HARVARD COLLEGE OBSERVATORY.

CIRCULAR 188.

THE COLOR INDEX OF S CEPHEI.

THE following study of the color index of S Cephei, has been made by Miss H. S. Leavitt.

One of the most valuable results of the long series of visual observations of variable stars made at this Observatory, and elsewhere, will be obtained when they can be compared with observations on contemporary photographs. For this purpose, an absolute scale of photographic magnitudes is necessary, and observations published before the adoption of the magnitudes of the stars in the North Polar Sequence, described in H.A. 71, No. 3, cannot be used without correction. For many long period variables we have now the material for comparison of visual and photographic magnitudes in all parts of the light curve. In 1896, many photographic observations were made for the 17 Circumpolar Variables discussed in H.A. 37, Part 1. Many of these could be seen on plates exposed 10 minutes with the 8-inch Draper Telescope, even when near minimum. It was found impossible to identify S Cephei with certainty on any plate, although its visual range, from about the eighth to the thirteenth magnitudes, was such that had it been no redder than other variables, T Ursae Majoris for example, it would have been easily photographed even when near minimum.

In 1897, a special effort was made to follow this variable, both visually and photographically, and 19 plates showing it clearly were obtained. Several attempts to obtain its spectrum on ordinary plates were unsuccessful, as no indication of its presence could be seen even when near maximum. A photograph on a plate stained with erythrosine and exposed through a yellow screen showed a conspicuous image having all the light concentrated near wave length 5600. Dunér gives the spectrum as of Type IV!! The observations in 1897, with a few on later plates, are given in Table I. The successive columns give the Julian Day, the length of exposure, the observed photographic magnitude on the scale of H.A. 71, No. 3, the visual magnitude read from a smooth curve, and the difference between the two. All the photographs were taken with

TABLE I.

MAGNITUDE AND COLOR INDEX.

J. D.	Exp.	Ptg.	Vis.	Color Index.	J. D.	Exp.	Ptg.	Vis.	Color Index.	J. D.	Exp.	Ptg.	Vis.	Color. Index.
	m.					m.					m.			
13932	34	14.48	8.38	6.1	14056	11	12.82	7.87	5.0	14223	24	14.50	9.02	5.5
13951	48	14.26	8.16	6.1	14063	18	12.62	7.90	4.7	15654	21	<13.9	8.48	>5.4
13984	48	13.72	7.88	5.8	14070	16	12.88	7.90	5.0	16007	20	13.37	8.35	5.0
14009	28	13.24	7.73	5.5	14076	16	12.82	7.89	4.9	16090	27	<14.0	8.07	>5.9
14032	59	12.92	7.70	5.2	14077	10	12.88	7.88	5.0	16412	20	14.7?	8.56	6.1
14044	22	12.88	7.76	5.1	14092	11	12.82	7.82	5.0	16416	40	15.00	8.50	6.5
14049	22	12.78	7.80	5.0	14094	11	12.78	7.81	5.0	19999	10	<12.8	7.8	>5.0
14051	9	12.88	7.81	5.1	14097	10	12.78	7.81	5.0	20333	10	<16.0	10.8	>5.2
14052	10	12.82	7.81	5.0	14140	20	13.09	8.16	4.9	20391	10	<16.0	10.0	>6.0

the 8-inch Draper Telescope except the last three, of which that taken on J. D. 19999 was photographed with the 4-inch Cooke Anastigmat, and the two last with the 16-inch Metcalf Telescope. The color equations of various visual observers differ by a magnitude or more for this star, and in themselves might be used to determine its color index. Fortunately, two observers, Mr. W. M. Reed and Miss A. J. Cannon, agree very closely in their sensitiveness to color and each made a large number of observations in 1897. The magnitudes in the fourth column, when given to hundredths, were read from a smooth curve depending on their estimates alone, as given in H.A. 37, Part 1. The magnitudes on the last three lines depend on observations by various persons, and are uncertain on account of unknown personal equations. The color indices in the last column are extremely large. They vary by about a magnitude, and it seems probable that there is a real difference depending on the phase. This is more clearly brought out in Table II in which the magnitudes, as read from smooth curves, are given for every 20 days for the period covered by photographs taken in 1897. The four columns give the Julian Day, the photographic and visual magnitudes, and the difference between the two. While the visual brightness increased half a magnitude between J.D. 13940 and J.D. 14100, the photographic brightness increased a magnitude and a half. The corresponding color indices are six magnitudes and five magnitudes, respectively. The color index again grows larger after maximum has been passed, but apparently the change in color progresses more slowly. These differences cannot be ascribed wholly to errors of obser-

TABLE II.

COORDINATES OF LIGHT CURVES IN 1897.

J. D.	Ptg.	Vis.	Color Index.	J. D.	Ptg.	Vis.	Color Index.	J. D.	Ptg.	Vis.	Color Index.
13940	14.38	8.29	6.09	14040	12.88	7.76	5.12	14140	13.09	8.16	4.93
13960	14.09	8.09	6.00	14060	12.80	7.89	4.91	14160	13.43	8.37	5.06
13980	13.76	7.90	5.86	14080	12.86	7.87	4.99	14180	13.73	8.56	5.17
14000	13.40	7.77	5.63	14100	12.80	7.83	4.97	14200	14.08	8.78	5.30
14020	13.09	7.70	5.39	14120	12.90	7.97	4.93	14220	14.44	9.00	5.44

vation, as the light curves are well defined, especially for the plates preceding and during maximum.

The visual and photographic observations are shown in Figure 1. Horizontal and vertical distances represent Julian Days on a scale of 100 days = 1 cm., and 1 magn. = 1 cm., respectively. Visual observations by Mr. Reed and Miss Cannon are represented by dots and open circles respectively, and are seen to be in good agreement. Observations on photographs are also represented by dots but occur in a much fainter part of the scale. The large color index is strikingly indicated by the wide blank space separating the two kinds of observations. Usually the visual and photographic light curves of long period variables come near together, showing color indices of from one to two magnitudes. To obtain the true color indices for various phases of S Cephei, the visual magnitudes represented in Figure 1 require correction for color equation to the standard system, but the corresponding photographic observations require little if any correction, as the color equation of the 8-inch Draper Telescope is nearly 1.0 magn., on the scale proposed in H.A. 71, 226.

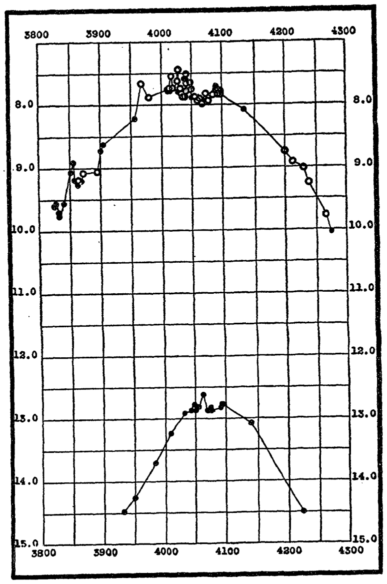

FIG. 1.

A curious result of the observations in 1897 is to show that the photographic and visual maxima were not simultaneous. The visual maximum apparently occurred about J.D. 14045 and the photographic maximum about J.D. 14080, more than a month later. The visual observations seem to indicate a secondary minimum about J.D. 14070, which is perhaps confirmed by the photographic observations for about the same date.

Color indices can be determined much more satisfactorily by comparisons of ordinary photographs with those taken on stained plates using color filters. This is especially true in the case of extremely red stars, for which the personal equation is liable to fluctuate in the case of visual observers. A comparison of plates taken with the 16-inch Metcalf Telescope, or the 4-inch Cooke Anastigmat which is attached to the same mounting, is convenient for this purpose. A preliminary determination of the color equation for ordinary plates taken with either instrument gives a value of about +0.8 magn., while for plates stained with erythrosine and exposed through a yellow screen it is about −0.2 magn. A comparison of the two kinds of plates, therefore, gives a color equation of about 1.0 magn., and color indices are probably nearly on the standard scale. On J.D. 19999, a yellow plate with the 16-inch was exposed simultaneously with the ordinary plate for which the magnitude of the variable, <12.8, is given in the third column of Table I. The observed photovisual magnitude was 7.66, and indicates a color index of more than five magnitudes. A yellow plate taken with the 16-inch on J.D. 20389 shows the variable as of the magnitude 9.36, while an ordinary plate taken two days later, as given on the last line of Table I, does not show the variable at all, although the images of sixteenth magnitude stars are seen. The resulting color index, depending on observations separated by two days, is at least six and a half magnitudes.

From this preliminary study, it is concluded that S Cephei has a color index of fully five magnitudes at maximum, that this increases as minimum is approached, and may become as great as six and a half magnitudes. The visual and photographic maxima are probably not simultaneous. Interesting results would probably be obtained from a similar study of other very red stars, whether variable, or not.

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