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Journal

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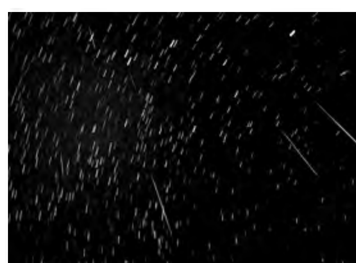

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President's Corner

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

Each summer, members of the Society from across the country (and from the U.S.) gather for our annual convention, the General Assembly. This year's gathering was hosted by the Vancouver Centre, and you can read and see more about it in this issue of the *Journal*. This GA was my 11th; my first was also in Vancouver, in 1991. It's quite a coincidence that the only Centre that's hosted two GAs while I've been attending them is my own Centre; this closed loop (a mathematical term!) gives me pause to reflect on the wonderful tradition in the Society that we call our *General Assembly*.

I have a vivid memory of each of the 11 GAs I've attended. That's quite remarkable, given my steadily deteriorating short-term memory. I think the reason I remember each so well is that every GA is unique. There are certain general guidelines that should be followed, but each Centre that hosts a GA can, and does, modify the template. The point, no matter the details, is for members of the Society to meet and to discuss astronomy and the business of the Society. These discussions take the form of lectures, workshops, and meetings. And the discussions often carry on late into the night in the presence of assorted liquid relaxants, giving a different meaning to the term *star party*.

What made the 2003 GA unique was its focus on the Royal Centenary of the Society. To commemorate this milestone in the Society's long and rich history, the local organizing committee — a few key members of which were Craig Breckenridge, Pomponia Martinez, and Norman Song — arranged for the presence of a representative of the Queen, the Lieutenant Governor of British Columbia, The Honourable Iona Campagnolo. The over-200 members who attended the plenary session on that fine Saturday morning at the University of British Columbia will never forget it. We were treated to twenty minutes of colourful entertainment by a group of local Chinese dancers. But Her Honour's presence is what made the morning special and made all the effort involved in arranging the unique plenary session worthwhile. The speech delivered by the Lieutenant Governor (which, by the way, is pronounced *Left*-enant Governor) struck a chord with the attendees. Instead of the formal congratulatory address that many expected, we were treated to an astronomically rich talk that captivated us. The address, which was personally written by Her Honour, struck all the right chords; Her Honour won the hearts of her audience when she mentioned how much she enjoyed watching the Perseids and that she had given a small telescope to a grandchild as a present.

I have always admired this remarkable woman, a pioneer

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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in Canadian politics, and being her official host during the three hours that she graced our 2003 General Assembly will surely be the highlight of my two-year term as president. As a little memento of her visit, I have sent her, together with a letter thanking her on behalf of all members, a copy of the 2004 *Observer's Calendar,* which includes a reminder of the 2004 Perseids.

The text of the Lieutenant Governor's address is reproduced in this issue of the *Journal,* along with the text of a lecture delivered by our expert historian, Peter Broughton (which Her Honour enjoyed immensely). I encourage those of you who were not present at the 2003 GA (and those who were), to read, and be inspired, by these addresses. Also included in this issue are a few selected photos, from among the over 1300 taken by our prolific digitally and photographically inclined members.

The other lingering memory of the 2003 GA that stands out in my mind is the dinner cruise that 200 GA attendees enjoyed on the evening of the plenary session. The weather was perfect, not a cloud in the sky; we Vancouver natives kept insisting that it's always like that here, but somehow and mysteriously our colleagues from elsewhere in the country have the impression that it's a tad wet out here. And we were treated to another wonderful talk, by David Levy, who is the undisputed master at inspiring audiences about astronomy. Once again, this dinner cruise took a substantial amount of organizational work, and I thank the GA organizing committee for undertaking this effort.

So, what's next? What special treats will the 2004 GA in St. John's, and the 2005 GA in the Okanagan, have in store? I have no idea, but I can't wait! Hope to see you there...

Editorial

by Wayne A. Barkhouse (editor@rasc.ca)

Canadian professional astronomers have caught "aperture fever!" Yes, this statement is a bit over the top, but it accurately describes a renewed push to insure that Canadian astronomers are active participants in the construction of one of the world's largest optical telescopes.

The next 10–15 year future of Canadian astronomy has recently been outlined by the government-established Long Range Planning Panel (LRPP). The LRPP put forward a list of key projects that will help maintain and enhance Canada's contribution in ground-breaking astronomical research. Among the key recommendations is that Canada should be involved in the design of a Very Large Optical Telescope (VLOT).

The largest optical telescope that Canada owns a significant share of is the 3.6-metre Canada-France-Hawaii Telescope located on Mauna Kea, Hawaii. This instrument has been the workhorse for Canadian optical astronomy since 1979 and our approximately 40% share has assured that a healthy number of observing hours is available to the astronomical community. Our involvement in the twin 8-metre Gemini Telescope Project has allowed Canadian astronomers access to a larger optical telescope in exchange for a reduced number of nights per year (150 nights per year on the CFHT compared to 90 nights per year on the two Gemini telescopes combined).

European astronomers have been privileged to have at their disposal a collection of four 8-metre telescopes as part of the Very Large Telescope Project. Also, European astronomers have not been shy in making it known that they have plans to develop a 100-metre optical telescope in the next 10–15 year timeframe.

Herein lies the quandary. Should Canada undertake the construction of a VLOT? If so, what aperture and at what percent of funding? A group headed by the California Institute of Technology is spearheading the construction of a 30-metre-class telescope that would complement the observations collected by the James Webb Telescope (the next-generation space telescope), in much the same way as the Keck telescopes (10-metres each) complement the Hubble Space Telescope. If Canada is to be involved in a 30-metre telescope, will we be able to afford a large enough piece of the pie to satisfy the Canadian astronomical community in terms of observing time? If not, can we really afford to be left out of the new generation of 50–100 metre telescopes? Why not join the European Southern Observatory, thus insuring access to a host of light collecting buckets?

Unfortunately, as with most things in life, all of these questions boil down to money. With sufficient funds, a perfect world would have Canada take part in the VLOT with a significant amount of observing time, while also maintaining a host of smaller optical telescopes (CFHT, DAO, etc.) to sustain a healthy balance between the different avenues of astronomical research. I don't pretend to have the answers to these important questions but strongly encourage everyone to actively participate in the decision-making process. Over the next several months and years the foundation will be laid for the next 10–50 years in Canadian ground-based optical astronomical research. Now is the time to speak up! (If only I had some of that gun registry money...)

News Notes
En Manchettes

DISK OF STARS AT THE CORE OF THE MILKY WAY

The core of our galaxy is a perilous place for a star to be born. Hidden from view by its intense gravity, a supermassive black hole is presumed to sit at the very centre of the Milky Way. Current thinking suggests that extreme tidal forces from the black hole should disrupt any nearby interstellar cloud and prevent stars from forming within 10 parsecs. However, recent high-resolution observations of the closest 0.4 parsecs of the galactic centre have revealed a cluster of young massive stars frantically orbiting the central object. But how could they have gotten there?

Yuri Levin and Andrei Beloborodov working at the Canadian Institute for Theoretical Astrophysics in Toronto have now proposed a compelling explanation (*Astrophysical Journal Letters*, June 10, 2003). Their analysis of the motion of thirteen young stars with measured three-dimensional velocities has shown that ten of them orbit in the same direction and in the same plane — much like the planets in our solar system. The remaining three stars orbit in apparently random directions and inclinations. To Levin and Beloborodov, the orientation of this disk points to a possible explanation of how these stars may have approached so close to the central black hole.

Levin and Beloborodov propose that the cluster formed from either an infalling molecular cloud or a gradual accumulation of gas drawn from the surrounding medium. The original angular momentum of the gas determined the orientation the cluster of massive stars. In a strange twist, the disk would also act like a fountain of youth. The dense disk of gas would capture older stars, and by accreting new material, the stars would become more massive and thus appear younger. The original disk of gas would eventually be accreted into the black hole or be blown away by stellar winds of the newly formed stars.

The closest star to the central black hole — designated S2 — orbits at an inclination of 75 degrees with respect to the orderly disk of stars. The two researchers propose that Lense-Thirring precession may cause this high inclination — an effect predicted by general relativity. Here the spin of the central black hole forces the orbital plane of nearby objects to rotate around the spin-axis of the black hole. Further observation of the nearest stars to the black hole should reveal the direction of the black hole's spin and confirm or refute the Lense-Thirring precession hypothesis.

MOST — READY, STEADY, AND GO

Figure 1. — Launch of ROCKOT carrying Canada's MOST satellite into orbit. Picture from www.eurockot.com.

The successful launch of the Multiple Orbit Mission (MOM), by the ROCKOT launch system, from Plesetsk Cosmodrome in Northern Russia on June 30 has seen the placement of Canada's MOST (Microvariability and Oscillations of STars) satellite safely into orbit. The multiple payload of the MOM consisted of placing eight micro- and nano-satellites, as well as a satellite simulator, into Earth-orbit.

The ROCKOT launch vehicle carried into space the Czech republic's MIMOSA spacecraft, MOST, and a whole host of nano-satellites, including the Japanese Cubesat and CUTE-1, the Canadian Can X-1, the Danish AAU Cubesat and DTUsat, and the US Quakesat. A ninth payload on the mission, a mass frequency simulator for the Russian MONITOR satellite, intentionally remained attached to the launch vehicle and will burn up during de-orbiting maneuvers. The Czech Astronomical Institute will use the MIMOSA satellite to make density measurements of the Earth's upper atmosphere. The Japanese spacecraft, Cubesat Xl and CUTE-1, are educational nano-satellites built by the University of Tokyo and the Tokyo Institute of Technology. The main scientific objectives of the CanX-1, AAU Cubesat, and DTUsat missions are star-imaging surveys.

A major milestone in the commissioning of the MOST satellite was achieved on July 24 with its successful "detumbling." Initial contact with the MOST satellite was made within a few hours of launch, and since that time engineers at the MOST Satellite Control Center have been gradually activating the satellite's subsystems by turning on and checking out the various items of equipment. All of the primary equipment on MOST has now been activated, and all items are functioning properly.

MOST was released from the launch vehicle spinning at a slow 3 degrees per second, completing one revolution every 2 minutes. At 7 a.m. local time on July 24, the Satellite Control Centre, located at the Space Flight Laboratory of the University of Toronto's Institute for Aerospace Studies in north Toronto, issued the command for MOST's attitude control subsystem to "detumble" the satellite. This is the simplest of MOST's several attitude control operating modes, using the on-board magnetometer (a 3-axis magnetic compass) and magnetic torque rods to slow down the satellite's spin rate.

At 8:30 a.m., telemetry was received from the satellite indicating that "detumbling" had been successful. MOST is now just barely spinning. With a residual rotation rate of about 0.05 degrees per second, the spacecraft now makes one complete revolution every 2 hours. The successful achievement of this milestone confirms the correct operation of much of the satellite's command and control equipment. Work is now underway towards the next milestone, which will see the activation of the satellite's active pointing control system.

The collection of science data, very precise measurements of the brightness of target stars, will proceed in early August with the completion of satellite commissioning. It is hoped that MOST will spend at least a year gathering scientific data. Up-to-date mission information can be found at `www.astro.ubc.ca/MOST/index.html`.

THE CANADIAN GALACTIC PLANE SURVEY

The Dominion Radio Astrophysical Observatory, in collaboration with an international consortium of astronomers, has now completed a high-resolution survey of the atomic hydrogen and radio-continuum emission from our Milky Way galaxy. The archived data from this survey are further being made publicly available through the Canadian Astronomy Data Centre.

Writing in the *Astronomical Journal* for June 2003, A.R. Taylor (University of Calgary) and collaborators have described the survey's aims and objectives. "Understanding the origin and evolution of galaxies is a central theme of modern astronomy," Taylor and co-authors begin their paper, and key to the understanding of how galaxies evolve is their study of the interstellar medium (ISM). Composed of a diffuse gas, the ISM, Taylor *et al.*, explain, "is a complex, dynamical medium, with structures in temperature, density, and velocity over a broad range of spatial scales." Multi-wavelength data on the major components of our Galaxies ISM make up the core of the survey. Radio telescopes have been used to map out the distribution of atomic hydrogen, magnetic fields, and the ionized and relativistic plasma regions. Millimetre wavelength observations provide data on the distribution of molecular clouds, while infrared observations map out the distribution of dust clouds and polycyclic aromatic hydrocarbons (PAHS).

The Canadian Galactic Plane Survey Web page (`cadcwww.hia.nrc.ca`) explains the data's technical organization. "The observations of 190 fields with the DRAO Synthesis Telescope are presented in thirty-eight 5 degree × 5 degree mosaics, covering Galactic longitudes from L = 74.2 to 147.3 degrees and latitudes from B = −3.5 to +5.5 degrees, with a resolution as small as 1 arcminute. For each mosaic (1024 × 1024 pixels), atomic hydrogen observations are presented as a data "cube" with 272 spectral channels having a velocity resolution of 1.3 km s−1 ... images at 1420 MHz and 408 MHz are [also] produced. Complementary images in the four infrared bands and data cubes of CO (J = 1–0) emission have also been created as part of the Survey."

METHUSELAH: OLDEST PLANET IDENTIFIED

Long before our Sun and Earth ever existed, a Jupiter-sized planet formed around a Sun-like star. Now, 13 billion years later, NASA's Hubble Space Telescope has precisely measured the mass of this farthest and oldest known planet. The ancient planet, nicknamed Methuselah by the discovery team, has had a remarkable history because it has wound up in a most unlikely and decidedly "rough" neighborhood. Indeed, it orbits a peculiar pair of burned-out stars in the crowded core of a globular star cluster.

The new Hubble findings close a decade of speculation and debate as to the true nature of this ancient world, which takes a century to complete a single orbit. The planet is 2.5 times the mass of Jupiter. Its very existence provides tantalizing evidence that the first planets were formed rapidly, within a billion years of the Big Bang, leading astronomers to conclude that planets may be very abundant in the universe.

The planet lies in the core of the ancient globular star cluster M4, located 5,600 light-years away in the constellation Scorpius. Globular clusters are deficient in heavier elements because they formed at an epoch before the heavier elements had been produced in abundance in the nuclear furnaces of stars and supernovae. Some astronomers have therefore argued that globular clusters cannot contain planets. This conclusion was bolstered in 1999 when Hubble failed to find close-orbiting "hot Jupiter"-like planets around the stars of the globular cluster 47 Tucanae. Now, it seems that astronomers were just looking in the wrong place, and that gas-giant worlds orbiting at greater distances from their parent stars could be common in globular clusters.

"Our Hubble measurement offers tantalizing evidence that planet formation processes are quite robust and efficient at making use of a small amount of heavier elements. This implies that planet formation happened very early in the universe," says Steinn Sigurdsson (Pennsylvania State University). Harvey Richer (University of British Columbia) further comments that it "is tremendously encouraging that planets are probably abundant in globular star clusters." Richer bases this observation on the fact that Methuselah was uncovered in a most unlikely place. Not only did the planet survive the gravitational interactions with its close neighbours, it is orbiting two captured stars (a helium white dwarf and a rapidly spinning neutron star) near the crowded core of a globular cluster.

The story of this planet's discovery began in 1988, when the pulsar called PSR B1620-26 was discovered in M4. The white dwarf companion to PSR B1620-26 was quickly found through its effect on the clock-like pulsar, as the two stars orbited each other twice per year. Astronomers later noticed further irregularities in the pulsar that implied that a third object was orbiting the others. This new object was suspected to be a

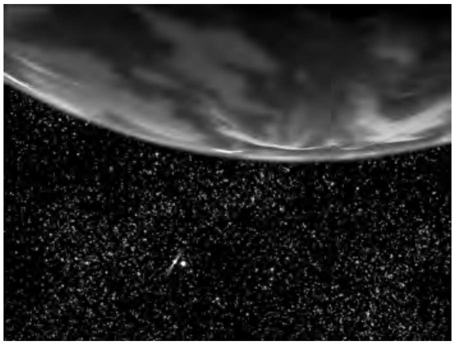

Figure 2. — A rich starry sky fills the view from an ancient gas-giant planet in the core of the globular star cluster M4, as imagined in this artist's concept. The 13-billion-year-old planet orbits a helium white dwarf star and the millisecond pulsar B1620-26, seen at lower left. The globular cluster is deficient in heavier elements for making planets, so the existence of such a world implies that planet formation may have been quite efficient and common in the early universe. Illustration courtesy of NASA and G. Bacon (STScI).

planet, but it could also have been a brown dwarf or a low-mass star. Debate over its true identity continued through the 1990s.

Sigurdsson, Richer, and their co-investigators settled the debate by measuring the planet's actual mass through some ingenious celestial detective work. Their study is based upon Hubble data obtained during the mid-1990s, taken to study white dwarf stars in M4. Sifting through these observations, they were able to detect the white dwarf orbiting the pulsar and subsequently measured its colour and temperature. Using evolutionary models computed by Brad Hansen of the University of California, Los Angeles, the astronomers estimated the white dwarf's mass. This in turn was compared to the amount of variation in the pulsar's signal, allowing the astronomers to calculate the tilt of the white dwarf's orbit as seen from Earth. When combined with the radio studies of the wobbling pulsar, this critical piece of evidence told them the tilt of the planet's orbit, too, and so the precise mass could at last be known. With a mass of only 2.5 Jupiters, the object is too small to be a star or brown dwarf, and must instead be a planet.

The planet has had a rough environmental ride over the last 13 billion years. During its formative years, the planet must have been subjected to an intense "bath" of ultraviolet radiation, and it must have been pummeled by supernova-driven shockwaves that ravaged the then young and newly forming M4 globular cluster. Around the time that multi-cellular life first appeared on Earth, the planet and parent star were plunging into the core of M4. In this densely crowded region the planet and its parent star passed close to an ancient pulsar, formed in a supernova when the cluster was younger, that had its own stellar companion. In a slow-motion gravitational dance, it is speculated, the parent star and planet were captured by the pulsar, whose original companion was ejected into space and is now lost. The pulsar, star, and planet were then flung by gravitational recoil into the less-dense, outer regions of the cluster. Eventually, as the parent star aged, it ballooned to a red giant and spilled matter onto the pulsar. The momentum carried with this matter caused the neutron star to "spin-up" and re-awaken as a millisecond pulsar. Meanwhile, the planet continued on its leisurely orbit at a distance of about 3 billion kilometres from the pair (approximately the same distance Uranus is from our Sun).

Because it formed so early on in the history of the universe, the newly discovered planet is probably deficient in elements such as carbon and oxygen. For these reasons, it is highly unlikely that the planet ever hosted life. Even if life arose on, for example, a solid moon orbiting the planet, it is unlikely to have survived the intense X-ray blasting that would have accompanied the "spin-up" of the pulsar.

Further discussion on the new planet and related links can be found at `hubblesite.org/newscenter/archive/2003/19/text`.

UNIVERSITY OF THE SKY

The University of Laval has been honored with an asteroid name. To mark the 150th anniversary of the University receiving its Royal Charter, the school's name has been bestowed to asteroid (14424) 1991 SR3. The Spacewatch telescope on Kitt Peak officially discovered asteroid Laval on the night of September 20, 1991. A previously unidentified image of the asteroid has also been found in a March 11, 1983 archive from the University of Tokyo's Kiso Observatory. A former Laval astrophysics student Yvan Dutil suggested the name while Peter and Robert Jedicke found a suitable asteroid that had yet to be named.

The asteroid is estimated to be about 9 by 22 kilometres in size, with an orbital period of 5.587 years, a semi-major axis of 3.149 AU, eccentricity of 0.116, and a rather high inclination of 21.77 degrees. Complete orbital parameters can be found at `neo.jpl.nasa.gov`, while other asteroid names with a Canadian connection can be found at `www.rasc.ca/faq/asteroids/home.htm`.

Remarks to 2003 General Assembly Delegates

by The Honourable Iona Campagnolo, PC, CM, OBC,
Lieutenant Governor of British Columbia

National President, Dr. Rajiv Gupta, Vancouver President, Mr. Bill Ronald, Organizing Committee Chair, Craig Breckenridge, Mr. Song, Society Delegates, Members of the Royal Astronomical Society of Canada, and honoured guests:

It is a signal honour to share with you in this General Assembly, particularly because as representative of Her Majesty Queen Elizabeth, the Queen of Canada, in British Columbia, I can acknowledge with respect the celebration of your hundredth anniversary of bearing the "Royal" designation, awarded to this Society by King Edward VII in 1903. I can also congratulate you on having been proudly founded in 1868, and in possession of a charter dating to 1890, so that (other than the NHL!), your organization is amongst the longest serving and surviving societies in our country.

I trust that you have all been well-welcomed by now to our "city of glass," as one of our gifted authors, Douglas Copeland, has named Vancouver, and that you are gradually adapting to our cultural imperative, requiring all to "stop and smell the roses" and to swim, sail, kayak, ski, or golf, all in one day, if so inclined, during your time with us.

With some 4,800 Members in 26 Canadian Centres your membership has over the years made significant contributions to the observational and educational dimensions of the science and art of astronomy to the public. When I typed the simple word "astronomy" into the search engine, I was ill prepared for the monumental response! It tumbled in on me, and like "Alice through the looking-glass," I was instantaneously "dropped" into your world of galaxy groups, newly discovered comets, elliptical galaxies, luminosity, variable stars, red giants, halos, nebulae, and even unexpectedly "volcanoes," to name a few of the terms that leapt from the Web pages to greet me! My trusty Toshiba laptop and I are generally joined "at the hip," so as it blinked back at me from "The sky online (for beginners)" and "Astronomy.com" and from your Society's excellent sites, I was amazed and grateful for the mass of information that speaks so well of the commitment and passion of Society members and your dedication to sharing the knowledge that you gain from your observations.

Not, I assure you, that I have been previously oblivious to astronomy! For example, my granddaughters and now my small great-grandson have long tolerated my waking them in the early morning hours of dark August nights, to bundle them into sleeping bags and onto lawn-chairs in the Comox Valley where I live, to watch the annual "celestial light-show" of the Perseid showers. This is my way of opening the world of astronomy to them; subsequent gifts of small telescopes and other incentives have made each new generation of our family at least semi-literate in the many realms of astronomy.

We customarily have had less luck with the Leonids, I confess, as our skies even in my original, northern home territory are generally lowering with low, dark clouds, winds, and heavy rain in November. Cloud-covered skies are one thing, but excessive urban light is another, and, like all of you, I look to the day when lighting our cities can be accomplished through an as-yet-to-be-discovered advanced technology that will do the job of providing appropriate security, but without the fierce "glow" that so inhibits the view of the heavens in heavily populated areas in our time. I am confident that is not beyond our capability; I can remember clearly, as I am sure can many of you of similar vintage, when our cities were swathed in thick blankets of impenetrable fog that has since been banished by new fuels, new technologies, and a new understanding of the harm caused by city-originated fog-banks. But then, as you know, Lieutenants Governor have no public opinions, no power, and at the best of times can only be said to have "influence," which is in this case slanted toward a secure and sustainable lighting system allowing us all to look beyond the glare of our own personal obstructions toward an unfettered sky.

I should perhaps remind you as a sometime "Northerner" that there are still great tracts of our nation where the skies can be easily seen. I think of the extensive Cassiar Valley that in my experience is wide open to the skies in summer and as black as only our heavy boreal forest can make it! I also expressly encourage any who have not done so to experience personally the vast expanses of Canada's three territories "north of 60," where in Yukon, North West Territories, and Nunuvut there are great expanses where you will see the wonderful Aurora

Borealis and stars so clearly drawn against the frosty skies that they guarantee an awed and admiring response from citizens and visitors alike from every corner of the earth! In everything from science to science fiction, the stars are never far from the fulcrum of study, whether Galileo or Gene Roddenberry popularizing near-technologies for use "where no one has gone before!" The romance of the stars is not lost on any of us, its science however is more closely guarded, and therefore we are all grateful to this Society for bringing ever closer the vital understanding of our place in the Universe and why the heavens must remain accessible.

That term "the heavens" is significant. It speaks of our evolution as human beings from earliest times, who have looked up to the skies and determined that it must be the home of the Gods, to which all have since personally aspired. From prehistoric Neanderthals, through the great caves of our own ancestors, through to the Egyptians, the Syrians, the Greeks, the Mayans, the Aztecs, the Inca, and the Celts, and many more, it is clear that the rudiments of your chosen field have been present throughout time. Similarly, inhabitants for more than 40,000 years of Australia, the Aborigines have encompassed the stars deep into their dreamtime myths, and in the myriad rich cultures of North America, Aboriginal Peoples have charted uncounted depictions of the stars. Here, within Canada's First Nations Peoples, who have been at home on this coast since time immemorial, in inlets, islands, and along our many great river banks, there has been created a wealth of diversity of cultures, languages, and spiritual beliefs, and all have looked to the heavens and seen the face of God to be interpreted through the wisdom of the natural world that they above all have personified.

If, like me, you have spent most of your working life in the air, subject to the tender mercies of uncounted air carriers, occasionally even in a torpor of a near-terminal jet-lag, you have yet always looked down from 30,000 feet in wonder at what most of the human continuum since the cave could only imagine. As the realms once separated from each other pass before us, as patterns of clouds evolve and change, as the great oceans and deserts pass below our silver passenger capsule, we cannot fail to be conscious of the enormity of human progress and the role that the sciences of flight and astronomy have played in the positive evolution of our lives.

When lunar-landing astronauts first sent us those remarkable photographs of our Earth as seen from the Moon, we understood, perhaps for the first time, why the late Dame Barbara Ward chose to name this tiny, vulnerable blue planet "Spaceship Earth." All 6.5 billion of us, hurtling through space in a certain orbit, remain residents of that same tiny, insignificant point of light. Our solar system locates us in the vast Milky Way Galaxy that is itself a diminutive presence in countless "billions and billions" of galaxies that the wonderful Carl Sagan so memorably imprinted on our minds. Yet we know that with our gift of human consciousness and imagination, we are empowered, perhaps even commanded, to continue to explore and to understand the seemingly ever-expanding dimensions of space.

Astronomical consciousness abounds throughout human history: Egypt's Akenaten, arguably our planet's first theist, was inspired by the Sun to the Amaran heresy, followed by the Nazca in Peru and Herodotus in North Africa. Even in spite of the persecution of Galileo by the Inquisition, there followed Michelangelo, Newton, and so many more including yourselves, who have all answered the call to the stars and have together advanced our knowledge of who we are and why we are here, through astronomy.

The telescope opened the road to the stars much more accurately and has given birth to many major advancements of our time. For example, the many satellites for both war and peace now ringing our world: can it be possible that "petite voyageur" continues its lonely quest ,"clicking its way" far beyond our Solar System to new galaxies that we cannot yet see? Giant Hubble, recovered from its "rocky" start, has opened a magnificent window onto a much "braver New World" than even Aldous Huxley might have imagined in the 1950s. As privileged members of this human family, we are compelled to look far beyond our own world and into the deeps of yesterday and the possibilities of an infinite tomorrow, all contained within the cosmos.

Canada is providing world-class leadership in many areas where our resources and expertise are taking roles in astronomical and space-sciences research. We are proud of the National Research Council work through the Herzberg Institute of Astrophysics (NRC-HIA) that manages Canada's major involvement with astronomical observatories in Hawaii and Chile, giving all of you the opportunity to explore the entire sky. As Canada's evergreen corner (our own Hawaii, particularly in February), two of Canada's own astronomical facilities are within hailing distance of this assembly. In Victoria, there is the Dominion Astrophysical Observatory and, in Penticton, the Dominion Radio Astrophysical Observatory. I hope that many of you will use your visit to this assembly to visit these sites and enjoy the beauties of B.C.'s capital city and the elegant wine country of the Okanagan. The NRC-HIA, by the way, also maintains a busy outreach and education program at its year-round interpretive Centre, modestly called the "Centre of the Universe" in Victoria.

At the Vancouver Centre in the MacMillan Planetarium you will find reference to the Centre's Canadian Amateur Research Observatory near Maple Ridge, where volunteers are using the Anthony Overton Memorial Telescope to patrol the sky for new supernovae, asteroids, and comets. Nearby is another oasis — the magnificent Maple Ridge/Ridge Meadows arts centre that I recently assisted in opening.

Canada's flag is firmly planted in such diverse disciplines as the Joint Subcommittee on Space Astronomy, the Canadian Space Agency, the Natural Sciences and Engineering Research Council, and across the great universities of our country. Global teamwork abounds, as in the "Odin" astronomy/aeronomy mission with Sweden, France, and Finland, or with the Japanese or Russian led initiatives in high orbit and space borne elements to provide imaging of intense radio sources seeking heretofore-unknown stellar phenomena. This General Assembly is being addressed by numbers of those, including great Canadians of proven expertise and international reputations, who are carving a new pathway to the stars for an anxious world.

While we are blessed with great and learned professionals, however, we cannot afford to ignore the enormous contribution to the body of knowledge made by the many gifted amateur astronomers in our midst. The educational value of amateurs' contribution to this science has been a key component in the establishment of numbers of Canadian planetaria and observatories as well as in numerous discoveries and adjunct supports of the professionals.

Your Society membership is also to be commended on its vigour and participation in its regular contributions across the gamut of astronomical phenomena. The many volunteers who enrich this Society make a special contribution to excellence in their chosen avocation through their work. I have seen similar enthusiasm for astronomy even in distant and deprived parts of our world, and while there, wondered as all of us do at the changes in the night sky as you shift continents and hemispheres and seasons.

Yet all of us are heartened by viewing the same sky that enchanted and guided even our most distant ancestors. The same heavens that inspired the earliest spiritual beliefs in something greater than just ourselves also guided the wise men to Jerusalem, the terrible armies of Alexander, Genghis Khan, Attila, and Napoleon, the Vikings to Newfoundland, and Vasco da Gama down the coast of Africa. Sir Francis Drake and his "brothers in arms" set sail confidently guided by the stars, as did John Cabot to New France and Captain Cook to our own coast, where for some 10,000 years before him the great coastal canoes of First Nations had held sway from Alaska to Baja. This procession of humanity stretches all the way to Neil Armstrong, proving that throughout human history astronomy has added to the sum total of our knowledge about who we are and where we are placed in the Universe.

Who among us who were alive at the time can ever forget the global excitement of July 20th, 1969 when, after four days of travel, Armstrong and Edwin Aldrin flew the Eagle Lunar Module from the Spacecraft Columbia, commanded by Michael Collins, onto the relatively flat and unobstructed Tranquility Base on the Moon? When that famous "Eagle landed," our human spirits "soared" and ,I suspect, many a member of your Society and many who were yet to be born were inspired in their determination to add to the sum total of human knowledge in the most extraordinary challenge to human endeavour of viewing ourselves within a cosmic concept.

On behalf of Her Majesty, Queen Elizabeth, the Queen of Canada, it is my honour to bring you all the greetings of all the citizens of British Columbia, to wish you an excellent experience of this General Assembly, and to thank you for your contribution to improving our knowledge not only of the world that we currently inhabit, but of the possibilities of worlds that are yet to come, where we might finally learn to honour our descendants in the same manner that most of our cultures have customarily honoured our ancestors!

What's in a Name?[1]

by Peter Broughton (pbroughton@3web.net)

Abstract

This year we celebrate the centenary of two parts of our name — "Royal" and "of Canada." The other parts are much older — "Astronomical" dates back to 1868 and "Society" to 1869. Bold optimism, strong leadership, and plans for a Dominion Observatory in Ottawa propelled the organization to seek a national mandate. Many factors, including the precedent of the Royal Society of Canada being established in 1882 by the Governor General, and a Royal Visit in 1901 influenced the wish for a royal cachet. This privilege was granted to our Society by His Majesty King Edward VII in early 1903.

The people and circumstances contributing to this significant milestone will be described as will other important events in Canadian astronomy about the same time. Subsequent developments in the Society's history will be considered briefly as evidence that we have lived up to the aspirations of a century ago.

1. Introduction

Your Honour, may I say what a real thrill it is for all of us that you, as Her Majesty's representative in British Columbia, are here with us to celebrate our centenary as a "royal" Society. From your comments it is clear that you are very much in tune with us. I wish to begin by referring to a couple of letters in our Society archives. They were written by your predecessor of one hundred years ago. In 1902, when these letters were written, Sir Henri-Gustave Joly de Lotbinière was the Lieutenant Governor of British Columbia, and the recipient, Arthur Harvey, was the Past President of our astronomical Society. As the letters show, both were visionaries in advocating the metric system. It is very gratifying to hear your Honour today showing similar foresight in promoting the preservation of dark skies for the enjoyment of future generations.

2. The Society 1868–1903

This year we celebrate the centenary of two parts of our name — "Royal" and "of Canada." The other parts are much older — "Astronomical" dates back to 1868 and the "Society" to 1869. While our organization is almost as old as the country itself, it was at first only a local group called The Toronto Astronomical Club. As a Torontonian I will never understand why my fair city is not always loved by the rest of the country, but I must admit that if our Society had retained its original name we would not be here celebrating the achievements of a highly respected national organization of 4700 members. In 1890 it formally organized as an Ontario corporation, "The Astronomical and Physical Society of Toronto," and started publications. Because this marked our beginning as a legal entity, we consider 1890 the date of the founding of our Society, and indeed we celebrated our centenary 13 years ago at the General Assembly in Ottawa. Incidentally, there was some controversy about that founding name "The Astronomical and Physical Society of Toronto," and it was not the "Toronto" part that gave offence. It was the word "physical" that upset the Victorian sensibilities of the wife of the President in 1900, George Lumsden. Mrs. Lumsden was mortified that her husband was associated with an organization that had such a vulgar word as "physical" in its name and wanted to see that part dropped. Some of us may not be surprised that

George Lumsden

Mrs. Lumsden did get her way. The offending word was expunged, and for a short time the Society reverted to its former name, The Toronto Astronomical Society.

3. Becoming Royal

Many factors influenced the desire of the members to become a royal society. There had been Canadian precedents of regiments, colleges, banks, and so on, but perhaps the most relevant was the Royal Society of Canada, which was founded in 1882 by the Marquis of Lorne, Canada's fourth Governor General. Unlike our own Society, this is an elite body with a limited and distinguished membership. One of its divisions does deal with science and aims to advance learning and research in Canada just as we do, though our approach is quite different. In spite of the fact that the astronomical society was open to anyone, it did manage to attract some prestigious members. Between 1890 and 1903, three of the astronomical Society's presidents were Fellows of the Royal

[1] An invited talk at the General Assembly of the RASC in recognition of the 100th anniversary of the Society's Royal designation June 28, 2003.

Society of Canada, and two were Fellows of the Royal Astronomical Society (in England). So it would be surprising if the membership of former presidents in these august royal societies did not make the prospect of a royal astronomical society in Canada seem more plausible not only in their eyes but also in the minds of those to whom application was made.

Of course many Canadians, because of their roots, felt a strong attachment to Britain. The meeting of the British Association for the Advancement of Science in Toronto in 1897, the same year as Queen Victoria's diamond jubilee, was an indication that scientific links overseas were strong. Queen Victoria's death early in 1901 was deeply felt. The royal visit to Canada later the same year by the Duke and Duchess of York (later King George V and Queen Mary) was wildly acclaimed, and then there was the coronation of Edward VII in 1902 with its *Pomp and Circumstance*. All these events brought the idea of royal affiliation to the fore.

Also important was the fact that the civil servant who shepherded the application through the proper channels was a member of our Society, Joseph Pope. He had served in the Conservative government as Sir John A. Macdonald's private secretary for many years and later wrote a two-volume biography of him. In 1902 he was Under-secretary of State in the Liberal Laurier government. The fact that he was highly valued by both political parties says a lot about his qualities. In Pope's autobiography, we read that he was attracted to astronomy when he was in his teens. He joined the Society in 1901 and later was one of the few chosen by the government to be part of the solar eclipse expedition of 1905 to Labrador. (Unfortunately, the day of the eclipse was cloudy.)

4. The Royal Petition

Joseph Pope made no mention of the Society's name change in his diary, but he did note that he came to Toronto on January 5, 1903 and "had a chat on various subjects with Lumsden." George Lumsden was not only Past-President of the Society;

R.F. Stupart

he was Provincial Secretary. So it would not be surprising if the two high-ranking civil servants had official business to discuss. However, it seems to me more than coincidence that only two days later the Society President R.F. Stupart signed his name to these quaint words addressed to the Governor General of Canada (the Earl of Minto):

> 7 January, 1903:
>
> Your petitioner having decided to change its name to that of The Astronomical Society of Canada has instructed its Council to solicit from His Majesty the King the privilege of prefixing to that new name the word "Royal"; for your Petitioner believes that such gracious permission would strongly stimulate its efforts in the promotion and diffusion of Astronomical Science and that its influence in this direction would be greatly extended thereby throughout His Majesty's Dominions.
>
> Your petitioner therefore prays that Your Excellency may be pleased to lay at the foot of the Throne this its humble prayer for the privilege of prefixing the word "Royal" to its name, and your Petitioner as in duty bound will ever pray.

The petition was supported with ten paragraphs of background and explanation in which were outlined the reasons why it was thought that the Society was worthy of the honour. The official reply came less than two months later:

> OTTAWA, 27th February, 1903
>
> Sir,
> Referring to the recent petition...,
> I have now the honour to inform you that the Governor General has received a despatch from the Secretary of State for the Colonies acquainting His Excellency that His Majesty the King has been graciously pleased to grant permission to the Toronto Astronomical Society to adopt the title of the Royal Astronomical Society of Canada.
>
> I have the honour to be, Sir,
> Your obedient servant,
> JOSEPH POPE
> Under-secretary of State

Joseph Pope

Of course, since the Society was an incorporated body, it then had to apply to the Ontario courts to have its name legally changed. The Chief Justice agreed to this on March 3, 1903.

5. Events of the Early 1900s

In considering the steps that led the

Society to adopt a new name, we should consider the scientific, political, and social context. Canadian professional astronomers had very practical work to do, as the following news item from 1900 implies.

OVER A LONG WIRE

Delicate Operation Being Conducted By Two Canadian Astronomers.

> Ottawa, Aug. 23. — Astronomers Klotz and King are at present engaged on the determination of the longitude of Vancouver. The astronomic clocks beat at the same time for a few minutes each night over the 3,000 mile circuit, and record automatically at the two observatories, Mr. Klotz being in Ottawa and Mr. W.F. King in Vancouver.

The longitude of Vancouver would have been an essential step in the Alaska boundary survey and in the laying of the transpacific cable, both of which were completed in 1903 and which were projects that preoccupied the astronomers. It was the Canadian amateurs who, in 1901, saw nova Persei blaze forth half a magnitude brighter than Capella and watched it carefully as it faded gradually in the succeeding months. One of them even studied the nova's changing spectrum. The brightest comet in nineteen years also attracted attention in May, 1901. These spectacular events undoubtedly aroused public interest in astronomy and may have emboldened those in the Society to broaden its mandate.

Politically, the fact that our Society became "Royal" and "Canadian" in 1903 is no coincidence. Strong monarchist tendencies and nationalism were powerful forces in the land at the time. That both could hold sway simultaneously may seem contradictory to those who think that ties to the monarchy are a throwback to our colonial roots and are therefore antithetical to the development of a nation state. But, in the early twentieth century, ties to Britain were seen as the best bulwark against the manifest destiny of the United States.

Canada's strong role in the British Empire was evident in imperial preferential tariffs introduced in the 1890s, in its enthusiastic support of the South African War, 1899–1902, and its prominent role in the transpacific cable, which linked us with Australia and New Zealand in 1903. Canadian nationalism was fuelled by a mood of self-confidence. The economy in the early 1900s was booming, and optimism was a characteristic of the time. It was in January, 1904, that Prime Minister Sir Wilfrid Laurier, reputedly said that the twentieth century would belong to Canada. Though historians have found no evidence that he ever uttered those words, the fact is that they capture the essence of Laurier and the times so well as to account for this legendary quote.

Laurier was ultimately responsible for providing the funding for Canada's first national observatory, the Dominion Observatory in Ottawa. It opened in 1905, and almost at once the astronomers recognized that the establishment of an astronomical society in Ottawa was important. They did not want to be a mere appendix to a Toronto group, even with the grand name of the Royal Astronomical Society of Canada. The degree of autonomy which Centres enjoy can be traced back to the concessions that the Ottawa group won back then.

6. Broadening the Society to Embrace All of Canada

The optimism felt in Canada generally was also apparent in the Society itself. Arthur Harvey noted in the Transactions for 1901:

> Our society, which began its course only twelve years ago, with a small membership, no meeting place except private houses, without an instrument or a single book, but which now has several fine instruments for our members' use, and a library of some 1000 astronomical and physical works, cannot but feel grateful to our sister societies and the government institutions which have liberally given us much in return for our little.

Another tangible indication of its optimism and confidence was the list of 28 distinguished Honorary and Corresponding members, mainly from overseas and the United States, whose names lent prestige to the young Society. The fact that a fledgling society would elicit the support of some of the most famous astronomers in the world is quite astonishing.

There was certainly a desire to expand the Society's sphere beyond Toronto but little knowledge of how to go about it. For a time, the most national aspect of the Society was its name! In 1903 there was only one representative on the governing Council from outside Toronto (D.B. Marsh from Hamilton) and no local Centres. There were a few regular members from outside Toronto, but only two from western Canada — G.A.F. Rayland of Battleford, N.W.T. (as it was then) and J.M. Burns of Vancouver. (There had been a member in Vancouver even earlier, Robert B. Ellis from 1894–99.) I am sorry that I know nothing about these people — perhaps someone in the audience will know or would like to find out who these early Society members were — 28 years before Vancouver gathered enough members to form a Centre of the RASC.

Although the Society's name became national in scope in 1903, a first step to broaden the Society's governance was not taken until February, 1906 by amending the Bylaws to include "other Vice-presidents living outside...Ontario, when deemed desirable by the Society." In September of that year the minutes record:

> The view was generally expressed that the objects of the Society might be better served and a more general interest in astronomy stimulated by the establishment of local branches in each province of the Dominion.... Dr. Chant and the

> Secretary were appointed a committee to consult...as to the best means of proceeding in the matter and report at the next council meeting.

Finally, at the annual meeting held in January, 1907, a committee was appointed to revise the Society's constitution. Two weeks later agreement was reached that the name of the publication should be *The Journal of the Royal Astronomical Society of Canada* — the name that it still carries. But the bylaws were not amended to reflect the national character of the Society until January, 1908 — nearly five years after the name change. The success of our current system of local Centres, as they are called, resulted from those changes in the Bylaws.

7. Have We Lived Up to Our Name?

Over the last century having "Royal" in our name has induced many, especially those outside our ranks, to attribute to us a certain patina of prestige which we insiders would have to admit is not quite justified. Perhaps the Society is a bit like the second Premier of this province — a colourful figure (as British Columbian Premiers sometimes are) with a great name. Originally he was William Alexander Smith but legally changed his name to one that we in this Society can all relate to — Amor de Cosmos. He justified this by saying, "its meaning tells what I love most, viz: love of order, beauty, the world, the universe." In case you have not heard of Amor de Cosmos, I can do no better than to use the words of historian George Woodcock, who said de Cosmos set himself three goals which he eventually won: "the union of the two Crown Colonies of Vancouver Island and British Columbia, the entry of the united British Columbia into Canada, and the achievement of responsible government in the Pacific province." Perhaps we RASCals who feel misunderstood by mainstream society as we endure freezing cold, hordes of mosquitoes, and sleepless nights to enjoy the splendour of the night sky, or like myself as I delight in untold hours researching the past, also feel a bond with Amor de Cosmos because of his unique character. He was described by one of his associates in a wonderful phrase as having "all the eccentricities of a comet without any of its brilliance."

Well, this is not the day to be self-effacing. Let us take a few moments to look back at the list Stupart provided in 1903 to see what has developed from some of those points he proclaimed as evidence of the Society's worthiness:

> *Encouragement of research and original work and regular publication of Transactions for distribution to members and scientific bodies throughout the world*

Our handbook was not even dreamt of in 1903, and our *Journal* coming out six times a year is a big advance over the old volumes that came out only once a year. The progress we made in publishing truly scientific work peaked some years ago. Some would say that aspect of our work became outdated.

> *Formation in Canada of affiliated societies with similar aims*

Twenty-seven Centres in every province is a huge accomplishment!

> *A steadily increasing library to which the general public may refer*

We still have a fine historical library — some of the collection was already in the Society in 1903. Is it an anachronism or can we make some of it a Web-based resource?

> *Acquisition of telescopes and other instruments*

Such equipment is in the hands of the Centres, where it belongs.

> *A list of distinguished scientific men who have accepted Honorary and Corresponding fellowship in the Society*

We still maintain a list of 15 Honorary members who lend prestige to the Society.

> *Fortnightly meetings at which papers are read and discussed, outdoor meetings and public lectures*

How many RASC meetings per year are there across the country now, I wonder? Hundreds, for sure!

So our old Society is doing quite well, and of course there are many things the Society now does which were not dreamt of in 1903. To outline them would take at least another hour. What's in a name? Quite a lot I would say!

Peter Broughton is a former RASC President and author of the Society's history, Looking Up. *He was very honoured to be asked to speak on such an illustrious occasion.*

Starburst in a Distant Quasar

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

When we look out into the Universe we look backwards in time. We see the Moon as it was about 1.25 seconds ago, the Sun as it was about 8 minutes ago, the nearest stars a few 10s of years ago, and the most distant galaxies as they were more than 10 billion years ago. The time in the Universe when the first stars and galaxies were formed has been relatively unexplored in part because of the distance of those galaxies — even the largest are tiny and faint — and in part because it has been difficult to know what to look for. Fabian Walter of the National Radio Astronomy Observatory in New Mexico and his collaborators around the world have just found the signature of lots of dense star-forming gas associated with a quasar at a redshift of 6.42 — when the Universe was less than a billion years old (see July 24 issue of *Nature*). Coincidentally, this quasar (SDSS J1148+5251) was featured in the News Notes section of the June 2003 issue of the *JRASC* (page 118).

Twenty-five years ago it was expected that young elliptical galaxies formed in one rapid and massive burst of star formation that lasted less than a hundred million years. The spherical bulges of spiral galaxies were believed to have formed similarly, but something prevented a large fraction of the gas from being converted rapidly to stars; this gas collapsed to a disk, and eventually spiral arms emerged. As models of galaxy formation become more sophisticated and observations probe farther back in time, astronomers have come to understand that this simplistic view probably is quite wrong.

Things started to change when data from the InfraRed Astronomical Satellite (IRAS) satellite revealed in the mid-1980s a population of galaxies undergoing collisions, mergers, and bursts of star formation. During the 1990s the model of "hierarchical accretion" became the dominant picture of galaxy formation: in this framework small protogalaxies combine over time to make bigger ones, analogous to the formation of planets in the Solar System from planetesimals. Hierarchical accretion explains the general lack of giant high-redshift galaxies but has run into trouble with the number of very luminous high-redshift quasars found recently by the Sloan Digital Sky Survey.

Quasars are powered by gas falling into supermassive black holes at the centres of galaxies. The conversion of gravitational potential energy into radiation under such conditions is far more efficient than nuclear fusion, which allows some quasars to emit more light than the rest of the host galaxy. There is a rough relationship between the mass of the black hole and the mass of the galaxy — in general, the black hole has one or two percent of the galaxy mass. Broadly speaking, the more massive the black hole, the brighter the quasar, assuming of course that it hasn't been starved of fuel to feed it.

Walter and his collaborators used the Very Large Array in New Mexico and the IRAM Plateau de Bure interferometer in southwestern France to detect emission lines from carbon monoxide molecules in the gas of the host galaxy surrounding the quasar. Not counting the ionized plasma, gas in normal galaxies comes in two varieties, atomic hydrogen with a temperature of about 100 K and molecular hydrogen with a temperature of about 10 K. The atomic gas is rather diffuse, and before the discovery of molecular hydrogen (in 1970) it was a mystery how stars could form from it — it simply doesn't get cold enough or dense enough to form stars except under very unusual conditions. Yet it is obvious that stars are forming in places like the Orion Nebula. The real breakthrough came when Phil Solomon (now at Stony Brook) realized that the bulk of the gas forming stars must be in molecular form. Molecular hydrogen (H_2) is hard to track down, though — it does not radiate efficiently at radio wavelengths. Solomon realized that certain molecules like carbon monoxide should be very important in determining the temperatures of the molecular clouds, as well as tracing their presence. Arno Penzias and Bob Wilson (of the cosmic microwave background fame) looked for and found CO associated with the Orion Nebula. The gas that forms new stars had finally been found.

Getting back to the IRAS galaxies, they had lots of molecular gas, and, based upon the infrared emission from dust that had been heated by massive new stars, they were estimated to be turning 1000 solar masses of gas into new stars each year! By comparison, our Milky Way galaxy converts only about one solar mass of gas into stars in a year. Searches for CO emission from quasars in the 1990s showed that some of them indeed had lots of molecular gas, and now Walter has found 20 billion solar masses of molecular hydrogen in the most distant quasar known. This huge amount of gas, along with the infrared emission previously seen, indicates that lots of stars are being formed in a massive galaxy at a very early time. This galaxy looks like the ultra-luminous infrared galaxies known in the more local Universe, but it may be surprising to see the same type of galaxy only 800 million years after the Big Bang.

How this fits into the bigger picture of early galaxy formation is not yet clear. Astronomers are searching for more distant quasars (and one galaxy with a higher redshift already is known) in order to build up a meaningful sample because it is hard (and often somewhat irresponsible) to draw general conclusions from a sample of one. But anytime you get new information on a most-distant source it's exciting!

Walter's observation was technically very challenging for the VLA and PdB interferometers because of the extreme distance to the galaxy, but the Atacama Large Millimeter-wave Array (ALMA) planned for Chile (construction should start later this year) should be able to detect CO emission that is much fainter (either from less gas or a greater distance). When ALMA comes fully online 8-10 years from now it will change our understanding of the early Universe at least as much as the Hubble Space Telescope and Keck telescopes have done.

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.*

Reflections

Meteor Showers and Comets

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

In recent years, both professional and amateur astronomers have shown tremendous interest in the Leonid meteor shower that takes place in mid-November. Like other meteor showers, this occurs when the Earth passes through a concentration of fine debris left by a comet along and around an orbit that passes very close to Earth's orbit. Unlike other such showers, the Leonids show a long-term periodicity associated with the time it takes the parent comet (55P/Tempel-Tuttle, in this case) to complete one orbit. As a result, intense Leonid storms only take place about every 33 years, giving every Earthling about two opportunities in a lifetime to observe one. However, the concentration of the stream is so narrow, one has to be at just the right longitude on Earth to see the peak of the shower in any given storm. People have been known to travel long distances to improve their chances of observing the Leonids. This November marks the 170th anniversary of an important Leonid storm observed in North America on the morning of November 13, 1833.

Prior to the 19th century, very little was known about meteors and meteor showers, although there is plenty of historical evidence that these events were noticed back to antiquity. Chinese and other records indicate that the Perseids were observed as early as AD 36, the Lyrids back to 687 BC, and the Leonids at least to AD 1002. Records also indicate that some showers that are weak today were much more prominent in the past, and vice versa. In the Middle Ages, the Taurids may have been as plentiful as the Perseids are today, and the Quadrantids were effectively non-existent. Simon Newcomb, writing 100 years ago in his book *Astronomy for Everybody*, remarks on the prominence of the Andromedid Shower, which is no longer seen today. The *Observer's Handbook 2003* lists the current prominent meteor showers on page 223.

In the 18th century, Halley, Chladni, and others argued that meteors had cosmic (*i.e.* extra-terrestrial) origins. Simultaneous visual measurements of meteors from different locations on Earth proved that the meteoric events took place in the

Figure 1. — A fanciful depiction of the Leonid storm of 1833.

Figure 2. — Simon Spivey of Lakefield, Ontario captured 7 Leonids on film in 5 minutes on November 18, 2001.

upper atmosphere, about 100 kilometres up. On November 27, 1872, an intense meteor shower was seen to emerge from the constellation Andromeda, and it was deduced that the material for this shower was the leftovers from Comet 3D/Biela, which earlier had broken into two parts and eventually disappeared (hence the "D" designation).

It was the spectacular Leonid meteor storm of November 13, 1833 that kick-started the scientific study of meteors and meteor showers. Many observers in North America reported the storm, and Prof. Denison Olmsted of Yale College gathered and published these data. The fact that all the meteors appeared to radiate from a point in the sky, and that the radiant was fixed relative to the stars in the constellation Leo, was highly indicative of cosmic origin. The next year, observations of the August Perseid meteors also indicated a fixed radiant and a cosmic origin. The scientists of the day were beginning to realize what the ordinary country folk already knew: every summer, the sky fills with "St. Lawrence's Tears" at about the time of that saint's August 10 festival.

In the 1860s, another Yale professor, Hubert Newton, with his student Josiah Gibbs, analyzed historical records to reveal that several meteor showers repeat with a period associated with the sidereal year (the motion of the Sun against the stars). This is consistent with a model of meteoric material in distinct orbits around the Sun, intersected by the Earth once a year. The Perseids and other showers give regular annual displays owing to the even distribution of meteoric particles along the orbits, while the 33 years between Leonid storms is caused by a "clumping" of material in one spot, the clump slowly travelling around the orbit. Newton's analysis successfully predicted the Leonid storm of November 13, 1866. Experts in orbital mechanics, such as John Couch Adams (the British astronomer famous for predicting the location of Neptune from anomalies in the position of Uranus), worked out the gravitational effects of Jupiter, Saturn, and Uranus on the orbit of the Leonid swarm, and were able to explain details of the Leonid shower's waxing and waning.

By this time it was noticed that the orbits of the fine material responsible for meteor showers had similarities to short-period cometary orbits: elliptical orbits of high eccentricity. Hubert Newton, Olmsted, and other astronomers had speculated on the connection between comets and meteors. Daniel Kirkwood finally proposed the currently accepted theory in 1861: meteor showers are the leftovers of old comets that have expired and fallen apart. This theory was soon validated by the history of Comet 3D/Biela and the Andromedid meteors, already mentioned. The identification of meteor showers with particular comets followed from orbit analysis: Schiaparelli (infamous for reporting canali on Mars) associated the Perseids with comet 109P/Swift-Tuttle. The Leonids were found to belong to comet 55P/Tempel-Tuttle. Austrian astronomer Edmund Weiss actually predicted the Andromedid shower of November 27, 1872 associated with Biela's Comet, and also worked out that the April Lyrid shower is associated with C/Thatcher (1861 I).

In recent years, analysis of the Leonid swarm has made several advances. The stream of meteors has been sub-divided into smaller streams associated with historical passages of the parent comet. One sees reference to the "1767 stream," the "1866 stream," the "1699 stream," and so on. Leonid showers of recent years (more precisely, peaks within showers) have been linked to particular streams. There are two reigning teams of Leonid forecasters: (1) Esko Lyytinen (Finland) and Thomas Van Falndern (USA), and (2) David Asher (UK) and Robert McNaught (Australia). A good summary of their work appears in the November 2002 issue of *Sky&Telescope*.

Gary Kronk has an excellent Web site on the history of the Leonid meteors: `comets.amsmeteors.org/meteors/showers/leonidhis.html`.

The forecasts for the Leonids are not that promising: gravitational perturbations by Jupiter will alter the meteor stream and it may be some time before fine meteor storms are seen again. One thing for sure: the Solar System is far from being a boring place to live!

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

REVIEW OF THE SOCIETY'S WORK BY THE PRESIDENT

The beginning of 1908 marked the completion of the eighteenth year in the history of this Society as an incorporated body. From March, 1890, until May, 1900, it was known as The Astronomical and Physical Society of Toronto, when its name was changed to that of The Toronto Astronomical Society, and three years later, to that which it now bears.

With the opening of the present year a fresh start is made, as the Society begins its work under a new constitution.

As astronomical organizations were being formed at various centres throughout the Dominion steps were taken, during the Presidency of my predecessor, towards the consolidation of these centres under the charter of The Royal Astronomical Society of Canada, thus giving to the Society a national character. This movement received the generous support of the Dominion Government, and I am pleased to say that a constitution has been framed which is acceptable to all; and a future of increasing membership, and of a wider usefulness is confidently anticipated.

by W. Balfour Musson,
from *Journal*, Vol. 3, pp. 1, January–February, 1909.

Research Papers
Articles de recherche

ABSTRACTS OF PAPERS PRESENTED AT THE 2003 CASCA ANNUAL MEETING HELD AT THE UNIVERSITY OF WATERLOO IN WATERLOO, ONTARIO, JUNE 1–3, 2003

Oral Papers/Les présentations orales

Photon Propagation Near Rapidly Rotating Neutron Stars, Sheldon Campbell and Sharon Morsink, University of Alberta

In general relativity, strong gravitational fields and rapid rotation generate a number of observable effects, including gravitational lensing and frame dragging. I will present new results of a code which traces the paths of photons that are emitted from a rapidly rotating neutron star and detected by an observer at infinity. Phenomenologically, the spacetime about an isolated rapidly rotating neutron star is that generated by a stationary rigidly rotating perfect fluid whose stress-energy tensor is dependant on the equation of state for the stellar matter. Assuming black body emission, the results include dependance of the signal's flux on the star's luminosity, mass, spin, and equation of state. These results have the potential to introduce new constraints on equations of state if the thermal spectrum of a rapidly rotating neutron star is observed.

Corkscrew Jets, David Clarke, Institute for Computational Astrophysics/Saint Mary's University, Rachid Ouyed, University of Calgary, and Ralph Pudritz, McMaster University

I will present results from 3-D MHD simulations in which a proto-stellar jet is launched from a thin, rotating Keplerian disc (maintained as a boundary condition) threaded with an initially uniform axial magnetic field. As the magnetic field is twisted by the rotating disc, an Alfven wave is launched from the disc into the hydrostatic atmosphere, launching a jet in its wake. Initially, this outflow behaves just as observed in the 2-D simulations of Ouyed and Pudritz (1997, *ApJ*, 484, 974), but when the perturbations applied to the disc are able to penetrate the computational domain, Kelvin-Helmholtz instabilities start to dominate the structure of the jet. Initially, all K-H modes are present, but again in time, the $m = 1$ mode dominates and the jet adopts a helical "corkscrew" structure whose pitch and radius is determined by a robust balance between magnetic stresses and the radial momentum imparted by the instability.

A full account of this and related simulations can be found in Ouyed, Clarke, and Pudritz, 2003, *ApJ*, 582, 292.

Splendors and Misery of Massive Stars in Starbursts, Laurent Drissen, Université Laval

Despite their small numbers and very short lifetimes, massive stars play a very important role in galaxies. Not only do they ionize their surroundings, but they inject huge amounts of energy and momentum in the interstellar medium and contribute to the metal enrichment of galaxies. I will review our understanding of the role massive stars play in the local universe, and in particular in starburst clusters and galaxies, and will outline some future research on this subject.

Asteroseismology: Matching Modes to Models, David Guenther, Saint Mary's University, and Kevin I.T. Brown, University of Western Ontario

The MOST satellite (P.I., Matthews, U.B.C.), scheduled for launch by the end of June 2003, will observe nonradial oscillations on stars, with the hope that the oscillation data can be used to study the physics of stellar interiors, such as convection, magnetic cycles, and chemical diffusion. Initially, though, the observations will be used to constrain the radii, compositions and ages of stars. In order to achieve these goals, the oscillation spectrum must be matched to the oscillation spectra of stellar models. To date, no systematic strategy has been devised to carry out and, more importantly, quantify the match so that an uncertainty analysis can be preformed. We describe a new strategy to match a set of low-degree nonradial oscillation frequencies to a stellar model. The method provides a measure of the quality of fit. We show applications of the method to the Sun and to recently published oscillation data for several stars.

This research was supported in part by an NSERC grant to DBG. The computations were carried out on Saint Mary's University's High Performance Computer, a component of the new Institute for Computational Astrophysics.

Dynamical Studies of Globular Clusters in Early-Type Galaxies Using Gemini G-MOS, Dave Hanes, Queen's University, Terry Bridges, Anglo-Australian Observatory, Ray Sharples, University of Durham, Karl Gebhardt, University of Texas, Duncan Forbes and Mike Beasley, Swinburne University of Technology, Steve Zepf, Michigan State University, Juan Forte, Instituto de Astronomia y Física del Espacio, and Favio Feifer, Observartorio Astronomico de la Plata

In a continuing campaign using the GMOS instruments on Gemini North and Gemini South, we are aggressively obtaining large samples of globular cluster spectra in order to study their host galaxies' dark halo profiles, orbital structure and the ages and abundances of the globular clusters. Our goal is to acquire spectra for about 200 globular clusters each around a variety of luminous early-type galaxies. Their velocities will be combined with stellar kinematics and x-ray data to provide a detailed picture of the current dynamical state of the galaxies. We will use our high-quality spectra to measure cluster ages and abundances, providing additional insights into the evolutionary history of the clusters and their hosts.

All galaxies have or will have supporting observations from deep long-slit absorption-line studies. In the end, we will develop a comprehensive picture for early-type galaxy evolution and the best comparison to extant theoretical models. In this presentation, I will describe our experiences of and the promise provided by the new GMOS instruments at the Gemini telescopes in ambitious studies of this sort.

Results from the Red-Sequence Cluster Survey, Henk Hoekstra, Canadian Institute of Theoretical Astrophysics, Howard Yee, University of Toronto, and Mike Gladders, Carnegie Observatories

I will present some recent lensing results based on the completed Red-Sequence Cluster Survey (RCS). Some of the topics that will be discussed are measurements of cosmological parameters, galaxy biasing and the properties of dark matter halos surrounding galaxies. I will also briefly discuss what we can expect from the RCS2, a 1000 square degree cluster survey, and the CFHTLS, which have both started recently.

The Galactic Inner Halo: Searching for White Dwarfs and Measuring the Fundamental Galactic Constant, Vo/Ro, Jasonjot Kalirai and Harvey B. Richer, University of British Columbia, Brad M. Hansen, University of California at Los Angeles, Peter B. Stetson, Herzberg Institute of Astrophysics, Michael M. Shara, American Museum of Natural History, Ivo Saviane, European Southern Observatory, R. Michael Rich, University of California at Los Angeles, Marco Limongi, Osservatorio Astronomico di Roma, Rodrigo Ibata, Observatoire de Strasbourg, Brad K. Gibson, University of Swinburne, Gregory G. Fahlman, Herzberg Institute of Astrophysics, and James Brewer, University of British Columbia

We establish an extragalactic, zero-motion frame of reference within the deepest optical image of a globular star cluster, a Hubble Space Telescope (HST) 123-orbit exposure of M4 (GO 8679, cycle 9). The line of sight beyond M4 (l, b = 351°, 16°) intersects the inner halo (spheroid) of our Galaxy at a tangent-point distance of 7.6 kpc (for Ro = 8 kpc). The main sequence of this population can be clearly seen on the colour-magnitude diagram (CMD) below the M4 main sequence. We isolate these spheroid stars from the cluster on the basis of their proper motions over the 6-year baseline between these observations and others made at a previous epoch with HST (GO 5461, cycle 4). Distant background galaxies are also found on the same sight line by using image-morphology techniques. This fixed reference frame allows us to determine an independent measurement of the fundamental Galactic constant, Vo/Ro = 25.3 ± 2.4 km s^{-1} kpc^{-1}, thus providing a velocity of the Local Standard of Rest, v = 202.7 ± 22.7 km s^{-1} for Ro = 8.0 ± 0.5 kpc. Secondly, the galaxies allow a direct measurement of M4's absolute proper motion, μ_{total} = 22.57 ± 0.67 mas yr^{-1}, in excellent agreement with recent studies. The clear separation of galaxies from stars in these deep data also allow us to search for inner-halo white dwarfs. We model the conventional Galactic contributions of white dwarfs along our line of sight and predict 7.9 (thin disk), 6.3 (thick disk), and 2.2 (spheroid) objects to the limiting magnitude at which we can clearly delineate stars from galaxies (V ~ 29). An additional 2.5 objects are expected from a 20% white dwarf dark halo consisting of 0.5 solar mass objects, 70% of which are of the DA type. After considering the kinematics and morphology of the objects in our data set, we find the number of white dwarfs to be consistent with the predictions for each of the conventional populations. However, we do not find any evidence for dark halo white dwarfs.

Fast Stars and Shy Neighbors: Results from a New Proper Motion Survey of the Northern Sky, Sebastien Lepine, American Museum of Natural History

I present exciting results from a new survey for stars with large proper motions, based on a re-analysis of the Palomar Sky Surveys with the ultra-efficient SUPERBLINK software. With over 400,000 confirmed high-proper-motion stars, the new survey constitutes a major improvement over previous proper-motion catalogs. Intensive, follow-up spectroscopic observations of thousands of selected high-proper-motion stars reveals the existence of a local population of faint halo dwarfs and subdwarfs, shows a simple method to find thousands of new white dwarfs, and explains why the current census of nearby (d < 25 pc) stars is incomplete and how the missing stars can be found.

Preliminary Results From The BOOMERanG 2003 Antarctic Long-Duration Balloon Flight, Carrie MacTavish, University of Toronto, and the BOOMERanG collaboration

In January of 2003 the BOOMERanG telescope completed a second successful long- duration balloon-borne flight over the Antarctic continent. During the 14-day flight the telescope scanned over 2000 square degrees of the sky at an angular resolution of approximately 10 arcminute at 145, 245, and 345 GHz. The reconfigured instrument containing polarization sensitive bolometers, an upgraded pointing system and existing flight-proven hardware from the 1998 Antarctic LDB flight make BOOMERanG a powerful probe for detecting small-scale anisotropies and polarization of the Cosmic Microwave Background and polarisation of dust in the Inter-Stellar Medium. Inflight performance will be discussed and preliminary results will be presented.

A Photoionized Herbig Haro Shock, P.G. Martin and Kevin Blagrave, Canadian Institute for Theoretical Astrophysics/University of Toronto

The spectra of Herbig Haro objects are usually characteristic of ionization and excitation in shock-heated gas, whether an internal shock in an unsteady outflow or a bow shock interface with the interstellar medium. Here, using deep optical echelle spectroscopy, we examine a Herbig Haro shock seen projected on the face of the Orion Nebula. We show that the spectrum of this gas is consistent with photoionization by θ^1 Ori C. By modeling this emission we gain interesting insights into the properties of the shocked gas, dust destruction, the He/H ratio, and foreground reddening.

Mapping the Most Extreme Stellar Populations in the Milky Way, Anthony Moffat, Université de Montréal, Mike Shara, American Museum of Natural History, Laurent Drissen, Université Laval, Rene Doyon and Nicole St-Louis, Université de Montréal, Carmelle Robert, Université

Laval, and Etienne Artigau, Université de Montréal

We are about to embark on a narrowband IR imaging survey of the optically obscured inner Galactic disk using the Observatoire du mont Megantic wide-field detector Cpapir at the CTIO (Chile) 1.5m telescope during a total of ~15 months, starting in April 2004. We will use narrow K-band filters (R ~ 100) centred on lines of H I, He I, He II, and C IV.

The core science programs include detection of essentially all Wolf-Rayet stars in the Galaxy (only 240 are currently known; there must be at least 2000 more, mostly located in the inner metal-rich Galactic disk), and a major fraction of the X-ray binaries and hot planetary nebulae in the Milky Way. Complete samples of each of these populations will be valuable probes of current star formation, stellar death, and binary star populations and distribution throughout the Galaxy.

Morphological Evolution of Galaxies: Studies with the Local SDSS Sample, Preethi Nair, University of Toronto

Recent large surveys of galaxies have tremendously advanced morphological studies, moving this field from the subjective art of morphological classification to a quantitative science of physical morphology. The challenge now is to link high-redshift (HST) galaxy observations with their low-redshift counterparts. Systematic studies have been initiated to quantify galaxy morphology and extend the structural parameters that form the basis of the Hubble sequence to higher redshifts. This comparative study however is not straightforward. Complications arise in interpreting observations due to redshift-dependent selection effects, biases, and incompleteness. The most fundamental difficulty has been the lack of a good, complete, digital sample of nearby galaxies. We are addressing the aforementioned deficiencies using the Sloan Digital Sky Survey (SDSS) as a local galaxy sample. We hope to undertake a fair comparison between low (SDSS) and high-redshift (HST/GOODS) galaxies while accounting for the redshift-dependent systematic effects introduced by luminosity evolution, reduced apparent size, under-sampling, bandpass shifting, and cosmological dimming.

Spherical NLTE Models of Metal Poor Red Giants, Ian Short, Saint Mary's University, and P.H. Hauschildt, Hamburger Sternwarte

As a first step toward more realistic modeling of the extremely metal poor (XMP) stars, we present plane-parallel and spherical LTE and NLTE atmospheric models of a variety of stellar parameters of the red giant star Arcturus, and study their ability to fit the measured absolute flux distribution. Our NLTE models include tens of thousands of the strongest lines in NLTE, and we investigate separately the effects of treating the light metals and the Fe group elements in NLTE. We find that the NLTE effects of Fe group elements on the model structure and flux distribution are much more important than the NLTE effects of all the light metals combined, and serve to substantially increase the violet and near UV flux level as a result of NLTE Fe over-ionization. Both the LTE and NLTE models predict significantly more flux in the blue and UV bands than is observed. These results suggest that there may still be important UV opacity missing from the models. We find that models of solar metallicity giants of similar spectral type to Arcturus fit well the observed flux distributions of those stars from the red to the near UV band. This suggests that the blue and near UV flux discrepancy is metallicity dependent, increasing with decreasing metallicity.

Out-of-Core Hydrodynamical Simulations of the IGM, Hy Trac, University of Toronto, and Ue-Li Pen, Canadian Institute for Theoretical Astrophysics

Reionization of the Universe is currently a hotly debated topic because of differing constraints on the reionization redshift given by SDSS and WMAP. At high redshifts, the intergalactic medium (IGM) contains the imprints of reionization and the free electrons resulting from the ionization process can be probed by the Sunyaev-Zeldovich (SZ) effect. We focus on the kinetic SZ (KSZ) distortion in the CMB, which results from the scattering of CMB photons off free electrons with bulk motion. The KSZ effect has a simple dependence on the ionized gas momentum and the amplitude of the distortion depends on the reionization redshift. We present some numerical results from high resolution, out-of-core hydrodynamical simulations. Out-of-core computation refers to the idea of using disk space as virtual memory and transferring data in and out of main memory at high I/O bandwidth. We can run cosmological simulations with up to 4000^3 fluid elements and 2000^3 particles on CITA's 3 terabyte SCSI disk array and 32 processor Alpha server.

Tracking the Formation and Evolution of Magnetic Fields in Intermediate- and High-Mass Stars with the ESO VLT, Gregg A. Wade, Royal Military College of Canada, S. Bagnulo, European Southern Observatory, J.D. Landstreet, University of Western Ontario, T. Szeifert, European Southern Observatory, H. Hensberge, Royal Observatory, Belgium, and G. Lo Curto, European Southern Observatory

About 10% of main sequence B and A stars exhibit organized magnetic fields with typical strengths ranging between a few hundred and a few tens of thousands of G. The presence of the fields has important consequences for the structure of the atmospheres of these stars, suppressing convection and leading to an amazing array of atmospheric peculiarities that effectively define these stars spectroscopically.

Remarkably, very little is known about the formation and evolution of these magnetic fields. In this talk, we describe an ongoing programme at the ESO VLT aimed at exploring the field formative phases by searching for magnetic stars in young open clusters with well-determined ages. Taking advantage of the PMOS (Polarised Multi-Object Spectroscopy) mode of the VLT FORS1 instrument, we have been able to observe up to 8 cluster members simultaneously, increasing the survey rate by nearly an order of magnitude as compared to conventional spectropolarimetric strategies. Within the context of this study, we have discovered several very young magnetic Ap and Bp stars. Among these is HD 66318, a strongly magnetic (14.5 kG) A1p star in the galactic cluster NGC 2516 with an age of 165 Myr. This star has completed only 16 ± 5% of its evolution along the main sequence, suggesting that magnetism in upper-main sequence stars develops at or before the stars reach the ZAMS (Zero-Age-Main Sequence).

Spectroscopy of the Optical Counterpart to the IXO in Holmberg 9, Diane Wong, UC Berkeley, Steve Eikenberry, University of Florida, and Dave Rothstein, Cornell University

Intermediate-luminosity X-ray objects (IXOs) are non-nuclear point X-ray sources with X-ray luminosities $L_x = 10^{39}–10^{40}$ erg s^{-1}. Much interest in them has been generated of late due to the advent of Chandra, and on the theoretical front, viable mechanisms of creating the new class of intermediate-mass black holes (IMBH, 10–1000 solar mass) that must be necessary if accretion onto these IXOs is to obey the Eddington limit.

Radio observations have been used successfully on the IXO NGC 5204 X-1 to rule out some of the known candidates for explaining the IXO phenomenon (Wong *et al.* 2003). However, the multiwavelength approach to deciphering IXOs has been under-utilized until now. We present our latest results in a long-term multi-wavelength IXO project. We show our progress in classifying the optical counterpart to the IXO in Holmberg IX using spectra, taken at Palomar Observatory.

Poster Papers/Les présentations affichages

Searching for Mushroom-type Worms in the Canadian Galactic Plane Survey Data, Ashish Asgekar, Jayanne English, and Samar Safi-Harb, University of Manitoba

The Galactic disk and halo are dynamically linked, and structures of interstellar gas at the disk-halo interface, such as supershells and "worms," may mediate such an interaction. Worms are dusty, neutral-Hydrogen (H I) structures observed to rise perpendicular to the Galactic plane. The data from the Canadian Galactic Plane Survey (CGPS) revealed that a previously-catalogued worm, GW123.4-1.5, has a mushroom-shaped geometry. We have systematically searched for similar worms in the CGPS data and are in the process of creating a catalog. The confirmed worms will be correlated with the morphology and kinematics of H I expected to be associated with old supernova remnants (SNRs). This effort is an attempt to establish a possible evolutionary sequence between SNRs and mushroom-shaped clouds, as was suggested by one of the plausible numerical models for GW123.4-1.5. We detail our methodology for visual examination of H I cubes, present some candidates, and discuss a couple of them in detail.

Polarization in the Young Cluster NGC 6611: Circumstellar, Interstellar, or ... Both?, Pierre Bastien, Université de Montréal, François Ménard, Laboratoire d'astrophysique de l'Observatoire de Grenoble/Canada-France-Hawaii Telescope Corporation, Patrice Corporon, Département de physique, Université de Montréal, Nadine Manset, Département de physique, Université de Montréal/Canada-France-Hawaii Telescope Corporation, Frédérick Poidevin, Département de physique, Université de Montréal, Gaspard Duchêne, Department of Physics & Astronomy, University of California at Los Angeles, and Jean-Louis Monin, Laboratoire d'astrophysique de l'Observatoire de Grenoble

The polarization of more than 70 A/B stars in the cluster NGC 6611 was measured at the mont Mégantic and Pic du Midi observatories. This young cluster is located at 2.1 kpc. We want to sample the circumstellar material around these young stars, most likely circumstellar dust that polarizes the stellar light. Most stars have a polarization of a few percent, probably interstellar, but some have a larger polarization, going up to 14 %.

A New Quest for Pulsating ZZ Ceti White Dwarfs, P. Bergeron and G. Fontaine, Département de physique, Université de Montréal

Pulsating hydrogen-line (DA) white dwarfs — or ZZ Ceti stars — are found in a narrow range of effective temperature, roughly between 11,200 K and 12,500 K. They have usually been discovered on the basis of their photometric colour indices (Johnson, Stromgren, or multichannel). Because of the inherent uncertainties associated with these colour measurements, the discovery rate using this selection criterion has always remained very low. Moreover, evidence based on colour indices suggests that the instability strip is contaminated with non-variable stars, a result that would imply that not all DA white dwarfs should become variable as they cool off through the instability strip. We present an improved method based on spectroscopic fits to the Balmer line profiles that yields accurate determinations of the effective temperature and surface gravity for white dwarf stars. This spectroscopic technique applied to all known ZZ Ceti stars reveals that they are located in a very narrow region of the T_{eff}–log g plane in which no non-variable white dwarfs are found, in agreement with our understanding that ZZ Ceti stars represent a phase through which all DA stars must evolve. We further show how the spectroscopic technique has been applied to predict the variability of many new variable stars, with a success rate of 100% so far.

On the O II Ground Configuration Energy Levels, Kevin Blagrave and Peter G. Martin, University of Toronto/Canadian Institute for Theoretical Astrophysics

We present a revised set of energy levels for the O II $2p^3$ ground configuration, with emphasis on the splitting within the ^2P and ^2D terms. Ground configuration energy levels can be deduced from lab measurements of permitted ultraviolet transitions that originate in upper levels of the ion, but the most accurate way to measure the energy levels has been from the forbidden lines in planetary nebulae. We extend this method to H II regions using high-resolution spectroscopy of the Orion nebula, covering all six visible transitions within the ground configuration. We report a revised splitting of the ^2D term while confirming the splitting of the ^2P term. The energies of the ^2P and ^2D terms relative to the ground (^4S) term are constrained by requiring that all six lines give the same radial velocity. This velocity is found to be consistent with independent limits placed on the motion of the O^+ gas.

The New Sub-mm/Radio Correlation in Spiral Galaxies, Rupinder Singh Brar and Judith A. Irwin, Queen's University

We present continuum observations of the edge-on spiral galaxies NGC 3044, NGC 4157, and NGC 5775 made with the Giant Metrewave Radio Telescope (GMRT) and the Submillimetre Common-User Bolometer Array (SCUBA) on the James Clerk Maxwell Telescope (JCMT). We report the detection of dust at very high-latitudes, in one case extending up to 5 kpc from the disk of NGC 5775, and high-latitude spurs of non-thermal radio emission. We find a strong correlation between metre-wavelength radio emission and sub-mm emission in the disk and at high-latitudes. The type and location of the emission indicates that the link is not via star formation, but may be more fundamental. Possible explanations for this startling correlation between cold dust and synchrotron radiation is discussed.

Developing a Technique to Match an Observed Oscillation Spectrum to Stellar Models, Kevin I.T. Brown, University of Western Ontario, and David Guenther, Saint Mary's University

Stellar non-radial oscillations (p-modes) are ideal tools to test stellar evolution and to provide information about stellar properties. We develop a technique that will match observed low-degree p-mode oscillation frequencies to stellar models and will quantify the quality of fit. Here we present the development, testing, and final form of this mode matching technique. The mode matching technique will be applied to published stellar oscillation data where constraints on mass, age, composition, surface temperature and luminosity will be obtained entirely from oscillation data.

This research was conducted by KB in partial fulfilment of a M.Sc. and was supported in part by an NSERC grant to DBG. Computations were performed on Saint Mary's University's High Performance Computer, part of the new Institute for Computational Astrophysics.

On Type I X-ray Bursts and Angular Momentum Conservation, Coire Cadeau and S. Morsink, University of Alberta

Type I X-ray bursts are thermonuclear flashes occurring on the surface of accreting neutron stars in low-mass X-ray binaries. Type I X-ray bursts generally exhibit oscillatory brightness, at a frequency thought to be largely determined by the angular velocity of the underlying star and angular momentum conservation; in particular, an expected increase in frequency as the burning matter falls back to the underlying star has been observed from a variety of sources (see Strohmayer & Bildsten 2003 for a review). If correct, this model also predicts a latitude dependence on the frequency of burst oscillations. We present an analysis of some public data from NASA's Rossi X-ray Timing Explorer satellite examining whether such an effect is observable.

The Rapidly Oscillating Ap Star HR 1217: Evidence of Magnetically Perturbed Oscillation Frequencies, Chris Cameron and Jaymie Matthews, University of British Columbia, Margarida Cunha, Centre for Astrophysics of the University of Porto, David Guenther, Saint Mary's University, Werner Weiss, University of Vienna, and The Whole Earth Telescope Collaboration

HR 1217 is a magnetic, chemically peculiar, Ap star that exhibits pulsation modes of low degree and high overtone. Like other Ap stars, HR 1217 exhibits anomalous abundances that are unevenly distributed across its surface. It is believed that the strong magnetic field stabilizes the atmospheres of Ap stars enough that elements can diffuse under radiative, gravitational, and magnetic forces to be stratified both radially and horizontally. There is now evidence that the magnetic field is also perturbing the oscillation modes present in HR 1217. We present a revised frequency analysis of photometric data obtained during a Whole Earth Telescope (WET) campaign in late 2000 and discuss how the magnetic perturbation models of Cunha (2001) can be used to explain the strange frequency shifts observed in HR 1217.

Galaxy Cluster Evolution According to Pinocchio, Kevin Casteels and Ray Carlberg, University of Toronto

Over the summer of 2002 I worked for Dr. Ray Carlberg researching the evolution of "dark matter halos" using a simulation called Pinocchio. Pinocchio is similar to an N-body simulation, but is based on an analytical perturbative approach, called Lagrangian Perturbation Theory, which speeds up the runtimes greatly and allows larger simulations to be run. I will be presenting merger histories and statistics that this simulation predicts for galaxies and galaxy clusters. Using programs I wrote to analyze the Pinocchio output, I was able to obtain Merger History Trees for halos (galaxies) as well as other useful things like merger rates, mass accretion rates, and Merger Correlation Functions. I will be presenting each of these and their implications for actual galaxies and the evolution of the universe.

Testing the Pulsation Theory in Hot Subdwarf B Stars: FUSE Observations, Pierre Chayer, University of Victoria/John Hopkins University, G. Fontaine, M. Fontaine, R. Lamontagne, and F. Wesemael, Université de Montréal, and J. Dupuis, John Hopkins University

So far, 30 hot subdwarf B stars (sdB) show low-amplitude (a few to tens of millimag), short-period (100-500 s), and multiperiodic luminosity variations. The pulsations are driven by an opacity bump, which is caused by the presence of a local enhancement of the iron abundance in the envelopes of these stars. The diffusive equilibrium between gravitational settling and radiative support in the stellar envelopes explains the enhancement of iron. Observations show that sdB stars with similar effective temperatures and gravities can either be variable or non-variable objects. Theoretical models show that a weak stellar wind may affect the extent of the iron reservoir and thus inhibit the driving mechanism. Because this stellar wind is expected to leave its mark on the photospheric heavy elements abundance patterns, we analyze FUSE spectra of a dozen of such pulsating and non-pulsating sdB stars. These FUSE observations provide a test of the explanation for the driving of the observed pulsations.

Low-Cost All-Sky Camera Systems for Meteor Studies, Martin Connors, Athabasca University, M. Foote, Athabasca University and University of Alberta, B. Martin, King's University College, D.P. Hube, University of Alberta, R. Spalding and J. Chavez, Sandia National Laboratories, T. Trondsen and M. Syrjasuo, University of Calgary, and A. Ling, Edmonton Centre RASC

Low-light all-sky cameras, monitoring continuously, can provide valuable data for meteor studies, and the opportunity to both determine fall locations of meteorites and the orbits of the progenitor meteoroids. Since there are only a few cases of recovered fallen meteorites with well-established orbits, bolide detection for recovery has been the focus of the monitoring program to date. In three years of operation of cameras provided for northern Alberta by Sandia Laboratories, one case has merited a field search, while camera data showed some other potentially promising bolides not likely to have produced a recoverable meteorite. A more sensitive new camera has been developed, and it should also prove better adapted to winter conditions in Canada. Sensitivity is needed primarily for calibration purposes, but could allow extension to studies of fainter meteors not expected to produce meteorites. We describe quantitative aspects of the sensitivity and field of view of this and other cameras, as tested in the laboratory and the field. The new meteor camera systems will be well suited for low-cost monitoring simultaneously from multiple locations. The new camera network will feature triggered acquisition, digitally logged, and will be able to demonstrate remotely controlled campaign mode operation. We have used motion detection software on Linux computers, and a custom designed acquisition system called Sentinel, for automatically detecting meteor events. Case studies from detected events will be presented.

Properties of an Isolated M dwarf: Barnard's Star, Michael De Robertis, York University, and P.C. Dawson, Trent University

A number of fundamental properties of Barnard's Star can be established using its recently measured angular diameter, together with its large and precise parallax, and a spectral energy distribution that extends from the UV to the mid-IR. Accurate knowledge of those parameters leads in turn to useful constraints on the star's metallicity and mass. Effective temperature estimates obtained by other, less direct, methods are compared with the definitive result.

Two-Dimensional Evolution and Hydrodynamics of a 20 Solar Mass Star, Robert Deupree, Institute for Computational Astrophysics/Saint Mary's University

Two-dimensional simulations of the evolution of a 20 solar-mass star are compared to one-dimensional evolution sequences. The results for a nonrotating model agree quite well with those of one-dimensional codes, although the inclusion of the inertial terms in the 2-D calculation produces an extra loop in the HR diagram. This extra loop results because it takes time to slow down the envelope and the stellar radius overshoots the value that corresponds to the initiation of core helium burning. Calculating a rapidly rotating model using the traditional 1-D assumptions about convective zone boundaries produces significantly aspherical convection zones during hydrogen shell burning and core helium burning, but not during core hydrogen burning. 2-D hydrodynamic simulations to test these assumptions show that the asphericities are reduced, but do not disappear.

Model Atmospheres for Cool White Dwarfs with Metals and Molecules, Patrick Dufour and Pierre Bergeron, Université de Montréal

White dwarf stars represent the endpoint of more than 95% of the stars in the Galaxy. Since they cool down relatively slowly, the coolest and thus oldest white dwarfs are still visible, and they can thus be used as cosmochronometers to measure the age of the various components of the Galaxy. Detailed model atmosphere calculations are required to infer cooling ages from fits to observational data, and they are also used as boundary conditions for white dwarf cooling models. Previous model atmosphere analyses of cool white dwarfs by Bergeron, Ruiz, & Leggett were based on pure hydrogen and pure helium, as well as mixed hydrogen/helium atmospheric compositions, which are appropriate for most white dwarf stars. However, white dwarfs showing carbon molecular bands or metal lines — DQ and DZ stars, respectively — require more sophisticated model atmospheres. We present preliminary results on new models that are currently being developed, and discuss the astrophysical implications on the temperature scale of cool white dwarfs and their chemical evolution.

Diamond, PAH and the UIR Bands, Walt Duley, University of Waterloo, Simon Petrie and Robert Stranger, Department of Chemistry, Australia National University

The unidentified infrared emission (UIR) bands are generally attributed to emission from neutral or ionized polycyclic aromatic hydrocarbon (PAH) molecules but observations indicate that no single molecular species is responsible for the full range of spectral features. Detailed analysis reveals that the UIR bands contain spectral components that can be associated with aromatic rings, aliphatic hydrocarbon groups and, in specialized circumstances, hydrogenated diamond. Simulation of IR spectra of such heterogeneous structures is required in the absence of laboratory data. In this context, we have investigated some aspects of the structure and vibrational spectroscopy of a class of locally aromatic aromatic hydrocarbon (LAPH) molecules combining aromatic rings bridged with alicyclic hydrocarbon chains. We show how understanding the IR spectra of LAPHs may yield insight into the composition and structure of the UIR emitters.

This research was supported by a grant from the NSERC (WWD) and by allocation of supercomputing resources at the ANU from the Australian Partnership of Advanced Computing (SP & RS).

The Galactic Plane at BOOMERanG Frequencies, Paula Ehlers, University of Toronto, and The BOOMERanG Collaboration

Thermal emission from dust in the galactic plane may be seen at mm and sub-mm wave frequencies. In cases where the material is very cold, emission may not be seen in Far-IR observations, but the presence of this material can be deduced from comparison of IR to mm wave maps. Data from BOOMERanG (Balloon Observation of Millimetric Extragalactic Radiation and Geophysics) (B98 and B03) are a rich source of information about cold dust in a part of the southern galactic plane that has never before been seen at these frequencies (90–400 GHz). These data allow us to study some of the properties of the dust, such as distribution, density and temperature, as well as non-thermal sources of emission, and, with new maps of polarized emission from B03, the 2003 flight, the structure of magnetic fields over the area.

X-Atlas: Chandra Grating Spectra of Hot Stars, Nancy Remage Evans, Jonathan Slavin, Vinay Kashyap, Joy Nichols, Eric Schlegel, Mihoko Yukita, Jen Lauer and Beth Sundheim, Smithsonian Astrophysical Observatory

The Chandra X-ray Observatory is obtaining transmission grating spectra of many hot stars. We present a prototype of Chandra Spectral Atlas of Hot Stars, which will include publicly available grating spectra of WR, O, and B stars of representative spectral classes. Currently, there are 20 HETG spectra of 14 unique objects in the archives, and we will add more as they become public. We have created montages of the spectra themselves facilitating comparisons of features present in different stars. We also provide a montage of selected lines which illustrate a variety of line shifts, line widths, and asymmetries. We have converted the high-res grating spectra to the lower resolution of the CCD in order to compare them with low resolution spectra from ACIS images, and also to fit them using the Chandra CIAO software package SHERPA. The atlas will be available through a dedicated Web site.

Financial assistance was provided from the Chandra X-ray Center NASA Contract NAS8-39073.

G11.11-0.12: Evidence for Magnetic Support in a Filamentary Molecular Cloud?, Jason D. Fiege, Doug Johnstone, R.O. Redman, and P.A. Feldman, NRC Herzberg Institute of Astrophysics, and Sean J. Carey, SIRTF Science Center, Caltech

We present a detailed analysis of the G11.11-0.12 filamentary infrared dark cloud, which compares the 850 μm emission of this source with the magnetic Fiege & Pudritz model and Stodolkiewicz model of filamentary clouds, and the non-magnetic Ostriker model. We discuss a novel computational technique that we developed to explore the parameter space of each model. We show that G11.11-0.12 is consistent with the magnetically supported (poloidal field-dominated) regimes of both magnetic models. Toroidal field-dominated models, which are consistent with other filaments, are ruled out for this source. The Ostriker model cannot be ruled out, but observations favour a high central density that is more consistent with the magnetic models. We predict the polarization structure of G11.11-0.12 and discuss the capability of our modeling technique to fit all of the Stokes parameters simultaneously to provide improved constraints once polarimetry data are obtained.

FUSE Observations of Stellar Wind Variability in O-Type Supergiants, Alex Fullerton, University of Victoria / Johns Hopkins University, D.L. Massa, SGT, Inc., R.K. Prinja, I.D. Howarth, and A.J. Willis, University College London, and S.P. Owocki, Bartol Research Institute, University of Delaware

We report on spectroscopic time series observations of stellar wind variability obtained with the Far Ultraviolet Spectroscopic Explorer (FUSE) satellite for two O-type supergiants in the Large Magellanic Cloud. The resonance lines uniquely accessible to FUSE probe the ionization and density structure associated with the recurrent discrete absorption components (DACs) in the stellar winds of these stars in unprecedented detail. Our analysis confirms that the DACs are at least partially due to density enhancements that propagate through the wind.

RXTE Monitoring of the 65-ms X-ray Pulsars PSR J1811-1925 in G11.2-0.3 and PSR J0205+6559 in 3C 58, Fotis Gavriil, McGill University, S.M. Ransom and M.S.E. Roberts, McGill University/Massachusetts Institute of Technology, V.M. Kaspi, McGill University, B.M. Gaensler, Harvard-Smithsonian CfA, E.V. Gotthelf, Columbia University, and S.S. Murray and P.O. Slane, Harvard-Smithsonian CfA

The X-ray Pulsars PSR J1811-1925 and PSR J0205+6559, in the historical supernova remnants G11.2-0.3 and 3C 58 respectively, have characteristic ages much greater than the ages of their remnants. This likely implies that their current spin periods, ~65 ms, are close to their birth spin period. Alternatively, these pulsars may have unusually high braking indices. Despite the striking similarities in the pulsars' spin parameters and historical ages, the two have very different pulse shapes and X-ray luminosities, which could imply different emission mechanisms and/or geometries. We report here on regular Rossi X-ray Timing Explorer/Proportional Counting Array (RXTE/PCA) timing observations of these pulsars that were designed to measure their braking indices. For PSR J1811-1925, we provide a preliminary phase-coherent timing solution that includes a significant $d(d\nu/dt)dt$. The braking index we measure is > 3. This could be a manifestation of timing noise; further observations can test this. For PSR J0205+6559, excessive timing noise has made long-term phase-coherent timing of this pulsar difficult, but preliminary results imply a braking index significantly greater than 3 as well. We also report on a preliminary analysis of the phase-averaged and phase-resolved spectra of both sources.

This work is funded by NSERC, CIAR, NASA, and a McGill University Tomlinson Fellowship.

Precision Radial Velocities Made Easy, David F. Gray, University of Western Ontario

I will describe a simple method for measuring radial velocities that can be used with many spectrographs. Precision ~ 15 m s^{-1} has been attained with the high-resolution coude spectrograph at the Elginfield Observatory, and I am optimistic that this can be improved still by a factor of perhaps two. This technique has several advantages, including 1) a built-in reference spectrum, supplied by nature, 2) relatively little overhead time lost from a night of observing, making it more efficient than many schemes using absorption-cells, and 3) the stellar spectrum image is not hurt in any way, unlike the commonly-used iodine-absorption-cell technique that essentially makes the image useless for anything except measuring the radial velocity. This last advantage is particularly important to those of us who need the spectrum intact for detailed astrophysical analysis.

The Secular Evolution of the Primordial Kuiper Belt, Joseph Hahn, Lunar and Planetary Institute

A model of the secular interactions that are exerted between planets and a particle disk is described. The particle disk is treated as discrete gravitating rings having a finite thickness h due to the particles' dispersion velocities. Since a ring's thickness softens its gravitational potential, the system's time-evolution is readily obtained from the classical Laplace-Lagrange secular solution but with the Laplace coefficients softened over a scale h/a. This rings model is then used to simulate a number of Kuiper Belts having masses M = 30 earth-mass (*e.g.,* its primordial mass) down to its present mass of ~0.2 earth-mass. As long as these Belts remain sufficiently thin, these systems are awash in apsidal density and nodal bending waves launched by the giant planets. Initially, long apsidal density waves propagate outwards until they reflect at either the disk's outer edge or at a Q-barrier, whereupon they return as short density waves. These short density waves are typically nonlinear, and they are responsible for large variations in the disk's surface density. The giant planets also launch long nodal bending waves, and they have an interesting property in that they stall further downstream. Additional cosmogonic implications of apsidal and nodal waves in the early Kuiper Belt will also be described.

GMRT Observations of NGC 3079, Judith A. Irwin, Queen's University, and D.J. Saikia, National Centre for Radio Astrophysics

NGC 3079 is unique among spiral galaxies, showing well-defined radio lobes extending from a strong compact nucleus. It may be the closest analogue of an EGRS, providing a laboratory for understanding the starburst/AGN relationship in galaxies. To investigate the broader scale outflow in this galaxy as well as the properties of its non-thermal emission, we have obtained new 1280 MHz, 610 MHz, and 327 MHz data using the Giant Metre-Wave Radio Telescope near Pune, India. These data show the well-known radio lobes along with some new features, some of which extend much farther than previously known. A discussion of the properties of the emission and its relationship to other components will be presented.

Why Are There So Few Cool Ap Stars?, Noémie Johnson and G.A. Wade, Royal Military College of Canada

The Fp stars represent the coolest examples of the magnetic upper main sequence chemically peculiar Ap/Bp stars. Fp stars are remarkably rare — whereas about 10% of all A0V stars can be identified as magnetic, only about 1% of F0V stars have been so classified. Most strikingly, for spectral types later than about F4, essentially no Fp appear to exist.

Why are there so few cool Ap stars? We investigate two potential explanations. First, we explore the possibility that there are in fact many Fp stars, but that they remain unidentified because their spectral peculiarities are difficult to differentiate from the already-rich spectra of F stars. Secondly, we consider that the observed deficiency of Fp stars is a result of magnetic field evolution. Because spectral type F0 corresponds to the onset of strong envelope convection, we speculate that convection advects magnetic field below the photosphere, rendering the star "non-magnetic" (and therefore non-Fp). Such a process would necessarily influence weaker fields more intensely than stronger fields, leading to observable consequences for the weak-to-strong field ratio.

This talk presents the first results of this investigation.

The Cool ISM of NGC 5866, Glenn Kacprzak and Gary Welch, Saint Mary's University

The nearly edge-on S0 galaxy NGC 5866 is notable for its massive molecular interstellar medium, prominent central dust lane, and large IRAS 100 micron flux. The galaxy is relatively isolated, and neither the kinematics nor morphology of the gas suggests that a merger has taken place. Instead, NGC 5866 may be entering an era of star formation fueled with gas donated by its aging stellar population. Are we seeing a counter example of the popular view that galaxies evolve through mergers? We are exploring that possibility using multi-transition CO observations and SCUBA imagery of NGC 5866.

We analyze the dust and gas components of the interstellar medium using techniques such as the large-velocity-gradient (LVG) models and a three-dimensional Monte Carlo radiation transfer code. The paper describes our progress to date.

Nonradiative Black Hole Accretion: Magnetically-Frustrated Convection, Christopher Matzner, University of Toronto, Ue-Li Pen, Canadian Institute for Theoretical Astrophysics/University of Toronto, and Shingkwong Wong, National Taiwan University

We investigate the physical nature of nonradiative accretion onto black holes, means of MHD simulations with 1400^3 grid points — the largest to date. These show the development of a hydrostatic, superadiabatic envelope that convects and accretes remarkably slowly due to the frustrating effects of global magnetic-field structures. The physics of this remarkable result, its implications for black hole accretion, and its relation to prior theoretical models will be discussed.

Discovery of a Huge YSO Interaction Region in Camelopardalis, Marshall L. McCall, York University, Ronald J. Buta, University of Alabama, and Tyler J. Foster, University of Alberta

During the course of a wide-field *VI* survey of galaxies in the IC 342/Maffei Group, an extended source that looks like an inclined disk with a jet coming out of it was discovered in Camelopardalis. The predominating disk component is 6.8 arcminute across in *I*, which corresponds to 4.0 ± 1.6 pc at the estimated distance of 2.0 ± 0.8 kpc (the Perseus Arm). The jet extends 3.8 arcminute (2.2 pc) outward from the core along a direction about 20° from the minor axis of the disk. Near the centre of the disk is IRAS 04261+6339, which is a pair of unresolved Hα sources whose spectra have revealed to be young stellar objects (YSOs). In the far-infrared, the spectral energy distribution of the pair is similar to that of the star in Holoea (IRAS 05327+3404), which is recognized as a transition between Class I and Class II YSOs. However, the flux in the optical and near-infrared is significantly enhanced relative to the far-infrared, suggesting that these YSOs are less obscured. POSS and 2MASS images reveal only a hint of nebulosity, and only in the immediate vicinity of the stars. No extended emission is seen at Hα. The nebula is tentatively identified as an old remnant of an outflow from a binary YSO, glowing as a consequence of the photoluminescence of silicon nanoparticles.

The Science of BLAST, Vjera Miovic, University of Toronto, D. Wiebe, G. Marsden, M. Halpern, P. Martin, C. B. Netterfield, D. Scott, and the rest of the BLAST Consortium

BLAST (the "Balloon-borne Large-Aperture Submillimetre Telescope") will probe the sub-mm to conduct unique galactic and extragalactic surveys. We expect to reach the following science goals: detection of up to 1500 high-redshift galaxies through the large extra galactic sub-mm surveys, maps of extended regions of the Galactic plane and observations of solar system objects. The extragalactic surveys will provide us with photometric redshifts of distant galaxies and thus constrain the star-formation epoch. These surveys are also expected to help constrain the clustering and bias of far-IR galaxies. BLAST will also study the distribution of dust in large nearby galaxies. The Galactic plane maps will help explain interstellar dust evolution, and probe the Initial Mass Function of protostars. For the realisation of the BLAST experiment and instrument development, see the accompanying poster by Marsden *et al.*

Automated Telescopes at the University of Toronto, Stefan Mochnacki, University of Toronto, and Marc Castel, ROBOsky

At the University of Toronto, we try to give our undergraduates the opportunity to do real research, and to enable this we have modernised our undergraduate observatories. We have retrofitted for automated operation the 40-cm Boller and Chivens Cassegrain reflector at the St. George Campus and the 30-cm Questar Maksutov on a Byers mount at the Scarborough Campus. We have adapted commercially available "off the shelf" equipment and software developed mainly for the advanced amateur market. The 40-cm B&C telescope is fitted with an SBIG SGS spectrograph; we have achieved RMS pointing precision of under 30 arcseconds, and expect to refine this to about 12 arcsecond. Scripted operation has been demonstrated, and a Web interface allows students to obtain observations using their home computers and the Internet. The 30-cm Questar is fitted with a 1024 × 1024 thinned back-illuminated CCD, providing an imaging field of 19 arcminute square at 1.1 arcsecond per pixel. Remote operation has been achieved. Examples of observations with each telescope are presented.

Detection of the Reionization Epoch using Small Radio Telescopes, Sasa Nedeljkovic and C. Barth Netterfield, University of Toronto, and Ue-Li Pen, Canadian Institute for Theoretical Astrophysics

The formation of the first luminous objects in the Universe defines the beginning of the epoch of reionization, in which the Universe makes the transition from a neutral to almost completely ionized state. This epoch may be detectable via observations of the 21-cm hydrogen line. For the range $20 > z > 5$, the 21-cm line will be redshifted in the frequency interval 70-240 MHz. The reionization of the Universe is expected to form a small temperature step of approximately 0.02 K in the whole-sky spectrum somewhere in the given bandwidth. A method of measuring this yet-unseen signature has been proposed, and numerically evaluated. The 21-cm Reionization Experiment (TREX) will utilize wideband digital spectrometers on a series of two or more precisely scaled small radio antennae measuring the spectrum of the sky in the 150-250 MHz. The current discrepancy between WMAP polarization determination of $z_{rei} \sim 15$ and SDSS $z_{rei} \sim 6.1$ can be resolved by this experiment. This poster shows the results of numerical simulations, the TREX instrument design and the current status of the experiment.

Observing Simulated Galaxies, Jennifer O'Neill, University of Toronto

Comparisons between hydrodynamical galaxy simulations and observations are becoming more detailed as the resolution increases for both. To facilitate these comparisons, as well as remove some systematic biases, I am creating images of simulated galaxies as if they had been viewed through a telescope. The original simulated results (mass, position, and age of stars and gas) are converted to wavelength-dependent luminosity by way of a spectral synthesis code. The stellar light is then propagated through the dust using radiative transfer techniques, and 2-D images of the galaxies are created at various viewing angles. These images are then modified according to the telescope properties (background level, psf, Q.E., and noise) to create pictures that can be directly compared to observations. Presently I am exploring the quantitative morphological classification of simulated high-redshift galaxies compared to the Hubble Deep Field data.

Polarization and Radial Velocity Fields of Fragmenting Filamentary Molecular Clouds, Russell O. Redman, J.D. Fiege, and P.A. Feldman, National Research Council of Canada, and S.J. Carey, Caltech

Numerous filamentary molecular clouds appear to be in the process of fragmenting. There is some evidence that magnetic fields help to support and stabilize these filaments, and should play an important role in their fragmentation into chains of dark cores. We present theoretical models showing the predicted 2-dimensional polarization and radial velocity fields for fragmenting filaments as functions of inclination and time. The basic observational properties of several such filaments are discussed, including examples from the MSX catalog of infrared-dark clouds, which is in preparation.

Large Frequency Drifts During Type I X-ray Bursts, Vahid Rezania, University of Alberta

We study the spin-down of a neutron star atmosphere during the Type I X-ray burst in low mass X-ray binaries. Using polar cap acceleration models, we show that the resulting stellar "wind" torque on the burning shell due to the flowing charged particles (electrons, protons, and ions) from the star's polar caps may change the shell's angular momentum during the burst. We conclude that the net change in the angular momentum of the star's atmosphere can account for rather large frequency drifts observed during Type I X-ray burst.

Canadian Perspectives on Future Instruments for the Gemini Telescopes, Harvey Richer, University of British Columbia, Dennis Crabtree, National Research Council of Canada/Herzberg Institute of Astrophysics, Roberto Abraham, University of Toronto, Douglas Welch, McMaster University, Doug Johnstone and J.J. Kavelaars, National Research Council of Canada/Herzberg Institute of Astrophysics

At the end of June, Gemini will be hosting a meeting to review plans for the next generation of instrumentation for both of its telescopes. Gemini has arranged for the discussions to be organized around four themes: extragalactic, resolved stellar systems, star formation, and planetary. Each theme group will have a number of members from the Gemini community and they will be expected to crystal-gaze into the future direction of their area. Science is expected to dominate the discussions with instrument concepts flowing from the scientific debate. In Canada, the Canadian Gemini Office organized a meeting that was held in early May in Montreal. The discussions were along the same themes that will be reviewed at the full Gemini meeting. I will present the outcome of the Canadian meeting and hope that this will foster further discussion on the scientific and instrumentation future of our largest national telescopes.

The Nature of M33's Carbon Stars, Jason Rowe, H.B. Richer and J. Brewer, University of British Columbia, and D.R. Crabtree, National Research Council of Canada

Using the CFH12k imager, photometry of 1.3 million stars is used to investigate AGB stars in the nearby spiral galaxy M33. AGB are identified and classified into M and C-type stars. We use the ratio of C-stars to M-stars (C/M ratio) to investigate the metallicity distribution throughout the disk. The C/M ratio is found to increase and then flatten with galactocentric distance.

Scientific Visualization of Magneto-Hydrodynamic Simulations: The JETGET Tool, Jan Staff, Michael Jorgensen, and Rachid Ouyed, University of Calgary

Scientific visualization has proven a useful tool for analyzing MHD simulations. The simulated astrophysical system is typically complex and therefore thorough analysis is difficult. We have developed a new tool, namely JETGET, for such a purpose. It has been useful in the identification of new phenomena one otherwise might not look for. JETGET turned out to be important when developing a better intuitive understanding of the problem, checking for errors, and more effectively communicating the results. This visualization tool can also be useful for direct experiment/theory comparisons. We will here describe it in details.

WZ Carinae: A Possible Addition to the Astrophysical Zoo?, David Turner, Saint Mary's University, Leonid N. Berdnikov, Sternberg Astronomical Institute, and M.A. Abdel-Sabour, Egyptian National Research Institute of Astronomy and Geophysics

Rates of period change for individual Cepheid variables in the Milky Way are being used to examine the parameters of stars as they cross the Cepheid instability strip. Studies so far have been very successful in mapping the variation in pulsation amplitude of Cepheids across the strip, identifying specific strip-crossing modes for individual variables, distinguishing overtone pulsation from fundamental mode pulsation, and supplying evidence for very low-level chaotic period changes in some variables. Yet a number of curiosities in the Cepheid sample have become evident. One of them is the case of WZ Carinae, a 23-day southern hemisphere Cepheid for which archival data have been obtained with the aid of the Harvard Observatory Photographic Plate Collection. In all but the earliest two photoelectric studies of the star, the O-C data (differences between Observed and Computed times of maximum light) for WZ Car follow a consistent trend indicative of a decreasing period for the variable. Yet the oldest photoelectric observations for the star and photographic data from the first half of the twentieth century follow a consistent trend indicative of an increasing period for the variable!

A possibly simplistic conclusion is that the star simply ceased its redward evolution through the instability strip towards the cool edge around 1970 or thereabouts, and then began a blueward evolution towards the hot edge of the instability strip. In other words, the changeover from core helium burning to shell helium burning in this 12 solar mass star may have begun while the star was still crossing the instability strip rather than in a red supergiant stage after exiting the strip. Alternatively, the O-C data can be interpreted as evidence for random changes in period for the star, albeit at the very low level that is diagnostic of such effects in Cepheids. Light travel-time effects in a binary system can be eliminated as a third possibility because they generate unrealistic results for the masses of the stars in the system. What could decide the matter is an examination of future trends in the star's observed light curve. In the past thirty-five years the O-C trend has been a bit too regular to be consistent with chaotic period changes. In addition, a changeover from core helium burning to shell helium burning occurring in the middle of the instability strip could help to explain an observational dearth of long-period Cepheids lying on the red edge of the strip.

The Circumstellar Envelope of Zeta Tauri through Optical Interferometry, Christopher Tycner and John B. Lester, University of Toronto, and Arsen R. Hajian, United States Naval Observatory

We present the optical interferometric observations of the Be star Zeta Tauri obtained simultaneously in many spectral channels covering a wide spectral region. The observations were obtained using the Navy Prototype Optical Interferometer which allows, through its multi-wavelength response, a high quality calibration of the squared visibilities corresponding to the H-alpha emission from the circumstellar environment. We have modeled the signature due to the circumstellar emission as an elliptical Gaussian envelope and compare our best-fit model parameters to those already in the literature. Furthermore, we demonstrate how Monte Carlo simulation can be very valuable, or even necessary, in the estimation of the uncertainties of the derived model parameters.

Cartographie partielle haute résolution de la température électronique de la nébuleuse d'Orion, Simon Villeneuve, Université Laval

L'évaluation de la température électronique à l'intérieur des nébuleuses planétaires et nébulaires (zone H II) est un problème qui perdure depuis les années 50. Plusieurs évaluations de la température ont été faites pour la nébuleuse d'Orion, mais elles ont été faites sur des champs disparates et très étendus. Nous comptons évaluer la température électronique à l'aide de données prises au TCFH par le Prof. Gilles Joncas avec l'Optically Adaptative System for Imaging Spectroscopy (OASIS), un spectromètre à pupilles. Les configurations utilisées pour la prise des données vont nous permettre d'utiliser certaines raies de S II et de N II qui nous donneront respectivement la densité et la température électronique. Puisque les 11 champs pris au TCFH s'étendent sur environ 210″ × 40″ et que chacun de ces champs compte environ 1200 spectres, notre cartographie atteindra une résolution inégalée dans la littérature.

The evaluation of the electron temperature inside the planetary and diffuse (H II regions) nebulae is a problem that subsists since the fifties. Many temperature evaluations have been made for the Orion Nebula, but they have been done on really large and separated fields. We want to evaluate the electron temperature with some data taken by Dr. Gilles Joncas at the CFHT with the Optically Adaptative System for Imaging Spectroscopy (OASIS), a pupils spectrometer. The configurations used allow us to use some S II and N II lines that will give us respectively the electron densities and temperatures. Considering that our 11 fields taken at the CFHT cover 210″ × 40″ and each of them have about 1200 spectra, our carthography will have a higher resolution than one can find in the literature.

CO Molecular Gas in IR Luminous Galaxies, Lihong Yao and E.R. Seaquist, University of Toronto, Nario Kuno, Nobeyama Radio Observatory, and Loretta Dunne, University of Wales

I will present the first statistical survey of the properties of the ^{12}CO (1–0) and ^{12}CO (3–2) line emission (measured at a common resolution of 15″) from the nuclei of a nearly complete subsample of 60 IR luminous galaxies selected from SCUBA Local Universe Galaxy Survey (SLUGS). The measured ^{12}CO (3–2) to (1–0) line intensity ratios vary from 0.22 to 1.72 with a mean value of 0.66 for the sources observed, indicating a large spread of the degree of excitation of CO in the sample. These CO data, together with a wide range of data at different wavelengths obtained from the literature, allow us to study the relationship between the CO excitation conditions and the physical properties of gas/dust and star formation in the central regions of galaxies. Our analysis shows that there is a non-linear relation between CO and FIR luminosities, such that their ratio LCO/LFIR decreases linearly with increasing LFIR. We also find a possible dependence of the degree of CO gas excitation on the density of star forming activity. Using the large velocity gradient (LVG) approximation to model the observed data, we investigate the CO-to-H_2 conversion factor X for the SLUGS sample. The results show that the mean value of X for the SLUGS sample is lower by a factor of 10 compared to the conventional value derived for the Galaxy, if we assume the abundance of CO relative to H_2, ZCO = 10^{-4}.

Studies of the RV Tauri Phenomenon, John Percy and Farisa Mohammed, University of Toronto

RV Tauri (RVT) stars are low-mass yellow supergiant pulsating variable stars whose light curves show alternating deep and shallow minima. They are related to the Population II Cepheid (CW) variables and to the yellow semi-regular (SRd) variables. Percy, Hosick and Leigh (2003 PASP 115, 59-66) used self-correlation analysis of MACHO photometry to study the relationship between RVT and CW variables in the LMC. They showed that the self-correlation behaviour of the RVT variables could be explained in terms of double-mode pulsation in which the ratio of the two periods is close to 2:1. In the present paper, we describe the results of self-correlation and Fourier analysis of a large body of visual photometry of 10 bright RVT and SRd variables, namely AG Aur, AV Cyg, SU Gem, AC Her, SX Her, TT Oph, UZ Oph, TX Per, R Sct and V Vul. Our results are consistent with the LMC results, and suggest that the RV Tauri phenomenon is two-dimensional: (i) the relative amplitudes of the two modes, and (ii) the closeness of the period ratio to 2:1. There is therefore a "spectrum" of behaviour from CW to RVT to SRd. Supported by NSERC Canada.

Education/La pédagogie

Astronomy — A Black Hole for Teachers!, Mars Bloch, Toronto District School Board

Elementary and secondary students are learning about astronomy in classrooms all across the country, but what are they learning and how are they being taught? Many teachers who are required to teach astronomy do not have the required background knowledge and, in some cases, provide minimal time for this area of study. This creates challenges to ensure that students have programs that develop concepts and skills related to astronomy with accurate and up-to-date information. How teachers value astronomy as a science is often reflected in how it is taught, learned, and portrayed. These challenges can be overcome by partnerships between the educational community and the research community, to ensure that the wonders and mysteries of the Universe are opened up for study to all Canadian students. This session will discuss the intended curriculum, and the challenges of implementation, including how partnerships can help to meet these challenges.

Partnerships in Canadian Astronomy Education, John Percy, University of Toronto

The development of the Canadian Astronomy Education and Public Outreach Initiative is being done on a relative shoestring, so we must take advantage of partnership opportunities with like-minded organizations wherever possible. Since astronomy is a multi-faceted science, which can be communicated through a wide variety of formal and informal education channels, partnerships are effective as well as efficient. In this paper, I will describe several examples of programs and projects in which I work with knowledgeable and receptive partners, in educational organizations, to achieve a wider impact: Girl Guides of Canada and Scouts Canada (resource material for their program requirements in astronomy); Ontario Institute for Studies in Education (basic research on effective teaching and learning of astronomy, pre-service teacher education); Science Teachers Association of Ontario (in-service teacher education, resource material); the Royal Astronomical Society of Canada (*SkyWays* teachers' guide); Greater Toronto Area Astronomy Education Network (integrated astronomy events and resources for students, teachers, and the general public). The eventual goal is to make the results of these partnerships available on the CASCA Education Web Site.

Supported by NSERC PromoScience, and Enterprise, Opportunity, and Innovation Ontario.

A Laboratory/Observing Manual for First-Year Astronomy, David G. Turner, Saint Mary's University

From many years of teaching first-year astronomy courses for science majors, the author has assembled a modest collection of 16 laboratory exercises and 8 observing projects that make a suitable learning component of a full-year course in introductory astronomy and astrophysics. The exercises are an eclectic mix of lab projects and observing challenges adapted from published laboratory manuals, modified from exercises generated by current and former colleagues, and created independently by the author himself. Many have seen several years of use but have been edited to eliminate ambiguous wording and faulty descriptions, up to a point. Although a few exercises need to be replaced because they are overly difficult or relatively weak as learning experiences, the collection is now in the form of an electronic file that can be made available for the use of colleagues, either as the basis for their own laboratory manual or for use as is. Sample copies are available for perusal.

Education Notes
Rubriques pédagogiques

A DECADE'S PROGRESS IN DISTANCE EDUCATION ASTRONOMY

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Abstract. Astronomy is now a well established discipline area at Athabasca University, and it is useful to review changes in the past decade. Our astronomy courses are offered entirely by distance education. Course materials are based on a study guide and textbook, but with supplemental materials, some computer-based, forming an important part of them. Regular contact with a qualified tutor is also an important part of the Athabasca University distance education model. We now offer two first-year courses, a senior geology course with strong astronomical links, and the opportunity to obtain senior-level credit for independent research. Both first-year courses are surveys of the entire field of astronomy. One is at an introductory level with no prerequisites. The second is more mathematical and detailed, including computerized laboratory exercises. Through these courses, Athabasca University provides the opportunity for Canadians anywhere to study astronomy at the university level. In addition to describing progress we attempt to evaluate the reasons for the growth of distance education astronomy. Astronomy enrollment now approaching 200 students represents a tenfold increase in a decade.

Résumé. L'enseignement de l'astronomie est maintenant bien établi à Athabasca University, ce qui rend utile de considérer les changements qui ont eu lieu au cours de la dernière décennie. Nos cours d'astronomie sont enseignés complètement par les techniques d'instruction à distance. On fournit aux étudiants un guide d'études ainsi qu'un manuel, mais des suppléments, en partie informatisés, constituent une partie importante des cours. Ce modèle d'instruction à distance comprend aussi des interactions régulières avec un tuteur. Nous offrons en ce moment deux cours au niveau de première année d'études universitaires, un cours de géologie lié à l'astronomie, et un cours de recherche indépendante. Les cours de première année traitent de tout le domaine de l'astronomie. Le premier de ces deux cours est au niveau de débutant, mais le suivant se sert plus des mathématiques et comprend des exercises de laboratoire informatisés. Ces cours offrent aux canadiens partout l'occasion d'étudier l'astronomie au niveau universitaire. En plus de décrire ces cours, nous essayons ici d'expliquer la croissance de l'instruction à distance en astronomie. Nos inscriptions se chiffrent à 200, dix fois plus qu'il y a dix ans.

1. Introduction

Distance Education (DE) is the presentation of an educational curriculum through self-study materials, often supplemented by regular contact with an instructor. DE is suitable for offering educational opportunities to students in the widely dispersed locations typical of Canada. Athabasca University (AU) primarily uses "asynchronous home study" methods, which means that students may start and progress through courses on their own timeline (subject to time limits), and do so at home. AU also has an open admission policy so that anyone may enter introductory level courses. Students must write invigilated exams in order to obtain credit for the astronomy courses (and most others at AU). An overall passing grade and a pass on exams are required to get course credit. At present, over 24,000 students worldwide are enrolled at AU. This makes AU a small university on the world scale where distance universities may have hundreds of thousands of students (Jones 1998), but a major DE force in North America. Most AU students are Canadian,the majority being from Alberta. Our first astronomy course (Connors 1992a) was introduced in 1989, which was the fifteenth year of the university's existence. We now have about 200 astronomy students, a modest number compared to programs in Britain (Jones 1995) and France (Gerbaldi & Xerri 1998), but again significant both in terms of DE in North America, and in terms of number of astronomy students at a Canadian institution.

In AU courses, the regular contact with an instructor is usually in the form of "tutoring." The materials are designed for individuals studying at home, but the tutor is available regularly to be contacted for help on difficult points. In this way, occasional obstacles to progress can be dealt with, and progress optimized. A toll-free number is available for students to contact tutors during certain tutorial periods, but in practice email is now used for the bulk of student-tutor interactions. In the astronomy courses, the contact with the tutor is more formalized in that "telephone" quizzes (often now done by email) are used as a small component of evaluation. The main purpose of these quizzes is to ensure contact and support as the student progresses. They also prepare the students for the final exams, which have the same general format.

2. Science 280

Science 280, Introduction to Astronomy and Astrophysics, was offered from 1989 to 1996 as a broad introduction to astronomy at a pre-calculus level (Connors 1992a). In common with all courses described below and most AU courses, this course used a commercial textbook (Freidlander 1985), supplemented by extensive materials produced at the university. This contrasts with the practice of preparing entire course packages, as done, for example, at Britain's Open University (Jones 1995). The course included a computer-based laboratory (observing simulation) done in students' homes on a DOS-based computer (Connors 1992b). Widespread availability of PC-compatible computers enabled this course to bring astronomical education, including an "observational" component through the laboratory simulations, to Canadians who otherwise would not have had access to it.

3. Astronomy 200

Astronomy 200 (Introduction to Astronomy and Astrophysics I) replaced Science 280 in 1995. This is a somewhat mathematical survey course based on Freeman's *Universe* textbook (Freedman & Kaufmann 2002) accompanied by a customized study guide. The course is a three-credit "one-term" course that nominally takes six months to complete. It carries laboratory credit due to its large assignment set based on simulated observations. A computer and printer are required to complete the lab exercises in this course: the university's surveys of students indicate this requirement is no longer a barrier to access. A non-credit introductory lab gives both steps to follow and results for a study of eclipses and the orbit of the Moon. This exercise not only shows how to use the computer program, but touches on subject matter that often causes problems for students.
The course proceeds in a fairly standard route through five units:

- Unit 1 Humanity and the Cosmos
- Unit 2 Tools of the Astronomer
- Unit 3 The Solar System
- Unit 4 Stars and Their Properties
- Unit 5 Galaxies and Cosmology

The first unit is a general introduction to astronomical phenomenology and history. The second has the most content from physics and is often regarded as the most difficult. The solar system unit is descriptive, while the unit on stars reinforces physical concepts. The last unit covers large scale structure. Each unit has a telephone quiz and an associated lab exercise. It is mandatory to submit labs in order to proceed through telephone quizzes and be allowed to write the exam. This attempts to overcome the tendency of students to put off the rather difficult labs until the end of the course and then perhaps never finish them (and thus fail the course).

When the course replaced Science 280, laboratories were updated to an early planetarium program, *SkyGlobe* by Mark Haney, distributed as shareware. Later, when software was included with the textbook, the option was given to use *Starry Night* in the simulated observation portion. Other labs are based on large data sets and Hubble data. The lab topics are:

- Lab 1 Motions of the Sun and Moon
- Lab 2 Planetary Motion
- Lab 3 The Nearest Stars
- Lab 4 Distances to Clusters
- Lab 5 Galactic Structure

The first two of these are done with planetarium programs and are rather lengthy. The other labs have options. One can use data (Connors 1993) from the Astronomical Data Systems' CD-ROM to make an HR diagram for nearby stars, estimate distances to clusters, and study distribution of stars in our galaxy, or look at spectra, HR diagrams, and Hubble's law using CLEA labs (Marschall 1997; Marschall 1998). The last lab has a further option to use Hubble Space Telescope data for Cepheid variable stars to estimate the distance to the Virgo cluster (Dutkevitch 1998). The course is updated every few years as new textbook editions come out, and lab materials are similarly updated.

4. Astronomy 205: Universe – The Ultimate Frontier

Astronomy 205 was introduced as a lower-level introductory course in 1996. This course does not stress mathematical concepts, yet surveys the entire field of astronomy and discusses astrophysics. The course was developed since many people interested in astronomy were taking SCIE 280/ASTR 200 without adequate preparation, and not doing well. It matches numerous 3-credit general astronomy courses for non-Science majors and uses the textbook *Horizons* (Seeds 2002), with a purchased study guide (Lattanzio *et al*. 2000) linking this text to a videotape series. This series was broadcast for a number of years with a wide audience, but most students preferred to borrow tapes from the university library. Since this borrowing service is offered by mail and is free of charge, it is a good way to have tapes on hand for viewing when convenient.

This course is laid out slightly differently from ASTR 200, with only four units (each with telephone quizzes):

- Unit 1 Exploring the Sky
- Unit 2 The Stars
- Unit 3 The Universe of Galaxies
- Unit 4 Planets in Perspective

Although the motion of planets is discussed in the first unit along with the historical introduction to astronomy, their physical properties are studied in detail only at the end of the course. Aspects of stars and galaxies are in between, without any particular unit stressing quantitative physics.

A small portion of course credit derives from actual observational work, focusing on the Moon and stars. This portion has not been particularly successful, in part due to poor weather conditions that can interfere with observing. It is now supplemented optionally by use of a planetarium program. Students appear to take this course largely due to a desire for course credit and likely with less of an interest in practical astronomy than might be hoped. This may explain the lack of interest in doing real observations. Similarly, an attempt to have students understand spectra by observing them with a diffraction grating has not been very successful, possibly due to unclear instructions. In a recent course revision this exercise has been retained but simplified.

What has been more successful as an innovative inclusion is a book report. The term "book" is interpreted widely and a movie or software review may be used. Generally, attempts to review a textbook are discouraged since the students generally are not qualified to do so. There are strict requirements on length (concise) and format and some very interesting and insightful reports have been submitted. It is required that the report be presented in the context of what has been learned in the ASTR 205 course.

Despite the "general interest" nature of this course, we find that few people enroll purely for self gratification. Rather, they usually wish to obtain university level Science credit for application toward a degree. It is possible to combine ASTR 205 and ASTR 200 (taken later) into six credits of introductory astronomy. Many institutions will recognize this for equivalence since the level attained by the end of ASTR 200 is similar to that attained in one year of campus-based study.

5. Advanced and Future Courses

Astronomy 495, Projects in Astronomy and Astrophysics, allows university credit to be obtained for senior undergraduate level research work. To date there have been no enrollments in ASTR 495. Other Science subject areas typically get a few enrollments per year in project courses. Only new work can be presented for such courses, although it may be the analysis of data gathered previously. A project proposal and contract outlining the conditions of success ensure that a high standard is applied to evaluation. We offer this course as an analog to courses in Science that do get enrollments. Many such enrollments are by visiting students having obtained senior preparation elsewhere.

Geology 415: Earth's Origin and Early Evolution is nominally in Geology, but has a heavy emphasis on meteorites. Of its six units, five (Earth in the Solar System, Geochemical Tools and the Origin of the Elements, Types of Meteorites, Origins of Meteorites, and Formation of the Solar System and the Construction of Earth) are closely related to astronomy. A senior distance education course in this subject area is not available elsewhere, to our knowledge.

DE courses require a large investment to be made up front (Cravotta 2003): an entire course must be coherently laid out, involving many people in addition to the instructor. Possible senior astronomy courses at AU would likely be in the area of planetary science, reflecting faculty expertise and to provide a link from the junior courses to GEOL 415. The Open University has around 500 students in an advanced course in cosmology (Norton *et al.* 2001), suggesting that there is a demand for even such advanced topics among DE students.

6. Enrollment Trends

DE from Athabasca University has grown in popularity in recent years. This is likely partly due to technological progress, but more to a growing knowledge of the availability of the educational offerings, an appreciation that the DE mode of study is well suited to working people, and other factors not related to technology. The present enrollment figures for astronomy at Athabasca University are comparable to those of many larger campus-based universities, but the growth rates appear to be much higher.

Figure 1 shows enrollment in the university and in selected science courses. The overall enrollment at the university, as shown by the dotted line in the graph, has approximately doubled from the 1993–1995 timeframe to 2000. Further growth to 2001 was about 5% and trends at the time of writing indicated strong growth in 2002 also. While this is impressive, the astronomy subject area has grown

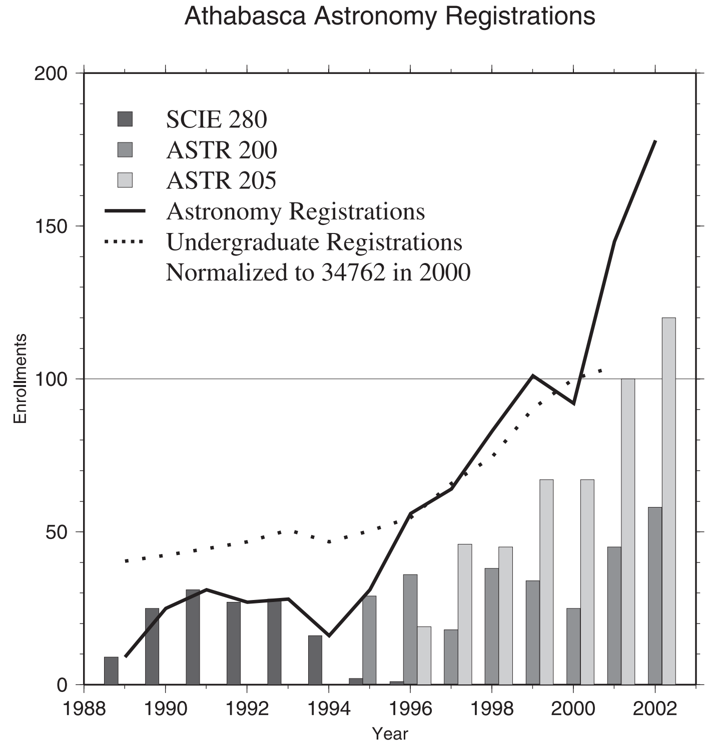

Figure 1. — Enrollments in astronomy courses at Athabasca University through Spring 2002 (extrapolated to a whole year). SCIE 280 is shown in black, ASTR 200 in dark grey, and ASTR 205 in light grey. Total astronomy registrations are shown by a solid line. For comparison, the total enrollment at the university has been normalized to 100 in the year 2000 and is shown by a dashed line. Note that students may begin any month of the year, so that these enrollment figures are not "start of term class sizes."

at an even greater rate, as shown by the solid line. From 1995 to 2000, enrollment approximately *tripled*. In 2001 and as projected to 2002, *at least 50% more* growth took place.

Although the "Science-stream" ASTR 200 course has seen a doubling of enrollment since 1995, *most of the growth* in the astronomy subject area is due to the non-major ASTR 205 course. *As a science option for non-Science students, a general introductory Distance Education Astronomy course seems to be in great demand.* In both 1998 and 1999, AU made attempts to offer this popular course in classroom sessions. Despite good advertising and the cooperation of the local Edmonton Space Science Centre (now Odyssium) where the classes were to be held, there was little interest in these courses and they had to be cancelled. We thus conclude that the distance education *format* is very attractive to students.

Due to the differing growth rates of the two streams of astronomy courses, we also conclude that there are likely two distinct groups of students taking our courses. There is a steady demand for a Science-stream course, although that demand is not growing as quickly as the demand for the non-Science-stream course. This claim is partly reinforced by enrollment trends in 1999–2000 when the ASTR 200 course had to be temporarily closed for course material revisions. A dip in overall astronomy enrollment took place even though we were actively redirecting students to ASTR 205 as a temporary replacement for ASTR 200. Apparently some students wanted or needed a Science-stream course to the point that they did not enroll in ASTR 205 instead when ASTR 200 was not available, and overall numbers suffered. We also note that enrollments dropped in 1994 when ASTR 200 was about to replace SCIE 280. This was a time of weakness in overall enrollments but a possible interruption in course availability during the transition period appears to have depressed enrollments.

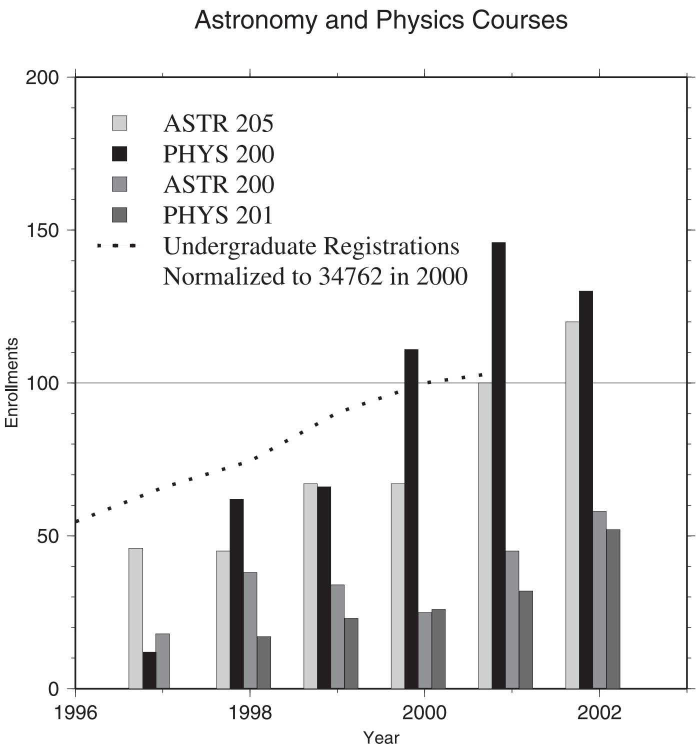

Figure 2. — Enrollments in physical science courses at Athabasca University from 1997 to 2002. ASTR 205 is shown in light grey, PHYS 200 in black, ASTR 200 in mid grey, and PHYS 201 in dark grey. Normalized total enrollments are shown by a dotted line.

Figure 2 shows enrollment in ASTR 205 and PHYS 200, "entry-level" first year courses, and ASTR 200 and PHYS 201 which are "second-term" first year courses. We make this distinction based on the idea that ASTR 200 and ASTR 205 have a different demographic as discussed above, while PHYS 201 has strongly enforced prerequisites, to prevent inexperienced students from entering, while PHYS 200 does not.

PHYS 200 has shown even stronger enrollment growth since 1998 than has ASTR 205. 1997 should not be counted as a predecessor course affected enrollment figures. Possibly, though, growth in PHYS 200 has leveled off, whereas ASTR 205 continues to grow. The facilitator of growth in PHYS 200 is almost undoubtedly the fact that Athabasca University offers, to the best of our knowledge, the only completely self-contained laboratory physics course that can be taken through home study. In general, however, these "entry-level" courses seem to show roughly correlated growth rates.

Apart from the one year of 1998, the "second-term" equivalent courses ASTR 200 and PHYS 201 also show correlated growth. Again this supports the idea that there are two groups of students taking our courses: one looking for entry-level courses and one ready for more advanced work.

A further aspect of Athabasca University's enrollments, shared by astronomy and other courses, is that the largest proportion of students remains Alberta-based. Since we no longer offer classroom-based courses in significant numbers, our courses can be thought of as equally available across the country and indeed the world. That most of our students are from Alberta is usually attributed to lack of familiarity to students outside the province. Tuition fees are also modestly higher for Canadians from outside Alberta, and significantly higher for foreign residents. Nevertheless, enrollments from Alberta have now declined to slightly less than half, from slightly more than half in 1997. Meanwhile, the percentage of students from Ontario has doubled to nearly 25%. Thus, our geographic enrollment base is becoming more representative of the population distribution in the English-speaking part of the country (while courses in the French language are handled by the Télé-université du Québec). This may be contrasted with the situation in 1992 (Connors 1992a) when 86% of the students were from within Alberta. Our desired path of future expansion is indicated by the fact that U.S. accreditation is being sought to allow growth there. While we do not present here any direct evidence that these enrollment trends are shared by the astronomy courses, they most likely are, and thus we may claim to be growing in importance in contributing to astronomy education in the whole of Canada.

7. Success Rates

Pass rates in our physical science courses are shown in Figure 3. These run below the nominal AU university average of 60 to 65%, and do not greatly differ from those about a decade ago (Connors 1992a). Most failures are due to attrition, while withdrawals within a preliminary trial period (one month) are without penalty and also not counted here as enrollments. Since students regulate their own progress, including when and whether to write exams, actual failure rates are low, about 10%. Most often, students who are not doing well take late withdrawal from the courses, with academic penalty but not counting

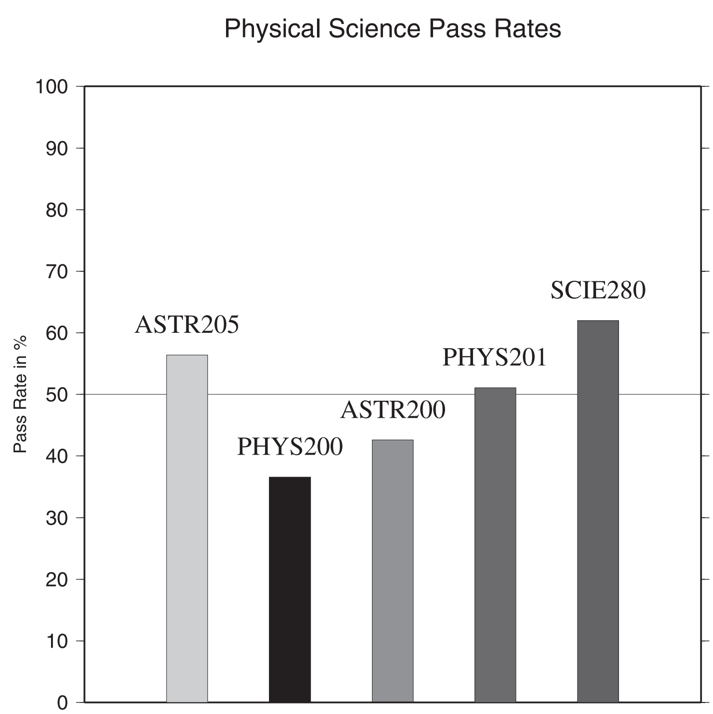

Figure 3. — Pass rates in physical science courses at Athabasca University. General science course ASTR 205 has the highest pass rate. See text for further discussion.

as a failure. In Britain (Jones 1998) and France (Gerbaldi & Xerri 1998), pass rates in astronomy surpass even the AU university average rate. This may reflect the preparation of the students or some instructional features.

PHYS 200 has a much worse pass rate than does ASTR 205. This is likely due to the intensive laboratory-based nature of PHYS 200. In that sense ASTR 205 is a much easier course for an unprepared student. The pass rate for ASTR 200 is not as high as that for PHYS 201 despite both being for more prepared students. Most students looking for entry-level general science courses now properly take ASTR 205. However, there are still likely a number who feel they would like to take the mathematically-oriented lab astronomy course, but who cannot cope once enrolled. On the other hand, PHYS 201 has a vigorously enforced prerequisite, so that this decision is not left to students, and those allowed to enter have already demonstrated ability to succeed in a difficult course (usually PHYS 200). Strangely, SCIE 280 of the early 1990s had the highest pass rate of all, despite being a lab course very similar to ASTR 200. It is possible that the lab content was easier, or that the smaller number of students who enrolled self-selected so that only more capable students took the course.

Other factors may also have affected student pass rates. The central databases of pass rates and other information about students are an important asset as Athabasca University attempts to improve distance education in general. The above general comments on aspects of enrollment and pass rates could lead to a more general study aimed at improving learning in astronomy. Clearly, as distance education astronomy comes to play a larger role, it is important to understand the factors in student success in it.

It is also important to understand what role technology may play as DE astronomy (and science in general) expands. Improvements in planetarium programs do not appear to have improved pass rates; perhaps the converse is true. This deserves further study.

8. Conclusions

Astronomy Distance Education is thriving at Athabasca University, with respectable first-year courses and a high growth rate. Since these courses are available to all Canadians, this is an important development on the national scale.

There appear to be two groups of students taking AU physical science courses and the general students appear to be well served by ASTR 205, the "non-science" version of introductory course. Significantly more complex courses such as ASTR 200 suffer from a low pass rate and there may be several factors behind this.

With tracking statistics such as those maintained by Athabasca University, the impact of variables such as new technological techniques can be assessed and those variables changed to optimize student learning and success.

ACKNOWLEDGEMENTS

We thank Institutional Studies at Athabasca University for statistical data.

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Society News/Nouvelles de la société

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

National Council Meetings

Congratulations to the Vancouver Centre for hosting the 2003 General Assembly. Everyone who contributed did a wonderful job, and I hope that everyone had a **Great** time at the events and tours that were scheduled.

The 2004 GA is being hosted by the St. John's Centre in Newfoundland and Labrador on the July 1st-to-4th weekend, so keep those dates open and experience a very rich and valuable time with other RASC members. For further information please visit `www.rasc.ca/ga2004.html`.

At the GA in Vancouver, we did have two National Council Meetings, one on June 27 (NC032) and another on June 29 (NC033). At the NC032 we welcomed a new Centre to join the RASC. Belleville Centre, which is halfway between Toronto and Kingston, is in the Quinte Area. They are a very active group, and are currently building a telescope. Please visit the RASC Web site, `www.rasc.ca` to view their home page. Welcome Belleville to the RASC.

Also, at the NC032 meeting, several members received their Messier and NGC certificates. Messier Certificate awardees at that meeting are:

David Barrie (Regina), Bob Brann (Regina), Sean Ceaser (Winnipeg), Sam Ferris (Regina), Paul Heath (Halifax), André Hiotis (Ottawa), Michael K. Holzer (Regina), Mark Kaye (Kingston), Kevin Kell (Kingston), Wendell Shuster (Okanagan), Jim Tisdale (Okanagan), Tenho Tuomi (Saskatoon), Harold Tutt (London), and Norman F. Welbanks (Kingston).

The NGC Certificate awardees are:

Michael K. Holzer (Regina), Jose Ordenes (Sarnia), Stan Runge (Winnipeg), Susan Sawyer-Beaulieu (Windsor), Gail Wise (Winnipeg), and Terry Millard (Unattached).

Congratulations to you all, and may you have clear skies to continue with your next observing challenge.

On a sad note, Vancouver Centre and we have lost a valuable member to the Society. Dr. Anne Underhill passed away on July 2, 2003. Upon retirement, Dr. Underhill returned to Vancouver where she became an Honorary Professor in the Department of Geophysics and Astronomy at UBC and received an honorary Degree, Doctor of Science. She was also an honorary member of the Society.

Meeting minutes should be available before the October meeting, for those who are interested in the details of the workings of the RASC and its council.

Upcoming Events

There will be a National Council (NC035) meeting on October 25, 2003 in Toronto, Ontario. There was a special National Council (NC034) meeting on September 14, 2003 by phone.

Request for Help

On our trip out west to the GA in Vancouver, we were fortunate enough to spend several days on the Island. We visited the H.R. Macmillan Space Centre and the Dominion Astrophysical Observatory but one of the many highlights of our trip was to visit a fellow RASC member in Courtenay, B.C., in the beautiful Comox Valley. Ed Majden showed us his observatory, and his Sandia All-Sky Camera set up at the Sandia Bolide Detection Station. Ed has been doing the all-sky search for fireballs (bolides) for many years now. Currently he has become the "Un-official coordinator" for taking on the project for all of the west coast network, but he would like some help to get more stations hooked up on the west coast. The set up is quite simple and would assist in spotting fireballs (bolides), which in turn would help with calculating the trajectory of and finding any meteorites that may fall to earth. From the AMS Meteors Web site (`www.amsmeteors.org/spectro.html`) you can see Ed's setup, and the meteor spectroscopy work that has been done on the bolides. If you are interested and want to learn more, contact Ed at `epmajden@shaw.ca`.

Later on at the GA, one of the talks was on the Sandia Labs All-Sky Camera Network, given by Dr. Doug Hube and the work that the University of Alberta, Athabasca University, and King's University College, all of Edmonton, Alberta, have been doing. For more information on this setup, visit `www.casca/ca/ecass/issues/fall2000/features/allsky/allsky.html`.

For a list of All-Sky Camera setups in the western provinces visit `miac.uqac.ca/MIAC/network.htm`.

If anyone does see a fireball (bolide) it is imperative to document all information, like: time, direction, any sound, colour, or any fragments detected. There are more details that can be used, but if you go to the `miac.uqac.ca/MIAC/` Web site, they have a form that you can fill out, plus pointers as to what you should look for, just in case you are one of the lucky ones to see a bolide. This can be a great help to discovering the path the bolide has taken and where a possible meteorite may end up.

There is talk of a South Eastern Ontario All-Sky Camera setup coming in a few months. This would be a very good project for all members of the RASC to participate in, plus it helps researchers and scientists with the location and the finding of space rocks, part of the origin of our universe.

A Tribute to David Levy

by Leo Enright (tcorbor@frontenac.net)

On Thursday, June 5, I attended the Spring Convocation of the Science Faculties at McGill University in Montréal, an event at which our Honorary President, David Levy, received a degree of Doctor of Science *honoris causa*. I was indeed pleased to be able to attend such an impressive ceremony held at the huge R.H. Tomlinson Fieldhouse. Along with the one for David, Honorary Doctor of Science Degrees were given also to the Nobel Prize winner and theoretical physicist Steven Weinberg, who delivered the convocation address, and to the internationally famous chemist and Order of Canada Officer Howard Alper. After the long ceremony, at which hundreds of graduating students from fourteen different Science Faculties received their degrees, it was good to be able to join David, his wife Wendee, and other members of his family at the reception, which took place in a gymnasium on the McGill campus. That evening, David and Wendee honoured their commitment to have dinner with the President of McGill at his residence. Later, along with several amateur astronomers from Montréal and London, I was pleased to join them at a downtown restaurant for conversation and reminiscences, such as always take place when long-time members of the RASC gather after not seeing one another for some time. My heartiest congratulations go to a most worthy recipient of this degree from McGill University.

I wish to share with Society members the citation for David as it appeared in the program for the Spring 2003 McGill Science Faculties Convocation:

Honorary Degree of Doctor of Science
David H. Levy
BA (Acadia University)
MA (Queen's University at Kingston)

As a young child in Montréal, David Levy remembers asking his brother to show him the Big Dipper. At age twelve, forced to stay at home with a broken arm, David read a book about the solar system and decided he wanted to become an astronomer or an author of books on astronomy. In 1965, while still a teenager, David saw his first comet, Ikeya-Seki. Soon he began searching for other comets with his telescope in his Montréal backyard.

Indefatigable in his quest for comets, David nevertheless also studied English literature. He received a bachelor of arts from Acadia University in Wolfville, Nova Scotia, then a master's from Queen's University in Kingston, Ontario. Each university has subsequently awarded David Levy another degree: an honorary doctorate in science for his comet discoveries.

Dr. Levy became an international celebrity in 1994 when, with world-renowned astronomers Eugene and Caroline Shoemaker, he discovered the comet Shoemaker-Levy 9. The comet's impact with Jupiter created a mushroom cloud larger than Asia. As no one had ever seen a comet crash into a planet, the images of these collisions became front-page news and forever changed our perception of the Earth's place in the Solar System.

Shoemaker-Levy 9 was not the first comet discovered by Dr. Levy. Since his first comet in 1984, he has discovered twenty more, thirteen with the Shoemakers at the Mount Palomar Observatory in California and eight from his own backyard.

Dr. Levy has been a leader in the popularization of scientific knowledge. He appears regularly on television, was part of the Emmy-award winning writing team for the Discovery Channel documentary *Three Minutes to Impact*, and has created *Comets are Coming!*, a show for sixty planetariums in Canada and the USA. He has a weekly radio program in Tucson, is a regular speaker across the continent, and presents a program for the schools in every community he visits. Dr. Levy is also an instructional specialist with the University of Arizona's Project ARTIST, a program designed to bring astronomy into the elementary schools of Arizona.

A prolific writer, David Levy is the author or editor of twenty-nine books that span historical, cultural, literary, and scientific domains. As the science editor of *Parade Magazine*, he reaches more than seventy-eight million people. He is also a contributing editor to both *Sky and Telescope* and *SkyNews* magazines. His book *More Things in Heaven and Earth* is a compilation of ideas from astronomers and poets about the night sky.

Perhaps not since the Renaissance have we seen such broad enlightenment in astronomy. Moreover, David Levy has achieved that most desired goal of a scientist — he has changed the way people understand the universe.

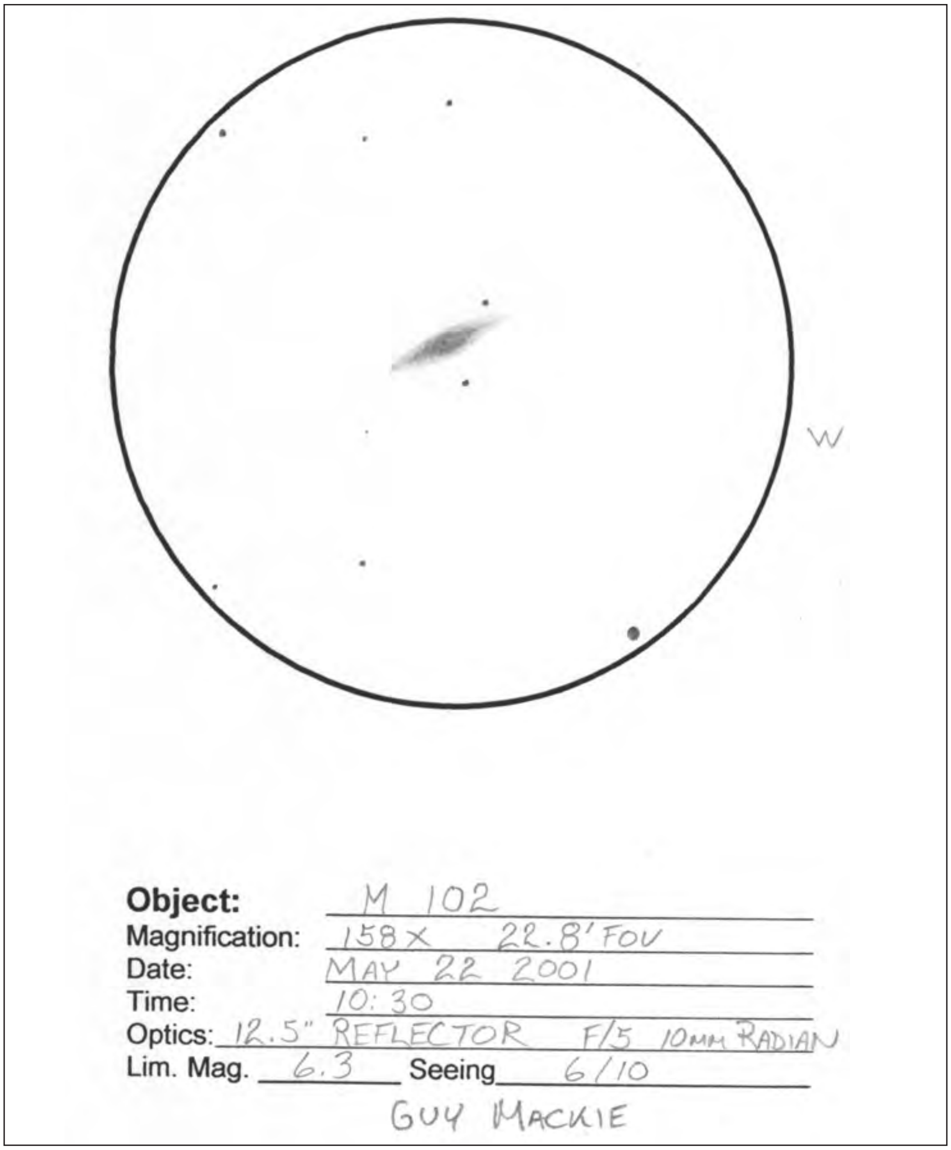
A long-time Kingston Centre member and Beginner's Observing Guide *editor, Leo Enright is a retired secondary school teacher who continues to study and photograph the pristine skies above his observatory overlooking Sharbit Lake. His email address recalls one of his favourite variable stars.*

Draconian Discoveries, Disparities, and Doppelgängers[1]

by Guy Mackie, Okanagan Centre (guy.m@shaw.ca)

While browsing through the Messier List of the RASC *Observer's Handbook* I noted one object with a total of three question marks in its reference information. How could my natural astronomical sense of inquiry not be piqued? Alan Dyer hints at part of the story behind the question marks in his "The Messier Catalogue" introduction found in the *Observer's Handbook*. A more detailed explanation of this object's uncertain identity can be found in the book *Messier's Nebulae and Star Clusters* by Glyn Jones. I am speaking here of the "clerical error" that is M102, in the constellation Draco the Dragon.

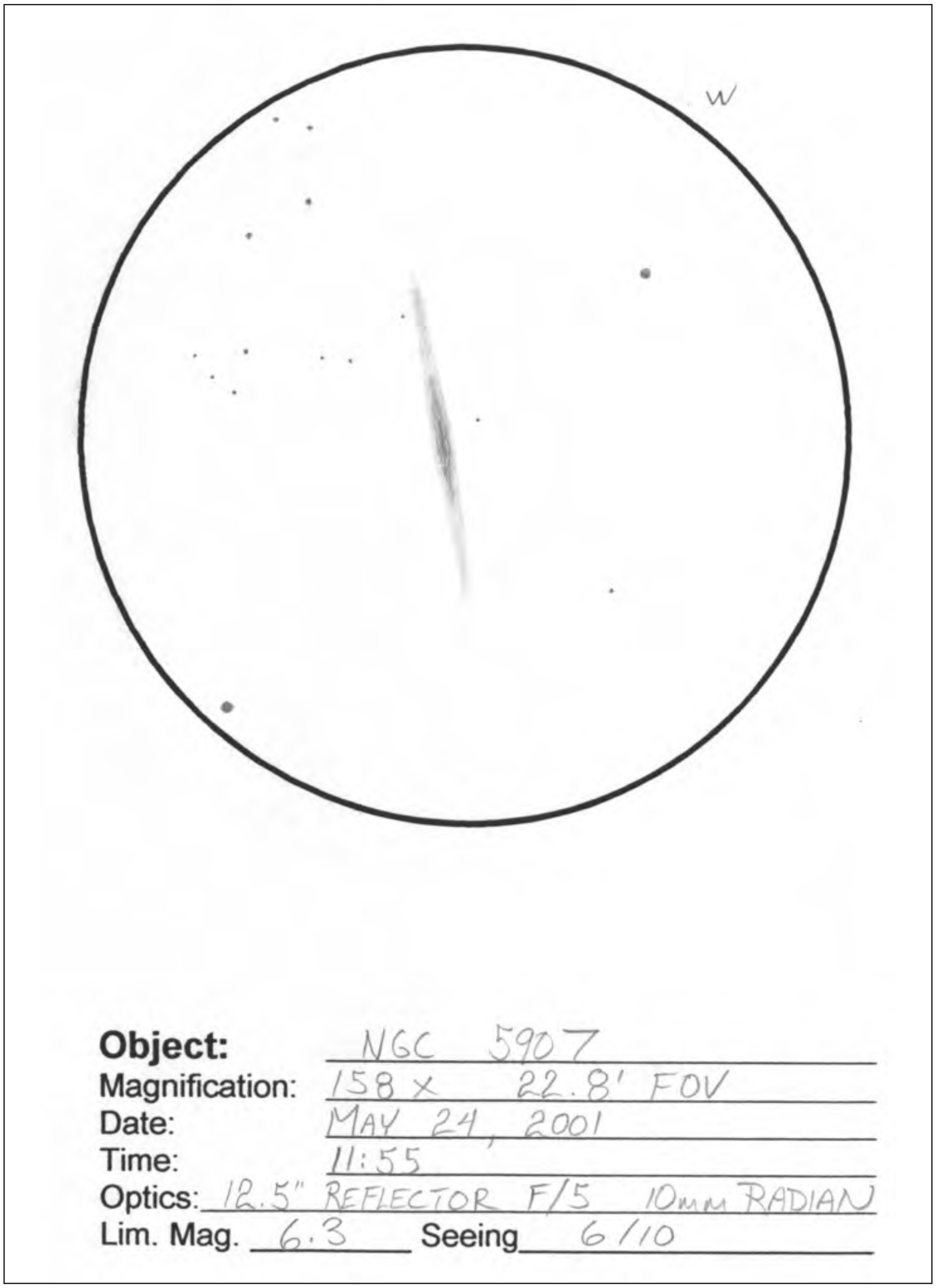
The tale of M102's identity crisis is a labyrinth of misprints, miscalculations, mistakes, and miscommunication, beginning with the last minute inclusion of observations by Pierre Méchain, which Messier did not have time to check before publication of his final Catalogue. Glyn Jones recounts the detective work done by Admiral Smyth, Harlow Shapley, J.L.E. Dreyer, and Helen Hogg, trying in hindsight to find the most likely candidate for the original observation. A lingering doubt about the true identity of M102 remains to this day and similar mysteries cloak M47, M48, and M91. The story of the lost identity of M102 makes for entertaining research and sheds light on the methods and human fallibilities that bring to life the personalities of some of the central players in the history of astronomical discovery. Alan Dyer identifies NGC 5866 as M102 for our RASC Messier List since it is the historical best fit, and I hope that while observing NGC 5866 you will consider some other historical mysteries that share the stage with M102.



As James McRae, Okanagan Centre Librarian, would say, "You will find M102 near the hockey stick of Draco" — where most people see triangles James sees only hockey sticks! In this case the hockey stick is the three stars Eta, Theta, and Iota Draco that mark where Draco turns the corner east of the handle of Ursa Major. M102 is about four degrees southwest of Iota. To make a quick one-stop hop, start from Iota and go towards the first star (Eta) in Ursa Major's handle following roughly the same line and same distance as between Eta and Theta Draco. It's easy once you are familiar with it.

The 9.9-magnitude **M102** is nestled closely between two faint stars (11.25 and 12.20 magnitude) making a positive

[1] From the Cambridge International Dictionary of English: **doppelgänger,** noun, the spirit of a living person which has exactly the same physical appearance as them: seeing your doppelgänger is said to be a sign that your death is imminent.



identification straightforward. Using my 12.5-inch Starmaster reflector and a 10-mm Radian eyepiece to yield 158× I see a bright elongated core area surrounded by a bright oval disk that I see as 5´ × 2.5´. Averted vision reveals a tiny nucleus that twinkles intermittently.

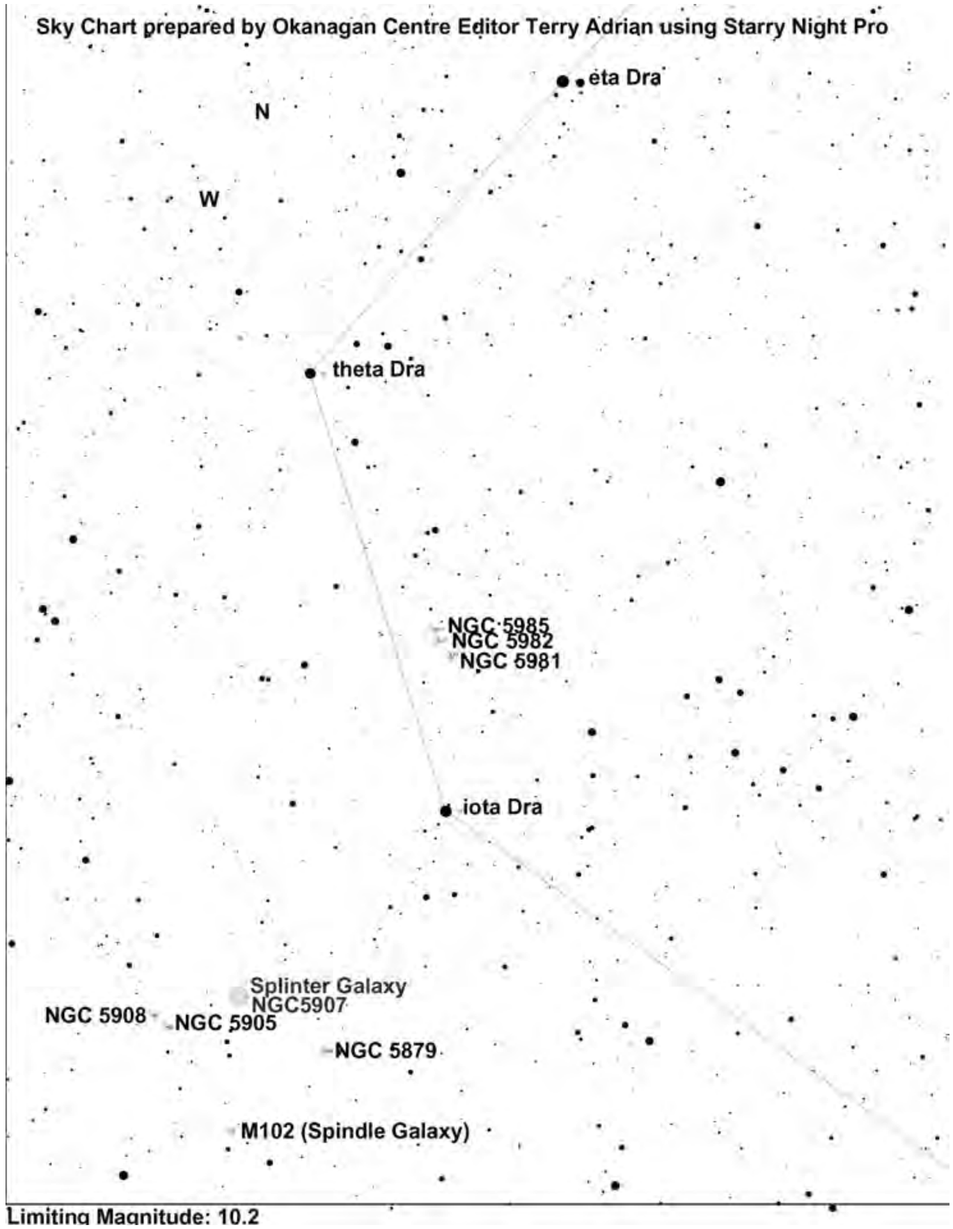
Using M102 as a jump off point there are many other rewarding discoveries for you to make in the Dragon's domain. It is a short journey from M102 to the showpiece (!!) Finest NGC Object **NGC 5907**. A medium power view of M102 will have the 7.6 magnitude star SAO 29401 just over 10´ southwest of the M102 core. Slide your scope 50´ northeast of M102 using the line of SAO 29401 and M102 as a pointer. Here you will find the 7.9-magnitude star SAO 29440 that is the first in a crooked line of three stars that point, as though it were their sole purpose, directly at 10.3-magnitude NGC 5907. Aptly referred to as the Knife's Edge, the Splinter, or the Needle, this edge-on 12´ × 2´ spiral lives up to all nomenclature hyperbole. Allow some time for your eye to adjust in order to appreciate the full extent of the elongated disk as it stretches out much further than you might initially think. The elongated core will silhouette a subtle dust lane under good seeing conditions.

I use the disk of NGC 5907 as a pointer guide and with a slight drift towards M102, move 40´ south of the southern tip of the disk to find what I have coined as the Dragon's Diminutive Doppelgängers or **NGC 5908** and **NGC 5905**. When I observe this face-on/edge-on pair of galaxies, separated by only 12´, I am reminded of the comparative spiral galaxy view angles of M81 and M82. It is the relative view and the size-to-separation distance that makes the two galaxy pairs doppelgängers in my imaginative opinion. Using a 10-mm Radian eyepiece to yield 158×, nearly edge-on NGC 5908 has an elongated streak of a core area surrounded by a faint 11.8-magnitude 3´ × 1´ elongated disk. Face-on spiral NGC 5905 glows weakly at 11.7-magnitude with a dim round disk of about 3´ diameter brightening slightly to a small core area. Both galaxies hold in direct vision at 125× through James McRae's 8-inch SCT from the clear and steady mountaintop skies at the 2002 Mount Kobau Star Party.

In 1844 Admiral Smyth described **NGC 5879** as "probably the object seen by Méchain," referring with reservations to another possible M102 candidate. Again I use the disk of NGC 5907 as a pointer guide to find NGC 5879. At a distance of 58´ northwest of the north tip of the disk of NGC 5907 it is located at almost a mirror of the positions of NGC 5905 and NGC 5908. Using a 10-mm Radian eyepiece to yield 158× I see NGC 5879 as being very similar in shape and structure to M102, but at a magnitude of 11.6 it is considerably dimmer: a small, elongated core surrounded by a 4´ × 1´ faint disk.

A most amazing sight awaits stargazers with larger apertures on the other side of the hockey stick. I was first shown the "triple-stack-variety-pack" of **NGC 5982, 5985**, and **5981** in Wallace Helter's 10-inch Orion Dobsonian at the 1999 Mount Kobau Star Party. The straight line and even spacing of these three galaxies, one elliptical, one face-on spiral, and one edge-on spiral, characterize this group. The face-on NGC 5985 is the largest and most easterly of the group. Using 158× it is an elongated blur: a dim 11.1-magnitude 4´ × 2´ disk surrounds a small core region. At the mid-point of this chain is the elliptical galaxy NGC 5982, the meat in our galactic sandwich, which at 11.1-magnitude is visually the brightest of the trio. Using 158× the 2´ diameter disk of NGC 5982 has a star-like nucleus, which is set in a bright core area. Anchoring the western end, and always the first to drift out of the field of view in an un-driven reflector, is the dim slash of NGC 5981. In my twelve and a half inch reflector this 13.0-magnitude edge-on galaxy is a dim elongated 2´ × 0.5´ streak with a slightly brighter slash of a core area. Wallace Helter's ten-inch will reveal all three galaxies in this 16´ long chain, but edge-on NGC 5981 fades to "averted imagination" in James McRae's eight-inch SCT.

Good luck, keep your head up . . . and keep your stick on the ice!



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Project Pluto, Guide 8 Software, www.projectpluto.com

Guy Mackie is president of the Okanagan Centre of the Royal Astronomical Society of Canada. He enjoys observing "Old Light" with his 12.5-inch telescope and then sketching and describing what he sees. He wishes to thank Alan Dyer for suggesting resource materials for this article; his thoughtful and generous guidance is very much appreciated.

Johannes Kepler's *Harmonice mundi:* A "Scientific" version of the Harmony of the Spheres

by Bruno Gingras, McGill University (bgingr@PO-Box.Mcgill.Ca)

Abstract: Today the notion of the "harmony of the spheres" is merely a myth, which one encounters as a metaphor in poems and novels. However, for many centuries, philosophers, music theorists, and astronomers took this idea very seriously. The great astronomer Johannes Kepler (1571–1630) was no exception. His book *Harmonice mundi*, published in 1619, is considered the last serious attempt to find musical harmony in the motions of the heavens. In an age in which empirical science was quickly overtaking theoretical speculation, Kepler sought to construct a cosmological theory which would include all the recent developments in the field of astronomy, of which many were his own discoveries, while at the same time preserving the essence of the ancient tradition of "celestial harmony."

> *Ironically, Kepler's revival of the ancient theory of celestial harmony came at just the time when a more exact knowledge of planetary distances and motions — which he himself had brought about — was making it nearly impossible to sustain the old theory. The* Harmonice mundi *was the final flowering of that theory, a fantastically detailed attempt to stretch the original idea to accommodate the New Astronomy that Kepler himself had created.* (Stephenson 1994)

Today the notion of the "harmony of the spheres" is merely a myth, which one encounters as a metaphor in poems and novels. However, for many centuries philosophers, music theorists, and astronomers took this idea very seriously, to the point that no serious discussion of astronomy or music theory dared omit a section on the "music of the spheres" (Stephenson 1994). The great astronomer Johannes Kepler (1571–1630), who nowadays is known mainly for the three planetary laws that bear his name, but who also wrote extensively on mathematics, astrology, music theory, and cosmology, was no exception. His book *Harmonice mundi,* published in 1619, is considered the last serious attempt to find musical harmony in the motions of the heavens (Stephenson 1994). In an age in which empirical science was quickly overtaking theoretical speculation, and in which observations that contradicted the opinion of ancient philosophers were no longer dismissed, Kepler sought to construct a cosmological theory that would include all the recent developments in the field of astronomy, of which many were his own discoveries, while at the same time preserving the essence of the ancient tradition of "celestial harmony."

In order to put Kepler's contribution in proper perspective, we will briefly recount the historical evolution of this tradition from the Greek Antiquity to the Renaissance, before turning our attention to Book V of the *Harmonice mundi*, which expounds Kepler's theory of celestial harmony.

Since Greek Antiquity, philosophers and thinkers have linked cosmology and music. This tradition, which seemingly goes back to Pythagoras, was defined by Gouk (2002) as a "speculative tradition assuming that audible music is a tangible expression of the underlying principles which govern the harmonious relations between the elements of all significant structures in the cosmos." The fact that sensible qualities such as consonance could be expressed by simple numerical ratios may have led the Pythagoreans to expect to find similar correspondences in other phenomena, including the structure of the universe (Walker 1978). By the time the numerical ratios for musical intervals were discovered, astronomy was already an established science, whose observations could be mathematically or geometrically expressed, and it was perhaps inevitable that music theory and astronomy would quickly become linked (Walker 1978). According to Aristotle, the Pythagoreans asserted that the circular rotation of the heavenly spheres produced sounds, in the same way as bodies rubbing together make noise.[1] Since the distances between the planets were thought to be in the same proportions as the ratios of musical

[1] The heavenly spheres were thought to be concrete objects, made of a solid matter. Briefly, the general view of the universe was that Earth was at its centre, and that the planets and stars (including the Sun) were located on transparent spheres that rotated around the Earth. The highest sphere, which accomplished a full rotation daily, contained the so-called "fixed stars," while each of the planets would be located on an inner sphere. Note that, until the discovery of Uranus in 1781, only six planets were known: Mercury, Venus, Earth, Mars, Jupiter, and Saturn.

concords, they must have made harmonious sounds. The Pythagoreans believed that we could not hear those sounds because they were with us since birth, and that, having never experienced the absence of the celestial harmonies, we could not notice their presence.

Among the earliest and most authoritative sources of the tradition of heavenly music are two passages from Plato, one from the *Timaeus* and another from the *Republic*. The myth of Er, in the tenth book of the *Republic*, relates the vision of a warrior killed in battle who came to life on his funeral pyre. In this vision, the heavenly spheres are described as eight concentric circles in the heavens, each carrying a siren that uttered one note, and the combination of all eight notes creates a concord of a single harmony. The *Timaeus* is a dialog that describes the construction of the world. In essence, this passage, which greatly influenced later cosmological theories, asserts that the world was created by building a sphere whose components were divided according to ratios corresponding to musical intervals, and that the basic units from which physical objects were built were the five regular polyhedra, or "Platonic solids," namely the tetrahedron, the cube, the octahedron, the dodecahedron, and the icosahedron (Stephenson 1994).

There were two main systems according to which the early planetary "scales" were constructed. In the most ancient system, traditionally attributed to Pythagoras, the heavenly bodies were assigned notes in a scale by associating the distances between them with the intervals between the notes of the scale. In other words, musical intervals were seen as an analogy for the distances among celestial objects (Godwin 1987).[2]

In a second system, which appeared later, notes were assigned to specific planets in relation to their speed of motion. Certain authors, such as Nicomachus (early 2nd century AD; Figure 1) and Cicero, used successive notes of the scale, while others used only fixed notes of the Greater Perfect System and Lesser Perfect System, that is, notes that constituted boundaries of a tetrachord. Ptolemy's *Harmonics*, one of the most influential treatises on music theory, and an important source for Kepler, presented such a system (Figure 2). Ptolemy was also known as an astronomer, and his *Mathematical Treatise*, now known as the *Almagest*, exposed a detailed astronomical theory that exerted a powerful influence up to the 16th century. In this treatise, Ptolemy developed the theory of epicycles to account for the retrograde motion of the planets. Briefly, he argued that the circle and the sphere are the most perfect geometrical figures since they represent perpetual unchanging motion, and that all celestial motions should be explainable using those two figures. The retrograde motion of planets was explained by proposing that they rotate around a small circle (the epicycle), which rotates itself around a main sphere (the deferent), thus tracing out loops (Figure 3; Martens 2000). Ptolemy's geocentric model of the solar system, with 8 spheres rotating around the Earth, was generally accepted until the Renaissance (from the closest to Earth to the farthest, these spheres were respectively those of the Moon, Venus, Mercury, the Sun, Mars, Saturn, Jupiter, and the fixed stars; Murchie 1961).

1	2	3
Note		Scale of Nicomachus
Nete	d'	Moon
Paranete	c'	Venus
Paramese	b♭'	Mercury
Mese	a	Sun
Hypermese	g	Mars
Parhypate	f	Jupiter
Hypate	e	Saturn

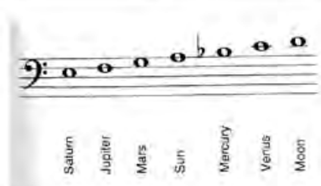


Figure 1. — Planetary scale of Nicomachus (from Stephenson, *The Music of the Heavens*)

While medieval astronomy was heavily indebted to Ptolemy, music theory and practice was defined for centuries to come by Boethius (c. 480–524 AD). His encyclopedic treatise *de Institutione Musica* proposed a division of music into *musica mundana* (the music of the spheres), *humana* (the influence of music on the human soul), and *instrumentalis* (the music sung or played on a instrument). Boethius also coined the term *quadrivium* to indicate the grouping together of the four liberal arts of geometry, mathematics, music, and astronomy (Gouk 2002).

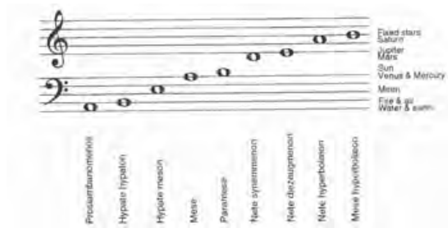


Figure 2. — Ptolemy's planetary music (from Stephenson, *The Music of the Heavens*)

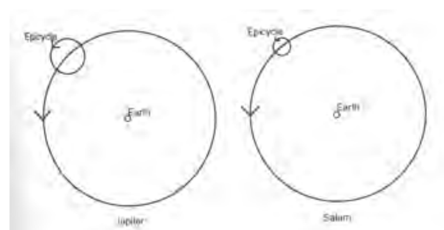


Figure 3. — Geocentric model for Jupiter and Saturn (from Martens, *Kepler's Philosophy and the New Astronomy*)

During the Middle Ages, although the notion of music of the spheres was kept alive as a literary metaphor, the tradition was becoming increasingly petrified and transmitted solely through copying of ancient texts (Chailley & Viret 1988). The situation was to change drastically during the Renaissance, as the rediscovery of the Antiquity, combined with important progresses in astronomy, instilled a renewed vitality into this moribund tradition.

Although a few ancient Greek philosophers, such as Aristarchos of Samos in the 3rd century BC, and medieval

[2] Unfortunately, there are no remaining detailed accounts of such systems, and it is not known exactly which notes were associated to which planets.

astronomers such as Nicholas de Cusa (1401–1464), had proposed that the Earth was revolving around the Sun and even rotating around its own axis, Ptolemy's geocentric system was not seriously challenged until 1543, when the Polish astronomer Nikolaus Koppernigk, better known as Copernicus, published a revolutionary treatise in which he suggested that the Earth revolves daily around its own axis and annually around the Sun, which is at the centre of a system of revolving planets. Although the Earth was traditionally believed to be flat, the travels of Colombus and Magellan had opened up the possibility that the Earth was spherical (Murchie 1961). Copernicus' system explained the apparent retrogressions in the motions of the planets, by saying that the Earth was passing outer planets or was being passed by inner planets along its annual course (Figure 4; Martens 2000). The Copernican, or heliocentric, system had the advantage of being much simpler than the Ptolemaic system, but the disadvantage of contradicting the appearances (after all, the Sun and the stars *seem* to be rotating around the Earth), and there was no empirical evidence that clearly favoured one system or the other.

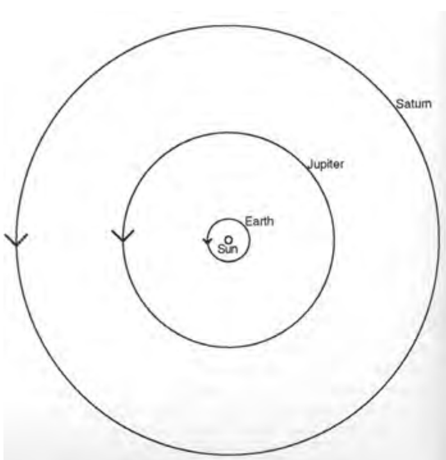


Figure 4: Heliocentric model for Jupiter and Saturn (from Martens, *Kepler's Philosophy and the New Astronomy*)

One of the advantages of a heliocentric system was that it allowed one to determine the order and relative distances of the planets, by taking the radius of the Earth's orbit as an arbitrary unit. Under the Ptolemaic system, the ratio of the radius of the deferent (main sphere) to the radius of the epicycle for a single planet could be evaluated, but there was no common unit of measurement and the relative distances of the planets could not be determined empirically (Martens 2000). However, while the Ptolemaic system allowed planetary distances to be modeled such that the spheres of the planets would nest on top of each other and that the relative distances would follow musical intervals, the distances determined by the Copernican system seemed arbitrary. At a time when the common assumption was that the world was God's creation, it was difficult to explain why God would have chosen such an arbitrary construction. Moreover, the Danish astronomer Tycho Brahe (1546–1601), renowned for the accuracy of his observations, had noticed that, if Copernicus' theory was true, then the stars were far more distant from the Earth than was previously supposed, since their relative position in the sky did not seem to change, and it was difficult to accept that there would be such a wide gap between Saturn (the outermost planet at the time) and the fixed stars.

This is the context in which Kepler began his career as an astronomer, in the last decade of the 16th century. Kepler had first intended to become a Lutheran minister, but changed his mind after discovering the science of astronomy. Kepler's initial doubts about abandoning his religious vocation were washed away when he realized that he could still commune with God through the study of the heavens, by showing how the harmony and beauty found in the structure of the universe were a reflection of His creation: "I was determined to be a theologian: I was distressed by this for a long time. But look! Even in astronomy my work worships God."

Kepler received his initial training in astronomy from Michael Maestlin, a respected astronomer and convinced Copernician. Maestlin had shown that the trajectory of the comet of 1577 could only be satisfactorily explained under a heliocentric system. Moreover, he was attracted by the simplicity and appeal of the Copernican theory. This had important consequences for Kepler, who was to become the most fervent advocate of the heliocentric system.

In 1596, at the age of twenty-five, Kepler, who was not yet an established astronomer, published his first book, *Mysterium cosmographicum*, which is concerned with the reasons for the number, magnitude, and motions of the planetary spheres. Basically, Kepler assumed that God created the world according to a plan, and, following the Pythagoreans and Plato, he supposed that this plan was grounded in a particular mathematical structure, the reflection of which could be found in the harmony and beauty of the world. The universe represented the Trinity: "the Sun in the center, which was the image of the Father, the Sphere of the fixed stars, or the Mosaic waters, at the circumference, which was the image of the Son, and the heavenly air which fills all parts, or the space and firmament, which was the image of the Spirit." The number and magnitudes of the planetary spheres were accounted for by the interpolation of the five regular polyhedra or Platonic solids; since there are only five regular polyhedra that could be inserted between the spheres, there could only be

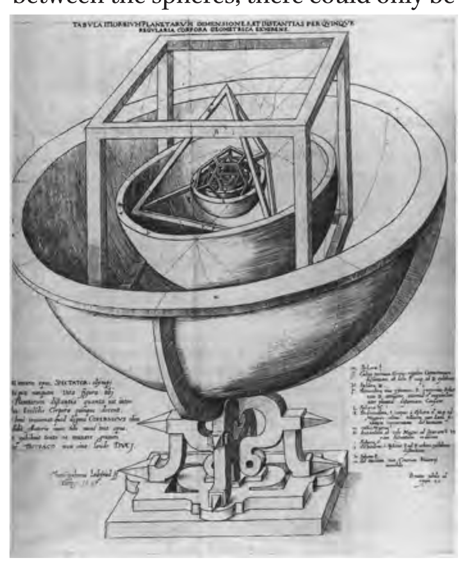


Figure 5. — Kepler's polyhedral theory (from Kepler, *Mysterium cosmographicum*). The spheres represent the planetary orbits, between which are inscribed the five Platonic solids.

six possible planets (Figure 5). There is no mention of music in the *Mysterium cosmographicum*, although, as soon as 1599, Kepler was planning to write a cosmological theory that made use of musical intervals. Many observers, including Kepler himself, have noticed that the *Mysterium cosmographicum*, although published when he was only twenty-five years old and still in the early stages of his career as an astronomer, already presents the main questions that will occupy Kepler for the rest of his life.[3]

In the hope of being able to use Brahe's observations to develop his cosmological theories, Kepler visited him and was appointed as his assistant in 1600. Somewhat unexpectedly, he succeeded him as court mathematician in Prague upon Brahe's death in 1601. In the words of Kepler himself, the reason he came to Prague "was the hope of completing my study of the harmony of the world, something I have long meditated, and which I could only complete if Tycho [Brahe] were to rebuild Astronomy or if I could use his observations." Thus, as J.V. Field (1988) has pointed out, it can be said that, if Kepler's cosmological theories exercised no perceptible influence on the development of cosmology, they did at least influence the development of Kepler's astronomy.

Indeed, Kepler is mostly remembered nowadays for having discovered the three laws of planetary motion, while his cosmological theories are known only to a few historians of science. In 1609, Kepler published the *Astronomia nova*, which expounded his first and second laws of planetary motion, derived from his study of the orbit of Mars. These laws, which are still valid today, state that 1) the orbit of every planet is an ellipse with the Sun at one focus, and 2) the straight line joining a planet and the Sun sweeps over equal areas during equal times. However, Kepler had not forgotten about the goals he had set for himself when he began his career, and he "combined his search for physical causes with a vision of the world as a manifestation of divine harmony" (Kepler 1619). In his correspondence, Kepler often alluded to the work of Ptolemy, which clearly had not only greatly influenced him, but inspired him to develop his own theory of the harmony of the world that would take into account not only the recent developments in astronomy, but also those of music.[4]

The *Harmonice mundi*, which had been planned in 1599 but whose publication was delayed until 1619, represents the crowning achievement of Kepler's work in celestial harmony. The *Harmonice mundi* consists of five books, which treat harmony in its geometrical, mathematical, musical, astrological, and astronomical aspects.[5] The astute reader will notice that, if one allows the disciplines of astronomy and astrology to be grouped together (as they were often until the Renaissance) for comparison purposes, the structure of this treatise precisely follows the traditional disciplines of the *quadrivium* as enunciated by Boethius. Books I and II deal with geometrical and mathematical theorems, more specifically with geometrical symmetries that give rise to all manifestations of harmony. According to Kepler, harmony was based on the geometrical relations between physical quantities, rather than in the purely numerical relations on which Pythagorean harmonic theory was based; for him, remarks Walker (1978), "harmony, musical or of any other kind, consists in the mind's recognizing and classing certain proportions between two or more continuous quantities by means of comparing them with archetypical geometric figures."

Book III presents Kepler's theory of musical harmony. Although not a musician by trade, Kepler was certainly a competent music theorist, whose training as a theologian allowed him to write authoritatively on such matters (Gouk 2002). Since Kepler gave a preponderance to geometrical relations over numerical ones in the establishment of harmony, it is perhaps not surprising that he developed a theory of consonance based on geometry, rather than on numerical intervals.[6] His reasons for doing so were that while numbers are discrete quantities, musical intervals are continuous, like geometrical figures. Moreover, Kepler remarked that numbers are abstract entities, while geometrical figures exist in physical things (Field 1988). Like Ptolemy, for whom he professed the utmost respect, Kepler gave precedence to observed phenomena when constructing theories. Hence, as it was the case with Ptolemy, the ear's judgment about what sounded pleasing was an important criterion for choosing among theoretical possibilities (Stephenson 1994). Since Kepler believed thirds and sixths to be consonant, and given the fact that contemporary composers used them freely, he felt that these intervals should be accounted for by his geometrical theory, and consequently decided to favour just intonation over Pythagorean tuning.

Books IV and V apply the mathematical and musical theorems introduced in Books I to III. Book IV provides a theoretical foundation for the

[3] Martens (2000) quotes Kepler: "Almost every book on astronomy which I have published since that time could be referred to one or another of the important chapters set out in this little book [the *Mysterium cosmographicum*], and would contain either an illustration or a completion of it."

[4] According to Stephenson (1994), "there can be no doubt that Kepler's painstaking investigations into the sublime harmonies of the planets were inspired by the belief that the greatest astronomer of antiquity had attempted to pursue a similar research program. He regarded Ptolemy's work in harmonics in much the same way as his work in astronomy: he regarded both as brilliant, even inspired, attempts to answer questions of fundamental importance."

[5] Note that here, as elsewhere in the text, "harmony" is used in its more general meaning of "pleasing arrangement," and does not necessarily refer to musical sounds.

[6] see Walker, p. 13.

astrological influence of harmonic aspects observed between heavenly bodies. Finally, Book V proposes a model that uses geometrically and musically harmonic proportions for the construction of the solar system. In Book V, Kepler also presents his third law of planetary motion, which states that the squares of the periods of revolution of the planets are proportional to the cubes of their respective mean distances from the Sun. However, this law, discovered in May 1518 when the *Harmonice mundi* was already sent to the printer, could not be truly woven into the main argument of Book V.

It is in Book V that Kepler presents the most complete and definitive assessment of his theory of celestial harmony, which, by his own admission, had occupied him for twenty years. As an introduction, Kepler expounds his theory of geometric harmony, already exposed in the *Mysterium Cosmographicum*, according to which the number of planets and the distances between them can be accounted for by nesting the five Platonic solids between the six planetary spheres. However, he admits that this model is only an approximation.[7] For that reason, Kepler sought, for twenty years, to find a better alternative. In the meantime, he had discovered the eccentricity of the orbital motions, which had led him to propose his first two laws of planetary motion. Because of the eccentricities of the orbits, explains Kepler, the Platonic solids are not sufficient to account for the structure of the universe: "On careful consideration, we shall plainly reach the following conclusion, that for establishing both the diameters and the eccentricities of the orbits in conjunction, more basic principles are needed in addition to the five regular solids" (Kepler 1619). This is where the musical intervals, whose geometrical origin had been demonstrated by Kepler in Book III, come into play.

The second half of this article will appear in the December 2003 issue of the *Journal*.

Bruno Gingras is a Ph.D. candidate in music theory at McGill University, Montreal. He is interested in counterpoint and music perception/cognition, and more generally in ways to combine his interest in music with his interest in science.

[7] Stephenson (1994) notes that "In the Mysterium cosmographicum, Kepler had not been really able to resolve the discrepancies between the proportions implied by the polyhedral theory, on the one hand, and the relative distances of the planets according to astronomy, on the other."

Computation of Model Asteroid Lightcurves: Practice vs. Theory

by Maxwell B. Fairbairn (mbfairbairn@hotmail.com)

Introduction

The theory of the photometry of asteroids modelled as rotating triaxial ellipsoids has been presented in the *Journal* (Fairbairn 2003). It was seen that in order to generate a lightcurve it was necessary to evaluate a double integral, which must be done numerically. As presented, the theory may seem to imply that it is necessary to repeatedly evaluate many bulky equations in order to do so, resulting in a program that is slow to execute. This is not the case. Here we present a description of a method of lightcurve computation based on approximating the asteroid surface as a set of connected triangular facets.

Method

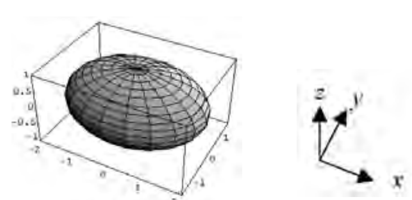
The equation of the triaxial ellipsoid

$$\frac{x^2}{a^2}+\frac{y^2}{b^2}+\frac{z^2}{c^2}=1 \qquad (1)$$

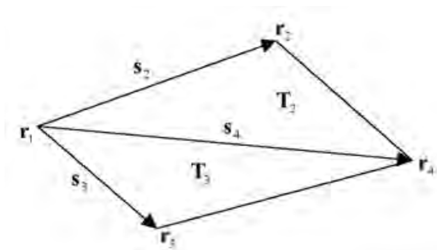
can be written in parametric form as

$$\begin{aligned} x &= a\cos\Theta\sin\Phi, \\ y &= b\sin\Theta\sin\Phi, \\ z &= c\cos\Phi, \qquad (2) \\ 0 &\le \Theta \le 2\pi, \\ 0 &\le \Phi \le \pi. \end{aligned}$$

A view of such an object, as rendered using Wolfram's *Mathematica*, with semimajor axes a = 2, b = 1.5, c = 1, is shown:



In this picture it can be seen that the surface has been approximated by a set of quadrilateral facets, of which the vertices are points on the surface of the ellipsoid. Consider one such facet whose vertices have position vectors $\mathbf{r}_1, \mathbf{r}_2, \mathbf{r}_3$, and $\mathbf{r}_4$, as calculated by equation (2) and then rotated. The figure shows the facet with each vertex labelled according to its position vector.



We now introduce three vectors $\mathbf{s}_2, \mathbf{s}_3$ and $\mathbf{s}_4$, which define two triangles $\mathbf{T}_2$ and $\mathbf{T}_3$.

$$\begin{aligned} \mathbf{s}_2 &= \mathbf{r}_2 - \mathbf{r}_1, \\ \mathbf{s}_3 &= \mathbf{r}_3 - \mathbf{r}_1, \qquad (3) \\ \mathbf{s}_4 &= \mathbf{r}_4 - \mathbf{r}_1, \end{aligned}$$

The respective areas of these triangles are

$$\Delta A_2 = \tfrac{1}{2}\left|\mathbf{s}_2 \times \mathbf{s}_4\right|, \Delta A_3 = \tfrac{1}{2}\left|\mathbf{s}_3 \times \mathbf{s}_4\right| \quad (4)$$

and the corresponding outward unit vectors normal to the surfaces are

$$\hat{n}_2 = \frac{s_2 \times s_4}{\left|s_2 \times s_4\right|}, \hat{n}_3 = \frac{s_3 \times s_4}{\left|s_3 \times s_4\right|} \quad (5)$$

If irradiated from the x-direction the cosines of the angles of incidence and reflection are

$$\cos\theta_i = \mu_0 = \hat{n} \cdot i, \quad (6)$$
$$\cos\theta_r = \mu = \hat{n} \cdot \hat{u}$$

where û is the unit vector in the direction of the observer. The relative magnitude that determines the lightcurve profile is then determined by summing the contributions of those facets that are both irradiated and visible to the observer:

$$m = -2.5 \log \sum_{\mu_0, \mu > 0} \sigma \Delta A \quad (7)$$

where *e.g.*

$$\sigma = \frac{\mu_0 \mu}{\mu_0 + \mu}$$

if the Lommel-Seeliger law is the chosen reflectance rule.

Discussion

The advantages of using this technique are that no bulky equations are required and that since dot and cross products are simple equations, the resulting program will execute much more rapidly than one designed by following the theory to the letter[1].

Computation can begin with, say, a 20×20 grid, which can be increased until the desired accuracy is achieved, by comparing computations of the projected areas ($\sigma = \mu$) to those of special cases, *e.g.* full phase equatorial and pole-on views, for which simple analytical expressions exist.

There is, of course, nothing new about modelling surfaces using triangular facets and it is especially appropriate for modelling irregular surfaces. A better method of triangulation than that described here is *octant triangulation*; see *e.g.* Kaasalainen & Torppa (2001).

From its shaky beginnings using triaxial ellipsoids as the shape model, the science of lightcurve inversion has advanced in recent years to the point where its resolving power is in the same class as Earthbound radar scans and space telescopes. There is little call nowadays for the triaxial ellipsoid except in special circumstances, see *e.g.* Kaasalainen, Torppa & Muinonen (2001); this reference is a "must see" for anybody interested in the asteroids.

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Kaasalainen, M., Torppa, J., & Muinonen, K. 2001, *Icarus*, 153, 37

Max Fairbairn completed his M.Sc. in Astrophysics at the University of Victoria, B.C., in 1972. Since then he has taught Physics and Computer Programming at various tertiary institutions. He lives near Sydney, Australia.

[1] Which the author had to do to verify the theory. The result was indeed a slow program. Using triangulation, the program executes "instantly."

Eclipse Flips

Eclipse Flips

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

when twilight falls among the stars
i sit and tinker with your moods
i hear your thoughts, i move the tides
i am your God, i am your Muse
i can be fire, i can be war
i am the daughter of Zeus
but tonight there won't be light
'cause i can't shine without you

— Patricia Barber, The Moon

The Moon tinkers with moods like wonder and mystery and obsession. Falling into the latter camp was one Theodor Ritter von Oppolzer (1841–86), a talented Viennese astronomer who wrote hundreds of papers, mostly on the orbits of asteroids and comets. His mathematical gifts were such that he reputedly knew by heart some 14,000 logarithms. Oppolzer's Muse was the Moon, and in particular its quirky dance with Earth and Sun that leads to periodic eclipses. He undertook to produce a "work of lasting value for science" by predicting particulars for all eclipses (excepting penumbral lunar) for centuries into the future and millennia into the past (`scienceworld.wolfram.com/biography/Oppolzer.html`).

Shortly after his death, Oppolzer's magnum opus *Canon der Finsternisse* (*Canon of Eclipses*) was published. It included painstakingly complete details for a staggering 8000 solar eclipses and 5200 lunar eclipses, from −1207 to 2163. The introductory section, which runs over 20 full-size pages for solar eclipses alone, details the copious calculations required for each eclipse, resulting in tables fully 35 columns wide. Oppolzer did have the cutting edge technology of the day at his disposal, administering a network of some ten "computers" of Type A: flesh and blood.

The immensity of the task, and the timing of the Canon's publication, led three independent resources for this column to choose the identical adjective, "monumental." An unabridged reprint with English translation was published three quarters of a century later in 1962. In their introduction, Menzel and Gingerich stated: "Although numerous eclipses have been examined with greater accuracy, no similar series of computations has been undertaken on such a grand and comprehensive scale." (Oppolzer 1887, 1962)

In an excellent example of interdisciplinary symbiosis, Oppolzer's Canon was a treasure trove not just for scientists, but also for historians, who compared the calculations with historical accounts of ancient eclipses. Such research inevitably revealed discrepancies, not in Oppolzer's methods but rather shortcomings in the theory of lunar orbital motion. Enterprising scientists, led by Oppolzer himself prior to his death, used the discrepancies to further improve the theory, eventually succeeding to the degree that modern eclipse predictions are to the nearest tenth of a second, albeit with the help of computers of Type B: silicon.

Over the shorter term, Oppolzer's method was accurate enough that over a century ago he predicted the upcoming total lunar eclipse of November 9, 2003 to reach greatest eclipse at 01:18 UT with semi-duration of totality of 12 minutes. The precise predictions of modern eclipse guru Fred Espenak are 01:18:32.5 UT and 12^m16^s respectively (Espenak 2002).

There are some remarkable happenings in the world(s) of eclipses just now. In November we will have an unusual double consisting of a total lunar and a total solar eclipse, on November 9 and 23 respectively, one near each node of the lunar orbit.

Most years contain two eclipse seasons, which occur at mean intervals of 173.31 days, slightly less than half a year due to the effect known as the regression of the nodes. This is why eclipses occurred in June and December last year, May and November this. In the large majority of cases there is exactly one each solar and lunar eclipse per season, with one of the two being central — either a total lunar, or a total or annular solar. Currently these bunch up as three, or in the current case, four total lunar eclipses at intervals of six lunations (the "semester"). A group of 4–6 central solar eclipses follows at similar intervals. This slow rotation is due to there being 173.31/29.53 = 5.87 synodic months per eclipse season, so the most central event in each eclipse season occurs at intervals of …6, 6, $5\frac{1}{2}$, 6, 6, 6... months, with the ½ signifying the flip from solar to lunar.

According to the NASA Eclipse pages, there are between 216 and 232 central eclipses of the two types per century, in ~211 eclipse seasons (`sunearth.gsfc.nasa.gov/eclipse/`). Central solar eclipses — including total, annular, and hybrid — are more than twice as common; in the period 1800–3000 there is an average of 154 per century, compared to only 70 total lunar eclipses. This is consistent with the findings of Steel (2001) that central solar eclipses are certain if the Sun passes within 10° of a node, and possible up to 12° distant. The Full Moon must be within a more stringent 3.75° (certain) to 6° (possible) of a node for a total eclipse to occur. In a significant sample I found no instances of an eclipse season without a central event for either Sun or Moon, leaving precious few "extras" to double up.

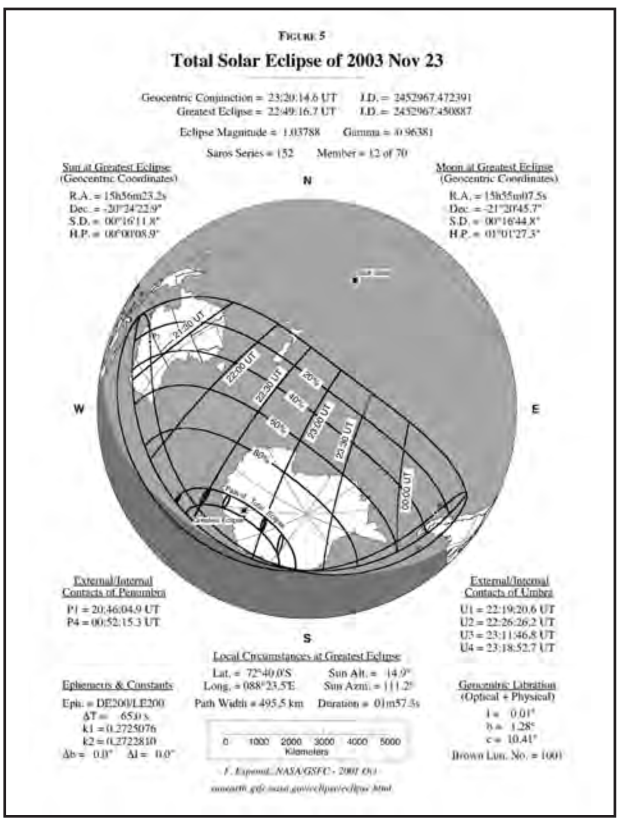
The last time two true total eclipses occurred in the same eclipse season was in autumn 1985, with both occurring 18 years 11 days prior to their modern counterparts. This is the well-known Saros period after which Sun, Earth, and Moon all return to very near the same relative positions. Long series of eclipses and other phenomena recur at such intervals, with only slight changes in character from one member to the next. I refer the interested reader to Roy Bishop's excellent article on "Eclipse Patterns" in the *Observer's Handbook* (Bishop 2002).

The next occasion of two total eclipses within a fortnight occurs in March–April, 2015. Relaxing the rules to allow for annular solar eclipses, one finds a few more double central eclipses, one in 1990, another in 2008. Unexpectedly, one occurs in May 2003.

This is therefore an exceptional year in that *all four eclipses are central*; two total lunar eclipses, one total solar and one annular solar. Since it is impossible to have two total solar eclipses a semester apart, this is as good as it gets. The May 31 annular and November 9 lunar are the first and last central events of their respective Saros series, meaning no repetition of this year's quadruple in either 1985 or 2021. Finding no further examples in Espenak's *Fifty Year Canons* (1987), and having difficulty with Oppolzer's German, I had to crash the 'net to find out how rare this foursome is.

I found 2003 is the only time four central eclipses will be visible from Earth between 1957 and 2043. Using the more stringent requirement that the centre line itself must cross Earth, 2003 is the only four-central-eclipse year between 1939 and 2044.

A related phenomenon is the tetrad, in which four total lunar eclipses occur at intervals of one semester. A tetrad is underway in 2003–04. Given that fewer than 30% of all lunar eclipses are total, it would seem unlikely for four in a row



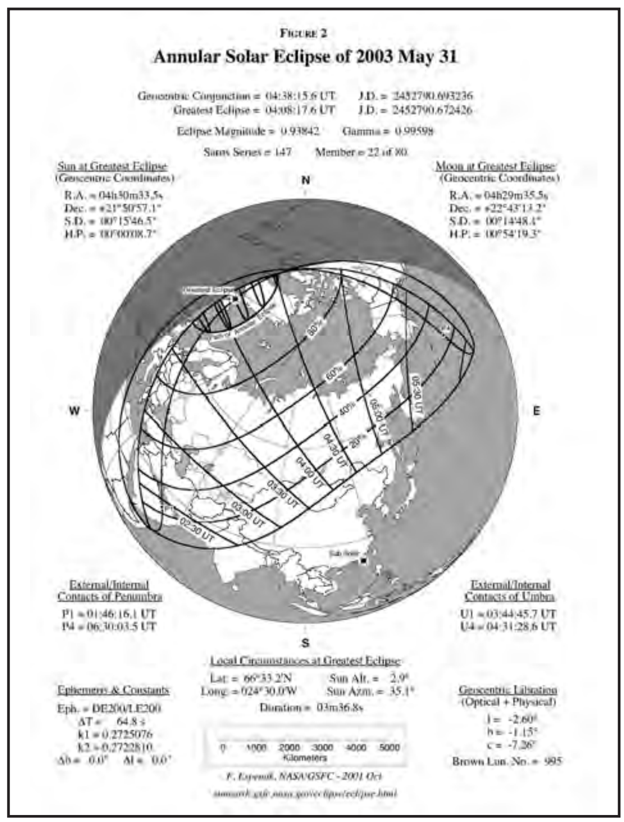


Figure 1. The two solar, polar eclipses of 2003. The first is technically a "central" eclipse as the centre line just barely touches the globe near the terminator, but is such an extreme grazing event as to have no northern limit; the single semi-circle passing through Greenland represents the southern limit of totality. In the case of November,s total eclipse the northern limit, represented as the upper of the double semi-circle passing through Antarctica, is actually closer to the South Pole than the southern limit! In both cases the eclipse occurs over a week after the Sun has passed the lunar node. (Eclipse figures reproduced from the *Observer's Handbook* with the kind permission of Fred Espenak of NASA/GSFC.)

to occur, but the celestial rhythms are such that tetrads occur at the rate of four-to-eight per century for close to 300 years, followed by a further three centuries with exactly zero tetrads. This six-century periodicity shows up in many eclipse phenomena, and is sufficiently (read: obsessively) interesting to warrant an entire future column. Suffice to say that we are currently in a tetrad-rich period, with the current quartet the first of eight in this century. The last occurred in 1985–86, the next in 2014–15, with that 29-year interval representing a little-known, yet important, eclipse period known as the Inex. Note the interesting "coincidence" that these dates mimic our previous findings re: last and next instances of two total eclipses in one month.

This is no fluke. What these groupings have in common is that each eclipse must be a near- grazing event, where the Moon just sneaks within the limits of totality, what Littmann, Willcox & Espenak (1999) describe as the "Danger Zone." Figure 1 shows that 2003's "central" solar eclipses occur at the opposing polar regions of Earth. The antumbral shadow of May's unusual annular eclipse passed "north of the North Pole" very near the terminator; from the earthbound perspective the eclipse path progressed from E-W, "backward" to the norm. A similar situation will occur during November's Antarctic eclipse.

Near grazing totalities are *de rigeur* with tetrads as well. Meeus (1997) points out the remarkable fact that currently the first eclipse of all tetrads commences in the first half of the calendar year, usually in March–May. This is a critical clue, as the first two events of a tetrad are certain to straddle the aphelion of Earth's orbit, as are the last two.

Let's examine in detail the current tetrad, whose individual members are shown in Figure 2. Given the Moon's place in "opposition" during a total lunar eclipse, its position mimics the Earth's ecliptic longitude. The eclipse figures at my disposal are presented in R.A. rather than longitude, but for rough purposes it shouldn't matter, especially at six-month intervals where declination (absolute) values are similar:

No.	Date	RA	Separation
A	May 16, 2003	$15^h 31^m$	
B	Nov. 09, 2003	$02^h 56^m$	171°
C	May 04, 2004	$14^h 48^m$	178°
D	Oct. 28, 2004	$02^h 11^m$	171°

The eclipses all occur at 177-day intervals — expected since a semester is simply 6 lunations at 29.53 days per (give or take a few hours) — but their rotation on the sky is clearly affected by Earth's eccentricity. The figure of 171° is critical: in 177 days the nodes regress approximately 9°, so that in November the ascending node is 180° – 9° = 171° from the position of the descending node in May. This makes the relationship of Moon to node very similar between eclipses A and B and again between C and D. There is a significant difference between eclipses B and C; during Earth's one perihelion passage of the tetrad the node shifts some 7° relative to the Full Moon, flipping from one edge of the Danger Zone to the other. All four eclipses therefore fall within Steel's parameters of ± 4–6° of a node.

In a subsequent email exchange, Meeus (2003a) himself made a similar point in different terms:

> "The fact that tetrads can occur is due to the eccentricity of the Earth's orbit. If this orbit were nearly circular, no tetrads were possible. This is explained in my French article (Meeus 2003b). The 'secret' of the tetrads is that, if the first eclipse takes place around April, then the Earth's equation of the centre is maximum and positive (+2 deg); then at the next eclipse (6 months later, around October) the equation of the centre is maximum but negative.
> Although the eccentricity of the lunar orbit is larger, it hardly affects the picture because the Moon's motion is much more rapid than the Earth's."

If the orbit were circular, Earth would turn just under 175° in a semester. The switch from +2° to −2° in Meeus' "equation of the centre" figures shows the Earth's orbit is roughly 4° out of round. The true RA values after half-year intervals should be ± 4° of 175°, in extremely good agreement with the "Separation" column above.

During a tetrad-rich era there are more total lunar eclipses — e.*g*. 85 in this century — but very few of them are deeply central. The grazing nature of the events through one hemisphere of Earth's umbral shadow makes for relatively short periods of totality, and a significant imbalance in refracted illumination. This November 9, the Moon is passing through the extreme southern portion of Earth's umbra, with the fifth shortest totality of the 85. The south limb of the Moon therefore will be significantly better lit than the north. This will exaggerate the natural asymmetry between the Moon's bright southern highlands and dark northern maria. The eclipse of October 28, 2004, also visible from North America in the evening hours, passes through the northern portion of the umbra. This will have the opposite effect of reducing the albedo imbalance, giving the two eclipses a completely different appearance that should be obvious to the alert naked eye.

I must admit to having shared Oppolzer's magnificent obsession with eclipses for at least a few weeks this summer. Of course, Theodor and I have long been close. Oppolzer is sufficiently famous (and sufficiently dead) to have a lunar crater named after him (Rükl 1991). A prime piece of lunar real estate it is, too; a 43 km crater centred on 1.5° S, 0.5° W, making it the most central named feature on the Moon. Except one. At 1.1° N, 0.4° E lies a small, obscure crater known as Bruce.

Acknowledgements

The assistance of Jean Meeus (RASC Honorary Member) is gratefully acknowledged.

In fairness, the philanthropy of Catherine W. Bruce, 19th century American patron of art and science, should also be acknowledged.

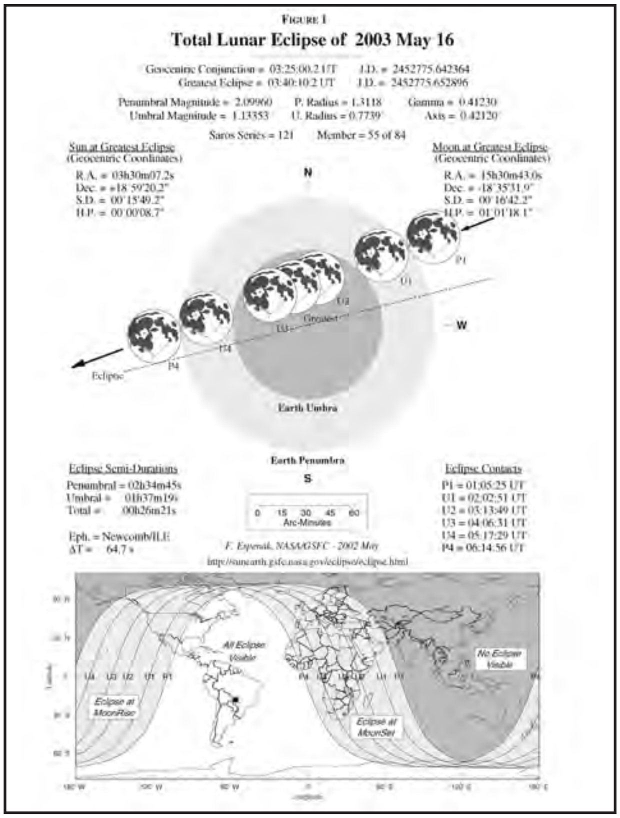
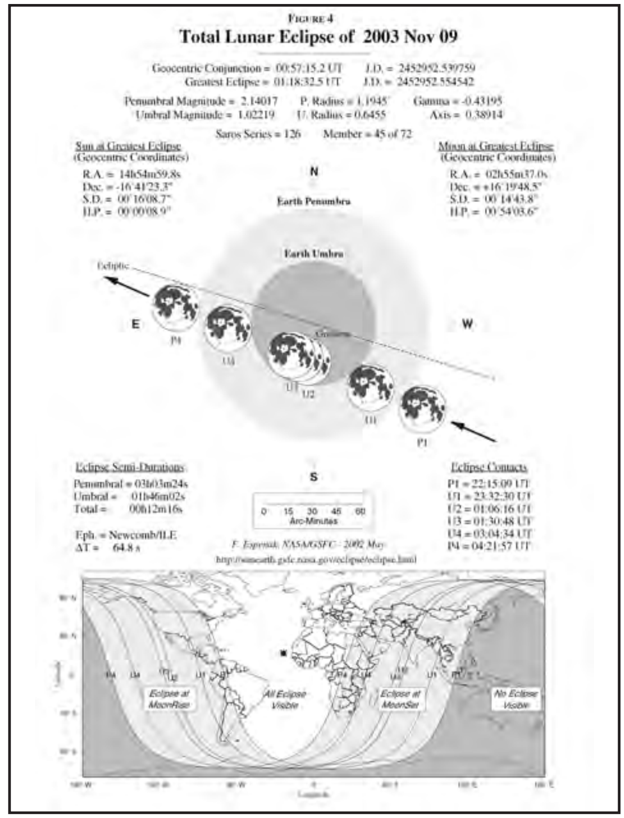


Image A



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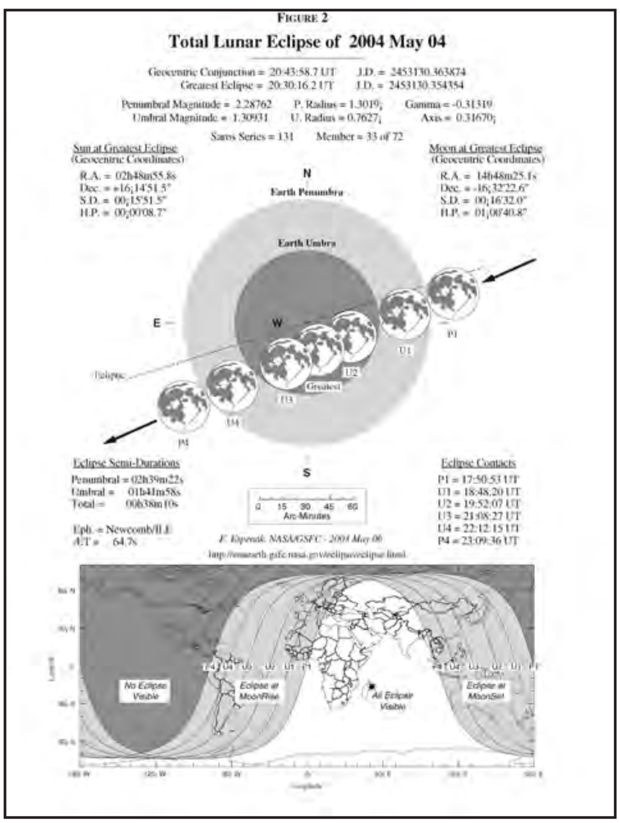

Image C

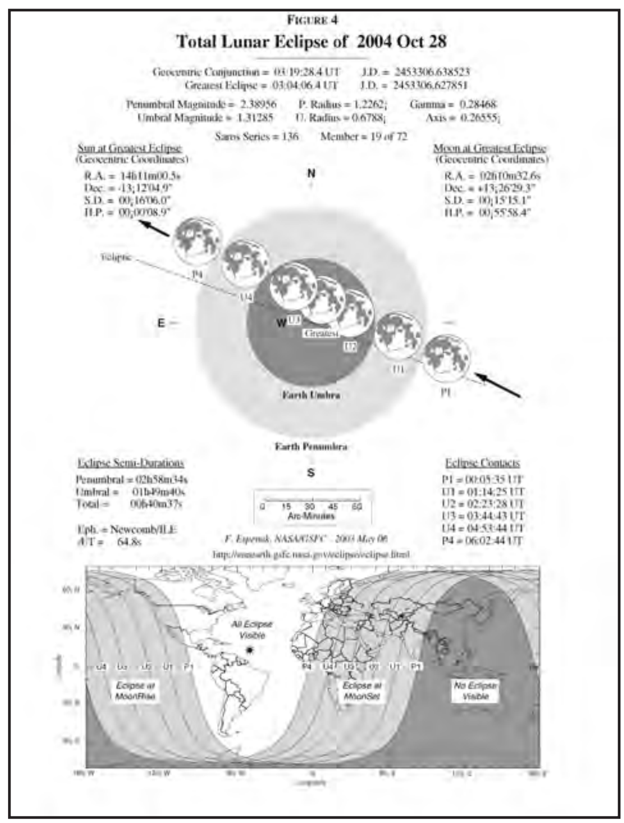

Image D

Figure 2. — The current tetrad. The group can be considered as two similar pairs of events occurring at the Moon's opposing nodes — not unlike pairs of Venus transits — as shown in the columns. Note that 2A and 2B occur before the Moon reaches the node, and 2C and 2D occur well after, fundamental to all tetrads. This arrangement forces tetrad members to pass through Earth's shadow in the sequence N-S-S-N or S-N-N-S.

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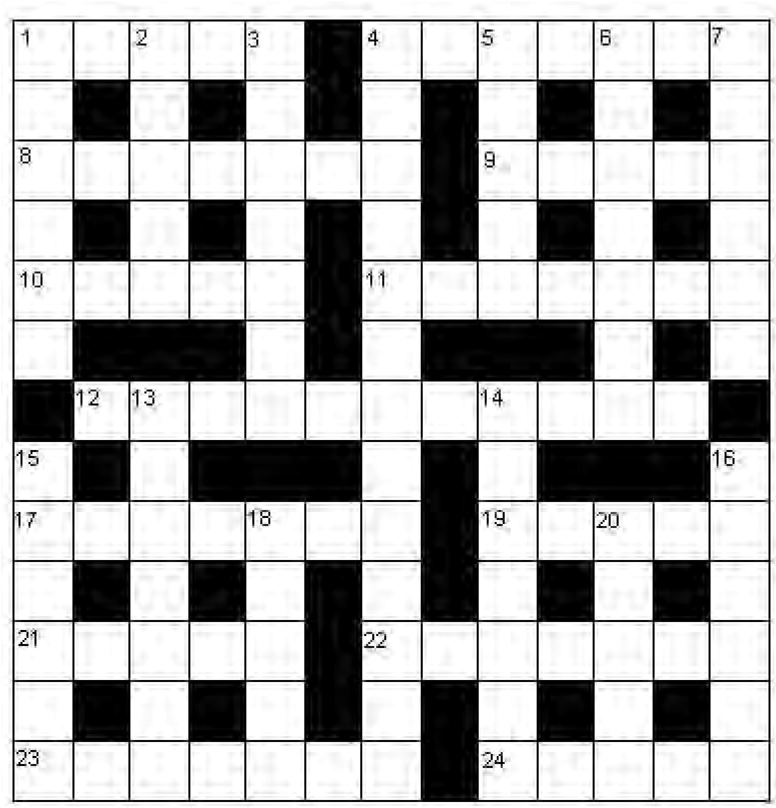
Bruce McCurdy is active in astronomy education with RASC Edmonton Centre, Odyssium, and Sky Scan Science Awareness Project. He currently serves National Council as Astronomy Day Coordinator. The Orbital Oddball has been observing and obsessing over our own odd orb for one Saros.

Astrocryptic

by Curt Nason, Moncton Centre



ACROSS

1. If Walter sounded worse he'd filter sunlight (5)
4. Unusual tin star seen at the meridian (7)
8. It starts telling a long story about an arrow (7)
9. Modified Ricoh camera captures Jupiter's ethereal fluid (5)
10. Was she French at noon, this Ochoa of Atlantis? (5)
11. Lunar period will not be phased out (7)
12. Star wheel plan is here about the head of Pyxis (11)
17. Collapse catastrophically when I am to trudge eastward (7)
19. Crown jewel is a real jewel to mother (5)
21. Endless crater eroded, leaving barely detectable amount of elements (5)
22. Edison got confused after one was electrically charged (7)
23. Nothing French about man who described space-time (7)
24. Fly high around the pole using batty navigation system (5)

DOWN

1. He'll be returning no more parallax measurements (6)
2. Go all around an eclipsing variable (5)
3. Dragon's yellow eye lies within delta nineteen degrees (7)
4. Incredibly, Ares is right on an area of Mars (7,6)
5. Negative particle drives Druyan around an active moon (5)
6. Dismantled car shed highlights our queen (7)
7. Dark spot on Europa where Cadmus wrecked the car (6)
13. His nebular hypothesis transformed Capella (7)
14. Lunar rille first seen at Harvard, but the Sun returned to 1957 (7)
15. Star painter revealed telescopic torus (6)
16. Film maker sounds sheepish to the German (6)
18. The last nebula in Sagittarius (5)
20. Heavy electron bombardment blows apart some nuclei first (5)

Awards for Excellence in Astronomy at the 2003 Canada Wide Science Fair

by Frederick R. Smith, St. John's Centre (frsmith@morgan.ucs.mun.ca)

The Youth Science Foundation Canada (YSF), the parent body for science fairs in Canada, estimates that yearly over half a million Canadian junior high and high school students undertake science and technology projects, most of which are entered in school science fairs. Approximately 25,000 of these are entered in one of the 90 regional science fairs and the top projects then go on to compete in the annual Canada Wide Science Fair (CWSF).

A CWSF is an exciting event. Most are held at universities and the students spend a week living in residence, being judged for two days, going on day-long field trips, attending formal banquets, and of course the big event, the Awards Ceremony. Naturally science is forefront in the students' minds but a major objective of the organization is to allow young people from all parts of Canada to meet and exchange ideas and learn about their country.

The regional science fair committees affiliate with the YSF and the school population base is used to determine how many students a region may send the CWSF in any one year. Projects may be entered by one student or a team of two. Each year the CWSF is held in a different location and there is always competition from the regions to hold a CWSF. Years of planning are needed for a national fair and the bidding for any one fair will take place four to five years before the event.

The sites chosen for the next four years are: 2004 St. John's, Newfoundland, 2005 Vancouver, British Columbia, 2006 Chicoutimi, Quebec, 2007 Truro, Nova Scotia.

The 2003 Canada Wide Science Fair was held from May 10 to May 18 at the University of Calgary. Over 460 students set up 362 projects in the Olympic Oval and gave over 250 judges lots of hard but enjoyable work. As in previous years the first day of judging was for medals in the various divisions and the second day for the Special Awards donated and usually judged by sponsors such as the RASC.

Figure 1. — Sarah Ball, Andrea Kovesi, and Fred Smith (left to right).

This year I had the pleasure of judging for the RASC Awards with Dr. W.J.F. Wilson, Assistant Head, Department. Physics and Astronomy, University of Calgary. We had seven nominations for the Awards and after much deliberation we awarded junior and senior awards but felt there were no appropriate intermediate entries.

The Junior Award went to Andrea Kovesi from the Ottawa Science Fair region for her project titled "Twinkle, twinkle little star?" Andrea is interested in light pollution and our ability to see stars from within the city. She photographed the sky at different distances from the city and analyzed the pictures to determine the relationship between the number of visible stars and the distance from home.

Royal Astronomical Society of Canada
Award for Excellence in Astronomy

Junior, Intermediate and Senior Awards consisting of a certificate, $200 and a one year membership in the RASC

CWSF Divisions:
Biotechnology
Computing and Mathematical Sciences
Earth and Environmental Sciences
Engineering
Life Sciences
Physical Sciences

CWSF Levels:
Junior: Grade 7 and 8
Intermediate: Grades 9 and 10
Senior: Grades 11 and 12 (or equivalent)

The Senior Award went to Sarah Ball from the Western Newfoundland Science Fair for her project titled "Looming Large 2003." Sarah won the Senior RASC Award last year but this year her project on teaching astronomy through computer technology is far more extensive and is getting to the point where she should be able to market her work as a teaching aid.

We welcome Sarah back to the RASC for another year and Andrea as a new member.

For more information on this year's Canada Wide Science Fair go to `cwsf2003.org` and for information on science fairs in general go to `www.ysf.ca`. Readers with questions are welcome to contact the author at `frsmith@morgan.ucs.mun.ca`.

Frederick Smith is a member of the RASC St. John's Centre. He teaches introductory astronomy and astrophysics at Memorial University of Newfoundland and is actively involved with regional and national science fairs in addition to the RASC. He is a member of the host committees for CWSF 2004 and RASC GA 2004 both of which will be held in Newfoundland.

International Science and Engineering Fair (ISEF)

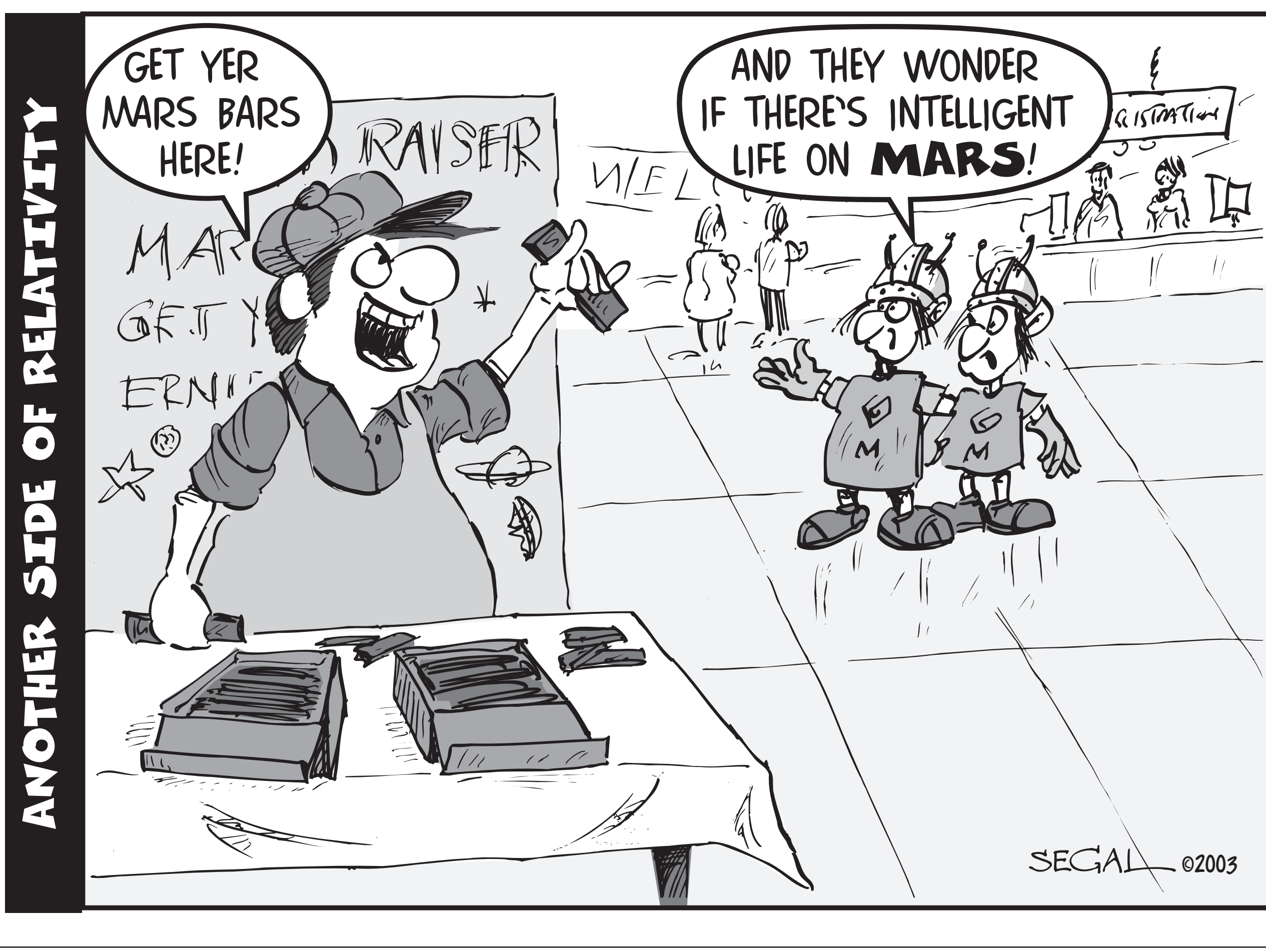
Canadian students did well at this year's ISEF held in Cleveland, Ohio. Congratulations to Jonathan Sick (age 17) of Calgary for his advanced telescope design. Jonathan won the American Astronomical Society and the Astronomical Society of the Pacific Award ($3,000US), the Optical Society of America Award ($1,000US) and the Intel Foundation Best Use of Computing Award. He was also one of three Canadians to win an award offered by the Patent and Trademark Office/US Department of Commerce/Patent and Trademark Office Society. These awards are designed to encourage students to apply for patents on their projects. For more information go to `www.ysf.ca`.

St. John's Newfoundland in 2004

Canada Wide Science Fair 2004: May 15 to 23

Transit of Venus and marking the 1761 Transit Observations from St John's: June 8

Royal Astronomical Society of Canada General Assembly 2004: July 1–4



A Gallery of Images

The Honourable Iona Campagnolo, PC, CM, OBC, Lieutenant Governor of British Columbia address the 2003 GA (photo: David Lee)

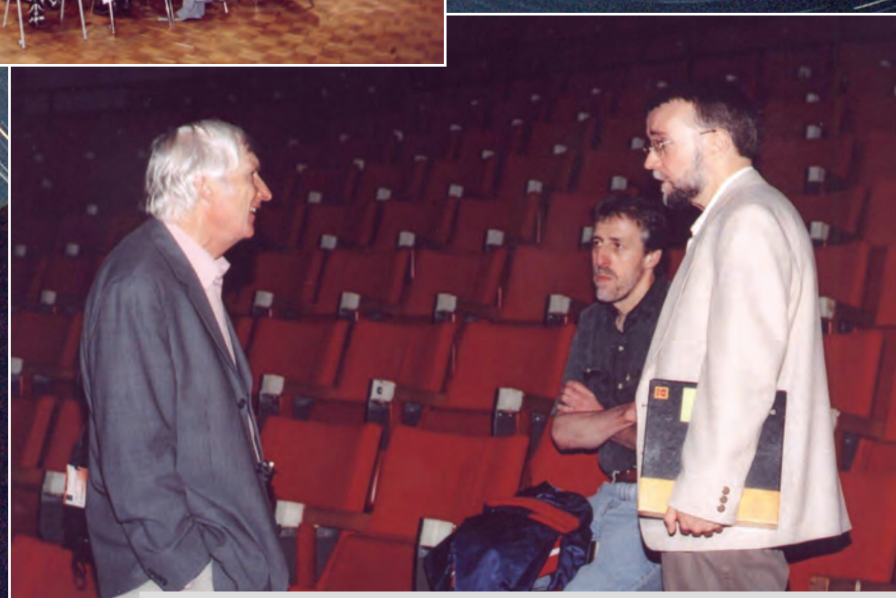
Guest speaker Alan Dyer (photo: Ed Hanlon)

Presentation of RASC service Awards (photo: Ed Hanlon)

GA 2003

Democracy in action at the 2003 GA
(photo: Ed Hanlon)

Great food, great fun at the 2003 GA Banquet
(photo: Ed Hanlon)



From left: Ruth Northcott Speaker, Dr. Gordon Walker, columnist Ken Hewitt-White and Speaker Eric Dunn (photo: Ed Hanlon)

A tour of UBC's Liquid Mirror and Vancouver Centre's CAROp (photo: Ed Hanlon)

Saturday night dinner cruise (photo: Ed Hanlon)

Lunch at the GMSO and Space Centre (photo: Bob Nelson)

GA 2003

David Levy, centre, and Jack Newton, right, with David's longtime friend and Kingston Centre Member, Angelika Hackett, left (photo: Jason Rickerby)

A little-known tradition – the Pyramid (photo: Jason Rickerby)

The Official 2003 GA Group Photo (photo: Ed Hanlon)

Background image by Ron Berard from the *2004 Observer's Calendar*

The Sky Disk of Nebra

by Philip Mozel, Toronto Centre (phil.n.mozel@attcanada.net)

Many readers of the *Journal*, when outside at night, will have in their possession a chart of the constellations. In this, they are carrying on a tradition whose origins have recently been pushed back to 1600 BCE by the so-called Nebra Disk. That we even know of the disk's existence is due largely to the spadework not of archaeologists but of police.

Discovered in 1999 atop the 252-metre-high Mittelberg Hill near the town of Nebra (180 km south-west of Berlin) the object is a bronze disk 32 cm across, the diameter of a dinner platter. Embossed on its surface are representations of what seem to be a crescent moon, a full moon (or sun), twenty eight stars (although the count varies with different authors), and an arc, which may represent a ship for carrying the sun or moon. A cluster of seven stars may depict the Pleiades although the arrangement is not similar to the actual cluster. All are highlighted in gold leaf. Curves on opposite sides of the disk may show the extremes of summer and winter solstice sunrise and sunset.

The suggestion has been made that, rather than being a map in the usual sense, the disk simply displays stars in their order of heliacal rising. To "read" this information from the disk it is conceivable that some kind of mechanical pointer was used. An image of a simple astrolabe may spring to mind. In any case, such information would have been important for timing the planting and harvesting of crops as the seasons passed.

Numerous alternate explanations of the iconography abound. The arcs may represent rainbows or even the Milky Way. The twenty-eight stars might be a count of the number of days in the lunar cycle. We will probably never know. What does seem clear is that this is the first explicit evidence of central-European celestial symbolism from the mid-2nd millennium BCE and the oldest representation of the sky, anywhere, that is not purely artistic.

Figure 1. — The Nebra Disk (courtesy of www.nebra.net).

The Bronze Age find site is also of interest. The remains of a circular wall some 200 m in diameter encloses the summit and is surrounded by a system of trenches. The nearby forest contains 1000 barrows (graves) from the period. Dating of associated artifacts, such as swords and axes, suggest the area was in use from circa 1600 to 700 BCE. The site has been described as a German Stonehenge partly because, from the Mittelberg Hill, the summer solstice sun sets behind the distant Brocken Mountain, the most important in the Harz Range. On the first day of May, the sun sets behind the Kulpenburg, the highest hill of the Kyffhauser. Some researchers have gone so far as to call the Nebra Disk a pocket version of Stonehenge. Plans for reconstructing this ancient "observatory" are in the works.

The disk's "first light" after its long burial was not without incident. Removed from the ground by treasure hunters it remained in criminal hands for several years. When a recent attempt was made to sell it, a police sting operation recovered this astronomical treasure and resulted in the arrest of its unlawful keepers.

Study of the disk and its meaning, as well as the excavations at Nebra, continue.

Thanks to Martin Fischer, for translating, and to Edwin Krupp, Griffith Observatory; Lis Brack-Bernsen, University of Regensburg and Gerd Grasshoff, University of Bern.

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

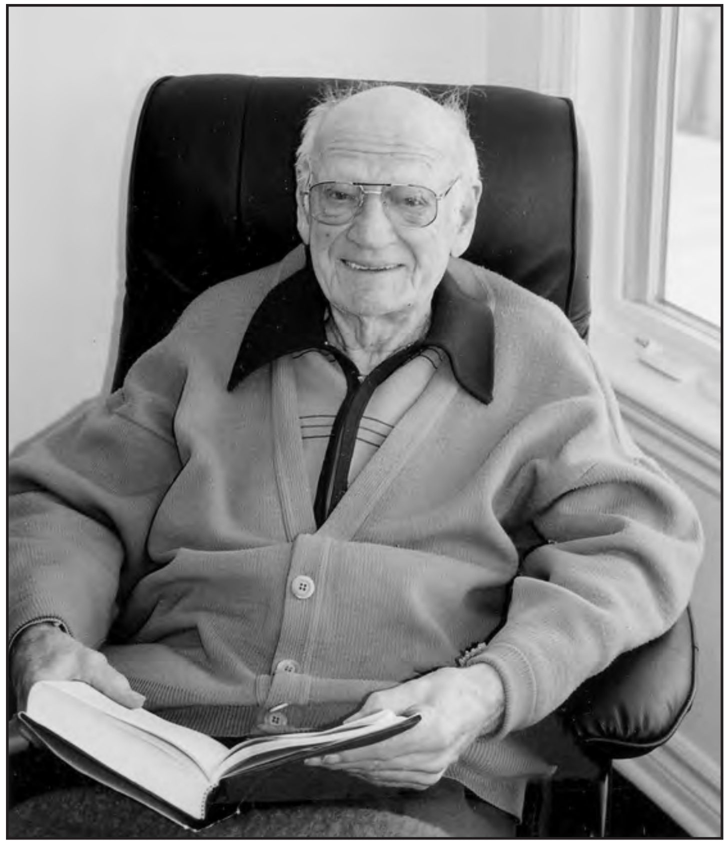
Obituary
Necrologie

Hugh Noel Alexander Maclean (1915–2003)

by Ron Gasbarini, Niagara Centre

Hugh Noel Alexander Maclean, a founding member of the Niagara Centre, died on June 11, 2003 in his 87th year. Born on December 25, 1915 in St. Catharines, Ontario, Hugh retired from Conroy Industries in St. Catharines where he was a production worker. Hugh's interest in astronomy began in the late 1950s when a friend gave him a telescope. Soon afterwards, Hugh joined the Greater Niagara Astronomical Society (GNAS). In 1960, the GNAS applied to become a Centre of the RASC (Hugh was one of several people involved with the transition), and a year later it became the Niagara Falls Centre, which was renamed the Niagara Centre in 1975 to reflect its regional membership base, much like the original GNAS. During the 1960s, Hugh held various offices, including National Council Representative (1964–65), Vice-President (1962), and eventually served as President several times in the 1960s and 1970s. The Niagara Falls Centre and neighbouring Hamilton Centre held various joint social activities during those decades, including an annual softball game that Hugh always enjoyed. (He was an exceptional athlete in his youth.) Hugh maintained close ties with several members of the Hamilton Centre, including Ken Chilton and the Reverend Norman Green. His last involvement with the Hamilton Centre was as a member of the 1984 General Assembly (GA) Organizing Committee. (The Niagara Centre co-hosted the GA that year.)

Hugh's serious observational work began in the 1960s when he made detailed logs and drawings of what he observed. These included many finder charts for and sketches of comets, and several small paintings of nebulae. Hugh had a fascination with comets; his favourite was Comet Bennet (C/1969 Y1), a naked eye comet that was prominent in Ontario's evening sky during the early part of 1970. Hugh was also a regular participant in the Society's Comet and Nova Search program. Hugh's later observational work included the precise timing of hundreds of lunar occultations that were regularly submitted to the International Occultation Timing Association. These included several graze expeditions in the 1970s that Hugh organized. Hugh made highly detailed notes of these observations that could easily be assembled into various volumes. The Centre is fortunate to have in its possession all of Hugh's recorded observations since the 1960s. Hugh's other observational interests included aurorae, lunar eclipses, the planets, and double stars.



Hugh Noel Alexander Maclean (1915–2003)

Hugh was also instrumental in the Centre's incorporation in 1975 and was part of the original production team of the Centre's newsletter, the *Niagara Whirlpool*, during the early 1980s. Hugh was also keen on providing talks and slide shows to local schools and organizations as well as at the Centre's monthly meetings, and setting up his telescope at most observing nights for the public. He particularly enjoyed spending the day chatting with members of the public at the Centre's mall displays at the Niagara Square Shopping Centre. He was also a fixture at the annual Centre banquets and on the Centre's Board of Directors for most of his forty-three membership years in the Niagara Centre. When he wasn't observing, Hugh enjoyed being an avid telescope maker. He built several telescopes out of common household hardware — they were truly "home-made!"

In recognition of his outstanding service to the Niagara Centre, Hugh received the Service Award of the RASC in 1984.

What mattered most to Hugh during his involvement with the Niagara Centre was to bring astronomy to the average person. By doing so, members and strangers alike developed an appreciation for the wonders of the night sky. For some, it became a life-long passion. He selflessly availed himself to many new members over the years, especially youth members, and provided invaluable assistance to them in their study of astronomy and involvement with the Niagara Centre. He provided transportation for several people, including myself, to Centre activities and helped members with their personal projects (I fondly remember Hugh spending many hours helping me construct my first Newtonian telescope when I was a teenager in the 1970s). This was very typical of Hugh — he generously donated his time and talents to any member who required a helping hand.

For his many years of service, dedication, and contributions to the Niagara Centre, Hugh was ultimately honoured by having an asteroid named after him on June 12, 2003. On the recommendation of Peter Jedicke, currently the 1st Vice-President of the Society, and his brother Robert (a physicist who works in Hawaii and a long-time member of the Niagara Centre who was also encouraged by Hugh), the International Astronomical Union approved the asteroid naming. Discovered by the Spacewatch telescope on September 28, 1998 at the Kitt Peak National Observatory, Arizona, the asteroid is officially known as Asteroid 14146 Hughmaclean (1998 SP42). This is indeed a fitting tribute to a man whose dedication to astronomy and the Niagara Centre was substantial. To further acknowledge Hugh's many contributions to the Niagara Centre, the Board of Directors decided to name a new observatory after him. This soon-to-be-constructed building, which will be much larger and better equipped than the existing facility, will be known as the "Hugh Maclean Observatory."

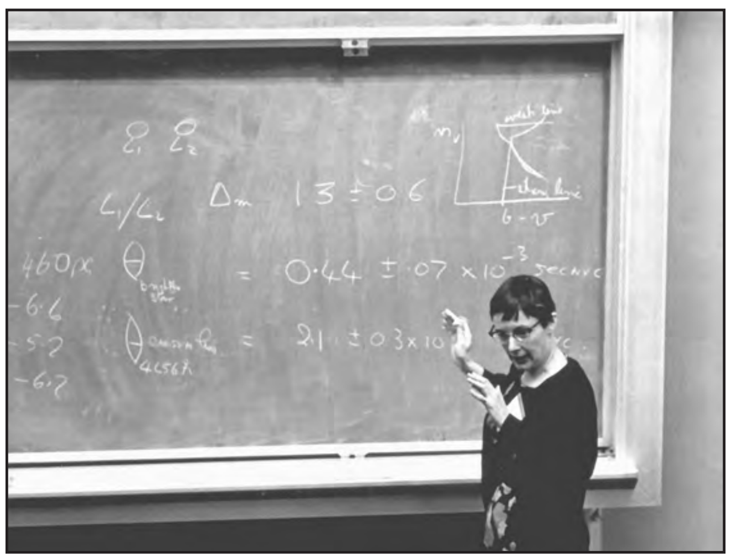
Hugh's other interests included big band swing music, jazz, piano playing, and sports. He learned how to play the piano to indulge in jazz first-hand. Hugh was also an accomplished sportsman in his youth. As a young man in the 1930s he competed in field lacrosse matches in the Ontario Junior Lacrosse League. He was a member of several championship teams during those years; football and basketball were also pursuits at the time. He served in the Postal Corps in wartime and was active in the Credit Union movement and with the Dunlop Drive Seniors Centre, St. Catharines, Ontario, where he was an avid dancer.

Hugh was a highly-respected and well-liked member of the Niagara Centre and was an inspiration to all those who have had the pleasure of his company. He was a modest, caring, and generous man whose passion for and dedication to astronomy and the Society he cherished left a lasting impression on those around him.

He will be greatly missed.

Anne Barbara Underhill (1920–2003)

by Dan Collier, Vancouver Centre



Anne Barbara Underhill (1920–2003)

Anne Barbara Underhill, distinguished astronomer and astrophysicist, a member of the RASC for over 60 years and lately an Honorary Life Member, died peacefully in Vancouver on July 3, 2003. She is survived by her stepmother Helen, brothers David, Ken, Peter, and Bruce, and sister Pat.

Dr. Underhill and I met only once, at Vancouver Centre's annual meeting in 2000 when we honoured her longtime membership in the Society and awarded her a certificate. The duty of looking after the Centre's membership records is mine, and the ceremony came about chiefly because there had not been a similar one for many years. All I knew of Dr. Underhill was that she was one of our longest-running members, and so I applied to National Council on her behalf for a membership certificate. This was approved during the Society's 2000 General Assembly, and Isaac McGillis of National Office inscribed the certificate and sent it to me in due course. But as Dr. Underhill was quite elderly and did not attend meetings at our Centre, time passed with the certificate sitting on my desk.

One day, a whim led me to get out a volume of *Burnham's Celestial Handbook* to look up something in Lacerta, the Lizard. I am not sure if Dr. Underhill liked lizards, but I know she liked animals, for she would send me postcards with animals on them to inform me of changes in her mailing address. Anyway, my habit of thumbing books left-handed took me past the section on Libra, and for just a second, "A.B. Underhill" flickered into my vision. It was the name on the certificate! The entry was for 48 Librae, a shell star with an unusual spectrum that had interested her. Suddenly, the certificate on my desk gained a great deal of importance. Thanks to her friend and former colleague Robert Garrison, Dr. Underhill was persuaded to accept her certificate in person.

Anne Underhill might have followed her father's career in civil engineering if the customary barriers had not barred women from entering that field. She instead took up chemistry, physics, and mathematics, and received her bachelor and master's degrees in physics from UBC with first-class honours. She then moved to the University of Toronto to continue her studies, but there being no possibility of completing a degree in astrophysics in Canada, she moved again, to the University of Chicago, where she received her Ph.D. in 1948. As a grad student she worked for a time at Yerkes Observatory near the end of Otto Struve's period there as director.

The committee that considered her Ph.D. was august, consisting of Struve, Jesse Greenstein, and Subrahmanyan Chandrasekhar. If they foresaw an interesting and productive career in store for her, they were correct. After an American NRC Fellowship took her to Copenhagen University for a short period, she settled at the Dominion Astrophysical Observatory in Victoria. Visiting lectureships took her briefly to Harvard College Observatory and the Institute for Advanced Studies at Princeton. In 1962, she moved to the University of Utrecht to take up a new chair as Professor of Astrophysics.

While at Utrecht, in addition to teaching duties, she continued her studies of the atmospheres of hot stars, particularly *B, O,* and Wolf-Rayet types. Such stars, of course, emit much of their flux in the ultraviolet, and the most interesting features of their spectra cannot be studied from the ground. No doubt she was intrigued with the potential of space-based astronomy. Around the time of her Ph.D., the first rocket-astronomers had been sending ultraviolet spectrographs above the atmosphere upon surplus German rockets. During her time at Utrecht, space-based astronomy began to mature.

In 1970, Dr. Underhill's career took an exciting turn when she moved to NASA's Goddard Space Flight Centre. As Chief of GSFC's Laboratory for Optical Astronomy, she directed the scientific programs for the Orbiting Astronomical Observatories. These large and complex satellites were the first to investigate the sky in detail at ultraviolet wavelengths, and pioneered technologies later used in the Hubble Space Telescope. Two of the four OAOs failed to return any data, but the losses were more than balanced by the success of the International Ultraviolet Explorer (1978–1996). The IUE's success is owed very largely to Dr. Underhill's participation. Another of her responsibilities, OAO-3, known as *Copernicus*, also led to great success. Later, as a Senior Scientist for NASA, she focused again on her interest in the atmospheres of early-type stars. By 1985, she had moved back to Vancouver to accept an honorary position at UBC in retirement.

She was a very active worker, producing over 200 papers; 40 alone were directed at the local thermodynamic equilibrium (LTE) theory of hot stellar atmospheres. She often sought insights from new fields in applied science like satellite observatories and computer simulations. Co-workers report that she defended her ideas with great vehemence. In professional contact the emotions could soar, and her opponents could come away miffed; but in person she was always gracious and generous of spirit.

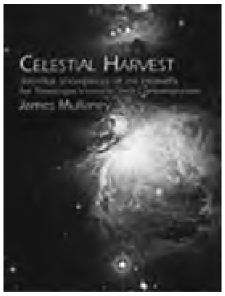
Her best-known books are *The Early Type Stars* (1966, with V. Doazan) and *B Stars with and without Emission Lines* (1982). About a dozen articles and reviews by her were published in JRASC over the years, all on topics of astrophysics. Activities away from astronomy included choir singing and birding.

Dr. Underhill was a member of the American Astronomical Society, the Royal Astronomical Society, the Canadian Astronomical Society, the Astronomical Society of the Pacific, and the Netherlands Astronomy Club, among others. She served as President or Vice-President on Commissions of the International Astronomical Union concerned with spectra and stellar atmospheres. Under Dr. Chandrasekhar, she served on the editorial board of the *Astrophysical Journal* in 1962–63. She was awarded an honorary D.Sc. by York University in 1969, and another by UBC in 1992. The Royal Society of Canada elected her a Fellow in 1985. In 1996, the RASC made her an Honorary Life Member in recognition of her contributions to our understanding of the stars.

The characteristic by which Anne Underhill is most remembered was a deep devotion to science. Her peers surely had this in mind when an asteroid discovered in 1960 received the name "Underhill." Physically, like Anne was, the asteroid is a diminutive presence in our Solar System. Probably most of us will never glimpse it, but I hope that someone who reads these words does try, in the hopes of understanding what is lost when a life like Anne's is closed.

Reviews of Publications
Critiques d'ouvrages

Celestial Harvest, by James Mullaney, pages 103 + iv, 21 cm × 28 cm, Dover Publications Inc., 2002. Price $11.95 US softcover (ISBN 0-486-42554-1).



> *"Stargazing will let you personally tap into the cosmos in a way that will not only relax your tired body and frayed nerves, but at the same time elevate your spirit and let your mind soar as you roam star-struck through the wondrous corridors of creation."*
>
> — James Mullaney

Celestial Harvest, with the subtitle "300-Plus Showpieces of the Heavens for Telescope Viewing and Contemplation," is a very good observing guide covering a wide range of objects as far south as −45 degrees declination. It is especially good for those who enjoy observing a variety of celestial targets like notable single stars, colorful variable stars, glittering double stars, and of course, fine deep-sky objects. James Mullaney is an accomplished observer, astronomy writer, lecturer, and planetarium director who has a passion for the night sky that shines through clearly in this book. He has included a collection of over 100 quotes, from many authors, about the joys of observing the night sky. An example:

> *"The appeal of stargazing is both intellectual and aesthetic; it combines the thrill of exploration and discovery, the fun of sight-seeing and the sheer joy of firsthand acquaintance with incredibly wonderful and beautiful things."*
>
> — Robert Burnham, Jr.

Celestial Harvest is organized in a landscape view format that includes for each listing: (i) a numerical designation, (ii), a name, if it has one, (iii) the right ascension and declination, (iv) the type, (v) its magnitude, (vi) size, (vii) angular separation, for double stars, (viii) a description, and (ix) blank lines for notes. Missing is a listing for the position angles of double and multiple star components, which will make it difficult to identify some of the more challenging ones listed. The descriptions focus mainly on visual interpretations by a number of prominent observers, including Mullaney, that are reminiscent of *Burnham's Celestial Handbook*. The descriptions are glowing and spectacular, but are totally integrated, leaving the reader to wonder who said what. In some cases they continue on long after the point has been made. Some of the descriptions include interesting scientific information. More of that would have complemented the impressive descriptions, and made the book more educational and generally readable.

The objects in *Celestial Harvest* are listed alphabetically by constellation, rather than by the usual practice of listing them chronologically as they rise in right ascension. That is not a bad concept, although the author should have included a seasonal listing of constellations as a guideline for progressing through the list. As the subtitle of *Celestial Harvest* implies, the book contains many showpiece objects to observe, but with nearly 170 of them being double stars, you will really need to be a double star enthusiast to fully appreciate the book. I personally enjoy the beauty and challenge of double star observing, and find it refreshing to see an observing guide that is not predominantly focused on deep-sky objects. There are also about 40 interesting single and variable stars listed, the best of which are several deep-red carbon stars. For RASC members who are familiar with our Explore the Universe, Messier, and Finest NGC programs, *Celestial Harvest* only includes about 20–25 new deep-sky objects that are visible from Canadian latitudes, some of which are well known, like the Scutum Star Cloud and Orion's Belt Stars.

In conclusion, James Mullaney has done a great job of producing an observing list that is strong in both its universality and its versatility. *Celestial Harvest*, with its generous number of single, double, and variable stars, as well as deep-sky objects, is well suited as either a suburban or dark-sky observing guide. I would not hesitate to recommend it as an affordable addition to your library. Here is another elegant quote from the book:

> *"As soon as I see a still, dark night developing, my heart starts pounding and I start thinking 'Wow! Another night to get out and search the universe. The views are so incredibly fantastic!'"*
>
> — Jack Newton

Christopher Fleming

Christopher Fleming is Chair of the RASC Observing Committee, and Observer's Chair in the London Centre. He writes a monthly column in the London Centre Newsletter, Polaris*, and enjoys all types of observing, especially deep-sky, lunar, double stars, and variable stars.*

What Your Astronomy Textbook Won't Tell You: Clear, Savvy Insights for Mastery, by Norman Sperling, pages 183 + vi; 15 cm × 23 cm, Everything in the Universe, 2002. Price $24.95 US softcover (ISBN 0-913399-04-3).

When you pick this book from the shelf,

be prepared for a rollicking read. It is fun! The language is down-to-earth and jargon-free. The writing style is straightforward and friendly. The book does not take itself too seriously. You will find it hard to put down because it just keeps going, like the Energizer bunny, with interesting topic after interesting topic. The author calls it a hodge-podge, but it is an organized hodge-podge that follows a logical order. The book is divided into five sections plus the appendices: beginnings, sky motions, the Solar System, the stars, and galaxies and cosmology.

Section 1: Beginnings contains a foreword written by David Levy. While the book tries to get to the essence of what astronomy is all about, the forward gets to the essence of what the book is all about. And that is, in Levy's words, "to help clarify what is really important and beautiful about astronomy." The section also contains a short essay on the scientific process by Brad Schaefer, and an amusing and illuminating essay titled "12 Bad Words," by David Morrison. The book is off to a great start.

Each of the book's sections deals with its topic by first putting it into historical perspective, with respect to the way science works. There is a lot of gentle humour as the scientist pokes fun at the science of astronomy and its practitioners. He makes it crystal clear that science is, above all else, a very human endeavour.

Sperling draws attention to the most common misconceptions and misunderstandings in astronomy. He makes his point through the use of many examples. They fall into several categories that he has labeled: "boners, oxymoron, debunk, unknown," and "reset mindset." Anyone who has been teaching astronomy will recognize them and immediately feel right at home.

Every section of the book has a subsection titled, "From my Least-attentive Students." Reproduced here are some of the astronomical gaffes committed by Sperling's introductory astronomy students over his many years of teaching. They are funny and point out very clearly the most common misunderstandings and misconceptions that befall the unwary. On the other hand, it is discouraging to see such poor language skills in university students. Here are several randomly chosen examples, complete with errors provided by the original authors:

> *"copernvics theory claimed that the sun was in the center of the earth."*
> *"The earth has some primary advantages: a nitrogen atmosphere, relatively stable cluster and liquor water."*
> *"Massive stars die because of dust clouds, they eventually break into particles and disintegrate into a black hole. The black hole represents warmth, the climate is warm and allows for a combustible effect for the large floating stars thus forming white dwarfs."*
> *"Our universe are in a disk plane which support each other."*
> *"The galaxies consist of three. elliptical which is the movement spiraling. Our galaxies is within the disk which provides movement against each other."*
> *"Our universe was formed by the third star."*

You get the picture.

The "Least-attentive Students" contributions are printed in a variety of different fonts from the rest of the book. That serves a couple of purposes. First, it makes the sections stand out from the rest of the text. Second, the non-standard fonts remind the reader that they are not the words of the author, but rather those of his students.

There is a third effect of the varied fonts. The reader is slowed down in his or her reading progress. We may not like having our reading slowed down, but it does force us to think about what we are reading and what might, or might not, have been going on in the students' minds as they wrote their answers. On the surface, some of what they write is comical. Dig a little deeper and it is very instructional.

Page 69 contains an interesting chart labeled, *"Take a Nebula, Condense and Stir,"* which is actually an H-R diagram extended from the stars back to the least massive and coolest objects in space: the comets and meteoroids. The chart demonstrates that everything out there is just one part of a larger continuum. That is a rather difficult concept to digest, and the diagram is crowded on the page. It requires careful examination to understand the diagram and to appreciate what it illustrates. The chart deserves to be a full-colour, carefully illustrated, large-format poster. According to Sperling's Web site (`www.everythingintheuniv.com`), it will soon be available as a poster. I cannot wait to see it.

What Your Astronomy Textbook Won't Tell You is a gem. For those who teach introductory astronomy, it is filled with interesting perspectives on familiar subjects. For students of astronomy, it provides clear and helpful insights into what can be a confusing subject. Amateur astronomers will enjoy the different viewpoints on their hobby. From first to last it is fun, informative, and refreshing. Sperling knows and loves his subject. His book successfully serves the double purpose of clarifying confusion and making learning a pleasure.

Mary Lou Whitehorne

Mary Lou Whitehorne is a "lifer" in the RASC and has been an active member of the Halifax Centre since 1986. She is the author of the Society's latest publication, Skyways, an Astronomy Handbook for Teachers. *Mary Lou recently finished her third term as Halifax Centre President, and now enjoys "Heckler's Row" privileges that come with being Past President.*

Mars Observer's Guide, by Neil Bone, pages 160; 12.5 cm × 19.5 cm, Firefly Books Ltd., 2003. Price $14.95 Cdn softcover (ISBN 1-55297-802-8).

Mars Observer's Guide by Neil Bone is aimed at the beginning Mars observer. The book is organized into ten chapters along with a 58-word glossary, a 585-word index, and an appendix that lists additional books, magazines, and other information. There is also a two-page forward at the beginning of the book written by Richard McKim, the director of the Mars section of the British Astronomical Association. *Chapter 1: Observing the Red Planet* and *Chapter 2: Mars as a Planet* serve as a good introduction for the beginner. The reader learns about the face on Mars in the first chapter, and learns about the orbit of Mars in the second chapter. The volcanoes, geology, faults, water outflow features, craters, atmosphere, and impact basins on Mars are also described in the second chapter.

Chapter 3: Equipment Basics and *Chapter 4: The View from Earth* focus on how to observe Mars. The reader learns what an ideal planetary telescope is, and is introduced to several types of telescopes. Chapter 3 also describes telescope mountings, eyepieces, and filters, plus tips for making good drawings, photographs, and images of Mars. Chapter 4 contains over a dozen drawings of Mars along with a map of Mars. In addition, this chapter describes the polar caps, surface features, white clouds, and dust storms of Mars.

The next three chapters: *Mars in 2003, Mars in 2005*, and *Mars in 2007-8*, give previews for the 2003, 2005, and 2007-8 Mars apparitions. The chapters have tables that list the position of Mars for various nights, its magnitude, angular diameter, and distance (from Earth) for every five days during the next three apparitions. There the reader also learns what to look for when observing Mars.

The next two chapters: *Early Explorers* and *Space Age Mars*, describe the history of Mars exploration starting from the seventeenth century. The material found there describes the Martian canal controversy and the successful Viking missions.

The last chapter: *Life on Mars*, gives a good summary of the three *Viking Lander* experiments that looked for signs of life on Mars. A good review of the Antarctic meteorite ALH 84001 is also given in chapter 10. ALH 84001 is believed to originate from Mars and, at one point, many believed it contained fossil bacteria.

After reading the book, I feel that it is well written and suitable for the beginner or intermediate level amateur astronomer. The tables in the book for the next three apparitions will serve as a valuable guide for the next five years. I highly recommend the book to anybody who wants to learn more about Mars or who would like to be updated on the latest Mars research.

Richard Schmude, Jr.

Dr. Richard Schmude, Jr. is currently a professor at Gordon College in Barnesville, Georgia, where he teaches astronomy, chemistry, and physical science. Richard has observed Mars for over 15 years, and has published several papers about the planet in the JRASC.

M33 and NGC 604 Face-On

Composite image formed using RegiStar from 4 exposures, each 60 minutes on gas - hypersensitized Kodak RG200 colour negative film using a 14.5-inch f/8 classical Cassegrain

— Photo by Tony Hallas from the *2004 Observer's Calendar*

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

NATIONAL OFFICERS AND COUNCIL FOR 2002-2003/CONSEIL ET ADMINISTRATEURS NATIONAUX

CENTRE ADDRESSES/ADRESSES DES CENTRES

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

Calgary Centre
C/O Calgary Science Centre, PO Box 2100 Station "M", Calgary AB T2P 2M5

Charlottetown Centre
C/O Clair Perry, 38 Mt Edward Road, Charlottetown PE C1A 5S2

Edmonton Centre
C/O Edmonton Space & Science Centre, 11211 – 142 Street
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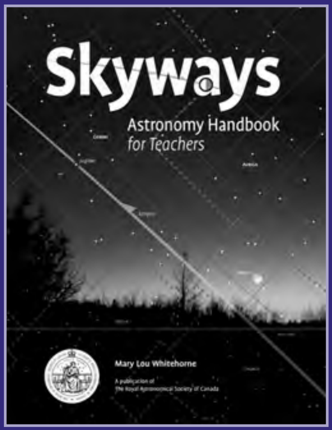

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