June / juin 2006 Volume/volume 100 Number/numéro 3 [718]

Journal

The Journal of the Royal Astronomical Society of Canada Le Journal de la Société royale d'astronomie du Canada

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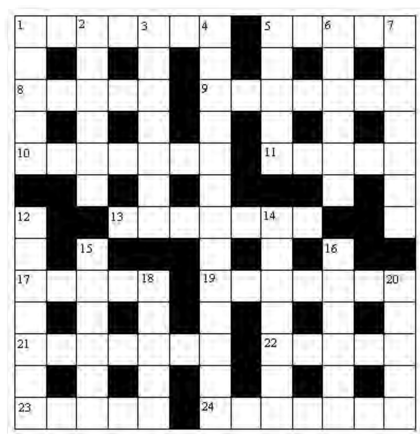

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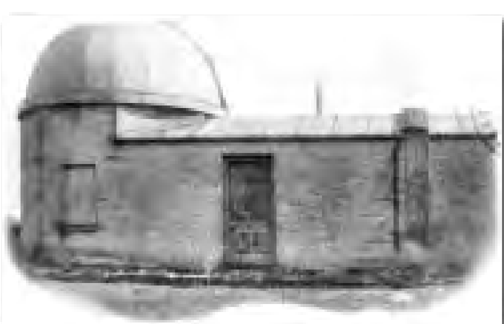

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SOCIÉTÉ ROYALE D'ASTRONOMIE DU CANADA

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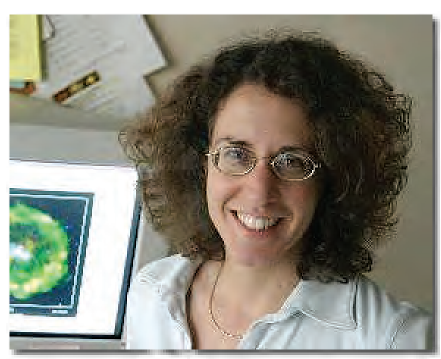

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Editorial

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

This has been an interesting transition — from proofreader of the *Journal* to its production manager. Very interesting indeed!

Our production team works very well together and many hours have been spent getting us on track — in fact we are no longer behind schedule but rapidly approaching a point where we can take a breather and contemplate the skies instead of a computer screen. This June issue may even make it into your hands ***before*** June!

The interesting part for me is seeing the progress of the *Journal* through the different stages, from a document submitted by a columnist, through the first editing stage, to the first proofreading, to the designer for layout and conversion to a PDF document, then to the second stage of proofing the layout (and fixing more errors), to final signoff. Seeing the whole process from a completely different angle is an education in itself. There is much activity (sometimes frantic!) behind the scenes of which the average reader is blissfully unaware.

This is the second of our on-line full-colour *Journals* and, judging by the e-mails flowing into the editor-in-chief's inbox, people like the "new" *Journal*. Jay Anderson is trying to strike a fine balance between lots of interesting new and relevant columns, while keeping within the strict budget restraints imposed by our current deficit situation. A bit of a "Catch-22," since we want to generate interest while at the same time cutting costs. We have much more material than we have room in our publication. Maybe that's a good thing?

To diverge slightly, but keeping to the topic of budget restraints, last year I spoke with Randy Attwood, one of our past presidents. We were talking about getting minutes from past National Council and Annual Meetings onto the Society's Web site. He and current President, Peter Jedicke, had been slowly picking away at 100 years of minutes. It was a tough slog, since some of the older minutes are in longhand, and do not scan quite as nicely as a typed page (OCR software doesn't recognize handwriting at all, in fact!). As the conversation progressed, I volunteered to help do some of the scanning and checking the scanned documents for accuracy, before placing them on the Members' Only section for all to see — PDFs to view the original documents, htm files for the scanned versions.

Most of the '60s, '70s, and '90s are now done and available on the Web site at: `www.rasc.ca/private/minutes`. Work continues on completing the decade from 1980 to 1989, plus the earlier years.

Now getting back to the subject of the budget - the minutes are a fascinating read because we are repeating history (again) — the *Journal* and *Observer's Handbook* editors struggled in

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.

The *Journal of The Royal Astronomical Society of Canada* is published at an annual subscription rate of $80.00 by The Royal Astronomical Society of Canada. Membership, which includes the publications (for personal use), is open to anyone interested in astronomy. Annual fees for 2006: Youth, $34.25; Ordinary, $55.00; Life Membership, $2,100 Applications for subscriptions to the *Journal* or membership in the RASC, and information on how to acquire back issues of the *Journal* can be obtained from:

The Royal Astronomical Society of Canada
136 Dupont St
Toronto ON M5R 1V2, Canada
Internet: nationaloffice@rasc.ca
Web site: www.rasc.ca
Telephone: (416) 924-7973
Fax: (416) 924-2911

Canadian Publications Mail Registration No. 09818
Canada Post: Send address changes to 136 Dupont St, Toronto ON M5R 1V2
Canada Post Publication Agreement No. 40069313

We acknowledge the financial support of the Government of Canada, through the Publications Assistance Program (PAP), toward our mailing costs.

U.S. POSTMASTER: Send address changes to IMS of NY, PO Box 1518, Champlain NY 12919.
U.S. Periodicals Registration Number 010-751.
Periodicals postage paid at Champlain NY and additional mailing offices.

ISSN 0035-872X

the 1960s, seeking ways to make the publications more interesting, while at the same time keeping the costs below budget. There was a concern that the 1974 *Observer's Handbook,* at $3 per copy, was pricing itself out of the market (but the motion passed anyway)! In the January 1983 National Council minutes we see that the Editing Committee projected a $36,000 deficit — publications costs were much greater than revenue (and still are). The Executive Committee and National Council Representatives worried that life memberships were costing much more than the fees collected. Not much has changed. As George Santayana said, "Those who cannot learn from history are doomed to repeat it."

Of interest to those with an historical inclination, many of the people whose memories are honoured in RASC awards, memorial funds, and observatories were active members: *Observer's Handbook* Editor Ruth Northcott was ill and in hospital in May 1967 (she died in 1969); Ken Chilton was an energetic National Council Rep in the '70s; Drs. Millman and Climenhaga received quite a bit of ink; Helen Sawyer Hogg was president of the Canadian Astronomical Society (now CASCA), in 1982.

So on one of those cloudy or rainy nights when you have some free time, (and after you finish reading the online *Journal*) browse over to the members' section and read about our predecessors and how they were dealing with Society business, "Away back then."

The Dresden (Ontario) H6 Chondrite, Part II: Classification, Estimated Fireball Trajectory, and Possible Origin

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(received: November 23, 2005, revised: February 8, 2006)

Abstract

The Dresden (Ontario) meteorite fell in southwestern Ontario on the early evening of July 11, 1939. We re-examine this historic Canadian fall, consider the mineralogy, physical properties, and bulk chemistry of the meteorite, and estimate its trajectory and pre-atmospheric orbit based on visual accounts of the event. Mineralogical examination of several fragments of the meteorite reveals poor definition of chondrule margins, lack of glass, and the presence of minor feldspar, confirming Dresden (Ontario) to be an H6 ordinary chondrite. The bulk of the stone has undergone a low level of shock (S2) as indicated by generally clean extinction of silicate grains. A 12-g bulk sample of the Dresden (Ontario) main mass has elemental abundances that agree well with the H-chondrite average. The bulk density for Dresden (3.48+/-0.07 g/cm^3) and porosity (4.9%) are also typical of H chondrites. Several accounts of the fall event constrain the Dresden fireball to have had a ground projection azimuth of ~050, passing from north of London, Ontario southwestwards toward Dresden. The tightly grouped strewnfield of fusion-encrusted fragments recovered ~10 km southwest of Dresden, Ontario suggests that the fireball trajectory was steep. Dark-flight simulations using the 050 azimuth best reproduce the recovered strewnfield distribution with an entry angle of >70°. The range of potential orbits derived from this inferred steep trajectory is consistent with previous orbits measured for meteorite-producing fireballs, and suggest that the Dresden meteoroid had an Apollo asteroid-type orbit, with a perihelion just inside that of the Earth's and a low-to-moderate inclination. The Dresden (Ontario) H6 chondrite is thus petrologically and dynamically similar to other H chondrites with known orbits. A comparison of the known H-chondrite orbits with a modelled debiased distribution of near-Earth objects indicates that the H chondrites were most likely delivered to the Earth via the ν6 and the 3:1 resonances, thus strengthening the dynamical case for the linkage of H-chondrite meteorites with the S-type asteroid 6 Hebe as suggested by Gaffey *et al.* (1993).

Résumé

Le météorite Dresden (Ontario) est tombé dans la région sudouest de l'Ontario au début de la soirée du 11 juillet 1939. Une réévaluation de cette chute historique canadienne a considéré la minéralogie et la chimie globale du météorite. Nous ré-examinons cette chute historique canadienne, en considérant la minéralogie, les caractéristiques physiques et la chimie globale du météorite. Basée sur les observations visuelles de l'événement, nous évaluons la trajectoire du météorite et l'orbite pré-atmosphérique. L'examen de la minéralogie de plusieurs fragments du mériorite indique la faible définition de la marge de chondres, le manque de verre et la présence mineure de feldspath, ce qui confirme que Dresden (Ontario) est un chondrite ordinaire H6 (S2). Le grade pétrologique 6 a été alloué sur la base de la faible définition de la marge de chondres, le manque de verre et la présence mineure de feldspath. La masse de la pierre a subi un taux de choc (S2) plutôt faible tel qu'indiqué par l'extinction généralement nette de grains de silicate. L'analyse multi-éléments d'un échantillon de 12g de la masse principale de Dresden (Ontario) démontre une abondance d'éléments qui s'accorde bien avec celles de la moyenne des chondrites de type H. La densité estimée de la masse de Dresden (3,48+/-0,07 g/cm^3) est aussi typique des chondrites H. Plusieurs rapports de la chute indiquent que le bolide Dresden aurait été limité à une projection terrestre de l'azimuth de ~050. Le bolide a passé au nord de London, Ontario et a poursuivi une direction sudouest. Selon le groupement serré du champ d'éparpillement des fragments récupérés à environ 10 km au sudouest de Dresden, Ontario, une trajectoire raide semble indiquée. Plus particulièrement les simulations de vols en noirceur utilisant l'azimuth 050, avec une pente raide d'entrée dépassant 70 degrés, reproduisent le mieux la distribution du champ d'éparpillement des fragments recouverts. La gamme d'orbites potentielles provenant de cette trajectoire raide est consistante avec les autres orbites mesurées de bolides de météorites. Ceci fait croire que le météorite Dresden avait une orbite de type astéroïdale Apollo, avec périhélion juste à l'intérieur de celle de la Terre et une inclinaison faible à modérée. Le chondrite Dresden (Ontario) H6 est donc semblable dynamiquement et pétrologiquement aux autres chondrites H avec orbites connues. Une comparaison d'orbites de chondrites H mesurées à l'aide d'instruments avec une distribution modelisée d'objets proches de la Terre indique que les chondrites H ont plus probablement été déposées sur la Terre par les résonances v6 et 3:1. Ceci met nettement en valuer leurs liens avec les astéroïdes de type S Hebe 6, tel que suggéré par Gaffey *et al.* (1993).

Keywords: Dresden (Ontario) meteorite, H6 chondrite, density, porosity, bulk chemistry, fireball trajectory, near-Earth objects, 6 Hebe

1. Introduction

A spectacular fireball, resulting in the fall of the Dresden (Ontario) H6 chondrite, occurred on the evening of July 11, 1939. It was seen from a wide area of southern Ontario and the northeastern United States (Colgrove, 1939). During the following days several fragments of the meteorite totalling ~48 kg were recovered ~10 km southwest of Dresden, Ontario by local residents and passers-by. Other museums and private collections account for the remainder (see Appendix in Plotkin, 2006). All of the known fragments were collected shortly after the fall and have a characteristic well-preserved black fusion crust (Fig. 1).

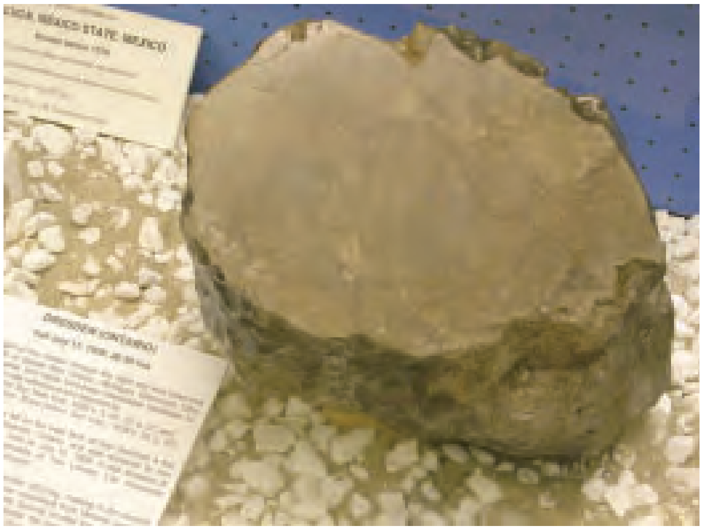

Figure 1 —The Dresden (Ontario) 40.01 kg main mass, with cut face displayed. The meteorite's dark fusion crust is ~1 mm thick and well-preserved. Internal brecciation is clearly visible, defined by dark hairline fractures which envelop centimetre- to decimetre-size chondritic clasts. Width of the cut surface is 32 cm.

The fall was documented by Colgrove (1939), Pleva and Colgrove (1939), and Millman (1940), but an anticipated mineralogical follow-up never materialized. Dresden (Ontario) has languished relatively unstudied for six decades. It appears in meteorite catalogues (*e.g.* Grady, 2000), and is featured together with many other chondrites in synoptic surveys of olivine composition (Mason, 1963), rare-gas measurements for cosmic-ray exposure (CRE) ages (Graf and Marti, 1995), and abundance and isotopic composition of boron (Zhai and Shaw, 1994). Two undergraduate B.Sc. honours theses (Rhodes, 1975; Sibbick, 1986) at the University of Western Ontario have been written on Dresden (Ontario), featuring petrographic analyses of samples from the main mass along with measurements of elemental abundances for selected olivine and pyroxene grains and for chondrules.

In this contribution we present new observations on the mineralogy, bulk chemistry, and bulk-material properties of the meteorite, to update the basis for its H6 chondrite classification. We also attempt to constrain the Dresden meteoroid trajectory and its range of most-likely pre-atmospheric orbits based on reported visual accounts of the event and the strewnfield mass distribution. Finally, we compare the handful of known H-chondrite orbits with a modelled debiased distribution of near-Earth objects (Bottke *et al.* 2002) to assess more generally the relationship of the H chondrites with possible source regions in the main belt of asteroids.

2. Dresden (Ontario): the meteorite

The Dresden (Ontario) meteorite is not widely distributed: approximately 90 percent of the recovered mass from the fall resides with the main mass at the University of Western Ontario, with smaller fragments in the Canadian National Collection (Ottawa), and with the Royal Ontario Museum (Toronto). Other museums and private collections account for the remainder (see Appendix in Plotkin 2006). All of the known fragments were collected shortly after the fall and have a characteristic well-preserved black fusion crust, even on recently rediscovered fragments (Fig. 1).

2.1 Specimen appearance

An 1885-g sample in the Canadian National Collection at the Geological Survey of Canada (sample 0408.002) displays faces varying from rounded (gently convex) to uneven, with numerous shallow imprints 0.5 to 4 cm in diameter. In a few small areas the otherwise-intact black fusion crust has been abraded sufficiently to reveal abundant metal grains, each no more than 1 mm in size. The crust is quite typical for an ordinary chondrite, with no prominent flow lines. The crust is locally granular, presumably where it has flowed over and around hackly, protruding metal grains. Sample 11870 in the Royal Ontario Museum collection, mass 1814 g, reveals a brecciated internal texture with light and dark silicate-dominated clasts (maximum dimensions 0.5-10 cm). Metal grains are mostly <1 mm in size. Similar features were found in the previously unknown 252 g "Cumming" fragment (Plotkin, 2006).

2.2. Sample preparation and bulk properties

The Dresden (Ontario) main mass at the University of Western Ontario was sampled in 1973 with a 2.0-cm diameter coring device (Rhodes, 1975), producing three cores that penetrated to the centre of the meteorite (core samples 7612-101, -102, and -103). Two polished sections were available, one each from 7612-101 and -103, and these were gently re-buffed for the present study. Two additional polished specimens (a third thin section and a thin, but still opaque, slice in a 25-mm mount) were prepared from 7612-102, and a portion of this sample was reserved for bulk chemical work. The polished surfaces examined in this study total 8.8 cm^2 (in transmitted light) to 11.9 cm^2 (in reflected light).

Samples 7612-101 and -102 were measured with digital micrometer and laboratory balance, their cylindrical form allowing for a ready estimation of bulk density. Sample 7612-101 weighed 15.700 g, volume 4.593 cm^3 (density 3.418 g/cm^3); 7612-102 weighed 21.632 g, volume 6.263 cm^3 (density 3.454 g/cm^3), for an overall estimated bulk density of 3.44 g/cm^3. Bulk density for a 157-g "McKim" fragment was measured directly via the Archimedean method using a "liquid" of 40-µm glass beads (method of Consolmagno and Britt, 1998) in a repeatable fashion. We obtain a density of 3.48 ± 0.07 g/cm^3, in good agreement with the estimated bulk density from the other two samples. A helium-gas Quantachome Multipycnometer was used to determine the grain density, and hence the porosity of sample 7612-103: the grain density is 3.66 ± 0.10 g/cm^3, yielding a porosity of 4.9% for the meteorite.

Most stony meteorites have densities in the range 3-4 g/cm^3, with lower values for carbonaceous meteorites and higher densities for stony irons. In a review of 265 pieces of 157 H chondrites, measured densities vary from 2.80 to 3.80 g/cm^3, with a mean of 3.40±0.18 g/cm^3, and the average porosity for H chondrites is 6.4±4.2 % (1σ, Britt and Consolmagno, 2003). Dresden (Ontario) is therefore quite typical of H-chondrite density and porosity.

2.3. Dresden (Ontario) mineralogy and textures

The Dresden (Ontario) meteorite is an ordinary chondrite with abundant visible metal, poorly defined chondrule margins, minor coarse feldspar in the matrix, and an apparent absence of glass. These petrographic features suggest significant metamorphism of an H chondrite and are the hallmarks of the highest petrologic grade, H6. The visually estimated mineralogy for four samples, in area (volume) percent includes 12% metal (Ni-Fe alloys kamacite and taenite), 7% troilite (FeS), 3% coarse olivine crystals, 14% moderately to rather ill-defined chondrules, accessory chromite, 1% feldspar, minor secondary Fe oxide, and a granular, silicate-dominated matrix (63%) of grain size <0.1 mm, in which are dispersed angular masses of metal, troilite, and smaller grains of chromite.

The coarse olivine grains are generally subhedral, angular, unstrained, and up to 1 mm in maximum dimension. As is typical of H chondrites, Dresden (Ontario) has magnesium-rich olivine of Fa20 composition (Mason, 1963 and Rhodes, 1975; Fa19 based on two analyses in Sibbick, 1986). Matrix pyroxene is low-calcium orthopyroxene ($Of_{17}En_{82}Wo_1$) based on the recalculated mean of electron-microprobe analyses of four grains; Sibbick, 1986), a form of pyroxene typical for H6 chondrites. Plagioclase feldspar is found throughout the matrix as interstitial-unstrained to slightly strained grains that are often albite-twinned and as large as 0.1 to 0.4 mm. Rhodes (1975) used X-ray diffraction to obtain a sodium-rich plagioclase composition of $Ab_{86}Or_{14}$. Chondrules are mostly 0.2-2.0 mm in diameter, and exhibit five common morphological types (porphyritic olivine, excentroradial pyroxene, orthopyroxene, and fine-grained and barred olivine chondrules; Hutchison 2004).

The overall order of formation of the opaque minerals is first chromite, then metals, then troilite. The chromite is generally well-formed and fine-grained, at 0.08-0.10 mm in diameter. The metal alloy kamacite forms embayed grains <1 mm in diameter, and thin veinlets typically 0.2-0.3 mm wide. Taenite metal occurs as an accessory phase, forming thin lamellae and small granules in both disseminated and veinlet kamacite. The sulphide troilite occurs as a dusting of minute (1-5 μm) blebs in some chondrules, and as larger anhedral masses up to 200-400 μm in the matrix. Some coarser sulphides exhibit polygonal domains consistent with recrystallization.

Despite the presence of minor hairline veinlets infilled by metal (Figs. 2, 3), the small compass of the polished samples provides little evidence for the brecciation seen in larger pieces of the stone (Fig. 1). Troilite occasionally penetrates fractures in silicate chondrules (Fig. 4). The shock state is assigned as S2, as olivine is generally unstrained, plagioclase only locally strained, and the metal veinlets are of restricted occurrence (see Stoffler *et al.* 1991). Many ordinary chondrites are breccias, and Dresden (Ontario) is no exception, hence it remains possible that sections from other parts of the mass would reveal higher degrees of shock.

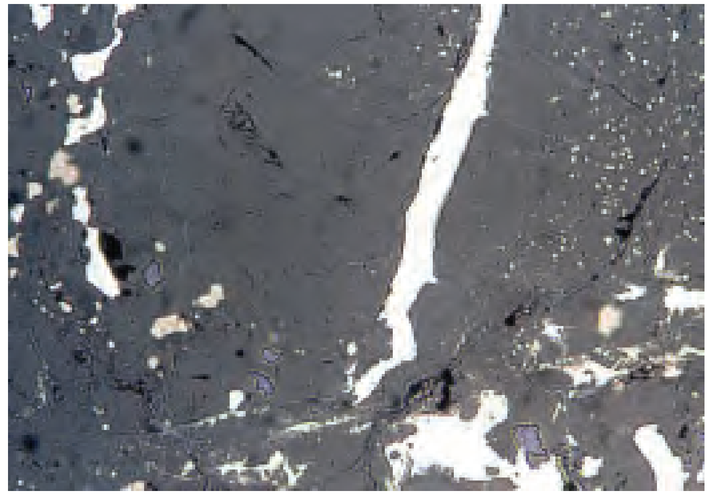

Figure 3 — A veinlet of kamacite, cutting the margin of a very-fine-grained chondrule, which lies adjacent to a pyroxene chondrule speckled by tiny troilite blebs (top right), is itself truncated and offset by a later fracture that contains traces of metal and troilite. Metal, sulphide, and chromite are all visible in the fine granular groundmass of the chondrules (*e.g.* left margin). Photomicrograph in plane-polarized reflected light, long-axis diameter of field of view *ca.* 1.4 mm. Section 7612-102, D-4.

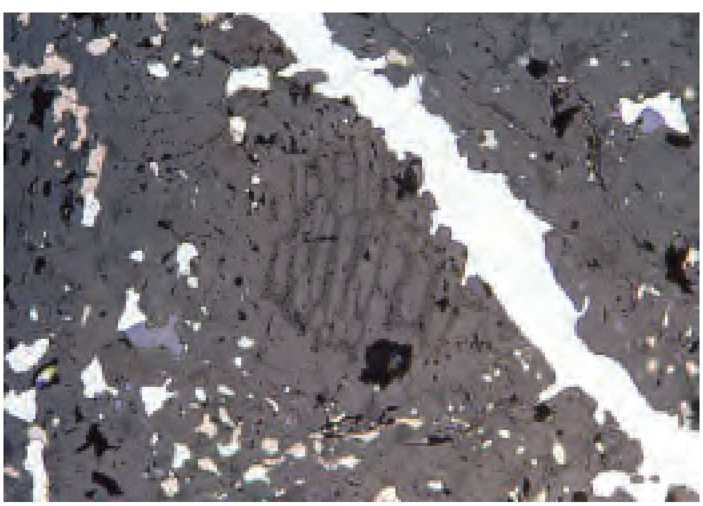

Figure 2 — A veinlet of kamacite traverses the fine-grained, sulphide- and metal-flecked groundmass of the meteorite, skirting a barred olivine chondrule. Photomicrograph in plane-polarized reflected light, long-axis diameter of field of view *ca.* 1.4 mm. Section 7612-102, D-4.

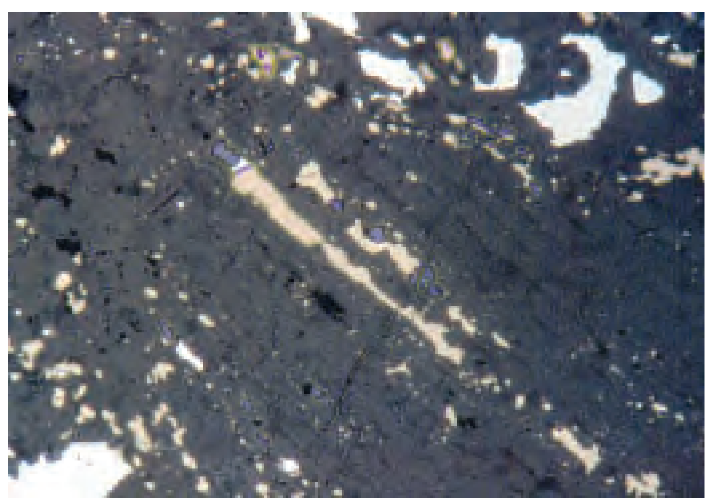

Fig. 4. A barred chondrule invaded by troilite parallel to the bladed fabric (most probably olivine crystallites with interstitial planes of devitrified glass). Coarser kamacite and fine-grained troilite and chromite are visible in the groundmass. Photomicrograph in plane-polarized reflected light, long-axis diameter of field of view *ca.* 1.4 mm. Section 7612-101, D-2.

2.4. Bulk chemistry

Analytical work by Activation Laboratories was conducted with an 11.63-g slice of core 7612-102. The procedures were as follows: 1) The sample was pulverized with agate pestle and mortar; 2) The abundances of major and trace elements were determined by inductively-coupled plasma atomic-emission spectroscopy and mass spectrometry (ICPAES, ICPMS) and instrumental neutron-activation analysis (INAA); 3) FeO was determined separately by titration; 4) The high Ni content was assayed separately; 5) A separate digestion was employed with the ICP analyses to ensure quantitative recovery of chalcophile elements. The largest uncertainty concerns the treatment of iron which, in contrast to most terrestrial rocks, is present in three valence states (Fe^{2+}, Fe^{3+}, and as metallic Fe). Measured elemental abundances are presented in Table 1.

Dresden (Ontario) is of impressively "average" chondritic composition. The INAA result of 28% total Fe agrees well with the estimated H-chondrite mean of 27.5% preferred by Hutchison (2004, p.29). The bulk atomic Mg/Si ratio is 0.858, indistinguishable from a mean value of 0.857 for H, L, and LL chondrites (Berczi and Lukacs, 2003). The total REE (all 14 stable rare-earth elements) content is 3.136 ppm; the chondrite-normalized ratio of representative light and heavy REE, $(La/Yb)_N = 1.07$ (calculated from the values of Anders and Grevesse 1989). Most other abundances agree extremely well with H-chondrite averages, the only significant deviation being the surprisingly low assay for S. Discrepancies may be due in part to the observed metal veinlets and otherwise uneven distribution of metal and sulphide. The measured S/Se ratio is 600, which is low relative to a global average for chondrite (including carbonaceous chondrite) falls of 2500±270 (Dreibus *et al.* 1995). Dresden contains 0.61 ppm Ir (1.27 × chondritic) and 0.297 ppm Au (2.14 × chondritic). Measured boron abundance from the Dresden (Ontario) fragment at the Geological Survey of Canada is 1.13 ppm (Zhai & Shaw 1994), somewhat higher than that found in other H chondrites.

Table 1. Bulk chemistry of Dresden (Ontario) H6 chondrite.

Oxide/element (wt.%)	*Dresden*	*H chondrite mean*
SiO_2	35.96	36.15
TiO_2	0.09	0.10
Al_2O_3	1.96	2.14
Cr_2O_3	0.53	0.53
Fetotal	28.00	27.50
MnO	0.26	0.30
MgO	23.92	23.21
CaO	1.68	1.75
Na_2O	0.82	0.86
K_2O	0.08	0.09
P_2O_5	0.24	0.25
Ni	1.90	1.60
Co	0.10	0.08
S	0.46	2.00
Total 1	96.00	96.56
Fe^0	16.80	16.50
$FeO+Fe_2O_3$ as FeO	14.41	14.15
Total 2	99.21	99.71

Analysis of an 11.63-g slice from Dresden sample 7612-102. Mean H-chondrite values are recalculated from Hutchison (2004, p.29). Total 1 is low because O in FeO and lesser Fe_2O_3 is not assigned (there may also be minor losses on ignition due to H_2O in secondary oxyhydroxides, "limonite," plus traces of C). Total 2: content of Fe^0 (Fe in alloy) is estimated as a group average of 60% of the INAA value for total Fe (Hutchison, 2004), and the balance recalculated as FeO (data from Wilson 2004; Activation Laboratories Report A04-0148; FeO and Fe_2O_3 were assayed at 28.24 and 10.02% respectively). Below: selected minor and trace element values (in ppm by weight).

Cr	3600
Co	980
Ni	18990
Cu	89
Zn	111
Ga	7
Ge	11.1
Ba	10
Se	8
Ag	2.7
La	0.31
Ce	0.78
Yb	0.20
Ir	0.610
Au	0.297

2.5. Dresden (Ontario) classification and context

Taken together, the petrographic observations, bulk elemental abundances, and previously reported compositions of major silicate phases all indicate that the Dresden (Ontario) meteorite is best classified as an H6 [S2] chondrite.

H chondrites are the most "ordinary" of ordinary chondrites, comprising nearly half of the ordinary chondrites and 30.9% of all known meteorites (6962 H chondrites/22507 known meteorites as of December 1999; Grady, 2000). The H chondrites are so named because they are chondrule-bearing meteorites that are "high" in free Fe-Ni metal content (*cf.* Van Schmus & Wood 1967), as opposed to "low" metal (L) and "very low" metal (LL) chondrites. The petrologic grades for H chondrites (ranging from H3 to H6) indicate increasing degrees of thermal metamorphism, with the majority of H chondrites being of the highly metamorphosed grades H5 or H6. Dresden (Ontario) is thus not an exceptional meteorite, but it is nevertheless a significant mass representative of H6 chondrite material that stems from an observed fall.

In one scenario, the H chondrites are thought to represent a parent body of >200-km diameter that underwent internal heating shortly after its formation in the early Solar System, thus creating an "onion-skin" body whose volume was mostly occupied by H6 and H5 chondritic material covered by a thin, less-altered veneer of H4 and H3 chondrites (Binzel *et al.* 1991). Subsequent collisional disruption of this parent body (or bodies) would have made H chondrite of all types available to subsequent collisional ejection even if reassembled into a "rubble pile" of debris, thus accounting for the predominance of the H5 and H6 types among the H chondrites (Gaffey & Gilbert 1998).

If the H chondrites are derived from a particular parent body and delivered to the Earth by some dynamical mechanism(s), then it is useful to assess the fireball trajectories of H chondrites so as to constrain the dynamical method of delivery, and possibly identify the source region and parent body for the H chondrites. There are only a few H-chondrite falls with well-constrained, instrumentally measured orbits (Borovicka e*t al.* 2003). In the next section we estimate the Dresden fireball trajectory from published eyewitness accounts and constrain the range of possible orbits of the Dresden meteoroid, for comparison with those H chondrites with known orbits.

3. Dresden (Ontario): fireball trajectory and possible orbit

The fireball associated with the Dresden meteorite fall was witnessed over a wide area of southern Ontario and the northeastern United States (Fig 5a). However, only a few eyewitness accounts are available

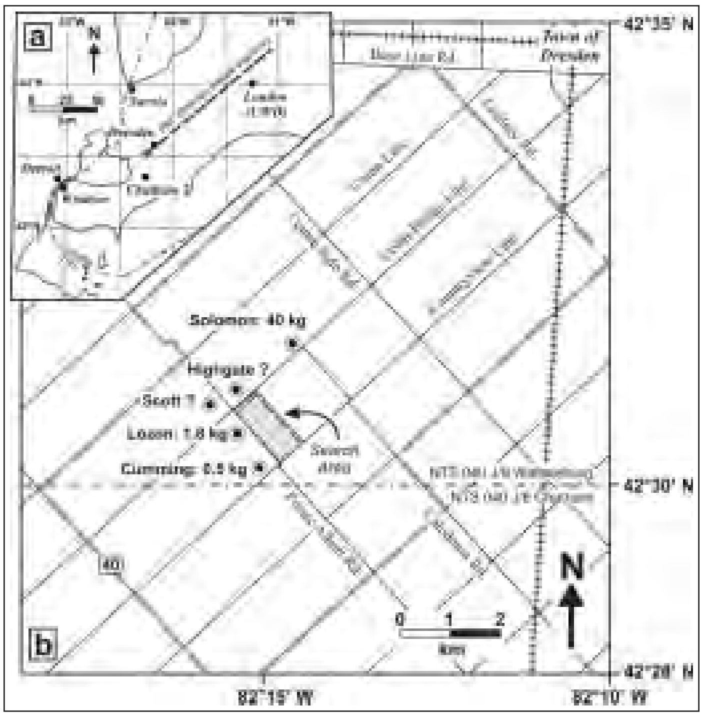

Figure 5 a — Inferred ground projection of the July 12, 1939 Dresden fireball over southwestern Ontario. The fireball was observed to pass to the north of London, and headed southwest where it produced meteorites near Dresden, Ontario; b) Inset map of the Dresden (Ontario) strewnfield of the recovered known fragments and their masses. Names with "?" indicate possible small finds that are unconfirmed (Plotkin, 2006). The close proximity of large and small fragment masses suggests a steep entry angle for the meteorite-producing fireball.

in the literature with directional information that might help establish the orientation of the fireball path in the atmosphere. As such, the Dresden fireball trajectory cannot be constrained as accurately as has been done for widely seen and instrumentally observed events (*e.g.* Brown *et al.* 1994). Nevertheless the published eyewitness reports for the Dresden event do offer some key constraints upon its possible trajectory.

3.1 Fireball observations and estimated radiant azimuth

Several eyewitnesses from Wallaceburg (about 10 km northwest from the fall location) reported the fireball as moving to the southeast. Other observers reported the fireball as "laying to the east" of Chatham and Wallaceburg. It was also reported that the fireball left "...a rather short trail of light in the sky" (*Chatham Daily News,* July 12, 1939). Given that the meteorite fall occurred slightly south and east of Wallaceburg, this suggests the fireball azimuth had to be such that the fireball was moving generally from the north to the south. This is further confirmed by the observations of J. Ultviugt of Chatham (almost due south of the meteorite fall location), who states that:

> "From where I was standing the meteor streaked across the constellation of Ursa Major. Sitting on the lawn facing SSW, I was not looking at the exact spot where the celestial wanderer appeared...the bright flash...came from the direction of the setting sun."

The centre of Ursa Major at the time of the fireball (20:45 EDT, July 11, 1939) was at an azimuth of 310° and an altitude of 60° as seen by the observer in Chatham. The sun had set 30 minutes earlier at an azimuth of 302°, consistent with his description. This observation would appear to further rule out a trajectory from the south.

By far the most detailed report, however, is that from W.G. Colgrove, then President of the London Centre of the Royal Astronomical Society of Canada. He observed the fireball from the campus of the University of Western Ontario and describes it as follows (Colgrove, 1939):

> "On the evening of July 11 (1939) at 8:45 [p.m.] a few of us were standing on the upper campus of the University of Western Ontario at London watching the first stars appear when suddenly a great flare from the north-east lighted up the lawns and trees all around us. It was the passing of an unusually bright meteor which immediately exploded high in the air and somewhat behind us and then, shooting a little to the north overhead, whizzed toward the south-west leaving a trail of bluish-green light about 5° wide and extending from north of Vega to near Spica. [...] The main feature lasted only about four seconds, but it was the grandest moving sky picture I have seen since the great comet of 1882."

Colgrove's description establishes that the ground projection of the path went nearly overhead (just to the north) of the UWO campus, moving to the southwest, or from right to left as seen from UWO. Vega at the time of observation was at an altitude of 55° and at an azimuth of 079°. Between Vega and Polaris at this time (still in heavy twilight), only the dim stars of the head of Draco were present, so we may assume the trail began near 50-60° elevation and at an azimuth north of Vega, at an approximate azimuth near ~040°. Spica at this time lay to the southwest (217 azimuth) at an altitude of 29°. Assuming that the trail began near an azimuth of 040° and an elevation of 60°, the approximate lower limit for the maximum elevation (given the other uncertainties in the account) is ~70°. For reasonable first heights of visibility (near 80 km; *cf.* Ceplecha *et al.* 1998), the path was no more than 30 km north of the viewing location, and probably closer. The resulting azimuth for the radiant (using the meteorite recovery location as the other fiducial point along the ground projection of the path) is ~050°, with a line connecting UWO and the fall location giving an azimuth of 054.7°. We thus assume from Colgrove's observation at UWO that the fireball radiant azimuth is constrained to be ~050° and no greater than 054.7°. The short-trail observation at Wallaceburg is also consistent with a 050 azimuth, because such an azimuth would have produced a foreshortened view of the fireball trajectory as seen from Wallaceburg.

The distance between UWO and the fall location is nearly 100 km, so assuming a height at UWO near 80 km, an approximate entry angle of ~40° is obtained. Colgrove (1939) concluded his description of the event by noting that his compilation of other Dresden fall reports (which are not available to us) suggested a trajectory from the northeast towards the southwest, consistent with our path.

3.2 Fireball entry angle

The 050 azimuth determined from the Dresden eyewitness accounts is clearly more reliable than the entry angle, a pattern similar to that found for other fireball events (*cf.* Brown *et al.* 1996). To further refine the entry angle we examine the fall distribution of meteorites recovered on the ground. Figure 5b shows the strewnfield immediately to the southwest of Dresden, giving the locations of recovered fragments and their known masses. Most notably, the smaller fragments lay to the south and south-west of the main (Solomon) 40-kg mass, opposite to the distribution expected for a fireball approaching from the northeast. The most massive fragments are less affected by atmospheric drag, having the smallest surface-area-to-mass ratios, and so usually move further downrange than smaller specimens (Ceplecha *et al.* 1998).

However, two additional observations may explain this puzzling fragment distribution: The smallest fragment (0.5 kg) is located only 2 km to the southwest of the large (40 kg) main mass, a very small ground distance between two fragments of such different masses. As an example, the 1994 St. Robert (Quebec) meteorite fall had a similar spread in surface-area-to-mass ratios across a distance of 8 km with a fireball entry angle of 60° (Brown *et al.* 1996). In addition, all recovered Dresden fragments have well-developed fusion crusts, indicating that the fragmentation event(s) to produce the strewnfield must have occurred before or during ablation in the upper atmosphere, and not close to the ground. The small extent of the ground ellipse for the Dresden fall thus suggests a very steep entry angle.

To switch the mass-sorting order along the ellipse (assuming our 050 trajectory azimuth result is robust), the winds in the upper atmosphere need to have had a significant tail-wind component along the trajectory path. A strong tail wind in combination with a steep trajectory makes it possible for smaller fragments to be "blown" downrange of larger fragments, as has been encountered before with the Johnstown, Colorado and Holbrook, Arizona falls (Nininger, 1963).

A numerical simulation of "darkflight" paths in the atmosphere was performed for fragments from the Dresden fall after ablation ceased (procedure of Brown *et al.* 1996). The winds in the upper atmosphere are unknown at the time of the fall, but in the summer months at this latitude, tropospheric winds are generally from the west or northwest (Beer, 1974). The average winds observed for July 11 over the years 1992-2005 at the fall location are generally from azimuth 300° from ground-level to 30-km altitude and have peak tropospheric speeds near 30 m/s at 12 km altitude. Darkflight runs including masses of 40 kg, 2 kg and 0.5 kg were performed for ejection heights of 25 and 15 km (defined as the height at which the fireball velocity falls below 4 km/s) and for a range of zenith angles. Using our estimated azimuth of ~050° and entry angles from overhead to 30° from the horizontal, it is apparent that the azimuth-300 crosswind would move smaller fragments to the southeast of the main mass, but not further along the trajectory. At entry angles shallower than 60°, the smallest-to-largest observed fragment separations were >6 km, at least three times that observed from the Dresden strewnfield. Entry angles of ~30° produce fragment separations of >10 km.

The closest fit to the Dresden strewnfield observations is found by assuming a tropospheric wind direction of ~040°, producing a ~30 m/s tailwind relative to the 050 fireball trajectory. In this manner, a near-vertical entry angle allowed the smallest fragment (0.5 kg) to travel 1.8 km further downrange of the largest fragment (40 kg), due to the tailwind. Entry angles of less than 75° result in the larger fragment moving further downrange than the smaller mass. We are thus led to conclude that the entry angle for the fireball was very steep, potentially >70°, suggesting that at the time of the first fireball observation by Colgrove it was encountering atmosphere at >80 km or that the upper atmosphere tail-wind may have been unusually strong, permitting a slightly less-steep entry angle.

3.3 Possible Dresden heliocentric orbit

As noted above, the fireball azimuth is the best-determined parameter from the few observations, and the interpreted steep entry angle requires an additional but reasonable assumption that the tight strewnfield mass distribution rules out a shallow fireball trajectory. The final and least-constrained parameter required to calculate a possible orbit for the Dresden meteoroid is its entry velocity. The possible heliocentric orbit for Dresden assuming a fireball azimuth of 050° and an entry angle of 85°, 75°, or 65° is shown for a range of entry velocities in Table 2.

The steep entry angle of the fireball and its arrival in the early evening, local time, together provide a good constraint on the perihelion distance *(q)* of the Dresden meteoroid orbit. Perihelion is the most robustly determined feature of the estimated orbit for Dresden because the fall geometry is largely insensitive to entry velocity (possible q in Table 2 has a narrow range from 0.96028 to 1.0145 astronomical units for reasonable entry velocities). The unknown entry velocity mostly affects the estimated orbital eccentricity *(e)* and semi-major axis, which for low entry velocities of ~12 km/s is closer to circular with a perihelion (Q) just slightly greater than 1 AU, and for higher velocities becomes more eccentric with perihelia well beyond Jupiter (Table 2).

Entry velocity is dynamically constrained to be less than 21 km/s for Dresden to have had an asteroidal-like orbit (with a Tisserand parameter >3; *cf.* Bottke *et al.* 2002) and to be consistent with the expectation that meteorites could be produced (*cf.* Wetherill & ReVelle 1981). For steep trajectories the entry velocity maximum cut-off is even lower, close to 18 km/s.

The range of potential orbits are consistent with previous orbits measured for meteorite-producing fireballs (Borovicka *et al.* 2003), and suggest that the Dresden meteoroid encountered the Earth pre-perihelion at the descending node of its Apollo asteroid-type orbit. The Dresden orbit most likely had a

Table 2. Representative possible orbits for the Dresden (Ontario) meteorite.

Fall location: 42.5 deg N; 82.25 deg W (Fig. 5). Symbols are: *alt* altitude of the radiant (in°), *azm* azimuth of the radiant, best estimated as 050, *vel* is entry velocity in km/s, *RA* and *Dec* are the apparent right ascension and declination of the radiant, *a* is the semi-major axis in AU, *e* is the eccentricity, *i* is the inclination of the orbit, ω is the argument of perihelion, Ω is the longitude of the ascending node, *Q* is the aphelion distance in AU, *q* is the perihelion distance, and *T* is the Tisserand parameter.

alt	*Azm*	*vel*	*RA*	*Dec*	*a*	*e*	*i*	ω	Ω	*Q*	*q*	*T*
85	50	12	241.5	47.1	1.18	0.141	8.1	190	109.678	1.35	1.01453	5.3
85	50	13	240.6	46.7	1.32	0.232	11.2	189	109.678	1.63	1.01422	4.9
85	50	14	240.1	46.5	1.48	0.314	13.5	188	109.678	1.94	1.01399	4.5
85	50	15	239.8	46.3	1.67	0.393	15.4	188	109.678	2.33	1.01380	4.1
85	50	16	239.6	46.2	1.92	0.471	17.1	188	109.678	2.82	1.01364	3.7
85	50	17	239.4	46.1	2.25	0.549	18.7	188	109.678	3.48	1.01349	3.4
85	50	18	239.3	46.1	2.72	0.628	20.0	187	109.678	4.43	1.01336	3
85	50	19	239.1	46.0	3.46	0.707	21.3	187	109.678	5.90	1.01324	2.6
85	50	20	239.1	46.0	4.77	0.788	22.5	187	109.678	8.53	1.01312	2.2
85	50	21	239.0	45.9	7.79	0.870	23.6	187	109.678	14.58	1.01302	1.8
alt	*Azm*	*vel*	*RA*	*Dec*	*a*	*e*	*i*	ω	Ω	*Q*	*q*	*T*
75	50	12	261	53.4	1.09	0.071	9	207	109.678	1.16	1.00922	5.7
75	50	13	258.1	52.7	1.17	0.137	12.5	199	109.678	1.33	1.00967	5.4
75	50	14	256.5	52.4	1.26	0.201	15.1	196	109.678	1.52	1.00969	5
75	50	15	255.5	52.1	1.37	0.265	17.4	195	109.678	1.74	1.00961	4.7
75	50	16	254.7	51.9	1.5	0.328	19.3	194	109.678	2	1.0095	4.4
75	50	17	254.2	51.7	1.66	0.393	21.1	193	109.678	2.31	1.00938	4.1
75	50	18	253.8	51.6	1.86	0.458	22.7	192	109.678	2.72	1.00925	3.8
75	50	19	253.4	51.5	2.12	0.525	24.2	192	109.678	3.24	1.00912	3.4
75	50	20	253.2	51.4	2.48	0.593	25.6	191	109.678	3.95	1.009	3.1
75	50	21	252.9	51.4	3	0.663	26.9	191	109.678	4.98	1.00888	2.7
alt	*Azm*	*vel*	*RA*	*Dec*	*a*	*e*	*i*	ω	Ω	*Q*	*q*	*T*
65	50	12	285.2	55.6	1	0.041	9.3	295	109.678	1.04	0.96028	6.1
65	50	13	279.7	55.5	1.04	0.057	13.3	245	109.678	1.1	0.98524	5.9
65	50	14	276.7	55.4	1.1	0.094	16.3	223	109.678	1.2	0.99332	5.6
65	50	15	274.7	55.3	1.16	0.137	18.9	213	109.678	1.31	0.99652	5.4
65	50	16	273.3	55.1	1.22	0.184	21.1	208	109.678	1.45	0.99812	5.1
65	50	17	272.3	55.1	1.3	0.233	23.2	205	109.678	1.61	0.99904	4.9
65	50	18	271.5	55	1.4	0.284	25.1	202	109.678	1.79	0.99961	4.6
65	50	19	270.9	54.9	1.51	0.337	26.8	201	109.678	2.02	0.99999	4.4
65	50	20	270.3	54.8	1.64	0.392	28.5	199	109.678	2.29	1.00024	4.1
65	50	21	269.9	54.8	1.81	0.448	30	198	109.678	2.63	1.00041	3.8

perihelion just inside that of the Earth's and had a low to moderate inclination.

4. Origin of the Dresden (Ontario) H6 chondrite

The Dresden (Ontario) meteorite is an H6 [S2] chondrite, an exemplary representative of the H-chondrite group. It was collected immediately after its arrival and remains available in several research collections for further study (Plotkin 2006). Based on the limited reported observations of the 1939 fall, a range of possible orbits has been estimated for the Dresden meteoroid. In this section we consider the possibilities for the origin of the Dresden (Ontario) meteorite and for other H chondrites.

In the past 20 years significant advances have been made in exploring the linkages between types of meteorites and with their possible parent bodies in the Solar System (McSween 1999). Attempts to link meteorite classes with possible parent bodies in the Solar System can be made by matching the measured spectral reflectance of asteroidal (and other) bodies with those properties in the meteorites (Gaffey *et al.* 1993), and by dynamical modelling of the delivery of meteoritic material from different regions and source bodies in the inner Solar System (Farinella *et al.* 1993; Gladman *et al.* 1997).

The major planets (primarily Jupiter) largely control the orbital distribution of the main-belt asteroids through gravitational perturbations, producing regions in orbital element *(a,e,i)* space that are either swept virtually clean or show concentrations of asteroids due to resonant interactions with the major planets (Nesvorny *et al.* 2002). In addition, recent work (Gladman *et al.* 1997; Vokrouhlický & Farinella 2000) suggests that the orbits of sub-metre to km-size bodies within the main belt can undergo slow diffusion over some millions of years via non-gravitational effects (*e.g.* the Yarkovsky force) until such a dynamical "escape-hatch," like the 3:1 mean-motion resonance with Jupiter, is encountered. Transfer to an Earth-crossing orbit due to gravitational perturbations is then relatively rapid, and the average lifetime of these objects in Earth-crossing orbits is 2 to 7 million years (Gladman *et al.* 1997; Bottke e*t al.* 2002).

Using a numerical simulation of transfer rates from the main-belt asteroids, Bottke *et al.* (2002) have derived the probability in *a,e,i* space of transfer from specific dynamical "escape-hatches" for any given Earth-crossing orbit. It may thus be possible to place dynamical constraints upon the tentative linkages of meteorites classes with potential source asteroids by identifying the most likely delivery mechanisms that would produce a population of Earth-crossing meteoroids that match known meteorite orbits.

Ordinary chondrites have been suggested to be related to a subset of S-type asteroids, called S(IV), based on similarities in their reflectance spectra (Gaffey *et al.* 1993). The S(IV) subtype asteroids are concentrated near the 3:1 mean-motion resonance with Jupiter, at 2.5 AU. A prominent member of the S(IV) subtype, asteroid 6 Hebe, has an orbit that is close to both the 3:1 mean-motion resonance and the ν6 secular (orbital-inclination) resonance with Saturn, located near *i*=15-16 deg for *a*=2.426 AU (Bottke *et al.* 2002). Asteroid 6 Hebe has been proposed to be the probable parent body of the H chondrites, based on its proximity to both 3:1 and ν6 resonances, and on its similarity with the reflectance spectra of H chondrites (Gaffey and Gilbert, 1998). Modelling of the dispersal of collisional fragments from 6 Hebe indicates that >1 million years after the initial fragment-producing collisional event, the diffusion of fragments into the ν6 resonance is heavily favoured over their migration into the 3:1 mean motion resonance, and that the flux of meteoroids from 6 Hebe to the Earth should therefore be dominated by delivery via the ν6 resonance (Vokrouhlický & Farinella 2000). If 6 Hebe is the parent body for H chondrites, then the known orbits of H chondrites should demonstrate a dynamical affinity for the 3:1 and especially ν6 resonances.

Of the seven known orbits for meteorite-producing fireballs, four of them produced H chondrites (Pribram, Lost City, Peekskill, and Moravka; Borovicka *et al.* 2003). Another H chondrite fall (St. Robert; Brown *et al.* 1996) has a somewhat less-constrained orbit that is nevertheless useful for comparison with the debiased distribution of near-Earth objects (Bottke *et al.* 2002). All five of these H-chondrite known and "most likely" orbits are given in Table 3, along with the possible Dresden orbits from Table 2 with reasonable entry velocities of 14 to 18 km/s. We then apply the numerical simulation of transfer rates from the main-belt asteroids of Bottke *et al.* (2002) to assess the probability in *a,e,i* space of the transfer from specific "escape-hatches" for each of the known or inferred H-chondrite orbits.

For the known H-chondrite orbits in Table 3 the greatest transfer probabilities are typically from the ν6 secular resonance (60-65%, excepting Moravka and Pribram), whereas the 3:1 mean-motion resonance has a relatively low transfer probability (5-17%, excepting Pribram). The orbit for Pribram is distinct from the other H chondrites in *a,e,i* space, and shows a high transfer probability from the 3:1 resonance and a much lower probability from the ν6 resonance (55% and 14%, respectively). Also of note is the significant transfer probability for all H-chondrite orbits from Mars-crossing resonances (MC; 18-32%, and dominantly so for Moravka at 69%), which reflects the possibility for the passage of asteroids related to the H-chondrite complex through orbits having intermediate dynamical interactions with Mars before achieving Earth-crossing status.

The family of Dresden orbits calculated for an 85° entry angle and a range of possible entry velocities has a large transfer probability from the ν6 secular resonance, echoing those for the known orbits of Lost City, Peekskill, and St. Robert (Table 3). Collectively, the calculated H-chondrite orbits given in Table 3 suggest that the ν6 secular resonance may be the dominant "escape hatch" for delivering H chondrites from the main-belt into Earth-crossing orbits.

Pribram's orbit implies that the 3:1 resonance may also be an important delivery mechanism, suggesting that there may be (at least) two dynamically distinct pathways for generating Earth-crossing bodies of H-chondrite composition. The existence of two H-chondrite

Table 3. Known H-chondrite orbits and their possible source regions.

Fall	*type*	*a*	*e*	*i*	*Q*	*q*	***OB***	***3:1***	***MC***	**ν6**
Moravka[1]	H5	1.85	0.470	32.2	2.71	0.9823	0	14.1	**68.8**	17.1
Pribram[2]	H5	2.40	0.671	10.48	4.01	0.7894	7.0	**55.1**	24.2	13.8
Lost City[3]	H5	1.66	0.417	12.0	2.35	0.9670	0	8.5	31.4	**60.0**
Peekskill[4]	H6	1.49	0.410	4.9	2.10	0.8860	0	16.8	18.2	**65.0**
St. Robert[5]	H5	1.90	0.480	0.7	2.86	1.0158	9.5	5.3	20.2	**65.0**
Dresden 14	H6	1.48	0.314	13.5	1.94	1.0140	0	11.6	34.2	**54.2**
Dresden 15	H6	1.67	0.393	15.4	2.33	1.0138	0	2.6	38.7	**58.7**
Dresden 16	H6	1.92	0.471	17.1	2.82	1.0136	0	17.1	14.1	**68.8**
Dresden 17	H6	2.25	0.549	18.7	3.48	1.0135	0	29.9	6.1	**64.0**
Dresden 18	H6	2.72	v8	20.0	4.43	1.0134	23.1	**42.8**	17.4	11.4

Symbols are: *Fall* - meteorite fall with calculated orbit and reference, *type*, petrologic type of H chondrite, *a* is the semi-major axis in AU, *e* is the eccentricity, *i* is the inclination of the orbit, *Q* is the aphelion distance in AU, *q* is the perihelion distance. The probability of delivery (in %) to a given H-chondrite orbit from various dynamical regions in the main belt (in bold) are: ***OB*** - outer main belt; ***3:1*** - the 3:1 mean motion resonance with Jupiter; ***MC*** - Mars crossing; ν**6** - the "nu-6" sidereal-motion resonance with Jupiter and Saturn. This work is adapted from Bottke *et al.* (2002). References: [1]Borovicka *et al.* 2003; [2]Ceplecha, 1977; [3]McCrosky *et al.* 1971; [4]Brown *et al.* 1994; [5]Brown *et al.* 1996. Dresden 14 through 18 represent orbital solutions that vary the entry velocity from 14 km/s to 18 km/s for an entry angle of 85°.

populations has been determined on the basis of time-of-day fall statistics and cosmic-ray exposure (CRE) ages (Graf *et al.* 2001). Most H chondrites fall in the afternoon or evening, local time, and exhibit a range of CRE ages with a peak at ~7.6 Ma. A subset of H5 chondrites do not show this prevalence of afternoon falls relative to morning falls, and show a distinct peak of CRE ages at 7.0 Ma as well as greater tritium (^{3}H) loss, indicating that these meteorites may come from the disruption of a distinct "H5" parent body at 7.0 Ma and that they collectively may have had greater exposure to solar heating in orbits with lower perihelia than is experienced by most H chondrites.

From their simulations, Vokrouhlický and Farinella (2000) note that fragments derived from an initial collision-ejection at 6 Hebe typically undergo several further fragmentation events before arriving at Earth. Dynamical considerations are consistent with the idea that the H-chondrite meteorites encountered by the Earth do not come directly from a parent body like 6 Hebe, but were ejected from some intermediate body, possibly already in an Earth-crossing orbit. The existence of distinct H-chondrite populations (Graf *et al.* 2001) also suggests that the Earth is encountering meteoroids from compositionally distinct fragments of the H-chondrite parent body, and not directly from the parent body itself.

Taking 6 Hebe to be the initial source of H chondrites, there would be an expected "background" population of meteoroids that have undergone many collisional events prior to their delivery to the Earth via the ν6 secular resonance (Vokrouhlický & Farinella 2000). In this scenario, these meteoroids would be expected to exhibit a wide range of CRE ages and petrologic types. Punctuating this background H-chondrite meteoroid population could be a subset of H chondrites with a distinct H_5 composition and CRE age that would reflect the recent disruption of a substantial fragment from 6 Hebe. These meteoroids would on the whole have experienced fewer collisional events, and could be delivered by the 3:1 mean-motion resonance, especially if their parent fragment had already encountered the 3:1 resonance prior to its disruption. In the initial million years following ejection directly from 6 Hebe, fragments will encounter the ν6 and 3:1 resonances more or less equally (VVokrouhlický & Farinella 2000), so the injection of a fresh, short-lived stream of H-chondrite meteoroids via the 3:1 mean-motion resonance appears possible.

We emphasize that the transfer probabilities cannot uniquely identify the region in the main belt from which the H chondrites emerged, but taken as a whole they do suggest that the H-chondrite parent asteroid is located near the ν6 and the 3:1 resonances, and that the ν6 resonance may be the dominant delivery mechanism, at least for the handful of H chondrites with known orbits to date. These findings are consistent with the proposition that asteroid 6 Hebe is the probable parent body for the Dresden (Ontario) meteorite and the majority of the H chondrites.

5. Acknowledgements

We thank Howard Plotkin for the inspiration to pursue further work on the Dresden (Ontario) meteorite. Devon Elliott kindly provided the 157-g "McKim" Dresden fragment for bulk density measurement. Other original Dresden samples used for analysis, including thin sections from main mass samples 7612-101 and 7612-103, were borrowed from the collection at the University of Western Ontario. A polished mount and section from sample 7612-102 were prepared by George Taylor at the Department of Geology, University of Toronto. Bulk analysis of Dresden (Ontario) 7612-102 was conducted at Activation Laboratories Ltd. of Ancaster, Ontario. Figure 5 was drafted with the aid of GMT mapping software (Wessel & Smith 1998). PGB acknowledges support from the Natural Sciences and Engineering Research Council of Canada and the Canadian Research Chairs program.

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Appendix 1: Glossary of mineralogical terms

Here is a quick guide to some mineralogical terms commonly applied to meteorites and found in this article: for concise explanations of many more terms, see the glossary in Norton (1994).

Chromite – a common, chromium-rich member of the *spinel* family of cubic oxides, with essential components Fe, Cr, and O, generally with appreciable Mg and Al.
Crystal form – increasingly perfect developments of crystal form may be termed *anhedral* (shapeless) to *subhedral* or *euhedral* (with ideal form, *e.g.* cubes of chromite). Reaction of a crystal with its surroundings may result in corrosion, such that its faces become *embayed*.
Metal – the Ni-Fe alloys most often found in meteorites are *kamacite* and *taenite*, typically with about 5 and 30 weight percent Ni, respectively.
Olivine – a *silicate* mineral with essential Mg and Fe (plus Si and O). The most iron-rich compositions are termed *fayalite*.
Orthopyroxene – a subset of the *pyroxene* silicate family, with orthorhombic symmetry, possessing essential Mg and Fe. *Enstatite* refers to the most magnesium-rich compositions.
Plagioclase – a common silicate of the *feldspar* family, with exchangeable Ca and Na, frequently characterized by repetitive side-by-side stacking of crystals known as "*albite twinning*."

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Giovanni Virginio Schiaparelli

by Michele T. Mazzucato

This famous Italian astronomer was born in Savigliano, Cuneo, on March 14, 1835, and died in Milano on July 4, 1910. His father Antonino Schiaparelli and his mother Caterina Schiaparelli were third cousins, both born in Occhieppo Inferiore, in the province of Biella. Like their forefathers were for centuries, they were kilnmen, makers of bricks and tiles, leading a hard but honourable life.

Giovanni Virginio Schiaparelli (1835-1910)

Giovanni Virginio (Figure 1) was the first of eight children. He had two brothers (Eugenio and Celestino) and five sisters (Margherita, Elojsa, Maria, Emilia, and Clementina), all born in Savigliano in their house at 3 Via San Pietro. The Schiaparelli family had moved there two months after the birth of Giovanni Virginio, the only one born in the first house located in Martinetto (Figure 2). The Martinetto house no longer exists.

In 1910, as a memorial to the famous astronomer, the municipality placed a tablet outside the house. The inscription reads[1]:

Fanciullo e adolescente
queste mura accolsero
l'astronomo
Giovanni Schiaparelli
1835-1910

Schiaparelli received his first lessons from his parents: writing and calculation from his father, reading from his mother. He went to primary school and to the gymnasium (high school) in Savigliano. Afterwards, Schiaparelli went on to Torino University where in 1854 he acquired his degree with full marks in hydraulic engineering and civil architecture.

Figure 2 — A rare picture of the house where Schiaparelli was born. The house no longer exists; it was located southeast of Savigliano, beyond the Mellea River, in a place called Martinetto. Photo from *Brevi cenni su G.V. Schiaparelli (Peyretti)*

An inscription, posted on the high school where the spirit of the future astronomer developed, says[2]:

Esploratore del firmamento
Storico della Scienza astronomica antica
Giovanni Virginio Schiaparelli
seguiva gli studi secondari
in queste scuole classiche
1841-1850.

While in high school in Savigliano Schiaparelli had the good fortune to become friends with theologian don Paolo Dovo, a

[1] As a child and a boy, these walls received the astronomer Giovanni Schiaparelli 1835-1910.

[2] Explorer of firmament, historian of ancient astronomical science, Giovanni Virginio Schiaparelli completed his high school studies in this classical school, 1841-1850.

learned and zealous priest at the church of Santa Maria della Pieve. Don Paolo was well-versed in astronomy. With passion and skill, he gave Schiaparelli his first lessons in astronomy, starting his great love for this field of study.

It is in this period that the very young Schiaparelli drew a solar clock. This sundial still exists, in a good state, on the apse external wall of the church. He signed it as a present from a pupil to the teacher.

Later, he would often invite his teacher and friend to the Specola di Brera in Milano, where Schiaparelli carried out his astronomy research (Figure 3). A memorial tablet placed in 1912 on the church says[3]:

Quì
all'amorevole disciplina educato
di un modesto virtuoso Sacerdote
Giovanni Schiaparelli
l'anima adolescente
dischiuse ed iniziò
allo studio misterioso del firmamento
acquistando
nella scienza sublime degli astri
gloria universale
——————————————————————-
i concittadini auspice il Municipio
ne eternano la memoria
2 giugno MCMXII
N. a Savigliano 14 marzo 1835
M. a Milano 4 luglio 1910

The lure of astronomy began when Schiaparelli was seven years old. On the morning of July 8, 1842 his mother called him to look at a solar eclipse. In the autobiographical letter he wrote on April 29, 1907, to writer-journalist Professor Onorato Roux, Schiaparelli wrote about that event:

> *A very rare event occurred soon after, to direct my ideas towards heavenly things (...) I put on my trousers quickly, I went to the window: it was just the time of total disappearance of the solar disc (...) My wonder increased even more when I was told that some men were able to predict such phenomena by date and time. I had, then, the wish to be one of them and the ambition to witness the forces that govern the universe.*

In Torino University he attended classes in mathematics and astronomy held by Giovanni Antonio Amedeo Plana, Quintino Sella, and others. He did very well and, with the help of Sella and Luigi Federico Menabrea, obtained a scholarship from the Sardo-Piemontese government to continue his astronomy studies abroad.

In February 1857 he went to Berlin where he studied astronomy under Johann Franz Encke (of comet fame). At the same time, he took mathematics, ancient and modern geography, meteorology, and physics under other famous teachers living in Berlin at the time; teachers such as Johann Christian Poggendorff, Karl Willhelm Weierstrass, and Georg Adolph Erman. Schiaparelli remained in Berlin until April 1859, moved temporarily to Potsdam Observatory and then, in June 1859, to Pulkovo Observatory where he practiced astronomy under Friedrich Georg Willhelm Struve, the son Otto Willhelm Struve, and Friedrich August Theodor Winnecke.

Schiaparelli was in Pulkovo when, in August 1859, the government of Piemonte appointed him Second Astronomer at Brera Observatory (the first institute for scientific research in Milano, built in 1764), however, it is only when he came back to Italy in June 1860 that he was able to begin this employment. Nearly two years later, on August 29, 1862, he became First Astronomer and Director of the Observatory, following Francesco Carlini. Schiaparelli obviously found Brera to his liking as he remained there until he retired in June 1900, leaving the direction of the Observatory to his successor Giovanni Celoria.

In 1865 he married Maria Comotto, the daughter of an engineer of Milano, with whom he had five children: two boys (Attilio and Emilio) and three girls (Ester, Eva, and Emma), all born in Milano.

In October 1864 representatives of fifteen European countries took part in the first International Geodetic Conference held in Berlin. This conference initiated the founding of the Europäische Gradmessung in 1867 that later became the International Association of Geodesy. The Kingdom of Italy was represented by Schiaparelli. Following the commitment taken by Italy at the 1864 international conference, the then Minister of Public Education, Domenico Berti formed the Italian Geodetic Commission (Commissione Geodetica Italiana). Schiaparelli was a member of this Commission.

The Commission held its first meeting in Torino from June 3 to 7, 1865, directed by General Giuseppe Francesco Ricci, Chief of the Ufficio Superiore dello Stato Maggiore (Headquarters of the Defence Staff). Other members included two other well-known astronomers: Giovanni Battista Donati, director of the Astronomical Observatory of Arcetri-Firenze, and Annibale de Gasparis, director of the Astronomical Observatory of Capodimonte-Napoli. Also in the Commission were Federico Schiavoni and the Colonnello Ezio De Vecchi, both belonging to the Ufficio Tecnico dello Stato Maggiore. This Commission had a fundamental role in the field of Italian geodetic sciences. It promoted and directed Italian studies in astronomy, geography, topography, and cartography, as a section of the International Union of Geodesy and Geophysics until it was abolished in 1977.

In the years from 1883 to 1899 Schiaparelli had an important role, scientific and organisational, in the birth of the International Latitude Service. This service was promoted by astronomer Emanuele Fergola after he had observed a change in the latitude of Napoli in 1872 through observations along the same parallel.

[3] Here, educated to the loved doctrine of a modest virtuous priest, Giovanni Schiaparelli, the young soul was exposed and initiated to the mysterious study of the firmament, obtaining universal glory in the sublime science of the stars. —- The fellow-citizens and the Municipality for eternal memory 2 June 1912 B. in Savigliano on 14 March 1835 D. in Milano on 4 July 1910

Figure 3 —The monument to Schiaparelli, taken from the newspaper *Il Saviglianese* when unveiled (1925). It was created by the famous sculptor Annibale Galateri (1864-1949).

The aim of the Service was to study latitude variations and the movement of the poles of rotation of our planet.

In 1900 Schiaparelli left the Specola di Brera and retired to private life, though not to rest. He dedicated the last ten years of his life to the completion of many projects, keeping his mind alert and active until his death due to a brain thrombosis. On that sad occasion on July 4, 1910, the Hon. Luigi Luzzatti, President of the Council of Ministers, wrote a personal telegram to the Schiaparelli family: *"A ray of celestial thought has died: Italy lost its greatest and most glorious scientist."*

At the Brera Observatory, a tablet unveiled on June 15, 1917 is dedicated to the great astronomer. Written by Professor Celoria, it says[4]:

A
Giovanni Schiaparelli
per scoperte, opere, dottrina
uomo di grande dottrina
fama
decoro e lustro della R. Specola di Brera e del R. Istituto Lombardo
la Commissione per le onoranze
i sottoscritti memori.

He is now resting next to his wife, in the family vault in the Camposanto Monumentale cemetery in Milano.

Schiaparelli was a member of several Italian and foreign academies. He received a host of important honours, in Italy and abroad, including: the Gold Medal of the Società Italiana delle Scienze, called *"dei quaranta"* (1868); the Joseph-Jérôme Le François de Lalande award of the Académie des Sciences in Paris (1868) for his studies on shooting stars and again (1890) for his observations on the rotation of Mercury and of Venus; the gold medal of the Royal Astronomical Society in London (1872), and the gold medal of the Imperiale Accademia Tedesca Leopoldina Carolina dei Naturalisti (1876). On January 26, 1889 Schiaparelli was appointed Senatore of Regno d'Italia. His scientific work was monumental.

He made fundamental observations of Mars, where he discovered the "canali" in 1877. The word was translated into English as "canals" implying artificiality, as opposed to "channels" which could be natural. We continue to use some names given by Schiaparelli to surface details during his observations between 1877 and 1884. Because of his studies of Mars, he was called "the King of Mars" and "the Columbus of a new world."

[4] To Giovanni Schiaparelli for discoveries, works, teaching — a man of great doctrine, the reputation, honour and prestige of the R[oyal] Specola di Brera and of the R. Istituto Lombardo - the Commission, by the Hon. and the undersigned, in memorial

Other important research was carried out on double stars and binary systems (observations made over 25 years, from 1875 to 1900), on Venus and Mercury, and on meteor showers. In 1862 Schiaparelli noted the relationship between some showers and the orbits of periodic comets, particularly the association between the Perseids and comet P/Swift-Tuttle 1862 III. This was explained in great detail in five letters (1866-1867) addressed to the Jesuit father Angelo Secchi, and kept today in the archives of the Università Pontificia.

On April 29, 1861 Schiaparelli discovered a new minor planet. It was the 69th of a series that had begun on January 1, 1861 with the discovery of Ceres by Giuseppe Piazzi. The new minor planet was named Hesperia, from the name that Greek people used for Italy. For this discovery the Regio Governo of Italy appointed him Cavaliere Mauriziano.

Observations of Comet P/Swift-Tuttle 1862 III and the discovery of the asteroid Hesperia were made by Schiaparelli through a modest equatorial sector built in 1774 by Jeremiah Sisson, son and heir of Jonathan Sisson. The Sissons were a family of prestigious builders of astronomical and geodetic instruments. The equatorial sector was the only instrument available in the Brera Observatory for off-meridian observations.

Schiaparelli's discoveries encouraged the Minister of Public Education to devote the funds needed to give a more updated and efficient instrument to the Specola in Milano. In February 1875 a new 22-cm equatorial refracting telescope, built by Georg Merz, was placed in the northeast tower of the Observatory. Through it Schiaparelli was able to begin his most rewarding planetary research. His work was not narrowly-focussed but encompassed astronomical history, geodesy, meteorology, geophysics, and stellar statistics.

Schiaparelli taught at the Instituto Tecnico Superiore in Milano and at the University in Pavia. In all, he produced 253 major scientific works and 4000 pages of letters and scientific correspondence. All were written during his 40 years at Brera.

His memoirs were published in *Le opere di G.V. Schiaparelli* by the Reale Specola di Brera, made into 11 volumes edited by Hoepli in Milano (1929-1943). His scientific correspondence is held by the Archivio Storico of the Astronomical Observatory in Brera.

In a letter written in 1907 to Professor Giovanni Marchesini, director of the *Review of Philosophy, Pedagogy and Other Sciences*, Schiaparelli described his intellectual portrait in this way: "Little memory, no genius, much patience and an everlasting curiosity about everything."

In Savigliano, a square, a school, and a monument are dedicated to the famous astronomer (Figure 4). The monument was unveiled on November 15, 1925, in the presence of many dignitaries, including His Highness the Royal Duke of Pistoia, Filiberto di Savoia-Carignano representing His Majesty the King Vittorio Emanuele III, Pietro Fedele, Minister of Public Education representing the national government, and Professor Emilio Bianchi, Director of the Reale Osservatorio Astronomico of Brera in Milano.

On the front of that monument are the famous Latin lines written by Schiaparelli to Professor Tito Vignoli, director of the Museo Civico di Storia Naturale in Milano, in his *memoria III* on Mars. Translated, it says: "Note how Mars looks different any time when, on its perpetual motion, it rotates on its axis!" In his honour, a detail of Mercury's surface was called "Liguria" although Schiaparelli was born in Piemonte.

Schiaparelli's name adorns a Martian crater (500-km diameter, at latitude 3°S, longitude 343°W), a 29-km lunar crater, a ridge on Mercury (24°N, 164°W), and minor planet 4062 Schiaparelli, discovered on January 28, 1989 by astronomers at San Vittore Observatory in Bologna.

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Mario Maccagno, Director of Il Saviglianese 1994

Born in the same city as Schiaparelli, Michele T. Mazzucato is an amateur astronomer, a member of the Italian Astronomical Society and of other scientific associations, and an active member of the research team of the Observatory of Pian dei Termini, primarily in the astrometry of our Solar System's minor planets (MPC 104). Raymond Auclair aided in the translation of the original.

On Seeing D2

by Martin Beech, Campion College, University of Regina (Martin.Beech@uregina.ca)

It was just as I remember when, as a young boy, I first saw the giant trilithons of Stonehenge. I stood in awe-struck silence. Before me then, in majestic stillness, rose an object almost beyond comprehension; a puzzling relic from the ancient past. Once a structure with a function and purpose known to all that surveyed it, Stonehenge is to us a steadfast mystery — an enduring skeleton of weathered stone upon which we may but hang conjecture and superstition.

It was not Stonehenge, however, that held me in thrall this past summer, but Charles Babbage's Difference Engine Number 2 (hereafter, D2). This incredible machine resides in a quiet corner on the second floor of the Science Museum in London. It is a sublime object. Made of resplendent brass and hardened-steel cogs, cams, levers, and springs, it is a calculating machine beyond comparison. From the very first glimpse, it is clear that D2 is a machine born of a brilliant and subtle mind. Embedded in D2, if ever there was such an example, is the essence of human imaginative greatness. Unlike Stonehenge, however, D2 is an ancient ghost given substance in modern times.

Charles Babbage (1791–1874) was a truly remarkable man and his genius touched upon many subjects (Swade, 2000). Calculating machines and computation, however, were his life-long passions. The origins of Babagge's interest in calculating machines began at an early age when, as an undergraduate at Cambridge University, he, along with long-time friend John Herschel and several other students, formed the Analytical Society. The first formal meeting of the society[1] was held on May 11, 1812. One of the great preoccupations of Analytical Society members, and Babbage in particular, was the testing and evaluation of numerical tables — especially tables of logarithms. Such tables were typically constructed via the method of differences[2] whereby only additions and subtractions are needed to obtain the required results. Human computers were employed to make these long and tedious calculations, and these same computers (prone as we all are) made occasional arithmetical mistakes. Not only did errors result through calculation slips, however, they were also introduced at the copying and typesetting stages. Baily (1824) provides an overview of the mathematical tables commonly used by astronomers in the early nineteenth century — for indeed, they were the lifeblood by which precision reductions of data could be made. Alarmingly, however, for one particular set of tables Baily comments that on just one page "no less than 40 errors occur, not one of which is noticed in the printed list of the errata." In many ways, the situation was desperate. Indeed, Sir John Herschel commented in all seriousness (Swade, 2000) to the British Chancellor of the

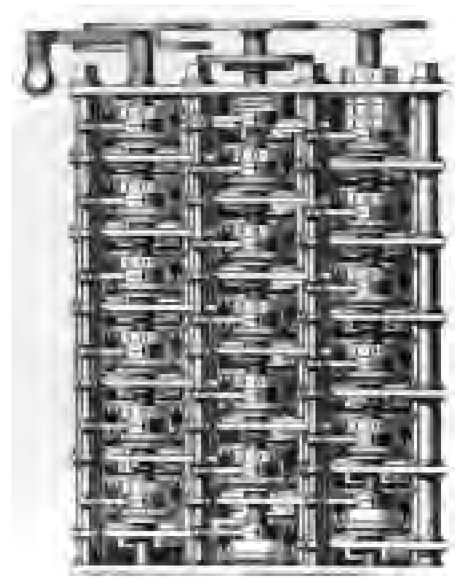

Figure 1 — While a complete Difference Engine Number 2 was never fabricated in Babbage's lifetime, a working (and programmable) arithmetic unit was assembled for its predecessor Difference Engine Number 1 in 1832. The portion constructed represented about one-seventh of the (unfinished) full-size machine, and contained nearly 2000 gears and levers (Swade, 2000). The arithmetic unit is on display next to D2 at the Science Museum in London, and it measures some 72 x 59 x 61 cm.

[1]Babbage and eight friends apparently made the decision to form the Analytical Society on May 7, 1812 (see `www.scholarly-societies.org`). During the first meeting the members outlined their goals as being the promotion of analytical techniques, the discouragement of geometrical demonstrations in calculus, and the abandonment of Newton's fluxion notation in which a "dot" (rather than Leibnitz's "d") is used to indicate differentiation. The Analytical Society was formally dissolved at the end of 1813 when Babbage and the other founding members graduated from Cambridge. Babbage and Herschel considered the possibility of rejuvenating the Analytical Society, on a national basis, in 1817, but nothing ever came of the proposal.

[2]Babbage (1864, p. 49) explains that "the Difference Engine is not intended to answer special questions. Its object is to calculate and print a series of results formed according to given laws." For this reason, difference equations are adopted as an iterative method of generating tables of specific sequences of numbers. The triangular numbers 1, 3, 6, 10, 15, 21,... can, for example, be generated by the difference equation: $T_n - T_{n-1} = \Delta_{1n}$, $T_0 = 0$, where $\Delta_{1n} = n$, for n = 1, 2, 3, 4, 5,... is the sequence number.

Exchequer in 1842, that "an undetected error in a logarithmic table is like a sunken rock at sea yet undiscovered, upon which it is impossible to say what wrecks may have taken place." The sentiment is, indeed, literally true — errors in printed logarithm tables could result in shipwrecks and the loss of life at sea because of faulty navigational determinations (observational error aside).

During an Analytical Society meeting in which logarithmic tables were being checked, Babbage recalls that at one stage his head began to loll forward, his eyes focused in a dream-like state on the expansive tables spread out before him. A friend noticing his glazed expression asked what he was dreaming about, to which Babbage replied, "I am thinking that all these tables might be calculated by machinery (Babbage, 1864)." This "dreamer's" comment literally changed Babbage's life and it led him directly to the consideration of how such calculating machines might be designed and constructed. Babbage realized that the unavoidable calculating and printing errors that riddled the mathematical tables of the time could be swept away, at a single stroke, by a machine capable of being programmed to do a set of calculations and that could print out its own results.

On Tuesday, January 18, 1820 astronomer Sir John Herschel recorded in his diary: "Spent morning at Dr. Pearson's. Babbage came about 1 hr. Read over & arranged address for circulation with the notice of formation of ye Astronomical Soc. Dined & returned with Dr. P. and Babbage to the meeting of the Ctee in the evening (Turner, 1923)." Thus were the origins of the Royal Astronomical Society in London laid, and ultimately Babbage was to become the Society's first Secretary (1820-1824). Amongst the very first papers published in the *Memoirs of the Astronomical Society* (Royal charter was not to be bestowed until 1831) was, "A note respecting the application of machinery of the calculation of astronomical tables" by Babbage (1822a). In this remarkably short communication, dated June 14, 1822, Babbage announces that he has designed and built an "engine" to construct "tables of square and triangular numbers, as well as a table from the singular formula $x^2 + x + 41$, which comprises amongst its terms so many prime numbers[3]." Francis Baily[4] commented in November 1823 that he had seen Babbage's machine and that it performed "all that it was intended to do, not only with perfect accuracy, but also with much greater expediency than [he could] perform the same operations with a pen (Baily, 1824)." Sadly and remarkably the calculating engine that Babbage demonstrated to the assembled Fellows of the [Royal] Astronomical Society in June of 1822 has been lost. Not only has the engine disappeared but no plans or drawings relating to its design or construction have ever been found — as Swade (2000, p. 85) comments, "it remains one of the unfound treasures of the history of the period."

While this first difference engine was limited to performing very specific sets of calculations, in a second communication to the Society, read on December 13, 1822, Babbage (1822b) outlined his plans for a much grander and more versatile calculating engine. Babbage's Herculean efforts to construct a working version of D2 (and its predecessor D1) have been told many times over, and they need not be repeated here. History does tell us, however, that a completed version of D2 was not to be made in Babbage's lifetime (Figure 1). The machine on display in the Science Museum, however, is D2 exactly as designed by Babbage, but it was built by modern engineers[5] and completed in 1991. Indeed, the D2 that I saw this past summer is the embodiment of a dreamer's musings realized in physical form some 179 years after its articulation.

Next to the cabinet enclosing D2 stands a television display. The screen, with clockwork repetition, shows a video sequence of D2 in action. The human operator must turn a massive crank four times around to complete one step of each calculation. It takes some considerable effort to turn the machine over and the operator can be seen to arch his back, with one leg set back slightly behind the other, as the full force of his body is pressed into the machine. Human sweat is converted literally into physical number. After each turn of the hand crank there is a solid and reassuring 'clank' from the machine. Indeed, the sound of that numinous 'clank' still haunts me now. It was the sound of certainty; a confidence announced. A true and infallibly correct calculation has been completed. Towards the end of each calculation cycle a series of levers, which signify a carry of ten, ripple along the addition gear columns. The levers undulate like the legs of a sure-footed millipede — their motion is rhythmical and precise, and I couldn't help but think that I was seeing a fluidity of live mathematics. Surely, even the ancient music of the spheres could not have sounded as sweet and as

[3]The triangular numbers were discussed in note (2). The sequence of squares 1, 4, 9, 16, 25,… can be generated by the difference equation $T_n - T_{n-1} = \Delta_{1n}$, $T_0 = 0$, where $\Delta_{1n} = (2n - 1)$, and where n = 1, 2, 3, 4, 5,… is the sequence number. The "singular formula" that is rich in primes provides the sequence: 41, 43, 47, 53, 61, 71, 83, 97, 113 as x runs from 0 to 8. This sequence of numbers contains 100% of the primes between 41 and 53, 75% of the primes between 41 and 71, and 50% of the primes between 41 and 113. As x increases, so the fewer the number of sequential primes generated in a given sequence. The prime sequence can be generated by the difference equation $T_n - T_{n-1} = \Delta_{1n}$, $T_0 = 41$, where $\Delta_{1n} = 2(n - 1)$.

[4]Francis Baily (1774-1844) was one of the founding members of the Astronomical Society and at various times served as its Secretary and its President. He is perhaps best remembered for the eclipse phenomenon known as "Baily's Beads," a phenomenon he described after observing the 1836 annular eclipse. Baily was awarded the Society's Gold Medal in 1827 for his completion of the "Cavendish experiment" in which a pendulum is used to determine the gravitational constant.

[5]It should be noted that the failure to construct a fully functional version of D2 in Babbage's lifetime was not because the engineering and manufacturing skills did not exist in the Victorian Era. The problems surrounding its manufacture were entirely related to squabbles between Babbage and the manufacturers, and delays relating to the decision on who should pay for the machine and concerns relating to how much it might cost to construct (Swade, 2000).

harmonious as the engagement of gears and levers that I heard from D2 this past summer. I was both hypnotized and enthralled.

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Martin Beech teaches astronomy a Campion College, University of Regina, and has an ongoing fascination with the history and construction of calculating machines and mechanical models depicting the motion of objects within our Solar System.

My First Variable-Star Observation — A Series of Misadventures

by Tim R. Crawford (StarBoyCTX@yahoo.com)

In 2000 I decided to give my telescope a permanent home and and built a roll-off roof observatory where we had a weekend cabin, about 95 km north of Anchorage, Alaska. Being so far north, deep-sky objects for the visual observer were somewhat limited due to both the high latitude and the summer months when there is no truly dark sky, so I was a bit restless. Then, in mid-2001, I read an article about the American Association of Variable Star Observers (AAVSO) and was attracted to the concepts of both being able to make a scientific contribution as well as extending my observing options. I immediately ordered their *Visual Observing Manual*.

As you know, to every endeavour there is a learning curve. I hope part of mine will help to shorten yours should you choose to engage in making your own valuable scientific contributions through observing variable stars.

After reading the manual I thought, "Well, this is pretty easy and straightforward." The first challenge was to figure out just what I was going to observe. Whoops, now just how was I supposed to figure this out? There were so many stars listed in their database.

Then I read something about SS Cygni in another publication — surely a sign. So I went to the AAVSO Web site (`www.aavso.org`) to download a chart. Oh, my gosh! B.gif, B.ps, BR.gif, BR.ps, and ditto for "D" and then "E," a total of 12 charts to choose from. The good news was that the magnitude spread (8.2–12.4) on the chart looked like it was within my range. I decided to try one at random and chose the D.ps chart, which would not print. I must have done something wrong; so I tried it again. After the second failed attempt I decided that I would take the hint and try another file: D.gif. That one worked. What did I know about PostScript files (as I later learned that the .ps indicated)? I got my first star chart printed out, and boy was I anxious to get to it!

That weekend I was all excited to get the roof opened up so that I could make my first observation. To be sure that I knew what I was doing, I had re-read the manual again earlier that week. This time I discovered something called Julian Date that I must have missed on the first read; that looked a little complicated to me at the time but I figured I could work it out after I got my first observation.

Friday night arrived and I got the scope all set up. Wait a minute. How the devil do I find the field? I looked in the Meade manual as they have this big star listing in the back. SS Cyg was not listed. I did some more reading and determined that I could enter the coordinates into the hand paddle; I quickly did this and it only took me three tries to get it right.

Now what? Here I am at the eyepiece and I will be darned if I can figure out whether or not I am looking at the right field. Nothing seems to match up with the chart. I decided to go back and re-enter the coordinates in case I had messed up that third try; the telescope beeped and the field looked about the same.

My arms were getting tired of holding the chart while having to take my glasses on and off to look though the eyepiece. Then, of course, to take my glasses off, I had to take my gloves off. I decided to find something to lay the chart on, located a stool and set it up just below my waist. I went back to studying the field and gave up after 20 minutes of looking at the chart and the field. Some of it looked similar to the chart but maybe upside down and/or backwards. I decided to do some more reading the next day.

I must have missed it before but I now discovered that since I have a SCT, I needed to print out the **reversed** charts (that is what those Rs in the file names indicated). Well, since I had no computer access at the cabin I had to wait and print out the reversed chart (BR.gif) the following week. Bad news! The following weekend the skies were all clouded over.

Two weeks later I am back at the eyepiece with a reversed chart and this time I knew how to quickly enter the coordinates. Well, that is better! The star field almost matched the chart. Hey, if I turn it a bit to the right it does. I finally found the right field and I could actually see SS Cyg — my very first variable star! I carefully looked at a number of the comparison stars and wrote down my first observation (12.3). Whoops, I almost forgot to write the time down (9/29/01, 10:37 p.m. ADST).

When I got back home I was all excited to get on the Web and report my observation. I opened up the manual to make sure I knew what to place in each field. Up came the entry screen, which I studied. What is this Julian Date (JD) stuff? Oh yeah, now I remembered, I was going to figure that out. Guess I had better sign off and come back the next day.

I studied the manual again that night. It explained how to calculate the JD and time so finally the next morning I was able to make my first report. Since then, of course, I have discovered that they also accept Universal Time and that is a lot more user-friendly to work with. About four days after entering my very first observation, staff member Aaron Price e-mailed me my "official" observer code (CTX) and I was on my way.

It also did not take me too much longer after that to discover programs that would let me pre-enter targets, which would let me choose a star from the list, and then the program would slew the scope to the target. That sure saved a lot of work. (I originally used a program called ScopeDriver, but now use a program called AstroPlanner; both of the programs work well and there are others.) I also learned about the field of view (fov) differences between the various charts, simply by reading the scale at the bottom of the chart. One of the most important lessons was learning about the significance of the eye-relief parameter of eyepiece specifications, which encouraged me to purchase some eyepieces I could use without having to remove my eyeglasses with cold fingers.

Today the AAVSO has all kinds of lists to choose from as a place to begin observing and lots of on-line help as well. The AAVSO even has a mentoring program available. The best place to learn how to make a visual variable-star observation is at: `www.aavso.org/aavso/about/powerpoint.shtml`.

I am glad that I did not give up or get discouraged during my own learning curve as now, four years later, I have made just over 13,000 observations and have migrated to using a CCD camera. Over that period, the coldest that I ever observed was at −36°C. Cold-weather observing is another story in itself; although today, having retired to the coast of Oregon, I do not have to worry too much about the cold anymore.

Variable-star observing is a rewarding option for all observers, since the data are needed and used by the professionals. If you are thinking about giving variable-star observing a try then I hope you will profit from a few of my initial mistakes and do yourself a big favour by checking out the AAVSO's Web site. While I like to encourage folks to become a member of the AAVSO, you do not have to be one to make observations and receive your own observer initials or to download charts and take advantage of the many learning tools they have available.

The RASC Web site also has a variable-star section with a good introduction, FAQs, sample charts, and an excellent article *How To Observe Variable Stars,* among its features.

Now for the most important part of this: remember, *there is no such thing as a dumb question!*

Resources mentioned in this article:

The AAVSO *Visual Observer's Manual* is available for purchase or download at:
`www.aavso.org/publications/manual`

RASC Variable-Star Section
`www.rasc.ca/observing/variablestars/index.html`

Astroplanner and *ScopeDriver* are commercial programs. Details are available here:
`www.ilangainc.com/astroplanner`
`www.adpartnership.net/ScopeDriver`

Tim Crawford is an avid variable-star observer and a member of the Portland, Oregon Rose City Astronomers. He can sometimes be found teaching variable-star observing to beginners at the Oregon Star Party.

The Big Zit

by Michael Attas, JRASC (attasm@aecl.ca)

The face of Jupiter is breaking out. The Great Red Spot, a storm on Jupiter twice as wide as the entire Earth, now has a companion. The Great Red Spot has been a distinctive feature on the largest planet in our Solar System since it was first noticed over 300 years ago. In contrast, the new storm, officially known as Oval BA, appeared only in 2000 when three smaller storms merged after colliding. Oval BA started off white, the same colour as the three storms that formed it, but recently it has begun to change colour.

Late in 2005 Oval BA gradually turned brown, and this year it has become reddish — the same hue as the Great Red Spot. About half the size of that more famous and older storm, it's big enough to be viewed by amateur astronomers with backyard telescopes (see Figure 1). Why are these storms red? Planetary meteorologists aren't sure, but they have theories. One theory is that the storms lift material from deep within Jupiter's atmosphere and transport it high above the surrounding cloud tops. There the material can be altered by the Sun's ultraviolet radiation to produce new, red compounds. The details are unclear. Moreover, this is not the only possible explanation.

A competing theory first aired on CBC Radio's *Music and Company* on March 9. The host, Tom Allen, known primarily as a broadcaster and trombonist, is also a keen observer of human nature. Tom speculated, "...that Jupiter, despite the fact that it's so enormous and gassy, is really a relatively young planet, and it's going through sort of an adolescence. These are red spots that are appearing on its surface, as in human adolescents. And they storm and fume and go through various changes, and then, over time Jupiter will settle down and have a clear complexion, get a job, and go bowling. And that's going to be something to see."

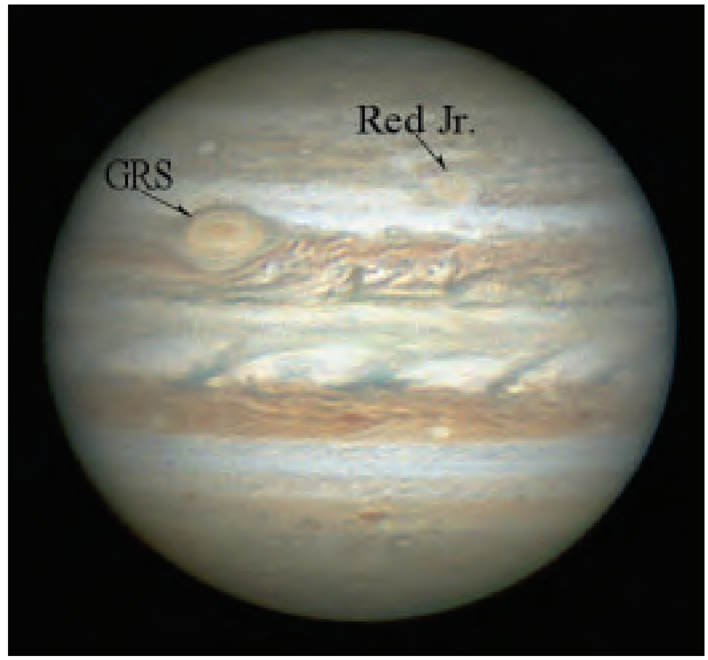

Figure 1 — Red spots on Jupiter, photographed by amateur astronomer Christopher Go on April 7, 2006 at 16:04 UT. The new red spot can be seen above and right of the traditional red spot. (Image reversed, as in a Newtonian telescope.) Used with permission of Christopher Go.

Source: `http://science.nasa.gov`

The Woodstock College Observatory - II

by Philip Mozel, Toronto Centre (phil.mozel@sympatico.ca)

Introduction

As described (long ago) in Part I, a well-equipped astronomical observatory was built on the grounds of Woodstock College in Woodstock, Ontario in 1879 (Figure 1). The primary force behind its establishment was Jabez Montgomery, a teacher at the college. The major instruments included an 8-inch Fitz refractor, a 2-inch transit, and a 2.5-inch Dollond telescope. Montgomery would leave the college for the University of Michigan in 1879 having set the observatory on a firm footing.

During most of its existence the observatory was under the direction of Newton Wolverton. Born and raised locally, he served in the American Civil War with his brothers (Hoy, 2005) and eventually played a large role in the educational community.

The busiest period at the observatory occurred around the time of the 1882 transit of Venus. The event was periodically observed through clouds although no useful results could be obtained. The observatory endured into the twentieth century, the last known observations being of Comet Halley. The observatory disappeared completely around 1920 (Mozel 1982).

Although the first part of this article appeared in 1982 (long ago indeed!), this seems to be an appropriate time for an update since the 125th anniversary of the observatory's founding has recently passed and the 25th anniversary of Part I is approaching. Furthermore, all the instruments once housed in the building are still missing. Perhaps a reader has clues to their fate. Finally, by using the Internet, which was not available during my original research, a few more particulars about the observatory have been wrested from dusty repositories and are presented here.

Comet Observing

A major attraction during the early years of the observatory's existence was comets. For example, a number of students and their friends observed a comet from the observatory in the summer of 1881 but readers of the local newspaper were warned that, "The result is very disappointing. The telescope, of course, only magnifies an extremely small portion of the comet at once, giving it the appearance of so much illuminated vapour. Those who expect to see something startling had better not go" (Anon. 1881). The comet referred to was possibly the one discovered by Tebbutt in Australia on May 22 and which peaked at about first or second magnitude (Kronk 1984).

Observing improved the following year when the Great Comet of 1882 appeared. Discovered while an easy naked-eye

Figure 1 — The Woodstock College Observatory, possibly from a postcard. Courtesy of the Toronto Library Board.

object, it achieved brightness so great it was visible during the daytime next to the sun (Kronk 1984)! Wolverton was then prompted to make the following assessment of astronomical knowledge:

> What are comets made of? I don't know. Each celebrated astronomer has a distinct theory of his own. This is necessary in order that he may be great. When I aspire to be a celebrated astronomer I expect to propound another theory, all my own. I have no theory now. I can tell you nothing more about this wonderful celestial visitor, farther than this: it has come from no-one knows where; has suddenly rushed around the sun, passing unusually near to it, and is now speeding away to no-one knows where. Has it ever visited us before? No one knows. Will it ever delight the eye of mortals again? No one knows (Wolverton 1882a).

In December 1883, Wolverton described another comet, Pons-Brooks:

> Early Thursday evening I carefully examined the comet. I used powers ranging from 50 to 500, but with none could I get a well-defined nucleus. The luminous tail — if such a poor thing can be called a "tail" — has to me the appearance of being extended directly towards us. I made it 20 seconds in diameter, almost round, and it seemed to vary much while I was looking at it. I made the distance of the densest part to be about 2 sec. from a star of about the 5th magnitude. Last evening, Sunday, I thought I saw it with the naked

> eye, but am not sure (Wolverton 1883).

Quite likely he did since other observers reported seeing it without optical aid (Kronk 1984).

Time and Weather

There were intentions that, besides conducting astronomical and educational programs, the observatory would provide time to the town. A transit instrument, apparently provided by the federal government, arrived and was "…firmly planted upon the stone which has been waiting for the last three years to receive it…. It has given time to all the clocks and watches in Ontario for the last forty years…. At noon, Tuesday last, the college bell rang at noon for the first time probably" (Wolverton 1882a).

By the following month Wolverton could declare that "In the observatory the transit instrument is in position; the chronometer from Greenwich has been received, also the equatorial telescope and driving clock. Preliminary observations relative to the transit of Venus are being taken every night" (Wolverton 1882b).

Wolverton was still discussing time with town politicians in 1888 when he was

> …heard, on motion, with reference to his request of a grant of $200 for the Woodstock Observatory. He expressed it as his opinion that if the instruments which were now offered them at so low a figure were obtained it would greatly advertise the town and benefit it; besides the giving of the correct time would be a great boon. (Anon. 1888).

The observatory also regularly recorded and published information on local weather conditions including high and low temperatures, high and low air pressure, strongest wind, duration of sunshine, total rainfall, total snowfall, as well as rise and set times for the Sun and Moon (Anon. 1887). This information was disseminated at least as far as London, Ontario (Anon. 1885). This role seems to have been taken over from pre-observatory days since, by January 1889, 14 years of continuous observations had been made (Anon. 1889). Wolverton's record keeping was good enough that his "precise testimony on weather conditions at the Birchall murder trial in 1890 was critical for the prosecution" (Symons 2001).

Leaving Woodstock

In 1891 Wolverton left Woodstock to become President of Bishop College in Marshall, Texas, but returned to Muskoka every summer to vacation. After seven years in the U.S. he bought a 1000-acre farm on the edge of Brandon, Manitoba, eventually becoming connected with the founding of Brandon College. In 1907 he was granted a doctorate from McMaster University, an institution with roots traceable to Woodstock College.

Moving to British Columbia the next year, Wolverton joined his son who had a fruit farm there. Eventually establishing a land development company and a ranch, he became active in both church and political affairs. He lived in Nelson for 23 years before moving to Vancouver, dying there in 1933 at the age of 88 (Carder 1988).

After the First World War, enrolment quickly plummeted to the point where keeping the doors open was no longer warranted and Woodstock College closed in 1926. The buildings were then leased to Trinity College, an Anglican college based in Port Hope, for two years. Then, in 1929, the Catholic Redemptorist Fathers bought the site and used it as St. Alphonsus Seminary until 1958. The buildings remained vacant until they were torn down to make way for College Avenue Secondary School, which opened in 1963 (Scriven 1981).

The college, the observatory, the instruments are all gone. Many people, in three different countries, have been contacted over the years in a search for information about the demise of the observatory and the instruments' fate, all to no avail. The closest I have come since the appearance of Part I is an 1883 postal cover depicting one of the telescopes. After two decades of searching, it was sold a mere matter of days before I became aware of it!

Needless to say, I will gratefully receive any further information the reader may have. Hopefully, a couple of more decades will not have to elapse before this story reaches a conclusion!

Acknowledgements

Thanks to all the many people over the years that have helped me dig into the history of the observatory and the mystery of the missing instruments. Special thanks to Bob McCall for his enthusiasm in keeping the ball rolling.

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A New View of Vega

by Leslie J. Sage (Lsage@naturedc.com)

Vega is one of those stars known to all amateur astronomers in the northern hemisphere. It is the second-brightest in the northern sky, and one of the three making up the "Summer Triangle" that we Canadians look for after a long, snowy winter. Many professional astronomers are also intimately acquainted with Vega, because it has for quite a while been a fundamental calibrator for photometry (comparing the brightness of stars) and spectrometry (comparison of spectral lines). A group of astronomers, led by Deane Peterson of SUNY Stony Brook, has used an optical interferometer in Arizona to show that Vega is rotating very rapidly — at about 93 percent of its break-up speed — but is seen almost pole-on (see the April 13 issue of *Nature*). These data have resolved some puzzling discrepancies that had brought into question Vega's usefulness as a standard. A second group, led by Jason Aufdenberg of NOAO in Tucson, used another interferometer to reach essentially the same conclusion. That paper is available as astro-ph 0604260 at `www.arxiv.org`, and it is awaiting publication in the *Astrophysical Journal*.

Vega has been thought to be a "simple" star. It has very narrow lines (except for hydrogen) in its spectrum, which usually means that a star is slowly rotating. It defines the class A0 V in the O, B, A, F, G, K, M system that has been used to classify stars for almost 100 years, and it forms the basis of the magnitude system, setting the zero point for wavelengths from ultraviolet through the near infrared.

Curiously, though, Vega's absolute visual magnitude seems about 0.5 magnitude brighter than other A0 V stars, and its radius seems rather larger than expected. The spectral lines have peculiar shapes, which can only be modeled by a rapidly rotating star seen almost pole-on (looking down on the north or south pole of the star). But if that were true, then the models of stellar atmospheres and interiors that are calibrated against Vega would have to be changed. Richard Gray hypothesized about 20 years ago that Vega could best be understood as a rapidly-rotating star, but it is only now that technology has enabled Peterson and Aufdenberg to demonstrate that this is indeed the correct explanation. In fact, changing Vega's status from a "simple" star to a more complicated one will cause ripples throughout modern astronomy because of its status as a standard.

Optical interferometers, though they have been around for almost 20 years, have only recently come into their own. Compared to radio interferometers such as the Very Large Array in New Mexico, there are formidable problems obtaining and reducing the data. It is therefore significant that two separate groups, using different instruments, have reached the same result.

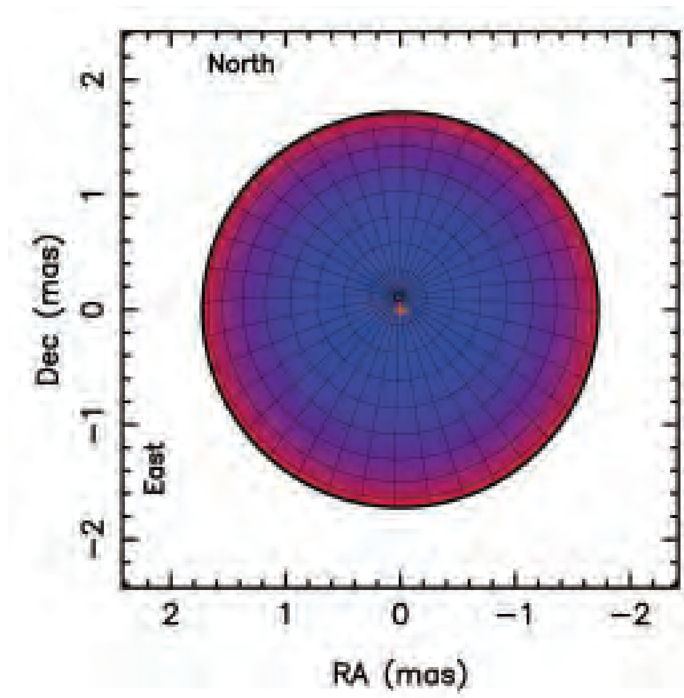


Figure 1 — Vega as it appears from Earth, with the cool equatorial region in red, and the hot polar region in blue. The red cross marks the pole. Axes show offsets relative to Vega's position. Figure courtesy of D.M. Peterson and *Nature*.

Peterson used the Navy Prototype Optical Interferometer, which is located on Anderson Mesa, south of Flagstaff, Arizona, where Lowell Observatory has their main telescopes. Aufdenberg used the Center for High Angular Resolution Astronomy (CHARA) Array on Mount Wilson, outside of Los Angeles, also home to the historic 100-inch telescope. Peterson worked in the optical (32 narrow bands spanning the range from 4500 Å to 8500 Å, while Aufdenberg worked in the near-infrared (2.1 microns). Both groups found that Vega is rotating very rapidly — about 93 percent of the speed where it would begin to break up because its gravity would not be strong enough to keep the outer layers bound. This has the effect of making its equator bulge quite substantially, such that at the equator its diameter is about 20 percent greater than at its poles. This explains the anomalous diameter measured some years ago, as well as the excess brightness — Vega has a larger radiating area than previously thought, so it is emitting more light in the polar direction.

Because the equatorial gas is further from the centre, it is much cooler (7500 K) than the polar gas (10,000 K). This complicates calculations of its composition, which in turn feeds into uncertainties about its age. Vega was discovered by the IRAS satellite to be surrounded by a disk of dust where asteroids get ground up through collisions to produce something like the material that gives the Solar System its zodiacal light. Peterson estimates Vega's new age to be in the range of 400-600 million years, far older than previously thought, which will affect models that describe how long dust can survive around stars before being blown out (or replenished).

I met Deane on my first day as a graduate student at Stony Brook, where his kindness to the new students is legendary. The world of astronomy is very small, but even so it gives me great pleasure to be able to write about the person who was so welcoming to me in the fall of 1983.

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

A Tale of Two Eclipses

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

I'm not what you could call an eclipse chaser. In fact I've only ever seen two total solar eclipses in my life: July 20, 1963 and March 29, 2006.

My first eclipse observation, and one of the earliest memories in my life, was the partial solar eclipse of November 23, 1946, which I observed from my front yard in Montreal at the tender age of five.

Isabel Williamson of the Montreal Centre organized the expedition to the 1963 total solar eclipse. The track crossed the St. Lawrence Valley east of Montreal, passing through the towns of Grandmère on the north shore and Plessisville on the south shore. The Montreal Centre maximized its chances by setting up scientific eclipse stations near both towns, in fenced transformer stations belonging to Hydro-Québec. This was to guarantee that we wouldn't be swarmed by the general public. The Centre also operated an "eclipse special" train from Montreal to Grandmère, mainly for the public.

I was assigned to the Victoriaville site, along with most of my regular observing buddies, including Klaus Brasch and Constantine Papacosmas. There was also a young kid from New Brunswick named Alan Whitman at our site. The eclipse was late in the afternoon, and the weather, which had been promising all day, started to turn cloudy as totality approached. I used a Jaegers 52-mm f/25 achromatic refractor to observe, with a pinhole cap during partial phases (no front-end solar filters in those days) that I removed at totality. I concentrated on photography at totality but, because of passing clouds, only managed three images, each of which showed a "different" corona because of the clouds. Because of my concentration on photography, and the meteorological interference, I don't remember much about totality other than a pearly-grey corona and a few bright pink prominences. I do have a vivid memory of partying late into the night (the eclipse was on a Saturday) and being awakened at 6 a.m. by the pealing of the Victoriaville church bells.

In the intervening years I observed various partial eclipses, plus the annular eclipse of May 10, 1994 that I watched from my back yard in Toronto. I planned to go on a couple of eclipse expeditions, but either the timing or the state of my bank account prevented it. When I heard that Ralph Chou was organizing an expedition to the solar eclipse this year to Libya, followed by a week in Italy, Louise and I decided to go for it, since our son David was finally of an age where we could safely leave him home while we both travelled. Interestingly enough, two other members of the Montreal Centre's 1963 expedition were also in Ralph's group: Jim Low and Dave Zackon; both had been at the Grandmère station.

The internal air flight from Tripoli to Benghazi dictated travelling very lightly, so I decided to take my Coronado Personal Solar Telescope for the partial phases. Because of my experience in 1963, I decided not to attempt photography at totality, but to sit back and enjoy the view visually, knowing that many fine photographers would be capturing images far better than I could manage. I brought my 10 × 50 binoculars to aid in observing details of the corona.

In Libya the church bells of Victoriaville were replaced by Muslim calls to prayer, amplified by huge speakers from every mosque. Our eclipse site was in the middle of the Libyan Sahara, a six-hour drive south of Benghazi. We drove through ever-more-barren desert, finally leaving the highway for the eclipse camp. There we found a tent city with thousands of inhabitants, purpose-built by the Libyan government. We went to bed early on the eve of the eclipse, only to be rudely awakened a few minutes later by the first of what seemed like an endless series of fireworks displays that continued long past midnight!

Eclipse morning dawned perfectly clear, and remained so all day. I set up my PST and observed no less than eight prominences around the Sun's limb. As the Moon covered the Sun's face, the solar surface detail seemed to grow more intense. We shared the Hα view with others in our group and many local people who had driven down for the day to see the eclipse. Finally, only a fine sliver of the Sun remained, and I had a memorable view of Baily's Beads as the total phase began. Then I kicked back, grabbed my binoculars, and simply enjoyed the spectacle of the eclipsed Sun hanging high in a deep blue sky, surrounded by a compact but very complex corona. Unlike my experience in 1963, totality seemed to go on forever, and I felt filled up with the wonder of this great natural phenomenon.

Geoff Gaherty was very active in the Montreal Centre back in the'50s and '60s until he got a life. After thirty years he returned to the fold, this time with the Toronto Centre. At an age when most people are retiring, he's suddenly become gainfully employed working for the Royal Ontario Museum and Starry Night Software.

Deep-Sky Contemplations

by Warren Finlay (warren.finlay@interbaun.com) and Doug Hube (jdhube@telus.net)

Summer and vacation are two words that conjure pleasant images of lakes, loons, and lazy afternoons. In our northern country, however, deep-sky observing wanes in early summer because even at midnight, twilight refuses to let night have its due. Avid deep-sky lovers are known to plan on spending part of their summer in more southerly latitudes to solve this problem. An alternative approach is to observe brighter objects that do not lose their lustre in deep twilight. One such object is NGC 6543 [RA(2000) = $17^h\ 58.6^m$, DEC(2000) = +66° 38′], a planetary nebula in Draco that sits a little over 3000 light-years from us.

As with all planetary nebula, this object is a relative newcomer to the sky, being but a few thousand years old. Before taking on its current dying-ember status, the central star sputtered off the clouds of gas that now surround it. That gas is now being lit up by ionizing radiation emitted by the hot (50,000 K) 11th magnitude central star that can be seen shining like a summer firefly in the nucleus of the much cooler (7000-9000 K) nebula. Professional telescopic images reveal a series of ring-like structures outside the central region that are actually spherical shells, each with a thickness of about 1000 AU. These shells formed when the progenitor star had a many-thousand-year coughing fit, emitting bursts of mass roughly every 1500 years. These shells are expected to merge within a thousand years, highlighting the transient structure of planetary nebulae.

The central region of the nebula (about 20″) appears as a small bright disk in the eyepiece. Professional telescopes reveal that this bright core region consists of two overlapping ellipsoids

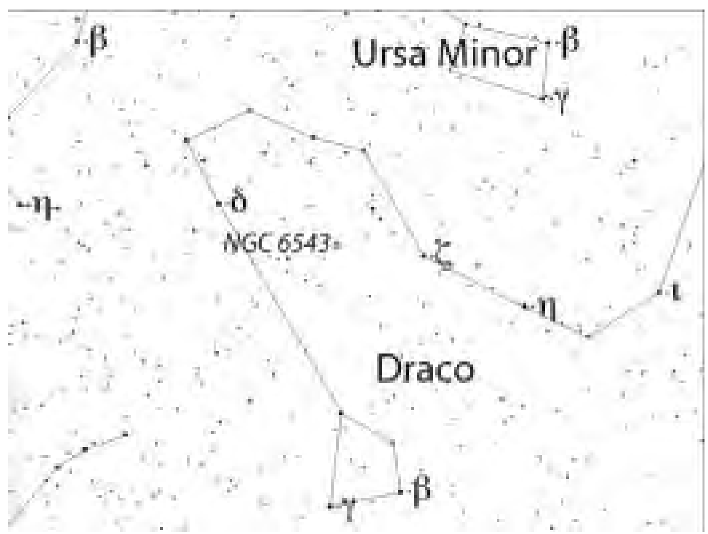


Figure 1 — Position of NGC 6543 in Draco.

with major axes at PA 25° and 115°. The PA 25° ellipse is thought to be the result of a fast wind from the central star slamming into slower-moving gas ejected earlier. It formed a little over 1000 years ago. The PA 115° ellipse may be an earlier ballistic ejection. Near the ends of the PA 25° ellipse are small jet-like protrusions that are just visible in large amateur telescopes. These jets are about 2000 years old, being intermediate in age between the inner core and surrounding rings.

About 100″ west of the nucleus, far out in the 330″ diameter halo, is a bright knot visible in professional telescopic images.

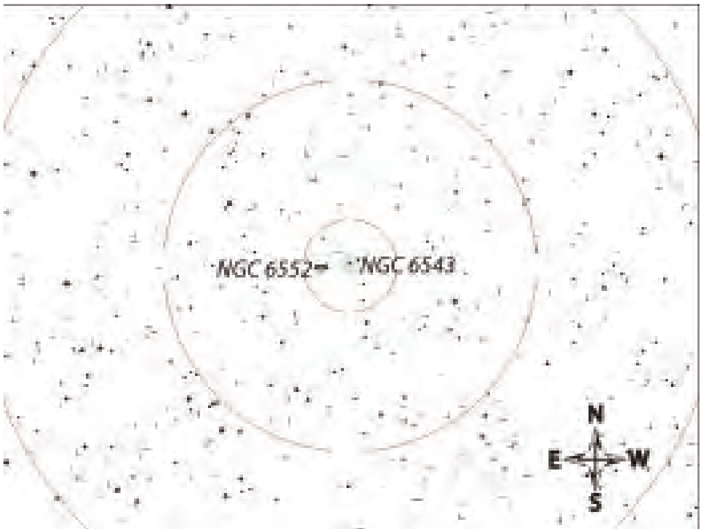


Figure 2 — Finder chart shown with 0.5° and 2° Telrad circles (and part of 4° circle).

Figure 3 — 50'X50' POSS image of the field that includes NGC 6543 and NGC 6552.

This feature is thought to be a dense relic of the original red-giant wind of the nucleus, *i.e.* the progenitor star burped just before it started making a planetary nebula. While NGC 6543 is sometimes referred to as the Cat's Eye Nebula, its highly complex structure is perhaps more aptly described as the Dog's Breakfast Nebula.

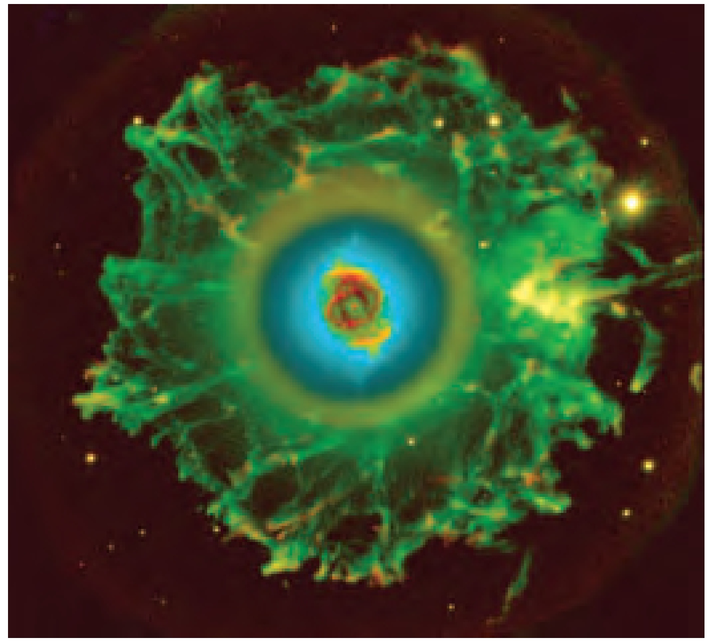


Figure 4 — Image of NGC 6543 by Romano Corrad with the 2.6-m Nordic Optical Telescope.

At magnitude 8 and with high surface brightness (14 mag. /arcsecond^2), NGC 6543 is bright enough to be readily visible in most scopes even during early summer when astronomical twilight never falls. You might want to also observe this nebula later in summer under dark skies, perhaps at a summer star party, and see if you can find NGC 6543's little-known neighbour, NGC 6552. Lying 9´ west, this is a dim, barred spiral galaxy (1´ × 0.7´, mag. 13.6, surface brightness 22 mag./arcsecond^2). It can be difficult to observe even in a 10-inch scope unless you have dark, transparent skies. NGC 6652 is a Seyfert galaxy, so it has an active galactic nucleus (AGN) that emits intense X-rays due to gas falling into a supermassive central object. Cold matter surrounding the nucleus cloaks and scatters these X-rays so that their spectrum differs from that normally associated with an AGN. At a distance of about 300 million light-years, this galaxy is 10^5 times further away than NGC 6543, making it and 6543 one of the oddest couples in the sky and well worth a visit in the eyepiece this summer.

Warren Finlay is the author of Concise Catalog of Deep-sky Objects: Astrophysical Information for 500 Galaxies, Clusters and Nebulae *(Springer, 2003) and is this year's RASC Simon Newcomb Award recipient. Doug Hube is a professional astronomer retired from the University of Alberta.*

Painting the Sky

by Don Van Akker, (don@knappett.com)

Binoculars are still your best option for general exploring — a telescope that hangs around your neck. Like any other telescope, they benefit from a steady mount, and there are many binocular mounts to choose from out there. Unfortunately, most of them are 'way too elaborate, and many actually eliminate binoculars' two biggest advantages: instant portability and spur-of-the-moment convenience.

This idea originated some years ago from a *Sky and Telescope* item about steadying binoculars with a pole sander. That didn't work for us because the pole sander plate was difficult to hold to the binoculars, and if you strapped it on, the binoculars were then flopping around at the end of a five foot pole.

A rubber ball on a telescoping painter pole seemed a natural. It nestles under the bridge of the binocular without shifting so that it doesn't need to be attached. It is instantly adjustable for height, and with the pole extended you can even use it to look straight up.

Use an eight-foot painter pole and the kind of brightly coloured 2.5-inch solid-foam rubber ball that you played with when you were a kid. Push a sharp knife about 1.5 inches into the ball making two short deep cuts in the shape of an X. Force the threaded end of the painter pole into the center of the X and wind it in until the shoulder seats against the ball.

A word of caution here: if your spouse is not an astronomer keep this out of sight. Otherwise you may find that instead of exploring the heavens, you will be painting the kitchen.

Don Van Akker makes his living digging holes and putting buildings in them. He observes from the rain coast with his wife Elizabeth so he has many free evenings to work on these ideas.

Figure 1 – A view of the binocular rest in operation. The rubber ball is attached by inserting the threads on the head of the pole sander into a deep "X" cut into the ball.

Figure 2 – a view of the extensible pole sander with rubber ball attached.

Ramblings of a Variable-Star Addict

An Amazing RR Lyrae Star — XZ Cygni

by Richard Huziak, Saskatoon Centre (Huziak@SEDSystems.ca)

Now prominent in the eastern sky, Cygnus heralds the arrival of summer. The rich Milky Way star fields in Cygnus give us hundreds of variable stars. One of the most fun of these variables is XZ Cygni (XZ Cyg), a bright example of the RR Lyrae class of variable stars. More precisely, it is an RRab star, described below.

RR Lyrae stars are pulsating stars. This class of stars is named after its brightest example, RR Lyrae. RR Lyrae stars have masses of a few times that of our Sun, and that have just evolved off of the main sequence, meaning that they are fusing hydrogen into helium in a spherical shell-shaped region surrounding a hot helium core. At this stage of their evolution, there exists a periodic instability in their atmospheres: a layer of helium absorbs light from the star's core, and as it does, many helium atoms lose an electron. This absorption of light makes the atmosphere of the star "puff up" and become fainter at the surface. When these free electrons recombine with a parent helium atom, then all this light that was absorbed is released and the star appears brighter. While releasing this light, the star's atmosphere relaxes or loses its "puffiness." This pulsation is thus directly related to the cyclical brightening and dimming of the star. The mechanism is similar to that of classical Cepheid stars, but RR Lyrae stars have shorter periods, generally one-half to one day.

Another difference from classical Cepheids is that RR Lyrae stars are of Population I, *i.e.* found in the halo of the Milky Way Galaxy, whereas Cepheids of Population II are confined to the Galaxy's disk. Cepheids are also more massive than RR Lyrae stars. RR Lyrae stars were first found in abundance in globular star clusters, so they are often referred to as cluster variables (see the amazing animation at the *Astronomy Picture of the Day* Web site given in the *Internet Resources* section). It is now known that these variable stars are distributed over the whole Galaxy.

XZ Cyg is found off of the upper wing of Cygnus, just north of θ (theta) and ι (iota) Cyg. It is in the middle of a small asterism I call "The Kite." The Kite is composed of three stars that form the triangular body of the kite with two other stars coming off as the kite's tail. This asterism is a few degrees across and so is visible in my spotter scope as I star hop up from θ and ι Cyg. The Kite can be seen in any small spotter, but observing XZ Cyg's light cycle requires at least a 3-inch to 4-inch scope and ideal viewing conditions. If you use GOTO technology or setting circles, set them to +56° 23′ 18″, 19h 32m 28s (epoch 2000.0).

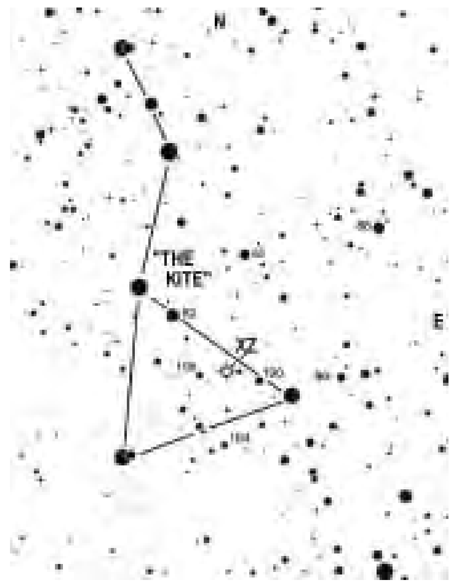


Figure 1: Find XZ Cyg in "The Kite" by star hopping to the north of θ and ι Cyg. This chart is part of the AAVSO XZ Cyg chart available from their Web site. South is up and east to the left in this 2°-wide view. The chart is used with permission of the AAVSO.

Once you have located the star field, find XZ Cyg and study the comparison stars you will use. XZ Cyg could be at just about any magnitude between 8.8 and 10.5, but if you catch XZ Cyg near 10.4 or 10.5, it is nearing the turning point toward maximum. If so, observe the star at least every 10 minutes, because the rise in brightness begins abruptly, and too long of a gap may mean you miss the whole rise! Once you have noticed that the star is brightening, observe it every 5 minutes until the rise is complete, then for the next 1.5 to 2 hours to complete enough of the light curve so that useful timing measurements can be made from your data. Measurements of this star are taken at the time of maximum light, so the most important parts of the curve are the rise and the hour after the peak has occurred.

XZ Cyg completes a pulsation cycle every 0.4667 days (11 hours, 12 minutes), varying from V=8.8 to 10.5. The exciting aspect of the cycle is that the brightening branch takes only 53 minutes to rise 1.7 magnitudes from minimum to maximum. This brightening is followed by a more casual 10-hour fade.

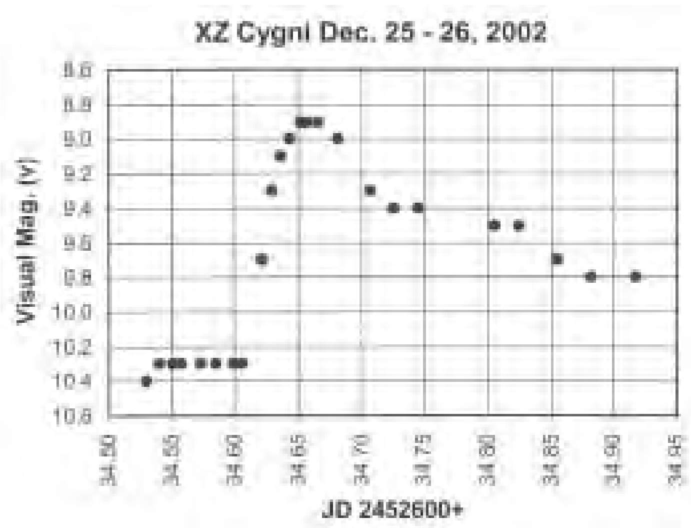


Figure 2: The visual light curve of XZ Cyg. Note the rapidity of the rise – only 53 minutes, though the exact shape of the rise is affected by the Blazhko Effect. The light curve repeats every 11.2 hours!

Catching a rise is breathtaking, and I am always amazed at how fast this star brightens.

Data on these stars are used by professional astronomers to study the primary and multiple pulsation periods, the Blazhko effect, and minute changes in the stars' periods. XZ Cyg's period also changes over time, indicating that changes are occurring in the pulsation mechanism.

The Blazhko Effect

Though most RR Lyrae stars show very repeatable light curves from cycle to cycle, some RR Lyrae stars do not play the same game, and exhibit what is known as the Blazhko Effect. In the early 1900s, Russian astronomer Sergei Blazhko noticed that XZ Cyg and some other RR Lyrae stars show variable rise times and different maximum brightnesses on subsequent cycles. The Blazhko Effect is not well understood but may be related to an underlying secondary pulsation period. Whatever the effect turns out to be, it makes for more interesting observing of this star since each rise could hold a new surprise.

Subclasses of RR Lyrae Stars

RR Lyrae stars are broken into three sub-groups based on the shape of their light curves, *i.e.* on how their brightnesses change with time:

RRab stars have a very sharp rise to maximum, followed by a quick decline, then a slower fade back to minimum. Standstills or bumps may occur on the declining branch. These stars have a range of generally just over one magnitude and a period of 12 to 20 hours. At one time these starts were broken into RRa and RRb sub-classes but have been combined in recent years.

RRc stars show a slower rise to maximum, followed by a similar fall to minimum, making the light curve more symmetrical. The range is typically 0.5 magnitude, and the period is generally 5 to 10 hours.

RRd stars vary in two beating periods, the fundamental and first overtone periods. This combination has the effect of showing a constantly changing light curve of about 0.5 magnitude amplitude and a period of 4 to 10 hours. These stars may be similar to δ (delta) Scuti variables, discussed in the previous RZ Cas article. (*JRASC*, Feb. 2006)

Internet Resources

"The Impulsive XZ Cygni" American Association of Variable Stars (AAVSO) Web site, Variable Star of the Season: `www.aavso.org/vstar/vsots/0802.shtml`.

Finding charts:
`www.aavso.org/observing/charts`.

Ephemerides and other observing aids:
`www.aavso.org/observing/programs/rrlyrae/rrlyrephem.shtml`

Coolest video animation of RR Lyrae stars in globular star cluster M3. You will never look at globulars the same way! Found at `http://antwrp.gsfc.nasa.gov/apod/ap041012.html`

Rick Huziak, Past-President of the Saskatoon Centre, Chair of the Saskatchewan Light-Pollution Committee, and enthusiastic observer, loves to write about his favourite subject — variable stars.

Carpe Umbram

by Guy Nason, Toronto Centre (gnason@rogers.com)

Summertime and the living is easy…
One of these mornings you're gonna rise up singin'
Then you'll spread your wings and you'll take to the sky…

— From *Porgy and Bess*
George and Ira Gerschwin, 1934

Normally summertime brings fewer asteroidal occultations than other seasons, simply because we enjoy fewer hours of darkness. However, this year we in Canada have more opportunities than normal to spread our wings and take to the sky. If you haven't observed an occultation before but think you might like to become an occultationist, go to `http://toronto.rasc.ca/content/HowItsDone.shtml`, which describes a variety of ways to make useful observations. If you are an old hand at this, why not talk up the enterprise at your Centre meetings and encourage others to participate?

Below is a chart of asteroidal occultation opportunities over populated Canada for June, July, and August. Events are included if the target star is magnitude 12.5 or brighter; it is 10° or higher above the local horizon; the predicted drop in brightness (Δ-mag) exceeds 0.4; and the Sun is more than 18° below the horizon (unless the target star is relatively bright). I remind you that because of rather long lag times, the data below, although the best available at the time of writing, may be superseded by newer information as the event draws near. A few days before the scheduled event, please check `www.asteroidoccultation.com`, the Web site of IOTA's Steve Preston, for the latest information, including finder charts, for occultations in your area. In addition, check out Charlie Ridgeway's *Google* maps a month or so ahead of time at `http://digitalmagic.i8.com/Astronomy/Occultations`.

Notes:

Jun 23 Philomela: The shadow path is 193 km wide and runs from Rimouski to Windsor, passing directly over Ville de Québec, Montréal, Ottawa, Kingston, Belleville, Toronto, Hamilton, Niagara Falls, Kitchener-Waterloo, London, and Sarnia along the way. One event that casts its shadow on 13 RASC Centres (and several other clubs) is truly unique. If the weather cooperates, I'd like to see an exceptionally good turn-out for this one. The star should be easily within range of 8-inch and larger telescopes. The unusually long maximum duration should yield a very good resolution of the asteroid's size and shape.

Jul 9 Sisigambis: This event occurs at the beginning of astronomical twilight, and the 95% sunlit Moon is only 14° away from the target star. However, the relative brightness of the star should over.come these hurdles, so those residing near the path, from Manitoulin Island to Sudbury, are encouraged to give this one a try.

DATE 2006	TIME (UT)	ASTEROID		STAR MAG	Δ-MAG	MAX DUR (Secs)	PATH
Jun 23	04:32	196	Philomela	12.0	0.5	24.8	QC - ON
Jun 26	04:25	1980	Tezcatlipoca	10.4	4.7	0.7	sSK
Jul 09	07:33	823	Sisigambis	7.9	6.4	1.7	cON
Jul 10	06:34	1847	Stobbe	8.5	6.1	2.3	nwON
Jul 26	02:53	558	Carmen	8.4	4.8	4.6	QC – cON
Aug 01	05:48	169	Zelia	10.3	1.9	5.1	cON
Aug 06	07:20	558	Carmen	12.3	1.4	4.8	cON
Aug 12	05:41	509	Iolandia	11.8	1.4	4.9	nMB – sBC
Aug 14	05:33	429	Lotis	11.8	1.7	9.6	cMB – sSK
Aug 14	09:51	144	Vibilia	9.9	2.9	4.2	swBC – AB
Aug 16	07:25	407	Arachne	11.5	2.7	3.3	sSK – nMB
Aug 16	08:43	601	Nerthus	12.0	2.2	6.7	cSK – sBC
Aug 20	07:31	429	Schurer	5.6	11.0	0.9	SK only
Aug 21	08:42	144	Vibilia	10.1	2.7	4.5	swON
Aug 22	08:04	338	Budrosa	11.6	1.4	5.6	nMB – sBC
Aug 30	07:19	567	Eleutheria	10.3	3.7	6.7	sSK – cMB

Jul 26 Carmen: Actually, July 25 at 10:53 p.m. EDT. There will be no Moon for this event, but the occultation happens just at the end of astronomical twilight. At magnitude 8.4, the star should be fairly easy to hunt down, but it's a good idea to practice finding the star and working out a viable star-hop a few nights beforehand. You won't have much time for searching "on the night." The 155-km-wide path runs from Sept-Îles, Québec to Goderich, Ontario, just a bit north of the Philomela path a month earlier.

Aug 6 Carmen: Ontarians will enjoy Carmen's reprise, this time passing from Mattawa to the Bruce Peninsula, visiting North Bay and Parry Sound along the way. But the star is much fainter and the Moon is only 32° away and 87% sunlit. It will be a challenge.

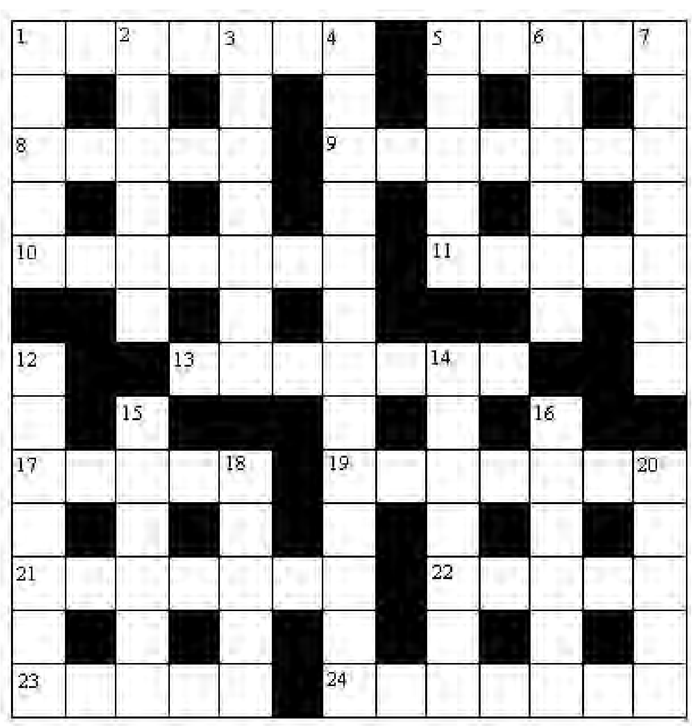
Aug 20 Schurer: Saskatchewanians have this one all to themselves. At magnitude 5.6, this is the brightest target star on the list, which means that binoculars are sufficient for timing this occultation. The degree of confidence in the predictions is very low, however, so I strongly suggest checking the above Web sites as the event draws near. The 26-kilometre-wide path could shift significantly, but for now it is predicted to pass between Moose Jaw and Regina, east of Saskatoon and east of Prince Albert.

So there you have it: a good selection of occultations that should keep us busy all summer from Québec to British Columbia. Curiously, there are no predicted events for Atlantic Canada this summer. Sorry about that! I'll see what we can arrange for you in the fall.

Guy Nason, Murphy's chronicler from the Toronto Centre, tries to find all sorts of ways to thwart the "Lawgiver of all that can go wrong." He has an eclectic choice of music.

Astrocryptic

by Curt Nason, Moncton Centre



ACROSS

1. Stellar sister comes back in strategy attempt (7)
5. Observatories arrayed across Colorado mesas (5)
8. Lunar valley drilled between dawn and dusk (5)
9. Lamplighter leads eagle to a California lakebed for meteorites (7)
10. Seniors pore into law of sunspot drift (7)
11. Jupiter's titanic nemesis loses its tail in feverish prefix (5)
13. His galaxy group oddly has pent energy released (7)
17. Bayer at Moon from uranium plus mixture (5)
19. Former Councilor-in-Training leads magazine head like auroral electrons (7)
21. One returns after aluminum found in California by bullish sister (7)
22. The last Greek to circle a million (5)
23. Misshapen bone I saw as an asteroid (5)
24. Choose right ascension for 17 Tau (7)

DOWN

1. Sounds like a stellar bull ring (5)
2. Scream in pain from Sun-like dwarf (6)
3. Alien surrounds the French men with oxygen or iron (7)
4. Heavenly parents turned one pallasite (5 & 7)
5. It follows a tailless duck but leads from our motto (5)
6. She stars in summer opener, appearing all winter (6)
7. Steer wildly around a double in Ophiuchus heading to a star in Taurus (7)
12. Fish eater glowing off east coast of North America (7)
14. Badly clone a Y chromosome to make a sister (7)
15. Sun god landed on the Moon (6)
16. The road circles below Tycho (6)
18. Sound system rounded off to the nearest cubic metre (5)
20. Gary's state drops in on Orion's mournful slayer (5)

Dr. Victoria Kaspi

by Philip Mozel, Toronto Centre (phil.mozel@sympatico.ca)

In 1967 Jocelyn Bell was part of a team using a radio telescope to hunt quasars. She discovered a repeating signal from space whose beat was so regular that some thought the source might be artificial. The somewhat irreverent nickname "LGM," or "Little Green Men," was quickly applied.

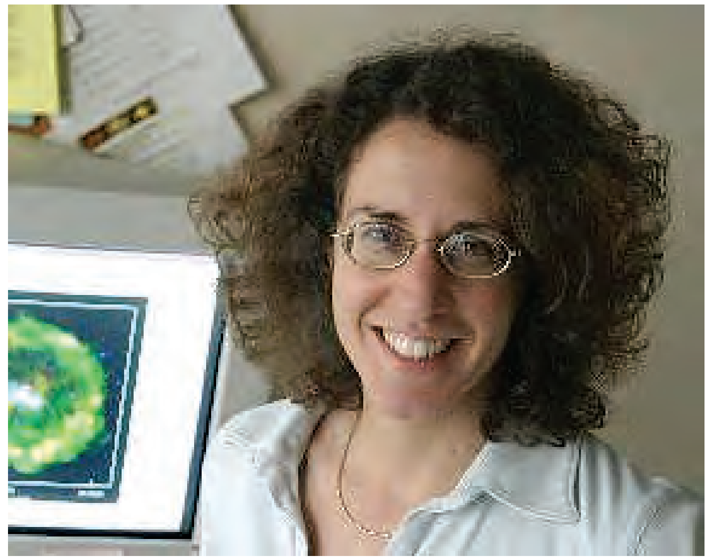
An explanation for the LGMs was forthcoming relatively quickly — they were rapidly spinning neutron stars, or *pulsars,* the collapsed cores of giant stars. But the actual details of how these objects work, in their various incarnations, continue to occupy the research time of scientists such as Dr. Victoria Kaspi of McGill University.

Dr. Kaspi is intrigued by neutron stars — all aspects of neutron stars. Her *curriculum vitae* lists timing, high-precision timing, searching, birth properties, evolution, supernova-remnant associations, pulsar-wind nebulae, binary dynamics, binary evolution, and high-energy properties (X-ray, gamma-ray) as particular areas of interest. That seems to about cover it! One might say she comes by this interest honestly, having been born just one month before Jocelyn Bell's discovery.

It is neutron stars that allow us to explain objects like LGMs. As a neutron star spins rapidly, energetic beams of radiation are squirted from the magnetic poles. If such beams sweep over Earth, we detect pulses. In essence, pulsars are like interstellar lighthouses. No little green men are required.

One always deals in superlatives when discussing pulsars. Take their rotation, for instance. They can spin at incredible speeds, and the team of which Dr. Kaspi is a member has found the current neutron-star record holder for spin rate: 716 rotations per second! That's fast, but not fast enough for Dr. Kaspi. She needs to find the maximum rate possible in order to constrain theoretical models of neutron-star structure. How fast might this be? Dr. Kaspi feels that 2000 times per second "is currently within the realm of possibility" and, if found, will rule out most models. Beyond this speed a neutron star is likely to break up. (In a similar way there is a maximum observed spin rate for asteroids, beyond which they apparently fly apart. This provides clues about their composition and structure.)

There are a number of impediments to finding such rapidly rotating pulsars, such as the fact that the majority of rapidly rotating (*i.e.* more than 100 rotations per second) neutron stars tend to be found in binary systems. These may undergo eclipses, and if you are not looking at the right time, you will not see anything. For example, the 716× rotator is in eclipse 40 percent of the time.



Dr. Victoria Kaspi

Rapidly spinning neutron stars are such strange objects that when the term "anomalous" is applied, it should come as no great surprise. Hence the classification of *rare anomalous X-ray pulsars* (AXPs). Rotational energy and accretion of material from a binary companion have both been ruled out as energy sources for AXP X-rays. However, Dr. Kaspi's group demonstrated that some are *magnetars:* neutron stars with the strongest magnetic fields ever measured. Instabilities in their magnetic fields cause "star quakes," with an attendant release of x-rays and gamma rays that may be millions of times brighter than any other known repeating source of energetic outbursts. Dr. Kaspi's research group has proven that the AXPs and the so-called *soft gamma ray repeaters* share a common nature.

Most of us have no experience with magnetic fields beyond those that hold pieces of paper to the refrigerator door. However, Dr. Kaspi explains, the magnetic field of a magnetar at the Moon's distance would wipe clean the magnetic strip of all the credit cards on Earth. The magnetic effects would also likely disrupt the electrical system of our bodies — which would meanwhile be getting fried by the magnetar's X-rays. Clearly, these are objects to be studied from a respectful distance!

Such studies require specialized equipment. Dr. Kaspi uses radio telescopes such as those at Greenbank, West Virginia (home to the world's largest, fully-steerable radio telescope) and the giant 305-metre dish at Arecibo, Puerto Rico. She also uses space-based instruments such as the *Rossi X-Ray Timing Explorer* satellite and the *Chandra X-ray Observatory*.

Astronomers constantly seek to push back the frontiers of our vision by building bigger, better, and more sensitive devices. Dr. Kaspi has recently served on the steering committee for one such instrument, the *Square Kilometre Array* (SKA). This radio telescope will consist of a million square metres of collecting area spread over as many as several hundred individual stations thousands of kilometres apart. It will conduct studies in five major areas: searching for extrasolar terrestrial planets; the origin and evolution of large-scale (*i.e.* cosmic) magnetic fields; galaxy evolution and dark energy; formation of the first galaxies; and, close to Dr. Kaspi's heart, pulsars.

Many pulsars are expected to be partnered with other neutron stars or even black holes in binary systems and, when discovered, will allow sensitive tests of Einstein's theory of general relativity by observations of their behaviour in the intense gravitational field of such a system. Canadian scientists have, according to Dr. Kaspi, a "clever and innovative" design for the SKA and so may have a great deal of input with our international partners about how this instrument is built.

As Dr. Kaspi goes about her business of looking for new pulsars, she works as part of a team that includes…the Borg! However, she need not worry about aliens with a bad attitude since the Borg she works with is a supercomputer consisting of 52 nodes of processors. It is one of the world's most powerful supercomputers dedicated to "assimilating" the huge amounts of radio-telescope data acquired in pulsar research.

As you might guess, Dr. Kaspi is a big science-fiction fan, particularly of *Star Trek*. She also enjoyed the movie *Contact* because, while research is not conducted quite the way it is depicted in the movie, science *is* presented in a positive light. On the down side, her entire research career was quickly dismissed when an early signal in the film turned out not to be artificial, but "only" from a pulsar!

Another plus in the film is that it depicts a woman doing science. The lack of women in science is an issue of some concern to Dr. Kaspi (as indeed it has been to other scientists interviewed for this column). In her particular research group, the majority are female, a rare occurrence, but Dr. Kaspi is on a committee working to recruit more women into astronomy.

Dr. Kaspi was born in Austin, Texas but grew up in Montreal from the age of seven. She then lived in the United States for the next decade, eventually returning to Canada because the research environment here was on the upswing. She draws a distinction between the way research is conducted here versus south of the border. For example, in seeking funding in this country, one is asked how the research will benefit Canada and how it will make the country greater and better recognized internationally. There is a feeling of "We are in this together." In the U.S. there is more competition with colleagues, and grant proposals must be written every year. In Canada, a scientist may be funded for several years, thereby leaving more time for actual research.

Dr. Kaspi began as a physics major and worked in experimental particle physics for three summers, finding the experience fascinating. While at Princeton she and other students were encouraged to do some work in areas other than their primary interest, so she took on an astronomy project. The rest, as they say, is history. Dr. Kaspi is now the Canada Research Chair in Observational Astrophysics at McGill University.

Like many busy people today, Dr. Kaspi is an expert at multitasking. The pace of her career is frenetic, and she has a family with two children. When asked where she gets all the time she admits that "It is very hard. I get little sleep and drink lots of coffee!" Life is mainly divided between work and family. Fortunately for astronomy, Dr. Kaspi seems to possess the energy of the very pulsars she studies!

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

WEB ACCESS TO THE 2006 ISSUES OF THE *JRASC*

The 2006 issues of the *Journal* can be accessed from the RASC Web site at `www.rasc.ca/currentjrasc` (userid="jrasc"; password="pelican"). Issues are posted immediately after the final production version is complete.

A CALL FOR SUBMISSIONS

Anyone interested in submitting their astronomical drawings to the Editor-in-Chief for possible use in the RASC Journal should send them to `editor@rasc.ca`

Film & Pixel

The Cocoon Nebula

The Cocoon Nebula (IC 5146) is both an emission and reflection nebula. IC 5146 is powered by the hot and luminous B0 star at the centre of the image, whose surface temperature of 30,000 to 35,000 degrees allows it to generate the ultraviolet flux needed to ionize the surrounding gases. The central star began to shine only 100,000 years ago. This image was captured by Serge Théberge on August 6, 2005 using an 8-inch f/4.6 Newtonian, a Paracorr corrector, and a Vixen R200SS mounting. The camera was an SBIG ST-10XME. The image is composed from six ten-minute exposures for each of the RGB filters.

NGC 3953

NGC 3953, a neighbour to M109, is a barred spiral galaxy lying at a distance of 46 million light years. It is slightly more inclined and has more tightly wound arms than its better-known companion. In 2001 astronomers discovered a supernova in this galaxy. NGC 3953 was captured by Albert Saikaley using a Celestron 11 @ f/7, an ST-10XME camera, and an SBIG A07 guider. The exposures were: 110 minutes in L, 40 minutes in R, 40 minutes in G, and 80 minutes in B.

Across the RASC
du nouveau dans les Centres

An Invitation to the RASC 2007 General Assembly June 28 to July 1, 2007, Calgary, Alberta

On behalf of the organizing committee for the 2007 General Assembly of the Royal Astronomical Society of Canada, I would like to invite you to Calgary next year — June 28 to July 1 — to attend a unique "Astronomy Roundup." The 2007 GA is special because our colleagues from the American Association of Variable Star Observers (AAVSO) and the Association of Lunar and Planetary Observers (ALPO) will be joining us for a joint conference.

We have many interesting and enjoyable events planned for this GA, which will be held on the campus of the University of Calgary.

The events include workshops hosted by the RASC, AAVSO, and ALPO; technical paper and poster sessions; a tradeshow; and a tour to the University of Calgary's Rothney Astrophysical Observatory, home to one of Canada's three 1.8-m class telescopes. For those who wish to extend their stay, two fascinating field trips are scheduled, and southern Alberta offers many vacation options.

The GA begins on Thursday, June 28, a day devoted to an RASC Council Meeting and local tours of Calgary for those spouses, partners, and early-arriving delegates who do not need to attend the Council Meeting. Several half-day workshops will occur on Friday, June 29. After a day of learning and sharing, our official welcome will occur during the Icebreaker and Murphy slideshow. The technical paper sessions will begin on Friday afternoon and continue on Saturday, June 30 and Sunday, July 1. The poster sessions and tradeshow will be available every day. The actual General Assembly of the RASC membership is scheduled for Sunday morning and the wrap-up banquet for Sunday evening. You can get up-to-date information at the GA Web site: `www.rasc.ca/ga2007`.

For those who can linger after the GA, two day-long, guided field trips are scheduled for July 2 and 3. On one, you will travel to the Alberta Badlands to examine the famous K/T boundary and then explore the world-renowned Royal Tyrrell Museum. The second guided tour takes you to the heart of the Rocky Mountains where you will study periglacial deposits that are similar to parts of Mars.

If the 2007 GA is the beginning of your vacation, consider that the Calgary Stampede begins a few days after the GA on July 6. While most people think about heading west to the Rockies, I'd encourage you to consider some really different choices. Just a few hours south of Calgary is Head-Smashed-In Buffalo Jump, a UNESCO World Heritage Site, where you can step back five-thousand years into our prehistory — plan ahead and you could even camp in a traditional tepee! Or head east to the Cypress Hills Interprovincial Park and Dark-Sky Preserve — the largest and darkest dark-sky preserve in Canada.

Plan to come to Calgary for the 2007 Astronomy Roundup. Attending the RASC GA is an excellent way to learn about and keep up with the many activities and accomplishments of your friends and the Society. There is something for everyone, whether you are a regular attendee or this is your first GA, and it will be especially enjoyable to share this experience with our colleagues from the AAVSO and ALPO.

Bob King
Calgary Centre
Chairman, 2007 GA Organizing Committee

An Invitation: The 2006 Saskatchewan Summer Star Party

The Regina and Saskatoon Centres of the RASC wish to invite all of our fellow astronomers to attend the Saskatchewan Summer Star Party (SSSP) this coming August 24 to 27 at the Cypress Hills Inter-provincial Park, 32 kilometres south of Maple Creek, Saskatchewan. Come out and share your love of astronomy with 250 of your closest friends. This year marks the 10th anniversary of this popular event, held under some of Canada's clearest skies in Canada's largest Dark-Sky Preserve.

The evening observing sessions Thursday, Friday, and Saturday nights at the Meadows Campground are complemented by the daytime activities. On Thursday, August 24 we are holding the ever-popular Wienie Roast. A new event this year is the *Digital SLR Astrophotography Workshop* led by Alan Dyer. This extra-cost event is scheduled for the Friday afternoon. Friday night features an informal short presentations session (please participate — we will have video, slide, and overhead projectors available). A swap table will be set up Saturday morning in the Meadows for those who would like to buy or sell equipment or accessories. Saturday afternoon features formal presentations.

The keynote Lucien Kemble Memorial Lecture will be given by our special guest Scott Young, President of the RASC, whose presentation is entitled *Pluto vs. the Ice Dwarves: Conflict at the Ragged Edge of the Solar System.* After the evening banquet, we will move up to the Meadows for a Walk-Around Social, followed by more observing. We also have door prizes, astronomy books, and posters for sale, an astrophotography contest, shirts, pins, and more! All talks take place in air-conditioned comfort in the conference room at the Cypress Park Resort Inn.

If you register before August 1, costs are $20 single, $30 couple, and $40 family. If you register after this date, costs are $30 single, $40 couple, and $50 family. The *Astrophotography Workshop* is $30 per person; attendance is limited and must be registered for in advance.

For more information contact

Bill Hydomako, SSSP Registrar
E-mail: wm.hydomako@sasktel.net
Tel: (306) 384-4781

SSSP Web site: www.usask.ca\psychology\sarty\rasc\starparty.html.

Reviews of Publications
Critiques d'ouvrages

England's Leonardo: Robert Hooke and the Seventeenth-Century Scientific Revolution, by Allan Chapman, pages 330 + xv, 16 cm × 24 cm, Institute of Physics Publishing Ltd., 2005. Price £24.99 or $39.99 US hardcover (ISBN p-7503-0987-3).

Most science students become aware of Robert Hooke very early in their studies, be it in physics, astronomy, biology, physiology, or even geology. Some of you may have been introduced to Hooke through the episode of *The Inventors Special*, "Isaac Newton: A Tale of Two Isaacs" or the BBC documentary *"Robert Hooke: Victim Of Genius"* viewed during the tercentenary of Hooke's death in 2003. Probably what stuck most strongly in your memory was Hooke's difficult personality and immoderate desire for recognition and for priority of ideas — traits that resulted in many friends and colleagues who later turned on him. However, those programmes also demonstrated his ingenuity, his commitment to experimental science, and the impact that he had on seventeenth-century science.

My first understanding of Hooke's impact relates to his attempts and claims to have observed stellar parallax — the only direct means to prove the Copernican model of the Solar System. In researching that episode, I began to understand the way Hooke thought and reacted to his fellow scientists, most of whom were also members of the Royal Society of London, *e.g.* such luminaries as Newton, Flamsteed, Wren, Boyle, Huygens, and G.D. Cassini. Those readings led me to his diaries, some of which were published in 1935 by H.W. Robinson and W. Adams, and by R.T. Gunter. Those works covered Hooke's most productive years from the 1670s to 1690s. His diaries are the scientific equivalent of the famous Samuel Pepys' diaries. Pepys was, in fact, a contemporary and later friend of Hooke. Hooke's diaries show a man obsessed with getting his due, but also one who would submit himself to virtually any substance to discover the cure for his many physical complaints, a substance which he also hoped would prolong his life. Margaret Espinasse's *Robert Hooke* (1956) was the first modern biography and is still probably the most widely read work on him. She based her analysis on the published diaries. A more recent contribution to Hooke scholarship, edited by S. Shapin and S. Schaffer, *Robert Hooke: New Studies* (1989), also brings new material to light. Still, despite the man's fame and achievements, no portrait of Hooke survives, although he noted that he sat for a portrait artist in 1674. Thus we are left to such books as Chapman's *England's Leonardo* to build a mental image of that extraordinary man, his intellect, and his impact, but here we also find recently commissioned "portraits" based on contemporary descriptions.

The breadth of Robert Hooke's interests and scientific endeavours — astronomy, geology, medicine, horology, and even architecture — is well illustrated by Chapman. It is that breadth that makes Hooke stand out from his illustrious contemporaries, who generally excelled in specific disciplines. Chapman follows Hooke's position as Curator of Experiments, beginning in 1662, to the Royal Society of London, a position that fed his broad interests and provided an outlet for his discoveries in the three or four experiments he demonstrated weekly. Hooke was made a Fellow of the Society in 1663 and Professor of Geometry at Gresham College in 1665, the same year he published his most influential publication, *Micrographia,* which included many outstanding illustrations of insects and cells completed by Hooke using a microscope of his own design. In 1677 he succeeded to the position of Secretary to the RSL, and he held both positions until he relinquished the Secretary's post in 1683. In those positions he had weekly, if not almost daily, contact with England's scientific elite. Hooke therefore had an almost unique view of the scientific problems being researched in his day, as well as the reaction of the scientific community to disasters like the Great Plague and Great Fire of London. On the non-scientific side, the chapter titled "Friends, Mistresses, Religion and Politics: Hooke's Inner World" provides a look into the personal associations and social life of Hooke and his times, some of which Chapman describes as "unsavoury."

Overall, *England's Leonardo* is well organized and edited, and thoroughly referenced. There are 33 "plates," though plate is perhaps a misnomer. The illustrations are black and white reproductions of modest size, with most having appeared in a variety of books, including some of Chapman's, in recent years. However, Chapman has included ones illustrating many of Hooke's innovations, and examples from *Micrographia.*

I would recommend reading the diaries published in 1935 prior to delving into Chapman's *England's Leonardo.* Building a first-hand image of Hooke before reading other material will serve you well and will allow you to judge the books that have since appeared. The various authors provide valuable insights, but, to my mind, the scientist's own words and cryptic notes best provide a sound basis on which to build an understanding of his complex character. Hooke is one of the most remarkable scientists in one of the most remarkable periods of scientific achievement — one not repeated in many respects, especially astronomy, until the late 20th century. If you find 17th-century science interesting, learning about it though the eyes and mind of Robert Hooke as interpreted by Allan Chapman will make it even more interesting. Chapman's book provides a competent and interesting synthesis of 50 years of analysis of Robert Hooke scholarship published since Espinasse's biography.

Randall Brooks

Randall Brooks is Acting Director of the Collection and Research Division, Canada Science and Technology Museum. He, like Chapman, has researched the precision of historic astronomical instruments of the 17th to 19th centuries.

Sun Observer's Guide, by Pam Spence, pages 159, 12.5 cm × 20 cm, Firefly Books, 2004. Price $14.95 paperback (ISBN 1-55297-941-5).

This is an attractive, well-illustrated, introductory, but reasonably comprehensive guide to observing the Sun. But don't rush out to buy it before reading the rest of this review! Its size, paperback format, and waterproof cover make it easy to carry and use.

Before examining a book I check to see who the author is, but all the cover tells me about Pam Spence is that she is "an experienced astronomer." A few hints scattered through the book indicate that she probably lives in the U.K. (*Pam Spence is the former editor of* Astronomy Now, *a British magazine similar to* Astronomy – *ed.*)

The book has nine chapters. The first five begin with a description of the Sun, followed by a discussion of instruments for the observer, tips on how to observe the Sun, and advice on making and analyzing observations. Chapter six addresses solar eclipses, and chapter seven is concerned with photography of the Sun. The last two chapters describe various aspects of the Sun-Earth interaction, followed by solar astronomy as done by professionals using ground-based observatories and satellites.

Despite my favourable initial impression of the book, while making notes for this review I became so exasperated that I wrote, "How can a book with so many errors see the light of day?" A review is not the place to list all errors, but I have selected several to illustrate the problems with the book and why I became exasperated (my comments are in parentheses):

p. 6: "The Sun is the ultimate source of all light and energy on the Earth." (If that were true, astronomy would be restricted to the Solar System, and nuclear power would not be possible.)

p. 22: "a series of lines known as the Balmer series, which are found in the red part of the spectrum." (Only one line of the series occurs in the red.)

p. 26: "Another problem with reflectors is that the secondary mirror is at the focal point, so can become very hot." (The secondary mirror of a reflecting telescope is not at the focal point.)

p. 27: "Once one axis of an equatorially mounted telescope is lined up with the celestial pole, the other axis allows the telescope to move in the direction that directly follows the movement of celestial objects." (It is the axis aligned with the pole that provides this motion.)

p. 31: "[Fraunhofer] lines are produced when electrons absorb energy when changing to lower energy levels." ("lower" should be "higher.")

p. 49: (To determine the orientation of a projected solar image, the technique of noting the track of a sunspot as the image drifts across the observing screen determines the orientation of the sky's RA/DEC grid. It does not determine "the inclination of the Sun's axis of rotation.")

p. 51: "At noon the Sun is overhead at the maximum altitude it will reach that day, with the solar equator horizontal." (At solar noon, the solar equator can be tipped by as much as 26° to the horizontal. Indeed, on several pages the author does not clearly distinguish the orientation of the solar equator from that of a line of constant declination, or the north point on the solar disk from the north pole of the Sun's axis of rotation. I found such vagueness frustrating. I can imagine how confused it would make a reader who was trying to understand those pages.)

p. 58: "In June and December the Sun's axis is perpendicular to the Earth's orbital plane." (The Sun's axis is always at 7 degrees to that plane.)

p. 60: "B_0 varies from −7.2° to +7.2°, a negative value indicating that the Sun is tipped away from us, causing the lines of latitude to curve downward slightly and the heliographic latitude of the center of the disk to move up above the visual center of the disk." (In this instance it is the north pole of the Sun that is tipped away from us, causing the lines of latitude to curve upward. Also, the heliographic latitude of the centre of the disk is precisely that; it does not "move" in the fashion stated.)

p. 76: (The equation given for the area of a sunspot is incorrect: the term r_0 should be squared. It is not merely a typographical slip, for the author proceeds to use the incorrect equation in four examples, and in each example she also makes a numerical error!)

p. 87: "Occasionally Sun, Earth and Moon will lie in the same plane and an eclipse will take place." (The Sun, Earth, and Moon always lie in the same plane because three points define a plane.)

p. 88 and 151: "The line of nodes completes a revolution in 6585.32 days. This period is known as the saros." (This revolution period is about 6797 days and is not equal to the Saros.)

pp. 111, 113, 114: (The author refers to telephoto lenses as being "more powerful" and having greater "magnification." A better description would use the terms focal length and image scale.)

p. 120: (Regarding the four-minute difference between the sidereal day and the solar day, the author states), "This is the reason for adding a day to the year every 4 years." (The four-minute difference has nothing to do with leap years.)

p. 126: "E. Walter Maunder examined data on the carbon-14 content of tree rings…" (The isotope carbon-14 was discovered in 1940, twelve years after Maunder's death.)

p. 138: "… the inner Lagrangian point — a point between the Sun and the Earth where the gravitational attractions of the two bodies effectively cancel out." (Cancellation does not occur at that point.)

p. 152: "Total eclipse: An eclipse in which one body is totally covered by the shadow of another." (In the case of a solar eclipse on Earth, that never happens.)

Among other problems are several statements about electrons orbiting around the atomic nucleus (a model that was abandoned 80 years ago); use of the American rather than the international spelling for the SI unit of length, the metre; no mention of the pinhole-mirror technique for producing a solar image (a much more convenient and versatile method than a conventional pinhole); despite the 2004 publication date, no mention of digital cameras in the chapter on photography; a somewhat repetitive, disorganized, and often incorrect description of how to determine the orientation of the Sun in the sky.

The chapters with the fewest errors are as follows: 3 (How to Observe the Sun), 6 (Solar Eclipses), and 9 (Professional Solar Astronomy). That is not surprising since the author has observed three solar eclipses (p. 115), and she mentions "working professionally on data from the *Yohkoh* satellite" (p. 61). However, she should have had a competent person read the entire manuscript before sending it off to the publisher. With more care and advice, the *Sun Observer's Guide* could have been a much better book.

Roy Bishop

Roy Bishop is a Past-President of the RASC. He was Editor of the Society's Observer's Handbook *for 19 years.*

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Observer's Calendar — 2006

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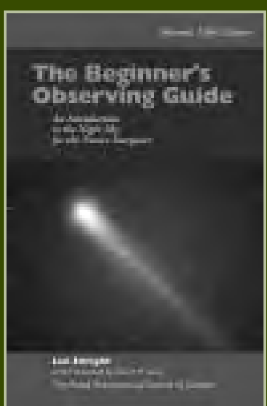

The Beginner's Observing Guide

Extensively revised and now in its fifth edition, The Beginner's Observing Guide is for a variety of observers, from the beginner with no experience to the intermediate who would appreciate the clear, helpful guidance here available on an expanded variety of topics: constellations, bright stars, the motions of the heavens, lunar features, the aurora, and the zodiacal light. New sections include: lunar and planetary data through 2010, variable-star observing, telescope information, beginning astrophotography, a non-technical glossary of astronomical terms, and directions for building a properly scaled model of the solar system.

Written by astronomy author and educator, Leo Enright; 200 pages, 6 colour star maps, 16 photographs, otabinding.

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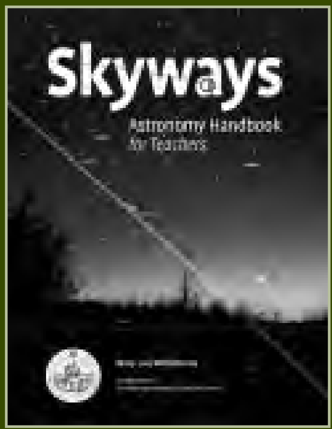

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