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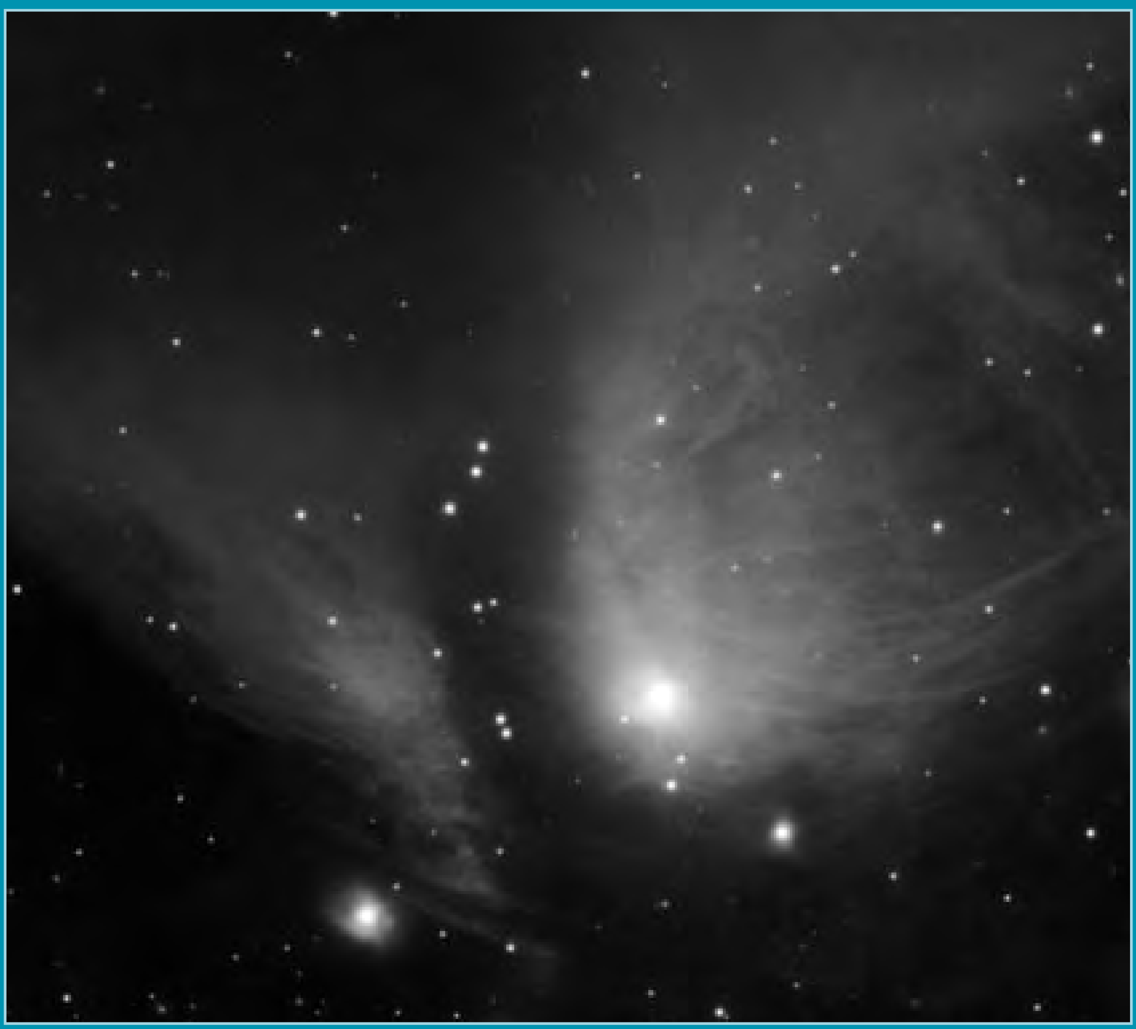

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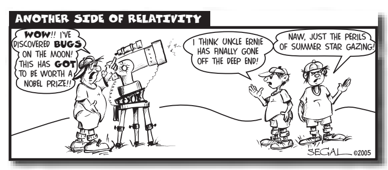

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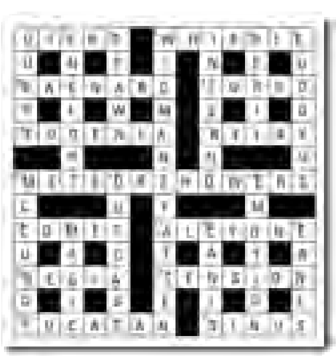

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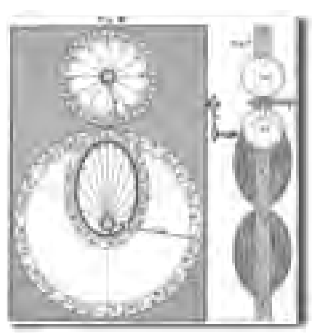

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Editorial

by Michael Allen (mlfa@mail.wsu.edu)

All scam artists use it. Every astronomer who regularly interacts with the public has seen it. I speak of the tactic of drawing the scientist into debate over superstition. The simple act of a scientist being seen discussing pseudo-scientific issues places those issues on the same footing as real science. Therefore, pseudo-science accrues credibility, and as a consequence the debate is already lost.

So-called "intelligent design" (ID) theory is the latest attempt by creationists to corrupt the public's perception of science and, equally dangerous, to pollute the minds of our youth through the education system. Their underlying premise is the same as always: that evolution is "only a theory" and therefore other "theories" should be represented equally. What is not acknowledged by ID advocates is that there is a difference between a scientific theory, and a non-scientific one. Scientific theories are supported by observation; they fit into our larger body of descriptions of our Universe; and, if given a set of mechanisms that all generate the same result, they favour the simpler over the more complex (in accordance with Occam's Razor).

There is a lot of money behind ID in the USA, and like the West Nile Virus, ID will soon be moving, in force, north of the border. For those of you who wish to readily attack ID, I recommend the article, "15 Answers to Creationist Nonsense," in the July 2002 edition of *Scientific American* (`www.sciam.com`). Arm ourselves we must; although common sense has won in the courtroom, a set of new propaganda devices will ensure that debate will continue in public society. As an example, I note that two creationist films have been produced, one of which was shown at the Smithsonian Museum of Natural History, and the other was scheduled to be broadcast on the American PBS network before being pulled at the last minute (see the "What's New" column of the American Physical Society, `www.aps.org`).

In 1764, Voltaire wrote that "superstition sets the whole world in flames; philosophy quenches them." I encourage each and every one of us to embrace the scientific and educational principles upon which the RASC was founded. Let's all get out into the community and help quench the conflagration of unreason.

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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News Notes
En Manchettes

TAKING THE PULSE OF POLARIS

The Pole Star is the closest and brightest member of a group of variable stars called classical Cepheids. But not only is this famous star a variable but its variability has actually changed dramatically over the last two centuries. Today, sensitive photometers have revealed that Polaris has nearly stopped varying.

Cepheids are stars between about 3 and 20 solar masses that have left the safety of the main sequence and are on their way to becoming red supergiants and eventual death. After leaving the main sequence these stars enter a section of the Hertzsprung-Russell diagram known as the "instability strip." While inside the instability strip, the stars pulsate like a steam engine as their interiors become more opaque to outgoing radiation. According to stellar evolutionary theory, as the interior of the star evolves, the star may cross through this strip numerous times. Each time the star exits the strip it should stop pulsating. Few classical Cepheids have ever been observed to cease their pulsations, therefore Polaris is a critical case study in stellar evolution.

Now a team of astronomers led by David Turner of Saint Mary's University in Halifax have reassessed the historical data on Polaris and have added some of their own. Their efforts have produced a nearly unbroken record of the changes in Polaris from 1844 to 2004 (*Publications of the Astronomical Society of the Pacific,* February 2005).

Turner and his team were particularly interested in some of the earliest observations done by Johann Friedrich Julius Schmidt (1825-1884) who was employed at observatories in Düsseldorf, Bonn, and Olmütz where he made nightly naked-eye estimates of the brightness of Polaris. Using more modern analytical techniques, these previously dismissed observations now have surprising value. Combined with observations from such historical figures as Pannekoek, Pickering, Hertzsprung, de Sitter, de Vaucouleurs, and Canada's own J.D. Fernie, the team has deduced a systematic increase in the period of light pulsation of 4.5 seconds per year for the interval between the years 1844 and 1963. They also found a light-amplitude decrease of 0.019 magnitude per century.

Examining the most recent data, including their own recent photometry done from the Burke-Gaffney Observatory at Saint Mary's University, the team also found a discontinuity in the star's continuous period increase occurring around 1963. For a few years the period of Polaris stopped increasing and actually started to decrease. The team speculates that this event may have been caused by a small but sudden change in the star's radius (by as little as 0.055%). The same period change could also be produced by Polaris consuming a planet of about seven times the mass of Jupiter.

These period changes are consistent with current stellar evolutionary models. Using newly refined distance estimates for Polaris, models suggest that it is crossing the instability strip for the first time and heading towards the red side of the H-R diagram. This is a brief and thus rare event — estimated to occur in only 1 to 2 percent of all known Cepheids. Nonetheless, there is still much to be learned. When asked to comment on his work, Turner was puzzled that "observationally Polaris seems to fall near the centre of the instability strip rather than on its edge. So, are the pulsations dying away or going through a short-lived hiatus?" Turner goes on to suggest that "the instability strip for first crossing Cepheids is bluer than that for regular Cepheids, so the location of Polaris near the centre of the main instability strip, in conjunction with its disappearing pulsations, is also consistent with a first crossing."

WE'RE NUMBER ONE!

New figures from the Institute for Scientific Information (ISI) rank Canada number one in the world of international astronomy. This is the only area of scientific research where Canada leads the world.

The Institute for Scientific Information rates the quality and impact of scientific research worldwide by measuring the citation rate of research papers. To calculate the citation rate, ISI monitors recognized journals in all disciplines of science, and tabulates how often a specific research paper is cited in subsequent published research. The frequency with which a paper is cited is a strong indicator of both its quality and impact on a specific field of study.

According to the recently released figures (available at `www.in-cites.com`) Canada now ranks first in the world in astronomy. Canadian researchers, the ISI statistics show, contributed to 4,836 research papers in space science (astronomy) over the past ten years. In all, these papers were cited in other published studies 76,921 times, giving Canada an overall citation rate of 15.91, the highest of any country. In contrast, American astronomers averaged 15.18 citations per paper, English astronomers 14.85, and Russians 4.96 citations per paper.

"The fact that Canada ranks number one in citations is of no surprise to me," says Dr. Matt Mountain, Director of the international Gemini Observatory. "Canadian astronomers are producing some of the best astronomy in the world, some of it right here at Gemini, and the instruments and software developed by Canadian teams are second to none."

According to Dr. Greg Fahlman,

Director-General of NRC's Herzberg Institute of Astrophysics, Canada's success is based on a strategy of focused investments. "We invest in facilities and projects that build upon our existing strengths and then focus most of our research on the big scientific questions of our time, such as the mysteries of dark matter and dark energy."

Because Canada builds state-of-the-art instruments for the best orbiting and ground-based telescopes in the world, says Fahlman, Canadian astronomers have access to the world's foremost observatories where they can, in turn, work at the forefront of astronomical research.

We also, says Dr. René Racine, Professor Emeritus at the Université de Montréal, have an exceptional university community that includes and trains not only observational astronomers and instrumentalists, but some of the best theoretical and computational astrophysicists in the world. By working as a unified community, with significant interchange between theoretical and observational astronomers, Canada has created a powerhouse of discovery.

Highly cited Canadian projects include the Canada-France Redshift Survey and the Gemini Deep Deep Survey, projects that examine the structure and composition of galaxies at great distances from ours. Projects such as these are changing our understanding of the early Universe. In theoretical astrophysics, researchers such as J.R. Bond and C.B. Netterfield at the University of Toronto and M. Halpern at the University of British Columbia are highly cited for work in the physics of the very early Universe, the origin and evolution of cosmic structure, dark energy, and dark matter.

"While it's wonderful for Canada to be ranked number one in astronomy in 2005, our long term goal," says Dr. James Hesser, President of the Canadian Astronomical Society, "is to keep Canada at the forefront of astronomy." To do this, he emphasizes, we must maintain a strategy that clearly works — wise investment in key scientific questions — a strategy laid out in the Long Range Plan for Canadian Astronomy and Astrophysics in the 21st Century, a report published in 2000.

"In the Long Range Plan," says Hesser, "we set clear, ambitious targets focused squarely on key questions concerning the origins of structure in the Universe."

The report, he says, lays out Canada's vision for astronomy for this decade and beyond, allowing us to focus our energy and resources on areas where we can have the most impact. Several of the recommendations made in that report, including Canadian participation in the Atacama Large Millimetre Array and the *James Webb Space Telescope*, are receiving funding. Fulfillment of this commitment, says Hesser, will ensure that Canada will continue to play a lead role in international astronomy in the decades to come.

For more information on the ISI statistics, a listing of Canada's astronomy citation superstars and Canadian astronomy highlights, including Canada's Long Range Plan visit `www.astro.umontreal.ca/~casca/PR/ISI-background.html`.

IMAGES TO ORDER

Using a big research telescope in Hawaii is a dream for most amateur sky watchers. That dream recently came true for two Canadian amateur astronomy groups. On May 15 their stunning images were unveiled during a special ceremony at the Canadian Astronomical Society annual meeting held at the Université de Montréal (Montréal, QC) from May 15 to 17.

The two images both show stars in early stages of their life. The 8-m diameter Gemini North telescope was used to image RY Tau, a star emerging from its stellar cocoon (Figure 1), at the request of the Club d'astronomie de Dorval, Quebec. The Big Sky Astronomical Society of Vulcan, Alberta requested an image of the Pleiades (figure 2), to be taken with the 3.6-m diameter Canada-France-Hawaii Telescope.

The groups won the opportunity to request these images after a Canada-wide contest. The contest, which began in 2004, solicited proposals from more than a hundred amateur astronomy clubs throughout Canada as a way to thank them for the work they do to support and excite the public about astronomy. The winning proposals were selected by a process similar to that used by professional astronomers, where selection criteria include scientific merit and an assessment of the uniqueness of the observation.

Gilbert St-Onge is a member of the Quebec group that requested the image of RY Tau. "Our group knew that this object was unique and hadn't been observed in detail with a big telescope like Gemini," he says. "I feel like we've not only made a pretty picture, but probably provided some new and valuable data for the pros!"

Gemini Astronomer Tracy Beck, who studies these stellar incubators, agrees. "This object is a classic, and one of the first-known examples of the remains of a stellar nursery," she said. "I believe this is by far the deepest and most detailed image ever taken of this object and scientists will no doubt use this data for important research in the future." The Gemini image was taken with a camera known as GMOS (Gemini Multi-Object Spectrograph), which was partially built in Canada.

The image of the Pleiades requested by the Alberta group will also have its uses. "I firmly believe that a beautiful image of the Pleiades will inspire many students across the country to develop a life-long interest in the science of astronomy," James Durbano wrote in his winning proposal. "It could even influence a young mind somewhere in our great country to pursue astronomy as a career."

The selection committee agreed, and also said that such an image has never been taken at high resolution by such a large telescope before. They also felt the group's request was an excellent use of MegaCam, the new giant camera on CFHT. This camera can capture in one pose a surface of more than one square degree, which is four times the surface on the sky covered by the Sun or the full Moon. The Pleiades star cluster covers a relatively large area on the sky, and other modern telescopes would not be able to photograph the entire thing.

The contest to request the images was organized by a team of scientists who coordinate Gemini observations for Canada (through the Canadian Gemini Office) at the National Research Council of Canada's Herzberg Institute of Astrophysics in Victoria (BC). The contest will probably be run again in the future.

The two winning proposals can be viewed at: `www.hia-iha.nrc-cnrc.gc.ca/cgo/contest_e.html`. In addition, the CFHT image of the Pleiades and the Gemini image of RY Taurus can be downloaded at: `www.gemini.edu/pr2005-4/images`.

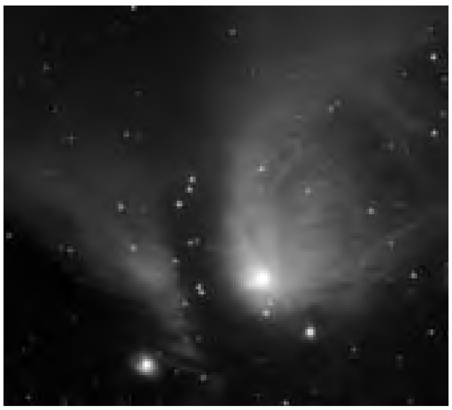


Figure 1 – Image of stellar nursery RY Taurus obtained by the Gemini Multi-Object Spectrograph as part of a Canadian contest for amateur astronomers. The image reveals tremendous detail in the wispy remains of the gas cloud that formed the bright star at bottom/centre. This system is approximately 140 parsecs (450 light years) away, and spans about 2/3 of a light year across. The central object is a variable star that ranges in visual magnitude from about 9 to 11 with an irregular period.

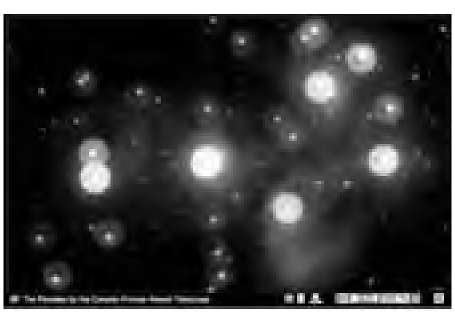


Figure 2 – The Pleiades (M45) taken with the new MegaCam on the 3.6-m diameter Canada-France-Hawaii Telescope.

TOPPLING MARS

Since the time billions of years ago when Mars was formed, it has never been a spherically symmetric planet, nor is it composed of similar materials throughout, say scientists who have studied the planet. Since its formation, it has changed its shape, for example, through the development of the Tharsis bulge, an eight-kilometre high feature that covers one-sixth of the Martian surface, and through volcanic activity. As a result of these and other factors, its polar axis has not been stable relative to surface features and is known to have wandered through the eons as Mars rotated around it and revolved around the Sun.

Now, a Canadian researcher has calculated the location of Mars' ancient poles, based upon the location of five giant impact basins on the planet's surface. Jafar Arkani-Hamed of McGill University in Montréal, Québec has determined that these five basins, named Argyre, Hellas, Isidis, Thaumasia, and Utopia, all lie along the arc of a great circle. This suggests that the projectiles that caused the basins originated with a single source and that the impacts trace the Martian equator at the time of impact, which was prior to the development of the Tharsis bulge.

Writing in the *Journal of Geophysical Research (Planets),* Arkani-Hamed calculates that the source of the five projectiles was an asteroid that had been circling the Sun in the same plane as Mars and most of the other planets. At one point, it passed close to the planet, until the force of Martian gravity surpassed the tensile strength of the asteroid, at which point it fragmented. The five large fragments would have remained in the same plane, that of Mars' then-equator. They hit in different spots around the Martian globe, due to Mars' rotation on its then-axis and the differing lengths of time the fragments took before impacting on Mars.

Arkani-Hamed describes the locations of the resulting basins, only three of which are well preserved. The two others have been detected by analysis of Martian gravitational anomalies. The great circle they describe on the Martian surface has its centre at latitude –30° and longitude 175°. By realigning the map of Mars with that spot as the South Pole, the great circle marks the ancient equator.

Arkani-Hamed estimates that the mass of the asteroid captured by Mars was about one percent of that of Earth's Moon. Its diameter was in the range of 800 to 1000 kilometres, depending upon its density, which cannot be determined.

The significance of Arkani-Hamed's findings, if borne out by further research, is that the extent of presumed underground water on Mars would have to be reassessed. "The region near the present equator was at the pole when running water most likely existed," comments Arkani-Hamed. "As surface water diminished, the polar caps remained the main source of water that most likely penetrated to deeper strata and has remained as permafrost, underlain by a thick groundwater reservoir. This is important for future manned missions to Mars."

A Lamplighter Moment[1]:

Foaming at the Rivermouth

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

Time goes by; it's "the time of your life"
— Peter Gabriel,
Dancing with the Moonlit Knight[2]

I wander to the river yonder and ponder its grandeur.

I chance upon a favourite rock close to the water's edge, a diamond-shaped boulder with a flat top just big enough for one to stand comfortably or perhaps for a sufficiently determined couple to snuggle up close. At first the spot is surrounded by a day camp of child anglers, but moments after my arrival they are summoned by an unseen clock, their voices and laughter gradually red-shifting into background radiation in the treed distance. I am alone.

The river flows by in its quietly inexorable manner. In the brilliant morning sunlight its water twinkles and tinkles a rhapsody in blues, in some ways entirely different from the pale emerald current that last met my eyes at this spot on an overcast Monday, in others entirely the same. One summer's day flows into the next as patiently as time itself.

Yet that time is not infinite, eventually the glacier that feeds the river will be spent. I pause to think that the reservoir of my life's blood is also receding, in even the best-case scenario more than half squandered. What do I have to show for the time of *my* life?

Precious little, I often think, but I do have my undeniably unique understanding of the Universe. Occasionally, my mind resonates in tune with a phi-dimensional cosmos, stuck on "open" in a golden ratio of attention to distraction, fact to speculation, holism to reductionism, perception to reality. Now is such an occasion, a Lamplighter Moment.

I gaze again at the water and think of miracles. Each twig, each leaf, each spruce needle that floats by is its own little wonder, whether scrutinized under the microscope or considered as part of the collective, miraculous whole. I recall Hubert Reeves' beautiful description in *Atoms of Silence* of the Milky Way, each star an unresolved leaf in a distant forest.

An unidentified bird with a high cheep and a low flight path inscribes a wide circle inches above the river before disappearing into its nest hidden among the tall grasses at water's edge. This draws my attention to the shoreline nearer my feet, where water and dirt compromise as life-giving mud. I examine the irregular progress of the shoreline which, mathematicians have proven, is best described by fractal geometry.

From the high grass emanates the hum and chirp of insect life, meant to be heard but not seen. A wasp works its way through the weeds, paying much less attention to me than I to it. I delight to see a butterfly flutter by, its progress as erratic as a perfectly thrown knuckleball; is this just efficient use of air currents, or a highly evolved defence mechanism designed to make predators miss?

Small islands of froth float along the river's surface, occasionally being

[1] Dedicated to the memory of Father Lucian Kemble (1922-1999), *a.k.a.* "Lamplighter," who touched the lives of countless members of the RASC through his love for all aspects of observing. A "Lamplighter Moment" is simply an occasion where, through careful observation of the mundane, one unexpectedly discovers something profound, a feat frequently achieved by Lucian Kemble during his lifetime. This section is intended as a part of the *Journal* devoted to guest articles by authors describing their own Lamplighter moments.

[2] Songs from Selling England by the Pound, by Genesis, 1973.

deposited in its muddy fringes. Who knows what microscopic miracles might be bubbling within? I marvel instead at the laws of physics. How can it be that a simple word like "foam" can describe such mundane, centimetre-scale features as these, and also the structure of the Universe on its grandest scale?

A largish flock of some 40 Canada geese flaps into my world, engaging in noisy and continuous conversation, presumably about the weather. After a cool and dismal week no doubt they too welcome today's blue skies and warming sunshine. They seem aware of the imminence of their departure date so are testing their wings. Upon closer listen to slight variations in tone and pitch, I find I can distinguish individual voices in the cacophony and conclude that only about half of them are talking at once. The geese veer from their flight path along the river and soar directly through my zenith, affording a superb private viewing of their classic V formation. Instead of disappearing into the distance as expected, they circle and give me a long second look, finally transiting directly in front of the brilliant morning Sun; another miracle to ponder.

I reflect on each of these things — rocks, leaves, bugs, birds, currents, fractals, Sun, Milky Way, intergalactic foam, children — and realize that each bears a degree of complexity worthy of a life's work. But while isolated studies would yield immense riches of largely unrelated details, all such research should bear this common query: how does each individual miracle fit into The Big Picture?

Looking again at the river's edge my eyes notice what my mind has been trained to ignore: the imprint of humankind on the natural treasures of the home planet. Scattered here and there are papers, plastic wrappers, a cardboard stick dispossessed of its lollipop. No doubt some of this refuse was deposited by the little miracles I encountered earlier. Scowling, I bend to pick up the clutter within my line of sight in the endlessly futile homage to the pristine. My applause is white noise, my reward a fleeting moment of serene union with nature.

Returning to the rock, I wonder how long it has remained in this spot. Ten years? A hundred? A thousand? I plunge through the surface tension of the present to consider the fullness of time. Will my rock still be here next week? Will I? What lies ahead of time's arrow? The details occupy an enormous probability cloud, mined with uncertainty from the quantum scale to the catastrophic. In the well-chosen words of Hubert Reeves, "the Universe is transparent in the direction of the future." In the biggest Big Picture, however, its fate seems assured: inexorable expansion into endless entropy, the ultimate fading nebula. Even the mightiest river eventually runs its course.

The sands of time were eroded by the river of constant change.

— Peter Gabriel, *Firth of Fifth*[2]

Bruce McCurdy is fortunate to have shared long conversations with Fr. Lucian Kemble on such grand topics as astronomy, cosmology, philosophy, music, nature, and mathematics. He considers Lamplighter Luc a truly inspirational figure in his adult life. Bruce's fascination with the dimension(s) of time dates back to grade school when he first read H.G. Wells' The Time Machine.

On Ptolemy's Equant, Kepler's Second Law, and the Non-existent "Empty-Focus" Cometarium

by Martin Beech, Regina Centre (beechm@uregina.ca)

"What goes around, comes around"
A well-known saying derived from
— The Epistle of Paul to the Galatians, 6:7.

Introduction

Historians are often interested in questions that ask why something came about; be it an idea, a theory, or an experiment. Here, in contrast, I would like to explore a question that asks why something didn't come about. Chronologically, the ideas that preface the question begin with a mathematical convenience first expressed by Claudius Ptolemy *ca.* AD 150. The question then turns to the laws of planetary motion, as introduced by Johannes Kepler in the early 1600s, and finally it relates to the 18th and 19th century design history of mechanical cometaria. The discussion will begin, however, with a look at cometaria.

Cometary Mechanics

A cometarium is a mechanical device for demonstrating the motion of a comet, in an elliptical orbit, about the Sun. James Ferguson (1710-1776), well known in his time as an itinerant lecturer on astronomy, further characterized the cometarium as follows: "This curious machine shows the motion of a comet or eccentric body moving round the Sun, describing equal areas in equal times" (Ferguson 1764). In this latter sense, the cometarium is also, therefore, a mechanical device for demonstrating the observable consequences of the first two of Kepler's three laws of planetary motion.

John Theophilus Desaguliers (1683-1744), who, like Ferguson, was a well-established lecturer on astronomy and an early promoter of mechanical sciences according to Newtonian principles (Wigelsworth 2003; Baillon 2004), is credited with the construction of the first cometarium. Indeed, Desaguliers presented his new machine to the assembled Fellows of the Royal Society of London on March 8, 1732 (Beech 2002, 2004)[1]. A cometarium built by instrument maker J. Rix[2] *ca.* 1750, in anticipation of the first-predicted return of Halley's Comet in 1758, is shown in Figure 1. From Rix's model it can be seen that Kepler's first law, the Ellipse Law requiring that the comet move along an elliptical path, is mechanically solved by simply restricting the comet marker to move in an elliptical groove. The apparent demonstration of Kepler's second law, the Areal Law (which requires that the Sun-comet line sweeps out equal areas in equal time), is a little more complicated to achieve, but it has been ingeniously brought about by the use of a set of elliptical pulley wheels in the cometarium's drive train. The elliptical pulley wheels are constrained to roll one against the other in a continuous fashion by a cat-gut string wound in a figure-of-eight fashion about their perimeters (Millburn 1981; Beech 2004). The drive train configuration of a cometarium designed by James Ferguson is shown in Figure 2.

Figure 1 – Cometarium designed by John Rix, *ca.* 1750. Photograph courtesy of the Smithsonian Museum.

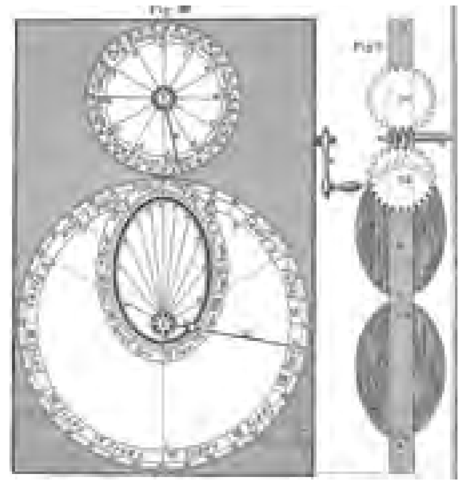


Figure 2 – Ferguson's design for a cometarium. In the left-hand image the upper smaller circle indicates the mean anomaly, while the lower larger dial indicates the true anomaly. The difference between the angles read off from these two dials would give the so-called *equation of centre,* which is a measure of how much the comet's motion deviates from that of uniform circular motion. The image is from Ferguson (1764).

In common with their more widely manufactured cousins, the orrery and the planetarium[3], cometaria were intended to be strictly demonstration devices. They were not designed to "explain" what physical processes actually produced Keplerian motion, nor were they designed to be accurately predictive. Rather, their purpose was to get an "idea" across to an audience — comets (and planets) move more rapidly at perihelion than they do at aphelion.

Given that a cometarium can only illustrate the consequences of Kepler's first two laws, the engineer and instrument maker is in principle afforded a great deal of freedom with respect to the design of a cometarium's drive train. All that the drive train has to ensure is that a comet-actuating arm sweeps out equal areas in equal intervals of time from the Sun focus and that the motion is along an elliptical path[4]. While the latter condition is easily accomplished mechanically (see Figure 1), the former requirement actually poses a relatively non-trivial problem for the engineer (Beech 2004). The mechanical problem, of course, is that Kepler's laws, as Isaac Newton first demonstrated in his *Principia Mathematica*, published in 1687, are a consequence of the conservation of energy and angular momentum, and the fact that gravity behaves as a centrally acting force. Mechanical devices with gears, springs, and levers may certainly demonstrate the consequences of these deep and fundamental physical concepts, but they cannot explain them.

With the above all being said, it appears, however, that the various manufacturers of early cometaria managed to completely overlook the simplest possible mechanical construction for the approximation of Kepler's second law.

The Equant

Claudius Ptolemy introduced the idea of the equant point in his *Magna Syntaxis*, written circa AD 150. Specifically, the equant point is the location from which an imaginary observer would "see" the centre of a planetary epicycle move around the deferent with an apparently uniform speed (Hoskin 1997). As seen, therefore, from the eccentrically offset Earth, the motion of the epicycle's centre would appear to be non-uniform (see Figure 3); speeding up near perigee and slowing down near apogee. By placing the equant and the Earth at locations equidistant from the deferent centre, Ptolemy was able to develop a highly accurate model for the description of planetary motion (Evans 1998). Indeed, it was a model not to be superseded or outdone in its accuracy for some 1400 years.

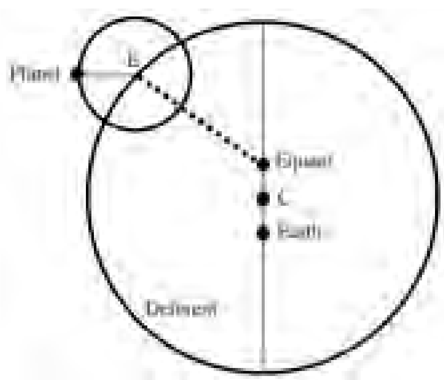


Figure 3 – Outline of Ptolemy's planetary model. The equant and the Earth are placed equidistant about the centre of the deferent *(C)*. An observer at the equant point would "see" the epicycle centre *(E)* move along the deferent at a uniform rate.

In the Platonic sense of "saving the appearance," Ptolemy's planetary hypothesis and his use of the equant worked exceptionally well. The introduction of the equant, however, was a topic of great concern to Ptolemy's later commentators. What was the physical nature of this point in space, and why was it, and not the Earth, the centre of apparent uniform motion? Such questioning, of course, is governed by the commentator's specific expectations and it also relates to the kind of model that the commentator is hoping to see established. A physical theory, for example, requires knowledge of how the planets are actually distributed in space, and their motion requires an explanation in terms of quantifiable forces. A purely geometrical representation of planetary motion, on the other hand, simply has to provide a correct answer. Within the context of a physical theory the inclusion of an equant is unjustified (indeed, it is unphysical), but in a purely geometrical theory it is a brilliant device by which highly accurate planetary predictions can be made.

The "Empty" Focus

There are no direct references to the second, non-Sun (or empty) focus in Kepler's laws of planetary motion. Indeed, it is a point in space that "exists" only because the geometrical construction of an ellipse requires that there be two foci. This said, the empty focus does have some of the same characteristics as Ptolemy's equant. To demonstrate this point, consider the perihelion to aphelion angular velocity ratio applicable to a comet for an imagined observer located at the empty focus. The equation for the velocity of a comet in an elliptical orbit is

$$V^2(r) = \mu\left(\frac{2}{r} - \frac{1}{a}\right) , \qquad (1)$$

where a is the semi-major axis, μ is a constant, and r is the distance from the Sun (located at the Sun focus). The perihelion, p, and aphelion, q, distances (as recorded by an observer at the Sun) are further given by $p = a(1 - e)$ and $q = a(1 + e)$ respectively, where e is the orbital eccentricity. Now, for an observer at the empty focus, the perihelion to aphelion angular velocity ratio (where, remember, the perihelion and aphelion points are defined relative to an observer at the Sun focus) is such that

$$\left.\frac{\omega_{perihelion}}{\omega_{aphelion}}\right]_{\substack{empty\\focus}} = \frac{V(p)/q}{V(q)/p} = 1 . \qquad (2)$$

In other words the angular velocities at perihelion (closest point to the Sun) and aphelion (furthest point from the Sun) are the same for the imagined empty-focus observer, irrespective of the orbital eccentricity. This result comes about through the transposition for the observer at the empty focus of the q and p distance terms (see Figure 4). For an observer at the Sun focus the perihelion to aphelion angular velocity ratio is given by the

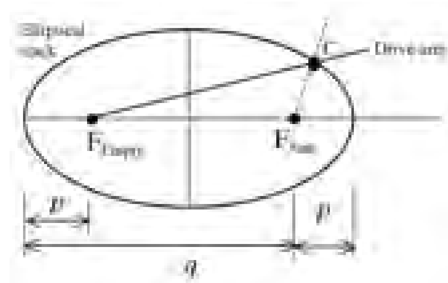


Figure 4 – Elliptical track parameters. *C* represents the location of the comet, *p* is the perihelion distance and *q* is aphelion distance as defined from the Sun focus. The essential mechanical feature of the empty-focus cometarium is that the comet marker *C* is driven around the elliptical track by a radial arm rotating with constant angular velocity about F_{Empty}. The F_{Sun} — *C* radial arm will correspondingly rotate about F_{Sun} at a non-constant rate: moving faster at perihelion and more slowly at aphelion, thereby demonstrating the main observable consequence of Kepler's second law.

relationship $[(1 + e) / (1 - e)]^2$, which becomes increasingly large as $e \to 1$.

The approximate equant property of the empty focus was, in fact, well known to 17th and 18th century astronomers (Russell 1964). And, indeed, practitioners such as Seth Ward (1617-1689), Savilian Professor of Astronomy at Oxford University (and also Bishop of Salisbury), used it explicitly to calculate planetary positions — as Ward described in his *Astronomia geometrica*, published in 1656. Interestingly, Ward also suggested in his 1653 work *De Cometis,* that comets moved on closed, elliptical orbits about the Sun and he further argued that because comets were "eternal" they would reappear in the skies at periodic intervals. In contrast, Kepler had argued in his *De Cometis Libelli Tres* (published in 1619) that comets were ephemeral objects formed spontaneously out of "fatty" impurities in the ether that traveled according to the rules of rectilinear motion.

The "Empty-Focus" Cometarium

With the above comments having been established, here is the missed historical opportunity. If the empty focus has properties similar to that of the equant, why not "drive" a cometarium via a uniformly rotating arm emanating from the empty focus? Such a drive train would be mechanically straightforward in its construction and it would not require the manufacture of non-circular pulleys and/or gears[5]. In addition, the empty-focus drive would, in fact, be no less accurate in its demonstration of Kepler's second law than the more complex elliptical wheel drive-train model (Nuttall & Millburn 1985).

A measure of just how well an empty-focus cometarium might illustrate Kepler's second law can be gauged according to a set of equations first developed by W.C. Brenke (1936). With reference to Figure 4, let the drive arm at the empty focus move at a constant rate appropriate to that of the mean anomaly $M = (2\pi / P)\, T$, where P is the orbital period and T is the time since perihelion. Let also the corresponding angle swept out by an arm emanating from the Sun focus be φ. Without developing the equations here[6], it can be shown that the true anomaly ν (as measured from the Sun focus and derived in accordance with Kepler's equation[3]) and φ are related according to a series expansion in terms of sin ($k\,M$), where k = 1, 2, 3…. Importantly, however, it transpires that the first term in the series varies according to the order of the eccentricity squared. Indeed, for small eccentricity the maximum difference between the two terms is $\nu - \varphi = e^2 / 4$. Brenke's analysis indicates, therefore, that under low-eccentricity conditions only a small error will be incurred by "driving" a cometarium from the empty focus.

I can offer no good reason why no single historical instrument maker ever thought to construct an empty-focus cometarium. The approximate equant properties of the empty focus would have been well known to 18th-century practitioners of astronomy, and the problems of "working" and re-threading the elliptical pulley wheel drive train were commonly articulated complaints (Millburn 1981; Macdonald & Morrison-Low 1994). In short, the cometarium design introduced by Desaguliers was unwieldy and, as noted above, was inaccurate in its depiction of Kepler's second law. John Millburn (private communication) has noted with respect to this last point that Desaguliers, and all subsequent users of his twin elliptical pulley wheel design, were probably unaware of its deficiencies. On this understanding, the original design was presumably thought to be optimal and therefore didn't need re-working (in spite of the difficulties of constructing elliptical pulleys and in its usage). It might further be argued that to an 18th-century practitioner of astronomy the invocation of a "practical" use for the empty focus (even if in a hidden mechanical sense) would have been viewed as just too much of a backward step. Backward, that is, in the sense that it apparently resurrected the "problematic" equant point. Likewise, if an empty-focus drive mechanism was made visible to the audience it would clearly defeat the sentiments of the Newtonian message, which requires that it is a central force extending towards the Sun (situated firmly at the Sun focus) that determines the motion of a comet.

References

Baillon, J-F. 2004, Stud. Hist. Phil. Sci., 35, 533

Beech, M. 2002, J. Ast. Hist. Heritage, 5 (2), 155

Beech, M. 2004, Bull. Sci. Instrument Soc., No. 82, 29

Brenke, W.C. 1936, Popular Astron., 44, 76

Evans, J. 1998, in The History and Practice of Ancient Astronomy (Oxford University Press: Oxford)

Ferguson. J. 1764, Astronomy Explained upon Sir Isaac Newton's Principles (3d ed.; London)

Hoskin, M., ed. 1997, The Cambridge Illustrated History of Astronomy (Cambridge University Press: Cambridge)

Macdonald, A., & Morrison-Low, A.D. 1994, A Heavenly Library: Treasures from the Royal Observatory's Crawford Collection (Royal Observatory: Edinburgh)

Millburn, J.R. 1981, Space Edu., 1(2), 55

Nuttall, J.E., & Millburn, J.R. 1985, private communication

Russell, J.L. 1964, Brit. J. Hist. Sci., 2(5), 1

Wigelsworth, J.R. 2003, Isis, 94, 435

Notes:

1 There is a possibility that the first cometarium was constructed a number of years before the 1732 demonstration took place at the Royal Society. In his syllabus to *An Experimental Course of Astronomy,* published in 1725, Desaguliers entices his potential audience with the boast that "several new Machines and Experiments [have been] purposely contriv'd." And, with respect to Lecture 8 specifically, Desaguliers comments that he will deliver "Experiments to shew, how the *Regularity* of the *Coelestial Motions* depends upon the *Action of Gravity* — and in what Manner it causes the *Comets* and *Planets* to *accelerate*

their Motion, as they approach towards the SUN, and *retard* it as they recede from the SUN." Desaguliers presented experiments to the Royal Society on a regular basis from as early as 1714, and was particularly well known for his popularization of Newtonian mechanics and for his experiments concerning the new science of electrostatics.

2 A housing list for the various extant cometaria can be found at the author's Web site: `hyperion.cc.uregina.ca/~astro/comet/Index.html`.

3 David Brewster explains the difference between a planetarium and orrery in his review article for the *Edinburgh Encyclopaedia* (Edinburgh, Blackwood, 1830): A planetarium displays the correct relative orbital motion of the planets, while an orrery displays both the relative orbital and spin motions of the planets and their associated moons.

4 Technically one can think of a cometarium as a mechanical device for solving Kepler's equation where the eccentric anomaly E is related to the mean anomaly M by the relationship: $M = E - e \sin (E)$, where e is the orbital eccentricity. The eccentric anomaly is then in turn related to the true anomaly υ; the angle swept out by the line joining the Sun and the comet. In this manner the uniform motion of the input drive, corresponding to the variation in the mean anomaly, is mechanically converted (via the elliptical gear train) into the non-uniform motion exhibited by the true anomaly as swept out from the Sun focus. In Beech (2002) it is shown that a drive-train composed of elliptical pulley wheels will not actually provide a true demonstration of Kepler's second law. This being said, a method for determining the correct wheel profiles capable of producing a true demonstration of the second law is described in Beech (2004).

5 During the writing of this article I was delighted to learn that J.R. Millburn (private communication) had, in fact, built in the mid-1960s a classroom demonstration model of an empty-focus cometarium.

6 Brenke (1936) shows that the difference between $\upsilon - \varphi$ is given by the formula:

$$\nu - \varphi = \frac{e^2}{4}\sin(2M) + \frac{e^3}{12}[5\sin(3M) - 3\sin(M)] + ...$$

We find, accordingly, that when the eccentricity is $e = 0.25$ (*i.e.* an eccentricity similar to that of Pluto's orbit), there is a maximum difference of approximately 1 degree between υ and φ. The maximum difference between υ and φ amounts to 3 degrees when $e = 0.4$ and 5.6 degrees when $e = 0.5$.

Martin Beech teaches astronomy at Campion College, the University of Regina and has had a long running fascination with the history and construction of mechanical models depicting the motion of objects within our solar system.

The Perils of Amateur Astronomy, Part 2

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

Last issue, I described my early perilous astronomical activities, during my childhood and teenage years. I ended with my mother's comforting thoughts that her teenage son was staying up late at night, but not getting into trouble with the police…

Of course, it was only a matter of time before the police caught up with me. One night in the 1980s, I went to Hartlen Point, Nova Scotia (near Halifax), in search of dark skies to the south. I was hoping to scan the southern Milky Way for some star clusters and nebulae. I set up my telescope and settled down to wait for my eyes to adapt to the darkness. Now, any astronomer will tell you that it takes from fifteen to thirty minutes for the eye to adjust its sensitivity so that faint objects can be discerned against the dark background. Once achieved, exposure of the eye to any bright light immediately destroys the dark-adaptation; causing this to happen is grounds for justifiable homicide, in the astronomer's view. Just as I was ready to start some serious "deep-sky" observing at the telescope, I heard a car slowly crunching along the gravel road behind me. I kept my back to the headlights to avoid their glare, and only turned around when the car drew alongside. I had barely made out the RCMP logo on the car door when they snapped on their door-mounted spotlight, steered it at my face, and sautéed my retinas. After a brief pause during which the RCMP sized up the situation and I miraculously kept my cool, one of the policemen made the brilliant observation, "Stargazin', eh?"

On another occasion, another observer and I were setting up our telescopes in the parking lot of a historic house owned by the N.S. Museum. It was after hours, but the Halifax Centre of the RASC had permission to use the site, which had excellent dark skies, by prior arrangement with the Museum — or so we thought. As usual, we were working in the dark to preserve our night vision. Suddenly, the door of the keeper's house flew open, and a howling beast bounded out, galloping in our direction. He was followed by the keeper; it was not hard to tell from his silhouette in the doorway that he was carrying a rifle. Dog and man advanced menacingly, Fang baring his teeth, Rambo brandishing his firearm. "Who's there? What's going on?" Fearing for our lives, I had to think fast: dropping everything, I reached for my wallet, frantically looking for my RASC membership card that certified that I was a Life Member — and presumably entitled to a jury trial before sentencing. I held it up to his flashlight beam as he approached. "Don't shoot," I pleaded, "we're astronomers!"

Within a few minutes we had both man and beast settled down. The keeper turned out to be a pleasant sort of chap, and he was armed only with a .22 calibre rifle. Apparently, he had not received the message that we would be there that night and, quite frankly, I think he was every bit as scared as we were. We let him look through the telescope at a few things; then he went back inside to watch the Saturday Night Movie. Even Fido warmed up to us, now leaping up playfully and knocking us flat on our backs, then happily sinking his teeth deep into our shins. Good dog!

My wife and I went south to see Halley's Comet. Actually, we went south for a Caribbean holiday, but it all started with me idly mentioning to her what a shame it was that we in Canada were to have such a lousy view of Comet Halley in April '86 and how lucky the Jamaicans were to have a ring-side seat. Next thing I knew, she was on the phone to the travel agent, booking a package holiday to St. Kitts. I have never seen her so interested in astronomy before or since; nevertheless, for the sake of the bank account, I kept quiet about the total eclipse of the Sun in Hawaii in July 1991. We were back in the Caribbean in February 1998 for the total solar eclipse. On that trip we were accompanied by our 11-year-old daughter, who we strongly suspect was conceived on the 1986 Caribbean comet trip.

We had a lovely time in St. Kitts, and I took a suitcase about half-full of binoculars, telescope accessories, and photographic equipment, not to mention my small C-90 telescope that neatly fits under the airplane seat. I had no trouble getting in to St. Kitts with all this gear, and I had no worries about returning to Canada through Toronto airport. My troubles started when our carry-on luggage — including my telescope in its plastic case — passed through the X-ray machine. All that glass and metal provided a wonderfully sharp and complex image on the monitor and must have set off some sort of silent alarm, for I soon had three concerned and serious-looking officials assisting me with my passage through Customs and Immigration. One of them produced a Phillips screwdriver and was clearly in a mood to take apart the instrument there and then; he evidently thought it might be a bomb, or at least a nifty place to hide drugs. I was able to satisfy their curiosity and to save my telescope by pointing out the "window" conveniently placed at one end of the tube for inspection purposes.

My next adventure took place in the New Forest, west of Southampton on the south coast of England. The New Forest is hardly new, having been created about 900 years ago after the Norman Conquest, and is not much of a forest, by Canadian standards. A lot of the New Forest is covered by low-lying heath and gorse bushes, and the stands of timber are restricted to several enclosures within the park. The land was taken from the commoners by William the Conqueror to create a royal game preserve, although he did permit the commoners to graze their horses and cattle there, a right they retain to this day. When I first saw the park, I thought that the large areas of treeless, undeveloped land away from the city lights would make an ideal observing location. Later on, when mid-summer was approaching, I was surprised to learn that the local astronomy club I joined had no tradition of observing the Perseid meteor shower. Accordingly, I organized a meteor-observing expedition for my friends and me for a Saturday night in early August.

The evening turned out to be a great success, with several people experiencing their very first meteor shower. We were so absorbed in the heavenly show that at first we didn't notice we were not alone. Eventually, we became aware of movements about us on the heath, accompanied by heavy exhalations and the thud of hoof-steps. We had been joined by a herd of gregarious New Forest ponies! Apparently, we had set up our camp right smack in the middle of one of their stomping grounds. We spent the rest of the night nervously keeping one eye on the sky and the other on the ponies, who had developed an alarming curiosity about our telescopes and camera gear.

These days, now that I am a family man, I find that I have left behind the perilous side of astronomy. I don't often suit up and brave the icy-cold Nova Scotia nights to observe at the telescope. Occasionally, I wander outdoors with my binoculars to peek at the odd bright comet or to view a conjunction of planets. Most of my observing is done from the safety of my armchair, wrapped up in a book or watching an astronomy-related show on the telly. Once in a while, I go to the monthly meetings of the Halifax Centre of the RASC. "No, I don't get out much anymore," I tell my astronomy buddies.

A story about this article: in 1991, I submitted the article for consideration for the Simon Newcomb Award (under the old rules) but at the time it was found not to be serious enough. After licking my wounds, I submitted the same article as an entry in the Personal Essay category of the 15th Annual Writing Competition sponsored by the Writers' Federation of Nova Scotia. To my surprise, it won first prize in its category. It is on my Web page, but I have prepared this updated version (in two parts) for archival purposes.

This is my 50th article for *JRASC* since I began in June 1997, and my last regular contribution. I will continue to contribute (if *JRASC* survives) but I have decided that this will be on an occasional basis, when I have something worthy of print. I have thoroughly enjoyed writing these columns, and I thank everyone for their emails and kind comments on the articles. It is most gratifying when RASC members and other readers show their appreciation.

David (Dave XVII) Chapman is a Life Member of the RASC and a past President of the Halifax Centre. By day, he is a Defence Scientist at Defence R&D Canada–Atlantic. Visit his astronomy page at www3.ns.sympatico.ca/dave.chapman/astronomy_page.

Orbital Migration within our Solar System

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

With all the excitement surrounding the ongoing discoveries of Jupiter-mass planets around other stars, we can sometimes forget that our own Solar System continues to pose some mysteries. Alessandro Morbidelli of the Observatoire de la Côte d'Azur in France and Hal Levison of the Southwest Research Institute in Boulder, Colorado, and their colleagues, have now solved several of these mysteries all at once (see the May 26, 2005 issue of *Nature*).

Prominent amongst these mysteries are the orbital eccentricities of Jupiter, Saturn, and Uranus, and the inclinations of the orbits of Saturn, Uranus, and Neptune to the plane defined by Jupiter and the Sun. As the planets most probably formed within the thin disk of gas and dust surrounding the early Sun, they should all lie in the same plane and have quite circular orbits. In astronomy-speak, the gas and dust are very dissipative — which simply means that the individual particles that are not on smooth, circular orbits will rapidly collide with other particles, and the differences will be smoothed out. This will leave a nice, flat disk of material out of which the planets form.

Moreover, there is a puzzling period, about 3.8 billion years ago, when the Earth-Moon system was subjected to an intense bombardment by asteroids. Why should this have happened 700 million years after the formation of the Solar System? This time, called the period of Late Heavy Bombardment, is of considerable interest to astronomers for multiple reasons. What was the source of the asteroids and/or comets that suddenly entered the inner Solar System? All models lead to the conclusion that the inner Solar System (*i.e.* inside the orbit of Jupiter) was cleared of material by this point, except for the asteroids left in the stable asteroid belt.

Finally, Jupiter is accompanied in its orbit by two groups of asteroids — known as the Trojans — which lead and follow it by 60 degrees. While the presence of the asteroids can be explained — they lie in gravitationally stable zones — their spread in orbital inclinations is far greater than any conventional means of capturing asteroids will allow.

The model that Morbidelli and Levison and their colleagues have come up with explains all these problems, within a simple and elegant framework, given just one initial assumption, which was that Saturn's orbit was just interior to the point where it would make exactly one orbit around the Sun for each two orbits made by Jupiter. This is called the 2:1 orbital resonance. A resonance is very important in planetary dynamics because it is a configuration that converts the orbital energy of the larger body into random motions of the smaller body. An everyday example of a resonance is "pumping" on a swing, or sloshing water in a bathtub at just the right frequency to rapidly build up a large wave.

Although the inner Solar System was largely cleared of asteroids and planetesimals within the first 50 million years of its history, there most probably still was a large disk of bodies outside the orbit of Neptune. Many previous studies of the behaviour of giant planets have shown that they can migrate in their orbits due to interactions with the disk. In Morbidelli and Levison's model of the Solar System, this slow migration took about 700 million years until Jupiter and Saturn hit their 2:1 resonance. At that point, things happened very rapidly because Jupiter and Saturn are so massive relative to all of the other bodies in the Solar System (except for the Sun, of course). The orbits of the giant planets were stirred (not shaken), both in their eccentricities and inclinations, while Uranus and Neptune were unceremoniously shoved much further out. They interacted with the disk of bodies that was previously beyond Neptune's influence, throwing many of them towards the inner Solar System. Some of these bodies hit the Earth and Moon, causing the Late Heavy Bombardment, and others were captured by Jupiter into the stable orbits at the Trojan points. The planets settled down into their present positions when the disk of bodies was largely disrupted over a period of ~30 million years (model estimates range from 10-150 million years).

The length of time it took the Solar System to settle down again is very sensitive to precisely how the planets interacted, but the planets' final positions are not. Rather, they are most sensitive to the collective mass of bodies in the disk. The best "fit" occurs with a disk of ~30 Earth masses of bodies. This is a fairly modest amount of material, and not at all outside what is likely to have existed.

Morbidelli and Levison have a clear prediction for this explanation: the Late Heavy Bombardment period should have started with a very sharp spike of material hitting the Moon. While current data cannot (yet) confirm this spike by dating sufficiently accurately the craters arising from this period, the push to return astronauts to the Moon holds out the possibility of it being confirmed within the next 15 or so years.

Even without that confirmation, though, the explanation has that kind of elegance about it that usually tells scientists they've hit upon the truth. So the next time you're looking at Jupiter or Saturn in your telescope, imagine them moving around the early Solar System and shaking up the rest of the outer bodies like marbles on a rubber sheet.

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.*

FROM THE PAST — AU FIL DES ANS

FIRST REGULAR MEETING OF THE CANADIAN ASTRONOMICAL SOCIETY AT THE UNIVERSITY OF TORONTO, NOV. 11-13, 1971

The Canadian Astronomical Society, which was founded in May, 1971, held its first regular meeting at the University of Toronto, Nov. 11-13, 1971, on invitation of Prof. D. A. MacRae, Head of the Department of Astronomy and Director of the David Dunlap Observatory. Seventy-eight members registered for the meeting and total attendance, including wives, was about one hundred.

The meeting opened with a pleasant social evening at the David Dunlap Observatory, Richmond Hill, on Thursday, Nov. 11. Sessions for papers were held on Nov. 12 and 13 and 32 papers were presented at these sessions; abstracts of these papers follow this note. The Society Dinner was at the Faculty Club on Friday evening, Nov. 12, and all present signed a letter of congratulation to one of our absent members, Dr. Gerhard Herzberg, recently announced as the Nobel Laureate in Chemistry. After dinner the R.M. Petrie Memorial Lecture was given by Dr. C. S. Beals on "The Forms of Impact Craters Related to the Thermal History of the Lunar Surface."

by Peter M. Millman
from *Journal,* Vol. 66, p. 65, February 1972.

Research Papers
Articles de recherche

ABSTRACTS OF PAPERS PRESENTED AT THE 2005 CASCA ANNUAL MEETING HELD AT THE UNIVERSITÉ DE MONTRÉAL IN MONTRÉAL, QUEBÉC, MAY 15 to 17, 2005

ORAL PAPERS/LES PRÉSENTATIONS ORALES

How Black Holes Make Jets: Clues from X-ray Spectroscopy, David Ballantyne, Canadian Institute for Theoretical Astrophysics

X-ray reflection features allow constraints to be placed on the accretion geometry around accreting black holes. Here, I will review what we have learned about the inner regions of accretion flows in radio-loud AGN from X-ray reflection analyses. New results from *XMM-Newton* will also be presented. I will then draw together all the findings to discuss how the accretion geometry affects the launching of relativistic jets.

The Terrain for Planck in the CMB Landscape, J. Richard Bond, Canadian Institute for Theoretical Astrophysics

Canada is significantly involved in *Planck,* an ESA satellite officially scheduled for an August 2007 launch. It will survey the entire sky in 9 frequency bands using MMIC HEMTs and 50 bolometers, many polarization sensitive, with a best fwhm resolution of 5 arcminutes, far out in the damping tail of the primary CMB power spectra in total intensity (TT) and polarization. *Planck* will make major advances in the two CMB frontiers: E-mode and B-mode polarization at high and low multipoles L; secondary TT anisotropies arising from nonlinear effects at high L. Other CMB data will complement *Planck,* including from 8 years of *WMAP,* ambitious ground-based experiments such as QUaD, BICEP, Polarbear, ACT, SPT and Quiet, and the balloon-borne Spider, the latter four with > 1000 detectors. Forecasts for power spectrum and cosmological parameter estimations for *Planck* alone are contrasted with those from combinations of these various experiments, and with the state for current CMB polarization data, in particular new results for EE and TE power spectra from CBI. Apart from exquisite improvements for the E-mode, *Planck,* and Spider have good shots at detecting the low-L B-mode, a direct imprint of zero-point quantum gravity waves and a "holy grail" for future CMB research.

Discovery of Germanium, Arsenic, Selenium, Tin, Tellurium, and Iodine in the Atmospheres of Cool DO White Dwarfs, P. Chayer, University of Victoria/John Hopkins University, S. Vennes, J. Dupuis and J.W. Kruk, The Johns Hopkins University

We analyze *Far Ultraviolet Spectroscopic Explorer (FUSE),* Goddard High Resolution Spectrograph, and *International Ultraviolet Explorer* spectra of the cool DO white dwarfs HD 149499 B and HZ 21, and identify photospheric lines of elements beyond the iron group. Germanium (Z = 32), arsenic (33), and tellurium (52) are detected in both stars. Selenium (34), tin (50), iodine (53), and perhaps bromine (35) are also observed in HD 149499 B. The observation of arsenic, selenium, tellurium, and iodine is a first for white dwarfs. Light elements such as carbon, silicon, phosphorus, and sulfur are observed in both stars, but nitrogen is only detected in HZ 21. We carry out a spectral synthesis analysis for both stars. The mass fractions of elements heavier than iron range from about a factor of 3 to a factor of 1000 relative to the Sun. We propose that both stars show the effect of nucleosynthesis during the asymptotic giant branch phase of their evolution.

Education and Public Outreach: More than just Glamour!, Doris Daou, Spitzer Science Center/IPAC

The National Aeronautics and Space Administration (NASA) has a clear set of goals and objectives related to education and public outreach. These goals follow directly from NASA's mission "to inspire the next generation of Explorers." Making progress towards achieving these goals has become an important part of the broad justification for public support of space science.

NASA's Science Mission Directorate and the Office of Education and Public Outreach are committed to using space science as a vehicle for deepening the understanding and appreciation of science, mathematics, and technology. For this commitment NASA has formulated the objectives to

1) improve student proficiency in science, technology, engineering, and mathematics by using education programs, products, and services based on NASA missions, discoveries, and innovations; and

2) improve science, technology, engineering, and mathematics instruction with unique teaching tools and experiences that are compelling to teachers and students.

Here we will explore various Education and Public Outreach initiatives created in support of these objectives.

Nonspherical Effects in the Evolution of Close Binary Stars, Robert

Deupree and Amanda Karakas, Institute for Computational Astrophysics

2-D stellar evolution sequences have been calculated to assess the applicability of the assumptions traditionally made in 1-D calculations for the evolution of close binaries. The companion in the 2-D calculations is assumed to be a gravitational point source. These calculations are performed from the ZAMS to very close to when mass transfer would begin. We find that the interior properties of the models, such as the time history of the central temperature, central density, and convective core mass are essentially unchanged in the 2-D models from the 1-D results. This is true even though the convective core is not quite spherically symmetric, but slightly elongated in the direction of the companion. We treat the 2-D model surface as an equipotential. The surface matches that of a Roche potential closely until the elongation toward the companion is close to that required for mass transfer. Moreover, the surface evolution as Roche lobe overflow is approached becomes so rapid that the surface may not be able to adjust sufficiently fast to remain an equipotential. We conclude the 1-D approach is satisfactory through the events covered by our calculations except possibly just before mass transfer begins.

Discovery of the Pre-Main Sequence Progenitors of the Magnetic Ap/Bp Stars?, Dominic Drouin and Gregg Wade, RMC, S. Bagnulo, ESO, J.D. Landstreet, UWO, E. Mason, ESO, D. Monin, DAO, J. Silvester, RMC, E. Alecian and C. Catala, Obs. de Paris LESIA, T. Bohm, Obs. Midi-Pyrenées, J.-C. Bouret, OAMP Marseille, and J.-F. Donati, Obs. Midi-Pyrenées

The magnetic Ap/Bp stars represent about 5% of all intermediate-mass main sequence stars, and are characterised by strong, globally-ordered surface magnetic fields. The physical impact of the presence of these fields is clear: atmospheric structure, photospheric chemical abundances, mass loss, rotation, and ultimately stellar evolution are all modified, to various extents, due to the interaction of the magnetic field with the stellar plasma.

Remarkably, the origin of these magnetic fields remains a total mystery. In order to trace the presence of these fields back to the pre-main sequence (PMS), we have undertaken an extensive search for magnetic fields in the Herbig Ae/Be (HAeBe) stars, the PMS progenitors of the main sequence intermediate-mass stars. Using both the FORS1 spectropolarimeter at the ESO-VLT and the brand-new ESPaDOnS spectropolarimeter at the CFHT, we have surveyed over 50 HAeBe stars for the presence of longitudinal magnetic fields. Here we review the details of our investigation, and announce the detection of magnetic fields and chemical peculiarities in the HAeBe stars HD 72106 and HD 101412. These detections may well represent the identification of the pre-main sequence progenitors of the magnetic Ap/Bp stars.

At the same time, we fail to confirm claims by Hubrig *et al.* (2004) of the presence of magnetic fields in the Herbig Ae star HD 139614.

The Spiral Structure of the Galaxy's Second Quadrant in H I and H II, T. Foster, HIA/National Research Council

The spiral design of the Milky Way's second quadrant ($90° \leq l \leq 180°$, $-3° \leq b \leq +7°$) is determined from new distances to 70 H II regions and 20 Supernova Remnants (SNRs), and to the H I peaks typically associated with the spiral arms. The H I modelling method of Foster (2005) is used. This is an alternative method to kinematic and spectrophotometric distance determinations, from which the long-standing disagreement between the distances to the H I arms and H II regions descends. Results of these classical distance methods are shown to exceed upper-limit distances to many objects. Most importantly, the discrepancy between the H I and H II Perseus arm is resolved with the new method. The Perseus spiral arm is found to be very well defined by the majority of optically brilliant H II regions, and similar spiral structure is followed by the density peaks of neutral hydrogen. A logarithmic spiral design with pitch angle of 10 degrees best describes the Perseus H I arm. An important new observation is that SNRs are found to cluster together with groups of star formation regions.

Cold Hydrogen, Spiral Structure, and the Evolving ISM, Steven J. Gibson, A.R. Taylor and J.M. Stil, University of Calgary, P.E. Dewdney and L.A. Higgs, Herzberg Institute of Astrophysics, C.M. Brunt, University of Massachusetts, and S.T. Strasser, University of Minnesota

Cold atomic gas contains some 30% of the mass of the interstellar medium (ISM) in clouds occupying only a few percent of the ISM volume. The arcminute resolution of the International Galactic Plane Survey (IGPS) allows these clouds to be imaged over a large area as 21cm-line H I self-absorption (HISA) shadows against warmer background H I emission. The IGPS HISA features have several characteristics in common with molecular clouds: (1) rich, intricate structure over many size scales; (2) concentration at radial velocities expected for spiral arms; and (3) gas temperatures often in the few tens of Kelvin range. Despite these similarities, many HISA features lack CO emission. Equilibrium ISM models require molecular gas to maintain the cold H I temperatures seen in both HISA and continuum absorption studies. But what if the HISA clouds are not in equilibrium? We suggest that the IGPS HISA may trace cooling atomic gas in transition to the molecular phase, following passage through a spiral arm shock. Such ISM evolution is a natural precursor to massive star formation in spiral arms.

The Blue Bump in Spectral Line Bisectors, David Gray, University of Western Ontario

Most spectral lines in stellar spectra are slightly asymmetric. This asymmetry is conveniently expressed by using the bisector of the line. Bisectors of solar lines typically have a slightly distorted C shape, and many cool stars mimic the Sun. But there are very significant differences from one star to the next depending primarily on the vigor of the granulation and the structure of the star's atmosphere. The interesting relation discussed here is the coupling of the height of the "blue bump" (blue-most point on the bisector) with luminosity: the more luminous the star, the lower the blue bump. As a luminosity discriminant, the blue bump is about five times better than a standard spectral type classification. As a revealer of secrets about stellar atmospheres, it tells us that the brighter the star, the higher in the atmospheres the granulation penetrates. These results are based on observations taken at the Elginfield Observatory at UWO.

MOST, *Modes and Models,* David Guenther, Saint Mary's University, and the *MOST* Science Team

Stellar model analysis of the first successful seismic observations of a star from space are presented. The low frequency radial p-modes of eta Boo observed by *MOST (Microvariability and Oscillations of STars)* are used to constrain eta Boo's composition, mass, and age. *MOST* is a micro-satellite specifically designed to observe parts-per-million luminosity variations in bright stars. The *MOST* data when combined with ground-based observations imply that the outer layers of our standard models of eta Boo are inaccurate.

Discovery of PAHs in the Halo of NGC 5907, Judith Irwin, Queen's University, and Dr. Suzanne Madden, CEA/Saclay, Service d'Astrophysique

We report the discovery of mid-IR aromatic hydrocarbon spectral features in the halo of the edge-on galaxy, NGC 5907. This galaxy has a low star formation rate and previous searches for high latitude ionized gas and optically absorbing dust produced only upper limits. We have used archival *ISO* data in the LW2, LW5, LW6, LW7, LW8, and LW10 bands of ISOCAM and find high latitude emission in the 7.7 and 11.3 micron features as well as the combined 6.2, 7.7, and 8.6 micron features of LW2. The high latitude emission is highly structured, similar to that seen in other galaxies in different wavebands, and have characteristic scale heights of 3 to 5 kpc. Note that there is some controversy about using the term PAH for the mid-IR spectral features, but we use it here for consistency with most of the literature.

Highlights of Science Results from the Odin *Submillimetre Satellite,* Sun Kwok, University of Calgary

Odin is an international astronomy/aeronomy mission led by Sweden, with Canada, France, and Finland as partners. Canadian contributions include optical design, integration, and testing of the submillimetre receivers and spectrometers, development of software for command and telemetry extraction, scheduling, data analysis, as well as participation in the operation of the satellite.

Since *Odin* was the second submillimetre telescope in space and the first to have tunable receivers, it allows many molecular transitions to be detected for the first time. Its wide spectral coverage also makes possible the observations of broad lines in stellar envelopes, galaxies, and planetary atmospheres. Highlights of science results include the first spectral scan of Orion KL in the 485-585 GHz range, the detection of isotopic lines of the ground-state transition of water, very low abundance limits for molecular oxygen, anomalously high abundance of water and ammonia in carbon star envelopes, and detection of water in comets and the atmospheres of Mars.

Support of the *Odin* work in Canada was provided by the CSA and NSERC.

The Quasar 3C454.3: An Extragalactic Reference Source for the Gravity Probe B *Mission*, J.I. Lederman, N. Bartel, R.R. Ransom and M.F. Bietenholz, York University, M.I. Ratner, I.I. Shapiro and D.E. Lebach, CfA, and J.-F. Lestrade, Obs. de Paris

We have observed the quasar 3C454.3 at 3.6 cm with a VLBI array of 12 or more stations about four times per year since 1997 in support of the NASA-Stanford *Gravity Probe B* mission *(GP-B)*. *GP-B* is designed to measure the geodetic and frame-dragging effects predicted by general relativity via the measurement of the precessions of four gyroscopes in a drag-free orbit about the Earth. A "guide star," HR 8703 (IM Pegasi), serves as the positional reference for the *GP-B* spacecraft relative to which the precessions are measured. The quasar 3C454.3, in turn, serves as a distant extragalactic source relative to which the motions of HR 8703 can be measured in an inertial frame. Our mission requirement is to determine the proper motion of HR 8703 relative to an inertial frame with standard error < 0.15 mas yr^{-1}. Structural changes in 3C454.3 over the course of our several years of observations could have a significant impact on the astrometric accuracy that we can attain. In this talk I will discuss the degree of stability of the structure of 3C454.3 over 31 epochs of observations, focus on some observed structural changes, and examine the effects of these changes on our astrometric results for HR 8703.

Observing Massive Stars with the MOST *Satellite: The Enigmatic WN8 Star WR123,* Laure Lefèvre, A.F.J. Moffat and S.V.M. Marchenko, Université de Montréal, and the *MOST* Team.

We present the results of intense visual-broadband photometric monitoring of the highly variable WN8 Wolf-Rayet star WR123, obtained by the *MOST (Microvariability and Oscillations of STars)* satellite. This first Canadian astronomical space telescope observed WR123 every 30 seconds for 38 days non-stop during June/July 2004. The extraordinarily rich light curve enables one to clearly see the apparently chaotic behaviour of this star. Fourier analysis shows that no periodic signal is stable for more than ~7 days in the low-frequency domain (f < 1/d) and that no so-called "strange-mode" pulsations are found in the high-frequency domain (f > 10/d) down to the level of 0.2 mmag, an order of magnitude lower than theory predicts. On the other hand, there seems to be a relatively stable ~10 h periodic component throughout the whole run in the mid-frequency domain (1/d < f < 10/d). A 10 h period is probably too short to represent the rotation of the star itself as it exceeds by a factor of a few the break-up velocity of such stars (the radius and mass for WR123 are given in Crowther 1995). It is also too short to be orbital in nature as it would imply that the companion is orbiting inside the star itself. This 10 h period must be related to pulsational instabilities (although with a longer period than expected) and may thus be the key to finally revealing the motor in the high level of variability in this object, and others among the peculiar population of WN8 stars — and possibly beyond.

Direct Exoplanet Imaging around Sun-like Stars: Beating the Speckle Noise with Innovative Imaging Techniques, Christian Marois, Lawrence Livermore National Laboratory, R. Doyon, R. Racine, D. Nadeau, D. Lafreniere, P. Vallee and M. Riopel, UdeM, and B. Macintosh, LLNL

Indirect surveys have now uncovered more than 150 exoplanets, but are limited to planets close to the star and measure only the projected mass and orbital parameters. Both photometry and spectroscopy of exoplanets are required to derive their physical characteristics. The star to exoplanet intensity ratio (>10^8 in the near infrared) and the relative separation (< 0.5 arcseconds) significantly complicate this endeavour. Current ground- and space-based direct imaging surveys achieve an intensity ratio up to 10^4 at 0.5″ separation, a factor 10,000 from the desired goal. These surveys are limited by uncorrected atmospheric turbulence and optical surface imperfections that produce quasi-static speckles that look like exoplanets, but much brighter. Two techniques will be discussed to attenuate this speckle noise. The first is the Simultaneous Spectral Differential Imaging technique (SSDI), acquiring a number of images simultaneously at different adjacent narrowband wavelengths and combining them to attenuate speckles. The second is the Angular Differential Imaging technique (ADI), taking multiple observations while rotating the telescope or waiting for sufficient field rotation to subtract static speckles and to preserve the companion flux. Results from a dedicated SSDI camera "TRIDENT" that was mounted under PUEO/CFHT and from an ongoing ADI survey at Gemini with Altair/NIRI will be presented. Future work involving a new type of detector, the Multi-Color Detector Assembly (MCDA), will also be discussed. Combining these observation strategies and new detectors are of particular interest for specialized exoplanet finder instruments for 10-m telescopes that are currently under study, like ExAOC at Gemini, and future space-based observatories like *TPF.*

Canada's Little Space Telescope That Could: Another Year of Scientific Surprises From the MOST *Microsatellite,* Jaymie Matthews, University of British Columbia

At CASCA 2004 in Winnipeg, I announced the first scientific results from the *MOST (Microvariability & Oscillations of STars)* mission, launched in summer 2003. These included the controversial null detection of acoustic oscillations in the light output of Procyon, at odds with theory and groundbased spectroscopy, and the first direct measurement of differential rotation in a star other than the Sun, kappa 1 Ceti.

A year later, by CASCA 2005 in Montreal, I'll be able to share even more exciting astrophysics, including: ultraprecise photometric studies of exoplanetary systems like 51 Pegasi, tau Bootis, and HD 209458; new perspectives on massive stars like zeta Oph and the Wolf-Rayet star WR 123; the definitive eigenfrequency spectrum of a pulsating chemically peculiar star (HR 1217), which provides an acid test for theories of magneto-acoustic coupling; and seismology of pulsating protostars in the open cluster NGC 2264.

I'll also return to Procyon, shedding more light on the oscillation controversy by showing how *MOST* observations compare to 3-D hydrodynamical simulations of granulation in that star. And between February and May, *MOST* will monitor a G dwarf and a K dwarf to search for true analogues of the solar 5-min oscillations. Too much to fit into 50 minutes, but I'll try to convey a broad flavour of the diverse *MOST* science (and, as usual, I'll talk really, really fast).

Modelling Dusty Circumbinary Disk around B[e] Supergiant RY Sct, Alexander Men'shchikov, Institute for Computational Astrophysics, Saint Mary's University, and Anatoly Miroshnichenko, Ritter Observatory, University of Toledo, Toledo OH, USA

The supergiant RY Sct is an eclipsing binary system with a fairly large infrared (IR) excess caused by the presence of circumbinary dust. Many strong forbidden lines ([O I], [N II], [S III], [Fe II]), in combination with the near-IR excess, put it in the list of peculiar Be or B[e] stars. Although RY Sct is one of the best-studied systems, even its basic physical parameters remain unreliable. Recent IR images of the system, obtained with a 0.3 arcsec resolution at the 10-m Keck telescope, showed the dusty disk at the wavelengths 3-20 μm and stimulated us to perform its detailed modelling using our 2-D radiative transfer code. Our model reproduces all available observations of RY Sct obtained during the last few decades. The modelling demonstrated that the observations cannot be described by a single model at one moment in time, implying rapid changes in the dusty disk during the last 20 years. Assuming that a temperature of 27,000 K describes both components of the binary and that its distance is 1.8 kpc, its total luminosity is 4.2×10^5 solar luminosity. The model disk has the optical depth of 0.04 and the opening angle of 26° (between the boundaries). Dust in the disk exists between 60 AU and 10^5 AU, where it blends into the interstellar medium. We observe the disk almost edge-on, at an angle of 14° to its midplane. The total mass of the disk is 0.017 solar mass. There is a strong density enhancement at 1800 AU from the binary, which emits most of the IR radiation and is prominent in the Keck telescope images. Presumably, the dense ring has been created by a fast wind that swept out and compressed the previously lost material in the older and slower stellar wind. Our model predicts that presently there is a large amount of small, hot dust grains in the dust formation zone, whose emission changed the shape of the SED of RY Sct in the near IR. The dust density must now be significantly greater in the dust formation zone, suggesting a much higher mass-loss rate or dust-to-gas mass ratio or much lower wind velocities than before, or a combination of these factors.

Herschel/SPIRE: Mission Overview and Canadian Contribution, David Naylor, Peter Davis, and Trevor Fulton, University of Lethbridge, James di Francesco, HIA, Mark Halpern, UBC, Peter Martin, U of T, Douglas Scott, UBC, and Christine Wilson, McMaster University

The *Herschel Space Observatory* is an ESA cornerstone mission currently scheduled for launch in August 2007. *Herschel* will conduct astronomical observations across the far-infrared and submillimetre spectral range with unprecedented sensitivity. *Herschel* employs a large (3.5-m) passively cooled, low-emissivity telescope and will operate at the Sun-Earth L2 point for a period of at least three years, providing a large amount of observing time at wavelengths that cannot be accessed from even the best ground-based sites. The instrument payload will be cooled with an on-board supply of liquid helium, which determines the mission lifetime. Canada is involved in both the SPIRE and HIFI instruments on *Herschel.* The main scientific goals of SPIRE will be reviewed and the current performance figures derived from testing of the flight model instrument, a role in which Canada is actively involved, will be presented.

Starforming Galaxies at High Redshift as seen by SCUBA and Spitzer, Alexandra Pope, Douglas Scott, and Anna Sajina, University of British Columbia, Mark Dickinson, NOAO, Colin Borys, Caltech, Ranga-Ram Chary, SSC, and Glenn Morrison, NOAO

Both SCUBA and *Spitzer* are able to select high-redshift starforming galaxies that contribute significantly to the cosmic infrared background. Our understanding of galaxy evolution is dependent on making the connection between these two high-redshift galaxy populations and determining how they are related to galaxies in the local Universe. While infrared luminous galaxies selected by *Spitzer* are much more numerous than the SCUBA population, there is significant overlap. This overlap can be explored using the multiwavelength dataset from the Great Observatories Origins Deep Survey (GOODS) Northern field, as it contains both the deepest *Spitzer* observations and a large SCUBA imaging campaign. We find that 90% of the SCUBA galaxies in GOODS North are detected in all 5 of the available *Spitzer* bands. This additional photometry along with optical and radio detections allow us to obtain accurate photometric redshifts and fully characterize the spectral energy distribution of an unbiased sample of SCUBA galaxies. Given that we have the first sample of sub-mm sources, which is almost completely identified, our results have important implications for future extragalactic sub-mm surveys with SCUBA-2. Based on our results, which make use of the deepest follow-up data, we can make predictions for the optimal depth at optical, infrared, and radio wavelengths for follow-up observations and stress that the deep infrared imaging should be a top priority.

A Zoo of Pulsar Wind Nebulae: Clues from High-Resolution X-ray Observations, Samar Safi-Harb, University of Manitoba

Plerions (or Pulsar Wind Nebulae, PWNe) are an ideal laboratory to study the physics of neutron stars, relativistic shocks, particle acceleration, and the interaction between pulsar winds and their surroundings. The Crab Nebula has been recognized for decades as the prototype for plerions, a class that includes about a dozen objects in our Galaxy. Some of these objects however have (peculiar) properties that differentiate them from the Crab Nebula, including a low-frequency spectral break and weak (or absence of) X-ray pulsations, suggesting that these are plerions of a "second kind." I will briefly overview the properties of these objects and the theory advanced to explain them. I will then highlight the X-ray studies of a few objects, and describe how future *Chandra* and *XMM* studies will shed light on the intrinsic properties of their powering engines and their environment.

Catching the Fast Migrators: Interactions between Gap-Opening and Sub-Gap-Opening Bodies in a Protoplanetary Disk, Edward Thommes, CITA

Young planets interact with their parent gas disk through tidal torques. An imbalance between inner and outer torques causes bodies the mass of gas-giant solid cores, ~ 10 Earth masses, to undergo orbital decay on a timescale generally shorter than their formation time ("Type I" migration). This makes the first stage of giant-planet formation problematic; however, bodies that do manage to reach gas-giant size (of order 10^2 Earth masses) open a gap in the disk and subsequently migrate more slowly, locked into the disk's viscous evolution ("Type II" migration). In a young planetary system, both types of bodies likely coexist. If so, differential migration will result in close encounters between them. We numerically investigate the resulting dynamics, and find, as has been previously suggested, that sub-gap-opening bodies have a high likelihood of being resonantly captured when they encounter a gap-opening body. A gas-giant planet thus tends to act as a barrier in a protoplanetary disk, stopping smaller, faster-migrating protoplanets outside of its orbit. In this way, a gas-giant planet may facilitate the formation and survival of subsequent planets — in particular, the next gas-giant's core.

Origin of the Initial Mass Function: Simulations of MHD Turbulence, David Tilley and Ralph Pudritz, McMaster University

One of the long-standing problems in star formation is how a giant molecular cloud (GMC) fragments into stars, and why these stars are not all the same. A scenario that has the fragmentation driven by turbulent motions in the GMC has had great success in reproducing the observed mass distribution of stars. We present a series of numerical simulations of MHD turbulence with initial conditions similar to that found in the centre of a cloud like Orion. Our initial conditions are determined from two primary parameters, one controlling the strength of gravity (the number of Jeans masses on the grid), and one controlling the strength of the magnetic field (the ratio of the gas pressure to magnetic pressure). We identify whether individual cores are bound via the full virial equation, and calculate the distribution functions for the core masses and specific angular momenta. We find that in order to produce a star cluster with cores that are well-magnetized and that have a core mass spectrum resembling the IMF, we find that a large number (~30) of Jeans masses must be initially present, which argues for a rapid cloud/cluster formation.

POSTER PAPERS/LES PRÉSENTATIONS AFFICHAGES

In Search of the Rotation Rate of Wolf-Rayet Stars, Chené André-Nicolas and N. St-Louis, Université de Montréal

The rotation rate of Wolf-Rayet (WR) stars is a fundamental parameter, but still entirely unknown. However, for certain WRs, it is currently well known that perturbations at the surface propagate in the wind and generate large-scale structures. The affect of the star's rotation on these structures, called Co-rotating Interacting Regions (CIR), can be seen by spirals generated in the wind, which in turn produce periodic variations in spectral lines. By studying the frequency of these variations it is possible to determine the rotation period, and thus the rotation rate of WR stars. The following shows how we monitored several CIRs in numerous stars in order to determine the intrinsic rotation rate of WR stars.

Time-resolved Photometry and Spectroscopy of T dwarfs, Étienne Artigau, René Doyon and Daniel Nadeau, Université de Montréal

When substellar-mass objects cool, they successively go through the M, L, and T spectral types; the latter being the coolest extension of the HR diagram. The L/T transition is defined as the moment when methane spectroscopic signature appears in the near-infrared. Also, the dust clouds that seclude a large fraction of metals in the dwarf atmosphere sink below the photosphere at this transition. This disappearance of clouds has a significant effect on the L/T dwarf colours and has been invoked to explain the rapid change of colour of brown dwarfs around 1200 K.

The position of some brown dwarfs at the L/T boundary and early T in the near-infrared colour-magnitude diagram also suggests that their surface can be partially cloudy. Because of rotation, this patchy distribution of clouds can result in temporal variability. If very short-lived (*i.e.* a few hours at most) atmospheric patterns exist, variability can also arise on timescales shorter than the rotation period. Time-resolved observations of T dwarfs thus have the prospect of confirming the uneven cloud cover of L/T transition and early-T brown dwarf atmospheres and determining the lifetime of such cloud patterns. Using the CFH and OMM telescopes, we undertook near-infrared photometric and spectroscopic observations of a sample of T dwarfs to look for such a variability. I will discuss these results and their implications for brown dwarf atmospheric models.

POL-2: A Polarimeter for SCUBA-2, Pierre Bastien and É. Bissonnette, Université de Montréal, P. Ade, G. Pisano and G. Savini, Cardiff University, T. Jenness, Joint Astronomy Center, D. Johnstone and B. Matthews, Herzberg Institute of Astrophysics

SCUBA-2 is a bolometer array camera for use at the James Clerk Maxwell Telescope (JCMT) and is currently under development in the UK, Canada, and the USA. This new instrument will work in two wavelength bands, 850 and 450 microns, and is currently scheduled to start operation in 2006. Here we present current options for a polarimeter, POL-2, that is being built for SCUBA-2.

The polarimeter will have an achromatic continuously rotating half-wave plate in order to modulate the signal at a rate faster than atmospheric transparency fluctuations. Such a modulation should improve significantly the reliability and accuracy of sub-mm polarimetric measurements. The signal will be analyzed by a wire-grid polarizer. For calibration, a removable polarizer will also be available. The components, in the order that the radiation will encounter them, are the calibration polarizer, the rotating wave plate, and the polarizer. The components will be mounted in a box fixed permanently in front of the entrance window of the main cryostat of SCUBA-2. All components will be mounted so that they can be taken in and out of the beam remotely, making it very easy and fast to start doing polarimetry at the telescope. Software will be provided to control all the basic functions of the polarimeter. A data reduction pipeline capable of producing near publication quality results will be provided for both on-line and off-line reduction of polarimetric data.

This polarimeter will be the most sensitive instrument for the detection of polarized radiation in the submillimetre regime. This will be possible by taking advantage of the extra sensitivity, imaging speed, and improved image fidelity of the new SCUBA-2 camera.

Solar Flares: Avalanche Models and Data Assimilation, Eric Bélanger, Paul Charbonneau, and Alain Vincent, Université de Montréal

Solar flares play an important part in space meteorology because they can eject charged particles that are the source of the geomagnetic storms on Earth. These storms can interfere with communication satellites and overload electric transformers. We need first to understand the physical mechanisms at the origin of flares and to be able to predict them sufficiently in advance. Several models to explain the mechanism of solar flares were suggested. We have investigated the self-organized criticality (or avalanche) model where an instability related to the reconnection of the magnetic field lines is propagated. The techniques of data assimilation were applied to a 2-D avalanche model. Data assimilation generates better forecasts by taking advantage of both the theoretical/numerical models and the observations. With the increase in computational power and the numerous satellites *(SOHO, TRACE)* observing the Sun with an improved spatial and temporal resolution, these methods will surely give us a better understanding of solar flares.

FUSE *Observations of PG 1716+426 stars,* Jean-Philippe Blanchette, Université de Montréal, P. Chayer, Johns Hopkins University, F. Wesemael, G. Fontaine, and M. Fontaine, Université de Montréal, J. Dupuis and J.W. Kruk, Johns Hopkins University, and E.M. Green, University of Arizona

The PG 1716+426 stars are pulsating subdwarf B stars known to exhibit very low amplitude (≤ 5 mmag), long-period (2000-8000 s), multiperiodic luminosity variations. These variations are associated with high radial order g modes. In the PG 1716+426 stars, the k driving mechanism is currently thought to be similar to that which is relevant to the hotter, shorter-period EC 14026 stars. The driving is linked to an opacity bump associated with a local enhancement of the abundance of iron and, presumably, other iron-peak elements in the envelope brought about by radiative element support. The PG 1716+426 stars might represent an ideal testing ground for this model, as they have cooler temperatures and likely lower stellar-wind mass-loss rates than the EC 14026 stars. In this work, we describe a set of *FUSE* spectra secured with the aim of testing these ideas, and provide a preliminary analysis of the abundances of iron peak elements in the sample of five PG 1716+426 stars observed to date.

The FUSE *Spectra of two WC4+O5-6 III-V binaries in the LMC,* Philippe Boisvert, S.V. Marchenko, N. St-Louis, and A.F.J. Moffat, Université de Montréal

O stars are the most massive of the main-sequence stars. Wolf-Rayet (WR) stars are evolved O stars that have lost most or all of their hydrogen. Both emit stellar winds with very high terminal velocity and very high density. The mass loss for these stars is then also very high, and that affects profoundly their evolution. Such strong winds also have impacts on the local interstellar medium by pushing it and by increasing its metallicity. For all these reasons, it is of the greatest interest to better know the properties of these winds. One of the best ways to do it is to study the wind-wind collision in a O+WR binary system. Such a collision leads to the formation of a cone-shaped shock surface around the star having the wind with the lowest momentum. This cone spins with the orbital motion, which induces variations in the binary spectrum with phase. These variations allow deducing a lot of information about the geometry of the shock cone and about the winds of both stars. My project is on two WR+O binaries in the Large Magellanic Cloud (LMC): Br22 and Br32. These two systems have almost identical spectral types (WC4+O5-6 III-V), but have periods of respectively 14.9 and 1.9 days. This great similitude makes them very interesting to study in parallel. Also, both systems have been intensively studied in the optical spectrum recently (Bartzakos 2001). My work is to complement this latter work by studying the far-ultraviolet portion of the spectra, obtained at different phases with the *Far Ultraviolet Spectroscopic Explorer* (FUSE), a satellite spectroscopic telescope. The strongest lines in this portion is OVI_1032-1037 (OVI is only observable with FUSE) and CIII_1175. I fitted these lines with a program made by Sergey Marchenko. This code accounts for the orbital geometry of the stars and the cone, the atmospheric eclipses, and the extra emission produced by the shock region. With that, I have been able to put constraints on many parameters of the stellar winds in Br22 and Br32.

Binary Black Holes in Merging Ellipticals: Evolution of the Binary and Consequences on the Structure of the Host Galaxy, Silvia Bonoli, University of Toronto, and John Dubinski, Department of Astronomy & Astrophysics, University of Toronto

We use N-body simulations to study the merging of two elliptical galaxies with central supermassive black holes. The study of merging of bulges with a central point mass is of relevant astrophysical interest, since the formation of binary black holes seems to play a major role in the evolution of the properties and the structure of merged galaxies. Previous simulations (*e.g.* Makino 1997; Milosavlievic & Merritt 2001) have shown that the central stellar density profile, the stellar orbits, and the global structure of merging relics are strongly influenced by the presence of a black hole binary system. Our simulations have the advantage of higher resolution and more realistic galaxy models. We use two self-consistent models. The first is from Widrow & Dubinski (2005), consisting of an Hernquist profile for the stellar component (Hernquist 1990), a Navarro, Frenk, and White dark halo (Navarro, Frenk, & White 1996), and a central massive particle. We constructed a second model, consisting of a Jaffe density profile for the stellar component (Jaffe 1983), an Hernquist profile for the halo, and a central massive particle. We are studying the evolution of the binary black holes, their effects on the host galaxy, and we are examining the origin of the empirical relation between the mass of the central black hole and the galaxy central velocity dispersion (Magorrian et al. 1998; Gebhardt et al. 2000; Ferrarese & Merritt 2000). We are also investigating if this relation and the Fundamental Plane (Djorgovski & Davis 1987; Dressler *et al.* 1987) are preserved during mergers.

A Deep-Field Infrared Observatory Near the Lunar Pole, E.F. Borra and O. Seddiki, Université Laval, J.R.P. Angel, S.P. Worden, D. Eisenstein, and S. Silvanandam, Steward Observatory, University of Arizona, P. Hickson, University of British Columbia, and K. Ma, University of Houston

A study has been made of the feasibility and scientific potential of a 20-to 100-m aperture astronomical telescope at the lunar pole, with its primary mirror made of spinning liquid at < 100 K. Such a telescope, equipped with imaging and multiplexed spectroscopic instruments for a deep-infrared survey, would be revolutionary in its power to study the distant Universe, including the formation of the first stars and their assembly into galaxies. Our study explored the scientific opportunities, key technologies, and optimum location of such a Lunar Liquid Mirror Telescope (LLMT). An optical design for a 20-m telescope with diffraction limited imaging over a 15-arcminute field has been developed. It would be used to follow up on discoveries made with the 6-m *James Webb Space Telescope,* with more detailed images and spectroscopic studies, as well as to detect objects 100 times fainter, such as the first high-redshift star in the early Universe. A model was made of a liquid mirror spinning on a superconducting bearing, as will be needed for the cryogenic, vacuum environment of the LLMT. Reflective silver coatings have been deposited for the first time on a liquid surface, needed to make infrared mirrors at ~80 K. Issues relating to polar locations have been explored. Dust on the optics or in a thin atmosphere, though unlikely to be problematic at the poles, should be investigated *in-situ*. Issues relating to polar locations have been explored. Locations at or within a few km of a pole are preferred for deep-sky cover, and allow for long integration times by simple instrument rotation. This revolutionary mission concept could provide a scientific focus to NASA's planned exploration of the Moon, just as currently *HST* stands as a major achievement of its Shuttle Program.

Dusty Halos and the Sub-mm/Radio Correlation in Spiral Galaxies, Rupinder Brar and Judith Irwin, Queen's University

Observations with the Giant Metrewave Radio Telescope (GMRT) and the Submillimetre Common-User Bolometer Array (SCUBA) on the James Clerk Maxwell Telescope (JCMT) have recently revealed a sub-mm/radio correlation in the disks and high-latitudes of edge-on spiral galaxies. Along with evidence for this correlation, its origins and implications towards the famous FIR/radio correlation are discussed. The SCUBA observations at 450 and 850 microns have provided not only the means to calculate global dust temperature and mass, but also an unprecedented spatial description of the temperature and mass of cold dust in our sample. Finally, energy and temporal considerations for high-latitude dust are examined to help identify the means of dust transport to the halo.

A High Resolution Study of Galactic Depolarization Features, Christy Bredeson, J.S. Dever, and A.R. Taylor, University of Calgary

By looking at the Galaxy in radio wavelengths, we gain knowledge about the magnetic fields of our Galaxy and the properties of gases in the interstellar medium. One curious feature seen in images of polarized radiation from the plane of the Galaxy is dark depolarization structures, or canals. These structures, not present in total-intensity maps, take the form of dark filamentary or ring-like channels, and are seen throughout the Galaxy, primarily on arcminute scales. Much controversy exists as to the nature of these filaments; previous observations have not been conclusive due to their low resolution. Presented here will be an investigation and analysis of these depolarization features using recently obtained high-resolution data from Arecibo Observatory, providing an unparalleled view of these structures.

Close Pairs of Galaxies: Merger and Mass Accretion Rate Evolution at High Redshift, Carrie Bridge and Ray Carlberg, University of Toronto, Patrick McCarthy, Carnegie, and Dave Patton, Trent University

Galaxy mergers and interactions are an integral part of the paradigm describing the formation and evolution of galaxies. In particular, mergers at high redshift provide convincing evidence of the heirarchical assembly of galaxies. Characterising galaxy mergers and in turn the merger rate evolution can directly test models describing how galaxies evolve and how structures are formed in the Universe. One of the most promising measures of the galaxy merger rate is the evolution in the population of close pairs. Currently this measurement is highly uncertain, and strongly debated. I will discuss our current understanding of the merger rate evolution and why it is important to study. I will then show how my thesis work, which involves the CFHT Legacy Survey and LCIR Survey, will measure close pairs in the redshift range $0.5 < z < 3.0$, which is at the very peak period of galaxy formation.

Galaxy Clusters at z > 1 in the IRAC Shallow Survey, Mark Brodwin, Caltech/JPL, P. Eisenhardt, A. Gonzalez, A. Stanford, D. Stern, A. Dey, and B. Jannuzi, IRAC Shallow Survey, NDWFS, and AGES Survey Teams

The IRAC Shallow Survey (Eisenhardt *et al.* 2004) is a wide-field (8.5 deg^2) 3.6-8 um survey in Boötes designed to study the evolution of large-scale structure since $z = 2$. A primary goal of the survey is to carry out a search for high redshift $1 < z < 2$ galaxy clusters. In addition to the powerful cosmological constraints provided by this sample, it will permit a study of the mass assembly history in rich environments, including an investigation of the "downsizing" phenomenon reported in several recent studies (*e.g.* Treu *et al.* 2005). Our cluster search methodology consists of a wavelet decomposition of structure in dz = 0.2 photometric redshift slices. This technique takes full advantage of the extensive ancillary data in the Boötes field, and, importantly, makes no assumptions about the colours of cluster members, which are increasingly uncertain at redshifts approaching $z = 2$. We have discovered ~20 high-significance cluster candidates at $1 < z < 2$ and are pursuing follow-up observations.

Simultaneous Radial-Velocity and High-Resolution Spectroscopic Monitoring of Cool Giant Stars, Kevin Brown and David F. Gray, University of Western Ontario

We present results from the simultaneous radial velocity and line profile monitoring of cool giant stars. Spectroscopic observations with resolving power of R = 100,000 were made using the University of Western Ontario's Elginfield Observatory. The radial-velocity measurements use telluric lines within the spectrograph as a reference against which the stellar spectra are compared. Our technique avoids contamination of the observed stellar spectrum by the reference spectrum, a commonly encountered problem in precision radial-velocity measurements. We are then able to measure line-depth ratios and other spectroscopic parameters of interest in concert with the radial-velocity measurements. This approach is useful for studies of pulsation, granulation variations, surface features, magnetic cycles, non-radial oscillations, and orbital motion arising from extra-solar planets or binary-star companions.

Chiaroscuro: From Pericentre Glow to Apocentre Enhancement — Illuminating the Secular Structure of Dusty Planetary Systems, Chris Capobianco and Dr. Joseph M. Hahn, Saint Mary's University

Asymmetries are routinely observed in circumstellar dust disks, such as those seen at beta Pictoris, epsilon Eridani, AU Microscopii, HD107146, *etc.* Two broad categories of phenomenon are often invoked to explain these asymmetries: asymmetric scattering of starlight by dust (due to forward scattering, which makes the near side of an inclined disk appear brighter than the far side) and planetary perturbations (which can organize the dust orbits in nested, elliptical streamlines). Furthermore, the nature of a dusty disk's asymmetric appearance is wavelength dependent. When viewed via the disk's thermal emission, stellar heating of dust near periapse leads to the pericentre glow feature seen in images of dust-disks (Wyatt *et al.* 1999). However maps of reflected starlight of a disk reveal an apocentre enhancement, due to dust loitering near apoapse (Marsh *et al.* 2005, astro-ph/0501140). The aim of this work is to address these two broad categories, and to illustrate how it is possible to distinguish their effects in the appearance of a circumstellar dust-disk. To model the effects of planetary perturbations, we consider for now only single-planet systems, and we neglect the effects of radiation forces on the dust. We also assume that the planet's secular perturbations are the dominant disturbance in the disk. To account for the disk's asymmetric scattering of starlight, we use a Henyey-Greenstein function to describe the phase function for dust grains. Using this simple model, a disk's asymmetry is governed by just three parameters: the planet's eccentricity *(e),* the disk's inclination *(i),* and the light-scattering parameter *(g).* Comparison of synthetic optical-depth maps of dusty disks generated using our models can then be used to discriminate between these two competing phenomenon. We will also present a simple analytic expression that relates the disk's surface brightness profile to *e, i,* and *g,* and will also present preliminary results for our analysis of the beta Pictoris system.

Galactic FUV Extinction Determined Using FUSE, Stefan Cartledge and Geoffrey Clayton, Louisiana State University, Karl Gordon, Steward Observatory, U.J. Sofia, Whitman College, and Mike Wolff, Space Science Institute

We present an extinction analysis of sight lines selected from all public *FUSE* observations of Galactic O and B stars. Over 90% of Milky Way extinction curves sampled from IR through UV wavelengths (UV coverage provided by *IUE*) conform to the CCM family of curves based on R(V), a single parameter linked to grain size (Cardelli, Clayton, & Mathis 1989, *ApJ,* 345, 245; Valencic, Clayton, & Gordon 2004, *ApJ,* 616, 912). The far-ultraviolet (FUV) portion of this formulation, however, was based only on a few sight lines observed by *Copernicus*. *FUSE* has observed a large number of diverse sight lines through the Galaxy, and a preliminary sample including paths characterised by a wide range of R (Sofia *et al.* 2005, *ApJ,* in press) suggests that CCM does not predict extinction in the FUV as accurately as it does at *IUE* wavelengths. We include in this poster a selection of sight lines from among the sample we are studying in search of a more accurate FUV extinction description.

One Megacam Field is not Enough! The Huge Nearby Dwarf Galaxy NGC 6822, Serge Demers, Université de Montréal, and Paolo Battinelli, INAF, Osservatorio Astronomico di Roma

Four Megacam fields, covering a 2 × 2 degree area centred on NGC 6822, are used to investigate the structure of this Local Group dwarf. The position and magnitude of nearly one million stars have been measured by Terapix. Elliptical isodensity contours are deduced from star counts to show that the stellar halo of NGC 6822 has an ellipticity of 0.35. The position angle of the major axis, at 65 degrees differs considerably from the H I disk whose PA = 120 deg. Isodensity contours can be traced to a semi-major axis of 37 arcmin, implying that NGC 6822 has a diameter of at least 11 kpc, certainly comparable in size to the SMC.

NIR Photometry and Colours for the Bulge and Disk Components of Spiral Galaxies, Xiaoyi Dong, Christopher J. Ryan, and Michael M. De Robertis, York University

We present *J* and *K´* photometry, as well as *J–K´* colours, for the bulges and disks of a sample of approximately 100 spiral galaxies taken from the *Revised Shapley-Ames Catalog* and the *Second Reference Catalogue of Bright Galaxies*. Data were obtained from 2MASS, subject to the criteria that the apparent *B* magnitude $B_T \leq 12.5$ mag and the declination $\delta > 0°$. The bulge and disk components have been deblended using GALFIT, a two-dimensional galaxy fitting program. The sample galaxies, representing morphological types Sa through Sc ($T = 0–5$), have also been studied in some detail spectroscopically by Ho, Filippenko, & Sargent (1997). Colour-magnitude diagrams and colour gradients for each of the galaxies are also presented and described. We illustrate the Simien and de Vaucouleurs diagrams — bulge-to-disk ratio vs. morphological type — for the *J* and *K´* bands. While there is a clear trend with morphology, there is a large dispersion for each morphological type.

An Improved Model Atmosphere Analysis of Cool DQ and DZ White Dwarfs, Patrick Dufour and P. Bergeron, Université de Montréal

We report on a detailed analysis of cool white dwarfs showing carbon molecular bands (DQ stars) or metallic lines (DZ stars). Photometric and spectroscopic observations of a large sample of DQ and DZ stars are analyzed with new model atmospheres appropriate for these stars in order to derive improved atmospheric parameters (Teff, log *g*, and chemical abundances). We show how the presence of molecular and metallic features observed in the spectra of DQ and DZ stars provides us with a unique opportunity to probe the physical conditions met in their atmospheres. We discuss the astrophysical implications of our results on our understanding of cool white dwarfs, notably on the thickness of the helium layer, the chemical composition, and the temperature scale of these stars.

FUSE *Observations of ZZ Ceti Stars,* Jean Dupuis, Johns Hopkins University, Nicole Allard, Institut d'Astrophysique de Paris, Pierre Chayer, Johns Hopkins University/University of Victoria, Guillaume Hebrard, Institut d'Astrophysique de Paris, John Kielkopf, University of Louisville, and Jeff Kruk, Johns Hopkins University

We present *FUSE* observations of the brightest known ZZ Ceti stars, G226-29 and G185-32. These stars help define the blue edge of the ZZ Ceti instability strip in which hydrogen-rich white dwarfs are found to pulsate with period ranging from 100 to 1000 s. The spectra are detected between 1050 and 1180 Å and show strong absorption features due to quasi-molecular satellites of H_2 and H_2+ as well as an absorption feature at 1130 Å due to a resonance in the bound-free cross section of H−. We explore the potential of these features in helping constraint the stellar parameters for these two key white dwarfs.

Light Pollution in Québec: Progress Report, Yvan Dutil, ABB Bomem

Quebecers are among the worst light polluters in the world, producing 2 to 3 times more light than Americans or Europeans. Nevertheless, there is hope of losing this infamous title in the near future. Recently, there was a large increase in awareness both from the public and policy makers and action is now taken to preserve the dark sky elsewhere in Quebec.

A Dark-Sky Preserve is now being put in place around Mont Mégantic Observatory. With a radius of 50 km, it will be will be, once completed, one of the largest in North America. In addition, the city of Sherbrooke is putting in place its own dark-sky policy to complement the protection provide by the preserve. These efforts are expected to stop the growth of light pollution at Mont Mégantic, which has doubled in the last 25 years. Even the cities of Montréal and Québec are taking action against the light pollution.

This is a good example of how a few dedicated persons can change perceptions and fight efficiently against light pollution.

The Effect of Large-Scale Power on Very-Small-Scale Structure in CDM Simulations, Pascal Elahi, Larry Widrow, and Rob Thacker, Queen's University

There is a growing interest in small-scale dark-matter structures. Some theories have proposed that substructure exists down to Earth masses. Such objects might produce features in the energy spectra measured by both direct and indirect dark-matter detection experiments. The study of very-small-scale structure in the CDM-dominated Universe presents a special challenge for computational cosmology. We present the results from a series of numerical experiments designed to quantify any effects due to large-scale density fluctuations that might hinder or aid the formation of structure. Preliminary results that suggest the inclusion of large-scale power enhances the formation of large-scale structures while removing small-scale substructure.

Chandra Observations of Open Cluster h Per, N.R. Evans, S. Wolk, N. Bizunok, B. Spitzbart, F. Seward, and S. Kenyon, Smithsonian Astrophysical Observatory, T. Barnes, University of Texas, and J.M. Pasachoff, Williams College

We have obtained a 40 ksec ACIS observation of the open star cluster h Per in December 2004, from which we have identified more than 200 X-ray sources and found optical counterparts for many of them. We are processing the h Per data with the ANCHORS pipeline, which is being used to process *Chandra* observations of star forming regions in a uniform manner. This will provide fits to the instrumental low-resolution spectra for cool pre-main sequence stars in h Per including fluxes, temperatures, and absorption.

Monte Carlo Simulations of the Galactic Population of Radio Pulsars, Claude-André Faucher-Giguère and Vicky Kaspi, McGill University

We report on a detailed Monte-Carlo-based population synthesis of isolated, non-recycled Galactic radio pulsars, with the goal of constraining the properties of the underlying population. Recent major surveys, improvements to models of the interstellar medium, and new astrometric measurements make such a study particularly timely. We find no evidence for bimodality in the space velocity distribution, with a 1-D exponential model having 3-D mean velocity (380 ± 50) km s^{-1} describing the data adequately. We find strong evidence for a depletion in the population near the Galactic Centre. We find good evidence for a correlation between radio and spin-down luminosities. Our best estimate for the Galactic radio pulsar birthrate is (3.9 ± 0.1) psr century^{-1}, where the quoted error is statistical only.

Fundamental Properties of SNRs in the CGPS, Konstantin Fedotov, Roland Kothes, and Tyler J. Foster, NRC, Dominion Radio Astrophysical Observatory

As the most significant source of chemical enrichment, energy input, and cosmic ray production in the interstellar medium, supernovae play an important role in the evolution of our Galaxy. Detailed understanding of the properties of Galactic supernova remnants (SNRs) — sizes, energies, statistics, *etc.* — are thus of great importance in astrophysics. High-resolution (~1´) wide-field images of all major constituents of the Galactic ISM are now available in the Canadian Galactic Plane Survey (CGPS). We present a review of SNR properties based on data from the CGPS. We have included 36 SNRs, located in the Galactic plane between 65° and 170° of Galactic Longitude. The spectral-index distribution peaks as expected at $\alpha = -0.5$, typical for mature adiabatically expanding shell-type SNRs. Newly determined distances and systemic velocities indicate that all of the SNRs are located in the spiral arms. Unlike in the recent published literature we do not find a clear correlation between radio surface brightness and diameter of the SNRs (Σ-D relation). Additionally we found that for most SNRs the peak polarization observed at 1420 MHz falls sharply for foreground dispersion measures DM greater than ~25 pc cm^{-3} or distances larger than about 2.5 kpc, indicating a relation between beam depolarization and foreground electron density.

Braking the Gas in the beta Pictoris Disk, Rodrigo Fernandez, Yanqin Wu, and Alexis Brandeker, University of Toronto

The main-sequence star beta Pictoris has a well known debris disk composed of gas and dust, which is thought to be a remnant of (possibly still ongoing) planet formation. This system poses an interesting puzzle: due to strong radiation force, several constituents of the gas are expected to reach high radial velocities, a result that contradicts observations, which show the gas to be consistent with Keplerian rotation around the star. A braking mechanism is thus acting on these accelerated particles. We have explored several physical mechanisms that can account for slowing down the accelerated gas. The ultimate goal is to constrain the late gas evolution in circumstellar disks, an issue directly related to the formation of gaseous planets.

Rotation and Chemical Abundances of Magnetic Ap/Bp Members of the Open Cluster NGC 6475, Colin Folsom and Gregg Wade, Royal Military College, John Landstreet, University of Western Ontario, and Stefano Bagnulo, European Southern Observatory.

Membership in the open cluster NGC 6475 (age = 220 Myr) has been confirmed for the four magnetic Ap/Bp stars HD 162305, HD 162576, HD 162725, and HD 320764. High-resolution spectra of the Ap stars, obtained within the context of the POP project with the UVES spectrograph at the ESO-VLT, were modelled in detail using LTE spectrum synthesis. Based on direct comparison of the observed and calculated line profiles, projected rotational velocities and photospheric abundances of 11 elements have been derived.

Deep Ecliptic Survey of the Kuiper Belt, Wesley Fraser, University of Victoria, JJ Kavelaars and Jason MacWilliams, National Research Council

Here we present the results of a deep ecliptic survey of the Kuiper belt. The survey has an arial coverage of 2 square degrees, to a limiting magnitude of m_50 ~ 25.5 in R band. The search process involved use of image subtraction to remove background sources. Consecutive images were shifted and stacked at rates of motion physical to KBOs. We present a measure of the luminosity function, as well as a measure of the inclination and size distributions from this result. Evidence for the location of the plane of the belt is also discussed.

The Discordance of Mass-Loss Estimates for Galactic O-Type Stars, Alex Fullerton, University of Victoria/John Hopkins University/Space Telescope Science Institute, D.L. Massa, SGT, Inc./NASA's Goddard Space Flight Center, and R.K. Prinja, University College London

We have used new *FUSE* and archival *Copernicus* and *Orfeus* observations of the P v resonance doublet to estimate mass-loss rates for a standard sample of Galactic O-type stars. Since P^{4+} is expected to be the dominant ion in the winds of mid-O stars, its ion fraction is known *a priori;* and, since P is much less abundant than C or N, its resonance lines are rarely saturated and provide reliable measurements of the ionic column density. The mass-loss rates derived from P v wind profiles are typically 10 to 20 times smaller than those obtained from observations of H alpha line emission or radio continuum emission, both of which are "density squared" diagnostics. We interpret this discrepancy as an indication that the winds of O-type stars are strongly clumped.

An Empirical Study of the ZZ Ceti Instability Strip, Alexandros Gianninas, Pierre Bergeron, and Gilles Fontaine, Université de Montréal

ZZ Ceti stars are pulsating hydrogen-line (DA) white dwarfs, which are found in a rather narrow strip within the T_{eff}-log *g* plane: the ZZ Ceti instability strip. Historically, the instability strip has been studied by analyzing the ZZ Ceti stars themselves. However, an analysis of the photometrically constant DA white dwarfs that lie near the instability strip can be just as insightful. Therefore, in an effort to delineate better the boundaries of the ZZ Ceti instability strip, we have gathered optical spectra for all known constant DA white dwarfs near the instability strip. By comparing the Balmer-line profiles to synthetic spectra generated from model atmospheres, it is possible to determine with great accuracy the atmospheric parameters of these stars. These spectra have been secured as part of a broader observing campaign during which we are hoping to identify new candidate ZZ Ceti stars as well. Indeed, already two of our program stars have showed themselves to be genuine ZZ Ceti pulsators, PB 520 and G232-38. Luminosity variations in the latter were recently discovered by us at the Observatoire du mont Mégantic.

The Unquiet State of Violent Relaxation, Richard Henriksen, Queen's University

In 1967 Lynden-Bell presented a statistical mechanical theory for the relaxation of collisionless systems. Since then this theory has been studied numerically and theoretically by many authors. Nakamura in 2000 gave an alternate theory that differed from that of Lynden-Bell by predicting a Gaussian equilibrium distribution function rather than Fermi-Dirac. More recently Henriksen in 2004 has used a coarse-graining technique on cosmological infall systems that also predicts a Gaussian equilibrium distribution function. These relaxed states are thought to occur from the centre of the system outwards. Simulations of cosmological cold dark-matter halos however persist in finding central density cusps (the NFW profile), which are inconsistent with the predicted distribution functions and perhaps with the observations of some galaxies. Some numerical studies (*e.g.* Merrall & Henriksen 2003) that attempt to measure the distribution function of dark matter do find Gaussian functions, provided that the initial asymmetry is not too great. Moreover recent work at Queen's reported here by MacMillan, suggests that it is the growth of asymmetry during the infall that produces the cusped behaviour. So put briefly, the essential physics of dark-matter relaxation remains "obscure" as does the validity of the theoretical predictions. "Violent virialization" occurs rapidly, well before subscale relaxation, but the scale at which the relaxation stops (and why) remains unclear. I will present some results that argue for wave-particle relaxation (Landau damping as frequently suggested by Kandrup) and in addition I will suggest that the evolution of isolated systems is very different from that of systems constantly disturbed by infall. Isolated systems may become trapped in an unrelaxed state by the development or existence of multipolar internal structure. Nevertheless a suitable coarse graining of the system may restore the predicted distribution functions.

UVIT: Canadian Partnership in the ASTROSAT *Orbiting Observatory,* John Hutchings, Herzberg Institute of Astrophysics, and the UVIT science team

ASTROSAT will be launched by the Indian Space Research Organisation in 2007 for a 5-year mission. The observatory consists of four X-ray telescopes and two UV imaging telescopes (UVIT), all co-aligned and operating simultaneously. CSA has partnered with ISRO to provide the photon-counting UV detectors for UVIT. The Canadian science team will share the UVIT team time, and the Canadian community will use 5% of the open time. We describe the instruments and highlight the science that will be possible with UVIT.

A New Generation of Solar Metallicity Stellar Models, Michael Jensen, Florian Maisonneuve, and Lorne Nelson, Bishop's University

The calculation of highly accurate stellar atmospheres and envelopes can be very resource intensive when millions of stellar models must be computed (*e.g.* population syntheses or binary mass loss). Since the outer layers require most of the CPU cycles needed to calculate a single stellar model, it is more efficient to compute a grid of outer boundary conditions *a priori* and then to interpolate this archived data when computing actual evolutionary tracks. Using the most sophisticated input physics (*e.g.* OPAL opacities, Alexander and Ferguson low-temperature opacities, SCVH equation of state, Allard and Hauschildt non-gray atmospheres) we have calculated the outer boundary conditions for a wide range of masses (0.01 to 10 solar masses) and luminosities. We use these in conjunction with the same physical inputs in the interior to calculate the observed properties of various stellar models. In particular, we present the latest generation of models with masses near the end of the main sequence or in the brown dwarf range. All of the data is being made available for download on the Web server at `physics.ubishops.ca/bc`.

The Perseus Molecular Cloud: Towards a COMPLETEr Understanding, Helen Kirk, University of Victoria/NRC-HIA, Doug Johnstone, NRC-HIA/University of Victoria, James DiFrancesco, NRC-HIA, Josh Walawender and John Bally, University of Colorado, Boulder

We present results of an analysis of the Perseus molecular cloud using a combination of 850um continuum data to trace small-scale structure and near-IR extinction data to trace the large-scale structure of the cloud. We analyze the structure in both maps, including fitting "clumps" found in the sub-millimetre to Bonnor-Ebert spheres. The cumulative mass distribution of the sub-millimetre clumps is shown to be dominated by low-mass clumps, with a slope similar to that of the stellar Initial Mass Function. We also demonstrate that the sub-millimetre clumping is only found toward the higher column density regions. This is similar to the extinction-threshold recently discovered for star-forming regions in the Ophiuchus molecular cloud. We conclude by presenting 2-micron molecular-hydrogen images of the Perseus B1 region indicating that some of the sub-millimetre clumps, which are often assumed to be prestellar, are powering jets and thus contain deeply embedded young protostars.

Molecular Outflows in Corona Australis, Lewis Knee, Herzberg Institute of Astrophysics

The region around R CrA in the nearby Corona Australis cloud is a region of very active low- to intermediate-mass star formation to judge by the large number of embedded sources and Herbig-Haro nebulae found there. Molecular outflows traced by millimetre-wave line emission from CO are the tracer of the kinematics and morphology of large-scale mass loss from star formation, and are needed to investigate the dynamical effects of mass loss on molecular cloud structure and evolution. Here, we present results of a large-scale CO mapping survey of the R CrA region using the Swedish-ESO Submillimetre Telescope. Complex and numerous outflow structures are found, and a preliminary picture of large-scale outflow blowout from the molecular cloud is outlined.

Intriguing Giant Pulses from the Millisecond Pulsar B1937+21, Vladislav Kondratiev, York University, Vladimir A. Soglasnov and Michail V. Popov, Astro Space Center of the Lebedev Physical Institute, Moscow, Russia, Norbert Bartel, Wayne Cannon, and Alexander Yu. Novikov, York University, and Valery I. Altunin, JPL, Pasadena, USA

We made observations of giant radio pulses of the millisecond pulsar B1937+21 with the NASA/JPL 70-m radio telescope at Tidbinbilla, Australia, at 1.65 GHz. The strongest detected giant pulse had a flux density of 65,000 Jy and a true width less than 15 ns. This corresponds to a brightness temperature $T_b \geq 5 \times 10^{39}$ K, the highest observed in the Universe. We present the results of our detailed analysis of 309 detected giant pulses from the pulsar B1937+21. We discuss the shape and width of giant pulses, their arrival times, their influence on other emission characteristics, and their intensities. We estimate the energy volume density of the radiation of the giant pulses and compare it with that for the plasma and the magnetic field. We suggest that the generation of giant pulses is directly related to discharges in the pulsar polar cap region.

Massive Black Holes, IGM Magnetic Fields, and their Interconnections, Philipp Kronberg, Dept. of Physics, University of Toronto and Los Alamos National Laboratory

A sequence of only partly understood physical processes produces the largest energy transfers in the Universe. Recent research at LANL has focused on this collection of puzzles, to the point where we can now better understand and quantify some of the plasma processes involved. It begins with a galaxy's central black-hole/accretion disk system.

Via collimated jets, huge volumes of space are energized by a process that very efficiently extracts the BH's gravitational infall energy. In this process, the magnetic energy released into space is comparable to the photon energy released by QSOs. Observations indicate that 10^8 solar-mass galactic black holes inject 10^{61} ergs or more into intergalactic space, thereby converting accretion energy on AU scales into comparable amounts of magnetic and CR energy in the IGM. The latter constitutes "captured energy," as distinct from the photon energy, which propagates away at *c*.

This process appears to involve spatially distributed particle acceleration in the IGM, and it may lead us to solve the mystery of the origin of the mysterious ultra-high energy cosmic rays (UHECRs).

Comparison of Optical and UV Spectra to Detect Double Degenerates, Charles-Philippe Lajoie and Pierre Bergeron, Université de Montréal

The search for unresolved white dwarfs in binary systems is presently an intense field of research because they represent the most likely progenitors of Type Ia supernovae. However, the number of such double degenerate systems detected so far is small compared to the number expected from binary evolutionary models, and cannot account for the observed rate of Type Ia supernovae. A different approach for detecting these unresolved binary systems is to look for discrepancies between effective temperatures obtained from fits to the hydrogen Balmer lines and those derived from the ultraviolet energy distributions. We report on the results of more than 150 hydrogen-line white dwarfs selected from *IUE* archives. Even though known double degenerates clearly stand out in our analysis, most of the observed discrepancies can be explained by the presence of interstellar reddening or by the presence of heavy elements in the atmosphere of the hottest stars in our sample.

Science Camera Design for EXAOC, Jean-François Lavigne, Université de Montréal/INO/HIA, Simon Thibault, Institut national d'optique, René Doyon and David Lafrenière, Université de Montréal

Direct detection of extra-solar planets in the next few years will allow scientists to learn more about planets' composition, temperature, atmospheric structure, and formation processes. Such detections require extremely high contrast and demand very precise instrumentation. Once the wavefront coming from a nearby star has been corrected by an extreme adaptive-optics system and has gone through a coronagraph, planet detection is limited by speckle noise. A science camera is then required to suppress a significant amount of this noise, identify the planet, and characterize it. The work that has been done in two concepts of science camera for the Extreme Adaptive Optics Coronagraph (EXAOC) conceptual design for Gemini will be presented.

The Energy Dependence of the X-ray Pulse Shape of Her X-1, Denis Leahy, University of Calgary

Various geometries for the accretion column/emission region on the surface of the neutron star in Her X-1 have been considered. Only a filled cone-shaped region can yield the observed pulse shape. The resulting accretion column model is also consistent with the 35-day evolution of the pulse shape, which is caused by occultation of the emitting region by the inner and outer edges of the accretion disk. Here this model is described, and additionally is applied to observations of the X-ray pulse shape at several different X-ray energies. The result is that the emission spectra of the top surface and the side surface of the accretion column are both derived from observations. The resulting spectra are compared to theoretical calculations of emission from strongly magnetized plasma.

Diffusion in the Atmospheres of CP Stars, Francis LeBlanc, Université de Moncton, and Dmitry Monin, Dominion Astrophysical Observatory, NRC

Atomic diffusion can dominate other hydrodynamical processes and create abundance gradients in the atmospheres of some stars. This abundance stratification can modify the physical structure of the atmosphere. It is then imperative to include the effect of elemental stratification in the modelling of stellar atmospheres. Recent results of atmospheric modelling including diffusion based on a modified version of the PHOENIX code will be presented. Difficulties and uncertainties arising from these models will also be discussed.

Three-Dimensional Magnetic Fields in Realistic Simulations of Stellar Core Collapse and Bounce, Matthias Liebendoerfer, CITA

The evolution of massive stars ends with an inner iron core that is unstable to gravitational collapse. Its dynamics is determined by electron capture on nuclei in the condensing matter. When the energy-dependent neutrino mean free path becomes short, emitted neutrinos escape in a competition between thermalization and diffusion. This process is accurately captured in spherically symmetric simulations with Boltzmann neutrino transport (*e.g.* Liebendoerfer *et al.* 2005, *ApJ,* 620, 840). Here, I present a simple parameterization of the comprehensive treatment of neutrino physics so that multi-dimensional simulations {of the collapse phase} can include the results of state-of-the-art neutrino transport in an efficient and accurate way (Liebendoerfer, astro-ph/0504072). With the application to the 3-D MHD simulations of Liebendoerfer, Pen, & Thompson (2005, to be published in *Nucl. Phys. A*), realistic three-dimensional simulations of slowly rotating collapse with magnetic fields become feasible to narrow the configuration space at bounce, *i.e.* at the onset of the not fully understood supernova explosion. The evolution of the magnetic field is followed for different choices of the uncertain initial values at the onset of collapse. Until a few milliseconds after bounce, a mainly compression-induced field amplification of about two orders of magnitude is found in the hot material layered around the protoneutron star. Larger magnetic fields are trapped within the protoneutron star. After bounce, the magnetic field lines entangle in the layers where convection is driven by entropy gradients. Cross-view stereograms are shown to visualize their evolution in 3-D.

Testing von Zeipel's Law, Catherine Lovekin, St. Mary's University, and R.G. Deupree, St. Mary's University/Insititute for Computational Astrophysics

Traditionally, rapidly rotating stars have been studied assuming the surface can be described as an equipotential surface with a simple point-mass approximation to the gravitational potential and that the centrifugal force can be written as a potential, as is true for conservative rotation laws. Variation in surface temperature and luminosity can then be calculated using von Zeipel's law. We test these assumptions using the results of 2-D stellar evolution calculations for rapidly rotating main-sequence stars. For uniformly rotating stars, we find the spherically symmetric point-mass potential is a good approximation, except for the equatorial regions when v ~ vcrit. For more extreme, but still conservative, angular momentum distributions, the interior mass distribution results in a significant deviation from the spherically symmetric gravitational potential deep inside the star, but not necessarily at the surface. This produces distortion of the deep interior equipotential surfaces, which results in surface temperatures and luminosities significantly different from those predicted by von Zeipel's law.

Prospects and Forecasts for Large Yield Cluster Surveys, Subhabrata Majumdar, CITA, Toronto

Upcoming large yield Sunyaev-Zeldovich and optical galaxy cluster surveys are poised to answer fundamental questions about the nature of our Universe. At the same time they are well suited to explore in great detail the physics of clusters of galaxies as well as the thermal history of the intra-cluster medium. In this talk, I'll illustrate how yields from these cluster surveys can be used to probe the nature of dark energy, constrain generic theories of inflation, and precisely estimate the amplitude of mass fluctuations in our Universe. I'll also touch upon implications for cluster physics.

Fragmentation of Molecular Clouds, Hugo Martel, Université Laval, Neal J. Evans and Paul R. Shapiro, University of Texas at Austin

We have performed high-resolution SPH simulations of the fragmentation of molecular clouds, leading to the formation of a dense cluster of protostellar cores. Our SPH algorithm uses particle splitting in order to achieve very high resolution and ensure that the Jeans mass is properly resolved throughout the simulations.

The collapse of molecular gas and its conversion to protostellar cores follows four distinct phases: Growth, Collapse, Accretion, and N-body. We found that competitive accretion is a local phenomenon, with distict regions inside the cloud having different accretion histories. As a result, the correlation between birth rank and final mass of cores is quite weak. The final mass distribution of the cores is lognormal. The mean value is unrelated to the initial Jeans mass of the cloud, and is entirely determined by the resolution limit of the simulations.

A 0.5 Msec Glance at the Supernova Remnant G21.5-0.9 with the Chandra X-ray Observatory, Heather Matheson and Samar Safi-Harb, University of Manitoba

G21.5-0.9 is one of approximately 15 currently known Galactic filled-centre supernova remnants (plerions), the most well-known being the Crab Nebula. These filled-centre remnants lack a supernova remnant shell and typically have a larger size in radio than in X-ray. Early *Chandra* observations of G21.5-0.9 showed that the 40″ radius plerion surrounded a 2″ compact centre, and revealed a faint 150″ radius X-ray halo around G21.5-0.9, making its size in X-ray larger than its radio size. The origin of the X-ray halo remains uncertain. It has been suggested that the halo could be partially due to dust scattering since G21.5-0.9 is a bright and heavily absorbed source (Safi-Harb *et al.* 2001). We will present an analysis of the brightest regions in the halo of G21.5-0.9 and show the results of a search for line emission using 0.5 Msec of data acquired with the Advanced CCD Imaging Spectrometer (ACIS) on the *Chandra X-ray Observatory* over the last six years. We will also show the deepest and highest resolution image of G21.5-0.9 to date. This deep image reveals for the first time 1) a limb-brightened morphology in the eastern section of the halo, and 2) a rich structure in the inner (40_-radius) bright plerion including wisps and a double-lobed morphology with an axis of symmetry running in the northwest-southeast direction.

Evaluating the Performance of the GAIA Space Mission on and with EclipsingBinaries: Three Problematic Systems, SV Cam, BS Dra, HP Dra, E.F. Milone and M.D. Williams, RAO, University of Calgary, P.M. Marrese, University of Leiden, U. Munari and A. Siviero, University of Padova, J. Kallrath, University of Florida, BASF, and T. Zwitter, University of Ljubljana

GAIA is a reconfirmed Cornerstone Mission of ESA, with an anticipated launch date of 2011. Its primary purpose is to study the kinematics and structure of the galaxy for which it will be equipped to do micro-arcsecond astrometry, multi-band photometry, and radial-velocity spectroscopy on a billion of the brightest stars. *GAIA* will carry out its five-year survey mission from the L2 point of the Earth's orbit. It is expected to discover of order one million eclipsing binaries, which alone may keep ground-based observatories busy on follow-up programs for decades to follow. Here we will review the general benefits of *GAIA* for stellar and galactic astronomy, and discuss its potential for SB2 eclipsing binaries in particular. A group headed by U. Munari (Univ. Padova) has demonstrated *GAIA*'s importance in a series of tests of the precision and accuracy of fundamental stellar parameters from analyses of light and RV curves of selected systems. The trials conservatively make use only of *Hipparcos-Tycho* photometry and ground-based echelle spectroscopy matching *GAIA*'s spectral (Ca triplet) region and approximate resolution (~12,000). Here, we describe the determinations of fundamental parameters for three of the most recently studied systems: SV Cam with complicated light curves and, in the data analyzed in this study, only 1 RV curve; BS Dra with non-solar metallicity; and HP Dra with a small eccentricity and a significant time derivative of the argument of periastron. The latter two systems have partial, sparsely observed eclipses, which make the radiative properties difficult to determine. Although the three systems represent limiting cases, the results are nevertheless encouraging, with uncertainties in one or more components approaching 2% in some parameters, and derived distances falling close to or within the errors of the *Hipparcos* determinations, for all three systems. Some of the work described here was supported by NSERC grants to EFM.

Weighing the Most Massive Stars, Anthony Moffat, Olivier Schnurr, André-Nicolas Chené, and Nicole St-Louis, Université de Montréal

HR diagrams of the brightest stars in nearby galaxies indicate that there exists an upper luminosity limit to star formation. One can assign real masses of stars at that limit, although with low confidence because of uncertainties in current stellar models. Understanding the physics of massive stars is important because these stars dominate the light and ecology of the Universe, not only at the present epoch, but also and especially during the first generation of stars (pop III), expected to be dominated by stars in the range 100-1000 solar masses. The only viable way to determine (or calibrate) masses is by "weighing" them in binary systems. The most massive stars are expected to be formed in the most massive, densest young stellar clusters, like the core R136 of 30 Dor in the Large Magellanic Cloud or its much closer clone NGC 3603 in the Galaxy. Telescopes in space or adaptive-optics systems on large groundbased telescopes are needed to cleanly resolve such stars in order to obtain the necessary high-precision radial velocities and light curves to define the orbits and obtain the masses. We discuss recent progress on this topic, with emphasis on our own attempt to determine the masses of the components of the brightest star (A1, a known main-sequence eclipsing system of type WN6ha + O3: and period 3.7724 d) in the core of NGC 3603, first using *HST*/STIS (instrument failure) then using VLT/SINFONI (in progress). With A1 being one magnitude intrinsically brighter than the current record holder WR20a (WN6ha + WN6ha, P = 3.686 d, 83 + 82 solar mass), we expect masses for A1 of ~ 100 solar mass if $L \propto M^3$, or more likely, ~200 solar mass if $L \propto M$.

Chandra *and* RXTE *study of the Western Lobe of W50 and Galactic Microquasar SS 433,* Alyssa Moldowan and Dr. Samar Safi-Harb, University of Manitoba

W50 is classified as a Galactic supernova remnant and harbors SS 433, an X-ray binary consisting of a compact object accreting matter from a companion star at a super-Eddington rate and shooting out jets at 0.26c. A summary of Master's thesis work on this system will be presented in two parts. First, a 75 ksec *Chandra* observation of the western lobe of W50 is presented, which provides the highest-resolution X-ray image obtained to date. We have confirmed that at the site of interaction between the SS 433 western jet and the interstellar gas the emission is non-thermal in nature. Correlating the X-ray emission with radio and infrared observations, we find that the helical pattern seen in radio is also observed with *Chandra*. No correlation is found between the X-ray and infrared emission. Second, the *RXTE* study of SS 433 is presented. This will be the first complete spectral analysis of SS 433 up to X-ray energies of 70 keV. The emission from SS 433 is well described by a bremsstrahlung model, and in some cases a power-law model, with two Gaussian lines. The temperature, flux, and photon index are correlated with the binary phase and radio flares.

NGC 1569 — A Huge Starburst in a Nearby Dwarf Galaxy and its Consequences, Stefanie Muehle and Ernie R. Seaquist, University of Toronto, Uli Klein, University of Bonn, Susanne Huettemeister, University of Bochum, and Eric M. Wilcots, University of Wisconsin

Photometric studies suggest that the nearby (D = 2 Mpc) dwarf irregular galaxy NGC 1569 has experienced a major burst of star formation for at least the last 25 Myr. Other pieces of evidence are numerous Hα filaments along the minor axis and a strong, metal-rich galactic wind, which may lead to the loss of metal-enriched gas to the IGM. We show how the starburst has affected the properties of the neutral atomic and molecular gas in this metal-poor galaxy. In addition, we report the detection of the likely trigger and a possible gas reservoir of the unusually strong starburst.

Using Spitzer *to Detect z > 1 Galaxy Clusters,* Adam Muzzin, University of Toronto

The IRAC camera on board the *Spitzer Space Telescope* has the ability to make deep, wide-field maps of the sky in the near-infrared. IRAC will play a central role in discovering large numbers of galaxy clusters at very high redshift, and will also give a unique perspective on the evolution of their galaxy population. We have applied the cluster red-sequence technique (Gladders & Yee 2000) to six square degrees of data from the CFHT Legacy Survey and the *Spitzer* SWIRE survey and have detected approximately 80 cluster candidates at z > 1.0. Our sample includes candidates at $z = 1.85$, making these by far the most distant large scale structure detected by old populations. I will present examples of these rare objects and discuss plans to discover an additional 500-1000 clusters at $z > 1$ using the *Spitzer* SWIRE survey.

Listening to FM and Chasing Meteors, Sasa Nedeljkovic and C. Barth Netterfield, University of Toronto

This poster will show how a digital radio spectrometer working between 50 and 150 MHz can be used for meteor detection. The spectrometer is connected to a small wide-frequency, wide-beam antenna. With better than 50 kHz spectral resolution, the instrument can resolve individual FM radio and TV stations. Existing commercial transmitters over the horizon will be used as transmitters for the forward scattering method of meteor detection. Given the frequency, directivity, and power of transmitters, and time evolution of the reflection, we can extract dynamical parameters of the meteor using only one receiver.

Type Ia Progenitors: The Single Degenerate Channel, Lorne Nelson, Bishop's University

There has been considerable debate over the true nature of the progenitors of Type Ia supernovae (SNe). Two of the most favoured binary models assume that the progenitor donor is either a degenerate dwarf that transfers matter onto another white dwarf (DD + CO), or that the donor is a main-sequence or red-giant branch star that loses matter to a white dwarf (MS + CO). For both cases it is assumed that the transferred matter burns in a quasi-steady state on the surface of the white dwarf thus allowing it to increase in mass. Assuming that the mass of the CO WD eventually exceeds the Chandrasekhar limit, a Type Ia SN ensues. The problem with both scenarios is that the synthetically inferred number of events does not match the observed frequency of Type Ia SNe. We have calculated a large number of evolutionary tracks to determine which systems can succeed in producing Type Ia SNe. It is shown that many more systems than previously thought can survive the initial mass-transfer phase and thereby allow the CO WD to accrete sufficient matter. We also examine the behaviour of the accreting COs in these binaries and show that many can remain smaller than their Roche-lobe radii during phases of thermal instability (hence avoiding the merger of the binary). We are presently carrying out a population synthesis to determine if enough progenitor systems can survive so as to match the inferred frequency of Type Ia events.

The Dark Matter Distribution for the SINGS Galaxies, Marie-Hélène Nicol, Université de Montréal

Results obtained from a study of the mass distribution of 10 spirals galaxies from the SINGS sample are presented. The H-alpha rotation curves were obtained using Fabry-Perot techniques. For each galaxy, the high resolution H-alpha rotation curves derived from the velocity fields are combined with low-resolution H I data. The goal of the study is to determine accurately the inner slope of the rotation curves, which strongly constrains the parameters of the mass models. Two well-known halo density profiles are compared: dark halos with a central density cusp (NFW profile), and a pseudo-isothermal sphere profile, which is much flatter in the centre.

The Colliding Winds of WR146 — Seeing the Works, Evan O'Connor, UPEI & NRC, S. Dougherty, NRC, J. Pittard, University of Leeds, UK, and P. Williams, University of Edinburgh, UK

WR146 is a WC6+O8 colliding-wind binary (CWB) system that exhibits both thermal emission from the stellar winds of the components, and bright non-thermal emission from the wind-collision region (WCR) where the stellar winds collide. We present high-resolution radio observations from 1.4 to 43 GHz that were obtained with the Very Large Array (VLA) plus the Pie Town antenna of the Very Long Baseline Array, giving observations with a resolution of 30 mas at 43 GHz. Our VLA observations at 22 GHz now span eight years, which show that the system has moved 62 ± 6 mas, with a proper motion of $\mu_\alpha = (-3.65'' \pm 0.17)$ mas yr^{-1} and $\mu = (-6.46'' \pm 0.4)$ mas yr^{-1}. It is now possible to move observations from the past decade to a common epoch. Comparison of the VLA data with observations with MERLIN and the European VLBI Network reveal the location of the WCR relative to the stellar components, and provide key parameters of the two stellar winds. Using new radiative transfer models of colliding-wind systems (Dougherty *et al.* 2003; Pittard *et al.* 2005), that include synchrotron self-absorption, the Razin effect, inverse-Compton cooling, Coulombic cooling, and free-free absorption, we attempt to fit both the spectra and the multi-frequency images of WR146.

A Millisecond Pulsar with a Puzzling Optical Companion, Fernando Pena and Marten van Kerkwijk, University of Toronto

Over the decades, many different models have been suggested for how elementary particles interact at densities well above nuclear. The resulting different equations of state (EOS) predict different constituents in neutron stars and lead to different mass-radius relations. Distinguishing the various possibilities appears possibly only using empirical constraints on neutron stars, such as the maximum mass. The millisecond pulsar (MSP) PSR J1740–5340 is an excellent target for measuring an accurate mass, as it is in a binary with a bright (V~17) companion star. The binary also poses a number of intriguing puzzles. In particular, the companion is very luminous for its mass, does not show any sign of heating by the copious pulsar spin-down emission, and appears not to be corotating with the orbit despite nearly filling its Roche lobe and the orbit being circular. I will discuss the above questions in the light of new high-resolution UVES/VLT spectra from the companion star to PSR J1740–5340.

Studies of Yellow Semi-Regular Pulsating Stars, John Percy, Jaime Coffey, Jennifer Hoe, Anna Molak, and Claudia Ursprung, University of Toronto
Semi-regular pulsating variable giants and supergiants of spectral types F, G, and K (SRd variables in the *General Catalogue of Variable Stars*) are undergoing thermal loops from the asymptotic giant branch (AGB) in the H-R diagram, or are in transition from the AGB to the

white dwarf stage. They are related to the Population II Cepheids, and the RV Tauri stars, and may form a continuous spectrum of behaviour with these stars. In this paper, we describe studies of the evolution of five SRd variables, as deduced from period changes. We also discuss the question of whether SRd variables show the long secondary periods that are observed in about half of all RV Tauri stars — the "RVB stars."

A Comparison of Atmospheric Parameters for Subdwarf B Stars Derived from Lyman and Balmer-Line Analyses, Caroline Pereira, François Wesemael, and Pierre Bergeron, Université de Montréal

The use of Balmer-line profiles to determine atmospheric parameters of subdwarf B stars is a well-established method that relies on a comparison of spectroscopic observations with synthetic spectra generated from model atmospheres to determine atmospheric parameters, namely the effective temperature, surface gravity, and photospheric helium abundance. A similar analysis can be carried out using the profiles of the Lyman lines covered by current far-ultraviolet observations. We present observations for a sample of ten subdwarf B stars for which both optical and far-ultraviolet spectra were secured using the 2.3-m telescope at Steward Observatory and the *FUSE* satellite archives respectively. We then examine the important role played by the numerous lines of heavy elements in the *FUSE* range and provide a preliminary assessment of the impact of these lines on the atmospheric parameters derived from ultraviolet data.

Who's in the Driver's Seat: Magnetic Fields or Turbulence?, Frédérick Poidevin and Pierre Bastien, Université de Montréal, Jason D. Fiege and Brenda C. Matthews, Herzberg Institute of Astophysics

New polarization data at 850 microns of OMC2 in Orion A are presented. These measurements trace the direction of magnetic fields in the densest parts of the filamentary molecular clouds and form a part of the comparison of magnetic-field directions at various spatial and density scales. They allow us to put constraints on existing models, and better understand the competitive role of magnetic fields and turbulence in the ISM and in the process of star formation.

Observations and Analyses of the Cepheid SZ Tauri, J. Postma and E.F. Milone, RAO, University of Calgary

Baade-Wesselink and maximum likelihood methods have been used to analyze coeval sets of photometric and spectroscopic observations and archival optical and infrared data of the Cepheid variable SZ Tauri. New periodic and epoch values have been determined that differ marginally from previous values. The light curves exhibit nearly sinusoidal variability. This presentation will demonstrate the new software developed and used by JP to determine Baade-Wesselink and Balona radii. The authors appreciate observing time at Mt. Laguna Observatory in 2004, and thank its director, P. Etzel. This work was supported in part by NSERC grants to EFM.

Rotational Velocities of Selected F-Type Stars, Jenny Power and David F. Gray, University of Western Ontario

Measurements of rotation velocities of a number of selected F-type stars were performed based on observations obtained at the University of Western Ontario Elginfield Observatory high-resolution spectrograph. Rotation velocities were determined by comparing the Fourier transform of the Fe I line at 6065.48 Å to the model rotation profile. Errors of 1 to 2% were found.

Abell 43 a Pulsating Hydrogen Rich PG 1159!, Pierre-Olivier Quirion, G. Fontaine, and P. Brassard, Université de Montréal

We modeled the hybrid PG 1159 type star ABELL 43. We show that the kappa-mechanism, due to ionization of C k-shell, in the envelope of this hydrogen rich PG 1159 is the only one needed to drive g-mode pulsation. There is thus, in contradiction with some recent publication, no need to invoke any new or exotic mechanism to explain instability in this star. Our instability band extends from 2600 s to 5520 s for l = 1 modes and overlap recent photometric observations of ABELL 43.

The Origin of Brightness Variations in BC Cygni, Mina Rohanizadegan and David G. Turner, Saint Mary's University, Elena N. Pastukhova and Leonid N. Berdnikov, Sternberg Astronomical Institute

The type-C semiregular variables are M-type supergiants like Betelgeuse that undergo fairly regular periodic brightness fluctuations superposed upon seemingly irregular modulations. Most of the 55 recognized Milky Way supergiants belonging to the class are multi-periodic, with radial pulsation believed to be one source of their luminosity changes. Here we investigate the origin of the brightness variations in the SRC variable BC Cygni, which, as a member of the open cluster Berkeley 87, has a well-established reddening and distance. Simple interior models for the star are used in conjunction with adiabatic pulsation to investigate likely pulsation periods for the star, which seem to lie around 700 days. We also consider the possibility that some of the brightness modulations arise from the movement of starspots across the stellar surface through rotation or from a longer-term spot cycle. The main periodicities in BC Cyg are near 696 days (pulsation), 240-350 days (rotation?), and ~3750 days (spot cycle?). We also present arguments for similar types of variations in other members of the SRC class.

Are Narrow-Line Seyfert 1s Fueled by Secular Evolution?, Christopher J. Ryan and Michael M. De Robertis, York University

Narrow-Line Seyfert 1 galaxies (NLS1s) are a curious subset of active galactic nuclei, displaying an overall spectral signature consistent with a Seyfert 1 galaxy but with remarkably narrow permitted emission lines. As with all AGN, the source of the intense non-thermal radiation emitted by these objects is widely accepted to be accretion onto supermassive black holes lurking at the centres of the host galaxies. To account for the unusual spectral properties, it has been postulated that NLS1s possess relatively lower-mass black holes accreting material at a significant fraction of their Eddington limits. In order to test this hypothesis, we have analyzed high-spatial resolution NIR data obtained with the KIR/AOB system at CFHT. Using the two-dimensional decomposition algorithm GALFIT, J- and K´- band images of a sample of 11 NLS1s were separated into their constituent components. Black-hole masses were then determined by applying the established correlation between mass and host bulge luminosity, recalibrated for NIR wavelengths using 2MASS data. We have found that the NLS1s in our sample do not follow the correlation between black-hole mass and stellar velocity dispersion exhibited by other active galaxies. Numerical simulations recently published by Di Matteo *et al.* (2005) suggest that the mass-velocity dispersion correlation is the product of galaxy mergers, which can initiate the transport of fuel to an otherwise dormant black hole. The departure from this relation for NLS1s may therefore reveal that the underlying trigger in these objects is secular evolution rather than violent interactions.

Multi-wavelength Study of Galaxy Rotation Curves and its Application to Cosmology, Amélie Saintonge, Riccardo Giovanelli, Martha P. Haynes, and Karen L. Masters, Cornell University, Christian Marinoni, Osservatio Astronomico di Brera, and Thierry Contini, Observatoire de Toulouse

Rotation information for spiral galaxies can be obtained through the observation of different spectral lines. While the H-alpha(6563) line is often used for galaxies with low to moderate redshifts, it is quickly redshifted into the near-infrared and becomes unavailable for ground observers at $z>0.4$. This is why most high-redshift surveys rely on the [OII](3727) line. Using a sample of 32 spiral galaxies at $0.155 < z < 0.25$ observed simultanously in both H-alpha and [OII] with the Hale 200-inch telescope, the relation between velocity widths extracted from these two spectral lines is investigated. The velocity widths are determined both from the construction of rotation curves and from the fitting of Gaussian models to one-dimensional spectra. The widths are also compared to those retrieved from the Sloan Digital Sky Survey. The sample of galaxies is then used along with precursor VIRMOS/VLT Deep Survey observations to perform the angular diameter - redshift test to find constraints on cosmological parameters (w, Omega-M, Omega-lambda). To provide calibration, local values of half-light radii, magnitudes, and surface brightnesses are calculated for the standard rods of the angular diameter - redshift test, using data from the SFI++ catalog of galaxies.

NLTE Strontium and Barium in Metal-Poor Red Giants, Ian Short, Saint Mary's University and Institute for Computational Astrophysics

We present atmospheric models of red-giant stars of various metallicities, including extremely metal-poor (XMP, [Fe/H] = −4) models, with many chemical species, including, significantly, the first two ionization stages of Strontium (Sr) and Barium (Ba), treated in non-local thermodynamic equilibrium (NLTE). The abundances of Sr and Ba are significant because they indicate the relative importance of the nucleosynthesis of light and heavy neutron-capture elements in the chemical evolution of the galaxy. Initial results indicate that for some lines with abundant diagnostics, the predicted line strength and, hence, the inferred abundance, is dependent on two aspects of the modelling: 1) whether Sr and Ba themselves are treated in LTE or NLTE, and 2) whether many other chemical species are also treated in LTE or NLTE. This study underscores the importance of using physically realistic atmospheric models to infer the chemical evolution of the galaxy from stellar spectra.

A Evolutionary Study of Magnetic Ap Stars in Three Open Clusters, James Silvester, Queen's University/RMC, and Gregg Wade, RMC

I will present the first results of a study of magnetic chemically peculiar stars in open clusters. Using high-resolution circular spectropolarimetric observations obtained using the MuSiCoS spectropolarimeter on the 2-metre Bernard Lyot telescope at Pic du Midi observatory, chemical peculiarities and magnetic field strengths have been determined for six Ap stars in three open clusters. The aim of this study is to provide new information about the evolution of chemical peculiarities and magnetic fields of Ap stars.

Because open-cluster ages can be accurately determined based on the evolution of chemically normal stars, this method allows the determination of the evolutionary state of chemically peculiar cluster members without the requirement that they be accurately positioned on the HR diagram (a procedure fraught with complications).

Anisotropic Turbulent Diffusion in Radiative Zones of Stars, Nathalie Toqué, Université de Montréal, François Lignières, Laboratoire d'Astrophysique de Toulouse-Tarbes, OMP, and Alain Vincent, Département de Physique, Université de Montréal

Modelling the chemical element transport in radiative zones of stars is one of the main difficulties in stellar evolution theory. Observations of chemical abundances on the surface of stars show that microscopic diffusion cannot explain the abundances anomalies. Other processes such as turbulent transport caused by instability in radiative zones must be taken into account. We are especially interested in turbulent diffusion generated by shear instabilities and we study a highly simplified version of flows in stellar radiative zones. The flow is under Boussinesq approximation, it is two-dimensional and stably stratified. The tracer representing a non-reactive chemical element is released in the flow. We will show the results of direct numerical simulations with increasing stratification. To calculate the vertical diffusion coefficient, we use two different approaches. First, the tracer mean flux is linked to the mean vertical gradients, which enables us to define a turbulent diffusion coefficient. Then, we calculate the Lagrangian diffusion coefficient from the vertical displacement of Lagrangian particles with Taylor diffusion theory. This study shows two different states of the transport dependant on stratification. For a moderate stratification, the vertical diffusion coefficient decreases faster than what is predicted by mixing-length theories. This seems to result from high anisotropy between vertical and horizontal motions. At highest stratifications, we observe that mean vertical displacement of Lagrangian particles is under-diffusive and approaches an asymptotic limit. The hindrance of vertical transport of chemical elements, which has been observed and predicted, is not taken into account in current stellar evolution models.

Using Cepheid Period Changes to Test Stellar Evolutionary Models, David Turner, Saint Mary's University, Mohamed Abdel-Sabour Abdel-Latif, NRIAG Egypt, and Leonid N. Berdnikov, Sternberg Astronomical Institute

Rate of period change in Cepheid variables is a parameter that can be predicted from stellar evolutionary models, provided the instability strip-crossing mode is known. Different evolutionary models predict different rates of period change for the same strip crossing, which suggests that observed rates of period change in Cepheids are useful for testing how well different models match real stars. From a compilation of observed period changes in about 200 Cepheids that we have completed in recent years, we examine how closely the observational data match model predictions. In general, the observations are consistent with model predictions, yet there are a number of distinct differences indicating a need for further refinements to existing stellar evolutionary models. In addition, rate of period change for Cepheids is a parameter that may be useful for establishing the location of individual Cepheids within the instability strip, independent of interstellar extinction.

A Spectral Survey for Dust Formation in Type II Supernovae, Doug Welch, McMaster University, and Geoff Clayton, Louisiana State University

Over 50% of dust production in the Galaxy is from old stellar systems (AGB stars & Type Ia SNe). However, the origin of dust in high-redshift galaxies is expected to be much different. Such galaxies have been observed to contain abundant dust even though they are quite young. After only 1 Gyr, there has not been time for low-mass stars to evolve to the AGB. Using estimates from our Galaxy, the timescale for injection of stardust into the ISM by AGB stars is about 2.5 Gyr. Evidence from pre-solar dust grains implies that Type Ia SNe are also significant sources for interstellar dust locally, but these too are old systems that may not have had time to evolve by the epoch of our observations of high-redshift galaxies. Dust production in high-redshift galaxies therefore is expected to be dominated by Type II SNe. The condensation of dust in SN ejecta is still not well understood. One reason is that detection of newly-formed dust in SNe in nearby galaxies has been extremely rare. In August 2004, we began a program with Gemini/GMOS to study dust formation in Type II SNe. We were able to obtain spectra, as well as VRI photometry, of 14 Type II SNe with ages of 200 to 650 days. Dust formation in the SNe ejecta is indicated by a sudden decrease in continuum brightness in the visible due to increased dust extinction. This is accompanied by the development of asymmetric, blue-shifted emission-line profiles, caused by dust forming in the ejecta, and preferentially extinguishing redshifted emission from material on the far side of the SN. We will present early results from this study as well as the late-time evolution of the spectrum of the Type II supernova 2002hh in NGC 6946 obtained in August, October, and December 2004 with Gemini North and GMOS.

Discovery of Spectroscopic Variations in the DAB White Dwarf GD 323, François Wesemael, C. Pereira, and P. Bergeron, Université de Montréal

We report the discovery of spectroscopic variations in GD 323, the prototypical DAB white dwarf. Simultaneous optical spectroscopic observations over five consecutive nights of GD 323 are used to reveal quasi-periodic variations in both the hydrogen and helium absorption lines over a timescale of hours. The amplitude of the variation of the equivalent width of Hβ is ~ 30%. Moreover, the strength of the hydrogen lines is shown to vary in opposite phase from that of He I λ4471. These results suggest that the model currently thought to be the most viable to account for the simultaneous presence of hydrogen and helium lines in GD 323, namely a static stratified atmosphere, may need to be reexamined. Instead, a model with an inhomogeneous surface composition, resulting perhaps from the dilution of a thin hydrogen atmosphere with the underlying helium convection zone, may be a better representation of GD 323. The observed variation timescale of ~ 3.5 hours is consistent with the slow rotation rate of white-dwarf stars.

Sleeping with an Elephant: Asteroids that Share a Planet's Orbit, Paul Wiegert, The University of Western Ontario, Martin Connors, Athabasca University, Ramon Brasser, Queen's University, Seppo Mikkola, University of Turku, Greg Stacey, Athabasca University, and Kimmo Innanen, York University

Under special circumstances, relatively small asteroids are able to safely share the orbit of a much larger planet. The best known examples of such "co-orbital" bodies are the Trojan asteroids of Jupiter, over 1700 of which are known to travel either 60 degrees ahead of or behind this giant planet in its orbit. The stability of such configurations might be thought to depend on the asteroid giving the planet a wide berth. In reality, co-orbital asteroids may approach their planet relatively closely, to within a few times its Hill sphere (which is five times the distance to the Moon in the case of the Earth). For many co-orbital bodies such approaches occur rarely or not at all, but recently examples of co-orbital states that become trapped near their planet have been found. Such "quasi-satellites" may remain near their much larger partner for thousands of years, though in actuality they are not true satellites and continue to orbit the Sun. Here we discuss the behaviour of some recently discovered co-orbital asteroids with emphasis on 2004 GU9, recently found to have a long-lived quasi-satellite state relative to the Earth.

Searching For Connections between Velocity Anomalies and Galaxy Characteristics: A Preliminary Exploration, Theresa Wiegert, Jayanne English, and Jason Fiege, University of Manitoba, and Rob Swaters, University of Maryland

Neutral hydrogen (H I) rotation curves of several nearby galaxies will allow us to model the mass distribution of their gas disks and characterize their dark-matter content. We are exploring ways of classifying galaxies by their rotation curves. Additionally we hope to detect features that do not orbit with the disk. These anomalous velocity features provide important clues about a galaxy's evolution since they are either due to gravitational interactions or star-formation processes. This poster presents our preliminary exploration of the rotation-curve classification criteria, curve fitting, and modelling of the mass distribution of the gas disk. We also plan to apply a genetic algorithm to the H I data in order to determine a family of suitable gravitation potentials for dark-matter halos.

A New Variable Star Search Program at the Rothney Astrophysical Observatory, Michael Williams and E.F. Milone, RAO, University of Calgary

We describe a variable-star search program being carried out on a 0.5-m f/1 Patrol Camera at the RAO. The detector is a 4K × 4K chip mounted in an FLI camera, purchased by P. Brown (UWO). The 4.4 by 4.4 degree image frames provide stellar images of ~2 pixels (FWHM). Results from the first well-studied night sequence reveal a significant number of apparently real variability detections. Most of the variability is seen in stars in the range 11 to 14 magnitudes in the natural system (approximately Johnson-Cousins R), with < 0.1 mag 1 sigma errors. Theoretical predictions show that we should be able to achieve 1 sigma errors smaller than 0.02 mag for stars brighter than ~12 mag. Results show that we are close to the theoretical noise levels. In this first surveyed field there are 1100 stars with 1 sigma error levels below 0.02 mag, so this search program is expected to yield a large number of low-amplitude detections. The Patrol Camera is a former Baker-Nunn satellite tracking camera, modified by DFM Engineering as part of a retrofit supervised by M.J. Mazur, in a collaboration funded by grants from the Alberta Science Research Authority (to EFM), and others (to A. Hildebrand and P. Brown). The modifications included replacement of the original tri-axial with an equatorial mounting and the curved-film plane with the 4k CCD array. The paper will describe the data set, search software, sample light curves, and new variable-star discoveries. The survey is being carried out by MDW as part of his Ph.D. program and is being supported in part by NSERC grants to EFM and the University of Calgary Department of Physics & Astronomy.

Spectral distortions to the CMB from the Recombination of H & He I, Wan Yan Wong, University of British Columbia, Sara Seager, Carnegie Institution of Washington, and Douglas Scott, University of British Columbia

All of the atoms in the Universe were ionized at times earlier than about one-hundred-thousand years. When this plasma recombined there must have been several recombination photons produced for every atom — can we detect these cosmological recombination photons? We have performed the first detailed calculation of the line intensities of the 2p–1s Lyman-alpha transition of hydrogen, as well as for the 2s–1s 2-photon transition of hydrogen and the corresponding He I transitions. The sum of all these lines gives a non-trivial shape to the spectral distortion, which may help tailor an experiment to their detection. Although challenging, detecting these roughly 100 micron distortions would provide incontrovertible evidence that the Universe was once a plasma, and potentially probe the details of physics at the recombination time.

Society News/Nouvelles de la société

by Stan Runge, Secretary (stanrunge@hotmail.com)

A former manager of mine would begin the speech for his retiring employee with the phrase "It is with mixed emotions that we are here today." It describes exactly how I feel as I take over the role of Secretary of the RASC. To begin with, I am sad to see the departure of our previous Secretary, Kim Hay. Kim just finished her second term, meaning she has spent the last six years on the Executive Council. In doing so, she has worked closely with at least three Presidents, and has been involved with all the key issues of the day. So I know she will miss all of the activity, but more importantly, all of the wonderful and dedicated people on the Executive. Kim will now seek out other tasks that need to be done within the RASC, as I am sure she cannot stay away for long.

As Kim passed over responsibilities to me, she said that if ever there was something that appeared to need to be done, I should take it upon myself to get it done. That attitude of hers was no more apparent than in the fact she created the first Secretary's Handbook. Yes, she passed me a binder full of information that would help me to prepare for my new job. As well, she has dramatically expanded the RASC Manual, which is featured on-line in the members' area. I believe it is probably three times the size, now at a healthy 124 pages. I sincerely "thank you" Kim, for all you have done.

It was with great excitement that I accepted this position. Having been involved with the RASC for over 30 years, I am committed to help in any manner I can. I have been focused mainly within my own centre in Winnipeg, serving in most positions, but more recently as Centre Treasurer and National Representative. So this is my chance to participate even more with the National part of the organization. I hope I can bring my "Centre" concerns and needs to the forum.

In my time on National Council as the "Rep," I have realized that it is an important position, because it is the true interface with the RASC nationally. It is a two-way position, where one must bring the local clubs' needs to the attention of the National Council, but also bring the needs of Society to the Centres. This was no more evident than in the recent requirements to not only raise the fees, but also to consider changes to the ways that the monies are distributed. I should let you know that there are efforts going on to produce an information source for new National Representatives, to help bring them up to speed more quickly.

One of my assigned Secretary tasks is to write this column, to bring you the Society news. A couple of things that I wanted to mention first is that Peter Broughton has stepped down as Chair of the Historical Society, a position he has held for many years. I am sure the Executive thanks Peter for all of wonderful efforts.

Next, his term having expired, we needed to replace Dr. Roy Bishop in the role of Honourary President. The position will be filled by yet another distinguished former National President, Dr. Robert Garrison.

As I write this article, the General Assembly in Kelowna is still very fresh on everyone's mind. I am sure that all those who attended will be telling their Centres about the wonderful effort put on by the Okanagan Centre. The presentations, the planned events like the Banquet, and the off-hour activities all seemed to have gone off without any problems. One special preparation they did was to have our National President Peter and his wife Diane led into the banquet by a bagpiper, bringing a dream to life.

As in other years, this GA featured National Council meetings, and the Annual General Meeting, with controversial items. All but two Centres had representation. Although there were very different opinions on how the matters would be best resolved, it did show we are united in our passion to resolve the needs and concerns of the RASC. One major issue was on how to move into a new age of communications with an electronic version of the *Journal*, as a cost saving measure.

At the AGM, there were a number of motions and By-law changes to be voted on, as highlighted in your copy of the 2004 *Annual Report*. I want to report that the Proxy votes outnumbered the number of people at the meeting and did play a vital role in one of the votes. I will just provide a brief summary of the results here.

1) The motion for the increase in Society membership fees, plus the associated By-Law #1 changes (section 1 and 2) was approved.
2) The proposal to explicitly allow official notices to be sent to members electronically (By-law section 3) was approved.
3) The proposal to change the procedure for changing membership fees and a change of the fixed distribution of fees between National and Centres was defeated (section 4).
4) Proposal to change the Centre practice in the use of basic surcharges was approved (section 5).

5) The motion for the appointment of Auditors: Tinkham & Associates was approved.

Unfortunately, I don't have room in this article to explain all the implications of these issues, nor some of the other items that were discussed in Council. I think that it is important for all of the membership to discuss what happened with their National Representatives. I will try to document some in the next *Journal* issue, so that the unattached members can understand what is happening.

Finally, I want to finish up on an observing note. The Observing Committee chaired by Chris Fleming has come out with a printed version of the Isabel Williamson Lunar Observing Program. The spiral-bound booklet was available for a mere six dollars, plus shipping if required. It provides members with yet another program on which to focus their observing skills. After all, we are an organization whose mandate is to promote astronomy and observing.

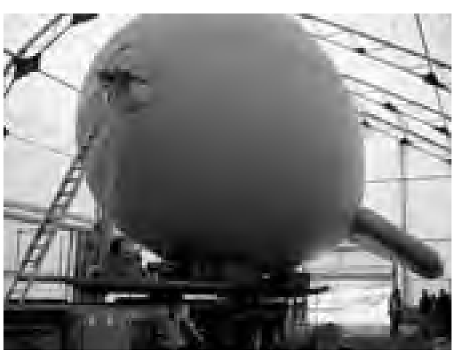
Clear Skies.

GA 2005 *OutTakes*

A selection of memorable moments from the 2005 GA

"Maybe we can reach the sky!"
Photo: Jim Low

"Holy picture tube! How many channels will that monster pick up?"
Photo: Jim Low



Bob – the "Big Orange Balloon"
Photo: Jim Low

"Sorry, but your order call is out of order!"
Photo: Jim Low

A big welcome!
Photo: Kim Hay and Kevin Kell

Society Launches Sustaining Membership Program

by Denis Grey, Chair, Membership & Promotion Committee (denis.grey@sympatico.ca)

Sustain: *To hold up, to bear, to maintain, to support.*

In 2004 the average Royal Astronomical Society of Canada (RASC) member donated to the National Society (choose one):

A. $21.45
B. $15.14
C. $5.47
D. $0.56
E. None of the above

For the correct answer see below.

The RASC has a unique place in Canada and around the world as a vibrant national astronomy organization. Many members may not realize that the RASC is also a registered charity as defined in the *Income Tax Act*. As a registered charity we can undertake programs and help to sponsor activities that will make a difference in advancing astronomy in Canada. Some examples include:

- Funding observatory development projects
- Funding amateur research
- Assisting with a national light-pollution abatement program
- Providing education and outreach materials

In terms of what can be done the sky is literally the limit.

Beginning in August 2005, the RASC will be launching a new program designed to make donations easier and simpler for all of our members. The Sustaining Membership program will invite members who are renewing their membership (either as a regular or youth member) to choose to be a *Sustaining Member.* If you sign-up for Sustaining Membership then the additional fee will be treated as a donation to the Society and you will receive a tax receipt. Here is an example:

Membership Class	Regular Membership	Sustaining Membership
Ordinary	$55.00	$110.00
Youth	$34.25	$69.00
Life	$1,100.00	$55.00 per year

The Sustaining Membership amount shown above is a minimum — there is no maximum donation. As a Sustaining Member of the Society you will receive our heartfelt thanks — along with a notation of your donation in the *Journal* (unless you choose to remain anonymous).

Under a formula agreed to by our National Council, Sustaining Membership donations will be split between the Society and a new special-purpose fund — the **Centre Projects Fund.** This fund will be used to support local initiatives at Centres across the country and allow our shared resources to advance astronomy without impacting the annual budget process. It can be thought of as a "foundation" for advancing astronomy.

Life Members will also be invited to contribute as Sustaining Life Members and our Life Members will receive an annual renewal notice that will invite them to contribute to our Society's well-being through this program.

The new Centre Projects Fund will replace specific grants given by the Society to Centres and is meant to be self-sustaining — in other words the total amount of money in this fund will be available for projects — not just the annual income stream. In the past, the Society has given grants and loans to Centres for projects such as:

- Eccles Ranch Dark-sky Site Improvements (Calgary & Edmonton Centres)
- Construction of an observatory building (Toronto Centre)
- CARO project (Canadian Amateur Research Observatory) (Vancouver Centre)

With a permanent fund established it is expected that these initiatives will be easier to fund and develop with the support of your National Society. A condition of any grant from the new Centre Projects Fund will be a full report to the membership in the *Journal* of the application of the funds so you can see what your money is doing for astronomy in Canada.

The first Sustaining Memberships will be reported in the next issue of the *Journal*. If you would like to be among the first to contribute you may download an application form at `www.rasc.ca/map/sustaining.pdf`.

Your support of this program will help to ensure its success. I encourage every member to consider either a regular donation or a Sustaining Membership in 2005.

The answer is $0.56 per member. Note that this amount does not include donations directed to individual Centres.

Denis Grey is a Sustaining Life Member of the RASC Toronto Centre where he enjoys an excellent selection of 1st, 2nd, and 3rd magnitude stars.

The Skies Over Canada Observing Committee News

by Christopher Fleming (observing@rasc.ca)

The General Assembly of the RASC was held this year in the picturesque City of Kelowna, British Columbia and I extend a sincere "thank you" to all members of the Okanagan Centre who did an outstanding job of organizing a truly memorable GA. The Okanagan Valley is located in the heart of south-central British Columbia and is a land of breathtaking beauty. My appreciation for the awesome geology of western Alberta and British Columbia began when looking out from a window seat on an Air Canada flight to Kelowna via Toronto and Vancouver. I was amazed at how extensive the mountains in that area are and how they cover vast areas of the entire province of B.C. I had pictured them to be spectacular but limited to a relatively narrow band overlapping the Alberta and British Columbia provincial border.

Flying out to Vancouver before connecting to Kelowna turned out to be a bonus sightseeing tour and the view of Greater Vancouver from the connecting flight as it banked over that famous city, on the way to Kelowna, was awesome. As we approached the Okanagan Valley it was like entering a land of make believe and the promise of its incredible beauty was realized and etched into my memory for life. On the bus trip to the Dominion Radio Astrophysical Observatory (DRAO) the view of the spectacular landscape in this area was, for a person from Ontario, like exploring another planet and it did indeed satisfy my desire for such a trip! The DRAO was impressive and seeing the original, and still operational, 26-metre dish close up was very nostalgic, as well as the newer array of seven movable dishes.

For the Observing Committee the big news from the GA in Kelowna was the official adoption and launch of the new Isabel Williamson Lunar Certificate Program. It has been in the works for over five years and we are proud to say that it developed well beyond our original expectations and can be accurately described as a program rather than a simple list of features. This project has been a goal of mine since joining the Observing Committee and I have been actively observing the Moon, and seeking out the best features for the program, since 1999. As the project moved forward other notable RASC observers joined in and as a result several enhancements were added such as lunar geology, challenge features, graphics, and so on.

Special recognition is given to Denis Grey who played a key role in organizing the project and to Terry Millard who provided a great deal of expertise. We also recognize Simon Hanmer of the Geological Survey of Canada who did a comprehensive review of the lunar geology featured in the program and to Richard Wagner who made that possible. In addition, we acknowledge the contributions experienced lunar observers Geoff Gaherty, Bruce McCurdy, Alister Ling, Roger Fell, as well as others for their suggestions and encouragement. Geoff is also credited with recommending that Isabel Williamson by honoured as the namesake for the program. Special thanks also to David H. Levy who wrote an inspiring forward about Isabel Williamson and about the rewarding experience of exploring our nearest neighbor in space. Observing the incredible surface of the Moon is as much about the appreciation of its artistic beauty as it is about its educational value.

The Isabel Williamson Lunar Certificate Program is available in booklet format from the RASC eStore or from Centres that have stocked copies of it. The booklet comes in either a deluxe coil binding or a less expensive, but quite good, cerolox binding that costs about $1.50 less. Since we have printed them in large quantities, it is unlikely that you will save any money by making the booklets yourself, but you are welcome to do so. The electronic PDF version of the program can be found on the RASC Web site at: `www.rasc.ca/observing/lunar` and we invite you to give it a try.

The Explore the Universe Certificate program features a good primer for lunar observing that covers the phases of the Moon, orbital motion, the major impact basins or maria, and several prominent impact craters. The lunar-phases portion requires that the observer identify and record four of the eight options given. The eight options are a Waxing Crescent Moon within three hours after sunset, a First Quarter Moon eighteen hours before or after the exact time of that phase, a Waxing Gibbous Moon three to four days after First Quarter, a Full Moon within eighteen hours of the exact time, a Waning Gibbous Moon three to four days after Full, a Last Quarter Moon within eighteen hours, and a Waning Crescent Moon within three hours before sunrise. Since a New Moon is not observable the eighth option is to observe the orbital motion of the Moon by noting its changing position in the sky against the background stars or of a stationary terrestrial object such as a tree.

The lunar basins or maria portion of the program requires the observer to identify and record observations of six of the twelve options given. The options are Mare Crisium, Mare Fecunditatis, Mare Nectaris, Mare Tranquillitatis, Mare Serenitatis, Mare Vaporum, Mare Frigoris, Mare Imbrium, Mare Nubium, Sinus Iridium, Mare Humorum, and Oceanus Procellarum. The impact-craters portion requires the observer to identify and record observations of six of the twelve major craters listed. They are Petavius, Cleomedes, Posidonius, Theophilus, Aristoteles, Ptolemaeus, Plato, Tycho, Clavius, Copernicus, Gassendi, and Grimaldi. Note that all of the features are listed chronologically so that they will rise and set in order as the terminator moves over the lunar surface.

The Prince George Centre, through the efforts of Brian Battersby, is now offering an innovative course in astronomy based on the Explore the Universe Certificate. It is called NOVA (New Observers to Visual Astronomy) and if you would like more details about this excellent public-education program you can go to the following Web site address directly: `www.vts.bc.ca/pgrasc/nova/nova.html` or you can look for it via links on the Prince George Centre Web site. The Observing Committee encourages local observing and education committees to consider using the NOVA program as a model for an RASC Centre astronomy course. The Public Education Committee may also create a complete course package, including materials, for the NOVA program that will be available to Centres.

We are glad to report that there have been two Explore the Universe Certificates awarded since our last report, and those fine observers are listed in Table 1.

There have also been two Messier Certificates awarded since our last report and those talented observers are listed in Table 2. Special congratulations to Past-President Randy Attwood who has been seeking a Messier Certificate for many years. Way to go!

In addition, there have been four Finest NGC Certificates awarded since our last report, and we are delighted to award one to an observer in Eugene, Oregon, U.S.A., who is a member of the Vancouver Centre. A list of the skilled Finest NGC recipients can be found in Table 3.

Congratulations to all!

The Asteroids Section features charts containing the orbital position of several bright asteroids that will be visible in 2005, and during September and October you will be able to print charts for the asteroids (3) Juno, (4) Vesta, (19) Fortuna, (20) Massalia, and (89) Julia. Those asteroids will all be brighter than tenth magnitude at that time, and the charts will display nearby stars to tenth magnitude on a five degree or greater vertical field layout. Dates for the position of each asteroid will be listed at three day or longer intervals, and nearby bright "finder stars" will be highlighted. In many cases the finder stars are bright enough to be seen visually and therefore a *Telrad* or similar pointing device can be used to target the field printed on the charts. Otherwise a typical finder-scope or binoculars with be sufficient to find the brightest star in the field.

The Variable Stars Section features direct links to genuine American Association of Variable Stars Observer's (AAVSO) magnitude estimate charts for Mira-type Long-Period Variables that will reach maxima in 2005, and that will be brighter than magnitude 8.0. For September and October 2005, you will be able to print charts for S Herculis, S Coronae Borealis, R Aquarii, V Monocerotis, and R Cancri. We also have direct links to charts for several other variable star types and you will find them on the Sample Charts 2 page. Many of the most interesting variable stars in the night sky are listed there as well as the positions of possible nova outbursts.

The Comets Section has provided accurate finder charts for several comets since being launched last autumn, most notably for C/2001 Q4 (NEAT), C/2004 Q2 (Machholz), and C/2003 K4 (LINEAR). We will continue to post charts for currently visible comets, some to as faint as fifteenth magnitude, that will challenge even the most demanding observers with large telescopes.

The Special Projects Section has been updated quite significantly and now features resources from across the RASC. The purpose of this upgrade is to provide a wider range of content than was possible by committee members alone. By tapping into key Web pages from Centres and individuals across Canada, visitors to the national Web site will be more likely to find the information they are looking for. This should increase Internet traffic to and from the local Centres and that will be mutually beneficial. We invite you to have a look at `www.rasc.ca/observing/projects` and if you have a Web page that you would like us to post there, please let us know.

Clear Skies.

Christopher Fleming is Chair of the RASC Observing Committee and Observers Chair in the London Centre. He enjoys all types of observing especially Deep-Sky, Lunar, Double Stars, and Variable Stars. Chris is also a musician and Webmaster of the London Jazz Society's Web site.

Table 1. Explore the Universe Certificate Recipients.

Name	Centre	Date Awarded
Greg Dean	Okanagan, B.C.	April 2005
Keith Johnstone	Calgary, Alta.	May 2005

Table 2. Messier Certificate Recipients.

Name	Centre	Date Awarded
Stephen Keefer	Toronto, Ont.	April 2005
Randy Attwood	Toronto, Ont.	May 2005

Table 3. Finest NGC Certificate Recipients.

Name	Centre	Date Awarded
Richard Weatherston	Sarnia, Ont.	April 2005
Robert Burbank	Toronto, Ont.	May 2005
Michael Hanes	London, Ont.	May 2005
James Jackson	Eugene, Oregon, U.S.A.	May 2005

Orbital Oddities

Noon Moon

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

If you want to write a song about the moon
Walk along the craters of the afternoon
When the shadows are deep and the light is alien
And gravity leaps like a knife off the pavement

If you want to write a song about the heart
Think about the moon before you start

— Paul Simon, *Song About the Moon*

One gets a skewed view of the Universe way up here in the Great Blight North, home of aurora borealis and noctilucent clouds, perpetual twilight and persistent forest fire smoke. At 53° 33′ N, we Edmontonians are located halfway between the "midnorthern latitudes" favoured by astronomy magazines and the Arctic Circle. The invisible colures of the celestial grid meet the horizon at a sufficiently oblique angle to provide at least a taste of what our still more northerly neighbours face.

I've always wanted to see the Midnight Sun, but my life's brief adventures in the Northwest Territories have been limited to locales south of the Arctic Circle: Fort Simpson, Yellowknife, Rankin Inlet, the Nuclear Winter known as Norman Wells. It occurs to me that most *northerners* have never seen the true Midnight Sun.

However, it *is* possible to observe from many of these locations, an analogous phenomenon I call the Noon Moon — more specifically, the noon *Full* Moon. (Call it the Circumpolar Moon if you like, or the True North Strong and Free Moon, but they don't make for catchy column titles.)

The Arctic Circle is defined by the Earth's tilt, and is tangent to the extremes of the ecliptic (the solstices). However, the orbit of the Moon is itself tilted to the ecliptic plane by 5° 09′, a second sine wave superimposed on the first. Every month the Moon crosses the ecliptic at two points called nodes. These are not fixed points; due to the competing gravitational influence of the Sun and Earth, the nodes move westward around the ecliptic at a fairly rapid rate, completing a full rotation (the "regression of the nodes") in 18.61 years. We are fast approaching the next maximum of this cycle: on June 19, 2006 the Moon's ascending node Ω passes through the First Point in Aries (Ω = 0°). The tilt of the Moon's orbit will then be piggybacked atop the tilt of the ecliptic, and the two sine waves are fully constructive (see Table 1).

The Moon will achieve extremely high and extremely low declinations throughout 2006, although the effect is obvious already. In the years leading up to "lunar max," as now, observers at any latitude might notice the Moon cresting the meridian exceptionally high — or low — in the south. As it passes through Taurus and Gemini, it is 5° above the northernmost part of the ecliptic, at a declination of +28° and change. Similarly, when it passes through Sagittarius it is 5° south of the winter solstice point and therefore at declination < −28°. The previous maximum was in 1987, the next in 2025. At the other extreme, in 1997, 2015, *etc.*, the Moon's *descending* node crosses the First Point, the sine waves are destructive, with flattened declinations of ± 18° at most (Bishop 1996; Gupta 2004).

Variations in lunar declination were monitored in ancient observatories such as Stonehenge, and are easily observable by even the most casual skywatcher with a long enough attention span. I have been observing this effect for almost one full revolution of the nodes now, it having been brought to my attention at the last maximum courtesy of Lovi (1987).

The regression of the nodes governs such phenomena as occultation series of stars within the zodiacal band and dates of eclipse seasons, which also regress forward through the calendar. Since the nodes are near the equinoxes at the time of lunar max, that's when eclipses occur. 2006 eclipses will occur March 14 and 29, September 7 and 22. Equinoctial eclipses will next happen at declination minimum around 2015, when the nodes will have rotated 180°.

More fundamentally, this cycle affects the Moon's appearance in the sky. Here at 54° latitude, the Moon can be above the horizon for as few as ~6 to as many as ~19 hours a day just now; a decade ago, these figures were a more balanced ~9 to ~16 hours. The Moon's altitude at the meridian now ranges steeply from 8 to 65 degrees, compared to a shallower 18 to 55 degrees at minimum. The azimuth of moonrise/set is 22° more extreme in each quadrant.

This extra tilt merely accentuates Luna's natural rhythms. The Moon reaches similar declinations each month as it passes through Taurus and Sagittarius, but its phase is of course dependent on the position of the Sun. The high (northern) Moon will be a thin waning crescent in July, a thick waning crescent in August, third quarter in September, full around the December solstice, and first quarter around the vernal equinox. So it is every year, but especially near lunar max with its enhanced ecliptic.

Deep sky observers will appreciate that understanding lunar visibility times also means understanding lunar *invisibility* times. Dark-sky observing windows at lunar max are significantly different from the flat Moon of a decade ago, even more heavily concentrated in one half of the month. In March that waxing Moon seems to hang around all night, but dark sky conditions begin to prevail only two or three days after Full Moon and moonrise times take giant steps later each night thereafter. The opposite is true in the fall, the waxing Moon sets pretty early and there is predawn observing to be had well into the gibbous phase.

The Harvest Moon effect is amplified during periods of high declination (Meeus 2002). Here in Edmonton as the Moon rushes northward up the ecliptic moonrise times can be < 10 minutes apart at lunar max, compared to about half an hour at declination minimum. Although less prominent at other times of year, there are similar clusters of rise/set times every successive month at regressing phases but around the same sidereal time.

The further north one goes the more extreme these effects become. Strange things start to happen once the combined terrestrial latitude (62°, roughly Yellowknife) and lunar declination (> +28°) add up to greater than 90°. The Moon becomes circumpolar at its crest, and displays unusual properties against the local horizon throughout the month.

Let's check out the moonrise/set tables beginning on page 122 in the *Observer's Handbook 2005*. The extreme right column, 62° north latitude (introduced to the annual *Handbook* since the last maximum), displays some very peculiar qualities, with the Moon following a weird retrograde rhythm each month; entire passages of the Music of the Spheres written in a negative time signature.

This December the New Moon, five degrees below the Sun, sets at 13:15 local time on December 1, and stays below the horizon for three days before rising at 13:30 on the 4th (see Table 2). The waxing Moon then begins to rise at least five minutes *earlier* each day, somewhat similar to a star at fixed coordinates. Except the Moon is rushing eastward around the ecliptic at 12-15° per day. How can it be rising earlier?

The key point is that it's moving *north*eastward, along an arc that is better than parallel to the local horizon. At the opposite horizon, where northward and eastward have an additive relationship, moonset time rushes later by almost two hours per day.

The Full Moon rises at 12:15 local mean time on the 15th, an hour and a quarter earlier than the 4th, and by now almost due north. It doesn't set until 12:32 on the 17th, 48 hours later, also almost due north. On the 16th, it officially doesn't set at all, and theoretically will be visible due north at local noon.

The lunar downfall is equally as spectacular as its rise. The waning Moon continues to set around local noon for almost a fortnight, but now the daily moonrises are delayed as the azimuth of events rushes towards due south.

Over a lunation the moonrise/set intervals average out to the usual 50 minutes per day of eastward motion that rule the tide tables. But from the oblique perspective of our hypothetical Yellowknife observer, the daily deviations from this norm caused by north/south movement are on the scale of an hour, and group together for maximum effect.

By January 2006, moonrises are bunched around 11:00 LMT, followed by a fortnight of moonsets around 10:00, February moonrises around 9:00 and so on (NAO/HMNAO 2003). Observers at lower latitudes will experience less extreme moonrise/set clusters centred on the same local times.

There are other smaller effects the circumpolar Moonwatcher must account for. One is topocentric correction, in which the northern observer's position high up the globe shifts the Moon's declination approximately 1 degree south of its geocentric position.

Atmospheric refraction corrects for most of this. Russ Sampson, an expert on this topic, measured atmospheric refraction from many sunrises/sets from Edmonton, with an average around 0.7° and a significant variability depending on the time of year (Sampson *et al.* 2003). Russ wrote to me:

> As our current research is showing, the variability of the refraction at or near the horizon depends on your climate (*i.e.* geographical location). It appears that in a cold continental climate like Edmonton or Yellowknife, the variability will be relatively large but for a maritime (especially tropical maritime like Barbados), the variability appears to be minimal.... The higher latitudes are famous for extreme astronomical refraction events. From Edmonton I've seen as much as 2 degrees and some historic events have measured as much as 5 degrees (Sampson 2004, private communication)!

Such mirages of the Sun (the "Novaya Zemlya Effect") have been reported by RASC life member Stephen Bedingfield from his long-time home in Cambridge Bay, Nunavut (69° 06´ N). In 2001 the Sun "rose" unexpectedly on December 12, *two weeks* into "the Long Night" (~Nov.29 to Jan.15), when the solar depression angle was > 2° (Bedingfield 2005, private communication).

Whether the Moon is bright enough for such extreme mirages is an open question, especially in broad daylight as the Noon Moon must be viewed from "southerly" latitudes like Yellowknife. It's probably worth a look from anywhere north of 60 to watch for the high declination Moon of any phase scraping the northern horizon. Bring your binoculars! Look any month on or around the day of greatest declination north, conveniently listed on the left hand pages of the Sky Month by Month section of the *Observer's Handbook*. Time of day of lower culmination will jump ahead a couple of hours from one month to the next, in step with the regressing lunar phase, but always around 18h sidereal time.

RASCals in Canada's northern territories, consider the Noon Moon an(other) observing challenge. I would be pleased to correspond privately with all who attempt to observe it.

Table 1. Extreme geocentric declinations of the Moon, 1950-2050 (Meeus 1997).

The Moon's ascending node crosses the vernal equinox at regular intervals of 18.61 years (left column). While this can happen on any day of the year, the maximum declinations always occur around the equinoxes. The tilt of the Moon's orbit itself varies by some 17′ — a third sine wave rippling through the other two — with a maximum inclination of 5° 17′ coinciding with the nodes' alignment with the Sun every 173.3 days. The extreme declinations occur 90° from the nodes, and therefore always occur at quarter phases in the spring or fall at values near 28° 43′.

Typically the two maxima of a given cycle occur at opposite lunar phases at an interval of a fortnight, but in 2006 they are separated by six lunations with both occurring at third quarter. To prove the position of the nodes, in each case there is a lunar eclipse a week before the maximum, and a solar eclipse a week after.

The interval from one maximum to the next is either ~18.5 or 19.0 years. The latter period is the well-known Metonic cycle in which the Moon returns to the same phase on the same date (**boldface**).

Ω = 0°	**Max North**	**Max South**
Aug 17, 1950	Oct 3, 1950	Sep 19, 1950
Mar 29, 1969	Mar 25, 1969	Mar 11, 1969
Nov 8, 1987	**Sep 15, 1987**	Sep 29, 1987
Jun 19, 2006	**Sep 15, 2006**	**Mar 22, 2006**
Jan 29, 2025	Mar 7, 2025	**Mar 22, 2025**
Sep 10, 2043	Sep 25, 2043	Sep 12, 2043

Table 2. Moonrise and set table for 62° N, 0° W, December, 2005 (Gupta 2004).

Date	**Phase**	**Rise**	**Set**
1	NM	9:52	13:15
2		does not rise	
3		does not rise	
4		13:30	16:10
5		13:19	18:27
6		13:12	20:29
7		13:06	22:21
8	FQ	13:01	—
9		12:56	0:05
10		12:51	1:46
11		12:46	3:28
12		12:41	5:13
13		12:36	7:03
14		12:30	9:00
15	FM	12:15	11:09
16		does not set	
17		14:40	12:32
18		16:35	12:23
19		18:19	12:17
20		19:54	12:12
21		21:24	12:07
22		22:51	12:03
23	LQ	—	11:58
24		0:17	11:53
25		1:46	11:48
26		3:20	11:43
27		5:04	11:37
28		7:01	11:30
29		9:17	11:16
30		does not rise	
31	NM	11:52	13:12

Dedication

This article is dedicated to Dr. Roy Bishop whose gravitational influence can be felt all the way from Nova Scotia to Alberta.

References

Bishop, R.L., Editor 1996, The Observer's Handbook 1997 (University of Toronto Press: Toronto), 45, 88

Gupta, R., Editor 2004, The Observer's Handbook 2005 (University of Toronto Press: Toronto), 77, 122, 133

Lovi, G. 1987, Sky & Telescope, 73-1, 57

Meeus, J. 1997, Mathematical Astronomy Morsels (Willmann-Bell Inc.: Richmond), 26

Meeus, J. 2002, More Mathematical Astronomy Morsels (Willmann-Bell Inc.: Richmond), 11

Nautical Almanac Office 2003, USNO/HM Nautical Almanac Office, UK, Astronomical Phenomena for the Year 2006 (U.S. Government Printing Office: Washington), 33

Sampson, R.D., Lozowski, E.P., Peterson, A.E., & Hube, D.P. 2003, PASP, 115, 1256

Bruce McCurdy has felt the pull of the Moon since the Apollo 8 mission two revolutions of the nodes ago. He has been actively observing our satellite for one Metonic cycle.

Dr. Sara Seager

by Philip Mozel (phil.mozel@sympatico.ca)

In 1990 the *Voyager 1* spacecraft was commanded to "check its rear view mirror" and photograph the Solar System it was rapidly leaving behind. From a distance of six billion kilometres the planets were no more than specks. But one, a "pale blue dot," stood out from the rest, not due to its brightness but because it was home: Earth. Today, astronomers are on the verge of replicating this feat by finding a new Earth, orbiting not the Sun, but another star.

Only seventy-five years ago Pluto, the last planet of the Solar System (as far as we know) was detected. Just ten years ago, the first of many extrasolar planets was discovered. To date, all have been comparable to Jupiter in size. Finding much smaller terrestrial planets will be correspondingly more difficult. Dr. Sara Seager is using her expertise to help track them down.

Dr. Seager is a Staff Scientist in the Department of Terrestrial Magnetism, Carnegie Institution of Washington, and the Chair of the Astronomy Focus Group of NASA's Astrobiology Institute. NASA defines astrobiology as "the study of the origins, evolution, distribution, and future of life in the Universe." One role of the Focus Group is to foster dialog between astronomers, on the one hand, and scientists working in astrobiological fields, on the other. A future, high profile result of this cooperation will be the *Terrestrial Planet Finder (TPF)* mission. Dr. Seager, with her interest in detecting and characterizing extrasolar planets is, naturally, involved.

One current method of detection is to observe planets transiting their parent star. The planet is not actually seen but a slight drop in light from the star indicates the planet is there. (Those who observed the transit of Venus in June 2004 will appreciate how little light is actually lost!). Dr. Seager co-runs a program that looks for Jupiter-class planets of short period that regularly transit. From such observations one may determine the planet's mass, size, and atmospheric qualities. To aid in foretelling what such atmospheres will be like, Dr. Seager makes predictions based on radiative transfer models and knowledge of the planet's properties and distance from its star. Her prediction of sodium in the atmosphere of the giant planet HD209458b led to the first detection of an extrasolar planet atmosphere by the *Hubble Space Telescope* in 2001.

Dr. Sara Seager

TPF will go beyond this. The first phase involves an orbiting visible light telescope equipped with a coronograph for blocking the light of the parent star, rendering the much dimmer planet visible. (Some readers may have used a similar technique to locate, for example, the dim moons of Mars: an occulting bar in the focal plane of the eyepiece may be used to hide the overwhelmingly bright planet). The *TPF* coronograph, however, will allow the detection of planets "fainter than any galaxy seen by the *Hubble Space Telescope*." Launch is currently scheduled for 2016.

The second phase involves the launch, around 2020, of two formation-flying spacecraft to create an infrared interferometer. Together, *TPF's* three orbiting observatories are expected to detect and gather information about Earth-like planets around as many as 150 stars up to 45 light years away.

Alright, so we find an Earth-like planet. Next comes *the* question: is it inhabited? How can we tell at such huge distances? By looking for non-equilibrium chemistry. Spectroscopic examination of the planet will determine if molecules such as oxygen are present. Oxygen is so reactive that it will not long persist in a planet's atmosphere unless there is a source of replenishment. Plant life is one possibility. But there are other, non-biological sources as well. For example, water on the surface might be constantly evaporating. Water molecules, due to photo-dissociation, may then split into hydrogen and oxygen. Determining if we have discovered extra-terrestrial life will be tricky especially since we presently only know how to look for Earth-type life. Dr. Seager admits, "We are rather narrow minded right now."

Dr. Seager, on the other hand, has a rather expansive mind. She began her professional astronomical life as a cosmologist and investigated the Universe during the so-called recombination epoch. At this time, some 300,000 years after the big bang, photons were just about finished interacting heavily with matter. We see this time manifested today in the cosmic microwave background radiation. Dr. Seager and her colleagues published a seminal paper on the subject.

Then it happened, the event that catapulted her career in a completely new direction: the discovery of the first extra-solar planet in 1995. She decided that such planets provided a much more fertile field for research and quickly immersed herself in the new topic.

Like a number of astronomers appearing in this column, Dr. Seager followed a familiar path into astronomy. When she was young, her father took her to RASC star parties and for tours at the David Dunlap Observatory. She eventually joined the Society in the late '80s or early '90s. But it was at an open house at the University of Toronto's Department of Astronomy that she learned that well, yes, you can actually do astronomy for a living! There was no turning back. She returned to the university to obtain a BSc. in Mathematics and eventually a Ph.D. in Astronomy from Harvard.

One day we will surely discover other Earths in the deep reaches of space. One can only imagine what a thrill it will be for astronomers such as Sara Seager who, to paraphrase John Keats, have "...a new blue dot swim into their ken."

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

GA 2005 *OutTakes*

Seven Past-Presidents - can you name them all?
Photo: Jim Low

"Hey! They're finally feeding us!"
Photo: Kim Hay and Kevin Kell

"OK, who forgot the wine glasses?"
Photo: Kim Hay and Kevin Kell

Here's lookin' at you!"
Photo: Kim Hay and Kevin Kell

Murphy and Me

by Guy Nason, Toronto Centre (gnason@rogers.com)

I arrived at Forks of the Credit Provincial Park with two hours to spare. It was a dark February evening and I was there to record the occultation of a 10th magnitude star in Leo by the asteroid (112) Iphigenia. The park, an hour's drive northwest of Toronto, is often used by members of the Toronto Centre as a relatively dark observing site. I chose it on this occasion because it was on the centreline of the predicted occultation path. All was going well, but I have done this sort of thing enough to know that Mr. Murphy and his Law are never far away. I am sure you are all familiar with Murphy's Law: "If anything can go wrong, it will." Occultations, especially winter occultations, are among Mr. Murphy's favourite playgrounds.

Despite my respect for Mr. Murphy, my confidence was high. The sky was clear, my batteries were charged, all of my equipment was present and accounted for, and I had lots of warm clothing. I was in good shape.

I should have known better than to think that Murphy wouldn't put in an appearance. My first clue to his presence came when, after squirming into my snowmobile pants (these things shrink a bit every year!), donning my sheepskin coat and sheepskin hat, and pulling on my boots (guaranteed to −100°C), I reached for my special super-warm gloves. Oops! No gloves, other than the light dress gloves I wear while driving. They are totally inadequate for wrestling cold metallic equipment around at −13° C. It looked like Murphy was in attendance, after all.

I wouldn't succumb without a fight. I rummaged around in the bowels of my van, looking for a pair of old work gloves I could pull on over my dress gloves. I sifted through bungee cords, toolboxes, a winter safety kit, old rags, a trailer hitch, and other detritus and … what's this? A pair of long-lost ski gloves were hiding under the driver's seat. They would do fine under the circumstances. Sometimes it pays to be messy. Take that, Murphy!

So, properly clad, I proceeded to set up and align my telescope (an equatorially mounted, motor-driven 8-inch f/5 Newtonian). I opened my folding trestle table and placed on it my eyepiece case, shortwave receiver, TV/VCR combination unit, "surveillance" camera (that would eventually replace the eyepiece and send a video image of the target star to the TV/VCR), and assorted cables.

As an anti-Murphy measure, I had practiced finding the target star on two previous nights, so I had no trouble at all star-hopping to it, despite the nearby Full Moon. So far, so good, but something odd was happening. Despite the running drive motor, the star was slowly drifting across the field of view. I checked that the clutches were tight and that the right-ascension drive motor was indeed stepping along. Yes, they were and yes, it was. The 6-volt battery pack must be down on power, even though I had checked it earlier that day. I changed to my back-up power pack and even placed a chemical hand-warmer packet inside it. Still the stars drifted. I could overcome this fault by periodically repositioning the star using the slewing controls; however, it did slow down the rest of the set-up process since I had to check and adjust the drive every minute or so. One for Murphy.

The shortwave receiver was set up and I scanned frequencies to find the strongest time signal. On this night there was only one acceptable choice: CHU at 3.330 MHz, and even it was a bit noisy. So I pulled out my home-made auxiliary antenna (25 feet of insulated wire with an alligator clip soldered onto one end), strung it out its full length and clipped it to the receiver's antenna. Ah, much better!

The 12-volt deep-cycle batteries I use to power the TV/VCR and the camera were in great shape and performed admirably throughout. So did the camera. The only hitch was that, compared to the low-power eyepiece, the camera has a very narrow field of view, so the time it took the star to drift across the screen was reduced to about 15 seconds. Annoying, but manageable.

In addition to the video signal, I also need to put an audio time signal on tape in order to have a precise timing of the disappearance and reappearance of the star. I choose to do this with a microphone, rather than by a direct line from the shortwave receiver to the VCR. That way, I can make pertinent comments as required without disturbing the time signal recording. So I got out my little preamp/microphone unit and plugged it into the TV/VCR and positioned it near the shortwave where it could pick up the beep-beep-beep of CHU. This took a bit of fiddling to get the balance right, and while repositioning the microphone, it came apart in my hand! The microphone itself is a very small device with a multipin connection to the cable. It has very, very small pins. There was no way I could put this back together in the dark, in the cold, without jeweller's tools (and without plenty of patience). Damn you, Murphy!

All was not lost as I could still use the direct-line method, rather than the microphone. Luckily, I had the right cable in my kit, so I dug it out and plugged it in — one end to the receiver's "Earpiece Out," and the other to the VCR's "Audio In." This method worked fine and beat Murphy back into the shadows where he belongs.

Despite these glitches, things were still reasonably under control. They weren't ideal, but I was ready with good video and audio signals on tape. I would begin recording about four minutes prior to the predicted disappearance time and I still had about 30 minutes to spare.

That was the problem. I had lots of time to tinker, even though I should have known better. Surely the recording would be more esthetically appealing if the field were oriented with north up and west to the right, just like a star chart. Re-orienting the image is easy to accomplish simply by rotating the camera in the focuser. That's when Murphy gleefully leaped from the shadows. While adjusting the camera, the screen went blank. I had lost the signal!

One thing I had learned long ago is that a loss of signal is almost always caused by cables, especially in cold weather. So I wiggled cables until the signal came back. Then, while holding the video cable just so, I taped it to the camera housing in such a way as to maintain the delicate internal connection. Signal restored; but since this took several minutes, the target star was now gone! I had to remove the camera, reinsert an eyepiece, go star-hopping again, centre the target and replace and refocus the camera. Which I did.

D (for "Disappearance") minus 15 minutes and counting. (Always counting; this is one countdown that cannot be placed on hold.) It was all right, though, because I still had lots of time and the video orientation was now correct. Everything was A-OK. Then along came Murphy, again. In moving about to keep warm, I bumped the counterweight shaft and lost the star. What a klutz! What to do? I wasn't confident that I had enough time to start the star-hop all over again, but on the screen was a pattern of stars I recognized. I was sure the target was up and to the left from it. So I nudged the telescope up and over…*et voila!* There's the target. Whew! Murphy was defeated again!

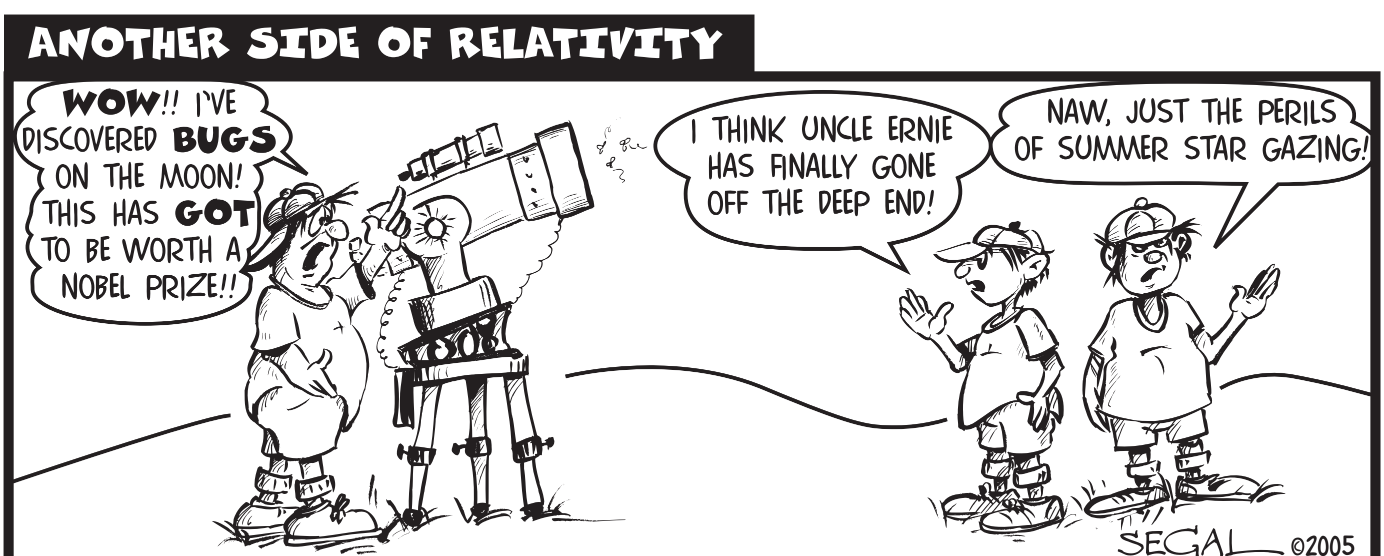
Murphy is no quitter, though. With two minutes to go before I was to start recording, the CHU broadcast began to fade. Worse, an evangelical broadcast from Macon, Georgia was increasing in power and walked all over the nice couple in Ottawa who, in fine bilingual fashion, told me the time every minute. I tried other frequencies used by CHU and WWV, the American counterpart in Colorado. This is why we use receivers with presettable tuners. No searching the dial; just push the buttons. Unfortunately, none of the other seven preset frequencies was intelligible. I was stuck with hymn-singing and preaching over a fading CHU signal. Knowing that the time signal could be coaxed out of the sermon later by people more talented than I at that sort of thing, I pressed on. I had to concede this round, by split decision, to Mr. Murphy.

That's when my adversary got serious. At D minus 2 minutes, with the tape recording and the star slowly drifting across the screen, the telescope drive failed completely. Suddenly, the star shot across the screen and off the edge! Yikes! The batteries were dead! I was out of 6-volt power packs, so I grabbed the telescope tube and pushed it westward. This got the star back on the screen, but it bounced around quite a bit while I held pressure against the clutch. I barely managed to hold it on-screen as it glowed away brightly and continuously.

And continuously. And continuously. D time came and D time went and three more minutes came and went and the star, though dancing merrily on the screen, persisted without so much as a flicker. After all this battling with Mr. Murphy, I had recorded a miss. This was a hollow victory at best, but my observed miss might still be useful as a constraint on the asteroid's actual size, provided that others elsewhere were successful. I kept that thought in mind while I shut down my equipment and proceeded to pack everything back into the van.

Murphy wasn't finished yet. Being the sore loser he is, he just had to take one more cheap shot. While packing up the shortwave radio, the telescoping antenna snapped off in my hand. Sheesh! That guy just never gives up!

Guy Nason is Past President of the Toronto Centre and a member of International Occultation Timing Association (IOTA). He has been chasing occultations and solar eclipses for about 15 years.



Reviews of Publications
Critiques d'ouvrages

Astronomical Heritages: Astronomical Archives and Historic Transits of Venus, edited by Christiaan Sterken and Hilmar W. Duerbeck, pages 342 + ix, 15.5 cm × 24 cm, 2004. Order from: C. Sterken (csterken@vub.ac.be). Price 25 € (euro) surface shipped, 37 € overseas airmail, softcover (ISBN 9080553867).

We amateur and professional astronomers are normally concerned with the here-and-now of astronomy — what we can see in the sky, and how to describe and interpret it. Occasionally, however, something reminds us about the long-ago-and-far-away of astronomy. The June 8, 2004 transit of Venus, for instance, was the first since 1882. Nobody alive on Earth had witnessed the phenomenon. We had to depend on reports from earlier times, when astronomical photography was in its infancy and electronic records were a thing of the future.

We might ask whether *our* observations and theories will be preserved for the future. Early 20th century astronomy was preserved on photographic plates. Their future is in question. Elizabeth Griffin, based in Victoria, B.C., is leading an international campaign to digitize and preserve such records. Much of late 20th-century astronomy was preserved on magnetic tape — a less-than-permanent medium. Today, astronomers and their information science partners are struggling with issues of how to publish and preserve research papers and data. What are the relative merits of an electronic versus paper medium? And, with the advent of electronic communication, how much of the correspondence of the great (and not-so-great) astronomers will be preserved for historians of the future? Archiving is a current issue, not just an historical one.

Who speaks for the astronomical past and future? The International Astronomical Union (IAU), for one; it was founded in 1922 "to promote and safeguard astronomy…and to develop it through international co-operation." Membership is free for qualified professional astronomers, so there is no barrier to astronomers from disadvantaged countries. Its Commissions and Working Groups co-ordinate the international aspects of astronomy.

Astronomical Heritages is a product of two IAU Working Groups. It is a collection of papers edited by two astronomers whose interests extend well beyond their own research expertise to broader issues such as astronomical history, heritage, publishing, and the role of amateurs in astronomy. The book is divided into two equal halves: the first dealing with archives of early modern astronomy, and the second dealing with observations of the 18th and 19th century transits of Venus.

In the opening paper, S.M.R. Ansari describes nine Indian observatories dating from the "modern" era — post-1792, as compared with the great stone observatories of earlier times, in places such as Delhi and Jaipur. Some modern observatories in India were established by local rulers, others by the colonial government, by private individuals, or by colleges. Though Ansari gives two dozen references to archived information, his comments suggest that much other information has not been located, or is lost entirely.

Brenda Corbin then describes the situation at the U.S. Naval Observatory, one of the powerhouses of 19th century astronomy and one that launched eight different expeditions to observe the 1874 transit. Yet the results, though meticulously prepared and even set in type, were never published, in part because of lack of funding. As for archiving, there are plans to move the USNO archives to the National Archives, which is not a bad idea given that a weekend water leak at USNO in 2004 was a definite threat to their well-being.

Wayne Orchiston then provides impressive "potted" (one-page) histories of astronomy in Australia and New Zealand, along with master lists of the archives available in each country. That is followed by a much more detailed 27-page article by Orchiston on John Tebbutt (1834–1916), Australia's foremost 19th century astronomer, an amateur with an international reputation. Tebbutt's archives are large, varied, and well-preserved in the Mitchell Library in Sydney, a valuable resource for present and future historians.

Magda Stavinschi and Vasile Mioc take a much broader definition of "archives" in describing the two-thousand-year history of astronomy in Romania; they include stone and wood structures, sanctuaries and churches, sundials, pictographs on coins, and even eggs, inscriptions on walls, oral history, as well as fifteen centuries of writings and five centuries of observatories. Other papers in the first half of the book describe archives in France, Georgia, Germany, Italy, Japan, and the United Kingdom.

The second half of the book is devoted to discussions of expeditions to observe the 18th and 19th century transits of Venus. The discussions are interesting for many reasons, including the fact that we are in the midst of the 21st century transits (I watched the June 8, 2004 transit from my back garden).

One reason why the Venus transits are interesting is because of the individuals involved, some of whom are not well known. For instance, the memorably-named Maximilian Hell (1720–1792), an Austrian, traveled to the far northern tip of Scandinavia to observe the transit of 1769 — successfully. I leave it to you to read about the intrigue surrounding Hell's results. Another paper describes the role of the Austro-Hungarian navy in transporting scientists to their destinations, including a very detailed account of the corvette *Erzherzog Friedrich*. It reminds us that astronomical "observing runs" are much different (and easier) today than in the past.

The centrepiece of the last half of the book is Wayne Orchiston's 90-page paper on "The 19th Century Transits of Venus: an Australian and New Zealand Overview." Profusely illustrated with over 50 photos, sketches, and diagrams of the transit, of the people who observed it, and of the observatories, telescopes, and instruments they used, the paper is a wonderful celebration of astronomical "people and places."

The editors Christiaan Sterken and Hilmar Duerbeck and two colleagues close the book with an account of the Belgian astronomer Jean-Charles Houzeau, his innovative technique for measuring the images of the Sun and of Venus, and his expeditions to Texas and to Chile.

The book is well produced, generally clearly written, and could be understood and appreciated by almost any reader of the *Journal*. All in all, it provides an interesting balance between perspective and detail, and between past and present; much has changed in two centuries, but much has stayed the same. This is a book that I shall continue to browse for many years to come.

John Percy

John Percy is Professor of Astronomy and Astrophysics at the University of Toronto, and Director of Science Education Programs on the university's Mississauga Campus. He is a former National President of the RASC.

Astrocryptic

by Curt Nason, Moncton Centre

We present the solution to last issue's puzzle

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

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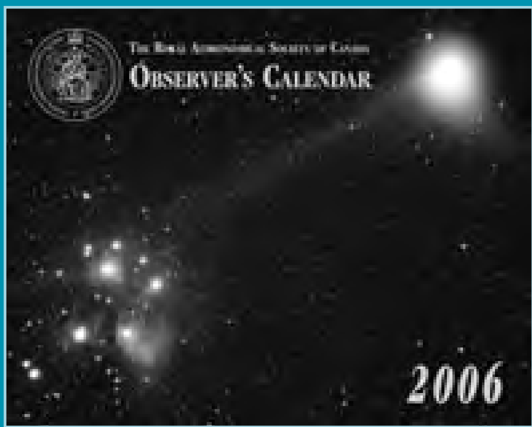

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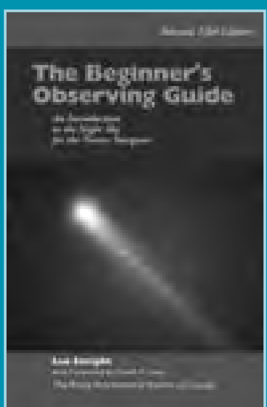

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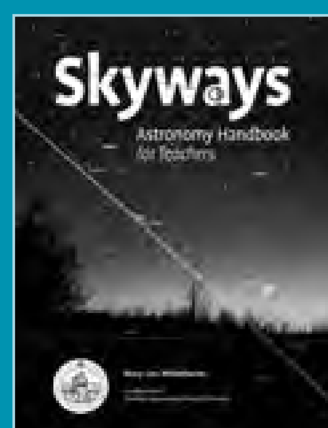

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