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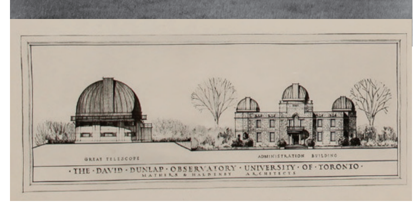
The David Dunlap Observatory in 1938.
Photo Courtesy of the University of Toronto Archives–Digital Image No: 2004-28-2MS.



The western elevation view of the proposed David Dunlap Observatory site from the architectural firm Mathers and Haldenby, Toronto 1932, showing the administration building and the large dome for the 74″ telescope. Photo Courtesy of the University of Toronto Archives.

Research Article / Article de recherche

The David Dunlap Observatory at 80

by Lee Robbins, Librarian, Department of Astronomy & Astrophysics, University of Toronto (robbins@astro.utoronto.ca), and R.A. Rosenfeld, RASC Archivist (randall.rosenfeld@utoronto.ca)

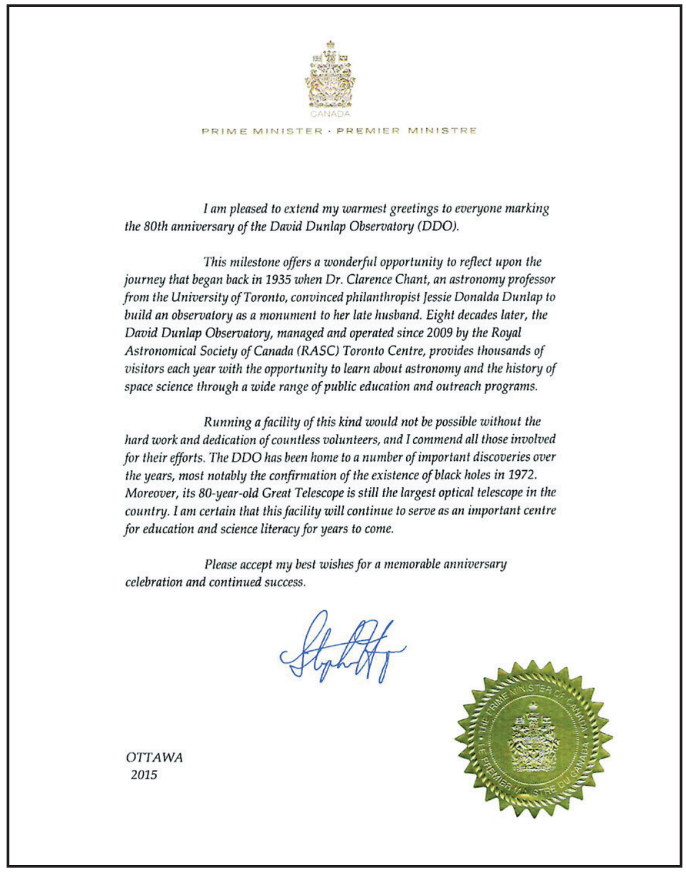
Abstract

Eighty years ago this last May 31, the David Dunlap Observatory (DDO) was officially opened before an assembled crowd of 1300 invited astronomers, university and political figures, and members of the general citizenry. The 74-inch (1.88-m) reflector at its heart remains the second-largest optical telescope ever erected in Canada.[1] To mark that event, a curated exhibition of rare astronomical artifacts tied to the building and use of the observatory was mounted concurrently with a symposium featuring reminiscences of former University of Toronto DDO staff, discussions of the cultural and scientific legacy of the installation, current programs and plans of the DDO RASC Toronto Centre staff, and innovative projects of the Dunlap Institute for Astronomy & Astrophysics, University of Toronto.

The Event

On Saturday, 2015 June 13, members of the University of Toronto's Department of Astronomy & Astrophysics, the Dunlap Institute for Astronomy & Astrophysics, and the Toronto Centre of the Royal Astronomical Society of Canada (RASC) celebrated the 80th anniversary of the opening of the David Dunlap Observatory (DDO). The event had its genesis more than a year prior in discussions between Lee Robbins, Librarian of the Department of Astronomy & Astrophysics at the University of Toronto, Randall Rosenfeld, Archivist of the RASC, Karen Mortfield, Public Affairs Coordinator for the Toronto Centre of the RASC, and Michelle Johns of the RASC Toronto Centre. About 80 invited guests participated in the day-long event, including 3 generations of the Dunlap family.

The occasion included displays of rare artifacts from the observatory, highlighting key elements of its conception, construction, and the scientific harvest of the dome in the early years (ca. 1935-1972).[2] Various films produced at or about the DDO over the decades were shown, including a Pathé reel of the construction of the 74-inch telescope in England by Sir Howard Grubb, Parsons and Co. Ltd., a short interview with Clarence Chant, the DDO dedication ceremony in 1935, and the National Film Board of Canada (NFB) documentary *Universe* (1960).



CANADA

PRIME MINISTER · PREMIER MINISTRE

I am pleased to extend my warmest greetings to everyone marking the 80th anniversary of the David Dunlap Observatory (DDO).

This milestone offers a wonderful opportunity to reflect upon the journey that began back in 1935 when Dr. Clarence Chant, an astronomy professor from the University of Toronto, convinced philanthropist Jessie Donalda Dunlap to build an observatory as a monument to her late husband. Eight decades later, the David Dunlap Observatory, managed and operated since 2009 by the Royal Astronomical Society of Canada (RASC) Toronto Centre, provides thousands of visitors each year with the opportunity to learn about astronomy and the history of space science through a wide range of public education and outreach programs.

Running a facility of this kind would not be possible without the hard work and dedication of countless volunteers, and I commend all those involved for their efforts. The DDO has been home to a number of important discoveries over the years, most notably the confirmation of the existence of black holes in 1972. Moreover, its 80-year-old Great Telescope is still the largest optical telescope in the country. I am certain that this facility will continue to serve as an important centre for education and science literacy for years to come.

Please accept my best wishes for a memorable anniversary celebration and continued success.

OTTAWA
2015

Figure 1 — Reproduction of the letter of congratulations from former Prime Minister Stephen Harper, on the occasion of the 80th anniversary celebrations of the DDO.

Figure 2 — The portraits of David and Jessie Dunlap unveiled by Bryan Gaensler and Paul Mortfield, a gift from the Dunlap Institute for Astronomy & Astrophysics.

Figure 3 — Photograph of three generations of the Dunlap family standing inside the 74-inch telescope dome.

Paul Mortfield, President of the RASC Toronto Centre, kicked off the event, welcoming all the guests and speakers, particularly the Dunlap family, and the then local Member of Parliament, Costas Menegakis, who presented members of the RASC with a letter of congratulations from Prime Minister Stephen Harper (Figure 1).

Bryan Gaensler, Director of the Dunlap Institute for Astronomy & Astrophysics, presented the Toronto Centre with excellent framed reproductions of the Joshua Smith (1880-1938) paintings of David (1934) and Jesse Dunlap (1924), as a gift from the Dunlap Institute for Astronomy & Astrophysics (Figure 2). The originals of these paintings originally hung in the DDO administration building, and today are part of the University of Toronto Art Collection (University of Toronto Art Collection 2006-084; University of Toronto Art Collection 2006-092).

David M. and J. Moffat Dunlap, grandsons of David Alexander Dunlap and Jessie Donalda Bell Dunlap, headed up the representation of the almost dozen members of the Dunlap family at the event. David M. Dunlap addressed those present on his family's relationship with the DDO, how pleased they were to see the gift that brought forth the DDO eight decades ago productively reinvisioned for the 21st century in the creation of the Dunlap Institute for Astronomy & Astrophysics, while at the same time witnessing the flourishing of the DDO as an instrument for education and public outreach (EPO) in the capable hands of the Toronto Centre of the RASC (Figure 3).

Short summaries of the presentations by the other speakers follow below. Several of the talks offer valuable material not previously recorded on the work and character of the DDO when it was an academic institution.

The morning and afternoon sessions were agreeably divided by a buffet lunch in a tented area on the sunny DDO grounds. A celebratory cake in the shape of the observatory was displayed to, and dispatched by, the guests. During the lunch break, attendees were specifically invited to view the curated exhibition of artifacts, visit the DDO telescopes (the 74-inch, and the recently restored 19-inch R.K. Reynolds reflector), and see the historical films.

The David Dunlap Observatory—The Prehistory

John Percy

Although the University of Toronto received its charter in 1827, its founders could not agree on whether it should be Anglican or secular, and it was not until 1853 that the university and its University College were firmly established (Friedland 2013). Coincidentally in 1853, the Toronto Magnetic and Meteorological Observatory (TMMO) was established on present university land by the Province of Canada, on the site of an 1840 British Admiralty magnetic observatory, constructed of logs, and the surviving stone building was commissioned (Beattie 1982, 109-110). The "Met Office" moved north to expanded quarters on Bloor Street in 1908–1909, and the 1853 TMMO building was saved from demolition by being moved a short distance, and became the present day Stewart Observatory.

Initially, astronomy and the other sciences were taught (rather descriptively) under the rubric of natural sciences. Practical astronomy was offered by the School of Practical Science (i.e. engineering, not formally part of the university until 1906), and mathematical astronomy was taught in the fourth year of the university's mathematics program. In 1878, James Loudon, Professor of Physics, created the first laboratory in Canada for undergraduate physics students, but it was not until 1887 that a separate Department of Physics was established. Clarence Augustus Chant (1865–1956), the "father" of astronomy at the University of Toronto, was one of the first beneficiaries of this new department and its laboratories; he received his B.A. in physics there in 1890.

Chant rejoined the department in 1892 as a lecturer. The university was growing rapidly at the time, as professional schools (such as education, engineering, and medicine), and religious colleges (St. Michael's, Trinity, Victoria, and others) affiliated with it. In the next three decades, Chant established a separate budget for astronomy, developed lecture and laboratory courses in observational astronomy and astrophysics, and created a separate Department of Astronomy—even though he had begun as a junior faculty member, was not a researcher, and was the only astronomer in his department. Knowing something of university administration and politics, I find his accomplishments remarkable. He spent 1900–1901 at Harvard, where he obtained a Ph.D. and a strong introduction to "modern" astronomy and astrophysics.

Meanwhile, public interest in astronomy and other sciences had been growing; it had been promoted by the York Mechanics Institute (1830), the Royal Canadian Institute

(1849), the Toronto Astronomical Club (1868), and—in the university—the University College Literary and Scientific Society (1854). Chant was not only an excellent teacher, but was also an enthusiastic and effective communicator to the public, through lectures, popular articles, and a best-selling book *Our Wonderful Universe* (1928; 1940, and numerous foreign language editions). He was also the guiding light for The Royal Astronomical Society of Canada (incorporated in 1890) for half a century. In 1924, he was joined on faculty by astronomer Reynold K. Young (1886-1977), a Canadian with a Ph.D. from the University of California, who was a prolific researcher. Chant could now, through his lectures and articles, promote the need for a major observatory for the university and the city for the purposes of astronomical research, training advanced students, and public education.

A glimmer of hope appeared after one of his public lectures in 1921, in the form of David Dunlap, who expressed an interest in the observatory project. Dunlap was a lawyer who had become wealthy as a result of mining ventures in Northern Ontario. Sadly, Dunlap died in 1924, but in 1926, Chant approached Dunlap's widow Jessie and persuaded her to donate to the university an observatory that would be a memorial to her late husband. As for a site, the university campus, and even city parks were no longer suitable for a major observatory, so Chant and Mrs. Dunlap went for a drive and settled on a site in the country, in Richmond Hill, not too far from the city. The rest is history; on 1935 May 31, the David Dunlap Observatory opened, housing the second-largest telescope in the world.

The Dunlap Institute for Astronomy & Astrophysics: Past, Present, and Future

Bryan Gaensler

The Dunlap Institute for Astronomy & Astrophysics is very much a 21st-century research institute at the frontier of our understanding of the Universe. Nevertheless, it is a matter of pride that all our activities are still very firmly rooted in the vision established by Jessie Donalda Dunlap when she established the David Dunlap Observatory 80 years ago.

Specifically, the Dunlap Institute's programs and initiatives across astronomy have four clear themes: innovative technology, ground-breaking research, training the next generation, and public engagement in science. In pursuing these topics, we aim to ensure that the generosity of the Dunlap family is translated into a legacy of discovery and knowledge about the cosmos extending for many centuries.

In modern astrophysics, innovative technological approaches sometimes involve enormous structures of glass and steel, and at other times require unique approaches in computing and software. The Dunlap Institute embraces and combines both approaches. One of our flagship projects is the Canadian Hydrogen Intensity Mapping Experiment (CHIME), a radio telescope 100 metres across that we and our collaborators have recently constructed in British Columbia. But CHIME is unlike almost any other telescope you've ever seen; it has no moving parts, and the images are constructed not by steering or pointing the telescope, but via the combining of billions of signals per second in a powerful new supercomputer. Using CHIME, we aim to understand the nature of the mysterious Dark Energy that dominates the cosmos, and that is causing the Universe to accelerate in its expansion (Dunlap Institute for Astronomy & Astrophysics, CHIME).

In sharp contrast, the Dunlap Institute has led the development of the innovative Dragonfly array. Dragonfly is a robotic telescope that uses lenses, rather than traditional mirrors—lenses that are just 40 cm across, 5000 times smaller than the giant telescopes now under construction in Chile and Hawaii. And yet, through superb optics and exquisite calibration, Dragonfly has discovered new galaxies fainter than any ever previously detected (Dunlap Institute for Astronomy & Astrophysics, DRAGONFLY).

Our astrophysics research is focused around the use of innovative instruments like these to see the Universe in new ways. One recent example is the Gemini Planet Imager (GPI), with which we have achieved one of the holy grails of modern astronomy; directly imaging planets orbiting other stars. While thousands of these "exoplanets" have been discovered, the vast majority are detected indirectly, through the way they affect the light of their parent stars. Direct imaging of these worlds is extremely challenging, because they are enormously fainter than the adjacent star. However, GPI masks out the light from stars, allowing us to see the faint planets around it. Using GPI, we are not only seeing new distant planets, but are also seeing the rings of debris around stars that denote planets in the process of formation (Gemini Planet Imager Exoplanet Survey).

Much closer to home, we are using radio telescopes to make spectacularly detailed images of the Earth's ionosphere. Astronomers usually view the ionosphere as an annoying foreground, much like streaks on a dirty car windshield. But by focusing on the streaks rather than the view behind them, we have discovered that the Earth's ionosphere is riddled with giant tubes of plasma, along which energetic particles spiral downward toward the ground from the depths of space (Dunlap Institute for Astronomy & Astrophysics, Distant Radio Galaxies Reveal Hidden Structures Right Above Our Heads).

While pursuing this frontier research, we maintain an unwavering focus on training the next generation of scientists and engineers. Part of this training is of course through our science, which almost always involves young students, and postdoctoral researchers. But research skills are not built just through experience or osmosis; we also run dedicated research training activities throughout the year. Our annual Dunlap Instrumentation Summer School draws students from all over the world, teaching them hardware skills that they will never find written in any textbook. This is a unique event, unlike anything else offered across the worldwide astronomy community (Dunlap Institute for Astronomy & Astrophysics, Summer School). And we have extended our activities globally, having run two very successful summer schools in Nigeria over the last couple of years (Dunlap Institute for Astronomy & Astrophysics, West African Summer School). Further engagement with Africa is now in the planning stages.

Finally, we have never lost sight of the fact that we have a deep responsibility to the wider community. Astronomy is the "gateway science," with a unique capacity to excite and inspire. To this end, the Dunlap Institute is heavily engaged in a huge range of outreach activities, ranging from the traditional public lectures and viewing nights, to "Astronomy on Tap" in the pub; from solar viewing on the sidewalk, to major events such as the Transit of Venus and lunar eclipses, each attracting upwards of 10,000 people.

The future is exciting. The Dunlap Institute continues to expand, both in its number of personnel, and in the scope of its ambitions. As we move into the era of billion-dollar telescopes, on-line education and citizen science, we aim to remain at the forefront of discovery, education, and engagement.

The Long Road to the Dome

R.A. Rosenfeld

In North America, the first great age of civic and collegiate engagement with astronomy materialized on the townscape in that aspiring prestige construction, the astronomical observatory. This epoch commenced before the American Civil War, and ended before Canada's entry into the Second World War. Edifices of skilled industry intended to impart, symbolize, and even occasionally produce science, civic and college observatories were popular with patrons of diverse means wishing to endow their own Uraniborgs for personal, local, or memorial glory. The *urbs* of Toronto, with its university and astronomical society, was no exception.

Exceptional, however, was the interval separating desire from fulfillment. Looking back from 1935 May 31, it must have seemed to the members of the city's astronomical community as if they had just emerged from over 40 years unwilling sojourn in the wilderness of perpetual disappointment. What they got in the end was not what they'd originally wanted; it was both more, and less.

In 1892, the Society attempted to entice Hart Massey to place an observatory atop Massey Hall (*TAPST* 1892 [1893], 84). The industrialist was politely sympathetic, but progress on the concert venue was too far advanced to accommodate an observatory. The site, while conveniently accessible, would not offer the most pristine of skies, and traffic may have affected the stability of the mount, particularly if the observatory was a late addition past the time to install a pier suitably isolated from sources of vibration. Had it been built, the Society's Massey Hall observatory would in time have been Toronto's less striking analogue to the Urania Zürich (1907; Mirwald 2014, 215-220).

During 1894–1896, members attempted to develop a proposal to establish a popular observatory (*TAPST* 1894 [1895], 79; *TAPST* 1895 [1896], 62; *TAPST* 1896 [1897], 24-25). It fared no better than the previous essay.

By 1898, The Toronto Astronomical & Physical Society could launch a campaign for a "People's Observatory" in early summer, with a $100 seed grant from the City of Toronto (Lindsay 1898; Anon. 1898). The desired instrument, as specified in the printed prospectus for the campaign, was a refractor equivalent in aperture to the *carte du ciel* astrographs and guidescopes (10 to 13-inch O.G.; Académie des sciences 1887, 102-103; Chinnici 2008). Among the trustees of the project listed in the prospectus is one "C.A. Chant, B.A." The document makes no mention of the use of the projected facility for research, or higher education—a fault pointed out by A.T. De Lury, Andrew Elvins, and others (APST Regular Meeting minutes 1898 June 14, 438-439; APST Council minutes 1898 July 19, 3). The Urania Observatory in Berlin was cited as a model for the "People's Observatory" of Toronto (APST Regular Meeting minutes 1898 June 14, 439). It is interesting to note that the successful *Volkssternwarten* in German-speaking continental Europe were the likely inspiration for a "People's Observatory" for Toronto (these are treated in Mirwald 2014; for Berlin, see 140-181). Unfortunately, this campaign failed to meet the minimum requirements for minimal success.

Ever optimistic, like a coyote in pursuit of a roadrunner, the observatory backers tried a fresh initiative in 1903. A committee was formed, which included the Director of the Meteorological Service of Canada, a Deputy Provincial minister and FRAS, an IAU member, and one current and two past RASC presidents (Rosenfeld 2013, 264). This was to be a cooperative project between the RASC and Trinity College (the then Provost was a Society member, and future council member); the College agreed to donate the land. The principal instrument was to be a 12-inch O.G. refractor (in the same aperture class as the instrument in the previous plan), and the observatory was to serve as the headquarters of the Society (Rosenfeld 2013, 265). Success once more eluded the observatory's promoters.

A personal triumph for Chant at about this time (1905) was the establishment of the sub-department of astrophysics in the university, but the lack of progress in achieving an observatory somewhat hampered the observational aspect of the program. As an interim measure, Chant sought and received access to the Meteorological Observatory's equatorially mounted 6-inch O.G. refractor, their transit instrument, and several of their staff as instructors (Chant, 1952, 753-754). That same year, Chant went on a pilgrimage to American observatories to examine their equipment, and seek advice from their directors. Lewis Boss, of the Dudley Observatory, recommended to Chant that a students' observatory be situated on or near the campus, and a research observatory "should be easy of access"(!), advice that struck him as sensible (Chant, 1952, 757).

The next try was in 1914, with Chant assuming the mantle of principal observatory promoter. As in the previous endeavour, the observatory was to be a joint university and RASC installation, but it differed in the increased grandeur of its movers' aspirations. The "Royal Astronomical Observatory" would be sited in "Observatory Park," located overlooking the Cedarvale Ravine bordering Bathurst Street, and would house 20-inch and 9-inch telescopes (almost certainly refractors), and the RASC library. "Sketch plans" were drafted by the noted architectural firm of Sproatt and Rolph. The timing was not of the best, however, and the commencement of the Great War meant the plan appeared to cop it, to use the trench slang of the time (Chant 1952, 765-770; Broughton 1994, 162).

The effort was revived in 1919. An astronomical delegation appeared before the city's Board of Control, including RASC members prominent in the city, such as the Provost of Trinity College, the Rev'd T.C.P. Macklem, and the Director of the Meteorological Service, Sir Frederick Stupart. Chant had prepared a memorandum on the observatory, which was distributed to enlist support. The memorandum, delegation, and other efforts had some success, for the city donated the land. The city's broadsheet dailies bestowed their blessings on the scheme, as did the Assistant Superintendent of the Canadian Geodetic Survey, and the Chief Astronomer and Director of the Dominion Observatory in the nation's capital (Chant 1952, 778). Chant also managed to secure Edward Emerson Barnard, an Honorary Fellow of the RASC, and one of the great and good of astronomy—famous for his comet discoveries, his finding of the fifth moon of Jupiter (Amalthea), and his much reproduced astrophotographs—to give two well-attended lectures in Toronto in March of 1920, to help publicize the observatory campaign (Chant 1952, 779-780). Another Honorary Fellow, George Ellery Hale, offered moral support, and fund-raising advice (Chant 1952, 781). Despite the prominent endorsements, the donated land, and Barnard's star turn, the effort failed like all those that came before. Why?

Oliver Wendell Holmes, who died the year the DDO was opened, is famously quoted as saying: "I like paying taxes. With them I buy civilization" (McGee 2011, 50). Most of the wealthy elite of Toronto demurred from the sentiment of the American jurist, preferring passive-aggressive revolt against buying civilization for others. One prominent banker told Chant that the newly instituted imposition of income tax on the rich robbed them of any desire to be philanthropically generous (Chant 1952, 783-784). The banker doubtless knew his clients. In 1906, Chant estimated he required $18,000 for a 20-inch refractor, and $8,500 for its enclosure. By 1922, he had revised the wish list to a reflector with a 60-inch primary mirror, which would have required nearly $200,000 (Chant 1952, 787-788). Depending on how one tallies up the observatory attempts, this was either the fourth, or the seventh time unlucky.

In 1921, David Dunlap, a member of Toronto's financial elite, *did* express interest in Chant's project. The basis for his interest seems to have been a genuine personal regard for astronomy, which Chant gently cultivated. He invited David Dunlap to became a RASC member, and advised him of rudimentary astronomical resources for astronomically curious members of his circle (Chant 1952, 783; 785-787). Unfortunately, David Dunlap succumbed to ill-health a year and a half after making Chant's acquaintance, apparently well before his interest could turn to active patronage. To many, the prospect for an observatory in 1924 may have seemed little better than it was in 1892. There was a difference this time, however, and that difference was Jesse Donalda Dunlap's choice to become the patron of the observatory project her late husband had heard Chant describe.

There were few models for female patronage of astronomical projects, and none of them were Canadian. Catherine Wolfe Bruce's (1816–1900) support for astronomy in the United States and Western Europe was outstanding (Payne 1900)—although she did not found any observatories, she provided funds for expensive equipment, programs, publications, and salaries, the last three being rarely funded by others. The only female founder of a North American observatory of whom I am aware, prior to Mrs. Dunlap, is Blandina Dudley (1783–1863), who established the Dudley observatory in memory of her husband, C.E. Dudley (1780–1841), in 1856 (Wise 2004, 15-16). C.A. Chant would have been well aware of both precedents, and might have cited them to Mrs. Dunlap when approaching her for patronage for a major Canadian observatory in memory of her husband.

In the Canadian context, endowing a research institution in the physical sciences was rare, and having a woman do so was unprecedented. Mrs. Dunlap could have chosen any variety of means to create a legacy for David Dunlap. Had she followed her husband's pattern of philanthropy, she would have been expected to endow the Methodist Church, or a medical institution, or an art gallery, or museum, or an ornithological cause in his name, rather than an observatory. In the obituary in *The Globe* those are all mentioned as interests of his and recipients of his past support, but nothing is said of astronomy (Anon. 1924). It is greatly to Mrs. Dunlap's credit that she took the unorthodox decision to found the David Dunlap Observatory in memory of her husband. The crucial factor that made the difference between the all-too-numerous failed attempts of the previous four decades, and the successful campaign resulting in the David Dunlap Observatory, was Jesse Dunlap's inspired patronage. Without her, the saga of the unbuilt observatory would doubtless have continued.

Mrs. Dunlap's gift may very well have inspired at least one other donation of a Canadian observatory, Frances Amelia Cronyn's gift of the Hume Cronyn Memorial Observatory to Western (1940).[3] Both C.A. Chant and Mrs. Dunlap participated in its opening ceremonies. One wonders if Chant reflected that the Cronyn Observatory was exactly the model of the observatory the Toronto astronomical community tried so hard to obtain over the first three decades of their effort: it was both Western's university observatory, and London's civic observatory; it was equipped with a 10-inch O.G. refractor; it was sited in easy proximity to the city's core; and it was planned to run with RASC involvement. What Toronto got was a major research telescope, on a site too far removed to take on the range of EPO functions of a *Volkssternwarten*. Pursuing greater "power of penetrating into space," to use William Herschel's colourful phrase, while certainly a prime research imperative, is not without its costs (Herschel 1800).

Universe: a Cinematic Triumph

R.A. Rosenfeld and Mike Reid

The National Film Board of Canada's (NFB) documentary *Universe* (1960) was a remarkable achievement in its time, and is still worth seeing today (NFB Universe). The DDO featured in the film as the portal through which Solar System and galactic vistas could be imaginatively conceived out of the sober stuff of science. Partly shot in a university setting, the film's life continues within that setting, for one of us screens portions of it in a basic astronomy survey for non-science students. Astronomy has developed hugely since the film was made, yet this artifact of a pre-dark-matter and pre-dark-energy cosmology can still provide teaching points centred around the non-fixity of the techniques and results of science, different choices in data-centred representations of remote phenomena, and the use of media for relaying science. The film is a journey "there and back again," and its context and making invite inquiry.

Imagine it's the 1950s...

Students sometimes have to be reminded that *Universe* was made before WiFi, digital editing programs, and CGI. Special effects were analogue, manufactured through the clever manipulation of physical constructs through varying factors, such as lighting, shooting angle, and velocity. In *Universe*, the urban-core landscape of Toronto functions as the locus of the "ordinary," the place where familiar activities are done by familiar beings, us, on a human scale in our manufactured landscape. Except that the passage of time has added another layer of alterity to what the original audiences experienced, for the city is both familiar, and unfamiliar. The cityscape feels the same, yet most of the structures have been replaced or altered, the tram cars are there, but they look vintage, the men wear fedoras, but there are no hipsters.

In retrospect, the 1950s seem more notable for cinematic science fiction than cinematic science. Robert Wise's classic *The Day the Earth Stood Still* (1951), with its alien Klaatu, his message of world peace for an anxious world, his robot Gort, and their flying saucer designed by Frank Lloyd Wright (Ruse 2015, 186), looks as vintage as Toronto's 1950's tram cars. Its visual aspect no longer possesses the persuasive force to evoke a possible future. This decade also saw the beginnings of *real* space exploration, namely the successful launch of Sputnik 1 on 1957 October 4. With it came the promise of actually "travelling" to the vistas imaginatively presented in *Universe.* The succession of scientific probes that have become the habitual extension of our senses, in seeing and touching space, is one promise of 1950's futurism, which we are presently living.

It is remarkable that the extension of "sight" into other wavelength regimes, combined with continual improvements in resolution, data storage, and processing during the intervening decades, has not entirely eroded the apparent verisimilitude of the space vistas presented in *Universe.* Who were its creators, how did they realize their project, and what was its immediate influence?

Creating Universe

Roman Kroitor and Colin Low provided the primary creative impetus for the film. According to Low, the idea to do "a film about an astronomer" originated with Kroitor (NFB Colin Low). Kroitor received academic training in philosophy and psychology, and was interested in experimentation and technical innovation in film (McSorley 2006; Langdon 2012—he would go on to invent the SANDDE stereoscopic 3-D animation technique, and co-invent the IMAX film system). Low, too, was willing to innovate, and later noted:

> "*...in Paris in 1949, I met Berthold Bartosch, the famous pioneer animator. He was planning a new film that he said*

was on the cosmos. His equipment was very simple but very ingenious, and he showed me how he planned to execute it with three-dimensional models. I was struck by his audacity and ingenuity...I remembered some of Bartosch's ideas on time exposure and the importance of extreme depth of field. The 35 mm rushes on asteroids began to look very good in action. The asteroids were clinkers from the furnace travelling on a panner that we built for Grant Munro for a puppet film that he was making" (NFB Colin Low).

A few more details on methods have been published: "For *Universe*, the surfaces of the moon and neighbouring planets[!] were created by such unconventional techniques as working asbestos powder and flour into a cardboard base" (James 1977, 546). It is interesting to note that *Universe* was made by Unit B, the sponsored films and animation studio, and not Unit D, the scientific and cultural films studio.

Kroitor and Low's vision required considerable ongoing experimentation during the years of production (1953–1960), and that meant expert skill, and the funds to pay for technicians, and materials. The special-effects team was headed by the inventive and versatile Wally Gentleman. The original budget estimate was $60,000, a very large outlay for an NFB documentary at that time. In the end, the film cost $105,146 (Evans 1991, 76-77; Jones 2005, 80). The "sky-rocketing" costs nearly imperilled the film (clearly the worlds of film and big-science share this ever-present danger).

The original purpose of *Universe* was "not so much to convey facts about the universe as to invoke a sense of wonder about it" (Jones 2005, 80), and it fit well into the venerable Enlightenment quest for the sublime. A commentator in the decade after its release wrote: "Model animation combined with photographs and drawings create an interplanetary landscape that has been matched only by in-space photographs of the real thing" (James 1977, 491). *Universe* was a success in more ways than one.

Stanley Kubrick was so impressed by the special effects that he discussed his project with Low, hired Wally Gentleman, and secured the narrator of *Universe*, Douglas Rain, to voice Hal in *2001: Space Odyssey* (Jones 2005, 81). NASA ordered 300 or more prints of *Universe* for training and EPO, it won 23 awards including an Oscar nomination, and by the early 1990s was the second-most widely distributed and lucrative NFB production (Evans 1991, 76-77; Jones 2005, 81).

The "film about an astronomer" did in fact feature an astronomer, Donald MacRae (1916–2006), who became director of the DDO five years after *Universe* was released, and was important in building up the department, and Canadian involvement in the next generation of telescopes after the 74-inch, both optical and radio (Seaquist 2006). Don MacRae's role in *Universe* was just one aspect of his commitment to EPO—he was also instrumental in securing funding for the McLaughlin Planetarium. Unit B was known for its

Figure 4 — Helen Sawyer Hogg and the DDO 74-inch telescope (reproduced courtesy of the University of Toronto Archives).

practice of "Direct Cinema" (a less intrusive form of *cinéma vérité*), and the scenes of urban Toronto are certainly part of the stuff of that tradition. At first glance the scenes with Don MacRae might persuade that they are also examples of Direct Cinema, but there are hints that that they are products of artifice: "Roman Kroitor and Dennis Gillson had shot a great live-action sequence of the astronomer and the observatory. I had pushed for lighting that would match the spectacular effects" (NFB Colin Low).

For much of *Universe*'s original audience, Don MacRae working with the 74-inch was their first exposure to a "realistic" filmic sequence of an actual professional astronomer acquiring data. Wherever *Universe* was screened in the post-Sputnik space age, Don MacRae in the DDO formed *the* image of the astronomer at work for many school children, and adults. That is a quieter cinematic triumph than an Oscar nomination, but it is no less significant.

Helen Sawyer Hogg

Christine Clement

In my remarks about Helen Hogg today, I do not intend to provide a complete biography. That information is available from a number of sources (Clement & Broughton 1993; Cahill 2009; Department of Astronomy & Astrophysics, Helen Sawyer Hogg). Rather I intend to share with you a few of my own memories and reflections on Helen's life and career.

I begin with this beautiful photo of Helen standing beside her beloved David Dunlap 74-inch telescope (Figure 4). Over a period of 35 years—until she was 65 years old—Helen observed with this telescope. More on that later. Lee Robbins, the U. of T. astronomy librarian, located this in the Helen Sawyer Hogg collection at the U. of T. Archives. And Paul Mortfield pointed out that Helen is holding a copy of the RASC *Observer's Handbook*. This is very fitting because the RASC, and the Toronto Centre in particular, held a special place in Helen's heart. January 1951 was a low point in her life—after the sudden and tragic death of her husband Frank, who was the director of the DDO when he died.

Helen's friends in the Toronto Centre gave her encouragement when she needed it badly. For the previous 10 years, Frank had written a weekly astronomy column for the *Toronto Star* and Helen played an active role in the preparation. She typed it, edited it, and sometimes even wrote it! What was to become of the column after Frank's death? Members of the Toronto Centre had the answer: Helen should write it! They conducted a fervent letter-writing campaign to the *Toronto Star* suggesting that she be invited to write the column. Back in 1951, the ability of women to carry out professional activities was not recognized in the way it is today. So the support of the Toronto Centre made a big difference. She continued with the column for the next 30 years—until January 1981 (Sawyer Hogg 1981a; 1981b; RASC, Eric Briggs, With the Stars). On looking back later in life, she acknowledged that the column would never have lasted for such a long time without the interest of her loyal readers, many of whom were members of the RASC.

During her years at the DDO, Helen also carried out an active research program with the 74-inch telescope. Beginning in the summer of 1935, she photographed globular clusters in order to identify and investigate their variable stars. Over the next 35 years, she obtained approximately 2700 photographs of 52 globular clusters.

It was interesting to be in the dome with her because her knowledge of the night sky was legendary. She knew exactly where all "her" clusters were located and on nights that were partly cloudy, she knew which ones she could reach in the breaks between the clouds. The DDO site was not ideal for observing variable stars in globular clusters, but Helen knew how to make the best of it. In 1971, the program was transferred to the Las Campanas observatory in Chile where the sky was darker and clearer. Also—in May, June, July—the prime season for observing globular clusters, the nights were longer there—which was advantageous for deriving accurate periods of variable stars.

Helen's globular-cluster program was conducted at the Newtonian focus, located at the top end of the telescope. In order to access the camera, the observer had to perch in the Newtonian cage—about 30 feet above the concrete floor (Figure 5). Some tricky manoeuvres were required to make the operation run smoothly and efficiently.

Figure 5 — Helen Sawyer Hogg at the Newtonian focus of the 74-inch telescope (reproduced courtesy of the Department of Astronomy & Astrophysics, University of Toronto).

When making photographic observations, it is necessary to load an unexposed plate into a plate holder, and remove it when the exposure is completed. This exchange takes place in the darkroom located on the floor below. Helen devised a clever scheme for transporting the plates up and down; she used a sturdy handbag attached to a long rope.

Another challenge was to guide the exposure. For this, the observer had to be positioned close to the camera, but the cage was attached to the dome, not the telescope. Thus, as the telescope tracked westward, it would drift away and the dome had to moved, but not too much! "Move the dome west 2 inches!," Helen would sometimes call out from her high perch. This was a challenge for telescope operators who had never worked during a session with the Newtonian focus. Generally, when one moves the dome, one moves it a few feet. But this was not feasible when the observer was in the Newtonian cage. If the dome was moved too far, she would crash into the telescope.

Most of you are aware that Helen grew up in New England. Her involvement with globular-cluster research began when she arrived at Harvard in the fall of 1926 to work with Harlow Shapley. She was very productive during her time at Harvard.

Shapley had made a name for himself in 1917 when he determined that the Sun was not at the centre of the Milky Way—a conclusion he reached based on observations of globular clusters (Sawyer Hogg 1965). His work was carried out at Mount Wilson, but in 1921 he moved to Harvard to become director of the observatory.

One of the benefits of his move to Harvard was that he had access to Harvard's extensive collection of globular-cluster photographs, offering an opportunity to strengthen his conclusion about the scale of the Milky Way. However, he had to find the right person to work on the project. It took him almost five years to solve that problem.

The solution came in January 1926, when the renowned Harvard astronomer Annie Cannon paid a visit to Mount Holyoke College in South Hadley, Massachusetts. At the time, Helen Sawyer was an enthusiastic astronomy major in her senior year. She was invited to lunch with Annie, and asked to show her around. After that, one thing led to another, and in September 1926, Helen arrived at the Harvard College Observatory to help Shapley with his book on star clusters (Sawyer Hogg 1988, 11-13).

In her collaboration with Shapley, Helen studied variable stars, but she also used the Harvard plate collection to derive general properties of clusters—integrated magnitudes, magnitudes of their brightest stars, angular diameters, degree of concentration—in order to understand how these parameters are related to a cluster's intrinsic brightness so that its distance can be determined.

In those days, the best method for determining a cluster distance was to estimate the brightness of its RR Lyrae variables, but that was not a viable method for most clusters.

Shapley's 1917 analysis included 68 clusters, but only 5 had RR Lyrae stars (Shapley 1930, vii-viii). His Harvard analysis with Helen included 93 clusters, 19 with RR Lyrae stars, but not all of these variables had been fully investigated, i.e. their periods had not been determined. There was more work to be done!

During her years at Harvard, Helen met and married Frank Hogg, a fellow graduate student and a Canadian. In 1931, a year after their marriage, they moved to Victoria, where Frank took a position at the DAO. In the course of carrying on her research with Shapley, Helen had recognized the importance of identifying and investigating variable stars in globular clusters. At the DAO, she was in a perfect position to do this herself. So in 1931, she set up her own observing program using the 72-inch reflector at the DAO. Then, when the family relocated to Richmond Hill in 1935, she continued the program with the DDO 74-inch.

As we all know, Helen made a name for herself as a newspaper columnist and as an expert on RR Lyrae variables, but she also had considerable impact with some of her other scientific publications. After her experience with Shapley, she was an expert on the general properties of globular clusters, and was often invited to write review articles on the subject (e.g. Sawyer Hogg 1959).

She also recognized that there was a great need for bibliographies summarizing globular-cluster research—long before the days of the Internet, or the Harvard Astrophysics Data System. In addition, she published catalogues of variable stars in clusters to enable researchers interested in the subject to get a clear picture of exactly what work had been done.

She carefully monitored every piece of literature that was received in the Observatory library. When new material arrived, it was placed in a special drawer and not put out for general circulation until Helen had gone through it. As a result, she kept up to date with recent developments in the field, and this was valuable for her bibliographic work, and for her newspaper columns.

Throughout her life, Helen travelled to some very interesting places, and in 1958 she made it to Samarkand, the centre of the empire of Timur, also known as Tamurlane the Great. Its heyday was in the 14th and 15th centuries.

In 1958, the General Assembly of the International Astronomical Union was held in Moscow. It was a time when the Soviet Union was opening up to westerners after the death of Stalin. And one of the post-conference tours was to Samarkand. Samarkand had astronomical significance because, in the first half of the 15th century, it was ruled by Timur's grandson Ulug Beg, who was a mathematician and astronomer. The organizers of the 1958 conference wanted the visiting astronomers to have a chance to see Ulug Beg's observatory, which among other instruments, featured a monumental quadrant ("Fakhrī sextant") built into a hill. That was why Helen went.

In the mid-20th century, the living conditions in Central Asia were very primitive, so it was quite an adventure. If any of you have attended a banquet in Russia or the Soviet Union, you will know they like to propose toasts—and the tour to Samarkand was no exception. For each toast, the men were required to empty their glass of vodka, and then it was refilled for the next toast. Helen reported that the men in their group were "under the weather" the following morning. Sometimes there are advantages to being a girl.

Attending the conference in the Soviet Union gave Helen the chance to make personal contact with astronomers behind the Iron Curtain, and she made the most of it. She corresponded regularly with astronomers in Moscow, Prague, and Budapest, and did everything she could to make sure that their papers were cited—something western astronomers were not always willing to do during the Cold War.[4]

In recognition of her life-long achievements, Helen received many awards and honours, including appointment as a Companion of the Order of Canada in 1976.

Reminiscences of Radio Astronomy at the DDO 1956–1966

Ernie Seaquist

My presentation in celebration of this 80th anniversary describes briefly the radio astronomy work at DDO during the decade 1956–1966. The work was a collaboration between the Departments of Astronomy and Electrical Engineering of the University of Toronto, with Donald A. MacRae and J.L. Yen as the respective co-leaders. It was initiated to allow graduate students to train in the relatively new field of radio astronomy, and to produce research at the level of a Master's degree. Though the work included both solar and cosmic observations, the principal effort was in the latter area with focus on absolute measurements of the flux densities of strong radio sources, such as Cas A, and Cyg A, and the galactic-background emission. Such absolute measurements are essential to calibrate the larger surveys of discrete radio sources and Milky Way surveys.

The work was conducted in the field to the immediate east of the DDO administration building, but some of the later work was carried out at the University of Toronto site of the Algonquin Radio Observatory (ARO). Figure 6 shows the various antennae that were used in the DDO work (circa 1960), together with the "radio shack" that housed the receiver

Figure 6 — Image of the DDO radio observatory, taken looking east from the roof of the DDO Administration Building, ca. 1960. The two antennas on an east-west baseline to the left are wire mesh parabolic cylinders used together with one of the pyramidal horns in an early phase of the interferometric work on discrete sources. At centre right are the two pyramidal horns arranged as an east-west interferometer and used in the final phase of this work. They are shown straddling the mounting tower for an unrelated "zig-zag" antenna used for solar measurements. The radio shack housing the receiver is clearly visible. The antenna to the immediate right (south) of the radio shack is a prototype segment of an east-west array intended to be part of a much longer array at 707 MHz at the Algonquin Radio Observatory. This array was never built, and the prototype section was never used as a radio telescope on its own (reproduced courtesy of the Department of Astronomy & Astrophysics, University of Toronto).

operating at a frequency of 320 MHz (approximately 1 metre wavelength). The principal antennae used were the two pyramidal horns to the right of the centre of the photograph, which were aligned east–west as an interferometer with a baseline of 60 metres. Interferometric measurements are superior to single antennae for measurements of point-like sources. The pyramidal horn was used because of its simplicity, and its accurately determined collecting aperture, essential for measuring absolute fluxes. Figures 7 and 8 show details of one of the two pyramidal horns and the horn reflector antenna that was used at ARO. The latter antenna was especially well adapted to absolute measurements of extended galactic emission, and was of the same type used by Penzias and Wilson for their discovery of the Cosmic Background Radiation (CBR).

The primary measurements conducted were of the absolute flux densities of the discrete sources Cas A and Cyg A at 320 MHz, which led to the publication of an accurate flux primarily for Cas A (MacRae & Seaquist 1963). A second important set of measurements was made of the absolute brightness of the North Celestial Pole at 320 MHz and 707 MHz, using respectively the pyramidal horn and horn reflectors (Wall, Chu, & Yen 1970). Such measurements required careful calibration of the antenna side lobes, so background spillover thermal emission from the ground could be subtracted.

An interesting note about the latter measurements was brought to light by one of the authors, Jasper Wall, sometime after the aforementioned discovery of the CBR. The existence of the CBR and its approximate brightness of 3K were inferable from the DDO and ARO measurements because the radio spectral index (or ratio of fluxes at the two frequencies) were significantly influenced by the CBR, so that it was consistent with the spectral index of galactic synchrotron emission only after the CBR contribution is first removed from each measurement (Wall 2009).

Work at DDO wrapped up in the mid-1960s largely due to increasing levels of radio interference from traffic on nearby roads, and shortly thereafter by the emergence of the 46-metre radio telescope at ARO, Canada's first national facility for radio astronomy, open to all Canadian astronomers.

The David Dunlap Observatory: Present & Future

Paul Mortfield

When the Dunlap observatory and lands were sold in 2008, the new owners of the property posted a note looking for an organization to run the facility. This was a wonderful opportu-

Figure 7 — A close up of the west element of the pyramidal horn antenna interferometer used for the Cas A absolute flux measurements and the antenna used for measurements of the absolute brightness of the North Celestial Pole at 320 MHz. The dimensions of the aperture are 2.76m x 3.70m. This type of antenna was used because its electrical collecting aperture area can be readily computed from the electromagnetic theory of waveguide apertures (reproduced courtesy of the Department of Astronomy & Astrophysics, University of Toronto).

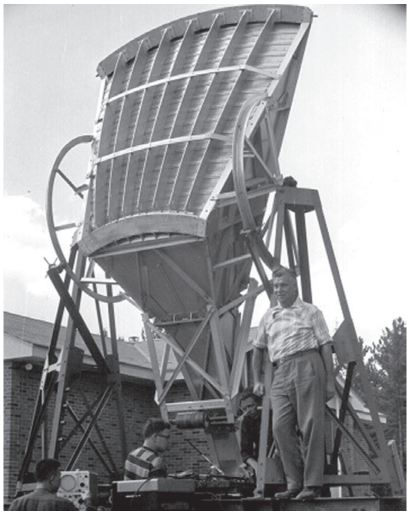


Figure 8 — An image showing preparatory work on the horn reflector antenna at the University of Toronto site of the Algonquin Radio Observatory. It was used to measure the absolute brightness of galactic emission at 707 MHz at the North Celestial Pole (reproduced courtesy of the Department of Astronomy & Astrophysics, University of Toronto).

nity for the Toronto Centre of the RASC to step up to a challenge. The Toronto Centre, a registered charity, has a long history of providing astronomy education and outreach programs around the greater Toronto area, including assisting with the outreach programs at the Dunlap Observatory since its opening in 1935.

Since assuming stewardship of the facility in 2009, the Toronto Centre has ensured that the David Dunlap Observatory in Richmond Hill, Ontario, continues to function—indeed, to thrive—despite all odds. The group has welcomed more than 25,000 visitors to the observatory, offering a rich variety of public outreach and education programs to school groups, and Scouts and Guides, as well as to the general public. Members focus on delighting visitors with views of the night sky, increasing their understanding of astronomy, and encouraging young people to pursue careers in the sciences (Figure 9).

These programs, run entirely by volunteers, require more than 2500 person hours per season. In addition, about 1500 additional volunteer hours are dedicated to the ongoing maintenance of the Great Telescope and its precinct. This also includes re-aluminizing the 2.5-ton primary mirror. The observatory team has been trained in all the operations and maintenance processes by 40-year observatory veteran, Archie de Ridder.

The Toronto Centre now offers Family Nights that are tailored to the needs and interests of parents with young children. A "Space Crafts" room has been set up in one of the classrooms of the Administration Building, where, with arts-and-crafts supplies, creative Toronto Centre volunteers encourage youngsters to create their own constellations, build an alien (or become one), and learn about space through hands-on activities.

The "Skylab" was created out of a large, somewhat battered office space. Members painted the walls "projection-screen white," installed carpeting, and sewed large pillows for lounging. They then installed a projector and audio system, to allow the projection of any space-based programming across a seven-metre expanse of wall, to create an immersive, educational experience. A team of trained presenters delivers a range of age-appropriate outreach programs.

In Ontario, high-school students are required to complete 40 hours of community service before graduation. Because of its charitable status, the Toronto Centre is able to offer a student intern program at the DDO involving several dozen York Region students each season. Several students have returned to their schools and started their own astronomy clubs. A number of the DDO's former high-school interns are now pursuing university degrees in the sciences.

We're creating a Space Science Campus within the administration building to provide daytime-school field trips and science-based after-school and weekend programs that cover astronomy, robotics, and citizen science. In addition, we're looking to create York Region's first maker space, and to include gallery exhibit space for community events. We will add a small automated telescope into one of the domes on the roof to be used for imaging requests from Ontario classrooms and students studying astronomy. The telescope will provide images of requested celestial objects and observational data, allowing students to analyze variable stars, asteroids, and exoplanets as part of their studies. It's an exciting component

Figure 9 — Outreach efforts by members of the Toronto Centre of the RASC, under the 74-inch dome (reproduced courtesy of The David Dunlap Observatory, RASC Toronto Centre).

that allows students access to real data to study astronomy first hand. We'll also use the observatory telescopes for live webcasts as virtual observing sessions for classrooms wishing to interact with scientists, and space experts.

With its new mission in science education, the David Dunlap Observatory will continue to be a centre of excellence to inform and inspire the community to look up and wonder about the amazing universe around us for many years to come (the DDO). ✶

Contributors

Christine Clement is an Emerita Professor in the Department of Astronomy & Astrophysics at the University of Toronto. Her research specialty is variable stars in globular clusters, and other stellar systems. She was a student and a long-time professional collaborator of Helen Sawyer Hogg's.

Professor Bryan Gaensler commenced as Director of the Dunlap Institute for Astronomy & Astrophysics in January 2015. He is a radio astronomer who works on cosmic magnetism, time-domain science, and the diffuse Universe.

Paul Mortfield is the present Director of the David Dunlap Observatory. He is a member of NASA's Education Products Review team, is chair of the Solar Division of the American Association of Variable Star Observers (AAVSO), and is a noted astrophotographer.

John Percy is an Emeritus Professor at the Department of Astronomy & Astrophysics at the University of Toronto, and a Fellow of the RASC. His association with DDO began in his undergraduate days, in 1961. He is the inaugural recipient of CASCA's Qilak Award for Astronomy Communications, Public Education, and Outreach.

Dr. Mike Reid is Lecturer and Public Outreach Coordinator for the Dunlap Institute, and a radio astronomer. In 2015, he was a winner of a University of Toronto Early Career Teaching Award. He is the Chair of CASCA's Education & Public Outreach Committee.

Lee Robbins is Head Librarian of the Department of Astronomy & Astrophysics of the University of Toronto, and is the former librarian of the DDO. Before taking up her present appointment she was a librarian at Fermilab. She has an interest in the historical artifacts of the physical sciences, on which she has published.

R.A. Rosenfeld is the Archivist of the RASC. He has published on astronomical artifacts and the people who produced and used them, from the Middle Ages to the modern period. He is a recipient of the RASC's Simon Newcomb Award, and, like his colleagues John Percy and Lee Robbins, serves on CASCA's Heritage Committee.

Ernie Seaquist is an Emeritus Professor and former Chair of the Department of Astronomy & Astrophysics at the University of Toronto, and a former Director of the David Dunlap Observatory. He is a radio astronomer, and still conducts research on the ISM in active star-forming galaxies. He is a recipient of CASCA's Carlyle S. Beals Award.

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Endnotes

1 The largest is the University of British Columbia's 6-metre liquid-mirror telescope, the Large Zenith Telescope, located in UBC's Malcolm Knapp Research Forest (first light 2003), and the third largest is the Dominion Observatory's 72-inch (1.83-m) telescope, at Saanich, B.C. (first light 1918).

2 The bulk of the items on display were drawn from the holdings of the Department of Astronomy & Astrophysics of the University of Toronto, with the remaining items coming from the collections of the Archives and Records Management Services (UTARMS) unit within the Department of Rare Books and Special Collections of the University of Toronto. Other artifacts from the University of Toronto era of the DDO were donated to the Canada Science and Technology Museum (CSTM) in 2008.

3 I owe this possibility to a suggestion of Dr. Dale Armstrong and colleagues of the London Centre of the RASC.

4 Her sense of rapprochement was shared with her mentor, Harlow Shapley.