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Journal

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PROMOTING ASTRONOMY IN CANADA

December/décembre 2012
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Inside this issue:

A tangle of red and blue in Cygnus.

Astrophotographers take note!

This space is reserved for your B&W or greyscale images. Give us your best shots!

Barry Schellenberg from the Calgary Centre provides us with this intriguing narrowband image of the Elephant Trunk Nebula (IC 1396) taken in July while a fat gibbous Moon dominated the sky. Barry used a Borg Astrograph 101Ed at f/4.1 with a 3-nm Hα filter. Exposure was 20×300 s using a QSI 583WS camera.

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Société Royale d'Astronomie du Canada

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Front cover *— Howard Trottier shot this image of NGC 6914, a tangle of stars and nebula in the heart of Cygnus, in late July and August. "Towards the middle of the frame, the blue nebula fades gradually in colour and intensity, giving way to very dark clouds in an apparent transition that seems almost unique in the sky!" he notes. Howard used a PlaneWave Instruments CDK17 telescope with an Apogee U16M camera. Exposure: Lum, 200 m; Hα 170 m; R, 130 m; G, 140 m; B, 260 m for a total exposure of 15 hours.*

Journal

The *Journal* is a bi-monthly publication of The Royal Astronomical Society of Canada and is devoted to the advancement of astronomy and allied sciences. It contains articles on Canadian astronomers and current activities of the RASC and its Centres, research and review papers by professional and amateur astronomers, and articles of a historical, biographical, or educational nature of general interest to the astronomical community. All contributions are welcome, but the editors reserve the right to edit material prior to publication. Research papers are reviewed prior to publication, and professional astronomers with institutional affiliations are asked to pay publication charges of $100 per page. Such charges are waived for RASC members who do not have access to professional funds as well as for solicited articles. Manuscripts and other submitted material may be in English or French, and should be sent to the Editor-in-Chief.

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President's Corner

Glenn Hawley
President, RASC

The President, as of this writing, has made his first Presidential Centre Visit tour, taking in the Vancouver, Sunshine Coast, and Victoria Centres over Thursday, Friday, and Saturday on the last weekend in September. It is difficult to time these things to coincide with Centre general meetings, but I had very useful and informal get-togethers with some of the more active members of each of those Centres. They now know more about the By-laws, the presumed reasoning behind the government's changes and constraints, and more about some of the consequences. They also now know probably more than they ever wanted to know about the Helm Fund story.

Over the next months, I shall be trying to visit as many Centres as I possibly can, though with 29 of them in the Society now, it becomes an ever-more-difficult task for each succeeding President to try to visit all of them during a 2-year term. ✶

Size of the Black-Drop Effect *versus* Telescope Resolution During the 2004 and 2012 Transits of Venus

By Michel Duval, Marc Brault, André Gendron*, Jean-Marie Gohier, Giolles Guignier, Gilbert St-Onge*, Richard Sauvé, Marjolaine Savoie, Alex Stefanescu, Frank Tomaras, and Yves Tremblay*
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Abstract

The black-drop effect during the 2012 transit of Venus against the Sun has been photographed by amateur astronomers in Dorval (Montréal, Canada), confirming that the black-drop effect is produced by the optical halos observed around Venus and the Sun at contact points. A quantitative relation between the size of the black-drop effect and the optical resolution of the telescopes used is presented.

Résumé

Le phénomène de la goutte noire pendant le transit de Vénus de 2012 devant le Soleil a été photographié par des astronomes amateurs à Dorval (Montréal, Canada), confirmant que le phénomène de la goutte noire est produit par les halos optiques observés autour de Vénus et du Soleil aux points de contact. Une relation quantitative entre la taille du phénomène de la goutte noire et la résolution optique des télescopes utilisés est présentée.

1. Introduction

The transits of Venus (ToV) against the Sun in June 2004 and 2012 have been observed by a large number of amateur and professional astronomers around the world. Extensive investigations by amateur astronomers on the "black-drop effect" during the ToV of 2004 in Dorval have been published in the *JRASC* by Duval *et al.* (2005). It was shown that the effect can be explained very simply by the disappearance of the optical halos inside Venus and outside the Sun at contact points. This paper investigates further the relation between the size of the black-drop effect and the optical resolution of the telescopes used in 2004 and 2012.

Instrument	Size	Author	Resolution in arcseconds
Reflector	N/A	SDO	1.2
Schmidt-C.	8-inch	G. Guignier	2.1
Refractor	80-mm	Y. Tremblay	2.7
Newton	8-inch	M. Savoie	3.2
Refractor	80-mm	F. Tomaras-1	4.2
Reflector	8-inch	M. Brault	6.3
Reflector	8-inch	R. Sauvé	6.5
Reflector	11-inch	A. Gendron	7.3
Newton	6-inch	A. Stefanescu	7.3
Camera	Telephoto	J.M. Gohier	9.0
Camera	Telephoto	F. Tomaras-2	10.5

Table 1 — List of instruments used

2. Instrumentation

The amateur instruments used in Dorval to take photographs of the black-drop effect in 2004 and 2012 are indicated in Table 1. A photograph taken in 2012 by the *Solar Dynamics Observatory (SDO)*, and available on its Web site, was also used in this paper for comparison. The resolution of the instruments in arcseconds was deduced from the width of the halos around Venus as indicated in section 3.

3. Results and Discussion

Photographs of the black-drop effect at contact II of 2012 or contact III of 2004, in Dorval, are presented in Figure 1, respectively, from left to right and top to bottom.

In the previous investigation (Duval *et al.*, 2005), it was shown that the optical halos observed around Venus in the photographs are mostly due to the imperfect resolution of the telescopes used, and that the contribution of the "solar limb-darkening effect" (Pasachoff 2012, Schneider 2004) to the formation of the halos and the black-drop effect is significant only with professional telescopes of very high resolution, not with amateur telescopes of relatively low resolution. Indeed, in Figure 1, the halos around the Sun are not darker than those around Venus, as would have been the case if the limb-darkening effect had contributed significantly to the halos around the Sun.

It was shown that these halos are "blurring" from the bright Sun into the dark disk of Venus and into the dark sky. The apparent black disk of Venus in the photographs is thus

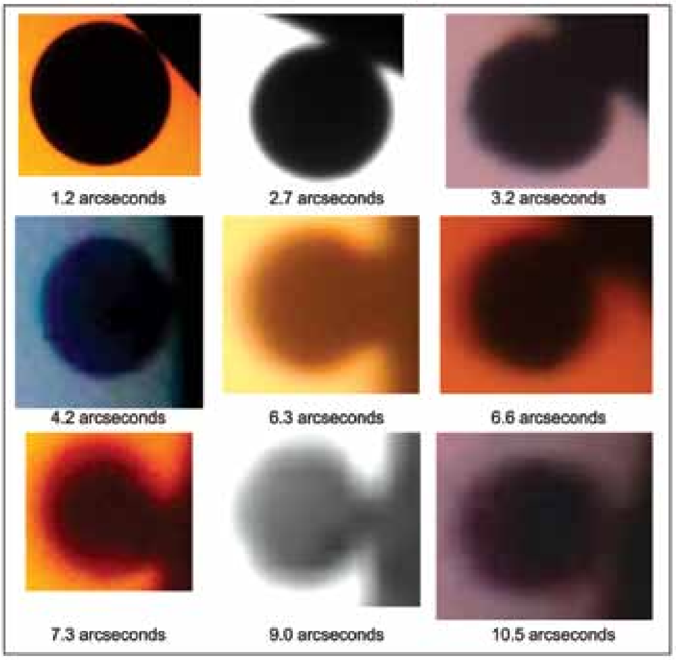

Figure 1 — Photographs of the black-drop effect during the ToV of 2012, taken by the SDO, Y. Tremblay, M. Savoie, F. Tomaras-1, M. Brault, R. Sauvé, A. Gendron (ToV of 2004), J.M. Gohier, and F. Tomaras-2, respectively from left to right and top to bottom. The resolution of the telescopes used is indicated in arcseconds, as deduced from the width of the halos around Venus and the Sun.

smaller than the real disk of Venus, which actually corresponds to the apparent disk of Venus PLUS the internal halo around Venus. Similarly, the apparent bright disk of the Sun in the photographs is larger than the real disk of the Sun, which corresponds to the apparent bright disk of the Sun MINUS the external halo around the Sun. The relative position of the apparent and real disks of Venus and the Sun previously shown in our 2005 paper to explain the black-drop effect.

A schematic representation of the halos and black-drop effect observed in 2004 at Dorval around Venus and the Sun at contact III (egress of Venus from the Sun) is shown in Figure 2, representing Venus moving from the left to the right side of the figure, *i.e.* from the bright (yellow) Sun into the dark (blue) sky. This representation is a schematic but accurate reproduction of the photographs taken in 2004. The apparent disks of Venus and the Sun are represented by a black line and the real disks by a dotted line. The halos are located between the black and dotted lines.

In Figure 2, immediately after the real disk of Venus has come in contact with the real disk of the Sun ("Real contact IIIa"), a portion of the real disk of Venus is above the sky and not any more above the Sun ("Contact IIIb"). The halos around this portion of Venus and the Sun therefore disappear, and this portion appears as black. This causes the black-drop effect, which increases in size at "Contact IIIc" and even more so at "False contact IIId" (which corresponds to the contact between the apparent disks of Venus and the Sun). The black-drop effect then disappears as Venus continues its way into the sky and leaves the Sun.

The same explanation applies to the halos and black-drop effect observed in 2012 in Dorval at contact II (ingress of Venus into the Sun) but in reverse order. To follow the sequence of events at contact II in 2012 with Figure 2, simply replace III by II in Figure 2. Venus in this case moves from the right to the left side of the Figure, *i.e.* from the dark (blue) sky into the bright (yellow) Sun. The black-drop effect starts at "False contact IId," then disappears at "Real contact IIa," as Venus continues its way onto the Sun.

It was also shown in 2005 (Duval *et al.*) that the diameter of the real disk of Venus, available in the *Observer's Handbook* (58.2 arcseconds in June 2004) can be used to calculate the width of the halos around Venus in arcseconds. If, in the photographs, x = the width in cm of the halo around Venus, y = the diameter in cm of the real disk of Venus (its apparent black disk + the halo), then the width of the halo around Venus in arcseconds = 58.2 (x/y). It was also shown that the width of the halos can be used to evaluate the optical resolution of the telescopes used, providing values that are very

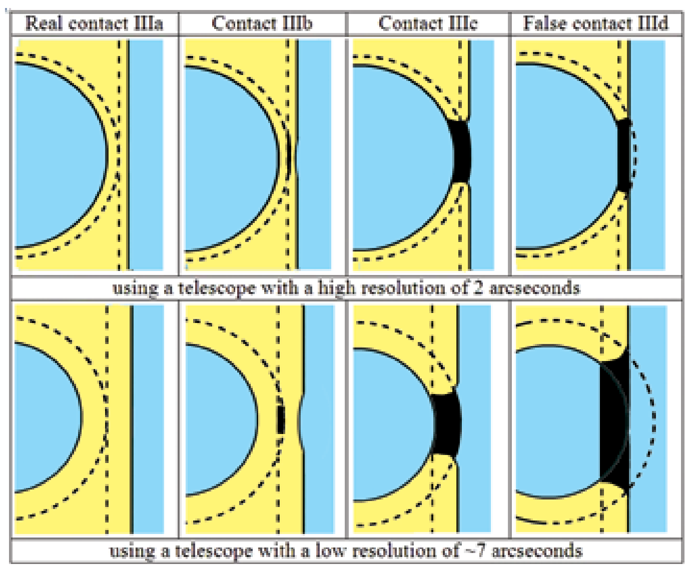

Figure 2 — Schematic representation of the halos around Venus and the Sun, and of the black-drop effect during contact III of the ToV of 2004 in Dorval, using telescopes of relatively high (2 arcseconds) and low (~7 arcseconds) resolution.

Dotted lines = real disks of Venus and the Sun.
Black lines = apparent disks of Venus and the Sun in telescopes.
Colour codes: yellow = apparent disk of the Sun;
blue = apparent disk of Venus and sky beyond the Sun (both are actually black);
black = black-drop effect as seen in telescopes.

This schematic representation also applies to contacts IId to IIa of the ToV in 2012 in Dorval.

similar to those based on the "point-spread function" of professional astronomers. The optical resolution of the telescopes used in this paper and thus calculated is indicated in arcseconds in Table 1 and Figure 1.

The resolution of the amateur telescopes used is mainly affected by the quality of their optical components and collimation. Since all photographs of the black-drop effect were taken from the same place (Dorval) at approximately the same time, the basic seeing conditions were the same for all telescopes. However, small variations of the local seeing conditions (*e.g.* small clouds) may also have contributed to the overall resolution and width of the halos in individual photographs not taken at exactly the same time. There was of course no seeing effect at all in the photograph taken from space by the *SDO*.

Photographs in Figure 1 correspond to contacts IIc of 2012 and IIIc of 2004 as defined in Figure 2. They have been adjusted to provide approximately the same visual diameter for (the apparent black disk of Venus + its halo) in Figure 1. The apparent black disk of Venus thus appears smaller, as it indeed is, in photographs taken with telescopes of lower resolution.

The lower the resolution of the telescope, the larger the halos around Venus and the Sun and the larger the black-drop effect. This has been quantified by calculating the surface of the black-drop effect in the photographs of 2004 and 2012, and by expressing it in Figure 3 as a percent of the surface of the apparent black disk of Venus, as a function of telescope resolution.

4. Conclusion

The photographs taken in Dorval during the Transit of Venus of 2012 confirm the observations made during the transit of 2004. They indicate that the "black-drop effect" for amateur-grade small telescopes is mostly due to the optical halos appearing around Venus and the Sun because of the imperfect resolution of the telescopes used. A quantitative relation between the size of the black-drop effect and the resolution of the telescopes used during the transits is presented. ✶

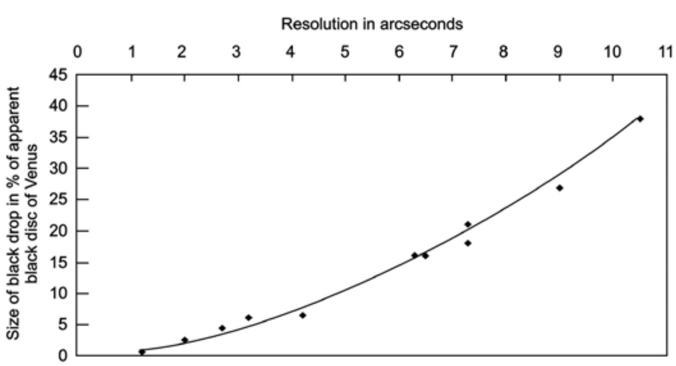

Figure 3 — Graph showing the size of the black drop (expressed as a percent of the surface of the apparent black disk of Venus) versus resolution of the telescopes used, from photographs taken by the SDO, G. Guignier, Y. Tremblay, M. Savoie, F. Tomaras-1, M. Brault, R. Sauvé, A. Gendron, A. Stefanescu, J.M. Gohier, and F. Tomaras-2, respectively from left to right in the graph.

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The Grand Schism in Canadian Astronomy III: Exploring the Origins of the Conflict

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Introduction

This article is the third and final in the author's outline of the personal, political, and technical background that led to the demise of the Queen Elizabeth Telescope and the construction of the Canada-France-Hawaii telescope.

Rebuilding the Dominion Observatory

The Dominion Observatory (DO) that Beals undertook to rebuild in 1947 was like a rudderless ship whose crew provided little motive power. He hastened the departure of its weakest members and terminated programs that had either reached their goal (*e.g.* providing a "law" for the differential rotation of the Sun) or proven unproductive (*e.g.* stellar spectroscopy and photometry). In his recruitment drive, he aimed high, very high. When rumours reached him in 1947 March that Gerhard Herzberg, future Nobel Laureate, was proposing to leave Yerkes Observatory and return to Canada, Beals made him an unofficial offer of the position of Head of the Solar Division. Herzberg politely declined; he did not want to be confined to a single astrophysical discipline. The two men became and remained fast friends and scientific allies. Beals had established a reputation as a pioneer of stellar spectrophotometry. He harboured the notion of turning that experience toward the Sun if he could find a suitable collaborator. In 1949, he appointed Jack Locke to rebuild the solar spectrograph from scratch and to initiate a new program of infrared spectrophotometry of the solar atmosphere.

By 1947, there was no longer a huge disparity in numbers between astronomers and geophysicists at the DO. External circumstances during Beals' 17-year tenure acted to tip the balance so strongly in favour of geophysics that, when he retired, the directorship of the Dominion Observatories passed for the first time to a geophysicist. Departmental reorganization in 1950 had created a new Dept. of Mines & Technical Surveys (MTS) with the renamed Observatories Branch as one of its five branches. Beals did his utmost to maintain a realistic balance in supporting the aspirations of both astronomers and geophysicists. When he was convinced of a new initiative for astronomy, he was undeterred by departmental mandates: witness his rapid success in establishing Dominion Radio Astrophysical Observatory (DRAO) (Part II).

Political concern over Canada's claim to sovereignty over the Arctic Archipelago grew rapidly after WWII and the onset of the Cold War. Scientific programs that took Canadian geophysicists to the High Arctic were strongly supported by MTS—in particular, the International Geophysical Year (IGY, 1957-58) and the Polar Continental Shelf Program (established 1958 and now operated by Natural Resources Canada). In each case, additional funds came to the DO with additional staff positions for the geophysical divisions. Hodgson (1994, pages 4-5) provides tables showing the growth of staff and budget from 1947 to the dissolution of the Observatories Branch in 1970. During the Beals' years (1947-1964), total permanent staff increased by a factor of 5, and the total budget by a factor of 12 (adjusted for inflation). No wonder that period is fondly recalled by its participants as a Golden Age.

Despite this largesse, not everyone was happy. Successful as he was in improving working conditions, Beals could not improve basic physical deficiencies of the Ottawa site. Initiatives in solar spectroscopy were hobbled from the start when Plaskett and King placed their horizontal solar telescope on the north side of the DO. Not only was the instrument in shadow for the winter months, its horizontal layout at ground level (and below!) meant the solar image was always blurred as it passed through the most turbulent daytime layers of the atmosphere. The Division of Positional Astronomy had designed and was building a new Mirror Transit Telescope (MTT) on the CEF, about 50 m south of the DO's front entrance. It was intended to improve the accuracy of transit instruments for measuring stellar positions to a mean error of 0.10″ in declination and 6 ms of time in right ascension (Labrecque 1963). The city of Ottawa had grown right around the CEF, so that its night skies were no longer dark. It was understood that the MTT would be moved to a superior site when it met specifications.

The bulk of geophysical data was acquired out in the field with portable instruments or at fixed stations that grew in number during the Beals' years. It might appear that the geophysicists were unaffected by conditions at their home site. Not so. Geological irregularities on the CEF (a fault line ran under the DO's west wing) precluded or hampered innovation of advanced geophysical instruments of high sensitivity and precision.

Figure 1 — The Sir John Carling Building under construction as viewed from the dome of the Dominion Observatory, late autumn 1964. The roof of the Director's House is in the left foreground.

Matters came to a head in 1960 when we got wind of the Dept. of Agriculture's plan to erect an 11-storey office block (the Sir John Carling Bldg.) on the CEF some 300 m due east of the DO (Figure 1). Beals listened to our pangs of anxiety about this encroachment on "our" skies. When he challenged us to suggest a better location for the DO, someone proposed the Gatineau Park, a large conservation area in Québec. A short drive across the Ottawa River from the DO, the park's main feature is the Eardley Escarpment rising 270 m from the floor of the Ottawa Valley. That escarpment extends over more than 30 km, running NW from the city of Gatineau and encompasses a huge wilderness area. Beals took this suggestion seriously. He promptly got permission from the Chairman of the NCC for the DO to set up a test site in a clearing near the highest point of the escarpment. The following summer the observatory's carpenter erected a prefabricated garage to house our instruments.

This site-testing project was an exercise in futility that wasted several man-years of effort. Had the outcome of our tests been favourable, the public's zealous guardianship of Gatineau Park would have been a formidable obstacle against development of an observatory that needed a road extension and power lines through a wilderness area. Wintertime access would always be problematic. I have not found a paper trail to confirm my suspicions that the agreement between Beals and the chairman of the National Capital Commission (NCC) was limited to short-term tests with no intention of following up with a permanent facility.

None of us at the time fully understood the atmospheric physics underpinning sites with good seeing. Simplistic ideas prevailed: a mountaintop was *ipso facto* a better location than a valley. Beals himself, talking of the advantage of a British Columbia location over something near Ottawa, said that nothing "could be as good as a mountain site in milder and less changeable climate with about a mile of air beneath them" (Beals 1964b). He badly misjudged the changeability of the climate on a B.C. mountain top outside the summer months. Not until after the commitment had been made to Mt. Kobau did Canadian astronomers interact with meteorologists who had a far better understanding of mountain-top climate and air turbulence. Daytime tests of seeing in the Gatineau were to my mind pointless without expanding considerably our forest clearing on the escarpment and erecting a rigid tower to support a telescope and observer at a height around 20 m. I limited my contribution to a comparison of sunshine hours measured at the DO to those on the Eardley Escarpment. Astronomers from the Division of Positional Astronomy air-lifted a 30-cm Tinsley reflector by helicopter to the escarpment. They estimated nighttime seeing visually from a selection of close binary stars.

Figure 2 — Technical Assistant Anatol Kryworuchko enters the Dominion Observatory's cabin on the Eardley Escarpment, early autumn 1963. The long tubular shaft behind the chimney supports a weatherproof cylindrical housing for a large-diameter photovoltaic cell. A matched unit was installed on the roof of the Geophysical Laboratory on the CEF. The outputs of both cells were fed into strip-chart recorders.

When news broke in March 1962 that staff at the Dominion Astrophysical Observatory (DAO) were conducting site surveys in the mountains around the Okanagan Valley in B.C. for a major reflecting telescope, I was dismayed. The scale of DAO's project threatened to postpone indefinitely a decision for a new site near Ottawa for the the Dominion Observatory's (DO's) astronomy programs. More than two years' effort on our site-testing project showed no significant difference between conditions on the escarpment and the Central Experimental Farm (CEF). This was to Beals' liking. In a letter (Beals 1963) to R.M. (Bert) Petrie, the Director of the DAO, he stated: "Our seeing tests in the Gatineau, *as expected*, do not indicate any decisive superiority over Ottawa and this result causes us to take a renewed interest in the B.C. sites" (italics added). Our result had been obtained at considerable cost in time and money. If it was expected, why incur those costs in the first place? My early conviction that Beals was playing a subtle game with the Gatineau project is confirmed from his letters that touch on this subject. On the one hand, Beals gave his Ottawa staff a make-work project to keep them busy and quiet on the matter of relocating their programs. On the other hand, he was building a case for consolidating all the federal government's astronomers in B.C.

Beals ran out of time for his rebuilding project in June 1964. He had generously supported the development of modern instrumentation for positional astronomy and for solar physics, as he had for programs across all divisions of the Dominion Observatories. With retirement imminent, he proposed, in a memo to his Deputy Minister (Beals 1964a), his solution to the problem of bad observing conditions in Ottawa: combine all the astronomical activities in one location in B.C. Petrie's initial vision for Mt. Kobau was as an outpost for DAO. When Petrie suggested that additional telescopes might eventually be moved from DAO to Mt. Kobau, Beals concurred. In his final letter on this issue weeks before his retirement, Beals added: "If this were done and the best of the Ottawa equipment were moved too, we would have pretty nearly the finest observatory in the world" (Beals 1964c).

In the same letter, Beals clarified his position on what had become a contentious issue with Petrie: a national institute for advanced research in astronomy next to a university, presumably the University of British Columbia (UBC), to serve the interests of a multi-disciplinary national observatory on Mt. Kobau. Petrie was not persuaded. It fell to the new Director of the renamed Observatories Branch of MTS, John Hodgson, to attempt to bring Beals' vision of a national institute of astronomy to fruition. In his attempt to do so, he provoked as much anger from the UofT's Astronomy Dept. as did the disappointing climatic data from Mt. Kobau.

The Proposed National Institute for Advanced Research in Astronomy

When Plaskett died in 1941, prospects for the 23-year-old DAO appeared bright for decades to come. But technological strides made during WWII—in radar, rockets, and photoelectric sensors—gave rise to entirely new branches of astronomy. New ways of acquiring information about the Universe with radio telescopes and from space platforms came about just as the newest giant telescope, the 5-m on Mt. Palomar, swung into action. Astronomy's frontiers were quickly pushed far beyond the grasp of the DAO's telescope. Barely two decades after Plaskett's death, his scientific heirs at DAO were pleading the case for a new telescope with double the aperture. Bigger telescopes with the latest optical and electronic innovations had price tags higher than their prewar antecedents, often higher than single institutions could afford. Cost-sharing partnerships became the norm. In 1959, the Astronomer Royal, Sir Richard Woolley, came to Ottawa with the intent of persuading the Government of Canada to participate in the creation of a large Commonwealth Telescope to be located in Australia. The failure of his mission was interpreted by senior Canadian government astronomers as a sign to confine their ambitions for new telescopes within our borders. An initial reaction by some of DAO's astronomers was to go it alone and build a large, single-purpose, reflector to feed a beam into a coudé spectrograph room containing the largest mosaic of gratings they could afford. That scheme, according to a private conversation I had with Graham Odgers in September 1966, sparked their search for a suitable mountain top in B.C.'s interior. To what extent Petrie fostered a go-alone scheme is unknown. Beals, however, would never have supported any scheme involving the expenditure of millions with such narrow objectives.

Beals recognized that DAO's natural partners were Canadian universities with astronomy departments. No mechanism existed for cost-sharing of major astronomical projects between provincially funded universities and a federally operated observatory. Thus it was up to DAO to secure federal funding for a major telescope. At the time, it alone possessed staff with the technical expertise to lead the telescope's design team. But if it were to be a national facility, what role would the universities have in its governance? That question was put to Beals and his Deputy Minister, W.E. Van Steenburgh, when they appeared in late March 1964 before the NRC's governing body in Ottawa to drum up support for the new telescope. Beals' report (Beals 1964c) to Petrie is worth quoting in part:

> *...Members of the NRC were inclined to insist that universities and other institutions (such as NRC!) should have a definite voice in policy and management and the Deputy Minister agreed with them.*
>
> *It would probably be a good thing therefore to give some thought to the formal organization of what, regardless of its value, will almost certainly be a new Institute for advanced research in Astronomical Sciences with a board of directors not unlike a miniature Research Council with representation across Canada. My own impression is that a good preliminary proposal along these lines could go a long way toward assuring the success of the project so I recommend it to your attention.*

Beals' letter produced consternation at DAO. Petrie's reaction against perceived managerial interference bore echoes of Plaskett's paranoia four decades earlier when DAO was being stripped of its status as an independent branch of the Dept. of the Interior (Petrie 1964a). There is no doubt that Petrie recognized the importance of a major new Canadian telescope to the healthy development of astronomy in Canadian universities (Petrie 1963). Yet, his views on engaging universities in the functioning of a national facility can best be described as paternalistic. Petrie and his senior staff set down their objections on paper for Beals' benefit to the proposed institute (Petrie 1964b). The tone of exclusivity in their remarks was precisely what the academics on NRC's governing board were warning against. Beals' response (Beals 1964d) clarified NRC's concern:

> *...What the National Research Council people were concerned about was [that] Universities and outside institutions should have a voice in scientific policy and particularly in the assignment of observing time. They were obviously concerned lest our Department, which was asking for a truly National telescope should claim exclusive jurisdiction over these important matters.*

Most revealing were DAO's estimates of how and when an astronomical institute would develop (Petrie 1964b): "...a Research Institute might well develop, in a decade or so, as the growth of university students supplies an increased number of qualified astronomers seeking research opportunities within Canada"; and "...It is foreseen that, ultimately, a separate institute will exist in the general location of the large telescope but this might well be after a decade or two of operation."

Petrie and his staff misjudged student demographics for the 1960s. A towering wave of post-war Baby Boomers was washing ashore on campuses across Canada. Large numbers, stimulated by the post-*Sputnik* space race, enrolled in astronomy courses. In their brief supporting a national observatory, the Dept. of Astronomy at UofT produced enrolment statistics of graduate students in their department since 1930 (MacRae 1963). The ramp-up that began in 1960 was so abrupt that, in the two academic years spanning 1962-1964, as many M.A. degrees in astronomy were awarded as in all the preceding 25 years. Toronto had the largest astronomy department in Canada but was by no means alone. At universities with established astronomy and physics programs, enrolments increased as abruptly. And new universities or existing small colleges across Canada established their first programs in astronomy in response to the perceived threat represented by *Sputnik* to world leadership in science. The need by Canadian universities for advanced facilities in astronomy was already urgent.

On becoming Director of the Observatories Branch (the renamed Dominion Observatories) in the summer of 1964, John Hodgson took a different tack around a national observatory's governance. He deviated from Beals' plan for the institute of astronomy as a vehicle for the universities to participate in the governance of the National Observatory. Following Cabinet approval of the QEII Telescope (in September 1964), he persuaded the Dept. of MTS to appoint a National Advisory Committee for Astronomy (NACA). A third of the 15-member NACA represented five universities across Canada, two members represented the NRC, and the remainder were drawn from different sections of the Observatories Branch of MTS. His ideas had been shaped by the success during the post-WWII era of NRC's Associate Committee on Geodesy and Geophysics in co-ordinating the impressive growth of earth sciences in Canada's government departments and universities. He was to find to his dismay that the earlier experience was not to be duplicated happily by astronomers.

The NACA's role was to advise the Minister of MTS on policy issues related to the creation of a National Astronomical Observatory on Mt. Kobau. Those issues would include the co-ordination of federal astronomical programs with those in Canadian universities and the methods by which astronomical research and teaching could be stimulated within Canadian universities. Establishment of the NACA was thus a broad-minded attempt on the federal side to provide an inclusive role for the universities in steering the new national facility. With responsibility for governance issues assigned to that committee, Hodgson proposed that the National Institute of Astronomy be the administrative centre of the National Astronomical Observatory on Mt. Kobau.

Whereas Beals and Petrie had skirted around relocating the meteor, positional astronomy, and solar programs from Ottawa to B.C., Hodgson included them without hesitation in his plans for the institute. The University of British Columbia (UBC) was favoured by Beals, Petrie, and Hodgson as the location for the institute and the Optical Shop that would figure the mirrors of the QEII Telescope. The President and Dean of Science of UBC were highly pleased at this prospect. The location of the institute in Vancouver was debated by the NACA at its first meeting in October 1965. The sole contrary opinion came from Prof. J.F. (Jack) Heard. Earlier that year, Heard had stepped down as head of UofT's Astronomy Dept. and Director of DDO, but he remained alert to his department's interests. Unhappy with the great boon proposed for UBC, he did not come right out and say so. Ever the moderate, Heard cautioned that "...government astronomers might find that association with university functions could become a distraction to their astronomical research." The minutes of the meeting are silent as to which university functions might be so insidious as to subvert an unwary civil servant's career.

Such niceties were not observed by Heard's successor, Prof. D.A. (Don) MacRae. He mounted a vicious attack on the institute and the Mt. Kobau site in the form of a five-page polemic (MacRae 1967). His anger was fuelled by the release of the lengthy feasibility study of the Mt. Kobau National Observatory by the consulting engineers, A.B. Sanderson & Co., in the spring of 1967. The section written by Hodgson on the National Astronomical Institute came in for heavy scorn. Just months earlier, at a meeting of the National Committee for Canada of the IAU, MacRae had praised DO staff for their efforts to modernize their programs. Now he dismissed DO's programs included in the institute's plans for astrometric, meteor, and solar astronomy as unimpressive. He sounded a clarion call for the National Institute to support space astronomy and radio astronomy. MacRae lauded the recent success of the Canadian Long Base-Line Experiment for being first in the world to measure the diameter of quasars. After urging more resources to keep that advantageous position, he ended with a swipe at the "parties" who proposed the institute for "their insufficient grasp of research aims or of educational problems in modern astronomy." His intended target may have been John Hodgson. But the ideas behind a National Institute of Astronomy, as shown above, originated with academics on the National Research Council and later modified by Beals and Petrie.

While in full rhetorical flight, however, MacRae tipped his hand to reveal what really embittered him. He remarked: "Canada's National Institute of Astrophysics is to be abruptly established in a community which has never demonstrated a particularly strong interest in astronomical research." For MacRae to imply that UBC was barren ground on which to implant a National Institute of Astronomy was an appalling insult to the scientific reputation of that institution. Like any polemicist, MacRae ignored facts that did not support his point of view. For example:

- UBC graduates Bert Petrie, Andy McKellar, and Anne Underhill became three of Canada's most distinguished astrophysicists without benefit of an undergraduate course in a department of astronomy.

- UBC graduate Arthur Covington abandoned doctoral studies at Berkeley in high-energy physics to contribute to Canada's wartime research on radar at NRC's laboratories in Ottawa. Using surplus microwave gear, in 1946, he was the first to show that microwave emission above sunspots far exceeded that from the quiet Sun's background, thus becoming Canada's first radio astronomer.

- The head of UBC's department of physics at the time was George M. Volkoff, once a graduate student in Berkeley of J. Robert Oppenheimer. Volkoff published his very first paper with Oppenheimer, on neutron stars. Based on his thesis, this seminal 1939 work calculated the collapse of a star during a supernova explosion into a neutron core. Far ahead of its time, this work on neutron stars remained an exotic scientific novelty until the discovery of pulsars, three decades later.

- Dean of Science, Dr. V. Okulitch, had appointed Dr. M.W. Ovenden from the University of Glasgow to teach UBC's first course in astronomy beginning in the fall term of 1966.

- Canada's world-beating experiment in long-baseline interferometry, lavishly praised by MacRae earlier in his submission, would not have happened at all without the mathematical analysis prepared by UBC professor of physics, H.P. (Herb) Gush. As early as 1964, Gush had sketched out how signals received independently from the same point-like quasar by two widely separated antennas could be correlated afterward with a computer to produce interferometric radio "fringes" (Gush 1988).

Even if MacRae had been aware of the above facts it would have made little difference to the vehemence of his attack. For he was out to block, by any means, any existential threat to his department's claim as Canada's premier school of astronomy. In so doing he crossed a line in the debate over the merits of the entire QEII Project. Heretofore, criticism from the Toronto astronomers had been based on factual evidence, such as demonstrations of the superiority of Chilean sites, or cautions against skewing the design of the telescope heavily in favour of spectroscopy, both put forth by Prof. Sidney van den Bergh. By disparaging persons and institutions, MacRae lowered the level of debate and invited retaliation. It came when the QEII Project in its entirety was later cancelled. Virulent articles against the Toronto astronomers appeared in the Vancouver and Victoria press. Had MacRae muted his comments on the institute and focused his criticism on the site chosen for the QEII Telescope, he would have stayed on solid ground. By overplaying his hand, he offended a great many people and damaged his credibility.

MacRae's unyielding insistence on a site for Canada's National Observatory in the Southern Hemisphere did eventually bear fruit, even as the QE II Telescope Project sounded its death rattle.

Death-bed conversion to a Chilean site

What had begun as a well-intentioned attempt at the most senior administrative levels in Ottawa and Victoria to create a National Observatory for both government and university astronomers dissolved amidst partisan bickering. The last chance to salvage the project came with the appointment by the Science Secretariat of the Privy Council Office of a Working Group in early June 1968. They were to evaluate the merits of the QE Telescope, the Carnegie Southern Observatory (CARSO), a proposal by the Carnegie Institution of Washington to build a 200-inch southern telescope in Chile (Gaizauskas, *JRASC, 105*, 104) proposal, and other astronomical projects of the Government (see Part I). The Working Group, chaired by cosmic-ray physicist D.C. Rose, included C.S. Beals, retired Dominion Astronomer, and Prof. W.H. Wehlau, Head of the Dept. of Astronomy at the University of Western Ontario, as its astronomical experts. An eminent astrophysicist, Prof. H.C. van de Hulst of the University of Leiden, The Netherlands, was hired as an outside consultant. Beals had played a major role before his retirement in laying out the organizational groundwork for the QEII Telescope, National Observatory, and National Institute of Astronomy in Western Canada. He hardly rated as a neutral party. He freely admitted afterward that he brought to the Working Group a solid conviction that Mt. Kobau was the correct choice for Canada's National Observatory. It therefore came as a shock, especially to the staff at DAO, to learn after the cancellation of the QEII Telescope that the Working Group's first recommendation had been to build the telescope on a suitable site in Chile, not on Mt. Kobau. What made Beals change his mind?

It came about during the Working Group's hearing in Toronto in July 1968, a town-hall meeting including graduate students. Presentations from university staff were followed by a free-wheeling debate during which a pro-Chilean sentiment was clearly dominant. In putting the case for continuing with the QEII Telescope on Mt. Kobau before the large number of graduate students, Beals challenged them with a stark choice: the QEII Telescope on Mt. Kobau or no telescope at all, which would they prefer? He was completely taken aback by their swift and unanimous response: no telescope. This left an indelible impression on him, as he explained in the following paragraphs of a letter he sent a few weeks later to Prime Minister Trudeau (Beals 1968a):

> *... My own feelings in this matter ... have, until recently been very strongly in favour of continuing with the original plans for an observatory in Canada. During the last two months however after a series of detailed studies which have included interviews with astronomers in all parts of Canada, I have, very reluctantly and with many misgivings, been forced to the conclusion that the interests of Canadian astronomy over the next 50 to 100 years would be best served by establishing a Canadian observatory in a suitable site in Northern Chile.*
>
> *This conclusion has been based on two main factors. The first, already mentioned, is the superiority of the Chilean observing conditions which indicate that a period of one and a half months in Chile would accumulate as many observations as an entire year at a Canadian site. The second factor, probably more important, is the attitude of approximately thirty young Canadian astronomers in the age group from mid twenties to early thirties. These young men, some highly gifted, the ones who would be using the telescope between the late 1970's* [sic] *and the year 2000, have spoken with one voice in their conviction that they would be deprived or even betrayed in their scientific careers if they were not granted the opportunity to work on the frontiers of astronomy, at what is now considered to be the best site available on the surface of the earth*

Beals had financed his own advanced education by teaching school. Important missions during his lifetime were to encourage young people to pursue scientific careers and to advance the ablest whenever possible. The paragraphs cited above express his genuine impulse to achieve these aims, even at the cost of abandoning deeply entrenched personal convictions.

Beals was also an ardent Canadian nationalist. This accounts for his determined support of Mt. Kobau as the site for a National Observatory, despite steadily mounting evidence against its suitability. That nationalism played an important role in his complex dealings over the CARSO offer.

What became of the CARSO offer to Canada?

The Working Group's recommendations were: (1) to place the QEII Telescope in Chile or (2) to join in the CARSO project *and* to complete the QEII Telescope on Mt. Kobau. Either alternative involved additional spending beyond existing estimates for developing Mt. Kobau. The second one however more than doubled the cost. There had been ample warning during 1968 that cost-cutting had become the order of the day in Ottawa following Canada's lavish celebrations of its Centenary during the previous year. It made no sense to raise so costly an alternative. Beals' explanation to Wright (cited in Part I) that the second alternative was meant as a *quid pro quo* to keep development of Mt. Kobau alive rang hollow to my ear. Something else had to be at play for him to back a clearly losing proposition.

The scope of the CARSO offer was breathtaking: with half the financing, Canadian astronomers would get half the observing time on a 200-inch reflector, a 72/48-inch wide-field Schmidt telescope, and a 60-inch reflector, relocated from existing telescopes on Mt. Palomar to a mountain in Chile. In today's money, the Canadian share approached $60 million CAD, a bargain in the view of the proposal's proponents. Most Canadian optical astronomers, including those at DAO, were enthused by this proposal. Its stiffest opponent was none other than C.S. Beals. Here's how he expressed his opposition to Prime Minister Trudeau (Beals 1968a):

> *... While this proposal has many advantages and would certainly represent the path of least resistance, I believe it would in the long run prove detrimental to Canadian astronomy. It is hard to see how any foreign group could join such a massive and entrenched institution as Mount Wilson-Palomar with the associated California Institute of Technology without suffering absorption and loss of identity. There would be an almost inevitable tendency for the Canadian members to adopt the psychology of satellites and followers rather than leaders. In such an integrated institution there would be little incentive for scientists to stay on the Canadian side and the result would almost certainly be the loss of our best young men to United States institutions.*
>
> *During the middle years of the Dominion Astrophysical Observatory in Victoria, B.C., eminent members of the staff such as R. M. Petrie and A. McKellar had ample opportunities to take up positions in the United States but they remained in Canada because they had a strong Canadian base which engaged their loyalty and offered them opportunities for advancement and leadership. ...*

In a letter Beals wrote on the same day to Dr. J.M. Harrison, Energy, Mines, and Resources (EMR) Assistant Deputy Minister (ADM), he began with the same words to state his concern about the CARSO offer, but ended more bluntly (Beals 1968b):

> *... In fact I would regard it as an almost perfect set-up for filtering off our best people for the benefit of U. S. astronomy. While I do not suspect any clearly thought out sinister intentions on the part of the Americans (they just want our money), CARSO looks to me like a takeover bid for Canadian astronomy with the funds moving in the reverse of the usual direction. In the business world a takeover is usually rather expensive for the taker. In this case he would be getting from 11 to 15 million plus a lot of free labour!*

The clearest explanation of Beals' manoeuvring comes in a letter he wrote to his long-time personal friend, Arthur Crooker of the Physics Department at UBC (Beals 1969). He expressed himself with greater candour than he did even with close associates like Ken Wright when he denounced the astronomers at the UofT for their aggressive attack on the QEII Telescope project in 1967:

> *... The damage done at that time might conceivably have been remedied if it had not been for the CARSO offer which presented the Toronto astronomers with a vision of reflected glory as camp-followers of Mt. Wilson-Palomar, which they found irresistible. As a consequence they redoubled their campaign of lobbying and were able to capture several key figures in the Government which had been hostile to the Mt. Kobau project from the start.*

Although Beals had referred several times to shadowy "key figures in Government supporting CARSO" in correspondence with Ken Wright, this is the only indication I have found that influential unknown persons had always opposed the Mt. Kobau project. A later paragraph in the same letter at last lays bare his motives:

> *... When the crunch came and it became clear that some kind of compromise would have to be reached* if the game were not to be lost by default to the very powerful group in favour of CARSO alone, *I took the stand that I would not consider any solution that did not involve the use of the 150 in. mirror, the optical shop at U.B.C. and the use of the expertise of [the optical design team] at Victoria. The other side took the stand that they would not consider any solution that did not involve a southern hemisphere site. Hence the report and the denouement of which you are of course aware* (emphasis added).

This is how Beals devised a poison-pill strategy to prevent a hostile takeover of his vision for Canada's National Observatory, although he himself would not have expressed it in those terms.

Senior bureaucrats in Ottawa had additional reasons to be concerned about the CARSO offer. The late 1960s were years of political turmoil in Chile, culminating with the election of a Marxist government in 1970. A bloody coup followed three years later with the installation of a military dictatorship. American and European astronomical stations were unaffected during these events. Nevertheless, Ottawa's mandarins were wary about supporting an expensive project in a politically unstable environment. Even without that uncertainty, spending the bulk of Canada's contribution abroad on a joint international project was politically risky. In order to cut costs, the most technically advanced work would probably have been done by those manufacturers in the U.S.A. who had built the existing telescopes. Infrastructure on site would most likely have been built by Chilean contractors. Use of the Canadian optical facilities intended for grinding and polishing the mirrors for the QEII Telescope was discussed without arriving at a firm commitment. Too few spin-offs left for Canadian manufacturers to pick up would be viewed as a political liability. Then there was the prickly question: just how far should support for Canadian astronomers go?

At the Toronto hearing of Rose's Working Group in July 1968, a crippling blow was delivered to the Mt. Kobau project. Prof. MacRae had Douglas Hube, a postdoctoral fellow, analyze the number of observing hours needed on the telescope at the David Dunlap Observatory to provide data sufficient to complete his and three other doctoral theses at the UofT. The amounts of clear sky at Richmond Hill and Mt. Kobau were similar. Hube's conclusion of an average of 200 hr/yr meant only 2 - 3 Ph.D. candidates a year would consume the entire time allotment for the universities if the QEII Telescope were placed on Mt. Kobau. Given the rapid growth of enrolment of graduate students in astronomy across Canada, MacRae pronounced the observing time on Mt. Kobau to be totally inadequate for a National Observatory.

Hube's data were eye-openers for ADM Harrison. He viewed that data in a financial framework as well as a temporal one. His rough calculations, based on the proposed Canadian share in the CARSO project, showed that federal subsidies for astronomical doctorates would be provided at triple the rate for geological doctorates. Later, when Harrison had more reliable figures for Canada's share of costs for CARSO, he found (Harrison 1969):

> *…that the operating costs per [Canadian] astronomer would be $200,000. A recent study in the U. S. concluded that the cost per graduate student should not exceed $50,000 in any science… On this basis then, there would seem to be good support for [Carnegie Institute of Washington's] apparent reluctance to make such a facility available to the graduate student.*

Harrison's finding implied that, if Canadian astronomers were to insist on the CARSO offer as their top choice, they would have to reconsider very carefully who among them were qualified to use those costly facilities.

The CARSO offer did not lapse with the cancellation of the QEII Telescope Project. It had been the first choice among the alternatives considered by Prof. Van de Hulst, the Working Group's Consultant. His opinion is interesting in the light of what happened in keeping the CARSO offer alive. Less inclined to fear American hegemony of the project, van de Hulst felt that Canadians were in an excellent position to bargain for significant manufacturing to be done in Canada on the three proposed CARSO telescopes (van de Hulst 1968).

Harrison's musings on the merits of astronomy's needs relative to other sciences raised basic questions that were referred in May 1969 by EMR to the Science Council of Canada. There they were assigned to its committee on Physics and Chemistry chaired by Prof. H.E. Petch, University of Waterloo. That committee submitted its report to the Government on 1969 September 23. The Petch Committee concurred with Rose's Working Group that NRC become the focus for Canada's federal interest in astronomy. The Petch Report came out solidly in favour of the CARSO offer with the proviso that a list of conditions be met. But that recommendation arrived at a time when astronomers were distracted. In addition to ongoing reorganization of astronomy from EMR to NRC, a different advisory structure for astronomy was being adopted to conform to NRC's rules for Associate Committees. There was also a tussle over possession of the assets of the QEII Project. So the CARSO offer, now NRC's responsibility, faded into the background behind more pressing issues.

A consortium of five western universities under the name WESTAR acquired the quartz mirror blank and other assets from the QEII Project. They proposed to complete an observatory on Mt. Kobau with funds raised from the provinces and the private sector. The transfer was delayed until mid-June 1970 due to competition for those same assets by commercial interests and to legal complications. As for the other Canadian astronomers, the bitter struggle over the QEII Telescope had altered their mindset. No longer would they accept restrictions against extraterritorial sites. They began agitating for a large all-Canadian telescope in Chile. Thus, by 1971, when the first meetings were being held of NRC's new Associate Committee on Astronomy (ACA) and of CASCA (Canadian Astronomical Society/Société Canadienne d'Astronomie), no less than four large telescope projects were mooted: WESTAR's proposal for Mt. Kobau; the CARSO offer; an all-Canadian 4-m telescope for a Chilean site; and a joint Canada-France venture involving a 3.6-m telescope on Mauna Kea, Hawaii.

The final effort to revive the CARSO offer, to my recollection, was made by MacRae at the May 1972 meeting of NRC's ACA at the U. de Montréal. He urged consideration of other possible alternatives to an all-Canadian 4-m telescope, principally the CARSO offer, at a Southern Hemispheric site. In his opinion, the site chosen by French astronomers was less desirable because it lay north of the equator. By this time, however, discussions with the French astronomers had reached the point where a detailed, carefully costed proposal could be presented to the Government of Canada. A bandwagon was assembling for a joint Canada-France venture; MacRae eventually realized he had to ditch CARSO and jump aboard or be left behind.

The original CARSO proposal was never realized. The Carnegie Institution of Washington instead joined with several American universities to install entirely different instruments at the Las Campanas Observatory, Chile, most notably the twin 6.5-m Magellan telescopes. The great success of the Canada-France-Hawaii Telescope broke Canadian inhibitions

Figure 3 — Marking a new beginning, Mauna Kea, mid-January 1974. The distant mound at centre left has been flattened in preparation for laying the foundation for the Canada-France-Hawaii Telescope. The cement slab shown in the inset (lower right) was centrally located on the flattened mound. The ring bolt was presumably used during the process of laying out the circular base for the dome. The first telescope building on Mauna Kea (centre right) has long since been moved. Its location has been taken over by Gemini North.

against spending on major astronomical projects with international collaborators. Canadian astronomers now enjoy access to the Gemini Telescopes in Chile and Hawaii and to the Large Millimetre/sub-millimetre Array (ALMA) in Chile's Atacama Desert. Even more ambitious proposals are being planned.

It's taken a long drive on a bumpy road to get from the surveyors' transits installed next to Ottawa's Parliament Hill to world-class facilities that span the entire sky and keep Canada's astronomers at the forefront of research (Figure 3).

Acknowledgments

I have relied heavily, though not exclusively, on John Hodgson's two-volume history of the Dominion Observatories for the founding of the DO and its development until the post-WWII years. Electronic copies are now freely available from the Government of Canada Web site at:

http://geogratis.gc.ca/api/en/nrcan-rncan/ess-sst/-/%28urn:atom:author%29Hodgson%2C%20J%20H

My personal experience differed from his during the dispute over the development of Mt. Kobau. Thus I bring a different perspective to the story.

During his tenure as Dominion Astronomer, Beals' effectiveness for preserving and advancing the astronomical programs at DO and DAO, and for initiating radio astronomy at DRAO, was widely appreciated and admired. Because he retired just before the QEII Telescope Project was approved, his important role behind the scenes is less well recognized. His vehement opposition to the CARSO proposal is revealed here for the first time. Because I use many quotations from his letters, I provide their archival references to confirm their authenticity.

I thank Paul Herzberg for providing copies of his father's first exchange of letters with Beals. I am indebted for comments on the manuscript by Ian Halliday, Ron Niblett, and Gordon Walker, long-time colleagues who experienced, in different ways, the Golden Years of expansion at the Dominion Observatories after WWII and the turbulent aftermath of the late 1960s. I am especially indebted to my wife Barbara for making astute suggestions to improve clarity throughout. ✶

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So Long, Neil Armstrong

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On August 25, a true space hero, Neil Armstrong, died at the age of 82. He had just celebrated his birthday less than three weeks earlier (August 5), and it was a surprise for most of the world that Armstrong was seriously ill. He died from complications after recent heart bypass surgery. I guess he was "flying under the radar"?

In honour of a great man, I have put together a philatelic tribute using stamps from around the world to show how he and his fellow astronauts (Buzz Aldrin & Michael Collins) were recognized in the past. Take a moment to study the First Day Cover from the U.S.A. of their historic lunar landing on 1969 July 20. Note the use of the Lunar Excursion Module (LEM) "Eagle" in the cachet—the spaceship that Armstrong piloted to the lunar surface. The cancellation is a double commemoration of both the actual landing date and the first day of issue for the 10-cent airmail "First Man on the Moon" stamp (1969 September 9). I included an overlay on this cover of an Armstrong stamp from a series issued by Qatar on 1969 December 6 that shows him in his flight suit. Beside this is an airmail stamp from Ras Al Khaima showing Armstrong in a suit with the LEM descending to the lunar surface in the background.

The other stamps show the Dominica stamp from 1970 February 2 depicting Armstrong stepping off the LEM onto the lunar surface. The Apollo 11 crew is shown in the margin of the stamp sheet. Below this is the famous Apollo crew suspended in front of a lunar image issued by Ajman.

What a mission, what a crew, what a man. "One small step for a man, one giant leap for mankind."
God speed Neil Armstrong! ✶

A Half-Century of Astronomy Outreach: Reflections, and Lessons Learned

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Figure 1 — The author, then and now. Left: receiving the RASC Gold Medal from Ruth Northcott in 1962. Right: with the CASCA Qilak Award in 2012.

Abstract

I reflect on my half-century of experience in astronomy outreach in Canada and beyond, on the organizations in which I have served, and on the factors that have contributed to success in outreach. One factor is partnership that builds on the strengths of two or more individuals or organizations, such as the pro-am partnership in Canada during International Year of Astronomy. Challenges remain: the lack of a science "culture" in Canada; the lack of funding for outreach; the low priority of outreach in many parts of the professional community; and the difficulties in reaching new and diverse audiences—especially underserved ones. For success, there is a strong need for astronomy outreachers to seek high-impact, high-leverage strategies, to make themselves aware of "best practices" in outreach, to make training part of their outreach activities, and to strive constantly for improvement by evaluating and/or reflecting on the results. I attribute my own modest successes to my mentors and role models, to the help of colleagues, students, and partner organizations and their members—not the least being the RASC—and to the sheer enjoyment of communicating astronomy to diverse audiences. This article is based on a presentation given to the Canadian Astronomical Society on 2012 June 6, on the occasion of my receiving the inaugural Qilak Award, for my work in communicating astronomy to the public.

Introduction

In June 2012, I was honoured to receive the inaugural Qilak Award from the Canadian Astronomical Society (CASCA: www.casca.ca) at their meeting in Calgary, for my work in communicating astronomy to the public (Figure 1). That was a month of reflection for me: it was the 50th anniversary of my graduation (and award of the RASC Gold Medal: Figure 1), as well as my 50th wedding anniversary. I've been an RASC member for over 50 years. For my Qilak Award lecture, I therefore chose to reflect on my half-century of astronomy outreach, and my observations and lessons learned. This article is based on that lecture. The slides of my award presentation are at: www.astro.utoronto.ca/~percy/qilak.pdf and on my outreach Web page: www.astro.utoronto.ca/~percy/EPO index.htm

Why does outreach matter? It's important to astronomy and astronomers to attract the next generation of astronomers and to promote the excellent work that Canada's professional and amateur astronomers are doing. We professionals need to be accountable; our salaries and research are publicly funded. We have an obligation to explain to the taxpayers what we are doing, and why it's interesting and relevant. I believe that we also have an obligation to inform and inspire the community in general, including teachers and their students. There is a special need to reach people from communities that are under-represented in science and technology, and develop their interest in and comfort with those subjects. And astronomy outreach is satisfying—as knows anyone who has shown the rings of Saturn, or explained about black holes.

In the Beginning

I landed on Canadian shores in 1946 and spent my first few years in Toronto's Cabbagetown slum; I was not born with a silver spoon in my mouth! I then moved to the suburb of Downsview a.k.a. "the sticks." I entered high school as a shy, nerdy kid, two years younger than my classmates. I somehow graduated as president of the student council, lead singer in the school musical, as well as a scholarship student. How did I accomplish this transformation? Encouragement at home, of course, but also *an excellent public school, teachers, and mentors.* Those of us involved in education should never forget the potential that we have to positively affect students' lives.

I was an undergraduate and then a graduate student in the Department of Astronomy, University of Toronto. There, I was influenced by role models who valued teaching and outreach as well as research: Don Fernie, Jack Heard, Helen Hogg, Don MacRae, and Ruth Northcott—all of whom also played significant roles in the RASC. If departments openly and actively value teaching and outreach, it is more likely that their students—especially their graduate students—will do so as well. As a graduate student, I had the opportunity to give school and public programs at the David Dunlap Observatory (DDO). Graduate students are still a cornerstone of my department's outreach activities, as they should be everywhere.

Like many graduates in my time, I took a detour into teacher's college and high-school teaching; I became "Mr. Percy." I've continued to support school science ever since, even after returning to professional astronomy. More to the point: I received a year of teacher training—which raises one of the great mysteries of academic life: why don't *all* university instructors receive initial or continuing training in teaching? After all, teaching is half their job!

Embarking on a Career

I was fortunate to get a faculty position at the University of Toronto's new Erindale Campus (now the University of Toronto Mississauga: UTM: www.utm.utoronto.ca). As a founding faculty member, I got to help develop campus-wide outreach programs. In 1969, our geophysicists were responsible for studying the magnetic properties of lunar rocks returned by *Apollo 11*. Thousands of people lined up to see the Moon rocks. Because we didn't have alumni, we created an "instant alumni" by forming partnerships with the community to organize public lectures, host the Peel Science Fair, and create enrichment programs for local schoolchildren. Most of all, I worked with faculty from many other disciplines, and these interdisciplinary connections have enriched my life and my career ever since.

My first "bosses" were important role models. Principal J. Tuzo Wilson was an eminent geophysicist and science communicator; on "retirement," he became director of the Ontario Science Centre. Dean Peter Robinson was a chemist, educator, and textbook author. Principals, deans, and department chairs can set a strong example by encouraging and supporting outreach, especially if they do it themselves.

Impacting the School System

The most powerful way to create public understanding and appreciation of astronomy is to ensure that it is present, and well taught, in the school curriculum, and I have been doing this for over 40 years. Initially, I simply responded to the curriculum but, starting in the 1980s, I found out how the Ministry of Education developed the curriculum, and got involved. By the 1990s, we made sure that astronomy was firmly rooted in the elementary and secondary school curriculum. We were aware of an impending curriculum revision, and we were proactive in offering our services to the Ministry. Since then, I have been a reviewer for the astronomy sections of the Ontario science curriculum.

That doesn't ensure that astronomy will be taught, or well taught. Textbooks help both students and teachers, and I have spent much time reviewing and even co-writing (Andrews *et al*. 1988) school science textbooks.

Teachers need additional support, through resources and professional development, to enable them to cover the curriculum—especially as few of them have any background in astronomy or astronomy teaching. My most enjoyable and effective partner in this respect has been the Science Teachers Association of Ontario (STAO: www.stao.org). I have contributed to their journal *Crucible* and presented at their 3-day conferences for 40 years, and was Honorary President during their 1990 centennial year; that was also the RASC's centennial year. At their 2009 (International Year of Astronomy: IYA2009) conference, there were two-dozen astronomy/space sessions. One of my personal IYA2009 projects was to partner with STAO to produce on-line resources for the grade 6 and 9 astronomy curriculum, with support from the National Research Council, the Dunlap Institute, and the Canadian Office of the Thirty-Metre Telescope Project (stao.ca/res2/astronomy-2.php).

If you want to have an impact on school astronomy, get to know the science people in your ministry of education, the publishers of textbooks and other resources, and the local science teacher's association. School boards can also be an effective partner, though they are occasionally "a tough nut to crack." Maintain an active email list of science and math teachers who are interested, connected, or influential.

Other Organizations

If I join a scientific or educational organization, I tend to get involved, rather than just be a dues-paying member. These organizations have been an important and enjoyable part of my career and life, both because of what they have accomplished, and because they have brought me such a large and diverse set of colleagues and friends.

The RASC (www.rasc.ca) is a good example. I joined in 1961, was a member of National Council from 1965 to 1984, and National President in 1978-80. I was Editor of the *Observer's Handbook* from 1970 to 1980 (the first not to die in office!) and a contributor for many more years. I was President of the Toronto Centre in 1970-71, and served several terms as Vice-President (Program), arm-twisting speakers from my various networks of colleagues; also promoting the Centre's public-education programs. I still support the Toronto Centre's public outreach program at the DDO. In 2003, I had the pleasure of successfully co-nominating the RASC for the national Michael Smith Award for excellence in science outreach, and attending the award ceremony in Ottawa. The RASC makes outstanding contributions to the public awareness, understanding, and appreciation of astronomy, and was an essential partner in the success of IYA2009. I urge my professional colleagues to support them.

My association with the Royal Canadian Institute (RCI: www.royalcanadianinstitute.org) dates from 1963, when I was an instructor for their summer enrichment program for high school students—a program that later morphed into the famous Shad Valley Program. I again became active in the 1980s, serving as President in 1985-86. The RCI is Canada's oldest continuously functioning scientific society. Nowadays, it is best known for its free Sunday afternoon science lectures for the public. They are videoed and archived and available to viewers anywhere there is an Internet connection. I still provide the RCI with names of potential astronomy speakers; they do the rest. It's an easy way to organize public astronomy lectures: find a group that organizes them and provide them with astronomy speakers. Astronomy always draws a crowd.

The Astronomical Society of the Pacific (ASP: www.astrosociety.org) is a world leader in creating and disseminating good astronomy educational resources (and lots of other things). I was active from 1993 to 2001, served as President in 1997-99, and am still on its Advisory Board. If you are looking for well-tested astronomy resources and activities for students or families, don't re-invent the wheel; look on the ASP Web site.

The American Astronomical Society (AAS: www.aas.org) is the organization of professional astronomers in the U.S.A. I served two terms on their Education Board. During the second, we worked to establish *Astronomy Education Review* (AER: aer.aip.org), a free on-line journal that is a leader in publishing refereed and non-refereed articles on astronomy education and outreach. It's well worth reading. Another notable project was motivated by the challenges to the teaching of evolution in US schools: we realized that there was no resource that explained to teachers how astronomers know that the Universe is very old, and changing. Four of us created a resource that is available on the ASP Web site.

I also served the AAS as Harlow Shapley Visiting Lecturer from 1977 to 2005. This program sends experienced astronomers to smaller institutions, without astronomy facilities, to give presentations to schools and the public, and to meet with college faculty, students, and administrators. We used this program as a model for the CASCA-Westar Lectureship. I inaugurated the CWL in 2002 in North Bay, Ontario, attracting a total of 700 people to school and public presentations. Sadly, the CWL program is now "dormant," and I have urged CASCA to find some way to revive it.

The International Astronomical Union (IAU: www.iau.org) is the world organization of professional astronomers. Its mandate is "to promote and safeguard astronomy...and develop it through international cooperation." It is administratively lean, and its funding is provided by national bodies (the National Research Council, in Canada's case), such that there are no individual membership fees. Any qualified astronomer can be a member. I've served as President of the IAU Commission (interest group) on Variable Stars and, for three decades, was active in the Commission on Astronomy Education and Development, serving as President in 1994-97. I find that, nowadays, many graduate students and other young astronomers are unaware of the value and importance of international astronomy development and the ethical arguments for its promotion. It's obviously not practical for developing countries to invest billions in "big astronomy." But astronomy is part of their culture. It should be part of their education system. It can attract students to careers in science and technology. And eventually, a few astronomers can engage in research, either through international collaboration, or through "small science" projects such as CCD observation of variable stars.

American Association of Variable Star Observers

I discuss the AAVSO (www.aavso.org) separately because, since 1985, it has had a major impact on my research on variable stars and stellar evolution, as well as my education and outreach activities. I have known about the AAVSO since the 1960s, because of the AAVSO Director's *Variable Star Notes* in the *JRASC*. The AAVSO was founded in 1911. I have recently been immersed in its 2011 centennial activities; as editor of the *Journal of the AAVSO*, I have edited its 600-page centennial issue. The AAVSO is the most significant organization through which skilled amateur astronomers can contribute to astronomical research. It's the epitome of "citizen science."

The AAVSO plays a particularly important role in the student research that I supervise (Percy 2008). It's a win-win-win situation. By analyzing archival AAVSO data on variable stars, my students develop and integrate skills in science, math, and computing. Useful science gets done. And, because we present the results at AAVSO meetings, and usually publish the results in the *JAAVSO*, AAVSO observers get motivating feedback on how their work contributes to science and education.

In 1987, I was a founding mentor for the University of Toronto Mentorship Program, which enables outstanding senior-high-school students to work on research projects at the university. These students are comparable, in ability, with undergraduates, and dozens of them have completed and published variable-star projects with me, mostly using AAVSO data. They are also an untapped resource for astronomy outreach, in their schools and to the public. In 2012, there were 200 participants in this program, in departments across the university. Sadly, my university has just eliminated this program, on the grounds that it is overly time-consuming for faculty (though not in my case!), and not effective as a recruitment tool.

Around 1990, I and my late colleague and friend, AAVSO Director Janet Mattei, independently realized that the observation and analysis of variable stars could be an excellent tool for science and math education. In my case, I had visited many small colleges where astronomy instructors were looking for simple lab and observing activities that would engage students and develop their research skills. With a $300K grant from the U.S. National Science Foundation (NSF), we developed *Hands-On Astrophysics*, a set of resources that could develop and integrate students' science skills by doing real science, with real data. HOA has since morphed into the more-powerful on-line *Variable Star Astronomy* (www.aavso.org/vsa). Its impact is high; it is now part of the preparation program for the U.S. Physics Olympiad, so thousands of talented high-school students are motivated to explore and master this material. The sad thing is that, in Canada, there is little or no funding for science education projects like HOA—nothing comparable with what NSF and NASA have provided in the U.S.

Institutions

Over the past half-century, I have been associated with three local world-class astronomy education facilities whose stories carry important lessons. I began my outreach experience at the David Dunlap Observatory (DDO: www.theddo.ca), then part of the University of Toronto. When it was opened in 1935, it housed the second-largest telescope in the world. (The third-largest was located at the Dominion Astrophysical Observatory, in Victoria.) For 50 years, it enjoyed great success in research, student training, and public education. Then, its use declined. Eventually, the DDO lands were sold to a developer and the proceeds used to endow a Dunlap Institute (DI), based on the university campus. The DI carries the Dunlap name and bequest into the 21st century. Its emphasis is on developing state-of-the-art instrumentation and carrying out challenging observations. Outreach is also a key part of its mandate, and its activities have included organizing the viewing of the 2012 transit of Venus by 6000 people in Varsity Stadium (Reid 2012). Meanwhile, the telescope and buildings at DDO have been preserved and proposed as heritage sites. The RASC Toronto Centre offers a public education program each Saturday evening in the summer, and professional astronomers, such as myself, support it by giving non-technical talks.

Prior to the 1960s, the DDO was the major centre for outreach in astronomy. In 1968, the McLaughlin Planetarium opened as part of the Royal Ontario Museum (ROM). From then until 1995, it was one of the world's leading planetaria and Ontario's most important astronomy education resource, attracting about 300,000 people each year—and that was before astronomy became compulsory in the school curriculum. The planetarium closed in 1995 in response to uncertainty about the "common sense revolution": the status and funding of the ROM and other provincial cultural facilities was in doubt. The ROM closed the planetarium in the belief that the site could be used for more lucrative purposes. It could not. It now serves as a storage area. The site has recently been sold to the university, probably for the expansion of its Faculty of Law. The ROM still offers planetarium shows using portable planetariums and has an excellent meteorite collection and exhibit.

The Ontario Science Centre (OSC: www.ontariosciencecentre.ca) is one of the world's leading science centres, and one of Canada's most popular cultural attractions (though it's sometimes difficult to convince people that science is "cultural"!). It's also Ontario's centre for astronomy education and outreach, with its exhibits, programs, workshops, and planetarium programs for students and teachers. I suspect that, if the McLaughlin Planetarium had been associated with the OSC, rather than with a museum like the ROM, it would not have closed. The OSC is also host to the RASC Toronto Centre, and they partner regularly in organizing star parties and other events. From 1992 to 1998, I was vice-chair of the OSC Board of Trustees. We were busy building Ontario's first OMNIMAX theatre and other projects, when the "common sense revolution" hit. But we persevered and succeeded. The OSC subsequently, through its *Agents of Change* project, added several innovative, interactive galleries, targeting new audiences—not just children. Unlike the ROM and the Art Gallery of Ontario, it has spent its capital funds on exciting new programs and exhibits, not fancy architecture.

Reaching Audiences, Old and New

International Year of Astronomy (IYA2009) was a resounding success in Canada. There were more than 3,600 events, reaching almost two million people directly, and many more through posters and the media (Hesser *et al.* 2010). I attribute this success to four factors: (i) the leadership by Jim Hesser; (ii) the effective partnership between CASCA, Fédération des astronomes amateurs du Québec (FAAQ: faaq.org), and the RASC; (iii) the work of hundreds of volunteers from these three organizations; and (iv) support from the Trottier Family Foundation. I definitely think that we outdid IYPhysics 2005 and IYChemistry 2011! IYA2009 was initiated by the IAU, and ultimately celebrated in 148 countries—twice the number of countries that belong to the IAU and/or carry out astronomical research.

In my experience, however, the majority of people who attend astronomy events are "the usual suspects," especially greying white males like myself. Following on the success of IYA2009, we embarked on *Beyond IYA*—outreach focused on reaching new audiences, especially youth from underserved communities, such as Aboriginal, rural/remote, and inner-city. We were supported by a grant from NSERC's *PromoScience* program, which enabled us to hire a part-time educator, Julie Bolduc-Duval. We were guided by the success in partnering with

Aboriginal communities during IYA, thanks to the work of Jim Hesser, Andy Woodsworth, Cheryl Bartlett, and her colleagues in the Mi'kmaq College Institute at Cape Breton University. BIYA has concentrated on providing "virtual" training and support to parks staff and other educators, across Canada, in English and French; groups and individuals such as myself have explored other avenues.

Astronomers—especially the older generation like myself—have been slow to harness the power of social media in reaching new audiences. That's one more argument for partnering with students in planning and doing outreach! We also seem to be enamoured with 60-minute lectures, in both our outreach and our university teaching. Attention spans, except perhaps for the die-hards, are actually only a few minutes. This is why engaging three-minute video clips (such as TED: www.ted.com) are becoming so popular. We also need to remember that not everyone relates to the more technical topics in astronomy; its interdisciplinary and cultural aspects can connect us with new audiences. And there's the need to reach those for whom English and French are not a first language. York University has offered public astronomy lectures in other widely spoken voices, and the University of Toronto translated its transit-of-Venus guides into a dozen other languages.

Reaching underserved communities is challenging. One needs to work, patiently and respectfully, with the communities themselves, and with the organizations that serve them. In Toronto, we had some success working with such groups. We also used astronomy's cultural connections to organize a one-day festival of multicultural astronomy—*One World, One Sky*—at the Ontario Science Centre, in partnership with the RASC Toronto Centre.

My most prolific IYA2009 partnership was with the Toronto Public Library, the world's busiest public library system. Their 100 branches are rooted in communities across the city, including underserved areas. Since 2009, I have made over 50 presentations in libraries in Toronto, to audiences of all ages. For the children's presentations, I recruited the help of Robby Costa, who had just graduated from my undergraduate science education program. For BIYA, I extended this program to rural libraries across Ontario. Libraries provide a venue, facilities, publicity, and an audience; just provide an astronomer!

My favourite IYA project brought astronomy to new audiences of tens of thousands of people, around the world: music-lovers. As a long-time follower and supporter of Toronto's Tafelmusik Baroque Orchestra, and knowing of their creative multimedia programs, I suggested that they develop an astronomy-themed program celebrating Galileo and IYA. The result was *The Galileo Project: Music of the Spheres* (www.tafelmusik.org/galileo/index.htm). This program has received rave reviews, has toured Canada, the US, Mexico, China, Malaysia, Australia, and New Zealand. An excellent DVD is also now available. We can definitely reach new audiences through astronomy's interdisciplinary connections and by linking our astronomical interests to our non-astronomical ones—in this case, music.

Another of my IYA partnerships was with Heritage Toronto (www.heritagetoronto.org). I have enjoyed and supported their heritage walks program for many years. So, for IYA, I developed a two-hour walking tour of astronomical sites, dating from 1838, in and around the university campus. This walk has attracted over a hundred people each year. It reminds us that there are many people interested in history and heritage. It also reminds us of the importance of our heritage and the need to preserve it. During IYA, we also established a partnership with the University of Toronto Institute for the History and Philosophy of Science and Technology (IHPST). This led to a very exciting and successful collaborative exhibit and symposium, leading up to the June 2012 transit of Venus. It also led to a project to catalogue and conserve the University's historic astronomical instruments, a project driven by IHPST graduate students (www.utsic.org).

Building a "Science Culture"

The heart of IYA2009 in Canada was "the Galileo moment"—a personal response to an astronomical observation, idea, or other experience. Canadians need to discover that science is interesting as well as important. Canadians excel as much in science as they do in hockey. Canada lacks a national organization to promote science, and science culture, though various such organizations have come and gone over the decades. We established the Science and Technology Awareness Network (STAN) in 2003. It now has over 380 member organizations, holds an annual networking conference, and maintains a Web site (www.scienceandtechnologynetwork.ca) with resources for outreach organizations. The driving force behind STAN was Dr. Bonnie Schmidt, President of *Let's Talk Science*—another important force in science education in Canada.

Science Rendezvous (www.sciencerendezvous.ca) is a one-day science festival, patterned on an event in Berlin that draws half a million people to science facilities annually. SR began in Canada at the University of Toronto. I was on the founding committee; the driving force was Professor Dwayne Miller. It is now a national event. This year, there were over 300 events, with over 2500 volunteers, reaching audiences totalling tens of thousands. The RASC Toronto Centre was an enthusiastic participant in 2012. SR brings the public to science settings, to chat with scientists, and experience science hands-on. A similar event began in New York at the same time with a similar-sized audience but a much larger budget!

Teaching University

The Qilak Award is specifically *not* awarded for contributions to formal education, but I can't resist making some comments about teaching university, and introducing two other organizations in which I am still active. In 2007, I was honoured to receive an inaugural University of Toronto President's Teaching Award, and to become a founding member of the President's Teaching Academy. The PTA strives to raise the profile and effectiveness of teaching, in cooperation with the University's Centre for Teaching Support and Innovation (www.teaching.utoronto.ca). I have a special interest in addressing the unfortunate situation whereby university instructors receive little or no initial or continuing education in teaching.

I'm also a core member of the Centre for Science, Math, and Technology Education (SMT: www.oise.utoronto.ca/smt/) at the Ontario Institute for Studies in Education (OISE/UT). I had approached OISE/UT once or twice in the distant past about a cross-appointment, but nothing resulted, probably because I am an "amateur" at education research. I finally got in "through the side door" as a result of a collaboration with a graduate student there. In SMT, I have learned more about science education research. In the spirit of subjecting our teaching and outreach to the same critical analysis that we do for our astronomy research, my goal, at SMT, is to connect it more closely to the science and math departments in the rest of the university. I have had limited success. This is a problem across North America: there is too little contact between science departments and those that train schoolteachers and conduct science-education research.

So, I have two messages: (i) there are "best practices" in teaching and outreach; we and our colleagues should learn about them; it will improve our success; and (ii) all teaching and outreach should be subject to assessment and improvement, either through formal education research, or at least through reflection, during and after the experience. See Percy (2002) for further thoughts.

I retired from undergraduate teaching in 2007. Now I teach later-life learners; I have organized and/or taught three different courses in the last year. Later-life learners are a receptive, interactive, enjoyable, significant, and growing audience (Percy and Krstovic 2001). My courses are anywhere from 40 to 250 in size. I also give one-off presentations to groups like Probus (www.probus.org/canada), a network of clubs for active retirees, associated with Rotary. I urge you to locate your local later-life learning group, and offer your services. They will do the rest!

The State of Astronomy Outreach

At the University of Toronto, astronomy outreach is alive and well. Our astronomical "triumvirate" of the Department of Astronomy and Astrophysics (DAA), the Dunlap Institute (DI), and the Canadian Institute for Theoretical Astrophysics (CITA) has an active outreach committee, chaired by Dr. Michael Reid, which organizes events such as the viewing of the transit of Venus (Reid 2012); public lectures by the likes of Mike Brown, Stuart Clark, Vicki Kaspi, and Dava Sobel; monthly tours organized by the graduate students; an outreach Web site (universe.utoronto.ca), as well as activities carried out by individuals such as myself. We are striving to continue to increase our impact, reach, and effectiveness through partnership and coordination. Many of our activities are in partnership with the RASC.

At the university level at U of T, things are less satisfactory. There are many outreach activities going on at the departmental level, but there is minimal institutional support and coordination. This is partly because we do not have a separate Faculty of Science, which is often the natural "home" for science outreach. A few years ago, a bout of coordination resulted in the creation of *Science Rendezvous.* A promising development is the recent appointment of astronomer and science communicator Prof. Ray Jayawardhana as Special Advisor to the President on Science Engagement.

Outreach by CASCA has grown significantly in the last decade, partly as a result of grant support, partly because of growing awareness of the importance of outreach, and partly because of IYA2009 and the success of the CASCA-FAAQ-RASC partnership. But, it's disturbing that two major initiatives—the Web site for teachers and students (www.cascaeducation.ca) and the CASCA-Westar Visiting Lectureship—are "dormant." Much effort was put into the Web site; it needs promotion, as well as maintenance. And, the CWL brings astronomy to underserved parts of the country.

As for the FAAQ and RASC: their outreach audiences far exceed those of CASCA (unless CASCA's numbers are grossly under-reported). And, FAAQ and RASC members do outreach voluntarily, above and beyond their other astronomical interests, and above and beyond their day jobs. They can benefit from partnership with professionals but, in many ways, they lead the way.

In Summary

I don't expect to do astronomy outreach for another 50 years, though I am still actively involved in it. I will be happy if Canada's amateur and professional astronomers, and their students, continue and expand our long tradition of communicating the excitement and importance to people of all ages! I hope my reflections will be useful.

Continued on page 248.

Figure 1 — *Les Marczi bribed the weather gods to capture this captivating image of the transit of Venus as the Sun set under a bank of horizon-hugging clouds.*

Figure 2 — *Members of the Winnipeg Centre who attended the Spruce Woods Star Party on September 14 were treated to a spectacular bolide about 1:20 in the morning. Only one camera was open and pointing in the right direction. Sheila Wiwchar caught the fireball as it descended toward the north horizon, breaking up under the handle of the Big Dipper.*

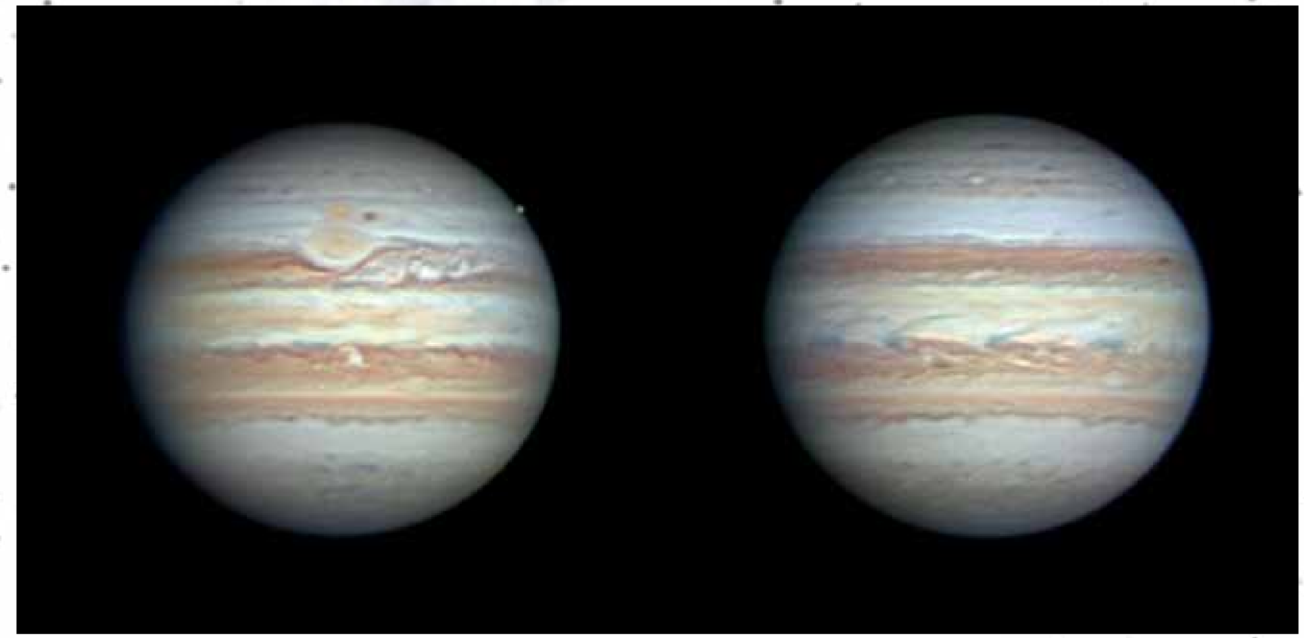

Figure 3 — *Rolf Meier from the Ottawa Centre sends us these two images of the opposite hemispheres of Jupiter in mid-September. On the left, the Great Red Spot dominates the planet's appearance, while Europa nudges the right-hand limb. Rolf used a C14 and Flea3 camera from Point Grey Research from his site west of Ottawa.*

Figure 4 — *Charles Banville from the Victoria Centre captured the "Blue Moon" of August 31 from Esquimalt Lagoon looking toward the Fisgard Lighthouse. Charles used a Borg 77EDII at f/4.3 on a tripod. Exposure was 1/3200 s at ISO 3200 with a Canon EOS 5D Mark II.*

Continued from page 245.

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Rising Stars

Dr. Linda Strubbe and the Black-Hole Diet

by John Crossen
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Whether conducting cutting-edge black-hole research or simple public outreach, Dr. Linda Strubbe is making a difference. Some astronomers contribute to science through their discoveries. Others plant the seeds of knowledge that will flower as new scientists and new discoveries tomorrow. Dr. Linda Strubbe does both.

In 2011, Dr. Strubbe graduated from U.C. Berkeley with a Ph.D. in astrophysics. Prior to that, she earned her M.A. in astrophysics from the same institution, and her B.A. (with honours) in astrophysics from the California Institute of Technology. She is currently in Toronto doing post-doctoral research in black-hole physics at the Canadian Institute of Theoretical Astrophysics.

During her graduate-school career, Dr. Strubbe was the author and co-author of several papers on aspects of her thesis topic: the process of black holes eating stars. When a star approaches too close to a super-massive black hole in the centre of a galaxy, the black hole's gravity can rip the star apart. The black hole then swallows a fraction of the star's gas, producing a luminous weeks-long flare as bright as a supernova. Studying these flares can teach us how the heaviest black holes and the galactic nuclei that host them grow together, by revealing the details by which black holes consume gas, and by teaching us about the distribution and motions of stars close to the black hole.

Figure 1 — Dr. Linda Strubbe.

Most recently (2012), Dr. Strubbe was co-author of a paper entitled *PTF10iya: A short-lived, luminous flare from the nuclear region of a star-forming galaxy.* She was part of a team of scientists from California, Israel, the UK, and Canada, led by Dr. Brad Cenko from U.C. Berkeley. This paper presented the first detection by the Palomar Transient Factory of a black hole eating a star, and showed that the properties of the event were broadly consistent with predictions Strubbe had made in her thesis. She noted, "This was the first candidate discovered due to its optical emission that was found in real time by a survey. Thus it could be followed up at other wavelengths and with a spectrum while the event was still going on."

But there's more to Linda Strubbe than cutting-edge black-hole research. She also has a passionate interest in public-outreach astronomy.

I'm an astrophysicist with a strong interest in education, particularly in the developing world. After visiting Brazil for a conference in 2009, I decided I wanted to come back to Latin America and get to know a community of people there, seeing if I could help by offering my primary expertise—teaching astronomy/science. After graduating with my Ph.D. from U.C. Berkeley in July 2011, I took a few months off, before starting a post-doc, to do astronomy outreach in South Africa and Guatemala.

The world Linda encountered was challenging on both economic and educational levels. Books were hard to come by and reading skills were frequently poor. Still, the interest in the stars and the quest for knowledge on all fronts was ripe amongst the young people as well as the adults. Her experience with a young girl is a perfect example:

Yesmin demonstrated the most tenacity of all the people I met during my trip. On a rainy afternoon during my second week, I passed 10-year-old Yesmin in the street in front of her house. "What's your name?" she asked me. Then, very directly, "Do you have books? Can you come and read with me?" I've never seen a North American child do anything like this. Of course, I said yes!

Over the subsequent days, she and her little brother Juan Carlos read with me Spanish versions of classics like Clifford the Firehouse Dog *and* Where the Wild Things Are *(borrowed from the Mountain School).*

In addition to sharing in the local culture and exchanging ideas, Linda organized some star parties with her humble space telescope—the plastic Galileoscope produced for IYA2009 (see galileoscope.org). Her experience at one of those star parties demonstrated the inspiring potential of astronomy outreach.

I had the amazing opportunity to know, learn from, and to make friends with people whose life situations are very different from my own. I'd also come with the idea (or hope) that most anyone in the world—even with very little education—would be curious about the Universe, its contents, and our place in it. And that night, with a throng of people excitedly jostling to see Jupiter, then the Moon, then Jupiter again, then the Moon again, I felt that this could well be true.

While there were many "Galileo Moments" shared at the eyepiece of the telescope in the Guatemalan Highlands, Dr. Strubbe has extended her involvement to Cape Town, South Africa, where she is a member of the International Astronomical Union's new Task Force on using school-level astronomy to promote international development. She noted that "I recently had an hour-long Skype session with a group of ten students in Cape Town and am chatting with a few of them regularly via Facebook. They are enthusiastic about astronomy and this project!"

Figure 2 — Dr. Strubbe and a future astronomer.

Dr. Strubbe is currently refining a program in Toronto that she began in Cape Town. In her words, "Astronomy can be an inspirational gateway to learning science and analytical reasoning, while fostering tolerance, respect, and a sense of global citizenship among people from diverse backgrounds."

Dr. Linda Strubbe continues to explore the Universe with the powerful tools of science, but she is also demonstrating that the simple act of sharing knowledge can bring the various peoples of this little blue planet closer together by inspiring them to journey farther out into the Universe.

A non-technical, introductory version of Dr. Strubbe's research thesis is available at: cita.utoronto.ca/~linda/Strubbe_intro.pdf. ✶

John Crossen has been interested in astronomy since growing up with a telescope in a small town. He owns www.buckhornobservatory.com, a public outreach facility just north of Buckhorn, Ontario.

Second Light

An Earth-mass Planet Orbiting α Centauri B

by Leslie J. Sage
(l.sage@us.nature.com)

As most astronomers (both amateur and professional) know, the α Centauri system is the closest stellar system to the Sun. Tiny Proxima is a little closer than the main components, α Cen A and B, which lie at a distance of just under 4.4 light years. Xavier Dumusque, of the Geneva Observatory in Switzerland, and his colleagues there and in France and Portugal, have discovered a planet with a mass similar to Earth's orbiting α Cen B (*Nature*, November 8 issue). The planet is nowhere near the habitable zone—its orbital period is just 3.24 days—but it demonstrates that we are closing in on the ultimate goal: an Earth-like planet in an Earth-like orbit around a Sun-like star.

In what follows, I will ignore Proxima, as it is too distant and faint to matter in the discussion.

A and B orbit their mutual centre of mass with a period of ~80 years. At the point of closest approach, they are separated by ~11 AU, and at their most distant by ~36 AU (Neptune is about 30 AU distant from the Sun). α Cen A is slightly more massive than the Sun, and therefore somewhat hotter. α Cen B is slightly less massive at 0.93 solar masses, with an effective surface temperature of ~5200 K. With half of the Sun's luminosity, the habitable zone of B encompasses approximately the region around 0.7 AU—something like Venus's distance from the Sun. A habitable zone, however, is notoriously tricky to define, because of assumptions about the planet's atmosphere.

Dumusque and his colleagues used the HARPS instrument mounted on the European Southern Observatory's 3.6-m telescope at La Silla to measure the changes in radial velocity induced on B by the planet. HARPS is currently the best instrument in the world to do this, but even so, the observations were very challenging. The signal is small, and removing the signals arising from gas motions on the star is a tricky task.

The observing strategy was quite intensive. B was observed for 10 minutes at a time, 3 times a night, for every possible night over a period of 3.5 years (from early 2008 to mid-2011, with a total of ~450 measurements). This was necessary in order to average out the signal arising from stellar oscillations, granulation, and instrumental noise, and remove contamination arising from stellar activity and binary motion. Even so, the signal is weak—at least by today's standards. There is certainly a periodicity of 3.236 days in the data, and it is quite likely to be a planet.

It is not yet known whether the planet transits the face of the star, so the orbital inclination is not constrained. The minimum mass of the planet, assuming that it is close to transiting, is 1.13±0.09 Earth masses. Dumusque calculates that there is a ten percent chance that it is transiting, but the transit could only be seen from space.

At 0.04 AU from B, the planet is too close to the star to be in the habitable zone, and likely tidally locked, so that one side of the planet always faces the star. But the radial-velocity signal of this planet is about the same as that of a four-Earth-mass planet at 0.7 AU, which would have an orbital period of ~200 days. The HARPS instrument therefore is capable of finding "super Earths" in the habitable zone of a Sun-like star.

Although there are at present no other planets known to be orbiting α Cen B, it is interesting to think about the long-term stability of planets in binary systems in case another one is found. The case for α Cen A has been studied computationally, and the long-term survival of planets when a companion star approaches within about 10 AU—for a putative planet 0.7 AU from B (in the habitable zone)—is in some doubt, because after sufficient time, the planetary orbit could become "chaotic" and eventually ejected from the system. Undoubtedly this discovery will lead to some computations to look at this in detail.

With an Earth-mass planet only four light-years away, science fiction is rapidly becoming science fact. ✶

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

Cosmic Contemplations

New Takes in Digital Single-Lens-Reflex (DSLR) Imaging

by Jim Chung, Toronto Centre
(jim_chung@sunshine.net)

There are some who believe that DSLRs are a low-cost introduction to astrophotography that allows them to graduate to dedicated thermally cooled astrophotography cameras. This statement is true but is perhaps not the whole picture. I am a firm believer in the journey being as important as the destination, so even though I have both QSI and SBIG cameras, I still very much cherish and regularly use my Canon DSLR.

When I image at a dark site, it is typically a significant investment in time and money to get there, so I want to maximize my chances of success. In this regard, a DSLR is the key, because it reduces the amount of gear required and also simplifies the capture process. I can fit my unguided Kenko Skymemo mount, Canon T2i body, two lenses, extra batteries, and green-laser pointer into one knapsack, and I am not just ready, I am airline ready! I started DSLR imaging more than seven years ago, but the technique continues to evolve and improve. Some topics that I will discuss in the future include the use of crop movie mode to take planetary images, and the introduction of the Leica M Monochrome (*not* the world's first consumer monochrome DSLR).

Unguided DSLR imaging requires a combined application of short focal length and short exposures. With a well-polar-aligned Kenko Skymemo, I can manage two-minute exposures with the excellent Canon L series 200-mm f/2.8 lens and retain consistently round stars. Shorter-focal-length lenses could accommodate longer exposures and achieve better image saturation. What you do not want to do is use high ISO settings on your DSLR to achieve "better" image saturation. Famed neurobiologist and creator of *Nebulosity* and *PHD* software, Craig Stark, recently wrote an article debunking the myth of high-ISO imaging. Increasing the ISO setting appears to increase the sensitivity of the sensor because the image is brighter, but the camera is merely amplifying both signal and noise, and you lose the dynamic range between the brightest and dimmest parts of the image. For the Canon bodies (although variations between models is likely), ISO 400 represents the highest setting before diminishing returns, as the system gain is already 0.6 e-/ADU (electrons per analog-to-digital unit), the setting closest to recording one photon for each change in pixel intensity in a 14-bit system (DSLRs do not operate at 16 bit).

Figure 1 — A before-and-after comparison of the back mount of a Canon 15-mm f/2.8 FD lens showing the Ed Mika-modified adapter.

We also want to minimize exposure time to minimize the noise accumulation from dark current (the spontaneous generation of electrons from circuitry heat with time). Canon DSLRs have always displayed excellent low-noise long-exposure qualities, and they keep improving with each generation, but appearances are deceiving. Craig Stark and others have long suspected that Canon preprocesses the data to achieve this performance, so that the raw files are not truly raw. The dark signal actually decreases with time during the first two minutes of a long exposure (and then resuming the expected linear increase of dark signal with time), which is naturally impossible. Canon keeps the background looking dark by shifting the histogram left and rescaling the contrast, but the noise signal is still present in the data, and more difficult to remove at processing.

Using quality lenses with large apertures (low f-numbers) can improve image quality by maximizing the signal in even a short exposure, but at great financial expense. An EF 50-mm f/1.2 lens has a manufacturer's suggested retail price of $1600. I do have a 1960s-vintage Canon FL 55-mm f/1.2 lens that I found through Kijiji (a network of online, local classified ads) for only $200 that I recently used to take a Milky Way mosaic at a RASC star party in Algonquin Park, Ontario.

In 1987, Canon had to significantly revise its lens-mounting system to allow for autofocus lens technology, increasing the flange back distance from 42 mm to 44 mm. This revision meant that decades worth of quality manual-focus lenses could no longer be used in today's DSLRs, as no adaptor can be made to place a lens deeper within the camera body. To be sure, you can purchase cheap eBay adaptors that have an optical element similar to a Barlow that allows infinity focus of vintage lenses, but at the cost of optical quality and the loss of aperture performance. The only recourse was to expensively have the lens custom altered. Barrie, Ontario, native and mechanical engineer/avid amateur photographer Jakub "Ed" Mika has come to the rescue!

Ed manufactures an easy and reversible all-brass conversion kit for my 55-mm FL lens that does involve some do-it-yourself removal of the old bayonet mount. He also manufactures a 0.75-mm-thick brass no-assembly-required adaptor for use with a variety of 1970s vintage FD telephoto prime lenses. These are all manufactured in his father-in-law's garage, which is outfitted with $35,000 worth of tooling and a pair of vertical CNC mills. Of course, he also had to amass a complete collection of FD lenses and almost every current Canon DSLR body to ensure fit and performance (see www.flickr.com/photos/ontarian/7900615032/in/photostream). Ed discovered that there was additional focus travel built into the FD telephoto primes to allow for temperature fluctuation—enough space to install a thin adaptor. Brass was chosen as the appropriate material, because it was soft enough not to damage the camera or lens flange but far stronger than aluminum and did not require anticorrosion coatings, whose thickness would have exceeded the demanding tolerances. In addition, a Dandelion AF-confirming chip bonded better to bare metal anyway!

The economics of this model are easily proven. My EF 200-mm f/2.8 lens cost me $600 used, the very similar FD version can be had for as little as $150 on eBay, and the only functionality you give up is autofocus, which is of no use in astrophotography. The weapon-sized EF 800-mm lens is $14k, while the FD 800-mm is about $3k, and although not particularly useful for astrophotography, allows me to indulge in the fantasy of becoming a sports photographer and getting those prime seats at the games. FD lenses high on Ed's list to acquire for astrophotography are the 14-mm f/2.8 L, 15-mm fisheye, 24-mm f/1.4 L, 35-mm f/2, 50-mm f/1.4 (but not the non-L 1.2—it has a shocking amount of chromatic aberration), 100-mm f/2, 135-mm f/2, and 200-mm f/2.8.

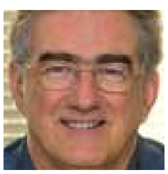
The FD 50-300 f/4.5 L zoom is amazing and my current favourite lens (and I am a prime shooter) and the TS (tilt shift) 35-mm f/2.8 would be great for astrophotography, as it has such a large image circle that there is next to no distortion at the corners of the image when used as a straight-on lens.

In closing, if I had to do it over again, I would purchase the FD 50-mm f/1.2 L, although it has a street value double my FL 55-mm f/1.2. The FD 50-mm was introduced in March 1971 as the first lens with an aspherical element that successfully dealt with the spherical aberration common in large spherical lenses (parallel light rays at the edge of the lens converge at a focal point closer to the lens than those passing through the centre, resulting in a "soft" image unless the lens is "stopped down" a couple of f numbers). At Algonquin, I had to shoot at f/2 instead of f/1.2, but at ISO 400 and 1-minute exposures, I had a full histogram nonetheless. ✶

Jim Chung has degrees in biochemistry and dentistry and has developed a particular interest for astrophotography over the past four years. He is also an avid rider and restorer of vintage motorcycles, which conveniently parlayed into ATM (amateur telescope maker) projects. His dream is to spend a month imaging in New Mexico away from the demands of work and family.

Society News

by James Edgar, Regina Centre
(jamesedgar@sasktel.net)



Centre executives have received monthly email packages from National Office. These are short "how-to" items—*RASC Membership Development News*—a forum to exchange membership recruitment and retention ideas and activities. The October issue gives tips written by our own members and wraps up with *Elements of a Membership Recruitment Plan*—points and relevant ideas on how to grow your numbers. Ask your executive about these tips, so you, too, can be active in your Centre's membership recruitment activities.

You will see that a Special Issue, *Environmental Impact of Light Pollution and its Abatement*, has come bundled with this issue of the *Journal*. Many people have worked long and hard behind the scenes to create this timely and important addition to our publications. Thanks to Heritage Canada's Canadian Periodical Fund for their generous assistance in this effort.

Also on the publications scene, Executive Director Deborah Thompson has developed new marketing brochures and a RASC "rack card" for insertion into our mailed publications. Good work by all concerned—keep it up! ✶

National Office staff, Kate Fane, Renata Koziol, and Deborah Thompson.

Through My Eyepiece

Accessorize!

by Geoff Gaherty, Toronto Centre
(geoff@foxmead.ca)

With the holiday season upon us, it is time to think of useful presents for the astronomers on your gift list, starting with you, of course.

The single most useful accessory for any telescope is an eyepiece. I have written a lot about eyepieces here in the past, so I will just give a few guidelines.

First, never cheat on quality. Eyepieces are for life, and will travel with you through many changes in telescopes. You really do get what you pay for, so consider the best. I am happier with two or three top-notch eyepieces than with a dozen cheap ones.

There are two directions to go with eyepieces, either wider fields or higher magnifications. The last few years have seen the bar raised on field width, with concomitant increases in price and weight. Be cautious about higher magnifications, as you hit a point of diminishing returns imposed by our turbulent atmosphere. I rarely find much use for magnifications higher than 300× no matter what telescope I am using, and even this limit is useful on only a few nights a year.

Regular readers will know I am enthusiastic about digital setting circles and GoTo mounts, especially for advanced observers looking to improve their efficiency and pleasure. One of my very first columns here was about binoviewers, and these remain among my most-used accessories. I find they significantly increase the amount of fine detail I can see, particularly on the planets, and they also allow me greater relaxation, which helps me see everything more clearly. Prices and weights have come down, but the catch with binoviewers is always that you need to buy eyepieces in pairs. I have found that wide-field eyepieces in binoviewers have problems merging images, and I am happiest with simple Plössls or orthoscopics; so is my wallet.

Beginners often want to buy filters, partly because they are inexpensive and partly because they believe they are a "magic bullet" that will suddenly make fine planetary detail and faint deep-sky objects pop out. The truth is that only observing experience will make the magic happen, with simple pencil sketching being the key to eye training. The only eyepiece filter I use regularly is an OIII, which I find really helps bring out faint diffuse and planetary nebulae. I own a hydrogen-beta filter that I use in my annual quest to see the Horsehead Nebula, but I do not recommend that individuals buy one. This type of filter is best thought of as a Centre purchase, to be shared among members.

Even though I am addicted to my Coronado PST ("Personal Solar Telescope" for the acronym challenged), I still find much pleasure in full-aperture white-light solar filters. I learned a long time ago from Guy Nason not to cheat myself with small partial-aperture filters, on the theory there is so much light coming from the Sun that aperture does not matter. The high optical quality and low cost of Baader solar film makes full-aperture filters feasible even on quite large telescopes, such as my 280-mm Schmidt-Cassegrain. I really like the simple, elegant, and *safe* cells Jim Kendrick makes for his Baader filters; the added security of nylon thumbscrews clinches the deal for me.

I own a whole bunch of coloured filters, but find I almost never use them, except maybe for Mars. I can see more detail on the planets with my natural colour vision than by looking at psychedelically coloured planets through filters. The only real advantage to most filters is that they reduce the glare of the brighter planets. In that case, I will often sneak a peek through my OIII filter, a well-kept-secret weapon of planetary observers.

I have found, with advancing age, that a permanent observatory is a wonderful accessory. Having my telescope constantly available in a SkyShed POD (Personal Observatory Dome) is a great incentive to take quick peeks at the sky. Now, I have started to accessorize my POD with a red observing light and a red digital clock.

I already mentioned sketching, but I would like to emphasize it as the royal road to observing skills. Get yourself some good-quality paper, good soft pencils, and, most importantly, an artist's stump—a tight roll of blotting paper sharpened at the end that is the key to smooth, realistic shading. There has been a lot of renewed interest in astronomical sketching lately, with drawings by our members being featured in the *Journal*, on the RASC Web site, and even on the cover of this year's Handbook. ✶

Geoff Gaherty received the Toronto Centre's Ostrander-Ramsay Award for excellence in writing, specifically for his JRASC *column, Through My Eyepiece. Despite cold in the winter and mosquitoes in the summer, he still manages to pursue a variety of observations. He recently co-authored with Pedro Braganca his first iBook:* 2012 Venus Transit.

On Another Wavelength

Mars Fascination

by David Garner, Kitchener-Waterloo Centre
(jusloe1@wightman.ca)

From the time of Schiaparelli's observation of *canali* on Mars in 1877, H.G. Wells' *The War of the Worlds* in 1898, and Percival Lowell's speculations in the early 1900s, we have been watching carefully for any signs that might indicate the possibility of life on Mars. We are fascinated by the idea.

By 1960, the USSR was sending probes to fly by the planet hoping to get close-up photos, but it was more than a decade before they achieved this goal. NASA succeeded with the flyby of *Mariner 4*, returning 21 photos in 1964. In 1976, the *Viking 1* and *Viking 2* missions were the first to successfully land on Mars and return over 50,000 images. NASA then took a decade off, but returned in 1997 with the *Mars Global Surveyor* (MGS) and its high-resolution camera. The images from *Surveyor* showed that weathering and winds on the planet, especially sand dunes, were responsible for the landforms, which were similar to desert dunes on Earth.

In the same year, NASA's *Pathfinder* mission landed a rover named Sojourner (Figure 1). The instruments on board Sojourner included three cameras, a meteorology package, and an Alpha Proton X-ray Spectrometer to analyze rocks and soil. Sojourner was 65 cm long, 48 cm wide, 30 cm tall, and weighed only 10.5 kg. Sojourner travelled approximately 100 metres in total and visited rocks called "*Barnacle Bill*," "*Yogi*," and "*Scooby Doo*," named after cartoon characters.

Figure 1 — The Sojourner rover

Four years later in 2001, *Odyssey* arrived in orbit around Mars with a mission to find evidence of past or present water and volcanic activity. The pictures sent back to Earth strongly suggested that long ago Mars had a great deal of flowing water. Using its gamma-ray spectrometer, the *Odyssey* found hydrogen in the polar regions of Mars, implying the presence of massive deposits of near-surface ground ice.

The rovers Spirit and Opportunity arrived in 2004, each positioned on opposite sides of Mars. The rovers' scientific objectives included searching for rocks and soils that held clues to past water activity, determining the geologic processes that shaped the local terrain, and assessing whether the environment was conducive to life. NASA's exploration strategy for its robotic missions, to find microbial life, has been to "Follow the Water." This strategy was very successful at the Meridiani Planum site explored by Opportunity, which is now believed to be a former saline lake or sea.

In 2006, the *Mars Reconnaissance Orbiter (MRO)* arrived. The *MRO* was designed to conduct reconnaissance and exploration from orbit. *MRO* contains a host of scientific instruments used to analyze the landforms, minerals, ice, monitor the daily weather, search for potential landing sites, and provide a new telecommunications system for future missions.

Based on the previous results obtained with *Odyssey*, the *Phoenix* lander descended to the Martian polar region in 2008. The instruments aboard were designed to search for an environment suitable for microbial life and determine planetary habitability in the ice-soil boundary. *Phoenix* was stationary rather than a rover, because the landing area was thought to be relatively uniform, so that travelling would be of little value. It was hoped that *Phoenix* would survive a winter, allowing it to monitor the polar ice as it formed around the lander, but unfortunately it did not endure the cold and dark as the fall season came to an end.

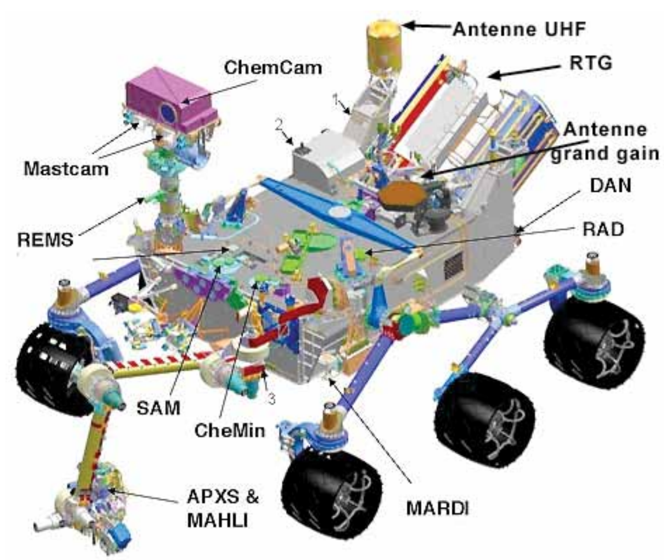


Figure 2 — Curiosity rover

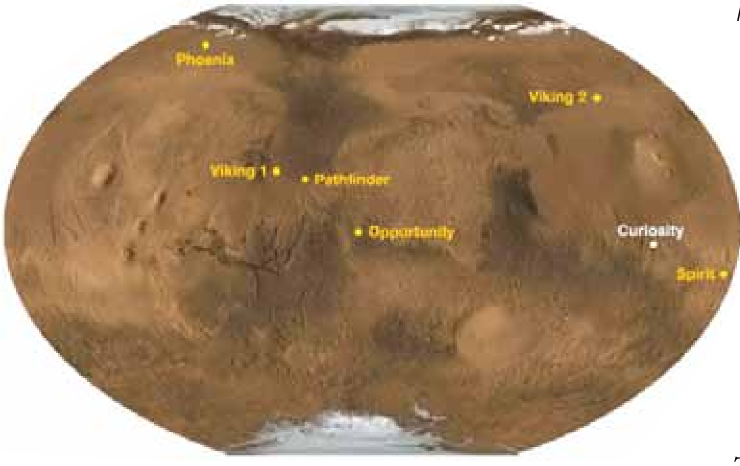


Figure 3 — The sites of NASA's rovers and landers

On August 6 of this year, the *Mars Science Laboratory (MSL)* successfully landed the rover Curiosity in Gale Crater near Mars's equator (Figures 3 and 4). One of the primary missions for Curiosity is to determine if the chosen area had ever been a potential habitat for life. Curiosity does not have any instruments to determine present-day biological processes or microorganisms; it is more like a prospector mining for evidence of whether life has ever existed on Mars.

The three requirements for habitability are: a) liquid water, b) the chemical ingredients of life, such as carbon-containing compounds (organic molecules), and c) a source of energy, such as sunlight. The choice of Curiosity's landing near the Gale Crater was based on data from the earlier *MRO* mission. That mission had mapped the area's mineralogy and found clay, silicates, and sulfates, which normally form in a wet environment.

Curiosity is a complete science lab on wheels (Figure 2). At 2.9 meters long, 2.7 meters wide, and 899 kg, it is larger and heavier than Spirit or Opportunity, and much, much larger than Sojourner. Curiosity, among other things, can detect many elements and organic molecules, including amino acids.

In Figure 2, note the location of the mast. At the top you can see the mast camera (MastCam). These are the eyes of the rover showing its surroundings in fine detail and, if needed, in 3-D.

Above MastCam, you can see ChemCam (Chemistry and Camera). This unit incorporates a rock-zapping infrared laser that can hit a spot with a million watts of power for five-billionths of a second. The resulting light flash at the target is collected and sent down an optical fibre to three spectrometers inside the rover. These spectrometers are able to identify a wide variety of elements in the rocks such as sodium, magnesium, aluminum, silicon, calcium, potassium, titanium, manganese, iron, hydrogen, oxygen, beryllium, lithium, strontium, nitrogen, and phosphorus.

If further analysis is required, Curiosity can drill into the rock and use its robotic arm to deliver a powdered sample to either the Chemistry and Mineralogy (CheMin) lab or the Sample Analysis at Mars (SAM) lab inside the rover.

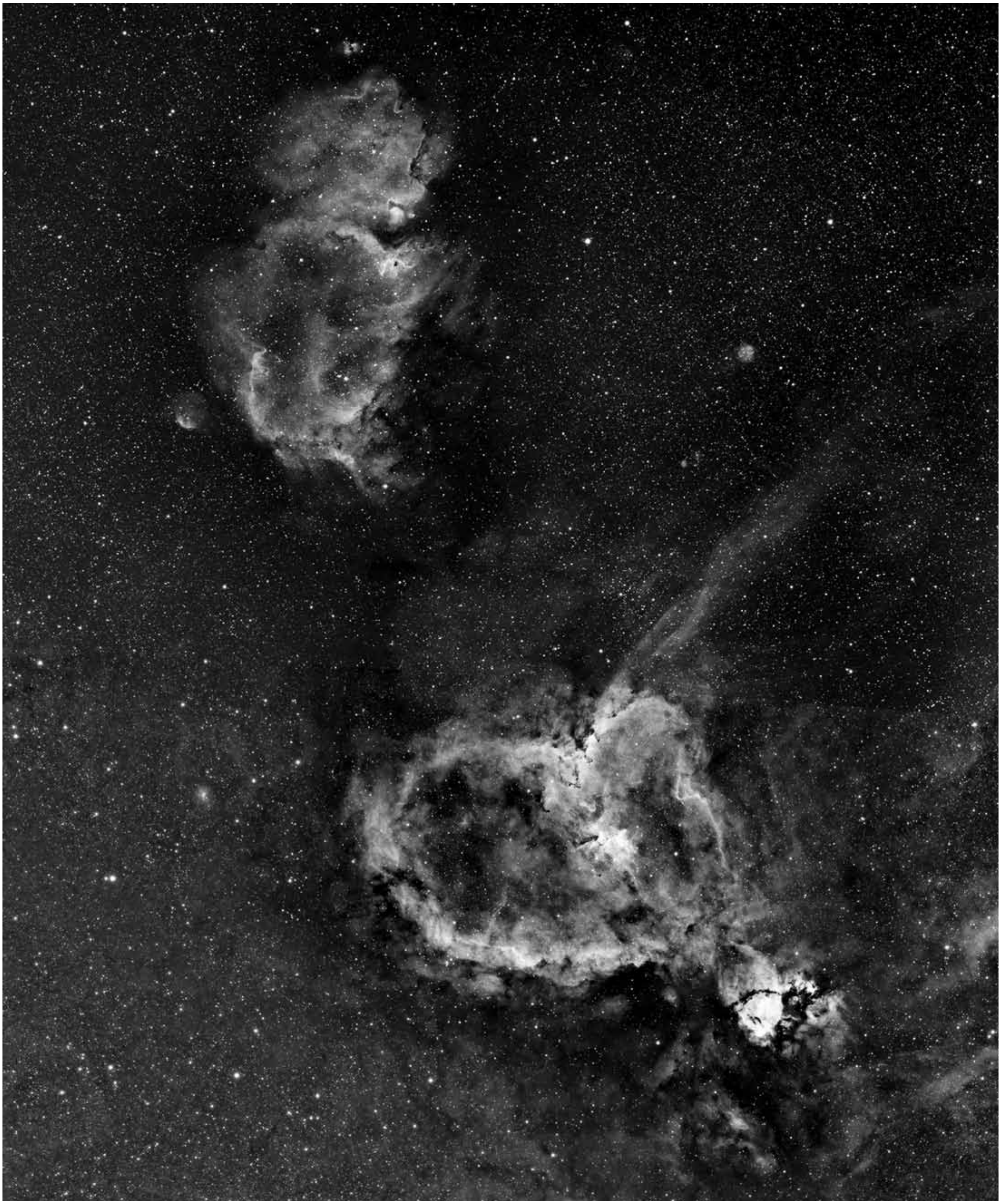
CheMin is the X-ray powder diffraction and fluorescence instrument located in the interior of Curiosity. Fine powder is poured into the instrument through an inlet tube on top of the vehicle. A beam of X-rays directed at the powder is diffracted by the crystal lattice of the minerals at characteristic angles, allowing the identification of the minerals involved.

The SAM instruments inside Curiosity are used to study the chemistry relevant to life—the carbon-based compounds that are the molecular building blocks of life. The three instruments are a Quadrupole Mass Spectrometer, a gas chromatograph, and a tunable laser spectrometer. These instruments measure the oxygen and carbon isotopes in carbon dioxide and methane to determine whether they have a geochemical or biological origin. Methane, one of the simplest organic molecules, is easily broken apart by ultraviolet light from the Sun. As a result, the methane gas already detected in the Martian atmosphere must have been produced recently. The SAM lab should give us a much better idea of how this methane gas is originating on Mars.

There are several other instruments aboard Curiosity that will need to be discussed in a future article. Yes, Mars is fascinating; and so are the instruments sent there to study it. ✶

Dave Garner teaches astronomy at Conestoga College in Kitchener, Ontario, and is a Past President of the K-W Centre of the RASC. He enjoys observing both deep-sky and Solar System objects and especially trying to understand their inner workings.

Figure 4 — The landing site shown by the ellipse in Gale Crater

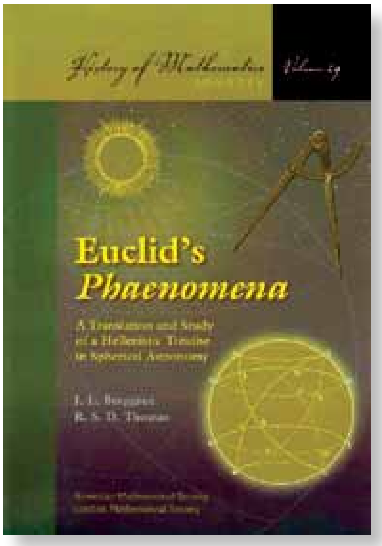


James Black shot this Hα mosaic of the Heart and Soul Nebulae using a Takahashi FSQ106ED at f/5 from his Light Waves Observatory near Pitt Meadows in British Columbia. The Heart and Soul lies about 6000 light-years distant in Cassiopeia and is a popular summer object for experienced deep-sky photographers. The two nebulae are very active star-making factories, with many of the embedded stars only a few million years old.

Great Images

Editor Jay Anderson tried out his new Hα filter on the Cygnus Milky Way using a Canon EF 50-mm f/1.2L lens at f/1.6 on a Canon 60Da. Exposures totalled 12 minutes at ISO 1600. The image shows northern Cygnus, from the North America Nebula to the Veil. Prominent in the image is the large amount of nebulosity along the Milky Way, past the Pelican Nebula and gamma Cygni. The most intriguing part of the image is the faint arc of nebulosity midway between the North America and the Veil that suggests an old supernova remnant.

Reviews / Critiques



Euclid's *Phaenomena*: A Translation and Study of a Hellenistic Treatise in Spherical Astronomy, by J. L. Berggren and Robert S. D. Thomas, pages 132 + xi, 25 cm × 18 cm, American Mathematical Society, Providence, Rhode Island, 2006. Price $36, softcover (ISBN: 978-0821840726).

In his marvellous article on "The Origin of the Constellations" published in *Vistas in Astronomy* in 1984, Archie Roy speculated on "The Sphere of Eudoxus," a putative bronze spheroidal celestial globe used by the 4th-century BC Greek astronomer and mathematician, Eudoxus, to describe events occurring in the night sky, primarily rising and setting times of constellations, albeit some two millennia prior to the era in which he lived. It was from those archaic descriptions of the sky cited in the poetry of Aratus that Roy, and before him Michael Ovenden, speculated on the likely century, terrestrial location, and culture in which many of the early constellations were first identified, thence to be described on the sphere of Eudoxus. The origin of the constellations has been a topic of great interest in archaeoastronomy for many years.

The sphere of Eudoxus comes to mind as one reads the current translation and study of Euclid's *Phaenomena* by Berggren and Thomas, a work resulting from a 1986 conference in Winnipeg that brought the two authors into contact with each other for future collaboration on *Translation and Study*. My interest in the work originated during attendance at the 1999 RASC General Assembly in Winnipeg, where I chanced to look up an old acquaintance at the University of Manitoba. Robert Thomas, who like me, and Margaret Atwood for that matter, is a graduate of Leaside High School in Toronto and was my floor don at Renison College in 1964-65 when I began studies at the University of Waterloo. The first edition of *Translation and Study* had been published, and Robert wondered if it might be of interest to the astronomical community, given its link to an early treatise on spherical astronomy by Euclid, a better known Greek astronomer and mathematician who resided in Alexandria a century or more after the era of Eudoxus. This review is the eventual result of that request.

Translation and Study is exactly as the title suggests, the first modern translation of an extant work, Euclid's *Phaenomena*, reworked and recovered from available descriptions in order to translate the original treatise and its accompanying figures into English, with added commentary to explain the more difficult portions of the narrative, which, in the case of *Phaenomena*, is literally the entire work. Spherical astronomy is a difficult subject outside the curriculum of most astronomers, and is of only fleeting appeal even to astrometry specialists steeped in the pages of Smart's *Spherical Astronomy*. My own copy of Smart's textbook has survived my student days and my years of teaching (perhaps torturing?) students in astronomy basics at Saint Mary's. *Phaenomena* is one of the earliest treatises on spherical astronomy, and was written by Euclid in the form of a textbook of 18 propositions and preceding lemmas, complete with dozens of depictions of the celestial sphere that the average reader may find difficult to comprehend.

It is those diagrams that detract most from the usefulness of *Translation and Study*. There are similar figures in the early sections of the text, but they seem to be the work of Berggren and Thomas. In them, great circles on the celestial sphere are depicted accurately in two dimensions as if viewing them projected on a celestial globe, that is, they are drawn as ellipses. That makes them easy to interpret. In later sections, however, projected great circles are depicted more like mirrored line segments, making it difficult to visualize what they are attempting to display.

The theorems and lemmas discussed by Euclid centre around the rising and setting times of various constellations of stars, from zodiacal groups along the ecliptic to more isolated circumpolar and non-circumpolar groups. *Phaenomena* addresses the rising and setting phenomena for all such groups of stars as viewed from Earth, something that can be easily visualized with a celestial globe (hence the reference to the sphere of Eudoxus) but which becomes rather tedious with poor diagrams, as in the later sections of the text. There are a number of curiously labelled great and small circles identified in the written text that refer to segmented lines in the figures, but that bear no similarity to the projected circles they are intended to describe. Perhaps mistakenly identified Greek letters in the original works were translated into English equivalents without confirming their correct sense? Such muddling of what the text and figures are intended to describe makes it tedious for the reader. It would greatly aid the presentation if Berggren and Thomas had used contemporary illustrations to augment or replace those available in what could be found of Euclid's original drawings.

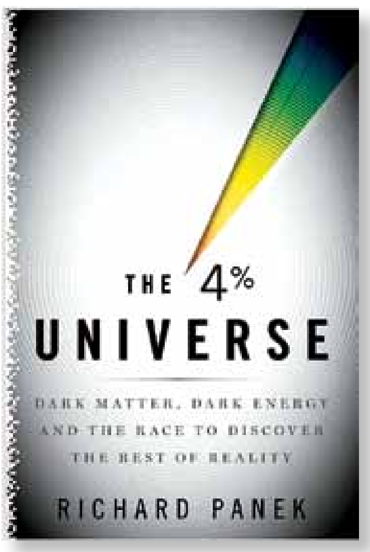
Translation and Study is not simply an early textbook on spherical astronomy, since it contains none of the trigonometric relationships found in contemporary texts. The emphasis, as noted, is on rising and setting times, something that can be depicted readily with a spinning celestial globe to mimic the Earth's rotation. The genius of Euclid was his ability to translate something visible on a three-dimensional object into mathematical proofs using relationships between segments of great circles and small circles. *Translation and Study* therefore provides an interesting glimpse at how early astronomers derived mathematical proofs for sometimes exotic theorems and lemmas.

Translation and Study is not a text for the faint of heart or the mathematically challenged. But the early sections and footnotes contain a lot that is of historical interest. For example, as noted by Berggren and Thomas, the English word for the polar regions, arctic, has its origins in the Greek word *arktoi*, for Bears. In the sky, of course, the Greater and Lesser Bears are always found around the north celestial pole.

Aside from an extraneous "the" on page 11 and concerns about probable typographical errors associated with some figures, the proofreading of the text appears to have been done with great care. It is difficult to know what else to mention.

– David G. Turner

David Turner is a life member of the RASC and Professor Emeritus of Astronomy and Physics at Saint Mary's University in Halifax. His first degree was in Mathematics at the University of Waterloo.



The 4 Percent Universe: Dark Matter, Dark Energy, and the Race to Discover the Rest of Reality, by Richard Panek, pages 297 + xvi, 23 cm × 16 cm, Houghton Mifflin Harcourt, Boston/New York, 2010. Price $26, hardcover (ISBN: 978-0-618-98244-8), also available in trade paperback, audio-book, and e-book formats.

Fortuna, the Roman goddess of luck and daughter of Jupiter, seems to have smiled agreeably on American journalist and writer Richard Panek concerning the subject matter of his book, *The 4 Percent Universe: Dark Matter, Dark Energy, and the Race to Discover the Rest of Reality*. How often does an author choose a cosmological topic to research, write on, and then publish, following which three key players in the narrative are named co-recipients of a Nobel Prize in Physics for the work the story tells? Panek certainly has a nose for a good yarn, and could not have asked for better timing of the book's publication, given that the 2011 Nobel Prize in Physics was announced in October 2011, after his book's appearance earlier that year.

Basically, *The 4 Percent Universe* tells the story of two research teams struggling with the concepts of dark matter and dark energy, studying supernovae, and on the hunt to understand the current Universe, its composition, life, and future. The book is written in the genre of the history and philosophy of science, a research approach that captures how scientific discoveries progress from the proverbial "a" to "b" and then to "c" (or, unexpectedly, somewhere else) with a deliberate focus on the principal "actors" involved.

The researchers in *The 4 Percent Universe*, and there were many, studied dozens of supernovae, specifically Type 1a supernovae—exploding dense stars known as white dwarfs. They found over 50 distant supernovae whose star-light was weaker than expected. That recorded weakness of light indicated to the scientists that the already-known expansion of the Universe was actually occurring at a surprising ever-accelerating rate. Specifically, our Universe's expansion was not slowing down, as had been intuitively thought. The acceleration was an astonishing discovery for humankind, and a long-term predictor of the Universe's icy and dark end eons from now. The situation of accelerated expansion is closely intertwined with the concepts of dark energy, dark matter, and baryonic (visible or ordinary) matter, which are well discussed in Panek's book, with one of the concepts finding its way into the unique "4 percent" reference in the book's title.

The 4 Percent Universe is organized into 12 Chapters and features a short Prologue and an Epilogue. Its logical approach to storytelling and its clear writing style foster a very manageable and entertaining read. No pre-knowledge of science, astronomy, or physics is required to grasp the narrative being unfolded before the reader. In essence, it is cosmology "lite." Any layperson, whether teenager, undergraduate student, or adult with a slight interest in astronomy, will have no difficulty in digesting the book's contents. It rests on strong research, extensive interviews with experts, and a focus on the people working the science, their personalities, teamwork, competitive spirit, and occasional foibles. We learn how petty or nasty some well-established scientists can become when the matter relates to priority of discovery, ownership of data, or simply guarding one's turf. But that is a relic side item that is greatly overshadowed by the discovery that has shattered the view of the Universe.

Panek shows how compromise and collegial teamwork have become the trend among the younger generation of physicists and astronomers, who have become increasingly more specialized in their respective fields, thereby requiring collaboration in an era of multi-spectrum observations: optical, radio, X-ray, gamma-ray, and the use of land-based and space-based technologies. We also read about the "Big Guns," the "Young Turk," the "Old Boys' Network," the rise of cosmology as a discipline, and technological change.

In a charming segue that highlights the technological and gender leaps taken by observational research in astronomy, Panek relates an exchange between William L. Holzapfel, a University of California at Berkeley astrophysicist and veteran of several stays at the South Pole Telescope, and an unnamed female graduate student manning a shift at a South Pole lab.

"Very exciting!" Holzapfel said one afternoon, entering the Dark Section lab that served as headquarters for the South Pole Telescope. Sitting at the controls was an incoming graduate student at Berkeley. She was knitting. "I can see the excitement is at a fever pitch," Holzapfel added. She shrugged and said she would prefer to be handling Bakelite knobs and huge levers. But that was not how telescopes worked anymore. "I hit 'go' and wait twenty minutes for a script to run. At least this way," she held up her knitting, "I get science and a sweater."

Panek is neither a scientist nor an astronomer. His academic credentials are a M.F.A. in Fiction from the University of Iowa, and B.S. in Journalism from Northwestern University. So why is he tackling such a deep, scientific subject matter? "I have a background in journalism; I have a background in fiction," wrote Panek about himself on the Goddard College Website where he is identified as a faculty advisor, M.F.A. in the Creative Writing Program. "I hoped that by combining my experience in conducting research with my experience in constructing narratives, I could make even a somewhat esoteric subject accessible to a general readership."

With that approach to crafting science-based, non-fiction narratives, Panek now counts three books to his credit about the history and philosophy of science for non-specialist readers: *Seeing and Believing: How the Telescope Opened Our Eyes and Minds to the Heavens* (Viking, 1998); *The Invisible Century: Einstein, Freud and the Search for Hidden Universes* (Viking, 2004); and *The 4 Percent Universe*. Mainstream institutions have supported Panek's work with a number of funding grants: a 2008 Fellowship in Science Writing from the Guggenheim Foundation, a 2007 Fellowship in Nonfiction Literature from the New York Foundation for the Arts, and an Antarctic Artists and Writers Program grant from the National Science Foundation.

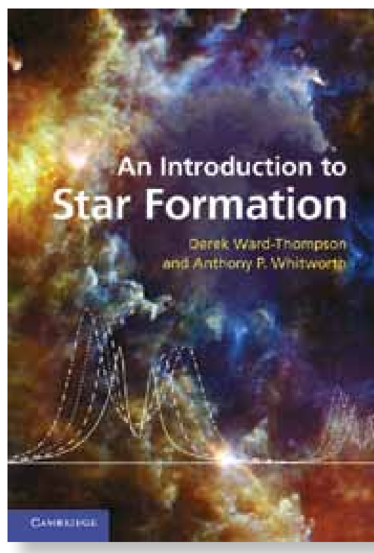
The "actors" that we read about in *The 4 Percent Universe* who were so serendipitously co-named Physics Nobel Laureates in October 2011 are Professor Saul Perlmutter (b. 1959) of the University of California at Berkeley Physics Department and an astrophysicist at the Lawrence Berkeley National Laboratory, Adam Riess (b. 1969) a Professor of Astronomy and Physics at the Johns Hopkins University and a Senior member of the Science Staff at the Space Telescope Science Institute, both in Baltimore, Maryland, and Brian Schmidt (b. 1969) an astronomer at the Research School of Astronomy and Astrophysics at the Australian National University, formerly known as Mount Stromlo and Siding Spring Observatories. As mentioned earlier, there were two research teams. Perlmutter led the Supernova Cosmology Project, which began in 1988, while Schmidt and Riess began work in 1994 on a similar project known as the High-z Supernova Search Team. The goal was to find and measure distant Type Ia supernovae.

Despite its multiple plusses, the book does have some flaws, as noted by Jonathan Feng in his book review, "Exploring the Dark Universe," in the January-February 2012 *American Scientist*, which comments on the misspellings and confusion regarding some of the terminology in subatomic physics. But Feng also notes that the errors "do little to diminish Panek's significant accomplishment," with which this reviewer agrees wholeheartedly. The errors can be easily corrected in a second edition.

Anyone who is interested in the world of the research physicist and astronomer and how modern cosmology is practiced is encouraged to pick up a copy of *The 4 Percent Universe* to give it a read. You will not only learn much, but you will also witness how robust scientific work can lead to the prestigious Nobel Prize.

– Andrew I. Oakes

Andrew Oakes is a long-time member of the RASC, an armchair amateur astronomer, and collects books on Copernicus and Galileo. He lives in Courtice, Ontario.



An Introduction to Star Formation, by Derek Ward-Thompson and Anthony P. Whitworth, pages 228, 17.5 cm × 25 cm, Cambridge University Press, 2011. Price $67 hardcover (ISBN: 978-0-521-63030-6).

The nature and evolution of stars is reasonably well understood, especially if the stars are single, not too rapidly rotating, not too magnetic, and not too close to the ends of their lives. The *formation* of stars, on the other hand, is less well understood, because the interstellar material from which they are born is inhomogeneous, turbulent, and magnetic. Once stars begin forming, they may interact with other stellar embryos through gravity, radiation, winds, and even explosions. The formation process may be further complicated by the presence of binary companions, outflowing winds, and accretion discs. And all of that is well hidden from us by the obscuring dust around them. Star formation research is therefore complex and challenging, but highly rewarding, and therefore very active.

An Introduction to Star Formation is intended as an introductory textbook for advanced undergraduate or graduate courses, or for self-study by established researchers who wish to enter the field or update their knowledge. It assumes a strong background in mathematics and physics, but does not require an advanced background in astronomy.

I am not an expert in star formation, so I shall not attempt to critique the technical content. In any case, the authors are senior, active, and experienced researchers and teachers at Cardiff University, Ward-Thompson primarily in observation, and Whitworth primarily in modelling and theory. I have, however, written a textbook for the same publisher, of approximately the same length, though at a lower level (*Understanding Variable Stars*, 2007), so I shall review *An Introduction to Star Formation* from the perspective of a textbook author and reader.

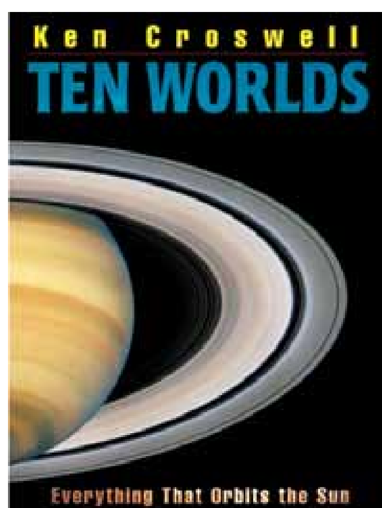
The book begins with an introductory chapter on the main constituents of a galaxy, which will be especially useful for readers with limited background in astronomy. The second chapter presents (or reviews) the essential physics necessary for understanding star formation—especially radiative transfer. The next chapter describes the methods of studying the atoms and molecules of the interstellar medium, in which star formation occurs. The authors then zero in on molecular clouds, which ultimately fragment and collapse to form star clusters, discussing the theory and observations of their flows, gravitational instability, turbulence, magnetism, and chemistry. The chapter on fragmentation and collapse addresses the question of the relative numbers of stars of different masses (the so-called initial-mass function), the formation of binary and multiple stars, as well as the gravitational, thermal, and magnetic processes involved in the formation of individual stars. The next chapter outlines the steps that occur once the forming object can be called a star (or at least a "protostar"), including the nature of the accretion disks around them. That includes useful information about the observation of accretion disks using millimetre-wave, infrared, and optical techniques. The authors then discuss the formation of rare, massive stars, whose radiation and winds are sufficiently strong to affect the star-formation process. The final chapter on "by-products and consequences of star formation" puts the topic into wider perspective, including phenomena surrounding star formation (disks, winds, binary and multiple stars, brown dwarfs), and also large-scale phenomena such as "galactic ecology," starbursts, and mergers of galaxies, concluding with one of the major questions in astronomy today: when and how did the first stars form in the Universe?

All of this is done in about 200 pages. That is good; I approve of concise textbooks. The authors convey the basic concepts, from which the reader can self-learn from the literature. The illustrations are numerous, well-chosen, and well-captioned (the authors have chosen to list the sources of the illustrations at the end of the book, rather than with each illustration). The many (500+) equations are clear and well-organized. There is a useful list of symbols and an adequate index. The authors are careful to flag those phenomena that are poorly understood, and to list and critique alternative explanations in the literature. I was particularly impressed by a list of ten questions, at the end of Chapter 1, which were significant, but lacked firm answers. For example: what determines the "initial mass function" of star formation—the relative numbers of stars of different masses (many low-mass stars, few high-mass stars). How are binary and multiple stars formed? And the big one: do most stars have planetary systems, and what fraction of them includes Earth-mass planets? Such questions would be excellent guides for graduate students seeking thesis projects.

On the downside: end-of-chapter references are restricted, almost entirely, to monographs and conference proceedings. It would have been useful, I think, to include key journal papers, especially review papers and "landmark" or "classic" papers in the field. One thing that I sorely missed was any reference to the history of the topic and the key people involved. There is mention of "Larson's scaling relations," "Hayashi tracks," "Henyey tracks," "Herbig-Haro objects," "Strömgren spheres," *etc*. but no mention of who those people were (including their first names), or any reference to their key papers. I believe that graduate students need some exposure to the history of astronomy and where they fit into it. But perhaps I am just getting old. Finally, expressing a personal bias, I would have appreciated a brief mention of how the study of the variability of young stellar objects, such as T Tauri stars, provides information about the last stages of star formation. But you can read that in my book.

– John R. Percy

John Percy is Professor Emeritus, Astronomy & Astrophysics, and Science Education, at the University of Toronto. His interests are in variable stars and stellar evolution, and in astronomy education and outreach. He has been an RASC member for 51 years.



Ten Worlds: Everything that Orbits the Sun, by Ken Croswell, pages 56, 23.5 cm × 31 cm, Boyds Mills Press, First edition 2006. Price $19.95 US, hardcover (ISBN: 1-59078-423-5).

I am already on record as approving wholeheartedly of Ken Croswell's writing style, as evidenced by my review of *The Lives of Stars* a few years ago (Turner 2010, *JRASC*, 104, 118). *Ten Worlds* was in my possession at the time, but was not reviewed. The first edition of the book predates the controversy over Pluto's planetary status, and was written while the naming of new planetary discoveries was still undergoing iterations. All of that has been addressed in the latest version of *Ten Worlds*, but this review is based on the earlier edition.

The title makes it obvious that the book is about the Solar System, but some readers may be asking how the count managed to reach ten when the original list of nine planets was recently reduced to eight by the IAU through the designation of Pluto as a dwarf planet. The answer is simple: *Ten Worlds* includes not only Pluto, but also the distant Eris, as distinct members of the Sun's family. It is a colourful, attractive, coffee-table book designed to entice readers as well as educate them. The stated age level is nine and up, so *Ten Worlds* should be of interest to everyone. Ken Croswell's clear writing style also adds additional flavour that keeps the mind fully engaged with the subject matter under discussion.

The book is laid out in the traditional order used when introducing the Solar System. It begins with the Sun, then proceeds through the major (and dwarf) planets in order of distance from the Sun, *i.e.* Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto, and Eris (identified as The Tenth Planet in the first edition), with stops along the way to discuss the seven largest satellites: the Moon, Io, Europa, Ganymede, Callisto, Titan, and Triton. Separate chapters discuss the asteroids, comets, and meteors, with an additional one on the birth of the Solar System. Concise tables summarize information on each, and there is a page devoted to the trivia of planetary extrema, such as hottest planet, slowest planet, longest day, *etc*. It is here that one finds an oft-repeated error that I hoped would be missing, namely Venus is listed as the planet with the longest day, when that honour belongs to Mercury. Venus has a longer spin period (243^{d} retrograde) than Mercury (59^{d}), but the length of its day (117^{d} retrograde), as measured relative to the direction towards the Sun, is much shorter than that of Mercury (176^{d}), which Croswell *does* get right in the chapter on Mercury. Puzzled readers need only consider the 4-minute difference between Earth's 24-hour day and its spin period (relative to the stars) of $23^{h}\ 56^{m}$.

Otherwise, the writing in *Ten Worlds* generally lives up to that expected by readers of Croswell's other books. His descriptions are carefully worded to elicit rich visual pictures of Solar System objects and are cleverly supported by the selection of large, colour images that illustrate the text. The colour enhancement that is possible for astronomical images can sometimes generate ghastly reproductions, but those in *Ten Worlds* are tastefully done, with some effort to attain realistic hues. If anything, it is the supporting text that is inaccurate. I doubt that any serious sky observer has ever mistaken the colour of Mars with that of blood, and the subtle greenish and bluish hues of Uranus and Neptune are rarely seen to the degree evident in the text images.

I like the descriptions that *Ten Worlds* uses to describe the essential information on each planet, including the historical aspects surrounding their discovery or the onset of new information. Some of the factual tidbits were less appreciated by me previously. On the other hand, there is also a tendency to promulgate many of the current explanations for Solar System oddities, without questioning their validity. I would have preferred to see more oddities left as simply mysterious, or with explanations that provide the rationale for their solution, the traditional Moon origin from a collision with Earth by a Mars-sized planetoid, for example. For those of us from an earlier generation, it sounds too much like Immanual Velikovsky in *Worlds in Collision*.

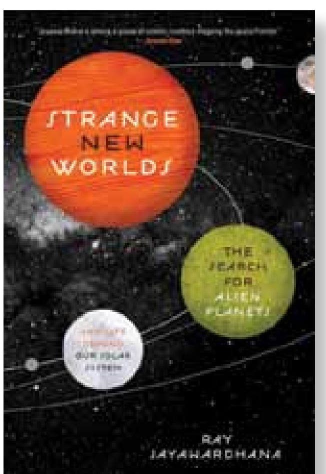
That leads to another quibble with *Ten Worlds*, namely the occasional shortage of insightful explanations for planetary phenomena. Croswell does provide informative explanations for peculiarities such as the colours of Mars, Io, Uranus, and Neptune, for example, but short changes our knowledge of asteroids, comets, and cratering on planetary bodies. Much of our knowledge of the Solar System originates from sound scientific principles applied in innovative ways. The use of polarization measurements of asteroids to deduce their reflectivities, and the perturbations of satellite (natural or otherwise) orbits to establish the distribution of matter inside planets come to mind. Perhaps such information was considered overly complicated for the average nine-year-old?

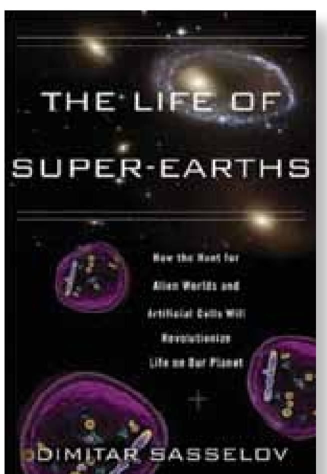
Unfortunately, Croswell also treats gravity in a manner that can cause confusion for readers. Descriptions like Jupiter "has so much mass its gravity pulls on things" stand in stark contrast to the description of gravity provided by Roy Bishop in the *Observer's Handbook* section on Orbital Motion, where he states that "no one has ever felt a force of gravity." That section also notes, "According to Einstein's General Theory of Relativity, gravitation is not a mysterious force that one mass exerts upon a distant mass; gravitation is the geometry (non-Euclidean) of the 4-dimensional spacetime within which we and the stars exist." Thus, while it may be fine to talk about the gravity of Solar System objects, it is incorrect to describe it using terminology that implies a mysterious force pulling on distant objects. I asked Roy about the problem, and finding a proper rewording for Croswell's descriptions may take effort. He suggested "its gravity has a particularly strong effect on objects nearby" for the Jupiter description above, but also wondered if it were realistic to attempt explanations of gravity without starting with Newton.

Except for the strong caveats stated above, *Ten Worlds* is interesting enough to make a useful introduction to the Solar System for novices, although I worry that its misconceptions may cause more grief for educators than it eliminates. Perhaps a new edition of the book can address such problems?

– David G. Turner

David Turner, a life member of the RASC and Professor Emeritus of Astronomy and Physics at Saint Mary's University in Halifax, edits book reviews for the Journal *with much assistance from Randall Rosenfeld. He has taught courses in Solar System astronomy many times in his career.*





Strange New Worlds: The Search for Alien Planets and Life beyond Our Solar System, by Ray Jayawardhana, pages 255, HarperCollins Publishers Ltd., 2011, Price $29.99, ISBN: 978-55468-447-2 (hardcover) and ISBN: 978-1-400-83813-4 (e-book).

The Life of Super-Earths: How the Hunt for Alien Worlds and Artificial Cells Will Revolutionize Life on Our Planet, by Dimitar Sasselov, pages 202 + xvi, Basic Books, Perseus Books Group, 2012, Price $25.99, ISBN: 978-0-465-02193-2 (hardcover) and ISBN: 978-0-465-02340-0 (e-book).

Amateur astronomers interested in the discovery, science, and structure of planets beyond our own Solar System do not have far to look to become acquainted with the impressive strides that have occurred in extra-solar planetary discovery and exploration in the late 20th and early 21st centuries. Two professional astronomers involved in such searches have published separate books (one in 2011 and the other in 2012) that take the general reader through a journey of exploration that fascinates, educates, and leaves one thirsting for more information in the current fast-paced era of extra-solar planetary discoveries.

Sophisticated technologies, creative search techniques, and detailed computer modelling have brought astronomers to a point where our Solar System can be identified, without a doubt, as one of many in our Galaxy, if not in the ever-expanding Universe. As we move forward through the second decade of the third millennium, other extra-solar worlds have now become common realities, formed around neighbouring or distant stars within our galactic home.

Strange New Worlds by Ray Jayawardhana provides a good and concise introduction to the subject of planetary discoveries. Jayawardhana is Canada Research Chair in observational astrophysics at the University of Toronto and a fellow at the Radcliffe Institute for Advanced Study, Harvard University. He begins his account by stating boldly that, "We are living in an extraordinary age of discovery. It is still the early days of planet searches, the "bronze age" as one astronomer put it, but the discoveries have already surprised us and challenged our perceptions many times over."

Strange New Worlds is divided into nine chapters, beginning with an introduction on the quest for other worlds. The author then takes the reader through the formation of planetary systems, false starts and "death star" planets, hot Jupiters and other surprises, the various extra-solar planet search techniques (transits, Doppler shifts, spectroscopy, microlensing), imaging of distant worlds, and the search for alien Earths (wet, rocky habitats). The last chapter discusses the signs of life. *Strange New Worlds* also contains a convenient 10-page glossary of terms to help the uninitiated understand scientific expressions that may not be commonly heard.

An anecdote relates the story of a 45-year-old mother of two sons from a suburb of Auckland, New Zealand, who sent data to Andrew Gould, a professor at Ohio State and leader of the Microlensing Follow-Up Network (MicroFUN) collaboration. Gould had earlier invited professional and amateur observatories to observe the light curve of OGLE-2005-BLG-071, a star expected to produce a rare high-magnification (microlensing) event. The star had been originally detected by the Optical Gravitational Lensing Experiment (OGLE) survey team with a 1.3-metre telescope in Chile. When Jennie McCormick responded to Gould's call the very next day with high-quality observations, he was so impressed that he asked for further observations. "It just shows that you can be a mother, work full-time, and still go out and find planets," said McCormick, who quit school at 16 and works as a personal assistant to the general manager of a storage-bin production company. Gould's professional colleague, Scott Gaudi, also acknowledges the help received from amateur astronomers.

Jayawardhana notes that current searches are for Earth twins, which could harbour life. He quotes Stephane Udry, a planet hunter at Geneva Observatory, predicting, "The golden age is still ahead of us, as we get close to addressing the question of life on other worlds."

The Life of Super-Earths by Dimitar Sasselov, professor of Astronomy at Harvard University, serendipitously continues the theme of the forthcoming golden age of planetary searches. Sasselov, who holds doctoral degrees from Sofia University, Bulgaria, and the University of Toronto, discusses the question of New Earths and the implications to human society of any future discovery of alien life forms, either primitive or more developed. Sasselov serves as the director of the Harvard Origins of Life Initiative and senior advisor at the Radcliffe Institute for Advanced Study at Harvard. He notes that finding signs of life elsewhere will be one of two efforts completing the Copernican revolution.

The Life of Super-Earths grew out of a general education lecture course on Life as a Planetary Phenomenon taught by Sasselov and a colleague at Harvard since 2005. Sasselov points out that the intent of the book is to introduce the subject at a popular level and to provide his own views on the questions being asked through planetary searches. Although he covers some of the subject matter concerning planet searches found in Jayawardhana's book, he takes the discussion to another level, which ensures the reader does not cover old ground. There is fresh insight and refreshing discussion, leaving the reader with an expectation of ground-breaking scientific opportunity yet-to-come, as well as a sense of the awe-inspiring potential of true discovery.

The Life of Super-Earths contains 12 chapters in each of two distinct headings: Part 1: Super-Earth; and Part 2: Origins of Life. The focus in the first section is on the search for Super-Earths, planetary bodies within a star's habitable zone that could possibly sustain life in some form. The second section deals with the concepts of chemistry, synthetic biology, long-term stability, and life. Sasselov argues that life is a system, a chemical system that, at least as we know it, seems to work only on small scales. He notes that life needs planets, life is a low-temperature phenomenon, and life seems to need environments allowing chemical concentrations. "Terrestrial planets [as opposed to gas giants] are unique in providing a range of rich chemical concentrations, energy sources, and sheltered environments. This is a profound realization!" he argues.

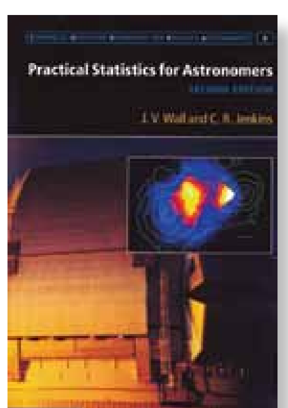
Sasselov asks rhetorically more than once in his book whether our Earth is the ideal planet for life, to which he answers "no, Super-Earths are better." According to Sasselov, super-Earths are "excellent cradles for life." We read that the habitable zone, indicated by the presence of surface water, depends on a comfortable distance/range of a terrestrial-type planet from its host star. Although the habitable zone concept helps in terms of temperature, it is not sufficient, since there are many other factors contributing to the habitability of a planet. Sasselov therefore prefers to discuss what he terms the habitable potential rather than zone. A bonus to the main text is a section of Notes that contains useful information nicely supplementing *The Life of Super-Earths*.

Both *Strange New Worlds* and *The Life of Super-Earths* are two books that should not be ignored by anyone interested in the search for planets outside our Solar System. Each volume has its own strengths and purpose, and both are recommended as companion and complementary reads. Of the two, *The Life of Super-Earths* is the most intriguing because of its focus on super-Earths, synthetic biology, and the discussion of a "new tree of life"—chemically different from what we have experienced here on Earth.

Future academics may well point to *Strange New Worlds* and *The Life of Super-Earths* as two fundamental short books that captured the spirit of the times in humanity's continuing search for a more advanced understanding of its place in the Universe. Both could be seen as akin to Galileo's *Dialogue Concerning the Two Chief World Systems* of 1632 and Copernicus's *On the Revolutions of the Celestial Spheres* of 1543, books that changed humanity's view of its place in the Universe of the day.

– Andrew I. Oakes

Andrew Oakes is a long-time member of RASC, an armchair amateur astronomer who collects books on Copernicus and Galileo, and someone who is fascinated with the present scientific era, the completion-times of the Copernican revolution. Andrew lives in Courtice, Ontario..



Practical Statistics for Astronomers, 2nd Edition, by J. V. Wall and C. R. Jenkins, pages 353 + xix, 23 cm × 15 cm, Cambridge University Press, 2012. Price $50.00 US, paperback (ISBN 978-0-521-73249-9).

With the publication of the first edition of *Practical Statistics for Astronomers* in 2003, Wall and Jenkins addressed the long-unfulfilled need for precisely what their title describes: a practical guide to statistics for people who are not statisticians. Astronomy is increasingly a statistical discipline, a science of large data sets designed for the rigorous testing of hypotheses. In everything, from the analysis of fluctuations in the cosmic microwave background, to counting statistics of individual X-ray photons, to the daunting task of describing the functional form of the stellar initial mass function, statistical rigour is essential.

Despite the centrality of statistics in modern astronomy, few graduate programs in astronomy include a course in statistics. In the introduction to *Practical Statistics*, Wall humorously alludes to the conversation he had with a fellow astronomer about the lack of statistical preparation among graduate students in astronomy. Predictably, having identified the problem, he was pegged to develop a solution. Hence this book, which does an admirable job of teaching statistics to astronomers, both efficiently and practically.

I should confess a bias. As a Ph.D. student who had not taken statistics since high school, I faced enormous statistical challenges in my own research. I sought high and low for a book that could explain statistics to me in language I could understand. Libraries are filled with statistical texts intended for mathematicians, but they mainly treat statistical problems in the abstract; I despaired of being able to adapt such highly abstract mathematics to my own scientific problems. For a neophyte statistician, the language of "null hypotheses" and "covariance matrices" can be bewildering. Practical statistics texts tend to be aimed toward researchers in medicine and engineering, where the statistical challenges may bear little resemblance to those encountered in astronomy. So, when the first edition of *Practical Statistics for Astronomers* (2003) was published midway through my Ph.D. degree program, I received it like manna from heaven.

Wall and Jenkins wisely begin at the beginning, with a short discussion of the scientific method and decision making. That is expanded in the second edition to include a timeline of the development of practical statistics. In their second chapter, the authors quickly and efficiently teach us the language of statistics, using the conventional example of rolling dice to define probability. The chapters are short and concise, with easy-to-read explanations of important topics such as Bayes' theorem, probability distributions, and Monte Carlo statistics. Exercises are given at the end of each chapter, but no solutions are given in the text itself. Oddly, beautifully worked solutions are available on Wall's Web site at www.astro.ubc.ca/people/jvw/ASTROSTATS/, but it is only mentioned in passing in the preamble to the book. Although it lacks solutions to the exercises, the second edition does include in each chapter more worked-out examples than did the first edition.

The second edition also expands the highly relevant discussion of data modelling and parameter estimation. The single short chapter from the first edition is broken into "basic" and "advanced" chapters in the second edition. Some of the language is modified to make it even more digestible to astronomers: "Surface distribution—2D statistics" becomes "Statistics of large-scale structure." A new epilogue gives an overview of the importance of statistics in modern astronomy, particularly in cosmology. Owners of the first edition may not need to rush to replace it with the second, but first-time readers of the second edition will appreciate the numerous small adjustments that make the book even more readable.

Practical Statistics for Astronomers is an excellent text and reference book for professional astronomers, especially those with little expertise in statistics. Because the book assumes little prior knowledge of statistics, the dedicated amateur who is familiar with calculus will be at home here, too.

– Michael Reid

Mike Reid is Director of Outreach and Education at the Dunlap Institute for Astronomy & Astrophysics at the University of Toronto, and is a Lecturer in the university's Department of Astronomy & Astrophysics. His work embraces high-mass star-forming regions at submillimetre wavelengths, the large-scale structure of the Universe, and gravitational collapse of molecular cloud cores. He finds it virtually impossible to escape from statistics.

It's Not All Sirius—Cartoon

by Ted Dunphy

Astrocryptic Answers

by Curt Nason

1 B	O	2 B	R	3 O	F	4 F	■	5 T	O	6 A	S	7 T
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10 H	I	D	A	L	G	O	■	11 A	L	12 V	A	N
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13 A	C	A	M	A	R	■	14 I	15 S	O	L	D	E
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17 I	N	D	U	18 S	■	19 A	C	C	R	E	T	20 E
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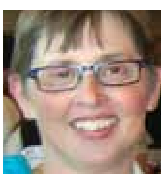
Call for Nominations for RASC National Awards



by Mary Lou Whitehorne, Awards Committee Chair (mlwhitehorne@hfx.eastlink.ca)

Do you know someone who has done outstanding work in the RASC?

Do they qualify for one of the RASC's national awards?

A list of national awards is given below. Please look within your Centre and among our unattached members for those bright and shining stars that deserve recognition. Go to rasc.ca/awards to check the requirements for these national awards, think about the contributions of those hard-working RASC members that you know, and nominate them for an award. Now is the time! Nominations are due on 2012 December 31.

RASC National Awards

The RASC sponsors several annual national awards that recognize achievement or service by our members. These awards include:

The **Chant Medal** is awarded, not more than once a year, to an amateur astronomer resident in Canada on the basis of the value of the work carried out in astronomy and closely allied fields, for original investigation, and specifically not for services to the Society, worthy though these may be.

The **Ken Chilton Prize** is awarded annually to an amateur astronomer resident in Canada, in recognition of a significant piece of astronomical work carried out or published recently.

The new **Qilak Award for Astronomy Outreach and Communication** recognizes individual Canadian residents, or teams of residents, who have made an outstanding contribution, during a particular time period, either to the public understanding and appreciation of astronomy in Canada, or to informal astronomy education in Canada, and to promote such activities among the members of the sponsoring organizations.

The **Service Award** is given to members in recognition of outstanding service, rendered over an extended period of time, where such service has had a major impact on the work of the Society and/or of a Centre of the Society.

The **Simon Newcomb Award** is intended to encourage members to write on the topic of astronomy for the Society or the general public, and to recognize the best published works through an annual award.

More detail, including eligibility and nomination requirements for each award can be found at www.rasc.ca/awards. Click on the links to individual awards for full information.

The deadline for nominations is 2012 December 31. Send your letters of nomination or questions about the awards program to Mary Lou Whitehorne, Awards Committee Chair at mlwhitehorne@hfx.eastlink.ca ✶

Mary Lou Whitehorne
Past President & Chair, Awards Committee
The Royal Astronomical Society of Canada.

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Journal

Great Images

Lynn Hilborn captured these galactic jewels in Canes Venatici with a total of six hours of exposure. NGC 5371, the largest galaxy, is a face-on barred spiral lying about 100 Mly distant. On the right is Hickson Galaxy Group 68, a cluster at a similar distance. Together the galaxies are known as the Big Lick Cluster. Lynn used a TEC 140 telescope at f/5.6 and an FLI ML8300 camera. Exposure: Lum: 19×10m; RGB each 12×5m.