ISAACS ROBERTS'S PHOTOGRAPHS OF CLUSTERS AND NEBULAE

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Isaacs Roberts (1829-1904) was one of the pioneers of deep-sky astrophotography. He took almost 2500 plates of deep-sky objects from 1883 to 1904[1].

Henry Draper (1837-1882) and Andrew Ainslie Common (1841-1903) showed what was possible in long exposure deep space astrophotography by imaging the Great Orion Nebula (M42). Roberts was the first to image a large variety of objects. These astrophotographs were published in a two volume set entitled "*A Selection of Photographs of Stars, Star-Clusters and Nebulae".* The first volume was published in 1893 and the second in 1899[2]. Isaacs Roberts sent copies of these volumes to several observatories and libraries around the world, including the library of the Lisbon (Royal) Observatory (Figure 1).

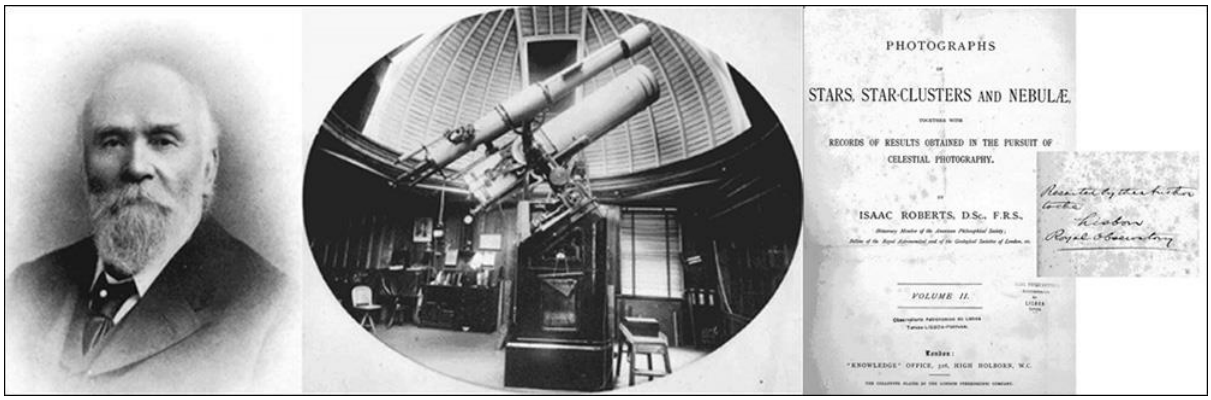

Figure 1- Isaacs Roberts (1829-1904) (left), Twin Equatorial: 20-inch reflector and 7-inch refractor (middle), Photographs of Stars, Star-Clusters and Nebulae, Volume II, presented by the author to the Lisbon Observatory.

Isaacs Roberts bought his first telescope in 1878 when he was 49 years of age. This first instrument made by Cook & Sons was a very expensive 7-inch[3]. Roberts used the Cook refractor mainly for visual observations at his home in Rock Ferry, Birkenhead.

In 1883 Roberts moved to Kennessee near the small village of Maghull. Soon after, he began experimenting with astronomical photography using portrait lens ranging in aperture from 3/8 to 5 inches. At this time Roberts was already 54 years of age. From 1883 onwards until his death in 1904 Roberts photographed almost every deep-sky object known and visible from the location of his observatory. He was the first to image, with considerable detail, several well-known objects:

[1] Roberts, D.K. (1907). Preliminary catalogue of Isaac's Roberts's collection of photographs of celestial objects. *Astronomische Nachrichten*, 174: 13-30. His widow, Dorothea Roberts compiled a catalogue of 2485 plates of stars, clusters, nebulae and other objects, of which the majority (1412) were obtained with a 20-inch reflector.
[2] Roberts, I. (1899). *Photographs of Stars, Star-Clusters and Nebulae*. Volume II. "Knowledge office, High Holborn, W.C.: 178 pp.
[3] The 7-inch Cooke refractor would have a cost more than a lifetime of wages of an average worker living in Liverpool in the 1870s.

Andromeda Galaxy (M31); Dumbbell Nebula (M27); Hercules Cluster (M13), Pleiades (M45); Bodes Galaxy (M81); Sombrero Galaxy (M104)[4].

The majority of Roberts' astrophotographs were made with two Grubb reflectors (18-inch and 20-inch). The 20-inch reflector was mounted in a Twin Equatorial (Figure 1). The two telescopes (20-inch reflector and 7-inch refractor could be independently moved in declination.

By 1890 Roberts moved to yet another location where he established a new observatory which he appropriately named "*Starfields*". The location of Starfields was on the summit of Crowborough Beacon, about 800 feet above sea level (Figure 2). Roberts described the facilities in 1891[5].

The observatory is placed on the summit of Crowborough Hill, in Sussex, which is one of the highest points in the South of England, and commands the horizon without material obstruction. The floor of the observatory is 780 feet 7-inches above sea level. The whole of the buildings are erected in a level platform of concrete, the top of which is above the ground, which slopes towards the south-cast. The buildings are one story in height, and the floors are raised fifteen-inches above the platform or terrace, and are on one uniform level throughout. The limit of one story in height permits the telescopes to be brought down to within twenty degrees of the horizon when pointed over the roof of the house. The observatory is placed due south, and is 20 feet square inside, with a transit room opening from it on the west side. Adjoining the observatory on the north side is a physical laboratory and chemical laboratory, with darkroom and photo enlarging arrangements. These and the observatory are connected with the dwelling house by a corridor, on one side of which is a mechanic's shop, heating chamber and library. At the end of the corridor is the dwelling-house. The dome of the observatory is hemispherical and constructed with wood ribs, sheeted with wood and covered with copper. The dome has two slits, each 3 feet 8-inches in width, parallel with each other, and 5 feet 8-inches from centre to centre. The shutters of the lower half of each slit slide horizontally round the dome, and the upper halves slide upon and over the top of the dome, so that both slits can be opened full breadth from the horizon to 18-inches beyond the zenith. By opening both slits the observatory is soon cooled down to the external temperature; but there is one disadvantage in this dual slit plan – it gives the dome a pole, which in some positions of the telescope is a little troublesome. The latitude of the observatory is N. 51^{o} 3' 7"; longitude E. 0h 0m 37s. The site of the observatory was selected after much inquiry and investigation as to probability of the occurrence of numerous clear intervals of sky during the year suitable for the pursuit of stellar photography, and although it is premature to express a decided opinion, I am quite safe in stating that this locality is an improvement upon the former site of observatory at Maghull. It may interest some to know that I commenced building the observatory and house in the month of September 1889, and by September 1890 the buildings were finished and occupied, and some ten tons weights of telescopes, apparatus, and books were dismounted, conveyed and re-erected on Crowborough Hill within twelve months' time. The photographic work was continued at Maghull till the month of June 1890, and resumed at Crowborough in the following October.

In the preface of "*A Selection of Photographs of Stars, Star-Clusters and Nebulae"* (Volume II) Roberts describes his aims:

[4] James, S.H.G. (1993). Dr. Isaacs Roberts (1829-1904) and his observatories. *Journal of the British Astronomical Association*, 103, 3: 120-122. Hughes, S. (2012). *Catchers of the Light*. eBook

[5] Roberts, I. (1891). New observatory at Crowborough Hill Sussex. *MNRAS,* 51: 118-119.

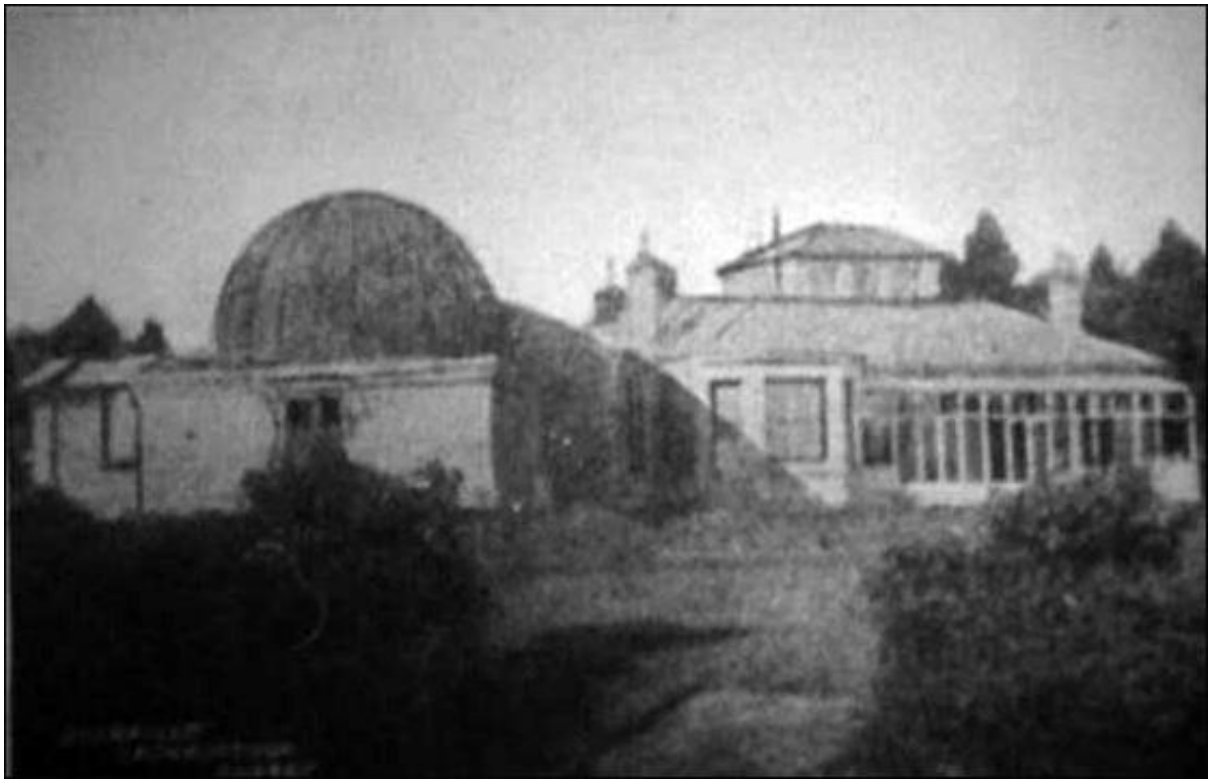

Figure 2- “Starfield”, Isaac Roberts's observatory and home in Crowborough, Sussex

My intention, in the pages following, is to convey in brief, and I hope clear form, my views concerning some of the results already obtained by the aid of photography in the elucidation of celestial problems, the complete solution of which cannot for many years yet be obtained; and I may here quote from the preface to the volume, issued in the year 1893, of A *Selection of photographs of Stars, Star-Clusters, and Nebulae*, the following paragraphs, which are applicable also to the present volume.

"It has been my aim, in publishing the photographs and descriptive matter introduced in the following pages, to place data in the hands of astronomers, for the study of astronomical phenomena, which have been obtained by the aid of mechanical, manipulative, and chemical processes of the highest order at present attainable; and that such data should be, as regards the photographs, free from all personal errors."

"The photographs portray portions of the Starry Heavens in a form at times available for study, and identically as they appear to an observer aided by a powerful telescope and clear sky for observing."

In the processes employed for obtaining the photographic illustrations contained in this volume the same instruments have been used, and the same care has been exercised in the production of the illustrations of the various objects as in the first volume; but owing to improvements in the manufacture of photographic films, and to the extended data now available beyond that which had been obtained up to the year 1893, when the first volume was published, certain deductions concerning the evolution of stellar systems are now permissible which six years ago would have been justly considered premature. The evidence now published appears to me of so striking a character that it should no longer be withheld from discussion. In presenting it I have endeavoured to avoid personal predilections or bias of any kind, and would only ask for the same fairness in any criticism to which my views may be submitted.

Isaacs Roberts.
Starfield, Crowborough Hill, Sussex.
December, 1899.

Issacs Roberts also described in Volume II the deterioration of Negatives and the discoloration of gelatine films (fading star images and nebulosity):

DETERIORATION OF THE NEGATIVES

If a reason had to be given in addition to the obvious advantage of this method of publication by printing the photographs with permanent ink it would be afforded by the fact that the records obtained by photography are peculiarly liable to be lost by accidental breakage of the glass negatives. Besides this there is the certainty that after the lapse of a limited number of years the gelatine films will become discoloured; the images will fade, and the faint stars and the faint nebulosities will entirely disappear from view.

I have had within my own experience proofs that the faint stars fade from the films, and will give the following examples: On the loth February, 1886, a photograph was taken of the region of the sky with the co-ordinates R.A. 9h. 40m. Dec. North 72° 0 at the centre of the plate; exposure 15 m.; area of the plate four square degrees.

Shortly after the photograph was taken I counted 403 star-images on the negative; and on 29th May, 1895, I again counted the stars on the same negative, and found only 272. Therefore, stars to the number of 131 had entirely disappeared from the film in the course of nine and a-quarter years.

Another photograph of identically the same region was taken with an exposure of fifteen minutes on the 22nd March, 1886, and soon after that date I counted 364 stars upon the negative. In May, 1895, I again counted the stars, and found only 234. Therefore, 130 star-images had disappeared from the film in the interval of nine and one-fifth years. These are only two of several instances I could adduce to prove that faint star-images fade from the negatives.

It follows from this evidence that the following photographs, which are printed in permanent form with printer's ink, though they fail to show all the faint stars and faint nebulosities that are visible on the original negatives, yet the objects are depicted to the degree of faintness that would be represented by stars of about the 17th magnitude; and it will be conceded that this is a great advance upon the records made from eye observations and drawings by hand-work, which were the only methods of astronomical recording till recent years, when the photographic method was introduced.

After the lapse of a few years, when other photographs of regions of the sky which are coincident with those here charted have been taken, the work of correlating may be profitably undertaken, for there will be ample material available, in a reliable form, for the astronomical measurers, computers, and deducers of laws. We in these days can only desire that we might live to see the results of their labours.

EFFECTS OF ATMOSPHERIC GLARE AND OF DIFFRACTION UPON THE FILMS OF PHOTOGRAPHIC PLATES.

Very sensitive gelatine films, such as are vised in photography, when exposed during several hours to the sky in taking stellar photographs, become more or less darkened during development. The darkening is chiefly due to atmospheric glare caused by star-light ; and the nebulous circles seen round the bright stars are caused by the glare and by diffraction effects produced by the objectives, or mirrors, of the instruments employed in photographing.

I have made some experiments to enable us to judge to what extent the glare and diffraction affect the finished photographs, a summary of which experiments may be given here. They were made by exposing simultaneously plates in the 20-inch reflector, the 5-inch lens camera, and to the sky in a blackened box, measuring 7-inches square by 12-inches in height, with the open end exposed to the zenith, the exposures respectively being made during precisely equal intervals of time. The plates were selected so as to be equal in sensitiveness, and the development was performed in a similar manner in each coincident trial.

The plates exposed in the box were 6-inches square, and equal areas on each of them were (1) left uncovered; (2) covered with black paper; (3) covered with different thicknesses of polished plate glass. The plates when developed showed the comparative effects of the unobstructed full sky glare as well as

the effects of the application of complete and partial covering with plates of glass or with densitometer figured scales.

The following are some of the results obtained : The plates referred to as measuring 6-inches square and exposed in the box to the sky at the zenith showed, after development, those parts which were covered with black paper as if they were clear glass no photographic effect being perceptible whilst the parts covered with polished plate glass of the respective thickness of 11.26, 2.52, and 45 millimetres, showed gradations in the darkening of the films proportional to the absorption by the glass and reflections from the surfaces. The parts which were exposed uncovered showed the films to the darkened by the sky glare to the density of the images of stars of about the 16th magnitude on plates exposed during the same time for two and a-half hours in the 20-inch reflector. Similar results were obtained by exposing plates during two and a-quarter hours in the 20-inch reflector, and simultaneously to the sky under a figured sensitometer scale.

These experiments point to a source of spurious nebulosity, and also to the probable limit of the applicability of the photographic method in the delineation of faint stars and faint nebulosity. So far as I am able at present to judge, under the atmospheric conditions prevalent in this country, the limit of the photographic method of delineation will be reached at stellar, or nebular, light of the feebleness of about 18th magnitude stars. The reason for this inference is that the general illumination of the atmosphere by star-light concentrated upon the film by the instrument will mask the light of objects that are fainter than about 18th magnitude stars.

Of course, the inferences here stated cannot be considered as the final solution of the problem, for photographs will have to be taken by various instruments under clear atmospheric conditions and the results checked by eye observations, aided by the most powerful telescopes, before finally can properly be pronounced.

ARRANGEMENT OF THE PLATES.

The plates are arranged in classes or groups so as to indicate apparent physical relationship between them, and the Right Ascensions are, as far as practicable, given in the order of time within each group.

The edge next to the printed heading on each plate is the south, and the lower edge the north; the right is the following, and the left the preceding edge.

The scales of the photographs, which are given in the letterpress, are such that by eye alignments of the stars, without the application of measuring instruments, changes which have taken place in their positions or in the structures of the nebulosities, if these changes should not be less than about five seconds of arc in extent, could be detected by comparing corresponding dual plates in this simple manner. The examination and comparison of stars, both as regards their positions and magnitudes, could thus be made in a single day though they should number several thousands on the dual photographs.

Besides this alignment method, measurements by scale and compasses, or by a réseau on glass or other transparent substance, or by a rectangular L-shaped metal rule divided into millimetres on both limbs, or by the superposition of the plates upon each either, are obvious methods available for detecting changes in the position angles and magnitudes of the stars shown on the photographs.

INSTRUMENTS

The instruments employed were the silver-on-glass reflector of 20-inches aperture and 98-inches focus; and a specially-made triplet portrait-lens of 5-inches aperture and 19.22 inches focus, by Messrs. Cooke & Sons.

DURATION OF THE EFFECTIVE EXPOSURES GIVEN TO PHOTOGRAPHIC PLATES

It is a general opinion that the longer the time a sensitive film is exposed, in a photographic instrument, under clear atmospheric conditions, the greater will be the number of stars and the extent of nebulosity imprinted upon the film. But so far as my experience enables me to judge, after twelve years' use of the 20-inch reflector, and more than two years' use of an excellent and specially-made

portrait lens combination of 5-inches aperture and 19-inches focus, the limit of photographic effect is reached sometime within ten to twelve hours on clear nights, and with very sensitive films, in the 20-inch reflector. With the 5-inch lens very much longer exposures may be given before the darkening of the films, by atmospheric glare and diffraction effects, reach the same degree of density as in the reflector.

The photographic effect produced by the 5-inch lens with an exposure of two or three hours and upwards is about two stellar magnitudes less than that given by the reflector in the same time and with films of equal sensitiveness. It would, therefore, appear that, given sufficient time, the atmospheric glare would, in both instruments, mask or extinguish the light of faint stars and faint nebulosity, which is provisionally assumed to be equal to that of 18th magnitude stars.

Figure 3- M31 (20-inch *f*/4.9) 90 min (October 17, 1895), M 33 (20-inch *f*/4.9) 135 min (November 14, 1895).

Figure 4- M 42 (20-inch *f*/4.9) 90 min (January 15, 1896), M 1 (500 mm *f*/4.9) 60 min (January 25, 1895).

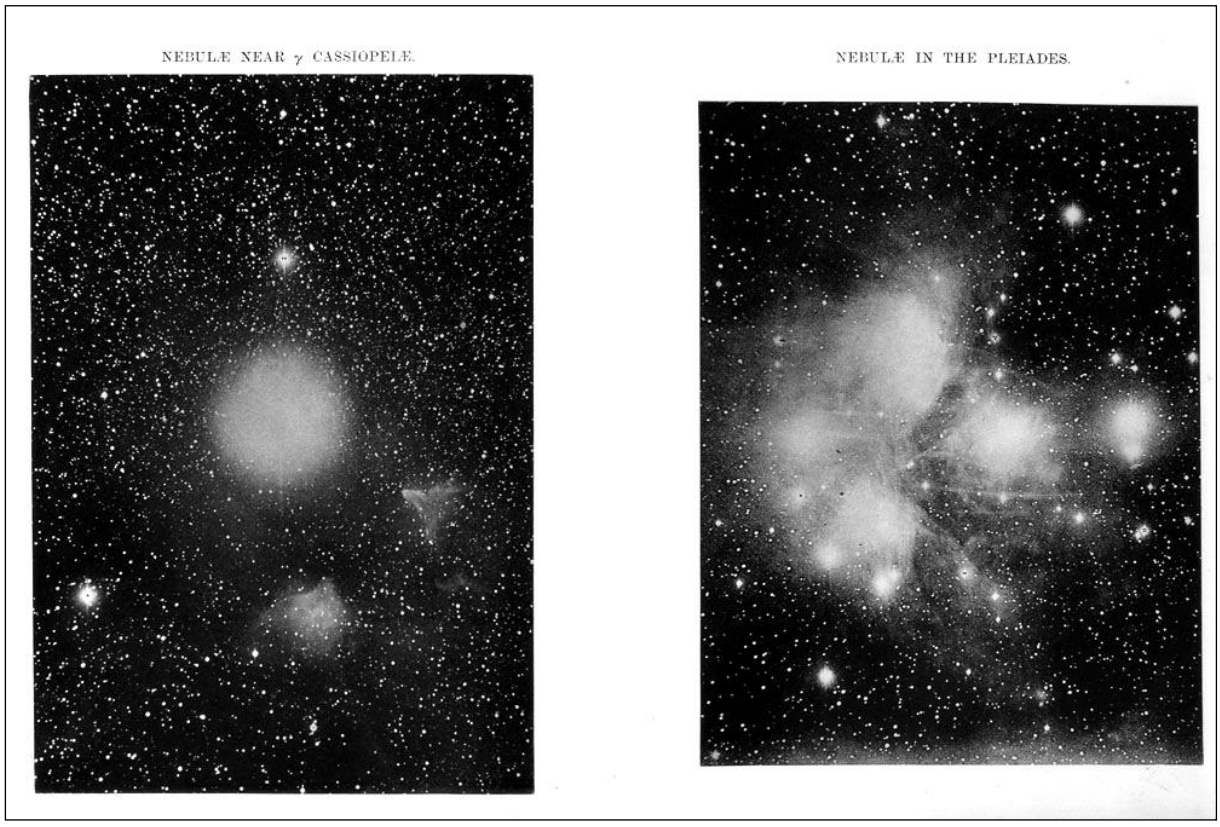

Figure 5- Gamma Cassiopeiae (20-inch *f*/4.9) 90 min (October 25, 1895), M 45 (20-inch *f*/4.9) 610 min (December, 22, 23 & 25, 1897).

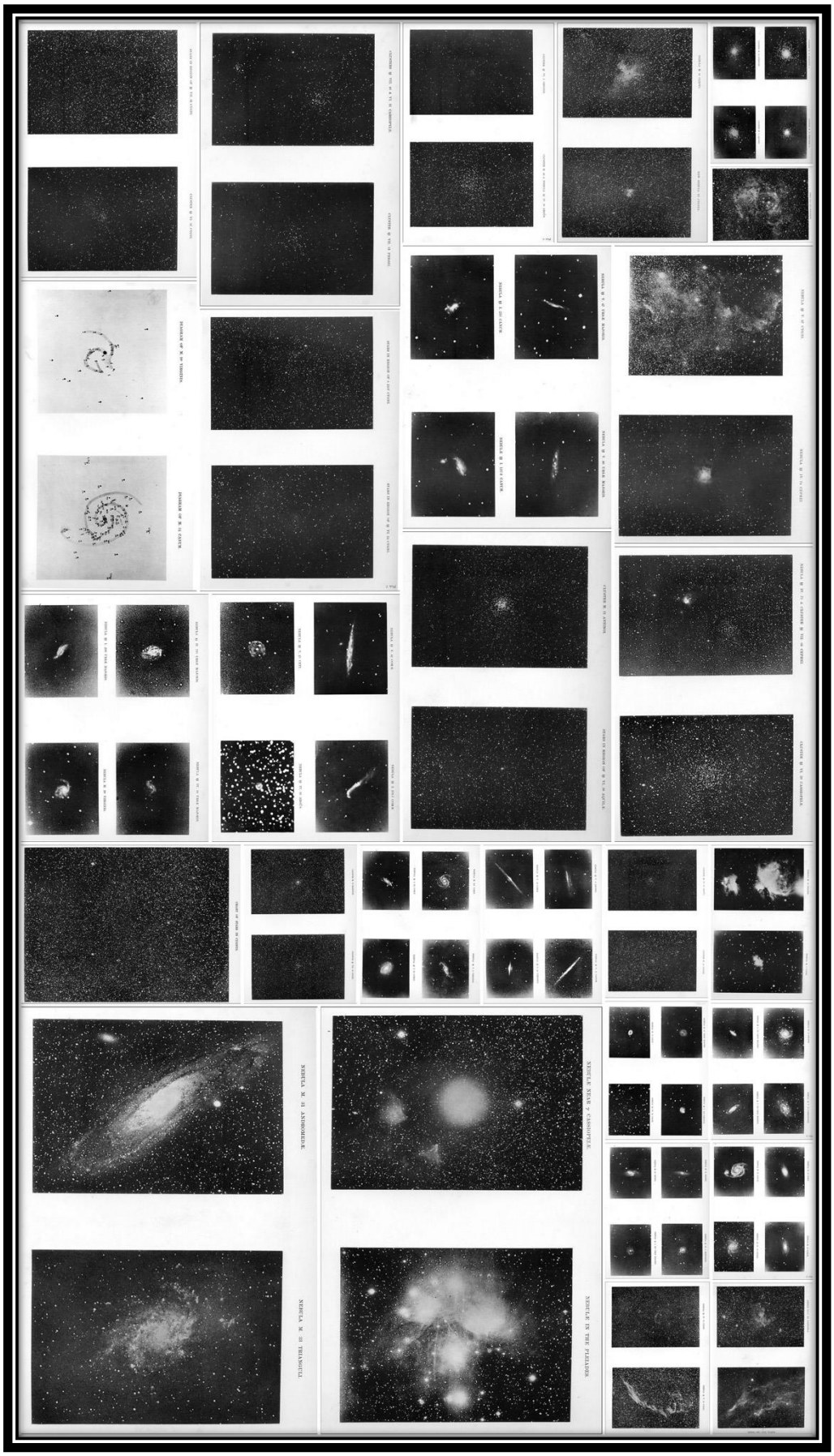

Figure 6- *Photographs of Stars, Star Clusters and Nebulae*, Volume II – Plates

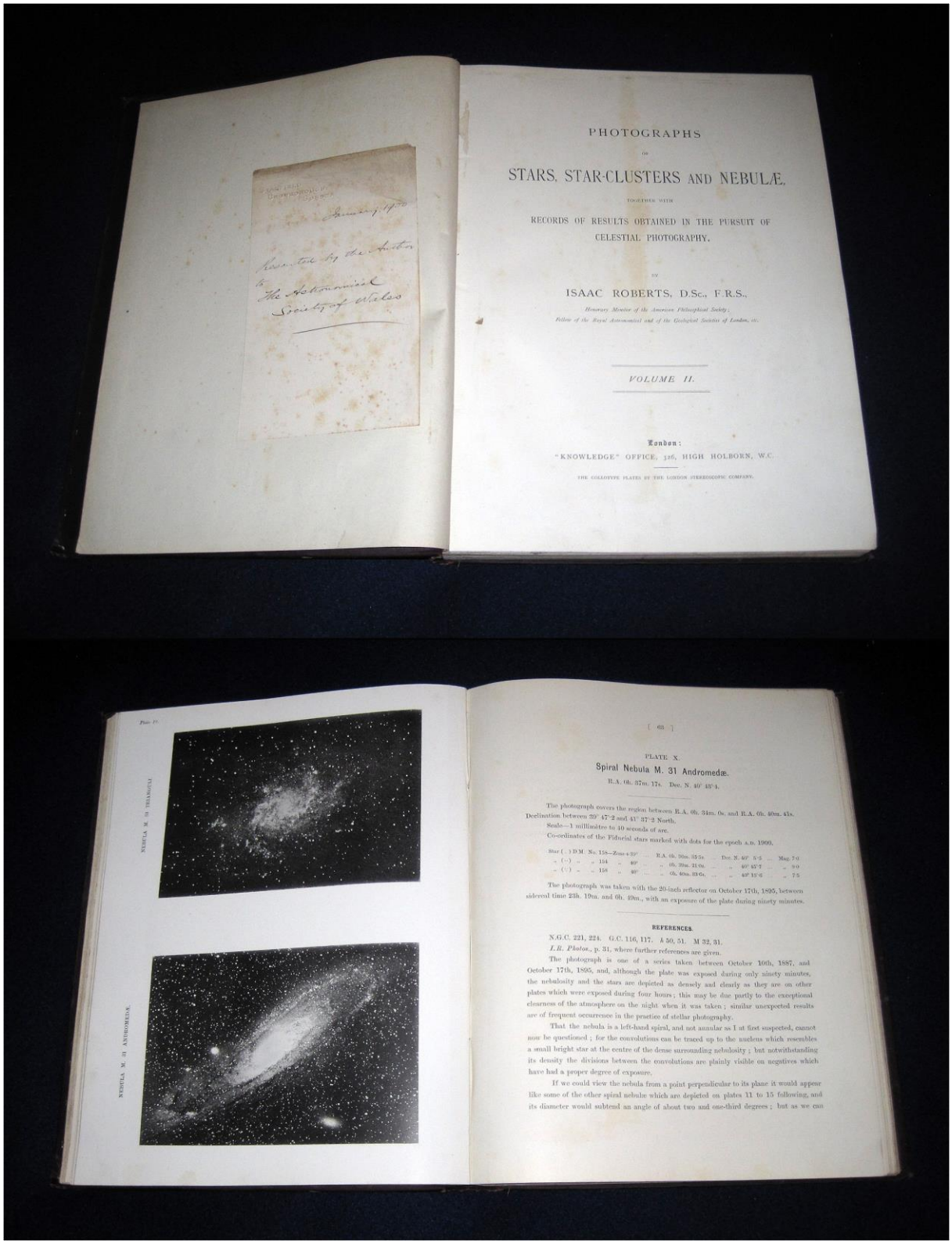

Figure 6- Roberts, I. (1899). *Photographs of Stars, Star-Clusters and Nebulae*. Volume II. "Knowledge office, High Holborn, W.C.: 178 pp. Author's personal copy.