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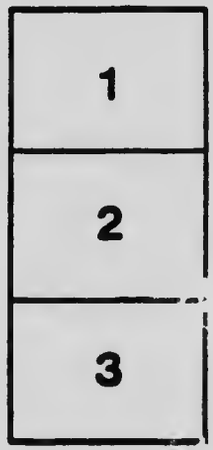

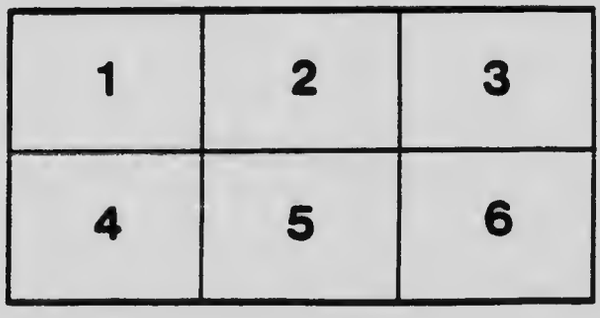

A NEW FORM OF SPECTRO-COMPARATOR

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A NEW FORM OF SPECTRO-COMPARATOR

By RALPH E. DE LURY

By employing a half-silvered surface and two microscopes, it is possible for one to construct a comparator possessing special advantages in the measurements and comparisons of photographs of spectra. The device may be arranged in several ways:

I. The microscopes may be set up with their axes intersecting on either side of the objectives and with the half-silvered surface at the intersection.

II. The microscopes may be set up with the axes of the objectives parallel. One beam of light, after passing through its objective, is turned by reflection through one or two right angles to meet, at the half-silvered surface, the direct or similarly reflected beam from the other objective.

The half-silvered surface transmits and reflects in either case about half of each beam; and the images, side by side or overlapping, may be observed in two directions at right angles to one another.

By employing the arrangement I in such form as shown in the diagram, it is possible to produce, with a minimum of optical surfaces, two sets of images in convenient positions for alternate measurement, the configurations appearing rotated 180 degrees with respect to one another. In the case of spectra, one eyepiece would show "violet right" and the other "violet left." Furthermore, in order to compare personal errors of measurement, two observers could conveniently measure together, one at each eyepiece, viewing each other's settings or making alternate settings. (Such a method of comparison between two observers should prove valuable in such observations as the transits of stars, occultations, etc.) To facilitate such comparisons in the measurements of spectra, the comparator should be made to rotate and should be set up on a narrow table with a seat on each side. To avoid the interference of reflections from the outside surfaces, the silvered surface should lie between two wedges or rectangular prisms of glass.

For arrangement II the Hartmann spectro-comparator[1] may be easily adapted by removing the usual silver mask between the components of the double-prism placed below the eyepiece, half-silvering the face of one of the prisms, and cementing the prisms together again with Canada balsam. With this device the Hartmann comparator possesses all the advantages it ordinarily has, and in addition the following:

1. One double-prism suffices for all comparisons. In the Hartmann instrument various kinds of masks are made between

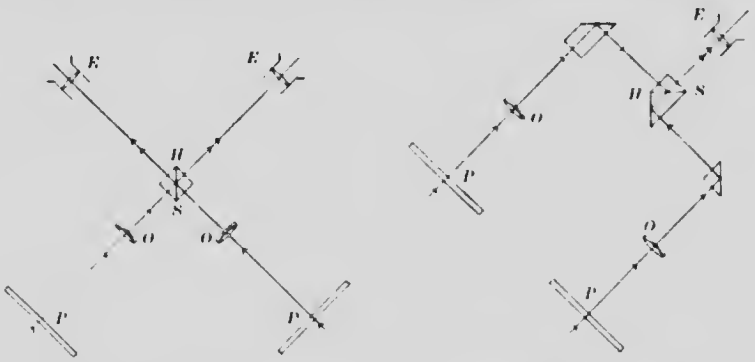

FIG. 1

I. New Form of Spectro-comparator II. Adapted Hartmann Spectro-comparator

E, eyepiece; *HS*, half silvered surface; *O*, objectives; *P*, photographic plates

the components of the double-prisms, to make possible the comparison of spectra of different configurations; and it is also necessary to focus both images at this mask in order to have the edges of the latter sharp. If the center of the mask be in focus, the outer edges are out of focus (as Hartmann pointed out), and this has a disturbing effect on the observer. Furthermore, a vertical line at this surface is in focus only at its middle and can therefore not be used for setting on spectrum lines in the ordinary way. These difficulties are all overcome by using the half-silvered surface. In this case the images may be brought to focus beyond the double-prism where masks of any desired configuration may be employed,

[1] *Zeitschrift fur Instrumentenkunde*, **21**, 205–207, 1906; also *Astrophysical Journal*, **24**, 285, 1906.

and where adjustable spider lines may be used when desired. Thus comparisons and line bisections may be made at the same time.

2. When the half-silvered surface is used, it is possible to place the images in coincidence in order to detect differences.

3. The new device makes possible the employment of the comparator for measuring photographs of spectra by the promising method suggested by Evershed, namely, that of using, with the negative to be measured, a positive plate made from it, and placed reversed to negative end for end.[1] I have adapted the Hartmann comparator for this purpose and have found it very satisfactory. It overcomes the disadvantages of the method Evershed has employed of sliding positive above negative, in that by the new method the films of positive and negative may be [illegible] in the same plane. (The difficulty of having the films not in the same focus has been practically overcome by Evershed by employing an objective of long focus.) The new method possesses [illegible] advantage in that the intensity or color of the beams of light from positive and negative may be altered independently, thus making it possible, by matching the intensities of the positive and negative or by increasing the contrast, to measure the displacements of spectral lines of almost any character, even the broad lines in stellar spectra.

4. By overlapping the spectra no parts of them need be cut out, as is the case in using the arbitrary masks of the Hartmann instrument.

In Table I are given the means of the measurements of displacements (produced mechanically) of 15 lines (λλ 4196.590 4291.630, intensities 1–5), of six exposures of the spectrum of the solar limb by: (1) the ordinary method of bisecting with spider line, taking the differences between means of four settings on the middle strip and means of two settings on each of two outside strips of spectrum, each way (violet right and violet left)[2]; (2) by measuring negative (violet left) with positive of itself (violet right) on the adapted Hartmann comparator, taking differences

[1] *Kodaikanal Observatory Bulletin*, No. 32, 1913.

[2] *Journal Royal Astronomical Society of Canada*, **5**, 398, 1911.

between means of two settings on the middle strip and means of two settings on each of the two outside strips of spectrum, each way (violet left and violet right). A comparison of the results of the two methods shows the practicability of the new device and the lessening (nearly halving) of the probable error of setting obtained by employing the positive-with-negative method.

TABLE 2

MEASUREMENTS OF PLATE L701 BY TWO METHODS

	I. BISECTION WITH SPIDER LINE, 1911						
	a	*b*	*c*	*d*	*e*	*f*	Means
Mean displacement in mm	0.0690	0.0690	0.0702	0.0690	0.0690	0.0686	0.0694
Probable error, single line	0.0029	0.0030	0.0027	0.0027	0.0015	0.0029	0.0026
Probable error of mean	0.0008	0.0008	0.0007	0.0007	0.0004	0.0008	0.0007
	II. POSITIVE-WITH NEGATIVE, 1917						
	a	*b*	*c*	*d*	*e*	*f*	Means
Mean displacement in mm	0.0692	0.0700	0.0708	0.0704	0.0690	0.0692	0.0698
Probable error, single line	0.0020	0.0014	0.0015	0.0012	0.0015	0.0014	0.0015
Probable error of mean	0.0005	0.0004	0.0004	0.0003	0.0004	0.0004	0.0004

When the adapted Hartmann comparator is used, remeasurements of solar rotation plates show good agreement with my earlier measures by the method of bisection of lines; and the comparisons promise to throw light on the systematic differences in the measurements of the same lines on the same plates by different observers. For example, the measurements of 19 lines, λ 5506.095–5688.436, Plate L845(1), are:

Bisection of lines by spider thread:

De Lury, mean of 9 measures, 1911–1916, is ... 1.618 km/sec.
Plaskett, mean of 2 measures, 1911, is ..... 1.605 km/sec.

Positive-with-negative:

Evershed, 1 measure, 1916, is ..... 1.636 km/sec.
De Lury, mean of 3 measures, 1917, is ..... 1.619 km/sec.

To test the applicability of the new form of comparator to the determination of stellar radial velocities, I have measured plates of β Geminorum with positives of solar standard plates (or vice versa),

selecting plates which had been previously measured[1] (by J. S. Plaskett) in testing the Hartmann spectro-comparator. Instead of groups of comparison lines and groups of stellar and solar lines being aligned in turn, as in the Hartmann method, these groups are brought into coincidence in turn, positive fitting into negative in a most satisfying manner. In all cases two settings were made on solar and stellar coincidences; and one on each of the two strips of comparison spectrum at each region. The plates were then reversed and measured in the same way. Less than a minute at each region each way was the average time expended. The measurements are given in Table II, and the degree of reliability of the measures may be judged by the following measurements of a zero displacement (22 regions) of solar standard 1462 with positive plates A and B from it:

1462 with positive A, −0.0010 mm
1462 with positive B, −0.0007 mm; 0.0000 mm; 0.0016 mm; 0.0004 mm
Mean, 0.00006 mm; or 0.04 km/sec.
Probable error of single measure, ±0.24 km/sec.; probable error of mean, ±0.14 km/sec.

(It is to be expected that the errors can be lessened considerably by adopting Evershed's method of using negative violet left and positive violet right, or vice versa, even though the measurement is in this case confined to a single comparison line and a single solar and stellar line — a method which has the obvious advantage of yielding information concerning the behavior of the individual lines.)

From Table II it will be seen that repeated measurements are close in the case of Plates 1527 positive A and 1520 negative, and much closer for 1527 negative and 1520 positive A. For the former the probable error of a single measure is ±0.43 km/sec.; and for the mean, ±0.22 km/sec.; while for the latter the probable error of a single measure is 0.07 km/sec.; and for the mean, 0.03 km/sec. This latter is a degree of accuracy seldom attained, I believe, for stellar plates of the low dispersion used, by either the bisection method or the Hartmann method for so few settings and

[1] *Report of the Chief Astronomer*, 1909, pp. 183 f.

regions. Accuracy of setting is dependent to a great degree on the careful balancing of the intensities of positive and negative when making the settings or when printing out the positive. The agreement between the overlapping-positive-with-negative measurements (De Lury) and the aligning-negative-with-negative measurements (Plaskett) is only fair; and both measures seem greatly superior to the agreement of the solar standards or of the stellar plates.

TABLE II

MEASUREMENTS OF β GEMINORUM BY TWO METHODS

(De Lury using positive-with-negative; Plaskett using the Hartmann method, negative-with-negative.)

β Gem. Plate	Sun Plate	No. of Regions	D (De Lury, 1917)			P (Plaskett, 1909)			Difference P−D km/sec.
			Measured Velocity km/sec.	Reduced Velocity km/sec.	Mean Velocity km/sec.	Measured Velocity km/sec.	Reduced Velocity km/sec.	Mean Velocity km/sec.	
1373−	1360+A	20	24.80	2.88	2.88	24.78	2.80	2.86	−0.02
1373−	1462+A	22	24.88	3.08	.....	24.23	2.43	.....	.....
1373−	1462+B	22	25.01	3.21	.....	24.31	2.51	.....	.....
1373−	1462+C	22	24.84	3.04	3.11	.....	.....	2.47	−0.64
1373−	1520+A	11	23.74	1.84	.....	25.01	3.11	.....	.....
1373−	1520+A	11	23.30	1.40	.....	.....	.....	.....	.....
1373−	1520+A	11	23.94	2.04	1.76	.....	.....	3.11	+1.35
1472−	1520+A	11	31.12	1.88	1.88	31.27	2.03	2.03	+0.15
1527+A	1520−	11	25.56	0.85	.....	27.03	2.32	.....	.....
1527+A	1520−	11	26.15	1.44	.....	.....	.....	.....	.....
1527+A	1520−	11	27.12	2.41	.....	.....	.....	.....	.....
1527+A	1520−	11	25.76	1.05	1.44	.....	.....	.....	.....
1527−	1520+A	11	26.31	1.60	.....	.....	.....	.....	.....
1527−	1520+A	11	26.13	1.42	.....	.....	.....	.....	.....
1527−	1520+A	11	26.00	1.38	.....	.....	.....	.....	.....
1527−	1520+A	11	26.12	1.41	1.45	.....	.....	2.32	+0.87
					2.22			2.50	+0.34

The main advantages of the new form of comparator are:

1. A minimum of optical surfaces are used.

2. Images may be brought into coincidence; and thus the Evershed positive-with-negative method of measuring spectra may be employed without the disadvantages found in using the positive over the negative and with the added advantage that the intensities of positive and negative may be altered independently and contrast gained by using colored filters.

3. Two sets of images are produced and may be observed in two different eyepieces, the instrument being in fact a *double* comparator.

4. In measuring spectra, the instrument may be used in the ordinary way of bisecting the lines with a spider thread; or it may be used as a comparator for overlapping or aligning, for which masks for various configuration may be readily interchanged.

SOLAR PHYSICS DIVISION
DOMINION OBSERVATORY, OTTAWA
April 1917