Feature Articles / Articles de recherche

A Short History of Astrophotography: Part 2

by Klaus Brasch

The first part of this concise history spanned the pre-photographic era from the mid-1700s to the mid-1800s, which saw great advances in telescope and supporting technology, including the invention of photography, to the 1960s at the start of the space age (Brasch, 2017). That era too saw major technological advances in astronomical instrumentation, photographic emulsions, electronics, and early computing capabilities (Wrubel, 1960).

In the 1950s and 1960s, Kodak produced several specialized spectroscopic emulsions for astronomical research, including the 103 series. Although designed for selected spectral sensitivity and reduced reciprocity failure, these were available in 35-mm format, but were also very coarse-grained. Because of this and although these films were also commercially available, pretty much all aspects of amateur astrophotography were a compromise. For instance, popular films like Kodak Tri-X Pan, though fast enough for short exposures to minimize the effects of atmospheric turbulence or seeing, were also very grainy, while more fine-grained films like Kodak Microfile or Plus X were rather slow and required relatively long exposures for the necessarily highly magnified planetary images. Much of that changed over time as better films were developed; culminating with the introduction of Kodak's ultra-fine-grained 2415 Technical Pan Film in 1981. The beauty of this film was its suitability for both planetary and deep-sky photography, since it could be developed for maximum dynamic range for planetary work and also hypersensitized for extended exposures of deep-sky objects (Covington, 1999).

Probably the last hurrah of film-based professional planetary research was the Lowell Observatory-led International Planetary Patrol Program (IPPP) (Brasch, 2016). With the launch of Sputnik 1 on 1957 October 4, and the arrival of the space age, interest in Solar System astronomy was rekindled among professional astronomers. Led by William Baum (1924-2012) and funded by the newly established National Aeronautics and Space Agency (NASA), the IPPP mission was to monitor the major planets photographically as continuously as possible using a network of observatories around the world. To those ends, standardized film and cameras were developed and used with specially modified 25–26.5-inch-aperture telescopes. Planets were photographed hourly at each station on Kodak 2498 RAR film, in sets of four 14-exposure sequences through red, green, blue, and ultraviolet (uv) filters, respectively, along with dates, time, observer, location, and colour, imprinted on each frame. By the time this project ended in the late 1970s, it had generated a database of some 1.2 million images of Mercury, Venus, Mars, Jupiter, and Saturn (Brasch, 2016). Among other findings, this work helped to demonstrate the 4-day retrograde motion of the Venusian cloud deck, a 90-day oscillation in Jupiter's Great Red Spot, and the density differential in particulates of Saturn's rings (Baum, 1973).

The IPPP's major scientific contributions, however, were with respect to Mars. This aspect of the program involved not only professionals but also many amateur astronomers, who were recruited thanks to the efforts of a key IPPP observer Charles (Chick) Capen (1926–1986). He made extensive use of colour filters for work with Mars, a tool he encouraged amateur observers in the Association of Lunar and Planetary Observers (ALPO) and elsewhere to also employ both visually and photographically. Collectively such efforts helped IPPP researchers clarify several Martian atmospheric phenomena,

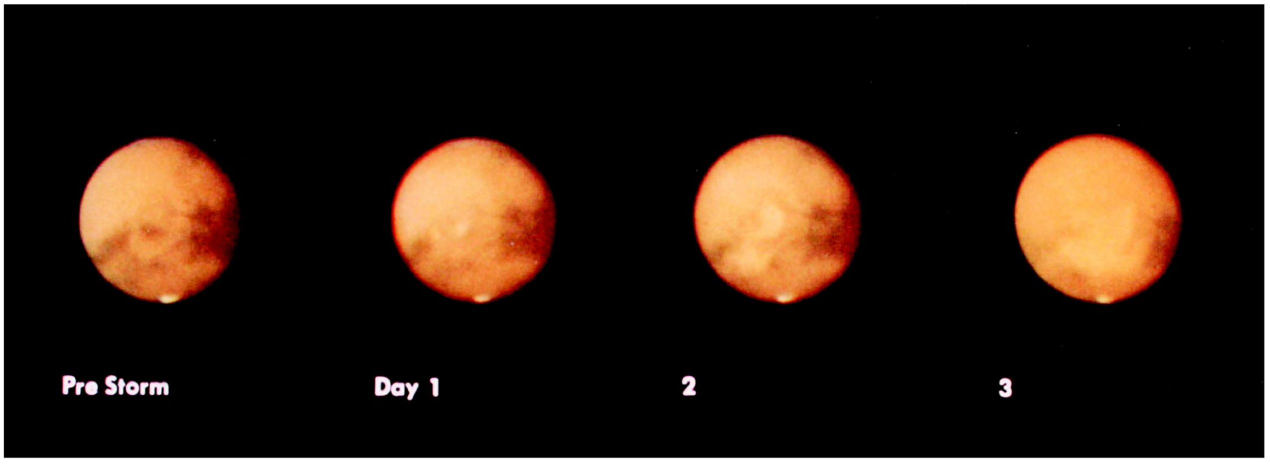


Figure 1 — IPPP colour images of a major dust storm developing over the Solis Lacus region on Mars in October 1973 (Lowell Observatory Archives).

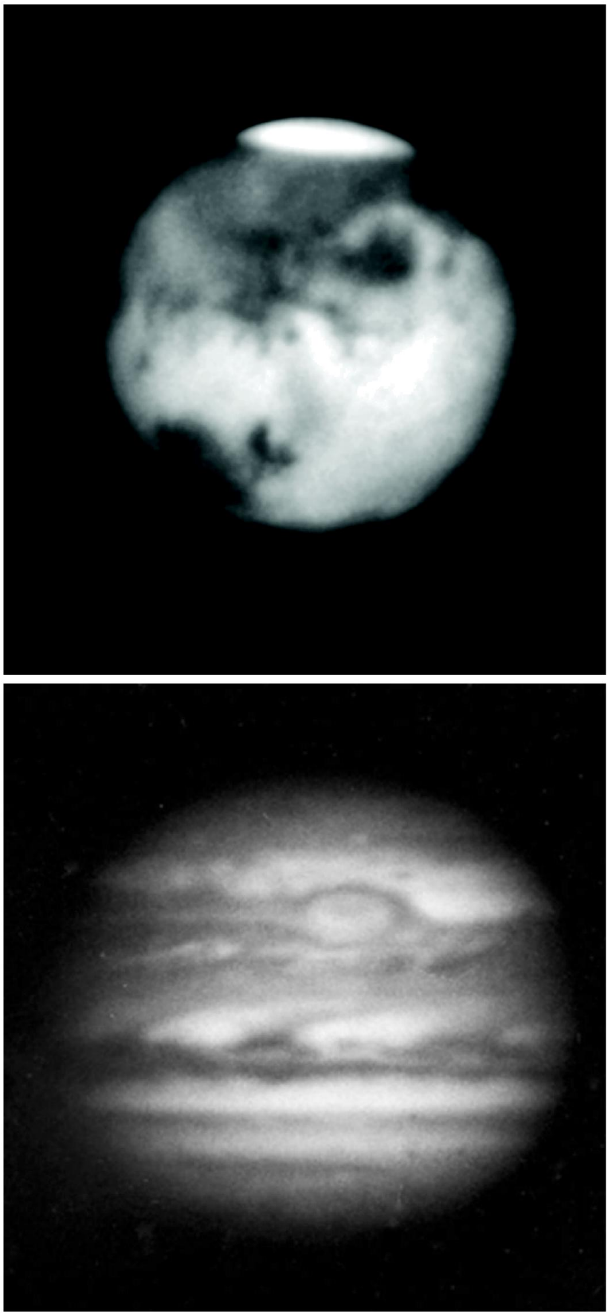


Figure 2 — Examples of some of the finest amateur photographs ever taken of Mars by Jean Dragesco with the 1-m telescope at Pic du Midi in 1988, and Jupiter by renowned planetary imager Don Parker with a 16-inch Newtonian in 1990, with Kodak Technical Pan film (Both Public Domain).

including various colour clouds, dust storm development, polar cap and hood changes, and such seemingly enigmatic phenomena as the "blue or violet" clearing. These findings helped to predict and document a major Martian dust storm in 1971, which coincided with the arrival of Mariner 9 at the planet and blocked the orbiter's view of the surface for several weeks before clearing, and similar storms in subsequent years (Figure 1).

Film-based planetary photography continued among amateur astronomers well into the 1980s and 1990s; again thanks to the availability of increasingly finer-grained and more sensitive emulsions like Kodak Technical Pan film and widespread use of filters and image stacking techniques (see Dobbins et al., 1988). Again, under the leadership of Chick Capen and other professionals, talented amateurs like Don Parker and Jean Dragesco were able to obtain planetary images of such quality that they complemented professional studies (Figure 2). Some amateurs, including the author (Brasch, 1993), combined visual detail with simultaneously taken photographs and then combined them into a single photo/drawing to include fine detail not captured on film (Figure 3). The digital age, however, was on the horizon. The first stage in this evolution was the development of high-resolution digital film scanners. This made it possible to extract far more information from film-based images than regular 35-mm slides or printing permitted; information which could then be processed by computer to enhance contrast, extend the dynamic range and sharpen detail (Covington, 1999; Dickinson and Dyer, 2002; Brasch, 2006). All this, however, was merely the prelude to direct electronic imaging a few years later.

Electronic and Digital Photography

In order to gain greater sensitivity than photographic emulsions could supply, astronomers started experimenting with television cameras in the late 1950s. Capable of amplifying light as much as 50,000 times, these cameras were developed, among other things, to track artificial satellites and other fast-moving object in the sky with great accuracy. One such camera, the Bendix-Friez Lumicon (Figure 4a), was adapted and tested for potential in astronomical research at Yerkes and McDonald Observatories in 1958–59 (Kuiper, 1959). Tests included observations of the Moon, Venus, Mars, Jupiter, and Saturn, as well as star fields and nebulae, using 40- and 82-inch telescopes and a variety of auxiliary lenses. Under the direction of renowned astronomer Gerard Kuiper, then-students Alan Binder and Dale Cruikshank worked with the camera on the Yerkes 40-inch refractor in 1959, and obtained several images of the Moon, Jupiter, and Saturn (Figure 4b). While these results were promising, the consensus was that the technology's usefulness was limited and not quite on par with photography at that time (Kuiper, 1959).

A decade later in 1969, W.S. Boyle and G.E. Smith of the Bell Laboratory invented CCDs (charge-coupled devices) although

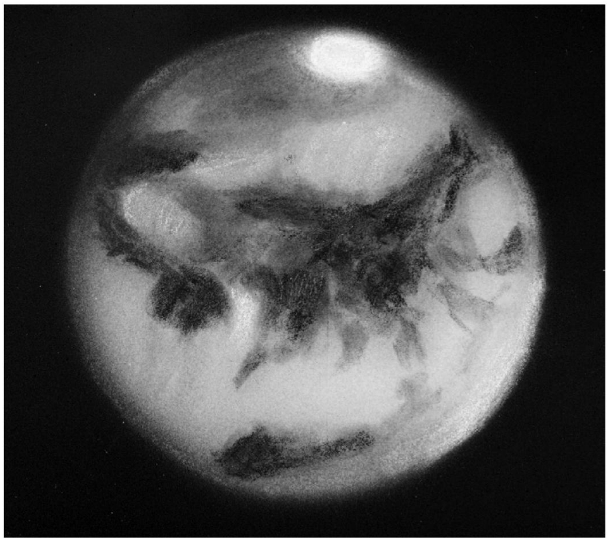
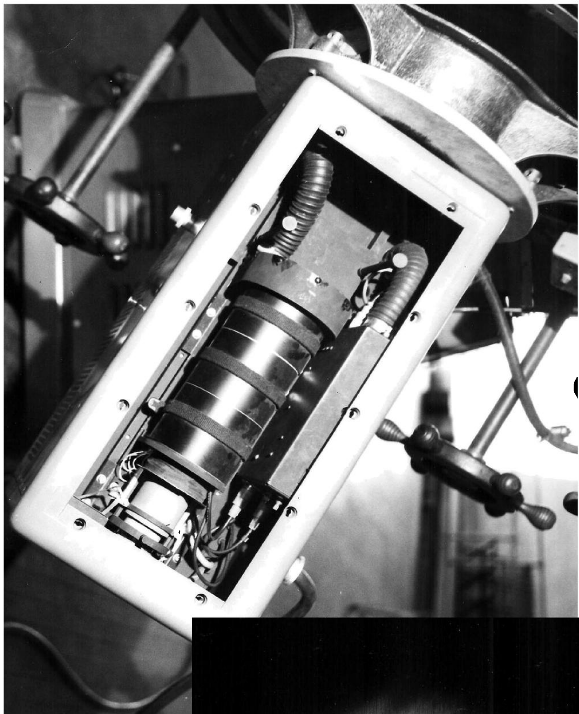
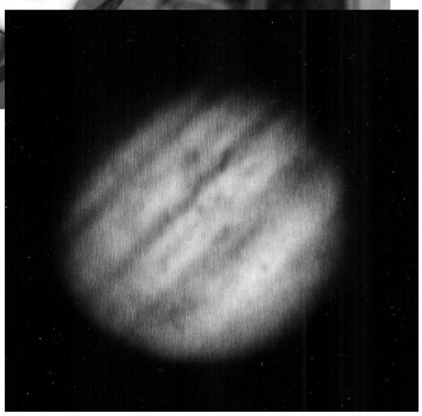


Figure 3 — Triple-stacked photo taken by the author with a Celestron 14 and Technical Pan film in 1988 (left) and a photo-drawing combination of simultaneously sketched visual detail.





Figs 4a, b — Bendix Lumicon TV camera and Jupiter, by A. Binder and D. Cruikshank, Yerkes Observatory (1959)

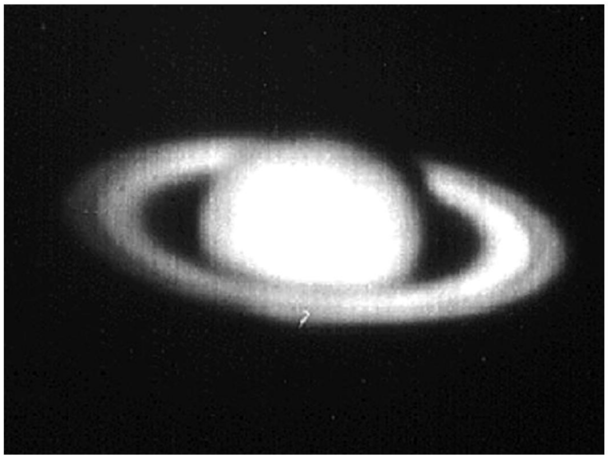


Figure 5 — First CCD image of Saturn by J. Janesick & B. Smith at Mt. Bigelow (1976)

these were not initially intended for astronomical purposes. The first astronomical CCD image of the Moon was taken in 1974 with a 100 x 100-pixel camera developed by the Fairchild Semiconductor Co., and the first images of Jupiter, Saturn, and Uranus were taken in 1976 by J. Janesick and B. Smith with the 61-inch telescope on Mt. Bigelow in Arizona (Janesick and Blouke, 1987) (Figure 5). While these initial results were not on par with photographic images, it was only a matter of time before CCDs were adopted by professional astronomers and became ubiquitous, both for imaging and photometry. CCD devices had several immediate advantages over photographic plates and films, including about 10-fold greater quantum efficiency, wider spectral sensitivity, and effectively no reciprocity failure. Those characteristics made them superior to even the best photographic emulsions for imaging astronomical objects. Moreover, digital images readily lent themselves to combining and stacking, thereby increasing the signal-to-noise ratio and image contrast.

In 1984, an innovative French amateur, Christian Buil, constructed his own rudimentary CCD camera and obtained the first colour digital images of Jupiter using the 1-m telescope at Pic du Midi Observatory (Figure 6). Amateur digital imaging began in earnest, however, in the early 1990s with the introduction of the ST-4 CCD camera by the Santa Barbara Group, and shortly thereafter the far superior ST-6. With it, Canadian amateur Jack Newton secured the first tri-colour image of the Dumbbell Nebula, M-27 (Figure 6) in 1990, as well as some excellent images of Jupiter and Saturn. These images were clearly far superior to any film-based photos, particularly in terms of dynamic range. Accompanying all this were also rapid improvements in the speed and versatility of personal computers and image processing software.

Equally dramatic though for lunar and planetary imaging, inexpensive webcams became available around 2000, which

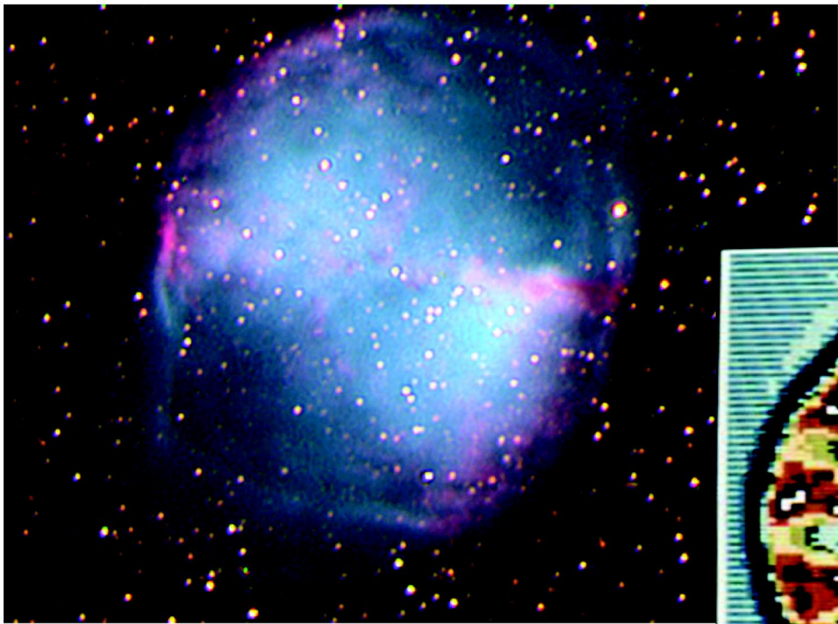
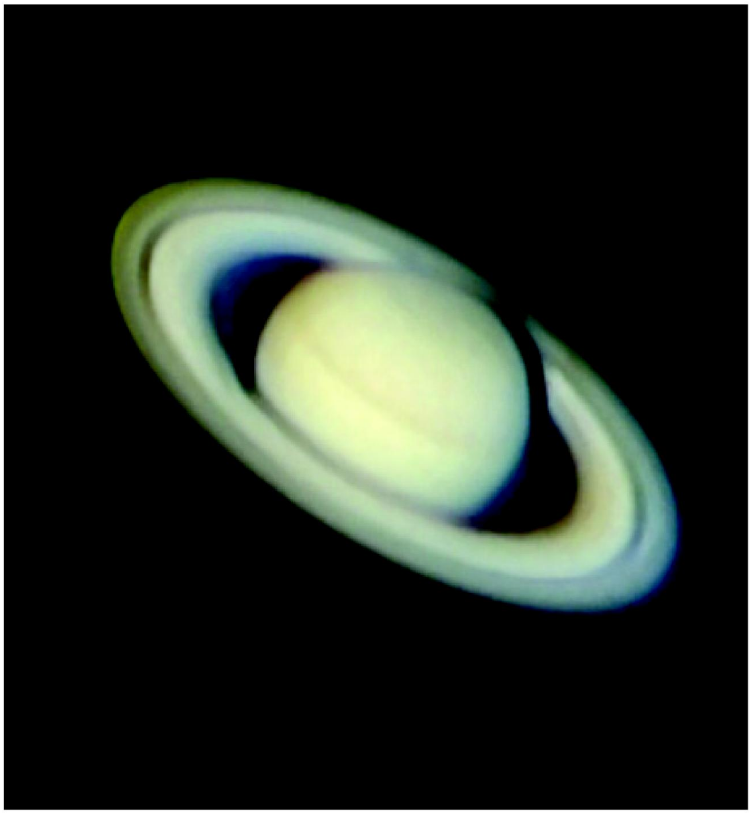
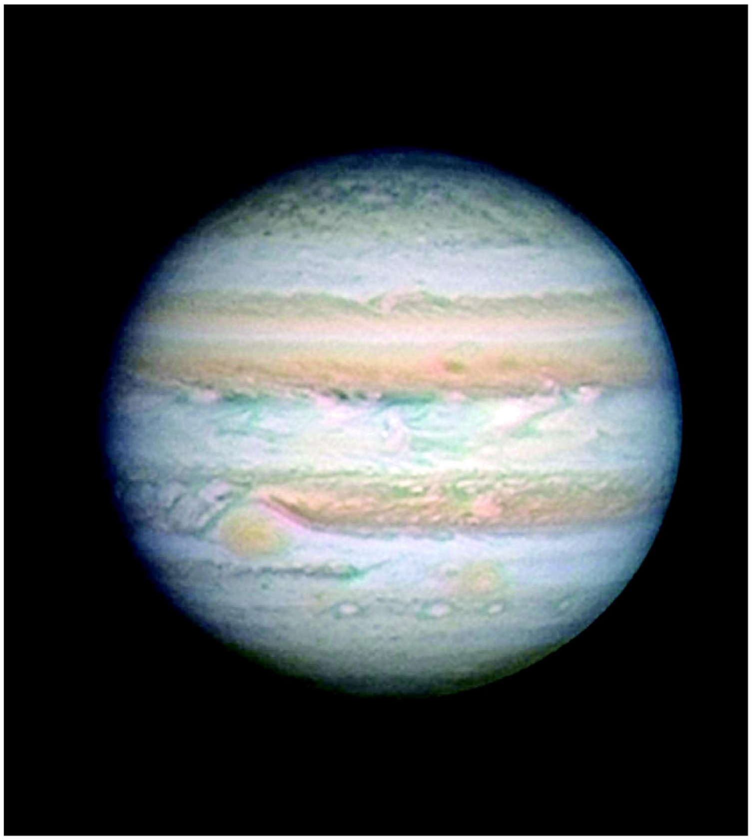


Figure 6 — First amateur colour CCD images of M-27 by J. Newton (1990) and first amateur CCD image of Jupiter by C. Buil (1984)





made it possible to quickly capture extended rapid-exposure videos of the Moon and planets (Figure 7). By subsequently applying software like RegiStax to the best images in a video sequence and stacking them together, it became possible to secure near-diffraction-limited lunar and planetary images, a major technological advance (Dickinson and Dyer, 2008). A decade later, webcam technology had improved to the point where medium-sized amateur telescopes could produce planetary images on par with those obtained by professionals (Figure 8).

A second revolutionary development to hit the scene in the early 2000s was the introduction of digital single-lens reflex (DSLR) cameras. Both Canon and Nikon led the way with the 6.3-megapixel CMOS (complementary metal-oxide) sensor 10D and the 6.1-megapixel CCD sensor D70, respectively, providing commercial high-resolution digital cameras that could compete directly with their film-based counterparts in both resolution and sensitivity. Shortly after that, Canon followed with their 8-megapixel 20D and 20Da; with the latter model specifically designed for deep-sky astrophotography through higher red-light sensitivity so important for imaging emission nebulosity. This advantage can be further amplified through aftermarket modifications that extended sensor sensitivity into the far-red portion of the spectrum to record the all-important hydrogen-alpha emissions. Today, spectrally modified DSLRs, with highly effective internal noise-reduction software and coupled narrow-bandpass filters, have become extremely popular with amateur astrophotographers (Dickinson and Dyer, 2015).

As the price of high-end CCD cameras has declined, while their capabilities in terms of ease of use, resolution, low noise levels, and high signal-to-noise ratios continue to improve steadily, many amateur astroimagers have reached a level of sophistication on par with professional efforts. Indeed, today more than

Figure 7 (top) — Saturn imaged in 2003 by R. Hess with a simple Philips ToUcam and a 10-inch Newtonian.

Figure 8 (bottom) — Jupiter, imaged in 2013 by Leo Aerts with a Celestron 14 and DMK camera, showing superb detail and diffraction-limited resolution.

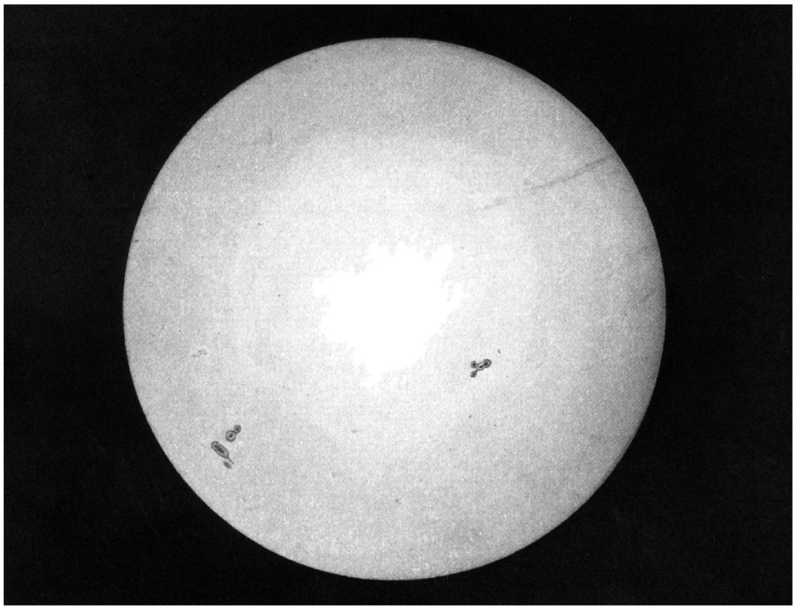


Figure 9 — First Daguerreotype image of the Sun by A. Fizeau and J.B. Foucault in 1845

ever, some amateurs are teaming with professional astronomers in such cutting-edge research as dwarf galaxy surveys, hunting for Kuiper Belt objects, spotting impact events on Jupiter, supernova searches and, most recently, exoplanet transit monitoring (Gary, 2010; NASA, 2015). In these regards, talented amateurs with quality optical and imaging equipment can devote extended periods of observing time, time that professionals often cannot obtain due to intense competition for instrument use at major observatories. In many ways, therefore, astronomy has come full circle, from a largely amateur undertaking in the 18th and 19th centuries, to renewed amateur engagement today thanks to unprecedented advances in optical equipment, imaging technology, and processing.

Photographing the Moon and Sun

Because of their brightness and large apparent size as seen from Earth, the Sun and Moon were natural targets for the first attempts at astrophotography. As early as 1839, Louis Daguerre endeavoured to photograph the Moon, but the image was blurred, and a year later J.W. Draper succeeded. As outlined previously (Brasch, 2016b), lunar photography advanced rapidly in the second half of the 19th century, culminating with the publication in 1903 of two major works.

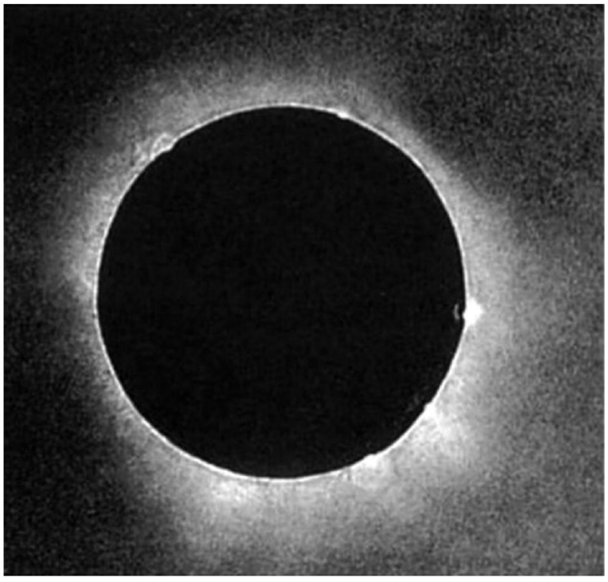


Figure 10 — First daguerreotype image of the solar corona by Berkowski during the 1851 eclipse

First was Edward Holden's *Lick Observatory Atlas of the Moon*, and second, the *Atlas Photographique de la Lune* by Maurice Loewy and Pierre Puiseux of Paris Observatory (Loewy and Puiseux, 1903). The latter would remain a major reference for lunar studies for the next 60 years, until publication by Kuiper et al. of the *Photographic Lunar Atlas* (Kuiper et al., 1960; Sheehan and Dobbins, 2001; Hughes, 2013).

In 1844 and 1845, Armand Fizeau and J.B. Foucault at Paris observatory obtained several successful daguerreotypes of the Sun (Figure 9). The first successful photograph of the solar corona was obtained during the total eclipse of 1851 July 28 by daguerreotypist Berkowski (Figure 10). He used a 6.1-cm (2.4-inch) telescope of about 80-cm focal length attached to a heliometer at Königsberg Observatory (now Kaliningrad, Russia) (en.wikipedia, 2016). A few years later, Warren de la Rue (1815–1889) in Britain devised the photoheliograph or solar telescope and applied stereoscopic methods showing that sunspots are depressions in the Sun's atmosphere (en.wikipedia, 2016b) (Figure 11), thereby verifying a theory advanced by Alexander Wilson of Glasgow in the 18th century (encyclopedia.com, 2008).

Advances in solar photography and spectroscopy progressed rapidly thereafter (Hughes, 2013), and took a giant leap forward in the 1930s with development of the coronagraph by French astronomer Bernard Lyot (1897-1952). This revolutionary instrument made possible not only direct photography of the solar corona (other than during a total eclipse) (Figure 12), but also spectral analysis and select visualization of solar features by means of narrow-bandpass filtration (Lyot, 1933). Today, of course, similar instruments are in wide use at professional observatories and also available to amateur astronomers (Hufbauer, 2007).

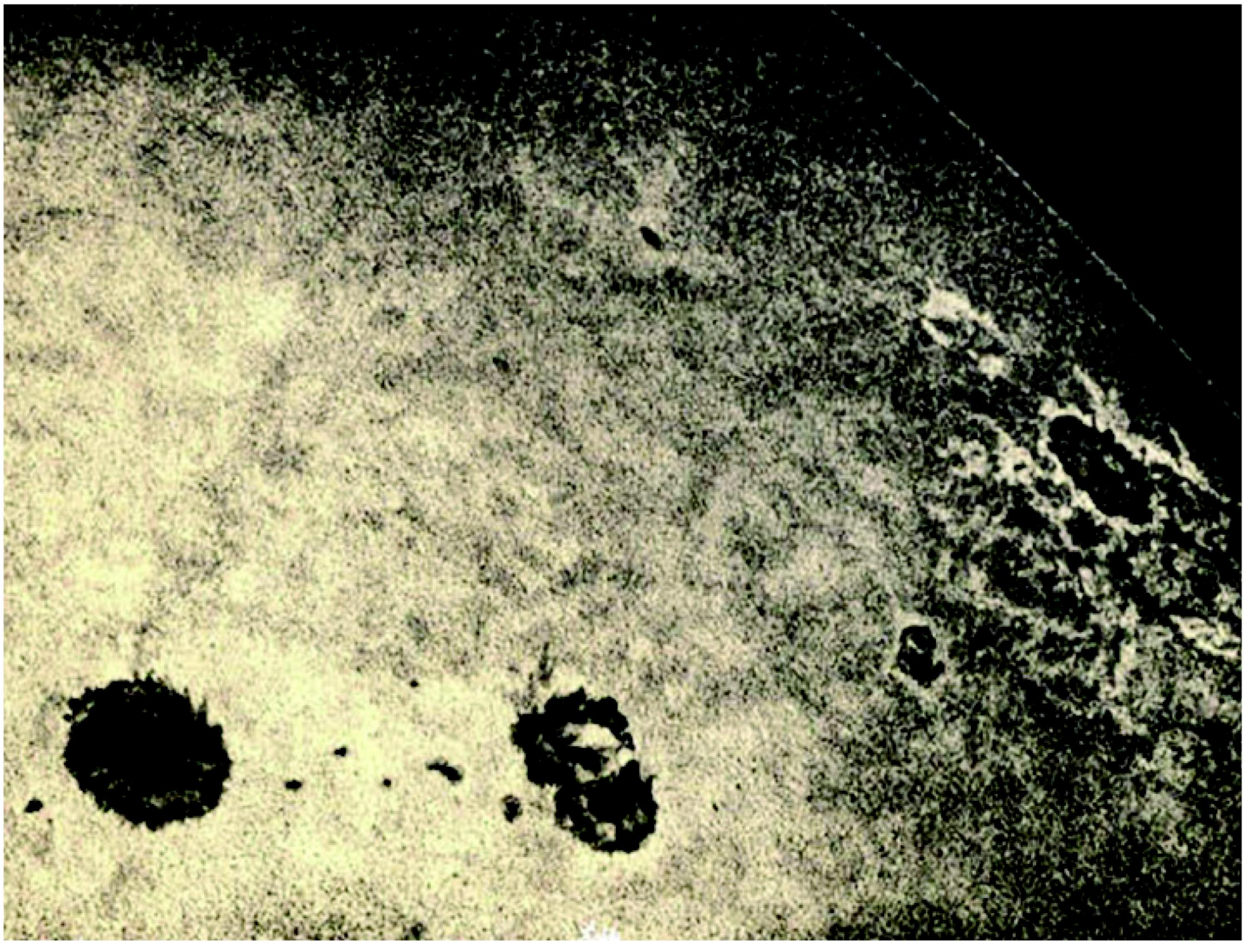


Figure 11 — Stereoscopic photo showing detail of sunspots and granulation by W. de la Rue in 1861

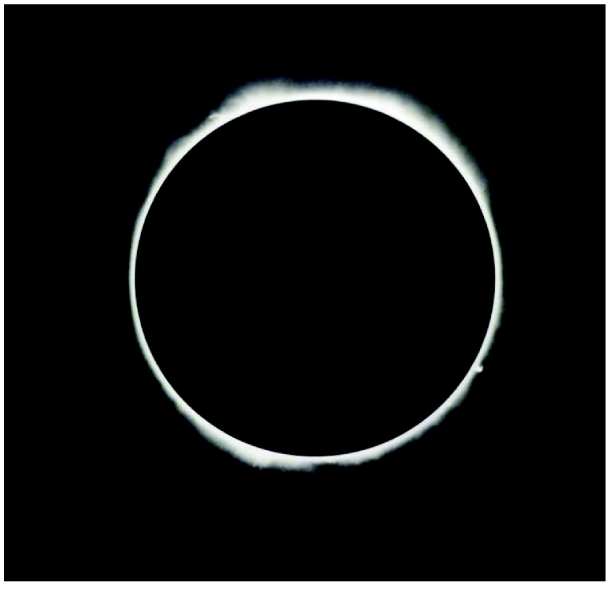


Figure 12 — Image of the solar corona by Bernard Lyot, inventor of the coronagraph (Wikimedia)

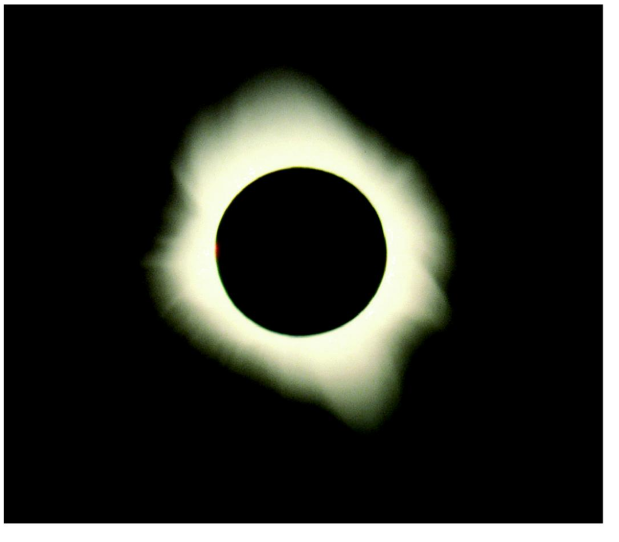


Figure 13 — The extensive solar corona of the 1991 total eclipse captured by the author with Fuji Velvia 50 film and a 300-mm lens. The slide was later digitized and processed in Adobe Photoshop to bring out subtle detail not evident on the original slide.

As with all aspects of photography in general, image quality of Solar System objects improved dramatically with each advance in photographic plate and emulsion technology. Notable in this regard were the development of dry plates and gelatin emulsions toward the end of the 19th century. These led to greater light sensitivity, image stability, resolution, and of course versatility, including celluloid-based films, inexpensive box cameras, and ultimately motion pictures. Photography subsequently became a popular profession and pastime, leading to mass production of cameras, which reduced equipment costs.

From the 1970s through the 1990s, 35-mm films saw major improvements in resolution, colour rendition, and saturation, as well as reduced reciprocity failure, a particular bane in astrophotography. That, coupled with film scanning and conversion to digital images, provided an extended lease on the use of film in amateur astrophotography. Solar-eclipse photography, in particular, became popular as literally thousands of "eclipse chasers" travelled to remote corners of the planet to hopefully catch those few precious minutes of totality and secure that once-in-a-lifetime photograph (Figure 13). Since then, advances in optics and imaging techniques have provided amateurs with dedicated solar telescopes and narrow-bandpass filters previously available only to professionals. Consequently, even modest aperture refractors, such as the Lunt 60 or 90-mm telescopes, coupled with 0.5–7-angstrom hydrogen-alpha filters, reveal solar-flare and prominence details unimaginable just a few years ago (Figure 14).

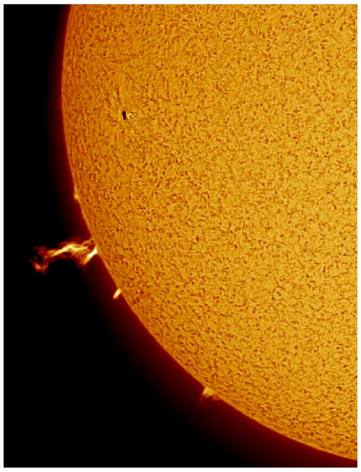
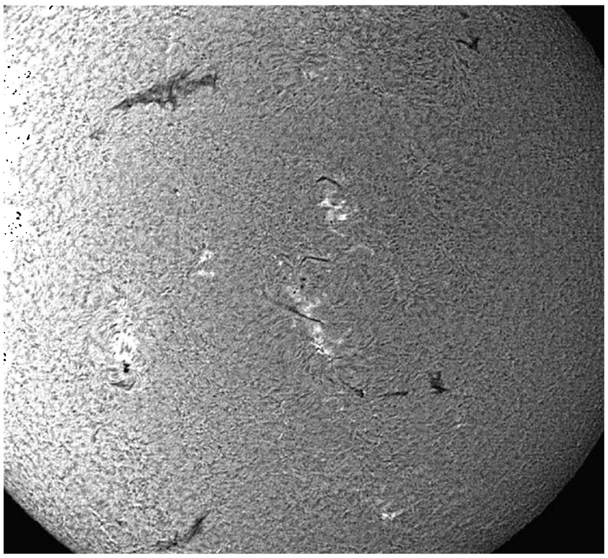


Figure 14 — Examples of amateur images taken with Lunt solar telescopes equipped with 0.7 angstrom h-alpha passing filters and high-resolution video cameras. The colourized image at left (E. Marlatt) shows limb prominences and the monochrome image below (F. Tretta) shows abundant photosphere filaments, sunspots, and granularity.



Epilogue

Perhaps the best way to summarize how far lunar, as indeed all types of astronomical imaging has evolved over the last half century or so, is illustrated in Figures 15a and b, featuring the magnificent craters Theophilus and Cyrillus. Thetop image is an enlargement of the 1963 Lunar Aeronautical Chart (LAC-78), prepared by the United States Air Force and NASA in planning for the Apollo Moon missions and early spacecraft exploration. The LAC series was based entirely on the best Earth-based photographs available at the time from Lick, Mt. Wilson, Yerkes, McDonald, and Pic du Midi Observatories, and augmented with visual detail obtained with the 24-inch Clark refractor at Lowell Observatory. These charts, therefore, marked the culmination of what was possible with the technology at the beginning of the space age.

The bottom image exemplifies what is possible with cutting-edge technology today. Using a Celestron 14, a DMK webcam, RegiStax, and AutoStakkert! software and skilled processing magic, Belgian amateur Leo Aerts routinely captures lunar images that far exceed what was done with much larger professional telescopes during the film-based era. It is now possible, in effect, to circumvent atmospheric turbulence by capturing thousands of video images in rapid sequence, and combining only the very best frames to generate diffraction-limited images with modest-aperture telescopes, that rival not only the best professional results but approach those obtained by spacecraft. ✶

Note: The author is greatly indebted to Lowell Observatory archivist Lauren Amundson, and amateur and professional astronomers Leo Aerts, Christian Buil, Dale Cruikshank, R. Hess, J. Janesick, Eric Marlatt, Jack Newton, and Fred Tretta, for use of their modern and/or 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 *magazine and* Sky & Telescope, *he enjoys astrophotography from his observatory in Flagstaff, Arizona.*

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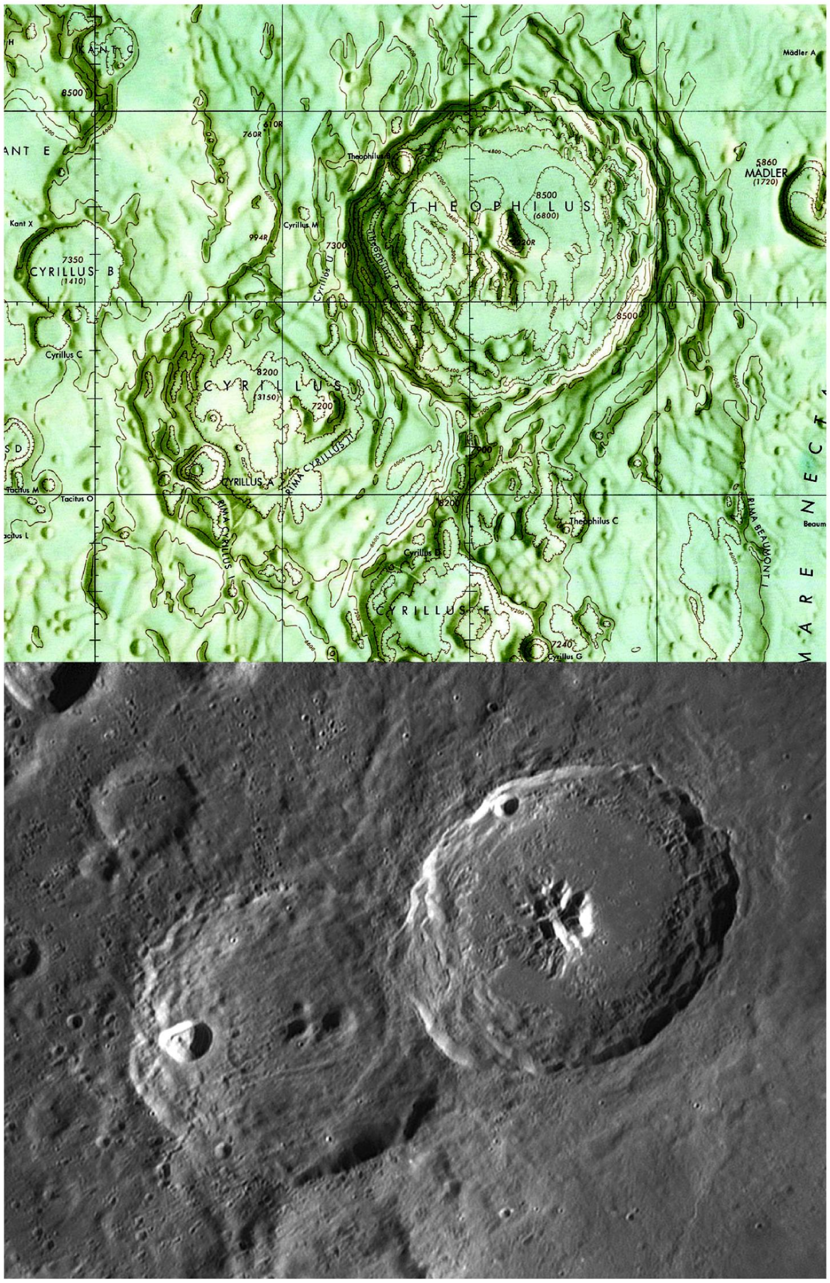

Figure 15 a,b — (top) 1963 Lunar Aeronautical Chart prepared by the United States Air Force and NASA, (bottom) amateur image captured by Leo Aerts.

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