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Journal

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August/août 2001

Journal

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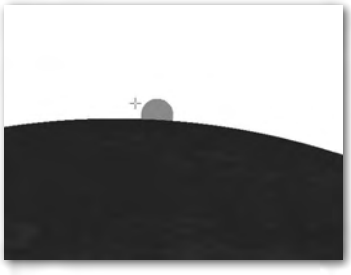

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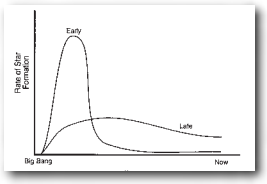

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President's Corner

by Robert F. Garrison (garrison@astro.utoronto.ca)

The year 2001 has been designated the International Year of the Volunteer. The RASC, as a society with over 4500 volunteers and only two part-time employees, is an outstanding example of the powerful impact such organizations can have on public information and enjoyment. Helen Hogg published a popular book with the title *The Stars Are For Everyone,* and indeed some knowledge of the starry night and its enjoyment, as well as the instrumentation and techniques used, should be available to anyone who wants it. However, with increasing light pollution and decreasing outdoor activities, the level of public awareness, even of such simple phenomena as the phases of the Moon, needs a boost. The RASC already has the ideal infrastructure and extensive experience needed in its existing programs in public education and outreach to contribute effectively. These programs can easily be expanded.

Education is a many-splendored thing. It certainly cannot be considered to be solely the purview of the schools. The number of variables in education is large and depends on both teacher and student, mentor and disciple, or parent and child. The ability to use the available educational resources also depends on such imponderables as curiosity, motivation, experiential background, assertiveness, and ability to assimilate new ideas. Education can be thought of as an attitude, personal or cultural, for which we are all responsible, whether we be source or recipient.

The RASC is in a good position to make significant contributions to public awareness of the sky through its outreach programs. Indeed, it has been doing so since 1868 through public lectures, workshops and star parties, as well as through publications like the *Beginner's Observing Guide*, the *Observer's Handbook*, and the *Journal*. We have matured into an organization of thousands of keen volunteers dedicated to enlightening the public about the beauty of the universe around us (in addition, of course, to enjoying it ourselves).

The Long Range Planning Panel of CASCA (Canadian Astronomical Society/Societe Canadienne d'Astronomie) has strongly recommended increasing public outreach over the next decade. The Long Range Plan for Astronomy and Astrophysics in Canada in the 21st Century, if implemented, will result in a revitalized research community, which hopefully will be committed to education and public outreach — principal mandates of the RASC. Our vast volunteer workforce could be an invaluable asset in joint efforts to promote scientific literacy on a grand scale. I think it could be quite an exciting venture.

Taking advantage of this initiative, former RASC President John Percy has secured a grant from NSERC (Natural Sciences and Engineering Research Council) for astronomy education and public outreach. The RASC has been included in his application as an effective vehicle for help in carrying out the mandate.

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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Some of the grant money may be available for especially cost-effective projects. It would be good to start a national discussion on how we could use a modest amount of seed money effectively. I believe in pursuing the goals of public education and outreach, especially for those of us paid from the public purse to carry out major research projects, most of which are quite expensive. We owe it to the tax-paying public to share the excitement of our progress in discovering the Universe around us and how it works.

This is also the year of retirement for me, since I turned 65 in May. After 30 June, I will sign in as Professor Emeritus. In the US, it is considered age discrimination to require professors to retire at age 65, but I prefer the Canadian approach to retirement, the overriding principle being to make room for younger people to have jobs and thus to keep them in the field. We retirees continue working and are available to share our wisdom; we just don't have to teach or sit on committees any more. This enables us to finish some of those large research programs that were disrupted by the urgency of the moment and to which we have not returned.

If I miss teaching, which I'm sure I will eventually, I can arrange to give a course to adults in Continuing Studies, where there are no tests, no essays, and no grades. What a dream! I will also have an easier time scheduling tours of the centres scattered among all ten provinces of this wonderful country without worrying about class schedules. The visits to centres are multipurpose: I meet the members, listen to their stories, hear their complaints (if any) about the National Office, and see or hear about their projects and activities. On the other hand, the centre's members learn something about their national president. So, if I haven't yet managed to visit your centre, expect a knock on the door sometime this year.

Royal Astronomical Society of Canada National Awards — Call for Nominations

The RASC sponsors several national awards. Their purpose is to recognize Society members for outstanding service to the RASC as well as excellence in all aspects of amateur astronomy. Members are encouraged to nominate candidates for these awards. The Awards Committee reviews all nominations and puts forward outstanding candidates to National Council for approval. Successful nominees are invited to attend the General Assembly the following summer to receive their awards.

Nominations for all four awards must be received at the National Office by December 31st, 2001 to be considered.

Service Award
The Service Award is presented to members who have performed outstanding service to a Centre or to the National Society over an extended period of time. The nominee must have been a member in good standing for at least 10 consecutive years prior to nomination. The service performed should have had a major, constructive impact on the Centre or Society, requiring a very substantial and continued commitment on the part of the nominee over a period of at least 10 years.

When submitting a nominee to the Awards committee, the nominating Centre (or individual if the nominee is an unattached member) must provide a statement establishing the suitability of the candidate.

Chant Medal
The Chant Medal was created in 1940 and is named for Prof. C. A. Chant. It is awarded to an amateur astronomer who has carried out a significant and original project that has contributed to the science of astronomy. The nomination of a Centre member should be submitted by the Centre itself.

Ken Chilton Prize
The Ken Chilton Prize was established in 1977 and is named after Hamilton Centre member Ken Chilton. It is awarded to a member resident in Canada in recognition of a significant piece of astronomical work carried out or published during the year. Any member can submit a nomination for consideration.

Simon Newcomb Award
The Simon Newcomb Award is intended to encourage members of the Royal Astronomical Society of Canada to write on the topic of astronomy, either for the Society or the general public, and to recognize the best published works through an annual award. Any member is eligible for the award. Nominations can be submitted by a member, a group of members, or by a Centre.

More information about these awards can be found in the RASC manual at the RASC web site. If you have any questions about the Society's awards, please contact the undersigned via email (attwood@istar.ca) or through the National Office.

Please submit nominations to:

Randy Attwood
Chairman - Awards Committee
attwood@istar.ca
or by mail to RASC National Office
136 Dupont Street
Toronto, ON
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Editorial

by Wayne Barkhouse, Editor-in-Chief

"Who ordered that?" This phrase was made famous by the Nobel laureate Isidor Rabi when the sub-atomic particle, the muon, was discovered in 1936. Just prior to this event, scientists believed that they were beginning to formulate a clear understanding of the workings of nuclear physics. Thus, the discovery of the muon came as a complete surprise. In hindsight (which is always 20/20), this marked the beginning of a deeper theoretical understanding of particle physics and eventually led to the so-called Standard Model.

At the beginning of the 1990s, cosmology had evolved to the point where the ultimate fate of the Universe would soon be known. Observations on the scale of galaxy clusters had demonstrated that the Universe contained at least 35% of the matter density required to halt the expansion. Strong theoretical arguments, involving the inflationary hypothesis, suggested that the density of the Universe was exactly equal to the critical density. This suggested, on scales much larger than galaxy clusters, that the measured density of the Universe would approach the critical value, with "dark matter" making the greatest contribution.

Since the discovery of the expansion of the Universe, astronomers have been trying to measure the deceleration parameter, the change in the rate of this expansion. One of the keys to measuring this parameter is the use of a "standard candle", an object whose intrinsic brightness is known, which can be compared to its apparent brightness to yield a distance. This has been very difficult to achieve since one needs an object that is very bright in order to observe it over a large distance and to correct for any evolutionary effects on its intrinsic brightness.

In the past couple of years, astronomers have been successfully using Type Ia supernovae to measure this deceleration parameter. To the surprise of most cosmologists, the results seem to indicate that the expansion of the Universe is actually increasing with time. This is, of course, the famous non-zero cosmological constant, introduced by Einstein in the early 1900s, in order to match theory with observations of that time.

This discovery, if it holds true, is one of those "Who ordered that?" events. The presence of a non-zero cosmological constant was not expected and represents a major step forward towards understanding the ultimate fate of our Universe. The supernova results indicate that the Universe is destined to expand forever with the average distance between galaxies increasing for all of time. The obvious questions to ask at this point are, "What is actually causing this increase in the expansion rate?" and "How does this fit in with our understanding of the four fundamental forces of nature?" Particle physicists are also very excited about this discovery, since their theoretical models yield a cosmological constant that is either zero exactly or many orders of magnitude different from the measured value. Like the presence of singularities in General Relativity, the cosmological constant is an indication that we don't have a complete theory of everything and that new physics remains to be explored.

The supernova results will be scrutinized in the years to come as scientists continue to add more data points. If the results hold up, this work will certainly receive the Nobel Prize, since it represents a fundamental leap forward in our understanding of the Universe. Personally, its nice to see that we don't know everything and I am looking forward to the next "Who ordered that?" event!

* * *

The August issue represents one year since I have taken over as the Editor-in-Chief of the *Journal*. I express my thanks to the production team for their hard work and dedication during this time and look forward to an exciting second year!

Correspondence
Correspondance

MESSIER MARATHON

In the recent invitation to attend the General Assembly of the RASC 2001 in London, there was a section which gave information about our national treasurer Michael Watson who has kindly agreed to run for that office. The information lists his very considerable accomplishments, including a statement that, in April 2000, he had observed 108 of the 110 Messier objects in a single night. We very heartily and sincerely congratulate Michael for this significant achievement, since very few observers have accomplished such a feat of observing in a single night.

We would like to point out, however, that Kingston Centre member, David Levy, holds the record for the Messier Marathon among the members of the Kingston Centre, for his accomplishment on the night of March 15–16, 1983. He observed 109 of the 110 Messier objects as listed in the *Observer's Handbook* and 34 other non-Messier NGC deep sky objects, for a total of 143 deep sky objects in a single night. All of those observations were precisely documented in his observing log for Observing Session # 6207. The only Messier object not recorded as seen was M30, although David did have it in his eyepiece. Twilight was too bright to allow recording it as a clear observation at 5:22 a.m.

This observation session was documented in two articles in *REGULUS*, the newsletter of the Kingston Centre of the RASC. The first is "An Amazing Messier Marathon" on pages 2 and 3 of the March-April 1983 issue, and the second is "David Levy's Amazing Observing Session Number 6207" on pages 17 and 18 of the May-June 1983 issue. The second article gives the numbers of the 109 Messier objects in the order in which they were observed, plus the 34 non-Messier NGC objects in the order in which they were observed. David wrote a description of the appearance of each one of the objects, and the precise viewing time each object was seen. Conditions were such that the gegenschein was "distinctly visible".

This observing session was also described by Terence Dickinson in an article in the Kingston *Whig-Standard* in late March, 1983. Following this article, *Whig-Standard* editorial writer, Mary Lasovich, described David's accomplishment as something that was "believed to be a world record for a single evening of star-gazing."

David remains willing to share information about his fabulous Observing Session # 6207.

We hope that references to these great observing accomplishments by Michael and by David will encourage other RASC members to do more deep-sky observing.

Kingston Centre

News Notes
En Manchettes

CANADIAN SPACE MISSION TO MARS

Be bold and "think big" was the challenge offered by Dr. Marc Garneau, Canadian Space Agency (CSA) Executive Vice President and Space Shuttle astronaut, to an enraptured audience of researchers at the recently held 3rd Canadian Space Exploration Workshop. In a pre-banquet speech Dr. Garneau called upon politicians, scientists, and industry to develop plans for a Canadian science mission to Mars. The mission, Garneau argued, should be built around clear scientific goals, highlight Canadian know-how and expertise, and also be ready to fly during the next Mars encounter launch window between 2007–2009.

To support the mission to Mars initiative the CSA will be awarding a number of research grants to develop mission profiles and research programs. To support the overall program, Garneau is calling upon the Canadian Government to provide some $500 million CDN worth of funding. The Space Exploration Meeting marked the beginning of the mission building process, calling as it did upon participants to develop a vision for Canadian involvement in space and solar system exploration. Further details may be obtained from the CSA web page and by following the links at `www.space.gc.ca`

PLASKETT MEDAL AWARDED

The 2001 Plaskett Medal has been awarded to Dr. Peter Brown of the University of Western Ontario. Presented each year, the Plaskett Gold Medal is granted to the author of the most outstanding Canadian

doctoral thesis in astronomy and astrophysics. The award is jointly conferred by the Canadian Astronomical Society and the Royal Astronomical Society of Canada.

Dr. Brown completed both his masters and doctoral work in the Physics Department at the University of Western Ontario under the supervision of Professor James Jones. His doctoral thesis was concerned with the study of the properties, evolution, and formation of the Perseid and Leonid meteoroid streams. The numerical models developed by Dr. Brown have enabled detailed predictions of Perseid and Leonid meteor shower activity to be made.

Dr. Ian Halliday presented the Plaskett medal to Dr. Brown during the RASC Annual Meeting in London, Ontario.

THE SCIENTIFIC IMPACT OF LARGE TELESCOPES

The debate as to whether size matters has finally been answered — yes, bigger is better! Writing in the *Publications of the Astronomical Society of the Pacific* (PASP 2001, 113, 385), Drs. C. Benn and S. Sanchez of the Isaac Newton Telescope Group at La Palma, have recently presented the results of a study they conducted on the scientific impact of large telescopes. Analyzing the citation counts of papers published by researchers using various telescopes from around the world, Benn and Sanchez find that the "impact" of individual ground-based optical telescopes is proportional to collecting area, and approximately proportional to capital costs. The findings presented by Benn and Sanchez support the argument that large telescopes really do deliver in terms of new discoveries and the number of scientific publications generated.

Telescopes in the 1- and 2-metre class range account for about 5% of the citations in the top-ranked astronomy papers published between 1991 and 1998; 4-metre telescopes account for about 10% of the top-ranked papers. While the Hubble Space Telescope accounts for some 8% of the top-ranked papers and has a scientific "impact" about fifteen times greater than that of a typical 4-metre telescope, it costs more than 100 times as much money to operate. The good news for Canadian astronomers is that between 1995–98, the 3.6-metre Canada-France-Hawaii telescope ranked best in the world for scientific "impact". In the time interval from 1989 to 1998 the CFHT ranked joint third with the United Kingdom Infrared Telescope (UKIRT) and the Blanco Telescope on Cerro Telolo (CTIO) with respect to publications cited in the journal *Nature*. The most highly ranked, *Nature*-cited telescopes in the 4-metre class range were the William Herschel Telescope at La Palma and the Anglo-Australian Telescope at Siding Springs in Australia.

U OF T PROFESSOR HONOURED

Professor Richard Bond, Director of the Canadian Institute for Theoretical Astrophysics at the University of Toronto has been elected a Fellow of the Royal Society of London. The august body of the Royal Society was founded in 1660, and election to a Fellowship is considered to be one of the highest scientific accolades. With his election Professor Bond joins a distinguished group of some 1300 other Fellows of which just fifty-two are Canadians.

In its honour list the Royal Society cites Professor Bond for his fundamental contributions to physical cosmology and other areas of astrophysics. Bond's citation also notes that he has made seminal contributions to the understanding of supermassive objects, dark matter, supernovae and the origin and growth of large-scale structure in the Universe.

Also included in this year's Royal Society election list is Sir Patrick Moore, who has been given a special honourary fellowship for his many contributions to and long-term promotion of astronomy. Readers will be familiar with Dr. Moore's articles in this journal and from his numerous books on astronomy. He is also an honourary member of the RASC.

PLANETARY AND SPACE SCIENCE CENTRE OPENS AT UNB

April 3rd saw the official opening of Canada's very first Planetary and Space Science Centre (PASSC). Situated at the University of New Brunswick, the Centre, explains Dr. John Spray, longtime geologist at UNB and first Centre Director, "will be Canada's national database for NASA's space science archives and Canadian space science databases."

Not only will the PASSC be an important national database but it will also support research programs concerned with terrestrial impact structures, shock metamorphic processes, and meteorites, as well as Martian and lunar geology. Later this year, in collaboration with Dr. Richard Grieve of the Geological Survey of Canada (GSC), the PASSC will take charge of the World Crater Inventory. In addition, the impact crater collection of the GSC, consisting of some 11 km of rock core samples, will eventually be housed at the PASSC. Further details of the archives and the crater inventory may be found at: www.unb.ca/web/passc/

KID-SCOPES

Millennium Project

by Roman Unyk (Roman.Unyk@gov.ab.ca)

It's simply amazing how a fifteen-minute discussion over coffee can turn into three years and over 2500 hours of work. The initial idea for this project was conceived by Dave Robinson, a professional electrical engineer, work colleague, and recent member of the RASC. The idea seemed simple. He believed that the greatest impediment to young people gaining a true appreciation of astronomy was the availability of a decent telescope for a good hands-on experience.

In our province, school children get an introduction to astronomy in Grade 6. Unfortunately, this introduction is almost always a classroom discussion with some demonstration and maybe a video clip. At most there is a field trip to the local space and science centre for a planetarium show with maybe a chance to look through a real telescope for a couple of minutes. What if a schoolteacher or Scout troop leader could borrow a robust 6-inch reflecting telescope for a week or two at no cost? The troop could take it along for a camping trip. The teacher could arrange for a class demonstration and an evening of hands-on observing with parents welcome to attend. The idea seemed plausible. Some phone calls to a few teachers and troop leaders gave us the answer. Demand would be high.

The next step was to design the telescopes. From our coffee-break discussions, a few guiding principles soon emerged.

(1) Each telescope had to be virtually indestructible. After all, these instruments would have to endure abuse at the hands of a group of twelve year olds.

(2) The telescopes had to have a reasonable aperture to show something more than the Moon and a few planets, but had to be small enough for easy transport.

(3) Optics had to be of very high quality and had to remain in alignment through transportation and abuse. A poor view would do more harm than no view at all. We certainly did not want to check and realign the optics every time a telescope was returned.

(4) The mounting had to be rigid and easy to assemble without requiring handling of small parts. Good optics would be a waste if the view were shaky. Nothing is more frustrating than losing nuts or bolts in the snow.

(5) The telescopes had to be driven and have clutches on both axes to eliminate the need for lock knobs.

(6) Finally, funding was limited.

Figure 1 — Rear view of the mirror mounting support structure.

How many to make? Dave and I live on opposite sides of the city, so we could keep one or two scopes at each location to make borrowing more convenient. It would also be nice to make an extra scope for the RASC to add to their existing loaner program. Thus, five was the magic number.

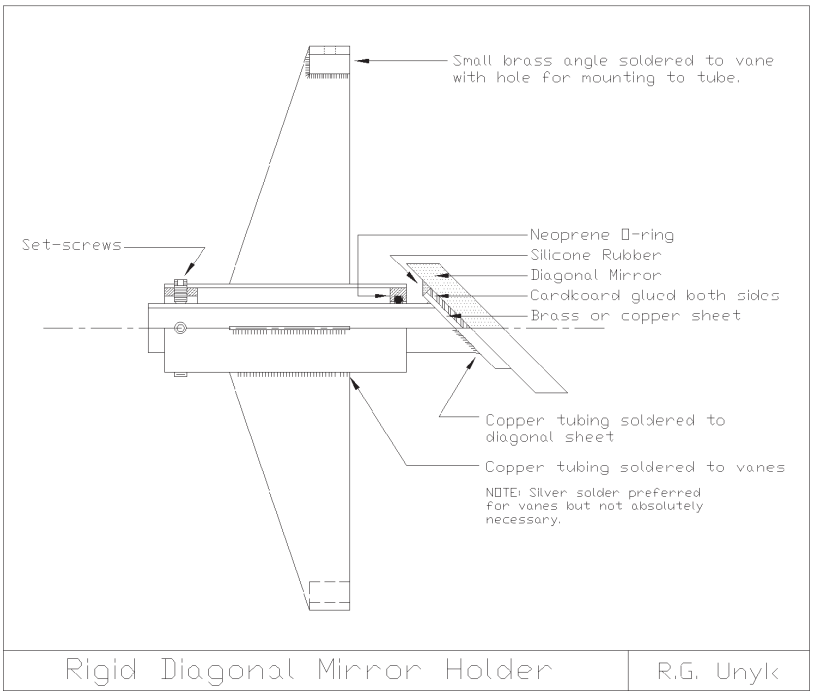


Figure 2 — Schematic diagram of the diagonal mirror holder assembly.

Dave and I work for the same division, so we spent many coffee breaks and lunch hours on the design. We wanted the perfect compromise. Such a contradiction in terms takes time, but in the end we were happy with the result. Dave put together a presentation and approached the RASC Edmonton Centre for funding. After some months we got the go-ahead.

The next task was to gather materials. Our estimates required that some items be bought cheaply or, better yet, be donated. Dave created a brochure that we used to pry forth discounts whenever significant items were purchased. A little PR goes a long way. Barry Arnold (Arnold Optics) provided five sets of better than 1/10 wave peak-to-peak optics for the price of four. René Van Struen (Vanguard Steel/Ringball) was able to arrange for us to buy almost all the ball bearings at about 75% off list. Don Linton (Engineered Plastics) donated all the plastic and many of the plastic parts machined to shape. Endura Manufacturing donated all the epoxy and polyurethane paint and supplies for the project. These savings allowed us to construct the telescopes for the budgeted amount of about $650.00 US each. Since the focusers and finders are inexpensive commercial products, the tube assemblies look traditional. There are, however, some interesting features.

The rear disk of the mirror mount is made of clear plastic to allow the mirror and mounting components to be viewed. Allen head fasteners are used so inquisitive children cannot easily make adjustments. The springs are very strong so vibration during transport will not change the collimation. As an extra precaution, the mirror itself is prevented from shaking or rotating in its cell by small beads of silicone rubber. A black cardboard ring has been added to prevent light entering the back of the tube (see Figure 1).

The spider mounts are based upon a design I have been using for the last 25 years but the vanes are much thicker to prevent cuts should youngsters put their hand down the tube. As can be seen from Figure 2, the diagonal mirror is simply glued to the holder through an intervening piece of cardboard. The silicone acts as a second attachment mechanism and prevents moisture affecting the paper. I have never had a diagonal come loose, nor have any shown signs of being deformed by stress. The round shaft is held in place at the mirror end by a tight fitting O-ring. This design allows the rod to be moved in or out and rotated, but the fit is tight enough to keep it accurately aligned in the sleeve. Four set-screws allow the rod to be tilted up or down and left or right. With a decent jig and careful assembly, the small amount of adjustment is more than ample. The design is exceptionally rigid, and easy to align and will never go out of alignment even under the worst vibration of transportation.

All components were mounted in seamless aluminum tubing obtained from an irrigation supplier in southern Alberta. Painting was a messy affair. The tubes required a little body work, and had to be acid etched and epoxy primed. The following day a two-component, metallic blue automotive finish was applied. To speed up the process we mounted the individual tubes onto a length of cardboard sona-tube. Dave kept the works rotating while I sprayed. This process allowed a heavy coat to be applied with a glass smooth finish without a single sag or run.

The cradles are also made of seamless aluminum tubing. Machined plastic spacers have been attached to the telescope to act as a bearing to allow tube rotation. There is a snug interference fit to prevent rattle. The clutched declination shaft is not driven, nor has it a slow motion control. However, the arm has been slotted and a drive can be added in the future.

Steel was chosen for the fork because it was much less expensive than aluminum. Although steel is three times heavier, it is also three times stiffer, so for hollow sections, the performance is the same. Using the 0.083- inch thick steel tubing for our fork is equivalent to using 0.25-inch thick aluminum tubing of the same outside dimension. Hollow sections are also very stiff in torsion. Having dimensions of 2×3 inches in the arms and 3×3 inches in the base, these forks are exceptionally stiff.

The forks attach to the stainless steel polar shaft with a single large brass nut. The complete tube assembly with attached fork weighs less than 28 pounds. The fork contains a stainless steel socket with tapers to match the polar shaft. The nut has a taper that locates the fork when tightened. This design enables the declination shaft to be consistently aligned

Figure 3 — A newly completed telescope ready for use.

Figure 5 — An unguided, fifteen-minute exposure of the North American Nebula taken with a Vivitar zoom 210-mm, f/4.5, telephoto lens using Kodak Ektachrome P-1600 film.

to within three arcminutes of perpendicular to the polar axis. It provides a very rigid coupling but requires that one of our design principles be compromised. Fortunately only one tool is required and the nut is quite large so it is not easily lost (spares have been made anyway).

Figure 3 shows the unusual configuration of the mounting. The drive box is pointed upward so children can examine the components through a lexan window. A stepping motor and gears drive the 0.25-inch 28 threads per inch stainless steel rods. The brass block transmits this motion to the 7.971-inch long tangent arm through a nylon pin which has been machined 0.002 inch oversize to ensure there is absolutely no backlash. The telescope moves about 1.15 arcseconds per step. A crude form of micro-stepping is used to smooth these steps so that there are no induced vibrations. A small MC68HC705K1 micro-controller is used to operate the motor windings, count the steps and vary the duration between steps to compensate for tangent error so as to produce an accurate sidereal rate for 80 minutes. The odd length of the tangent arm was necessitated by the resolution of this micro-controller's timer. The hardware and programming also provide for fast or slow slewing, should long exposure photography be considered in the future. The complete drive box, gel-cell battery, and aluminum legs weigh 27 pounds. I built the first prototype of this drive to photograph comet Hale-Bopp and have tested the new kid-scope mount with unguided photographs last August. As can be seen from Figure 4 and 5, the drive is more than adequate for the intended purpose.

Figure 4 — An unguided, six-minute exposure of Comet Hale-Bopp taken with Kodak Ektachrome P-1600 film using a 480-mm f/6 semi-apochromat lens.

The design and construction of these scopes have been a learning experience. Dave and I put in a tremendous amount of time to ensure the telescopes actually work as well as we had planned at the start. I would like to specifically thank him for the masterminding of this project and all his effort throughout. It is hoped that, by the time this article sees print, the transport boxes will have been completed and the telescopes will be in the hands of children.

Roman G. Unyk is a professional mechanical engineer specializing in control systems. He has been a member of the RASC since 1969 and has constructed many telescopes from small refractors to a 14.25-inch f/5 Newtonian on a large permanent fork mount in a roll-off roof observatory.

Lamplighter Moment[1]

Visual Observing From Saskatchewan

by James Edgar, Regina Centre (jedgar@sk.sympatico.ca)

In my job on the railway as a freight conductor, I often get the chance to do some naked-eye viewing (lots of night work!). The night of February 19, 2001 was one of wonder that lasted well into the next morning. I left my home of Melville, Saskatchewan on my westward trip in mid-afternoon. As the day drew down to sunset, I looked for the "green flash," but it was absent. What I did see was a magnificent spire of light rising several degrees off the top of the Sun's disk. I attributed the spire to ice crystals in the prairie air.

After completion of the first leg of our trip, my Locomotive Engineer and I spent the night about 130 miles west of Melville, in Watrous, Saskatchewan, where the temperature neared –25°C at 21:00 CST. We stayed at a motel there, while our train travelled to us operated by a crew from Biggar. As we prepared for sleep, I took a good long look at the night sky, which was exceptional in its clarity.

The usual constellations and asterisms were visible for that time of winter night: Orion glittered due south, Ursa Major was standing on his tail in the north, Venus was just about disappearing in the west, and Jupiter outshone Saturn higher in the southwest. There was little scintillation; the seeing was crystal clear.

By 04:00, when I took my call, the temperature had dropped to –30°C, with little wind. Ursa Major was returning to horizontal, the "drinking gourd" seemingly dripping down onto Leo's back; Cassiopeia's "W" lay straight north; Mars closely hugged Scorpio's "Graffias" in the southwest, with Antares just breaking the horizon. The crisp, cold air seemed to make the viewing even better than it was earlier (knitted gloves plus leather mitts with woollen liners couldn't keep my fingers from freezing, though!).

Image: Starry Night

I was finished my train marshalling by 06:45 and getting ready to head for home on a daylight run. The sun was just starting to brighten the eastern sky. By 07:00, our eastbound train was on the move, adding a puny 60 miles/hour to Earth's speed toward the terminator. At 08:02, sunrise was a fact and dawn was over for another day. The Sun completely cleared the distant horizon at 08:15, with just a hint of a thin crescent Moon hanging off to the southeast. Earlier, when I first saw it, the Moon's waning limb looked just like a discarded sliver of fingernail, barely visible above a purple haze of refracting ice crystals. Fifteen minutes later, it was lost in the Sun's glare. Though I knew where to look, I couldn't see the Moon.

What a pleasurable way to spend one's workday. Surely Lamplighter would have enjoyed being there himself to view it all.

James Edgar is a transplanted BC-ite who began a serious love affair with astronomy in the early 1970s as a volunteer docent at the MacMillan Planetarium in Vancouver, teaching school kids about space with a travelling "Bingo" game in a suitcase. More recently, while attached to the Regina Centre, he stargazes alone and away from city lights in Melville, Sask. James is also part of the production team for the JRASC *and the* 2002 Observer's Handbook.

[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, something achieved by Lucian Kemble fairly regularly during his lifetime. This section is a regular part of the *Journal* devoted to guest articles by authors describing their Lamplighter moments.

The Titius-Bode Rule, Part 1: *Discovering the Asteroids*

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

For quite some time, I have been fascinated by the Titius-Bode rule (also simply called Bode's law). This simple arithmetic formula is an approximate fit to the spacing of the planetary orbits in the Solar system. As far as I know, there is no scientific explanation of the rule, and it is widely believed to be a coincidence. In this month's column, I will review the history of the Titius-Bode rule, including its apparent success in predicting the distance of undiscovered bodies. In the next issue, we will explore the scientific validity of the Titius-Bode rule and similar relations.

Johann Daniel Titius (1729–1796)

Whether or not you believe that the Titius-Bode rule has any scientific basis, it runs like a golden thread through the tapestry of 18th and 19th century astronomy, joining diverse efforts to discover new bodies in the solar system. The story begins with the German astronomer Titius, born in Konitz, Prussia (now Chonize, Poland). He was raised by his uncle, a naturalist who encouraged Johann's interest in science. Titius received a Master's degree from the University of Leipzig and became a professor at the University of Wittenberg, a post he held for the remainder of his life.

The lasting contribution of Titius to science is his observation in 1766 that the mean distance of the known planets from the Sun approximately follows a sequence that can be expressed in a simple formula. Titius published his findings by inserting a paragraph into his German translation of the book *Contemplation de la nature* by Swiss naturalist Charles Bonnet[1] (1720–1793). Others had noticed the sequence, but apparently only Titius saw the arithmetic relation. From Mercury out to Saturn, the formula for the mean radii of the planetary orbits (in astronomical units) is as follows:

$$D = 0.4 + 0.3\,n,$$
where $n = \{0, 1, 2, 4, 8, 16, 32\}$.

Note the doubling in the space between successive orbits. The degree of success of this formula is shown in Table I.

A little low here, a little high there, and one anomaly: the "missing" planet at 2.8 A.U. Not too bad! Unfortunately for Titius, no one acknowledged his curious relation until much later.

Johann Elert Bode (1747–1826)

Bode, another German astronomer, was a bit of a child prodigy. Born in Hamburg, he was the son of a teacher, and by the end of his teenage years he was already writing astronomy textbooks. He was an assistant to the mathematician Johann Heinrich Lambert[2] (1728–1777) and eventually became director of the Berlin Observatory in 1786. In 1801 he produced *Uranographia*, consisting of 20 star charts and a large catalogue of star positions.

Bode popularized the Titius formula in the second edition of one of his popular astronomy textbooks, and other astronomers began calling it Bode's law, especially after William Herschel (1738–1822) discovered Uranus at orbital distance 19.6 A.U., exactly the distance Titius and Bode would have "predicted." However, there remained the anomalous gap between Mars and Jupiter, which astronomers such as Kepler (1571–1630) had suggested was too wide, and must contain an undiscovered planet. Now the search was on!

Giuseppe Piazzi (1746–1826)

Piazzi was an Italian priest trained in philosophy, but he took up mathematics and astronomy later in life. In 1780, the independent kingdom of Naples asked Piazzi to establish observatories in Palermo and Naples. He went on a fact-finding trip to France and England, where he fell off William Herschel's observing ladder and broke his arm.

On New Year's Day, 1801, working from the observatory in Palermo, Sicily, Piazzi fortuitously discovered an 8th-magnitude object in the constellation Taurus. He was in the process of cataloguing the positions of stars using a precision instrument fabricated by Jesse Ramsden (1735–1800). By the rate of its daily motion

Table I: Planetary orbit data supporting the Titius-Bode rule

Distance from Sun in A.U	*Mercury*	*Venus*	*Earth*	*Mars*	-	*Jupiter*	*Saturn*
True (mean)	0.39	0.72	1.0	1.5	-	5.2	9.6
Titius-Bode rule	0.4	0.7	1.0	1.6	2.8	5.2	10.0

[1] Bonnet was the first to make use of the word evolution.

[2] Lambert proved π to be an irrational quantity and introduced the term *albedo* to quantify the diffuse scattering of light by bodies.

among the stars, Piazzi suspected that the object occupied an orbit between Mars and Jupiter. Eventually he lost track of his object and could not recover it in the Sun's dazzle. Piazzi made some attempts to determine an orbit, but he fell sick and turned his observations over to Bode and others.

At that time, the young German mathematician Johann Karl Friedrich Gauss (1777–1855) had just developed the method of least squares for fitting model curves to data. From the few observations that Piazzi had made, he was able to calculate an orbit for the new object. This calculation enabled the Hungarian amateur astronomer Baron Franz Xavier von Zach (1754-1832) to recover the object and confirm that its orbit indeed lay between Mars and Jupiter.

Piazzi, credited with the discovery, named his object Ceres after the patron goddess of Sicily. Ceres turned out to be the first of thousands of minor planets in the zone. Herschel suggested they be called "asteroids," owing to their star-like appearance, as they were dim and did not show disks like the planets. In Piazzi's lifetime, only 4 asteroids were discovered.

I hear you asking, "So, what about the Titius-Bode rule?" It turns out that Ceres has an eccentric orbit, but the semi-major axis of the ellipse is 2.77 AU, making it an excellent candidate for the missing planet in the Titius-Bode sequence, except for the fact that its diameter of about 1000 km falls short of the diameter of a full-size planet. The astronomers were not satisfied with this small fry and continued looking for the big fish.

Heinrich Wilhelm Matthäus Olbers (1758–1840)

Olbers was a German medical doctor, but a very dedicated amateur astronomer, having converted the top story of his house into an observatory. He was a keen comet hunter, discovering five in his lifetime, and he worked out a method for determining comet orbits from observations. Following the death of the last of his family in 1820, he devoted his life entirely to astronomy. He is probably best known for being the first to ask "Why is the night sky black?" His discussion of this topic has come to be known as "Olbers' paradox."

Olbers was a leader in the effort to find a planet between Mars and Jupiter. He belonged to a group of six astronomers known as "the celestial police," who were coordinating the search for the planet deemed missing by the Titius-Bode rule. The group included fellow amateurs von Zach and Johann Hieronymous Schröter (1745–1816). They intended to recruit other astronomers (including Piazzi) to the organized chase; however, their plans were somewhat foiled by Piazzi's accidental discovery. Not discouraged, Olbers carried on the hunt and soon discovered two asteroids: Pallas in 1802 and Vesta in 1807. In between, Karl Ludwig Harding (1765–1834) discovered Juno in 1804. It became evident that there were several minor planets occupying the space reserved for the elusive planet, and Olbers was the first to suggest the planetary-explosion origin for the asteroids. (It is now believed that the asteroids are remnants from the birth of the Solar system and that the asteroid belt marks the transition between the inner and outer zones of the Solar system.)

As an interesting aside, a little digging on the Internet uncovered the site `pdssbn.astro.umd.edu/nodehtml/sbdb.html` which has an interactive search engine linking asteroid numbers, official designations, and names. Asteroids 998–1002 and 1998 have names relevant to this article, as shown in Table II.

If Titius-Bode were not a scientific rule but a mutual fund, and if you had invested early, this would have been a good time to sell. The rule, based on minimal evidence, had been bolstered by the discovery of a major planet. Following that, astronomers had been encouraged by belief in the rule to search for a "missing" planet, leading to the discovery of several minor planets. Pretty good dividends! The share price was about to fall, however.

Neptune and Pluto

In my April 2001 *Reflections* column, I described the discovery of Neptune by Johann Galle (1812–1910), based on the calculations of Urbain le Verrier (1811–1877). Applying standard techniques of celestial mechanics, Le Verrier analyzed anomalies in the motion of Uranus and deduced the existence and position of a trans-Uranian planet. In 1846 Neptune was discovered to follow an orbit of radius 30.1 AU, while the Titius-Bode rule suggests 38.8 AU. Interestingly, both le Verrier and Adams used the Titius-Bode rule in their analysis, but I expect this was more along the lines of an educated guess to get the iterative calculations started, rather than a critical assumption. If you hadn't sold your Titius-Bode shares by then, you were about to lose the shirt off your back!

American astronomer Clyde William Tombaugh (1906–1997) discovered Pluto in 1930. The orbit of Pluto is odd in many respects, so it is not surprising that its semi-major axis of only 39.5 AU is a far cry from the Titius-Bode "prediction" of 77.2 AU. The Titius-Bode rule was quickly losing its appeal as a scientific tool.

Science or Numerology?

Looking back on what I have written, I think I have ended up being a little harsh on the Titius-Bode rule. There are few scientific rules that do not break down eventually when you push their application

Table II: Asteroids with connections to the Titius-Bode law

Asteroid Number	*Asteroid Name*	*Discovery Date*	*Discoverer*
998	Bodea	1923-08-06	K. Reinmuth
999	Zachia	1923-08-09	K. Reinmuth
1000	Piazzia	1923-08-12	K. Reinmuth
1001	Gaussia	1923-08-08	S. Belyavskij
1002	Olbersia	1923-08-15	V. Albitzkij
1998	Titius	1938-02-24	A. Bohrmann

beyond the limit. In this case, the rule is based on observations, not derived from fundamental theory, so the limit of applicability is not so clear. Is there any scientific basis to the Titius-Bode rule, or is it simply an odd bit of numerology? We will examine this question next issue, and possibly find answers. Stay tuned! Don't sell those shares yet!

References

Asimov, A. 1982, Asimov's Biographical Encyclopedia of Science and Technology (2nd ed.; Doubleday: New York)

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

Moore, P. 1983, The Guinness Book of Astronomy Facts and Feats (2d ed.; Guinness Superlatives Ltd.: Enfield)

David Chapman is a Life Member of the RASC and a past President of the Halifax Centre. Visit his astronomy page at: www3.ns.sympatico.ca/dave.chapman/astronomy_page

Second Light

Bending Light Around Stars And Planets

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

The first experimental confirmation of Einstein's General Theory of Relativity occurred during a solar eclipse in 1919, when Eddington found that light from distant stars was deflected from a straight line as the photons passed by the Sun. Because the fabric of space is warped by mass, the path of the light is bent just as it would be if it went through a glass lens. This means that massive objects in space can act as lenses — gravitational lenses. This can happen on large scales, when galaxies bend the light of background quasars; or on small scales, as with the Sun. Recently, Kailash Sahu of the Space Telescope Science Institute and his collaborators have investigated gravitational lensing at an intermediate scale — that of star clusters. They discovered what appears to be a substantial population of low-mass objects in a globular cluster as those objects bend the light from stars in the central bulge of the Milky Way (see June 28, 2001 issue of *Nature*).

When a body passes between us and a distant star (or very distant quasar), photons travelling on paths that would not normally intersect with us can be bent towards us, making the distant star brighter for a time. To see how this works, take a magnifying glass and pass it in front of your face while looking at a streetlight. As the centre of the lens gets closer to the exact line of sight between your eye and the light, the light gets brighter. Gravitational lensing works similarly, with the unique telltale signature that light of all wavelengths is magnified equally — that shows astronomers that the star itself is not variable, but rather that lensing is taking place.

" When a body passes between us and a distant star (or very distant quasar), photons travelling on paths that would not normally intersect with us can be bent towards us, making the distant star brighter for a time."

The phenomenon was first demonstrated when the spectra of a tight cluster of quasars were all shown to be identical — the light from one quasar was refracted into multiple images as the photons passed by a massive galaxy on their way to us. Microlensing was discovered in 1993 by the MACHO and EROS collaborations (see October 14, 1993 issue of *Nature*); both of these projects were searching for microlensing of stars in the Magellanic Clouds by the so-called "machos" — massive compact halo objects — in the halo of the Milky Way. Although the identities of the lenses remain controversial, some may be normal stars within the Magellanic Clouds themselves, some may be white dwarfs in the halo of our Galaxy, and some are probably brown dwarfs and maybe even free-floating planets.

Globular star clusters are compact spherical groups with radii of just a few parsecs, but containing about 100,000 to 1,000,000 stars. Most globular clusters formed very early in the history of our Galaxy, when the prevailing conditions — such as gas temperature and density — probably were quite different from today. Whether the range of stars formed under those conditions was significantly different from what we see in the Galaxy today is an important question, but one that is extremely difficult to answer. Within the present-day Milky Way much of the gas of new stars is found in low-mass stars like the Sun, or even smaller ones. Unlike the massive stars that blow off copious winds before ending their lives as supernovae, much of the gas in low-mass stars remains locked up.

Low-mass stars are dim, and therefore difficult to see. Some component of the "dark matter" associated with our Galaxy must be in the form of low-mass stars — astronomers want to know just how much. This question also is relevant to the "starburst" galaxies — those that are now forming stars at 1000 times the rate seen in the Milky Way. If they make lots of low-mass stars, they will quickly exhaust the available supply of gas. Some people believe that there may be similarities between the conditions in a starburst galaxy and in the early Milky Way, so the globular clusters could serve as a probe of the starbursts as well as reveal what happened as our Galaxy was forming.

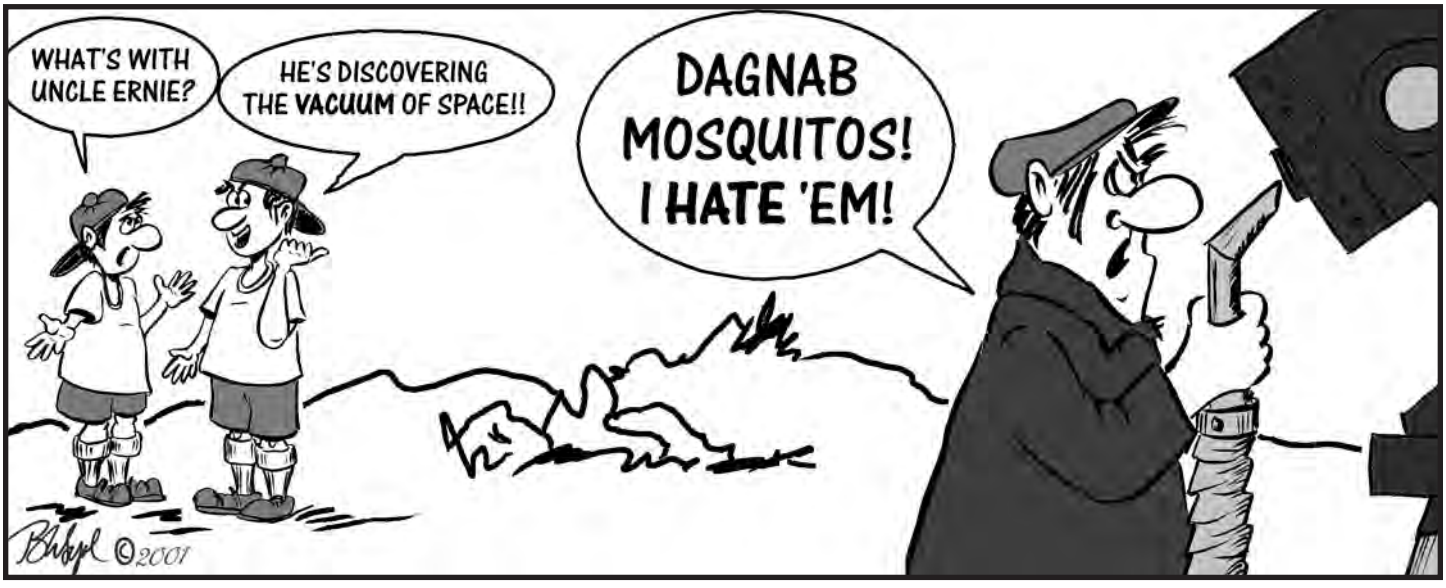
Gravitational microlensing is a direct probe of the density of low-mass objects in a globular cluster. If you know the distance to the cluster and how it is moving, then it is relatively easy to determine the masses of the lenses, and that is just what Sahu and colleagues have done.

The globular cluster M22 lies in front of the background spherical bulge of stars that dominates the central region of the Milky Way. Its distance is well determined, and the bulge provides a large number of stars to be lensed. With a series of 43 observations spread over about four months, Sahu and colleagues found one clear lensing event with a well-determined light curve amongst the 83,000 stars monitored; they calculated the mass of the lensing object to be 0.13 (+0.03 – 0.02) solar masses. Even more intriguing, though, was the discovery of six events that were not resolved in time — each appears as a single bright event against the uniform brightness of the star the rest of the time. As the length of the lensing event is related to the mass of the lens, these unresolved spikes — if they arise from lensing — indicate the presence of a substantial number of objects with masses only about 1/4 of the mass of Jupiter! These objects could contribute up to about 10 percent of the globular cluster mass.

Regular readers of this column may remember that, in the June issue (*JRASC*, 95, 108), I wrote about stars swallowing planets that had been gravitationally scattered in their solar systems, like balls on a pool table. The scattering process would often involve the ejection of a planet or two, to form the free-floating ones that perhaps have been seen by Sahu and colleagues. Thirty years ago, people wondered if there were any planets outside our Solar System; now it seems we are awash in them.

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

ANOTHER SIDE OF RELATIVITY



Research Papers
Articles de recherche

CANADIAN THESIS ABSTRACTS

Compiled by Melvin Blake (blake@aries.phys.yorku.ca)

Observational Signatures of Convection in Solar Type Stars
by Devon Hamilton (hamilton@astro.utoronto.ca)
University of Toronto, Ph.D

In this thesis, a new technique for studying convection is developed using relative line-shifts. The technique is tested using the sun's visible flux spectrum and the most current Fe I line positions available, and can be applied at significantly lower spectral resolutions and signal-to-noise ratios than has been done previously. These line-shifts show a clear dependence on both line strength and wavelength. Similar observations in the solar intensity spectrum demonstrate that the effects of limb darkening on the line-shifts are relatively minor. Because the solar intensity spectrum has been observed well into the infrared, it is used to study the line-shift techniques over the broadest possible spectral region. The Fe I line-core shift distributions show clear evidence of a dependence on line strength at all wavelengths, and sensitivities to wavelength are found at shorter wavelengths. Line-shifts are also determined for 1323 CO lines between 2.2 and 5.5μm. Clear evidence of line strength dependency is found at all wavelengths, and interesting line-shift behavior is found when the excitation energy and quantum numbers of the CO transitions are examined. A similar study of CO and OH line-shifts is done using a sunspot umbral spectrum, and the convective motions are greatly suppressed. Line-shifts are also examined in the infrared spectrum of six cool giant stars. The vigorous nature of convection seems to decline with T_{eff}, which is consistent with expectations.

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 Tuesday, 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."

Two business meetings of the C.A.S. were held on Nov. 12 and 13 respectively. The following appointments to positions on Council were approved:

President: Helen S. Hogg, University of Toronto.
1st Vice-President: Alan H. Batten, Dominion Astrophysical Observatory.
2nd Vice-President: Gilles Beaudet, Université de Montréal.
Secretary: Peter M. Millman, National Research Council of Canada, Ottawa.
Treasurer: Jeremy B. Tatum, University of Victoria.
Representative to C.A.P.: W. L. H. Shuter, University of British Columbia.
Representative to R.A.S.C.; René Racine, University of Toronto.

It was announced that, as of Nov. 12, the C.A.S. had 121 Ordinary Members and 24 Student Members, making a total of 145 members in all. The proposed constitution was approved in principle and some of the more contentious clauses were dealt with in detail. The thanks of the Society were expressed to Professor MacRae and his staff for their work in making this first meeting such an outstanding success. The invitation of Professor Gilles Beaudet to hold the second meeting at the Université de Montréal in May, 1972, was accepted.

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

ABSTRACTS OF PAPERS PRESENTED AT THE 2001 CASCA ANNUAL MEETING HELD AT MCMASTER UNIVERSITY IN HAMILTON, MAY 26–29, 2001

Contributed Papers/Présentations orales

Nano-Engineered Liquid Mirrors, E. Borra, COPL/Laval University, and A. Ritcey and H. Yockell, Laval University

In a recent article (ApJL, 1999, 516, L115) we have argued that liquid mirrors can be tilted by as much as a few tens of degrees. This feat is contingent on the development of viscous high-reflectivity liquids. Our latest mirrors use nano-particles that self-assemble to create reflective surfaces. We shall report on the status of the project. Work on the development of viscous reflecting liquids has progressed very well and we have reached several milestones. We have demonstrated first surfaces having excellent optical qualities. We have spread our nano-particles on viscous liquids. We have reached peak reflectivities of 80% with ease and expect to do better in the future. The technology should be portable to very large surfaces and promises to make large tiltable mirrors at very low costs since the mirrors are made of inexpensive chemicals and are very light. We expect that an 8-m diameter mirror should weigh on the order of 50 kg, a low weight that results from the fact that it is made of a 1-mm thick layer of water to which we add inexpensive chemical compounds. The support system simply consists of a rigid container.

The Canada-France Deep Fields Survey, Mark Brodwin, University of Toronto, H. J. McCracken, LAM, S. J. Lilly, NRC/Herzberg Institute of Astrophysics, S. Foucaud and O. Lefevre, LAM, and D. Crampton, NRC/Herzberg Institute of Astrophysics

The Canada-France Deep Fields (CFDF) is a deep, wide-field, multi-colour imaging survey whose primary goals are to study the clustering and luminosity evolution of galaxies over the range $0< z < 1$. Data acquisition and reduction are essentially complete, and the analysis phase has begun. In this talk I'll introduce the survey, discuss some initial results, and present simulations which demonstrate the feasibility of the primary science goals. In addition I'll briefly describe some of the other analyses currently underway, including studies of the statistical properties of *U*-band dropouts and extremely red objects, as well as a determination of the evolution of the UV luminosity density of the universe.

The Magnetic Field in the Plane of the Outer Galaxy as Seen through the CGPS, Jo-Anne Brown and A.R. Taylor, University of Calgary

Despite huge advances in technology, *in-situ* measurements of the interstellar magnetic field are not yet possible. Instead, observations must be done indirectly. One such method is based on the fact that the plane of polarization of radio waves is changed upon propagation through a magnetized plasma by a process called Faraday rotation. Thus, examining the emissions of extragalactic objects (galaxies and quasars) allows us, in essence, to sample the magnetic field along their lines of sight. Our study of high resolution polarization data from the Canadian Galactic Plane Survey (CGPS) has yielded over 300 radio sources with well-defined rotation measures (RM), corresponding to a density of roughly one source for every square degree. This is ten times greater than previous RM surveys in the same region. As a result, these sources reveal structures and detail in the magneto-ionic medium never before observed, including a localized positive RM "bubble" in the predominantly negative local arm (l = 92°). This bubble is of particular interest, since the sign of the RM can only be affected by the direction of the magnetic field. Conversely, the predominance of negative RMs suggests, in contradiction to previous work, that there is no global magnetic field reversal in the outer Galaxy.

The Blue-to-Red Supergiant Number Ratio of the RSG-rich Galactic Open Star Cluster NGC 7419, Geneviève Caron, Anthony Moffat, and Nicole St-Louis, Université de Montréal

The problem of the blue-to-red supergiant number ratio (B/R) in stellar clusters and elsewhere is still not resolved. Theory and observations are still miles apart. Especially interesting in this context is the Galactic open cluster NGC 7419 because it contains a record of 5 RSGs, but only 1 BSG according to Beauchamps *et al.* (1994). This means that the B/R ratio would be only 0.2 ± 0.2 instead of 1.9 ± 0.8 as for 11 other Galactic open clusters of similar age (~ 15 Myr) and metallicity ($\sim Z_{solar}$). Is the difference due to a statistical fluke or does it have another explanation? One possibility is that the photometry carried out by Beauchamps *et al.* is error-prone, such that NGC 7419 does actually have more BSGs than claimed. We attempt to bypass the various problems associated with doing and interpreting photometry at high interstellar extinction in NGC 7419 (A_V = 6.7), via spectroscopy in a more easily accessible red band centred at $\lambda \sim 8700$ Å, for the 7 brightest intrinsically blue members of NGC 7419. Since no classification scheme is available in that wavelength range, we devised one based on an elaborate network of spectra taken in the same band with the same setup of stars with known spectral types between O9 and B5. Our results indeed confirm those of Beauchamps *et al.* that the B/R ratio in NGC 7419 is unusually low. Presumably there is still a problem in the stellar models of massive stars, which may not include all the physics (*e.g.* rotation: Maeder & Meynet 2000).

The Mass Function of Protostellar Clumps from Non-stationary Accretion, Charles Curry and Michael Fich, University of Waterloo

Recently derived mass spectra of dense cloud cores in several star-forming regions exhibit a remarkable similarity to the field star initial mass function. This suggests that a theory able to explain the late-time mass function of the cores may be more germane to the problem of the stellar IMF than previously thought. We present mass spectra resulting from a simple model of non-stationary accretion for an ensemble of dense cores, building on earlier work by Zinnecker & Myers.

The Dynamical Evolution of Galaxies in Clusters, John Dubinski, University of Toronto, and D. Koranyi and M. Geller, Harvard

We present new results from N-body experiments designed to explore the dynamical evolution of galaxies within clusters and the general cosmological environment. An analysis of more than 200 merger remnants reveals structural and kinematical features similar to elliptical galaxy populations and a fundamental plane scaling relation close to the real one. We discuss the origin of elliptical galaxy scaling relations. A new hybrid, PM treecode has been developed and applied in a new experiment using more than 300 million particles to follow the dynamical evolution of 2000 spiral galaxies distributed within a 100 Mpc cosmological volume.

L'astronomie avec WebCT, Yannick Dupont, R. Lamontagne, F. Wesemael, C. Carignan, and S. Demers, Université de Montréal

Depuis plus de 20 ans, le département de physique de l'Université de Montréal offre un cours d'introduction à l'astronomie aux étudiants hors département. Ce cours descriptif est généralement enseigné sous forme magistrale, avec une très forte composante audiovisuelle. Un recueil de notes en français est produit et mis à la disposition des étudiants. Au cours de la dernière année, nous avons créé une version électronique du cours dans l'environnement WebCT. Cet environnement intègre les fonctions connues du Web (accès au réseau internet, courrier électronique, *etc.*) à des fonctions plus spécifiques à l'enseignement (gestion des étudiants, plan de cours, évaluations, *etc.*). Pour cette première année, l'objectif à court terme était de 1) combiner l'accès aux notes de cours sur WebCT à un accès direct et rapide aux images et simulations numériques présentés en classe, mais auxquelles les étudiants n'avaient pas accès précédemment; et 2) permettre à ces derniers d'accéder, par le biais d'hyperliens, à une documentation supplémentaire sur les sujets abordés en classe. Nous présenterons le site et ses particularités, des statistiques sur son taux d'utilisation, nos projets de développement pour la prochaine année, et discuterons du potentiel d'enseignement à distance offert par WebCT.

Intracluster Stars in the Virgo Cluster, Patrick R. Durrell and R. Ciardullo, Penn State University, J.J. Feldmeier, CWRU, G.H. Jacoby, WIYN, and S. Sigurdsson, Penn State University

Deep HST F814W images of a field 41′ from M87 have been obtained as part of a survey of the Virgo Cluster's intracluster (IC) star population. The luminosity function of the stellar objects in this field (combined with IC stars detected in a field studied by Ferguson *et al.* 1998) reaches $I_{lim} \sim 27.5$ and shows an excess of objects (above that of the background HDF-N and HDF-S fields) with $I > 27$. We attribute this feature to the presence of IC red-giant (RGB) stars in intracluster space. These stars contribute ~ 10% of the total light in the Virgo cluster, a number comparable to that derived from surveys of IC planetary nebulae. Based on the location of the RGB tip and the extent of the AGB, we suggest that the dominant intracluster star population is old ($t > 2$ Gyr) and of moderate metallicity ($-1 <$ [Fe/H] < 0); this is consistent with models of tidal stripping in low-mass spiral and elliptical galaxies. We cannot, however, rule out the presence of a more metal-poor population.

Bipolar Outflows and the Anisotropic Collapse of Magnetized Protostars, Jason Fiege, CITA, Richard Henriksen, Queen's University, and Thibaut Lery, DIAS

We discuss a new self-similar model for the time-dependent and non-isotropic collapse of a magnetized, self-gravitating core. Bipolar outflows are generated as infalling material is deflected toward the symmetry axis by poloidal pressure gradients. Remarkably, this model is an exact solution to the equations of time-dependent self-gravitating MHD, which can be expressed in closed analytical form. We place this new collapse model within the broader context of our steady-state self-similar models of protostellar outflows. A new version of this model is discussed, which is particularly appropriate for the youngest outflow sources, in which most of the material resides in a massive circumstellar envelope.

The Red-Sequence Cluster Survey, Mike Gladders and Howard Yee, University of Toronto

The Red-Sequence Cluster Survey (RCS) is the largest moderately deep imaging survey ever undertaken. The survey data consist of 100 square degrees of R and Z' imaging to a depth 2 magnitudes past M^* at $z = 1$. Begun in mid-1999, the RCS is now 75% complete, and preliminary analyses of the data already illustrate the tremendous power of the survey for finding and characterizing clusters to redshifts as high as $z = 1.4$. We illustrate this success with a number of example clusters, including a sample of new strong-lensing clusters at $z > 0.5$. Time permitting, many of the astrophysical applications of the RCS will be shown, including a measurement of Ω_M and σ_8 via the cluster mass function, weak and strong lensing analyses of the cluster and group sample, evolutionary studies of the cluster galaxy populations to $z = 1$, and a measurement of the two-point correlation function of the general early-type galaxy population to $z = 1$. Some suggestions for future directions for optical-IR imaging surveys for clusters and the potential for overlap between these surveys and future SZ and X-ray surveys will also be made.

Betelgeuse: Giant-Cell Convection?, David F. Gray, University of Western Ontario

Giant convection cells have been predicted and are generally expected to occur in the atmospheres of supergiant stars like Betelgeuse. But high resolution spectroscopic observations taken over several months at the Elginfield Observatory show spectral lines with remarkably stable shapes, especially considering the very significant changes the star shows in the central depths of its spectral lines and in its apparent magnitude. Either giant convection cells do not occur in the photosphere of Betelgeuse, or else they have very small velocities and/or contrast so that no spectroscopic signature is produced.

Globular Clusters as Dynamical Probes of M87, Dave Hanes, Queen's University, P. Cote, Rutgers, D. McLaughlin, Berkeley, T. Bridges, AAO, G. Harris, University of Waterloo, J. Hesser, DAO, D. Geisler, Chile, D. Merritt, Rutgers, and M. G. Lee, Seoul

For decades, globular clusters have been considered ideal "fossil tracers" of the galaxy formation process, first interpreted in the context of monolithic collapse and enrichment models. The manifest correlations between the spatial, dynamical, and metallicity distributions of globular cluster systems (GCSs) hold the promise of distinguishing between competing formation models in galaxies of all kinds. Until recently, however, such studies were unfeasible much outside the Local Group and its two dominant spiral galaxies. The development of multi-

spectroscopic instruments on 4-m class reflectors has permitted a welcome extension of dynamical studies to giant elliptical galaxies at Virgo-like distances. The extension is timely: in recent years, it has become increasingly clear that at least some old GCSs display properties consistent with (although perhaps not exclusively predicted by) an origin via a major merger or interaction. One such discovery is that many GCSs display a striking bimodality in colour, a finding which has been interpreted as arising from two major formation episodes, with the second having been sparked by a galaxy-galaxy interaction. (Such interpretations are further supported by the discovery that young globular clusters are being formed in vigorous galaxy mergers in the present-day universe.) Using the CFHT MOS instrument, we have defined the largest database of pure Population II dynamical "test particles" yet associated with any external galaxy: we have robust velocities for more than 300 tracers in the halo of M87, the central giant elliptical galaxy in the Virgo Cluster. Our study reaches to larger spatial scales than did earlier work, thus providing important leverage on dynamical models. Moreover, our inclusion of precise multi-colour photometry allows us to distinguish and study separately the dynamical states of the red and blue globular cluster sub-populations. We have discovered significant dynamical differences, and will offer various interpretations.

Lensing in Red-Sequence Cluster Survey Fields, Henk Hoekstra, CITA and University of Toronto, and Mike Gladders and Howard Yee, University of Toronto

The Red-Sequence Cluster Survey is a 100 square degree shallow survey designed to find a large number of high redshift clusters of galaxies. The data are also suitable for a wide variety of lensing studies. To date a number of new strong lensing clusters have been discovered, which show bright arcs. These systems are ideal for follow-up observations. They allow us to study the dark matter distribution in cluster cores, and to constrain cosmological parameters. In addition, the survey data themselves are useful for weak lensing studies. We have studied the lensing signal by large-scale structure (cosmic shear) which provides an important measure of some cosmological parameters (*e.g.*, Ω_m and σ_8). Another application is the study of the average properties of the halos of field galaxies, in particular their extent. For the first time, we have found strong constraints on the sizes of the halos. In this talk I will give an idea of what one can do with the RCS data set, and what to expect in the very near future.

Cosmology with Future Deep Galaxy Cluster Surveys, Gilbert Holder, University of Chicago

Upcoming cluster surveys will provide large catalogues of massive clusters of galaxies. The evolution of the cluster abundance with redshift should provide very precise measurements of the matter density, Ω_m, and the normalization of the matter power spectrum, σ_8. In addition, the cluster abundance will be an excellent probe of the density, Ω_x, and equation of state, w, of the dark energy. As a concrete example, upcoming surveys using the Sunyaev-Zel'dovich effect are shown to be able to measure cosmological parameters to an expected accuracy of a few percent.

Cosmic Velocity Fields and Large-scale Structure from Large-scale Surveys, Mike Hudson, University of Waterloo

I will briefly review the status of recent large-scale peculiar velocity surveys. Several recent surveys have arrived at *apparently* contradictory conclusions concerning the convergence depth of the dipole motion of the Local Group with respect to the Cosmic Microwave Background. I will show that, when proper allowance is made for errors due to sparse sampling, no survey is inconsistent with the others. When all surveys are combined, this suggests that substantial contributions to the Local Group's motion arise from scales beyond 60 h^{-1} Mpc. In the second 5 minutes of my talk, I describe a major new large-scale survey of 100 X-ray selected clusters in the nearby Universe ($cz <$ 20000 km s^{-1}). This is an all-sky spectroscopic and two-colour imaging cluster survey being conducted primarily from CTIO and KPNO (approx. 60 4-m nights) as an NOAO survey program. The primary science goals are cosmic velocity fields and studies of the cluster environment and galaxy evolution therein. For further details, see: `astro.uwaterloo.ca/~mjhudson/research/flows/nfp`

Sub-millimetre Surveys of Star-Forming Regions — New Clues, Doug Johnstone, University of Toronto

I will present sub-millimetre maps from large area surveys of molecular clouds. Analysis of these data reveal that the initial breakup of the molecular cloud into star-forming clumps produces an IMF-like distribution of masses, and thus the numbers of both low- and high-mass stars are determined by the preconditions of the cloud fragmentation. The physical properties of the clumps, while complicated to measure, suggest a balance between thermal pressure support and gravitational forces within a high pressured external medium. The clustering of the star-forming clumps matches critical column density fragmentation models, implying that turbulent support is lost within coherent regions of the molecular clouds, leading to breakup and fragmentation. The column density within these coherent regions (10s of A_V) matches the values required to block UV photons from penetrating and ionizing the interior of the molecular cloud.

Outreach Programs at the Planétarium de Montréal, Nathalie Martimbeau, Planétarium de Montréal

The Planétarium de Montréal is expanding its outreach programmes for the fall of 2001. Its already popular traveling suitcase program, Trousse d'exploration du système solaire, will have a counterpart called Trousse d'exploration de la Lune. Two more programmes will begin in the fall of 2002. Les étoiles à l'école uses the Starlab Planetarium to do interactive astronomy in schools, and Projet Astro-Québec is a local expansion site from the ASP's original Project Astro, pairing teachers and astronomers to teach astronomy in the classroom.

Dynamics at the Inner Edge of the Asteroid Belt, Rosemary McNaughton, University of Toronto

The Hungarias are a ragged band of asteroids orbiting at around 1.9 AU, just inside what is typically defined as the inner edge of the main asteroid belt at 2 AU. They are dynamically distinct from their neighbors, having highly inclined orbits and low eccentricities. I will discuss the results of my numerical surveys of the region in connection with the local secular and mean-motion resonances.

Hunting Poseidon's Shadow: The Secular Response of a Self-Gravitating

Kuiper Belt to Neptune, Douglas McNeil and Martin Duncan, Queen's University, Hal Levison, SWRI, and John Dubinski, CITA/University of Toronto

The resonance between the precession frequencies of Neptune and Kuiper belt objects near 39 AU ordinarily increases the random velocity of the KBOs sufficiently to significantly erode the disc, and this has been demonstrated in test particle simulations. However, work by Ward & Hahn (1998) suggests that if the Kuiper belt were self-gravitating (as it must have been in earlier epochs), then waves might be set up in the disc which would damp down this excitation. If true, this would have serious implications for our present understanding of the dynamical history of the inner Kuiper belt. In our previous work (McNeil 2001) we were unable to reproduce Ward and Hahn's predictions for the massive disc. To continue our investigations, we have parallelized Duncan, Levison and Lee's (1998) symplectic integrator Swift_SyMBA and modified it to incorporate Dubinski's (1996) parallel treecode for the self-gravity of the disc. Preliminary results are discussed.

Galactic Starburst NGC 3603 from X-rays to Radio, Anthony F.J. Moffat, Université de Montréal, M.F. Corcoran, Goddard, I.R. Stevens, Birmingham, and S.V. Marchenko, G. Skalkowski, A. Muecke *et al.*, Université de Montréal

NGC 3603 is the most massive and luminous visible starburst region in the Galaxy. We present the first Chandra/ACIS-I X-ray image and spectra of this dense, exotic object, accompanied by a deep cm-wavelength ATCA radio image at similar ~ 1″ spatial resolution, and HST/ground-based optical data. At the S/N > 3 level, Chandra detects hundreds of X-ray point sources (compared to the 3 distinct sources seen by ROSAT). At least 30 of these sources are definitely associated with optically identified cluster O and WR type members, but most are not. A diffuse X-ray component is also seen out to ~ 2′ (4 pc) from the centre, probably arising mainly from the large number of merging/colliding hot stellar winds. The point-source X-ray fluxes roughly correlate with the bolometric brightnesses of the member O/WR stars, with large scatter. Some exceptionally bright stellar X-ray sources may be colliding wind binaries. The radio image shows resolved sources (1) in the cluster core near where the X-ray/optically brightest stars with the strongest stellar winds are located, (2) from all three known proplyd-like objects (with thermal and non-thermal components), and (3) from the peripheral regions of triggered star-formation.

Stellar Pollution, Norman Murray, CITA, B. Chaboyer, Dartmouth, P. Arras, CITA, B. Hansen, Princeton, and R. Noyes, Harvard

We study spectroscopically determined iron abundances of 640 solar-type stars to search for the signature of accreted iron-rich material. We find that the metallicity [Fe/H] of a subset of 466 main sequence stars, when plotted as a function of stellar mass, mimics the pattern seen in lithium abundances in open clusters. Using Monte Carlo models we find that, on average, these stars appear to have accreted ~ 0.5 earth masses of iron while on the main sequence. A consistency check is provided by a much smaller sample of 19 stars in the Hertzsprung gap, which are slightly evolved and whose convection zones are significantly more massive; they have lower average [Fe/H], and their metallicity shows no clear variation with stellar mass. We argue that our sun is likely to have accreted a similar amount of iron; in this respect, most systems resemble ours, rather than the currently known extrasolar planetary systems. These findings suggest that terrestrial-type material is common around solar- type stars. Results for (roughly 50) stars with planets are even more striking — they have accreted an average of 5 earth masses of iron.

Simulations of Hierarchical Galaxy Formation, Julio Navarro, University of Victoria

I will present our latest results concerning simulations of galaxy formation in a hierarchically clustering universe. I will emphasize recent progress on the viability of Cold Dark Matter on the scale of individual galaxies. In particular I plan to concentrate on the halo substructure, the evolution of galaxy discs in realistic CDM halos, and the origin of disc galaxy scaling laws.

Sub-millimetre Fourier Transform Spectroscopy of the Orion Molecular Cloud, David Naylor, B. G. Gom, and E. A. Pope, University of Lethbridge, G. R. Davis and B. Hesman, University of Saskatchewan, D. Johnstone, University of Toronto, J. Bally, University of Colorado, and H.E. Matthews, JACH

The proximity of the Orion molecular cloud provides a unique opportunity for studying star formation. Recent SCUBA images at 450 and 850 μm reveal a remarkable variety of structures including candidate pre-stellar cores, cores containing Class 0 protostars, shocks, and PDR fronts. Spectral index maps obtained from these images yield values in the range $2 < \gamma < 4.5$ (where $S_\nu \sim \nu^\gamma$). While structure in the sub-millimetre spectral index map is thought to be dominated by dust emissivity and temperature variations, a significant contribution to the total measured flux may arise from narrow spectral lines that fall within the SCUBA band-passes. In December 2000 we obtained complete spectral scans of the 850 μm band of the two brightest regions in the Orion molecular cloud (KL and S) with the JCMT facility receiver B3. Preliminary analysis reveals a forest of weak lines, as expected, but no reliable continuum component can be seen in these spectra due to the insensitivity of the heterodyne technique to the dc component. During this run we also obtained a spectrum of the Orion KL region using the University of Lethbridge Fourier transform spectrometer (FTS). The two spectra will be compared to illustrate the potential of the FTS for measuring simultaneously both the line and continuum emission components of molecular cloud sources.

The Canadian Astronomy Education and Outreach Initiative, John R. Percy, University of Toronto

The Canadian astronomy community has recently embarked on a new Education and Public Outreach (EPO) initiative; see the December 2000 issue of *Cassiopeia* for further details. This initiative was prompted by the report of the Long-Range Planning Panel; by the appearance of astronomy in new school science curricula in Canada; by the widespread interest in EPO by Canadian astronomers (professional and amateur) and undergraduate and graduate students; and by the availability of federal and provincial funding for science promotion. In this presentation, I will outline the organization, strategy, and progress of the initiative, and seek your comments and support. A key factor in the success of this initiative will be the continued

enthusiastic participation of Canadian astronomers and their institutions. This initiative has been supported by CASCA and by the Promo Science program of NSERC Canada.

Building the M31 Globular Cluster System, Kathy Perrett, Queen's University, Terry Bridges, AAO, and Dave Hanes, Queen's University

Various models have been proposed to describe the formation of galaxy halos, including monolithic or multiphase collapse, mergers and accretion. With the aim of probing the dynamical and chemical enrichment history of our nearest large spiral galaxy neighbour, we have conducted a spectroscopic study of the M31 globular cluster system. This work has yielded precise radial velocities (good to 12 km s^{-1}) and metallicities for over 200 of M31's globular clusters, many of which have no prior spectroscopic data. We compare the spatial, kinematic, and metal abundance properties within metallicity subpopulations of the M31 clusters and discuss these in the context of the proposed galaxy formation models. In addition, we are using these observations to search for the presence of substructure in the three-parameter space of position, velocity, and metallicity. The ultimate objective is to provide a detailed understanding of the formation and enrichment processes which have occurred in the halo of M31.

Star Formation Thresholds and the Origins of Stellar Masses, Ralph Pudritz, McMaster University, and Shantanu Basu, University of Western Ontario

A typical star in the Galaxy forms as a member of a stellar group within the most massive clumps inside self-gravitating molecular clouds. Molecular clouds are known to be highly turbulent, and are probably supported against global gravitational collapse by the pressure from both chaotic magnetic turbulence, as well as more ordered magnetic fields. We show that under these circumstances, it is inevitable that star formation must proceed within fluctuations that exceed a critical column density threshold. Turbulent and magnetic support are damped out at higher column densities. We investigate the spectrum of masses that is associated with those fluctuations that exceed a critical threshold for various models of molecular cloud clumps, and turbulence. Our results provide an explanation of the so-called initial mass function for the stellar mass spectrum. They also constitute a physical picture of why star formation is clustered and not isolated.

The VLA Galactic Plane Survey: Preliminary Results, Tim Rothwell and P. G. Martin, University of Toronto, A. R. Taylor and S. Strasser, University of Calgary, and J. M. Dickey, University of Minnesota

The International Galactic Plane Survey (IGPS) is a project to map, in high angular (and where applicable, velocity) resolution, the components of the ISM in the plane of the Galaxy. As part of this project, the Very Large Array was used last summer to collect data in H I from $18° \leq l \leq 67°$ and $b = \pm 1.3°$ to 2.0°. This survey joins regions covered by the Southern Galactic Plane Survey (SPGS) and the Canadian Galactic Plane Survey (CGPS). We present here a brief overview of the VLA Galactic Plane Survey and some mosaic images from preliminary processing of the ~ 60 GB of data.

Evolutionary and Pulsational Models of Metal-Poor Subdwarfs, Evgenya Shkolnik and J. M. Matthews, University of British Columbia, and D. B. Guenther, Saint Mary's University

Metal-poor subdwarfs (MPSDs) are probably the Sun's oldest neighbours and are almost certainly low-amplitude p-mode pulsators, like the Sun. One of the goals of the MOST Space Telescope project (due for launch in 2002–2003) is to detect MPSD oscillations and apply asteroseismology to refine the calibration of globular cluster isochrone fitting and possibly set a lower limit to the age of the Universe. To be able to interpret the eigenfrequency data, a comprehensive grid of non-adiabatic, non-radial pulsation models for MPSDs was generated for the first time using a code developed by Guenther (1994). Each pulsation model was calculated from a structural evolutionary model using the Yale Stellar Evolution Code with Rotation (YREC) which included up-to-date physics such as both He and heavy element diffusion and the latest EOS and opacity tables. The grid spanned the following ranges: helium abundance $Y = 0.235$ to 0.255 (consistent with estimates of primordial Y); heavy element abundance $Z = 0.0002$ to 0.01 (consistent with MPSD spectra); mass $M = 0.7$ to 1.0 solar masses; and age $A = 5$ to 16 Gyr. From the calculated eigenfrequencies of each model, the large and small frequency spacings ($\Delta\nu$, $\delta\nu_{0,2}$) were derived as defined by asymptotic pulsation theory (Tassoul 1980). These spacings are sensitive diagnostics of the mass and main-sequence age of the star. Combining MOST's resolution with the uncertainties in the input parameters, MOST data could refine MPSD masses to better than ± 0.005 solar masses and ages to ± 0.05 Gyr (average errors assuming the input physics are correct).

Searching for the Most Massive Stars in the Giant H II Region 30 Doradus, Gwen Skalkowski, Anthony Moffat, and Nicole Saint–Louis, Université de Montréal

30 Doradus is the most intense starburst among the galaxies of the local group. Therefore, this is where it makes most sense to search for the most massive stars known in the Universe. Masses derived from evolutionary models range up to 120 solar masses. Masses from spectroscopic methods (*i.e.* line formation in the photosphere or in the wind) are significantly below those determined with evolutionary tracks, with differences increasing up to a factor of two for the most luminous stars. We are studying the masses of the 30 Dor massive stars using the most direct method possible with a minimum of assumptions, *i.e.* Keplerian orbits for binaries. This will lead us to the real masses of massive stars and, we hope, solve the mass discrepancy problem. We have repeated spectra for ~ 200 stars in 30 Dor for which we can determine the (short) binary status. These spectra will be combined with photometric data to derive the orbital inclinations and the masses for eclipsing systems. Here, we present the first results of this search.

Neutral Hydrogen in NGC 5433 and its Environment, Kristine Spekkens, Cornell University, and J. A. Irwin and D. J. Saikia, Queen's University

We present the first spatially resolved neutral hydrogen observations of the edge-on starburst galaxy NGC 5433 and its environment. We find that NGC 5433 is in a much richer environment than previously thought. We detect H I in one of the two previously identified apparent companions and have a tentative detection for the second. We also detect two new faint companions, both between 17th and 18th magnitude,

indicating that these are dwarfs in the group rather than background galaxies. Thus, NGC 5433 is in a group of at least 5 galaxies spanning over 250 kpc in a filamentary structure. A variety of evidence suggests that interactions are occurring in the group. NGC 5433, itself, is found to be very massive for its morphological type and has a thick H I disc. Higher resolution observations will confirm whether this high latitude H I emission correlates with known radio continuum disc-halo outflow features.

Measuring the Temperature and Density of the Galactic H I Using the CGPS and VGPS Datasets, Simon Strasser and A.R. Taylor, University of Calgary

In this talk we will present preliminary results of atomic hydrogen 21 cm line absorption towards background radio sources in the Canadian Galactic Plane Survey (CGPS) and the VLA Galactic Plane Survey (VGPS). By studying the absorption towards background sources, together with the emission measured "off-source," we obtain the spin temperature and optical depth of the atomic interstellar matter as a function of distance along the line-of-sight to each source. The CGPS and VGPS datasets cover a large region of the Galactic plane with a velocity resolution of 1.2 km s^{-1} and an angular resolution of 1 arcminute. The sensitivity of these surveys allows measurements on weak background sources, achieving an area density on the sky of close to one sample every square degree. When complete, the results will provide a measure of the range of atomic hydrogen temperature states in the interstellar medium and the variation of atomic hydrogen properties with position in the Galaxy.

The International Galactic Plane Survey, A. Russell Taylor, University of Calgary

The Dominion Radio Astrophysical Observatory has completed a 5-year observing project to image the radio emission from a 70° section of the Galactic Plane as part of the Canadian Galactic Plane Survey (CGPS). The DRAO observations provide simultaneous radio continuum images at two wavelengths, 74 cm and 21 cm, and spectral line images of the 21 cm line of neutral atomic hydrogen. The Canadian Galactic Plane Survey was the first large-scale spectral-line aperture synthesis survey of the Galaxy. This survey formed part of an international collaboration to create a database, within the CGPS region, of arcminute scale resolution, high spatial dynamic range images of all known major components of the Galactic interstellar medium. Initial results reveal wide-spread features and processes in the interstellar medium that are not readily visible by other means, including, for example, unusual atomic hydrogen structures related to the vertical transfer of matter and radiation between the disc and halo of the Galaxy, Faraday rotation structures that allow study of the magnetic field and diffuse ionized component in the plane of the Galaxy, and a cold atomic phase of the neutral medium that may provide a link between global shock phenomena in the galaxy and the formation of molecular clouds. Based on the success of the CGPS, a new global alliance has been forged to obtain a high-resolution 3-D image of the entire Milky Way Galaxy. The International Galactic Plane Survey (IGPS) is a Canadian-led collaboration that includes eight of the world's major radio astronomy facilities in Canada, the US, Australia, Sweden and Germany.

The Angular Momentum Problem in Numerical CDM Cosmogony: Half Way There?, Robert Thacker, University of California at Berkeley, and H. M. P. Couchman, McMaster University

We present a smoothed particle hydrodynamic (SPH) simulation that reproduces a galaxy that is a moderate facsimile of those observed. The primary failing point of previous simulations of disc formation, namely excessive transport of angular momentum from gas to dark matter, is solved by the inclusion of a supernova feedback algorithm that allows energy to persist in the model ISM for a period corresponding to the lifetime of stellar associations. The inclusion of feedback leads to a disc at a redshift $z = 0.52$, with a specific angular momentum content within 40% of the value required to fit observations. An exponential fit to the disc baryon surface density gives a scale length within 17% of the theoretical value. Runs without feedback, with or without star formation, exhibit the drastic angular momentum transport observed elsewhere.

Gravitational Lensing and Large Scale Structures, Ludovic Van Waerbeke, IAP/CITA, Y. Mellier, IAP, F. Bernardeau, CEA/SPhT, and E. Bertin, IAP

I will present the most recent cosmic shear measurements done so far with "small" surveys and present oncoming plans for the future involving much larger surveys. Then I will discuss the implications and the role that weak lensing could have in big projects like MAP, SLOAN, Planck, *etc*.

The Canada-UK Deep Sub-mm Survey: The Hidden Phases of Galaxy Evolution, Tracy Webb, University of Toronto, S. J. Lilly, NRC/Herzberg Institute of Astrophysics, S. Eales, W. Gear, D. Clements, and L. Dunne, University of Cardiff

The last few years have seen great progress in the field of galaxy formation and early evolution. Work by many groups using SCUBA on the JCMT has revealed a population of high-redshift dusty objects which are responsible for a significant fraction of the energy output of the universe, over all time. The Canada-UK deep sub-mm survey, the largest survey of its depth, has detected over 40 of these objects. I will discuss the current status of the survey, focusing on what we can say about the multi-wavelength properties and redshifts of these galaxies.

Poster Papers/Présentations "Posters"

Construction Status of the Montreal Infrared Spectrograph, SIMON, Loïc Albert, R. Doyon, and D. Nadeau, Université de Montréal

The Montreal Infrared Spectrograph, SIMON, is currently under construction at the Laboratoire d'astrophysique expérimentale at the Université de Montréal and should achieve first light by the end of this year. SIMON, which is both an imager and a multi- object spectrograph, is based on a 1024×1024 HgCdTe 0.8–2.5 microns detector and is designed for the Mont Mégantic Observatory as well as the CFHT. SIMON is composed of two distinct cryogenically cooled cryostats: the largest houses the optics, filter wheel, and the detector; the other contains the masks wheel for spectroscopic capabilities and is designed to be cycled rapidly between consecutive nights. The

latter cryostat was machined this winter and is undergoing flexure tests, while construction of the optical cryostat is near completion.

The Re-ionization of the Universe, Rennan Barkana, Canadian Institute of Theoretical Astrophysics

The first sources of light re-ionized most of the hydrogen in the universe by redshift seven. This most-recent phase transition in the universe is interesting in its own right, since it should be accessible to upcoming observations, and since its study should teach us much about galaxy formation. Furthermore, the process of re-ionization influenced many aspects of the subsequent formation and evolution of galaxies. This talk will focus on constraints that re-ionization sets on the properties of dark matter.

Major Upgrade at the Mont Mégantic Observatory, Pierre Bastien, L. Albert, É. Artigau, C. Carignan, R. Doyon, O. Hernandez, R. Lamontagne, R. Leclerc, S. Marchenko, D. Nadeau, R. Racine, M. Riopel, D. St–Jacques, L. Turbide, and P. Vallée, Université de Montréal, G. Jones, and J.–R. Roy, Université Laval

4.7 CDN million dollars have been raised for the renovations of the infrastructure of the Mont Mégantic Observatory and its 1.6-m Ritchey-Chretien telescope. The renovations are now about half way completed (1.5 years out of 3) and about half of the budget has been spent. The work on the observatory, the telescope, a link by fiber optics, and the various instruments currently under construction will be presented. The instruments include: a new bonnette, an adaptive optics system, a Fabry-Perot interferometer for the visible spectrum (FANTOMM), an infrared spectrograph/imager (SIMON), and a wide-field infrared imager.

Constraints on Molecular Cloud Core Shapes from Observational Data, Shantanu Basu and C.E. Jones, University of Western Ontario, and J. Dubinski, University of Toronto

We conduct an analysis of the shapes of molecular cloud cores using recently compiled catalogues of observed axis ratios of individual cores mapped in ammonia or through optical selection. We apply both analytical and statistical techniques to de-project the observed axis ratios in order to determine the true distribution of cloud core shapes. We find that neither pure oblate nor pure prolate cores can account for the observed distribution of core shapes. Intrinsically triaxial cores produce distributions that agree with observations. The best-fit triaxial distribution contains cores that are more nearly oblate than prolate.

The Precise Mass Project: A DAO Survey of Red Giant and Supergiant Masses, Philip D. Bennett, University of Colorado and Saint Mary's University, and S. Yang, University of Victoria

We report on the status of the Precise Mass Project, a continuing program started in 1994 on the DAO 1.2-m telescope. The objective is to determine masses of red giants and supergiants in binary systems to a 1–2% accuracy. We have obtained approximately 2000 CCD stellar spectra to date from a sample of about 60 stars, most of which have been reduced to 1-D co-added spectra. Determination of radial velocity orbits are now underway, using telluric lines as a velocity fiducial. To recover orbital inclination angles (needed to remove the *sin i* degeneracy inherent in spectroscopic orbit solutions), we propose to obtain interferometric observations of the program stars from the Navy Prototype Optical Interferometer (NPOI) near Flagstaff, AZ.

The Globular Cluster System of NGC 3115, Steven J. Bickerton and D. A. Hanes, Queen's University, W. E. Harris, McMaster University, M. West, University of Hawaii, and J. J. Kavelaars, McMaster University

The lenticular galaxy NGC 3115 sits in isolation at a distance of about 9 Mpc. Photometric observations of the galaxy made with the CFH12K detector at the Canada-France-Hawaii telescope have provided the deepest wide field images of the galaxy to date, revealing its entire globular cluster system. The comprehensive data show a clear bimodality in the colour distribution of NGC 3115 suggestive of a merger or other evolutionary event in the distant past. These observations are in agreement with previous work by Kavelaars & Hanes in 1996, and Kundu & Whitmore in 1998, in which they only examined limited samples of the population. With the entire cluster population represented, it is possible to explore other aspects of the system including the spatial distribution of the two sub-populations. Preliminary results, including the *B–R* colour distribution, the globular cluster luminosity function, and the specific frequency, are presented.

The Centre of the Crab Nebula: Moving Wisps in Radio, Michael Bietenholz, York University, D. A. Frail, NRAO, and J. J. Hester, Arizona State University

We present three high-resolution radio images of the Crab nebula, taken in 1998.6, 1998.8 and 2000.1 with the VLA. These are the best radio images of the Crab to date. We show that, near the pulsar, there are significant changes between our three observing epochs. These changes have an elliptical geometry very similar to that of the optical wisps. One radio wisp in particular can be unambiguously identified between two of our observing epochs, and moves outward with an apparent velocity of 0.24 *c*. The similarity in both morphology and behavior of the present radio wisps to the optical wisps suggests they are associated. This implies that the radio wisps, like theoretical ones, are likely manifestations of the shock in the Crab pulsar's wind. This, in turn, suggests that the radio emitting electrons are accelerated in the same region as the ones responsible for the optical to X-ray emission, contrary to most current models.

How Many Independent Cosmological Parameters can be Measured with Current CMB Data?, Richard Bond, Dimitry Pogosyan, Carlo Contaldi, and Simon Prunet, Canadian Institute of Theoretical Astrophysics, Barth Netterfield, University of Toronto, and the Boomerang Collaboration

With the just-released new round of Boomerang data, plus information from all other CMB experiments, some cosmological parameters are being measured with reasonable accuracy, but others are not. We present the formalism (parameter eigenmodes) for how to think about this problem, which codifies near-degeneracies that do not allow us to determine, for example, the cosmological constant to high accuracy with CMB alone, but why the baryon and cold dark matter abundance can be well determined. We also describe how supernova and large scale structure information breaks some of these near-degeneracies. We apply the formalism to such problems as quintessence (giving a

dynamic to the dark energy) and to setting constraints on radically broken scale invariance of the inflaton spectrum.

H I around Sculptor dSph, Antoine Bouchard, Université de Montréal

H I observations of the Sculptor dwarf spheroidal galaxy (dSph) have shown that it was not as devoid of gas as previously thought (Carignan *et al.* 1998). With new, higher- resolution data, we found that the morphology of the clouds surrounding Sculptor suggests they are being stripped away from the galaxy.

Halo Dust Emission of NGC 5775, Rupinder Brar and J. A. Irwin, Queen's University

There is now a small but important amount of observational evidence for the presence of high-latitude (*i.e.*, ≥ 1 kpc) dust in galaxies. This dust is best detected by observing edge-on spiral galaxies with sufficient sensitivity and spatial resolution. We compare observations of halo dust emission with radio data to determine whether a spatial correlation observed in M82 occurs in other galaxies with halos as well. We present the results of JCMT SCUBA observations taken of NGC 5775 at 450 and 850 microns and show evidence for dust emission at high latitudes.

Gravitational Lensing of Polarized Sources, Christopher Burns and C. C. Dyer, University of Toronto

Polarization has been shown to be invariant under gravitational lensing and therefore can be used to constrain lensing models. In particular, if the polarization is correlated with the intrinsic morphology of the source (for example, the synchrotron emission from radio jets), then one can detect weak gravitational lensing by measuring deviations from this correlation. This technique has the advantage of continuously sampling the lensing potential and can therefore constrain the shape of the mass distribution. In the case of multiple imaging, the polarization can add constraints to the lensing model, since it is mapped as a vector quantity as opposed to a scalar. This paper will describe the technique and results of using polarization to constrain gravitational lens models.

FUSE Observations of the Metal-rich White Dwarf WD0621–376, Pierre Chayer, University of Victoria and John Hopkins University, S. Vennes, ANU, and N. Lehner, John Hopkins University

We present and analyze the FUSE spectrum of the hot DA white dwarf WD0621–376. Two observations were obtained using the large and medium slits (LWRS, MDRS) resulting in an exposure time of 18,147 s. The spectrum covers 905–1187 angstroms with a resolution of about 0.06 angstroms. The FUSE spectrum shows the strong hydrogen Lyman lines and many photospheric lines such as C III, N IV, O IV, Si IV, P V, S IV, S V, S VI, and Fe V. It also displays interstellar H I, D I, C II, C III, N I, N II, N III, O I, Si II, Ar I, and Fe II features. By combining the FUSE and IUE data we perform an abundance analysis of WD0621–376's atmosphere and find log(C/H) = –5.9, log(N/H) = –6.6, log(O/H) = –5.9, log(Si/H) = –5.5, log(P/H) = –6.2, log(S/H) = –5.4, log(Fe/H) = –4.5, and log(Ni/H) = –5.5. WD0621–376 is one of the most metal-rich white dwarfs. It has comparable heavy element abundances to those observed in WD2211–495, which has similar atmospheric parameters.

High Latitude H I in NGC 2613, Tara Chaves and Judith Irwin, Queen's University

Studies of edge-on spiral galaxies have revealed a number of cases in which kpc scale H I features extend from the disk into the halo region. We have obtained VLA CnB and D array 21 cm H I observations of NGC 2613, an edge-on spiral galaxy 26 Mpc away. We report that NGC 2613 is an extremely massive galaxy with a nearby companion galaxy (ESO 495–G 017). We have found three high latitude features above the plane, symmetric with three below the plane in NGC 2613. All six features show a multiple velocity structure, with several "spurs," as well as a trend to lag behind the disk gas with increasing distance from the plane. Two of the H I features show a strong correlation with large extensions in the continuum emission, with the continuum arranged on the perimeter of the H I. We postulate that these features were formed by some mechanism internal to the galaxy, possibly by spatially correlated supernovae or by the action of a pre-existing relativistic jet flowing through the plane of the galaxy.

Unification: UV & IR Observations of Interstellar Dust Along the Same Sightlines, Geoffrey C. Clayton, Louisiana State University, K. D. Gordon, Steward Observatory, M.J. Wolff, SSI, and L. Valencic, LSU

Studies of interstellar dust in the UV and IR wavelength regions have been, up to now, two separate worlds. UV extinction has been studied along diffuse, moderately reddened sightlines, while IR studies of PAH's and other features rely on observations of heavily reddened dark cloud sightlines. Using STIS on the HST, we are obtaining UV extinction curves for sightlines more heavily reddened than any previously observed. In addition, we are obtaining IR spectra of the 3.1 μm ice feature and the 3.4 μm C–H stretch feature for a sample of sightlines for which UV extinction curves already exist. We are producing a significant sample of sightlines with both UV and IR data so that we may investigate the effects on UV extinction of mantling on interstellar grains and investigate the role of PAH's in UV extinction. We are gaining a better understanding of the physical properties of dust grains and how these properties vary in the different environments in which the dust is found. These data are being used to constrain dust grain models such as the Discrete Dipole Approximation (DDA) and the Maximum Entropy Method (MEM).

A Catalogue of Variable Stars in Globular Clusters, Christine Clement, A. Muzzin, Q. Dufton, T. Rosebery, and J. Wang, University of Toronto, and J. Rowe, University of British Columbia

Three editions of the Catalogue of Variable Stars in Globular Clusters were published by the late Helen Sawyer Hogg in 1939, 1955 and 1973. She intended to publish a fourth edition and, in preparation for this, she entered material from the relevant papers published between 1973 and 1988 on reference cards. An electronic version of the 1973 catalogue was produced with the material from the 1973–1988 reference cards included. This was made available to the astronomical community in 1997. Work on the catalogue has continued and the updated version can be obtained from the Web site of Christine Clement (`www.astro.utoronto.ca/~cclement`). We will present graphs and tables to illustrate the variable star content of Galactic globular clusters. This research has been supported by the Natural

Sciences and Engineering Research Council of Canada.

The Canadian Large Adaptive Reflector, P. Dewdney, B. Veidt, A. Gray, A. Willis, and B. Carlson, NRC/Herzberg Institute of Astrophysics, M. Nahon, University of Victoria, S. Stiemer, University of British Columbia, and D. Halliday, AMEC Dynamic Structures

The Canadian Large Adaptive Reflector (CLAR) is simultaneously targeted to carry out deep spectral surveys of the nearby universe in H I, to serve as an ultra-sensitive pulsar telescope, and as a technical prototype for the Square Kilometer Array (see companion abstract, Taylor *et al.*). The CLAR will be a completely new design of radio telescope that will depend upon a range of technologies not previously exploited for radio astronomy (Carlson *et al.* 2000). The design is a 300m parabolic reflector that exploits a long focal length to permit the construction of a very large reflector parallel to the ground, which does not have to be tilted to steer the telescope. Instead, steering is accomplished by moving the focal point alone, while adjusting the shape of the reflector. The main design trade-off requires the focal apparatus to be suspended at 750 m altitude by an aerostat — a method that has been extensively studied and will soon be under test at the National Research Council's Dominion Radio Astrophysical Observatory (DRAO). Each component of the telescope presents unique challenges. We will discuss current design ideas for: 1) Multi-tethered Aerostat System and control, 2) Focal Apparatus: Structure and control, 3) Feed: RF design, 4) Feed: beam-forming and data transmission, 5) Actuated reflector and control, 6) Spectral line back-end (*i.e.* correlator system), 7) System design and overall control.

Reference

Carlson, B.R., *et al.* 2000, in Radio Telescopes, ed. H.R. Butcher (Proceedings of SPIE Meeting: Munich), 33

Tracing Diffuse H_2 in the Galactic Plane, Kevin A. Douglas and A. R. Taylor, University of Calgary

Recent studies of the gas and dust in high latitude cirrus clouds indicate the presence of diffuse molecular hydrogen gas that is not traced by the usual surrogate CO emission. These studies require an accurate census of the emission from dust, atomic hydrogen and carbon monoxide. The multi-wavelength datasets of the Canadian Galactic Plane Survey (CGPS) allow arc-minute scale comparisons of these constituents over a large portion of the plane of the Galaxy. We have extended the technique used in high latitude clouds to search for evidence of diffuse H_2 in the Galactic Plane. A detailed investigation of common-resolution CGPS datasets will provide a measure of this diffuse component. Our initial results indicate distinct regions of non-CO traced H_2 in the Galactic Plane. In addition, we have been allocated time on FUSE to probe a number of lines of sight to confirm the presence of H_2 via absorption lines of background stars.

PG 0112+104: The Hottest Helium-Line White Dwarf Below the DB Gap, Patrick Dufour, F. Wesemael, A. Beauchamp, and P. Bergeron, Université de Montréal, and R. A. Saffer, Villanova University

No helium-line white dwarf has been observed up to now with an effective temperature between 45,000 K, the coolest DO star, and 30,000 K, the hottest DB star. This gap in the cooling sequence is likely to hold important clues for our knowledge of the spectral evolution and cooling of white dwarf stars. PG 0112+104 is the hottest known DB star (T_{eff} ~ 30,000 K), which — according to current spectral evolution schemes — may well have become a helium-line object only fairly recently. It also defines the blue edge of the instability strip of the variable DB (V777 Her) stars. We present a complete re-analysis of this star, which makes use of a variety of data. These are archival low-dispersion IUE data, more recent FOS observations, high-dispersion GHRS data at Lα, and optical spectroscopy in the blue part of the spectrum and around Hα. Our aim is to determine self-consistent values for the hydrogen abundance and effective temperature of this key object, values that may help us constrain the evolutionary history and structural properties of this unique star.

Recycling the ISM: Radio Continuum and FIR Emission in Cygnus, Jayanne English, University of Manitoba, and A. R. Taylor, University of Calgary

Combining multi-wavelength datasets from the Canadian Galactic Plane Survey, we obtain a new perspective on a region of our own Milky Way Galaxy that is being energized and recycled by the creation and destruction of massive stars. For example, SNR G84.2–0.8, obscured by a dark cloud delineating the North America Nebula in optical data, shows rich detail at 1 arcmin resolution in 21 cm radio continuum DRAO data. Combined with 74 cm continuum plus 25 μm and 60 μm IRAS data, our colour image distinguishes between thermal star forming regions, SNR and dust clouds and illuminates their relationship. It also shows the variation in spectral indices of the SNR scattered throughout the 10 degree wide mosaic. While some of these are at kpc distances, other SNR and H II regions are clearly cradled by, and ionizing, the dust and gas which resides more locally.

The Galactic Extinction and Distance of Maffei 1, Robin Fingerhut, M.L. McCall, M. M. DeRobertis, R. L. Kingsburgh, M. Kolmjenovic, H. Lee, and R. Ross, York University, and R. J. Buta, University of Alabama

We have obtained low and high resolution spectra for the core of the highly-reddened elliptical galaxy Maffei 1. From these data, we have measured the velocity dispersion and radial velocity with unprecedented accuracy. We have also obtained the first measurement of the Mg_2 index. The radial velocity is found to be $+61 \pm 4$ km s^{-1}, which is significantly higher than the currently accepted value of -10 km s^{-1}. We have also found that elliptical galaxies display a well-defined correlation between the Mg_2 index and effective *V–I* colour, allowing us to arrive at the most accurate extinction measurement to date for Maffei 1. In combination with modern photometry, our measurements make possible the determination of a Fundamental Plane distance for the first time.

First Results of a Systematic Search for Wolf-Rayet Binaries in the Magellanic Clouds, Cedric Foellmi, Université de Montréal

During the past two years, I have carried out an intensive campaign of observing the Wolf-Rayet population in the Magellanic Clouds. After 72 nights on various telescopes, and obtaining 1200 spectra, the first preliminary results come out. The main purpose of this project is to test the formation of WR stars in low metallicity (Z) environment, because the binary channel is expected to take on more and more

importance, as Z decreases. From the data, it seems that the binary frequency of the WR population in the SMC is close to 100%, as expected from theory. On the contrary, the binary frequency in the LMC seems to be significantly lower than the 52% expected, and should probably be compared to that of the Galaxy: 30%. These results should also be incorporated later into a starburst synthesis code. Additionally, after observing 69 stars, some of them deserve particular attention. As an example, the LMC star BAT129 has a radial velocity amplitude from peak to peak of more than 600 km s^{-1} in less than 3 days. After a brief presentation of the project, I will review the main interesting features of the preliminary results.

FUSE Observations of Stellar Wind Variability in Sk −67°166, A. W. Fullerton, University of Victoria and John Hopkins University, D.L. Massa, Emergent IT and GSFC, R. K. Prinja, I. D. Howarth, and A.J. Willis, UCL, and S. P. Owocki, Bartol and University of Delaware

We present results from an 18-day campaign to monitor stellar wind variability in Sk −67°166 (HDE 269698), an O4 If+ star in the Large Magellanic Cloud, with the Far Ultraviolet Spectroscopic Explorer (FUSE) satellite. Optical depth enhancements that progress from blue to red through the absorption trough are prominent in all unsaturated P Cygni profiles, particularly the resonance doublets of S IV and P V. Related variability is evident in the resonance lines of S VI and O IV. The variations are qualitatively similar to those observed in the Si IV wind lines of the Galactic supergiant ζ Puppis [O4 I(n)f] during a 16-day monitoring campaign with IUE. The FUSE observations contain diagnostic information about the nature of the structures responsible for the observed variability. In particular, the relative amplitudes of the variations in S IV and S VI provide the first empirical constraint on the ionization equilibrium of these structures in an O star wind, while the variability of O VI traces the distribution of very hot gas.

This work is based on observations made with the NASA-CNES-CSA Far Ultraviolet Spectroscopic Explorer. FUSE is operated for NASA by the Johns Hopkins University under NASA contract NAS5–32985.

The NStars (Nearby Stars) Project at the DDO, Robert F. Garrison, David Dunlap Observatory and University of Toronto, R. Abdool, C. Capobianco, T. Karmo, and A. Naraghi, University of Toronto

Garrison, with R. O. Gray (Appalachian State University) and C. J. Corbally (Vatican), is working on a large-scale survey to provide a homogeneous set of high-quality MK spectral classifications for nearby stars. The NStar project is a new NSF/NASA program to provide a homogeneous database for all stars in the solar neighborhood (in two levels: < 20 pc and 20–40 pc). In this collaboration, the David Dunlap Observatory (DDO) will provide high S/N CCD spectra for all stars hotter than M0, closer than 47 pc, and with declinations from 40 degrees to the northern pole. The Helen Sawyer Hogg Telescope (HSHT, now in Argentina) will provide the same for declinations −30 degrees to the southern pole. Using synthetic spectra, the MK types will be calibrated and fundamental parameters will be derived. The details and progress of the DDO share of the project will be presented.

The Hidden Realm of Cold Interstellar Hydrogen, Steven J. Gibson and A. R. Taylor, University of Calgary, C. M. Brunt, P. E. Dewdney, and L. A. Higgs, NRC/Herzberg Institute of Astrophysics

A large fraction of the neutral atomic hydrogen (H I) in the Galaxy is hidden from direct view. Arcminute resolution 21 cm line maps from the Canadian Galactic Plane Survey (CGPS) reveal numerous cold hydrogen clouds as H I self-absorption (HISA) shadows against warmer background emission. HISA has traditionally been thought to trace the small fraction of atomic gas in molecular clouds. However the HISA features in our survey do not correlate in strength with CO emission, and they display only a limited physical association with CO. It may be that the CO is a less reliable tracer of molecular hydrogen than is usually assumed, or perhaps we are seeing different mixtures of H I and H_2 in different clouds. If the latter is true, HISA may be tracking gas in transition from the atomic to the molecular state. Much of the strongest HISA in our survey is found at velocities expected of gas downstream of the Perseus spiral shock, where molecular condensation is expected to occur. In our ongoing investigation of this and other possible models of cold interstellar hydrogen, we consider the properties of the HISA clouds and their distribution in space revealed by the CGPS data.

Resonant Stellar Wind Ejection in the Be+Neutron Star Binary, LS *I+61°303*, Philip Gregory, University of British Columbia

The binary star LS I+61°303 is remarkable for its periodic radio outbursts every 26.5 days. We recently discovered a 4.3 year periodic modulation of the phase and amplitude of these outbursts using the Gregory-Loredo Bayesian algorithm for detecting periodic signals of unknown shape. In this paper the results are interpreted in terms of a resonant ejection of an equatorial wind from the Be star primary, interacting with the neutron star companion.

References

Gregory, P.C. 1999, ApJ, 520, 361
Gregory, P.C., Peracaula, M., & Taylor, A.R. 1999, ApJ, 520, 376

Asteroseismology of Intermediate Mass Stars, David Guenther, Saint Mary's University

The oscillation spectra of intermediate mass stars evolving from the zero-age main sequence to the base of the giant branch are presented. Significant features of the oscillation spectra are noted, including those that will be easily observable by MOST and other space-platformed telescopes designed to observe stellar oscillations. Specific seismological indicators of radius, mass, and age are identified.

Tidal Disruption of Substructure in Galaxy Clusters, Eric Hayashi and J. F. Navarro, University of Victoria

Over-merging in the context of cosmological N-body simulations is defined as the absence of substructure in the dark matter halos of galaxy clusters due to numerical or physical disruption mechanisms. In early simulations of galaxy clusters the rapid disruption of bound clumps of N-body particles produced a smooth, featureless cluster mass distribution that did not resemble a real galaxy cluster, where luminous matter is concentrated in discrete galaxies. We investigate recent claims (Ghigna *et al.* 1998, Klypin *et al.* 1999) that the over-merging problem has been resolved in the latest generation of cosmological simulations simply because of increased numerical

resolution. Semi-analytic models of satellite mass loss based on the results of N-body simulations are used to construct a toy model for the dynamical evolution of a galaxy cluster. We find that tidal disruption of satellites is sufficient to erase most substructures within the central regions of the cluster after a Hubble time. The number density of surviving substructure halos predicted by our model is compared with the results of cosmological simulations and observations from the Canadian Network for Observational Cosmology (CNOC) cluster survey (Yee *et al.* 1996). The density profile of surviving satellite halos is similar to that of the Virgo cluster simulation of Ghigna *et al.* (1998), and is not consistent with the observed distribution of galaxies in the CNOC ensemble cluster. We conclude that over-merging due to physical disruption mechanisms remains a problem in the central regions of cluster simulations. This suggests that a dissipational hydrodynamic component is needed to properly model the dynamics of galaxy clusters, as was originally proposed by White & Rees (1978).

The Host Galaxy and Optical Light Curve of the Gamma-Ray Burst GRB 980703, Stephen Holland, University of Notre Dame, J. Fynbo, ESO, J. Hjorth, Copenhagen, J. Gorosabel, DSRI, H. Pedersen, Copenhagen, M. Andersen, Oulu, A. Dar, Technicon, B. Thomsen, Aarhus, P. Møller, ESO, G. Björnsson, Iceland, A. Jaunsen, ESO, P. Natarajan, Yale University, and N. Tanvir, Hertfordshire

We present deep HST/STIS and ground-based photometry of the host galaxy of GRB 980703. The host is a blue, slightly over-luminous galaxy with $V_{gal} = 23.00 \pm 0.10$ and $(V–R)_{gal} = 0.43 \pm 0.13$. It has an apparent star-formation rate of 8–13 solar masses per year. The galaxy has a Sérsic $R^{1/n}$ profile with $n \sim 1.0$ (*i.e.*, an exponential disc) and a half-light radius of 0.13″ (= 1.47 proper kpc). The residuals of the fit reveal a somewhat irregular morphology, but GRB 980703 does not appear to be related to any sub-structure in the host. The galaxy is a typical compact star forming galaxy, similar to those in the Hubble Deep Field North. The *R*-band light decay is consistent with a single power-law decay of slope $\alpha = -1.37 \pm 0.14$. There is a flux excess ~ 20 days after the burst that is consistent with an underlying Type Ib/c supernova like SN1998bw.

SCUBA-2: A New Generation Wide Field Imager for the JCMT, Wayne Holland and William Duncan, UKATC/Edinburgh, and Ian Robson, Joint Astronomy Center/Hawaii

We describe SCUBA-2 — the next generation continuum imaging camera for the James Clerk Maxwell Telescope. The instrument will capitalize on the success of the current SCUBA camera, by having a much larger field-of-view and improved sensitivity. SCUBA-2 will therefore be able to map the sub-millimetre sky several hundred times faster than SCUBA to the same noise level. All areas of astronomy are expected to benefit — from large-scale cosmological surveys to probe galaxy formation and evolution to studies of the earliest stages of star formation in our own Galaxy. Perhaps the most exciting prospect that SCUBA-2 will offer is in the statistical significance of wide-field surveys. The poster will describe the key science goals as well as some of the new technology that will be used in the construction of the instrument.

Parallel PM/Tree and SPH, Robin Humble, Canadian Institute of Theoretical Astrophysics, J. Dubinski, CITA/University of Toronto, and J. Kim and C. Park, Seoul

We have added Smoothed Particle Hydrodynamics to the new cosmological PM/Tree code of Kim, Dubinski and Park. The resulting code is capable of large gravitational and hydrodynamic calculations of order 512^3 particles on 32 processors. The SPH implementation uses the existing scalar tree infrastructure to efficiently find neighbouring particles, and requires only small modifications to the existing MPI parallel communication routines. Minimizing tree traversal overhead and re-use of neighbour information are performance features of the SPH implementation. The fluid code has been tested to be momentum conserving, and preliminary results with shock tubes, the Zel'dovich pancake and clusters have been obtained.

Hydrogen Abundances of Hot DB White Dwarfs, Chris Hunter and F. Wesemael, Université de Montréal, R.A. Saffer, Villanova University, and P. Beregeron and A. Beauchamp, Université de Montréal

We present recent spectroscopic observations of a sample of helium-line white dwarfs of spectral type DB. Our sample includes most of the stars which define the instability strip of the variable DB (V777 Her) stars. Significant uncertainties remain in the location of the blue edge of this strip because of the unknown hydrogen abundance in most hot DB stars. For the hottest stars, this uncertainty can be as large as ~ 3000 K. We conducted a spectroscopic search at Hα as a way of constraining the hydrogen content. We find that two cool pulsating DB stars show Hα absorption. In these objects, hydrogen may play an important role in understanding the pulsation properties. As well, the hotter DB stars are expected to have recently undergone a change in their dominant photospheric constituent from hydrogen to helium, upon exiting the "DB gap". An accurate temperature scale may help constrain the time scale over which this chemical evolution can occur.

HST Observations of the Old LMC Clusters NGC 1786, NGC 2210 and Reticulum, J.A. Johnson, OCIW, M. Bolte, UCO/Lick, and P. B. Stetson and J. E. Hesser, NRC/Herzberg Institute of Astrophysics

We present HST *V* and *I* photometry of three old LMC globular clusters: NGC 1786, NGC 2210 and Reticulum. These clusters span a wide range of central densities as well as distances from the LMC. We compare their colour-magnitude diagrams (CMDs) with the fiducial from the CMD of NGC 2257, an LMC cluster of similar metallicity ([Fe/H] ~ –1.8). We find that these three clusters have the same age as NGC 2257 to within 2 Gyr. Previous work (Olsen *et al.* 1998; Johnson *et al.* 1999) has established that the other clusters in the LMC with ages greater than 8 Gyr, including NGC 2257, all formed within ~ 2 Gyr of each other and at the same time as the classic old Galactic globular clusters such as M92. These new results now mean that there are 11 old LMC clusters that have ages very similar to each other. An initial epoch of star cluster formation therefore happened in a short period over a large volume of space, a volume much larger than is now covered by the present-day optical LMC.

Modeling Spectral Lines from Collapsing Molecular Cloud Cores, Carol E. Jones, Shantanu Basu, and T.A.A. Sigut, University of Western Ontario

We are investigating a variety of gravitational collapse models for

molecular cloud cores using a non-LTE approach to radiative transfer. These models allow us to compute theoretical molecular line profiles to compare with new observations. Currently we have included the molecule CS for a simple spherically symmetric collapse model. We have plans to include other molecules, such as NH_3, N_2H^+, $C^{18}O$, and HCO^+, which trace the densest regions of molecular cloud cores. This work enables us to decipher the physical properties of observed molecular cloud cores.

Studying Sequential Star Formation with Multi-Wavelength Survey Data, Jennifer Karr, University of Toronto

The triggering of star formation through interaction with an expanding H II region or other disturbance in the ISM could have a strong influence on star formation. However, the importance of sequential star formation can be difficult to determine, due to the complex environments of star formation regions and the difficulty of determining the causality of the triggering. This poster will discuss a study of sequential star formation in the Galactic Plane using data from the Canadian Galactic Plane Survey. The spatial and wavelength coverage allows the investigation of triggering from a statistical standpoint, in a variety of locations and physical conditions.

A Massive Cold Atomic Hydrogen Supershell in the Outer Galaxy, Lewis B.G. Knee, Dominion Radio Astrophysical Observatory, and Christopher M. Brunt, DRAO and University of Calgary

The bulk of the mass of the Galactic interstellar medium is in the form of warm (10^3–10^4 K) and cool (50–100 K) atomic hydrogen (H I) gas. Cold (10–30 K) regions are thought to be dominated by dense clouds of molecular hydrogen. Observational limitations have meant that cold H I is rarely observed, and our knowledge of its abundance and distribution in the interstellar medium is poor. The few known cold-H I clouds are much smaller in size and mass than typical molecular clouds. Here we report the discovery that the H I supershell GSH 139-03-69 is very cold (10 K). Approximately 2 kpc in size and more massive than the largest molecular cloud complexes, it is by a wide margin the largest and most massive cold-H I structure yet identified in our Galaxy. The existence of immense structures in the interstellar medium which are composed of cold atomic hydrogen runs counter to the well-entrenched view that cold gas resides almost exclusively in clouds dominated by molecular hydrogen.

Analysis of Clumped Material in the Rho Ophiuchi and Orion B Molecular Clouds, Helen Kirk and D. Johnstone, University of Toronto

We present sub-millimeter maps of the Rho Ophiuchi and Orion B molecular clouds taken at the JCMT. We model the clumps as 2D circular Gaussians and extract them from the map via chi-squared fitting. The applicability of this simple analysis is discussed. The resultant clouds are examined to derive the physical properties such as clump mass and radius. This leads to a computation of the mass function, which mimics the stellar initial mass function and is in good agreement with that found by Johnstone *et al.* (2000, 2001). The two-point correlation function, showing that the clumps are clustered in both clouds, and further analyses are also presented.

The Comet Supernova Remnant and its Unusual Pulsar, Roland Kothes, Dominion Radio Astrophysical Observatory, Serge Pineault, Université de Laval, and Bulent Uyaniker, DRAO

We propose that the pulsar associated with the γ-ray source 3EG J2227+6122 and the supernova remnant (SNR) G106.3+2.7 are the result of the same supernova explosion. The whole structure is located at the lower eastern edge of an H I bubble which includes extended regions of molecular gas at the northern and eastern edge. The radial velocities of both the atomic hydrogen and the molecular material suggest a distance of 800 pc. At this distance, the bubble has an outer diameter of about 20 pc, and the SNR is 14 pc long and 6 pc wide. The pulsar created a shell like synchrotron nebula resembling a bow shock and its wind has formed an H I shell of 0.4 solar masses by ionizing the atomic hydrogen in its vicinity.

The Magneto-Ionic Medium in the Local Spiral Arm, T.L. Landecker, B. Uyaniker, R. Kothes, and A.D. Gray, National Research Council/Dominion Radio Astrophysical Observatory

We present arcminute-resolution images of polarized radio emission at 1420 MHz covering 117 deg^2 in the Galactic plane in Cygnus, made as part of the Canadian Galactic Plane Survey. Large, nearby supernova remnants (SNRs) are seen as polarized objects, while the emission from more distant SNRs appears unpolarized, probably "depolarized" by the superposition of many different Faraday-rotation cells within the telescope beam. We conclude that all polarization features that we detect in this field are within 2 kpc, probably within the local spiral arm. We describe a number of specific polarization features which have no counterpart in total intensity; they are features of the "Faraday screen", the magneto-ionic medium along the line of sight. The telescope is very sensitive to changes in polarization angle, and can detect Faraday rotation effects from ionized regions, which are below the detection limit in total power.

Model Atmospheres with Elemental Stratifications, Francis LeBlanc, Université de Moncton, and A. Hui-Bon-Hoa, Observatoire de Paris-Meudon

Model atmospheres calculated with a modified version of the PHOENIX stellar atmospheric code, which includes elemental stratifications, will be presented. The stratifications of the various elements included in this code are obtained via the radiative diffusion process and the atmospheric structure is simultaneously calculated taking into account the abundance changes. Results will be presented for several types of chemically peculiar stars. The future potential of such models will also be explored.

Carbon Star Survey of NGC 6822, Bruno Letarte and Serge Demers, Université de Montréal, and Paolo Battinelli, Osservatorio Astronomico di Roma

We used the *R, I, CN* and *TiO* photometric system to observe the Local Group irregular galaxy NGC 6822. Observations were secured at the Dupont telescope, on Las Campanas, and with the CFH12K camera at the CFHT. Over 600 carbon stars were discovered. Their spatial distribution extends radially, well into the huge neutral hydrogen cloud surrounding NGC 6822. Details of the photometric properties will be presented.

Stellar Model and Pulsation Spectra of Epsilon Eridani, Peter MacDonald and David Guenther, Saint Mary's University

Stellar evolution models and their associated pulsation spectra are presented for the nearby star Epsilon Eridani (K2 V). This analysis was performed in preparation for future observations with the MOST satellite. These results represent the latest stellar model and asteroseismological analysis of the dwarf star and include a possible age indicator for Epsilon Eridani.

Black Hole Growth and the $M_{BH} - \sigma$ Relation, Joseph MacMillan and R. N. Henriksen, Queen's University

Recent observations suggest a strong correlation between the mass of a central black hole and the velocity dispersion of its host galaxy. We examine this problem in the framework of an adiabatic growth model, in which the black hole grows slowly enough to conserve the actions of the system.

An Accurate Analytic H_4 Potential Energy Surface, P. G. Martin, CITA and University of Toronto, and A. I. Boothroyd, Caltech

Unique diagnostics of the density, temperature, and velocity field in regions of star formation are provided by the quadrupole emission lines of molecular hydrogen (H_2). Interpretation depends critically on collisional rate coefficients. Our previously published rates for H + H_2 are in use in astrophysical simulations of photodissociation regions, interstellar shocks, and pre-galactic clouds. Present calculations of rates for H_2 + H_2 from first principles use an accurate H_4 *ab initio* potential energy surface (PES), the ultimate version of which — a 400-parameter fit spanning 6-dimensions — we report on here. To improve the coverage in conformation space, 42079 new *ab initio* H_4 interaction energies were calculated, using a multiple reference (single and double) excitation configuration interaction MRDCI program; the lowest excited states were computed, as well as the ground state. The *ab initio* energies have an estimated rms random error of about 0.5 millihartree (0.3 kcal mol^{-1}) and a systematic error of 1 millihartree. A new analytical H_4 PES was fitted to 48180 *ab initio* energies (and to an additional 13367 points generated at large separations), yielding a significant improvement over previous H_4 surfaces. This new PES has an energy-weighted rms error of 1.15 millihartree relative to the 48180 energies, comparable to the estimated error in the energies themselves. The new PES also fits the van der Waals well, to an accuracy of about 5%. For relatively compact conformations (energies higher than the H_2 dissociation energy), the conical intersection between the ground state and the first excited state is the largest source of error in the analytic surface.

Cyclopropenylidene in CRL618, Henry Matthews, NRC/Herzberg Institute of Astrophysics and JAC, and Suzanne C. Madden, Saclay

We report observations with the JCMT of the cyclic molecule C_3H_2 in the remnant AGB envelope of the protoplanetary nebula CRL618. In a short series of observations covering a total of about 5 GHz of non-contiguous frequency range, we find the sub-millimetre spectrum of this object to be extraordinarily rich; ten of the 30 certain and probable spectral features are identified with C_3H_2. We use these data to carry out a preliminary excitation analysis, relate them to ISO observations of CRL618, and discuss the potential for the use of C_3H_2 in other astrophysically similar targets.

Hot Settling Flows onto Rotating Black Holes, Mikhail Medvedev and N. Murray, CITA

A new hot accretion flow onto a rapidly rotating neutron star has recently been discovered by Medvedev & Narayan. This flow is similar to the standard advection-dominated accretion flow (ADAF) in some respects, namely it is geometrically thick, optically thin, relatively radiatively inefficient, and two-temperature, with cool electrons and hot (nearly virial) protons. However, the physics of the flow is drastically different from ADAF. The settling flow extracts rotational energy of a rapidly rotating star via a strong viscous torque in the boundary layer where the flow meets the star surface. The extracted energy is converted into heat (again, by viscosity) and is radiated away. The star spin-down rate and the flow luminosity strongly depend on the star rotational velocity, whereas they are completely independent of the accretion rate (so long as it is less then a few percents of Eddington). Such a flow forms around neutron stars rotating at velocities of about ten percents of the Keplerian velocity. One might think that no settling flow may occur around a black hole because of the no-slip condition at the horizon. However, the torque may be transported from the hole via magnetic stresses. If magnetic fields threading the horizon are anchored in the accretion flow, angular momentum which powers the settling flow is extracted from the hole via the Blandford-Znajek process rather than viscous stresses. The settling flow onto a black hole may be accompanied by collimated jets. The relation to blazars and microquasars is discussed.

Relaxation and Virialization of Collisionless Polytropes, Thomas E.C. Merrall and R. N. Henriksen, Queen's University

The phase-space evolution of a polytropic gas is investigated using the collisionless Boltzmann equation. The probability distribution function (PDF) of the system is taken to be of the standard form $f = K[(-2E)]^{n-3/2}$. Evolution of the density profiles is followed for various values of the polytropic index n, and initial virial ratio of the cluster, with certain features appearing consistently throughout the parameter space. This has possible implications for the study of low surface brightness galaxies. Preliminary results are presented.

$C^{18}O$ as a Surrogate for Molecular Hydrogen, George F. Mitchell, Saint Mary's University, Lorne Avery, NRC/Herzberg Institute of Astrophysics, Doug Johnstone, University of Toronto, and Nick Tothill, Saint Mary's University

The H_2 content of molecular clouds is often obtained from isotopomers of CO by applying a fixed CO/H_2 abundance ratio. This procedure is suspect because of the possibility of condensation of CO on cold grains. A systematic study of CO depletion and its dependence on gas properties requires an independent measure of the molecular hydrogen column density, as well as observations with reasonably high resolution. We have obtained ^{13}CO and $C^{18}O$ maps of a number of fields in the Rho Ophiuchi and Orion B molecular clouds. We also have sub-millimetre maps of continuum emission from dust, acquired using SCUBA on the JCMT. A comparison of dust column density with $C^{18}O$ column density shows that CO is strongly depleted in

certain gas clumps but not in others. We cannot yet point to any physical difference between clumps, which could explain this difference in CO depletion.

Unusual Sub-millimetre Emission Towards the Gamma-Ray Burst of February 22, 2001, Gerald H. Moriarty-Schieven, NRC/Herzberg Institute of Astrophysics and Joint Astronomy Centre, D. A. Frail, NRAO/VLA, and S. R. Kulkarni, Caltech

The bright gamma-ray burster GRB010222 was observed over several epochs with the SCUBA bolometre array on the James Clerk Maxwell Telescope, starting a mere six hours after the burst and concluding 18 days later. The flux density of the source was relatively constant over this time period, with an average flux density at 350 GHz (850 μm) of 3.73 ± 0.53 mJy. In contrast to the bright sub-millimetre emission, the source is weak or undetectable at millimetre wavelengths. The relative constancy of the 350 GHz flux density and the steep spectrum between 220 GHz and 350 GHz (spectral slope > 2.4) cannot be reconciled with standard afterglow models. Free-free or synchrotron self-absorption in the millimetre band is unlikely because the source is detectable at centimetre wavelengths. It is also unlikely that the emission arises from dust reprocessing of the burst (flash). Thus we conclude that the sub-millimetre flux originates as a distinct emission component, separate from the main afterglow emission. The simplest hypothesis is that the sub-millimetre flux arises from the host galaxy. Indeed, the sub-millimetre flux of the host (assumed to be at a redshift of 1.467) is typical of star-forming galaxies selected in SCUBA surveys. The estimated star formation rate is 500 solar masses per year — typical of the sample of dusty, high redshift starburst galaxies (*e.g.* Smail *et al.* 2000; astro-ph/000823). This inference is entirely consistent with models in which GRBs are related to the core collapse of massive stars. If true, it may be possible to exploit the extreme luminosity of GRBs and their accompanying afterglows to probe star formation in the early Universe.

A Fitting Approach to Cosmology using Null (Observational) Coordinates, Ishak B. Mustapha and K. W. Lake, Queen's University

Using a convenient set of coordinates on the null cone, we construct a perfect fluid cosmological model. Special cases are studied. We will present our results on the model and discuss briefly a fitting approach to cosmology where the Cosmological Principle is not assumed *a priori*. How can we re-interpret the results from the Supernovas? How can other recent results from observational cosmology be used within this framework?

On the Formation of Helium Dwarfs in Double-Degenerate Binaries, Lorne Nelson and E. Dubeau, Bishop's University

Many helium-degenerate dwarfs (HeDD's) have recently been discovered in binary systems, including a few in isolation. The vast majority of these have been found in double-degenerate systems consisting of a white dwarf or neutron star companion (*e.g.*, a binary millisecond pulsar). Starting from progenitor systems in which the compact companion has already been formed, we analyze the subsequent mass-transfer evolution of these binaries and follow those systems that ultimately produce HeDD's. We explore the dependence of the properties of the He-degenerate dwarfs on such variables as the metallicity, mass of the accreting compact companion, and the mass and state of nuclear evolution of the donor star at the start of mass transfer. By investigating the cooling of the degenerate dwarfs after mass transfer has ceased, we can place constraints on the properties of some of the observed He-degenerate dwarfs and on the properties of the binary itself (*e.g.*, the ages of binary millisecond pulsars). We also find that relatively young, low-mass (< 0.2 solar masses) HeDD's are likely to experience very strong hydrogen shell flashes soon after their envelopes have collapsed.

Numerical Simulation of Barred Galaxies, Jennifer K. O'Neill, John Dubinski, and Roberto G. Abraham, University of Toronto

Although barred spiral galaxies have been the objects of both observation and theory for some time, many aspects remain a mystery. Some current problems being debated are the pattern speed of the bar and its evolution, the edge-on characteristics of bars, the final kinematics of a collapsed bar, and the evolution of barred galaxy morphology as a whole. Using a parallel treecode, we are numerically simulating a barred galaxy using much higher resolution than in the literature (500,000 and 10 million particles vs 300,000 using particle-mesh code (Sellwood 2000)) to determine convergence of the above kinematical and dynamical properties, and the effect of noise on these conclusions. The high resolution results will then be compared with observations in order to determine the effect of bar dynamics on galaxy morphology.

Autocorrelation Analysis of RV Tauri Stars, John R. Percy and Nathan Leigh, University of Toronto

RV Tauri stars are yellow supergiant pulsating stars, which show alternating deep and shallow minima in their light curves. As part of a project to develop a quantitative measure of "RV Tauri-ness" in pulsating yellow supergiants, we have carried out autocorrelation analysis (AA) of a sample of RV Tauri and related stars. AA has proven to be a useful adjunct to power spectrum analysis in the study of other kinds of variable stars that are not strictly periodic. We began by testing AA on visual and photoelectric measurements of bright RV Tauri stars; these data were supplied by the American Association of Variable Star Observers (AAVSO). We then applied AA to data on 13RV Tauri stars and 20 related stars in the LMC, obtained as part of the MACHO Project (Alcock *et al.* 1998, AJ, 115,1921). The results will be described. We thank NSERC Canada for research support, and the AAVSO, Karen Pollard, and Doug Welch for providing data.

The D/H Ratio in Orion, Rene Plume and Ted Bergin, Harvard-Smithsonian Center for Astrophysics

We present an examination of the HDO/H_2O ratio of the molecular gas in Orion BN/KL. To derive the HDO/H_2O ratio, we use: (1) a single point observation of the H_2O 1_{10}–1_{01} transition using the Sub-millimeter Wave Astronomy Satellite (SWAS), whose resolution is ~ 4′, and (2) a 22 point map of the 1_{01}–1_{00} transition of HDO from the Caltech Sub-millimeter Observatory (resolution of 15″). Both data sets have high signal-to-noise ratios and a velocity resolution capable of distinguishing among the varied velocity components present along the line-of-sight. We focus on the HDO/H_2O ratio in the hot core and the molecular outflow. In the hot core, we find that $HDO/H_2O \sim 4$ times 10^{-4} whereas, in the molecular outflow, we set an upper limit of $HDO/H_2O < 5$ times

10^{-4}. We will also show how models of the deuterium chemistry can be used to constrain the origin of the observed water and HDO.

All-sky Component Separation Method with uneven Sky Coverage, Simon Prunet, CITA, R. Teyssier, CEA, and F.R. Bouchet, IAP

The ability of future satellite CMB experiments (MAP, Planck) to give high-precision measurements of the Cosmic Microwave Background power spectrum depend heavily on our ability to use the different frequency bands to disentangle the cosmic signal from foreground emissions (Galactic and extragalactic). The traditional methods to address these issues (Wiener filtering, Maximum Entropy) are usually expressed in Fourier space where they decouple mode by mode in the case of a simple uniform noise. This simplicity breaks down however if the noise becomes inhomogeneous (this includes variations in sky coverage, or regions excluded on purpose from the analysis, *e.g.* the Galactic plane). We present here an original method that solves exactly the multi-frequency Wiener filtering problem for an inhomogeneous, uncorrelated pixel noise. The method relies on an iterative, conjugate gradient solver applied to the Wiener equation, and takes advantage of fast spherical harmonics transforms (HEALPix package). We will show the results obtained on simulated MAP data.

VLBI Imaging of the Gravity Probe-B Guide Star HR 8703, Ryan Ransom, N. Bartel, and M. F. Bientenholz, York University, D. E. Lebach, M. I. Ratner, and I. I. Shapiro, CfA, and J.–F. Lestrade, Observatoire de Paris–DEMIRM

Multi-epoch VLBI observations at 3.6 cm have been made of the RS CVn binary star HR 8703 (IM Pegasi) in support of the NASA-Stanford relativity gyroscope experiment, Gravity Probe B (GP-B). Here, we present a selection of phase-referenced images of HR 8703 produced from observations between January 1997 and August 2000. Our images show radio source structures that vary in size and complexity, ranging from a single, compact emission component less than 1 milliarcsecond (mas) in size, to multiple emission components extending over 2–4 mas. Moreover, images from temporal subsets of several observing sessions show, on hour time scales, structural evolution in the radio emission and motions of the radio centroid of up to approximately 1 mas. We discuss our efforts to locate the sources of the radio emission within the HR 8703 binary system, and examine the implications of our astrometric results for the GP-B experiment.

A New Deconvolution Method For Radio Interferometry, Rob Reid, University of Toronto

A new method is presented for producing images from interferometric data with both phases and amplitudes. The method, "smear fitting", models the source as a set of elliptical Gaussians and then broadens them to account for uncertainty in their shapes and locations. This produces much sharper resolution for high signal to noise components than CLEAN, and does not require re-weighting of the data. Although only Gaussians have been used for modeling to date, smear fitting could be extended to use other functions as components, and will be extended to multi-frequency, multi-polarization, simultaneous fitting soon. Sample images will be shown, with a brief comparison to CLEAN and maximum entropy.

The International Liquid Mirror Telescope Survey, Nathalie Robitaille, Université Laval, E. F. Borra, COPL–Laval, and J. Surdej, Institut d'astrophysique de Liège

The ILMT is a 4-m LMT, presently under construction, that will be located in Chile. It will observe the same strip of sky night after night with wide-band filters, reaching a nightly limiting magnitude of about 24. Co-adding 4 years of data will reach 27th magnitude and access 150 square degrees of sky. Variable objects (AGNs, Supernovae), gravitational lens research, astrometric studies (solar system and galactic neighborhood), extragalactic studies, are among the main science drivers. As an example of the power of the survey, let us consider the Type Ia supernova search: we expect to find, and obtain, light curves for several thousands of Type Ia supernovae per year to $z = 1$.

Multi-Wavelength Studies of Possible High-Mass Star Formation in G79.3+0.3, Russell O. Redman, P. A. Feldman, and S. Côte, NRC/Herzberg Institute of Astrophysics, F. Wyrowski, University of Maryland, C. R. Kerton, NRC/Herzberg Institute of Astrophysics, D. D. Balam, University of Victoria, and S. J. Carey, Boston College

Observations at a variety of wavelengths, from visible through to 21 centimetre continuum, are combined in a preliminary analysis of the relationships among the young stars, gas and dust in the MSX Infrared-Dark Cloud (IRDC) G79.3+0.3. Near the bright SCUBA source G79.3+0.3 P1, observations at 10.7 μm with OSCIR on Gemini North and at 3 mm with BIMA suggest that a small cluster of stars may be in formation. Observations are also presented of an apparent ring of warm dust and gas surrounding the H II region G79.307+0.277.

Photometry of Faint Objects in the Kepler Field of View, Christopher Ryan and J. J. Caldwell, York University

A photometric investigation of HST wide-field images has been completed in support of a proposed NASA mission called Kepler. This Discovery-class mission will conduct a photometric survey of 100,000 nearby main sequence stars in search of transits by Earth-size planets with relatively short orbital radii. If such planets are common, and assuming that planetary orbital axes are oriented randomly, it is expected that Kepler will detect approximately 175 terrestrial planets throughout its four-year lifetime. It is possible that an unresolved optical double at the detection limit of the telescope could imitate a transit event. At York University, we have completed reductions of HST pure parallel WFPC2 data from the STScI archive in an effort to determine the statistical importance of this problem. Preliminary indications suggest that Kepler could significantly reduce the potential for mis-identification by moving its field of view, from one centered on a galactic latitude of five degrees, to one centred on approximately ten degrees.

Crowded Field Photometry with Small Telescopes, Jason Rowe, University of British Columbia

Small telescopes equipped with CCDs can be used to search for variables in the crowded cores of globular clusters. With the advancement of image subtraction, a method that allows two CCD frames to be subtracted, it is possible to monitor variability that would otherwise

be hard to detect. The image subtraction technique has been applied to *V* band frames of the globular cluster M13 which were obtained in an urban location. Eight new variables have been discovered for which I present light curves and periods.

Hydrodynamical Simulations of the Sunyaev-Zel'dovich Effect, Marcelo Ruetalo, University of Toronto, J. R. Bond, CITA, and J. Wadsley, McMaster University

The Sunyaev-Zel'dovich (SZ) effect, which allows the detection of the hot gas component of the large-scale structure of the Universe as intensity perturbations on the CMB, will very likely become the most important probe of hot intra-cluster gas in the near future. In recent years, simulated SZ maps have been generated from hydrodynamical simulations of cosmic structure formation in order to make theoretical predictions of the observability of the effect, but the results are far from conclusive. We have performed high resolution simulations, generated simulated maps and are currently working on making a more thorough analysis of them.

Orbits of Two Eccentric Giants, C.D. Scarfe, University of Victoria

New orbits have been derived from DAO Coudé scanner velocities for the eccentric binaries 6 Persei and HR 8078. For 6 Persei the new orbit supersedes that of Christie (ApJ, 83, 433). The period is 1576 days and the eccentricity is 0.882. This result, and an argument of periastron of 267 degrees, causes most of the steep rise in velocity to be covered in only two weeks. The binary nature of HR 8078 has hitherto escaped detection, presumably because its eccentricity of 0.748, coupled with an argument of periastron of 195 degrees, causes its radial velocity variation to occur almost entirely in a single year of its 2682-day period. The remaining elements for 6 Persei are T = JD 2448731, K = 19.9 km s^{-1} and γ = 25.9 km s^{-1}. Those for HR 8078 are T = JD 2447533, K = 8.7 km s^{-1} and γ = –20.3 km s^{-1}. The mass functions are 0.133 solar masses for 6 Persei and 0.054 solar masses for HR 8078.

The Super-Eddington Branch of the Core Mass (Envelope Mass) Luminosity Relation, Nir Shaviv, CITA

Recent developments in the understanding of luminous systems have shown that as atmospheres approach the Eddington limit, they become porous and allow a larger flux, though without impeding as much force. Consequently, steady-state super-Eddington luminosities are possible, with the generation of only a "modest" wind. The various additional components are tied together in a stellar structure code. We find a super-Eddington branch in the Core Mass Luminosity relation. Unlike the sub-Eddington branch, its luminosity depends on envelope mass as well. The behaviour of classical novae, which are super-Eddington objects, is nicely described by the theory.

The r-modes of Rotating Fluids, Yousef Sobouti and V. Rezania, IASBS

An analysis of the toroidal modes of rotating fluid, by means of the differential equations of motion, is not readily tractable. A matrix representation of the equations in a suitable basis, however, simplifies the problem considerably and reveals many of their intricacies. Let Ω be the angular velocity of the star and (ℓ, m) be the two integers that specify a spherical harmonic function. One readily finds the following: 1) Because of the axial symmetry of equations of motion, all modes, including the toroidal ones, are designated by a definite azimuthal number m. 2) The analysis of equations of motion in Ω^2 order shows that Coriolis forces turn the neutral toroidal motions of (ℓ, m) designation of the non-rotating fluid into a sequence of oscillatory modes with frequencies $2m\Omega/\ell(\ell+1)$. This much is common knowledge. One can say more, however: a) under the Coriolis forces, the eigendisplacement vectors remain purely toroidal and carry the identification (ℓ, m). They remain decoupled from other toroidal or poloidal motions belonging to different ℓ's. b) the eigenfrequencies quoted above are still degenerate, for they carry no reference to a radial wave number. As a result the eigendisplacement vectors, as far as their radial dependencies go, remain indeterminate. 3) the analysis of equation of motion in Ω^4 order reveals that the forces arising from asphericity of the fluid and the square of the Coriolis terms (in some sense) remove the radial degeneracy. The eigenfrequencies now carry three identifications (s, ℓ, m), say, of which s is a radial eigennumber. The eigendisplacement vectors become well determined. They remain zero order and purely toroidal motions with a single (ℓ, m) designation. 4) two toroidal modes belonging to ℓ and $\ell \pm 2$ get coupled only at Ω^2 order. 5) a toroidal and a poloidal modes belonging to ℓ and $\ell \pm 1$, respectively, get coupled but again at Ω^2 order. Mass and mass-current multipole moments of the modes that are responsible for the gravitational radiation, and bulk and shear viscosities that tend to damp the modes, are worked out in much detail.

GSH 138-01-94: An Old Supernova Remnant in the Far Outer Galaxy, Jeroen Stil and J. A. Irwin, Queen's University

The properties of the H I shell GSH 138-01-94, discovered in the Canadian Galactic Plane Survey are discussed. It is a rare example of a nearly intact circular shell with both the near and the far sides visible. The radius (37.3 ± 2.2 arcminutes), expansion velocity (11.8 ± 0.9 km s^{-1}), central velocity (–94.2 ± 0.5 km s^{-1}), and the centre, were determined from a fit to the observed line of sight velocity distribution across the area of the shell. The most important aspect of GSH 138-01-94 is its location, 24 kpc from the Galactic centre, in the far outer galaxy. The large distance implies a radius of 180 pc and expansion age of 4.3 million years. The properties of GSH 138-01-94 are consistent with the remnant of a single supernova explosion that occurred more than 4 million years ago. It is significantly older and larger than old supernova remnants in the solar neighbourhood. This is interpreted as an environmental effect. Supernova remnants can expand to larger size in a low density, low metallicity, environment. Also, the low frequency of supernovae in the far outer galaxy makes it improbable that adjacent supernova shells collide and loose their identity. GSH 138-01-94 may be representative of very old supernova remnants that may exist mainly in an environment different from the solar neighbourhood, such as low-surface-brightness galaxies, dwarf galaxies, and the outskirts of most spiral galaxies. Finding a large expanding shell such as GSH 138-01-94 in an unexpected location is the merit of a high resolution survey like the CGPS.

Investigating the Local Phase-Space Density of Dark Matter, David Stiff and L.M. Widrow, Queen's University, and J. Frieman, Fermilab

In the cold dark matter model of structure formation, galaxies are

assembled hierarchically from mergers and the accretion of sub-clumps. This process is expected to leave residual phase-space substructure in the Galaxy's dark halo, including partially disrupted clumps and their associated tidal debris. The presence of any remaining substructure would have many implications for dark matter (WIMP and axion) detection experiments. However, traditional numerical simulations currently do not have the resolution required to thoroughly study this issue. We develop alternative methods for probing this residual substructure and studying its effects on dark matter detection experiments. Results indicate that there is a high probability of a low density, kinematically cold stream passing through the solar neighbourhood today. Such streams introduce significant artifacts into the dark matter detection spectra and must be considered when analyzing detection results.

Survey Science with the Canadian Large Adaptive Reflector, A. Russell Taylor, University of Calgary, P. E. Dewdney and S. Côté, NRC/Herzberg Institute of Astrophysics, C. Carignan, Université de Montréal, and N. Bartel, York University

As part of the technology development for the Square Kilometre Array, Canadian engineers and scientists are developing a prototype radio telescope, the Canadian Large Adaptive Reflector (CLAR). The CLAR concept allows for the construction of radio telescopes with very large aperture, while at the same time the long focal length of the reflector and the implementation of phased-array receivers at the prime focus provide a large instantaneous imaging area on the sky. As part of the Canadian Long Range Plan for Astronomy, Canada will work toward construction of a prototype CLAR around the middle of this decade. The strawman design for the CLAR prototype is a 300-metre aperture working up to frequencies of 1.4 GHz, equipped with a multi-beam phased array providing a field-of-view of 0.8° at that frequency. The CLAR prototype will be the largest fully-steerable radio telescope in the world. This combined with the large field-of-view will make it an unprecedented powerful instrument for deep spectral imaging over large areas of the sky. Until construction of the SKA itself, the CLAR will provide our most sensitive view of the radio Universe. We are developing a plan to operate the CLAR prototype as an all-sky survey telescope. By equipping the CLAR simultaneously with several back-end instruments, an all-sky survey taking three or four years will: 1) chart the large scale distribution of galaxies in atomic hydrogen out to redshift close to 1 (complementing and extending the Sloan Survey at optical wavelengths), 2) reveal the structure and dynamics of the cosmic web responsible for wide-spread Lyman α absorption systems, 3) map the atomic hydrogen gas and synchrotron radiation in the Galactic halo at arcminute scales — not only charting the structure of the Galaxy and the Local Group, but providing critical foreground images for deconvolution of spacecraft data aimed at mapping the small scale structure of the Cosmic Microwave Background, and 4) detect several thousand new pulsars and explore their physics through sensitive timing analysis. We present initial ideas relating to the implementation of these surveys.

Spectral Line Contamination of SCUBA sources at 850 microns, Nick Tothill, Saint Mary's University, D. Johnstone, University of Toronto, George F. Mitchell, Saint Mary's University, and D. Naylor, University of Lethbridge

Sub-millimetre continuum imaging is an important tool in the study of the interstellar medium. However, the continuum filter passbands include numerous spectral lines; the flux of these lines is included in the measurement of the broadband flux, and may be misinterpreted as continuum flux. We have carried out a targetted spectral line survey of several sub-millimetre continuum sources in Orion B in order to assess the importance of this effect. We estimate that 10% to 20% of the continuum flux at 850 microns is actually due to molecular transitions. There are no reliable data for the 450 micron window, but it seems likely that the spectral line contamination will be significantly less. This degree of contamination does not pose serious problems for the estimation of dust mass from continuum flux, since the likely error is similar to the calibration uncertainty. However, the difference in the level of contamination between 450 and 850 micron passbands is likely to lead to errors in the derived spectral index. The spectral index is used to derive information about the dust composition (via the wavelength-dependence of the dust emissivity) and sometimes the temperature. It is therefore important to understand the effects of spectral line contamination on this quantity, in order to interpret the results of the latest large-area SCUBA surveys of molecular clouds.

A New Mapping of the Cepheid Instability Strip, David G. Turner, Saint Mary's University

Results are presented from new work on the interstellar reddening of classical Cepheid variables in our Galaxy. The analysis is based upon a database of carefully derived field reddenings for a subset of stars (including members of open clusters and associations), as well as photometric reddenings obtained from reddening-independent systems. When other photometric reddenings for Cepheids are tied to the new system in conjunction with the photometric data base of Cepheid photometry of Berdnikov, the data provide a detailed mapping of the Cepheid instability strip that yields new insights into its features.

Magnetics and Energetics of a Dark Bok Globule, Jacques P. Vallée, NRC/Herzberg Institute of Astrophysics, J. S. Greaves, JAC and ROE, and J. D. Fiege, CITA

A polarized ring of high linear polarization values (5 to 11 percent) encircles the central peak of thermal dust emission of a Class 0 young stellar object, Bok globule CB068, as observed with the JCMT at 850 microns with 14-arcsec angular resolution. The polarized ring is broken at two places, towards the axis of the narrow CO bipolar outflow. On this scale of 0.01 to 0.1 pc, turbulence appears to be weaker than magnetism and seems to decay due to (i) a radial gas density gradient and (ii) an aligned magnetic field that favours the travel of magnetic waves in or out of the clump.

The Improved Grain Model in Cloudy, Peter van Hoof, P. G. Martin, and J. C. Weingartner, CITA, K. Volk, University of Calgary, and G. J. Ferland, University of Kentucky

The first grain model was introduced to *Cloudy* in 1990 to facilitate more accurate modeling of the Orion nebula (for a detailed description see Baldwin *et al.* 1991, ApJ, 374, 580). In subsequent years, this model has undergone some minor revisions but remained largely the same. Recently, our knowledge of grains has been greatly advanced by the results from the ISO mission. In view of these rapid developments we

have undertaken a comprehensive upgrade of the grain model in *Cloudy*. The two main aims were to make the code more versatile and to make the modeling results more realistic. The new features of the grain model (built-in Mie code, resolved size distributions, improved treatment of quantum heating) will be discussed and comparisons with the old grain model will be given. We will show that the new grain model can give significantly better modelling results. We have also undertaken an upgrade of the grain physics and will present comparisons for the photo-electric heating rates and collisional cooling rates of the gas with detailed calculations by Weingartner & Draine (ApJS, in press). We find that the two models are in excellent agreement.

Entropy in Galaxy Clusters, James Wadsley, McMaster University, F. Governato, Milan, S. Ghigna, University of Washington, J. Stadel, University of Victoria, T. Quinn, University of Washington, and H. Couchman, McMaster University

The galaxy cluster X-ray Luminosity–Temperature relation does not extend simply into the group regime. One explanation is that widespread heating from galactic winds has effectively set a minimum entropy. We present results investigating the effectiveness of this mechanism as part of ongoing numerical studies of the evolution of hot gas in galaxy clusters.

Electron-Ion Recombination on Grains and Polycyclic Aromatic Hydrocarbons, Joseph Weingartner, CITA, and B. T. Draine, Princeton

With the high-resolution spectroscopy now available in the optical and satellite UV, it is possible to determine the neutral/ionized column density ratios for several different elements in a single cloud. Assuming ionization equilibrium for each element, one can make several independent determinations of the electron density. Of the clouds for which such an analysis has been carried out, these different estimates disagree by large factors, suggesting that some process (or processes), besides photo-ionization and radiative recombination, might play an important role in the ionization balance. One candidate process is collision of ions with dust grains. Making use of recent work quantifying the abundances of polycyclic aromatic hydrocarbon molecules and other grains in the interstellar medium, as well as recent models for grain charging, we estimate the grain-assisted ion recombination rates for several astrophysically important elements. We find that these rates are comparable to the rates for radiative recombination for conditions typical of the cold neutral medium. Including grain-assisted ion recombination in the ionization equilibrium analysis leads to increased consistency in the various electron density estimates for the clouds along the lines of sight to 23 Orionis and HD 215733. However, not all of the discrepancies can be eliminated in this way; we speculate on some other processes that might help.

A Survey of Earth's L4 Lagrange Point: Initial Results, Paul Wiegert, York University, C. Veillet, CFHT, M. Conners, Athabasca, K. Innanen, York University, and S. Mikkola, Turku

A survey of the region surrounding the Earth's L_4 Lagrange point was conducted using the Canada-France-Hawaii Telescope and the new CFH12K wide-field CCD imager, in the hopes of finding asteroids at or near this point. An optimized search technique was used, involving tracking at the anticipated rate of the target bodies, near real-time scanning of images, and duplication of fields to aid in detection. Roughly nine square degrees of sky were searched and two Earth-crossing asteroids were found, 2000 PM8 and 2000 PO30, which pass in the vicinity of the L_4 point but are not themselves Lagrange point asteroids. The second object was detected easily at an R magnitude of 22, suggesting our technique works well. Our survey supports the earlier conclusion by Whitely & Tholen (1998) that a large population of such asteroids does not exist, though a comparison with theory (Wiegert *et al.* 2000) suggests that we can still only place an upper limit of 50–120 objects at the L_4 point owing to its large apparent size on the sky.

Saturation of Pulsation Amplitudes Across the H-R Diagram, Yanqin Wu, CITA, and P. Goldreich, Caltech

What drives pulsation? What limits the amplitudes of pulsation in a star? These are the two fundamental theoretical questions one could ask about any type of pulsating star. Recently, we have made some progress towards answering the second question. We found some simple scaling relations that discriminate between stars with large pulsation amplitudes (RR Lyraes, Cepheids, Miras, *etc.*) and those without (white dwarfs, sdB stars, some δ Scuti stars). One may apply this understanding to predict amplitude behaviour in stars that are believed to undergo pulsational instability, but not yet discovered; or to search for pulsation across the H-R diagram, targetting stars with potentially large amplitudes.

Searching for Missing Baryons by Sunyaev Zel'dovich Effect, Pengjie Zhang, University of Toronto, and Ue-Li Pen, CITA

CMB experiments and Big Bang Nucleosynthesis predict that baryonic matter accounts for about 5% of the total matter in the universe. Less than 10% of this baryonic matter is in easily detected stars and the Inter-stellar Medium. The majority remains undetected and is believed to be in a diffuse form — the Intergalactic Medium (IGM). It is believed free electrons in the IGM scatter off CMB photons and change the temperature of the CMB sky. This is called the Sunyaev-Zel'dovich (SZ) effect. We will show how to probe for those missing baryons using this effect and how powerful it is.

Society News/Nouvelles de la société

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

National Office

If anyone has any questions or problems with their membership or about the RASC generally, please do not hesitate to contact either Bonnie or Isaac (888-924-7272 or rasc@rasc.ca). They will be glad to assist you. Along with all the other duties at National Office, which are moving along smoothly, they now look after a Japanese meditation garden located out front. Bonnie and Isaac are working only 4 days a week for the summer months.

Membership Renewals

The majority of membership renewals are coming up in September, so when you receive your first renewal notice, it would be a great jump on the year to send it in. This not only saves on further renewal notices and postage, but when you pay right away, you can be guaranteed that both the *Journal* and *SkyNews* will be delivered uninterrupted. You can also renew your membership on-line at www.store.rasc.ca

Congratulations To....

In March, we had several recipients of awards, for which these members should be very proud. It gives the rest of us the encouragement to achieve the same goal. Joyce Carley, Robert R. Chapman, and Dave Halliday of the Toronto Centre and Michael Hanes of the London Centre received their Messier Certificates. Paul Markov of the Toronto Centre received his NGC Certificate. (Passed under motions 20010104/20010105) Remember, in order to receive these certificates, you must fulfill the viewing requirements, send a copy of your logbook to National Office or have your logbook reviewed by two witnesses, complete the designated form and send it off to the National Office. See your centre's observing chair for more information or contact the National Office.

Passing Friends...

Over the past year we have lost many fellow astronomers and friends. Our sympathies and thoughts go out to all family members and friends of those who have passed on.

RASC Deceased Members July, 2000–June 30, 2001

Harold Charlesworth (Victoria), George Glass (Ottawa), Dr. Charles Maunsell (Victoria), Dr. C. Muses (Unattached), H. K. Nelson (Okanagan), Mr. Forston & R. Shandler (Victoria), C. M. Simmons (Unattached), Gordon Taylor (Kingston), Dr. Hendrik & C. Van de Hulst (Honorary Members), Dr. Irwin Vanderhoof (Kingston), Robert H. Bulbrook (Ottawa), Al Furlong (Hamilton), Bryce Heartwell (Edmonton), Dr. F. Shirley Jones (Toronto), John Knechtel (Toronto), David V. Lewin (Toronto), Ronald Rodgers (Ottawa), Frederic P. Scholer (Toronto), Kevin J. Whalley (Sarnia), Arthur Covington (Kingston), Sid Lee (Calgary), Charles W. Manion (Kingston), Dr. Donald K. Norris (Calgary), Antony Overton (Vancouver), Ron Pow (Kingston), Jacques Richard (Moncton), and Georges Seguin (Toronto).

On May 26, 2001, I attended the Memorial Service for Arthur Edwin Covington at the Kingston Unitarian Fellowship. Arthur was born September 21, 1913 and died March 17, 2001. He is survived by his wife, Charlotte, children (Nancy, Eric, Alan and Janet), and 5 grandchildren. It was very nice to be able to share and learn of the personal side and the science side of Arthur. As the first Solar Radio Astronomer in Canada, he had a very full life of science and radio astronomy in Penticton, BC, and Ottawa, Ontario. Some of his colleagues from the NRC (Victor Gaizauskas, Norman Broten, and John Galt) were present to give us their memories of this great man. It was a true honour to know him.

A display is set up at the Queen's library of the Riche-Covington Collection (documents and books in the telecommunications and astronomical sciences from World War II.) Though only some articles are on display, most of the rest of the collection is located in the depths of the building. Many other pieces of Arthur's collection are on display throughout the library.

CALLISTO'S CALYPSO

by Bruce McCurdy (bmccurdy@freenet.edmonton.ab.ca)

On September 27, 2001, residents of Canada will be ideally situated to observe a rare partial eclipse of a satellite of another planet.

Observing Log 1998/09/16-17: "Callisto — Started to look at eclipse event just before its scheduled 22:31 MDT disappearance. Callisto was faint but obvious just W. of Jupiter's N. pole. It remained visible for many minutes after 10:31. Presumably due to its shallow angle against Jupiter's limb, the entire event should last much longer than one occurring near the equator! Noted the same thing upon reappearance. Got scope set up just before 00:57 reappearance, but Callisto was already easy and obvious. Nonetheless, it kept brightening for many more minutes, not reaching its full brightness until at least 20 minutes after predicted midpoint. I would have liked to have started looking for this earlier, but something came up. Still, what I saw was consistent with earlier observation, and with theory."

I love observing the perpetual tango of the Galilean moons, in large part because there *is* such a close connection between theory and observation. There are four moons, one giant planet, one light source, and one observing station (Earth). With a little applied thought one can calculate what will logically happen in four-dimensional space-time and watch it unfold with the grace and precision of a square dance.

Jupiter and its four bright companions are often compared to a miniature inner solar system, with Ganymede taking the role of Earth and one year compressed into one week. However, Jupiter rules the roost with an iron — or at least metallic hydrogen — grip, its immense gravitational well locking its four major moons into nearly perfectly circular, equatorial orbits, and the three inner ones into a 4:2:1 resonance. Due to their proximity to the giant planet, these three are engaged in an endless sequence of mutual phenomena where the satellites alternately pass in front of and behind the giant planet on each orbit. An introduction to these phenomena appears on Page 182 of the *Observer's Handbook 2001*, followed by predictions for this year's events (Gupta 2000). Serious observers, such as members of the Jupiter section of the Association of Lunar and Planetary Observers (ALPO), time these events, taking particular interest in eclipses, where the moons disappear into Jupiter's shadow.

Although tiny compared to their master planet, the Galilean moons have finite discs. These mutual phenomena are therefore not instantaneous, like occultations of stars, but take a few minutes. The listed predictions in the *Handbook* are for the midpoint of each event.

I was treated to an object lesson of the relative speed of these events on January 20, 2000, the night of a total lunar eclipse. During the full hour it took for our own satellite to gradually pass into Earth's shadow at its leisurely speed of about 1 km s^{-1}, as luck had it there were a pair of complementary events around Jupiter, as first Io, then Europa emerged from the giant's shadow. Although each is Moon-sized, it took only five or six minutes from the pinprick of first visibility to full illumination, thanks to Io's orbital velocity of 17.3 km s^{-1} and Europa's of 13.4.

Unlike the three inner moons whose passages of Jupiter occur like clockwork on every orbit, events involving Callisto are more rare. This shy, distant, and slightly independent member of the quartet has to be coaxed back onto the dance floor every few years.

Callisto is by far the furthest of the big four at 1,885,000 km from the King of Planets. Even though that is five times the Moon's distance from Earth, it zips around Jupiter in only 16.689 days at the vigorous rate of 8.2 km s^{-1}. But that's the slow lane compared to the inner moons. Also, at some 4,800 km in diameter, it's one of the biggest satellites in the solar system. As a result, mutual events involving Callisto, such as its eclipse by Jupiter described in my observing log above, should naturally take a little longer than those of the inner moons.

But this particular event unfolded extraordinarily slowly, long enough for even me to form a coherent thought. As my notes suggest, I postulated the major retardant was the extremely shallow angle at which Callisto was cutting through Jupiter's shadow. Since this was the night of opposition, one could readily see how Callisto would be virtually grazing Jupiter's north pole, unfortunately during mid-eclipse. The Jovian system has a relatively slight but very detectable inclination of 3.1°. Due to its greater distance, Callisto is the one moon which will appear to pass by and "miss" Jupiter when the tilt of the system is opened up to anything over about 2° (Seidelmann 1992). Accordingly,

Callisto undergoes a series of eclipses, each lasting around three years centred on the Jovian equinoxes. Near the solstices, no eclipses occur for a similar period of about three years. The following is derived from a table called "Eclipse Series of Callisto" (Meeus 1995):

Date of the first eclipse of the series	*Number of eclipses in the series*	*Direction*	*Date of the last eclipse in the series*
1978 Jan 26	65	N-S	1981 Jan 2
1984 May 9	60	S-N	1987 Jan 22
1989 Nov 26	65	N-S	1992 Nov 2
1996 Mar 9	60	S-N	1998 Nov 23
2001 Sep 27	66	N-S	2004 Sep 20
2008 Jan 9	60	S-N	2010 Sep 23

One can immediately detect a pattern of roughly three years on, three years off, one south-to-north series and one north-to-south every 11.86-year Jovian orbit. The difference in series lengths is due to the fact that Jupiter is on average closer to perihelion during a south-to-north series, and therefore sweeps through the arc of possible eclipses at a faster orbital speed.

In the fall of 1998 we were approaching the end of a series, so I reasoned the oblique angle that Callisto was passing through Jupiter's polar shadow would become even more extreme. Furthermore, I concluded that since Callisto is a disc, not a point, that the big moon should undergo a series — I guessed two or three — of increasingly shallow *partial* eclipses as it gradually emerged from the shadow zone. (This is analogous to a Saros cycle, which always begins and ends with a series of partial solar eclipses visible from the polar regions of Earth.)

To visualize the geometry, move your telescope next door to Saturn, whose rings reflect entire orbital paths. Saturn's ring system is much more compact than that of Jupiter's moons, but compensates with a much greater tilt. Imagine Io circling in the position of the crepe ring, shifting back and forth across the equator but never straying too far from it. Callisto's orbit, meanwhile, is analogous to the very outside edge of the A ring. Look at the very oblique angle this outer edge of the back ring currently makes with Saturn's south pole. That's what's happening with Callisto at the moment.

With a synodic period of about 16.75 days, every fourth eclipse of Callisto occurs at approximately the same local time. As luck had it, a series of four eclipses after September 17 was the final event involving Callisto that was predicted in the *Observer's Handbook*, namely that of November 23, 1998. The intervals between disappearance and reappearance had quickly shortened from a predicted 146 minutes for the September 17 eclipse, to 130, to 111, to 88, to 56 for the November 23 event, to none at all after that. In that 67-day interval since my first observation, Jupiter had moved from opposition to quadrature, but was still ideally placed in the late evening sky with Callisto now its furthest removed from Jupiter's glare. Furthermore, November 23 was my regular Sunday night volunteer shift at the Edmonton Space & Science Centre's Public Observatory where I could observe the event through a battery of excellent telescopes. Having thought through the geometry, I confidently predicted that despite the *Handbook's* tables, Callisto would remain at least faintly visible throughout its November 23 event; it would be a partial, rather than a total eclipse. And sure enough, logic won out yet again.

As Callisto faded very gradually, four chilled volunteers — Larry Wood, Sherrilyn Jahrig, Terry Samuel, and myself — repaired to a local doughnut shop for sustenance. Larry set up his 12.5-inch Newtonian just outside the door to allow us to take turns observing and avoid freezing. Despite extreme light trespass, Callisto remained visible throughout mid-event as a faint point, perhaps two or three magnitudes fainter than normal but most certainly there. Success!

Buoyed by this correct guess, I concluded that the first "non-eclipse" on Callisto's next pass behind the giant planet might also be a shallow partial, with Jupiter's shadow now certain to miss Callisto's equator but still likely to fall on a significant fraction of one hemisphere and cause an observable drop in brightness. The back of my mental envelope suggested it might dim by perhaps 0.5 or 0.8 magnitude centred around 00:57 UT on Dec. 10. I put out an APB on the RASCals Discussion List to observe Callisto around this time. For us in Edmonton this was early evening, but this time a temporary but observationally fatal "Murphy Cloud" foiled Larry and me. (My notes conclude: "Just when you think chaos and entropy might lose their icy grip for a moment, ambiguity comes through and rules the day. Grrr.")

Fortunately, observers from other RASC Centres from St. John's to Okanagan had risen to the task, and I received a number of reports. A few even trickled in from south of the border. Virtually all with a decent view of the event concluded that Callisto had faded noticeably at the prescribed time, although details varied. Once again, (limited) success!!

Of course, all this is nothing truly new. Like most of my "discoveries," this was yet another principle that had been understood for so long that it has long since been gathering cobwebs far outside of the popular literature. In this case, a list of *Galilean Satellite Eclipse Predictions* I subsequently obtained from John Westfall of ALPO commented:

> "The last Callisto eclipse of the present series will be on 1998 Nov. 23; although a partial eclipse may occur on Dec. 10, centred on 00:55m Dynamical Time." (Westfall ~1998)

One can experience great satisfaction on independently arriving at a correct conclusion, original or not, through simple logic and deduction. Furthermore, through the magic of the Internet, my blowing

the dust off an old concept caused a number of people to haul out their scopes for a look. The joint observation even got reported in *Sky & Telescope* (Seronik 1999).

Enough about 1998. In the fall of 2001 the next eclipse series will begin on Callisto, with each successive pass now going deeper into Jupiter's shadow. A simulation on *Guide 7.0* suggested a series of about four partial eclipses beginning with a virtual graze on August 8, followed by increasingly greater partials on August 24, September 10, September 27, and October 14, with the first to be a nearly undetectable slight fade — essentially, a penumbral eclipse — and the last featuring a slow, deep descent beyond the vanishing point of all but very large telescopes.

All of North America is favoured to observe what I feel will be the best partial event. This will occur in the wee hours of Thursday morning — hey, you can't win 'em all! — September 27. In agreement with Meeus' list in the table above, the *Handbook* lists this as the first official eclipse of Callisto, predicted to last 47 minutes centred around 07:00 UT. This event should roughly duplicate the one of November 23, 1998 that Larry and I observed so easily. Of course, the visibility of Callisto will depend to some extent on the aperture and quality of the observer's telescope.

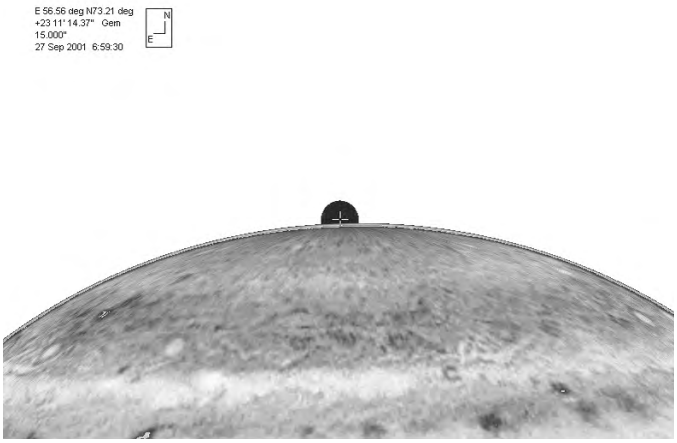


Figure 1 — The "total eclipse" of Callisto of September 27, 2001, as seen from a particularly hot vacation spot, the north pole of the Sun. That part of Callisto is visible from the vantage point of the light source proves that it cannot be entirely in Jupiter's umbral shadow. (All diagrams courtesy of Larry Wood and the author; use of *Guide 7.0* simulations courtesy of the kind permission of Bill Gray of Project Pluto.)

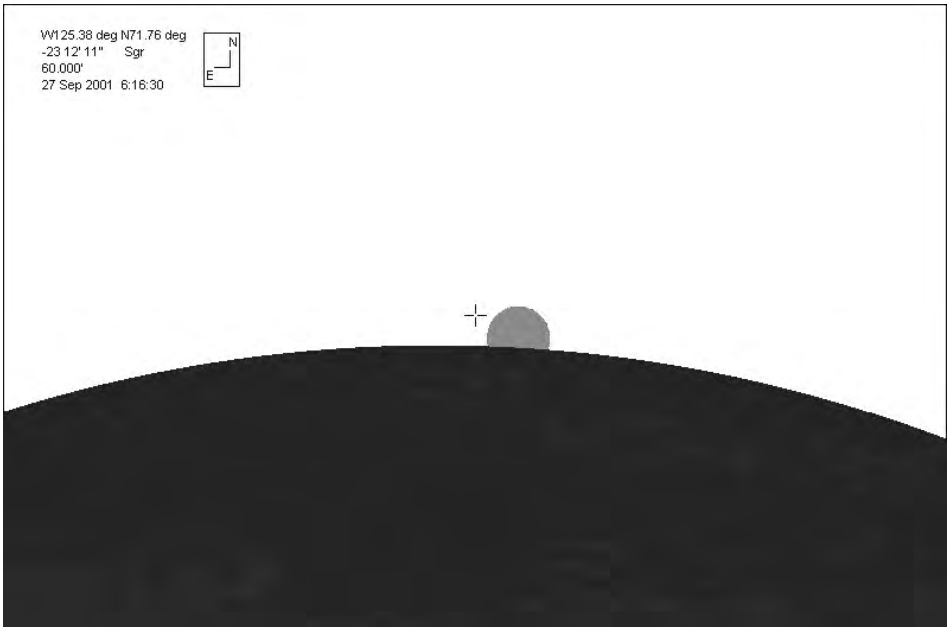


Figure 2 — The complementary view from frigid Callisto reveals a surprising symmetry. This is the view from 45° N. latitude at mid "eclipse." The background star forming a pimple on Jupiter's broad, black limb is commonly known as "The Sun," only six arcminutes wide compared to Jupiter's four degrees. Note that this image is at 6:17 UT, subtracting the 43 minutes of light time that this scene will require to reflect back to Earth.

The accompanying figures give an approximate rendering of what will be transpiring, through Bill Gray's outstanding *Guide 7.0* software program, as seen from the vantage points of the Sun, Callisto, and Earth, respectively. From our perspective (Figure 3), Callisto seems surprisingly far from Jupiter to fall into its shadow. Don't be fooled. If you are experiencing ideal observing conditions, try to spot an actual partial phase on Callisto's disk. I recently observed this effect on Ganymede when it appeared elongated in the correct orientation midway through a disappearance, although I suspect it would likely be much more difficult on dusky Callisto, especially since Jupiter's penumbral shadow is particularly broad at that distance (at some 3,367 km, it's 70% the diameter of Callisto itself.)

Where and when should you look? David Lane's *Earth Centered Universe* program is ideal for such questions. It predicts that in my hometown of St. John's, Newfoundland, Jupiter will appear 45° above the ESE horizon at 4:30 a.m. NDT (accepting the rather unlikely assumption of neither rain, drizzle, nor fog.) With a tip of the hat to our newest Centres, in Charlottetown and Moncton it will be almost 40° above the E. horizon at 4:00 ADT; in Thunder Bay about 22° up at 3:00 EDT; in Regina 12° high at 1:00 MDT/CST; and in Kelowna and Prince George, a challenging 4° above the NE horizon at midnight PDT. For those Toronto Centre members who have no idea where any of those other places are, in Universe Central Jupiter will be at 28 degrees altitude at 3:00 EDT.

As a consolation prize, observers on the west coast should have a shot at the previous event, just before sunrise on Sep. 10 centred on 12:50 UT. This will be analogous to the partial eclipse of Dec. 9, 1998, with Callisto fading by a few

Figure 3 — The view from Edmonton, Alberta, shows the positions of the Galilean moons as seen through a standard Newtonian telescope at the beginning of Callisto's fade. The other moons can be used for brightness comparison purposes (Io = 5.4, Europa = 5.7, Ganymede = 5.0, Callisto = 6.0 when fully illuminated). In addition, a magnitude 6.9 mag star, SAO 78921, is located about 12 arcminutes to the WSW of Jupiter (beyond the upper left of this diagram, but easily within the telescopic field of view). During the course of the partial eclipse, Callisto should temporarily become dimmer than this star.

tenths of a magnitude at most.

Callisto eclipses throughout the upcoming apparition of Jupiter should continue to be very leisurely and interesting events, with those visible from parts of North America listed below. Remember to start watching many minutes before the predicted times, which are midpoints.

Date	Disappearance	Reappearance
2001 Nov 16	12:15 UT	14:18 UT
2001 Dec 3	06:12 UT	08:32 UT
2001 Dec 20	00:11 UT	02:45 UT*
2002 Feb 8	06:13 UT	09:22 UT
2002 Feb 25	00:16 UT	03:35 UT
2002 May 3	00:29 UT	04:21 UT

** Dec. 20 reappearance very close to Jupiter's limb*

Note how the lengths of the actual eclipses rapidly increase as Callisto progressively passes through lower latitudes of Ju-piter's shadow. As it does so, the amount of time it takes to fade or brighten should diminish as the angle of incidence becomes less oblique. When the Jovian system is edge-on in the spring of 2003, eclipses of Callisto will last close to five hours, the longest of any of the satellites.

I request the reader who takes the opportunity to observe one or more of these events to please send your own observing log to the writer at my e-mail address cited above. If possible, record the exact time that you observe the first or last vestige of light from Callisto, or if it remains visible throughout, the moment that it seemed the faintest.

References

Gupta, Rajiv (Editor), Observer's Handbook 2001, University of Toronto Press, 2000 pp.182-188

Meeus, Jean, Astronomical Tables of the Sun, Moon, & Planets, Second Edition, Willmann-Bell Inc., 1995, p.58

Seidelmann, P. Kenneth (Editor), Explanatory Supplement to the Astronomical Almanac, Revised Edition, United States Naval Observatory, 1992, pp. 348-349

Seronik, G, Callisto's Vanishing Act, Sky & Telescope, March 1999, p.116

Westfall, John E., Timing the Eclipses of Jupiter's Galilean Satellites, ALPO pamphlet (~1998).

Bruce McCurdy is a Past President of the Edmonton Centre and is a 15-year volunteer at the Edmonton Space & Science Centre's Public Observatory. He is very experienced in thinking in circles and on his good days can make the jump to ellipses.

The Closest I Will Ever Get To The Moon

by Daniel LeBlanc, Moncton Centre (leblrous@nbnet.nb.ca)

I am sure I share the following childhood memory with many of my fellow astronomers who, like me, spent countless hours under the big nighttime sky exploring new worlds, wondering, or just imagining what could be — dreaming the incredible dream.

As a young boy in the mid-60s, I can still remember spending cold evenings in my parents' driveway looking through Dad's Tasco refracting telescope and hoping to see something "cool" like an alien in a fast moving spaceship waving as he went past. My hopes of seeing such things never became real.

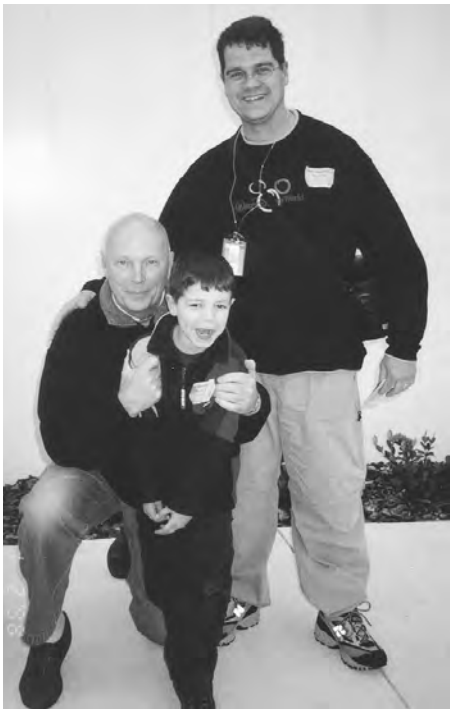
My interest in astronomy, at that time in my life, was not what you would call intense. I was only a 6-year-old kid and a child's imagination, at that age, is constantly nurtured by daily experiences that go beyond the end of the universe. Everything you do you experience on the most amazing spaceship of all — your imagination, something many of us lose later in life when we "grow up".

I remember one very late night, back in 1969, when my Dad woke my sister, brother, and me to watch the "Moon Shot" on our old Zenith black-and-white TV. This was the same TV where I spent countless hours watching Batman and Robin save the free world from the evils of the criminal underworld. As my brother and sister adjusted to all the excitement, they were not impressed and shortly returned to their beds to count all those friendly sheep they had missed. I asked myself what could be so interesting on TV that night for my parents to wake me from a deep sleep. Then I saw a spaceman climb from the shadowy spider-looking machine and hop effortlessly to the ground on a place I learned was the Moon. The same Moon that often lit up our backyard on those hot summer nights when my friends and I camped outside in our orange three-man tent until the Bogeyman of the night chased us back to our houses. From that day on, the Moon, the stars, and the great heavens above were never quite the same for me.

The years went by, my interest changed to sports, the Moon was no longer in NASA's sights and, of course, I discovered girls. I married later and was blessed with two sons who are now six and eight years old.

In January of last year, my wife and I started planning a dream vacation to Disney World in Orlando, Florida — a dream we had both shared since childhood. Now that our boys were old enough to enjoy the trip, we booked our vacation for Christmas, which of course, for my sake, included a day at the Kennedy Space Center. As we were getting ready for our departure, my wife asked me if I was looking forward more to Disney World or the Kennedy Space Center. Although I was excited about going to Disney World, it was the Kennedy Space Center that was my real dream.

We left for Florida on December 16th and spend five days in Disney World, visiting the Magic Kingdom, Animal Kingdom, EPCOT Center, and Disney Studios. Our stay on land was followed by a three-day cruise on the *Disney Wonder.* This was certainly a memorable vacation and a great experience. Then, in the wee hours of December 24th, the cruise ship docked at Port Canaveral, very close to our next destination, the Kennedy Space Center. After our arrival at Cape Canaveral, we picked up a rental car. As I was looking over the vehicle's instrument panel and familiarizing myself with the controls, I asked the co-pilot (my wife) for our next planned destination. She replied with a smile "the Kennedy Space Center." For me, the two-week voyage was now only beginning. As I pulled out of the parking lot, like all great astronauts before me, flying in their spacecraft for the first time, I asked my navigator the big question "Left or right?" and then the voyage began.



The author and his son with astronaut Story Musgrave

It was 8:30 AM. I was now entering the gateway to the universe, the home of NASA's space shuttle fleet. In fact, like all pioneers before me making their first voyage, first landing, or first space walk, I too was first — the first one that day in NASA's parking lot, a little embarrassing for the family. After spending an incredibly long time getting through the gate, we purchased the special pass for a tour of NASA's restricted areas. The special tour, called *Then and Now*, took us by bus to many restricted areas such as historic launch sites of the Mercury, Gemini and Apollo eras and then on to those used by the current space shuttle program. As we started our fascinating tour in an air-conditioned bus, the tour guide gave us

lots of information and handouts and we stopped at many sites. We even got the chance to see a mighty Saturn V rocket like the one that took Neil Armstrong, Edwin Aldrin, and Michael Collins from the Earth to the Moon. The entire tour lasted three hours and I would not recommend it for small children (not to mention my dear wife who, only twenty minutes into the tour, was sleeping in an upright position.) As our bus came to the end of what I deemed an incredible voyage, we continued our adventure towards the Kennedy Space Center Visitor's Complex, where we enjoyed numerous sights, including the two IMAX theatres. My kids enjoyed the space store the most. It is the largest of its kind in the United States and I purchased a few collectible items to add to my basement shrine.

Close to the end of the day, my wife noticed a man leaving one of the buildings at the Visitor's Complex and she said, "Isn't that the actor in the movie 'Mission to Mars'?" I looked on with complete amazement; it was not just an actor but a real-life astronaut. I immediately positioned myself to make sure he could not get away. I said "Sir, can I please speak to you for just one moment?" Courteously, he stopped and I told him that I had followed many of his flights into space including the rescue mission that he had commanded in 1993 to save the *Hubble Space Telescope*. He had been in space more often than any other astronaut to date, but with all the excitement, I could not even remember his name. When, he asked me where I was from , I responded by giving him the last place I was when leaving Canada, and said "Montreal". After regaining my composure, I replied that I was from Moncton and he said that he knew Moncton. I responded, "You've been to Moncton?" and he said, "Sure, one day I flew over it a dozen times". This was a joke on his part, of course.

I asked him if we could get a picture together and he was happy to do so, kneeling down to pose for a picture with my younger son and me, which came out very nicely. Afterwards, I thanked him and said goodbye. It was certainly the highlight of my day and even of my trip. Still not remembering his name, I immediately rushed to the space store looking for something, anything, with his identity in hopes of clarifying my lost memory. Then it all came flying back; he was Story Musgrave, America's best known current spaceman.

Yes, this long awaited voyage was, no doubt, a dream come true and probably the closest I will ever come to the Moon. The Kennedy Space Center in Florida is a must to see for any space enthusiast. I am sure you will get a real blast out of it — I did and I am still trying to land!

Daniel LeBlanc is a native of Moncton, New Brunswick and an amateur astronomer. Daniel is the Vice President of the Moncton Centre and president of the Moncton Beauséjour Astronomy Club.

The "Markov 1" Asterism in Hercules

by Paul Markov (pmarkov@ica.net)

Reading "The Mackie 1 Asterism" article in the April issue of the *Journal* (JRASC, 95, 77) renewed my interest in an observation I had made on July 4, 2000. On that night I was star hopping to the Dolidze-Dzimselejsvili ("DoDz" hereafter) open clusters in Hercules and while on my way to DoDz 9, I passed by the star Xi Herculis (also known as 92 Herculis). Just north of this third magnitude star, I noticed a small grouping of stars that stood out quite well in a shape very similar to that of the "teapot" asterism of Sagittarius. Since it was not labelled as a cluster in any of my star charts, I moved on to the much less impressive DoDz open clusters and promptly forgot about it.

After reading Guy Mackie's article I thought I should revisit this star grouping and see if anyone knew more about it. I too contacted Dr. Brent Archinal (formerly of the U.S. Naval Observatory), an expert on open star clusters. Dr. Archinal confirmed that this grouping did not have a designation in any of his atlases or catalogues. He suggested I try to determine whether this was a physical cluster by analyzing the proper motions and V and B magnitudes for each of the component stars. Following his advice, I found that the proper motions of the nine brightest stars in the grouping are all very different. This result indicated that each star is traveling in a different direction, implying the group could not have been a physical cluster. Dr. Archinal agreed with my cursory analysis, however he warned me that the available data (from the *Tycho-2* star catalogue) may not be all that accurate and that the error margin of the proper motions could be very large, adding uncertainty to my conclusion. He also noted that there does not seem to be a pattern for the *V* and B magnitudes, and because this grouping is quite far away from the plane of the Milky Way, the probability of it being a physical cluster is reduced.

Whatever its real nature, this grouping is a very interesting telescopic target and makes for a good asterism, at the very least. Dr. Archinal suggested the asterism be named "Markov 1" or "Markov J1757.2+2929", as per the International Astronomical Union's nomenclature guide lines, and also expressed an interest in including Markov 1 in an upcoming book he is co-authoring (with Steve Hynes of the U.K.) called *Star Clusters*.

A Digitized Sky Survey image of the "Markov 1" asterism.

I proceeded to register the designation "Markov 1" with the International Astronomical Union and in just one week the IAU responded with their acceptance. The "Markov 1" designation has been included in the IAU's *Dictionary of Nomenclature of Celestial Objects* at: `cdsweb.u-strasbg.fr/cgi-bin.Dic` I can continue to add objects, should I find any more, under the "Markov" designation.

"Markov 1" is located at right ascension $17^h\ 57^m$, declination 29° 29′. It is comprised of nine bright stars ranging from magnitude 8 to 10. Its size is approximately 15 arc-minutes, and is easily visible with a small telescope even from light polluted skies. The asterism, which is just 0.25° north-west of Xi Herculis, a magnitude 3.7 star, shows up well on both the Digitized Sky Survey image and *Uranometria 2000.0* (star chart 116) and can be observed during most of the year, except winter.

Paul Markov is a program manager at ATI Technologies Inc. in Toronto, and has been an avid deep sky observer since 1982. Look for his new section "Maintaining an Observing Logbook" in the 2002 Observer's Handbook.

The Case of the Elliptical Galaxies and the Missing Gas

by Patrick Kelly, Halifax Centre (patrick.kelly@dal.ca)

If you are like me, your knowledge of the gas content of galaxies can be summed up quite succinctly: spiral galaxies have lots of gas, elliptical galaxies have none. At its May meeting, the Halifax Centre's main speaker, Dr. Gary Welch of the Astronomy and Physics Department of Saint Mary's University, gave the audience a totally new perspective on a subject that many amateur astronomers, indeed many professional astronomers, thought was an area in which nothing new could be learned.

Dr. Welch started off his talk by treating us to a quick tour of the main types of galaxies: spirals, S0 galaxies, and ellipticals. According to Dr. Welch, ellipticals are boring to look at — even in large telescopes! He then described the famous "tuning fork" diagram, which Hubble had used to categorize galaxies, and how some early attempts to explain galactic evolution had used this diagram to demonstrate that "early" galaxies (the ellipticals) evolved into "later" forms (the spirals).

As we now know, that theory to explain galactic evolution does not work. All galaxies have an age of approximately 10 billion years, and all contain stars that are about the same age. The biggest difference between early and late galaxies appears to be that the early types used up their gas a long time ago, and as a result, are no longer making new stars, while the later types are still forming stars, even at the present (see Figure 1).

So, how do we check to see if elliptical galaxies really have no gas left? Simple, we look for it. Keep in mind that when astronomers say "gas" what they really mean is hydrogen, as it makes up most of the gas in the universe. Hydrogen gas in a galaxy is typically found in three "temperatures": hot, warm, and cold.

Hot gas (10^6–10^7 K) gives off X-rays, which precludes looking for it from the ground as X-rays are blocked by the Earth's atmosphere. An X-ray satellite like *ROSAT* is required to find this hydrogen. Dr. Welch showed images from the *ROSAT* Web site, including an image of the Andromeda Galaxy in X-ray and in visible light. Though he did not know what telescope they used to obtain the visible light image, he did not recall the brighter areas of M31 being yellow and lime green! It is thought that the hydrogen discovered in this manner is bound to stars, and thus not available for new star formation.

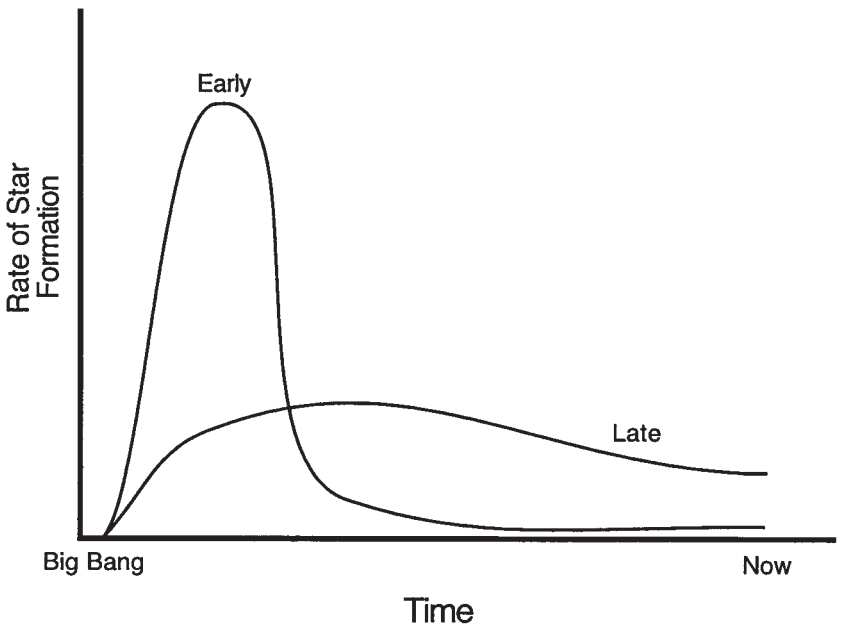


Figure 1

Warm gas (about 10,000 K) gives off visible light and makes up the well-known H II regions, of which the Orion Nebula is one of the best examples.

Cold gas (10–1000 K) emits radio waves and comes in two "phases." When it is in very tenuous form it exists mostly as atomic hydrogen. These areas are H I regions and can be easily detected by the 21-cm radiation that they emit. Not only are H I regions easy to detect with radio telescopes, there is also a direct correlation between the strength of the signal and the amount of gas.

The other form of cold hydrogen is much harder to detect. It is found in much denser regions of gas called molecular clouds. Due to the increased density, the hydrogen is not atomic but exists in the molecular form, H_2. The hydrogen molecule is composed of two identical hydrogen atoms and is symmetric. As a result, it doesn't emit radio waves of any frequency, making it difficult to detect. In Dr. Welch's own words, "Bummer!"

To find molecular hydrogen, we have to look for other molecules, called tracer molecules, which do emit radio waves. Assuming that the ratio of hydrogen to the tracer molecule in molecular clouds is similar to what it is in later-generation stars, we can calculate the amount of hydrogen gas present. Carbon monoxide

(CO) is often used as a tracer for hydrogen as it is made up of two different atoms, which allows it to emit lots of radio waves. It is usually assumed that there are about 10,000 hydrogen molecules for every CO molecule that is detected. This method is not foolproof as there are galaxies known to have active star formation, implying that they have lots of molecular hydrogen, but showing very little CO emission.

Consider CO data of NGC 4310 that had been obtained at a wavelength of 2.6 mm (see Figure 2). As most galaxies are moving away from the Milky Way, there is a Doppler shift in the wavelength, for which corrections must be made. The resulting data use radial velocity, rather than wavelength, to produce a graph of this form.

The area under the curve gives a measure of the amount of CO, which in turn, allowing for the assumptions previously mentioned, allows one to calculate the amount of hydrogen gas. Unfortunately, there is an additional complication. The intensity of the spectral line for a fixed amount of CO depends on the square of its distance from us. This, in turn, means that the amount of hydrogen is also dependent on knowing an accurate distance to the galaxy being studied. For historical reasons, astronomers don't directly measure the actual amount of hydrogen. Instead, they use the ratio of the mass, M (in solar units), to the luminosity (L, also in solar units) of the stars in a galaxy. Since the luminosity also depends on the square of the galaxy's distance, the ratio cancels out any effects caused by an uncertain distance. (According to Dr. Welch, once you use this ratio for a few years, you do not think of it as being such an odd way to measure the amount of hydrogen.) For the Milky Way, M/L = 0.4. For late galaxies, it ranges from 0.1 to 1.0, while for early-type galaxies it is much less than 0.01. He pointed out that this value is really an upper limit because you cannot actually detect it.

Using these techniques on the Milky Way, we get an interesting census of where the hydrogen is found. The H II regions, like the Orion Nebula, while visually

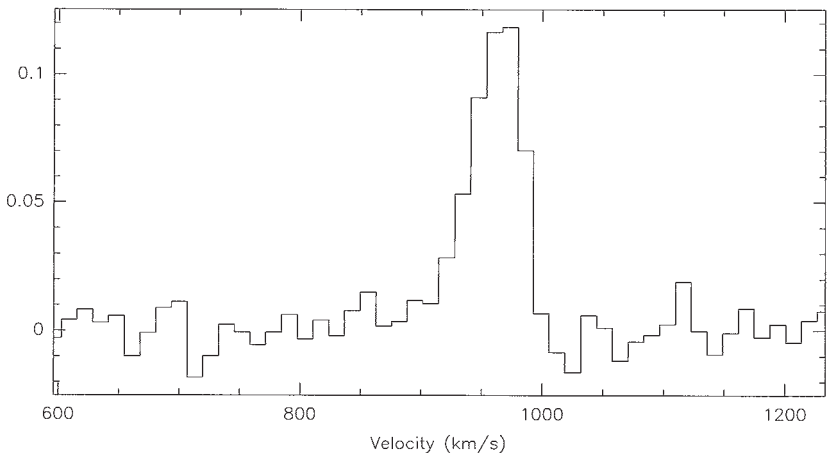


Figure 2

spectacular, account for a negligible amount of hydrogen. Most of the hydrogen is in the form of atomic hydrogen, which is two to three times as abundant as molecular hydrogen.

So in the opening we said that elliptical galaxies should have no hydrogen gas left, and we now know how to detect gas in spiral galaxies that should have gas in them. This is where Dr. Welch introduced us to a new way of looking at ellipticals because we have a small problem. Gas will be returned to the interstellar medium. Stellar evolution provides two methods for this to occur (even in elliptical galaxies that have used up all of their gas): a "fast" method and a "slow" method.

The fast method involves the Type II supernova explosions produced by the deaths of massive stars. These, though infrequent, return about 90% of the exploding star's mass to the interstellar medium. Type Ia supernovas, produced by the collapse of a white dwarf in a binary star system, also produce a sudden burst of gas that resupplies a galaxy's gas reserves. Single stars and less massive stars also contribute significantly during their later stages of life, including the planetary nebula phase, but at a much slower rate. While these types of stars only return about 50% of their material, there are a lot of them and they would provide a more continuous supply of hydrogen to form new stars.

Accounting for these sources of "recycled" hydrogen, the value of M/L for a typical early-type galaxy should be about 0.1, more than ten times the observed value and near the lower range for spiral galaxies. So where is the gas in elliptical galaxies?

Dr. Welch said he has been looking at this problem by studying four elliptical galaxies in the Local Group: M32 and M110 (the two bright companions of the Andromeda Galaxy), NGC 185, and NGC 147. The "near pair" of M32 and M110 have interacted with Andromeda while the "far pair" have not. He described them as "four peas in a pod" because all four galaxies appear to be identical. They all have a luminosity of about 1% that of the Milky Way, they are all about 10% of the size of the Milky Way, they all are dominated by the light of old stars, and they all have a similar percentage of stars that appear to have been formed about one billion years ago (in the recent past for a galaxy).

Given their similar appearance, it is reasonable to assume that all four should have the same amount of gas. There are no visible signs of H II regions, and X-ray satellites have found no hot gas. Dr. Welch and several colleagues have been using a wide variety of radio telescopes to search these galaxies for cool hydrogen.

Keeping in mind that we are expecting M/L to be about 0.1, how much gas is there when you actually look? Consider the far pair first. For NGC 147, M/L <0.001, while NGC 185 yields a value for M/L of 0.01, both indicating much

less gas than expected. In the case of NGC 185, it can be argued that the recent burst of star formation was followed by a series of Type II supernovas which pushed all of the gas out of the galaxy, and that the little that we see today is a result of a billion years of "outgassing" from less massive stars. What about NGC 147? Could all of its gas have been removed by a "continuous" series of Type Ia supernovas? If so, why hasn't that happened to NGC 185 as well?

Maybe we can learn more by looking at the near pair. For M32, M/L < 0.00002! It has **no** gas. M110, on the other hand, has an M/L ratio of 0.002. Did M110 lose all its gas on its last pass through the disk of M31? If so, then an M/L value of 0.002 is what would be expected from outgassing since that encounter. However, this argument does not work for M32, which should have as much gas as M110. Alternatively, if M32 is so poor in gas due to cleansing by Type Ia supernovas, then why didn't the same thing happen to M110?

So how did two of the galaxies (NGC 185 and M110) end up with so much more gas than the other two (NGC 147 and M32)? Did they recently pick it up from intergalactic space? Do they have a lower rate of supernova explosions than the other two, and if so, why? Could their gas be arranged such that it is not coupled to the gas from supernova explosions? (There is definitely enough energy to do the job!)

It is obvious that more galaxies of this type need to be studied. According to Dr. Welch, this is what you always say when you want to get more telescope time! The next step will be to look at the 28 "normal" S0 galaxies that lie within 20 Mpc of the Milky Way and are in the northern sky. It is hoped that with more study, the case of the missing gas may soon be solved.

When not involved in astronomical activities, Patrick Kelly is the Director of Faculty Computing for the Faculty of Architecture at Dalhousie University. He frequently loses the arm wrestling competition held before each Halifax Centre meeting to determine who will write the meeting report for the next issue of Nova Notes, *the Centre's newsletter. This article is based on one such report. His other interests include hassling Dave Lane about the inferiority of "Windoze" computers compared to Macintosh systems, and waiting patiently for the Montreal Canadians to win their next Stanley Cup.*

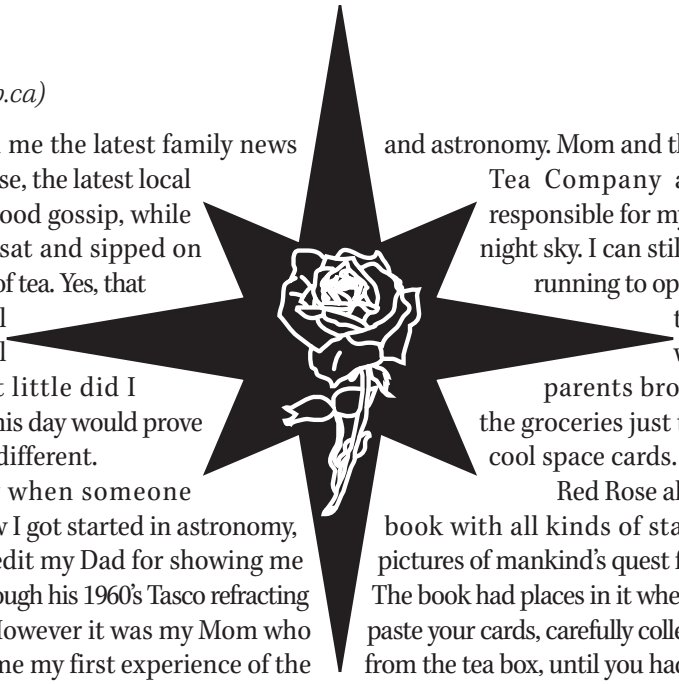
AstroQuotes

"'Twas brillig and the slithy toves
Brought plans of telescopes fair to see.
The Jabberwock, he clapped his hands
And said,"That's just for me.""

- Malcolm Longair

There's a Rose on that Star

by Daniel LeBlanc, Moncton Centre (leblrous@nbnet.nb.ca)



Let me take you back to the year 1966. I am five years old. It is during the Cold War. Everybody I know, including my Dad, has a brush cut. You can buy a bag of potato chips, a soft drink, and a chocolate bar for less than 25 cents. On this particular day in July, it is hot — very hot. The day before this, my Dad showed me a picture in the newspaper of a man actually frying an egg on the road.

It is 7:00 in the morning. Mom and I always woke up together on those hot summer days while my baby brother slept on. My older sister had left the house earlier to go to the beach with neighbours and my Dad was putting in his regular day's work at the office. Mom liked waking up fairly early, as she enjoyed preparing breakfast before my baby brother's wake-up cry. Mom put on the frying pan, poured me a cold glass of "freshly squeezed" Tang orange juice crystals, then two eggs plopped into our home frying pan. That was followed by Mom carefully placing two pieces of bread into the family toaster — a toaster like no other launch system I know.

In those early years of space exploration, sending a man to the Moon is only a few years away, however the Russians still have the edge on us. That is something people are quite worried about, with the Cold War and all. Back then I really did not know much about all that stuff. After all, I was just a five-year-old kid having breakfast with his mother. On those mornings, she always shared with me the latest family news and, of course, the latest local neighbourhood gossip, while she quietly sat and sipped on her hot cup of tea. Yes, that was a typical daily ritual for me, but little did I know that this day would prove to be quite different.

Today when someone asks me how I got started in astronomy, I usually credit my Dad for showing me the stars through his 1960's Tasco refracting telescope. However it was my Mom who really gave me my first experience of the great night sky and its countless treasures. Back in 1966, I often asked myself how my Mom knew so much about things like spaceships and weird-looking planets with rings around them. I soon discovered that Mom's mysterious knowledge of these things did not come from books or television shows, but merely from that second cup of tea. Her knowledge of the night sky came from a little brown, white, and red box with a picture of a red rose on it. Yes, a box which contained bags of tea as well as three little collector's cards, which were full of information on space exploration and the science of astronomy.

In the late 1960's, the Red Rose Tea Company introduced collectibles as an incentive to purchase their tea. These ranged from different series of cards, covering many topics, to porcelain figurines. Of them all, the one series of cards I will never forget was the series on space flight and astronomy. Mom and the Red Rose Tea Company are totally responsible for my love of the night sky. I can still remember running to open that little tea box when my parents brought home the groceries just to get those cool space cards.

Red Rose also offered a book with all kinds of statistics and pictures of mankind's quest for the stars. The book had places in it where you could paste your cards, carefully collected weekly from the tea box, until you had completed the whole series. I can still remember when I sent away for that little booklet. It was probably the first time I ever sent away for anything in my life. Weeks, and even months, went past as I checked the community mailbox daily. Then one foggy, rainy day in October, a package with my name on it emerged as I turned and pulled on the big rusty lock that faithfully guarded my family's collection of bills and junk mail. It was Red Rose's gift to me that hooked me on the stars.

Unfortunately, it has been a long time since Red Rose included cards that were capable of inspiring children and adults with a passion for astronomy. Pity.

Daniel LeBlanc is a native of Moncton, New Brunswick and an amateur astronomer. Daniel is the Vice President of the Moncton Centre and president of the Moncton Beauséjour Astronomy Club.

by Fae Mooney (faemooney@kermode.net)

It's two o'clock in the morning. My rattle-y old alarm clock jangles me awake. Hubby, letting out a low moan, rolls over, dragging the covers with him.

While the rest of the world slumbers, I'm stumbling sleepily from bed. I stagger to the back door and peek out –

A star twinkles and smiles in the dark sky, beckoning me...

Good, the clouds are gone.

By the dim red glow from a night-light (to preserve my night vision) I fumble my way into some warm clothes. My miniature Samoyed-Poodle pup, West Wind, her bright eyes wide with anticipation, thinks this is great. She prances around me, tail swirling, and — Out the door! She dashes ahead of me, so excited she stumbles on the porch step. I'm right behind her.

This is summer's climax: the Perseid Meteor Shower.

Tucked away in the northwest corner of British Columbia, surrounded by mountains and forests, I stretch out on my chaise in the backyard, gaze up into the fathomless darkness overhead, and watch for a diamond streak to slash through the black expanse.

The view is good from my backyard. Well, pretty good. The sky is not vivid black — a slight late-summer haze washes out the dimmest stars. But that's okay. I like where I am. It's accessible. And close to the warm bed I've just left.

The trees around my yard frame my view of the sky. They're home to busy little red squirrels and a multitude and variety of birds. Just as the stars bring me pleasure at night, these little creatures add pleasure to my days.

" Tucked away in the northwest corner of British Columbia, surrounded by mountains and forests, I stretch out on my chaise in the backyard, gaze up into the fathomless darkness overhead, and watch for a diamond streak to slash through the black expanse."

The air is still, sweet, moist, fresh. All is quiet, except for the occasional peep or chirp from a drowsy bird nestled in one of the evergreens that surround me. Not even a mosquito to distract.

Only my little pup, gnawing on my elbow.

A satellite drifts by above us.

Crystal Capella, that golden star, glimmering and glittering high in the northeast, slowly emerges from behind a cottonwood.

Perched above a nearby hemlock, like a star on a Christmas tree, Polaris sparkles high in our northern sky.

Was that a – ??? Yes! A meteor! A short slash through Cassiopeia, that giant "W" sailing overhead.

Westie jumps up on my stomach, swipes at my cheek with her nose, distracting me.

Is that another? To the west? Caught by my peripheral vision? Or just my eyes betraying me? Perhaps...

There! Two! Twins! One right after the other, streak behind the poplar, slicing through Auriga, dwelling place of Capella.

If I see just one silvery trail of stardust then it has been a successful night. All too often I see none — it isn't always moon glow that washes them out, or my northerly latitude with endless summer twilight, or even the aurora that sometimes illuminates the sky. More often than not it's a liquid form of shower, falling from an overcast sky. But I'm lucky tonight.

The slightest breath of a breeze brushes across my face and rustles the leaves of the poplars.

A silvery streak pierces the black, heading toward Polaris. Another slices through Cassiopeia. I prickle with excitement.

Westie races around the chaise, then returns to gnaw on my elbow. Another diamond streak slashes open night's black cover, heading westward.

The rest of the world sleeps. There is only me, my mischievous little pup, and — the whole universe...

I need to look up into a starry sky.

Stretching out on a chaise on a mild summer night frees the mind from day-to-day clutter, just lying back and enjoying the starry view, thrilling to a sudden streak of luminosity overhead, and indulging in some contemplation inspired by the celestial happenings.

Questions that humans have asked for millennia I ponder, like — what is man? In this natural reality, only a speck of stardust. Like the meteor that just streaked overhead.

It's good to be reminded of this. And during the Perseid Shower a human mind has the opportunity to stretch beyond the perceived and reach out to reality.

Silently, another silvery streak pierces the dark. Absent-mindedly I've been stroking little West Wind who has settled down by my side. The stars of Cassiopeia play peek-a-boo overhead from between the leaves of the weeping birch.

One last glance around the sky, in the hope of seeing one last streak of luminous stardust...

It's time to say good night to my celestial friends, and thank my Creator who, in His great wisdom, placed them there.

It's time to reclaim my place by my slumbering hubby's side.

Westie curls up on the rug next to my slippers. I drift into a dream. Overhead the gentle celestial shower continues...

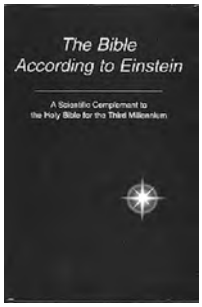
Unattached member and freelance writer, Fae Collins Mooney loves to spend the best part of every day enjoying her natural surroundings at her home in northwestern British Columbia.

Astrocryptic

by Curt Nason, Moncton Centre

The answers to last issue's puzzle

Reviews of Publications
Critiques d'ouvrages



The Bible According to Einstein: A Scientific Complement to the Holy Bible for the Third Millennium, by the Jupiter Scientific Publishing Company, pages 634 + v, 16 cm × 23.5 cm, Jupiter Scientific Publishing Company, 1999. Price US$34.95, hardcover (ISBN 0–9655176–9–1).

The Bible According to Einstein is a serious-looking book with its all-black cover, somewhat reminiscent of many of the books that used to line the library shelves of my departed father. He was an educated man of the cloth, and his library was full of books on theology, religious studies, Greek and Roman history, and so on. I stared at the unassuming black book when I received it. The title caused me to raise an eyebrow.

The first thing one notices about *The Bible According to Einstein* is that there is no credit line for the author. It is the first book I have ever seen published with no credited author, none whatsoever! A bit of Web research solved that particular riddle. Since the authors are emulating the Bible, it was felt that, like the Bible, they would remain anonymous. After that somewhat dubious beginning, and in the light of "not judging a book by its cover (or author)," I moved on to the printed pages. I must confess that I have not read the entire book, at least not from cover to cover. I have delved into it from time to time, and for a week I perused it quite diligently. But it grows tiresome, something like waltzing on a layer of not-quite-thick-enough ice over three feet of soft snow. Everything is fine until you accidentally break through; then you have to climb back up again and brush yourself off. After reading a dozen pages of this book at a time, I found that I needed to get away from it to clear my thinking. I had to "brush myself off" too many times. Let me elaborate.

What is the book about? It is a summary of the science of astronomy. It includes a tour of the latest space probe knowledge of the solar system, a good summary of current thoughts on the formation of our solar system, descriptions of the material found in interstellar space and implications for star formation, and descriptions of galaxies, including mergers and active cores. The big problems in astronomy and cosmology are well examined, including a good description of the expanding universe, complete with implications for both the long past and the far future. There is a review of the cosmological consequences of relativity, well laid out descriptions of the missing mass problem, and so on. The latest discoveries in genetics and the formation of life are touched upon. It is all here, so why the hesitation?

Did I mention that it is all written in "King James Bible" style, 17th century English? It is as if somebody took a modern astronomy text back to the 17th century and had King James' translators rewrite the text in their dialect. If you do not believe me, here is a quote from the "Eighth Book of Physics, called Electromagnetic Waves" chapter 4, entitled "Photon Energy and Momentum," beginning at the 3rd verse.

"And let it be known to thee, and all around thee, that the momentum of a photon shall be its energy divided by the speed of light. Thus a photon of low energy shall have a low momentum, and a photon of high energy shall have a high momentum and also a stronger impact when it strikes another thing. And so a photon's energy and its momentum shall walk hand in hand — when one goes up, the other shall go up; when one goes down, the other shall go down…"

If you find yourself reading that twice, you are not alone. I had to reread almost every second passage. It was, to say the least, a little frustrating. Yet, in all fairness, I must admit that the book has its moments, and does contain some excellent descriptions of difficult concepts. The frustration is that if it had not been transcribed into pidgin King James English, it would have been a reasonable layman's guide to astronomy.

The obvious next question is, Why? Why go through all of the effort to create such a text, then spend all the effort making it cumbersome to read? What does the book hope to accomplish? I see two possibilities.

The first possibility is to use it as a teaching tool for the believers. Is it possible that people who would normally shun the scientific truth may just pick up and have their eyes opened by the familiar (to them) text structure and phrasing of *The Bible According to Einstein*? Is the book capable of introducing the ever-expanding world of science to those who hide behind the crutch of religious belief? Could it make a difference to those who are even now pushing many American state governments to include so-called "creationism" as an alternative reality to scientific thinking in their public education system? I do not think that is very likely. From personal experience, that type of person is not very open minded to such a "radical" revision. Many of them hold the text of the Bible very sacred, literally "The Word of God." They would dismiss this book as yet another example of the "Devil's work," another attempt by the evil side to corrupt their "Good Book."

The second possibility is the potential of *The Bible According to Einstein* to fulfil some of the desire, perceived or otherwise, of the scientific mind for spiritual nourishment. Those wonderful skeptics, who question and analyze everything until they cannot find anything else to learn, then move on to another topic. Do they need more? If you are reading this, there is a good possibility you are a skeptic. You are like those who, according to Chet Raymo in his excellent book *Skeptics and True Believers* (ISBN 385–25755–4), are "a little lost in the vastness of the cosmos, but they trust the ability of the human mind to make sense of the world." Will you find this book fills an inner spiritual need, that it brings you closer to spiritual satisfaction than a new Nagler eyepiece? I suspect not. Instead, you likely agree with me that it is a book that was ruined by a translation gimmick in an attempt to stand out in a crowd. It could have been at least a reasonable summation of an amazing universe, since the text has many well-written descriptions of what can be quite complex events. (For example, the four-page description of what happens in the core of a type II supernova prior to detonation is very clear and thoroughly researched. Indeed, it is one of the better descriptions of this astounding event I have ever read.) Another possible direction for this type of book might be to present an examination of age-old questions and beliefs in the light of modern science (such as Paul Davies' highly recommended book *The Mind of God*, ISBN 0–671–79718–2), but alas, the authors chose neither of these.

What we are left with is a well-written science text, in a form of English that Mary Queen of Scots might have found enlightened, but which will now please neither skeptic nor true believer. As much as I find it a shame, I must conclude that the book is doomed to the cheap pile in front of the local *Chapters* book store… pity.

Douglas Pitcairn

Doug Pitcairn is a computer technician in the Faculty of Architecture at Dalhousie University and teaches first-year astronomy part-time in the Department of Astronomy and Physics at Saint Mary's University.

See the Stars: Your First Guide to the Night Sky, by Ken Croswell, pages 32, 23 cm × 32.5 cm, Boyds Mills Press, 2000. Price $25.99, hardcover (ISBN1–56397–757–5).

In 1990 Harvard-trained astronomer Ken Croswell published his Ph.D. thesis on stars of the Milky Way halo and thick disk. Since then, his work has been published in *Science*, *New Scientist*, *Astronomy*, and *Sky & Telescope*. Three previous books, *The Alchemy of the Heavens, Planet Quest*, and *Magnificent Universe*, have been well received. With his fourth monograph, *See the Stars*, Croswell has written the book he wishes he had as a child, and with the addition of colour photographs by Akira Fujii, it can be appreciated by adults as well.

Rated for children ages 8 and up, *See the Stars* is an excellent first guide to observing. Organized by month, each month features a single constellation. A 9 × 12-inch labelled, colour photograph of the constellation faces a page containing a smaller line drawing, a chart listing the dates and approximate times of several viewing opportunities, and a half page of text.

Each section reveals a new concept along with reinforcement of several basics, such as star colour and its relation to temperature, the light year, and differences in star brightness. Some point of interest for each constellation is emphasized. While variables, double stars, nebulae, and clusters are listed, the description is not limited to the specifics of the constellation, but rather explores what can be said about the constellation as a whole as well.

Orientation is covered on several scales. Sunrise and sunset are given as tools to define points on the horizon. While an important feature of the Big Dipper is its use in finding the North Star, the reader is reminded of its unique visibility year 'round here in the northern hemisphere.

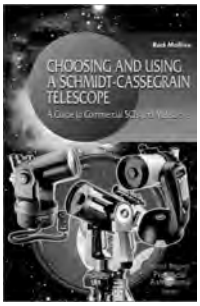
For each month's observations, Ken Croswell has selected twelve of the brightest and best star patterns. For example, the teapot pattern of Sagittarius in August houses the centre of our Galaxy. In October, by turning our gaze outward to the double cluster of Perseus, we learn about the basic shape of the Milky Way's spiral arms.

Four constellations that lie on the ecliptic, each marked with "planet alert," introduce the plane of the solar system and the concept of change in the night sky. A basic algorithm given at the back of the book helps to identify planets spotted with the unaided eye. Aspects of stellar birth and evolution are described in the section on the Orion Nebula, Arcturus is identified as a more mature version of the Sun, and the unified motion across the line of sight of many of the stars within the Big Dipper is noted as suggesting their common origin.

See the Stars includes stories about how the constellations are represented in legend, as well as notes about the meanings of many star names. There are even suggestions for observing such as dressing warmly and being careful about safety factors, as well as an introduction to the star-hopping technique. The constellations are easily identified when the photograph is used in conjunction with the accompanying line drawing. The book presents astronomy as something that can be enjoyed by anyone with an interest in nature. It also has great potential to get observers outside throughout the entire year. The text is straightforward and non-technical, and with its sprinkling of basic science to promote the interpretation of one's observations, *See the Stars* will surely pique the interest of young readers. Parents interested in introducing their child to science or encouraging a science-based hobby should consider this book a great place to start.

Susan Gagnon

Susan Gagnon is an active member of the Kingston Centre and a regular observer of celestial objects.



Choosing and Using a Schmidt-Cassegrain Telescope, by Rod Mollise, pages vii + 355, 15.6 cm × 23.3 cm, Springer-Verlag London Limited, April 2001. Price $59.95 soft cover.
(ISBN 1–85233–631–5)

For those of us who grew up in large families, having a big brother is usually a mixed blessing. On the other hand, having an astronomical "big brother" is decidedly a "good thing," especially when he is a practical-minded expert on the complex world of Schmidt-Cassegrain Telescopes. Rod Mollise is an active amateur astronomer from Mobile, Alabama, who has been observing for thirty-five years, including twenty-five with a Schmidt-Cassegrain telescope (or "CAT" for Catadioptric). Rod's further credentials come from moderating one of the most popular e-mail lists on the subject — SCT-User — where participants have come to recognize his down-home, folksy style of writing.

In *Choosing and Using a Schmidt-Cassegrain Telescope*, Rod Mollise makes a case for the Schmidt-Cassegrain telescope as the best general-purpose telescope available for the amateur, and explains its current popularity. He traces its history from the point at which Celestron International solved the corrector-plate production problem to today's computerized scopes. A mostly current review of recent Celestron and Meade models is included, which just squeezed in the *Nexstar 8* but missed the *Meade LX90* and *Nexstar 11* models. More importantly, the section clearly explains the pluses and minuses of small, medium, and large scopes as well as the mysteries of focal ratios to the uninitiated. The Maksutov-Cassegrain (MCT) variant is also explored along with its advantages and disadvantages.

In the "using" part of the book, the author provides a very appropriate and detailed check-out and first light procedure that covers the whole process from unpacking, alignment, and set-up to initial field use. Certainly in comparison with the manual that came with my telescope, that section of the book is definitely more appropriate for the first-time user. The notations on what is considered normal for a telescope, and what is not, are certainly useful and anxiety-reducing.

A detailed review of every SCT user's financial nemesis — accessories — is valuable for pointing out the true benefits and drawbacks of specific items. In particular, Rod makes a strong case for a focal reducer and the latest model eyepieces while pointing out what benefits you will see at the eyepiece. Another chapter on the "care and feeding" of an SCT covers both routine and traumatic maintenance and is complemented by a listing of home-made accessories that can make your viewing easier. Finally, an introduction to the demanding sport of astrophotography is included that provides a realistic overview of what you must do to achieve good results.

The book is part of Patrick Moore's *Practical Astronomy Series*, and is aimed at amateurs who are already beyond their first few books and are interested in additional detail and advice. The book mostly succeeds in that but offers a lot more value to the first-time or potential SCT buyer than to someone who has owned (and actively used) an SCT for a year or more. For example, homemade accessories are touched on, but there is a lot of information out there that could be added to make the book more attractive to the experienced user.

The book is also interesting because it marks a convergence between traditional book publishing and web-based astronomy. Rod Mollise has built a reputation through his moderation of the SCT-User e-mail list since July 1999. That means he is adding the knowledge gleaned from over 27,000 e-mail messages (and counting) on the subject to his own life experience. I expect that we will see more of the same kind of writing in the future as booksellers look to ensure the acceptance of their products in the marketplace.

Denis Grey

Denis Grey is a five-year member of the RASC (Toronto and London Centres) and is presently working his own 8-inch "CAT" into his life.

Obituary
Nécrologie

Ronald Ogilvy Pow (1928–2001)

Ron Pow (left) with Keith Withnall.

Long-time Life Member Ron Pow died peacefully on April 18, 2001 at the Royal Victoria Hospital in Montreal. Ron was for many years a member of the Montreal Centre where he held a number of important posts on the Board of Directors, including that of President in 1986/1987. He held strong views on how a Centre should be managed and always expressed those views honestly and constructively. He will be remembered for the support he brought the Centre at a time of transition. For the past couple of years, Ron belonged to the Kingston Centre.

For most of his career, Ron worked as a self-taught engineer for Northern Electric, and his passion for astronomy was matched by an equal attraction to astronomical gadgets, the bigger and more complicated, the better. He always had 'plans' for this equipment, many of which could not be realized once his health began to deteriorate. Ron loved the social and scientific aspects of amateur astronomy too, attending as many General Assemblies as possible with his wife, Ruth. He enjoyed the paper sessions and the parties with equal gusto.

Aside from Ruth, Ron leaves his daughter, Debbie, her husband and their three children, as well as a sister, Ann Arkell. He will also be remembered by his many friends in the RASC and in Star Seekers, the other astronomy club of which he was a member in Montreal. He also had numerous friends in the Montreal Camera Club and in the Gaelic class he had attended in the past couple of years. Ron was a man of many interests and his endearing eccentricities will ensure that he won't soon be forgotten.

Sidney Grant Lee (1947–2001)

The laugh was unmistakable, rich, hearty and piercing. While we were observing at a public event or just at a meeting of the Observers Group at the Wilson Coulee Observatory, it would shatter the night air and tell everyone present that somewhere out on the field, Sid was about. Everyone knew Sid Lee and his passion for sharing the wonders of the night sky with anyone who wanted to learn. We won't hear that wonderful sound anymore, but none of us at Calgary Centre will ever forget it. Our dear friend Sid Lee passed away April 28, 2001, age 53, after being ill for about a month.

We won't forget how he loved to laugh, and we will long remember the amazing contributions he made to the many organizations involved in Astronomy in the Calgary area. His name is enshrined on the Presidents Award, the Peter Sim Memorial Award, and the RASC's National Service Award, yet he was a very humble individual and usually quite embarrassed at such accolades. His long time friend Greg Key, in his eulogy noted that Sid would have been embarrassed at the huge turnout for his memorial service held at the Calgary Science Centre's Discovery Dome.

Sidney Grant Lee held a Masters Degree in Electrical Engineering and was a specialist in computer programming and applications for the oil patch when computers were in their infancy. He worked hard and was able to enjoy early retirement starting in 1995. While he was always a valued and active RASC member, after this retirement he devoted his energies full time to RASC educational matters as well as spending huge amounts of time supporting the good works of the Calgary Science Centre where they viewed him as one of the staff. In addition he acted

as a liaison between the University of Calgary's Department of Physics and Astronomy, the RASC, and the Science Centre. If there was an astronomical gathering of any description that was open to the public by any of these organizations, you knew Sid would be there. Frequently he wouldn't just be there but likely arranged the event or played a key role in seeing it happen as planned.

Sid is survived by his sister Lynda, of Jasper, Alberta. He is also survived by his huge extended family of friends from his working career and in the world of astronomy. For most of us in the Calgary Centre, Sid was family. He was our friend, our mentor, indeed our conscience as we worked together to further the cause of bringing the important issues of the night sky to the masses. Sid's departure doesn't leave big shoes to fill; it leaves about twenty pairs of big shoes to fill. It will take the volunteer efforts of many other members to pick up the torch that Sid held so high. Calgary Centre is strong and we will carry on, though we will miss our friend dearly. It's a good bet that most of our long-time members will still swear they heard that roaring great laugh, as if he were still standing right beside us, long into the future.

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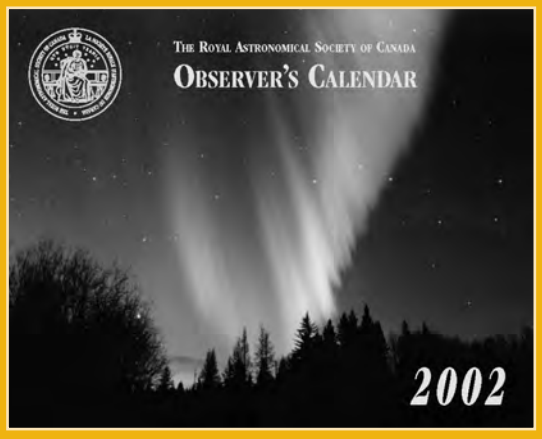

Observer's Calendar — 2002

This calendar was created by members of the RASC. All photographs were taken by amateur astronomers using ordinary camera lenses and small telescopes and represent a wide spectrum of objects. An informative caption accompanies every photograph.

It is designed with the observer in mind and contains comprehensive astronomical data such as daily Moon rise and set times, significant lunar and planetary conjunctions, eclipses, and meteor showers. The 1998, 1999, and 2000 editions each won the Best Calendar Award from the Ontario Printing and Imaging Association (designed and produced by Rajiv Gupta).

Price: $15.95 (members); $17.95 (non-members)
(includes postage and handling; add GST for Canadian orders)

The Beginner's Observing Guide

This guide is for anyone with little or no experience in observing the night sky. Large, easy to read star maps are provided to acquaint the reader with the constellations and bright stars. Basic information on observing the Moon, planets and eclipses through the year 2005 is provided. There is also a special section to help Scouts, Cubs, Guides and Brownies achieve their respective astronomy badges.

Written by Leo Enright (160 pages of information in a soft-cover book with otabinding which allows the book to lie flat).

Price: $15 (includes taxes, postage and handling)

Promotional Items

The RASC has many fine promotional items that sport the National Seal. Prices include postage and taxes. Included are a *Cloth Crest* (size 11cm with the background white and the stitching in royal blue - $11), *Lapel pins* (blue, white, and silver - $5), *Golf shirts* (white, available in small and medium - $24), *Stickers* (size 7.5cm, blue with white overlay - $1 each or 2 for $1.50), *Thermal mugs* (in blue and white - $5.50), *Toques* (Black with Yellow lettering - $17), *Key chains* (Clear arcylic and Blue/white - $2.50).

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