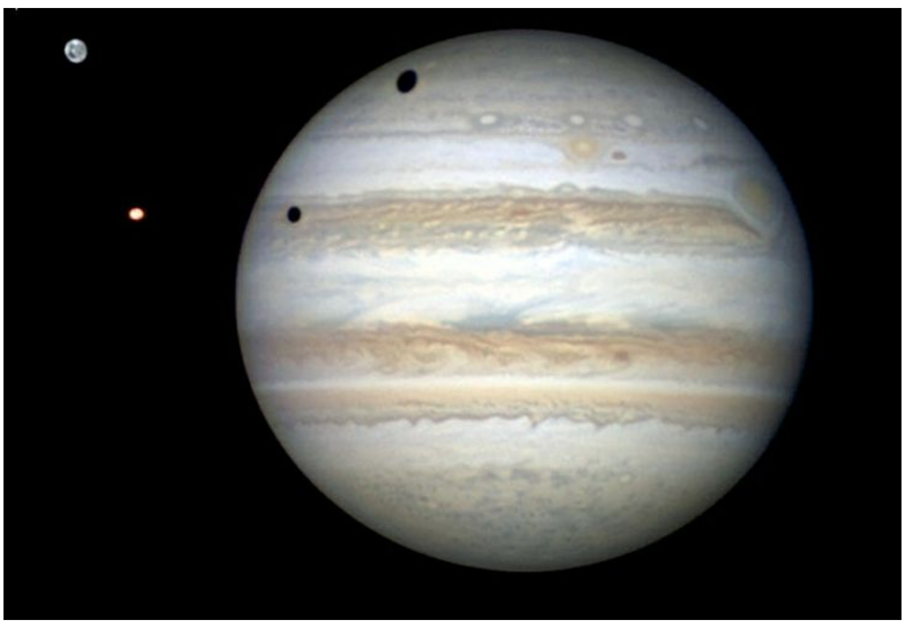
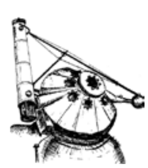
The Springfield Telescope Makers & The Hartness House Inn

Present

The Hartness House Workshop: Sub-Arc-Second Spatial Resolution Imaging

Thursday August 4, 2016





Welcome to the 2016
Hartness House Workshop

Sub-Arc-Second Spatial Resolution Imaging

Chair, Dr. Thomas Spirock
Co-Chair & Registrar, Daniel Lorraine

Hartness House Workshop   August 4, 2016
Sub-Arc-Second Spatial Imaging

8:30 – 9:00 **Registration and Coffee**
Host Dan Lorraine, Los Angeles Astronomical Society

9:00 – 9:05 **Words of Welcome**
David Tabor, President, Springfield Telescope Makers

9:05 – 9:20 **Sub-Arc-Second Imaging with a 13” Schupmann Telescope at Stellafane**
James Daley and Dr. Thomas Spirock
In 1995 the Springfield Telescope Makers completed construction of a 13", F-10 Schupmann Medial Telescope. The basic design and advantages of this type of telescope will be discussed and the most up to date imaging results, including sub arcsecond resolution images from the recent oppositions of Mars, Jupiter and Saturn, will be presented.

9:20 – 10:00 **The Inner Planets Mercury and Venus: The Secret Ways to Capture Them**
Frank Melillo
The two inner planets of our Solar System, Mercury and Venus, have the reputation of being the most difficult objects to image, especially at a high resolution. Most advanced amateurs neglect these planets due to their close proximity to the sun, and they don’t want to chance it with their large telescopes. While Mercury and Venus are often seen closer to the horizon, they are often blocked by trees, houses and even observatories themselves. Most telescopes are on a permanent pier and have a very limited portability to go around. Because of this, amateurs often feel disappointed. But there are secret ways to capture these planets at ease in detail, and smaller telescopes can do just fine.

10:00 – 10:40 **High Resolution Planetary Imaging with a Video Camera: Lucky Imaging**
Dr. Arnold Ashcraft
In spite of the fact that the atmosphere seldom affords a clear, high resolution view of the planets with a telescope, it is possible to obtain high resolution images by taking many thousands of short exposure images, sorting them by quality, aligning and stacking them and then enhancing faint details of the image by wavelet analysis. Inexpensive digital video cameras used as webcams, surveillance cameras, and machine vision cameras are used for this purpose. Proper optical coupling of the camera to the telescope to ensure correct digital sampling is critical and will be explained in the talk. Sources of cameras suitable for this purpose and the free software for processing the images will be given including recommendations for inexpensive cameras for the beginner. Many examples of excellent images both those obtained by the speaker as well as amateur astronomers around the world will be shown.

10:40 – 11:00 **Break**

11:00 – 11:40 **Concepts and Techniques for Producing (near) Diffraction-Limited Planetary Images**
Wayne Jaeschke
Many amateur telescopes are capable of producing high-resolution planetary images. This discussion focuses on techniques for achieving near diffraction-limited images of the planets using amateur telescopes and high-speed videography from typical suburban locations. Topics explored include the three "tenets" of planetary imaging and best practices for adhering to each of them, such as optimization of the observation location, recognizing optimal target conditions, data acquisition, data processing, and the variations between monochrome and color imaging. Also discussed will be practical applications of sub-arcsecond planetary imaging, such as planning and capturing an eclipse of one of Jupiter's moons, the spokes of Saturn's rings, orographic clouds over Olympus Mons, and how to recognize the unexpected in planetary images.

11:40 – 12:20 **Analyzing High Resolution Images of Jupiter**
Dr. Richard Schmude
During the past few years a number of individuals have submitted high-resolution images of the planets including Mars and Jupiter. I have used these images to measure the size of Mars' polar caps and the oval features on Jupiter. Regarding Mars, I have measured a mean radius of 8.1 ± 0.3 degrees (or 480 km) for the radius of the Permanent North Polar Cap. This value is close to historical values. I have also been able to measure small changes in the size of the Temporary North Polar Cap (TNPC). For example there was no statistical difference between the TNPC in the years 2000, 2011-12 and 2013-14. There was, however, a difference in the TNPC for 2009-10 and 2000. Regarding Jupiter, I have measured the shapes and sizes of the Great Red Spot and the white ovals in several of Jupiter's currents. Shapes and sizes of oval features will be presented.

12:20 – 1:35 **Lunch & Porter/Hartness Museum Open House**

1:35 – 2:15 **Speckle Interferometry of Double Stars From My Backyard Observatory**
Dr. Arnold Ashcraft
Speckle interferometry was formerly the province of the professionals, requiring very expensive cameras and two meter class telescopes, completely out of the realm of amateur astronomy. Recent advances in low noise CMOS optical sensors have made it possible to build and sell relatively inexpensive digital video cameras capable of obtaining the short exposure images of the speckle patterns from very close double stars. At the same time, advances in computer technology has placed in our hands affordable computers capable of the heavy load of mathematical processing needed to convert the speckle patterns into autocorellograms from which the spacing and position angles of the double stars may be determined. Free software created by gifted amateur astronomer programmers makes it all possible. I will show how to obtain accurate and precise measures of the separations of double stars right at the resolution limit of an eleven inch aperture telescope (about 0.4 arc seconds) using a camera costing only $359.

2:15 – 2:55 **Sub-Arc-Second Observing at the US Naval Observatory**

Dr. Geoff Chester

One of the primary missions of the U.S. Naval Observatory is to "Determine the positions and motions of celestial bodies", a mission we have been fulfilling since our establishment as the Navy's Depot of Charts & Instruments in 1830. Since that time we have made increasingly precise observations of stars to support the increasingly stringent demands of celestial navigation from the time of wooden ships to the space age.

Today the USNO is the source of the world's most precise astrometric star catalogs, all of which have been made using ground-based instrumentation. Utilizing modern digital imaging techniques we can now measure the physical parameters of double stars to a precision dictated by the Rayleigh criterion for a given optical telescope. The USNO Robotic Astrometric Telescope (URAT) program is intended to produce an astrometric catalog of all stars brighter than ~magnitude 17.5 with position errors on the order of 10-15 mas using a 400-megapixel hybrid CMOS-CCD camera on an 8-inch astrograph. USNO's newest project, the Navy Precision Optical Interferometer (NPOI) is a six-station interferometer array capable of resolving close binary sources to the milli-arcsecond level and producing astrometric data to that same precision for the brightest stars in the sky.

I will discuss the evolution of these program and products and look at the future of sub-arcsecond astrometry.

2:55 – 3:15 **Break**

3:15 – 3:55 **Robo-AO: The First Robotic Adaptive Optics Instrument**

Dr. Reed Riddle

Robo-AO is the first and only fully automated adaptive optics laser guide star adaptive optics (AO) instrument. It was developed as an instrument for 1-3m robotic telescopes, in order to take advantage of their availability to pursue large survey programs and target of opportunity observations that aren't possible with other current AO systems. Robo-AO is the most efficient AO system in existence, and it can achieve an observation rate of 20+ science targets per hour. In more than three years of operations at Palomar Observatory, it was quite successful, producing technology that is being adapted by other AO systems and robotic telescope projects, as well as several high impact scientific publications. Now, Robo-AO has been selected to take over operation of the Kitt Peak National Observatory 2.1m telescope. This will give Robo-AO KP the opportunity to pursue multiple science programs consisting of several thousand targets each during the first three years it will be on the telescope.

3:55 – 4:35 **Solar Telescope Optimized for Imaging Solar Granulation**

James Daley

A small but scalable solar telescope, utilizing moderately narrow band filters will be described. The design is optimized for CMOS detectors, operated in fast framing mode, followed by advanced image stacking techniques. Recent test results will also be presented.

4:35 – 5:20 **Highest Resolution Observations of the Sun Using the Latest Technologies At Big Bear Solar Observatory**

Dr. Philip R. Goode

The world's most powerful solar telescope (the "NST") has been observing the Sun from a mountain lake in Big Bear, CA for seven years with ever increasing capabilities. The NST is the first facility-class solar telescope built in the US in a generation. The latest results will be shown with particular emphasis on data from light corrected by our newest adaptive optics systems including early results from the first operational multi-conjugate adaptive optics (MCAO) at a solar observatory. An overview of the telescope's latest post-focus instrumentation will be given, which includes spectro-polarimeters covering the visible through the near infrared. Particular attention and discussion will be concentrated on images and movies illustrating the high resolution capabilities of the NST.

5:20 – 6:20 **Cocktail Hour**

6:20 – 7:20 **Dinner**

6:20 – 7:20 **Teaching Old Telescopes New Tricks**

Dr. Geoff Chester

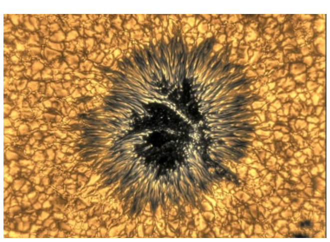
The U.S. Naval Observatory has been at the forefront of astronomical research in America for over 180 years. Over the course of those years we have employed a variety of instruments, some of which continue in regular use today.

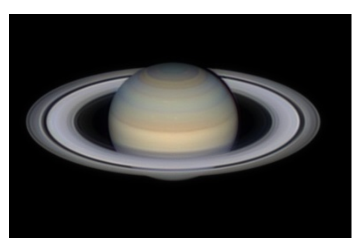
In 1873 we purchased the 26-inch "Great Equatorial" refractor from the firm of Alvan Clark & Sons. At the time it was the largest refractor in the world, and in 1877 astronomer Asaph Hall used it to discover the moons of Mars.

When the Observatory relocated to its present site in 1893 we moved the Great Equatorial, providing it with a new Warner & Swasey mounting. We also purchased a 12-inch refractor with a lens made by the Clark firm and a mounting made by George Saegmüller that was put into service in 1895.

Both of these instruments are still in use today, with the 26-inch making routine observations of double stars and the 12-inch used for visual observations for tours and personal use by the staff.

I have had the opportunity to use both instruments in my efforts to make high-resolution planetary and lunar images. In this talk I will detail the joys and pitfalls of using these fine old instruments which are now producing results that are in all likelihood far beyond the wildest expectations of their makers.





History of Astrophotography Timeline

Pedro Ré

1800- Thomas Wedgwood (1771-1805) produces "sun pictures" by placing opaque objects on leather treated with silver nitrate; resulting images deteriorated rapidly.

1816- Joseph Nicéphore Niépce (1765-1833) combines the camera obscura with photosensitive paper.
1826- Joseph Niépce produces the first permanent image (Heliograph) using a camera obscura and white bitumen.

1829- Niépce and Louis Daguerre (1787-1851) sign a ten year agreement to work in partnership developing their new recording medium.

1834- Henry Fox Talbot (1800-1877) creates permanent (negative) images using paper soaked in silver chloride and fixed with a salt solution. Talbot created positive images by contact printing onto another sheet of paper. Talbot's The Pencil of Nature, published in six installments between 1844 and 1846 was the first book to be illustrated entirely with photographs.

1837- Louis Daguerre creates images on silver-plated copper, coated with silver iodide and "developed" with warmed mercury (daguerreotype).

1839- Louis Daguerre patents the daguerreotype. The daguerreotype process is released for general use in return for annual state pensions given to Daguerre and Isidore Niépce (Louis Daguerre's son): 6000 and 4000 francs respectively.

1839- John Frederick William Herschel (1792-1871) uses for the first time the term Photography (meaning writing with light).

1839- First unsuccessful daguerreotype of the moon obtained by Daguerre (blurred image – long exposure).

1839- François Jean Dominique Arago (1786-1853) announces the daguerreotype process at the French Academy of Sciences (January, 7 and August, 19). Arago predicts the future use of the photographic technique in the fields of selenography, photometry and spectroscopy.

1840- John William Draper (1811-1882) obtains the first successful (correctly exposed) daguerreotype of the moon using a 13 cm reflector with a long focal length (20 min exposures).

1841- Henry Talbot patents his process under the name "calotype".

1842- Austrian astronomer G.A. Majocchi obtains the first photograph of the partial phase of a solar eclipse on a daguerreotype in 1842 (July, 8) (2 min exposure).

1844/1845- According to J.D. Arago, a large number of daguerreotypes of the sun were obtained by Armand Hippolyte Louis Fizeau (1819-1896) and Jean Bernard Léon Foucault (1818-1868) at the Paris observatory. One of these photographs, taken on April 2, 1845, still survives (figure 1).

1849/1852- William Cranch Bond (1789-1859) and John Adams Whipple (1822-1891) obtain a series of lunar daguerreotypes with the 38 cm Harvard refractor (40 s exposures) (Figure 2).

1850- First star photograph (α Lyrae, Vega) obtained by John Adams Whipple and William Cranch Bond using the 38 cm Harvard refractor (daguerreotype, 100 s exposure).

1851- Frederick Scott Archer (1813-1857), improves photographic resolution by spreading a mixture of collodion (nitrated cotton dissolved in ether and alcohol) and chemicals on sheets of glass. Wet plate collodion photography was much cheaper than daguerreotypes; the negative/positive process permitted unlimited reproductions. The process was published but not patented.

1851- First daguerreotype of a total eclipse of the Sun obtained by M. Berkowski , recording the inner corona and several prominences (July, 28) (Figure 3). In Rome Angelo Secchi (1818-1878) records the partial phases of the eclipse (daguerreotypes) (162 mm refractor, 2.5 m focal length).

1852- First wet plate collodion images of the Moon obtained by Warren de la Rue (1815-1889) using a 33 cm reflector with 3.05 m focal length. Mount without a clock drive.

1853- J. Phillips photographs the Moon with a 159 mm refractor (3.35 m focal length) (60 s exposures).

1854- Joseph Bancroft Reade (1801-1870) uses a 60 cm reflector to photograph the sun (wet collodium). These images reveal the solar molted appearance (photosphere).

1855- Warren de la Rue publishes A series of twelve photographs of the Moon.

1856/1858- Lewis Morris Rutherfurd (1816-1892) photographs the Moon and the Sun using an achromatic refractor of 285 mm aperture.

1857- George Philips Bond (1825-1865) (son of W.C. Bond) photographs (wet collodion) the double star Mizar (ζ UMa) and Alcor (80 UMa) using the 38 cm Harvard refractor (Figure 4).

1857- Warren de la Rue obtains images of Jupiter and Saturn with a 33 cm reflector. The exposures (12 s for Jupiter and 60 s for Saturn) were unsuccessful (the planet images measured only 1/2 mm on the plate).

1858- Warren de la Rue tries to image comet Donati without success. M. Usherwood records the comet with a 7 s exposure.

1858- George Philips Bond shows that the magnitude of stars could be derived from astronomical photographs (stellar photometry).

1958/1859- Warren de la Rue publishes the first stereographs of the Moon (by obtaining images at different librations) (Figure 5).

1858/1872- Warren de la Rue obtains daily images of the Sun (weather permitting) using the Kew photoheliograph. A total of 2778 Sun photographs were obtained between 1862 and 1872.

1860- Warren de la Rue photographs (wet collodion) the total eclipse of the Sun in Spain (July, 18) with the Kew photoheliograph (60 s exposures) (Figure 7). Angelo Secchi also obtains excellent photographs of the same eclipse (Spain).

1861- Warren de la Rue mentions the possibility of conducting a photographic survey to obtain a Star Map of the whole sky (astrometry).

1861- James Clerk Maxwell (1831-1879) demonstrates a color photography system involving three black and white photographs, each taken through a red, green and blue filter.

1865- Lewis Morris Rutherfurd obtains excellent Moon images using a specially corrected (photographic) 290 mm lens (Figure 7).

1864/1865- Henry Draper (1837-1882) images the Moon using a 40 cm reflector built by himself.

1871- German astronomer Hermann Carl Vogel (1841-1907) obtains excellent photographs of the Sun using a 294 mm refractor equipped with an electrical shutter (1/5000 to 1/8000s exposures).

1871- Richard Leach Maddox (1816-1902), proposes the use of an emulsion of gelatin and silver bromide on a glass plate, the "dry plate" process.

1871- Lord (James Ludovic) Lindsay (1847–1913) photographs the total eclipse of the Sun (December, 12) at Baikul (Figure 8).

1871- Lewis Morris Rutherfurd records the solar molted appearance with some detail.

1872- Henry Draper records the spectrum of α Lyra using a 720 mm reflector.

1872- Henry Draper records for the first time a star spectrum (Vega) using a 72 cm reflector and a quartz prism.

1873- Edward Walter Maunder (1851-1928) installs at the Greenwich observatory a photoheliograph to record the Sun on a daily basis. Maunder is best remembered for his study of sunspots and the solar magnetic cycle that led to his identification of the period from 1645 to 1715 known as the Maunder Minimum.

1874- Pierre Jules César Janssen (1824-1907) develops the photographic revolver to record the transit of the planet Venus across the face of the sun, on 8 December 1874.

1875- Henry Draper photographs the spectra of almost all the bright stars using a 29 cm lens and a quartz prism located close to the photographic plate.

1876- William Huggins (1824-1910) uses the dry plate for the first time to record spectra. From 1876 to 1886, Huggins and Miller photograph the spectra of all the first and second magnitude stars (60 min exposures).

1876/1878- In 1876 Jules Janssen presents his first solar photographs to the French Academy of Sciences (10 to 70 cm diameter). These wet collodion images were obtained with a 150 mm refractor with exposures of 1/500 to 1/6000s. During 1877/1877 Jules Janssen obtains a high number of solar photographs showing the solar granulation (photosphere) for the first time.

1879- Andrew Ainslie Common (1841-1903) photographs Jupiter using his 91 cm reflector (5.30 m focal length) (1 s exposures, images 1 mm wide).

1879/1883- Henry Draper photographs the spectra of 50 stars.

1880- Henry Draper obtains the first photograph of the Orion nebula (M 42) on September, 30. Draper used a 28 cm Alvan Clark refractor supported by an equatorial mount also built by Clark (51 min exposure) (Figure 9). Draper obtains two other photographs of M 42 on 1881/1882 with longer exposure times (104 min and 137 min).

1881- First successful image of a comet (Tebbutt 1881 III) obtained by Jules Janssen on June, 30. Janssen used a dry plate and an exposure of 30 min (50 cm f/3 instrument) (Figure 10). The same comet was also imaged by H. Draper, A. Common and M. Huggins.

1882- David Gill (1843-1914), of Cape observatory, photographs the great comet of 1882 using a portrait lens of 63 mm aperture (f/4.5) (Figure 11).

1882- W. Huggins photographs of the spectrum of a nebula (M 42) for the first time (45 min exposure).

1882- Edward Charles Pickering (1846-1919) starts a program at the Harvard observatory using objective prisms. This setup enabled Pickering to obtain several spectra on a single plate.

1883- Andrew Ainslie Common photographs the Orion nebula using his 91 cm reflector on January 30. The 37 min exposure reveals stars that were not detected visually, for the first time. On February 28, Common obtains a deeper image with an exposure of 60 min (Figure 12).

1885/1886- The Henry Brothers: Paul Henry (1848-1905) and Prosper Henry (1849-1903); photograph Jupiter and Saturn using the Paris observatory 33 cm refractor (3.43 m focal length). These were the first successful planetary images (Figure 13).

1887- Amédée Mouchez (1821-1892) hosts the first meeting of the "Carte du Ciel" Project at the Paris observatory. Eighteen observatories agreed to cooperate and to adopt, as a standard design for a photographic telescope, the 33 cm refractor developed by the Henry brothers.

1885/1899- Isaacs Roberts (1829-1904) obtains a long series of photographs from 1885 to 1897 and publishes two volumes with these results (the first in 1893 and the second in 1899, both with the same title Photographs of Stars, Star Clusters and Nebulae).

1887/1899- William Edward Wilson (1851-1908) records several deep-sky images at the Daramona observatory (Westmeath, Ireland). The Wilson photographs are practically unknown today (Figure 14).

1888/1890- William Henry Pickering (1858-1939) successfully photographs Mars using two refractors (38 cm and 32 cm aperture) at Pic du Midi observatory (France).

1890- Edward Singleton Holden (1846-1914) obtains high resolution images of the Moon using the 91 cm Lick refractor.

1894/1910- Moritz Loewy (1833-1907) and Pierre-Henri Puiseux (1855-1928) obtain 6000 photographs (500 nigths) of the Moon using the 60 cm Paris observatory Coudé refractor. The Atlas Photographique de la Lune was edited from 1896 e 1910 by the Paris observatory (Figure 15).

1899- James E. Keeler (1857-1900) starts a photographic survey of nebulae at the Lick observatory (Mount Hamilton, California). Keeler used the Common reflector (91 cm aperture) that was offered to the observatory by Edward Crossley (1841-1905). The images obtained by Keeler were the best of its kind until the end of the century.

1889- First of a long series of wide-field deep-sky astrophotographs obtained by Edward Emerson Barnard (1857-1923). Lick Observatory, Crocker telescope, Willard 6" lens (Figure 16).

1899- The German astronomer Julius Scheiner (1858-1913) records the spectrum of M 31 with an exposure of 7 ½ h proving that it was composed of individual stars.

1901/1902- George Willis Ritchey (1864-1945) obtains a series of excellent photographs of nebulae using the Mount Wilson 60 cm reflector.

1903- Jules Janssen publishes his monumental work Atlas de photographies solaires (Gauthiers-Villars).

1909/1911- G.W. Ritchey records several star clusters and nebulae with the 1.52 m f/5 Mount Wilson reflector (exposures of up to 11 h obtained during several nights). These photographs had a resolution of about 1" (Figures 17 and 18).

1911- E.E. Barnard obtains excellent images of Saturn using the 1.52 m Mount Wilson reflector (Figure 19).

1913- E.E. Barnard publishes Photographs of the Milky Way and of Comets. Publications of Lick Observatory, vol. 11. These images were obtained from 1892 to 1895 using the Crocker telescope (Figure 20).

1918- First photographs of nebulae obtained by F.G. Pease (1881-1938), with the Hooker 2.54 m reflector at Mount Wilson.

1924- Edwin Hubble (1889-1953), using the 2.54 m Hooker Telescope, was able to identify Cepheid variables in the Andromeda galaxy and estimates it's distance (800 000 light years). Hubble changed astronomers' understanding of the nature of the universe by demonstrating the existence of other galaxies besides the Milky Way.

1927- Publication of Atlas of Selected Regions of the Milky Way", five years after the disappearance of E.E. Barnard. Most of the plates included in the Atlas (40 out of 50) were obtained at Mount Wilson Observatory with the Bruce Telescope (Figures 21 and 22).

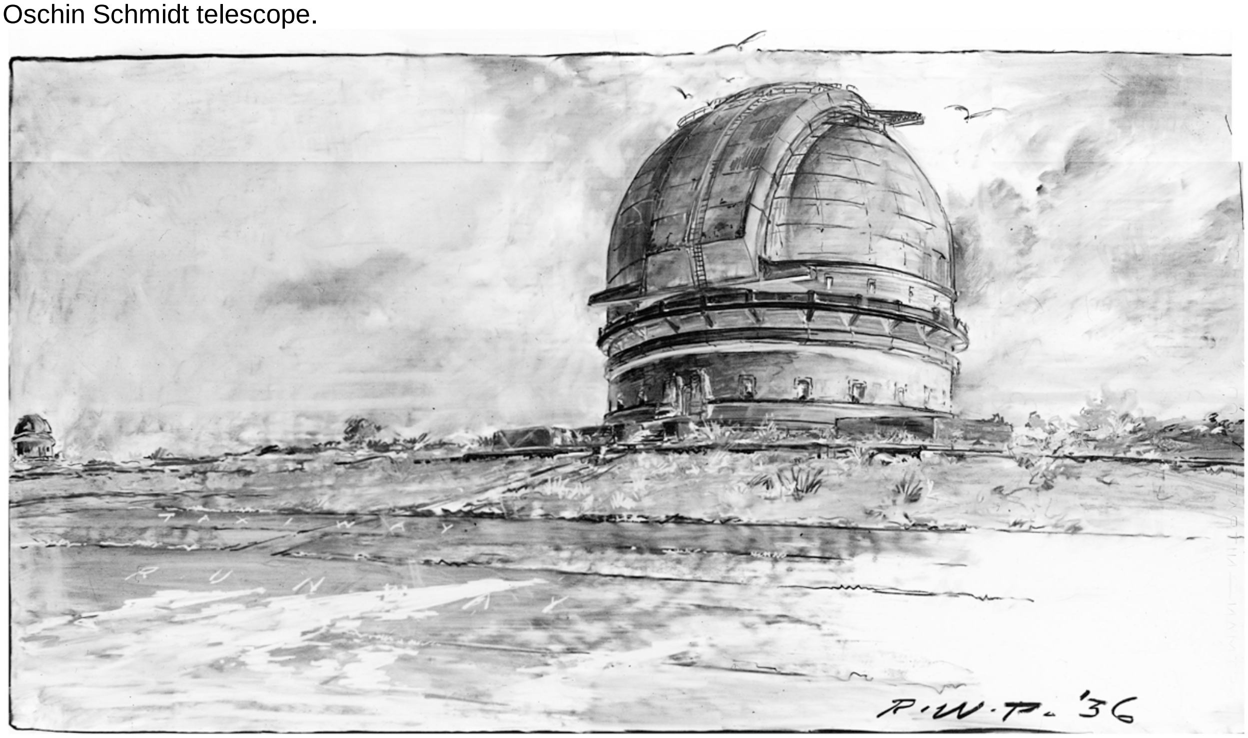
1929- Edwin Hubble, based on photographs of spectra (exposures of tenths of hours), discovers that the degree of the redshift observed in several galaxies increases in proportion to their distance to the Milky Way. This became known as Hubble's law, and would help establish that the universe is expanding.

1929/1934- French astronomer Marcel de Kerolyr photographs nebulae and galaxies using the 80 cm f/6 reflector of the Paris observatory astrophysics station at Haute Provence.

1936- Milton Lasell Humason (1891-1972) images galaxies at 240 000 000 light-years with the Hooker telescope.

1948- Edwin Hublle uses the 200 inch (5.08 m) Hale telescope for the first time.

1948/1958- The Palomar Observatory Sky Survey (POSS), was completed in 1958 (the first plates were shot in November 1948 and the last in April 1958). This survey was performed using blue-sensitive (Kodak103a-O) and red-sensitive (Kodak 103a-E) photographic plates on the 48 inch (1.22 m) Samuel Oschin Schmidt telescope.



Photos by Damian Peach

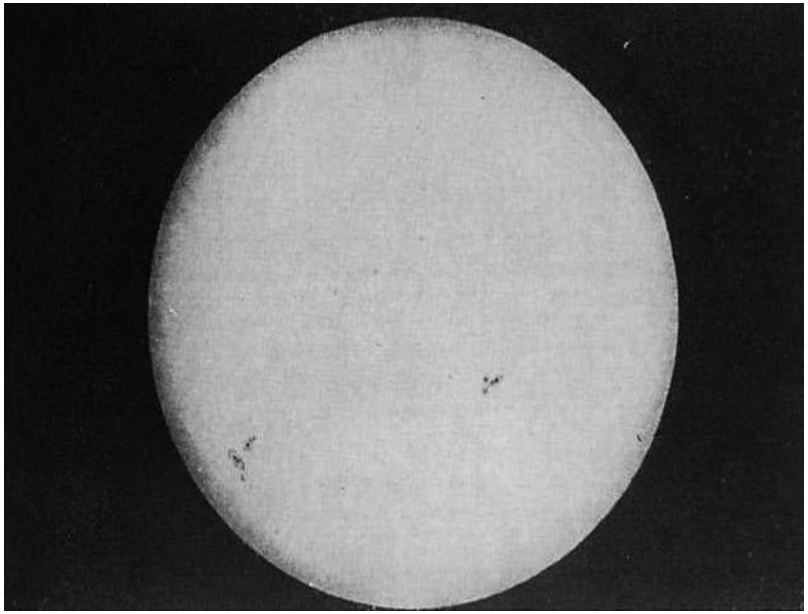


Figure 1 - Daguerreotype of the Sun obtained by Fizeau and Focault on April 2, 1845 (Paris Observatory)

Figure 2- Lunar daguerreotype obtained by John Adams Whipple on February 26, 1852 (Harvard observatory)

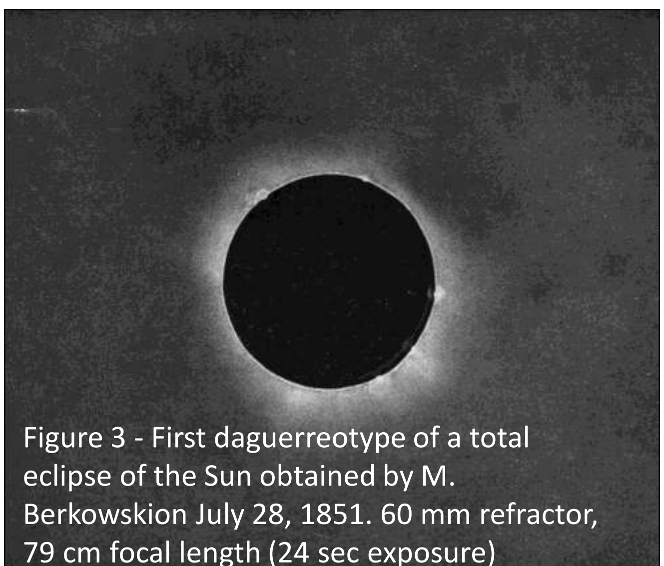


Figure 3 - First daguerreotype of a total eclipse of the Sun obtained by M. Berkowskion July 28, 1851. 60 mm refractor, 79 cm focal length (24 sec exposure)

Figure 4- Wet collodion image of Alcor & Mizar obtained by in 1857 by G.P. Bond using the 38 cm Harvard refractor

Figure 5 - Two stereographs of the moon by Lewis M. Rutherfurd and Henry Draper

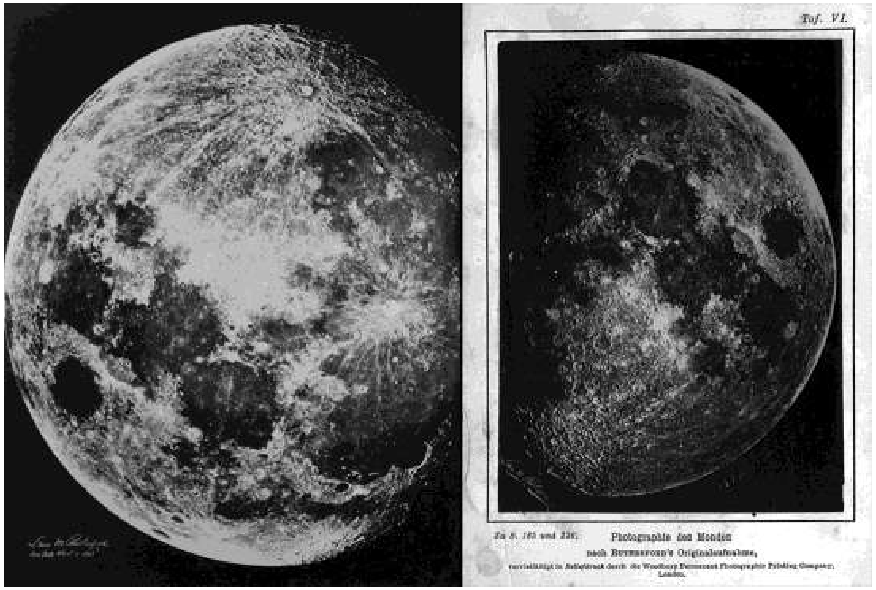


Figure 6 - Wet collodion Moon images obtained by Lewis M. Rutherfurd in 1865

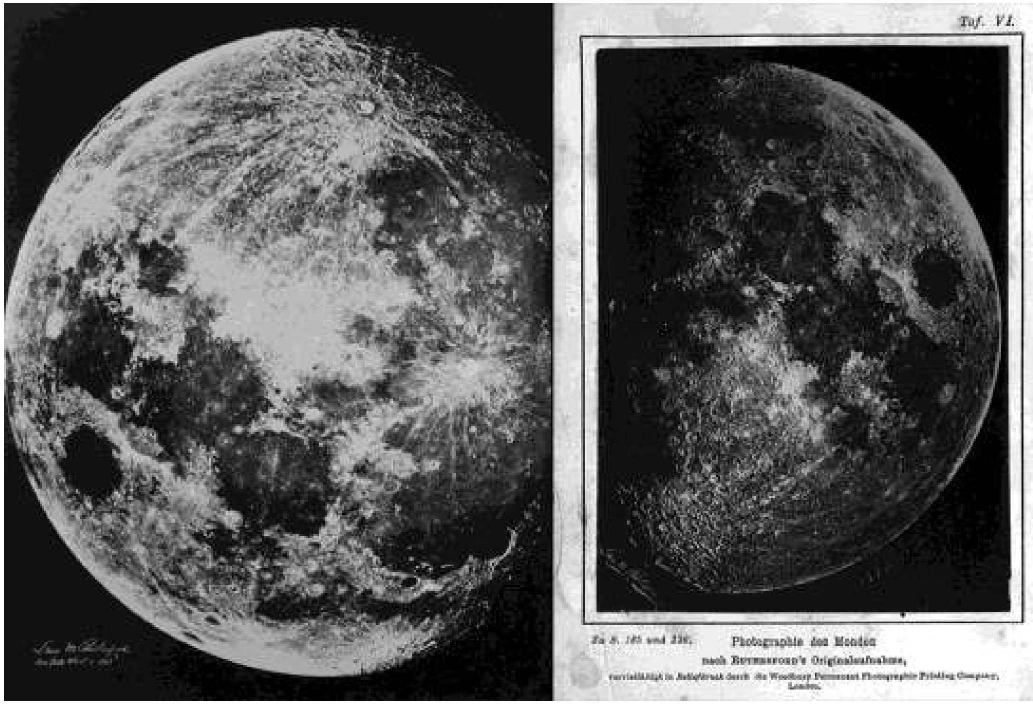


Figure 7 - Wet collodion Moon images obtained by Lewis M. Rutherfurd in 1865.

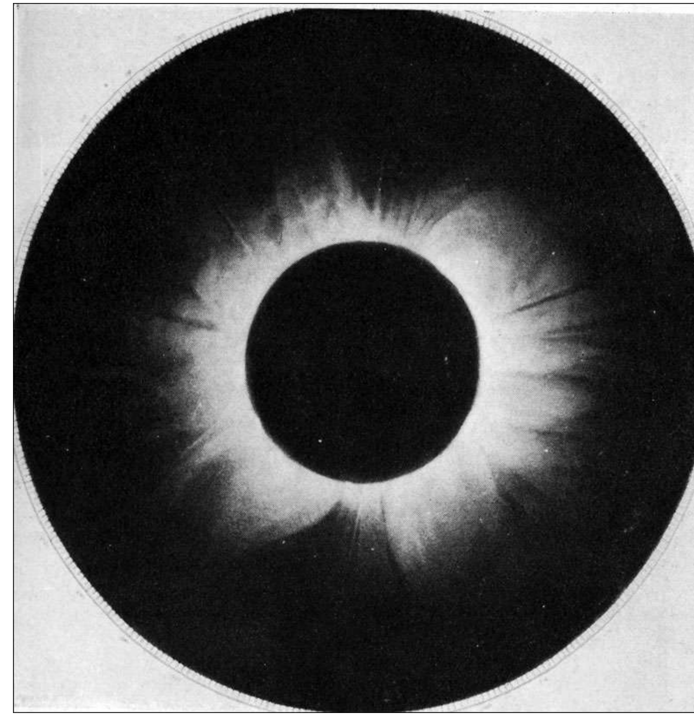


Figure 8 - Wet collodion image of the December, 12, 1871 total Eclipse of the Sun obtained by Lord Lindsay at Baikul (12 cm refractor, 84 cm focal length). Image obtained during a solar maximum.

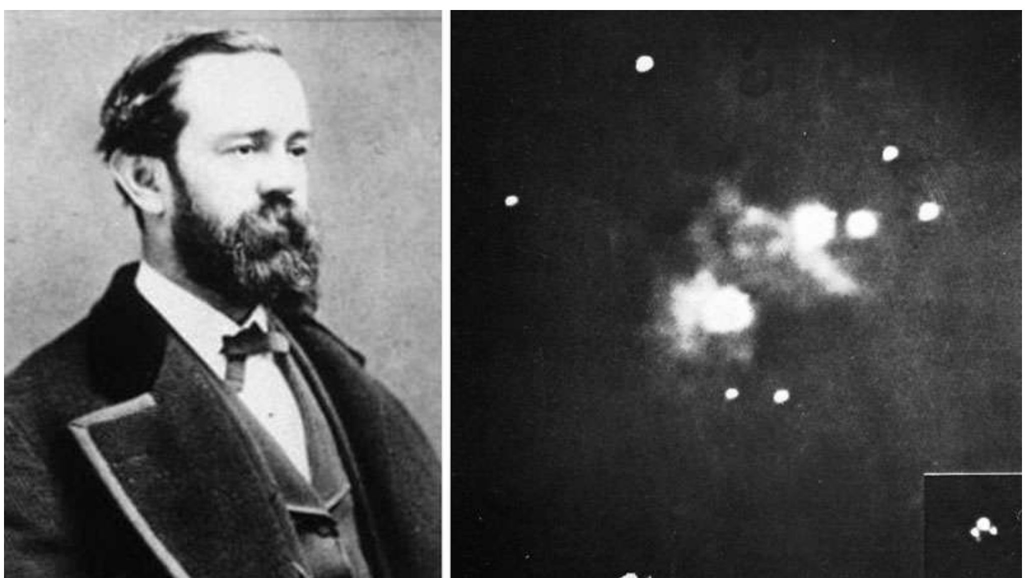


Figure 9 - First image of the Orion nebula (M 42) obtained by Henry Draper on 1880

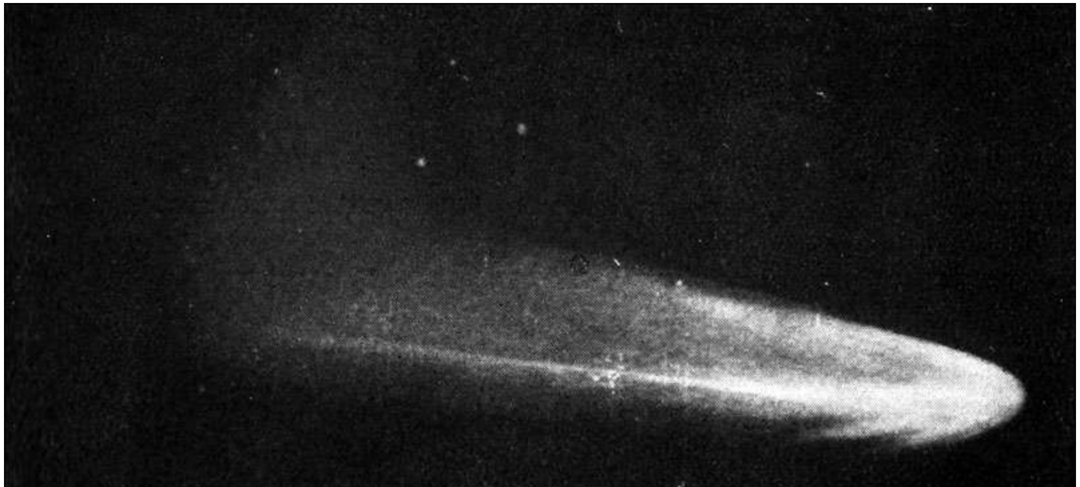


Figure 10 - First photograph of a comet. Image obtained by Jules Janssen on June, 30, 1881 (dry plate, 30 min exposure)

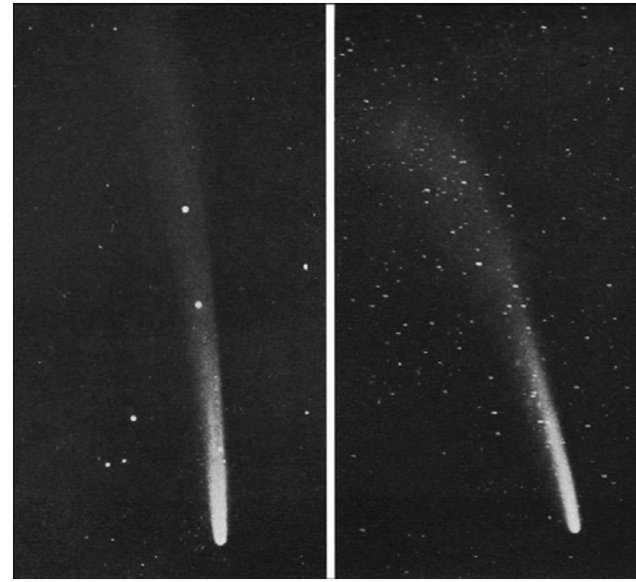


Figure 11 - Photograph of the great comet of 1882 obtained by David Gill on October, 19 (Left) and November, 7 (Right). Exposures of 30 min and 110 min respectively

Figure 12 - Photograph of M 42 obtained by Andrew A. Common on February 28, 1883, 91 cm reflector, 60 min exposure

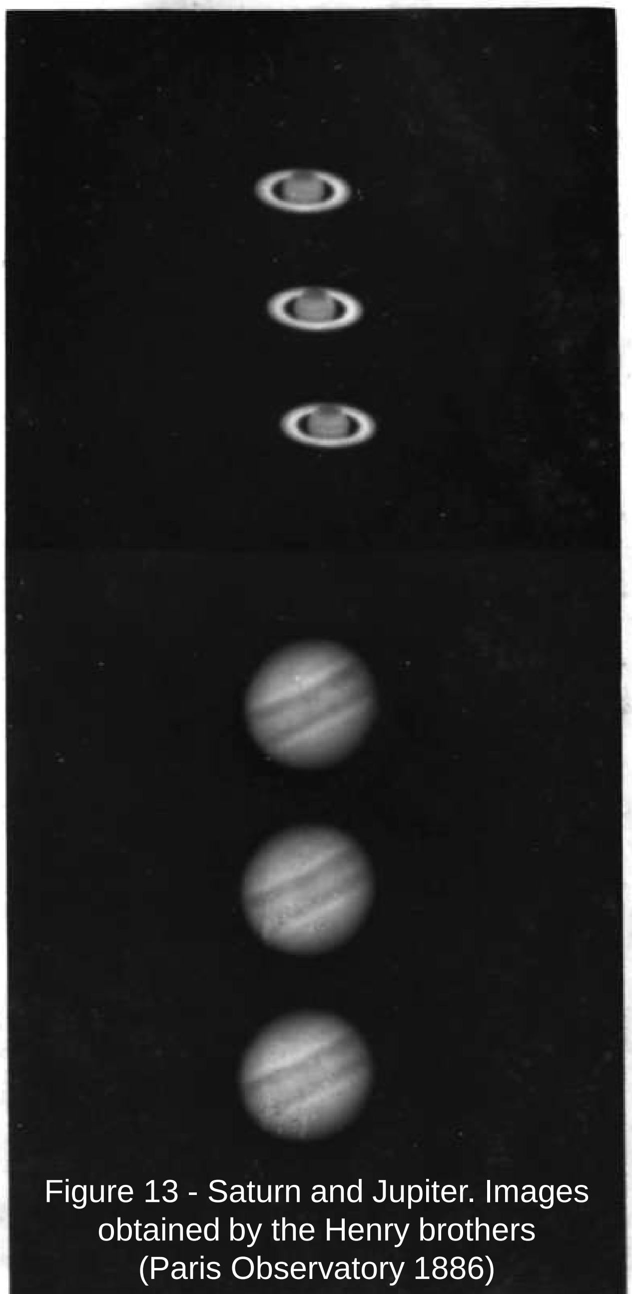


Figure 13 - Saturn and Jupiter. Images obtained by the Henry brothers (Paris Observatory 1886)

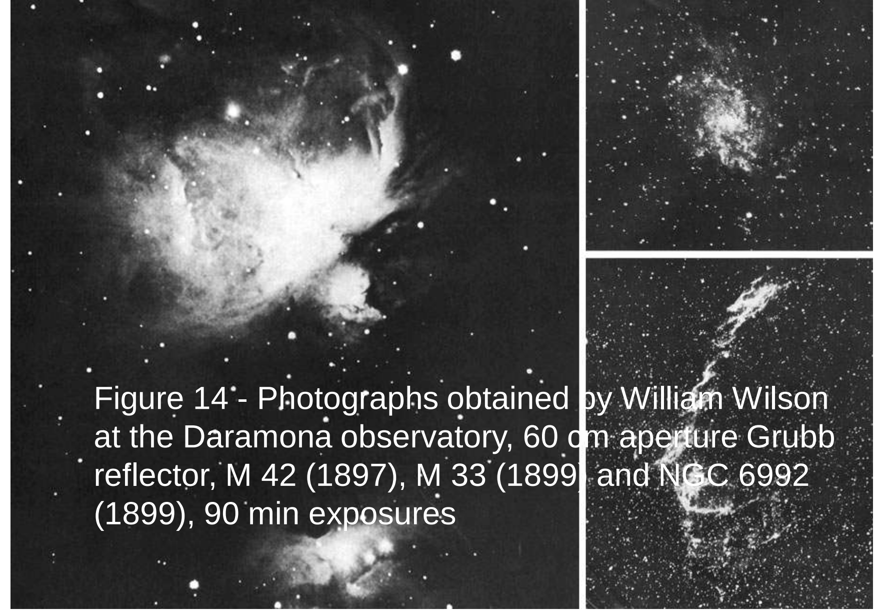


Figure 14 - Photographs obtained by William Wilson at the Daramona observatory, 60 cm aperture Grubb reflector, M 42 (1897), M 33 (1899) and NGC 6992 (1899), 90 min exposures

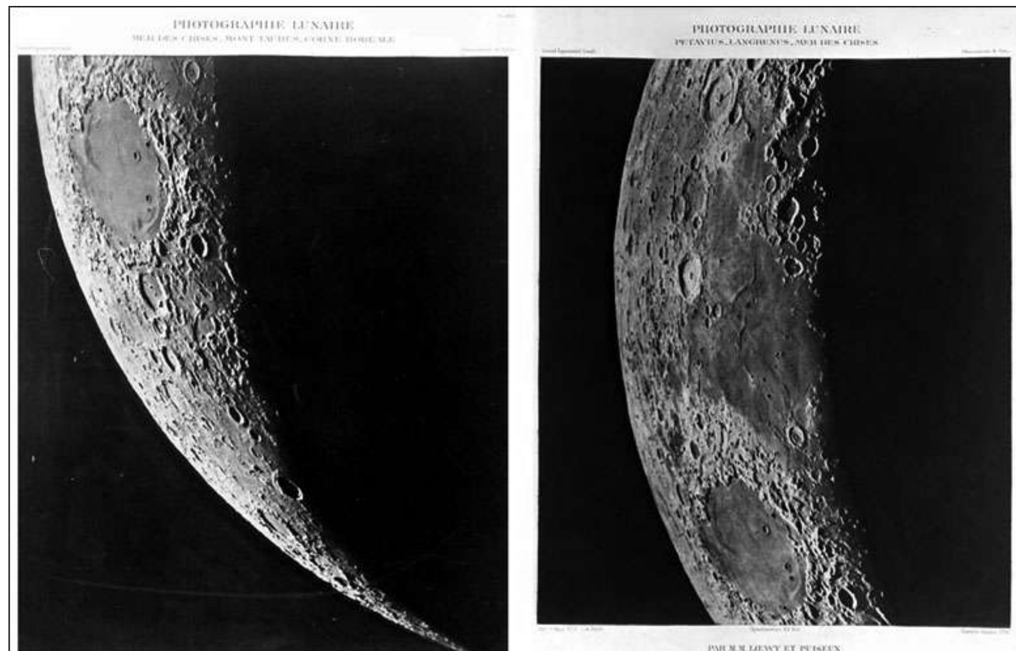


Figure 15 - Atlas photographique de la lune, héliogravures **,** Paris, 1896-1910, Collections de l'Observatoire de Paris.
Images obtained on March 7, 1897

Figure 16 - One of the first wide-field images obtained by Edward E. Barnard. Lick observatory, Croker telescope, 6” Willard lens (August 1, 1889, 3h 7m exposure)

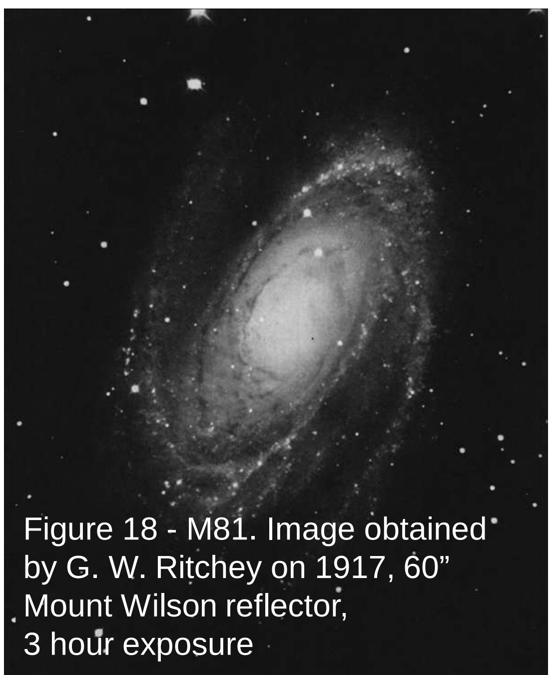


Figure 18 - M81. Image obtained by G. W. Ritchey on 1917, 60” Mount Wilson reflector, 3 hour exposure

Figure 17 - M 3. Image obtained by G. W. Ritchey on April 9, 1910, 60” Mount Wilson reflector, 3 ½ hour exposure

Figure 19 - Saturn images obtained by E.E. Barnard with the 60” telescope, Mount Wilson Observatory (1911)

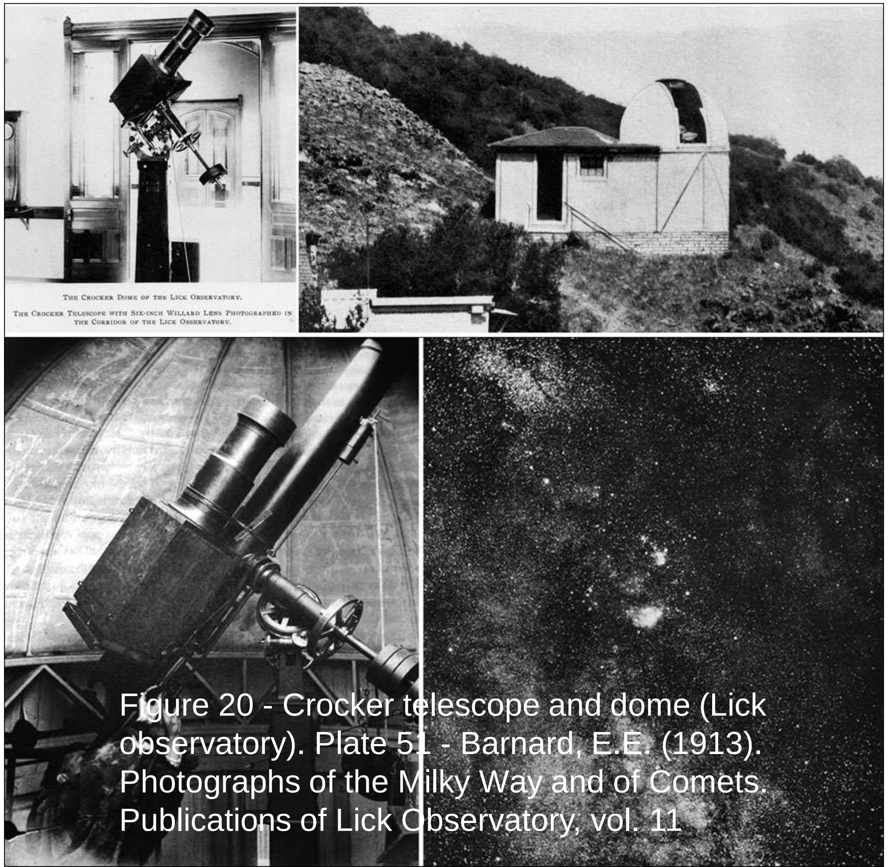


Figure 20 - Crocker telescope and dome (Lick observatory). Plate 51 - Barnard, E.E. (1913). Photographs of the Milky Way and of Comets. Publications of Lick Observatory, vol. 11

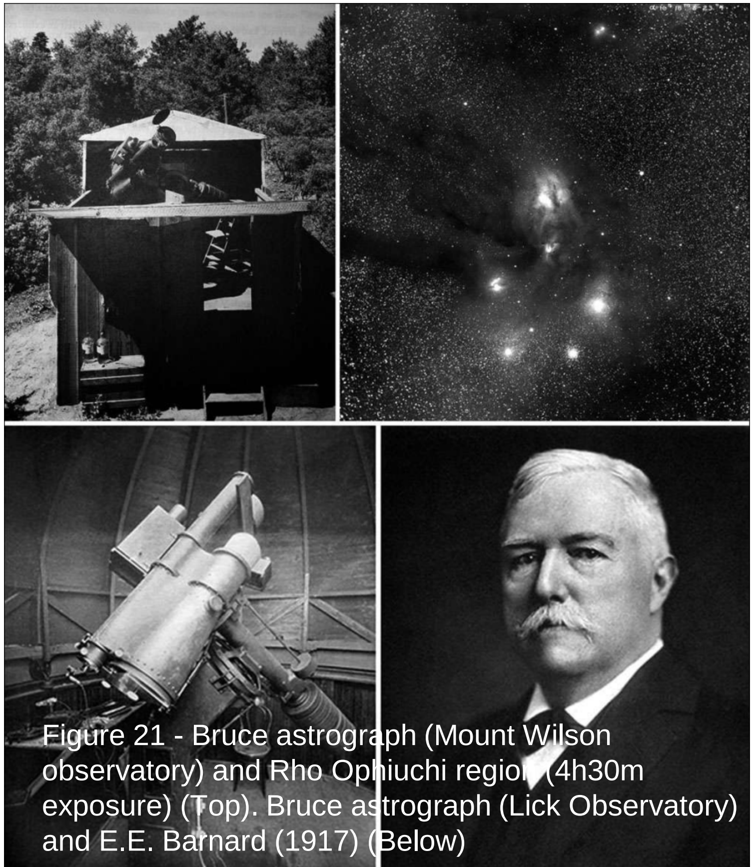


Figure 21 - Bruce astrograph (Mount Wilson observatory) and Rho Ophiuchi region (4h30m exposure) (Top). Bruce astrograph (Lick Observatory) and E.E. Barnard (1917) (Below)

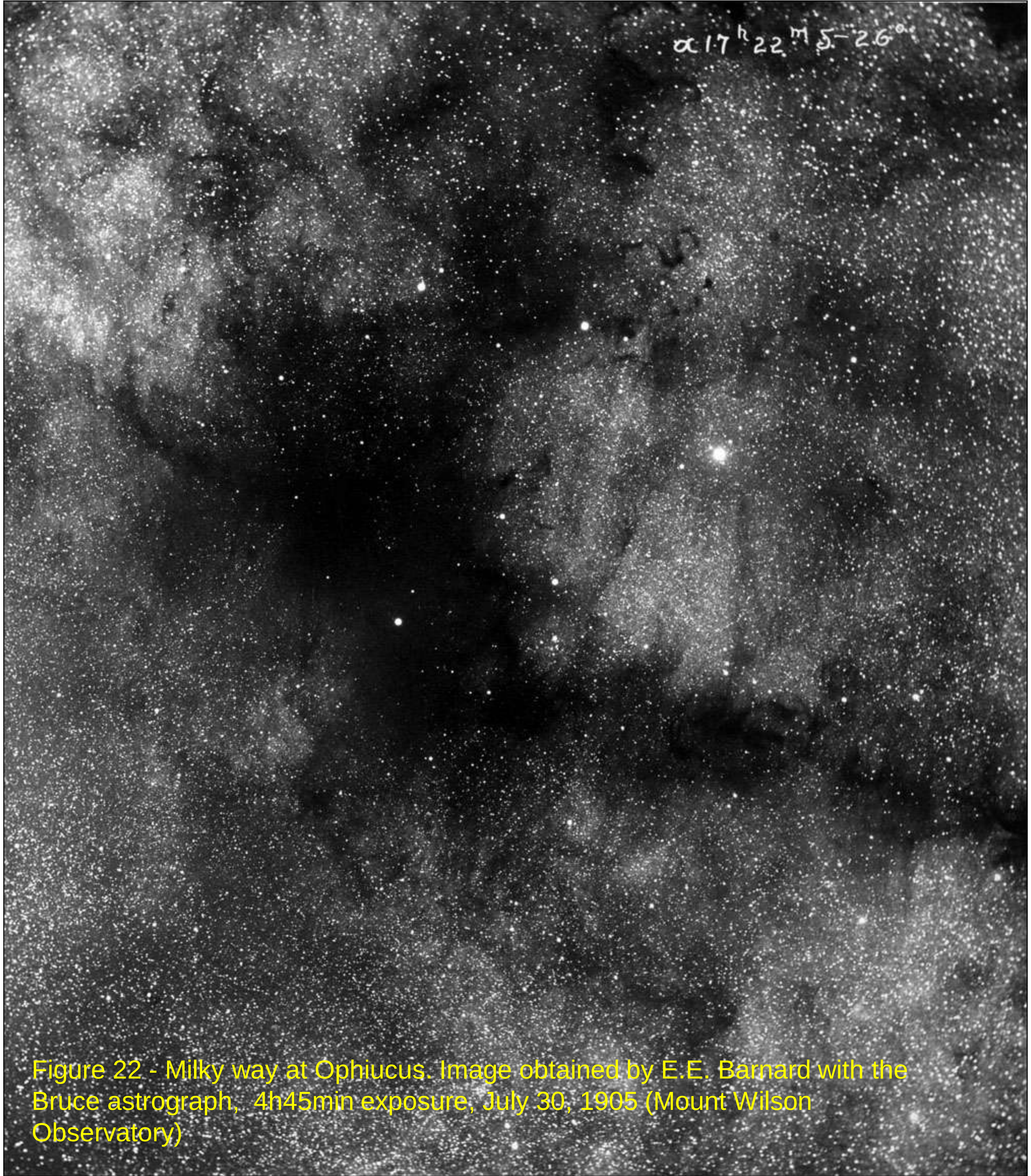
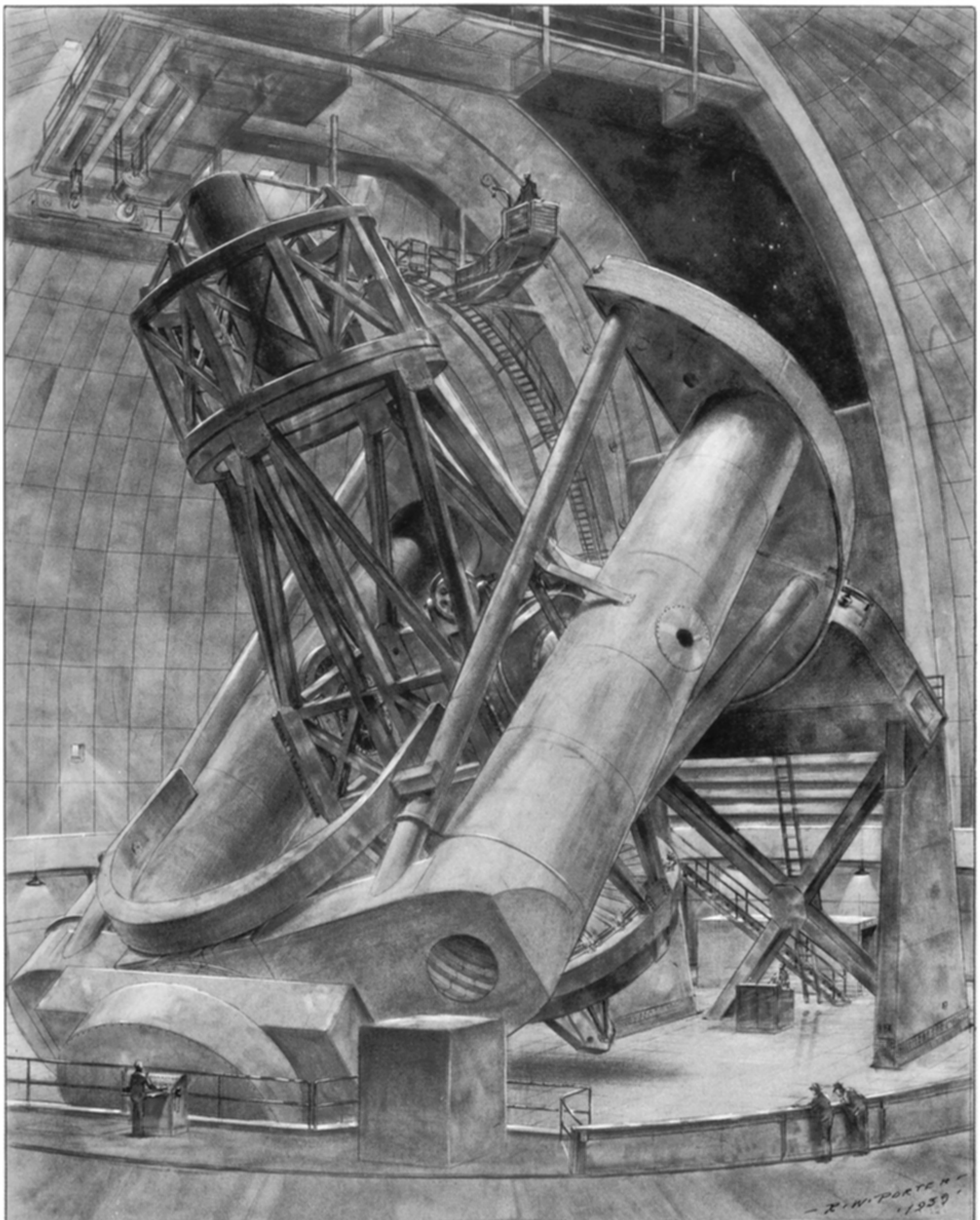
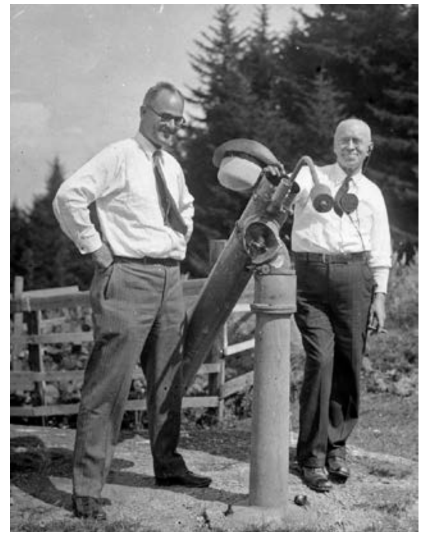


Figure 22 - Milky way at Ophiucus. Image obtained by E.E. Barnard with the Bruce astrograph, 4h45min exposure, July 30, 1905 (Mount Wilson Observatory)



THE · TWO · HUNDRED · INCH ~
TELESCOPE · LOOKING · NORTHWEST

Enjoy the Stellafane Convention



Thanks for supporting the Hartness House Workshop