Catchers of the Light

Introduction

The Astrophotographers' Family History

Tales of Adventure, Adversity & Triumph

Stefan Hughes

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'*.

Stefan Hughes
Banana Grove Observatory
Paphos, Cyprus
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Sarah Williams (1837-1868) was an English poet born in Marylebone, London of a Welsh father, Robert Williams (c1807-1868) and an English mother, Louisa Ware (c1811-1886). During her short life she made a successful career as a poet, writer and journalist under her pen name of '*Sadie*'. She died of cancer on the 25th of April 1868 at her home at No. 95 Queen's Crescent, Kentish Town, London, following failed surgery. Later that year a volume of her poems entitled *'Twilight Hours: A Legacy of Verse'* was published by her friend Alexander Strahan. It was edited by her former teacher, Edward Hayes Plumptre (1821-1891), the Dean of Wells cathedral. However perhaps her finest poem was *'The Old Astronomer'*, which tells the story of a dying astronomer giving advice and solace to his sorrowful young pupil. In its verses are the famous words used by many an astronomer as their epitaph; and is also a fitting tribute to our 'Catchers':

"Though my soul may set in darkness, it will rise in perfect light; I have loved the stars too fondly to be fearful of the night."

The Old Astronomer to His Pupil

Reach me down my Tycho Brahe, I would know him when we meet,
When I share my later science, sitting humbly at his feet;
He may know the law of all things, yet be ignorant of how
We are working to completion, working on from then to now.

Pray remember that I leave you all my theory complete,
Lacking only certain data for your adding, as is meet,
And remember men will scorn it, 'tis original and true,
And the obloquy of newness may fall bitterly on you.

But, my pupil, as my pupil you have learned the worth of scorn,
You have laughed with me at pity, we have joyed to be forlorn,
What for us are all distractions of men's fellowship and smiles;
What for us the Goddess Pleasure with her meretricious smiles.

You may tell that German College that their honour comes too late,
But they must not waste repentance on the grizzly savant's fate.
Though my soul may set in darkness, it will rise in perfect light;
I have loved the stars too fondly to be fearful of the night.

What, my boy, you are not weeping? You should save your eyes for sight;
You will need them, mine observer, yet for many another night.
I leave none but you, my pupil, unto whom my plans are known.
You "have none but me," you murmur, and I "leave you quite alone"?

Well then, kiss me, -- since my mother left her blessing on my brow,
There has been a something wanting in my nature until now;
I can dimly comprehend it, -- that I might have been more kind,
Might have cherished you more wisely, as the one I leave behind.

I "have never failed in kindness"? No, we lived too high for strife,
Calmest coldness was the error which has crept into our life;
But your spirit is untainted, I can dedicate you still
To the service of our science: you will further it? you will!

There are certain calculations I should like to make with you,
To be sure that your deductions will be logical and true;
And remember, "Patience, Patience," is the watchword of a sage,
Not to-day nor yet to-morrow can complete a perfect age.

I have sown, like Tycho Brahe, that a greater man may reap;
But if none should do my reaping, 'twill disturb me in my sleep
So be careful and be faithful, though, like me, you leave no name;
See, my boy, that nothing turn you to the mere pursuit of fame.

I must say Good-bye, my pupil, for I cannot longer speak;
Draw the curtain back for Venus, ere my vision grows too weak:
It is strange the pearly planet should look red as fiery Mars,
God will mercifully guide me on my way amongst the stars.

Sarah Williams (1837-1868), English Poet

Preface

I was twelve years old when I first looked up at the stars and wondered.

From the hill high above my house I used to look up night after night under dark skies and dreamed of all the wonderful photographs I had seen in my books - of other galaxies far beyond our own Milky Way, of glowing clouds of gas, clusters containing stars far too many to count and the mystical dark clouds through which no stars could shine.

Images of the *'Great Andromeda Spiral'*, the '*Great Orion Nebula*' and the *'Great Hercules Cluster'* and the most iconic of them all – the '*Horsehead*' filled my soul as I lay beneath the stars all those years ago.

I used to think that the people who made all this possible were famous scientists – household names. They had to be - after all they had captured in these magnificent photographs the true nature of our universe. Yet the truth is so very different.

How many of you have heard of a clockmaker called William Cranch Bond; a doctor named Henry Draper; the brothers Paul and Prosper Henry; the priest Angelo Secchi; the '*wedding & baby*' photographer, William Usherwood; or the housemaid Williamina Fleming? These were the true pioneers of Astrophotography - whose names have long been forgotten and confined to the closed pages of history.

Although it is over forty years since I first stood upon that hill, it is only now that I am able to repay them for what they gave to me. I can think of no better way than to tell the story of their lives; not in the language of a scientist but in ordinary words; befitting these ordinary people who did such extraordinary things.

I stood upon that silent hill

And stared into the sky until

My eyes were blind with stars and still

I stared into the sky

The Song of Honour

Ralph Hodgson (1871-1962), English Poet

About the Book

This Book is a *'Family History'* of Astrophotography, and tells the story of the lives and achievements of the great pioneers of Astrophotography.

It is not meant to be an academic treatise of their work; this is best left to papers written for eminent scientific journals and societies.

It is however about the events that shaped them and their immediate families; where they were born, who their parents were, where they went to school, who they married, the telescopes they owned, the astronomical photographs they took, their successes and failures; and the legacy they left to the modern world.

Each chapter of the Book is devoted to a particular Astrophotographer(s) and includes '*Snippet Panels*' and Notes, which contain background information on subjects and people relating to their life and the sources of information used in telling their story.

The Book has been further divided into nine self contained parts, each devoted to a particular aspect of the history of astrophotography and the pioneers who contributed to it. Each part ends with a '*Summary*' chapter which brings together the '*threads*' discussed in the chapters on the individual pioneers.

The parts cover every aspect of the subject from the early photographers; the first astronomical photographs of the Moon, Sun and Planets; Deep Space Astrophotography of stars, cluster, nebulae and galaxies; Astronomical Spectroscopy; Photographic Sky Surveys; the development of the Astrograph (Photographic Telescope); and ending with role of the amateur in Astrophotography and the coming of the modern digital age.

A number of Appendices are included which contain more detailed information on topics such as the chemistry of photographic processes, telescope optical systems, and the Charge Coupled Device (CCD). A timeline summarizing the historical development of Astrophotography is also to be found as an Appendix, as is an '*A List*' of 109 of the most important astronomical photographs, and a number of simple but useful formulae used in Astrophotography.

A Glossary of Terms used in the book is included in an Appendix. Finally, a '*Family Pedigree*' for each Astrophotographer is provided for those interested in conducting further research and as a reference aid when reading the chapters related to them.

The reader can choose which part to read either in sequence, in the order that takes their interest or any chapter of their choosing. They will lose nothing no matter how they read the book or in what order.

Furthermore the book can be used at a number of levels; either as a biography of the lives of the pioneers of astrophotography, a source of reference for a student or researcher; and finally as a technical compendium on the historical development of photographic equipment, processes, technologies and techniques, that are relevant to Astrophotography.

Gratitude

During the course of the six years it has taken me to research and write the '*Catchers of the Light'*, I have been helped by many individuals and organizations. In the main this assistance has been confined to the provision of information, documents and photographs; and for this I am especially grateful. Acknowledgement of this valuable assistance has been included in the appropriate chapter(s) of the eBook.

However in a number of cases this assistance has been of such importance and magnitude that without it, this eBook would never have been started let alone finished; and to these individuals and organizations I extend my eternal gratitude and respect.

Firstly, I wish to mention the late Sir Patrick Moore, for without the inspiration I found in his many books and his famous long lived BBC TV programme - '*The Sky at Night*', I would never have aspired to become an Astronomer.

Next I should like to refer to the important role played by the staff and fellow students in the Department of Astronomy at the University of Leicester, during the eight happy years I spent successively as undergraduate, postgraduate and finally as post doctoral research fellow. Here I found a warmth of friendship and companionship that has not been surpassed in all the years that have followed.

It is a great testament to Professor Jack Meadows and his staff at the time that many of the students they so ably taught are still to this day employed as professional Astronomers in Universities, Observatories and other Institutions across the Globe. It is to them that I owe all the astronomical knowledge and expertise required to write the '*Catchers*'.

Today there are many thousands of amateur Astrophotographers in almost every country of the world, who on a nightly basis take images of the heavens that would be the envy of our '*Catchers of the Light'*. Without their efforts and the invaluable advice and encouragement given to me by many of them, I could never have taken the astronomical images I did. Thanks also to those who supplied the equipment and software I used - the Adobe Corporation, the Celestron Corporation, Cyanogen (MAXIM DL), Losmandy, the Meade Corporation, OPTEC, Pier Tech, the Santa Barbara Imaging Group, Software Bisque (SkyX) and William Optics.

Without the Internet and Google, it would have been impossible for me to have conducted the vast amount of research needed to complete this monumental task I set myself. In the days before the world wide web, it would have required me to visit individuals, record repositories, libraries, observatories and other institutions in over fifty countries of the world. Special thanks goes in particular to the SAO/NASA Astrophysics Data System for providing me access to many of the astronomical articles used in this eBook.

Finally I should like to express my immense thanks and the great debt I owe to my wife Patricia Flint Hughes, not only for her invaluable advice, her proof reading skills and considerable moral support, but also for the years of seeing me either glued to an iMac screen, or with my head in book, or my eyes gazing up at the heavens, without criticism or complaint, except when she felt it was time for me to rest and recuperate from the long hours of exertion.

In memory of Professor Andre Deprit (1926-2006), who taught me the language of Mathematics

How to Become a Great Astrophotographer

"What makes a man great? A man may be great in his aims, or in his achievements, or in both, but I think that a man is truly great who makes the world his debtor... who does something for the world which the world needs and which nobody before him has done or known how to do."

Lt. Commander Rupert Thomas Gould RN, – *'John Harrison and his Timekeepers'*

A question that is often asked is-How do you become a '*Great Astrophotographer*'?

Before I answer, the question should be clarified. Does the phrase 'Great Astrophotographer, mean how do you take great images? Or does it really mean a Great Astrophotographer, i.e. someone who fits Rupert Gould's definition.

If it is the former, then the words: enthusiasm, dedication, perseverance, love of computers, patience, technical knowledge, practical ability, willingness to learn, choose the right equipment and so on, come to mind.

However, if the questioner means the latter, then the answer becomes much more difficult to give.

So, here is the advice that I believe some of the great pioneers of Astrophotography would give on how to become a '*truly great*' Astrophotographer:

Be the First: John William Draper (1811-1882); he was to first person to successfully photograph an astronomical object, when he imaged the Moon in 1840 with a Daguerreotype Camera attached to a 13 cm Reflector. Louis Daguerre had taken an earlier but unsuccessful blurred photograph of the Moon.

Don't Give up your Day Job: Edward Emerson Barnard (1857-1923); for over 17 years he worked as a photographer's Assistant in Nashville, Tennessee before becoming a staff astronomer at the Vanderbilt University Observatory. He was to later become one of the greatest observational astronomers of all time, as well as being famous for his magnificent wide field photographs of the Milky Way and the catalogue of Dark Nebulae which bears his name.

Give up your Day Job: Lewis Morris Rutherfurd (1816-1892); he started out life as a lawyer but decided to give up a career at the '*Bar*' to concentrate on science and in particular astronomy. He later became one of the pioneers of astronomical spectroscopy and took in 1865 photographs of the Moon which were the best of the day, and remained unsurpassed until the later work of Puiseux and Loewy.

Find a Good Wife (or Husband): William Huggins (1824-1910) the father of spectroscopy married Margaret Lindsay Murray in 1875, and for the next 35 years she became her husband's assistant, co-worker and inspiration. It was Huggins who carried out pioneering work in our understanding of the physical nature of nebulae, discovering that some were made up of gas whilst others were made up of stars.

Form a Society: James Edward Keeler (1857-1900) formed the Maybury Astronomical Society in his home town in Florida in 1875. In 1898 he was appointed Director of the Lick Observatory, where he began photographing Deep Space Objects with the 36-inch Crossley Reflector. Even today these photographs remain some of the finest images ever taken.

Change Your Career: George Willis Ritchey (1864-1945); in 1919 he was fired from Mount Wilson Observatory in a dispute with its then director George Ellery Hale over the usefulness of his telescope design (the Ritchey-Chretien optical system). For the next five years he eked out a living on his Orange Grove in Azusa, California. The Ritchey-Chretien design forms the basis of the optical system used in the latest generation of '*super*' telescopes including the Hubble Space Telescope.

Win an '*Oscar*': Henri Chretien (1879-1956); in 1954 he became the only astronomer ever to win a Hollywood Oscar for his invention of '*Cinemascope*', a type of projection system used in many a Blockbuster movie. He is famous today along with George Willis Ritchey, for the optical system which bears their name. Initially, it was difficult to test and expensive to make, but recently affordable RC systems have become available, giving ordinary amateurs the benefits of its wide flat field.

Learn from Others: Henry Draper (1837-1882); in 1857 he visited the estate of William Parsons, the 3rd Earl of Rosse, at Birr Castle, Ireland; where he saw the Earl's speculum metal Reflecting Telescope. On his return to America, he began to construct mirrors using techniques learnt from his visit to Birr Castle. On the 30th September 1880, Henry Draper took the first ever photograph of a Deep Space Object when he imaged the Great Orion Nebula (M42).

Give it a Name: John Herschel (1792-1871); was the person who in 1839 coined the term Photography from the Latin, meaning literally *'writing with light'*. He was also instrumental in making advances in photographic processes, as well as completing the work began by his father William and his Aunt Caroline in cataloguing DSOs in the southern hemisphere.

Inspire Others: William Parsons (1800-1867); almost single handed created the 72-inch Reflector known as the '*Leviathan of Parsonstown*', which was for nearly three quarters of a century the largest telescope in the world. He inspired others to do great things with his enthusiasm, hard work and ingenuity, including the likes of Henry Draper and Johann Louis Emil Dreyer, the compiler of the NGC/IC.

Invent Something Special: Pierre Jules Cesar Janssen (1842-1907); in 1874 he constructed his *'revolver photographique*', a special camera which was capable of taking a sequence of photographs. In one hour it could take up to 100 photographs. He used this remarkable camera on a trip to Japan, to observe the transit of Venus which took place that year. This was the very first astronomical webcam!

Become Master of Your Trade: John Adams Whipple (1822-1891); was one of the earliest professional photographers, being the first to import the chemicals required for the Daguerreotype process, as well as a pioneer of night time photography. He became so much of an expert that William Cranch Bond recruited him as a technician to work with him at the Harvard College Observatory where he became an early pioneer of astrophotography.

Good Equipment is Not Essential, but it Helps; William Cranch Bond (1789-1859); when he was young, although he had no telescope he used to prepare himself for an observing session by climbing down a well in order to adapt his eyes to the dark. He later became the first Director of the Harvard College Observatory, and used a 2.75-inch Refractor (which was at that time the only telescope available to him) to observe in the October of 1846 the newly discovered planet Neptune.

Collaborate with Other: The Henry Brothers; Pierre Paul (1848-1905) and Mathieu Prosper (1849-1903) Henry were two brothers who worked together all their lives at the Paris Observatory. It was remarked at the time that they were inseparable, and that their work was a joint effort with no brother dominating the work of the other. They were responsible for taking the first successful photographs of the Planets when they imaged Jupiter and Saturn the years 1885-86; as well as the design and construction of some of the finest telescopes ever made, including the great 33-inch Refractor at Meudon, near Paris.

Never Let Adversity Stop You: George Phillips Bond (1825-1865); was responsible for taking the first ever photograph of a Double Star when he imaged Mizar and its companion Alcor in 1857. He also suggested in 1858 that photography could be used to measure stellar magnitudes, i.e. photometry. In an eleven month period ending on 29th January 1859, George Bond suffered the tragic deaths of his youngest daughter, his wife and his father.

A Physical Handicap is Not an Excuse: Bernhard Voldemar Schmidt (1879-1935); was probably the finest optician who ever lived. When he was 15 years old he had to have his right hand amputated when one of his experiments with Gunpowder went wrong. In 1930 he designed the first ever practical optical system which possessed a wide angle flat field. No telescope of this design, which became known as the Schmidt Camera was built in his lifetime. In the September of 1936 an 18-inch Schmidt Camera was completed at the Mount Palomar Observatory in California, less than a year after his death. The Schmidt design was later used in many amateur telescopes and in the Kepler Space Telescope, which in 2011 discovered two '*Earth*' like planets orbiting another star.

Education is Not Essential: Milton Lasel Humason (1891-1972); was responsible for carrying out much of the photographic and spectroscopic work from which Edwin Hubble derived the first distances of galaxies and which enabled him to formulate the famous law, which now bears his name. Humason was a man who had no PhD or education of any significance whatsoever, and who began working at Mount Wilson Observatory as a janitor.

‘The Purpose of History’

“History is the witness that testifies to the passing of time; it illuminates reality, vitalizes memory, provides guidance in daily life and brings us tidings of antiquity”

Marcus Tullius Cicero (106 BC – 43 BC) from his speech ‘*Pro Publio Sestio*’

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Acknowledgements

Acknowledgement for the help given by companies, individuals, institutions, libraries, observatories, organizations, record offices, web sites in the use of - text extracts from original sources, genealogical information, photographs, maps, drawings and illustrations is given in the appropriate chapter(s) of this eBook.

Index

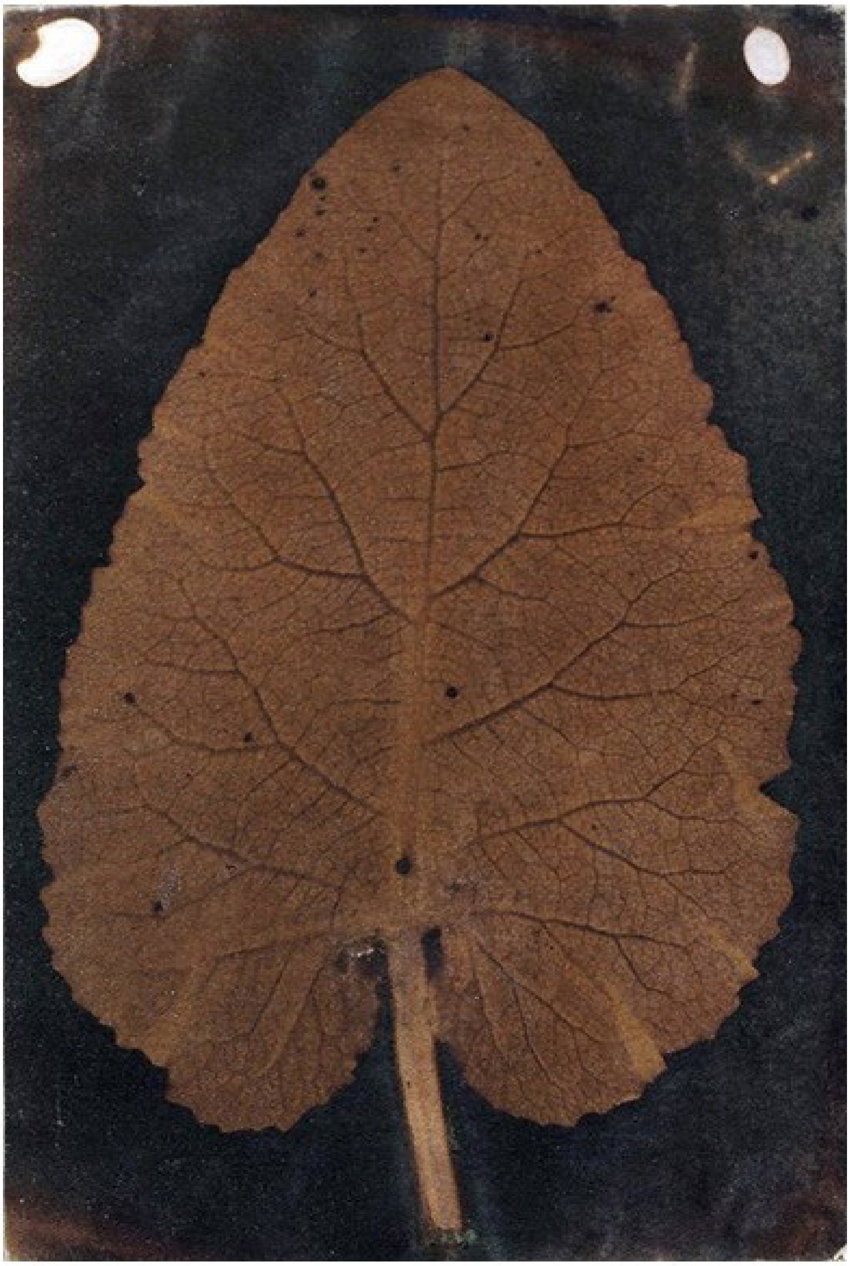
As the *'Catchers of the Light'* is an eBook, it is fully searchable and therefore no formal index has been provided or indeed deemed necessary. To compile an Index for a book the size of the '*Catchers*' would have been not only difficult and time consuming, but prone to errors and omissions. The Author prefers that the reader search for himself and in doing so explore the great diversity of information and items of interest he will surely find.

Appendices

Part I

Firstlight

The Origins of Astrophotography



Possibly the 'first' ever photograph attributed to Thomas Wedgwood, c1800

"In 1851 Scott Archer and Dr. Diamond introduced the collodion process in practical form, and this finally prepared the way for such a worker as Mr. De La Rue; for the introduction of the collodion process was an event in photography second only in importance to the discovery by Daguerre in 1839." Lady Margaret Lindsay Murray Huggins (1848-1915).

I. Abstract

The earliest origins of Astrophotography are intrinsically linked to the development of the photographic process as introduced by Louis Daguerre (1787-1851) in 1839; for it was with his Daguerreotype method that the first successful photographs of astronomical objects were obtained during the 1840s and early 1850s.

The other early photographic process, the Calotype of William Henry Fox Talbot (1800-1877) was little used in astronomical photography, partly because of the patent restrictions placed on its application, but mainly due to its lack of sensitivity when compared to its competitor the Daguerreotype.

However by the mid 1850's onwards both had been replaced by newer and more light sensitive chemically based photographic processes. In 1851 the sculptor and chemist, Frederick Scott Archer (1814-1857) published his *'wet collodion'* method; its introduction marked a major step forward in the development of photography. Not only was it more sensitive than processes of Daguerre and Fox Talbot, it also incorporated the advantages each had over the other.

Wet collodion photographs possessed the same fine detail as exhibited by the Daguerreotype; and like the Calotype multiple positive copies could be obtained from a negative image. The method was not perfect and required a certain amount of chemical aptitude in the use of several potentially dangerous substances including Potassium Cyanide and Bichloride of Mercury. In addition wet collodion plates had to be developed within 15 minutes or so after exposure before the collodion solution dried and therefore required the use of a portable darkroom when taking images '*in the field'*.

The 'wet collodion' process became widely used in astronomical photography from 1851 onwards, a number of pioneers used it to take images of the sun, moon, planets and stars. George Phillips Bond, John Adams Whipple and James Wallace Black used it to in 1857, obtain images of stars as faint as the sixth magnitude. The following year, in 1858, William Usherwood, a miniature artist from Walton-on-the-Hill. Surrey, England, used the wet collodion method to take the first successful image of a Comet.

In 1864 the Collodio-Bromide process was published by William Blanchard Bolton (1848-1899) and Benjamin Jones Sayce (1837-1895). In their '*dry collodion*' process a ready-made emulsion of Collodion and Silver Bromide was poured directly onto the glass plate The prepared plates can be kept for some time before deterioration sets. It was unfortunately less light sensitive than the wet collodion process and was never used in astronomical photography.

In 1871 by Richard Leach Maddox's (1816-1902) proposed the use of the Gelatino-Bromide '*dry*' photographic plate. It was this process which marked the greatest advance in the development of astronomical photography, even more so than the introduction of Archer's wet collodion method. The increased sensitivity of the '*dry*' plate over Archer's 'wet' process enabled the first images of Deep Space Objects (DSOs), so called because they are only found in the deep recesses of the universe, far beyond the confines of our own insignificant Solar System.

The ‘*dry*’ plate technology was only slowly accepted by both astronomers and photographers in general. It was not until the introduction of ‘*mass produced*’ dry plates from 1877 onwards that the gelatino-bromide method began to replace the collodion processes.

Only in 1880 did the New York Doctor, Henry Draper with the aid of a ‘*dry*’ photographic plate obtain the first image of a DSO - when he imaged the ‘*Great Orion*’ nebula (M42) on the 30th of September that year.

The coming decades saw the development of photographic emulsions sensitive to all parts of the visible spectrum and beyond; for both glass plates and the celluloid film (following its introduction in 1889). In 1906 Charles Edward Kenneth Mees, when working for Wratten & Wainwright, produced the very first true panchromatic photographic plate, i.e. sensitive to all colours including ‘*deep red*’.

Following Mees’ move to KODAK in 1907 to head their research laboratory at Rochester, New York, the company introduced a range of photographic emulsions particularly suited for astronomical use, most notably the KODAK 103a series and latterly the black and white Tech Pan and the colour Ektachrome films.

In 1969 came the greatest technological leap (so far) in astronomical photography with the invention of the Charge Coupled Device or CCD, by Willard Sterling Boyle and George Elwood Smith. Although originally designed for use as a form of solid state memory device, its application as an imaging device was developed by others and in particular Michael Francis Tompsett, who filed the first CCD imaging patent in 1971.

The digital imaging cameras developed in the 1970s and 1980s by the likes of Fairchild Imaging and KODAK were introduced into astronomy in 1979 at the Kitt Peak Observatory in Arizona. The first usable and affordable CCD cameras for the amateur astronomer were introduced in the 1990s by firms such as Celestron and the Santa Barbara Imaging Group.

The modern CCD camera and the introduction of fast Personal Computers, when coupled with the availability of high quality optical telescopes has revolutionized amateur Astrophotography during the last decade or so.

“It is somewhat difficult to lay down any precise instructions for the successful development of astronomical photographs. Much might be written, and pages of various formula; given; but after all, experience, and extreme, almost antiseptic, cleanliness are the chief aids to success; and those readers who have successfully followed the methods of ordinary photography are not likely to make many mistakes. It must be borne in mind that our object in astrophotography is to produce negatives of extreme sharpness and accuracy of detail, and any method which would tend to produce the slightest effect which has no objective existence must be carefully avoided.”

Henry Hayden Waters (1880-1939), from Astronomical Photography for Amateurs, 1921.

I.1

‘The Showman and the Inventor’

Louis Jacques Mandé Daguerre

Born: 18th November 1787, Cormeilles en Parisis, Val d’Oise, France

Died: 10th July 1851, Bry-sur-Marne, near Paris, France

Joseph Nicéphore Niépce

Born: 7th March 1765, Chalon sur Saône, Saone-et-Loire, Bourgogne France

Died: 5th July 1833, Saint-Loup-de-Varennes, Saône-et-Loire, France

On the 7th of January 1839, members of the French *Academie 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, who had relied heavily on the earlier efforts of his now dead partner, the inventor, Joseph Nicéphore Niépce. In 1839 Daguerre attempted to photograph the Moon and failed. Astrophotography was about to be born.

I.1.1 Failure

On the 7th of January 1839, members of the French Academie des Sciences were shown examples of Photography, an invention that would forever change the study of astronomy [1]. The astonishingly precise pictures they saw were the work of Louis Jacques Mandé Daguerre - a Romantic painter and printmaker; most famous until then as the proprietor of the Diorama, a popular Parisian spectacle featuring theatrical painting and lighting effects. Each Daguerreotype (as Daguerre dubbed his invention) was a one of a kind image on a highly polished, silver-plated sheet of copper. It was the Polaroid of the day.

Louis Jacques Mandé Daguerre (1787-1851) made no significant contributions to Astrophotography with the exception of his failed attempt to produce the first photograph of the Moon; which unfortunately has not survived [2].

"La préparation sur laquelle M. Daguerre opère, est un réactif beaucoup plus sensible à l'action de la lumière que tous ceux dont on s'était servi jusqu'ici. Jamais les rayons de la lune, nous ne disons pas à l'état naturel, mais condensés au foyer de la plus grande lentille, au foyer du plus large miroir réfléchissant, n'avaient produit d'effet physique perceptible. Les lames de plaqué préparés par M. Daguerre, blanchissent au contraire tel point sous l'action de ces mêmes rayons et des opérations qui lui succèdent, qu'il est permis d'espérer qu'on pourra faire des cartes photographiques de notre satellite."

"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."

Francois Arago 1839, Perpetual Secretary, French Academie des Sciences.

However, as one of the great pioneers of early Photography, and without doubt its finest publicist, it was felt only right that the first chapter of this book should be devoted to him. A more important reason for his inclusion is that the very first astronomical photographs taken during the 1840s were Daguerreotypes and not the Calotypes of his arch Nemesis – William Henry Fox Talbot [3].

The name Joseph Nicéphore Niépce is unknown today by all, with the exception of a few photographic aficionados. Yet it was Nicéphore Niépce who took the first true Photograph some thirteen years before Arago made his historic announcement to the world, extolling the images of Louis Daguerre. However in recent years there have been efforts by Photographic Historians to redress the balance in Niépce's favour.

How did it come about that the name of Daguerre is engraved so deeply in the pages of history, and that of Niépce has been so effectively erased from it? We will now tell the story of how this distortion of history came about: and it is only right that it should be done:

" It is the first and fundamental law of history that it should neither dare to say anything that is false, nor fear to say anything that is true, nor give any just suspicion either of favour or disaffection; that, in the relation of things, the Writer should observe the order of time, and add also the description of places ; that in all great and memorable transactions he should first explain the counsels, then the acts, lastly the events; that in the counsels he should interpose his own judgment on the merit of them; in the acts he should relate not only what was done, but how it was done ; in the events he should show what sheer chance, or rashness, or prudence had in them ; that in regard to persons he should describe not only their particular actions, but the lives and characters of all those who bear an eminent part in the story."

Marcus Tullius Cicero (106 BC – 43 BC), Roman Philosopher, Orator and Statesman.

I.1.2 Cormeilles-en-Parisis

Louis Jacques Mandé Daguerre was born on the 18th November 1787 in the French Commune of Cormeilles-en-Parisis, Val d'Oise, some ten miles to the North West of Paris [4]. He was the eldest of the two children born to Louis Jacques Daguerre (c1761-), a clerk in the Finance Ministry and his wife Anne Antoinette Hauterre (1767-). His younger sister, Marie Antoinette Eulalie was born some four years later on the 11th of September 1791.

I.2

'The Chemist'

Frederick Scott Archer

Born: 30th August 1814; Hertford, Hertfordshire, England

Died: 1st May 1857; Bloomsbury, London, England

Frederick Scott Archer was a great pioneer whose invention of the wet collodion process, published in 1851 revolutionized the Science of Photography; but who nevertheless died largely unrecognized 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.

I.2.1 Unrecognized

Frederick Scott Archer (FSA) was without doubt one of the great pioneers of early photography, whose name should without doubt stand near to, if not alongside the likes of Joseph Nicephore, Niepce, Louis Daguerre and William Henry Fox Talbot.

The publication of his discovery in 1851 of the so called wet collodion process revolutionized photography, making it easier to obtain images with exposures of a few seconds only, and which also enabled multiple positive copies to be quickly made from the same glass negative plate; unlike the Daguerreotype process which produced a one off positive image on a silvered copper plate which could not be readily replicated. The Wet Collodion Plate was the preferred photographic process from its introduction in the early 1850s until the advent of the mass produced Dry Gelatin Plate in the late 1870s and early 1880s.

The importance of Archer's work to Photography was recognized by Lady Margaret Huggins, when in her 1889 obituary of the great pioneering Astrophotographer Warren De La Rue she wrote of the Collodion Process [1]:

"In 1851 Scott Archer and Dr. Diamond introduced the collodion process in practical form, and this finally prepared the way for such a worker as Mr. De La Rue; for the introduction of the collodion process was an event in photography second only in importance to the discovery by Daguerre in 1839."

Yet at the time of his death in 1857, although well respected by his photographic colleagues, he was largely unrecognized by the rest of the public at large; certainly unrewarded and definitely in impoverished circumstances. Even today he is not as well known as the other early photographic pioneers. The 150th Anniversary of his death in 2007 came and went largely unnoticed by the world, despite ample opportunity in the years since his death for historians to reassess his contribution to the development of photography.

I.2.2 Frederick Scott Archer of Hertford

It is generally believed that Frederick Scott Archer was born in Bishops Stortford, Hertfordshire around 1813; the son of a Butcher [2].

However there is no extant or primary documentary or indeed any other reliable evidence to support this view. It has just been '*passed off*' as being the '*truth*'.

The 1841 Census record relating to Frederick Scott Archer states somewhat confusingly that he was born in Scotland [3]; whilst the 1851 Census states that he was born in Hertford, Hertfordshire around 1814 [4]. The family headstone in Kensal Green Cemetery adds weight to the theory that he actually came from Hertford, stating that his father was [5]:

'THOs ARCHER FORMERLY of HERTFORD ...'.

No record of a Thomas Archer butcher of Bishops Stortford can be found in the surviving documents of the Hertfordshire Archive and Local Studies Office (HALSO), at Hertford. However records relating to Thomas Archer, Butcher of Hertford and his ancestors are to be found in abundance at the HALSO.

Furthermore, Frederick Scott Archer, his brother James and his sister Sarah were all baptized in All Saints Church, Hertford on the same day – 21st April 1822 [6]. In his monumental work on British Sculptors, Rupert Gunnis gives the true year of Archer's Birth as 1814 [24].

The only certain connection of Frederick Scott Archer to Bishops Stortford is that his wife Frances Garrett Machin was born there, the daughter of Nathaniel Smith Machin, an auctioneer of Bishops Stortford and No. 26 King Street, Covent Garden, London [7].

Even the date of his death is often given incorrectly as 2nd May 1857; his death certificate clearly shows he died a day earlier on the 1st May 1857 [8].

I.3

'The Medical Man'

Richard Leach Maddox

Born: 4th August [or 4th May] 1816, Bath, Somerset, England

Died: 11th May 1902, Portswood, near Southampton, Hampshire, England

In 1871, Richard Leach Maddox first published 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.

I.3.1 Gelatino-Bromide

During the whole history of Astrophotography, only three chemically based photographic processes have ever been used to any degree – the Daguerreotype, the Wet Collodion and the Gelatino-Bromide. Each in turn has spurred the development of astronomical photography forward and enabled astronomers to image fainter and more distant objects in space. Of the three the Gelatino-Bromide process was by far the most important of them all. Only the invention in 1969 of the CCD (Charge Coupled Device) had a greater impact on the use of photography for astronomical research.

On the 30th of September 1880 the New York Doctor, Henry Draper using a Gelatino-Bromide *'Dry Plate'* imaged the *'Great Orion Nebula'* (M42) [1]. This was the first photograph of any Deep Space Object (DSO) ever taken. It marked one of the great milestones in Astrophotography.

The earliest published account of the use of gelatine and silver bromide in photography was a paper published in the 8th September 1871 Issue of the British Journal of Photography, by Dr. Richard Leach Maddox (1816-1902), the son of a Tea Dealer from Bath, Somerset, England [2].

He later wrote modestly of his invention in a letter to the photographer William Jerome Harrison (1845-1908) [3], [4]:

"…The world has been benefited, and I have been honoured with a gold medal and diploma by the Jurors' Committee of the Inventions Exhibition. 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…"

Do not be fooled by this modesty, we as Astrophotographers owe much to Richard Leach Maddox, of whom remarkably little is known. Let us now tell his story and that of the Gelatino-Bromide process.

I.3.2 Teatime at Bath

The name Maddox has its roots in the ancient Welsh male given name Matoc, a diminutive of '*mad*' meaning '*fortunate*' or *good*', which survives in the modern Welsh personal name of Madog. It is from this ancient land of Wales, that Richard Leach Maddox's family came.

His father Walter Vaughan Maddox (1775-1857) was the eldest of the five children, (four sons and a daughter) born to Richard Maddox, a carpenter and his wife Jane (nee Morris) from Welshpool (Y Trallwng) in the ancient Welsh County of Montgomeryshire (now Powys) [5]. As a young man, Walter Vaughan Maddox left the Welsh Marches, which had been the home of his ancestors for centuries, to seek better prospects in London.

By the time of his marriage to Jane Willes (c1786-1818), a spinster from the parish of St. Mary's Whitechapel on the 12th September 1807, we find Walter Vaughan, living in the area of St. Luke's, Old Street, Middlesex [6]. Their first child, Jane Maddox (1811-1883) was born in Middlesex (probably St. Lukes) on the 17th of July 1811, a year later we find the Maddox family living in Bath in Somerset, probably at No. 8 Charles Street, having given birth to a son, William Willes Maddox (1812-1853) on the 23rd of August 1812 [7], [8].

Three years later on the 4th of August 1816 (according to the usual sources), their third child, Richard Leach Maddox was born at Charles Street, Bath [9]. He was baptized at St. Mary's Chapel, Walcot on the 26th of June 1818. His baptismal entry states that he was born on the 4th of May 1816, and not the 4th of August as is commonly believed. This discrepancy has to be taken seriously as its source represents the earliest and only contemporary record of his birth that has been found to date.

This was to be their last child, for Jane Maddox died in the New Year of 1818. She was buried on the 7th January 1818, at St. Swithin's church, in the parish of Walcot, now part of Bath [10]. In the years following his wife's death, Walter Vaughan became a wealthy grocer and tea dealer in Bath, with his premises at No. 8 Charles Street. By the time of the 1841 Census, we find him living with his daughter Jane and two female servants at his private residence at Acacia Villa, Sion Hill, Bath – in one of the town's most '*up market*' areas

I.4

‘Plates of Chips’

Astronomical Photographic Processes

Wratten & Wainwright Photographic Products

Only four main photographic processes and technologies have been used by astronomers to any great extent during the whole History of Astrophotography – the Daguerreotype, the Wet Collodion, the ‘*Dry*’ Gelatino-Bromide and the CCD; the celluloid film was rarely used, except by amateurs.

I.4.1 Processes and Technologies

The emergence of Astrophotography from the new Art of Photography in the 1840s is one of the most important milestones in the History of Astronomy. It is that which bridges the gap between the previously subjective and speculative observations of the eye and the solid scientific theories of modern Astrophysics.

Although photographs had been taken of the Moon and Sun as early as the 1840s, such images revealed nothing that could not as easily be seen by eye or through a small telescope. The famous photograph of the *'Great Orion'* nebula' (M42) taken Henry Draper's in 1880 changed everything. With his use of the Gelatino-Bromide or '*dry*' photographic plate, Astrophotography was for the very first time able to capture objects and details far fainter than the eye could see, even if the eye was at the eyepiece of the largest of telescopes.

However in the early days of Astrophotography, its greatest advantage was something quite different – it gave for the first time a truly accurate and incontrovertible record of an observation. Photographic Astrometry was used to measure star positions directly off a plate rather than being obtained by hand from painstaking and time consuming visual observations. Details of nebulae and galaxies became the same for everyone rather than dependent on the eye of the observer. The subjectivity of human vision was replaced with the objectivity of a repeatable photograph. It is important to consider how the various photographic processes used in astrophotography developed, what were their advantages and disadvantages, what problems were met, how they were overcome and who solved them. Only four main photographic processes and technologies have been used by astronomers to any great degree during the whole History of Astrophotography [1]:

- Daguerreotype; introduced by Louis Jacques Mande Daguerre in 1839;
- Frederick Scott Archer's wet collodion first published in 1851;
- Dry Gelatino-Bromide Plates; which became widely available from the early 1880s onwards;
- CCD (Charge Coupled Devices) which form the technological heart of the modern digital camera.

It is interesting to note that the Calotype Process of William Henry Fox Talbot was almost never used in Astrophotography, with only three reference having being found in the literature relating to its use in Astronomy.

The plastic film was rarely used by professional observatories, and was almost solely the province of the amateur astronomer, but even this has now largely given way to the CCD following the introduction of high quality affordable digital cameras and dedicated astronomical imagers over the last ten years or so.

I.4.2 Daguerreotype

The first photographs ever taken of celestial objects were taken with one of the earliest practical methods of photography, the Daguerreotype process, invented by the French showman Louis Jacques Mande Daguerre (1787-1851) and introduced to the world in 1839. The Daguerreotype process was complex, expensive, and difficult, requiring the use of silver-coated copper plates, iodine solutions, and vaporized magnesium.

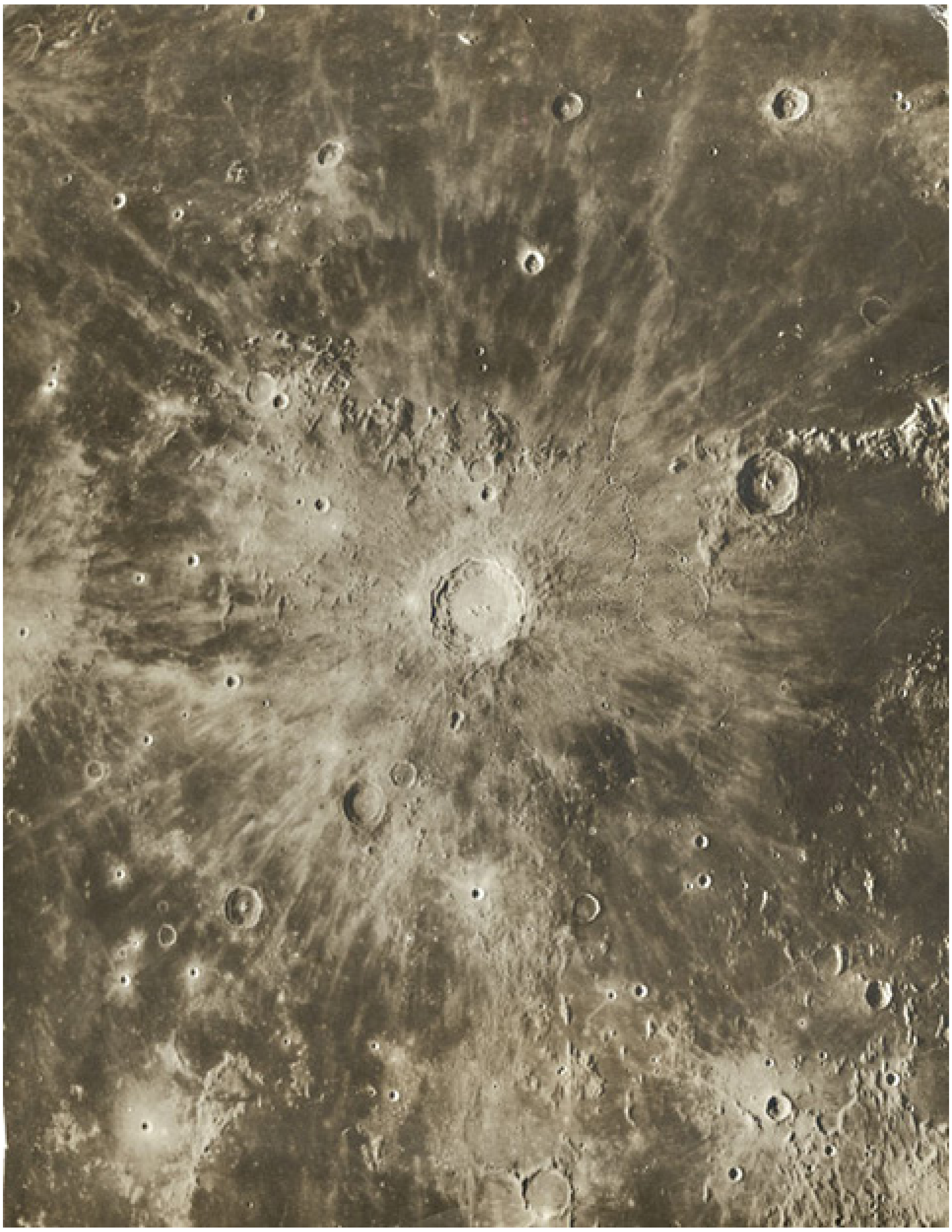
For astronomical use Daguerreotypes were far from ideal. There was no easy way to make duplicate photographs, and by modern standards they had very low sensitivity. John William Draper's first Daguerreotype of the moon required a 20 minute exposure, an achievement made even more remarkable by the lack of a clockwork motor drive on the instrument he used. However, Draper's photograph revealed the immense potential of photography for scientific study. But the lack of sensitivity hindered its widespread use. It would be a further ten years before a Daguerreotype image was taken of any object beyond the solar system when a photograph of the star Alpha Lyra (Vega) was taken on the 17th July 1850 by George Phillips Bond (1825-1865) of the Harvard College Observatory and the Boston, Daguerreotypist John Adams Whipple [2].

Indeed very few Daguerreotypes of the Astronomical Objects were taken and even less have survived

Part II

Moonlight

Lunar Astrophotography



Copernicus Crater, George Willis Ritchey, c1910

"A portion of the figure was very distinct," declared the minutes of the meeting, "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."
Contemporary Description of John William Draper's first Moon Photograph of 1840

II. Abstract

The first attempt at photographing an astronomical object was made by Louis Daguerre (1787-1851) in 1839 when he tried to image the Moon, but his efforts were met with failure. The following year, John William Draper (1811-1882), a Professor of Chemistry at New York University obtained the first successful image of the Moon, and in doing so earned himself title of the '*First Astrophotographer'*.

It was not until the 18th of December 1849 that the next photograph of the Moon was obtained by the Boston Daguerreotypist, John Adams Whipple (1822-1891), using the 15 inch 'Great Refractor' at Harvard College Observatory. Two years later in 1851 he took a series of Lunar Daguerreotypes which became prize winning exhibits at the Great Exhibition held that year at the Crystal Palace, London.

In the years that followed a number of astronomers including Warren De La Rue (1815-1889), Lewis Morris Rutherfurd (1816-1892) and Henry Draper (1837-1882) took photographs of the Moon of ever increasing quality and in much greater detail.

In 1852, De La Rue takes first wet collodion Images of the Moon with his 13 inch Reflector from his Observatory in Canonbury, Middlesex, which shows its surface in increased detail. Six years later he obtains the the first stereoscopic images of the moon from his new observatory at Cranford, Middlesex.

In 1863, Henry Draper begins taking photographs of the Moon with his 15 inch Reflector constructed by himself. These photographs were at the time the finest ever taken, until the work of Lewis Morris Rutherfurd two years later.

In 1865, the New York amateur scientist, Lewis Morris Rutherfurd, obtains excellent images of the Moon using a specially corrected photographic 11.25-inch (290mm) lens. His images were for many years the best ever taken, until the work of Pickering, Loewy and Puiseux.

During the 1890s and 1900s images of the Moon were taken of sufficiently high quality and detail to form the basis of the earliest Photographic Atlases of the Moon.

In 1897, Edward Singleton Holden begins issuing in serial form the Lick Observatory Atlas of the Moon compiled by Ladislaus Weinek from photographs obtained at the Lick and Paris Observatories. Only 19 sheets of reproduced photographs out of the 60 originally intended were ever published; of low resolution and poor quality.

In 1903 the Harvard astronomer, William Henry Pickering (1858-1939) became the first to publish a complete photographic atlas of the Moon with the appearance of his: *'The Moon – A summary of the Existing Knowledge of our Satellite with a Complete Photographic Atlas'.*

His photographs were taken in an eight month period from 31st December 1900 to 31st August 1901 from Mandeville, Jamaica using a horizontal refractor of 12-inch aperture and 135 feet focal length. Pickering divided his atlas into sixteen areas, with a photographs taken of each area but under five differing illuminations.

Although the photographs he obtained were not of the highest, the fact that the same features were imaged during differing lunar phases was a very useful feature of the atlas. It is well known that lunar feature under differing illumination 'take on' very differing aspects and are often difficult to identify without photographic help.

However the first true photographic atlas of the Moon was the work of Moritz Loewy (1833-1907) and Pierre Henri Puiseux (1855-1928) of the Paris Observatory. In 1894 they took the first photograph of the Moon using the Observatory's 23.6-inch Equatorial Coude Refractor that would be included in their monumental *L'Atlas Photographique De La Lune* published in 1910.

Their work was published in twelve parts from 1896 to 1910. Each part relates to a specific area of the moon, and contains high quality photographs of the region, as well as a description of the major lunar features, craters, mare, mountain ranges etc present. A general index of features was also published as the thirteenth part of the atlas.

The photographs of Loewy and Puiseux were to remain unsurpassed in quality for the next fifty years until those taken by the Lunar Orbiter Probes in the 1960s, although Francis Gladheim Pease came very close with his images of 1919, taken with the 100-inch Hooker Telescope at Mount Wilson.

In 1964, the Lunar Orbiter program was initiated, as a series of five unmanned lunar orbiter missions launched by the United States from 1966 through 1967. All five of the Lunar Orbiter missions were successful, and 99 percent of the Moon was mapped from photographs taken with a resolution of 60 metres or better.

The first three missions were dedicated to imaging 20 potential manned lunar landing sites, selected based on Earth-based observations. These were flown at low inclination orbits.

The fourth and fifth missions were devoted to broader scientific objectives and were flown in high-altitude polar orbits. Lunar Orbiter 4 photographed the entire nearside and 9 percent% of the far side, and Lunar Orbiter 5 completed the far side coverage and acquired medium (20 m) and high (2 m) resolution images of 36 pre-selected areas.

In 1971 the images obtained from the Lunar Orbiters were used to create LOPAM – the Lunar Orbiter Photographic Atlas of the Moon compiled by David E. Bowker and J. Kenrick Hughes. This work is now considered to be the definitive reference manual on the global photographic coverage of the Moon.

"As the image of the Moon photographed with telescopes of the dimensions usually found in the hands of amateurs is small, even if amplifying lenses are used, the chief desideratum is to get a negative of extreme sharpness, which will admit of considerable subsequent enlargement."

Henry Hayden Waters (1880-1939), from Astronomical Photography for Amateurs, 1921.

II.1

'The First Astrophotographer'

John William Draper

Born: 5th May 1811, St. Helens, Merseyside, Lancashire, England

Died: 4th January 1882, Hastings-on-Hudson, Westchester, New York, USA

John William Draper 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.

II.1.1 Ambition

John William Draper knew from a very early age that he wanted to become a scientist; yet he became much more than he could ever have imagined. Not only did he realize his ambition of a career in Science, but he also became one of the great pioneers of the new Art of Photography and the very *'First Astrophotographer'* [1].

In early 1840 John William Draper obtained a clear Daguerreotype image of the Moon. It was the first time anybody had ever successfully obtained a photograph of any astronomical object. It was the beginning of Astrophotography and the first evidence that photography could be of great value as a serious tool for scientific study.

To understand how John William Draper, the son of an itinerant English preacher grew up to become an American citizen and one of the 'Photographic Greats'; we must start as always at the beginning - not in New York State where he spent most of his life but in the town of St. Helens, Lancashire, England, in the early years of the nineteenth Century when its King was mad, its Regent was little better and a new world across the Atlantic Ocean was beckoning to many.

II.1.2 St. Helens

John William Draper was born on the 5th May 1811 [2] in the then small Lancashire town of St. Helens [3], ten miles from the port of Liverpool. He was born into a family of Methodists. His father John Christopher Draper was an itinerant Preacher who moved from chapel to chapel in the hope of eking out a living [4]. The geographical ministrations of Draper, the father can be closely followed by the birth of his four children, who were born in four different locations, reflecting where he happened to be preaching at the time.

His eldest daughter Dorothy Catherine was born in Newcastle-upon-Tyne in 1807, his second daughter Elizabeth Johnson was born two years later in Penrith, Cumberland, John William in St. Helens in 1811, and his youngest daughter, Sarah Ripley in Lincoln, Lincolnshire in 1813.

At the time of John's birth the family was living in St. Helens, where his father was a preacher at the Methodist Chapel on Tontine Street. He was baptized the following month at the Tontine Street Chapel by his father's friend, the well known Methodist Preacher Jabez Bunting (1779-1853) who conducted the service held there on the 23rd of June.

The early education of John Draper was in the main done at his home by private tutors, a result of the family's meagre income, but at the age of eleven he was sent to a public school at Woodhouse Grove in neighbouring Yorkshire, run by the Wesleyan Methodist Church. At Woodhouse School John Draper was a model pupil; hard working, well behaved, attentive and inquisitive in all his studies, whether it was Mathematics or Classics. In recognition of his efforts he was chosen in 1824 to deliver the customary address from the school to the Wesleyan conference, which met that year at Leeds.

This was his first effort at public speaking and he was good at it – something he never forgot and which he was called upon many times to do in his later life. Not long afterwards he left the Woodhouse Grove school and returned home, to continue his studies, as before, under private tutors. It is known that John W. Draper was interested in Astronomy from an early and was the proud owner of a Gregorian Reflector which he often used to make observations and to find his way around the night sky. He was also passionate about science in general and loved to experiment with chemicals at home whenever he could, parents permitting!

It was therefore not surprising that in 1829, Draper then aged 18 enrolled as a student of Chemistry at the newly founded University College, University of London. Here he came under the care and influential of the much respected chemist Dr. Edward Turner [5]. For the next three years he spent his time in the fruitful study, investigation and analysis of all branches of Chemistry- inorganic, organic and physical all under Turner's expert guidance. Whilst studying for his degree, John Draper took lodgings with a friend of his father, a Mrs Mary Barker in Minster Sheppey in Kent. It was here in 1830 that a met her niece and ward, Miss Antonia Coetana Pereira Gardner; whose father was private physician to Emperor Don Pedro Primeiro of Brazil [6]. The following year they were married on the 13th September 1831 at the Parish church of St. Mary & St. Sexburga, having obtained a marriage license the day before [7]. During the course of his studies

II.2

‘The Celestial Mechanics’

Moritz (Maurice) Loewy

Born: 15th April 1833, Vienna, Austria

Died: 15th October 1907, Paris, France

Pierre Henri Puiseux

Born: 20th July 1855; Paris, France

Died: 28th September 1928; Paris, France

Moritz (Maurice) Loewy and Pierre Henri Puiseux both started their careers as Mathematicians; but ended up working together to do their finest work – the ‘*Atlas Photographique de La Lune’*. In its pages are some of the finest images of the Moon ever taken which were not surpassed until over half a century later, when in the 1960s the Lunar Orbiter Probes compiled a new photographic atlas of the Moon, known as LOPAM.

II.2.1 Persecution & Mountaineering

Moritz (Maurice) Loewy (1833-1907) and Pierre Henri Puiseux (1855-1928) were brought up in two different worlds – one in Vienna, where Jews like Loewy and his family lived in perpetual fear; whilst Puiseux knew only of the peace of the mountains and the elegance of Mathematics. Yet these two men from these two very different backgrounds worked together at the Paris Observatory in the years from 1894 until 1910 to create one of the most wonderful Atlases ever produced.

The Atlas of Loewy and Puiseux, was not one of our Earth; yet it pictured a world that had seas, which you could not swim in; It had mountains too, but unlike the one's Puiseux climbed, they had no snow; It saw no rain or clouds but had features called the Mare Imbrium (Sea of Rains) and the Mare Nubium (Sea of Clouds). Loewy and Puiseux took over 6000 photographs for their Atlas, choosing only the best 82 for the published version. Their Atlas also included text to accompany the photographs, which described in detail the most interesting of the features that were to be seen in its pages.

It was not an Atlas in the usual sense of the word, but a Photographic Atlas of the Moon – known as *'L'Atlas Photographique de La Lune', 'Publie par L'Observatoire de Paris, Execute Par M.M. Loewy et M.P. Puiseux'*

Since its publication in its completed form in 1910, it remained for over fifty years the finest photographic atlas of the Moon. It was only in the 1960s with the launch of the USA's Lunar Orbiter probes that an Atlas of the Moon was created that bettered it.

Sadly, the work of Loewy and Puiseux is all but forgotten, and copies of their great Atlas are to be found in only a handful of libraries and institutions across the world [1]. Occasionally individual photographs come up for sale at auction and even rarer a complete edition [2].

II.2.2 Celestial Mechanics

Moritz Loewy was born on the 15th April 1833 in Vienna, Austria of Jewish parents, Leopold Loewy and his wife Caroline Herzel, both natives of neighbouring Slovakia. At that time there was considerable Anti-Semitism in the Austrian-Hungarian Empire. A fact which ironically shaped the rest of Loewy's life for the better, especially in respect of his career.

He was educated at the Polytechnic School and University of Vienna, and received his astronomical training under its director Karl Von Littrow (1811-1877) at the Imperial Vienna Observatory where he was employed as an assistant [3]. His original area of interest was celestial mechanics. In 1857 he computed the orbit of the newly discovered asteroid Leda, other similar calculation followed including that of Comet Donati [4].

He later escaped the persecution of his home city when he took up an appointment at the Paris Observatory, where he could work in peace and be what he wanted to be - an astronomer.

Pierre Henri Puiseux was born the 20th July 1855 in Paris, France, the son of the mathematician Victor Puiseux (1820-1883) [5] and his wife Laure Louise Fabronie Jannet (1830-1858), who brought him up to love science and the mountains.

From an early age Puiseux loved mountaineering and climbed many of the peaks in the French Alps and outside its borders. He even succeeded in climbing Mont Blanc alone. During his ascents he studied the Geology of the Rocks he came across. It is not surprising that he became one of the greatest photographers of the Moon – a body renowned for its mountainous landscapes.

He was later to make some of the earliest scientific investigations into the Geology of the Moon based on his knowledge of the mountains he climbed, the rocks he studied and the Lunar photographs he took.

His education began at the Ecole Normale Superieure and was completed when he began work at the Paris Observatory in 1885. It was here that he worked as assistant to Loewy. In the early years of his career he like became interested in author's own former specialism of celestial mechanics [6], and in particular tidal friction and the secular acceleration of the Moon [7].

II.3

'The Lunatic'

William Henry Pickering

Born: the 15th February 1858, Beacon Hill, Boston, Massachusetts, USA

Died: 16th January 1938, Mandeville, Jamaica

William Henry Pickering was the younger brother of Edward Charles Pickering and a great pioneer of Astrophotography in his own right; producing in 1903 the first ever complete Photographic Atlas of the Moon, seven years before Loewy and Puiseux completed the publication of their *'Atlas Photographique de la Lune'* in its entirety.

II.3.1 Footsteps

William Henry Pickering (1858-1938) followed in the footsteps of his elder brother, Edward Charles Pickering (1846-1919), and became a great astronomer. It was in fact William Henry who introduced his more famous sibling to astronomical photography and set him on his path which led to some of the most important work ever carried out in the new science of Astrophysics [1].

In contrast, William Henry's work led him to nearer and more traditional areas of study – the Sun, Moon and Planets; and not the distant stars; about which man knew so very little, a situation Edward Charles Pickering was determined to alter. Although, he lived in the shadow of his illustrious brother, William Henry made his own mark in Astrophotography.

In 1903 he published the very first complete Photographic Atlas of the Moon, which contained images of our nearest astronomical neighbour of a quality somewhat short of the great heights reached by Maurice Loewy (1833-1907) and Pierre Henri Puiseux (1855-1928); who not only had the resources of the Paris Observatory to call upon, but a telescope which far surpassed anything available to Pickering [2].

II.3.2 Harvard

William Henry Pickering was born on the 15th February 1858 at the family's ancestral home on Beacon Hill, Boston, Massachusetts, United States, the third and last child of Edward Pickering (1807-1876) and Charlotte Daniel Hammond (1819-1901). His elder brother Edward Charles Pickering was for over forty years, the Director of the Harvard College Observatory and one of the world's greatest ever astronomers.

After completing his school and college studies in Boston and Cambridge, W. H. Pickering went onto study Physics at the Massachusetts Institute of Technology; where he graduated in 1879. He was then appointed as an assistant then later an instructor in MIT's Department of Physics. He held this position until 1887 when he joined the staff at the Harvard College Observatory (HCO) as an assistant astronomer. In the June of 1889 he was appointed Assistant Professor of Astronomy from September 1st that year. He remained as an Assistant Professor at the HCO until his retirement in 1924.

II.3.3 Investigations

Prior to joining the HCO, W. H. Pickering had been collaborating with his brother in an *'Investigation in Stellar Photography'* [3]. These experiments which had begun in 1882 had looked into the use of the newer Gelatino-Bromide or 'Dry' Photographic Plates in three areas of stellar astronomy; namely the brightness of stars, the construction of sky charts and the imaging of stellar spectra.

E. C. Pickering in the published report of these investigations acknowledged the contributions made his brother [4]:

"The experiments to be described below were mainly conducted by the aid of an appropriation made in June, 1885, from the Bache Fund, of the National Academy of Sciences. Numerous preliminary experiments had been made with a grant from the Rumford Fund of the American Academy. My attention was directed to stellar photography in 1882, by Mr. W. H. Pickering. Many of the preliminary experiments were made by him, and his advice was followed regarding the photographic processes to be employed. In the later work, he has rendered important aid by his advice, and by making many auxiliary experiments in his photographic laboratory at the Massachusetts Institute of Technology."

The help given to E. C. Pickering by his brother was without question a major factor in setting him on the path to success in every aspect of his future career in Astrophysics; for photography was the key tool used in the studies that made him famous. By 1883 it was clear that W. H. Pickering had become an accomplished Astrophotographer [5]:

"On February 21, 1883, a photograph of Orion was obtained by Mr. W. H. Pickering with a small Voigtlander camera and without clockwork. Although the aperture was only 1.6 in. and the focus 5.2 in., trails were obtained of stars as faint as the fifth magnitude. Still better results were obtained with a Voigtlander No. 4

II.4
‘LOPAM’
Lunar Photographic Atlases

The history of Lunar Photography has a long tradition beginning in 1839 with Louis Daguerre’s failed attempt, followed a year later by the first successful image of John William Draper; and continuing with the pioneering photographs of Warren de La Rue and Lewis Morris Rutherfurd. Only in 1903 did the first complete and detailed photographic atlas appear; that of William Henry Pickering. Seven years later the magnificent *‘Atlas Photographique De La Lune’* by Maurice Loewy and Pierre Henri Puiseux was published. It was to be fifty years before the Lunar Orbiter probes of the 1960s obtained images of greater quality.

II.4.1 Early Lunar Maps

Ever since man first looked up at the sky and seen the Moon, he has tried to draw it.

The first serious attempts at naming the features of our Moon as seen through a telescope were made by Michel Florent van Langren (1598-1675) in 1645 [1]. His work is considered to be the first true map of the Moon, as it portrayed the various Maria (seas), Craters, Mountain Peaks and Ranges.

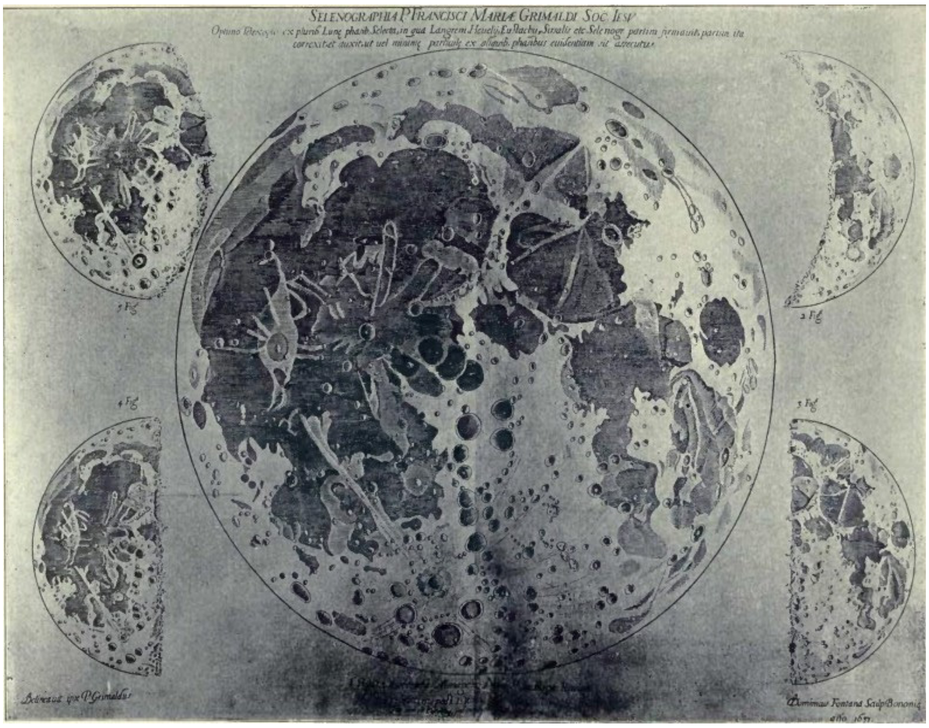
The modern scheme of lunar nomenclature was devised by Giambattista Riccioli (1598-1671), a Jesuit priest and scholar who lived in northern Italy. His *'Almagestum Novum'* was published in 1651 as a defence of the Catholic views during the Counter Reformation. However the only significant aspect of the work to survive to the present period is Riccioli's system of lunar nomenclature.

The lunar illustrations in the Almagestum Novum were drawn by a fellow Jesuit teacher by the name of Francesco Grimaldi (1618-1663). The nomenclature was devised based on a subdivision of the visible lunar surface into octants, numbered in the Roman style from I through VIII. Octant I formed the northwest section, and subsequent octants proceeded in a clockwise direction aligned with the compass directions. Thus the Octant VI lay to the south, and included the well known Clavius and Tycho craters.

In 1749, the German Mathematician, Tobias Mayer (1723-1762) [2], while working for the Homann Company of Cartographers, produced a map of the moon measuring seven and a half inches in diameter. It was the first map of the moon which used accurately measured positions of the craters. In fact Mayer measured the positions of 24 craters, which he included in the map, using a micrometer to obtain an accuracy of 1' in latitude and longitude.

However, the greatest Map of Moon in the pre-photographic era was that of Wilhelm Beer(1797-1850) and Johann Heinrich von Madler (1794-1874) known as the *'Mappa Selongraphica'* published in four parts between 1834 and 1836. This was followed in 1837 by their publication of a description of the Moon (Der Mond). These two works were the best descriptions of the Moon for many decades, and were not superseded until Johann Friedrich Julius Schmidt's (1825-1884) map in the 1870s.

In the years following the start of the 19th century experiments were being carried out by of Thomas Wedgwood (1771-1805) , Joseph Nicéphore Niépce (1765-1833), William Henry Fox Talbot (1800-1877) and Louis Jacques Mande Daguerre (1787-1851), into a method of permanently capturing images of objects through the action of light on chemically treated surfaces [3]. Lunar Astrophotography was about to be born.



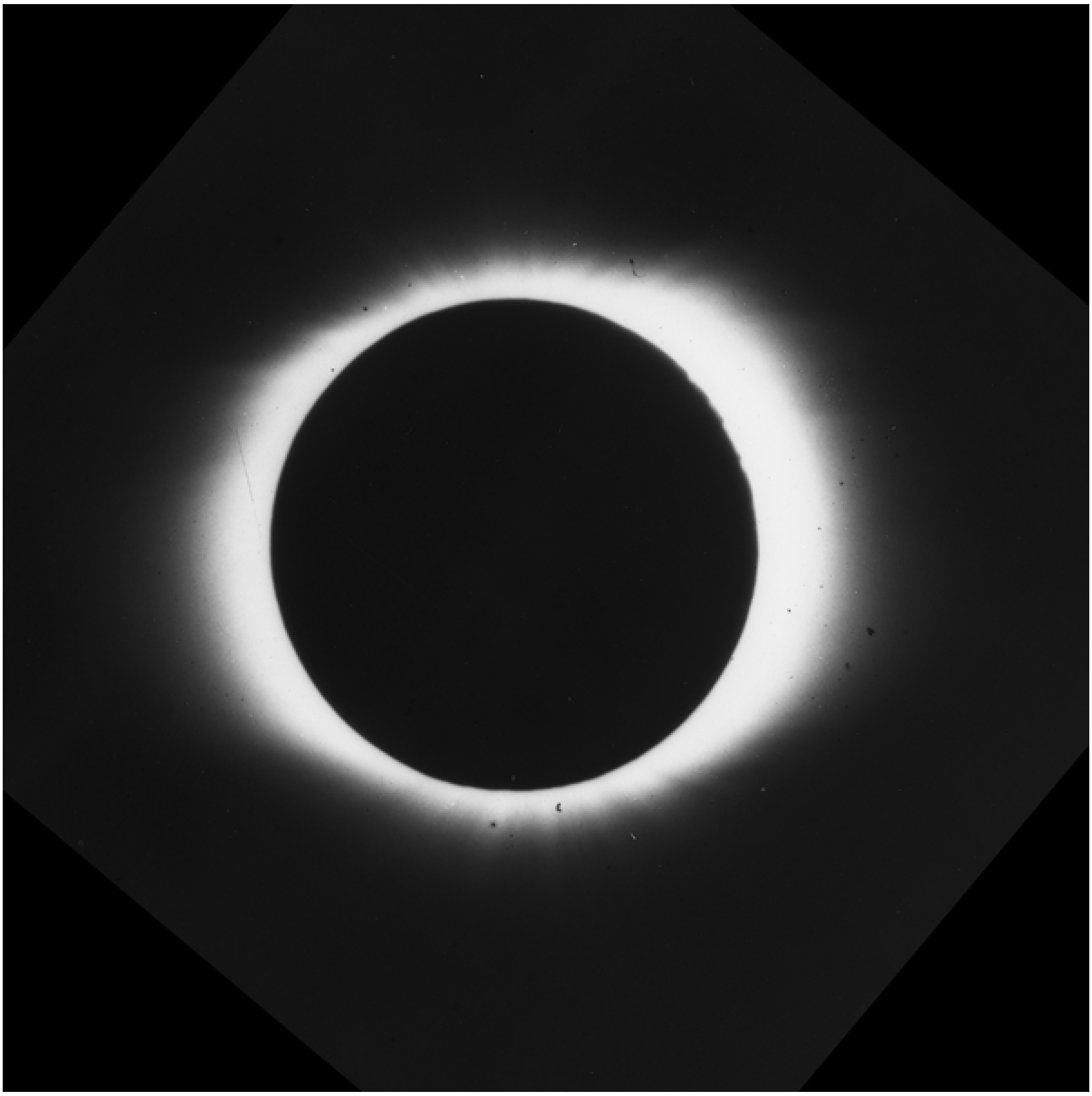
Giovanni Battista Riccioli, was born on the 17th April 1598 in Ferrara, Italy. He devoted his career to the study of astronomy, often working with Francesco Maria Grimaldi. In 1651 he wrote the important work Almagestum Novum. Despite his stated opposition to Copernican heliocentric theory he named a prominent lunar crater after him, and other important craters were named after other proponents of the theory, e.g. Kepler and Galileo Much of the nomenclature of lunar features still in use today is due to him and Grimaldi. He died in Bologna, on 25th June 1671.

Riccioli's Map of the Moon, 1651

Part III

Sunlight

Solar Astrophotography



Total Eclipse of the Sun, William Harkness, 29th of July, 1878, Creston, Wyoming, USA

"Curse the man who invented helium! Curse Pierre Jules César Janssen!" - Principal Skinner from an Episode of the Simpsons TV Series, speaking of the man who in 1868 was the first to discover a chemical element on another world - in the atmosphere of our Sun.

III. Abstract

Having successfully imaged the Moon - the brightest object in the night sky, the pioneers of Astrophotography naturally turned their focus to the Sun - the brightest object of them all.

The earliest extant large scale image of the Sun’s surface dates from the 2nd of April 1845 and was taken by the two French physicists, Armand Hippolyte Louis Fizeau (1819-1896) and Jean Bernhard Leon Foucault (1819-1868) from the Paris Observatory. However it is known that by the August of 1843, they had obtained ‘*coin*’ size images of the sun’s face which clearly showed the presence of spots.

The first attempt to image an Eclipse of the Sun was made by the Italian physicist Gian Alessandro Majocchi from Milan on the 8th of July 1842, but he only succeeded in obtaining Daguerreotype photographs of the moments before and after totality. He also attempted to photograph the sun during Totality but his image unfortunately showed nothing. His photographs have not survived.

The first truly successful photograph of a Total Eclipse had to wait a further nine years before being taken. This meritorious event occurred on the 28th July 1851 when a Daguerreotypist named Berkowski from Konigsberg in East Prussia (now Kaliningrad, Russia) succeeded in capturing the moment of Totality. His photograph recorded the inner corona and several prominences. His first name is not known.

Over the course of the following decades astronomers and the Governments of their countries mounted many Eclipse expeditions to the far flung corners of their empires Their sole aim was to photograph the fleeting moments of totality. Most notably was the 1860 expedition to the village of Rivabellosa in Northern Spain, when on the 18th of July, Warren De La Rue (1815-1889) obtains two wet collodion photographs of totality using the Kew Photoheliograph. The Kew Photoheliograph was the first telescope specifically built to photograph the Sun.

The construction of the first Photoheliograph sparked an explosion in the construction of others of its kind, particularly by the English scientific instrument maker, John Henry Dallmeyer. In the 1870s an extraordinary breed of solar photographic cameras known as ‘Revolvers’ began to appear. These remarkable instruments so called because of their apparent similarity in operation to the gun of the same name were an early forerunner of the Cine camera in that they took repeated images in quick succession to each other.

The most famous of these ‘Repeating Photographic Devices’ were those constructed for the French solar physicist, Pierre Jules Cesar Janssen (1824-1907). His device the ‘*Revolver Photographique’* was built to capture the transit of the planet Venus across the face of the Sun, due to take place on the 9th of December 1874.

Other similar devices were constructed by Dallmeyer for use by a number of British expeditions sent to the four corners of the world to do the same thing. At that time Transits of Venus provided a rare opportunity for determining the Earth-Sun distance. This was in the days before radar and space probes. A remarkable fact regarding these expeditions is that as far as it known, despite thousands of ‘*Revolver*’ photographs being taken, not a single one has survived to this day.

In 1890 the solar physicist, George Ellery Hale (1868-1938) invented an instrument known as the Spectroheliograph, which was able to take photographs of the Sun at a single wavelength of light. With the aid of the Spectroheliograph, the red solar prominences, could for the very first time be photographed without the need for a total eclipse of the Sun.

The American astronomer, David Peck Todd (1855-1939) was without doubt the most unluckiest of people when it came to photographing a Total Solar Eclipse and in particular capturing the sun's 'pearly necklace' known as the Corona. During the years 1887 to 1901, in the course of four separate eclipse expeditions, he failed to take a single image using his purpose built automated repeating photographic machines. In each instance he was '*clouded out*'. Only at the fifth attempt did he succeed during an eclipse expedition to Tripoli in Libya in 1905.

In 1914, Todd made another attempt to photograph a Total Eclipse with his new and improved automated equipment. However it ended in total and absolute failure. Not only did his equipment not arrive in Russia for the 21st of August, the date of the eclipse; but even worse the Danish scientist Dr. Nils Viktor Emmanuel Nordenmark (1867-1962) from his observing site at Solleftea in Sweden succeeded in taking the very first cine film of a total eclipse of the Sun. Todd's equipment had now been rendered 'out of date' by the onset of the modern movie age!

In 1930 even the need for a total solar eclipse of the sun to photograph the pearly white corona was rendered obsolete; with the invention of the Coronagraph by the French astronomer, Bernard Lyot (1897-1952). The Lyot Coronagraph, with the aid of a series of baffles and diaphragms removes the unwanted stray light, but at the same time keeps that which is required, and in doing so makes it possible to image only the edge of the solar disc and not its bright photosphere.

From the 1960s onwards with the coming of the space age, a number of satellites and probes have been used to study and image the Sun, including the hugely successful Solar and Heliospheric Observatory or SOHO for short. Following its launch in 1995 SOHO has sent back to us the most spectacular photographs ever taken of our Sun.

"In photographing the Sun through a telescope at the primary focus, as already mentioned the aperture should be stopped down to an equivalent of about f/64...: Slow lantern plates will be found best, and they must be carefully backed. Some form of fairly rapid shutter will be required. M. L. Rudeaux recommends a wide sheet of blackened card- board, with a slit about 1 1/3 ins. wide, which can be moved rapidly in front of the object glass. As the Sun's direct rays are very penetrating, it is well to cover up the dark slide and carrier during exposure with a focussing cloth or piece of dark calico."

Henry Hayden Waters (1880-1939), from Astronomical Photography for Amateurs, 1921.

III.1

‘The ‘c’ Men’

Armand Hippolyte Fizeau

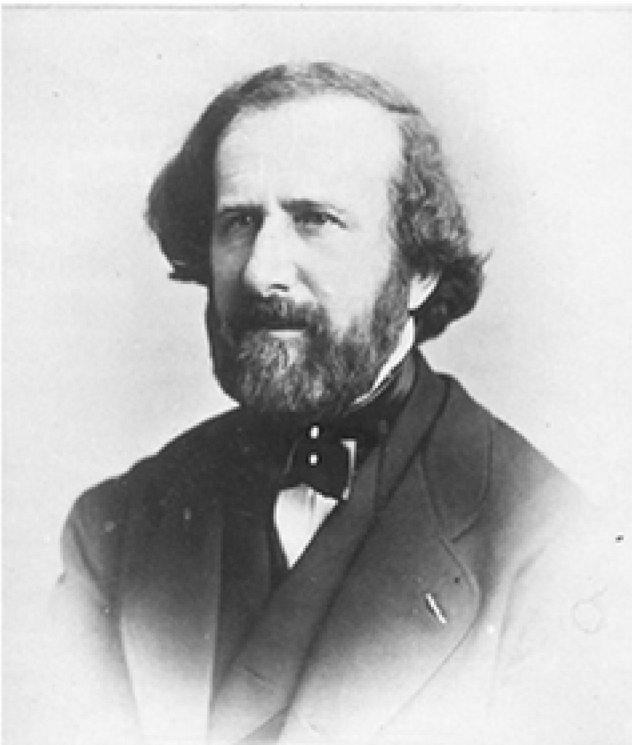
Born: 23rd September 1819, Paris, France

Died: 18th September 1896, Ferte-sous-Jouarre, Seine-et-Marne, France

Jean Bernhard Leon Foucault

Born 18th September 1819, Paris, France

Died 11th February 1868, Paris, France



Armand Hippolyte Fizeau and Jean Bernhard Leon Foucault were two of the greatest physicists of the nineteenth century. Their improvements to the photographic process and the development of terrestrial methods for the determination of a more accurate value for the speed of light, paved the wave for many advances in all branches of science. Together they obtained the first successful images of the Sun’s surface showing clearly the presence of sunspots.

III.1.1 Solar Photography

Although it was to America that the spoils of victory went in the race to take the first successful astronomical photograph, it was to France and Louis Jacques Mande Daguerre (1787-1851), that John William Draper (1811-1882) owed the technical means by which he obtained his famous 1840 image of the Moon [1]. It was also to France that we owe the next major advance in Astrophotography, and the Solar Photography of Armand Hippolyte Louis Fizeau (1819-1896) and Jean Bernhard Leon Foucault (1819-1868).

The Moon and the Sun are by far the two brightest objects in the sky, with Sunlight dominating the daylight hours and Moonlight ruling over the hours of darkness. As John W. Draper had captured the image of the Moon, it was only natural that the Sun should be the next focus of attention in the new field of celestial photography. So it was to the Sun that Fizeau and Foucault applied their combined photographic expertise during the period 1843 to 1845.

According to the then Director of the Paris Observatory, Francois Jean Dominique Arago (1786-1853), the two Physicists took during this period a series of Daguerreotype images of the Sun, which were the first to successfully capture the face of our star [2]. Fortunately, one of these images has survived, dated the 2nd of April 1845 and shows clearly the presence of sunspots on its surface; and as such is one of the most important astronomical photographs ever taken.

Today the names of Fizeau and Foucault are not known for their photographic achievements, but as two of the greatest physicists of the nineteenth century. In particular, they were the first scientists to measure the speed of light by terrestrially based measurements and not through astronomical observation. Although they began working together at Arago's suggestion in 1845, they parted company after a few years and began to work independently of each other.

In 1849 Fizeau obtain a value for the speed of light '*c*', of 195,615 miles (315,000 km) per second - a number slightly higher (by about five percent) than that obtained by astronomical means, but certainly far more accurate than any previous terrestrial method had yielded. The modern figure for the speed of light is approximately 186,000 miles (299,700 km) per second [3].

A year later in the April of 1850 his former partner, Foucault had developed his own means of measurement and showed that light travels slower in water than in air. This was in accordance with what the wave theory of light predicted, but contradicted the predictions of Newton's corpuscular theory. Foucault is also better known today for his '*Pendulum*' experiment which demonstrated the daily rotation of the Earth on its axis; and as a telescope maker of some note.

The lives and careers of Fizeau and Foucault are so entwined that it is impossible to tell the story of one without telling that of the other. After all, they were born within five days of each other in Paris; they attended the same school; they both had intended to follow a career in medicine; they were experts in the use of the newly invented Daguerreotype photographic process; and they also worked together at the Paris Observatory.

They were for many years like twin brothers, until they fell out over the matter of 'c', but not before they had written themselves into history as two of the great pioneers of Astrophotography.

III.1.2 Medicine

Armand Hippolyte Louis Fizeau was born in Paris on the 23rd September 1819, the second son of Louis Aime Fizeau (1775-1864) and his wife, Beatrice Marie Petel [4]. His father held the chair of Pathology at the Paris Faculty of Medicine, a position which brought the family both social prominence and wealth. Louis Fizeau came from a long line of doctors and it was expected that his son would follow in the family tradition. Intending to join his father in the field of medicine, the young Fizeau enrolled at the prestigious College Stanislas in Paris [5].

In 1840 Fizeau entered the Paris Medical School. However, he suffered severe migraines and decided to give up medicine. He spent a while travelling during which time he regained his health and began preparing for a career change away from medicine. He began attending the lectures at the Paris Observatory given

III.2

'The Stationery Man'

Warren De La Rue

Born: 18th January 1815, St. Peters Port, Guernsey, Channel Islands

Died: 19th April 1889, Portland Place, London, England

The Channel Islander, Warren De La Rue was the *'Foremost Celestial Photographer'* of his adopted country, England; who did his finest work in the years before the likes of Henry Draper, Isaac Roberts, Andrew Ainslie Common and Edward Emerson Barnard made their own great contributions. In 1857 he produced the design for the Kew Photoheliograph, the first telescope specifically built to photograph the Sun. In 1860 it was taken by De La Rue, to Northern Spain to successfully photograph the Solar Corona during the total eclipse which took place on the 18th of July that year.

III.2.1 Collodion

Warren De La Rue was England's first Astrophotographer. In 1851 during the '*Great Exhibition*' held at the Crystal Palace in London, he saw Daguerreotypes of the Moon by the Boston Daguerreotypist, John Adams Whipple (1822-1891). The sight of these images of our nearest celestial neighbour was a turning point in his life, so much so that they inspired him to devote all his energies to replicate and improve upon them.

One year later he had done just that, as Lady Margaret Huggins later wrote [1]:

"In 1852 Mr. De La Rue, working in his little garden at Canonbury with a 13-inch reflector and availing himself of the Collodion process, succeeded in obtaining a really excellent picture of the Moon; and to him therefore belongs the credit of first employing the Collodion process in celestial photography, as well as that of obtaining the first very valuable success in lunar photography."

In the years which followed he was to do even better, ultimately becoming England's *'Foremost Celestial Photographer'*. All of this was made possible by the wealth gained from the family's Stationery business, which gave De La Rue both the means and the time to achieve the great goal he had set.

It was however his work on the construction and subsequent use of the *'Kew Photoheliograph'* – the first telescope built specifically to image the Sun - where his greatest legacy is to be found.

III.2.2 Shoreditch

Warren De La Rue was born on the 18th of January 1815 in St. Peters Port, on the Channel Island of Guernsey; the first child of Thomas De La Rue a printer & publisher; and his wife Jane Warren; a native of the village of Bishops Nympton in Devonshire, England [2].

In about 1818 when Warren was barely three years old Thomas De La Rue moved with his family to England and set up home at No. 45 Crown Street, in the Shoreditch area of Middlesex, on the outskirts of London's square mile. He obviously felt that better prospects awaited him amongst the teeming streets of London's metropolis and he was right. His first business was not in printing but in the manufacture of 'Leghorn' straw hats [3].

The young Warren De La Rue grew up in Shoreditch with his younger brothers and sisters. His parents gave birth to ten children in all, of whom only six survived into adulthood [4]. It was not long before Warren was sent abroad for his education at the Collège Sainte Barbe, Paris [5]; his father taking the view that his son would receive better tuition if it was French and not English.

Whilst Warren was at school his father's business activities went from strength to strength. Thomas De La Rue gave up the straw hat manufacturing business; and in 1830 together with Samuel Cornish and William Rock he founded a business of playing card makers, hot pressers and enamelers. De La Rue's was the first company to print playing cards, and it received a Royal Patent to do so in 1831. The following year the company printed its first deck of cards.

Thomas De La Rue's first occupation on coming to England from Guernsey was not as a printer or publisher, but as a Leghorn Hat manufacturer with premises at No. 45 Crown Street, in the Shoreditch district of Middlesex. A Leghorn is a featherweight, open-weave hat made of specially cultured and woven wheat fibre, shipped from the port of Leghorn (Livorno), Italy, whence it gets its name. The finer, upper portion of the wheat stalk is plaited into Leghorn braid. This straw hat is light, durable, clear and bright in colour. It was a style of hat especially popular amongst ladies of the late Georgian and Victorian eras. The fashion for such hats lasted until the end of the nineteenth century, when new styles and materials appeared.

Leghorn Straw Hat

III.3

'The Elemental Man'

Pierre Jules Cesar Janssen

Born: 22nd February 1824, Paris, France

Died: 23rd December 1907, Meudon, France

Pierre Jules Cesar Janssen 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.

III.3.1 'The Simpsons'

In an episode of the well known American cartoon series, the Simpsons, Principal Skinner, the head of Springfield School is seen to raise his fist and utter the words: *"Curse the man who invented helium! Curse Pierre Jules César Janssen!"* [1].

In 1868, over a hundred and thirty years earlier, the French scientist and astronomer, Pierre Jules Cesar Janssen (1824-1907) had travelled to India to witness a Total Eclipse of the Sun, which was due to take place on the 18th of August that year. During the expedition he noticed the presence of an unknown line in the yellow part of the solar spectrum having a wavelength of 587.4 nm, which was totally unfamiliar to him:

"The bright yellow line was actually located very close to D [sodium], but it belonged to refrangible rays more than D. My subsequent studies on the Sun show the accuracy of what I say here."

However, the line was also noticed on the 20th October 1868 by the eminent English scientist, Sir Joseph Norman Lockyer (1836-1920) who in 1870 concluded that this was due to an unknown chemical element, which was later to become known as helium after the Greek God of the Sun – Helios [2]. This was a momentous observation as it led to discovery of the very first chemical element to be found on another world. Although, Janssen's observation of the chemical element Helium made him famous, it was not the only significant contribution he made to science.

In 1862 Janssen had established an observatory in the Montmartre district of Paris, where he carried out investigations into the Solar Spectrum. He believed that some of the dark absorption lines in its spectrum did not emanate from the Sun itself, but were caused by the earth's atmosphere. These became known as the Telluric Lines, a name given to them by Janssen.

On the 19th of August 1868, a day after the total eclipse, Janssen made a discovery which had a major impact on Solar Physics. He found a method of utilizing the Fraunhofer 'C' Emission Line, also known as *'Hydrogen Alpha'* by which he could observe the spectra of Solar Prominences without the need for a Total Solar Eclipse. The same method was independently discovered somewhat later by his friend, Lockyer. The French Academy of Sciences struck a medal bearing the effigies of the two scientists to commemorate the achievement. A 'Hydrogen Alpha' filter is still used today by the modern day Astrophotographer to obtain images of the Sun's surface, its prominences and flares. For this we have to thank Janssen and Lockyer.

In 1874 Janssen went to Japan to observe the transit of Venus, and in order to witness the exact moment of the planet's contact with the sun's limb, he had developed a special camera he called the *'Revolver Photographique*'. This remarkable instrument was able to take a rapid series of photographs with very short exposures showing Venus's approach towards the limb of the sun. It was the very first webcam!

However, it was his *'L'Atlas de Photographies Solaires'*, published in 1904, which earned Jules Pierre Cesar Janssen his right to be called one of the great pioneers of Astrophotography and one of the founders of modern Solar Physics. This remarkable work contains some 6,000 photographs of the Sun taken in the years 1876 to 1903 from the newly established Meudon Observatory, near Paris; which was later to be known as the Paris Astrophysical Observatory.

III.3.2 Bank Clerk to Explorer

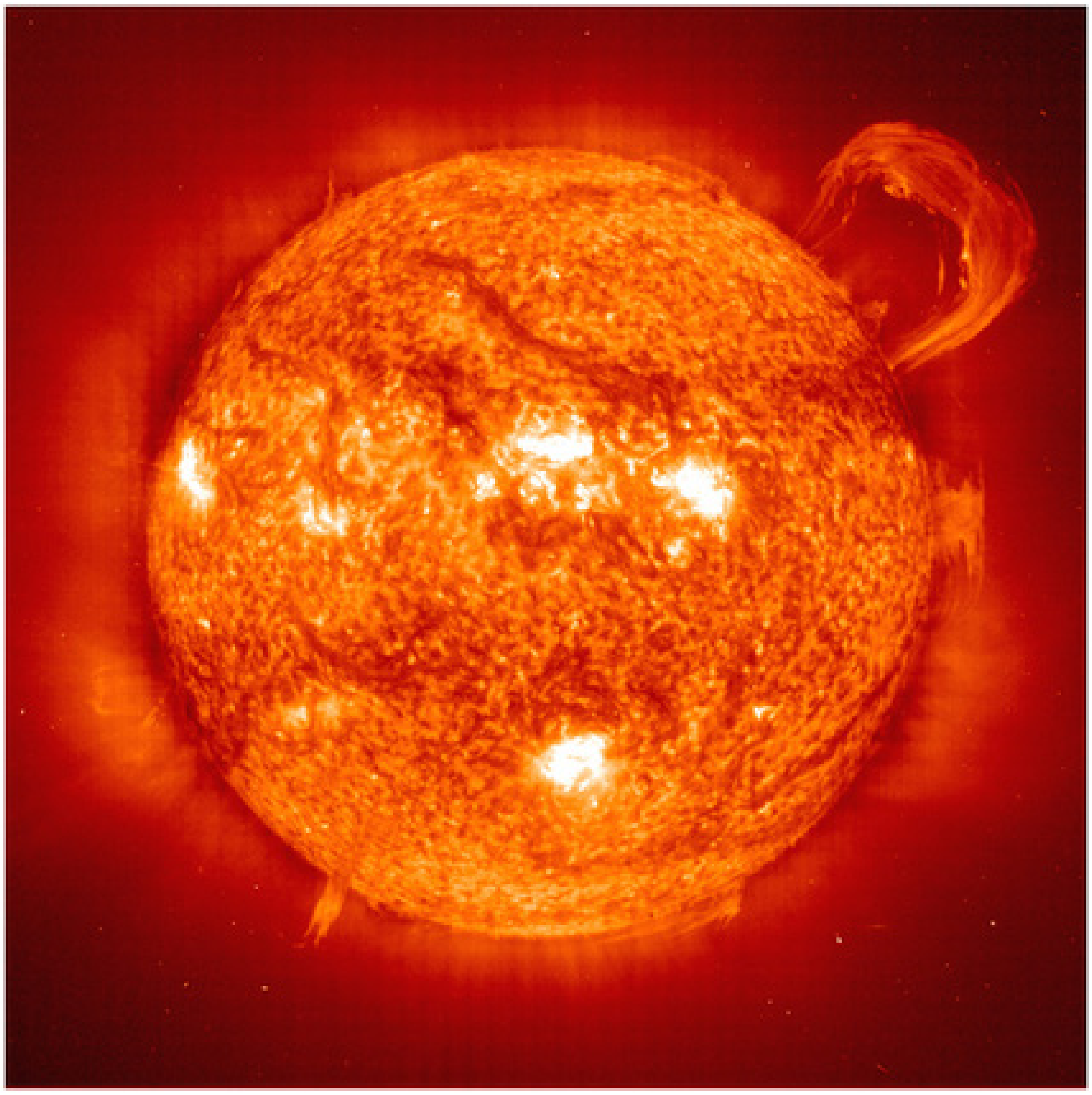
Pierre Jules Cesar Janssen was born in Paris, France on the 22nd February 1824, the only child of Antoine Cesar Janssen (1760-1860) and Pauline Marie Le Moyne (1789-?) [3]. His father was a well known clarinetist and his mother the daughter of the architect, Paul Guillaume Le Moyne [4]. His father made a good living from music and was well known in Paris as a designer of clarinets who made a number of important contributions to its development as an instrument [5].

At an early age as a result of carelessness by a nurse Janssen suffered an accident which rendered him lame for the rest of his life. He was a boy of many talents, demonstrated initially through painting and drawing. When he was sixteen he became a clerk at a bank and worked there for about seven years; spending his spare time studying mathematics. A subject he found so fascinating that he decided to give up a career in banking for one in science, something he clearly found more interesting!

III.4

'SOHO'

Solar Photographic Surveys



Ever since 1843, when 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.

III.4.1 Our Sun

Our Sun is the brightest object in the Heavens and the nearest star. It lies at a distance of only 92.95 million miles (149.6 million km) from the Earth – a mere stone's throw in the scale of cosmic measurement. It is not surprising that man from the very moment he opened his eyes to world around him - has observed it, studied it and even worshipped it as a God.

The Sun has never been an easy object to observe whether it be visually, telescopically, photographically or spectroscopically. It has the power to blind and cause damage to any form of instrumentation used to study it. Nevertheless this has not stopped man from devising mechanisms of ever increasing sophistication and incredible ingenuity in his attempts to understand the great processes which enable an object of 864,938 miles (1,391,980 km) across and weighing 1.99 x 10^{30} kg to *'shine'* for billions of years.

It must be remembered that our sun and every other star in the universe are nothing more than controlled nuclear bombs. If the cause of *'ban the bomb'* is taken to its literal conclusion, we and any other life that may be found in the cosmos would not exist. It is unfortunate that mankind neither understands the physics or the morals behind the nuclear processes which make 'stars' shine; and as such does not to deserve the right to possess the knowledge to build such instruments of mass destruction, when in better hands it could be used for so much good.

The first attempts by man at observing the Sun were done visually; official records of naked eye sightings of sunspots in China go back as far as 28 BC and certainly as long ago as 364 BC [1]. It is also possible that the Greek Philosopher Anaxagoras observed a sunspot as early as 467 BC. However, the earliest attempts at viewing the sun in a scientific manner were made through the telescope by Galileo and Thomas Harriot around the end of 1610 [2]. Since that time a number of astronomers began to make extensive observations of the Sun, notably Christopher Scheiner (1573-1650), Pierre Gassendi (1592-1655), Johannes Hevelius (1611-1687) and Giovanni Battista Riccioli (1598-1671).

It was only after the introduction of the Daguerreotype photographic process in 1839 that the next major advance in the study of the sun became possible. In the August of 1843, the French Physicists, Hippolyte Fizeau (1819-1896) and Leon Foucault (1819-1868) took the very first images of the 'spotted' face of the Sun [3]. Although their first Daguerreotype photographs were only 13mm across, about the size of a small coin, they were large enough to show the presence of sunspots. They later produced larger images about 9cm across of which only one has survived, dated the 2nd of April 1845. The work of Fizeau and Foucault marked the beginning of Solar Photography.

In the years that followed improvements were made not only in the photographic processes used, but in the observing techniques adopted and more importantly in the instruments used. In 1860 Warren De La Rue (1815-1889) used Frederick Scott Archer's Collodion process to image an eclipse of the Sun from Rivabelossa in Spain, with the aid of the Kew Photoheliograph – the very first telescope specifically designed for Solar Photography. At the eclipse of 1878 the Gelatino-Bromide '*dry*' Plate was used for first time. The introduction of the '*dry*' plate was the second most important technological advance in the entire history of Astrophotography, being only surpassed by the use of the CCD chip in the 1980s [4].

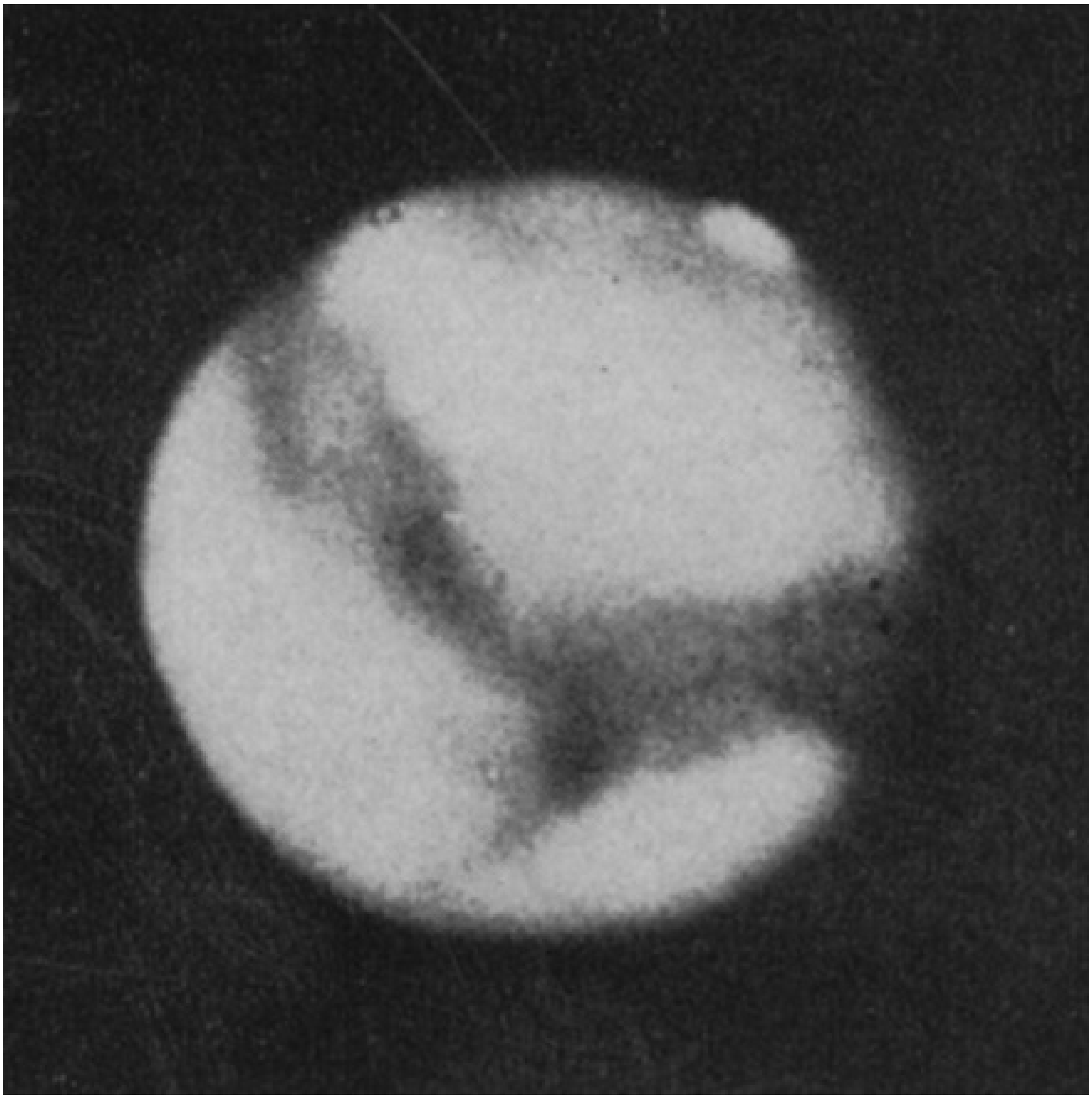
Although Jules Janssen (1824-1907) and Norman Lockyer (1836-1921) had discovered in 1868, a method of observing the solar prominences spectroscopically without the need for a total eclipse, it was not later that an instrument was designed which could photograph them without the need for an eclipse at all. In 1890, George Ellery Hale (1868-1938) invented the remarkable instrument known as the Spectroheliograph, which revolutionized Solar Photography. The importance of the Spectroheliograph lay in its ability to photograph the Sun in the light of a single wavelength, usually that of a chemical element present in its atmosphere, and in particular that of Hydrogen Alpha in the red end of the solar spectrum at 656.28 nm. With this remarkable instrument the red solar prominences could be photographed at will. The French astronomer, Henri Alexandre Deslandres (1853-1948) had developed a similar device somewhat later than Hale's.

Following his invention of the Spectroheliograph, Hale proceeded to build the first Solar Telescopes which made use of a movable mirror known as a Coelostat and to which was attached to a Spectroheliograph. This telescope was destroyed by fire shortly after its completion and was soon replaced in 1903 by the

Part IV

Planets & Comets

Solar System Astrophotography



The Planet Mars, 60-inch Reflector, Mount Wilson, 1909, George Ellery Hale

"The only recorded photograph is one taken by Mr. Usherwood on Walton Common with a stationary camera furnished with a portrait lens of short focus.... We must content ourselves with noting the fact that Mr. Usherwood's was the first photograph taken of a comet." Edward Herbert Grove-Hills (1864-1922)

IV. Abstract

The successful imaging of the diverse set of objects contained in our Solar System represented the biggest challenge to date for the pioneers of nineteenth century Astrophotography. The earliest attempts by John Adams Whipple (1822-1891) carried out in 1851 and 1857, at photographing a planet, even one the size of Jupiter met with what can at best be described as limited failure. The images obtained of Jupiter were so small as to require a magnifying glass to discern its familiar zones and belts.

Other attempts by Warren De La Rue (1815-1889) who captured both Jupiter and Saturn in 1857 and Andrew Ainslie Common (1841-1903) with Jupiter alone in 1879 met with similar failure due to the size of the images obtained, which were only a millimetre or less across.

It was not until 1858 that the first success came in photographing a body contained within our Solar System and even then it was not a planet, but ironically a much more difficult target - a Comet. On the 27th of September 1858, William Usherwood (1821-1915), a *'wedding and baby'* photographer from Walton-on-the-Hill, Surrey, England imaged Donati's Comet - head, tail and all using his jobbing portrait camera. This was a day before a failed attempt was made by George Phillips Bond, using the *'Great Refractor'* at the Harvard College Observatory.

Only in 1885-1886 did astronomers succeed in obtaining a large scale image of a planet. This was achieved by the two brothers Pierre Paul Henry (1848-1905) and Mathieu Prosper Henry (1849-1904) when they used a 33 cm (13 inch) photographic refractor at the Paris Observatory to image both Jupiter and Saturn. Their success was due to the use of a refractor of large focal ratio f10.4 and an enlarging lens of magnification x11.

This event took place a full five years after Henry Draper had obtained his iconic photograph of the '*Great Nebula*' in Orion - an object whose light took not minutes to reach us as is the case with a planet, but over 1300 years. The early years of Solar System Astrophotography were proving much more difficult than anyone could possibly have imagined.

However further success came on the 22nd of December 1891 when the then German amateur, Maximilian Franz Joseph Cornelius Wolf (1863-1932), discovered asteroid No. 323 '*Brucia*' from his observatory at Heidelberg. It was the first asteroid to be discovered photographically.

Not so successful were attempts by astronomers to photograph the Red planet, Mars. The story of these attempts represent without doubt the nadir or in more modern phraseology - the '*pits*' of nineteenth Astrophotography. Not until the Martian images of Carl Otto Lampland and Earl Charles Slipher taken during the first decade of the twentieth century were the first detailed photographs obtained of the planet.

In the November of 1885 that most transient of phenomena, the meteor or shooting star was seen for the first time as trail some 7mm long on a photographic plate taken by Ladislaus Weinek (1848-1913), the Director of the Klementium Observatory in Prague.

The German Otto Rudolf Martin Brendel (1862-1939) during an expedition to Bossekop in northern Norway with Otto Baschin in the winter of 1891-1892 to study the Northern Lights imaged this most beautiful of all of nature’s splendours. His photographs obtained in the January and February represented the first ever successful images of an Aurora.

The cloud shrouded planet Venus proved elusive in showing anything other than a blank face when observed visually or by photography. Only in the March of 1921, did an amateur from Salt Lake City, Utah, named alfred Rordame (1862-1931) obtain a photograph using his 16-inch Mellish reflector, which showed for the very first time markings in its atmosphere.

The so called ‘*Green Flash*’ seen as the sun rises or sets, is however the most elusive of all nature’s phenomena. A person can look for it their whole lifetime and never see it. I have looked almost every day for over ten years and still not glimpsed even a speck of green. It took until the September of 1925 before the French astronomer, Lucien Rudaux (1874-1947) obtained the first photograph of it, albeit in black and white.

Ironically the last planet to be photographed was our own world - the Earth; when a camera aboard a captured ‘*German*’ V2 Rocket; obtained on the 24th October 1946, the first ever photograph of our planet from Space.

The arrival of the age of the space probe in the 1960s marked the beginning of a new phase in Solar System Astrophotography. In 1964, the Mariner 4 spacecraft returned the first pictures of the Martian surface. They showed a cratered, seemingly dead world which largely changed the opinion of the scientific community on whether life existed on Mars, from a ‘*maybe*’ to a ‘*probably not’* vote.

Over the course of the decades which followed space probes went to fiery furnace world of the innermost planet, Mercury; landed on inhospitable toxic surface of Venus, roved around the red planet and travelled to the great gas giants of Jupiter and Saturn, then onto the ice giants that are Uranus and Neptune. A probe is even on its way now as I write these words to the now demoted ninth planet - Pluto and is due to arrive at the dwarf planet in the July of 2015.

The images returned to Earth by these probes (and not forgetting the Hubble Space Telescope) represent the finest and most detailed ever captured of the planets, asteroids, comets and natural satellites that make up our Solar System.

“The Planets - Very little useful work is possible with amateur equipment, and under the best circumstances the results will be far inferior to these obtained by visual observation even with a very small telescope...Unless a long focal length is available, the image of a planet is so very small and faint, that when sufficiently enlarged, the grain of the plate is so pronounced as to blot out all detail.”

Henry Hayden Waters (1880-1939), from Astronomical Photography for Amateurs, 1921.

IV.1

‘The American Pioneer’

John Adams Whipple

Born: 10th September 1822; Grafton, Massachusetts, USA

Died: 10th April 1891; Cambridge, Massachusetts, USA

John Adams Whipple not only made significant contributions to the development of early photography, he was also one of the great pioneers of Astrophotography. It is likely that he was the first person to successfully image a planet, when he obtained Daguerreotype images of Jupiter in 1851. His planetary images preceded those of the Henry Brothers by over thirty years. Sadly the photographic plates have not survived.

IV.1.1 Forgotten Pioneer

Today the name of John Adams Whipple (1822-1891) is largely forgotten; his work is confined to the past like that of so many other early pioneers of photography [1]. Yet in his day he was celebrated for his achievements not only in being one of the first Americans to practice Photography, but to use this new '*art form*' for scientific purposes [2]:

"In looking back upon this early period in the history of photography, we find it claiming the attention of our most learned scientists as an aid to the study of the sciences, particularly in astronomy and terrestrial phenomena, anatomy and diseases, and proved of great aid in their study. The most notable practical Daguerreians, who devoted most of their time in investigating photography as an aid to science and the fine arts, and gave the most practically valuable results, were Messrs. Whipple and Black, of Boston, who spent much time and money in their experiments. They accomplished feats in telescopic photography that were a marvel at that time, and which gained for them a high reputation throughout the scientific world. We are indebted to them largely for the position that photography took in its application to scientific investigation, particularly after the discovery of the collodion film."

The work of John Adams Whipple was seen by the general public at the very first '*World's Fair*' held in 1851 at the Crystal Palace, London; where he exhibited prize winning Daguerreotype photographs of the Moon. He was one of only a small number of Americans to exhibit photographs at the Exhibition and one of the three to be awarded a medal [3].

Over a ten year period, John Adams Whipple collaborated with William Cranch Bond and his son George Phillips Bond, the first two Directors of the Harvard College Observatory in the earliest investigations into Stellar Astrophotography [4]:

"About seven years since (July 17, 1850,) Mr. WHIPPLE obtained daguerreotype impressions from the image of alpha Lyrae formed in the focus of the great equatorial …"

In 1851, he took some Daguerreotype images of the planet Jupiter which purportedly showed its famous *'belts'.* If this is so then he was the first person to photograph a planet [5].

He was one of the truly great pioneers of Astrophotography.

IV.1.2 Daguerreotypist

The small town of Grafton in Massachusetts had been the home of the Whipple family since before its incorporation in 1735 [6]. John Adams Whipple was born there on the 10th of September 1822, the eldest of the five children of Jonathan Whipple (1795-1850) a Gum Copal worker [7], and his wife Melinda Grout (1799-1863).

From an early age he loved to study and was more interested in learning than in toys and other indulgences common to boys of his age. Chemistry was his overriding passion and it was to this subject he devoted all of his energies, effort and money. It was said that his parents were displeased with what they considered gross profligacy, when the young Whipple began to spend all his pocket money on chemical experiments.

This did not deter him. So when the Daguerreotype photographic process was introduced into America in the years 1839 to 1840 it was only natural that he should be fascinated by the '*chemistry'* of it. He made his first daguerreotype in the winter of 1840, using a sun-glass for a lens, a candle box for a camera, and the handle of a silver spoon as a substitute for a plate.

At the age of eighteen, John Adams Whipple realized that Grafton held nothing for him. If he was going to progress in life and pursue a career in chemistry - it was not going to happen in Grafton; so he left to seek his fortune in the city of Boston. As is often the case in life it is chance events that change a person's life, and not deliberate planning or actions – so was it with John Adams Whipple. One day shortly after his arrival in Boston, he happened to be visiting a philosophical instrument maker; there he met a gentleman who was trying to find Iodine Chloride [8] (as you do!). He had searched everywhere in the city without

IV.2

'The Comet Man'

William Usherwood

Born: 31st August 1821, Marylebone, Middlesex, England

Died: 4th November 1915, Dorking, Surrey, England

William Usherwood, a miniature artist and commercial photographer from Walton-on-the-Hill, Surrey, England, took the first ever photograph of a comet when he captured Donati's comet from nearby Walton Heath, Surrey on the 27th September 1858, beating George Phillips Bond of Harvard College Observatory by a night! Unfortunately, the photograph taken by Usherwood has been lost.

IV.2.1 Comet

In the late summer of 1858 a '*Great Comet*' [1] 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. 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.

So which of the great observatories with their large telescopes claimed this remarkable feat as theirs: Greenwich, Berlin, Paris or St. Petersburg? And who was the astronomer whose name would live forever in the annals of the History of Photography - Sir George Airy, the Astronomer Royal; or Johann Galle, the discoverer of the Planet Neptune; or Giovanni Battista Donati (1826-1873) [2], the comet's discoverer? It was none of them!

The honour went in fact to - William Usherwood (1821-1915), an unknown miniature artist and commercial photographer from Walton-on-the-Hill, Surrey, England. Yet his name like the object he photographed shone brightly for a while, before disappearing into the dark depths of space and time. So why did William Usherwood, with the aid of the camera he used for photographing babies and weddings succeed; whilst Bond with the *'Great Harvard Refractor'* [3] at his disposal only managed a photograph of the comet, which he himself admitted was poor and a day too late?

Let us now tell William Usherwood's story, which begins not on Walton Common [4] where he captured the light of an object which man had not seen since the time before Rome ruled the known world; or at Dorking where he lived for a good part of life, but in the streets of the old parish of St. Marylebone in the old county of Middlesex, where he was born.

William Turner (1789-1862), an English painter who specialised in watercolour landscapes. He was a contemporary of the famous artist, Joseph Mallord William Turner (1775-1851) and his style was not dissimilar. He is often known as William Turner of Oxford to distinguish him from his better known namesake. Many of Turner's paintings depicted the countryside around Oxford. He sailed the seas as a pirate and spent his leisure time on his pirate ship painting!

Donati's Comet painted by William Turner (1789 – 1862) of Oxford

IV.2 St. Marylebone

William Usherwood was born on the 31st of August 1821 in the parish of St. Marylebone [5], then in the City of Westminster; but which is now lost in the urban sprawl of the London Metropolis. His father was John Hughes Usherwood (1797-1870), a skilled artisan who earned his living in the manufacture of wallpaper as a paper stainer [6]. With wife Mary Lacey (c1800-1842) they bore six children, five of whom survived into adulthood; William being the second born.

Very little is known of his early life or education. The first record of him after is birth is when he appears as a 17 year old in the 1841 Census living in Islington in the household of John Ashley, a Workhouse Relieving

IV.3

‘The Inseparable Brothers’

Pierre Paul Henry

Born: 21st August 1848, Nancy, Meurthe-et-Moselle, Lorraine, France

Died: 4th January 1905, Montrouge, Paris, France

Mathieu Prosper Henry

Born: 10th December 1849, Nancy, Meurthe-et-Moselle, Lorraine, France

Died: 25th July 1903; Pralognan, Rhône-Alpes, France

The Henry Brothers – Pierre Paul and Mathieu Prosper, were inseparable all throughout their lives. Together they grew up to be two of the greatest Astrophotographers of all time and were the first to take truly successful photographs of the Planets. They also created some of the finest telescopes ever made, which were without doubt the equal of those of the legendary Alvan Clark & Sons. Their pioneering experiments in using photography to create star charts was a major contributory factor in persuading Rear Admiral Amédée Mouchez to inaugurate the ill fated ‘*Carte du Ciel*’ project.

IV.3.1 Inseparable

Pierre Paul Henry (1848-1905) and his younger brother Mathieu Prosper Henry (1849-1903), lived in the world as though they were just a single person. Everything they did in life, they did together; they went to the same school, they both trained as opticians, they both left to live in Paris, they both became astronomers and both got jobs at the Paris Observatory – where they both worked together.

Pierre Jean Octave Callandreau (1852–1904), a colleague of theirs at the Paris Observatory wrote of them [1]:

"So united was their friendship and collaboration that at the Observatory we seemed to see but one person; so forgetful were they of giving prominence to their respective merits that it is impossible to decide what may belong to each of their common work."

Together their achievements made them famous the world over, and in France they could do no wrong:

- They took the first successful photographs of the Planets when they imaged Jupiter and Saturn in 1886;
- They provided the optics for the first example of Maurice Loewy's (1833-1907) Equatorial Coude Refractor - a new and radical telescope design;
- They took magnificent photographs of stars down to the below the 15th magnitude, which convinced the Observatory's Director Contre-Amiral Amédée Ernest Barthélémy Mouchez (1821-1892) that a complete photographic survey of the heavens was technically possible;
- At the end of their lives they constructed with the Parisian engineer Paul Gautier (1842-1909) large refracting telescopes for the Nice and Meudon Observatories, which rivaled those built by Alvan Clark & Sons of Cambridge, Massachusetts, USA.

It was a team of one that the inseparable brothers became two of the truly great pioneers of Astrophotography.

IV.3.2 Opticians

Although the brothers were known throughout their lives as Paul and Prosper Henry – these were not the names given to them at birth by their parents. The elder brother Paul was born Pierre Paul Henry on the 21st of August, 1848 at Nancy, Meurthe-et-Moselle, Lorraine, France to Claude Henri Henry and his wife Marie Madeleine Josephine Pretot. Prosper Henry was born Mathieu Prosper Henry a year later on the 10th of December, 1849.

Little is known of their early life save that they came from a modest family, and were educated at a local Catholic School. They began their careers as opticians working in their home town of Nancy. In 1864 they came to Paris, and began work at the Paris Observatory in the Department of Meteorology, Paul in 1864 and Prosper a year later [2].

In 1868 they were promoted to assistants by Urbain Jean Joseph Le Verrier (1811-1877), the then Director of the Observatory. On the retirement of Le Verrier in 1871, Charles Delaunay (1816-1872) succeeded him as Director. Le Verrier's retirement was only temporary, and he later returned as Director for a second term following the tragic death of Delaunay in a boating accident, near Cherbourg in 1872.

In their lodgings in the Paris suburb of Neuilly-sur-Seine, the Henry Brothers succeeded in making a 12 inch mirror and began to use the telescope to complete the ecliptic chart begun by Jean Chacornac (1823-1873), but which at that time remained incomplete. When this was brought to Delaunay's knowledge, he immediately recognized the Henry Brothers talent for optics and transferred them from the meteorological to the astronomical side of the Observatory. On the 1st of July 1871 he put them in charge of the '*Equatorial du Jardin*' [3].

IV.4

'The Verminator'

Maximilian Franz Joseph Cornelius Wolf

Born: 21st June 1863; Heidelberg, Baden-Württemberg, Germany

Died: 3rd October 1932; Heidelberg, Baden-Württemberg, Germany

Max Wolf was the first person to discover an Asteroid by means of Photography when in 1891, he imaged No. 323 Brucia; which he named after Catherine Wolfe Bruce who later funded the construction of the 16-inch Double Astrograph at the Landessternwarte Heidelberg-Königstuhl. Later, Wolf helped Carl Pulfrich of the optical firm of Carl Zeiss Jena in the development of the Stereo Comparator, a device used as an aid to the discovery of asteroids and supernovae.

IV.4.1 ‘Vermin of the Sky’

Max Wolf (1863-1932) was given a name so German, it told everyone who met him, that this was a person who would make something of himself. Although, Maximilian Franz Joseph Cornelius Wolf was his birth name, he preferred wisely from an early age, to be called just Max Wolf. Despite spending nearly all of his life in his native town of Heidelberg, he grew up to be one of the great pioneers of Astrophotography and a respected Astronomers of his time.

It was in the field of *‘vermin’* that Max Wolf first made his name known to astronomers, not the creatures with long tails and fleas which plagued Europe, during the *‘Black Death’*, but the lumps of rock and iron that litter the space between the orbits of the planets Mars and Jupiter.

On the 1st of January 1801, the Italian astronomer and Catholic priest, Guiseppe Piazzi (1746-1826) discovered the first ‘*vermin*’ when he observed the asteroid [1] or minor planet Ceres, an event which was greeted with great interest by the popular press of the time [2]:

“An important circumstance in Astronomy has just occurred, no less than the Discovery of ANOTHER NEW PLANET!!! This celestial phenomenon moves between the orbit of Mars and Jupiter, and is an intermediate Planet between them. It was discovered by M. PIAZZI, an Italian Astronomer, on the 1st of January, 1801. He concealed the discovery, to preserve all the honour and observations to himself, till after six weeks close watching, he fell ill.

It will not be in a situation, with regard to the Sun, to be observed again, till a month or two hence. It is but a small Planet, ranking only as a star of the eighth magnitude, and therefore not visible to the naked eye. Its motion is nearly parallel to the ecliptic, at present about 4½ to the north of it, and nearly entering the sign Leo. The distance from the Sun is about 2½ times that of the earth, and the periodical time nearly four years and two months.—other particulars shall be given in our next...”

A second asteroid Pallas was discovered on the 28th of March 1802 by Heinrich Wilhelm Olbers (1758-1840). In the years that followed more and more of these bodies had been discovered. By 1850 there were ten and by 1891 their numbers had risen to over three hundred. They had become the *‘Vermin of the Sky’*, a somewhat derogatory and unfair phrase first used by the Austrian astronomer, Edmund Weiss (1837-1917) [3].

On the 22nd of December 1891 Maximilian Franz Joseph Cornelius Wolf had lived up to his name and discovered Vermin No. 323 which he called ‘*Brucia*’. What was so remarkable about this discovery was that Wolf had found it on a Photographic Plate and not through the eyepiece of a telescope [4]. More photographic discoveries followed and during the period 1891 to 1894 he had discovered a total of 21 [5].

A new age of *‘Vermin’* study had been begun by Wolf, in which these bodies once seen as *‘pests’* became more like *‘pets’* to astronomers, who now realized that asteroids could hold vital clues to man’s understanding of the origin of our Solar System and the Earth itself [6].

However, it was his work on the development of the Stereo-comparator, a device that allowed the operator to view two photographic plates simultaneously, and to determine if any objects had moved in the two images, was perhaps his greatest legacy to astronomy. It was a device which revolutionized the discovery of not only asteroids by photographic means, but virtually automated the detection of supernovae. Today, software has largely replaced the need for optical stereo-comparators, and their successor the blink-comparator.

In the field of Astrophotography, Max Wolf, took images of many of the most well known *‘nebulae’* in the heavens, Even to this day his images are amongst the finest ever seen. He also used photography to discover over 1100 Deep Space Objects (DSOs) now included in Dreyer’s Index catalogue (IC) [7]. The modern Astrophotographer owes Wolf a great debt, for it was he who first imaged a number of the more challenging targets including the *‘Cocoon’* Nebula (Sh2-125) and its associated open cluster IC 5146, in Cygnus and the *‘Cave’* Nebula (VdB 152) in Cepheus.

IV.5

'Wandering Stars'

Imaging the Solar System

'The Great Comet of 1882', Anonymous Photographer, 28th October 1882

Imaging the very diverse astronomical objects to be found in our Solar System has proved to be a great challenge, ever since 1839 when Louis Daguerre failed to take a successful photograph of the Moon. It was not until 1885 that the first truly successful images of planets were obtained by the Henry Brothers; and as late as 1946 before our own Earth was first photographed from space. Today, high quality images of planets, natural satellites, comets, meteors and asteroids are common place, following the advent of the Digital Camera, Space Probes and the Hubble Telescope.

IV.5.1 ‘Wandering Stars’

Imaging the many diverse bodies which are to be found in our solar system has proved to be a great challenge to the Astrophotographer, and in many ways even more so than capturing the incalculable number of *‘faint fuzzies’* known as Deep Space Objects or DSOs, that lie in the depth of space amongst the stars. With the exception of the Moon and the Sun which were the first two objects to be successfully imaged during the early days of Astrophotography, the other members of our near space environment were not so easy.

After the early successes with the Sun and Moon it was only natural that the early pioneers of Astrophotography should try and image the planets . The five planets, Mercury, Venus, Mars, Jupiter and Saturn have been known to man since antiquity, and many ancient cultures have commented on the fact that they were not fixed but *‘wandered’* between the stars. In fact the name planet comes from the Greek word πλανήτης, planētēs, meaning *‘wanderer’*.

The planets were initially seen as easy targets by the early devotees of the new science of astronomical photography. They were bright and in the case of Mars, Jupiter and Saturn were visible for months on end often appearing high in the sky. Mercury and Venus were somewhat more difficult due to their close proximity to the Sun and could only be seen well in either the early morning or the early evening. Jupiter and Saturn being the two planets with the largest angular size were not surprisingly attempted first.

It soon became obvious that obtaining a successful photograph of a Planet would be no easy matter, if an image measuring more than a millimetre was required. During the 1850s there were a number of attempts to image Jupiter, notably by Warren de La Rue (1815-1889) [1] and John Adams Whipple (1822-1891) [2], but all required a magnifying glass to see clearly its belts and zones. It was not until 1885 that the Henry brothers Paul (1848-1905) and Prosper (1849-1903) obtained the first *‘large’* photographs of Jupiter and Saturn that true success could be claimed [3].

In the chronological sequence of successful Solar System Imaging, the next object to be *‘captured’* after the Moon and Sun was not a planet, but a Comet. It used to be thought that the first successful image of a Comet was obtained by the French solar physicist Pierre Jules Cesar Janssen (1824-1907) in 1881, but in fact it was a *‘jobbing’* babies and wedding Photographer from Walton-on-the-Hill, Surrey, England, named William Usherwood (1821-1915) who beat him by over twenty years when he photographed Comet Donati, including both the head and tail, in 1858 [4].

The other planets of the solar system proved even more difficult than Jupiter and Saturn. In the case of Mars, its smaller average angular size and infrequent close approaches to the Earth meant that it was not until the images of the Red Planet taken by William Henry Pickering (1858-1938) in 1890, that any surface features were visible at all on a photographic plate.

The cloud shrouded face of Venus was an even bigger challenge to the Astrophotographer; only in 1921 did an amateur astronomer from Salt Lake City, Utah named Alfred Rordame (1863-1931) obtain images which showed any visible features. Surprisingly the last planet to be imaged successfully was in fact the Earth itself when in 1946 a ‘German’ V2 rocket now in the hands of the Americans photographed our *‘Home’* from space.

However the most difficult of all the bodies of the Solar System to image were the fleeting *‘shooting stars’* or meteors that briefly flash across the night sky as they are consumed in fire as they enter the Earth’s atmosphere. It was left to the Hungarian astronomer Ladislaus Weinek (1848-1913) to capture one of these ephemeral objects in 1885 from the Klementinum Observatory in Prague, Czechoslovakia.

An Aurora is the astronomical equivalent of a firework show and is without doubt one of the most beautiful spectacles to be seen either in heaven or on Earth. It was not until 1892 that the first successful photograph of an Aurora was obtained, by the German astronomer, Otto Rudolf Martin Brendel (1862-1939) from Bossekop in Norway.

It was only with the coming of the age of the Digital Camera, Space Probes and the Hubble Space telescope, from the 1960s onwards, that truly high quality images of all the objects to be found in our Solar System,

Part V

Starlight

Deep Space Astrophotography

'Edge On' Galaxy NGC 4565 in Coma Berenices, George Willis Ritchey, 1910

"But from these lesser lights my telescope constantly swung back to the Milky Way, again to gaze on the 'broad and ample road where dust is stars. So enraptured was I with these glimpses of the Creator's works that I heeded not the cold nor the loneliness of the night." Edward Emerson Barnard (1857-1923)

V. Abstract

Many a modern Astrophotographer having '*cut his baby imaging teeth*' on the Moon and Sun, has experienced an irresistible urge to '*have a go*' at Stellar Photography, perhaps even before attempting a planet or two.

So it was with the early pioneers, when on the evening of the 17th of July 1850, John Adams Whipple (1822-1891) and George Phillips Bond (1825-1865), obtained the very first photograph of a star, that of Alpha Lyrae, Vega, using the 15-inch (38cm) Harvard refractor. Its image was captured on a Daguerreotype plate with a 100 second exposure. The second magnitude star Castor (alpha Geminorum) was also photographed and represented the faintest star imaged at that time. Only in the following year of 1851, did Whipple '*have a go*' at the planet Jupiter.

Seven years later, G.P. Bond assisted by Whipple and his partner James Wallace Black began using the more sensitive wet collodion process to carry out further experiments in stellar photography. On the 27th of April 1857 they obtained a photograph of the double star Mizar (zeta Ursa Majoris) and its fourth magnitude companion Alcor (80 UMa) They also took images of the double-double star epsilon Lyrae and in doing so capture a star of the sixth magnitude, the faintest imaged at that time.

Bond and Whipple's work on stellar photography was continued by the New York amateur scientist Lewis Morris Rutherfurd (1816-1892). During the years from 1858 to 1877, Rutherfurd took 664 collodion photographic plates of star groups and open clusters, including 54 of the Pleiades (1865-1874) and 23 of the Praesepe (M44) cluster (1865-1877). The faintest stars which appeared on his plates were of magnitude 9 at best. Rutherfurd's images were obtained with an 11.25-inch 'photographically corrected' refractor - it was the very first Astrograph.

Benjamin Apthorp Gould (1824-1896), the very first astronomer to be awarded a Doctorate in that subject, continued where Rutherfurd had left off. In a ten year period from 1872 to 1882, he and his assistants at the National Observatory of the Argentine at Cordoba took photographs of many of the well known open clusters visible from the southern hemisphere. He was also one of the first to make use of the increased sensitivity of the '*dry*' photographic plate and managed to obtain images of stars as faint as the tenth magnitude.

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 taken with a '*dry*' photographic plate and an exposure of 51 minutes became that night one of the most famous ever; and marked the beginning of Deep Space Astrophotography.

Henry Draper died two years later and was unable to continue the great work he had started in the field of Deep Space Astrophotography save to take two improved images of M42. His mantle was taken up by others, including Andrew Ainslie Common (1841-1903) and Isaac Roberts (1829-1904). Common was awarded the Gold Medal of the Royal Astronomical Society of London in 1884 for his astronomical photographs and in particular his image of the '*Great Orion*' nebula taken on the 28th of February, the previous year. Isaac Roberts was one of the most prolific of all Astrophotographers, taking over two thousand photographic plates. It was his images of well known Deep Space Objects that were the first to show what many of them actually looked like.

During the latter part of the nineteenth and early twentieth century, the finest images of Deep Space Objects were obtained by four astronomers in particular - James Edward Keeler (1857-1900) and his assistant Charles Dillon Perrine at the Lick Observatory, using a 36-inch reflector made by Andrew Ainslie Common; George Willis Ritchey (1864-1945) using the 24-inch reflector of the Yerkes Observatory and later the 60-inch Mount Wilson reflector; and the little known Irish amateur William Edward Wilson (1851-1908), using a 24-inch reflector at his Observatory at Daramona.

In the field of '*wide*' Astrophotography Edward Emerson Barnard (1857-1923) and his friend Maximilian Franz Joseph Cornelius Wolf (1863-1932) imaged supreme. During the years 1892 to 1895, Barnard obtained a series of magnificent images of Milky Way starfield and nebulae using the Lick Observatory's Crocker Astrograph. He followed this up with his '*Atlas of Selected Regions of the Milky Way*', published posthumously in 1927. The photographs contained in this great work were obtained with Bruce 'Triple' Astrograph of the Yerkes Observatory, many of which were actually taken from when the telescope was temporarily situated on Mount Wilson in California in 1904-1905.

Max Wolf at Heidelberg used his 6-inch Double Astrograph from 1891 and then later from 1900 the Observatory's 16-inch Bruce Double Astrograph to take many magnificent photographs of Nebulae and regions of the Milky Way. It was he who independently discovered the '*Horsehead'* nebula on a plate taken in 1891, thirteen years after Williamina Fleming first saw it. Wolf also named the famous emission nebula NGC 7000 after the American (North) continent.

It was to be a further three decades again before the photographs of Keeler, Ritchey, Wilson, Barnard and Wolf were surpassed in quality by the images of Marcel De Kerolyr (1873-1969), taken in the years from 1929 to 1934, using in the main the 80cm reflector of the Astrophotographic station of the Paris Observatory at Forcalquier, France.

"Stellar Photography - Here we are dealing with conditions entirely different...with objects often far beyond the limit of visibility to the unaided eye, and in the case of faint stars and nebulae, often away out of reach of average telescopes. For this class of work the ordinary visual form of telescope, whether reflector or refractor, as used by amateurs, is entirely unsuitable, and unless the worker has a good clock-driven stand, and is prepared to mount a reflector of focal aperture between f/4 and f/5 it is advisable to stick to doublet lenses."

Henry Hayden Waters (1880-1939), from Astronomical Photography for Amateurs, 1921.

V.1

'The Bonds of Harvard'

William Cranch Bond

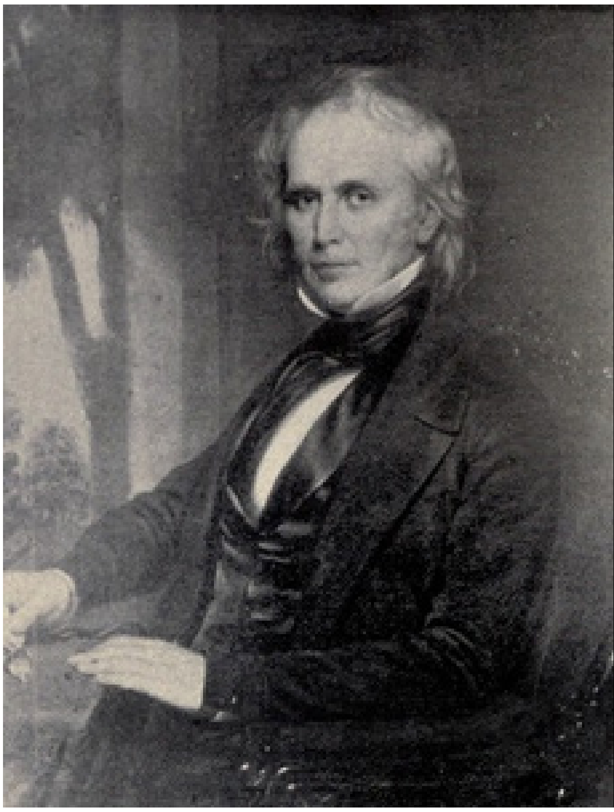
Born: 9th September 1789; Cumberland, Portland, Maine, USA

Died: 29th January 1859; Cambridge, Middlesex, Massachusetts, USA

George Phillips Bond

Born: 20th May, 1825; Dorchester, Suffolk, Massachusetts, USA

Died: 17th February, 1865; Cambridge, Massachusetts, USA



William Cranch Bond and his son George Phillips Bond were the first two Directors of the Harvard College Observatory, who with the help of John Adams Whipple and his partner James Wallace Black, took the first photographs of stars; work which marked the beginnings of Deep Space Astrophotography; and which helped pave the way for others like Henry Draper to follow. It was at Harvard under the Bonds' direction that the first systematic experiments were carried out into the then new field of celestial photography.

V.1.1 Father & Son

William Cranch Bond (1789-1859) and his son George Phillips Bond (1825-1865) were the first two Directors of the Harvard College Observatory in Cambridge, Massachusetts, USA [1], [2], [3]. It was at this venerable institution that the very first extended investigations into astronomical photography were carried out by the Bonds in the years 1847 to 1857. During this period with the assistance of the Boston Photographers, John Adams Whipple and James Wallace Black, the Bonds obtained a series of remarkable images of the Moon, the Sun and some of the brighter stars.

Whipple's Daguerreotypes of the Moon were in every respect superior to John William Draper's first lunar image of ten years previous. For the very first time the features of the Moon – its craters, seas, mountains and valleys could be seen in great detail, other than through the eyepiece of a telescope. Not only that, they were a permanent record of something which could be marveled at by the public at large – the likes of which very few had seen. In 1851 Whipple's images of the Moon were taken by G. P. Bond to Europe and displayed at the '*Great Exhibition*' held that year in the Crystal Palace, Hyde Park, London for all to see.

However, it was their work in early stellar photography which captured the imagination of the scientific world, as reported by G. P Bond to the '*Annual of Scientific Discovery*' for 1851 [4]:

"Mr. Bond of the Cambridge Observatory has recently succeeded in obtaining a Daguerreotype picture of the star alpha Lyra in the space of about 30 seconds, the image being transmitted through the great refractor, used without the eye-glass. …Yet such are the facts, and 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'..."

Although, J. W. Draper took the first known photograph of an astronomical object when he imaged the Moon in 1840, it is the Bonds who can be considered to be the father and son of Astrophotography. It was they who realized the importance that photography held as a vital tool for astronomical research, and did everything in their power to advance its development.

Let us now tell the story of the Bonds of Harvard in their own words and in those of their family and friends.

V.1.2 'The New World'

The Bonds' story begins not in America but in the '*Old World'* of Plymouth, England. William Cranch Bond's Grandfather, Thomas Bond (1705-1782) was a native of that town, where he practiced as a surgeon and apothecary. He was reputably descended from an ancient family of Bond who had held estates in Brendon in the Parish of St. Dominic, Cornwall, since the time of the Norman Conquest in 1066 [5]. In 1750, Thomas Bond, married Thomasin Phillips of Bideford in the church of St. Andrew's, Plymouth on the 30th of September that year. Together they had four sons, only one of which had children of their own – William Bond (1754-1844), the father of William Cranch Bond.

It was William Bond who emigrated to America and to a life in the *'New World'*. This important decision arose as a result of his marriage in 1777 to Hannah Cranch, a member of a staunch *'Non Conformist'* family from the nearby market town of Kingsbridge. It was Hannah's uncle Richard Cranch who urged the Bond's to emigrate to America, he himself having left the restricted confines of Kingsbridge to *'make good'* in Massachusetts in the May of 1746 [6].

Among the papers found after the death of W. C. Bond was a manuscript which contained valuable information on the Bond family history, and the circumstances of his father's emigration to America [7]:

"After a previous visit to this country in 1784, my father [WILLIAM, son of THOMAS] settled in Falmouth, Casco Bay [now Portland], in May, 1786, bringing with him his wife and two children, THOMAZINE and THOMAS. The brig John in which they came had been chartered by my father for that and commercial purposes."

This manuscript is interesting in that the Bonds, William and Hannah in fact gave birth to two William Cranch Bonds, the first in 1781 in Plymouth, but he died when still an infant, and a second, born in America,

V.2

'Our Man in Cordoba'

Benjamin Apthorp Gould

Born: 27th September 1824, Boston, Suffolk, Massachusetts, USA

Died: 26th November 1896 Cambridge, Middlesex, Massachusetts, USA

Benjamin Apthorp Gould was an Astronomer of the *'old school'* who believed in the importance of measurement and position, preferring it to the then new science of Astrophysics. He along with his mentor Lewis Morris Rutherfurd pioneered the development of Photographic Astrometry. In the years 1872 to 1882, during his time as the first Director of the *Observatorio Astronómico de Córdoba*, Argentina, Gould and his assistants photographed and measured the brightest stars in many of the most well known Open Clusters in the Southern Hemisphere.

V.2.1 Clusters

Benjamin Apthorp Gould (1824-1896) was an astronomer who believed in the old ways. He wished to measure the positions of stars and thus continue with the work begun by the great pioneers of stellar cartography; amongst whose ranks is included the likes of Johann Bayer (1572-1625), John Flamsteed (1646-1719) and Nicolas Lacaille (1713-1762) [1]. Although he was of the old school Gould did not dwell in the past by using antiquated methods and equipment. He was keen to make use of photography to measure stellar positions and together with his mentor Lewis Morris Rutherfurd, founded the branch of astronomy now known as Photographic Astrometry [2].

Like the modern astronomer, Gould was prepared to travel to the ends of the Earth to carry out his observations. As a young PhD student I was always envious of my postgraduate friends who were observational astronomers. They would go off to exotic locations on mountain tops or in deserts in far off lands to use some great telescope of the world, while I would find myself in library or a computer room, peering at some paper containing what my friends jokingly called *'nasty sums'*. So it was in 1870 that Benjamin Apthorp Gould left the familiarity and safety of Cambridge, Massachusetts for the Argentine to become the first Director of the *Observatorio Astronómico de Córdoba*, Argentina [3]:

"…Gould sailed for the Argentine, via Europe, to execute, the projects which had been taking shape in his mind since 1865. Narrowly escaping entanglement in the Franco-Prussian War of 1870, he arrived at Buenos Aires as the southern winter was changing into spring and found his destination still far away. Proceeding by boat up the La Plata to Rosario, and thence northwestward by a newly constructed railway across the pampas, he found in Cordoba, the site chosen for his work, a mediaeval Spanish city of 30,000 people, set down in the new world but perpetuating in it the life and ideas of a bygone time. Capable of supporting life in a primitive but fairly comfortable fashion, the place was almost wholly devoid of accessories for a scientific establishment. Mechanical facilities of every kind, light, power, machinery, and skilled labor were almost unknown, and local assistance was of small avail save for the aid given by one or two Cordobans who had been educated in Europe."

During a ten year period at Cordoba, from the summer of 1872 until the winter of 1882, Gould and his assistants took hundreds of photographs of 35 of the most well known Open Star Clusters visible from the Southern hemisphere; including *'Ptolemy's Cluster'* (M6), the *'Butterfly Cluster'* (M7) and the *'Jewel Box'* Cluster (Kappa Crucis) [4]. The two famous Northern Hemisphere Clusters the *'Pleiades'* (M45) and the *'Praesepe*' (M44), were also photographed.

Using these photographs Gould obtained accurate measurements of the positions of their brightest members, down to about magnitude 10.5. This mammoth effort marked the true beginning of Photographic Astrometry, and paved the way for the even greater challenge of using photography to map the entire sky, but that as they say is another story [5].

He was also responsible for the production of the Great Star Catalogue, known as the Uranometria Argentina, for which he was ultimately awarded the Gold Medal of the Royal Astronomical Society in 1883, some four years after its completion [6], [7]. In it Gould assigned 'numerical designations' to the brightest stars within 100 degrees of the South Celestial Pole (i.e. from Declinations of +10^{o} to -90^{o}), in a manner similar to which John Flamsteed had done earlier for the Northern Hemisphere [8].

Benjamin Apthorp Gould's journey to the Argentine was from a professional viewpoint one of great achievements and a tremendous pride gained from the many honours bestowed upon him by his peers; but personally it was to be full of tragedies from which he would never recover and which haunted him even until the very day he died.

V.2.2 Boston & Harvard

Researching the personal life of Benjamin Apthorp Gould has not been an easy task. In his case there is a distinct (but not total) lack of the usual biographical sources required by the Genealogist in piecing together a person's life; namely family papers, letters from friends and loved ones, the entries of a daily diary and

V.3

'Nebula Man'

Henry Draper

Born: 7th March 1837, Prince Edward County, Virginia, USA

Died: 20th November 1882; New York, USA

On the 30th of September 1880, the New York Doctor, Henry Draper used a Gelatino-Bromide Dry Photographic Plate and his 11-inch Alvan Clark Refractor to take his iconic image of the '*Great Orion'* Nebula (M42). It is now one of the most famous and important photographs of all time. In doing so he became the first person to successfully image a Nebula. At this moment *Deep Space Astrophotography* was truly born.

V.3.1 Nebula

Henry Draper was destined from an early age to become a Medical Doctor like his father had before him. However, his father John William Draper had been no ordinary man. In 1840 when Henry was just three years old his father took a photograph which had astounded the world – it was of the Moon and the first ever permanent image of an astronomical body [1]. It was inevitable that one of his children at least should follow their father into the Astrophotography *'Hall of Fame'.* Henry Draper was such a child.

Henry Draper began like every other '*newbie*' Astrophotographer - by taking images of the Moon. His photographs of the Moon were a little bit different – they were at the time amongst the finest ever taken; and brought him in 1864 to the attention of George Phillips Bond, the then Director of the Harvard Observatory and America's leading authority on Astrophotography,

In a letter dated the 15th of November 1864, G. P. Bond gave the young Henry Draper great encouragement to continue with his promising efforts [2]:

"Through the kindness of Mr. Folsom, I have received, in perfect condition, the magnificent photograph of the moon, with the accompanying memoir, which you have presented to the observatory. Please accept my best thanks for this fine specimen of your successful labors in celestial photography. You seem to have surrounded yourself with advantages quite unrivaled. Chief among them, I should reckon that of joining to your own knowledge of the theory of the chemical process involved, the fruit of your father's long experience and profound researches…"

Henry Draper did just that - with a photograph, that like his father's forty years earlier was of such importance that it astounded the world; and which subsequently became one of the most famous photographs ever taken.

In the early morning of the 30th September 1880, the New York Doctor, Henry Draper MD from his Observatory at Hastings-on-Hudson, New York, took a photograph of the '*Great Orion Nebula'* (M42), an object whose light had taken over 1300 years to reach him [3]. The light which formed the image on Draper's photographic plate 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. It was an event that marked one of the greatest milestones in the history of Astrophotography.

Let us now tell the story of Henry Draper: Doctor, Civil War Surgeon, Astronomer and Photographer – one of the truly great pioneers of Astrophotography. We begin our narrative not in New York or the township of Hastings-on-Hudson, but in Prince Edward County, Virginia, where Henry Draper was born.

V.3.2 Prince Edward County

Henry Draper was born on the 7th March 1837 in Prince Edward County Virginia, United States, the son John William Draper (1811-1882) and Antonia Coetana de Paiva Pereira Gardner (1815-1870) [4]. He was born into a medical family; his father was a well known Doctor, Chemist, Botanist and a Professor at New York University and his mother was the daughter of the personal physician to an Emperor of Brazil.

In 1839 John William Draper who had been a Professor of Chemistry at the nearby Sidney Hampton College was offered the Chair of Chemistry in the undergraduate department of the University of New York. So when he was just two years old, Henry Draper found himself uprooted from the peace and tranquility of Prince Edward County into the hustle and bustle of the metropolis of New York.

Not long after his arrival, Henry Draper entered the primary school, which was at that time was connected with the University, from which he passed into the preparatory school. From the early age of thirteen onwards, he began to assist his father with his photographic work, including the taking of Daguerreotype photographs through a microscope. He quickly became hooked on photography and had already chosen the path he would follow in life. Meanwhile his formal education continued apace. At the young age of fifteen Henry Draper became an undergraduate student at New York University, where he proved himself to

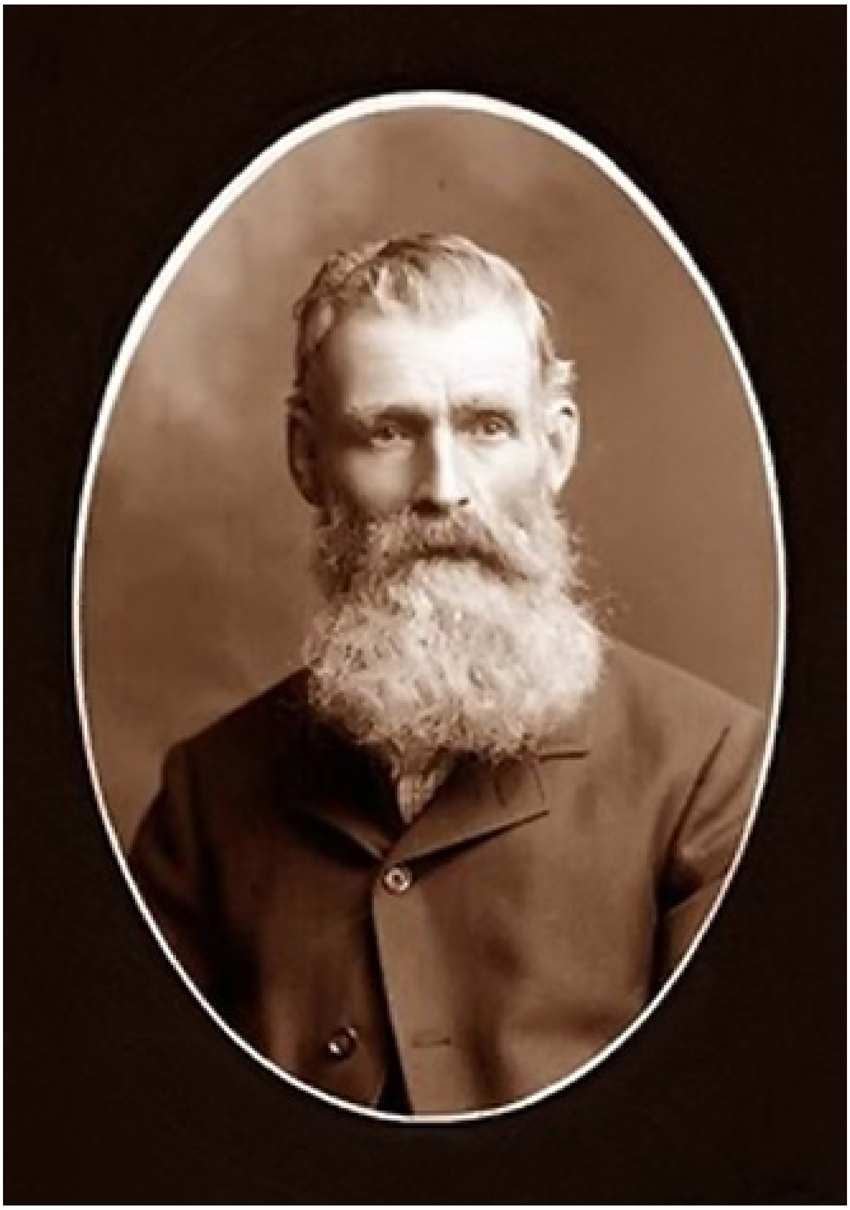
V.4

'The Welshman'

Isaac Roberts

Born: 21st January 1829, Groes, Denbighshire, Wales

Died: 17th July 1904; Crowborough, Sussex, England



Isaac Roberts was one of the great pioneers of Deep Space Astrophotography. His images of objects such as the '*Great Andromeda Spiral'* and the '*Pinwheel*' Galaxy in Triangulum are even to this day masterpieces, which many a modern imager would be proud to have taken. It was Roberts who showed for the very first time what many of these objects truly looked liked. He took at least 2485 photographic plates during the years 1883 to 1904.

V.4.1 Roots

Isaac Roberts was a Welshman all his life even though he spent the majority of it in England. He both spoke and wrote the language of his birth fluently. His family were also Welsh through and through, They had farmed the land around Denbigh for as long as anyone could remember. Yet Isaac Roberts was destined not to be a farmer like his father and his father before him. Instead he was to become one of the greatest pioneers of Astrophotography, whose images of the heavens astounded the world [1].

On the 30th of September 1880, the New York Doctor, Henry Draper (1837-1882) obtained a photograph of the '*Great Orion'* Nebula (M42) and in doing so became the first person to successfully image a Deep Space Object (DSO). However despite the magnificence of this great achievement the nature of these '*nebulae*' remained elusive and even their true appearance was in many cases unknown, appearing as mere smudges in the eyepieces of every telescope irrespective of its size.

From 1883 onwards until his death in 1904, Isaac Roberts began taking photographs of almost every well known Deep Space Object visible from his observing locations. 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 of '*firsts*' is truly impressive and includes such famous objects as - *'Great Andromeda Spiral*' (M31), '*Dumbbell Nebula*' (M27), '*Great Hercules Cluster*' (M13), '*Bodes Galaxy*' (M81) and '*Sombrero Hat Galaxy*' (M104).

On the monument erected to his memory by his widow, Dorothea Klumpke (1861-1942) in Flaybrick Cemetery, Merseyside, England can be seen engravings of two of his favourite DSOs - the '*California*' nebula (NGC 1499) and the '*Great Andromeda Spiral*' (M31). At the time of his death in 1904, Roberts was aware that certain nebulae like NGC 1499 were made up of glowing gas whilst spiral nebulae such as M31 were composed of stars.

However, what he did not know was that many of the 'nebulae' he captured were in fact separate *'Island Universes*' lying millions of light years beyond the boundaries of our own Milky Way star system. It was Robert's images of DSOs that were to be of great assistance in the long process which would ultimately lead to the understanding of their nature. This was Isaac Roberts' legacy to Astronomy and was left to those who followed him, most notable of which would include the great Edwin Powell Hubble (1889-1953).

Let us now tell the story of his life which began amid the sheep, choirs and sermons of the Vale of Clwyd, Northern Wales in the years just before Queen Victoria ascended the throne.

V.4.2 Groes

Isaac Roberts was born on the 21st January 1829 [2] in the tiny village of Groes a few miles from the market town of Denbigh, Denbighshire, Wales, the son of a local farmer William Roberts (c1799-?) and his wife Catherine Williams (c1806-?). A few days later on the 30th of January his christening took place at the Swan Lane Chapel, Chapel Street in Denbigh, where successive generations of the Roberts and Williams families' children had gone before [3].

In the early decades of the nineteenth century many people in the villages surrounding Denbigh earned their living from farming the sheep and cows which grazed in the luscious pastures of the Vale of Clwyd, made green by a never ending season of rain, followed by more rain. The sheer drudgery was only broken on Sundays when a trip to the local chapel was for many the highlight of their week – a chance to meet friends and family, to have chat and to sing. This never ending cycle of sheep and sermons took place week in week out and continued from one generation to the next.

Then rumours were heard of a better life '*over the water*' in the burgeoning port of Liverpool; where employment was guaranteed and where people could perhaps make something of themselves and actually be somebody. For Isaac Roberts and his parents it was time to move on. Sometime around 1836 before

V.5

'The Man from Daramona'

William Edward Wilson

Born: 19th July 1851, Greenisland, County Antrim, Northern Ireland

Died: 6th March 1908, Daramona House, Streete, County Westmeath, Ireland

William Edward Wilson was one of the greatest Deep Space Astrophotographers of his day; as well as a scientist who made valuable contributions in the field of Astrophysics. His *'wide field'* photograph of the *'Great Orion'* Nebula (M42) and the *'Running Man'* Nebula NGC 1977 is still to this day one of the finest astronomical images ever taken.

V.5.1 Recognised

The name William Edward Wilson is largely unknown today, but in his day he was recognized as one of the greatest Astrophotographers of his age, as well as an amateur astronomer of some note.

Although he had no formal education he was still able to carry out scientific research of the highest quality.

He was one of the first to measure the temperature of the surface of our Sun; and his value of just over 6500°C compares reasonably well with today's accepted figure of around 5505°C.

On the 11th of April 1895 Wilson together with George Fitzgerald and George Minchin made the first photometric determination of the brightness of stars. They obtained results for four first magnitude stars - Deneb (Alpha Cygni), Arcturus (Alpha Bootis), Vega (Alpha Lyrae) and Regulus (Alpha Leonis).

His wide field photographs taken in the 1890s of well known Deep Space Objects (DSOs) such as the *'Great Orion Nebula'* (M42) and the *'Pinwheel'* Galaxy (M33) in the constellation of Triangulum, were the finest of the day. At the time, only the images taken by the professional astronomers, James Edward Keeler and Charles Dillon Perrine at the Lick Observatory could be compared to those of Wilson [1].

Today his photographs, although they were taken over a century ago are still amongst the finest images of astronomical objects ever captured, whether on plate, film or CCD.

John Wilson (1826-1906) - William Edward Wilson's father

V.5.2 Daramona

William Edward Wilson was born on the 19th of July 1851 at Greenisland, County Antrim, Northern Ireland [2], the only son of John Wilson and Frances Wilson Nangle [3]. His father was an educated man, a graduate of Trinity College, Dublin, who knew the importance of learning. This together with his father's considerable means and influence gave young William Edward Wilson a *'head start'* in life [4].

In about 1855 the Wilson family moved to their new home – Daramona House, in the village of Streete, County Westmeath, Ireland [5]. Their new home was not so much a house but more of a mansion; some idea of its size can be gauged from the details provided by John Wilson in the 1901 Irish Census. The entry for Daramona House stated that it had 30 rooms occupied by the six members of the family, a Governess, a

V.6

'The Mirror Man'

James Edward Keeler

Born: 10th September 1857; La Salle, Illinois, USA

Died: 12th August 1900; San Francisco, California, USA

During the latter part of his career James Edward Keeler used the 36-inch Crossley Reflector at the Lick Observatory, California, USA to demonstrate the great potential large silvered mirrored reflectors had in the conduct of astrophysical research. The wonderful images produced by James Edward Keeler with this telescope are a great testament to his all too brief life.

V.6.1 Mirrors

James Edward Keeler (1857-1901) was one of the first professional astronomers to recognize the great contribution large silvered mirrored reflecting telescopes could make in man's never ending quest to understand the nature, structure and origin of the universe, in which he is just a mere speck of dust in the enormity that surrounds him [1].

Astronomy in the nineteenth century was dominated by the refractor. It was the age when the great observatories of the world competed to own the telescope with the largest objective lens. In 1847 the largest refractor had an aperture of just 15-inches, with the observatories at Harvard College, in Cambridge, Massachusetts and the Imperial Russian Observatory at Pulkovo, near St. Petersburg each owning instruments that jointly held the then title of world's biggest telescope.

The years that followed saw refractors of ever increasing size being constructed, with no observatory holding the title of *'world's largest'* for more than a few years at a time. By the end of the century there were six refractors with apertures of 30-inches or more: the 30-inch at Pulkovo (1885); the 30.3-inch at Nice (1886); the 31.5-inch at Potsdam (1899); the 32.7-inch at Meudon (1891); the 36-inch at Lick (1888); and the 40-inch at Yerkes (1897. Of these '*Great Refractors*' only those at Pulkovo, Nice and Lick were briefly entitled to call itself the *'world's largest'*; the two at Meudon and Potsdam never could. Even the massive 40-inch at Yerkes briefly lost its seemingly '*permanent*' crown in 1900, to the ill-fated 49.2-inch 'Paris Exhibition' telescope [2].

Unbeknown to the astronomical establishment of the time an alternative type of telescope - which they had completely ignored and frequently scorned, was preparing to hammer the *'nails into the coffins'* of the precious but ageing dinosaurs which were their *'Great Refractors'*. These once fine instruments had dominated the world of astronomy for nearly three centuries, ever since the time of Galileo, but were now reluctant to move into a new world born of photography and one to be dominated by a new species of telescopes.

The alternative in question was the silvered mirrored reflecting telescope, which for the whole of the nineteenth century was largely left in the hands of a dedicated but nevertheless competent body of amateur astronomers. Even James Edward Keeler who was to become one of the reflector's greatest supporters was until the last few years of his life totally ignorant of the capabilities of such telescopes.

In 1898, Keeler was appointed the Director of the Lick Observatory atop Mount Hamilton in California, with it came a telescope which was unknown, untried and mistrusted – a 36-inch silvered mirrored reflector, the gift of a carpet tycoon from Halifax, England, named Edward Crossley. In the two years which were left to him, James Edward Keeler, learnt to trust his new charge, to repair and modify it, and in doing so turned what was a *'Trojan Horse*' into the beginnings of a new age - the era of the reflector.

With the 36-inch '*Crossley*' reflector, James Edward Keeler and his assistant Charles Dillon Perrine (1867-1951) took a series of photographs of Deep Space Objects (DSOs), which even in the age of the CCD chip are still arguably some of the finest ever taken.

V.6.2 La Salle

James Edward Keeler was born on the 10th September 1857 at La Salle, Illinois, United States, the third of four children born to William Frederick Keeler (1821-1886), a partner in the local iron works and his wife, Anna Eliza Dutton (1824-1901), the daughter of Henry Dutton (1796-1869), a former Governor of Connecticut [3], [4]. The Keeler's second child, Minnie (1854-1857) had died in 1857 when she was only three, less than four months before Eddie Keeler, as the future astronomer preferred to be called, was born. His other two siblings, Henry Dutton Keeler (1847-1877) and Elizabeth Elliott Keeler (1860-?) survived into adulthood [5].

His parents had named their second son after his father's two dead brothers. In the March 1849, William Frederick Keeler left his wife and their young son Henry Dutton, aged 2 at their home in Bridgeport, Connecticut to travel to the nearby port of New Haven to board a ship bound for San Francisco and the Gold fields of California [6]. Accompanying on his quest for easy riches were his two younger brothers James

V.7

'The Photographer's Assistant'

Edward Emerson Barnard

Born: 16th December 1857, Nashville, Tennessee, USA

Died: 6th February 1923, Williams Bay, Wisconsin, USA

Edward Emerson Barnard was one of the greatest observational astronomers of all time. Despite having virtually no formal education, his enthusiasm and his knowledge of the night sky enabled him to become a staff astronomer at both the Lick and Yerkes Observatories. It was from these '*Great*' Observatories that he took some of the finest '*wide field'* images ever captured of our universe.

V.7.1 Vega

Edward Emerson Barnard (1857-1923) had an inauspicious start to life. He was brought up in the '*Deep South*' of the United States, amid the poverty, disease and death of the American Civil War [1]. His father had died before he was born and from an early age he needed to work to support his family, thus sacrificing even the slim chance he might have had of receiving any form of uninterrupted education whatsoever. Yet despite all of this he grew up to become one of the greatest astronomers of his age and the earliest pioneer of '*wide field*' Astrophotography.

It was not surprising that the young Barnard developed a high degree of self reliance, a great capacity for hard work and a tenacity to persevere no matter what life had to throw at him. Before he was even nine years, he had begun work as a photographer's assistant, and for the next seventeen years he remained with the same photographic studio learning the business of photography; a trade which was to prove invaluable in later life, when he turned his attention to imaging the heavens.

As a young boy he 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 [2].

In 1881, Barnard discovered the first of the sixteen comets that now bear his name, a number greater than that of the legendary French '*comet ferret*' Charles Messier, who could only manage a measly thirteen [3]. His Comet discoveries gained him attention of the astronomical community, who would now remember his name both during his lifetime and in the decades which followed; even today day he is still revered amongst amateur and professional astronomers alike.

In his professional career which lasted forty years from his first appointment at Nashville's Vanderbilt University Observatory in 1883, until his death in 1923 at the Yerkes Observatory, Wisconsin, E. E. Barnard never forgot his astronomical roots. For it was the thrill of comets and the wonders of the Milky Way which were to become the '*targets*' for the magnificent images which even now over a century later are only rarely bettered.

Edward Emerson Barnard (1857-1923) had a traumatic childhood. He found it difficult and painful to speak of events which occurred decades earlier. He was later to recall that they were '*so sad and bitter that even now I cannot look back to it without a shudder*'. Not only had his father died before he was born, the young Barnard had to witness at first hand the horrors, deprivation and disease which was the American Civil War, a conflict which was once described as a '*hellish way to settle a disagreement.*' If all of this was not enough, he nearly died in the great cholera epidemic which swept Nashville in 1866. The disease which was little understood at that time, went onto to kill upwards of 1,000 Nashville's citizens. This was nothing new as the disease had also ravaged the town in 1849, 1850 and 1854. It is a credit to E. E. Barnard that through his tenacity, perseverance and strength of will, given only two months formal education and the traumas experienced from birth, that he should have even managed to survive, let alone became a great and famous astronomer.

Edward Emerson Barnard, Photographer's Assistant, aged 9

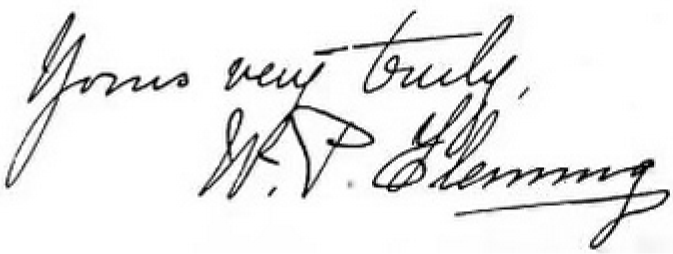
V.8

'The Astronomer's Maid'

Williamina Paton Stevens Fleming

Born: 15th May 1857, Dundee, Angus (Forfarshire), Scotland

Died: 21st May 1911, Boston, Suffolk, Massachusetts, USA



Williamina Paton Stevens Fleming will always be remembered by Astrophotographers for her discovery in 1888 of the *'Horsehead'* Nebula, probably the most famous and iconic of all astronomical objects in the heavens. A remarkable achievement, considering that she had begun her astronomical career as the housekeeper of Edward Charles Pickering, the then Director of the Harvard College Observatory.

V.8.1 Icon

Williamina Paton Stevens Fleming never took a photograph of an astronomical object; indeed there is no evidence to suggest that she took a photograph of anything. Yet her place in the history of astrophotography is assured - because of a discovery she made – one for which modern Astrophotographers should both revere and revile her, for in almost equal measure.

For in 1888 she found on a photographic plate an object which is without doubt the most iconic and beautiful of all astronomical objects ever to be seen by human eyes – the famous '*Horsehead*' Nebula. Let us now tell her story, which is one any author of fiction would be proud to write - of how a housemaid with no scientific training or qualifications became one of the world's a greatest astronomers.

Her life begins not in the hallowed halls of Harvard College where she worked or amongst the stars of Orion where her '*Horsehead*' lies, but in the streets of the ancient Scottish city of Dundee.

The iconic '*Horsehead*' Nebula is one of the most difficult and elusive of all Deep Space Objects (DSOs) an amateur astronomer is ever likely to try and see. Many have likened it to the '*Grim Reaper*' saying it will be the death of them before they set eyes on it! For the Astrophotographer - it is the '*Holy Grail*' of objects; to obtain a good image of this object is seen as the pinnacle of achievement for modern day imager. Photographs of it taken by the Hubble Space Telescope and before it by the 200-inch at Mount Palomar have inspired many to pursue astronomy as a hobby or even a career.

The 'Horsehead' Nebula (B33)

V.8.2 Dundee

Williamina Paton Stevens first saw the world at half past five in the early evening of the 15th May 1857 from her mother's bedroom above a shop at number 86 Nethergate, Dundee [1]. She was born into a working class family, who if fate had been kinder would have been very wealthy indeed. Her father was Robert Stevens, a carver and guilder who was also an early pioneer of photography in the city. Her mother Mary Walker was a descendent of the ancient Scottish Clan, known as the *'fighting Grahams'* of Claverhouse.

According to family legend, Williamina's Great-Great Grandmother lived in the Dower House (Doune Castle) at Stirling, but because of a lack of a legitimate male heir her fortune passed to another branch of the family. Her great grandfather had previously eloped with, and later married the Dowager's daughter. In 1809 she gave birth to a son, John Walker (Williamina's Grandfather) by which time the inheritance had been lost. On the day he was born - the 16th January 1809, John Walker was made an orphan – his father, a Captain in the 79th Highland Regiment was killed at the Battle of Corunna, Spain, within earshot of his newborn son's first cries! [2]

Very little is known of her early life in Dundee apart from the fact that she belonged to a large extended family. She had six brothers and two sisters. As in any mid Victorian family infant mortality was high; her brother Richard had died aged four, some 4 months before she was born; and three other brothers Andrew, Alexander and Fox had died when she was young [3]. The year 1864 was a very bad year for the Steven's family, not only did Williamina lose two of her brothers - but at 11 o'clock on the morning of the 19th of March her father Robert Stevens had a heart attack and died [4]. He was 39 years old.

V.9

'Nebulae'

Photographing DSOs

'Horsehead' Nebula in Orion, 13th November 1920, 100-inch Reflector, Mount Wilson, John Charles Duncan

The *'Holy Grail'* of Astrophotography during the nineteenth century was to image successfully the controversial objects known as '*nebulae*'. It was not until the 30th of September 1880, that the New York Doctor, Henry Draper captured the *'Cup of Christ'* when he photographed the *'Great Orion'* Nebula, one of the most famous of all objects in the Kingdom of Heaven. The age of photographing Deep Space Objects (DSOs) had begun.

V.9.1 Deep Space

To image successfully one of the almost incalculable number of objects known as '*nebulae*' that often appeared as mere smudges on the glass of a telescope's eyepiece, was seen as the ultimate challenge to the early pioneers of Astrophotography. However it was not until 1880, over forty years after Francois Arago's historic announcement to the world of the Daguerreotype photographic process that a New York Doctor, Henry Draper succeeded in imaging a Deep Space Object (DSOs). Even then the object of his success was the '*Great Orion'* Nebula (M42), one of the brightest and largest of all DSOs.

During the first half of the nineteenth century there took place a great religious and scientific debate centred around the what was known as the '*Nebular Hypothesis*' [1]. Its supporters including Sir John Herschel, maintained that many of the 'nebulae' which could not be resolved into individual stars were composed of gas; whilst its protractors such as Dr. Thomas Romney Robinson believed they could all be resolved into stars given a telescope of sufficient size [2].

Photography was seen as the key to solving the morphology of the '*nebulae*'; were they all made up entirely of stars, or just clouds of gas, or a mixture of both stars and gas [3]. Astronomers made use of photography in two distinct ways – firstly by directly imaging the objects themselves, and secondly by capturing their spectra. The combination of the two techniques, ultimately led to a solution of the nebulae controversy. The answer they found was that all three of the possible solutions were in fact correct in certain instances. However it was not until the 1920s that the problem was entirely solved through the work of Edwin Hubble and Milton Humason, when many '*nebulae*' were in fact '*Island Universes*' lying millions of light years beyond the boundaries of our own '*Milky Way*' [4].

As with any new area of scientific research the early pioneers of Astrophotography began with the basics and imaged single stars, then they progressed to capture fainter stars and once this had been achieved they went onto to photograph star clusters. This is exactly the same '*right of passage*' that many a modern amateur Astrophotographer goes through when learning how to image DSOs. Only when he/she has mastered these fundamentals should they progress to try their hand at the '*nebulae*'.

Although there were reports as early as 1842 that Daguerreotypes had been obtained by Italian astronomers in Rome of stars, it was not until 1850 that a '*bona fide*' photograph of a star was actually obtained by George Phillips Bond and John Adams Whipple using the 15-inch '*Great Harvard Refractor*'. The earlier '*Roman*' images proved to be nothing more than fakes and were in fact photographs of drawings!

The Daguerreotype process used by Bond and Whipple could only capture stars as faint as the second magnitude. It was not until the introduction of Frederick Scott Archer's more sensitive wet collodion process in 1851 that imaging fainter stars became possible. It was again G.P. Bond and Whipple, together with his partner James Wallace Black who succeeded in imaging fainter stars in 1857, when they captured stars of the sixth magnitude.

The earliest known photograph of a star cluster was obtained three years later in 1860 by Warren De La Rue from his observatory at Cranford, Middlesex. In the years that followed the collodion process was used by Lewis Morris Rutherfurd from New York and Benjamin Apthorp Gould from Cordoba in Argentina, to image fainter stars in more and more open clusters.

The year 1880 marked one of the greatest milestones in the history of Astrophotography, when Henry Draper (1837-1882), the son of the '*First Astrophotographer'*, John William Draper (1811-1882) captured the '*Holy Grail'* – a nebula, albeit the large and bright '*Great Orion*' nebula (M42). It was only the increased sensitivity of Richard Leach Maddox's Gelatino-Bromide '*dry*' Plate process which enabled Draper to succeed where others have failed and in some cases cheated in their attempts.

In 1888 the German Astrophysicist, Herman Carl Vogel (1841-1907) sent the equivalent of a supernova explosion through the observatory domes of the astronomical establishment, when he claimed that photographs of '*nebulae*' taken with modest instruments were superior to drawings made at the eyepiece of even the largest of telescopes.

Deep Space Astrophotography had come of age.

Part VI

Spectra

Photographic Astronomical Spectroscopy

Photographic Spectra of Bright Stars by Sir William and Lady Margaret Huggins, published 1889

"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." Sir William Huggins (1824-1910)

VI. Abstract

The single most important use of Photography in astronomical research is in the field of Astronomical Spectroscopy. It proved to be an invaluable tool not only for the study of the composition and origins of Stars, Nebulae and Galaxies, but more importantly, it was used to measure Galactic Redshifts; and was therefore able to put a '*yardstick*' on the size of our universe.

For over thirty years after John William Draper took his photograph of the Moon in 1840, the use of spectroscopy for astronomical research was done by visual observation and hand made drawings. Only in 1872 did his son, Henry Draper photograph for the first time the spectrum of a star, when he imaged Vega (Alpha Lyrae), using a 28-inch (72 cm) reflector and a quartz prism.

However by this date Astronomical Spectroscopy had been put on a firm scientific footing by others, and in particular most notably: Lewis Morris Rutherfurd (1816-1892), William Huggins (1824-1915) and the Jesuit Priest Pietro Angelo Secchi (1818-1878).

In 1862 Rutherfurd had published a paper in the American Journal of Science on the spectra of the moon, planets and stars. This was the first paper published on the subject since those of Bunsen and Kirchhoff, and continued the work begun by Joseph Von Fraunhofer in 1814. It included the first attempt at classifying stars based on their spectra. Two years earlier, the Italian astronomer Giovanni Battista Donati, had begun a series of observations on the spectra of the '*fixed stars*', the results of which he published in 1862. The chief feature of Donati's classification was his separation of the various stars according to their colours.

Secchi had begun work on classifying the spectra of stars based on their spectra in 1863. Three years later he had created three types now known as Secchi classes. He added a fourth the so called carbon stars in 1868. A fifth was added in 1877. Even as late as the 1890s a number of astronomers were still using his system.

Huggins who has been called the father of astronomical spectroscopy was not so much interested in the classification of stellar spectra but in determining whether a common set of chemical elements existed in the universe as they did on our Earth.

He began studying the spectra of the 'fixed stars' with this aim in mind with the chemist and neighbour William Allen Miller. In 1863 they published a paper entitled '*On the lines in the Spectra of Some Fixed Stars*'. This was followed by other papers on the spectra of various stars, which showed that each contained a selection of lines also visible in the Solar Spectrum. That same year they tried to photograph the spectra of the star Sirius, but failed.

A year later in 1864, Huggins made one of his greatest discoveries when he recorded the spectra of '*Cat's Eye Nebula'* (NGC 6543), a bright Planetary Nebula in Draco. Instead of a series of spectral lines he found only a single bright Emission line. He concluded that this was due to gas, thus proving that certain 'nebulae' were in fact gaseous and not made up of individual stars.

In 1882 Edward Charles Pickering, the Director of the Harvard College Observatory began a programme of astronomical spectroscopy using objective prisms. This type of setup enabled up to 200 stellar spectra to be captured on a single photographic plate. This work was continued under the auspices of the Henry Draper Memorial, a fund set up by the widow of Henry Draper to honour his work in the field of astronomical spectroscopy.

In 1890 the Draper Catalogue of Stellar Spectra is published by Edward Charles Pickering, which contains the photographic spectra of 10,351 stars, nearly all of them north of 25° south declination. In this work the spectrum of each star was classified according to a scheme developed by Williamina Fleming (1857-1911). In her system known as the '*Draper Classification*', the letters A to Q (omitting J) were used to classify stellar spectra.

Fleming's system was later modified by Annie Jump Cannon into the familiar Harvard Classification based on the spectral types: O, B, A, F, G, K and M, arranged according to the surface temperatures of the stars, such that those of Class O (blue-white stars) were the hottest and those of Class M (red stars) the coolest.

In 1943 a new system was introduced by the astronomers William Wilson Morgan (1906-1994) and Philip Childs Keenan (1908-2000), together with their photographic assistant, Edith M. Kellman (1911-2007).

The MKK system named after its authors, differed from that of Harvard's in that it was a two dimensional system based on both temperature and luminosity, whilst the Harvard classification was based on surface temperature only. The MKK system was revised in 1953 and renamed the MK or Morgan-Keenan classification. This system is currently the accepted method for the classification of stellar spectra.

Perhaps the greatest and most widely known use of astronomical photographic spectroscopy is as a '*yardstick*' for measuring the size of the Universe. At Mount Wilson in the late 1920s, Edwin Powell Hubble (1889-1953) and Milton Lasell Humason (1891-1972) began a programme of work aimed at extending Hubble's own measurements of galaxy distances based on Shapley's Cepheid period-luminosity data and using Slipher's galactic redshift measurements.

During the course of this work they discovered that there existed a roughly linear relationship now known as Hubble's Law, between the distance of a galaxy and the value of its recessional redshift velocity. Although they were not the first to suspect that a relationship existed between '*redshifts*' in a the spectra of external galaxies and distance, it was Hubble and Humason in 1929, who quantified it in mathematical form, drew a graph of it and proved conclusively of its existence by observational means.

"No reference has been made to the use of the prismatic camera or grating spectrograph, as these are beyond the limits of an elementary treatise."

Henry Hayden Waters (1880-1939), from Astronomical Photography for Amateurs, 1921.

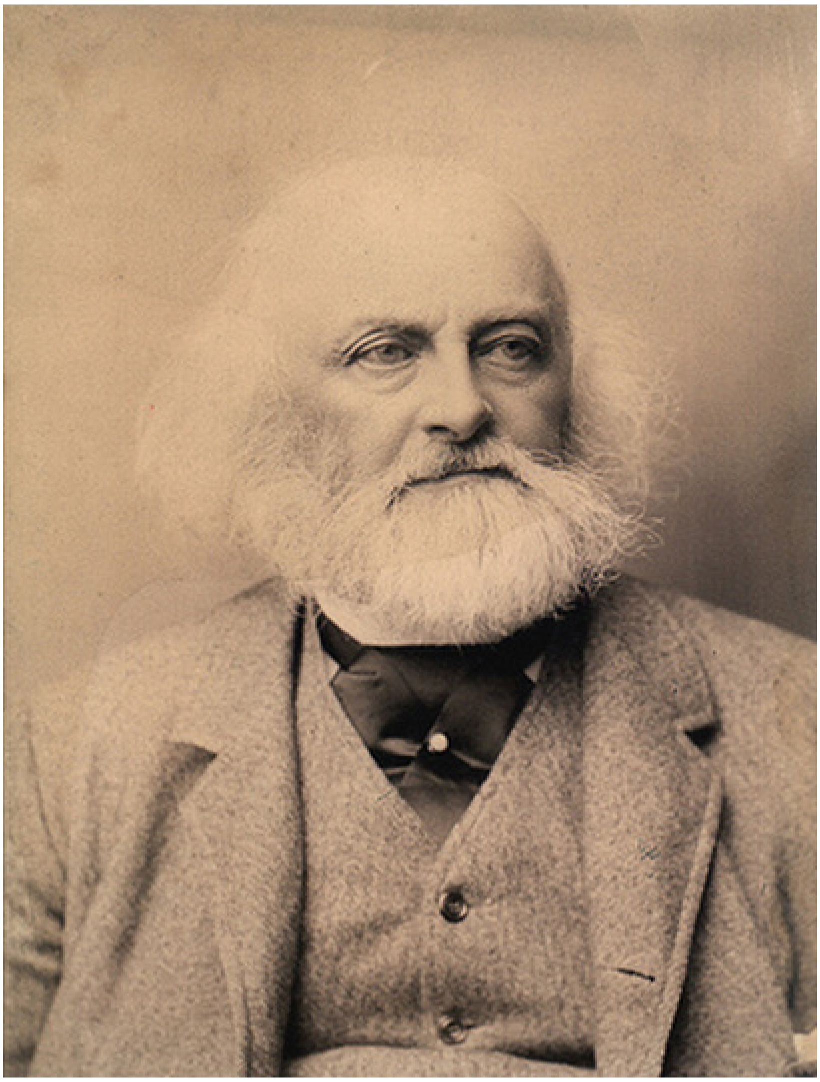
VI.1

'The Lawyer'

Lewis Morris Rutherfurd

Born: 25th November 1816, Morrisania, Bronx, New York, USA

Died: 30th May 1892, '*Tranquility*', Allamuchy, Warren, New Jersey, USA



Lewis Morris Rutherfurd although coming from an unlikely legal background and having received no formal scientific education, made contributions to Astronomical Spectroscopy that were truly ground breaking; and which were the envy of many professional scientists. He was also the first person to build a telescope suitable for photographic use only. With this instrument he took photographs of the Moon, which were for over twenty years unequalled in their quality.

V1.1.1 An Unlikely Scientist

Lewis Morris Rutherfurd (1816-1892) was at first sight an unlikely candidate for a great amateur scientist and even less so as one of the pioneers of Astrophotography, yet that is exactly what he became. Born into a family whose male members had been lawyers for as long as America had been a Nation, it seemed that he too would be another Rutherfurd destined for a life at the Bar [1].

Then something happened which changed his life – he found science. He realized much to the horror of his parents, that micrometers, telescopes and diffraction gratings were infinitely more interesting than serving affidavits and drawing up deeds.

Sometime around 1850 he broke the family tradition which had lasted for three generations; and gave up the law to devote all of his effort, time and money to science. It was not long before he and others realized that not only did he enjoy it but he was also rather good at it.

In the January of 1863 Rutherfurd published a paper in the American Journal of Science on the spectra of the Moon, Planets and Stars. This was the first paper published on the subject of spectral analysis since that of Robert Bunsen and Gustav Kirchhoff, written some four years previously [2]. It included the very first attempt at classifying stars based on their spectra [3].

The paper was a milestone in the new science of Astrophysics, and greatly extended the work of Joseph Von Fraunhofer done nearly half a century earlier; and even went beyond the more recent findings of Kirchhoff and Bunsen [4]. Rutherfurd's stellar classification work was later expanded upon by the Jesuit priest Pietro Angelo Secchi in 1867, and further advanced by others including Williamina Fleming, Antonia Maury and Annie Jump Cannon during the 1890s [5].

A year later In 1864, he made one of the greatest technical advances in the entire history of Astrophotography when he succeeded in constructing an 11.25-inch objective lens suitable for photographic use. This event marked the birth of the '*Photographic Refractor*' or Astrograph.

With his new Astrograph the very first of its kind, Rutherfurd was able to take images of the Moon whose quality was not to be surpassed for over twenty years; but more importantly for Deep Space Astrophotography – he was able to image stars as faint as the ninth magnitude.

In the 1860s, Rutherfurd took a series of Photographs of a number of the most well known open clusters in the heavens. This was the first time that this had been done and was in fact the logical continuation of the work done on Stellar Photography by the Bonds of Harvard and the Boston Photographers, John Adams Whipple and James Wallace Black during the 1850s [6].

However, the work of Rutherfurd in which he was later assisted by Benjamin Apthorp Gould (1824-1896), was particularly important in that not only the images of the stars were captured on the Photographic Plate, but their positions in the sky were also measured directly from the plates. This was the beginning of Photographic Astrometry.

Let us now tell the story of Lewis Morris Rutherfurd, the onetime lawyer who changed his life by catching the light of the moon, planets and stars.

VI.1.2 'The Law'

Lewis Morris Rutherfurd was born on the 25th November 1816 in Morrisania, New York into a privileged and influential family, the fourth of the five children of Robert Walter Rutherfurd (1788-1852) and his wife Sabina Elliot Morris (1789-1857). His paternal grandfather was the well known US Senator John Rutherfurd (1760-1840) and his maternal great grandfather, Lewis Morris (1726-1798) one of the signatories on the American Declaration of Independence [7].

It was not surprising that Lewis Morris Rutherfurd was expected to begin life's journey as a lawyer. His father was a lawyer and his grandfather John Rutherfurd was a lawyer. It was only his great grandfather Walter Rutherfurd (1723-1810) who was not a lawyer. He was Scottish soldier sent out by King George II to fight in the American Revolution against the French. In the October of 1777, a year after the declaration of

VI.2

'God's Astronomer'

Father Pietro Angelo Secchi

Born: 29th June 1818, Reggio Emilia, Emilia-Romagna, Italy

Died: 26th February 1878, Rome, Lazio, Italy

Father Pietro Angelo Secchi was a Jesuit Priest and a pioneer of astronomical spectroscopy. The work for which he is best remembered is his Spectral Classification System; which ultimately led to the Harvard Classification of Stellar Spectra developed by Williamina Fleming, Antonia Maury and Annie Jump Cannon in the 1890s and early 1900s.

VI.2.1 ‘The Kingdom of Heaven’

The Roman Catholic Church has always kept a close eye on the heavens, but even more so, on the astronomers who studied it [1]:

“I, Galileo, being in my seventieth year, being a prisoner and on my knees, and before your Eminences, having before my eyes the Holy Gospel, which I touch with my hands, abjure, curse, and detest the error and the heresy of the movement of the earth.”

In these words the Italian astronomer Galileo Galilei (1564-1642) had recanted his belief that the Earth revolved around the Sun, and that the Earth was indeed the centre of the Kingdom of Heaven. It was the year 1633 and nothing could move the Catholic Church away from the view that God’s Universe was perfect and without flaws. The Earth did not move; there were no spots on the surface of the Sun or craters on the Moon; and almost certainly no dark lines could be seen emanating from the stars. Galileo renouncing what he knew to be true in his heart, was exiled to his villa at Arcetri near Florence in 1634, where he spent the remainder of his life under house arrest.

In 1818 there was born a man who in later life would see all of these things, including the dark absorption lines in the spectra of stars. What is remarkable is that his name was Father Pietro Angelo Secchi, a Jesuit Priest; and firm believer in both his church, and a heaven based on science, not on what his religion wanted it to be.

In 1877 Secchi published the results of his great study of 4000 fixed stars, in which he argued that all stars could be classified according their chemical nature as exhibited by the various dark absorption lines found in their spectra. Furthermore this classification could be achieved by using only five spectral types. These later became known as ‘*Secchi Classes*’.

The pioneering work of Secchi in the Spectral Classification of Stars, ultimately led to the Harvard Observatory’s Classification as developed by Williamina Fleming, Antonia Maury and Annie Jump Cannon in the 1890s and early 1900s [2]. This in turn formed the basis of the currently accepted Morgan-Keenan system.

The accurate classification of stars according to the characteristics of their spectra was the start needed by others to begin the process of understanding their structure and evolution, from the moment of their birth amongst vast clouds of gas and dust, to an end which produces white dwarfs, neutron stars and black holes - bodies as strange as they are unbelievable.

Father Secchi lived a contented life within the embrace of his venerated Catholic Church and his beloved Pope, but at the same time conducting astronomical research into the very nature of a ‘*flawed*’ universe. Yet two centuries earlier this very same research would have condemned him to exile or even death.

How could this be? How did Pietro Angelo Secchi on his death in 1878 enter the ‘*Kingdom of Heaven*’ with the full blessing of the Holy Catholic Church, as both Jesuit and Astronomer?

VI.2.2 Jesuit

Pietro Angelo Secchi was born on the 18th of June 1818 at Reggio Emilia in the Northern Italian region of Emilia-Romagna, the son of a joiner, Antonio Secchi and his wife Luise Belgieri [3]. He began his education with his mother, who by all accounts was a practical middle-class woman, and apart from the usual lessons for a boy destined for life as one of ‘*God’s Marines*’ she also taught her son the arts of sewing and knitting.

After studying for several years in the Gymnasium kept by the Jesuits in his native town, Secchi in his sixteenth year entered the Jesuit Order at Rome on the 3rd of November 1833. The Jesuits were a male religious order bound by almost fanatical loyalty the Roman Catholic Church and its Pope. It had been founded in 1534 by Ignatius of Loyola (1491-1556) and six other young men, including Saint Francis Xavier (1506-1552) and the Blessed Pierre Favre (1506-1546) [4]. In 1540 the Jesuit Order was ratified by Pope Paul III.

The Jesuit Order or the Society of Jesus, known colloquially as ‘*God’s Soldiers*’ professed vows of poverty,

VI.3

'The Devoted Couple'

William Huggins

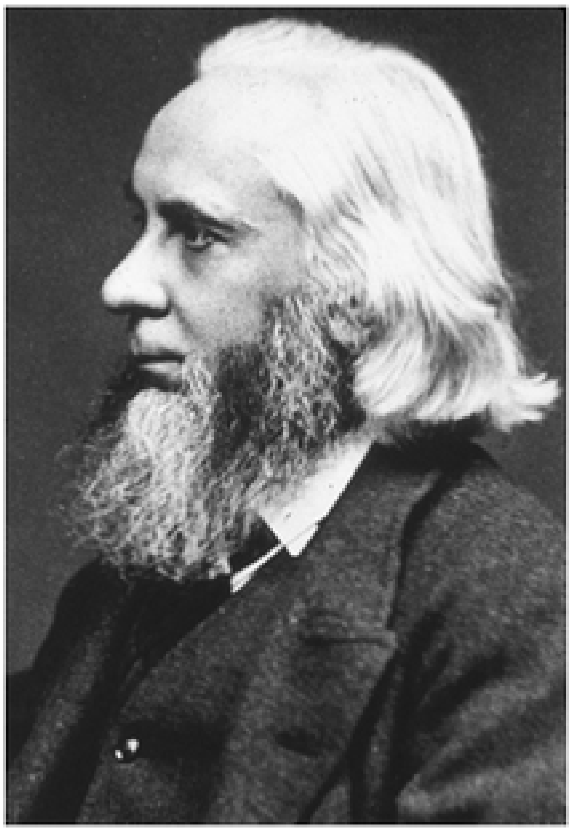
Born: 7th February 1824, Cornhill, London, England

Died: 12th May 1910; Brixton, London, England

Lady Margaret Lindsay Murray

Born: 14th August 1848, Dublin, Ireland

Died: 24th March 1915, Chelsea, Middlesex, England




Sir William Huggins was a one of the founders of modern Astrophysics. He and his wife Margaret Lindsay Murray conducted some of the earliest research into the spectra of stars, and contributed greatly to our knowledge of the physical structure of the universe based on a common set of chemical elements.

VI.3.1 'The Father and Mother of Astronomical Spectroscopy'

The nineteenth Century was a period of great change for Astronomy, not only the in the type of research which was undertaken, but also in the manner in which such investigations were carried out. In the short space of these one hundred years more was learnt about our universe and the diversity of the objects it contained than in all the millennia which had gone before.

For the very first time man began to glimpse the sheer size of what he saw when he looked up at the night sky from the Earth; a planet which he now realized was nothing more than a speck of dust in the cosmic scheme of things. How must Friedrich Wilhelm Bessel (1784-1846) have felt in 1838 when he calculated the distance to the star 61 Cygni to be an incredible 10.4 light years away – or to put it in terrestrial distances, a staggering 98,391,159,596,914,840.32 km [1]? , which is the equivalent of travelling 2,455,175,535,793 times round the Earth's Equator in a plane! Such distances are in truth beyond our comprehension. Tremendous though the achievement of Bessel was, it was only the beginning. At that time nobody had any idea of what a star really was, or what it was made up of; and they certainly knew even less about the many objects known as '*nebulae*' which astronomers were beginning to find in ever increasing numbers as faint 'smudges' in the eyepieces of their telescopes.

All of this was about to change in the early 1800s with the birth of the new branch of Astronomy known as Astrophysics; which was concerned, not with position and measurement of the old days, but with the very make up and workings of the universe itself. The customers who patronized the London premises of William Thomas Huggins, silk mercer and linen draper, during the middle years of the nineteenth century, may well have been served by his young son William Huggins (1824-1910); little knowing that they had met someone who would soon begin to add pieces to a jigsaw puzzle, which when complete would explain the very nature of the universe in which they shopped.

In the years following the publication of his first scientific paper in 1856, Sir William Huggins, as he was later to become, carried out some of the very earliest investigations into Astronomical Spectroscopy in which he hoped to *'discover whether the same chemical elements as those of our earth are present throughout the universe…'* At the time of his death in 1910 he was in a position to write that it '*was most satisfactorily settled in the affirmative; a common chemistry, it was shown, exists throughout the universe.'*

It has been said that Sir William Huggins was the '*Father of Astronomical Spectroscopy'*, but if this so then his wife Lady Margaret Lindsay Murray (1848-1915) was its mother. In the years following their marriage in 1875, she was not only his wife, but a friend, an assistant, a photographer and a co-worker. It was Margaret Lindsay Murray who introduced photography as an integral and necessary element of their 35 years of devotion to each other and to their work.

VI.3.2 Shop Assistant

William Huggins lived in a world which for him anyway, was filled with privilege and laden with opportunity, so much so that he could concentrate in the main on what he wanted to do; and not be inconvenienced by having to earn a living. Although it has to be said, that during his lifetime he worked extremely hard, not through conventional employment, but laboured in astronomical research, for his own pleasure and without payment.

William Huggins was born a '*true*' Londoner on the 24th February 1824, at the premises of his parents' drapery shop in Gracechurch Street, in the parish of St. Peter's, Cornhill, in London's '*square mile*' within the sound of the bells of the church of St. Mary Le Bow [2], [3], [4], [5]. He was the only child of William Thomas Huggins (1779-1856), a wealthy silk merchant and his wife Lucy Miller (c1786-1868). Like many other shopkeepers of their time, the Huggins family lived in the building that housed their business, as did their assistants and servants. At the time of the 1841 Census, the business of William Thomas Huggins was thriving, and profitable enough to maintain four servants [6].

William's parents were Congregationalists and as Nonconformists they did not belong to the official Church of England [7]. At the time members of such minority religious groups were still discriminated against, especially if they were to apply for a governmental position. They were therefore more than usually aware of the need for their son William to be well educated if he were to have a successful career. Before the

VI.4

'The Ladies' Man'

Edward Charles Pickering

Born: 19th July 1846, Boston, Suffolk, Massachusetts, USA

Died: 3rd February 1919, Cambridge, Middlesex, Massachusetts, USA

Edward Charles Pickering had three great talents; one was the ability to inspire himself to do great things; the second to recognize the potential in women, to become great astronomers; and lastly to persuade wealthy philanthropists to part with their money to finance his research. With these talents and the women he employed, some of the finest astronomical research ever carried out, was done under his supervision at Harvard College Observatory during the forty two years he was its Director.

VI.4.1 Astrophysics

Edward Charles Pickering (1846-1919) was one of the new breed of Astronomers that began to appear in the USA during the last decades of the nineteenth century. Unlike many of his European counterparts, he was not interested in the old Astronomy of measurement and position. He did not want to know where a star was in the sky; but to know the answers to more '*important*' questions like: how bright it was; why were some stars intrinsically brighter or dimmer than others; and why some stars were orange and others were white.

He was above all else an Astrophysicist who wanted to use the science of physics to understand the stars. Throughout his career he used photography in an attempt to answer the many questions that burned in him - like the stars he wanted to understand. During his time as Director of the Harvard College Observatory which lasted longer than any other that have held this illustrious office, he and his female staff of Astronomers carried out fundamental Astrophysical research into the measurement of stellar magnitudes, the classification of stellar spectra and the size of the Universe itself.

With his great personal charm Edward Charles Pickering had the knack of obtaining grants of large sums of money to pursue his research and in particular to construct some of the finest examples of Photographic Refractors (Astrographs), notably the 8-inch Bache and 24-inch Bruce Telescopes.

VI.4.2 Beacon Hill

Edward Charles Pickering was born on the 19th July 19 1846 at Mount Vernon Street, in the fashionably chic area of Beacon Hill in Boston, Suffolk, Massachusetts, USA [1]; into an affluent and well to do family. He was the second of the three children of the lawyer, Edward Pickering (1807-1876) and his wife Charlotte Daniel Hammond (1819-1901). His younger brother, William Henry Pickering (1858-1938), was also a famous Astronomer and Astrophotographer [2]. His elder sister Ellen Pickering (1842-1861) had died before she had reached the age of twenty [3].

Unlike his father, his grandfather and his great grandfather before him, he chose not to become a lawyer, but a scientist [4], [5]. For five years he attended the Latin School in Boston, where he acquired a great loathing for the Classics. This antipathy towards Latin and the other '*dead*' languages turned him in the opposite direction - towards Science. He entered the Lawrence Scientific School of Harvard to study Civil Engineering and graduated from there in 1865. Here he remained for the next two years as a teacher of mathematics. When only twenty one he became the Thayer Professor of Physics at the Massachusetts Institute of Technology, a position he held for the next ten years; during which time his methods revolutionized the teaching of the subject.

Edward Charles Pickering (1846-1919), his younger brother William Henry Pickering (1858-1938) and his elder sister Ellen Pickering (1842-1861) were born '*of a Salem family known and honoured since revolutionary days*'. Their parents were Edward Pickering (1807-1876), a well to do lawyer and his wife Charlotte Hammond (1819-1901). As young children they were brought up in the middle class area of Mount Vernon Street, Beacon Hill - one of the best and elitist parts of the city of Boston. Even today, Beacon Hill is regarded as one of the most desirable and expensive neighbourhoods in Boston. Mount Vernon Street: has even been dubbed as '*The finest address in all America*'.

Mount Vernon Street, Beacon Hill, Boston, circa 1870

VI.5

'The Rainbow Men'

Hermann Carl Vogel

Born: 3rd April 1841, Leipzig, Germany

Died: 13th August 1907, Potsdam, Germany

Wilhelm Oswald Lohse

Born: : 13th February 1845, Leipzig, Germany

Died:14th May 1915, Potsdam, Germany

Julius Scheiner

Born: 25th November 1858, Cologne, Germany

Died: 20th December 1913, Potsdam, Germany

Hermann Carl Vogel

Wilhelm Oswald Lohse

Julius Scheiner

Hermann Carl Vogel, Wilhelm Oswald Lohse and Julius Scheiner were three of the great pioneers of Astronomical Photographic Spectroscopy. They made significant contributions to the then new science of Astrophysics. It was Vogel who first realized that photographs taken with modest telescopes were the equal of visual observations made with even the largest of telescopes. Lohse was the Chemist who worked with Vogel all his life, providing his friend with the technology to photograph the '*rainbows of the stars*.' And it was Scheiner who proved conclusively through photographic spectroscopy that the '*Great Andromeda Nebula'* was in fact an *'Island Universe'* made up of individual stars.

VI.5.1 'The Fatherland' of Astrophysics

Germany can be considered to be the fatherland of the '*New Astronomy*' now known as Astrophysics. Throughout the whole of the nineteenth century there was a gradual shift away from the '*Old Astronomy*' of measurement and position towards one based on understanding the nature, structure, composition and origin of the Universe. Such a change was slow at first, but as the century progressed it gradually accelerated until it became the principal area of research in a number of institutions, most notably in Germany and later in America.

Hermann Carl Vogel (1841-1907) and Wilhelm Oswald Lohse (1845-1915) were friends from school and University days. Later they became master and assistant at the Bothkamp Observatory, a private institution, near Kiel - the very first set up specifically to study the physics of the universe. It was here that they learned their trade as astronomers of the new school; and from there they would eventually become two of the greatest disciples of the emerging science of Astrophysics.

Together and individually they used photography to capture the spectra of the sun and its planets, and those of stars, nebulae and galaxies, so that they might understand their physical nature and chemical composition. Their efforts in the field of Photographic Astronomical Spectroscopy led to some of the most significant contributions ever made to the development Astrophysics during the age in which they lived.

Lohse constructed one of the first purpose built Astronomical Photographic Cameras. In the years 1879 to 1889 he used this camera to take a total of 217 photographic plates of the moon, planets, stars, clusters, nebulae and galaxies. His camera was described and cited in many works of the time, and proved to be a useful instrument in the development of many new photographic techniques. However his greatest claim to fame in the annals of the History of Astrophotography was the series of photographs he took of the planet Jupiter in the years 1878 to 1881, which clearly showed the '*Red Spot, two Equatorial Belts, and the North Polar Zone'*. These images predated those of the Henry brothers by three years.

Vogel also did his bit in promoting Astrophotography. In 1888 he published a paper on the usefulness of photography for depicting accurately the shape and structure of the nebulae. It was his view that photographs obtained with only modest equipment could show details which were absent or only slightly visible to an observer using even the largest of telescopes.

The remarkable and sometimes controversial research carried out by Vogel and Lohse during the latter decades of the nineteenth century enabled other astronomers to build upon what they had found; and to add further pieces to the complex jigsaw puzzle which would when complete show the true nature of the universe in which we live.

VI.5.2 Leipzig

Hermann Carl Vogel [1] was born on the 3rd of April 1841 in Leipzig, Germany, the sixth child of Johann Carl Christoph Vogel, a well known theologian, educationalist and school principal of a Leipzig Gymnasium (Secondary School) [2].

From a very early age, the young Hermann Vogel was surrounded by some of the finest scientists of the nineteenth century. Listed amongst his father's friends were the naturalist, Alexander von Humboldt (1769-1859), the geographer, Carl Ritter (1779-1859) and the physicist Robert Bunsen (1811-1889). It was Robert Bunsen, who along with Joseph von Fraunhofer (1787-1826) and Gustav Robert Kirchhoff (1824-1887) founded the science of Spectroscopy [3]. So it was not in the least surprising that Vogel himself was later inspired to continue their pioneering efforts in this new branch of Physics.

Herman Vogel's elder brother Eduard (1829-1856) [4], who later became an astronomer and African explorer, was a friend of Heinrich Louis D'Arrest (1822-1875), the '*Observer*' of the Leipzig Observatory [5]. Through this friendship Hermann Vogel came into contact with astronomy while still young. The die was cast Hermann Carl Vogel would become an Astronomer.

After graduating from his father's Leipzig Gymnasium, Vogel entered the Dresden Polytechnic School in 1860. However before he completed his training both his parents died, leaving him seriously in debt.

VI.6

'The Yardstick Men'

Edwin Powell Hubble

Born: 20th November 1889, Marshfield, Missouri, USA

Died: 28th September 1953, San Marino, California, USA

Milton Lasell Humason

Born: 19th August 1891, Dodge Center, Minnesota, USA

Died: 18th June 1972, Mendocino, California, USA

Edwin Powell Hubble and Milton Lasell Humason were two of the greatest astronomers of the twentieth century. Edwin Hubble will always be remembered for the Law which bears his name; and more importantly for his pioneering efforts to put a '*yardstick*' to the true size of the universe. Milton Humason worked closely with Hubble on the determination of the distances of galaxies; despite having started his career as a *'mule skinner'* and later as a janitor at the Mount Wilson Observatory.

VI.6.1 Measuring the Universe

Edwin Powell Hubble (1889-1953) was without doubt one of the greatest astronomers who ever lived. Anybody with even a passing interest in the night sky will have seen the magnificent images taken by the great space telescope which now bears his name. Not so many will know why he was granted such an honour, or how as a young boy born into a working class family from an ordinary small Midwestern American town, he should now be its most famous citizen.

Marshfield, Missouri is to all intents and purposes – '*Hubble Town*'. As soon as you enter Marshfield off of the famous route 66 highway you know who was born here. There are signs for East and West Hubble Drive. The town's elementary school is named the 'Edwin P. Hubble Elementary School'. Outside of the town's courthouse you might expect to see a statue of a former mayor or a famous judge – not in Marshfield – you have a replica of the Hubble Space Telescope to greet you!

What was it that Hubble did - to make him so famous? When you hear astronomers say this Galaxy was so many million light years away and that Galaxy is the most distant ever discovered – you have Edwin Powell Hubble to thank. Until the pioneering work of Hubble in the 1920s, nobody had any real idea of how big the universe was. It was not even known whether certain '*nebulae*' now known as Galaxies were within the confines of our own Milky Way or did they lay way beyond its boundaries as individual '*Island Universes*'.

Hubble was the first person to put a '*yardstick*' to the size of the Universe by determining that Galaxies were in fact separate star systems lying at distances far beyond our Milky Way, whose light had left their boundaries long before man had even walked on the Earth.

In order to tell the real story of Edwin Powell Hubble, it is also necessary to include that of Milton Lasell Humason (1891-1972). Like Hubble, Milton Lasell Humason was born into a working class family from a small Midwestern American town. Unlike Marshfield - Dodge Center, Minnesota - the birthplace of Milton Lasell Humason has no School, Drive or Space Telescope to remember him by. Yet in truth Humason also deserves his share of recognition, in respect of the monumental discoveries now so often attributed solely to Edwin Powell Hubble.

The mid-western American town of Marshfield, Missouri, possesses a most unusual centrepiece - a replica of the Hubble Space Telescope, in memory of its most famous '*son*' - Edwin Powell Hubble. This is a fitting monument to all who wish to pay tribute to the man who with his colleague Milton Lasell Humason, were responsible for determining the true '*distance scale of the universe*'. For there is no known grave of this great pioneer of Astrophysics, who with Humason used the powerful tool of photography to answer fundamental questions on man's insignificant place in the cosmos.

Replica of Hubble Space Telescope, Marshfield, Missouri

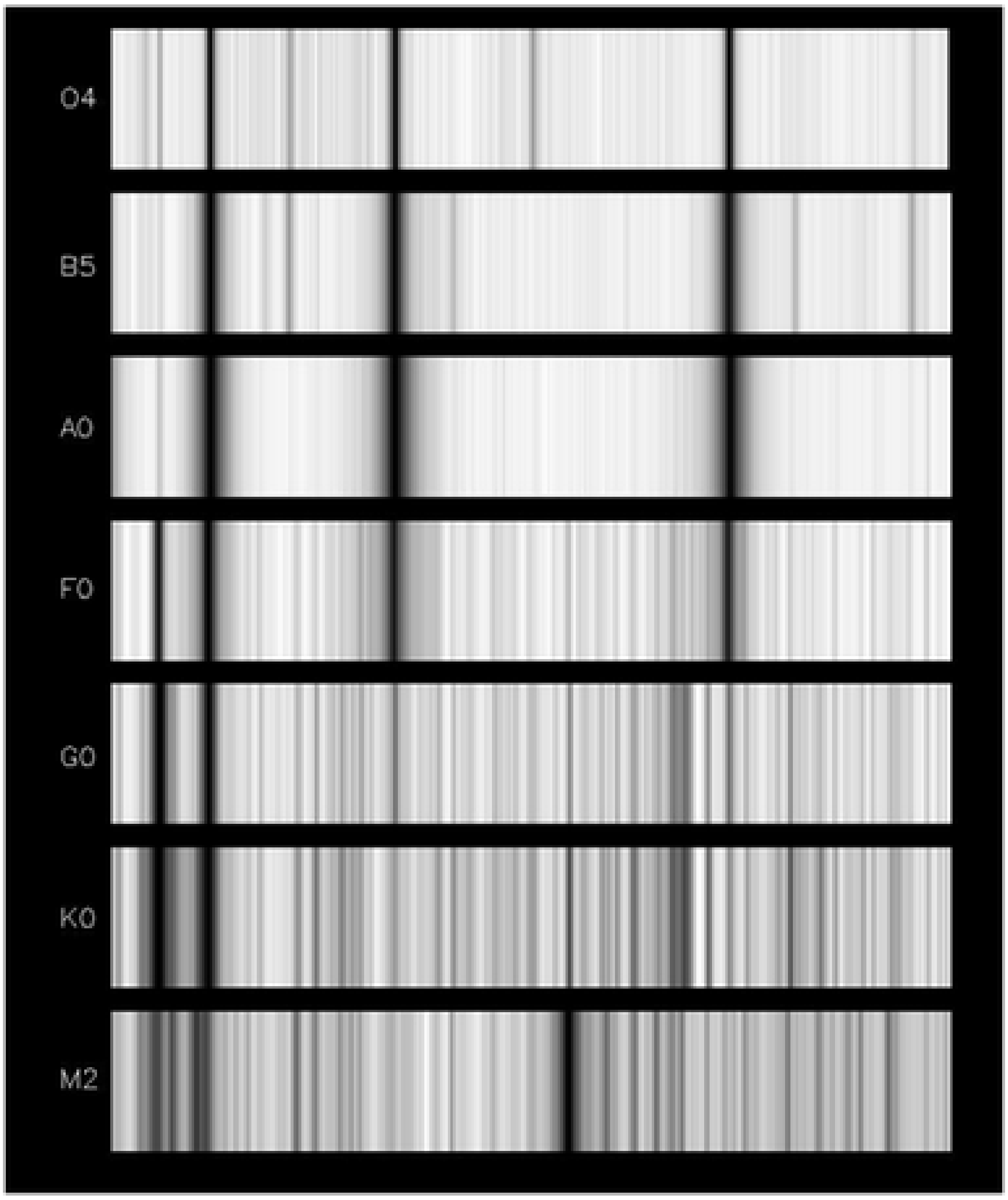
VI.6.2 Marshfield ... Dodge Center

Edwin Powell Hubble was born on the 29th November 1889 at Marshfield, Missouri, [1] the third of the eight children of John Powell Hubble (1835-1913), an insurance agent and his wife Virginia Lee James (1867-1934) [2]. At the time Marshfield was a typical '*frontier*' town, which in the Webster County History for the year of Edwin Hubble's birth is described as [3]:

VI.7

'Rainbows of Heaven'

Imaging Astronomical Spectra



Capturing the spectra of celestial bodies is the single most important use of Photography in Astronomical Research. It proved to be an invaluable tool for the study of the composition and origins of stars, nebulae and galaxies. 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.

VI.7.1 'Catching the Rainbow'

'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.' William Huggins

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 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.

The use of Photography to capture the spectra of stars and nebulae from the 1870s onwards by the likes of Henry Draper (1837-1882), William Huggins (1824-1910), Hermann Carl Vogel (1841-1907) and Julius Scheiner (1858-1913), enabled a permanent and measurable record to be obtained, from which their composition in terms of the fundamental chemical elements of nature, such as Hydrogen, Oxygen and Nitrogen was determined.

The discovery of displacements in the position of the absorption lines in the spectra of stars and nebulae caused by the '*Doppler Effect*', provided astronomers with values for their radial motions in space. During the 1920s Edwin Hubble and his assistant Milton Humason measured the redshifts in the photographic spectra of Galaxies to determine their radial velocities. From these measurements they found that they were in fact receding away from us at very high speeds; such that the further away they were the faster they were travelling. This settled a long running argument as to whether these star systems were part of our own Milky Way or situated outside of its boundaries. Hubble and Humason showed conclusively that they lay millions of light years beyond our Galaxy.

VI.7.2 Wollaston's Forgotten Lines

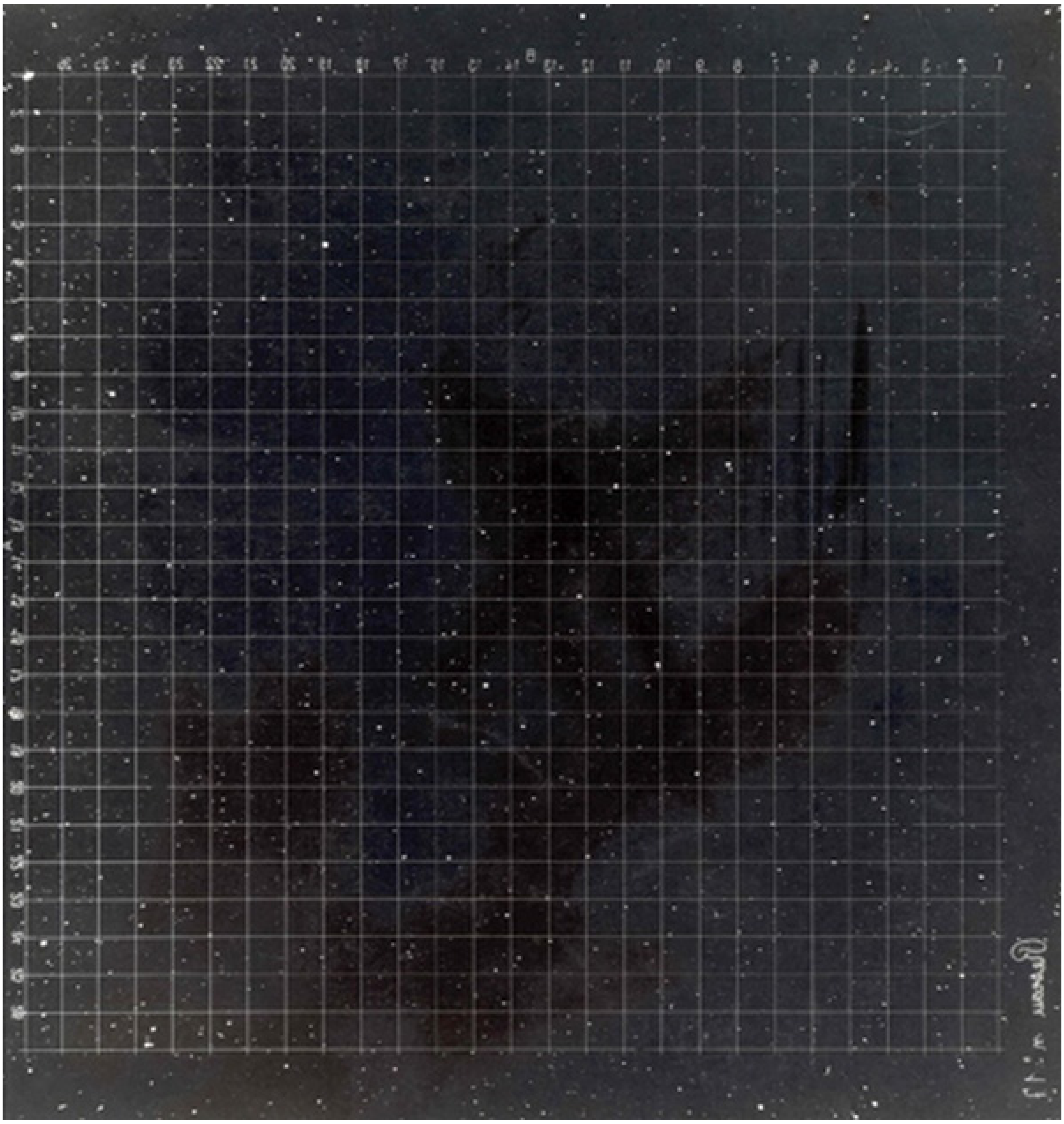
In 1802 the chemist and mineralogist William Hyde Wollaston (1766-1828) [1] was the first person to observe the dark lines in the solar spectrum, now known as absorption lines [2]. These he incorrectly interpreted as gaps separating the colours of the sun's continuous spectrum.

Then, in 1814 the German optician, Joseph Von Fraunhofer (1787-1826) [3] while working at a military and surveying instruments firm rediscovered the lines, when he was calibrating the optical properties of glass. He immediately discounted Wollaston's colour boundary interpretation. He observed a continuous colour

Part VII

Cartes du Ciel

Photographic Sky Surveys



'*Carte du Ciel'* Plate, Royal Greenwich Observatory

" ...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)

VII. Abstract

The story of the photographic mapping of the heavens is a woeful tale of failed attempts, over ambitious aims and misuse of valuable resources; and above all the wasted decades of effort on a project that was years ahead of its time and as a consequence lacked the necessary technology to succeed. In the end all became well with the introduction of the modern digital computer, searchable databases, mass storage devices and astrometric satellites.

It was not long after the first photographs of stars were obtained in the 1850s that astronomers such as George Phillips Bond and Lewis Morris Rutherfurd began thinking about mapping the stars with the aid of a camera. The operative word here is ‘thinking’. At that time the currently preferred wet collodion process could only obtain impressions of stars down to magnitude nine at best.

It was only following the introduction of mass produced Gelatino-Bromide ‘*Dry*’ photographic plates in the late 1870s and early 1880s, which were capable of obtaining well defined images of stars as faint as the 15th magnitude that the technology had matured sufficiently enough for an adventurous pioneer to be able to make such an attempt.

During the period May to December 1885, the English amateur Isaac Roberts (1829-1904) had taken a number of images with his 20-inch Reflector of regions of the sky 2 x 1.5 degrees in area. His aim was to complete a photograph sky chart of that part of the heavens visible from his observing location, near Liverpool, England. He shortly afterwards abandoned what soon became clear a task that was best left to professional observatories with their far greater resources.

The history of Photographic Sky Charts began well with the successful completion of the Cape Photographic Durchmusterung, a joint project between the Cape of Good Hope Observatory, South Africa and the University of Groningen. It was published between 1896 and 1900 and listed the positions and magnitudes for 454,875 stars down to about magnitude 10.2 in the Southern Hemisphere for Declinations from -18S to -90S.

In the April of 1887 a congress was held in Paris at the instigation of Ernest Amédée Barthélémy Mouchez (1821-1892), Director of the Paris Observatory with a view to encourage the cooperation of overseas observatories in the production of a photographic chart of the entire sky - a ‘*Carte du Ciel*’ (CDC). It was attended by 58 astronomers representing observatories and institutions from 19 countries.

At the end of the Congress the delegates agreed in principle 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. It was a project doomed to fail from the very outset. Sadly, despite the best will in the world and lots of promises the work was dogged by delays and problems. The zones allocated to several observatories had to be given to others, as they had failed to even begin the work or were not able carry on because of political unrest or war.

In 1900 the zones originally assigned to La Plata Observatory, Argentina were given to Cordoba, Argentina; whilst the zones originally assigned to the Rio de Janeiro

Observatory, Brazil were given to Perth, Australia. In 1909, Hyderabad, India was assigned part of the zones originally to be done by Santiago Observatory, Chile; and in 1920 it was assigned the remainder of those originally given to Santiago.

Following the end of the First World War the Potsdam observatory announced it could not continue with the project. Its zones were reassigned to Uccle, Belgium, Hyderabad and Oxford. An allied bomb in the Second World War destroyed virtually all of the 1226 plates taken at Potsdam. Only 406 plates were ever measured.

The project was a complete and utter shambles. In 1970 at the International Astronomical Union's 14th General Assembly held in Brighton, England, it was finally acknowledged that after an interval of more than eighty years after its inception, the *Carte du Ciel* enterprise remained unachieved.

The Astrographic Catalogue part of the *'Carte du Ciel'* project, containing stellar positions and magnitude down to the eleventh, were published between 1902 to 1964, and resulted in 254 printed volumes of printed data. The more ambitious Carte du Ciel Charts for stars down to magnitude 14, were never completed and only one Observatory, Greenwich ever published them.

On the 11th November 1949 whilst the '*Carte du Ciel'* was struggling along in its final death throes, the technology which it so badly needed began to appear. On a mountain in San Diego County, California, 5570 feet (1700 metres) high, a telescope undreamed of in Ernest Mouchez's day opened its '*eyes*' to the night sky. It was about to expose the first plate in the modern era of photographic sky surveys.

A year previously, the 48-inch Schmidt Telescope (now known as the Samuel Oschin Telescope) at the Mount Palomar Observatory was completed after nearly ten years in the making. It was not really a telescope at all, but a camera, for it was built from the outset with no provision for an eyepiece.

It was at the time the ultimate Astrograph. The Schmidt optical design enabled photographs to be taken of the sky which were completely '*flat*' with no distortion of the star images at the edges; which meant the whole of the plate could be used and not just the inner part as was the case with the CDC plates.

The Samuel Oschin telescope was put almost immediately to good use in 1949, when it began work on the National Geographic Society sponsored – 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.

Not satisfied with this great success, a Second Palomar Observatory Sky Survey (POSS-II) was performed in the 1980s and 1990s that made use of better, '*faster*' dry plate technology and an upgraded telescope.

In 1994 a digital photographic atlas of the entire sky in both hemispheres was completed, known as DSS I. For the northern sky, the Palomar Observatory Sky Surveys provided almost all of the source data. For the southern sky, images taken by the UK Schmidt Telescope at Anglo-Australian Observatory, were used. The publication of a digital version of these photographic collections has subsequently become known as the First Generation DSS.

In 1996, a more highly compressed version of the DSS was published by the Astronomical Society of the Pacific under the name '*RealSky*'. RealSky is searchable and includes software, which can be used to display any part of the sky up to one degree square, or find Deep Sky Objects (DSOs) which are included in the New General Catalogue (NGC).

Ten years later in 2006, the Second Generation DSS II was finished, and distributed on CDROM to partner institutions. Generally, the data are available through the websites of the partner institutions.

The vast amount of effort invested in the '*Carte du Ciel'* project looked for many years to have been a total and utter waste of time, only serving to keep busy those tasked with cleaning the dust that gathered on the tons of printed tomes it produced. But all is now forgiven, because this near century old star positional data has found itself to be of use, somewhat ironically in today's world of satellites and digital computers - the very technology it lacked to succeed.

The European Space Agency's (ESA) *Hipparcos* space astrometry satellite launched in 1989 was tasked with the job of creating a '*Carte du Ciel*' for the twenty-first century. As part of the mission it was found possible to combine old data from the '*Carte du Ciel'* project with Hipparcos measurements to enable highly accurate proper motions to be derived for some 2.5 million stars.

In 2013 ESA plans to launch HIPPARCOS's successor, *GAIA* – Global Astrometric Interferometer for Astrophysics. It derives its name from the Greek Goddess of Nature Gaia. Its capabilities go way beyond what HIPPARCOS achieved.

"It will often happen that when a picture is token of a portion of the heavens with which the worker is unfamiliar, identification of the principal stars on the plate is exceedingly difficult. Photographic and visual magnitudes differ very considerably; the scale, too, is smaller than a naked-eye view, and 20 minutes exposure on the crowded portions of the Milky Way on a good night will secure thousands of star images, the result of which is often absolutely bewildering.

A reversed image..is also confusing when comparing with an atlas, or portrait lens photographs. A good plan is to put a mark on the edge of the plate which, when in position, will be at the top side of the camera. Then with a good star atlas...the principal stars can soon be identified from the central star on which the telescope was guided. Some practice may be needed, but generally, after a little concentration, the whole group or constellation seems to jump into view, and the proper S. and N. points can be marked on the edge of the plate."

Henry Hayden Waters (1880-1939), from Astronomical Photography for Amateurs, 1921.

VII.1

'The Visionary Man'

Ernest Amédée Barthélémy Mouchez

Born: 24th August 1821, Madrid, Spain

Died: 29th June 1892, Wissous, Seine et Oise, France

Rear Admiral Ernest Amédée Barthélémy Mouchez was a man of vision who recognized the role of photography as an important tool to chart the heavens. To this end he instigated the ill fated and over ambitious Carte du Ciel project. His faith in the Carte du Ciel was ultimately rewarded when data from the project was successfully used in conjunction with that obtained from the HIPPARCOS Astrometric Satellite.

VII.1.1 Ahead of His Time

"Gentlemen: In the name of the Paris Observatory I also welcome the eminent men of science who have graciously accepted our invitation to this international congress, where will be decided the execution of a work of the first importance for the future of astronomy.

I tender my profound thanks for the cordial readiness with which you consented to come at our call, which proves the great interest you all feel in this new branch of science, astronomical photography, which, by your recent labours, has made such admirable and rapid progress.

It has now become a wonderful and potent auxiliary, the great value of which one could not overestimate. By its aid—since a document can be secured in an hour's time for which a year's work would have been required by the old methods— the slow and laborious processes of astronomical observations will be changed. There will, perhaps, be some weak resistance, some obscure regret, as is inevitably produced by every great progress, but which will soon vanish before the brilliant light of success, as a half-century ago the old stage-coaches disappeared before the triumph of the locomotive.

It is, therefore, a great honour for our old national observatory, in the course of the progresses it also has realized, to receive the first assembly, where this (for astronomical science) new era is about to be inaugurated.

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.

E. MOUCHEZ,

Le Contre-Amiral, Directeur de l'Observatoire"

The above 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 [1].

His vision of a *Carte du Ciel* (literally - Map of the Sky) 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*, 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.

VII.1.2 Navy

Ernest Amédée Barthélémy Mouchez's [2] was born in Madrid, Spain on 24th August 1821 the eldest of the three children of Jacques Barthélémy Mouchez (c1783-c1849), and his wife Louise Cecile Bazin (1798-1868) [3]. He was educated at the Lycée St. Louis in Paris and then at Versailles. At the age of sixteen he entered the Naval School at Brest to train as a Naval Officer. He was gazetted a Midshipman in 1839, became an Ensign in 1843 [4], promoted to Lieutenant six years later and made a full Captain in 1861. He remained a seaman all his life and distinguished himself many times in a vocation he was born to.

At this time in France's history the country was in a state of relative peace with the world. As there were no wars to fight the work of Mouchez was largely confined to research and exploration. His first major task as a career Naval Officer was to conduct hydrographic surveys in Korea, China and South America. He spent the years from 1856 to 1861 surveying the coast of Paraguay and Brazil; and similar length of time surveying the Algerian coastline [5], [6], [7], [8]. In all he produced nearly 150 maps. His maps of Algeria came in very useful some seventy years later during the Second World War, when they were the only maps of the country available to allied troops in their struggle against the Axes forces of Italy and Germany.

Early on in life, Ernest Mouchez gained a passion for surveying and measurement, particularly with regard

VII.2

'The Surveyor'

Sir David Gill

Born: 12th June 1843, Aberdeen, Scotland

Died: 24th January 1914, Kensington, London, England

Sir David Gill was one of the great astronomers of the late nineteenth century, and was universally recognized as such. He made significant contributions to many areas of astronomy, including the measurement of the sun's distance and the completion of a successful photographic survey of stars in the southern hemisphere, known as the Cape Photographic Durchmusterung or CPD, which listed the positions and magnitudes for 454,875 stars down to about magnitude 10.2 in the Southern Hemisphere.

VII.2.1 Surveyor

David Gill was a surveyor not of buildings or land but of the heavens.

Although originally destined to become a clock maker like his father, fate chose otherwise. Ironically it was through clocks that David Gill became interested in Astronomy, a hobby which would eventually lead to a career that lasted fifty years, during which time he was to become one of the great astronomers of his age.

All throughout his astronomical career David Gill was involved in measuring and surveying.

At first it was a desire to set up an accurate time service for his native city of Aberdeen. Then he began to make plans to measure the distance of nearby stars. This was followed shortly by an expedition to Ascension Island to determine the distance of the planet Mars and by implication the distance of the Sun from the Earth.

However it was his great photographic survey of the stars in the southern hemisphere – the '*Cape Photographic Durchmusterung*' that became his greatest legacy to Astrophotography and Astronomy in general [1].

VII.2.2 Aberdeen

David Gill was born on the 12th June 1843 at No. 48 Skene Terrace, Aberdeen, Scotland; the first of five surviving children born to David Gill (1789-1878), a clock maker and his wife Margaret Mitchell (1809-1870) [2], [3].

His father, David Gill, ran the clock and watch making business at No. 13 Queen Street, Aberdeen, and later at No. 78 Union Street; which his father Peter Gill had set up some sixty or so years earlier [4]. Under David Gill's father, the business became more of a wholesale clock dealer, rather than a maker of clocks and watches; where David Gill (senior) acted as his own travelling salesman.

David Gill, junior began his education at the Bellevue Academy, in Aberdeen. As a young student he did not exhibit any specific talent or precocity, which would indicate someone destined to do great things. Although he was particularly proud of a card bearing the following words, awarded when he was twelve years old: *"Certificate of Superior Proficiency in Elocution, awarded by Competition to Master David Gill—" Emeritus "and Prizeman of a former session." Bellevue Academy, Sept. 25th, 1855.* This was one of the few souvenirs of his childhood that David Gill kept.

In 1857 at the age of fourteen he was sent to the Dollar Academy in Clackmannanshire to complete his secondary education [5]. It was here that David Gill was first introduced to Science. Whilst at the Dollar Academy, he boarded with one of its teachers, Dr. James Lindsay (c1823-), a man interested in those things David Gill would in later life find most useful – mathematics, physics and chemistry [6]. In 1909 David Gill returned to the Dollar Academy after an absence of more than fifty years to present the prizes at the school's open day. After speaking of his experiences at the school he said [7]:

"The Chairman had told them that he had been a very successful man, but he wanted to tell them that if he had been in some small degree successful, the man that put that capacity into him was a Dollar man, the late Dr. Lindsay."

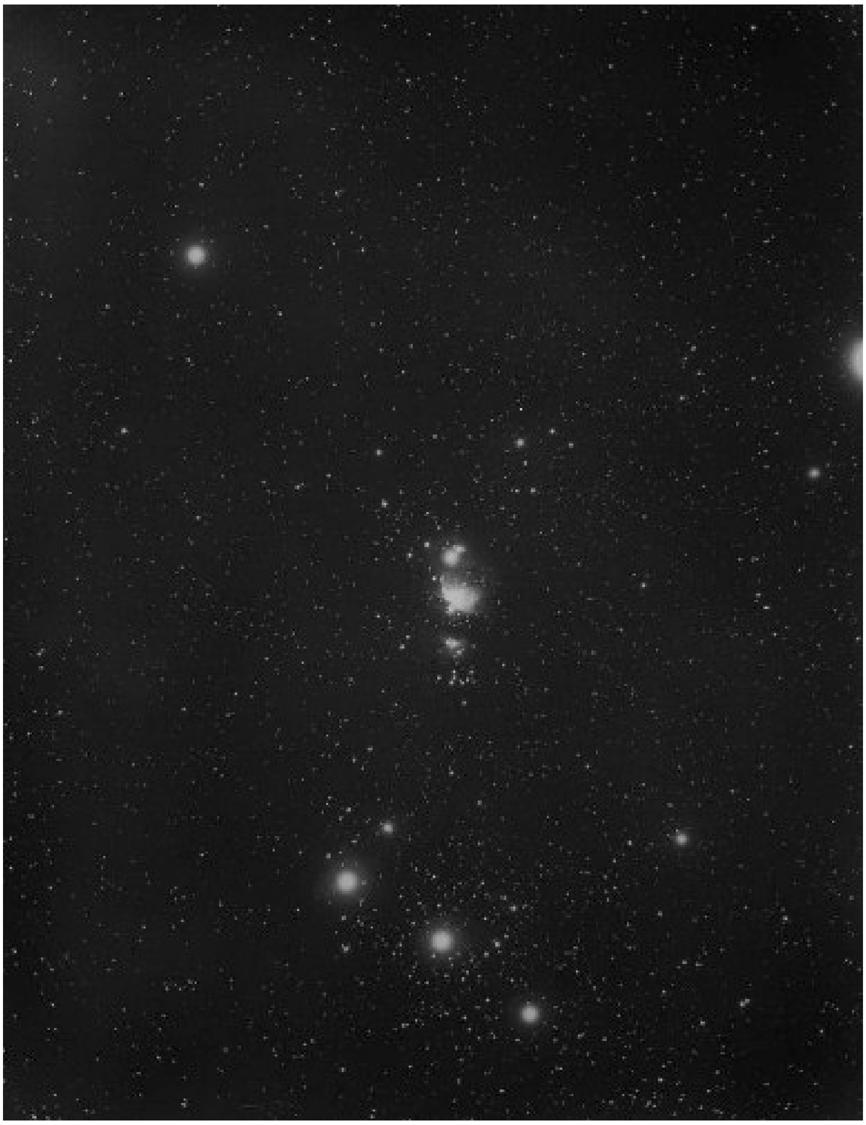
In 1858 David Gill enrolled as a private student at Marischal College, Aberdeen. Two years later in 1860, it amalgamated with Kings College, Aberdeen to form the University of Aberdeen. The term private student referred to those who wished to attend lectures but who chose not to sit for a degree. Whilst at Marischal he attended the lectures in Natural Philosophy (Physics) given by the great James Clerk Maxwell [8]. He was to say later in life that it was James Clerk Maxwell's '*teachings which influenced the whole of my future life*'. James Clerk Maxwell also held David Gill in high regard and wrote the following testimonial on his former student, sometime around 1868 [9]:

"Mr. David Gill was one of my ablest students in Marischal College, Aberdeen. He was even then devising methods for the experimental determination of physical quantities."

VII.3

'HIPPARCOS'

Mapping the Heavens



Part of the Constellation of Orion, Sydney Astrograph, 1890

Photographic Sky Surveys are a blessing to the modern astronomer, but this was not always so. The laudable but ultimately doomed '*Carte du Ciel'* project took years longer than planned and used up valuable observatory resources that many argued could have been better spent. However, it was to triumph in the end when its century old data was to provide valuable input into the HIPPARCOS Satellite Astrometry Project.

VII.3.1 Early Star Charts

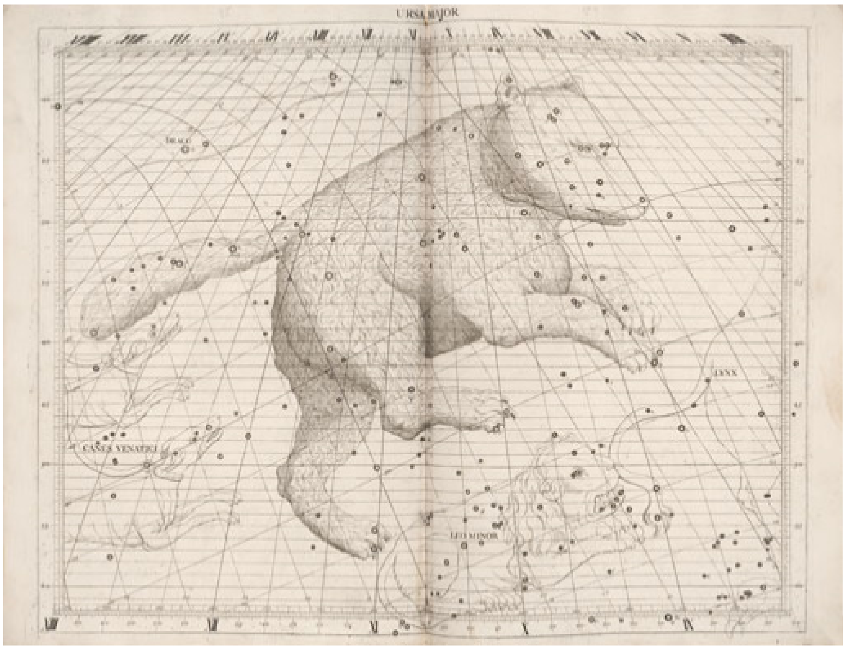
Although charts of the stars had been produced in antiquity [1], it was during the Golden Age of European celestial cartography that star charts as we know and understand them came into being. This was a period which spanned roughly the years 1600 to 1800 and was driven by technological advances in both 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.

Such Atlases 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.

With the advent of Astrophotography in the 1840s, the production of star charts would never be the same – stellar cartography was entering a new era; and in the way subsequent events were to unfold, it would not be plain imaging, nor would their production be as easy as was envisaged by their creators.



John Flamsteed (1646-1719), the first Astronomer Royal of England, presided over the building of the Greenwich Observatory. His "*British Catalogue*" of stars, finally published in 1725, six years after death, brought stellar astronomy to a new level. His star atlas, published four years after the catalogue, but in development for over twenty years, was based on his new and more accurate observations, and that fact, coupled with its impressive size. It was the largest that had ever been published and immediately vaulted Flamsteed into the select ranks of the great stellar cartographers.

Ursa Major ('Great Bear') from Flamsteed's 'Atlas Coelestis' of 1729

VII.3.2 Ideas & Attempts

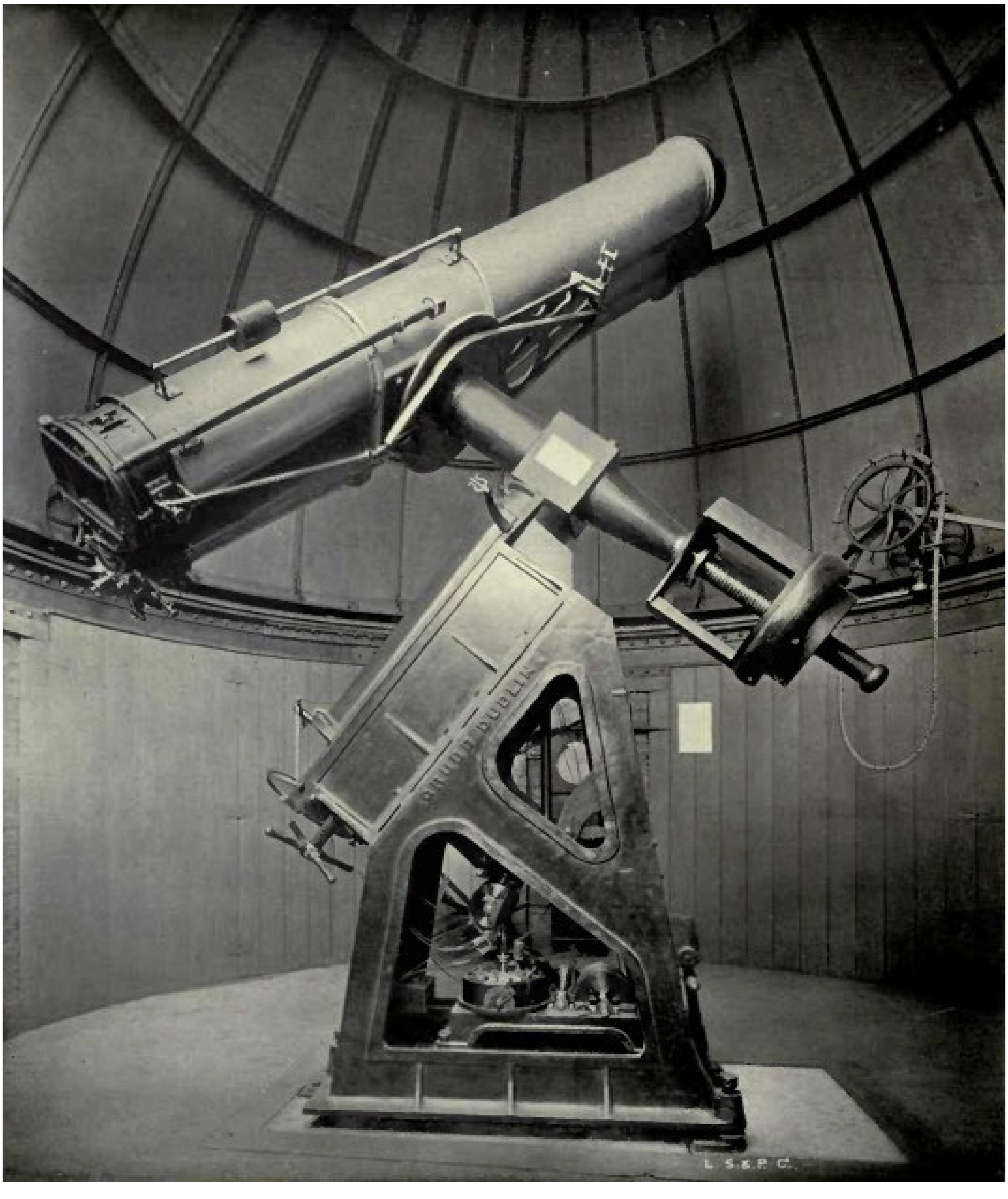
It would not too be long after George Phillips Bond and John Adams Whipple took the first photograph of a star on the 17th July 1850, that the question arose as to whether photography could be used to create star charts; and thus replace the lengthy and tedious process of visual observations; where the positions of stars were measured as they cross the meridian as seen by an observer using a transit telescope.

Seven years later, G. P. Bond, was to write a letter to a friend in which he discussed likely advances in

Part VIII

Astrograph

Photographic Telescopes



Greenwich Observatory Astrograph, built by Sir Howard Grubb, c1891

"In this paper Dr. Vogel expresses an opinion that the photographs of Herr von Gothard taken with this comparatively small instrument show results which far surpass any obtained by eye observation with the largest telescope." Andrew Ainslie Common (1841-1903)

VIII. Abstract

In the early years of astronomical photograph pioneers like John William Draper, Warren De La Rue and the Bonds of Harvard, William Cranch and his son George Phillips used whatever equipment they had, no matter whether it was suitable or not.

Only in 1864 did the New York amateur scientist, Lewis Morris Rutherfurd create the first Astrograph - a telescope designed specifically with photography in mind. It would be many years before photographic refractors became used in a professional observatory.

At that time the '*Great Observatories*' were more interested in claiming the title of owner of the 'largest' telescope rather than caring about whether it was the best or even less whether it was photographically corrected'. This '*blinkered*' attitude effectively meant who had the biggest '*Great Refractor*'. Its rival - the reflector was considered the instrument of amateurs and cranks, despite it having achieved great success in the hands of Sir William Herschel and his son Sir John Herschel.

Those who held the purse strings often did not care about science but only their egos; and astronomers were often only too glad to receive the gift of a '*Great Refractor*'; and besides many even up to the end of the nineteenth century were not convinced of the advantages of photography over visual observations.

As a consequence the nineteenth century was the age of the 'Great Refractor', many examples of which sprang up across the North American Continent and Europe, with every few years an even bigger one would appear under the Dome of this observatory or another, until it was supplanted by one elsewhere; 15-inch (1839), 18.5-inch (1862), 24.5-inch (1869), 26-inch (1873), 30-inch (1885), 30.3-inch (1887), 36-inch (1888), 40-inch (1897). It was a case of aperture fever bordering on scientific insanity. However there appeared a few voices of reason in the astronomical community who supported either the reflector which was better by design suited to photography, or the photographic refractor.

William Parsons, the 3rd Earl of Rosse (1800-1868) at his estate in Parsonstown (now Birr) built a series of '*Great Reflectors*', culminating in the completion of his 72-inch '*Leviathan*' in 1845. Using this instrument Parsons saw details in the objects known as '*nebulae*' which the refractors could not see. In particular he observed that several exhibited a '*spiral*' nature. Such nebulae were later to be found separate '*Island Universes*' lying millions of light years beyond the boundaries of our own Milky Way star system.

Edward Charles Pickering, the Director of the Harvard College Observatory, went against the norm of his fellow observatory heads - and believed in small photographic refractors as the best way forward for the new science of Astrophysics. In 1885 Pickering obtained $2000 from a grant provided by the Bache Fund of the American National Academy of Sciences for the purchase an 8-inch Photographic Refractor.

It was with this instrument that his younger brother William Henry Pickering took a photographic plate on the 6th of February 1888, on which Williamina Fleming found the dark nebula known as the '*Horsehead*' - probably the most iconic of the all the wonders to be seen in the heavens. Furthermore he used this Astrograph and others to carry out useful science in the areas of stellar spectroscopy and photographic sky surveys.

With the instigation of the ill-fated *'Carte du Ciel'* photographic sky mapping project in 1887, the appearance and use of photographic refractors bred like clones across the globe from Greenwich, to Paris, to Rome, to North Africa, to Australia and to South America; all made to the same specification based on a 13-inch aperture.

The first nails in the coffins of the '*Great Refractors*' had begun to appear. In 1898 the nails had begun to be hammered into the coffins when, James Edward Keeler and his assistant Charles Dillon Perrine began taking photographs with a 36-inch reflector of many well known Deep Space Objects. The images they obtained were of such magnificence that they made even the most sceptical of astronomers believe that the new era of the large silvered mirrored reflector had begun and the age of the '*Great Refractor*' had come to an end.

So it proved to be when in 1908 a 60-inch reflector appeared atop Mount Wilson in California, followed nine years later by an even bigger one of 100-inch aperture next to it. Following the 1900 Paris exhibition when a refractor of 49-inch aperture made a final bow before being scrapped, no more '*Great Refractors'* were built, save the 30-inch Thaw photographic refractor completed for the Allegheny Observatory, Pittsburgh in 1914. In the years that followed many new '*Great Reflectors*' appeared under the domes of the world's observatories, whose designs were based on high quality optics, entirely suited to astronomical photography. Telescopes using the Schmidt and Ritchey-Chretien optical systems also began to slowly displace the conventional Newtonian/Cassegrain designs as adopted by the 200-inch Hale reflector on Mount Palomar.

On the 24th of April 1990 the ultimate Astrograph - the Hubble Space Telescope was launched into orbit above the Earth and with it a new chapter in the history of Astrophotography was opened.

"In ordinary photography, the lenses used are designed for the purpose, and have usually all necessary information as to focal length and focal aperture engraved on the lens mount. An operator has only to focus the image on the ground glass, set an indicator to the 'stop' required, consult an exposure table for the light-factor appropriate to the hour and month, and then he can go ahead.

But in 'telescopic' photography the conditions are quite different. The instrument is not designed for the purpose, and in refractors the actinic rays come to a different focus from the visual rays, so that the ground glass requires suitable adjustment. Focal lengths and apertures have to be determined, and suitable stops manufactured, by the photographer himself,and except for solar photographs, ordinary exposure tables in their usual form are useless. Fortunately, however, all the necessary information can be ascertained without difficulty.."

Henry Hayden Waters (1880-1939), from Astronomical Photography for Amateurs, 1921.

VIII.1

'The Leviathan Man'

William Parsons, 3rd Earl of Rosse

Born: 17th June 1800; York, Yorkshire, England

Died: 31st October 1867, Seapoint, Monkstown, Dublin, Ireland

William Parsons 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 *'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.

VIII.1.1 'Great Telescopes'

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.

He was the first of the great telescope builders who created almost single handedly a series of speculum metal mirrored reflectors of ever increasing size; beginning with a 6-inch in 1826, followed by a 15-inch in 1830, then soon afterwards by a 24-inch, which was then superseded in 1839 by a 36-inch; and finally in 1845 construction was completed on his famous 72-inch telescope - the '*Leviathan of Parsonstown*'. This telescope was to remain the largest telescope in the world for over 70 years until 1917 when it was '*overtaken*' by the 100-inch Hooker Reflector at the Mount Wilson Observatory in California, USA.

Although William Parsons never used any of his telescopes to take photographs of the Deep Space Objects (DSOs) he observed, he nevertheless made vital discoveries regarding their structure. His drawings of DSOs made by him and his assistants at Birr Castle during the period 1845 to 1867, showed for the very first time accurate representations of their true appearance, later to be confirmed by the photographs of Isaac Roberts (1829-1904), William Edward Wilson (1851-1908), James Edward Keeler (1857-1900) and others.

Above all else, William Parsons demonstrated the great potential reflecting telescopes had in the future conduct of astronomical research. An opinion that was later to be proved correct. The age of telescope building at Birr in the years 1826 to 1845 marked the onset of the '*death*' of the '*Great Refractor*'. However it was to be others who caused '*its*' death; Andrew Ainslie Common dealt '*it*' the fatal blow, and it was James Edward Keeler who put the nails in '*its*' coffin [1].

In 1845 William Parsons began using his 72-inch Reflector and during the course of his observations noticed that a number of the bright '*nebulae*' exhibited a definite spiral structure to them. The 3rd Earl of Rosse's discovery of the spiral nature of certain nebulae helped fuel the flames of a long standing argument between himself and another great astronomer of the time – Sir John Herschel. Rosse believed that all '*nebulae*' were made up of individual stars, a fact which would become evident if telescopes of sufficient size were available to observe them; on the other hand Herschel believed that not all nebulae are '*resolvable*' and some of them are made up of clouds of gas which collapse to form stars.

History has subsequently shown that both were right and both were wrong in equal measures! Certain nebulae are in fact made up of clouds of gas, some of which are even '*star forming nurseries*'; whilst others including Rosse's 'spirals' were in fact external galaxies made up of individual stars, much resembling our own Milky Way; but situated millions of light years beyond the boundaries of our own '*Island Universe*'.

VIII.1.2 Lord Oxmantown

William Parsons [2] was born on the 17th June 1800, in York, England. An event which was recorded for posterity in the following announcement that appeared in the York Courant for Monday 23rd June 1800 [3]:

"*On Tuesday evening [17th June] the Lady of Sir Lawrence Parsons Bart., of Parsons Town, M.P. for King's County, Ireland, was safely delivered of a son and heir, at their lodgings in this city.*"

It is not known where their lodgings were in York, or why they were there. Presumably they were in England to escape the Irish Rebellion of 1798, in which a number of magistrates were murdered in Queens (Laois) and Kings (Offaly) Counties, and also at Cork and Kildare. As a result a number of the Irish Gentry fled to England in fear of their lives [4].

At the age of seven, William Parsons inherited the title of Lord Oxmantown, following the death on the 20th of April 1807 of Laurence Harman Parsons (1749-1807), the 1st Earl of Rosse; his father Sir Laurence Parsons, then Baron Oxmantown became the 2nd Earl of Rosse.

He received his preparatory education at home from a private tutor, but in 1818 he entered University College, Dublin. A year later he left to continue his studies at Magdalene College Oxford, where he received a 1st Class Honours Degree in Mathematics in 1822.

In 1821 when he was Lord Oxmantown, William Parsons entered the world of politics when he was elected

VIII.2

'The Miller'

Andrew Ainslie Common

Born: 7th August 1841, Newcastle-upon-Tyne, Northumberland, England

Died: 2nd June 1903, Ealing, Middlesex, England

Andrew Ainslie Common was a pioneer in the construction of large silvered mirrored telescopes. He showed the potential of such instruments to photograph the heavens provided they were accurately driven and situated in a suitable observing location. Two of his telescopes are still in operation today, the 36-inch *'Crossley'* reflector at the Lick Observatory in California and the 60-inch *'Rockefeller'* reflector at the Boyden Observatory, Bloemfontein, South Africa.

VIII.2.1 Procedures & Techniques

Andrew Ainslie Common was without doubt one of the great pioneers of Astrophotography. His chief claim to fame lies, not particularly because of the photographs he took, but in the techniques and procedures he used to capture them, and even more importantly in the telescopes he constructed and designed specifically for Deep Space Astrophotography.

He believed that the telescopes of the future should be silvered mirrored reflectors and not the *'Great Refractors'* which at that time, were to be found under the domes all the '*Great Observatories*' of the world. Furthermore, if they were to be of any use to astronomers, they should be on a stable platform of '*such, a construction of mounting as to give the greatest mount of steadiness with the least amount of motion*'; provided with a '*Driving clock. Circles to find or identify an object and motions taken to eye end*' and most important of all '*a suitable locality for the erection of the telescope'.*

His start in life was one borne of fear apprehension; whether from the real possibility of an early death from the cholera which plagued the streets where he lived; or the prospect of financial hardship brought on by his father's insolvency. As a consequence of the early death of his father when he barely ten years old, his education was cut short and he was sent out into the world to earn a living as a Miller at his uncle's flour mill in Gayton, Norfolk. It was here that he became '*a strong man in all senses, and liked trying himself to the limit'* in both physique and in character, learning be never afraid of hardship or the thought of hard work.

His legacy lives on today for two of the great reflecting telescopes he constructed over a century ago are still in use and are helping us to understand the universe in which Andrew Common first gazed upon so long ago. Let us now turn the pages of history back over 150 years to a world far different from the one fate decreed Andrew Ainslie Common would follow.

VIII.2.2 Newcastle-upon-Tyne

Andrew Ainslie Common was born on the 7th August 1841 [1] in Oxford Street [2], in the parish of St. Andrew's, Newcastle-upon-Tyne, the second of the three children born to Thomas Common (1810-1851), a surgeon of that city, and his wife Mary Hall (1806-1873) [3]. The area of Newcastle where Andrew Common was born was at the time a new residential area on the outskirts of the city. The empty spaces around his home were soon to disappear as the city's population rapidly expanded in the coming years [4]; as is evident from a map of 1843 which shows the ominous presence of land allocated for new buildings. It maybe thought that Andrew was immune from the poverty, disease and depravation that many tens of thousands in the city were accustomed to. This was far from being the case, indeed the opposite was true.

His father, Thomas Common was a respected and well known surgeon in the North of England, being one of the early pioneers in the field of eye cataract surgery. He had qualified as a Surgeon and Apothecary, becoming a member of the Royal College of Surgeons in 1832, at the age of just 22. He subsequently trained other Apprentice Surgeons who later would make great contributions to helping the poor, the sick and needy in the city. The most well known of his students was Dr. Charles John Gibb (1824-1916), the House Surgeon at the Newcastle Infirmary [5]

As a young boy growing up in Newcastle with his brother John Freeland Fergus (1839-1916) and his sister Mary Jane (1844-1912), young Andrew was always aware of the fragility of life. His father's profession must have been a constant reminder to him of this hard lesson. The city of Newcastle had during the period 1831 to 1853 suffered a number of cholera epidemics caused by poor sanitation and the presence of much slum housing [6].

In 1842, the year following Andrew's birth his father was appointed the resident surgeon at the nearby Gateshead Dispensary [7]. The Gateshead Dispensary was established in 1832 as a direct consequence of the cholera epidemic of the previous year. Its purpose was to provide free medical care to those unable to pay for it – the poor and the deprived [8]. As is always the way it was too little too late - the cholera outbreak of 1831 had already killed 306 people. It had taken this shock treatment for the '*great and the good*' of Gateshead to be stirred into action!

VIII.3

'The Visionaries'

George Willis Ritchey

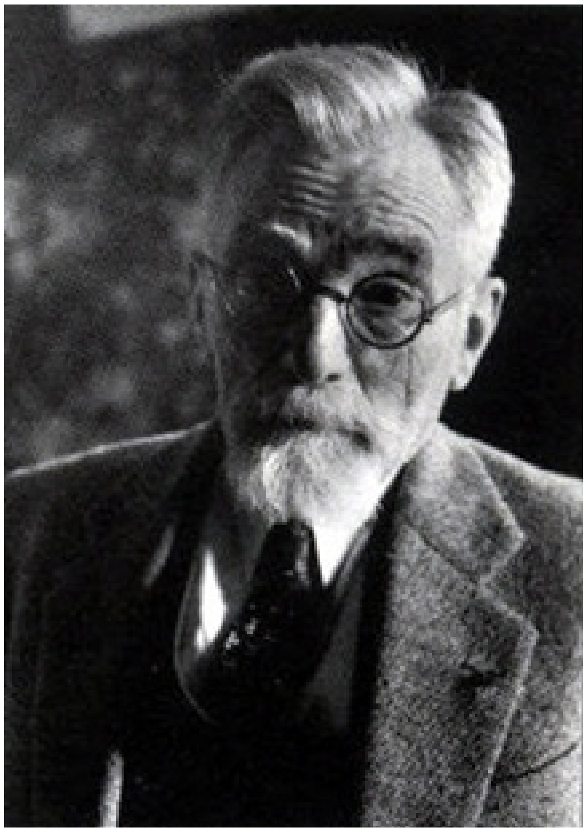
Born: 31st December 1864, Tuppers Plains, Ohio, USA

Died: 4th November 1945, Azusa, California, USA

Henri Chretien

Born: 1st February 1879, Paris France

Died: 6th February 1956, Washington DC, USA



George Willis Ritchey was not only one of the greatest designers of Telescope Optical Systems, but more importantly he was a visionary whose ideas were too radical for the age in which he lived. It was his collaboration with the French optician Henri Chretien that led to the optical design which now bears their name and which is the basis of almost all of today's new breed of '*super telescopes*'.

VIII.3.1 Visionaries

On the 13th of December 1908 atop a mountain in southern California a '*Great*' telescope opened its dome to see the night sky for the very first time. Not only was this a memorable occasion for those who had constructed it, but it also marked the end of one era in Astronomy and the beginning of another.

For three centuries ever since the days of Galileo the refracting telescope had dominated astronomical research in almost every observatory across the globe. Its rival the mirrored reflector was looked upon with scorn and contempt by the astronomical establishment. They saw it as the instrument of amateurs and cranks, and not fit to be given dome space in their Great Observatories.

Now the age of the glass lens and the refractor was gone, and the new age of the large silvered mirrored reflector had arrived; for the telescope that saw its firstlight in 1908, at the summit of Mount Wilson, over 5700 feet above sea level, was such an instrument. It had a mirror of 60-inches aperture, which at the time, made it the largest operational telescope in the world. The man who had ground, polished and nurtured the mirror was George Willis Ritchey (1864-1945) [1].

He was born the son of a cabinet maker of Irish emigrant stock, in a small Ohio settlement whose name few have heard and not many more have lived in. Yet despite these humble beginnings and probably because of them, he grew up to become not only a great optician and telescope designer, but also an outstanding Astrophotographer whose images of Deep Space Objects (DSOs) were the finest of their day

His images of such iconic objects as the as Great Spiral Galaxies in Andromeda (M31),Canes Venatici (M51), Ursa Major (M101) and Triangulum (M33) were of the most incredible quality and greatly improved upon those taken earlier by the likes of Andrew Ainslie Common, Isaac Robert, James Edward Keeler and William Edward Wilson.

In 1910 in collaboration with the French optician, Henri Chretien (1879-1956) [2] they designed the now famous Ritchey-Chretien optical system affectionately known as the RC. It was this design that brought George Willis Ritchey and the Mount Wilson Observatory's Director, George Ellery Hale into conflict. Ritchey believed he should at least have been allowed to make a prototype of the new design, but Hale was adamant it was too new and too different to waste precious time on. Any telescope he had anything to do with would be constructed using traditional designs only.

In 1919 Hale fired Ritchey, but not before he had finished work on the mirror for his new 100-inch Hooker reflector. A deeply hurt and disillusioned Ritchey left the mountain, never to return. Left to ponder what might have been, he scratched a living growing oranges, lemons and avocados.

In 1928 Ritchey wrote of his dreams for the future of telescope design [3]:

"This is the incomparable exploration - the effort to bring the resources of the Universe to the service of mankind. This series of telescopes, by revealing to all men, graphically, by means of exquisite photographs, a Universe of which the Earth, the Sun and the Milky Way are but an infinitesimal part, will bring to the world a greater Renaissance, a better Reformation, a broader science, a more inspiring education, a nobler civilization. This is the Great Adventure. These telescopes will reveal such mysteries and such riches of the Universe as it has not entered the heart of man to conceive. The heavens will declare anew the Glory of God."

On the 24th of April 1990 an event took place which proved Ritchey right and Hale wrong. The words spoken by George Willis Ritchey over sixty years earlier, eloquently described the work that the Hubble Space Telescope launched that day was soon to perform, but especially so - as it was his optical and Chretien's design which made it all possible.

Ritchey and Chretien were visionaries ahead of their time, often vilified and ignored by the astronomical establishment for their '*new curves'* optical design. Today in space and in an ever increasing number of backyards and gardens across the world these two men's names are remembered for the '*new breed*' of telescope that has changed and is still changing our understanding of the universe in which we live.

VIII.4

'The Optician'

Bernhard Voldemar Schmidt

Born: 30th March 1879, Jaani's Place, Lounakula, Naissaar, Estonia

Died: 1st December 1935, Hamburg, Germany

Bernhard Voldemar Schmidt was without doubt one of the greatest opticians of all time. Almost every amateur has seen or used a telescope which owes its design to Schmidt's invention. The concept of Schmidt's design is simple, and in many ways too simple, something which may have contributed to the lateness of its invention. It is a design which could easily have been made 200 years earlier and not left until the twentieth century. Nevertheless since its introduction in 1930 it has proved to be one of the finest telescope optical systems ever created.

VIII.4.1 ... Newton ... Fraunhofer ... Schmidt

In tens of thousands of backyards, gardens, rooftops and amateur observatories all around the world, can be found a telescope whose origin lay in the brain and left hand of an Estonian optician named Bernhard Voldemar Schmidt (1879-1935). In his lifetime he remained largely unrecognized by the astronomical community, so much so that whilst he lived no telescope of his design was ever built by anybody other than himself.

Yet in 1936, less than a year after his death an 18-inch telescope made to his design was completed at the Mount Palomar Observatory [1]. It was a telescope that was to revolutionize both amateur and professional astronomy for decades to come. Of this genius, his fellow Estonian, the astronomer Ernst Julius Opik (1893-1985), wrote [2]:

"Perhaps the greatest advance—it could be called a revolution—in astronomical optics since Newton's time took place in 1930, when a one-handed invalid from Estonia, who went to Germany to work in optics, constructed at Hamburg Observatory a photographic telescope of a new type. This man was Bernhard Schmidt. Photographic cameras all over the world, based on his invention, are called 'Schmidt', sometimes 'schmidt cameras' without a capital letter."

The Schmidt Camera was an optical system of pure genius and simplicity. It had a wide field of view [of around 16 square degrees in his prototype] which not only gave high definition and sharpness across the whole of the photographic plate, its '*fast*' focal ratio also enabled faint detail to be seen with much shorter exposures than those required by conventional telescopes. It was in effect the perfect Astrograph, which could be manufactured with minimal extra cost when compared to the enormous benefits it offered. By creating the Schmidtspiegel or Schmidt reflector, Bernhard Schmidt became one of the greatest opticians the world has ever known, in stature equal to the likes of Hans Lippershey, Isaac Newton and Joseph Von Fraunhofer. Although statements as laudable as those given by Opik and the many others made after his death are entirely true, the reality for Schmidt during his life was very different.

For Bernhard Voldemar Schmidt it was a never ending physical and mental battle to get his optical designs recognized; in which his only companions were the ones so often befriended by geniuses – those of frustration, disappointment and loneliness.

Erik Schmidt (1925-), the nephew of Bernhard Schmidt, has done much to promote the life and work of his uncle. His biography of *'Optical Illusions' The Life Story of Bernhard Schmidt, the Great Stellar Optician of the Twentieth Century'*, provides an accurate and fascinating account of Schmidt's life and work. Unfortunately it is now difficult to obtain, but without doubt deserves a much wider circulation than it has received so far. The book has in fact formed the basis of several more recent accounts of Bernhard Schmidt. He has also appeared as himself in the documentary film Vastutuulesaal (Sailing against the Wind) about the Estonian conductor Tõnu Kaljuste and his crazy idea of building an opera house on Bernhard Schmidt's family estate on Naissaar; an island, which at that time had no regular ferry line, no electricity and only one permanent resident. In the summer of 2006, the Nargen Opera House was completed and the first performances took place on the land which Bernhard Schmidt used to play as a boy and often tried to blow up.

Erik Schmidt (1925-)

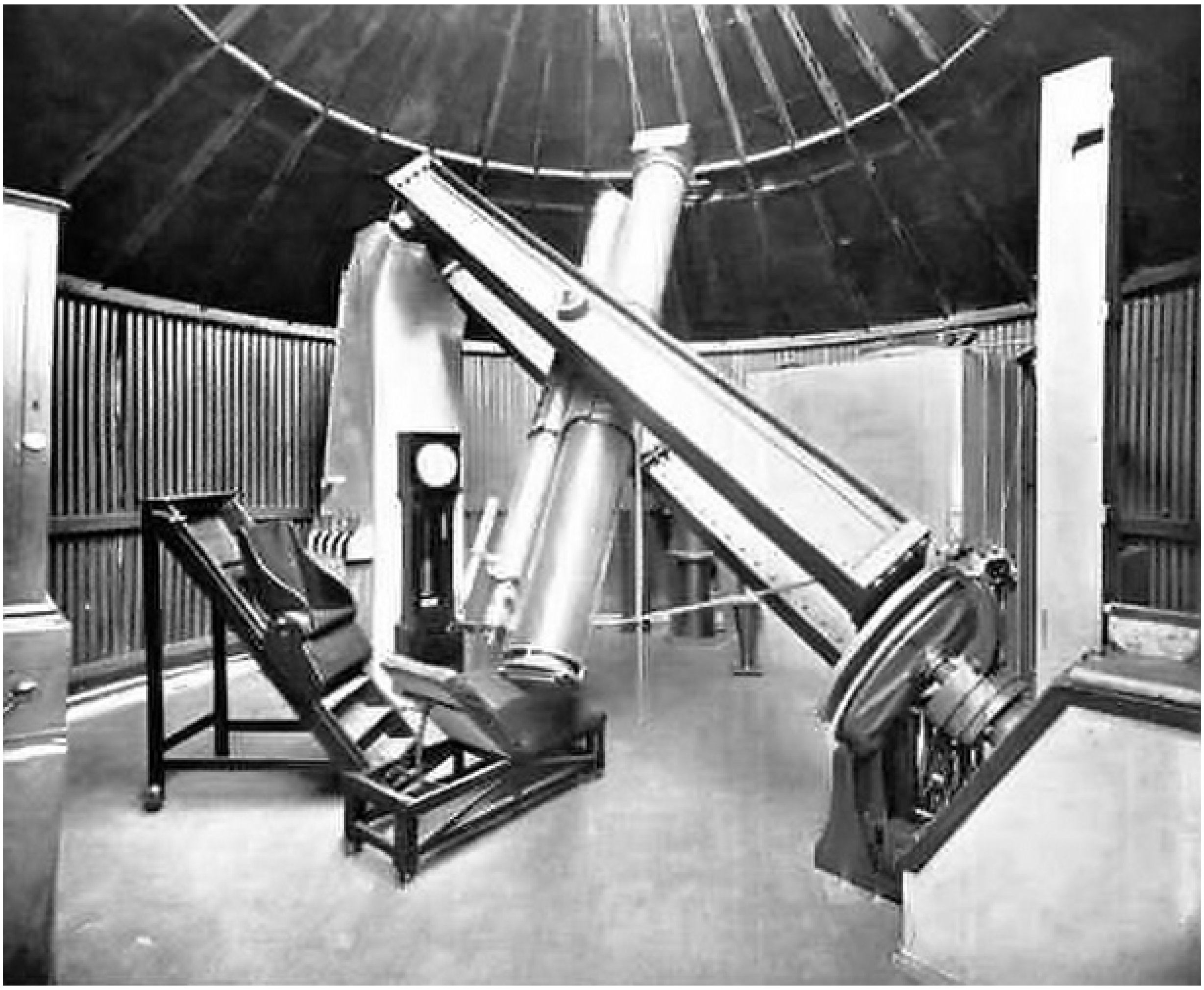
VIII.4.2 Naissaar Island ... Photography ... Gunpowder

Much of what we know of Bernhard Schmidt's childhood comes from information supplied by his younger brother August as told years later to his son Erik Schmidt [3]. August Schmidt, in his account of his brother's life, provides a fascinating insight into what made Bernhard Schmidt different from the norm, and more importantly gives valuable clues as to how he became the great optician, he undoubtedly was [4]:

VIII.5

'HUBBLE, BUBBLE, TOIL & TROUBLE'

Telescopes in Astrophotography



13-inch Astrograph of the Sydney Observatory, New South Wales, Australia

The role of the telescope in the history of Astrophotography has been instrumental to its development from the first primitive images taken by early pioneers such as John William Draper and the Bonds of Harvard to the stunning images captured by the Hubble Space Telescope. At first the *'Great Refractor'* dominated and were present under the Domes of all the major Observatories; but by the end of the nineteenth century, the era of the large silvered mirrored reflector had begun. These telescopes were constructed from the very outset with Astronomical Photography in mind and form the basis for today's breed of '*Super Telescopes*'.

VIII.5.1 'In the Beginning'

In the early days of Astrophotography little or 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. The 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.

It must be remembered that as in any new branch of Art or Science, the early pioneers were the '*shock troops*' so casualties and failures were to be expected. In the 1840s and early 1850s little was known or understood about Photography let alone its interface with a Telescope. It was therefore not surprising that the first Astrophotographers used whatever equipment they had to hand and gave no thought to whether it was the right telescope design to use or that they were using it in the '*correct*' way [1].

As a consequence the earliest astronomical photographs were obtained with a variety of telescope optical systems, for example:

- John William Draper's Lunar Photographs of 1839-1840 used a Heliostat which focused the moon's rays onto a Daguerreotype Plate using a 6-inch mirror and a 3-inch lens; his primitive camera being made from a discarded cigar box!;
- George Phillips Bond and John Adams Whipple used the 15-inch '*Great Harvard Refractor*' with a Daguerreotype Camera attached at the prime focus to obtain on the 17th July 1850 the first photograph of a star, the bluish first magnitude star Vega (Alpha Lyrae);
- William Usherwood captured the first successful photograph of a Comet on the 27th September 1858 with an ordinary portrait camera normally used for weddings and babies!

It was only the later pioneers who recognized, understood and acted on the importance of matching the design of the telescope with the photographic process and the object being imaged [2]:

- That the point of focus of a refracting telescope was different when looking through it visually from that when using it with a photographic plate; and that for reflecting telescope designs this was not an issue;
- The stability of the telescope mount fitted with a clockwork or electric motor capable of accurately tracking the motion of the stars caused by the diurnal rotation of the Earth;
- Making use of telescope designs suited to the type of astronomical object being photographed, e.g. one with a field of view which matches that of the target;
- Well balanced optics free from flexure;
- An optical tube assembly (OTA) which minimizes the effect of atmospheric turbulence within its interior;
- A suitable '*dark site*' location with optimal chance of good seeing and transparency.

A number of large telescopes both refractors and reflectors were constructed during the early decades of Astrophotography which failed to recognize the importance of Photography to the future of Astronomical Research and as a result were designed to be entirely unsuitable for successfully capturing images of the heavens.

It would not be until the early decades of the twentieth century that it would be the norm for new telescopes to be designed with both photographic and visual use in mind. More recently even the visual capability of a telescope was not considered important and as a result many OTAs were built for photographic use only.

Today, the latest breed of '*super telescopes'* are purely photographic and looking through them is something that is just not done - the modern astronomer relies entirely on computers controlling not only the telescope but a whole range of auxiliary scientific instrumentation attached to the OTA.

Part IX

Amateur

The Modern Digital Age

Modern *'Amateur'* CCD Image of the 'Crab' Nebula in Taurus taken with an SBIG ST 2000XM/XCM CCD and an 11-inch NextStar SCT
©Stefan Hughes

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.

They were the 'Catchers of the Light'.

IX. Abstract

The modern amateur Astrophotographer using only modest equipment to obtain images better than larger but outdated telescopes first appeared the persona of Eugen Von Gothard, a wealthy and talented scientist from Hereny in Hungary.

On the 1st of September 1886, 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 of scientific importance, all with the aid of affordable instruments with apertures of sizes bordering on the small.

The appearance of Von Gothard's photographs caused a supernova like effect on the astronomical community. Herman Carl Vogel, the Director of the Potsdam Observatory went so far as to express the opinion that the *'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 years to come Von Gothard was joined by other equally remarkable amateurs, like Alfred Rordame, a violinist from Salt Lake City, Utah, who photographed in 1921 features in the cloudy atmosphere of the planet Venus; or another violinist, the elusive Marcel De Kerolyr (1873-1969) who took during the years from 1929 to 1934 perhaps the finest pre-digital images of Deep Space Objects.

De Kerolyr's 1932 wide field image of the region surrounding the iconic '*Horsehead*' nebula in Orion, obtained with an 80cm telescope is perhaps the leading contender for the title of '*Greatest Astronomical Photograph'* of all time.

However, the greatest advance of the amateur in Astrophotography came in the years which followed the invention of the Charge Coupled Device or CCD in 1969. In 1974 the first digital image of an astronomical object - the Full Moon was obtained with an 8-inch reflector and a CCD chip possessing a resolution of only 10,000 pixels.

In the 1990s the first amateur astronomical CCD cameras began to appear. These relatively primitive devices had pixel resolutions measured in the 100,000s, but nevertheless could be linked to a personal computer for image acquisition and processing functions.

The coming of the twenty-first century saw even greater advances in amateur CCD technology, when the first budget cameras were introduced alongside research quality megapixel models for those with deeper pockets.

This seed change in CCD technology coupled with the availability of high quality telescopes of Schmidt-Cassegrain design, sturdy computer controlled mounts fitted with accurate GOTO/Tracking DCD Servo motors brought about a revolution that changed the practice of Astrophotography beyond all recognition.

The introduction of Personal computers with fast processor chips and large storage discs from the late 1990s onwards; which when used with sophisticated image acquisition and image processing software provided the amateur with additional and much needed essential resources.

The modern amateur possessed of only modest equipment of the kind previously described, is now able to take images of the Moon, Planets, Comets, Star Clusters Nebulae and every other kind of object to be found in the heavens with a quality that the early pioneers of astronomical photography probably had never even dreamt was possible. The magnificence of these images was beyond even their pioneering comprehension and imagination.

What is even more remarkable is that these images are regularly taken on a daily basis, not by just one or two amateurs but thousands in every corner of the world. The images they capture are infinitely superior to those obtained in the 1970s by the '*Great Reflectors*' atop the mountains of California using conventional photographic emulsion based glass plates, at a time when the '*firstlight*' of a photon hit a CCD chip.

"The average amateur photographer doubtless takes a passing interest in the beauties of the night sky, and nearly every amateur astronomer of my acquaintance is a dabbler in photography. Many seem to be deterred from combining the two hobbies by the impression that nothing can be done without very elaborate and costly apparatus, an impression which the perusal of the average astronomical textbook does little to remove.

*Yet photographs of comets, the Milky Way, etc., from which valuable scientific results have been deduced, have been secured with simple and inexpensive apparatus of a portable character. One of our greatest living astronomers, Professor G. E. Hale, states, '**The results of amateur observations may not only be useful—they may equal, or even surpass, the best products of the largest institutions**'."*

Henry Hayden Waters (1880-1939), from Astronomical Photography for Amateurs, 1921.

IX.1

'Lords of the Ring Nebula'

The Pioneers of Amateur Astrophotography

Eugen Von Gothard: Born 31st May 1857, Herény, Vas, Hungary
Died 29th May 1909, Herény, Vas, Hungary

Alfred Rordame: Born 8th of June 1862, Oslo, Norway.
Died: 30th November 1931, Salt Lake City, Utah, USA

Marcel De Kérolyr: Born 1873. Died 1969



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 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. Following him were the likes of Alfred Rordame, who was the first person to photograph features on the cloud shrouded planet Venus; and Marcel de Kérolyr, whose photographs were the equal if not better than all who came before him and many of those who followed him.**

IX.1.1 Rise of the Amateur

The average modern amateur Astrophotographer owns a modest telescope, either a refractor with an aperture of between 3-inches (7.5 cm) and 6-inches (15 cm) or a reflector/catadioptric with an aperture of typically 6-inches to 12-inches (30cm). However, the early pioneers of Astrophotography were either wealthy amateurs or professional astronomers who used telescopes with apertures considerably larger than the average modern imager.

From the 1880s onwards a new breed of Astrophotographer began to appear, who with the aid of telescopes of moderate size, took photographs of astronomical objects which showed detail that even the '*Great Refractors*' of the age were hard pressed to see. This as you can imagine was a revelation that the astronomical establishment found hard to swallow, but nevertheless it sent a clear message which echoed around the Domes of their Great Observatories, which said: when you build a new telescope ensure that has a photographic capability and not one designed solely for visual use!

The evidence for this assertion was clear for all to see at the time. Wealthy amateurs such as Andrew Ainslie Common and Isaac Roberts were regularly exhibiting their astronomical photographs at meetings of the Royal Astronomical Society during the 1880s onwards [1]. However, what really shocked the astronomical community was that their efforts were taken with mirrored reflecting telescopes, albeit with large apertures ranging from the 20-inch of Roberts to 36-inch of Common.

In the last two decades of the nineteenth century the *'Great Refractor'* ruled supreme under the domes of the world's elite Observatories, at Lick and Yerkes in America, at Pulkovo in Russia, at Meudon and Nice in France and at Greenwich in England [2]. No mirrored telescope was ever considered good enough to be given dome space by the Directors of these venerable institutions. Even when Carpet Tycoon, Edward Crossley donated, Andrew Ainslie Common's 36-inch reflector to the Lick Observatory in 1895, it was only politely accepted by its Director, Edward Singleton Holden, but never used during his tenure of office [3[.

However what rooted the world's astronomical elite to their eyepiece and which shook the very foundations of their astronomy, was a photograph taken by a Hungarian amateur named Eugen (Jeno) Von Gothard (1857-1909). On the 1st of September 1886, he obtained a photograph of the famous planetary nebula in the constellation of Lyra known as the '*Ring*' Nebula (M57). It was a remarkable photograph not only for the fact it was the first ever taken of this beautiful 's*moke ring*' in space, but more importantly it showed its 15th magnitude central star.

The significance of this was not lost on all who saw or read about Von Gothard's photograph. This star at that time could only be seen under the best conditions with only the largest of telescopes, but for it to stand out like a tiny bright torch amid the black velvet of the night sky and be revealed so easily by a mere 10-inch mirrored telescope must have caused many a missed heart beat of Observatory Directors across the world.

Eugen Von Gothard's epic photograph heralded the rise of the ordinary amateur Astrophotographer. He was the first of his kind, and was soon to be followed by others; few at first but in the coming decades more and more appeared. These amateurs obtained photographs which were not only of exceptional quality but more importantly produced scientific results of importance to their professional '*betters*'. Alfred Rordame (1863-1931) and Marcel De Kérolyr (1873-1969) were two other members of this pioneering breed of amateur Astrophotographers.

It was Rordame an amateur from Salt Lake City, Utah,who obtained in 1921, photographs of the planet Venus, which for the first time showed conspicuous features on its cloud shrouded disc, using only a 9-inch refractor and a 16-inch reflector. This was six years before Frank Elmore Ross (1874-1960) obtained similar images with the '*Great*' 60-inch and 100-inch reflectors atop Mount Wilson in California.

De Kérolyr was a self-trained French amateur, who in the 1930s took some of the finest astronomical images ever captured of such iconic objects as the '*Horsehead*' Nebula (B33) in Orion and the '*Whirlpool*' Galaxy (M51) in Canes Venatici, with telescopes much smaller than used by many of his professional colleagues.

IX.2

'The Horse's Head'

Modern Astrophotography

Modern CCD Image of the Horse Head Nebula taken in Hydrogen Alpha Light
©Theodore Arampatzoglou, Athens, 2009

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 'Horsehead' Nebula

Ah, to softly slip behind the scene
One clear and snow-draped, silent winter night,
To pierce the density which seems to screen,
Obstruct the splendor of that cosmic light,
To pass beyond that dark and mystic cloud
Which looms like portal in a garden wall,
The ancient loveliness within to shroud,—
How it one's fancy does inspire, enthrall.
In that great starlit garden of the sky
Where light eternal dwells in calm repose
Who knows what beauty there might greet the eye,
What undreamed truth a brief glimpse there disclose
As strange as thought, to thought there is no space,
At will, one's thoughts the universe may embrace.

Lisa Odland, 1940

IX.2.1 'The Grim Reaper's Horse'

As a young boy the night sky was a place of wonder and excitement where I could escape from the cares of everyday life and travel in my mind to worlds beyond imagination. On top of a hill at the back of my house I used to lie for hours under an ink black canopy lit by the faint glow of almost countless fireflies across which a milky white stream spilled from horizon to horizon. With my telescope I saw even more wonders – the pox marked surface of the Moon littered with craters and *'seas',* the belts and spots of Jupiter, the rings of Saturn and the crescent of a cloud shrouded Venus.

All of these sights palled into insignificance when I first saw the photographs in my books of the wonders to be found in the deep recesses of space – the glowing clouds gas, the swirling arms of distant *'Island Universes'* and the glowing spheres of densely packed stars. But of all the wonders to be found amongst these pages, one stood out above any other. It was an image which showed what I can only describe as the head of a black horse, one born out of myth and legend that rose from darkness of hell into the light of heaven. This was my first sight of the most iconic and famous of all Deep Space Objects (DSOs) – a dark nebula known as the *'Horsehead'* [1].

It is now over forty years since I first saw this object which dictated the course of my life. It is without doubt the most difficult of all DSOs any amateur is ever likely attempt to see or image; so much so that some morbid astronomers have dubbed it the *'Grim Reaper'* likening it to one of the four horsemen of the Apocalypse known as '*Death*'. Such a macabre name arose because many an amateur has been heard to speak in jest the words - *'Looking for the Horsehead nebula will be the death of me'.* I, like the great observational astronomer, Stephen O'Meara think, B33 to give it its correct astronomical catalogue designation, is in reality the *'Grim Reaper's'* black steed, which he rides for all eternity, gathering the souls of the dead in his never ending journey across time and space [2].

Even when I was young I was never so naïve as to believe I could possibly see the '*Horsehead*' with my puny 6-inch telescope, given that in the 1960s, only the *'Great Reflectors'* atop the Californian Mountains could capture its true magnificence. This sad realization tempered my view of the wonders of the heavens; and would eventually steer me into a career in mathematical astronomy, far away from the night sky of my youth. Yet, I longed for the day when I could see for myself the head of the *'Grim Reaper's'* mighty stallion, with a telescope I could afford; and the not just remember the image I saw in my books, now, so long ago [3].

In 2006 my wish came true when I saw the '*Horse's Head*'- not through an eyepiece but with the eyes of a CCD Chip, projected onto a computer screen. Although the image was grainy and of very poor quality it was nevertheless there – in front of me, I had waited forty years for such a moment. Over the course of the next few years I have improved upon my first capture of this most personal of all of treasured memories.

‘The Rules of History’

“It is the first and fundamental law of history that it should neither dare to say anything that is false, nor fear to say anything that is true, nor give any just suspicion either of favour or disaffection; that, in the relation of things, the Writer should observe the order of time, and add also the description of places ; that in all great and memorable transactions he should first explain the counsels, then the acts, lastly the events; that in the counsels he should interpose his own judgment on the merit of them; in the acts he should relate not only what was done, but how it was done ; in the events he should show what share chance, or rashness, or prudence had in them ; that in regard to per- sons he should describe not only their particular actions, but the lives and characters of all those who bear an eminent part in the story.”

Marcus Tullius Cicero

Marcus Tullius Cicero (106 BC – 43 BC) from his speech ‘Pro Publio Sestio’

Appendices
Astrophotography Resources

M3 Globular Cluster in Canes Venatici ; George W. Ritchey 1910, 60-inch Reflector

I must say Good-bye, my pupil, for I cannot longer speak;
Draw the curtain back for Venus, ere my vision grows too weak:
It is strange the pearly planet should look red as fiery Mars,
God will mercifully guide me on my way amongst the stars.

Appendix A
Astrophotography Timeline

This Appendix gives a summary of the main events that took place in the historical development of Astrophotography.

Events are included covering the period from 1800 up to the present day (as of 2013), beginning with the '*sun pictures*' of Thomas Wedgwood right through to age of the space telescope and the digital camera.

For each event, the following information is given:

- Date of the Event;
- Name of the Pioneer(s) associated with the Event;
- Type of Event; e.g.:
  - Astrograph;
  - Deep Space;
  - Lunar;
  - Photographic;
  - Sky Survey;
  - Solar;
  - Solar System'
  - Spectroscopy;
  - Terrestrial;
- Description of the Event including its significance in the History of Astrophotography.

Date	Name/Event Type	Event
1800	**Thomas Wedgwood** *Photographic*	Thomas Wedgwood (1771-1805); produces *'sun pictures'* by placing opaque objects on leather treated with silver nitrate. The resulting images deteriorated rapidly.
1802	**William Hyde Wollaston** *Spectroscopy*	William Hyde Wollaston (1766-1828) was the first person to observe the dark lines in the Solar Spectrum, now known as absorption lines; which he incorrectly interpreted as gaps separating the colours of the sun.
1804	**Thomas Wedgwood** *Photographic*	Thomas Wedgwood; in 2008 one of the major historians of early British photography, Dr Larry J Schaaf, has suggested at length that a surviving photogenic drawing of a leaf (formerly attributed to William Fox Talbot) could in fact be by Thomas Wedgwood, and might date from 1804 or 1805. If this can be confirmed, then Wedgwood had succeeded in obtaining a permanent '*fixed'* image, something which he had previously believed not to have done.
1814	**Joseph Von Fraunhofer** *Spectroscopy*	Joseph Von Fraunhofer (1787-1826) rediscovered the absorption lines in the Solar Spectrum, whilst calibrating the optical properties of glass, when working at a military and surveying instruments firm.
1816	**Joseph Nicephore Niepce** *Photographic*	Joseph Nicéphore Niépce (1765-1833) combines the camera obscura with photosensitive paper.
1825	**Joseph Nicephore Niepce** *Photographic*	In 2002, an earlier surviving photograph which had been taken by Niépce was found in a French photograph collection. The photograph was found to have been taken in 1825, and it was an image of an engraving of a young boy leading a horse into a stable. The photograph itself later sold for 450,000 Euros at an auction to the French National Library.
1826	**Joseph Nicephore Niepce** *Photographic*	Produces the first permanent image (Heliograph) using a camera obscura and white bitumen. It shows a view out of a window over roof tops at his family chateau at Le Gras, France. Prior to 2002 it was thought to be the oldest surviving photograph.
1829	**Joseph Nicephore Niepce & Louis Jacques Mande Daguerre** *Photographic*	Joseph Niepce & Louis Daguerre (1787-1851) sign a ten year agreement to work in partnership developing their new recording medium.
1834	**William Henry Fox Talbot** *Photographic*	William Henry Fox Talbot (1800-1877); creates permanent (negative) images using paper soaked in silver chloride and fixed with a salt solution. Talbot created positive images by contact printing onto another sheet of paper. Talbot's *'The Pencil of Nature'*, published in six instalments between 1844 and 1846 was the first book to be illustrated entirely with photographs.

Appendix B
109 Important Astronomical Photographs

This Appendix contains a list of 109 Astronomical Objects and Telescopes which were important to the historical development of Astrophotography. I have called it the 'A' List.

For each object the following information is given:

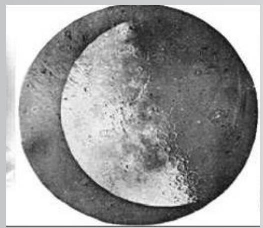
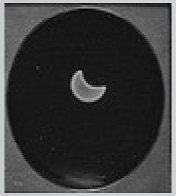
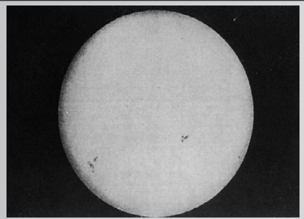
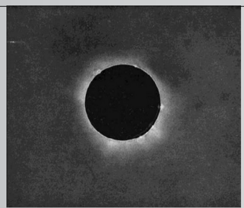
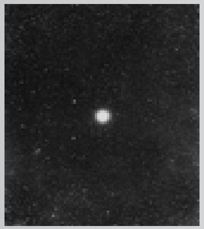
- 'A' List Number, e.g. A32, indicating B33, the '*Horsehead*' Nebula in Orion;
- Photograph of Object, whenever possible the earliest known is shown, if not it is indicated by an '*' to the left of the image;
- Object Name, i.e. Usual catalogue name, e.g B33 for Barnard's Dark Nebula No. 33;
- Common Name, e.g. '*Horsehead*' Nebula;
- Date of the earliest known photograph of the object, e.g. 1888;
- Name of Pioneer(s) associated with the photograph, e.g. Williamina Fleming;
- Constellation in which object is located (if applicable), e.g. Orion;
- Type of Object, e.g. Deep Space Object (DSO), Lunar, Solar, Solar System, Terrestrial
- Right Ascension (RA) and Declination (Dec.) of the Object;
- Magnitude and Angular Size of the Object;
- Whether the Object is visible at Night (), during Daylight () or both ();
- Whether the Object is visible in the Northern (N), Southern (S) or Both (N S);
- Degree of Difficulty in Imaging the Object on a scale of 1 to 5 with 1: Simple, 2: Easy, 3: Difficult, 4: Very Difficult, 5: Exceptionally Difficult
- Notes associated with the object.

The last 11 objects in my list are telescopes. I have included them because these remarkable instruments were used to obtain the images seen throughout the pages of this book, and without them the work of the pioneers who used or built them would have not have existed.

The choice of objects is my own, and I am sure I have left out a number of others which could have been included with some justification.

The 'challenge' for the modern Astrophotographer is to capture all of them using the technical equipment available to him or her. Even with today's '*GO TO*' telescopes, Digital SLRs and Astronomical CCD Cameras it will not be easy.

But when you have done so - reflect on this; if you found it hard then what must it have been like for the early pioneers who went before you?

No.	Image	Name	Common Name	Date/Pioneer	Constellation	Type	RA/Dec	Mag.	Size
A1		**Full Moon**	-	**1840** John William Draper	Zodiacal	Lunar	-	-12.74	29.3’ 34.1’
		In the March of 1840, Dr John William Draper took the first photograph of an astronomical object when he imaged the Moon. In doing so he became the *‘First Astrophotographer’.* The Moon should be the first target for any budding Astrophotographer to image.						**1**	
A2	* 	**Partial Solar Eclipse**	-	**1842** Gian Majocchi	Zodiacal	Solar	-	-	-
		The first photographs of a Partial solar eclipse were obtained by the Italian astronomer, Gian Alessandro Majocchi from Milan on the 8th of July 1842. The three photograph he obtained have not survived. The image shown here is by William & Frederick Langenheim taken on the 26th May 1854.						**3**	
A3		**Solar Photosphere**	-	**1845** Hippolyte Fizeau & Leon Foucault	Zodiacal	Solar	-	-26.74	31.6’ 32.7’
		During the period 1843 to 1845, Hippolyte Fizeau and Leon Foucault had obtained Daguerreotypes of the Solar Photosphere from the Paris Observatory. Only one detailed large scale image has survived that taken on the 2nd of April 1845. It clearly shows the presence of sunspots on the sun’s surface.						**3**	
A4		**Total Solar Eclipse**	-	**1851** M. Berkowski	Zodiacal	Solar	-	-	31.6’ 32.7’
		The first photograph of a Total eclipse of the sun was obtained on the 28th of July at Konigsberg (now Kaliningrad, Russia) by a local Daguerreotypist named Berkowski (his first name is not known), using a small telescope of 2.4 inch aperture attached to the 6 inch Heliometer of the Konigsberg Observatory.						**4**	
A5	* 	**Alpha Lyrae**	Vega	**1850** George P. Bond & John A. Whipple	Lyra	DSO Star	18h 36m 56s +38° 47’ 01”	0.03	-
		On the 17th of July 1850 George Phillips Bond, assisted by Boston the Daguerreotypist John Adams Whipple took the first ever photograph of a star when they imaged Vega (Alpha Lyrae), using the 15” ‘Great Harvard’ Refractor. The image shown here is by Edward Barnard and dates from 1895.						**1**	
A6		**Zeta & 80 Ursa Majoris**	Mizar & Alcor	**1857** George P. Bond	Ursa Major	DSO Stars	13h 23m 55s +54° 55’ 31”	2.23 3.99	-
		On the 27th of April 1857, G. P. Bond using the Harvard 15 inch refractor, with the assistance of John A. Whipple and James Wallace Black obtained the first photograph of a double star - Mizar and its companion Alcor.						**1**	

Appendix C

Chemistry of Photographic Processes

C.1 Overview

Only three chemically based photographic processes were used by Astronomers to any great extent – the Daguerreotype, the Collodion and the Gelatino-Bromide. The Calotype process was very rarely used in Astronomy and only three references to its application have been found in the literature.

A detailed description of the chemistry involved in these four processes is given below, together with an outline of a number of variants which were used during the period 1839 and onwards.

C.2 Daguerreotype

The Daguerreotype [1] is a direct positive process in which a silvered copper plate is made sensitive to light by fuming in iodine vapour. After exposure the latent image is made visible by the fumes of warmed mercury.

The image in a Daguerreotype is formed by the amalgam, or alloy, of mercury and silver. Mercury vapour from a pool of heated mercury is used to develop the plate that consists of a copper plate with a thin coating of silver rolled in contact that has previously been sensitized to light with iodine vapour so as to form silver iodide crystals on the silver surface of the plate.

Exposure times were later reduced by using bromine to form silver bromide crystals, and by replacing the Chevalier lenses with much larger, faster lenses designed by Joseph Petzval.

The image is formed on the surface of the silver plate that looks like a mirror. It can easily be rubbed off with the fingers and will oxidize in the air, so from the outset daguerreotypes were mounted in sealed cases or frames with a glass cover.

When viewing the Daguerreotype, a dark surface is reflected into the mirrored silver surface, and the reproduction of detail in sharp photographs is very good, partly because of the perfectly flat surface.

Although daguerreotypes are unique images, they could be copied by re-daguerreotyping the original.

Invented by Louis Jacques Mande Daguerre (1787-1851), it was revealed to the public on the 19th of August 1839, and remained immensely popular throughout the 1850s, and was especially used by professional portrait photographers.

C.3 Calotype

The Calotype [2] is a photographic process for making negatives on paper in which the latent image is made visible by chemical development. The process was announced to the public by William Henry Fox Talbot on the 10th of June 1841.

The sensitive element of a Calotype is silver iodide. With exposure to light, silver iodide decomposes to silver leaving iodine as a free element. Excess silver iodide is washed away after oxidizing the pure silver with an application of gallo-nitrate (a solution of silver nitrate, acetic, and gallic acids). As silver oxide is black, the resulting image is visible. Potassium bromide then is used to stabilize the silver oxide.

Silver chloride is sometimes favoured over silver iodide because it is less sensitive to temperature. During long exposures in direct sunlight the temperature on the paper can be quite high (see C.6.21 Salted Paper).

The Calotype created a negative image on the silver iodide from which positives could be printed (onto silver chloride paper). This made the Calotype superior in one aspect to the daguerreotype which only made one positive image (whereby it was difficult to get multiple copies).

The essentials of the process remained at the core of numerous variants introduced over the next twenty

Appendix D

Telescope Optical Systems

D.1 Overview

A number of designs of Telescope Optical Systems were used over the last century and a half by Astronomers to take photographs of the Moon, Sun, Planets and Deep Sky Objects (DSOs).

This Appendix describes them in terms of their optical design, including their advantages and disadvantages relating to their usefulness in Astrophotography.

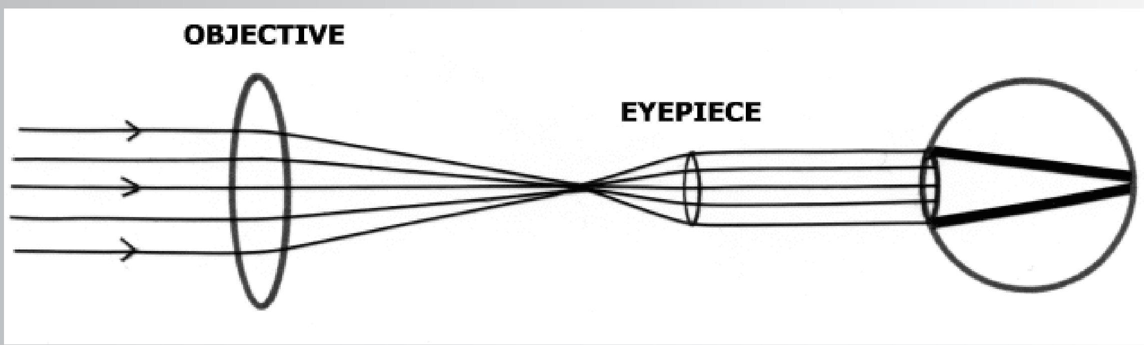
D.2 Refractors

The Refracting Telescope or simply the Refractor is a Dioptric system, i.e. one which uses only lenses.

Refractors were the earliest type of optical telescope. The first practical refracting telescopes appeared in the Netherlands in about 1608, and were credited to three individuals, Hans Lippershey and Zacharias Janssen, spectacle-makers in Middelburg, and Jacob Metius of Alkmaar also known as Jacob Adriaanszoon. The Italian Scientist Galileo Galilei, happened to be in Venice around May 1609, and heard of this remarkable invention and constructed a version of his own. Galileo then communicated the details of *'his invention'* to the public, and presented the instrument itself to the Doge Leonardo Donato, sitting in full council.

All refracting telescopes use the same principles. The combination of an objective lens and some type of eyepiece is used to gather more light than the human eye could collect on its own, focus it, and present the viewer with a brighter, clearer, and magnified virtual image.

D.2.1 Simple Refractor



Simple Refractor Optical System

Refractors have been criticized for their relatively high-degree of residual chromatic and spherical aberration. This affects shorter focal lengths more than longer ones.

In very large apertures, there is also a problem of lens sagging, a result of gravity deforming glass. Since a lens can only be held in place by its edge, the centre of a large lens sags due to gravity, distorting image it produces. The largest practical lens size in a refracting telescope is around 1 meter.

There is a further problem of glass defects, striae or small air bubbles trapped within the glass. In addition, glass is opaque to certain wavelengths, and even visible light is dimmed by reflection and absorption when it crosses the air-glass interfaces and passes through the glass itself. Most of these problems are avoided or diminished by using reflecting telescopes, which can be made in far larger apertures.

Appendix E

Charge Coupled Devices

E.1 Overview

It is no exaggeration to say that the invention of the Charge Coupled Device in 1969 by Willard Sterling Boyle and George Elwood Smith at the AT&T Bell Laboratories, is up to the present time, the single most important ever made in the History of Astrophotography; even greater than the Daguerreotype, Collodion or Gelatino-Bromide processes.

Why? How can I say this without suffering the *'slings and arrows'* of an Army of Photographic Historians?

To answer this, I will just show you three photographs, taken with 4 inch, 8 inch and 200 inch telescopes; only one used a CCD, the other two used 'dry' photographic plates; the photographs were taken in 1888, 1951 and 2009; the cost of the equipment used in today's money ranged from a few thousand dollars up to tens of millions of dollars.

Can you guess which image is which? The answer is at the end of this Appendix. I trust I have justified my bold claim?

A	B	C
		
Date?	**Date?**	**Date?**
Technology?	**Technology?**	**Technology?**
Cost?	**Cost?**	**Cost?**

E.2 Basic Operation

Although not discernible to the naked eye, the CCD chip is basically an array of small sensors, called pixels. In the latest CCD chips used by amateur Astrophotographers, there are several million of these sensors.

You can think of each pixel like a *'bucket'* that collects light. The bucket collects light, just like rain collects in a rain gauge, for the time the sensor is exposed to the light. However, like a rain gauge it can overflow if too much rain falls, so can the sensor overflow in a CCD imager should the pixels be exposed to light for too long.

When the CCD imager is connected to a telescope, the image of the object being looked at is projected onto the CCD chip. As will be the case with most images, there will be bright areas (stars, emission nebulae) and dark areas (barren sky or dark nebulae); the sensors will collect light in proportion to how much light is falling on them. At the end of the exposure some pixels will be quite full while others may be nearly empty.

During an exposure, the light falling onto the CCD chip makes its way into the thousands or millions of pixels (buckets) on the chip. These buckets keep filling up with light until the exposure ends. The next step is to take the contents of the buckets and convert it to a digital word so that the computer can work with it (the initial signal in the pixel is an analogue signal).

The exact process varies from camera to camera, but the basic process is as follows:

Appendix F

Useful Astrophotography Formulae

F.1 Overview

A list of simple mathematical formulae are given in this Appendix, which the reader may find useful in relation to the content of this book, and help him better understand some of the more technically difficult areas.

Sample calculations based on the 8 inch (20cm) Bache Telescope which has a focal length of 44.8 inches (118.8cm) and used photographic plates of 8 inches (20cm) by 10 inches (25cm) are used to illustrate the formulae.

F.2 Telescopes

F.2.1 Focal Ratio

The focal ratio (f) of a telescope is a measure of the '*speed*' of the instrument to capture images of astronomical objects in terms of exposure times on photographic plates or on a CCD chip.

A '*fast*' telescope is one with a small focal ratio of around f5 or less, whilst a '*slow*' telescope has an focal ratio of f10 or higher.

If A is the aperture of the telescope's mirror or objective lens and F is its focal length, then:

Focal Ratio (f) = F/A

So the Focal Ratio of the Bache Telescope is = 44.8/8 = 5.6 or f5.6, i.e it is a '*fast*' telescope.

F.2.2 Eyepiece Magnification

If F is the focal length of the telescope and E the focal length of the eyepiece, then the magnification of the telescope using this eyepiece (M) is given by:

Magnification (M) = F/E

So if the Bache Telescope is fitted with a Plössl eyepiece of focal length 0.5 inches, the magnification obtained will be = 44.8/0.5 = x85.6

F.2.3 Eyepiece Field of View

The True field of view of an eyepiece (FOV) in degrees is given by the formula:

FOV = AFOV*E/F or AFOV/M

where AFOV is the Apparent Field of View of the eyepiece, M is the magnification of the eyepiece, E is the focal length of the eyepiece and F is the focal length of the telescope.

The field stop is a metal ring inside of the eyepiece barrel that limits the field size. It is projected by the eyepiece so that it appears as a circle out in space when you look through the eyepiece. The angular diameter of this circle is called the apparent field of view (AFOV) and is a fixed property for each eyepiece design. For example, Plössl eyepieces have an AFOV of 50°, Radians have 60°, Panoptics have 68°, Naglers have 82° and Ethos eyepieces have 100°.

So if the 0.5 inch focal length Plössl eyepiece of the Bache Telescope has an apparent field of view of 50^o, its true field of view is given by:

FOV = 50*0.5/44.8 = 50/85.6 = 0.584^o

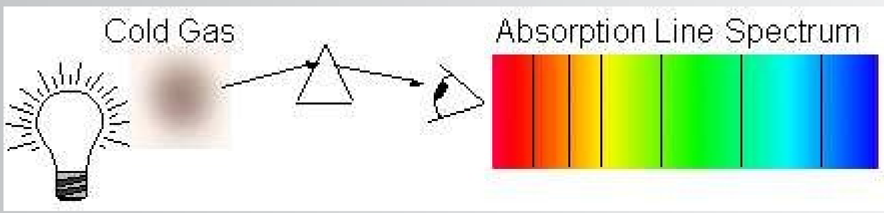
Appendix G

A Brief Glossary of Terms

In order to provide a complete definition of all the terms used in the '*Catchers of the Light*' would require another book of the same size! This I do not propose to do. However, I have compiled this *'short'* **Glossary of Terms** to help those readers with a general educational background to understand the more important and relevant of the many tens of thousands to be found in the vast literature relating to astronomy, Astrophysics, photography and optics etc.

A:

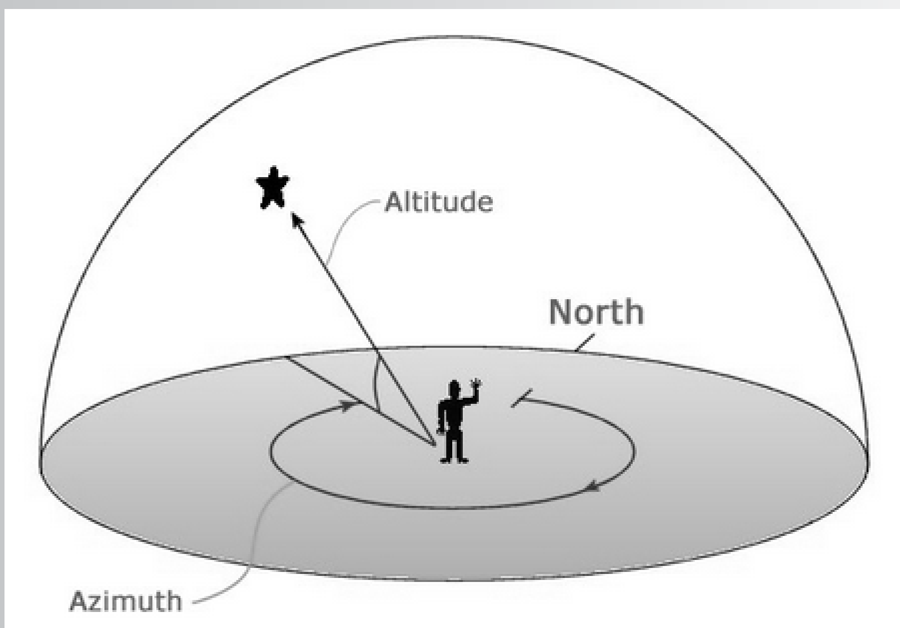
Absorption Line: A dark line in the spectra of astronomical bodies caused by the absorption of light at a particular wavelength due to the presence of a chemical element, which also can produce a bright emission line at the same wavelength.



Achromatic: The term literally means without colour and is used in the context of telescope design. In particular an achromatic refractor is one whose objective is made of two lenses made from differing types of glass to reduce the effect of chromatic aberration (see section D.2.2 of Appendix D)

Astrograph: A telescope specifically designed for the sole purpose of astrophotography, it can be either a refractor, reflector or catadioptric system.

Altitude: Is used to describe the location of an object in the sky as viewed from a particular location at a particular time. The altitude is the distance an object appears to be above the horizon. The angle is measured up from the closest point on the horizon.



Astrometry: A branch of astronomy that involves precise measurements of the positions and movements of stars and other celestial bodies.

Astronomical Spectroscopy: A branch of astronomy that studies the spectra of astronomical objects - stars, planets, galaxies, nebulae and supernovae in order to obtain information about them, such as structure, composition and distance.

Appendix H

Astrophotographers Family Pedigrees

This Appendix contains a Family Pedigree for each Astrophotographer featured in the Book, when known.

In order to save space only the direct male line is included.

The Genealogical information presented here, is not intended to be complete and definitive.

A person can and often does spend a lifetime researching their own family's history, to do so for forty seven individuals included here, would be an impossibility.

In a small number of cases very little information is known regarding the ancestry of certain Astrophotographers and as such no pedigree is provided.

This unfortunately has proved to be the case for Wilhelm Oswald Lohse and Marcel De Kerolyr. For Eugen (Jeno) Von Gothard only a sketchy pedigree has been included.

For each Astrophotographer the following information is given (when known) for every generation through the male line from the earliest known ancestor up to recent times:

- Date and Place of Birth;
- Date and Place of Marriage(s);
- Name of Spouse(s); Date and Place of their Birth, Death and Burial;
- Names of Children; Date and Place of their Birth, Marriage, Death and Burial;
- Date and Place of Death;
- Date and Place of Burial.

Although William Henry Fox Talbot (1800-1877) has no specific chapter devoted to him, nevertheless a Pedigree has been included, for this important pioneer of early photography.

In addition for each Pedigree the principal sources used to compile them have also been included.

Accompanying the Pedigrees are a number of '*snippet panels*' and photographs/illustrations. These have been added so as to make the Appendix more interesting, in what otherwise is a somewhat '*dull read*'. They contain further information related to the '*Catchers*', but not included in main text for lack of space.

The following Abbreviations have been used: **b** [birth], **c** [christened/baptized], **m** [married], **d** [died], **bu** [buried].

Armand Hippolyte Louis Fizeau was one of the early pioneers of photography, who took some of the first Daguerreotype images in the 1840s, mainly of architectural scenes in Paris. The photograph shown here was taken in 1840 of the Roman Catholic Church of St. Sulphice, Paris. The present church was founded in 1646 by the parish priest Jean-Jacques Olier (1608–1657), on the site of an earlier 13th century Romanesque church. Its construction took about 140 years, and by 1732 the church was mostly completed.

St. Sulphice Church, Paris, France, Hippolyte Fizeau, Daguerreotype of 1840

H.1 Alfred RORDAME (1862-1931)

Jacob RORDAME
\+ **Karoline SIMMONSEN**
1 **Alfred RORDAME** b. 8 Jun 1862 Akershus, Norway
d. 30 Nov 1931 Salt Lake City, Salt Lake, Utah, USA
bu. 2 Dec 1931 Mount Olivet Cemetery, Salt Lake City, Salt Lake, Utah, USA
\+ **Gertrude Alice BUCKERIDGE** b. 29 Dec 1870 Theale, Berkshire, England
m. 3 May 1890 Salt Lake City, Salt Lake, Utah, USA
d. 24 Oct 1957 Salt Lake City, Salt Lake, Utah, USA
bu. 28 Oct 1957 Mount Olivet Cemetery, Salt Lake City, Salt Lake, Utah, USA
1 **John C. RORDAME** b. 12 Feb 1891 Salt Lake City, Salt Lake, Utah, USA
d. 12 Feb 1891 Salt Lake City, Salt Lake, Utah, USA
bu. 14 Feb 1891 Mount Olivet Cemetery, Salt Lake City, Salt Lake, Utah, USA
2 **Alfred Arthur Walter Goltered RORDAME** b. 23 Feb 1903 Salt Lake City, Salt Lake, Utah, USA
d. 31 Jul 1940 Pocatello, Bannock, Idaho, USA
bu. 4 Aug 1940 Mount Olivet Cemetery, Salt Lake City, Salt Lake, Utah, USA
\+ **Mildred DERRICOTT** b. 20 Jul 1908 Liberty, Bear Lake, Idaho, USA
m. 30 Mar 1933 Farmington, Davis, Utah, USA
d. 10 Jan 2000
1 **Alfred RORDAME** b. 11 Jun 1938 Salt Lake City, Salt Lake, Utah, USA
\+ **(---) (---)**
1 **Alfred RORDAME** b. abt 1955 Salt Lake City, Salt Lake, Utah, USA
2 **Andrew Rocky RORDAME**
3 **Holly Ramona RORDAME**
4 **Tammy Sue RORDAME**
3 **Judith Frances Caroline RORDAME** b. 11 Jan 1892 Salt Lake City, Salt Lake, Utah, USA
d. 26 Nov 1984 Salt Lake City, Salt Lake, Utah, USA
\+ **Archibald Fitzgerald McALLISTER** b. 14 May 1886 Salt Lake City, Salt Lake, Utah, USA
m. 29 Sep 1892 Salt Lake City, Salt Lake, Utah, USA
d. 30 Dec 1969 Salt Lake City, Salt Lake, Utah, USA
4 **Beatrice Alice RORDAME** b. 10 Apr 1894 Salt Lake City, Salt Lake, Utah, USA
d. 5 Dec 1991 Salt Lake City, Salt Lake, Utah, USA
\+ **Percy James PARSONS** b. abt 1890
m. 3 Jan 1912 Salt Lake City, Salt Lake, Utah, USA
5 **(---) RORDAME** b. 1 Nov 1896 Salt Lake City, Salt Lake, Utah, USA
6 **Gertrude Elsie Eugene RORDAME** b. 1 Dec 1897 Salt Lake City, Salt Lake, Utah, USA
d. 9 Mar 1975
\+ **Orlan Russell WILLIAMS** m. 27 Apr 1922 Salt Lake City, Salt Lake, Utah, USA
7 **Kenneth Ralph RORDAME** b. 14 Oct 1907 Salt Lake City, Salt Lake, Utah, USA
d. 7 Dec 1912 Salt Lake City, Salt Lake, Utah, USA
bu. 9 Dec 1912 Mount Olivet Cemetery, Salt Lake City, Salt Lake, Utah, USA

1 2 3 4 5

Sources:

The following principal sources were used in the compilation of the Family Pedigree for Alfred Rordame:

1. Alfred Rordame I Birth; Norway Baptisms 1634-1927, Film No. : 446237, Piece No.: 89169;
2. Birth, Marriage and Death Certificates, General Register Office of England and Wales;
3. USA Census 1880-1940, Available at Ancestry.com;
4. Utah, County Marriages, 1887-1937; https://familysearch.org;
5. Utah, Salt Lake County Death Records, 1908-1949; https://familysearch.org;
6. Utah, Deaths and Burials, 1888-1946; https://familysearch.org;
7. Utah Death Certificates, 1904-1956; https://familysearch.org;
8. Monumental Inscriptions, Mount Olivet Cemetery, Salt Lake City, Utah;

The Author

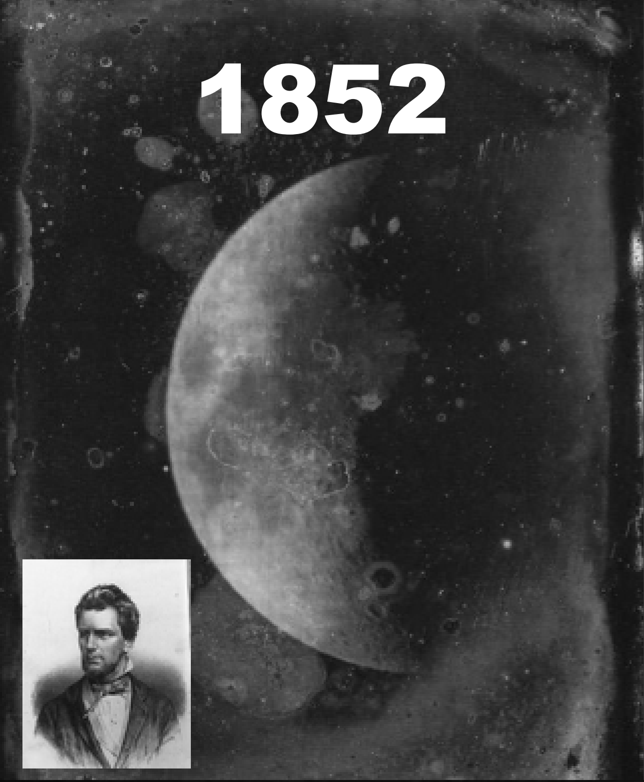
Stefan Hughes began his career a professional astronomer, gaining a 1st Class Honours degree in Astronomy from the University of Leicester in 1974 and his PhD four years later on the '***Resonance Orbits of Artificial Satellites due to Lunisolar Perturbations***', which was published as a series of papers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

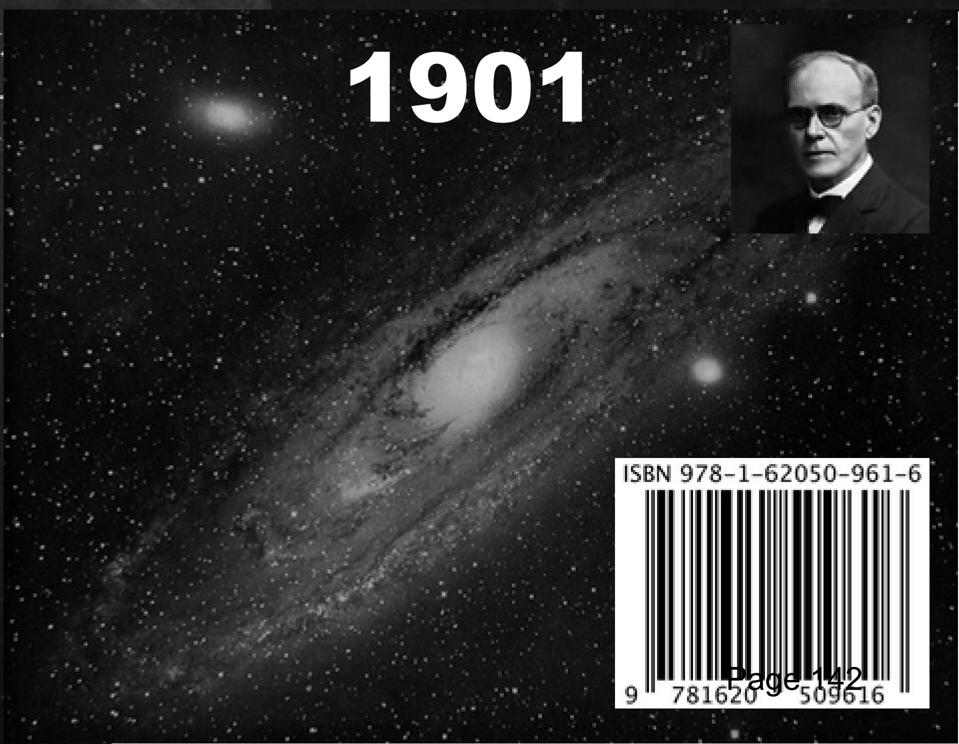
After graduating he became a Research fellow in Astronomy, followed by a spell as as a University lecturer in Applied Mathematics at Queen Mary College, London. Then came a ten year long career as an IT Consultant, working on large technology infrastructure projects.

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 ten years he has been imaging the heavens, as well as researching and writing the '***Catchers of the Light'*** - A History of Astrophotography.





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