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EVIDENCE OF THE BENDING OF THE RAYS OF LIGHT ON PASSING THE SUN, OBTAINED BY THE CANADIAN EXPEDITION TO OBSERVE THE AUSTRALIAN ECLIPSE

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ABSTRACT

The Canadian expedition to Western Australia to observe the total eclipse of the sun, September 21, 1922, was equipped with one camera of eleven-foot focus and lens of six-inch aperture. Two plates were secured with this instrument, suitable for testing the deflection of light in a gravitational field. On each plate eighteen star images were measured. The results are in harmony with the displacement predicted by Einstein's general theory.

In the spring of 1921 Mr. Chant obtained permission from the President of the University of Toronto to order a photographic lens of aperture six inches and focal length eleven feet, which he hoped he would be able to use for testing the Einstein theory at the eclipse of September, 1922. Knowing that Director Campbell, of the Lick Observatory, intended to observe this eclipse, provided suitable means of transport to Wallal on the north-west coast could be secured, Mr. Chant kept in communication with him, but it was not until November that it was learned that the Australian Government would provide facilities for taking the parties from the United States and Canada to the desired point.

Meanwhile plans for the camera were drawn, but a grant for its construction was not available until January, 1922. The work was at once begun, and many difficulties were encountered, one being a strike in the engineering trades in England, which prevented the delivery of a suitable driving clock.

It was hoped that an astronomer from the Dominion Observatory, Ottawa, would co-operate in the preparations and would take the camera to Tahiti to secure the night comparison plates. However this could not be arranged and the details of the construction of the apparatus, as also the packing and shipping, devolved on Mr. Chant, while the comparison plates were obtained through assistance from the Lick expedition, as mentioned below. About a month before the date of sailing a telegram was sent to Mr. Young, at Victoria, to ask if he could accompany the expedition, and with the approval of Director Plaskett and the permission of the Department of the Interior.

he became a member of the party. The Canadian party, consisting of Mr. Chant, Mr. Young, Mrs. Chant and Miss Elizabeth Chant, sailed from Victoria on June 17, the mounting for the camera going on the same ship, while the camera itself had gone to Tahiti and then to Sydney some time before.

As a narrative of the expedition, including a summary of the results, has already appeared in the Journal of the Royal Astronomical Society of Canada, we shall aim here to give only a few details regarding the apparatus and also a fuller account of the measurement of the plates.

The lens of the camera was of the symmetrical four-element type and was made by McDowell of Pittsburgh. Its aperture was 6 inches and focal length 11 feet. The "tube" of the camera was of open iron work, the cross-section being 13 inches square and the length being, of course, 11 feet. The corner strips were of angle-iron $\frac{1}{4}$-inch thick, and the sides of the tube were made rigid and strong by iron braces $\frac{1}{4}$-inch thick and $1\frac{1}{2}$ inch wide, which were riveted to the angle-iron. It was covered first with heavy farmer's satin and then with rubber sheeting. One end of the tube was covered by an iron plate bearing the collar into which the lens screwed. This collar could be adjusted in order to collimate the lens. The camera back was made from aluminium. It was carried on the ends of four steel rods which moved in holes in metal blocks, brazed within the tube to the angle-iron corners, for the purpose of focussing the image on the plate. The back could be clamped in any position and a steel scale allowed one to record the position of the back. The plate holders were of aluminium and were made with great care, so that in each case the film of the photographic plate should be at the same distance from the lens.

On two opposite sides of the camera tube, and about mid-way in its length, iron plates $\frac{1}{4}$-inch thick and 13 inches square were riveted, and at the middle of each of these there was bolted a half of a flange coupling, bored out to take the steel declination axis $1\frac{3}{16}$ inches in diameter.

The tube was designed and the working drawings for it were made by C. R. Young, B.A.Sc., C.E., Professor of Applied Mechanics in the University of Toronto. The camera, including the plate-holders, was made in Toronto by the Consolidated Optical Co.

The photographic plates were of plate glass $\frac{3}{16}$-inch thick, specially supplied by the Eastman Kodak Co., of Rochester. The emulsion was Seed 30.

The general design of the mounting resembled that of the great 100-inch reflector at Mount Wilson. The polar axis was in the form of a wooden rectangular frame 8 feet long and 23 inches wide (outside measure) and 6 inches deep. The frame was constructed from seasoned hard maple, three strips 6 inches wide and $\frac{7}{8}$-inch thick being glued and then bolted together. The frame itself was glued at the corners, and securely held together by long bolts at the ends. The corners were further strengthened by screwing iron plates across them. Upon each end of the frame a planed $\frac{3}{8}$-inch iron plate was bolted and upon this was mounted a half-flange coupling bored to receive the steel axis. At the upper end the axis was $1\frac{3}{16}$ inch in diameter, and at the lower, $2\frac{7}{16}$ inches, and they both turned in S.K.F. ball bearings.

The "piers" were of wood, braced in each direction. The top was a heavy block of maple, with a sheet of metal on it upon which the bearings of the polar axis rested. The two piers were bolted and screwed together and when taken to pieces were packed in a single box which weighed 225 pounds. The mounting was made at the University of Toronto.

The camera was held in declination by an iron rod, one end of which was fastened to the lower end of the tube and the other to the wooden rectangle. There was a slot in the end attached to the camera which allowed a limited variation in the declination, but during observations the rod was clamped tight, that is, the declination was fixed.

The camera was moved in right ascension by a clock (made by Cooke) mounted on the inner face of the north (or lower) pier. It drove the camera as a telescope is driven, by worm and worm-wheel. There was a differential slow motion on the clock intended to be driven by electric motor, but in the present case it was operated by a cord which made one loop about its spindle, and the two ends of which were held by the observer as he looked into the guiding telescope. By pulling one end or the other a very slight motion could be given to the instrument. The guiding telescope had an aperture of $4\frac{1}{2}$ inches and a length of about 6 feet, and the power used in guiding was about 180. It was known that at the time of the eclipse β Virginis would be about $2\frac{1}{2}°$ from the sun's centre, and the guiding telescope was mounted so that when the axis of the camera was directed towards the sun's centre the axis of the telescope was directed towards the star, which could therefore be used to guide upon. A second small finder was mounted on the camera. It had a lens of $\frac{3}{4}$-inch aperture and 12 inches focus, mounted at one end of a wooden tube, while the other end was covered with a piece of ground glass on which intersecting lines were drawn. When the image of the sun was at the intersection of the lines it was also at the centre of the photographic plate.

To protect the camera from the wind, the flying dust and the direct sunlight, a wall of cotton duck 14 feet high was built around it. A portion of the roof of this shelter could be pulled aside for making observations. The dust was very bad, being very fine and penetrating. In order to prevent it rising, the ground inside and around the shelter was covered with red sand carried some 500 yards by the aborigines. Much of the time this sand was kept moist by sprinkling water upon it.

The entire camera, the mounting, the duck for the shelter, the photographic plates and other supplies (not including lumber and cement secured at Perth, W.A.) were packed in fourteen boxes, of which the entire weight was 2,200 pounds. The box containing the polar axis was the heaviest and weighed 290 pounds, but as it was flat it was easy to carry. The box containing the piers weighed 225 pounds, and each of the others weighed less than 200 pounds. Thus they were all convenient for transportation.

Practically everyone had reached the camp by Thursday, August 31, but the last package of freight was not delivered until Saturday afternoon. By the following Saturday, September 9, the erection of the instrument was nearly completed. The next week was occupied in making adjustments. The focus of the camera was obtained by photographing the stars at night, and the adjustments for meridian and latitude were made by observing the motion of the stars. The camera objective was collimated and the camera back was adjusted so as to be at right angles to the axis of the camera. As practically every night was clear, good progress was made in this work.

The weather at the time of the eclipse was perfect—a clear blue sky and no wind. Two plates for testing the Einstein theory were obtained, each with an exposure of 45 seconds. We had intended to secure three plates, each with an exposure of 60 seconds, but an unfortunate accident prevented us carrying out this programme. As has been stated, the camera was given a slow motion in R.A. by means of a cord held in the observer's hands as he looked into the guiding telescope. In our rehearsals we used a portion of fishing line and it was found quite satisfactory. As a special precaution a new piece of the line was substituted for the old one on the morning of the eclipse; but when the guiding star, β Virginis, suddenly appeared about 30 seconds before totality began, in the anxious endeavour to bring the camera exactly into position with the star on the cross-hairs, the cord snapped. It was quickly tied together and replaced in position, but valuable time had been lost and only two plates could be obtained, each with a reduced time of exposure.

From our experience at the camp, we decided to develop all our eclipse plates at Broome, where we knew we would have to wait a week before the ship from Singapore would arrive to take us back to Fremantle. By using rainwater and ice made from rain water the developing was accomplished without serious difficulty. The developer used was Rytol.

The night comparison plates were obtained for us through the generous co-operation of Dr. Campbell and Dr. Trumpler. The latter offered to secure them if he should have time after taking those for the Lick party. Consequently, the camera was shipped in May to Tahiti, special declination axes having been made so that it could be mounted in the Lick polar axis.

The plates were measured on the Repsold measuring engine of the Dominion Astrophysical Observatory by Mr. Young and Mr. W. E. Harper. The computation necessary for the reductions of the measures were performed by Mr. Young. An account of this work follows.

Table I contains a summary of the plates secured at Tahati and Wallal.

TABLE I

Plate		Observer	Date, 1922	Local M.T.		Exp.		Field	Temp. F.	Barom.
				h	m	m	s		°	in.
C7	Tahiti	Trumpler	June 10	8	24·4	2	30	Eclipse	73·5	30·39
			June 10	14	43·2	1	0	Check	70·5	30·39
E1	Wallal	Chant and Young	Sept. 21	1	33·6	0	45	Eclipse	80	30·1
C8	Tahiti	Trumpler	June 10	14	51·4	2	30	Check	70·5	30·39
			June 11	8	22·4	2	30	Eclipse	74	30·36
E2	Wallal	Chant and Young	Sept. 21	1	34·7	0	45	Eclipse	80	30·1
			Sept. 21	7	43·0	2	30	Check	70·5	30·3
C9	Tahiti	Trumpler	June 11	8	44	4	0	Eclipse		Taken through glass.
			June 11	14	50	4	0	Check		

The identifications of the star images on the eclipse fields and their approximate positions and magnitudes are given in Table II. The unit of distance was taken as fifty minutes of arc. It was discovered upon examining the check regions that the stars had not always been placed in the same relative position to the optic axis. The images on C9 and those taken at Wallal were in the same positions but for C7 and C8 other, guiding stars were used and the fields were displaced. In order to have the regions superimposed, the plates had to be shifted sideways and the increased area prevented the pair being mounted on our measuring engine. The area common to the two plate was considerably reduced, so that the value of the check was diminished. These facts taken in conjunction with the important consideration that the stars on the two plates were not in the same position relative to the optic axis of the lens made us decide to forego the measurement of the check stars.

TABLE II

No.	B.D.	Mag.	x	y	D	No.	B.D.	Mag.	x	y	D
	°						°				
1	+0·2831	8·3	−2·91	−1·32	3·19	11	0·2870	9·2	+1·41	−0·67	1·56
2	+0·2843	6·9	−1·70	−1·09	2·02	12	2·2499	8·0	+1·43	+1·51	2·08
3	+3·2560	9·0	−1·47	+2·00	2·48	13	0·2877	9·3	+2·05	−1·14	2·35
4	+2·2489	4·3	−1·21	+1·44	1·88	14	0·2878	9·0	+2·06	−1·16	2·35
5	−0·2510	8·4	+0·06	−2·44	2·44	15	3·2588	9·5	+2·07	+2·16	2·99
6	+0·2858	8·3	+0·11	−1·37	1·38	16	0·2880	8·2	+2·20	−0·58	2·28
7	+1·2628	7·4	+0·23	+0·62	0·66	17	0·2881	9·5	+2·20	−0·60	2·29
8	−0·2512	8·9	+0·41	−2·44	2·47	18	1·2641	9·3	+2·33	−0·02	2·33
9	+1·2633	8·4	+1·08	+0·35	1·13	19	0·2883	8·8	+2·37	−0·65	2·47
10	+1·2636	7·5	+1·33	−0·06	1·33	20	2·2509	7·8	+2·89	+1·07	3·08

The images of stars Nos. 11 and 15 were very faint and diffuse and outside of a few preliminary settlings were not measured.

The last plate in the table of observations numbered C9, which was taken by Trumpler at Tahiti, was exposed with the glass side towards the lens and the focus was altered so as to give good definition. This plate was clamped firmly to plate number C7 film to film, so that the two sets of images were nowhere more than 1 mm. apart. The pair of plates was then mounted on the measuring engine, C9 being nearest the objective of the microscope. The measurement was always made through the same glass plate and care was taken always to superimpose the plates so that the images on C9 and those on the other plate were in the same relative positions. The clamps extended along the two ends of the plates and held them very firmly, as measures of the images could be repeated after an interval of several days. The plate was oriented so that the double way micrometer of the microscope measured as nearly as possible the differences in right ascension and declination and so that the main slides of the engine moved also in the same co-ordinates. From five to eight settings were taken on each pair of images in both co-ordinates by Mr. Young and then by Mr. Harper. As the plates were not disturbed between these measures, they naturally agreed within the accidental error of measurement and the means were taken. The plate was then turned through 180 degrees and the settings repeated. The scale of the microscope was checked from time to time by measuring divisions on a silver scale so placed on the measuring engine that the turn of a small lever directed the microscope from the film towards the scale and at such a distance as to have the same focus as the plate being measured. Small changes probably occurred during the process of measurement, but these would be of secondary importance and were neglected. When plates C7 and C9 had been compared, E1 to C9, C8 to C9, E2 to C9 were treated in the same way. By subtracting the differences obtained from C7 to C9 from those from E1 to C9 we obtained the relative positions of the images C7 to E1. The differences C8 to E2 were similarly obtained.

The observations were next corrected for differential refraction and aberration. The amount of the refraction and aberration at Tahiti and Wallal was computed rigorously for each star. This work was probably quite unnecessary, as the corrections are small and differential formulae would have been sufficient. Allowance was also made in two cases for the proper motions of the stars in the interval between taking the plates at Tahiti and those at Wallal. In the case of β Virginis, star number 4, allowance was made also for the effect of annual parallax. The corrected differences for the eighteen images measured are shown in Table III.

TABLE III

	*E*1-*C*7		*E*2-*C*8			*E*1-*C*7		*E*2-*C*8	
	Δx	Δy	Δx	Δy		Δx	Δy	Δx	Δy
1	−2·512	+2·920	−1·809	+1·131	10	−2·143	+1·646	−1·705	+0·778
2	−2·376	+2·569	−1·772	+1·032	12	−1·697	+1·547	−1·619	+0·719
3	−1·483	+2·404	−1·350	+0·936	13	−2·543	+1·497	−1·820	+0·759
4	−1·590	+2·359	−1·530	+0·945	14	−2·590	+1·474	−1·856	+0·764
5	−2·816	+2·121	−1·812	+0·916	16	−2·389	+1·397	−1·835	+0·749
6	−2·527	+2·036	−1·758	+0·902	17	−2·406	+1·363	−1·783	+0·698
7	−1·815	+1·960	−1·626	+0·957	18	−2·192	+1·324	−1·804	+0·669
8	−2·805	+1·983	−1·863	+0·863	19	−2·358	+1·339	−1·833	+0·718
9	−2·036	+1·676	−1·661	+0·786	20	−1·936	+1·119	−1·679	+0·564

The measured differences Δx and Δy were equated to expressions of the form

$$ax + by + c + \alpha Ex = \Delta x$$

$$dx + ey + f + \alpha Ey = \Delta y$$

The constants c and f depend on the lateral shift of the scale plate on the plate to be measured. In order that these quantities might be as small as possible, we have manipulated the observed Δx's and Δy's by adding or subtracting a constant quantity for each plate. The constants b and d depend on the orientation of the plates. The analysis should show $-b = d$. The quantities a and e are due to differences in scale value which may arise from the focal length of the system changing or from the inclination of the plate varying. In the latter case we would expect that the scale in the x direction would differ from the scale in the y direction. We adopted the same methods as used by the observers from the Lick Observatory to assure ourselves that the plate was as nearly as possible perpendicular to the optic axis of the camera, in fact we were kindly loaned the same micrometer telescope (cf L.O.B. No. 346, p. 44) and were helped in the operation by Dr. Trumpler. It is impossible, however, to obtain perfect adjustment. The terms involving the inclination of the plate enter into the solution as second powers of x and y. We have not included terms beyond the first order and under these circumstances the general effect of the solution is to modify the scale values in the two co-ordinates so as to take care of the omitted higher powers as far as possible.

The quantity α denotes the deflection of the light at unit distance from the sun and α (*E*x) and α (*E*y) are simple functions of x and y, giving the deflection in right ascension and declination of a star whose co-ordinates are x and y. By including this term in the solution we assume that an effect is present of the nature predicted by Einstein but of unknown amount. Mathematically there is no reason for the solution yielding positive values for α. If the Einstein effect is small or absent, it should be shown by the solution yielding small or δ negative values for α. On the other hand, consistent positive values obtained for α from the solution are confirmatory to a shift being present. We see no objection to the inclusion of this term.

The observation equations built up as indicated are shown in the following tables.

OBSERVATION EQUATIONS X CO-ORDINATE.

No.	*c*	*b*	*a*	α	*E*1–*C*7	*E*2–*C*8
1	1·00	−1·32	−2·91	−0·28	+0·304	+·054
2	1·00	−1·09	−1·69	−0·42	0·440	·091
3	1·00	+2·00	−1·47	−0·24	1·333	·513
4	1·00	+1·44	−1·21	−0·34	1·226	·333
5	1·00	−2·44	+0·06	+0·01	·000	·051
6	1·00	−1·37	+0·11	+0·06	·289	·105
7	1·00	+0·62	+0·23	+0·51	1·001	·237
8	1·00	−2·44	+0·41	+0·07	·011	·000
9	1·00	+0·35	+1·08	+0·84	·780	·202
10	1·00	−0·06	+1·33	+0·75	·673	·158
12	1·00	+1·51	+1·43	+0·33	1·119	·244
13	1·00	−1·14	+2·05	+0·37	·273	·043
14	1·00	−1·16	+2·06	+0·37	·226	·007
16	1·00	−0·58	+2·20	+0·42	·427	·028
17	1·00	−0·60	+2·20	+0·42	·410	·080
18	1·00	−0·02	+2·33	+0·43	·624	·059
19	1·00	−0·65	+2·37	+0·39	·458	·030
20	1·00	+1·07	+2·89	+0·30	·880	·184

OBSERVATION EQUATIONS Y CO-ORDINATE

No.	*f*	*d*	*e*	α	*E*1–*C*7	*E*2–*C*8
1	1·00	−2·91	−1·32	−0·13	+1·801	+·567
2	1·00	−1·69	−1·09	−0·27	1·450	·468
3	1·00	−1·47	+2·00	+0·32	1·285	·372
4	1·00	−1·21	+1·44	+0·41	1·240	·381
5	1·00	+0·06	−2·44	−0·41	1·002	·352
6	1·00	+0·11	−1·37	−0·72	·917	·338
7	1·00	+0·23	+0·62	+1·42	·841	·393
8	1·00	+0·41	−2·44	−0·40	·864	·299
9	1·00	+1·08	+0·35	+0·27	·557	·222
10	1·00	+1·33	−0·06	−0·03	·527	·214
12	1·00	+1·43	+1·51	+0·35	·428	·155
13	1·00	+2·05	−1·14	−0·21	·378	·195
14	1·00	+2·05	−1·16	−0·21	·355	·200
16	1·00	+2·20	−0·58	−0·11	·278	·185
17	1·00	+2·20	−0·60	−0·11	·244	·134
18	1·00	+2·33	−0·02	−0·00	·205	·105
19	1·00	+2·37	−0·65	−0·11	·220	·154
20	1·00	+2·89	+1·07	+0·11	·000	·000

Normals were formed from the observation equations in the usual way. All the stars were given the same weight. During the progress of measurement weights were assigned according to the appearance of the image. The best images were given weight 2 and those which were fainter and more diffuse weight 1. Considerable doubt was felt, however, as to the advisability of using these in the solution. It is a common experience that the measures of faint images, provided they are strong enough to be measurable, prove as reliable as measures of those which are much stronger, and apparently more trustworthy. In the formation of the first set of normals all the stars measured were included and the following values of the constants resulted.

x Co-ordinate

	c	*b*	*a*	α
*E*1–*C*7	+·701	+·303	−·043	+·053
*E*2–*C*8	+·185	+·088	−·032	+·011

y Co-ordinate

	f	*d*	*e*	α
*E*1–*C*7	+·910	−·298	−·038	+·014
*E*2–*C*8	+·308	−·078	−·041	+·080

The agreement of the constants *b*, *d* and *a*, *e*, is fairly satisfactory. Though there are considerable discordances in the values of α they are all positive. The value of one revolution of the micrometer screw is 13″·3. The values for the Einstein constant at the limb of the sun which correspond to the values of α are 1″·32 for the x co-ordinate and 1″·96 for the y co-ordinate.

The representation of the star positions by substitution of the constants in the observation equations showed that most of the stars were fairly accordant, but that stars numbers 1, 3, 7 gave residuals over one second of arc. The residual of star number 7 was in a direction which would tend to make the solution yield an Einstein shift even if none were present. A second solution was made forming normals with stars 1, 3, 7 omitted. This solution gave the following values for the constants.

x Co-ordinate

	c	*b*	*a*	*α*
*E*1–*C*7	+·721	+·300	−·054	+·031
*E*2–*C*8	+·177	+·071	−·042	+·052

y Co-ordinate

	f	*d*	*e*	*α*
*E*1–*C*7	+·912	−·300	−·040	+·014
*E*2–*C*8	+·309	−·080	−·029	+·018

The values of α yielded from the x co-ordinate make the Einstein constant at the limb of the sun 1″·73. In omitting stars 3 and 7 from the y co-ordinate, the weight of the solution is much diminished, as can be seen from the observation equations. The values of α are, however, positive. They correspond to an Einstein constant 0″·66 at the limb of the sun. Star number 7 is the most important star on the plate, and a third solution was made putting this star in but omitting numbers 1 and 3. The values of the constants from this solution are shown below.

x Co-ordinate

	c	*b*	*a*	*α*
*E*1–*C*7	+·729	+·303	−·064	+·067
*E*2–*C*8	+·177	+·071	−·042	+·051

y Co-ordinate

	f	*d*	*e*	*α*
*E*1–*C*7	+·912	−·300	−·041	+·015
*E*2–*C*8	+·310	−·080	−·042	+·080

A summary of the results from the three solutions is shown in the following table:

		x Co-ordinate	y Co-ordinate	Mean
1	All stars	1″·32	1″·96	+1″·75
2	1, 3, 7 omitted	1″·73	0″·66	+1″·42
3	1, 3 omitted	2″·47	2″·00	+2″·16

The mean given in the last column is the weighted mean formed by giving weights as indicated from the co-efficients of the normal equations in the solution.

The displacement of the stars outward from the sun was next calculated on the basis of solution number three. They are shown in the table below and are plotted on the accompanying graph. The full line shows the expected displacements on the basis of the Einstein shift being 1″·75 at the limb of the sun. The large circles represent stars which were assigned weight unity in the course of the measurement and the smaller circles those which received half weight.

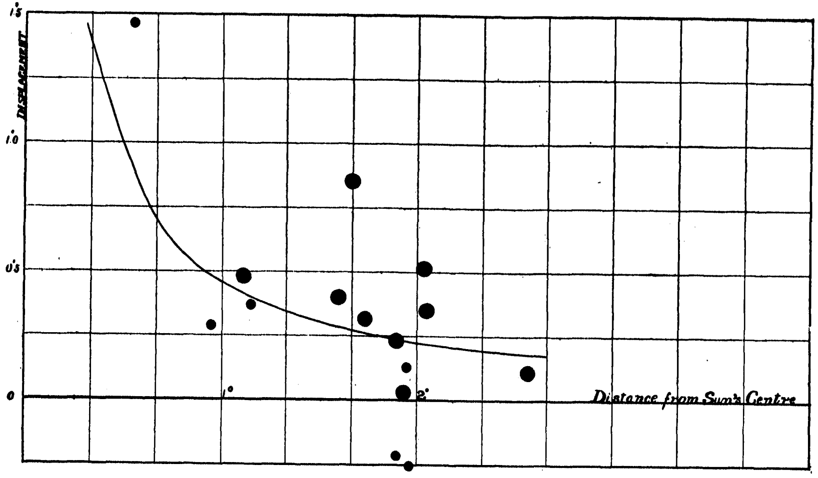

TABLE OF STAR DISPLACEMENTS

Star	Weight	Displacement	Expected	Star	Weight	Displacement	Expected
		″				′	
2	1	+0·85	0·28	12	1	+0·32	0·27
4	1	0·40	0·30	13	½	0·13	0·22
5	1	0·51	0·21	14	½	−0·25	0·22
6	½	0·37	0·40	16	½	−0·21	0·24
7	½	1·46	0·85	17	1	+0·23	0·24
8	½	0·87	0·21	18	1	0·03	0·24
9	½	0·29	0·48	19	½	0·35	0·22
10	1	0·48	0·41	20	1	0·11	0·18

These observations show considerable departures from the curve, but it must be admitted that they satisfy some line drawn on a slant from the upper left corner downwards towards the lower right. If we were to omit the Einstein shift altogether, it would be necessary to fit the residuals into a change of scale value, which would be equivalent to drawing the base line from the point O, O, upwards towards the right. This would not satisfy the observations so well. The mathematical solution confirms this by consistently assigning positive values to the α term. Considering the small number of stars the agreement with the amount predicted by Einstein is surprisingly good. They are not of sufficient accuracy to say what law it follows, but they are, however, in harmony with the amount predicted.

In conclusion, we would acknowledge the indebtedness of the expedition to various persons and bodies. The University of Toronto supplied the apparatus, bore the cost of its freight and a portion of the ocean travel. The Dominion Government gave leave of absence to Mr. Young and contributed his ocean fare. But the services rendered by the Australian Government were especially great. They gave free transport of the entire party from Sydney, 2,700 miles across the continent to Fremantle, 1,550 miles up the west coast to Wallal, and then return to Sydney. In addition, a body of men from the Royal Australian Navy, under Commander H. L. Quick, transferred the freight, landed the party on the shore, set up the camp and supplied sustenance, assisted in mounting the instruments and in observing during the eclipse; and, when all was over, assisted in embarking again. The hospitality of the citizens of Australia was unbounded and will never be forgotten.

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