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HENRY DRAPER

RESEARCHES ON ASTRONOMICAL SPECTRUM-PHOTOGRAPHY

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RESEARCHES

ON

ASTRONOMICAL SPECTRUM-PHOTOGRAPHY.

BY THE LATE

PROFESSOR HENRY DRAPER, M.D., LL.D.

Extracts from the Original Note Books,

WITH AN INTRODUCTION AND DESCRIPTION OF THE APPARATUS,

BY PROFESSOR C. A. YOUNG;

AND MEASUREMENTS AND DISCUSSION OF THE PLATES,

BY PROFESSOR E. C. PICKERING.

ALSO, REPRINTS OF DIFFERENT PAPERS UPON THE SUBJECT, AS ORIGINALLY PUBLISHED BY DR. DRAPER.

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1884.

VIII.

RESEARCHES UPON THE PHOTOGRAPHY OF PLANETARY AND STELLAR SPECTRA.

By the late Henry Draper, M. D., LL. D.

With an Introduction by Professor C. A. Young, *a List of the Photographic Plates in Mrs. Draper's Possession, and the Results of the Measurement of these Plates by* Professor E. C. Pickering.

Presented April 11, 1883.

Introduction.

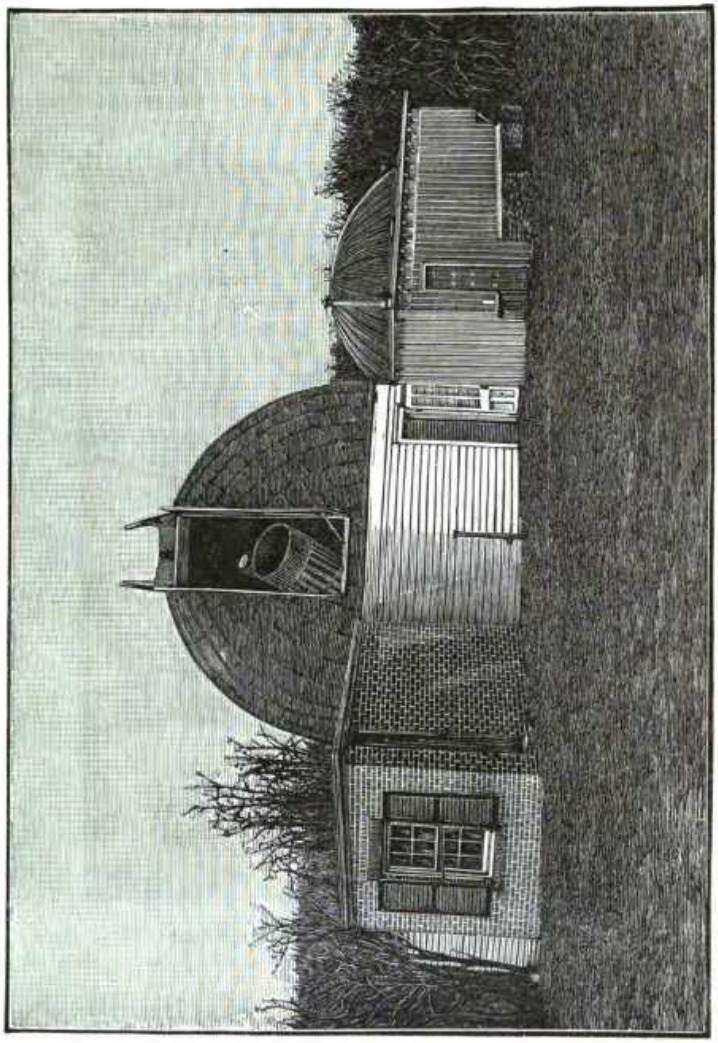
The early successes of Dr. Draper in the construction of his 15½-inch reflector, and his photography of the moon, together with his studies in spectrum photography in 1869 and 1870, led him to desire to extend his work to the investigation of stellar spectra. It was with this object specially in view that he constructed in 1869 and 1870 his great 28-inch silvered glass reflector, which was finally completed and ready for work in 1871, and in May, 1872, he obtained his first photographs of the spectrum of *a* Lyræ, by merely inserting a quartz prism in the path of the rays just inside the focus of the small mirror. The plates obtained on this occasion failed, however, to show any lines.

In August of the same year he succeeded by the same method in getting plates showing four lines in the spectrum of the same star, the least refrangible line being near G.

Other lines of work connected with investigations of the solar spectrum, and with the superintendence of the photographic preparations for the transit of Venus in 1874, occupied most of Dr. Draper's time for the next two or three years.

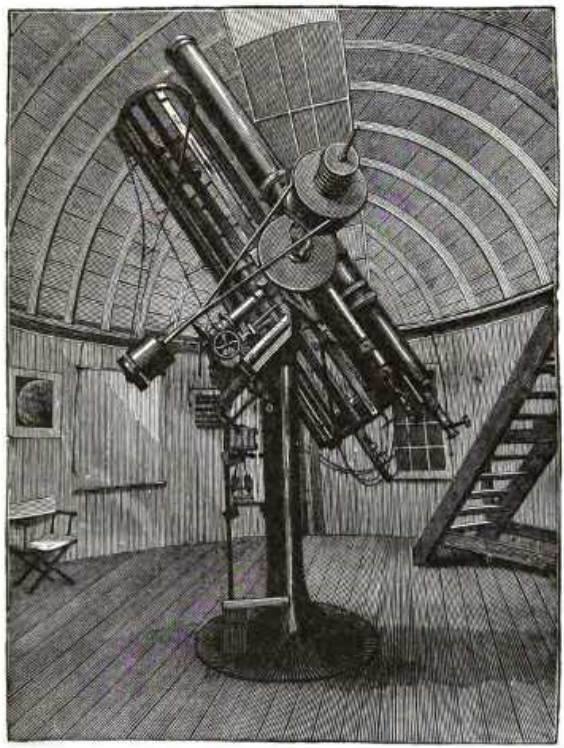
In 1875 he obtained a fine 12-inch refractor from A. Clark & Sons, which he mounted upon the same stand with his 28-inch reflector, and in 1876 he resumed his operations upon stellar spectra, and obtained a number of photographs, some of them with this 12-inch instrument and some with the 28-inch.

In the summer of 1880 he exchanged the 12-inch instrument for an 11-inch by the same makers, the new instrument having a special cor-



recting lens fitted to be placed in front of the object-glass to adapt it to photographic work.

At first, and until 1879, wet collodion plates were used in all these experiments; after that date, he used exclusively the dry plates of Wratten and Wainwright, to which, during a visit to England in 1879,



the attention of Dr. Draper was called by Dr. Huggins, whose admirable work in the same line of research is so well known to every one interested in such matters.

As will be easily understood, these operations upon stellar spectra were by no means carried on continuously, but only during Dr. Draper's summer residence at his country place, and in the intervals of other,

to him, even more absorbingly interesting investigations, and urgent business occupations.

The observations were made in his private observatory at Hastings-on-the-Hudson, Lat. 40° 59′ 25″, Long. 73° 52′ 25″. Elevation above sea, 220 feet.

The pictures of the Observatory and of the Great Equatorial render unnecessary any detailed description of the mounting and general arrangement of the instruments.

The difficulties of the research proved to be very great. At first the limitations imposed upon the time of exposure by the use of the wet process made it almost impossible to get impressions of sufficient strength. This difficulty, however, is now a thing of the past, having vanished with the introduction of the modern dry-plate processes. Another difficulty, however, which increases with the time of exposure, is that of securing a sufficiently accurate movement of the driving-clock. Dr. Draper was obliged to construct no less than *seven* before he succeeded in getting one that was perfect. Other difficulties which were more or less completely overcome relate to the firm and rigid connection of the parts of the spectroscope with each other, and with the sensitive plate; to the effect of temperature upon this connection, and upon the dispersive power of the prisms employed; and to the method of obtaining a satisfactory reference spectrum for comparison with that of the star under examination. Of course, also, every one knows that operations of this kind are much more sensitive than visual observations to atmospheric conditions. A slight haze, which is rather an advantage than otherwise to ordinary work, cuts off the actinic rays to such an extent as to increase the needed time of exposure many fold. On some evenings, apparently good, it will take 30 minutes or an hour to obtain a picture as intense as could be obtained on others in 5 or 10 minutes.

Another serious practical difficulty should also be mentioned, — the fact that Dr. Draper's residence was distant more than two miles from his observatory; and this of course involved many absolute disadvantages and some loss of opportunities, as well as much inconvenience.

It is not necessary to give here any full description of the telescopes employed. It is enough to say that the great reflector constructed by Dr. Draper himself has a mirror of silvered glass 28 inches in aperture, with a focal length of 148 inches. It was generally fitted up in the Cassegrainian form, the small convex mirror, also of silvered glass, having a diameter of 8 inches and a negative focal length of 29 inches. It was placed 33 inches inside the principal focus of the great mirror.

Dr. Draper tried the effect of replacing the small convex mirror with a flat of 16 inches diameter for photographic work, but the result was not satisfactory.

In the use of the reflector for photographic and spectroscopic purposes it was found extremely difficult, in fact impossible, to hold the great mirror with sufficient firmness to keep the star image accurately in place, without at the same time distorting the glass and injuring the definition. In this respect the refractors had greatly the advantage, though of course they were much inferior in the amount of light.

The 12-inch refractor needs no special description. It had a focal length of 183 inches, and its color-correction was adjusted for the use of achromatic eyepieces, instead of the usual Huyghenian eyepieces. The correction, however, did not vary materially from that of other telescopes by the same makers, the difference of focal length between the mean rays of the spectrum and H amounting to about $\frac{8}{10}$ of an inch. It was an excellent instrument for all visual purposes, and is now owned by the Lick Observatory. For photographic purposes, however, it was decidedly inferior to the 11-inch instrument which succeeded it.

The focal length of the 11-inch telescope without its photographic corrector was about 176 inches; with the corrector applied, it was shortened by 24 inches.

With reference to the driving-clock it is only necessary to say that its regulator was a heavy conical pendulum, or rather pair of pendulums, weighing some 15 pounds, and so hung that their revolutions were sensibly isochronous through quite a range of inclination. Whenever by increase of driving power or decrease of resistance one of the balls rose above a certain limit, it acted, without affecting the radial motion of the ball, upon a friction spider which absorbed the superfluous energy in the manner made familiar by the chronographs constructed by the Clarks and by Fauth & Co., and now so common in our observatories. The regulator revolved once a second. The gearing and driving screw were constructed, for the most part, by Dr. Draper himself, with the utmost care and accuracy; and it may safely be said that in its ultimate perfected condition the driving-clock was as good as any in existence, keeping a star upon the slit for an hour at a time when near the meridian and not disturbed by changes of refraction.

In the course of the operations a great many forms of spectroscopic apparatus were employed. At first, as has been mentioned, a quartz prism was used, simply interposed in the path of the rays a few inches

inside the focus, without slit or lenses; and with this, after one or two unsuccessful trials, he first obtained a satisfactory spectrum of Vega showing four dark lines.

Afterwards direct vision prisms used in the same way were tried, and spectroscopes made up of such prisms, some with a slit, some without, and some with a cylindrical lens to give necessary width to the spectrum. The arrangement finally settled upon, however, and with which all the plates measured by Professor Pickering were made, was the following. A star-spectroscope by Browning, with two 60° prisms of dense (*but white*) flint glass, was used, of the form designed by Dr. Huggins for stellar observations. The telescope and collimator each had a focal length of 6 inches, with an aperture of $\frac{3}{4}$ of an inch. The parts were very carefully braced together to prevent any slip or movement. The slit was covered with a diaphragm having a hole at the centre, and painted with phosphorescent paint to make the aperture visible in the dark: there was also a movable "finger," by which any part of the slit could be exposed at pleasure, so as to obtain spectra of different objects on the same plate side by side for reference.

At the eye-end of the spectroscope-telescope the eyepiece and micrometer were removed, and a block of hard wood was fitted on in such a way as to carry the little photographic plate. This was a small bit, about an inch square, cut from a plate of commercial size. A small positive eyepiece was mounted on the block, so that the operator could at pleasure examine the yellow and red portion of the spectrum which projected beyond the sensitive plate into the field of view, and in this way assure himself that the clockwork was driving properly, and that all the adjustments remained correct.

The whole apparatus weighed less than five pounds, and screwed on to the eye end of whatever telescope it was used with.

On the most careful examination, it is very difficult to see how any perceptible alteration in the relative position of the different parts could ever have occurred. Still, the bracing employed was not absolutely symmetrical, and there may have been a little "twist" when the instrument was transferred from an object near the zenith on one side of the meridian to one near the horizon on the other.

For the most part the development of the plates was by ferrous oxalate, though the alkaline development and pyrogallic acid were both used on some occasions.

The pictures obtained with this arrangement were about one sixteenth of an inch in width and about half an inch long, extending from a point between the Fraunhofer lines F and G to a point near M.