RESEARCHES IN STELLAR PHOTOMETRY DURING THE YEARS 1894 TO 1906, MADE CHIEFLY AT THE YERKES OBSERVATORY

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Researches in stellar photometry during the years 1894 to 1906, made chiefly at the Yerkes observatory by John A. Parkhurst

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DURING THE YEARS 1894 TO 1906

MADE CHIEFLY AT THE

YERKES OBSERVATORY

BY

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RESEARCHES IN STELLAR PHOTOMETRY.

By John A. Parkhurst.

INTRODUCTION.

The problems of stellar photometry are closely connected with many cosmic questions, primarily with the light changes of variable stars; but they have an equally important bearing on the questions of stellar distribution and evolution. It has been said by good authorities that it is of more importance to measure the light than the place of a star, and if one considers merely the astonishing number of variable stars now being discovered, it will be admitted that the importance of stellar photometry can scarcely be overestimated. The material here submitted is the natural outgrowth of the writer's variable-star work, the plans being extended as the instrumental and other facilities were improved.

The following contribution is offered towards the solution of several photometric problems, among them being:

(1) The accurate determination of complete light-curves of twelve variable stars of long period, having faint minima.

(2) The question of the behavior of variable stars during their faint stages which can only be observed with the largest apertures.

(3) The adaptation of the Pickering "equalizing wedge photometer" to the determinations of magnitudes.

(4) The photometric measurement of very faint magnitudes, and their relation to estimates founded on the limit of visibility of different apertures of telescopes.

I wish to acknowledge here the efficient assistance rendered in the reductions by Miss Kate Bloodgood, also by Mr. F. R. Sullivan of the observatory staff, who recorded all the photometric measures made with the 40-inch telescope.

HISTORICAL.

The writer's variable-star work began at Marengo, Illinois, in May, 1893, with visual comparisons by Argelander's method of a list of long-period variables, including at first the circumpolar stars in Professor E. C. Pickering's pamphlet, "*Variable Stars of Long Period*," published in 1891; with additions, from time to time, of new variables which were not receiving sufficient attention elsewhere. By the end of 1899 the number of observations amounted to about 5,000, furnishing data for determining 162 maxima and 116 minima. Provisional results were published in the *Astronomical Journal*, vols. 13 to 21, and in *Popular Astronomy*, vols. 2 to 8. This work was made possible largely by the kind assistance of P. S. Yendell, of Dorchester, Massachusetts, who with great patience gave the instructions needed by a beginner and corrected the errors into which one was so likely to fall; also of Henry M. Parkhurst, of Brooklyn, New York, who, beside

other assistance, made photographic copies of the forty *Durchmusterung* charts, then out of print, making possible the finding of the newer variables and the identification of the brighter comparison stars; and of Prof. E. C. Pickering, who furnished charts and photometric magnitudes of many of the comparison stars.

The instrument used so far was a 6.5-inch reflector by Brashear, but connection with the Yerkes Observatory for three months in 1898 and since January, 1900, has made possible the extension of the work to the determination of the minima of very faint stars, fixing the photometric magnitudes of the stars used for comparison, and making photographic charts of the fields surrounding the variables.

PLAN OF WORK.

Two points were determined from the start: (1) To follow the variables as far as possible throughout their period; (2) to give special attention to the positions and identifications of the comparison stars. To carry out the first point, preference was given to circumpolar stars, which could be followed the year around. To fulfill point 2, the coordinates of the comparison stars from the variable were measured with a filar position micrometer, at first on the 6-inch, afterwards for twenty fields with the 40-inch for the faint stars. The completion of the 24-inch reflector in 1901 made it possible to accomplish this object much easier and better by photography, so beginning in November of that year plates were taken to show the faintest comparison stars used.

The addition of the Pickering equalizing wedge photometer to the outfit in 1900 made it possible to complete the plan of work by adding (3) the determination of the photometric magnitudes of the comparison stars, based on standard stars which had been measured both at Harvard and Potsdam. The publication of the Harvard catalogue and the approaching completion of the Potsdam work, including all stars north of the equator to magnitude 7.5, furnished the basis for this work, but it did more than that; it called for a minute comparison of the two magnitude systems in conditions of practical work. It is not enough to know the average differences between the two systems; the practical question is, What systematic differences will be found in standards selected for a particular field? To anticipate the results discussed in Chapter XIV it may be stated here that the irregularities found in the systematic differences leave an outstanding uncertainty of about 0.1 magnitude in stars as bright as 7.0.

ESSENTIALS FOR GOOD VISUAL COMPARISONS.

Among the precautions kept in mind to insure good visual comparisons, the following were foremost:

(1) The two stars to be compared were made parallel to the line of the eyes. To the writer this precaution was of the utmost importance, for if two equal stars were placed in a vertical line the lower would appear more than half a magnitude the brighter. The required position of the stars was easily secured with the 6-inch reflector by turning the tube in its cradle.

(2) Two or three comparison stars were used at each observation if they could be found in proper distances and magnitudes, though this rule often conflicted with the two following.

(3) The stars to be compared should be in the same field, and

(4) The interval in brightness should be less than half a magnitude. If this limit was exceeded the comparisons were weighted in the reductions, inversely as the interval.

(5) Prejudice which would arise from anticipating the star's expected changes, was avoided by postponing the reductions till the maximum or minimum was completed. The observing list was long enough so that the previous observations were usually forgotten at the time of a comparison.

(6) The comparison of too bright stars was avoided by reducing the aperture when necessary.

(7) Light in the eyes was avoided by using for recording a one-candlepower incandescent lamp, so shielded as to illuminate faintly a circle one or two inches in diameter on the record book.

ESSENTIALS FOR GOOD PHOTOMETER MEASURES.

Experience taught the necessity of close adherence to the following principles:

(1) A sky free from clouds and of uniform transparency is the prime requisite. A "patchy" sky is a signal to stop photometric work. All observers agree to this in theory, but their adherence to it is a variable quantity, yet it is doubtless the largest single factor affecting the quality of the work. According to my experience a lack of transparency amounting to a perceptible haziness is liable to introduce a systematic error in the night's measures. This is not the "local" error entering when distant regions, like polar and equatorial, are compared; but it shows in measures of a field limited to one degree in diameter.

(2) Measures of a field should be repeated immediately, in inverse order from the first set, to eliminate progressive changes (*a*) in the transparency of the air and (*b*) in the brightness of the artificial star. Under (*a*), at least in the climate of the northern Middle States, progressive change in the transparency of the air is to be expected from hour to hour, and I suspect that this is true in all except a few favored regions. Admitting this, the duty of repetition in inverse order follows. The neglect of this apparently obvious precaution in most photometric work is difficult to explain or justify.

(3) The real and artificial stars should resemble each other closely. This was possible in the present work with the 6- and 12-inch telescopes, the stars being usually indistinguishable, but it was not always possible with the 40-inch.

(4) The stars to be compared should be in a uniform relative position. The practice of the writer has been to place them in a horizontal line, with the real star to the left of the artificial, and distant about 0.4 the space between the two images of the artificial star. Following the principle mentioned under (1) in "Visual comparisons" this uniform position seemed preferable to the four recommended by Professor Ceraski.

(5) Nothing but the photometer lamp should be in the circuit from the storage cell supplying the current, and there should be no sliding contacts in the circuit; all should be soldered or screwed. The lamp should burn very nearly at its specified candlepower.