INSTRUCTIONS

for use of the

POLARIZING PHOTOMETER

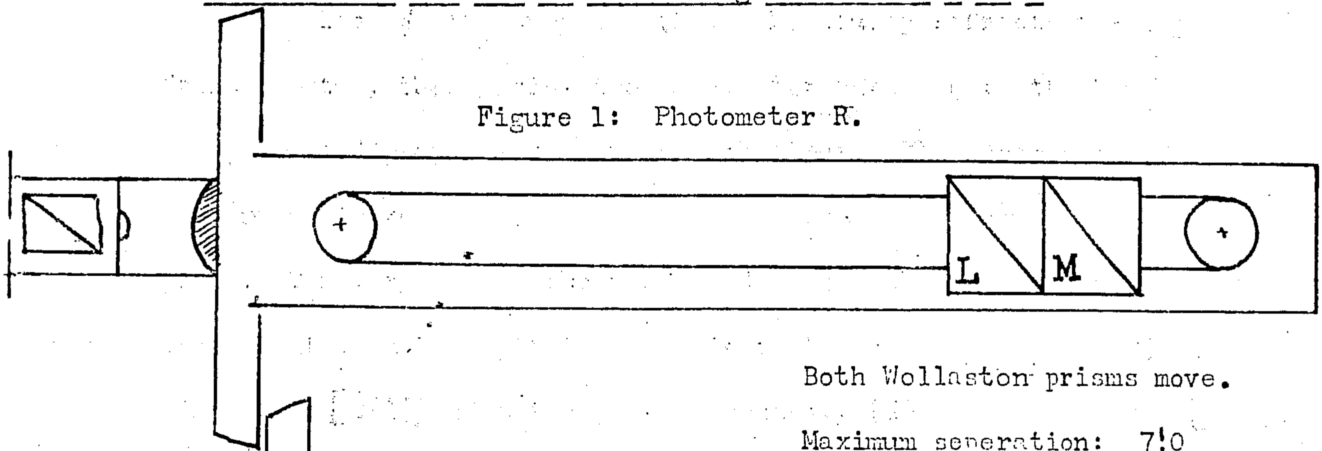
Robert G. Tull

University of Illinois Observatory

May 1, 1957

Instructions for use of Polarizing Photometer R or W.

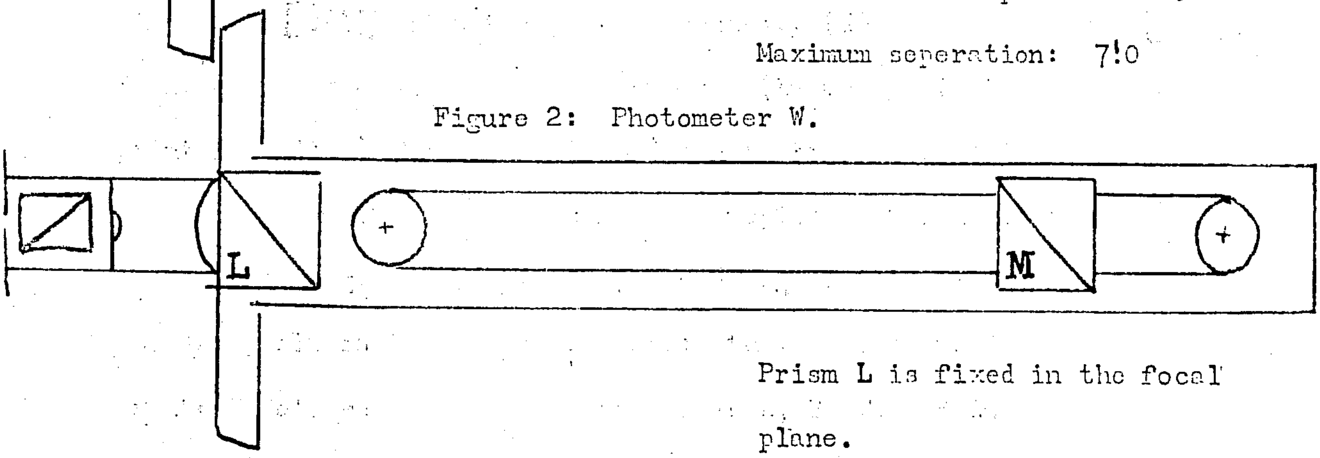
Figure 1: Photometer R.



Both Wollaston prisms move.

Maximum seperation: 7'.0

Figure 2: Photometer W.



Prism L is fixed in the focal plane.

Maximum seperation: 3'.5

The two forms are interchangeable by means of two separate carriers for prism L, one of which can be attached to the carrier for prism M, and the other of which slips into place in the focal plane. Photometer W corrects a tendency of photometer R in which the exit pupils from the two stars being compared are not precisely superposed, but overlap each other, thus introducing some error in the readings.

GENERAL

Each Wollaston prism (L and M) doubly refracts the light from the star, thus giving two images for each star; the images are polarized perpendicularly to each other. The separation of the images increases as the prisms are moved away from the focal plane. Thus, by moving the prism and also rotating the entire instrument as needed, it is possible to bring the ordinary (O) image of star 1 [O(1)] next to the extraordinary (E) image of star 2 [E(2)]. Then, by rotating the entire instrument (by means of the black painted handles) through 180°, O(2) can be brought next to E(1).

The Nicol prism behind the eyepiece is then rotated until the images (e.g., O(1) and E(2)) are of equal intensity, and the angular position is recorded. Note: this will occur in 4 positions of the Nicol; record all 4 positions as A, B, C, and D. Then the magnitude difference is

$$\Delta M = 5 \log_{10} \cot\left[\tfrac{1}{4}(B+D-A-C)\right]$$

PROCEDURE

The procedure adopted at Harvard was to take a group of six sets of 4 readings each (i.e., A, B, C, and D are 4 readings of one set), reversing the images () in the middle of each set and rotating the photometer 180° after the 1st, 3rd, and 5th sets. Note the time at the middle of the 1st and 6th sets and take the mean as the time of observation (except for rapidly varying stars, in which case note time at the middle of each set).

Then, if the index is to the right of the vertical plane, record R; if to the left, record L. The mean of the sets R and L are determined separately to allow for possible difference in optical path (dirt, etc.) for the two stars, and residuals are taken by subtracting these from the individual readings. The mean of R and L gives the required magnitude difference.

It is possible to increase magnification for special jobs (e.g. occultations of stars by planets) by installing a Barlow lens, with its adapter tube, in the focal plane of the Wollaston prism carrier.with the photometer R arrangement. If photometer W is desirable, the Barlow can be put in the other carrier and placed in front of lens L, with strips of paper or Scotch tape of prevent the carrier from sliding. See below.

Figure 3: Carriers for prism L

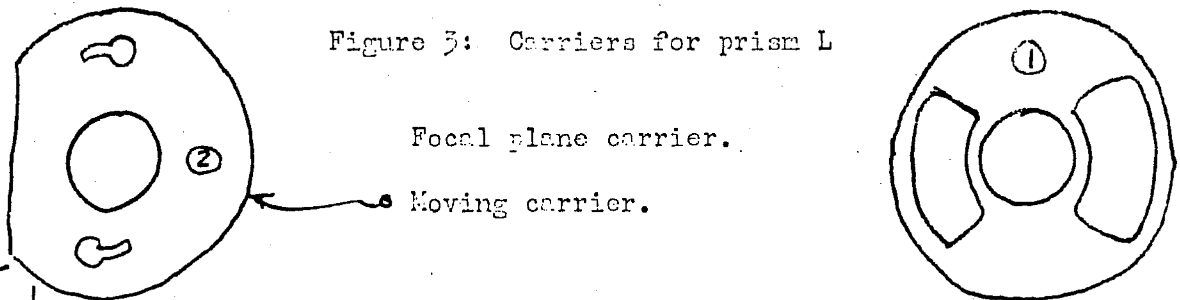


Figure 4: Photometer R with the Barlow lens.

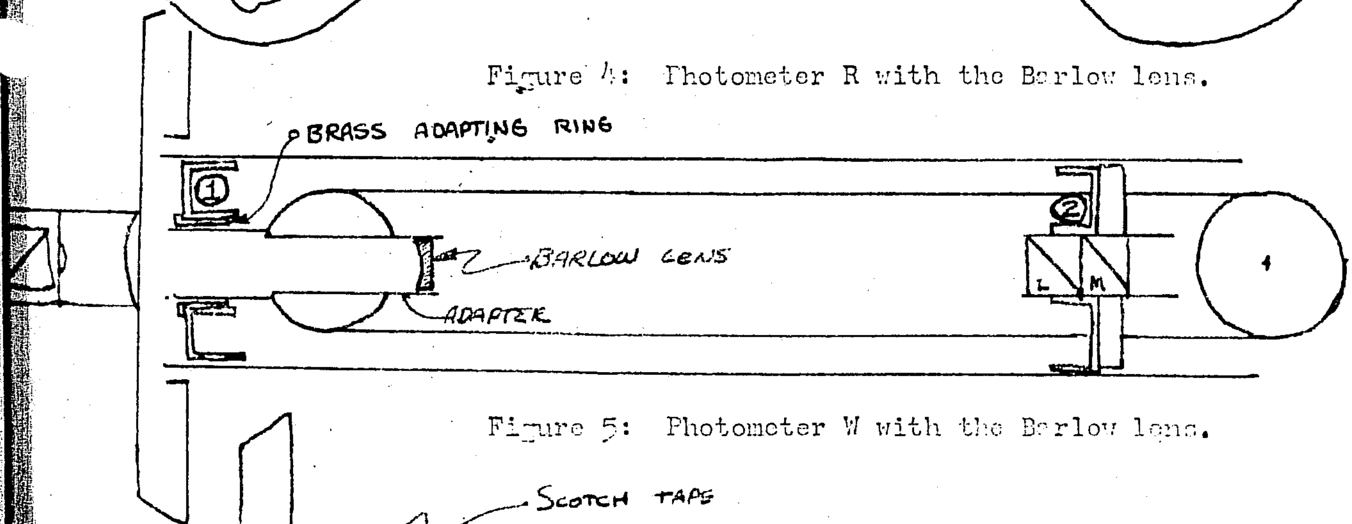
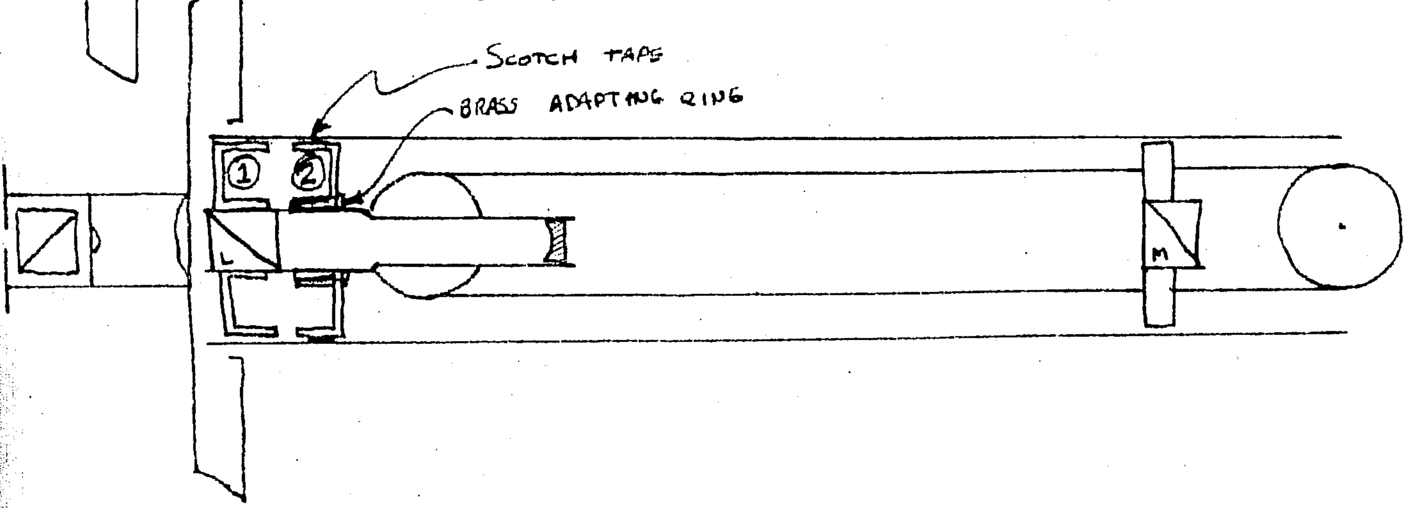


Figure 5: Photometer W with the Barlow lens.



Use in connection with write-up already with photom

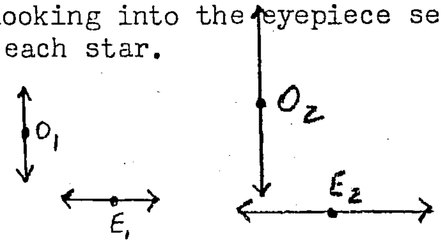
THE POLARIZING PHOTOMETER

This instrument utilizes the polarizing properties of doubly-refracting crystals to measure stellar magnitudes.

Two stars are selected whose images can be obtained in the field of the instrument. One of these must be of known magnitude since the instrument only determines δm.

The essentials of the instrument are two doubly refracting crystals whose separation is variable, and an analyzer of polarized light, rotatable about the axis joining the two crystals. By varying the distance between the crystals, the distance between the emerging E and O rays can be varied. By rotation of the whole instrument about the axis of the telescope, the E rays can be moved around the O.

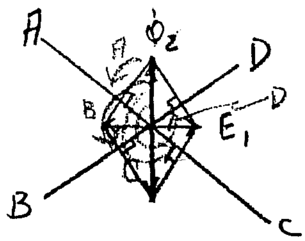
The eye, looking into the eyepiece sees, if the analyzer is removed, 4 images, 2 from each star.



The intensity of the O and E images for one star will be equal, as indicated above, but will differ from those of the second star.

The method is to superimpose E_1 and O_2 (or E_2 and O_1), then by rotating the analyzer, to find the positions of equal brightness from which δm may be obtained as follows:

Consider pair E_1 and O_2; the planes of vibration of the E and O rays remain mutually perpendicular, we consider them horizontal and vertical, respectively, forconvenience. We then have



Postions of equal intensity occur at A, B, C, D.

Now--

$$I_e(E_1) \cong 1/2\ I_o(1)$$ emerges from the crystals, where $I_o(1)$ is the flux density (ergs/cm^2/sec) loosly called "intensity" of incident light from star 1.

Also $$I_e(O_2) \cong 1/2\ I_o(2)$$

(The intensity may be further cut down by the two crystals themselves and whether 1/2 is the proper value will have to be determined; it is close)

At angle A, the emergent "intensities" are equal, hence

$$I_T(E_1) = I_T(O_2) \quad \text{from the analyzer}$$

Choosing the vertical as the reference direction, and recognizing that Malus' Law applies:

$$I_T(E_1) = I_T(O_2)$$

$$I_e(E_1) \cos^2 A = I_e(O_2) \cos^2 (90 - A)$$

Now, $m_1 - m_2 = 2.5 \log_{10} \frac{Io(2)}{I(1)} = 2.5 \log_{10} I_e(O_2)/ I_e(E_1)$

$$m_1 - m_2 = 2.5 \log \frac{\cos^2 A}{\cos^2 (90 - A)} = 5 \log \frac{\cos A}{\cos(90 - A)}$$

$$= 5 \log \cot A$$

At angle B:

$$I_e(E_1) \cos^2 (\pi - B) = I_e(O_2) \cos^2 \left(B - \frac{\pi}{2} \right)$$

Hence $$\log \frac{I_e(O_2)}{I_e(E_1)} = 2 \log \frac{-\cos B}{\sin B} \qquad \cos B < 0$$

$$= 2 \log - \cot B$$

and $\delta m = 5 \log(-\cot B) = 5 \log (\cot(-B))$

Similarly at angle C we get $\delta m = 5 \log \cot C$

and at angle D we get $\delta m = 5 \log \cot(-D)$

Thus the object of the experiment is to determine angle A as accurately as possible. The shows this may be done by taking the mean of 4 measures:

$A, (\pi - B), (C \pm \pi), (\pi - D)$; i.e. $\frac{1}{4}(A + C - B \pm D)$

hence $\delta m = 5 \log \cot \frac{1}{4}(A + B - B - D)$

Thus the formula quoted may be derived.

Robert Roeder, for 314, 1961

RR/mr