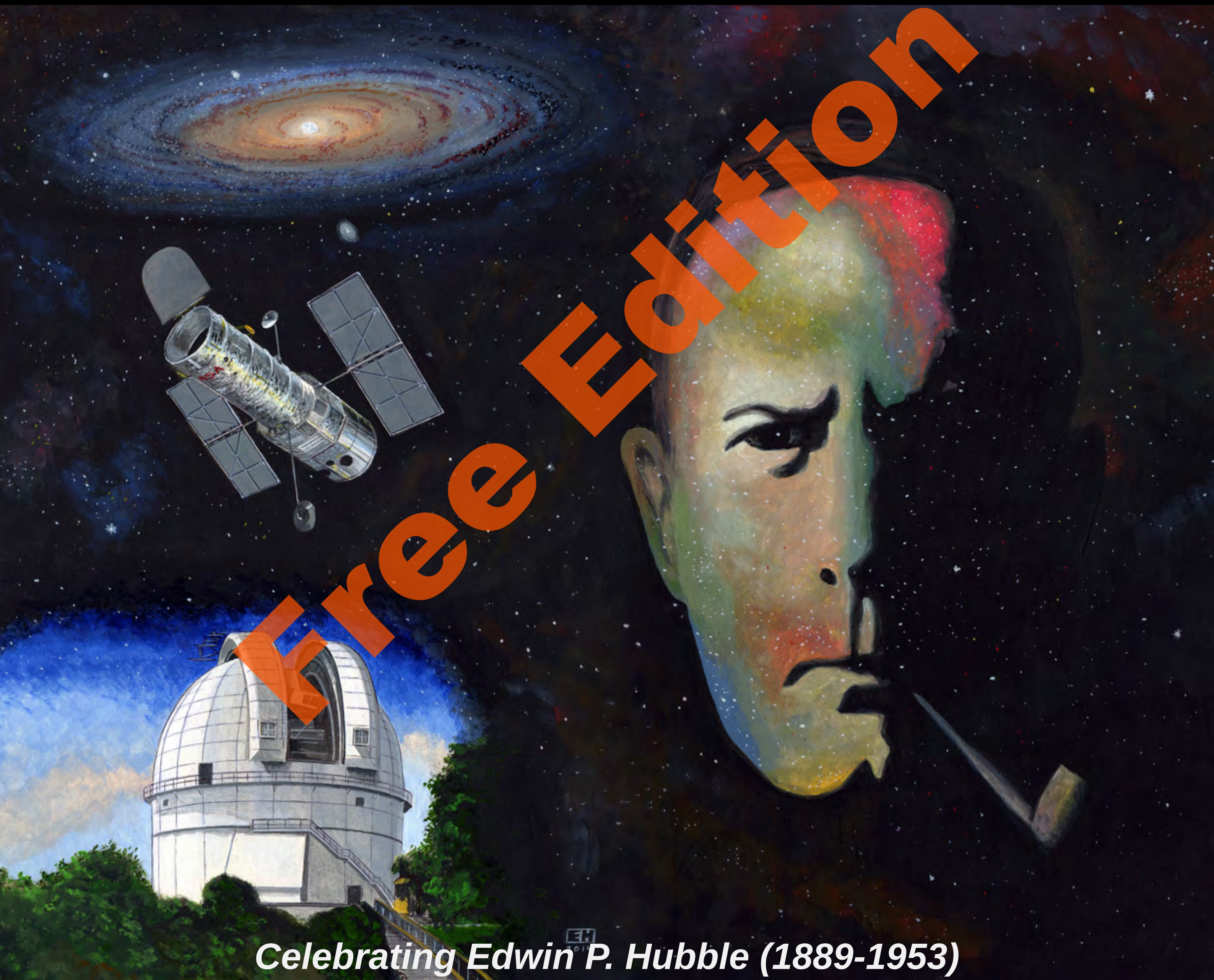
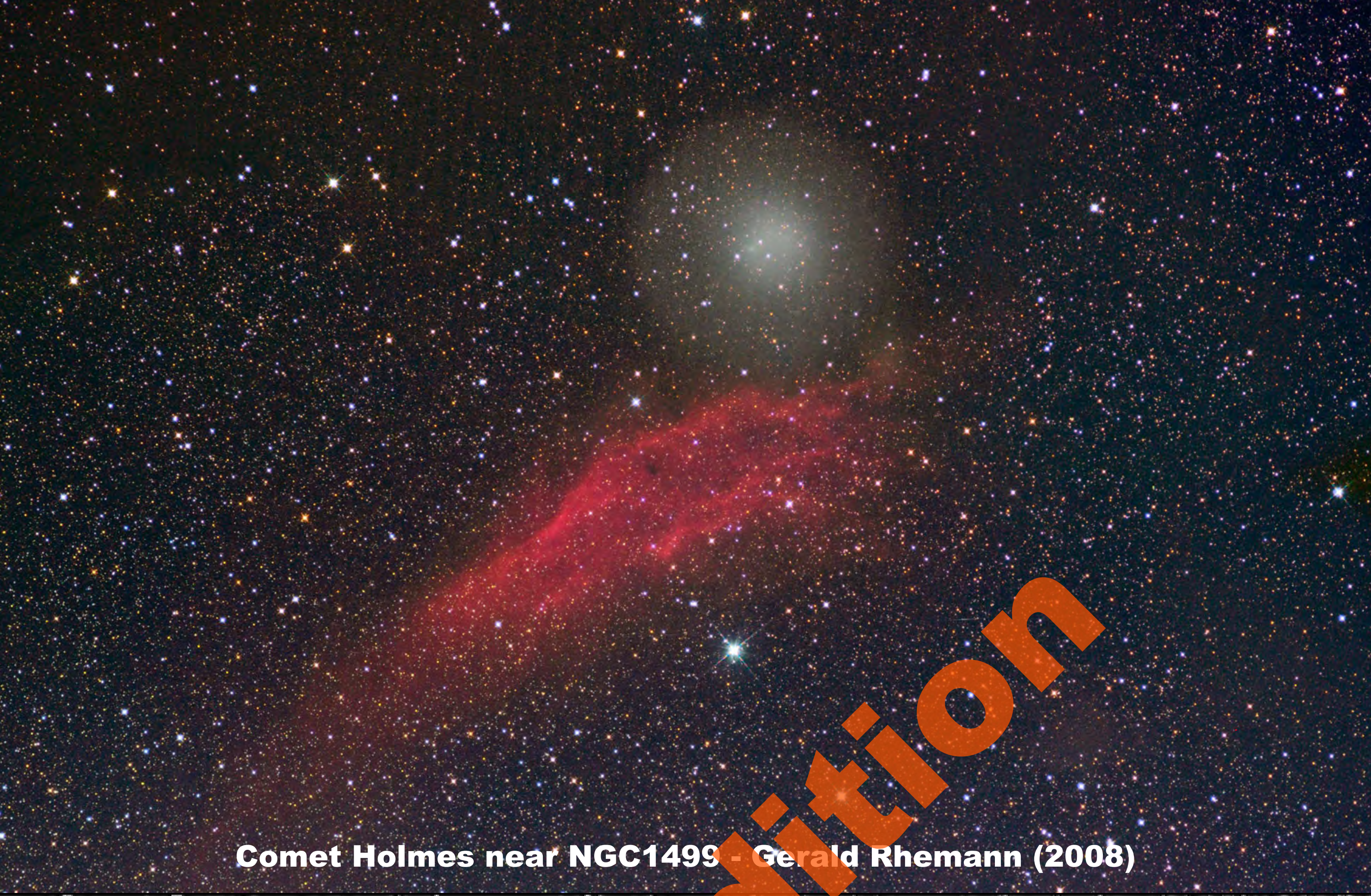
The Ages of Astrophotography

1839 - 2015

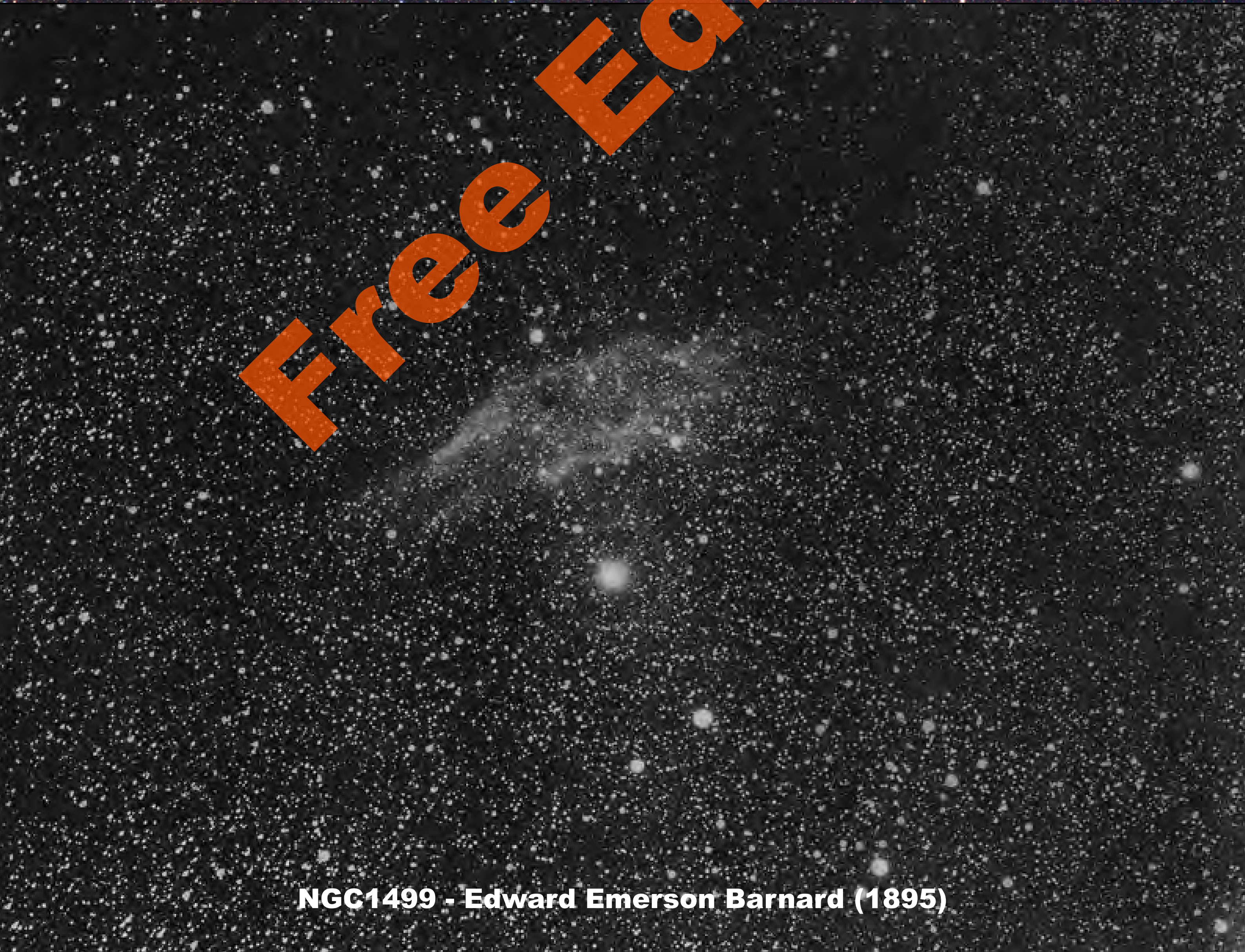


Celebrating Edwin P. Hubble (1889-1953)

Stefan Hughes



Comet Holmes near NGC1499 - Gerald Rhemann (2008)



NGC1499 - Edward Emerson Barnard (1895)

Comet Ikea-Zhang Encounter with M31 - Gerald Rhemann (2002)

Comet Homes Encounter with M31 - Edward Emerson Barnard (1892)

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2005

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Preface

As a young boy growing up in awe of the stars, I suffered a great disappointment and frustration - for I could never truly see the universe as it was in the photographs of my books. Through the eyepieces of my telescopes, which got bigger with each passing year I could only glimpse the myriad of stars of the two great globular clusters in Hercules; or pick out the faint '*fuzzies*' that were star systems beyond our own *Milky Way*; or sense the magnificent glowing gas of the '*Great Nebula*' in Orion - and when I looked for the dark head of the '*Grim Reaper's Horse*' rising into the light- I saw nothing, but the need for an even bigger telescope! I knew I could never have a '*Great Reflector'* atop a Mountain or even an ageing Large Refractor at the edge of a City, so I gave up and became a Theoretical Astronomer where my only instruments were main frame computers programmed with the language of Mathematics, but I never forgot the wonder of the stars.

Now half a century later, the modern amateur astronomer need not feel the disappointment or frustration as I did. Every night across the world in almost every country, in backyards, gardens, on hills or in deserts they image the heavens. With their modest equipment costing just a few thousand dollars they can see all that I could not; and with it capture the Night Sky with a quality far superior to the photographic plates taken by the '*Great Telescopes*' in my books. The digital age of the CCD '*Chip*' has arrived.

My previous book the '*Catchers of the Light'* told the story of the History of Astrophotography through the '*Forgotten Lives of the Men and Women Who First Photographed the Heavens*'. The present volume tells of the '*Ages of Astrophotography*' through the images themselves. It features 100 of the most important, iconic and famous of astronomical objects, instruments, surveys, telescopes and cameras. For each '*object*' two images are depicted side by side, one taken by an early Pioneer of Astrophotography and a second imaged by one of today's finest Astronomical Photographers. Whenever possible the modern image is taken with the same '*framing*' as that of the earlier photograph. Through these 100 objects the History of Astrophotography is told from the Age of the first Daguerreotypes up until the present Age of the CCD camera. The book is divided into nine parts covering every aspect of the subject from its Origins, the Moon, Sun, Solar System, Deep Space, Spectroscopy, Photographic Sky Surveys, Telescopes and the Digital Age.

It is entirely fitting that '*Ages of Astrophotography'* should have a '*Past & Present*' theme and feature the images of both the early Pioneers of Astronomical Photography and their Modern Counterparts - for they have each seen the Spiral Nature of Galaxies, witnessed the magnificence of the Globulars, looked upon the beauty of the Gaseous Nebulae and even captured the '*Grim Reaper's'* Horse. It is for them this book has been written, so that anyone with even a passing interest in the Stars can learn of how they became the '*Catchers of the Light*' - and in doing so wrote the History of Astrophotography.

The year 2015 represents a milestone in Astrophotography, for it marks 125+ years since the birth of Edwin Powell Hubble (1889-1953) and 25 years since the launch of the great space telescope which bears his name. In 1923 Hubble made the most important astronomical discovery using photography of all time, when he imaged a Cepheid Variable star in the '*Great Andromeda Spira*l'; and in doing solved the '*problem of the nebulae*' and proved that Lord Rosse's '*Spirals*' were 'island universes lying behind the confines of our own Milky Way star system. It was this photograph which laid a '*yardstick*' on the size of the universe.

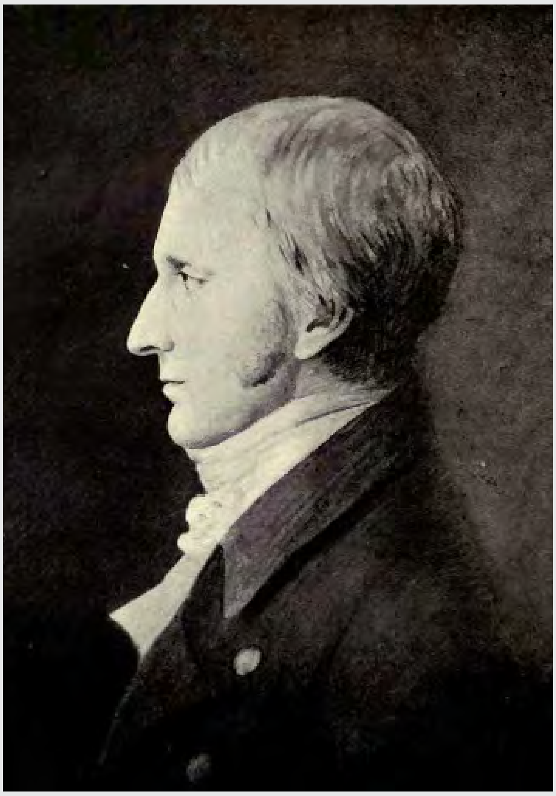
This book has been written as a tribute to Edwin Powell Hubble's memory - and to honour him as probably the greatest of all the '*Catchers of the Light*'. Stefan Hughes, Pafos, Cyprus, 2015.

Front Piece

'Great Andromeda Spiral' (M31) - Max Wolf (1907)

Front Cover: From a painting by the Dutch Space Artist, Ed Hengeveld and commissioned in 2014 by the Belgian astronomer, Philip Corneille FRAS, in celebration of the 125th anniversary of the birth of Edwin Powell Hubble (1889-1953) and the upcoming 25th anniversary of the launch of the Hubble Space Telescope (1990-2015+).

Beginnings



Thomas Wedgwood was one of the earliest pioneers of Photography, who in the 1790s began a series of experiments which led to his famous but impermanent '*sun pictures*'. He was born on the 14th May 1771 in Etruria (now part of Stoke-on-Trent), Staffordshire, England, the youngest son of the potter Josiah Wedgwood. His interests in art and science grew from the influence his father, and from a close association with many of the important figures of the day, including the polymath, Erasmus Darwin and the painter George Stubbs. In 1800 Wedgwood perfected a repeatable method of chemically staining an object's silhouette to a media by coating it with silver nitrate and exposing it with the object on top, to natural sunlight, then preserving it in a dark room. It was an event which marked the birth of photography as we know it today. Whilst undergoing treatment for Tuberculosis at the Pneumatic Clinic in Bristol, he met a young chemist named Humphry Davy (1778-1829). In 1802 Davy wrote up his friend's work for publication in Journal of the Royal Institution. Wedgwood died of Tuberculosis on the 10th July 1805 at his home in Tarrant Gunville, Dorset. He was buried six days later in the local churchyard of St. Mary's.

Thomas Wedgwood (1771-1805)

The year 1802 marked the publication of the first volume of the journal of the Royal institution of London. On page 171 can be found a paper entitled:

"An Account of a method of copying Paintings upon Glass, and of making Profiles, by the agency of Light upon Nitrate of Silver. Invented by T. WEDGWOOD, ESQ. With Observations by H. DAVY."

The paper began with the words, that described the very first account of experiments that ultimately would lead to an invention, that is used by countless millions of people every day across the globe - **Photography**:

"*White paper, or white leather, moistened with solution of nitrate of silver, undergoes no change when kept in a dark place; but on being exposed to the daylight, it speedily changes colour, and after passing through different shades of grey and brown, becomes at length nearly black. The alterations of colour take place more speedily in proportion as the light is more intense. In the direct beams of the sun, two or three minutes are sufficient to produce the full effect. In the shade, several hours are required, and light transmitted through different coloured glasses acts upon it with different degrees of intensity. Thus it is found that red rays, or the common sunbeams passed through red glass, have very little action upon it: Yellow and green are more efficacious, but blue and violet light produce the most decided and powerful effects.*"

Thomas Wedgwood's original experiments carried in 1800 only succeeded in obtaining '*photographs*' of opaque objects by placing them on leather or paper treated with silver nitrate, unfortunately the resulting images deteriorated rapidly. It was to be a further two decades later that the French inventor, Joseph Nicéphore Niépce, produced the first true photograph, a permanent image obtained using a camera obscura and a photosensitive media.

In 1839, Louis Jacques Mandé Daguerre, Niépce's one time partner announced to the world his Daguerreotype process and in the same year failed in his attempts to photograph the Moon with it. The following year, a New York University, Professor of Chemistry, John William Draper succeeded and Astrophotography was born.

The '*Ages of Astrophotography*' through its '*A*' List of 100 '*objects*' tells of the events and people that have shaped the evolution of astronomical photography from its first tentative beginnings in the 1840s to the time of the digital camera and the space telescope

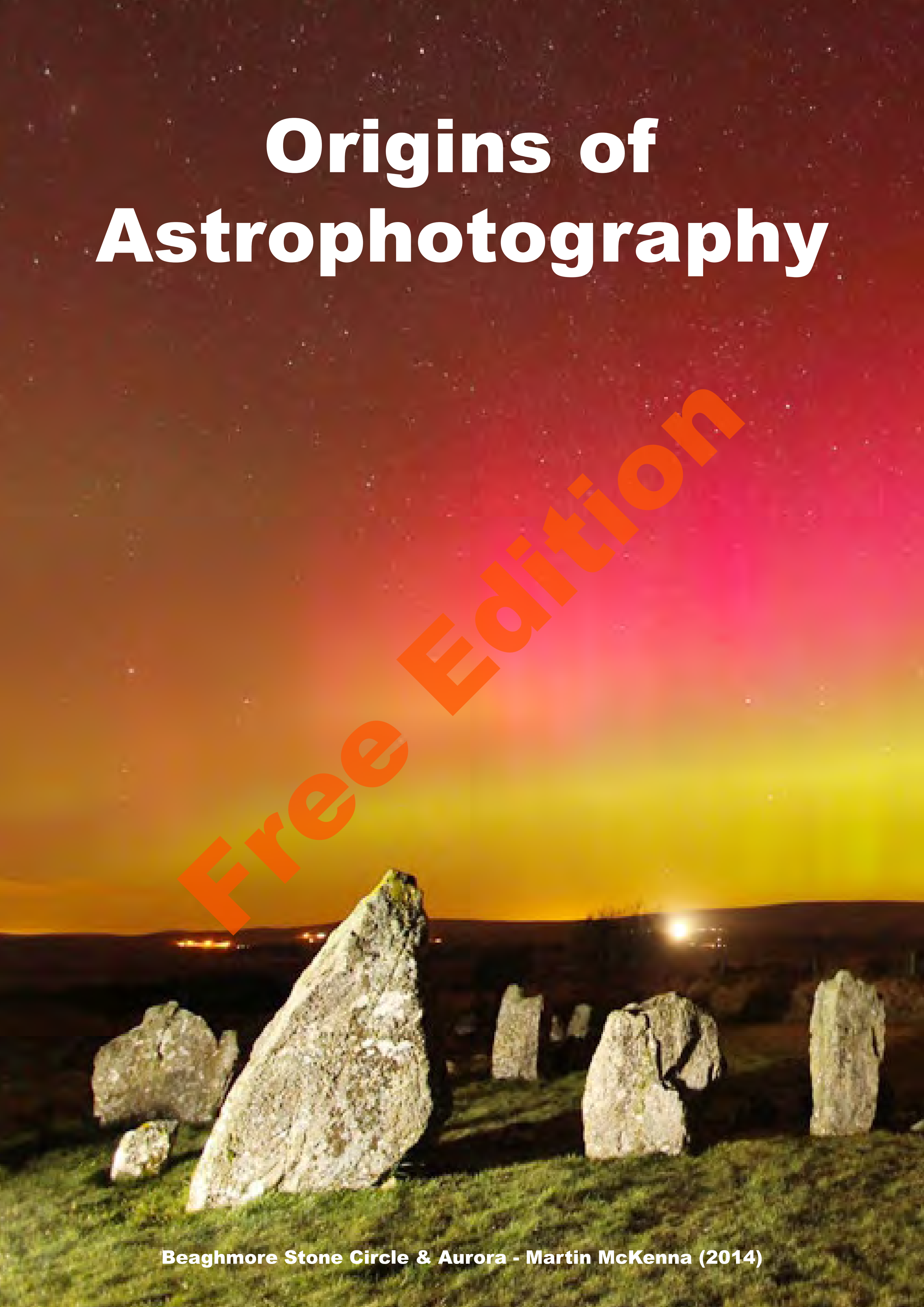
It will feature the work of almost ALL of the today's greatest Astrophotographers, whose images have been seen by millions in countless newspapers, magazines, books, posters, journals, blogs, websites and TV programmes across the globe. These 28 imagers given below represent a '*Hall of Fame*' of some of the finest astronomical photographers alive today:

Theodore Arampatzoglou from Greece;
Jean Pierre Brahic from France;
Dr. Miloslav Druckmüller from the Czech Republic;
Jim Ferreira from the USA;
Bernd Flach-Wilken from Germany;
R. Jay GaBany from the USA;
Dr. Robert Gendler from the USA;
Paul Haese from Australia;
Gordon Haynes from England;
Jason Jennings from Australia;
Dr. Walter Koprolin from Austria;
Thierry Legault from France;
Dr. David Malin from Australia;
Paul Martin from Northern Ireland;
Martin McKenna from Northern Ireland;
Jim Misti from the USA;
Tor-Ivar Naess from Norway;
Damian Peach from England;
Professor Pedro Ré from Portugal;
Gerald Rhemann from Austria;
Eddie Trimarchi from Australia;
Daniel Verschatse from Chile;
Christian Viladrich from France;
Richard Walker from Switzerland;
Peter Ward from Australia;
Volker Wendel from Germany;
Anthony Wesley from Australia;
Hunter Wilson from the USA.

In addition leading manufacturers who have made the modern age of Astrophotography possible are represented - by the Santa Barbara Imaging Group of California, the first manufacturer of astronomical cameras for the modern amateur; and Diffraction Limited of Ontario, Canada, the developer of Maxim DL, the astronomical image acquisition and processing software of '*choice*'. Their digital technology is used by all of the featured imagers and without them none of the modern images featured in the book could ever have been taken.

This book is dedicated to work of the pioneers of the first age of astronomical photography, many of whose names have long been forgotten; and also to the modern day '*imagers*' who have continued through their efforts to keep alive the memory of these early pioneers, and in doing so have created a new '*Age of Astrophotography*'.

Origins of Astrophotography



Beaghmore Stone Circle & Aurora - Martin McKenna (2014)

1. Stone Circles to Space Telescopes

Origins of Astrophotography

Animal 'Testing' a New Photographic Emulsion, c1880

"The process of M. Daguerre is much more sensitive to the action of light than those which had been used so far. Never before has natural moonlight produced any perceptible physical effect, even when magnified with the largest lens, or focused by the biggest reflective mirror. The plates prepared by Mr. Daguerre, bleach on the contrary the surface under the action of these same rays and it is hoped when he is successful with his experiments, one will be able to make photographic charts of our satellite."

On the 7th of January 1839, members of the French Académie des Sciences were shown images that would provide Astronomy with the means to unlock the very secrets of creation. What they saw was the work of a Parisian showman, named Louis Jacques Mandé Daguerre. In 1839 Daguerre attempted to photograph the Moon and failed. Astrophotography was about to be born.

It might be thought that the Origins of Astrophotography arose through the work of the early pioneers of Photography, but this is much too simplistic a view. It does not take into account the fact that man desired to capture a permanent record of the Moon, Sun and Stars thousands of years before the time of Niépce, Daguerre and Fox-Talbot. The truth lies in a time when man built great circles of stone so that he might understand the workings of the bodies he saw in the sky above, and the close relationship he knew to exist between life and death itself. He even made intricate ceremonial '*Golden Hats*' decorated with symbols that predicted with extraordinary accuracy the movement of the Sun and Moon. In doing so he had created the earliest astronomical almanacs over three thousand years before Old Moore's Almanac (first published by Francis Moore in 1697).

Joseph Nicéphore Niépce (1765-1833) is credited with having taken the first true photograph, i.e. a permanent image of an object on a media. Sadly his name is largely forgotten today unlike other early pioneers of photography such as Louis Daguerre and William Henry Fox Talbot. However recently Photographic Historians have tried to redress the balance by giving Niépce the due credit he deserves. This unfortunately has been at the expense of the reputation and efforts of Daguerre. A balanced view of history should recognise the major contributions of all three, as well as the earlier work of Thomas Wedgwood (1771-1805) on '*heliographic*' impressions. Each in their own way have made Photography what is today, and the question of bias should not enter into any scholarly treatment of their work.

Joseph Nicéphore Niépce (1765-1833)

Newgrange is a 5000 year old passage tomb in County Meath, Ireland. It is located about one kilometre north of the River Boyne and was built during the Neolithic period around 3200 BC, thus making it older than Stonehenge and the Egyptian pyramids at Giza. It is famous for the fact that at the time of the Winter Solstice (21st December) its passage and chamber are illuminated by the Sun. There has been much written about the astronomical significance of the strange marking found at Newgrange and it has been suggested that it may well have been the earliest observatory ever constructed.

Entrance to Newgrange Passage Tomb, c1898

It is to the Chinese and Arabs that we owe the earliest work on the concept of the Camera. In 1050 AD, Shen Kuo (1031-1095) the Chinese polymath and statesman began experimenting with the Camera Obscura, and was the first to apply geometrical and quantitative attributes to it in his book the '*Dream Pool Essays*', written in 1088. However, Shen was not the first to experiment with the Camera Obscura, the forerunner of the modern camera. The philosopher Mo-Tzu (470-390 BC) was the first to describe some of the principals of the Camera Obscura, but it was the Arab scientist, Ibn al-Haytham (965-1040 AD) who was the first person to give a clear description and early analysis of the '*Pin Hole*' camera, in his book of Optics - '*Kitab al-Manazir*', written from 1011 to 1021.

Shen Kuo (1031-1095)

A.1 - Stonehenge & A.2 - Hubble Space Telescope

Stone circles have long known to be associated with the movement of our Sun and Moon. As such they can be considered to be the earliest known astronomical observatories. The stone circles in the British Isles and Brittany were constructed as a part of a megalithic tradition that lasted from 3,300 to 900 BC, during the Late Neolithic and Early Bronze Age. The original purpose of the megaliths still remain to to some extent uncertain, although archaeological excavations have shed some light on the matter. It is now widely believed that they were constructed for ritual or ceremonial reasons which were closely related to solar and lunar alignments of the stones themselves. In a smaller number of cases, some were also used as cemeteries, with burials being made in and around the circle. By the late mediaeval period, stone circles were largely ignored, forgotten and rarely written about. In the last century or so many of these monuments were adopted as '*sacred sites*' by adherents of contemporary Pagan religions such as Neo-Druidism, Wicca and the Goddess movement, who have used them for their own '*pseudo-magical*' rites. Whatever their true purpose they remain to this day millennia after their original construction, sites of fascination for the many hundreds of thousand of people who visit them each year. The most famous examples of stone circles include those at Calanais on the Scottish Isle of Lewis; and at Stonehenge and Avebury in Wiltshire, England.

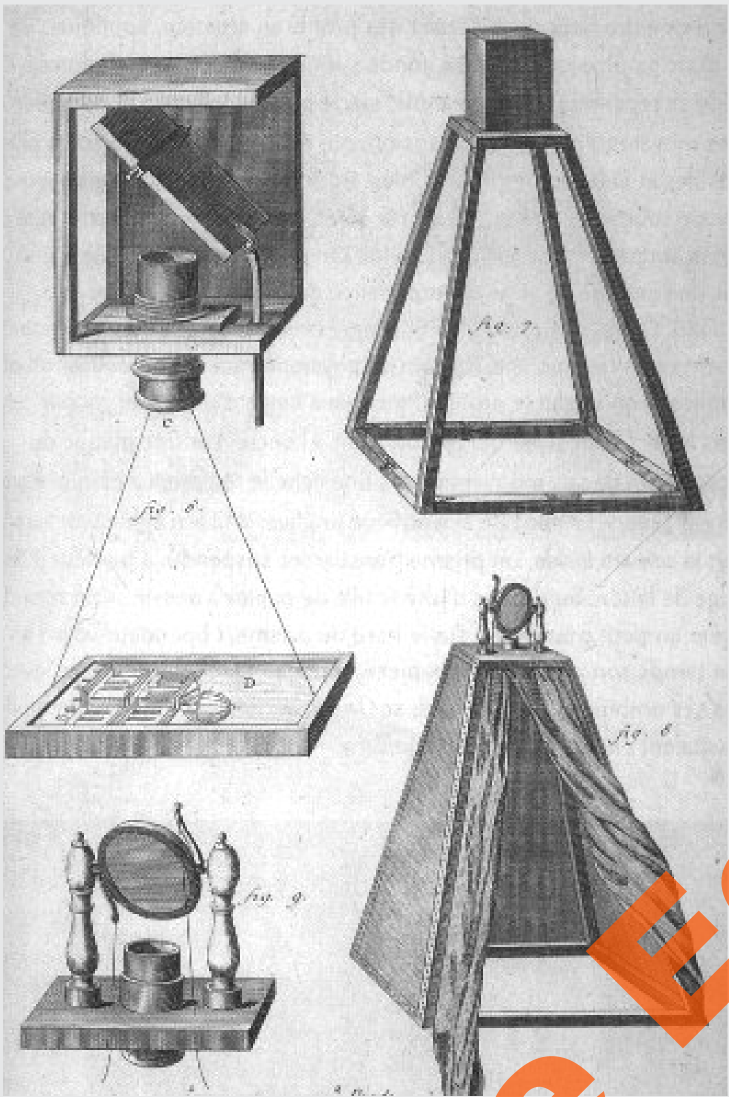
The Callanish Stone Circle is situated near the village of Calanais, on the Scottish Isle of Lewis is widely believed to have served as a prehistoric lunar observatory. The circle consists of a central stone just under five metres in height, surrounded by a circle of thirteen stones, which were quarried and erected at the site during the Neolithic era, sometime between 2900 to 2600 BC. Prior to 1857 they had been buried up to 1 metre in depth in the bogs until a local landowner had the peat removed.

Callanish Stone Circle, Isle of Lewis, Scotland

The Golden Hat of Schifferstadt was discovered in 1835 in a field near the town of Schifferstadt in Southwest Germany. It dates from the Bronze Age. It is one of only four known '*Golden Hats*', the others being - the Avanton Gold Cone (incomplete, found at Avanton near Poitiers in 1844, circa 1000–900 BC); the Golden Cone of Ezelsdorf-Buch (found at Ezelsdorf near Nuremberg in 1953, circa 1000–900 BC) the tallest known specimen at c. 90 cm; and Berlin Gold Hat (found probably in Swabia or Switzerland, circa 1000–800 BC). These rare objects are made of thin sheet gold and were attached externally to long conical and brimmed headdresses which were probably made of some type of organic material. The symbols on them are believed to represent a lunar and solar calendar. This knowledge was of great importance to Bronze Age Society for the determination of religiously important events such as the Summer and Winter Solstices.

Golden Hat of Schifferstadt, circa 1300-1400 BC

A.3 - Camera Obscurae



The Camera Obscura or '*Pinhole Camera*' is the forerunner of the early Photographic Camera. It consists of a box or room with a hole in one side. Light from an external scene passes through the hole and strikes a surface inside, where it is inverted, but with the colour and perspective of the original subject perfectly preserved.

The resulting picture can then be projected onto paper, andin addition be copied to produce a highly accurate representation of the scene. A 16th century improvement to the Camera Obscura suggested the use of lenses and mirrors to produce an upright image.

The device however has one major drawback in that the projected image is transient and disappears once the Camera Obscura is moved or the subject matter is removed. In this respect it differs from the Camera used by the early pioneers of Photography who projected the subject onto a metal or glass plate coated with a light sensitive media. Such a method was used in the early Daguerreotype and Calotype (or Talbotype) photographic processes, as adopted by their inventors Louis Daguerre and William Henry Fox Talbot in the 1830s.

Camera Obscura Design - Diderot's and D'Alembert's Encyclopédie (1751-1780)

In the Victorian era with the advent of the seaside holiday the Camera Obscura even became a tourist attraction for bathers. The photograph to the right appears to be a Victorian bathing machine converted to a portable Camera Obscura. It was taken on the New Brighton Beach near Liverpool, England, towards the end of the 19th Century. During the latter half of the 19th century, New Brighton developed as a very popular seaside resort serving Liverpool and the Lancashire industrial towns, and many of the large houses were converted to inexpensive hotels. A pier was opened in the 1860s, and the promenade from Seacombe to New Brighton was built in the 1890s. After the Second World War its popularity fell into decline like many other seaside resorts, particularly with the coming of cheap overseas holidays in the 1970s.

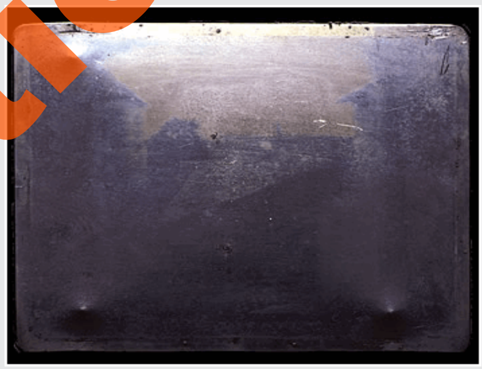
Portable Camera Obscura on a Victorian Beach

A.4 - Daguerreotype Plates

Louis Jacques Mandé Daguerre (1787-1851) was one of the early pioneers of Photography. Together with his one time partner, the inventor, Joseph Nicéphore Niépce (1765-1833) they developed the earliest photographic process which obtained a permanent image on a media. This process became known as the Daguerreotype. Daguerre developed his interest in photography through his collaboration with the artist, Charles Bouton, with whom he co-founded the Diorama, a spectacular means of entertainment based on enormous paintings on semi-transparent linen through which light was transmitted and reflected. The lighting could be manipulated to represent changes of seasons or times of day, and the realistic effects captivated audiences. On the 7th of January 1839, Daguerre's, the politician and astronomer, François Arago (1786-1853) announced the discovery of the Daguerreotype process to the French Académie des Sciences - Astrophotography was about to be born.

Louis Jacques Mandé Daguerre (1787-1851)

However it was Niépce who is generally agreed to have taken the first true photograph when in 1826, he captured a view from a window onto the courtyard of the family château at Le Gras, Chalon-sur-Saone, In 1826 Niépce began using a professionally made Camera Obscura. The camera was made by Charles and Vincent Chevalier, the famed Parisian opticians. On a summer's day in 1826, Niépce finally succeeded after a decade of trying. With the help of the Chevaliers' Camera Obscura he at last captured a '*permanent*' view of his courtyard, something he must have despaired of ever doing.



The 'First Photograph' - Joseph Nicéphore Niépce (c 1826)

The earliest surviving photograph of the Moon is a Daguerreotype taken in 1849 by the American Editor and Publisher, Samuel Dwight Humphrey (1823-1883). He was also an established New York Daguerreotypist of several years experience having written a number of books and articles on the Daguerreotype Process. His image was taken at 10.30 p.m. on the night of the 1st of September 1849 when the nearly full Moon appeared over the town of Canandaigua, New York. Although it shows no discernible detail on its surface, being just a series of multiple images, nevertheless represents an important contribution to the History of Astrophotography. He then gifted his photograph to the Harvard College, President Jared Sparks, where it remains one of its most prized possessions in the University's archives. The earliest known successful photograph of the Moon was that taken in 1840 by the New York University Professor, John William Draper (1811-1882). Unfortunately his photograph and other important work was destroyed in a fire at the University of New York in 1865.

Daguerreotype of the Moon (1849) - Samuel Dwight Humphrey

A.5 - Collodion Plates

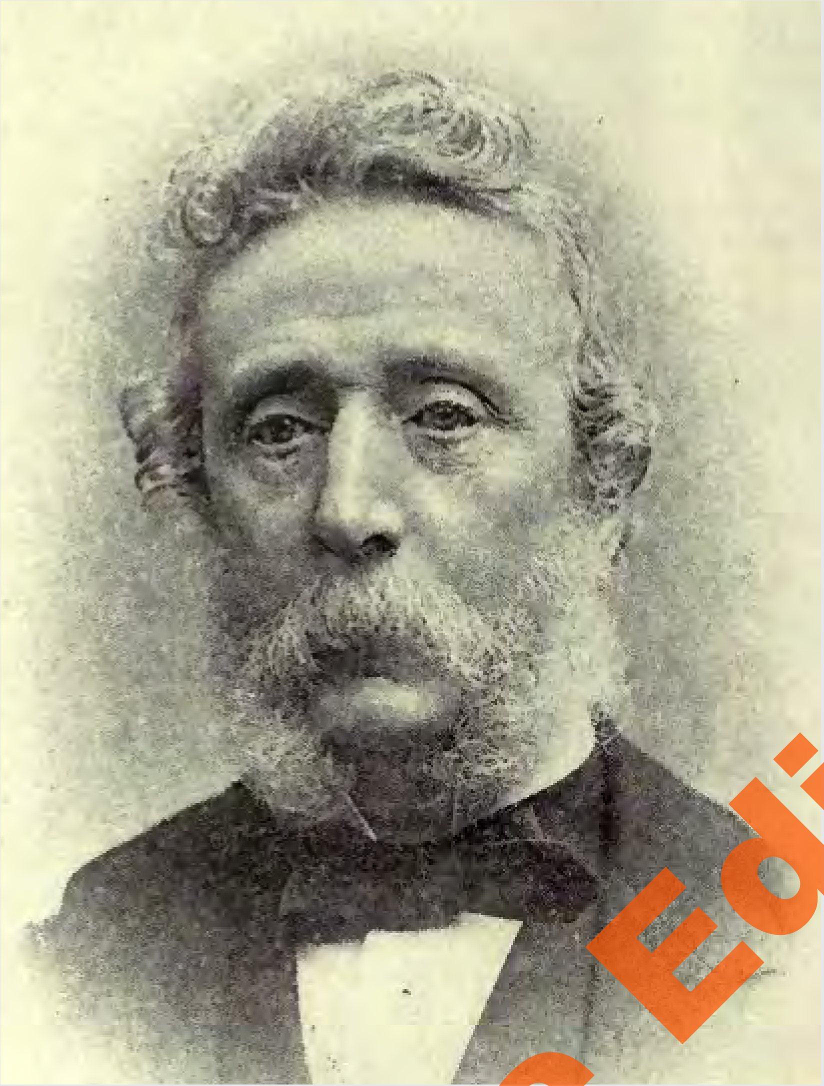
The sculptor, Frederick Scott Archer's (1814-1857) invention of the Wet Collodion process, published in 1851 revolutionized the science of Photography; but who nevertheless died largely unrecognised and in virtual poverty. It was his process which brought photography within the reach of the ordinary man, and also enabled astronomers to capture images of the heavens only hinted at by the earlier Daguerreotypes. Apprenticed to a London Silversmith, he became fascinated with the coins that he saw in his master's shop and which inspired him to become a Sculptor. Like many Artists of the time he took up Photography in order to explore this new form of media. He went further by trying to improve upon the poor sensitivity of the Calotype process of William Henry Fox Talbot. His new process spread a mixture of Collodion (nitrated Gun Cotton dissolved in ether) and light sensitive chemicals onto a glass plate. This negative-positive process permitted unlimited reproductions and far greater sensitivity than the earlier methods. The process was published but not patented. It had the disadvantage that the exposed plate had to be developed within 15-20 minutes, otherwise it dried and became useless.

Frederick Scott Archer (1814-1857)

By the mid 1850s the wet collodion process had all but replaced both the Daguerreotype and Calotype as the preferred photographic process. The fact that it was free of patent restrictions for professional and amateur photographers alike greatly helped its popularity as did its ability to produce detailed images which could be easily copied. Astronomers also used it as a matter of course on several eclipse expedition during the 1860s and 1870s, most notably those that went to Spain to photograph the eclipse which took place on the 18th of July 1860. It was also used at the total solar eclipse of the12th December, 1871 at Baikul, South Canara, India. The drawing to the right is by Edward Stanford from a photography taken by Henry Davis (1825-1900), the assistant to the amateur scientist Lord James Ludovic Lindsay (1847-1913), the 26th Earl of Crawford.

Drawing after Henry Davis, Collodion Photograph of Total Eclipse of Sun 1871

A.6 - Gelatino-Bromide 'Dry' Plates



In 1871, the medical Physician, Richard Leach Maddox (1816-1902) was the first to publish the use of Gelatino-Bromide to the create '*Dry*' Photographic Plates. It was this process which began the next revolution in Astrophotography. Its increased sensitivity over that of the Collodion process meant that images of Deep Space Objects (DSOs) could be obtained for the very first time, by pioneers such as Henry Draper, Isaac Roberts, William Edward Wilson, James Edward Keeler and others. It was later found out that many of these objects lie at distances millions of light years beyond the boundaries of our own insignificant '*Milky Way*' star system. Maddox once modestly said of his discovery: "*Do not for one moment suppose I ignore the work of other hands perfecting the gelatino-bromide process, and thus giving it its worldwide value in all departments of photography, especially that far reaching one of its adaptation to astronomical research. I am only too thankful to feel that I have been merely the stepping-stone upon which others have safely put their feet…*"

Richard Leach Maddox (1816-1902)

Dry plates not only eliminated messy wet chemicals at the camera, but also eliminated the need to develop the plate immediately after exposure. This in turn eliminated the need for the camera to be near a darkroom, and for the first time ever the photographer could travel with previously prepared plates (perhaps manufactured by someone else), take photographs, and develop them at a later time. Photography was becoming something that almost anyone could do. The first application of the new '*dry*' plates in Astrophotography was in capturing the moment of totality during solar eclipses. The Total Solar Eclipse of 1878, which took place on the 29th of July that year on was the first that made use of Gelatino-Bromide plates. Several expeditions used them, including that of William Harkness's to Creston, Wyoming, USA, where he was assisted by assisted by the photographer, Joseph Rogers and the telescope maker, Alvan Graham Clark. Their work is shown to the right.

'Dry' Plate of Total Solar Eclipse 1878 - William Harkness

Capturing the Moon

Moon in Colour - Theodore Arampatzoglou 2014

2. The Lunatics
Capturing the Moon

Moon (1854), 24-inch Refractor; Moon (2010), 9.25-inch SCT

The Ancient Philosophers of the Classical World of Greece and Rome believed that the Full Moon induced certain susceptible individuals into fits of madness, arguing that it provided light during nights which would otherwise have been dark, resulting in a temporary insanity through sleep deprivation.

This clearly applied to those who first photographed the Moon, otherwise why would the French astronomers Maurice Loewy and Pierre Henri Puiseux spend 16 years of their lives taking over 6000 Photographs of the Moon or what could cause the American, William Henry Pickering to believe that the dark patches on the Moon's surface were caused by seasonally migrating swarms of insects.

Were they Lunatics or determined individuals with an overwhelming desire to create the two Magnificent Atlases of the Moon that now bear their names?

John William Draper (1811-1882) is generally recognized as the father of photographic portraiture as well as being the '*First Astrophotographer*'. In 1840, he was the first person to successfully image an astronomical body, when he obtained a Daguerreotype photograph of the Moon, after a number of earlier failures. Louis Daguerre had made an earlier but unsuccessful attempt to '*Daguerreotype*' the Moon the previous year, as explained by his friend and advocate François Arago: *"Never had the rays of the Moon, not necessarily in its natural state but condensed in the mechanism of a great lens or a large reflecting mirror, produced any physical or perceptible effect. The plate prepared by M. Daguerre whitens on the contrary to such a point under the action of these very rays and with the operations that follow we can hope that we will be able to make photographic maps of our satellite."* All of which in plain English meant literally NOTHING!

John William Draper (1811-1882) - The First Astrophotographer

However it was John Adams Whipple (1822-1891) who first obtained Lunar images which showed clearly any detail on the surface of our satellite. In the years 1851 up until 1860, with the assistance of his partner James Wallace Black (1825-1896), and George Phillips Bond (1825-1865) of the Harvard College Observatory, he produced many fine Daguerreotype and Collodion images of various phases of the Moon. The image (to the right) shown here was taken just after First Quarter, is a Salt Print taken from the original Collodion Negative and dates from the last years of his collaboration with the Bonds of Harvard. The dark smooth floored crater Plato (bottom centre) and the impressive crater Copernicus can be clearly seen near to the Lunar terminator. The large magnificent crater Clavius with its chain of smaller craters inside its rim is also visible towards the top of the photograph coming out from the darkness.

Moon (c1857-60) - John Adams Whipple & James Wallace Black

Warren De La Rue (1815-1889), a native of the Channel Island of Guernsey, but who spent much of his life in and around London, began taking Collodion photographs of the moon from 1852 onwards up until the 1860s, at first from his home at Canonbury and then from a purpose built observatory in the then small village of Cranford in Middlesex (now blighted by London's Heathrow airport). All of these were taken with his 13-inch Reflecting Telescope at first without any form of drive mechanism to track the movement of the Moon. A clockwork motor was later fitted in 1857 shortly after his move to Cranford. However he is best remembered today for his Solar and Eclipse Photography. In 1863 "*A Series of Twelve Photographs of the Moon. Photographed by A.A. Turner, from Original Photographs by Warren de la Rue, F.R.S.*" was published, the cover sheet from this publication is shown here (Left).

Twelve Views of the Moon - Warren De La Rue, c1857-63

A.7 - First Quarter Moon & A.8 - Last Quarter Moon

The earliest known attempt to photograph the Moon was made by Louis Daguerre in 1839. It ended in failure and to make matters worse all his telescopic and microscopic efforts and many of his early Daguerreotypes were lost on the 8th of March 1839 when a fire destroyed his Paris workshop. The first known successful attempt was by the New York Professor of Chemistry, John William Draper. During the winter of 1839-40, John William Draper took a series of Daguerreotypes of the moon, focusing the moon's rays on the plate using a three-inch lens and a six inch mirror. In his earliest attempts, the Moon was somewhat reminiscent of a blob floating in a primordial gunk. This unsightly image was due in the main to the low light levels of the Moon obtained by Draper and the long exposure time needed for a Daguerreotype. He persisted and was finally successful: "*By the aid of a lens and Heliostat I caused the Moon beams to converge on a plate, the lens being three inches (76mm) in diameter. In half an hour a very strong impression was obtained. With another arrangement of lenses I obtained a stain nearly an inch (25mm) in diameter in which the dark spots might be indistinctly traced.*"

John William Draper c1864

Moon 1839-1840 - John William Draper

On the 23rd of March 1840, John William Draper was happy to report to a meeting of the New York Lyceum of Natural history, later to become the New York Academy of Sciences, that he had been successful in utilizing a small daguerreotype camera to photograph the Moon's surface on a one inch diameter plates with a twenty minute exposure. "*A portion of the figure was very distinct, but owing to the motion of the Moon, the greater part was confused. The time occupied was twenty minutes, and the size of the figure was about one inch in diameter. Daguerre had attempted the same thing but did not succeed. This is the first time that anything like a distinct representation of the moon's surface has been obtained.*"

A.9 - Full Moon & A.10 - Lunar Eclipses

Lunar Nomenclature

A Lunar Eclipse occurs when the Moon passes directly behind the Earth into its umbra (shadow). It can also only take place at Full Moon when the Sun, Earth, and Moon are aligned (in '*syzygy*') exactly, or very close to, with the Earth in the middle. In most calendar years there are two Lunar Eclipses; in some years one or three or none occur. A Lunar Eclipse lasts for a few hours, whereas a Total Solar Eclipse lasts for only a few minutes When such an event takes it often produces a spectacular '*Blood*' Red Moon as shown in this photograph taken by the Portuguese Astrophotographer, Pedro Ré of the Lunar Eclipse which took place on the 3rd of March 2007. A Takahashi FS102 f/8 Refractor and a Canon 350D DSLR with 5 exposures of 8 seconds '*median sum*' combined were used to capture the event.

Lunar Eclipse - Pedro Ré (2007)

A.11 - Mare Imbrium (Sea of Showers)

The map to the left shows the region of the Moon in the vicinity of the two large Maria - Mare Imbrium and Mare Serenitatis. It was compiled by Maurice Loewy and Pierre Henri Puiseux for their '*L'Atlas Photographique De La Lune*' and corresponds to the area covered by '*Plate XXIII - Mer de la Sérénité - Archimedes - Platon*' taken on the 19th of September 1894. This region contains much of interest and is a popular target for the modern day imager, as are all five of the *Lunar* '*targets*' included in this book. It covers most of the Mare Imbrium (right), the Montes Appeninus (top right), the Mare Serenitatis (top left) and the Mare Frigoris (bottom). Of particular interest is the crater Plato with its dark glass like surface, lying within the Montes Alpes (to bottom right) the bottom right; the wrinkled ridges on the otherwise smooth surface of the Mare Serenitatis; the lone 2.1km high peak Mons Piton; and the Vallis Alpes, a valley which bisects the Montes Alpes.

Map of Mare Imbrium & Mare Serenitatis Loewy & Puiseux

The photograph shown to the left of the Mare Imbrium was taken by Lewis Morris Rutherfurd from the Rutherfurd-Stuyvesant Mansion, New York, using an 11.25-inch photographic refractor constructed by himself with the help of the telescope maker Henry Fitz. It made use of the tube of his earlier achromatic refractor. It is a print from an original wet collodion glass plate negative and dates from the 18th of April 1865.

Mare Imbrium - Lewis Morris Rutherfurd (1865)

The American Lawyer, turned scientist, Lewis Morris Rutherfurd (1816-1892) used the Wet Collodion process to take a magnificent series of photographs of the Moon during the period 1865 to 1871. The images obtained by Rutherfurd depict the Lunar landscape in a degree of detail not seen before, and which were not to be surpassed until the work of Maurice Loewy and Pierre Henri Puiseux at the Paris Observatory in the 1890s. In the period from 1858 to 1877 Rutherfurd took 435 collodion photographic plates of the Moon. On the 13th of November 1890, Lewis Morris Rutherfurd donated to Columbia University, New York his entire collection of over 1400 photographic plates of the sun, moon, the Solar Spectrum and star groups.

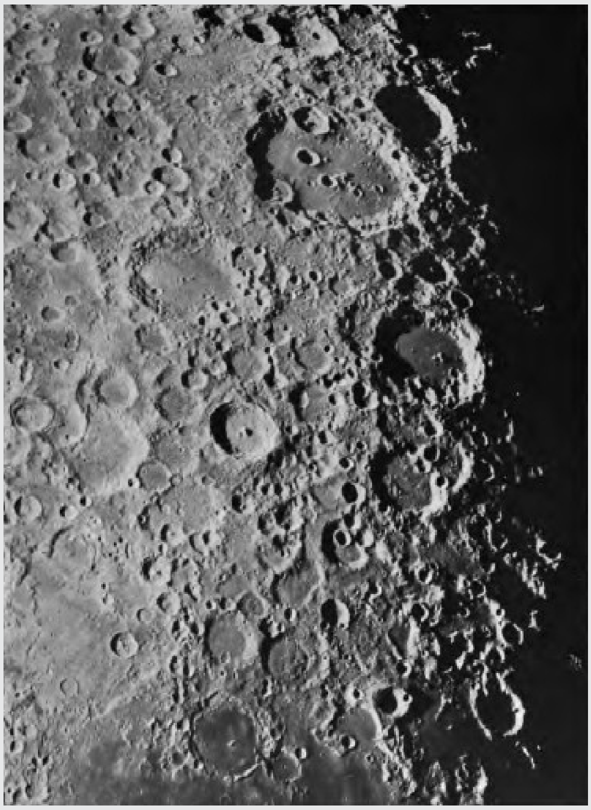
A.12 - Clavius & Southern Uplands

The map to the left shows the region of the Moon in the vicinity of the large crater Clavius and the Southern Uplands. It was compiled by Maurice Loewy and Pierre Henri Puiseux for their '*L'Atlas Photographique De La Lune*' and corresponds to the area covered by '*Plate VII - Clavius – Tycho –Hesiode*' taken on the 23rd of February 1896. This part of the Moon is an extremely crowded vista pitted with craters of all shapes and sizes. The crater Clavius is one of the largest formations on the Moon, and is the third largest crater on the visible near side, with a diameter of 225km and a depth of 3.5km. The large crater Rutherfurd, lying on its southern wall (top), is named after Lewis Morris Rutherfurd. The 86km crater Tycho (below Clavius on the Map), gives rise to the Moon's most stunning example of a ray system which spread in distinct lines for hundreds of kilometres in all directions. They represent the illumination of the material ejected from crater when it was formed by a meteoritic impact.

Map of Clavius & Southern Uplands - Loewy & Puiseux

The photograph to the right of the crater Clavius and the surrounding Southern Uplands was obtained by George Willis Ritchey using the 40-inch Refractor at the Yerkes Observatory, Williams Bay, Wisconsin, USA, and is described by him in '*Photography Astronomical Photography with the Forty Inch Refractor and the two Foot Reflector of the Yerkes Observatory*', pp. 392-3, published by the University of Chicago, 1904:

"The photograph of Clavius and the surrounding region...is also from the same negative as that of Copernicus. At the time when this photograph was taken the conditions of libration and of illumination were unusually favorable for this region of the Moon's surface. Clavius, with its numerous included craters and other details; Longomontanus and Wilhelm, in which the details of the ramparts and of the crater floors are unusually well shown; the extremely rough country north of Wilhelm; and the " metropolitan " crater Tycho conspicuous for its enormous depth, are among the most remarkable objects of this region."



Clavius & Southern Uplands - George Willis Ritchey (1901)

A.13 - Mare Tranquillitatis (Sea of Tranquility)

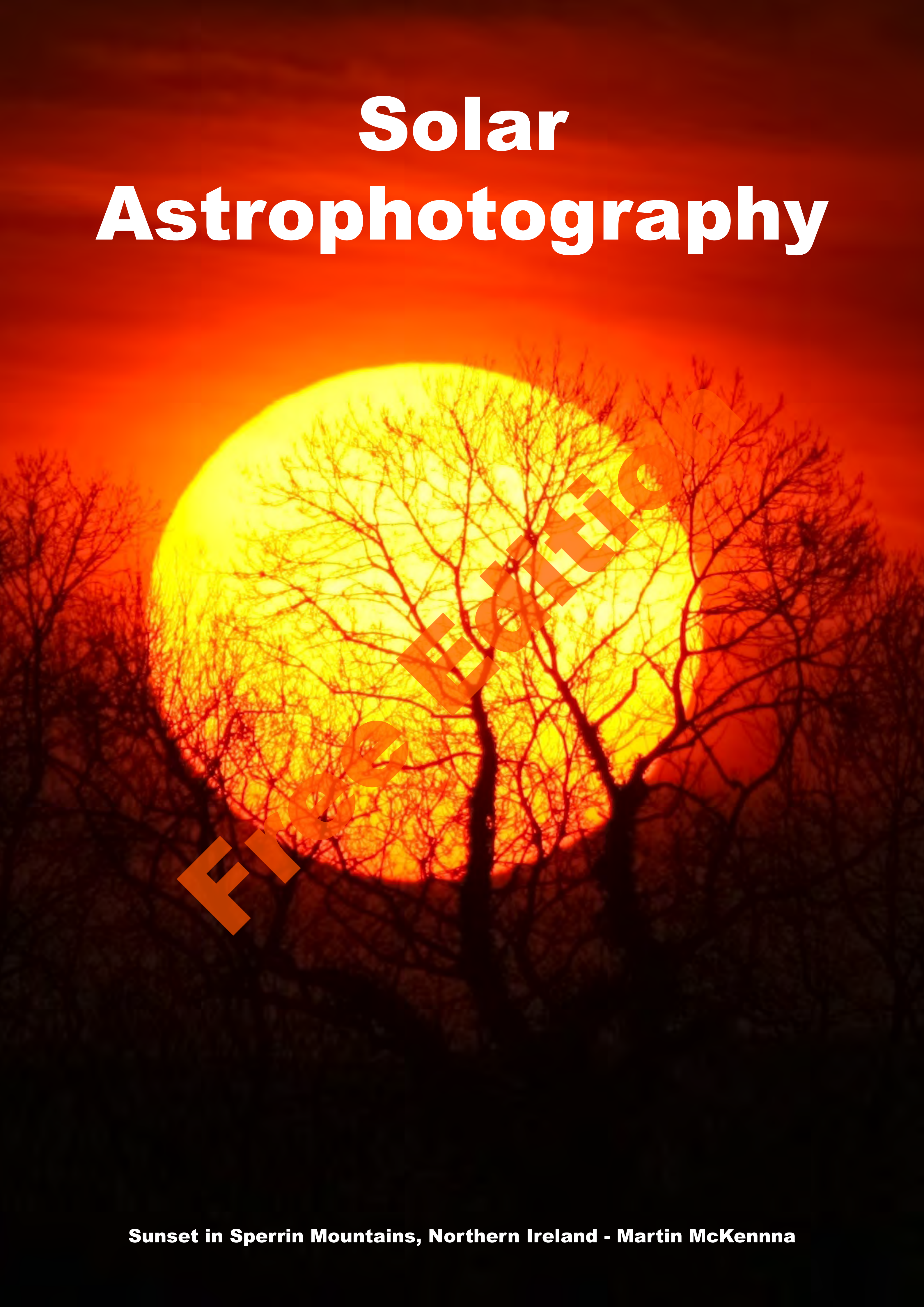
The map to the left shows the region of the Moon in the vicinity of the Mare Tranquillitatis. It was compiled by Maurice Loewy and Pierre Henri Puiseux for their '*L'Atlas Photographique De La Lune*' and corresponds to the area covered by '*Plate XXXII - 'Gutenberg – Mer de la Tranquillité – Pliny*' taken on the 16th of February 1899. The Mare Tranquillitatis is unusual in that it has a slight bluish tint relative to the greyscale of the rest of the Moon. It stands out quite well when an RGB image is produced. The colour is likely due to a higher than normal metal content in its basaltic soil or rocks. In the February of 1965, the Ranger 8 spacecraft was deliberately crashed into the Mare Tranquillitatis, after successfully transmitting 7,137 close-range photographs of the Moon in the final 23 minutes of its mission. It was also the landing site for the Apollo 11 mission on the 20th of July 1969.

Map of Mare Tranquillitatis - Loewy & Puiseux

The two images to the right of the Mare Tranquillitatis (top left) and Mare Serenitatis (middle) region were taken by W. H. Pickering from the Harvard College Observatory's Outstation in Mandeville, Jamaica, and form part of his Photographic Lunar Atlas of 1903. The differing illuminations amply illustrate why the inexperienced amateur often has difficulty in identifying certain lunar features when they are well away from the terminator. That below left of the Mare Tranquillitatis is from the CLA

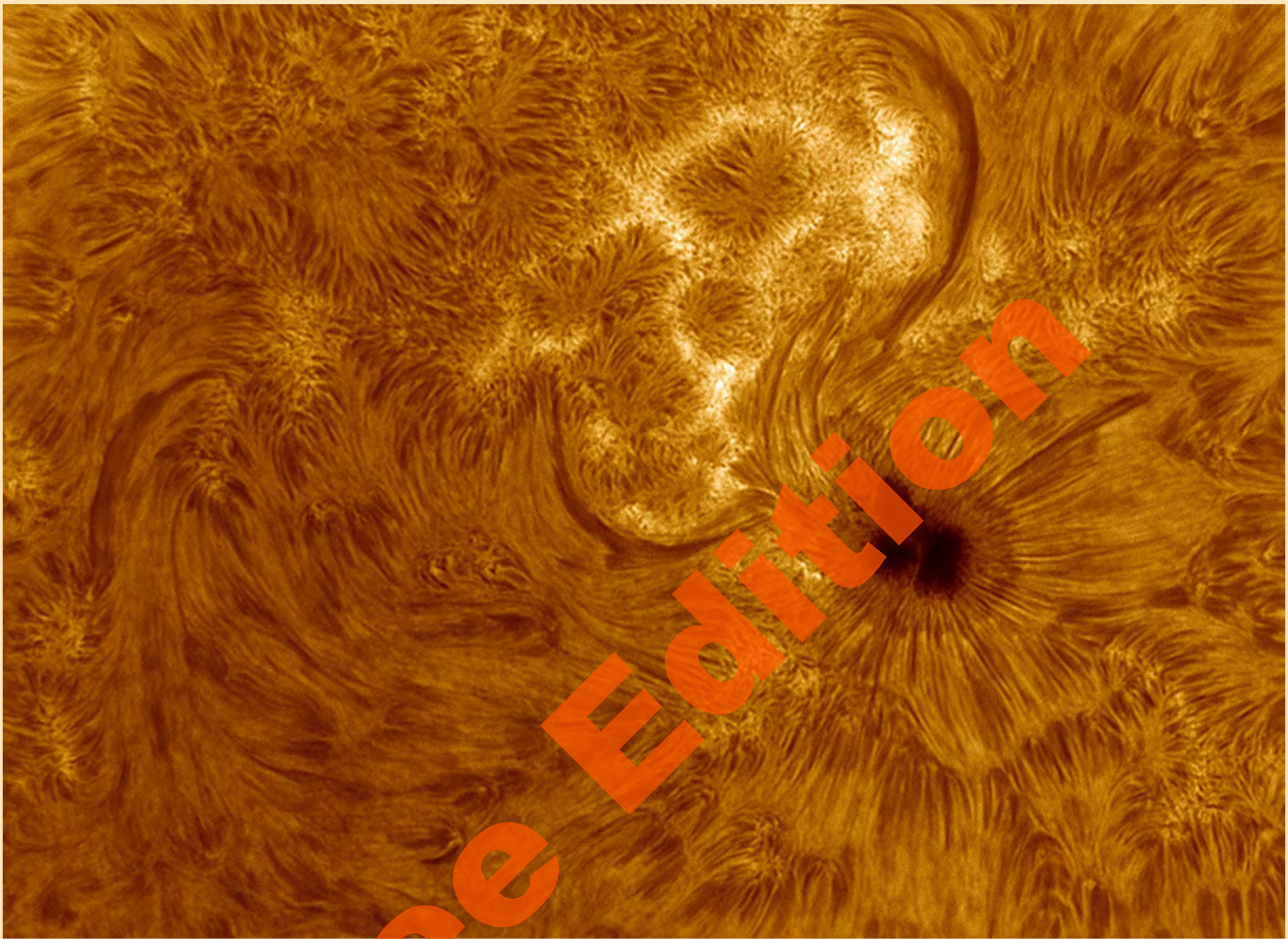
Mare Tranquillitatis - CLA (Left); William Henry Pickering (1903)

Solar Astrophotography



Sunset in Sperrin Mountains, Northern Ireland - Martin McKennna

3. The Sun Seekers
Solar Astrophotography



Solar Disc 5th April 2013 - J. P. Brahic

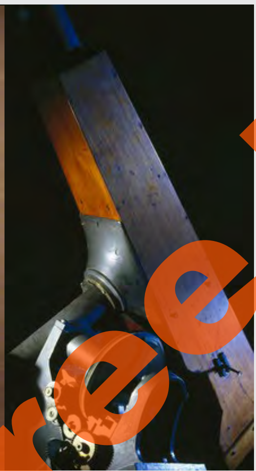
Ever since 1843, when the French Physicists Hippolyte Fizeau and Leon Foucault began taking the first images of the Sun, photography has been an important tool in helping man to understand the physics of our star. In the years since, many telescopes both on the ground and in space have been trained on its surface. With each passing generation we begin to understand more about the complex processes which make our Sun shine; and which ultimately supports all life on Earth.

The history of man's efforts to capture a permanent image of the Sun is long and complex, and begins in the earliest days of Photography. The first known attempt to photograph the Sun was made in 1842 when the Italian Physicist Gian Majocchi, failed to capture the moment of totality at the eclipse of the 8th of July that year from Milan, but succeeded in obtaining Daguerreotypes of the moments preceding and following totality. Nine years later, the Daguerreotypist, known only as Berkowski, succeeded at Konigsberg (now Kaliningrad, Russia), when he obtained photographs of the Solar Corona and Prominences at the eclipse of the 28th of July 1851. In the meantime the French Physicists, Hippolyte Fizeau and Leon Foucault obtained a series of Daguerreotypes from Paris of the Solar Photosphere in the period 1843 to 1845.

Partial Solar Eclipse - John Adams Whipple (1851)

The earliest involvement in North America with Solar Astrophotography, began at the 1851 eclipse, which was only partial from their location. The Boston Daguerreotypist John Adams Whipple, captured a photograph of the Partial Solar Eclipse of the 28th of July 1851, using the 15-inch Refractor at the Harvard College Observatory, in Cambridge Massachusetts, where he had been collaborating with its then Director, William Cranch Bond on a program of astronomical photography since 1847. At the Annular Solar Eclipse of the 26th of May 1854, several astronomers, including William H. C. Bartlett of the West Point Military Academy obtained photographs of the event.

William Holmes Chambers Bartlett (1804-1893)



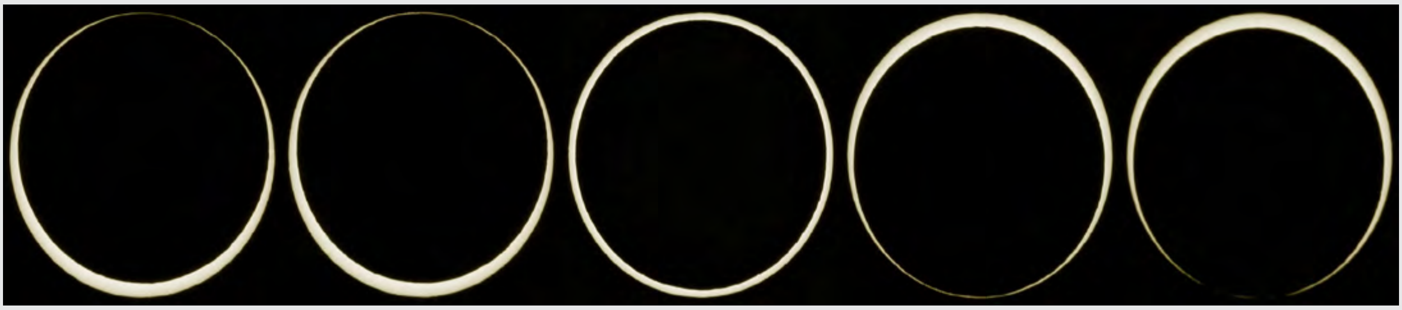
The Channel Islander, Warren De La Rue (1815-1889) was the '*Foremost Celestial Photographer*' of his adopted country, England. In 1857 he produced the design for the Kew Photoheliograph, the first telescope specifically built to photograph the Sun. In 1860 he took it, to Rivabellosa in Northern Spain, where he used it to successfully photograph the Solar Corona during the total eclipse which took place on the 18th of July that year. He was also well known for his photographs of the Moon and for his early attempts at wide-field Astrophotography. He was inspired to take up Astrophotography after seeing Whipple's Lunar photographs.

Warren De La Rue (1815-1889); Kew Photoheliograph

Pierre Jules César Janssen (1824-1907) used photography to study the Sun and was therefore one of the founders of Solar Physics. In 1868, during an expedition to India to witness a Total Eclipse of the Sun, Janssen noticed the presence of an unknown line in the yellow part of the Solar Spectrum at a wavelength of 587.4 nm; which was later found to be produced by a new and as yet undiscovered element – now known as Helium. This was the first chemical element to be discovered on another world. During his lifetime he made many important discoveries in Solar Physics, including in 1877, the granulation effect seen on the Solar Photosphere, and the design for the '*Photographique Revolver*', a mechanical device which could take repeated images of the Sun and which bore a close resemblance to a Gatling Gun. In 1903 he completed his '*Atlas de Photographies Solaires*', which contains some 6000 images of the Sun.

Pierre Jules César Janssen (1824-1907)

A.14 - Partial Solar Eclipses
& A.15 - Annular Solar Eclipses



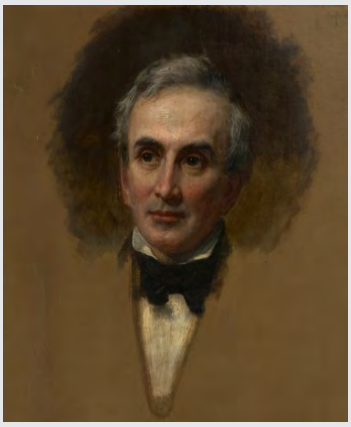
Annular Solar Eclipse - Pedro Ré (10th March 2005)

An Annular Solar Eclipse is one in which totality occurs, but the sun is still visible as a bright ring surrounding the dark face of the moon. This effect is caused by the Moon whose orbit is not circular, being at a slightly greater distance from the Earth than is necessary for a total eclipse to occur. Although Berkowski had previously obtained successful Daguerreotypes of a Total Solar Eclipse in 1851, it had not been visible from North America. So when the first opportunity arose to capture a Solar Eclipse (albeit an Annular one) in North America since the invention of Photography, several astronomers of the time took the opportunity to photograph the event.

An Annular Solar Eclipse took place on the 26th May 1854 which was visible from the Northern States of America. A number of astronomers photographed the event, including William Holmes Chambers Bartlett, a Professor of Physical Sciences at the US Military Academy at West Point, New York. He later described the results of his efforts: "*Through the kindness and professional skill of Mr. [Charles Henry Victor] Prevost [1820-1881] of New York, who was induced to come to West Point for the purpose, I was enabled also to obtain nineteen photographs of as many different phases. The photographs were made by means of a small camera adapted to the eye-end of a refracting telescope of which the aperture was six inches and the solar focal length eight feet. The impressions were taken within the interval required to remove an opaque cap from the object-glass and replace it again without loss of time, so that the effect may, for all practical purposes, be said to have been instantaneous.*" The efforts of Bartlett and Prevost differed from the others who photographed the event in that they used a variation of the Calotype process rather than the preferred Daguerreotype.

Partial Solar Eclipse - William H. C. Bartlett & Charles H. V. Prevost (1854)

Stephen Alexander (1806-1883), Professor of Mathematics and Astronomy at the College of New Jersey (now Princeton University) made efforts to observe and photograph it from Ogdensburg, New York "*because it presented the advantage of being the western most of all those stations near the line of the central eclipse which were at all readily accessible; it being at once foreseen, that not only must the phenomena therefore occur in fact a very little earlier than at stations farther east, but also at an earlier period of the day as measured by the local time. In addition to this, it seemed not impossible that the western stations might be in the enjoyment of a clear sky, while the eastern stations, rather closely located in longitude, were perhaps to be all overshadowed by a coast-storm.*"



Stephen Alexander (1806-1883) by Daniel Huntington (1816-1906), c. 1856

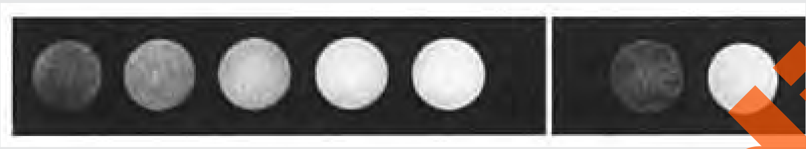
A.16 - Solar Photosphere

The French Physicists, Jean Bernhard Leon Foucault (1819-1868) and Armand Hippolyte Fizeau (1819-1896) were two of the 19th Centur's leading Physicists, who are best known today, for their determination of the speed of light in both air and water.

However during their early careers they worked together at the Paris Observatory under its then Director François Arago, on a programme of photographing the Solar Photosphere and its Spectrum in the period 1843 to 1845.

They obtained their first, albeit '*coin*' sized images of the Sun's surface in the August of 1843.

Leon Foucault (1819-1868) & Hippolyte Fizeau (1819-1896)



Coin Sized Daguerreotypes of the Solar Photosphere - Foucault & Fizeau (1843)

The Solar Photographs taken by Fizeau and Foucault are something of a mystery. The exact numbers of photographs they obtained and the period during which they were taken have been lost to us. Only one Daguerreotype photograph dated the 2nd of April 1845, is known to have been taken with any degree of certainty, and is the one included in François Jean Dominque Arago's '*Popular Astronomy*', shown here on the left.

After 1845 Foucault and Fizeau began concentrating their efforts on developing terrestrial methods for the determination of '*c*'. Unfortunately, the two scientists soon dissolved their partnership over a personal matter, and began conducting their experiments independently.

Solar Photosphere, (1845) - Leon Foucault & Hippolyte Fizeau

"Two distinguished philosophers, MM. Fizeau and Foucault, by receiving, at my request, a very rapid impression of the disc of the sun upon daguerreotype plates, have verified by photography the results at which I arrived by photometry. Fig. 163. (Plate XII.), faithfully represents the photographic image of the sun which they obtained in 1845. This very remarkable image shows perfectly well the slight excess of the luminous intensity of the centre over the borders. MM. Fizeau and Foucault had besides the good fortune to seize the images of two groups of spots which are seen on the figure with all their details." François Arago in Popular Astronomy Vol. I, Chapter XXIII, p. 461, 1855.

A.17 - Total Solar Eclipses

The photograph left of a Total Solar Eclipse was taken by the Portuguese amateur astronomer, Pedro Ré from El Saloum in Egypt near to the Libyan border on the 29th of March 2006. Observing conditions were ideal during the whole event - clear skies, low turbulence and no wind. Totality for this Eclipse of the Sun was visible within a narrow corridor from Brazil and extended across the Atlantic, Northern Africa, and Central Asia where it ended at sunset in Western Mongolia. A Partial Eclipse was visible within the much broader corridor which included the Northern two thirds of Africa, Europe, and Central Asia. **Note**: Pedro's splendid photograph was obtained with a Takahashi FS60C F/5.9 refractor and a Canon 350D camera.

Total Solar Eclipse - Pedro Ré (2006)

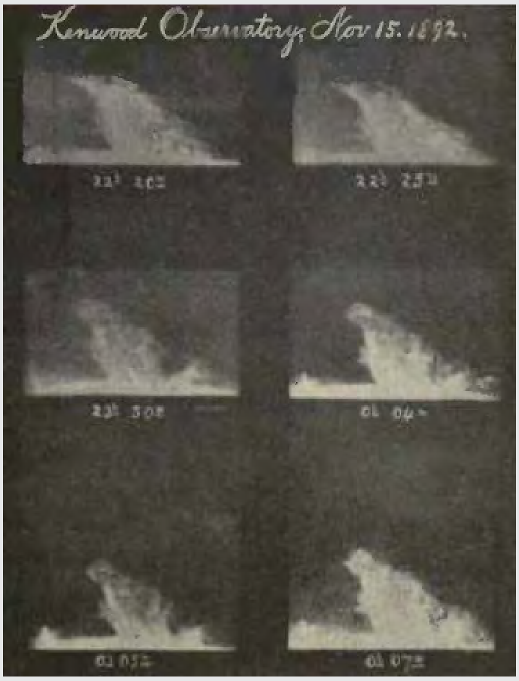
The first attempt to photograph a Total Eclipse of the Sun was made by the Italian physicist, Gian Alessandro Majocchi (1795-1854) from his home in the Northern Italian city of Milan on the 8th of July 1842. His efforts were only partially successful as he failed to capture the all important moment of totality: "*... a few minutes before and after totality an iodised plate was exposed in a camera to the light of the thin crescent, and a distinct image was obtained; but another plate exposed to the light of the corona for two minutes during totality did not show the slightest trace of photographic action. No photographic alteration was caused by the light of the corona condensed by a lens for two minutes, during totality, on a sheet of paper prepared with bromide of silver.*"

It was to be a further nine years before the first successful photograph of the moment of totality was obtained. For the Total Eclipse of the 28th of July 1851, Dr. August Ludwig Busch (1804-1855), the Director of the Konigsberg Observatory in Germany gave instructions for a local Daguerreotypist named Berkowski (his first name is not known) to image the eclipse. Busch himself was not present at Konigsberg (now Kaliningrad, Russia), but preferred to observe the eclipse from nearby Rixhoft.

The telescope used by Berkowski was attached to the 6½-inch Konigsberg Heliometer and had an aperture of only 2.4 inches (6.1 cm), and a focal length of 32 inches (81.2 cm) inches. Commencing immediately after the beginning of totality, Berkowski exposed a Daguerreotype plate for 84 seconds in the focus of the telescope, and on development an image of the Corona was obtained. He also exposed a second plate for about 40 to 45 seconds but was spoiled when the Sun broke out from behind the Moon.

Total Solar Eclipse - Berkowski (1851)

A.18 - Solar Prominences & Flares



In 1890, George Ellery Hale (1868-1938), while still a student at the Massachusetts Institute of Technology invented the Spectroheliograph, an instrument that was to change the face of Solar Physics forever. With a Spectroheliograph a photograph could be obtained of the Sun as seen through a single wavelength of light; which was selected more often than not to correspond to one of the chemical elements present in the atmosphere of our star. For the very first time with the aid of the Spectroheliograph, the fiery red Solar Prominences could be photographed without the need for a Total Eclipse of the Sun. In 1891 a Spectroheliograph built by John A. Brashear according to Hale's specifications, was installed at Hale's own Private Observatory, next to the family home, in Kenwood, Chicago, Illinois. From January 1891 to June 1896, photographs of the Solar Prominences were regularly taken by Hale and his assistant, Ferdinand Ellerman (1869-1940) with the aid of the Spectroheliograph, attached to a 12-inch Brashear Equatorial Refractor.

Solar Prominences - George Ellery Hale (1892)

In 1897 Hale became the first Director of the newly established Yerkes Observatory at Williams Bay, Wisconsin. That same year the 12-inch Refractor and its dome were incorporated into the north tower of the Observatory. However the Kenwood Spectroheliograph was superfluous to requirements. The Brashear Refractor was required for other work, nor was it suitable for use with the Observatory's new 40-inch Refractor.

Unfortunately this historic instrument appears to be lost and its whereabouts or fate remain unknown.

Kenwood Astrophysical Observatory Spectroheliograph (1897)

In 1904, mules helped drag the Snow Solar telescope and other sundry building materials up the narrow, winding path to the top of a mountain, 5712 feet above sea level.

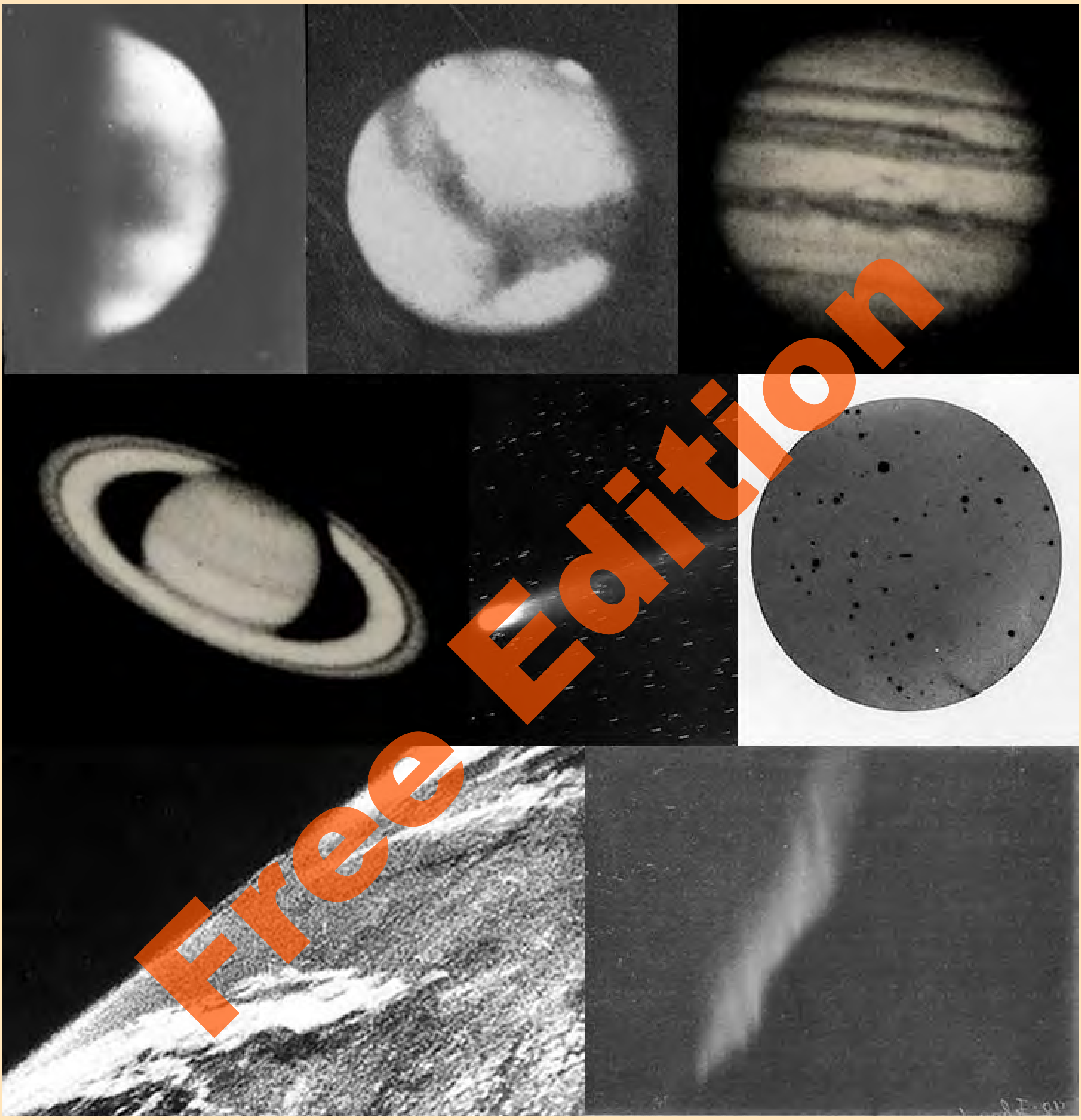
This was the beginning of the Mount Wilson Solar Observatory as it was then known. The benefactor for this telescope was the wealthy Chicago heiress Helen Snow who named it after her father, George Washington Snow.

Snow Solar Telescope - Mount Wilson (c 1910)

Photographing the Solar System

The Solar System - According to Damian Peach

4. Planets, Dwarfs & Vermin
Photographing the Solar System



Of all the many diverse objects to be found amongst the stars, it was those in our own Solar System that represented the biggest challenges and those which produced the greatest failures amongst the early Pioneers of Astrophotography. It was only in 1885-86 that the two French brothers Paul and Prosper Henry obtained any decent sized images of the Planets, when they successfully photographed the two Gas Giants. Jupiter and Saturn - five years after Henry Draper's iconic photograph of the '*Great Orion Nebula*', whose light had started its journey, when the Prophet Mohammed was spreading the word of Islam and Ancient Rome was no longer ruled by Emperors, but by Barbarian tribes.

Somewhat surprisingly the first body of the Solar System (other than the Sun and the Moon) to be successfully imaged was not Jupiter or Saturn but a Comet. Even more remarkable was that it was not obtained by an astronomer or at a large Observatory, but by a miniature portrait artist and '*jobbing*' photographer. On the 27th of September 1858 William Usherwood, captured Donati's Comet, '*head and tail*' from Walton Common, Surrey, England. He was in the right place, at the right time and more importantly with the right equipment. The photograph on the left is of Comet C/1882 R1, taken on the 14th of November 1882 by David Gill, from the Cape of Good Hope Observatory, South Africa.

Comet C/1882 R1 - David Gill (1882)

Incredibly it was to be some twenty seven years after Usherwood's Cometary photograph that a sensibly sized and distinct image of a major planet was obtained. Towards the end of 1885 and early the following year, the two French brothers, Paul (1848-1905) and Prosper Henry (1849-1903) working at the Paris Observatory, captured the first truly successful planetary photographs of the Gas Giants, Jupiter and Saturn. There had been earlier attempts, notably of Jupiter by John Adams Whipple at Harvard in 1851 and again in 1857; and in 1857 when Warren De La Rue photographed Jupiter and Saturn. But these were only tiny images a few millimetres across or indistinct at best. The photograph of Jupiter pictured to the right is by Francis Gladheim Pease, taken with the 100-inch Reflector, at Mount Wilson, on the 15th of March 1921. The satellite Ganymede and its shadow can be seen on the planet's surface.

Jupiter - Francis Gladheim Pease (1921)

During the Andromedid meteor shower of 1885, the Austro-Hungarian Astronomer, Ladislaus Weinek, captured the first photograph of a Meteor or '*Shooting Star*' at Prague on the 27th of November. It was to be some years later that the process of capturing photographs of Meteors became less '*hit & miss*'. In 1899 Wiliam Lewis Elkin (1855-1913) at Yale experimented with the photography of meteors through a rapidly rotating shutter that broke the trails into segments of equal duration. By photographing simultaneously from two stations he hoped to get, not only the heights of the meteors, but also their velocities. Unfortunately his stations were only a few miles apart and were too close together for height determinations; with the result he could get only their angular velocities; and not their true speeds through the atmosphere. Only much later was Elkin's technique successfully applied by others including Willard James Fisher (1867-1934), Peter Mackenzie Millman (1906-1990), Ellen Dorrit Hoffleit (1907-2007) and Fred Whipple (1906-2004). With stations separated by over 20 miles, they could get reliable determinations of heights and velocities of meteors.

Meteor Camera - William Lewis Elkin (1899)

A.19 - Comets

In the late summer of 1858 a '*Great Comet*' appeared which was so bright it could easily be seen in broad daylight; people were awed by it, artists painted it and the great astronomers of the day tried to photograph it. It had been discovered on the night of the 2nd of June 1858 by the Italian astronomer Giovanni Battista Donati, who was observing the heavens from the Florence Observatory at Arcetri, 5km outside of the city. In the sky that night near to the border between the constellations of Cancer (Crab) and Leo (Lion), he saw a '*small nebulosity of 3'* in diameter through the eyepiece of his telescope, in a position where no known star or nebulae was to be found. He had found Comet C/1858 L1), better known as '*Donati"s Comet*'. The famous Astrophotographer, Warren De La Rue attempted to capture it and failed. George Phillips Bond (1825-1865), the son of the Director of the Harvard College Observatory, even succeeded in photographing it on the 28th of September of that year. However he would later find out that he was beaten to it – by a single day, and therefore lost his claim of being the first person ever to photograph a Comet.

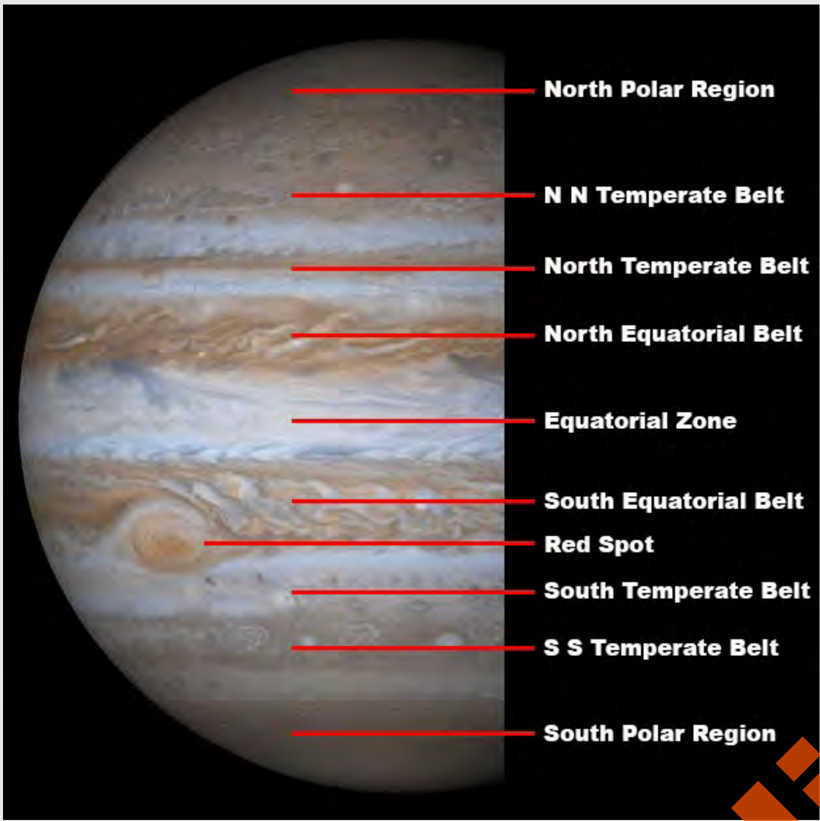
William Usherwood (1821-1915)

Of the three reported attempts to photograph Donati's Comet during the September of 1858. Only one of these was successful, that of William Usherwood. The other two attempts, both by respected astronomers failed. The photograph to the right shown here is a positive print of part of the original collodion negative taken by George Phillips Bond on the 28th of September 1858. In his notebook entry, Bond records: "*Think this took. On examination with microscope this plate exhibits an undoubted image of 15" diam. & Oval. Sky not quite clear & clouded suddenly*". The tail of the comet is not apparent in his six minute exposure. Bond's attempt at imaging Comet Donati was without doubt a complete failure.

The other failed attempt was by Warren De La Rue. His sixty second exposure revealed nothing. He had intended to make a further attempt, but owing to the death of his mother on the 22nd of September 1858, this was never accomplished, and so Usherwood took all the credit.

Comet Donati (1858) - George Phillips Bond

A.20 - Jupiter



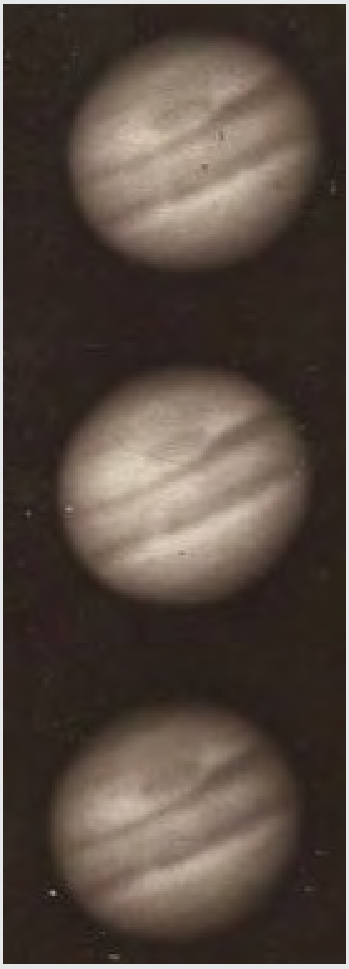
The very first recorded attempt to image a planet was made in 1851 by the Boston Daguerreotypist John Adams Whipple (1824-1891) with the assistance of George Phillips Bond (1825-1865), using the 15-inch '*Great Harvard Refractor*'. On the 22nd of March 1851, George Phillips Bond recorded in his notebook the tantalizing words: "*… Succeeded in Daguerreotyping Jupiter. Six plates were taken by Whipple and 'could distinguish the two principal equatorial belts – Time about as long as the Moon required or not much longer … The experiments were repeated on the 8th and 9th of October, 1857, by Mr. WHIPPLE, using the collodion process, with a like result.*" Despite Bond and Whipple's best efforts, they only met with partial success, as their photographs have not survived we will never found out how good they were.

Jupiter's 'Belts', 'Zones' & Regions in 2000 - Cassini Probe

Paul Henry (1848-1905)

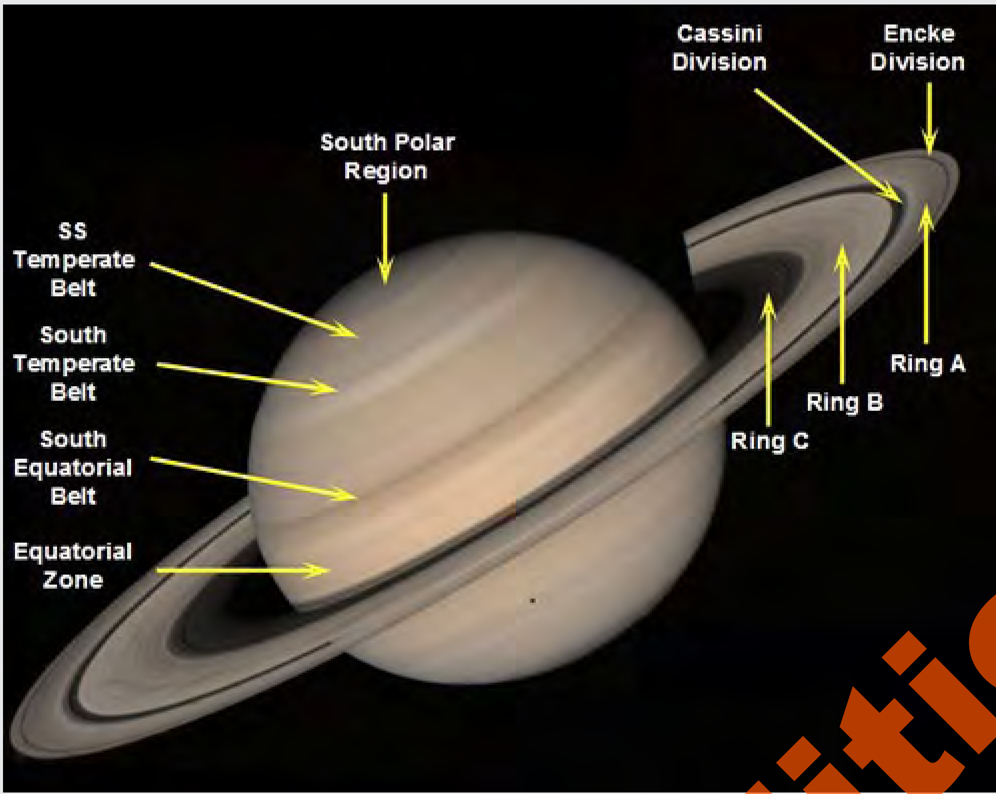
Prosper Henry (1849-1903)

Finally in late 1885 and early 1886, the two brothers, Paul and Prosper Henry at the Paris Observatory, met with success, when they successfully photographed both Jupiter and Saturn. It was not long after the Henry Brothers success in imaging the Gas Giants with an enlarging lens that others, including the English amateur astronomer, Andrew Ainslie Common, '*cottoned on*' and did the same: "*A new mirror for the 5-foot telescope was completed in July [1891], and some experiments have been made in photographing Jupiter to determine the exposure necessary and the definition obtainable. With the primary image a good picture is obtained with the quickest exposure that can be given by hand. About 2s gives a dense image and all the visible satellites, with an enlarging lens giving an image of about ½", 3s to 6s gives ample density, up to 1-inch from 8s to 10s gives sufficient density. For further enlargement the time is, of course, proportional. About 1¾ -inch diameter is the largest we have tried, but this was done on an unfavourable night.*"



Jupiter and 'Red Spot' 21st April 1886 - Paul & Prosper Henry

A.21 - Saturn

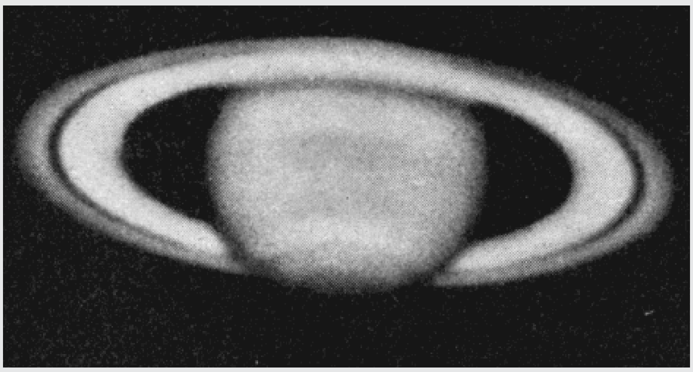


The '*Belts and Zones*' of Saturn are much less pronounced than those of Jupiter, with a less '*disturbed*' appearance. However it is its magnificent system of rings and the divisions separating them that distinguishes Saturn from all the other major planets in our Solar System. A schematic showing the location and names of Saturn's principal '*Belts and Zones*' and its Rings, including the Cassini and Encke Divisions is shown to the left, superimposed on an image from the Cassini-Huyghens probe.

Saturn's Belts & Rings

"A photograph of Saturn has been taken by direct enlargement of the primary image by means of a non-achromatic ocular giving a magnification of eleven times, which goes far beyond anything yet done in planetary photography, as can be seen from the paper prints that have been received. This photograph gives promise of most satisfactory results from the application of this method of direct enlargement of the primary image to planets, double stars, the Moon, and other objects." The photograph of Saturn as described in this 1886 report published in the MNRAS is shown to the right. It was taken on the 21st of December 1885 by the two French Brothers, Paul and Prosper Henry, at the Paris Observatory using a 13.4-inch Photographic Refractor. Their success in producing for the first time large scale images of the Gas Giants - Jupiter and Saturn was due to the use of a x11 magnifying lens which resulted in images of these planets which clearly showed detail on their surfaces. Any '*newbie*' Astrophotographer wishing to image a planet is always told by his more experienced brethren that they must use a telescope with a large focal ratio or increase its effective focal length with the aid of an enlarging lens (now called a Barlow lens). This is exactly what the Henry Brothers did.

Saturn (1885) - Paul & Prosper Henry



The particularly fine photograph of Saturn and its rings was obtained by Edward Emerson Barnard on the 7th July 1898 with the 40-inch Yerkes Refractor: "*The two northern belts were more in contrast, or darker near the limbs of the planet. The inner bright ring was brightest toward the Cassini division, where the brightness was rather narrow. I could not see with certainty any division in the outer ring... The polar cap was darker than the darkest part of the ball.*"

Saturn (1898) - Edward Emerson Barnard

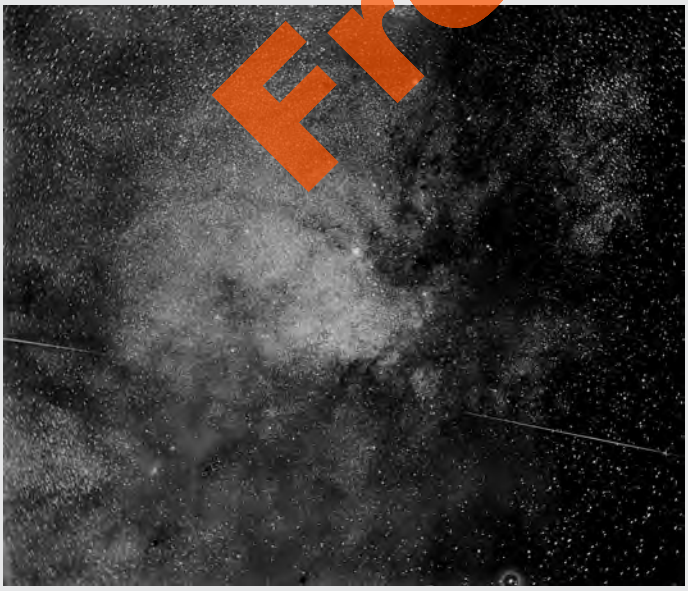
A.22 - Meteors

In 1885, Ladislaus Weinek (1848-1913), the Director of the Klementium Observatory in Prague, succeeded in the difficult task of capturing a Meteor on a photographic plate. His photograph taken from Prague, during the Andromedid meteor shower of the 27th of November that year. It was his intention to determine the heights of Andromedid meteors from two sites, one at Prague and a second, 75 miles distant at Jena. Only one photograph was successfully taken, that at Prague, Jena failed to obtain a recognisable image. The Andromedids meteor shower is associated with the Comet 3D/ Biela, the shower occurs when the Earth's orbit passes through the tail of the comet. Biela's Comet largely broke up between 1843 and 1852, leading to particularly spectacular showers in subsequent cycles, most notably in 1872 and 1885. Today, the peak activity is currently less than three naked eye meteors per hour around the 14th of November each year.

Ladislaus Weinek (1848-1913)

In 1906 the German astronomer, Maximilian Franz Josef Cornelius Wolf, better known simply as Max Wolf, published a portfolio of 12 astronomical subjects entitled '*Stereoskopie Stereobilder vom Sternhimmel*'. Series I. The meteor trail shown to the left was captured by Wolf on the 7th of September 1891 was No. 4 in this collection. This remarkable image one of the earliest obtained of a Meteor, was captured using a 5-inch Kranz Portrait Lens of 20-inch focal length. A truly incredible achievement, considering Wolf had only taken up Astrophotography the previous year. He later exhibited a Stereogram of this photograph at the Royal Photographic Society of London's 56th Exhibition in 1911, along with 50 or so others of various astronomical subjects, including: Comets, Minor Planets, Deep Space Objects, and Milky Way '*Star Clouds*'.

Meteor Trail (1891) - Max Wolf



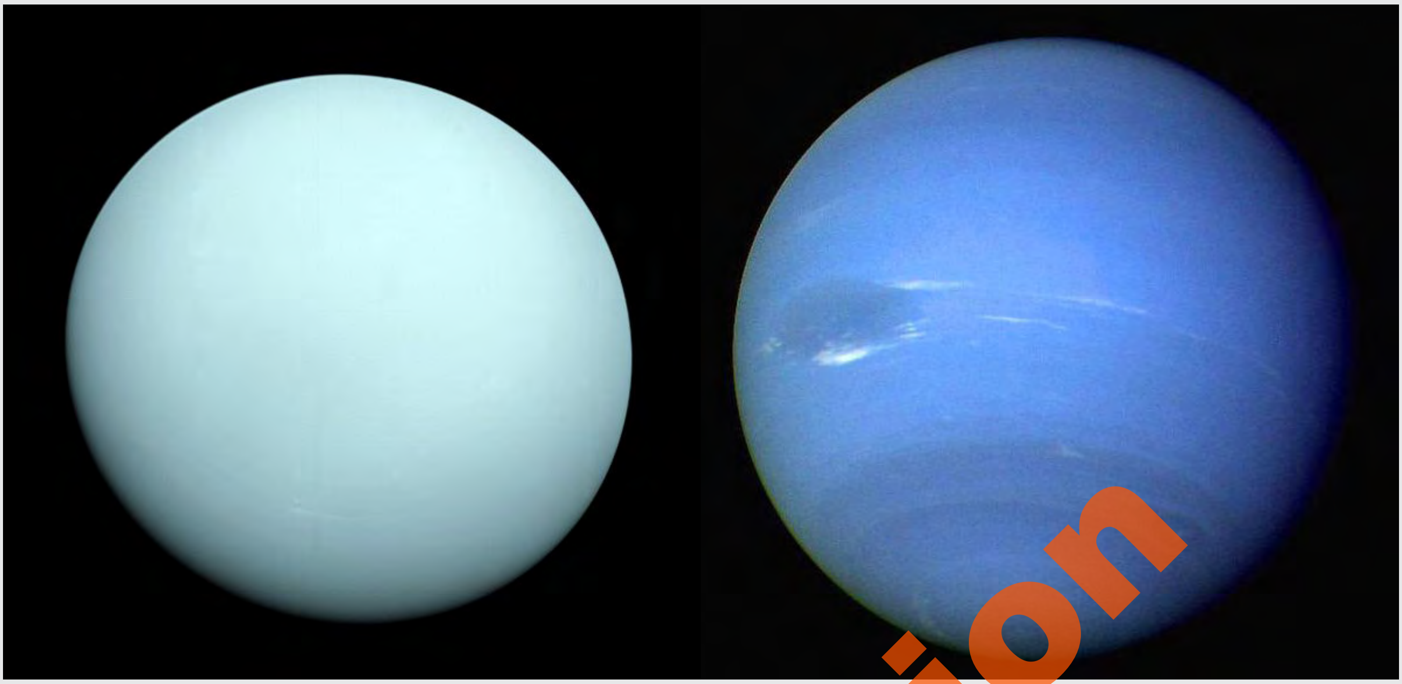
The photograph to the left shows to perfection the Great Star Clouds of the Milky Way that run through the constellation of Scutum, in the vicinity of the '*Wild Duck*' Cluster (M11).

It was taken by Edward Emerson Barnard on the 20th of April 1904, with an exposure of 2 hours 40 minutes using the Yerkes Observatory's, Bruce Astrograph.

It has the added bonus as Barnard pointed out, that it "*... shows the trails of two meteors which were nearly in a straight line, so that, at first thought, one would suppose it was the trail of one meteor which had been interrupted near the middle of its flight*".

Two Meteor Trails in Scutum (1904) - Edward Emerson Barnard

A.23 - Uranus & A.24 - Neptune



Uranus in 1986 (Left) & Neptune in 1989 (Right) - Voyager 2 Probe

The first recorded photograph of Neptune was by the Henry Brothers, taken about the same time as that of Saturn, probably in the December of 1885. Neptune and its satellite, Triton was also captured in 1890-91 by Isaac Roberts from Crowborough, Sussex, England with a 20-inch reflector: "*Sixteen photographs of the planet Neptune were taken at my observatory between December 9, 1890, and February 24, 1891, with exposures of the plates varying between fifteen minutes and three hours respectively. Upon eight of the plates the satellite is to be seen... The diameter of the photographic image of Neptune in my telescope is about equal to the major axis of the projected orbit of the satellite. The satellite can, therefore, be photographed only when it is somewhere within the distance of about 450 of the line of apsides, and if the planet did not mask the satellite in the other parts of its orbit the orbital motion would be too rapid to permit a photographic image being formed... The Photographs do not indicate the presence of any other satellite than the one discovered by Lassell [Triton]*" Isaac Roberts, "*Photographs of Neptune and its Satellite*", MNRAS, 1891, Vol. 51, pp. 439-440.

The disc of Uranus was first captured on a photographic plate, some three years later in 1889, at Ealing, Middlesex, England, by Albert Taylor (1865-1930), the assistant to Andrew Ainslie Common, with a 5-foot reflector: "*Uranus has been examined on every available occasion since the end of April. On April 30th all four satellites were seen, and in addition a faint point of light nearer to the planet than Ariel is. On other clear nights two faint points of light have been seen very near the planet, and several have been noted in the neighbourhood. The movement of Uranus is such that stars only a little more than a diameter distant from it would appreciably alter their positions in three or four hours, and the persistence of these points of light so near the planet during several hours' observations decidedly indicates that they are satellites. There is also some evidence of a satellite between Titania and Umbriel; but in this case, as in others, the bad weather and the haze, combined with the low altitude of Uranus, have rendered continuous observations impossible, and evidence of rotation round the planet is not conclusive. With only moderate powers Uranus does not show a perfectly sharp disc, but this may be due to haze and other atmospheric influences. No markings are visible on it, and nothing like a ring has been seen round it. Photographs of Uranus have been taken which show a disc without projections of any kind, and faint indications of the brightest satellites. Titania is apparently nearly a day late as compared with the ephemeris.*" Report on Observatories - Ealing, Albert Taylor, Observatory, 1889, Vol. 12, pp 263-265;

These early photographs could at best only show tiny featureless discs of the two '*Ice Giants*' - Uranus and Neptune. This would only change with the advent of the CCD, the launch of the Hubble Space Telescope and the arrival of the Voyager space probes at these remote planets.

A.25 - Minor Planets (Asteroids)

The robot spacecraft Galileo currently exploring the Jovian system, encountered and photographed two asteroids during its long journey to Jupiter. The second Asteroid it photographed, Ida, was discovered to have a moon which appears as a small dot to the right of Ida in this picture. The tiny moon, named Dactyl, is about one mile across, while the potato shaped Ida measures about 36 miles long and 14 miles wide. Dactyl is the first moon of an asteroid ever discovered. The names Ida and Dactyl are based on characters in Greek mythology.

Asteroid Ida and its Moon, Dactyl (1993)

The first Minor Planet (or Asteroid) to be discovered photographically was captured on the 22nd of December 1891, by the German astronomer, Max Wolf using a telescope with a 5-inch portrait lens. The asteroid No. 323 was later named by him '*Brucia*' in honour of Catherine Wolfe Bruce (1816-1900), the American benefactress who had funded a new telescope , a 16-inch '*Double*' Astrograph for the Heidelberg State Observatory, of which Wolf was its Director. In the years which followed Wolf was to be credited with a further 247 discoveries – a truly staggering number: *"I commenced photographing minor planets in August 1890, using both a telescope lens of 16.2 cm aperture and, 262 cm focal length, and an aplanatic lens of 6 cm aperture and 44 cm focal length. I was seeking for several lost asteroids at the time during several nights, and used ten plates with long exposures. I had no success because I could not employ suitable lenses, the focal length of the first employed being too long, and the aperture of the second too small. To photograph minor planets both a large field and a marked brightness of image is required."*

Maximilian Franz Joseph Cornelius Wolf (1863-1932)

The Austrian astronomer, Edmund Weiss (1837-1917) was the man responsible for calling asteroids the '*Ungeziefer des Himmels*' or '*Vermin of the Sky*'. He was born on the 26th of August 1837 in Frývaldov, Austrian Silesia, now Jeseník, Czech Silesia, His childhood was spent in England where his father was a physician in Richmond, Surrey. After his father's death he returned home and attended a local school before gaining his degree in Astronomy in 1858 from the University of Vienna and his Doctorate two years later. In 1869 he became a professor at the University of Vienna. In 1878 he succeeded, Karl Von Littrow as director of the Vienna observatory, a position he held until his retirement in 1910. At Vienna he published a number of papers on a variety of subjects including the magnitudes of minor planets, the connection between comets and meteors, the meteor swarm of Halley's comet and the nebulae in the Pleiades. He died on the 21st of June 1917 in Vienna after a long and painful illness.

Edmund Weiss (1837-1917)

A.26 - Aurorae

In 1889 an article appeared in the appropriately named '*Journal Heaven and Earth*', which contained two drawings of an Aurora that were claimed to be based on photographs taken by the Danish schoolteacher Sophus Tromholt (1851-1896), while he was stationed at Kautokeino in Norwegian Lapland during the first Polar Year (1881-1884). It was later proved that the article was mistaken. The German meteorologist Adolf Karl Otto Baschin directly questioned Tromholt about it and was told that these attempts at Auroral photography were unsuccessful.

Although, Tromholt used the fastest photographic plates available to him and even with exposure times of 4 to 7 minutes, he obtained no trace of an image. However, in 1885 Tromholt reported he had succeeded in his attempts with an Aurora which took place at Christiania (Oslo), Norway. This also proved to be something of an obfuscation: *"as he now informs me [Carl Siewers] that, although the plate was exposed for eight and a half minutes, the said impression is so faint and imperfect that it cannot be reproduced as a positive."*

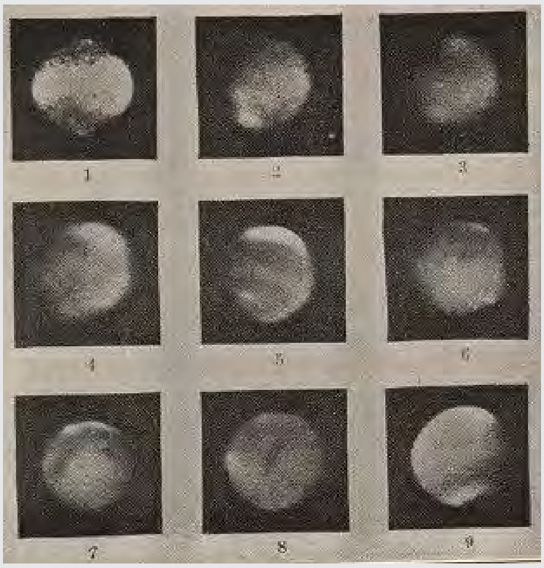
Adolf Karl Otto Baschin (1865-1933)

Otto Rudolf Martin Brendel was a German astronomer and physicist, who in the winter of 1891-1892, travelled to Bossekop in Northern Norway with Baschin. It was their intention to study and photograph the splendid Aurorae which were visible from there. It was Brendel's job to take the photographs.

He took with him a camera borrowed from Otto Jesse (1838-1901) of the Berlin Observatory, which had previously been used to successfully image Noctilucent clouds in 1889. His camera had a 210 mm focal length lens, of 60 mm diameter and a '*fast*' focal ratio off f3.5; and a very wide-field of view of some 20° x 30°. The photographs were to be taken on 9 x 12 cm high-sensitivity photographic plates obtained from the Schleussner company, and others which were sensitized by Brendel himself by wetting them in a bath of a special silver compound. In the January and February of 1892, Brendel succeeded in obtaining the very first photographs of an Aurora.

Aurora in 1892: 1st February (top); 5th January (bottom) - Bossekop, Norway

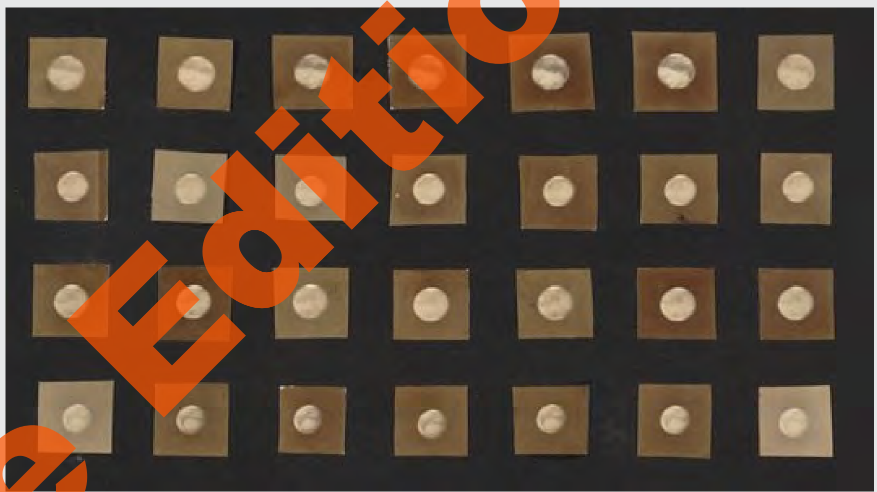
A.27 - Mars



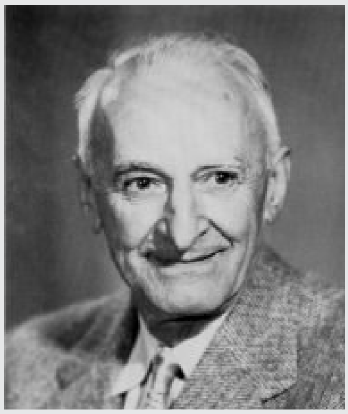
The photographs of Mars shown left, are probably the earliest taken of the '*Red*' planet, which show any form of detail on its surface. They were obtained by William Henry Pickering: "*In the spring of 1888 [No. 1] a series of photographs of Mars was obtained with the Boyden 13-inch telescope in Cambridge. The image of the planet was enlarged by means of a positive eye piece to a scale of 6" to the millimetre upon the photographic plate, an exposure of about five seconds being usually given. In 1890 a longer series of photographs [No. 2-9] was taken with the same instrument from the summit of Mt. Wilson in southern California. Owing in part to the fact that a greater enlargement, amounting to 2" to the millimetre, was used, but chiefly to the superior atmospheric conditions of that locality, this second series of photographs gave much more detailed results...*"

Mars (1888-90) - William Henry Pickering

In 1907, Percival Lowell's assistant, Carl Otto Lampland (1873-1951) produced a series of Martian photographs taken with the 24-inch refractor at the Lowell Observatory, which at the time were the best ever taken. The images although only a few millimetres in size clearly showed the changing face of the '*Red*' planet. Over the next few decades Lowell and his Observatory became renowned for their Planetary Photography.



Mars (1907) - Carl Otto Lampland



Percival Lowell (1855-1916); Carl Otto Lampland (1873-1951); Earl Carl Slipher (1883-1964)

The astronomers, Percival Lowell, Earl Carl Slipher and Carl Otto Lampland were solely responsible for developing the photography of Mars to the point of success, following the dismal failure of their nineteenth century predecessors. During the course of their careers at the Lowell Observatory in Flagstaff, Arizona they personally took tens if not hundreds of thousands of photographs of Mars. This huge output was the result of their determination not only to study the seasonal changes in the planet's surface features, but also to prove the existence of its '*canals*'. Lowell and Slipher, certainly went to their graves believing in the existence of them.

A.28 - Mercury & A.29 - Venus

As far as Mercury was concerned, Astrophotography was of no use in determining the nature of its blank face, a view shared by Earl Carl Slipher. At the 41st Meeting of the Astronomical Society of the Pacific held in New York in 1928, he reported on some recent photographs of the major planets, including Mercury: *"Examples of yellow and violet photographs of Mercury, the first ever obtained, were shown. Some faint markings have been recorded but the matter of photographing a planet so near the sun by using violet light is difficult and the observational material is too meagre as yet for general discussion."*

Mercury in 1942 - Pic Du Midi Observatory; Mercury (2007) - Damian Peach

The photograph above left of the planet Mercury was obtained at the Pic du Midi Observatory in the French Pyrénées by Henri Camichel in July/August 1942, using a 15-inch Refractor (0.38m) borrowed from the Toulouse Observatory. This represents one of the few photographs taken of Mercury before the space age. The image shown above right of Mercury is a modern digital photograph taken in the Infra-Red on the 27th of May 2007, by the English amateur Damian Peach from Barbados in the West Indies.

During 1941 and 1942, Bernard Lyot, Marcel Gentili and Henri Camichel, took a series of photographs of the major planets from the Pic du Midi Observatory, in the French Pyrenees. The telescope they used was an old 15-inch Refractor made by the Henry Brothers and borrowed from the Toulouse Observatory. Lyot in a paper written in 1945, described their observations and photographs of Mercury: "I*n July and August, 1942, a long stretch of fine weather made observations possible with the 0.38-meter refractor. Between July 8 and August 13, 27 days could be utilized; during these days images were often excellent for several hours after sunrise and sometimes also before sunset. The objective was shaded from the sun by a screen supported by the dome and held some 12 meters from the shutters. Thus it was possible to observe Mercury even on the day of conjunction, August 2, at 1° 40' from the sun. Most of the time a magnification of 500 could be used; and this showed, on the 5" disk, spots comparable to those of the moon, seen with the naked eye. The drawings of Gentili and Lyot all show the same configurations, which turn from day to day simultaneously with the terminator. A series of plates taken by Camichel, combined in composite positives, confirms the principal details."* Bernard Lyot, 1945, ApJ, Vol. 101, pp. 255-259. By some miracle they had been able to work despite France and the rest of Europe being in the grip of a long and bloody war. The true nature of Mercury as a hot inhospitable lunar like world pitted with craters would only be revealed with the Mariner 10 space probe of 1974-1975; and the Messenger (**ME**rcury **S**urface, **S**pace **EN**vironment, ***GE***ochemistry, and **R**anging) mission, launched in August 2004.

Very few photographs of Venus were ever taken prior to the space age. This was because it never showed anything other than a blank featureless disc. It was not until 1921 that photographs were taken which revealed markings in its cloud covered atmosphere These images were taken by the Salt Lake City based, astronomer, Alfred Rordame (1863-1931), who worked as a collector for the local lighting company. The photograph (right) depicted here is an enlargement of the original which was taken by Rordame on the 14th of March 1921, at 7.30 pm, using his 16-inch Mellish reflector. Rordame also took a series of daylight images of Venus on the 17th of July 1921, using a '*9-inch Alvan Clark equatorial of exquisite definition*', which revealed similar markings to his earlier photograph. His image of the 14th of March 1921 was the first photograph taken which showed any form of marking on the face of the planet Venus.

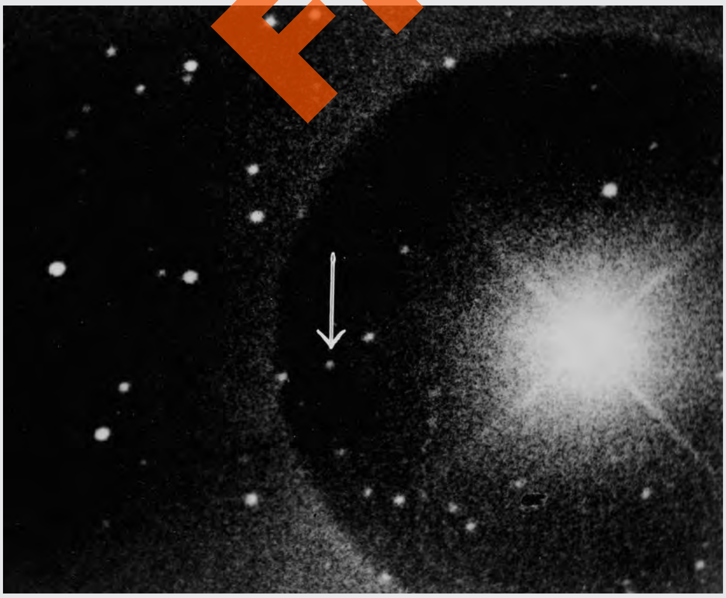
Venus (1921) - Alfred Rordame

A.30 - Pluto & A.31 - Other Dwarfs

Pluto, (Left) and its satellite Charon (Right) on 13th July 2015 - New Horizons Probe

The discovery of the Pluto, the '*Ninth*' planet of the Solar System, now relegated to the status of a '*Dwarf*' planet, is one of great disappointment and false hopes. Following the discovery of the planet Neptune in 1846, subsequent observations in the late 19th century caused astronomers to speculate that the orbit of it's not so near neighbour, Uranus was being disturbed by another planet besides the newcomer. Percival Lowell not surprisingly took up the challenge and tried to find '*Planet X*'. However, he died in 1916 before it was found, just as well because unbeknown to Lowell his observatory had captured two faint images of Pluto on the 19th of March 1915, but did not recognize them for what they were.

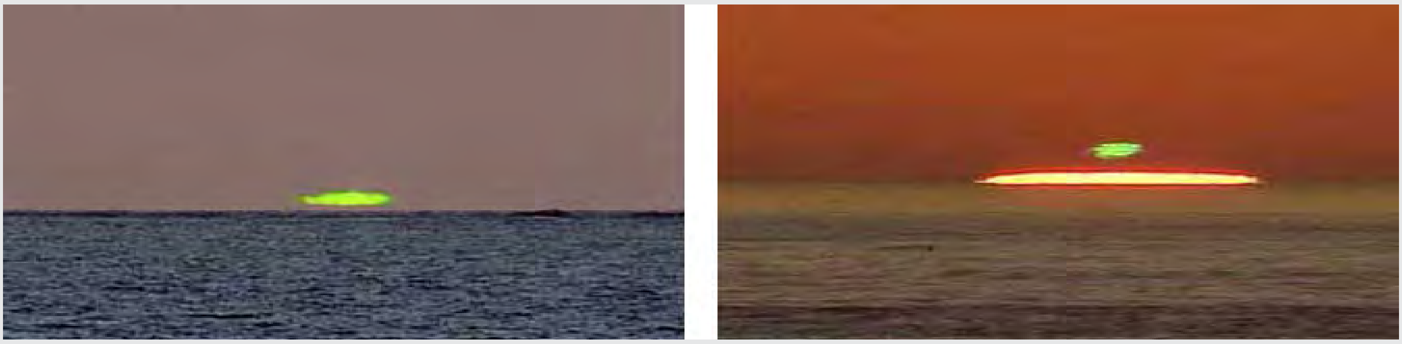
It was left to Clyde Tombaugh, a then young man of 23 from Kansas who had in 1929 just arrived as a raw recruit to the Lowell Observatory's staff, to find '*Planet X*'. This he duly did on the 18th of February 1930. Its discovery was made possible by Tombaugh's use of the '*Blink Comparator*', a device used to detect the movement of objects in two photographic plates taken at different times. From almost the very moment of its discovery, Pluto became the disappointing child of the solar system family. Once found, Pluto's faintness and lack of a resolvable disc cast doubt on the idea that it was Lowell's Planet X. Estimates of Pluto's mass were revised downward throughout the 20th century. In 1978, the discovery of Pluto's moon Charon allowed measurements of Pluto's mass to be made for the first time. Its mass was found to be extremely small, being roughly 0.2% that of the Earth, far too small to account for the discrepancies in the orbit of Uranus. Today its discovery is now classed as a pure coincidence and that Lowell's '*Planet X*' never existed.



The ultimate humiliation for the young Pluto came on the 24th of August 2006, when the International Astronomical Union (IAU) declared it to be a dwarf planet and excluded it from the class of the other big planets. This decision arose because of the discovery that it is just one of several '*large*' bodies within the newly charted Kuiper belt. To me and many other astronomers Pluto will always be the '*Ninth*' planet of the Solar System. The photograph of Pluto to the left was taken shortly after Tombaugh's discovery, by George Van Biesbroeck in 1930 using the 24-inch Yerkes Observatory's Reflector. The bright star to the right is δ Geminorum.

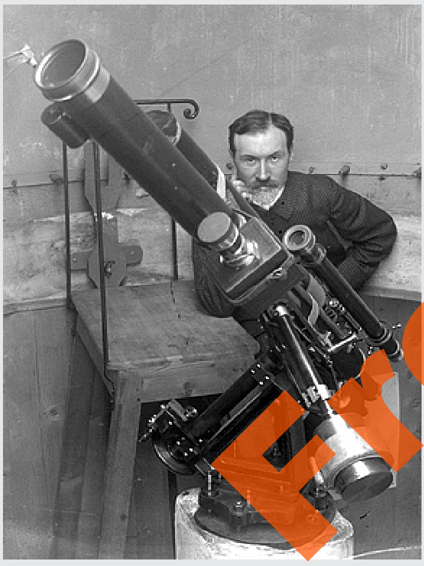
Pluto (1930) - George Van Biesbroeck

A.32 - Earth (Terrestrial Phenomenon)



Green Flash - Puerto Escondido, Mexico

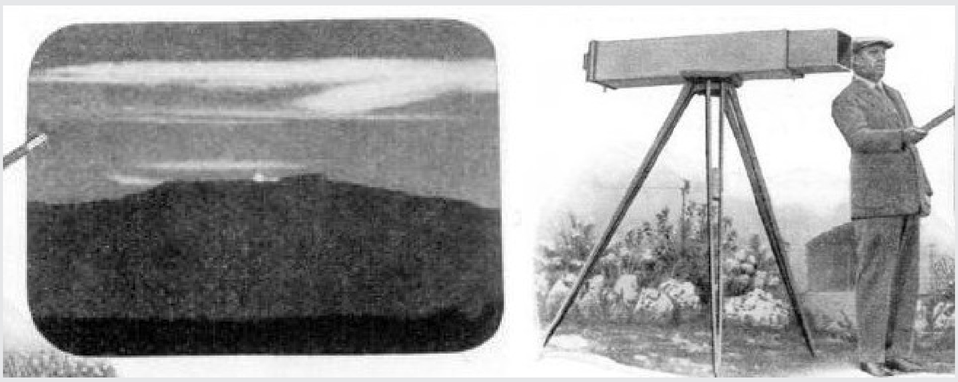
The rare atmospheric phenomenon known as the '*Green Flash*' was eloquently, if somewhat romantically summed up in a scene from the Hollywood '*Blockbuster*' - '*The Pirates of the Caribbean - At World's End*', when the Pirate Captain Hector Barbossa asks the mate Joshamee Gibbs: "*Ever gazed upon the green flash, Master Gibbs?*" - "*I reckon I seen my fair share. Happens on rare occasion. The last glimpse of sunset, a green flash shoots up into the sky. Some go their whole lives without ever seeing it. Some claim to have seen it who ain't. And some say*" - "*It signals when a soul comes back to this world from the dead*", interjects the pirate Pintel. The two photographs of the '*Green Flash*' pictured above were taken off the coast at the popular tourist centre at Puerto Escondito (Spanish for '*Hidden Port*') in Mexico, which by all accounts is for some unknown reason, a regular host to this phenomenon, and has been seen and photographed on numerous occasions. I personally have looked for it for nearly fifteen years, when the sun sets over the Mediterranean Sea, which overlooks my balcony in Paphos, Cyprus; and have only ever seen it once!



"In clear weather when the sun is setting behind a sharply defined horizon the last tiny speck of the disappearing disk is sometimes seen to turn vivid green for an instant, or, in exceptionally clear weather, blue. The first speck of the disk seen at sunrise often shows the same coloration. The phenomenon is called the 'green flash,' and is an effect of "dispersion'; i.e., the separation of the colours of which sunlight is composed owing to different degrees of bending by the atmosphere. In France a very skilful photographer of atmospheric phenomena, M. Lucien Rudaux, has taken many telescopic photographs of the green flash. His first picture was obtained in September, 1925, on the shore of the English Channel, as the sun sank into the ocean to the westward." Lucien Rudaux (1874-1947) was a French astronomer and artist, who was best known for his space theme paintings of the 1920s and 1930s. He was also the Director of the Observatory at Donville, Normandy. A crater on Mars was named after him.

Lucien Rudaux (1874-1947)

Marcel De Kérolyr was very fortunate for not only did he see the '*Green Flash*', he also managed to take the very first colour photograph of this rare optical phenomenon in early 1931 from his home at Forcalquier, Alpes-de-Haute-Provence, France.



Green Flash - Marcel De Kérolyr (1931)

Imaging Deep Space

The 'Sagittarius Triplet' - Daniel Verschatse, Chile

5. The Problem with Nebulae

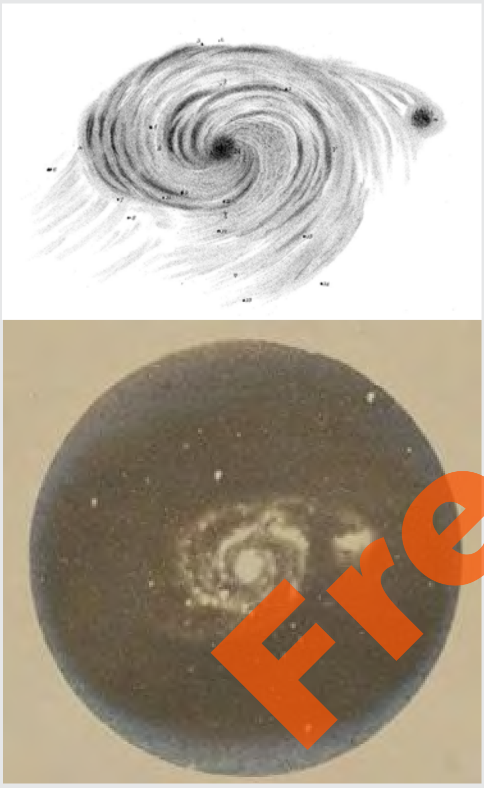
Imaging Deep Space

'Great Orion Nebula' (M42) - Henry Draper, 30th September 1880

The 30th of September 1880 marked one of the greatest milestones in the History of Astrophotography. On that date, Dr. Henry Draper (1837-1882), the son of the '*First Astrophotographer*', John William Draper (1811-1882), using an 11.25-inch Alvan Clark photographic refractor obtained the very first photograph of a '*Deep Space Object*', when he imaged the '*Great Orion'* Nebula (M42). His photograph obtained with a '*dry*' photographic plate and an exposure of 51 minutes became that night one of the most famous ever taken; and marked the beginning of Deep Space Astrophotography.

Open Cluster: NGC 7789; Globular Cluster: M14; Nebula NGC 1977 - Isaac Roberts

Many a modern amateur begins with the imaging of a single bright star, followed by a fainter one, then a well known double star, then a famous open cluster, followed by a wider field, then an iconic bright nebula, a bright galaxy or maybe a large globular cluster and finally one of the countless faint '*fuzzies*' that they have seen but cannot quite see what they really are. It was in this same exact manner that Deep Space Astrophotography had its beginnings. The first single star (Vega) was photographed in 1850, a double star (Mizar)in 1857, followed in 1860 by an open star cluster (M45), an emission nebula (M42) in 1880, a large spiral galaxy (M51) in 1883, a globular cluster (M13) in 1886 and lastly the more difficult and fainter galaxies from about 1890 onwards.



"The night of the 5th of March, 1845 was the finest I ever saw in Ireland. Many nebulae were observed by Lord Rosse, Dr. Robinson and myself. Most of them were, for the first time since their creation, seen by us as groups or clusters of stars; while some, at least to my eyes; showed no such resolution. Never, however, in my life did I see such glorious sidereal pictures as this instrument afforded us. Most of the nebulae we saw I certainly have observed with my own achromatic; but although that instrument, as for as relates to magnifying power, is probably inferior to no one in existence, yet to compare these nebulae, as seen with it and the six-feet telescope, is like comparing, as seen with the naked eye, the dinginess of the planet Saturn to the brilliancy of Venus…"

These words were written by the astronomer, Sir James South and related his experiences when looking through the eyepiece of the then newly completed 72-inch Reflector, known as the '*Leviathan of Parsonstown*' and seeing for the first time the '*faint fuzzies*' as they really are. William Parsons (1800-1867), the 3rd Earl of Rosse's, '*Leviathan*' was for nearly three quarters of a century the largest telescope in the world and with it discovered the '*Spiral*' nature of those '*Nebulae*', which we now call Galaxies.

'Whirlpool' (M51): William Parsons (1845); Isaac Roberts (1889)

Above are two representation of the famous '*Whirlpool*' Galaxy (M51) in the constellation of Canes Venatici (Hunting Dogs). The one on the top left is of a drawing made by William Parsons. The drawing was made in April 1845, and circulated at the June meeting of the British Association for the Advancement of Science. It was not until 1923 with the discovery of a Cepheid variable star in the '*Great Andromeda Spiral*' (M31) by Edwin Powell Hubble, that Lord Rosse's '*Spirals*' were in fact shown to be Extra-Galactic, lying outside of our own '*Milky Way*' star system. The second image is of a photograph taken by the Welshman Isaac Roberts (1829-1904) from his Observatory, at Maghull, near Liverpool, England on the 29th of April 1889. It was Roberts who was largely responsible through the two thousand or so photographs he took in the years 1883 to 1904, for showing for the first time what many of the objects which Lord Rosse had glimpsed, truly looked like. He had captured a permanent record of them on a photographic plate which we can still see today. Many of them are to be found in the pages of this book.

Stars & Clusters

M103 Open Cluster in Cassiopeia - Isaac Roberts (1892)

A.33 - ‘Fixed Stars’: Vega & Other Bright Stars

“Mr. Bond [George Phillips] of the Cambridge Observatory has recently succeeded [17th of July 1850] in obtaining a Daguerreotype picture of the star alpha Lyra [Vega] in the space of about 30 seconds, the image being transmitted through the great refractor, used without the eye-glass. The picture is quite distinct, and about the size of a pin’s head.” In this manner the local press of the day reported on the first photograph of a Star, by George Phillips Bond (1825-1865) and the Daguerreotypist, John Adams Whipple. Of the photograph Bond said: ‘*... that light, moving at the rate of 190,000 miles in a second of time, would require more than twenty years to traverse the intervening space ... it follows that the ray of light which made the first impression on our Daguerreotype plates took its departure from the star more than twenty years ago, long before Daguerre had conceived his invention.*’ It had been G. P. Bond’s father, William Cranch Bond, who had in 1847 began at the Harvard College Observatory, the first experiments ever conducted in Astrophotography.

William Cranch Bond (1789-1859)

As a young boy, the famous Astronomer and Astrophotographer, Edward Emerson Barnard acquired a great interest in astronomy long before he had ever owned or even used a telescope. He was often to be found after dark lying on his back in an old wagon looking up at the stars. On summer evenings he later recalled, after dusk had fallen, a bright white star shone high above his home. It was a sight which fascinated him and for some unknown reason it always remained his special star. He never forgot this star, only years later did he learn that it was called Vega.

Vega - Edward Emerson Barnard (1895); Palomar Observatory Sky Survey

On the 12th of February 1840, William Cranch Bond took up the position of first resident astronomer at the newly inaugurated Harvard College Observatory - without pay. Only in 1846 was he given a salary as its first Director. The following year the ‘*Great Refractor*’ was installed in its new dome and Astrophotography at Harvard began.

Harvard College Observatory, c1847

A.34 - M45 ('Pleiades' Open Cluster) in Taurus

The '*Pleiades*' open star cluster is a popular target for the modern Astrophotographer, made famous by the beautiful sapphire blue nebulosity that bathes its principal stars. The photograph to the left of M45 is by Edward Emerson Barnard, taken at the Lick Observatory with the 6-inch Crocker Astrograph.

It is part of Plate No. 13 from Barnard's '*Photographs of the Milky Way and of Comets Made with the Six Inch Willard Lens and Crocker Telescope During the Years 1892 to 1895*', published in 1913. Barnard's image clearly shows the nebulosity, which is caused by the reflection of light off of dust clouds in the vicinity of the hot white stars in the cluster.

M45 - Edward Emerson Barnard (1895)

On the 5th of January 1886, Henry Brothers, Paul and Prosper wrote the following letter, which they sent to the Royal Astronomical Society in London, announcing their discovery of the Pleiades Nebulosity: *"Nous avons reconnu à l'aide de la photographie, l'existence d'une nébuleuse nouvelle dans les Pléiades. Cette nébuleuse est voisine de l'étoile Maïa, qu'elle contourne; en partie, et d'où elle paraît s'échapper. Elle affecte une forme spirale bien caractérisée et son étendue est de 2' ou 3' environ. Il nous a été possible d'obtenir l'image de la nébuleuse sur 3 épreuves différentes: le 16 Novembre et les 8 et 9 Décembre derniers. Nous ajouterons que, jusqu'à présent, nous n'avons pu l'apercevoir dans nos télescopes. Nous avons l'honneur de vous adresser, Monsieur le Président, une reproduction agrandie, du négatif original, montrant la nébuleuse avec les étoiles environnantes..."*

A 'Poor' Image of M45 - Henry Brothers (1885)

The photograph of the '*Pleiades*' shown to the left is by James Edward Keeler, obtained with a four hour exposure, using the 36-inch '*Crossley*' Reflector of the Lick Observatory on the 28th of December 1899. It is Plate No. 8 in Publications of the Lick Observatory, Volume VIII, '*Photographs of Nebulae and Clusters Made with the Crossley Reflector*'. Keeler's photograph clearly shows the wispy nebulosity enveloping the principal stars of the Pleiades. This Nebulosity was the talk of the Royal Astronomical Society of London, in the early part of 1886: *"A nebula has been discovered in the "Pleiades, near Maia, so very faint that it is doubtful if it has ever been seen, or would have been found otherwise; and, judging from a copy of the original negative published in L'Astronomie of Feb. 1886, the nebula near Merope, about which there has been so much discussion, is distinctly seen on the plate,"* MNRAS, 1886, Vol. 46, p. 246.

M45 - James Edward Keeler (1899)

A.35 - NGC 869 & NGC 884 ('Double Cluster') in Perseus

"The two well-known clusters in the sword-handle of Perseus, when seen on a photograph which has been exposed in a 20-inch reflector for three hours, present an appearance of grandeur that can only be fully realised by aid of the photographic method. The enlargement from the negative taken on January 13, 1890, is now before us, and any written description will convey only a very inadequate idea of it. The stars are densely crowded in the clusters, as well as in the surrounding and intervening spaces, and by looking at the photograph from a distance of about 18 inches from the eye, the festoon-like groupings of the stars are very striking; but at present I only attach to these combinations a fortuitous character, for we well know by experience that the eye readily sees patterns and groupings on any surface that is made up of a large number of small pieces in close contiguity. This general statement is not intended to exclude the possibility, or even probability, that numerous stellar systems will in time be found amongst the various star groups shown on photographs" Isaac Roberts, MNRAS, 1890, Vol. 50, p. 315.

'Double Cluster' or 'Sword Handle' - Isaac Roberts (1890)

The pioneering photograph of the '*Sword Handle*' NGC 869 & NGC 884) in Perseus shown on the following page, is one of a series made by Paul and Prosper Henry during 1885 and 1886, to test the capabilities of their 13.4-inch Astrograph, which they had recently completed for the Paris Observatory. This instrument was to be the prototype for those used in the '*Carte du Ciel*' photographic survey of the sky, that was inaugurated in 1887.

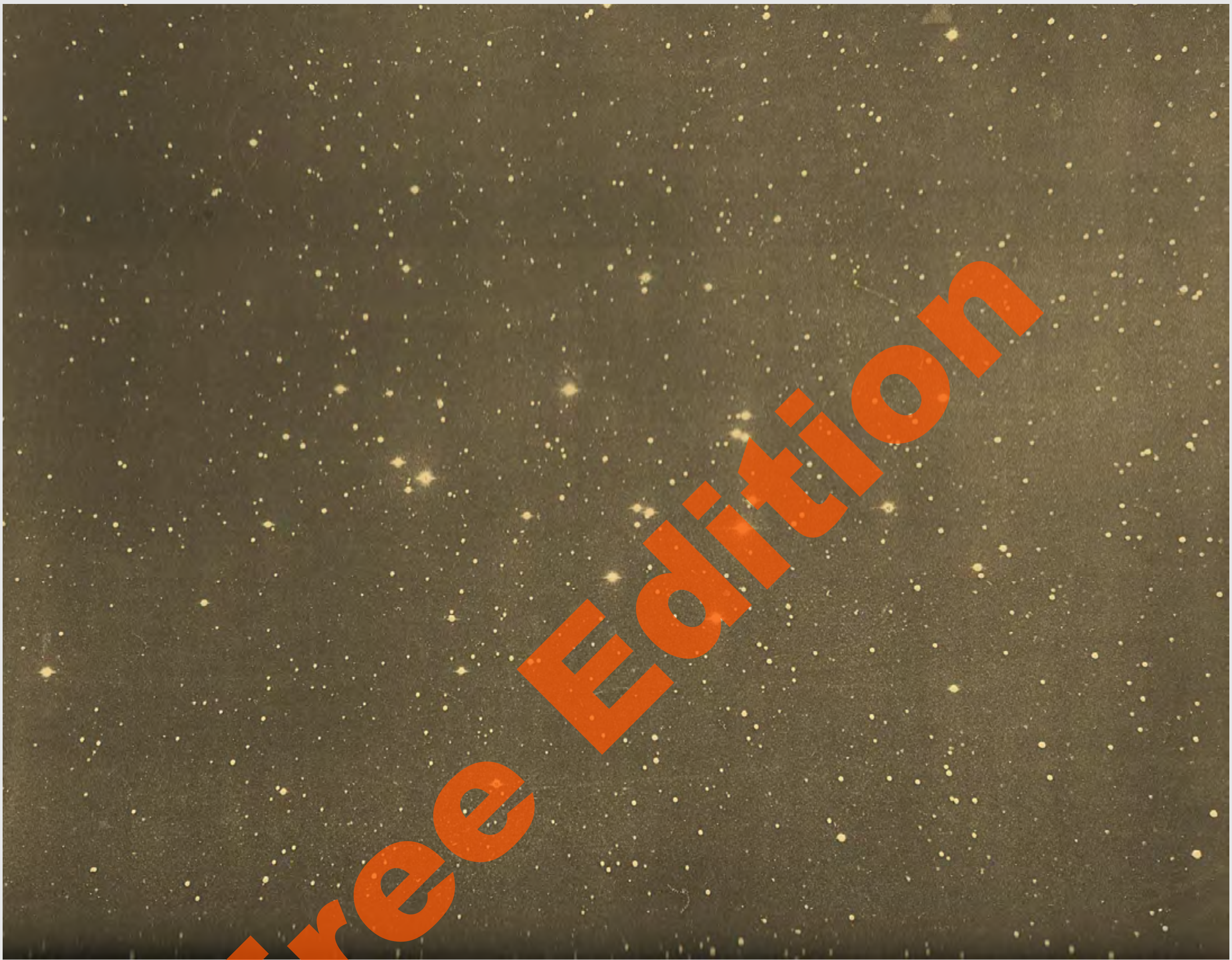
In the August of 1884 the Director of the Paris Observatory, Rear Admiral Mouchez presented to the French Academy of Sciences on the Henry Brothers' behalf, a photograph of theirs, which they had taken with a smaller 6.5 inch (16cm) Photographic Refractor, covering six square degrees of the sky containing 1500 stars from the sixth to the twelfth magnitude. The exposure used was only forty five minutes. Such was the success of their work that they were commissioned to construct the 13.4 inch (34cm) Photographic Refractor.

The Henry Brothers interest in Astrophotography stemmed from 1871, when they were given the task of completing Jean Chacornac's (1823-1873) charts of the ecliptic, which had begun in 1852, but were never completed. In all there were 108 charts each 13-inches square covering a 5 degree field of view and containing stars down to the thirteenth magnitude. Chacornac had only completed, thirty six of the charts and had mapped about 60,000 stars, leaving a further 72 charts still to be done.

When they began mapping the region of the '*Milky Way*', they became so alarmed at the number of stars involved - upwards of 100,000 for each chart, that they began to experiment with photography as a means of saving time.

A.36 - M44 (‘Praesepe’ or ‘Beehive’ Open Cluster) in Cancer

During the years 1890 to 1894, Isaac Roberts took a series of photographs of well-known open clusters including amongst others - the ‘*Double Cluster*’ in Perseus (1890); M44 in Cancer (1891); M34 in Perseus (1892); M38 in Auriga (1892); M52 and M103 in Cassiopeia (1892); M35 in Gemini (1893), M36 and M37 in Auriga (1893), M50 in Monoceros (1893) and M46 in Puppis (1894).



M44 - Isaac Roberts (1891)

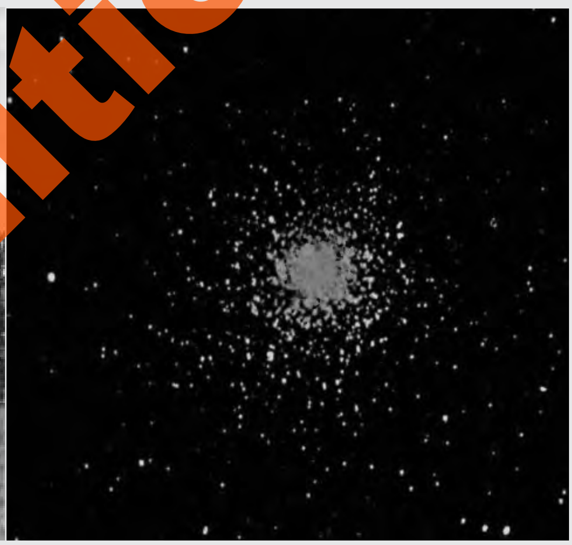
“The photograph [of the ‘Beehive’ or ‘Praesepe’ open star cluster in Cancer] now presented is an enlargement to three and a half times from a negative which was taken on February 13, 1891, and is intended to serve as a chart of the stars between RA. 8h 30m and 8h 38m, declination N. 19° 19’ to 21° 19’, covering four square degrees of the sky. The exposure was given during ninety minutes in the 20-in reflector [at Crowborough, Sussex]. The negative shows many faint stars that cannot be copied on the enlarged photograph, and I propose to engrave (direct from the negative) this and some other clusters, as illustrations of the advantage of the engraving process over the photographic in showing all the stars, including the faintest, that may be on any negative and in eliminating from the chart specks on the film that would in any photo-printing process appear as, and be mistaken for, stars.” This is a description by Isaac Roberts, taken from MNRAS, 1891, Vol. 51, p. 441, and relates to his photograph shown above of the ‘*Beehive*’ or ‘*Praesepe*’, open star cluster in the constellation of Cancer, the Crab, of the 13th of February 1891.

The photograph on the following page of the ‘*Praesepe*’ is by the Austrian amateur Astrophotographer, Walter Koprolin. It was taken on the 6th of February 2005 with 4.9-inch f/3.8 Wright-Newtonian and a Modified Nikon D70 DSLR from Ebenwaldhöhe, Lower Austria. The total exposure time was 12 minutes.

A.37 - M13 (‘Great Hercules Globular Cluster’)

“The photograph [of the ‘Great Hercules’ Globular Cluster (M13)] covers 20.4’ in RA and 16.3’ in Declination, and was taken ... with the 20-inch reflector [at Crowborough, Sussex] on May 28th, 1895, between sidereal time 14h 51m and 15h 51m. With an exposure of the plate during sixty minutes. Scale—1 millimetre to 12 seconds of arc.” This was not the first photograph of the ‘*Great Hercules*’ Globular Cluster (M13), that Isaac Roberts had taken. He had previously imaged it in 1887, from his old Observatory at Maghull, near Liverpool: *“The two photographs (enlarged 3 times and 15 times) are from a negative taken, with an exposure of 60 minutes, on May 22 of this year [1887].”*

M13 - Isaac Roberts (1895)



Daramona House: M13 - William Edward Wilson (1894)

The photograph of M13 shown to the left is by James Edward Keeler, obtained with a two hour exposure, using the 36-inch ‘*Crossley*’ Reflector of the Lick Observatory on the 22nd of June 1900. It is Plate No. 53 in Publications of the Lick Observatory, Volume VIII, ‘*Photographs of Nebulae and Clusters Made with the Crossley Reflector*’. The Globular Star Cluster in Hercules designated as Messier 13 contains some 100,000 individual stars, many of which are more luminous than the sun. The distance of this cluster is 34,000 light years and it forms one of the outermost members of our ‘*Milky Way*’ Galaxy. Many amateur astronomers consider M13 to be the finest example of a Globular Cluster visible to be observers in the northern hemisphere. The Omega Centauri Globular Cluster is the southern sky’s equivalent.

M13 - James Edward Keeler (1900)

Intergalactic Nebulae

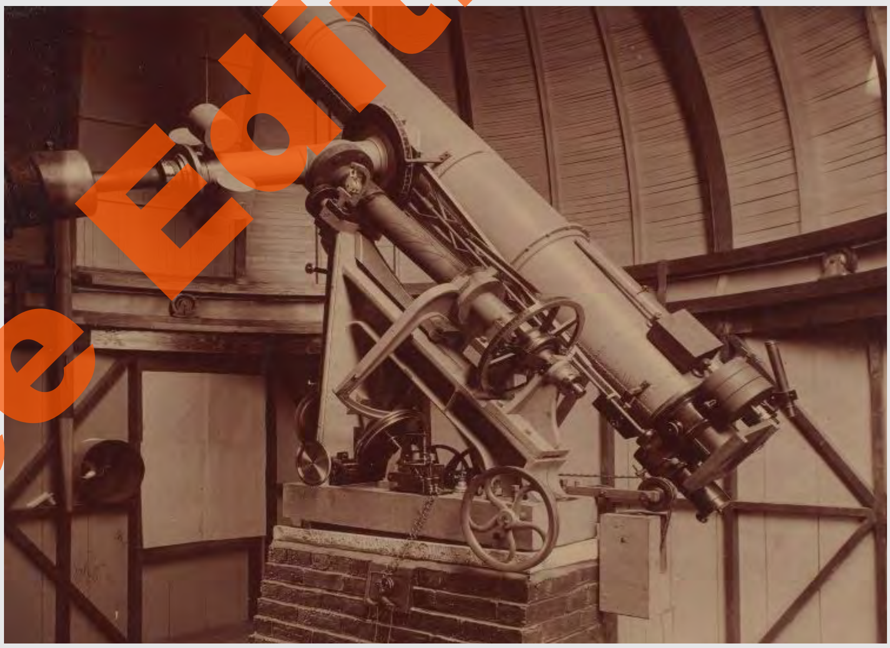
M17 ‘Swan’ Nebula in Sagittarius - James Edward Keeler (1899)

A.39 - M42 (Great Orion Nebula) & A.40 - NGC 1977 (Running Man Nebula) in Orion

The '*Great Orion*' Nebula (M42) was the very first Deep Space Object to be successfully photographed. It was captured by the New York, Doctor, Henry Draper on the 30th of September 1880 with a 51 minute exposure. He took two further photographs, the second on the 11th March 1881 with an exposure of 104 minutes, and the last on the 14th of March 1882, with an exposure of 137 minutes (pictured here to the left). All were obtained with the then relatively new Gelatino-Bromide photographic plates. Although his first photograph only showed the central portion of the nebulae in any detail, his two later attempts with longer exposures, began to show finer detail further away from its core. Later images by Andrew Ainslie Common, William Edward Wilson, James Edward. Keeler and George Willis Ritchey brought out its great size and complex structure. Draper's success gave astronomers the hope of obtaining for the very first time accurate and permanent images of the true nature of these objects which had plagued their very souls for many years, but also the ability to study them from photographs in the comfort of daylight.

M42 - Henry Draper, 14th March 1882

The telescope Draper used by Draper to take his photographs of M42 was a then new 11-inch Alvan Clark Photographic Refractor (pictured right) at his Observatory, next to the family home at Hastings-on-Hudson, New York State. Draper's success in obtaining his photographs of M42 was due not only to the quality of the Clark Refractor and his foresight in using dry plates, but more importantly to the clock mechanism of the mount. He was obliged to construct no less than seven driving clocks before he succeeded in getting one that was perfect.

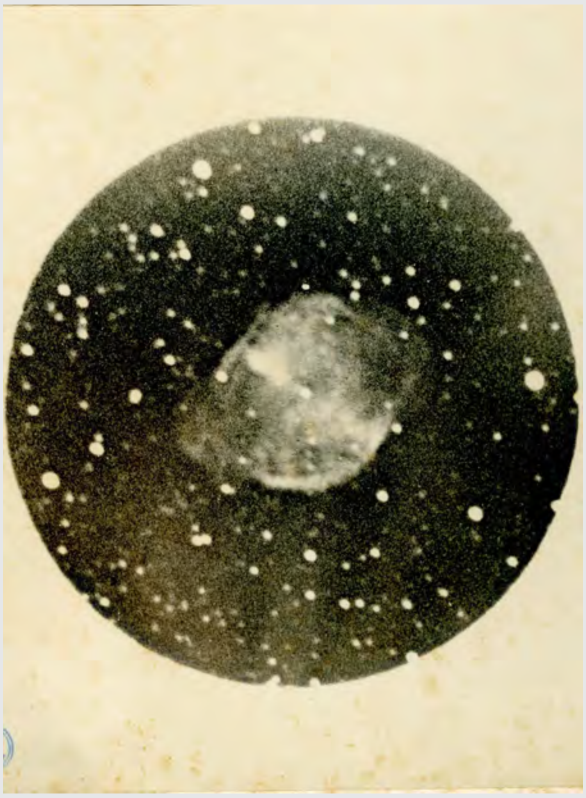


11-inch Clark Refractor of Henry Draper, Hastings-on-Hudson, c1880

"During the night of September 30, 1880, I succeeded in photographing the bright part of the nebula in Orion in the vicinity of the trapezium. The photographs show the mottled appearance of this region distinctly. They were taken by the aid of a triple objective of eleven-inches aperture, made by Alvan Clark & Sons, and corrected especially for the photographic rays. The equatorial stand and driving clock I constructed myself. The exposure was for fifty [sic] [one] minutes." Henry Draper

Henry Draper Observatory - Hastings-On-Hudson in 1880

A.41 - M27 ('Dumbbell' Planetary Nebula) in Vulpecula



The photograph of the famous '*Dumbbell Nebula* (M27), shown left is by Isaac Roberts. It was taken on the 3rd of October 1888 (magnified x15 from the original negative), with a three hour exposure, using his 20-inch Grubb Reflector, at his Observatory at Maghull, near Liverpool, England. It is known that he took at least eight others of M27 whilst at Maghull: *"Seven photographs of this nebula [M27] also were obtained between July 31 and October 10 this year [1887], with exposures varying between 15 minutes and 2 hours duration; but the atmospheric and other circumstances during the opposition this year were unfavourable to long exposures, and the light of the nebula is very feeble. Therefore this photograph taken on August 27 last [1887], with exposure of 90 minutes (enlarged 15 times), does not exhibit the details that could be shown under good conditions, but it is clearly an elliptical nebula, and the drawing of it by Mr. Lassell in the Memoirs of the Society for 1866 (omitting the stars and internal details) agrees well with the photographs, and so also does the drawing by the Earl of Rosse in 1861."* Isaac Roberts, MNRAS, 1887, Vol. 48, p.30.

M27 'Dumbbell' - Isaac Roberts (1888)

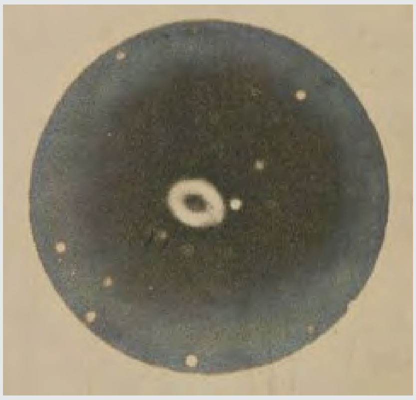
In the Summer of 1890 Isaac Roberts moved his home and observatory from Maghull to a more suitable location: "*The observatory is placed on the summit of Crowborough Hill, in Sussex, which is one of the highest points in the South of England, and commands the horizon around without material obstruction.*" He named his new Observatory, appropriately '*Starfield*'. Sadly it is no more, but was demolished in 1995 to make way for a modern housing estate. Even worse, it was its owners, the local council who sold it to the builder!

'Starfield' - Isaac Roberts' Observatory, Crowborough, Sussex

The photograph to the left of the '*Dumbbell*' is by Marcel De Kérolyr, taken with the 80-cm Forcalquier Reflector. Normally very little is known about his images, but fortunately in this case a silver-gelatin print has survived which gives the following cryptic details. On the front: '*25 Oct. 1932 - Chère Madame et amie ...*" and on the back: *"détails de la Dumbbell pris au 0m 80cm. Je vous l'envoie 'en cachette' car je n'ai pas encore l'autorisation de M. Esclangon — alors ne la montrez pas je vous prie. M. de Kérolyr, [scale :1 mm = 16"5.] 140 x 105 mm."* By way of interpretation the photograph was given by Kérolyr to a friend who he asks not to let on, as he did not have the permission of Ernest Esclangon, the then Director of the Paris Observatory.

M27 - Marcel De Kérolyr (1932)

A.42 - M57 ('Ring' Planetary Nebula) in Lyra



"Seven photographs of this annular nebula [the 'Ring' planetary nebula (M57) in Lyra] were obtained [at Maghull] between July 14 and 31, 1887, with exposures varying between 10 and 60 minutes' duration. The enlargements (one 3 times and the other 25 times) which I now submit are from the negative taken on July 31, with an exposure of 20 minutes. Each of the negatives exposed for 15 minutes and upwards shows with much density the ring. The central star is also visible on each, though it is faintly seen on some..." The photograph shown here dates from the 14th of July 1887, taken with a 60 minute exposure, using his 20-inch Grubb Reflector.

M57 - Isaac Roberts (1887)

On the 1st of September 1886, a Hungarian amateur astronomer named Eugen Von Gothard using a '*mass produced*' 10 inch reflecting telescope photographed for the first time the central star of the famous '*Ring Nebula*' (M57) in the constellation of Lyra. This landmark photograph heralded the rise of the amateur in Astrophotography. Prior to this date '*celestial photography*' was the sole province of the wealthy or the professional astronomer who owned or had access to large and expensive custom made telescopes. He was the first true pioneer of amateur Astrophotography.

M57 (1892 & 1886 - inset) - Eugen Von Gothard

In1874 , the Hungarian aristocrat and astronomer, Baron Miklós Konkoly Thege (1842-1916) purchased a 10.25-inch Equatorially Mounted Reflector 6-feet 5-inches focal length, from the London telescope and scientific instrument maker, John Browning, for own his private observatory. In 1881 he donated the telescope to his friend Eugen Von Gothard to be used in his Herény Astrophysical Observatory. With this telescope and '*Astrokameras*' of his own making he took a series of fine photographs of the Sun, Comets, Nebulae and Galaxies.

Eugene (Jeno) Von Gothard (1857-1909); Miklós Konkoly Thege (1842-1916)

The photograph to the right of the '*Ring*' Nebula is one of the earliest ever obtained. It was taken over four nights from the 8th to the 11th of September 1890 by Louis Montangerand (1866-1943) at the Toulouse Observatory, with a total exposure of nine hours, using its 13-inch CDC Astrograph. He had been employed in 1883 by the Observatory's Director, Benjamin Baillaud, when just seventeen: "*I found this young Montangerand, who seems very good, at Toulouse. I gave him the cot because he had brought only a mattress, blanket, pillow and sheets. For his meals, the easiest thing will probably be to have him board in town, which will make him walk a bit.*

'Annulaire de Lyre' - Louis Montangerand, Toulouse Observatory (1890)

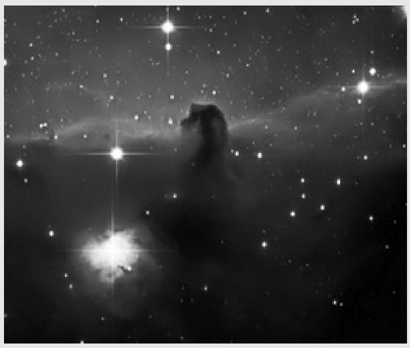
A.43 - B33 ('Horsehead' Nebula) Region of Orion

The first '*sighting*' of the dark nebula B33 in Orion, better known as the '*Horsehead*' Nebula was made by Williamina Paton Stevens Fleming of the Harvard College Observatory on photographic plate B2312, which had been taken on the 6th February 1888 by William Henry Pickering, with an exposure of 90 minutes, using the 8-inch Bache Astrograph. Plate B2312 covered an area of sky about 10 degrees square, of which the inner 7 degrees provided good definition. It was a momentous moment in the History of Astrophotography.

'Horsehead' - William Henry Pickering (1888)

'Horsehead ' - Isaac Roberts (1900) **'Horsehead' - Max Wolf (1901)**

The photograph above left of the '*Grim Reaper's Horse*' is by Isaac Roberts, taken on the 25th January 1900, with an exposure of two and a quarter hours, using his 20-inch Grubb Reflector, at Crowborough, Sussex, England. He described it dismissively as "*...a stream of nebulosity 54 minutes of arc in length [IC434], with an embayment free from nebulosity dividing it in halves...*" The '*wide-field*' image above right, of the Zeta Orionis region, was taken by Max Wolf on the16th January 1901, with the 16-inch Wolf Double Astrograph, at the Heidelberg State Observatory, Germany. Wolf had in fact, independently of Williamina Fleming, discovered the elusive '*Horsehead*' on an earlier plate taken ten years previously on the 2nd of January 1891 (bottom left), in which he used a Kranz-Euryscope Portrait Lens of 5.25-inch aperture, mounted on a 6.4-inch equatorial refractor as a guiding telescope. The total exposure time on the plate was an incredible 5 hours 30 minutes, although the quality of the image was not that good.

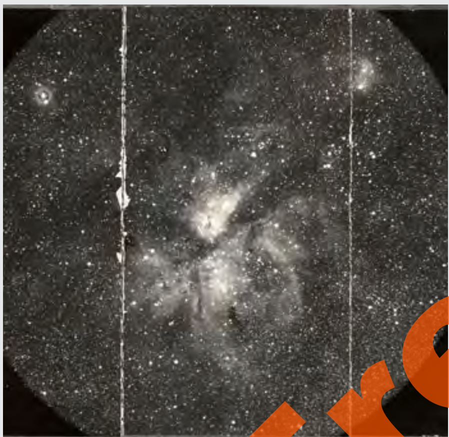


Horsehead: Max Wolf (1891); Edward Emerson Barnard (1913); Author (2009)

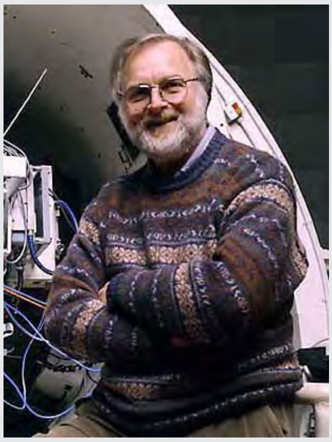
A.44 - NGC 3372 ('Eta Carinae' Nebula)

The Eta Carinae Nebula (NGC 3372) despite being four times larger and even brighter than the '*Great Orion*' its is much less well-known. This is neglect is purely because of its southerly location and the fact that there were less astronomers and large observatories to study it, following its discovery by Nicolas Louis de Lacaille in 1751–52 from the Cape of Good Hope. It is also for this reason why the first known photograph was taken as late as 1890, by Henry C. Russell at the Sydney Observatory. It is a popular target for '*southern*' Astrophotographers, and a '*wannabe*' for those in the north. The nebula takes its name from the white hypergiant star Eta Carina which is found inside its boundaries as are several open clusters, including Trumpler 14 and 16. Within the nebula is a much smaller one, immediately surrounding Eta Carinae, known as the Homunculus Nebula (Latin for Little Man). It is believed to have been ejected in an enormous outburst in 1841 which briefly made Eta Carinae the second-brightest star in the sky.

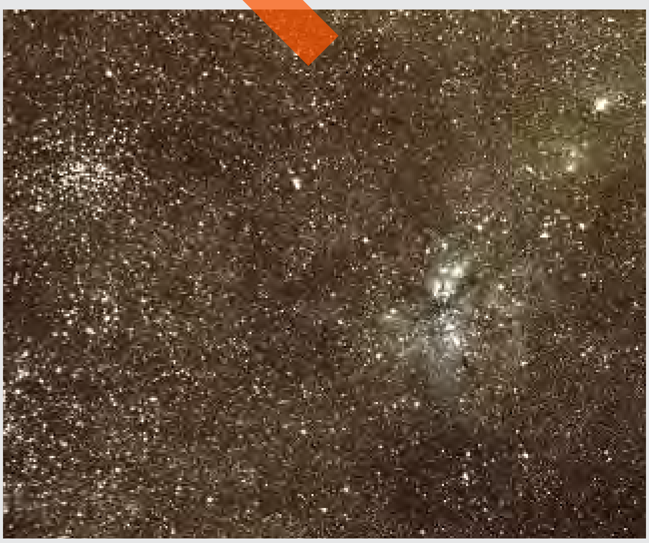
Eta Carinae Nebula - David Malin AAO



The somewhat battered and creased, but nevertheless fine photograph to the left of the nebulosity surrounding the star Eta Carinae was taken on the 2nd of May 1922, with the 24-inch Bruce Telescope of the Harvard College Observatory's outstation at Arequipa, Peru. The exposure used was two hours twenty minutes. The reason it is such bad condition is that it was found folded inside the Boyden Observatory's correspondence book for 1922.



'Eta Carinae Nebula' (1922) - 24-inch Bruce Telescope; David Malin



"Eta Argus [Carinae] taken with the star camera and 5.75 hours exposure...The scale is 12.4 inches = 1°; and it brings out in a satisfactory way most, but not all, that the negative contains... In the denser parts I have counted over 100 stars in a square inch, or more than 3500 stars in a degree, and in some places they run up to 130 in a square inch, upwards of 4500 in a degree, and the enlargement has lost many of the fainter stars visible on the negative. The mottled appearance of the nebula and its vast extent are strikingly brought out. The scale in the original negative is not large enough to divide some of the close groups, hence they appear in the enlargement as one star." Sydney Observatory, 11th April 1891, H. C. Russell.

'Eta Carinae' Nebula (NGC 3372) - Henry Chamberlain Russell (1890)

A.45 - IC 4604 ('Rho Ophiuchi' Nebula) in Ophiuchus

The Rho Ophiuchi Nebula (IC 4604), which takes its name from the star that it envelopes and the constellation in which it is found, is one of the most colourful and imaged parts of the sky. The image of the Rho Ophiuchi region to the left is by David Malin, taken with the 48-inch UK Schmidt telescope at Siding Spring, Australia, shows to perfection the variety of sights to be seen. The bright star to the bottom left, bathed in a yellow glow, is the '*Red Giant*' Antares in the neighbouring constellation of Scorpio; to its right can be seen the more distant Globular Cluster M4 (NGC 6121); and above and to the right of M4 there is a Red Emission Nebula, surrounding Sigma Scorpii.

Rho Ophiuchi itself can be seen near the top within the cloud of Blue nebulosity which surrounds it. A number of '*Dark Dust Lanes*' can also be seen running between all of this. This completes a heavenly scene, that no human artist could ever hope to match or even conceive. The Rho Ophiuchi region represents one of the closest star forming regions in our Galaxy, a mere 400 light years distant, and has as a result, been extensively studied by astronomers.

Rho Ophiuchi Nebula - David Malin - UK Schmidt

The photograph to left is Plate 2 from Part I of an '*Atlas of the Northern Milky Way*' published in two parts between 1934 and 1936, by Frank Elmore Ross in collaboration with Edward Emerson Barnard's niece, Mary Ross Calvert (1884-1974), who was a female '*computer*' at the Yerkes Observatory. It is a magnificent wide-field view of the region of the Rho Ophiuchi Nebula (top), taken in May 1931 at Flagstaff, Arizona, with a Camera having an objective lens of 5-inches in diameter and a 35-inch focal length, built to his own design by the telescope maker James Walter Fecker. (1891-1945) A three hour exposure on an Imperial Eclipse photographic plate was used, showing stars down to as faint as magnitude 17.0. At Flagstaff the camera was attached to the mounting of a 13-inch Reflector.

Wide-field of Rho Ophiuchi Nebula - Frank Elmore Ross (1931)

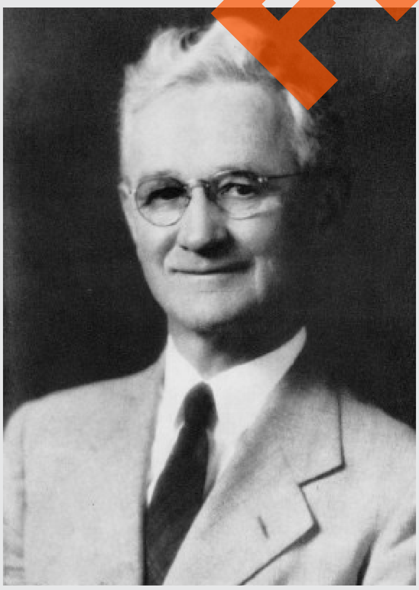
A.46 - M8 ('Lagoon' Nebula) in Sagittarius
A.47 - M20 ('Trifid' Nebula) in Sagittarius

The evocatively named '*Lagoon*' (NGC 6523) in the constellation of Sagittarius, object number 8 in Messier's famous catalogue, is one of the brightest and most beautiful of the many emission nebula to be found in the southern hemisphere. Although visible from more northerly latitudes, it is best seen and imaged from locations south of the equator (see Peter Ward's magnificent photograph featured on page 197).

M8 is an active star forming region, some 4000 to 6000 light years distant. With a large angular size of 90 x 40 arc minutes, and a physical size of 110 by 50 light years, it is much larger and more elongated than that indicated by Keeler's photograph shown here on the left. It is one of only two star forming regions visible to the naked eye in the northern hemisphere, the other being the ubiquitous '*Great Orion*' Nebula (M42).

M8 - James Edward Keeler (1899)

The photograph of the '*Lagoon*' shown above is by James Edward Keeler, obtained with a four hour exposure, using the 36-inch '*Crossley*' Reflector of the Lick Observatory on the 7th of July1899. It is Plate No. 56 in Publications of the Lick Observatory, Volume VIII, '*Photographs of Nebulae and Clusters Made with the Crossley Reflector*'. Keeler's photograph shows it as an oval shaped nebula with a brighter central core. It also hints at the fainter nebulosity outside of the oval, which in the later image by Frank Elmore Ross (1931) clearly extends the nebula into something more resembling a rounded oblong.



Frank Elmore Ross (1874-1960) was one of the finest opticians of the twentieth century specialising in the design and construction of astronomical cameras and correcting lenses. It was his initial training as a Mathematician which enabled him to excel in these areas. He also made practical use of his cameras and lenses by taking magnificent photographs of many well-known astronomical objects, and in particular those of Mars taken in 1926 and Venus a year later, using the 60-inch and 100-inch Mount Wilson reflectors; and his wide-field images of the Northern Milky Way. His correcting lenses were particularly important in that they increased dramatically the size of the usable fields of the '*Great Reflectors*' atop Mount Wilson, and later the 200-inch Hale telescope at Mount Palomar. His magnificent 1931 photograph of the '*Lagoon*' taken with the 60-inch Mount Wilson Reflector (see page 196), is a testament to his greatness as an Astrophotographer.

Frank Elmore Ross (1874-1960)

A.48 - M16/IC 4703 ('Eagle' Nebula) in Serpens Caput
A.49 - NGC 1499 ('California' Nebula) in Perseus

The Messier object, M16 in the constellation of Serpens Cauda (Serpent's Tail), is often referred to as the '*Eagle*' Nebula. It is in fact the open star cluster NGC 6611. The actual nebulosity itself is IC 4703, which was discovered in 1876 by Etienne Leopold Trouvelot, using the 26-inch Refractor at the US Naval Observatory in Washington. Both discoverers of M16, Jean-Philippe Loys de Chéseaux in about 1745, and Charles Messier on the 3rd of June 1746 refer only of a cluster and no nebula. Whatever M16 is, it will always been known as the '*Eagle*', one of the most magnificent of DSOs.

M16 - David Mailn - AAO

The photograph to the right of the '*Eagle*' Nebula is by John Charles Duncan, taken over the two nights of the 25th to 26th of August 1920, using the 60-inch Mount Wilson reflector, with an exposure of 205 minutes on a '*Seed 30*' photographic plate. According to Duncan he was lucky to have captured it so well, because at the time he described the observing conditions as '*thick sky and poor seeing*'. Duncan also gives some background on the history of this object and writes (ApJ, 1920, Vol. 51, pp. 7-8.): "*This object was discovered by Messier in 1764. In the catalogues of Herschel, Webb, Smyth, and Dreyer it is described simply as a star cluster, no mention being made of the nebula, though Messier says the stars are 'mixed with a feeble light.' The nebula was detected photographically by Barnard in 1895 and Roberts in 1897. Though Messier seems to have been the only early observer to perceive the nebula visually, it is no more difficult than the nebula in the Pleiades, and I have seen it easily with the 12-inch refractor of the Whitin Observatory.*"

Note: This image was included in the first of Duncan's six papers on "*Photographic Studies of Nebulae*", published in the years 1920-1949.

M16 - John Charles Duncan (1920)

A.50 - M1 ('Crab' Nebula) Supernova Remnant in Taurus
A.51 - NGC 2237 ('Rosette' Nebula) in Monoceros

The so called '*Crab*' Nebula (M1) in the constellation of Taurus is the remnant of a supernova, which was recorded by Chinese Astronomers in 1054. The image of the '*Crab*' pictured to the right was created by David Malin from photographic plates taken on the Palomar 5m telescope in the 1960s. These plates had been taken in various colors for scientific analysis, but it was also possible to reconstruct and combine three of them (each one in red, green and blue part of the spectrum) to obtain this color image. This is the same principal used in modern digital process of LRGB image combination.

M1 - David Malin (1995)

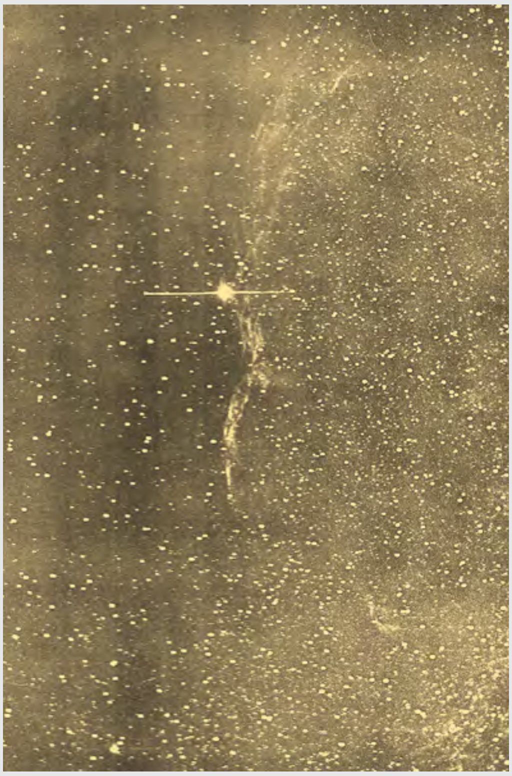
It was William Parsons, 3rd Earl of Rosse, who gave the '*Crab*' its name. It was based a drawing made in around 1844, with his 36-inch Reflector, in which it resembled a Crab. A few years later, when the 72-inch telescope was in service, he produced an improved drawing of considerably different appearance, but the name stuck. In 1844 he gave the following description: "*.. a cluster; we perceive in this, however, a considerable change of appearance; it is no longer an oval resolvable Nebula; we see resolvable filaments singularly disposed, springing principally from its southern extremity, and not, as is usual in clusters, irregularly in all directions. Probably greater power would bring out other filaments, and it would then assume the ordinary form of a cluster. It is stubbed with stars, mixed however with a nebulosity probably consisting of stars too minute to be recognized. It is an easy object, and I have shown it to many, and all have been at once struck with its remarkable aspect.*"

The 'Crab' in 1844 - William Parsons

"*The photograph [M1] covers 15'.3 in RA and 21'.8 in Declination, and was taken with the 20-inch reflector on January 25th, 1895, between sidereal time 4h 30m and 5h 30m, with an exposure of the plate during sixty minutes. Scale—1 millimetre to 8 seconds of arc... The photograph shows the nebula to be elongated in s.f. [south following] to n.p. [north preceding] direction; irregular in outline, and somewhat resembles an island, with deep bays at intervals round its margin. The original negative shows mottling and rifts in the nebulosity, and that one of the rifts curves near the n.f.[north following] margin; another extends across from the n.f. [north following] to the s.p. [south preceding] side, with a star of about the 14th magnitude at its centre. There are also some star-like condensations involved in the nebulosity.*" A description of the '*Crab*' extracted from Isaac Roberts', '*Photographs of Stars, Star-Clusters and Nebulae*', 1899, Volume II, p.169. The earliest known photograph of M1 was also taken by Roberts on the 2nd of February 1892.

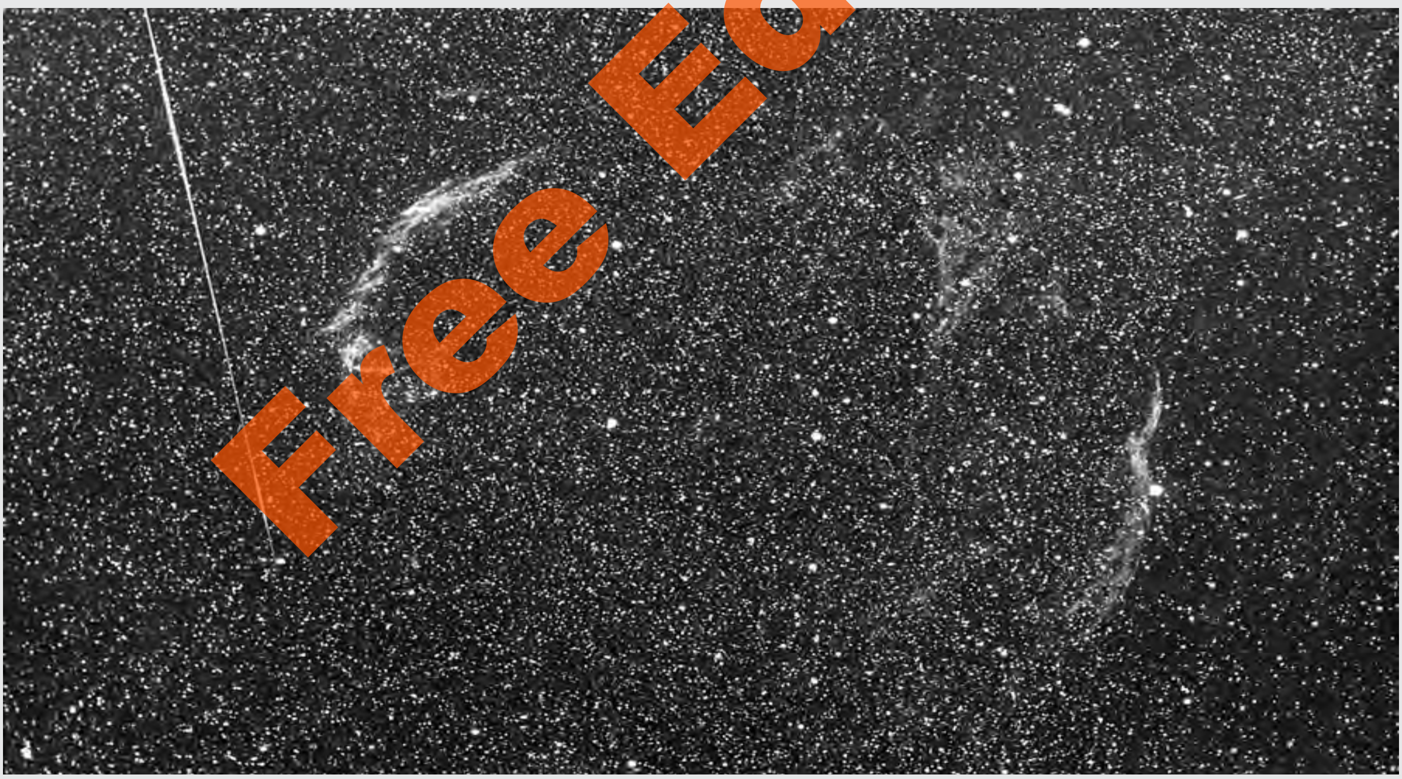
M1 - Isaac Roberts (1895)

A.52 - NGC 6960 ('Witch's Broom' Supernova Remnant) in Cygnus



"The enlarged photograph now presented was made from a negative, taken with the 20-inch reflector, on 1891 September 28, and exposure of the plate during four hours of clear sky, and represents the region round the double star, 52 Cygni, RA 20h 41m, declination 30° 20' N, on the following side of which is the remarkable nebula H V. 15 ['Witch's Broom' Nebula, NGC 6960 in Cygnus]... . It is more than two degrees in length from north to south, and forty-seven minutes of arc in breadth on the following side of 52 Cygni, which it barely touches by a slight projection. The nebulosity is of a very faint streaky character.. The nebula as a whole is not symmetrical, but seems to be made up of detached patches of light covering the large area, and a much longer exposure than four hours will be required to show the connections of these diffused patches of light. It will be observed on examination of the photograph that the stars on the following side of 52 Cygni are very much more numerous than they are on the preceding side. The bright part of the nebula seems to form almost a defined boundary between the stream of the Milky Way stars and those on its preceding side. The straight line across 52 Cygni was caused by a sudden gust of wind during the exposure of the plate.

'Witch's Broom' Nebula NGC 6960 - Isaac Roberts (1891)



NGC 6960 & NGC 6992 - Edward Emerson Barnard (1909)

The above wide-field photograph of the Western and Easter Veil Nebula showing NGC 6960 (towards the bottom right) and NGC 6992 (towards the top left) was taken on the night of the 16th of July 1909 by Edward Emerson Barnard with the 10-inch Bruce Astrograph of the Yerkes Observatory. Note the bright meteor trail to the left of NGC 6992 which is an added bonus to an already magnificent image. It is sad to think that the telescope which took the image is lying in bits in the basement of the Observatory which it served so well for many years.

A.53 - NGC 7000 ('North American' Nebula) in Cygnus
A.54 - IC 5146 ('Cocoon' Nebula) in Cygnus

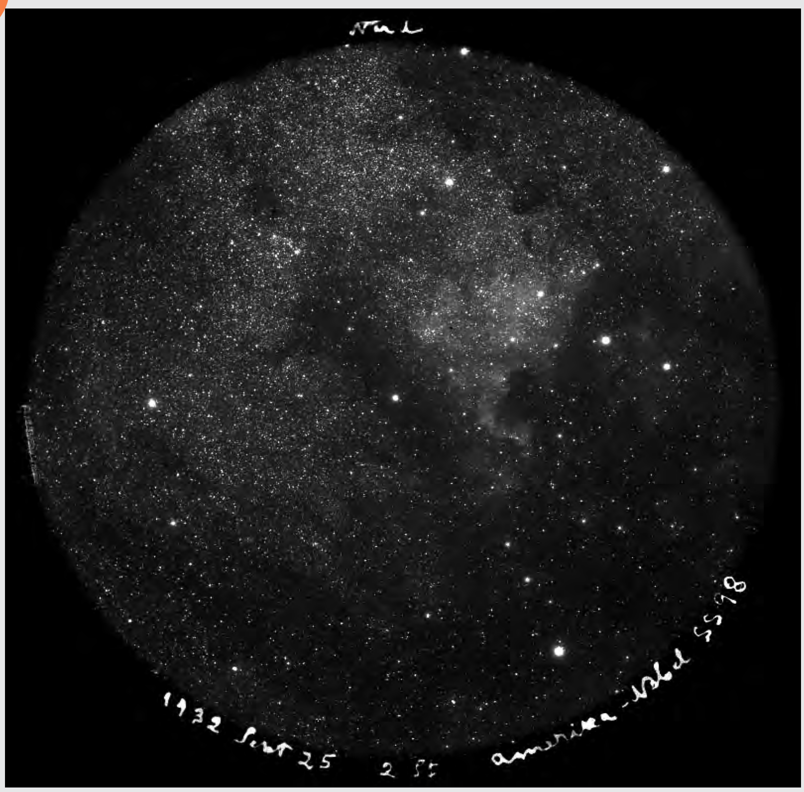
The large emission nebula in the constellation of Cygnus, known as the '*North American*' Nebula (NGC 7000), is so called because of its striking likeness to that continent. Although NGC 7000, was discovered by Sir William Herschel in 1786 it was Max Wolf who first photographed it on the 1st of June 1891 with a 5-inch Kranz portrait lens. In 1901 Wolf named it the '*Der Amerika-Nebel im Cygnus*'. In 1903 Wolf's friend Edward Emerson Barnard wrote a paper which included the footnote: "*The 'North American Nebula' would perhaps be more definite, for it is North America to which Dr. Max Wolf intends the compliment.*"

As a result of Barnard's remarks, Wolf subsequently renamed it the '*North American*', the name by which it is now known. The photograph to the left is a wide-field view of the region of the '*North American*' Nebula, by Edward Emerson Barnard, taken at the Lick Observatory with the 6-inch Crocker Astrograph. It is Plate No. 77 from his '*Photographs of the Milky Way and of Comets..*'

Wide-field of NGC 7000 - Edward Emerson Barnard (1895)

The photograph to the right of NGC 7000 was taken on the night of the 25th/26th of September 1932 by Bernhard Voldemar Schmidt using his prototype 14.5-inch wide-field, Schmidt Camera. That same year, Schmidt published a three page article in the '*Mitteilungen der Hamburger Sternwarte in Bergedorf*' [*Communications of the Hamburg Observatory at Bergedorf*], which contained no mathematics to explain the optics of his design, only four photographs.

These photographs more than justified an optical system, which although ignored in his lifetime, would less than 80 years later be used aboard a '*Great*' Space Telescope, to find the first planets orbiting a distant star. A remarkable achievement for a man who had only one hand, and who was never given an official position at any Observatory.



NGC 7000 - Bernhard Schmidt (1932)

A.55 - NGC 7293 ('Helix' Planetary Nebula) in Aquarius
A.56 - NGC 2261 ('Hubble's Variable Nebula') in Monoceros

In 1937, the new '*Palais de la Decouverte*', built for the '*Paris Exposition Universelle*', opened. The centre piece of the exhibition was crowned by De Kérolyr's montage of the '*Milky Way*': "*The astronomy section is reached by a large stairway surrounded on two sides by a balcony thirty meters long. In this hall are installed the objects which because of their dimensions could not be placed in the rooms. On the floor there is an Orrery thirteen meters in diameter, including, with their movements all the bodies of the solar system whose diameter exceeds 1000 kilometres. On one of the sides of the balcony a panel twenty meters long illustrates with coloured globes in relief, the stellar evolution. On the other side, a photographic reproduction of the northern Milky Way, twenty meters by four and a half, obtained through combining the twenty-nine negatives of M. de Kérolyr of the Paris Observatory Station at Forcalquier.*" Robert Lancement, '*Astronomy at the Palace of Discovery in Paris*', Popular Astronomy, 1940. Vol. 48, pp. 188-195, p. 192.

Helix Nebula NGC 7293 - Marcel De Keroly (c1935)

The above image of the '*Helix*' by Marcel De Kerolyr appeared as Planche XVIII in Giono's '*Le Poids Du Ciel*' and was taken sometime around 1935 with the 80-cm Reflector at Forcalquier. NGC 7293 is a bright (magnitude 7.6) and large (25 arc minutes in diameter) planetary nebula in the faint constellation of Aquarius, known as the '*Helix*'. It was discovered by the German astronomer, Karl Ludwig Harding (1765-1834), probably before 1824, and is one of the closest of all the brightest planetary nebulae, at about 700 light years. It is similar in appearance to the Cat's Eye Nebula (NGC 6543) and the Ring Nebula (M57), but somewhat larger, more akin in size to the well-known Dumbbell Nebula (M27).

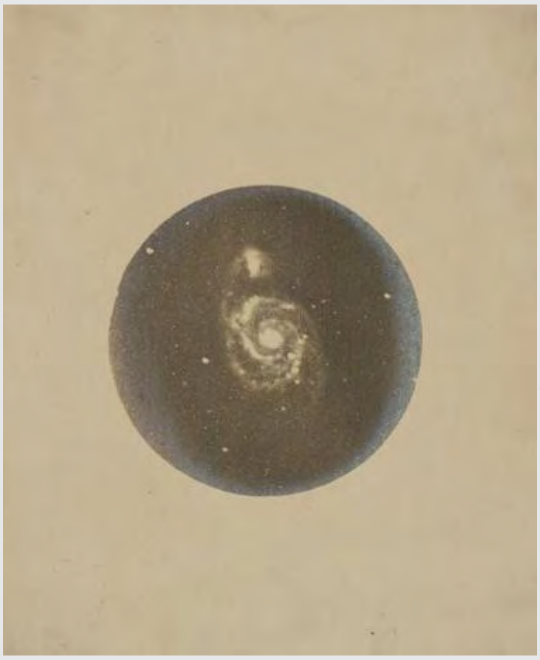
This splendid photograph of the '*Helix*' Planetary Nebula (NGC 7293) in Aquarius is by Edwin Powell Hubble. It was taken with the 100-inch '*Hooker*' Telescope, Mount Wilson Observatory. It was taken around the time Hubble was working on the Classification of Galactic Nebulae, and in 1922 he wrote of what he called the helical nebula in Aquarius: "... NGC *7293, the largest recognized planetary. Photographs made with the 100-inch reflector show three or four small non-galactic nebulae, including one spindle, within the luminous area of the planetary. The great size and galactic latitude of NGC7293 render it highly probable that the planetary is relatively near, at least nearer than the small nebulae, which, therefore, must be considered as shining through the planetary.*" 1922, ApJ, Vol. 56, p. 179.

NGC 7293 - Edwin Powell Hubble (c1922)

Extragalactic Nebulae

NGC 4565 in Coma Berenices - Milton Lasell Humason (1950)

A.57 - M51 ('Whirlpool' Galaxy) in Canes Venatici



"The photograph [of the famous 'Whirlpool' Galaxy (M51) in the constellation of Canes Venatici, the 'Hunting Dogs'] which is now presented is an enlargement to ten times the negative of M 51 Canum Venaticorum, R.A. 13h 25m, Dec. + 47º 45'. The negative was taken on April 28, 1889 [at Maghull, with a 20-inch Grubb reflector], with an exposure of four hours, and it adds considerably to our knowledge of the structure and the surroundings in space of this ... Referring now to the photograph before us, we see much more than the spiral form of a nebula with apparently two distant nuclei, for we see that the spirals have broken up at relatively short intervals into stars which are either coincident with, or very closely follow, all the convolutions of the spiral." Isaac Roberts, MNRAS, 1889, Vol. 49, pp. 389-390.

The earliest known photograph of M51 was that obtained by Andrew Ainslie Common in 1883, with a 36-inch Reflector.

M51 - Isaac Roberts (1889)

"This photograph was taken on the 6th of March. 1897, with an exposure of the plate for 1h 30m. The print here reproduced is enlarged 10 times linear, and shows that the numerous convolutions have an apparent tendency to form into denser knots, which again have cometary tails which are curved like a plume away from the central nucleus. In the original negative both nuclei can be seen to be stellar. Sir J. Herschel, Mr. Lassell, and Lord Rosse have described and drawn this nebula. The latter, using his great 6-feet reflector, depicts it fairly like the photograph, but even with the use of this great instrument he was evidently unable to see the numerous details here photographed."

William Edward Wilson's description of his photograph of the '*Whirlpool*', from '*Astronomical and Physical researches made at Mr. Wilson's Observatory at Daramona Westmeath*", published privately.

M51 - William Edward Wilson (1897)

The photograph of the '*Whirlpool*' shown to the left is by James Edward Keeler, obtained with a four hour exposure, using the 36-inch '*Crossley*' Reflector of the Lick Observatory on the 10th of May 1899. It is Plate No. 47 in '*Photographs of Nebulae and Clusters Made with the Crossley Reflector*'. M51 was the first Galaxy to be recognised as having a '*Spiral*' structure: *"In Sir John Herschel's figure, it appears as two nebulae entirely separate, the one being larger than the other; but when analysed [in 1845] with the great reflector [William Parsons, 72-inch Reflector], it is found to contain many stars, with something like spiral coils issuing from the principal nebula, and throwing off luminous radiations, the stars appearing principally in the spiral lines. The small attendant nebula, too, in place of being separate from the principal one, is connected with it by resolved and unresolved stars, forming a luminous band like a portion of an irregular spiral."* '*Vestiges of the Natural History of Creation*', by Robert Chambers, 1846.

M51 - James Edward Keeler (1899)

A.58 - M31 ('Great Andromeda Spiral' Galaxy)

The photograph of the '*Great Andromeda Spiral*' Galaxy (M31) shown on the left is by Isaac Roberts. It was taken on the 29th of December 1888, with a four hour exposure, using his 20-inch Grubb Reflector, at his Observatory at Maghull, near Liverpool, England. This was not his first of M31 photograph, he had taken one earlier in the year: "*The photograph which accompanies these notes was taken on October 1 last [1888], and it throws a very different light to that hitherto seen by astronomers upon the constitution of the great nebula, and we shall not exaggerate if we assert that it is now for the first time seen in an intelligible form.*" Isaac Roberts, MNRAS, 1888, Vol. 49, p.65. It was however, his very first image of M31 taken on the 10th October 1887 that was Isaac Roberts' own personal favourite of all the 2485 photographs he had taken in the years 1883 to 1904. It is even found on the monument erected to his memory by his widow, Dorothea Klumpke (1861-1942) at the Flaybrick Cemetery, near Liverpool.

M31 - Isaac Roberts (1888)

The photograph to the right of M31 is by Edward Emerson Barnard, taken at the Lick Observatory with the 6-inch Crocker Astrograph. It is Plate No. 4 from Barnard's '*Photographs of the Milky Way and of Comets.*.' M31 like our own '*Milky Way*' is known to contain a class of stars known as Cepheid variables, named after the first of their class, the star Delta Cephei in the constellation of Cepheus. These stars possess a very useful characteristic. The longer the period of their variability the more luminous they are, such that two Cepheids with the same period have the same intrinsic brightness. Furthermore and more importantly this '*Period-Luminosity Relationship*' can be quantified mathematically, which means that knowing a Cepheid's period, its Luminosity (or Absolute Magnitude) can be found and therefore its distance. Cepheids act as '*standard candles*' and were used by Edwin Powell Hubble to measure the distances of the troublesome '*Spirals*', first seen by William Parsons, 3rd Earl of Rosse, possibly as early as the 5th of March 1845, through the eyepiece of his newly completed 72-inch '*Leviathan*' Reflector. In doing so, Hubble showed that our single-lone Galaxy that others had believed, was in fact just one of an almost incalculable number of others spread out across the vast distances of space.

M31 - Edward Emerson Barnard (1895)

Magellanic Clouds: A.59 - LMC in Dorado/Mensa & A.60 - SMC in Tucana

Large & Small Magellanic Clouds - Daniel Verschatse (2003)

The Magellanic Clouds (or Nubeculae Magellani) are two Southern Hemisphere, Irregular Dwarf Galaxies. The Large Magellanic Cloud (LMC) and Small Magellanic Cloud (SMC) are satellites of our *'Milky Way'*, and lie at distances of 163, 000 and 200,000 light years respectively. Although they are now named after the Portuguese explorer, Ferdinand Magellan who saw them on his voyage of 1519-1522, they were in the past often referred to by astronomers as the Nubecula Major and Nubecula Minor.

In 1891, Henry Chamberlain Russell (1836-1907), Government Astronomer, at the Sydney Observatory, New South Wales, Australia, published *'Photographs of The Milky-Way & Nubeculae taken at Sydney Observatory, 1890'*. In it were 14 prints taken from glass negatives on Ilford gelatin photographic plates of the Southern *'Milky Way'* and important Nebulae within it, notably the Large and Small Magellanic Clouds and the Eta Carinae (Argus) Nebula. Two additional plates, one of part of the constellation of Orion, and another of a larger view of the '*Great Orion*' Nebula, were included for comparison purposes with the southern hemisphere plates. Russell was assisted in taking the photographs by James Walter Short (1865-1943), who had been appointed in 1890, to help with the Observatory's 13-inch Photographic '*Carte du Ciel*' Astrograph, then under construction.

Henry Chamberlain Russell (1836-1907)

In 1890 the Sydney Observatory was in the process of constructing a 13-inch Astrograph to be used on the ill-fated '*Carte du Ciel*' Photographic Survey. The equatorial mount was being constructed by the Sydney firms of Mort's Dock & Engineering Co. and the Atlas Engineering Co., but the objective lens was being made by Howard Grubb of Dublin. In 1890, the mount was complete, but the objective lens had not arrived from Ireland. As a consequence Russell's '*Milky Way*' photographs had to '*make do*' with what they had. The most suitable was in fact a 6-inch Dallmeyer Portrait Lens of 32-inch focal length, which gave sharp definition over a field of about 4.5 inches on the 6.5 x 8.5 inch plates.

Sydney Observatory (1874)

A.61 - M65, A.62 - M66 & A.63 - NGC 3628
'Leo Triplet' Galaxies in Leo Major

"The photograph of the nebulae M 65, 66 and H. V 8 Leonis [NGC 3628], R.A. 11h 14m, Decl[ination], 13º 50' North, was taken with the 20-inch reflector [at Crowborough, Sussex] on 1894 February 28, with exposure of the plate during three hours forty minutes, and the copy now presented is enlarged to the scale of 1 millimetre to 24 seconds of arc. **M65**: *"The photograph shows the nebula to be a symmetrical ellipse with a well-defined stellar nucleus surrounded by dense nebulosity, in the midst of which is a spiral ring filled with nebulosity; and this, together with the nuclear condensations, are surrounded with two elliptical rings of nebulosity separated by a dark space. Five star like condensations of nebulosity are involved in the rings, and one bright star is in the dark space between the rings on the south following side of the nucleus. The whole nebula is even more symmetrical than the Great Nebula in Andromeda, and is clearly of that type ; but I have not before seen a spiral with a stellar nucleus, both of which are involved in the dense central nebulosity."* **M66**: *"The photograph shows the nebula to be an imperfect spiral with a well-defined stellar nucleus which forms the pole of the convolutions, involved in which I counted fourteen nebulous and star-like condensations. They are all involved in what appears suggestive of a state of transition into the perfect form of spiral nebulae, several of which have been photographed, and some of them presented to the Society [RAS]."* **NGC 3628**: *"The photograph shows it like a nebulous ring viewed edge-wise, with a large dense central condensation, and that the ring along its periphery is divided into two parts parallel with each other by a broad dark band, or ring, which shuts from view the light of the central condensation. The two extremities of the diameter of the supposed nebulous ring show expansions of the nebulosity, and there are two stars apparently involved in the faint nebulosity at the south following extremity."*

M65 (Top), M66 (Middle) & NGC 3628 (Bottom) - Isaac Roberts (1894)

This was how Isaac Roberts described his photograph (above) of the '*Leo Triplet*'- M65, M66 and NGC 3628, in the constellation of Leo Major which he obtained on the 28th of February 1894, using his 20-inch Grubb Reflector at his '*Starfield*' Observatory, in Crowborough, Sussex, England.

At the time that Roberts presented his photograph of the '*Leo Triplet*' to the Royal Astronomical Society of London, he made the following observation:

"I may add that the time is approaching, if it has not already arrived, when discussion concerning the developments of these gigantic celestial bodies may be profitably undertaken, for reliable evidence showing their forms and structures is rapidly accumulating. The existing classification of the nebulae into bright, faint, very faint, very large, &c., is much too indefinite a description of the objects as they are now depicted to us by photography. They will require a classification which will define the principal characteristics of their forms, structure, brightness, and their spectra." Isaac Roberts, MNRAS, 1894, Vol. 54, pp. 507-509.

It was to be over forty years before Edwin Powell Hubble in 1936, produced his famous '*tuning fork*' classification of these nebulae. When Roberts wrote his words in 1894, it was not known that they were in fact, separate '*star systems*' like our own '*Milky Way*', but lying millions of light years beyond its boundaries.

A.64 - M63 ('Sunflower' Galaxy) in Canes Venatici
A.65 - NGC 4631 ('Whale' Galaxy) in Canes Venatici
A.66 - M101 ('Pinwheel' Galaxy) in Ursa Major

The photograph [of the 'Sunflower' Galaxy (M63) in Canes Venatici] covers 20'.4 in RA and 16'.3 in Declination, and was taken with the 20-inch reflector [at Crowborough, Sussex] on May 14th, 1896, between sidereal time 13h 13m and 16h 8m, with an exposure of the plate during two hours and fifty-five minutes. Scale—1 millimetre to 32 seconds of arc... The photograph shows the nebula to be a right hand spiral, with a bright stellar nucleus in the centre of dense nebulosity. The nebula is viewed rather obliquely, but the convolutions appear to be very regular in form, and studded with a large number of faint stars and stellar condensations." Isaac Roberts, *'Photographs of Stars, Star-Clusters and Nebulae'*, 1899, Volume II, p.103.

M63 - Isaac Roberts (1896)

"The photograph of the nebulae H V. 42 [NGC 4631] ... Comae Berenicis, RA. 12h 38", Decl. 33 deg. North, was taken with the 20-inch reflector [at Crowborough, Sussex] on 1894 March 29, with exposure of the plate during three hours ... is enlarged to the scale of 1 millimetre to 24 seconds of arc... The photograph shows the nebula much resembling a mackerel in form and markings, the head being on the following and the tail at the preceding end... the interior is a mixture of nebulous condensations and stars with fairly well-defined margins, seventeen of which I counted involved in the nebula, besides several condensations of nebulous matter. There is no certain central nucleus, though there is a bright star near the centre, touching the northern edge. The nebula seems to be a circle or an oval seen nearly edgewise, but with the southern edge a little elevated." Isaac Roberts, MNRAS, 1894, Vol. 54, p. 438

NGC 4631 - Isaac Roberts (1894)

From 1883 onwards until his death in 1904, Isaac Roberts (1829-1904) began taking photographs of almost every well known Deep Space Object visible from his observing locations, first from Maghull (until the summer of 1890) near Liverpool and then later at Crowborough, Sussex. In many cases he was the first person to image a particular object and as such it was his eyes which saw the fainter and more elusive of them as they truly are, ahead of any other person who had ever lived. His list is truly impressive and includes many famous objects. In 1886 he first imaged the Dumbbell Nebula' (M27) on the 27th of August; and in 1887 it was the '*Great Andromeda Spiral*' (M31) on the 1st of October. However he did '*lose*' out when it came to the *'Great Hercules*' Globular Cluster (M13), his image of the 22nd of May 1887, is pre-dated by that of the Henry Brothers, who took theirs sometime before the February of 1886.

Isaac Roberts (1829-1904)

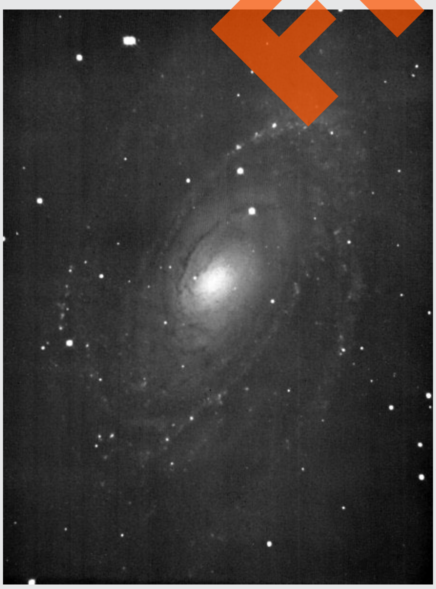
A.67 - M81 ('Bode's' Galaxy) & A.68 - M82 ('Cigar/Staburst' Galaxy) in Ursa Major

"The photographs [of M81 (Bode's Galaxy) and M82 (Cigar or Starburst Galaxy) in Ursa Major] were taken [from Maghull] on March 31, 1889, with an exposure of 3 and a half hours [using a 20-inch reflector]. One is enlarged five times and the other fifteen times the negative, and they show that the nebula M81 is of a spiral character, and so differs from the other nebulae, which have been already photographed, and differs also from the written descriptions of it which have been published by Sir John Herschel and by the Earl of Rosse. Sir J. Herschel refers to it as a 'remarkable object, extremely bright, extremely large, suddenly very much brighter in the middle, and with a bright nucleus.' The Earl of Rosse confirms these statements, and adds that it extends about 8'; from the nucleus to the north and does not extend beyond the first two stars... [M82], particularly the negative, shows it to be probably a nebula seen edgeways, with several nuclei of a nebulous character involved, and the rifts and attenuated places in it are the divisions of the rings, which would be visible as such if we could photograph the nebula from the direction perpendicular to its plane." Isaac Roberts, 1889, MNRAS, Vol. 49, p.362.

M81 & M82 - Isaac Roberts (1889)

The first photographs of the Galaxy pair M81 (*Bode*'s) and M82 (the '*Cigar*' or '*Starburst*') in Ursa Major was by Isaac Roberts on the 31st of March 1889 as described above. This pair is a popular imaging target which can be captured in the same field - one perfect and a nearly '*face on*' spiral; and the other an irregular slender riot of colour and activity. The photograph of M81 and M82 to the right is by the Austrian, amateur, Walter Koprolin. It was taken on the 12th of March 2007, using a 9.5-inch f/4.9 Newtonian Reflector and a Canon 350D from Ebenwaldhöhe, Lower Austria.

M81 & M82 - Walter Koprolin (2007)



The '*face on*' Spiral Galaxy, Messier 81 (NGC 3031) in Ursa Major was first discovered by Johann Elert Bode in 1774, as such it is often referred to as *'Bode's Galaxy*'. In 1779, both Pierre Méchain and Charles Messier re-identified it. It was subsequently listed in Messier Catalogue, as M81. It has often been described as the perfect example of a Spiral Galaxy, with its uniform and graceful arms, especially compared with its near neighbour, M82.

*"In February 1910 two negatives of Messier 81 were secured with the new plate-carrier. The illustration ... is from the one taken February 5; exposure 4h 15m; Seed "23" plate; scale of half-tone plate, 1 mm= 676; enlargement from original negative, 4.1 diameters; In this case*the seeing did not go above 5 (scale of 10)."* Taken from George Willis Ritchey's description, ApJ., 1910, Vol. 32, p. 34.

M81 (Bode's Galaxy) - George Willis Ritchey (1910)

A. 69 - M104 - ('Sombrero Hat' Galaxy) in Virgo
A.70 - NGC 253 ('Sculptor' Galaxy) in Sculptor

"The photograph [of the 'Sombrero Hat' Galaxy (NGC 4594)] covers 20'.1 in RA and 16'.3 in Declination, and was taken with the 20-inch reflector on April 27th, 1897, between sidereal time 13h 6m and 14h 30m, with an exposure of the plate during ninety minutes.. Scale—1 millimetre to 12 seconds of arc... The photograph shows the nebula to be probably a spiral, and that the dark line across it is due to the less dense portion of the convolutions being now turned edgewise in the direction of the earth, thus obscuring a part of the nucleus and of its dense surroundings ; while the light of those parts of the convolutions is too feeble to affect the film. The line therefore appears dark on the photograph, and indicates the thickness or depth of the nebula. Isaac Roberts, *'Photographs of Stars, Star-Clusters and Nebulae'*, 1899, Volume II, p.141.

M104 - Isaac Roberts (1897)

The photograph to the right of the *'Sombrero Hat'* is by Francis Gladheim Pease, taken on the 3rd May 1916, with the 60-inch Reflector at the Mount Wilson Observatory. The exposure time was 132 minutes. Included in his '*Photographs of Nebulae with the 60-inch 1911-1916*'. ApJ, 1917, Vol. 46, p. 41 and Plate VIe. This was the first true *'edge on'* image of this iconic object and shows its '*dust lane*' well.

M104 - Francis Gladheim Pease (1916)

The '*edge on*' spiral M104 (NGC 4594) in Virgo known as the *'Sombrero Hat'*, so called because of its striking resemblance to the broad rimmed Mexican headgear of the same name, is one of the most well-known and photographed of all astronomical objects. In 1921, the French astronomer, Camille Flammarion found Charles Messier's personal Catalogue list, including his hand-written notes. He was able to identify an uncatalogued entry, corresponding to No. 4594 in Dreyer's New General Catalogue. Since then the '*Sombrero Hat*' Galaxy has been universally known as M104, one of the last objects in Messier's Catalogue.

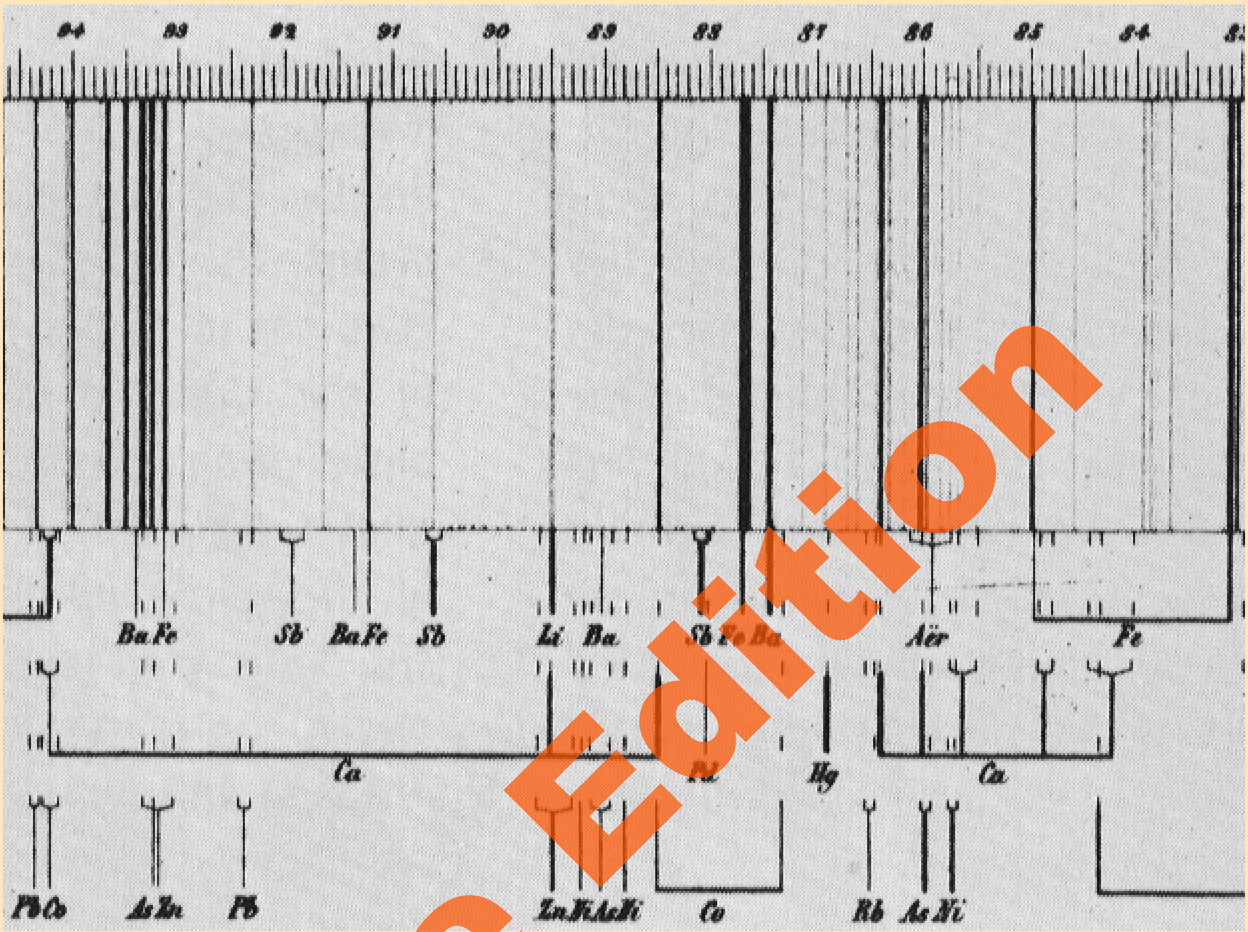
M104 - 200-inch Hale Telescope (2013)

Photographic Astronomical Spectra

Aurora - Northern Norway, Tor-Ivar Naess

6. Rainbows of Heaven

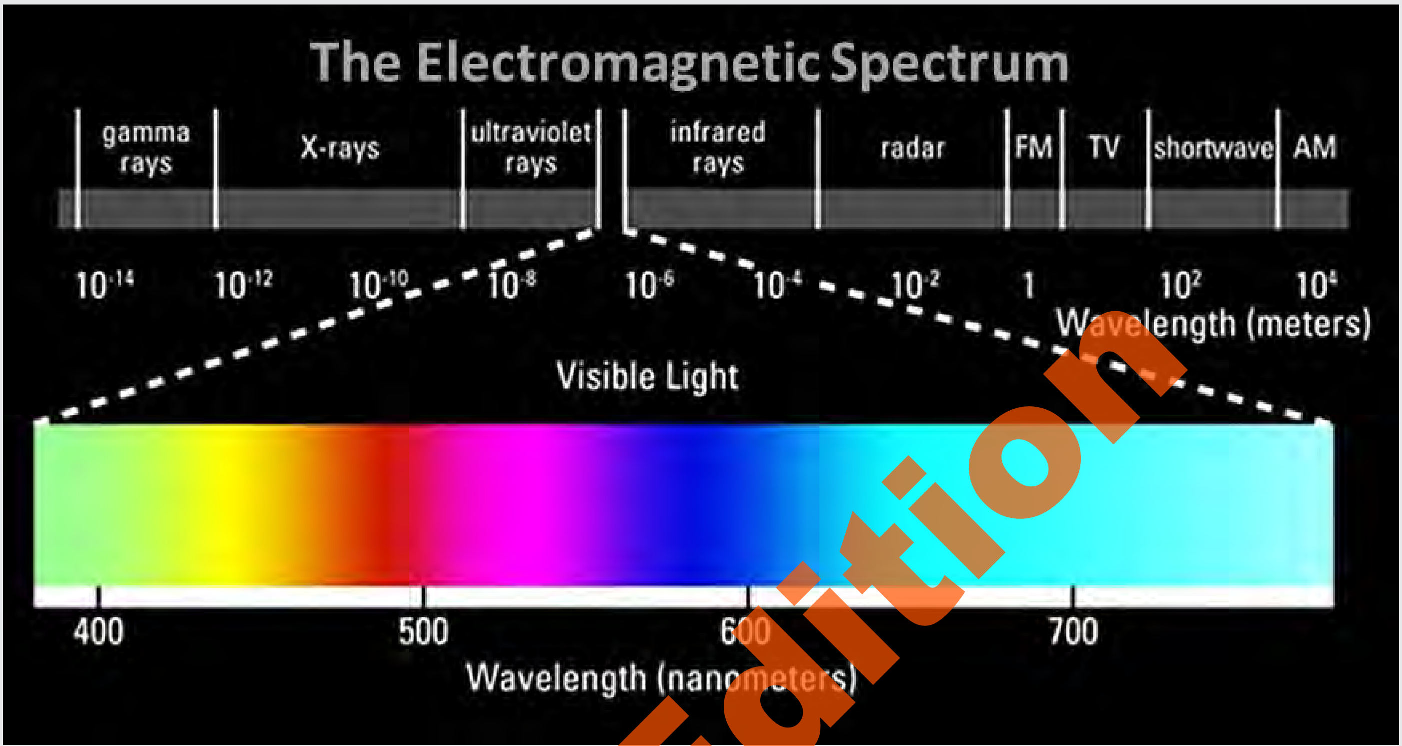
Photographic Astronomical Spectroscopy



**Extract from a Map of Solar Spectrum (1863) by Gustav Kirchhoff.
Showing the Location of the Fraunhofer Lines
And the Chemical Elements that Produced Them**

"One important object of this original spectroscopic investigation of the light of the stars and other celestial bodies, namely to discover whether the same chemical elements as those of our earth are present throughout the universe, was most satisfactorily settled in the affirmative; a common chemistry, it was shown, exists throughout the universe." **The Scientific Papers of Sir William Huggins, Footnote to the 'Spectra of Stars', p. 49, William Wesley & Son, 1909.**

Capturing the Spectra of the Moon, Sun, Planets, Stars, Nebulae and Galaxies is the single most important use of Photography in Astronomical Research. It has proved to be an invaluable tool for the study of the composition and origins of these bodies. More important still it was used to measure Extra-Galactic 'Redshifts'; and was therefore able to put a 'yardstick' on the size of our Universe.



Electromagnetic Spectrum

A Rainbow is one of the most beautiful of all nature's sights. It also gave man one of his first clues in the long road to understanding the complex structure of the Universe. A rainbow is an example of a Continuous Spectrum – i.e. one that shows light at all wavelengths, both visible and invisible. Such a spectrum is typified by the seven colours of the rainbow – Red, Orange, Yellow, Green, Blue, Indigo and Violet, first described in 1671 by Sir Isaac Newton.

These seven colours only represent the visible portion of the Continuous Spectrum. In 1800, the German-English astronomer Sir William Herschel (1738-1822) first showed that the Continuous Spectrum was composed of '*light*' which is invisible – when he detected the rise in temperature of a thermometer beyond the red part of the spectrum – the Infrared. This was followed in 1801, with the discovery of the Ultraviolet part of the spectrum by the German physicist Johann Wilhelm Ritter (1776-1810). We now know that sunlight has a continuous spectrum; made of an electromagnetic radiation of all wavelengths from those of the longest, Radio, through Microwaves, the near Infrared, Visible, Ultraviolet, X-Rays and to the shortest, Gamma Rays. All hot '*blackbodies*' such as the Sun produce a continuous spectrum.

A second type of spectra is to be found in the Universe – discrete spectra, i.e. ones that produce energy at only certain wavelengths. Discrete spectra in turn are classified further into two distinct types - Emission Line Spectra, consisting of one or more bright lines; and absorption line spectra made up of dark lines in an otherwise Continuous Spectrum.

It is these types of Spectra – Continuous and Discrete which provide the fundamental clues as to structure of our Universe. Continuous Spectra are indicative of Stars and Star Systems like our own Milky Way; whilst the Discrete Spectra are indicative of Gaseous Nebulae. It was only with the introduction of the science of Astronomical Spectroscopy in the early years of the nineteenth century, that man had his first glimpse into the true nature of the Universe in which he lived.

A.71 - Spectroscopes & Spectrographs

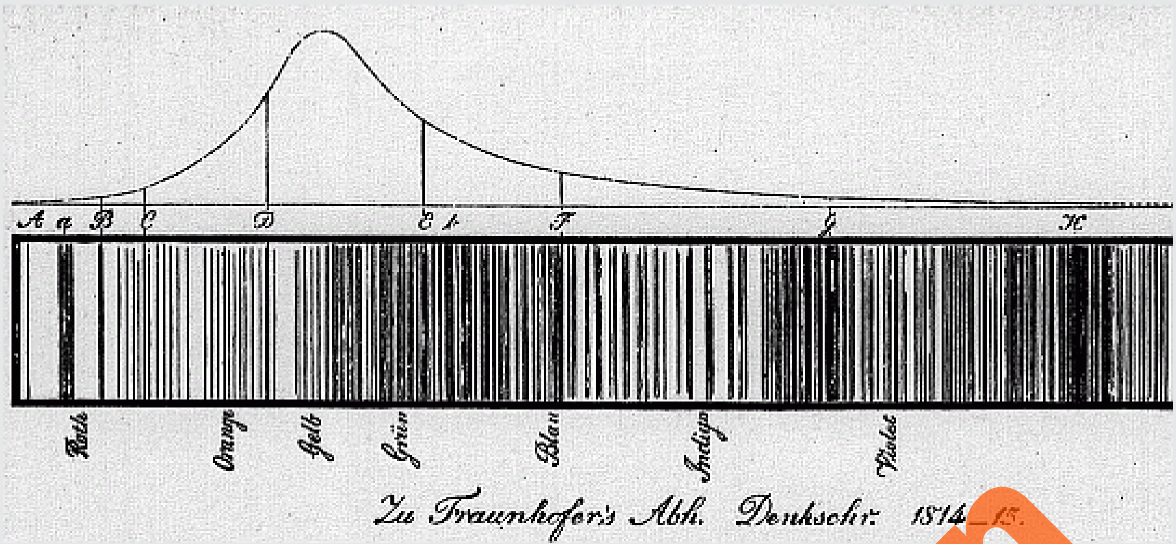
In 1814 Joseph Von Fraunhofer (1787-1826) rediscovered '*Wollaston's Forgotten Lines*', using an instrument known as a Spectroscope (left). This essentially simple device consisted of a prism on a rotating table, with a microscope through which the spectrum of the light source can be seen. By rotating the prism different parts of the spectrum can be seen. A scale of wavelengths is marked on the table, which can be read with the aid of a simple micrometer. With this ingenious device Fraunhofer also observed the spectra of Mars and Venus and a number of the brightest stars, including, Betelgeuse (Alpha Orionis) and Capella (Alpha Aurigae). The design of the spectroscope remained largely unaltered for well over half a century.

The First Spectroscope - Joseph Von Fraunhofer (1814)

Hilger Spectroscope (1875) - Sydney Observatory

In 1875 Henry Chamberlain Russell, the Government Astronomer of New South Wales, purchased for the Sydney Observatory, a Spectroscope made by the London optical instrument makers, Adam Hilger. & Co. In design it was little different from the Fraunhofer's original Spectroscope of 1814. It is believed that Russell made some use of the Hilger Spectroscope, but soon concentrated on the '*Old Astronomy*', including the '*Carte du Ciel*' Photographic Astrometric project. The firm of Adam Hilger & Company was established in 1874 by the German immigrant Johann Adam Hilger (1839-1897). Following Adam Hilger's death in 1897, his younger brother Otto took over the running of the company. In 1902, Otto Hilger (1850-1902) died and Frank Twyman (1876-1959) took over as General Manager. Prior to the First World War their main products had been optical parts, sold mainly to range-finder manufacturers Barr and Stroud, and the manufacture of specialized finished instruments, including Spectroscopes and Spectrographs. After the end of WWI a significant holding in the company was sold to T. Cooke and Sons of York without knowing that Vickers held the majority of shares in Cooke. The new parent company wished to bring Hilgers into line with the rest of its organization; Twyman did not believe this to be in the best interests of Hilgers and, in 1926, bought back the shares. In 1948, Adam Hilgar Ltd., was amalgamated with E. R. Watts and Son as Hilger and Watts Ltd. In 1969 it was taken over by the Rank Organisation.

A.72 - Solar Spectrum

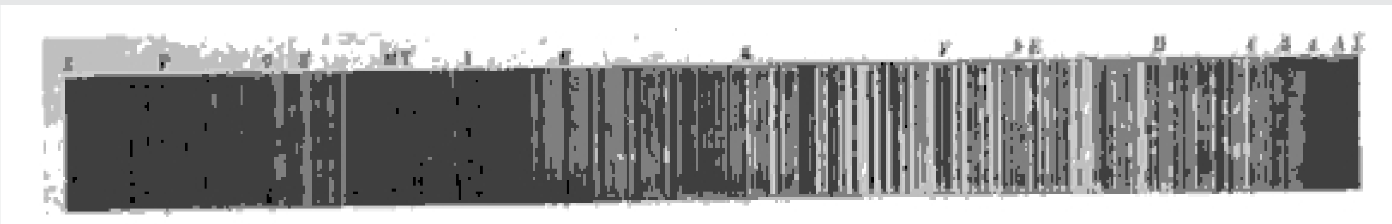


Drawing of Solar Spectrum 1814 - Joseph Von Fraunhofer

In 1814 Joseph Von Fraunhofer was working for the Reichenbach & Utzschneider Glassworks at Benediktbeuern in Germany. It was here that he discovered the dark lines in the Solar Spectrum which now bear his name. At the time he was studying the refraction and dispersion properties of different kinds of glass with the aim of making improvements to the design of achromatic refracting telescopes. To do this he set up a series of experiments with his various samples of glass to determine whether sunlight produced the same results as the light from a lamp he had been using. When Fraunhofer shone a small beam of sunlight onto his prism, he was surprised to find a vast number of dark lines, 574 in total in the Solar Spectrum. The most marked of these he catalogued, denoting them by letters—the same nomenclature, by which they are often referred to even now. In particular, the Fraunhofer C, F, G and h lines correspond to the alpha, beta, gamma and delta lines of the Balmer series of emission lines of the Hydrogen atom.

Alexandre Edmond Becquerel (1820-1891) was a French physicist and optician who is best known today for his work on Light and the Solar Spectrum. On the 13th of June. 1842 he took one of the earliest (and probably the first) photograph of the Solar Spectrum and its Fraunhofer Lines. In 1840 he discovered that the silver halides, normally insensitive to red and yellow light, became sensitive to these wavelengths when subjected to blue, violet and ultraviolet light. As a consequence Daguerreotypes and other photographic materials could be developed by bathing them in strong red or yellow light rather than the usual chemicals. In practice this technique was rarely used. In 1848 he was even able to produce colour photographs of the Solar Spectrum, but the exposures required were extremely long and impractical. Also the images could not be '*fixed*' and Becquerel's '*rainbow*' remained only if kept in total darkness.

Alexandre Edmond Bequerel (1820-1891)



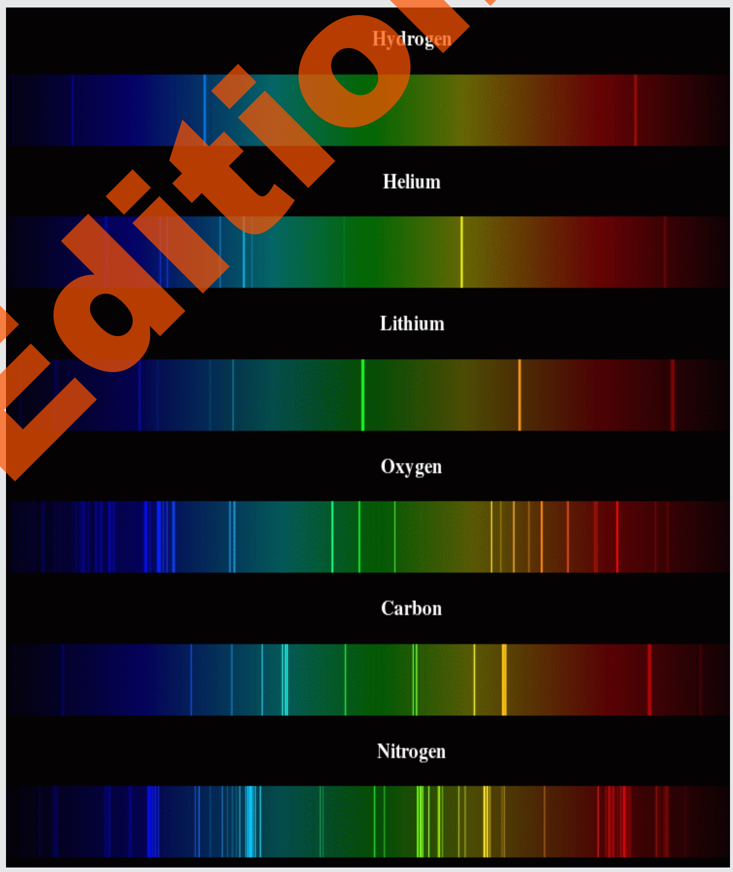
Photograph of Solar Spectrum - Alexandre Edmond Bequerel (1842)

A.73 - Emission Lines

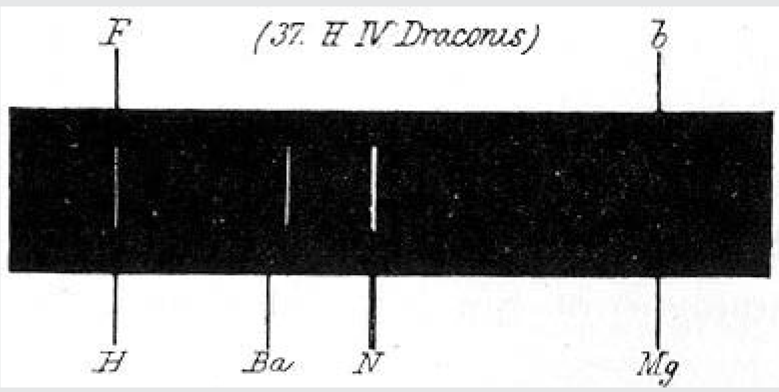
William Huggins (1824-1910) often called the '*Father of Astronomical Spectroscopy*', made from his Observatory at Tulse Hill in South London, extensive visual and photographic observations of the spectra of '*fixed stars*', the moon, planets and '*nebulae*' (inter-galactic & extra-galactic) over the period beginning in1863 and ending with his death in 1910. For 35 years from 1875 to 1910, he was assisted in his work by his wife, Margaret Lindsay Murray (1848-1915). During the course of his work he showed that the Universe was made up of the same elements that were present on the Earth, as well as showing that emission nebulae such as the '*Great Orion*' (M42), were made up of both gas and stars; whilst planetary nebulae, like M27 were purely gaseous. He also suspected that the '*Great Andromeda Spiral*' (M31) had a continuous spectrum, indicating that it was be made up of stars .

Father of Astronomical Spectroscopy - Sir William Huggins (1824-1910)

In 1865 William Huggins turned his attention to the '*Great Orion*' Nebula: "*The results of telescopic observation on this nebula [M42] seem to show that it is suitable for observation as a crucial test of the correctness of the usually received opinion that the resolution of a nebula into bright stellar points is a certain and trustworthy indication that the nebula consists of discrete stars after the order of those which are bright to us. Would the brighter portions of the nebula adjacent to the trapezium, which have been resolved into stars, present the same spectrum as the fainter and outlying portions? In the brighter parts, would the existence of closely aggregated stars be revealed to us by a continuous spectrum, in addition to that of the true gaseous* matter? *The telescope and spectrum apparatus employed were those of which a description was given in my paper already referred to. The light from the brightest parts of the nebula near the trapezium was resolved by the prisms into three bright lines, in all respects similar to those of the gaseous nebulae...*"



Emission Line Spectra of Common Elements in the Universe



On the 29th of August 1864, William Huggins observed the spectrum of the '*Cat's Eye*', Planetary Nebula (NGC 6543), 37 H IV Draconis (in William Herschel's Catalogue) and found a single bright emission line produced by the inert gas Nitrogen as well as fainter emission lines of Hydrogen, Barium and Magnesium. A spectrum consistent with NGC 6543 being a purely gaseous nebula.

A Drawing of the Spectrum of NGC 6543, William Huggins, 1864

A.74 - Stellar Spectra

The photographs of the spectra of Arcturus (Alpha Bootis), class A1 and Al Jabhah (Eta Leonis), class A0, shown left, were taken by Edwin Brant Frost and Walter Sydney Adams using the Bruce Spectrograph at the Yerkes Observatory, shortly after its completion in around 1901.

Stellar Spectra: Arcturus (Top); Eta Leonis (Bottom)

The pioneering work of Fraunhofer, Kirchhoff and Bunsen in the field of Astronomical Spectroscopy, had showed that the dark Absorption ('*Fraunhofer Lines*') present in the Spectra of the Sun and Stars were an indication of their chemical composition and the elements of which they were made. As a direct result, William Huggins, together with his friend and neighbour, the noted chemist, Dr. William Allen Miller, decided to pursue their own research on the '*Spectra of the Fixed Stars*'.

In 1863 and 1864 they published a series of papers which showed that each star exhibits a sample of the same lines visible in the Solar Spectrum. Their work was a great step towards the conclusion that the same chemical elements are the building blocks of everything in the Universe. Of the 46 stars studied only two were subject to a detailed examination by Huggins and Allen, i.e. Aldebaran (Alpha Tauri) and Betelgeuse (Alpha Orionis). A further nine, Arcturus, Beta Pegasi, Capella, Deneb (Alpha Cygni), Pollux, Procyon (Alpha Canis Minoris)), Rigel (Beta Orionis), Sirius (Alpha Canis Majoris) and Vega (Alpha Lyrae) were looked at briefly and some analysis of their spectra was carried out. The spectra of the remaining 35 were subject to only a cursory investigation. In the case of Aldebaran and Betelgeuse, their spectra were compared with that of the Sun and those of sixteen terrestrial chemical elements to determine which non metals and metals were to be found in these two stars...

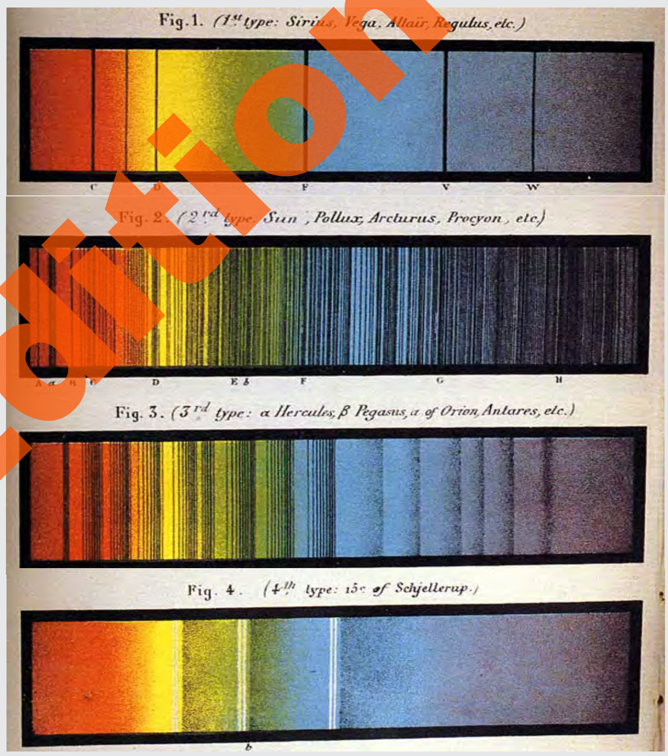
They found that of the sixteen elements found on the Earth: "*Nine of these spectra exhibited lines coincident with certain lines in the spectrum of the star. They are as follows:—sodium, magnesium, hydrogen, calcium, iron, bismuth, tellurium, antimony, and mercury.*" In 1875 William Huggins married Margaret Lindsay Murray (1848-1915), the daughter of a Dublin Solicitor. Although William Huggins had been introduced to photography at the early age of fifteen, he made little use of it until after his marriage. However by 1876 Huggins was once again using photography and successfully, almost certainly due to the influence of his new wife, who was herself an experienced photographer. In the following years Photography became an integral part of their spectroscopic work, for it soon became apparent that Margaret Huggins was not only his wife, but a very capable co-worker, and remained so for the next 35 years until William Huggins' death in 1910.

Lady Margaret Lindsay Murray Huggins (1848-1915)

A.75 - Stellar Classification

In 1860, the Italian astronomer Giovanni Battista Donati (1826-1873), began a series of observations on the '*Spectra of the Fixed Stars*', the results of which he published in 1862 (see MNRAS, 1863, Vol. 23, pp. 100-107). The chief feature of Donati's classification was his separation of the various stars according to their colours. He classified Sirius, Vega, Procyon, Fomalhaut, and Rigel as white stars; Altair and Capella as yellow stars; Arcturus and Pollux as orange stars; and Aldebaran, Betelgeuse, and Antares as red stars. From his observations it became clear that the spectra of stars were closely related to their colour. However Donati's approach did not begin to explain what stars were made of. This could only be done by classifying them according to observed characteristics in their Spectra.

Giovanni Battista Donati (1826-1873)



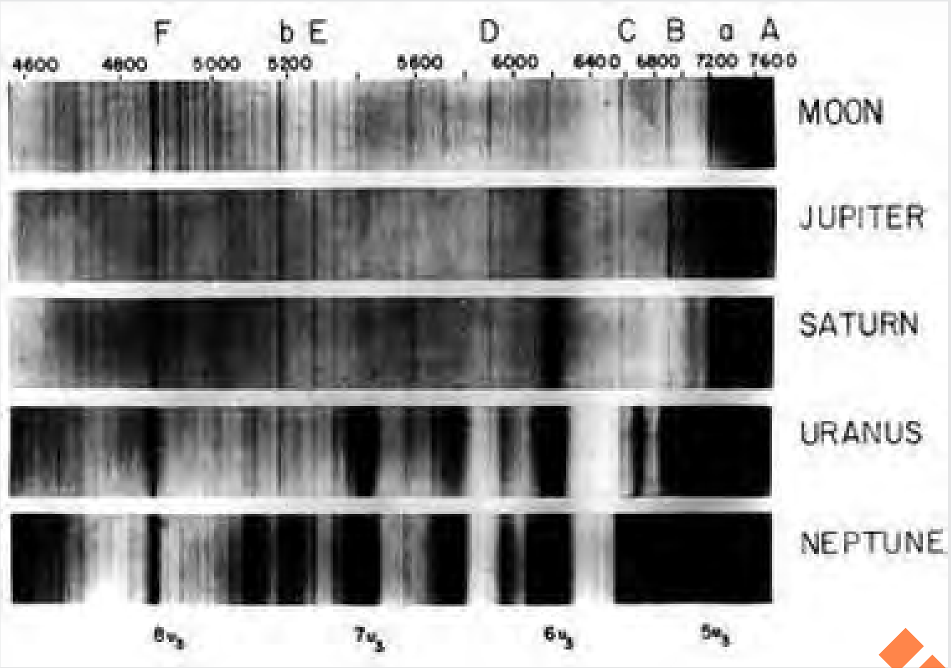
The earliest attempt at classifying stars according to the differences observed in their Spectra was carried out by, Lewis Morris Rutherfurd (1816-1892). In the December of 1862 he published a paper in the American Journal of Science, which ended with the first tentative steps towards a system for the classification of stellar spectra:

"The star spectra present such varieties that it is difficult to point out any mode of classification. For the present I divide them into three groups: First, those having many lines and bands and most nearly resembling the sun, viz., Capella, Beta Geminoram, Alpha Orionis, Aldebaran, Gamma Leonis, Arcturus, and Beta Pegasi. These are all reddish or golden stars. The second group, of which Sirius is the type, presents spectra wholly unlike that of the sun, and are white stars. The third group, comprising Alpha Virginis, Rigel, etc.; are also white stars, but show no lines; perhaps they contain no mineral substance or are incandescent without flame."

The Four 'Secchi Classes' of Stellar Spectra

The first system of Stellar Classification to receive wide spread acceptance was that of the Italian Jesuit Priest, Father Pietro Angelo Secchi (1818-1878). In 1863 he had begun a detailed study in which he analysed the spectra of some 4000 stars and by 1866 he had classified them into three specific types. In 1868 he added a fourth type. These four types later became known as '*Secchi Classes*', and for a number of years represented the definitive system of classification. A fifth Class was added in 1877. Even as late as the 1890s it was widely used by a number of astronomers. *"**Type I**: This includes the white or blue stars ... Sirius, Vega, Altair and many of the brighter stars are examples. The spectrum is characterized by the breadth and intensity of the dark lines of hydrogen. The metallic lines are very faint or entirely absent. **Type II**: These are the yellow stars like our sun. Their spectrum resembles that of the sun very closely, consisting of a great number of fine dark lines. Pollux, Capella and Arcturus are good specimens. **Type III:** This class includes the red and orange stars and most of the variable stars. The spectrum is crossed by numerous dark bands or flutings, which are sharply defined on the blue side and shade off towards the red. Alpha Orionis, Alpha Herculis, Antares and Omicron Ceti are good examples. **Type IV:** This includes a small number of faint stars, mostly of a deep reddish color. The spectrum resembles that of Type III ... The star 152 Schjellerup is the best example of this class."* Julius Scheiner, '*Die Spectralanalyse der Gestirne*', 1894. Translated by Edwin Brant Frost.

A.76 - Lunar, Planetary & Cometary Spectra



In 1902, Vesto Melvin Slipher of the Lowell Observatory began a programme of photographing Planetary Spectra. Even at that time no real progress had been made in identifying the constituents of planetary atmospheres, save that the Moon had none, but Mars had at the very least a tenuous one, and the Giant planets had very extensive ones. In 1931 his work was discussed by Rupert Wildt, who interpreted some of the absorption bands of Jupiter as belonging to the toxic gases Ammonia and Methane.

Lunar & Planetary Spectra - Vesto Melvin Slipher (1904-5)

Following his work on the photographic spectra of Uranus and Neptune in 1904, and that of Jupiter and Saturn in 1905, Slipher repeated it, this time making use of the latest red sensitive photographic plates:

"*In 1906 and 1907 the writer, through experimenting with the new sensitizing dyes - pinachrome, orthochrome T, pinaverdol, pinacyanol, pinachrome blue, homocol and dicyanin, found a combination of dyes which renders the commercial dry plate fairly uniform into the red as far as to wave-length 7000, beyond which point it drops rather rapidly, but is sufficient at A to faintly record that line in the prismatic Solar Spectrum. This plate has accomplished much by bringing under observation a new region of the spectrum—one peculiarly susceptible to selective absorption by planetary atmospheres. With the aid of it the spectra of Jupiter, Saturn, Uranus and Neptune have now all been photographed with greater extension into the red than any previous photographic or visual observations, and a number of lines and bands have been discovered.*" Vesto Melvin Slipher, Lowell Observatory Bulletin No. 42, '*The Spectra of the Major Planets*', p. 231.

The earliest work on the spectra of the major planets was carried out by Fraunhofer, who wrote in 1817: "*The spectra of the light of Mars and Venus contain the same fixed lines as the sunlight, and these lie in exactly the same position, — at least the D, E, b and F lines do, whose relative position could be accurately determined…*" In these few words, Fraunhofer had hit upon the problem faced by astronomers during the early years of Planetary Spectroscopy, that the observed spectra of the planets merely mirrored to a large extent that of the Sun, as a result of sunlight being reflected from their atmospheres. The secret to the successful study of the spectra of planets was therefore to remove the spectral lines produced by the Sun from the planet's spectrum, and the spectral lines that were left were by implication those produced by the atmosphere of the planet itself.

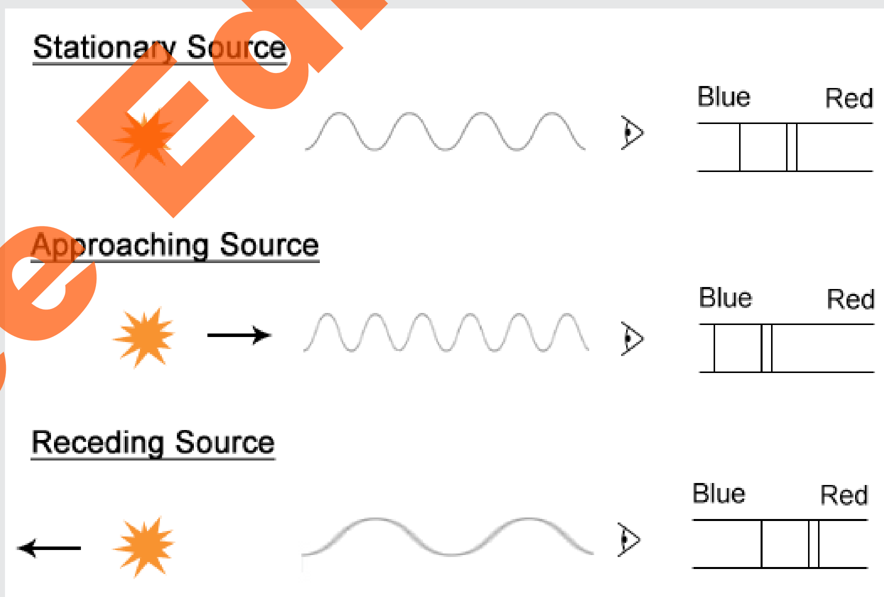
The first detailed work on the spectra of the moon and planets by telescopic means was carried out by Huggins and Miller in the period 1862 to 1864. Initially they saw nothing other than the '*mirrored*' lines of the Solar Spectrum, but after "*we have had a spectrum apparatus constructed by Mr. BROWNING, optician, of the Minories [London]… The imperfect evidence which analysis by the prism affords of the existence of atmospheres around these planets, notwithstanding the high probability, amounting almost to certainty in the case of Jupiter, that such atmospheres do exist, may receive an explanation in the supposition that the light is chiefly reflected, not from the planetary surfaces, but from masses of cloud in the upper strata of their atmospheres.*"

A.77 - Doppler Shifts

Christian Andreas Doppler (1803-1853) was an Austrian physicist and mathematician, whose greatest claim to fame is the paper he published in 1842 entitled: "*Über das farbige Licht der Doppelsterne und einiger anderer Gestirne des Himmels*" (On the coloured light of the binary stars and some other stars of the heavens). In it Doppler sought to explain (incorrectly) the colour of binary stars by postulating that the observed frequency of a wave depends on the relative speed of the source and the observer. If a star were to be moving towards us its colour would shift towards the blue part of the spectrum, the greater the speed the bluer it would look. Similarly if the star was receding from us its colour would appear redder, i.e. its light would exhibit a '*redshift*'.This phenomenon is now known as the '*Doppler Effect*'. The Doppler effect of sound was verified by Buys Ballot in 1845. It would be some years later before its applicability to light was shown by experimental observation to be true, when Hermann Carl Vogel and Wilhelm Oswald Lohse in 1870, measured the Doppler shift in the Sun's rotation.

Christian Andreas Doppler (1803-1853)

The first attempt at measuring the Doppler Shift in stars was published by William Huggins in 1868, with his somewhat inaccurate* results on the radial velocity of the '*Dog*' star, Sirius: "*There remains unaccounted for a motion of recession from the earth amounting to 29.4 miles per second, which we appear to be entitled to attribute to Sirius.*" *The modern value is around - 4.7 miles per second [−7.6 km/s'], Huggins' value was both an overestimate and in the wrong direction; the minus means it is approaching the Sun.



Doppler Effect in Stars

Huggins in his 1868 paper gave some background to the '*science*' involved his studies: "*In 1841, Doppler showed that since the impression which is received by the eye or the ear does not depend upon the intrinsic strength and period of the waves of light and of sound, but is determined by the interval of time in which they fall upon the organ of the observer, it follows that the colour and intensity of an impression of light, and the pitch and strength of a sound will be altered by a motion of the source of the light or of the sound, or by a motion of the observer, towards or from each other.*" William Huggins, "*Further Observations on the Spectra of some of the Stars and Nebula, with an Attempt to determine there from whether these Bodies are moving towards or from the Earth, also Observations on the Spectra of the Sun and of Comet II., 1868*", Phil. Trans. Roy. Soc, 1868, Vol. clviii, p. 529. At the time it was not entirely accepted that the '*Doppler Effect*' was true for anything other than sound, and the leap to include its applicability to light was a bold move on Huggins' part. However, work by the likes of James Clerk Maxwell and others were influencing the scientific community towards leaning in favour of this view.

A.78 - Galactic Spectra



Vesto Melvin Slipher (Left); Edwin Powell Hubble (Middle); Milton Lasell Humason (Right)

It had been known for sometime before Edwin Powell Hubble began his work on the distances to the '*Spirals*' in the 1920s that the wavelengths of the absorption lines in their spectra were in the main shifted towards the red, due to the fact that they were receding away from us at great velocity. Hubble has often been incorrectly credited with discovering this '*redshifts*' in the Galaxies. The existence of high radial velocities in the Extra-Galactic '*Nebulae*' had in fact first been observed in 1912 by Vesto Melvin Slipher (1875-1969) at the Lowell Observatory, in Arizona, when he obtained a '*blueshift*' for M31, corresponding to an approaching radial velocity of -300 km/s. Two years later in August 1914 Slipher presented his results on the spectroscopic observation of fifteen '*nebulae*' to a meeting of the American Astronomical Society. Out of the 15 galaxies he observed, 9 had significant '*redshifts*' and 2 others were redshifted (see table below). This was before Hubble had even begun his Ph.D Research (which he completed in 1917). Slipher's work was carried out using the Lowell Observatory's Brashear Spectrograph with its 24-inch Clark Refractor. The photographs of the Spectra were taken with a 3.25-inch Voigtländer Portrait Camera, which replaced the usual 18.5-inch camera, in order to reduce the exposure times by a factor of 30.

N.G.C.	Velocity	
221	— 300 km	These nebulae are on the south side of the Milky Way.
224 †	— 300	
598	—	
1023	+ 200 roughly	
1068	+ 1100	
7331	+ 300 roughly	
3031	+ small	These are on the north side of the Milky Way
3115	+ 400 roughly	
3627	+ 500	
4565	+ 1000	
4594	+ 1100	
4736	+ 200 roughly	
4826	+ small	
5194	± small	
5866	+ 600	

Radial Velocities of 'Spirals' - Vesto Melvin Slipher (1914)

Photographic Maps of the Stars

Orion at Night - Martin McKenna (2014)

7. Surveyors of the Sky

Photographic Maps of the Stars

Royal Belgium Observatory(Uccle)- Carte Du Ciel Astrograph

" ...to catalogue the stars on each plate, to measure them for the purpose only of getting their places written down, would be the most utter waste of time, labour, and money that it could enter the mind of man to conceive."

Andrew Ainslie Common (1841-1903) & Herbert Hall Turner (1861-1930), commenting on the Carte Du Ciel Project of 1887.

"The history of the Astrographic Catalogue endeavour is one of dedicated individuals devoting tedious decades of their careers to a single goal. Some believe it is also the story of how the best European observatories of the 19th century lost their leadership in astronomical research by committing so many resources to this one undertaking. Long portrayed as an object lesson in over ambition, the Astrographic Catalogue has more recently turned into a lesson in the way that old data can find new uses."

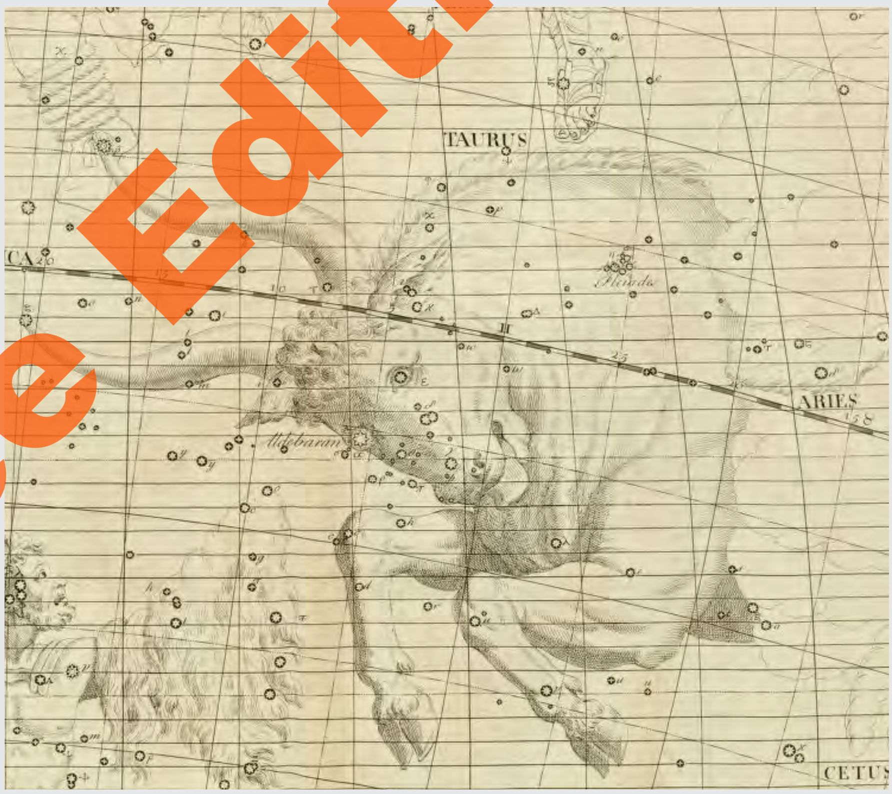
Sean Urbain of the US Naval Observatory, commenting in 1998 of the ultimate redemption of the Carte Du Ciel Project.

The earliest known attempts by man to chart the heavens can be found amongst the '*Ice Age*' paintings in a cave at Lascaux in France. The map, which is thought to date back 16,500 years, shows three bright stars known today as the Summer Triangle, Vega, Altair and Deneb. A map of the Pleiades star cluster in Taurus has also been found among the Lascaux frescoes. Another pattern of stars, drawn 14,000 years ago, has been identified in a Spanish Cave.

'Ice Age Star Map', from a Cave at Lascaux, France, circa 14,500 BC

Although charts of the stars had been produced in antiquity, it was during the Golden Age of European Celestial Cartography that star charts as we know and understand them came into being. This was a period which spanned roughly the years 1600 to 1800 and was driven by technological advances in both astronomical observation and printing techniques. In the course of these two hundred years, four major star atlases were produced; the '*Uranometria*' of Johann Bayer (1603); the '*Firmamentum Sobiescianum sive Uranographia*' of Johannes Hevelius (1690); John Flamsteed's '*Atlas Coelestis*' (1729); and the '*Uranographia*' of Johann Elert Bode (1801). It was in the pages of these beautiful maps that the 88 constellations as we know them were first depicted in their entirety. During this period of stellar cartography, the Bayer and Flamsteed notations for the brightest of the stars were also introduced.

John Flamsteed (1646-1719), the first Astronomer Royal of England, presided over the building of the Royal Greenwich Observatory. His '*British Catalogue*' of stars, finally published in 1725, six years after his death, brought stellar astronomy to a new level. His '*Atlas Coelestis*', was published four years after the catalogue, but in development for over twenty years, was based on his new and more accurate observations. That fact, coupled with its impressive size (it was the largest that had ever been published), immediately vaulted Flamsteed into the select ranks of the Great Stellar Cartographers. The Constellation of Taurus the Bull from his Atlas is shown to the right.



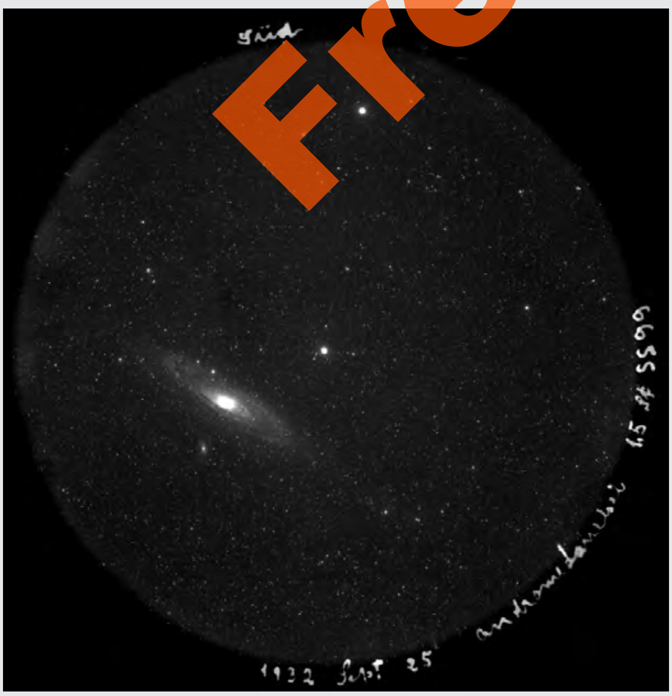
The Constellation Taurus from John Flamsteed's - Atlas Coelestis (1729)

Atlases like Flamsteed's were works of art in which visual beauty coincided with astronomical content. It was only in the nineteenth century that accurate star catalogue were produced which plotted the positions and brightness of tens or hundreds of thousands of stars. The most famous of these was the Bonner Durchmusterung (Bonn Survey) or simply the BD. The BD was produced by the three German astronomers, Friedrich Wilhelm August Argelander (1799-1875), Adalbert Krüger (1832-1896) and Eduard Schönfeld (1828-1891). This monumental work was published between the years 1852 and 1859; and which gave the positions and brightness of more than 324,000 stars, although it did not cover much of the southern half of the sky. The accompanying charts, published in 1863, were the most complete and accurate made until that time. This was the last star map to be published without the use of photography.

A.79 - Star Fields

Warren De La Rue: Observatory at Cranford (Left); 13-inch Reflector (Right)

In 1860 Warren De La Rue (1815-1889) made the first tentative steps at imaging star fields and whole constellations, from his Observatory in Cranford, Middlesex, using a portrait lens attached to the mount of his 13-inch Reflector: “*The next subject to which I have to call your attention is the photographic depiction of groups of stars—for example, such as form a constellation like Orion,—in other words, the mapping down the stars by means of photography. I have made several experiments in this direction, and have obtained satisfactory results, and I believe that at last I have hit upon an expedient which will render this method of mapping stars easy of accomplishment. The instrument best adapted for this object is a camera of short focal length compared with its aperture, like the ordinary portrait-camera,—the size of the lens being selected to suit the scale of the intended photographic map, and the camera, of course, mounted on an equatorial stand with a clock-work motion. The fixed stars depict themselves with great rapidity on a collodion plate; and I have experienced no difficulty in obtaining pictures of the Pleiades by a moderate exposure even in the focus of my telescope; they would be fixed much more rapidly by a portrait-camera. The difficulty in star mapping does not consist in the difficulty of fixing the images of stars, but in finding the images when they are imprinted; for they are no bigger than the specks common to the best collodion...*” Report of the British Association, 1861, p. 95.



In order for truly successful photographs of starfields to be obtained, astronomers had to overcome a number of problems - producing photographic plates which were sensitive enough to capture fainter stars; finding techniques that could distinguish real stars from ‘*plate defects*’; and the construction of photographic telescopes capable of capturing wide-fields with realistic exposure times. Over the course of the century all of these difficult issues would be resolved, not without a great deal of effort and many failures. In 1885 the first steps were taken: “*The greater capabilities of photography, through the increased sensitiveness of the modem dry plate, in its application to astronomical work, become every day more apparent. The most recent successful results, particularly in stellar photography, have been obtained during the past year by MM. Paul and Prosper Henry, of the Paris Observatory.*”

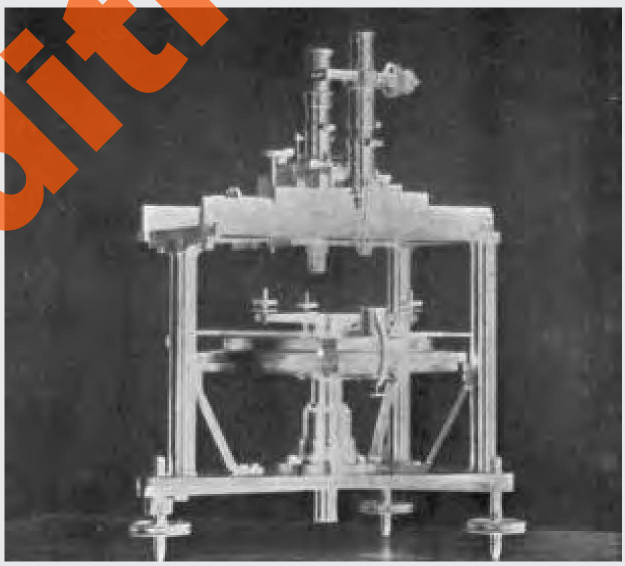
Wide-field - ‘Great Andromeda Spiral’: 14.5-inch Schmidtspiegel (1932)

A.80 - Photographic Astrometry

Following the completion of his first telescope, an 11¼ inch visual refractor, Lewis Morris Rutherfurd and the telescope maker, Henry Fitz (1808-1863) began the construction of a series of telescopes of ever increasing complexity. During 1859, they conducted experiments aimed at devising a combination of lenses which would be suitable for Astrophotography. Their efforts led to the construction of the first '*Photographic Telescope*' or '*Astrograph*'. In 1864 Rutherfurd completed the construction of an 11¼ inch objective lens suitable for photographic use. He realized that a good practical focus for light at the wavelengths most suited to the blue-violet sensitive photographic plates in use at that time could only be obtained by separating the crown and flint lenses by such an interval that the focal length of the combination should be about 5% shorter than that required for visual use. Although such a separation of the lenses would be entirely unsuitable for visual observations, it would produce perfectly focused photographic images.

Lewis Morris Rutherfurd (1816-1892) Age 50

Lewis Morris Rutherfurd built his first Photographic Plate measuring Micrometer at the end of 1865. A later and more sophisticated model was built in 1872 (illustrated right). One of similar design was given to his friend Benjamin Apthorp Gould, who wrote of it: "*During my stay at Cordoba I received from Mr. Rutherfurd the valuable gift of a micrometer similar to his own ; but it was impossible for any measurements to be undertaken there: although the instrument was subsequently employed for a large portion of the plates, being obliged to make a visit home, early in 1883, I brought with me this micrometer, and a number of the plates; and arranged for the work of measurement to be commenced at once and carried on in my absence after returning to Cordoba.*"



Photographic Plate Measuring Machine, c1872

The photograph to the left is of a Photographic Plate measuring machine used by the Sydney Observatory for its work on the '*Carte du Ciel*' (CDC) project. It was made in about 1915, by the English firm of Troughton and Simms of England and was based on an innovative design by Professor Herbert Hall Turner of Oxford University. Turner found that the screw system initially used to measure plates was very labour intensive and instead devised an eyepiece scale measuring machine. This reduced the time taken to measure the stars on each photographic plate quite considerably. Turner during his career had a special interest in the CDC project and was responsible for the zone allocated to the Oxford University Observatory. He also devised new and improved methods for the determination of star co-ordinates from photographic plate measurements, specifically for the CDC. See H. H. Turner, MNRAS, 1893, Vol. 54, p.11.

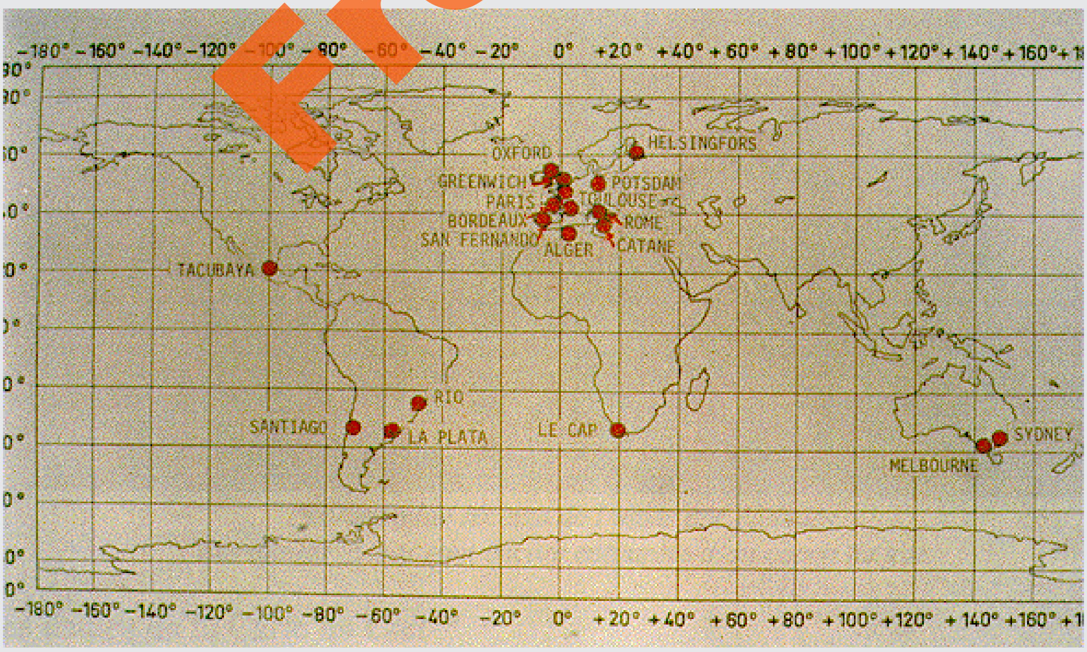
CDC - Photographic Plate Measuring Machine, c1915

A.81 - 'Carte du Ciel' Photographic Sky Survey

"It will be a glorious and never-to-be-forgotten date in its history, as will be likewise memorable the grand work which we wish to leave as a legacy to future generations—a work which we might define as an inventory, as exact and as complete as possible, of the visible universe at the close of the nineteenth century." Theses words were spoken by Ernest Amédée Barthélémy Mouchez (1821-1892) at the opening of the '*Congres Astrophotographique*' held in Paris from the 16th to the 25th of April 1887, to inaugurate the ill-fated '*Carte du Ciel*' (Map of the Sky) project.. His vision never came true in his lifetime. History has written a different ending to that predicted by Ernest Mouchez – one of problems, delays, acrimony, over ambition, failure and ultimate redemption. Whatever is written of Ernest Mouchez concerning the '*Carte du Ciel* (CDC), nobody can deny that he was a Visionary; who tried to do something that at the time was impossible from the outset, but which today is taken for granted – a Complete Photographic Chart of the Heavens.

Ernest Amédée Barthélémy Mouchez (1821-1892)

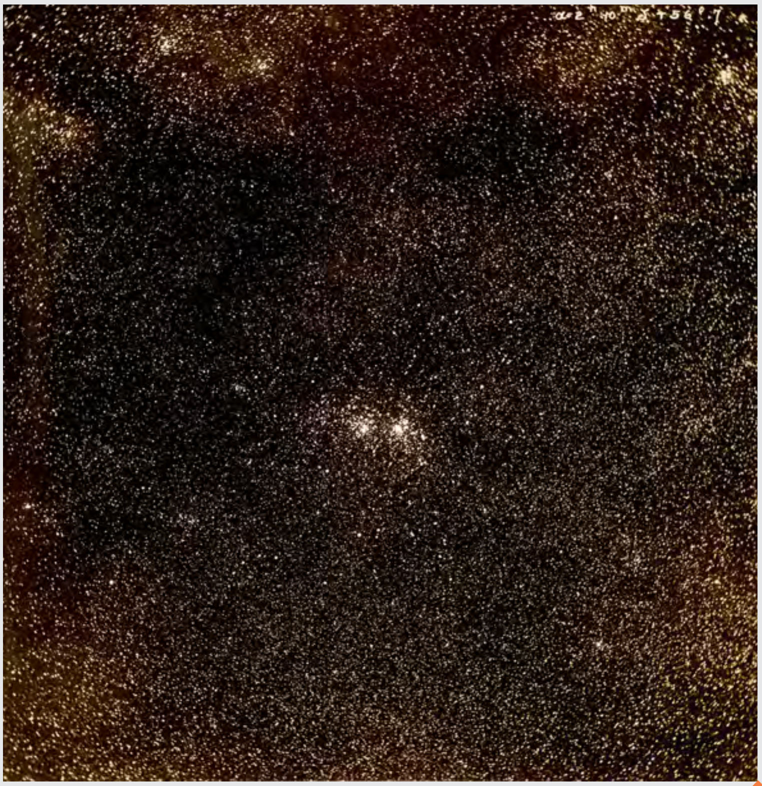
The '*Carte du Ciel*' (CDC) project attempted to be the next logical step towards the ideal photographic sky map. The '*Carte du Ciel*' (literally, a Map of the Sky) was a massive international astronomical endeavour initiated in 1887 to photograph, catalogue and map the positions of millions of stars as faint as the 11th magnitude and ultimately to extend this to those of the 14th magnitude. Eventually twenty observatories from around the world participated in exposing and measuring more than 22,000 (glass) photographic plates in an enormous observing programme extending over several decades. Three other Observatories although initially offering their resources to the project did not in the end do so and took no active part in the undertaking, i.e. Santiago, La Plata and Rio de Janeiro. The twentieth observatory, i.e. Edinburgh in Scotland also assisted in measuring some of the plates re-allocated to the Perth Observatory from Rio de Janeiro, but took no actual photographs. The CDC was eventually abandoned by the IAU in 1970 and deemed to be '*unfulfilled*', techno-babble for a failure!



The map to the left shows the original 18 Observatories of the CDC of which 10 were from Europe, 1 from Central America, 2 from Africa, 3 from South America, 2 from Australia and 0 from North America, who rather wisely did not participate, preferring to concentrate on the then new science of Astrophysics.

Original 'Carte du Ciel' Observatories, 1889

A.82 - Milky Way & Star Clouds



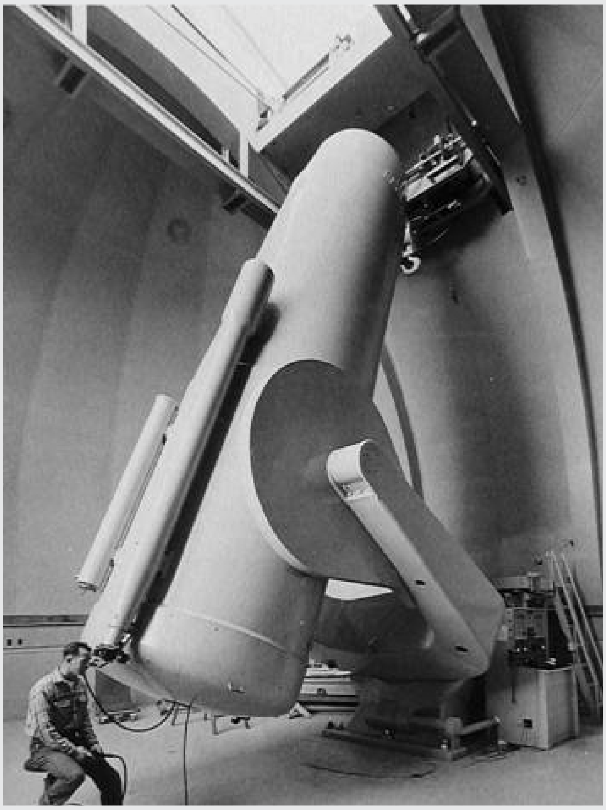
Edward Emerson Barnard and Max Wolf photographs of the Star Clouds of the '*Milky Way*' represented the pinnacle of wide-field Astrophotography for several decades. In the December of 1904, the newly completed Yerkes Observatory's, Bruce Astrograph was transported to the Mount Wilson Solar Observatory at the invitation of its Director, George Ellery Hale. For the next nine months, Edward Emerson Barnard used it to take forty of the fifty plates for his '*Photographic Atlas of Selected Regions of the Milky Way*'. It was not until 1927 four years after his death that Mary Ross Calvert, the niece of E. E. Barnard, and the then Director of the Yerkes Observatory, Edward Frost finally succeeded in publishing Barnard's, Atlas. The photograph to the left of the Double Cluster in Perseus, was taken by Barnard, on the 15th of September 1904, at the Yerkes Observatory. It is the first plate from his Atlas.

'Double Cluster' in Perseus, Edward Emerson Barnard, 1904

The funding for the '*Bruce Triple Astrograph*' came from Miss Catherine Wolfe Bruce (1816-1900) who donated in 1897 to the Yerkes Observatory, the sum of $7000 for its construction and an observatory to house it. The telescope was in fact a compound of three separate telescopes, a 10-inch '*doublet*' of 50-inches focal length; a 6.25-inch lens of 35-inches focal length; and a 5-inch guiding refractor, all mounted into a single structure to form a powerful photographic survey instrument. John Brashear ordered the Glass Blanks for the 10-inch Achromatic Objective from Mantois of Paris. These were delivered in May 1899, and by the September 1900 Brashear had completed the Doublet. The objective produced a perfectly flat field of some 7 degrees, and an overall acceptable field of 9 degrees. The focal ratio of the main 10-inch telescope was a 'fast' f5. The instrument was finally completed and placed in its observatory in April 1904. The delay in its construction was in the main caused by the unrealistic and impractical specification imposed on Brashear by Edward Emerson Barnard. The Bruce Astrograph now lies in bits in a basement of the Yerkes Observatory, all but forgotten.

Bruce Astrograph, Yerkes Observatory, c1905

A.83 - Palomar & Digital Sky Surveys



The 48-inch Schmidt telescope at the Palomar Observatory is a standard Schmidt camera telescope using both lenses and mirrors to create a wide-field of view for photographing large sections of the sky at one time. Construction on the Schmidt telescope began in 1939 and was completed only in 1948, as a result of a delay caused by WWII. This instrument was first used to carry out the Palomar Observatory Sky Surveys (POSS I & II) of the entire Northern Hemisphere and nearly half of the Southern Hemisphere. In 1987 the telescope was renamed, after Samuel Oschin (1914-2003) and his wife Linda had made a substantial donation to the Palomar Observatory. The optics and electronics of the Oschin-Schmidt have been upgraded over the years and now incorporates an achromatic corrector lens, provisions for auto-guiding. Between 1999 and 2001, it was modified for robotic operation and the original photographic equipment was replaced with its first CCD camera. 3-array image covered about 3.75 square degrees. The telescope control system was upgraded to enable automatic operation and continuous, automatic survey of sky every clear night.

48-inch Oschin-Schmidt Telescope, Mount Palomar Observatory

The Samuel Oschin telescope was put almost immediately to good use in 1949, when it began work on the National Geographic Society sponsored – First Palomar Observatory Sky Survey (NGS-POSS I). It was completed in 1958, less than ten years after it began – a feat which was meant to be achieved by the CDC. Unlike the CDC which did not use a single astronomer or observatory from the USA, the POSS was an all American affair with their greatest astronomers actively taking part. Among the primary minds behind the project were Edwin Hubble, Milton Humason, Walter Baade, Ira Sprague Bowen and Rudolph Minkowski. The survey was originally meant to cover the sky from the north celestial pole to -24° declination. However the survey was finally extended to a declination of -30° at the plate centres, giving irregular coverage to as far south as -34° declination, and utilized a total of 936 plate pairs.

The POSS I utilized 14-inch square photographic plates, covering about 6° of sky per side (approximately 36 square degrees per plate, i.e. nine times larger than the CDC. Each region of the sky was photographed twice, once using a red sensitive Kodak 103a-E plate, and once with a blue sensitive Kodak 103a-O plate. This allowed the colour of celestial objects to be recorded to a certain extent. The limiting magnitude of the survey varied depending on the region of the sky, but was on average went down to stars as faint 22nd magnitude; the CDC only went down to magnitude 14 or 15 at best. The first plate was exposed on the 11th of November 1949; with 99% of the plates being taken by the 20th of June 1956; the final 1% were not completed until the 10th of December 1958. It was a great success and gave high quality images.

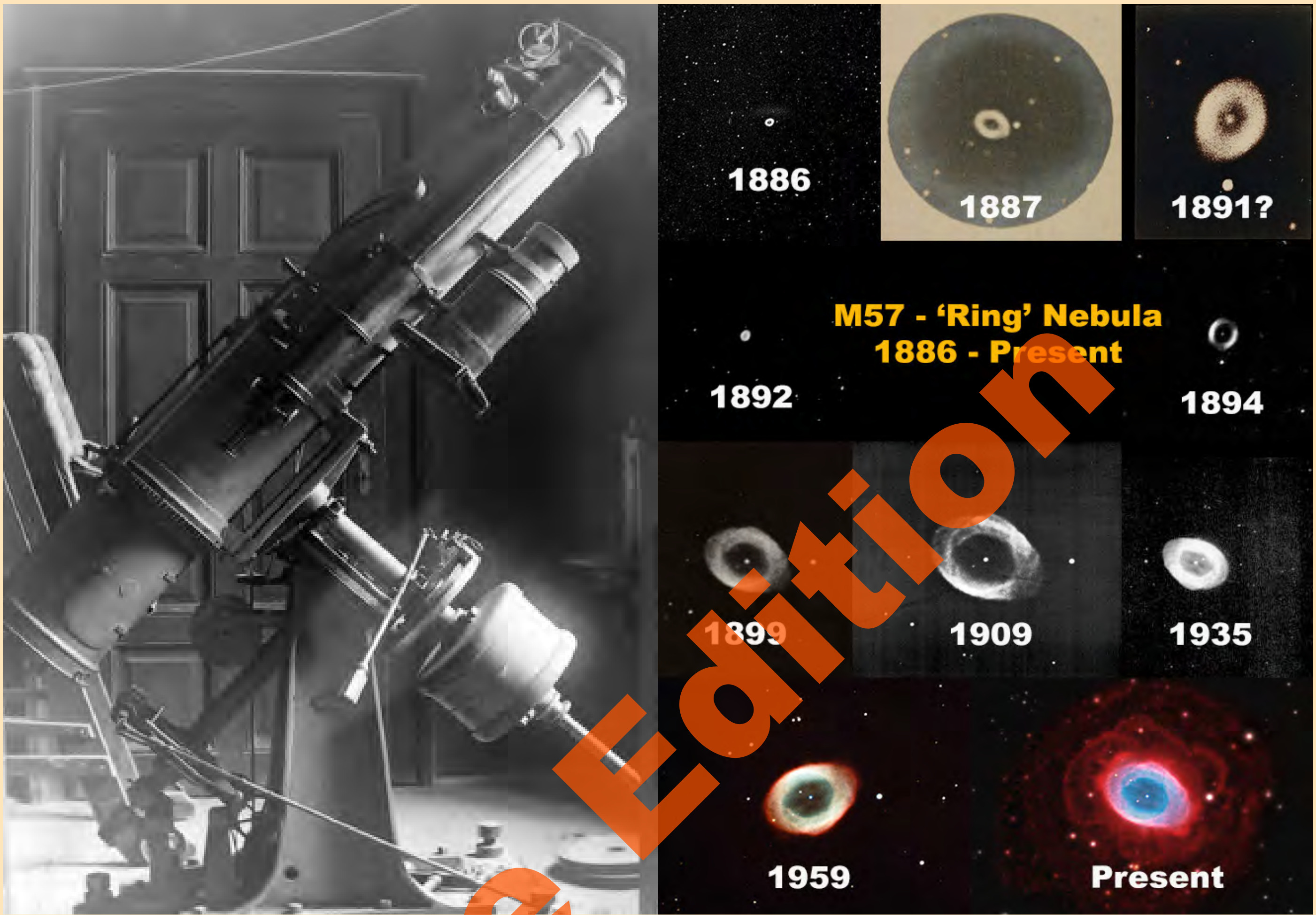
POSS I Red Plate - NGC 281 in Cassiopeia

Telescopes of Astrophotography

Window to the Stars - 200-inch 'Hale' Telescope

8. Coming of the Astrograph

Telescopes of Astrophotography



Eugen Von Gothard's 10-inch Reflector (Left); Ring Nebula (1886-Present)

On the 1st of September 1886, Eugen (Jeno) Von Gothard took a photograph of the famous '*Ring*' Nebula (M57) in the constellation of Lyra using a '*mass produced*' 10.25-inch reflector made by John Browning of London. His photograph clearly showed its faint 15th magnitude central star, a feat only possible visually by instruments much larger than his.

This photograph heralded the rise of the amateur in astronomical photography, who not only took high quality images, but ones which were of scientific importance, all with the aid of affordable instruments with apertures bordering on the small.

The appearance of Von Gothard's photographs caused a '*supernova*' within the astronomical establishment of the day. Hermann Carl Vogel, the Director of the Potsdam Astrophysical Observatory went so far as to express the opinion that:

'Photographs of Herr Von Gothard's taken with this comparatively small instrument show results which far surpass any obtained by eye observation with the largest telescope'.

In the early days of Astrophotography no attention was given to the many factors which are now known to be essential if a successful image of an astronomical object is to be obtained. Early pioneers such as John William Draper and the Bonds of Harvard were just happy to have taken a photograph which gave a fair representation of their chosen target whether it be the Moon, the Sun or the brighter stars. As a results their photographs were obtained with a variety of telescope systems. In the 1840s and1850s little was known or understood about Photography let alone its interface with a telescope. It was not surprising that the early Astrophotographers used whatever equipment they had, and gave no thought to whether it was the right telescope design to use or that it was used in the '*correct*' way.

15-inch Merz & Mahler Refractor (1839) at the Pulkovo Observatory in 1876

The years which followed the first astronomical photographs of the 1840s and 1850s until the end of the nineteenth century was the '*age of the refractor*', when this telescope design ruled supreme amongst the '*Great Observatories*' of the world. The use of large reflecting telescopes was relegated to wealthy amateurs such as William Parsons, the 3rd Earl of Rosse, and William Lassell, the brewing tycoon. It was a common perception amongst the astronomical community of the day, that those who built silvered mirrored reflectors, and especially the astronomers who advocated their superiority over the glass lens of the refractor, were considered misguided individuals who did not follow the establishment line. In 1839, the year Daguerre's new photographic process was announced to the world the largest refractor was the 15-inch Merz & Mahler Refractor at the Pulkovo Observatory, in St. Petersburg, Russia. That same year, William Parsons completed his 36-inch speculum metal reflector, then the largest operational reflector; Sir William Herschel's larger '*four-feet*' speculum was no longer in use, having made its last observation in 1815, and was dismantled in 1840 by his son Sir John Herschel. In 1847, the 15-inch '*Great Refractor*' at the Harvard College Observatory was completed. It together with its identical Pulkovo '*twin*' were at that time the largest of their kind. Of the two, it was the Harvard twin, that not only is still in existence today, but was the first telescope of any major Observatory to be used for Astrophotography. During a period of some ten years or so from 1849 until about 1860, John Adams Whipple, assisted by his partner, James Wallace Black and the Harvard astronomer, George Phillips Bond, took a series of photographs of the Moon, Sun, Planets and Stars, using the 15-inch '*Great Harvard Refractor*'. Only the objective lens of its twin has survived, the rest was destroyed at the Siege of Leningrad (Saint Petersburg) during the Second World War (8th September 1941-27th January 1944).

In a period spanning less than twenty years, William Parsons, the 3rd Earl of Rosse, constructed at his Birr Castle estate, no less than five speculum metal reflecting telescopes culminating in 1845 with the completion of the 72-inch '*Leviathan of Parsonstown*'.

It was with this telescope in the March of 1845, that he became the first to describe the '*Spiral*' nature of certain '*nebulae*', now known to be Extra-Galactic in origin, when he observed the famous '*Whirlpool*' Galaxy, M51 in Canes Venatici.

36-inch & 72-inch Reflecting Telescopes - Birr Castle, Ireland (c1845)

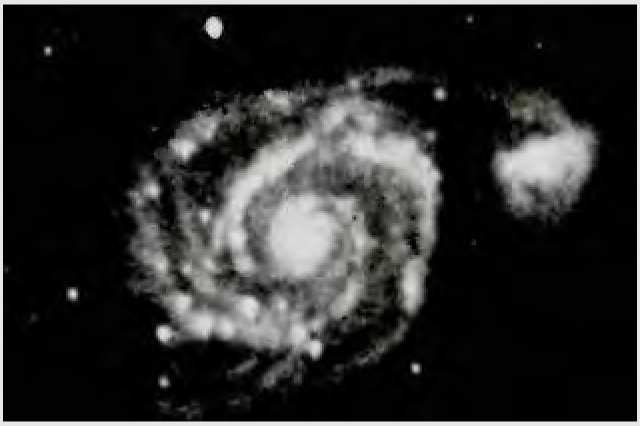
A.84 - 72-inch 'Leviathan of Parsonstown' (1845)

William Parsons (1800-1867), the 3rd Earl of Rosse was born into an age when wealthy amateur scientists could and did make great contributions to our understanding of the universe in which we live. Above all else, he demonstrated the great potential the Reflecting Telescope had in the future conduct of Astronomical Research. An opinion that was later to be proved correct. In the years 1826 to 1845, he constructed no less than five speculum metal reflecting telescopes with mirrors of 6-inch, 15-inch, 24-inch, 36-inch and finally 72-inch in diameter. His work marked the onset of the '*death*' of the then, all dominant '*Great Refractor*'. He was the '*Great Telescope*' Builder, whose 72-inch Reflector was for almost three quarters of a century the largest telescope in the world. He did something no one else had done before or since - create almost single handedly a telescope of such a size, and use it to, as he himself put it: '*afford us some insight into the construction of the material universe*'. He made drawings of Deep Space Objects (DSOs) which showed for the very first time what many of them truly looked like. It was he who first discovered with his '*Leviathan of Parsonstown*' the '*Spiral*' nature of certain nebulae, which are now known to be extragalactic in origin, lying millions of light years beyond our own '*Milky Way*' star system.

William Parsons, 3rd Earl of Rosse (1800-1867)

It is not generally known but William Parsons, did try his hand, albeit unsuccessfully, at Astrophotography, but only with his smaller 36-inch speculum metal reflector. In a letter to the photographic pioneer William Henry Fox Talbot on the 2nd of February 1854, he wrote: "*We have recently made some attempts here to Photograph the Moon but with little success. With Thomas's Collodion* our 3 feet speculum gave a tolerably strong impression in 25", but during so long an exposure the variations of the air were considerable and there was no sharp definition. The experiment was made with the telescope fixed, and the plate moved by the clock. The slide containing the plate was adjusted to the Moon's apparent motion by a micrometer eye piece, with a line in it truly parallel to the slide. The adjustment was easy and accurate...*"
*Richard Wheeler Thomas (1823-1881), London Chemist.

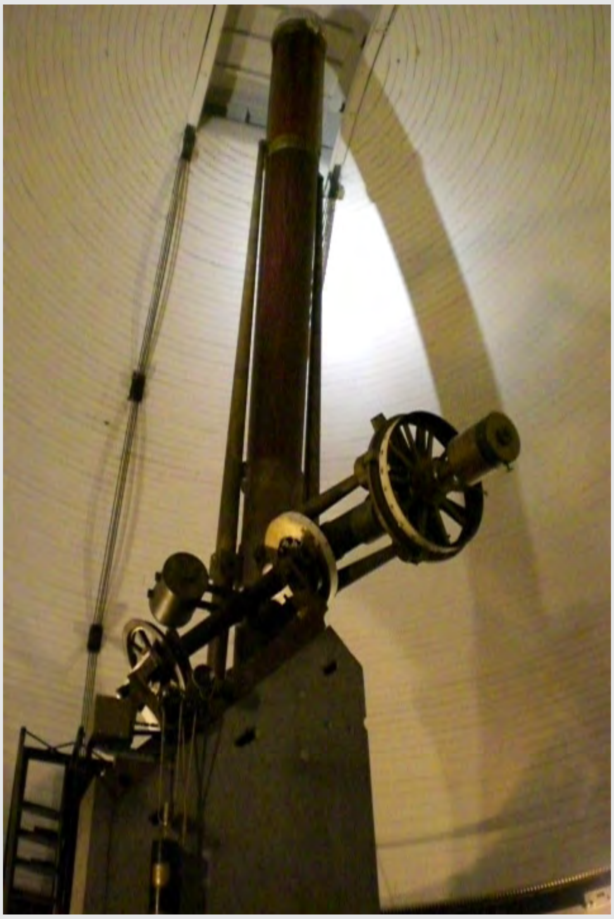
The 72-inch 'Leviathan of Parsonstown', c1854, 3rd Countess of Rosse



The famous '*Whirlpool*' Galaxy (M51) in Canes Venatici was the first '*Spiral*' identified by William Parsons, possibly as early as the 5th of March 1845 or at the latest the following month. It was by his own admission a popular target: "*This object has been observed twenty-eight times with the 6-feet instrument; it had been repeatedly observed previously with the three-feet instrument*". The Irishman, William Edward Wilson of Daramona House, Sreete, County Westmeath, took this photograph of M51 in 1897 (left) , with a 90 minute exposure.

Photograph of M51 'Whirlpool' Spiral, William Edward Wilson, 1897

A.85 - 15-inch 'Great Harvard Refractor' (1847)



The 15-inch refracting telescope of the Harvard College Observatory has always been known as the '*Great Refractor*'. Although modest in size according to today's standards, in its day it was equal in size to the largest in the world. It was constructed in 1847 by the Munich Firm of Merz and Mahler, who in 1839 had built an identical telescope for the Imperial Observatory at Pulkovo, near Saint Petersburg, Russia. It was intended to be a '*Great*' telescope befitting the status of the newly inaugurated Harvard College Observatory, and was proudly declared to be so by its Director, William Cranch Bond: *"If we may credit the declaration of its makers, Messrs. Merz and Mahler of Munich in Bavaria, this instrument is the most perfect of its kind that the art of man has ever produced. Its only rival is the Great Refractor of the Imperial Central Observatory of Russia. The extreme diameter of the object-glass of the telescope is fifteen and a half English-inches; the effective aperture is fourteen and ninety-five hundredths-inches; the solar focus is twenty-two feet and six-inches. The distance from the outer surface of the object-glass to the point of intersection of the declination and polar axes, is thirteen feet seven-inches. From the same point to the solar focus of the object-glass, it is eight feet eleven-inches."*

15-inch 'Great Harvard Refractor'

The object glass arrived at the observatory on the 4th December 1846, separately from the main bulk of the telescope, which came some six months later: *"The parallactic mounting of the telescope arrived at the Observatory on the afternoon of Friday, June 11th, 1847. It came packed in thirteen large cases, which, together with their contents, were estimated to weigh about six tons. In order to facilitate the mounting or putting together the parts of this instrument, I had caused a strong platform to be erected at a convenient height round the stone pedestal, with proper framework, blocks, and tackle. To guide the stone-cutters in giving the right inclination to the top surface of the granite pedestal for the reception of the massive bed-plate of the equatorial, a triangle of wood was constructed, having such a relation between its sides, that a plumb-line and level attached would always indicate the required inclination."*

Prior to its arrival, careful preparations had been undertaken to welcome such a '*Great*' instrument. Land was purchased at the present Observatory Hill site on Garden Street, to which the equipment from Dana House was moved in 1844, while construction proceeded on the Sears Tower to house the refractor, a residence, and various other buildings. The Sears Tower surrounds a granite pier that rises 43 feet to the observing floor from its 22 foot diameter base 26 feet below ground. The pier, in turn, is topped by an 11 foot high, 11 ton granite block that carries the telescope mount. Originally, doors on three sides of the dome led to small iron balconies on which portable telescopes could be set up. Only the north balcony remains and probably is original.

The 30 foot observatory dome, weighing approximately 14 tons, is of frame construction, and was reputedly built by a whaling shipwright and is sheathed in copper. The eight 8-inch iron spheres, which served as bearings on which the dome turned, were replaced in the early 1940's by a more modern support system. One of the '*cannon balls*', flattened from wear, is on exhibit in the dome; the rest were donated for scrap metal during World War II. A number of significant achievements in astronomical research quickly followed, as befitting an instrument which cost $20,000 in 1847.

A.86 - Kew Photoheliograph (1858)

The Kew Photoheliograph was the first of its kind - a photographic telescope or Astrograph specifically designed and constructed to take images of the Sun. Its origin lies in a letter written by Sir John Herschel to Colonel Edward Sabine, Secretary of the Royal Society, dated the 24th of April 1854: "*I consider it an object of very considerable importance to secure at some observatory, and indeed at more than one, in different localities, daily photographic representations of the sun, with a view to keep up a consecutive and perfectly faithful record of the history of the spots. So far as regards the general delineation of the whole disk, and the marking out on it, in reference to the parallel to the equinoctial passing through its centre, the places, sizes, and forms of the spots, there would need, I should imagine, no very powerful telescope,—quite the contrary; but it should be equatorially mounted, and ought to have a clock motion in the parallel…*" As a result of Herschel's plea, the Royal Society of London allocated a grant to the committee of the Kew Observatory to that end. Warren De La Rue took up the challenge and produced the design for the Photoheliograph and Andrew Ross of London, the respected optical instrument maker was given the commission for its construction.

Kew Photoheliograph - Now

In essence the Kew Photoheliograph consisted of a small refracting telescope enclosed in a wooden case at the end of which was fitted a photographic plate holder. The completed design was described by De La Rue in the following words:

"*The object-glass of the photoheliograph, it will be remembered, is of 3.4 inches clear aperture and 50 inches focal length, but the whole aperture is never used; it is always diminished more or less; and generally to about 2 inches, by a stop placed in front of the object-glass. The focal image of the sun at the mean distance is 0.466 inch. The focal image is not, however, received directly on the sensitive plate, as in the case of taking lunar and planetary photographs, but is enlarged before it reaches it by means of a secondary combination of lenses (an ordinary Huyghenian eyepiece), which increases the picture to about 4 inches in diameter, thus magnifying the image about eight times linear, and diminishing the intensity of the light 64 times.*"

Warren De La Rue, '*Present State of Celestial Photography in England*', British Association for the Advancement of Science, 1859, p. 150.

Warren De La Rue (1816-1882)

The photoheliograph was essential complete by the end of 1857, and transferred to the Kew Observatory, where it took its first picture of the Sun in the March of 1858: "*The Photoheliograph erected in the dome of the Observatory was fully described in the last Annual Report; it has been repeatedly at work since the beginning of last March, and excellent photographic pictures of the solar spots and faculae were obtained. Certain alterations have been made by Mr. Welsh in order to regulate the time of exposure of the collodion plate to the sun's action; with these alterations the instrument gives very good results, but certain improvements in the arrangements of the secondary magnifying lens are under consideration, with the view of avoiding the depiction on the collodion negative of the inequalities in the glasses which compose it.*"

A.87 - Seven Equatorial Coudés (1882-1892)

In 1871 the Austrian astronomer, Maurice Loewy (1833-1907), developed for the Paris Observatory, a revolutionary new design for the mounting of meridian telescopes Although the design was received enthusiastically by the Observatory's Director, Charles Delaunay, nothing was done at the time. This delay was due to Delaunay's untimely death in 1872; the result of a tragic boating accident near Cherbourg. It was not until 1882 that work began on the construction of the what became known as the '*Petit*' Equatorial Coudé or Elbow Equatorial Refractor. In 1888, two more Coudés became operational, one at Algiers and a second at Lyon. Two years later, two more were put into service, one at Besancon and another at Loewy's former Observatory at Vienna. A sixth, the *'Grand Equatorial Coudé'* at Paris, and the final and seventh Coudé at Lyon, were both completed in 1892.

Vienna Observatory Equatorial Coudé

"In principle the Equatorial Coudé may be described as an adaptation of the form of transit instrument with axial view to the requirements of an equatorial, by the addition of a plane mirror, inclined at 45o, outside the object-glass, this mirror being capable of rotation about the axis of the telescope, so as to reflect into the latter the rays from any object in a perpendicular plane. The axis of the instrument is mounted as a polar axis between two piers, the telescope being broken at a right angle near the lower pivot, so that the rays from the object-glass are reflected by an internal mirror up the polar axis to the hollow upper pivot, where the image is formed. The rotation of the outer mirror thus brings into the field the image of any object in the hour-circle perpendicular to the object-end of the telescope, and by the rotation of the polar axis, as in an ordinary equatorial, the telescope is directed to any hour-angle. The declination-axis in the Equatorial Coudé is the axis of the object end of the telescope about which the outer mirror turns, and the declination-circle placed at the eye-end, in the same plane with the hour-circle, is connected with the axis of the outer mirror by gearing, so that the observer at the stationary eyepiece has both the hour and declination circles immediately under his eye. He can thus direct the instrument to any object without moving from his chair, and his observations are made under the most favourable conditions for his own comfort, similar to those under which the microscope is used by the student of natural history. The observing room, which may be artificially warmed, is quite separated from the object-glass, and other external parts of the instrument. These latter are protected from the weather by a suitable hut, which can be rolled away on rails before observing, so that the optical parts of the equatorial are in the open air under the best conditions for establishing an equilibrium of temperature."

The above excellent description of the workings of this remarkable instrument was given by William Henry Mahoney Christie (1845-1922), the then Astronomer Royal at a meeting of the Royal Astronomical Society in London in 1889. To the right is a photograph of the eyepiece of the 23.6-inch '*Grand Equatorial Coudé*', the larger of the two Paris Observatory's Coudés, in its '*warm and cosy*' room, away from the cold and winds experienced by normal astronomers using the '*Great Refractors*' found in every other European and North American Observatory.

'Le Grand Equatorial Coudé' - Eyepiece (c1900)

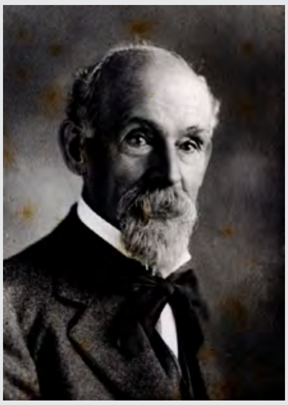
A.88 - 6-inch Crocker Astrograph (1892)

6-inch Willard Lens from the Crocker Astrograph

In 1890, Edward Singleton Holden, the then Director of the Lick Observatory, made the following announcement in the Publications of the Astronomical Society of the Pacific, which signalled the beginning of the work for which Edward Emerson Barnard is best remembered - his magnificent wide-field photographs of the '*Milky Way*': "*The Hon. C. F. [Charles Frederick] Crocker has authorized the construction of an equatorial stand to take the Willard photographic telescope bought by him for the observation of the eclipse of December, 1889. The mounting will be made by Mr. Brashear, and will be provided with a driving clock, controlled in the manner invented by Mr. [James Edward] Keeler. The Willard lens, together with a 5-inch Dallmeyer camera (lent to us by Mr. Pierson), will be mounted side by side, for the present, and will be employed by Mr. Barnard in making photographs of the Milky Way.*"

The 6-inch Willard lens came into the possession of the Lick Observatory by a very tortuous route, as described by Barnard: "*The advent of the Willard lens into astronomical work was due to the total eclipse of the Sun, which was visible in northern California on January 1, 1889... Mr. Ireland was especially fortunate in being able to secure the use of a large portrait lens of some 6 inches aperture and 31 inches focus, which he borrowed for the occasion from Wm. Shew, a photographer on Montgomery Street, San Francisco, who had used the lens, which had originally cost several hundred dollars, for making fashionable portraits (especially in the later sixties). Though Mr. Ireland had no equatorial mounting for the lens, his photographs were very successful, particularly in showing the great extent of the coronal streamers. Impressed by the excellent results from this lens, Director Holden purchased it from Mr. Shew for the Lick Observatory with funds provided for the purpose by Hon. C. F. Crocker.*"

Charles Frederick Crocker (1854-1897) - Railway Tycoon



The Pittsburgh telescope maker, John Alfred Brashear (1840-1927), was given the task of re-working the Willard Lens and the construction of a suitable equatorial mounting. Barnard gave the following information on the lens: "*Diameter of the front lens, 5.85 inches = 148.6 mm. Solar focus, 42.59 inches = 108.2 cm. Diameter of the back lens, 6.73 inches = 171.0 mm. Solar focus, 70.2 inches = 178.3 cm. The distance from the rear surface of the front lens to the surface of the back lens was 12.8 inches. A diaphragm of 3.83 inches aperture was placed between the two sets of lenses at a distance of 5.54 inches from the front lens. A recent determination from negatives made in 1895 gave: Focus: 30.66 inches = 778.9 mm. Scale: 1 inch = 1°.87; i.e. 1 cm. = 0°.73*"

John Alfred Brashear (1840-1920)

A.89 - 36-inch 'Common'/'Crossley' Reflector (1879)

"The Crossley reflector, at present the largest instrument of its class in America, was made in 1879 by Dr. A. A. Common, of London, in order to carry out, and test by practical observation, certain ideas of his respecting the design of large reflecting telescopes. For the construction of the instrument embodying these ideas, and for some fine astronomical photographs obtained with it, Dr. Common was awarded the gold medal of the Royal Astronomical Society in 1884. In 1885 [sic.], Dr. Common, wishing to make a larger telescope on a somewhat similar plan, sold the instrument to Edward Crossley, Esq., F. R. A. S., of Halifax, England. Mr. Crossley provided the telescope with a dome of the usual form, in place of the sliding roof used by its former owner, and made observations with it for some years; but the climate of Halifax not being suitable for the best use of such a telescope, he consented, at the request of Dr. Holden, then Director of the Lick Observatory, to present it to this institution..."

James Edward Keeler, From Introduction to: *Photographs of Nebulae and Clusters Made with the Crossley Reflector.*

Andrew Ainslie Common (1841-1904)

"The 3-ft. Reflector has taken up a good deal of time. The dome for this instrument is now complete: it can be moved round once in five minutes or once in twenty-four hours by a water-engine with two speeds. The observing platform and gallery are suspended from the dome, and therefore the observer moves with the dome. The opening is 6 feet wide from top to bottom, and extends from the horizon to 3 feet beyond the zenith. The shutter is in two pieces, which move horizontally; and one handle opens and closes both in about one minute."

36-inch 'Crossley' Reflector - Bermerside Observatory

In 1872, the Halifax, Carpet Tycoon, Edward Crossley (1841-1905) had built for himself and his family, a Victorian '*Gothic Pile*' known as Bermerside House in the village of Skircoat Green, near Halifax, Yorkshire. The following year he completed the Observatory to go with it, which he described as: *"a handsome stone building placed so as to form the western termination of the south front of the house and conservatory... The main block of the observatory is 20 ft. square, rising to a height of 27 ft. above the ground to the foot of the dome; the upper floor is 15ft. above the ground floor. This upper floor contains the large equatoreal telescope, 9 1/3-in. aperture, by Messrs. Cooke."* In the latter part of 1884 his Observatory took possession of Andrew Ainslie Common's three-foot telescope, later known as the '*Crossley*' Reflector.

Edward Crossley (1841-1905)

A.90 - 40-inch Yerkes Observatory Refractor (1897)

The 40-inch Yerkes Observatory's '*Great Refractor*' was at the time of its construction in 1897, the largest of its kind ever made. Today over a century later it has not lost this title. It also played a pivotal role in the History of Astrophotography, not only with regard to the photographs it took, but more importantly because of the work of the astronomers who used it; the telescope makers who constructed it; and the entrepreneurs who envisaged and financed its very existence. Four men were from the outset, closely linked to the 40-inch Yerkes Refractor. George Ellery Hale convinced the Chicago tycoon Charles Tyson Yerkes (1837-1905) to finance the telescope. Yerkes was a convicted embezzler with a reputation for dishonest deals, but he liked the idea of his name being attached to a famous telescope. He said he would pay whatever it took, but insisted repeatedly that the telescope had to be the largest in the world. The famous firm of telescope makers, Alvan Clark & Sons, were hired to build the 40-inch Refractor at the Yerkes Observatory. George Willis Ritchey was the astronomer, Hale hired to test the photographic capabilities of the latest and nearly the last '*Great Refractor*' ever constructed.

Charles Tyson Yerkes (1837-1905)

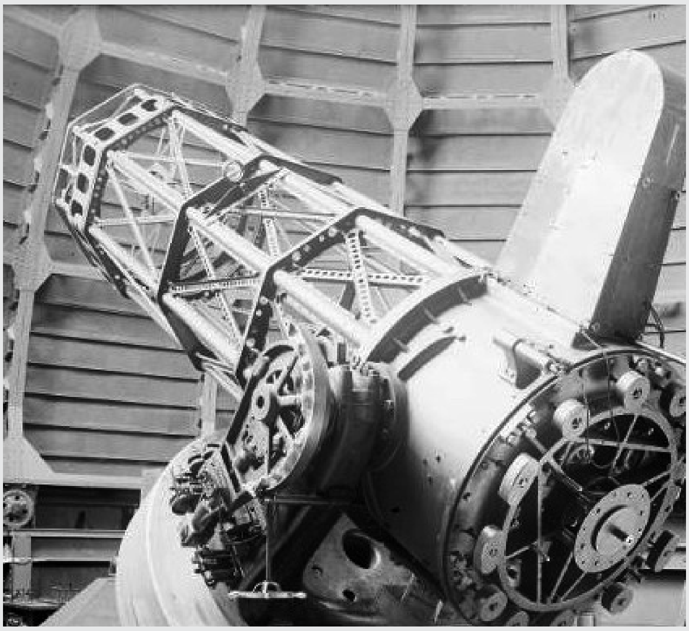
George Ellery Hale was born into a world of privilege and wealth. His father William Ellery Hale (1836-1898) had earned his fortune from the elevators needed for the many skyscrapers being built in Chicago. From the very outset he was indulged by his parents to the extreme, no more so than in the construction of the Kenwood Observatory, Hale's very own private Astrophysics Research Institution, built next to the family home in the suburbs of Kenwood, Chicago.

Hale was also instrumental in the construction of four major optical telescopes - the 40-inch Yerkes refractor (1897), the 60-inch (1908) and 100-inch (1917) reflectors at Mount Wilson, and the 200-inch Hale Reflector at Mount Palomar (1948).

It was also Hale who encouraged and actively promoted the career of the then unknown astronomer, George Willis Ritchey, who he had met through the Chicago Section of the Astronomical Society of the Pacific. In 1897 Ritchey joined the staff of the Yerkes Observatory as its Superintendent of Instrument Construction, to work with Hale, who was its first Director.

George Elley Hale (1868-1938) in 1910

A.91 - 60-inch & A.92 - 100-inch Mount Wilson Reflectors



By the time George Ellery Hale was thirty years old, he had everything. He was rich, successful and talented. He was the Director of a '*Great Observatory*' with the largest '*Great Refractor*' in the world at its focal point. Yet he was not contented. The truth was that neither the Yerkes Observatory or its 40-inch '*Great Refractor*' was what he really wanted. He was a '*mirror man*' who believed that the monster telescopes of the future would be large silvered mirrored reflectors and that to get the best out of them they should be atop high mountains where the '*seeing*' was at its best. He wanted to build a '*Great Reflector*'. On the 13th of December 1908 his visionary telescope saw the light of the stars for the first time. Six days later it took its first photograph.

60-inch Reflector - Mount Wilson Observatory, c1910

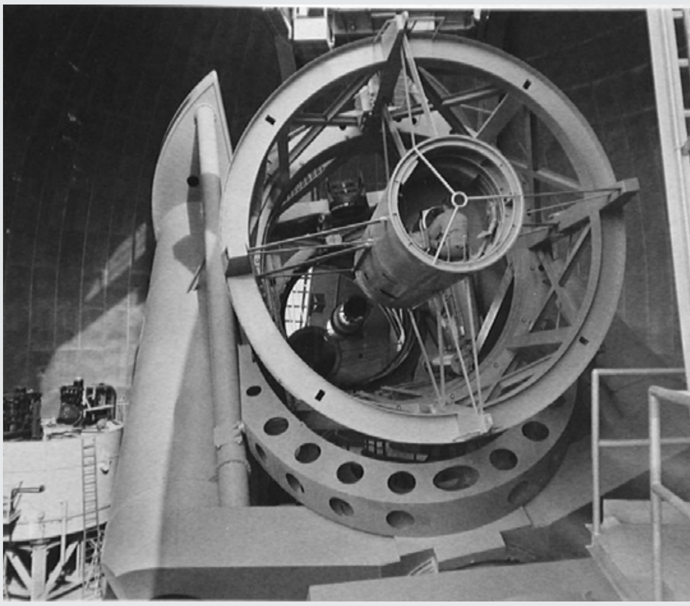
In 1904 the Mount Wilson Solar Observatory was completed, with initial funding from the Carnegie Institution for Science. Hale had applied two years earlier to the recently formed Carnegie Institution of Washington for the establishment of a new observatory devoted to solar research on Mount Wilson. He also proposed that a 60-inch reflector for Astrophysical Research be built at the same location as part of a larger plan. By the September of 1907, George Willis Ritchey had finished grinding the 60-inch mirror for the world's largest telescope. It was ready for its mount, but its mount was not ready for its mirror.

60-inch Reflector on its Way to Mount Wilson by Truck, 1908

On the 18th of April 1906, an earthquake had hit the city of San Francisco, close to Union Iron Works where the mount for the 60-inch reflector was being constructed and nearing completion. By what can only be described as a near miracle, the mount survived and escaped intact, despite the severe destruction that the earthquake had caused to Union Iron Works itself. Nevertheless, severe delays of many months resulted from the ensuing reconstruction programme and a series of inconvenient worker disputes. However by the July of 1908 the mount was ready to make its precarious journey by truck and donkey to the summit of Mount Wilson.

60-inch Reflector on its Way to Mount Wilson by Mule, 1908

A.93 - 200-inch 'Hale' Mount Palomar Reflector




200-inch 'Hale' Reflector, c1950; 'Great Orion' Nebula (1959), 200-inch 'Hale'

The 200-inch Hale reflecting telescope atop Mount Palomar in southern California, is without doubt one of the greatest scientific instruments to be built by man in his time on Earth. It was until recently, arguably the most famous telescope ever made. Ever since it saw '*firstlight*' at its dedication on the 3rd June 1948 it has been at the forefront of Astronomical research; but with the coming of the Hubble, Herschel and Kepler space telescopes it has lost some of the '*starlight*' it once held. The idea for the construction of a telescope with a mirror with twice the diameter of the '*Hooker*' and four times its surface area was first proposed by George Ellery Hale in 1928. The necessary $6 million funding for the project was provided by the Carnegie Institution of Washington, as Hale reported in 1935:

"Such considerations doubtless determined the Rockefeller boards, which had previously made large grants to the California Institute, to offer it funds in 1928 for the construction of a 200-inch reflecting telescope, together with all the buildings and equipment necessary to render this instrument as efficient as possible. Two conditions were made by the donors: the assurance of the active co-operation with the California Institute in this project of the Mount Wilson Observatory of the Carnegie Institution of Washington and the provision by the California Institute of an adequate endowment for the new Astrophysical Observatory. The president and Executive Committee of the Carnegie Institution, as well as the director of the Mount Wilson Observatory, quickly and cordially assented to the first of these conditions, while the trustees of the California Institute were no less prompt in agreeing to obtain an endowment."

On the 25th of March 1936, the 200-inch (5.1m) mirror blank for the Hale telescope of the Palomar Observatory began its cross-country trip aboard a special railroad car. An event which became something of a national spectacle. James Murphy, of the Chicago, Burlington & Quincy Railroad commented at the time: "*The mob was so dense that the yard master had to call city police to help clear the tracks of an estimated crowd of 10,000. . . and autos coming from as far as you could see.*" The photograph to the left shows a group of people with Edwin Hubble (on the right) greeting the 200-inch Pyrex disc as it arrived at Lamanda Park in Pasadena, California on the 10th of April 1936.

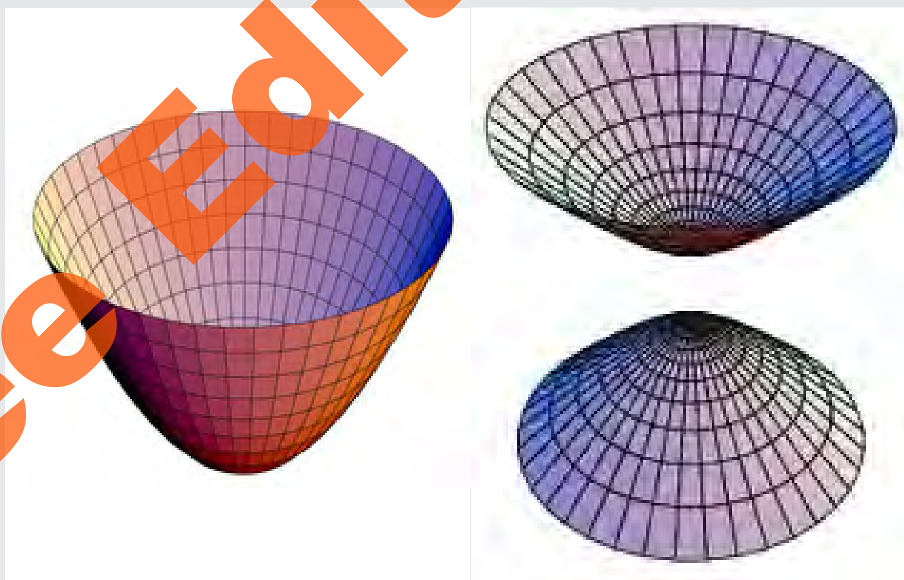
Arrival of 200-inch Pyrex Disc at Pasadena in 1936

A.94 - Ritchey-Chrétien Astrograph (1927)

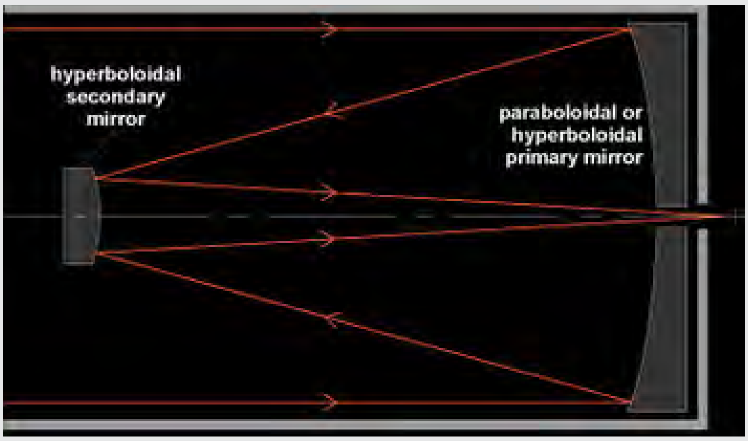
In the March of 1910, the French astronomer and optician, Henri Chrétien (1879-1956) arrived at the Mount Wilson Solar Observatory on a fact finding mission to learn about astrophysical research as carried out by an astronomical observatory at the '*cutting edge*' of modern science. There he met George Willis Ritchey for the first time. In a letter dated the 7th of September 1910, Ritchey wrote to the inventor and scientist, Dr. Elihu Thomson (1853-1937): "*With the co-operation of M. Henri Chrétien, a French astronomer who has been here for six months, and who has been working with me in making and studying the reflector photographs, I have just designed or developed a new type of reflecting telescope...*" It was the beginning of a long road which eventually led to the production of the first Ritchey-Chrétien telescope, seventeen years later.

'Pleiades' (M45) - George Willis Ritchey & Henri Chrétien (1930)

The primary mirror of both a Newtonian and Cassegrain optical design of telescope are Paraboloids, which were adopted by Hale for the 60-inch and 100- inch reflectors on Mount Wilson, and also for the larger 200-inch at Mount Palomar. The '*new curves*' telescope as proposed by Ritchey and Chrétien differed from these conventional designs in that the primary mirror was a Hyperboloid. A design which Hale refused to use and led to him sacking Ritchey in 1919.



Newtonian & Cassegrain Paraboloid (left); RC - Hyperboloid (right)



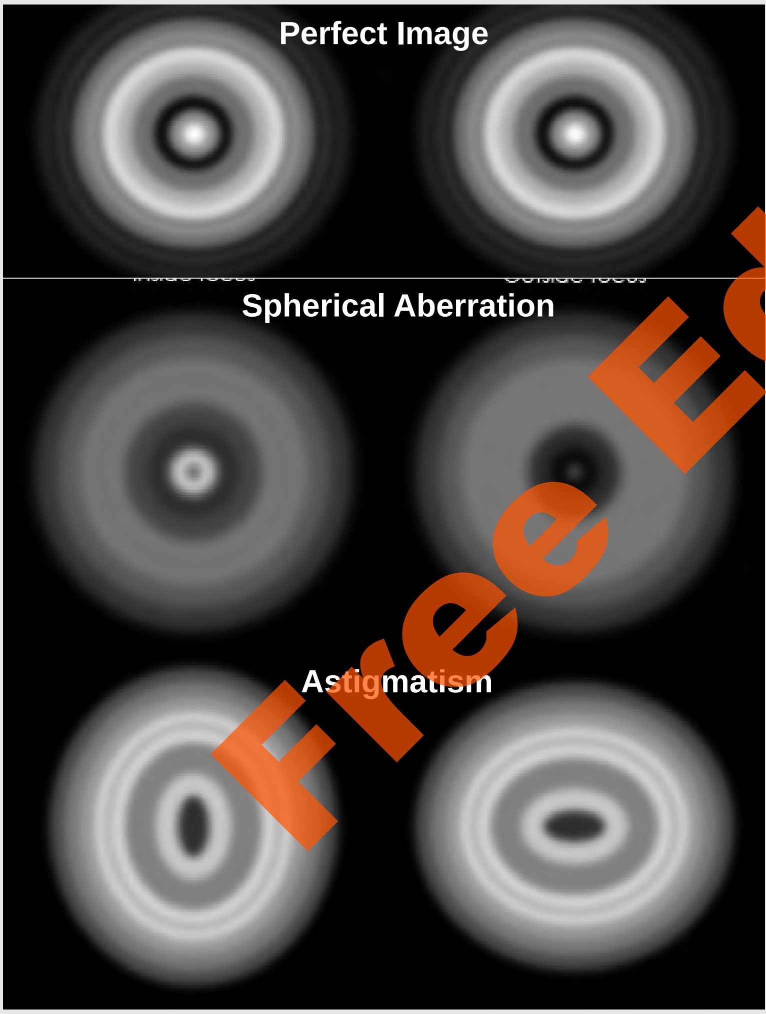
The Ritchey–Chrétien telescope or RCT is a specialized Cassegrain telescope designed to eliminate coma, thus providing a large field of view compared to a more conventional configuration. An RCT has a hyperbolic primary and a hyperbolic secondary mirror. As with the other Cassegrain reflectors, the RCT has a very short optical tube assembly and compact design for a given focal length. The RCT offers good off-axis optical performance.

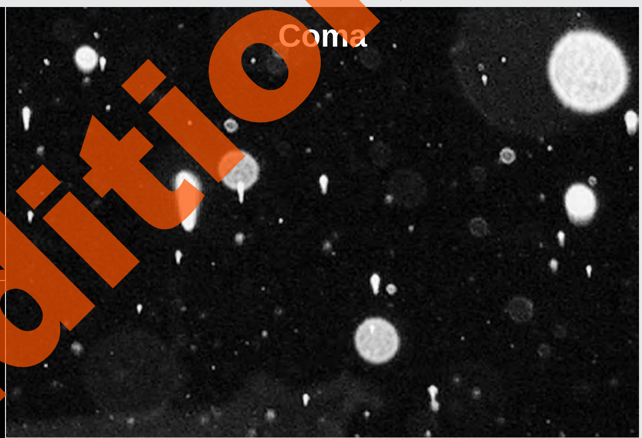
Ritchey-Chrétien Design

A.95 - Schmidtspiegel Astrograph (1930)

It is often the way that the best inventions are the simplest. The fact that they appear later than they should, is simply because they are too simple. So it was with the '*Schmidtspiegel*' or Schmidt Reflector. It is a design which could easily have been made two centuries earlier and not left until 1930 when Bernhard Schmidt made the first of its kind. Schmidt with an idea which can only be described as one of pure genius, introduced into the design the revolutionary optical element known as a '*Corrector Plate*' - a slightly curved lens, which was special in that it was convex near its centre, concave at its edges and flat in between. By doing so he had created an optical system which was a hybrid of both a mirrored reflector and a glass lens refractor. It was the first example of a type of telescope optical system known as a Catadioptric, i.e. one which includes both lenses and mirrors. He had created the almost perfect Astrograph.

Bernhard Voldemar Schmidt (1879-1935)





Prior to the construction of the first Schmidt Camera in 1930, all other Astrographs or Photographic Telescopes (with one exception) had fields of view which were not '*flat*' across their entirety, i.e. they suffered from defects in their optics which produced imperfect star images towards the edges. In contrast the Schmidtspiegel produced perfect star images across the whole of its '*wide*' field of view. Any telescope is only as good as its weakest link, but without good optics, it is useless no matter how stable its mount is or how accurately its drive mechanism tracks. Their are four major defects in a telescope's optics.

Telescope Defects (Spherical Aberration, Astigmatism & Coma)

Firstly, Chromatic Aberration, i.e. the inability to bring to focus at the same point different wavelengths of light, which results in irritating coloured effects. Secondly, Coma, results in off-axis point sources such as stars appearing distorted, appearing to have a tail (coma) like a comet. Coma is an inherent property of telescopes using parabolic mirrors. Thirdly, Spherical Aberration, occurs due to the increased refraction of light rays when they strike a lens or a reflection of light rays when they strike a mirror near its edge, in comparison with those that strike nearer the centre. Fourthly, Astigmatism, is where rays that propagate in two perpendicular planes have different foci, to form an image of a cross, the vertical and horizontal lines will be in sharp focus at two different distances.

A.96 - Amateur Telescopes

The average amateur of the late nineteenth and early twentieth century, who wished to pursue Astrophotography, did not have the luxury of expensive '*wide-field*' photographic refractors or large silvered mirrored reflectors, but had to make use of smaller more conventional optical designs – a visual refractor or a Newtonian reflector. It was not until the late 1860s that '*mass produced*' and sort of affordable high quality instruments became available to the amateur. In 1867 the London optician John Browning published what he called euphemistically called '*A Plea for Reflectors*'; it was in fact an astronomical equipment mail order catalogue, the very first of its kind. In the first decades of the twentieth century, telescope makers like John Edward Mellish began to appear, who produced designs more akin to those used by the modern amateur, but without the benefit of electric motors and GOTO functions.

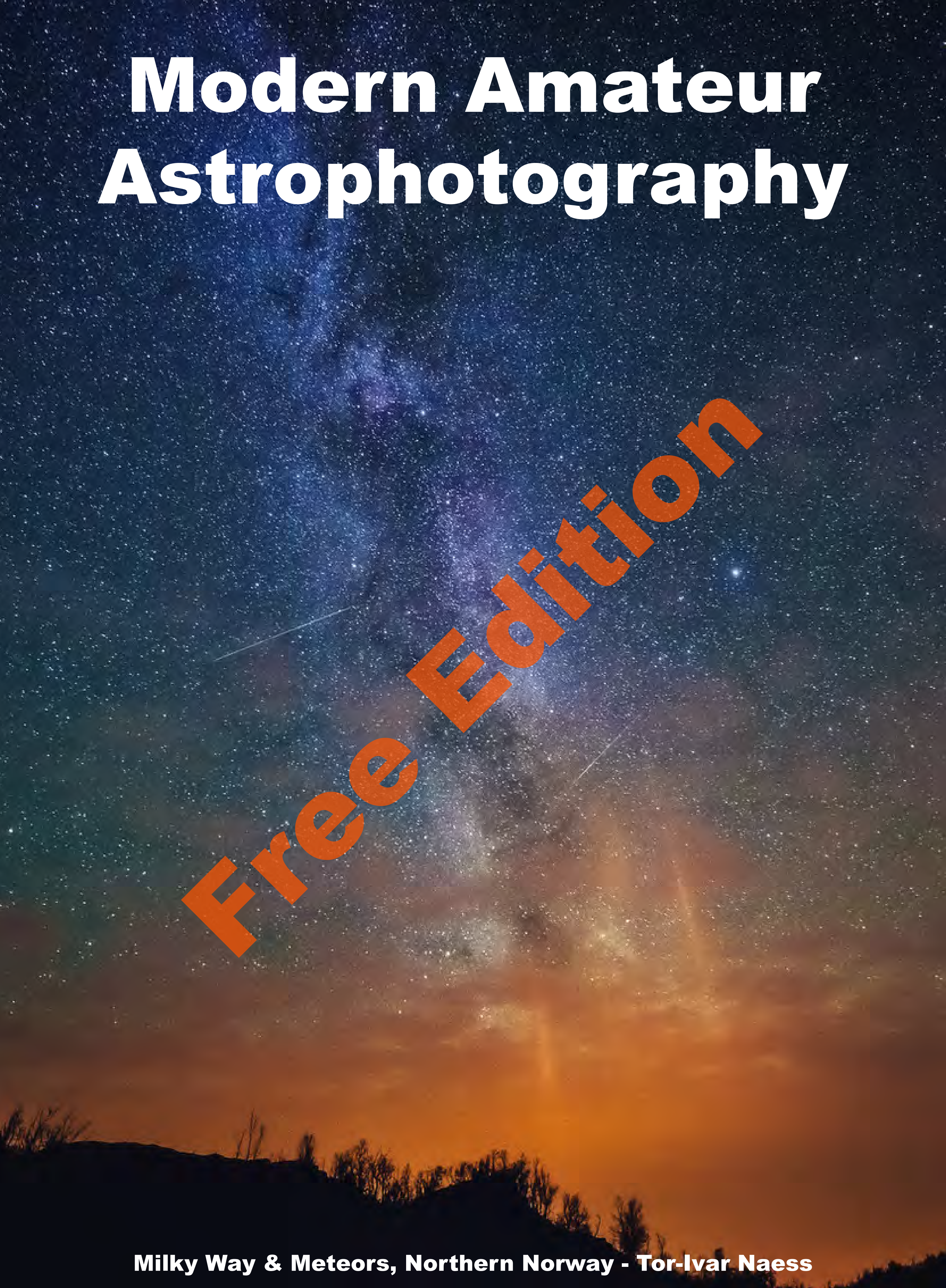
John Edward Mellish (1886-1970)

John Edward Mellish (1886-1970) was one of the foremost amateur telescope makers of the first half of the 20th century. He grew up on his grandfather's farm, near the village of Cottage Grove, Wisconsin and because money was scarce he only ever attended grade school, after which he went to work on the farm. At the age of sixteen he got his first telescope - a small '*spyglass*' which he used to try to look at the moon and stars, but was so small it could see very little. He then bought himself a '*bigger*' telescope for $4, through which he could see some features on the Moon. His first '*proper*' telescope was a 2-inch refractor which cost him $16, which he had earned by helping an uncle who was a carpenter. He later recalled: "*With it, I was able to see many new stars and, I tell you, I was happy then*". As with many a young amateur astronomer he yearned for an even bigger telescope: "*I wanted so much to see some of those stars the books told of, stars that were out of reach of my little instrument.*" He decided to make one for himself and ground a 6-inch mirror. In his long career as a telescope maker spanning near on half a century, Mellish made many instruments both reflectors and refractors, some of them are still in use to this day: "*In my life I made and sold over 100 refractors from 3-inches to 12.5-inches; I worked several 24-inch mirrors and six 36-inch mirrors and quite a number of other mirrors from 18-inches to 32-inches in diameter.*"

By the 1930s amateur telescopes existed which were of high quality, there were other which were built to a limited budget and were somewhat more basic in their design. Most notably was the one built by the Detroit amateur Henry Kramer based around the use of his '*Coal-Scuttle*' (left). A more sophisticated 10-inch Newtonian Reflector on an Equatorial Mount, by John Edward Mellish, belonging to the Evergreen Observatory in Eugene, Oregon, is featured to the right, together with a number of its assistants.

'Bucket' Telescope; Mellish 10-inch Reflector 1944, Evergreen Observatory

Modern Amateur Astrophotography



Milky Way & Meteors, Northern Norway - Tor-Ivar Naess

9. Modern Amateur Astrophotography

Plates, Films & Chips

Zeta Orionis Region - Eddie Trimarchi

'Horsehead' Nebula with Plate, Film & Chip

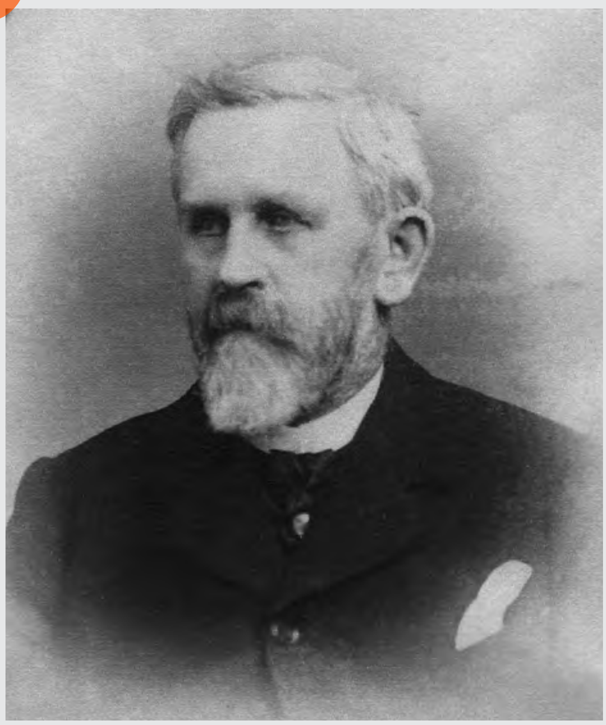
In 1969 Willard Sterling Boyle and George Elwood Smith at the AT&T Bell Laboratories invented the Charge Coupled Device, otherwise known as the CCD; and with it was born the age of Digital Astrophotography. Today many amateur astronomers possessing only modest equipment costing just a few thousand dollars, are regularly capturing images of the heavens, far superior to the photographic plates taken four decades ago by the great reflectors atop the mountains of southern California - in the days when the CCD chip saw the '*firstlight*' of a photon. The CCD Chip has revolutionized modern Astrophotography beyond all recognition from the seemingly crude attempts made by the early pioneers of the 19th century to the magnificent coloured images of the modern digital camera. As to what will happen in the next two centuries of Astrophotography is anybody's guess, but whatever happens, nothing can take away the work of those described in these pages.

The '*firstlight*' of modern amateur Astrophotography shone decades before the first photons hit the pixels of a digital camera. Its story is a tale of three photographic technologies - plate, film and chip; where the end of the first helped the emergence of the second, and in turn its demise was the result of the rise and total dominance of the last. All of this was made possible by the introduction of affordable high quality telescopes together with the development of the PC, GOTO technology and specialist image processing software. It was the efforts of George Eastman of Kodak, and his chemist, Charles Edward Kenneth Mees in making photography easier and affordable to both astronomers and the general public at large, that formed the bridge between a photographic process borne of chemistry to one driven by the mathematics of the digital age and the modern necessity of the personal computer.

John Browning (c1833-1925)

John Browning (c1833-1925) of London was a well known optician and scientific instrument maker during the second half of the nineteenth century. From his shop at No. 63 The Strand and his factory at Southampton Street he provided a wide range of mathematical, scientific and optical equipment. He was responsible for introducing the first telescope equipment supplies catalogue which he called a '*Plea for Reflectors*'. With this catalogue the amateur astronomer of the day, could equip himself with everything he could desire from telescopes, eyepieces, spectroscopes, barometers, thermometers and books. His telescopes were used by a number of well known Astronomers and Astrophotographers, including Lord James Ludovic Lindsay (1847-1913), Edward Ball Knobel (1841-1930) and Eugen Von Gothard (1857-1909). His reflecting telescopes were for the time very advanced and including features such as setting circles and a clockwork motor drive. Browning was the first person to produce '*mass market*' and affordable amateur astronomical telescopes.

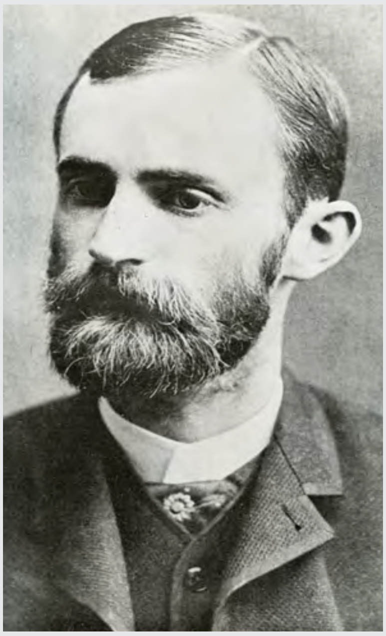
The earliest Gelatino-Bromide '*dry*' plates, i.e. those produced during the 1870s and early 1880s, were essentially Monochromatic. Monochromatic plates were only sensitive to blue, violet and ultraviolet light, slightly sensitive to green and practically insensitive to the rest of the spectrum, including red and the infrared. In practice Monochromatic plates were not entirely suitable for astronomical or spectroscopic use, where the correct representation of the many shades of Gray was particularly important. Furthermore, astronomers were slow to take up the use of these early '*dry*' plates. At that time they had to be prepared by hand. It was not until they began to be '*mass produced*' from the late 1870s onwards by firms such as Wratten & Wainwright of London and Anthony & Co. of New York, that pioneer Astrophotographers like, Henry Draper, William Huggins, Benjamin Apthorp Gould, Andrew Ainslie Common and Isaac Roberts began using them for celestial photography.



Frederick Charles Luther Wratten (1840-1926)

Frederick Charles Luther Wratten (1840-1926) and Thomas Henry Wainwright founded the photographic manufacturing company Wratten & Wainwright in 1877. Wratten's son, Sidney Herbert Wratten (1871-1944) invited Charles Edward Kenneth Mees to join the firm as Managing Director in 1906. It was here in 1906, that Mees produced the first true panchromatic plate at their Croydon factory. In 1912, Wratten & Wainwright was taken over by the Kodak Company. That same year Mees joined Kodak's research laboratory in Rochester, New York.

A.97 - Film Images



George Eastman (1854-1932) was born into a family that fell on hard times, but through sheer hard work coupled with an inventive mind and a gift for organization, he was able by his mid-twenties to found the Kodak Company; a name known by anyone who has ever owned, used or even heard of a camera. In the April of 1880, George Eastman began his photographic business, when he leased the third floor of a building at 101 State Street in Rochester, New York, and began to manufacture dry plates for sale using his newly patented plate making machine. In doing so he had taken his first steps in making photography available to the masses. He later wrote of this early period in his company's history: "*The idea gradually dawned on me that what we were doing was not merely making dry plates, but that we were starting out to make photography an everyday affair.*" It was his ultimate aim - "*to make the camera as convenient as the pencil.*" This was an approach which would eventually lead to his famous slogan – *'you press the button we do the rest'*. Eastman realized that if he was to achieve his stated aim he would have to develop a lighter and more flexible support other than glass for photographs.

George Eastman (1854-1932), Founder of Kodak, c1880

In 1884, Eastman perfected the technique of coating photographic emulsion on paper and then load the paper onto a roll holder, which was used in place of the conventional glass plate holder. The following year he marketed the very first flexible photographic film with advertisements that stated: "*Shortly there will be introduced a new sensitive film which it is believed will prove an economical and convenient substitute for glass dry plates both for outdoor and studio work.*" Although his new system of photography using roll holders and a paper based film was a great success it was still not perfect. He sought an alternative solution which did not use paper.

Kodak Celluloid Film c1889

In February 1889, Kodak's chemist, Henry Morris Reichenbach (1863-1916) succeeded, by coating the paper with a layer of plain, soluble gelatin, and then with a layer of insoluble light-sensitive gelatin. After exposure and development, the gelatin bearing the image was stripped from the paper and transferred to a sheet of clear gelatin. It was then varnished with collodion. George Eastman had now created the very first transparent plastic film, which was shortly to revolutionize virtually all areas of photography and especially amateur photography. However despite the obvious benefits of the new plastic film based process, it would still be a number of years before it became almost universal.

Kodak Factory in 1898

A.98 - Film Cameras

In 1900, George Eastman launched the famous Brownie Camera, which sold for a paltry $1. The Brownie camera became the symbol of low cost photography and introduced the concept of the snapshot. The first Brownie, introduced in the February of 1900, was a very basic affair, consisting of a cardboard box camera with a simple meniscus lens that took 2.25-inch square pictures on 117 roll celluloid film, is illustrated to the left together with its original packaging.

Kodak - Box Brownie Camera in its 'Box', c1901

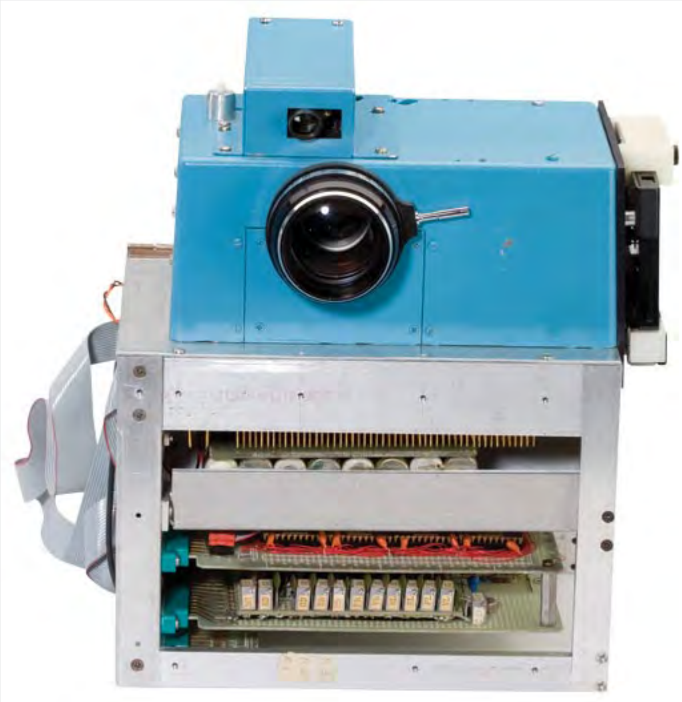
Although plastic film was largely the province of the Amateur Astrophotographer it was not taken up to any large extent until the 1960s with the introduction of affordable Single Lens Reflex Cameras (SLRs). Prior to this, the photographic plate was the preferred technology for amateurs. In his book '*Astronomical Photography for Amateurs*', Henry Hayden Waters, published in 1921 over thirty years after Kodak introduction of celluloid film, no mention of its use is included, only that of '*dry*' photographic plates. In an SLR camera, a mirror and prism system (hence '*reflex*', from the mirror's reflection) allows the photographer to view the subject through the lens and see exactly what will be captured, as opposed to the viewfinder of a conventional camera, where the image could be significantly different from that captured.

The photographic single-lens reflex camera (SLR) was invented in 1861 by the author and inventor, Thomas Sutton, but only a very few of his SLRs were ever made. The first 35mm prototype SLR was the Russian Спорт (Sport), constructed in 1934, but not sold commercially until 1937. The first true 35mm SLR was German Ihagee Kine Exakta of 1936. In 1952 the Japanese produced their first SLR, the Asahiflex I made by the Asahi Optical Company. This model marked the beginning of the rise of Japanese as SLR camera manufacturers, such as Minolta, Yashica and Nikon. In 1957 the Asahi Pentax SLR, which ultimately led Asahi to rename itself Pentax.

Asahiflex 35mm SLR - First Japanese Built SLR Camera, 1952

The SLR camera proved to be for the Amateur Astrophotographer, the easy and convenient means of taking photographs of astronomical objects, in that it made use of plastic film rather than the photographic plate. The use of the '*dry*' photographic plate was inherently more difficult than film, and required a high level of skill not only in the acquisition of the image but in the production of the final glass negative and the paper positive prints. However the production of negatives and positive prints from film could be easily done by the amateur with relative inexpensive equipment or taken to professional outlets to be developed. However from 2004 onwards, the availability of suitable films for Astrophotography began to become scarce when the likes of Kodak began to discontinue popular series such as Tech Pan. The equally popular Kodak Ektachrome E200 Colour film was discontinued in 2011, and was soon followed by others, until as of now (2015), this type of photographic media is all but extinct.

A.99 - Digital Cameras



In 1975 Kodak produced the first true CCD camera, i.e., one which could take a digital picture and store it on a permanent media. It was a crude, low resolution and bulky affair, with a pixel resolution of 100 x 100, weighing in at a heavy eight pounds (3.5kg). In appearance it was more akin to a toaster than a camera. Its developer, Steve Sasson was of the opinion that his device would not become a practical reality until the 1990s. A prediction which proved to be remarkably accurate. In 1986, Kodak produced the world's first megapixel sensor, capable of recording 1.4 million pixels that could produce a high quality 5 x 7-inch photographic print. Five years later in 1991 Kodak introduced the first DSLR - its Digital Camera System (later known as the DCS 100). It used a Nikon F-3 SLR body and a Kodak 1.3 megapixel sensor. A modern DSLR camera can have a sensor resolution of 10 megapixels or more.

First Digital Camera - Kodak 1975

Fairchild Imaging was founded by the American scientist and industrialist Sherman Fairchild (1896-1971). It was Fairchild who invented an efficient 'between-the-lens' camera shutter and the associated timing mechanism which enabled accurate aerial photography for the first time. He founded over 70 companies, many in the Aviation Industry, including Fairchild Aircraft, Fairchild Industries, Fairchild Aviation Corporation and Fairchild Camera and Instrument. In 1973 one of his companies Fairchild Imaging became the first company to successfully develop and produce a commercial CCD. Since that time, Fairchild Imaging has delivered hundreds of thousands of imaging devices in every shape, size and configuration for applications as diverse as Astrophotography, Aerial Photography, Medical Imaging and Military Satellite Surveillance. The company is now owned by the British firm BAe Systems.

Fairchild Imaging First CCD Chip Produced in 1973

The first commercially developed CCD chip was produced in 1973 by the American firm, Fairchild Imaging. In 1976 the company went one step further when they began selling the very first CCD camera, the Fairchild MV-101, with a 100 x 100 pixel chip, giving a resolution of a mere 0.01 megapixels. At the time of its release the MV-101 would set you back to the tune of some $4000. It was shown to the public for the first time at a Technology show hosted in 1975 at the Lincoln Centre, New York. An earlier version of the Fairchild MV-101, the MV-100 was demonstrated in October 1973, but did not reach the commercial market. It was the size of a cigarette packet, measuring 3.5 x 1.5 x 2.25-inches. It weighed six ounces and had a power consumption of about a watt.

Globular Cluster M22 in Sagittarius - John Charles Duncan (1918)

The dates of the two photographs shown above and on the following page of the Globular Cluster M22 (NGC 6656) in the constellation of Sagittarius, are separated by some ninety years. They amply illustrate the tremendous progress made by Astrophotographers in their ability to capture the ultimate '*picture in light*'. What is more remarkable is that Duncan's photograph of 1918 was taken with the 60-inch reflector, then the second largest operational telescope in world, whilst Hunter Wilson's 2009 image was obtained with relatively modest equipment. The principal factor which makes his closer to the '*Holy Grail*' of Astrophotography is the use of modern digital ACCDs and image processing software.

Appendices

Region of NGC 2264 in Monoceros - Gordon Haynes (2012)

‘Catchers of the Light’

“Every day our eyes catch the light of our memories – time spent with family, the journey to work, a special holiday, a beautiful sunset or a dark starlit night. Each image captured is a picture drawn in light – a photograph: only to be lost in our minds or forever forgotten. Nearly two hundred years ago a small group of amateur scientists achieved what had eluded mankind for centuries – the ability to capture a permanent record of an image seen by their own eyes – a moment in time frozen onto a surface. They had discovered Photography.”

They were the ‘*Catchers of the Light*’.

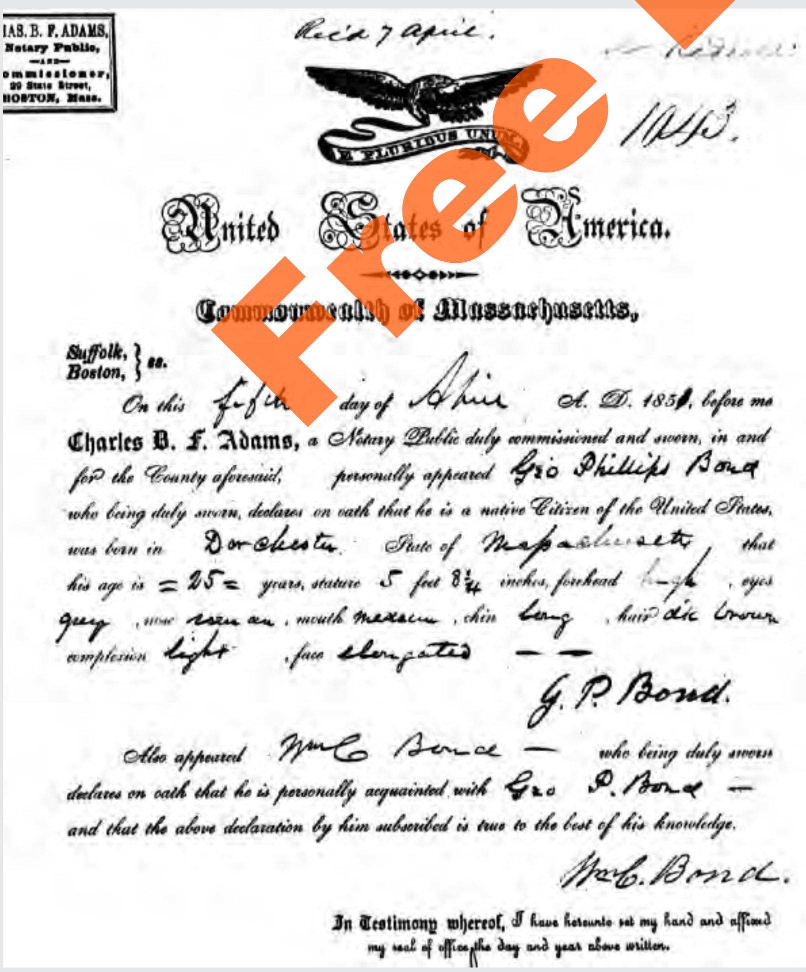
Appendix A
The Pioneers

This Appendix provides short biographies of many of the first pioneers associated with the early years of Photography, as well as the astronomers and other individuals, both amateur and professional who made significant contributions to development of Astrophotography in imaging the many and diverse objects to be found in the Universe.

For each pioneer featured the following information is provided when known:

- Date and Place of Birth;
- Name of Father and Mother;
- Important Role played in the History of General or Astronomical Photography;
- Date and Place of Death;
- Place of Burial.

A photograph of the individual is also given which is different from that to be found in the main text, or if no alternative is available a photograph of their gravestone or some other relevant object. For example there is no known photograph of George Phillips Bond (1825-1865), so an image of his passport application of 1851 is given, which provides the only information on his physical appearance, and states that he was 5 feet 8 inches tall, with dark brown hair, grey eyes, and elongated face and a light complexion.



CHAS. B. F. ADAMS, Notary Public, —AND— Commissioner, 20 State Street, BOSTON, Mass.

Rec'd 7 April.

E PLURIBUS UNUM

United States of America.

Commonwealth of Massachusetts,

Suffolk, Boston, } ss.

On this fifth day of April A. D. 1851, before me Charles B. F. Adams, a Notary Public duly commissioned and sworn, in and for the County aforesaid, personally appeared Geo Phillips Bond who being duly sworn, declares on oath that he is a native Citizen of the United States, was born in Dorchester State of Massachusetts, that his age is = 25 = years, stature 5 feet 8¼ inches, forehead high, eyes grey, nose medium, mouth medium, chin long, hair dk brown complexion light, face elongated — —

G. P. Bond.

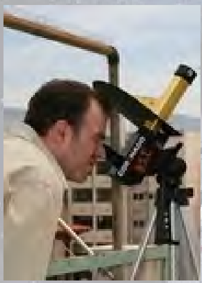
Also appeared Wm C Bond — who being duly sworn declares on oath that he is personally acquainted with Geo P. Bond — and that the above declaration by him subscribed is true to the best of his knowledge.

Wm C. Bond.

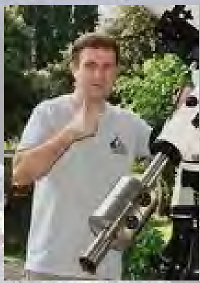
In Testimony whereof, I have hereunto set my hand and affixed my seal of office the day and year above written.

Our only clue as to what George Phillips Bond looked like are the details given by him on his Passport Application, dated the 5th of April 1851 (shown to the left). Four days later, he left the port of Boston with his brother, Richard, bound for Liverpool, England, on a fact finding mission to visit the leading European observatories of the day. Shortly after arriving in England on the 21st of April, he visited the '*Great Exhibition*', which was held at London's Crystal Palace in Hyde Park, between the 1st of May and the 11th of October 1851. He took with him the Lunar Daguerreotypes of John Adams Whipple, which caused a sensation amongst both the public and the judges alike, one of which was described by the judging panel at the exhibition which included the great Sir John Herschel as: "*one of the most satisfactory attempts that has yet been made to realise, by a photographic process, the telescopic appearance of a heavenly body*."

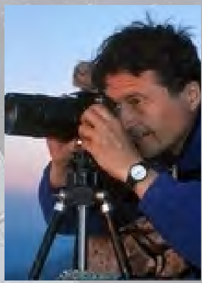
The Modern 'Catchers'



Theodore Arampatzoglou
Deep Space
Greece

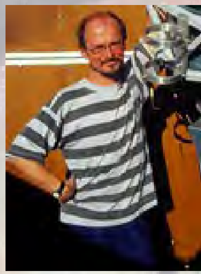


J. P. Brahic
Solar
France



Miloslav Druckmuller
Eclipse
Czech

Jim Ferreira
Spectra
USA



Bernd Flach-Wilken
Deep Space
Germany

R. Jay GaBany
Deep Space
USA

Robert Gendler
Deep Space
USA

Paul Haese
Deep Space
Australia

Gordon Haynes
Deep Space
England

Jason Jennings
Wide-Field
Australia

Walter Koprolin
Deep Space
Austria

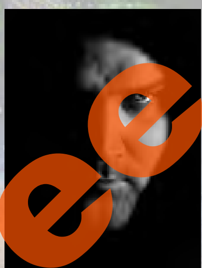
Thierry Legault
Lunar
France

Paul Martin
Terrestrial
Northern Ireland

David Mailin
Deep Space
Australia

Martin Mckenna
Terrestrial
Northern Ireland

Jim Misti
Deep Space
USA



Tor-Ivar Naess
Aurora
Norway

Damian Peach
Solar System
England

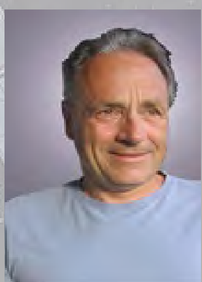
Gerald Rhemann
Comets
Austria

Pedro Re
Solar
Portugal

Eddie Trimarchi
Deep Space
Australia

Daniel Verschatse
Deep Space
Chile

Christian Viladrich
Solar System
France



Richard Walker
Spectra
Switzerland

Peter Ward
Deep Space
Australia

Volker Wendel
Deep Space
Germany

Anthony Wesley
Solar System
Australia

Hunter Wilson
Deep Space
USA

Appendix B
The Imagers

The following imagers have previously been '*featured*' in the main text in recognition of the significant contribution they have made to the development of modern digital Astrophotography:

- Martin McKenna from Northern Ireland (Origins);
- Thierry Legault from France (Moon);
- Jean Pierre Brahic from France (Sun);
- Damian Peach from England (Solar System);
- Robert Gendler from the USA (Deep Space);
- Jim Ferreira from the USA (Spectroscopy);
- Jason Jennings from Australia (Photographic Sky Maps);
- Anthony Wesley from Australia (Telescopes);
- David Malin from Australia (Modern).

Their biographies can be found at the start of the indicated part of the book. Biographies of the following imagers can be found in this Appendix:

- Theodore Arampatzoglou (Greece);
- Miloslav Druckmüller (Czech Republic);
- Bernd Flach-Wilken (Germany);
- R. Jay GaBany (USA);
- Paul Haese (Australia);
- Gordon Haynes (England);
- Walter Koprolin (Austria);
- Paul Martin (Northern Ireland);
- Jim Misti (USA);
- Tor-Ivar Naess (Norway);
- Pedro Ré (Portugal);
- Gerald Rhemann (Austria);
- Eddie Trimarchi (Australia);
- Daniel Verschatse (Chile);
- Christian Viladrich (France);
- Richard Walker (Switzerland);
- Peter Ward (Australia);
- Volker Wendel (Germany);
- Hunter Wilson (USA).

Here they give their own stories of how they came to take the magnificent astronomical images that appear in the pages of this book; and more importantly to tell of the passion they have - which has made them the worthy successors to the men and women who first photographed the stars. They are the modern '*Catchers of the Light*'.

End Piece

The ‘Monkey Head; (NGC 2174) in Orion, Theodore Arampatzoglou

Further Reading

The '*Further Reading'* list given below represented some of the more important sources relating to the History of Astrophotography, additional references to more specific topics can be found in the main text.

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11. '*Photographs of the Moon'*, Warren De la Rue, MNRAS, Vol. 18, p. 257;
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14. '*Photographic Atlas of the Moon'*, William H. Pickering, Annals of the Astronomical Observatory of Harvard College, Vol. LI, 1903;
15. '*Photographic Atlas of the Moon'*, Kuiper, G. P., D. W. G. Arthur, E. Moore, J. W. Tapscott, and E. A. Whitaker. 1960, Chicago: University of Chicago Press;
16. '*Digital Lunar Orbiter Photographic Atlas of the Moon'*, Bowker, David E. and J. Kenrick Hughes , Lunar & Planetary Institute, 2004;

Photographic Sources

A detailed list of the sources of the photographs, maps, drawings and illustrations contained in the present volume is given below, including the name of the author (where known), its date of origin (where known), the holding repository (imager, observatory, library, museum, university, website, etc.) and the page in the book where it is to be found. My heartfelt thanks and eternal gratitude is extended to all those listed, who have contributed to the '*Ages of Astrophotography*' in this most important manner.

Front Cover

'Celebrating Edwin P. Hubble' from a painting by Ed Hengeveld, courtesy of ©Philip Corneille.

Inside Cover

© **Gerald Rhemann**: Comet Holmes & NGC 1499, Comet Ikea-Zhang & M31 (2002); **Edward Emerson Barnard**: NGC 1499 (1895), Comet Holmes & M31 (1892), Lick Observatory;

Introduction

© **Robert Gendler:** M42/NGC 1977 (2005), p.i; © **Gerald Rhemann**: ; **Max Wolf**, 'Die Milchstasse', 1925: M42/NGC 1977, p.i; M31, p.iii; **R. B. Litchfield**: Thomas Wedgwood, p.iv, '*Thomas Wedgwood: The First Photographer*', 1903;

1. Stones Circles to Space Telescopes

Philip Rupert Acott: *Stonehenge (1877)*, p.11; **British Library**: Nevil Story-Maskelyne, *Collodion of Moon (1857)*, p.23; John Dilwyn Llewelyn & Thereza Llewelyn, *Collodion of Moon (1857-58,) p.23*; **chinaculture.org**: Shen Kuo, *Portrait*, p.3; Mo-Tzu, *Drawing*, p.14; **Diderot's and D'Alembert's Encyclopédie**: *Camera Obscura Design*, p.13; *Camera Obscura Principles*, p.14; © **Robert Gendler &** © **Jim Misti**: *M3 (2005)*, p.28; **Harvard College Observatory**: John Adams Whipple: *Daguerreotype Moon (1851)*, p.5; *Daguerreotype of Moon* (1852), p.19; *Daguerreotype of Moon (1849)*, Samuel D. Humphrey, p.17; **Hamburg Observatory:** *Bernhard Voldemar Schmidt,* p.10; **Hastings-on-Hudson Historical Society:** Henry Draper, p.22, *Moon at Last Quarter*; **Historical Museum of the Palatinate in Speyer**: *Golden Hat of Schifferstadt*, p.9; **Jena Friedrich Schiller University**: Berkowski: Copy *Daguerreotype of Total Solar Eclipse* (1851), p.18, © **Martin McKenna**: *Beaghmore Stone Circle*, p.1; *Himself*, p.7, *Monea Castle*, p.8; © **Sean McKenna**: *Frederick Scott Archer Grave (2001)*, p.24; **Mount Wilson Observatory:** George Willis Ritchey: M3 (1910), p.27; © **NASA**: *Kepler Space Telescope,* p.9*; Kepler-20 Line up,* p.9*; Hubble Space Telescope*, p.12; **Richard Mudhar of Megalithia.com**: *Callanish Stones*, p.9; **National Media Museum, Bradford**: Frederick Scott Archer (c1856), p.21, by Robert Cade; Lewis Morris Rutherfurd, *Full Moon (1858)*, p.22; **National Museum of American History, Washington DC:** John William Draper, *Daguerreotype of Solar Spectrum (c1840)*, p.18; **Newgrange.com:** *Newgrange (c1898)*, R. Welch, p.3; **Nikon Corporation**: *Nikon D7100*, p.16; **Henry Phillips**: *Total Solar Eclipse (1868)*, p.5; **Harry Ransom Center, University of Texas:** *Portrait Joseph Nicéphore Niépce (c1795)*, after ink & watercolour by C. Laguiche, p.3; Joseph Nicephore Niepce, *Courtyard at Le Gras (1826)*, p.17; **Joseph Bancroft Reade**: *Self-Portrait (c1850s)*, p.5; © **Pedro Ré**: *DSLR Image of Moon (2008)*, p.20; **Isaac Roberts**: *M74 (1893)*, p.6; **Royal Greenwich Observatory**: *Greenwich Photoheliograph (c1873)*, p.4; **Royal Society of London**: *Portable Camera Obscura (1694)*, Robert Hooke, p.4; **Christoph Scheiner:** *Helioscopium (c1625)*, p.4, '*Rosa Ursine*' (1626-1630); **Bernhard Voldemar Schmidt**: *Portrait with Telescope, Hamburg Observatory (1926)*, p.10, University of Tartu; **Science Museum, London**: *Camera Obscura (c1800-1830)*, p.15; **University of**

Abbreviations

ADC: Analogue to Digital Converter.

Alt: Altitude.

AJ: Astronomical Journal.

AJP: American Journal of Photography.

AN: Astronomische Nachrichten.

AnHar: Annals of the harvard College Observatory.

ApJ: Astrophysical Journal.

AReg: Astronomical Register.

AU: Astronomical Unit.

Az: Azimuth.

bhp: brake horse power.

BJP: British Journal of Photography.

CLA: Consolidated Lunar Atlas

CR: Comptes Rendus des Seances de L'Académie des Sciences, Paris.

CCD: Charge Coupled Device.

CDC: Carte du Ciel.

cm: Centimetre.

CPD: Cape Photographic Durchmusterung

Dec: Declination.

DSLR: Digital Single Lens Reflex.

ESA: European Space Agency.

f: Focal Ratio.

FL: Focal Length.

FSA: Frederick Scott Archer.

HCO: Harvard College Observatory.

HCO Cir.: Harvard College Observatory Circular

HM: Her/His Majesty's

HST: Hubble Space Telescope.

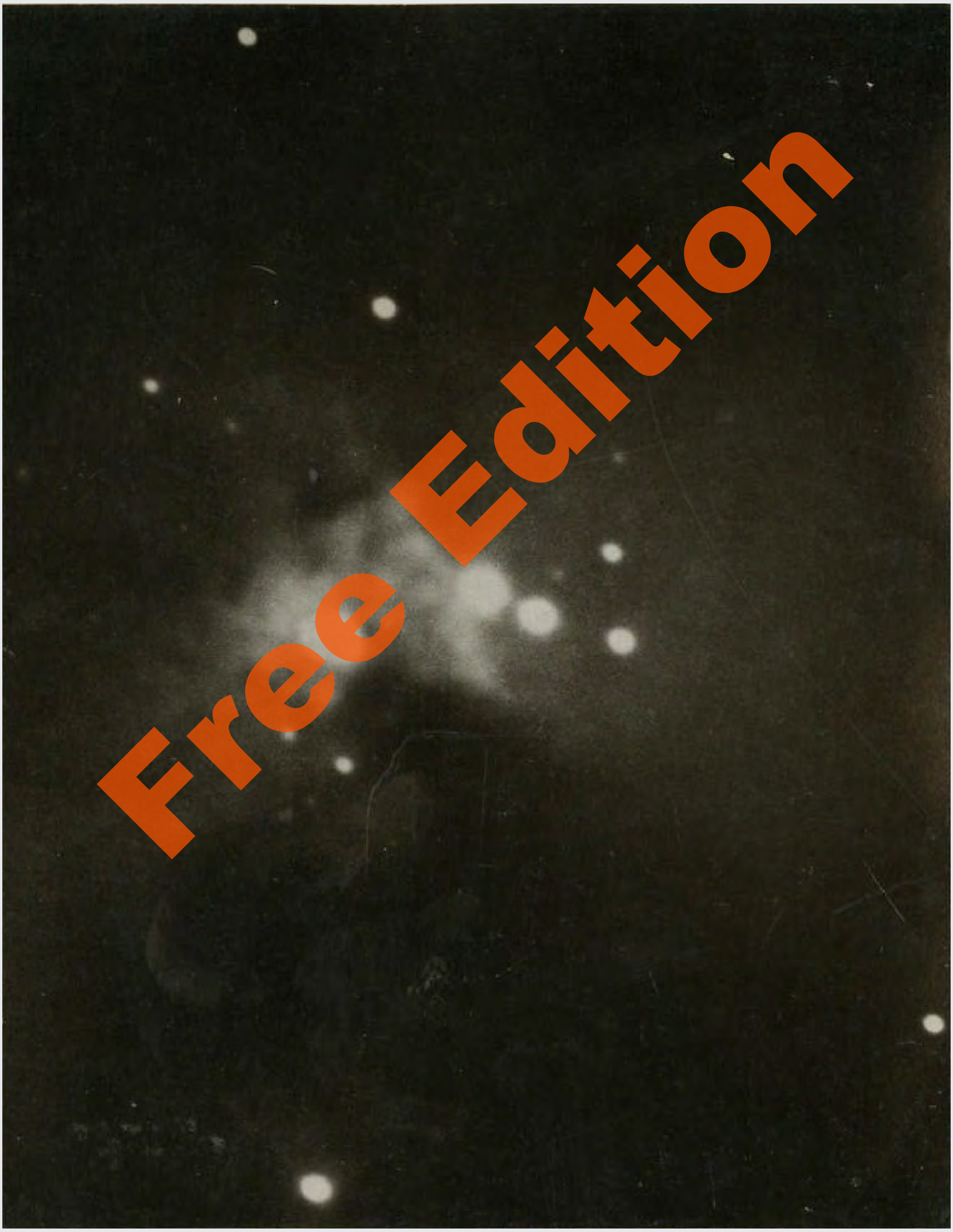
IAU: International Astronomical Union;

IEEE: Institute of Electrical and Electronics Engineers

JBAA: Journal of the British Astronomical Association.

Acknowledgements

The Author would first like to thank the 28 Astrophotographers who have graciously agreed to contribute their magnificent photographs, without whom this book could never have been written, and whose names are found next to their work. My gratitude also goes out to all the many institutions, libraries, museums, societies and observatories who have made available the hundreds of pioneering astronomical photographs to be found throughout the book (see Photographic Sources for a list of their contributions). Finally my heartfelt appreciation to Philip Corneille and the Space Artist Ed Hengeveld for freely making available the unique and highly relevant painting which is to be found on the front cover of the '*Ages of Astrophotography*'.



'Great Orion' Nebula (M42) - Henry Draper, 11th March 1881

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The Author

Stefan Hughes began his career as a professional astronomer, gaining a 1st Class Honours degree in Astronomy from the University of Leicester in 1974 and his PhD four years later on the '*Resonance Orbits of Artificial Satellites due to Lunar-Solar Perturbations'*, which was published as a series of papers in the Proceedings of the Royal Society of London.

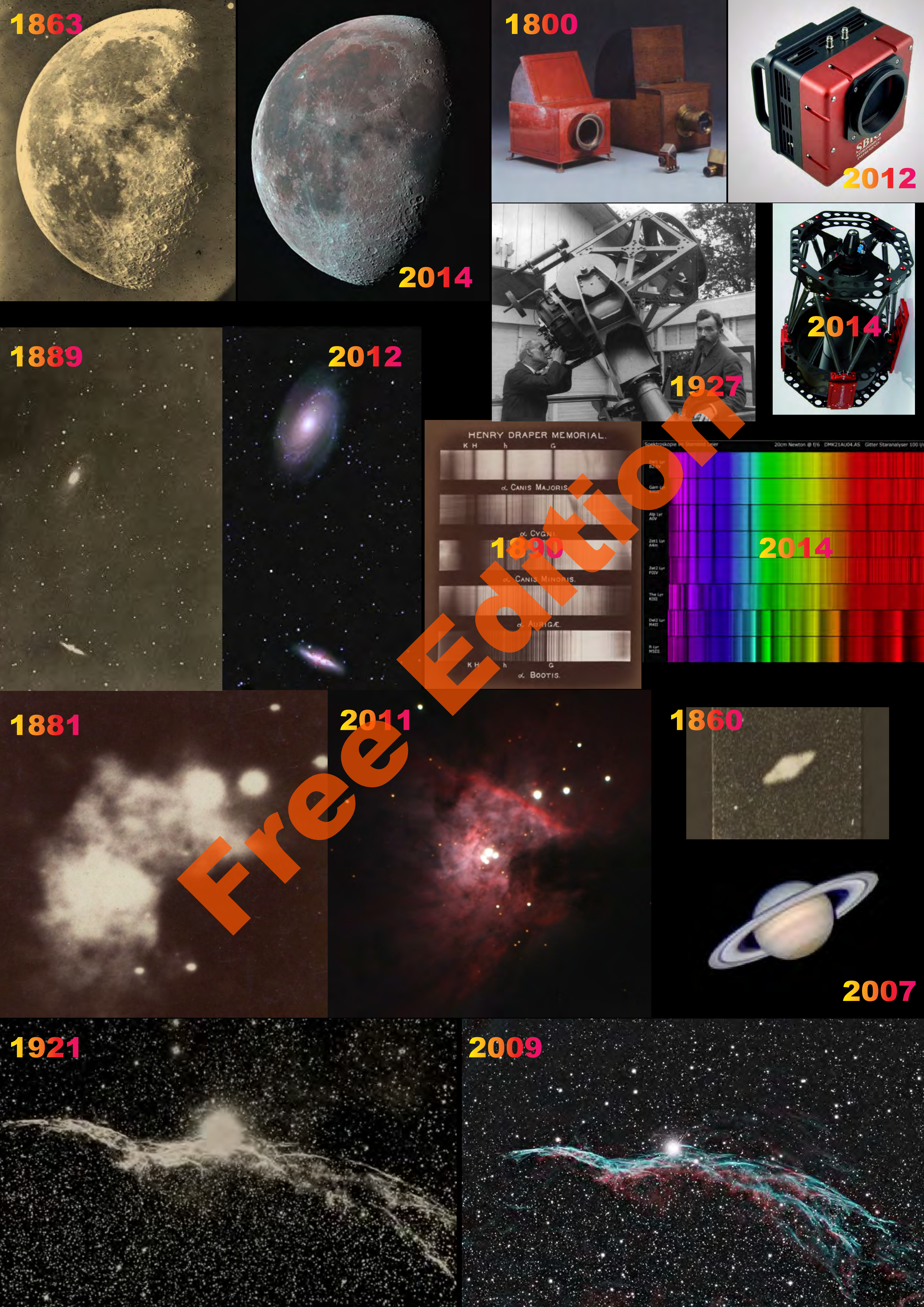
After graduating he became a Research fellow in Astronomy, followed by a spell as as a lecturer, firstly in the Department of Engineering at Warwick University and then in Applied Mathematics at Queen Mary College, University of London. Then came a ten year long career as an IT Consultant, working on large technology infrastructure projects for an international software house.

In '*mid life*' he spent several years retraining as a Genealogist, Record Agent and Architectural Historian, which he practiced for a number of years before moving to the Mediterranean island of Cyprus. During his time working as an Architectural Historian and Genealogist, he was a regular contributor to Family History and Period Property Magazines.

For the past fifteen years he has been imaging the heavens, as well as researching and writing the '*Catchers of the Light*' - '*Featuring the Forgotten Lives of the Men and Women Who First Photographed the Heavens*'.

He has now completed the '*Ages of Astrophotography*', the sequel to his magnum opus, which is dedicated to all the amateur Astrophotographers across the world, for their contributions to the latest chapter in the History of Astronomical Photography.

They are the modern '*Catchers of the Light*.


1863
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α Canis Minoris.
α Aurigæ.
α Bootis.
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