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Journal

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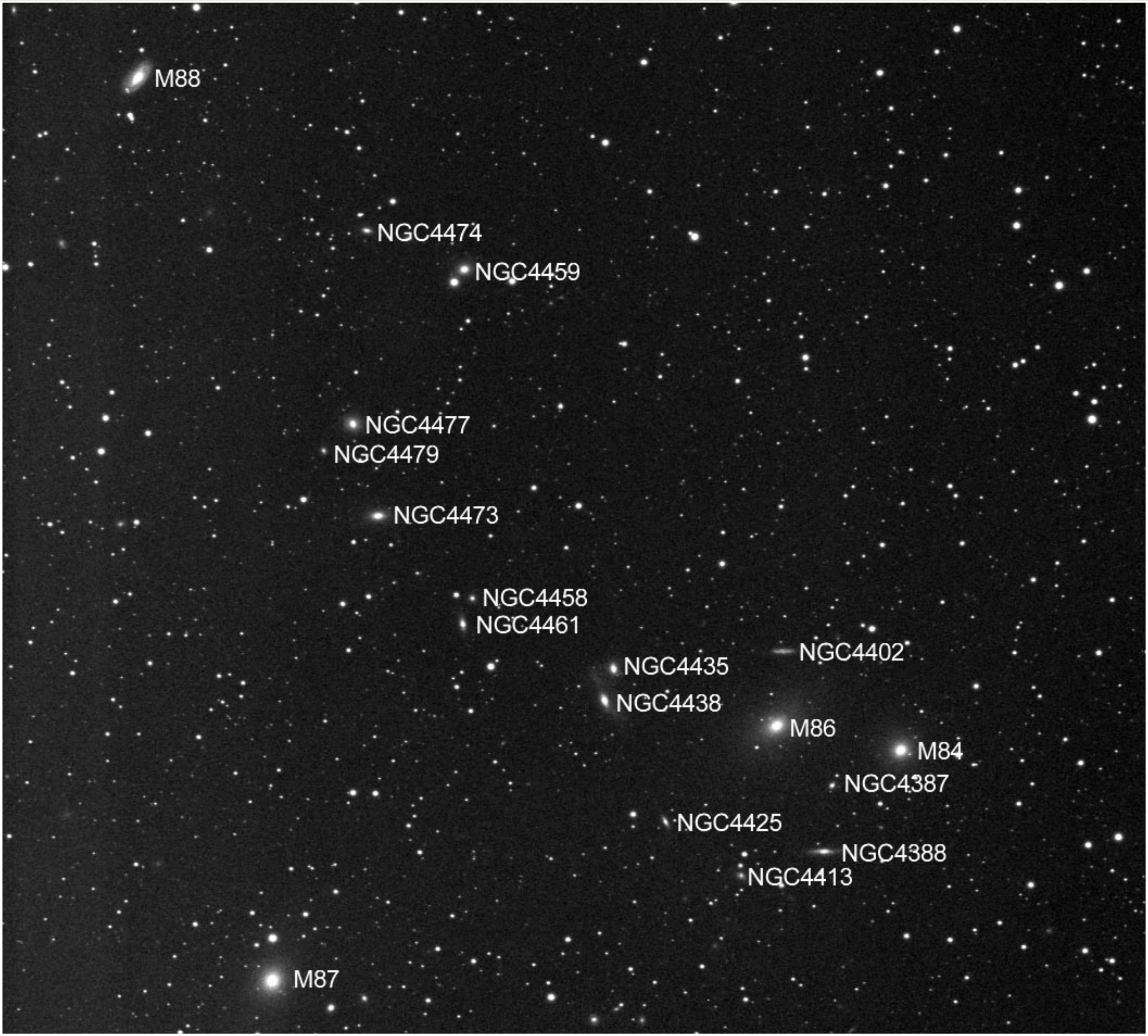

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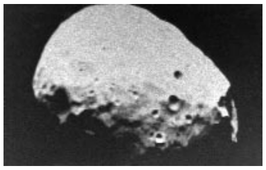

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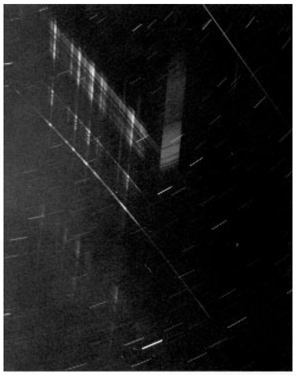

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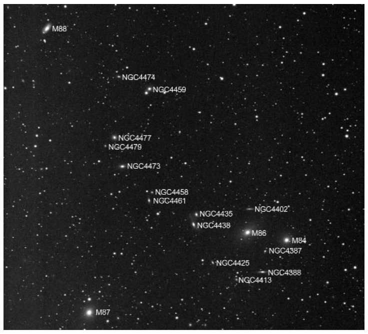
ACROSS THE RASC
DU NOUVEAU DANS LES CENTRES

Cover Photo:
The heart of the Virgo
Cluster of Galaxies.
See page 99.

(photo by Peter Ceravolo)



From the Editor

by David Turner

I was walking through the corridors of my home institution a short time ago when my eyes were drawn to a printed message posted on a bulletin board. The message was an announcement and call for papers for the 1998 meeting of CASCA to be held in Toronto. Although CASCA, the Canadian Astronomical Society/Société canadienne d'astronomie, is known to hold its annual meetings at various locations across the country, I knew that the 1998 meeting was being held in Québec. I was also standing outside the offices of the Department of Anthropology at the time. It seems that the "other" CASCA, the Canadian Anthropology Society/Société canadienne d'anthropologie, is holding *their* annual meeting in Toronto in 1998.

Abbreviations and other shorthand designations are fairly commonplace in today's world, perhaps more so in astronomy and other sciences. Yet sometimes it is difficult to keep up with the changing terminology. At one time, for example, the abbreviation CCD, which is now commonly employed to designate the charge-coupled device, was used by photometrists to denote a colour-colour diagram. The alternate term for the latter, the two-colour diagram, is now abbreviated to TCD in the astronomical literature. Doubtless it has many other meanings as well. Although professional astronomy is replete with such terms and unit abbreviations — *e.g.* AU, CFHT, kpc, mas, etc. — the amateur side of the field also has its share of jargon — *e.g.* GA, ECU, Dob, etc. The problem, as noted by Halifax Centre member David Chapman, is that the frequent use of such jargon may act as a deterrent to those who have demonstrated an initial interest in astronomy. At meetings of the RASC the terminology sometimes flows so thickly that it may be dissuading many who are new to the field from learning more about the RASC and its activities. Where jargon and terminology are minimal, interest is more easily maintained. The success of television's *Star Trek* series and its spin-offs may be a good example of how to avoid the abuse of jargon. There the term warp drive is never referred to as WD, and Ferengi Rule of Acquisition number six is never designated FRA 6.

A new provider, Redgull Integrated Design, headed by Brian Segal, a long-time astronomy enthusiast and a former member of the Halifax Centre, is now handling the assembly of the *Journal*. The basic concept for the "new" *Journal* developed in 1997 with input from Strategic Ink remains unchanged, but certain modifications to the layout, design and typeface will be evident. The future of some changes may depend upon their associated costs as well as how well they are received by RASC members. Feedback would be appreciated.

In time-honoured journalistic fashion we have included an April Fools' item in this issue, a practice initiated with the April 1997 issue. Despite the reputation of the writer, this editorial is *not* the item. ◉

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.

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President's Corner

by Douglas B. George

Thanks to El Niño, it has been a very bad winter for observational astronomy in many parts of the country. The phenomenon is also a prime suspect in the ice storm that left many members in my part of the country freezing in the dark. There was one silver lining in all this: a few hardy members reported doing some observing without the adverse effect of light pollution! Perhaps we can look forward to more clear skies in the coming spring.

The February National Council meeting was a mostly quiet affair — one of the rare occasions when the meeting ended early. There are a few highlights to report.

On the recommendation of the Awards Committee, National Council approved Society awards for a number of members. Our most prestigious award, the Chant Medal, will be presented to Bertus Rhebergen of the Hamilton Centre for his long-term solar observing program. Service Awards were approved for Sandy Ferguson of the Saskatoon Centre, David Lane of the Halifax Centre, and Roger Hill of the Hamilton Centre. I have known all three of the Service Award recipients for many years and all are greatly deserving of the honour.

Also approved were Messier Certificates for Christopher Fleming of the London Centre and Randy Klassen of the Vancouver Centre, plus the NGC Certificate for Douglas Stuart of the Thunder Bay Centre.

The RASC finances are in very good condition. Our Treasurer, Rajiv Gupta, presented the financial statements for 1997 and the budget for 1998. Last year came in with a solid surplus, and a surplus is also forecast for next year. However, there are some dark clouds on the horizon; for example, the Federal Government has changed the rules for its Publications Assistance Program. The new rules are not compatible with our fee structure, and thus the RASC will no longer qualify for the lowest postal rates. That will increase our postal costs for the mailing of the *Journal* substantially.

The University of Toronto Press membership database services were reviewed. In most cases the system worked well over the past year; overall the membership renewals came in significantly faster than in previous years. However, there were some problems, especially with a number of Toronto Centre members. We are working with U. of T. Press to make improvements, and hopefully the system will work even better next year. Most importantly, David Lane of the Computer Use Committee is working on a method to transfer electronic membership lists to all Centres directly via e-mail. The lists will identify all current members, as well as additions, address changes, and deletions. It will be a significant improvement for all Centres to have more rapid membership list updates in a computer-readable format.

As always, there were significant discussions concerning our publications. We have recently shifted our desktop publishing services to a new contractor; however, there are some issues concerning cancelling the previous contract that are still being worked out. Randy Attwood, our 1st Vice-President, has been successful in finding an interested distributor for our publications. It will allow the Society to better promote its publications to the general public.

Finally, the Nominations Committee presented its nominations for next year's Executive. My term as President ends at the Victoria General Assembly, and all but one of the other Executive positions are changing as well. The Committee has nominated Randy Attwood as President, Robert Garrison as 1st Vice-President, Rajiv Gupta as 2nd Vice-President and Michael Watson as Treasurer. Any additional nominations from the membership at large must be signed by five voting members of the Society and received by the Secretary at least 60 days before the Annual Meeting. ◉

Correspondence
Correspondance

ON TELESCOPE CLOSURES

Dear Sir,

Your October Editorial (JRASC, 91, 187, 1997) discusses what can only be described as an astronomical funding paradox — the mothballing of active and productive observing facilities, reductions in staffing levels and closures of whole observatories as cost-cutting measures simultaneous with the erection of hugely expensive facilities in remote sites — and deplores the consequential loss of domestic facilities that allow access for the public. Several issues are at work here, and together they raise important questions concerning the placement of priorities in astronomy. Difficult though it is from our inside view to comprehend fully those trends that we dislike and which may cause us pain, it is nonetheless helpful to analyse the forces at work and their various tugs on different areas of astronomy. However, one outstanding principle does appear to have been neglected, namely that to produce healthy flowers on a plant it is essential to nourish the roots adequately.

The science of astronomy developed from the contributions of people who had the freedom and encouragement to follow the lines that fascinated them. Their many publications of catalogues, surveys and measurements have stood the test of time for their homogeneity, even if the precision in them has since been superseded. Those foundation efforts mopped up large numbers of man-years (often mostly woman-years, but that is another story). Today a proposal to carry out a comparable project in a similar way would be heavily criticised for its expenditure on human resources, though an *N*-billion dollar telescope or satellite (which will presumably do the jobs better, but only the one set that it was designed for) may cost the equivalent of many groups of people doing a wide variety of other things as well, *and* gaining fulfilment. We thus identify one important nutrient: investment in people.

Astronomers, consciously or otherwise, tend to be either "broad sweepers" or "ultimate refiners" (Pagel 1981). Obviously both types are important; it requires an increasing scope of new ideas, new techniques and new methodologies to enable a steady burrowing down to greater depths until solutions to existing problems are reached, while the arrival of new technologies and new data will indeed open up new problems that were hitherto unrecognized. That is part of the magnetism of research, and it helps the subject not a whit to divert all resources into the new channels and to leave the previous tasks unfinished and unfinishable; many instruments, once disbanded, cannot be restored without expense, and expertise, once lost, is costly to re-train or impossible to recover. Continuity up to a reasonable conclusion is therefore vital; otherwise, when funds are not limitless, only frustration will be purchased.

Bright-star experts, faint-object enthusiasts, galaxy pundits and laboratory astrophysicists are all manning different fronts in a general assault to understand the universe. Competition between these various factors may keep grant applicants on their toes, but dispersive elements become more prominent than cohesive ones if the competition is too keen. Thus, designs for high-dispersion spectrographs for bright stars must be compromised to accommodate faint objects too, so they lose their edge; sites still suitable for stellar spectroscopy are abandoned because they are no longer suitable for galaxies; telescope-time committees seem reluctant to award time for bright-star programmes, and disciplines that are currently unfashionable are *ipso facto* not represented on peer-review committees that advise on the allocation of resources. But research is a structured adventure into what is inherently unknown, and if some of the paths are barred from entry the outcome is likely to be biased, incomplete and therefore unsatisfactory. Complementarity, not competition, should guide assessment panels, and the *rôle* of a research field, not the number of papers published about it, should be the higher criterion. In this model the active amateur is also a vital contributor, both as a collaborator and as a liaison with the public.

Astronomy has always been (and if light pollution can be controlled it always will be) a popular science. Cosmic events fire the imagination and, in regions where the weather is not a regular dampener, an observatory's "public viewing" nights are always well attended. Space organizations, having a growing conscience for public relations exercises, can stage exhibitions or run theme parks. Many smaller observatories do not have public relations resources, so catering for the local public and visitors reduces to a matter of charity from a few noble souls, themselves perhaps once enthused by chance as you yourself were. Fortunately the public of any age, 8– to 80+, can still visit observatories. Fortunately, too, amateur groups continue to flourish, and to populate the sorts of astronomy that fascinate them in particular. For strong mutual support and inter-communication, Canada's amateur astronomy activity is exemplary and its public relations capacity high. Should that entrepreneurial potential of such groups be encouraged by professionals for their own ends?

Since the public plays a crucial part in national astronomy by contributing large proportions of the costs, it is important that we, as beneficiaries, demonstrate reasonable accountability for the facilities that have been thus operated. Were I holding the public purse-strings, I would want to know more about the usage being made of existing resources of data and whether the gains from a new proposal would *in the longer term* outweigh the concomitant losses. Unfortunately it has somehow got across to the public that it is the most "exciting" findings (which the media popularize as such) that require the highest funding priorities. The same public should recognize that its own untethered enthusiasm for new ventures is actually helping to bring about the disappearance of the domestic telescopes which your Editorial laments.

To maintain a workable balance of all these vital nutrients — people, continuity and complementarity — will require policy changes at the local level. It is essential to play down the image that astronomy is mainly to do with fantastic pretty pictures and speculative theories, and to inculcate an understanding that good research relies upon the healthy functioning of all its limbs. I know there are many who deplore the trends which are causing the closures of telescopes and of observatories, yet the body of dissenters, even thus united and of considerable number, does not appear to have much clout. Nevertheless the battles against continuing human resistance have given birth to a certain resilience, and excellent projects are springing up that connect unwanted telescopes in global schemes. Their goals will be the sort of surveys and monitoring which are root and branch to the more visible flowering tips. Wider recognition of those efforts and assurances of support from their beneficiaries is one type of local policy change that needs to be implemented without delay.

Yours sincerely,

Elizabeth Griffin
Oxford, United Kingdom

Reference

Pagel, B. E. J. 1981, ESO Workshop on *High-Resolution in Spectroscopy*

METEORITES FROM MERCURY?

Dear Sir,

A *News Note* in the October 1997 issue described how the Canadian National Meteorite Collection acquired a major addition, the Terry Schmidt collection, in exchange for a portion of the Abee, Alberta, meteorite. I have been privileged to see much of the new collection and it is quite remarkable indeed. One can only be impressed with the negotiating skills of the curator, Dr. Richard Herd, in arranging for this collection to come to Canada. Abee is an enstatite chondrite meteorite, a type whose physical and chemical properties differ from the ordinary chondrites and the *News Note* includes the interesting suggestion that it may represent impact debris from the planet Mercury. This invites discussion by astronomers as well as the geological community.

Fifteen years ago, serious consideration was being given to the possibility that some meteorites might represent impact debris from Mars, although the idea was far from being generally accepted. A study of orbital evolution of such objects was published by George Wetherill (1984) in which he showed that a small fraction of such debris could indeed reach the Earth, spending the order of 10 million years in transit. Today we are confident that a dozen objects in our collections, including a couple in the Schmidt collection, represent just such samples of the surface of Mars. Wetherill conducted similar calculations for impact debris from Mercury. Although the escape velocity from Mercury is somewhat less than from Mars, he found that slightly higher ejection velocities were required to put debris from Mercury into an orbit that could reach Earth. He devotes only one short paragraph to the possibility of meteorites from Mercury, stating "the yield of meteorites from Mercury is found to be at least a factor of 100 lower than from Mars." Thus it would appear there is only about one chance in 10 that we have even one such sample in all our meteorite collections.

Is the Abee meteorite, by chance, such an elusive sample? The visual observations of the Abee fireball, together with the known time of the event, allowed Griffin *et al.* (1992) to define the orbit with some confidence. In particular, the perihelion point was near 0.95 A.U., less than a fifth of the way between Earth and Venus, and the orbital inclination was very small. Orbital dynamics dictate that debris from Mercury would have to have a perihelion near the orbit of Mercury. Planetary perturbations tend to reduce this value, not increase it dramatically. Debris from Mercury would likely be swept up near its orbital aphelion, when the Earth would overtake it from behind (an Aten-type orbit with semi-major axis less than 1 A.U.). Also, any meteorite with perihelion near the orbit of Mercury would have a radiant position in the sky very different from that observed for Abee. The orbital data for Abee are actually in complete agreement with an origin within or near the asteroid belt. Thus, astronomers are forced to the conclusion that Abee does not offer us a sample from the planet Mercury and some heating mechanism in the asteroid belt must be responsible for the physical and chemical peculiarities of the enstatite chondrite meteorites.

Yours sincerely,

Ian Halliday
Ottawa, Ontario

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Griffin, A. A., Millman, P. Y. & Halliday, I. 1992, "The Fall of the Abee Meteorite and its Probable Orbit," JRASC, 86, 5

Wetherill, G. W. 1984, "Orbital Evolution of Impact Ejecta from Mars," Meteoritics, 19, 1

Focal Plane

Reflections on Fog Reflections

by Fr. Lucian J. Kemble, Lumsden, Saskatchewan (luckem@sk.sympatico.ca)

The 1998 winter on the Saskatchewan prairies was overall quite mild, hovering slightly below zero, with little snow for some time. However, there was a lot of fog for several weeks and, rather unusual for our location, a lot of freezing mist and hoarfrost from the dampness. There was no ice storm, thankfully, or, unfortunately, much opportunity for quality observing.

Yet I have had some good observations by way of unusual, very subtle things that I have not noticed in years. On Saturday evening, February 8th, I had to replace a priest for evening Mass at the small town of Southy, northeast of where I live (ironically *north* of Regina) — a drive of about 45 minutes. The late afternoon Sun was not visible, the sky a milky-white-out, with visibility in the damp fog of about 1 kilometre or less. Those who have never driven prairie roads and highways may not know that one can sometimes drive for dozens of kilometres in a straight line with only the black pavement ahead in a pure white sea of ditch and field and with only an occasional farm house, barns and clumps of bare poplars and bushes to dot the white expanse — some might wrongly say "to relieve the boredom" (not me!).

In such a situation, as on that evening, by careful observation I was able to see at the end of the tapering, vanishing-point road ahead a very subtle darkening of the foggy sky just above the road. The darkening was a very diffuse fan of only slightly darker fog, readily visible on direct vision. Most of the time one's ability to see the phenomenon required a lot of indirect vision, back and forth eye movement, etc. It was a type of inverted, very suffuse, mirror image of the tapering road. Pondering on such an at first quite surprising effect years ago, I came to realize that the ditches and fields were reflecting their snow-covered whiteness up into the fog. The highway, free of snow and quite black, did not reflect as much light and so made the fog a shade darker. It is a very nice effect.

Now, what has this got to do with amateur astronomy observing? A lot, as it turns out. For one thing my experiences with the phenomenon have made me appreciate, especially on this recent occasion, the subtle, the beautiful, the unexpected. (The experience will remain long after I will have forgotten the congregation, the good singing, my sermon, etc.) And it has found a marvellous application at the telescope in helping one to detect faint wisps and clouds, barely discernible spiral details in galaxies, and subtle mottling in dim nebulosity, for example that surrounding the difficult Horsehead, etc.

I wonder at this point just how much our magazines and their "wham-bang" presentation in startling colour contrasts, computer enhancement, glaring shock titles, etc., are responsible for the way we lose sight of the common, often unnoticed things. If one is totally captivated by the "wow," the explosions, blasts, etc., as depicted on the covers and pages of *Sky & Telescope*, *Astronomy*, *Discover* and others, and the constant assault on the senses of television and blockbuster movies, one will find the rest rather banal and boring. I am sure there were a lot of little "boring" animals (our own insignificant ancestors among them) scooting around in T Rex's habitat.

It would seem that the big fear and blight in today's all-pervasive visual and audio assaults is of being "bored." I once read a review of a new book on astronomy in which the reviewer remarked that the illustrations were black and white photographs of the same "old, tired, boring" galaxies. What? "Boring" galaxies? I pity the reviewer. One of my most treasured volumes is Hubble's huge atlas of black and white photographs — pre-CCD colour imagery — of galaxies. Have any true observers ever been bored with the real sky, whose objects are, effectively, only in black and white? Pity the poor young budding observer who picks up *Sky & Telescope* hoping to find some clues as to what he/she can hope to see in his/her binoculars or small reflector. I will tell you one thing. I am rapidly beginning to find the "splash" stuff a crashing bore. I make a plug for the subtle, the wonder, in little things: the almost imperceptible glow of a small 14th magnitude galaxy, the tendrils and clouds of dark and light in so many of the Messier objects, the shades of gray in clouds and fog, the "non-reflectivity" of highway fog, shades of gray on the lunar surface, bands on Jupiter, the subtleties of a Bach fugue, the iridescence of a sunlit bluebird's feathers…and so on.

Granted, computer-enhanced, false-colour pictures of astronomical objects are necessary and have provided researchers (some of whom may have never looked through a telescope, let alone used naked eyes under a dark sky) with valuable new data. I have nothing but respect for such practitioners. But are we beginning to lose the small, unobtrusive, simple things? A TV/Nintendo kid at my telescope once remarked, on seeing the tiny image of Saturn, "Is that all?" What did he expect — a sound and sight big screen Nintendo spectacular?

I am reminded here of the Old Testament prophet who sought God in the huge, the majestic and the mighty — of storm and wind and fire and tempest (in other words, in the spectacular). Do you know where he finally felt the presence of God? In the wafting across his cheek of a gentle breeze as he stepped out of his cave or something to that effect — I never was good at remembering book, chapter and verse.

A friend, with whom I discussed the whole subject, recently made the wonderful comment, "Why only the spectacular? Why, for example, are all the so-called heroes either movie stars or professional athletes? What about the small, the seemingly insignificant, the obscure?"

As for me, well, I grew up a simple, curious kid on a simple farm with simple delights and have never lost the capacity to *see* along the whole gamut (or spectrum) of beauty — even with my 75-year-old, diabetic-blurring eyes.

To all observers, then, "Clear skies or even foggy, boring ones," so long as they bring new experiences of the wonderful.

Fr. Lucian was born in 1922 on a small farm in southern Alberta. After spending four years during World War II as a radio operator, he entered the Franciscan Friars in 1946. Ordained in 1953 after 7 years' study in Philosophy and Theology, he has spent almost all of his priestly life in teaching and preaching. A member of the RASC for over 27 years, he works with a Celestron 11 on Byers Mount in a shelter at St. Michael's Retreat, Lumsden, Saskatchewan. His main interest in astronomy is searching out deep-sky objects, of which he has over 5550 observed, drawn and noted on file. His other main interests are photography, music and reading.

News Notes
En Manchettes

DAVID DUNLAP OBSERVATORY ON TV

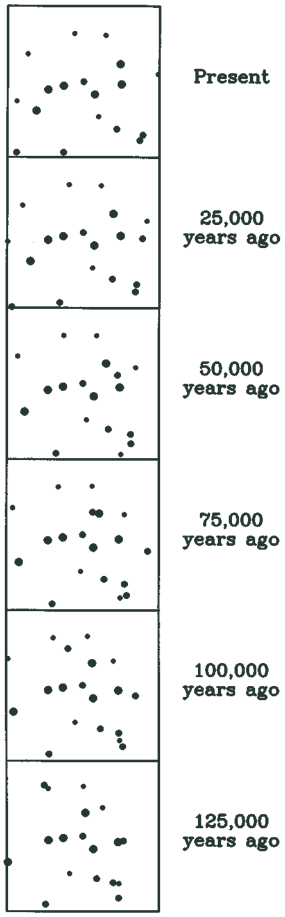
The dome for the 1.88-m telescope at the University of Toronto's David Dunlap Observatory.

The dome for the 1.88-m telescope of the David Dunlap Observatory of the University of Toronto is beginning to become a familiar sight on television for those who pay attention to commercial breaks. As a result of an arrangement made with the Observatory Director last year, permission was given for the telescope dome to be used as the backdrop in a few commercial film shoots. The dome now appears very briefly in some commercials appearing on North American cable television, where its characteristic bi-level catwalk serves to revive fond memories in its many past and present users. Watch for it on your local cable channels.

URSA MAJOR THEN AND NOW

Novice observers are often puzzled by the fact that some constellations seem to have no resemblance to the creatures or objects for which they are named, while others do carry a marked similarity to their namesakes. The constellation of bright stars that constitute Ursa Major, the Great Bear, is a good example of the problem, in spite of its now familiar Dipper (or Plow) shape. The constellation of the Bear is common to such a diverse variety of ancient cultures, from the ancient Egyptians and Greeks to the indigenous peoples of North America (see story by Owen Gingerich, *Sky & Telescope*, 67, 218, 1984), that one is led to ask whether or not there was a time in the distant past — prior to migrations across the land bridge between Siberia and Alaska — when the bright stars of Ursa Major did possess features similar to those of a bear. Russian researcher Alex Gurshtein has previously noted that, because of the rapid proper motions across the sky of most Dipper stars, the constellation's appearance changes markedly over the passage of several millenia. Several years ago Russian philologist Y. A. Karpenko argued that one must go back almost 100,000 years before the stars take on the configuration of a she-bear of that era. That corresponds closely with the oldest dates identified for the appearance of *Homo sapiens*.

The newly published astrometric data from the *HIPPARCOS* mission permit a closer examination of such a solution. The stars of Ursa Major are located in the sky roughly 65° from the apex of the Sun's motion relative to nearby stars, so their locations change temporally in rather dramatic fashion. The accompanying figures illustrate the appearance of the brighter stars of Ursa Major and adjacent constellations



The appearance of the constellation of Ursa Major at different points in the past.

for various epochs, including a point in time 125,000 years in our past. In order to avoid the complexities of precession and the changing location of the north celestial pole, the views have been centred for convenience on Megrez (δ Ursae Majoris). The appearance of the constellation does change significantly over time scales of several millenia, although it must be left to individual interpretation how closely the general appearance comes to that of a she-bear. The appearance of the constellation 100,000 to 125,000 years ago does have some similarity to the profile of a bear's face.

ASTEROIDS WITH CANADIAN CONNECTIONS

(7840) HENDRIKA = 1994 TL_3 (*from Minor Planet Circular 31027*)

Discovered 1994 Oct. 5 by G. C. L. Aikman at the Dominion Astrophysical Observatory, Victoria.

Named in honor of Hendrika Cornelia Marshall Aikman (nee Grootendorst), beloved wife of the discoverer.

(5953) SHELTON = 1987 HS

Discovered 1987 Apr. 25 by C. S. Shoemaker and E. M. Shoemaker at Palomar.

Named in honor of Ian Shelton, Canadian astronomer, best known for his discovery of the supernova in the Large Magellanic Cloud on 1987 Feb. 24. During his four years as resident observer at the University of Toronto Southern Observatory, he participated in programs with astronomers world-wide, and more recently he has generously contributed to the astronomical education of schoolchildren, parents and teachers. Name suggested and citation prepared by D. MacCormack and R. Garrison.

TEAM OF PARACHUTISTS TO HUNT FOR METEORITES

A fantastic new approach has been devised to facilitate the rapid recovery of meteorites. The old, low-tech, standard operating procedure of conducting ground-truth traverses has been found to be far too slow and boring to maintain the interest of even veteran meteorite searchers (never mind novices). The new approach utilizes the aerodynamic technique of skydiving to perform an elevated, sequential search progression (an airborne traverse). Meteorite searches now have the potential to be extremely rapid and exciting!

A bold member of the Royal Astronomical Society of Canada has fearlessly (been) volunteered to spearhead field testing of the new procedure. His considerable experience in parachuting will be a great asset to the development of the program. The research will be undertaken at the RASC's top secret site (Area 52), located somewhere in western Canada.

Preliminary testing revealed that the swinging motion of one individual under the canopy resulted in substandard performance. Subsequent field tests will utilize much larger parachutes that would accommodate six to eight observers at a time, who would descend with their backs together and facing outwards in order to maximize stability and increase the field of vision to 360 degrees. Security is a top priority, as it would be a devastating setback to the new project should another meteorite recovery competitor gain access to the experimental results. Another reason for caution is that we simply do not have the manpower to handle the anticipated huge influx of meteorite hunters that will flock to participate in our program. Watch for the next progress report on April 1, 1999!

ERRATUM

In the article "Astrophysics at the University of Alberta" that was published in the February 1998 issue of the *Journal*, the reference to "E. S. Campbell" should be to "E. S. Keeping."

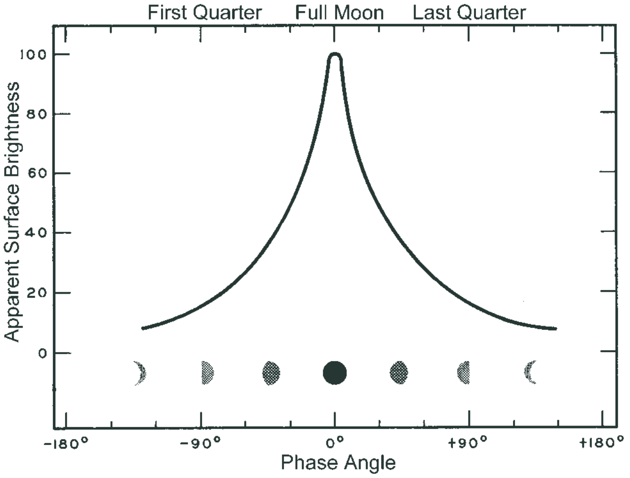
Questions & Answers
Questions et réponses

Near-Moon Photography

I have been photographing comets using an equatorial mount and drive to take exposures with a length of several minutes to get details in the tails of the comets. In some instances the Moon is up at the same time and will either be near the comet in a crescent phase or far from the comet but near full. My question is this: Is there a rule of thumb or a way to compute when the effect is worse or least bad for photography? In other words, is a full Moon 160° away worse than a quarter Moon 70° away or a crescent Moon 30° away, or does it depend so much on local atmospheric conditions that no generalization is possible?

Peter Nelson
Victoria, B.C.

There are two factors at work here: the total amount of light the Moon is reflecting towards us and how that light is distributed across the sky. Take a look at the accompanying graph that shows how much light is reflected from the Moon in its various phases. I have adapted the diagram from an article in the August 1960 issue of *Sky & Telescope* magazine that was written by the astronomer Otto Struve. The surprising feature of the graph is that the Moon essentially doubles in brightness during the week around Full Moon (about four days on either side of the Full Moon). The effect is related to the composition of the surface grains that reflect light straight back at the light source very well, but not so well to the side. Since the Sun is at our back around Full Moon, the Moon brightens considerably. So, I would say that shooting pictures of a comet is not such a good idea at that time, even if the Moon is in the opposite part of the sky. The situation improves considerably before First Quarter and after Last Quarter.



I also consulted with well-known astrophotographer Jack Newton who has noticed that the sky is essentially perfectly dark if the Moon is less than 30% illuminated. Just to remind everyone, I should point out that First and Last Quarters do not correspond to 25% illumination — they are 50% illuminated. The "Quarter" refers to how much of its orbit around the Earth the Moon has completed (or has yet to complete). Since the Moon's orbit takes roughly twenty-nine days, you can quickly calculate the approximate percentage of illumination each day. It goes from 0% (New Moon) to 100% (Full Moon) in about fourteen to fifteen days (and back to New Moon in the same time, of course) so there is a change in illumination of roughly 7% per day.

The second half of the query deals with the scattering of moonlight by the Earth's atmosphere. There is usually a glow around the Moon — does it extend far enough to cause a problem in seeing a comet? To research this part of the question I turned to books describing the scattering of light from the Sun. The Sun and the Moon are the same angular size and colour, just different in brightness. As a result, they should produce the same sort of sky glow. My first reaction was that the glow we see around the Sun or Moon is caused by the air molecules themselves, but that is incorrect. According to the book *Color and Light in Nature* by Lynch and Livingston, the glow we see, called the aureole, is caused by water droplets and dust and smoke particles in the atmosphere. Dust and smoke particles, unlike air molecules, scatter a lot of light forward into our eyes, which means that you will see a strong glow. Water droplets simply pass some of the light through, though they will refract some of the light to cause a brightening and also a rainbow. Yes, there are such things as moonbows — rainbows caused by the Full Moon — but they are very faint. On very clear days you might notice that the sky seems uniform in brightness right up to the Sun. The same effect works at night with the Moon.

So, how far does the scattering effect extend? Even if there are a lot of dust and water droplets, the effect is limited in range to about five degrees around the Sun or the Moon. If the Moon is up, the area affected by scattering is greatly reduced if a large weather system has gone through and a high pressure system is moving in, as both tend to be associated with air that is relatively dust free.

The main problem on a clear, dust-free night will be general sky glow. Aside from light scattered from the sky next to the Moon, you also have light cast all over the atmosphere by the Moon. (Scattering of the same kind of light from the Sun is what gives us a blue sky.) Since it is the intensity of the light source that affects the general sky brightness, the previous information about how much light the Moon reflects to us becomes important. The amount of general sky glow should be proportional to the brightness of the Moon.

There is one last thing to consider with sky glow — the sky near the horizon. The brightness of a particular point on the sky depends upon the number of particles that lie along the line of sight. The effect of such obscuring particles is referred to as "optical depth" and is proportional to the number of particles seen. As you look at the sky near the horizon, you are looking through a greater amount of atmosphere and a correspondingly greater number of particles. At 20° above the horizon the sky glow is twice that at the zenith, and at 10° it increases to five times the amount overhead.

The bottom line of all of this is that the dominant effect is how much light is being reflected from the Moon and therefore its phase, and not where it is in the sky. That should be your biggest concern. ◉

Don Moffatt
ScienceWeb Editor
scienceweb.dao.nrc.ca
(*reprinted from the Victoria Centre's* Sky News)

Feature Articles
Articles de Fond

A Lifetime of Stargazing

by John Howell, Victoria Centre

Beginnings

My earliest recollection of the attraction of the night sky occurred in September 1926 when I was eight years old. It was a Sunday evening in Bristol, England, and my parents and my brothers and I were strolling home from having visited my maternal grandmother. It was a walk of about four miles on a balmy evening. I was pushing my youngest brother, 16-month-old Ted, in his stroller. Ted suddenly pointed his finger toward the huge, tinted sphere of the Moon and announced, "Bubloon!"— his word for balloon. He was silent for the next hour, all the way home, and his eyes never left his wonderful discovery. He was completely mesmerized by the sight of the lovely Harvest Moon in all its serene beauty in the darkening skies.

I had been introduced to astronomy a year earlier by a lesson in elementary school arithmetic. My teacher in second year introduced us to large numbers, including thousands and their multiples. The teacher noted as an example that the Moon was about 250 thousand miles from the Earth. For the next category, millions, he told us that the Sun is much farther from the Earth than the Moon, although they are about the same size in the sky. Its distance of 93 million miles from the Sun was beyond my comprehension.

I was well-travelled as a child, having sailed across the Atlantic Ocean from Southampton when I was less than three years old. I was told that the sailing distance to Halifax was 3,000 miles and that it was about 2,000 more miles by Colonist Car to Calgary, Alberta, about four days and nights by railroad. It was a marvelous adventure that I thoroughly enjoyed and still do as a world traveller. For me the encounters with many different cultures have been part of my education.

At age six I returned to Bristol with my family, leaving my eldest brother, nineteen-year old Les[1], in Calgary working for the Hudson Bay Company and also planning to be married. In Bristol it was a ten-mile bus trip to and from school each day, during which I spent the time performing mental arithmetic. Having been introduced to the concept of distance and knowing that a return trip to Calgary covered 10,000 miles, I worked out how long it would take for the bus to reach the Moon travelling at 50 miles per hour. I calculated that it would be the equivalent of 25 return journeys to Calgary from Bristol, or 250,000 miles. Since it would take two hours to cover 100 miles, I calculated that the bus could travel 1,200 miles over the course of a twenty-four hour day, or 2,400 miles in two days time. I calculated using multiples of ten that a distance of 24,000 miles could be covered in twenty days, or about three weeks, and a distance of 240,000 miles in about thirty weeks, in excess of six months. The old bus would never make it! There must be a faster way to get to the Moon. At the same rate of travel, a bus would take about two years (4 times 6 months) to cover a distance of 1 million miles (about 4 times 240,000 miles), or about 186 years (2 times 93) to cover the 93 million miles to the Sun. That is more than two normal life spans.

To me it seemed inconceivable for the human brain to comprehend such distances. Yet, like my young brother, I was not only fascinated by my discovery but also completely enthralled by the large scale of distances in the astronomical world. My reading had introduced me to the other planets of the solar system: Venus, Mars, Jupiter, Saturn and the other gas giants, and the swift-moving and elusive Mercury. It was now my goal to find them in the starry night skies. Thus began my first love affair — astronomy. It has been a lifelong affair that I have not once regretted.

Searching for the Planets

My next enchantress was the planet named for the Goddess of Love — Venus. Its brilliance was unmistakable and its movement among the constellations was relatively easy to note. By now I was a confirmed stargazer, as I have been for a lifetime. The ruddy colour of Mars also gave away its presence in the sky, and, as the months passed, I watched it wandering among the twinkling stars, a movement that confirmed its identity. I discovered two other stars that did not scintillate (twinkle) like the others and also noticed that they moved quite an appreciable distance relative to the others from one winter

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[1] Les later discovered that work at a refinery was more interesting and more lucrative. It was his news about the availability of jobs for power engineers at the upgraded Leduc refinery in Alberta following the discovery of oil there that resulted in my decision to immigrate to Canada in April 1957 with my wife, son and two young girls.

to the next. From library books I determined that the brighter one was Jupiter; the other one was Saturn. It took several more decades for me to locate the planet Mercury, but I am now able to see it every year or two when it is at its greatest elongation east or west of the Sun — a feature of which I became aware when I became a life member of the RASC in 1958 and made regular use of the *Observer's Handbook*.

My travels brought me back to Calgary in 1957, at the beginning of the Space Age following the launch of Sputnik, the first artificial satellite. Along with over a hundred others, I became a charter member of the Calgary Centre when it became a new satellite of the national association (the RASC) in January 1958.

On Space Travel

In 1925 city authorities all over Britain initiated building projects for the construction of model cities under the political slogan of "Homes for Heroes to Live In." About fifty families of wounded veterans of the Great War (1914–18) were housed in one such development — Sea Mills, located on the outskirts of Bristol. The area had grown to 15,000 by 1928 when my parents moved there. Sea Mills had a newly-constructed shopping centre and sports fields, and a library was its next addition. My mother was an avid reader, so the entire family became regular visitors. I told the librarian of my interest in astronomy and she ordered many new books on the discipline when she found them listed. It was wonderful for a twelve-year-old to have access to a galaxy of books at no cost. It seemed like Christmas every day.

My astronomical knowledge began to expand much like the expansion of the universe. It came alive with the discoveries of Hubble and Humason, who used the 100-inch telescope on Mount Wilson in California to observe spectroscopic "red shifts" for galaxies everywhere in the heavens. I learned a new language consisting of the terms parsecs, light years, and megaparsecs. My mother often gave me strange looks when I tried to discuss astronomy during meal times.

I read Jules Verne's story of a trip to the Moon, but explained to my family that a gigantic cannon would not be a practical way of sending people there. To me the technique appeared scientifically unsound — the only sensible way would be to use rockets. At the time they were being used in Germany to send mail between cities at speeds greater than those reached by aeroplanes of the era. I did not foresee the night in London when I would feel the shock of two V2 rockets striking the vicinity of Paddington. The noise of their supersonic approach was almost as terrifying as the explosions themselves. I realized immediately that it was the beginning of mankind's use of rockets for research beyond the atmosphere. I did not appreciate that it would develop as quickly as it did and that we would see a man walking on the Moon in my lifetime.

Jupiter's Satellites


Jupiter's Galilean moons, easy targets with only a pair of ordinary binoculars.

At the beginning of World War II I bought a used pair of 7× binoculars and began to explore the sky as an amateur astronomer. I served at sea as a marine engineer and located the planet Jupiter during my first clear night on board ship in the Atlantic Ocean. To my delight I was able to spot the four Galilean satellites — three on one side of the huge gas giant and one on the other. I observed Saturn later that evening, but was disappointed to view it as only an elongated blob. Although it was definitely not a star, the rings could not be discerned as such. Viewing it properly required better resolving power than supplied by my ancient binoculars. A less-than-one-week-old Moon was wonderful, with craters in abundance, and a couple of sunlit mountain peaks were a pleasant surprise near the cusps. The ship carried no lights since it was wartime. Once the Moon had set some time near midnight, the stars were everywhere.

The ship I was on carried troops to Durban, South Africa — reinforcements for the Desert War west of Egypt. Once when I went off duty at midnight, a deck officer noticed me stargazing and was surprised. "You won't spot any submarines up there," he commented. "I'm on lookout too, just in case we are on a collision course with a meteor," I replied. A few days later we were far enough south for me to see the Magellanic Clouds for the first time. I had also heard about the magnificent Southern Cross, but it turned out to be somewhat of a disappointment. It is a well-shaped and unmistakable cross, but does not compare with Orion or Ursa Major. I did not complain, since I enjoyed being on that ocean cruise. As long as the war remained at a distance, I was happy. Circumstances did change, but that is another story.

Tracking Satellites

Following the formation of the Calgary Centre, some members took part in a world-wide effort called Moon Watch. The launch of so many man-made objects into orbit with no existing tracking networks resulted in growing uncertainties in their orbital positions. There was a potential risk that such orbiting objects might collide with the first vehicles to carry men into space, so a call went out to amateur astronomers to participate in the visual recovery and monitoring of lost satellites. One such call was answered by Calgary member Eldon (Buck) Rogers, who organized a dozen of us into a Moon Watch team. The National Aeronautics and Space Agency (NASA) supplied Buck with several 8× M13 elbow telescopes that had been taken from WWII tanks. Many amateur telescope makers use them as finders on their home-built Newtonian telescopes. Along with other members and their small portable scopes, we had enough eyes to create a "fence" of five or more observers. Buck also had information on times when objects were predicted to come into view, along with the constellations to monitor. We set up to monitor the star fields using an overlapping system. Each small M13 scope had a 5° field of view, so the area under scrutiny was quite wide. Most objects were as bright as 4th to 8th magnitude and their tumbling made some of them flash on and off, so they were easily found by members of the team. Although Operation Moon Watch was established worldwide, after about two years it fell out of use as a new tracking network came into operation. We all felt that we had somehow contributed to the safety of astronauts during those early years of the space programme.

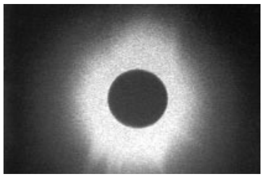
Two large aluminum balloons named *Echo I* and *II* were launched during the winter of 1963-64. The balloons were used to reflect radio waves to test whether or not they might improve worldwide communications. They were easily spotted in orbit because they were brighter than magnitude zero, almost as bright as Sirius. I was a power engineer at a refinery in Calgary at the time, and was on duty one night when the plant shut down because of a breakdown. Management urged us to repair the problem as quickly as possible, because unscheduled stoppages cost the company a quarter of a million dollars a day in lost revenue. Everyone worked twelve hour shifts to make repairs, and it was during one such April night at about 1 a.m. that I spotted *Echo II*. I knew it would take ninety minutes to complete its orbit, so I told a few workmates to watch for it around 2:30 a.m. It appeared exactly on schedule, and as word of its appearance got out everyone stopped work in order to go outside to view it. Our boss noticed the sudden silence from the noise of metal working and used the loud speaker system to find out what had caused the stoppage. He threatened to dismiss whoever was responsible!

Daytime Observing

In July, 1967, Canada celebrated its 100th birthday, with all major communities commemorating it with a public event or project. The RASC Calgary Centre proposed a facility that was accepted by the city fathers from among many other submissions, and created the Calgary Centennial Planetarium, now the Calgary Science Centre, much to our delight. It included an observing deck with four telescopes — two reflectors and a pair of refractors — that were manned by members of the Centre during public stargazing sessions. That summer I followed Venus as it neared conjunction with Earth. It was very bright at the time, at magnitude –4 or better, and I regularly found it with my naked eye in the middle of the afternoon. I could locate it with binoculars and then position myself so that the direction to the planet was aligned with a power pole. Following that, I could locate it without optical aid for a week or more. At the planetarium I used a telescope pier to locate it for visitors. Shown Venus in a 6-inch telescope, they would invariably mistake it for the Moon because of its crescent shape. Peering along the telescope tube to spot it in the sky with unaided eyes would soon convince them otherwise.

One afternoon a school teacher brought her grade three class to the planetarium, accompanied by her octagenarian grandmother. It was quite a surprise for a dozen youngsters to see a "star" during daytime. The elderly lady wished to observe it as well, but after a glimpse through the eyepiece she tried unsuccessfully for several minutes to spot it with her unaided eye along the telescope tube. About half an hour later she came back to my location and tried again. Suddenly, with an excited cry she finally spotted it with her own eyes. That is one of the bonuses of being a public educator in astronomy. The teacher was impressed not only with the demonstration for her students but also with the manner in which I helped her grandmother achieve something that gave her such pleasure. George Ball, a Victoria Centre member, can easily locate Mercury, Venus, Mars, Saturn and Jupiter during daylight using the setting circles on his telescope, and I have had several pleasant mid-day observing sessions with him. The bright planets are quite accessible at any time if you truly wish to find them.

Eclipse Chasing



A total solar eclipse, an event that cannot be observed only once.

On Saturday, July 20th, 1963, an eclipse of the Sun that was visible across Canada inspired several RASC centres to plan viewing expeditions. Members of the Calgary and Edmonton centres drove nearly a thousand miles north to Fort Providence in the Northwest Territories to enjoy the spectacle. It took place just after noon at 12:38 p.m. and was the first of my eclipse-chasing forays. I have chased four eclipses since then, the most recent being the one visible from the Caribbean in February. The next one I plan to view will occur in England on August 11th, 1999. It should be quite a day in Cornwall since I also plan to watch the Perseid meteor shower that night.

Monday, July 15th, 1963, was my last day of work at the refinery before taking time off for that first expedition. I had arranged to work the shifts of colleagues, something we often did to help each other get time off as needed. About noon that day I glanced at the 75% sunlit Moon still some distance from the Sun and thought about its motion and how much sky it would cross each day in order to pass in front of the Sun the following Saturday. My brother and colleague Les was surprised to learn that I was looking at the Moon, an object he thought was only visible at night. I told him that on Saturday he could watch it cover more than half the Sun in Calgary while I was watching it being totally eclipsed in the Northwest Territories. I have often wondered how many other people are unaware of the fact that the Moon is easily seen most days of the month during either daytime or night-time.

Planetary Satellites

In 1963 I bought a 10-inch f/8 Newtonian reflecting telescope[2], complete with a dome. Both were purchased from a Calgary Centre member who was transferred to California. Mr. Knox decided that moving his observatory presented too much of a problem, so he put it up for sale. Several other members wanted it and offered him more than I could afford, but he felt I would use it for serious observing. I was very fortunate to have him place his trust in me. I next built the first of three observatories to house it, since I moved several times.

I used the telescope to view the seven brightest planets on numerous occasions before trying to glimpse Pluto. Sometime around 1967 I watched for it to occult a star as predicted, but the occultation never occurred — as announced later. I eventually spotted Pluto in 1994 when it had a near-miss with another star. I was with Jack Newton using the 25-inch telescope in his Mount Matheson Observatory. It was exciting to watch Pluto slowly approach the star until both small spots of light merged into an elongated object through the eyepiece. Over the next twenty minutes the blob slowly changed and swung end for end, until the two objects gently drew apart.

It was my hope to observe as many satellites of the planets as were visible through my 10-inch telescope. I began with Saturn, which has seven satellites of twelfth magnitude or brighter; I have always found the beautiful ring system of the planet attractive. One evening I casually observed the rings for a short while when suddenly a tenth magnitude meteor flashed across my field of view. It shot neatly past Saturn from pole to pole, much to my astonishment. That was the only telescopic meteor I have ever observed over many hundreds of hours spent at the eyepiece.

Another startling and unexpected observation occurred while I scanned Mars in 1964. Suddenly the red planet was joined by a glaringly-bright artificial satellite at about magnitude −2 or −3. I actually reared back from the eyepiece in alarm! Glancing out of the dome, I spotted the huge, bright, aluminum balloon *Echo II* silently speeding past in its orbit. When I looked through the telescope again, Mars was back to normal. I located *Echo II* again in the finder scope, but its speed was so great that it left the field of view within five seconds. Its brightness was indeed startling. I consider it to be an example of “clear night sky pollution” for amateur stargazers.

Meteor Showers

An activity that I find very enjoyable on a balmy summer evening is a relaxing meteor count. It is generally a two-night session since the Perseid shower reaches a maximum on August 11th and 12th. A location at sea level on the coast of British Columbia has distinct disadvantages since the atmosphere tends to obscure most of the faint meteors that one might spot from a greater altitude. The finest displays I have witnessed occurred while I attended the Mount Kobau Star Party, which is always planned so that it coincides with the Perseids. The clear dark skies at the mountaintop’s 6,000-foot site allow one to see a great number of meteors of fourth, fifth, or even fainter magnitude that are not visible at sea level. An hourly count of seventy or eighty meteors is not uncommon and often counts of over 100 are registered. Particularly bright meteors are spectacular, rivaling Venus in their brilliance. Jupiter is a poor second by comparison.

I normally watch a shower using a tape recorder with a short wave receiver tuned to the time signal from WWV, Boulder, Colorado. I then record the magnitude and approximate star field traversed by each meteor as it appears. When the tape is played back later, the background sound effects usually include a chorus of “ooohs” and “aaahs” and an occasional “beautiful” or “wonderful.” I often add my reaction and description. From Mount Kobau a few meteors appear as bright as fireballs, especially ones that leave a long trail and have terminal explosions. Meteor counting on Saltspring Island normally turns into a count of artificial satellites instead. In 1991 my wife Carol and I logged 26 orbiting objects between 11 p.m. and midnight. There are an enormous number of artificial satellites in orbit now and it is a full-time job for the tracking network to keep them under surveillance.

In the late 1960s I once observed a rare daytime fireball. lt occurred just as people were heading home from work, and the Calgary Centennial Planetarium (now the Calgary Science Centre) received a flood of telephone calls of sightings. I interviewed a dozen eyewitnesses, one of whom insisted that he saw it through his south-facing picture window. The object had in fact crossed the northern skies during its flight. All other eyewitnesses viewed the event in the north, so I explained to the man that he could not have seen it in the south, that it must have been seen out of his kitchen window which faced north. Upon checking his home I found a mirror in his hallway had reflected the image of the meteor onto the picture window in the front of his house. He was adamant that he saw it in the south. The same fireball is believed to have skipped off the top of the atmosphere back into space.

I have also observed the fall of a meteorite that was subsequently recovered. At the time I was using my C8 at a dark site sixty miles west of Edmonton with an excited six-year-old family member in attendance. A very bright meteor

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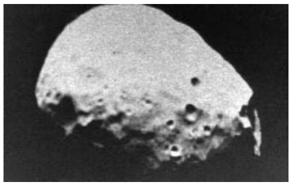
[2] It was later purchased by the wife of the late Glen Reed, who donated the telescope to the Calgary Centre in 1996.

suddenly plunged virtually to ground level as viewed from my location. I telephoned the Edmonton Planetarium with my report — along with dozens of others who saw it — and a search was carried out by Dr. Ian Halliday. The ground was covered by snow at the time and a small meteorite was eventually recovered by the search team. It was named the Innisfree meteorite after the small community in Alberta, some 100 miles from my observation point, where it was recovered.

The Moons of Mars


Using a 1 mm-wide section of exposed film to block the glare of Mars, I was able to observe its moon Phobos visually.

About twenty years ago Mars was quite close to the Earth in its orbit and I observed it fairly regularly. According to the *Observer's Handbook*, the two satellites of Mars, Phobos and Deimos, have magnitudes of 11.6 and 12.7. Both are well within the capability of my telescope, so I tried to observe them using the same technique adopted a century ago by their discoverer, American astronomer Asaph Hall. Keeping Mars out of the field of view, I searched for many hours trying unsuccessfully to spot the pair of elusive satellites. I finally gave up. Later I decided to try something different. I snipped a 1 mm-wide section from a fully-exposed roll of film that was available and placed it across the centre of an eyepiece. The next evening the film neatly hid the glare of the red planet as I resumed my quest. I spotted nothing on one side of Mars, so tried the other. I soon spotted a small, faint object that was swiftly approaching Mars. Success! Because it closed in on Mars so quickly, I was certain that it had to be Phobos at magnitude 11.6. Several nights later I detected both moons quite close together. I tried the same technique a few times with an 8-inch telescope on Mount Kobau, but because Mars was much farther away on those occasions I was unable to spot the satellites.

After a lifetime of observing adventures, I still enjoy the wonderful panorama of the night skies. In my advancing years I have developed cataracts that are a nuisance when it comes to observing. They can be treated surgically and I hope to have them removed by the time of the Victoria General Assembly. I shall continue to indulge in viewing my heavenly friends while it is still possible, since I remain devoted to the beauty of the night skies. ◉

JOHN HOWELL is a retired electrical worker who spent most of his working life employed at the Alberta refineries of Imperial Oil. Born in England, he served at sea as a power engineer during World War II prior to moving to Alberta. In 1958 he became a founding member of the Calgary Centre. He and his wife Carol are both life members of the RASC — John for the past 40 years. He has served as a member of the executive of both the Calgary and Victoria centres, never being far from the action and always displaying concern for the best interests of the Society. He has rarely missed a General Assembly, a fact of which he is quite proud! He is also a member of the British Astronomical Association and the British Interplanetary Society. His interests in astronomy have included eclipse chasing, astrophotography and meteor photography, and he relaxes with his stamp collection.

NOTE

The Astronomical Almanac to be Revised

Users worldwide rely on *The Astronomical Almanac* as a key source of essential, fundamental astronomical data. This annual volume is a joint publication of the Astronomical Applications Department of the U.S. Naval Observatory and H.M. Nautical Almanac Office of the Royal Greenwich Observatory. Both offices are now conducting a thorough review of the content and format of the publication, with the goal of making it more relevant to modern users. Some proposed changes include: adoption of the International Celestial Reference System (ICRS), introduction of a more modern ephemeris of the solar system to replace DE200/LE200, provision of a companion CD-ROM to the printed book, and removal of outdated sub-sections.

The entire contents of the book are being reviewed item by item. Some tabular data may be removed entirely. Other data may be moved to the CD-ROM, or may be replaced or complemented by software that can calculate, then display or print, the data. Changes are expected to be introduced into the edition for 2002.

In order to assess the needs of users of *The Astronomical Almanac*, the two offices are conducting a survey, which is available on the World Wide Web at www.ast.cam.ac.uk/nao/survey.html. Unless users of *The Astronomical Almanac* make their needs known in detail, decisions on changes will be entirely at the discretion of the production staff. Therefore, all users are strongly encouraged to take the time necessary to complete the survey, which will close on 1 August 1998. Early responses will be more effective in influencing the planning.

If a user has no access to the World Wide Web, an abbreviated paper version of the survey may be obtained by writing to:

U.S. Naval Observatory, Astronomical Applications Department, 3450 Massachusetts Avenue NW, Washington, DC, 20392-5420, U.S.A.

Poetry About The Planets

by Walter George Smith, Kingston Centre

One of the events held at the Kingston General Assembly was the poetry contest. I received many favourable comments on the poems that I presented, and thought that there would be enough interest from other members to publish them in the *Journal*. For those of you who attended the GA, I hope that what I present here will also provide a bit of background on how I came to write the poems that you heard.

Meditations on the Fate of Man

Mortal as I am I know that I am born for a day
But when I follow at my pleasure
The serried multitude of stars in circular course
My feet no longer touch the earth
Ptolemy, 2nd Century AD

As stargazers we all know there is magic in the night sky, a magic that speaks eloquently on a clear night from a dark viewing site far removed from light pollution. With that vision firmly in mind, I recently began a serious quest to track down the origins of some of Ptolemy's most cherished astrological beliefs. Who was it who first concluded that the seemingly pointless wanderings among the fixed stars of the pristine lights that we now know are the planets was a measure or prophesy of happenings on Earth? The quest soon took me back much further in history than I had first anticipated, back in fact to the time when the last Ice Age was ending, back to a time when an ancient and well-developed culture was looking to the heavens and contemplating the very reasons for human existence. That culture and civilization was the Vedic civilization of ancient Bharat, the country we now know as India.

Here was an agricultural economy that had derived a survival calendar from contemplation of the night sky and calculations derived from those observations. It noted that the Moon, which dominates the night sky with its regular phases, only occupies a limited sweep through the sky's immensity. The Moon's position, recorded daily, could be registered in one of twenty-seven different positions, which they named "lunar mansions," and the clusters of stars within them as "constellations." They witnessed the rotation of the heavens and observed the same constellations rising over the eastern horizon. The Sun also inhabited the lunar mansions, changing its position within them as the year progressed. It became convenient to describe the Sun's monthly position, which changed at the rate of two and a half lunar mansions per month, with the simpler term "sun sign." In that way the sun signs of the Zodiac were defined, decimal arithmetic was invented for ease of computation, and the scene was set for the mystical contemplation of that all-pervading night sky magic. As I became immersed in the ancient questions addressed to the sky in those times, the sky's own poetry possessed me.

The Wanderers

What Gods are these
To freely move
Amidst the circling sky?
By what acknowledged power
Do they in wandering
Declare a new abiding law
Dispel my fears
And grant me substance for my dreams?

Although this one bright light brought joy and good fortune, another slow moving messenger spent two and a half years in each sun sign going retrograde at various irregular periods. It seemed to bring discipline to the wilder human emotions. It opened the mind to responsibilities of a religious nature. It was the keeper of the transmigration of souls and the master of reincarnation after death. It disciplined the human soul to the progression of time.

Chronos

Harsh keeper of my bonded soul
Whose resting hand restrains, witholds
To teach thy laws of discipline
So as you linger in my fate appointed sky
Sustain me through your dark constraint
Of mortal wish's planned design
And lead me down the starlit path
Of incarnation's progress line

And what about that red wanderer, going around the zodiac in two years playing with retrograde motion for four and a half months at a time? A manifestation of red fire, red blood, of anger, strife, and warfare, but also the keeper of energetic enterprise and leadership. Oh, for its benefit without its strife!

Martial

Oh, fire, whose ruby gleam
Of distant light so far away
Bring not to me the heart's dismay
As quarrel, strife, and temper.
But forge my forces, inward lodged
For those which garnered
From your solitude
A nobleness impart,
And crown this mortal
With a fearless form
Of leadership

And so let us return to our meditating Rishi as the morning twilight rises to hide the light of love just as the first red fleck of the Sun's disk comes to the eastern horizon.

Love's Dawn

Resplendent beacon of my heart's desires
Resplendent beacon of reflected fusion's fires
Resplendent beacon whose morning watch conspires
To steal my heart in wonderment.
Resplendent beacon of the morning skies
Resplendent beacon as the darkness dies
Resplendent beacon watch the sun to me arise
And fold my love in wonderment.

And if this freely wandering light is a sign of love made manifest, what of that lesser light that sometimes also appears and darts about so near the danger of the Sun's furnace heat?

Mercurial

This point of light
That moves unhindered
Near the furnace of the sun
Does it bring messages
From outer Gods
To this bright inner God of ours?
And when it vanishes
From earthbound mortal sight
Is it away on some unspoke design
Of intercourse between divinities?

Other wandering lights exhibited a different kind of behaviour. Two, in particular, moved slowly and methodically through the sun signs with occasional backtracking but exhibiting a steady forward progression through the signs. One, almost as bright as the star of love, spends a year in each sun sign whilst going retrograde four times during the course of the year. It spoke to the morning meditator of beneficence and a cycle of life's good fortunes. It visited each sign in turn and spent a whole year in each. It hinted of blessings related to its movements in the heavens, and of "the tides in the affairs of men which taken on the flood."

Jovial

Joyful herald of Good Fortune's touch
Stand watchful in the cold black night
And when my mortal wishes rise
In tune with your most awesome beams
Bring forth my hopes
Of freedom manifest?
And what appointed message
Bring they down to man,
What fate made manifest
To quell all feared uncertainty?

That civilization had an advanced concept of cosmology based solely upon the human senses. It could see, hear, smell, touch and taste the material world, and it sought to take such experiences to all things including the heavens. Their cosmology described material existence in terms of a vocabulary vastly different from that of modern physics, but it did recognize subatomic particles and such "Vedic quarks" had names quite far removed from ours. The religious practices of the civilization's elders (the Vedic Rishis) required them to meditate during the two hours preceding sunrise. In their experience they encountered the mystique of the morning star and the 263-day period of its connection to sunrise (and also sunset), a period strangely identical to that of human gestation.

Seated quietly under the black mantle of the night with its slowly rotating and sparkling jewels of light, the Rishi became aware of his breath and his heartbeat. Those he interpreted as the energy of movement (breath) and the energy of transformation (heartbeat). As he absorbed energy with each inspiration, he noted the steady beating of its transformation. Transformation into what? Transformation into structure, transformation into him, transformation into all that out there. The energy of movement and the energy of transformation could give birth to a universe of which he was just a small (but uniquely conscious) part, but also a part that might for certain attributes be depicted by a map of the heavens transfixed at the moment of his first breath, and a map related to the journey from his first breath to his last. The map could be restricted to the sun signs and the positions within them of the wandering stars (the planets). The sign on the eastern horizon was termed the "ascendant." It changes every two hours and varies according to the latitude of the place of birth. Signs rising in sequence after the ascendant were termed "houses," for it was in them that the wanderers were found to reside. Each house was given attributes that were related to various categories of human activity and concern. After lengthy and detailed observations spread over a long period of time, it became possible to predict the movement of the wanderers and thus their effect on human affairs.

And what of the bright light that heralds the approaching Sun before the dawn of a new day? What of this guardian of fecundity, that every day of its morning visitation becomes reflected in the morning dew? Does it give birth to heart's desires and all the mindful longings brought out of meditation from the dying night? Might it be the God of love? As the blackness of the eastern sky gives out to blue, then lightens to azure along the horizon's line, and next advances through tints of green to a golden apricot expanse, a sense of coming birth intensifies — birth of a new day coming, birth of me in my new day coming. Bring me forth into this bright day, resplendent beacon of my heart's desires, and, like him, enter into the gift of this day seeking to retain that peace which the magic of the night sky grants, speaking quietly to the mortal soul in meditation.

The Stargazer Blessing

Peace of the quiet earth to you
Who live on her cooled magmas' rim.
Peace of the Mantle of Night to you
In the knowledge of Time's turning trim.
Peace of the Endless Deep to you
From leptons, gluons, and quarks
From uppers and downers
From strange and truth
From beauties joyously charmed
And photons swimming the vast dark black
With gravitons unharmed.
Peace, Peace, Peace.

And, as I close these new poetic meanderings on ancient themes, I am mindful of some words of an earlier poet, words written by Lord Byron (1788-1824):

Ye stars which are the poetry of heaven
If, in your bright leaves, we would read the fate
Of men and empires — 'tis to be forgiven.

Dr. Walter G. Smith is an American Board-certified toxicologist and also a licensed pharmacist. His career included periods as a university professor in the United Kingdom, as research director in the pharmaceutical industry and seventeen years as a scientist in regulatory affairs with the Canadian federal government. In retirement he has returned to the love of the night skies that he first encountered in blacked out Britain during the Second World War. His other interests at the present time are amateur ornithology, North American marine history, the history of herbal medicine and the medical applications of hatha yoga, which he practices every morning and now teaches. He is a volunteer staff member of the Marine Museum of the Great Lakes in Kingston, Ontario, and a member of the Kingston Centre. He keeps a telescope at his lakeside cottage in the dark sky corridor north of Kingston.

Second Light

Fuzzy Young Galaxies

by Leslie J. Sage

When we look at nearby galaxies through a small telescope, we generally see rather regular structures: the majestic spiral features of M31 (the Andromeda galaxy) and M81, or smooth, featureless elliptical systems such as M32 and M110 (dwarf companions to M31). The question of why there are two[1] distinct types of galaxies, and how and when they formed, has been vexing astronomers for almost 75 years, since Edwin Hubble demonstrated that they are separate "island universes" from our own Milky Way galaxy. Some recent modelling by M. Noguchi (26 March 1998 issue of *Nature*) of how gas behaves in a forming galaxy sheds new light on the problem.

Only recently, from observations with the repaired *Hubble Space Telescope* and the Keck telescopes on Mauna Kea, have we been able to see galaxies back when the universe was only twenty percent or less of its present age (see the accompanying image, which shows a portion of the Hubble Deep Field). Most such galaxies, it turns out, have very peculiar shapes. Is it because they are colliding with one another? That has been the general idea developed over the last couple of years.

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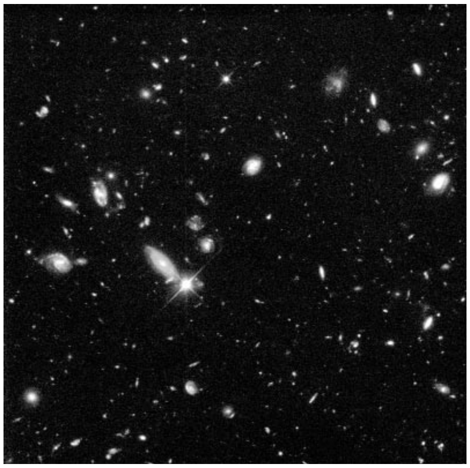
[1] More refined observations have resulted in different subcategories of spirals — the lenticular and barred galaxies.



The Hubble Deep Field. Most of the objects here are very distant galaxies.

Because galaxies were closer together early in the universe's history, collisions should have occurred much more frequently then. If the present-day galaxies were built up of clumps of material, there must have been many clumps whizzing around them at one time. But, such young galaxies detected telescopically are often substantially smaller than the ones we see today. In some respects they appear more like the dwarf irregular galaxies of the local universe, except that they are much more common.

Colliding galaxies often have tails that extend far from their nuclei; the tails are generally thought to arise because of tidal effects during interactions. A substantial fraction of interactions will lead to mergers between galaxies, if not on one particular encounter then on another one at some future time, as their mutual orbit brings them close together again. Recent research (particularly by Josh Barnes and Lars Hernquist) has shown that many mergers of spiral galaxies will produce, over about a billion years, a new elliptical galaxy that contains most of the stars and gas of the original spirals.

Such mergers often lead to spectacular bursts of star formation as the gas essentially falls towards the centre, where it rapidly cools and condenses into very dense clouds of molecular (mostly hydrogen) gas. The clouds can then give birth to a new generation of very massive stars; indeed, the total luminosity (by which I mean the intrinsic brightness) of the new stars alone can often exceed the luminosity of the precursor galaxies, sometimes by a factor of ten!

But, is that really what happened? Noguchi believes that a substantial fraction of the peculiarly shaped galaxies can be explained by spontaneous bursts of star formation within the gas-rich environment of the young universe, rather than by interactions. The idea is analogous in some ways to the situation in local dwarf irregular galaxies, where the light is often dominated by several regions of massive star formation, which are also thought to have started spontaneously.

He begins his simulation with a large spherical cluster of gas clouds, with a total mass about equal to that of a normal spiral galaxy of today, orbiting their common centre of mass. As the clouds interact with each other, the gas collapses towards the plane of rotation over approximately a billion years, forming large clumps with masses about equal to those of modern-day dwarf galaxies. The star formation rate reaches a peak around that time, and of course stars form within such sub-galactic clumps (that is where the gas out of which they form is located).

The appearance and evolution of such very young galaxies is intriguing. Although the underlying physical reality (according to the model simulation) is a group of billion-solar-mass sized clumps in a thick disk orbiting their centre of mass, the light from the conglomerate is dominated by stars within the clumps. It gives the galaxy a patchy and irregular appearance much like the peculiar galaxies detected in the Hubble Deep Field. Over the next billion years the largest clumps fall into the centre of the new galaxy to form the spherical bulge. The smaller clumps, combined with the later infall of additional gas, form the smooth disk over a time scale of about two billion years. The characteristics of the disk and bulge are quite similar to the characteristics of normal spiral galaxies near us.

Does such a process describe how spiral galaxies formed? It is too early to tell, but such an approach certainly looks promising. It is difficult to understand how a normal spiral could be constructed from separate small galaxies that merge together unless possibly they are mostly gaseous — everything indicates that the merger of galaxies that are already dominated by stars will produce ellipticals. Presumably the Hubble Deep Field contains the precursors of both spiral and elliptical galaxies. The ellipticals could arise from mergers of galaxies that already have lots of stars, while the spirals could have been created through a process like that proposed by Noguchi.

In their earliest stages, nascent ellipticals and spirals are probably very difficult to differentiate from one another. In principle, one might distinguish them by determining which ones are rotating smoothly (spirals) and which ones have fragments whose relative velocities differ by a large amount (ellipticals). In practice, however, it is extremely difficult to observe a spectral line (and thereby obtain information about the motion) even from the total light of a galaxy in the Hubble Deep Field, let alone from the individual clumps. We may have to wait for the next-generation space telescope to find out how galaxies actually form.

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.*

Reflections

Sundials: Tempus Fugit and Caveat Emptor

by David M. F. Chapman

A well-designed sundial can be a pleasing addition to a park or garden, providing a focal point for flowerbeds and landscaping. In these days of atomic clocks and digital watches, using a sundial to tell time seems terribly passé and laughably imprecise; sadly, the sundial has declined in stature from useful timepiece to just another lawn ornament. In spite of this, for astronomers and gardeners alike there is something appealing about a timepiece that is intimately connected to the energy source for earthly life (*i.e.* the Sun) and whose motion derives from the rotation and revolution that govern the daily and seasonal cycles of our planet.

The earliest form of sundial must have been a hunter's spear jammed in the ground. A thoughtful hunter would quickly learn to associate the changing length of the spear's shadow with the passage of the day. (It reminds me of an old boy scout trick for finding the cardinal directions: every few minutes place a pebble at the end of the shadow cast by a vertical shaft fixed firmly in the ground. Before long, you will have a line of pebbles oriented roughly east-west. It works best around noon, the proof of which is left to the reader.) The Greeks liked the stick-in-the ground concept so much, they gave it a name: the gnomon. Sundial designs evolved from the simple gnomon, and the requirement to measure smaller subunits of the day throughout the various seasons of the year gave rise to some sophisticated designs indeed. One can even account for the inclination of the Earth's axis to the ecliptic plane and the eccentricity (*i.e.* the non-circularity) of the Earth's orbit, which together introduce corrections of up to plus or minus a quarter of an hour. (Readers are referred to the discussion on page 70 of the 1998 RASC *Observer's Handbook*.) Consequently, a properly designed sundial is capable of indicating the time correctly to an accuracy of a minute or better.

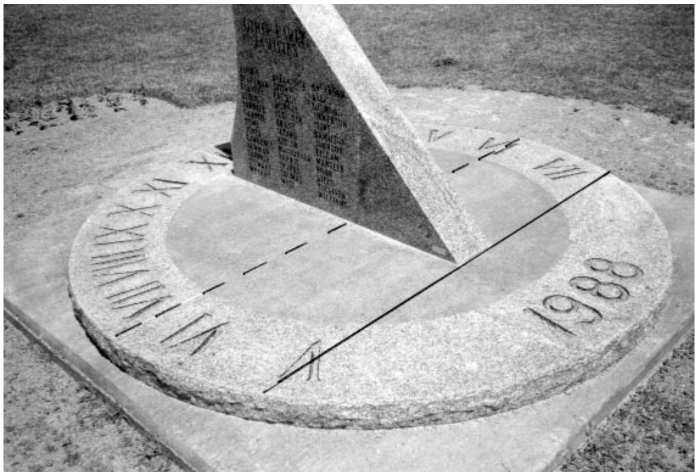

This sundial, found in a British cemetery for fallen Canadian airmen, is a good example of correct dial markings.

In spite of the sundial's triumph of astronomy, geometry, and mathematics, today there are many mass-produced models being manufactured and sold that violate the fundamental principles of sundial design and — accordingly — are hopeless timekeepers. This article attempts to provide the reader with some tips on choosing a sundial that not only looks nice in the garden but also tells time correctly. (There are many books on sundial design and construction, some of which may be available in your public library or from astronomy book dealers. Internet surfers may want to take a ride on the world-wide web page http://www.ph-cip.uni-koeln.de/~roth/slinks.html, which has more links than you can shake a gnomon at.)

The following points apply to the horizontal plane sundial, which is the most common form. (It is my experience that builders of the less common sundials — such as the vertical plane sundial or the equatorial sundial — tend to have a firmer grasp of sundial design principles and make fewer errors.) A horizontal sundial consists of a horizontal dial plate with hour markings and a gnomon plate mounted in a vertical plane (or a gnomon shaft mounted at an angle).

1. Angle of the gnomon. The slanted edge of the gnomon — which casts the time-telling shadow — must be straight and form an angle with the horizontal plane equal to your geographical latitude. That is driven by the requirement for the edge of the gnomon to be parallel to the Earth's polar axis. The latitude probably only needs to be known to an accuracy of about one or two degrees, so a student atlas should be able to provide the required value. Interestingly, a sundial properly designed for a latitude other than your own is still perfectly usable, as long as you tilt the base north or south by the appropriate angle to align the gnomon edge with the polar axis. By doing that you are simulating installation at the design latitude.

2. Position of the gnomon. The gnomon should be aligned along the 12:00 noon direction on the dial and perpendicular to the 6 a.m.–6 p.m. line of the dial, with the toe of the gnomon exactly touching the line. The last criterion is the most common fault I have observed in poorly constructed sundials, which often are correct in all other respects. If we ignore for the moment the equation-of-time correction, the Sun, at the 6 o'clock position (morning or evening), is 90 degrees from the



The Seaview Park sundial, a memorial to the black settlers of north-end Halifax, is a good example of poor dial markings. The 6 a.m. and 6 p.m. marks should be on the solid line at the toe of the gnomon, but are closer to the dashed line, which bisects the dial.

meridian. At such times the shadow of the gnomon falls exactly in the east-west direction on the dial plate, which should be the same as the 6 a.m.–6 p.m. line.

3. Dial plate markings. Unlike a clock, there is no universal set of hour marks for the horizontal sundial; the angles between the hour marks are unequal and depend upon the latitude. It would be difficult to check their accuracy before purchasing a sundial, but you can at least check that there are no gross errors. For instance, as mentioned above, the 6 a.m. and 6 p.m. marks should be opposite one another and the straight line joining them should be perpendicular to the 12 noon line. The angles between successive hours should be larger near 6 o'clock than the angles near noon. The hour lines, if marked, should appear to radiate from the toe of the gnomon where it touches the 6 a.m.–6 p.m. line.

A sundial that passes the above tests will probably function reasonably well as a timepiece, if mounted perfectly

FROM THE PAST AU FIL DES ANS

THE MEETING OF MARCH 15

The Society met in the Physics Building of the University of Toronto at 8 p.m., the President, Mr. J. R. Collins, in the chair.

Prof. Alfred Baker, of the University of Toronto, gave the lecture of the evening, his subject being "Sun Dials."

The earliest mention of sun dials is the reference found in the book of Isaiah, which was written about 600 B.C. The first dial whose construction is known was that of Berosus, a Chaldean astronomer, 300 B.C. His dial was a hemispherical bowl, placed with its rim perfectly horizontal; wires intersecting at the centre made a knot, the shadow of which described an arc upon the inside of the bowl. This arc was divided into twelve equal parts called the temporary hours, and as each was the twelfth part of each period of daylight, the hours varied considerably from season to season.

This form of sun dial existed far into the Christian era, being replaced by more accurately constructed ones in the 14th and 15th centuries, which in turn were superseded by clocks and watches in the 18th century.

Prof. Baker explained the accurate construction of the equatorial, horizontal and vertical dials, developing the trigonometrical formulae involved. Three methods for properly placing the dial in the meridian were described, as it is most essential that the dial be correctly orientated.

The older dials were elaborately decorated, and invariably had mottoes engraved upon them, suggesting the flight of time, and old age's rapid approach. The lecturer gave some two dozen of the most interesting examples of the mottoes found on the dials of both continents. It is interesting to note that the earliest Anglo-Saxon inscription in England is found on the sun dial at Newcastle, in Northumberland, dating from 670 A.D.

When the University of Toronto fire occurred in 1890 the Tower bell was melted, and from the metal Prof. Baker made a dial, bearing the Latin hexameter: "Ecce sonans, olim, mutum nunc, auguror horas" (Formerly noisily, now silently, I mark the hours). This interesting timepiece was placed in the Dean's garden, where it remained for several years. It was finally removed however, shortly before one Hallowe'en.

J. A. Pearce, *Recorder*

from *Journal*, Vol. 15, p. 165, April, 1921 horizontal and aligned to True (not Magnetic) North. However, if there is something fishy about the gnomon angle, the gnomon location or the dial markings, then it is bound to disappoint. Antique sundials, constructed when their timekeeping accuracy was valued, are usually first-rate. Modern sundials can be just as good, if not better, but I have seen some whoppers. There is a “nature” store in my city that sells sundials, but about one out of three is bogus. Ditto for the leading garden store. At a craft fair in Quebec City, I had to show a sundial vendor that one of her gnomons was mounted backwards on the dial!

An embarrassing example of a poorly constructed sundial can be found in Seaview Park in Halifax. As a memorial to the black settlers of Africville, this piece of carved granite is a fine monument, but it gets an F for sundial design. The gnomon is cut at the right angle and is oriented to True North. Unfortunately, the locations of the hour markings and the gnomon are incorrect. With a little expense and with the aid of a sundial consultant (ahem!), the sundial could be put right; however letters to the various officials concerned have gone unanswered.

To end on an upbeat note, I chanced upon a fine sundial craftsman at a local craft fair last Christmas: Terry Mollins of Pebble Stone, Ltd., P.O. Box 1297, Shediac, N.B. E0A 3G0, tel. (506) 532-4935. Terry’s dials are attractive and they appear to be correctly made (at least they passed my 3-point test). I am sure there are other Canadian suppliers out there, and I would love to hear about them. ◉

David M. F. Chapman has just completed a two-year term as President of the RASC Halifax Centre. He became interested in astronomy at the age of 8, and studied physics at the University of Ottawa (B.Sc., 1975) and the University of British Columbia (M.Sc., 1977). Since then, he has performed research in ocean acoustics at the Defence Research Establishment Atlantic. He occasionally writes astronomy scripts for the StarDate *and* Earth&Sky *radio broadcasts.*

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TRACKING A FIREBALL FROM EYEWITNESS ACCOUNTS WITH REFERENCE TO THE WEST COAST EVENT OF 1995 DECEMBER 22[1]

by Jeremy B. Tatum
Climenhaga Observatory, University of Victoria

(Received May 26, 1997; revised August 28, 1997)

Abstract. Two methods are described whereby the trajectory of a fireball can in principle be calculated from eyewitness accounts. Practical experience, however, is very different, and I recount the difficulties encountered in trying to delineate the track of the December 22, 1995, fireball over Vancouver Island.

Résumé. Deux méthodes sont décrites par lesquelles la trajectoire d'un bolide peut, en principe, être calculée à partir de comptes rendus de témoins visuels. L'application de ces méthodes est toutefois très différente. Je relate les difficultés rencontrées lorsque j'ai tenté de déterminer la trajectoire, au-dessus de l'Ile de Vancouver, du bolide du 22 décembre 1995. KL

1. Introduction

The sighting of a bright fireball by an individual is a rare event indeed, and even an astronomer whose business it is to gaze at the sky may be counted lucky if he or she sees a very bright one in a lifetime. Nevertheless, although such an experience for an individual is rare, fireballs are remarkably common, some forty or fifty of them being reported over Canada every year to the Meteorites and Impacts Advisory Committee (MIAC). For a few of them, reports are so widespread that members of the Committee and others interested in the phenomena have the task of interviewing witnesses, measuring angles, and trying to determine the track of the object and where it might have landed.

When a meteoroid approaches the Earth, it does so in an orbit that is approximately a hyperbola with respect to Earth. This is a result of Earth's gravitational attraction, which pulls the meteoroid away from its original path and has the effect (known as "zenith attraction") of moving the radiant towards the observer's zenith compared with where it would be if the meteoroid were unaffected by Earth's gravity. When the meteoroid enters Earth's atmosphere, the path is distorted from hyperbolic form. If photographic records of the fireball are obtained from different stations with time marks along the track (effected, for example, by the use of a rotating shutter), detailed measurements of the photographs enable one to calculate not only the track through the atmosphere and the impact point, but also the heliocentric orbit of the meteoroid before Earth encounter. A detailed analysis of how to perform the necessary calculations has been given by Ceplecha (1987).

In the absence of photographic records, however, one has to rely upon eyewitness accounts, and high-precision computations then become impossible and inappropriate. Indeed, for the short interval of time during which witnesses see a fireball streak across the sky, there is probably nothing to be gained from the assumption that the track through the atmosphere is anything other than a straight line. In the simple analysis followed here, it is assumed that the visible fireball track is indeed linear, even though, it might be remarked, witnesses are often under the impression (which I believe to be illusory) that the path is highly curved. The errors in eyewitness estimates of angles (often of order tens of degrees) do not permit a more refined analysis.

Interviewing witnesses involves asking them various qualitative details, such as the colour of the fireball, whether any sound was heard, speed, and so on. But the most important of all is the measurement, from witness accounts, of the azimuth[2] and altitude of two points on the apparent track. From them one can calculate the track.

I know of two simple methods of calculating the track from such observations that are based upon a linear track, and I refer to them as Azimuths Only and Intersecting Planes. Huziak & Sarty (1994) have described the Azimuths Only method, as well as their techniques and experiences of interviewing witnesses, and they have developed an excellent computer program for carrying out the necessary calculations. They have kindly used their program for analyzing actual observations of fireballs that I have investigated in British Columbia. They made brief reference to a conference paper by Hawkes *et al.* (1993) on the Intersecting Planes method. I devised essentially the same method myself while analyzing local fireball sightings, and I thought I would take the opportunity to describe the method here, and also to describe my attempts to apply it to the eyewitness accounts of the fireball seen over Vancouver Island on December 22, 1995.

2. Azimuths Only

Since the method has been described in detail by Huziak & Sarty (1994), I describe it only very briefly here. The investigator merely marks out the azimuths of two points on the track as indicated by one witness, and then does the same thing for the same two points as seen by a second witness (figure 1). Where the two pairs of azimuths intersect gives the ground track of the object. Now that the distance of the ground track is known, the altitudes can be used

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[1] Based on a paper presented at the October 1996 meeting of the Meteorites and Impacts Advisory Committee to the Canadian Space Agency, held in Saint-Hubert, Québec.

[2] Azimuth is taken here to mean azimuth from true north, not magnetic north. In practice measurement of azimuth is often made from geomagnetic north with a magnetic compass, and it is the responsibility of the investigator or interviewer to make the appropriate correction for magnetic declination.

to calculate the height of the object and hence the track in three dimensions can be calculated.

When the calculation is performed, either a flat or a spherical Earth can be adopted. Most astronomers believe the Earth to be approximately spherical; however, the very large uncertainties inherent in eyewitness estimates of altitude and azimuth give one pause to consider whether the extra sophistication of the spherical Earth calculation is worth the candle. If pairs of photographs with identifiable starry backgrounds are obtained, the answer would clearly be yes; with visual observations by surprised observers the answer is probably no. The Huziak & Sarty program adopts a spherical Earth and, since the calculation is done by computer, there is no extra work involved in using the spherical solution.

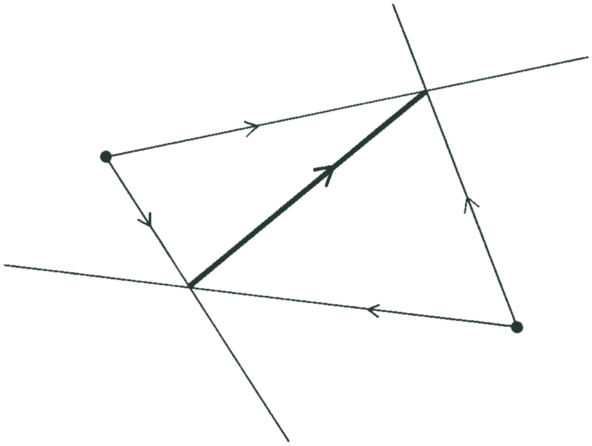

Fig. 1 — An illustration of the Azimuths Only method for deducing the ground track of a fireball. Two witnesses, represented by dots, observe a fireball (thick track). The azimuths of the lines of sight from each witness to the beginning and end points of the track intersect at the ends of the ground track, thus enabling the distance to be determined.

It will be noted that, in the initial part of the calculation to find the distance of the ground track, only azimuths are used, and that might be thought to be a disadvantage of the method. Some investigators, however, find that witness estimates of altitudes are less reliable than their estimates of azimuths, and indeed their altitude estimates may actually be misleading. Therefore, in practice there may well be an advantage rather than a disadvantage to initially using only the azimuths. One small disadvantage of the method in comparison with the Intersecting Planes method is that it requires that both witnesses see the same two points on the track. If that is in fact the case, the Azimuths Only method may well be the method of choice; if it is not, the preferable method may be the method of Intersecting Planes.

3. Intersecting Planes

As in the Azimuths Only method, either a flat or a spherical Earth may be adopted. In the analysis presented here the Earth is flat; the precision of eyewitness accounts hardly justifies further sophistication.

In figure 2, *O* is an arbitrary origin of co-ordinates on the surface of the Earth, perhaps the position of the investigator's home observatory. The x-axis is to the east, the y-axis to the north. Witness *A* is situated at the point (x_A, y_A). He reports the spherical co-ordinates, referred to his local co-ordinate system, of one point *M* on the meteor track as (θ_1, ϕ_1) and of another point *N* as (θ_2, ϕ_2). (In practice the angles recorded are the altitude, which is $90° - \theta$, and the azimuth eastwards from the north point, which is $90° - \phi$.) He does not know the distances r_1 and r_2 of the points *M* and *N*.

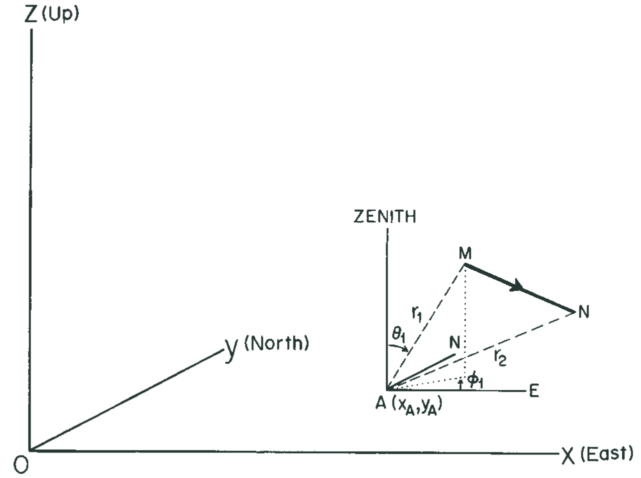

Fig. 2 — An illustration of the Intersecting Planes method for deducing the track of a fireball. A witness at *A* observes a fireball *MN*. The witness records the spherical angles θ_1 and ϕ_1 of beginning point *M*, and θ_2 and ϕ_2 (not drawn) of the end point *N*. The three values define the plane *AMN*. If a second witness makes similar observations, the track of the fireball is determined by the intersection of the two resulting planes.

From such information we know that the meteoroid track was somewhere in the plane *AMN*, the co-ordinates of the points *A*, *M*, *N* being

$$A\,(x_A, y_A, 0)$$
$$M\,(x_A + r_1 \sin\theta_1 \cos\phi_1, y_A + r_1 \sin\theta_1 \sin\phi_1, r_1 \cos\theta_1)$$
$$N\,(x_A + r_2 \sin\theta_2 \cos\phi_2, y_A + r_2 \sin\theta_2 \sin\phi_2, r_2 \cos\phi_2)\,.$$

The equation of a plane passing through three points (x_1, y_1, z_1), (x_2, y_2, z_2), and (x_3, y_3, z_3) is

$$\begin{vmatrix} x & y & z & 1 \\ x_1 & y_1 & z_1 & 1 \\ x_2 & y_2 & z_2 & 1 \\ x_3 & y_3 & z_3 & 1 \end{vmatrix} = 0\,. \tag{1}$$

On application of that to the three points *AMN*, we find that the meteoroid track was in the plane

$$a_1 x + b_1 y + c_1 z + d_1 = 0\,, \tag{2}$$

where $$a_1 = \sin\theta_1 \cos\theta_2 \sin\phi_1 - \cos\theta_1 \sin\theta_2 \sin\phi_2\,, \tag{3}$$

$$b_1 = \cos\theta_1 \sin\theta_2 \cos\phi_2 - \sin\theta_1 \cos\theta_2 \cos\phi_1\,, \tag{4}$$

$$c_1 = \sin\theta_1 \sin\theta_2 \sin(\phi_2 - \phi_1)\,, \tag{5}$$

and $$d_1 = -a_1 x_A - b_2 y_A\,. \tag{6}$$

As expected, the equations do not contain r_1 or r_2.

In a similar manner a second observer at a different location reports different altitudes and azimuths, from which it is deduced that the meteoroid track must be in the plane

$$a_2x + b_2y + c_2z + d_2 = 0 , \qquad (7)$$

where the new coefficients are determined from her observations of altitude and azimuth. It is not necessary that the two witnesses report on the same two points of the track.

The meteoroid must therefore be at the intersection of the planes given by equations (2) and (7). This intersection is a straight line, and the analysis assumes that the meteoroid travelled in a straight line while it was being observed. A critic who believes this assumption to be incorrect and who attempts the calculation of a more precise trajectory should first interview a few witnesses to experience them. The reality is that measured angles from eyewitness accounts quite commonly disagree by thirty, forty or even fifty or more degrees, and witnesses often disagree even as to the direction in which the object was moving.

The projection of the track on the horizontal plane, *i.e.* the ground track that will be drawn on a map, is the z-eliminant of equations (2) and (7), which is

$$ax + by + c = 0 , \qquad (8)$$

where $$a = a_1c_2 - a_2c_1 , \qquad (9)$$

$$b = b_1c_2 - b_2c_1 , \qquad (10)$$

and $$c = c_2d_1 - c_1d_2 . \qquad (11)$$

The height z of the meteoroid above any point (x, y) on the ground is given by the solution of either equation (2) or equation (7) for any point (x, y) that satisfies equation (8). As a check against mistakes, z should be computed from both equation (2) and equation (7).

If the meteoroid were to continue along the straight line given by equations (2) and (7), it would reach the ground at a point (x_∞, y_∞) given by the solution of equations (2) and (7) with $z = 0$, which is,

$$(x_\infty , y_\infty) = \left(\frac{b_1d_2 - b_2d_1}{a_1b_2 - a_2b_1} , \frac{a_2d_1 - a_1d_2}{a_1b_2 - a_2b_1} \right) . \qquad (12)$$

It will, however, presumably not continue along a straight line but will drop before that point. How far before?

Figure 3 shows the ground track given by equation (8). Witness A last saw the meteor at the point N in figure 2. The point on the ground vertically below N is N_0 in figure 3. This point lies at the intersection of equation (8) with the relation,

$$y = y_A + (x - x_A) \tan \phi_2 ,$$

that is, at

$$x = \frac{b(x_A \tan \phi_2 - y_A) - c}{(b \tan \phi_2 + a)} \qquad (13)$$

The y-coordinate of N_0 is then found by substitution in equation (8), and the z-coordinate of N — *i.e.* the height of the meteoroid when it was last seen by witness A — is found from equation (2) or equation (7) (or both, as a check on the arithmetic). The impact point should be between N_0 and (x_∞, y_∞).

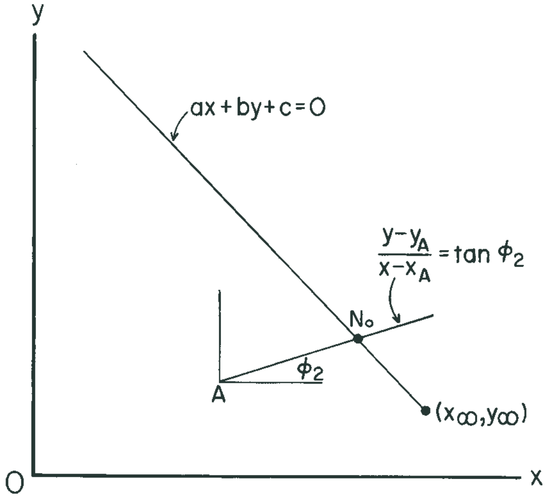

Fig. 3 — The ground track of a fireball. The line $ax + by + c = 0$ is the ground track, and the line AN_0 is the azimuth of the end point as seen by witness A. The point (x_∞ , y_∞) is the point where the track, assumed to be linear, intersects the ground. The meteorite presumably lies between that point and N_0.

In the following hypothetical example, distances are expressed in kilometres and angles in degrees. We shall suppose that the (x, y) coordinates of the witnesses A and B are (15, 5) and (30, 15) respectively. For his first clear view A reports $\theta_1 = 25°.5$, $\phi_1 = 54°.5$, and for his last clear view he reports $\theta_2 = 36°.7$, $\phi_2 = 16°.7$. For her first clear view B reports $\theta_1 = 29°.6$, $\phi_1 = 202°.9$, and for her last clear view she reports $\theta_2 = 33°.6$, $\phi_2 = 242°.9$.

Equations (2) and (7) for the two intersecting planes are:

$$0.1260x + 0.3162y - 0.1577z - 3.4712 = 0$$

and $$0.2683x + 0.1598y + 0.1757z - 10.4445 = 0 .$$

Equation (8) for the ground track is:

$$0.06444x + 0.08076y - 2.257 = 0 .$$

The linearly extrapolated impact point is, from equation (12),

$$(x_\infty , y_\infty) = (42.4, - 6.0) .$$

The point N_0 is

$$(x, y) = (25.0, 8.0) ,$$

and the height of the point N is $z = 14.0$.

If the same calculation is repeated for witness B, it will be seen that her end point was a little closer to (x_∞ , y_∞). Thus, for her, her N_0 is at

$$(x, y) = (26.0, 7.2) ,$$

at height $z = 13.2$.

The meteorite, if it landed, is therefore likely to be between (26.0, 7.2) and (42.4, –6.0).

4. December 22, 1995

At 6:57 a.m. PST ($14^h\,57^m$ UT) on the morning of December 22, 1995, a brilliant fireball — said by witnesses to have lit up the entire countryside — was seen from the southern half of Vancouver Island, from several locations in Washington State (including an airline pilot at 22,000 feet, or 6700 m), and from as far away as Merritt on the British Columbia mainland. I interviewed about 80 witnesses, including 52 *in situ* interviews in which I asked the witnesses to re-enact what they had been doing, and I measured their indicated altitudes and azimuths of two points on the track with a compass and inclinometer. What many of the witnesses had been doing, incidentally, was jogging, delivering newspapers, relaxing in hot tubs (a very frequent activity of fireball witnesses), lying in bed, captaining ferries or flying airliners. The remaining 30 or so witnesses that I did not interview *in situ* I interviewed by telephone. While some of them helped to confirm the general appearance of the fireball, I did not use any numerical data from telephone interviews in the actual computation.

Having all of the above equations at my disposal, all duly programmed for the computer, and a nice easy numerical example to follow, I felt sure that the going would be easy. I would just run the data through the computer and go and pick up the meteorite the following day. I was about to learn some facts of life.

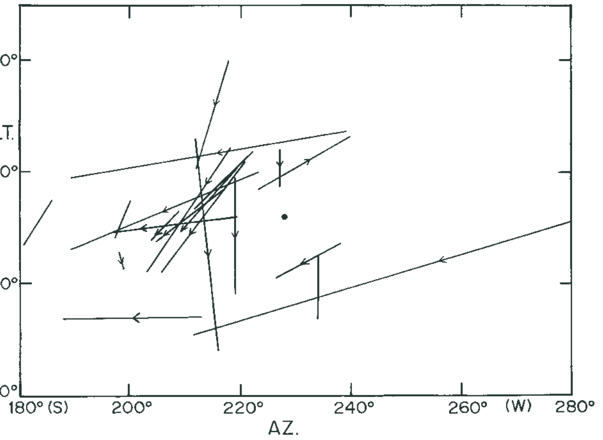

Fig. 4 — Impressions of the track of the December 22, 1995, fireball from 25 nearby witnesses.

Widely separated observers will, of course, see the fireball in different parts of the sky, and that is how the equations are able to predict where the meteorite falls. Witnesses in close propinquity, however, should largely agree as to where they saw the fireball. Alas, that is not the case in practice. In order to see how well witnesses were agreeing with one another, I gathered together the reports of 24 witnesses, all of whom happened to have been within about a couple of miles (3 km) of each other. Their reports should have been relatively unaffected by parallax, and they would all have seen the object travel in more or less the same path across the sky. In figure 4 we are looking roughly southwest, with due south at the left hand of the figure and west near to the right. The figure covers 100° in azimuth and 70° in altitude. It can be seen that quite a few witnesses saw the meteor moving downwards and to the left, at an azimuth of around 210° and an altitude of around 30°. But there were some remarkable variations. To four witnesses the meteor seemed to be travelling almost horizontally, including one witness who saw it moving across 70° of sky. Yet seven witnesses saw it moving almost vertically. Several tracks were very short, including one that indicated just a single bright flash and no trail at all. Two witnesses saw it move from left to right, and three witnesses were unsure of the direction of motion — their tracks are those without arrows.

We are not in any way to blame the witnesses for such discrepancies — indeed we are to be grateful to them for taking the time and trouble to recall as well as possible what they saw. It must be remembered that the appearance of a bright fireball is an exceedingly startling phenomenon, whose arrival is completely unexpected. It lasts but a few seconds and there is no replay. Conditions are not in the least conducive to precise measurement, and indeed a few witnesses quite understandably experience fear. Some months after the event I had the good fortune to see a bright fireball myself, and I proved to be just as unreliable a witness as anybody. We can in no way find fault with those who faithfully and as accurately as they could reported what they saw. Yet it is more than evident that it would be a meaningless exercise to compile the data uncritically into the data file of a computer program and expect anything like a reasonable result.

For the record I reproduce in Table I the latitudes and longitudes of all witnesses from whom I was able to obtain unambiguous altitudes and azimuths of two points (not necessarily the same two points for all observers) on the track. In spite of the difficulties mentioned above, attempts were made both by myself, using an Intersecting Planes program, and Gordon Sarty, using an Azimuths Only program, to try to make the best reasonable sense out of the data. Our results are in broad agreement as to the general direction of flight and probable end point. In brief, I believe that the object came in from over the Pacific Ocean moving a little bit south of east, and it exploded while over the Olympic Peninsula in Washington State, sending a large fragment vertically downwards over that heavily forested and very mountainous area. This accounts for some witnesses seeing an object travelling over a long distance over a roughly horizontal path, others reporting just a single bright flash, and still others describing the movement as vertically downwards.

It was never directly over Vancouver Island or, indeed, any part of Canada. Sarty's solution for the impact point was 47° 50′.5 N, 123° 21′.3 W, which is about two miles south of Lake Lillian in Olympic National Park. The closest witness was a Park Ranger, Mr. Jon Preston, stationed at Elkhorn Ranger Station. The computed track would make the meteorite pass almost directly overhead from that station, and land a little to the east. However, Mr. Preston's observation was clear in that the end point was somewhat to the west of him, which is more to be relied upon than the formal solution. In any case, the conclusion is that, if a meteorite did land, it would most likely have landed in very rugged and remote terrain in an area of Olympic National Park to the west of Elkhorn Station. The probability of finding the stone from a ground or air search is not high.

At the time of the MIAC meeting when I described the event, I asked in somewhat gloomy terms whether the effort of interviewing fireball witnesses and performing the necessary calculations was worth while. The value of following such reports has been discussed by Hawkes & Lemay (1993), as well as by Huziak & Sarty (1994). One has to balance the effort involved against the probability of recovery. The probability of recovery on the mountainous and forested west coast of British Columbia is very remote indeed, even under ideal conditions. This is not itself a deterrent, for gaining experience in how to carry out a search could be put to good use when a fireball appears over more favourable territory, such as the Prairie Provinces. One thing that became clear was that it is too big a task for a single person to interview all the witnesses within a few days of an event.

An alternative possibility would be to establish a network of trained interviewers over a suitable area, so that, when a fireball appears, witnesses over a large area can be interviewed rapidly. But is it all worth it, or should one admit that interviewing witnesses and trying to recover a meteorite after a fireball sighting is very unlikely to lead to recovery of a meteorite? I think the general feeling at the meeting, a feeling which I tended to share, is that it is not really worth the effort involved, and that there were better ways of pursuing the study of meteoritics. That was the conclusion I reluctantly came to.

Then, at 6:13 PST on the morning of December 17, 1996, a brilliant fireball lit up the countryside all over Vancouver Island and was seen from as far away as Salem, Oregon. A noise like that of an express train or a jet aircraft was heard over the central part of the island, and some 800 witnesses telephoned to the University of Victoria, the Dominion Astrophysical Observatory, and the Macmillan Planetarium in Vancouver. My resolve to ignore it was put severely to the test.

The story of that one will have to wait for another meeting and another article...

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Table I.
Witness Observations of the December 22, 1995, Fireball Near Vancouver Island

Latitude N	Longitude W	Altitude (1)	Azimuth (1)	Altitude (2)	Azimuth (2)
48° 26´.7	123° 29´.6	40°	223°	26°	189°
48° 25´.2	123° 28´.7	25°	234°	14°	234°
48° 28´.7	123° 21´.1	32°	220°	29°	196°
48° 29´.6	123° 24´.4	43°	221°	29°	209°
48° 25´.0	123° 22´.1	47°	239°	39°	189°
48° 25´.3	123° 18´.7	42°	221°	22°	206°
48° 27´.2	123° 17´.3	14°	213°	14°	188°
48° 24´.4	123° 21´.2	26°	198°	22°	199°
48° 46´.9	123° 26´.6	30°	204°	19°	204°
48° 39´.4	123° 33´.8	27°	200°	22°	200°
48° 43´.8	123° 38´.5	28°	212°	20°	204°
48° 26´.8	123° 24´.0	35°	293°	11°	211°
48° 28´.0	123° 25´.5	39°	217°	18°	217°
48° 24´.2	123° 42´.1	48°	243°	30°	213°
48° 24´.2	123° 42´.1	26°	194°	20°	189°
48° 21´.8	123° 47´.3	56°	263°	40°	234°
48° 22´.9	123° 31´.0	47°	248°	34°	210°
48° 39´.2	123° 24´.1	42°	228°	12°	196°
48° 28´.2	123° 21´.4	33°	209°	27°	203°
48° 36´.9	123° 24´.5	53°	10°	37°	204°
48° 47´.3	123° 41´.2	25°	178°	15°	178°
48° 29´.6	123° 24´.4	29°	222°	29°	208°
48° 27´.2	123° 26´.7	42°	220°	22°	203°
48° 30´.2	123° 24´.3	35°	186°	27°	181°
48° 22´.5	123° 43´.8	36°	196°	34°	183°
48° 29´.0	123° 24´.0	46°	212°	8°	216°
48° 26´.8	123° 22´.3	36°	217°	27°	204°
48° 27´.9	123° 26´.2	35°	200°	28°	197°
48° 52´.4	123° 31´.8	48°	320°	32°	353°
48° 39´.5	123° 22´.5	29°	166°	12°	163°
48° 29´.0	123° 20´.9	48°	231°	35°	229°
48° 35´.0	123° 22´.0	16°	211°	11°	208°
48° 35´.0	123° 22´.0	25°	220°	17°	209°
48° 29´.9	123° 22´.0	27°	238°	21°	226°

Invited Review Paper

COSMIC MAGNETISM IN FIFTEEN EASY STEPS

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Abstract. This brief overview attempts to convey the wonders of magnetic fields in astronomy. Presented are sketches of known magnetic fields that exist over a broad range of astronomical sizes, ranging from Earth size to cosmic dimensions, and comments on the physical processes involved. The review is presented as a series of schematic views, each one covering a frame 100 times larger than the one previous. In this manner figure 1 examines human scales (1 metre = 100 cm), figure 2 examines scales 100 times larger (100 metres = 10^4 cm), figure 3 examines scales 100 times larger again (10 thousand metres = 10^6 cm) and so on. Cosmological scales are examined in figure 14 (100 trillion trillion metres = 10^{28} cm).

Résumé. Dans ce rapide "survol" pour un grand auditoire, j'ai essayé de transmettre les merveilles des champs magnétiques en astronomie. J'utilise des dessins montrant les champs magnétiques tels qu'observés entre la Terre et les confins de l'univers, et j'ai noté au passage les processus physiques pertinents. Chaque figure couvre un espace 100 fois plus grand que la figure précédente. La figure 1 couvre l'échelle humaine (1 mètre = 100 cm), la figure 2 couvre une échelle 100 fois plus grande (100 mètres = 10^4 cm), la figure 3 couvre une échelle 100 fois plus grande (10 mille mètres = 10^6 cm), etc. Figure 14 couvre l'échelle cosmologique (100-tera-tera mètres = 10^{28} cm).

1. Introduction

Any electric charge in motion — an electric current — creates an associated magnetic field. A circular current loop confined to a plane creates a magnetic field that passes through the plane of the loop. The creation process also works in reverse; a permanent magnet moved across an electric wire creates an electric current in the wire, as in a bicycle's dynamo.

In a bar magnet, each atom has an associated electron moving in a circular loop in a plane with an axis identical to the axis of the bar magnet. That gives rise to a combined, imaginary, long circle in a plane with its axis being the axis of the bar magnet. It results in a large, concomitant, magnetic field along the axis of the bar magnet.

Opposite magnetic poles always attract each other, while similar poles repel each other. The law of magnetic force — the Biot-Savart law — states that the force between two electric currents is such that two long parallel wires attract each other if the currents are in the same direction but repulse each other otherwise. Many electric appliances in a home possess electric currents that can generate a magnetic field at a short distance. Since the current is an alternating current (back and forth), the magnetic field direction alternates correspondingly. When a hair dryer is moved close to someone's head, a moving magnetic field sweeps across the head. The typical magnetic field strength is quite weak, around 10 milligauss (= 1 microtesla). Magnetic fields have long been claimed to affect humans (Mesmer, etc.), but so far the effects remain unproven. Recent trials have examined the possibility that moving magnetic fields can affect dreams when applied to the temporal lobes, but no effects were found at low magnetic field levels (Taubes 1997; Saint-Germain 1996).

Experience indicates that there are regions of space near a magnetized body within which magnetic forces can be detected. A compass needle aligns itself along the local magnetic lines on Earth and points toward its magnetic poles. Magnetic fields are also found everywhere in interstellar space, over both short and huge distances. They hold great promise for a detailed physical understanding of the dynamic universe.

In general, magnetic field lines are in some ways akin to tubes or pipelines, inside of which ionized hydrogen particles, elongated dust grains and relativistic high-energy electrons are trapped. As a result, the trapped particles can move along, but not across, the direction of the magnetic field lines.

The importance of magnetic fields can be summarized by the following considerations:

- Very strong magnetism can literally "glue" you to the surface of a pulsar.
- Too much magnetism can prevent life. Since strong magnetism can act as a buffer to stop an interstellar cloud from collapsing gravitationally, it could prevent star formation, planet creation and the emergence of life and subsequent intelligence.
- Strong magnetic fields can act as channels for particles, "weather" on the Sun being an example. Properly situated on the Sun, a large burst of particles from a solar active region can travel along the interplanetary magnetic field lines — which act as magnetic channels — to the Earth. The solar particles may later play havoc with radio communications on Earth. Interstellar weather also has detectable effects. Strong magnetism can play a significant role in small-scale phenomena, such as guiding the propagation of cosmic rays or shock waves.
- Strong magnetism can shield the Earth by affecting or deflecting particle trajectories. On Earth the magnetic field of our planet acts in this manner to prevent dangerous solar and interstellar particles from striking the surface of our planet, and changes the trajectories towards Earth's two poles.
- Magnetism can also align cosmic dust grains.
- It may also act as a tracer or record of the astronomically recent

dynamical life of a galaxy in motion. The tidal interaction between two galaxies will leave behind in intergalactic space gas clouds and magnetic fields with orientations that can indicate the history of the encounter.

- Magnetic field lines in interstellar space are compressible, *i.e.* they can be frozen or tied to the material (gas and dust) around them so that expansion (such as by stellar winds) weakens magnetism while compression (by stellar collapse) amplifies it.

For more information about this magnetic entity that can act as a glue, buffer, channel, shield, aligner, or tracer, or become compressible, detailed reviews of magnetism on small scales (stellar to protostellar to cloudlet) have been published by Vallée (1998), Bastien (1996), Königl & Ruden (1993), Vallée & Bastien (1996) and others. Detailed reviews of magnetism on large scales (galactic to intergalactic to cosmological) have recently been published by Vallée (1997), Beck *et al.* (1996), Kronberg (1994), Vallée (1996) and others.

2. How do we Measure Magnetic Fields from a Distance?

Magnetic fields of planetary (~10^5 km) or interplanetary (~1 A.U.) dimension are most often measured with *magnetometers* on board spacecraft sent from Earth. Those of circumstellar (~100 A.U.) and protostellar (~1000 A.U.) dimension are most often measured with *polarimeters* mounted on telescopes on Earth. They detect either the bright emission from particles (hydrogen gas, thermal dust or non-thermal electrons) trapped by the magnetic fields, or the perverse absorption effects that such particles have on the light coming from more distant objects before it reaches Earth. Dust grains in interstellar space can also be aligned by magnetic fields. In the process an elongated grain spins end-over-end around a short rotation axis that is on average parallel to the magnetic field direction. Since infrared emission by dust grains tends to be mainly perpendicular to the magnetic field direction (the Barnett effect), there is less emission by the dust grain in the direction parallel to the magnetic field.

To observe emission from dust grains, one needs telescopes operating at wavelengths in the extreme infrared (~800 micrometres) and far infrared (~100 micrometres) spectral regions. Canadian astronomers using the 15-m James Clerk Maxwell Telescope (JCMT) on Mauna Kea — for which the National Research Council of Canada provides 25 % of the support — regularly carry out such observations. To observe dust absorption one needs telescopes operating in the near infrared (~5 micrometres) and optical (~0.5 micrometres) spectral regions. Such observations can be made using the 3.6-m Canada-France-Hawaii Telescope (CFHT) on Mauna Kea — for which the National Research Council of Canada provides 42.5 % of the support — or the twin 8-m Gemini telescopes on Mauna Kea and Cerro Pachón — for which the National Research Council of Canada provides 15 % of the support — once they are completed.

Over the large distance scales that encompass interstellar (~1 kiloparsec), galactic (~10 kiloparsecs), intergalactic (~1 megaparsec) and cosmological magnetic fields, one observes emission from non-thermal particles with telescopes that operate at centimetre wavelengths (*e.g.* 3 cm to 30 cm) in the radio region. Non-thermal particles are typically electrons travelling at close to the speed of light; when trapped by a magnetic field, they travel forward in spiral loops around the magnetic field line while they emit telltale synchrotron radiation. The synchrotron emission by non-thermal relativistic particles is at a maximum when one views perpendicular to the magnetic field direction and at a minimum when one views along the magnetic field lines. In addition, the radio waves coming from more distant objects experience a change during the voyage from the emitting source to the receiving telescope on Earth resulting from the Faraday effect. In the Faraday effect the angle of wave polarization (direction of maximum intensity; angular direction in the sky) rotates in direct proportion to the distance traveled, depending on the presence of magnetized plasma between Earth and the source of emission. The amount of angular rotation of the wave also depends on the observing wavelength, so observations from Earth at many wavelengths will reveal the amplitude of the *intervening* magnetic field in interstellar space within our Milky Way, as well as its direction.

3. Magnetic Field Strengths

In general small compact objects have the largest magnetic field strengths, while large low-density objects have weaker magnetic field strengths. Examples listed in Table I encompass strengths that range from one millionth of a Gauss up to one thousand million million Gauss (= 1 PetaGauss). One Gauss is defined as the unit of magnetic induction in the international cgs system; it is worth 0.0001 tesla in the international SI units. The Earth's magnetic field is a bipolar field that measures about 0.5 Gauss at its surface.

4. Magnetic Field Shapes

The following series of examples is intended to provide a means of visualizing magnetic fields occurring over a variety of scale sizes, where each step differs from the one adjacent by two orders of magnitude (a factor of 100).

Step 1:	Natural magnetism of a compass
Frame size:	10^0 metre = 1 metre = 100 centimetres
Magnetic field shape:	dipole
Magnetic field strength:	~0.1 to 1500 Gauss

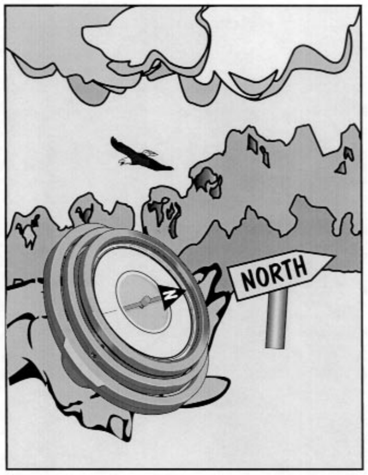
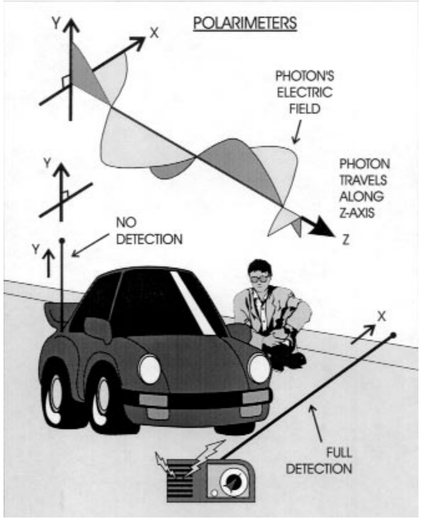


Fig. 1 — A frame size of 1 metre (= 10^0 m = 10^2 cm). Magnetic fields on the surface of the Earth can be detected using simple hand-held compasses or more precise aircraft-type compasses.



A typical compass is depicted in figure 1. A compass can be built up to ~1 metre in size and encompasses a magnetized bar magnet. The field of the bar magnet is not large, but is sufficient to interact with the Earth's magnetic field. Such a device is capable of indicating the direction of Earth's north geomagnetic pole, which is useful for travels in the woods or on the high seas. Fish, bees and birds also sense the Earth's magnetic field, the last for navigational purposes at night under cloudy skies (Weindler *et al.* 1996; Gould 1996a,b).

Fig. 2 — A frame size of 100 metres (= 10^2 m = 10^4 cm). Magnetic fields are found in all electromagnetic waves coming from space or radio stations. Long thin antennas can be used to detect such waves through the effects that the electric components of the waves have on the electric particles in the long antenna.

Step 2:	Antennas and waves
Frame size:	10^2 metres = 100 metres = 10^4 centimetres
Magnetic field shape:	circular around antenna
Magnetic field strength:	~0.1 Gauss

A long thin antenna, which can be 100 metres or more in length, is depicted in figure 2. Electrons can be driven up and down an antenna by applying an alternating voltage to it, thus creating an associated magnetic field. One can also use it to detect incoming electromagnetic waves, as with telecommunications on Earth. An antenna can act as a selective, directional detector to capture incoming radio waves emitted by AM or FM stations or arriving from distant cities (much farther than the 100 metre scale).

Traveling electromagnetic waves consist of magnetic fields moving at right angles to electric fields. The electric field of an incoming wave forces the electrons in a long antenna to move up or down the antenna, if the antenna is pointed properly along the direction of the electric field of the wave (Lorrain & Corson 1970). By rotating a long antenna, one can find the direction of maximum electric intensity of the incoming wave. One then deduces the direction of the maximum magnetic intensity of the wave (at right angles to the maximum electric intensity).

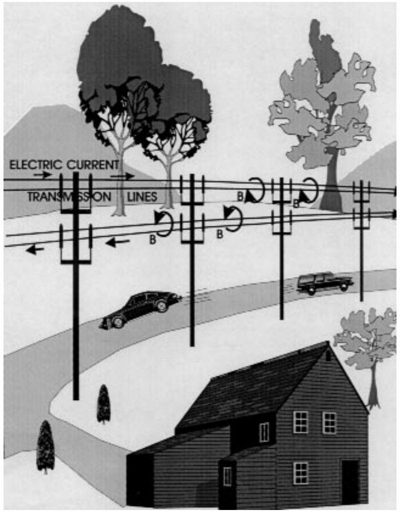


Fig. 3 — A frame size of 10 km (= 10^4 m = 10^6 cm). Magnetic fields are found near transmission lines, often not far from human habitation.

Step 3:	Long transmission lines
Frame size:	10^4 metres = 10 kilometres = 10^6 centimetres
Magnetic field shape:	circular around long lines
Magnetic field strength:	~100 Gauss

The type of circular magnetic fields often found around the long wires of transmission lines, on the order of 10 kilometres or more in length, are depicted in figure 3. Variable magnetism is created in transmission lines by running an alternating current through them. Such currents cause alternating magnetic fields (Lorrain & Corson 1970).

Step 4:	Auroras
Frame size:	10^6 metres = 1000 kilometres = 10^8 centimetres
Magnetic field shape:	polar
Magnetic field strength:	0.1 Gauss

An aurora, a luminous transient phenomenon appearing in the Earth's atmosphere near the regions of the magnetic poles, is depicted in figure 4. Auroral displays are produced when jets of solar particles are channeled by the Earth's magnetic field toward the poles of the Earth, where they encounter at high speed the local gas particles in Earth's upper atmosphere, typically at altitudes of about 100 km. The collisions energize the local gas particles, which de-excite by emitting light in the visible part of the spectrum. The Earth's magnetic field acts both as a *shield* against solar particles and as a *channel* towards the poles. Its presence is revealed when it is illuminated by aurorae.

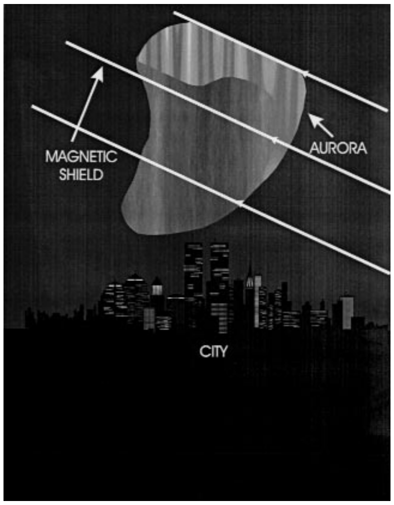


Fig. 4 — A frame size of 1000 km (= 10^6 m = 10^8 cm). Good examples of magnetic fields outlined on such scales are provided by auroral displays, which appear somewhat like dancing curtains.

Step 5:	Compressed fields and belts
Frame size:	10^8 metres = 100 000 kilometres = 10^{10} centimetres
Magnetic field shape:	compressed/extended dipole
Magnetic field strength:	1 milliGauss

Figure 5 represents magnetic fields on objects that have dimensions of 10^8 metres. The fields are often seen as compressed dipoles. Magnetometers have shown that the Earth's magnetic field has a dipolar shape. Physically, the magnetic dipole is generated by a geo-

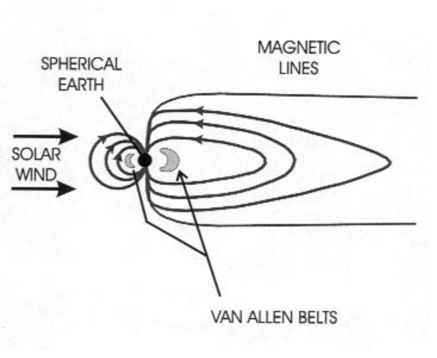


Fig. 5 — A frame size of 10^8 m (= 10^{10} cm). Planetary magnetic fields on objects of such size are normally found to be compressed dipoles, such as those of the Earth and other planets as well as those around some of the larger moons of planets.

dynamo inside the molten liquids below the Earth's crust and mantle. It originates from an idealized current (charged fluid motion) going circularly in a ring deep beneath the Earth's surface. The Earth's interior can be pictured as consisting of successive shells surrounding the central 1200-km radius solid crystalline metallic inner core. The first is a 2300-km thick liquid molten iron-alloy metallic outer core, then the lower mantle, and next the upper mantle (together the two mantles cover 2900 km). Motions of charged fluids inside the liquid molten iron-alloy metallic outer core produce the Earth's dipolar magnetic field via magneto-hydro-dynamical (MHD) processes in the electrically conducting fluid of the outer core. An important energy source for the Earth's dynamo is the crystallization of iron at the inner-outer core boundary, which drives convection in the liquid outer core (Olson 1997; Jeanloz & Romanowicz 1997).

The surrounding environment often compresses the resulting dipolar magnetic field. Such is the case for the magnetic fields around the Earth and other planets. The interplanetary wind emitted by the Sun creates a ram pressure compression on the side facing the Sun and an entrainment of the magnetic field lines on the side opposite. Some of the particles are trapped in the van Allen belts around the Earth. The full length of the tail on the extended/night side can reach as far as 220 Earth radii. By way of comparison, the Moon is only 60 Earth radii away from the Earth.

Step 6:	Fluid motion and starspots
Frame size:	10^{10} metres = 10 million kilometres = 10^{12} centimetres
Magnetic field shape:	normal dipole
Magnetic field strength:	10 Gauss

Figure 6 is a sketch of an ideal dipolar magnetic field, as found very near the poles of the Sun and other stars. The magnetic dipole is generated physically by a dynamo inside the Sun. It is believed to be caused by a charged current (fluid motion), idealized as running in a ring beneath the Sun's surface. The current solar interior is onion-like, with a nuclear-burning core out to ~0.2 solar radius, followed by a radiative zone or shell out to ~0.6 solar radius, a convection zone or envelope out to ~0.98 solar radius, and finally by the photosphere out to 1 solar radius. The main energy source of the solar dynamo is differential rotation inside the 20,000-km overshoot layer located around 0.6 solar radius at the interface between the Sun's radiative shell and its convection zone (Parker 1983, 1993).

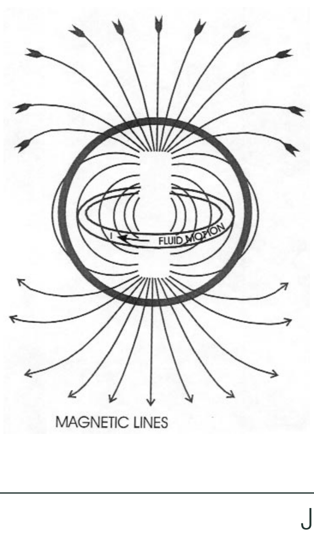


Fig. 6 — A frame size of 10^{10} m (= 10^{12} cm). Stellar magnetic fields on such scales, such as those around the Sun and other stars, frequently have a dipolar shape near the stellar surface.

Localized sunspots (not shown) on the Sun and starspots on the surface near the equatorial zone of a star can have magnetic field strengths of 2000 Gauss. Sunspots tend to be paired by a localized dipolar magnetic field. The regions of solar activity with which they are associated tend to migrate slowly on the Sun's surface over the course of the sunspot cycle of ~11 years.

A dipolar magnetic field is "frozen" into the gas of a star during the contraction from a normal star to a degenerate star, and will remain dipolar-shaped. However, its intensity B will increase in proportion to r^{-2}, so a star with a radius of 4×10^6 km and $B = 10$ Gauss will end up as a pulsar with $r = 10$ km and $B = 10^{12}$ Gauss. Extreme pulsars are called magnetars (Thompson & Duncan 1997).

Step 7:	Interplanetary medium
Frame size:	10^{12} metres = 10^{14} centimetres = 6.6 A.U.
Magnetic field shape:	Archimedes spiral
Magnetic field strength:	50 microGauss

The interplanetary magnetic field is depicted in figure 7. Magnetic fields of such sizes have been measured by magnetometers on board spacecraft travelling between the nearby planets. Interplanetary magnetic fields in the solar system have a shape roughly that of an Archimedes spiral owing to the rotation of the Sun, and originate near the Sun. Their strengths are on the order of 50 microGauss near the Earth (1 A.U.), decreasing with distance from the Sun to about 20 microgauss at a distance of 2 A.U. or ~300 million kilometres (Forsyth *et al.* 1996).

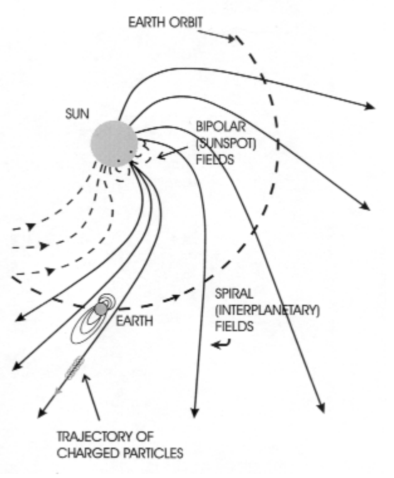


Fig. 7 — A frame size of 10^{12} m (= 10^{14} cm). Interplanetary magnetic fields have been measured by magnetometers on spacecraft travelling between the nearby planets. The interplanetary magnetic field exhibits a shape like that of an Archimedes spiral, and originates near the Sun.

Step 8:	Protostellar envelope and embedded protostar
Frame size:	10^{14} metres = 10^{16} centimetres = 660 A.U.
Magnetic field shape:	poloidal?
Magnetic field strength:	1 milliGauss

Figure 8 pictures the interior of lenticular gaseous objects in which a future star is forming. Such a protostellar envelope

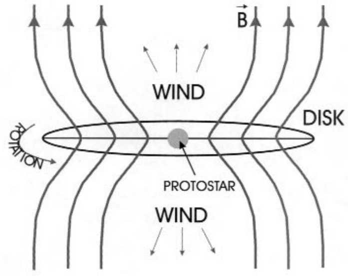


Fig. 8 — A frame size of 10^{14} m (= 10^{16} cm). Magnetic fields on such scales are often found in the envelopes of protostars (0.001 to 0.1 parsec in diameter), and encompass the protostar and its gaseous accretion disk. The initial shape of the magnetic field is often (but not always) poloidal (perpendicular to the elongation of the accretion disk). The rotation of the oval disk may later twist the original magnetic field into a toroidal shape.

containing a protostar and a disk often displays a poloidal magnetic field perpendicular to the disk (Pudritz 1986; Pudritz & Silk 1987), although sometimes a toroidal magnetic field is observed within the disk (Uchida & Shibata 1985). Telescopes operating at extreme infrared wavelengths have just begun to map the polarized dust emission, and hence the magnetic fields, in protostellar objects. The oval disk is probably similar to how the protoplanetary nebula for the Sun appeared about 4.5 billion years ago.

Step 9:	Cloudlet
Frame size:	10^{16} metres = 10^{18} centimetres = 0.3 parsec
Magnetic field shape:	poloidal?
Magnetic field strength:	0.5 milliGauss

The expected magnetic field lines in a small interstellar cloudlet are depicted in figure 9. Astronomers often measure distances in parsecs, where 1 parsec equals 3.1 x 10^{16} metres = 3.26 light years = 206,265 A.U. Since it is a new area of astronomy, there are more theories than observational data on magnetic fields in interstellar cloudlets. One of the more popular theories predicts that a spherical dust cloud will collapse slowly by gravity along the magnetic field lines. The process will form a flattened, circular structure, with the interstellar magnetic field thus often, but not always, predicted to be perpendicular to the elongated cloudlet, *i.e.* the magnetic field running along the short axis of the cloudlet (Pudritz 1985). At one or a few spaces inside the cloudlet some gas peaks may become unstable to self-gravity and a protostellar disk may form at each peak. The cloudlet can be thought of as a small nursery with a few protostars inside.

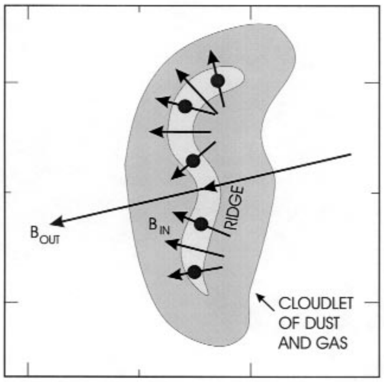


Fig. 9 — A frame size of 10^{16} m (= 10^{18} cm). The magnetic field exhibited by a cloudlet of dust and gas in interstellar space is able to penetrate to its interior, shown here containing a small nursery of protostars. Arrows depict magnetic field lines. Poloidal magnetic fields are frequently, but not always, detected.

Step 10:	Cloud complex composed of many stellar nurseries
Frame size:	10^{18} metres = 10^{20} centimetres = 32 parsecs
Magnetic field shape:	bending arc
Magnetic field strength:	0.5 milliGauss

Figure 10 illustrates the results of polarization observations toward a dust cloud complex. A long cloud complex composed of many stellar nurseries or cloudlets is a good example of an object possessing magnetism inside on the scale of the whole object. M17 is a bright H II region located near the star at the top left of the figure. M17, the 17th fuzzy object in the catalogue assembled by the French astronomer Charles Messier in the 18th century, is located about 7200 light years away in the constellation of Sagittarius. The dusty complex molecular cloud M17-SW is, as the designation implies, located southwest of M17. It is depicted in various shades, from an outer giant halo to a bright inner ridge area. The region of the inner ridge links the dense regions (labeled P1 to P6) observed with the JCMT (Vallée & Bastien 1996).

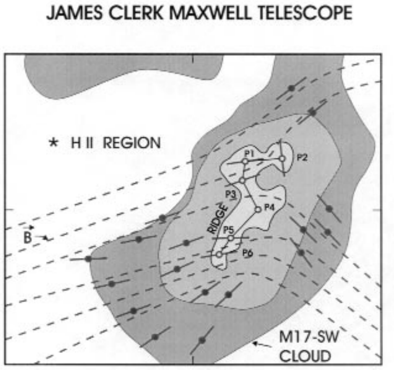


Fig. 10 — A frame of size 10^{18} m (= 10^{20} cm). Magnetic fields, shown as dashed lines, detected using the 15-m James Clerk Maxwell Telescope for the long, elongated, dusty molecular cloud complex M17–SW. Several nurseries of protostars (dotted points) have been detected. The interstellar magnetic field lines originating at left bend in the cloud core (the central ridge), and split into two outgoing components at right.

The dashed structures are actually the interstellar magnetic field. The JCMT measurements for regions P1, P2, P3, P5 and P6 show a *bending* of the magnetic field over a short distance (P4 showed no polarization). No known theoretical model has ever predicted such magnetic field bending, with the lines being parallel to the edge of the gas at left, then perpendicular to the gas ridge (centre), then exiting parallel to the edge of the gas at top right.

Inside dusty magnetized gaseous clouds, cloudlets and protostars the magnetic field, designated *B*, increases as the gas density *n* increases, and follows the law $B \sim n^{0.5}$ for equilibrium conditions (Heiles 1987; Whitworth 1991; Chaboyer & Henriksen 1990; and others).

Step 11:	Magnetized supershells and interarm regions
Frame size:	10^{20} metres = 10^{22} centimetres = 3.2 kiloparsecs
Magnetic field shape:	spherical shell
Magnetic field strength:	10 microGauss

The results of polarization observations for magnetic field lines within a radius of about 2 kiloparsecs of the Sun are shown in figure 11. The Sun is depicted by the circled dot at the centre of the diagram and arrows show the direction of the nearby interstellar magnetic field. Large curved lanes identify the two nearby major spiral arms of our Galaxy, the Perseus and Sagittarius-Carina arms (the Cygnus feature is not represented). The overall magnetic field direction is clockwise north of the Sagittarius-Carina arm, but it becomes counterclockwise near the Sagittarius arm.

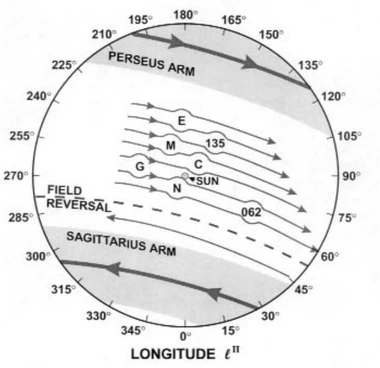


Fig. 11 — A frame size of 10^{20} m (= 10^{22} cm). Interstellar magnetic fields are found between the stars and around supershells created by the combined winds of the very hot stars in stellar associations. The lines of the larger scale magnetic field are distorted outwards (in three dimensions) in such supershells (each with a diameter near 200 pc) by the ram pressure of the expanding gas.

The localized small spherical magnetic field deviations are caused by slowly expanding nearby supershells. A supershell is a thin dusty magnetized gaseous envelope around a relatively empty cavity that is created by the ram pressure of stellar winds and explosions from hundreds of hot young stars located near its centre. They have typical diameters of about 200 parsecs. The supershells are labeled in figure 11: C = Cetus arc, E = Eridanus shell, G = Gum Nebula, M = Monogem ring, N = Loop I superbubble = North Polar Spur, 062 = G062–23+13 shell and 135 = G135–40–10 shell. The "G" designation lists successively the galactic longitude, galactic latitude and galactic radial velocity of the centre of the object.

Inside the wall of an advancing supershell the magnetic field *B* increases in strength as the gas density *n* increases, following the law $B \sim n^{1.0}$ for shocked conditions (Vallée 1993, 1997; Kamaya 1998).

Step 12:	Galactic disk
Frame size:	10^{22} metres = 10^{24} centimetres = 320 kiloparsecs
Magnetic field shape:	axisymmetric spiral
Magnetic field strength:	5 microGauss

A schematic picture of the whole Milky Way galaxy is presented in figure 12. The largest spiral galaxies have dimensions of close to 100 kiloparsecs, if you include the extent of the H I disk and dark matter halo reaching way beyond the optical stellar image. In the figure is shown the Milky Way disk as seen from above, with the curved lanes representing major spiral arms and the Sun depicted by a circled dot (at 8 kiloparsecs from the galactic centre). At least four major spiral arms are recognized: the Perseus arm, the Sagittarius-Carina arm, the Norma-Scutum arm, and the outer Perseus arm, which appears to be an extension of the "3-kiloparsec arm" wrapped once around the galactic centre (see Vallée 1995a, 1996). In this representation the Cygnus-Orion feature is treated as a spur off a major arm.

The arrows represent the directions of the interstellar magnetic fields. The overall magnetic field direction is clockwise over most of the Milky Way, except within a small zone near the Sagittarius arm — inside which a counterclockwise magnetic field is found. The Milky Way is characterized mostly by an axisymmetric spiral (ASS) global magnetic field structure. The area marked "D" is a potentially large superbubble in that distant location.

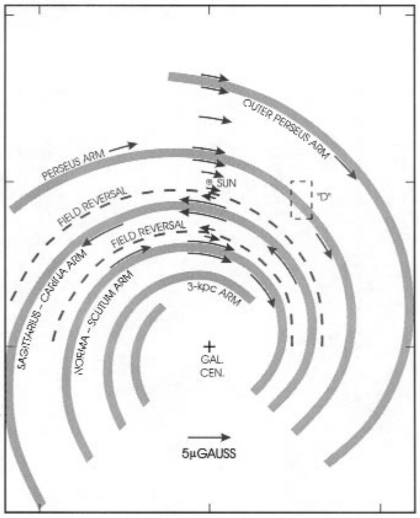


Fig. 12 — A frame size of 10^{22} m (= 10^{24} cm). Galactic magnetic fields on such scales, such as those associated with the Milky Way galaxy, have a spiral shape. The large-scale magnetic field lines, shown as arrows, follow the spiral shape of the optical stellar arms. The Sun is located ~8 kiloparsecs from the galactic centre (depicted by the plus sign). The region on the opposite side of the galactic centre from us represents a "zona galactica incognita" that remains to be observed.

Inside the relative voids in the Galaxy where the gas density *n* is less than 100 cm^{-3}, the magnetic field strength *B* increases as the gas density *n* increases following the law $B \sim n^{0.1}$. Such a relationship arises as a result of the gas gliding along the field lines (Vallée 1990a, 1995b).

At the Milky Way's nucleus investigators have found some large, highly organized filaments (not shown here) that sustain a parallel magnetic field with a strength of roughly 1 milligauss. The magnetized filaments are localized in bundles of magnetic fields, while the rest of the volume is pervaded at best by a diffuse magnetic field well below 100 microgauss (Uchida & Güsten 1995).

There is a extended region, referred to here as the "zona galactica incognita," on the other side of the galactic centre, where very little is known. A rough scale for the strength of the galactic magnetic field is shown at bottom.

Step 13:	Tidally affected galaxy
Frame size:	10^{24} metres = 10^{26} centimetres = 32 megaparsecs
Magnetic field shape:	bisymmetric spiral
Magnetic field strength:	10 microGauss

Figure 13 illustrates one of the four morphological shapes for the neutral hydrogen gas H I and one of the two morphological shapes discussed for the galactic magnetic fields m_{azim}. Tidal interactions between two galaxies can influence the shape of the galactic magnetic field and not just the shape of the gas. Both H I and magnetic field complexities can have a common origin in a deformed gravitational potential, which may itself arise from a tidal encounter with another galaxy or a long bar straddling the galactic nucleus. A more rigorous classification system was proposed by Vallée (1995c) for the observed distribution of neutral hydrogen H I. It was based upon four basic shapes for the radio H I contours: MD = 1 for a simple quiescent appearance of the H I isophotes, MD = 2 for H I isophotes exhibiting a moderate degree of deformation, MD = 3 for a strikingly complex deformation of the H I isophotes, and

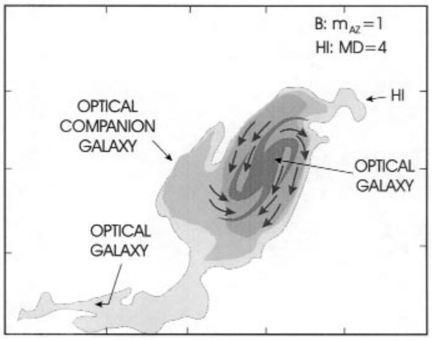


Fig. 13 — A frame size of 10^{24} m (= 10^{26} cm). Magnetic fields on such scales are affected by the dynamics of weakly interacting galaxies. The dynamo magnetism of a galaxy could therefore change during a tidal interaction. Initially, when the H I gas deformation was negligible or minor, the global magnetic field shape was axisymmetric (ASS or m_{azim} = 0) so that all magnetic field lines at the same radial distance from the centre of the galaxy spiraled inward. When the H I gas deformation is large or extreme, the global magnetic field shape becomes bisymmetric (BSS or m_{azim} = 1) so that all magnetic field lines at the same radial distance from the centre of the galaxy tend to spiral inwards over half of the galaxy but outwards over the other half.

MD = 4 for an extreme deformation of the H I isophotes.

Likewise, the magnetism of galaxies has been found to be described by either an axisymmetric spiral (ASS) or a bisymmetric spiral (BSS) pattern. An axisymmetric spiral is such that all measurements at a constant distance from the centre of the galaxy reveal the magnetic field to be spiraling inward (say). It is also referred to as the "zeroth order azimuthal dynamo mode m_{azim} = 0." For a bisymmetric spiral the magnetic field will be found to be spiraling inward in half of the galaxy while in the other half it spirals outward. A bisymmetric spiral is also referred to as the "first-order excited dynamo mode m_{azim} = 1."

A one-to-one observational relation-ship has been found between the shape of the galactic magnetic field (ASS or BSS) and the shape of the neutral hydrogen gas distribution (MD = 1 to 4). A simple shape for the neutral gas radio isophotes (MD = 1,2) is always found to coincide with a simple shape for the galactic magnetic field (ASS), while a more complex neutral gas shape (MD=3,4) is always found to coincide with a more complex galactic magnetic field shape (BSS).

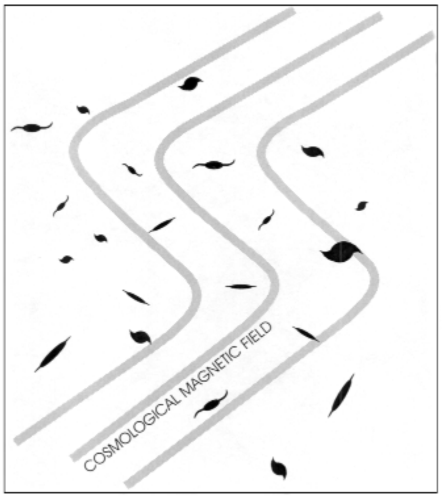


Fig. 14 — A frame size of 10^{26} m (= 10^{28} cm). Such dimensions encompass galactic superclusters aligned at the edges of voids and having diameters of 200 Mpc, as well as cosmic intercluster gas on scales of ~10 Gigaparsecs. Cosmological magnetic fields are difficult to detect, owing to their intrinsic weakness. Upper limits of about 1 nanoGauss are set for the strengths of cosmological magnetic fields.

Step 14:	Cosmological
Frame size:	10^{26} metres = 10^{28} centimetres = 3.2 Gigaparsecs = a spectral line red shift of roughly 3.5
Magnetic field shape:	random?
Magnetic field strength:	less than 1 nanoGauss

Figure 14 depicts a possible, but as yet undetected, cosmological magnetic field permeating the gas between clusters of galaxies. Clusters of galaxies are distributed along "walls" interspersed with "voids" having diameters of 200 Megaparsecs or so. No measurable magnetic fields have yet been detected in voids or their adjacent walls, or in the larger scale cosmological realm. Upper limits of 1 nanogauss have been set by observations with current detector sensitivities (Kronberg 1994; Vallée 1990b).

Step 15:	Big Bang era
Frame size:	10^{28} metres = 10^{30} centimetres = 0.32 Teraparsec = a spectral line redshift of roughly 50
Magnetic field shape:	inside a distant shell
Magnetic field strength:	less than 10^{-16} Gauss

No picture for the next step exists as yet. There are no magnetic field observations that reach to such distances from Earth. Our most sensitive telescopes can image galaxies only to a spectral line redshift of about 5 or so. The development of a picture for this step must await the development of visionary telescopes far better than the ones that exist at present.

Some theories predict the existence of faint emission from a distant shell near the surface of last scattering for the 2.73 degrees Kelvin (2.73 K) cosmic microwave background radiation. The latter was produced at a wavelength redshift of $z \approx 1400$ (Kosowsky & Loeb 1996) following the Big Bang at a very early stage of the universe. Some have predicted that such a distant shell may possess a very weak magnetic field. However, its strength is still below what our best telescopes can presently measure. Such discoveries are waiting to be made, with more sensitive detectors and telescopes, by a new generation of astronomers.

5. CONCLUSIONS

Magnetometers on board spacecraft have revealed a lot about the environment of the Earth and planets. The main magnetic field model is that of the planetary dynamo's dipole, compressed by the impact of the solar wind, twisted by rotational effects, and affected at times by solar magnetic storms. Polarimetric observations with telescopes at radio and optical wavelengths are the only way to reliably map the magnetic fields in interstellar, galactic, and intergalactic space.

Observations with radio telescopes have so far revealed a surprising magnetic picture, with unexpected results like the widespread bending of magnetic fields in elongated interstellar clouds. In addition, a general gas collapse along the magnetic field lines is seen in flattened disks. The main magnetic model found to apply in galaxies is that which matches the galactic dynamo's azimuthal ASS and BSS shapes, which trace azimuthally in the galactic disk around the galactic centre.

More observations need to be made with existing radio telescopes and optical telescopes, notably at extreme infrared wavelengths, to clarify the picture of magnetic fields in large elongated clouds, small cloudlets and flattened protostellar disks, and their effects on planet formation.

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Table I.
The Range of Magnetic Field Strengths.

cgs System	SI Units	Objects
1 PetaGauss	= 100 GigaTesla	magnetars (gamma-ray repeaters)
1 TeraGauss	= 100 MegaTesla	pulsars (neutron stars)
1 MegaGauss	= 100 Tesla	white dwarf stars
200 kiloGauss	= 20 Tesla	strongest lab magnets on Earth
1500 Gauss	= 150 milliTesla	sunspots
1500 Gauss	= 150 milliTesla	ordinary iron magnets (poles) on Earth
40 Gauss	= 4 milliTesla	SiO masers near protostars
10 Gauss	= 1 milliTesla,	Sun's poles
4 Gauss	= 400 microTesla	Jupiter's surface
0.5 Gauss	= 50 microTesla	Earth's surface
1.5 milliGauss	= 150 nanoTesla	Earth-synchronous orbit (24^h)
500 microGauss	= 50 nanoTesla	nose of compressed magnetopause of Earth
350 microGauss	= 35 nanoTesla	basalt rocks on the Moon
50 microGauss	= 5 nanoTesla	interplanetary space near Earth (1 A.U.)
10 microGauss	= 1 nanoTesla	Earth's tail current sheets
5 microGauss	= 0.5 nanoTesla	interstellar space (Milky Way disk)
1 microGauss	= 0.1 nanoTesla	distant interplanetary space

JACQUES P. VALLÉE is a Research Officer at the National Research Council of Canada's Herzberg Institute of Astrophysics in Victoria, and serves as astronomical information agent and technical secretary for committees. He occasionally makes use of international astronomical research facilities in which the National Research Council is a partner. He earned his B.A., B.Sc., and M.Sc. degrees from the Université de Montréal and his Ph.D. in 1973 from the University of Toronto. His scientific career has entailed postings in Leiden (1974–1975), Ottawa (1976, 1981–1987, 1992–1995), Kingston (1977–1980), Grenoble (1988), Edinburgh (1989–1991), and lastly Victoria (1996 to present). His professional interests focus on the study of magnetic fields in all types of small and large astronomical objects, and he has published over 120 refereed papers. His hobbies include collecting miniature houses from different countries.

Research Note

METEOR SPECTROSCOPY WITH INEXPENSIVE HOLOGRAPHIC GRATINGS

BY EDWARD P. MAJDEN

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(Received August 1, 1997; revised August 12, 1997)

ABSTRACT. The use of inexpensive film acetate interference (holographic) transmission gratings for meteor spectroscopy is described. The practice should open the interesting field of meteor spectroscopy to more amateur participation.

RÉSUMÉ. Nous décrivons l'usage de grilles de transmissions holographiques (d'interférences), fabriquées de film acétate bon marché, pour la spectroscopie des météores. Cette pratique offre à plus d'amateurs le domaine intéressant de spectroscopie des météores.
SEM

All early meteor spectra were obtained with objective prisms mounted on conventional cameras (Millman 1954). In the 1950s the transmission diffraction grating began to be used for meteor spectroscopy and soon became the desired dispersive element (Halliday 1958). Gratings offer several advantages over objective prisms.

1. The dispersion is much more linear, permitting easier wavelength identification.
2. The "zero" order image provides a zero wavelength reference for wavelength determination (when it is present on the film).
3. They are more readily available in sizes to cover large lens apertures.
4. A variety of groove spacings is available, thereby permitting a wide choice of dispersions.
5. Transmission grating blanks are relatively thin, clear plates of optical glass that provide better transmission in the near ultraviolet and blue end of the spectrum than flint glass prisms.

The disadvantages include the following:

1. The surface of the epoxy resin replica grating is quite fragile and cannot be cleaned by the usual methods for cleaning glass prisms.
2. Since some of the light is spread into more than a single order, they are not as efficient as prisms at longer wavelengths.
3. For amateurs the cost of a precision replica grating is relatively high, thereby discouraging participation in this most interesting field.

I have looked at other methods that would be less expensive for amateurs to adopt. Several years ago I examined some thin film mounted replica transmission diffraction gratings. The ones I looked at were too inefficient for meteor work, so I gave up the idea. Recently I corresponded with American Meteor Society Director Dr. David Meisel, University of Victoria astronomer Dr. Jeremy Tatum and Mr. Stephen Edburg at NASA/JPL. All suggested that I take a look at a so-called holographic, thin-film grating sold by Learning Technologies Inc. They were manufactured for the program *Project Star* (Sadler 1991) for educational purposes. According to them, the spectra produced by such gratings looked bright and might work for meteor spectroscopy, and they were also reasonable in cost. The literature included with the *Project Star* gratings suggested that the holographic gratings were one hundred times more efficient than acetate film gratings. Since I was already using a precision replica grating on one of my cameras, I could compare the two gratings by taking controlled exposures of stellar spectra. In fact, Dr. Meisel sent me some samples of the gratings for testing.

First I had to mount the thin film holographic grating in some sort of mount. I removed a skylight filter from a standard 67-mm filter holder (that size fits my 2¼-inch square camera). A local glass company cut two disks, the same diameter as the filter, out of some flat plate glass. Since it was just a test, I did not check the glass for optical flatness (which would probably have been a good thing to do). Here is a word of caution: thin film replica gratings are delicate and one can transfer finger marks to their surfaces very easily. I suggest that latex surgical-type gloves be used when handling such material. I carefully sandwiched the film replica between the two glass disks and secured them in my filter holder with the retaining ring. My intention was to record stellar spectra through both gratings and then to examine the intensity of the images to see if their efficiency was comparable or nearly so. The next problem was getting clear skies.

On June 8/9, 1997, the night looked promising, so I set up my camera to do the test. The first two exposures were taken with my precision replica grating. They served as my control frames. The third exposure was taken with the holographic grating sandwich mounted on the same lens and camera. The exposure commenced at 00:12 PST. Partway through it at 00:18 PST a brilliant –4th magnitude, slow-moving fireball crossed the field. What a stroke of luck! Getting a meteor spectrum on the first exposure with the holographic grating is like winning the lottery. Generally it takes 100 hours of exposure time to secure a meteor spectrum during non-shower periods.

The spectrum is reproduced in figure 1. It is not perfect but I am still pleased. Preliminary examination of the spectrum indicates

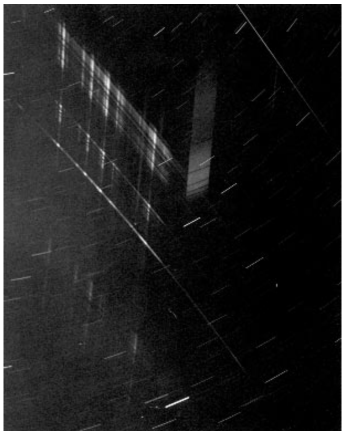

Fig. 1 —A holographic grating meteor spectrum secured on the night of June 8/9, 1997, at 00:18 PST from Courtenay, British Columbia. The spectrum was obtained using a f/2.8 75-mm focal length lens (set at f/4.0) on a Bronica roll film camera and recorded on Kodak Tri-X Pan Pro 120 roll film developed in HC-110 for 11 minutes. The meteor was a slow-moving fireball with several bursts along the trail. Stars show as streaks in this 10-minute exposure from 00:12–00:22 PST. The bright star at the bottom of the field is Vega, spectral type A0, and its absorption-line spectrum is visible in the upper part of the field running across the stars of Draco. The meteor streaked across the north part of Draco and is the streak across the upper right portion of the field. Its first order and second order spectra are visible to the left of field centre and to the lower left, respectively. The bright line near the red end (bottommost streak in this orientation) of the first order meteor spectrum originates from Na I. Other lines will be identified when the spectrum is measured.

that inexpensive holographic gratings will work for meteor spectroscopy. The grating is not as efficient as the blazed side spectrum of a precision replica grating, but it is at least as good as, if not better than, the non-blazed side spectrum. With very bright meteors the blazed first order spectra are often overexposed, thereby making it difficult to resolve spectral lines. The same problem should not exist to the same degree with the holographic replica grating. Things are not perfect however. The holographic grating does not have a blaze and the grooves have a sinusoidal shape. For the holographic grating used here, which is ruled at 750 lines mm^{-1}, the dispersive angle is 23°.5 at a wavelength of 550 nm. The second order spectrum appears much weaker than with a precision replica grating since the grating is designed to concentrate most of the light into the first order spectrum. Higher orders are very much weaker with the holographic grating, so a precision replica diffraction grating is still preferred for meteor spectroscopy. An objective prism can only produce a single spectrum for each object in the field of view, so the use of a so-called holographic grating provides the advantages of linear dispersion and possibly the recording of higher orders for very bright meteors.

Holographic gratings of the type used for this project will be especially useful for large aperture lenses. For example, you can make a full aperture objective grating at very reasonable cost for a f/2.5 305-mm, (12-inch focal length) Kodak Aero Ektar lens for under $20. Such a lens-grating combination is equal to the systems used by professional meteor spectroscopists. Lenses of the same type are available on the surplus market for US$100 to US$200, depending upon condition. The lens will also cover an 8 × 10 plate.

Appendix I provides some sources for replica transmission gratings. Included is the address for Learning Technology Inc., where holographic replica gratings are available.

The spectrogram illustrated here has been sent to Dr. Vladimir Getman at Penn State University for measurement. Dr. Getman is a technical advisor to the American Meteor Society. He is a former Russian meteor specialist now working in the U.S.A. When his work is completed we hope to publish a joint paper on the spectrum.

I would like to thank Dr. David Turner, editor of the *Journal*, for his suggestions and help in preparing this paper.

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V9N 5R8

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Millman, P. M. 1954, Amateur Telescope Making: Book Two, "Meteor Photography" (Scientific American: New York), p.544

Sadler, P. 1991, "Project Spectra for Classroom Investigations," The Physics Teacher, Oct., p. 423

APPENDIX I.
Some Sources for Transmission Gratings

Precision Replica Transmission Gratings:

David Richardson
Grating Laboratory of Spectronic Instruments Incorporated
820 Linden Avenue
Rochester, New York
U.S.A.
Telephone: (716) 262-1331, Fax: (716) 454-1566

Diffraction Products Incorporated
P.O. Box 1030
Woodstock, Illinois, 60098
U.S.A.
Telephone: (815) 338-6768, Fax: (815) 338-7167

Interference (Holographic) Film Replica Gratings:

Learning Technologies Incorporated
59 Walden Street
Cambridge, Massachusetts, 02140
U.S.A.
Telephone: (USA) 800-537-8703 or (617) 547-7724

ED MAJDEN is a retired electronics armament systems technician for RCAF/CAF, now called com/radar/systems. He was first introduced to meteor studies and spectroscopy while a student member of the Regina Astronomical Society in the 1950s. He set up his own program of meteor spectroscopy in 1972. He is a life member of the Victoria Centre, an AMS affiliate and a Meteoritical Society member. He was recently elected an associate member of the Meteorites and Impacts Advisory Commitee and is also part of Jeremy Tatum's fireball interviewing network on Canada's west coast.

Education Notes
Rubriques Pédagogiques

THE TWIN PARADOX?

by Gordon E. Sarty
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Have you heard the twin paradox story in relativity theory? Well, the story goes something like this. Suppose a pair of identical twins, Alice and Elizabeth, are born in an age of interstellar travel, say on January 1, 2200. At the age of 18 years, Alice enrols in astronaut school while Elizabeth decides to pursue law as a career. At the age of 25, Alice takes command of a starship and embarks on a trip to the star Arcturus to investigate rumours of intelligent life. Elizabeth stays at home on Earth to run her criminal law practice. Arcturus is 37 light years away, but that is no problem for Alice since her starship can easily attain 99.5% of the speed of light. According to Einstein's special theory of relativity in which moving clocks run slow, Alice will experience a time dilation factor of 10 relative to Elizabeth at that speed. So, if Alice stays at Arcturus for 5 years, the round trip takes 79 years to complete from Elizabeth's perspective back on Earth while the total time invested by Alice according to her clock is only 12.4 years. When Alice arrives back on Earth she will be a young 37 years old while Elizabeth will be 104 years old, possibly enjoying the benefits of medical research that allows people to live disease-free lives of up to 150 years.

When Einstein's theory of relativity was first popularized early in this century, some people viewed the twin story as paradoxical and argued that Einstein's theory led to a logical contradiction[1]. The paradox people observed that Alice's time dilation factor was computed with Alice travelling at 99.5% of the speed of light relative to Elizabeth. But, they argued, if everything is relative then we could equally regard Elizabeth as travelling at 99.5% of the speed of light relative to Alice (which is true), so that Elizabeth's time dilation factor should be 10 relative to Alice. Elizabeth would then wind up younger than Alice in the end[2].

In fact there is no paradox and the story as originally told is the correct version. The resolution of the paradox and understanding of why the original story is correct depends upon a proper understanding of the theory of relativity.

Before we examine the proper resolution of the paradox, let's briefly consider a popular resolution of the twin paradox. The popular resolution says that the time dilation formula is a formula from the theory of special relativity which deals only with constant velocities and not with accelerations. Since Alice had to accelerate (turn around) at Arcturus, you need to invoke general relativity to see the whole picture. That interpretation is completely incorrect. General relativity is about gravity and how it manifests in the curvature of space-time; it is not required to describe accelerations in the flat space-time of special relativity. You can predict how accelerated objects behave from special relativity using only the tools of calculus. The mystery of the twin paradox does not require general relativity for its resolution.

So let's get the proper ideas about special relativity together. The first principle of special relativity to appreciate is that the basic laws in the theory describe physics relative to an *inertial frame*. This is a big point. In relativity things are not haphazard relative to everything else; things are relative to an inertial frame. Confusion generally arises, however, because there is no one single, special inertial frame.

What is an inertial frame? It is frame (a co-ordinate system or frame of reference) in which Newton's first law — the law of inertia — holds. In such an unaccelerated frame, an object free of net external forces will move at constant velocity. This is a purely physical definition; inertial frames can only be found through experimentation. For example, if you swing a bucket of water around your head and attach a frame of reference to the bucket, that frame will not be an inertial frame because of the centrifugal forces felt in the bucket. When you find an inertial frame, then you can describe another inertial frame as one that is exactly the same as the frame you began with except that it is moving with a constant velocity relative to the first frame and the origin (the zero point) might be different. So the universe contains an infinite collection of such abstract inertial frames, all moving at constant velocities relative to each other. Although it is difficult to define a perfect inertial frame, to a very good approximation we can take the Sun as being the centre of an inertial frame. Certainly such an inertial frame is good enough for most engineering purposes such as planning interstellar flights. According to the *Observer's Handbook*, Arcturus is moving at a velocity of at least 5 km s^{-1} relative to the Sun. Ignoring minor details like the revolution of the stars about the centre of the Milky Way galaxy, we could also take Arcturus as being the centre of an inertial frame.

With the idea of an inertial frame in mind, we can start to think about the idea of space-time. Space-time is a four dimensional

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[1] Editor's Note: Many JRASC readers will recall the debate concerning the "twin paradox" (or the "clock paradox," as it is also known) that occurred between the philosopher Herbert Dingle and the physicist W. H. McCrea in the pages of *Nature and Science* in 1957–58 (see, for example, Darwin 1957; Bronowski 1963; Sachs 1971). Dingle believed the paradox to be a true one and argued that it represented a fatal flaw in relativity theory. The argument finally lapsed when Dingle was reduced to objecting to relativity on the grounds that it would be immoral to postpone the date of one's death by relativistic means!

[2] The argument was made that, in terms of velocity, either twin could regard the other as the traveller, in which case each should find the other younger. It is based upon the assumption that the situations of Alice and Elizabeth are symmetrical and interchangeable — which is in fact incorrect.

geometrical concept. In Newton's physical theory space and time are treated pretty much separately, but in relativity space and time are connected by a special geometry. In ordinary three-dimensional Euclidean space, the shortest distance d between two points (x_1, y_1, z_1) and (x_2, y_2, z_2) is given by the Euclidean formula:

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2} \ .$$

In space-time, the "shortest distance" D between two points (events) (x_1, y_1, z_1, t_1) and (x_2, y_2, z_2, t_2) is given by the Lorentzian formula:

$$D^2 = c^2(t_1 - t_2)^2 - (x_1 - x_2)^2 - (y_1 - y_2)^2 - (z_1 - z_2)^2 \ ,$$

where c represents the speed of light. Actually, to find the "shortest distance" in space-time we need to take the square root of the Lorentzian formula after discarding any negative signs that might crop up. Space-time geometry is considerably different from the everyday Euclidean geometry that we are all used to! It is important also to note that space-time is best described relative to an inertial frame. That is, the co-ordinates (x, y, z, t) refer to distance and time co-ordinates relative to the chosen inertial frame.

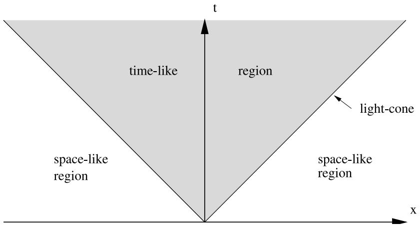

Fig. 1 — Space-time is divided into two regions by the light cone. The light cone represents the history of a pulse of light emitted at the origin of the space-time diagram. Inside the cone is the time-like region where the "distance" to the origin, as given by the Lorentzian formula, is a positive number. World lines that describe the histories of physical entities starting out from the origin will remain within the time-like region. Outside the light cone is the space-like region where the "distance" to the origin, as given by the Lorentzian formula, is a negative number.

To understand space-time geometry, it helps to draw a picture. It is impossible to draw in four dimensions and difficult to draw in three, so it helps to forget about two of the space co-ordinates, y and z. That simplifies our picture to only one co-ordinate of space, x, and one co-ordinate of time, t, and results in the space-time diagram shown in figure 1. Notice that the light cone on the diagram splits space-time into two regions. The light cone is defined as the set of points in space-time where the Lorentzian distance to the origin is zero. In other words, on the light cone

$$x^2 = c^2 t^2 \ .$$

The region labelled "space-like" is where the Lorentzian formula gives a negative number, *i.e.*

$$x^2 > c^2 t^2 \ ,$$

and the region labelled "time-like" is where the Lorentzian formula gives a positive number, *i.e.*

$$x^2 < c^2 t^2 \ .$$

The histories of physical entities, like Alice, can be described on space-time diagrams by curves known as *world lines*. If the world line starts at the origin, at (x, t) = (0, 0) in the space-time co-ordinate system, then it can never cross the light cone. Why? It is because in special relativity travel at faster than the speed of light is not permitted. Geometrically the light speed limit means that the world line cannot cross the light cone. Do not think that the space-like region is not physical, however; it just represents regions of space-time that the physical entity starting at (0, 0) cannot reach or communicate with. Also, note that thinking of time as the "negative of distance" is meaningless. Time and space in relativity theory just happen to be intermingled in a geometry that can be described using the Lorentzian formula.

Before we return to Alice and Elizabeth, we further need to understand the concept of *proper time.* Proper time is one of the most important geometrical concepts to come out of relativistic space-time thinking. Physically, proper time is the interval measured by a clock attached to the observed object. It is the time actually "experienced" by something or someone. (An "improper" time will be one measured by two different clocks at two different places.) Geometrically it is very similar to arc length in ordinary Euclidean geometry. Suppose I draw an arbitrary line (not necessarily straight) on a piece of paper and ask, "How long is this line?" In other words, "What is the arc length?" One way to compute the arc length is to approximate the given line or curve with a series of short straight lines as shown in figure 2. The lengths of each of the short straight lines can then be computed with the Euclidean distance formula and summing them will approximate the arc length. To get a better approximation, one can use shorter straight lines. To get an exact arc length, one can use calculus and integrate infinitesimally short straight lines!

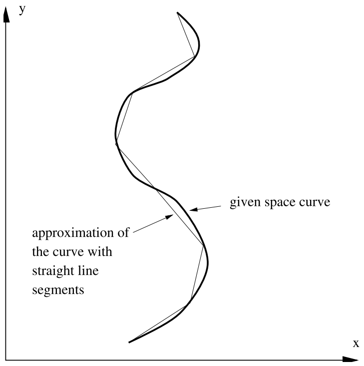

Fig. 2 — The arc length of an arbitrary curve in ordinary Euclidean space can be approximated by summing the lengths of short straight-line segments that together approximate the given curve. The shorter the lengths of the individual straight-line segments, the more accurate is the estimate of the arc length. The Lorentzian length of world lines in space-time diagrams can be computed in the same manner by using short line segments to approximate the given world line. The Lorentzian arc length of a given world line represents the *proper time* actually experienced by the physical entity associated with the world line.

The proper time experienced by someone making a relativistic trip can be computed using the Lorentzian space-time geometry in exactly the same way that arc length is computed in Euclidean space. The trip can be described by a world line curve on the space-time diagram. The world line of someone leaving the origin on a space-time diagram will remain within the light cone, as mentioned before, and the slope of the curve will never be less than 45 degrees on a diagram where time is measured in years and distance is measured in light-years (so that $c = 1$). Such geometrical restrictions on the world line are once again required by the notion that nothing can travel faster than the speed of light. The Lorentzian arc length of a traveller's world line is the actual proper time experienced by the traveller. The bizarre fact to remember about drawing space-time pictures is that as the world line in a space-time drawing *increases* in length, the proper time experienced by the traveller *decreases*.

Now we can properly resolve the apparent paradox of Alice and Elizabeth. Simply draw their world lines on a space-time diagram using the inertial frame centred at the Sun, as shown in figure 3. Elizabeth's world line is represented in space-time by a straight line that connects the Earth at year 2225 to the Earth at year 2304. (Note that the world lines of the Sun and the Earth are essentially the same.) Alice's world line is represented by a straight line connecting the Earth's world line to Arcturus's world line, plus a line representing her 5-year stay at Arcturus and another straight line that connects Arcturus's world line to Earth's. Alice's world line is clearly longer than Elizabeth's in the drawing, so the proper time experienced by Alice is *less than* that experienced by Elizabeth. For those who may still have doubts, the fact will remain that no matter what inertial frame is chosen to describe the situation, Elizabeth's world line will always be composed of one straight line and Alice's will always be composed of three straight line segments. The proper time experienced by Alice will always be less than that experienced by Elizabeth no matter how you view the situation.

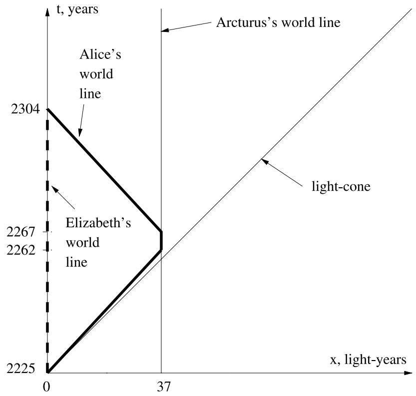

Fig. 3 — The world lines of Alice and Elizabeth. No matter what inertial coordinate system you use, the Lorentzian length of their world lines will remain constant. Alice will age 12.4 years while Elizabeth ages 79 years.

One last point. Introducing realistic accelerations into the space-time picture will only round out the corners in Alice's world line. It is clear that Alice will still arrive home younger than Elizabeth in such a situation because her world line will still be longer than that of Elizabeth. It is all very simple, isn't it? Notice, as well, that we have not had to invoke general relativity to resolve the "paradox." Thank goodness! General relativity is a much more difficult theory to comprehend than special relativity. Special relativity can be understood with a good high school mathematics background (calculus helps too). General relativity requires an understanding of differential geometry, which is notoriously difficult to pick up. But that is another story.

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References

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Appendix I. The Time Dilation Formula

For those wishing to check the numbers used in Alice and Elizabeth's story, the time dilation formula is:

$$\Delta t_1 = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}\,\Delta t_2$$

where v is the relative velocity of Alice and Elizabeth, Δt_1 is the time experienced by Elizabeth and Δt_2 is the time experienced by Alice while moving. Doesn't the formula look like it could work both ways? It doesn't. It is just a summary of the Lorentzian arc length calculation discussed in the main text.

GORDON SARTY works by day to contribute to the science of medical imaging at the Royal University Hospital in Saskatoon, working to realize the ideal of long disease-free lives. His education for that occupational privilege, a Ph.D. in mathematics from the University of Saskatchewan, included differential geometry and its application to relativity. Although not an expert on relativity, Gordon does claim to understand the underlying mathematics.

Society News /Nouvelles de la société

NATIONAL AWARDS TO SANDY FERGUSON, DAVID LANE, ROGER HILL AND BERT RHEBERGEN

On February 14th the National Council of the Royal Astronomical Society of Canada approved a number of recommendations from the Awards Committee regarding the presentation of the Chant Medal and Service Awards for 1998. The citations for the award winners are presented here.

Sandy Ferguson

Nominated for the Service Award
by Richard J. Huziak and Erich Keser

The Saskatoon Centre would be honored if the Committee would consider the recognition of one of our members for the National Service Award this year. The member is Ms. Sandy Ferguson.

We have been exceptionally fortunate to have Sandy active in our Centre. Sandy is a lifetime amateur astronomer, being a long-time member of the Ottawa Centre and, for the last seven years, a member of the Saskatoon Centre. In Ottawa Sandy was very active, holding the positions of 2nd and 1st Vice-President along with other executive positions. In 1991 she moved from Ottawa to Saskatoon to be nearer to her family. Since joining our Centre she has served in the executive positions of Librarian, Activities Co-ordinator, Councilor, Newsletter Editor and Youth Group Co-ordinator. Sandy has also served on the National Council as the Astronomy Day Co-ordinator.

Sandy is an endless promoter of astronomy within the RASC, in the school system, in the community and via the media. She gives dozens of presentations each year to Cubs, Beavers, Brownies and school groups at the Beaver Creek Conservation Camp and the Brightwater School Camp, and in the classrooms for young children just beginning to learn about the wonders of the sky. Sandy also appears monthly on a local television entertainment show, ‘Eye on Saskatchewan,’ promoting the RASC and important astronomical events. In her spare time Sandy also co-coordinates our Binocular Observing Program and the Saskatoon RASC Children’s and Youth Astronomy Groups (involving about two dozen participants), for which she opens up her home twice each month. Despite her busy schedule, she also helps organize three or four local star parties each year and is a major contributor to the success of our newly initiated Cypress Hills Star Party.

We are proud to have such a dedicated, inspired and hard-working member as a part of our Centre and as part of the National organization. For her dedication she has earned the Membership Certificate and Messier Certificates.

On behalf of all of the members of the Saskatoon Centre, we graciously ask that the Awards Committee accept Sandy as the next recipient of the National Service Award.

David Lane

Nominated for the Service Award
by David M. F. Chapman and Mary Lou Whitehorne

On behalf of the RASC Halifax Centre executive and membership, we wish to propose that David ‘Dust’ Lane be considered for the RASC Service Award in 1998. Since Dave joined the RASC in 1986, he has provided exemplary service to the RASC at both the Centre and National levels, and he has tirelessly promoted astronomy to the general public.

Dave did not remain long as an ordinary member (he has always been an extraordinary member!); he joined the Centre executive in 1989 as Secretary and has remained on the executive ever since. He spent two years as Secretary, one year as Observing Chair, six years as Editor of *Nova Notes*, and was elected Treasurer for 1998. In 1994 and 1995 he was Centre President as well as the newsletter editor. From 1991 to 1993 he worked countless hours to assist in the organization and running of the 1993 RASC General Assembly. Dave became a Life Member of the RASC in 1993. At the national level Dave has been involved in the Computer Use Committee and has been an indispensable member of the Publications Revitalization Committee. He was responsible for the set-up of the RASC internet list server discussion group and continues to maintain it and other RASC web sites.

In Halifax, Dave has been a key player in all of the public astronomy events the Centre has sponsored over the last decade. Included is Nova East, the Centre’s annual star party, in which he has frequently taken the leadership role. He has also been part of the volunteer team that conducts free public planetarium shows on Thursday nights and has participated in astronomy promotional events at schools, on television, and over the radio. During the planning and initial construction of the Centre observatory at St. Croix, Dave Lane provided the sort of levelheaded counsel we have grown to expect from him, not to mention hours of back-breaking labour.

Through his personal interests and activities, Dave has put astronomy on the map in the local area, nationally and globally. He is a keen observer, completing both the Messier and NGC observing lists of deep-sky objects with several fine telescopes he has constructed. With Paul Gray he conducted a systematic search for extragalactic supernovae, eventually discovering supernova SN1995F, for which both received the RASC's Ken Chilton Prize in 1995. He designed, coded, and distributed his own desktop planetarium software — the Earth-Centered Universe — an accomplishment that earned him the RASC's Chant Medal.

Dave Lane's involvement in astronomy and his dedication to the RASC show no signs of flagging. He is the glue that holds together the RASC Halifax Centre and much of the National RASC. We feel that the mass of evidence is sufficient to qualify him for the RASC Service Award many times over. Please consider him for this distinction.

Roger Hill

Nominated for the Service Award
by Colin A. Haig and Michael Jefferson

The Hamilton Centre of the Royal Astronomical Society of Canada nominates its past president J. Roger Hill for the honor of receiving the National Service Award for 1998.

Roger Hill has been a member of both the Hamilton and Toronto Centres since the early 1970s. He was a contemporary of the Hamilton Centre's well-known president, Ken Chilton, and was very active as a regular member. He was involved as a worker or co-ordinator for several observing events including solar eclipses and occultations, has acted as presenter at public shows, has served on the Centre's board of directors and has been Centre President on three occasions. He is a previous winner of the Centre's William Fautley Award for the advancement of astronomy. His efforts over a considerable time span have had a profoundly positive impact on the Hamilton Centre. We feel that he meets or exceeds the necessary qualifications for the Society's Service Award.

During the early days of his membership, Roger Hill was a very active and interested amateur astronomer and observer. Being a passionate follower of solar eclipses, he traveled to remote locations or took vicarious interest in as many of them as time and budget would permit. He was also a devoted attendee of our monthly meetings and he fondly recalls the public star parties of the Hamilton Centre in which he participated. During the mid-1980s he found it necessary to leave the Hamilton Centre for the Toronto Centre when he changed residence, but shortly afterwards he relocated back to our area and rejoined the Hamilton Centre.

The Hamilton Centre subsequently experienced a number of internal political and organizational problems that created an unsettled climate over the course of the next half-decade. In the autumn of 1993 the Centre experienced a schism, the likes of which it had never known before, and some of the membership left to form a new organization. Although the Hamilton Centre limped on as best it could through the rest of 1993 and into the autumn of 1994, the Centre's future was rather bleak. The total number of members present at the fall meeting was less than a dozen. Two long-standing members agreed to chair the meeting, where they made impassioned speeches and attempted to bring new life into the group. It worked! People volunteered for jobs and tasks that no one could be found to do in the past. At some point during that period a volunteer arose to be the new chair of the Hamilton Centre. It was Roger Hill. His action produced almost magical results since many others then stepped forward to volunteer for still-unfilled tasks and board positions. The incident highlighted Roger's skill at inspiring others to come out to help the Centre.

During that period Roger Hill was able to inspire both active and less involved members to become involved on a more committed basis. Things began to happen:

1) The membership rolls increased to almost the same levels that they enjoyed in the days of Comet Halley; groups of dissimilar interest reunited.
2) The Centre's funding increased significantly as a result of the larger membership and the increased activity in its public education programs. Under Roger's leadership we were involved not only in public programming at the observatory, but also at the McMaster University Planetarium.
3) The number and variety of guest speakers improved since he took office, and the quality of procedure in meetings also took a turn for the better.
4) The observatory programs, along with the regular maintenance and improvements to the facility, have all been noticeably strengthened.
5) Under Roger's management the Centre's observatory became computerized and we now have E-mail, Internet access and electronic imaging capabilities. We were also invited to take part in a NASA on-line conference on Comet Hyakutake as a result of NASA's awareness of our photographic and electronic images of the comet.
6) Some work in radio astronomy was done using his equipment and under his direction.
7) He also graciously loaned the observatory his own telescope when the Stuart instrument was being repaired and we needed CCD imaging capabilities.
8) Finally, there were times when either a speaker did not

> appear or one was not scheduled that Roger ran the meeting almost single-handedly, speaking off-the-cuff and encouraging the participation of other members with their various strengths and skills.

With due respect to Ken Chilton and the Reverend Dr. D. B. Marsh, we have not known a more dynamic or more dedicated Centre president than Roger Hill. From filling in as national representative for an overworked vice-president to finishing last year as acting president, Roger has never flinched from his commitment to any aspect of the Society and the Hamilton Centre. We heartily endorse his acceptance for the National Service Award in 1998.

BERT RHEBERGEN

Nominated for the Chant Medal
by Colin A. Haig and the Hamilton Centre

On behalf of the Hamilton Centre of the Royal Astronomical Society of Canada, we wish to nominate Bertus ("Bert") Rhebergen for the Society's Chant Medal in recognition for his ongoing solar observations spanning the years from 1973 to the present.

Bert Rhebergen, a long time member and accomplished amateur observer, completed his 1000th solar observation earlier this year. His observations span several years on a frequent, nearly daily, basis (weather permitting). He has been a member of the RASC since 1978 and has been actively involved in the operational and observational activities of the Hamilton Centre, serving on its Board as Observing Director and Maintenance Director. His observational skills are exceptional and he has taken considerable time to impart his knowledge to newer members as well as to assist in their development as observers, particularly in the areas of solar and double star observations.

He began making solar observations in 1973, and started record keeping in 1983. His regular, frequent observations began in 1988 as a result of an interest in the solar eclipse visible in the South Pacific. His interest developed from other Hamilton Centre members, including Rev. D. B. Marsh and Dr. J. Bell, who were active solar observers. While Rev. Marsh and Dr. Bell carried out work from about 1920 to approximately 1980, Bert Rhebergen's observations have proceeded to the present, and reached 1000 observations on July 6th 1997 — over 15 years of recorded observations. Bert, who is a humble individual, has not gone to great efforts to promote himself or his work, but the Hamilton Centre strongly feels that his work has been of considerable value to our Society and recognizes that he has successfully continued the efforts of his predecessors.

Bert Rhebergen has made his work available to Hamilton Centre members for several years now, usually by presentations at general meetings or during observing sessions. His observations are currently available in printed form and we expect to have them available on the Hamilton Centre's World Wide Web site soon. In 1996 Ms. Ev Rilett analyzed his data and produced some computer-generated plots of his sunspot numbers, which were found to correspond well with data reported from other sources.

Bert's detailed drawings of the Sun's disk and features, made with small telescopes at either the observatory or his workplace, have been recorded with all of the observational information needed to make them useful to others: dates and times, location and temperature (if outside of norms), general sky conditions, estimates of seeing, estimates of sky transparency, telescope used (usually a 4.5-inch f/11.6 reflector or his 60-mm refractor), and relative sunspot numbers. Sample observations are included with our letter of nomination, and a complete copy of his work will be made available in printed form to the library at the RASC National Office.

CONGRATULATIONS TO...

- **RANDY KLASSEN** (Coquitlam, British Columbia) and Christopher Fleming (London, Ontario) on their successful completion of the requirements for Messier Certificates, which were recently awarded to them by National Council.

- **DOUGLAS L. STUART** (Thunder Bay, Ontario) on his recent award of a Finest NGC Certificate by National Council.

- **John Percy**, professor of astronomy, Erindale Campus, University of Toronto, who was recently honored by the University of Toronto's Ontario Institute for Studies in Education as one of six recipients of the Institute's Distinguished Educators Award for 1997. John's citation recognizes his role as an international leader in astronomy education.

At the Eyepiece

Capturing the Heart of Virgo

by Alan Whitman, Okanagan Centre

How many galaxies have you ever seen at once? There is a marvellous knot in the Virgo Cluster where ten galaxies crowd into my 20-cm Newtonian's 61× field. Start by examining the two bright ellipticals M84 and M86, only 17′ apart. Take your time because they are the last bright objects that you will see for awhile. Each has a prominent nucleus. (All descriptions refer to the view through a 20-cm reflector.) M84 is an E1 galaxy, while M86 is a more oblate E3.

Our first spiral, spindle-shaped NGC 4388, lies 16′ south of the two Messier objects, forming an equilateral triangle with them. The New General Catalogue (NGC) describes this large magnitude 11.1 galaxy as "very faint." While NGC 4388 is not exactly prominent, I find it to be a good example of why the NGC descriptions need to be read with a grain of salt. I doubt that the transparency was all that great on the night that "very faint" was penned by a 19th century observer.

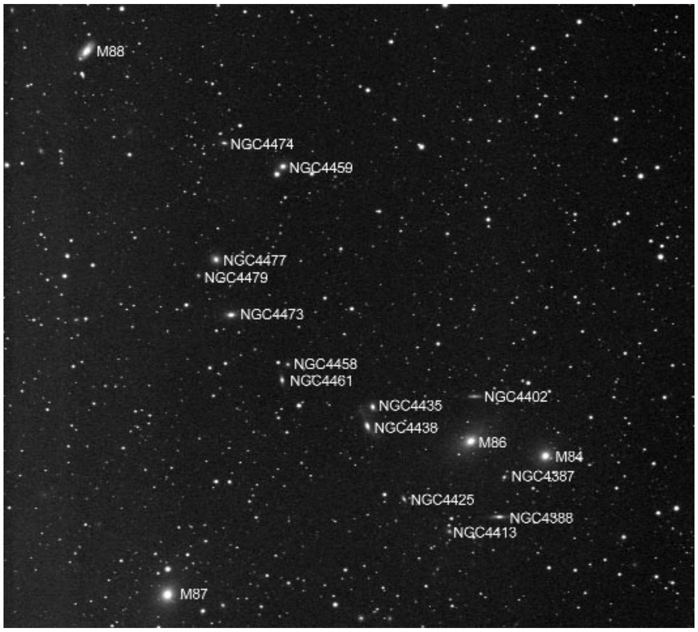
Carefully examine the very centre of the above triangle and you should be able to pick out tiny NGC 4387. Despite the NGC's description — "pretty faint" — this magnitude 12.0 galaxy's relatively high surface brightness makes it less of a challenge than most 12th magnitude galaxies.

Look 10′ north of M86 to find NGC 4402, an edge-on spiral. *Burnham's Celestial Handbook* states that it has "a prominent equatorial dust lane." I can state unequivocally that Burnham was not using a 20-cm for that observation! Has anyone bagged this dark lane using big glass?

Now extend the line from M84 to M86 about 20′ and you will come to The Eyes, NGC 4435 and NGC 4438. Both "eyes" have "pupils" — nuclei.

Another edge-on galaxy, faint NGC 4425, lies 20′ south of NGC 4435. "Faint" is what I have written in my logbook entry for the magnitude 11.9 lens-shaped spiral; the NGC labels it "pretty faint." NGC 4425 is at the midpoint of an arc from NGC 4388 to NGC 4438. As a further check, NGC 4425 forms an equilateral triangle with NGC 4435 and M86. Now you are learning how to navigate the thickest parts of the Virgo Cluster. Forget star hopping — galaxy hop!

With your new skill, take on the toughest galaxy yet, the only one not visible at 61× in my scope. Extend a line from NGC 4402 through M86 exactly twice its length. You will be equidistant from your most recent find, NGC 4425, and from NGC 4388, 12′ from either. Note the star field and switch to a moderate power. NGC 4413 was detected with averted vision at 116× on an Okanagan night with excellent transparency and very good seeing. (The former is standard in the Okanagan, but the latter is rare.) Since 13th magnitude (photographic) NGC 4413 was not visible at low power, this galaxy, while in the field, is not one of the ten visible at once.



The heart of the Virgo Cluster annotated with many of the galaxies mentioned in this column. (Image taken by Peter Ceravolo atop a 7000-ft mountain in south-eastern Arizona with a 440-mm Mak-Newtonian Astrograph of his own design and construction.)

To spot galaxies number nine and number ten, extend the line from M86 through The Eyes by the same length and curve very slightly northwards. There you will find another pair, NGC 4458 and NGC 4461 — a smaller pair of eyes! They are magnitudes 12.1 and 11.2, respectively. When the last two galaxies were just far enough inside the edge of my 20-mm Erfle eyepiece's field that I could still discern them, M84 was barely inside the opposite edge. Ten galaxies visible at once, count 'em!

The edge of this remarkable field is not the natural end to our tour. Hop onwards to M88, following the curve from M86 through The Eyes and "the small eyes." Just where the next bauble on the necklace should be, 10th magnitude NGC 4473 appears. Tighten your northwards curve, leaving Virgo behind, and you are upon NGC 4477 in Coma Berenices — easy at magnitude 10.4.

My 20-cm Newtonian could not pick up magnitude 12.5 NGC 4479 just 3′ south of NGC 4477; but a 1996 tour with the Prince George club's 0.6-m Cassegrain at 120× made short work of 4479. It was hardly sporting to jump that much in aperture for the second attempt I suppose, but then I do not like missing objects!

Cruise on northwards through the wide pair NGC 4459 (magnitude 10.4) and NGC 4474 (a magnitude 11.8 E6) and then shade your eyes — Messier ahead! Bright M88 sports a nucleus, as do NGC 4461, NGC 4473, NGC 4477 and NGC 4459. Four of the five are spirals, but NGC 4473 is an E4 elliptical. A nucleus is about all the detail that amateur telescopes reveal in most Virgo Cluster galaxies — their glory is in their sheer numbers.

Because the fuzzies are so close together, such a galaxy-hop was easy even with the big Cassegrain's tiny 24′ field of view. There would be no point in listing the celestial co-ordinates of this month's objects, since the three-degree long chain of galaxies is anchored by bright Messier objects at both ends.

Certain objects demand attention whenever they are well placed. The finest jewel in Virgo is Gamma Virginis, a matched pair of magnitude 3.5 pale yellow suns. The pair has been closing for all of the 36 years that I have observed it. In 1962 they were an easy 5″.0 target for my new 60-mm refractor. They are now 1″.8 apart and accelerating towards periastron passage in the binary's 170-year orbit. Watch over the next nine years as they close to only 0″.3 in 2007!

The author of an observing column writes in a curious time warp. The sky he describes always lies a full season ahead; the most recent descriptions in his logbooks of the objects about which he writes are at least nine months old. Thus, he is frequently found observing the black predawn skies, checking some detail, while making resolutions to the effect that his logbooks will be more carefully written in future!

My deadline for this column was February 15th. When Spica culminated at three o'clock that morning, it was a magical moment for what it portended. Spica is the key to the south, the key to wondrous objects below the horizon. I cannot know with certainty that my perfect record in the Moon's shadow will continue on February 26th. But I do know that one morning very soon I will stand on the Sky Deck of the *MS VEENDAM* and look straight down from Spica, and there, 36 degrees lower, will be a naked-eye fuzzy patch, Omega Centauri. My *Astroscan* will resolve the king of the globulars and linger long. Then I will sweep back north along the line towards Spica, but be halted by two of the southern sky's finest galaxies, Centaurus A and M83.

Retired weatherman Alan Whitman provided weather consultation to three successful Caribbean total eclipse cruises in February. Alan requests detailed observing reports from amateurs who have completed their Messier list for use in At the Eyepiece. E-mail him at: awhitman@vip.net.

Starlab Update from Nova Scotia

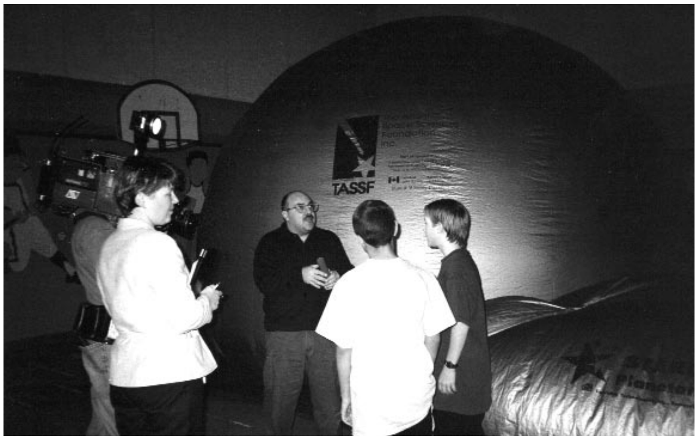
by Mary Lou Whitehorne, Halifax Centre

"What is inconceivable about the universe is that it should be at all conceivable." — Albert Einstein.

The Atlantic Space Sciences Foundation's new Starlab portable planetarium program has been very active since it arrived in Nova Scotia. The Starlab, also known as the "Space Bubble" or the "Inflatable Universe," made its public debut on March 17th, 1996, at the Halifax Shopping Centre, where free planetarium shows were presented all day with over 400 people sitting in on the shows. Since then it has traveled to many schools, been the centrepiece of a number of teacher workshops, appeared on *Breakfast Television*, and has been the focus of a lot of fun, excitement and learning for many, many Nova Scotians.

In the spring of 1996, Starlab traveled to eight schools under a special introductory program, where a planetarium operator went with it and presented educational programming to the students. Everywhere it went it got rave reviews.

Each teacher workshop brought more Starlab teachers on line and further increased its demand. Teachers immediately recognized the potential that Starlab represents for learning, and as soon as they had it in their school for a day or two they began devising their own individual programs and finding more and more ways to incorporate it into the curriculum at all grade levels. The teachers are scientists at heart — they all seem to love to experiment with it!



With September of 1997 came the beginning of a new school year and the start of the Starlab program as it was originally intended. Our freshly minted Starlab teachers began booking it for one-week time slots at their schools, and it began its travels across Nova Scotia. As of this writing, Starlab is booked into April 1999, some 10,700 students have enjoyed the experience, nine Starlab teacher workshops have been held and more are scheduled (there is a waiting list of teachers requesting workshops), and the calls just keep coming in.

Everybody is having fun with the Starlab. Teachers love it and their students are unabashed fans — they go crazy with excitement when Starlab comes to their school. One school managed to get 900 kids through it in one week! Several schools have had "Parents' Night" or "Community Night" and invited parents and community groups to their school for an evening to enjoy it. Still other schools have used it as the focus for "Space Week" or "Space Month" where it has served as the centrepiece for a wide range of activities and studies in astronomy and space sciences.

That kind of response to the Starlab is very rewarding for the participants, but even more rewarding for members of The Atlantic Space Sciences Foundation (TASSF) who are seeing their facility being put to such active and fruitful use in Nova Scotia. That was what we had intended all along. It is extremely gratifying to see our dream come alive in the enthusiasm and excitement of young Nova Scotians as they embark on their journey into the future.

The Atlantic Space Sciences Foundation can be reached at:
P.O. Box 31011, Halifax, Nova Scotia, B3K 5T9
Phone: (902) 864-7256, (800) 511-3500
Fax: (902) 492-3170
E-Mail: tassf@hercules.stmarys.ca
Website: http://halifax.rasc.ca/tassf

The response from teachers, students and parents to the Starlab has been overwhelmingly positive. Here is a sample of some of the feedback:

"We had a wonderful time with the Starlab. I cannot begin to tell you how many lives that we have touched with the experience. We had it open to the public; we had our entire school through it; we could not believe the knowledge that the children had after only one visit. Everyone enjoyed Starlab very much!"

Judy, Rita and Susan, Starlab Teachers
Sir William Dawson School
Pictou, Nova Scotia

"Thanks for the extension; it avoided great disappointment because of a storm day. The students were actually hoping there would not be a storm day! So many people rave about Starlab that it will be in such demand and hard to book. But I shall try again. I feel I had great success and enjoyed it."

Bruce King, Starlab Teacher
Milford School
Milford Station, Nova Scotia

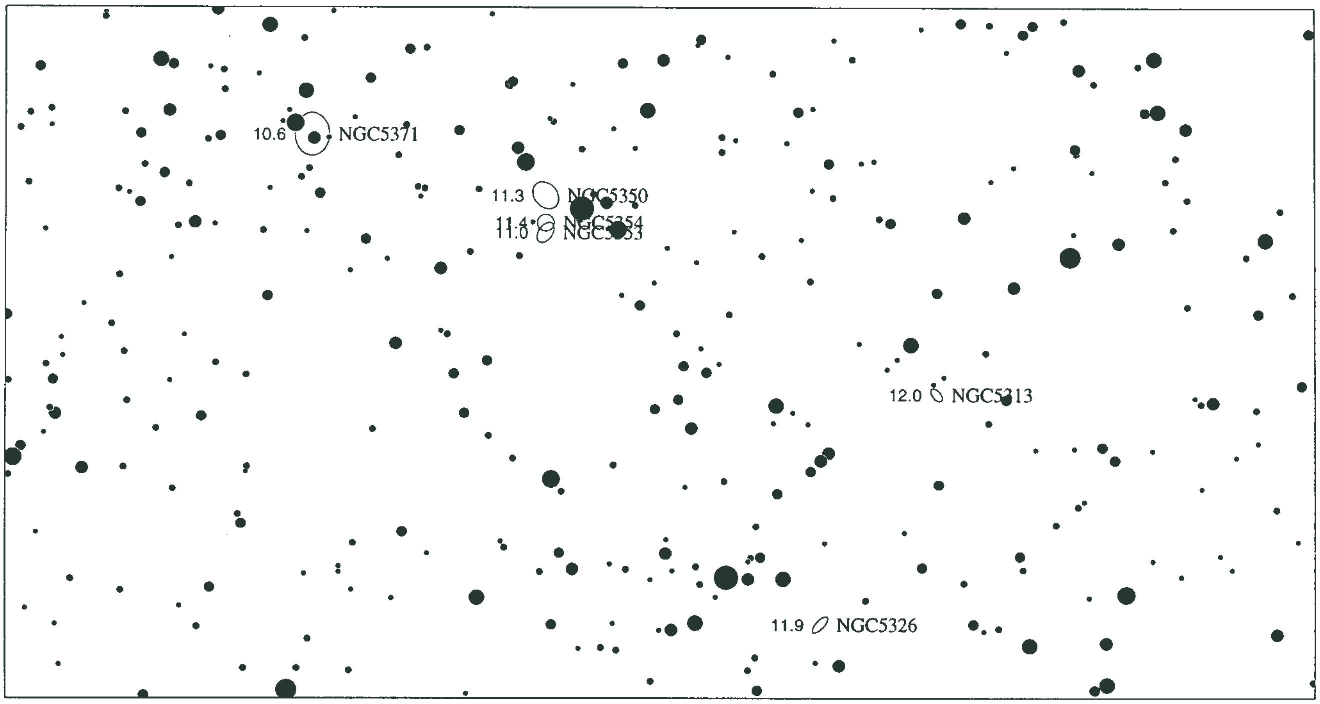
TASSF Activities for 1997

Schools Visited	21
Non-school Venues	4
Television Appearances	2
Teachers Trained	90
Halifax Planetarium	6,800
• Public Programming	5,000
• Tailor Made Universe	1,800
Starlab attendance	10,700
• Student Attendance	9,100
• Public Attendance	1,600
Grand Total	**17,500**

Mary Lou Whitehorne, astronomy educator extraordinaire, is a board member of the Atlantic Space Sciences Foundation (TASSF) and the co-ordinator for the Starlab. She is also the regional manager for the Canadian Space Agency's Atlantic Regional Space Resource Centre

Scenic Vistas: The NGC 5353 Group

by Mark Bratton, Montreal Centre



The brighter members of the NGC 5353 galaxy group located in eastern Canes Venatici. (Chart prepared by Dave Lane)

Riding high overhead on warm spring evenings, the little constellation of Canes Venatici belies its modest size by being home to hundreds of galaxies both bright and faint. Some, like M63, M51 and M106, are spectacular showpieces, but there exist many others that are just as intriguing. In the east central part of the constellation, far from any bright stars, is the NGC 5353 galaxy group. Here, in an area of about one square degree, the observer will find eleven New General Catalogue (NGC) galaxies with visual magnitudes ranging from 10.6 to 13.8.

It is not an easy group to locate, however, as it lies in a relatively blank area of the sky. The best way to get there is to centre your telescope on Gamma Boötis and follow a chain of about fifteen stars (of magnitudes six to eight) westward about seven degrees. That will place you at the very heart of the galaxy group and in its most spectacular field.

You are now in the NGC 5353 group proper, a collection of five galaxies grouped together in a field that rewards high magnification. Three of the galaxies are bright and should be easy in scopes of 150-mm or larger. NGC 5353 is an S0 galaxy, an elongated oval with extremities that taper to soft points. NGC 5354 is a round elliptical very much brighter towards the middle. The most interesting of the three is NGC 5350, a little fainter but larger and slightly elongated north-south. Its envelope is diffuse and the core is a little brighter but larger than the average galaxy core. The other two galaxies, NGC 5355 and NGC 5358, are very faint, small smudges of light. NGC 5355 is a little brighter, but NGC 5358 is easier to locate, being due north of a tight pair of thirteenth magnitude stars.

Northeast of the group is NGC 5371, the brightest galaxy in the field. It is isolated but is easily located due south of a wide pair of eighth magnitude field stars. Although the envelope is diffuse, the centre is bright and brightens to a sharp, stellar nucleus.

The other galaxies in the field are all located south of the NGC 5353 group. NGC 5337 and NGC 5346 are a fairly faint pair. NGC 5337 is the brightest, an elongated streak of light oriented north-south. NGC 5346 is the faintest of the eleven galaxies at magnitude 13.8 and appears as a hazy smudge of light that is oriented NNE–SSW.

One field east is a brighter pair, NGC 5311 and NGC 5313. Neither galaxy displays a bright core. NGC 5313 is the visually more interesting of the two, a much elongated object oriented NNE–SSW with a smooth, well-defined envelope. NGC 5311 is smaller, but well-condensed with an opaque envelope. It is pretty much round.

The last galaxy in the group is NGC 5326, a bright well-defined galaxy elongated WNW–ESE. It is quite condensed and displays a bright core. All eleven of the galaxies were easy to see in my 400-mm reflector, but amateurs using smaller telescopes will probably meet with varying degrees of success in picking off the fainter members. Certainly NGC 5313, NGC 5326, NGC 5350, NGC 5353, NGC 5354 and NGC 5371 should not pose too much trouble for the patient amateur with a 150-mm to 200-mm telescope, and the others are not necessarily out of reach depending upon the observer's experience and sky conditions. Surrounding the galaxies and a little farther afield are many more which I have yet to observe. It is truly a remarkable area of the sky.

Mark Bratton has had a life-long interest in astronomy and first became acquainted with the RASC in November of 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 was recently elected as president of the Centre. He is the single parent of an eleven year old boy, Kristopher, and his greatest joy, besides his son of course, is slowly exploring the skies with a 375-mm reflector from the deck of his small country cottage near Sutton, Québec.*

Saskatchewan Summer Star Party 1998

by Erich Keser and Sandy Ferguson, Saskatoon Centre

> *"Ah, the delights of the 1997 SSSP (Saskatchewan Summer Star Party) skies! Clouds were, fortunately, absent but the clear nights testified to the admirable, wonderful sky view from the Cypress Hills observing site … I have rarely seen such clarity and depth in the summer skies, certainly comparing favourably with the best I'd seen. The summer Milky Way was truly spectacular and its wonders so abundant and clear — naked eye, binocular or telescopic. With no nearby light pollution … the sky was very dark."* Lucian Kemble, OFM

And so Father Luc's lyrical description of our 1997 Saskatchewan Summer Star Party has its attendees longing to return this summer, when the Regina and Saskatoon Centres of the Royal Astronomical Society of Canada will be holding the Second Annual SSSP on the weekend of July 24–26 in beautiful Cypress Hills Interprovincial Park (Centre Block).

The 'gate' to the well-blocked off and spacious Meadows observing area. (photo by Erich Keser).

At an elevation of 1200 metres, Cypress Hills is the highest point in mainland Canada between Labrador and the Rockies. This great plateau of cool, green lodgepole pine forest and alpine meadows in the southwest corner of Saskatchewan has a unique natural history because it was missed by the last ice age and its elevation and isolated location make for superb dark-sky viewing.

Cyprus Hills Park is a wildlife paradise, however there are no large preditors. (photo by Kim Mysyk)

Cypress Hills Interprovincial Park is also a full family resort and includes water sports, golf and mini-golf and riding stables as well as indoor activities. They are well tucked-away from the extensive system of hiking and riding trails that provide access to the park's abundant birds, wildlife, orchids and interesting geology. There is also good trout fishing nearby. In-park accommodation includes rental suites in the Park Lodge, rental cabins and condominiums, camping and trailer sites, while there are two excellent B&B establishments a short drive away.

Observers will be welcome to set up for the duration in a spacious, light-protected area of the Meadows Campground reserved for SSSP use. The area will be supervised co-operatively by participants, who can also camp near their telescopes if they wish. Official observing will begin on the night of Thursday, July 23rd, and end on the night of Sunday, July 26th, but the skies and setting are so good that some will likely begin earlier or stay later, as they did last year. In addition, SSSP'98 will feature a wide variety of daytime activities, including astronomy presentations and discussion groups in the park's meeting hall, astrophoto displays and contests, a swap table and children's activities that will culminate in a dramatic presentation.

Featured this year will be a presentation by Alan Dyer entitled "Shooting the Northern Skies," which he describes as a "blowout show" of his exceptional astrophotographs; a special “Meteorites and Impact Structures” audio-visual session in memory of Eugene Shoemaker by geologists Don Hladiuk (Calgary Centre), Chas. Zsoka (Regina) and Kim Mysyk (Saskatoon Centre), and a panel presentation of images and impressions of the great 1998 solar eclipse. Veteran observer Father Lucian Kemble will again be taking an active part in the proceedings, and there are opportunities for less formal talks by attendees, who may present their slides, overheads and videotapes.

In response to tremendous interest from new and young astronomers, and partners and friends of astronomers, there will be more introductory talks for beginners, and Edmonton Centre’s Murray Paulson will provide a special session of his “Binocular Starwalk of the Night Sky” geared to newcomers. The Regina Centre will be conducting the tenth iteration of their public Star Night for campers at Lookout Point and will sell this year’s edition of their beautiful T-shirts (pre-ordering is advisable!). Renowned area chef Jim Saville of the Spring Valley Guest Ranch will provide the Saturday evening Banquet. There may also be another meteorite search on Sunday.

The Regina and Saskatoon Centres welcome everyone to our second annual Saskatchewan Summer Star Party. Make this your “Prairie Summer” and join us in big-sky country for a fun-filled, family-oriented weekend of astronomy and summer activities. ◉

For more information contact SSSP Registrars Ellen and Les Dickson (e-mail: dickson@sk.sympatico.ca), Rick Huziak (306) 665-3392 or Erich Keser at (306) 374-4262 (e-mail: keser@duke.usask.ca) or write to: SSSP’98, RASC Saskatoon Centre, P.O. Box 317, RPO University, Saskatoon, SK, S7N 4J8.

A Call for Papers for the 1998 General Assembly

The General Assembly Planning Committee is inviting anyone interested in presenting a paper at the papers sessions to submit a notification of their wishes as early as possible.

The deadline is Friday, May 1, in order to meet publication deadlines, but we want to encourage all interested members to notify us of their wishes well before that date. Please note that papers will be allotted fifteen minutes each, including questions.

Prior to May 1 you should submit the following:

a) an abstract of your paper, to a maximum of 100 words, for inclusion in the program brochure;
b) a brief biographical sketch (maximum 100 words);
c) a slate of required audiovisual equipment for your paper.

This information should be sent to:
Gary Shearman
Chairman, 1998 GA Papers Sessions
1216 Clovelly Terrace
Victoria BC
V8P 1V6

or e-mail to **shearman@freenet.victoria.bc.ca.**

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Room 110, St. Paul's College, 430 Dysart Rd., Winnipeg, MB,
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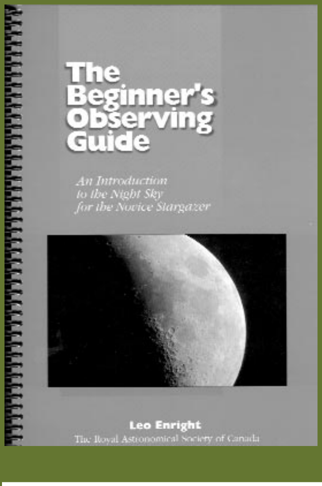
Publications from
The Royal Astronomical Society of Canada



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.

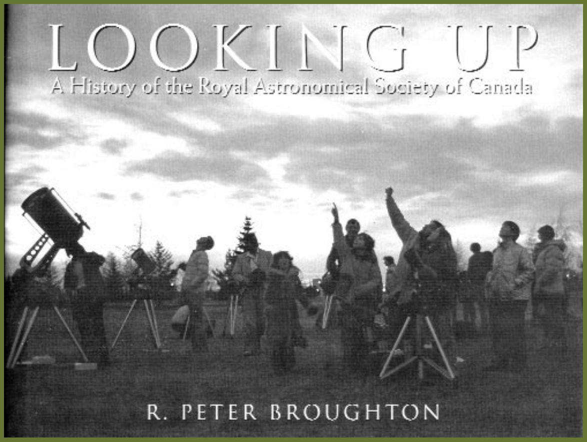
Written by Leo Enright (160 pages of information in a soft-cover book with a spiral binding which allows the book to lie flat).

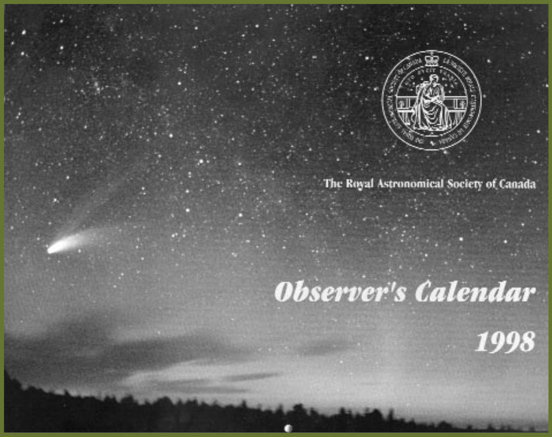
Price: $12 (includes taxes, postage and handling)

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)





Observers Calendar — 1998

This calendar was created by members of the RASC. All photographs were taken by amateur astronomers using ordinary camera lenses and small telescopes and represent a wide spectrum of objects. An informative caption accompanies every photograph. This year all but one of the photos is in full colour.

It is designed with the observer in mind and contains comprehensive astronomical data such as daily Moon rise and set times, significant lunar and planetary conjunctions, eclipses, and meteor showers. (designed and produced by Rajiv Gupta)

Price: $14 (includes taxes, postage and handling)

*** Special Discount — Looking Up and the BOG — $50 — All three publications — $60 ***

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