DEPARTMENT OF THE INTERIOR

CANADA

HON. CHARLES STEWART, *Minister*. W. W. CORY, C.M.G., *Deputy Minister*.

PUBLICATIONS

OF THE

Dominion Observatory

OTTAWA

R. MELDRUM STEWART, M.A., Director

Vol. VIII, No. 7

Photometry with a 6-Inch Doublet

By

R. M. MOTHERWELL, M.A.

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1924

CONTENTS

ILLUSTRATIONS

86602—1½

FIG. 1—Camera Hut

FIG. 4—Telescope and Cameras

PHOTOMETRY WITH A 6-INCH DOUBLET

PHOTOGRAPHIC EQUATORIAL

When the photographic telescope [1] of the Dominion Observatory was mounted in a separate building (Fig. 1), the 6-inch doublet then purchased was figured for stellar photometry by the extra-focal method of Parkhurst and Jordan.[2] Both the 6-inch and 8-inch doublets give excellent negatives in stellar photography but the discs formed by the 8-inch, when the plate is within or without the focus, are too uneven to permit of accurate measurements of their densities. The 6-inch being figured with a view to extra-focal work gives fairly even discs when the plate is set at least 5 mm. outside the focus. If the plate is closer to the focus the discs are too uneven to measure, a light centre making it almost impossible to get accurate measurements. This is a very unfortunate condition as it means the out-of-focus images must be at least 1 mm. in diameter and this necessitates, for stars below the seventh magnitude, an exposure so long that the plates will be fogged by the city lights. In other words, the 6-inch is not suitable for extra-focal photometry of the fainter stars. This difficulty was soon realized and the work embraced in this article was carried out, having in mind a focal method by which the fainter stars might be reached.

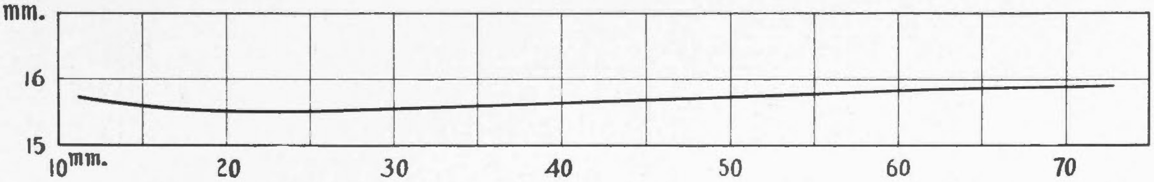

Fig. 2—Spherical Aberration Curve—6-inch Doublet

The 6-inch doublet was thoroughly tested for spherical and chromatic aberration by the Hartmann [3] method. Fig. 2 shows a maximum spherical aberration of slightly over 0·4 mm. and Fig. 3 gives the colour curve. The field of the doublet is reasonably flat,

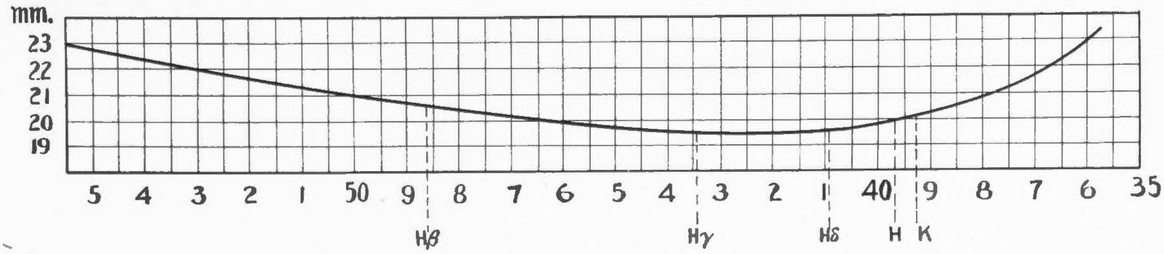

Fig. 3—Colour Curve of 6-inch Doublet

good definition being obtainable on focal plates over a field of about 9° diameter. For extra-focal work, however, the curvature of the field necessitates a correction which will

[1] Jour. R.A.S.C., Sept.-Oct., 1914.
[2] A. J., Vol. 26, p. 244, 1907.
[3] Zeitschrift für Instrumentenkunde, Vol. 24, pp. 1, 33 and 97, 1904.

be dealt with in detail in a subsequent paragraph. This correction limits the available field to a radius of about 3°; adapters are therefore fitted in place of the 8 by 10-inch plate holders and 4 by 5-inch plates used. The 4 by 5-inch plate holders can be moved 25 mm. in declination either way from the central position so that a series of exposures can be made on one plate.

The guiding telescope with a focal length of 52·5 inches and aperture of 4·5 inches is sufficiently powerful to permit of very accurate guiding, even for focal plates. This is, of course, very necessary as the instrument is used for direct photography of star fields and comets. There are also two 8-inch objective prisms of 15° and 25° angles. These can be mounted, separately or together, on the 8-inch doublet and are used for photographing spectra of comets and star fields. The combined prisms give a spectrum slightly over one-half inch between H_β and K. The guiding telescope can be moved in declination, but not far enough to guide directly on the object whose spectrum is being photographed. The eye-piece can also be moved in any direction, linear and circular scales on the eye-end of the tube providing a check on any setting should it be necessary to repeat the observation at another date. This shifting of the eye-piece is especially useful in photographing comets with tails of a length greater than the radius of the plate. The telescope and mounting are shown in Fig. 4.

PHOTOMETRIC METHOD

Sensitometer Box

The sensitometer box (Fig. 5) is similar to those used in other observatories but perhaps a brief description might be given. There are twenty light brass tubes, each 75 mm. long and 10 mm. in diameter, set parallel in a brass box 129 mm. by 101 mm. by 80 mm. Over each end of the box is a thin brass plate pierced with circular holes opposite the centre of each tube. The holes in the back plate are 0·8 mm. diameter. Those in the front plate vary from 0·739 mm. to 4·360 mm. In each tube are two diaphragms to prevent reflection of light from the walls of the tubes, and the front and back plates and interior of each tube are coated with a dull black paint to further reduce reflection.

The sides of the box extend 3 mm. beyond the back plate, thus forming a holder for the photographic plate. A light-tight cover fits over the end of the box and inside this cover are two springs which press the photographic plate tightly against the back plate.

A metal framework (see Fig. 6) which can be rotated by an electric motor holds the sensitometer in such a position that the front end points toward the pole through an opening in a window of the dark room. A fixed frame in front of the box contains several sheets of opal glass which render the illumination of the front plate openings more uniform, and the rotation of the box during exposure eliminates, to a great extent, irregular illumination due to lack of uniformity in the thickness of the opal glass sheets.

The light passes through the openings in the front and back plates and strikes the photographic plate, producing thereon a circular image of the same size as the openings in the back plate. The relative densities of these images depend on the relative diameters of the openings in the front plate. These diameters were measured several times in two coördinates and the mean is given in the second column of Table I. The third column

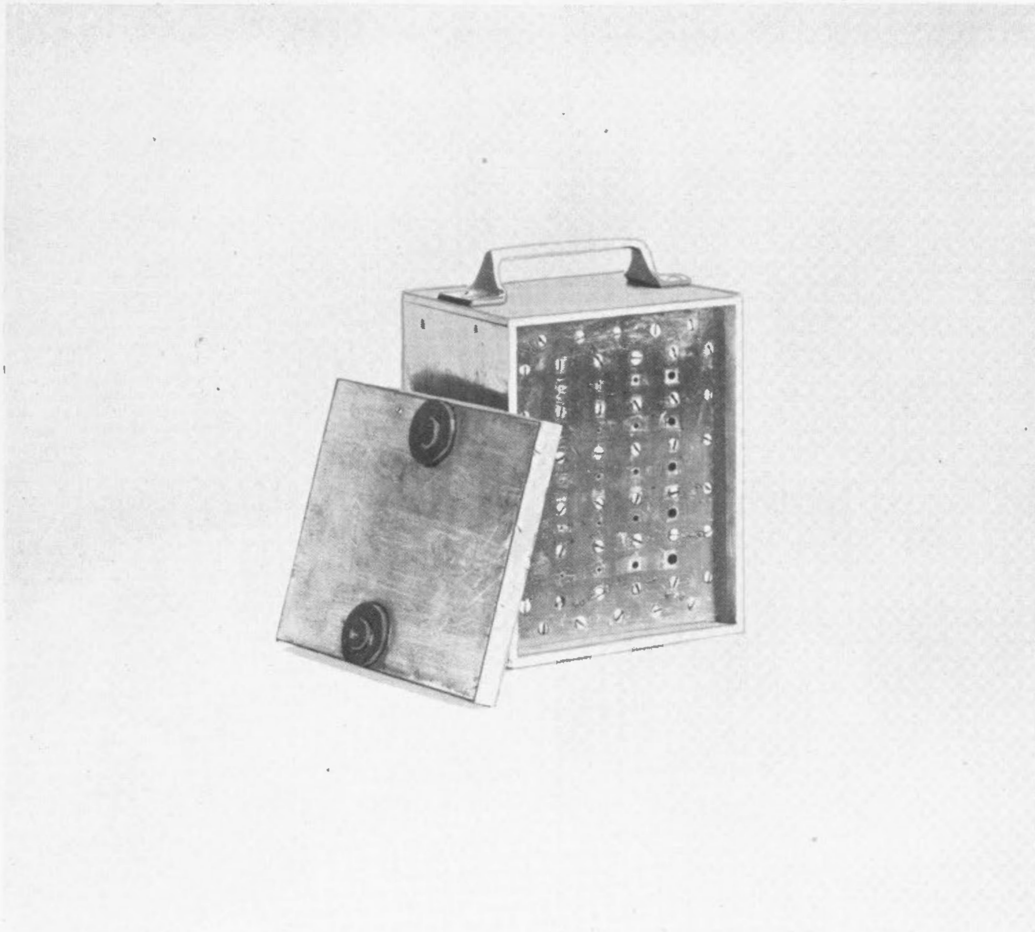

FIG. 5—Sensitometer Box

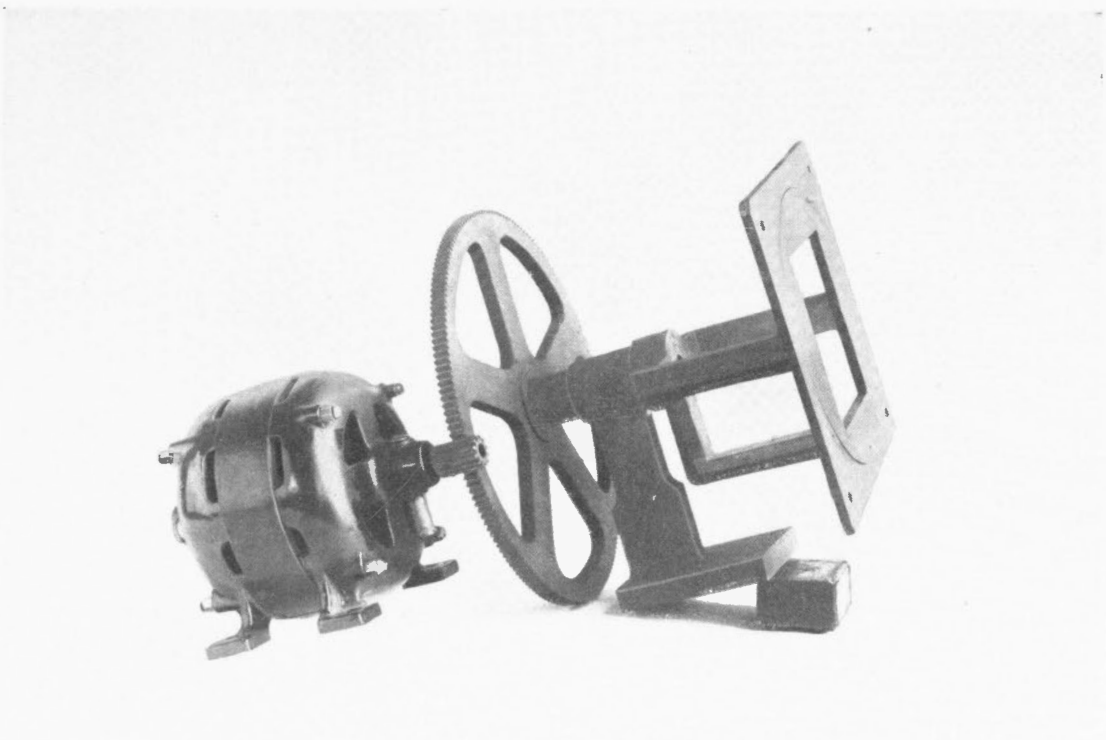

FIG. 6—Mounting for rotating Sensitometer Box

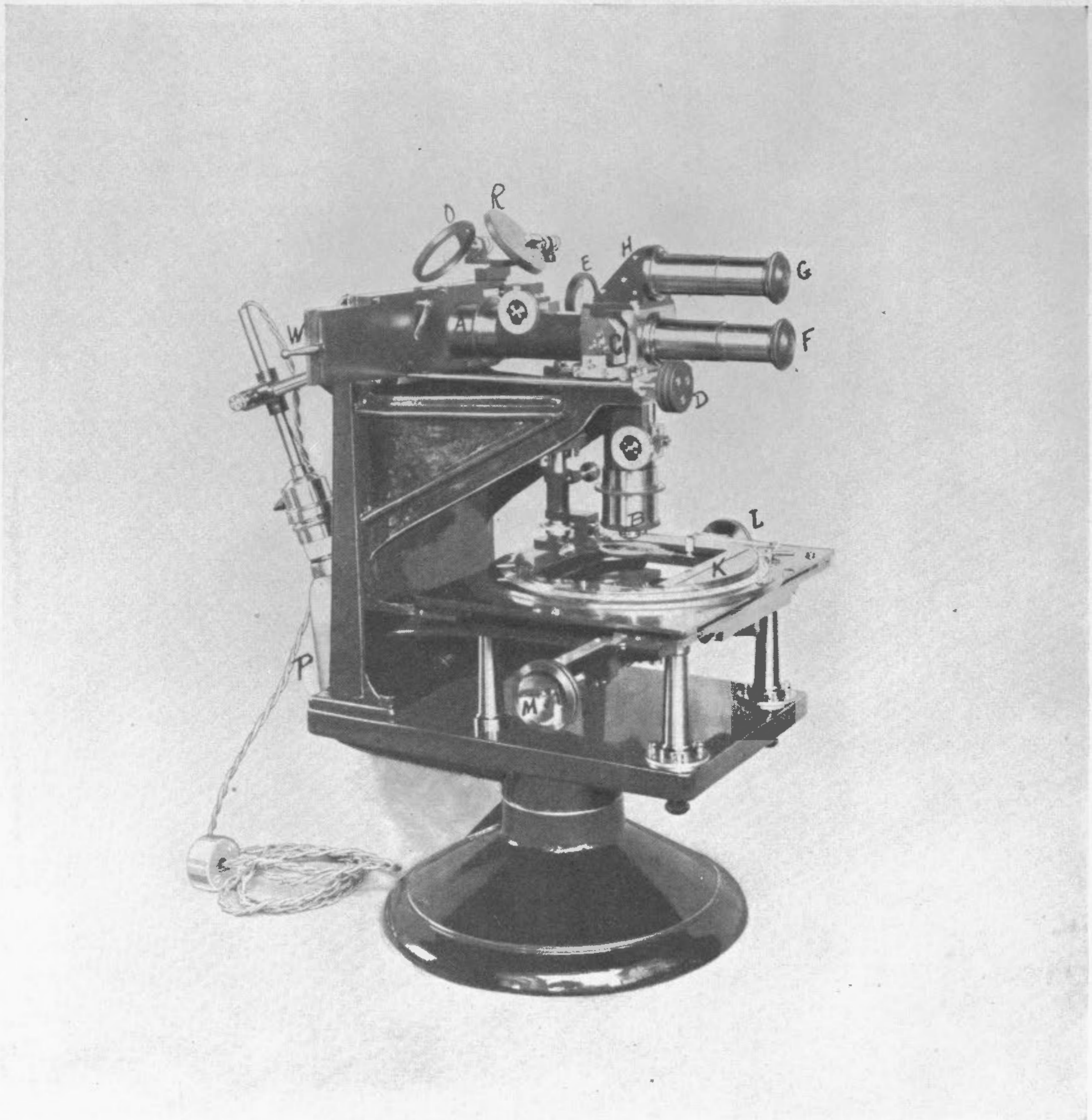

FIG. 7—Microphotometer

gives log D², the logarithm of the relative area, hence the logarithm of the relative amount of light admitted by each hole. Column four gives the relative amount of light expressed in magnitudes. Column five is 4·00 minus column four, thus expressing the relative magnitudes of the images produced through the sensitometer openings in a form convenient for use in stellar work. The application of these relative magnitudes to the star images on the plates will be fully explained in a later paragraph.

TABLE I

Hole	Diam.	Log D²	Δ Log D² / ·4	Δ Mag.	Hole	Diam.	Log D²	Δ Log D² / ·4	Δ Mag.
	mm.					mm.			
1	0·7391	9·73740	0·000	4·00	11	1·8109	0·51580	1·946	2·05
2	0·8229	9·83072	0·233	3·77	12	2·0192	0·61036	2·182	1·82
3	0·8788	9·88778	0·376	3·62	13	2·1919	0·68164	2·360	1·64
4	0·9677	9·97146	0·585	3·42	14	2·4535	0·77958	2·605	1·40
5	1·0388	0·03306	0·739	3·26	15	2·7532	0·87968	2·855	1·15
6	1·1302	0·10634	0·922	3·08	16	2·9920	0·95192	3·036	0·96
7	1·1887	0·15012	1·032	2·97	17	3·3170	1·04150	3·260	0·74
8	1·3284	0·24662	1·273	2·73	18	3·6066	1·11420	3·442	0·56
9	1·4122	0·29976	1·406	2·59	19	3·9089	1·18410	3·617	0·38
10	1·6103	0·41380	1·691	2·31	20	4·3609	1·27916	3·852	0·15

Exposure and Development of Plates

Seed 30, Gilt Edge, plates have been used for all photometric work as they are fast and comparatively free from chemical fog. The holders are loaded in the dark (no red light) and wrapped in black cloth until the telescope is ready. The dome is kept dark during exposure, only a 2 c.p. lamp enclosed in a wooden tube being used. It was originally intended to expose each plate in the sensitometer box on the following day, just before developing, but for reasons which will be given later this practice was soon given up and only a certain number of plates of each emulsion exposed in the sensitometer box.

Hydrochinone developer has been used in all the work. The formula as given by Prof. Parkhurst follows:—

A.		B.	
Water	64 oz.	Water	64 oz.
Sulphite of soda, dry	2 oz.	Sulphite of Soda, dry	2 oz.
Hydrochinone	2½ oz.	Potassium Carbonate	8 oz.
Sulphuric Acid c.p.	2 drs.	Potassium Bromide	200 grs.

Equal parts A and B.

A wooden tank 18 by 8 by 8 inches, lined with block tin, is used to control the temperature of the developer. In the winter this tank is filled with water and an electric heating element controlled by a contact thermometer, whose bulb is in the water, keeps the temperature of the water at 20° C. In the summer the water from the tap runs around the tank, the flow being regulated according to the temperature of the room. The developer is put in an Eastman developing tank which is then put in the temperature bath and the plates immersed as the timer is started. The developer is kept in 16-oz. bottles which stand in one end of the temperature tank so that the developer is always at the required temperature. The time of development is eight minutes. The plates are then fixed for twenty minutes on edge in a hypo bath, to which has been added Velox liquid hardener. This has proved to be an excellent fixer both for clearness of plates and keeping properties of the fixer. There is some doubt as to the effect of developing from one to six plates in the same quantity of developer. Whether there would be any change in the form of the reduction curve has not been investigated.

Measurement of Plates

The densities of the sensitometer images and the out-of-focus images of the stars are measured with a Hartmann microphotometer, shown in Fig. 7. This instrument is similar to that used by Prof. Parkhurst and fully described in Astrophysical Journal, Vol. 10, p. 321. A and B are microscope objectives through which the light shines from source P., two mirrors reflecting the light into these objectives. C is a Lummer-Brodhun cube, in the centre of which a small silvered portion reflects the light from B to the eye-piece F, while the remaining surface of the cube C permits the light from A to pass directly to F. The photographic plate to be measured is placed on the table K and adjusted by means of screws L and M until the star image is directly beneath B. In this way the intensity of the light through B is controlled by the density of the star image. Now in the centre of the field of view of F we have the light coming through the image whose density we wish to measure. Around this we have the light from A. To equalize the two parts of the field of view a photographic wedge W is placed in front of A. This wedge can be moved across the field of A by the knurled head D until the light through A just equals that through B. A millimetre scale to the right of A gives the position of the wedge for each setting.

The eye-piece G, together with the 45° prism H, gives a clear view of the plate through the objective B, only a very small part in the centre of the field being obscured by the silver spot on C. By means of the plate carrier K, controlled by screws L and M, one can quickly bring any part of the photographic plate within the field of the objective B. In this way it is very easy to set the silver spot on the desired star image. The lens E magnifies the scale on the wedge carrier, thus giving quick and accurate readings to one-tenth of a millimetre. O and R are mirrors for reflecting the light from the source P to the scale. The source P is a 40-watt Mazda lamp, frosted. The light passes through ground glass before being reflected to objectives A and B.

The wedge W was very kindly furnished by the late Professor E. C. Pickering. The plates used being Seed 30 and the wedge being made from Seed 23, the difference in grain is very apparent when wedge and plate are in focus. This trouble was eliminated by adjusting objectives A and B so that the plate and wedge were both 2·0 mm. out of focus.

Three settings are made on each image and the mean taken as the scale reading. When the instrument was first adjusted an extra-focal plate of the Pleiades was measured several times and the mean of these measures is used to check up the instrument from time to time. In this way any change due to moving of the wedge or lamp, or defects in the mirrors, will be readily detected. Excellent agreement has always been obtained in repeating measures at irregular intervals.

Reduction of Measurements

The first step in the reduction of the scale readings of the microphotometer to relative star magnitudes is the construction of the so-called reduction curve. A plate which has been exposed in the sensitometer box before developing is placed in the instrument and the sensitometer images measured. These measures or scale readings are plotted against the relative magnitudes of the openings in the front plate of the sensitometer box, as given in the last column of Table I. A smooth curve through the plotted points gives the desired reduction curve. By means of this curve all wedge readings for star images may be converted to relative magnitudes.

It was at first intended to expose each plate in the sensitometer box and so have a separate reduction curve for each plate. This would require extra measuring but would provide for individual characteristics of all plates. However, even after much experimenting the sensitometer images often failed to give a satisfactory reduction curve. Lack of uniformity due to differences in the time of exposure in the sensitometer box was eliminated by cutting down the light so that the exposure was never less than one minute. The chief difficulty, however, was a sudden increase or decrease in density between successive rows of images, this change being lengthwise, crosswise or radial. The first produced a change in the slope of the curve for each row of images, the second gave a change in the height of the curve for each row while the last caused a bending of the curve for each row. A large percentage of the plates gave satisfactory curves but the number which gave useless curves was such as to lead to other methods. Moreover, a sudden change in the brightness of the sky while one was in the dark room often led to over or under exposure of the plate. Consequently it was decided to measure from eight to a dozen plates for each emulsion and take the mean curve. This was done for several emulsions and there has been such good agreement among the curves of the various emulsions that all measures to date have been re-examined and reduced by a curve formed from the means of the emulsions. Fig. 8 shows this curve. In view, however, of the experience of other observers regarding the change of the reduction curve with the change of emulsion a few trial curves are made for each emulsion. To date, however, the mean curve has been quite satisfactory.

Correction for Sky Fog on Plates

So far the reduction curve referred to is one constructed from measures on plates whose film measures have never been more than 6·0 on the microphotometer scale. This film measure is a setting made on the plate close to the star image under measurement. Such settings are made beside every image measured to detect any irregularities or defects around the image and also to determine the amount of fog over the surface of the plate. Where these film readings are more than 6·0 a change is produced in the form of the reduction curve, the lower end of the curve being raised. Knowing this fog effect before drawing up the specifications of the sensitometer box, the openings were so planned as to group them about the bend of the reduction curve but in the drilling of the plate the drills available did not permit of this being done to the extent desired. The following procedure serves to give any change in the reduction curve due to sky fog. Two exposures, one about five times the other, are made of the same star field on the one plate. This

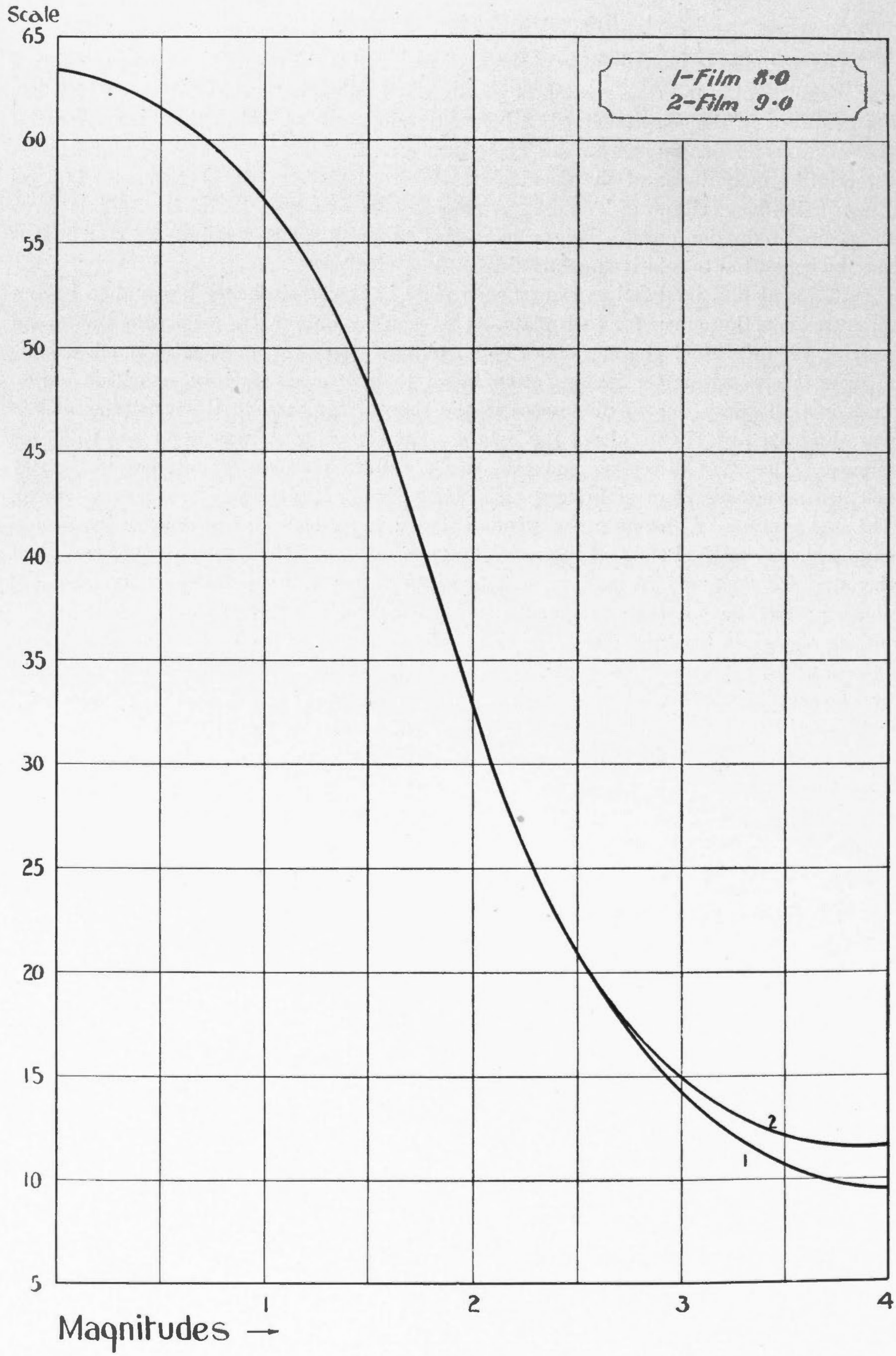

Fig. 8—Reduction Curve

gives dense images and faint images of the same stars and the difference between these dense and faint images, expressed in magnitudes, should be the same for each pair. The denser images fall on the straight part of the curve which is unaffected by sky fog. The lower part of the curve, on which the measures of the fainter images fall, is then adjusted until there is the same difference for all pairs. This gives the correct reduction curve for any particular film reading of the plate. When the sky fog is so dense as to give a film reading beyond 10·5 the effect on the reduction is such as to render it useless for accurate reductions. Consequently, all plates with film readings greater than 10·5 are discarded. Any exposure sufficiently long to give measurable images of the fainter stars fogs the plate well beyond film reading 10·5, so it will be readily seen that this method is not suitable for photometric work at this observatory.

Correction for Curvature of Field of Camera

Since the focus of the centre of the field of the camera is longer than that of the outer parts of the field, the centre of the plate is not so far out of focus as are the surrounding parts. Consequently, the size of the star image increases according to its distance from the optical centre. This increase in the size of the image means that the image of a star will be more dense when it is in the centre of the plate than if it were out some distance. In order that we may have the relative magnitudes of the stars on the plate it is necessary to apply a correction dependent on the distance of the star from the centre of the field. This correction is determined in the following manner. The telescope is set so that Polaris or some other star near it is in the centre of the field, a star near the pole being chosen so that there will be no marked change in zenith distance during the exposure. After an exposure sufficient to give a good image the telescope is moved about 20 minutes in declination and another exposure made. This is repeated across the plate to a distance of about 3 degrees each way from the centre. Care must be taken to have the exposure times as nearly the same as possible, and also the sky must be uniformly clear during the entire series of exposures. The densities of the resulting images are measured and converted to relative magnitudes from the reduction curve.

These relative magnitudes are subtracted from the magnitude of the central image and the resulting differences plotted against the distances of the respective images from the centre. The curve thus formed (Fig. 9) gives the corrections necessary to reduce all measures to the centre of the plate. Table II gives these corrections in tabulated form. Any errors in the curve due to wrong exposure time or uneven sky are reduced to a minimum by taking the mean of a large number of plates.

Atmospheric Absorption

As the effective field of the 6-inch doublet as used in photometric work has a diameter of nearly 6 degrees the zenith distances of the stars on a plate differ. If the field being photographed is far south or far east or west of the meridian, this difference in zenith distance means a difference in the relative magnitudes due to a difference in the atmospheric absorption. The zenith distance of the centre of the plate at the middle of the exposure and also the angle pole-star-zenith are measured directly from a globe and the differences in zenith distance, ΔZ, between the centre star and the others are then read directly from the plate by a graphic method of Prof. Parkhurst's. Using the extinction

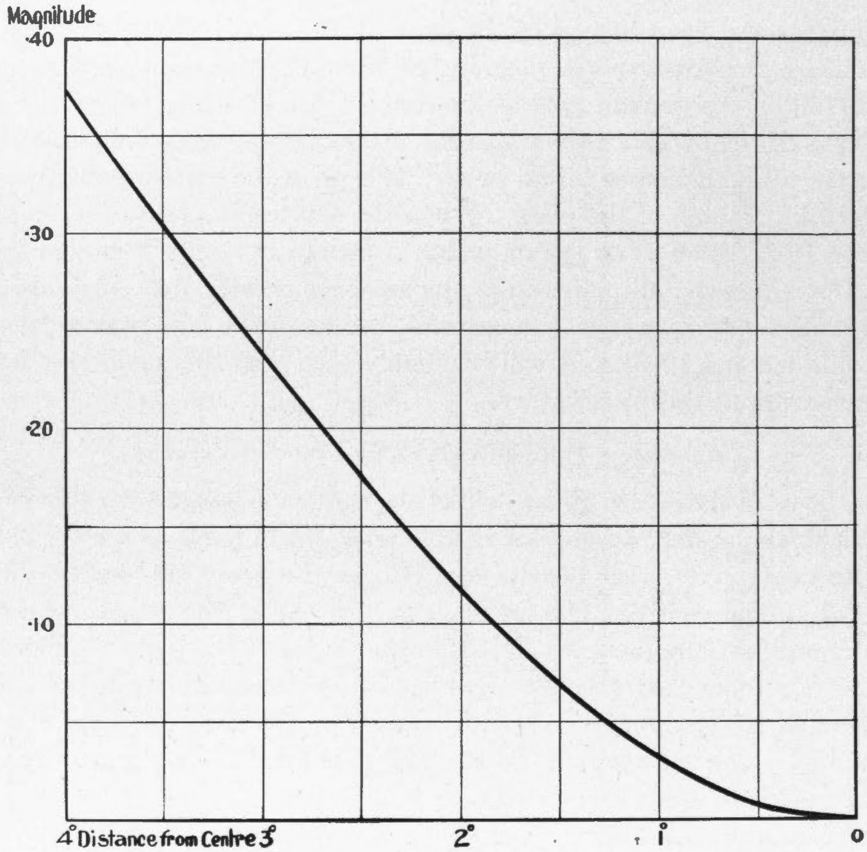

Fig. 9—Correction Curve for Distance from Centre of Plate

curve of Wirtz[1] the change in magnitude, ΔM, due to the difference in zenith distance, ΔZ, is determined. Table III gives the quantity, $\frac{\Delta M}{\Delta Z}$ for various zenith distances as derived from the Wirtz curve. This quantity multiplied by ΔZ gives the required ΔM.

TABLE II

CORRECTIONS FOR DISTANCE FROM CENTRE OF FIELD

ρ Distance from centre	Correction*	ρ Distance from centre	Correction*	ρ Distance from centre	Correction*	ρ Distance from centre	Correction*
°	M	°	M	°	M	°	M
0·1	0·00	0·9	0·03	1·7	0·09	2·5	0·18
0·2	0·00	1·0	0·03	1·8	0·10	2·6	0·19
0·3	0·00	1·1	0·04	1·9	0·11	2·7	0·20
0·4	0·01	1·2	0·05	2·0	0·12	2·8	0·22
0·5	0·01	1·3	0·06	2·1	0·13	2·9	0·23
0·6	0·01	1·4	0·06	2·2	0·14	3·0	0·24
0·7	0·02	1·5	0·07	2·3	0·15	3·1	0·26
0·8	0·02	1·6	0·08	2·4	0·17	3·2	0·27

*This correction is necessarily negative as the distance out of focus increases with distance from centre; hence the images are larger and less dense, and the star would appear to be fainter than it really is. To correct for this apparent faintness we must increase its magnitude, that is, apply a negative correction.

[1] A. N., Vol. 154, p. 349, 1900.

TABLE III

Zenith distance	$\frac{\Delta M}{\Delta Z}$	Zenith distance	$\frac{\Delta M}{\Delta Z}$	Zenith distance	$\frac{\Delta M}{\Delta Z}$	Zenith distance	$\frac{\Delta M}{\Delta Z}$
°	*M*	°	*M*	°	*M*	°	*M*
10	0·001	37	0·007	50	0·013	58	0·020
15	0·002	40	0·008	51	0·014	59	0·021
20	0·002	42	0·009	52	0·015	60	0·023
25	0·003	44	0·010	53	0·016	61	0·025
30	0·005	46	0·010	54	0·017	62	0·028
34	0·006	47	0·011	55	0·018	63	0·030
35	0·006	48	0·011	56	0·019	64	0·032
36	0·007	49	0·012	57	0·019	65	0·035

The following sample reduction of some stars on plate No. 517, as given in Table IV, will make clear the method of measurement and reduction of the star images.

TABLE IV

Plate 517 (part) H.A. $=2^h\cdot8$ W; $z=36°\cdot5$; $q=128°\cdot5$; $\frac{\Delta M}{\Delta Z}=\cdot007$

Star	Scale Reading	Rel. Mag.	ρ	ΔZ	Corrn. for ρ	ΔM	Corr'd. Rel. Mag.	Park. Mag. −Corr'd. Rel. Mag.	Final Mag.	Observed Mag. −Park. Mag.
B.D.			°	°						
77° 641	46·8	1·19	0·5	±0·1	−·01	·00	1·18	5·42	6·53	−·02
77 634	54·9	0·86	1·1	−0·3	−·04	·00	0·82	5·54	6·22	−·14
78 562	25·1	2·09	1·3	−0·8	−·06	−·01	2·02	5·47	7·42	−·07
77 627	25·1	2·09	1·7	−0·9	−·09	−·01	1·99	5·44	7·39	−·04
79 511	21·6	2·30	1·4	−1·3	−·06	−·01	2·23	5·27	7·63	+·13
80 519	20·8	2·36	2·2	−1·9	−·14	−·01	2·21	5·32	7·61	+·08
79 540	25·7	2·06	1·5	0·0	−·07	·00	1·99	5·36	7·39	+·04

H.A. is the hour angle of the centre of the plate at the middle of exposure.
z is the zenith distance of the centre of the plate at the middle of exposure.
q is the angle pole-star-zenith and is measured directly from a globe. This angle is necessary in order that ΔZ may be read graphically from the plates.
$\frac{\Delta M}{\Delta Z}$ as stated above is from Wirtz's extinction curve and its value, depending on the zenith distance, is given in Table III.

Column (1) gives the B.D. number of the star.
Column (2) gives the density of the star image in terms of the scale on the microphotometer.
Column (3) gives the relative magnitude of each star as read from the mean reduction curve.
Column (4) gives the distance of each star from the centre of the plate.
Column (5) gives the difference in zenith distance between each star and the centre of the plate.
Column (6) gives the correction for reducing each measure to the centre of the plate, being read directly from Table II.
Column (7) gives the correction for atmospheric absorption being derived from ΔZ and Table III, which gives $\frac{\Delta M}{\Delta Z}$ for the zenith distance of the centre of the plate.
Column (8) gives relative magnitudes to which the corrections have been applied.
Column (9) gives difference between Parkhurst's magnitudes and the relative corrected magnitudes. The mean of the quantities in column (9) gives the quantity to be added to column (8) to give the final magnitudes as in column (10). For this plate the mean of column (9) was 5·49.
Column (10) gives the residuals, observed magnitudes minus Parkhurst's magnitudes.

While the most outstanding sources of error have doubtless been taken care of by the methods described there are still possible sources of minor errors. The variation in the thickness of the glass in the photographic plate must produce errors which are classed as accidental along with all other irregularities of the film not revealed by the film readings. The sky fog is taken care of up to a certain density beyond which it is well to discard the plate. Also much greater accuracy is assured by discarding all measures of star images below 20 and above 55 as the reduction curve is much more uncertain beyond these points and there is a lack of agreement between successive settings of the wedge.

TABLE OF EXPOSURES

TABLE V

Plate	Date					Julian Day	Exposure	
		d	h	m	s		h	m
	1917—							
267	April	21	15	52	55	2421340·6617	0	10
268			16	17	55	340·6791	0	10
269			17	18	55	340·7215	0	10
270			17	46	55	340·7409	0	10
276	May	14	15	51	56	363·6610	0	10
	1919—							
517	July	24	16	47	00	2422164·6993	0	15
518			17	16	00	164·7194	0	15
530	Sept.	26	14	01	30	228·5844	0	15
536	Oct.	29	15	21	30	261·6399	0	15
	1920—							
539	May	10	14	50	00	455·6181	0	15
540			16	03	00	455·6687	0	15
541			16	33	00	455·6896	0	15
542	June	7	15	00	00	483·6250	0	15
543			15	56	30	483·6642	0	15
544			16	26	30	483·6851	0	15
545	June	11	15	52	00	487·6611	0	8
546			16	12	30	487·6753	0	15
547	June	13	15	50	30	489·6601	0	15
548			16	16	00	489·6778	0	8
	1921—							
585	Mar.	3	17	32	00	752·7306	0	24
586			18	17	30	752·7622	0	25
587	April	1	17	16	00	781·7194	0	10
588			17	59	00	781·7493	0	30
589	April	5	17	25	30	785·7260	0	15
590			17	56	00	785·7472	0	30
591			18	43	00	785·7799	1	00

CATALOGUE OF RESULTS

Star B.D.	Plate	Position, 1900		Spec.	Magnitude		P.E.	O-P
		R.A.	Dec.					
°		h m	° ′					
77 27	536	00 43·6	77 25	A_5		7·10	....	+·20
85 19	589	00 55·0	85 43	K_0	5·55			
	590	....	....	....	5·54	5·54	·00	+·07
88 4	587	00 55·6	88 30	A_2	6·32			
	588	....	....	....	6·34			
	589	....	....	....	6·36			
	590	....	....	....	6·37	6·35	·01	−·08
73 51	536	00 57·6	73 50	A_0		6·87	....	+·12
86 17	589	00 59·1	86 37	K_0	7·31			
	590	....	....	....	7·28			
	591	....	....	....	7·27	7·29	·01	−·06
76 40	536	01 12·0	77 02	G_5		7·24	....	+·01
75 58	536	01 13·8	76 11	K_0		7·99	....	+·10
73 66	536	01 13·8	74 03	A_2		7·26	....	−·03
75 59	536	01 13·8	75 43	A_3		6·68	....	+·06
77 49	536	01 15·0	78 12	A_2		6·45	....	+·14
73 75	536	01 21·0	73 41	G_5		7·58	....	−·16
73 81	536	01 29·2	73 47	B_8		6·46	....	−·07
77 58	536	01 31·6	77 28	B_9		6·58	....	−·06
75 72	536	01 36·0	75 22	F_0		7·24	....	−·13
74 84	536	01 42·7	75 06	F_5		7·13	....	−·12
75 76	536	01 46·2	75 44	A_5		7·10	....	−·10
74 87	536	01 48·7	74 50	G_5		7·51	....	−·01
86 51	589	03 33·9	86 20	F_5	6·22			
	590	....	....	....	6·12	6·17	·03	+·04
89 13	587	07 58·0	88 56	A_3	7·19			
	588	....	....	....	7·08			
	589	....	....	....	7·15			
	590	....	....	....	7·15			
	591	....	....	....	7·19	7·15	·01	+·03
79 328	267	10 05·8	79 27	A_0	6·87			
	539	....	....	....	6·88	6·87	·00	−·08
81 343	539	10 25·7	81 01	G_5		7·52	....	+·05
76 393	267	10 26·6	76 14	G_5	5·89			
	539	....	....	....	5·96	5·92	·02	+·05
77 406	539	10 32·9	77 45	A_0		7·37		
81 349	267	10 33·6	80 57	A_0	6·77			
	539	....	....	....	6·73	6·75	·01	+·04
78 359	539	10 34·5	77 56	B_9		7·32	....	−·25
76 402	539	10 43·5	76 32	A_3		7·26	....	−·01
80 347	539	10 50·7	80 13	F_8		7·71	....	+·03
76 406	539	10 51·5	76 15	F_5		7·80	....	−·01
78 567	539	10 52·0	78 18	G_5		7·19	....	−·01
88 64	587	11 04·2	88 11	B_8	7·36			
	588	....	....	....	7·28			
	590	....	....	....	7·42			
	591	....	....	....	7·38	7·36	·02	+·09
78 385	539	11 16·0	77 55	F_5		7·72		
80 370	585	11 54·5	80 09	F_8		8·17		
87 101	588	11 54·6	87 33	A_2		7·78		
81 389	585	11 55·1	81 28	Ma		7·98		

CATALOGUE OF RESULTS—*Continued*

Star B.D.	Plate	Position, 1900 R.A.	Position, 1900 Dec.	Spec.	Magnitude		P.E.	O-P
°		h m	° ′					
76 439	540	11 58·8	76 37	A_3		7·56		
86 176	587	11 59·7	86 08	F_5	6·75			
	588	......	......	......	6·82	6·78	·01	+·10
77 461	268	12 00·2	77 28	K_0	6·80			
	540	......	......	......	6·81	6·80	·01	−·03
75 469	268	12 04·9	75 13	F_5	6·61			
	540	......	......	......	6·64	6·62	·01	+·02
78 411	268	12 07·1	78 00	A_0		6·47	......	−·07
78 412	268	12 07·5	78 10	A_5		5·47	......	+·07
87 107	587	12 13·9	86 59	F_2	6·61			
	588	......	......	......	6·67	6·64	·02	+·10
88 71	587	12 14·4	88 15	F_0	6·43			
	588	......	......	......	6·54			
	589	......	......	......	6·48			
	590	......	......	......	6·55	6·50	·02	+·14
81 400	585	12 31·1	80 48	F_2		7·50	......	+·05
80 389	585	12 34·1	79 46	G_0		7·46	......	−·04
86 182	587	12 34·6	86 17	F_0	7·28		·03	
	588	......	......	......	7·37	7·32	......	+·04
81 402	585	12 41·9	81 10	A_0		6·44	......	+·05
76 470	540	12 51·1	75 57	K_0		7·83	......	+·05
76 473	540	12 55·9	76 00	K_0	7·00			
	541	......	......	......	7·01	7·00	·00	−·05
81 412	585	12 58·6	81 25	G_0		7·84	......	−·07
86 187	588	12 59·7	86 25	F_8		8·03	......	−·04
77 506	540	13 10·4	77 44	A_2	7·73			
	541	......	......	......	7·69	7·71	·01	
81 416	585	13 11·5	81 00	G_5		7·17	......	−·04
85 222	588	13 18·7	85 17	G_0		7·65		
79 422	269	13 26·1	79 10	G_5	6·46			
	541	......	......	......	6·48	6·47	·01	+·05
76 492	541	13 32·6	76 17	A_0		7·63	......	−·09
77 519	269	13 39·7	77 20	A_5	6·61			
	541	......	......	......	6·62	6·61	·00	−·06
78 466	269	13 42·2	78 34	K_0	6·94			
	541	......	......	......	6·93	6·93	·00	+·07
76 502	541	13 48·5	76 04	F_0		7·48	......	−·19
86 201	588	13 59·4	86 14	F_0		7·54	......	−·05
75 529	269	14 06·2	75 04	A_3	6·41			
	541	......	......	......	6·42	6·41	·00	−·02
78 478	269	14 09·2	78 01	K_0	6·31			
	541	......	......	......	6·33	6·32	·01	−·05
81 482	586	14 33·0	81 15	G_5		7·63	......	−·02
80 448	586	14 36·4	80 06	K_0		7·78	......	+·19
76 536	542	14 48·1	76 29	A_2	7·48			
	547	......	......	......	7·59	7·53	·04	+·05
86 217	588	14 49·6	86 22	K_0		8·01		
81 495	586	14 55·0	81 09	A_0		7·20	......	+·04
78 501	542	14 55·4	78 34	K_0	7·53			
	547	......	......	......	7·56			
	586	......	......	......	7·60	7·56	·01	+·04

CATALOGUE OF RESULTS—*Continued*

Star B.D.	Plate	Position, 1900 R.A.	Position, 1900 Dec.	Spec.	Magnitude		P.E.	O-P
°		h m	° ′					
83 431	586	14 57·1	82 55	G_0		6·34	...	+·14
77 592	270	15 34·4	77 41	K_5	6·55			
	542	...	...	...	6·75			
	543	...	...	...	6·76			
	545	...	...	...	6·76			
	547	...	...	...	6·67			
	548	...	...	...	6·82	6·72	·03	+·09
80 480 }	586	15 35·0	80 47 }	G_5		6·84	...	−·04
481 }	...	15 35·2	80 47 }					
81 517	586	15 35·9	81 06	K_0		7·85	...	−·07
76 563	542	15 36·8	76 47	A_2	7·63			
	543	...	...	...	7·52			
	547	...	...	...	7·59	7·58	·02	−·04
82 463	586	15 38·1	82 36	F_0		7·15	...	−·10
81 523	586	15 42·9	80 56	G_5		7·79	...	−·04
80 487	542	15 45·1	80 18	F_2	7·15			
	547	...	...	...	7·16			
	586	...	...	...	7·13	7·15	·01	−·05
85 265	588	15 47·2	85 13	...		7·77		
81 531	586	15 51·4	81 14	K_2		8·34	...	+·04
83 453	586	15 53·8	83 15	A_2		7·44	...	−·17
82 470	586	15 55·0	82 39	F_0		8·19		
75 579	542	15 57·4	75 52	G_5	7·75			
	547	...	...	...	7·69	7·72	·02	−·10
85 269	587	15 57·4	85 35	A_5	6·91			
	588	...	...	...	6·85	6·88	·02	−·19
73 707	543	16 05·4	73 25	F_5		7·15	...	−·20
77 616	270	16 06·8	77 04	A_0	5·66			
	276	...	...	...	5·68			
	543	...	...	...	5·77			
	545	...	...	...	5·71			
	548	...	...	...	5·69	5·70	·01	+·11
76 594	270	16 13·7	76 08	B_8	5·19			
	276	...	...	...	5·21			
	545	...	...	...	5·17			
	548	...	...	...	5·14	5·18	·01	·00
75 586	543	16 15·0	75 28	K_2		7·68	...	−·11
82 481	586	16 19·5	82 19	A_2		7·84		
73 713	276	16 16·2	73 38	A_0	5·83			
	543	...	...	...	6·03			
	545	...	...	...	5·91			
	548	...	...	...	5·90	5·92	·03	−·02
76 596	276	16 20·4	75 59	F_0	5·24			
	545	...	...	...	5·14			
	548	...	...	...	5·18	5·19	·02	+·01
76 600	543	16 23·0	76 23	A_3	7·14			
	545	...	...	...	7·15			
	548	...	...	...	7·13	7·14	·00	−·09
82 485	586	16 25·0	82 49	...		7·62		
77 627	517	16 34·9	77 39	G_5	7·40			
	543	...	...	...	7·46			

CATALOGUE OF RESULTS—*Continued*

Star B.D.	Plate	Position, 1900		Spec.	Magnitude		P.E.	O-P
		R.A.	Dec.					
° ′		h m	° ′					
	544				7·37			
	546				7·41	7·41	·01	−·02
80 519	517	16 37·7	80 00	G_0	7·62			
	544				7·52	7·57	·03	+·04
77 628	517	16 37·8	77 53	A_2	7·70			
	543				7·76			
	544				7·61			
	546				7·68	7·69	·02	
78 562	517	16 39·9	77 57	F_8	7·43			
	543				7·52			
	544				7·38			
	546				7·41	7·43	·02	−·06
79 508	544	16 41·8	79 24	F_2	7·98			
	546				8·03	8·00	·02	
79 511	517	16 43·6	79 06	K_0	7·64			
	544				7·52			
	546				7·58	7·58	·02	+·08
74 680	543	16 44·2	74 04	A_2	7·02			
	545				7·01			
	548				6·97	7·00	·01	+·01
77 634	276	16 47·5	77 41	F_2	6·27			
	517				6·23			
	543				6·40			
	544				6·44			
	545				6·27			
	546				6·36			
	548				6·31	6·33	·02	−·03
75 608	543	16 56·0	75 33	F_0		7·09	....	+·06
77 639	517	16 56·8	77 01	F_0	7·58			
	543				7·60			
	544				7·57			
	546				7·57	7·58	·00	−·03
77 641	517	17 00·9	77 48	A_0	6·59			
	544				6·67			
	546				6·69	6·65	·02	+·05
79 540	517	17 25·8	79 24	A_5	7·40			
	530				7·35			
	544				7·43			
	546				7·34	7·38	·01	+·03
80·544	517	17 27·2	80 14	K_2	7·65			
	518				7·35			
	530				7·51			
	544				7·55			
	546				7·49	7·51	·03	+·19
79 556	518	17 44·2	79 16	F_2	7·54			
	530				7·69	7·61	·05	−·06
79 564	518	17 55·6	79 21	F_2	7·76			
	530				7·77	7·76	·00	−·01
78 616	518	17 55·8	78 19	K_5	7·86			
	530				7·78	7·82	·03	+·10
78 621	518	18 00·1	78 41	F_2	7·79			

CATALOGUE OF RESULTS—*Concluded*

Star B.D.	Plate	Position, 1900		Spec.	Magnitude		P.E.	O-P
		R.A.	Dec.					
° ′		h m	° ′					
	530	....	....	....	7·71	7·75	·03	−·06
86 272	587	18 07·8	87 00	A_3	5·86			
	589	....	....	....	5·79			
	590	....	....	....	5·88	5·84	·02	−·07
79 587	530	18 30·6	79 09	K_0		7·85	....	+·06
79 590a	518	18 33·1	79 33	A_5	7·56			
	530	....	....	....	7·62	7·59	·02	+·01
77 699	518	18 34·6	77 28	K_0	6·98			
	530	....	....	....	7·04	7·01	·02	+·09
77 702	518	18 42·3	77 35	F_0	7·19			
	530	....	....	....	7·20	7·19	·00	−·06
88 112	588	19 22·5	88 59	Mb	7·97			
	591	....	....	....	7·92	7·94	·02	−·15
87 205	589	22 24·2	87 34	A_2	7·34			
	590	....	....	....	7·34			
	591	....	....	....	7·38	7·35	·01	−·13
85 399	589	23 24·4	85 52	A_6	6·78			
	590	....	....	....	6·75			
	591	....	....	....	6·79	6·77	·01	−·02
85 401	591	23 27·5	86 00	....		7·46		
86 344	589	23 27·8	86 45	A_4	5·67			
	590	....	....	....	5·64	5·65	·01	+·03
85 403	589	23 30·4	85 38	....	7·22			
	590	....	....	....	7·13			
	591	....	....	....	7·19	7·18	·02	
85 409	589	23 54·8	86 09	....	6·71			
	590	....	....	....	6·64			
	591	....	....	....	6·67	6·67	·01	

Column (1) gives the B.D. number of the star.
Column (2) gives the number of each plate on which each star was measured, the date of exposure of each plate being given in Table V.
Columns (3) and (4) give the position for 1900.
Column (5) gives the Harvard spectral type.
Column (6) gives the magnitude derived from each plate and also the mean magnitude for each star.
Column (7) gives the probable error of the mean magnitude.
Column (8) gives the difference between the Ottawa magnitude and that contained in Yerkes Actinometry.

The probable errors given in column (7) were plotted against the distance, ρ, of each star from the centre of the plate as a check on the values given in Table II. The resulting curve of the normal places was a line practically parallel to the ρ ordinate, so that the probable error is evidently in no way dependent on the position of the star image on the plate.

Similarly it was shown that there was no connection between the probable error and the spectral type.

The residuals in column (8) were plotted against spectral type, distance of star from centre of plate and magnitude, respectively, no apparent relation existing in any case.

All the plates listed in Table V were measured at least twice and the average taken, the measures being practically identical. The question of obtaining measurable plates, however, has been a problem owing to the proximity of the city lights. Where the exposure exceeded fifteen minutes there were at least five bad plates for every good one. The results, however, agree very closely with the magnitudes of the Yerkes Actinometry, as published by Prof. Parkhurst. The writer had the privilege of studying photometric work under the direction of Prof. Parkhurst and has followed his method as closely as possible.

DOMINION OBSERVATORY,
OTTAWA, CANADA,
September, 1924.