Figure 4 shows the radiance of the nighttime sky over the RAO as measured by the Zenith-SQM over the two-month block of time of March and April 2014. Radiance in NSU is plotted as a function of time relative to local midnight. A red horizontal line corresponding to 2 NSU is included to help guide the eye. The change in the duration of the night is noticeable over this time span. There is a small range in radiance minimum, but on a couple of nights the radiance goes slightly below 2 NSU. For the RAO, these are very dark nights.

Figures 5 shows the overall results in two-month interval bins so that the change in that interval over the years can be examined. There appears to be some seasonal variation between winter and summer, with summer nights reaching NSU = 2 consistently. The winter month nights are generally ~0.5 NSU brighter, which might be attributable to snow cover and seasonal festive lighting.

Looking across the ~3 years of data, the sky brightness seems to be holding quite constant, with perhaps a hint of a slight darkening. If so, this would be consistent with Cleland's observations in his *JRASC* 2016 article. Even a constant sky radiance is quite amazing, given the marked population growth of Calgary and subsequent development. Perhaps the City Planners are getting things right with regard to smart lighting.

The RAO is extremely fortunate to be sitting under such lovely dark skies, when the clouds and the Moon cooperate.

The true importance of this analysis is that it serves as a baseline of comparison for the future. As stated in the introduction, development is ramping up in the rural areas around the observatory. The Dark Sky Initiative bylaw has been on the books for seven years now, and for the most part, the RAO's neighbors are doing a great job keeping their lights down and off. But looming in the near future is the construction of the last leg of the City's ring road, and a new residential development, bringing many bright lights closer than ever before. We're working hard to keep stakeholders and neighbours educated so as to keep the RAO under dark skies for as long as possible.

Two final notes. First, the RAO has several hand-held SQMs which are available for loan. If any RASCal would like to give them a try, feel free to contact the author to make arrangements. And second, the 2018 Annual General Meeting of the RASC is being held in Calgary. This is a very special AGM for the RASC as it marks the 150th anniversary of the Society in Canada, and the 60th anniversary of the Calgary Centre. If you come to Calgary to partake you are invited on a free tour the RAO. Transportation and meal will be provided. ✶

Feature Articles / Articles de fond

A Short History of Astrophotography: Part 1

by Klaus Brasch

Abstract

In the past several years, two excellent histories of astronomical photography have been published (Ré, 2010 and Hughes, 2013). The former is available only as e-book and the latter in both e and paper formats. In addition, several websites have collections of vintage astronomical photos and illustrations (see e.g. Pinterest 2016). Each presentation places emphasis on different aspects of the story, as have we. Ré's work makes no effort to be comprehensive, highlighting instead selected individuals and applications to the end of the film age. Hughes's monumental work covers a very broad array of topics, with again emphasis on the people and the social settings of their respective eras. Our focus here is on Solar System photography and the evolution of the technologies that have advanced both the science and art of astronomical imaging from Daguerreotype to web cams and CCDs. We also place great emphasis on contributions by amateur astronomers.

Introduction

As we gaze in awe at the spectacular images of Solar System objects provided by *Hubble* and other space telescopes, assorted satellites, probes, and surface landers, it's easy to forget that prior to the start of the space age in the 1960s, our knowledge about these bodies was fragmentary at best and downright wrong at worst. Most of what was known to that point was based on three centuries of visual telescopic work, the bulk with modest telescopes and by amateurs, and less than a century of spectroscopic, photometric, and photographic work, which really came into its own only in the 20th century.

Thus as late as the 1960s, the rotation periods of both Mercury and Venus had not been determined with precision, and any knowledge of surface conditions on Venus was shrouded by the planet's dense and enigmatic atmosphere. Some visual observations at the time even suggested that permanent or semi-permanent surface markings could be glimpsed through gaps in the rapidly moving Venusian cloud deck (Dollfus, 1961). Our ignorance about conditions on Venus at that stage is nicely summarized by Roger Launius in his 2014 November 7 blog (Launius, 2014) on *Visions of Venus at the Dawn of the Space Age*: "…perhaps surprisingly, in the first half of the twentieth century a popular theory held that the sun had gradually been cooling for millennia and that as it did so, each planet in the solar system had a turn as a haven for life of various types." Although it was now Earth's turn to harbour life, the theory suggested that Mars had once been habitable

Figure 1 — Venus that never was (Schenk, 2012)

and that life on Venus was now just beginning to evolve. Beneath the clouds of the planet, the theory offered, was a warm, watery world and the possibility of aquatic and amphibious life. "It was reasoned that if the oceans of Venus still exist, then the Venusian clouds may be composed of water droplets," opined JPL researchers as late as 1963; "if Venus were covered by water, it was suggested that it might be inhabited by Venusian equivalents of Earth's Cambrian period of 500 million years ago, and the same steamy atmosphere could be a possibility" (Figure 1) (Schenk, 2012).

Likewise, despite having been scrutinized more closely than any other planet, our understanding of the ever-tantalizing Red Planet Mars in the early 1960s was at a crossroads (Brasch, 2016). Though the infamous "canals" debate was largely (but not completely) over, the nature of the planet's albedo features remained unclear, the true make-up of the polar caps and associated seasonal changes was only partly understood, and there was still the fading hope that lichen-like vegetation covered at least parts of the surface (Richardson and Bonestell, 1964). This hope was based largely on spectroscopic work by William Sinton in 1958, hinting that absorption bands due to organic C-H bonds were detected over the Martian dark features but not its deserts. Based on this evidence and the long-observed seasonal changes on the planet, the authors concluded "If there is extraterrestrial life in the Solar System, Mars is the only planet for which we have the slightest evidence for it." This view was perhaps best illustrated by the magnificent vision of future space exploration as depicted by Chesley Bonestell (Figure 2).

Although Jupiter's features and moons had been judiciously monitored telescopically since the mid-1800s, the physical nature and chemical composition of the Great Red Spot and other atmospheric phenomena was still poorly characterized in the pre-space era. Much of what was known was largely based on visual work by amateur astronomers engaged in long-term central-meridian timings of Jovian features in order

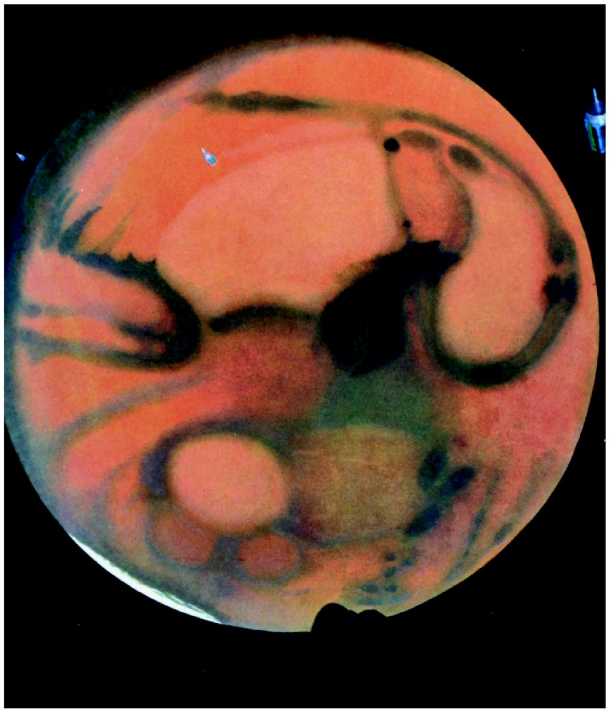


Figure 2 — Mars as depicted by Chesley Bonestell ca. 1960 (Wikicommons)

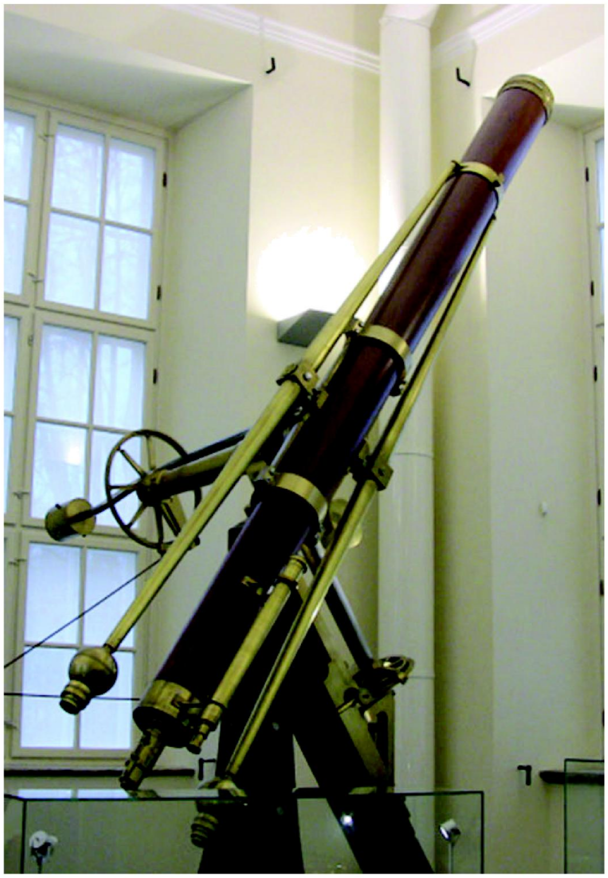


Figure 3 — Great Dopart Refractor (Tartu Observatory)

to determine their rotation and relative drift rates (Peek, 1958). Finally, major uncertainties also existed about Saturn's atmosphere and complex ring system (Baum, 2009), and virtually nothing was known of the composition and dynamics of the atmospheres of Uranus and Neptune and the surface of Pluto.

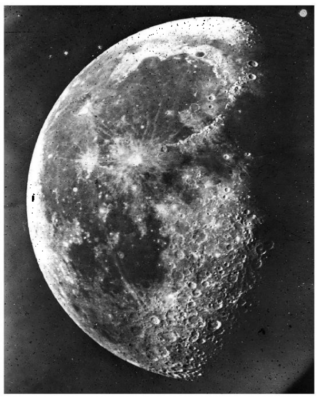
All that changed in 1957, with the launch of the first artificial satellite *Sputnik 1* and the International Geophysical Year (IGY), which made it clear that the long-anticipated space age had arrived, and that worldwide scientific cooperation could at last be achieved. *Sputnik* and the IGY provided the impetus for many of my generation to view science not only as an exciting adventure, but also as a vocation that could lead to the advancement of knowledge and betterment of humanity. Naive perhaps, in retrospect, but youthful idealism that propelled many of us toward rewarding careers as scientists and engineers, researchers and teachers who would impact several subsequent generations.

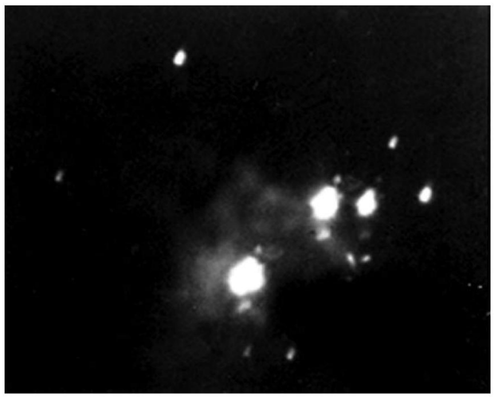
Beyond Visual Astronomy

The mid-1700 to 1800s saw several important technological developments that greatly improved both the quality of astronomical observations and extended them beyond the visual realm. Numerous individuals and devices played pivotal roles in this regard. Key among them was the invention of the achromatic lens, likely in 1733 by Chester Moore Hall (and possibly others) and patented in 1758 by John Dollond in England, and the English fork equatorial mount by Henry Hindley of York around 1740. Although it would take several decades and additional trial and error by John Dollond and his brother Peter, and Alexis Clairault in France and others, before quality crown and flint achromatic telescopes were produced, they were applied almost immediately to astronomy (Learner, 1981). Around 1814, gifted German optician and instrument maker, Joseph von Fraunhofer (1787–1826) invented the spectroscope and diffraction grating, and went on to manufacture vastly improved refracting telescopes, including the legendary 9.4-inch (24 cm) Great Dorpat Refractor in 1824 (Ré, 2010). This equatorially mounted telescope, complete with clock-drive mechanism, became the prototype of all subsequent refracting telescopes and mounts (Figure 3). Recently restored, this historic telescope is still housed at Tartu Observatory in Estonia. At last refracting telescopes became available that were not overwhelmed by chromatic and other aberrations and could automatically track objects across the sky. Shortly after that, multi-talented French physicist Leon Foucault, inventor of the pendulum named after him, also first applied silver to glass telescope mirrors (1857) and developed his famed knife-edge test for telescope mirrors. Coupled with development of the fork and English equatorial mounts by Jesse Ramsden, William Lassell and others eventually led to the rise of large glass-mirrored reflecting telescopes, replacing the cumbersome speculum metal mirrors used prior to that (Learner, 1981). Finally, the mid-1800s saw the development of photographic methods, which revolutionized astronomical research for good.

The Dawn of Astrophotography

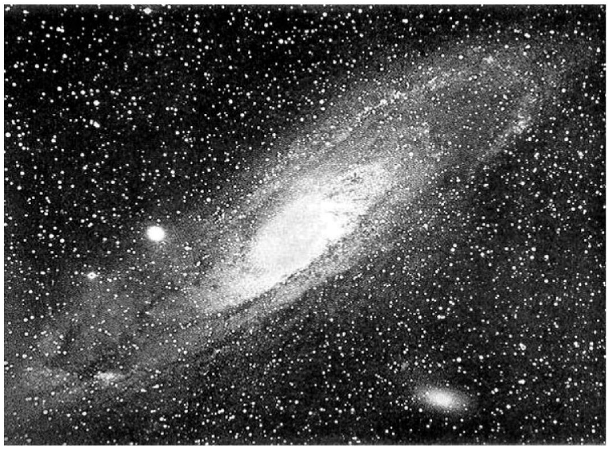
In 1839, Louis Daguerre in France commercialized a metal-based process to take stable photographic images. This complicated wet-plate method known as daguerreotype, was used a year later, by the talented English-born American scientist, J.W. Draper, (1811–1882), to capture the first daguerreotype image of the full Moon in 1840 (Figure 4). It took several decades more before Henry Draper (1837–1882), the son of J.W. Draper and a New York physician and amateur astronomer, first imaged the Moon and the Orion Nebula in 1880, using the newly invented dry-plate photographic method (Figures 5-6). This was followed three years later by a much-improved image of M42 by English astronomer and telescope maker, A.A. Common (1841–1903). This long-exposure image (Figure 7) showing extensive nebulosity, earned him the gold medal of the Royal Astronomical Society. In 1887, Welsh engineer Isaac Roberts (1829–1904) obtained the first long-





Figures 4 — J.W. Draper's first daguerreotype of the full Moon (Wikicommons)
Figures 5 — H. Draper's first dry-plate of the Moon (Wikicommons)
Figures 6 — H. Draper's first dry-plate of the Orion Nebula (Wikicommons)

Figures 7 — A.A. Common's much improved photo of M42



Figures 8 — Isaac Robert's superb 1887 photo of the Andromeda nebula (Wikicommons)

exposure photograph of the Andromeda Galaxy (Figure 8), a magnificent image even by modern standards that also earned him the gold medal of the Royal Astronomical Society. For more details, see Hughes (2013).

While there was clearly no single "father" of astrophotography, Henry Draper certainly qualifies as one of them. In addition to obtaining the first photographs of the Orion Nebula, he also secured many other fine images of celestial objects, including the first spectrum of the star Vega and the first wide-field image of a comet.

Successful large-scale planetary photography was not achieved until 1885, however, when the brothers Pierre Paul Henry (1848–1905) and Mathieu Prosper Henry (1849–1904) used a 33-cm (13 inch) photographic refractor at the Paris Observatory to image both Jupiter and Saturn (Figure 9). They did this using a refractor of large focal ratio (f/10.4) coupled with an 11x enlarging lens. These two innovative astronomers were not only capable instrument makers and astrophotographers but also key players in the *Carte du Ciel* (Map of the Sky) and the *Astrographic Catalogue* (Astrographic Chart) projects. These were complementary components of a 19th-century international astronomical effort to catalogue and map the positions of millions of stars down to 11th or 12th magnitude.

Arguably, however, few astronomers of that era were as versatile and productive as E.E. Barnard (1857-1923) (Figure 10). Born to a poor family in Nashville, Tennessee, he eventually rose to prominence at Yerkes Observatory and as professor of astronomy at the University of Chicago. In addition to being an exceptional visual observer, he also discovered Saturn's moon Iapetus, Jupiter's 5th moon, Amalthea, Barnard's Star, and 15 comets; he really excelled at astrophotography. Although he mastered all aspects of astrophotography, his crowning achievement was a stunning series of wide-angle photographs of the Milky Way, revealing for the first time its many dark nebulae and clouds of interstellar dust (Figure 11). These images, still used today, were published posthumously in

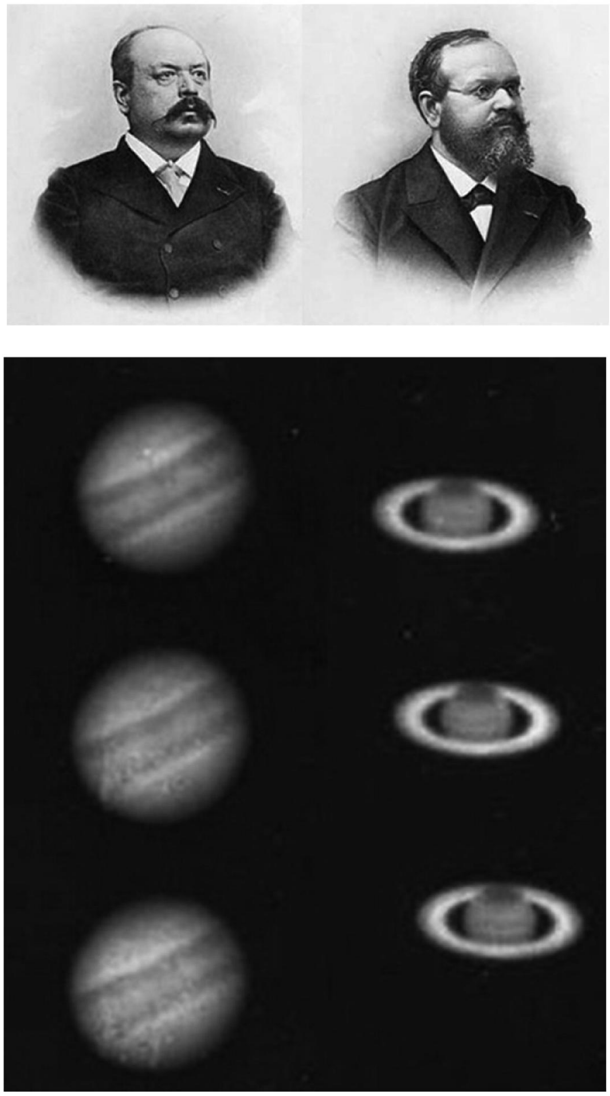


Figure 9 — The brothers Pierre and Mathieu Henry and their first detailed photos of Jupiter and Saturn taken in 1885 at Paris Observatory

1927 as *A Photographic Atlas of Selected Regions of the Milky Way* (Sheehan, 1995; Sheehan and Conselice, 2015).

The early 1900s saw a flourish of quality astronomical photography, including both Solar System and deep-sky objects, as well as spectroscopy. Among the earliest high-resolution planetary photographs were those obtained in 1904 by Carl Otto Lampland (1873–1951) with the 24-inch Clark refractor at Lowell Observatory (Figure 12). Lampland designed and built special enlarging cameras for planetary photography, while also maintaining telescopes, including the observatory's 42-inch reflector, with which he subsequently obtained many excellent images of star clusters and nebulae. He built thermocouples to measure temperatures of the planets, and noted large differences between night and day temperatures on Mars, implying a thin atmosphere. In addition to having an asteroid named in his honour, impact craters on both the Moon and Mars also bear his name (Putnam, 1994).

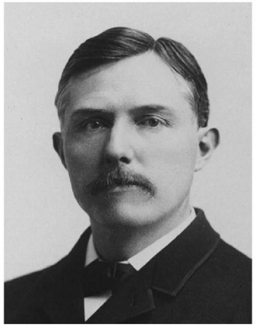


Figure 10 — E.E. Barnard (Wikicommons)

Planets, due to their small apparent diameter, and thereby requiring long telescope focal lengths and/or image amplification, as well as excellent optics and seeing conditions, proved immensely difficult to photograph successfully in the late 19th and early 20th centuries. Moreover, the grainy "isochromatic" plates of the day were not sufficiently red sensitive to register Martian surface detail well. Much of that changed with the introduction of panchromatic photographic plates in 1909, coinciding with a particularly favourable opposition of Mars. The result was that several observatories, including Lowell, Lick, Mt. Wilson, and Pic du Midi, obtained some of the first truly detailed images of the Red Planet (Figure 13).

Figure 11 — One of E.E. Bernard's superb wide-field photos of the Milky Way (Wikicommons)

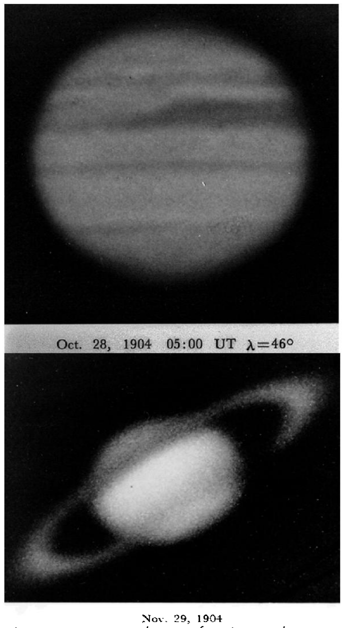


Figure 12 — 1904 photos of Jupiter and Saturn by C.O. Lampland (Lowell Observatory)

Ever loyal to his employer Percival Lowell, Lampland devoted his early efforts to attaining images of Mars sharp enough to reveal the putative "canals," which several visual observers claimed to have seen. Lowell was of course their most ardent proponent, maintaining they were irrigation canals of a dying, water-starved civilization on Mars. Indeed, as late as 1921, in a report titled "Is Mars Habitable?" (Lampland, 1921), Lampland states unequivocally that in the 1905 opposition of the planet, he "…succeeded in photographing several canals, and at the next opposition of 1907 obtained greatly improved results in photographing practically all the canals observed visually at that opposition."

Even after most other prominent observers at the time had largely dismissed the canals as spurious, E.C. Slipher (1883–1964) (Figure 14), Lampland's successor as master planetary photographer at Lowell Observatory, strove valiantly to capture convincing images of Martian canals. To that end he adapted and perfected a method of effectively combining several images taken in sequence using a method called integration printing (Brasch, 2014). This resulted in sharper, less grainy, and with more contrast, detailed images of the planets than could be generated with single exposures using the grainy photographic emulsions of the day. Slipher used this technique to great advantage for the rest of his career, and obtained some of the finest planetary images of the first half of the 20th century (Slipher, 1962; 1964) and (Figure 15). By combining this approach with selective-filter photography, Slipher and others were able to clearly reveal the dramatic

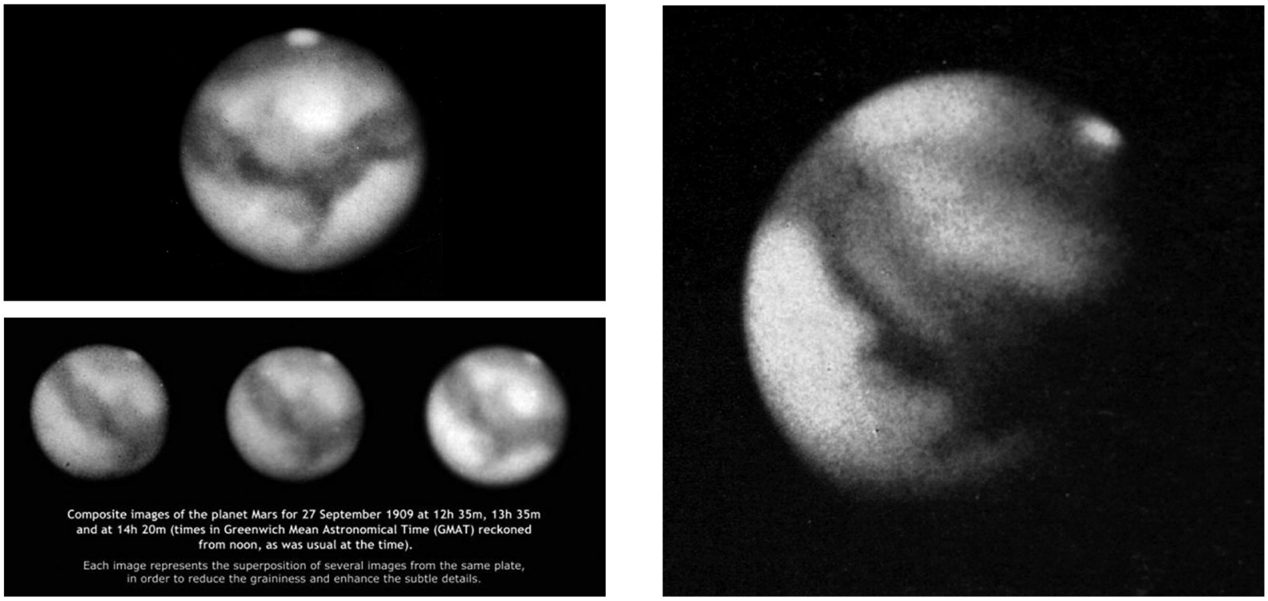
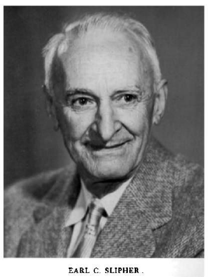


Figure 13 — Mars photos taken during the 1909 opposition by E.E. Barnard (Yerkes), G.E. Hale (Mt. Wilson) and F. Baldest (Pic du Midi), respectively, using newly developed panchromatic plates. (All images Public Domain)

changes in the Venusian cloud deck. This labourious and time-consuming printing technique became standard practice at other major observatories as the photographic equivalent of image stacking, routinely practised today by digital astroimagers.

In 1958, Lowell astronomers H. Johnson, R.F. Neville, and B. Iriarte (Johnson et al., 1958), applied this same method of integration printing to generate a composite photograph of the Pinwheel Galaxy M33, using several 45-minute exposures of the galaxy on Kodak 103a-0 plates, obtained with the same 13-inch photographic refractor with which Pluto had been discovered nearly three decades earlier (Johnson et al., 1958). Prints were then made from a single such plate and compared to a composite image generated by combining the other ten plates with the same superpositioning apparatus developed by E.C. Slipher. The composite reveals an impressive increase in structural detail and a gain of 1.2 magnitudes over the single exposure, from 18.5 to 19.7. For details see (Brasch, 2014).

During the first half of the 20th century, study of the Moon and planets was essentially abandoned by most professional astronomers in favour of galactic astronomy and stellar physics. Thus, with the exception of a handful of professionals, among them Gerard Kuiper at Yerkes, several astronomers at Paris and Pic du Midi observatories (Dollfus, 1961; 2010), and of course Lowell Observatory, Solar System studies became primarily the purview of amateur astronomers. Consequently, such largely amateur organizations as the venerable Société Astronomique de France (founded in 1887), the British Astronomical Association (founded in 1890), the Royal Astronomical Society of Canada (founded in 1903), and relative newcomer, the Association of Lunar and Planetary Observers (ALPO, founded in 1947), focused their efforts on



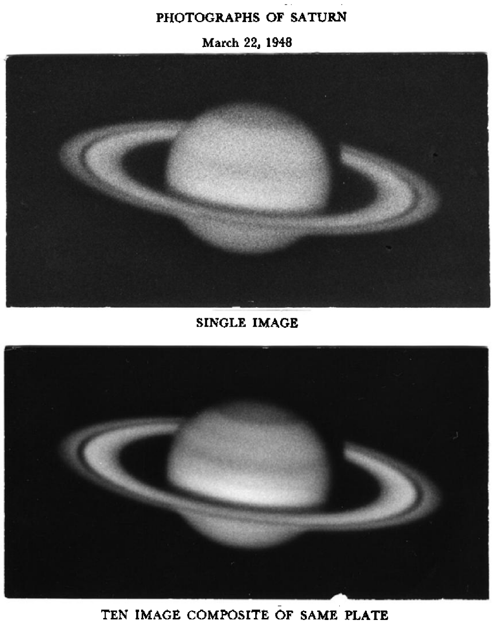
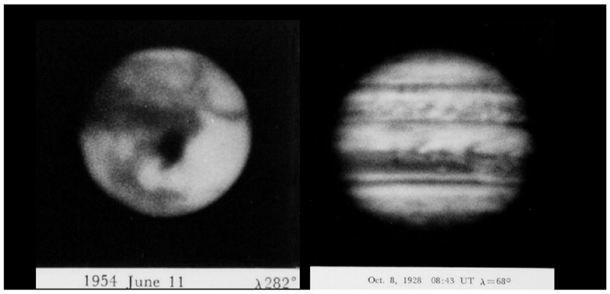


Figure 14 (left) — E.C. Slipher, and Figure 15 — a ten-image composite of Saturn showing reduced grain and higher contrast.



Figures 15a, 15b — Examples of some of E.C. Slipher's finest photographs of Mars and Jupiter compiled using integration printing. (Lowell Observatory archives)

monitoring lunar and planetary features, both visually and (eventually) photographically.

Modern amateur astrophotography began in earnest in the late 1950s and early 1960s, at a time when a number of suitable panchromatic and relatively fine-grained 35-mm films became available. In addition, affordable single-lens reflex cameras were manufactured, which quickly became favourites of amateur photographers (Brasch, 2012). At the same time, books like Henry E. Paul's *Outer Space Photography for the Amateur* (Paul, 1960) and *The Messier Album* by Evered Kreimer and John Mallas (1979) provided crucial "how to" information for thousands of hobbyists, and popular magazines like *Sky & Telescope* and *Astronomy* regularly featured amateur astrophotos and technical advice. In the realm of deep-sky photography at that time, German amateur Hans Vehrenberg was in a league of his own, beginning in 1965 with his photographic *Atlas Stellarum* and culminating with publication of his *Atlas of Deep-Sky Splendors* (Vehrenberg, 1983).

As with all photographic emulsions available then, most were black and white, very grainy, and suffered from marked reciprocity failure, and even excellent colour films like Kodachrome and Ektachrome were generally too slow for most astrophotography. This is not to imply that colour films were not used for planetary photography, or that professional astronomers did not experiment with them. In this regard, two examples stand out. During the two very favourable oppositions of Mars in 1954 and 1956, W. Finsen at Union Observatory in South Africa (Finsen, 1961) and Robert Leighton at Mt. Wilson observatory, produced the first and remarkably detailed composite images of the planet on Kodak colour films (Figure 16). Among other things, these images finally revealed the true hues of most Martian features, including the diffuse albedo markings, clouds, polar regions, and dust storms (Finsen, 1961). By the mid-1960s and 1970s, new fine-grained colour films became available, yielding correspondingly more detailed planetary colour images, including some that approached modern digital images.

Perhaps the finest film-based image of Saturn was taken in 1974 by Stephen Larsen at Catalina Observatory, near Tucson, Arizona (Figure 17). The 61-inch Kuiper telescope, now part of Stewart Observatory, was built in 1965 specifically for the Lunar and Planetary Laboratory founded to study the planets and map the lunar surface for the Apollo program. This remarkable composite image of Saturn was produced using 16 images taken in rapid succession with the telescope. Larson describes how this complex procedure was carried out: "We had just built a bulk 100 ft. 35-mm camera with a date and time stamp exposed onto the film, and [I]was trying it for the first time. I was not impressed with the seeing, so stopped the aperture down to 40″. Got everything set up and focused, started exposing and went downstairs for some coffee. The Ektachrome film was processed commercially in Tucson, and I spent a few hours picking out the best images. There must have been a spell of good seeing with a couple dozen good images in a row that could be combined. Our method of compositing was to project the image onto a reference print attached to a sliding light-tight 4 x 5 film tray. The film could be moved precisely in the enlarger head to null out the reference print. The enlarger was turned off in the dark, the film tray moved in place, and a short exposure made before returning the reference print to position the next image. Resolution was sufficient that you could see some differential atmospheric dispersion at the planet's edge. I attached a dispersion compensator usually used at the telescope to effectively bring the RBG color layer together to eliminate the disper-

Figures 16 — Figure 16: Examples of early planetary photos using Kodachrome and Ektachrome films; Mars 1954 by W. Finsen (Union Observatory), Mars 1956 by R. Leighton (Mt. Wilson), Jupiter 1967 by Charles Capen (JPL/NASA). (All public domain)

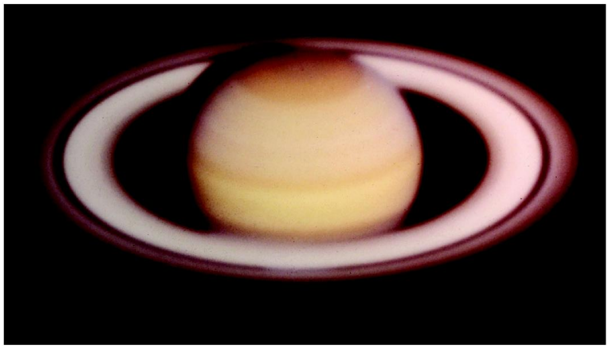


Figure 17 — This remarkable composite image of Saturn was produced in 1974 by Stephen Larson at Catalina Observatory using 16 images taken in rapid succession with the 61" Kuiper telescope. (Courtesy S. Larson)

sion. Once all the exposures were made, I processed the 4 x 5 Ektachrome film in tanks the standard way. Such composites reduced the film grain noise by approximately the square root of the number of images used (~4x in this case)."

He further adds: "Of course, today, amateurs do this digitally with video rate cameras and software to select the best images and then co-add them. This is followed by digitally sharpening the image. This last sharpening was not done back in the film days. All we could do was alter the brightness, contrast, and color balance." ✶

Note: The author is indebted to Lowell Observatory archivist Lauren Amundson and Stewart Observatory astronomer Stephen Larson for use of their historic images.

Klaus Brasch is a retired bio-scientist and public program volunteer at Lowell Observatory. He first joined the RASC in 1957 and has been an avid amateur astronomer ever since. A frequent contributor to JRASC, SkyNews, Astronomy Technology Today, Astronomy *magazine and* Sky & Telescope, *he enjoys astrophotography from his observatory in Flagstaff, Arizona.*

References

Baum, R. (2009) From 'overlapping light' to outer ring: A history of visual detection of material exterior to the bright rings of Saturn, *J. Br. Astron. Assoc., 119, 4*, 188–202.

Brasch, K. (2012) Fifty years of astrophotography, *JRASC, 106, 4*, 165–169.

Brasch, K. (2014) Origins of Stacking, *Sky & Telescope*, March, 68–74.

Brasch, K. (2016) The Dawn of Global Planet Watches, *Sky & Telescope*, January, 52–54.

Dollfus, A. (1961) Visual and Photographic Studies of Planets at Pic du Midi, in *The Solar System* vol. III *Planets and Satellites*, Chapter 15, ed. Kuiper, G.P. and Middlehurst, B.M., 534–571, The University of Chicago Press

Dollfus, A. (2010) "The first Pic du Midi photographs of Mars," 1909, *J. Br. Astron. Assoc. 120, 4*, 240–242.

Finsen, W.S. (1961) Color Photographs of Mars, in *The Solar System* vol. III *Planets and Satellites*, Chapter 17, ed. Kuiper, G.P. and Middlehurst, B.M., 573–574, The University of Chicago Press

Hughes, S. (2013) *Catchers of the Light: A History of Astrophotography* www.catchersofthelight.com/

Johnson, H., Neville, R.F., and Iriarte, B. (1958), *Lowell Observatory Bulletin, Vol. IV, 93*, 83–85.

Kreimer, E. and Mallas, J. (1979) *The Messier Album*, Cambridge University Press, Cambridge, UK

Lampland, C.O. (1921) *Is Mars Habitable?* Lowell Observatory Archives

Launius, R. (2014) https://launiusr.wordpress.com/2014/11/07/visions-of-venus-at-the-dawn-of-the-space-age/

Learner, R. (1981) *Astronomy through the Telescope*, Van Nostrand Reinhold, Co., New York, USA

Paul, H.E. (1960) *Outer Space Photography for the Amateur*, Amphoto, New York, USA

Peek, B.M. (1958) *The Planet Jupiter: the observer's handbook*, Faber and Faber Ltd., London

Pinterest (2016) www.pinterest.com/geisterportal/vintage-astronomy/

Putnam, W.L. (1994) *The Explorers of Mars Hill*, Phoenix Publishing, West Kennebunk, Maine, USA

Ré, P. (2010) History of Astrophotography Timeline www.astrosurf.com/re

Ré, P.: Joseph von Fraunhofer (1787-1826) and the Great Dopart Refractor www.astrosurf.com/re/fraunhofer_great_dorpat_refractor.pdf

Richardson, R.S. and Bonestell, C. (1964) *Mars*, Harcourt, Brace & World, Inc., New York, USA

Schenk, P. (2012) *The Venus that never was* http://stereomoons.blogspot.com/2012/08/the-planets-at-50-venus-mars.html

Sheehan, W. (1995) *The immortal fire within: The life and work of Edward Emerson Barnard*. Cambridge: Cambridge University Press.

Sheehan, W. and Conselice, C.J. (2015) *Galactic Encounters*, Springer, New York, USA

Slipher, E.C. (1962) *Mars, the Photographic Story*, Sky Publishing Corp and Northland Press, Flagstaff, AZ

Slipher, E.C. (1964) *A Photographic Study of the Brighter Planets*, National Geographic Society, Washington, DC

Vehrenberg, H. (1983) *Atlas of Deep-Sky Splendors*, 4th edition, Sky Publishing Corp., Cambridge, Mass, USA