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Journal

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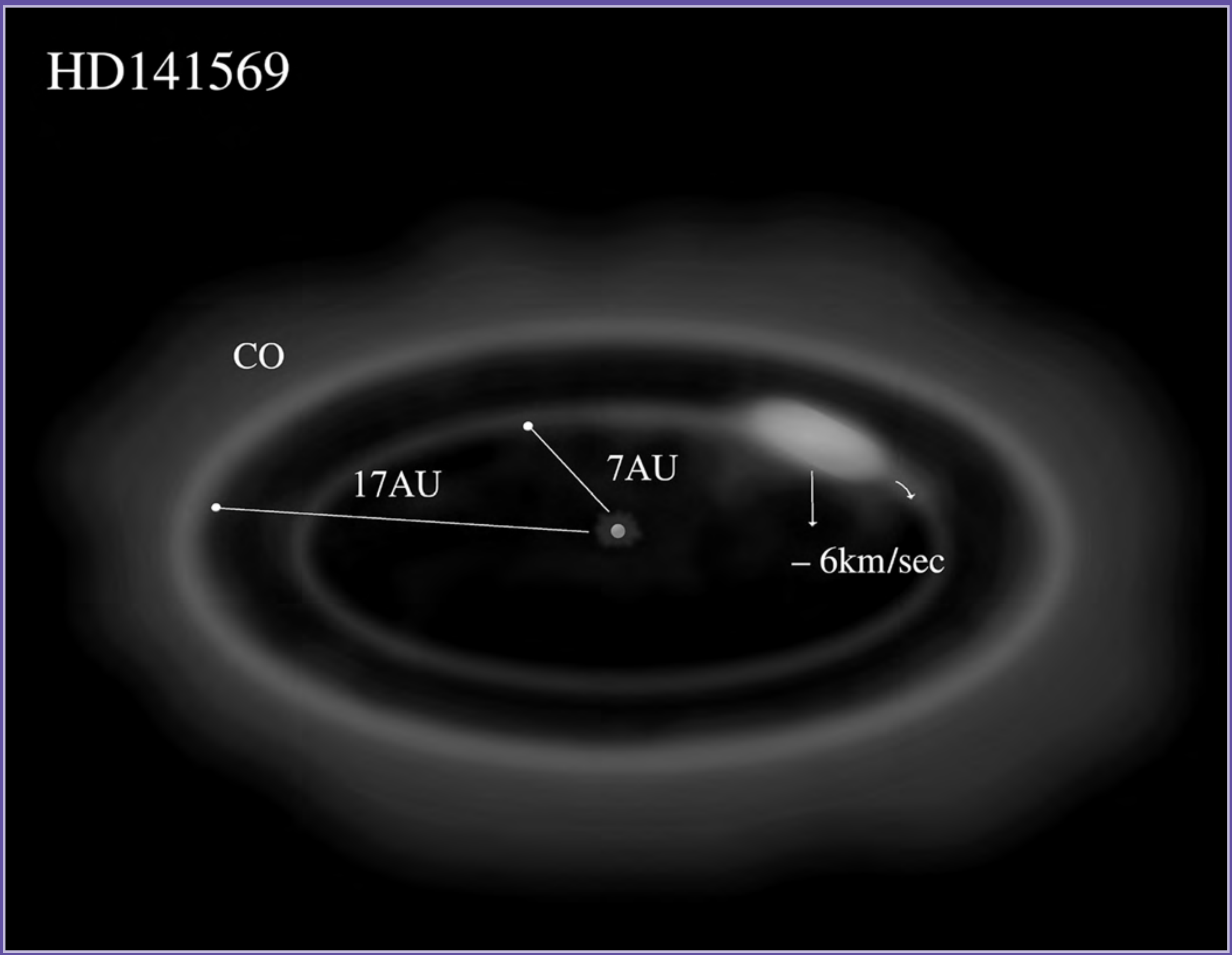


INSIDE THIS ISSUE

August/août 2002

Journal

Vol. 96, No. 4 Whole Number 695

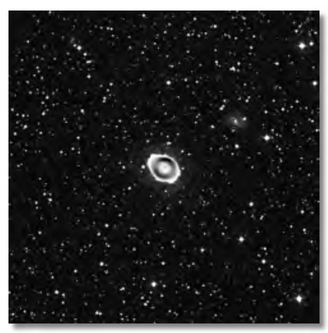
contents

table des matières

FEATURE ARTICLES/ARTICLES DE FOND

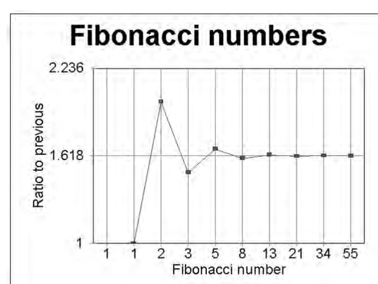
RESEARCH PAPERS/ARTICLES DE RECHERCHE

COLUMNS/RUBRIQUES



Planetary Nebulae
p. 144

A new sundial in Victoria
p. 147

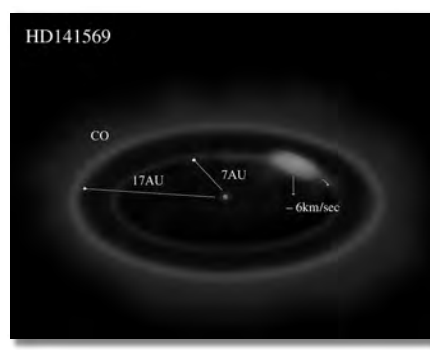


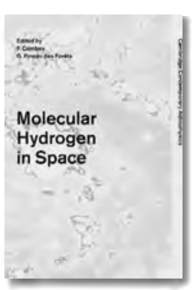
Hall's Balls
p. 170

AstroCryptic Answers p.176

New life for Vancouver's telescope
p. 174

Cover:
An artist's impression of how H_3^+ emission (glowing regions) might be distributed around HD141569. The large bright spot on the right side of the figure is the proposed proto-planet, while the bright ring is the warm inner edge of the gas disk that is being evaporated by the new star at the centre.
p. 151





Book Review
p.155

President's Corner

by Rajiv Gupta (gupta@interchange.ubc.ca)

I assume the position of President of the RASC with eagerness and gratitude, but at the same time with some trepidation.

After having been a member of the National Executive for eight years, I am eager to fulfill the duties of President, in particular the travel to Centres, which my predecessors have all said is the most enjoyable aspect of the position. This travel allows the President to get to really *know* the Society. Also, I am eager to influence the direction of the Society in ways that may be uniquely available to the President, and to continue to contribute to its administration.

My gratitude is deep and broadly directed. First, I am grateful to my predecessor, Dr. Robert Garrison, under whose leadership the Society has flourished over the past two years. Bob joined the Executive six years ago with relatively little experience within the Society at the national level but with plenty of experience in astronomy as a well-known Professor of Astronomy at the University of Toronto. He quickly came "up to speed" on the administration of the Society and brought to it a unique perspective as a professional astronomer. While he cared passionately about the Society, Bob led in a calm, dignified manner, often cooling discussions down when they became overheated. Bob explained the importance of perspective in a recent *President's Corner*, and the Society benefited from his wisdom and perspective during his term as President.

Bob loves to travel. Even though he retired from his professorship a year ago, he maintained a rigorous travel schedule, both on professional and RASC matters. His travels often took him to exotic locations such as Turkey, Chile, and Argentina. No matter where he was, Bob kept up his RASC work; it seemed somehow incongruous to receive e-mail messages from the University of Toronto Southern Observatory in Chile, under its spectacular skies, on mundane RASC administrative matters such as fee increases. During his two years as President, Bob visited an incredible twenty-three of the twenty-six Centres, delivering captivating talks that captured his broad experiences within astronomy. The Society and its Centres, and members of the Executive with whom you have worked for the past six years, will miss your leadership and inspiration, Bob!

I am also grateful to other recent Presidents whose initiative and leadership are also responsible for the strong state the Society is currently in. In particular, I am grateful to Doug George, who during his term from 1996–1998 initiated fundamental reforms in the operation of the Society, and to his successor Randy Attwood, who completed the implementation of these reforms. The Society now has a robust and powerful "in-house" membership and customer tracking system that has greatly streamlined its operation and given it substantial capabilities which it previously lacked. We also have an arrangement with

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.

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the publishers of *SkyNews* magazine that is likely largely responsible for the tremendous growth in membership — over 50% — the Society has seen in the past six years. Our bimonthly mailings of the *Journal*, with its Society news and survey and research articles, and *SkyNews*, with its spectacular colour images and unique Canadian perspective on popular astronomy, provide benefits to all members.

Finally, I am grateful to other members of National Council and the Executive for all their hard work in the running of the Society. In particular, I am very happy that Michael Watson, with his tremendous expertise and skill, is continuing as the Society's Treasurer, and that Kim Hay and Peter Jedicke, with all their experience, are also continuing on the Executive. I welcome Scott Young to the Executive. As the youngest among us, Scott has tremendous energy, which together with his background in the popularization of astronomy will, I am sure, lead to him making substantial contributions to the Society.

So why, with the great shape the Society is in and its many strong leaders — past and present — do I have some trepidation? For the same reason that I felt uncertain about taking over the editorship of the *Observer's Handbook* from Roy Bishop a couple of years ago: when something is working so well, you don't want to screw it up! Editing the *Handbook* has, however, reinforced my conviction that the Society has tremendous talent within its membership, and drawing on this talent makes any leadership task within the Society more manageable. I intend to fully exploit the main resource within the Society — its members — during my term as President. I know that members will not mind, but rather eagerly help, as is the tradition within the Society. This help may take any form, including suggestions on how the Society may be further improved; I'm all ears! Together, we'll be able to hand over to my successor in two years an even stronger Society, which he or she will also feel privileged and honoured to lead.

Editorial

by David M.F. Chapman, Contributing Editor (dave.chapman@ns.sympatico.ca)

When the *JRASC* Editor asked me to write a guest editorial, I agreed right away and immediately regretted it. What to say? I did a little research to see what was involved, and discovered something about our esteemed editor: between writing his doctoral thesis and editing *The Journal*, he had found time to study the works of Mark Twain, particularly *Tom Sawyer*. He learned the lesson well! I also discovered that the specifications for a guest editorial are loosely defined, so I should have no problem. So here goes…

I have just returned from the 2002 General Assembly in Montreal (my whereabouts when the Editor e-fingered me). The only other GA I took part in was hosted by the Halifax Centre in 1993, making this year's GA the first I have travelled to. I was somewhat apprehensive — although I have been an RASC member for about 20 years, I don't "do" meetings, and I don't know very many RASCals. In the end, I discovered that the RASC is a group of friends I hadn't met yet.

It must have helped that I have been writing a *JRASC* column for five years and have served on the Awards Committee for three years. Thanks to the *Journal* and e-mail, I have been in touch with RASC members across the country and beyond, people I never would have encountered otherwise. So it was fun to finally meet up with them and put names to faces. Of course, I met a few new faces and names as well. Generally, I found the RASC to be a fairly congenial group of normal folks (apart from being obsessed with astronomy).

The logistical arrangements were good. It was a blast staying in a university residence again, even if it was a women's residence. All weekend, there was a fierce battle waged over possession of the washroom near my cell… er, room. At first light, a crack team of commandos from the Provisional Wing of the RASC would occupy the washroom long enough for the lads to shave, shower, *etc*. (Clues that it was a women's residence: no urinals and no electric shaver outlets.) Later in the day, a "Women's Washroom" sign would appear on the door of the same facility. Next day, same routine. The residence must have known astronomers were coming, as they planned a power outage for the first night to work on the electrics. (No kidding, they posted advance notices!) We had a good chance to put our dark-adapted vision to use in our rooms that night.

I attended my share of business meetings. Despite being a Centre President for two years, I have not been very interested in RASC administration or politics, however, business must be conducted, and this seemed to proceed in an orderly and collegial (if sometimes emotional) manner. I even managed to influence a decision! The Gupta Administration will do just fine.

I enjoyed Saturday's contributed oral presentations, although the individual papers were a bit uneven. I appreciate the fact that the RASC is an inclusive and tolerant organization. Papers contributed by members portray a true cross-section of the society, and I hope this tradition continues. All of the invited speakers were good, but I must confess my favorite was Paul Hodge. His paper on Barnard's Galaxy was an excellent balance of history and science (and length).

On the last day, I was inducted into the RASD: the Royal Astronomical Society of Daves. I cannot reveal the secrets of the ceremony, but I passed, and I may now sign my name Dave XVII.

I did not intend to give a GA report, which I imagine will appear elsewhere, but I did want to pass on these few impressions. Thanks to Mark Bratton and his team for taking on the organization and execution of the event. I returned from Montreal feeling significantly more connected to the RASC as a national organization. I almost regretted not going to more GAs in the past! I would like to encourage those of you who have never made the pilgrimage to consider going to a GA when the opportunity presents itself. They wander about the country, so you should not have to travel too far if you are patient. The next two are coastal GAs: Vancouver in 2003 and St. John's in 2004. Will I go? How could I miss St. John's? I am not positive, but I am pretty sure I won't wait another nine years!

News Notes
En Manchettes

ONE FOOT IN THE GRAVE

It is now a well-accepted observation that the demise of the dinosaurs, some 65 million years ago, was an event hastened along by the impact of a large asteroid or comet. A recent research paper in the May 17,2002 issue of *Science* (296, 1305, 2002), however, now further suggests that the rise to dominance of the dinosaurs, some 200 million years ago, was also the result of a large impact event. The story, so argue Paul Olsen of the Lamont-Doherty Earth Observatory in Palisades, NY and co-workers, including H.-D. Sues of the Royal Ontario Museum, is written in an iridium anomaly, fern spore data, and the fossilized animal track information derived from rocks marking the transition to the Mesozoic era. The small, but distinctive, iridium anomaly is the smoking gun for a bolide impact, and the simultaneous fern spore spike is indicative of a time of climactic devastation (ferns tend to thrive under harsh conditions). The fossilized animal tracks literally show a turnover from a world dominated by the tread of reptiles to one dominated by large theropod dinosaurs. Olsen and co-workers argue that the fossilized track data reveal a rapid dinosaur ascendancy. Indeed, within 10,000 years of the impact event, it appears that the dinosaur ancestors had evolved to fill the environmental niches left vacant by the impact that devastated Triassic reptiles.

CANADIAN EH?

The list of named asteroids continues to grow at a rampant pace, but keeping track of asteroids with Canadian related appellations will be easier with the new Web page being maintained by RASC 1st Vice-President Peter Jedicke. From (729) Watsonia to (24899) Dominiona, all the details are available at `www.rasc.ca/faq/asteroids/home.htm`

JOURNAL BACK ISSUES

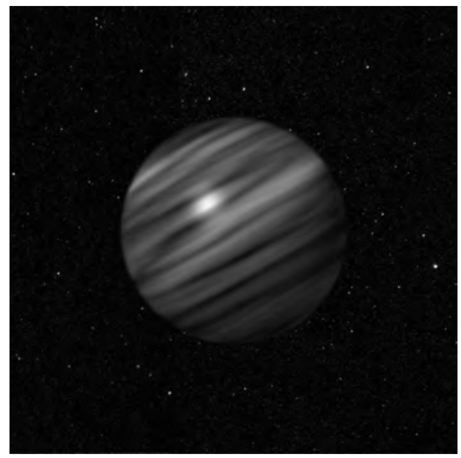
Need volume 3 (1909) of the RASC *Journal* to check on that article concerning "the doctrine of probabilities" by W.F. King, but the local library is closed? Well, fear not, the complete canon of RASC *Journals*, from the 1907 first volume to April 2001, is now available on-line. As part of the NASA Astrophysics Data System, the RASC *Journal* can now be accessed in electronic format (up to a one-year embargo limit set on current editions) at `absabs.harvard.edu/article_server.html`. The service also provides a titles/authur/abstracts search engine.

BROWN DWARFS UNDER THE WEATHER

Université de Montréal astronomers have detected, for the first time, variability in brown dwarf stars. Presenting their findings at the International Astronomical Union conference held in Hawaii in May 2002, the Montreal group argued that signs of "cloudy weather" had been detected on a number of low mass, Jupiter-sized, brown dwarf stars.

By monitoring the infrared radiation from brown dwarf stars over many months with the 1.6-metre telescope at the Observatoire du Mont-Mégantic (for more details and images see `www.astro.umontreal.ca/omm/`), the Montreal group detected tell-tale variations that were likely caused by the motion of clouds in their outer atmospheres. These clouds may be similar to the Great Red Spot of Jupiter, or they may be localized temperature inversions like the dark spots on our own Sun.

Dr. René Doyon of the Université de Montréal commented that "this variability phenomenon in brown dwarfs will allow us to understand their atmospheres better, and help us investigate giant planets outside our own Solar System." Brown dwarfs bridge the gap between stars and massive gas-giant planets. Unlike stars, they have insufficient mass to ignite nuclear reactions in their cores. As a result, they are extremely faint in visible light and emit most of their energy as infrared radiation.



An artist's impression of a brown dwarf (image by Douglas Pierce-Price, Joint Astronomy Centre)

THE OLDEST STARS

Announcing their findings at the recent Canadian Astronomical Society meeting in Penticton, B.C., Drs. Ralph Pudritz (McMaster University) and Melinda Weil (City College of San Francisco) have suggested that giant gas clouds, up to a thousand times more massive than any observed in our Milky Way, formed within young galaxies when they were only a billion years old. These massive star factories are of special interest because they are the likely sites for the formation of the oldest star clusters known in the universe — the globular star clusters.

The computer simulations run by

Pudritz and Weil model the collapse of so-called supergiant clouds (SGCs). The SGCs are produced, it is argued, within young, newly forming galaxies. The mass spectrum of these supergiant clouds is similar to the mass spectrum that we see for the cradles of star formation in our own galaxy, namely the Giant Molecular Clouds (GMCs). The main differences between the star-forming clouds is their size — 1 kiloparsec for SGCs and only tens of parsecs for GMCs, and their mass — only a million times the mass of the Sun for GMCs but up to a billion times the mass of the Sun for the SGCs.

One of the interesting results of the work by Pudritz and Weil is that the supergiant nurseries for the globular clusters have no difficulty in forming in different cosmological models. While cosmologists are learning a great deal about the structure and age of the universe from a variety of observations, there is still great latitude in the exact cosmology that governs our universe. Pudritz and Weil show that supergiant clouds should form in galaxies irrespective of different cosmological models. The main difference that results from using different cosmological models is the exact age at which the globular clusters achieved "first light."

"Our findings suggest that the formation of the first star clusters in the universe was not too different in character from the formation of star clusters that we see nearby us in the Milky Way — such as the famous Trapezium star cluster in the Orion Nebula," noted Pudritz. The main difference, however, is that "the Orion star cluster is a dwarf by comparison — thousands of Orion clusters could neatly fit into a globular star cluster."

LARGEST MODEL UNIVERSE SIMULATIONS

Canadian astrophysicists have run the world's largest gas particle cosmology simulation on the SHARCNET supercomputer at McMaster University. The most recent results from the 270 million particle hydrodynamical simulation of galaxy clusters were presented by Dr. James Wadsley at the Canadian Astronomical Society's annual meeting in Penticton, B.C.

The simulation of a cubic portion of the universe 1.3 billion light-years across using 135 million gas and 135 million dark matter particles was created by Wadsley and by Dr. Hugh Couchman (McMaster University). The simulation is capable of modeling structures larger than the "Great Wall" of galaxies and yet is also capable of resolving "details" down to the size of galaxy clusters and even large galaxies. The massive simulation was run using the parallel computer program "Gasoline" on 88 processors of the McMaster supercomputer *Idra*, taking 50 days to complete (a time equivalent to some 11 years processing on a single computer). *Idra* is the 112-processor Compaq supercomputer cluster at McMaster purchased as part of the SHARCNET project. SHARCNET (for further details see `www.sharcnet.ca`) is a project undertaken to develop a network of high-performance computing clusters in Ontario and is funded by the Ontario Research and Development Challenge Fund and the Canada Foundation for Innovation.

Images and movies of the simulation are available at: `imp.mcmaster.ca/images`

CFHT GOES OVER TO THE "DARK SIDE"

Canadian and French astronomers are set to embark on a massive exploration of the universe using a unique new instrument. The Canada-France-Hawaii Telescope Legacy Survey (CFHTLS) will be the largest observing project in Canada over the next five years. Its goals are to determine the properties of the dark energy that is driving the acceleration of the universe, to measure the amount of dark matter precisely, and to study the dark chunks of rock and ice left over from the formation of the Solar System.

The CFHTLS will run for approximately 500 nights over the next five years at the 3.6-metre (142-inch) Canada France Hawaii Telescope (CFHT) on Mauna Kea, Hawaii. This is the first time a large telescope has been so dedicated to a single project. The CFHTLS will take over 2000 pictures with the newly-built MegaCam, the world's largest astronomical camera. MegaCam is capable of taking a one square-degree picture of the sky at a time (for comparison, the Moon takes up only ¼ of a square degree).

There are three major components to the CFHTLS: The first component constitutes the Ultra Deep Survey, which will help astronomers choose among the possible candidates for "dark energy." Dark energy is a repulsive force that has been proposed to explain the apparent acceleration of the universe. This acceleration was first noted in 1998 by astronomers studying images of approximately 80 supernovae. The UltraDeep Survey will find about 2000 new supernovae, some as distant as 10 billion light-years. This will be the largest sample of supernovae from any ground-based telescope. The second component, known as the Deep Survey, will allow astronomers to create maps of the distribution of dark matter. Dark matter is an unknown substance that makes up over 90% of the gravitating mass in the universe. Dark matter cannot be seen directly, but its gravitational field will bend light that travels through it in a process known as gravitational lensing. The Deep Survey pictures will contain approximately 2,000,000 galaxies. The galaxies will be analyzed to determine how the light that we receive from them has been distorted by the presence of intervening dark matter. The third component of the CFHTLS is the Ultra Wide Survey, which will study Edgeworth-Kuiper Belt Objects, chunks of rock and ice that orbit our Sun out beyond Neptune and that are the leftover planetesimals in the disk that formed our Solar System.

The CFHT is operated by the National Research Council of Canada, le Centre National de Recherche Scientifique in France, and the University of Hawaii. The CFHTLS is supported by the Centre National de la Recherche Scientifique and the Institut National des Sciences de l'Univers in France, the Canada France

Hawaii Telescope, and the National Research Council and the Natural Sciences and Engineering Research Council in Canada.

THE 2002 PLASKETT MEDAL

Edward W. Thommes is the recipient of the Plaskett Medal for 2002. Awarded jointly by the Royal Astronomical Society of Canada and the Canadian Astronomical Society, the gold medal is presented to the Canadian graduate who is judged to have submitted the most outstanding doctoral thesis in astronomy or astrophysics during the past two calendar years.

Working under the supervision of Professor Martin Duncan (Department of Physics and Astronomy at Queen's University) Thommes's doctoral dissertation was concerned with the formation of Uranus and Neptune. Aspects of Thommes's thesis work were recently published in the May 2002 issue of the *Astronomical Journal* (123, 2862). The published work considers the planet formation scenario in which the ice giants Uranus and Neptune are deemed to have formed in the Jupiter-Saturn region of the early solar nebula, but were subsequently scattered outwards to their present locations by the rapid formation of gas-giant Jupiter. Thommes *et al.* suggest in their paper that Uranus and Neptune are examples of ice cores that lost the runaway gas accretion race to become Jupiters.

Call for notes. If you have any News Note items that you would like to bring to our attention please forward the information via e-mail to martin.beech@uregina.ca.

Planetary Nebulae in *Lyra*

by Mikkel Steine (mikkel@messier45.com)

In the fall of 2001 I began an observing project with the goal of observing all of the planetary nebulae in the constellation Lyra. It seemed both a feasible project and an exciting one since the planetaries in Lyra, from the well-known Messier 57 to the faint Abell 46, are very diverse, both in brightness and as observational challenges.

Initially my research showed that there were seven planetaries in Lyra, but it seems that one of them really is a galaxy catalogued in the CGMW and LEDA databases (see list of sources below). In Steven Hynes' book *Planetary Nebulae* one more was listed, but this is an M-type star. After I posted the first version of this article on the Internet, Steve Gottlieb wrote me about yet another planetary in Lyra that was discovered by Strigl in 1996 and named Si 1-2 in SIMBAD. So with one deletion and one addition I ended up again with seven planetary nebulae as the targets for my observing project.

Using a 10-inch f/5 Dobsonian telescope, I have observed and drawn five of the planetary nebulae on my list. Abell 46 and the very difficult new discovery Si 1-2 remain as hopeful targets for the future. I'm not sure if these two objects are even possible to observe with the 10-inch but I will continue to try. Published images can be misleading about the visibility of an object and there is no better way to tell whether the object is visible than to try finding it with one's own telescope.

Fig. 1: Image of planetary nebula Messier 57 (The Ring Nebula).

Fig. 2: Image of planetary nebula Minkowski 1-64

Messier 57, or the Ring Nebula, is an object that most amateur astronomers will be familiar with. With a visual magnitude of 14.7, the central star is not easy to see, but with pristine quality skies I have observed it at 140×. I have never tried to see the outer shell around M57, and I am not sure it is within reach of the 10-inch. The rest of the objects on my observing list are more demanding of the observer, as some are real tests in proper usage of maps and of observing skills.

The next planetary I observed was **Minkowski 1-64**, called by some "the other ring nebula in Lyra." When I observed this nebula no ring structure was revealed to me, at least not under the far-less-than-perfect conditions during my observation. The nebula is hard to locate, as there are very few distinct waypoints for star hopping, however, once on the correct field, and using a UHC, UltraBlock, O III, or similar narrow- or broad-band filter, Minkowski 1-64 will be revealed. The map in Hynes also helps, even if the maps in this book tend to be somewhat misleading, as it is impossible to know the magnitude of the stars depicted. You have to look for patterns of brighter stars in the map that you may recognize in your scope.

NGC 6765 was more difficult to find than I thought it would be. It's in a very rich field of stars and so it does not

Fig. 3: Image of planetary nebula NGC 6765

stand out in any way. The nebula lies inside a triangle of stars and is very mottled in its appearance. I believe it is a bipolar planetary and it has a very irregular shape. The delicate structure of this object is revealed under good conditions and, at 140×, I saw a thick rod NE-SW with more nebulosity around it on both sides. Locating this object is fairly easy as long as you find the very distinct group of stars three-quarters of the way between M56 and NGC 6765.

Kohoutek 3-27 was a very difficult observing challenge. It was quite easy to locate the correct field using M56 as the starting point, but I found it hard to positively identify the object. It required averted vision to see a very faint but defined annular nebula of less than three- tenths of an arcminute in size. The DSS image shows a nice little ring; hence you may call it "the third ring nebula in Lyra." I will return to observe this object often because it is a good measure for the sky conditions and also because of its beautiful round shape.

Fig.4: Image of planetary nebula Kohoutek 3-27

Stephenson 4-1 (St 4-1 in Hynes, Sp 4-1 in SIMBAD) is not difficult to observe under good conditions, but the first time I tried I was very uncertain about the identification. On my next attempt I was better prepared with an accurate map and very good conditions. At 140× power, St 4-1 appears stellar and is located right next to a 10^{th} magnitude star. Using my UltraBlock filter removed all doubt by revealing the nebular emission aspect of its spectrum, as all but the star indicated in my map lessened in brightness. The *Guide* software gives a slightly erroneous position, but the position in the table given here is correct.

Fig. 5: Image of planetary nebula Stephenson 4-1

Now it gets tough! **Abell 46** is a true challenge with its total visual magnitude of 14.3 smeared out over an area with a diameter greater than one arcminute. It is no easy task to observe this object with a 10-inch telescope. The first and only time I've tried to observe Abell 46, the conditions were near perfect; however, I did not have a proper map and I had only a few minutes before it dropped behind a tree. so I lost my race against the horizon and have yet to make a positive identification of Abell 46. Using 50× power, I did notice a very gentle brightening in the general area were it should have been, but did not have time to decide if I should dismiss this as mere wishful thinking. While I have been unable to make a positive identification, I will certainly continue to try when it is better placed to observe from my location. I believe that a good 12-inch scope will reveal this object.

Fig. 6: Image of planetary nebula Abell 46

Strigl 1-2 is a beautiful, but very faint and quite large, perfect ring of gas with what looks like — but probably isn't — a double star at its centre. The very faint appearance on DSS images, combined with a 72-arcsecond diameter and a rich-background star field, makes this a truly challenging object. It is probably not possible to observe Strigl 1-2 with a 10-inch or even a much larger telescope, but I will continue to try, especially when conditions are near perfect. Finding the field stars and confirming that the nebula is beyond reach of the 10-inch is also a worthwhile observation.

Fig. 7: Image of planetary nebula Strigl 1-2

Kohoutek 4-9 is, as previously noted, dropped from the list since it's most likely an M-type star. I believe it is quite a faint star with the visual magnitude of about 16.8. This visual magnitude is based on the red and blue magnitudes from the USNO A2.0 catalogue and hence is very uncertain.

Earlier, I thought **Kohoutek 2-6** to be a planetary nebula and also tried to observe it with no luck, as it disappeared behind the same tree that had hidden Abell 46 a few minutes earlier. Checking DSS later revealed nothing at the given position, however, there was a nebulous object close by that might be mistaken for a planetary. In *Guide* this was identified as the galaxy LEDA 166555 of unknown magnitude. DSS shows what actually looks like two colliding galaxies with one of them throwing out a spiral arm that looks much like a planetary arc. Even though this object probably isn't a planetary, it should be fun to try and observe it.

Fig. 8: Image of planetary nebula Kohoutek 2-6

Figures 1–8. All images are 15′′ × 15′′ in size and show the nebulae on different linear scales. Red and blue Digital Sky Survey II images were combined to create the final images. The central part of M57 has been overlaid with an inverse image taken by the author to show the inner structure of the nebula.

In summary, Abell 46 and K 3-27 will require near-perfect seeing conditions before they can be identified with a 10-inch telescope and it is probably necessary to rule out Strigl 1-2 as a target for a 10-inch telescope. The other objects are easier to observe. I have seen NGC 6765 in an 8-inch SCT and I believe that the rest of objects on my list, are possible to be observed with good telescopes with apertures from six to eight inches, depending on the skill and persistence of the observer. Remember that there is no shame in trying, however small your telescope. Arranged by degree of difficulty to observe, the seven planetaries of Lyra are: M57, NGC 6765, Min 1-68, St 4-1, K 3-27, Abell 46 and Si 1-2.

Mikkel Steine, a Norwegian amateur astronomer, began his interest in astronomy at an early age, observing and drawing the Sun, Moon, and planets with a 60-mm Unitron refractor. In 1995, he started serious observing and has observed most open clusters on the northern hemisphere reachable with his 14×100 Wachter binoculars. As often as the sky and time permit, he is out in the woods hunting faint patches of old light, using a 10-inch Dobsonian.

Notes:

The PN class is listed even for non-PNs because the classification indicates the visual form of the object, which is useful for observers.

For K 2-6 and Si 1-2, I have not found any magnitude estimate in the literature. The magnitudes for these objects given above are educated guesses.

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Name	RA	Dec	Type	PN Class	Mag.	Size
Abell 46	18 31 18.79	+26 56 17.2	PN	IIIb (II)	14.3v	67″×60″
K 2-6	18 41 03.2	+26 56 16	GX	IV	17	30″×24″
Min 1-64	18 50 01.65	+35 14 35.2	PN	IV	13.3v	17.5″×16.8″
M57	18 53 35.1	+33 01 45	PN	IV (III)	8.70v	86″×62″
K 4-9	18 53 41.1	+28 32 15	1ST	I	16.8v	
St 4-1	19 00 26.60	+38 21 06.4	PN	I	13.0	2″
Si 1-2	19 06 07.25	+27 13 00.4	PN	IV	18	72″
NGC 6765	19 11 07.19	+30 32 54.0	PN	V	12.9v	40″
K 3-27	19 14 30.05	+28 40 44.0	PN	IV	14.3v	16.4″

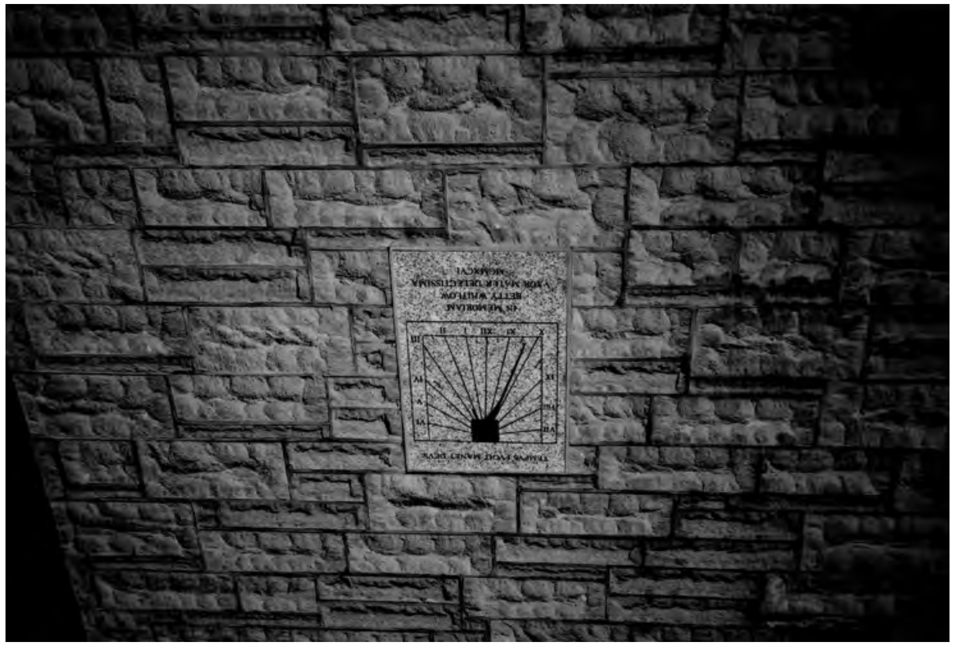
A New Sundial in Victoria

by Alan H. Batten (Alan.Batten@NRC.CA)

Perhaps, for Canada, this is the year of the sundial; I had already prepared a draft of this paper, thinking that it was some time since this *Journal* had carried an article about sundials, when I received my copy of the February number, with the article by Michael Attas about the new sundial in Pinawa, Manitoba (Attas 2002). In an age when we can use atomic vibrations to measure the passage of time more precisely than any other physical quantity, sundials might seem little more than a curious survival of the past. After all, nearly everyone owns at least one digital watch or clock, which keeps time better even than mechanical timepieces do, while a sundial, by its very nature, indicates time according to the variable apparent motion of the Sun. A.P. Herbert (1967), in an amusing and readable — but not always accurate — book on dials, quoted a couplet from Hilaire Belloc:

I am a sundial, and I make a botch
Of what is done much better by a watch.

Despite all this, as Attas's article showed, sundials still have a fascination for people, many of whom may be unaware of the distinction between apparent and mean time. Perhaps the fascination comes from an instinctive feeling that we are returning to the origin of our notion of the passage of time, which once could be measured only by watching the motions of the Sun, Moon, and stars. At any rate, the design and construction of dials is an area of the science of astronomy where amateurs and professionals can meet on equal terms. Indeed, some of the best-known books on sundials have been written by amateur astronomers, who are attracted either by the challenge of designing and constructing a dial that will show time accurately, or by the dials themselves as *objets d'art*. Probably the best known such book in English is



The new dial in position on the wall of Christ Church Cathedral, Victoria, B.C. (photograph by David Barlow).

Sundials: How to Know, Use, and Make Them by R. Newton Mayall and Margaret W. Mayall (1938, with a revised edition in 1958), but there are also good books in both French and German. The Mayalls wrote for people without a background in spherical trigonometry, on which the theory of sundials is based, and presented the formulae needed to construct a variety of dials in a simple form, without derivation. They also showed how to lay out the face of a dial geometrically, without any recourse to trigonometric formulae. Nowadays, when even inexpensive pocket calculators give trigonometric functions and square roots at the press of a button, calculation from the formulae is so easy that the geometrical construction is hardly necessary.

The new dial in Victoria, B.C., is much smaller than the one in Pinawa. A former Dean of Christ Church Cathedral in Victoria decided to give a sundial for the outside wall of the Cathedral, in memory of his late wife, and he asked me to advise him on the astronomical aspects of its design. While I have been familiar with spherical trigonometry since my first undergraduate year, half a century ago, I had never previously had occasion to apply it to this particular problem, so I was glad to be able to consult not only Mayall and Mayall, but several other texts as well. To specify the design from an astronomical point of view, one must first define the direction of the *gnomon* (the edge that casts the shadow) and then specify the angles that the lines marking the various hours (and for this dial, half-hours) make with a fixed direction in the plane of the dial. As Attas has explained, the gnomon must always point to the celestial pole of the appropriate hemisphere. For a horizontal dial, such as the one in Pinawa, it is sufficient that the gnomon make an angle with the (horizontal) plane of the dial equal to the latitude of the place and that the gnomon is also accurately aligned north-south. For a vertical dial, the computation of the direction is a little more complicated. Not only must we know the latitude of the place, but also the orientation of the wall on which the dial is to be mounted. Thus, a horizontal dial is good for all places of a given latitude (although I suspect that many mass-produced ones are used over a wider range of latitude than they should be) but a vertical dial is specific to the building for which it is designed. After the angles needed to determine the direction of the gnomon have been specified, the next task of the designer is to determine the directions of the various hour-lines. Again, the calculation of hour-lines is a little more complicated for a vertical dial than for a horizontal one, but can be done either geometrically or by means of fairly elementary spherical trigonometry.

In Victoria, we are fortunate that the longitude and latitude of the Dominion Astrophysical Observatory are well determined: the latitude is 48° 31´ and the Cathedral is about 8 kilometres south of the Observatory. I estimated from a map that the Cathedral's latitude is 48° 26´, in good agreement with the value of 48° 25´ given in standard reference works for "Victoria" — a value probably appropriate to the Legislative Buildings that are a little south of the Cathedral. Determining the orientation of the wall required more effort. Traditionally, although there are exceptions, Christian churches are oriented towards the east, but for various reasons that orientation is often only approximate. The Cathedral and its associated buildings occupy a complete city block; even commercially available maps suggest that the street grid in that part of Victoria does not run exactly north-south and east-west. The two avenues that are roughly parallel to the main axis of the Cathedral appear to run to a point about 10° south of east. I was able to obtain from the Cathedral authorities a large-scale plan of the block with accurate compass bearings of the four roads that define it. In fact, neither the two streets nor the two avenues are precisely parallel to each other, and the Cathedral itself is not precisely parallel to either avenue! Nevertheless, from the plan I could deduce that the "east" end of the Cathedral is pointed 7° 33´.6 south of east and the "south" wall, on which it was proposed to mount the dial, is actually facing the same amount to the west of south. I did later make measurements of both the latitude and the orientation, based on the shadow at noon of a simple plumb line. The results approximately confirmed my adopted values, but I retained the latter as probably being more accurate.

In the technical language of sundial theory, my problem was to design a southward facing dial declining 7° 33´.6 to the west, for a latitude of 48° 26´. Had I been content to use the formulae of Mayall and Mayall, this would have been half-an-hour's work at most. I disliked, however, simply plugging numbers into a formula whose derivation was not given. The derivation is not trivial because one is dealing with angles in and between three planes and it is not always easy to visualize how these angles can be related by the formulae used in spherical triangles. I therefore searched for other texts that might give derivations of the formulae found in Mayall and Mayall. Indeed, Rohr (1965) gives a general formula and its derivation, from which, in principle, the particular formulae given by Mayall and Mayall for different types of dial may be derived. They look rather different, because Mayall and Mayall departed from the standard forms of mathematical notation, but they are not as much different as they look. Nevertheless, they are not identical: I could not derive one from the other and when I calculated the hour-lines by the two formulae, I obtained different results. Both formulae gave the same result at noon, of course, but the further one went from noon, in either direction, the more the results of the two calculations diverged, amounting to approximately 20° at 6 a.m. and 6 p.m. (They then converge again, but the location proposed for the dial limits it usefulness to at most between 7 a.m. and 6 p.m.) Obviously, the question of which formula to be used had to be resolved before astronomical specifications for the dial could be given to the Cathedral Architect.

At first, because I could find no obvious flaw in Rohr's derivation, I was inclined to favour his formula, even though the geometrical construction given by Mayall and Mayall agreed with their own formulae; but then I consulted a third book, by a professional astronomer, Bigourdan (1956), who wrote what must be the closest thing to a standard work on sundial theory (*gnomonique* in French). His formulae for the hour-lines are equivalent to those of Mayall and Mayall and he gives at least a partial derivation. Fortunately, this is an area of astronomy in which standard texts do not rapidly go out of date! Bigourdan's book convinced me that the formulae of Mayall and Mayall are correct. Even so, in order to be quite certain before the final version of the dial was (quite literally) engraved in stone, I made a plywood mock-up of the dial and mounted it on the wall in the approximate position intended for the final version, and spent two days near the summer solstice marking the position of the shadow each half-hour for as long as the Sun was shining on the wall. Despite the vulnerability of my mock-up to wind, which blew intermittently on the two days and affected the precision of some of my measurements, the results were unequivocal. Only one of the observed positions of the shadow on the second day, when my observations were more reliable, differed by more than 2° from the prediction of Mayall and Mayall and most were within 1° of their predicted values. I am now convinced that the formulae given by Mayall and Mayall are correct.

That problem having been solved, we next had to decide what time the dial should show. Readers of this *Journal* will be familiar with the various reasons for the apparent time shown by a dial differing from the mean time shown by a clock. In particular we must take account of the *equation of time*, arising from the eccentricity of the Earth's orbit and the tilt of the Earth's axis to the plane of that orbit. Of course, dials can be constructed to show mean time throughout the year: they have their place in the gardens of enthusiasts, or outside museums and observatories, where they can be used as a teaching tool, but the Cathedral precincts attract not only parishioners, but also many who use them as a short cut or, in the summer, as a pleasant outdoor place for eating lunch. Such people might well consult a simple dial to get an approximate idea of the time, but are most unlikely to make the effort needed to read an analemmic dial. We settled for a simple dial giving apparent time, together with a table of corrections and a brief explanation just inside the Cathedral.

Victoria, however, has at least one thing in common with Pinawa: it is well to the west of the standard meridian of its time zone. For millennia, dials have shown local apparent time because that was the only time that mattered to the inhabitants of any given place. Every town or city kept its own local time until the advent of railroads made relatively rapid long-distance travel possible. Now, of course, we all keep the standard time of whichever time zone we find ourselves in. In British Columbia we keep Pacific Standard Time, which is the local mean time of the 120th meridian of longitude west of Greenwich. This meridian runs down the middle of the southern part of the Province, about halfway between Kamloops and the Okanagan Valley, while, further north, it is actually the province's eastern boundary. Most of the population of British Columbia, and especially that of both Vancouver and Victoria, live to the west of the standard meridian. Victoria is not so far west of its standard meridian as Pinawa is; the Dominion Astrophysical Observatory is $13^{m}\ 40^{s}.17$ west of the standard meridian (*i.e.* local noon at the Observatory is later by that amount than local noon on the standard meridian) and the difference of longitude between the Cathedral and the Observatory is negligible in this context. Thus, if the dial had been designed to show local apparent time, it would have a built in "error" (compared with clock time) of nearly a quarter of an hour, in addition to the variations caused by the equation of time. A dial keeping local apparent time would, in effect, show mean time for about a couple of weeks in October-November, when the longitude correction nearly cancels the equation of time, and be consistently behind clocks and watches for the rest of the year, the delay amounting to nearly half an hour in mid-February and varying between about ten and twenty minutes during the summer months, when the equation of time is rarely more than five minutes in either direction. This might confuse potential users of the dial to the extent that they would soon give up trying to read it. We decided, therefore, just as the Pinawa designers did, to display the local apparent time of the standard meridian. This is easily done by calculating the angle the hour-line should make with the vertical for a time $13^{m}\ 40^{s}.17$ before each hour (and half-hour) but labelling the lines as hour and half-hour lines. The result may seem odd to those who know that, at local noon, the shadow of the gnomon must be cast vertically downwards, but people who do not know about the equation of time will find that, except for the extra hour introduced by the change to daylight time, the dial will agree with their watches, to within a few minutes during most of the year. The relative smallness of our dial precluded us from adopting the elegant solution adopted in Pinawa of engraving two circles of figures so that users could read either daylight or standard time, as appropriate. We did consider labelling the hour lines for daylight time. A case could be made for doing so in Victoria; daylight time is in effect for more than half the year, and the dial is likely to be usable for a higher proportion of the hours during that period. We believed, however, that more people would remember to add an hour in summer than would think to subtract one in winter, so we chose to show standard time. People who read the dial will, therefore, obtain a time that is always within a quarter of an hour of Pacific Standard Time, even if they do not know about the equation of time. Those who do understand the correction needed, and apply it, should find that they can read time from the dial as accurately as they need for most purposes.

When all these details had been settled and the necessary calculations completed, the detailed design of the dial was placed in the hands of the Cathedral Architect. Both the donor and I had envisaged a dial engraved on a metal plate to be affixed to the Cathedral wall. The Architect speedily convinced us that a granite slab set in the wall would be better. The result has vindicated his judgment and he and his team have produced an easily legible dial that is also a fitting memorial. The dial was installed and dedicated (by the present Dean) on February 20, 2002, not quite a year after I was first asked about its design. The Sun obligingly shone for the occasion, although the very next day I wondered if I should have designed a "raindial"! The mason cementing the dial in place remarked almost casually "It reads about 2:20." Standard time was, in fact, just before 2:35 p.m. and the dial was expected to be 14 minutes behind standard time on that date. I do not remember if the mason consulted his watch before speaking but I am fairly certain that he did not know the value of the equation of time on that date, if, indeed, he knew about the equation of time at all. His unbiased reading of the dial was, in fact, more reassuring to me of the correctness of my calculations than any reading I could have made myself at that point. The limited number of checks that I have been able to make since indicate that the shadow reaches the hour-lines within about a minute of the expected time. It does not follow, of course, that all users of the dial will always read the time to within a minute. Estimating the position of the shadow between hour lines will inevitably introduce an uncertainty whose amount will depend on the individual user's skill and experience, but a careful user of the dial who remembers to correct for the equation of time should be able to tell the time to within a few minutes on any sunny day of the year.

An interesting approximate check can be made on the dial by moonlight. A sundial can be used as a "moondial" provided a correction, which varies with the phase of the Moon, is made for the time difference between the transits of the observer's meridian of the Sun and Moon. A famous dial in Queen's College, Cambridge, incorporates a table of such corrections so that an approximate time may be read from the dial on any night that the Moon is bright enough to cast a clear shadow (Mayall and Mayall 1938, pp. 172-5). For a fifteen-day-old Moon, the correction is 12.5 hours. Nearly a week after the installation of the dial, we had a full Moon and a clear night in Victoria. As I happened to be passing the dial at about 9:00 p.m., I made a quick check and did, indeed, find the dial indicating about 8:30 a.m. While the check is necessarily approximate, it was nevertheless encouraging!

As I have already remarked, sundials may seem something of an anachronism in an age in which almost everyone can afford a watch that will be much more precise in its time-keeping, as well as being easier to read. Public clocks have always been useful, however, and dials neither have to be wound up nor are they dependent on the electricity supply! Cathedrals and churches, which, at least in Europe and eastern North America, are often prominent buildings near the city centre, have been favourite places for dials and, later, mechanical clocks. Church bells have similarly doubled as means of indicating hours, or even the quarters. Some large European cathedrals have served also as astronomical observatories, as Heilbron (1999) has recently documented. A small hole made high in a cathedral wall admits a ray of sunlight that shines on the floor inside. The position of the spot of light varies not only with the time of day, but also throughout the year. From observations made over time, a meridian line can be drawn on the floor of the church and it can be used over several years to determine the dates of the equinoxes and solstices. The Church's interest in this was primarily to improve the determination of the date of Easter, but astronomers were quick to take advantage of the opportunity to determine other things, particularly the obliquity of the ecliptic (they were interested to see if this varied). This kind of cooperation continued over several centuries, and was even going on while the Church and Galileo were confronting each other. Unfortunately, the confrontation is remembered and the cooperation largely forgotten. I like to think that in Victoria, in a small way, we have renewed the cooperation.

Acknowledgments:

I am grateful to Dean Brian Whitlow for inviting me to help him in this project, to my friend David Barlow for practical help in mounting the mock-up dial made to test the two formulae and for permission to use his photograph of the dial, and to James Kerr, the Cathedral Architect, and his team who bodied forth my rather abstract calculations and gave them a local habitation and a name.

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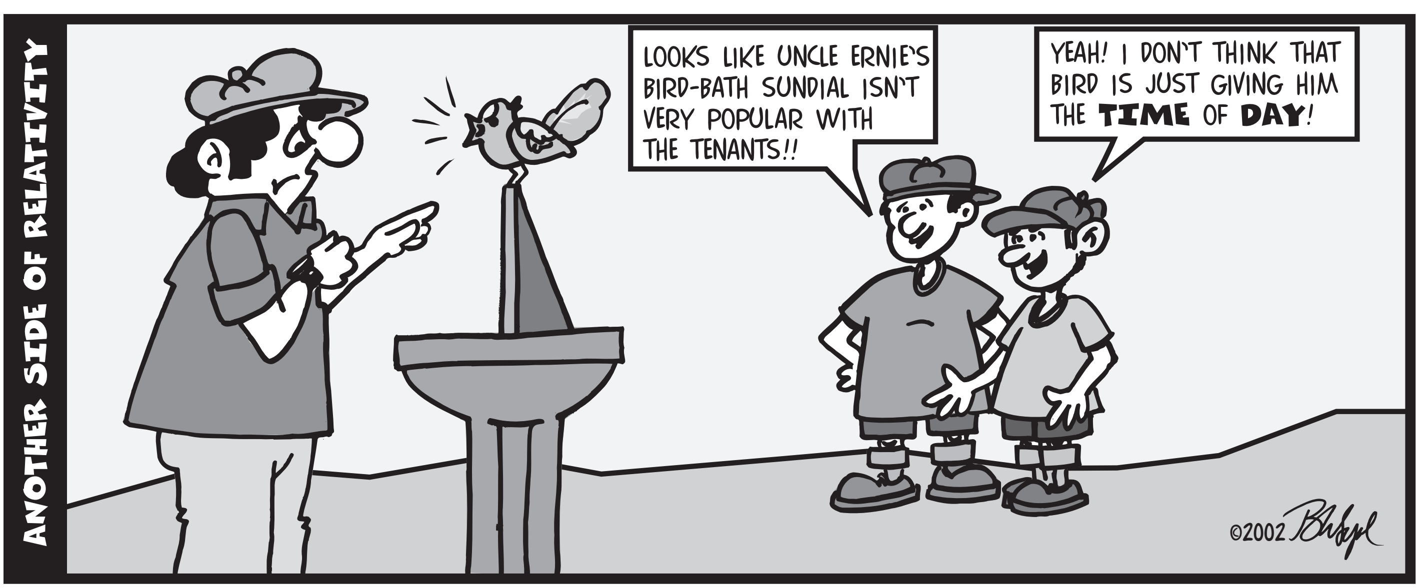
Alan Batten is a former Editor of this Journal*, a former President of our Society and a former Vice-President of the International Astronomical Union. He was on the staff of the Dominion Astrophysical Observatory for 30 years and has continued as a Guest Worker there for more than another 10. As this article demonstrates, he continues, in retirement, to dabble in astronomical matters. In the coming academic year he will help to teach a course in the Department of History of the University of Victoria on "Science and Religion in the West: From the Scientific Revolution to the Present."*



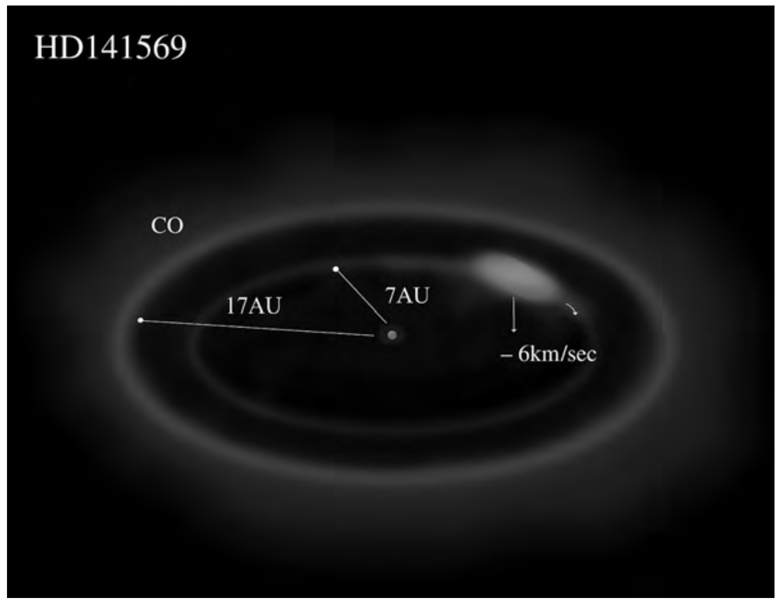
A **Gas-Giant Planet** in the Making?

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

Given all the planets in our Solar System, and the 80 or so that have been discovered around other stars, you would think that making one would be pretty simple. The trouble is, we just do not understand how gas-giant planets (like Jupiter and Saturn) and ice-giant planets (like Uranus and Neptune) are made. The detection of a possible proto-planet — a gas giant caught in the midst of forming — by Sean Brittain and Terrence Rettig of the University of Notre Dame promises to accrete more evidence for the formation process (July 4, 2002 issue of *Nature*).

The theory for making Earth-like planets is pretty well developed: dust grains clump together to build boulders, which themselves collect into larger bodies until there is a "runaway" process at the end. Almost all the dust mass ends up in a few planets with masses of up to 20 times the Earth's mass, with the most massive ones being in the Jupiter-Saturn region. This can happen in a few million years or less, and seems fairly straightforward, but forming gas-giant planets like Jupiter, which is over 300 times the mass of the Earth and mainly hydrogen gas, is much more difficult in theory. While massive cores could in principle accrete the necessary gas through their gravity, it is not at all clear that they could do so before the early Sun blew away the gas left over from its formation. Observations of other young stars have suggested that the gas is dissipated from the inner regions in less than about five million years. In other words, there is enough time to form Earth, but not enough to form Jupiter. Yet Jupiter obviously exists, so our theory is at best incomplete.

Alan Boss of the Carnegie Institution has an alternative theory for forming gas-giant planets. He thinks that a region of the proto-solar nebula — the cloud of gas out of which the Sun formed — collapsed directly to make Jupiter and Saturn, in a way very analogous to the way the cloud collapsed to form the Sun. His models suggest that this can happen very rapidly — in thousands of years, rather than millions — but these models are very controversial.



The figure shows an artist's impression of how H_3^+ emission (glowing regions) might be distributed around HD141569. The large bright spot on the right side of the figure is the proposed proto-planet, while the bright ring is the warm inner edge of the gas disk that is being evaporated by the new star at the centre.

Regular readers of this column may remember that about a year and half ago I wrote about the discovery of gas-rich disks around some young stars (*JRASC*, February 2001, page 15). That observation seemed to remove one of the big problems with planet formation, because those stars are old enough to allow Jupiter-like planets to accrete their gas. Those data have been hotly debated also, so the issue remains as open as it was several years ago. As difficult as it is to make gas-giant planets around Sun-like stars, it is even harder when the stars are more massive because the stars evolve more rapidly, and therefore blow away the surrounding gas even more quickly.

Brittain and Rettig have been studying a class of objects known as Herbig AeBe stars. These are very young A or B stars characterized by emission lines in their spectra (hence the "e"). They are more massive counterparts of the T Tauri stars that are surrounded by dust, and they mark the transition from the proto-star phase (heated by collapse), to the "zero-age main sequence" (heated by thermonuclear fusion at their centres). They found emission from carbon monoxide (CO) molecules and also from H_3^+ ions coming from the region around the star HD141569. This is a B9.5 star estimated to be 5-10 million years old. While CO in the cold outer portion of the dusty disk surrounding HD141569 has been seen before, Brittain & Rettig are looking at different molecular transition lines, in the infrared rather than the millimetre region of the spectrum. These lines trace warmer gas in a region between 17 AU and 50 AU from the star. In our Solar System, this is the region between Uranus and the Kuiper Belt, but because HD141569 is much more luminous than the Sun, in a sense it is the equivalent of seeing CO in about the Jupiter-Uranus region based on the equilibrium temperatures. Interestingly, even if the CO traces molecular hydrogen with about the same efficiency as in a molecular cloud — one CO molecule for every 10,000 H_2 molecules — there is still much less than a lunar mass of gas.

The CO data are important for constraining the mass of gas in the disk, but the important result is the discovery of emission from H_3^+. H_3^+ has been seen in emission only in the upper atmospheres of Jupiter, Saturn, Uranus, and Neptune, so the implication is that the H_3^+ might be in a proto-gas-giant planet in the midst of formation. The observed emission is unlikely to come from an object as small as Jupiter, because the surface area would be much too small to produce the lines they see. Instead, they suggest that the proto-planet has not yet collapsed to a Jupiter-like object. The H_3^+ lines differ in their velocities from the CO lines, suggesting that they arise in different regions of the disk. Moreover, astronomers know that H_3^+ is very reactive and probably could not exist in the same region as the CO.

Before you get too excited, though, there is another possible explanation for the H_3^+. As noted by Brittain & Rettig, they may be seeing the inner surface of the gas cloud that is being dissipated by HD141569. As the hydrogen molecules are dissociated (broken up into hydrogen atoms) by the star's ultraviolet radiation, they can recombine to form a transient population of H_3^+ ions. (The inner surface of the cloud is being pushed out by the star during the usual process of clearing out the new system.) In this case, although the molecules are spatially separated the line velocities should be the same. This is not what Brittain & Rettig observed, however.

There are observational ways to distinguish between those options. If the H_3^+ emission comes from a proto-planet, the lines should reflect the orbital velocity of the gas at that distance from the star. If the molecules are distributed in a disk, the centre of the line should be at the same velocity as the star. Higher resolution observations will be needed to clarify these issues for HD141569. Paradoxically, Brittain & Rettig did not see any H_3^+ emission from the younger star AB Aurigae, which has a more massive dust disk than that around HD141569 and therefore might be more expected to have H_3^+ emission associated with the disk. If the emission truly comes from the inner surface of a gas ring, then many Herbig AeBe stars should have H_3^+ around them, which does not appear to be true at this point.

Assuming that the H_3^+ emission does mark the existence of a proto-planet, Brittain & Rettig find that their data are consistent with the properties of something about five times the mass of Jupiter, with a diameter of roughly 2 AU. If confirmed, this would mean that enough hydrogen to make Jupiter-like proto-planets exists around at least one star 5-10 million years after the star was born.

No doubt this result will prove to be as controversial — and as hard to confirm — as the one I wrote about over a year ago. It will be fun watching the show evolve!

Dr. Leslie J. Sage is Senior Editor, Physical Sciences, for Nature Magazine *and a Research Associate in the Astronomy Department at the University of Maryland. He grew up in Burlington, Ontario, where even the bright lights of Toronto did not dim his enthusiasm for astronomy. Currently he studies molecular gas and star formation in galaxies, particularly interacting ones.*

The Astronomical Basis of Our Calendar, Part 3: **The Special Holidays**

by David M.F. Chapman (dave.chapman@ns.sympatico.ca)

This 3-part *Reflections* is a précis of a talk I presented in January 2002 to the RASC Halifax Centre entitled "A Date with the Stars: The Astronomical Basis of Our Calendar." This talk was developed from the knowledge and insight I have gleaned over the years from reading and thinking about the topic. In the last issue, I showed how various types of calendars were generated from the cycles of the Moon and the Sun, and how successive refinements have created a calendar year that very closely approximates the length of the tropical year, that is, 365.24219 days. The motivation for these refinements was to maintain the position of important religious holidays with respect to the seasons. In this third and last part, I will look at the determination of special holidays and traditions such as Easter, Christmas, St. John's Day, New Year's Day, Chinese New Year, Jewish New Year, Hallowe'en, Groundhog Day, and May Day. I will show that these days have special connections with the Sun and the Moon, and that our "modern" calendar has embedded remnants of ancient beliefs and customs.

The Quarter Days

The cardinal points of the calendar are the *quarter days*: the equinoxes and solstices that mark key points in the seasonal calendar: the vernal (Spring) equinox occurs when the Sun is on the celestial equator, passing from south to north, on or around March 20; the summer solstice occurs when the Sun is at maximum declination north, on or about June 21; the autumnal (fall equinox) occurs when the Sun is on the celestial equator, passing from north to south, on or around September 22; the winter solstice occurs when the Sun is at maximum declination south, on or around December 21. If the Earth's axis were not inclined away from the perpendicular to the ecliptic plane, these dates would have no relevance. In Roman times, at the start of the Julian calendar, these dates were a few days later, closer to the 25th of the month. Just before the Gregorian calendar reform in 1582 C.E., these dates occurred on day 10th-13th of their respective months.

Emperor Flavius Constantine

Constantine was the first Christian ruler of Rome, although one could argue he was a fairly casual Christian, at best. He was largely influenced by his mother, Helen, who took her beliefs more seriously. Constantine was somewhat of a pragmatist, adopting the cross as his emblem following a prophetic dream the day before he won a decisive military victory. As an ex-pagan, he was equally influenced by the cult of the Persian Sun god Mithras, a child deity born to a virgin mother (sound familiar?). Being Emperor, Constantine had no difficulty making the seven-day week official and declaring "Sun"day to be the weekly holy day. In attempting to unify the Empire, Constantine convened a council of Christian holy men to meet in Nicaea, Turkey in 325 C.E. Their task was to end all the internal squabbling among the various Christian sects and come up with a common creed and church calendar.

Easter

The most important date in the Christian calendar is the celebration of the Resurrection of Christ following his Crucifixion. As this event is connected with the Jewish Passover, which is (in part) a vernal festival of rebirth, the determination of Easter is based on the Hebrew Lunar-Solar calendar; however, the Church did not want to abandon the Friday-Sunday sequence of the original event, so a somewhat complicated formula was devised to ensure that the Resurrection is always celebrated on Sunday. In short, Easter is the Sunday after the first Full Moon following the vernal equinox. The Council of Nicaea did not prescribe how "full moon" and "vernal equinox" were to be determined; this was left to interpretation, and problems arose due to the assumption that the equinox *always* occurs on March 21 and the forecasting of full moon dates according to tables rather than by astronomical observation. To resolve these problems, Pope Gregory XVIII found it necessary to reform the calendar itself (see Part 2). In recent years, there has been a proposal to use precise astronomical principles to establish both the vernal equinox and the full moon following, so that all Christian denominations would have the opportunity to celebrate Easter on the same day; however, it should come as no surprise that the various authorities involved cannot agree even on this.

Christmas

Originally, Christmas was not an important Christian holiday, and there is no record of it being celebrated before C.E. 336. Constantine is credited with placing the feast of the birth of Christ on December 25, to coincide with the end of the Roman festival of Saturnalia and the winter solstice, the birthday of Mithras. Many of our "Christmas" customs are derived from the pagan practices observed at this time of year: general merriment and good will, lights and candles, gift-giving, Christmas evergreens, Yule logs, *etc.* Scholarly investigations and the Bible itself (shepherds watching flocks by night, during the lambing season) suggest a spring birth for Christ.

St. John's Day

Six months after Christmas (winter solstice), on June 24 (Summer Solstice), we have the Christian feast of St. John the Baptist, who has an important supporting role in the story of Christ. Most saint days mark the anniversary of the death of a saint, but June 24 is celebrated as the birthday of St. John. This is a significant holiday in the Province of Québec and is a traditional European festival day, often involving bonfires and other activities. I personally witnessed a huge bonfire event on Saint John's Eve when I visited Ireland twenty years ago. At intervals along the coast, communities would build huge bonfires, lit at dusk. Each community would watch for the flames from the bonfire further up the coast before lighting theirs. I am not sure who went first, but in this way a chain of bonfires would slowly spread along the coastline.

New Year's Day

New Year's Day has not always been January 1, but Julius Caesar certainly attempted to establish that day, the first day of the month immediately following the winter solstice. Many European countries observed New Year's Day on March 25, the one-time vernal equinox. Britain continued this practice as late as 1752, when that country switched from the Julian calendar to the Gregorian calendar. A remnant of this lives on in the start of the U.K. taxation year, April 5, which was the Gregorian equivalent of March 25.

Jewish New Year

The Hebrew calendar, a lunar-solar calendar, is somewhat complex. New Year's Day (Tishri 1) occurs approximately on the new moon closest to the autumnal equinox, in order that Passover (Nisan 15) takes place on a full moon near the vernal equinox. The range of dates for the Jewish New Year in the Gregorian calendar is September 23 ± 16 days. In 2002, Jewish New Year takes place on September 7.

Chinese New Year

The Chinese calendar is yet another complex lunar-solar calendar. New Year's Day is determined by the second new moon after the winter solstice, so the range of dates is February 3 ± 15 days. In 2002, Chinese New Year took place on February 12. For several years, Canada Post has issued postage stamps commemorating Chinese New Year, each depicting the animal from the Chinese zodiac associated with that year. The year that started in 2002 is the Year of the Horse.

Cross-Quarter Days: Hallowe'en, Groundhog Day, May Day

Some pagan societies, including the Celts that spread across Northern Europe, regarded the quarter days as the midpoints of the seasons, so they celebrated the beginning of their seasons on the cross-quarter days halfway between the quarter days: these days occur approximately at the beginning of February (Imbolg), May (Beltane), August (Lammas), and November (Samhain). On these days, traditional festivals were celebrated, often with the assistance of bonfires. The New Year would begin with Samhain, which lingers on today as Hallow'en and All Saint's Day; Imbolg is what we call Groundhog Day or Candlemas; Beltane is May Day. There does not appear to be a modern-day equivalent to Lammas (although I note that many Canadian provinces celebrate a civic holiday in early August!). For me, Hallowe'en and Groundhog Day mark the beginning and the end of the winter period of long, dark nights, whose midpoint is the Winter Solstice (Christmas). It is interesting that Imbolg (Groundhog Day) is coincident with the period in which Chinese New Year occurs. (Coincidence, or something more?)

Conclusion to Part 3

In this series, I have sketched the connection between the astronomical cycles of the Moon and the Sun and "our" calendar: the Gregorian or civil calendar. The subject is vast, and books and articles continue to appear. For those who missed the previous installments, I would like to repeat the information of two books I have found useful in my research: Isaac Asimov's *The Clock We Live On* (Collier, New York, 1963) and Jacqueline de Bourgoing's *The Calendar: History, Lore, and Legend* (Harry N. Abrams Inc., New York, 2001). The first book is out of print but may be found in used book stores; the second is current. (The ISBN number is 0-8109-2981-3.) The author is a French academic who has produced a television series on the calendar for French television. She published the book in 2000, and this is a translated version. Highly recommended!

Other useful books:

E.C. Krupp, *Beyond the Blue Horizon* (Harper Collins, New York, 1991);

David Ewing Duncan, *Calendar* (Avon, New York, 1998); and

Duncan Steel, *Marking Time* (Wiley, New York, 2000).

Some useful Internet URLs:

Calendars, `webexhibits.org/calendars`;

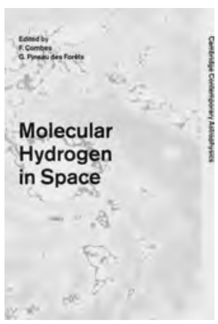
Claus Tøndering, The Calendar FAQ; `www.tondering.dk/claus/calendar.html`;

The Calendar Zone, `www.calendarzone.com/`; and

L.E. Doggett, Calendars, `astro.nmsu.edu/~lhuber/leapyear.html`

David Chapman is a life member of the RASC and a past President of the Halifax Centre. At the RASC General Assembly in Montreal, he was inducted into the RASD: the Royal Astronomical Society of Daves, which (among other things) entitles him to sign his postings to RASCals Listserver as "Dave XVII." By day, he is Acting Chief Scientist at Defence R&D Canada–Atlantic. Visit his astronomy page at `www3.ns.sympatico.ca/dave.chapman/astronomy_page`.

Reviews of Publications
Critiques d'ouvrages



Molecular Hydrogen in Space, edited by F. Combes and G. Pineau des Forets, pages 326 + xix, 18 cm × 25.5 cm, Cambridge University Press, 2000. Price $69.95US, hardcover (ISBN 0–521–78224–4).

It is surprisingly easy to overlook the fact that molecular hydrogen, H_2, is the most abundant molecule in the universe. There are at least two reasons for that. First, molecular hydrogen exists only in specialized environments — usually deep inside cold, dense clouds of gas and dust, albeit in large quantities (a cloud with a mass a million times that of our Sun consists of about 65% molecular hydrogen). Second, it is an inconspicuous species by nature, only rarely emitting the telltale radiation that can be picked up by astronomical detectors. Molecular hydrogen is both neutral (uncharged) and homonuclear (made up of identical atoms), so it interacts very little with its surroundings. Thus it is infrequently prompted to "do" anything, such as rotate or vibrate, that would lead to the absorption or emission of a photon.

Until very recently, astronomers were forced to deduce the amount of molecular hydrogen in a given region from measurements of more conspicuous, but far less abundant, molecules like carbon monoxide (CO). Such techniques have the key disadvantage that the correction factor needed to convert the number of the tracer molecules into an equivalent number of molecules of H_2 is poorly known. Obtaining a direct measurement of H_2 is therefore particularly advantageous since one is able to determine not only the amount of H_2 but also the relative abundances of different species and, in some cases, different elements.

Molecular Hydrogen in Space, the proceedings of a conference held in Paris in the fall of 1999, contains many articles by experts in the field and highlights both the difficulty and the importance of a proper accounting of molecular hydrogen. The opening article by astrochemistry pioneer Alex Dalgarno reviews the various means by which molecular hydrogen is detected. The molecule has been detected as both emission and absorption features in the infrared and ultraviolet regions of the spectrum. Only ultraviolet absorption features probe molecular hydrogen in its cold, unexcited state. Such detections are important, not just because most of space is cold and unexciting, but because of the intriguing possibility that most of the molecular hydrogen, by mass, may be "hiding" in such conditions (more on that presently).

Two recently launched satellites, the *Infrared Space Observatory* (ISO) and *Far Ultraviolet Spectroscopic Explorer* (FUSE), have revealed previously unobserved reservoirs of hydrogen gas. The observations were discussed by a number of authors. Molecular hydrogen heated to a temperature of a few hundred degrees by radiation from nearby stars or by shock waves generated from protostellar outflows has been detected by ISO in a number of locations within our Galaxy. That has allowed astronomers to test theoretical models of the phenomena responsible for the production of the molecular hydrogen, as discussed by Van den Ancker and collaborators.

The amount of molecular hydrogen seen at very large redshifts — "long ago and far away" — can be used to constrain models and simulations of the expanding universe, as discussed by Abel, Palla, and collaborators. The key question is: are there any stars out there of "primordial" composition, namely hydrogen-rich with no heavy elements, which could tell us about the very young universe? Stars form from the gravitational collapse of gas clouds, provided that the latter are sufficiently cold. It is argued that primordial gas is not as adept at cooling itself as the gas found in the interstellar medium today, which has a higher content of

...continued on page 176

Research Papers
Articles de recherche

ABSTRACTS OF PAPERS PRESENTED AT THE 2002 CASCA ANNUAL MEETING HELD AT DOMINION RADIO ASTROPHYSICAL OBSERVATORY IN PENTICTON, MAY 11–14, 2002

J.S. Plaskett Medal/La médaille J.S. Plaskett

On the Formation of Uranus and Neptune, Edward W. Thommes, Astronomy Department, University of California at Berkeley

The outer giant planets, Uranus and Neptune, pose a challenge to theories of planet formation. They exist in a region of the Solar System where long dynamical timescales and a low primordial density of material would have conspired to make the formation of such large bodies (~ 15 and 17 times as massive as the Earth, respectively) very difficult. In this work, the existing model for post-runaway accretion, as well as numerical simulations, are used to show that such bodies are unlikely to have formed far beyond the region of Jupiter and Saturn. A model that addresses this problem is proposed: instead of forming in the trans-Saturnian region, Uranus and Neptune underwent most of their growth among proto-Jupiter and -Saturn, and were scattered outward toward their present orbits when Jupiter acquired its massive gas envelope. Numerical simulations show this model to be quite robust, readily reproducing the configuration of the outer Solar System for a wide range of initial conditions. Simultaneously, the model may also help to account for the present state of the Kuiper belt.

Oral Papers/Les présentations orales

Using the Accuracy of Helioseismology to Constrain Proton-Proton Fusion, Kevin I.T. Brown, Malcolm N. Butler, and David B. Guenther, Department of Astronomy and Physics, Saint Mary's University

The proton-proton fusion cross-section found at the heart of the Standard Solar Model is unconstrained experimentally and relies solely on theoretical calculations. The use of an Effective Field Theory provides an opportunity to constrain the proton-proton cross-section experimentally. However, this process is complicated by the appearance of two-body effects in the form of an unknown parameter, $L_{1,A}$. We present a method whereby the Standard Solar Model and the accuracy of helioseismology are used to limit the value and range of the unknown parameter, $L_{1,A}$. Using this method, $L_{1,A}$ is limited to a value of 7.0 fm^3 and an uncertainty range of 1.6 to 12.4 fm^3, which are consistent with theoretical estimates. This technique will aid in testing the accuracy of potential models used in the determination of the proton-proton cross-section and in constraining parity-violating $\nu(\bar{\nu})$–d break-up reaction of interest for the Sudbury Neutrino Observatory.

Relating the Spectrum of Type I X-ray Bursts to Spin Changes of Neutron Star Atmospheres, C. Cadeau and S. Morsink, Department of Physics, University of Alberta

Type I X-ray bursts are thermonuclear flashes occurring on the surface of accreting neutron stars in low-mass X-ray binaries. Measurements have shown that the brightness of these bursts is not constant, but oscillatory. The varying brightness is thought to be attributable to an inhomogeneity in the burning process, and so the frequency of the observed oscillations is related to the spin rate of the neutron star. It has been proposed by Strohmayer *et al.* that the burning "shell" of accreted matter decouples from the star, and that its spinning is governed by the conservation of angular momentum (see Strohmayer *et al.* 1997, *ApJ*, 486, 355). We adopt this picture, and present results relating the shape of a bright spot in the atmosphere to the frequency spectrum of a burst.

Deuterium Abundance in the Local Interstellar Medium: Results from the FUSE Mission, P. Chayer, Department of Physics and Astronomy, Johns Hopkins University, and Department of Physics and Astronomy, University of Victoria

The measurement of the deuterium abundance in a variety of environments is one of the key projects of the Far Ultraviolet Spectroscopic Explorer (FUSE) mission. I present results obtained by the FUSE PI team which has determined the column densities of D I, O I, and N I along seven sight lines in the local interstellar medium. The measurements were made using FUSE spectra of the white dwarfs HZ 43A, G191-B2B, WD 0621-376, WD 1634-573, WD 2211-495, and the sub-luminous subdwarfs Feige 110 and BD+28° 4211. These spectra, which have typical resolution of about 15 km s^{-1} and typical S/N of 30 to 100, show faint D I absorption lines in the blue wings of the Lyman series lines. Five of the stars, located at distances between 37 and 78 pc, are within the Local Bubble. The two other stars are at distances of 104 and 179 pc and their sight lines penetrate the H I wall. Reliable H I column densities were measured for five of these sight lines using HST and IUE data. Combining the D I and H I column densities for the five sight lines, we obtained N(D I)/N(H I) = $(1.51 \pm 0.07) \times 10^{-5}$. We found no evidence for variability of D/H or O/H in the FUSE results.

This work is based on data obtained for the Guaranteed Time Team by the NASA-CNES-CSA FUSE mission operated by the Johns Hopkins University. I am a Canadian representative to the FUSE

Project supported by CSA under PWGSC.

Direct Constraints on the Velocity Expansion Law of Winds from Hot WN Stars, A.-N. Chené, Département de physique, Université de Montréal

Hot, massive stars display severe mass-loss rates (up to $10^{-4}\ M_{\odot}yr^{-1}$) due to radiation-driven stellar winds. Hence, they strongly influence the ISM even before the final supernova by depositing large amounts of matter enriched with heavy elements (C, N, O mainly) and by ionization through their strong UV radiation. However, it is not yet fully understood how the driving mechanism works in detail. In a quest to approach this fundamental question, we concentrate our efforts on isolating and determining one key wind characteristic, the velocity expansion law, by studying inhomogenities as tracers propagating outward in the wind. These inhomogeneities can probably best be described by supersonic, compressible turbulence (*cf.* Moffat *et al.* 1994; Henriksen 1994; Lépine *et al.* 1996) and may be related to small-scale radiative instabilities, leading to the formation of shocks and blob-like structures in the wind (Gayley & Owocki 1995; Feldmeier *et al.* 1997). These manifest themselves, in the case of strong-wind, WR, and *Of* stars, as small excess emissions superposed and moving on underlying wind emission lines. By following the motion of these blobs as a function of time, one can derive the velocity law of the stellar wind with very few assumptions and hence, assuming mass-conservation, the density profile of the wind.

Using the 1.60-m telescope at Observatoire du Mont Mégantic (Québec), we have obtained highly resolved time series of spectra of the two Galactic Wolf-Rayet stars WR3 and WR152 (both of the extremely hot, N-enhanced spectral type WN3). An analysis was carried out using the He II λ4686 emission line, which is formed relatively close to the star (ionization potential ~ 54 eV) and in which the velocity gradient is still very large. For the first time, we have obtained insight into previously unstudied regions of the wind. We present here the preliminary results of our study.

Shapes of Molecular Cloud Cores and the Filamentary Mode of Star Formation, C.L. Curry, Department of Physics, University of Waterloo

Using recent dust continuum data, I generate the intrinsic ellipticity distribution of dense, starless cores. Under the hypothesis that the cores are all either oblate or prolate randomly-oriented spheroids, a satisfactory fit to observations can be obtained with a gaussian prolate distribution having a mean intrinsic axis ratio of 0.52. Further, I show that correlations exist between the apparent axis ratio and both the peak and total flux density of emission from the cores, the sign of which again favours the prolate hypothesis. The latter result shows that the mass of a given core depends on its intrinsic ellipticity. Monte Carlo simulations are performed to find the best-fit power law of this dependence. Finally, I show how these results are consistent with an evolutionary scenario leading from filamentary parent clouds to increasingly massive, condensed, and roughly spherical embedded cores.

The Evolution of Galactic Disks in the CDM Cosmology, Andreea S. Font and Julio F. Navarro, University of Victoria

A long-lasting problem in our understanding of the evolution of the Galaxy is the question of how its disk responds to encounters with the numerous dark matter sub-halos predicted by the Cold Dark Matter (CDM) model. Previous studies have given us a clear understanding of the interaction between a disk galaxy and a single dark matter satellite. We present here the results of an N-body simulation of a Milky Way-type galaxy embedded within a realistic distribution of dark matter substructure, which includes hundreds of satellites within the virial radius of the galaxy halo. We followed the evolution of the system over the course of a Hubble time and determined the global response of the disk in terms of heating and tilting. Comparisons with the present heating rate in the disk allow us to assess the validity of the CDM models.

The Galactic Plane Region Near l = 94°: Extinction Distances to Four Objects, T. Foster, Department of Physics, University of Alberta, Edmonton, and D. Routledge, Department of Electrical and Computer Engineering, University of Alberta

We have devised a new method based on extinction by interstellar dust for determination of distances to sources in the Galactic plane, and apply the method to objects near $l = 94°$, $b = 1°$. The method uses a combined optical and radio approach to find consistently accurate reddenings to both thermal and non-thermal sources, and to the Galactic edge. The optical reddening parameter R (the ratio of total-to selective-absorption) is calculated from optical and radio data, verifying that a smooth dust distribution and a standard optical reddening law are valid for this direction. We construct models of the radial distribution of material in the Galactic dust disk, accounting for exponentially decreasing density with galactocentric radius and with z. The models also take account of the Galactic Warp, which is prominent at this longitude. The reddening-distance relation (RDR) on the line of sight is modelled towards four objects near $l = 94°$, namely one supernova remnant (3C434.1), and three H II regions (NRAO 655, WB89-73, and G93.6+1.3).

New *reddening-velocity* relations (RVR), derived from ^{12}CO and CGPS H I radio line data, are presented as observational evidence supporting the proposed models of the reddening distribution. The RDR models are then compared with the observed RVRs, and a new mapping of distance to line-of-sight velocity is produced for this direction. A new Galactic rotation curve is thereby suggested for $l = 94°$, showing significant deviation from flat (circular) rotation. The distances to the four objects are found, and shown to be markedly smaller than those derived using their systemic velocities and a flat Galactic rotation curve.

Probing a Be Star Disk with a Neutron Star, P.C. Gregory and C.D. Neish, Phyics and Astronomy, University of British Columbia

We explore a method for investigating the density and velocity structure of the Be star equatorial disk in LS I +61° 303. The analysis is based on variable radio emission that arises from accretion by a neutron star orbiting within the disk. The analysis indicates that every ~ 4.6 years the *Be* star ejects an outward-moving shell in the equatorial disk. The velocity of the shell appears to be constant at a value of 1.1 ± 0.1 km s^{-1}. We propose that the ejection of each new shell may be triggered by the interaction of a short-lived relativistic wind (ejector phase) from the neutron star with the rapidly rotating Be star.

A New Outer Galaxy Molecular Cloud Catalogue: Application to Molecular Cloud Distances, C.R. Kerton, DRAO HIA NRC Canada, C.M. Brunt, DRAO HIA NRC Canada & Dept. of Physics and Astronomy, University of Calgary, and C. Pomerleau, Département de Physique, Univ. de Montréal

We have generated a new molecular cloud catalogue from a reprocessed version of the FCRAO Outer Galaxy Survey (OGS) of ^{12}CO (J = 1–0) emission. The catalogue was created using a two-stage object identification algorithm. We first identified contiguous emission structures of a specified minimum number of pixels (4 pixels) above a specified temperature threshold (0.8 K). Each cloud identified in this first stage was then analyzed using a modified CLUMPFIND algorithm, where localized emission enhancements are identified as separate objects. The final catalogue contains basic data on ~ 14,600 objects.

Using the catalogue we have developed a technique to determine non-kinematic distances to molecular clouds in the OGS by utilizing the systematic variation of the observed angular size-linewidth relationship (ASLWR) with distance. The ASLWR is first calibrated using known non-kinematic distances to molecular clouds associated with H II regions. The calibrated relation can then be used to determine non-kinematic distances to other molecular clouds. The technique also has been applied to data from the BU/FCRAO Galactic Ring Survey of ^{13}CO (J = 1–0) emission where it provides another method to solve the near-far distance ambiguity in the inner Galaxy. We believe that this technique could be applied to any properly calibrated dataset and foresee applications in interferometric observations of distant molecular clouds.

DRAO is operated as a national facility by NRC Canada. The CGPS is a Canadian project with international partners and is supported by a grant from NSERC. C.P. participated in this study through the Women in Engineering and Science (WES) program of NRC Canada.

Massive Carbon-Rich Wolf-Rayet Stars Spiraling Dust into the ISM, Anthony F.J. Moffat, Département de physique, Université de Montréal, and Sergey V. Marchenko, Department of Physics and Astronomy, Western Kentucky University

We have used the mid-IR detector OSCIR at Gemini North to image at λλ 8, 12, and 18 μm three of the numerous IR-emitting, "cool," massive Wolf-Rayet stars of the carbon-rich WC sequence. While two of the stars (WR104, WR118) observed show slightly extended structure, one (WR112) reveals a well-resolved multi-arc shaped dust spiral extending out to 3 arcseconds from the central star, qualitatively similar to the much smaller dust spirals found previously in the near-IR for 2 other cases (WR98a, WR104). The dust spirals are due to the formation and ejection of hot dust. The dust is almost certainly formed in the compressed region of the shock cone where strong winds collide in a massive binary system, one component of which is a WC9 star. From the dust-spiral geometry we deduce the binary orbit. From the spatial distribution of the multiwavelength mid-IR data we deduce the dust temperature, composition, and mass distribution. We find that the dust is mainly composed of amorphous carbon with particle sizes close to 1 μm, orders of magnitude larger than dust-formation theory predicts. *At least* 20% of the 6×10^{-7} $M_\odot$ yr^{-1} initially-formed dust reaches the ISM, despite the hostile environment close to the hot pair. Massive stars are expected to dominate star-formation in the early Universe; such stars that pass through a binary stage similar to that of WR112 may have provided the first heavy-element based dust, leading to possible formation of terrestrial-like planets.

The Canadian Astronomy Education Initiative: A Progress Report, John R. Percy, Erindale Campus, University of Toronto

Last year, coincident with the beginning of a new century and millennium, the Canadian astronomical community embarked on a major new education and public outreach initiative. It was led by CASCA, in partnership with the RASC and other organizations. It was catalyzed by a new long-range plan for astronomy in Canada, by a heightened interest in science education and literacy, by the appearance of astronomy in the core curriculum in several provinces, and by the availability of modest funding from governments. In this presentation, I shall discuss the considerable progress made since last year: organization; additional funding; inauguration of the CASCA-Westar Lectureship; other initiatives within CASCA; new partnerships with other organizations; needs surveys of some target audiences; new on-line resources; and new local initiatives (in the Greater Toronto Area, for instance). Supported by CASCA, and NSERC PromoScience.

Globular Cluster Formation in CDM Cosmologies, Ralph E. Pudritz, Department of Physics and Astronomy, McMaster University

Star clusters are associated with galaxies of all Hubble types, and range in mass from the hundreds of stars typical of Milky Way star clusters, to the millions of stars seen in super star clusters (SSCs) in starburst galaxies and globular clusters in galactic halos. Star clusters, rather than single stars, are the representative products of star formation (*eg*. Pudritz, 2002, *Science*, 295). The current evidence suggests that star clusters and SSCs form in massive clumps within giant (GMCs), and supergiant molecular clouds (SGMCs) respectively. The latter, predicted to have masses up to several 10^8 $M_\odot$ (Harris and Pudritz 1994, McLaughlin and Pudritz 1997), have recently been observed in the merging Antennae galaxies (Wilson *et al*. 2000).

We have done a careful examination of the formation of self-gravitating clouds within the assembling dark matter haloes in hierarchical cosmological models (*e.g*. Weil and Pudritz, 2001). Our high-resolution smoothed particle simulations are designed to determine whether or not the predicted SGMCs are formed, and have the predicted mass spectrum of agglomerating objects (as for GMCs). Our first paper showed that this mass spectrum has the number of clouds per unit mass scaling as $dN/dM \propto M^{-1.7 \pm 0.1}$. In this presentation, I show that similar results are found in our recent simulations of the formation of self-gravitating clouds in λCDM cosmological models. The consequences that these results have for galaxy formation will be discussed.

VLBI Imaging and Astrometry of the Gravity Probe B Guide Star HR 8703, R.R. Ransom, N. Bartel, and M.F. Bietenholz, Department of Physics & Astronomy, York University, D.E. Lebach, M.I. Ratner, and I.I. Shapiro, Harvard-Smithsonian Center for Astrophysics, and J.-F. Lestrade, Observatoire de Paris-DEMIRM

Multi-epoch VLBI observations at 3.6 cm have been made of the RS CVn binary star HR 8703 (IM Pegasi) in support of the NASA-Stanford relativity gyroscope experiment, Gravity Probe B (GP-B). Here, we present a selection of phase-referenced images of HR 8703 produced from 19 sets of observations between January 1997 and June 2001. The images show radio-source structures that vary in size from less than 1 mas to about 3 mas. Moreover, images from temporal subsets of several observing sessions show on hour timescales both structural evolution in the radio emission and motions of the radio centroid of up to ~ 1 mas. Based upon an astrometric analysis of the phase-referenced positions obtained at each epoch, we have (1) made precise determinations of HR 8703's parallax and proper motion, and (2) apparently detected the major axis of the orbit of the larger (giant) star in the HR 8703 binary. We discuss the observed source structures and motions in the context of the configuration of the HR 8703 binary system, and examine the implications of our astrometric results for the GP-B experiment.

3-D Simulations of the Gravitational Collapse of Logatropic Molecular Cloud Cores, M.A. Reid, R.E. Pudritz, and J. Wadsley, Department of Physics and Astronomy, McMaster University

We have conducted fully 3-D simulations of the collapse of molecular cloud cores obeying the logatropic equation of state. The logatrope is a phenomenological equation of state designed to account for turbulent support in molecular cloud cores. We simulated the collapse of cores with initial masses of 1, 2.5, and 5 $M_\odot$, beginning from initial states of hydrostatic equilibrium and continuing until the central protostar had accreted 90% of the mass of the core. I will summarize the results of these simulations, contrasting them with the results of similar simulations using an isothermal equation of state and highlighting their potential to explain existing observations of collapsing cores.

We simulate the collapse of both singular- and nonsingular- (*i.e.* pressure-truncated) logatropic spheres. These are analogous to the singular isothermal sphere and Bonnor-Ebert sphere of the isothermal case. We have shown that, in the collapse of a *nonsingular* logatropic sphere, there is a ~ 10^5 yr period of slow accretion onto the central object preceding the formation of a singular density profile. The accretion then picks up rapidly, continuing at a vigorous pace of a few × 10^{-6} $M_\odot$ yr^{-1}, until about 50% of the mass of the molecular cloud core has been accreted. The accretion rate then declines steadily until all of the mass has been accreted. This behaviour of the accretion rate is notably similar to that seen in observed molecular cores. The abrupt increase in the accretion rate immediately following the formation of a singular density profile can be likened to the transition between the preprotostellar and subsequent so-called "Class O" stages of a collapsing core. We note in particular that the decline in the accretion rate after 50% of the core has been accreted is strongly suggestive of the transition from the Class O to the Class I stage; that is, between the envelope-dominated disk-dominated emission stages.

The CANSERV "notice" Program, An Exercise in Software Engineering, Raymond Rusk and Russell O. Redman, National Research Council of Canada, Herzberg Institute of Astrophysics

Astronomy provides numerous examples of "real-world" problems that can be used to teach software engineering, small enough to be completed in a single-term course, but with enough complexity and ambiguity to provide a realistic challenge. We present here an example in the re-engineering of the "notice" program used at the HIA to inform astronomers requesting JCMT time through the CANadian SERVice (CANSERV) observing program of the progress of their proposals. Although the original program has served well for several years, it is tied closely to the UNIX mail system which is gradually being phased out at HIA in favour of MS Exchange Server. The tcl/tk scripting language used in its implementation is relatively difficult to extend and maintain compared to some other programming languages.

The re-engineering of "notice" was used as a term project by SENG 365 students at the University of Victoria. A required course in the Engineering and Computer Science program, SENG 365 examines techniques for the development and maintenance of software systems. It covers the complete life cycle of software products including the entire range of software development artifacts from requirements specification and design documents, code, test plans, and test implementation to maintenance documents.

Traditionally, 40–50% of the class mark in SENG 365 is assigned to team work on various software development assignments. Teams consist of 3 to 5 students and there are usually 8 to 10 teams. As the instructor for SENG 365, Raymond Rusk saw the re-engineering of the "notice" program as a useful real-world project that could be done by the students during the January-April 2002 term. This poster describes the work of eight student teams, each of whom do a complete re-engineering of the "notice" program.

From the student's perspective, this project has interesting real-world software development components such as communication with an IMAP server and with a relational database. And the "notice" project, as well as serving as a software engineering exercise, provided an opportunity for these upper-year Computer Science and Engineering students to communicate with real "clients" at the Herzberg Institute.

X-Rays from Supernova Remnants — Their Engines and their Interaction with the ISM, S. Safi-Harb, Physics and Astronomy, University of Manitoba

A supernova explosion is one of the most energetic events in the universe, a remarkable event that marks the death of a star and the birth of a compact star. The explosion energizes its surroundings for tens of thousands of years and forms a shell of hot X-ray emitting material — the supernova remnant (SNR). The collapsed core of a massive star forms a neutron star that can reveal itself as a pulsar, a jet source, or via an X-ray nebula (*a.k.a.* plerion). Studying supernova remnants and their stellar corpses thus helps us 1) study the fate of dying stars and the formation of compact objects, 2) probe the scattering of elements cooked by the stars before they die, and 3) examine the way neutron stars and SNRs energize the interstellar medium. X-ray observations of Composite-type SNRs (those that have a shell plus a plerion) have proven to be particularly useful in addressing these goals.

In this talk, I will review three decades of observations dedicated to the study of neutron star-SNR associations and interactions. I will highlight the X-ray observations of Composite-type SNRs, and will focus on recent X-ray observations (including CHANDRA and XMM) that, in the past two years, have greatly improved our understanding of these objects and at the same time revealed new classes of puzzling X-ray sources. I will end my talk with the current questions and problems that are stimulating a synergy of theoretical work and that need to be addressed with new X-ray and multiwavelength observations.

H I Structure in the Galactic Plane: A 21-cm Continuum Absorption Study, Simon T. Strasser and A. Russell Taylor, University of Calgary

An important property of the Milky Way Galaxy that is not well understood yet, is its large scale distribution of gas. This issue is difficult to address because it requires a lot of time to observe a significant part of the Galaxy at high resolution. With the Canadian Galactic Plane Survey (CGPS) and other similar projects we have, for the first time, an arcminute resolution dataset that covers a large part of the Galactic plane.

I present a study of 21-cm background continuum source absorption in the CGPS. With a density of about 0.6 sources per square degree, giving us around 400 sources, we are able to sample the structure and state of the gas for a wide range of Galactocentric radii using an ON-OFF method. The main focus of my talk is on the temperature distribution found with the help of a simple two-component model. Further I briefly discuss the density and cloud distributions. Finally I present a case study of a possibly very cold (below 40 K) neutral hydrogen feature.

Turbulence and Structure Formation in Molecular Clouds, D.A. Tilley, R.E. Pudritz and J. Wadsley, McMaster University

The nature of the mechanism by which stars form in a molecular cloud is not well understood. While we can identify several stages in the evolution from molecular clouds to protostars (filament, clump, core), the link between these stages needs to be developed further. A possibility gaining acceptance is the idea that the turbulent nature of the molecular cloud compresses the gas to high enough densities that the self-gravity of the gas becomes strong enough to induce collapse.

While much attention has been devoted to studying the statistical properties of hydrodynamic and hydromagnetic turbulence in a self-gravitating medium, a detailed examination of the properties of the individual structures that form has not been performed. We performed simulations to assess whether the structure of cores and filaments produced in a turbulent fragmentation scenario is consistent with the one-dimensional results predicted through analytic theories (Ebert 1955, Bonnor 1956, Ostriker 1964, Shu 1977), or if the non-homogeneity of the turbulent initial conditions prevent the idealized geometries of the analytic theories from being applicable.

Our 3-D hydrodynamic simulations used the ZEUS-MP code. We set up an initial turbulent velocity field with an isothermal equation of state and self-gravity of the gas. The simulations were performed on an 8-processor Beowulf cluster at McMaster University. Our results suggest that while a significant portion of the initial turbulent energy remains, the density profile of a typical core has a flat central region, followed by a region with a power-law of the form $\rho \propto r^{-1}$–$r^{-1.5}$, which is observed in regions of massive star formation (van der Tak 2000). This is different than the structure of a core predicted for Bonnor-Ebert models of isothermal gas, which behaves as r^{-2}. It is consistent, however, with the models of hydrostatic equilibrium for a gas with a logatropic equation of state $P/P_0 = 1 + A \ln(\rho/\rho_0)$ (McLaughlin & Pudritz 1996). However, we do find that if the structures form after the turbulence has decayed to a significant extent, the r^{-2} structure found in a Bonnor-Ebert sphere is recovered.

Hydrodynamical Simulations of the Sunyaev-Zel'dovich Effect, J.W. Wadsley, Department of Physics and Astronomy, McMaster University, M.I. Ruetalo, and J.R. Bond, Canadian Institute for Theoretical Astrophysics, University of Toronto, and M.D. Gladders, Department of Astronomy and Astrophysics, University of Toronto

Utilizing Canadian supercomputing resources (SHARCNET), we have produced the largest particle-based hydrodynamic simulation to date at 2×512^3. In a 400 Mpc cosmological cube (in the favoured Lambda cold dark matter cosmology) this dynamic range captures structures larger than the APM Great Wall down to large galaxies. The homogenous simulated dataset provides precise estimates of the clustering of galaxy clusters and weak gravitational lensing shear, a sample of over 1000 X-ray clusters and detailed maps of the Sunyaev-Zel'dovich (SZ) effect.

The SZ effect will likely emerge as the most important probe of the hot IGM in the near future. Our simulated SZ maps predict what the experiments should see, including the angular power spectrum measured by CBI. The Planck satellite will be able to resolve more than 10,000 clusters in its multifrequency survey of the entire CMB sky, adding greatly to our understanding of the distribution and evolution of moderate redshift clusters. Higher-angular resolution will be achieved by interferometers like AMIBA and the SZA or bolometers like Bolocam at CSO.

Using an "extended-source" model of the highly non-gaussian SZ distribution developed from the high-resolution simulations we demonstrate that, although gas distributed in filaments and membranes in the IGM have non-negligible SZ signals, the observable range for planned experiments is dominated by the "concentrated source" picture. Optical photometric surveys such as the "Red-Sequence Cluster Survey" can be used to localize the identified SZ sources in redshift, and allow us to identify supercluster structures, *i.e.* to deproject SZ maps. To understand the complex residual maps after unwanted extended-source removals, much development work is required.

Poster Papers/Les présentations affichages

Search for Angular Expansion in Five Compact Planetary Nebulae, O.B. Aaquist, Grant MacEwan College, Sun Kwok, Department of Physics and Astronomy, University of Calgary

We present new VLA images at 15 GHz of the five compact planetary nebulae IC 5117, M1-61, M3-35, M2-43, and Hb12. These images are compared with older maps in an attempt to detect expansion. In two of these, Hb12 and M2-43, clear signs of expansion are evident. Applying the method of expansion parallax, new lower-distance limits for all sources are estimated.

A Search for Radio Pulsation from the X-ray Millisecond Pulsar SAX J1808.8-3654, Ashish Asgekar, Department of Physics and Astronomy, University of Manitoba

The recently discovered X-ray millisecond pulsar in a suspected Low-Mass X-ray-Binary system, SAX J1808.8-3654, was searched in its X-ray quiescence state for a possible pulsed-radio signal at 327 MHz using the Ooty Radio Telescope. The pulsar was observed for 10 minutes in each run to minimize the effect of period variation due to its orbital motion; a total of 10 such scans were analyzed. This search was tuned for the known binary-system parameters, where the effects of binary acceleration on pulsar periodicity and some possible extra dispersion due to the passage of the radio pulse through the extended wind from the companion were taken into account. No radio pulsations were detected, which translates into a flux density limit of 0.8 mJy (3 sigma) if all the data sets were combined.

The Cosmic Background Imager and its Implications for Cosmology, J. Richard Bond[1], C. Contaldi[1], B.S. Mason[2], S.T. Myers[3], S. Padin[2], T.J. Pearson[2], U.-L. Pen1, D. Pogosyan[1,4], S. Prunet1, A.C.S. Readhead[2], M.I. Ruetalo[1], J. Sievers[2], J.W. Wadsley[5], and P. Zhang[1] (1. Canadian Institute for Theoretical Astrophysics, University of Toronto, 2. Caltech, 3. NRAO, 4. University of Alberta, 5. McMaster University)

CMB temperature anisotropies are geometrical mappings of sound waves when this "oldest light in the Universe" decoupled from matter some 14 Gyrs ago. Here we report on our analysis of CBI, a 13 element 0.9-m dish interferometer operating at 30 GHz in the Atacama plateau in Chile. CBI probed three 2.4×2.7 sq. deg. mosaic fields and three 45′ *fov* deep fields in the year 2000 observing campaign at angular resolutions characterized by multipoles l from 300 to 3000. CBI shows evidence for damping in the power spectrum to $l \sim 2000$, interpreted as due to the finite width of the photon-baryon decoupling region and the viscosity at that time. We show such cosmic parameters as the mass-energy densities in ordinary (baryonic) matter, "cold" dark matter, and "vacuum" dark energy and the power law index of primordial fluctuations can be accurately inferred from this data in conjunction with COBE, and are in good agreement with values obtained from Boomerang, DASI, and Maxima, which probe to $l < 1000$. The respective power spectra also agree in the overlap region. The deep fields reveal an excess of power for $l > 2000$ that could be due to secondary anisotropies associated with nonlinear effects in matter evolution. We explore with hydrodynamic studies whether the Sunyaev-Zel'dovich effect in clusters and groups in CMB-calibrated structure formation theories could account for the anomaly.

Diffuse Infrared Excess Features in the Canadian Galactic Plane Survey, K.A. Douglas and A.R. Taylor, University of Calgary

As part of a multi-wavelength study of the main constituents of the interstellar medium in the Milky Way, we investigate the possibility of tracing diffuse molecular hydrogen (H_2) through an excess in dust opacity. The dust column density inferred from infrared (IRAS) observations is found in some regions to be greater than predicted by correlations with neutral atomic hydrogen (H I) and carbon monoxide (CO). The Five College Radio Astronomy Observatory's entire CO (J = 1–0) Outer Galaxy Survey region is studied in the context of the Canadian Galactic Plane Survey datasets, to provide arcminute scale intercomparisons of the H I, CO, and dust features. After converting dust emission into optical depth, we compare the relative contributions of these species and identify areas where the dust opacity is greater than expected if a constant dust-to-gas ratio is assumed. An excess of dust that is not accounted for by either H I or CO may provide evidence of diffuse H_2 that is not detectable by the standard CO proxy. Alternatively, this may show evidence of local or wide-scale variations in the assumed correlation between dust and gas.

Kinematics of Planetary Nebulae in M51's Tidal Tail, P.R. Durrell, Penn State University, J.C. Mihos, and J.J. Feldmeier, Case Western Reserve University, G.H. Jacoby, WIYN Observatories, and R. Ciardullo, Penn State University

The galaxy pair NGC 5194/95 (M51) is one of the closest and best known interacting systems. Despite its notoriety, however, many of its features are not well known. For example, extending westward from the smaller NGC 5195 is a very low surface brightness tidal tail, visible only in the deepest broadband exposures. This feature has not been well studied, either observationally or theoretically. Our previous [O III] λ5007 survey of M51 (Feldmeier, Ciardullo, and Jacoby 1997) revealed a number of planetary nebulae spatially co-incident with this tidal tail. These objects present us with a unique opportunity to study a galaxy interaction in progress. To this end, we spectroscopically observed 36 of our planetary nebulae candidates using the WIYN telescope + Hydra. Of these, twenty-seven are associated with the tidal tail(s) surrounding NGC 5195, with the remaining 9 located south of the primary galaxy NGC 5194. We have derived the velocities of the planetary nebulae and outline their basic properties. Our velocity errors are less than 17 km s^{-1}, giving us enough resolution to constrain models of the interaction. We also present new self-consistent numerical models of the M51 system to interpret these observations.

There Goes The Neighbourhood: The Galactic Extinction and Distance of the Dominant Members of the IC 342/Maffei Group of Galaxies, Robin L. Fingerhut, Marshall L. McCall, Michael De Robertis, Robin L. Kingsburgh, Michael Kolmjenovic, and Henry Lee, Robert Ross, York University, Michael G. Richer, Observatorio Astronómico Nacional, Instituto de Astronomía, UNAM, and Ronald J. Buta, University of Alabama

Two techniques for determining the Galactic extinction of heavily obscured galaxies are applied to the three dominant members of the highly-reddened IC 342/Maffei group of galaxies, revealing these objects to be among the brightest galaxies in the Northern sky. The first technique is applied to the giant elliptical Maffei 1 and involves the application of a well-defined correlation between the Mg_2 index and effective *V–I* colour for elliptical galaxies. The Galactic extinction for Maffei 1 is thereby determined using a measurement of the Mg_2 index from spectra of the galaxy core. In combination with modern photometry and a revised velocity dispersion measured from high-resolution spectra, an *I*-band Fundamental Plane distance to this galaxy is determined for the first time. The second technique is applied to the giant spirals Maffei 2 and IC 342. It involves a comparison of the dust-to-gas ratio in spirals of similar morphological type using observations of the Balmer decrement in extragalactic H II regions combined with measurements of azimuthally-averaged H I column densities. Revised distances to these galaxies are obtained from the Tully-Fisher relation in the *I*-band. The revised distances are consistent with what would be suspected for the Hubble Flow, making it highly unlikely that these galaxies interacted with the Local Group since the Big Bang.

A Spatially Resolved CHANDRA X-ray Spectroscopy of Supernova Remnant G292.0+1.8 Containing PSR J1124-5916, M.E. Gonzalez and S. Safi-Harb, Physics and Astronomy Department, University of Manitoba

G292.0+1.8 (MSH 11–54) is an oxygen-rich supernova Remnant (SNR) having a centrally filled morphology in the radio- and hard X-ray energies, and a shell-like morphology in the soft X-rays. We present archival observations of this composite-type SNR obtained with the CHANDRA X-ray observatory. The ~ 8 arcminute diameter remnant covers the S3 back illuminated chip of the ACIS detector. The data were reprocessed using the charge transfer inefficiency corrector available from the Penn State University development team, as well as the latest FITS Embedded Function (FEF) files developed for the ACIS chips (released 2001-09-13). In this poster, we present broadband and lines images tracing the distribution of the X-ray emitting ejecta and the non-thermal emission from the SNR. The broadband (0.3–10 keV) image of G292.0+1.8 has a strikingly similar morphology to the SNR Cas A, and reveals a network of arcsecond-scale filaments and knots, dominated by line emission. However, unlike Cas A, no emission from Fe-K is detected. At the soft energies (below 2.5 keV), the X-ray spectrum reveals emission from O, Ne, Mg, Si, and S. The hard band image (above 2.5 keV) reveals a high energy nebula with a luminosity of ~ 3.4×10^{33} ergs sec^{-1} in the 0.5–8.0 keV range (at an assumed distance of 4.8 kpc). This nebula surrounds the recently discovered 135 ms radio pulsar J1124–5916 (Camilo *et al.* 2002). In addition, our spatially resolved spectroscopy on sub-arcminute scale reveals a multi-temperature plasma at different ionization states. Assuming a Sedov phase, we estimate an age of ~ 3000 yrs for the remnant. This age is a factor of two larger than previously calculated from optical observations, and in close agreement with the characteristic age of 2,900 yrs derived for the newly discovered pulsar.

Globular Clusters in NGC 5128: Stalking the Fundamental Plane, G.L.H. Harris, Department of Physics, University of Waterloo (Visiting Fellow, Mt Stromlo Observatory), W.E. Harris, Department of Physics and Astronomy, McMaster University (Visiting Fellow, Mt Stromlo Observatory), S.T. Holland, Department of Physics, University of Notre Dame, and D.E. McLaughlin, Space Telescope Science Institute

The structural properties of real Milky Way globular clusters fill only a narrow range in parameter space known as the fundamental plane (FP). McLaughlin (2000) has recently shown that the FP can be expressed remarkably simply by noting that any King model is completely specified by four input parameters: cluster luminosity (L), central concentration ($c = \log (r_t / r_c)$), mass-to-light ratio (M/L), and binding energy (E_b). Moreover, the observational constraints: $M/L \approx$ const and $E_b \sim L^2$ then require that globular clusters lie on a two-dimensional plane while the remaining two (c and L) determine the scatter about the FP.

We have obtained measurements of King-model parameters for 27 globular clusters in NGC 5128 based on HST STIS and WFPC2 images. Adding similar data from Holland *et al.* (1999) we have 43 globular clusters in this nearby elliptical with known structural properties. We find the following: (a) King-model profiles match the clusters extremely well, (b) a small number of the brightest clusters show "extra-tidal light" extending well beyond the nominal tidal radius, (c) the NGC 5128 cluster system contains relatively more high ellipticity clusters ($\varepsilon > 0.2$) than the Milky Way, and (d) the clusters of both galaxies inhabit the same extremely narrow region of the FP.

Thus, our data are consistent with the claim that globular clusters are fundamentally the same type of object from one galaxy to another. They are old star clusters with similar M/L and King-model structures.

Modeling the Colliding-wind Spectra of the 19 Day WR+OB Binary in the Massive Triple System θ Muscae, G.M. Hill, W.M. Keck Observatory, and A.F.J. Moffat & N. St-Louis, Depart. de Physique and Observatoire du Mont Mégantic, Université de Montréal

High signal-to-noise ratio, moderate resolution spectra, providing full phase coverage of the 19 d WC6+OB binary θ Mus (WR 48, HD 113904), have been obtained and show dramatic variations of the C III λ5696 emission line profile. We have modeled these line profile variations using a purely geometrical model that assumes the emission arises from two regions, an optically thin spherical shell around the WR star and a cone-shaped region that partially wraps around the *OB* star. The cone shaped region represents the shock front arising from the collision between the winds of the two stars. This work builds upon our earlier study of WR 42 and WR 79 and uses a completely new code for the modeling, which includes the effects of turbulence. We now find much better agreement between the orbital inclination angles found for these stars and those determined using other methods. The fitting parameters found via modeling the C III λ5696 profile variations of θ Mus are used to infer that the *OB* companion most likely has a spectral type of O6V or O7V. The modeling presented here continues to show the exciting promise of a better understanding of WR star fundamental parameters.

A New Method of Time Series Analysis for Pulsating White Dwarfs, Chris Hunter, Université de Montréal

A number of white dwarfs were discovered to exhibit multi-periodic luminosity variations. White dwarfs are expected to possess stratified atmospheres enveloping their degenerate cores. The thickness and chemical composition of these layers act as resonance boundary conditions which allows only a few periods to reach the surface. The observed periods can be used to infer the atmospheric structure. In some of these stars, only a few periods are seen; measurements lack sufficient information to constrain the models. Perhaps the most extreme case is the DBV White Dwarf PG 1351+489, which exhibits a light curve characterized by a single pulsation period.

The focus of this project is to investigate alternate methods that may be used to extract more information from the measurements. We explore Bayesian probability theory as a new approach to time-series analysis. The usual Fourier analysis asks the question: What is the harmonic frequency of our data? With this new approach, we are able to demand more from our measurements. We can ask questions about the frequency, the pulsation shape, and the validity of our harmonic pulsation model.

Rich, Young Clusters in the CFHT Open Star Cluster Survey, Jason Kalirai, Department of Physics & Astronomy, University of British Columbia, Paolo Ventura, OAR, Harvey Richer, UBC, and Gregory Fahlman, CFHT

We continue our study of rich Galactic clusters by presenting deep CCD observations of NGC 2168 and NGC 2323. Both clusters are found to be rich (contain ~ 2000 stars each) and young (≤ 200 Myrs old). The CMDs for the clusters exhibit rich, clear main-sequences stretching over 14 magnitudes in the V, $B-V$ plane. Comparing these long main-sequences with those of earlier clusters in the survey, as well as with the Hyades and Pleiades systems, has allowed for accurate distances to be established. Analysis of the luminosity and mass functions suggest that despite their young age, both clusters are somewhat dynamically relaxed and exhibit signs of mass segregation. We also find some interesting white dwarf candidates that may be the remnants of quite massive ($M \geq 5 M_\odot$) progenitor stars. Spectroscopic follow-up of these, and other white dwarf candidates in the survey, is currently being proposed.

A New Outer Galaxy Molecular Cloud Catalogue: Application to Outer Galaxy Star Formation, C.R. Kerton, DRAO HIA NRC Canada, C.M. Brunt, DRAO HIA NRC Canada & Dept. of Physics and Astronomy, University of Calgary, and C. Pomerleau, Département de Physique, Univ. de Montréal

We have generated a new molecular cloud catalogue from a reprocessed version of the FCRAO Outer Galaxy Survey (OGS) of ^{12}CO (J = 1–0) emission (102.5° < l < 141.5°, –3.03° < b < 5.4°, –152 < v_{lsr} < 40 km s^{-1}). The catalogue provides a concise description of the OGS and contains basic data, such as peak and centroid positions and spatial and velocity FWHM, for ~ 14,600 objects.

The catalogue has been used as a starting point for examining star formation in the outer Galaxy. Previous molecular line surveys have necessarily made pointed observations toward samples of IRAS sources selected on the basis of such things as colour, flux quality, and brightness. The new OGS catalogue allows us to rapidly examine all of the IRAS sources in the OGS survey region for associated molecular material.

By examining the association of molecular material with randomly chosen positions in the survey we can obtain a quantitative ranking of possible associations with IRAS sources. We have detected a number of previously unexamined highly probable outer Galaxy IRAS-CO associations.

DRAO is operated as a national facility by NRC Canada. The CGPS is a Canadian project with international partners and is supported by a grant from NSERC. C.P. participated in this study through the Women in Engineering and Science (WES) program of NRC Canada.

Neutral Atomic Hydrogen Tails near a Wolf-Rayet and Of Star: A Shock-dissociated Mass-loaded Flow? Lewis B.G. Knee, Dominion Radio Astrophysical Observatory, and Bradley J. Wallace, Defence Research Establishment Ottawa, and Magdalen Normandeau, Magnetic Resonance Science Center, University of California

Neutral atomic hydrogen (H I) 21-cm line mapping from the Canadian Galactic Plane Survey reveals long (~ 60 pc) narrow H I tails from the vicinity of the Wolf-Rayet star WR 5 and the luminous *Of* star HD 17603. The tails appear to be gas dissociated from molecular clouds and accelerated away from the stars. We investigate the possibility that the molecular gas is being shock-dissociated and entrained in strong stellar winds from one or both stars.

Revised Kinematic Distances to 9 Galactic Supernova Remnants using the TASS in the Perseus Arm, Roland Kothes[1,2], C. Brunt[1,2], and B. Uyanıker[1] (1. National Research Council of Canada, Herzberg Institute of Astrophysics, Dominion Radio Astrophysical Observatory, and 2. Department of Physics and Astronomy, University of Calgary)

New kinematic distances for 9 Galactic second quadrant supernova remnants located in the Perseus arm were determined. By taking spiral shock effects inside the Perseus arm into account we get more reliable kinematic distances. For well-known SNRs like Cas A and Tycho we established kinematic distances that now agree with values determined otherwise by more reliable methods. For other SNRs, especially those located in the anti-centre region, we calculate much shorter distances, which give more reasonable characteristics for the SNRs. Those shorter distances were already proposed by various authors but never proven before.

Gravitational Light Bending Effects on X-ray Pulsar Profiles, D. Leahy, Department of Physics and Astronomy, University of Calgary

Neutron stars are seen observationally as strong X-ray emitters in close binary systems and as radio pulsars. Theoretical calculations using various equations-of-state of nuclear matter at high density give different internal structures, and different mass-radius relations for neutron stars (*e.g.*, see Lattimer & Prakash 2001, *ApJ*, 550, 426). Depending on the equation of state and the neutron star mass, the ratio of neutron star radius R to Schwarschild radius R_s varies from ≈ 1.8 to large values (≥10 for masses less than 0.5 $M_\odot$). Restricting to the observed masses of neutron stars, all near 1.4 $M_\odot$, the variation in R/R_s is ≈ 2 to 4. A comparison of equations of state with particle accelerator data (Heiselberg & Pandharipande 2000, *Ann.Rev.Nuc.Part.Sci.*, 05, 481) provided further restrictions, which if applied to 1.4 $M_\odot$ neutron stars, result in $R/R_s \approx 2.6$ to 3.1. With such compact sizes, radiation from near the surface of neutron stars takes a significantly curved path to the observer (important for $R/R_s < 4$ to 5). This light-bending has been considered previously in calculations of pulse profiles from emitting surface regions on rotating neutron stars: first for circular surface emission regions (Riffert *et al.* 1993, *ApJ*, 406, 185) and then generalized to hollow asymmetric offset surface emission (Leahy & Li 1995, *MNRAS*, 277, 1177). Only recently have pulse shapes been calculated for raised emission regions. Kraus (2001, *ApJ*, 563, 289) calculates the emission from conical shaped emission regions, which might be expected as an approximation for accretion along magnetic field lines. The work reported here was carried out at nearly the same time as the above work. The improvements of this work from Kraus (2001) are: some important errors are corrected here; approximations in the light-bending are calculated more accurately here; and more general geometries for the emission region are allowed. The difference between flat space and light-bending flux distributions is dramatic. A number of cases will be illustrated for different sizes of emission regions and for different sizes of neutron stars, which can be parametrized by R/R_s.

The Large-Scale Structure of NGC 6334 at Sub-mm and Mid-IR Wavelengths, H.E. Matthews, Joint Astronomy Centre and National Research Council of Canada, M. Cohen, Radio Astronomy Laboratory, University of California, and W.H. McCutcheon, Dept. of Physics & Astronomy, University of British Columbia (currently at University of Kent)

NGC 6334 is a galactic star-forming region in Scorpius. Extensively studied at optical, infrared, and radio wavelengths, the region consists of several major sites of star formation, with an apparent trend in age running from the oldest sites in the southwest, to the very heavily obscured regions in the northeast.

We present images of the entire region obtained at wavelengths of 850 and 450 μm with the bolometer camera SCUBA at the JCMT, and compare these data with images obtained by the MSX satellite at wavelengths between 8 and 21 μm. The SCUBA images allow a census of the dust mass and the identification of possible star-forming clumps. A particularly striking feature of these images is a very narrow curved ridge of dust emission, which seems to link most of the star-forming centres.

The MSX images contain extensive emission from PAHs at 8.3 and 12.1 μm in the photodissociation regions associated with massive young stars, and reveal more concentrated cool dust emission from embedded objects at 14.6 and 21.3 μm. The youngest regions in the northern end of NGC 6334, which show clearly in the sub-mm regime, are invisible to MSX. This is also true of the sub-mm ridge, but in other regions, conversely, bright mid-IR emission is not accompanied by sub-mm emission.

In this paper we use these datasets to investigate the apparent evolutionary trend through the star-forming sites in NGC 6334, to discuss dust grain properties, and to speculate on the significance of the ridge of material seen in the sub-mm images.

Status of the IRWG-Recommended New Infrared Passband System, E.F. Milone, Rothney Astrophysical Observatory, Physics & Astronomy Dept., University of Calgary, and Andrew T. Young, Department of Astronomy, San Diego State University

Over the past several years a portion of the passband system designed by Young, Milone, & Stagg (*A&AS*, 105, 259-279, 1994), as part of the IAU Comm 25 IR Working Group mandate to improve the quality of infrared photometry, has been in use on the 1.8-m Alexander R. Cross Telescope at the RAO in order to provide a set of standard star observations to which observations by others could transform. The filters for these passbands, namely, *yZ, yJ, yH*, and *yK*, were manufactured by Customs Scientific (Tucson) close to the specifications of the designs, which optimally place the passbands within the terrestrial atmospheric windows and determine maximum widths such that small errors in creating the filters do not substantially degrade the properties of the passbands.

Here we discuss the signal to noise of both designed and realized passbands and, on the basis of superior S/N and transformability properties between observing sites of widely varying water vapour content, recommend this system for future broadband infrared photometry.

This work was supported in part by grants to EFM from NSERC and the University Research Grants Committee of the University of Calgary.

The Open House Program of the Rothney Astrophysical Observatory, E.F. Milone, F.M. Babott, T.A. Clark, D.J.I. Fry, P. Langill, and R. Plume, Rothney Astrophysical Observatory, Dept. of Physics & Astronomy, University of Calgary

The Open House program (OHP) at the RAO has showcased the research carried out in the Department of Physics & Astronomy and more generally by the astronomical community for the past six years. The Open Houses, which are offered once per month during spring and summer, have attracted more than about a thousand people annually. They are staffed mostly by volunteers and have several components that ensure a high level of success in terms of both impact and participation regardless of the quality of the night.

The main components of the OHP are:

- Tours of the facilities with instructors stationed at critical points in the RAO compound;
- Views through a battery of telescopes on the observing terrace, operated by students and by members of the amateur astronomy community (mainly the RASC, Calgary Centre);
- Displays of current events in astronomy and work at the RAO, in particular;
- A series of popular-level talks in the RAO's classroom throughout the evening;
- A "kiddie korner," where the youngest astronomers are shown sky wonders through small telescopes with easy access; and,
- When sky conditions permit, setting on and viewing selected objects with the RAO's major telescopes.

Upgrades of the facilities during the current year will enable remote operations and will permit groups far from the RAO to participate in viewing objects and perhaps even see the classroom presentations during the Open House, thus enlarging the circle of impact. The benefits to the astrophysics programs at Alberta schools are obvious, but even more important is the outreach to the community as a whole, which ultimately supports the work of all astronomers.

Physical Conditions of Molecular Clumps in Orion B, G.F. Mitchell, and N.F.H. Tothill, Department of Astronomy and Physics, Saint Mary's University, D. Johnstone, Herzberg Institute of Astrophysics, and G. Moriarty-Schieven, Joint Astronomy Centre

JCMT observations of the 218 GHz lines of formaldehyde towards clumps in Orion B North (identified in the submillimetre continuum) show narrow linewidths (< 1 km s^{-1}) and cool temperatures (25–35 K), which agree very well with the temperatures derived using a Bonnor-Ebert analysis. Several of the clumps show an additional, broader, component that is significantly warmer; these clumps have consistently high degrees of concentration, enough to make them critically self-gravitating. Moreover, the narrow-line clumps have linewidths that indicate turbulence at about the sound speed, possibly sufficient to support them against collapse. We suggest that our observations may be tracing the difference between star-forming and non-star-forming clumps.

Fourier Transform Spectroscopy of the Orion Molecular Cloud, D.A. Naylor, E.A. Pope, and B.G. Gom, University of Lethbridge, G.R. Davis, University of Saskatchewan, and D. Johnstone, HIA

The proximity of the Orion molecular cloud provides a unique opportunity for studying star formation. Recent SCUBA images at 450 & 850 μm reveal a remarkable variety of structures including candidate pre-stellar cores, cores containing Class 0 protostars, shocks, and PDR fronts. Spectral index maps obtained from these images yield values in the range $2 < \gamma < 4.5$ (where $S_\nu \propto \nu^\gamma$). While structure in the submillimetre spectral index map is thought to be dominated by dust emissivity and temperature variations, a significant contribution to the total measured flux may arise from narrow spectral lines that fall within the SCUBA band-passes.

In May 2001, we reported the first direct detection of the line and continuum components of emission in the 850 μm band from the Orion KL region obtained using a Fourier transform spectrometer. In December 2001, we obtained matching spectra in both the 450 and 350 μm bands. Line and continuum emission components are again seen in both bands. These spectra will be presented and the results analyzed to illustrate the potential for measuring simultaneously both the line and continuum emission components of molecular cloud sources.

Multiperiodicity in Small-Amplitude Pulsating Red Giants, John R. Percy, Astronomy & Astrophysics, Erindale Campus, University of Toronto, and Gurtina Besla, Astronomy & Astrophysics, University of Toronto

Study of multiperiodicity in pulsating stars can be useful for constraining the properties, structure, and processes within those stars; it is part of the wider topic of asteroseismology. Red giants are poorly understood because of their highly convective structure. We have identified multiple periods in three small-amplitude pulsating red giants — RZ Ari, BC CMi, and V523 Mon — using almost 5000 days of photoelectric data. The periods are in the range of 20 to 60 days. We have been able to avoid most of the problems of alias periods by analyzing seasonal data as well as aggregate data. We have identified the periods as likely being low-order radial modes, by comparing the observed period ratios with theoretical values determined by Ostlie & Cox, and Xiong, Deng & Cheng. We compare these identifications with independent ones by Percy & Bakos, using Q-values or pulsation constants.

Supported by NSERC Canada.

A Particularly Interesting Dissociating Star in NGC 7129, C.R. Purton, R.S. Roger, and P.E. Dewdney, Dominion Radio Astrophysical Observatory, H.E. Matthews, Joint Astronomy Centre, and G.F. Mitchell, Dept. of Astronomy and Physics, Saint Mary's University

The reflection nebula NGC 7129 and environs is an intensively studied region of current star formation. Recent observations at 21-cm wavelength (Matthews *et al.* 2002) found a small, well-defined H I feature whose position and velocity place it in that region, coincident with the B-type star BD+65° 1638. The H I feature is interpreted as a zone around BD+65° 1638 in which hydrogen molecules have been dissociated by radiation from the star, thus elevating BD+65° 1638 to the status of "dissociating star." The system is very similar to the prototype dissociating star IRAS 23545+6508 (Dewdney *et al.* 1991), except for a significantly larger spread in velocity of the H I. Radio continuum and IR data suggest BD+65° 1638 to be right on the birthline defined by Palla and Stahler (1993), consistent with a very young age for the H I zone derived from modelling. Characteristics of the system are consistent also with the idea that some disruptive process severely limits the lifetimes of such dissociation zones (Purton 2002), and the large velocity spread of the H I suggests that in this case we may be witnessing the early stages of the disruption.

The Collimation of Protostellar Jets from Magnetized Keplerian Disks, Conrad Rogers and Ralph Pudritz, Department of Physics and Astronomy, McMaster University

One of the enduring models for protostellar jets is that they are highly collimated, magnetized winds from accretion disks. There is no unique model describing the structure of the magnetic fields that thread these disks. This motivates a study of magnetic field geometry and its role in launching protostellar jets.

We performed a series of numerical simulations using the ZEUS-2D MHD code. We extend the results of Ouyed and Pudritz (*ApJ*, 482, 712, 1997) by simulating many different initial field configurations. The disk is represented by a fixed boundary in the simulations, surrounded by a corona initially in hydrostatic balance. Our simulations pertain to scales below those resolved by HST (15 AU at Taurus).

Beyond a critical opening angle the magnetic field lines "lift" material from the disk centrifugally and accelerate it in high-velocity, well-collimated jets. We find that the collimation of the jet varies systematically with the initial configuration of the threading magnetic field. This has important implications for models of protostellar disks and their associated jets.

The Nature of M33's AGB Stars, J.F. Rowe, H.B. Richer, and J. Brewer, University of British Columbia, and D.R. Crabtree, Herzberg Institute of Astrophysics

Carbon stars are luminous AGB stars that are good tracers of galactic properties. Using the four-band photometric system of Brewer *et al.* (1995), AGB stars can be classified into M, S, and Carbon (C) types. The wide-field, CFH12K imager was used to observe most of the disk of the metal-poor, spiral galaxy M33 allowing the AGB population to be classified. We use this information to investigate: the chemical abundance profile of the disk using the C/M-star ratio that tracks metallicity; the spatial behaviour of the C/M-star ratio throughout the disk; the consistancy of the C-star luminosity function over a range of metallicities as a test of using C-stars as distance indicators.

WFPC2 Photometry of Faint Sources in the Kepler Field of View, Christopher Ryan and John Caldwell, Department of Physics and Astronomy, York University

A photometric study of archived images obtained by the Hubble Space Telescope (HST) has been undertaken in support of the NASA-sponsored Kepler search for extrasolar planets. This Discovery mission will monitor 100,000 nearby Main Sequence stars along the Cygnus arm of the Galaxy with apparent visual magnitudes between 9 and 14 for transits by Earth-size planets with relatively short orbital radii. Under the assumptions that such planets are common around solar-type stars and that planetary orbital axes are oriented randomly, it is expected that Kepler will detect up to 640 terrestrial planets over a four-year lifetime. To achieve the necessary photometric precision and minimize noise due to spacecraft motion, Kepler will intentionally defocus target PSFs to 1.05 $arcmin^2$. However, a consequence of this design feature is the inclusion of background luminous sources in the measured flux of a target star. If such a background source were an eclipsing binary system with apparent visual magnitude between 19 and 25, the resulting periodic variation in flux could be misinterpreted as a planetary transit for low signal-to-noise events. To determine the statistical significance of this issue, HST WFPC2 data obtained from the STScI archive have been reduced. From these data, the variation in total star counts as a function of Galactic latitude was determined. The maximum apparent number density of faint stars per unit WF chip area, equal to 1.56 $arcmin^2$, was found to be approximately 400. The presence of eclipsing binary optical doubles in the Kepler field of view is therefore a potentially significant source of false positive signals. The issue can be mitigated by including all photometric information in the data stream sent by the spacecraft, and by studying the areas around Kepler target stars with ground-based telescopes and the HST.

Modulation of Ca II H&K Emission by Extrasolar Planets, E. Shkolnik, and G.A.H. Walker, University of British Columbia, and D.A. Bohlender, HIA/NRC

We have detected modulation of the Ca II H&K reversal structure in the spectra (R = 110,000) of four out of five 51 Peg-type stars whose planets have orbital periods between 3 and 4 days. The spectra were acquired during four nights at CFHT in August 2001. The results are preliminary but we see no similar activity for τ Ceti or the Sun, which have no close, Jupiter-mass companions. Saar and Cuntz (2001) predict that short period planets interacting tidally and magnetically with the chromosphere of the parent star would produce detectable effects in the H&K reversals at ~ 1% level. The nightly variations are coherent in both H and K but we cannot confirm orbital synchronization at this stage.

Changes in the Character of S-Component Sources at 21 cm Wavelength During the Rising Phase of the Solar Activity Cycle, Ken Tapping, Herzberg Institute of Astrophysics, Heather Cameron, Department of Astronomy, University of Toronto, and Tony Willis, Herzberg Institute of Astrophysics

The DRAO Synthesis Radio Telescope has been used to map the Sun during the rising phase of Cycle 23, and the properties of the sources have been compared with other indicators of solar activity. In addition, time-variability of these relationships have been examined.

We find that the brightest radio emission at this wavelength occurs when the host region has reached its greatest growth, which is at variance with what we see at 2.8 cm wavelength, where sources are at their brightest when their respective host regions are growing most rapidly. In general the brightest sources lie in regions that are magnetically complex. However, the strongest relationship is between the brightness temperatures of the sources and their areas, so that $T_b \propto A_r$, and that the constant of proportionality is related to where the Sun is in its activity cycle.

The sources are believed to be due to free-free thermal emission from plasma trapped in magnetic fields overlying active regions, and that the variations in the relationship between the brightness temperatures of the sources and the areas of their respective active regions is due to a systematic change in the structure of the corona overlying active regions as a function of the phase of the solar activity cycle.

A Survey of Molecular Gas in S0 Galaxies, Gary A. Welch, Department of Astronomy and Physics, Saint Mary's University, and Leslie J. Sage, Department of Astronomy, University of Maryland

We present results from the first survey of molecular gas in a volume-limited sample of field S0 galaxies. CO emission is detected from nearly 75 percent of our sample members. The molecular gas is almost always located inside the central few kiloparsecs, meaning that in general it is more centrally concentrated than in spirals. After adding published H I observations to determine the total mass of neutral gas, we investigate whether monolithic and/or hierarchical galaxy formation models can explain what we have found.

Does the Mushroom Affect the Surrounding Medium: Sharpless 184 and the Cauldron, J.L. West, Department of Physics and Astronomy, University of Manitoba

Two features were analyzed in a Canadian Galactic Plane Survey data cube acquired at 21 cm using the Dominion Radio Astrophysical Observatory with approximate centre coordinates of 123.37, −5.57 (Galactic). This region is located near the southern end of the Mushroom, near the cap (English *et al.* 2000). The features were studied to attempt to determine if there was association with the Mushroom cloud. The first feature is NGC 281 (Sharpless 184), an H II region. In particular, a small cloud with a velocity ~15 km s^{-1} greater than the rest of the nebula was examined in some detail. The cloud was characterized and the results were shown to be in agreement with those of Roger *et al.* (1981). The second feature is a triangular region of emission we have dubbed the Cauldron. No evidence of direct association was found in either of the features studied. However, preliminary data on the Cauldron reveal velocity features that may be relevant to the question of how the Mushroom's motion affects the surrounding medium.

Modeling the Transits of Extra-solar Planets Using the Wilson-Deviney Code, M.D. Williams and E.F. Milone, Department of Physics and Astronomy, University of Calgary

We present a method of modeling extra-solar planet transits using University of Calgary versions of the Wilson-Devinney code (WD). Although WD was developed to model binary star systems, it is also ideally applicable to star-planet systems. WD uses a method of differential corrections to solve for the physical parameters of the stellar system from the observed light curves. An advantage of WD is that it allows for a simultaneous solution using many light curves (at different wavelengths) and the radial velocity curves of either component. This allows for a self-consistent solution given all available data. Also, the shapes of the bodies are modeled as tidally-distorted instead of spherical bodies. This is can be useful in distinguishing short period binary stars from extra-solar planet system in cases where radial velocity data are not available as we demonstrate. We present the results of modeling the transiting system HD209458 and an example of possible planet detection that was ruled out by detailed modeling.

A 10-FOOT REFLECTOR PROMISED

In some of the newspapers of the Pacific Coast have appeared statements regarding a great observatory which is to be erected in Seattle, Wash., and which will contain a reflecting telescope ten feet in diameter, the mirror to be supplied by Mr. T. S. H. Shearmen, of Vancouver, B.C. In order to secure authoritative information the present writer asked Mr. Shearmen if he would prepare a statement for the *Journal* and this he has promised to do. It will soon be forthcoming and in the meantime I am permitted to quote the following from a personal letter:

> Many years ago I devised a method of casting and annealing glass of any desired thickness and diameter and I have, therefore, not the slightest doubt regarding the successful outcome of the contract that I signed in May for the construction of a 10 ft. reflecting telescope. The donor of the observatory is Mr. Charles H. Frye, of Seattle. Mr. Frye has been a great collector of paintings and other works of art during recent years. Mr. Frye is now prepared to deal with the observatory plans that I have brought to his attention, in the same liberal manner.
>
> The great speculum will be completed in May, 1922, and then the plans for the observatory building will be considered. The tentative plans include a branch observatory in Hawaii or other tropical site. With a view to such work I spent six months in the Hawaiian Islands in 1914-1915. In the course of that investigation I found several ideal locations for a branch observatory.
>
> It brings back pleasant recollections to write a few lines for the Royal Astronomical Society of Canada, as I well remember meeting its early members and founders, such as the late Mr. Carpmael, Mr. Elvins, Mr. A.F. Miller, and others.

Mr. Shearmen at one time gave instruction in astronomy in Woodstock College and later lived in Brantford, Ont. We hope he may be successful in his great task.

by C. A. Chant,
from *Journal*, Vol. 15, pp. 384-385, December, 1921

CANADIAN THESIS ABSTRACTS

Compiled By Melvin Blake (blake@ddo.astro.utoronto.ca)

There Goes the Neighbourhood: The Extinction and Distance of the Dominant Members of the IC 342/Maffei Group of Galaxies
By Robin Fingerhut (Rfinger@yorku.ca), York University, MSc.

Two techniques for determining the Galactic extinction of heavily obscured galaxies are applied to the three dominant members of the highly reddened IC 342 / Maffei group of galaxies, revealing these objects to be among the brightest galaxies in the Northern sky. The first technique is applied to the giant elliptical Maffei 1 and involves the application of a well-defined correlation between the Mg_2 index and effective *V–I* colour for elliptical galaxies. The Galactic extinction for Maffei 1 is thereby determined using a measurement of the Mg_2 index from spectra of the core of the galaxy. In combination with modern photometry and a revised velocity dispersion measured from high-resolution spectra, an *I*-band Fundamental Plane distance to this galaxy is determined for the first time. The second technique is applied to the giant spirals Maffei 2 and IC 342. It involves a comparison of the dust-to-gas ratio in spirals of similar morphological type using observations of the Balmer decrement in extragalactic H II regions combined with measurements of azimuthally averaged H I column densities. Revised distances to these galaxies are obtained from the Tully-Fisher relation in the *I*-band.

Special attention to the determination of broadband reddening coefficients is used in this analysis to account for shifts in effective wavelengths, which can be significant for highly reddened galaxies. In addition, by restricting the distance analyses to the *I*-band, uncertainties are minimized in the photometric parameters owing to the extinction. The revised distances are consistent with what would be suspected for the Hubble Flow, making it highly unlikely that these galaxies interacted with the Local Group since the Big Bang, as has been previously hypothesized.

Spectroscopy and Photometry of Binary Stars in Old Open Clusters
By Melvin Blake (blake@ddo.astro.utoronto.ca)
York University, Ph.D

We have performed a spectroscopic and photometric study of six contact binary stars in four old open clusters, M67, Praesepe, NGC 6791, and NGC 752, in order to evaluate their suitability for measuring the distance to their respective clusters. The technique being tested uses the cosine Fourier coefficients of the light curves of the binary stars, and the mass ratios obtained spectroscopically, to provide distances to the binaries.

The contact binary TX Cnc was used to obtain the distance to Praesepe, that we find to be $(V - M_V)_o = 6.30 \pm 0.08$, which is in good agreement with the values of $V - M_V = 6.20 - 6.35$ found in colour-magnitude diagram (CMD) studies. We obtained a distance modulus of $(V - M_V)^o = 12.71 \pm 0.44$ for V7 in NGC 6791, the oldest cluster in our survey. This agrees, within ~ 1σ, with the values of $13.3 \leq (V - M_V) \leq 13.42$ obtained by isochrone fitting of the cluster CMD. Our spectroscopic study of QX And in NGC 752 provided a distance modulus of $V - M_V = 8.30 \pm 0.07$ for this cluster. This compares to a value of $V - M_V = 7.9 \pm 0.1$ obtained by Milone *et al.* (1995) using the same star, but is in good agreement with $V - M_V = 8.25 \pm 0.10$ obtained by Daniel et al. (1994) from the CMD.

The distances to the clusters as determined from the contact binaries using our procedure do not seem to give systematically smaller or larger distances as compared to CMD fitting. However, we have measured the distances to only three clusters and only one object per cluster, and so establishing any systematic differences may require a larger survey. For the four clusters in this work, our new distance moduli and those of CMD fitting are in good agreement in all cases. We conclude that contact binaries could very well provide good distance indicators to their parent clusters. Surveys such as the Canada-France-Hawaii Telescope Legacy Survey will discover many contact binaries for which full least-squares orbital solutions will not be possible due to the large volume of data. The technique developed here should provide good preliminary orbital parameters for such binary star systems.

The cosine Fourier coefficients of the light curve of EV Cnc in M67 lie off the grid of values for contact binaries, which leads us to speculate that this star may be an Algol system, rather than a contact binary. EV Cnc also exhibits the O'Connell effect, which in this case may be caused by a hot spot created on the surface of the primary by the impact of a gas stream. Consistent with this idea is the fact that EV Cnc's velocity curve exhibits blue-shifted velocities near the secondary eclipse, which may be due to a gas stream that transfers mass from the secondary to the primary in a semi-detached system. As a result, EV Cnc in M67 was found to be unsuitable for distance determinations. Our photometry of the contact binary AH Cnc in M67 indicates a possible new feature in its light curve. After secondary minimum, this star exhibits a 0.1 magnitude increase in brightness over a short time scale. Such a phenomenon has not previously been reported in any of the W UMa stars.

Society News/Nouvelles de la société

by Kim Hay, National Secretary (kimhay@adan.kingston.net)

National Events

It's hard to believe that almost a month has gone by since the General Assembly was held in Montreal, Quebec at McGill University from May 17 to May 19.

The Montreal Centre, who hosted the weekend, did a wonderful job despite the small glitches that seem to show up at all General Assemblies. They gave all who attended a wonderful welcome and a warm fuzzy feeling. Many of us visited the I.K. Williamson Observatory on top of the mountain and got to see first-hand the problems with light pollution. The weekend was filled with meetings, both on the national level and on the personal level. Good friends and good times. It is always a pleasure to meet up with fellow RASCals you haven't seen for a while and to meet new friends. Many awards were handed out (listed below) at the end of the General Assembly, which closed with the banquet. Though the banquet featured interesting topics raised by Geoff Gaherty, door prizes, and song, the most touching part of the evening was the standing ovation friends and peers gave to our Past President, Dr. Robert Garrison, in recognition of his time in office. We wished him well for the future, and in return, he regaled us with his memories and stories of past accomplishments. We will miss you at the helm, Bob, but we know that you are not too far away to lend a hand when needed. Good luck with the retirement, and we all wish you the best on your trips through the parks and countries around the world.

Congratulations

As stated in the above paragraph, there was a long list of Society award recipients. At the National Council meeting on May 17, 2002, the Messier Certificate Award recipients were Tim Hunter (Toronto) and Scott Wilson (Regina), and the Finest NGC Certificate recipients were Ken Kingdon (Kingston), Joyce Carley (Toronto Centre), and John C. Mirtle (Calgary Centre).

On Friday night in the reception lounge of the Royal Victoria College, two very special awards were handed out to members of the RASC who need no introduction. When you mention their names, a smile comes across your face, and you know and understand that these two individuals love astronomy and have given their all to spread the word and educate others.

This year's recipient of the Chant Award is Dr. Roy Bishop. The Chant Medal of the Society was established in 1940 in appreciation of the great work of the late Prof. C. A. Chant in furthering the interests of astronomy in Canada. This medal, awarded to an amateur astronomer who is a resident in Canada, is given on the basis of the value of work carried out in astronomy and closely allied fields and specifically not in the services of the Society, worthy though this work may be.

Our second award of the evening was the Simon Newcomb award, and this went to Dr. David Levy, who was very surprised and at a loss for words. The Simon Newcomb Award is intended to encourage members of the RASC to write on the topic of astronomy for the Society or the general public; the award recognizes the best published works annually. The award is named in honour of the astronomer Simon Newcomb (1835-1909), who was born in Nova Scotia and later served for twenty years as Superintendent of the American Ephemeris and Nautical Almanac Office at the United States Naval Observatory in Washington. The award was created in 1978 by the National Council on the initiative of the RASC Halifax Centre.

To round out our evening, David Levy gave us a splendid talk and slide show on his observing over the years from its beginnings to his current projects at various observing locations, and he let us share with him his love of the night sky.

At the annual banquet, Vance Petriew received the Ken Chilton Prize for his keen observing, which led to his discovery of Comet C/2001 Q2 on August 18, 2001 at the Saskatchewan Summer Star Party. These days it is difficult for an amateur to become a comet discoverer. The Chilton Prize was established in 1977 by the National Council of the Society in remembrance of Ken E. Chilton, an active member of the Hamilton Centre. The prize is awarded annually to an amateur astronomer residing in Canada in recognition of a significant piece of astronomical work carried out or published during the year.

In the last Society News, it was stated that the RASC was looking for a replacement for Dave Lane, the *Journal's* production manager, who has held the position over five years and has supervised the whole process of the *Journal* with great care and expertise. Well, we have found a new production manager, David Garner (jusloe@wightman.ca) from the Kitchener Centre. Congratulations, David, on your new job, and many thanks to Dave Lane for his past work. Good luck, Dave and Michelle, on the house and the wedding from all of us.

On behalf of the Royal Astronomical Society of Canada, I wish to extend congratulations to all of the above winners in their accomplishments in the field of astronomy.

Upcoming Events

The next National Council meeting will be held at 10:00 am on October 26, 2002 at Gowling Lafleur Henderson LLP, Suite 4900, Commerce Court West (southeast corner, King and Bay Streets), Toronto ON. The Toronto Centre (www.rasc.ca/toronto/) has invited all members of council and guests to their observatory (E.C. Carr Observatory) in Collingwood for an evening of observing and conversation after the meeting.

The General Assembly for 2003 will be held in Vancouver and hosted by the Vancouver Centre. Bookmark www.rasc.ca/vancouver/ga2003 to keep up to date on the coming events for the GA.

Remember, the Royal Astronomical Society will be celebrating its 100th year in 2003. It's a great society; let's make it last another 100 years. It's the members who keep the Society going, so thanks to everyone.

If you or your Centre know of any upcoming events in your area, please send your information to me at (kimhay@kingston.net) so that we can include it in the *Journal* and let all the rascals know.

Have a great summer and clear skies.

Orbital Oddities

Hall's Balls

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

"Those who claim that the mathematical sciences are not concerned with goodness and beauty miss the truth... The greatest species of beauty are order, proportion, and limit, which are above all the objects of mathematical research."

— Aristotle, *Metaphysics*

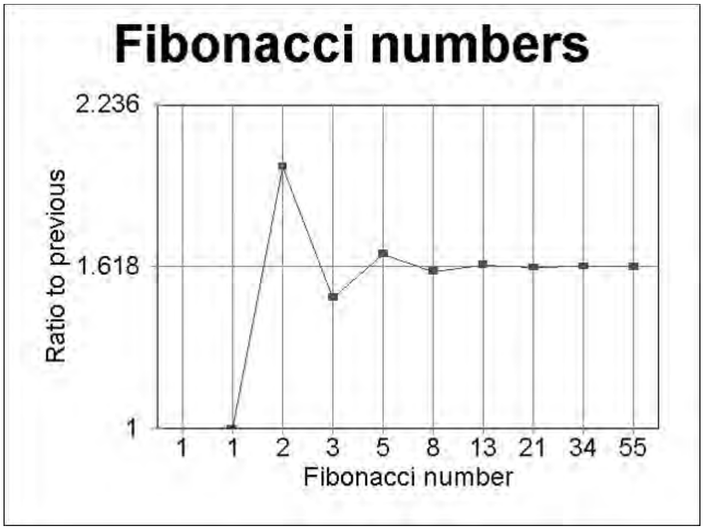
August, 1877: With Mars nearing its closest approach to Earth in a generation, Asaph Hall was the new man in charge of the world's most powerful telescope, the U.S. Naval Observatory's 66-cm Alvan Clark refractor. Located on the banks of the Potomac River, the site had the most unpromising name of Foggy Bottom.

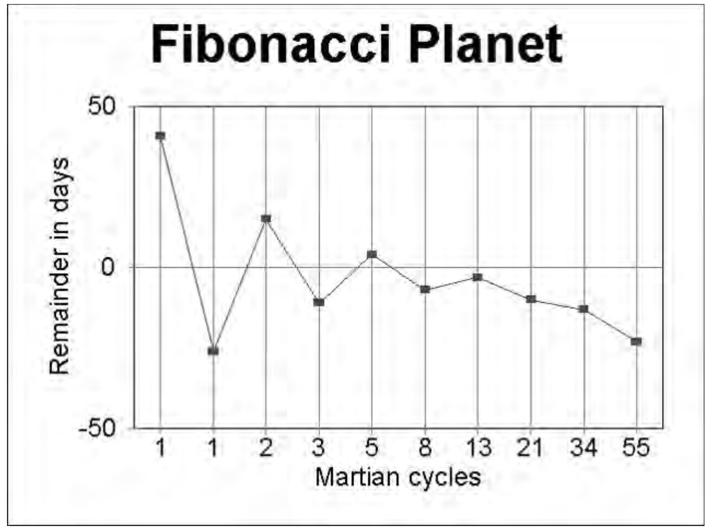
The popular wisdom of the day was that Mars had no moons. William Herschel had hunted unsuccessfully for them at the perihelic opposition of 1783, although later that decade he discovered Mimas and Enceladus near the rings of Saturn, as well as Oberon and Titania encircling Uranus (Kluger 1999). At Mars' most recent perihelic opposition in 1862, the Copenhagen Observatory's H.L. d'Arrest also found no satellites despite a systematic search.

Asaph Hall was undeterred by the absolute statements of the textbooks. Having taken responsibility for the Foggy Bottom scope from Simon Newcomb two years previously, Hall wanted to make a name for himself. He calculated that any Martian moons must be closer to the planet than previously figured, and took special steps with his giant refractor to scan Mars' immediate environs while keeping the brilliant planet itself out of the field of view. He successfully observed Phobos on August 11, recovered it on August 16, then discovered the even fainter Deimos the next night. In discovering these tiny balls of light, Hall once again proved the axiom, don't believe everything you read (Sheehan 1996).

As this issue of *JRASC* goes to press, the astronomical community is marking the 125th anniversary of Hall's breakthrough. Coincidentally, this is happening only one year before another close perihelic opposition of Mars. Or is it a coincidence at all?

One of the recurrent themes of this column is patterns and periodicities that pertain to planetary paths. The planets each have regular intervals after which approximately similar apparitions recur. Generally these can be divided into short- and long-term periods, with the latter achieving a greater degree of similarity because of the much greater sample period,





The figures show the similarity and ultimately the difference between the Fibonacci sequence and Martian cycles. In the former case, the ratios of successive iterations converge towards Φ at a rate that itself converges on Φ^2. Note that the range for the Y-axis has been set from 1 to √5 (2.236...); the midpoint is therefore (1 + √5)/2 = 1.618... = Φ. Subsequent (unshown) graphs up to at least the 40th Fibonacci number show virtually identical corkscrew patterns at ever finer scales.

In the case of Martian cycles, the major and minor cycles that both represent "1" have been transposed due to the actual mathematical relationship with other cycles (17 year cycle first, then 15, 32, 47, 79…). A Fibonacci relationship is simulated for several iterations; however, at 8 cycles the rate ceases to converge towards zero. Therefore, at 13 the sign does not change from minus to plus, and subsequent iterations rapidly diverge towards meaninglessness.

in much the same manner that the mathematical term π is slightly more accurately represented by the fraction 355/113 than the simpler 22/7.

Last issue we examined opposition series involving Jupiter, finding an approximate repetition after 12 years and a much more precise one after 83. The latter is comprised of 6 "major" cycles of 12 years each, and one "minor" one of 11. In the case of Venus, the major period of 8 years (minus 2.4 days) is so precise that it takes 30 of them to offset the very imprecise minor period of 3 years plus 72 days. The resultant long-term cycle of 243 years is fundamental to series of events such as transits of Venus.

The Red Planet has a most unusual pattern. With a synodic period of 780 days, on average Mars achieves opposition some 50 degrees further east than the previous apparition. The opposition point does a complete circuit of the sky in approximately 15.8 years, which is not a good match for what Mars actually does. There is a rough 15-year "minor" cycle which is less than a full rotation, or a 17-year "major" cycle which over-rotates somewhat. The upcoming close approach of August 27, 2003, for example, will occur in Aquarius and will not particularly resemble that of July 16, 1986 in Sagittarius, nor that of September 22, 1988 in Cetus near the Pisces border. Only by combining these imprecise short terms can we begin to spiral in on more accurate repetitions of previous oppositions, as per the following table:

Years	~Days	Martian Cycles	Major	Minor
2	+67	0	0	0
15	−26	1	0	1
17	+41	1	1	0
32	+15	2	1	1
47	−11	3	1	2
79	+4	5	2	3
126	−7	8	3	5
205	−3	13	5	8
284	+1	18	7	11

It should be immediately apparent that each period from the third term down is a combination of two above it in the table. Note that the study was confined to perihelic oppositions, when the synodic periods are somewhat exaggerated, and specifically to the date of closest approach to Earth rather than of opposition. The accuracy of repetition can best be seen in the (approximate) days column; each day represents an apparition more than one degree east (plus) or west (minus) of Mars' position at the original date. It is apparent that the best match in the medium term is the 79-year period in which the opposition point of Mars does five full cycles of the sky. The 126-year cycle is quite close as well; next August Mars will be in Aquarius, fairly close to its position when Asaph Hall made his momentous discoveries back in 1877.

As a pattern-finder I am, of course, fascinated by mathematics, particularly number theory. Amusingly, 2002 marks another anniversary: exactly 800 years ago, in 1202, the most influential mathematical work of the Middle Ages was published. The author was Leonardo of Pisa, better known as Fibonacci. *Liber abaci* (Book of the Abacus) introduced such basic ideas as the Hindu-Arabic numbering system, introducing to Europe the Indian numerals 1 through 9, plus zero. As Asimov acidly asserts: "Since Arabic numerals are only about a trillion times as useful as Roman numerals, it took a mere couple of centuries to convince European merchants to make the change" (Asimov 1977). Besides this crucial contribution to sanity in the western world, Leonardo's seminal work also delved into the figurative worlds of integers, fractions, geometry, and algebra (King 1994).

Today, however, Fibonacci is doubtless best remembered for the sequence of numbers that bears his name, where each term is calculated by summing the two preceding terms starting with the ubiquitous 0 and 1, generating the series 0, 1, 1, 2, 3, 5, 8, 13, 21... This simple progression has many remarkable properties, not the least of which was pointed out by the noted orbital mechanic Johannes Kepler, halfway between Fibonacci's time and the present day. Kepler noted that each iteration, when divided by its immediate predecessor, gets ever closer to the Golden Mean of $(1 + \sqrt{5})/2 = 1.6180339...$ Better known as Φ (*Phi*), this number is remarkable for its self-referential nature; for example ($\Phi + 1 = \Phi^2$); ($\Phi - 1 = \Phi^{-1}$); ($1 - \Phi^{-1} = \Phi^{-2}$). Indeed, in a few minutes armed only with spreadsheet software and an idea, I recently discovered that the consecutive Fibonacci ratios converge towards Φ at a rate which itself converges on Φ^2. (There's no record of even the great Kepler having done this!) This self-similarity on exponential scales is, simply put, the mathematics of spirals, and a concept of astonishing beauty (Clawson 1996; Conway and Guy 1996).

Finding applications of Φ in his studies of the Platonic solids, Kepler wrote: "Geometry has two great treasures: one is the Theorem of Pythagoras; the other, the division of a line into extreme and mean ratio [the Golden Mean]. The first we may compare to a measure of gold; the second we may name a precious jewel." (`www.mcs.surrey.ac.uk/Personal/R.Knott/Fibonacci/fib.html`).

The Golden Mean, or Divine Proportion as some reverentially call it, has applications in art, architecture, and aesthetics. It also occurs quite naturally. Although nothing in nature is infinitely perfect, Fibonacci relationships are nonetheless commonplace in the spiral patterns of sunflowers, pineapples, pine cones, snail shells, trilobite fossils, and the growth of honeybee populations (Ellis 1978). This relationship between pure mathematics and raw nature was a source of keen interest to the most perceptive observer I've had the privilege of knowing, the late Fr. Lucian Kemble. As he wrote in his final e-mail to me:

> "I think I might have given you [unfortunately, he hadn't] the whole packet of stuff I had on this several years ago — golden section of the Greeks and how to arrive at it and construct it geometrically, the Fibonacci sequence and Phi, the pentagram, side to diagonal, etc. I'm still trying to find out why it exists in nature. And the mystery of it. I can see why the Pythagoreans and others were fascinated. For example, the strange fact that 1 divided by Phi = 0.618033989 = Phi minus 1." (Kemble, private correspondence, 1999)

What does any of this have to do with Mars, you ask? Let's revisit the table, specifically the columns pertaining to Martian cycles. Remarkably, the first seven terms of the Fibonacci sequence are generated, mimicked to a degree by the numbers of major and minor cycles of which they are comprised. While I'm sure he would have agreed it's merely a nifty coincidence, Lamplighter Luc would have been delighted by this unexpected finding.

Over the longer term the relationship starts to break down. The last interval listed on the table is 284 years, a particularly exact repetition whose period is manifest in such events as transits of Earth as seen from Mars. 284 years is 18 Martian cycles, which in the context of this progression can be represented as 5+8+5; the next Fibonacci number is 21, or 5+8+8. At this point any similarities between Fibonacci and Mars have started to diverge towards irrelevance.

This is to be expected. Unlike its mathematical counterpart, nothing in the "real" Universe this side of a black hole, if that, is entirely self-referential. Mars is subject to the gravitational influences of Jupiter and Earth, and its own orbit is constantly evolving. Indeed, next summer the Red Planet will make its closest approach to Earth in several thousand years, the result of different, if less elegant, patterns in the still longer term which we will examine next time. As it approaches, amateur astronomers can take up the challenge: with modern medium- and large-aperture telescopes and appropriate accessories, it will be possible to follow Asaph Hall's lead and observe the Martian satellites.

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Bruce McCurdy has been active in astronomy and its public education outreach since the mid-1980s. He is a past president of the RASC Edmonton Centre and currently serves the National Council as Astronomy Day Coordinator. Bruce is the Education Development Coordinator of the SkyScan Science Awareness Project, an initiative of the Edmonton Area Radio Astronomy Group, which offers Grade 9 students a science curriculum-related project observing meteors using FM radios.

Delightful, Diminutive Delphinus

by Mark Bratton, Montreal Centre (mbratton@generation.net)

From now until well into the month of November, the Summer Triangle dominates the evening sky. Amateur astronomers are drawn here again and again during the warm summer months to observe the beautiful double star Albireo or the Ring and Dumbbell nebulae, to say nothing of the spectacular Veil. Unfortunately, some of the lesser constellations like Sagitta and Vulpecula get lost in the shuffle.

So too does the little constellation Delphinus. Situated on the shores of the Cygnus Milky Way, this small but attractive constellation contains no Messier objects and so is often passed over. That is too bad because there are some interesting objects to observe here. What follows is but a short sampling.

I do not usually mention binary stars in this column, but Delphinus has a beauty, ideal for the small telescope. Gamma Delphini consists of a pair of yellowish stars, magnitudes 4.3 and 5.1, which are separated by a little more than 10 arcseconds. Medium magnification will be enough to reveal these brilliant little points of light.

If your telescope has a clock drive and you feel like taking a break, shut it off and return to your telescope in exactly fifteen minutes. When you next look into your eyepiece, you will spy NGC 7006, a tiny globular cluster that is one of the most distant visible in a small telescope. Estimates place this cluster at well over 100,000 light-years from Earth, but because it is a tightly compressed cluster (concentration class I) it can be picked up even with an 8-inch telescope under light-polluted conditions. The brightest stars in the cluster are fainter than magnitude 15.5, however, and only very large telescopes can begin to resolve the cluster.

A little less challenging is NGC 6934, a globular cluster which is very attractive in a moderate aperture telescope. The cluster has a brilliant, well-compressed core and a substantial halo and is quite symmetrical in appearance. Using a magnification of 466×, I was able to resolve many stars in the outer halo and even a few near the centre, including a pair southeast of the core.

NGC 6905 is a moderately bright, though challenging, planetary nebula, which appeared quite round in my reflector and about 40 arcseconds in diameter; photographs show faint, bipolar extensions. The central star shines faintly at magnitude 14, and at 313× the star was intermittently visible. The outer envelope is very well defined.

The star-rich fields of Delphinus are also home to a number of galaxies, though by and large you will need at least a 12-inch telescope to start tracking them down. There is, however, a nice triplet which affords an interesting challenge to owners of 8-inch telescopes. NGC 6927, 6928, and 6930 can be viewed together in a high power field. At magnitude 14.5, NGC 6927 is the toughest, appearing as a faint, star-like spot at the western end of a chain of magnitude 13 stars. NGC 6928 and 6930 are both elongated galaxies glowing at about magnitude 12.5. NGC 6928 is the more interesting with a bright core and a magnitude 14 star visible due north of the core.

NGC 7003 is another faint galaxy that I would not ordinarily mention except for the fact that there is an intriguing equilateral triplet in the field almost due west of the galaxy. NGC 7003 can be found at RA $21^h\ 00^m.9$, Dec. +17° 48′.

A good guidebook and detailed star charts will lead to other interesting sights in this constellation. Challenge yourself sometime!

RASC member Mark Bratton, who is also a member of the Webb Society, has never met a deep-sky object he did not like. He is one of the authors of Night Sky: An Explore Your World Handbook.

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New Life for Vancouver's 0.5-m Telescope

by Craig Breckenridge, Vancouver Centre (craig.breckenridge@shaw.ca)

The Gordon MacMillan Southam Observatory has just completed a year-long retrofit of its main telescope. The original design of the 0.5-metre instrument had some inherent mechanical flaws that resulted in less than optimum performance. After much consultation with several groups, funding was arranged that would allow for the complete redesign of the telescope to bring it up to current standards. The story of that modernization is related here.

The original mount was a modified German equatorial design. It had its right ascension (R.A.) axis parallel to the Earth's rotation axis, as is necessary to track the stars as the Earth rotates. The declination axis was mounted at right angles to the R.A. axis, allowing for viewing north and south on the celestial sphere. The telescope was mounted on the end of the declination axis, requiring an excessive use of counterweights. First, counterweights were required to balance the telescope tube upon the declination axis. These were mounted on the rear of the telescope. The second set of counterweights was mounted on the declination shaft itself, opposite the telescope and its weights. A third set of counterweights was mounted opposite the telescope on the rotating part of the R.A. axis. All of these were necessary to keep the telescope balanced. The problem, of course, was that the mass of all of the counterweights not only had to be carried by the bearings and shafts on both axes, it also had to be moved by the motors that drove the telescope.

AMEC Dynamic Structures was employed to redesign the telescope. The crew that they assembled has been working together on telescopes since 1993. Several of the members of the team had participated in the design and construction of the Canada-France-Hawaii Telescope in Hawaii in the late 1970s and had gone on to work on telescope projects which included the Keck I and Keck II, Gemini, and Subaru. Since AMEC has such an extensive background in telescope design, they were the obvious choice to perform the upgrade. Initial discussions and financial considerations soon pointed out that the complete redesign of the scope would not include changing the optical configuration. Only the mount and control systems would be changed.

The first major items to be addressed were the mount style and the drive type. The old mount had a friction drive where steel belts were driven by stepper motors to turn the two axes. That format was kept due to loading considerations on the belts and motors. The new telescope would still have steel belts and would use DC motors instead of the stepper motors. These motors would be controlled differently and with higher accuracy. The mount chosen was a fork mount, which is almost universally regarded as a much more stable design.

Next came the mathematical analysis. In order to determine the sizes of members and shafts, the designers had to make educated guesses in order to determine the loads that had to be carried. These numbers would be monitored as the design process progressed in order to ensure that the initial assumptions were correct. Every aspect of the new telescope was examined to ensure that a sufficient safety factor was incorporated. Each item was then sized up and a new mass calculated. The drawings of each item and assembly to this stage were then sent out for review by experienced astronomers, volunteers, and engineers. Their comments were reviewed, and several further improvements were added to the design. In November of last year, fabrication and purchase of off-the-shelf items started.

Figure 1. The author (left) and Richard Job pose with the aluminum fork prior to stress relieving, heat treating, and machining.

Since most of the parts needed for this project were custom-made, a considerable number of them were made entirely in machine shops. The same shops used for the fabrication of parts for the large telescopes built by AMEC were engaged to manufacture this new telescope. Bearings were custom-made by SKF to ensure tight tolerances were maintained. Although these bearings are catalogue items for SKF, demand for the accuracy this project required is not very common. The new fork was assembled by a firm that has had previous experience working for AMEC for their "BLAST" project, a balloon-assisted telescope scheduled to

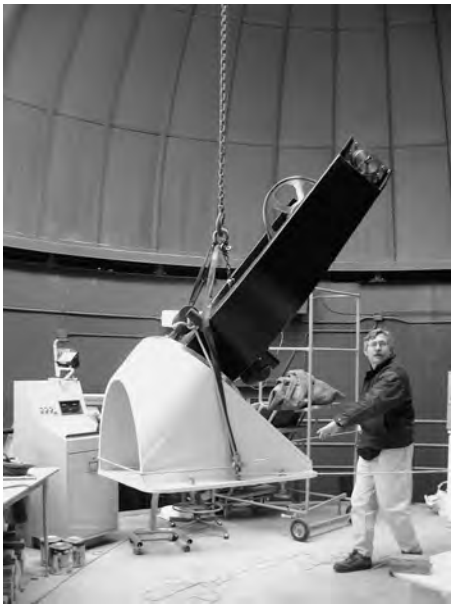

Figure 2. The telescope fork assembly being lowered into the observatory.

be launched in Antarctica this summer. The materials used for all parts were inspected to affirm that they were of the highest quality. Care was taken to ensure that these materials would not be subject to corrosion problems caused by the location of the installation (near the salt water).

Control of the new telescope is achieved with a software and hardware package from Astrometrics. This firm has a background of eight years in the design and manufacture of computer-controlled drive systems for telescopes ranging in size from amateur instruments to small research telescopes. The new package utilizes popular software packages such as *TheSky* and *Earth Centred Universe* to point the telescope. These programs allow the user to pick a star or feature on a planetarium-type display and then tell the telescope to move to it. To ensure that the telescope is pointing accurately, another program called *T-Point* is used to keep track of any mechanical deficiencies that may occur. *T-Point* will mathematically predict any correction required to ensure that tracking and aiming are perfect.

Provision has been made for further automation, including rotation of the dome and CCD imaging. A computer has been chosen to represent current state-of-the-art technology and expandability. There should be no problem keeping this telescope up-to-date. Another feature that has been added is the use of electronic clutches on both axes to ensure safety. Limit switches are also wired in and will be placed to limit travel and prevent cord wrap-up. Full positional locks have been provided to park the telescope at night and lock the telescope both in the vertical and horizontal positions.

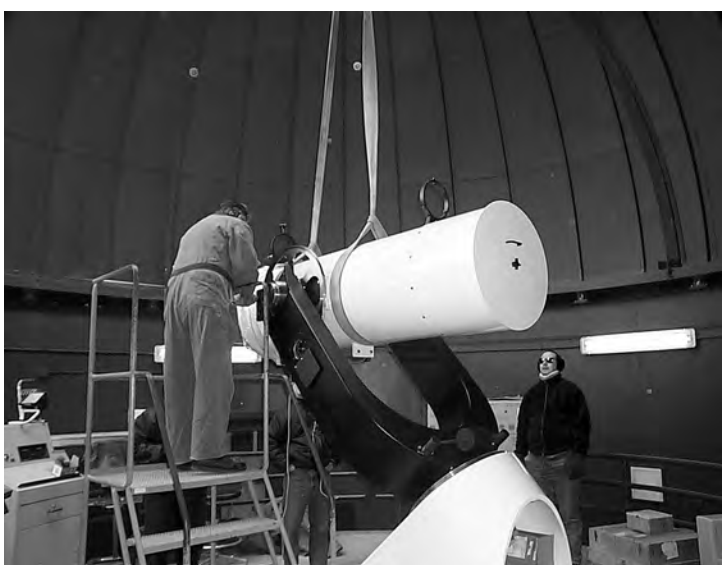

Figure 3. Pat Lavigne connecting the telescope tube assembly to the fork.

Figure 4. The completed telescope inside the observatory.

As a comparison, the old telescope had a mass of around 1,360 kilograms. Although the new telescope will have about the same mass, it will be distributed in a much different fashion. The old telescope carried most of its mass in counterweights and on the movable portion of the scope with only about 140 kilograms that was stationary. The new scope has a movable mass of 340 kilograms. Most of the mass in the new scope is in the base. The concrete upon which the new telescope sits has a mass of over 45 tons. That is probably more than the mass of the enclosing building! The old scope was driven by two 65 oz.-in. stepper motors with a combined gear ratio of around 800 to 1. The new motors are 200 oz.-in. DC motors and are servo-controlled. The gear ratio on the new system is 8000 to 1. We have added increased power and lightened the movable mass, which yields a more efficient design right from the start.

Craig Breckenridge is currently the squad leader at Amec Dynamic Structures Ltd. in Port Coquitlam, BC. AMEC is a world leader in the design, manufacture, and construction of large-aperture telescopes and amusement rides. Craig is the serving president of the Vancouver Centre and has been a member of the RASC since 1991. An avid amateur astronomer since 1965, he has taken every chance he can to marry his passion for the night sky to his chosen profession.

continued from page 155...

heavier elements as a result of nuclear processes occurring in previous generations of stars (the latter, remember, "cook" lighter elements into heavier ones within their cores). Also, the warmer the gas during gravitational collapse, the higher the masses of the stars that the clouds tend to form. Together such properties imply that primordial stars should have been more massive than those we see today. Yet, since high-mass stars "live fast and die young," there is no hope that any have survived to the present day. Is there any way to produce low mass, longer-lived stars from primordial gas? The jury is still out, but discovery of the exact process may well hinge on a better knowledge of how molecular hydrogen was cooled in the early universe.

The most interesting papers in the volume for me were those investigating the possibility that very large quantities of cold (3 to 10 degrees Kelvin) molecular hydrogen might continue to escape detection. Several papers in the volume (those by Schaefer, Combes, and Kalberla) make an explicit connection between cold molecular hydrogen, either in the form of Jupiter-like gas planets or dense clouds, and the enduring problem of dark matter. Shchekinov and collaborators point out, for example, that high-energy cosmic rays colliding with dense clumps of molecular hydrogen (distributed in an extended disk or a flattened halo around our Galaxy) will generate copious amounts of gamma rays. It is a lesson that, when something like molecular hydrogen is intrinsically difficult to detect, we should always be searching for new, possibly indirect, ways to do so.

Considerable effort has also been made to understand the formation process of molecular hydrogen itself. It is thought that molecular hydrogen formation begins with the sticking of two (or more) hydrogen atoms on a grain of interstellar dust, which provides a surface for the subsequent joining of the two atoms. The problem is distinguished from most others in astrophysics insofar as it can be profitably addressed in an Earthly laboratory. Pirronello, Williams, and collaborators described their experiments on the interaction of hydrogen atoms with small grains of amorphous carbon, graphite, and silicates under near-vacuum, low temperature conditions meant to simulate the interstellar medium. The former authors detected a significant enhancement of molecular hydrogen molecules leaving the grain surfaces as the temperature was raised from 7 to 20 degrees above absolute zero. By inference, much of the molecular hydrogen could be stuck to grains (and would therefore be undetectable) in the coldest clouds. On a related note, John Black, in his conference summary, raises the possibility that molecular hydrogen may exist as ice in such clouds. While still detectable spectroscopically, solid molecular hydrogen would have a very different signature from gaseous hydrogen and might constitute yet another hidden reservoir of interstellar matter.

As is true of most conference proceedings, *Molecular Hydrogen in Space* is not a volume for the casual reader. Among graduate students and researchers, however, it should have an enormously broad appeal because of the scope of its topics, which range from fundamental chemistry to planetary science to cosmology.

Charles Curry

Charles Curry is a postdoctoral fellow in physics at the University of Waterloo and a visiting astronomer at the University of Western Ontario. He lives in London, Ontario.

Astrocryptic Answers

by Curt Nason, Moncton Centre

The answers to last month's puzzle:

[1]A	C	[2]A	M	[3]A	R	■	[4]P	[5]E	R	[6]I	O	[7]D
D	■	L	■	T	■	[8]P	■	R	■	O	■	A
[9]A	P	P	U	L	S	E	■	[10]I	N	N	E	R
M	■	H	■	A	■	R	■	D	■	I	■	K
[11]S	P	A	N	S	■	[12]P	L	A	N	C	K	S
■	■	R	■	■	■	I	■	N	■	■	■	K
[13]R	A	D	I	[14]O	A	C	T	I	V	[15]I	T	Y
E	■	■	■	P	■	I	■	■	■	M	■	■
[16]D	I	[17]G	I	T	A	L	■	[18]D	U	B	H	[19]E
U	■	E	■	I	■	L	■	I	■	R	■	L
[20]C	O	N	I	C	■	[21]U	R	A	N	I	U	M
E	■	I	■	A	■	M	■	N	■	U	■	E
[22]S	H	I	E	L	D	■	[23]B	A	L	M	E	R

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