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Roger Hill, Editor

I don't know about you, but I'm getting excited about the Big Event next year—the Total Eclipse of the Sun in August. I'm fortunate to have seen three in the past: 1972, 1979, and 1991. I've seen quite a few partial eclipses and the annular one in 1994. I'm also looking forward to seeing Les Nagy and his wife, Paola, who are coming up from Chile for this. Les has twice been in the path of an eclipse: Shanghai in 2009, and Tahiti in 2010. Les was clouded out at both events, though. We're both hoping that it's my string that continues, not his!

We plan to view the eclipse from Nebraska at a KOA campground that will see several Hamilton Centre members join a large number of people from several other RASC Centres from London to Halifax. Initially, I had thought of renting a large travel trailer in Ontario, and dragging the thing 1700 km west (and back again). Thinking about it, though, it made sense to rent the trailer in Nebraska. We'll leave Milton early on Friday, the 18th, and drive to Lincoln, Nebraska, staying overnight. We'll pick the trailer and drive it to our base camp near Grand Island on Saturday the 19th. Les and I also had a look at other places we could go to after the eclipse. We had a look at Grand Canyon, which is about 18 hours away and Yellowstone, which is 12. Since we wanted this to be a vacation, rather than just driving around, we opted for Yellowstone, and Old Faithful. I've always enjoyed geology, and the chance to see active geology was too hard to resist. Although there are geysers in Chile, at a place called El Tatio (14,000 above sea level), the best time to view them is at dawn, when the air is cold and the contrast is high as the sun rises. The problem is that this means missing out on viewing the stars, so I've never made it to El Tatio, although if I ever find myself in San Pedro de Atacama in Chile at Full Moon, the geysers there will be high on the list.

So...Yellowstone was added as a destination, but at 12 hours away, we felt that this was still a bit far for a single day of driving, dragging the trailer, so we looked at some place to stop about half-way. The Devils Tower stood out, although it will add about an hour to the trip. It's a cool place, and I've stayed at the KOA campground there. The skies are pretty dark, the campground is nice and they show Close Encounters of the Third Kind every evening!

The search is now on for a stop on the way back from Yellowstone to Lincoln. Perhaps in Cheyenne, near the border with Colorado, or Mount Rushmore.

Regardless, it's shaping up to be a great trip.

Also coming up next year we'll be running the NOVA (New Observers to Visual Astronomy) course again. It was put on hiatus this past January, as we were waiting for the revamped course from National, or this coming January, whichever came first. The textbook for the new course is now available, but they are still working on the course itself. So, since there have been several inquiries, the old course will be run one last time, starting in late January or early February, depending on my schedule. I'll try to run it every two weeks, but sometime weather or other circumstances will force a change. I'll be running it on Monday nights, as before. You can find further details about the course further inside Orbit.

So, that's about it for this month. See you at a meeting, or at the Observatory.
Roger

Front cover photo from Jeff Booth. See Page 3 for more about it. For more discussion, head to the Forum...there's some really cool astronomy stuff being talked about

And now for something completely different - V2.0 - Comet Hale-Bopp by Jeff Booth

I think it is fair to say that before joining RASC national last year, I had been "interested" in astronomy for several decades. Even dabbled -- at the most basic level -- in photographing the night sky. That first Consumers Distributing telescope (Tasco) was used decades ago to attempt to photograph the Moon. I would have used an old Pentax 35mm film camera. I don't know which shook more, me holding that camera or the wobbly wooden tripod that purportedly supported the telescope's mount.

I mention this because recently there was discovered in a spare room here a box of old photos, negatives, etc. You may know the kind of box yourself, as a lot of people have these, stuffed away, out of the way, often for years. Only to be rediscovered much later. Well, in our version of that old box was a small black and white photographic print of the lunar landscape taken through one of the Tasco eyepieces, by a very much younger me trying to hold the Pentax camera still. It was pure afocal astrophotography. And guess what? ... there is a good bit of image there on that contrasty print, with the centre of the Moon rather overexposed but, never-the-less, a recognizable Astro Image No. 1.

Now, also in this dusty box from the past was a strip of badly exposed colour negatives. 35mm, of course. All of the six images on this strip of negs were of a long-forgotten attempt No. 2 at astro imaging -- two decades before I even thought of RASC, and long after that first "Moon shot."

Specifically, the second-attempt images were taken, I now recall, around 2 a.m. in a field on the North Service Road in Aldershot. Was coming back from Steel Town late one night. Was likely burning the midnight oil at the office. The field was right along Hwy. 403. Had the camera, this time a Ricoh 35mm, aiming roughly to the North. The target, this time, was none other than Comet Hale-Bopp. Must have been around 1995-96.

Best as I can recall, the images were all of the 30-60 second range. ISO??... likely 400. I would have used the tripod I've had since I was a teenager. (Still use it, too.) Just the camera on the tripod. The exposures, however, were awful. Messed up totally. That's why they were never printed. In those days, if your negatives were really bad, the photo processing labs would often and routinely not print the images, just send you back your awful negatives, to cry over.

However, since that time, we have happily lived through a digital revolution in photography. Heck, we even have a digital negative scanner here at the ol' homestead, in our home-based office. So, it didn't take long to take that horribly-exposed-and-never-printed strip of negatives over to the neg' scanner and see what might happen.

Some unexpected results showed up, thanks also to a little bit of PhotoShop work. Attached is this newbie's now-official Astro Images No. 2A & 2B. They are of Comet Hale-Bopp, imaged in the middle of that field in horribly light polluted and sky glowing Aldershot.

Some of the other images have different compositions and I am going to spend some more time with PhotoShop to improve them and this time -- enjoy them. Seems to me in days of yore, comets were thought to be portents of ill.

Not this time.

NOVA

New Observers to Visual Astronomy

by the Royal Astronomical Society of Canada

I've talked a fair bit about the NOVA course over the last few years. They have been, for me, among the astronomical highlights of my 46 years as a member of the Hamilton Centre. I had a lot of fun, I learned a huge amount, and I got the chance to meet some really great people. There were a number of objectives that the Centre wanted from the NOVA course, and it was very successful each time, so of course we wanted it done again!

There will be a charge of $5 a night after that,. The cost of the BOG will be included in the first session.

The first year we aimed for a session every three weeks, but the feedback we received indicated that every two weeks would have been better, so we tried that and it worked out a lot better for everyone. This may not be possible for me in 2017, but I'll try to keep it as close as possible to that. There were also some good suggestions made about how the first session was presented, and I spoke with NOVA instructors in other Centres (but in particular to Dave McCarter in London) about some of the suggestions. As a result, the first session will NOT contain a history of the Hamilton Centre, but will contain a very cursory look at some of the different objects visible in the night sky, and how to find them using a planisphere (included).

However, the objective of the NOVA Program is unchanged: To provide information and instruction to amateur astronomers.

All NOVA sessions will be held at the Hamilton Centre Observatory. The site offers a couple of advantages, including darker skies, a heated clubhouse and access to the 16" RC.

Each session will begin at 7:30pm, with an observing session (looking for a volunteer to help with this). This will be followed by classroom instruction and group discussions. There will be many opportunities for participants to ask questions, and I'll do my best to make sure that the classroom material is structured in such a way as to allow this. Participants can take advantage of the on site library for reference material including sky atlas', star charts, etc. All participants will also receive a copy of the Mag 7 Star Atlas, and a planisphere.

There will be homework, but unlike the previous years, we may actually discuss it!

Come on out and meet some of your fellow members to enhance your knowledge and skills in the ever changing field of amateur astronomy.

Here is an outline of the lessons planned:

1. Brief introduction to the course and the RASC; Planispheres.
2. Motions of the Sky and Seasons (Family Day...it could be moved to the following night.)
3. The Solar System.
4. Telescopes: Choosing and Using.
5. The Moon and Eclipses.
6. Charts, North, Distance, Position and Brightness.
7. Star Designations, RA, Dec. and Deep Sky Objects.
8. Stars and a brief history of the Hamilton Centre.

The course is open to all members of the Hamilton Centre regardless of age, experience or knowledge level. I'll publish the dates as soon as I get my work schedule for February onwards.

Dimming stars, erupting plasma, and beautiful nebulae By Marcus Woo

Boasting intricate patterns and translucent colors, planetary nebulae are among the most beautiful sights in the universe. How they got their shapes is complicated, but astronomers think they've solved part of the mystery—with giant blobs of plasma shooting through space at half a million miles per hour.

Planetary nebulae are shells of gas and dust blown off from a dying, giant star. Most nebulae aren't spherical, but can have multiple lobes extending from opposite sides—possibly generated by powerful jets erupting from the star.

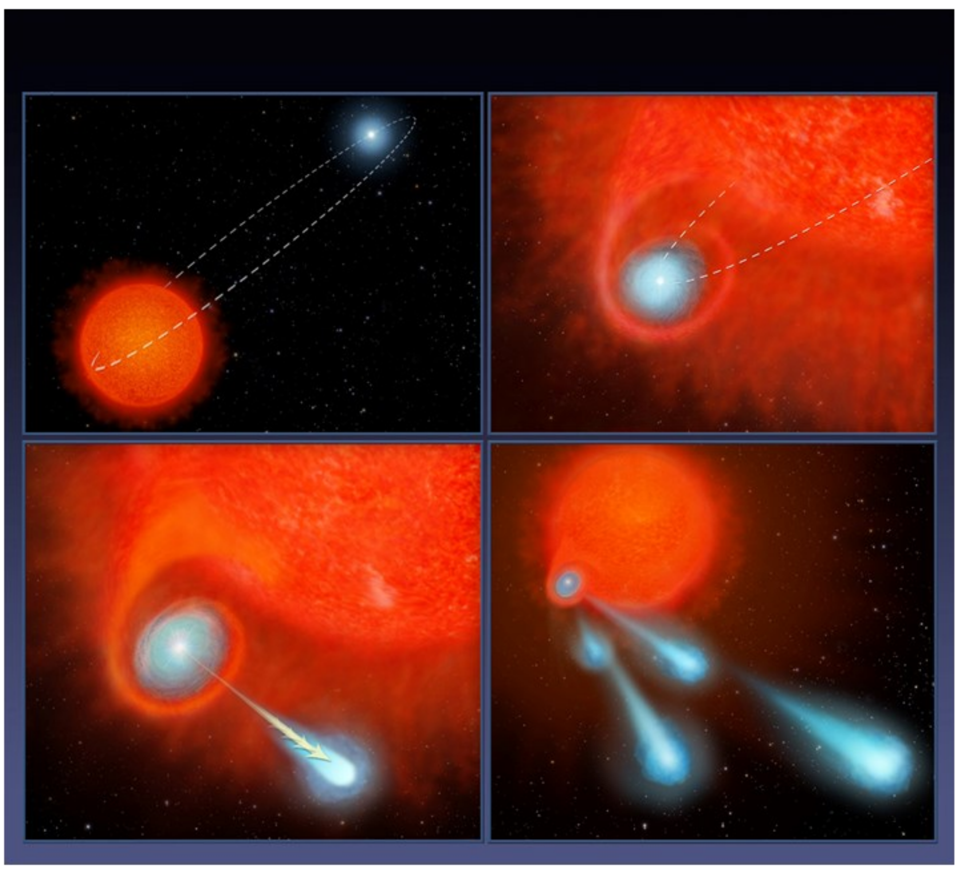
Using the Hubble Space Telescope, astronomers discovered blobs of plasma that could form some of these lobes. "We're quite excited about this," says Raghvendra Sahai, an astronomer at NASA's Jet Propulsion Laboratory. "Nobody has really been able to come up with a good argument for why we have multipolar nebulae."

Sahai and his team discovered blobs launching from a red giant star 1,200 light years away, called V Hydrae. The plasma is 17,000 degrees Fahrenheit and spans 40 astronomical units—roughly the distance between the sun and Pluto. The blobs don't erupt continuously, but once every 8.5 years.

The launching pad of these blobs, the researchers propose, is a smaller, unseen star orbiting V Hydrae. The highly elliptical orbit brings the companion star through the outer layers of the red giant at closest approach. The companion's gravity pulls plasma from the red giant. The material settles into a disk as it spirals into the companion star, whose magnetic field channels the plasma out from its poles, hurling it into space. This happens once per orbit—every 8.5 years—at closest approach.

When the red giant exhausts its fuel, it will shrink and get very hot, producing ultraviolet radiation that will excite the shell of gas blown off from it in the past. This shell, with cavities carved in it by the cannon-balls that continue to be launched every 8.5 years, will thus become visible as a beautiful bipolar or multipolar planetary nebula.

The astronomers also discovered that the companion's disk appears to wobble, flinging the cannonballs in one direction during one orbit, and a slightly different one in the next. As a result, every other orbit, the flying blobs block starlight from the red giant, which explains why V Hydrae dims every 17 years. For decades, amateur astronomers have been monitoring this variability, making V Hydrae one of the most well-studied stars.



Because the star fires plasma in the same few directions repeatedly, the blobs would create multiple lobes in the nebula—and a pretty sight for future astronomers.

If you'd like to teach kids about how our sun compares to other stars, please visit the NASA Space Place: http://spaceplace.nasa.gov/sun-compare/en/

Seeing Stars: The big science of building a giant telescope

by John S. Rosenberg, From The Harvard Magazine, May-June, 2013

We'll be able to see the beginning of the universe as we know it today," says Charles Alcock, director of the Harvard-Smithsonian Center for Astrophysics (CfA) and professor of astronomy—imaging the radiation signatures from ancient galaxies billions of light years from his hilltop office on Garden Street, near the Radcliffe Quad. Addressing that same frontier, Abraham (Avi) Loeb, Baird professor of science and chair of the astronomy department, characterizes the research as "the scientific version of the story of Genesis." Closer to home, so to speak, where the quest for "exoplanets" orbiting other stars has accelerated since the first discovery in 1995—and with it the search for chemical signs of life elsewhere—Wendy Freedman, chair and director of the Observatories of the Carnegie Institution for Science, in Pasadena, California, says, "We can now approach it from a scientific standpoint. It's no longer science fiction."

These scientists are giving voice to the curiosity that propels astronomy today. As they scan space, pursuing research on a vast scale—from the evolution of elements from the first simple building blocks (hydrogen, helium, and a trace of lithium) to the formation of stars, planets, and galaxies—they and hundreds of colleagues worldwide are also joined in a terrestrial enterprise: the Giant Magellan Telescope (GMT), an extraordinary instrument that will enable such discoveries. Patrick McCarthy, the astrophysicist who in 2008 became director of the nonprofit organization designing and building the GMT, says of the telescope and its associated analytical instruments, "This is where hardware meets science"—on an enormous scale.

Astronomy is the ultimate observational science. Humans have probably always looked skyward, noting the passage and patterns of the sun, moon, and stars. The eye is the essential instrument, and the subject of study is readily available—overhead. Astronomers cannot manipulate a star in a laboratory, or examine a black hole under a ventilating hood. They observe from afar.

The modern science of course embraces deep theoretical astrophysics, aimed at understanding, for example, how gas and dust became stars and galaxies distributed across space; Avi Loeb directs the CfA's Institute for Theory and Computation. Closely allied are computer simulations to emulate how those processes might unfold under enormous pressures at extreme temperatures, with unfamiliar conditions of matter and energy and scale. But the theorizing and models remain tethered to data. "Observations are crucial for stimulating the right ideas," as Loeb puts it. The GMT will help confirm or refute theoretical work about the first galaxies, he says. "If we're surprised, it's even for the better."

For those observations, the eye, however elegantly evolved, is inadequate. As Harvard undergraduates learn in Astronomy 100, "Methods of Observational Astronomy," the human pupil's size (half a square centimeter) constrains light-gathering; exposures are limited (blinking); and the eye perceives only the colors of the visible spectrum (electromagnetic radiation with wavelengths from 400 to 700 nanometers). Those features confine observations to relatively bright objects; limit resolution—the measure of blurring or overlapping of images, and hence of the fine details that can be seen—to about one foot at a distance of a mile; and as a practical matter restrict observation to only as far as a few million light years (a long way at nearly six trillion miles per light year, but barely beyond the windowpane in a universe with stars billions of light years distant).

Galileo's revolutionary telescope of 1609 represented a more than twentyfold gain over the eye's light-gathering area, quickly revealing features of the lunar landscape, multiple stars, and Jupiter's own moons. As Geoff Andersen explains in The Telescope: Its History, Technology, and Future (2007), "[R]esolution can only be improved by using shorter wavelengths of light and bigger telescope primaries [mirrors]." Moreover, "[A] larger mirror will collect a greater amount of light, and thus give us brighter images of distant objects and allow us to take images in a shorter amount of time"—the prospectus for telescope-makers ever since Galileo's epochal discoveries in Padua.

The scaling-up of the technology in the four centuries since has brought about gains of more than a million times the eye's collecting area. The Hubble Space Telescope's (HST) 2.4-meter mirror (orbiting above Earth's obstructing atmosphere) resolves a foot-sized object at 36,000 miles. Unblinking charge-coupled devices (the electronic cameras affixed to telescopes) can maintain an exposure for hours, as photons from faint, distant objects impinge. Far from being bound by visible light, telescopes can be crafted to collect shorter wavelengths (ultraviolet, x-ray, and gamma-ray radiation), as well as longer infrared, microwave, and radio signals—all of which bear useful information. And spectrographic instruments attached to those telescopes can discriminate thousands of times as many colors as the eye alone, yielding data about the composition, condition, and movement of objects incredibly remote and deep in time.

During the twentieth century, telescope apertures grew steadily, says Patrick McCarthy—from the 100-inch Hooker machine at Mount Wilson (1917) to the 200-inch Hale reflector (1948) at Palomar (both Carnegie Observatories projects, in California), to the current champions, with 10-meter mirrors (about 400 inches, assembled from multiple hexagonal elements), deployed at observatories in Mauna Kea, Hawaii, and the Canary Islands in the early 1990s and 2009, respectively. McCarthy, who puts his GMT work in perspective in part by keeping in his office an early-1800s brass library telescope, from London, says of that doubling every 30 to 40 years, "We're about due for that now."

Of this doubling, says Buell T. Jannuzi ’84, “It’s not quite like cathedral-building, but those who started it won’t use it.” The simile is not as cocky as it might sound. Conversations about a giant telescope began in 2000—and the current goal is to begin partial operation in 2019, according to Wendy Freedman, who chairs the GMT board of directors. (Board members include the CfA’s Charles Alcock, Clowes professor of science Robert Kirshner, and Smithsonian astrophysicist and lecturer on astronomy Jeffrey McClintock.) Engineering and scientific resources—and several hundred million dollars—are coming from the 10 members, so far, of GMT’s international consortium: Astronomy Australia, the Australian National University, the Carnegie Institution for Science/ Carnegie Observatories, Harvard, the Korea Astronomy and Space Science Institute, the Smithsonian Institution’s Astrophysical Observatory (Harvard’s CfA partner), the University of Texas, Texas A&M, the University of Arizona, and the University of Chicago. The finished project indeed will be cathedral-sized: the mirror assembly and its enclosure will be 22 stories tall—the height of Notre Dame’s towers—comprising 1,163 tons of steel and glass and electronics, all moving without perceptible vibration on an oil bearing as the apparatus follows astronomers’ targets across the Chilean night sky.

Like galaxies studded across a dark universe, there are clusters of astronomical expertise. Cambridge is one: the CfA’s constituents employ some 900 people, including about 350 Ph.D.s in astronomy and astrophysics (not to mention MIT’s substantial cohort). Pasadena is another, with the Carnegie Observatories and GMT’s headquarters; NASA’s Jet Propulsion Laboratory; and Caltech (a member of a different consortium designing a giant telescope for Mauna Kea; yet another consortium is based in Europe). A third is Tucson, home to the University of Arizona.

Early discussions among CfA, Carnegie, and Arizona scientists, partners in varying arrangements in telescopes in Chile and the United States, helped shape the GMT program, recalls Daniel Fabricant—a CfA astrophysicist, leading designer of optical and infrared telescopes (a chunk of the raw glass used to make large telescope mirrors sits by his window) and instruments, and member of the GMT scientific advisory board. He recently reviewed initial assessments of everything from optics to the stiffness and wind resistance of the prospective telescope enclosure (the site “is a mountaintop, after all,” he notes). “Everything looked good,” he says—but then again, “Every large optical device comes with a story—usually a sad one” of delays, escalating costs, and struggles to achieve the designed performance. A decade after the GMT analyses, he says, “Everything has a start. It’s the finish that’s hard.” As a result, it’s the rare astronomer who is privileged to work on two generations of leading telescopes, as he has been. Even so, an infrared spectrograph he proposed for use on the GMT won’t be one of the “first-light” instruments built for its first years of operation, and therefore is unlikely to come on line during his active career.

As a scientist, Jannuzi—professor of astronomy and head of the astronomy department at Arizona, and director of its Steward Observatory—may not wish to push the cathedral analogy too far, but creating the GMT has involved three engineering acts of faith. First, the telescope requires huge mirrors posing unprecedented technical challenges. Second, to operate most effectively, it must be equipped with a system to offset minute atmospheric disturbances of the telescope’s imaging—at thousandth-of-a-second intervals. And finally, the seven separate mirrors, each weighing 18 tons and shaped to minute tolerances, each nestled in a 31-ton steel cell, subject to the telescope’s motion and fluctuating temperatures and changing mountaintop winds, must be kept precisely aligned with one another. The first and second of those problems fell to the experts in Tucson.

• The mirrors. “We have only two sizes,” says J. Roger P. Angel, scientific director of the Steward Observatory Mirror Lab (SOML), “big and medium.” During a tour of the lab, nestled under the steeply raked east side of Arizona Stadium (“Home of the Wildcats”), Angel, Regents Professor of astronomy and optical sciences at Arizona, notes with amusement, “The world demand is one large mirror per year.” “Medium” mirrors include the 6.5-meter (21 feet) units fabricated in 1994 and 1998 for the twin Magellan telescopes operated by the Carnegie Observatories in Chile (with partners Harvard, MIT, and the Universities of Michigan and Arizona)—precursors to the GMT. The “large” diameter (8.4 meters; 27.5 feet) was realized in the 1997 and 2000 castings for the Large Binocular Telescope at Arizona’s Mount Graham observatory.

Making workable telescope mirrors on this scale has involved successive innovations: developing low-expansion borosilicate glass that is stable chemically, mechanically, and thermally; learning how to cast it, at 2,120 degrees Fahrenheit, in a rotating oven so the molten glass forms a curved shape, reducing the subsequent grinding and polishing time from decades to years; and molding the glass over and in between precisely contoured hexagonal columns of refractory material—to shape the curve of the reflecting surface and give the mirror the strength of bees’ classic honeycomb but at a finished weight a fraction of a solid-glass casting. After the cooled glass is removed from the kiln, the alumina-silica refractory material is washed out of the underside of the mirror blank with water jets. The resulting voids make it possible to bring the mirrors down to the temperature of the surrounding air within minutes (versus impossible cooling times for a solid-glass mass), readying a telescope quickly for nightly observing without thermal distortions in the glass.

Based on the precedent of the 8.4-meter mirrors for the Mount Graham binocular instrument, the GMT telescope arrays six such primary mirrors around a central seventh one. The assembled apparatus will have an effective diameter of 24.5 meters (80 feet); subtracting the gaps between the mirrors and the open aperture at the focus in the center, its collecting area of 368 square meters is 20 million times that of the human eye. Astrophysicists sometimes pursue highly abstract research, but they have a very tangible feel for their instruments—and a sense of humor. Reversing the usual order of observing space from Earth, use Google’s mapping tool to zoom in on the satellite view of Carnegie Observatories’ offices: 813 Santa Barbara Street, Pasadena. Rather than some multiplayer dodge-ball court, those circles painted on the parking lot are a full-size schematic of the GMT’s primary mirrors.

Making the separate segments operate as a unitary reflecting surface requires that the six outer mirrors be shaped asymmetrically, so that within the GMT, all of the collectors are focusing the photons they gather on a common point. Each of those outer, off-axis mirrors, Roger Angel says, has to be cast, ground, and polished to a more aspherical shape than any other telescope mirror in the world. Several participants describe the final form as resembling a potato chip, with a 14-millimeter variation from a symmetrical shape—equivalent to about 28,000 waves of green light. But across that irregular form, each identical outer mirror is expected to achieve a tolerance within one-twentieth of a wavelength of green light—about 20 nanometers (billionths of a meter). If scaled to the continental United States, the mirror glass would feature half-inch Rocky Mountains.

Achieving that shape and precision required perfecting a computer-driven, dynamic polishing tool that could adjust the polishing shape along the plane of the mirror blank. To be sure of their handiwork, the lab technicians subject the mirrors to four optical tests; for one, the equipment required a modified 400-ton testing tower, mounted on airbags to dampen external vibration, that was pushed through the SOML roof to the top of the football stadium. (Engineers are haunted by the initial failure of the Hubble; its mirror malformation was discovered only after its 1990 launch, and Space Shuttle astronauts had to install corrective optics in 1993.) From casting in 2005 to final testing, making the first GMT mirror took seven years. The second mirror was cast early last year; the third is scheduled for this August—when the Tucson summer can perhaps supply the first 100 degrees of heating; and GMT has contracted for the glass for the fourth blank.

The result, Angel says with satisfaction of his honeycomb mirrors—now that "large" orders are nearing what passes for mass production—is "the limit of how efficiently you can make a light-weight, stiff structure." If aliens are ever discovered inhabiting some of those newfound exoplanets, he half-jokes, their observations of Earthlings should depend on telescopes of similar design.

• Overcoming the atmosphere. In astronomers' ideal world, they would live without an atmosphere. It shields out (destructive but) interesting x-ray and ultraviolet radiation, and contains water vapor, making it opaque to much of the infrared spectrum. Turbulence, and differential refraction in cool and warm air, distort incoming wavefronts. Philip Hinz, an associate professor at Arizona—an institution with deep expertise in designing solutions to this problem—calls the resulting light received at an Earth telescope "corrugated and wavy." Think shimmering mirages on a hot day, or the romance—maddening for scientists—of a twinkling star.

One workaround is a satellite. But orbiting observatories are finicky and expensive (the James Webb Space Telescope, an infrared successor to the HST, is now expected to launch in 2018, years behind schedule, and to cost $8 billion or more—multiples of its initial estimate, and enough to choke off most other U.S. missions' funding). And they are hard or impossible to service and to fit with new instruments or controls (the Webb will orbit nearly a million miles from Earth).

The terrestrial solution is to site telescopes high and dry: on a mountaintop, as far up into the atmosphere as possible, in a relatively dry venue. Darkness—the absence of man-made light pollution—is also essential. Proximity to an ocean is a virtue: airflow over water is less turbulent than the air heated and cooled over land. Hence the Mauna Kea and Canaries sites—and the arid front range of the northern Chilean Andes, where Carnegie has operated its Las Campanas Observatories since 1969. There, at an altitude of 2,400 meters (nearly 8,000 feet), the 6.5-meter Magellan telescopes have established a record of outstanding natural imaging during more than a decade of operations (see "Tying Knots," May-June 2004, for a report on astronomical research at the site). And there, last year, a site was leveled atop a slightly higher adjacent peak—the bedrock pad for the GMT. (Its nearby support facilities will include the vacuum chamber where the glass mirrors receive their reflective coating of vaporized aluminum.)

Nonetheless, there are still atmospheric interferences aplenty above the site, so the GMT will encompass other technologies in a corrective system called adaptive optics.

Sidebar: A young astrophysicist finds clues to the origins of stars and galaxies by probing ancient, dwarf stars within and near the Milky Way

The seven primary mirrors, huge, heavy, and stiff, reflect the light they capture to seven matched secondary mirrors mounted above, within the telescope structure. There, the similarities end. The secondary mirrors, each 1.1 meters in diameter, will be extremely thin—disks of fragile but flexible two-millimeter glass—so they can be readily deformed. Philip Hinz explains that each mirror will be mounted on 672 tiny magnet-like actuators (the shape of button batteries comes to mind) capable of firing 1,000 times per second. As wavefront detectors analyze arriving light, the actuators are programmed to deform the secondary mirrors into what he calls a "quilted wavefront pattern the opposite of the incoming wavefront"—neatly offsetting atmospheric distortion and making GMT infrared resolution 10 times sharper than the HST's imaging.

Where astronomers are observing near a naturally bright guide star, the adaptive-optics system can use that light to calibrate the character of the wavefront. But for other kinds of viewing, or where there is no such reliable beacon, the GMT will, in effect, make its own stars. A series of six lasers, grouped in pairs around the periphery of the primary mirrors, can be beamed skyward; they are tuned to excite sodium atoms high in the atmosphere—creating tiny stars of known wavelength, whose light, captured by the telescope and wavefront detectors, will enable the needed adaptive corrections.

Assessing the achievements of the scientists and engineers who perfected these technologies, Peter A. Strittmatter, Regents Professor of astronomy and Jannuzi's long-term predecessor as director of the Steward Observatory (experience that has made him a hands-on historian of telescope technology during the past four decades), says, "The borosilicate brigade and adaptive [optics] are revolutionary for astronomy." Comparing the GMT's design to imaging assembled from multiple, interlinked observing instruments, he continues, "God doesn't let you get to the sharpness unless you have it all in one system." Of the GMT, he says, "The whole range of astronomy will be given a huge boost"—assuming one more critical issue is solved.

• The phasing problem. A final GMT challenge is keeping its huge mirrors properly aligned with each other. For all the precision of each primary glass element, the relatively large gaps between adjacent mirrors pose a challenge for proper focusing. Circumferential edge sensors indicate the mirrors' location relative to their neighbors. Each primary mirror is mounted on 165 load-spreading supports, with actuators to maintain proper shape and stiffness ("active optics") as the temperature changes and the telescope assembly moves. They and especially the secondary mirrors' high-speed actuators can be employed to establish and correct alignment, within a millionth of an inch.

Exquisite precision is required. Wavelengths of light arriving from space will hit the GMT's mirrors—and ultimately, the charge-coupled device or instruments (such as spectrographs)—at slightly different times. Getting the light thus collected in phase, with coherent patterns and a sharp focus, depends on repeated measurements and mirror adjustments to a fraction of a wavelength, before and during observing runs, according to Brian McLeod of the Smithsonian Astophysical Observatory. An instrument designer who helped build a 360-megapixel camera for the Magellan telescopes, McLeod worked with the Carnegie Observatories' Stephen Shectman to design a phasing camera for the GMT, using Milky Way stars as a reference.

Scientists from throughout the GMT organization hailed a recent, successful test of the camera, on one of the Magellan telescopes, for overcoming the last-frontier technical challenge to the next-generation machine. McLeod describes this and other projects as working with teams of engineers to keep complicated assignments on track, so that detailed designs meet the requirements for astronomical instruments. In other words, keeping the engineers themselves properly phased.

Writ large, the GMT program itself is in a similar state of precise phasing. At the organization's headquarters, on the third floor of a nondescript Pasadena office building, Patrick McCarthy and a few dozen colleagues are now in the thick of "big science" project management. Their network extends to McLeod and many others in Cambridge, responsible for the active optics and design of a "first light" spectrograph essential to the telescope's initial science mission (see "Exploring Exoplanets," page 36); to the mirror lab in Tucson and adaptive-optics experts there and in Australia; to teams in Texas and Korea—and beyond. The process comes together in formal project meetings and project-design-review spreadsheets of a size and complexity (with hundreds of individual tasks and dozens of columns of deadlines and critical check points) that perhaps only astrophysicists could truly enjoy.

Ticking off the status of the mirrors, adaptive optics, and phasing system late in the winter, organization chair Wendy Freedman says, "We've retired the greatest technical risks to the project. I feel extremely excited by all the recent progress. We're really making this happen." Assuming completion of the design reviews this fall, the GMT could proceed to construction next year. "Managing the planning is a challenge," she continues. "It's a big project."

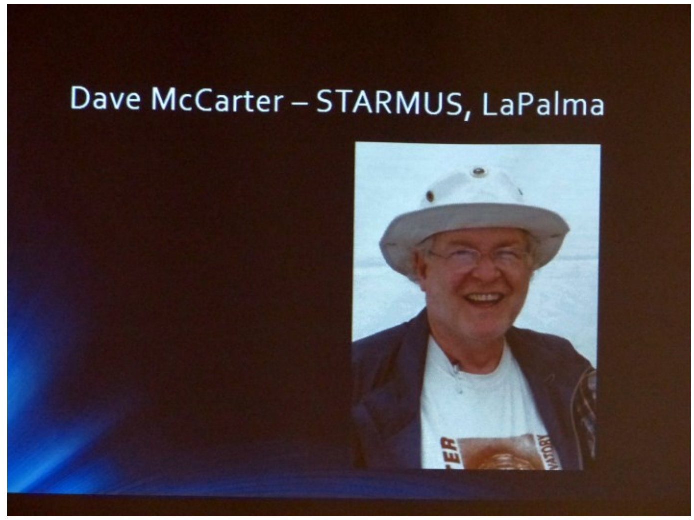
Given the change in the world economy and the financial circumstances of the GMT partners since their initial planning at the turn of the millennium, a relieved-sounding Freedman reports "huge progress in recent months, weeks, and days" on institutional issues as well. "One of the best things about this project," she says, is that the members are "like-minded academic institutions who all want to see this proceed" and are accordingly "assembling what they need to do internally" to fund the work (for which U.S. government support is, conspicuously, absent—as has been the case for many landmark terrestrial observatories during the past century). At the beginning of this decade, GMT and its associated instruments were estimated to cost some $700 million. Updated figures, reflecting the final design, the experience building the first mirrors, and inflation through anticipated completion, should emerge from the final design review and bidding late this year and early next. (In the meantime, the University's capital campaign could provide an impetus for meeting Harvard's 5 percent to 10 percent share of the GMT's construction costs.)

If that schedule holds, Freedman says, the GMT could begin operating in 2019, with the first four mirrors in place and an initial astronomical instrument or two. The remaining mirrors would arrive, by ship and truck, at annual intervals thereafter, enabling the full research program by 2022.

And then? Freedman highlights some elements of the GMT's scientific objectives, from characterizing exoplanets ("an extremely exciting areas for all of astronomy right now," not to mention the public at large) to a "staggering jump" in direct observation of stars and galaxies from the earliest universe. But beyond those carefully parsed plans, she says, every telescope since Galileo's modest instrument of 1609 has extended astronomical research beyond its practitioners' imaginations. "The unexpected, the unanticipated discoveries that come with new capabilities," she says, "that's what really excites people."

Hamilton Centre RASC, November 3, 2016: "Monthly Meeting" By Ed Mizzi

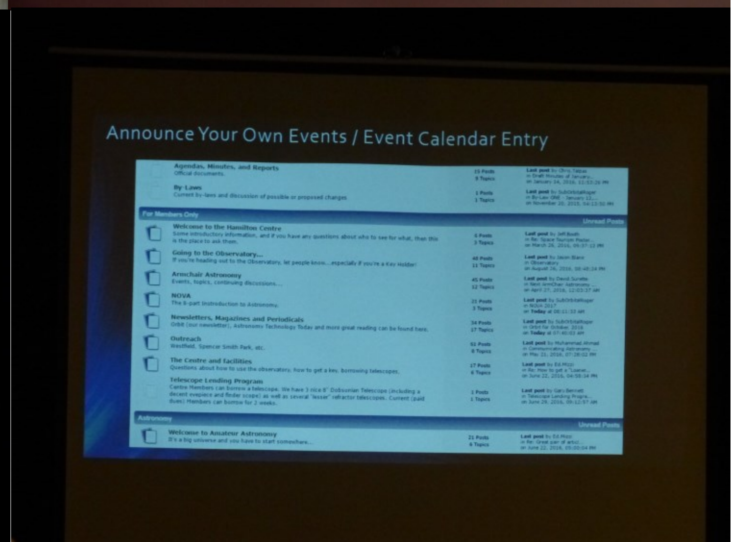
Here are the highlights of the November Monthly Meeting



- Gary Bennett, our President welcomed everyone to the meeting
- Ed Mizzi discussed Outreach programs and how to get involved. He will give a more in depth talk in December, involving teaching content and strategies.
- Bob Prociuk discussed current membership numbers and he offered a special welcome to a few new people who were at the meeting
- Andy Blanchard gave us some great news that AstroCATS 2017 is a GO, in a big part because David Surett has stepped forward to spearhead the event. However, any and all help is welcomed. Andy also announced that our club greatly benefitted from AstroCATS 2016, in terms of money raised.
- Gary B. followed up on the previous speakers and told the audience about the Survey he will soon launch. In the survey he will ask members about their interests, why they joined the club and what types of volunteer activities they wish to get involved in. He encouraged members to use our Forum as a way to communicate and get to know other members, as well as be involved in discussion on a wide variety of topics. Gary also spoke about the observatory and how he has fixed the 16" scope and that both broken computers have either been fixed or replaced. He also mentioned that members could obtain a 2017 RASC calendar for only $17, regular price $27.
- Gary also spoke about keys to the observatory and that members can pay for their keys with cash ($25) or through sweat equity by helping out with club events, clean up, etc. Members who already have a key will soon be contacted and be asked for their payment.
- Gary B. introduced our first guest speaker, Dave McCarter with his topic, "STARMUS" at Tenerife, Canary Islands, with Stephen Hawking. STARMUS was held June 27-July 2, 2016. Dave provided us with an entertaining synopsis of this great conference, including a short description of every speaker there. Another one of our long time, active members, Andy Blanchard also attended STARMUS and he interjected with a few stories of his own.
- Unfortunately we did not have time for the second speaker, Dave Dev, who graciously agreed to postpone his talk, about PHD Guiding, to the December meeting.
- Gary ended the meeting by thanking those who attended and inviting everyone for refreshments, after the meeting, at the Royal Coachman in Waterdown.


Welcome New Members
2017 RASC Calendars
2017
Regular Price: $ 27.00
Special Offer: $ 17.00


AstroCATS $$$ Results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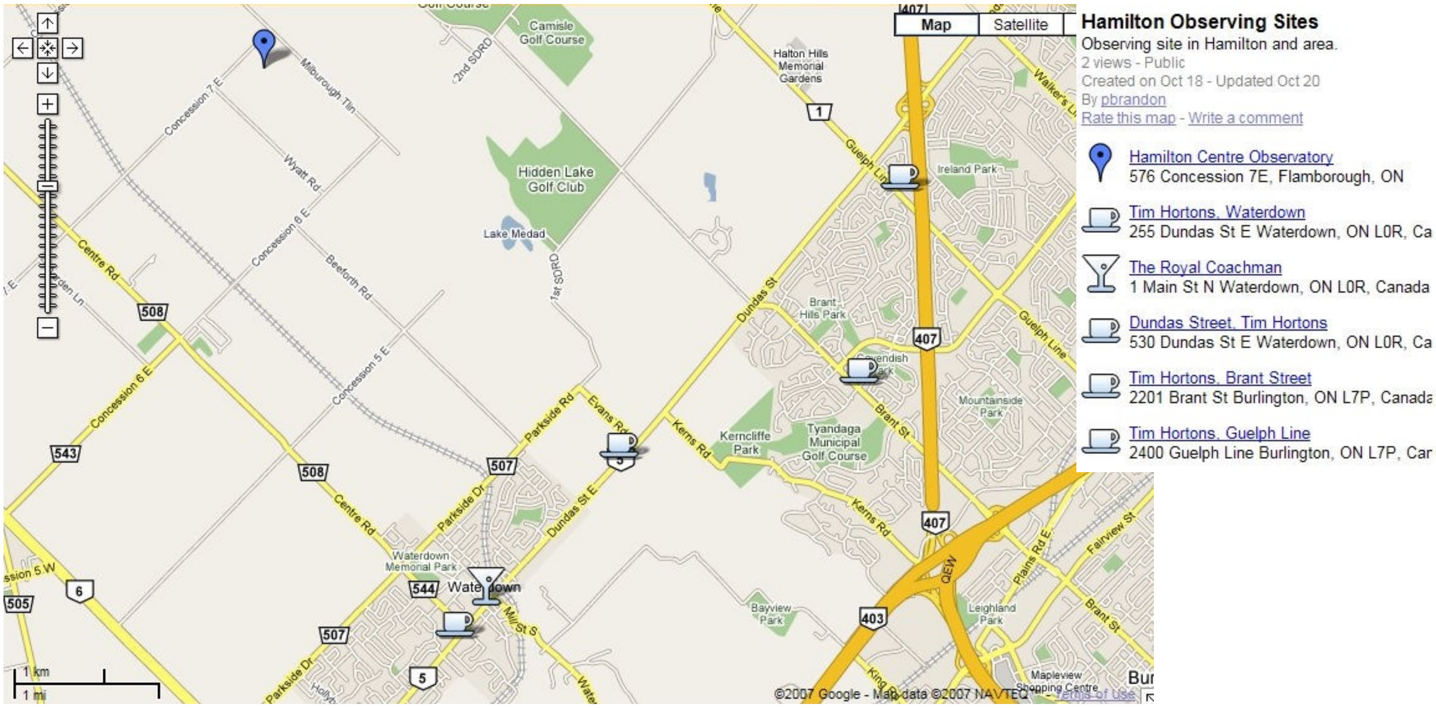

576 Concession 7 East, Flamborough ON
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P.O. Box 969
Waterdown, Ontario
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President	Gary Bennett
Vice President	David Surette
Secretary	Chris Talpas
Treasurer	Bill Leggitt
Observatory Director	Gary Colwell
Orbit Editor	Roger Hill
Special Projects	Bob Prociuk
Youth Outreach	Ed Mizzi
Councilor	Murray Romisher
Councilor	Dino diSabatino

Jacek Strakowski Took this image of Orion from near Lion's Head. He used a Nikon D700, with a 35 year old Nikkor Ais 85mm f1.4 at f/4, ISO 1600, 39 x 2 minute exposures with iOptron Skytracker, processed in PI.

This image was initially on the Forum, in the Astronomy/YourImages section. Frankly, if you’re not visiting the forum, you’re missing out on a good portion of Life in the Centre!

http://hamiltonrasc.ca/forum/