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Antares Palette

The Best of Monochrome.

Drawings, images in black and white, or narrow-band photography.

For the last several months, Ron Brecher has been shooting faint objects from the Sharpless Catalog. This Hα image shows the very interesting Sh2-86 (aka NGC 6820), a large emission nebula in Vulpecula. The roundish central nebula is about the size of the full Moon on the sky. The long, dark finger in the middle of the nebula is similar to that in the Eagle Nebula, which is sometimes called "The Pillars of Creation." Ron acquired this image under full Moon conditions using an SBIG STL-11000 camera on a 10-inch ASA Newtonian reflector at ƒ/6.8. Exposure was 42×10m + 3×20m Hα (a total of 8 hr).

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Front Cover —"Antares Palette" Steve Holmes captured this deep-sky image of the region surrounding Antares using an unmodified Canon 5D Mark II and a 200-mm ƒ/2.8 lens. Exposure was 32×5 minutes at ISO 1250 from the Kitchener-Waterloo Centre's observing site near Listowel, Ontario. To the right of the red emission nebula surrounding Antares is the globular cluster Messier 4. Several blue reflection nebulae and dark dust lanes complete the scene.

President's Corner

by James Edgar, Regina Centre
(james@jamesedgar.ca)

Over the three-day weekend of October 3, 4, & 5, the Board of Directors met in Toronto for the first time as a complete body (see Figure 1). One of our first mandates was to "Have fun!" and I believe that target was met in numerous ways. It takes time to gel into a cohesive group—after 22 hours of actual meetings in those three days, believe me, we gelled. There was no topic too big or too small to discuss, and our agenda covered them all, or so it seemed! We did have fun— just ask the Toronto Centre members we met at the David Dunlap Observatory on Saturday night.

We discussed items such as "How can we help our Centres provide outreach activities?" and "Is our Strategic Plan really what we want to focus on?" We asked ourselves "What will we be remembered for ten years from now? What is our legacy?" We scheduled at least one visit by a Board member to each Centre throughout the coming months. The subject of our finances (an important topic!) gave us much room for cogitation—Should we increase our spending? Should we increase our fees? Is it time to search for new, larger premises? Publish more? Pay for online publications? Find new ways to recognize our very important volunteers? What can we do to help our smaller Centres? Plus, many more…. We have several different avenues and byways to navigate before we get to where we want to go, but it's not necessarily the destination that is the journey—it has been said "Success is a journey, not a destination."

At our retreat, I charged our Board with these words, "Be an agent of change, for progress can only come with change." And I encourage all of our members to be agents of change—if it's not working, fix it! But, first and foremost, have fun!

Clear skies!

James ✶

Board of Directors 2014

Figure 1 — The Society Board of Directors at the fall retreat in Toronto. L-R: Dr. Chris Gainor, Randy Attwood, Craig Levine, Dr. Randy Boddam, Dr. Paul Schumacher, Robyn Foret. Seated: Dr. Karen Finstad, James Edgar, Colin Haig, Denis Grey. Photo: Renata Koziol

Figure 2 — The Society Office staff (and yours truly): Renata Koziol, Office Administrator; James Edgar, President; Julia Neeser, Marketing Coordinator; (kneeling at rear) Randy Attwood, Executive Director. Photo: Denis Grey

News Notes / En manchettes

Compiled by Andrew I. Oakes and Jay Anderson

Figure 2 — The emission of organic compounds from Comets ISON and Lemmon as determined by ALMA in August. Image: B. Saxton (NRAO/AUI/ NSF); NASA/ESA Hubble; M. Cordiner, NASA, et al.

Atacama Large Millimetre Array (ALMA) extends its reach

ALMA, the world's most powerful telescope, has successfully tested an antenna configuration in its most extended reach, producing the longest baseline yet of the still-expanding array of millimetre-wave dishes. The latest antenna position is seven kilometres from its nearest neighbour, four times longer than the previous arrangement. Over the next two months, baselines as long as 11 km will be established and tested.

According to Catherine Vlahakis, Program Scientist for the ALMA Long Baseline Campaign, "…successfully powering up an antenna for the first time over these long distances marks an important technical step towards increasing ALMA's ability to see objects in the Universe in fine detail." She adds that "this is the first step in a process of moving several antennas out to these longer distances. Once the rest of the antennas are also in place, we will be able to begin test observations of astronomical objects at higher angular resolution, and therefore in more exquisite detail, than ALMA has yet achieved." Eventually, ALMA will extend over reconfigurable baselines up to 18 km in length, giving a resolution of 0.005 arcseconds, some 10 times better than *Hubble*.

Even in its current arrangement, ALMA is bringing important new insights to the universe of astronomy. In recent weeks, researchers have detected the faint signal of two new organic chemicals near the centre of our galaxy. One of these organic compounds is unique in that it has a branched instead of a linear structure, the first time that this type of molecule has been found.

In another organic-molecule detection, ALMA was able to map the presence of HCN (hydrogen cyanide), HNC (hydrogen isocyanide), and formaldehyde (H_2CO) in Comets ISON and Lemmon. The millimetre-wave array was able to not only identify the molecules, but also determine their velocities relative to the comet nuclei and thus map the 3-D distribution of the chemicals. It seems that HCN is emitted radially, but HNC emerges with jets. HNC and H_2CO form within the coma, possibly from the breakdown of larger organic molecules.

ALMA is a partnership between the European Southern Observatory, the U.S. National Science Foundation, the National Research Council of Canada, the National Science Council of Taiwan, and the National Institutes of Natural Sciences (NINS) of Japan in cooperation with the Academia Sinica (AS) in Taiwan.

Figure 1 — Four ALMA antennas on the Chajnantor plain in Chile. ESO/José Francisco Salgado (josefrancisco.org)
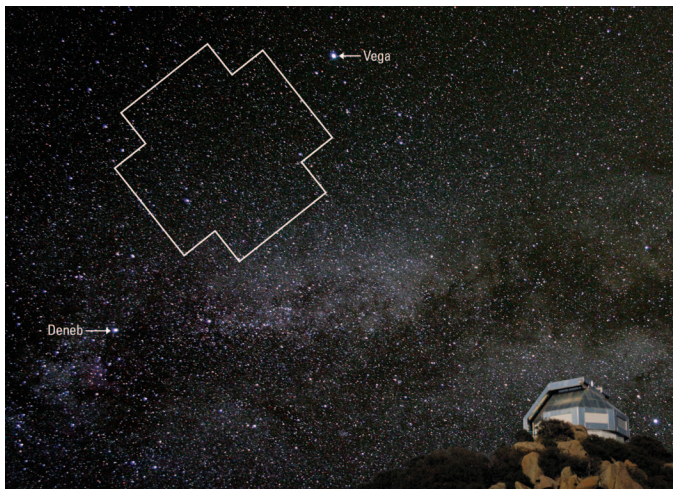
Figure 3 — The Kepler field of view rising over the WIYN telescope on Kitt Peak. Image: J. Glaspey & P. Marenfeld.

Half of exoplanets are in a binary-star system

About half the stars in the sky seem to be part of a binary- or other multiple-star system. Is this relationship also true of stars that harbour exoplanets in the *Kepler* dataset?

A team led by Dr. Elliott Horch of Southern Connecticut State University has shown that exoplanets are just as likely to be part of a binary system as the larger part of the stellar universe—about 40 to 50 percent. The team's study made use of the high spatial resolution of the WIYN telescope on Kitt Peak in Arizona and the Gemini North telescope on Mauna Kea in Hawaii. By using speckle interferometry, a process very similar to that used by amateur astronomers to image planets with Webcams, the science team was able to obtain a resolution of candidate stars better than that of the *Hubble Space Telescope*—about 0.05 arcseconds.

The NOAO press release notes that "For the majority of the *Kepler* stars, this means companion stars with a true separation of a few to about 100 times the Sun-Earth distance. By noting the occurrence rate of these true binary companion stars, the discoveries can be extended to show that half of the stars that host exoplanets are probably binaries."

Care had to be taken to ensure that the binary companion around the planet host star was not an unrelated foreground or background star. The research team relied on model simulations that used statistical properties of the binary stars and line-of-sight companions to eliminate erroneous binary identifications. A consequence of the finding that half of the host systems are binary is that now about half of the planets detected by *Kepler* cannot be assigned to a specific star.

The work has been accepted for publication in the *Astrophysical Journal*. The WIYN telescope is operated by the WIYN Consortium, which consists of the University of Wisconsin,

Indiana University, and the National Optical Astronomy Observatory (NOAO). Kitt Peak National Observatory is a division of NOAO, which is operated by the Association of Universities for Research in Astronomy Inc. under a cooperative agreement with the National Science Foundation.

Messier 54—more than it seems

A new image of M54 from the VLT Survey Telescope at the European Space Agency`s Paranal Observatory in Chile shows what appears to be a normal-looking globular cluster. However, M54 is not a part of the Milky Way's collection of 150 globulars, but instead belongs to the Sagittarius Dwarf Galaxy, which lies at a distance of about 90,000 light-years and is the closest external galaxy to our own. M54 apparently resides at the core of the dwarf system, which itself is composed primarily of four globular clusters.

Figure 4 — A wide-area view of M54 and the surrounding Milky Way stars. Image: ESA

Recent observations at the VLT telescope have been used to try to solve the Universe's lithium problem. When the Universe was created, a small amount of lithium formed along with the hydrogen and helium that were the main chemical constituents created in the Big Bang. Models of the early Universe and of stellar evolution can calculate how much lithium was formed and how much should be visible in old stars, but observations show that a large amount of the lithium is missing. Until recently, only stars in the Milky Way could be assessed for their lithium content, but the VLT has allowed this survey to be extended to the Sagittarius Dwarf. Alas, the results show that the amount of lithium in old stars in the Milky Way's companion is very similar to that in our galaxy, and so the problem remains. It appears that lithium was destroyed in the earliest stars, or has been gradually destroyed along the way, but the mechanism is still a mystery.

Andrew Oakes is a Contributing Editor to the Journal who lives in Courtice, Ontario. ✶

Citizen Science on the Faroe Islands in Advance of an Eclipse

by Geoff Sims (geoffrey.sims@gmail.com)
& Kate Russo (umbraphillia@gmail.com)

Abstract

On 2015 March 20, a total solar eclipse will occur in the North Atlantic, with the Kingdom of Denmark's Faroe Islands and Norway's Svalbard archipelago (formerly Spitzbergen) being the only options for land-based observing. The region is known for wild, unpredictable, and often cloudy conditions, which potentially pose a serious threat for people hoping to view the spectacle.

We report on a citizen-science, weather-monitoring project, based in the Faroe Islands, which was conducted in March 2014—one year prior to the eclipse. The project aimed to promote awareness of the eclipse among the local communities, with the data collected providing a quantitative overview of typical weather conditions that may be expected in 2015. It also allows us to validate the usefulness of short-term weather forecasts, which may be used to increase the probability of observing the eclipse.

Introduction

A total solar eclipse is one of the most amazing natural sights that one can witness. During this precise alignment of the Earth, Moon, and Sun, those fortunate enough to be situated in the path of the Moon's umbral shadow will observe daylight turn to eerie twilight darkness for a brief, few minutes. The total solar eclipse of 2015 March 20 will be visible from a narrow path traversing the North Atlantic and ending at the geographic North Pole (see the *Observer's Handbook 2015*, p. 126). The region of visibility includes only two landmasses: the Faroe Islands, and Svalbard. The total eclipse visibility path is shown in Figure 1.

As those who have seen a total solar eclipse will attest, the experience of totality can be described as euphoric, not to mention addictive. The eerie daytime darkness and elusive glimpse of the Sun's outer atmosphere—the corona—typically leaves one desperate to repeat the experience. More often than not this results in the self-diagnosed condition of "umbraphillia"—an addiction to being in the path of the Moon's shadow—and a personal goal to experience every subsequent total solar eclipse in one's lifetime.
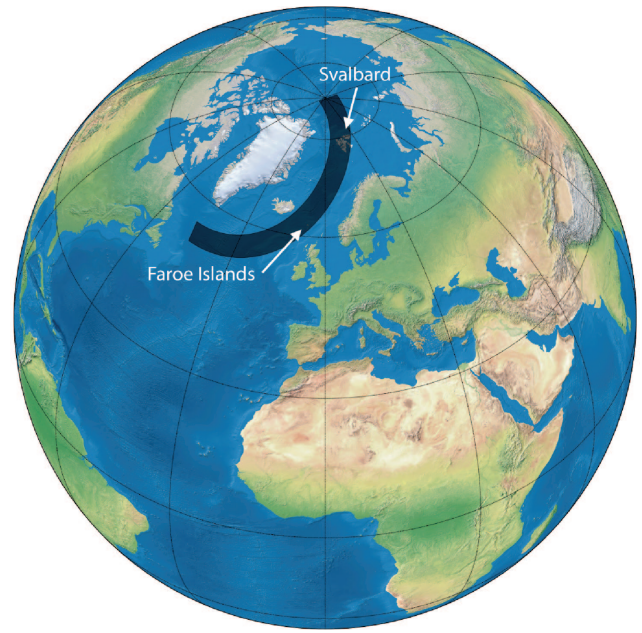
Figure 1 — Path of the total solar eclipse on 2015 March 20.

The Faroe Islands' large permanent population (~50,000 people), excellent infrastructure, and relative ease of access will likely tempt thousands of people from around the world to choose these islands as their preferred viewing location in March 2015. We travelled to the Faroe Islands in March 2014, one year before the eclipse, to share information about the impending event. We spoke with school, tourism, and government authorities, and advised them on how best to plan for this celestial event.

During this visit, we undertook a "citizen science" project to monitor cloud conditions across the islands with an emphasis on the impact clouds would have on potential eclipse viewing. The project had several aims: to involve the local community in eclipse preparations; to collate snapshot observational weather data from across the islands; and to determine the usefulness of short-term weather forecasts.

This paper presents the results of this project; this section introduced the eclipse that will occur in March 2015, and gave a background on our visit to the islands last March. The next section gives an overview of the expected weather across the eclipse path. This is then followed by a description of the weather project, with the results quantitatively analyzed in the final section.

Synoptic Situation

While it is currently possible to predict, with high precision, the paths of solar eclipses millennia in advance, there is one important factor that has the potential to prohibit the observation of eclipses, one that we cannot forecast with such accuracy: the weather. The North Atlantic is a cloudy and stormy place, no more so than in March, when it is subject to three major cloud-making influences: a humid, ice-free ocean

surface; a cold winter/spring atmosphere that saturates easily; and a location near the main track of low-pressure systems that leave the North American continent and venture across the North Atlantic and Barents and Greenland Seas. Both the Faroe Islands and Svalbard are impacted by the passage of these migrating depressions, though Svalbard less so than the Faroe Islands.

While the Faroe Islands have their wintery days, their more southerly location embeds them in the main circulation of the Gulf Stream, and temperatures are much warmer than in Svalbard. The islands have an alpine-like climate characterized by wind, cloud, and moderate summer and winter temperatures. Because they are more exposed to the main track of North Atlantic lows, the weather is highly changeable from day to day, and strong winds with heavy rain can arrive at any time of the year.

Locally, weather on both the Faroe Islands and Svalbard is strongly influenced by the terrain, as there is a substantial up-and-down character to the landscape in both locations. In particular, the lee side of a mountain or high hill tends to have a little less cloud than upwind sites.

Climate statistics show that "clear" and "overcast" skies are rare, that there is a modest frequency of "few" and "scattered" clouds, and there is a high frequency of "broken" cloudiness (home.cc.umanitoba.ca/~jander; also see the *Observer's Handbook 2015*, p. 144). On average, this amounts to a mean cloudiness of 75 percent in the Faroe Islands.

These statistics are derived from observations made at Vagar airport, and it is unclear how these averages generalize to the rest of the archipelago. Anecdotally, the Faroes are known for having extremely variable weather, a trait that was observed first-hand during our March 2014 visit. It was not uncommon to have overcast skies and rain one minute, followed by clear, blue skies the next.

Project Outline

The eclipse weather project was initiated with three main goals in mind. Primarily it was an outreach exercise, aimed to encourage local people to take an active interest in the sky conditions, creating an increased awareness of the eclipse and perhaps astronomy in general. Secondly, the data collected would provide an interesting overview of the weather—and in particular, the variability thereof—that may be expected to occur next year. Finally, it would provide a useful means to evaluate the reliability of short-term weather forecasts in the region.

In order to obtain a "snapshot" of the weather at a given time across the islands, volunteers around the islands were enlisted to make a photographic observation of the sky conditions each day at 9:40 a.m. (the time the total eclipse will occur) for the

entire month of March 2014. If a photo was not possible, they simply recorded one of five categories that best described the cloud situation with respect to the visibility of the Sun:

1. mostly clear
2. partly cloudy (Sun visible)
3. thin cloud (Sun partially visible)
4. partly cloudy (Sun obscured)
5. overcast

The categories were chosen to best represent the impact on potential eclipse observing. Categories 1 and 2 would be typically unobstructed viewing; category 3 would be obstructed viewing, although not catastrophic; while in categories 4 and 5 the Sun would be completely obscured.

There were 15 volunteers in total. The majority consisted of staff from the municipal tourism offices, located in the following towns and cities: Fuglafjørður, Klaksvík, Runavík, Sandoy, Tórshavn, Tvøroyri, Vágar, and Vágur. Involvement of tourism representatives was highly advantageous from an outreach perspective, as they will likely be the points of contact for many visitors and tourists next year. A number of additional volunteers took part in the project from the following areas: Eiði, Tórshavn, Tvøroyri, Søldarfjørður, Strendur, Vestmanna, and Viðareiði. In lieu of an observer on the far western isle of Mykines, a Webcam image captured each morning was used to expand spatial coverage.

The geographical distribution of participants (including the Mykines Webcam), is shown on the map in Figure 2.
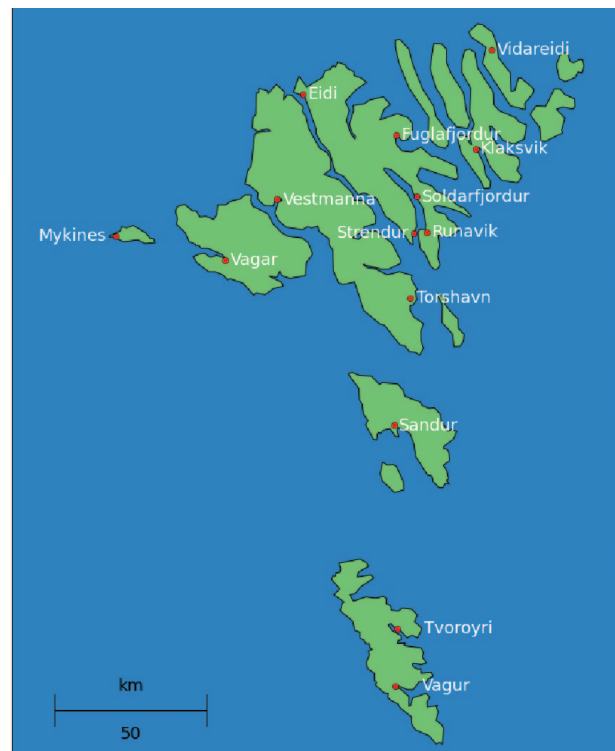

Figure 2 — Geographic distribution of participants in the eclipse weather project.
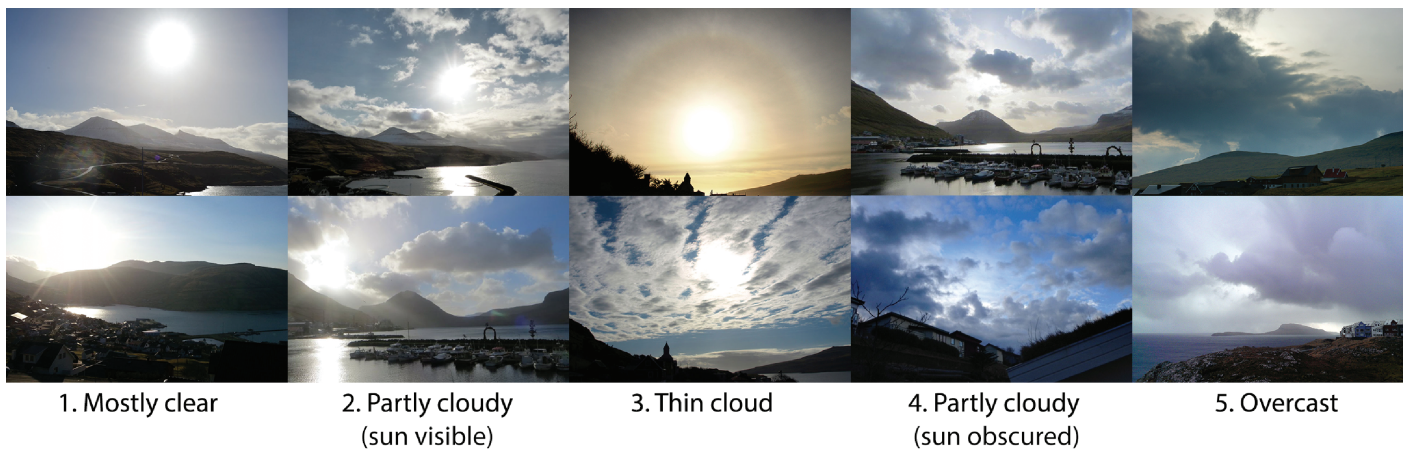
| 1. Mostly clear | 2. Partly cloudy (sun visible) | 3. Thin cloud | 4. Partly cloudy (sun obscured) | 5. Overcast |

Figure 3 — Sample selection of 10 photos across the 5 categories.

In addition to these observations, every day for each location we obtained the 24-, 12-, 6-, and 3-hour forecasts from the Norwegian Meteorological Institute (www.yr.no, hereafter, YR), which included cloud estimates along with wind speed and direction. For additional verification purposes, Webcam images were captured at half-hour intervals every day from the Landsverk network (www.landsverk.fo) and elsewhere, which totalled 47 cameras around the Faroe Islands and 3 across Svalbard.

Each photograph was categorized (manually, by eye) into the five aforementioned categories, which allowed a quantitative analysis to be performed. To avoid any bias introduced by missing observations, nearby Webcam images captured at 09:30 were used as proxies (*e.g.* by looking at the sky or shadows on the ground to infer sunshine). If no suitably close Webcams were available, a best guess was made given the other observations obtained that day.

Results

From a maximum of 465 observations that could have been submitted (15 observers for 31 days), we received a total of 381 reports (82 percent), of which 361 had corresponding photographs. Figure 3 shows a sample selection of photographs with their designated cloud categories.

Using the EXIF metadata stored in these photographs, we obtained the temporal distribution of observations, shown in the histogram in Figure 4. The sharp peak corresponds with the requested time for the images to be taken (09:40 UT). Approximately 85 percent of photographs were taken within 30 minutes of the nominal time.

As most photographs were taken with smart phones, it was assumed that the timestamps were automatically set by the mobile phone network and hence would be sufficiently accurate for our purposes. From digital cameras, it is likely the time stamps will have some error, and in some cases possibly be set to Daylight Saving Time (+1 hour).

It is noted that the spread of times at which observations were taken will introduce some inherent uncertainty, particularly given the extreme weather variability and its changes from minute to minute.
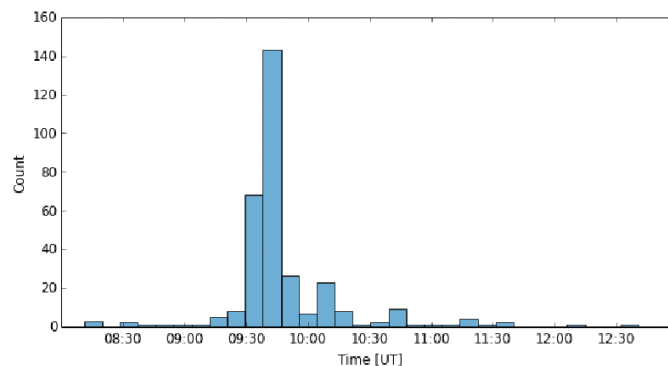
Figure 4 — Histogram of observation times.

The complete set of categorized observations, as well as the total cloud amount forecast six hours prior from YR, are presented in Figures 5 and 6.

- Only an extremely tiny fraction (2 percent) of reports were deemed "mostly clear," with "mostly cloudy" or "overcast" (categories 4 and 5) accounting for the vast majority of observations (Figure 6).

- Almost 50 percent of the time (15 days), at least one location was able to observe the Sun at the recorded time.

- There were 6 days (days 10, 13, 21, 22, 27, and 28), where conditions were "good" across most sites, although not one day existed where the entire archipelago experienced clear skies.

- The YR forecasts predicted most of the "good" observations, although on a number of occasions (days 2, 6, 20, and 29), clear skies were forecast in most areas, but not seen.

- A detailed inspection of Figure 5 provides a number of insights into the overall conditions, variability, and forecast
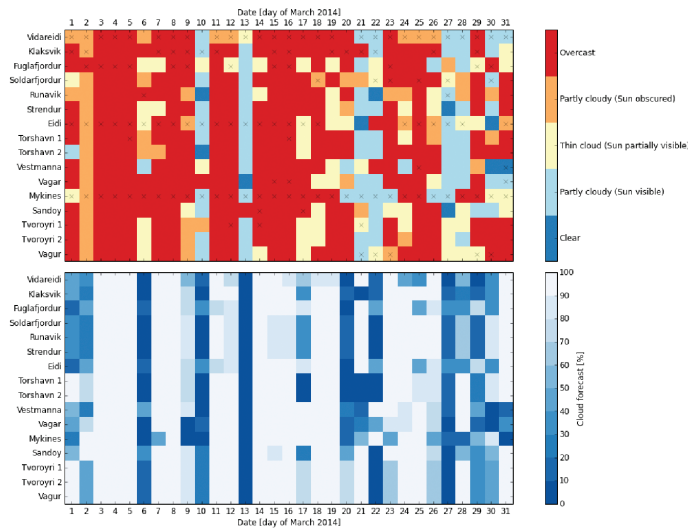
Figure 5 — Grid representation of every categorized observation (upper panel) and forecast (lower panel) obtained. An "X" indicates that the category was estimated from a Webcam or nearby site. The colour scales on both plots are not the same.
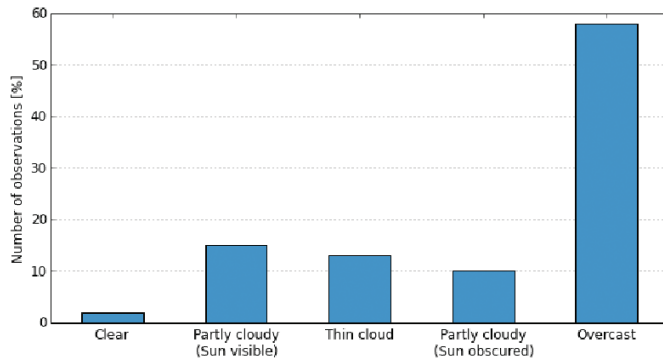
Figure 6 — Percentages of observations in each of the five categories.

accuracies within the month we examined, relating to the observed sky at 9:40 a.m.

• By looking at days that were cloudy everywhere except in one location (*e.g.* days 1, 6, and 24), there appears to be little correlation between site-specific forecasts and the actual observed conditions.
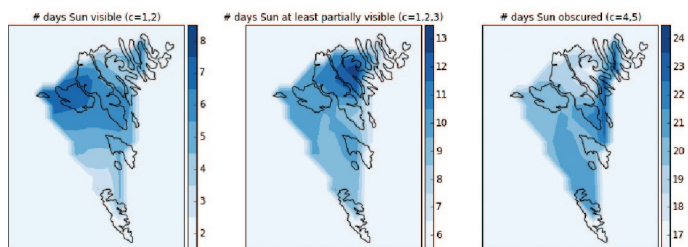
Figure 7 — Spatial variation in observed weather. Note that in the left and middle plots, the darker blue represents a higher number of clear mornings, whereas in the right-most plot the dark colour represents a higher number of cloudy mornings.

Despite having a sparsely spatially sampled dataset, it is possible to examine these aggregated statistics as a function of position. Figure 7 shows how the overall statistics varied over the islands, by using a natural-neighbour interpolation of the irregularly spaced data points to a regular grid, followed by a linear interpolation. The western isles of Vagar and Mykines appear to have the sunniest morning skies, while eastern locations generally experience a higher number of overcast mornings.

It is difficult to validate quantitatively the YR cloud forecasts, since they are averaged not only over an entire hour-long interval, but also over the entire sky. For each observation category, we have plotted the histograms of the forecast total cloud percentages (Figure 8), as obtained 6 hours prior to the observation. The histograms reiterate that while the forecasts are generally accurate, there were a number of occasions where cloudy forecasts had clear observations, and vice versa.
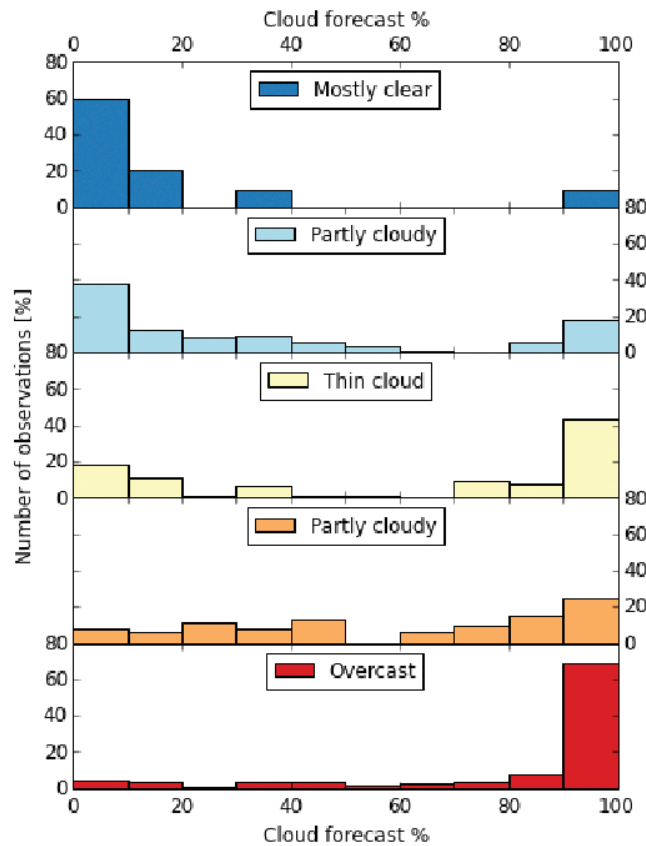
Figure 8 — Histograms showing fractional amount of observations in each category as a function of forecast cloud percentage.

Because the majority of photographs were classed in categories 4 and 5 (*e.g.* see Figure 6), the data in Figure 8 are hard to interpret from a forecast validation perspective. For example, although around 60 percent of all "clear sky" observations had cloud forecasts in the range 0–10 percent, if you consider every forecast within the range 0–10 percent, only 9 percent of those forecasts fell in the "clear sky" category (Figure 9).
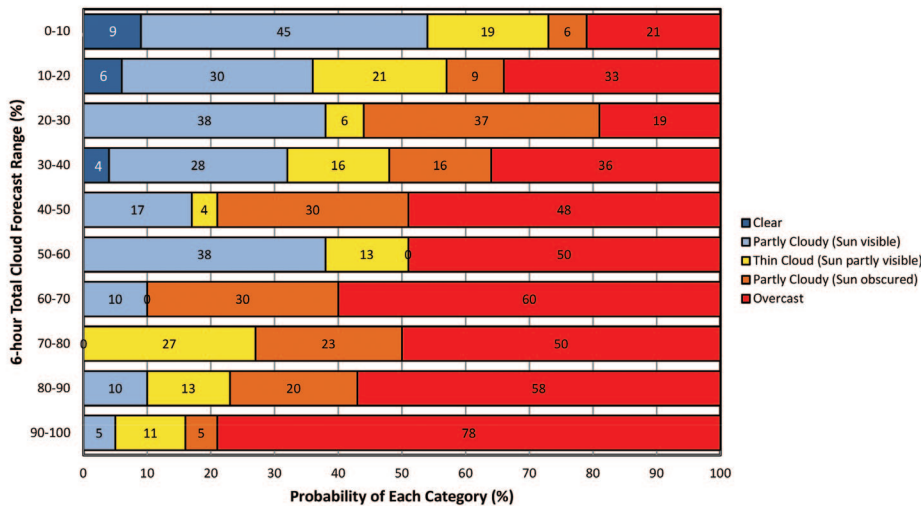
Figure 9 — Probability of observing a particular sky condition, for a given 6-hour forecast.

Figure 9 presents these statistics for all combinations, and is perhaps of most practical significance. That is, for a given forecast, it shows the probability of the actual sky conditions falling in any one of the five categories.

Conclusions

The Faroese community is eagerly awaiting next year's solar eclipse. The involvement of the tourism industries and other civilians in this citizen science project has heightened awareness of the eclipse, weather, and the sky conditions in general.

From a meteorological perspective, the project has confirmed that, in general, the weather in the Faroe Islands is both highly variable and often cloudy. Even the best days usually have some cloud present, and on these exceptional days, it is likely some locations will still remain overcast. On a more positive note, based on this one month of data, we can conclude there is an almost even chance that somewhere on the islands clear skies will be experienced on the morning of the eclipse, and overall that there is around a 30-percent chance of not being completely clouded over.

Short-term (6-hour) cloud forecasts, in general, give a good prediction of the observed conditions. However, owing to the extremely variable nature of the weather, a significant proportion of the time is insufficiently accounted for by these forecasts. For example, 20 percent of forecasts indicating only 10–20 percent cloud were, in fact, observed to be overcast.

Despite the weather challenges that this eclipse presents, the Faroe Islands remain the destination of choice for many eclipse chasers, owing largely to the excellent tourism, communication, and road infrastructures, combined with easy accessibility via regular scheduled flights from Europe.

Acknowledgements

GrayStar: A Web Application For Pedagogical Stellar Atmosphere and Spectral-Line Modelling and Visualization

by C. Ian Short, Department of Astronomy & Physics and Institute for Computational Astrophysics, Saint Mary's University, Halifax NS, Canada, B3H 3C3

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GrayStar is a stellar atmospheric and spectral-line modelling, post-processing, and visualization code, suitable for classroom demonstrations and laboratory-style assignments, which has been developed in *Java* and deployed in *JavaScript* and *HTML*. The only software needed to compute models and post-processed observables, and to visualize the resulting atmospheric structure and observables, is a common Web browser. Therefore, the code will run on any common PC or related x86 (-64) computer of the type that typically serves classroom data projectors, is found in undergraduate computer laboratories, or that students themselves own, including netbooks and tablets. The user requires no experience with compiling source code, reading data files, or using plotting packages. More advanced students can view the *JavaScript* source code using the developer tools provided by common Web browsers. The code is based on the approximate gray-atmospheric solution and runs quickly enough on current common PCs to provide near-instantaneous results, allowing for real-time exploration of parameter space. I describe the user interface and its inputs and outputs and suggest specific pedagogical applications and projects. Therefore, this paper may serve as a *GrayStar* user manual for both instructors and students. I have made the application itself, and the *HTML*, *CSS*, *JavaScript*, and *Java* source files available to the community. The Web application and source files may be found at www.ap.smu.ca/~ishort/GrayStar/.

1. Introduction

1.0.0.1.

The stellar atmospheres and spectroscopy component of the essential undergraduate major or honours astrophysics curriculum includes:

1) Relations among basic stellar parameters and overall radiation-related observables, as determined for spherical emitters of black-body radiation;

2) The astrophysical basis for the relations between MK spectral class and effective temperature, (T_{Eff}), and MK luminosity class and surface gravity ($\log_{10} g$), particularly the role of temperature, as determined by Saha-Boltzmann statistics for excitation and ionization equilibrium;

3) The basic physics that determines average vertical atmospheric structure, such as hydrostatic equilibrium (HSE) and the pressure equation of state (EOS);

4) The relation between atmospheric vertical-temperature structure and the distribution of the emergent surface intensity field in wavelength (spectral features) and in angle of emergence with respect to the local surface normal (limb darkening), as determined approximately by the LTE Eddington-Barbier relation; and

5) The relation between spectral line strength and shape, and the number density of absorbers in the relevant atomic energy level (*i.e.* the simple curve of growth (COG) of a spectral line).

These topics are crucially important for the astrophysical interpretation of spectra, not just from single stars, but also from optically thick structures generally, including interstellar medium (ISM) structures, disks on any scale, planetary atmospheres, and collections of spatially unresolved stars (integrated light populations), and are important for students going into many areas of astronomy and astrophysics.

1.0.0.2.

Because so many different physical laws and processes are involved in determining atmospheric structure and the value of observables, the natural approach to pedagogy (and research!) is the parameter perturbation analysis, in which we ask students to consider what might change if one stellar or spectral line formation parameter is varied while the others are held fixed. The basic imaginary apparatus for these pedagogical thought experiments is the "star with parameter knobs." The purpose of *GrayStar* is to make this imaginary apparatus a virtual apparatus, equipped with a virtual photometer, spectrophotometer, spectrograph, and optical interferometer, and to thus make the thought experiments into simulated experiments. This would serve both for in-class demonstrations that can form the basis of interactive pedagogy and for laboratory-style assignments where students investigate the dependence of structure and observables on parameters and explore relationships. This would be pedagogically useful in courses ranging from first-year undergraduate astronomy courses aimed at science majors, where one could demonstrate the parameter-dependence of the simplest observables, to introductory graduate courses, where one could explore the parameter dependence of the vertical atmospheric structure, demonstrate the implications of the Eddington-Barbier relation in detail, or have the students study, adapt, and enhance the source code itself. This is now more feasible than ever because personal computers now able to execute floating-point operation- and memory-bandwidth-intensive operations quickly enough to execute scientific computations that are not disk IO intensive and are thus now suitable for execution of scientific codes atat least at the pedagogical level of sophistication.

1.0.0.3.

The pedagogical need for a virtual star with "parameter knobs" suggests that we look to atmospheric modelling and spectrum synthesis codes and their suites of post-processing and visualization tools. However, research-grade atmospheric modelling and spectrum-synthesis codes, and their typical standard output files encoding observable data, are not necessarily suitable for wide pedagogical use for many reasons. Because research-grade codes must read in large data files containing atomic and molecular line data and converge on a structure solution iteratively, the results are not available instantaneously in a way that allows for real-time exploration with *ad hoc* parameters, even when run with their simplest level of realism. The university-supplied computers that typically serve classroom data projectors and that are found in undergraduate computing labs, and the computers that students typically own themselves, normally have mass-market graphical-user-interface- (GUI-) based operating systems (OSes) that are not equipped with the tools and libraries needed to compile, link, and run complex codes written in typical scientific programming languages such as *FORTRAN* and *C*. Neither are such computers particularly suitable for developing and running programs to read data files containing the results of pre-computed models and for plotting the contents thereof. Many first- and second-year astronomy courses are taught by instructors (*e.g.* part-time faculty, lecturers) who may not necessarily have the facility, nor the inclination, to obtain data files holding the results of research-grade atmospheric modelling and spectrum synthesis calculations, and to develop procedures for reading and plotting their contents, let alone to compile and run the codes themselves.

1.0.0.4.

GrayStar is a simple stellar atmospheric and spectral line modelling, post-processing, and visualization code that has been designed to be suitable for pedagogical use by instructors and students with no experience in producing an executable file from source code, producing routines to read data files, or with data visualization and who have access only to computers with mass-market GUI-based operating systems. The atmospheric structure is computed using the approximate gray solution (among other less-crude approximations described below), obviating the need for input- and output-intensive (IO-) intensive atomic and molecular "big data" handling and for iterative convergence. The code is written in *JavaScript*, is processed by a Web browser's *JavaScript* interpreter and the client's CPU, and displays its results in the browser window. As noted earlier, it is certain to run successfully on any computer for which a common Web browser is available.

1.0.0.5.

In addition to making the *GrayStar* executable universally and freely available through the World Wide Web (www.ap.smu. ca/~ishort/*GrayStar*), I also disseminate the *JavaScript* and *Hypertext Mark-up Language* (*HTML*) source code to any who are interested in having their own local installation, or in developing the code further. I stress the broader significance that common PCs running common operating systems are now powerful enough, and common Web browsers are now sophisticated enough interpreters, that the realm of pedagogically useful scientific programming is now accessible in a framework that is free, common, and allows both the application and its source code to be shared over the Web.

Figure 1 — A screen-shot of the input and textual output areas of the GrayStar *GUI*

1.0.0.6.

In Section 2, I describe the *GrayStar* user interface; in Section 3, I briefly describe some of the special considerations relevant to developing and deploying scientific modelling codes in *Java* and *JavaScript*; and in Section 4, I describe a number of pedagogical demonstrations and lab exercises for which *GrayStar* is ideally suited.

2. The User Interface

2.1. Input

GrayStar presents the user with a browser window with 12 labelled "text-box"-style input fields (Figure 1), four for stellar parameters and eight for spectral line parameters, as outlined below. (Note that in the case of a gray atmospheric model, the microturbulence parameter, ξ_T, is *only* a spectral line parameter, *not* an atmospheric parameter, because line extinction plays no role in determining the atmospheric structure.)

2.1.1. Stellar parameters

1) Effective temperature, T_{Eff}, in K,

2) Logarithmic surface gravity, $\log_{10} g$ in log cm s⁻¹, (log dynes gm⁻¹),

3) Multiplicative factor, *x*, for the Rosseland mean mass extinction coefficient, κ_{Ros}

In addition, the interface expects stellar mass, *M*, in solar units, $M_\odot$, for calculating the radius, *R*, and thus the bolometric luminosity, L_{Bol}, in solar units, for purely pedagogical reasons.

2.1.2. Spectral line parameters

These are divided into two groups: those that mainly affect line *strength* and those that mainly affect line *width* or shape:

2.1.2.1. Line strength

1) Line centre wavelength, λ_0 in nm,

2) Logarithmic *total* number density of the extinguishing species in the "A_{12}" system, $A = \log_{10} N/N_H + 12$

3) Unitless quantum mechanical oscillator strength, f_{lu}, of the corresponding bound-bound (*b–b*) atomic transition,

4) Ground state ionization energy, χ_I, of the neutral ionization stage in eV,

5) Excitation energy, χ_1 of the lower atomic energy level of the corresponding *b–b* transition, in eV, with respect to the ground state of the *neutral* stage.

If the value of χ_1 is *less* than that of χ_I, the spectral line corresponds to a *b–b* transition of the *neutral* ionization stage (I). Otherwise, it corresponds to a *b–b* transition of the *singly ionized* stage (II).

2.1.2.2. Line width and shape

6) Mass of the absorbing species in atomic mass units (amu) (affects *thermal* core broadening)

7) Microturbulent RMS velocity, ξ_T, in km s⁻¹ (affects *non–thermal* core broadening),

8) Logarithmic van der Waals damping enhancement factor, $\log_{10}\gamma$, (s⁻¹) (affects *wing* damping).
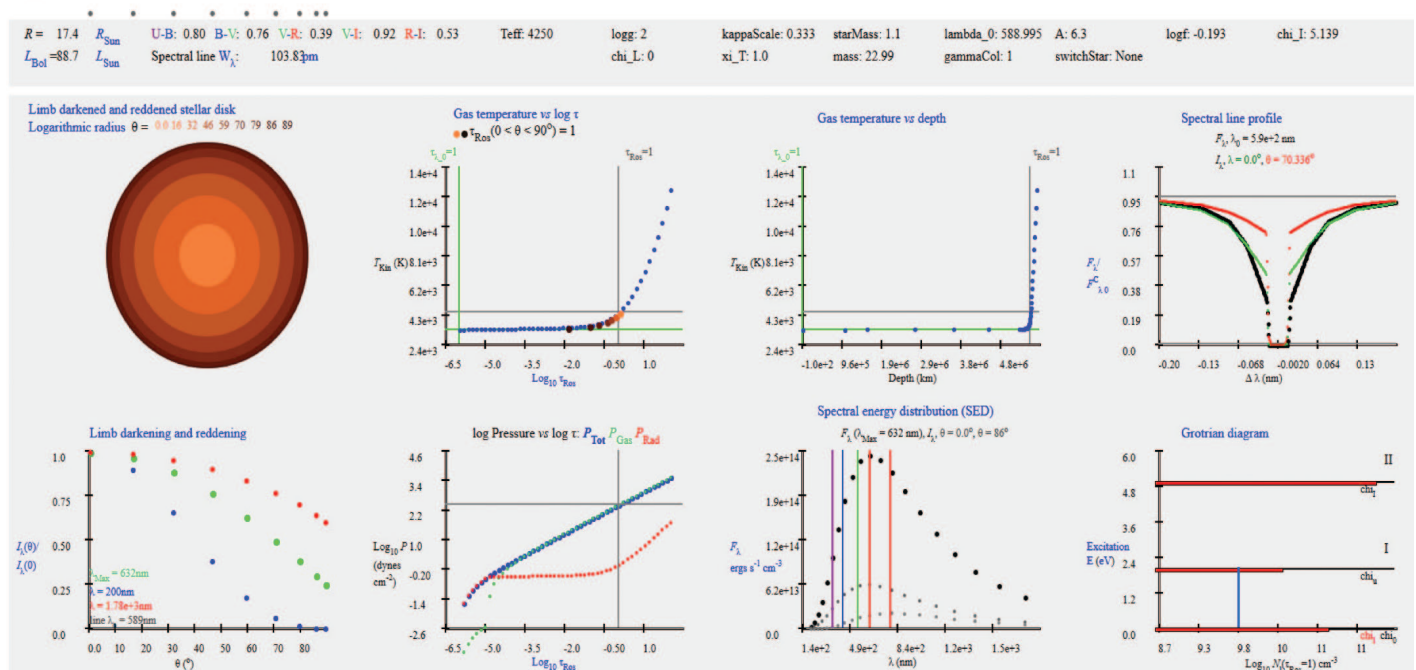

Figure 2 — A screen-shot of the output area of the *GrayStar* GUI showing the textual output section and the eight plots of the graphical output section.

2.1.2.3.

Because this is an instructional application, guidance is provided for determining physically realistic and illustrative values. The four stellar parameter input fields are pre-filled with default values for the Sun (T_{Eff}/log g/x/M = 5778/4.44 /1.0/1.0) and the eight spectral line parameter fields are pre-filled with default values that yield a moderate spectral line (*i.e.* with an approximately Gaussian profile) for a star with the Sun's stellar parameters. The cgs system of units is used consistently, except for those values where standard practice is to use other units to ensure well-normalized quantities (km s^{-1} for ξ_T, eV for atomic χ values). Moreover, the input fields are annotated with suggested ranges for the input values, and these ranges are enforced in the code itself to prevent students from inadvertently crashing the code by entering values that would lead to numerical pathologies. I have also added "tool tips" that present additional information about the input parameters when the user hovers over a label, for those field labels that are less self-explanatory, and most parameters labels are also linked to explanatory Web pages. If a user has their own installation of *GrayStar*, they can edit the links so that the fields point to local on-line resources.

2.1.3. Pre-set models

Finally, the user is given the option of selecting from among four pre-set standard stars: the Sun (G2 V), Vega (A0 V, photometric zero), Arcturus (K1.5 III), and Procyon (F5 V-IV), and three pre-set Fraunhofer lines: The Na I D$_1$ and D$_2$ lines, and the Mg I line. Comparison of the Na I D$_1$ and D$_2$ lines demonstrates COG effects in a multiplet (a doublet in this case), and the Mg I b$_1$ line demonstrates the T_{Eff} variation of a line arising from an excited level.

2.2. Output

When the user runs a calculation by clicking the "Model" button, textual information and eight graphs are immediately displayed with the results of the calculation (Figure 2):

2.2.0.1. Textual output:

The values of the 12 input parameters are echoed back to the user. This is important because the parameters used in the model may differ from those supplied if one or more parameters are outside the "safe" range. Any parameter that has been over-ridden is highlighted in red to draw the student's attention. The computed values of R and L_{Bol} are displayed in solar units, along with five photometric colour indices in the Johnson-Cousins $UBV(RI)_C$ system ($U-B$, $B-V$, $V-R$, $V-I$, $R-I$). The colour indices are normalized with a single-point calibration to a *GrayStar* model computed with Vega's input parameters (T_{Eff}/log g/x = 9550/3.95 /0.333 (Castelli & Kurucz 1994)). The equivalent width, W_λ, of the spectral line

is displayed in pm (picometres). The non-standard unit, pm (equal to 10 mÅ), was chosen for a pedagogically-motivated consistency with the units of wavelength (nm).

2.2.0.2. Graphical output

The GUI displays the following graphs:

1) A physically based limb-darkened and limb-*reddened* rendering of the projected stellar disk, scaled logarithmically with radius,

2) T_{Kin} *vs* logarithmic Rosseland optical depth, log τ_{Ros},

3) Kinetic temperature, T_{Kin}, in K *vs* geometric depth in km,

4) Logarithmic total pressure (log P_{Tot}), gas pressure (log P_{Gas}), and bolometric radiation pressure (log P_{Rad}) *vs* log τ_{Ros},

5) Limb darkening profiles, $I_{\lambda(\theta)}/I_{\lambda(0)}$ *vs* θ at the wavelength of maximum flux (λ_{Max}), at representative continuum wavelengths in the near UV and near IR, and at spectral line centre, (λ_0)

6) Surface flux spectral-energy distribution (SED), $F_\lambda(\lambda)$ *vs* λ, and surface intensity SEDs, $I_\lambda(\lambda)$, at θ values of $\approx 0°$ and $\approx 87°$ for the 200 (UV) to 2000 (IR) nm λ range,

7) the $F_\lambda(\lambda)$ spectral line profile and the $I_\lambda(\lambda)$ line profiles at θ values of $\approx 60°$ and $\approx 87°$

8) A Grotrian diagram showing the atomic energy, χ_1, and logarithmic level population, N_1, at τ_{Ros} = 1 of four key E-levels: the lower and upper levels of the $b-b$ transition and the ground states of the neutral and ionized stages, along with the transition itself.

2.2.0.3.

Plot 1) is labelled with the θ values of the emergent $I_\lambda(\theta)$ beams with respect to the local surface-normal, colour coded for consistency with the corresponding annuli in the limb-darkened, limb-reddened image. In plot 2) of T_{Kin} *vs* log τ_{Ros} the depths of τ_θ = 1 for each $I_\lambda(\theta)$ beam sampling the radiation field in angle is shown with colour-coded symbols that correspond to the limb-darkened and reddened rendering in plot 1). Therefore, plots 1), 2), and 5) work together to provide a powerful, direct explanation of limb-darkening in terms of the LTE Eddington-Barbier relation. In the plots 2) through 4) displaying the atmospheric structure, the depths where the continuum and line-centre monochromatic optical depths scales are approximately unity (depths of τ_{Ros} and $\tau_{\lambda 0} \approx 1$) are indicated. In plot 6) displaying the SEDs, the central wavelengths of the $UBV(RI)_C$ bands are indicated with appropriately colour-coded markers, and the value of (λ_{Max}) is displayed.

3. Modelling

3.0.0.4. *Java* and *JavaFX* development

To take advantage of the robust development support provided by Integrated Development Environment applications (IDEs), I developed the code in *Java*, using version 1.8 of the *Java Development Kit* (JDK 1.8). *Java* has strong data-typing and interface-declaration rules, allowing the IDE to immediately catch bugs caused by most common coding errors as the code is being developed, including those arising from a mis-match between the types and numbers of the arguments and of the parameters of a function (*i.e.* a *Java* "method"). Additionally, the IDE provides the usual standard out (*stdout*) and standard error (*stderr*) channels for the *Java* interpreter/compiler to communicate with the developer and provides robust error messaging. All these are crucial to developing scientific computational codes of even moderate complexity. This *development* version of the code uses the *JavaFX* library to provide the GUI, and has thus been named *GrayFox* and has also been made available to the community through the *GrayStar* Web site.

3.0.0.5. *JavaScript* and *HTML* deployment

Because the *Java Run-time Environment* (JRE) allows pre-compiled executable code to be downloaded and run on the client, and because *Java* has full file I/O capability, it poses a significant security threat. Therefore, a difficult and financially expensive security protocol requires the deployer of *Java* codes to digitally authenticate their code with a certificate purchased from a trusted certificate issuer, and this poses a significant barrier to the free and wide dissemination of such codes in the academic sector. To circumvent this difficulty of *Java* deployment, the code was ported to *JavaScript* and *HTML* for Web deployment. With *JavaScript* applications, the client browser downloads source code that can be visually inspected with typical browser developer tools, and *JavaScript* does not have file I/O capability. Therefore, the onerous and expensive authentication protocol is not required, and the code can be executed transparently by a client with typical default security settings. However, because *JavaScript* does not have IDE support, nor file I/O capability, it is more difficult to troubleshoot and debug. Therefore, the recommended work flow for further development is to develop the code in *Java*, then port it to *JavaScript* and *HTML* for deployment. Porting the modelling algorithms is straightforward because, with the exception of variable and function (*Java* method) declarations, the syntax is identical (an exception is object declaration, but I have been unable to think of a way in which object-oriented programming would benefit atmospheric modelling and spectrum synthesis!). This *deployment* version is called *GrayStar*. Because *Java* and *JavaScript* development of modelling codes

is not a strong part of the scientific programming culture, and because I will make the source code publicly available for those who wish to understand and develop it, or have their students study and modify it, I provide a significant level of detail in an additional paper that can be found at http://arxiv.org/abs/1409.1893.

3.0.0.6. *HTML* visualization

The biggest disincentive to scientific programming and visualization with *JavaScript* and *HTML* is the need to manually emulate the functionality of a plotting package (*e.g. IDL, gnuplot*) starting from the primitive ability of *HTML* to place a rectangle of given dimensions at a given location in the browser window, as specified in absolute device coordinates. However, the code in the graphical output section of *GrayStar* may be taken as a template for how this problem can be addressed, and adapted to other uses.

3.0.0.7.

GrayStar solves the static, 1D plane-parallel, horizontally homogeneous, local thermodynamic equilibrium (LTE), gray-atmosphere problem, evaluates the formal solution of the radiative transfer equation to compute the outgoing surface monochromatic specific intensity, $I_\lambda(\tau_\lambda = 0, \theta)$, and computes various observables including the SED, photometric colour indices, and the profile of a representative spectral absorption line using the "core plus wing" approximation to a Voigt function profile. (I note that all these approximations, *except the gray solution*, are not especially restrictive in the context of research-grade modelling!) The theoretical basis is taken entirely from Rutten (2003). The least realistic of these assumptions, by far, and the most expediting, is the gray solution, in which the monochromatic mass extinction coefficient, $\kappa_\lambda(\lambda)$, is assumed to be constant as a function of wavelength, λ (the Gray approximation), although it varies with depth, and the angle-moments of the radiation field are related through the first and second Eddington approximations. This yields an enormous simplification of the atmospheric structure problem in that the vertical kinetic temperature structure, $T_{\text{Kin}}(\tau_{\text{Ros}})$ can be calculated analytically, and the remaining structure variables (*e.g.* pressure, ($P(\tau_{\text{Ros}})$), density ($\rho(\tau_{\text{Ros}})$)) can be calculated in a single pass with no need for iterative convergence. The gray $T_{\text{Kin}}(\tau)$ structure is most conceptually self-consistent at depth in the atmosphere when it is computed on the Rosseland optical-depth scale, τ_{Ros} (*i.e.* $T_{\text{Kin}}(\tau_{\text{Ros}})$). Therefore, I set the gray value of κ_λ at each depth to be equal (approximately) to the corresponding Rosseland mean mass extinction coefficient (*i.e.* $\kappa_\lambda(\tau_{\text{Ros}}, \lambda) = \kappa_{\text{Ros}}(\tau_{\text{Ros}})$). The numbers of points sampling the atmosphere in τ_{Ros} (50), the radiation field in log λ (20), and θ (9), have been set to values close to the minimum that are useful to optimize the speed of execution.

4. Pedagogical applications

It is worth noting that the *GrayStar* GUI is an *HTML* Web page like any other, and thus the usual methods for managing the display of content, and for capturing textual content, are available. A presenter can enhance clarity by zooming, isolate areas of interest by re-sizing the browser, and show direct comparison of output from runs with different parameters by launching multiple instances of the browser, or by using multiple browser tabs, each running *GrayStar*. A student can capture textual output such as colour indices, W_λ values, *etc.*, by cutting and pasting to a common spreadsheet program for analysis and plotting. In particular, because *GrayStar*'s graphical output consists of *HTML* instructions to the browser's rendering engine rather than pixelated bitmap information (such as that encoded in jpegs, gifs, *etc.*), the graphics are scale-invariant and remain sharp at high zoom factors, which is an important consideration when presenting in large classrooms. The ability to conduct real-time numerical experiments with a simulated stellar atmosphere and spectrum in the classroom is suitable for interactive pedagogical methods in which, for example, the instructor has the students predict the outcome of a change in one or more parameters after discussing the situation among themselves.

4.0.0.8.

The following pedagogical applications of *GrayStar* modelling can serve as demonstrations during lecture presentations, or as lab exercises. These are only the most obvious applications that suggest themselves immediately—other applications may occur with experience. Plot numbers refer to the enumeration given in Section 2.

4.0.0.9.

1) Exploration of the variation of the value of peak spectral brightness, $\lambda_{\rm Max}$, and of the photometric colour indices with the value of $T_{\rm Eff}$, and comparison of the $T_{\rm Eff}$ variation of the different colour indices with each other (Plot 6),

2) The role of $P_{\rm Rad}$ in supporting a stellar atmosphere, and its variation with stellar parameters (Plot 4),

3) The role of $\kappa_{\rm Ros}$ in determining the scale height (geometric thickness) of a stellar atmosphere (Plot 3),

4) Comparison of F_λ and $I_\lambda(\theta)$ SEDs and line profiles and the relation to limb darkening, (Plots 6, 7, 5)

5) Exploration of the monochromatic limb darkening, $I_\lambda(\theta)$, with λ and relation to the atmospheric vertical structure, $T_{\rm Kin}(\tau_{\rm Ros})$, and the variation of the T sensitivity of the Planck function, $B_\lambda(T, \lambda)$, with λ (Plots 5, 2),

6) Investigation of how the line core width varies with both the mass of the absorbing particle and the value of $\xi_{\rm T}$, and of how line damping wing strength varies with $\log g$ to illustrate pressure (collisional) broadening,

7) Investigation of the curve of growth (COG, $W_\lambda(N_1, f_{\rm lu})$), of a spectral line by varying both A and $f_{\rm lu}$ throughout the range from a weak Gaussian line through to a strong line to a saturated line with Lorentzian wings, (Plot 7)

8) Comparison of the line strength (W_λ) variation with $T_{\rm Eff}$ among lines that belong to the neutral (I) and singly ionized (II) stages, and that arise from the ground ($\chi_\lambda = 0$) or an excited ($\chi_l > 0$) atomic E-level,

9) Investigation of the LTE Eddington-Barbier description of stellar spectral absorption line formation by comparison of the depths of $\tau_{\rm Ros} \approx 1$ and $\tau_{\lambda 0} \approx 1$ for lines of various strength, and the relation with the $T_{\rm Kin}(\tau_{\rm Ros})$ structure (Plot 2),

4.0.0.10.

At the advanced undergraduate or graduate level, students can be asked to modify and add to the source code itself. To modify and run the *Java* development version, instructors and students need to download and install *JDK 1.8* or later, and version 8.0 or later of the *NetBeans* IDE, both available free of charge from Oracle's Web site. To troubleshoot the *JavaScript* deployment version with diagnostic print statements (console.log()), the "Developer tools" accessible from the browser menu must be enabled, and the "console" selected.

5. Conclusions

GrayStar allows real-time exploration and investigation of stellar atmospheric structure and spectral line profiles with "on-demand" parameters suitable for classroom demonstration and student laboratory assignments. The *JavaScript* and *HTML* code is robustly platform independent across all common types of university-supplied and student-owned computers. *GrayStar* allows pedagogical demonstration of most, if not all, major topics in the undergraduate astrophysics curriculum that are related to stellar atmospheres and spectra. A local installation of *GrayStar* can be embedded in the local academic framework by editing the pedagogical links. In addition to making *GrayStar* available for local installation and use by the astronomy teaching community, I also encourage active development and adaptation of the code.

5.0.0.11.

JavaScript, a language that can be interpreted by any common Web browser and executed on nearly all personal computers, is sophisticated enough as a programming language to allow development of scientific simulations at a pedagogically useful level of realism. The ability of *JavaScript* to manipulate HTML documents allows the results of simulations to be visualized in the Web browser. Commodity computers are now powerful enough to execute such *JavaScript* simulations instantaneously. This allows "toy" models of natural and physical systems to be simulated and visualized in a way that allows for experimentation, classroom demonstration, and exploration of parameter space with no requirement of computational or visualization skills on the part of the instructor or student, and with no need to install special purpose software. Codes can be developed in *Java*, thus taking advantage of the powerful and mature developer support framework, including IDEs, and then straightforwardly ported to *JavaScript*.

5.0.0.12.

This opens up an entire vista of instructive possibilities, and the pedagogical stellar-atmospheric and spectral-line modelling described here is only one example. For example, within the field of stellar astrophysics, a similar approach could be taken for simulation of stellar interior structure in the polytrope approximation, allowing classroom demonstration and student laboratory investigation of the dependence of stellar structure and related observables on various independent parameters—a "stellar interior with knobs." I stress again the broader significance that common PCs are now powerful enough, and Web browsers are now sophisticated enough interpreters, that the realm of educationally useful scientific programming is now accessible in a framework that is free, common, and allows both the application and its source code to be immediately shared over the Web. ✶

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Deep-Sky Imaging with a Simple Achromatic Refractor

by Klaus Brasch, Unattached Member
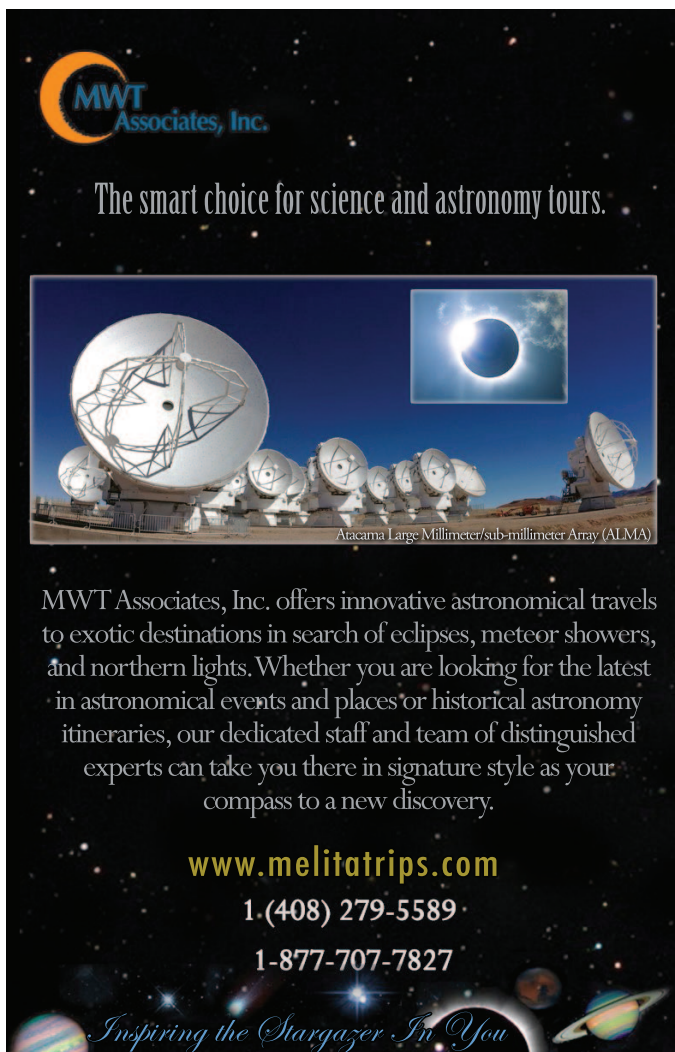*(krbrasch@earthlink.net)*

Most astrophotographers today agree that modern, three- and four-element apochromatic refractors (apos) are among the best imaging instruments available. It is hard to beat the tack-sharp, high-contrast, and incredibly detailed deep-sky images that even modest aperture apos can produce. A modern 80- to 150-mm apo can capture image detail unheard of just a few years ago. Moreover, unlike many larger compound telescopes, small refractors are usually portable, rarely require collimation, and are less affected by atmospheric turbulence. They are also less prone to dewing up and tend to reach thermal equilibrium relatively quickly.

So what is the down side? For one, high-end apos can be prohibitively expensive for many people, although costs are steadily dropping thanks to increasing availability of high-quality Chinese-made imports. Nevertheless, on a cost-per-aperture basis, apochromats will likely always be more expensive than other telescope designs. For instance, a modestly priced 80-mm imported apo will easily set you back between $800 and $1000 or roughly twice as much as a 200-mm imaging Newtonian. Likewise, Asian-made 150-mm triplet apos cost upward of $5000, while high-end telescopes in this aperture range can easily sell for twice that much. Fortunately, a number of manufacturers today also market so-called "ED" apochromats that are much more affordable though still quite expensive. ED apos are really doublets with one element made of extra-low dispersion glass for much better colour correction than a traditional achromatic doublet.

Does all this mean that if you already own a quality achromatic refractor with good optics but less than perfect colour correction and want to try your hand at deep-sky imaging, you are out of luck? A while ago, I would definitely have said yes, but recent experience has since shown me otherwise.

Two years ago I acquired a Canadian Telescopes (CT) 152-mm *f*/5.9 achromatic refractor (Figure 1). An identical telescope also manufactured by Kunming United Optics was marketed by Hands On Optics in the U.S. Not only had these Chinese-made instruments received excellent performance reviews by Terence Dickinson (2011) and Lawrence Carlino on Astromart, at around $800 they were also eminently affordable for quality refractors of this aperture. Like many amateurs who discovered astronomy in their teens in the 1950s, I had long coveted a large-aperture refractor as a true "richest field" telescope in short, a telescope that will show the most stars per field of view in the densest parts of the Milky Way. Typically, that meant a short-focal-ratio 5- or 6-inch refractor. My new CT-152 promised to fit that bill, and I was not disappointed.

Figure 1 — The CT-152 refractor shown in the author's observatory, mounted on a Losmandy G11.

When coupled with a premium 30-mm eyepiece with an 82° apparent field of view, this telescope provided eye-popping deep-sky views. At a magnification of 30× and almost a 3° actual field of view, this scope exhibited stunning clarity and high contrast, not only on the densest parts of the Milky Way but also with such showpieces as M31, the Orion Nebula, and, of course, the Pleiades. Under really dark skies and excellent transparency, it also revealed faint nebulosity in the Rosette and North America nebulae. Not bad for a classic 6-inch refractor.

While this telescope's residual chromatic aberration was not apparent, nor really mattered with deep-sky viewing, it became pretty evident on bright objects like the Moon and planets. Although using a light yellow or a minus-violet filter helped, it did not fully eliminate the blue/violet fringing. What was surprising, however, was how little fringing there actually was compared to classical achromatic telescopes, especially for such a short-focal-ratio lens. For more detailed optical evaluations see Brasch (2012) and Parkerson (2012).

Eventually, though, the astro-imager in me surfaced and I began to wonder how this impressive telescope might compare to my superb *f*/7 TMB-130 true apochromat. I am a dedicated DSLR fan and have owned several Hutech-modified Canon cameras for deep-sky imaging. These cameras are far more red sensitive than stock DSLRs and record the all-important Hα wavelength of emission nebulae while also blocking unwanted IR. To enhance contrast and filter out any residual sky glow and light pollution, I usually couple my cameras with an IDAS LPS-V3 or V4 filter. These narrow-band-pass filters transmit around 90 percent of both Hα and Hβ (Figure 2), while blocking most everything else. This combination is ideal for imaging all types of nebulae, even under moderately light-polluted suburban skies.

Figure 3 — (a) Image of M42 taken with the CT-152 without filter, showing bloated, red-haloed stars. (b) M42 as above, after insertion of an IDAS LPS filter, showing tighter, colour-free stars and enhanced contrast.

Unsurprisingly, one of my first targets was the ever-photogenic Orion Nebula. I used a Canon 50D for all initial testing. Shooting the nebula directly without the IDAS filter produced a most "colourful" result (Figure 3a). While detail and contrast in M42 itself was quite impressive, the stars had a wonderful psychedelic appearance that somehow reminded me of my student days in the 1960s! Even more surprising, however, was the image obtained when the IDAS filter was inserted (Figure 3b). Not only did M42 appear beautifully sharp and "contrasty," but the surrounding stars were also well defined, with no annoying colour fringe. Equally surprising, perhaps, was that despite my not using a field flattener, stars appeared remarkably well defined to the edge of the field with only slight elongation; quite amazing for an *f*/5.9 achromatic doublet. I routinely have to use a field flattener with my TMB-130 apo to avoid edge distortion, but apparently not with the CT-152. In part, one can attribute that to well-corrected spherical aberration and the relatively small APS-size sensor on the Canon 50D, but as shown below, it performed comparably well even with a full-frame Canon 6D.
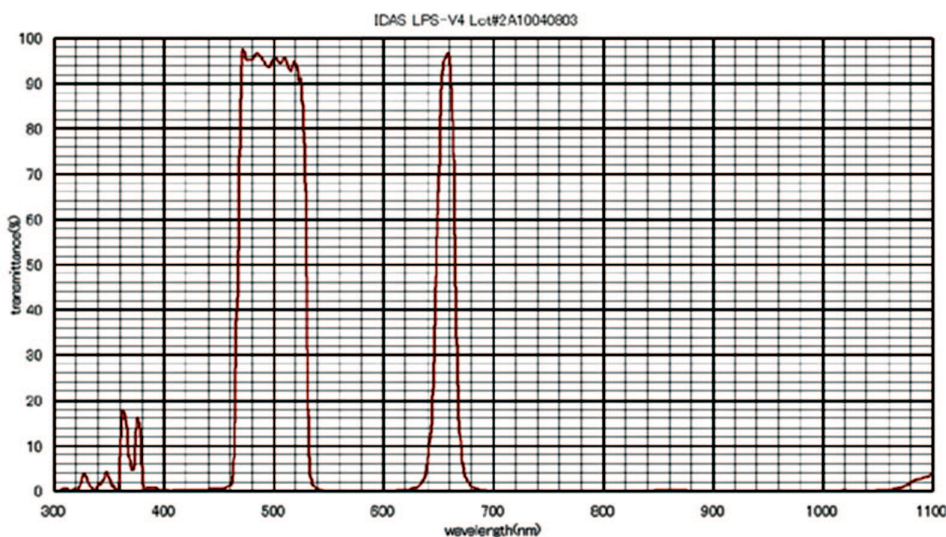

Figure 2 — Transmission plot of the IDAS LPS V4 filter

Encouraged by these initial results, I shot a variety of other deep-sky objects (Figures 4 to 6) with similarly pleasing results. All images shown are stacks of two or more exposures shot at ISO 800-1600, typically 3–5 minutes long, and then combined and processed in *Photoshop CS6*. Sadly, production of this truly fine telescope seems to have ceased. Hopefully, other manufacturers will step in and produce a similarly impressive and affordable short-focal-ratio refractor, perhaps even an ED doublet with better colour correction.

Figure 4 — The Double Cluster in Perseus is always a good star-test object. This IDAS-filtered image shows nicely rounded stars and only minimal edge distortion in the corners of the frame.

Figure 5 — The North America Nebula imaged with the CT-152 and IDAS filter with a full-frame, modified Canon 6D.

Figure 6 — (a) M8, the Lagoon Nebula, imaged with the CT-152 and IDAS filter. (b) M8 imaged with a TMB-130 ƒ/7 triplet apochromatic refractor and IDAS filter.

Do these results imply that you do not really need an expensive apochromat for deep-sky imaging? The answer really depends on your expectations. While the CT-152 images were surprisingly good, they do not quite stack up to those obtained with the smaller-aperture TMB 130, which has pinpoint stars, higher image contrast, and far more nuanced detail (Figure 6). However, my results do show that if you already own a quality achromat, perhaps an ED doublet, you might want to get yourself an IDAS LPS V filter or its equivalent and give imaging a try. You might be pleasantly surprised with the results. ✶

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Rising Stars

What Drove Ron Brecher Out of the House and Onto the Pages of the JRASC, *SkyNews,* and *Astronomy* Magazine?

by John Crossen
(johnstargazer@xplornet.com.)

When Ron Brecher's daughter was born, she brought, with her cute smiles, giggles, and coos, a trait shared by many newborns—night crying. Those tearful nights frequently found Ron walking up and down his driveway with his daughter, Chelsea, in his arms, looking up at the stars.

Ron had always been interested in astronomy, and these midnight treks rekindled his interest in the hobby, so much so that he eventually purchased a telescope using reward-club points. The idea was that he and his son, Todd, could see the Moon and planets up close while sharing some time together. Despite the telescope's myopic eyepieces, a tripod that swayed whenever a nearby sparrow broke wind, and a plastic finder best suited to stirring paint, Ron and his son persevered.

One night they stumbled upon Saturn. All it took was a first look at the ringed thing and Ron was mesmerized. Shortly thereafter, a friend gave him a copy of *NightWatch*, and Ron has never been the same since.

The first thing he discovered was that the telescope shown in *NightWatch* as a "Junk Scope" bore an amazing resemblance to the one he had purchased with those reward points. From that point on, Ron's adventures in astronomy followed a path familiar to many of us.

First came a better telescope, a Celestron Ultima 2000, followed in short order by better eyepieces, more books on astronomy, and if there was any money left, some camp gear for the inevitable summer star parties.

The Huronia Star Party and Starfest were Ron's launch pads. Those events provided him with the initial contacts and background to improve his observing skills. They also gave him an outlet for singing and guitar playing during the rare afternoon when he wasn't roaming the retail venues or taking in one of the talks.

Perhaps it was this artistic side that eventually pulled Ron into the astro-imaging camp. After all, words can only communicate a small portion of the night sky's wonders, but a picture can capture the sky's full magnificence and with it, the viewer's imagination. Ron started with the most basic equipment and

Figure 1 — Ron at his telescope.

technique available—a point-and-shoot camera held over an eyepiece that was trained on the Moon. Since those first Moon shots, Ron's skills as an astronomer and as an imager have risen as though propelled by an Atlas V rocket. In the span of a few years, Ron has become a seasoned deep-sky astro-imager and a valuable resource for others like him.

He has used numerous imaging systems and programs. And he has done so successfully from his home just outside Guelph, Ontario. Rather than an inky-black sky that we all dream of, Ron's night sky glows with car dealership lights and the usual light pollution brought on by a next-door neighbour that is a major city.

Nonetheless, Ron learned to circumvent the city lights using filters and processing to produce images that appear to have been shot somewhere on the sands of the Atacama. For the past two years, Ron has delivered seminars at Canada's AstroCATS festival in Hamilton. This year he returned to his old stomping grounds, Starfest, but this time he wasn't just another face in the crowd: he was one of the speakers. Rumour has it that he will be appearing at some major North American star parties in 2015.

Ron regularly gives talks on astronomy and astro-imaging to local astronomy clubs as well as at astronomy retailers. He has a following of fellow astro-imagers and admirers online who drool over his latest images. Ron's deep-sky images are now available for purchase from anywhere in the world via his Web site. Plus, he also offers one-on-one lessons on astro-imaging and image processing. Even so, Ron hasn't lost sight of the science behind the target he has imaged.

Every image he sends out to his online entourage is accompanied by a background summary of the science behind the object

Pen & Pixel

Figure 1 — Sadr (γ Cygni), in the middle of the Northern Cross formed by the constellation Cygnus, is a familiar star to summer Milky Way photographers, but this 4-hour image by Dan Meek shows it in an unfamiliar pose. The surrounding emission nebula, IC 1318, is crossed by numerous dark lanes of dust and gas in this exceedingly rich area along the galactic axis. Dan compiled this image using a NP127 telescope and a QSI583wsg CCD camera from Chain Lakes Provincial Park in Alberta.

Figure 2 — Bruce McCurdy of the Edmonton Centre sends us his "best shot" of the conjunction of Venus, Jupiter, and the crescent Moon above downtown Edmonton, acquired on the morning of August 23.

Pen & Pixel

Figure 3 — For people living in the southern hemisphere, the Southern Cross, formed by the four brightest stars in the constellation Crux, is a familiar sight. Almost as impressive is the dark patch lying to the lower left of the Cross, a dark nebula nicknamed "The Coalsack." The Coalsack is a cloud of light-absorbing dust and gas at a distance of about 600 light-years. Because of its apparent proximity and orientation to the Southern Cross, it is sometimes aptly referred to as the "Shadow of the Cross." Rick Stankiewicz sends us this image, taken while visiting Australia. Rick used a modified Canon EOS 50D and 50-mm lens at ISO 2000 with a 60-second exposure.

Figure 4 — The Winnipeg Centre's Ron Berard provides us with this composite image of the Milky Way above a Manitoba landscape. Ron collected 20, 30-second, untracked exposures of water and landscape to get a noise-free, starlit exposure of the scene, then combined it with a single 30-second exposure of the reflected starscape and a 5-minute, tracked exposure of sky. The several images were blended in Photoshop at the tree line. All were exposed using a Nikon D90 at ISO 800 with a Sigma 14-mm lens at ƒ/2.8. Brighter stars were further processed by making a layer mask of the sky with exposure gain turned down and saturation turned up to reveal star colours. A Gaussian filter was then applied to create halos.

itself. In addition to this celestial rap sheet, he includes the technical data involved in shooting and processing the object. His "techies," as he calls them, are also a valuable resource to others.

Ron invites anyone wishing to join his mailing list to contact him at www.astrodoc.ca and sign on. I've been on it for a couple of years and it is always a treat to view his work. Ron is now concentrating on imaging some less-familiar and very faint, deep-sky objects. With some 5000 objects in the NGC catalogue and 313 HII objects in the Sharpless Catalog, he has plenty of new targets to keep him busy for many years to come.

But Ron still keeps his eye to the eyepiece from the stepladder next to his 20-inch Dob, which is always set up in his garage. And, for night-sky quickies, he has the new (and greatly improved) six-inch scope that his son now lets him borrow—occasionally.

The journey that began in Ron's driveway has taken him quite literally to the stars. Along the way, he began to dream about doing astro-imaging for a living. Today he is beginning to see that dream has come true (though he is still working on the "for a living" part). ✶

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

Summary of the Visual Acuity Theory on the Origin of Aristarchos's 87 Degrees

by Alberto Gomez Gomez
(algomgom@gmail.com)

The Greek astronomer and mathematician Aristarchos (~310-230 BC) revolutionized our understanding of the cosmos. His half-moon experiment was designed to prove that the Sun is many times farther away than the Moon, and it put a lower bound for the Sun's distance. His ultimate take on the latter (as reported by Archimedes in the *Sandreckoner* 2.1) was "less than ten thousand Earth radii." The book he wrote explaining his figures is now lost, but the famous angle on which these are based has survived. The visual acuity (VA) theory on how he got this angle is summarized here.

According to Aristarchos, "When the Moon appears to us halved, its distance from the Sun is then less than a quadrant by one-thirtieth of a quadrant." Heath (1913:353) interpreted these words as meaning that the angular distance between what looks like a half moon to us and the Sun "is less than 90° by 1/30 of 90° [or by 3°] and is therefore equal to 87°."

This interpretation is correct, since this is the angle whose secant gives a solar distance that matches that ascribed to Aristarchos in *On Sizes* (Heath 1913:376) and in the *Sandreckoner* (1.9). (According to these sources, Aristarchos put the Sun somewhere between 18 and 20 times as far away as the Moon, and indeed 18 < sec 87° < 20, so this angle does the job.)

Heath applied his interpretation to the bright quadrant of the Moon. The original Greek text, however, does not exclude the other quadrant (that is, the dark one), so a Moon that is 93° from the Sun also appears to us halved. A wider interpretation is therefore that "the Moon appears to us halved when its
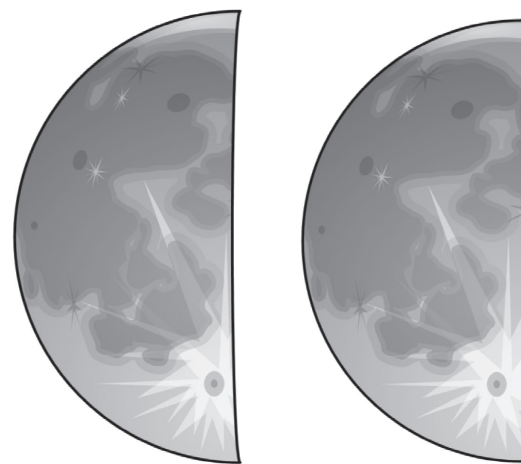
Figure 1 — These schematic drawings of the Moon at about dichotomy illustrate the limits of the human eye in determining the moment when the Moon is exactly at half phase.

distance from the Sun is either 87° or 93° [and of course anywhere in between]." So, according to Aristarchos, the Moon looks to us halved when its elongation from the Sun lies in the interval [87°, 93°]. Alternatively, it can also be said that the Moon looks to us halved when its phase angle is 90° ± 3°, spanning a total of 6°.

Why this angle should be chosen becomes apparent when noticing the connection between the typical resolution of the human eye—which is about *one* arcminute, the suggestive expression "*one-thirtieth* of a quadrant," and the width of the Aristarchan lunar disc—which is *thirty* arcminutes (or, as the *Sandreckoner* 1.10 put it, "one of seven hundred and twenty equal parts of the circle of the zodiac").

Could Aristarchos really have been using arcminutes this early in history? In July of 2010, the author (Gomez 2013:10,13,16) discovered that Archimedes's bounds for the Sun's width (in

Sandreckoner 1.16), though given to the nearest part of a right angle (as was then customary), had been generated sexagesimally, using the Babylonian system of dividing the circle into degrees and arcminutes or minutes of a degree. (Archimedes' bounds are simply 3′ either side of Aristarchos's own 30′ value.)

To this day, this finding constitutes one of the strongest proofs we have that at least some Greek astronomers had started to use sexagesimal degrees as early as the third century BC. The above connection between Aristarchos's 1/30 of a quadrant and the 30-arcminute-wide Moon constitutes yet another, especially since this choice of angle *explicitly* depends on whether it makes the Moon appear to us halved.

Indeed, choosing an angle wider than the 6° proposed by Aristarchos (that is, choosing a gap wider than one-thirtieth of the lunar disc) would result in the Moon appearing to us *not* halved (that is, either gibbous or crescent); then again, choosing a narrower gap would simply be asking bare-eyed observers to see what they cannot. (The latter would be a poor choice when trying to prove heliocentrism in field demonstrations; it's best to choose an angle that most observers can actually see and therefore not deny.)

The VA theory thus establishes a link between a change of 6° in the Moon's phase angle and a gap of one visual arcminute. Note that the former is an angle arrayed in three dimensions (from the centre of the lunar *globe* towards us) and the latter is a gap laid out in two dimensions (across the flat, lunar *disc*). The correspondence between these values is not exact (since the arcsine of the ratio of 1′ to the Moon's angular semi-diameter of 15′ is arcsin (1′/15′) ≈ 3°49′, which is not equal to 6°). Luckily, for observers on Earth, this difference is cancelled out almost completely by the effect of the Moon's daily wobble (caused by the Earth's rotation).

Because of this wobble, it takes nearly half a day (at about dichotomy) for the shadow on the Moon to sweep what looks like an arcminute of the lunar disc (to bare-eyed observers on Earth) and it takes almost exactly the same time for a change of 6° in the Moon's phase angle to occur (Gomez 2013:64). So Aristarchos's angle marks the moment when the Moon starts or stops to look halved to us, and can therefore be used to put a reliable lower bound for the Sun's size and distance. Had the human eye been able to see better than it does, a finer angle could have been chosen. This is just what Wendelin (Helden 1985:113) did in the 17th century when, with the help of telescopes, he repeated Aristarchos's experiment, improving previous estimates by more than 12-fold.

Further proof that Aristarchos knew about the limit of human vision is found in Proposition 4 of the book *On Sizes*, where there is a statement making clear that he took this limit to be less than one of 44 equal parts of a degree. As he put it (Heath 1913:371), "A magnitude seen under such an angle [of less than 1/3960 of a right angle] is imperceptible to our eye."

In *On Sizes*, this angle refers to a small gap between "great circles" sandwiching the point on the Moon's surface that is closest to Earth. (See diagram in Heath 1913:364.) This unquestionably proves that Aristarchos was familiar with the sort of calculations that involve applying the bounds of human vision to the analysis of gaps between great circles on the Moon; specifically, the one closest to us. The resemblance between this situation and that occurring at a half Moon, when the great circle of the shadow halves the Moon, is extremely suggestive.

The first person to put forward a connection between Aristarchos and human vision was the American astronomer-historian Dennis Rawlins, in whom the present author found inspiration. His approach, however, was like nothing that has been written here so far. So, what follows is a brief exposition of the original version of the VA theory on the origin of Aristarchos's figures.

According to Rawlins (2008:17), the limit of human vision is about one of 10,000 equal parts of a radian. This number comes from his reasoning that "the mean angular spacing of the cones at the foveal centre of the human retina is 0.4 to 0.5 arcminutes" (Rawlins 1982:263), and 0.4′ = (π/180 × 0.4/60) radians ≈ 0.0001 radians. So, following Rawlins (to the letter), we can say that the limit of human vision is 24″ to 30″ (which is another way of putting it).

He asserts that this value is "empirical" and he bases his theory on it. So, for example, a star subtending an annual parallax of this size is about 10,000 times as far away as the Sun, since cot (0.0001) ≈ 10,000. The shift of such a star could be spotted from Earth on a yearly basis, thus making it possible for bare-eyed humans to assess its distance at about 10,000 AU. This explains the size of the Universe ascribed to Aristarchos by Archimedes in the *Sandreckoner* (4.17)[1].

Rawlins (1991:170) also explains that Aristarchos may have found his famous angle by applying the visual limit of about 24″ or 30″ to the region departing by no more than this limit from *straightness* (that is, from the line whose points are all equidistant from both the centre of the Moon's disc and the point where the shadow bulges out most. This line perpendicularly bisects the semi-minor axis of the half ellipse formed by the shadow on the Moon's disc.). So Aristachos would have decided that the Moon looks to us halved when no point on the line separating the dark and the bright portions of the Moon is visually further than 24″ or 30″ from (the line called) *straightness* (Figure 2).

When this happens, the gap between the outermost point on the shadow line and straightness is 24″ or 30″ and that between the same point and the centre of the Moon's disc is twice as wide. From the time the Moon starts to look halved to us until it stops, the shadow spans four times the limit of human vision experimentally found by Rawlins. In short, the
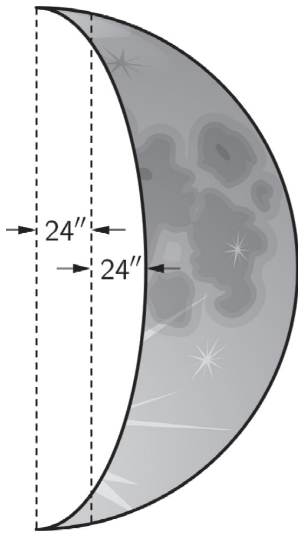
Figure 2 — Straightness, as defined by Rawlins, is the dashed line in the middle. For clarity of viewing, gaps are not to scale.

Moon looks to us halved when the shadow is less than 48″ or 1′ either side of true middle. This spans a total gap of 1.6′ or 2′ (of the 30′ making up the Aristarchan Moon).

This angular size corresponds to a spherical wedge of about 3° (since arcsin(0.8′/15′) ≈ 3°3′ and arcsin(1′/15′) ≈ 3°49′). This value is close to what Aristarchos described as just 1/30 of 90°.[2] Alternatively, Aristarchos's value is approached by the formulas arccos(0.8′/15′) ≈ 86°56′ and arccos(1′/15′) ≈ 86°10′.

So, Rawlins concludes that all the famous Aristarchan estimates for astronomical sizes can be explained as being based on taking the limit of human vision to be about 1/10,000 of a radian.

Since this angle is not plain to most people and since the use of radians is not attested so early in history, the author developed the alternative version of the VA theory on the origin of Aristarchan cosmology, which the reader met in the first part of this paper.

In order to help the reader decide which version of the VA theory makes more sense (if in fact any of them does), the author has created two interactive illustrations of each version, which may be found online by Googling the words *Rawlins' VA theory on Aristarchos*[3] and *Aristarchos' half moon*[4]. These illustrations can be used for testing the eye's ability to discriminate a half Moon on a computer screen, should the reader wish to do so. Just bear in mind that the fundamental difference between the two theories is that the total visual gap needed to tell a half Moon is 2′ in Rawlins's version and 1′ in the author's.

Also bear in mind that there is a huge gap between using computerized mathematical models of reality and reality itself. (The real thing is usually full of unexpected surprises!) So, no amount of playing around with any of these mathematical models can excuse the observation of the real Moon. Can you imagine what the effect of the different hues of grey on the uneven surface of the Moon is? Or, how the background of the sky figures? What about your own mind's expectations? Do they play a role? Is the observer's geographical position significant?

If you decide to take part in these observations and wish to share them with the author, please send your emails to the address provided. Both outdoor and indoor reports are welcome and will certainly help to decide between the two models presented in this paper, hopefully settling an age-long question. ✶

Endnotes

1 Notice that, to one decimal place, the cotangent of 24″ is 8594 and that of 30″ is 6875, which is not exactly the promised 10,000 figure, but again this is acceptable, since Archimedes insists that the sphere of the fixed stars is "less" than 10,000 times as far away as the Sun.

2 Note that Rawlins's method gets closest to 1/30 of 90º when a visual resolution of 24″ is used. Using a resolution of 25″ results in what an ancient Greek astronomer would likely describe as 1/28 of 90º and a resolution of 30″ results in what would be expressed as 1/24 of 90º. So the 24″ resolution is the one that works best here.

3 www.geogebratube.org/student/m144645

4 www.geogebratube.org/student/m6286

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Imager's Corner

Masked Stretching

by Blair MacDonald, Halifax Centre
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This edition continues a group of Imager's Corner articles that will focus on a few techniques that are useful in processing astrophotos. Over the next several editions of the *Journal*, I'll continue with a guide to several techniques that I find most useful.

In my last column, we looked at a way of using starless masks to bring out faint detail in an image. In this edition, I'll demonstrate how masked stretching can help to reduce noise in our images.

The basic idea is that the dim areas of an image tend to have the poorest signal-to-noise ratio. In order to keep this noise under control, we typically use inverse luminance masks and apply noise reduction at various stages of the processing. Masked stretching helps to prevent the noise in the dim areas from being stretched in the first place.

Let's use this 15-minute exposure of NGC 5982 (Figure 1). This image has had an arcsinh stretch applied and no other processing.

The first step in implementing masked stretching is to greatly stretch the image (Figure 2). Here I'm using *ImagesPlus*, so I like to use an arcsinh stretch, as it tends to limit star bloat.

Once the image is stretched, the feature mask tool is used to remove the stars in the image (Figure 3).

I must admit that the *Feature Mask* tool makes quick work of making the mask, but for those who don't have *ImagesPlus*, a slightly time-consuming but effective method for making the mask is on my tips page at www.nightanddayastrophotography.com/gallery/StarlessMaskGeneration.htm. The quality of the final image is very dependent on the quality of this mask, so take your time, remove the gradient, and clone out a few of the larger halos that remain. In this case, I've also made

Figure 1 — Noisy image
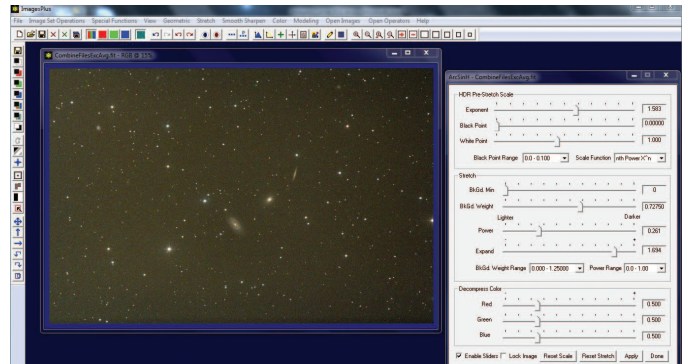
Figure 2 — Initial stretch

a pass at noise reduction to come up with the final mask for the next phase of the process (Figure 4).

Now return to the original unstretched image and stretch it again, but this time apply the mask to limit the stretch in the dimmer areas and prevent star bloat (Figure 5).

This produces the final image as in Figure 6.

Again, zooming in to the area around the larger spiral galaxy, you can see that the detail has been preserved, but the noise
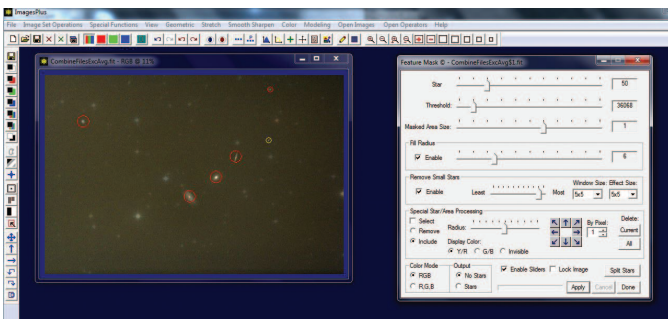
Figure 3 — Making the mask
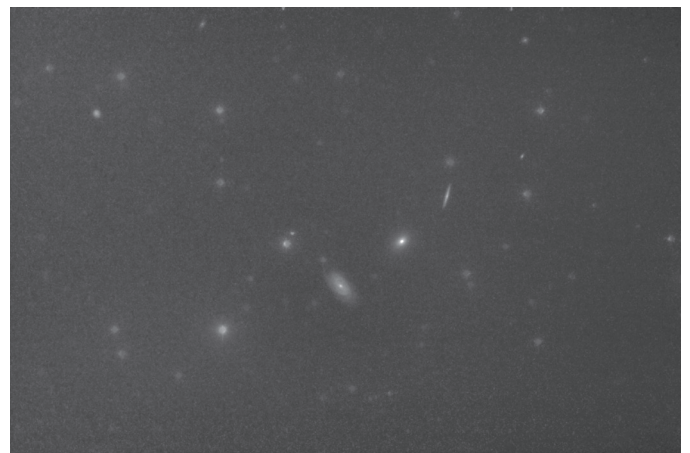
Figure 4 — Final mask
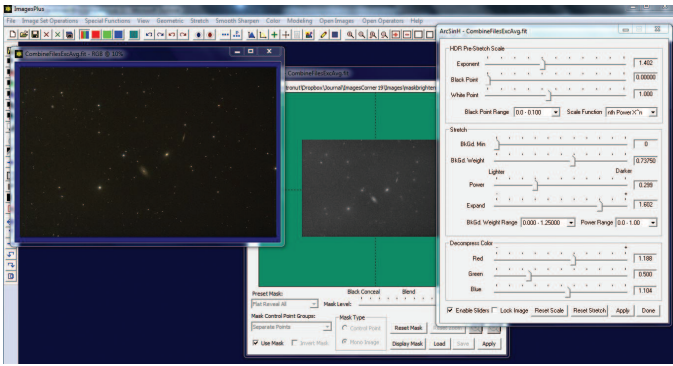
Figure 5 — Applying the masked stretch

Figure 6 — Masked, stretched image

has been greatly reduced. Compare this with a zoom of the original simple stretch from Figure 1 (Figure 7).

By limiting the stretch in the darker areas, the noise in the final image is limited, and star bloat is limited. Other than the noise reduction applied to the mask, no other noise reduction has been applied to the image itself.

From here, because of the low noise in the image, additional stretching and sharpening can be applied to arrive at a final image that would not be possible without the noise control offered by masked stretching.

Remember, this column will be based on your questions so keep them coming. You can send them to the list at hfxrasc@lists.rasc.ca or you can send them directly to me at b.macdonald@ns.sympatico.ca. Please put "IC" as the first two letters in the topic so my email filters will sort the questions. ✸

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

Figure 7 — A comparison of the original image and the masked, stretched image

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

John Percy's Universe

One World, One Sky

by John R. Percy
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International Year of Astronomy 2009 (IYA) was a celebration of the 400th anniversary of Galileo Galilei's development and first use of the astronomical telescope. As well as being celebrated very successfully in Canada (Hesser *et al.* 2010), it was commemorated in 147 other countries around the world. Many of these countries have no professional astronomers or astronomical research. Amateurs and educators "carried the ball." This reminds us that there is more to our science than professional astronomy and research.

Astronomy inspires awe and wonder. It has fundamental practical applications, and connections to history, philosophy, religion, language, arts, and culture. My favourite personal IYA project was my modest involvement in *The Galileo Project* [1], which was an outstanding fusion of arts, science, and the humanities.

Furthermore, there is more to astronomical research than the "big astronomy" done by the developed countries using billion-dollar instruments on the ground and in space. There is also "small astronomy" such as small-telescope research on variable stars (Percy 2013) that can be done by amateurs, students, and astronomically developing countries. Space activities, too, are carried out by many less-developed countries, thanks in part to the work of the UN Office of Outer Space Affairs [2].

Galileo Galilei, and the other figures in the Copernican revolution—Nicolaus Copernicus, Tycho Brahe, Johannes Kepler, and Isaac Newton—are well known because, in school and in public education, we teach about the Western science that has led to the science that we know today. But non-Western cultures have also played essential roles in the history and development of science, broadly defined. Astronomy has been an important part of society around the world, throughout time. It permeates philosophy, religion, culture, and language. Not many people realize that the calendars and religious celebrations of almost every culture are ancient and based on astronomy. Readers, you are part of a timeless, worldwide, astronomical community! We are *all* starstuff, and we have all shared in the same evolutionary development here on Earth.

Astronomy Through the Ages and Around the World

People have used the sky as a clock, calendar, and compass since before the beginning of recorded history. Astronomy was an essential technology. For instance: an impressive complex of dwellings and monuments, dating from 4500+ years ago, has recently been excavated on the remote Orkney Islands. It includes the Ring of Brodgar stone circle and the Maes Howe tomb, which is oriented to the setting sun at the winter solstice (Smith and Richardson 2014). Both new-agers and astronomers have erroneously read much more into such Neolithic monuments—especially Stonehenge. Proper interpretation requires an understanding of the culture and environment of the time and therefore a multidisciplinary collaboration with anthropologists and others. Nevertheless, it is clear that astronomical alignments are a common phenomenon.

In ancient Egypt, temples (such as Karnak, 3200 BC), monuments (such as the Great Sphinx of Giza, 3000 BC), and tombs (such as the Great Pyramid, 2540 BC) appear to be aligned with the compass points, reflecting the Egyptians' deep concern with the afterlife and the belief that the afterlife, and their pantheon of gods, was based in the sky. One of the most interesting recent discoveries about ancient Egyptian astronomy is that, three millennia ago, they had apparently observed the bright eclipsing variable star Algol and determined its period (Jetsu *et al.* 2013).

Figure 1 — The Ring of Brodgar, a Neolithic henge and stone circle in the Orkney Islands. Image: Wikimedia Commons/ Chmee2

Meanwhile, beginning about 700 BC or earlier, Mesopotamian observers were measuring the positions and motions of the Sun, Moon, and planets, developing mathematical models to predict these positions, and recording their observations, models, and predictions on clay tablets, presumably for religious and/or astrological purposes. Their astronomy was inherited by Hellenistic scholars—the Greeks, and others who shared their language and culture. By 400 BC, the Greeks were using the principles of geometry to determine the shape and size of the Earth, the relative size and distance of the Moon, including the fact that the Sun was many times bigger than the Moon and Earth. They realized that, if the Earth revolved around the Sun, some objects in the sky should show *parallax*—an apparent shift in position, due to the motion of the observer. They did not observe this effect.

Their more problematic achievement, attributed primarily to Aristotle, was to use "pure reason" to develop an Earth-centred model of the cosmos with four base elements—earth, water, air, and fire—and a perfect, unchanging *quintessence* of which celestial objects were made. This was the model that Galileo challenged and overthrew in 1609.

After Greek and Roman times, Western astronomy went into decline for a thousand years—the "Dark Ages." Fortunately, astronomy and other sciences remained alive in India, China, Byzantium, and the Islamic world. Essential concepts of mathematics were developed. Instruments and observatories were built—such as the great 15th-century observatory in Samarkand —and observations were made. Islamic observations played an important part in the work of Copernicus and Kepler. Chinese observers watched especially for unpredicted phenomena in the sky, and we now rely on their records for information about historical supernovae, novae, comets, and eclipses.

And in the New World

The classical Mayan civilization (flourished AD 300-900) was obsessed with time and so developed complex calendars based on both the Sun and on Venus. The development of these, of course, required systematic observation. Sadly, the Mayan accomplishments are now known mostly from pseudoscientific interpretations of the "end" or "turnover" of the Mayan calendar in December 2012—the "Mayan apocalypse." These interpretations were not supported by knowledgeable scholars of Mayan civilization and, of course, the "Mayan apocalypse" never happened. Likewise, the astronomy of the Incan civilization (flourished AD 1400-1600), including astronomical symbolism and alignments, was perverted by Erich von Däniken, in his popular but misguided books and documentaries. These are two more unfortunate examples of the appropriation of ancient astronomy by pseudoscientific fringe elements and the need to understand ancient astronomy within its cultural context.

Figure 2 — In October 2013, four young astronomers (all women!) from the University of Toronto conducted a one-week school in astronomy for 75 undergraduate students in Nigeria, using modern, inquiry-based methods of teaching. Photo courtesy of Dr. Linda Strubbe.

Pacific Islanders had a remarkable ability to use sky, land, and sea to navigate successfully over large distances and have been using these skills for hundreds, or perhaps thousands, of years. Their skill was noted and celebrated by Western explorers such as James Cook. Their knowledge was passed down orally, and still circulates among aboriginal Pacific navigators today.

Across North America, there are monuments and other artifacts that show that the native peoples observed the sky and used it for ceremonial and possibly practical purposes. Those monuments in the U.S. Southwest are especially numerous, well-studied, and publicized, but there are notable structures such as stone-circle "medicine wheels" elsewhere across the continent, including in Canada.

Canada's Aboriginal peoples have long used the sky for practical purposes. They knew and appreciated the relationship between Earth and sky, between the terrestrial and the celestial, and they incorporated the sky into their spiritual beliefs and ceremonies, as they still do today. This is also true of the Inuit, for whom the sky played an important role in their desolate Arctic environment (MacDonald 1998). An interesting application of these holistic views of science is *integrative science*[3], a way of "bringing together Indigenous ways of knowing and Western scientific knowledge"—an approach to education especially effective for Aboriginal people. The organizers of IYA in Canada made a special effort to establish effective, respectful partnerships with our First Nations communities (Hesser *et al.* 2010).

International Astronomy Development

Great civilizations have risen and fallen across time, around the world. Countries in Africa, which we would now consider to be undeveloped or developing, were once major sites of trade, culture, and learning. Currently, countries of the world

can be divided into those that are astronomically developed, astronomically developing, and astronomically undeveloped. In *every* country, astronomy already has some practical and cultural connections. The purpose of astronomical development is not to produce millions of professional astronomers but to use astronomy, through education, as a way to introduce young (and older) people to science and technology, to the wonders of nature, and to critical thinking, which are so important to the future of these countries. Several organizations are involved in astronomical development, notably the International Astronomical Union's (IAU) Commission 46 (Education and Development)[4], the Vatican Observatory Summer Schools[5], and, more recently, the Dunlap Institute at the University of Toronto[6]. The IAU offers an increasing array of development programs, mainly through its recently created Office of Astronomy for Development[7].

And in the supposedly astronomically developed countries, we are not so smart. Numerous studies, *e.g.* the Pew Research Center's 2013 "Public's Knowledge of Science and Technology"[8] show that, at least in the U.S., science literacy is mediocre at best. Over a third of Americans believe that astrology has some scientific basis and/or that the Universe was "created" a few thousand years ago and/or that space aliens have landed on Earth. Very few people understand the causes of simple astronomical phenomena such as seasons and lunar phases. About a quarter of Americans do not know that the Earth orbits the Sun.

How can you help? Do outreach (Percy 2014), and try to ensure that it reaches people of both genders, all communities, and all ethnicities, including our First Nations' peoples. In North America and many other countries, amateur astronomy has become the preserve of graying white males (like me); it needs to be diversified. Young people in our highly multicultural country need to know that astronomy can be, and is, done by all, for all. A follow-up project to IYA, *Beyond IYA*, specifically aimed to reach a wider audience—a real challenge. Find out more about international astronomy, and astronomical development. If your travels take you beyond the astronomically developed world, find out how you can support astronomical development there, as David Chapman did (Chapman 2014 and references therein). And remember: "the stars belong to everyone." ✶

Endnotes

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2 www.oosa.unvienna.org
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4 www.iaucomm46.org
5 www.voss2014.va
6 dunlap.utoronto.ca/education/west-african-summer-school
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Fun With Arduinos—Part 4

Controlling a DSLR Shutter

by Rick Saunders, London Centre
(ozzzy1@gmail.com)

In previous articles, I've built things like auto-guiders, focus controllers, and anti-dew heat controllers. This last Arduino article brings everything together for the imaging tinkerer: control of a DSLR shutter.

Shutter control for a camera that has a wired, remote port is fairly simple. The camera's circuitry looks at the various connections in the remote port, and if it sees one (or more) shorted to ground, then it performs a task such as a half press or full press of the shutter button. Some cameras require that the half press be active when the full button press is enabled, some don't. To keep things simple, I tied the two together, and so it will function with any DSLR that I've come across. This project provides both firmware and software.

I wanted to keep the inexpensive device that I built isolated from the expensive camera. This will keep any issues in the Arduino circuitry from making it through to the camera's circuitry. To do this I used an opto-coupler. These are chips that have an infra-red LED (or several) on one side and a photo-transistor on the other. When the LED lights up, the transistor passes current. As I wanted to control both the shutter (full press) and focus (half press) functions, I used a two-channel opto-coupler such as the PC827, though two single-channel chips would work. I tied both channels together on the input side so that both output channels "trip" at the same time. You can see this in the graphic (Figure 1).

Figure 1 — A schematic diagram of the shutter control unit.

The PC827's inputs are configured with the Arduino pin 13 connected to pin1. Pins 2 and 3 are tied together and pin 4 is connected to a 200-ohm resistor, which then connects to the Arduino's ground (GND). When the Arduino's pin goes HIGH, the two LEDs will illuminate, and the output side's transistors will activate.

The PC827's output in my circuit is connected to a 3.5-mm stereo jack (any other 3-lead connector will do). The two collectors (pins 8 and 6) on the PC827 are connected to the tip and ring. The two emitters (pins 5 and 7) are tied together and connected to the sleeve. Figure 1 shows one type of jack; if you find one that has different pins, then insert a 3.5-mm male-to-male plug into it, and check the pins against the male plug with a multi-meter.

For the Canon Rebel (or others that use a 2.5-mm stereo plug on the camera), pre-built cables are available on eBay. If you have something else, then the simplest way to make a proper cable for your camera is to buy a cheap manual remote on eBay, cut off the switch, and add the right plug for the jack used.

The device is completely USB powered and requires no batteries. Once it is connected to a computer, a serial port shows up. *Windows 7* and *8* should have the proper drivers.

Software

The software is fairly simple. First select the COM port for the device from the drop-down box and click the "Connect" button. If you have connected in the past, the software should show the correct port.

Figure 2: Breadboard layout during construction and testing.
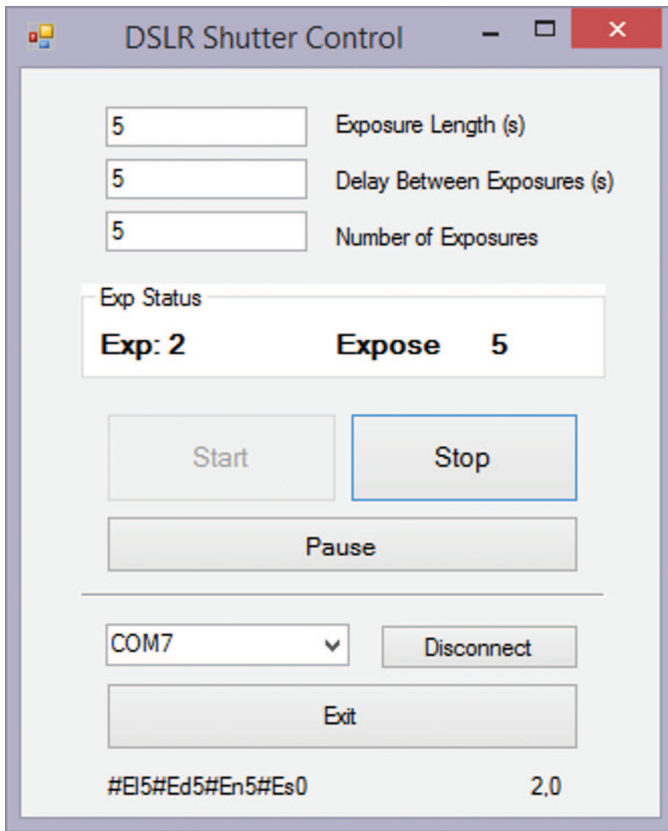
Figure 3: The input and output screen from the control software.

There are three text boxes for entering the length of exposure (in seconds), the delay between exposures (in seconds), and the number of exposures. When these are all populated with values, the Start button will be enabled. Click to start the sequence. To pause a sequence, click Pause. The Start button will show "ReStart." Click to resume the sequence. To stop the sequence, click Stop.

The status of the sequence shows up in the Group Box above the buttons. It will display the exposure number, whether it is currently exposing a shot or in delay, and the time left in the current function. At the bottom are shown the last serial command sent to the device on the left and the last serial data received on the right (Figure 3).

Everything you need will be on my Web site at www.togastro.com/ozzzy/ozinterval.zip.

Enjoy tinkering. ✴

Rick Saunders became interested in astronomy after his father brought home a 50-mm refractor and showed him Saturn's rings. Previously a member of both Toronto and Edmonton Centres, he now belongs to the London Centre and is mostly interested in DSLR astrophotography.

Great Images

Nicole Mortillaro captured the eclipsed moon of Oct. 8 in the arms of a construction crane from her home in Richmond Hill, Ontario, using a Canon 60d, 300mm f/5.6 lens at ISO 1600.

Second Light

The Early Universe Next Door

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

In the early Universe, there was very little other than hydrogen and helium. Almost every other atom (called "metals" by astronomers) was created inside stars and distributed through stellar winds, novae, and supernovae explosions. So the conditions under which star formation happened in the early Universe were very different from what we see in the Milky Way today. Models suggest that the first stars were massive, and that the efficiency of star formation—the fraction of gas converted into stars in a given period of time—was very low. But it is extremely hard to study star formation at high redshift. Fortunately, there are some relatively nearby galaxies whose "metallicities" (the abundance of atoms heavier than helium) are less than ten percent that of the Milky Way and which can therefore be used as proxies for the high-redshift galaxies. Yong Shi of Nanjing University, together with a group of collaborators from around the world, has studied the star-forming regions of two of these low-metallicity galaxies (Sextans A and ESO 146-G14) and found that the star formation efficiency is indeed very low—less than a tenth that of the Milky Way and comparable galaxies (see the 16 October 2014 issue of *Nature*).

This is a tricky problem. The normal way to study star formation is through use of the carbon monoxide molecule, which, at Milky Way-like metallicities, is the next most abundant molecule after hydrogen (H_2). CO radiates at ~115 GHz, and is easily studied using mm-wave telescopes (such as ALMA). But when the metallicity drops below about 1/3 of solar, CO becomes an unreliable tracer of gas. On the other hand, it's easy to observe atomic hydrogen using the spin-flip transition that emits at 21cm, and the distribution of star-forming gas can be studied using dust emission. But if there are no metals, then how can there be dust? This is indeed a big problem for the early Universe, but Shi needed only enough dust to trace the regions, which is not very much.

Shi used the Herschel Space Observatory (http://sci.esa.int/herschel/) at multiple wavelengths in the far-infrared region of the spectrum. The peak radiation for dust heated to ~30 K is a wavelength of about 100 microns. The hotter the dust, the shorter the wavelength of the peak emission. Observations at multiple wavelengths are necessary in order to determine the temperatures of the various regions of dust, and estimate the sizes of the dust grains. The grains can vary in size according to the physical conditions, and the temperature is related to grain
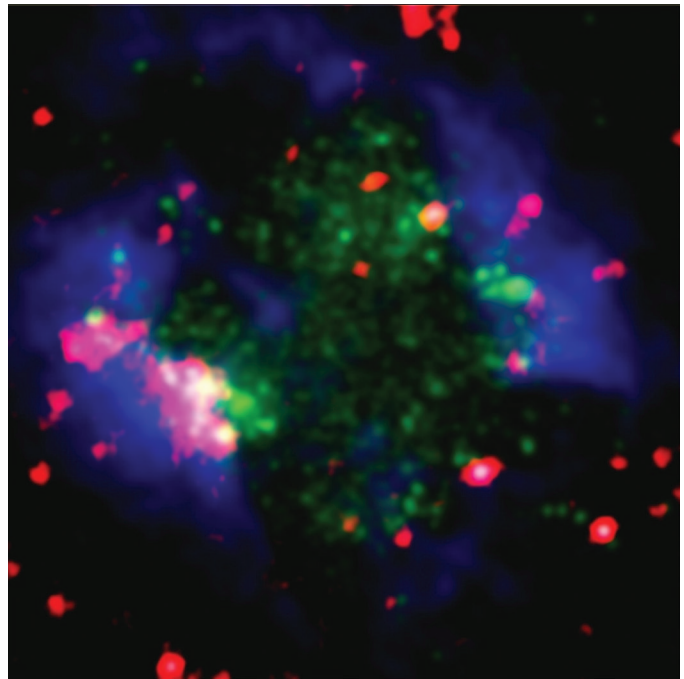
Figure 1 — A false-colour image of Sextans A, where the blue corresponds to the HI emission, the green is the far-ultraviolet emission, and the red is the far-infrared emission (which comes from the dust). The two large pink features are the largest star-forming clumps. Image courtesy of Yong Shi.

size in some size ranges. Shi could then calculate the mass of dust associated with the regions, correcting for the different temperatures and grain sizes.

Armed with maps of the distribution of dust and atomic hydrogen (using earlier observations by other people), Shi was able to estimate total gas masses. The procedure is rather complicated, so I will just explain the highlights. In regions where the gas is rather diffuse it is almost entirely atomic, and the gas is cold. Without young stars there is nothing to heat the grains. The gas-to-dust ratio in such regions is just a ratio of the observed mass of atomic hydrogen to the measured dust mass. One can then use the calculated gas/dust ratio as a multiplication factor for the regions where star formation is happening, where the gas is (usually) almost entirely in molecular form. Simply multiply the dust mass by the ratio, and bingo—you have the molecular gas mass. It is an observational fact that the gas/dust ratios do not vary substantially across galaxies, so the same ratio can be used to the precision astronomers are used to, which is about a factor of two.

Shi used some archival data from two different missions (*Spitzer*, in the mid-infrared, and *GALEX* for the ultraviolet) to calculate the star-formation rates. The efficiency is simply the star-formation rate divided by the total mass. For the four extremely metal-poor clumps in Sextans A and one in ESO 146-G14, the efficiency is a factor of ~100 smaller than in the Milky Way, and for two clumps in ESO 146-G14, it is a factor of 10 lower. These results are even lower than some theoretical

models have predicted, though the models typically assume that the star-forming gas is mostly atomic, while Shi infers a large amount of molecular gas.

If the gas in the star-forming regions is indeed molecular, it ought to have some CO associated with it, but the past observations of these galaxies were not sensitive enough to detect it. ALMA, however, should be able to detect it quite easily, in a fairly modest amount of time. It is possible that I will be able to report in a year or two that the CO has been seen.

So, we have had a glimpse of what the Universe looks like after the first generation of stars formed. We still do not know what the first stars were like, but I predict that we will be surprised—in astronomy we always are. The Universe has always proved to be weirder than anything we can imagine. ✶

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.*

Reviews / Critiques

How We See the Sky: A Naked-Eye Tour of Day & Night, by Thomas Hockey, pages 239 + x, 23 cm × 15 cm, University of Chicago Press, Chicago IL, 2011. Price $22, softcover (ISBN: 978-0226345772).

How We See the Sky is an overview of the sky and the phenomena that can be seen without optical aid, with "eyes and mind alone" (author's words). The author is interested in making the astronomy of the unaided eye accessible to everyone. Hockey, a professor of astronomy at the University of Northern Iowa, describes astronomy as a natural as well as a practical activity, with applications in navigation and time keeping. The book is much more than a practical naked-eye tour of the daytime and nighttime sky, and shows how astronomical phenomena have influenced human civilization. (Hockey has published on astronomical history and heritage, and is the general editor of Springer's *Biographical Encyclopedia of Astronomers*.) The author shows that, although we are generally not cognizant of how astronomy affects our lives, culture draws on the sky in many ways, as seen in language, myth, and metaphor.

How We See the Sky opens with a description of the sky and the movements of the Sun, then progresses through various topics before ending with phenomena that are not daily occurrences, such as comets and eclipses. Even though the astronomical aspects of the sky are divided into chapters, the author has created a very readable story that links the chapters into a thorough overview of the sky's astronomical details.

The first chapters present the celestial sphere, its apparent shape and extent, and the way we describe motions and locations on that intellectual construct. Next, several chapters explain the Sun and seasons, and how we have co-ordinated our lives with the various aspects of solar patterns for agriculture, as well as with its light and warmth. A separate chapter relates how seasons affect different peoples around the world, and points out how heliacal risings are the most important sky phenomenon in many cultures. Several more chapters describe the Moon and calendars, eclipses, and planets. A separate treatment discusses factors affecting our ability to understand what we see in the sky (including vision, light pollution, and twilight), and deriving the most out of our vision.

My impression is that most or all RASC members who read the book will very likely learn something new. For myself, I did not know that an almucantar is a circle of constant elevation on the sky, but now the concept of almucantars seems quite natural whenever I look at the sky and consider those circles. I did not know that the intersection of the ecliptic and the eastern horizon is called the horoscopium, or that a nocturnal refers to any device that indicates the time of night by the orientation of the circumpolar stars (such as the constellation Ursa Minor mentioned in the text). I was familiar with the method of estimating angular distances in the sky using an outstretched hand, and I have heard of a cross-staff used for measuring angles, but I did not realize that sailors of the Indian Ocean used a kamal for that purpose. I had not considered the origin of the planispheric volvelle, but the author's explanation of it adds to the general description and understanding of the angles that stars make with respect to the horizon.

A variety of other examples pertaining to details presented throughout the book that the reader may find informative or interesting includes the phases of Venus that might be seen with the unaided eye (according to Mesopotamian records), the Egyptian origin of the 24-hour day, and the fact that star colours are de-saturated and have significant amounts of white mixed with the pure colour. Besides explaining sundials and other instruments, including the ancillary sphere, the mariner's astrolabe, and sextant, the author also shows how to use a gnomon to find direction—and how Eratosthenes used such a device to find the circumference of the Earth.

Hockey presents a reasonable sample of astronomy and sky details as understood by various ancient civilizations and

cultures from around the world. The astronomical alignment of the Egyptian pyramids may be well known to most readers, but Hockey also provides examples of astronomical knowledge from native cultures of Argentina and the builders of Stonehenge and Newgrange (in Britain and Ireland respectively). References are made to astronomical knowledge evident in North American cultures, such as the Pueblo peoples in the southwestern desert regions, the more ancient Hohokam that resided in the modern state of Arizona, the builders of the Bighorn medicine wheel in Wyoming, and the Teotihuacan peoples that pre-dated the ancient Aztecs of Mexico. While constellations are probably familiar to the reader, the author also refers to the dark areas in the Milky Way and cultures that saw patterns in them, such as the aboriginal Australian constellations that perceptively formed patterns of cultural meaning out of those dark rifts. The difference in perspectives between the northern and southern hemispheres is illustrated when Hockey mentions the position of the Sun in the Milky Way and the resulting improved view of the centre of the Milky Way seen from the southern hemisphere.

The reader will most likely enjoy *How We See the Sky* for more than the information and perspectives presented in the author's light and personable style. The diagrams and photos are good illustrations that complement the text in topics such as obliquity, light pollution effects, and heliacal risings. In many cases, the author skilfully provides good descriptions of concepts without referring to illustrations, such as for relative motion and the rotating Earth, the equinoctial, acronical rising and setting, and stellar phase.

It is difficult to find any negative aspects of *How We See the Sky*. I found four typographical errors in the text, but they did not detract from the readability or accuracy of the material presented. The author's perspective is necessarily a geocentric view. That is appropriate for the observer's perspective of horizon phenomena such as sunrise and sunset, and the author correctly accounts for refraction and the resulting observable differences from perfect alignments. I thought that the description of tides was unnecessarily brief and could have been more thorough. In total, I thought that reasonable compromises were made in the amount of descriptive text and explanations for various phenomena.

Overall, *How We See the Sky* is an interesting and informative compilation of the various aspects of the night sky for sky watchers at any level of knowledge, from beginning stargazer to advanced amateur astronomer. It will be of greatest use to the amateur astronomer who has learned his or her way around the sky and is ready for a more thorough understanding of the fundamentals of naked-eye observing. ✶

Frank Dempsey, an atmospheric scientist by day, has been a RASC Toronto Centre member for over three decades. He is a long-time variable-star observer with an interest in all celestial phenomena. An Ojibway and member of Dokis First Nation, he has published on First Nations' starlore.
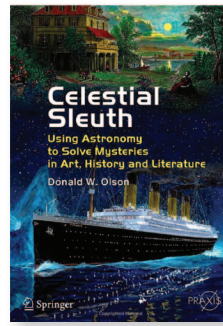
Celestial Sleuth: Using Astronomy to Solve Mysteries in Art, History and Literature, by Donald W. Olson, pages 355 + xvii, 24 cm × 17 cm, Springer Praxis Books, New York, 2014. Price ~$33, softcover (ISBN: 978-1-4614-8402-8).

Those who have been following Don Olson's articles on astronomical sleuthing in the pages of *Sky and Telescope* over the last two decades should welcome *Celestial Sleuth*, which collects all of his "cases" in one convenient location. The book also addresses a few of the questions that typically circulate on the RASC list, such as the origin of the term "Blue Moon," and so is of inherent interest to the average astronomer. Unlike astrophysical problems, which can entail analyses of observational clues of dubious reliability using techniques of uncertain applicability, the problems addressed in *Celestial Sleuth* are tied to basic astronomical phenomena. The problems relate to the location of the Sun, Moon, or bright planets in the sky at specific times of the day or night, peculiarities in terrestrial tides, and atmospheric phenomena of interest to sky gazers—all good stuff that should captivate the interest of the curious.

I had heard Olson give an invited lecture about some of the cases in *Celestial Sleuth*, so was interested in obtaining a copy of the book to peruse its full contents. Olson has organized all of his published cases, and perhaps a few others, into three broad categories: Astronomy in Art, Astronomy in History, and Astronomy in Literature. Each category is further subdivided into individual chapters according to a common thread. Astronomy in Art includes: Monet and Turner, Masters of Sea and Sky; Vincent van Gogh and Starry Skies Over France; Edvard Munch and Mysterious Skies Over Norway; and Yosemite Moonrises and Moonbows, the last of which investigates the photographs of Ansel Adams that contain astronomical scenes. Astronomy in History includes: Moons and Tides in the Battles of Marathon; Paul Revere's Midnight Ride; the Sinking of the *Titanic*; Lincoln; the Civil War Era; American Almanacs; and The Moon and Tides in World War II. Astronomy in Literature contains: Literary Skies Before 1800; and Literary Skies After 1800.

The prior publication of most of the cases in *Sky & Telescope* means that they are essentially reprinted in *Celestial Sleuth* as they originally appeared. Since Olson tended to use the same writing formula for most of those articles, it means that common phrases and questions are repeated frequently in the book, which rapidly becomes tedious for the reader. Similar phraseology also repeats frequently in each study, adding to the tedium. In most cases, it appears to be assumed that the reader has access to the same or similar desktop planetarium software for replicating the sky scenes for particular dates. Access to Google maps or a good atlas also seems to be

assumed, since no maps are included in the text (sadly). They would have made an excellent accompaniment to most articles, given that terrestrial location and date prove essential for a full understanding of the astronomical arguments.

Chapter one contains arguments used to identify the dates and locations for paintings by Monet and Turner in which celestial scenes are depicted, while chapter two tackles the identification of locations and dates for paintings by van Gogh that also contain celestial scenes. Olson takes pains to use historical and archival material to bolster his identifications. They are not based on planetarium software alone. Chapter three tackles the dates and locations of paintings by Edvard Munch of similar nature, beginning with *The Scream*, for which Olson solidly identifies a site for the painting near Oslo, Norway, that differs from the location adopted for the historical marker.

Olson then tackles a few other Munch paintings, of which *Starry Night* is the most mysterious, since it seems to portray constellation scenes fairly closely. Olson uses literature sources and what he identifies as the Pleiades cluster and the planet Jupiter in the painting to date the painting to late August 1893. But the "Pleiades" identified in the painting is a swarm around what looks like the star Delta in the W-shaped configuration of Cassiopeia, tilted correctly as seen in the early evening sky of late August. There is no indication of any stars belonging to Taurus, the parent constellation of the Pleiades, in the painting, while the bright star identified as Jupiter by Olson seems to lie close to where Alpha Persei is located relative to Cassiopeia. I would be interested in hearing from other readers of *Celestial Sleuth* about their thoughts. The chapter does end on an interesting note, as it deals with optical illusions resulting from viewing the same celestial object in the sky and in reflected light off a smooth, watery surface.

Chapter four considers the photographs of Ansel Adams that contain celestial scenes, ending with a discussion of moonbows as also witnessed by Mark Twain. The visit of Olson and his students to Yosemite for their detective work on Adams's photographs reveals their true life experiences, complete with their frustrations and unexpected discoveries. Librations of the Moon play an important role in defining the dates of Adams's photos, and are discussed thoroughly.

Chapter five begins the section on Astronomy in History with an unusual choice: the Battle of Marathon in Greece in the summer of 490 BC. I had not realized that the date of the battle revolved around an astronomical puzzle, but it turns out that understanding the Attican and Laconian calendar systems, and luni-solar calendar systems in general, is essential. The Athenian year began with the New Moon immediately following the summer solstice, while the Spartan year appears to have begun with the New Moon immediately following the autumnal equinox. How months in the two systems aligned in specific years can be used to explain why Sparta was not represented at the Battle of Marathon, in Attica, since they were still

celebrating the festival of Apollo Karneios, held during the first half of their month of Karneios, the eleventh month in their system. Fitting that into the Athenian calendar system, like a piece in a jigsaw puzzle, allows Olson to explain why the Athenians fought the battle unaided, except for a thousand Plataean allies, why the Persian fleet was still on the scene and had not yet retired across the Aegean, and why the Marathon runner is said to have died after completing his run, essentially because the battle took place in early August according to Olson, rather than mid-September as argued by others.

The remainder of chapter five discusses problems revolving around the where and when of Julius Caesar's invasion of Britain in 55 BC, the nature and timing of tides in Boston Harbour at the time of the Boston Tea Party in December 1773, and the specific details of Paul Revere's crossing of the Charles River in Boston in April 1775 and how he managed to escape being spotted by lookouts on the British ship Somerset. All are cases where tide times or location of moonrise are vital to understanding the situation, but, again, maps would have been useful here. The chapter ends with a discussion of whether or not the Moon played a role in the sinking of the Titanic in April 1912, noting a rare coincidence of perigees for Earth's orbit and the Moon's orbit with a Sun-Earth-Moon near alignment (full Moon) on 1912 January 3-4, that resulted in maximum tidal effects at that time, *i.e.* maximum tidal fluctuations in ocean water levels. The coincidence is lessened by Olson's subsequent discussion of times of passage for icebergs between their calving sites in Greenland and the North Atlantic, but is still interesting to consider.

Chapter six is devoted to Abraham Lincoln's famous "almanac trial," his described experience of the 1833 Leonid shower and Donati's comet of 1858, the evolution of the *Farmer's Almanac*, the origin of so-called Blue Moons, and how the phase of the Moon may have played a role in the death of Confederate general Stonewall Jackson at the Battle of Chancellorsville in May 1863. An extra feature is a discussion of a daylight sighting of the planet Venus during Lincoln's second inauguration in March 1865. These cases make very interesting reading.

Chapter seven is an interesting section dealing with the Moon and tides during World War II. Covered here is the lunar phasing during the Japanese attack on Pearl Harbour, restrictions on tide timing for the U.S. Marine landing on Betio in the Tarawa Atoll, the tide timing for the D-day landings in Normandy, and how moonlight helped contribute to the disastrous sinking of the *USS Indianapolis*, the cruiser that delivered the Hiroshima atomic bomb to Tinian. Having seen the PBS documentary on the sinking of the *Indianapolis*, with its horrific consequences for the crew members who survived the sinking and subsequent shark attacks and harassment for far too many days, I was curious about the circumstances surrounding the torpedo attack by the Japanese submarine *I-58* that led to the loss of the cruiser. Everything is clarified

by Olson's summary, although again a map would have been useful. The *Indianapolis* was ordered to sail from Guam to Leyte following delivery of the A-bomb, so took a course almost due west into the area where the *I-58* was lurking on patrol. The fact that *I-58* was almost on the *Indianapolis*'s course and that it surfaced following moonrise on a night when the *Indianapolis* was nearby and easily visible in the reflected glitter of the waning gibbous Moon, made the sinking inevitable, although much was made afterwards about the cruiser not sailing in a zig-zag pattern. Given the description of events and the course of the *I-58* in *Celestial Sleuth*, it would appear that such a course would only have delayed the inevitable. Olson's description of how events were governed by the effects of moonlight brought a much better appreciation for the sinking than that left by the PBS documentary.

I found Olson's deferential attitude to the U.S. Marine Corps and Navy when describing the events at Betio overly apologetic. Olson correctly notes that information on the tides at Tarawa was not known to World War II planners. Problems arose with the landings at Betio because high tide was abnormally low on 1943 November 20, preventing Marine landing craft from clearing the barrier reef protecting the island. Many lives were lost by the attacking force because of that. But Olson points out that tides are abnormally low when the Moon is furthest from Earth (apogean tides) and the Sun and Moon are in quadrature (neap tides at quarter phases), then calculates that there were only two dates during 1943 when such conditions applied: April 12 and November 19. The decision to land at Betio on November 20 was therefore poorly justified. Olson's calculations in this case did not require special software. The same information could have been gleaned from the *Nautical Almanac* if the Navy had consulted an astronomer. Julius Caesar and Pope Gregory consulted astronomers when they contemplated calendar reform, but its neglect in this instance resulted in many needless deaths.

Chapters eight and nine that follow are rather anticlimactic, discussing astronomical references in the literature before and after 1800. The list before 1800 includes a possible sighting of the zodiacal light referred to as a "false dawn" in *The Rubaiyat of Omar Khayyam*, a description of the unusually high tides on the coast of Brittany by Chaucer in *The Canterbury Tales* (the tides in Brittany and Normandy are affected in similar fashion to those along the Bay of Fundy coast of Nova Scotia), Shakespeare's inclusion of Tycho's supernova of 1572 in the opening paragraphs of *Hamlet*, and a possible reference to meteor showers or a spectacular fireball in William Blake's *The Tyger*.

The list after 1800 includes an interesting discussion of possible dates when Mary Shelley conceived of the plot line for Frankenstein, Walt Whitman's *Year of Meteors*, and the unusual Earth-grazing fireball referred to in James Joyce's *Ulysses*. I found it remarkable that Olson was able to take most of his class on the outings used to check the predictions used for his cases. Did the students, external research support, or his university supply travel stipends to get the entire class to the European locations investigated in *Celestial Sleuth*? Such extravagance would not be possible at my own institution.

Celestial Sleuth makes good reading for those interested in solving astronomical puzzles, but make sure you have reference material handy for maps and star charts. The layout of the book in terms of individual cases also means that the reader can skip from case to case in random order, without concern for the ordering arranged in the text. All in all, it is a good read, and a good source for individual insights. ✴

David Turner acted as his own celestial sleuth when he managed to decipher the hidden meaning behind the chancel ceiling star pattern emplaced in the original 1870 renovations of Saint John's Church in Lunenburg, Nova Scotia. That discovery led to the present replication at Saint John's, as featured on the Discovery Channel, as well as an ongoing investigation into the origin of the ideas that led to the original artwork.

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Letter to the Editor

A New Observing Challenge

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Carr Astronomical Observatory (CAO)
Committee co-chair RASC Toronto Centre http://rascto.ca/
National Observing Committee member
(blaken@computer-ease.com)

RASC members:

If you know me, you know I love looking at double stars and multi-star systems; I've viewed over 440 in my career. And slowly, I'm sticking my toes in the deeper waters of imaging and the accurate measurement of double stars.

In the meantime, I've built a list of candidate double-star and multi-star targets. This list might become the basis for a future RASC double-star observing certificate program.

I have over 150 candidates and I'd like to reduce this to a number typical in an observing program. I believe there's a good mixture of easy, challenging, and difficult choices—not only pairs, but some triples and quads, both of equal and of very different magnitudes, some plain and some colourful. Some of the doubles might be too low for our Canadian latitude. Some might be far too tight to resolve (not that splitting cleanly is a requirement). I've tried to choose targets that would work in 3-inch and 6-inch telescopes, but the list must be tested. After testing, some stars will be removed.

I'm looking to build a small team of enthusiastic and experienced double-star observers who will help me shake down the candidate list. I'd like each team member to view a variety of the candidates and report if they are good or poor choices for an observing program. One does not need to view all 150 entries; we will split up the checks across all the team members. These stars are sprinkled across the whole sky, *i.e.* some are in winter constellations. Testing will take some time, quite possibly a year.
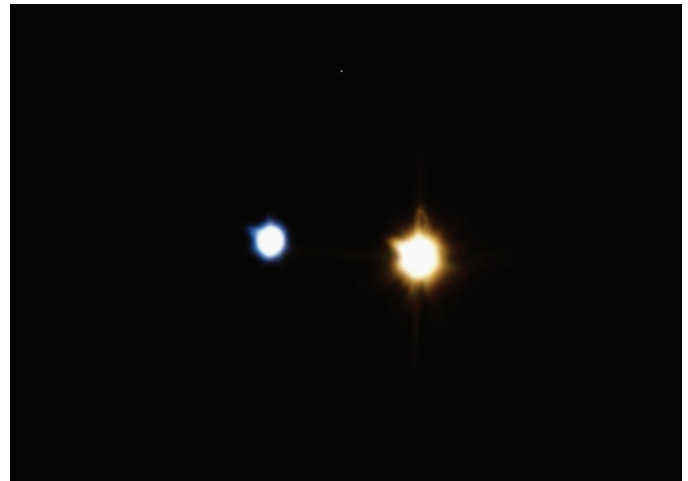
Figure 1 — Double star Albireo, http://boson.physics.sc.edu/~melton/dsgallery.html

So, are you interested? Would you be able to help me out over the next twelve months? Could you view a couple dozen or so multi-star systems from the candidate list? That's a significant time commitment. Then again, maybe you've already viewed and logged some!

I'd like the volunteers to send brief reports. I don't need detailed descriptions, position angles, accurate separation values; just an evaluation like "Nice double" or "That's a cool triple" or "I don't see any double star in the field." An experienced observer's impression of the quality of the candidate is what we need.

Do you have a variety of telescopes and eyepieces that you can use? Ideally, that would be a 6-inch or smaller aperture. If you don't have a small 'scope, that's OK, as you could choke down your big OTA with an easy-to-make aperture mask. What is needed is an array of oculars. Doubles require viewing at different powers so that we can say things such as "I could split it no problem at 100× in the 80-mm telescope."

Curious? Questions? Ideas? I look forward to hearing from you. It would be a pleasure to offer RASC members across the country some new observing goals.

Regards, Blake ✳

Is your address correct? Are you moving?

If you are planning to move, or your address is incorrect on the label of your Journal, *please contact the office immediately.*

By changing your address in advance, you will continue to receive all issues of SkyNews *and the* Observer's Handbook.

(416) 924-7973   **www.rasc.ca/contact**

Society News

by Karen Finstad, National Secretary
(nationalsecretary@rasc.ca)

One Sunday last March I was sitting innocently at home, putzing away on the computer with my dog Herschel lying quietly at my side, basically minding my own business. The phone rang, and a voice introduced himself as James Edgar (then National Secretary and now Fearless Leader). I admit I didn't immediately recognize the name, so when he told me the reason for his call was to ask if I'd be interested in taking over his position, I was—not to put too fine a point on it—flabbergasted.

I first joined the Edmonton Centre in 1974, as a physics undergrad, and have maintained my membership ever since. Meanwhile I studied astronomy and then cloud physics as a graduate student, followed by 18 years living in the U.S. I joined the Ottawa Centre on moving here about seven years ago, but have probably been their least-active and most-invisible member. I didn't know anybody on the National Executive, or even realize that it is now called the Board of Directors.

So why me? *I still don't really know.* Why did I say yes? The short answer is that I thought it would be good for a giggle. I also knew, from previous experience on not-for-profit boards, that it would be a ton of work, done for free. But then the RASC is close to my heart, and I was curious as to what goes on at the National level.

Now here I am, an utter newbie, learning from the ground up. Let's start with my job. I take minutes at all meetings of the Board and the Council. At the GA last June, I took notes during 11.5 hours of meetings. It was not boring. There were contentious issues and juicy interactions (read the minutes online). There will be 15 to 20 meetings a year, each with an agenda to be distributed and minutes to be written and posted. I also have to keep the Policy Manual, By-Laws, and Committee membership lists updated, keep track of correspondence, administer a dozen active email lists, and run the Public Speaker Program. Then there's writing this column and doing my share of Centre visits, not to mention the biggest job of the year: preparing the Annual Report. And that's only what I've discovered so far.

Yes, some of that's tedious. On the other hand, I'm meeting many new people, getting re-acquainted with old astrofriends, learning much about RASC history, publications, and educational initiatives. For all you other invisible members out there, consider me your mole on the inside, your guide to who's who on the National scene and what it is they do. My first impression? They are just human, but they all seem smart, and they work very hard.

In future contributions, as I continue learning this job, I hope to tell you more about the people who keep the RASC running, what they do on your behalf, and how they spend your dues. Stay tuned. ✶

Stars by the Sea!

2015 Royal Astronomical Society of Canada
GENERAL ASSEMBLY
HALIFAX, NOVA SCOTIA JULY 1–5
Full details at www.rasc.ca/ga

Astrocryptic

by Curt Nason
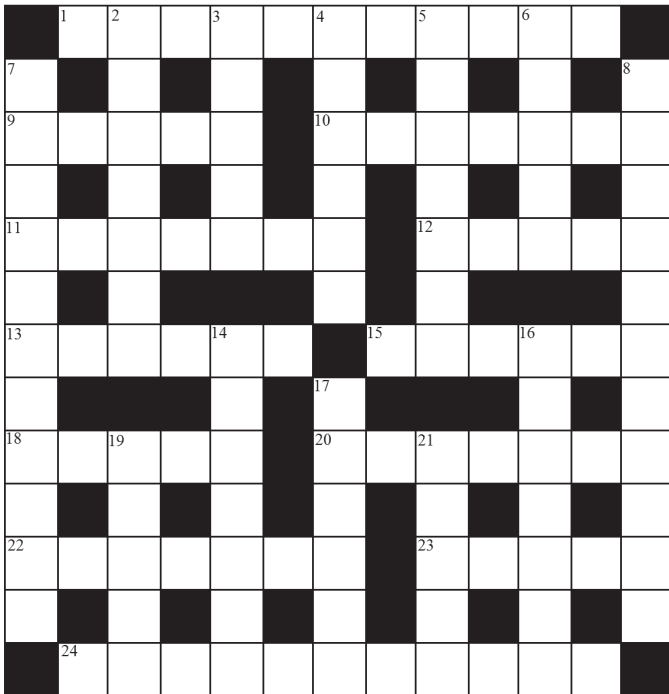
ACROSS

1. Sinuously peel to music under a constellation (11)
9. Vast lunar plain from Tippecanoe (5)
10. A comet probe rotates, rotates (7)
11. A Greek character in comic Ron James's act (7)
12. Dinner's served holding planets like Mercury and Venus (5)
13. Binary solar type in Dave's program starts pulsating in dish (3,3)
15. Inexpensive imager we initially begin calibrating before morning (6)
18. Okay, a mathematical ratio describes a relative of Camelopardalis (5)
20. Operator sat for camera with Jupiter rising at sunset (7)
22. Genius is confused about round and solid molten rock (7)
23. Volcanic moon enters virtual reality after a star in Carina (5)
24. Reassemble a rare mount I saw in an old star atlas (11)

DOWN

2. Smoothing a stellar name for Venus (7)
3. Hertzsprung ran back to catch the receding jet, losing time (5)
4. Light phenomenon, not necessarily light beer (6)
5. I'm in a sticky situation with my astronomy hobby (7)
6. Century-plus star atlas is not down and not back (5)
7. No cot is more rare than one belonging to a unicorn (11)
8. Our galaxy writer puts ad in Drew (5,6)
14. Fabulous creature separates the dogs in winter (7)
16. Rocking Mama leading in one ring division (7)
17. Serling backs away from total lunar ridge (6)
19. L'il comic guy developed brane theory (5)
21. Earth's beginning lost from Mercury or Venus vegetation (5)

Answers to October's Astrocryptic

ACROSS

1 LASER (Al, rev + ser); **4** JACQUES (2 def); **8** TRANSIT (anag); **9** POLAR (2 def); **10** INERT (i(ner)t); **11** RADIANT (anag); **12** MURRAY PAULSON (anag); **16** RUSSELL (R(slues, anag)l); **18** SAGAN (S(a GA)N); **20** MATAR (ram, rev around at); **21** IMAGING (imagine, swap e for g); **22** EMERSON (anag); **23** PAEAN (P(AE)an)

DOWN

1 LITHIUM (lit + h(i)um); **2** SPACE (2 def); **3** ROSETTA (treats, anag around o); **4** JET PROPULSION (anag around l (lunar start)); **5** CUPID (2 def); **6** UPLOADS (anag around o (hole)); **7** SPRIT (Spirit - 1=i); **13** ROSETTE (anag); **14** UNSHARP (sun, anag + harp); **15** NONAGON (no(nag)on); **16** RIMAE (lip (rim) + ea, rev); **17** EUROS (sure, anag around o); **19** GUIDE (2 def)

It's Not All Sirius

by Ted Dunphy

Try moving your azimuth sir, and let me have a look!

Great Images
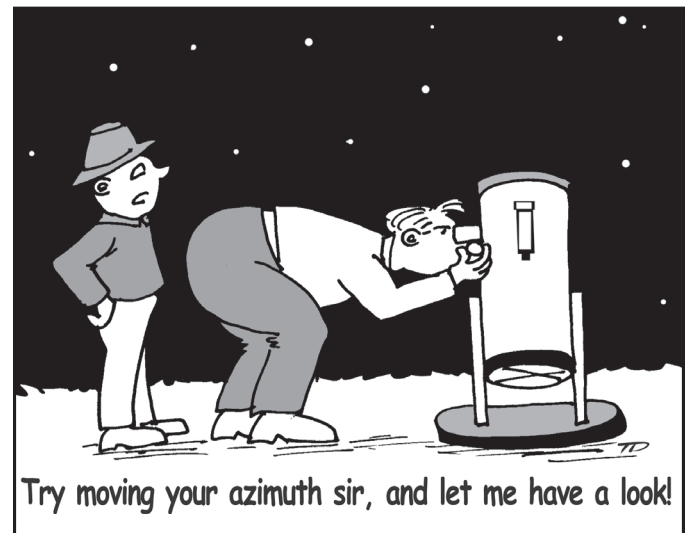
Is this the second solar analemma *ever* photographed from a location in Canada?

Find out more about this incredible image by Edmonton member Luca Vanzella, in a future issue of the *Journal*.
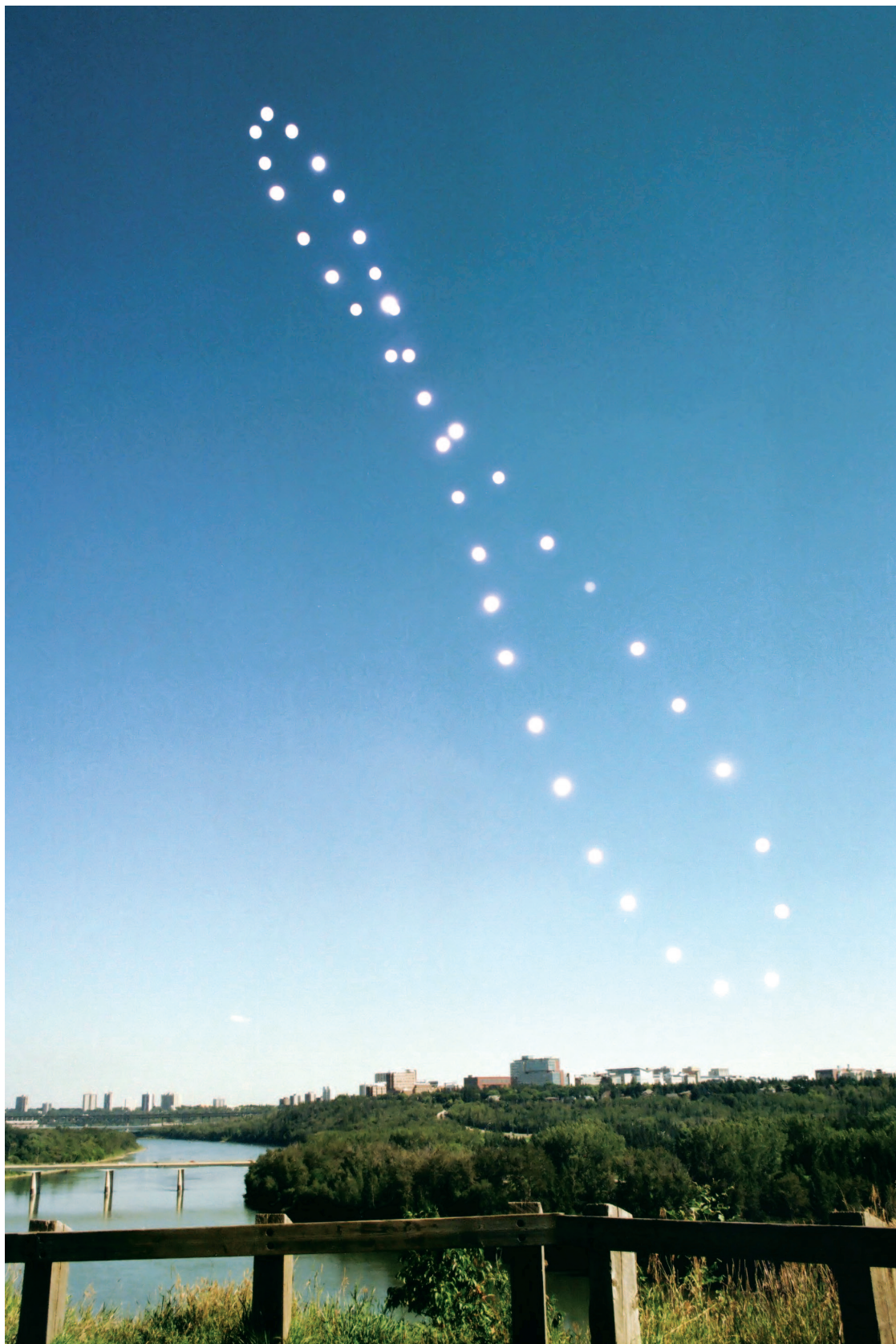
Figure 1 — The Solar Analemma over Edmonton (on a single frame of film). This is the composite film image, consisting of 38 separate solar exposures from 2013 September 20 to 2014 September 13 and a foreground exposure on 2014 August 11, all on a single frame of film. Each solar image was taken at 9:50 a.m. at St. George's Crescent in Edmonton. All images were taken using a Canon A-1 film camera with a 28-mm focal-length lens. The solar images were typically at 1/125 sec at ƒ/22, ISO 200. The camera was mounted on a tripod head affixed to a custom wooden mount that was placed on a park bench.

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Great Images

IC 443, the Jellyfish Nebula, is a supernova remnant (SNR), the spreading aftermath of a star that exploded 8000 years ago. The Jellyfish is unusual in having a compact structure on one side and a diffuse filamentary appearance on the other, instead of the more usual symmetry exhibited by most SNRs. Duncan Wilson captured the Hα photons that comprise this image through a Lunt 70-mm telescope with an Atik 460 camera and an exposure of 10×900 seconds.

Journal

Great Images

Using a TEC 140 telescope at ƒ5.3 and an FLI ML8300 camera, Lynn Hilborn acquired this image of Abell 1656 (Coma Cluster), a cluster that contains more than 1000 galactic members, from his WhistleStop Observatory at Grafton, Ontario. Exposure was 23×10m in L, and 9×5m in each of RGB.