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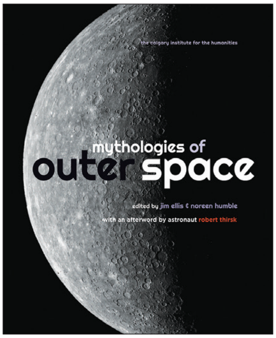

MYTHOLOGIES OF OUTER SPACE

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fifty years

philip p. langill

at the rothney

Not all universities in Canada fund and operate an astronomical observatory, but those that do typically install (or have installed) such telescopes on their main campuses. That's handy if public outreach is part of the activity, increasing access for the general public, but light pollution restricts what the telescopes can see and do. If a Canadian university hosts an off-campus observatory, it typically has a single telescope with one scientific instrument, probably a CCD (digital) camera plus filters, which satisfies the goal of teaching students how to collect and analyze astronomical data.

There is only one Canadian university that funds and operates a fabulous, advanced astronomical observatory far from its main campus, outside the city's bright lights, with multiple research-grade telescopes and instrument suites, and whose goal is to connect the public with astronomical researchers and scientists in training. This is the mission statement of the University of Calgary's Rothney Astrophysical Observatory (RAO) (see figure opposite).

The RAO was officially christened in January 1973, and it has changed immensely in the decades since. It is challenging to try and describe fifty years of research, teaching, and outreach, as there are so many cool stories to tell and so many awesome people involved. A good way might be to explore some of the more marked contrasts between then and now in three different areas: teaching and technology, public outreach and education, and research.

teaching & technology

In the late 1970s, the RAO was a "one-scope" observatory with two ATCO trailers joined to form the classroom. The sixteen-inch telescope (metric was just gaining traction) was totally manual, with a piggyback finder scope and eyepiece for finding and aligning onto a target star. There was no Internet, but computers were just becoming useful tools for collecting and storing data. Calgary had less than a quarter million people and was a small globe of light on the distant horizon to the northeast.

Imagine a class of about ten undergrads boarding a UCalgary van to leave campus and head out to the RAO to collect data for a class research project to study an interesting variable star. It's winter, so the sun is getting low as students board the van. The Moon and clouds have finally departed and it's looking like a dark and star-filled sky awaits.

Arriving an hour and a bit later, following narrow country roads and a one-lane bridge to cross Fish Creek in Tsuut'ina Nation territory, it's very dark. The students don't notice how cold it is because they are excited to see the telescope and dome and detector and computer, all queued up—it's going to be great! Standing around the perimeter of the dimly lit sixteen-foot-diameter dome, the telescope operator studies a polaroid photograph of a particular field of stars (that they made back on campus a few days before), then looks through the eyepiece. Using buttons on a hand paddle to carefully move the telescope back and forth, and oscillating their head back and forth between the photo and the eyepiece, it takes what seems like forever before they declare that the target star is in the sights of the telescope.

The detector is then fired up and the computer is booted. If all goes well, this whole process takes nearly an hour (if this is the first time a particular star is being hunted through the eyepiece, that could add another half an hour), and by now the students are frozen popsicles feeling a little less excited. And just when the Enter key is about to be pressed for the data acquisition to begin, something weird is noticed on the detector. The technicians and profs scratch their heads for a while, then somebody thinks to look up. Sure enough, the clouds are coming back. Rats! No data is collected, and what's more, that other course's assignment or exam that is looming and should have been worked on tonight didn't get any attention.

You would think this is the perfect way to deter students from doing an astrophysics degree at UCalgary. If these were ordinary students, and if this was an ordinary observatory, it is hard to know how the astrophysics program at UCalgary would have sur-

Previous spread: "The Rothney at night," Copyright the University of Calgary / Rothney Astrophysical Observatory (Alan Dyer).

vived these past fifty years. But there is something magically intangible about that picturesque spot overlooking the foothills of the Rocky Mountains. The Blackfoot people that first lived there must have bestowed onto the land a positive energy that lifts people's eyes to the star-filled sky.

Advance the clock to today, and here's how that same night of data gathering goes, with this same telescope, now christened the Clark-Milone Telescope (CMT). It's noon or shortly after and the RAO's AllSky camera, viewable online from campus, shows perfectly clear skies over the observatory. Real-time satellite imagery shows no chance of clouds tonight. An email goes out from the professor: "Team04, tonight's the night for you to collect your data—see you in Science B518 at sunset." Right on cue, the students are sitting in front of the workstations, logging in to the computers at the RAO that control the telescope and equipment. When the required level of darkness has been reached, they bring up a desktop planetarium program that shows where all the stars are in the sky, and they click on the target object. On the webcams they watch the telescope slew and the dome shutters open. They turn on the digital science camera, cool it down electronically, select a filter, and take a test image. If the focus is a bit off, it's quickly fixed. The star field is verified using online star maps, and in less than ten minutes, data is being recorded to the hard drive on the computer at the RAO for students to do their research project.

The telescope and camera work for many hours as the students monitor the sky for clouds and the equipment for glitches (and they work a bit on their looming assignments or exams). When the requisite amount of data is collected, they remotely stow the telescope and dome, turn off the instruments and motors, and just before high-fiving each other in celebration of a great night of data gathering, they click a button to start transferring the many hundreds of megabytes of data just acquired to their campus workstation for future analysis.

In the early days, after a productive night of observing (in the cold), the last task would be to spend about an hour copying the few megabytes of data to a bunch of floppy disks to take the data back to campus for analysis. Oh, wait, that's the second-last task. The last task would be driving home, exhausted and in the dark. Today, RAO telescopes and detectors are vastly more efficient and productive than ever, thanks to high-speed Internet and remote operation.

Additionally, electronic detectors themselves are becoming faster—and cheaper too! For example, the original CCD camera used with the Baker-Nunn Telescope (BNT), which was put into service in 1999, had sixteen million pixels (off-the-charts huge back in those days). The blazing fast readout electronics could transfer the image from the camera to the computer in only eighty seconds. This was cutting-edge technology, and researchers were very pleased not to have to wait the two hundred seconds or so, as was standard in the pre-USB world. That original camera was replaced in 2015 with one that has the exact same sensor with sixteen million pixels. The key difference is that the readout electronics are twenty times faster, and far less noise is produced.

This is fantastic because the BNT can collect twenty times more data in a night than it could before. That is so much data that, in actuality, it would have taken the BNT nearly a month to collect as many images, taking into account how many nights it would take and how many of those nights would be cloudy or clear. More data was collected with the new camera in the first three years of its service than was collected with the original camera over its whole lifetime (and the data is of higher quality due to reduced noise).

And now I'm sure you're wondering, what do students do with all this data? Well, pretty fantastic stuff actually. They aren't making new scientific discoveries, but they are making new personal discoveries by learning how to collect and analyze astronomical data with research-grade telescopes and detectors that they control. And through this experiential learning process they have confirmed the existence of planets around other stars, measured the temperature of the very hot ionized gas in the Orion Nebula, measured the incredibly huge distance and age of ancient globular clusters in our Milky Way galaxy, measured the radius of a tiny moon orbiting a dwarf planet in the outskirts of our own solar system, measured the speed of the Earth as it dashes around the Sun along its orbit, measured the enormous speed of ejected gas being blown away from exploding white dwarf stars, confirmed the existence of dark matter in the Milky Way galaxy, and much more.

It must be emphasized that these students are on the edge of doing research, and most are only in their second year. The projects they are given and the data they collect and analyze have never been collected and analyzed before. An excellent example is the supernova "event" in the galaxy M101. The galaxy is twenty-one million light years away which means twenty-one million years ago a star lost its desperate battle against gravity and was completely crushed. When the light from that explosion passed the Earth for a few months, undergraduate students scooped up some of it with RAO telescopes, and used that data to figure out some of the physics of supernova explosions.

public education & outreach

From the beginning, it has never been difficult to coax the public out to the RAO. Just put out the word that there would be an "open house," and the cars would arrive. Once each month the attached ATCO trailers would be full of inquisitive minds ready to hear about the latest astronomical discoveries. If it was clear too, an added bonus would be to have a look through an eyepiece at whatever heavenly wonder might be overhead. The capacity was around thirty people, but it was common to host forty to fifty.

Advance the clock to today, and here's what a typical month of outreach looks like at the RAO. Around 2005, a wonderful partnership was sparked between the RAO and the Calgary Centre of the Royal Astronomical Society of Canada (RASC), whose members—"RASC'als," as they are often called—love to show people the sky through their portable telescopes. The monthly events with the RASC were popular, and there was soon a need for more public viewing space. In 2006, a new state-of-the-art building with capacity for approximately 125 people replaced the thirty-year-old trailers. The popularity of these monthly events grew and grew, and just before the pandemic hit it was decided that the moniker "open house" could no longer be used, as the crowds were reaching 400–500 people—far beyond what could be managed (the parking lot overflow went all the way down to the highway gate, almost half a kilometre from the top of the hill where the action was). Today monthly ticketed events called "Space Nights" are organized, and the number of visitors is restricted to about 250. It all goes off without a hitch, thanks in large part to the RASC volunteers, and a fabulous group of organized UCalgary undergrad volunteers called "Team Astro."

"Space Nights" are popular indeed, but the vast majority of visitors to the RAO today come by the busload from K–12 schools associated with Calgary and surrounding school boards, and from special interest groups. Our brilliant RAO education specialist started going to local school conventions to set up a table and tell teachers about new educational programs offered at the RAO that connect to their school curricula. Uptake was slow at first, but by 2010 a few thousand students were visiting the RAO each year. Just before the pandemic hit, between "Space Night" events and school groups that come both day and night, the number of visitors had surpassed ten thousand per year. The pandemic is now in the rear-view mirror, and we are again seeing pre-pandemic numbers.

Outreach success is not just about numbers. All these visitors are visiting the University of Calgary. Philanthropic donations to the university and the RAO are increasing, and enrolment in our astrophysics program is rising. But undoubtedly many young people are getting the spark of inspiration to pursue STEM careers too. In today's world we need lots of smart young minds to grow into responsible science-based leaders to tackle the hardest problems this world has ever faced—and UCalgary, through the reach of the RAO, is driving that inspiration.

And it's not just about the visitors. Our UCalgary astrophysics and physics students are getting the unique opportunity to communicate to the public in the language of science. Explaining complex scientific concepts at a level that can be understood by laypeople young and old is a skill that can't be taught in the classroom and has to be practised as much as possible at every chance. The RAO facilitates this rich learning opportunity for UCalgary undergrads.

research

Astronomical research has two components: it is the endeavour to make new discoveries, and it is a check-and-balance process. The former is very challenging for any university-funded observatory as it requires exquisitely dark skies, top-notch equipment, and a group of people committed to the exploration. The latter is a follow-up partnership whereby reportedly new discoveries are re-observed to verify claims. Although the RAO strives to discover new things with its fabulous array of telescopes and detectors, its biggest contribution is partnering with other research groups to check and confirm.

The Baker-Nunn Telescope and its fast new camera, has already been mentioned, but its other unique features are a very large field of view and "fast optics." It is ideal for looking for tiny flashes of light, tiny variations in brightness over time, and tiny dots of light that are moving. After being equipped with the original digital camera, it spent the first decade of the 2000s searching the solar system for asteroids and comets, a task the BNT is perfectly suited for. At that time all the other research groups in the world also doing this work pointed their telescopes toward the well-known asteroid belt. The BNT was intentionally pointed away from this established population in the hope of finding evidence for a new population of asteroids and comets. The team was extremely dedicated to collecting data at every opportunity and writing new search codes on the fastest computers available to comb through the hundreds of megabytes of data collected per night, looking for the tiniest of moving dots of light to find objects orbiting around the Sun. They discovered two new comets and one new asteroid!

Today the BNT collects twenty times as much data per night, to look not just for moving specs of light but also transient flashes and tiny variations. The computers used to analyze the huge data set are number-crunching monsters. The RAO shares BNT data with researchers at the Dominion Astrophysical Observatory (DAO) in Victoria, BC, the Transient Name Server (TNS) of the International Astronomical Union, the International Comet Quarterly information website of Harvard University, the University of Barcelona, and the Czech Republic's Astronomical Society. With BNT data the DAO almost discovered a new comet (it had been discovered just a few months earlier) and almost discovered an exploding star in a nearby galaxy (it was reported to the TNS twenty minutes earlier by researchers in Japan). The RAO also provides data to Masaryk University, l'Observatorie de Paris, and the Global Meteor Network, primarily with the Clark-Milone Telescope.

The RAO's largest telescope, the Alexander Rothney Cross Telescope (ARCT), is named to recognize its original and leading benefactor. The ARCT was designed and built by UCalgary experts and craftsmen to study the universe at infrared wavelengths employing an innovative mounting system. It also had a set of tertiary mirrors allowing an entire suite of additional instruments to be mounted to the telescope. It was a thing of beauty filled with potential for astronomical discovery. Unfortunately, in studying the infrared universe, the ARCT encountered a host of barriers it never seemed able to penetrate. The tried and tested Rapidly Alternating Detection System (used with the CMT), a one-million-pixel CCD camera (pre-USB), and two different types of spectrographs were all mated to the scope over time, but none were able to produce research grade data.

Very recently, major upgrades to the ARCT have been made. Where there was a Windows XP computer, ribbon cable connections, and an antiquated control program, there is now a modern, powerful computer, high-speed USB connections, and a java powered multi-layered GUI (graphical user interface). Where there was 220-volt extension cords and Frankenstein-looking switches to manually open the big dome shutters, there is now clickable buttons in the GUI. Where there was a complex optical design involving multiple mirrors providing a small field of view, there is now just the primary mirror providing faster optics and wider field of view. Everything, including a CCD camera for scientific work and digital video camera for guiding, can finally be operated over the Internet.

The revised ARCT is so new it is just now being given its initial test drives. Once all the bugs are found and fixed, this big 1.83-metre telescope will be mated with the RAO's most valuable science instrument. Currently the very high-resolution echelle spectrograph (an instrument that splits light into its component colours) is mated to a small

0.20-metre telescope (mounted piggyback to the CMT). This echelle, being fed light from such a small telescope, is doing amazing work. When it gets light nearly one hundred times faster from the ARCT's primary mirror, real science will be done, and, possibly, new discoveries will be made.

a pathway for truth & reconciliation

It is customary at the University of Calgary to begin gatherings with an acknowledgement, in the spirit of Canada's Truth and Reconciliation Commission, honouring the many Native cultures in the Treaty 7 and Métis Nation territories in which UCalgary is located, and recognizing its fundamental connections to the rich Indigenous history of these lands. Rather than placing this acknowledgement at the beginning of this fifty-year reflection, it is given here with a story that connects research and teaching and outreach to what might well be the RAO's most important role at UCalgary.

Making new discoveries is the hardest thing to do in research, and the RAO's most famous discoveries were made by Rob Cardinal, a member of the Siksika Nation, which is a part of the Blackfoot Confederacy and on whose traditional lands the RAO resides. Rob got connected to the RAO through the University of Victoria, where he did an undergraduate degree in astrophysics. A very influential mentor of Rob's at UVic, and Canada's top asteroid discoverer, is Indigenous astronomer Dave Balam. Dave inspired Rob to join the search for those illusive bits of "leftovers" from when our solar system formed. He said it was the only astronomy that could truly matter to everyone in the world, depending on what you can find.

That opportunity came to Rob when the RAO's BNT came online in the early 2000s. It took years of toil, mostly alone and always in the darkness of night, to drive to the observatory and gather thousands of images. In the light of day and through cloudy nights he wrote and refined computer code to scrub the images and look for nearly imperceptible moving dots of sunlight reflected by tiny orbs. Indigenous astronomers are rare in Canada, and Indigenous astronomers who discover asteroids and comets are extra special.

A Piikani Elder, Leonard Bastein Weasel Traveller, honoured Rob by gifting him a Blackfoot name: Kakatos'ina. It translates as "Star Chief." In Siksika culture, great honours are truly great responsibilities. Today, Rob works as a consultant for the Siksika Board of Education as the STEM coordinator, and he honours the responsibility of his Indigenous name by teaching his young relatives about the sky and its beings and about the quest for knowledge through the lenses of both Western science and Indigenous ways of knowing.

The RAO has begun a journey to emulate Rob's teaching efforts with a new Indigenous initiative called Convergence: Where the People of the Land Greet the Sky. In accordance with the university's Indigenous strategy, ii' taa'poh'to'p, the RAO seeks to facilitate the convergence of Indigenous and non-Indigenous ways of knowing in the study of astronomy and the enjoyment of starry filled skies for all.

This is a new addendum to the RAO's mission statement. In an effort to follow this path, young and energetic and knowledgeable Indigenous summer students have been hired to help the RAO incorporate Indigenous perspectives into its educational and outreach programs.

the future

The past fifty years have been wonderful for UCalgary's RAO, and the future looks bright. Okay, hold on. When one is describing a fabulous observatory, the last thing you want to hear is that things are bright. Everything the RAO does—outreach, teaching, and research—all depend on dark, star-filled night skies. And in this regard the future, sadly, could be very bright.

From the perspective of a telescope, what does light pollution do? The modern digital camera is a marvel of technology filled with very tiny sensors called "pixels." A telescope scoops up light from above and focusses the stars onto the pixels. The pixels convert the particles of light they intercept into electrons. Finally, the computer counts the number of electrons in all the pixels and displays a digital image on the computer screen.

The stars pop out, of course, but what do you expect the counts to be when you look between the stars? If there are no stars there, then there is no light there, so the counts should be zero, right? In theory, that is correct, yet the computer finds electrons in those pixels, so light must have gotten there from somewhere. The source is not the blackness of space above the atmosphere; rather, it is the atmosphere the telescope looks through when it points at the stars.

The air particles are little reflectors bouncing around particles of light that originate not from the mysterious universe above but from a light bulb some distance away shining up into the night sky. When lights on the ground shine up into the sky at night, the atmosphere becomes a blanket of light. The telescope scoops up starlight and, at the same time, light from the blanket. Every pixel in the camera, including the ones that intercept star light, collects this “background” light.

Astronomers turn the camera into a scientific instrument by making measurements from the digital image. To measure the brightness of a star correctly, all these background counts need to be carefully accounted for. Explaining how this is done would take a semester—just ask our astrophysics students! Suffice it to say, there are techniques that work well. But wouldn’t it be nice if there were no background counts in the first place?

This is an example of how light pollution can be accounted for, and scientific goals can still be met. But what if the light pollution gets worse? What if the brightness of the atmospheric blanket grows? The first casualties are the tiny, faint dots of light, like the ones Rob Cardinal spotted, and which led to his discovery of comets and asteroids. The bright sky deposits more light onto the camera’s pixels than does the comet, thus drowning it out and rendering the comet invisible. And as the sky brightens more, the next-brightest interesting objects are erased from the sky. No amount of computer analysis or mathematical technique will bring these objects back into view.

This is what light pollution does from the perspective of a telescope, but we can’t forget that light pollution touches everything at night. In August 2023, the eighth International Artificial Light at Night (ALAN) conference was held at the University of Calgary. Including the online contingent, there were nearly 150 participants from almost thirty countries around the world. How many astronomers were among the participants? Just two.

The vast majority of the ALAN researchers are studying how the overuse of light at night is negatively affecting the natural world, from birds and animals to bugs and people. Other ALAN researchers are figuring out how best to measure and monitor it, or how to make smarter luminaries, or how cities and municipalities can manage light better. Light pollution a big global problem.

Fifty years ago, Calgary was a small globe of light on the distant horizon. Today it is bigger and closer to the RAO, and the nighttime sky is brighter. The university is constantly in communication with City of Calgary planners and developers and home builders to advocate for lighting strategies that will reduce light pollution. The RAO is constantly in communication with Foothills County councillors and local neighbours to advocate for the continued protection of the natural rural nighttime environment. The goal is to encourage everyone to use the absolute minimum amount of outdoor light at night, and only when outside using that light (and off otherwise), so that everyone can enjoy a star-filled sky, and the natural world can function as Mother Nature intended. If that can be achieved, people will be more in tune with nature, and RAO astronomers can continue to study the mysteries of the universe for at least another fifty years.

To find out more about the history and current work being done by the RAO, you can explore the observatory's website at https://science.ucalgary.ca/rothney-observatory.