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Journal

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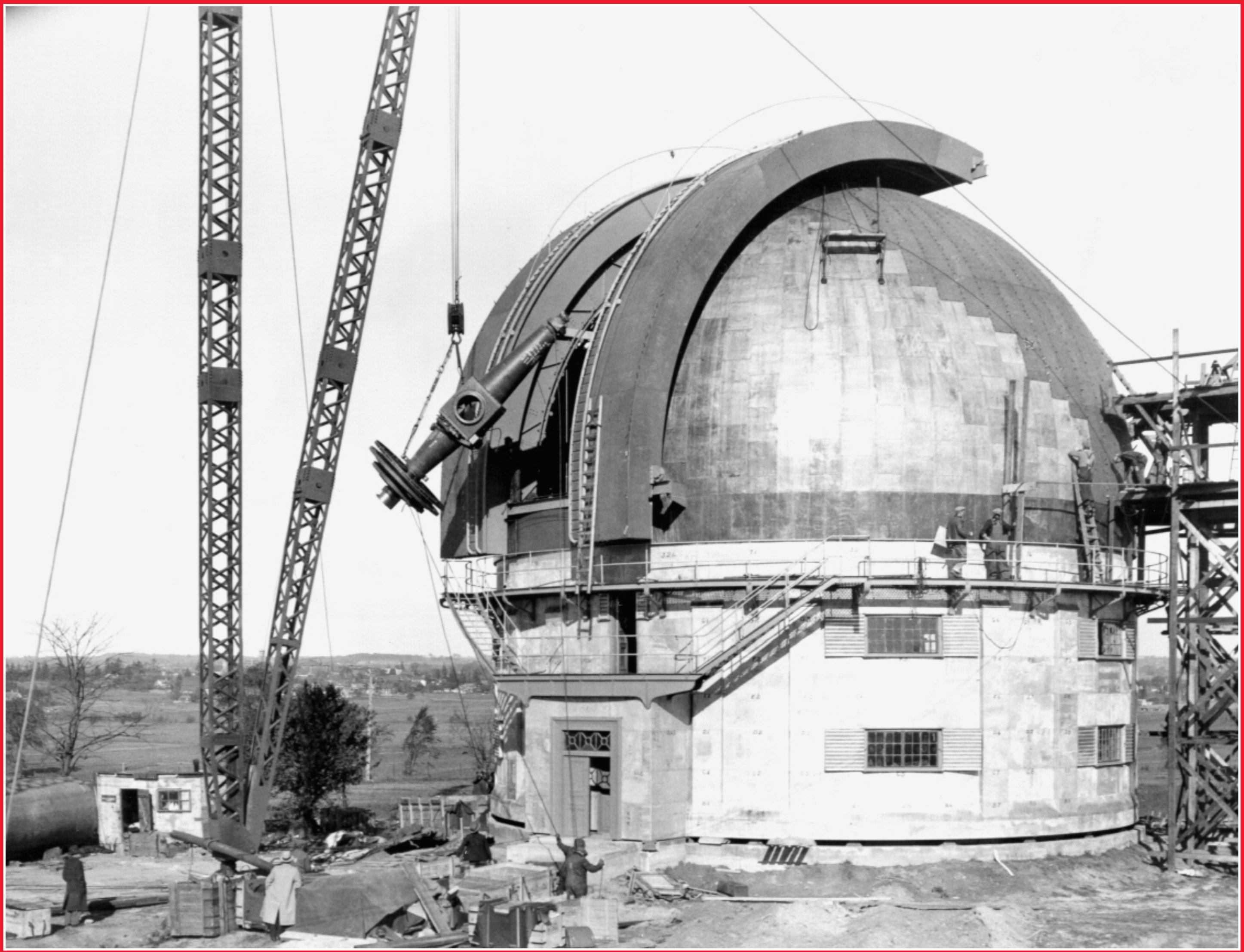

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February/février 1999

Journal

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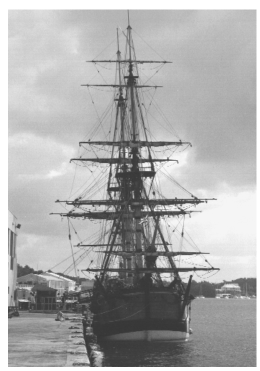

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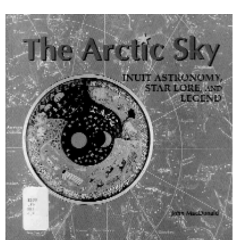

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ACROSS THE RASC
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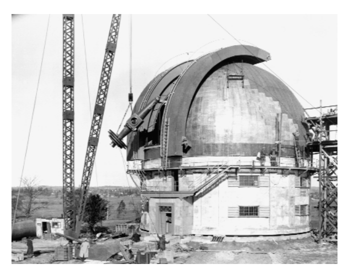

The 16-ton polar axis assembly is hoisted into the finished dome, David Dunlap Obeservatory, on October 23, 1933 (reproduced with permission from the Helen Sawyer Hogg Collection).

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From the Associate Editor

by Patrick Kelly

Well, here we are, with only a year to go before the year 2000. The new millennium will start, depending upon who you ask, in either the year 2000 or 2001. I do not plan to get into that debate, at least not in this issue. There are two issues related to the end of the millennium that I would like to dwell on.

Many people are probably aware of the "insect" that has received a lot of media attention over the last year — the millennium bug, *a.k.a.* the Y2k bug. It is the legacy of computer software, written when memory was so expensive that it was considered a waste of money and processing power to store all four digits of the year. To the surprise of the people who wrote the software, much of it is still being used decades later, and although the software has been upgraded over the years, the two-digit year problem still lurks in much of it. According to some prophets, the problems resulting from the failure to successfully correct the problem will result in the end of civilization as we know it, while other say that, at worst, we may be in for some inconvenience.

How will it affect amateur astronomers? Personally, I use an old-fashioned manually-driven Dobsonian telescope, and fixed my only millennium bug years ago, quite by accident, when I upgraded my star charts to *Sky Atlas 2000.0*. Will those who have older computer-controlled scopes find that once the last second of 1999 has gone by, their telescope, when asked to locate Mars, will point to where it was on January 1st of 1900? Has anyone actually checked to see if their computerized scope is "year 2000 compliant" and found it to be lacking? I would love to hear if anyone has actually tried it.

Another human characteristic is to look back, at the end the year, and review the high points and low points, the highlights that made the last year what it was. As we near the end of the 1900s, there is a tendency to see that type of activity applied to the entire century and even to the millennium. I would like you to stop and think about what you consider to be the astronomical highlights of both the last 100 years as well as the last 1000 years. It could be the most important discoveries, the most important people, or the most important events… let me know what you think and I will attempt to summarize the results in a future issue.

You may recall that in last year's February issue I requested input from members who shared (or did not share) both science fiction and astronomy as a hobby. I would like to thank the *member* who replied. I hope that there will be a better response this time!

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 one of the addresses given below.

The *Journal of The Royal Astronomical Society of Canada* is published at an annual subscription rate of $80.00 by The Royal Astronomical Society of Canada. Membership, which includes the publications (for personal use), is open to anyone interested in astronomy. Annual fees for 1998, $36.00; life membership is $720. Applications for subscriptions to the *Journal* or membership in the RASC, and information on how to acquire back issues of the *Journal* can be obtained from:

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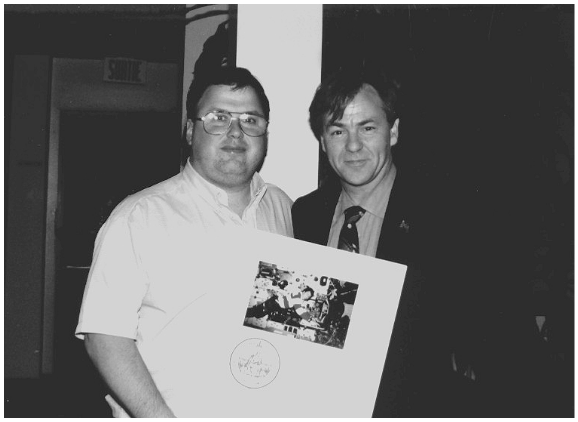
President's Corner

by J. Randy Attwood (attwood@istar.ca)

For my first President's message of 1999, I am happy to report on some important developments taking place at our National Office in Toronto.

By way of background, the University of Toronto Press currently handles the Society's membership system. The Press has processed renewals for all members for the past two years — that is, for all members except those in the Toronto, Saskatoon, and Calgary centres, which handle their own records. That process has caused us some problems, so, in order to improve service to our members, membership processing is being brought back to the National Office some time in the next few months. Another function performed by the National Office is the sale of our publications and products. A large percentage of our annual revenue, for example, comes from sales of the *Observer's Handbook*. This past autumn, during the height of the sales period, the task was handled manually, a chore that made us acutely aware of the need for new computer hardware and software to allow us to complete such large jobs more efficiently.



National President J. Randy Attwood (left) receives from Canadian astronaut Bjarni Tryggvason (right) the RASC cloth patch that flew on board the Space Shuttle *Discovery*. (Photo by David Shuman, Montreal Centre.)

The business decisions of the Society are made at meetings of the National Council. The autumn meeting was hosted by the Montreal Centre during the November 7th – 8th weekend. National Council representatives from many centres were in attendance, and it was a busy two days during which we discussed many important issues related to the functions of the Society. Decisions were made that will affect all members and that should result in more effective functioning of the Society.

It was decided at the autumn meeting to allocate limited funds to provide new computer hardware, as well as to acquire or develop software, to support the new National Office functions. Customized software for both the membership handling and publications distribution is currently being developed. A second computer has been purchased, and the two computers will be linked via a network. Once in place, the Society will have greater control over the services provided to members. In future, an individual dedicated to work solely on RASC matters will deal with all problems regarding membership. I personally feel that such changes are critical to the well being of the Society. Once we have both computer systems in operation, it is my hope that the Executive can turn its attention to other important issues within the Society.

Last autumn our Executive Secretary Bonnie Bird hired a part-time assistant, Isaac McGillis, to assist with the new functions. Isaac provided immediate service when hundreds of orders for the *Observer's Handbook* needed to be processed. In addition, Bonnie has been busy since the summer, planning renovations to the National Office to support the new responsibilities. By the time you read this, the National Office will sport a fresh coat of paint, new track lighting as well as additional lights, and new office furniture for both Bonnie and Isaac. When you are next in Toronto, I suggest that you take some time to visit our renovated National Office.

At the autumn meeting of National Council, National Secretary Raymond Auclair also announced his resignation as a consequence of personal commitments related to his employment. I take this opportunity to thank Raymond on behalf of the Society for all the effort he has expended as our National Secretary. I know he will continue in his unofficial role as National Council Representative for the Unattached Members Centre.

At the dinner in Montreal on November 7th following the meeting of National Council, Canadian astronaut Bjarni Tryggvason addressed those in attendance. Afterwards, Bjarni presented to the Society the RASC cloth patch that he took with him on his Space Shuttle flight in 1987. Our patch orbited the Earth 189 times in just under twelve days, travelling a total of 7.5 million km during that period. The patch is now mounted as a permanent display at the National Office in Toronto.

Most of us will agree that the *1999 Observer's Handbook* is yet another example of the excellent work done by editor Roy Bishop and his team, who have published an exceptional guide to the night sky. Another publication, the *1999 Observer's Calendar*, assembled by Rajiv Gupta, has been so popular that it has already sold out! Congratulations Rajiv on another superb job.

Finally I invite all members to make plans to attend the General Assembly being held this summer in Toronto. The seven-day meeting will be a unique astronomy event — one you will not want to miss.

Clear skies.

Correspondence
Correspondance

1999 ECLIPSE VIEWING IN ROMANIA, ADDENDUM

Dear Sir,

Thank you for publishing my announcement about the total solar eclipse on 11 August 1999 visible from Romania (JRASC, 92, 225, 1998, October). Following my last contacts with Ralph Chou of the Toronto Centre, we have released a possible expedition project for RASC Toronto Centre members to observe the eclipse in Romania. Ralph plans to publish an announcement about the tour soon. As a former Romanian astronomer, now a member of Toronto Centre, I am proud to co-operate with Ralph, who has a lot of experience in eclipses. Together with the SARM (Romanian Society for Meteors and Astronomy) and our tour operator in Romania, I am confident we can set up some packages combining astronomy with tourism, at accessible fees.

Please note that, as a result of a temporary technical problem with my provider, the eclipse web site published in the *Journal* is not presently available, but should be back soon. To keep people informed about the eclipse, I have set up a mirror site available at: `www.geocities.com/CapeCanaveral/Hall/9794/eclipsa.htm`. It includes information about the eclipse, SARM, and similar astronomy camps, and introduces people to seven packages including full descriptions, fees, maps and pictures of gorgeous Romanian sites to be seen next year. We also plan to include on the EuRo Eclipse 99 web site a link to the Toronto Centre's expedition (and other international groups attending the project next year).

Dr. Ovidiu Vaduvescu, ovidiuv@yahoo.com
Toronto Centre

THE BIG QUESTIONS

Dear Sir,

In his "Looking Up and Looking Down" paper in the October *Journal* (JRASC, 92, 244, 1998), Michael Attas asks some Big Questions: Where did it all come from? How will it end? and, biggest of all, Why? It is refreshing to have a scientist make comparisons between two disciplines as seemingly different as archaeology and astronomy and then come up with a summation that is purely philosophical.

The familiar image of scientific knowledge is one of graphs, charts and formulae with Greek notation, explaining the world as seen from a laboratory. For most of us, the question is: How does that affect me? It is my conviction that all information must relate to the Big Questions, even that defined as myth or legend. A familiar example is the biblical story of the creation, which seems to parallel our understanding of Big Bang cosmology, the introduction of light, and the formation of our planet. I have wondered where the scribe writing Genesis got his information without spectroscopes or a *Hubble Space Telescope*. He wrote for an audience of a different age, but his truth may be within us all.

Physicist Timothy Ferris has written, "If traces of cosmic history are etched in every scrap of matter, it is tempting to speculate about the extent to which cosmic history is woven through the human mind as well. Perhaps the dream of an ultimate unified theory is a form of cosmological nostalgia, and human science is a means by which the universe contemplates its past." Twenty-three hundred years ago Socrates said, "The soul has been forever in a state of knowledge and real learning is remembering."

Thank you Michael Attas, for helping us to remember.

R. A. Clark, rclark@wincom.net
Tecumseh, Ontario

RASC INTERNET RESOURCES

Visit the RASC Website

`www.rasc.ca`

Contact the National Office

rasc@rasc.ca

Join the RASC's E-mail Discussion List

The RASCList is a forum for discussion between members of the RASC. This forum encourages communication between members across the country and beyond. It began in November 1995 and currently has about 225 members.

To join the list, send an e-mail to listserver@rasc.ca with the words "subscribe rasclist Your Name (Your Centre)" as the first line of the message. For further information see: `www.rasc.ca/computer/rasclist.htm`

Feeding the Beast

by Joseph P. O'Neil, London Centre (joneil@multiboard.com)

> **"How strange it is to hear a person who has just laid out five months' wages for the dream eyepiece of a lifetime questioning the choice a month later by asking if something better could have been purchased instead."**

Some time ago I was driving slowly through an intersection when a young man, so intent on going wherever it was he had to be, crossed against the light and walked into the side of my car, fortunately resulting in no harm other than for scratched paint on the car. It would be easy to blame his actions on the "attitude of the youth of today," to use a popular catch phrase, but I have observed that our entire society is one that can develop a mindset on any topic. Then away we go, come hell or high water, without paying attention to what lies in the path ahead. Many such attitudes exist in amateur astronomy as well, so I thought I would air a few of them here.

TEN THOUSAND POWER WITH OUR MEGA-EXTREME SUPER RAMSDENS!

Eyepieces baffle me. In truth, as an observer I only need three, plus perhaps a Barlow lens. The three I consider essential are a good low-power wide-angle eyepiece, plus good mid- and high-power varieties. Yet there are eyepiece junkies like me with toolboxes full of various sizes and types of eyepieces, all in the quest for a better image. I still cannot figure out why I have both 12-mm and 12.5-mm eyepieces, for example.

A friend once showed me that a well made Kellner eyepiece in a good telescope can do wonders, but just try to find a high quality Kellner. Instead, brand A brings out the "X" eyepiece, brand B follows suit with the "Super X" model that has one more degree of apparent field than just the plain "X" model, and so the game of one-upmanship goes. The phenomenon is not restricted to the marketing of eyepieces either. I saw "Extreme BBQ Potato Chips" in the store the other day. I did not know if I should eat them or use them in my car's gas tank for better mileage.

The same attitude is carried to extremes in conversations at star parties or in discussions on the Internet. How strange it is to hear a person who has just laid out five months' wages for the dream eyepiece of a lifetime questioning the choice a month later by asking if something better could have been purchased instead. It makes me believe that eyepieces are second only to heroin in addictive properties, or that marketing and advertising have become so powerful that people no longer trust their own experience or decision making ability.

YOU ARE THROWING GOLD DUST DOWN THE TOILET

Some time ago the question "Do colour filters work when you are colour blind?" (in reference to planetary observing) came up on the Internet. Most answers, very reasonably thought out, came back, "Yes they do." Being colour blind myself, I can tell you they do not work for me, specifically in the colours I have trouble seeing. So I wrote back saying so. Amazingly, I received responses from non-colour blind people saying that I was wrong, that they do work, and here is why. If you ever want to be "weirded" out, go on the Internet and listen to the experts tell you why something works when first-hand experience says otherwise. Is it possible that what clicks in theory does not always apply in real life?

Consider the topic of exit pupils. Personally I think matching the size of the pupil of your eye to the exit pupil of an eyepiece or set of binoculars is not always a good thing. Humans make microscopic movements with each breath and heartbeat, so perhaps it is not such a bad thing to have an exit pupil larger or smaller so that you will always stay inside the boundaries of one or the other. I have never felt that an oversized exit pupil, especially in a pair of binoculars, is such a poor choice, although most people would regard this as "wasting light." Consider the following situation. I recently encountered a person who owns a very good pair of 7×50s, enjoys using them, and is comfortable observing through them. But, for the singular reason that he had been told light was being wasted, he now believes that his favourite equipment must be discarded for a pair with smaller exit pupils. Trying out new binoculars borrowed from a friend is fun and possibly educational, and some people just like to find excuses to spend money. For most of us, doing the best you can with what you have got and, more importantly, enjoying observing with what you already own, is the hardest lesson to learn.

> **"Amateur astronomy is like a tripod. One part believes in what you are doing, one part is learning, and one part is fun. Lengthen any leg too much and it all falls down…"**

HOW MANY ANGELS CAN DANCE ON THE HEAD OF A REFRACTOR?

It would be incorrect to blame manufacturers for our obsessions with which refractor or premium Newtonian has the best diffraction-limited optics. Some of the arguments are all in good fun, akin to arguing if the Shelby Cobra could outrun a Plymouth Hemi Cuda on the quarter mile track. Astronomers need something to do during cloudy weather, and, as a group, we do like to brag a little about our toys. There is one area of optical quality that does leave me with a queasy felling in the pit of my gut, that being optical coatings.

When optics are "multi-coated" (MC), exactly what are they multi-coated with? There are many formulae for optical coatings, and for the most part the exact composition is a closely guarded industrial secret. Just as important, perhaps even more so, is how the coating is applied in the first place. It is a skill equivalent to polishing a lens. Yet how many times do we ask, "Are the lenses all coated?" without realizing exactly what it is we want?

I have had occasion to look through instruments with simple, one-layer, magnesium fluoride coatings, and sometimes I find the optics in question to be superior to comparable, newer, "MC" optics. Not all coatings are created equal, and I sometimes wonder if coatings are used as a crutch for mediocre optics, much the way it is easier and less expensive to equip a telescope mount with electronic periodic error correction (PEC) than it is to machine a high quality worm gear in the first place. PEC and MC and other emerging technologies are wonderful additions to the arsenal of the amateur astronomer, but technology should not take the place of basic good workmanship. Rather, it should complement it.

I HAVE SEEN THE LIGHT, BUT NOT THE STARS

There is a sub-culture in amateur astronomy that lives in fear of coming out of the closet — specifically planetary and lunar observers. I do not refer to the learned members of the Association of Lunar and Planetary Observers, who take great pains to make accurate timings of the movements of the planets, or to the fact that most observers like to point their scopes towards the Moon and planets at the beginning of an observing session. My complaint lies with those individuals who spend the majority, *possibly all*, of their time observing the planets, or simply the Moon, without bothering to time occultations or make detailed observing notes.

Our race has landed on the Moon, 16-inch Dobsonians are now in common use, and amateur CCD cameras continue to push the envelope of how far and how faint we can see. So why do we spend time exclusively on what members of one Internet mailing list refer to as "shallow sky" observing? Because it is fun, because it is easy, because you can do a whole lot with just a small telescope, and mostly because it is pretentious to assume that, just because NASA has landed a few people on the Moon, there is nothing left to learn.

QUICKLY GRASSHOPPER, TAKE THE PLÖSSL FROM MY HAND

Amateur astronomy is like a tripod. One part believes in what you are doing, one part is learning, and one part is fun. Lengthen any leg too much and it all falls down, allowing whatever monsters dwell beneath reason and faith to feast again. It is not the level of observing that counts, for I consider anyone who even looks at the Moon through binoculars to be an observer. Rather, maintaining that balance is what makes astronomy all worth while. Spend time learning the difference between good and poor optics and you will be rewarded with a quality instrument, but don't spend too much time fretting over every little detail and specification. You will work yourself into such a state that you will never enjoy using any telescope, no matter how great it is. If you are puzzled by something you see in the sky, then take the time to learn about it. You will be rewarded with the enjoyment of recognition the next time you observe it, but you may spend all of your time trying to understand the phenomenon, with little connection to real life experience. You may even become lost in information overload, much like a rudderless ship.

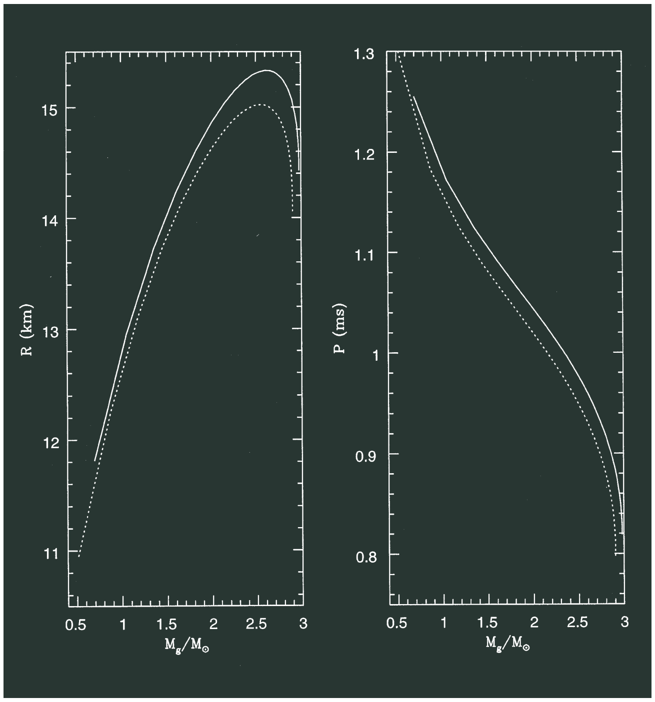
> **"It is not the level of observing that counts, for I consider anyone who even looks at the Moon through binoculars to be an observer. Rather, maintaining that balance is what makes astronomy all worth while."**

With regard to fun, if you ever find yourself at a star party some fine summer night and the clouds roll in thick and solid, and a good-natured soul cracks open a couple of bottles of *Jack Daniels*, a drink or two is nice for the sake of relaxation and the joys of camaraderie with your fellow observers. Overindulge on an empty stomach, however, and you will be rewarded the next morning with an experience not easily forgotten.

A member of the London Centre of the RASC, Joe O'Neil has been interested in astronomy since grade school. In his spare time he enjoys planetary and lunar observing from the light-polluted skies of London, and black-and-white astrophotography from the family farm near Granton, Ontario, about five kilometres due north of Western's Elginfield Observatory.

News Notes
En Manchettes

SKYRMION STARS



The equation of state for zero-temperature Skyrmion star models constructed by Ouyed and Butler results in the mass-radius relation shown at left, and the rotational period-mass relation shown at right. The solid line corresponds to models for pure neutron matter, and the dotted line to models for symmetric nuclear matter.

The role that the equation of state for dense matter plays in astrophysics has long been the subject of detailed theoretical and numerical investigations. Such investigations have largely been motivated by the fact that the behaviour of matter at nuclear densities and greater is not well constrained by experiment or observation. It has direct applications to neutron stars, however, for which the core matter has densities ranging from a few times the density of normal nuclear matter, $\rho_N = 2.5 \times 10^{14}$ g cm^{-3}, to an order of magnitude larger, depending upon the star's mass. Hundreds of pulsars are known at present, and their discovery rate remains high. There has therefore been an impressive rate of growth in the accompanying observational data for pulsars, which can be used to confront the many theoretical/numerical equations of state proposed so far.

Recently, Rachid Ouyed and Malcolm Butler of Saint Mary's University (*Astrophysical Journal*, submitted) developed a new equation of state that describes nucleons (protons and neutrons) by a single particle called the *Skyrmion*, first introduced by Skyrme in 1961. Their interest in such a model arose from its recent revival in possible connection with quantum chromodynamics (QCD), and especially from its mathematical simplicity relative to the more difficult solutions that entail QCD explicitly. The equation of state developed by Ouyed and Butler can be applied to densities as high as ten times the nuclear density. In their research they used it to construct zero-temperature models of compact stars in hydrostatic equilibrium — where the pressure established by the equation of state counterbalances the gravity of the compact star. They found stable solutions, which they call Skyrmion stars, for masses between 0.5 $\mathcal{M}_\odot$ and 2.95 $\mathcal{M}_\odot$ and radii between 11.0 km and 15.5 km. They estimate the rotation periods of such objects to lie between 0.8 and 1.3 milliseconds.

In the Ouyed and Butler model, the most massive Skyrmion stars rotate the fastest. That is a result of the unique behaviour of Skyrmions at high densities. Skyrmions shrink as the density increases (a result of Skyrmions having structure), which permits a high central compression of matter near the core of the star — thus greater gravitational binding energy. The most massive stars, which can withstand greater centrifugal forces, therefore possess the smallest periods of rotation.

ON BOARD *ENDEAVOUR*

In 1768 the British Admiralty, with the support of the Royal Society of London and King George III, sent an expedition to the South Pacific to observe the 1769 transit of Venus across the Sun. Decades earlier Edmund Halley had emphasized that accurate measurements of such rare events could be used to determine the Earth-Sun distance, the baseline that now underlies stellar parallaxes and the

Views of the *Endeavour* during its visit to Halifax in October 1998.

scale of the universe. The ship chosen for the voyage was the bark *Endeavour*, a collier from the east coast of England. The man chosen as leader of the expedition and commander of the *Endeavour* was Lieutenant James Cook of the Royal Navy. Both Cook and the *Endeavour* became legends as a result of the voyage.

In addition to observing the transit of Venus from Tahiti, Cook used the latest astronomical knowledge and equipment to determine longitudes with unprecedented accuracy, established that there was no large southern continent in that part of the world, observed a transit of Mercury from New Zealand, discovered that New Zealand consisted of two islands, made the first accurate survey of the coasts of New Zealand, charted the previously unknown east coast of Australia, and arrived three years later back in England having lost none of his crew to scurvy, the scourge of extended voyages prior to Cook's time. Three scientists accompanied Cook: botanists Joseph Banks and Dr. Daniel Solander, and astronomer Charles Green.

A replica of Cook's *Endeavour* sailed into Halifax, Nova Scotia, on October 9, 1998, like an apparition out of a time warp. Built in Australia at a cost of US$15M and commissioned in 1994, the *Endeavour* replica has been on an around-the-world voyage for the past two years. When the ship left Halifax on October 21 bound for the Caribbean, it was accompanied by *Observer's Handbook* editor Roy Bishop, who had the good fortune to occupy Dr. Solander's cabin as a passenger during the eight-day, Halifax-Bermuda leg of the voyage. In 1999 the *Endeavour* is scheduled to visit the west coast of North America (including Victoria and Vancouver in early autumn) before crossing the Pacific to return to Australia.

GRAVITATIONAL LENS DISCOVERED WITH CADC DATA

A team of American and Canadian astronomers, consisting of Phil Fischer of the University of Michigan, David Schade of the Dominion Astrophysical Observatory (DAO), and Felipe Barrientos of the University of Toronto, has discovered a new quadruple gravitational lens (August 20th issue of *Astrophysical Journal Letters*). Designated HST 1411+5211, it is the eighth such object discovered to date. Gravitational lenses are massive objects that bend passing light rays to produce distorted views of more distant objects, much like what happens when light is refracted by a lens. General relativity predicts that the gravitational field of massive objects will affect light in such a manner. In the present case, the gravitational field of an intervening galaxy or cluster of galaxies appears to be responsible for the illusion. Using a computer model to simulate the lens, the team determined that the best candidate for the lensing object was a cluster of galaxies. The light seen in the mirage appears to be that from a much more distant quasar.

The group found the celestial oddity buried in one of the *Hubble Space Telescope's* Wide Field and Planetary Camera (WFPC2) images. The data were stored at the Canadian Astronomy Data Centre located at the DAO in Victoria. It may be possible to use the images of the lens to "weigh" the object responsible for the mirage. The more massive the object, the greater the amount of bending. Such an analysis could help to establish the amount of "dark matter" present in the intervening galaxy or cluster of galaxies.

Gravitational lenses can also be used to estimate the Hubble constant, a measure of the expansion rate of the universe. The Hubble constant is a combination of speed and distance, usually measured in kilometres per second per megaparsec. The speed of the object can be found by measuring its redshift, while the distance must be determined independently. In principle, the distance to a gravitational lens can be established on the basis of variations in the brightness of the different components of the mirage. Each component of the imaged source in HST 1411+5211 will have a separate light path of different length. Depending on the exact path length and the strength of the gravitational field, any variation in the brightness of the background quasar will show up as delayed variations in each of the separate images. A measure of such time delays can lead to an estimate of the quasar's distance. Once the redshift of the quasar is measured, then a value of the Hubble constant can be found.

In order to measure the Hubble constant using the newly found gravitational lens, astronomers will have to monitor this strange object and watch for changes in the brightness of its components.

PAIR OF LOCAL GROUP GALAXIES MAY BE BINARY

Our current knowledge of two members of the Local Group of galaxies was recently the theme of a significant development. The two galaxies in question are NGC 147 and NGC 185, two small spheroidal galaxies (types dE5 and dE3, respectively) situated between the Milky Way and M31 — the Great Andromeda Galaxy. Since 1977 astronomers have assumed that the pair were not gravitationally bound, and therefore were not in orbit about one another. To make such a conclusion, *i.e.* to determine whether or not a pair of galaxies form a binary system, astronomers need to know the relative velocities of each, their masses, and their true spatial separation.

Sidney van den Bergh, of the Herzberg Institute of Astrophysics' Dominion Astrophysical Observatory in Victoria, recently examined the most current data for the two diminutive galaxies NGC 147 and NGC 185, and concluded that they may be tied together by their own gravity after all (October 1998 issue of the *Astronomical Journal*). Van den Bergh points out that earlier radial velocity measurements for each galaxy, which suggested that they were unlikely to be physically bound to each other, were based upon the emission-line velocity of a single planetary nebula in each. From such a small sampling it would be difficult to distinguish between the motion of the nebula within the galaxy and the motion of the galaxy itself. More recent absorption-line radial velocity measurements tied to the light of the stars in each galaxy indicate that they are moving slowly enough relative to one another to be indeed locked into a stable orbit about each other.

NGC 147 and NGC 185 are in the constellation of Cassiopeia, and are separated by less than a degree ($\alpha = 00^h\ 33^m.2$, $\delta = +48^\circ\ 30'$ and $\alpha = 00^h\ 38^m.9$, $\delta = +48^\circ\ 20'$, respectively). Both have a total blue magnitude (B_T) around 10.2. Their large apparent diameters result in each being of very low surface brightness, however, making them "challenge objects" for amateur deep-sky observers and imagers.

THE EARTH-MOON SYSTEM AND THE STABILITY OF THE INNER SOLAR SYSTEM

Recent work by Kimmo Innanen and Paul Wiegert of York University, and Seppo Mikkola of the University of Turku in Finland, suggests that the Earth-Moon system may be instrumental in the orbital stability and possibly the very survival of the inner planets (October 1998 issue of the *Astronomical Journal*). This surprising result came about through serendipity, a scientist's most productive collaborator. While testing different orbital computer models of the solar system, Innanen, Mikkola, and Wiegert found that without the presence of the Earth-Moon system the orbits of Mercury and Venus became unstable. The models showed that eventually Mercury and Venus would experience a close encounter, with the smaller Mercury being ejected from the solar system. Removing Mercury or Mars from the system did little to the orbits of the remaining inner planets, while the removal of Venus actually caused the orbits of Mars and the Earth-Moon system to become more stable over time.

It appears that the Earth-Moon system successfully suppresses an orbital resonance, or "beat," between the orbits of Venus and the gas giant planets. Much like the action produced by pumping your legs on a playground swing, orbital resonance can magnify a particular orbital motion or parameter. It appears that the Earth and the Moon break such a resonance by interrupting the orbital pumping action of the giant planets.

1998 LEONIDS — BOOM OR BUST OR PROMISE OF THINGS TO COME?

Preliminary reports indicate that the 1998 Leonids rank high in the list of unusual meteor showers, while not having come through as the predicted meteor storm. Except for Atlantic Canada, Canadian observers were largely clouded out, although some Canadians took part in expeditions to the predicted best longitude for observing the expected storm — the longitude of Asia and Australia. As it turned out, there was no narrow, storm-producing peak of activity; instead broad peaks of activity characterized the shower, allowing it to be seen worldwide.

Unexpectedly, there were two distinct components to the event, the night before the predicted "storm" peak having featured an impressive display of fireballs. Owing to the late evening rising time for the radiant, the observed fireballs were Earth-grazing, resulting in very long paths through the sky far from the radiant and making for spectacular meteors. An initial analysis available on the International Meteor Organization (IMO) Web site (`www.imo.net`) shows a high level of activity from the fireballs over at least twelve hours on the night of November 16 and 17 (UT), with a peak at 01:40 UT on November 17. Careful observation, including video observations, showed that there were few fainter meteors during that period, and the fireballs likely came from old material spewed off the source comet Temple-Tuttle, ejected long ago and since swept clear of smaller particles. The predicted peak night of November 17/18 featured the fainter meteors expected to make up the storm, but in quantities that never qualified for use of the term. The corrected zenithal hourly rates (ZHR) did not exceed by much those of a good Perseid shower. Observers favoured by clear skies in central Asia endured −30°C temperatures to see the shower, and may well have had fond memories of warm summer nights observing the Perseids. The IMO analysis indicates a weak peak in activity at 20:30 UT on November 17 for the fainter meteors.

The joint Canadian-U.S. mission to Mongolia reported technical success and recorded valuable scientific data about the Leonids, including joint observations on video from sites separated by about 50 km near Ulaan Baator, and real-time reporting of meteor rates to a data centre at the University of Western Ontario (UWO). A parallel mission to Australia recorded radar echoes from meteors with similar success. It remains unclear whether minor satellite malfunctions reported during the period of elevated activity can be attributed to the Leonids, but the expeditions succeeded in demonstrating a real-time monitoring method that could be used in satellite operations to minimize the potential for damage.

The broad nature of the observed meteor peaks makes predictions for the 1999 Leonids difficult. Analogies are being drawn to the 1965 Leonids, which featured broad peaks and fireball activity and were followed by the spectacular 1966 Leonid storm. UWO meteor analyst Peter Brown emphasizes, however, that such analogies can be misleading. Even careful analysis of the 1998 data may not allow much of a prediction for 1999. Observers in 1999 will have to hope that, like those who went out a night early for the 1998 event, they will get a pleasant surprise.

Questions and Answers
Questions et réponses

How to Photograph a Computer Screen

Q *Thanks to modern technology, the Internet contains thousands of excellent astrophotos in electronic formats such as jpg, gif, etc. How can I transform images from my computer screen into ordinary photographic slides that can be used with a standard projector? I would like to use visual material to spice up presentations for our astronomy club meetings, but cannot afford one of those nifty overhead projector devices that connect to a laptop. Can I photograph the computer screen?*

Blair Batty, Unattached Member
Simcoe, Ontario (bbatty@nornet.on.ca)

A It is quite possible to photograph images right off your computer screen, with good results. I do it all the time for slide shows. I will leave aside the copyright issue, and assume that you are talking only about photographing your own images.

Some pointers:

1. Use a tripod and self-timer or cable release.

2. Set your exposure time for no faster than $^1/_{15}$ second in order to smooth out the image scans and to avoid uneven looking slides. I use ~$^1/_2$ second or slower exposures for most of my photos.

3. Shoot at night or in a very dark room in order to avoid reflections on the screen, which can ruin your photos. Reflections can be a serious problem. When one looks at a computer or television screen, one's eye is very good at "filtering out" or ignoring reflections. Often I have thought that the screen that I was photographing was reflection-free, only to get the slides back and find them ruined.

4. Use a telephoto lens if possible in order to flatten the image. Even a standard 50-mm lens will cause straight lines on the computer screen to appear curved in your final photograph. I normally use a 100-mm lens.

5. Be aware that many films will cause your slides to appear significantly bluer than your eye sees the image on the screen. You may want to adjust the computer image toward the red before photographing it.

6. The viewfinders in many 35-mm cameras show only 90-95% of the actual field-of-view that will be captured on film. As a result, if you position your camera so that you think that you are shooting only the screen and have excluded the monitor case, you will probably be wrong! Move your camera even closer to the screen (*i.e.* crop the view more) than you think will be necessary. Then you will ensure that you get only the screen in your final slide.

7. Use a good graphics display program that is capable of displaying an image without any surrounding toolbars, etc. The best graphics display application, bar none, that I have ever seen (and that I have been using for about four years now) is an application called "CompuPic" from Photodex Corporation (go to `www.photodex.com` for a demo version). It is a phenomenal program.

Good luck!

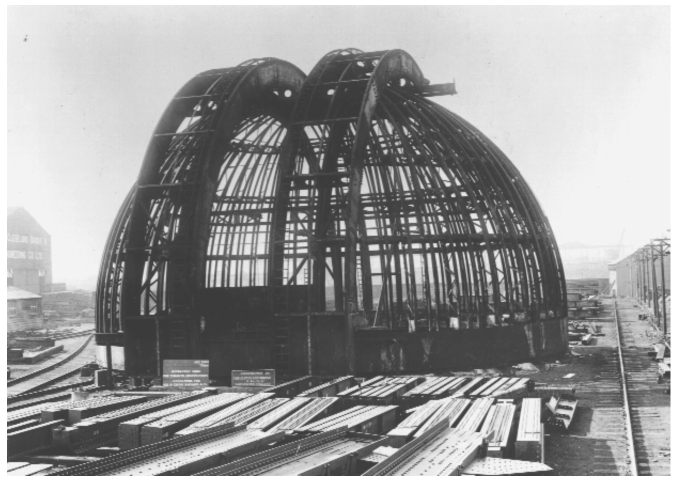
Michael Watson, Unattached Member
Toronto, Ontario

The Legacy Continues:
C. A. Chant and the David Dunlap Observatory

by C. H. Russell, Toronto, Ontario (zoozu@pathcom.com)

For over sixty years, the David Dunlap Observatory (DDO) north of Toronto has been one of Canada's premier astronomical institutions. Though it bears the name of the late David Dunlap, a wealthy lawyer and mining entrepreneur, the observatory is as much the legacy of Dr. Clarence Chant (1865–1956). Referred to by many as "the father of Canadian astronomy," Dr. Chant is best known for his contributions to astronomy education in Canada. He was a central figure in establishing the Department of Astronomy at the University of Toronto, where he introduced optional astronomy courses to the mathematics and physics curriculum in 1905. Chant was the faculty's sole astronomer until 1924, when one of his former pupils, Dr. Reynold K. Young, joined the department. Over the next ten years, Chant focused his remarkable energy on the establishment of the David Dunlap Observatory, retiring upon its completion.

Clarence Augustus Chant was born on May 31, 1865, to Christopher Chant (a cabinet maker) and Elizabeth Croft at Hagerman's Corners, Ontario. Though he grew up under the innumerable stars of the rural night sky, there is little evidence to suggest that Chant developed an early interest in astronomy. Indeed, while attending Markham High School in 1882, Chant actually forgot about the transit of Venus, an eagerly anticipated event that his schoolmaster had made preparations to observe. As a boy, however, he became fascinated with the workings of farm machinery, an interest that perhaps sowed the seeds of his future devotion to physics. Moreover, throughout his secondary school education he demonstrated "a certain facility" for mathematics.[1]



The dome skeleton under construction in England in August 1932 (from the University of Toronto Archives).

After completing his studies at Markham High School, Chant attended St. Catharines Collegiate Institute and York County Model School in Toronto. Still uncertain as to a career choice, Chant left the city in 1884 to work as a teacher in Maxwell, Osprey Township, for three years. Though successful and well liked as a teacher, Chant returned to Toronto in 1887 to attend University College at the University of Toronto. There he studied mathematics and physics under the guidance of Professor James Loudon, an important figure in Chant's career. Through Loudon's connections, Chant secured a position in the federal civil service in Ottawa upon graduation in 1890. After a year as a temporary clerk in the Auditor General's office, Chant realised that his prospects were limited, and wrote to Loudon in the summer of 1891 about the possibility of obtaining a position at the university. Loudon offered him a fellowship, and in 1892 Chant was appointed a lecturer in physics. He never looked back.

At that time, astronomy had no home of its own at the university; from 1890 to 1905 instruction in astronomy was available only to fourth-year students seeking honours in mathematics and physics. Before 1890 it was merely a component of natural philosophy studies.

Chant's appointment occurred in the same year that the university became federated with Victoria College, a Methodist institution that included astronomy courses in its curriculum. Victoria College was influenced greatly by the ideas of Egerton Ryerson, who believed that training in the sciences, particularly "the knowledge of the laws of the universe," was essential to a good education.[2] The union did not produce an astronomy department at the university, however, and the subject remained under the umbrella of the mathematics department.

After Chant joined the university,

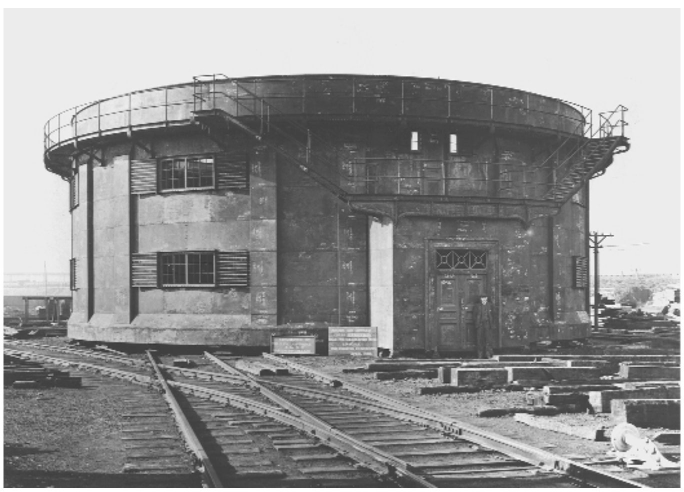
[1] Clarence Chant, *The David Dunlap Observatory Papers*, Box 010, Folder II, leaf 36.

[2] Egerton Ryerson, On the Course of Collegiate Education (1842), quoted in Richard Jarrell, 1988, *The Cold Light of Dawn: a History of Canadian Astronomy* (Univ. Toronto Press: Toronto:), p. 71.

The laying of the cornerstone for the David Dunlap Observatory, September 10, 1932. From left to right are: a stonemason, University President H. J. Cody and Moffat Dunlap (reproduced with permission from the Helen Sawyer Hogg Collection).

we see evidence of his keen interest in astronomy. Attracted by newspaper notices, Chant approached and was admitted to the Astronomical and Physical Society of Toronto in December 1892. That group was renamed the Toronto Astronomical Society in 1900, and became the Royal Astronomical Society of Canada in 1902. Chant served as its president from 1904 to 1907, and was editor of its *Journal* for many years.

The 1890s were active years for Chant. He taught physics and worked towards his Master's degree, which he received in 1900, and filled in for an ailing Loudon from 1895 to 1897. Despite his demanding schedule, he found time to enrich his life by attending concerts, lectures and plays. In 1894 he married Jean Laidlaw, by whom he had two daughters, and traveled to Germany in the summer of 1898 to study light theory. In late 1899 he directed operations for the first wireless telegraph message in Canada, sent from one end of a lecture hall to the other at University College. After receiving his graduate degree in 1900, Chant was granted a one-year leave of absence to pursue a doctorate in physics at Harvard. He returned to Toronto in 1901 with a Ph.D., having devised a new method of measuring the lengths of electric waves.



The University of Toronto's 61-foot circular Observatory building under construction in England in April 1933, showing the doors and external staircase (from the University of Toronto Archives).

Throughout the 1890s Chant came to lament "how little the University was doing for astronomy."[3] Eager to "improve this condition of things," Chant proposed the introduction of separate astronomy courses in 1904, the same year that he was installed as the president of the RASC.[4] The Senate of the university applauded Chant's initiative, and in 1905 six astronomy courses were added to the undergraduate calendar as an option for fourth-year students. That success was immensely gratifying to Chant, who noted in his memoirs the "great pleasure" he later felt, knowing that "[a]t one time... all the astronomers in Canada... had been my personal students."[5]

With an astronomy curriculum now in place, Chant understandably yearned for a well-equipped observatory on the university grounds. Astronomy students had to make do with limited access to a 6-inch refractor that was installed in the old Toronto Meteorological Observatory in 1882 to observe the transit of Venus. Unfortunately, there was no suitable location on the university campus for even a small facility. Chant began his quest for an off-campus site as early as 1906, and began obtaining quotes for observatory equipment from companies such as Warner and Swasey in Cleveland, the same company that provided the mount for the telescope at the Dominion Observatory in Ottawa, opened in 1905. After five years, Chant found what he judged to be a perfect spot for an observatory, on a ten-acre site owned by the City of Toronto. Located north of the city near present-day Bathurst Street and St. Clair Avenue, the land had been purchased by the City for the building of the failed Isolation Hospital. Chant began talks with the City to allow the construction of the "Royal Astronomical Observatory." The City was receptive to the idea, and it generated some excitement in the local press. It was not to be, however; World War I put the project on hold until 1919, after which a shortage of funds dashed all hopes for the observatory's completion.

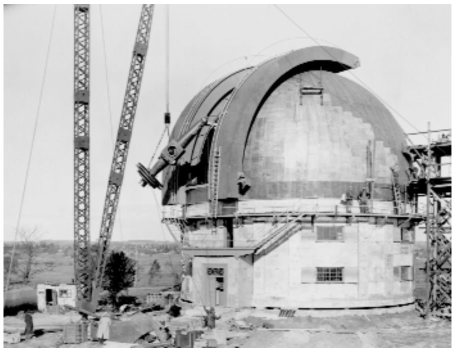
Disappointed but determined, Chant pursued Toronto's wealthy for financial support, but to no avail; as far as the sciences were concerned, the philanthropic spirit of Canada's well-to-do did not match that of their American counterparts. While large, privately endowed observatories were numerous in the United States, Canada had only two institutions, both children of the federal government: the Dominion Observatory in Ottawa and the Dominion Astrophysical Observatory in Victoria, opened in 1918. That was about to change, however.

In 1921 Chant delivered a public lecture on Wennecke's Comet, which had recently glided across Canada's skies. Among those in attendance was David Dunlap, who, bitten by the astronomy bug, expressed an interest in Chant's efforts regarding the establishment of a large observatory. Before making any firm financial commitment, however, Dunlap died in October 1924 at age sixty-one. Chant's dream of a large observatory fortunately

[3] Clarence Chant, *op. cit.*, folder XIII, leaf 289.

[4] *Ibid.*

[5] *Ibid.*, leaf 291.

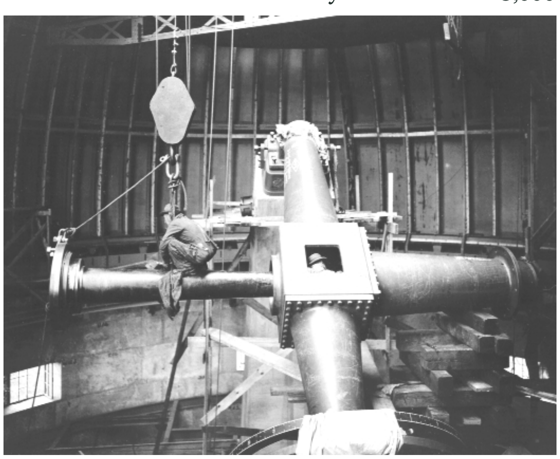


The 16-ton polar axis assembly is hoisted into the finished dome, October 23, 1933 (reproduced with permission from the Helen Sawyer Hogg Collection).

did not perish with Dunlap. He approached Dunlap's widow, Jessie Dunlap, in late 1926 with the idea of erecting an observatory as a monument to her husband. Mrs. Dunlap embraced the proposal warmly, promising to "keep it in my heart for consideration, for it appeals to me tremendously."[6] After meeting with Chant she agreed to finance the scheme, pending the settlement of her husband's estate.

Over the next four years Chant worked closely with Mrs. Dunlap to iron out the details of the project, on which he invited her input. They chose to keep the undertaking out of the public eye until all was ready. One of the details to be worked out was the new observatory's location. The site favoured by Chant in 1911 was unsuitable, as it now lay inside the city. Among the new sites considered was one three miles south of Aurora, Ontario, about 1,000 feet above sea level and 500 feet above the Toronto site. Though favourable from an astronomical point of view, it was rejected as being too distant from the university. Another potential site, near Hogg's Hollow north of Toronto, was good but not easily accessible. After inspecting topographic maps with fellow astronomer Reynold Young, Chant decided that a rise in the land just south of Richmond Hill was ideal. Upon seeing the site for the first time, Jessie Dunlap exclaimed, "this is the place!" and authorized its purchase for $28,000.[7] In May 1930, Dunlap gave the funding final approval and announced the project to the press.

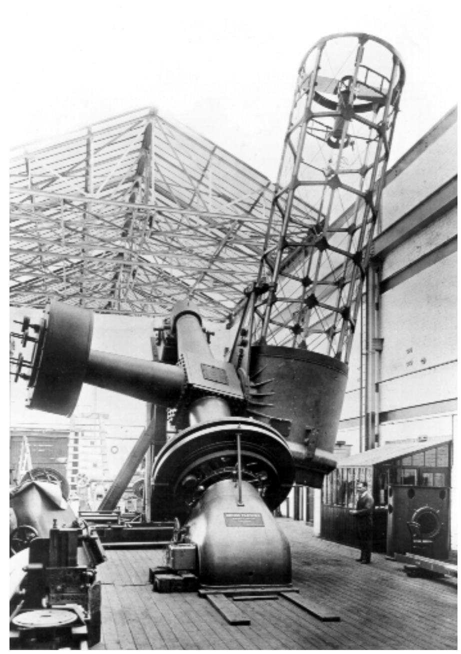
With the project on secure financial footing, Chant proceeded with the ordering of a 74-inch reflecting telescope from Grubb, Parsons and Company in England. The telescope would be the second largest in the world, surpassed only by the 100-inch instrument at Mount Wilson in California. Owing, however, to the death of the project's overseer in Britain, Sir Charles Parsons, Chant chose to have the mirror cast at Corning Glass Works in the United States to avoid delay. The mirror, twelve inches thick and weighing 5,000 pounds, was poured in the presence of Mrs. Dunlap and Chant in June 1933, then sent to Grubb-Parsons to be ground and polished. The mounting too was built in England, as was the observatory's copper dome — sixty-one feet in diameter and weighing eighty tons — and the main building that houses the large telescope. The structure took two years to complete and cost a total of $51,000. It arrived in Toronto on July 31, 1933, where it was reassembled by the Dominion Bridge Company, the company that later lowered the twenty-three ton telescope (without mirror) through the dome's fifteen-foot-wide slit using a special crane. The finished mirror was installed in May 1935.



The declination axis for the telescope is guided into position (reproduced with permission from the Helen Sawyer Hogg Collection).

The DDO's administration building, designed by Toronto architects Mathers and Haldenby, was finished in the same year at a cost of $109,160. It is capped by three smaller domes, the northern-most of which houses the 6-inch refractor from the old meteorological observatory.

Chant's vision of a world-class observatory became a reality on his seventieth birthday. On May 31, 1935, the opening ceremony was attended by such notables as Sir Frank Dyson, former Astronomer Royal of England, and Mackenzie King, who praised the David Dunlap Observatory as "a gift to science all over the world."[8] Chant retired the same day and moved into nearby Observatory House, where he spent his remaining years. Reynold Young became the Observatory's first director. In the ensuing years, Chant witnessed with satisfaction the growth of the observatory.



The 74-inch telescope is mounted in the shop of Sir Howard Grubb, Parsons and Company, Newcastle-Upon-Tyne (reproduced with permission from the Helen Sawyer Hogg Collection).

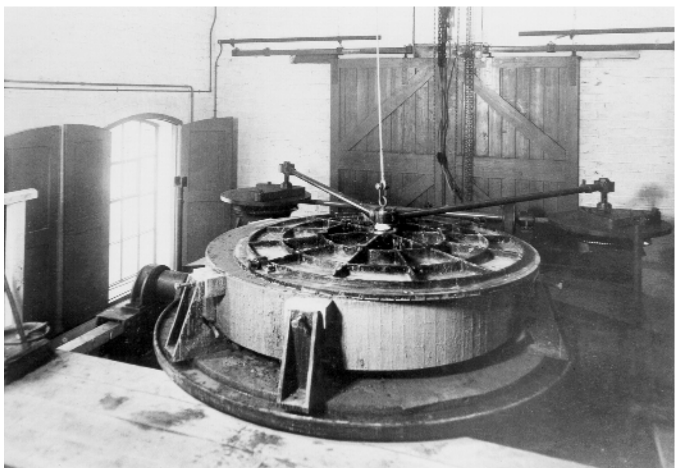
[6] *Ibid*., box XIII, Jessie Dunlap to Clarence Chant, December 9, 1926.

[7] Clarence Chant, 1954, *Astronomy in the University of Toronto: the David Dunlap Observatory*, (Univ. Toronto Press: Toronto), p. 40.

[8] "Special Convocation Observed," *The Globe*, June 1, 1935, p. 14.

Under Young the DDO began the compilation of a photographic resource base and initiated a study of the radial velocities of some 500 stars. The DDO staff expanded to include such noted astronomers as Dr. Frank Hogg, Ruth Northcott and Jack Heard. The staff was also complemented by Hogg's wife, Dr. Helen Hogg, and Peter Millman. Helen Hogg's work focused on globular clusters, while Millman carried out meteoric research. In the meantime Chant set to work on writing his autobiography, published in 1954. He passed away at Observatory House on November 18, 1956, near the institution he had laboured hard to build.

Chant's creation flourished throughout the following decades, and kept pace with the burgeoning store of astronomical knowledge around the world. The DDO added to its ranks more radio and theoretical astronomers, and in the 1960s constructed a radio telescope in Algonquin Park. By the mid-1980s, however, budgetary constraints placed that instrument's future in doubt; sadly, the dish was abandoned in 1991. At the close of the 1960s, the DDO found itself plagued by light pollution from the ever-expanding city of Toronto, an ongoing concern. The observatory responded by going international and erecting in 1971 a 0.6-m telescope at Las Campanas in Chile. That opened the southern skies for the University of Toronto, and it was at Las Campanas that the first naked-eye supernova to occur in over three hundred years, SN 1987A, was identified.



Grinding the surface of the 74-inch mirror, December 1933 (reproduced with permission from the Helen Sawyer Hogg Collection).

As the DDO looks forward to the year 2000 and its sixty-fifth anniversary, it does so hindered by city lights, no longer at the vanguard of observational astronomy. Nonetheless, it faces the new millennium with an undiminished importance of purpose: to remain the foremost institution in Canada for training the professional astronomers of the future — the great legacy of Clarence Augustus Chant.

C. H. (Mike) Russell is a freelance writer who is presently working on a novel and a short story collection about the working class of east-end Toronto. Born and raised in Toronto, where he lives, he earned his B.A. in History and English from the University of Toronto, and his M.A. in Canadian History from York University. His interests lie in the areas of history, astronomy, cycling, and philately, as well as writing (naturally!).

ASTRONOMY DAY — MAY 22ND, 1999

Astronomy Day occurs each year sometime between mid-April and mid-May on the Saturday closest to the 1st Quarter Moon. Astronomy Week starts the Monday before Astronomy Day and ends the following Sunday. Astronomy Day was first held in California in 1973, and has spread throughout the world as an international event. Usual activities include demonstrations of telescopes, models of the Solar System, games, children's crafts and model making, solar observations, computer simulations, and many other activities that help to describe and promote amateur and professional astronomy to the general public.

This year International Astronomy Week is May 17th through May 23rd.

Here is an opportunity for your Centre to "Bring Astronomy to the People." If you have ever experienced a public event like it, you will know the results are amazing. Common remarks are overheard, "Oh! I can see that," or "With only a pair of binoculars," or "That's cool" etc. My initiation to the event was last year, and I am looking forward to the Ottawa Centre's activities again this year.

To help support centre activities for Astronomy Day, a specific area on the RASC website (`www.rasc.ca`) will be dedicated to Astronomy Day 1999, and will be available by the time you read this. An Astronomy Day "care package" is also in the works, and will be ready soon. You will also find a wealth of useful information at: `www.skypub.com/astroday/astroday.html`

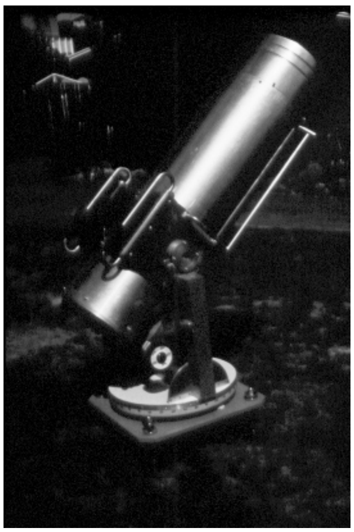
Contact the undersigned for additional information.

J. Peter Williams, RASC Astronomy Day Co-ordinator
E-mail: jpw@igs.net

Orion Upside Down[1]

by Ray Berg, Kingston Centre (berg3@netnitco.net)

I stepped out into the darkness of the cool evening and looked up to the northern sky. “Wow!” I thought, “Orion really *is* upside down here (and also to be found in the northern part of the sky)!” Thus began a month-long odyssey through three South Pacific countries from March 6 to April 6, 1998. My wife Lois and I had been planning our trip for over a year and a half, and it was to include sightseeing, scuba diving, fishing, and, of course, astronomy. We also had the good fortune to meet and discuss our plans with Albert Jones (New Zealand) and Tom Cragg (Australia) at the American Association of Variable Star Observers (AAVSO) Spring Meeting in Sion, Switzerland, the previous May. Their suggestions contributed greatly to the trip being a wonderful success. My main astronomy objective was to become acquainted with and to make a telescopic grand tour of the splendors of the southern skies, which included a short program of observation for selected variable stars.



The 32-cm f/4 reflector, with stainless steel tube and mount, used to make the grand tour of the Southern Skies in New Zealand.

At the suggestion of Albert Jones, we headquartered for two weeks in New Zealand at the Southern Heavens Homestay, a bed-and-breakfast that caters to astronomers. Located near Nelson at latitude 41°S on the South Island, the skies were wonderfully transparent. The smoke and dust encountered at home were absent, and the resulting clarity permited surprisingly good views of deep sky objects even when the Moon was full. Southern Heavens Homestay includes a domed observatory equipped with a 15-cm f/14 refractor for the use of guests, and a portable 32-cm f/4 reflector as well. Host Peter Knowles, an avid amateur who can talk astronomy non-stop, was pleased to act as our guide to such wonders as the magnificent globular cluster Omega Centauri, which appears as a massive ball of millions of suns in splendid profusion covering an area the size of the full Moon, the well defined loops of luminous haze in the Tarantula Nebula, sparkling coloured stars within the famous Jewel Box, and all the wondrous detail of other star clusters, nebulae, and double stars buried within the Magellanic Clouds. On three separate evenings, we revisited an old friend from the previous year: Comet Hale-Bopp, which appeared as a 9th magnitude fuzz-ball in the constellation Dorado, although it still managed to exhibit a short tail. I also began keeping a nightly watch on the bright orange variable star Eta Carinae, buried in the splendid expanses of the Keyhole Nebula, watching warily for a nova-like outburst that never came. This star has a history of brilliant flare-ups over the centuries, and, although it has been relatively quiet in recent times, it is expected to explode as a supernova at any time. The huge, bright nebula itself is beautiful beyond description, with dark lanes defining many individual islands of glowing light and intricate wispy detail. Within this immense gaseous complex I located the two small open star clusters Trumpler 14 and Trumpler 16, and a number of delicate double stars. Three other less impressive variable stars are near the edges of the nebula and they were checked once a week as well.

The author with the 15-cm f/14 refractor at Southern Heavens Homestay Observatory, New Zealand.

“Chelsie” helps to check out the New Zealand optics.

Daylight hours were usually spent hiking, trout fishing, or in general sightseeing. New Zealand is one of the most beautiful countries in the world, and is a photographer’s delight. We toured the entire South Island over a five day period, and found it to be a delightful collection of lush forests, wind swept seascapes, magnificent mountains and glaciers, scenic fiords, and rolling farmland. A few periods of clear daytime weather

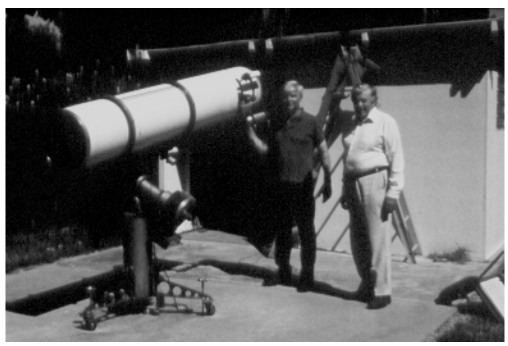
[1] Also published as “In Search of the Southern Cross” in AAVSO Newsletter Number 20, October 1998.

were also reserved for telescopic observing, including counting sunspots and viewing Mercury and Venus. The latter two presented quite a different appearance (particularly Mercury) from the shimmering blobs I have been used to seeing near the horizon, since here they were being observed at about noon and not far from the zenith. Their near quarter phase was very steady, and the day sky precluded the need for filters to tone down their brightness. Both planets were quite easy to locate using Peter's homemade sidereal clock, an ephemeris, and the setting circles on the pier-mounted 15-cm refractor. On our last evening, Peter hosted a small star party of New Zealand amateurs at his observatory. I discovered that they may be fewer in number than at home, but just as enthusiastic!

The Southern Heavens Homestay Observatory, New Zealand.

Leaving New Zealand, we traveled 2500 km northward to the remote island of Beqa, located just off the mainland of Fiji, for six wonderful days of scuba diving, saltwater fishing, and shell collecting. We found the Fijian people to be exceptionally friendly, cordial, and happy. The island is a secluded dark-sky site, and a small refractor was available for my use at the dive shop. The owner had used it only for terrestrial views, and was hoping I could show him some of the beautiful objects in his own night skies. However, my plans for star watching here were dashed by heavy cloud cover every evening.

Heading back southwest, we arrived after a long plane flight at Coonabarabran, the self-proclaimed "Astronomy Centre of Australia," since it is the location of the Siding Spring Observatory. It is one of the world's major observatory complexes, and includes Australia's largest optical telescope — the 3.9-m Anglo-Australian Telescope. Coonabarabran is also the home of retired professional astronomer Tom Cragg, who extended to us much-appreciated hospitality during our three-day stay in this small town (population 3,000 = dark skies!). By day Tom provided us with a private tour of the immense observatory complex, and acted as our guide through the nearby Warrumbungle National Park for a wildlife photo expedition. We discovered that in Australia kangaroos certainly do outnumber everything else, including people! By night, Tom and I scoured the sky with his 30-cm f/7 Cave Astrola reflector, through which we observed variable stars. Highlights included catching the dwarf nova VW Hydri in outburst and estimating the brightness of an R CrB-type star in another galaxy, W Mensae in the Large Magellanic Cloud, blissfully shining at its maximum brightness, which at a distance of 50,000 parsecs from our telescope, was magnitude 13.5. We also observed the *very* southern variable star R Octantis, located close to the South Celestial Pole at declination −81°, and made early observations of the new nova, N Sgr 98, which had appeared during our flight into Australia.



The author (left) and Tom Cragg (right) used this 30-cm f/7 reflector to observe southern variable stars in Australia.

Occasionally a detour was made to view a deep sky object such as 47 Tucanae, a very rich globular cluster containing uncountable stars that increasingly thicken into a dense, bright core. The object was particularly impressive when viewed in the giant field of an 11-mm Nagler eyepiece. The galaxy Centaurus A seemed much more distinct with the telescope, appearing as a bright, round, luminous glow, with a definite black bar cutting it in two and making it appear much like its photographs. In Carina we located NGC 3293, the Gem Cluster, with a bright, red, ruby-like star dominating the field of its other sparkling members. In my opinion, this open star cluster is more impressive than the Jewel Box cluster, of which it appears to be a miniature version. Alpha Centauri was easily resolved as two brilliant yellow suns, but a determined search failed to locate 11th magnitude Proxima Centauri, which currently may be too close to the bright primary pair for our aperture.

After a very memorable visit we bid Tom farewell and started on our final leg of the journey, to the Australian Outback. Playing the tourists, we visited (and climbed) Ayer's Rock, a gigantic monument of stone rising out of the desert wasteland. It is truly awe-inspiring. Since it is an aboriginal sacred site, absolutely no outdoor lighting is permitted anywhere in the area. Thus, at night I witnessed the darkest skies I have ever seen. The Southern Cross was high in the southeast, with brilliant Alpha and Beta Centauri acting as pointers below it. The Milky Way crossed overhead in a dazzling display of stars and bright patches of star clusters and nebulae. The Coal Sack nebula was absolutely black and seemed darker than the night sky. Incidentally, the galactic centre is nearly overhead at that locale, and on those dark evenings the true nature of the Milky Way as a galaxy began to become quite evident, with its spiral arms

Some people will go *anywhere* to observe from a dark site — the Australian Outback.

extending out in two directions from the enlarged hub formed around Sagittarius. Armed only with 10×50 binoculars, I drank in all of the beauty, and made additional magnitude estimates for a few bright variable stars (including the foreboding Eta Carinae). Ayer's Rock is truly a wonderful location to contemplate the universe! From there it was on to Alice Springs, where Lois and I rented a four-wheel drive vehicle and spent one day gem hunting in rugged country 150 km to the north. The following day found the two of us 150 km to the southwest, exploring the Henbury meteor crater field in equally desolate terrain. Nearly 5,000 years ago a large meteor exploded here in mid air and rained down debris that created a dozen craters, five of which are quite large. We spent an entire day playing astrogeologists, crawling up and down the impact relics, contemplating the enormous explosion that once occurred here, and taking many photos.

All too soon the month was up and we arrived in Sydney to board a plane back to Chicago, bringing our event-packed adventure to an end. Lois and I returned with a ton of notes, photos, and memories of our trip. Last but not least, we made a lot of new friends with whom we will keep in contact and hopefully will see again in the future.

Road hazard ahead — New South Wales, Australia.


Australian natives.

Ray Berg is an active amateur astronomer and a "remote member" of the RASC, attached to the Kingston Centre. A retired metallurgical engineer, he observes from his rural home in Crown Point, Indiana, and currently collects data for the AAVSO on dwarf novae, long period pulsating variable stars, and eclipsing binaries.

Reflections

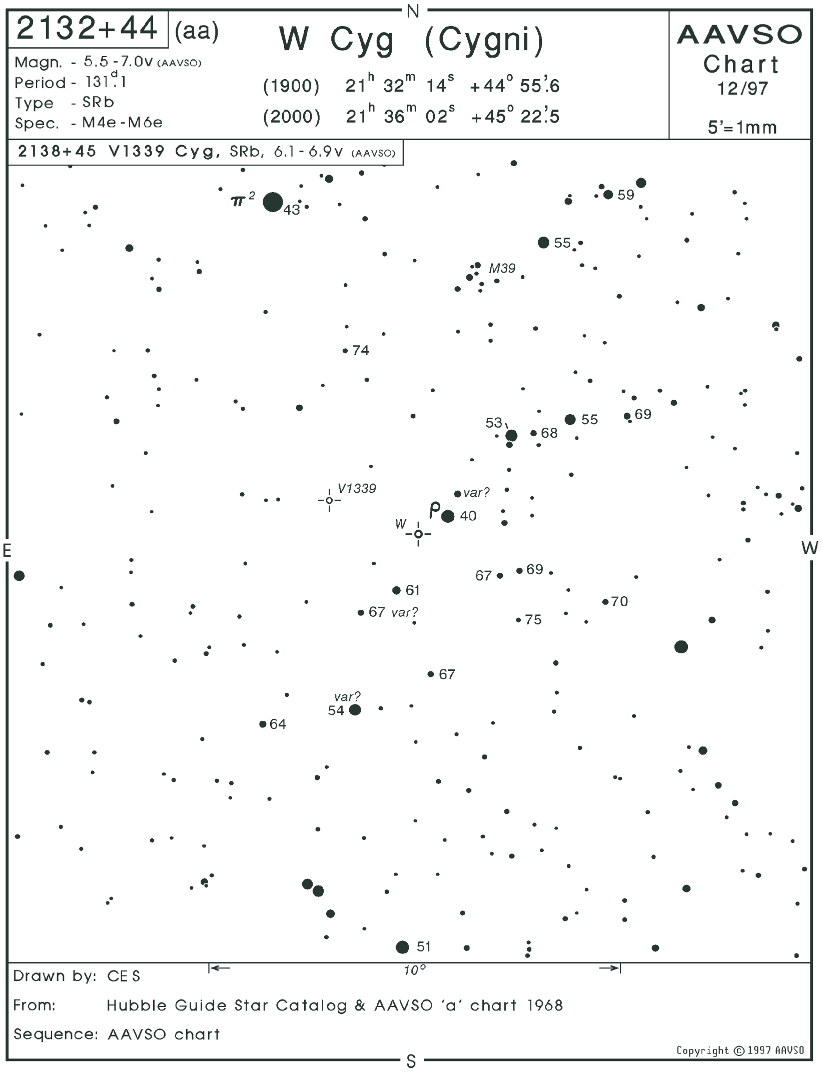
F. W. A. Argelander–*Star Charts and Variable Stars*

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

This year marks the 200th anniversary of the birth of Friedrich Wilhelm August Argelander (1799–1875), a German astronomer who is noted for his work in celestial cartography and for founding the science of variable star astronomy. Argelander was born in the Baltic port city of Memel in East Prussia (now the Lithuanian city of Klaipeda) on March 22, 1799. His father was a wealthy Finn, his mother, German. When the Prussian royal family fled before Napoleon's advance, two princes took refuge in the Argelander home; the elder prince eventually succeeded to the throne in 1840 as King Frederick IV. The event proved to be a critical encounter for Argelander in later life.

Argelander studied at Königsberg under F. W. Bessel, obtaining his Ph.D. in 1822. He was head of the Finnish observatories at Turku and Helsinki before returning to Germany in 1836. Here, as the new Director of Bonn University, he was able to parlay his personal friendship with the king into funds to build a new observatory, a project the previous director was unable to launch. In his new observatory, Argelander devoted himself to the visual survey of stars and celestial cartography. Between 1859 and 1862 he published the four-volume star atlas *Bonner Durchmusterung*, containing the positions of 324,198 stars in the northern heavens down to the ninth magnitude. The atlas was an extension of a survey conducted at the University of Königsberg by his professor, F. W. Bessel, who had accurately catalogued the positions of 50,000 stars. Argelander's atlas was the result of a survey of stars between the North Celestial Pole and the Celestial Equator (actually, between +89 degrees and −2 degrees) carried out in the years 1852–1861. It was the last principal star chart to be compiled before photographic techniques were introduced, and remained popular until 1950, its last reprinting.

Argelander and his assistants used the survey technique known as the "drift method," in which the telescope is fixed



The binocular field of W Cygni, the *Observer's Handbook* "Variable Star of the Year" for 1999. The star was named according to the convention introduced by Argelande (Reproduced courtesy of the AAVSO).

in declination and the star field is allowed to drift across the field of view while the Earth rotates. As each star passes a vertical line inscribed in the eyepiece focal plane, the time and vertical position of the transit is recorded, along with a magnitude estimate. In that way — and with some calculation — the position and estimated visual magnitude for every star visible with the 78-mm Bonn telescope was catalogued. (Positional accuracy was 0.1 sec in right ascension and 0.1 arcmin in declination; magnitude accuracy was 0.1 mag down to 9.5 mag, with fainter stars being arbitrarily assigned to 9.5 mag.)

The astronomer E. Schönfeld (1828–1891) extended Argelander's atlas down to declination −22 degrees, adding 133,659 stars in 1886. The Scottish astronomer Sir David Gill (1843–1914) also extended Argelander's work to the southern sky, working from South Africa. Using photographic survey methods, he and J. C. Kapteyn produced *The Cape Photographic Durchmusterung* for the Equinox 1875.0, containing more than 500,000 stars.

Argelander was the first astronomer to study variable stars in detail. When he began his study, only a handful of stars were known to vary in brightness. He introduced the naming convention that applies capital Roman letters (R, S, T,...) for the variable stars not already named in a constellation, as distinct from Bayer's system of Greek letters (α, β, γ,...) used for the "ordinary" stars. The sequence begins with the letter "R," standing for the German word "rot", or "red," recognizing that a large fraction of variable stars are coloured red.

The first star recognized to be variable was Mira, or Omicron Ceti, in the constellation Cetus, the Whale. The German astronomer David Fabricius (1564–1617) observed the star in August 1596, while searching for Mercury, but it had disappeared when he looked for it several months later. Bayer also recorded the star in 1603, but did not notice its fluctuations. It was not until 1638 that Johann Holwarda discovered that Mira is a star that varies between magnitude 1.7 and magnitude 10.1 with an irregular period of about 11 months. (One can see why Fabricius thought that Mira had disappeared!) Another variable star well-known at the time was Algol, or Beta Persei, discovered to be variable in 1669. Algol is an eclipsing binary, or "false" variable star, whose brightness varies as a result of one component of a double star passing in front of the other. Algol varies between magnitude 2.2 and magnitude 3.3 with a precise period of 2.867 days, owing to the cyclical eclipsing of its orbiting components.

Observing and reporting the brightness of variable stars is one field of astronomy in which the amateur can actually make a useful contribution with modest equipment. The co-operative measurements of many observers can be combined to produce accurate light curves of variable stars, whose study by professional means would be prohibitively expensive. For more information, consult the article "Variable Stars" on page 242 of the *1999 Observer's Handbook* or surf to `www.aavso.org`, the Internet home page of the American Association of Variable Star Observers.

David Chapman is a Life Member of the RASC and a past President of the Halifax Centre. In addition to writing "Reflections," he has written for SkyNews *and the U.S. National Public Radio program* StarDate, *mostly on historical and calendrical aspects of astronomy. In his other life, he is Head of the Naval Sonar Section of the Defence Research Establishment Atlantic.*

Shredded Galaxies in Clusters

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

Clusters of galaxies are very large structures in the universe. The questions of how they came to be and what made them the way they are today are among the most interesting in modern astronomy. As telescopes become more sensitive, it is possible to see fainter structures, which theorists then model using ever-faster computers. The recent discovery by Michael Gregg (of Lawrence Livermore National Laboratory) and Michael West (Saint Mary's University) of tidal streamers of stars inside the Coma Cluster of galaxies shows the effects of interactions between individual galaxies inside the cluster (see the 10 December 1998 issue of *Nature*). Such interactions gradually strip stars from the galaxies, building up a population of stars with no galactic home.

Fritz Zwicky discovered forty years ago that the Coma Cluster had a faint background light associated with it, and more recently Harry Ferguson (Space Telescope Science Institute) and collaborators identified isolated stars inside the Virgo Cluster (see the 29 January 1998 issue of *Nature*). An important question within the context of galaxy and cluster formation is whether the stars that make up the background light in Coma originally formed inside individual galaxies or from gas in the intracluster medium. Both possibilities relate to the order in which structures formed.

Gregg and West have now identified in the Coma Cluster streams of tidal debris left over from interactions between galaxies that did not merge. The mutual gravitational tides raised by galaxies as they pass each other pull out streams of stars and gas. Such structures are not dynamically stable, and in general will dissipate within one to two billion years. If the present is a typical time in the life of the Coma cluster, the fact that Gregg and West have identified three distinct streams (along with one previously-discovered smaller stream) implies that, over the age of the universe, the cluster has picked up the equivalent light of a very large galaxy.

An *R*-band image of the region of the Coma Cluster containing the streams of tidal debris.

How do such findings relate to how galaxies and clusters formed? Many theorists believe that 98% to 99% of the mass of the universe is in a form that has not yet been detected directly: the dark matter. All of the matter we *can* detect — stars, atomic and molecular hydrogen gas, hot (millions of degrees Kelvin) gas in clusters of galaxies, black holes (through heating the gas that falls into them) — amounts to only about 1% of the critical density, which is the density of matter needed just to stop the expansion when the universe is infinitely old. Theorists tend to prefer models in which the universe has the critical density. The processes that created matter from energy in the very early universe do not seem to allow more than about 2% of the critical density to be composed of baryons (mainly the protons and neutrons that are familiar from the world around us).

Within this picture of dark matter, people make computer models of how the universe should evolve as it expands and how the matter, which was originally very hot, cools to the temperatures we observe today. It is not an intuitively obvious process. For example, one might think that gas condensations the size of clusters or superclusters of galaxies formed first, then smaller condensations inside them made the primordial galaxies, and further condensations made the stars. If that were the way the universe worked, then there may be many isolated stars in clusters of galaxies. The models that are favoured today, however, do not work in such fashion. It appears that small galaxy-like condensations formed first. They merged together to build up bigger galaxies in a process called "hierarchical galaxy formation." Finally, the large galaxies attracted nearby ones through their mutual gravitation, and clusters started to form. Within the general picture of such models, one must explain how isolated stars and groups of stars came to be within a cluster, since all star formation should take place inside galaxies. Gregg and West have now shown how it might be accomplished, at least in the Coma Cluster.

Does that mean that over time galaxies will be eroded and the cluster will start to look like a huge galaxy, spread over a large volume? Probably not. The stars that have been stripped will tend over time to fall to the bottom of the cluster's "gravity well," where they could be accreted by a centrally dominant (cD) galaxy and provide a significant fraction of the luminosity in its outer regions. The net process then, is to erode smaller galaxies in clusters, while building a huge one at the centre. The more closely we look at the universe, the more interesting it becomes.

Dr. Leslie J. Sage is Assistant 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.

Astrocryptic

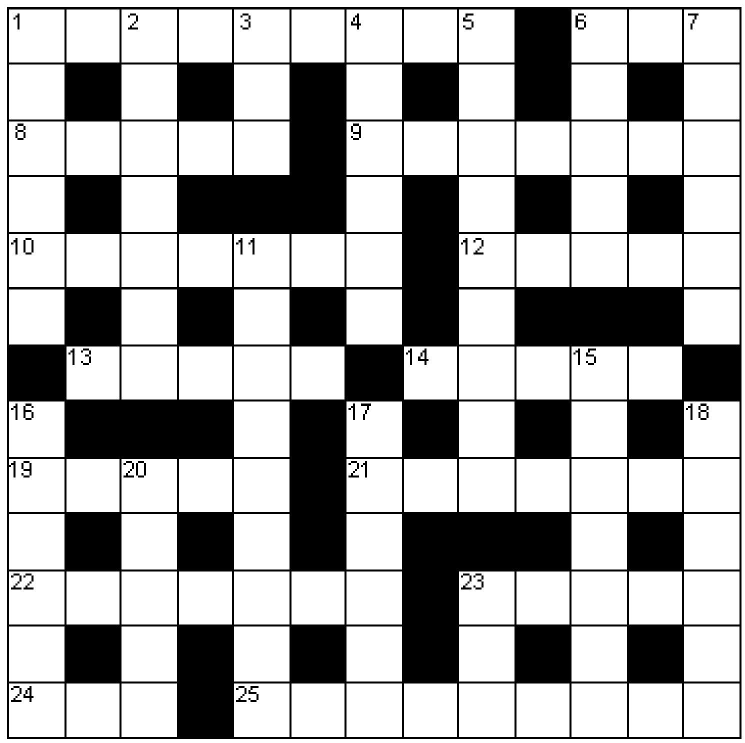
by Curt Nason, Halifax Centre

Across

1 A very hot star can make a towel fray (4-5)
6 Butter was the first sign of spring (3)
8 Speed soundly to circle the proposed dark matter (5)
9 Look through it to see Mars end catastrophically (7)
10 Shimmers seen around Ara and fatherless Europa (7)
12 Heartbroken wanderer (5)
13,14 Whether in sac or jam, it's the top dog down south (5,5)
19 Straight ocular, familiarly (5)
21 Lifeless at the beginning of Iapetus, and resistant to change (7)
22 The number one tide returns with this printing (7)
23 Sixties race for more room (5)
24 You wouldn't record your observations on one (3)
25 Use candle around Saturn (9)

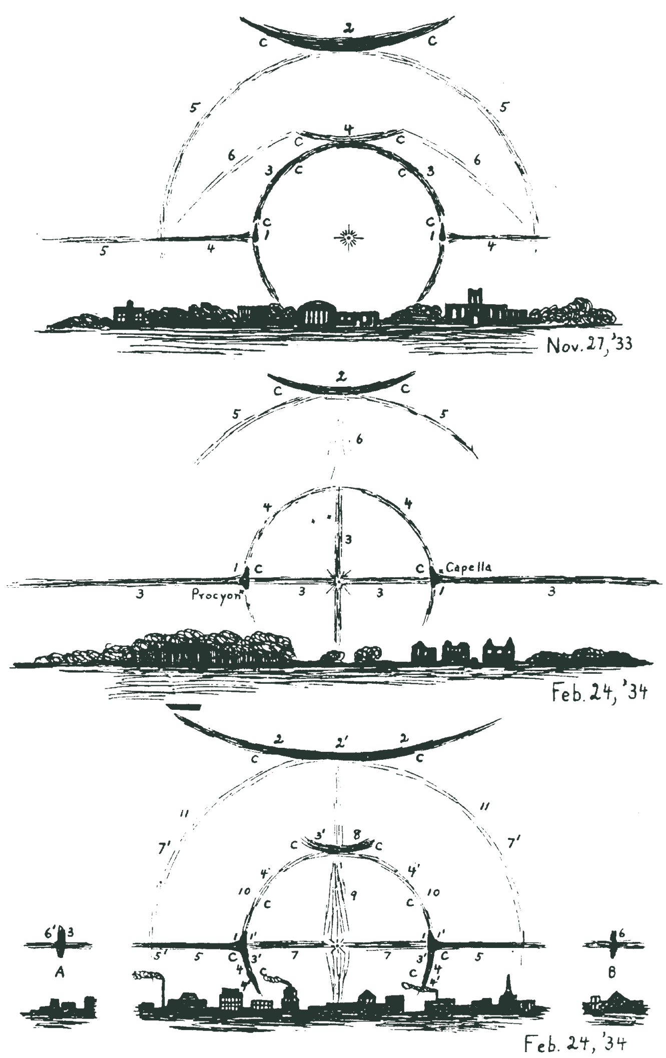
Down

1 Slue a BMW to see the marsupial (6)
2 The lizard can seek refuge in Aquila, certainly (7)
3 Sounds like the beginning of Rome, to a Greek (3)
4 Be agreeable about Edmund's eyepiece used in the observatory (6)
5 Violent anger devoured a Jovian belt (9)
6 Alcor's contractual clause (5)
7 Moths ingest nitrogen during lunar cycles (6)
11 One iron face described the meteor shower (4,2,3)
15 Interplanetary flight direction leads out to a drawback (7)
16 Behold, we will shortly visit the observatory (6)
17 Doubly charged to the tune of 6 million dollars (6)
18 Mix less argon in your collimation tools (6)
20 Camera adapter developed from endless strings (1-4)
23 The Spanish return for some sun (3)



SOLAR AND LUNAR HALOS

Notes and Queries



Two Solar Halos and a Lunar Halo seen in Toronto.

In the accompanying figure are sketches of two halos about the Sun and one about the Moon, as drawn by Dr. P. M. Millman. Those of the Sun were also observed by the present writer. The first sketch (at the top) represents a solar halo observed from the front campus of the University of Toronto between 1:50 and 2:00 p.m. on November 27, 1933; the second, a lunar halo observed from North Toronto between 2:00 and 2:30 a.m. on February 24, 1934; the third, a solar halo observed from near the corner of Bloor and Bay Sts., Toronto, between 8:30 and 9:30 a.m., February 24, 1934. The temperature readings on these three occasions were 25°, 2°, and 0° F, respectively; the reduced pressures were 29.4, 29.7, and 29.8 inches. The inner circle, with centre at the Sun or Moon, was about 45° in diameter in each case; the outer circle, 90° in diameter. The numbers on the sketches indicate a purely qualitative scale of brightness for different parts of the halos, the brightest features being numbered *1*. In the third halo the unprimed numbers refer to the appearance at 8:30 a.m., the primed numbers to the appearance at 9:30 1a.m. In this halo the horizontal circle extended entirely around the horizon, the bright spots indicated at A and B appearing on it at distances of 120° from the Sun. These same bright spots would probably have appeared in the case of the lunar halo had not light clouds and mist obscured the corresponding part of the sky. The parts of the halos lettered C exhibited prismatic colours. These were always strongest for the two dogs at *1* and the bow at *2*. The red end of the spectrum was nearest the Sun or Moon in each case.

by C. A. Chant,
from *Journal*, Vol. 28, p. 181, April, 1934.

WIDELY OBSERVED VISUAL FIREBALLS OVER CANADA, 1994 TO 1997

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Abstract. Between January 1994 and July 1997, visual descriptions of fireballs as communicated by observers in the general public were compiled. A total of nine events with apparently sufficient data for the computation of flight paths were recorded, and are reported here. The events occurred on January 27 and November 25, 1994, October 22, December 8, and December 22, 1995, February 29, June 23, and August 24, 1996, and July 16, 1997. The fireballs were observed variously over British Columbia, Saskatchewan, and Ontario, Canada. When the data were adequate, possible impact points and orbits were computed. Errors primarily in altitude estimates contribute to large uncertainties in the estimated impact point, while the unavoidable ignorance of the entry speed made it difficult to determine the origin of the bolides. In some cases, however, it was possible to make reasonable estimates of some of the five orbit parameters.

Résumé. Entre janvier 1994 et juillet 1997, les descriptions visuelles de bolides fournies par des observateurs provenant de la population ont été recueillies. Un total de neuf événements, dont les données étaient suffisantes pour le calcul de trajectoires, ont été enregistrés et sont décrits dans ce rapport. Ces événements ont eu lieu les 27 janvier et 25 novembre 1994, les 22 octobre, 8 décembre et 22 décembre 1995, les 29 février, 23 juin et 24 août 1996 et enfin le 16 juillet 1997. Les bolides ont été observés au dessus de la Colombie britannique, du Saskatchewan et de l'Ontario, au Canada. Dans les cas où les données ont été jugées suffisantes, les lieux possibles d'impact ont été calculés. Des erreurs, principalement dans l'évaluation de l'altitude, ont contribuées aux grandes incertitudes au sujet des lieux d'impact, tandis que le manque d'informations concernant la vitesse de pénétration a rendu très difficile l'établissement de l'origine de ces bolides. Toutefois, dans certains cas, il a été possible de faire une évaluation assez juste de quelques-uns des cinq paramètres d'un orbit. SEM

1. Introduction

Without a photographic observation network such as that associated with the Meteorite Observation and Recovery Project (MORP), it is necessary to rely on visual observations for the computation of the location of a possible fall resulting from a bright fireball. A bright, widely observed event always results in telephone calls by members of the general public to weather, police, and television or radio stations. Such reported information is frequently communicated to us, providing an opportunity for follow up by directly interviewing those who made the original reports and by seeking out others who observed the fireball. In the period from 1994 to 1997, data, apparently sufficient for flight path computation, were accumulated for nine events. Reports were collected by us or by Jeremy Tatum at the University of Victoria, who subsequently forwarded data to us for analysis. In the case of one of us (RH), the data presented here represent three events out of a total of 65 events that were reported: 15 in 1994, 17 in 1995, 15 in 1996, and 18 in 1997. In general, most of the data were not adequate for numerical analysis and were simply submitted to the archive of the Canadian Fireball Reporting Centre at Mount Allison University (`http://aci.mta.ca/Fireball/`) without further investigation. The data reported here were reduced using a statistical approach developed to analyze an earlier event (Huziak & Sarty 1994). The analyses provided estimates of flight paths and possible impact points, and allowed for the computation of possible orbits that the original meteoroid may have followed.

2. Data Collection and Reduction Methods

Data from the general public were gathered by telephone or by in-person visits following the interview techniques described by Huziak & Sarty (1994). During each interview the observer was asked to provide as many of the following eight parameters as possible: the time of the event, the observer's latitude and longitude, the altitude and azimuth of the point where the fireball was first seen, the altitude and azimuth of the point where the fireball was last seen, and the estimated duration. The last five parameters are often difficult to

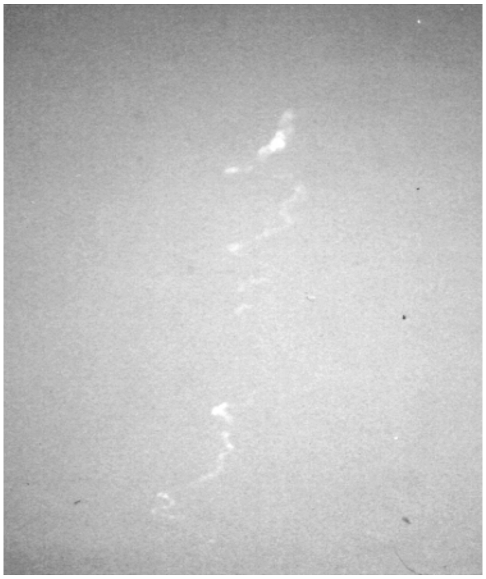

Fig. 1 — Photographs of the smoke trail left by the August 24, 1996 fireball (used with permission). *Left*: One of a series of six photographs of the smoke trail taken by Frank Cervenko from Kingston, Ontario, two to three minutes after the fireball had burned out. *Right*: Paul Ricker took his photograph from a boat on the Moira River about 10 km north of Belleville, west of Kingston. The trail is the bright, diagonal, broken line at the centre of the image.

obtain, and the observer is frequently more interested in describing the colour, brightness, and impressions of the event. When latitude and longitude were given by telephone or by a written report, uncertainties for the values on the order of one arcminute were typical.

There are many drawbacks to using parameters provided by witnesses in calculations. Experience indicates that altitude estimates are frequently too high, which results in a computed trajectory far above the Earth's atmosphere. In the "azimuth-first" computation method, described below, it was assumed that every observer reported roughly the same start and end point. Computing the trajectory using an alternative intersecting-planes approach (Ceplecha 1987) would avoid that assumption, but would also require that every observer provide complete data — azimuth and altitude — for both points. Frequently, an observer can only provide partial information, and such information cannot be used in an intersecting-planes calculation.

Because of the uncertainties in quoted altitudes and the partial information provided by most observers, we developed the MTRACK algorithm (Huziak & Sarty 1994), which uses azimuth information exclusively to provide a ground track, then makes use of the altitude information to project the ground track into the sky. In the latter, the observer's altitude data were used to determine the height above the computed ground track beginning and end points independent of the observer's original azimuth data. MTRACK also trims the data by rejecting intersections based on nearly parallel azimuth observations, by not computing azimuth intersections from observers whose locations are close, and by rejecting azimuth intersections that occur behind the observers' backs. The approach depends on averaging to offset the fact that the initial and final points reported were actually different for each observer.

A measure of the validity of the assumption that observers described the same start and end events was given by a computed uncertainty. It was defined as the 99% confidence interval based on Student-*t* statistics. The derived uncertainty also includes the effect of inaccuracies in the reported parameters and inaccuracies in the observer's reported location. In the calculations the mean computed flight path was extended to intersect with the Earth so that an apparent radiant could be computed. A rough estimate for the impact point was made using the ground point halfway between the flight path ground intersection point (FPGIP) and the ground point directly below the computed burnout point. Large uncertainties in a meteoroid's speed made it unproductive to consider a more sophisticated means of computing an impact point, such as by incorporating "parabolic" trajectories and aerodynamic forces.

In two cases (December 22, 1995, and August 24, 1996) there were enough complete data to attempt an intersecting-planes calculation in addition to the azimuth-first approach of MTRACK. With the intersecting-planes method, a line in space was computed for each pair of observers for which two sets of azimuth and altitude information were available. From the resulting collection of lines, an average line was computed. The azimuths reported by each observer were then used to specify the location of the beginning and end points of the observed flight on the average line so that altitudes could be computed. Based on an assumed visual magnitude of brighter than −10, it would be reasonable to expect the beginning altitude to be approximately 110 km and the burnout altitude to be approximately 60 km (McKinley 1961). Observational data that most closely reproduce such expected altitudes were therefore used to compute the beginning and end ground points under the visible flight path. Since the ground points are based on an average line in space, it was not possible to compute an uncertainty that matches the uncertainty computed by the azimuth-first method. While lower values for burnout altitude have been reported (Brown *et al.* 1996), the altitude assumed for the path computed by the intersecting-planes approach does not affect its intersection point with the Earth, nor does it substantially affect the subsequent orbital calculations.

Since a statistical method was used to compute the ground and flight path, it was natural to weight the data according to an assigned reliability based on impressions made during each interview. In cases where such assigned reliability weights were not made during the collection of the original reports, they were made subsequently on the basis of comments provided by the interviewer in the report. For example, many observers report that they definitely did not see the beginning or that the fireball disappeared behind a building, in which case the reported observations for the end points would be given a weight of zero. Reports of azimuths and elevations made relative to reference points, such as roads or buildings, were given a higher weight than reports that gave only numerical data. Such reliability factors range from 0 to 9. For reports with no obvious indication of uncertainty, a reliability factor of 1 was generally assigned. For data supported by references to buildings, roads, *etc.*, a reliability factor of 2 or 5 was assigned depending upon the detail given by the observer and upon the overall impression of credibility made by the observer. For *in situ* interviews made by Dr. Tatum, other values were assigned subjectively based upon the same criteria of observer credibility and perceived accuracy of the observations. We were careful not to let the assignment of reliability factors be biased by any guess at the fireball's flight path.

The set of reliability factors based upon interviewer impression was termed Reliability weighting factor Data set 1 (RD1). Such reliability factors were effective in producing a realistic flight path for the October 30, 1993, bolide (Huziak & Sarty 1994). In an effort to further improve the quality of a data set, the reported observer locations and azimuths were plotted on graph paper, and azimuth observations obviously discordant with the "consensus" were assigned weights of zero. The resulting modified weighting factor set was termed Reliability weighting factor Data set 2 (RD2). Both RD1 and RD2 were used as input to MTRACK to compute flight paths. For some smaller data sets, it was not possible to trim the data set based on such graphs because of the small number of observations.

Whenever a reasonable flight path could be computed, the program MORBIT (Huziak & Sarty 1994) was used to compute a possible orbit for the associated meteoroid. A patched conic method (Bate *et al.* 1971) was employed to make the transition from the computed Earth-centred hyperbolic orbit to a Sun-centred orbit. The uncertainty in the entry speed made it unproductive to consider the effect of atmospheric deceleration before the luminous flight; therefore, the orbital calculation began with an estimate for the pre-atmospheric velocity, v_∞. It was not possible to compute a definitive orbit from visual data alone because of the largely unknown entry velocity. Relatively small differences in entry speed can be tied to much larger ranges in the values for the orbital eccentricity (e) or semi-major axis (a) of the meteoroid. Other orbital parameters are less sensitive to variations in the entry velocity or even to small variations in the atmospheric entry flight direction. The longitude of the ascending node (Ω) depends primarily upon the time of observation, since it is determined by the position of the Earth in its orbit around the Sun at the time of the encounter and on whether the meteoroid was ascending or descending through the ecliptic plane. The orbital inclination (i) and longitude of perihelion (ω) are sensitive to variations in the entry speed and direction, but not overly so, and reasonable estimates for i and ω can be obtained from a good set of visual data (see §4).

Orbits were computed from the flight paths derived from the use of both the RD1 and RD2 weight sets when possible. In each case two entry speeds were used to specify two possible orbits. The first estimate for the entry speed was computed by dividing the length of the computed flight path by its average duration as determined from the visual data. When that resulted in a highly eccentric orbit for the meteoroid, a second estimate for the entry speed was established by stepping the fireball duration by one second intervals until the aphelion distance (q) was approximately between 3 and 5 A.U. — the region of the asteroid belt. While it cannot be known for certain that a particular meteoroid originates from the asteroid belt, Halliday *et al.* (1989, 1996) have demonstrated that it is true for many fireball meteoroids. It is therefore a reasonable first assumption to infer, when calculating its pre-entry orbit, that a fireball under investigation is produced by an object originating from the asteroid belt. When the first value adopted for the entry speed resulted in an orbit with an aphelion distance closer to the Sun than the asteroid belt, an orbit was computed for a second, smaller, entry speed in order to establish which orbital parameters were stable to variations in entry speed.

The opportunity to investigate a relatively large number of fireballs helped us to discover and correct two errors in the original MORBIT program. Once the program was corrected for those problems, it was evident that the originally computed right ascension of the apparent radiant for the October 30, 1993, fireball (Huziak & Sarty 1994) was incorrect, as noted by Brown (1995). In the course of reducing the data for the ten events reported here, we also discovered that the right ascension of the computed geocentric true radiant was incorrect (in MORBIT the two calculations are independent). The correct right ascensions for the October 30, 1993, event are 275° for the apparent radiant and 269° for the true radiant, not 352° and 311° as reported by Huziak & Sarty (1994).

3. Observations and Results

In what follows, a brief description of each fireball event is given along with tabulated quantitative data in Tables I to X. In addition, Tables XI and XII summarize the computed flight paths and possible impact points, respectively. Results for the orbital calculations are given in Table XIII. Refer to the tables for the ensuing descriptions. All dates are Universal Time (UT).

Table I
Quantitative Data for the January 27, 1994 Fireball

Obs No.	Latitude N (° ′ ″)	Longitude W (° ′ ″)	Begin Az (°)	Begin Alt (°)	End Az (°)	End Alt (°)	Dur (s)	RD[1] 1	RD 2
1	52:29:00	107:41:00	225	35	135	...	5	11101	11101
2	52:45:00	108:15:00	225	...	...	...	10	10001	10001
3	52:45:00	108:15:00	200	45	135	...	7	00101	10101
4	52:30:00	108:44:00	200	43	180	...	3	11101	11001
5	52:20:00	109:11:00	315	45	135	20	75	11110	11110
6	52:35:00	108:55:00	180	...	170	...	5	00101	00001
7	52:35:00	107:50:00	250	33	157	33	3	55151	05051
8	52:36:00	107:43:00	225	...	...	...	10	10001	10001
9	52:24:00	108:41:00	210	18	135	18	3	51111	51111
10	49:27:00	106:28:00	...	...	85	...	1	00500	00500
11	52:22:00	109:11:00	180	...	135	...	2	10100	00100

Notes: [1] RD = Reliability weighting factor Data set.
The numbers correspond to Beginning Azimuth, Beginning Altitude, Ending Azimuth, Ending Altitude, and Duration, respectively.

January 27, 1994. The fireball of January 27, 1994 occurred over Saskatchewan, and was originally reported by a member of the general public from Maymont, Saskatchewan, to a local radio station. One of us (RH) followed up on the report by putting a telephone number on the radio as well as in a weekly North Battleford, Saskatchewan, newspaper. A total of eleven reports were collected, with all of them containing at least one piece of information useful for computing the fireball's trajectory. A weather map indicated that only the southwest corner of Saskatchewan was clear, from the latitude of North Battleford and between the locations of Swift Current and Moose Jaw in longitude. Most other areas of Saskatchewan and Alberta were overcast. That left a fairly small hole in the cloud cover through which the fireball was observed. Observers generally agreed that the fireball was brilliant green — with some observers reporting yellow and orange in the fireball head — and that yellow fragments broke off the main fireball in flight. From the collected reports, the bolide occurred at approximately 1:26 UT. The recorded data and assigned RD imply an event duration of 5.8 ±3.5 seconds.

Although the observational data place the entry height lower than the burnout height, orbital calculations were performed because the computed ground track seemed reasonable. From the long event duration (16 or 19 seconds for RD1 and RD2, respectively) required to produce aphelion in the asteroid belt, it seems likely that the computed visible flight path is too short. The calculations indicate that the orbital inclination was in the 40° to 70° range, while the longitude of perihelion was in the range 150° to 170°. Since the entry height was lower than the burnout height, our estimates for the orbital parameters must be considered very crude; detailed orbit estimates are not included in Table XIII.

Table II

Quantitative Data for the November 25, 1994 Fireball

Obs No.	Latitude N (° ′ ″)	Longitude W (° ′ ″)	Begin Az (°)	Begin Alt (°)	End Az (°)	End Alt (°)	Dur (s)	RD 1	RD 2
1	52:14:00	106:37:00	45	30	355	18	2	10010	00010
2	51:29:00	109:23:00	30	30	30	10	...	11110	01010
3	52:12:00	106:32:00	165	15	75	00	2	00101	00101
4	52:12:00	106:37:00	35	...	35	...	5	10101	00001
5	52:14:00	106:34:00	75	45	70	10	6	11111	11111
6	52:42:00	106:42:00	80	40	75	18	4	11111	11111
7	52:43:00	107:45:00	80	38	75	25	4	11111	11111

November 25, 1994. Data for the November 25, 1994 event were collected by one of us (RH) by telephone. The fireball was seen in Saskatchewan and Manitoba, and was reported in the media. The general description indicated that the fireball was "as bright as the full Moon, and shooting sparks near the end of the flight," indicating some fragmentation. Eight observers were interviewed, but one witness was considered completely unreliable. The bolide flew through the atmosphere at approximately 4:12 UT and, based on the quantitative data, was visible for 4.2 ±2.7 seconds. Note that large computed uncertainties for the ground track end point locations arose when RD2 was used.

The flight paths computed from both RD1 and RD2 weights were used to compute possible orbits, with those for RDl generating plausible results for the eccentricity when used with the reported event duration. Perhaps the relatively slow entry speed of 17.3 km s^{-1} allowed observers to make relatively accurate estimates for the event duration. The computed aphelion of 3.44 AU lies at the inner edge of the asteroid belt. The computed orbital inclination of approximately 10° was reproduced for the RD2 flight path when a similar entry speed was used. The same was true for the argument of perihelion, which was computed to be around 145°.

October 22, 1995. The October 22, 1995, fireball was seen over British Columbia at approximately 3:30 UT. Data were initially collected by Chris Aikman of the Dominion Astrophysical Observatory, and followed up by Jeremy Tatum. The fireball was widely observed, with some observers hearing either delayed or simultaneous sound. The latter may be electrophonic (Beech *et al.* 1995) or psychological in origin. Five witnesses, in total, were interviewed *in situ*, with a compass and an Abney level being used to provide relatively reliable quantitative data. It was generally agreed among the observers that the head of the fireball was blue and the tail was red. According to one report, the fireball was luminous for three seconds. The positions of the observers were well placed to establish the beginning point on the ground track of the luminous flight path, but were very poorly placed for establishing the burnout point. In fact, no uncertainty was associated with the location of the burnout point because it was based on a single pair of observations.

Table III

Quantitative Data for the October 22, 1995 Fireball

Obs No.	Latitude N (° ′ ″)	Longitude W (° ′ ″)	Begin Az (°)	Begin Alt (°)	End Az (°)	End Alt (°)	Dur (s)	RD 1
1	48:54:00	124:18:36	...	...	40	35	3	00001
2	48:49:12	124:06:18	70	08	320	5	...	22220
3	48:49:12	124:06:18	40	8	330	5	...	22220
4	48:35:18	123:32:00	330	25	332	17	...	55550
5	48:49:12	124:06:18	40	50	320	5	...	44440

For an event lasting three seconds, the entry velocity associated with the flight path length is less than the escape velocity from the Earth, so a solar orbit is not possible. A reduction of the event duration to one second increases the entry velocity, and results in an orbit that intersects the Earth's orbit near aphelion. Considerably more observations would have been required to compute a good flight path and orbit for this particular event.

Table IV

Quantitative Data for the December 8, 1995 Fireball

Obs No.	Latitude N (° ′ ″)	Longitude W (° ′ ″)	Begin Az (°)	Begin Alt (°)	End Az (°)	End Alt (°)	Dur (s)	RD 1	RD 2
1	50:04:12	125:16:18	76	29	84	3	2	11111	11111
2	48:39:00	123:25:00	320	11	14	7	3	66661	66661
3	48:25:54	123:24:00	336	52	308	7	...	99990	99000
4	50:01:42	125:14:30	86	8	30	3	...	99990	99000
5	49:16:00	123:09:30	0	10	0	8	...	11110	00110
6	50:03:18	125:15:48	81	17	38	1	...	99990	99990
7	48:44:12	123:37:18	10	18	355	6	...	99990	99000
8	48:24:30	123:29:00	28	10	32	3	...	33330	00000

December 8, 1995. Eight reports from Vancouver Island, British Columbia, were reported to Jeremy Tatum of a fireball that appeared at 6:27 UT on December 8, 1995. Most observers said the duration was two to three seconds, when seconds were tapped out. MTRACK estimates the duration to be 2.5 ±5.0 seconds when all quantitative data are considered. Most observers described the meteor as green. All interviews were done *in situ* with instruments, and the observers were widely scattered geographically. The situation was therefore more favourable than that for the October 22, 1995 fireball. The accounts of observers 3, 4, 6 and 7 were quite good according to Dr. Tatum. The others were reported as being a little inconsistent.

The ground path computed by MTRACK had a relatively small uncertainty — particularly relative to the October 22, 1995 results — when both RD1 and RD2 were used. However, an unrealistic burnout height was computed using the RD2 weighting. Both computed flight paths were used for the computation of orbits, but it was expected that the RD1 flight path would produce a more plausible orbit. The unreasonably long duration of 57 seconds needed to permit an orbit originating in the asteroid belt for the RD2 data set confirmed that expectation. On the other hand, an event duration of 10 seconds, which is needed to produce an orbit originating in the asteroid belt for the RD1 data set, also seems unlikely. Perhaps the parent meteoroid for this fireball came from further out in the solar system, in which case it may have been of cometary origin.

Table V

Data for the December 22, 1995 Fireball not Previously Published

Obs No.	Latitude N (° ′ ″)	Longitude W (° ′ ″)	Begin Az (°)	Begin Alt (°)	End Az (°)	End Alt (°)
35	49:48:00	120:56:00	220	...	215	...
36	49:21:00	124:23:00	120	70	140	20
37	49:41:00	124:56:00	165	30	180	25
38	48:32:42	123:28:30	226	44	226	...
39	49:02:00	123:22:30	205	30	205	15
40	48:18:00	123:00:00	6	40	341	20
41	49:12:48	124:01:48	254	...	240	...
42	48:31:30	123:19:54	180	70	180	55
43	48:25:30	123:22:24	218	60	210	40
44	48:25:24	123:22:00	241	47	224	37

December 22, 1995. A complete description of the December 22, 1995 fireball is given elsewhere (Tatum 1998). In the present study we made use of incomplete data (see Table V) not presented in the previous description for a more detailed analysis, including computations of possible orbits. For completeness, a short description of the event follows.

The fireball was apparently quite spectacular, with people over a wide area of western British Columbia and Washington reporting that it lit up the entire countryside as bright as day. According to the witnesses' accounts, as collected by Jeremy Tatum, the object traveled over a long arc across the sky at a rather shallow angle to the horizontal as seen from Victoria, terminating in a sudden explosion. The brightest, or largest, fragment then shot almost vertically downwards, as seen from Victoria, leaving a near-vertical luminous train for 1–2 seconds. Many of the discrepancies among the various observers arose because some saw the meteor moving for a long arc horizontally, some saw only the bright flash of the disintegration, and others saw only the near-vertical train after the flash. A total of 53 reports were collected. The bolide was seen at approximately 14:13 UT. Two observers reported the duration for the luminous flight to be two seconds.

The ground paths computed using both the RD1 and RD2 weighting exhibit small uncertainty or scatter in the resulting end points. As is the case with the December 8, 1995 data, however, the computed burnout height for the RD2 path is unrealistically high. Similarly, the orbit computed with the RD1 data seems to be more realistic than the orbit computed from the RD2 data. In fact, the orbit calculated on the basis of the observed duration is quite plausible,

Table VI

Reliability Data for the December 22, 1995 Fireball[1]

Obs No.	RD 1	RD 2	Obs No.	RD 1	RD 2
1	99990	99990	23	99990	99990
2	88880	88000	24	44440	00000
3	77770	77770	25	55550	00000
4	99990	99990	26	99990	00000
5	99990	99990	27	99990	99990
6	99990	99990	28	88880	00000
7	77770	77770	29	99990	00000
8	88880	88880	30	99990	00000
9	55550	55550	31	11110	11110
10	99999	99999	32	99999	99999
11	55550	55550	33	88880	88880
12	88880	00880	34	99990	99990
13	77770	77770	35	40400	00400
14	99990	99990	36	55550	00000
15	77770	00000	37	33330	33330
16	88880	00000	38	55500	55500
17	77770	77770	39	55550	55550
18	99990	99990	40	11110	00000
19	77770	77770	41	40400	00000
20	66660	00660	42	11110	00000
21	99990	00000	43	44440	44440
22	99990	99990	44	55550	55550

Note: [1] Complete observer location, azimuth, and altitude information, in the observer order presented here, may be found in Tatum (1998).

with an orbital eccentricity of 0.75 and a semi-major axis of 2.14 A.U.

An attempt was also made to compute a flight path using the intersecting planes method. The result, however, was an extremely unrealistic flight path far above the Earth's atmosphere.

Table VII

Quantitative Data for the February 29, 1996 Fireball

Obs No.	Latitude N (° ′ ″)	Longitude W (° ′ ″)	Begin Az (°)	Begin Alt (°)	End Az (°)	End Alt (°)	Dur (s)	RD 1
1	48:20:48	123:34:54	200	52	297	17	5	11111
2	48:25:36	123:18:42	202	62	306	6	...	10100

February 29, 1996. Only two witnesses reported to Jeremy Tatum any quantitative data on the February 29, 1996 fireball, seen over Vancouver Island. One of the observers reported its duration as five seconds. The two witnesses were too close together to permit triangulation of the event.

June 23, 1996. The June 23, 1996 fireball was seen by several amateur astronomers in or near Fingal, Ontario, and Hastings, Michigan, at 6:55 UT, with three reporting quantitative data. Dave McCarter originally reported the data on the RASC E-mail list server, and the event was followed up by one of us (GES). The observations implied that the event duration was 3.3 ±2.8 seconds. Unfortunately, the three

Table VIII

Quantitative Data for the June 23, 1996 Fireball

Obs No.	Latitude N (° ′ ″)	Longitude W (° ′ ″)	Begin Az (°)	Begin Alt (°)	End Az (°)	End Alt (°)	Dur (s)	RD 1
1	42:55:00	81:20:00	175	28	130	16	3	11111
2	42:55:00	81:20:00	...	...	...	...	4	00001
3	42:39:00	85:17:00	60	30	45	20	3	11111

observations were not consistent enough to permit a flight path calculation — the reported azimuths do not intersect in front of the observers. The bolide was reported to be of magnitude −17 to −18 in Fingal, and about −4 in Hastings. From Fingal the bolide was seen to leave a white and sparkling silver trail, 20° to 25° in length. From Hastings, the trail was reported to be considerably fainter and of an orange color. Six to eight pieces were observed to fragment from the main fireball by one of the Fingal witnesses, and the pieces continued to arc further on their own, fading from yellow to deep red in the process. No sound was reported.

August 24, 1996. At about 00:00 UT on August 24, 1996 (local time, 20:00 EDT, Aug. 23), a bright fireball was seen over Kingston and other parts of eastern Ontario. As local sunset occurred at 23:57 UT, the fireball was observed against a bright, daylight sky. Based on preliminary reports of the fireball's brightness and several reports of sound, a telephone number and E-mail address were advertised for eyewitnesses to report their observations. Over 50 reports were received, of which 20% were submitted electronically.

Several reports involved measurements taken at the observing site, but most were from memory. The witnesses covered a wide geographic area, from Nepean, near Ottawa in the east, to Three-Mile Lake about 80 km south of North Bay in the north, to the town of Milton, west of Toronto, in the west. That spans 4° 05′ in longitude, or over 300 km, being somewhat less in latitude as a result of the lack of reports from the United States. Most of the original reports can be found at the World Wide Web site of the Meteorites and Impacts Advisory Committee (MIAC) to the Canadian Space Agency (`http://aci.mta.ca/Fireball/index.html`).

By almost all accounts, the fireball was very intense, like a flare, and much brighter than the Full Moon. Particularly noteworthy was the "corkscrew" shape of the lingering smoke trail (figure 1), which almost all witnesses described and which apparently lingered for a half hour or more after the fireball itself had burnt out. From preliminary azimuth data the ground projection of the burnout point was estimated to lie near Harwood, Ontario, on the east short of Rice Lake (longitude ~78° 09′ W, latitude ~44° 08′ N). Further advertising was then carried out in that region two weeks later, generating several other useful reports.

In total there were five reports of sound associated with the event. Three of them were simultaneous sounds, one a popping sound, one whistling, and one hissing. The fourth was a slightly delayed (by about two seconds) popping sound, and the fifth was a rolling thunderous sound, perhaps two to three minutes after the event. The last report was from Baltimore, Ontario, 13 km south of Harwood.

The event was also well photographed. The fireball itself was photographed by Sheila Howarth from Kingston. Because of the small image size, it was not possible to reproduce the photograph here. However, it can be viewed on the Queen's University World Wide Web site (`http://www.astro.queensu.ca`, under "Fireballs"). In addition, several photographs were taken of the smoke trail, including one taken near Belleville by Paul Ricker (figure 1, right) and a series of six slides taken by Frank Cervenko from Kingston (see figure 1, left). The

Table IX

Quantitative Data for the August 24, 1996 Fireball

Obs No.	Latitude N (° ′ ″)	Longitude W (° ′ ″)	Begin Az (°)	Begin Alt (°)	End Az (°)	End Alt (°)	Dur (s)	RD 1	RD 2
3	...	...	...	...	...	...	3	00001	00001
6	...	...	...	...	...	...	3	00001	00001
10	...	...	...	...	...	...	5	00001	00001
13	...	...	...	...	...	...	2	00001	00001
16	...	...	...	...	...	...	3	00001	00001
17	44:39:00	76:35:00	90	...	...	7	...	10010	00000
18	44:00:00	77:41:00	315	70	...	85	...	11000	11000
19	44:14:00	76:30:00	270	45	...	...	...	11000	11000
20	44:01:00	78:09:00	0	77	0	70	...	12110	12010
21	44:14:00	76:30:00	270	20	270	6	3	22221	22001
26	45:20:00	75:51:00	245	30	235	28	1	22221	22221
27	44:16:00	76:57:00	244	30	230	10	1	22221	00221
28	44:14:00	76:30:00	270	45	265	27	2	11121	11001
29	44:13:00	76:39:00	270	73	265	35	1	11111	11001
30	44:54:00	78:38:00	90	45	90	89	...	11100	00000
31	44:14:00	76:30:00	275	45	270	40	2	21111	21001
32	43:32:00	79:56:00	130	45	125	37	3	11111	00001
33	44:19:00	76:33:00	270	30	240	20	3	12221	12221
34	44:04:00	77:36:00	305	63	280	40	...	22220	22000
35	44:06:00	77:34:00	280	65	275	55	...	22220	22000
36	44:14:00	76:30:00	280	45	265	20	2	11111	11001
37	44:06:00	77:34:00	270	30	...	...	5	11001	00001
38	43:57:00	79:00:00	27	60	100	50	1	11111	11111
39	44:14:00	76:30:00	315	30	300	25	...	22220	00000
40	44:11:00	76:26:00	15	70	270	0	...	22220	00000
41	...	...	300	...	150	...	10	00001	00001
42	44:24:00	76:05:00	300	10	270	10	2	22221	00001
43	43:58:00	78:09:00	30	...	20	45	5	20111	20001
44	44:41:00	76:23:00	270	45	270	25	5	11111	00111
45	44:07:00	77:38:00	270	48	270	48	...	11110	11000
46	44:14:00	76:32:00	285	20	285	5	...	22220	22000
47	44:13:00	77:23:00	350	70	315	55	2	22221	00001
48	43:54:00	78:41:00	30	45	10	3	1	11111	11001
49	44:14:00	76:30:00	280	15	200	0	3	22221	22221
50	44:25:00	76:36:00	35	75	275	0	...	11110	00000
51	43:58:00	78:09:00	20	70	5	70	1	11111	11001
52	44:14:00	76:30:00	222	45	270	35	...	11110	00000
53	44:09:00	77:42:00	...	...	280	72	...	00110	00000
54	44:03:00	77:44:00	70	45	290	45	3	11111	00001
55	44:25:00	78:10:00	340	85	0	80	1	11111	11001
59	44:18:00	76:27:00	250	45	250	10	...	11110	00110

latter nicely illustrates the corkscrew appearance of the smoke trail. At least two other photographs of the smoke trail are also known to exist. The absence of background stars or identifiable landmarks in the photographs made their usefulness limited, but in principle (and in the future) photographs of a smoke trail could prove to be quite helpful in pinning down a trajectory.

Table X

Quantitative Data for the July 16, 1997 Fireball

Obs No.	Latitude N (° ′ ″)	Longitude W (° ′ ″)	Begin Az (°)	Begin Alt (°)	End Az (°)	End Alt (°)	Dur (s)	RD 1
1	52:35:00	107:55:00	203	...	203	...	...	10100
2	51:15:00	106:59:00	255	...	260	...	3	20201
3	50:21:00	108:10:00	270	20	270	10	1	11111
4	53:42:00	109:13:00	...	...	260	...	1	00101
5	51:00:00	112:00:00	128	35	143	20	2	11111

The observers' quantitative data implied that visible flight lasted 2.8 ±1.1 seconds. The flight paths computed using the RD1 and RD2 weightings were significantly different, with the orbit computed from the RD2 flight path being more energetic than the orbit computed from the RD1 flight path. The orbits computed from both data sets have aphelion distances of 8.5 A.U. (RD1 set) and 6.8 A.U. (RD2 set), both of which are reasonable. It seems likely that the original meteoroid had an orbital inclination near 45°.

In addition to the flight path computation using the azimuth-first method, a flight path was computed using the intersecting planes approach with the data weighted according to the RD1 set. A first computation using all data for which two azimuths and altitudes were reported resulted in an unrealistic flight path that was inside the Earth. A more realistic flight path was computed using only data with an assigned reliability of 2 or more, and is reported in Table XI. The burnout latitude and longitude from the RD1 azimuth-first computation agree much more closely with those determined from preliminary azimuth reports (see above) than do those computed from the RD2 data set (*i.e.* 13 km north of Harwood as opposed to 50 km southeast) or from the intersecting plane computation. The burnout point as calculated by the intersecting planes method is located just north of Kingston, in clear contradiction to the observers' data, even allowing for large uncertainties in their azimuth points, *etc.* A very large sample of observers from Kingston (much more than listed in Table IX) observed the burnout point, and some photographed the fireball and smoke trail to the west of Kingston.

July 16, 1997. The fireball of July 16, 1997 was observed at approximately 17:40 UT (11:40 a.m. local time) over Saskatchewan in a clear daylight morning sky. Reports of the event were originally made to Stan Shadick at the University of Saskatchewan's Physics Department, and subsequently followed up by one of us (RH). The bolide was described as brilliant white and blue by most of the observers, but cast no shadows although it was judged to be almost as bright as the Sun. One observer reported blue and green colours, and another reported a yellow orange colour. No tails or trains were reported. The observers' data indicate that the event was 1.8 ±3.1 second in duration. Calculations based on the quantitative data indicate that the associated meteoroid could have grazed the Earth's atmosphere and skipped back into space. However, the uncertainty associated with the flight path end point calculations is fairly large, especially for the burnout point. The orbital calculations indicate a low inclination orbit.

4. Discussion

Quantitative data sets based on general public observations were gathered and reduced for nine bright, widely observed fireball events. In five cases (January 27 and November 25, 1994, June 23 and August 24, 1996, and July 16, 1997) the data were gathered through telephone interviews or via E-mail. In the other four cases (October 22, December 8, and December 22, 1995, and February 29, 1996) the data were gathered through in-person interviews. In order of decreasing size, the number of observers contributing usable quantitative data were: 44 (December 22, 1995), 41 (August 24, 1996), 11 (January 27, 1994), 8 (December 8, 1995), 7 (November 25, 1994), 5 (October 22, 1995 and July 16, 1997), 3 (June 23, 1996), and 2 (February 29, 1996).

It was possible to compute a tentative flight path for eight of

Table XI

Results of Flight Path Calculation

Event	RD	Entry Latitude	Entry Longitude	Entry Altitude	Burnout Latitude	Burnout Longitude	Burnout Altitude
Jan. 27/94	1	52° 06′ ±10′	109° 00′ ±08′	53 ±22 km	49° 30′ ±62′	105° 07′ ±40′	253 ±79 km
	2	51° 27′ ±18′	109° 29′ ±20′	109 ±28 km	49° 33′ ±01′	104° 14′ ±24′	276 ±84 km
Nov. 25/94	1	52° 52′ ±11′	105° 42′ ±30′	112 ±119 km	53° 56′ ±62′	105° 46′ ±74′	40 ±39 km
	2	53° 20′ ±07′	96° 02′ ±577′	783 ±218 km	53° 58′ ±42′	93° 50′ ±1243′	361 ±231 km
Oct. 22/95	1	48° 56′ ±02′	123° 55′ ±02′	16 ±8 km	48° 49′	124° 06′	6 ±6 km
Dec. 8/95	1	50° 27′ ±16′	123° 47′ ±07′	94 ±42 km	51° 52′ ±35′	123° 49′ ±04′	35 ±8 km
	2	50° 07′ ±01′	124° 04′ ±06′	82 ±39 km	59° 18′ ±363′	123° 02′ ±08′	177 ±59 km
Dec. 22/95	1	47° 55′ ±02′	124° 03′ ±02′	73 ±10 km	47° 52′ ±07′	123° 34′ ±06′	35 ±3 km
	2	47° 52′ ±01′	124° 12′ ±01′	73 ±5 km	45° 44′ ±08′	124° 56′ ±06′	167 ±11 km
Aug. 24/96	1	44° 30′ ±04′	77° 56′ ±07′	132 ±40 km	44° 15′ ±06′	78° 08′ ±06′	53 ±15 km
	2	44° 22′ ±02′	78° 13′ ±04′	120 ±43 km	43° 47′ ±06′	77° 47′ ±43′	59 ±46 km
	IP[1]	44° 41′.63	77° 41′.38	111.1 km	44° 20′.97	76° 30′.10	59.0 km
Jul. 16/97	1	50° 26′ ±21′	110° 26′ ±76′	77 ±159 km	49° 59′ ±86′	113° 54′ ±533′	78 ±99 km

Notes: [1] IP = Intersecting Planes calculation.

the ten events. When the RD1 data set was used, five generated trajectories (November 25, 1994, December 8, 1995, December 22, 1995, August 24, 1996, and July 16, 1997) were plausible in terms of entry and burnout altitudes. The other three trajectories had either an entry altitude lower than the burnout altitude (January 27, 1994) or entry and burnout altitudes too low in the Earth's atmosphere (October 25, 1995). When the alternate weighting factor set, RD2, was used, there were no improvements in the computed flight paths; in fact, worse flight paths resulted for three cases. In one case where RD2 was substituted for RD1 as input for MTRACK (November 25, 1994), the generated flight path changed from a plausible one to one that was too high. In two cases (December 8 and December 22, 1995) the flight path changed from a plausible one to one having an entry height lower than the burnout height.

Table XII

Computed Flight Path/Ground Intersection Point[1] and Impact Points for Four Events

Event	RD	FPGIP Latitude N	FPGIP Longitude W	Impact Latitude N	Impact Longitude W	Apparent Radiant Alt	Apparent Radiant Az	α	δ
Nov. 25/94	1	52° 58′ 31″	105° 47′ 20″	52° 57′ 16″	105°46′ 28″	157°	83°	229°	46°
Dec. 08/95	1	52° 47′ 30″	123° 50′ 33″	52° 19′ 45″	123° 49′ 46″	179°	18°	296°	−19°
Dec. 22/95	1	47° 49′ 28″	123° 07′ 46″	47° 50′ 45″	123° 21′ 07″	278°	46°	127°	37°
Aug. 24/96	1	44° 04′ 06″	79° 16′ 01″	44° 09′ 28″	78° 11′ 51″	29°	67°	4°	63°
	2	43° 11′ 30″	77° 21′ 32″	43° 29′ 21″	77° 34′ 19″	332°	38°	159°	69°
	IP[2]	43° 55′ 20″	75° 06′ 07″	44° 08′ 09″	75° 48′ 06″	292°	25°	133°	33°

Notes: [1] Abbreviated FPGIP in column headings.
[2] IP = Intersecting Planes calculation.

Attempts to use an intersecting planes calculation illustrated once again (see also Huziak & Sarty 1994) that uncertainties in the estimates of altitude more than offset any gain in accuracy obtained by not assuming that every observer reports the same beginning and end point. With the intersecting planes method, large uncertainties in altitude translate into large uncertainties in the computed ground path, whereas the azimuth-first method does not use altitude information for the computation of the ground track. Only in the case of the extensive August 24, 1996 data set did the intersecting planes method produce a realistic flight path. Even then, only the highest quality observations could be used, since the scatter introduced by the low quality observations overwhelmed the good data. The separation of high quality data from low quality data was based on the subjective reliability weighting factors assigned to the observations.

A more objective method of rejecting data might be to adopt a multiple return averaging process in which data would be eliminated for pairs of observations for which the calculated trajectories fall outside the standard deviation of the mean trajectory. Multiple return averaging could be applied to both the azimuth-first and intersecting planes approach, but we did not implement that method here for several reasons. The primary reason is because the scatter introduced by the lower quality data is very large, and, without giving the higher quality data higher weight, the poor data can unduly influence the final result. Even if one begins with weighted data, there is still a problem in using a bad track to begin the averaging process. For example, in the case of the RD2 and intersecting planes calculations for the August 24, 1996 fireball, a flight path contradicted by photographic evidence would have been the starting point for the averaging. The azimuth-first approach is apparently not as sensitive to distortion by low quality data as the intersecting planes approach, and, for the August 24, 1996 event, produces the more plausible ground track. In future computations of fireball flight paths from sparse visual data, it might be better to ignore all but the highest quality altitude reports using, instead, altitudes based on physically probable heights for the beginning and end of the visible flight.

In modifying the reliability weighting factors from RD1 to RD2, azimuth observations that differed from the perceived "consensus" were effectively removed from the data set. The difference in results obtained with the RD1 and RD2 calculations shows the power of the statistical approach used by MTRACK to compute the flight path. It is better to let the averaging process remove inaccurate data than to try to remove them by "eyeballing" prior to computation. It should be emphasized, however, that interviewers record the beginning or ending azimuths and altitudes only when it is clear that the observer saw the actual start or end of the event. In three cases (January 27, 1994, December 8, 1995, and July 16, 1997), unrealistically high entry speeds, computed from the flight path length, were calculated (using RD1 weighting), implying that the computed length of the flight path was too short. That may arise if most of the observers reported a starting point occurring systematically too late. Recall that the azimuth-first algorithm adopts the false assumption that all observers witness that same beginning point for the fireball.

We have argued that overly early and overly late sightings should average out, but one can imagine scenarios in which one observation can skew all others. For example, suppose that most of the observers were on one side of the ground track, but one observer was on the other. The intersection of that one observer's beginning azimuth could intersect the azimuths of the observers on the other side of the path with only minor deviations in the individual intersections, but the mean point would be displaced in a direction transverse to the actual flight path. Such pathological cases might be identified if the pattern of azimuth intersections were preferentially orientated in some direction instead of being randomly scattered on the surface of the Earth. In addition, the resulting altitude calculations would be in error. A computed ground path that is associated with reasonable beginning and ending altitudes therefore has a higher probability of being correct than a ground path that is associated with ridiculous altitudes. As can be seen from the distribution of observers for the fireball events examined here (see below), it frequently happens that the majority of observers are not situated to one or the other side of the fireball track, but behind or ahead of the track. In that case the error introduced by the assumption that all observers saw the same beginning point is minimal, with the major uncertainty arising from the poor geometrical distribution of observers.

Observers for the events examined here were distributed as follows. For the January 27, 1994 event, all observers except one were on one side of the computed path. The one observer on the opposite side (observer 10) provided only an ending azimuth. In that case the type of error described above is possible for the end point, although observers 1, 3, 5, 9 and 11 provided consistent end point azimuths whose intersections with the observation of observer 10 heavily weighted the mean end point. Even though all beginning observations originated from one side of the computed ground track, they were remarkably consistent, which indicates that probably all observers (except for observer 5) reported the same beginning event. In any event, the resulting altitudes for the computed beginning and end points were unrealistic. For the November 25, 1994 event, all observers were considerably to the west of the computed south-north path, and a plausible trajectory resulted from data set RD1. For the October 22, 1995 fireball, three observers south of an east-west track provided consistent azimuths for the beginning point but inconsistent azimuths for the ending point. In that case the small number of observers prevented the computation of a reasonable trajectory. For the December 8, 1995 fireball, observers were situated on both sides of the computed ground track, but were all south of the beginning point with the track headed in a generally north direction. For the December 22, 1995 event, all observers were situated to the north of the computed ground track, with the RD1 path headed generally from west to east and the RD2 path headed generally from north to south. For the August 24, 1996 fireball, observers were situated on both sides of the computed ground track but the majority of the observers were on the eastern side. It is interesting that the RD1 ground track for that event is oriented from northeast to southwest, while the RD2 and intersecting planes tracks are oriented from the northwest to the southeast — with the intersecting planes track situated to the north of the RD2 track. Finally, for the July 16, 1997 event, observers 1 to 4 were situated behind the computed track and observer 5 was situated to the north of the computed east to west track. None of the observer arrangements were ideal in the sense of having observers located on both sides of the ground track, but neither is there any reason to suspect that an unreasonably large blunder is made by assuming that all observers witnessed the same beginning.

It has been suggested to us that a fireball ground track could be determined by finding observers who saw the fireball directly overhead. Regrettably, none of our data sets contain such an observation. There are a number of very high altitudes (*e.g.* 70°) reported, but, given the distribution of observers reporting the high altitudes, they likely represent overestimates of the observed altitudes.

The orbital calculations presented in Table XIII support the assertions made in section 2 regarding the sensitivity of the computed orbital parameters to variations in the assumed entry velocity vector. Values for the longitude of perihelion (ω) that differed by as much as 25° were obtained within individual RD sets for the January 27 and November 25, 1994, and July 16, 1997 events. In many other cases where the effects of variations in entry speed were made, the differences in the derived value of ω were less than 10°. Extremely large variations in the entry speed (*e.g.* the RD2 computations for the December 8, 1995 event) produce large variations in ω.

Similar effects can be seen in Table XIII for the computed orbital inclination (i). The effect of entry speed on the computed values for i and ω arises from the deflection of the meteoroid trajectory from its initial direction by the gravitational field of the Earth. A higher speed implies less perturbation of the original direction. Varying the direction of v_∞ produces similar effects on ω and i.

Averaging is a common technique used to remove noise, or scatter, from data, but where large scatter is present in the data, as is the case for quantitative fireball data collected from the general public, many data points are required for meaningful averaging. In the ideal case (*i.e.* Gaussian white noise), doubling the number of averages can increase the signal-to-noise ratio by a factor of $\sqrt{2}$. It might thus be expected that a fourfold increase in the number of observers would lead to a twofold increase in the accuracy of the computed flight path. In practice it could probably be expected that more than four times the number of observations would be required to achieve a twofold increase in the accuracy of the computed flight path, and, in turn, in the accuracy of the computed orbit. It will always be difficult to compute the orbit's eccentricity, however, because it is a highly non-

Table XIII
Computed Possible Orbits

Event	RD	Dur s	v_∞ km s^{-1}	q A.U.	q' A.U.	a	e	i	Ω	ω	α_R	δ_R	180°–λ_G	180°–λ_H
Nov. 25/94	1	4.2	17.3	0.84	3.44	2.14	0.61	11°.7	242°.6	143°.6	24°.3	45°.3	71°.6	20°.2
	1	3.0	24.2	0.77	...	...	1.44	1°.1	242°.6	149°.4	24°.5	45°.8	71°.8	29°.0
Dec. 08/95	1	2.5	67.8	0.70	...	...	7.17	33°.3	75°.6	12°.0	50°.4	−19°.3	63°.1	44°.6
	1	10.0	17.0	0.93	4.04	2.48	0.63	14°.4	75°.7	22°.2	49°.6	−29°.7	63°.9	17°.8
Dec. 22/95	1	2.0	26.9	0.31	2.14	1.22	0.75	16°.2	270°.2	96°.8	117°.0	36°.0	111°.5	47°.0
	1	1.5	35.8	0.20	...	...	1.12	27°.3	270°.2	246°.0	118°.1	36°.6	112°.1	61°.1
Aug. 24/96	1	2.8	30.4	1.00	28.1	14.5	0.93	43°.5	151°.1	174°.0	279°.2	63°.4	89°.4	43°.6
	1	3.0	28.4	1.00	8.54	4.77	0.79	41°.3	151°.1	173°.4	279°.3	63°.5	89°.5	41°.4
	2	2.8	34.3	0.69	6.76	3.72	0.82	51°.2	151°.1	225°.9	156°.9	67°.6	106°.0	56°.7
	2	2.0	48.0	0.69	...	...	1.81	65°.3	151°.1	207°.5	158°.6	68°.1	105°.6	69°.4
	IP	2.8	41.5	0.49	...	...	2.33	27°.8	151°.1	210°.6	170°.1	32°.7	84°.9	50°.4
	IP	5.0	23.4	0.65	6.83	3.74	0.83	14°.5	151°.1	228°.7	167°.2	30°.5	85°.9	33°.6

Notes: Column headings: v_∞ = entry speed, q = perihelion distance, q' = aphelion distance, a = semi-major axis, e = orbital eccentricity, i = orbital inclination, Ω = longitude of ascending node (ecliptic co-ordinates), ω = longitude of perihelion, α_R = true geocentric radiant, right ascension, δ_R = true geocentric radiant, declination, 180°–λ_G = angle between geocentric radiant and Earth's antapex direction, 180°–λ_H = angle between heliocentric radiant and Earth's antapex direction.

linear function of the entry speed. From our experiences here as well as reported earlier (Huziak & Sarty 1994), at least 50 reports from well-separated observers are required to obtain a fireball flight path whose beginning and end points are in agreement with the many azimuth observations and not the result of an average of widely spaced intersections. That suggests that in excess of 200 observations would be required to make a twofold improvement on the results achievable with 50 observations. The collection of 200 plus observations of a fireball event would be very labour intensive, and could only be accomplished if the fireball was seen by hundreds to thousands of people in a large geographical area.

It might be argued that data based on human sensory perception and judgment are not subject to the same principles of noise as data gathered by purely "mechanical" means, and that averaging should not be expected to reduce the noise or uncertainty when the data are reduced. It has been demonstrated, however, at least for reasonably well-trained observers, that averaged visual estimates of the brightness of the variable star β Lyrae can have a resolution approaching that of a photometer (Isles 1994). A good variable star observer knows that brightness estimates are just that — estimates. Presumably the art of making quick brightness estimates allows more autonomic sensory function than is the case for over-concentration and second-guessing an estimate. Fireball observers do not have the time to interpret the event as it happens because the observer is caught by surprise. For an observer who is objective, and such objectivity is a quality that can be evaluated during an interview, there is good reason to accept the data as reported. The results of the RD1 vs. RD2 calculations would seem to support that contention. Therefore, there is no reason to expect that positional estimates of a fireball's location made by people from memory should behave differently from brightness estimates of stars when large numbers of observations are averaged.

As remarked upon previously (Tatum 1998), the process of obtaining detailed, quantitative data from witnesses following a widely observed fireball is extremely labour intensive and time consuming. One might well ask if it is worth the effort. Such data can be collected for two reasons. One is to learn enough about the trajectory to estimate a possible fall location. The other is to learn enough about the trajectory to understand the meteoroid's original orbit, which would be especially valuable in case a meteorite were independently discovered. None of the computed fall locations in Table XII are accurate enough to warrant a search for a fallen meteorite, although all arise from computed trajectories that are, *prima facie*, plausible. It was argued in §2 and generally shown in Table XIII that the ascending node, orbital inclination, and longitude of perihelion might be estimated reasonably. It follows that the computed true radiant might also be close to the correct value. In the sample of events investigated, most required the assumption of an unrealistically long visible duration to correspond to an orbit originating in the asteroid belt. Three data sets (November 25, 1994, December 22, 1995, and August. 24, 1996), however, produced plausible orbits with credible fireball duration times. While definitely an inexact science, there does seem to be some merit in tracking down fireball observations for the purpose of estimating the orbit, especially when the data are carefully gathered through in-person interviews and instrumental measurements. Only when a large number of witnesses over a wide geographical area have provided visual sightings, or in-field instrumental measurements have provided supplemental data, should any time be spent actually searching a computed fall location for a meteorite.

5. Conclusion

A considerable amount of time has been spent both collecting and reducing quantitative fireball data gathered from the general public. In many cases, plausible flight paths can be determined and possible pre-entry orbits can be computed. In general, the quality of the final result improves in direct proportion to the quality of the original data. The quality of the observational data can be improved upon through *in situ* interviews and by collecting large numbers of observations. With data sets of poor quality, the azimuth-first algorithm for computing the fireball trajectory appears to provide the most reasonable results. As the quality of the data set improves, an intersecting planes algorithm for the flight path begins to become feasible, but only when the low quality observations are trimmed from the data. It is possible that, if enough events are pursued for quantitative data, one might someday lead to the recovery of a meteorite. Even if a meteorite were discovered independent of conclusions based upon interpretation of visual data, the visual data are still useful for estimating a pre-entry orbit — as was the case for the St-Robert fall (Brown *et al.* 1996).

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MONTE CARLO CALCULATIONS OF X-RAY REFLECTION SPECTRA FROM A CLOUD

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Abstract. The reprocessing of externally incident x-radiation by a spherical cloud of matter with typical cosmic abundances is calculated here by Monte Carlo methods. The detailed shapes for the fluorescent iron line and the spectrum of the reprocessed continuum radiation are presented for different optical depths of the clouds and for different geometries of illumination. This is the first work to consider such reprocessing by a spherical cloud, and is relevant to the situations that apply to galactic X-ray binaries and active galactic nuclei (AGN), since fluorescent iron lines and some fraction of the continuum X-ray emission observed from such objects result from reprocessing of radiation. A comparison of observations for iron line shapes with the theoretical line shapes presented here should allow one to determine whether the reprocessing is a matter of planar geometry (such as that for an accretion disk) or of spherical geometry (such as arises in a cloud), or some combination of the two.

Résumé. Le retraitement de la radiation x incidente externe par un nuage sphérique de matière à abondances cosmiques typiques est calculé à l'aide de méthodes Monte Carlo. Les formes détaillées de la ligne fluorescente de fer et le spectre de la radiation retraitée du continuum sont présentées pour différentes profondeurs optiques des nuages et pour différentes géométries d'illumination. Ceci est le premier travail à considérer un tel retraitement par l'entremise d'un nuage sphérique, et il est pertinent aux situations qui s'appliquent aux étoiles galactiques binaires à rayons X et aux noyaux galactiques actifs, étant donné que les lignes fluorescente de fer et qu'une fraction quelconque du contiuum en émission rayons X, observées dans tels objets, résultent du retraitement de la radiation. Une comparaison des observations des formes de lignes du fer avec les formes théoriques de ces lignes qui sont présentées ici devraient nous permettre de déterminer si le retraitement est liée à une géométrie planaire (tel que dans un disque d'accroissement) ou à une géométrie sphérique (tel que dans un nuage), ou une combinaison des deux.

SEM

1. Introduction

The effects of the reprocessing of X-rays (sometimes referred to as "reflection") by matter surrounding a central X-ray source have gained practical interest in the past few years. That is because the spectral data obtained in the hard X-ray region (energies greater than10 keV) by the third Japanese X-ray astronomy satellite *Ginga* (Astro–C) for active galactic nuclei (AGN) (*e.g.* Matsuoka *et al*. 1990; Pounds *et al*. 1990; Nandra *et al*. 1991) exhibit evidence for reprocessing in non-ionized matter. The evidence consists of a strong iron K_α emission line near 6.4 keV that is fluorescent in origin, and of an excess of the continuum spectrum above 10 keV as a result of electron-scattered X-rays (called the Compton reflection continuum). Both features were predicted by Lightman & White (1988) and Guilbert & Rees (1988). Lee *et al*. (1998) confirm the presence of a strong redshifted iron line and the Compton reflection continuum for the bright Seyfert 1 galaxy MCG-6-30-15 with the Rossi X-ray Timing Explorer. Their observations are the best so far of the Compton reflection continuum, and confirm the existence of reprocessing in non-ionized matter.

The fourth Japanese X-ray astronomy satellite *ASCA* (Astro–D) has obtained spectra from AGN at 1 to 10 keV with higher spectral resolution than previously attainable, and has resolved the iron line, which has resulted in the discovery of broad and redshifted line profiles (*e.g.* Tanaka *et al*. 1995). The line profile in the case of MCG-6-30-15 has a narrow component near 6.4 keV and a broad component extending to below 5 keV. It has been interpreted (Iwasawa *et al*. 1996) as being produced by reprocessing from the inner parts of an accretion disk — down to 6 r_g, where r_g is the Schwarzschild radius. The low energy of the iron line compared with its rest-frame energy of 6.4 keV is mainly attributed to gravitational redshift. The Doppler redshift for the iron line resulting from motion of the emitting matter in the accretion disk is also taken into account in the model, as well as an integration of the two effects from an inner to an outer disk radius. During a deep minimum (called DM) in the continuum flux from MCG-6-30-15, the broad component of the iron line profile was more redshifted; model fitting for the iron line therefore required the inner disk radius to be much smaller. The innermost stable orbit for a maximally rotating Kerr black hole (1.24 r_g) produced a satisfactory line profile. Weaver & Yaqoob (1998) have pointed out, however, that a better model for the iron line profile at DM was occultation of the central portion of the accretion disk, and that higher quality data were required to clearly distinguish different models. Another possible origin for the reprocessed radiation is from dense cool clouds rather than the accretion disk, which has the advantage that the time variability is more easily explained.

Recent work has shown that dense cool clouds are likely present in the central regions of AGN in addition to an accretion disk. Kunzic *et al*. (1997) showed that such clouds are the best explanation for the optical and ultraviolet (UV) radiation observed from AGN. The clouds can have either high covering fraction and be optically thin to Thomson scattering or low covering fraction and be optically thick to Thomson scattering. In either case, one expects the clouds to be confined to high density by magnetic pressure, which allows them to be cold (*i.e.* non-ionized). Sivron (1998) considered the non-linear behaviour of compact plasmas in the central regions around black holes, showing that they are unstable to large density fluctuations. He shows that the resulting time variability matches well that observed from AGN. Thus it is important to consider the effects of reprocessing continuum radiation by clouds in regions near the source of the continuum radiation.

In addition to the non-ionized matter, observational evidence has accumulated for the presence of low-density partially ionized matter, which is likely to be distributed throughout the region near the central X-ray source (*e.g.* Sambruna *et al.* 1997). Such matter has a different imprint on the X-ray spectrum, primarily absorption features below 1 keV, and does not affect the iron line at 6.4 keV.

Here we examine in some detail the expected effects of reprocessing by an externally illuminated non-ionized spherical cloud. Studies already have been done on reprocessing and iron line fluorescence for planar matter geometry. George & Fabian (1991) and Matt *et al.* (1991) have calculated the spectrum for reflection of X-rays off a disk of matter. Basko (1978) used an analytic first-scattering approximation to calculate the profile of the singly scattered iron K_α line wing. Hatchett & Weaver (1977) calculated the iron line profile for the isotropic scattering approximation. For spherical matter that is centrally illuminated, others have considered the calculation of equivalent widths (Makino *et al.* 1985; Makashima 1986; Leahy *et al.* 1989; Leahy & Creighton 1992, 1993). Other geometries have been considered. Bond & Matsuoka (1993) calculated the spectra from a three-dimensional cubical grid of cells, some containing source radiation and the others containing cold matter, in order to study the effects of the filling factor for cold gas on the reprocessed X-ray spectra. Sivron & Tsuruta (1993) calculated spectra for an assemblage of clouds around a central power law continuum source using the source function of Lightman & White (1988). The source function is for planar matter, so that they only get an approximation to the reflection spectrum for a spherical cloud. Neither of the previous two works calculates the shape of the fluorescent iron line.

The calculations presented here are for an externally illuminated spherical cloud, and include line-shape and continuum shape calculations. We assume that the cloud is small enough that the gravitational redshift does not vary across the cloud. The results are intended to be used for modeling the observed emission from sources such as AGN and X-ray binaries. Information about the geometry of the cloud can be found by comparing the simulated spectra with the observed spectra, particularly by examining the shape of the iron line, which is insensitive to uncertainties in the knowledge of the underlying source continuum spectrum.

The results given here, for reprocessing by an externally illuminated cloud, are of particular interest at this time. Moderate resolution data for iron emission lines are now being obtained with the ASCA mission (*e.g.* Leighly *et al.* 1997), and can be used for consistency tests. Higher resolution data will be obtained soon with the *Advanced X-ray Astrophysics Facility* (AXAF) mission, to be launched in the spring of 1999. The AXAF data will have sufficient resolution to allow a quantitative comparison with the simulated line shapes to provide a sensitive measure of the reflection geometry.

2. The Monte Carlo Simulations

The X-ray spectra obtained through reprocessing by cold matter are calculated using Monte Carlo methods, as described in Leahy & Creighton (1993). Here the source is assumed to have a power law spectrum within a specified energy range (taken to be 1 to 100 keV for the calculations presented here). The power law index α is the photon index: $N(E)\,dE \propto E^{-\alpha}\,dE$. The photon source is a point source located at position $(0, 0, z)$ in (x, y, z) Cartesian co-ordinates, where the cloud is located at the origin. The source emits photons with the desired spectrum, isotropically within the solid angle that just includes the cloud boundary. In such fashion only the reprocessed spectra are calculated, and an arbitrary amount of direct source spectrum can be added to the results, if desired. The parameter z is taken to be negative, so the source is located below the cloud and polar co-ordinate angle $\Theta = 0$ corresponds to photons travelling upward through the cloud; the condition $\Theta = \pi$ corresponds to photons back-scattered directly at the source. Figure 1 illustrates the source and cloud geometry.

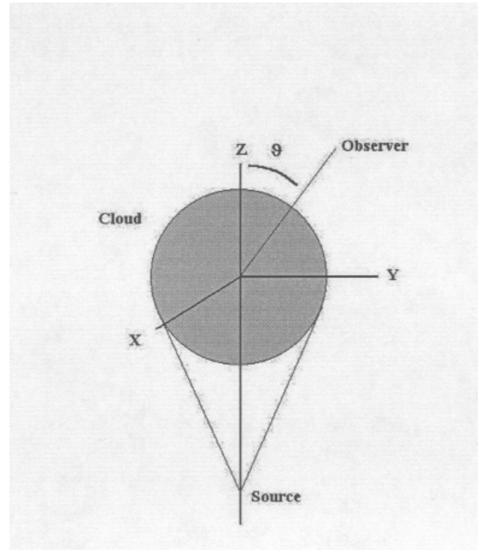

Fig. 1 — An illustration of the geometry for the externally illuminated cloud.

Within the reprocessing matter (cloud), photons may interact via Compton scattering off free electrons (including electrons bound to atoms), or they may experience bound-free interactions with the electrons of heavier atoms. The latter process may produce fluorescent photons. The fluorescent photons are traced separately from the continuum photons in order to determine the line shape.

The cloud is characterized by its optical depth for Thomson scattering, as measured from the centre to infinity. The Thomson scattering cross section per hydrogen atom is used, which differs from the usual value of 6.652×10^{-25} cm^2 by the factor 1.231. According to the preceding definition of optical depth, $\tau = 1$ corresponds to a column density of $N_H = 1.23\times10^{24}$ cm^{-2}. The bound-free absorption cross sections are from Morrison & McCammon (1983).

Compton scattering results in changes in the direction of propagation of the photon, as well as in an energy loss. Such a Compton energy shift is the most important factor in determining the fluorescent line shapes, and is an important factor in the shape of the reprocessed continuum radiation. The fluorescent lines that are included are iron K_α, iron K_β, and nickel K_α. The natural width for the fluorescent emission is about 3.5 eV, while the thermal broadening is approximately $0.4(T/10^6)^{1/2}$ eV, neither of which will produce a detectable line shape.

Continuum photons that escape the cloud are recorded in logarithmic-spaced energy bins between specified minimum and maximum energies; much finer linear energy bins are used to record the line-shapes for fluorescent line photons. In addition to the energy spectra, the simulations produce two more sets of output. The equivalent width of each line is calculated and the distribution of the number of photon scatters is recorded. The latter cannot be observed, but it is of assistance in interpreting the output spectra.

3. Results

The spectra for continuum and line, equivalent widths, and scatter distributions are calculated as a function of polar angle (angle from the source-cloud axis) for a set of different source-cloud distances and cloud optical depths. The spectrum of escaping photons is plotted with continuum photons binned into bins logarithmically spaced in energy. That is equivalent to plotting the density flux (energy per unit energy). The source spectrum with $\alpha = 1$ is therefore a horizontal line. It also implies that, for an incident spectrum with $\alpha = 1$, the ratio of reprocessed to incident radiation (for the continuum) is given by the same plot as for the reprocessed spectrum. The actual ratio of reprocessed to incident spectra is determined by dividing the photons per bin (y-axis value) by the (constant) number of photons per logarithmic energy bin in the incident spectrum.

The emerging photons from the cloud are binned into one of a set of equal solid angle polar angle bins. Here twelve bins or rings equally spaced in cosine Θ between $\Theta = 0$ and $\Theta = \pi$ were used. The polar angle obtained as a weighted mean over solid angle for each of rings 1 to 12 is (in order): 22°.8, 41°.3, 54°.2, 65°.4, 75°.5, 85°.2, 94°.8, 104°.5, 114°.6, 125°.8, 138°.7, and 157°.8. Those angles are also used as an alternate label to ring number for the rings.

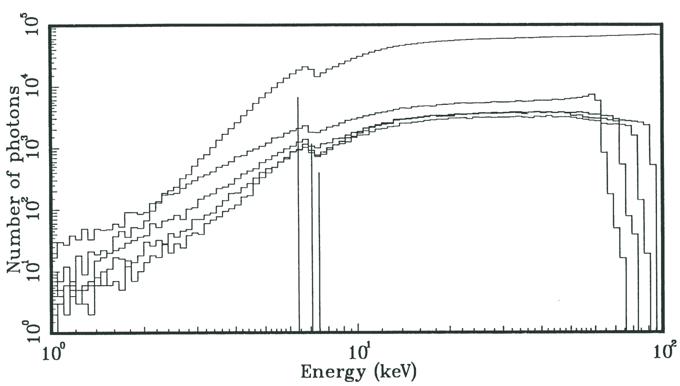

Fig. 2 — Simulated X-ray spectra for a uniform density sphere illuminated by a continuum power law source ($\alpha = 1$) at a distance of 10 R. The scattering optical depth is $\tau = 0.5$. The curves are for angle bins 1, 3, 6, 9, and 12 (see text). The ordinate (photons per logarithmic energy bin) is equivalent to energy per unit energy.

To illustrate the reprocessed spectra, figure 2 presents five continua spectra plus one set of line intensities. The Thomson optical depth from centre to edge of the cloud is 0.5, and the source is located far away from the cloud (at 10 radii). Spectra from angle bins 22°, 158°, 115°, 54°, and 85° (bins 1, 12, 9, 3 and 6) are shown (top to bottom at energy 60 keV; in order 22°, 158°, 115°, 85°, and 54° at 2.5 to 6 keV). The strongest line intensities are plotted and are from angle bin 12. The continuum spectrum for bin 1 is by far the most intense at energies above a few keV, since the optical depth is relatively low and it includes the direct radiation from the source which passes through the cloud without interaction. At energies below a few keV, the spectrum from bin 1 is subject to strong photoelectric absorption of the direct beam from the source, but it includes (as all the other angle bins) radiation at all energies that has Compton scattered within the cloud.

The reprocessed spectra are plotted for the energy range 1–100 keV, and sharp turnovers at 70–90 keV in the spectra for angle bins that do not contain direct radiation (*i.e.* other than bin 1) are seen. That is a consequence of Compton energy loss combined with the cutoff in the source spectrum at 100 keV. Had we extended our source spectrum to higher energies, the turnovers at 70–90 keV would not occur. (Recall that the source spectrum is a horizontal line in the plot). In figure 2 the absorption at low energies and the iron edge at 7.1 keV are clearly seen. As optical depth increases, the low energy absorption and iron edge depth increase. For angle bins 1 through 6, where the continuum radiation must pass through the cloud, the fluorescent line intensities increase at first, then decrease because of absorption. For angle bins 7 through 12, the line intensities increase with optical depth, then saturate. The large number of photons calculated in each simulation results in small statistical uncertainties ($N^{1/2}$ with N being the number of photons per chosen energy bin).

For $\tau = 0.5$, the spectra for angle bins other than 1 are about 1/10th the intensity of the spectrum for angle bin 1, except at low energy the ratio is much closer to 1. That is because the photons have a quite different distribution of paths (compared with those for a uniform slab) in order to reach the observer. The results are spectra with effectively lower absorption at lower energies.

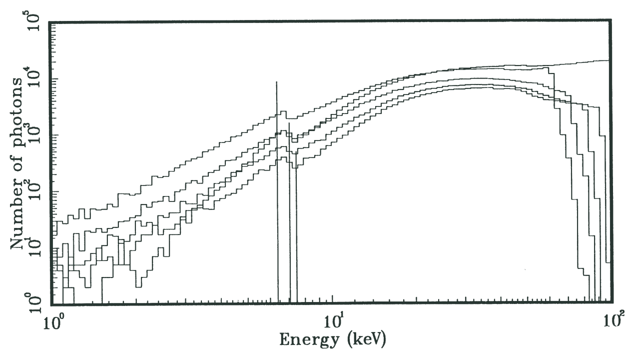

Fig. 3 — As in figure 2 but for $\tau = 2.5$.

The spectra for a far-away source (10 cloud radii) and optical depth 2.5 are shown in figure 3. At 60 keV, the angle bins are 22°, 158°, 115°, 85°, and 54° (top to bottom). Spectrum 1 is the steepest at energies below 20 keV, so that at 2.5 keV the order is angle bins 158°, 115°, 85°, 54°, and 22° (top to bottom). The line intensities shown are the strongest from angle bin 158°. In the high optical depth case, most photons scatter many times in the surface layers of the cloud, so that the spectra are not as different for different angle bins as in the lower optical depth cases.

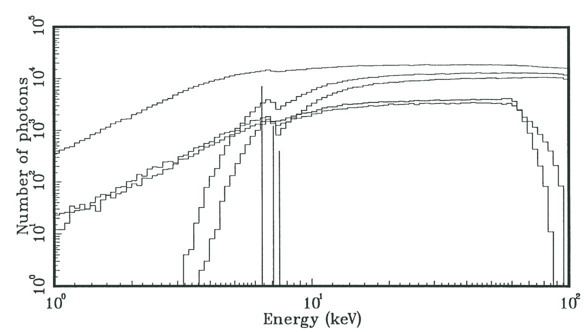

Fig. 4 — As in figure 2 but for a source distance of 1.0 R and $\tau = 0.5$.

The spectra depend strongly on source distance from the cloud. However, most of the variation occurs within a distance of one radius from the surface of the cloud. Figure 4 shows the spectra for $z = -R$, where the source is just at the surface of the cloud. There is a smooth transition in spectral shape towards that for $z = -10\,R$, which occurs mostly in the range of distances $z = -R$ to $z = -1.5\,R$. In figure 4 the spectra for angle bins 85°, 54°, 22°, 158°, and 115° are shown (top to bottom in the 10–70 keV range; in order 85°, 158°, 115°, 54°, and 22° at 3.8 keV), with the strongest lines from the 158° ring. The strong high energy (>10 keV) spectrum in the 85°, 54°, and 22° rings arises from the fact that those rings all contain source radiation that has passed through the cloud without scattering, in addition to reprocessed photons. Since the bins are all of equal solid angle, the continuum level decreases from 85° to 54° to 22° bins as a consequence of increasing scattering (and absorption) optical depth through the cloud. The 158° and 115° rings contain only scattered radiation. Like the far-away source case, the low energy absorption is strongest for the 22° ring and decreases monotonically with angle (up to 90°). However, combined forward scattering and small optical depth in the layers near the surface of the cloud at angles just under 90° cause the 85° ring to have a flat low energy spectrum like the larger angle bins. As the source is moved further away, the brightest spectrum (at low and high energies) shifts toward the smallest angle (22°) ring.

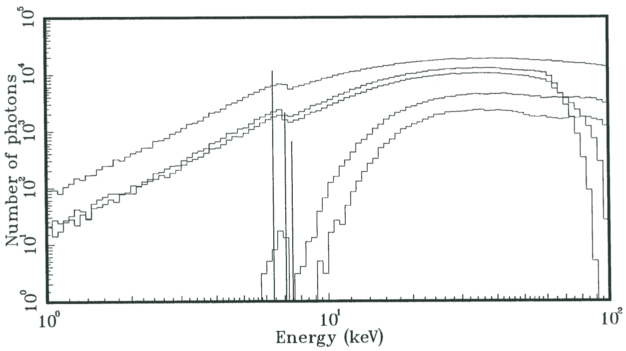

Fig. 5 — As in figure 2 but for a source distance of 1.0 R and $\tau = 2.5$.

In figure 5 are shown the spectra for the nearby source ($z = -R$) and large optical depth ($\tau = 2.5$). In the range 10–50 keV, the spectra are (top to bottom) from angle bins 85°, 158°, 115°, 54°, and 22°. The strongest lines, from the 158° ring, are also shown. The extreme absorption for the 22° and 54° rings is apparent, as well as the relatively flat low energy spectrum for the 85°, 115°, and 158° rings. The low energy spectrum is the result of photons that scatter in the surface layers of the cloud and suffer little absorption. In general, the slope of the low-energy scattered spectrum decreases monotonically with increasing angle from the source-cloud axis.

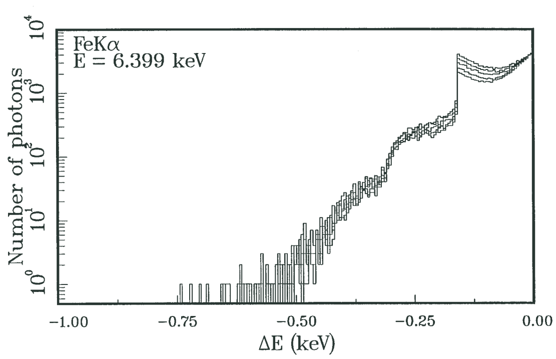

Fig. 6 — Simulated Fe K_α line profiles for a source distance of 10 R and $\tau = 0.5$. Top to bottom: angle bins 12, 9, 6, 3, 1.

The calculated fluorescent line shapes for Fe K_α are shown in figures 6 to 9, for the same four cases as for the continua spectra. The unscattered line photons are not plotted here and form a narrow peak at $\Delta E = 0$ keV. The curves are for the angle bins 158°, 115°, 85°, 54°, and 22° (top to bottom in all four figures). The 158° ring has the largest number of single back-scattered photons (the left side of the peak between $\Delta E = 0$ to -0.16 keV, hereafter called the first shoulder; the second shoulder is the region from $\Delta E = -0.16$ to -0.32 keV). It results from the anisotropic distribution of the fluorescent photons in the cloud (more on the side of the cloud facing the source). In the optically thin limit the line shape is independent of angle. For the far source and $\tau = 0.5$ case (figure 6), the variation of line-shape with angle is significant (*e.g.* there is a factor of two difference on the left side of

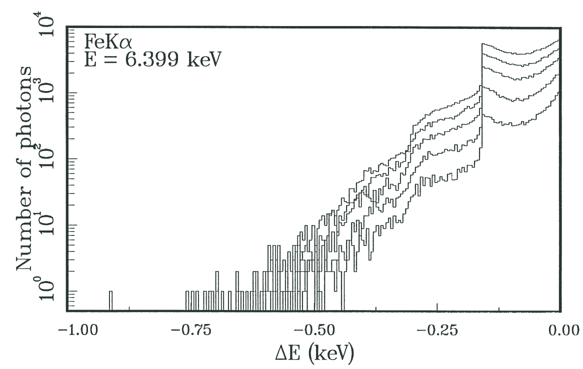

Fig. 7 — Simulated Fe K_α line profiles for a source distance of 10 R and $\tau = 2.5$. Top to bottom: angle bins 12, 9, 6, 3, 1.

the first shoulder). For the far source $\tau = 2.5$ case (figure 7), the shape of the first shoulder (and second shoulder) is nearly the same as for the same angle bin for the lower optical depth ($\tau = 0.5$), but the drop between the first and second shoulder is smaller. Also, the total number of scattered line photons is larger for angles larger than about 90°, and less for smaller angles when compared to the $\tau = 0.5$ case.

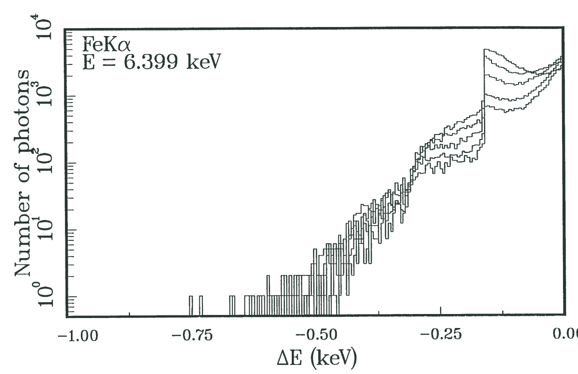

Fig. 8 — Simulated Fe K_α line profiles for a source distance of 1.0 R and $\tau = 0.5$. Top to bottom: angle bins 12, 9, 6, 3, 1.

As was the case for the continua spectra, the line shapes depend more strongly on angle for the nearby source case (figures 8 and 9). Also noticeable is a different line-shape for the back-scattering direction (topmost curve in figures 8 and 9). There are more fluorescent photons that escape which have scattered at 90°, since a large fraction of the incident photons are absorbed near the cloud surface for the source at $z = -R$. That has the effect of filling in the concave shape of the first shoulder of the fluorescent lines. For the near source case, the second shoulder is changed from being relatively flat at small angles (near

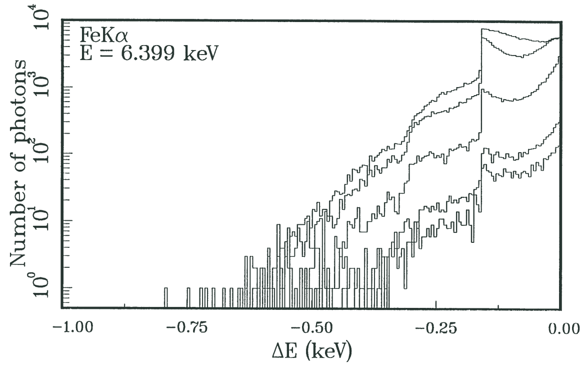

Fig. 9 — Simulated Fe K_α line profiles for a source distance of 1.0 *R* and τ = 2.5. Top to bottom: angle bins 12, 9, 6, 3, 1.

the source-to-cloud direction) to steep for large angles (back along the cloud-to-source direction). The effect increases with optical depth. The results for the Fe K_β and Ni K_α fluorescent line shapes are essentially the same as for Fe K_α, except that they contain fewer photons.

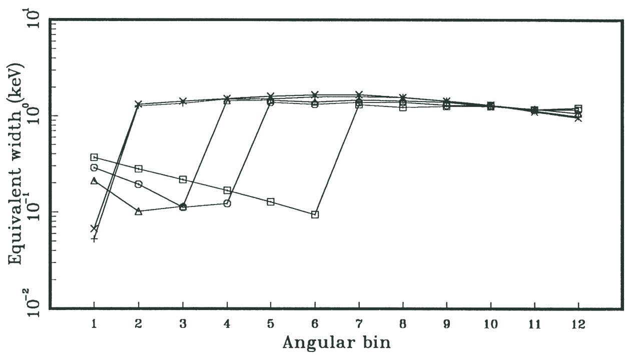

Fig. 10 — Equivalent widths as a function of angle for Fe K_α for τ = 0.5, for source distances of 1.0 *R* (squares), 1.1 *R* (circles), 1.25 *R* (triangles), 2 *R* (crosses), and 10 *R* (plus signs).

The equivalent widths of the Fe K_α fluorescent line are shown in figure 10 as a function of angle for τ = 0.5. The five curves are for different source-cloud distances. The symbols — square, circle, triangle, *X*, and plus sign — are for source distances of $z = -R$, $-1.1\ R$, $-1.25\ R$, $-2\ R$, and $-10\ R$. The sharp drop in equivalent width at smaller angles (bin 6 or less for $z = -R$, bin 4 or less for $z = -1.1\ R$, *etc.*) is the result of a jump in the continuum level produced by direct photons from the source that can reach the observer after traveling through the cloud. Aside from this effect, there is a smooth

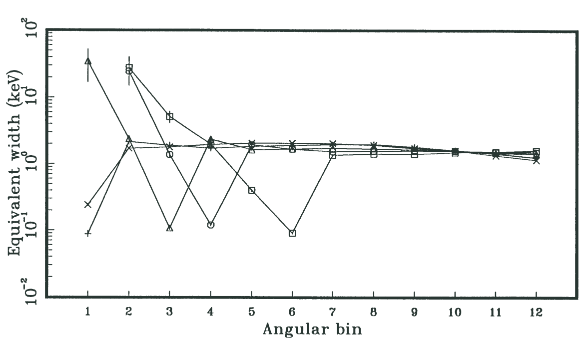

Fig. 11 —Equivalent widths as a function of angle for Fe K_α for τ = 2.5, for source distances of 1.0 *R* (squares), 1.1 *R* (circles), 1.25 *R* (triangles), 2 *R* (crosses), and 10 *R* (plus signs).

variation in equivalent width versus angle that is least for the near source case ($z = -R$) and greatest for the far source case ($z = -10\ R$). The equivalent width is large (1–1.7 keV) for the angles that only contain cloud-reprocessed radiation, and decreases away from the direction perpendicular to the source-cloud axis.

The high optical depth (τ = 2.5) equivalent widths are shown in figure 11 as a function of angle for the same source cloud distances as above. The behaviour is essentially the same as for lower optical depth (figure 10), except at small angles where the direct source radiation is much reduced.

4. Discussion and Conclusions

Monte Carlo methods have been used to simulate large numbers of photons from a point source illuminating a spherical cloud. Previous calculations of line profiles have only been for a disk geometry (except Leahy & Creighton 1993 for centrally-illuminated clouds). The resulting line profiles and continuum spectra resulting from spherical reflection depend strongly on the orientation with respect to the source cloud axis, as shown above. In contrast, for reflection from a disk geometry, the profiles for fluorescent iron lines depend only weakly on illumination angle (*e.g.* figure 5 of George & Fabian 1991).

The line-shapes calculated here depend strongly on the matter distribution. That is directly related to the distribution of the number of scatters for line photons and also the distribution of angles for the scatters. The geometry of the matter affects both of them. The line profiles from Fe K_α, Fe K_β, and Ni K_α should be nearly the same (except for the effect of the Fe *K* edge absorption on the Ni profile) for any given matter geometry. That has been verified in the simulations.

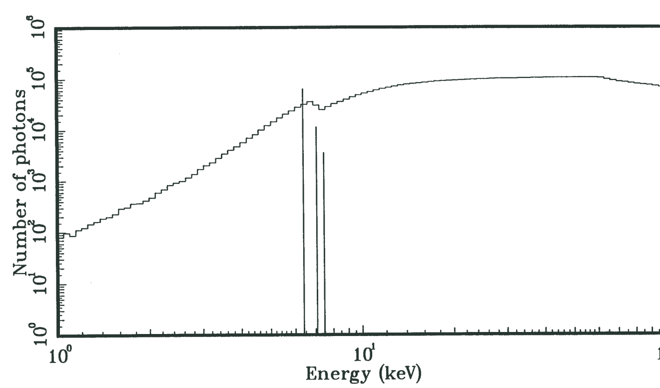

Fig. 12 — The X-ray spectrum, summed over solid angle, from a cloud with τ = 0.5 and a source distance of 10 *R*.

It is of interest to determine what an observer might see in a particular astrophysical situation. In this work, the reprocessed spectra from a single cloud at various distances and viewing angles from the central source have been calculated. It is quite possible that, for example, AGN X-ray emission consists in large part of X-rays reprocessed by reflection off a number of clouds surrounding a central X-ray continuum source. A good approximation to such a spectrum, omitting consideration of the direct source radiation, is to sum the reflection spectra over angle, weighted by solid angle. That has been done here, and the summed spectrum presented in figures 12 and 13 (for τ = 0.5 and τ = 2.5, respectively). The incident spectrum for such a case is a power law of index −1 (which would be a horizontal line on the figures),

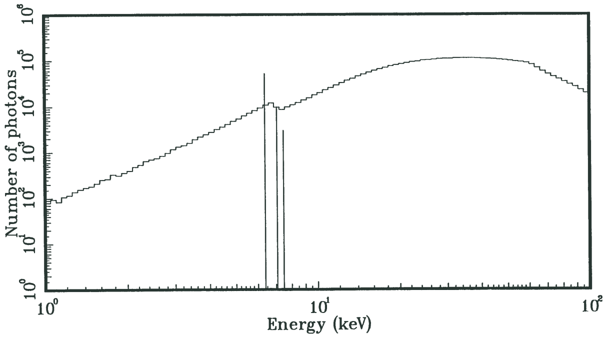

Fig. 13 — The X-ray spectrum, summed over solid angle, from a cloud with τ = 2.5 and a source distance of 10 *R*.

and the source-cloud distance is 10 *R* (where *R* = the cloud radius). As described above, for distances of 1.5 *R* or more the spectra are nearly the same, and the case for 10 *R* is an accurate representation of the far source-cloud case.

The continuum spectrum has the shape of the incident spectrum above about 15 keV (τ = 0.5) or 25 keV (τ = 2.5) — recall that the turnover for $E > 60$ keV is caused by the sharp cutoff in the incident spectrum at 100 keV. At lower energies (2 to 6 keV) the spectrum is approximately a power law with significantly flatter index than the source and with a strong iron edge feature. For τ = 0.5 the power law index is +2.6 for 2–6 keV radiation. For τ = 2.5 it is +1.9 for 1–6 keV radiation, and decreasing power law index from the iron edge to 30 keV, where the power law index regains a value of –1.0. The flat spectrum at low energies is similar to what one obtains in leaky absorber models (with a very small leakage factor). However, here there is no need to have any direct radiation from the source. Rather, the reflection off the cloud surface plays the role of providing a small amount of soft X-rays.

Another possible situation is that of a single cloud orbiting a central continuum source (or that where a single cloud dominates the reprocessing for a short period of time). Then one would see the X-ray line and continuum spectra evolve with time. The line spectra would follow a sequence such as shown in figure 6 (for the τ = 0.5, far cloud case), with viewing angle sequence corresponding to the time sequence appropriate to the cloud orbit. That is, for an orbit with an inclination of 90°, the line shape would cycle through the series of shapes for 0° to 180° to 0° (*i.e.* angle bins 1 to 12 to 1 — up and down through the series of shapes in figure 6). For high optical depth or near cloud cases, the line shape would cycle through the appropriate set of shapes shown in figures 7, 8, or 9. If the inclination of the orbit were less than 90°, then the observed line-shape would cycle through the shapes excluding those for illumination angles near 0° and 180°.

One can predict the continuum behaviour similarly. However, it is more complicated since there is also a direct continuum component of unknown normalization in addition to the continuum reprocessed in the cloud. Yet, as noted above, figures 2 to 5 also give the ratio of reprocessed to direct radiation from the cloud. One could thus study the variable component of the continuum radiation, ratio it to the constant component (the spectrum of the direct radiation), then compare it to the variability predicted.

Another possible geometry is that of radial infall of a cloud to the source. In such a case, a series of spectra at constant viewing angle but decreasing source-cloud distance would be seen. One could then compare the observed line-shapes as a function of time with a series of lines shapes calculated as a function of source-cloud distance — the first and last of the sequence would come from figures 6 and 8 for the low optical depth case or from figures 7 and 9 for the high optical depth case. Recent multi-wavelength, multi-epoch observing campaigns for the AGNs NGC5548 (Korista *et al.* 1995) and 3C390.3 (O'Brien *et al.* 1998), however, indicate that the velocity fields in the broad-line region are not dominated by radial infall. The X-ray emitting region is closer to the centre than the broad-line region (*e.g.* Nandra *et al.* 1998), so radial infall is still possible there.

More generally, any motion of the cloud with respect to the central source would produce a predictable sequence of shapes for the fluorescent lines and reprocessed continua spectra, via the source-cloud distance and viewing angle parameters. It would be of great interest to search for variable fluorescent line-shape spectra from AGN or galactic X-ray binaries on time scales appropriate to those corresponding to close orbits of clouds. The observational signature for the shape of fluorescent lines changing with time would provide a unique probe of the geometry of the system. After identifying a sequence of changing line-shapes, one could then examine the continuum spectra to separate the direct and reprocessed components to further learn about the cloud motion and continuum source properties.

The current spectral data available (with ASCA) do not have enough sensitivity and spectral resolution to detect the distinct spectral signature of the iron line from spherical clouds (*e.g.* figures 6 to 9) or its time variability. Only the brightest AGN have iron line profiles measured with ASCA. In a few cases, such as for MCG-6-30-15, the lines are too broad to be the result of reprocessing in a single small cloud. It is expected, however, that there will be many small clouds, with different Doppler and gravitational redshifts, that would contribute to the observed line profile. It is consistent that the observed profile is the result of such a set of clouds with redshifts appropriate for the central region around a black hole. In order to distinguish an origin in a set of small dense clouds from an origin in an accretion disk, however, higher resolution observations are needed. In particular the "double horn" shaped profile arising from Compton down-scattering (*e.g.* figure 6) would be detectable with AXAF, even if there were several clouds and the clouds had different Doppler and gravitational redshifts. If the number of clouds close to the continuum source were large and they had different redshifts, however, such a spectral signature would be smoothed out and not detectable.

The equivalent width is not a clear signature of reprocessing by clouds when compared to the case for a planar geometry such as that for an accretion disk. That is a consequence of an independent factor that affects the equivalent width of the iron line — motion of the continuum X-ray source that illuminates the reprocessing matter (Reynolds & Fabian 1997). The source could very likely be moving at an appreciable fraction of the speed of light, resulting in an equivalent width that can be appreciably greater than (or less than) that calculated for a stationary source.

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Education Notes
Rubriques pédagogiques

AN AMATEUR RADIO TELESCOPE FOR SOLAR OBSERVATION

by David Cleary

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Abstract. Building a simple radio telescope is relatively easy with a combination of persistence and the proper help. Surplus satellite television equipment can be modified to permit radio observations of the Sun and the Moon, as well as to allow the user to learn the fundamentals of radio astronomy. This article describes the steps taken by the author to assemble a radio telescope, and presents the results of his observations.

Résumé. La construction d'un simple radiotélescope est relativement facile, pourvu qu'on ait de la persistance et de l'aide convenable. L'équipement en surplus de télévision par satellite peut être modifié afin de permettre les observations par radio du Soleil et de la Lune, aussi bien que d'apprendre les connaissances fondamentales sur l'astronomie par radio. Cet article décrit les dispositions prises par l'auteur pour assembler un radiotélescope, et aussi présente les résultats de ses observations. SEM

1. Introduction

Between December 1997 and April 1998 I assembled a simple radio telescope that was able to observe solar radiation at radio frequencies. The telescope consists of a used satellite television (TV) system in the 12 GHz (Ku) band that was constructed with guidance via E-mail from William Lonc, professor emeritus of physics at Saint Mary's University in Halifax, Nova Scotia. My experiences may be helpful to others wishing to take beginning steps in the interesting field of radio astronomy.

The exercise allowed me to rekindle interests in both astronomy and electronics that were abandoned when I was a teenager in order to pursue other career goals. Much has changed since I worked with vacuum tubes and gazed at Saturn through a 3-inch refractor. At age forty and reflecting on life at this stage of maturity, I was ready to revisit the awe I felt as a teenager exploring an unseen part of our world.

Fig. 1 — The 34-foot Yagi FM antenna.

2. Failed FM Radio Telescope

My first radio astronomy project began in December 1997 using a standard home stereo FM receiver arrangement based on a design described by David L. Heiserman in his book *Radio Astronomy for the Amateur* (Heiserman 1975). It was not successful, perhaps because of my lack of experience. The construction of a 34-foot Yagi antenna (figure 1) mounted in my backyard, and the measurement of the noise it picked up, demonstrated just how much terrestrial interference there is in the radio spectrum. Varying household line voltages to the receiver, coupled with interference, made it impossible to observe the Sun in the commercial FM band. I learned that, in addition to ambient light, ambient radio transmissions also hinder the observation of astronomical sources.

By the end of December, I concluded that I needed to try a different tack. If the FM band was not going to work, what frequency should I use? Some books I scanned and a couple of radio astronomers I spoke with via E-mail suggested various frequencies for several antenna and receiver configurations. E-mail conversations directed me to the 600 MHz or 1420 MHz (the hydrogen line frequency) bands. But there were enough options to be confusing. A couple of people suggested that I contact William Lonc and read his book *Radio Astronomy Projects* (Lonc 1996). I contacted Bill via E-mail. He told me to read the book first, then talk with him about projects. It proved to be good advice. Once I read the book, he suggested that the simplest way to get started was to adapt a satellite TV system and do solar observations. That became my goal.

3. A Satellite Radio Telescope

Finding a satellite system within my budget was the first hurdle. After telephoning a number of retail satellite TV businesses and surplus yards looking for used dishes and receivers, I reached one satellite TV business that gave me a good lead. A staff member informed me that *The People's Network* (TPN), a broadcaster selling self-help programming via satellite, had recently switched its Canadian subscribers over from

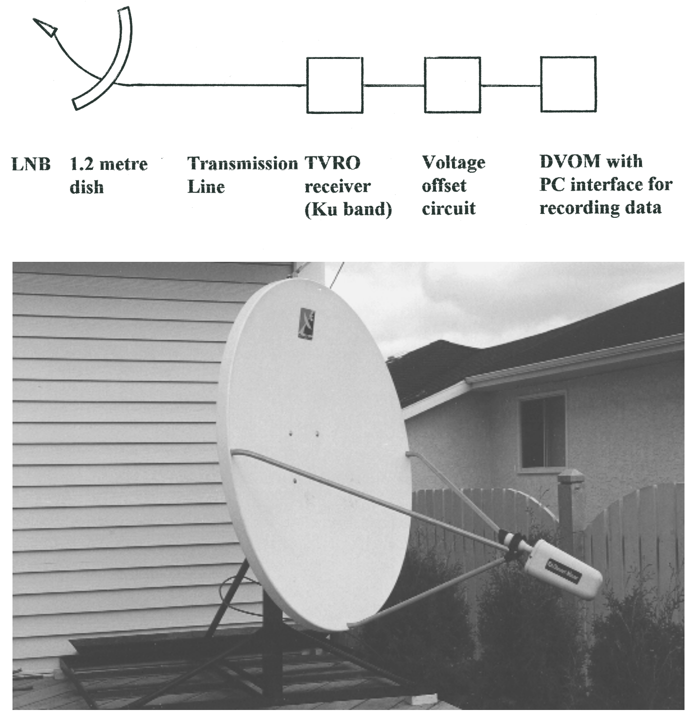

Fig. 2 — The 1.2-metre dish antenna and the block diagram of the Radio Telescope.

analogue to digital receiver systems. That meant there was a supply of relatively inexpensive used C or Ku band equipment lying around.

I contacted the local TPN representative, who was happy to give me the names of five people who wanted to sell their systems. I found one for $210. It included most of the features I needed: a 1.2-metre dish with azimuth and elevation mount, a Low Noise Block (LNB) converter at the focal point of the offset dish, transmission line, and switchable C and Ku band receiver (see figure 2).

My enthusiasm got the better of me, because I purchased the system without verifying that it had a signal strength meter or Automatic Gain Control (AGC) mechanism in the receiver. Either of the two features is necessary in order to observe signal variations from astronomical sources. Signal strength meters can be found on many FM stereo receiver systems. They are used to indicate when the receiver is tuned to a station. Most take the form of a meter that deflects proportionally to signal strength. Others can be a single LED, or a series of LEDs, that lights as the signal increases.

The receiver I purchased had a single LED that was affected by changing the channel tuning on the front of the receiver. It proved to have some other as-yet-undetermined purpose unrelated to signal strength, and was therefore of no help to me. In other words, the receiver had no signal strength meter. I had to find some other way of detecting signal strength. Sometimes satellite TV systems have a connection on the rear of the receiver that installers use to determine when they have located the satellite signal. It is called the Automatic Gain Control (AGC). Unfortunately, my receiver had no exterior AGC connection either.

That forced me to look inside the receiver itself for a signal strength connection. The receiver (Video Plus) is not a common brand, and I was unable to locate schematics or the original manufacturer. I spoke with several satellite TV suppliers, and eventually found someone who suggested that I check the tuner inside the receiver. The tuner is a small metal box fastened on the inside of the case at the back of the unit. The transmission line connects to the box from the LNB on the dish.

Satellite tuners generally have up to twelve pin connectors used for different functions within the receiver. The satellite technician suggested that I experiment with them to locate the AGC circuit. At Bill Lonc's suggestion, I first connected the system to a TV set to make sure the system was in fact able to detect a satellite signal. It was able to pick up several satellite channels, and I began the process of testing the pins using the satellite signal to evaluate the purpose of each pin.

With the TV set near the dish, I used the TV picture and sound as a way of verifying whether the dish was pointed on or off signal as I moved the dish. A voltmeter was connected between the chassis ground of the receiver and each pin in turn. I then took meter readings for each pin when the dish was pointed on and off signal. Some had no voltage, some showed constant voltage, and some varied depending on whether they were on or off signal.

Focusing on the three pins with variable voltages, I refined the investigation by connecting a digital voltmeter with a serial interface to a data-logging program on our home computer. That allowed the output from each pin to be graphed in turn as the dish was moved slowly from an off signal position, through the signal (on), past the signal to an off position again. One pin produced an erratic behaviour, another gave a strong response to the satellite, and the third produced a mild but consistent response.

Because the signal from a point source such as the Sun is known to create a bell shaped curve when passing through the beam of an antenna, I assumed that if I got a signal in the shape of a bell curve, I must have found the AGC circuit. Since the dish was moved manually, the jerky motion of the dish affected the signals produced in the first series of graphed tests. That rendered the data inconclusive. Because TV satellites are geostationary and require manual movement of the dish is required to locate the signal, satellites were not a satisfactory method of evaluating the system response on the three pins.

4. The Sun

It was time to try an observation of the Sun, which is a strong source of radio signals. There were a couple of ways to use the Sun as a signal to verify which of the three pins was the one I wanted. It also nicely coincided with my goal of observing the Sun.

Transit observations are a common and inexpensive way for amateur radio astronomers to observe celestial sources in the radio spectrum. By pointing the antenna southward along the north/south meridian at a particular elevation and allowing the sky to pass in front of the antenna beam, the observer can correlate detected signals with astronomical objects. A variation on the meridian transit method is to point the antenna just ahead of a known source and allow the rotation of the Earth to move the source through the antenna beam. With more expensive equipment it is possible to track objects across the sky, all the time observing their radio emission.

Not having a tracking system, I used the transit method to find the AGC pin on the tuner. The dish was aimed just slightly ahead of the Sun and the response on each of the three pins was recorded as the Sun passed through the antenna beam. The pin that had behaved erratically before did the same thing this time, and the one that responded strongly to the satellite showed no response. The third pin showed a stepped response, increasing as the Sun passed to the centre of the beam, then declining as it passed out of the beam. I had found the AGC, and coincidentally observed the Sun for my first time.

After the three months I spent determining a suitable frequency, finding a satellite system, and getting it operational for radio astronomy purposes, it was a tremendous thrill to finally see some results. With an optical telescope the results are immediate, and the observable sources are more or less unlimited. Someone interested in radio astronomy needs to have a curiosity for the mechanics of radio observing to stay interested.

5. Refining the Observations

The accuracy of my first observation was not very good, as evidenced by the stepped nature of the graph (see figure 3) where the voltage moved from a baseline of 2.65 volts, to 2.66 volts, then peaked at 2.67. The voltmeter was set to 20 volts dc. The next lowest setting is 2 volts. It was not possible to use the 2-volt range because the output voltage of around 2.65 volts direct current (Vdc) would have overloaded the meter. On the other hand, the lower range would have allowed better accuracy with more significant digits.

The high range setting meant the signal could theoretically have varied between a low of 11 millivolts and a high of 29 millivolts. At the

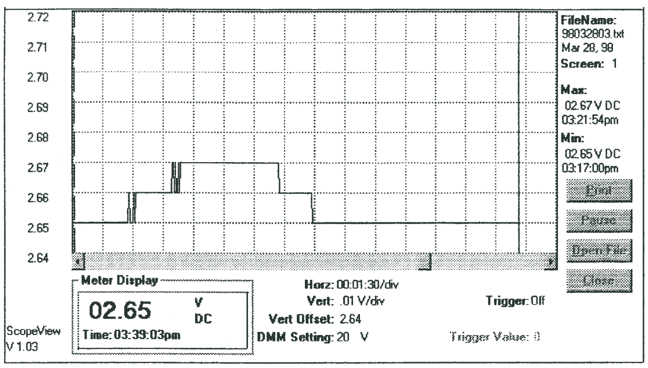

Fig. 3 — First Sun observation using 20 volts dc setting on voltmeter.

20-volt setting, the actual signal strength could have reached 29 millivolts by varying between 2.645 volts (rounded up to 2.65 because of the setting) and 2.674 volts (rounded down to 2.67). Inversely, it could have been 6 millivolts, with possible low and high readings spread between 2.665 volts and 2.654 volts. Each such reading would yield the same graphical results.

As a result, the signal strength could not be determined accurately at the setting I was using. Another uncertainty was whether or not I had pointed the dish accurately. Did the Sun pass through the centre of the antenna's beam, or through the side of the beam? If the dish was pointing off-centre to any extent, the strength of the signal would be lower. Also, the graph of the signal did not look like the nice bell curve that would be expected with a more finely graded scale at that frequency. Instead, it looked like a crooked little stile over a crooked little fence.

To solve the problem, a second observation was conducted. I attached a 100 K ohm potentiometer between the chassis ground of the receiver and the AGC pin, and read the signal between the centre-tap and ground of the potentiometer. By adjustment of the potentiometer, the baseline voltage could be offset to below 2 Vdc, making readings at the 2-volt setting significant to three decimal places rather than to the two places I was able to read at a setting of 20 volts.

The second observation showed a smooth bell curve (figure 4), but at not as strong a signal as I had expected. The circuit cut part of the total signal response off at the top end of the potentiometer. Since signals from astronomical sources are extremely small, signal loss has to be avoided at all costs.

The peak signal over the baseline voltage that I obtained using the potentiometer was 20 mV. After doing some calculations of projected signal loss at the top end of the potentiometer, I concluded that the

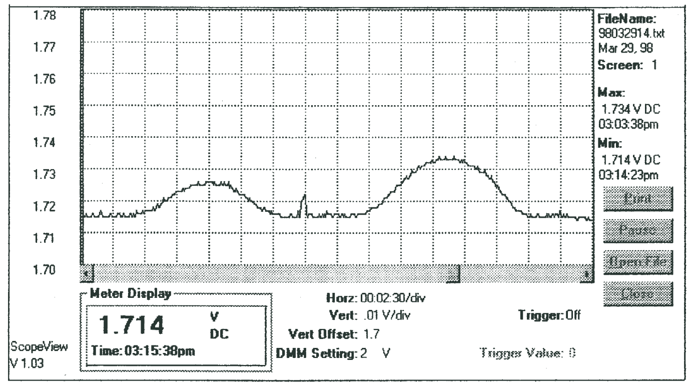

Fig. 4 — Two transits of the Sun. Note the first observation where the Sun passed off-centre to the beam. The bump between the two bell curves was made when the dish was moved manually past the Sun. The second bell curve was with the Sun passing through the centre of the beam. Note the signal strength of approximately 20 mV.

system could probably produce a maximum signal of approximately 30 mV over the baseline. For a satisfactory number of significant digits, that would require use of some other means other than the potentiometer to drop the voltage to a level readable at the meter setting of 2-volts. The results correlated nicely with the maximum signal that was possible within the limits of uncertainty associated with the first observation.

Once again Bill Lonc came to the rescue, with a simple circuit design that allowed me to drop the baseline voltage further, to the point where I was able to use the 200 mV setting on the meter, this time without signal loss. Bill's circuit uses two 1.5-volt D cell batteries and a potentiometer between the ground, meter, and AGC pin to cancel approximately 2.5 volts. The signal voltage could then be viewed against a very low baseline voltage. I was able to read a signal of 30 mV over the baseline, confirming the expected value (figure 5). Because of the voltage cancelling circuit, I was able to use the 200 mV setting on the voltmeter. At that setting the system was sensitive enough to record signal variations from vibrations of the dish as I walked across the deck while the Sun passed through the antenna beam (note the three lumps in the bell curve just after the peak shown in figure 5).

The beam of a parabolic dish antenna consists of a cone-shaped area in front of the antenna from which radio waves can be detected. The 1.2-m dish had a predicted beamwidth of 2°. Antenna beamwidth normally specifies the angular distance between the points where the signal reaches half its strength on either side of the peak signal (referred to as "half power points"). My observations had a variety of signal increases that depended largely on whether or not the Sun passed through the centre of the antenna. The first observation I could use to measure the antenna's beamwidth was done on April 5, 1998 (figure 5). The data displayed a response that lasted twelve minutes from the first noticeable increase, through the peak signal, to the baseline voltage once again. The time between the half power points was approximately 8.25 minutes.

At the equinoxes the Sun passes through 15° of arc each hour relative to the meridian of the observer. The amount decreases as a

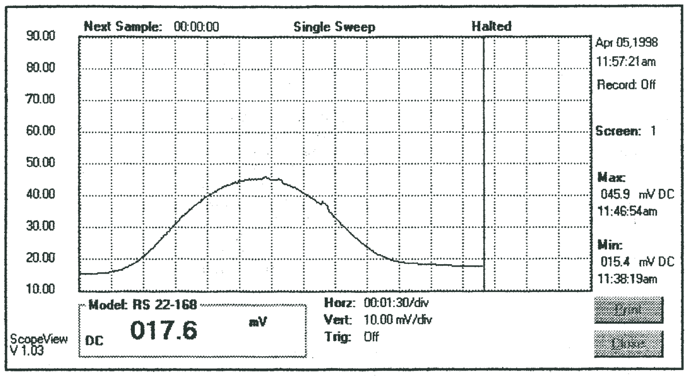

Fig. 5 — Solar observation using Bill Lonc's dc offset circuit. Note the 30-mV signal and the three bumps on the bell curve caused by vibration of the dish.

function of the cosine of the observer's declination. In other words, the arc traversed by the Sun decreases from its nominal value of 15° per hour the further the Sun is from the celestial equator.

On April 5, the date of the observation in question, the Sun's declination was approximately +6°. The half power point interval was 8.25 minutes. At the celestial meridian, the Sun traverses 1° in 4.0 minutes, but at +6° declination it takes 4.02 minutes. The calculated beamwidth of the observation is therefore $8.25/4.02\times1°$, or 1.9°. The antenna beamwidth is therefore close to the predicted 2°. Another observation on May 29 with the Sun at approximately +22° declination resulted in a calculated beamwidth of 2°. Further observations produced values that differed by no more than about 5% from the expected beamwidth.

6. The Moon

With successful solar observations under my belt, I decided to try looking at the Moon and other astronomical sources to see what I could detect. The Moon emits microwaves originating from its temperature. The nearly Full Moon, as observed in early April 1998, produced a signal response of 3 mV, one tenth the strength of the solar response (see figure 6).

7. Other Objects?

The dramatic reduction in signal strength between the Sun and Moon made me wonder if I would be able to see more distant objects. Attempts to see sources known to be strong radio emitters, such as Cygnus A and Taurus A, were not successful. Reference charts showing the strength of signals from such sources compared to the signal strength of the Sun at 12 GHz, clearly showed that I was dealing with emissions so weak that I would probably not be able to distinguish them from the background noise created within the receiver system itself.

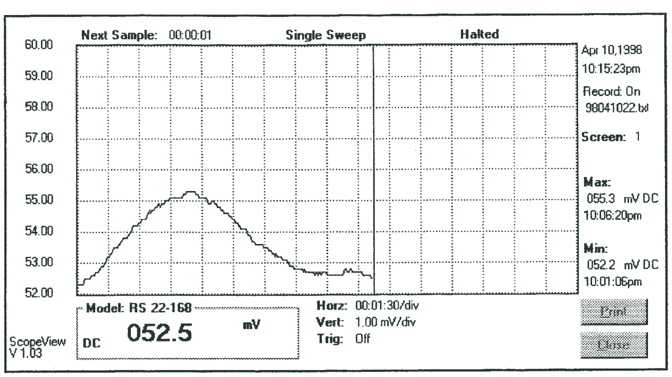

Fig. 6 — Lunar observation at nearly Full Moon on April 10, 1998. The signal strength from the Moon is approximately 3 mV.

After five months of research, construction, experimentation, and successful observation, I came to the limits of what my 1.2-m satellite TV system can observe. In the end, the system was not very expensive at $210 for the used dish, LNB, mount, transmission line, and receiver. I also purchased a Radio Shack RS 22–168A digital voltmeter with computer serial interface software included for logging data, which cost $190 — but which has been on sale for about $30 off since I purchased it, of course.

For anyone wanting to try radio astronomy, I have learned a couple of things that may be helpful. Be certain that your references are current. Earlier books or articles may provide helpful general information about the foundations of radio astronomy that have not changed much over time. But technological changes have made things possible in the late nineties that were not possible in the seventies or even mid-eighties. For example, one book written in the mid-seventies before the advent of satellite television, refers to the impracticality of using parabolic dish antennas for observing. They are now quite common in amateur radio astronomy. Strip chart recorders are another example. They used to be about the only option for capturing data, aside from taking periodic visual readings from the voltmeter. Now digital technology, such as I used, permits data to be recorded in electronic files that can later be analyzed using data processing techniques.

Finally, networking is a useful way of gaining experience without having to go through a frustrating amount of trial and error in the early stages. Nevertheless, I found it worthwhile trying one thing and another even though it netted no results. It gave me time to process information gained by reading and talking with others interested in radio astronomy. Getting to know the quirks of my particular receiver and dish through trial and error helped me to understand how my equipment worked. Even with help from others, there is no doubt that the simple radio telescope project like the one described here takes a fair bit of patience. But I found it fun and worthwhile.

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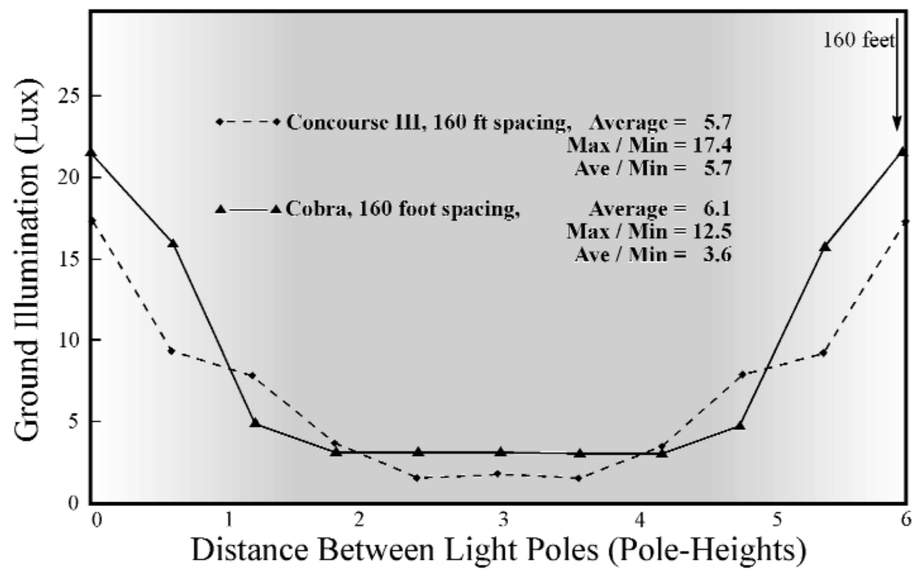
Helpful Arguments for Promoting Light Pollution Abatement

by Robert Dick, Light Pollution Abatement Committee (rdick@ccs.carleton.ca)

An argument used to rationalize the use of non-light polluting luminaires is the saving of energy from otherwise misdirected or wasted light. Unfortunately, such an argument will not convince municipal engineers and administrators. Other arguments must be used.

The modern High Intensity Discharge (HID) lamps, which include low and high pressure sodium (LPS and HPS) and metal halide (MH) bulbs, are so efficient that any "saving" from the reduction of glare amounts to only a few watts per luminaire. Glare from older luminaires is caused by light that shines or is scattered horizontally into the eyes of drivers and pedestrians. In astronomy we are also concerned that such light is scattered off low level dust and aerosols in our atmosphere, which results in artificial sky glow.

If an average 100-watt bulb shines for 12 hours per night over its lifetime of 30 years and if 5% of the light shines horizontally or up into the sky, the amount of "wasted" energy is about 2.4 billion joules. While that sounds like a lot of energy, it is equivalent to the energy consumed by a 150-watt bulb burning for 4,400 hours (one year of nights) — *i.e.* about 670 kilowatt hours. At a cost of eight cents per kilowatt hour (rural rates in Ontario), that amounts to only $54 over the life of the installation! Since the cost of a new, more efficient luminaire is anywhere between $70 and $250, any arguments for economy are non-starters! The expense of replacing the older luminaire is greater than the amount saved over its lifetime by replacing it with more efficient designs. And that does not consider the "cost to the environment" of manufacturing the new luminaire in the first place.

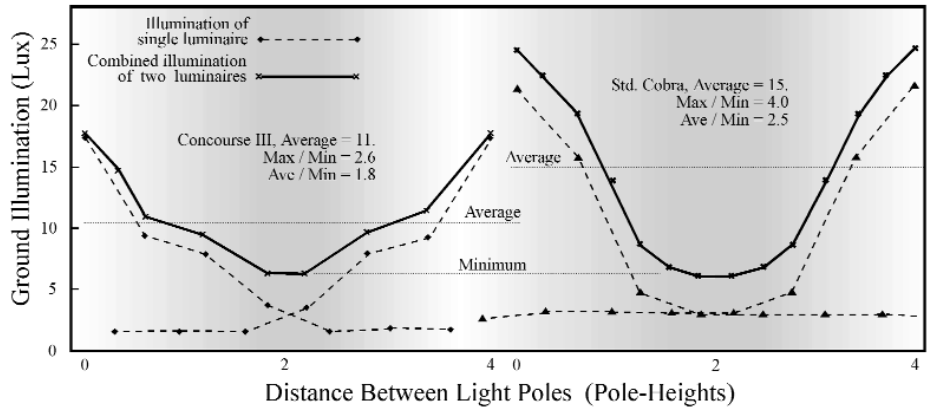


Notes:
1. Data based on Ottawa Hydro Commisioned Study by Cooper Lighting in the summer of 1995.
2. Illumination levels are based on the luminaire 27 feet above the road and 100 watt HPS lamps.

It gets worse when we consider street lighting specifically, since there is a fall-off in ground illumination away from the luminaire. There are two basic designs for roadway luminaires. The first uses the scattering process to distribute light, the second uses mirrors to direct and focus the light to where it is needed. The "older type" consists of a metal enclosure with a bulbous lens extending below it. I refer to the most common version as a "standard cobra," since it has a cobra head shaped enclosure. Different lens designs bias the scatter of light into different directions. The scattering process is basically a random process that results in light not going where you want it. They produce glare, light trespass and artificial sky glow, which is bad.

Becoming more widely used are luminaires that focus the light into preferred directions while minimizing light pollution. I refer to them as "sharp cut-off" luminaires. They are characterized by a flat window instead of a lens, and the light is focused by a system of internal mirrors. They take several forms, from square "shoe box" or round "hat box" shapes to cobra-like designs, but without the bulbous lens (cobra on a diet). For luminaires of this design no light shines above the horizontal, and the mirror system restricts light that shines within 10° below the horizontal. They minimize glare, light trespass, and artifical sky glow, which is good.

The "standard cobra" luminaires that produce so much glare do a good job of scattering light between lighting poles, as shown in the accompanying diagram (at left). Illustrated is a chart of the ground illumination between light poles: the solid line illustrates the light distribution for a standard cobra design that scatters the light with its bulbuous lens, while the dashed line illustrates the distribution of light from a sharp cut-off "shoebox" luminaire. The pole spacing of six pole-heights is typical for roadways. Notice that the illumination level directly under the shoebox luminaire (distance = 0) is less than that for the cobra luminaire. At a distance of one to two pole heights, however, the illumination levels are better for the shoebox design than for the cobra design. That is a consequence of the design of the shoebox, which directs the light from under the luminaire into the surrounding region. Arguments arise from the illumination level halfway between the poles. To produce the same level of illumination halfway between the poles using a non-light-polluting shoebox luminaire requires a shorter distance between the poles or 50% more light poles in the network (see diagram at right). Here, the data are simply re-plotted in order to illustrate that, by spacing the "sharp cut-off" shoebox design at four pole heights, the centre span illumination is the same as that achieved by the "standard cobra" design. Granted, the levels of glare have been reduced, so the illumination levels may be reduced as well with the same "visibility." To quantify it, however, requires a detailed study of the illumination system and interpretation of the illumination standards.



To install more poles becomes very expensive. Each additional light pole costs anywhere from $500 to more than $3,000, depending upon the details of the installation. The argument for reducing wasted energy will therefore not survive the scrutiny of cash poor or frugal municipalities.

The following two arguments can be used to support the use of low-glare, sharp cut-off luminaires:

1. Glare reduction improves the visibility of hazards, which is the primary reason for installing luminaires in the first place. Although the level of illumination between poles is less, if they are spaced six pole heights apart the elimination of glare may permit the reduction of mid-span illumination levels. Extra poles may not be necessary to maintain visibility.

2. Reduced glare also produces a more pleasing nighttime environment that attracts more people to enjoy being outside after dark. An increase in pedestrian traffic has been found to reduce crime (safety in numbers), and generally improves the social climate of an area.

In conclusion, the value of using sharp cut-off luminaires that limit or eliminate glare and light trespass lies in their creation of a safer and more secure night time environment, as well as in the enhancement of a community's social and cultural environment. We cannot calculate a dollar value for such benefits. However, life without them would be precarious and unfulfilling.

Robert Dick is the newly appointed Chair of the Light Pollution Abatement Committee. He has worked on a wide variety of engineering projects for both the military and commercial interests, and has been heavily involved in education in astronomy and light pollution abatement. He has also constructed several telescopes, the last being a 24-inch telescope housed in the observatory on the grounds of his country place at Rideau Ferry, Ontario.

At the Eyepiece

Light Shows

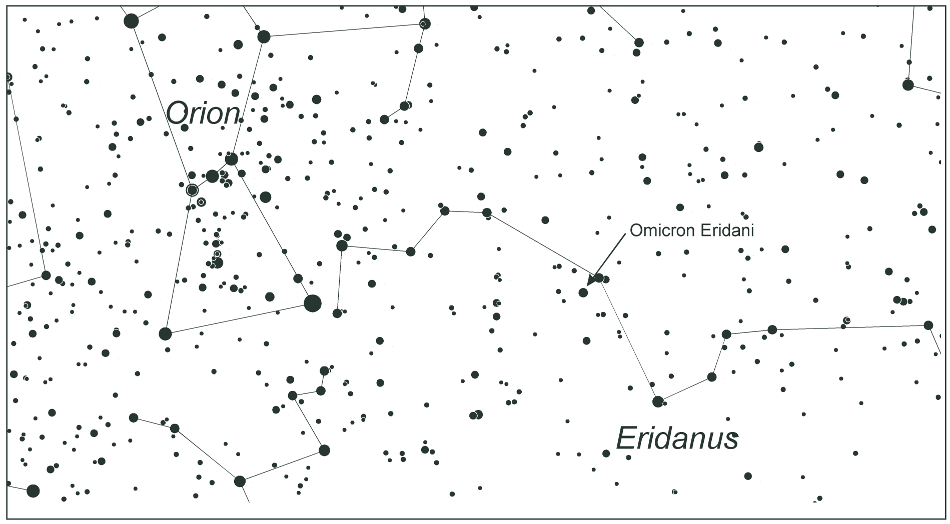
by Alan Whitman, Okanagan Centre, awhitman@vip.net

The most beautiful twilight skies are those ornamented by Venus or a crescent Moon with Earthshine. I think that I enjoy the sights in the nighttime sky while walking the dog in the evening at least as much as I do most telescope sessions.

This spring Venus returns to our evening twilight sky. Here is an entry in my logbook from the queen of the planets' last evening apparition: "A broad and bright band of light from Venus shone all the way across the lake this evening, brighter than any from the house lights on the opposite shore. (Not as exciting as seeing the fainter sheen across the waters reflected from Great Comet Hale-Bopp's tail during the lunar eclipse in March 1997, but very attractive nonetheless.)"

In spring, young crescent Moons leap higher each night. Probably the most dramatic one that I have ever enjoyed was on April 10th, 1997 when the Earthshine-lit leading edge of a 3.6-day-old waxing crescent occulted coppery Aldebaran — the first occultation I have viewed with the unaided eye.

Later that evening, a memorable aurora sprang up. Arching right across the Okanagan Valley from the western ridge to the eastern ridge, it featured green rays with some pink, even as far south as my location. Central Albertans witnessed a great all-sky aurora that blotted out all but magnitude –0.4 twin-tailed Comet Hale-Bopp and the brightest stars. Edmontonian Doug Hube, an RASC past president, saw "…thin, sinuous structures that wrapped themselves around the Moon and around the Comet." Prize-winning auroral photographer Leo Brodeur described the peak of the display from Cold Lake: "The colours appeared in layers, with the lowest becoming a beautiful rose, the next a medium yellow, then green and an intermittent thin blue top layer. I have never seen such a 'rainbow' pattern before."



A finder chart Omicron^2 Eridani (or 40 Eridani), the brightest member of a triple star system 15.6 light years distant (ECU chart prepared by Dave Lane).

Hunting the Home of the River Dwarves

The Halifax Centre's Daryl Dewolfe wrote: "Omicron^2 Eridani (or 40 Eridani) is the brightest member of a triple star system 15.6 light years distant. At magnitude 4.4, it is the eighth nearest naked-eye star. Component A is a Sun-like yellow dwarf with a mass 0.75 that of our Sun." When observed in his 145-mm Maksutov-Newtonian at 48× , it appeared as "a very bright creamy-white star." In 1783, William Herschel discovered a companion 83″ away. In 1910 the B companion was recognized as a white dwarf, the first of its type to be discovered. The dense, compact, planet-sized body turned out to be the second brightest white dwarf at magnitude 9.5, the only one easily visible in small telescopes. The white dwarf is "…twice the size of Earth, with a mass estimated to be almost half that of our Sun. To best see its true white colour," Daryl "found it was a good idea to first let the brighter A star drift out of the field-of-view." His curiosity was greatly aroused when he "…realized that the B component also had a C companion approximately 8″ away from it. This 11.1 magnitude object, first found by Otto Struve in 1851, is a red dwarf believed to have one-fifth the mass of our Sun." At 220×, "…the dusky-coloured C dwarf was well separated from the nearby B companion." His observations helped make Daryl's understanding of stellar evolution a lot more meaningful. He said: "As an active observer, it was a treat to see all the star types represented together in a single field-of-view in a telescope of relatively modest aperture."

Spiral Details in M83

One year ago in this column I wrote: "From Canada you cannot hope to do much more than find M83. However, it is one of the most impressive galaxies south of the celestial equator, so remember to re-observe it when you have a chance at a southern U.S. star party or while on a subtropical vacation."

Mark Bratton of the Montreal Centre reported: "On the few occasions when I have observed M83, it has usually appeared as a formless blob. However, in the spring of 1992 from the deck of the ski chalet on Mount Sutton, I had a great view of the galaxy with an 8-inch Celestron SCT. The sky was particularly transparent that evening and the galaxy just cleared the mountaintop, but I was able to observe curving extensions on both sides of the galaxy's core. I would love to repeat the observation sometime."

Before the Caribbean total eclipse, Haligonian Dave Lane modified his 13-inch Dobsonian to make it portable enough to transport as extra airplane luggage. Dave wrote: "Under optimal conditions, M83 is a wondrous object. Recently in Curaçao late at night, it was fantastic with spiral structure… in my 13-inch. The 'bar' was easy to see, with the wrapping arms picked out using averted vision."

M83 in Hydra. Image taken by Dave Lane, Ram Krishnan, and Greg Palman at the 1996 Winter Star Party using an Astro-Physics 130mm f6 refractor and a prototype *Triton* CCD camera of Ram's own design.

The Distance Lugged Varies with the Square of the Aperture

Eight Okanagan Centre observers held a Messier Marathon on March 28th-29th, 1998 near the top of a 1,200-metre pass on B.C. Highway 33, at latitude 49°.8 N. Our portable telescopes had to be carried through snow up to a high point that has fall-away horizons from east-southeast through southwest. Jim Failes and Stuart Kunstar hauled up the centre's **15-cm** Dobsonian in one trip, and said that it was a **200-metre** slog. It took me three trips to get my **20-cm** optical tube assembly, heavy equatorial mount, and accessories to the summit — a tough **300 metres** uphill, my logbook entry said. Centre president Ron Scherer arrived last and somehow had his **25-cm** Dobsonian set up and collecting Messiers only twenty minutes later. Ron's account in the centre's newsletter *FOCUS* tells of packing his equipment "…**600 metres** down the road and up a hill." There you have it — the distance lugged varies with the square of the aperture!

The lights of greater Kelowna (population 150,000) were behind ridges to the west with downtown about twenty-nine kilometres away. Penticton, Summerland and area, with a regional population of 50,000, glowed faintly forty-two kilometres to the southwest behind 2,200 metre mountains. From north through east to past south we enjoyed true wilderness skies, except for a few hours of night-skiing lights seventeen kilometres to the east on Big White Mountain. I rated the transparency as superb and the seeing as very good — the best night that I experienced in 1998.

We were all late starting, because of the trudge through the snow, and all of us failed on galaxies M74 and M77 as they set. It is unlikely that anything other than the nucleus could have been found in either Messier object through the tough combination of branches, twilight, very bright zodiacal light, and the background light dome of Kelowna.

After the M74 and M77 rush, I took a break for polar alignment and to set my setting circles, while the others jumped to it. Jim Failes inquired anxiously whether I had found M79 in Lepus yet. "What's the hurry?", I asked. "The square of Lepus hasn't set yet." Jim informed me that M79 was four degrees south of Beta Leporis and had probably set already. Oops! — but I found M79 three-quarters of a degree above the treetops in Penticton's light dome. If only the Sagittarius globulars had been so well-placed in the dawn!

After that, Jim, Ron and I rolled rapidly through the list, and all three of us were successful on every object until deep into morning twilight. Seven Messiers were prominent naked-eye objects, while my 7×50 binoculars were the quickest for twenty more. My 20-cm Newtonian found most of the others in the 1.3-degree field of my 30× eyepiece, with 61× and 116× used occasionally. I starhopped frequently, but used setting circles exclusively for the Virgo Cluster galaxies and the Ophiuchus globulars, as both areas are thick with NGC objects. Around one o'clock in the morning I was an hour or more behind Jim and Ron, who starhopped exclusively, but made up some time with the setting circles in Virgo and Ophiuchus. They reached Sagittarius half an hour before me.

We all missed various Sagittarius and Aquarius globular clusters as we hunted in the treetops of a distant mountain ridge. Spread out slightly as we were, one observer would find M54, M69, M70, M75, M72, or M2 in a gap between treetops that hid it from the other two. Ron Scherer found 104 Messiers, Jim Failes 103, and I finished with only 100.

The globular M30 was impossible from our latitude on March 29th, and M55 probably was as well. Of the two galaxies missed in evening twilight, M74 and M77, the latter's bright nucleus was perhaps possible if we had trained in advance. Ron's only other misses were the non-entity M73 (which none of us found in the bright twilight, as it is only a group of four stars of magnitude eleven and twelve) and the bright globular M2 (which Jim and I found easily through the luck of the treetop lottery).

I normally observe each object carefully for half an hour or more at various powers, so a Messier Marathon had always seemed anathema to me. Tom Cameron's article in the December 1997 *JRASC*, however, really gives the flavour of a Messier Marathon, and piqued my interest. I joined my centre's marathon at the last minute (after having just put in an all-nighter the previous night), without having done the necessary preparation of studying the situation at dusk and dawn. Fortunately, Jim Failes had printed up a list of the recommended observing order. That was an immense help, but it could not completely make up for my lack of study beforehand. Sagittarius rose far too late to be observing without a rhythm — I wasted precious minutes trying to starhop to the bright globular M55, which had not yet risen above the solid rock of a distant ridge, when I should have been hunting M69, M70, and M54 in gaps in the treetops.

That was probably only my second or third view of a few Messiers like M49, forgettable M40, and perhaps a few others. On the other hand, despite the constant rush of the marathon, the superb night demanded that I invest about ten minutes on each of three southern objects — I had my finest view, north of Texas, of the oblate globular cluster M19, and my finest views ever of M62 (which was slightly resolved around the edges at 116×) and M83. That was shortly after I had received Mark Bratton's description of details in M83, and, on such a wonderful night with M83 nearing culmination over wilderness, the galaxy showed a definite bar at 116×, surrounded by a slightly larger round glow.

I cannot remember when I have enjoyed myself so much at the eyepiece!

Try a Messier Marathon yourself this spring. New Moon is 10.3 days earlier this March, which will make M74 and M77 slightly easier, but the globulars of eastern Sagittarius and Aquarius will be even tougher. At my latitude, night shortens 2.3 hours between the March 17th, 1999, New Moon and the April 16th one, so marathoners will have to hustle if they choose April.

Alan Whitman observes with 7×50 binoculars, a portable 4-inch RFT (an Astroscan), an 8-inch f/6 Newtonian equatorial, and a 16-inch f/4.5 Newtonian equatorial in a backyard observatory. His skies, south of the Okanagan Valley's three cities, are frequently transparent enough to allow magnitude 6.4 stars to be seen with the unaided eye.

"The more success the quantum theory has, the sillier it looks."

Albert Einstein

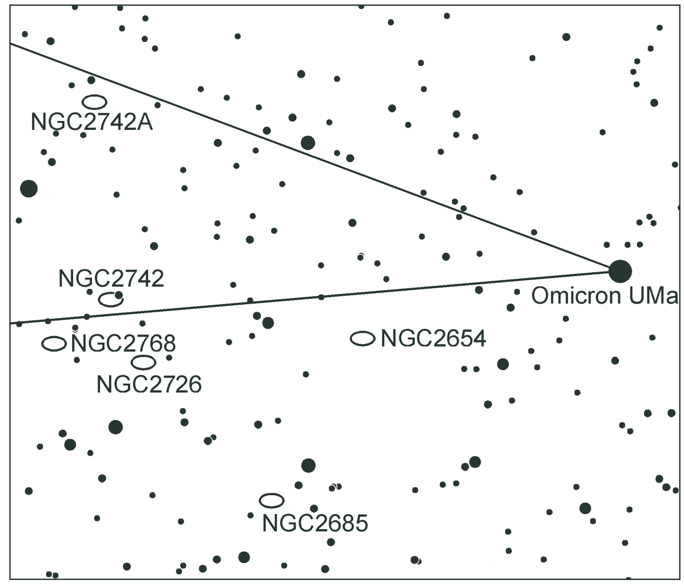
Scenic Vistas: The Bear Awakens

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

For much of the late fall and early winter Ursa Major hugs the northern horizon, but late winter evenings find it well into its long majestic climb up the eastern half of the sky. Because dominant Orion crosses the meridian during the early evening hours, many amateurs tend to ignore the Great Bear, leaving exploration of that region of the sky for more moderate spring evenings. But in spring the rapidly shortening nights find the galaxy rich western half of the constellation already plunging towards the northwest as darkness falls. Now is the time to profit from the still-long nights of late winter and to see what this part of the sky has to offer. An exhaustive survey is impossible in the space that I have available. Instead I will concentrate on a number of objects, for the most part little known to the casual observer, though each is fascinating in its own right.

We begin in the extreme western region of the constellation near the star Omicron Ursae Majoris, number 1 in Flamsteed's ancient star catalogue. Southeast from the bright star we come upon NGC 2685, a bright, peculiar galaxy sometimes known as the Helix Galaxy. In deep photographs one can witness an extraordinary sight — a faint ring of material appears to be circling around the core of the galaxy, perpendicular to the plane of the spiral arms. What is being seen is, in all probability, the aftermath of an act of galactic cannibalism. NGC 2685 seems to have plowed into a smaller galaxy, disrupting its structure and throwing much of its mass into orbit around its core. In my 15-inch reflector, the galaxy was quite bright, much extended northeast-southwest, with a large, prominent core that appeared elongated along the galaxy's major axis. The outer envelope was quite bright and much more prominent southwest of the core as compared to the northeast. At 272× there was even evidence of the polar ring. I saw faint extensions of the envelope to the northwest and southeast of the core.

Another bright galaxy in this region of the sky is NGC 2654, a little fainter than the preceding but fairly similar in form. It appeared as a fairly flat streak of light, oriented east-west and a little brighter with a faint stellar core. The edge-on galaxy displayed bright, well-defined extensions that fade abruptly into the sky background.



A finder chart in the "nose" of Ursa Major of many of the galaxies mentioned in this article (Editor's Note: one galaxy not mentioned in the article, NGC 2726, contained Supernova 1995F discovered by RASC members in 1995) (ECU chart prepared by Dave Lane).

A bright pair of galaxies lies a little further east. NGC 2742 is a bright, large oval galaxy, oriented east-west. Its surface brightness was fairly uniform and the galaxy appeared only marginally brighter to the middle. The outer envelope was well defined and faded suddenly into the sky background. Much brighter was NGC 2768, an E6 galaxy that held magnification well. Much elongated due east-west, the galaxy had a bright, sizable core. The main envelope was bright and faded gradually to an extensive secondary envelope.

Next on my list is NGC 3184. The large face-on spiral is easily located, as it lies in a low power field with Mu Ursae Majoris. At 146× in my Newtonian, the galaxy appeared perfectly round, bright though very diffuse. The galaxy brightened gradually to a faint stellar core, and the outer spiral arms faded very gradually, extending as far as a ninth magnitude field star located north of the galaxy.

Nearby is NGC 3198, a very large and bright galaxy easily seen even at 48× in my telescope. The galaxy was well defined and much extended in a northeast-southwest direction. It was bright and well defined along its major axis, though no core was visible at 146×. The envelope appeared very smooth, and the northeast and southwest extremities appeared rounded. The last galaxy of the survey is the remarkable NGC 3079, an object interesting in itself and also for the company it keeps. The peculiar, disturbed structure was quite evident, especially at 272×. The core was bright, elongated along the major axis and offset towards the south. There appeared to be a break just north of the core, and the extension appeared curved on the east side. A twelfth magnitude field star was visible at the north tip.

After observing the galaxy, I attempted to view something I knew would be a challenge. The object in question is known as Q0957+561 A and B, apparently the twin image of a single quasar. The image is double, according to researchers, because an intervening galaxy causes the light from the remote quasar to be split into two. The effect, which had been predicted by Albert Einstein, is known as a gravitational lens. In addition to splitting the image, the lens also brightens the image of the background object. Using a chart published in the October 1991 issue of *Sky & Telescope*, I gently nudged the telescope north to the field where I knew the gravitational lens to be. Inserting my 7-mm Nagler into the telescope, I patiently observed the field for about ten minutes, comparing each star visible with my finder chart. At the end of that time I gave up. I had been beaten — the quasar(s) were just too faint. I had identified stars down to magnitude 15.2, but no fainter. I would have to wait for another day.

There is more in that region of the sky, much more. A telescope, good charts, and observer determination are all that are required to explore the treasures of the universe.

Mark Bratton has had a life-long interest in astronomy, and first became acquainted with the RASC in November 1966 at the age of eleven. He did not become a member until twenty-five years later. He is currently the editor of the Montreal Centre's newsletter Skyward *and in his second term as president of the Centre. He is the single parent of a twelve year old boy, Kristopher, and his greatest joy, besides his son, is slowly exploring the skies with a 375-mm reflector from the deck of his small country cottage near Sutton, Quebec.*

My Experiences with Telescope Shaft Encoders

by Dan Collier, Vancouver Centre

"A shaft encoder is actually nothing more than a light bulb, a photocell, and a glass disk crammed into a case the size of a doorknob. When the shaft is turned, blips of electricity should dribble out along some wires."

I once wrote a treatise on the electronic shaft encoder. Though it lacked nothing for length and detail, I could not bring myself to reveal an embarrassing fact — I could not get the encoders on a certain manufacturer's Cassegrain telescope to work. The worst part was not that there were no faults in the devices; indeed, many were found and repaired. But, as soon as the telescope was turned back to the sky, the encoders would find another way to break down. At last the wretched urchins were finally brought to book. Now I can look forward to a few years of bliss before the rest of the telescope wears out.

A shaft encoder is actually nothing more than a light bulb, a photocell, and a glass disk crammed into a case the size of a doorknob. When the shaft is turned, blips of electricity should dribble out along some wires. The astronomer needs the encoders to find galaxies, nebulae, and what have you, because star hopping tends to be difficult with large telescopes. If you stick a couple of encoders on a telescope and cram the wire ends into a likely-looking socket on the back of your personal computer, there is a slim chance that you will be better informed as to which direction the telescope is pointing. However, an absence of blips is also a permissible state, not only for a working shaft encoder but also for one that is stone dead. The essential point is that when shaft encoders give trouble, there are no loud alarms or bright flashing lights to bring the problem to one's attention.

The situation has been aggravated by the introduction of the charge-coupled device, or CCD. The CCD is a glorified television camera used by astronomers to obtain images of astronomical objects. CCDs have all of the faults of orthodox cameras, plus a few vicious ones of their own. For starters you need an expensive computer just to view the images.

The sensitive area of a CCD is smaller than the film in a Minox camera. What is worse, there is no viewfinder. That is because you are only supposed to use CCDs on objects that are too faint to be seen through the telescope by unaided eye. Focusing CCDs is very difficult, but that is tolerable since they are worse at capturing detail than the grainiest film.

Only with shaft encoders can an astronomer hope to point a telescope accurately enough to capture the wonders of the deep sky with a CCD. "But the Andromeda Galaxy is so large," you say. "How could you miss it?" Actually the only part that stands out in light polluted skies is the nucleus, which is the size of Vancouver as seen from the distance of Toronto.

Never Say DIE

In all fairness, it should be stated that not all encoders are troublesome and unreliable. Some are a lot worse than that!

In order to avoid a potential lawsuit, I will not identify the firm who made my encoders. I will simply refer to them as the "Devil's Impious Engines," or DIE. Make that "Diabolical Instruments of Enslavement." How about "Damnation, Incessant and Eternal?" That has a nice ring to it.

When it comes to quality, DIE's products are said to speak for themselves. Unfortunately, what they want to say is "Help!" The quality assurance (QA) people are, without fail, the first in an unhealthy firm to show the signs of organizational breakdown. They can mess up reams of perfectly good paper before the front office can fire them. DIE's QA inspectors examine every nut, bolt, and washer, so at least you know you have reliable bolts. But, who allowed the production-line workers to leave vital connections unsoldered? And what about the lump of drilling swarf that I found lodged between the pins of a hex-inverter chip? On the bright side, FBI investigators have cleared DIE of any wrongdoing in the crash of TWA Flight 800.

Hard-Luckware

After one supremely frustrating evening with the telescope, my supervisor and I removed one of the encoders for examination. To our surprise, the anti-shock fitting that coupled it to the declination axis came apart in two pieces. That is not the sort of misfortune that should befall a shaft encoder. There was some 5-minute epoxy in the toolbox, so I used it to bond the fitting back together. Here is a tip: never use 5-minute epoxy to repair anything your life might depend upon, or you will be dead in 5 minutes. Use the 24-hour stuff to give yourself enough time to put your affairs in order.

If you want reasonable resolution from your encoders, it is necessary to gear them up. Rather than buy good gears, the telescope maker had mounted hockey pucks on the encoders so that they would roll on the scope's shafts. As any child who has played hockey will tell you, hockey pucks are not at all resilient in a Canadian winter. Their prerogative is to slide, not roll.

"The telescope maker had anticipated such frequent and total loss of control. If the telescope does get into one of its spins, the wiring can never be yanked out because it is all in curly cords like the one attaching the receiver to your telephone. Some would call this engineering pragmatism."

For his computer port, the telescope maker selected the Glitch-U Model 5 made by Giga-Gremlin Corporation. It was not a good choice. By releasing the Model 5, Giga-Gremlin set out to destroy any illusion in the customers' minds that a serious product was on offer. Our Model 5 would register a 7000° motion when the astronomer rotated the dome. Similar glitches occurred if the telescope was wiggled a little, or even if it was moved gently and carefully in one direction.

The wiggling business came to a head one afternoon when I was washing bird droppings off the telescope. (West coast wildlife is feared and respected by astronomers! Last year some mud-dauber wasps erected a nest on the primary mirror of my friend's Cave. He was able to scrape it off, but they rebuilt it within a few weeks, which should give you an indication of the number of clear spring nights we get.) In any event, I smeared some washroom soap onto a paper towel and started scrubbing. Although the parking brake on the telescope was set, the polar axis was free to wiggle a little. When I glanced down at the computer display, it indicated a three-point change of heading to the east. There I was, and with bird droppings everywhere as well. To add insult to injury, the birds came back and fouled the telescope all over again.

That was actually a blessing in disguise. I already knew that the encoder's signals would confuse the Glitch-U in similar circumstances. There was a circuit in the Hewlett-Packard literature that would help, but it had three TTL chips — obviously too complex, too risky. But, having nothing better to do, I decided to build it. That led to more problems.

The Telescope Dome as Safety Guard

There is an old joke about a broom that lasted fifty years. The brush was changed seven times and the handle five. The same thing happened to me. The software that came with the telescope was unrecognizable by the time I had it working more or less reliably. Very few of the original bits survived.

In a word, the software was awful. The main control program was written eighteen years ago for the Apple II and was like spaghetti. The hardware-test program that we desperately needed for analyzing the encoder problems did not work at all. Whenever we tried using it, the floating-point routine would issue a range-error message. That bug had me stymied for the longest time. I stared at it year after year until, out of the blue, a gestalt shift came over me and I was able to understand what was going on.

The MBF floating-point standard that Bill Gates employed in early Microsoft products always takes one of two states: "Me" or "Nobody." Gates eventually dumped MBF in favour of the IEEE format that Intel had etched into millions of its math chips. Nobody told Giga-Gremlin, however. G-G's driver software worked fine with MBF, but faltered when it encountered IEEE. That led to a crisis which the telescope maker barely managed to resolve with undocumented PEEK and POKE kludges. So the control program worked, but only sort of. You would not dare to take your eyes off the telescope whenever the old software was in use. If one of the encoders ceased to send pulses, the software behaved in the finest traditions of fault-tolerant computer engineering — it would whip the telescope about the dome in a blind flail.

There were tragedies, to be sure, but one accident had its comical overtones. Once when the facility was left temporarily unsupervised, the software ordered the Cassegrain to attack a large Dobsonian telescope sitting on the observatory floor minding its own business. Simply charging into its plywood rival was out of the question, since the collision would have simply bumped it out of reach. So our big Cassegrain gently nuzzled up to the Dob, pinned it against a bench, and tried to push it over. The Dob stood its ground. The only violence the Cassegrain could accomplish was knocking the teeth off its own gears.

The telescope maker had anticipated such frequent and total loss of control. He had provided a solid mounting cell that would support the heavy main mirror even if the telescope was pointed straight down. If the telescope does get into one of its spins, the wiring can never be yanked out because it is all in curly cords like the one attaching the receiver to your telephone. Some would call this engineering pragmatism.

The day finally arrived when the Hewlett-Packard circuit was connected to the encoders. Holding my breath, I switched on the telescope. Would it work? Would it be the end of my troubles? No. Everything that was bad before was now worse. Get the oscilloscope. Probe the wiring. Make modifications. Switch on. Another failure — this time total. Yipes! More probing. Head scratched raw.

All of a sudden there it was — a ground loop. I almost kissed my oscilloscope. The wires in the curly cords were small and flexible, so they had a lot of resistance. The resulting voltage drops had compressed the encoders' logic levels just enough so that the Schmitt-triggers in my circuit were triggering. A heftier curly cord from a defunct PC keyboard solved the problem.

Epilogue: About One Crisis Per Annum

Eight years have passed since the telescope was delivered. Here is a summary of the actions taken:

1. epoxied an anti-shock fitting together,
2. replaced a slipping rubber puck with gears,
3. epoxied the anti-shock fitting again,
4. reflowed cold solder joints,
5. blew out dust, swarf, and loose bits of solder,
6. put spike suppressors on the dome motors,
7. rewrote the computer software,
8. installed a signal conditioner, and
9. beefed up a curly cord.

And that was just for the declination encoder.

The telescope eventually started to work quite well, until a measly 4-40 set screw came loose. It turned out that a child had attempted to slew the 1,000-kilogram telescope by grabbing one of the encoder step-up gears. That was my fault for not putting a tamper guard over them.

By themselves the encoders actually did not function that badly. It was simply that the telescope was poorly engineered. Fancy electronic flim-flammery usually works well enough to bluff the buyer though the warranty period, but this telescope worked badly from day one. We should have taken warning from the initial peccadilloes — bad paint, clock drive going backwards, that sort of thing — just as we have been trained to do with politicians.

So we bid farewell to the astronomer's unloved and undrowned pet, the electronic shaft encoder. We now return control of your favourite publication to you.

Dan Collier is the National Council Representative for the Vancouver Centre, having served on the Centre's Council for seven years now. He has been a member of the RASC since 1989, although his interest in astronomy began in the 1960s. Born in Calgary, he is an engineering graduate of the University of British Columbia, and is currently (no pun intended) a self-employed electrical engineer. Dan takes care of the 50-cm Cassegrain telescope of the G. Southam Observatory, and conducts public observing nights there each week.

Childhood Memories of a Not-So-Famous Scientist

by Orla Aaquist, Keyano College, Fort McMurray (Orla.Aaquist@keyanoc.ab.ca)

I am not a famous scientist, although my plan out of high school was to become one. We sometimes read about how famous scientists were first inspired to pursue science as a career. In the quiet of my basement office, while waiting for research to happen, I began to ponder the events that determined my destiny. How different is my background compared to someone more renowned in the field, like Einstein or Feynman? Do famous scientists have a more colourful or interesting childhood than scientists who are not so famous? More to the point, "Why the hell am I not a famous scientist?"

"We sometimes read about how famous scientists were first inspired to pursue science as a career. In the quiet of my basement office, while waiting for research to happen, I began to ponder the events that determined my destiny."

As soon as I posed the question, however, I realized that it was not something I could answer in a few thousand words, nor in the time frame required for the completion of this column. To answer such a question, I would have to study the childhood memoirs of many famous scientists, and then I would have to interview many not-so-famous scientists and summarize their backgrounds. Then I would have to formulate some basis for comparison and write a paper or a book on my findings entitled, "A Comparison of Childhood Memories of Not-So-Famous Scientists with Those of Famous Scientists." Such a project would require me to travel extensively, seek out many not-so-famous scientists, extract their childhood memories, and write them down. Gosh, what a task! But wouldn't it make an interesting project? Wouldn't you want to read such a book?

Perhaps I can start by printing a brief account of my own childhood. Perhaps that will inspire others to summarize their early memoirs and send them to me for analysis. Perhaps I will obtain many responses and I will write a paper wherein I come to understand my own lack of success as a scientist. Perhaps the paper will make me famous, and I will join the ranks of *Famous Scientists.* In doing so, will I have invalidated my own research and lose my fame, thereby… becoming a famous barber who shaves every man who does not shave himself?

Until I was 18 years old, I did not know that I wanted to become a physicist, and it was not until I was 33 that I decided to study astronomy. It was pure coincidence that I fell into radio astronomy. I was off to a late start.

At the age of 17 I wanted to be a chemist because I had been playing with chemistry in my parents' basement since the age of 14. The love of science had come to me at the ripe old age of 13 in grade 8 science while dropping paperclips into a beaker that was already full of water, but seemed, somehow, to hold an unreasonable number of paperclips. I thought that the paperclips fit between the molecules of water. You see, I had not yet discovered surface tension, and I did not notice the build-up of water at the rim of the beaker. At the age of 13, the concept of paperclips fitting between molecules of water produces a much more appealing theory than surface tension.

Before the age of 13, my only scientific pursuits were in the field of reverse engineering and examining the effects of light refraction through a magnifying glass. When I was 11 years old, I received my first wristwatch, a new Timex. My older brother, Bent, got one too. After only a few days, his watch broke. When he wound it up, the minute and hour hand raced furiously around the face of the watch. I was so jealous! I wanted to trade with him, but he worked on the principle that any opportunity to torture and tease a little brother cannot go denied. So I set out to discover how my watch could be made to function in a similar fashion. That very afternoon, I ran up to my mother in great excitement proclaiming, "Look mom, my watch is now just as good as Bent's." She was not nearly as pleased as I was.

As for the episode with the magnifying glass, at an age of 9 or 10 I determined that a magnifying glass could focus the rays of the Sun and burn holes in dark, dry things. In particular, carbon paper could be made to burst into flames in just a few seconds of exposure. I spent many happy hours discovering what would burn and what would not. For example, white wet things hanging from a clothesline were not so easily affected by the heat-ray as dark, scurrying things. At one point I wondered just how long it would take for the white wet things to be scorched. I suppose that was my first true experiment. My mother never did catch me, but I do remember her wondering about several small holes in her new sheets.

What led me to the process of experimentation? It may have been my study of projectile motion a year earlier at the age of nine. It happened during a warm summer day when I borrowed my brother's new BB gun. It looked just like a Winchester rifle. You cock the lever below the trigger and the gun is loaded. A BB (a round pellet of copper) falls into the base of the barrel and air pressure builds up in a chamber. When you pull the trigger, the pressure is released and the pellet is forced out of the barrel to travel in an arc towards the target. Two things became obvious on that summer day. The first was a basic principle of projectile motion: "In order to hit the target you have to aim above the target." The second was Murphy's First Law of Motion: "If you aim at a target that you are not supposed to hit, then you are sure to hit it no matter how bad your aim or how far the target." In addition to the window, I aimed at a robin high up in a tree, way across the yard on the other side of the barn. To my horror, the robin fell to the ground. I had hit the poor bird right in the eye. I felt terrible, so I gave up shooting at living things. I decided to use my mother's laundry for target practice. That may have had something to do with the fact that I could easily recover and reuse the oily little pellets. I do not recall ever using the BB gun after then.

After learning about surface tension in grade 8, my next big boost into the world of science came with the discovery that I was the only student in my eighth grade science class that could balance chemical reactions. My teacher was so impressed that he let me help clean up the prep room at the back of the science lab. Lucky me. It was there that I was first exposed to real research. I set out to study "The Life Cycle of a Common House Fly" for entry into the local science fair. Unfortunately, the life cycle of my fly was only two days. I found the fly lying, unmoving, at the bottom of its jar. When I reached in with a pencil and poked at it, a white wormy thing squished out of its abdomen. And, my gosh, the white wormy thing moved! Yuck! Neat! Was it something new? I searched with great excitement for Mr. Harrison, my science teacher, but as is the case with many great scientific discoveries, no one is there to witness the event. I could not find him. When I came back the next day, the white wormy thing was all shriveled, and Mr. Harrison had no idea what it could have been. After that, I spent weeks, squishing flies, but the white wormy thing never re-emerged. I was very disappointed and I lost complete interest in biology. What a sad thing to happen so early in life.

Thereafter my interest in chemistry blossomed because my parents gave me a chemistry set for Christmas. So my research shifted from the science prep room at Welling Junior High to my parents' basement. Here I discovered the basics of chemistry: how to mix acids and bases to produce colourful salt solutions, and how to make carbon dioxide, oxygen and hydrogen. I think it was the first little explosive pop from my homemade brew of hydrogen and oxygen that attracted me to explosives. I obtained a book about them from the library and learned that my chemistry set had all the ingredients of gunpowder, except for carbon. But how difficult could it be to find carbon? For some reason I was never very successful with the mixture. My experimentation with the stuff, however, did teach me that it is not a good idea to dry gunpowder in my mother's oven, and my mother learned that it is a good idea to check the oven before turning it on.

After gunpowder became illegal at home, I discovered a great substitute: equal volumes of saltpetre and icing sugar. While my parents were away, I launched several rockets from my back yard using the mixture, but I became a little nervous when one of them actually traveled more than a few feet to land on our neighbour's house. It lay there, on the rooftop, smoldering. I almost phoned the fire department, but hid in the basement instead. Periodically I peeked out of the window to see if the situation was "under control." Luckily nothing happened, but it put a sudden end to my exploration into rocketry. Just think, had I not been frightened off, today I may have been working for NASA or the Canadian Space Agency.

Come to think of it, I spent a lot of time in my parents' basement doing things I would never let my own kids do. For example, I remember building a carbon arc from the carbon stems in a couple of old batteries. For power I used household current. Yup, that blew the fuse, but my parents were not home, so I continued. A step-down transformer was needed, but I did not have one, and I was in a hurry to "create light." I did not properly understand transformers anyway, and I figured that a big resistor would do the trick just as well.

I can hear some of you screaming, "Nooooo!" Actually I wanted a large variable resistor so that I could adjust the voltage across the carbon rods until I got the promised light without blowing the fuse. Two electrodes in a salt solution did the trick. By varying the distance between the electrodes I created my variable voltage, and after just a few adjustments (starting with the largest separation, of course) the carbon arc lit up the darkness of the basement. I was absolutely impressed at its brilliance. Although I did see the light, the remembrance of its creation still frightens me. So I keep a close watch on my own children. With the advent of Nintendo and 103 cable channels, however, there is very little chance that they are going to burn the house down.

In grade nine I took shop. In shop I built a metal box, a wooden box and a laminated fruit bowl. My mother still has the laminated fruit bowl. I also discovered radio waves. On one table in the shop the shop teacher had assembled a crystal radio consisting of an antenna wire strung across the shop's ceiling, a ground wire attached to the plumbing, a diode and earphones. When I put on the earphones I could hear the local radio station. So, for my 15th birthday my parents gave me an electronics kit that enabled me to build my own crystal radio, one that could be tuned. I spent some time trying to understand amplitude and frequency modulation, and then I was inspired to build a proper radio, one with vacuum tubes (now you know how old I am). Building the radio was fun, but trying to improve it was more fun. To a 15-year old, improving consists of "let's see what happens when we remove this element from the circuit." So, by the age of 15 I had discovered that there are several components in a radio that have no apparent function. I also discovered that it is a bad idea to work on an electrical device while it is plugged in. That revelation came one day when I was home alone. I was sitting at the kitchen table experimenting with my radio poking at the underside with a screwdriver. I had learned earlier that eliminating a device from the circuit could be achieved by shorting out the device, and that is what I was trying to do with the screwdriver. Somehow my free hand came in contact with the metal chassis and my working hand came in contact with the metal shaft of the screwdriver. I clearly remember the thought that raced through my brain. I thought that my brother had come home, sneaked up behind me and grabbed my shoulders. He did that on occasion, and I would like to report to you that the effect is very similar to 120 volts pushing alternating current across your chest. Fortunately, the screwdriver connection was precarious, and I found myself alone in the kitchen. I unplugged the radio and discontinued my research into radio waves until I was 33 years old, at which time I became a radio astronomer at The University of Calgary.

One last thing: as far back as I can remember I have had the desire to push buttons just to see what they do. It just seems to me that if someone put a button onto a device, then it is meant to be pressed. I have developed a very loose definition of "button," however. For example, at the start of term I received an order of AlNiCo magnets that my students will use to fish steel bearings out of a glycerin tube after their viscosity experiment. As I was unpacking the magnets, into my head popped a silly idea, "I wonder what will happen if I bring a magnet close to a computer monitor?" The temptation is similar to that of putting your wet, warm tongue on a frosty, playground monkey bar. I became aware of the monkey-bar "button" in grade six when one of the less bright male students, probably on a dare, yielded to the temptation. Of course, the magnet did not stick permanently to the monitor, but the weird colour pattern did. Now, do not be overly hasty to judge me. I have learned something over the years, you know. I ruined one of the old lab monitors that I hope my college will replace, and not my new 17-inch office monitor.

Orla Aaquist is the physics instructor at Keyano College in Fort McMurray. His rather varied career has included periods as an undergraduate at the University of Alberta (B.Sc.) and Queen's University (B.Ed.), a graduate student at the University of Calgary (M.Sc., Ph.D.), a high school teacher of physics and mathematics in Toronto, and "telescope instructor" at the Calgary Centennial Planetarium.

CALL FOR PHOTOS — 2000 RASC CALENDAR

Photos for the year **2000 RASC Calendar** will be selected in early May 1999, in anticipation of an early June press run.

All members of the RASC are encouraged to submit astronomical photos for consideration. Images can be of any type – deep-sky or solar system; prime-focus, piggyback, or fixed-tripod; emulsion- or CCD-based.

In order to preserve the highest quality possible, film-based images should be submitted as 8- by 10-inch prints. Electronic versions of these images may also be submitted, but prints should be available on request. CCD images may be sent in any standard electronic image format.

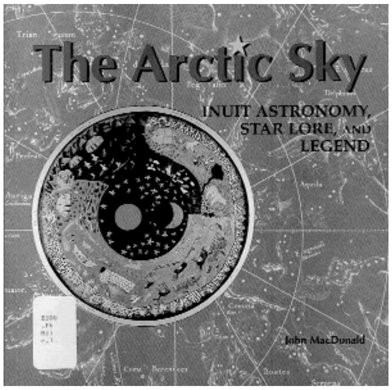
Prints, CDs, or disks (1.44 megabyte floppies, 100 megabyte Zip disks) should be sent to:

Rajiv Gupta
2478 W. 1st. Avenue
Vancouver BC V6K 1G6

so as to arrive by April 30, 1999. Electronic images under 1 megabyte in size may instead be sent by e-mail to gupta@interchange.ubc.ca. For further information about submissions, please contact me by email or by phone at 604-733-0682.

Rajiv Gupta
Editor, RASC Calendar

Reviews of Publications
Critiques d'ouvrages



The Arctic Sky: Inuit Astronomy, Star Lore, and Legend, by John MacDonald, pages ix + 313, 21cm×21cm, Royal Ontario Museum / Nunavut Research Institute, 1998. Price $29.95 soft cover. (ISBN 0-88854-427-8)

Long before the existence of electric lights and snowmobiles, a working knowledge of the night sky was an essential facet of life for Canada's northern peoples. Entire families accompanied hunters on excursions lasting for days. During a journey by dogsled, the father pointed out celestial objects and related their associations to his children. At the end of the travel day, while he built the nightly igloo, the mother told the children stories of the sky.

Today, streetlights reflecting from snow wash out the night sky in many northern communities as effectively as they do in the south. Meanwhile, snowmobiles have transformed hunting expeditions from leisurely family occasions to brief solo trips. Little by little a rich oral tradition of Inuit astronomy is dissipating. Fortunately, some of that tradition has now been preserved in this fascinating and thoroughly researched book.

John MacDonald, a manager at the Nunavut Research Institute, was first attracted to Inuit star lore by an interest in celestial navigation. From 1988 to 1997, as part of an oral history project, he conducted interviews with Inuit elders in the eastern Arctic settlement of Igloolik, and gathered the material that forms the foundation of this unique book. The material is further supplemented by accounts from Inuit living in other parts of the Northwest Territories, Northern Quebec, and Labrador. For comparison, MacDonald also consulted a selection of published or archived works, including the Royal Navy journals of Captain William Parry and the writings of ethnographers, Knud Rasmussen and Diamond Jenness.

Throughout the book, MacDonald links Inuit astronomical terms and star names to their European counterparts, using the context in which they were described to identify the more familiar stars or constellations. Names appear in Inuktitut, the language of the Inuit. (Indexes, arranged by the Inuit or European names, assist the non-Inuit reader.) Admittedly, the Inuktitut names are difficult to read and one tends to skip over them once it is clear which celestial object is being described.

The Inuit recognize thirty-three stars, two star clusters (the Hyades and the Pleiades), the Orion Nebula, and the Milky Way. Only six stars — Vega, Rigel, Aldebaran, Polaris, Procyon, and Sirius — have their own names. The remaining stars are absorbed into sixteen constellations that roughly overlap with Ursa Major and Ursa Minor, Aquila, Lyra, Boötes, and others. Taurus and Cassiopeia each have two versions in Inuit star lore, Orion enjoys three variations, and Gemini and Auriga have been combined into one unique constellation. The planets do not enjoy any special prominence in northern sky lore and are known collectively as "great stars."

MacDonald includes accounts of the Sun and Moon and eclipses, atmospheric phenomena, navigation, and time. The Sun and Moon are the most prominent characters in Inuit celestial lore. Unlike Greek mythology, the Sun is believed to be a woman and the Moon a man. Like their Greek counterparts they are brother and sister, but are caught up in an unwanted incestuous relationship that ultimately propels them into the sky. Several celestial objects and phenomena are explained by dysfunctional family relationships or are given simple, earthy interpretations. In all, three chapters are devoted to legends told by Igloolik Elders, their transcriptions in Inuktitut, and more legends from published works. The legends have slightly different versions, and their retelling sometimes feels repetitive.

The author tells us that artificial landmarks, like radar towers and radio masts, have now displaced the stars as beacons of navigation for younger hunters. Interviews with Igloolik Elders showed disagreement in the importance of the sky for wayfinding. Ironically, the book reveals that Polaris, known for its reliability in middle latitudes, is too far above the horizon to function as a directional marker in the high Arctic.

In addition to the stars, the book identifies other environmental cues that have been used as aids to orientation in the north, such as snow drifts, sea currents, the aurora borealis, and animal behaviour. Two optical effects included in this category are "water sky," caused by the reflection upward of the bright land-bound ice, in sharp contrast to the dark, open water beside it, and "looming," the inverted image of an object above the horizon produced by light refraction. (Occasionally, basking walrus can be spotted on the "looming" ice.)

Time of day in the north is traditionally told by Ursa Major (known by the Inuit word for caribou) revolving around Polaris and by the rising and setting of the non-circumpolar stars. The twenty-four hour cycle is divided into ten unequal segments, influenced by daily activities as much as by the Sun's position. Such traditional methods of timekeeping have been superimposed by European calendars and clocks that are used by the Inuit with varying levels of devotion.

The Inuktitut language has no word for "time" in the abstract sense. The author relates an anecdote about an official regaling an audience in an Arctic Québec community with the virtues of efficiency. His expression "time is money" was translated by his interpreter as "a watch costs a lot." Inuit do, however, measure time according to their needs. Nature's response to the solar cycle regulates northern life. Residents of Igloolik recognize thirteen Moon months and eight seasons that are associated with animal migrations and other seasonal changes, as well as social activities. *The Arctic Sky* includes a table associating the Moon months, seasons, celestial markers, biological and environmental markers, and selected social activities. For example, in early spring (upirngaksaaq) the increasing twilight renders the stars invisible, snowfall increases, jar seal pups are born, and Inuit baseball is played. The Inuit Moon month at that time, corresponding roughly to April and May, is named after the Inuktitut word for seal pups.

MacDonald states that the material in *The Arctic Sky* is presented for those who may value an alternative point of view to European star lore. The book is also informative as an account of the changing way of life in northern Canada. Interspersed throughout its pages are attractive colour photographs of Inuit art from the Royal Ontario Museum.

Material gathered in the oral history project that resulted in this book is now being used in Inuit schools in Canada's eastern Arctic. Perhaps this more formal means of transmission will help preserve traditional knowledge of the northern sky.

Diane A. Brooks

Diane Brooks is an Information Specialist with the Internet team at Indian and Northern Affairs Canada.

Fire in the Sky: Comets and Meteors, the Decisive Centuries, in British Art and Science, by Roberta J. M. Olson and Jay M. Pasachoff, pages xiv + 369; 20.5 cm×29 cm, Cambridge University Press, 1998. Price: US$74.95 hardcover. (ISBN 0-521-63060-6)

As its dust jacket proclaims, this product of a contemporary collaboration between an art historian and an astronomer aspires to "bring together the language of aesthetics with science for a greater appreciation of the works described." But, while readers are promised "a feast of celestial images," what they will find in *Fire in the Sky* is a lot of low contrast black and white pictures plus about 30 colour plates of average palatability.

The selection criteria for which items are reproduced in colour are obscure. For example, the authors devote to William Blake more than twenty-five pages that include ten of his delicious watercolors reproduced only in black and white. They include only one painting of Blake's in a colour plate, and that one happens to be murky. Yet they display two paintings of Donati's comet, which, in spite of being blue, are essentially intensity contrast images and therefore do not require the available range of colours.

If the text portion of the book is also to be described as a feast, it is a substantial meal but difficult to digest. Although the language is academically precise, the information about both the art works and their scientific context is often inaccurate and disordered. When one author finds a tasty but vague or misleading expression, it seems the other author spices it with his or her own understanding. Both authors are guilty of leaving out crucial ingredients while simultaneously using too many. (It is mildly annoying not to be told the nature of Arabella Stuart's tragic destiny, and yet be confronted in the next paragraph with the Earl of Haddington's curriculum vitae. In a similarly irritating passage, a discussion of telescope optics implies that no observatory built since the 1930s has any need to resurface its mirrors.) Strict adherence to chronological order is another weakness of the narrative, which scatters individual topics across the book. For example, Blake's work is described in two different chapters, with Caroline and William Herschel inserted part way through his life.

The book comprehensively documents artifacts from Britain concerned with comets and meteors that occurred over the Enlightenment, the Georgian, and Victorian periods. It is hence appropriate for anglophiles searching for examples of maps, portraits (of famous scientists or that include comet heraldry), illustrations by gentlemen (astronomers or otherwise), paintings of comets by artists (famous and anonymous), cometaria, satirical engravings, illustrated poetry and political commentary, tankards, valentines, historic photographs, and extensive footnotes. Although the British were eating up comets during the period in question, most of the artifacts, like the work of Blake, were made in response to "a symbolic tradition in literary and visual arenas." Nevertheless, the authors can enumerate practitioners simultaneously of art and science, as well as societies that spanned both disciplines. Unfortunately, their descriptions fail to illuminate the perspective of a time when the liberal arts were categorized under science. (For a revealing essay on the topic, see Lorraine Daston's "Fear and Loathing of the Imagination in Science" in *Daedalus*, Winter 1998.)

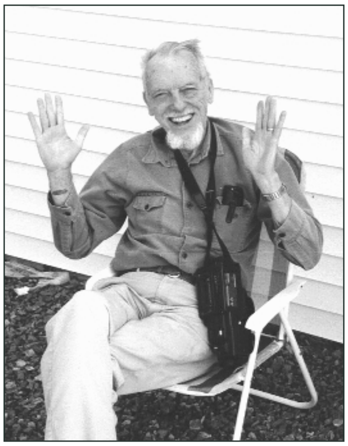
At times scholarly work has been converted into savory material for the public, but such is not the case with *Fire in the Sky*. Although it offers some nourishment for readers who fill their plates cautiously, the book is not an especially delectable feast celebrating the zest of visual art and astronomy, either separately or together. Packaged like a cornucopia of tasty tidbits, appropriate for adorning the coffee table, it belongs on the bookshelf with the encyclopedias and other dry pedagogical preserves.

Jayanne English

Jayanne English has a "three degree background" appropriate for someone with a serious interest in both art and science. After graduating from the Ontario College of Art, she received a B.Sc. at the University of Toronto and a Ph.D. in astronomy and astrophysics at the Australian National University (using modern telescopes that were resurfaced every several months). During her post-doctoral years at Queen's University, she became known for facilitating collaborations between scientists and the arts community. Currently she is at the Space Telescope Science Institute and is involved in the "Hubble Heritage Project" (`heritage.stsci.edu`*).*

Obituary
Necrologie

Murray Cunningham



Murray Cunningham, during a visit to the Halifax Centre's St. Croix Observatory during its construction in the fall of 1996.

Murray Cunningham (1923 – 1998), beloved Honorary President of the Halifax Centre, RASC, died on June 5th, 1998. Dr. Cunningham was educated at the University of Toronto and spent at least one winter working at the David Dunlap Observatory. He enjoyed telling the tale of his winter working as a student at the observatory, living near the observatory, with Farley Mowat, in a tunnel in an embankment.

Murray graduated from the University of Toronto Medical School in 1947. He did general practice in Saskatchewan, then postgraduate studies in radiotherapy in London, England, and on returning to Canada, practiced in Montreal. He spent two years in Rangoon, Burma, establishing a cancer treatment and radiotherapy unit. He joined the staff at the Victoria General Hospital in Halifax in 1961, until his retirement in 1986, and was physician-in-charge for several years.

He was a man of many interests: music, painting, sculpting, flying (he built and flew two light aircraft and used them in a "flying doctor" capacity during his years of practice in Saskatchewan), drama, woodworking, pottery, natural history, and politics. He had a lifelong interest in astronomy, and even as his health began to fail his passion for astronomy remained very strong.

Murray was a life member of the RASC and unique, in that he was the only active "bridging" member — one who was actively involved in the Halifax Centre during both of its incarnations. He was most active and a key supporter of the Centre when it was reborn in the early 1970s. His enthusiasm and support could be counted on for any and all Centre activities during those years. He occupied almost every executive position on the Centre Council at one time or another, including a couple of years as the Centre President. He often wrote articles for the Centre newsletter, and was a frequent and enthusiastic speaker at Centre meetings. His active participation, enduring support, keen enthusiasm and sense of humour ensured that he was well loved by the entire Centre membership. One Halifax Centre member summed Murray up nicely by calling him "my Reader's Digest Most Unforgettable Character."

Murray Cunningham was a true friend of the Halifax Centre and he will be greatly missed.

Mary Lou Whitehorne

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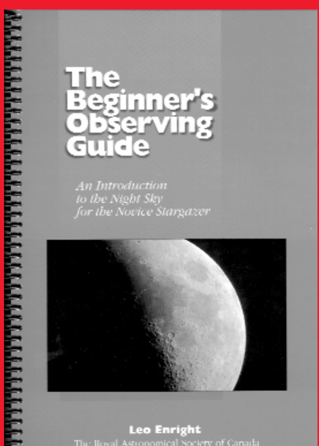
Promotional Items

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



The Beginner's Observing Guide

This guide is for anyone with little or no experience in observing the night sky. Large, easy to read star maps are provided to acquaint the reader with the constellations and bright stars. Basic information on observing the moon, planets and eclipses through the year 2000 is provided. There is also a special section to help Scouts, Cubs, Guides and Brownies achieve their respective astronomy badges.

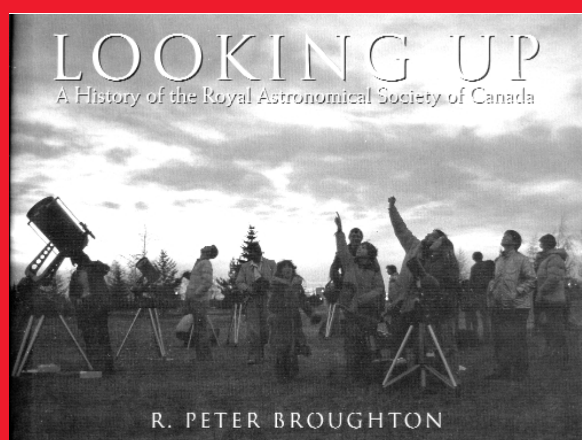
Written by Leo Enright (160 pages of information in a soft-cover book with a spiral binding which allows the book to lie flat).

Price: $12 (includes taxes, postage and handling)

Looking Up:
A History of the Royal Astronomical Society of Canada

Published to commemorate the 125th anniversary of the first meeting of the Toronto Astronomical Club, "Looking Up — A History of the RASC" is an excellent overall history of Canada's national astronomy organization. The book was written by R. Peter Broughton, a Past President and expert on the history of astronomy in Canada. Histories on each of the centres across the country are included as well as dozens of biographical sketches of the many people who have volunteered their time and skills to the Society. (hard cover with cloth binding, 300 pages with 150 b&w illustrations)

Price: $43 (includes taxes, postage and handling)



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