

ART. LIX.—*The Color Correction of certain Achromatic Object Glasses*; by Prof. C. A. YOUNG, Princeton, New Jersey.

THE recent discussions in this Journal upon the theory of achromatism will perhaps give interest to a brief statement of the results actually obtained in practice. I accordingly present the results of my measurements upon two excellent object-glasses which have come under my observation.

The first is that of the Dartmouth College Equatorial, made by the Clarks in 1871. It has an aperture of 9·36 inches and a focal length of 12 feet. It is considered by the makers a little under-corrected, but suits my own eye very well, in pleasant contrast to the violent over-correction of a 6-inch Munich glass which I had used for several years previous. The spherical aberration is very perfectly corrected. The curves are essentially those of Littrow (*Mem. Roy. Astron. Soc.*, vol. iii), a nearly equiconvex lens of crown, and a nearly plano-concave flint.

The other lens is that of the Equatorial belonging to the observatory of the John C. Green School of Science at Princeton. It has an aperture of 9·5 inches and a focal length of 138. It is constructed substantially upon the curves proposed by Gauss (*Gauss' Werke*, vol. v, p. 507, Göttingen Ed.), the radii and constants of the objective being as follows, viz:

	Inches.
Crown lens, meniscus, }	Radius of convex surface, 16·572
convex side outward }	Radius of concave surface, 57·425
	Thickness at center, 0·620
	Interval between lenses, 0·312
Flint lens, concavo convex, }	Radius of convex surface, 20·684
convex side next crown, }	Radius of concave surface, 13·871
	Thickness at center, 0·305

The radii were determined by a delicate spherometer.

The telescope is remarkably excellent in every respect, especially in the darkness of the field and the power of exhibiting faint objects, like the satellites of Mars and Uranus.

The observations on the Dartmouth telescope were made by myself in 1872; those on the Princeton instrument in 1879, partly by myself and partly by my assistant, Mr. McNeill. The number of observations on the Princeton telescope was from ten to twenty for each line of the spectrum examined; the figures for the Dartmouth instrument depend upon only five measurements each, and are of course somewhat less reliable.

The method of observation was in all cases substantially the

same. The spectroscope, arranged as for observation of solar prominences, is attached to the telescope, which is first pointed at the center of the sun. The portion of the spectrum to be examined is then brought to the middle of the field of view, and one of the longitudinal dust-lines (caused by particles between the jaws of the slit, always far more abundant than one would like) is made perfectly distinct by the focussing screw of the spectroscope. If the parts of the spectroscope all happen to be in exact adjustment, the true dark lines of the spectrum and these dust-lines will of course both be perfectly sharp for the same focal adjustment; but this is seldom the case for a fastidious eye.

This adjustment of focus having been accurately made, the telescope is then so directed that the edge of the sun's image shall cross the slit perpendicularly, and by sliding the whole spectroscope along its supporting bar a position is sought where the edge of the solar spectrum shall be perfectly defined as seen in the eyepiece of the spectroscope. When this has been accomplished the slit will evidently be exactly in the focal plane of those rays of the spectrum which occupy the field of view.

Of course if the object-glass is poor, or the air unsteady, no point of absolute sharpness can be found, and we have to be content with finding a minimum of indistinctness. But with good seeing and an object-glass well corrected for spherical aberration, the observation admits a really surprising degree of accuracy, successive determinations of the same point seldom differing, under such circumstances, as much as half a millimeter.

In this way the differences of focal length for different parts of the spectrum may be obtained with satisfactory precision: I say *differences* because the absolute focal length is all the time changing with the temperature, and that by a considerable amount; so that it is necessary to recur to and redetermine the zero point continually. This zero in my observations was the focal plane of the D lines.

In the table the first column contains the designation of the spectrum-lines observed, either by letters, or by their position on Kirchhoff's map; the second gives the wave length according to Ångström. The remaining columns explain themselves, except that  $dF$  denotes the difference, expressed in thousandths of an inch, between the minimum focal length, and that for the particular ray of the spectrum in question, while the columns headed  $\frac{dF}{F}$  contain the same quantity expressed in hundred thousandths of the focal length. I have added, for comparison, in the sixth column, the results of Lorenzoni for a Fraunhofer

object-glass of 1<sup>m</sup>·750 focal length; published in the *Astronomische Nachrichten*, vol. lxxviii, p. 289 (1871). His numbers were obtained by calculation and not by direct measurement, the computation being based upon Fraunhofer's determination of the indices of refraction for specimens of glass like that used in the lens.

Ray of Spectrum.		Gauss.		Littrow.	Fraunhofer.
Designation.	$\lambda$ .	$dF$	$\frac{dF}{F}$	$\frac{dF}{F}$	$\frac{dF}{F}$
A	7600	0·199 in.	·00145	·00172	--
B	6866	·097	69	97	·00064?
C	6561	·052	37	49	52
D	5890	·002	1	0	2
1235 K	5590	·000	0	--	--
1474 K	5316	·004	3	35	--
E	5269	---	--	--	15
b	5183	·011	8	--	25
c	4956	·035	25	--	--
F	4860	·059	42	129?	72
2500 K	4530	·197	143	--	--
f	4471	---	--	--	214
2796 K	4340	---	--	294	271
G	4307	·370	262	--	289
h	4101	·626	437	444?	452
H	3968	·810 in.	·00575	·00650?	·00582

A glance at the table shows that as to the extreme rays there is very little difference between the three objectives, but that for the middle rays the Gauss lens is decidedly the best, and the Littrow the worst. The same thing is still better shown by the diagram of the color curves. The ordinates of these curves are taken from the columns  $\left(\frac{dF}{F}\right)$  of the table: for abscissas I

have used the values of  $\frac{1}{\lambda}$ , i. e., the number of wave-lengths to a millimeter. If we take the wave lengths themselves as abscissas, the left-hand portion of the curve is so flattened and extended, and the right-hand portion becomes so steep as to make the figure very inconvenient.

A ? is appended in the table to a few of the numbers which do not seem to fall in well with the general course of the curve to which they ought to conform.

Princeton, N. J., April 14, 1880.