for research provided by comets Shoemaker-Levy 9, Hyakutake, and Hale-Bopp one decade later. The bulk of this second edition describes the wealth of information gleaned from those and other snowballs from Pluto's realm.

The first chapter, and the longest at 53 pages, is entitled "Comets in History." Rather than reiterate tales of ill omen, Brandt and Chapman lay their groundwork with an effective review of comet science. We are led through theories of composition and origin, from those of Aristotle to Halley and Whipple, and from the results of space missions to Halley and Giacobini-Zinner. The second chapter races through orbital parameters like a sun-grazer at perihelion before concentrating on non-gravitational forces and orbital resonance. Following Chapter 3's summary of professional observation techniques and comet space missions, we are prepped for the complete dissection of a comet.

Working inward, the authors devote a chapter each to the composition and dynamics of the three main parts of a comet: the tail, coma, and nucleus. Interaction with the solar wind plays such a prominent role in the appearance of a comet that it, too, has a chapter. These sections are the meat of the book and, to me, the most fascinating.

Comet tails come alive with intricate structures of dust, plasma disconnection events, and the discovery of a third tail — composed of sodium — in Hale-Bopp. A century of coma observations has resulted in the identification of numerous atoms and molecules, and an understanding of how they are produced. The chemistry lesson evolves to one of physics as the molecules are ionized and carried off by the solar wind. Finally, we get to the heart of the matter and learn the secrets of the nucleus unveiled by probes to comets Halley and Borrelly.

The final five chapters of *Introduction to Comets* are softer on the science and more befitting the title. The surprise outburst of Chiron in the late 1980s blurred the distinction between comets and asteroids, prompting an overview of the origin and composition of the latter. That leads to a description of cometary orbits and the possible origins of the Oort Cloud and Kuiper Belt. Shoemaker-Levy 9 had a significant impact on comet science and on promoting awareness of impact hazards. The authors summarize such events, including Chicxulub and Tunguska, and speculate whether comets were a prominent source of water, and perhaps life, on Earth. Looking ahead, they next describe the comet space missions in progress and scheduled for launch. It appears their last update was in the latter months of 2002, for they report on the mid-August failure of the *CONTOUR* launch but retain what the mission was to achieve. The final chapter, entitled "Comet Lore," is incongruous with the rest of the book. Leave the Bayeux Tapestry to the primers; it doesn't belong with partial derivatives.

John Brandt and Robert Chapman are both accomplished scientists and writers. Brandt's research papers have concerned plasma tails and solar wind interactions, while much of Chapman's career has been with NASA. *Introduction to Comets,* one of their several collaborations, has been written and edited well. I detected only a few minor errata, and in section 2.1.2.3 on asteroid designation conventions they imply the asteroid Mr. Spock was named for a fictitious person. Actually, it was named for a cat, one that resembled a famous eyebrow lifter.

Introduction to Comets is

illustrated richly with more than two hundred black and white photos, diagrams, and graphs. The illustrations are clear and relevant with concise descriptions. For numbers people, there are also twenty-eight data tables. A centre section of two dozen unnumbered pages contains coloured plates of photos and charts. Most of them were chosen for their aesthetic value or contrast enhancement, but a three-page spread depicting an asteroid collision is almost entirely gray on black. The References section lists the works alphabetically by author for each chapter, which I find more convenient than a chronological listing, followed by a short selection of suggested reading material.

Brandt and Chapman have targeted an audience of students, scientists, and interested members of the public. Much of the book is university level, but even readers who are cowed by formulae will be rewarded if they skim through the scary parts. The book will also serve as a useful reference for several years. I found myself returning to learn the origin of X-rays that were detected following the *Deep Impact* collision with Comet 9P/Tempel 1. With the success of *Deep Impact* and with other missions in the works, I expect to see the next update within a decade, perhaps under a new title.

Curt Nason

Curt Nason (nasonc@nbnet.nb.ca) is a member of the Moncton Centre and is employed as Senior Health Physicist at Point Lepreau Nuclear Generating Station. He has observed two dozen comets, beginning with a naked eye sighting of Kohoutek in 1974.

Norton's Star Atlas and Reference Handbook, by Ian Ridpath, 20th Edition, pages 195 + xi, 22.5 cm × 28.5 cm, Pi Press/Pearson Technology Group, Canada, 2004. Price $45.95 hardcover (ISBN 0-13-145164-2).

When asked to review the latest edition of *Norton's Star Atlas and Reference Handbook,* my first reaction was to say "no," but upon remembering its role in supporting my new-found interest in astronomy in the 1950s, I quickly agreed, curious as to what could deliver a star atlas, first published in 1910, into the 21st century?

How does *Norton's* compare with "modern" star atlases? The answer appears to be "not at all." It was clearly designed for the entry level to astronomy, for the budding enthusiast. It is actually a hybrid resource that combines a very acceptable set of star charts with an excellent reference to important astronomical terms, observing tips, and guides for exploring the night skies. In that respect it succeeds extremely well, with only our own venerable *RASC Observer's Handbook* matching or exceeding Norton's swath.

Because the neophyte astronomer is often faced with a myriad of complex terms upon entering "astronomical waters," the author/editor supplies, in chapter one, an extensive list of definitions that help to explain the motion of the stars and planets in our heavens and how they are connected to the Earth's annual orbit about the Sun. This understanding of motion and position is then used to describe our use of different time systems to keep track of what is "going on" in the sky.

With the observer's feet now solidly placed in time and space, chapter 2 explores the kinds of telescopes available to the amateur, provides useful observing techniques, and describes how fascinating objects in the sky can be captured by camera. In chapters 3 and 4 extensive descriptions are provided of Solar System members like the planets and their satellites, then of the stars and nebulae, ending with the far-flung galaxies in the depths of space. After whetting the amateur's appetite for more, the easily read star charts clearly show stars to magnitude +6.4 and deep-sky objects to 13th magnitude, both on the charts themselves but also in fine descriptive lists for each seasonal sky. The Milky Way and all the special targets are printed in green, making them stand out from the stars themselves.

A few items that were either omitted or underplayed are the role of radio astronomy for amateurs, the burgeoning renaissance in photography created by digital cameras, the huge resource base of the Internet, tabs on page borders for quick reference, as well as easy contact information to the many organizations keen on receiving the amateur's discoveries or observations.

The *Norton's* "formula" works well for the amateur astronomer with a newly acquired telescope and a yen to traverse the night skies. Setting aside the lack of good bibliographic references to the factual information provided, I cannot think of a better, more practical, Christmas gift to give to a budding astronomer, young or old, than this latest edition of *Norton's Star Atlas and Reference Handbook,* except, of course, including a copy of the *Observers' Handbook* for real-time activity in the sky.

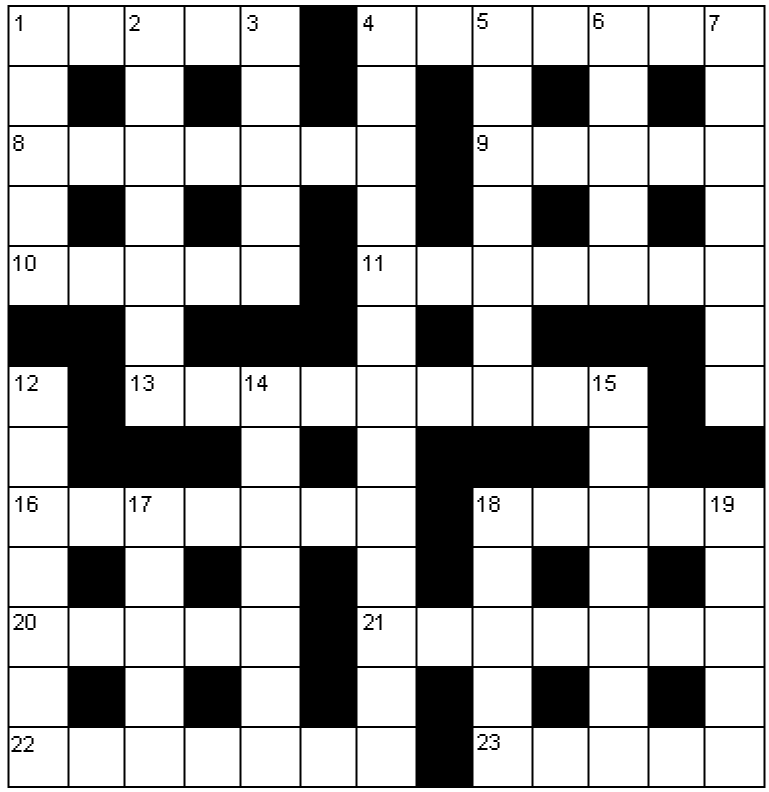
Franklin Loehde

Franklin Loehde is a former President of the Society, a retired physics teacher and administrator, and an active supporter of the RASC and local science centre in Edmonton.

Astrocryptic

by Curt Nason, Moncton Centre

ACROSS



1. Pants when reaching minimal mass for cloud collapse (5)
4. It tags a broken pointer in the sky (7)
8. A particular tail sees magnitude ten return to zero (7)
9. Compiles when the space station is around Toronto after beginning of Lent (5)
10. Lunar feature seen in the Imbrium Basin, usually (5)
11. All returned in an overturned drum to the Cambridge radio observatory (7)
13. Call Bok, he somehow knows the galactic core (5,4)
16. Races back with first quarter lunation to see a long period variable (7)
18. Stop limiting your view in the eyepiece (5)
20. Perplexed Bruin fan proposes galactic dark matter (5)
21. Curie was distressed to find tellurium in a calcium-rich meteorite (7)
22. Ancient science practised in stellar cores (7)
23. Endorses astrological constellations (5)

DOWN

1. 1A first named Jupiter and Mars eclipsing satellites, initially (5)
2. Big lane breaks up by ? Peg (7)
3. Drives the scope around soundly (5)
4. Cobbler tax paid by a comet team (9-4)
5. Io entangled in legal situation after he discovered it (7)
6. The magnetic flux measured in a satellite's launch (5)
7. Apparently, I passed perihelion and aphelion (7)
12. IAU star reassembled in Europe (7)
14. Meteorite found within region where the fall ended (7)
15. Hesperus is the star at this time (7)
17. Ursa Minor heads the Index Catalogue volume reference (5)
18. Concentrate on getting your sharpest view (5)
19. Speed up an orbit or drop into oceans (5)

Great Images

M33 and NGC 604 Face-On
The galaxy M33 in Triangulum appears here in an observatory-quality image taken only with amateur equipment. Young Population I stars in the spiral arms contrast with the older yellow Population II stars in the nucleus. Red NGC 604 at the upper right, with a diameter of 1000 light years, is one of the largest H-II regions in the universe.

(Photo by Tony Hallas from *Observer's Calendar,* October, 2004)

ANOTHER SIDE OF RELATIVITY

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

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CENTRE ADDRESSES/ADRESSES DES CENTRES

The most current contact information and Web site addresses for all Centres are available at the Society's Web site: **www.rasc.ca**

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Charlottetown Centre
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Edmonton Centre
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Moncton Centre
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Montreal Centre
PO Box 1752, Station B, Montreal QC H3B 3L3

Niagara Centre
PO Box 4040, St Catharines ON L2R 7S3

Okanagan Centre
PO Box 20119 TCM, Kelowna BC V1Y 9H2

Ottawa Centre
1363 Woodroffe Ave, PO Box 33012, Ottawa ON K2C 3Y9

Prince George Centre
7365 Tedford Rd, Prince George BC V2N 6S2

Centre de Québec
2000, boul Montmorency, Québec QC G1J 5E7

Regina Centre
PO Box 20014, Regina, SK S4P 4J7

St. John's Centre
c/o Randy Dodge, 206 Frecker Dr, St. John's NL A1E 5H9

Sarnia Centre
c/o Paul Bessonette, 160 George St, Sarnia ON N7T 7V4

Saskatoon Centre
PO Box 317, RPO University, Saskatoon SK S7N 4J8

Thunder Bay Centre
286 Trinity Cres, Thunder Bay ON P7C 5V6

Toronto Centre
c/o Ontario Science Centre, 770 Don Mills Rd, North York ON M3C 1T3

Vancouver Centre
1100 Chestnut St, Vancouver BC V6J 3J9

Victoria Centre
c/o David Griffiths, Treasurer, 333 - 1900 Mayfair Dr, Victoria BC V8P 1P9

Windsor Centre
c/o Ken Garber, 2831 Alexandra Ave, Windsor ON N9E 2J8

Winnipeg Centre
PO Box 2694, Winnipeg MB R3C 4B3