ART. III.—*Photography of Southern Star-clusters;* by C. S. SELLACK, at present Professor of Physics in the University of Cordoba, South America.

IN the beginning of last year, under an arrangement made with Mr. Rutherfurd in New York, and at the expense of some gentlemen from Boston, I went to Cordoba to take, in the Argentine National Observatory,* photographs of southern star-clusters, employing the methods of Mr. Rutherfurd. The method of Mr. Rutherfurd is the following. After an exposure of the photographic plate for some minutes, the telescope, which is driven by a good clockwork, is moved to another position by the slow motion, and a second exposure is made; then the telescope is stopped and an exposure made so that the image of the central star, while moving out of the field, leaves a trail. The images of the stars being double, the recognition and discrimination from specks produced by impurities of the plate is very much facilitated; the trail serves to fix a direction for the angles of position on the plate. When the trail could not be obtained for want of brightness of the central star, I made a third exposure some minutes distant from the first, by starting the telescope again after some minutes stopping.

The photographic refractor of about 0·280^{m} aperture, formerly owned by Mr. Rutherfurd, now property of the Cordoba Observatory, was to be used for the work. On my arrival in Cordoba the lens, which for a long time had been kept packed up in Cordoba, was found broken; the flint-lens was divided in two by a crack near the middle. The object of my voyage seemed to be frustrated. The optical refractor of the same dimensions, which the observatory possesses, proved unfit for photographic purposes. In using only one half of the broken flint-lens the intensity of light would have been too much reduced for the intended work. If anything at all was to be accomplished, the two pieces of the broken lens had to be fitted together.

I undertook this task with the assistance of a watchmaker in Cordoba, constructing an adjusting apparatus. On the circumference of each of the two segments of the lens, at the corners of the break and in the middle, were put three little metal clasps; pairs of pulling and butting screws, inserted in small metal pieces fastened on to the frame of the lens, worked on these clasps, so that with them the pieces of the lens could be lifted and lowered. A slight motion of the pieces of the lens parallel to its surface could be effected by little wedges, the frame giving some play to the lens.

* Under the charge of Dr. B. A. Gould.

The adjustment of the lens was to be done by continued photographing of stars, as the image is not sharp for mean visible rays, and even observation through a blue glass did not show it distinctly enough. The lens had to be taken out of the telescope for each correction, which was done many a hundred times. The image of the star was photographed, not only in its true focus, but at different distances before it, so that the section of the converging light was obtained; the shape and arrangement of light in these sections allowed a better judgment of the state of the different parts of the lens. As the object was not the adjustment of parts of a simple lens, but of the diverging lens of a system, it is obvious that mistakes in correcting the screws were easily made. Displacement of the two pieces of the lens produces double images in the manner of the heliometer, except that in this case the concave lens alone makes the effect; tilting of the pieces about the edge of the crack has a similar effect. The surface of the crack being very irregular, it was difficult to fit the pieces exactly together. Otherwise local tensions and changes of curvature were easily produced by which the image was deformed and the focus of parts of the lens changed. Continued wearisome experiments yielded at last an adjustment sufficient under the circumstances.

The lens gives now with short exposures a well defined, nearly circular, photographic image of stars of the first and second magnitude, and admits adjustment of the focus to $0{\cdot}2^{mm}$. In its former perfect state Mr. Rutherfurd obtained a trail on the photographic plate of stars of the third to the fourth magnitude, as of several stars in the Pleiades. The image of the broken lens does not seem to have the same concentrated sharpness; only slow moving stars, fainter than third magnitude, leave a trail. However, with exposures of eight minutes stars of the ninth magnitude, of white color, give a photographic impression; this result does not seem to have been surpassed formerly.

The greatest difficulty in stellar photography is to make the image on the plate stationary during a long exposure. The steadiness is absolutely necessary for the production of circular images; the images must be circular, because in elliptically lengthened images the eye cannot fix the center with the sharpness required for the measurements. Employing even the most perfect clockwork, the steadiness of the image is affected by the effect of the atmospheric refraction, by the variations in the refraction produced by disturbances in the atmosphere, and by the increase of refraction dependent on the zenith-distance.

The photographic image of stars is circularly spread by prolongation of exposure; this is principally the effect of the scintillating motion of the image, not of want of definition, as its amount depends on the state of the atmosphere. Bond has found the increase of the area of the image proportional to time. This admits the explanation of the scintillating motion as consisting of transversal vibrations round the central position in all azimuths, and with *uniform* velocity. When the state of the atmosphere produces a strong scintillating motion, the images of bright stars become very large by long exposures, and faint stars do not produce any impression. In great zenith-distances another obstacle combines with the increased scintillation, the strong absorption of chemical rays by the atmosphere.

The increase of refraction depending on zenith-distance. for an exposure of eight minutes, is computed in right ascension and declination for declinations from +20° to — 80° for Cordoba, southern latitude 31° 15′ 30,″ thermometer 20° C, and barometer 725 ^{mm}.

Differences of refraction.

Interval of Hour-angle,	+20° α	+20° δ	+10° α	+10° δ	0° α	0° δ	−10° α	−10° δ	−20° α	−20° δ	−30° α	−30° δ	−40° α	−40° δ	−50° α	−50° δ
	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″
0°– 2°	0·00	0·09	0·00	0·07	0·00	0·07	0·00	0·08	0·02	0·13	0·58	0·48	0·02	0·14	0·00	0·07
7°– 9°	0·11	0·67	0·11	0·57	0·14	0·56	0·23	0·62	0·51	0·77	1·54	0·34	0·63	0·68	0·17	0·39
13°–15°	0·34	1·18	0·33	0·97	0·38	0·90	0·55	0·93	0·97	0·92	1·61	0·29	1·08	0·64	0·46	0·62
28°–30°	1·51	2·63	1·30	1·95	1·29	1·58	1·23	1·50	1·69	0·94	1·88	0·36	1·65	0·29	1·17	0·63
43°–45°					2·75	2·37	2·33	2·01	2·50	1·17	2·39	0·59	2·19	0·04	1·79	0·38

Only the component of the refraction in right ascension can be reduced to less than 0·″1, by retarding the clock by the mean amount, and for intervals of 8^{m} within the given limits (with exception of the zenith-stars near culmination). The corrections of the clock per hour are:

Interval of Hour-angle,	+20°	+10°	0°	−10°	−20°	−30°	−40°	−50°	−60°	−80°
	s.	s.	s.	s.	s.	s.	s.	s.		
0°– 2°	0·00	0·00	0·00	0·00	0·01	0·33	0·01	0·00	0·00	0·00
7°– 9°	0·06	0·05	0·07	0·12	0·27	0·59	0·41	0·13	0·08	0·06
13°–15°	0·18	0·17	0·19	0·28	0·52	0·93	0·70	0·36	0·22	0·15
28°–30°	0·80	0·66	0·64	0·63	0·90	1·08	1·08	0·91	0·74	0·66
43°–45°			1·37	1·18	1·33	1·38	1·43	1·39	1·32	1·38

The component of refraction in declination cannot be eliminated. But the table shows that a double exposure of eight minutes can be made for all stars in which the motion of the image of the central star is less than 0·″2 or 0·004^{mm} on the photographic plate. The field comprehends a circle of 80′ diameter; however, the difference of the motion of stars near the border, and of the central one, is always less than 0.″1. The favorable time for taking photographs is for north culminating stars near culmination, for stars culminating near the zenith at some distance from culmination, for south culminating stars near culmination, or at greater hour-angle, when the parallactic angle is near right angle.

As the circumstances have been utterly unfavorable, the lens being broken, the clockwork not of sufficient delivery, the results of the enterprise could not fulfill the legitimate expectations of the liberal originators.

The objects of the southern heavens are numerous and glorious. I selected and photographed some twenty star-clusters, most of them in the constellation Argo, some in Canis Major and Scorpio. The cluster near Carinæ Argus gave a hundred and twenty-three stars on the photograph in the most favorable night. The Pleiades, the richest northern group, did not yield to Mr. Rutherford more than forty-five stars; in fact, the Pleiades do not contain within 40′ round Alcyone more than seventy-five stars, inclusive of the tenth magnitude. The groups near ρ Argus and Lacaille 4375 Argus gave about sixty stars; four other clusters t_2 Carinæ, Lac. 4145, Lac. 3134 Argus, Lac. 7478 Scorpionis about forty stars; altogether twenty-seven clusters, about eight hundred stars.

The elaboration of the results which the plates are capable of giving has been reserved to Dr. Gould.

The Argentine Government is going to provide a new photographic lens for the National Observatory, and has asked me to continue the experiments with the new lens.

Cordoba, March 8, 1873.