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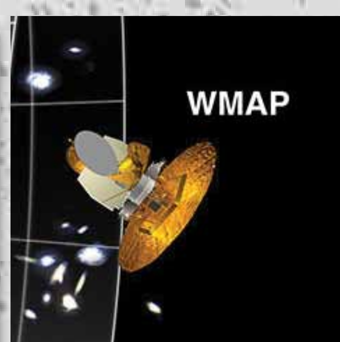

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On the Cover: Mike Wirth provides us with two spectacular lunar scenes from his home in northern Mexico. On the left, the craters Theophilus, Cyrillus, and Mädler form a rough line from top to bottom. In the right image, majestic terraced 93-km-wide Copernicus dominates the lava plains of Mare Insularum.

President's Corner

by Mary Lou Whitehorne, President, RASC

I am going to make a statement that not everyone may agree with: ***the National Executive team tries very hard to communicate often and openly with our Centres and members***. This column is only one of the several ways we try to do this. Other opportunities for communication come through the Bulletin, eNews on our Web page, the email announce list, and most importantly, through discussion papers and reports that are presented to National Council. I'll say more about this further along in this column.

Member surveys are communication tools, too. We do them from time to time as a way of finding out what our members are thinking, in a way that is separate and less random than monitoring all of our many RASC email discussion lists.

Not very long ago, all RASC members with an email address on file received a survey about the RASC. About 3200 surveys went out and 900 of you responded with thoughtful care and candour about your Society. A rate of response like this – 28 percent – is remarkably high and very gratifying to the executive team that sent the survey out. Clearly, many of you care very much about the RASC.

The survey results were overwhelmingly positive, and it is gratifying to know that a large majority of our members are happy with the benefits of membership in the RASC, and with the programs, products, and processes of the Society.

Enough about the present. What about the future? The survey was also a consultation with you about our future and about developing a strategic plan. You responded to the survey with hundreds of narrative replies to many of the survey questions. Your Executive Committee spent plenty of hours reading and digesting all that input. The wording of our new vision, mission, and values statements is a fusion of all the inspiring words and phrases that came from the hearts and minds of those 900 responding members.

With the survey results in hand, the Executive Committee went to work to build a draft strategic plan. This draft plan was presented first to National Council and then shared with our Centres for consultation and feedback. As of this writing, the consultation process is still ongoing. By the time you actually read this, the Executive hopes to have all of the Centre input in hand for the purpose of adjusting the draft strategic plan.

The draft strategic plan is not carved in granite. The Executive Committee hopes our Centres will give it due consideration and provide us with constructive feedback. The final strategic plan, when adopted by National Council, will give the Society direction, guidance, and milestones as we move ahead, engaging challenges and making decisions that will have an impact over the long term. It will provide a foundation for all other planning that we do as an organization. It will help establish priorities, provide focus and clarity, and it will communicate to everyone what is most important to the RASC.

I have received a couple of complaints about the consultation process we have chosen. While it would be nice to involve everyone in every decision at every level, I am sure all of you reading this will agree that full involvement from everyone from the very beginning would be an impossible process to manage successfully. I trust our members to agree that we have made a good start. I believe that, through the consultation process in place, everyone will have adequate opportunity

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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to contribute to the final strategic plan.

As mentioned in my first paragraph, there is much relevant background information to be found in the discussion papers and reports made to Council from the last year or so. These are posted on the members-only section of the Web site: `www.rasc.ca/private/reports/index.shtml`

I cannot stress enough that one of the most important links in communication between National Council and our Centres, is/are the National Council representative(s) from each Centre. These key people are essentially two-way information conduits, carrying information from the Centre to National Council, and vice versa. This is a hugely important role!

More information about the roles and responsibilities of National Council reps can be found on the members-only section of the Web site: `www.rasc.ca/private/council/membership.shtml`

For those of you who want even more background and context into what goes on in the Society, how things are done, and how decisions are made, there is plenty to interest you in the By-Laws and the RASC Manual. These are also posted on the members-only section of the Web site:

By-Laws: `www.rasc.ca/private/governance/bylaws.shtml`
RASC Manual: `www.rasc.ca/private/manual.shtml`

Happy reading, and happy communicating, everyone.
Quo Ducit Urania!

News Notes/ *En manchettes*

Compiled by Andrew I. Oakes (copernicus1543@gmail.com)

"Footprints" in dusty space around Stars lead to exoplanets

Dust tails around stars may help astronomers discover planets orbiting those stars – and these tails may be easier to notice than the planets themselves. Earth has such a dust tail through which the *Spitzer Space Telescope* traveled in 2010. The encounter gave astronomers a clear idea of what the tail actually looks like.

According to *Spitzer* project scientist Mike Werner, planets in distant planetary systems probably have similar dust tails and, in some circumstances, these dust features may be easier to distinguish than the planets themselves.

"So we need to know how to recognize them [the dust features]," he said in an information item released by *Science@NASA* in mid-November 2010.

This ability to recognize the phenomenon could be a big help to planet hunters trying to track down alien worlds, of which more than 500 have been pinpointed to date using other search methods. Directly imaging exoplanets is very difficult to do, as these extra-Solar System planets are hiding in the glare of the home stars they orbit, and are comparatively small and faint. "A dust tail like Earth's could produce a bigger signal than a planet does. And it could alert researchers to a planet too small to see otherwise," Werner said.

The reason for Earth's dust tail: the whole Solar System is dusty because interplanetary space is littered with fragments of comets and colliding asteroids. When the Earth orbits through this grubby environment, a tail forms in the rear, akin to swaths of fallen leaves swirling up behind a street sweeper.

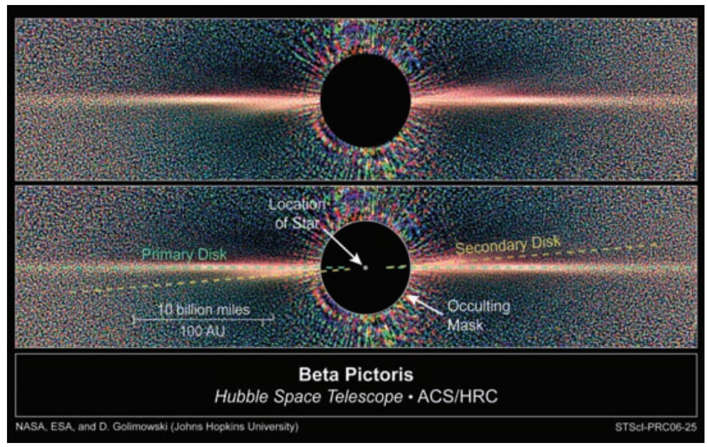

Figure 1: *Hubble Space Telescope* view of Beta Pictoris, an image taken 2003 October 1, shows a primary dust disk and a much fainter secondary dust disk. The secondary disk extends at least 38.4 billion kilometres from the star and is tilted roughly 4 to 5 degrees from the primary disk. The secondary disk is circumstantial evidence for the existence of a planet in a similarly inclined orbit. Image: NASA, ESA, D. Golimowski (Johns Hopkins University), D. Ardila (IPAC), J. Krist (JPL), M. Clampin (GSFC), H. Ford (JHU), and G. Illingworth (UCO/Lick) and the ACS Science Team

"As Earth orbits the Sun, it creates a sort of shell or depression that dust particles fall into, creating a thickening of dust – the tail – that

The Royal Astronomical Society of Canada

Vision

To inspire curiosity in all people about the Universe. To share scientific knowledge and to foster collaboration in astronomical pursuits.

Mission

The Royal Astronomical Society of Canada (RASC) encourages improved understanding of astronomy for all people, through education, outreach, research, publication, enjoyment, partnership, and community.

Values

The RASC has a proud heritage of excellence and integrity in its programmes and partnerships. As a vital part of Canada's science community, we support discovery through the scientific method. We inspire and encourage people of all ages to learn about and enjoy astronomy.

Earth pulls along via gravity," explains Werner. "In fact, the tail trails our planet all the way around the Sun, forming a large dusty ring." Mark Clampin of NASA's Goddard Space Flight Center said that in some stars' dust disks there are bumps, warps, rings, and offsets telling astronomers that planets are interacting with the dust. "So we can 'follow the dust' to the planets," said Clampin. "So far, we've seen about 20 dust disks in other solar systems. And in some of those cases, following the dust has already paid off."

Two recent examples are the bright southern star Fomalhaut, where, unexpectedly, a dust ring was found that led astronomers to track a planet by this "footprint" in the dust. Another *Hubble* image shows a dusty disk around Beta Pictoris, a star in the constellation Pictor, or "Painter's Easel."

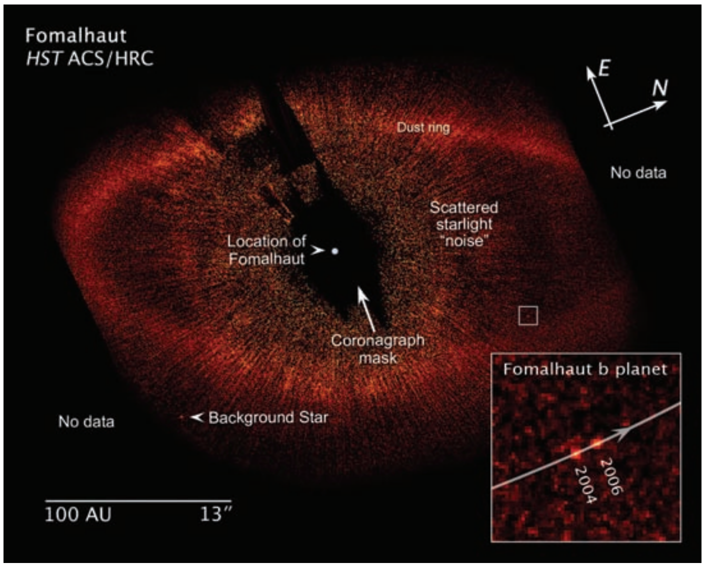

Figure 2: A sharp, composite photo from the *Hubble Space Telescope* details a surrounding ring of dusty debris around Fomalhaut, a bright, young star, 25 light-years from planet Earth. The tremendous glare from the star is masked by an occulting disk in the space telescope camera's coronagraph. The tiny point of light in the small box at the right is believed to be a planet about three times the mass of Jupiter orbiting 17.1 billion kilometres from the star (almost 23 times the Sun-Jupiter distance). Image: NASA, ESA, P. Kalas, J. Graham, E. Chiang, E. Kite (Univ. California, Berkeley), M. Clampin (NASA/Goddard), M. Fitzgerald (Lawrence Livermore NL), K. Stapelfeldt, J. Krist (NASA/JPL)

Snapshot of contemporary astronomy presented in Anthology

A book examining cutting-edge astronomy from around the world is available in electronic (PDF) format as a free download text from the European Organisation for Astronomical Research in the Southern Hemisphere (ESO).

Titled *Postcards from the Edge of the Universe – An Anthology of Frontline Astronomy from Around the World*, the book is a legacy of the International Year of Astronomy 2009 Cornerstone project *Cosmic Diary*, an astronomy blog.

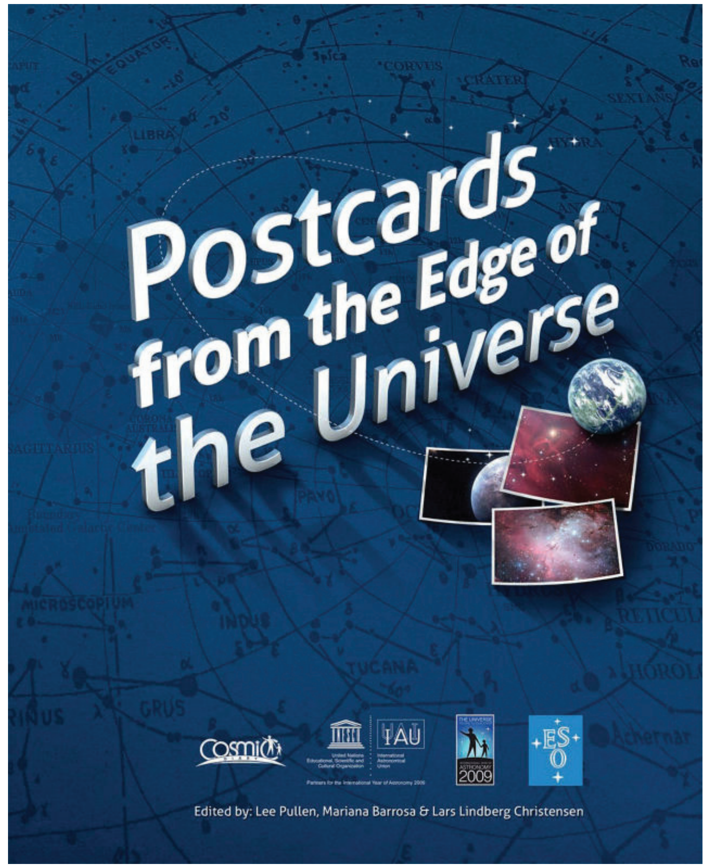

Figure 3: The free e-book in PDF format entitled *Postcards from the Edge of the Universe*; a hard copy costs € 9,90 (Lawrence Livermore NL), K. Stapelfeldt, J. Krist (NASA/JPL)

The text is based on a hand-picked selection of the best posts and science writing by 24 frontline astronomers. The edited anthology gives a snapshot of contemporary astronomy, with the four-page popular-science articles, all reflecting a personal flavour, as each contributor selected their own research topic, giving the reader a personal insight into work at the forefront of astronomy.

ESO is an intergovernmental science and technology organization in astronomy. Headquartered in Garching, near Munich, Germany, it consists of 14 member states – Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Italy, Netherlands, Portugal, Spain, Sweden, Switzerland, and the United Kingdom.

Postcards from the Edge of the Universe is available at the following link: `www.postcardsfromuniverse.org/`.

Visual representation depicts timeline of the Universe

Astronomers have developed a graphic representation of the evolution of the Universe, tracing its growth over the past 13.7 billion years, putting into context their theories of post-Big Bang expansion.

The timeline begins with the depiction of the earliest moment scientists can now probe, when a period of "inflation" produced a burst of exponential growth in the Universe as seen in the far left of the timeline. For the next several billion years, the expansion of the Universe gradually slowed down as the matter pulled on itself via gravity.

More recently (continuing horizontally to the right along the visual timeline), the expansion has begun to speed up again as the repulsive effects of dark energy have come to dominate the expansion of the Universe. In the scientists' graphic, size is depicted by the vertical extent of the grid.

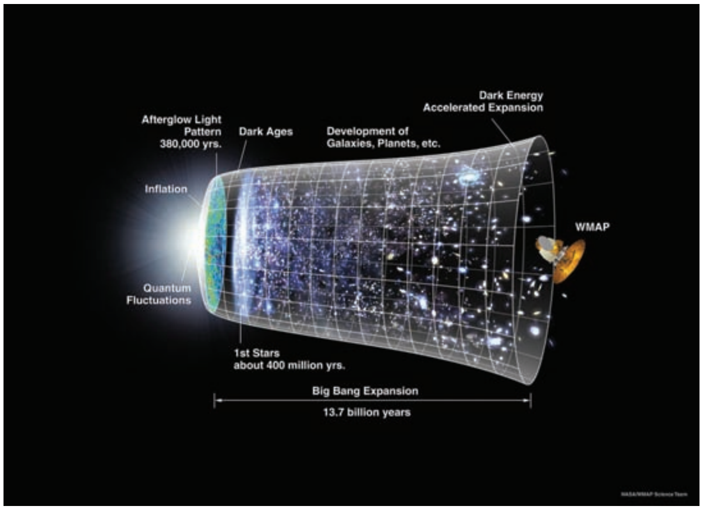

Figure 4: 13.7 billion-year timeline of the Universe. Image: NASA / WMAP Science Team

The afterglow light seen by NASA's *Wilkinson Microwave Anisotropy Probe (WMAP)* was emitted about 380,000 years after inflation and has traversed the Universe largely unimpeded since then. Astronomers believe the conditions of earlier times are imprinted on this light and that it forms a backlight for later developments of the Universe.

The *WMAP* satellite mission, which was designed to determine the geometry, content, and evolution of the Universe, ended its science observations on 2010 August 20. The complete nine-year data set is now being processed, with the final legacy data products to be released by 2012.

Imaged spiral results in scientific speculation

The *Hubble Space Telescope* has imaged an extraordinary spiral in near-infrared light that is causing astronomers to puzzle over what caused the strange spiral structure in the first place and why it actually glows. The preliminary speculation: that the glow may be caused by light reflected from nearby stars, while the spiral itself is the result of a star in a binary-star system entering the planetary nebula phase, when its outer atmosphere is ejected.

Figure 5: *Hubble* captures extraordinary planetary nebula spiral. Image: NASA, ESA, *Hubble*, R. Sahai (JPL)

The expansion rate of the spiral gas suggests that a new layer must appear about every 800 years, a close match to the time it takes for the two stars to orbit each other.

Spacecraft fails at Venus orbit insertion

The Japanese unmanned spacecraft, *Akatsuki*, has failed its attempt at self-insertion into orbit around Venus. The Japan Aerospace Exploration Agency (JAXA) estimated that the next opportunity for orbital insertion will not come for six years. Insertion was to have started as the spacecraft fired its primary thruster on last December 6. A communications blackout, expected for about 22 minutes during and after the engine burn, lasted more than 90 minutes, after which Japanese ground controllers regained contact with the spacecraft. *Akatsuki* was then communicating through its low-gain antenna.

Officials concluded that the spacecraft was in safe mode, was still alive but had failed to enter orbit around Venus as had been planned. According to a JAXA statement, the exploration agency "found that the orbiter was not injected into the planned orbit as a result of orbit estimation." Project officials have set up an investigation team to study the cause of the failure.

Awarding of Physics and Astronomy doctorates nearing 2000

The *2009 Survey of Earned Doctorates (SED)* from U.S. academic institutions reports that 49,562 research doctorates were awarded in 2009, up 1.6 percent over the 2008 total and representing the highest number ever reported by the SED.

Doctorates awarded in the science and engineering (S&E) fields were up 1.9 percent over 2008, owing entirely to growth in numbers of female S&E doctorate recipients. Doctorates awarded in S&E fields of study accounted for most of the overall growth in doctorate awards in 2009.

A total of 1891 Physics and Astronomy doctorates, which fall within the S&E category, were awarded in 2009, up from 1835 in 2008 and 1430 in 1999. The table below shows the progression over the past 11 years.

Eleven-year pattern of Physics and Astronomy Doctorates in the United States										
1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
1430	1389	1384	1264	1247	1349	1517	1565	1777	1835	1891

Data come from an annual census of individuals who receive doctoral degrees from research studies at accredited U.S. academic institutions. This census is a continuous examination of doctoral education ongoing since 1957.

The SED is sponsored by six federal agencies: the National Aeronautics and Space Administration, National Endowment for the Humanities, National Institutes of Health, National Science Foundation, U.S. Department of Agriculture, and U.S. Department of Education.

The 2009 survey was recently published by the National Science Foundation, Division of Science Resources Statistics.

Andrew I. Oakes is a long-time Unattached Member of RASC who lives in Courtice, Ontario.

Research papers
Articles de researche

Identification of a Megadome Near the Lunar Crater Kies: Morphometric Analysis and Proposed Intrusive Origin

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Abstract: In this article, we describe the morphometric and rheologic results for a large dome on the Moon situated near the lunar crater Kies, to the south of the well-known effusive lunar dome Kies π. The selenographic coordinates are determined to be 28.30° S and 23.82° W. This megadome, which we named Kies 2 (K2), has an elongated base diameter determined as 51.0 × 34.3 km. Using an image-based photoclinometry approach to reconstruct the three-dimensional shape of K2, we find that its height amounts to 55 ± 5 m, resulting in an average flank slope of 0.15°. The edifice volume corresponds to 37.7 km³. The examined dome is associated with a linear rille presumably formed by tensional stress, while a sinuous rille is crossing its surface. According to the determined morphometric properties, the dome belongs to class In1 in the classification scheme for candidate intrusive domes introduced in previous studies. We point out arguments against and in favour of an intrusive origin of K2 and discuss possible alternative modes of formation. Based on a laccolith model, we infer an intrusion depth of 11.4 km and an extraordinarily high magma pressure of 99 MPa for a lunar laccolith with the horizontal and vertical dimensions of the megadome K2.

Résumé: Dans cet article nous décrivons les résultats morphométriques et rhéologiques concernant un grand dôme sur la lune situé près de la cratère lunaire Kies, au sud du dôme effusif célèbre Kies π. Les coordonnées sélénographiques sont établies à 28.30° S et 23.82° O. Ce mégadôme, que nous avons nommé Kies 2 (K2), possède un diamètre de base de 51,0 × 34,3 kms. En utilisant une méthode photoclinométrique à base d'images afin de reconstituer la forme de K2 en trois dimensions, nous trouvons que sa hauteur atteint les 55 ±5 m, donnant une pente de 0.15° à son flanc. Le volume de l'empilement correspond à 37.7 km³. Le dôme étudié est associé à un canal linéaire, présumément formé par une tension directionnelle, tandis qu'un canal méandre traverse sa surface. Selon les propriétés morphométriques établies, le dôme fait partie de la classe In1 du système de classification pour candidature aux dômes intrusifs décrit dans les études antérieurs. Nous notons les arguments contre et en faveur de l'origine intrusive de K2, et nous discutons de la possibilité de modes alternatifs de formations. Basé sur un modèle laccolite, nous déduisons une profondeur d'intrusion de 11.4 km et une pression extrêmement élevée de magma de 99 Mpa pour un laccolite lunaire avec dimensions horizontales et verticales du mégadôme K2.

1. Introduction

The apparent internal origin of lunar domes was a major factor in endogenic interpretations of the *maria*, and their low profiles suggest a volcanism characteristic of fluid mafic magmas (Wilhelms, 1987). The extrusive origin of lunar domes and their similarity to terrestrial features like small shield volcanoes have been described in the literature (Head & Gifford, 1980; Basaltic Volcanism Study Project, 1981). Domes representing volcanic sources are smooth-surfaced and usually have a summit crater pit. Most vents related to domes appear to be associated with surrounding lava plains of known volcanic origin. The presence of a summit pit or vent argues against an intrusive or laccolithic origin for the majority of these features. In previous studies, we have examined a set of lunar domes with very low flank slopes, which differ in several respects from the more commonly occurring lunar effusive domes (Lena & Wöhler 2008a, Wöhler & Lena 2009). Some of these domes are exceptionally large, and most of them are associated with faults or linear rilles of presumably tensional origin. Lunar domes of a possibly intrusive nature were formed in different dome fields and are associated with a wide variety of lava types (Wöhler & Lena, 2009). All described candidate intrusive domes are characterized by very low flank slopes in the range 0.1°–0.9°. Structures with even lower flank slopes may exist, but they would be extremely difficult to observe. The profile of domes that are flat suggests that there was no gradual inclination at the vent (the rising lava did not build up the dome in a series of flows) but, possibly, a subsurface intrusion of magma (Wöhler & Lena, 2009).

Accordingly, these domes might be interpreted as surface manifestations of laccolithic intrusions formed by flexure-induced vertical uplift of the lunar crust (or, alternatively, as low effusive edifices due to lava mantling of highland terrain, or kipukas, or structural features). On the Earth, subsurface magmatic intrusions often form laccoliths, where magma flows under a surface of solidified lava and lifts it up. Johnson & Pollard (1973) recognize that laccolith formation is characterized by three distinct stages. During the first stage, a thin sill-like unit undergoes lateral growth. The second stage consists of vertical growth caused by flexure of the overlying strata due to the pressurised magma. If the flexure-induced vertical uplift exceeds a few hundred metres, piston-like uplift of a fault-bounded block may occur during the third stage of laccolith formation. With their low profile, *Lunar Orbiter* and *Clementine* images do not show these domes very well, due to the typically high solar angle under which these images were acquired. Hence, as part of our program of observing and cataloguing lunar domes, we have used high-resolution telescopic CCD images taken under oblique illumination conditions.

The Geologic Lunar Research (GLR) group has an ongoing project to study lunar domes with the purpose of their classification based on rheologic properties. In fact, given the diameter, height, and volume of a lunar dome, rheologic quantities, such as the effusion rate and the duration of the effusion process, can be inferred based on geophysical modelling (Wilson & Head 2003). The evident differences in dome shapes and rheologic parameters raise broad questions concerning the source regions of the various dome types and the corresponding implications for local and regional lunar volcanism; (1) the reasons why certain types of lunar domes are concentrated in certain areas of the lunar surface, (2) especially why domes with gentle flank slopes tend to be aligned, and (3) what differences in the lunar interior are responsible for the different lunar dome properties observed on the surface (Wöhler *et al.* 2007).

As a historical note of interest, an amateur lunar-dome catalogue was compiled in the 1960s as part of a joint effort between the Association of Lunar and Planetary Observers (ALPO) and the British Astronomical Association (BAA). A revised lunar-dome catalogue was published by the ALPO in 1992. It contains 713 domes, but also includes erroneous or incomplete data. When ALPO and the BAA first began their dome catalogue, the observers were using different maps, which in turn led to some of the domes in the catalogue being multiple observations of the same dome. Brungart (1964) determined values for the dome heights and flank slopes based on shadow length measurements in telescopic photography, but characterizes the results obtained as merely representing order-of-magnitude estimates. As an example, for the well-known domes Arago α and β near Arago crater in western Mare Tranquillitatis, a height of 700 m and 800 m with an average slope of 5.5° and 6.0° was reported, respectively. Results obtained by Wöhler *et al.* (2006) with photoclinometric and shape from shading analysis based on high-resolution telescopic CCD images, indicate lower heights of 330 m and 270 m, along with slopes of 1.5° and 1.3°, respectively.

In previous works, we have introduced a novel classification scheme for lunar domes based on their spectral and morphometric properties, and we have examined (for a variety of lunar *mare* domes) the relationship between the conditions in the magma source regions and the resulting eruption conditions at the surface (Wöhler *et al.* 2006, 2007). The Consolidated Lunar Dome Catalogue published online (Lena & Wöhler 2008b) contains all lunar domes that have been studied in detail by the GLR group and for which reasonably accurate morphometric properties could be determined. The catalogue is continuously updated according to ongoing observing and modelling activities.

The typical hemispherical or flat mound with summit pit is widely accepted to be the lunar equivalent of familiar small terrestrial shield volcanoes (Head & Gifford 1980). Many other lower rises have more-gentle slopes, have no summit pit, and sometimes lack the roughly circular outlines of classical domes. Magmatic processes involve the emplacement and solidification of igneous rock from molten material (magma) derived from a planetary interior. Plutonic or intrusive processes involve magma movement and solidification under the surface, while volcanic or extrusive processes correspond to the eruption and emplacement of magma on the surface (lava flows). Magma commonly reaches the surface through propagating dikes, its rise driven by the magma overpressure and thermal and chemical buoyancy variations.

In previous studies, we have proposed a classification scheme and interpretation of origin for domes with elongated shapes and very low slope, interpreting these domical objects or "swells" as the possible results of intrusive doming (Lena & Wöhler 2008a; Wöhler & Lena 2009). Intrusions are subsurface concentrations of magma that have locally uplifted the *mare* but do not erupt, a mechanism reported for terrestrial laccoliths and described in detail by Pollard & Johnson (1973). Although the diameters of the proposed intrusive lunar domes are typically twice as large as terrestrial laccolith diameters (Wöhler & Lena 2009), it is not still clearly understood from the available data if there was a particular period of lunar history when they were generated and how they relate to the *maria*. Laccoliths have recently been proposed to explain various geological features such as domes or floor-fractured craters on the surface of the Moon and also Mars and Mercury by Head *et al.* (2009). In comparison to the Earth, Michaut (2010a, b) shows, based on a numerical model of magmatic intrusions, that the smaller gravity and dryer crust of the Moon would lead to an increase of the characteristic elastic length scale for laccolithic intrusions by a factor of about two, which would explain the systematic differences in size between terrestrial and putative lunar laccoliths.

In this paper, our goal is to assess the evidence for an intrusive origin of the lunar megadome Kies 2 (K2) located south of the classical effusive dome Kies π based on telescopic CCD images acquired under strongly oblique illumination. We examine the morphometric characteristics by making use of a combined photoclinometry and shape-from-shading approach (Horn 1989, Wöhler & Hafezi 2005, Lena *et al.* 2006; Wöhler *et al.* 2006). The values obtained are used to derive information about the physical parameters of dome formation under the assumption of an intrusive mode of formation, providing a geological interpretation of our morphometric data.

2. Ground-based observations

Telescopic CCD images of the megadome K2 examined in this study are shown in Figures 1a and 1b. The images were taken under strongly oblique illumination conditions using telescopes with apertures of 200 mm and 315 mm. For image acquisition, a LVI 1392 Pro camera and an Atik CCD camera were employed. The images were generated by stacking several hundreds of video frames. For this purpose, the *Iris* and *Registax* software packages were used, relying on a cross-correlation technique similar to the one described by Baumgardner *et al.* (2000). The scale of the images is 350 m per pixel on the lunar surface. Due to atmospheric seeing, however, the effective resolution (corresponding to the width of the point-spread function) is not much better than 1 km. The images are oriented with north to the top and west to the left.

The image shown in Figure 1a was taken on 2009 August 15 at 03:50 UTC. The image shown in Figure 1b was acquired on 2009 July 16. It confirms the presence of the large structure. Using the *Lunar Terminator Visualization Tool (LTVT)* software package

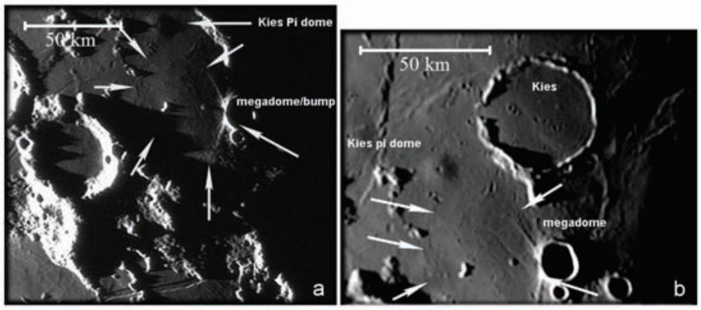

Figure 1: Telescopic CCD images of the lunar megadome Kies 2 of possibly intrusive origin.

by Mosher & Bondo (2006), we determined the selenographic positions of the examined megadome to be 28.30° S and 23.82° W. *LTVT* is a freeware program that displays a wide range of lunar imagery and permits a variety of highly accurate measurements in these images. Selenographic coordinates, sizes, and shadow lengths of features can be estimated based on a calibration procedure. This calibration allows *LTVT* to make the spatial adjustments necessary to bring the observed positions of lunar features into conformity with those expected from the Unified Lunar Control Network (ULCN). The ULCN is a set of points on the lunar surface whose three-dimensional selenodetic coordinates (latitude, longitude, and radial distance from the lunar centre) have been determined by careful measurement. Typically, these points consist of very small craters. According to Davies *et al.* (1994), the three-dimensional positions are expressed in the mean-Earth/polar-axis system.

3. Clementine imagery: Surface composition

For spectral analysis, we utilize the Clementine UVVIS five-band data set as published by Eliason *et al.* (1999). For all spectral data extracted in this study, the size of the sample area on the lunar surface was set to 2×2 km^2. Variations in soil composition, maturity, particle size, and viewing geometry are indicated by the reflectance R_{750} at 750 nm wavelength. Another important spectral parameter is the R_{415}/R_{750} ratio, which is correlated with the variations in TiO_2 content of *mare* soils. A corresponding relation was established by Charette *et al.* (1974), specifically regarding different basaltic units in Mare Tranquillitatis. A comprehensive characterization of spectral features attributable to titanium in lunar soils is provided by Burns *et al.* (1976). Relying on TiO_2 abundance data obtained with the *Lunar Prospector* neutron spectrometer, Gillis-Davis *et al.* (2006) demonstrate that other factors, such as ilmenite grain size or FeO content, may give a significant contribution to the UV/VIS ratio. According to these analyses, TiO_2 content is monotonously increasing with R_{415}/R_{750} ratio, but the correlation is only moderate and the data display a strong scatter. The third regarded spectral parameter, the R_{950}/R_{750} ratio, is related to the strength of the mafic absorption band, representing a measure for the FeO content of the soil, being also sensitive to the optical maturity of *mare* and highland materials (Lucey *et al.* 1998).

The spectral data of the dome K2 are listed in Table 1. Clementine UVVIS imagery indicates a 750 nm reflectance of $R_{750} = 0.090$, a moderate value for the UV/VIS colour ratio of $R_{415}/R_{750} = 0.6129$, indicating a moderate TiO_2 content, and a high R_{950}/R_{750} ratio of 1.0560 indicating a high optical maturity and thus a high exposure age of the dome surface. The absence of a spectral contrast between K2 and the surrounding surface indicates that the dome is not a piece of pre-existing elevated terrain later embayed by basaltic lava, a so-called kipuka.

4. Lunar Orbiter imagery

As very low solar-illumination angles are required to reveal the gentle slopes of lunar domes, most of these subtle structures do not appear in the available sets of orbital images. *Lunar Orbiter* image IV-125-H1 of the examined dome is shown in Figure 2. A slightly curved rille crosses the surface of the dome K2, indicating structural control by subsurface geology. A similar curvilinear structure can be found on the surface of the dome V1 in western Mare Serenitatis, for which the informal name "Valentine dome" was coined by A. Herring for the heart-shaped outline of this large structure, which does not conform to the circular outline of a classic effusive lunar dome; the observation of V1 by Herring on 1966 June 25 and further observations of this lunar feature are reported by Hill (1991). The dome K2 is a large and voluminous structure, similar to the domes Ar1, Ga1, V1, and M13 and therefore belongs to class In1 in the classification scheme of possible lunar intrusive domes introduced by Lena & Wöhler (2008a) and Wöhler & Lena (2009).

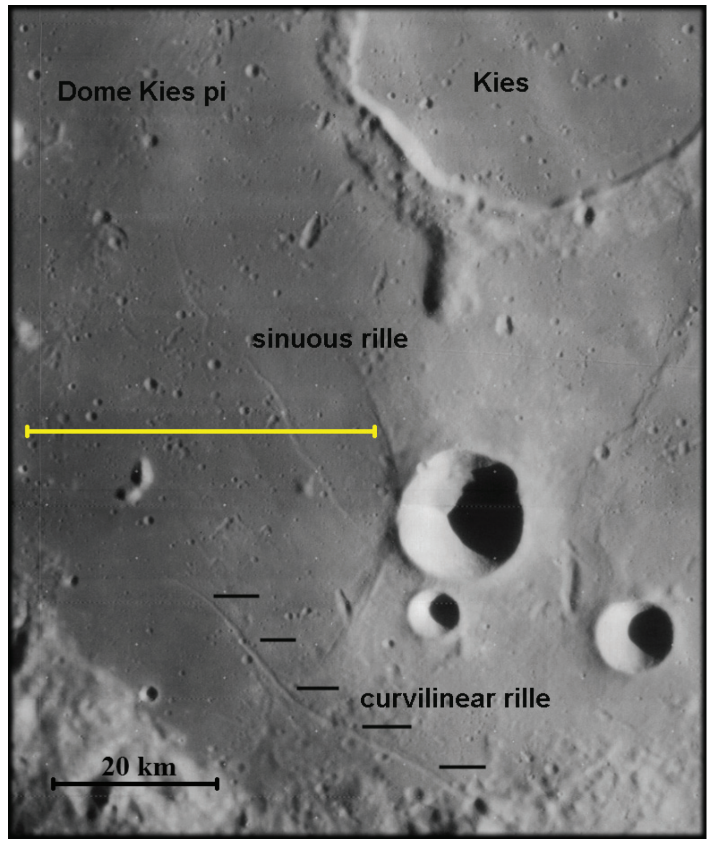

Figure 2: *Lunar Orbiter* image IV-125-H1 of the megadome Kies 2. Due to the comparatively high illumination angle, the dome itself is not visible, but the sinuous rille and the curvilinear rille on its surface are clearly apparent. The yellow line indicates the location of the cross-sectional profile shown in Figure 3c.

5. Digital elevation map

Generating an elevation map of a part of the lunar surface requires a three-dimensional (3-D) reconstruction. The *Clementine* spacecraft entirely mapped the lunar surface in 3-D at a resolution on the ground of 0.25 degrees in both longitude and latitude, *i.e.* better than 7.5 km, by means of laser altimetry. Although the obtained profiles nicely show large-scale features such as the huge South Pole Aitken Basin on the lunar far side, they do not reveal the 3-D structure of the lunar surface at small (kilometre) scales (Bussey & Spudis 2004). Parts of the lunar surface have been mapped in 3-D based on a stereoscopic analysis of image pairs acquired by the *Clementine* spacecraft and from the *Apollo* command modules orbiting the Moon (Cook *et al.* 1999). The resolution of the obtained surface profiles is 1 km on the ground, while the accuracy of the derived elevation values is no better than 100 m, which is not sufficient for measuring the heights of lunar domes. Recently, a global lunar digital elevation map (DEM), obtained with the *Lunar Orbiter* Laser Altimeter (LOLA) instrument on the *Lunar Reconnaissance Orbiter (LRO)* spacecraft, has been released. It has a lateral resolution of 1/64 degrees or about 500 m in the equatorial regions of the Moon (`http://pds-geosciences.wustl.edu/missions/lro/lola.htm`). A section of the LOLA DEM displaying the region around the megadome K2 is shown in Figure 3a. A rendered image obtained using LTVT, assuming the same illumination conditions as in Figure 1a, is shown in Figure 3b. The dome K2 cannot be easily distinguished as it is superposed on a *mare* surface inclined from the southeast towards the northwest. In the LOLA DEM, the elevation difference between the dome centre and its eastern border, corresponding to about 50 m, may be regarded as an approximate value of the dome height.

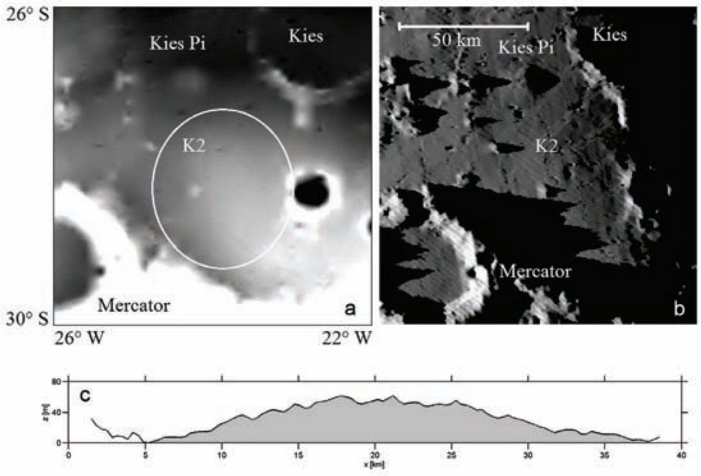

Figure 3: (a) Section from the LOLA DEM. The covered range of elevation values corresponds to 1200 m. (b) Image simulated based on the LOLA DEM using LTVT, assuming the same illumination conditions as in Figure 1a. (c) Cross-sectional profile of Kies 2 in east-west direction. The vertical axis is 50-times exaggerated and the curvature of the lunar surface has been subtracted. The rough shape of the surface is an artefact resulting from the image noise. The location of the profile is indicated in Figure 2.

We have also generated an elevation map of the megadome based on our telescopic CCD imagery. A well-known image-based method for 3-D surface reconstruction is shape from shading (SfS). It makes use of the fact that surface parts inclined towards the light source appear brighter than surface parts inclined away from it. (Apart from binocular vision, shading is one of the most important cues on which human vision is based.) The SfS approach aims for deriving the orientation of the surface at each image location by using a model of the reflectance properties of the surface and knowledge of the illumination conditions, finally leading to an elevation value for each image pixel (Horn 1989). It is especially suitable for the 3-D reconstruction of the dome K2 under study, since it extracts the height profile relative to the underlying surface, thus removing the previously mentioned overall inclination effect.

The SfS method requires accurate knowledge of the scattering properties of the surface in terms of the bidirectional reflectance distribution function (BRDF). A very simple model, the so-called Lambert model, assumes perfectly diffuse scattering, implying an intensity, R_L, of scattered light according to

$$R_L(\rho, \theta_i) = \rho \cos \theta_i \quad (1)$$

with ρ as the surface albedo and θ_i as the angle between the surface normal and the direction of incident light. But the Lambert model does not correspond very well to the true scattering behaviour of the lunar surface. A much more appropriate relation is the physically motivated BRDF by Hapke (1993) that is based on the theory of radiative transfer. It allows conclusions about certain surface properties such as average particle size, particle density, albedo of the surface material, or macroscopic surface roughness. It is not straightforward, however, to directly employ the Hapke model for 3-D reconstruction purposes. Therefore, in many astrogeologic applications, the simple, empirical Lunar-Lambert law is used according to

$$R_{LL}(\rho, \theta_i, \theta_e, \alpha) = \rho\,[2L(\alpha)\cos\theta_i / (\cos\theta_i + \cos\theta_e) + (1 - L(\alpha))\cos\theta_i] \quad (2)$$

with θ_e as the angle between the surface normal and the viewing direction and the Lunar-Lambert parameter $L(\alpha)$ as an empirical value depending on the phase angle α. This model is a weighted sum of the Lommel-Seeliger and the Lambert BRDF. Given a suitable choice of $L(\alpha)$, the Lunar-Lambert law fits the true scattering behaviour of a planetary surface similarly as well as the Hapke model. Values for $L(\alpha)$ have been tabulated by McEwen (1991) for planetary surfaces with a wide range of regolith properties.

For oblique illumination and perpendicular view we have $\cos\theta_i << \cos\theta_e \approx 1$, such that R_{LL} shows essentially the same behaviour as R_L, as it is the case for the examined dome. The dome is situated near the centre of the Moon's apparent disk ($\theta_e \approx 23°$), where the Lunar-Lambert BRDF differs only slightly from the Lambert model. The CCD image has been acquired under phase angles around 110°, where $L(\alpha) = 0.40$ for a low-albedo surface with the Hapke parameters of the lunar regolith (McEwen 1991).

The dome K2 has an elongated base area of 51.0 × 34.3 km^2 and a corresponding circularity (minor axis divided by major axis) of 0.67. Its height was determined to 55 ± 5 m using the image shown in Figure 1a, resulting in an average flank slope of 0.15° ± 0.02°. A cross-sectional profile of the northern part of the dome is shown in Figure 3c. Assuming a parabolic dome shape, the edifice volume corresponds to 37.7 km^3. The morphometric properties inferred for the dome K2 are summarized in Table 2.

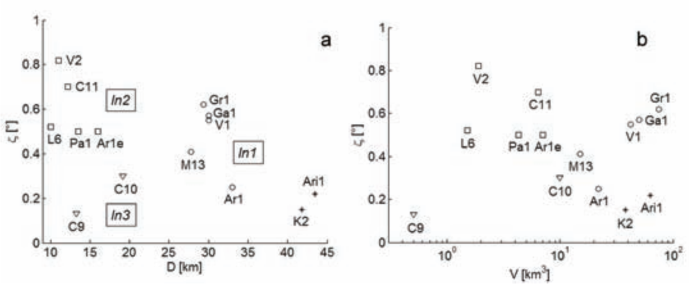

Figure 4: Morphometric properties of the candidate intrusive domes examined by Wöhler & Lena (2009), Wöhler et al. (2010), and in this study. (a) Diameter D vs. flank slope ζ diagram, also indicating the dome classes In1–In3. (b) Volume V vs. flank slope ζ diagram.

6. Dome classification and laccolith modelling

For candidate intrusive lunar domes, we have introduced three morphometric classes in previous works (Lena & Wöhler 2008a, Wöhler & Lena 2009). The first class, In1, comprises large domes with diameters above 25 km and flank slopes of 0.2°– 0.6°; class In2 is made up by smaller and slightly steeper domes with diameters of 10–15 km and flank slopes between 0.4° and 0.9°; and domes of class In3 have diameters of 13–20 km and flank slopes below 0.3°. While the morphometric properties of several candidate intrusive domes overlap with those of some classes of effusive domes, we show that a possible distinction criterion is the characteristic elongated outline of a candidate intrusive dome, as is the case for the examined megadome with an elongated base area of 51.0 × 34.3 km² and circularity of 0.67. Due to its large diameter and edifice volume, the megadome belongs to group In1, representing the known upper limit of this class (*cf.* Figure 4).

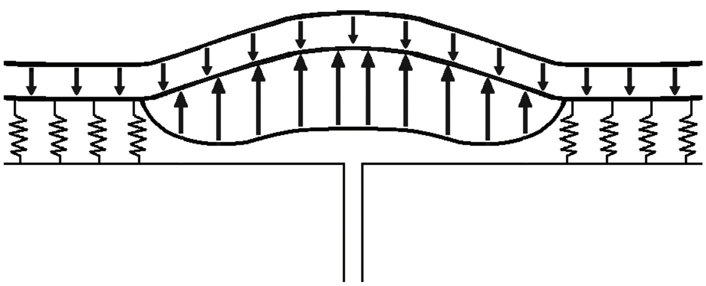

Figure 5: Sketch of a laccolith. The arrows indicate the pressure exerted by the weight of the overburden (downward arrows) and by the pressurised magma (upward arrows).

Kerr & Pollard (1998) introduce a laccolith model in which they treat the overburden of the pressurised magma as an elastic plate (Figure 5). The force, due to deflection of the plate, is compensated by overburden weight and the magma pressure, which decreases from the laccolith centre towards its border. The overburden has an overall thickness d and is assumed to consist of an upper basaltic layer and a lower layer consisting of brecciated basin-floor material. These layers have different coefficients of elasticity. A lower limit h_1 for the thickness of the upper basaltic layer can be obtained based on the relative extension of the material at the surface, which increases with decreasing curvature radius of the plate. The minimum thickness of the upper basaltic layer corresponds to $h_1 = 2\, r\, \sigma_{crit} / E_{basalt}$ with r as the curvature radius inferred from the DEM and σ_{crit} and E_{basalt} as the material-specific critical tensional stress and the coefficient of elasticity, respectively. If a stress larger than σ_{crit} is exerted on the material, a fracture occurs.

If the pressurized magma is treated as a classical Newtonian fluid, the magma pressure $p(x)$ obtains its maximum value p_0 in the centre of the laccolith and decreases to zero at its borders. Here, the x coordinate denotes the horizontal distance from the laccolith centre. According to Kerr & Pollard (1998), the deflection $w(x)$ of the overburden, *i.e.* the shape of the cross-sectional profile of the overburden, is then given by the solution of the fourth-order differential equation

$$F\, w''''(x) = q_0 - p(x) \qquad (3)$$

with F as the flexural rigidity of the overburden, $w''''(x)$ as the fourth derivative of $w(x)$, and q_0 as the overburden weight per unit area. The value of q_0 amounts to q_0 $p\, g\, d$, where $p \approx 2900$ kg/m³ denotes the rock density (not to be confused with the albedo p in Eqs. (1) and (2)) and $g = 1.6$ m/s² the lunar gravitational acceleration. Kerr & Pollard (1998) apply a correction to this basic model by taking into account the vertical compressibility of the overburden and the basement, but the effect of this correction turns out to be virtually negligible. Given the diameter D, the height h, the volume V, and the curvature radius r inferred from the DEM of an intrusive dome, the model yields values of the intrusion depth, corresponding to the overburden thickness d, and the maximum magma pressure p_0. A detailed description of the implementation of the model is given in the study by Wöhler & Lena (2009).

For the dome K2, we obtained a minimum thickness of the uppermost *mare* basalt layer of $h_1 = 1.2$ km, assuming a value of the critical stress of basalt of $\sigma_{crit} = 13$ MPa and a coefficient of elasticity of $E_{basalt} = 70$ GPa (Pollard & Fletcher, 2005). Furthermore, we have inferred an intrusion depth of $d = 11.4$ km and a maximum magma pressure of $p_0 = 99$ MPa.

7. Results and Discussion

7.1 Arguments against and in favour of the intrusive origin of the dome K2

As an alternative mode of formation for the megadome K2, one might think of effusive volcanism. However, in contrast to effusive lunar domes, which are characterized by relatively sharp and circular boundaries, K2 is of strongly elongated shape, its surface merges smoothly into the surrounding *mare* surface, and a clear boundary is absent. Furthermore, K2 has no effusive vent (but this may also be the case for effusive domes), and it is characterized by a much larger diameter and a much lower flank slope than all lunar effusive domes examined so far (Wöhler *et al.* 2006, 2007). Although the sinuous rille crossing the surface of K2 (*cf.* Figure 2) indicates flowing of low-viscosity lava, it is presumably not an outflow channel of K2, as its end points are both located on the elevation level of the surrounding *mare* surface; the rille traverses the complete dome surface and does not start on the dome summit. Hence, the sinuous rille was probably formed prior to K2 during a different phase of volcanism.

One might also consider K2 as a kipuka, *i.e.* an elevated "island" surrounded by the flooding *mare* lavas. Kipukas usually consist of a different material than the surrounding *mare*, such that a spectral contrast would have to be observed. A typical example of a lunar kipuka is the formation Darney χ located in western Mare Cognitum, an elevated section of highland terrain embayed by mare lava (Nichols *et al.* 1974). The absence of a spectral contrast between the megadome K2 and the surrounding surface, indicating that both consist of the same material, and the absence of a sharp boundary suggest that K2 is most likely not a kipuka.

Due to the fact that K2 is located near the border of the basin that includes Mare Nubium, another possible alternative mode of origin is its formation as a structural feature due to basin subsidence, *cf.* also domes of class 4 as defined by Head & Gifford (1980), or an effusive feature modified by structural deformation. However, the domes of class 4 as defined by Head & Gifford (1980) do not have large diameters or fractures on their summit, as it is the case for the dome K2.

It is commonly accepted that the upper few kilometres of the lunar crust are made up by the so-called megaregolith, i.e. blocks of several kilometres in size that were formed during the impact events that formed the large lunar impact basins. The megaregolith is covered by the finely grained regolith layer with a typical thickness of 20 m (Taylor *et al.* 1991). The block structure of the upper lunar crust may imply that the elastic plate laccolith model described in Section 6 is not fully appropriate. In contrast, the terrestrial crust is generally assumed to be more contiguous due to water-induced "healing" processes. However, the putative intrusion of magma leading to the formation of the megadome K2 may well have occurred below the megaregolith layer. In addition to that, the implications of the block structure of the lunar crust on the mechanical properties are not well understood quantitatively.

An intrusive origin of K2 is supported by the curvilinear rille on its surface, as such features are commonly interpreted as fractural features (Nichols *et al.* 1974; Wichmann & Schultz 1996) that may occur as a result of the flexural uplift of the laccolith. Such linear rilles are also associated with most candidate intrusive domes described by Wöhler & Lena (2009). Arguments against K2 being a kipuka instead of an intrusive feature are the smooth merging of its surface into the surrounding *mare* surface and the complete absence of a spectral contrast. Hence, sheet-like magmatic intrusion of laccoliths appears as a possible and plausible mode of formation for the megadome K2. The comparative numerical modelling of laccolith properties, especially their characteristic sizes and thicknesses, under terrestrial and lunar conditions recently performed by Michaut (2010a, b) is in favour of an intrusive interpretation of large, low, and smooth lunar structures like K2 in terms of the elastic plate model (*cf.* Section 7.3). However, alternative modes of formation cannot be definitely ruled out based on the available data.

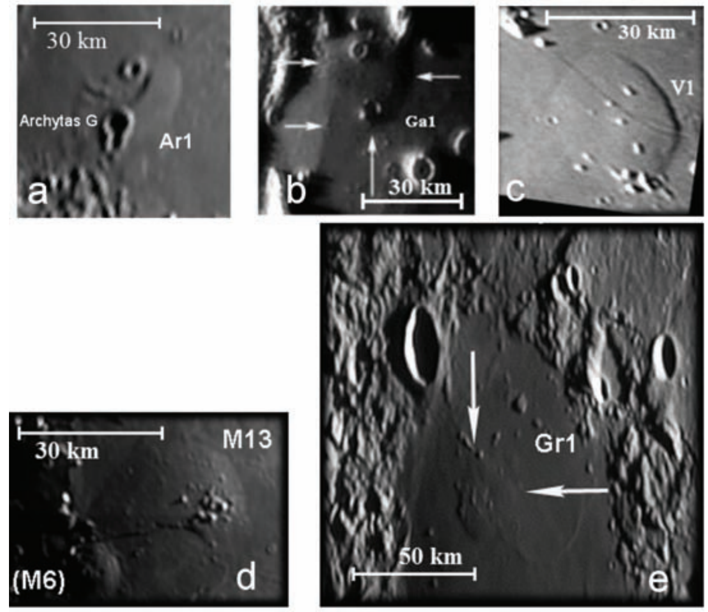

Figure 6: Telescopic CCD images of the large lunar domes of class In1 mentioned in the text and references (Lena & Wöhler 2008a; Wöhler & Lena 2009; Wöhler *et al.* 2010). (a) Dome Ar1 near the crater Archytas in Mare Frigoris. (b) Dome Ga1 near the crater Gambart in Mare Insularum. (c) Valentine dome V1 located at the western border of Mare Serenitatis. Image by K.C. Pau. (d) Dome M13 in Mare Insularum. (e) Dome Gr1 in Grimaldi crater. Image by K.C. Pau.

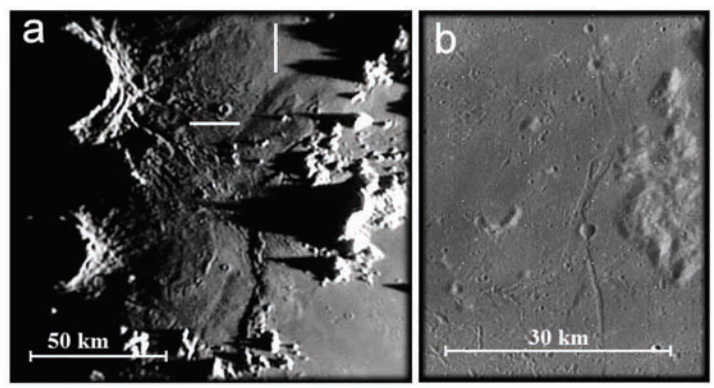

Figure 7: (a) Large dome Ari1 of probably intrusive origin near crater Aristillus. Telescopic CCD image acquired on 2009 May 01, at 19:30 UT. (b) Lunar Orbiter image IV-110-H1 showing the surface of the dome Ari1. A straight rille on the surface of Ari1 is apparent, while no sinuous rille is visible.

7.2 Morphometric measurements and laccolith modelling results

As described by Lena & Wöhler (2008a) and Wöhler & Lena (2009), the candidate lunar intrusive domes have smooth surfaces and low cross-sectional profiles merging smoothly into the surrounding *mare* lava plains. When assuming an intrusive origin of the dome K2, this would indicate that laccolith formation proceeded until the second stage according to Johnson & Pollard (1973), which is characterized by flexure of the overburden. The domes V1 (Valentine dome), M13 (near Milichius), and Ar1 (near the crater Archytas) display faults on their surfaces (*cf.* Wöhler & Lena 2009). These faults suggest that, to a limited extent, piston-like uplift according to the third phase of laccolith growth might have occurred for V1, M13, and Ar1. All domes of class In1 show fractures on their surfaces, probably formed by the tensional stress. Linear rilles traversing the summit are also detectable on two further large and low domes located in Grimaldi and near Aristillus, termed Gr1 and Ari1 (*cf.* Figures 6 and 7), which have recently been described by Wöhler *et al.* (2010). Table 3 reports the flank slope, diameter, height, and edifice volume of other intrusive domes described in previous studies (Lena & Wöhler 2008a; Wöhler & Lena 2009; Wöhler *et al.* 2010). The diameter *vs.* flank slope and volume *vs.* flank slope relations of these domes are illustrated in Figure 4. While the volumes of Ari1 and K2 are similar to those of the other domes of class In1, their diameters are larger and they are characterized by lower flank slopes.

If we assume that the curvilinear rille observed on the surface of the dome K2 is the result of tensional stress, the curvature radius of the dome surface inferred from our 3-D analysis yields a lower limit h_1 for the thickness of the uppermost *mare* basalt layer of 1.2 km, assuming a typical value of the critical stress of basalt of 13 MPa (Pollard & Fletcher 2005). In our previous studies (Wöhler & Lena 2009; Wöhler *et al.* 2010), the highest values of h_1 were found for the domes Gr1 and Ari1, corresponding to 0.7 km and 1.1 km, respectively.

The intrusion depth of 7.9 km and the magma pressure of 66 MPa inferred for Ari1 are already about twice as large as the highest values inferred for all other previously known domes of class In1 (Wöhler & Lena 2009). The size of Ari1 amounts to 54 × 35 km² and its height to 85 m. The megadome K2 shows a similar elongated shape and a dimension comparable to the dome Ari1, but with a lower height of only 55 m corresponding to a flank slope of 0.15°. When compared to Ari1 and the other domes of class In1, the dome K2 is characterized by a very deep intrusion (d = 11.4 km) and an extraordinarily high magma pressure of 99 MPa.

The dome K2 is associated with a linear rille and has a sinuous rille on its surface, the latter clearly indicating an effusion of lava (*cf.* Figure 2). According to the dike intrusion mechanisms described by Wilson & Head (1996, 2002), linear rilles were probably formed by the stress fields associated with dikes that ascended to shallow depths below the surface. Some non-volcanic hills are embayed by lavas. Presumably, these hills are part of the underlying rugged basin floor below the *mare* lavas. Due to the presence of different rilles, the megadome K2 is similar to the well-known Valentine dome V1, which shows a sinuous rille and a curvilinear rille on its surface that are well detected in Clementine imagery (Lena & Wöhler 2008a; Wöhler & Lena 2009). The sinuous rille can be interpreted as a lava channel that probably formed prior to K2 (*cf.* Section 7.1), while the curvilinear rille traversing the surface of K2 is likely due to a dike that remained subsurface, applying stress to the surface layers to form the rille. Furthermore, the flat appearance of K2 suggests that the rising lavas did not build up a dome through a series of flows, but that it was more likely formed by rising magma collecting in a subsurface pocket, leading to a subsurface intrusion. The resulting tensional stress produced the formation of the southern rille, and the dome was formed in a way similar to a terrestrial laccolith.

7.3 Comparison with terrestrial laccoliths

So far, the question of how realistic our laccolith modelling results for the megadome K2 are has remained open. To give a definite answer, in-situ measurements on the Moon are indispensable. However, we can compare our morphometric measurements and modelling results to in-situ analyses of terrestrial laccoliths. Typical terrestrial intrusion depths are 1.0–2.5 km for the Henry Mountain laccoliths (Jackson & Pollard 1988), 1.0–3.2 km for 12 laccoliths in the Ortiz porphyry belt in New Mexico (Maynard 2005), and 0.2–2.3 km for five laccoliths of the Miocene axis group in southwest Utah (Hacker *et al.* 2007). For one laccolith, drilling experiments revealed a thickness of 0.8 km. Nearly all these laccoliths have elliptical shapes with major axes of about 1–8 km and circularities (minor axis divided by major axis) between 0.5 and 0.7 – an exception is the large Pine Valley laccolith measuring 45 km by 20 km (Hacker *et al.* 2007).

On the Italian island of Elba, intrusive sheets are forming a so-called Christmas tree laccolith. The diameters of the individual intrusions correspond to 1.6-10 km, their thicknesses to 0.05-0.7 km, and their depths to 1.9-3.7 km (Dini *et al.* 2002; Rocchi *et al.* 2008). The formation of Monte Epomeo on the Italian island of Ischia is explained by Carlino *et al.* (2006) as a laccolithic intrusion of 10-km diameter located at a depth of 1 km, where the analysis is based on geochemical and gravity data, as well as geological field measurements. The resurgent block is delimited by faults, which indicates that the Monte Epomeo laccolith has undergone a piston-like uplift phase. Such delimiting faults are also observed for some of the putative lunar intrusive domes of class In1 (Wöhler & Lena 2009). Larger intrusion depths can be inferred indirectly based on seismic and gravity data, such as for the Vigneux leucogranite in southern Brittany in France, which has a diameter of 30 km and is emplaced at a depth of 10-15 km (Martelet *et al.* 2004).

Terrestrial laccoliths are typically smaller by a factor of about two than the putative lunar laccoliths regarded by Wöhler & Lena (2009), but display similar thicknesses. The dimensions of the lunar class In1 features, including the megadome K2, are similar to those of terrestrial "megalaccoliths" (Hacker *et al.* 2007), which are characterized by areal extents exceeding 300 km², corresponding to diameters larger than 20 km. While diameters below 10 km are common for terrestrial laccoliths, no lunar candidate intrusive domes with diameters in this range have been found so far. The elongated outline is a feature common to terrestrial laccoliths (*cf. e.g.* the geologic maps by Hacker *et al.* 2007) and lunar candidate intrusive domes. The inferred intrusion depth of 11.4 km of the megadome K2 is roughly four times larger than the values modelled by Wöhler & Lena (2009) for the other domes of class In1. However, the study by Martelet *et al.* (2004) shows that such deep intrusions may occur for terrestrial laccoliths.

The recent numerical modelling and scaling analysis by Michaut (2010a, b), of the magmatic intrusion processes leading to the formation of laccoliths, strengthens the hypothesis of an intrusive origin of large and low lunar domes similar to those described in this study and the work by Wöhler & Lena (2009). For lunar laccoliths, an adjustment of the gravitational acceleration and the crustal elasticity (for the dry lunar crust, the Young modulus E is assumed to be 2.5 times higher than for the terrestrial crust) leads to characteristic diameters of lunar laccoliths of 12-32 km. These modelled sizes are consistent with the observations by Wöhler & Lena (2009), while the megadome K2 is still somewhat larger. Furthermore, the model by Michaut (2010a, b) predicts similar thicknesses for terrestrial and lunar laccoliths, which is also in accordance with the observational data.

8. Summary and Conclusion

In this study we have performed an analysis of the morphologic, morphometric, and spectral properties of a lunar megadome K2 located south of the well known effusive lunar dome Kies. Its height amounts to 55 ± 5 m, resulting in an average flank slope of 0.15°. The edifice volume corresponds to approximately 37 km³. A slightly curved rille is crossing the dome surface, indicating structural control by subsurface geology, possibly due to rising lava collecting in a subsurface pocket, likely a laccolith. Moreover, the flattened appearance of K2 suggests that the rising lavas did not build up a dome through a series of flows. The dome K2 is a large and voluminous structure and belongs to class In1 in the classification scheme of possible lunar intrusive domes. According to the laccolith model by Kerr & Pollard (1998), it is characterized by a very deep intrusion depth of 11.4 km and an extraordinarily high magma pressure of 99 MPa, when compared to other candidate intrusive domes of class In1. The smooth cross-sectional dome shape indicates that laccolith formation proceeded until the stage characterised by flexure of the overburden, as described by Johnson & Pollard (1973). The resulting tensional stress produced the southern curvilinear rille, while the sinuous rille crossing the dome surface has presumably been formed prior to K2 during a different phase of volcanism.

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Glossary

lunar dome: Low, round, dome-shaped elevation on the Moon, often topped by a smooth-rimmed crater pit. For most lunar domes, a volcanic origin (outpouring of lava) is assumed, where the summit crater is interpreted as an effusive vent. These domes are commonly regarded as lunar analogues of terrestrial shield volcanoes. Some very large, low, and pitless lunar domes may have been formed by subsurface intrusion of magma.

effusion: Outpouring of lava on the surface.

intrusion: Moving of magma into empty spaces of the crust or between crustal layers.

laccolith: Magmatic body formed by an intrusion of pressurized magma between two adjacent layers of crustal rock, leading to an uplift of the crust.

linear rille: Straight groove on the Moon, commonly interpreted as the result of tensional stress.

LOLA (Lunar Orbiter Laser Altimeter): Instrument on board the *Lunar Reconnaissance Orbiter (LRO)* spacecraft. A laser altimeter measures the distance between the spacecraft and the surface by determining the time of flight of emitted laser pulses, which yields an elevation model of the surface given the position of the spacecraft.

LTVT (Lunar Terminator Visualization Tool): Free software for georeferencing of lunar images by tying them to the system of selenographic longitude and latitude coordinates.

photoclinometry: Transformation of a two-dimensional image of a surface into a three-dimensional elevation map based on the known direction of incident light and the known reflectance properties of the surface.

sinuous rille: Groove on the Moon running along a curved path, sometimes originating at vent-like features. They are commonly interpreted as outflow channels of lava or collapsed lava tubes.

ULCN (Unified Lunar Control Network): List of lunar features with precisely known selenographic longitude and latitude coordinate.

Dome	R_{415}	R_{750}	R_{900}	R_{950}	R_{1000}	R_{415}/R_{750}	R_{950}/R_{750}
Kies 2	0.0588	0.090	0.1006	0.101	0.1043	0.6129	1.0560

Table 1: Spectral properties of the megadome Kies 2, derived from Clementine UVVIS data.

Dome	h [m]	slope [°]	size [km]	V [km³]	h_1 [km]	d [km]	p_0 [MPa]
Kies 2	55	0.15	51 × 34.3	37	1.2	11.4	99
Ari1	85	0.22	54 × 35	63	1.1	7.9	66

Table 2: Morphometric properties of the megadome Kies 2 and the similarly large dome Ari1 near Aristillus, modelling results for the minimum basaltic layer thickness h_1, intrusion depth d, and maximum magma pressure p_0.

Dome	long. [°]	lat. [°]	slope [°]	D [km]	h [m]	V [km³]	class
Ga1	-14.84°	-0.75°	0.57	30	140	50	In1
V1	10.20°	30.70°	0.55	30	130	42	In1
M13	-31.53°	11.68°	0.41	27.8	100	15	In1
Ar1	0.71°	55.71°	0.25	33.0	70	22	In1
Gr1	-68.62°	-04.45°	0.62	36 × 24	160	75	In1
Ari1	05.67°	33.28°	0.22	54 × 35	85	63	In1
C11	36.75°	11.06°	0.70	12.2	75	6.4	In2
Pa1	-47.88°	-26.63°	0.50	13.5	60	4.3	In2
L6	-29.16°	47.08°	0.70	10	95	1.5	In2
V2	10.26°	31.89°	0.82	11	80	1.9	In2
C9	34.66°	7.06°	0.13	13.3	15	0.5	In3
C10	35.19°	10.00°	0.30	19.2	50	10	In3

Table 3: Morphometric properties of other domes of probably intrusive origin of classes In1–In3 according to preceding studies (Lena & Wöhler 2008a; Wöhler & Lena 2009; Wöhler *et al.* 2010).

Feature Articles/
Articles de Fond

The Square Kilometre Array (SKA): Scanning the Skies for Life – Where it Began, Where Else it Exists, and What it Signifies

by Maureen Arges Nadin, Thunder Bay Centre (mnadin@shaw.ca)

If you go far enough out
you can see the Universe itself,
all the billion light years summed up time
only as a flash, just as lonely, as distant
as a star on a June night,
if you go far enough out.

And still, my friend, if you go far enough out,
you are only at the beginning
– of yourself. (Jacobsen 1993, 155)

Numerous poets have waxed philosophical about time – that elusive and fragile thread that connects all our lives and the lives of every creature that has walked on this pale blue dot that we call home. Time – there is never enough of it, or sometimes there is too much of it, but no matter how you look at it – it's all about time. And, as most physicists can tell you, it's also about space, because they are eternally connected as Einstein revealed to us in his theory of general relativity (1915). The premise is complex and difficult to grasp for those of us not hard-wired for science. But, popular culture and numerous science-fiction movies featuring space travellers returning home without having experienced the same ravages of age as their earthbound counterparts, subliminally at least, helped us appreciate that there is a connection.

One of the most mysterious and compelling facts I learned when I first delved into amateur astronomy is that the starlight we see in our earthly skies actually left its source hundreds, thousands, or even millions of years in the past. That light we see with our naked eyes has travelled far through time. Stargazing is a lesson in history as well as in science. It is both overwhelming and humbling to consider what we might learn if we had the capacity to look back to the beginnings of our Universe – about the cosmos, the billions of galaxies, the other worlds that spin silently across vast distances, and, more importantly, our place in that Universe. What if we had a telescope large and powerful enough to look back in time and space to the moment right after the Big Bang, when stars and galaxies were just emerging from the legendary "primordial soup" and bringing the first glimmers of light to an evolving Universe? If all goes as planned, we will in fact have such a telescope, and it will experience "first light" or perhaps more accurately, "first signal," as early as 2016. And, when it does, it will bring us to the threshold of not only a brand-new chapter in the understanding of the Universe we live in, but quite possibly significantly closer to the ultimate soul-searching question that has been asked by every human being who has walked the terra firma of this planet – why are we here?

Figure 1 — Dr. Russ Taylor

In 1994, Dr. Russ Taylor, Professor of Physics and Astrophysics at the University of Calgary and Director of the Institute for Space Imaging Science, charted the future course of Canadian radio astronomy leading to our involvement in the Square Kilometre Array (SKA). In 2000, he spearheaded the Memorandum of Understanding to establish the International Square Kilometre Array Steering Committee (ISSC), which included personnel from 11 different countries (subsequently expanded to 20 participating countries through further agreements and structural changes). Canada has been involved from very early on in the SKA, a project billed as the radio telescope for the 21st century, and the instrument of a major revolution in astronomy.

The SKA will push the boundaries of radio astronomy by "marrying" the power and capability of new and exciting developments in radio-frequency technology with advancements in information and communication technologies. By combining leading-edge technologies and harnessing the efforts of teams of professional scientists, engineers, and technicians from various countries, it will turn on one extremely focused "eye on the sky" for the global community. We will be able to look further out into the radio Universe than ever before, with the largest, most sensitive radio telescope in the world. In common with many modern "big science" astronomy projects, the international nature of the SKA symbolizes unity in a common goal to discover our cosmic roots.

The inclusive international flavour of the project cannot be overemphasized; today it is a highly evolved collaborative programme, a trend that is set to continue. Guided by the SKA Science and Engineering Committee (SSEC), the present successor to the ISSC, the project combines the talents and dedication of scientists and researchers from numerous countries including Argentina, Australia, Brazil, Canada, China, France, Germany, India, Italy, the Netherlands, New Zealand, Poland, Portugal, Russia, South Africa, Spain, Sweden, the United Kingdom, and the United States. The international team is supported by a number of working groups that are interested in the full spectrum of issues that the SKA will explore, many of which are described as "key science projects" in the SKA Science Case Book. Nor have the immediate and long-range social impacts of the SKA on the communities in which it may eventually operate been neglected. Some of the initiatives in that regard have been ground breaking in their own right, and could serve as models for other big science projects, particularly those sited in disadvantaged communities.

But before we look at some of the things that the SKA will be able to do, it is important to appreciate how the array actually works, and the science and engineering that make it possible.

In its basics, a radio telescope works much like a classic reflecting telescope. The collector, which typically can be a parabolic dish, functions like a primary mirror, gathering electromagnetic radiation (light waves in the case of the reflector, radio waves in that of the radio telescope). The form of the dish focuses the electromagnetic radiation onto an antenna, the equivalent of the reflector's secondary mirror. The receiver amplifies and converts the radio waves to electrical signals, and can be thought of as somewhat analogous to the reflector's eyepiece and filter. The detector works like the eye or a CCD chip, enabling the electromagnetic radiation to be recorded, and the recorder/analyzer fulfils some of the tasks of the astronomer's brain at the end of the reflector's eyepiece, remembering and analyzing the data.

The promise and possibility of SKA data reshaping our view of the cosmos owes everything to the recent course of radio astronomy. When conjuring up celestial images of distant galaxies and colourful nebulae, the public usually thinks only of optical telescopes, such as the legendary *Hubble Space Telescope (HST)*, but many of the most dramatic discoveries of 20th-century astronomy were won in the realm of the radio region of the electromagnetic spectrum. A striking and well-known example is the Crab Nebula (M1, NGC 1952), a mass of dust and luminous gaseous filaments produced by the supernova of AD 1054, and a favourite of astrophotographers. It is also the site of the neutron star identified as the Crab Pulsar (PSR B0531+21), initially identified through radio observation, and the first such object to be connected with a supernova remnant. Viewing radio frequencies also allows astronomers to penetrate cosmic dust, and peer into areas of the Universe opaque at visible wavelengths and formerly shrouded in mystery – localities such as the centre of our galaxy (Burke & Graham-Smith 2009, 216-220), and those veiled cosmic nurseries where stars and planets are born, such as the iconic "Pillars of Creation" in the Eagle Nebula (M16, NGC 6611; Pound & Kane et al. 2005).

The SKA should prove a very powerful and flexible engine of discovery. It will have a collecting area of approximately one square kilometre (hence the telescope's name), with the SKA central region to contain about 50 percent of the total collecting area. When used in its "aperture synthesis" mode, in which the signals from separate antennae will produce images that have the angular resolution of an instrument the combined size of the entire collection, it will boast a diameter equal to the largest antenna separation – at least 3000 km. The array of antennae, resembling the ubiquitous satellite dishes that are such a familiar sight in our technological society, will be in the thousands. As planned, it will dwarf other yet-to-be-completed projects. The SETI Institute and the UC Berkeley Radio Astronomy Laboratory (RAL)'s Allen Telescope Array, an impressive undertaking in its own right, and an important "stepping stone" and developmental tool towards the SKA, will consist of 350 antennae with a collecting area of 10,000 m^2 upon completion.

The SKA will enjoy a very large field of view (FOV) with a goal at frequencies below 1 GHz of 200 square degrees, and of more than 1 square degree (about 5 full Moons) at higher frequencies. The survey speed of the instrument will be rapid at present-day scale, innovatively effected by the use of Focal Plane Arrays using phased-array technology to provide multiple FOVs. This technology will also make it possible for multiple users to observe different pieces of the sky simultaneously.

The SKA has the potential to look back in time to those events that occurred shortly (relatively speaking) after the Big Bang, when the Universe contained no light save for the faint glow left over from the Big Bang – aptly referred to as the Dark Ages by Big Bang cosmologists.

The SKA Science Case information booklet describes the project as a "discovery machine" but it is also a "questioning machine." And, the questions that it will ask are not small and they are not easy: What happened after the Big Bang and before the first stars and galaxies formed? Which came first, stars or galaxies? What is the mysterious dark energy? How are galaxies born and how do they evolve? In particular, the SKA will measure the amount of hydrogen, nature's most abundant and fundamental element, present in various galaxies across time, and this will help scientists determine the geometry of the Universe. The SKA Science Case tells us that this in turn will test "whether dark energy is a vacuum energy or something more exotic like evidence of a genuinely new physics of extra dimensions." For most of us, these are very powerful concepts, usually confined to the realm of science-fiction movies and books. Dark energy and alternate dimensions are heady abstractions; although we might be able to imagine the existence of another dimension, are we able to absorb the ramifications of such a discovery in terms of our own existence? The SKA will take us into new frontiers in more ways than just the hard science.

The SKA may even possibly address fundamental epistemological questions about how we do science, questions such as: Can we predict everything in the Universe on the basis of what we already know now? The SKA Science Case reminds us that, considering that the SKA's most productive years will be in the period from 2020 to 2050 and beyond, its primary users have yet to be born. And, the questions, aspirations, and searches that will propel their research are not yet known and may well be inspired by some of the early data that SKA reveals in the years from 2016 to 2020.

In the course of the SKA's ongoing scientific programme, its innovations in astronomy may potentially trigger responses in areas such as philosophy, spirituality, and religion. Perhaps these may even touch on questions such as: Who are we, how did we get here, and what is our purpose?

As I wrestled with the possible broader effects of the SKA's scientific programme, I was fortunate to be able to speak with Prof. Russ Taylor and gain his perspective on the intersections of science and philosophy.

"By charting a complete history of time, we will hope to understand whether the rise of life was encoded in the event that created the Universe," he patiently explained, "Is the world as we know it logically necessary as the result of the initial conditions of the Big Bang or was it an accident? In other words, was life necessary?" Or, as a philosopher pondering the same question from a more metaphysical perspective might ask – not so much as to whether life was necessary, but if it wasn't "accidental" in scientific terms, does if have a larger purpose or, indeed, does it have any purpose at all? Or, are we merely a random event?

Such metaphysical questions arising out of an astronomical research programme may potentially have a major impact on countless concepts that give rise to many of the world's major religions and philosophies.

Prof. Taylor is well aware of the depth of the questions that the SKA will not only pose, but seek to answer. "The questions we are asking border on philosophical and religious questions that are fundamental to understanding our place in the Universe. In probing to the far edges of the Universe, we are really asking questions about ourselves."

The SKA could also provide us with long-sought-after answers about the existence of other intelligent life. The sensitivity of the array is such that it could detect signals as weak as the "radiation leakage" that seeps from our planet daily as the result of the use of such everyday devices as cell phones, TV transmitters, and radar. The discovery of similar signals emanating from a planet orbiting another star would be what the SKA project describes as "a profound moment for humanity." The presence of such a signal, could, for the first time in our human history, lead us to reasonably conclude that we are not alone.

In the last 15 years, over 500 extrasolar planets have been detected. What if an intelligent, purposeful signal is detected by the SKA emanating from an Earth analogue? Such a discovery could both comfort and terrify us. For most of us, I would speculate, it would be something in between, but there is probably hardly a soul who would be unaffected. As we grow closer to the launch of what promises to be one of the most exciting and dramatic scientific undertakings of the 21st century, there is indeed much to ponder.

The SKA will bring together some of the finest scientific minds of our planet, and we can be proud that Canada and the University of Calgary are taking a lead role. It is expected to be complete and fully functional in 2020, although Prof. Taylor tells me that Phase One will be operational as early as 2016. The final site for the location of the array will be selected by 2011, and the two potential host countries for the project, South Africa and Australia, are currently developing their sites and building prototypes of the telescopes.

Five years, relative to the span of human history, is seemingly infinitesimal. But, in the time from now until 2016, the SKA could be producing its "first science." Those discoveries have the potential to be truly transformational in ways that we would expect and in some that we can hardly imagine.

The science that the SKA reveals will also bring us on a human journey that could challenge everything we have come to believe about ourselves, and the nature of our existence. To paraphrase the Norwegian poet Rolf Jacobsen: "If we go out far enough, we are only at the beginning – of ourselves." With the SKA, we will become time travellers, and like all intrepid pioneers, we must be prepared for what we find. In looking back and reaching an understanding of how our Universe and our planet were born, we may also come to know why. That revelation could potentially shake the foundations of many of our core belief systems. Are we ready?

Maureen Arges Nadin has been exploring uncharted territory in the world of freelance writing since 2005, after a successful 28-year career in the Public Service. She has been fascinated by the night skies since she was a small child, and was first struck by the wonder of space travel when Sputnik was launched. She is long-time member of the Thunder Bay Centre.

Acknowledgements

The author acknowledges the help of Prof. Russ Taylor for giving so generously of his time.

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New Facts From the First Galaxy Distance Estimates

by Ian Steer, NED-D (isteer@hotmail.com)

1. Introduction

A new database from the NASA/IPAC Extragalactic Database (NED) of galaxy Distances (NED-D), normally the source for the newest precision-based estimates, provides access to the oldest redshift-independent extragalactic distances in the publication record. Based on review of the astronomical literature in NASA's Astrophysics Data System (ADS), we found 290 legacy distances to 62 galaxies from 37 astronomical references that were published up to and including 1930.

Two new surprises emerge when the early distance estimates are placed in chronological order. First, before *Hubble* gained fame by publishing 71 distances to 32 galaxies, a total of 97 distances to 48 galaxies had already been published (*Hubble* 1926). Second, Hubble was not the first to discover but rather first to prove, based on his distance estimates, that a universe of galaxies exists beyond the Milky Way and that this universe of galaxies is apparently expanding (Hubble 1926, 1929). Though credit is given to Hubble, these discoveries, were first made but alas not proven, by Lundmark (1924a, 1925).

2. Standard Candles, Standard Rulers

A discovery by Miss Henrietta Leavitt led to the first standard-candle method for estimating galaxy distances (Leavitt 1908, 1912). Yet the discoverer of the Cepheid period-luminosity relation remained a footnote until very recently, when Leavitt's Law of Cepheids was fully credited (Freedman *et al.* 2009, Madore *et al.* 2009a, 2009b, and Marengo *et al.* 2010). Previously, most credit for the discovery had gone to Hertzsprung and, independently, Russell, as they were first to calibrate Leavitt's method and first to publish distances based on the method (Hertzsprung 1913, Russell 1913).

Improvements by Shapley (1918) led to a Cepheids-based distance to the Small Magellanic Cloud that remained fiduciary for decades. Hubble's first Cepheid distances weren't published until 1925. They were by far the best however, based on observations with the world's then-largest telescope, the 100-inch Hooker on Mount Wilson, CA, which began operating in 1918 (Hubble 1925a, 1925b).

Potentially, the first standard-candle extragalactic distance could be credited to Very based on novae (Very 1911). However, this estimate was un-calibrated and, giving less than a thousandth of today's distance to the Andromeda Galaxy (M31), unrealistic. The first calibrated novae-based distance, albeit to no particular galaxy but rather "distant spirals," was made by Curtis (1917), revealing an average distance of 6 Megaparsecs (Mpc) to a collection of galaxies, and changing the culture of astronomical thinking to accept much larger galactic distances than had been the earlier practice. Lundmark provided the first calibrated novae distances to a specific galaxy, publishing two estimates for the Andromeda Galaxy (Lundmark 1919). One year later, Curtis (1920) used novae to determine two new distances for M31, one of 0.23 Mpc and a second of 1.2 Mpc. The average of Curtis's distances placed Andromeda at 0.7 Mpc, within 7 percent the modern value of 0.75 ± 0.02 Mpc (Freedman *et al.* 2001) derived by NASA's *Hubble Space Telescope* (*HST*) Key Project (KP).

A third standard candle method used today – by brightest stars – was first employed by Shapley (1917) to place M31 at 0.31 Mpc. Others followed, including Lindemann & Lindemann (1919), Shapley (1923), and Lundmark (1921, 1924b, 1925), but it was Hubble (1926) who first used a Cepheids-calibrated version of the brightest stars method to provide accurate distances for 32 individual galaxies.

The first globular cluster standard-ruler measurement using average cluster radii was made by Shapley (1922), who used the method to place the Large Magellanic Cloud at 35 kpc, within 27 percent of the latest multi-methods-based estimate of 48 kpc by Freedman & Madore (2010), a value believed precise to within 3 percent. The technique is still in use today, particularly in NASA's *HST* Advanced Camera for Surveys (ACS) Virgo Cluster Survey (Jordan *et al.* 2005) and the ACS Fornax Cluster Survey (Masters *et al.* 2010).

3. Secondary Methods, Hubble and Lundmark

Two years before publication of Hubble's 1926 paper showing that galaxies were at very large distances, Lundmark used his nova distance of 0.2 Mpc to Andromeda from his 1919 paper to calibrate diameter distances to 44 other galaxies (Lundmark 1924a). Legitimately, he was the discoverer that these "nebulae" existed as "island universes" at vast distances, out to his furthest, NGC 1700, at 42 Mpc. Alas, extrapolating from one nova distance based on a single untried method (diameters) to other galaxies, did not convince his research colleagues. Hubble succeeded by employing two independent methods, both calibrated by Cepheids, one based on brightest stars and another based on galaxy apparent magnitudes to show conclusively that the distances indicated were reliable.

Lundmark (1925) actually hit upon Hubble's Law years before Hubble, writing "more distant spirals have higher space-velocity." It was however Hubble (1929) who put the distance-velocity relationship on a quantitative footing, justifying the future use of the term "Hubble's Law."

4. Others

The first extragalactic distance estimate was published by Nichol (1840), who determined a value of 0.6 Mpc for nearby spirals in general – not bad compared to, for instance, Andromeda at 0.75 Mpc. Opik (1922) estimated the distance to Andromeda at 0.45 Mpc, within 40 percent of the *HST* KP value, using an early Tully-Fisher relation based on spiral rotational velocity and galaxy brightness. Finally, a dozen improbable underestimates were published, some based on apparent (but erroneous) internal rotation and others based on proper motion, impossible then, barely possible now, and now only with low precision (Vieira *et al.* 2010 and references therein). Such underestimates fuelled the great debate of 1920 between Curtis and Shapley on island universes and kept the dialogue going until Hubble's 1926 paper, after which all such underestimates vanished from the record.

5. Summary

Credit for Hubble's discoveries of true extragalactic distances parallels that of the promotion of the heliocentric Solar System by Copernicus in 1543, the discovery of penicillin by Fleming in 1928, and of the route to North America by Columbus in 1492. Others had made earlier and similar claims – Eratosthenes, *c.* 250 BC for the Solar System, Tyndall in 1875 for penicillin, and Ericson, *c.* 1000 for the New World. Success went not to the first to make discoveries to their own satisfaction but rather to the first to prove them to the satisfaction of others. When it comes to the priority for discovery, convincing others is key.

For further reading, see *Miss Leavitt's Stars*, by George Johnson (W. W. Norton & Company, 2005) and, *The Day We Found the Universe*, by Marcia Bartusiak (Random House of Canada, 2010), *Man Discovers the Galaxies*, by Richard Berendzen, Richard Hart, and Daniel Seeley, (Columbia University Press, 1984) and *The Expanding Universe* by Robert Smith (Cambridge University Press, 1982).

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NED and NED-D staff will be at the AAS Meeting in Seattle, WA, 2011 Jan. 9-13.

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Things That Go Bump in the Night

by Miriam Martin, Cypress Hills Interprovincial Park (mmmartin@yourlink.ca)

I am an interpreter at Cypress Hills Interprovincial Park. I began learning astronomy in 2006 when the park bought a 10-inch Dobsonian for visitor programming purposes. As there were just two of us doing the astronomy program and neither of us knew much, we studied hard through the spring in order to be ready for the summer program. Our learning plans included taking the scope home to practice. I live on a ranch north of Maple Creek and am blessed with having dark skies above my house.

One night, while working on finding some Messier objects, I heard our horses thundering around to the west of the house. I figured something had spooked them up, but assumed they were still where they were supposed to be, and kept on with my hunt. A few moments later I heard hoofbeats – too close and too loud. Occasionally our horses get out. They graze and wander around, checking out my flowers, seeing if they can get into the barn and the grain barrel and generally don't get into too much trouble. But this night, I had set the scope up directly in the entry to the small grassy area just a few paces east of the house, where we keep the horses close at hand during calving season. Flicking my flashlight from red to white, I caught the eyeshine of five horses snorting and blowing in nervous excitement. They knew something strange was in the yard (me) and took off running again. Dilemma! Do I run to the barn and grab a couple of halters and a bucket of grain pellets, leaving the scope unprotected? Do I pack up the scope, making noise and light that may scare them out to the highway?

Horses often run to where they feel safe, which that night might have taken them right over the telescope. When I heard them in the trees bordering the ranch yard to the north, I sprinted to the corral next to the barn and opened the gate. I called to them, in the way we do when we want them to come in, and then sprinted back to the scope, worried that their panic would have them running the circuit of the trees that would bring them around and back to their spring field where the scope stood – alone, unprotected, and vulnerable. I imagined taking a hoof-printed Dob with cracked mirrors back to the Park, just as our summer astronomy program was about to begin.

Luckily, three of the horses came back to the barn and slipped into the corral. I ran to it and slammed the gate, then bolted back to the scope, wondering where the other two had gone. The scope glowed softly white in the starlight. I calmed down, figuring that if I could see it, so too could the horses. Assured that two horses were more able to avoid unexpected objects in the night than a group of five running through a narrow entry, I began my search for the remaining escapees. I found them grazing nearby but, nervous and flinchy, they wouldn't let themselves be caught. I decided to pack up and try to catch them later. It was a relief to get the scope safely into the house. Not long after, with the horses behind a securely shut gate and me tucked into bed, I resolved always to check the latches of gates before I set up the scope for a night of observing.

So far, no animals or telescopes have been harmed during observing nights at the Martin ranch.

Cosmic Contemplations

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

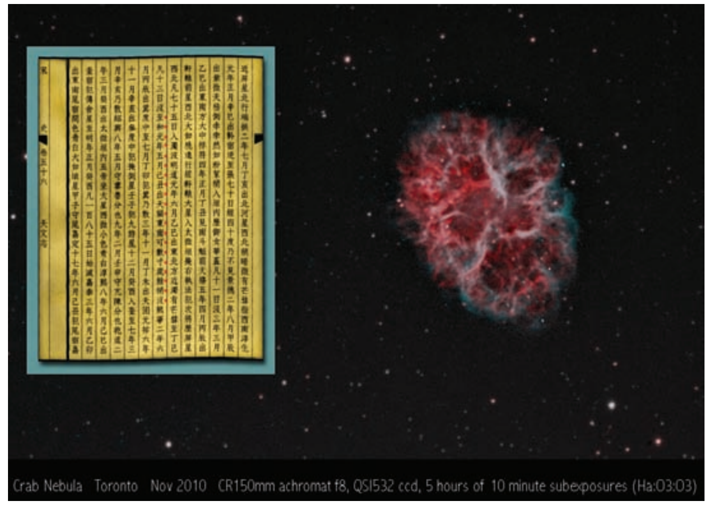
Current Concepts in Planetary Imaging

This story is not about fading A-list film icons appearing as well-to-do villains in an episode of *Colombo*. That was my childhood, when Wednesday nights mattered more to NBC than *Must See TV*'s Thursday nights. To my chagrin, this is about my late entry into the world of astronomy.

I remember the spring of 1997 well. My son had been born a few months earlier, and I remember setting out the trash one clear night in Gibsons, B.C., and looking up in the western sky to see my first comet ever, Hale-Bopp. It was clearly visible, tail and all. I looked at it for several seconds, and then went back inside. I've long since made up for my inexcusable lack of enthusiasm, but I did have a lot of pressing distractions at that time of my life. My interest in astronomy was first piqued in the summer of 1995, when my wife (then GF) and I were travelling two-up on motorcycle through the Okanagan Valley *en route* to Banff. I have never experienced such dry heat in Canada: we had shed our leathers to ride in regular clothes as we visited wineries and orchards, while temperatures peaked into the mid 40s. We also made a stop at the Dominion Radio Observatory at White Lake near Penticton, because I thought the pair of large white parabolic antennae made a good photo op. We went inside for a tour of the main building, and I was particularly drawn to a deep-space image accompanied by ancient Chinese text reporting the appearance of a *Tianguan* (ζ Tauri) "*guest star*" in AD 1054 that was so bright it was visible in daylight for 23 days. This guest star is the supernova SN 1054, which is now the pulsar at the heart of Messier 1, the Crab Nebula. The display went on to explain the historic significance of the Chinese text, being the first human-recorded observation of a supernova! It was a defining moment in my life, and it set in motion one of those inextricable micro-events that culminated in a rediscovered passion for astronomy about five years ago.

Strictly speaking, SN 1054 was not the earliest recorded observation of a supernova. That credit belongs to writings found on 14th-century BC (Shang Dynasty) oracle bones comprising the ninth chapter of *Yin-Xu-Shu-Qi-Hou-Bian*: "On the 7th day of the month, a great new star appeared side by side with the Antares (αSco)." Now recording this natural phenomenon is not particularly onerous or cerebral, it just takes a pair of keen eyes and dark skies (not in shortage back then!). What is astounding is the unbroken record of astronomical data-keeping from 206 BC to AD 1912 by the Chinese Emperor's Astronomical Bureau – the world's longest-lived civil service! So how was it possible for a single society to sustain this effort, when no others could?

As the leader of an agrarian economy, it was crucial for the Emperor to produce a calendar so that the impact on irrigation of the season, from snow melt in spring to the onset of the monsoon in mid-summer, could be predicted. He relied on a court-appointed Astronomer-Royal to use astronomical observation to maintain the accuracy of this calendar. By 484 BC, the year was determined



Jim Chung took a 956-year journey into the past to record the Crab Nebula in November last year using a CR150 achromat and QS1532 camera. The accumulated exposure totals 5 hours (30x10 min) in Hα, and OIII filters. The inset is the original Chinese description of the appearance of the "guest star" that is identified as the Crab.

to be 365.25 days long through the employment of bamboo-stalk sundials in the day and water-driven clocks at night. By AD 25, accurate observations of the lunar synodic period collected over many decades allowed the rough prediction of solar eclipses using a cycle that returned the spectacle to approximately the same longitude every 54 years (the *exeligmos*). A star chart of the complete sky containing approximately 1350 stars was completed in the 7th century AD (Tang Dynasty). Observations of novae, sunspots, and comets were studiously recorded from two official imperial observatories in the capital, and then compared with each other to avoid false reports. Records from outlying areas of the country were also forwarded to the bureau to confirm observations. Further evidence of the assiduous scientific conduct of the Astronomical Bureau can first be seen in Indian astronomers taking up residence in the capital, followed in later years by Islamic astronomers during the Yuan and Ming dynasties. These ancient applications of cultural tolerance and intellectual collaboration brought many advances in Chinese thought and science.

Astronomy may have been an empirical pursuit rather than a theoretical one in China, and the lack of deductive geometry resulted in a weakness for describing planetary movements, but the cosmological model of *Hsuan Yeh*, where space is infinite and celestial bodies float at rare intervals, is more enlightened than any model from the West. Western thought was hampered for a thousand years by the Greek fondness for circular planetary orbits and an Earth-centric model with the heavens populated by perfect and changeless bodies arranged in concentric crystalline spheres. The paucity of European astronomical observation prior to the Renaissance is attributed to this belief of a perfect cosmos, for surely there is nothing to see if nothing ever changes.

Europe, however, would be instrumental in bringing the wealth of ancient knowledge to light during a period of Chinese political instability. The Sino-Japanese war of the 1930s and the Second World War in the Pacific threatened to destroy valuable and

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Pen & Pixel

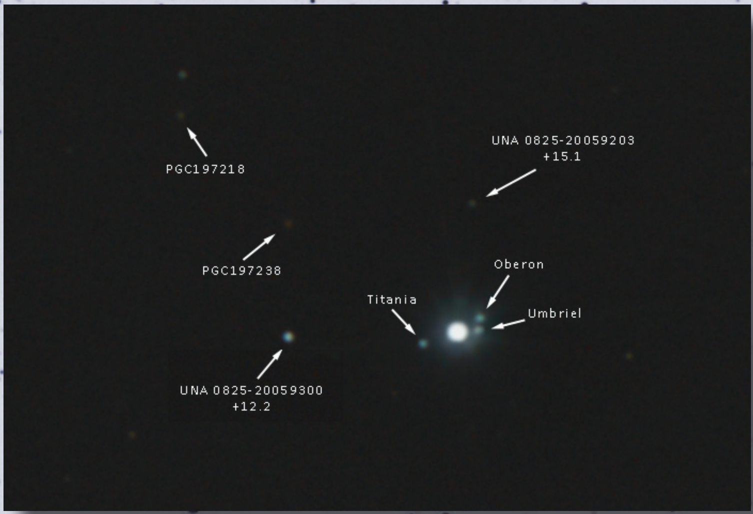

Figure 1: Massimo Torri brings us another annotated image of the moons of Uranus, along with a few faint galaxies captured in the field. This picture is a close-up of the original image taken through a 10-inch Newtonian reflector using a Canon 450D camera. Massimo notes "Three moons are clearly visible. Unfortunately, Ariel was only about 4.5″ away from Uranus and completely lost in the glare. I don't think I will ever get Miranda with my setup (too close and too faint)." Total exposure was 33x30 sec.

Figure 2: Les Marczi added a lengthy exposure through a 6-nm H-alpha filter to a background RGB image to compose this high-contrast view of the Horsehead Nebula in Orion. Les used an AP 130 EDF refractor with a telecompressor and a modified Canon 450D camera. Exposure was 3.5 hours in H-alpha at ISO 1600 and 2.5 hours in RGB at ISO 800.

Figure 3: As one of the most spectacular galaxy pairings in the sky, M81 and M82 never fail to impress both visually and photographically. The contrast between the quiet spiral form of M81 and the tortured convolutions of M82 are especially appealing in photographs. New Brunswick's Paul Gray caught the character of the two using an unmodified Canon XSi on an 8-inch f/4 AstroTech Newtonian telescope. Exposure was 37×5min at ISO 800, spread over two nights.

Figure 4: Kemble 2 is a group of magnitude 7-9 stars covering 20′ in Cassiopeia. The asterism is named for the late Fr. Lucian Kemble (1922 - 1999), a well-known Canadian amateur astronomer and Franciscan friar, who first described it in his notes. John Mirtle captured Kemble 2 last August from B.C.'s Mt. Kobau using a Takahashi FSQ refractor and SBIG ST-10XME camera with 10 1-minute exposures in each of R, G, and B.

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ancient Chinese texts, a fate that would likely have been repeated in later years during the purges of Mao's Communist regime. An unlikely Cambridge biochemist by the name of Joseph Needham was seconded by Churchill into the Diplomatic Corps and sent to war-torn China to rescue as much of the old knowledge as possible and to deliver scientific equipment and supplies to deprived Chinese researchers. He was uniquely qualified for this role – a stranger-than-fiction Indiana Jones-like personality. A natural polyglot, he taught himself Chinese with the help of a Chinese postdoctoral fellow who later openly became his life-long mistress. He was a brilliant and charismatic man who was able to improvise under trying conditions, including even Japanese attacks while travelling back and forth across China for a period of more than five years. Upon his return to Cambridge, he occupied a pair of small suites on the ground floor of Caius College (one of which would be later occupied by Steven Hawking) and began reading his staggering collection of Chinese books. One in particular was the 1888 edition of the largest book in the world, the *Kuchin Tu-shu Chicheng* or *The Complete Collections of Illustrations and Writings of Ancient and Modern Times* that was commissioned in 1700, took 26 years to write, and amounted to the sum of all Chinese knowledge at the time – in nearly 2000 volumes! Needham set out to write a seven-volume distillation of this knowledge entitled *Science & Civilization in China*. Though he died in 1995, the work continues to this day. The 24th volume was published in 2006, and there are more in the works.

Along with meticulous record keeping, the ancient Chinese used an equatorial coordinate system very similar to our modern one, making possible identification of unique Chinese constellations and star names. The Chinese calendar, based on a 60-day lunar cycle, is easily transposed to the Gregorian calendar so that exact dates and locations of astronomical phenomenon can be deduced. SN 1054 was readily identified as the Crab Nebula, especially as the remnants are clearly visible; it lies in close proximity to ζ Tauri, and its expansion rate agrees with a creation date some 950 years in the past. Since we now know the date of SN 1054 was 1054 July 4, we know the exact age of this pulsar and can refine existing theories about aging neutron stars, such as the rate at which their rotation slows as they age. With the launch of the *Chandra X-Ray Observatory* in 1999, mining Chinese astronomical data has never been easier. In AD 386, a guest star was recorded in the southern sky, and the transposed sky coordinates allowed *Chandra* to discover and confirm the remnants now known as G11.2-0.3.

In AD 240, the Chinese recorded the first observation of a major "broom star," later identified as the world's first recorded sighting of Halley's Comet. In AD 530, they recorded Halley with more precision, stating that, on September 1, it appeared one degree NW of star *Xiatai* (in Ursa Major). This precise date and location allowed mission controllers of the European Space Agency to refine the ephemerides of its 1986 apparition to allow a successful rendezvous of the *Giotto* spacecraft with its nucleus.

The precise timing of first and second contact of the lunar eclipse of AD 434 on September 4, using a water clock, was used recently to support the discovery of a reduction in the rotation of the Earth that cannot be explained merely by tidal forces exerted by the Moon and the Sun. It may be a result of slowing induced by tectonic rebound in the Northern Hemisphere as glaciers retreated from the last Ice Age, or by the expansion of the atmosphere due to the impact of recent global warming!

So, we come full circle as all good stories should. The past touches us profoundly here in the present as surely as Messier 1 reaches optimum elevation for imaging and viewing this winter!

Jim Chung has degrees in biochemistry and dentistry, and has developed a particular interest for astroimaging over the past four years. He is also an avid rider and restorer of vintage motorcycles, which conveniently parlayed into ATM projects, such as giving his Skywatcher collapsible Dobsonian a full Meade Autostar GOTO capability. His dream is to spend a month imaging in New Mexico, away from the demands of work and family.

Dear Readers:

During the early production of this February Journal, our designer, Brian Segal, became seriously ill. He is in Halifax hospital at this writing, and we wish him a speedy recovery.

In the meantime, we have had some special assistance from people who jumped in on short notice. We extend a very warm "Thank you!" to Jim Murphy for offering to help, and particularly Lynn Adams at Maritime Digital Colour. Great work on a very tight schedule!

If your printed issue is a little late, please understand that we did our very best under trying circumstances to get it to you with little delay.

Astronomical Art & Artifact

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Russell W. Porter, Albert G. Ingalls, and RASC

Amateur Telescope Makers (ATMs)

The ancient cosmologist Heraclitus the Obscure (535-475 BC) reputedly said: "you cannot step into the same river twice" (Kirk et al. 1983, 194-197)[1]. A later recondite commentator, Archivista the Lucid (date unknown), illustrated this as follows: "Someone took a bite out of my biscotto, and my hot espresso is now cold. The Universe is constantly metamorphosing. I wish I was alone in the Universe."

Most of us have indeed seen the face of amateur astronomy change before our eyes. The ready availability of electronic detectors, computer programmes and, in the developed world, very good but relatively inexpensive optical equipment is a development of about the last two and a half decades, devices veritably driven by desires [2]. At the time of Canada's Centenary – and the Society's – such plenty would have seemed either utopian, or alien. The wealthy always had a choice: Unitron refractors, Parks or Cave reflectors, Questar Maksutov-Cassegrains, or more recherché bespoke instruments. Good quality, commercially-produced telescopes were the stuff of fantasy launched off the pages of *Sky & Telescope*, or the back of the *Observer's Handbook*. Most of us were not wealthy. Those who wanted their own telescopes had to fashion them from glass, metal, and wood. The sole way the dream could be brought to Earth and materialized was through hard labour. The only approved and practicable cure for aperture fever was more labour.

Lest I leave the reader with the impression that amateur astronomers compelled to become amateur telescope makers (ATMs) were the Four Yorkshiremen writ large[3], the acquisition of amateur telescope-making skills was a gratifying burden for many, and even possibly most. Beyond the extension of personal expertise, the experience formed a common bond uniting many active amateurs. Even if one didn't grind a mirror or figure an achromatic object class, machine a focuser, or creatively cannibalize unlikely but serviceable parts for mount and drive, one could be sure of the company of those who did.

Visitors to the McLaughlin Planetarium in its florescence will recall the Toronto Centre's telescope-making workshop on the way to the lecture theatre below stairs. A trio of items in the planetarium's tiny boutique, new in their maroon covers and latterly pristine in their white dust-jackets, could also be found well-thumbed and dog-eared in the RASC ATMs' workshop: *Amateur Telescope Making*, *Amateur Telescope Making Advanced*, and *Amateur Telescope Making, Book Three*[4]. The fabled books were compiled by Albert G. Ingalls, with line drawings and cartoons by Russell W. Porter.

Porter, 1888-1958, and Ingalls 1871-1949, are often seen as the

Amateur Telescope Making, Amateur Telescope Making Advanced, and Amateur Telescope Making, Book Three.

"founders," or cardinal figures of the ATM "movement" (Cox 1958; Williams 1991; Willard 1976). There is some truth to that story, although Porter and Ingalls are more accurately seen as paramount figures whose advocacy and practice shaped the ATM movement in their day (Williams 2000, 141-170). Neither invented the ATM universe *ex nihilo*, from nothing. It is well known from standard ATM hagiographies that Ingalls was inspired by Porter, and less well known that Porter was inspired by Leo Holcomb (1910), who in turn was inspired by John Mellish (BEA 2, 766-767) and Albert Hassard, 1873-1940, who belonged to the RASC and was good friend of C.A. Chant (Chant 1928, 116-117; Collins 1940; Broughton 1994, 159). A RASC member and a Canadian was thus one of the Godfathers to Porter's and Ingalls' work.

Ingalls' books were not the earliest printed communications of his and Porter's methods. They were preceded by the long-running and highly influential "Amateur Scientist" (AS) column in *Scientific American*, inaugurated by Ingalls in 1928 and continuing until 2001[5]. The golden age of the column nearly coincided with that of the ATM movement itself (Ingalls wrote AS from 1928-1955, and C.L. Stong from 1955-1977, during which more articles appeared on telescope making than on any other subject). The extent of the RASC and Canadian contribution was properly stated for the first time in Tom Williams' thesis on the development of amateur astronomy in the United States (2000). In the spirit of that work, although not derived from it, Table 1 below lists details on the Canadian (chiefly RASC) contributions to AS, and Table 2 does the same for the ATM books.

The extent and breadth of our contribution to the ATM movement unofficially piloted by Ingalls and Porter is impressive. There is hardly room here to give it full narrative presentation, but the details are in the tables for readers to discover for themselves. I cannot close without a few observations.

It is clear that Ingalls thought very highly of the RASC. He informs *Scientific American* readers of *Journal* articles they should read (*e.g.* Table 1: 1930 May; Dec.; 1939 Apr. bis) – as well as articles they should read with caution (Table 1: 1936 Mar.; 1947 Apr. bis) – and he extols the *Observer's Handbook* (Table 1: 1937 Apr.; 1952 Mar.; May). He reports on developments in Canadian professional instrumentation and its application to ATMs that he deems noteworthy (Table 1: 1930 May; 1933 Aug.; 1938 Dec.; 1944 May; 1946 Mar. Table 2: I, pp. 64, 302, 333, 387, 397, 427-428; II, pp. 111, 376-392, 480-482). Ingalls occasionally gets details about the RASC wrong (*e.g.* he persistently misstated our mixed pro-am nature; Table 1: 1941 Dec.; 1946 Feb.; 1950 Sept.). On the whole, the individual and collective notice he gave us in such a prominent semi-popular wide-circulation publication can only have been to our benefit. Irregularly periodic free advertising at that level is something similar organizations can only dream about. *Scientific American's* reach easily exceeded that of *Sky & Telescope* and other astronomy periodicals. It's a pity we have nothing similar today.

It was a two-way street, of course. During WWII, when many of Ingalls' younger regular AS contributors were away on active service, some older RASC members faithfully provided content for his articles. Cyril G. Wates of Edmonton can be particularly singled out in that regard (e.g. Table 1: 1943 August, etc.; also see 1946 July for Ingalls' obit notice of Wates; Williams 2000, 167-168).

The relative standing of the Dominion Astrophysical Observatory (DAO) and the David Dunlap Observatory (DDO) in amateur and professional eyes as seen through AS and ATM 1-3 is arresting. The DAO's Brashear and Warner & Swasey 72-inch dominated the DDO's Grubb Parsons 74-inch. The DAO's reflector was seen as a model worthy of respect and emulation for amateurs (*e.g.* Table 1: 1949 May. Table 2: I, p. 64, 302; II, p. 515), whereas the DDO's principal instrument is never found in that role. The optics of the DAO 72-inch were considered superior to that of the DDO 74-inch (Table 1: 1942, Apr. Table 2: I, 333). I cannot offer a personal assessment of the truth of these rankings, but it is certainly striking that those assessments persist in the professional literature of optics, and the history of astronomy (King 1955/1979, 352-353, 387-392; Hearnshaw 1986, 169, 172-174 *et passim*; Riekher 1990, 282, 290; Hearnshaw 2009, 37-41, 88). The same works that rate the DAO instrument, its supplementary instrumentation, and research as path-breaking, tend to accord briefer mention to the DDO in most respects. The Radcliffe 74-inch is often illustrated as the most significant of the DDO class of reflectors.

The ATM spirit is far from dead in the RASC. Some of these efforts have been reported in *Sky & Telescope's* Telescope Workshop column, whose editor, Gary Seronik, is an outstanding RASC ATM. Many of us have made or adapted instrumental components for our work. The nature of ATM activity has evolved, with more designing their own computer programmes for various aspects of observing. And, some present-day RASC ATMs have become highly respected professionals; here it suffices to name Paul Boltwood (Boltwood Cloud Sensor©), Peter Ceravolo (Ceravolo Optical Systems, producers of the optics for the CSA *Microvariability & Oscillations of STars [MOST]* Satellite), Doug George (Diffraction Limited, of Maxim DL© fame), and Jim Kendrick (Kendrick Astro Instruments). To this illustrious list one can add Québec amateur astronomer and professional telescope maker Normand Fullum (Telescopes Normand Fullum, producer of striking wooden instruments with first-class optics, and the optics for Orion Telescope & Binoculars' 36, 40, and 50-inch primary mirror Dobs.). It's a fine tradition.

Table 1. RASC and Canadian ATMs and Professionals in Scientific American's *Amateur Scientist column, under the editorship of Ingalls, and Stong. Note: TN="telescope nut," an affectionate term used by ATMs of themselves and their colleagues*

Scientific American Issue	**Name**	**Details**
December 1928	A.R. Dunlop, New Westminster, BC	builds reflector (30.48-cm primary) and separately housed solar spectroscope - plans to build a Hale-type spectrohelioscope
July 1929	F. Moore, Pemberton, BC	builds grinding machine, and 27.94-cm primary (acccording to *JRASC* 23 [1929]: 371 M. died before he could finish the telescope, and the primary is given as 25.4 cm)
September 1929	A.R. Dunlop, New Westminster, BC	issues observing challenge: what are the closest double stars TNs can observe with the equipment they have built?
October 1929	H.L. Rogers, Toronto, ON	builds reflector (30.48-cm primary); GEM is on castors
November 1929	A.R. Dunlop, New Westminster, BC	produces accurate drawings of solar prominences – supplement Mt. Wilson records
December 1929	Dr. W.E. Harper, Victoria, BC in *JRASC*	Ingalls approves of H.'s list of telescopes with primaries or O.G.s ≥38.4cm published in *JRASC* 23 (1929): 351-355
April 1930	M.S. Groh, Toronto, ON	builds reflector (15.24-cm primary?)
May 1930	Dr. R.K. Young, Toronto, ON (DDO, Richmond Hill) in *JRASC*	Ingalls highly recommends Y.'s article on research/teaching reflector (48.26-cm primary) published in *JRASC* 24 (1930): 17-33
December 1930	"Prof." G.W. Ritchey in *JRASC*	Ingalls cites G.W. Ritchey's *JRASC* articles (22 [1928]: 159-177, 207-230, 303-324, 359-382; 23 [1929]: 15-36, 167-190) as the most extended discussion in English of the Ritchey-Chrétien design
May 1931	Stephen Stoot, Saint-Hyacinthe, QC	builds reflector (15.24-cm primary). S., an employee of Casavant Frères, uses a 16-gauge hand-rolled zinc organ pipe for the OTA. S. received advice from H.L. Rogers, Toronto, ON
December 1931	E.E. Gale, Port Perry, ON	builds reflector (primary unspecified) with his secondary school students; the α-axis is set into a boulder for stability

Scientific American Issue	Name	Details
August 1933	DDO, Toronto, ON (Richmond Hill)	Ingalls writes "it is well-known, a 76-inch [sic] telescope is soon to be built for the University of Toronto"
May 1934	Rev'd Cyril E. Martin, Preeceville, SK	builds reflector (15.24-cm primary)
October 1935	Cyril G. Wates, Edmonton, AB	W.'s telescope is chosen from among 100 candidates for the cover of *Sci. Amer.* Ingalls discusses W.'s designs for a support for a diagonal, and a 9-point flotation system for a primary
March 1936	Harold C. King, Calgary, AB in *JRASC*, and an anonymous "Canadian"	Ingalls asked by anonymous "Canadian" to refute K.'s advocacy of primaries thinner than 1:8 in *JRASC* 29 (1935), 228-230. I. states that it is premature to do so before running experimental trials to settle the issue
May 1936	Cyril G. Wates, Edmonton, AB	designs illuminated setting circles, and a drive for an English equatorial mount
June 1936	Dr. Nathaniel H. Alcock, Montréal, QC (McGill)	A. explores experimental mould for honeycomb pitch lap with Rev'd W.F.A. Ellison, director of Armagh Observatory
July 1936	Cyril G. Wates, Edmonton, AB	builds a finder scope using a steropticon lens for the O.G.
April 1937	recommendation of the *Observer's Handbook*	Ingalls explains that when in the past *Sci. Amer.* stopped printing monthly star charts few complained; he roundly endorses the RASC *Observer's Handbook* to meet the need
September 1937	Cyril G. Wates, Edmonton, AB	refines the Foucault test to determine the focal centre of zones; defends concept of a circular diagonal
November 1937	Bertram J. Topham, Toronto, ON	trials and tribulations of moving a 2nd-hand observatory across Toronto
March 1938	"Prof." G.W. Ritchey in *JRASC*	Ingalls refers to G.W. Ritchey's treatment of the Schwarzschild design in *JRASC* 22 (1928): 218-221, 321-322
September 1938	*contra* Cyril G. Wates, Edmonton, AB	Hindle (BAA), Steavenson (BAA), and Everest reply to W.'s advocacy of circular diagonals
October 1938	*re:* Cyril G. Wates, Edmonton, AB	Ingalls provides a biographical sketch of W., along with those of others of his principal TN contributors
December 1938	DDO mirror, Toronto, ON (Richmond Hill)	Ingalls lists Pyrex©disks made for professional reflectors; the DDO 1.88-m (given here as 1.93-m) was one of seven solid disks, a group separate from the ribbed disks supplementary to the Palomar 5.08-m (Ingalls' account implies that the DDO mirror as the test casting for the giant of Palomar is no more than a persistent urban legend)
April 1939	J.S. Plaskett, Victoria, BC	Ingalls recommends P.'s article on the testing of the McDonald Observatory's 2.08-m primary ApJ 89 (1939): 84-98 (=*Contributions from the McDonald Observatory, University of Texas* I)
April 1939 *bis*	H. Boyd Brydon, Victoria, BC in *JRASC*	Ingalls recommends offprints of B.'s articles on the design of small observatories (originally *JRASC* 32 [1938]: 49-62, 233-256, 329-339) and inexpensive telescope drives (*JRASC* 33 [1939]: 5-12)

Scientific American Issue	Name	Details
May 1939	Cyril G. Wates, Edmonton, AB	produces a Ronchi grating
March 1940	Cyril G. Wates, Edmonton, AB	at Ingalls' invitation, W. describes the Gaviola test for an optical surface
July 1940	H. Boyd Brydon, Victoria, BC in *JRASC*	Ingalls repeats his recommendation of Apr. 1939 *bis*
October 1940	Cyril G. Wates, Edmonton, AB	extended treatment of relative merits of diagonals and prisms as secondaries; introduced by Ingalls as nearly the last word
November 1940	H.S. McClung, Regina, SK	McC.'s "corneal reflex test," a modification of the Foucault test (more fully presented in *JRASC* 31 [1937]: 311-313)
April 1941	Cyril G. Wates, Edmonton, AB	Ingalls cites W.'s Oct. 1940 contribution and his predilection for flats over prisms
June 1941	Cyril G. Wates, Edmonton, AB	the preparation of samples to investigate the effect of different grades of abrasive on glass
October 1941	Cyril G. Wates, Edmonton, AB	making a "star" lap
November 1941	Cyril G. Wates, Edmonton, AB	in regard to a contemplated reprinting of ATM 4th ed., Ingalls remarks that W. thought the index in previous prints inadequate, and offered to redo it himself; also W. on a new method of zonal testing
December 1941	Cyril G. Wates, Edmonton, AB	most of the article is on W.'s Hindle-type grinding machine (reprinted from *JRASC* 35 [1941]: 33-38); also cites H. Boyd Brydon as in 1939 April *bis*. Ingalls mistakenly characterizes *JRASC* as "a journal which is entirely amateur even if 'royal'"
March 1942	J.S. Plaskett, Victoria, BC	reprints 1st half of Plaskett's paper on testing of the McDonald Observatory's 2.08-m primary (see Apr. 1939 *supra*)
April 1942	J.S. Plaskett, Victoria, BC	reprints 2nd half of Plaskett's paper (see above). Of the four professional mirrors for which the Hartmann criterion was then available, the DDO primary showed the worst aberrations, and the DAO primary the second-least severe
August 1942	Cyril G. Wates, Edmonton, AB	on the use of black stumping chalk to indicate areas of contact between mirror and tool
January 1943	Cyril G. Wates, Edmonton, AB	a test for the correctness of prism angles
April 1943	Cyril G. Wates, Edmonton, AB	centrifugal force and speed as factors affecting mirror figure during grinding and polishing
June 1943	Cyril G. Wates, Edmonton, AB	on collimation, a contribution Ingalls calls "lucid"
August 1943	Cyril G. Wates, Edmonton, AB	on the use of onion sacking for the creation of sub-facettes in a pitch lap

Scientific American Issue	Name	Details
September 1943	Cyril G. Wates, Edmonton, AB	dedication ceremony for W.'s gift to the University of Alberta of a reflector with a 31.75-cm Pyrex© primary with a finder of RFT design with a 10.16-cm primary, and a dome and building, all made by W.
October 1943	Cyril G. Wates, Edmonton, AB	impracticality of using an "outsized mosaic tool for grinding"
November 1943	E.K. White, Ymir, BC	builds reflector (20.32-cm primary) on attractive GE mount with drive
December 1943	Walter H. Hass, New Waterford, OH in *JRASC*	Ingalls recommends reprint of H.'s article "Does Anything Ever Happen on the Moon" (*JRASC* 36 [1942]: 237-272, 317-328, 361-376, 397-408), produced by a non-RASC source
December 1943 *bis*	Cyril G. Wates, Edmonton, AB, and H.W. Parnall, Foothills, AB	on mending broken tools
February 1944	Cyril G. Wates, Edmonton, AB	on reliability of the $^{1}/_{2}$ stroke; and contact as a function of abrasive grade
May 1944	DAO, Victoria, BC, and J.H. Hindle, Haslingden and Blackburn Lancs	H. said to have been commissioned to make a new 49.53-cm convex secondary for the Plaskett telescope – the commission does not appear to have been completed. Ingalls notes that H. frequently visited Canada on business
May 1944 *bis*	Cyril G. Wates, Edmonton, AB	notes on Barlow lenses
September 1944	Cyril G. Wates, Edmonton, AB	correction to W.'s piece of May 1944 *bis* by another reader, and W.'s supportive response
February 1945	E.K. White, Chapman Camp, BC	on use of an electric fan to deal with tube currents (reprinted from *JRASC* 37 [1943]: 377-378)
June 1945	C.H. Werenskiold, New York, NY	design of curved secondary supports (reprinted from *JRASC* 35 [1941]: 268-270)
February 1946	E.K. White, Chapmans Camp, BC	on the virtues of slow f-ratio Newtonian systems (reprinted from *JRASC* 39 [1945]: 307-310), introduced by Ingalls as "cogent." Ingalls again mistakenly characterizes the RASC as *solely* amateur
March 1946	re: Dr. R.K. Young, Toronto, ON (DDO, Richmond Hill)	American TN looking for correspondents to discuss Y.'s drive for the DDO 48.36-cm reflector (ATM, 376)
July 1946	Cyril G. Wates, Edmonton, AB	on the Brydon drive (Apr. 1939 *bis supra*); Ingalls laments W.'s recent death
April 1947	Jacques Labrecque, Montréal, QC	wonders why cerium oxide "regrinds" rather than polishes surfaces
April 1947 *bis*	*contra* Harold C. King, Calgary, AB	Ingalls finally answers the request of an anonymous Canadian to answer K.'s advocacy of thin mirrors (Mar. 1936 *supra*), finding fault with K.'s reasoning – a rare example of Ingalls' publicly aired criticism
June 1948	E.K. White, Chapmans Camp, BC	builds what is claimed to be the highest elevation observatory in Canada (1097.28 m above sea level); dome and walls rotate in tandem

Scientific American Issue	Name	Details
May 1949	DAO, Victoria, BC	Ingalls compares an American TN's cross-axis equatorial mount (mistakenly called an "English Yoke mounting") to the mount of the DAO's Plaskett telescope
August 1949	Walter H. Haas, New Waterford, OH	Ingalls again refers to H.'s "Does Anything Ever Happen on the Moon" (see 1943 December *supra*)
February 1950	Robert C. Fairall, Victoria, BC	builds a spectroscope
April 1950	H. Boyd Brydon, Victoria, BC in *JRASC*	Ingalls cites the "late" B.'s design of a "teepee" observatory (Apr. 1939 *bis supra*), calling it a "rare type… its chief merit is its simplicity"
September 1950	RASC	Ingalls cites the RASC in the context of significant national organizations (1700 members; 300 American), and mentions the *OH* and *JRASC*. Ingalls commits his old error of describing it as "a federation of amateur astronomers' clubs in 11 Canadian cities," to which he adds the new one of dating its foundation to the grant of the royal appellation (1903)
July 1951	H.L. Rogers, Toronto, ON	builds synchronome clock with a wooden pendulum
March 1952	recommendation of the *Observer's Handbook*	Ingalls cites the *OH* as a convenient source for solar ephemera (priced at US $0.40!)
May 1952	recommendation of the *Observer's Handbook*	Ingalls by implication gives the edge to the *OH* over the BAA's similar publication
January 1953	Walter H. Haas, New Waterford, OH	Ingalls again refers to H.'s "Does Anything Ever Happen on the Moon" (see Dec. 1943 *supra*)
May 1953	Canadian amateurs	Ingalls notes that the systematic record of Jovian cloud formations is entirely due to amateurs "mainly working in organizations… and has been taken up in the last few years… in Canada" (*n.b.* RASC efforts really only bore fruit later, *e.g. JRASC* 56 [1962]: 79-80, 251-252, 57 [1963]: 114-119, and 58 [1964]: 39, but could never match the achievements of the BAA, or ALPO)
November 1953	T.R. Macfarlane, Regina, SK	method of dividing setting circles based on chords
February 1954	E.K. White, Ymir, BC	deleterious effects of 17%-25% obstructions in planetary Newtonian systems, and the advantages of limiting the obstruction to 10%
April 1955	*A.G. Ingalls retires, replaced by C.L. Stong*	
December 1955	Wilfrid T. Patterson, Guelph, ON	technique for effectively utilizing high-quality war surplus achromatic O.G.s as telescope components; & machine for cutting worm gears
January 1957	International Geophysical Year (IGY) (Dr. Peter Millman NRC, Ottawa, ON)	invitation to Canadian amateurs to contribute auroral observations to the IGY Auroral Program through M., the Canadian coordinator

Scientific American Issue	Name	Details
June 1958	Stephen Stoot, Saint-Hyacinthe, QC	Charron-style pivot for a Foucault pendulum
September 1960	Ralph N. Buckstaff, Oshkosh, WI, Robert Evans, Victoria, BC, Prof. Walter A. Feibelman, Pittsburgh, PA, Franklin Loehde, Edmonton, AB, Walter J. Semerau, Kenmore, NY	L. and E. were the Canadian component of an amateur network collecting radio-frequency observations for an AAVSO solar flare patrol programme (genesis IGY preparations *ca*. 1955). F. collected excellent data, but L. & E. were not successful due to site interference and illness.
June 1964	Prof. Gordon F. Pearce, Waterloo, ON	builds series interferometer
June 1968	Prof. Gordon F. Pearce, Waterloo, ON	builds analogue computer
October 1969	T.R. MacFarlane, Regina, SK	technique to eliminate scratch-causing lumps in abrasives, and to render abrasives more efficient
January 1975	Sean Johnston, Burnaby, BC	builds a "recording" spectrophotometer
February 1976	*obituary for C.L. Stong, who wrote the column from 1957-1976*	©R.A. Rosenfeld

Table 2. RASC and Canadian ATMs and Professionals in ATM-*1-3*

Amateur Telescope Making (ATM) Volume	Name	Details
ATM I 4th ed. 1945 (1976), p. viii	Canada	Ingalls lists Canada among nations involved in the informal ATM network nourished by *Sci. Amer.*
I, p. 64	DAO, Victoria, BC	McDowell's (Brashear and Co.) crushed-ice solution to protecting the central aperture of the 182.88-cm primary during figuring
I, p. 246	A.R. Dunlop, New Westminster, BC	solar spectroscope (refers to *Sci. Amer*. Dec.1928 [year mistakenly given as 1929])
I, p. 296	H.L. Rogers, Toronto, ON	correcting a hyperbola
I. p. 302	DAO, Victoria, BC	Ingalls encourages TNs not to disparage "plate glass," noting that it was used for the "great Dominion Astrophysical Observatory's reflector"
I. pp. 307-308	H.L. Rogers, Toronto, ON	design of a finder scope
I, p. 323	"Prof." G.W. Ritchey in *JRASC*	see entry for *Sci. Amer*. Dec. 1930 in table 1
I, p. 333	DAO, Victoria, BC, and Dr. John Brashear, Pittsburgh, PA & Muskoka, ON	DAO 182.88- cm primary cited as the pinnacle of Brashear's career
I, p. 335	A.R. Dunlop, New Westminster, BC	replica grating solar spectroscope
I, p. 359	H.L. Rogers, Toronto, ON	picture of R.'s portable reflector (30.50-cm primary)

Amateur Telescope Making (ATM) Volume	Name	Details
I, p. 387	J.S. Plaskett in *Publications of the DAO*	Ingalls cites P.'s article on the DAO's 182.88-cm primary in discussing the effect of falling temperature on a mirror's figure; PDAO 1, 1: 42-48
I, p. 397	Dr. R.K. Young, Toronto, ON (DDO, Richmond Hill) in *JRASC*	Ingalls recommends Y.'s treatment on methods of parabolizing in *JRASC* 24 (1930): 20-24 (Y. not mentioned by name)
I, pp. 427-428	Dr. R.K. Young & V. Krotkov, Toronto, ON (DDO, Richmond Hill)	cites Y. & K. on their discovery of discrepancies between published tabular values and their experimental data on the reflectivity of silver films, and on the effects of age on the reflectivity for different wave lengths of different films; *JRASC* 23 (1929): 399-401
I, p. 437	Cyril G. Wates, Edmonton, AB	picture of W.'s nine-point flotation for a 22.86-cm primary
I, p. 492	RASC	contact information provided, *OH* recommended
ATMA II 1st ed. 1937 (1946), p. 111	J.S. Plaskett in *Publications of the DAO*	Ingalls recommends P.'s account of the Hartmann test *PDAO* 1, 1: 40-53
II, 187-191	W.T. Patterson, Guelph, ON	"Oculars at Small Cost"
II, 274-275	Cyril G. Wates, Edmonton, AB	"Adjusting the Polar Axis"
II, 290	Cyril G. Wates, Edmonton, AB	on setting circles
II, 376-392	Dr. R.K. Young, Toronto, ON (DDO, Richmond HIll) in *JRASC*	"The Building of a 19-Inch Reflecting Telescope", a reprint of *JRASC* 24 (1930): 17-33
II, p. 440	unidentified Canadian short-wave source	an American synchronome clock builder complains of interference from a Canadian short-wave source, when trying to receive the USNO time signal(!)
II, p. 444	Dominion Observatory (DO), Ottawa, ON	Ingalls, in listing Shortt clocks in North America, mistakenly locates Ottawa (and the DO) in the US!
II, pp.480-482	Dr. R.K. Young & V. Krotkov, Toronto, ON (DDO, Richmond Hill)	"The Deterioration of Silvered Glass Mirrors and the Reflecting Power of Polished Chromium Steel", a reprint of *JRASC* 23 (1929): 399-401
II, p. 506	Cyril G. Wates, Edmonton, AB	rouge test for contact of grinding surfaces
II, p. 515	DAO, Victoria, BC	the mounting of the Plaskett telescope the model for an American amateur's (PA) finely crafted telescope
II, pp. 544-555	Dr. Peter M. Millman, Toronto, ON (DDO, Richmond Hill)	"Meteor Photography"
ATM Bk. III 1st ed. 1953 (1979), pp. 141-144	Owen Gingerich, Boston, MA (at this time a graduate student, who later achieved fame as a noted historian of astronomy at Harvard; currently an Honorary Member of the RASC)	"Notes on a Spectrograph" (recounting G.'s experience as a recent undergraduate restoring and recommissioning an old lab spectrograph at Goshen College, IN © R.A. Rosenfeld

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Abbreviations

ATM 1=Ingalls, A.G. *et al.* (1925). *Amateur Telescope Making*. New York: Scientific American Publishing Co.

ATM 2=Ingalls, A.G. *et al.* (1937). *Amateur Telescope Making Advanced*. New York: Scientific American

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Abrahams ATM bibl.=Peter Abrahams. *Editions and printings of the Scientific American "Amateur Telescope Making" series* `www.europa.com/~telscope/atmbiblg.txt` (accessed 2010 November 22)

Four Yorkshiremen=Four Yorkshiremen Sketch, *Wikipedia* `http://en.wikipedia.org/wiki/Four_Yorkshiremen_sketch` (accessed 2010 November 26)

R.A. Rosenfeld is the RASC's Archivist. He was trained as a palaeographer and codicologist at the Pontifical Institute of Mediaeval Studies, and specialized in the technologies of written communication ca. AD 500-1500. He won second prize in the Boeing-Griffith Observatory Science Writing Contest for 2008, and the 2009 Ostrander-Ramsay Award for excellence in astronomical writing (Toronto Centre, RASC), and received a Certificate of Appreciation from the IAU for contributions to IYA2009.

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[1] The literal minded may wonder why anyone would even want to step into the river once. "The Obscure" seems a good epithet for a cosmologist.

[2] It must be admitted that, for better or worse, globalization has played a role in this change. The present author has certainly benefitted. If I followed the environmental chain of manufacture and trade for my modest 300-mm primary mirror Dob, I would doubtless have much for which to answer.

[3] http://en.wikipedia.org/wiki/Four_Yorkshiremen_sketch

[4] For details of editions and printings, see Peter Abrahams' (ATM bibl.) useful discussion. Differences, minor and not so minor, can be found between the diverse printings of the various editions of all three volumes. A more rationalized and easier to navigate edition in a larger format by Willmann-Bell (1996) is still available, but at the expense of jettisoning some material no longer deemed useful to contemporary ATMs, yet of definite historical interest all the same. For a real feel for Ingalls' collaborative text as a living workshop tool in the nearly six decades of its prime use, it is necessary to handle the pre-1996 printings, preferably ones thick with shop notes, manuscript and printed insertions, and chemical discolourations and stains. Should you happen upon a set, buy it!

[5] AS had a succession of different titles over the years, as Williams 2000, 152 note 18 attests, but as a whole it is usually referred to as AS.

Imager's Corner

by Blair MacDonald, Halifax Centre
(b.macdonald@ns.sympatico.ca)

Noise Reduction

This issue's question was sent in as an anonymous email: "*How can I reduce background noise in my images using* Photoshop*? When I reduce the background noise enough, the main image loses detail. Help*."

By far the best way to deal with noise is to not have it in the first place. Be sure to fully calibrate your images and ensure that you have plenty of exposure time. For most deep-sky objects (DSOs), this means an hour – and longer is better.

Having gotten that motherhood statement out of my system, sometimes you simply can't expose long enough. Weather, work, and family commitments intrude upon imaging time, and, sooner or later, you do have to sleep. This is where your favourite image processor comes in handy. I can't address *Photoshop* exactly since I use *Paint Shop Pro*, but the general procedure is the same – use multiple layers and masks to target the noise reduction where it's needed.

In general, all noise-reduction algorithms work by blurring the image somewhat to reduce the appearance of the noise. In cases where the background noise is high, this can lead to the loss of detail mentioned in the writer's question. The secret is to restrict the noise reduction to the dark areas of the image. In most images, the brighter parts are sufficiently exposed, while the dimmer parts may lack the required exposure to provide a good signal-to-noise ratio.

This targeting can be done with feathered selections, but it is a REAL PAIN to do this and still maintain decent stars. A better approach is to use two layers and a mask to target the noise reduction automatically.

First, duplicate the image on another layer, call this layer A. Name the bottom, original layer, B. Hide layer A and select layer B. Use your favourite noise-reduction command to reduce the noise in the background of this layer. Overdo it a bit to ensure a smooth, noise-free background. This will leave the main subject of the photo a little blurry and lacking in detail, as the writer has noted. Now this is where the layer magic happens: make layer A visible and place a mask made from it on top.

Masks allow the layer immediately below to show through where the mask is white. Where the mask is black, layer B will be visible and, when the mask is grey, a combination of the two is visible. This allows the mask to blend the two layers automatically. You can vary the brightness and contrast of the mask to let more or less detail from layer A show through. In areas of greatest detail, you can even paint the mask white. This gives the final image a noise-reduced background, where there is little detail and the most noise, and the original sharp detail where the image is bright.

The two images below show a "before and after" comparison of the technique; I've increased the brightness and contrast by the same amount in each image to make the noise more noticeable. The technique maintains detail in the brighter areas of the nebula and maintains tight stars, while significantly reducing the background noise to produce a more pleasing image for display or printing.

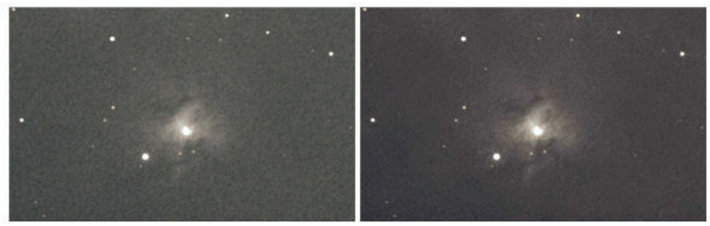


Figure 1: Images before (left) and after (right) background noise reduction.

Blair MacDonald is an electrical technologist running a research group at an Atlantic Canadian company specializing in digital signal processing and electrical design. He's been an RASC member for 20 years, and has been interested in astrophotography and image processing for about 15 years.

The Royal Astronomical Society of Canada is dedicated to the advancement of astronomy and its related sciences; the *Journal* espouses the scientific method, and supports dissemination of information, discoveries, and theories based on that well-tested method.

Second Light

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

A First Glimpse of the Epoch of Reionization – or Not

I assume that all my readers know about the Big Bang, which seems to be the birth event of the present Universe. After the first few minutes, the Universe settled down into something that would be at least partially recognizable to us, dominated by protons, electrons, helium nuclei (alpha particles), and photons. As it expanded over the next few hundred thousand years, it cooled to the point where the electrons could join with the protons to make hydrogen, and with the helium nuclei to make atomic helium. This event is called "decoupling," because the photons (light) became decoupled from matter, allowing the light to stream freely. We see this event recorded in the fluctuations in the microwave background. But, readers are probably not generally aware of the next "big event" in the history of the Universe – the epoch of reionization, where the hydrogen between the forming galaxies – the intergalactic medium – gets reionized. A first look using the 21-cm line of atomic hydrogen is reported in the December 9 issue of *Nature* by Judd Bowman of Arizona State University and Alan Rogers of Haystack Observatory. They find that the epoch must have lasted longer than ~3 million years, assuming it took place at z~11.

The physics of recombination are clear and relatively straightforward, which is why the WMAP results have ushered in the era of "precision cosmology." The seeds of the present Universe – clusters of galaxies, and sheets/filaments of clusters – were implanted at that time, and there is a fairly remarkable agreement between simulations and observations.

By contrast, the epoch of reionization is inherently messy astrophysics. There is no clear agreement on when it started, though it does appear to have ended somewhere around a redshift of 6. At that time in the Universe's life, there are complicated, non-linear relationships between distance, time, and redshift. Because the astronomical observable is redshift, we astronomers tend to fall back on that. Let me illustrate this with a few numbers. The WMAP data are interpreted to indicate that reionization took place roughly around redshift z~11. Bowman and Rogers found that the epoch must have lasted a redshift interval of $\Delta z > 0.06$. At a redshift of 11, this corresponds to a time of just 3 million years. But $\Delta z = 0.06$ at a redshift of 6 corresponds to 12 million years. So, I hope you will excuse the need to use the jargon of redshift.

The messiness arises because of multiple reasons. We do not know if the first stars formed outside galaxy-like structures, or inside. If on the outside, before galaxies started forming, then the first massive stars can start ionizing the intergalactic medium around them. However, if those stars formed inside galaxies, then the photons needed to ionize the hydrogen and helium in the intergalactic medium have to get outside the galaxies first – and young galaxies will contain lots of gas to intercept the photons before they even get to the edge. Recent estimates of the escape rate place it around five percent. We also do not know when the first black holes formed, and whether they did so in gas-rich or gas-poor environments, which returns us to the pesky escape problem. The black holes themselves will not ionize the gas, but they typically are surrounded by extremely hot disks of accreting gas that emit lots of x-rays. Brant Robinson of Caltech and colleagues have argued in a recent review article (see the November 4 issue of *Nature*) that there were enough photons from the early galaxies to reionize the intergalactic medium, but at this stage my own belief is that the situation remains unclear.

The question of what is ionizing the Universe also is linked to when the process began, and when it ended. Simulations of when the first stars formed are quite sensitive to various assumptions, and, as a result, they offer little real guidance as a way to disentangle the various factors. There is also the fact that reionization must take a period of time as the photons take time to travel from the regions where galaxies and stars are abundant, to the places farthest from the galaxies.

Bowman and Rogers took a very straightforward approach of looking at the 21-cm signal of atomic hydrogen, averaged over the whole observable sky from a radio-quiet location in Western Australia. If reionization occurred rapidly, they would see a distinct "step" in their spectrum, which goes from ~100 MHz (redshift z~13) to ~200 MHz (redshift z~6). They did not, and this places a lower limit on the length of the epoch of some millions of years.

In a sense, this answers a question that no one was asking, because no cosmologist thought that the epoch would be over that rapidly. But Bowman and Rogers have also stolen a march on the $10 billion+ proposed Square Kilometer Array that some astronomers have been pushing for a decade (and which was recently sidelined for a while by the Decadal Survey in the US, though other countries – including possibly Canada – are pressing on with preliminary work). The main scientific justification for the SKA is to study the epoch of reionization.

Such a study would face daunting technical challenges, but Bowman and Rogers have shown that they can be overcome, at least to some extent. However, teasing the complicated astrophysics of sources, times, distances, and extinctions out of 21-cm spectra seem to me to be the bigger challenge. There are three SKA "pathfinder" telescopes that will in the interim attempt to study reionization. Lofar (`lofar.org`) is already operational, and the Murchison Widefield Array (mwatelescope.org) will be finished in 2012. Finally, an array called PAPER (Precision Array to Probe Epoch of Reionization) has been discussed, but not yet funded or built. I would be happy to be shown to be wrong in a few years, if the pathfinder telescopes are able to do the disentangling.

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.*

Through My Eyepiece

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

21st-Century Beginners

By golly, we're now into the second decade of the 21st century! Maybe it's time to take a fresh look at the advice we give beginners who are looking to buy optics for astronomy.

One of the unfortunate realities of modern life is that most amateur astronomers are facing even worse light pollution today than what we thought was horrendous even a decade ago. With the move towards brighter, more efficient broad-spectrum outdoor lighting, notably LEDs, light pollution will be getting significantly worse in the years to come.

I am afraid that I am coming to believe that star hopping, as we knew it is a dying art. The old-time (read "a decade or two ago") starhopper with star atlas, binoculars, and wide-field eyepiece, is going the way of the Dodo. It is increasingly difficult to spot stars bright enough to pierce the murk over our cities, even with binoculars. At the same time, most working stiffs today have very limited time for hobbies. The idea of spending a few hours under a dark sky hunting down a faint galaxy, while romantically appealing, is just not what today's beginner is able or willing to do.

Fortunately, just as star hopping is becoming next to impossible, electronic assistance finally seems to be coming of age. The most recent generation of computerized telescopes is beginning to live up to its promise.

The early versions of GoTo telescopes expected beginners to spot two or three alignment stars. Beginners, who had shied away from learning constellations, suddenly found themselves needing to identify stars of which even amateurs with decades of experience had never heard. Now, newer computers have taken much of the pain out of alignment, so that it becomes a short prelude to a successful observing session rather than a frustrating and ultimately fruitless wild-goose chase.

Something to keep in mind when purchasing a GoTo mount is that you may do much better with an old-fashioned German equatorial than with the altazimuth mounts that are so common in GoTo telescopes. I've found my Orion Sirius German equatorial far easier to set up and use than my various Celestron altazimuths. Once the polar axis is reasonably well aligned and the time entered accurately, the mount pretty much knows where to point with hardly any additional alignment. After all, it "thinks" in sidereal time and knows where and when it is, which is really all that a mount needs to know. Tracking on a real equatorial is far smoother and quieter than the "double trouble" required to keep an altazimuth on target.

I must confess that, as I have gravitated more and more to digital setting circles and GoTo mounts over the past few years, I have been using my trusty 10x50 binoculars less and less. Nowadays they spend more time in our living room for nature viewing than they do around my neck in the observatory. I still love exploring a dark sky with 10x50s, but most of the time with my telescopes, I let the computer do the heavy lifting, while I spend my time at the eyepiece.

An interesting recent development has been the application of GoTo technology to medium-sized altazimuth scopes, notably Orion's SkyQuest GoTo Dobsonians. GoTo technology heretofore had mainly been applied to dinky little scopes like the ETX and giant custom Dobs, rather than to the workhorses of amateur astronomy, 8- to 12-inch Dobs.

Following on my earlier recommendations here, that my favourite size and form factor in a scope is a 10-inch f/4.8 Dob, then perhaps my revised ideal would be a 10-inch GoTo Dob like this:

For a serious visual observer, beginner or advanced, this has it all: aperture, resolution, comfortable seated observing, tracking, and accurate, simple GoTo capabilities.

Of course, just to be ornery, I've recently acquired something totally different: a 127-mm f/7.5 Explore Scientific apochromatic triplet refractor. You can never have too many telescopes. Of course, I'm mounting it on my Sirius GoTo equatorial.

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, particularly of Jupiter and variable stars. Besides this column, he contributes regularly to the* Starry Night Times *and writes a weekly article on the Space.com Web site.*

Gizmos

by Don van Akker, Victoria Centre (dvanakker@gmail.com)

A Rainy Afternoon

Meade tripods can be hefty brutes. The one that came with our 12-inch LX200 weighs all of 50 lbs and would hold up a Honda if you could find one with a tripod socket. What it doesn't hold up however is some extra eyepieces or the Meade hand paddle that is left dangling from its cord after the cheesy little cradle breaks off the mount. This tripod tray does all those things and is easy to make as well. It could be adapted to work on almost any tripod with tubular legs and a spreader.

Figure 1: The tray has both 1¼" holes and 2" holes for eyepieces. The bolt at the back extends through a hole drilled into the spreader for the purpose and has a wing nut on the underside.

Figure 2: The hand-paddle slot is the trickiest bit; beaver out the material very slowly by moving the jigsaw side to side, checking the fit as you go. Finish the edges with files and sand paper.

It was made of a piece of 1/8" aluminum that I happened to have around. You could buy a piece at a place like Metal Supermarket, or you could use plywood, which would probably work just as well.

Begin by making a template with a piece of cardboard and a utility knife. Lay it out with a ruler and a square and keep trimming until you get it right. I had to take a couple of tries at it so don't worry if it doesn't go right the first time. The notch for the hand paddle needs to be fitted to your particular unit. Just rough it in small on the template; the final trim can be done to the finished product.

Aluminum is a wonderful metal for amateurs because it can be worked with woodworking tools. Trace out the template with a marker and cut the shape with an ordinary jigsaw and a fine-toothed wood blade. The holes are cut with a hole saw, but could be cut with the jigsaw as well, if you are careful and patient. Drill a starter hole if you do choose the jigsaw route. Cut the hand-paddle notch with the jigsaw as well, working at it slowly and fitting as you go until it is just right.

Rough edges can be finished with sandpaper wrapped around a wooden block or dowel, and with a file.

The final product bolts to a hole drilled into the spreader of the tripod. Use a stainless-steel bolt and a wing nut.

A good way to pass a rainy afternoon.

Don van Akker and his wife Elizabeth are members of RASC in Victoria. Don can be reached at dvanakker@gmail.com. He would be glad to discuss solar power or any other Gizmos article if you drop him a line.

Obituaries

Dr. Allan Sandage (1926 - 2010)

by Sidney van den Bergh, Dominion Astrophysical Observatory

Allan Sandage

Allan Sandage who, at age 84, died of pancreatic cancer on 2010 November 13, was the leading observational cosmologist of the second half of the 20th century. He is linked to Edwin Hubble, the most prominent observational cosmologist of the first half of that century, by a joint paper on the brightest variable stars in M31 and M33 that Hubble and Sandage published together in 1953. Later that year Sandage also (posthumously) edited Hubble's last paper.

Sandage published over 500 research papers during his 60-year scientific career. Probably the most influential of these was his 1970 article "Cosmology: A Search for Two Numbers" that set the research agenda for a generation of observational cosmologists. Sandage himself never became deeply involved in the next phase of cosmology, which has been dominated by dark matter, dark energy, and the inflation of the Universe.

Allan Sandage obtained his Ph.D. degree from Caltech working under the direction of Walter Baade. Subsequently, he spent almost his entire career working at the Mount Wilson and Palomar Observatories, which are now known as the Carnegie Observatories. This provided him with almost unlimited access to the Palomar 200-inch telescope – at that time, by far the largest telescope in the world. He and his collaborators used this opportunity to study both the most distant known galaxies and the faintest stars in the oldest known star clusters. In its obituary, the *New York Times* wrote "Dr. Sandage was a man of towering passions and many moods, and for years, you weren't anybody in astronomy if he had not stopped speaking to you." [During the great distance-scale debate, Allan returned my letters to me unopened. In this debate, Sandage and Tammann had advocated a Hubble constant H_0 = 55 km/s/Mpc, whereas de Vaucouleurs and I favoured a value of H_0 ~ 80 km/s/Mpc.]

The beauty of such scientific debate is that it eventually gets resolved by better observations. In this case, observations of distant Cepheid variables with the *Hubble Space Telescope* showed that H_0 = 72 +/- 8 km/s/Mpc. This value is almost an order of magnitude lower than originally proposed by Hubble in his 1929 discovery paper on the expansion of the Universe. The two largest contributions to this enormous increase in the size and age of the Universe were provided by Baade's work, which showed that Cepheid variables were 1.4 magnitudes more luminous than previously believed, and Sandage's discovery that the "stars" that Hubble had used to determine the distance to the Virgo cluster were actually compact star clusters embedded in luminous H II regions.

Finally, Sandage's name will forever be associated with the work that he, Eggen, and Lynden-Bell did on the formation of our Milky Way system. They showed that our galaxy had formed by star formation in a rapidly collapsing, huge proto-galactic gas cloud.
In subsequent decades, this view was challenged by advocates of a model in which galaxies formed primarily by hierarchical mergers of smaller pre-existing "bits and pieces." More recently, a picture of galaxy evolution has emerged that contains elements of both the collapse and merger scenarios.

Allan was a deeply religious man. He thought that science illuminates brightly but only partly of reality. He felt that the world was too complicated in all its parts and interconnections to be due to chance alone.

Four books published by Sandage form a permanent memorial to him on my bookshelf: the *Hubble Atlas of Galaxies* (Sandage 1961); *Galaxies and the Universe* (Sandage, Sandage & Kristian 1975); A *Revised Shapley-Ames Catalog* (Sandage & Tammann 1981); and *The Carnegie Atlas of Galaxies* (Sandage & Bedke 1994).

Dr. Brian G. Marsden (1937-2010)

by R.A. Rosenfeld, RASC Archivist

RASC members will be saddened to learn that one of our most distinguished contributors to the *Observer's Handbook (OH)* has recently passed away. Dr. Marsden was a dedicated and notable expert on Solar System astrometry, but he was also keenly interested in the physical nature of the objects themselves. He was the long-serving Director of the International Astronomical Union's (IAU) Central Bureau for Astronomical Telegrams (CBAT), 1968-2000, and of the IAU's Minor Planet Center (MPC), 1978-2006, both located at the Smithsonian Astrophysical Observatory (SAO) on the Harvard campus. Any RASC member who discovered a comet, nova, or supernova, or contributed quality positional, photometric, or spectrographic data on new objects had cause to appreciate the intelligence, efficiency, and obligation of Dr. Marsden and his highly professional staff. As well as contributing conscientiously to the *OH*, Dr. Marsden published an interesting paper on the great Carl Friedrich Gauss (1777-1855) in this *Journal*: `http://adsabs.harvard.edu/abs/1977JRASC..71..309M`. The attraction of Gauss's legacy in celestial mechanics to the modern

Brian Marsden. Image: Harold Dorwin, Harvard-Smithsonian Center for Astrophysics.

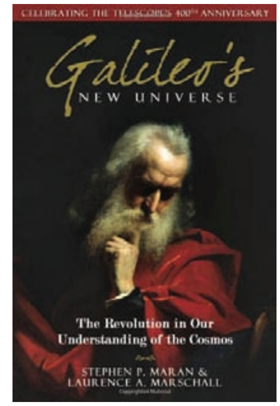
astrometrist with a sense of history proved well nigh irresistible.

Dr. Marsden, short of stature and vigorous in presentation, was a most engaging public speaker, an effective and ready debater, and the fortunate possessor of an even readier wit. At the notorious triennial IAU meeting in Prague at which Pluto was re-classified, and at which he resigned the directorship of the MPC, Dr. Marsden quipped that both he and Pluto had been retired on the same day. He had commenced his astronomical "career" as an amateur, interested and active both as an observer and calculator, and, while many amateurs disagreed with his reasoned stance regarding Pluto's status, they could respect the integrity of his position. Dr. Marsden was always a vigorous supporter of amateur astronomical work, and of pro-am collaboration (it came with the CBAT and MPC territory, as it were), provided it was of the highest calibre. He played a particularly important and welcomed role in encouraging amateurs to produce work of the highest quality, both for their own benefit and that of the science at large (Dunlop, S. & Garibaldi, M. Eds., *Stargazers: The Contribution of Amateurs to Astronomy*. Berlin-Heidelberg: Springer Verlag, pp. 64-76, 225-227). The lessons he taught should not be forgotten.

The "cheery herald of fear," as a *New York Times* headline impishly referred to him for his creative role in bettering the ephemerides of Near Earth Objects (NEOs), received many honours, among which was membership in the Det Norske Videnskaps-Akademi (Norwegian Academy of Science and Letters), and, most appropriately, the naming of asteroid 1877 Marsden (1971 FC) in his honour. He had his own discoveries to his name, including asteroid 37556 Svyaztie (1982 QP3), and the short-period comets of the Marsden Group, recently discovered from his analyses of Solar and Heliospheric Observatory (SOHO) data: `www.comethunter.de/groups/marsden.html`.

An excellent account of his life by one of his colleagues at the MPC can be found at `www.minorplanetcenter.org/mpec/K10/K10W10.html`.

Reviews/Critiques



Galileo's New Universe: The Revolution in Our Understanding of the Cosmos, by Stephen P. Maran and Laurence A. Marschall, pages 174+x, 15 cm × 23 cm, Benbella Books. Inc., Dallas, TX, 2009. Price $17.50 paperback (ISBN: 978-1-933771-59-5).

The "supertitle" of *Galileo's New Universe* is Celebrating the Telescope's 400th Anniversary, placing it in league with the multitude of books, videos, and other material published on astronomy, telescopes, and Galileo associated with the International Year of Astronomy 2009. An obvious question that comes to mind is "what more is there to say?" While most of the content of *Galileo's New Universe* is indeed available from other sources, what commends this book is the manner in which it is presented. Rather than wading through 400 years of technology and astronomical discovery since Galileo first raised his glass to the heavens, the authors have chosen to organize the material into one topic per chapter, each chapter in two parts: the first part takes us back to the early 1600s to review Galileo's astronomical discoveries and thoughts (and their impact), while the second part brings us back to the present to assess current astrophysical knowledge and the new directions in research. That transforms the book into a concise vehicle celebrating both Galileo's genius and the wonderful cosmic vista we enjoy 400 years on, all based on telescopic observations then and now.

The sections of *Galileo's New Universe* include: Introduction, The Long View: Galileo's Life and Legacy, Telescopes, The Moon, The Sun, Jupiter, Saturn, Venus, Comets, The Stars and the Milky Way, Cosmology, and Epilogue. There is a Bibliography containing 5–15 suggestions of books and articles per topic for further reading.

Dr. Stephen Maran worked 35 years for NASA, on the *Hubble Space Telescope* and other projects, and is the author of 10 previous books, including *Astronomy for Dummies®*. Laurence Marschall is a college professor and an award-winning writer, having published over 40 scientific articles, multiple popular articles, and a book: *The Supernova Story*.

The structure of *Galileo's New Universe* and its concise style leads to predictable gaps in the story. It is not the book for someone interested in the history of the telescope, for example. The time-warp narrative jumps from Galileo's small, homemade, simple refractor of 1609 to the huge, electronically equipped professional reflectors of today, necessarily leaving out the amazing developments in refracting telescopes – and the discoveries made with them – that immediately followed Galileo's initiative. That part of the history is simply outside the scope of the book.

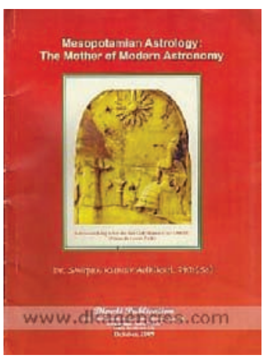
One topic that was new to me was Galileo's interpretation of comets. We are accustomed to the stories of Galileo's insight and strengths, but rarely hear about his blunders. I will not spoil the story, but let's just say "nobody's perfect."

While reviewing the book, I found I was constantly recalling images depicting Galileo's observations from other previous reading, since the book has no illustrations (apart from some tiny in-text samples). Inclusion of a few of Galileo's classic illustrations would have been helpful to the novice. The same could be said about the descriptions of telescopes then and now. (That must have been a business decision on the part of the publisher: adding illustrations increases page count and cost, but would it boost sales? And the topics covered are so broad, it would have been difficult to know when to stop adding graphics.) Astronomy is an observational science and it is a challenge to appreciate the visual aspects of the human endeavour through words alone.

I found *Galileo's New Universe* well-written and easy to read, and I wish I could be more positive about the experience. But I must confess that at present I am a little saturated with popular literature on Galileo/telescopes/astronomy with IYA 2009 come and gone. Surely I would have found the book refreshing if I had read it sooner. (Do not misunderstand me: I read it as soon as I got it!) *Galileo's New Universe: The Revolution in Our Understanding of the Cosmos* would be a good book for the imaginative reader (of any background) for whom the material is new and who wants quickly to absorb the significance of Galileo's astronomical contributions and our current view of the Universe.

David Chapman

David Chapman is an Assistant Editor of JRASC *and a member of the RASC Halifax Centre, assisting in outreach and dark-sky-preserve activities.*



Mesopotamian Astrology: The Mother of Modern Astronomy, by Swapan Kumar Adhikari, pages 56 + v, 21 cm × 28 cm, Dipali Publication: Howrah, West Bengal, 2009. Price $10 US paperback (ISBN-10: 81-901643-5-X).

The author of *Mesopotamian Astrology*, now retired, was Head of the Institution and Department of Mathematics, Ghusuri Uchcha Madhyamik Vidyalaya, West Bengal, India. Besides possessing a Ph.D. in mathematics, the author also has a B.Sc., M.Sc., and B.Ed. It is stated on the cover of the book that the author had previously published 3 books and 53 papers, with 3 papers currently accepted for publication. Among the author's publications is a 1998 paper on Babylonian mathematics in the *Indian Journal of History of Science*.

Another book dealing with Mesopotamian astral sciences and the development of mathematical astronomy in Mesopotamia is usually a welcome event, even if the research is not original. This particular addition to the subject, however, is disappointing because of the considerable number of errors it contains. There is nothing in Mesopotamian Astrology that can be deemed new. It seems the author's intention is to present succinct mathematical examples of key aspects of Babylonian mathematical astronomy. The author offers little explanation for the particular contents of the book. In the title page Adhikari states: "This book has been published for the remembrance of YEAR OF ASTRONOMY, 2009", and in the preface: "On the theme of IYA to identify our sky I have considered Mesopotamians for their contributions on the observations sky [*sic*]." The title provides the only indication of what the author is perhaps setting out to achieve.

The content of *Mesopotamian Astrology* contains eight short chapters, plus a six-page preface, a five-page introduction, and two pages of references. The main focus is mathematical astronomy: planetary theory, and lunar and solar theory. From Chapter II through to Chapter VII (39 pages) the author primarily gives solved mathematical examples. Judgment of how admirable the mathematical discussions are is beyond the abilities of the reviewer.

It is regrettable that *Mesopotamian Astrology* contains numerous factual errors, trivial and important, as well as unsupported assertions. The author appears to be uninformed on Babylonian astronomy generally and only comfortable with mathematical issues. It is neither an authoritative nor a reliable book on the subject. Numerous factual errors appear throughout (see below). The development of Babylonian astronomy is not adequately traced from its preoccupation with calendars and astral omens to the construction of ephemerides. Explanations are uneven in detail, and the contents appear mainly to reflect some notes the author has compiled on issues of personal interest, or perhaps for use in a lecture course in mathematics.

The production standards could have been better. *Mesopotamian Astrology* appears to be the product of desktop publishing on the part of the author, who seems to lack the required skills. The content is not well organized, and greater attention to page design and a less crowded layout would have aided readability. The text is not always clearly written, and at times there is a rather grand use of the English language. Adhikari's statements could often have benefitted from more attention to clarifying details. Sources for the mathematical examples are not identified, and dates for the material are rarely given. Transcriptions are rarely identified, and then not sufficiently. Misspellings are frequent throughout the book (use of a spell-check would have solved most spelling issues). Pagination could also be improved. The pages comprising the Preface and References are not numbered. The book would have benefitted from professional editing, proofing, and typesetting.

Illustrations, all in black and white, are a mix of maps (2), line drawings (16), and photographs (50). Most have been reproduced with sufficient clarity. The captions for some illustrations are loosely placed or even misplaced, and none of the illustrations are numbered to key them to the text. None of the illustrations are credited to their various sources; most are obviously taken from the Internet. Several of the illustrations seem irrelevant.

Outstanding studies such as Francesca Rochberg's *The Heavenly Writing* (2004), David Brown's *Mesopotamian Planetary Astronomy-Astrology* (2000), and Hermann Hunger and David Pingree's *Astral Sciences in Mesopotamia* (1999), are missing from the list of references. It is not indicated that the references given are those solely used by the author.

Despite the numerous shortcomings of *Mesopotamian Astrology: The Mother of Modern Astronomy*, the book could provide an introduction to Babylonian astronomy if carefully revised and corrected. In its present form, it is a flawed book and not suitable for everyone. Its numerous erroneous statements limit its usefulness to non-expert readers, particularly a general or uninformed audience with an interest in Babylonian astronomy. Mathematically inclined readers will no doubt enjoy those particular chapters of the book. Its low price at least makes it accessible.

The following are a few selective corrections and observations illustrative of the general problems. It is hoped that they can be corrected in a subsequent edition.

In the Acknowledgement, Otto Neugebauer is identified as German, when he was born in Innsbruck, Austria. François (misspelled) Thureau-Dangin is identified as German, but was born in Paris, France. Johann Strassmaier is misspelled. In the Preface, no attempt is made to define the terms "ancient" and "old" astronomy; the author claims that prior to 4000 BC certain rudiments of astronomy were established in Mesopotamia, but does not attempt to explain exactly what he believes they were. On page *iii*, the description of gods and goddesses includes the description of Anshar (sky god) as a god of earth, Kishar (earth goddess) as a goddess of heaven, Shulpae (god of feasting, fertility, and demonic powers) as an earth god, and Nintu (creatress of humankind, a birth goddess) as an earth goddess.

The text includes some oddities, *e.g.* page 1, offering assistance with pronunciation: "Thus we can say that modern astronomy has been sprung from Babylon (< Baby-Lion)." Bab-e-lon is a closer aid to pronunciation. On pages 1 and 2, the author implies that the Sumerians established the system of zodiacal constellations/signs. It is generally accepted that the evidence clearly shows the 12-constellation zodiac originated with the Babylonians in the 1st millennium BC. In the illustration caption on page 4, the author states that the *Mul.Apin* series contains nearly 200 astronomical observations. The tablets do not contain actual observations. It is believed the data are the result of averaging actual observations.

The illustrations also include some oddities, *e.g.* the photograph of *Mul.Apin* tablet 1 appears in composite with a photograph of the zodiac floor mosaic at the 6th-century AD synagogue at Beth Alpha, Israel, without the latter being mentioned. On page 5, the author's caption for a *kudurru* (boundary-stone) states: "Sumerian Astrological Tablet of 2300 B.C." The *kudurru* is BM 102485, and the inscription identifies it is as a land-deed from Governor Eanna-shum-iddina (of the Sealand) to his subordinate Gula-eres; and has been dated to the Kassite period, specifically 1125-1100 BC. A caption for another *kudurru* (identifiable as BM 90858) claims it is a tablet dating to 2000 BC and depicts 12 constellations. It is a Kassite period land-deed depicting only god/goddess symbols. Ursula Seidl, the present-day expert on *kudurrus*, maintains that *kudurru* iconography has no astral significance.

On page 14, the author accepts Willy Hartner's 1965 conjecture that the Sumerians were using a quartet of constellations as seasonal markers, but substitutes a date of 3000 BC for Hartner's 4000 BC. Hartner's conjecture is not supported by Assyriologists. On page 15, there is apparent support for Alex Gurshstein's 1993 gradualist concept of zodiacal development, *e.g.* the introduction over time of quartet sets of constellations to mark the tropical points, but that is also a debated topic. On page 15, the author states that astrolabes (planispheres) were oriented to the celestial equator, yet there is no word for "equator" in the astrolabe texts. The concept of a celestial equator was not recognized in those times. The central band of the god Anu roughly occupied (but did not identify) the equatorial region. The choice of a circular astrolabe illustration on the page, with the path of the ecliptic drawn on it, is unhelpful. Both it and the preceding illustration on page 14, with derived captions, have been taken from Figure 2.1 (page 18) and Figure 2.2 (page 20), of *Early Astronomy from Babylonia to Copernicus* by William O'Neil (1986) without acknowledgement. McNeil's circular astrolabe depiction can be considered redundant.

On page 19, the illustration caption and text refer to a Venus tablet of Uruk dated 3000 BC. The illustration identifies a cylinder seal (dated circa 3300-3200 BC) from the Uruk period, in the Eldermeyer Collection with three star symbols at the top that have been interpreted as representing the Sun, Moon, and Venus. The cylinder seal also contains two symmetrical curved signs, one star, and an ear pole with a pennon, corresponding to the symbol for Inanna. The decipherment may be *dingir.Inanna.Údsig* = "Goddess Inanna [star] of sunrise and sunset." On page 36, both the illustration caption and text claim that the god Marduk is depicted as a swan. The illustration identifies Marduk and the goddess of chaos Tiamat in the form of a dragon. Page 36 also contains an unclear discussion of several issues, and several misspellings. In one of the brief unclear discussions, the author attempts to identify Marduk and Tiamat with the Indian Bisnu (= Vishnu?) in the form of Hansa (a Swan).

On page 46, the illustration caption for a cylinder seal, though correctly identifying the god Shamash, is mostly erroneous. The author suggests that the scene depicts the sun-god Shamash setting on the horizon. The illustration identifies the cylinder seal of Adda the scribe (dated circa 2300-2200 BC), one of the most famous cylinder seals known from the Ancient Near East. Depicted on it are the five major deities of the Mesopotamian pantheon. The cylinder seal depicts the sun-god Shamash busy cutting his way through the two peaks of Mount Mashu in order to rise at dawn.

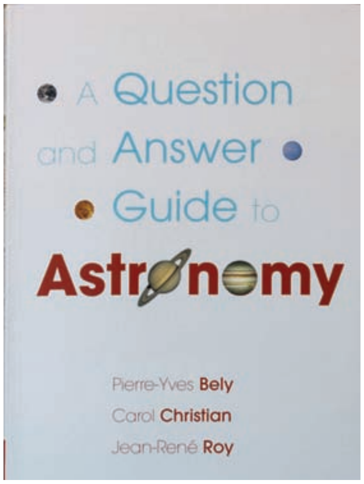
The two pages comprising Chapter VIII: Other Astro-Tablets is simply taken up with seven illustrations and their captions. On page 56, the illustration caption states: "A tablet describing asteroid." The author gives no reference for the statement and it is likely the information was taken from the Internet. The illustration identifies the tablets as K 8538, a late Babylonian planisphere (circular star map), dated by the Assyriologist Johannes Koch to circa 650 BC. The erroneous claim that it is a copy of a Sumerian record of an asteroid impact in 3123 BC has been generated by Alan Bond and Mark Hempsell, neither of whom is an Assyriologist, in their speculative book, *A Sumerian Observation of the Köfels' Impact Event* (2008).

Corrections are needed to the References at the end of the book. Number 38, *In Search of Ancient Astronomies*, omits the name of the book's editor, E.C. Krupp, and has 1978 instead of 1977 as the publication date by Doubleday & Company. The preceding number 37 *In Search of Ancient Astronomers*, 1979, is apparently the title of the McGraw-Hill paperback edition. It is also the title of the 1979 British edition published in London. Number 45, *Recherches sur l'Historie de Astronomie Ancienne* [*sic*], correctly *Recherches sur l'histoire de l'astronomie ancienne*, omits the name of the book's author, Paul Tannery.

Gary D. Thompson

Gary D. Thompson is a semi-retired occupational health and safety professional who lives in Melton, Australia. His astronomical interests include the history of constellations and star names, and the history of Babylonian astral sciences. He is an avid book collector, and over the past 40 years has built up an extensive library of material on Babylonian astronomy, including the works of pioneer Assyriologists such as Franz Kugler. His award-winning Web site Studies of Occidental Constellations and Star Names to the Classical Period: An Annotated Bibliography *(http://members.westnet.com.au/Gary-David-Thompson/index1.html) is a highly respected resource among professionals and*

amateurs. Currently he is writing detailed biographies of the early pioneers of Babylonian mathematical astronomy: Joseph Epping, Johann Strassmaier, Franz Kugler, and Johann Schaumberger.



A Question and Answer Guide to Astronomy, by Pierre-Yves Bely, Carol Christian, and Jean-René Roy, pages 280 + xiii, 18 cm × 25 cm, Cambridge University Press, 2010. Price $28.99 US softcover (ISBN-13: 978-0-521180-66-5).

The request to write a review of *A Question and Answer Guide to Astronomy* came as a surprise to me, but I relish the chance to do so, now that I have read the book. It is a good read, and the book is chock-full of answers to some compelling questions.

The questions begin with what appear, at first glance, to be simple things, and work up to some difficult-to-comprehend concepts. The first concepts, such as "Why do stars shine?" or "luminosity versus brightness" can be difficult enough for the young reader or the layman who lacks chemistry or physics training, so the progression in the book is not just from simple to complex. It is more of a comprehensive look at some common questions and some not-so-common ones, as well.

The topics and questions cover a diverse range, from distances to stars, the colours and ages of stars, the formation of the Solar System, asteroid impact threats, the Earth and Moon, meteor showers, the character of the Universe, telescopes, and the Messier objects, to name a few. A reader could go from front to back, as I did, or jump from one interesting subject to another. All of the questions are fascinating, as are the clear (for the most part) and interesting answers.

One can hardly refute the credentials of the authors; all three are at the peak of experience and knowledge in their respective fields. Bely has worked on large projects such as the Canada-France-Hawaii Telescope, the *Hubble Space Telescope*, and the *James Webb Space Telescope*; Christian is at the Space Telescope Science Institute; and Roy is scientific director at Gemini Observatory. Nevertheless, I encountered my first beef early in the book. Page 4 introduces the concept of "centrifugal force" without benefit of explanation, and then the term is used several times in subsequent pages to describe various aspects of orbital motion. *A Question and Answer Guide* contains no less than eight different answers all invoking "centrifugal force," which, in the words of Roy Bishop "is a fiction and its use in a popular description of motion obscures true understanding" (*Observer's Handbook 2010*, p. 31). The authors would have done a service to their readers by not using the term at all, or by clearly stating that it is an invented term, used only for description of effects in non-inertial systems.

The most disturbing use of the imaginary force is on page 102, where a description of Earth's tides is given as "...lunar attraction overcomes the centrifugal force on the side of Earth facing the Moon and this creates the predictable bulge of water. On Earth's other side, it is the centrifugal force that overcomes the lunar attraction and creates the second tide." Yikes!

A Question and Answer Guide could have been improved greatly by letting a competent proofreader check it thoroughly before publication. For example, there are two different treatments of capitalization ("Solar System" and "solar system") on the same page (p. 39). Also on the same page is a description "of our solar system, we imagine the Sun, the seven planets and their moons, …" Even the youngest school-aged child knows that removing Pluto from planetary status left eight planets!

A confusing diagram of sunspots is given on page 44, with adjacent sunspot polarity reversed, *i.e.* one pair of sunspots showing north polarity in the solar west and another pair showing south polarity in the west. On page 45 is the statement that the next solar maximum will occur in 2011. Understandably, the book was first published in French in 2008 and the English translation did not appear until 2010, so a lag can occur, but that is an inexcusable error that should have been caught and corrected. The Sun has just recently begun showing some sunspot activity for the first time in three years, and we are some years away from the next predicted maximum in mid-2013.

While still in the Solar System section, page 65 has a discussion on the Kuiper Belt, saying that objects "cluster in this band under the gravitational pull of the giant planets (Jupiter, Saturn, and Uranus)." What happened to Neptune? There are a few other noted errors: on page 106, the text "table below" refers to a table on the next page ("overleaf" would have been better), on page 176, the term "mediums" is used, instead of the correct "media," page 220 refers to a diagram "as in a below," where the diagram is actually above.

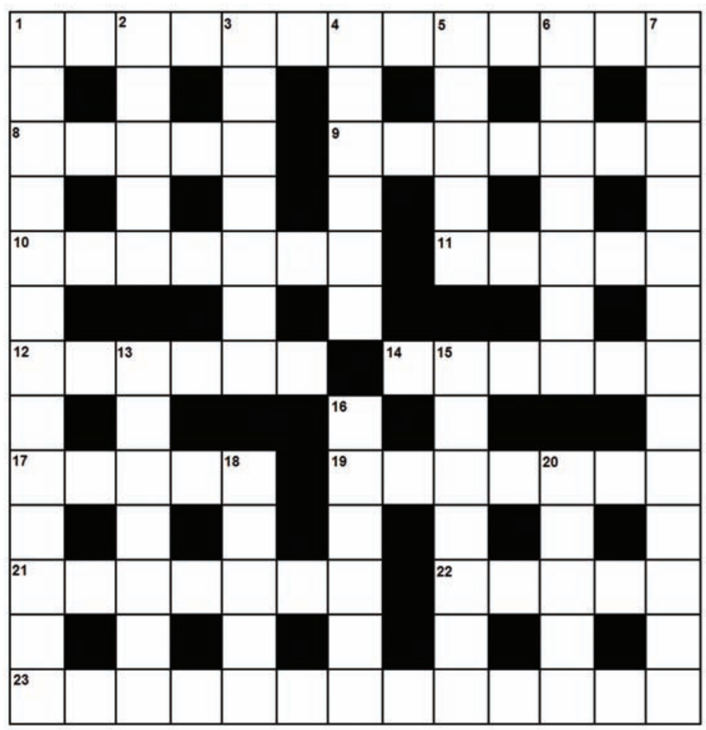
In spite of its shortcomings, *A Question and Answer Guide* to Astronomy has much to offer the reader seeking clear explanations of matters astronomical, both professional and amateur readers alike. In fact, the final questions (237 to 250) are devoted to amateur astronomy, with our own RASC cited in answer 250 as one of two Canadian umbrella organizations, along with the Fédération des astronomes amateurs du Québec, to contact when seeking an amateur club. The references, bibliography, and index that follow are welcome additions to a book of its nature and scope. It will hold a place of cherished value on my bookshelf for many years to come.

James Edgar

James Edgar is Production Manager of the Journal *of the Royal Astronomical Society of Canada, the Society's National Secretary and Recorder, and Editor's Assistant and proofreader for the* Observer's Handbook.

Astrocryptic

by Curt Nason



ACROSS

1. Blair averts a mishap south of Mira and Polaris (8, 5)
8. Diana turns around Neptune (5)
9. Bird, perhaps in M11, with identification gone bad (7)
10. Girl takes urban train to Libya's capital to meet Triton's founder (7)
11. Following the Sun, I would be a phase of matter (5)
12. Come out of eclipse, for example, about sunset (6)
14. A long way to go for a bad scrape (6)
17. The law of planetary distance is foretelling (5)
19. Romer looks back on the southeast with deep regret (7)
21. French star charter made all Dean lists (7)
22. Sister plants half a kiss on the archer's shoulder (5)
23. Karl and his radius (13)

DOWN

1. Disturb all stable Venn diagrams of radiation zones (3, 5, 5)
2. Roll off extensions where star trails have no start (5)
3. McKellar and Oakes; RASC's odd wardens (7)
4. Look healthy at the famous observatory (6)
5. Teams count meteors through Ursid estimates (5)
6. Crab's north and south star uses all wrong (7)
7. Time for alignment of Don's icy breakout before end of sentence (7, 6)
13. Red-nosed namesake of Kepler's Tables (7)
15. Yearly sky events when a canal backs up around Mars first (7)
16. Polite address of refractor man soundly hurts around roomer with no spectacles (6)
18. Nasty development for telescope maker (5)
19. Amazing debunker appears around nadir (5)

Society News

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

Every so often, we receive correspondence from someone outside the RASC that gives one a warm, fuzzy feeling. Here's one that we received in November – it's self-explanatory…

To Whom it may concern,
I am Ariane Dollfus, Audouin Dollfus's daughter. My father was an honorary member of your Society, and I wanted to thank you for having announced his death in your website. I read in this article that you will publish a longer notice in your journal. May I ask you if it is possible that you send me an issue of the journal when it will be published? I would be happy to be able to keep articles about my father, published after his death.
Thanks again, if my request is possible.
Ariane Dollfus

Our esteemed Archivist, Randall Rosenfeld, wrote on December 2:

Dear Mme Dollfus,

The obituary of your distinguished father has now appeared in the Dec. issue of the Journal of The Royal Astronomical Society of Canada. I will mail you a copy of the publication tomorrow, along with the longer manuscript version of the obituary. Your father was always most gracious towards The Royal Astronomical Society of Canada, and his honorary association added lustre to our scientific society. Please accept our heartfelt condolences on his passing.

Yours sincerely,
Randall

And, we received this reply the same day:

Dear Mr Rosenfeld
Thank you very much for informing me about the obituary of my father. I will be very interested to read it! My father was always very interested in keeping in touch with all the astronomers around the world. But as he was very modest, he never talked about his honorary missions, so that I now discover many functions he had around the planet! If you needed any documents about him and about his works, and if I am able to help you, I will be pleased.
Thanks for your message and your condolences, I will also send them to my mother,
Sincerely,
Ariane Dollfus

Errata: Last issue I reported on the Public Speaker Programme, but I missed writing that the Mississauga Centre jointly sponsored with Toronto Centre the talk given by Wilfred Buck, First Nations Astronomy Communicator from the Manitoba First Nations Education Resource Centre.

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Windsor Centre
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Winnipeg Centre
PO Box 2694, Winnipeg MB R3C 4B3

Great Images

Stuart Heggie decided to go big and coaxed the diffuse, faint and rarely imaged nebula Sh2-202 from its hiding place between Cassiopeia and Camelopardalis. Sh2-202 cannot be seen visually and in most exposures appears only as a faint cloud centred on open cluster Stock 23 (above and left of centre). Stuart used an Apogee U16M camera on a Takahashi FSQ refractor. Exposure was 20×5 min in H-alpha and 8×5 minutes in RGB.