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ON APERTURE CORRECTIONS FOR COMET MAGNITUDE ESTIMATES

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The results of a study into the effects of aperture on the observed brightness of comets are presented. Observations of 22 comets were used to determine the average aperture corrections for refractors and reflectors. The resulting aperture correction for refractors was only slightly less than that found by Bobrovnikoff. However, the aperture correction for reflectors was found to be less than one-third the value found by Bobrovnikoff for refractors.

Key words: comets — magnitude estimate

In the early 1940s Bobrovnikoff (1941*a*,*b*, 1943) determined an aperture correction to be applied to visual magnitude estimates of comets made with refractors. The need for this aperture correction comes from the fact that on the average a given comet will appear fainter when a telescope with a larger aperture is used to observe it. In fact, Bobrovnikoff found that on the average a comet will appear 0.066 magnitude fainter for each centimeter of aperture used. Based on a Fourier transform analysis Meisel (1970) indicated theoretical justification for such an empirical correction as an off-axis effect of a circular pupil function. Recently it has become apparent that the Bobrovnikoff aperture correction does not work for all types of telescopes. This situation led to the decision to undertake a study to reevaluate the aperture correction for refractors and to determine for the first time an aperture correction for reflectors.

Observations of 22 comets (see Table I) made by members of the Comets Section of the Association of Lunar and Planetary Observers (Milon 1972) were used to determine the aperture corrections. From these data comparisons were made between observations secured within $0\overset{d}{.}75$ of each other. Each comparison consisted of the determination of *delta aperture,* which is defined as the smaller aperture subtracted from the larger aperture, and *delta magnitude,* which is defined as the difference between the magnitudes obtained with these apertures.

The following restrictions and assumptions were made.

1. Only magnitude estimates made using the extrafocal method (Bobrovnikoff 1941*b*), in which the eyepiece is racked out-of-focus so that the comparison stars and the comet appear similar in size, were used. This is by far the most common method employed.
2. No magnitude estimate was used if there was any doubt concerning the aperture or type of telescope used in making that estimate.
3. Magnitude estimates made with the naked

TABLE I
COMETS USED

Comet	Number of Comparisons	
	Refractors	Reflectors
1959 IV	—	1
1960 II	—	3
1962 III	10	31
1962 VIII	2	4
1964 VI	1	—
1964 VIII	1	—
1965 VIII	70	7
1966 V	1	18
1967 II	—	2
1967 VII	16	22
1968 I	41	39
1968 IV	2	1
1968 VI	63	57
1968 VII	—	2
1968 IX	1	2
1969 VI	—	1
1969 VII	—	2
1969 IX	143	9
1970 II	76	—
1970 X	—	1
1970 XV	46	17
1971 V	7	8

eye were assumed to have been made with a refractor of zero aperture (Bobrovnikoff 1941*a*).

4. In the determination of the aperture correction it was assumed that when *delta aperture* = 0, then *delta magnitude* = 0 (i.e. the fitted line was forced through the origin).

The aperture correction for refractors ($APCOR_1$) was determined from 480 comparisons made between refractor observations. The average values of *delta aperture* and *delta magnitude* for these comparisons are listed in Table II. The aperture correction was found by determining the best fitting straight line through these points. The slope of that line represents the aperture correction in magnitudes per centimeter. The resulting value of $APCOR_1$ was 0.055 ± 0.008 (p.e.).

Although the value of $APCOR_1$ obtained in this study is slightly less than the Bobrovnikoff value it is felt that due to the small range of *delta aperture* used in this study that this result is essentially a confirmation of Bobrovnikoff's findings. In practice either value will suffice in most cases because refractor estimates are usually made with relatively small apertures.

In order to obtain the aperture correction for reflectors ($APCOR_2$) the magnitude estimates made with refractors were corrected to a standard aperture of 6.78 cm using Bobrovnikoff's aperture correction. In addition to the comparisons made between reflector observations, comparisons were also obtained between the corrected refractor estimates and the reflector estimates. Using this procedure a total of 227 comparisons were obtained. The average values of *delta aperture* and *delta magnitude* for these comparisons are listed in Table III. From these points the value of $APCOR_2$ was found to be 0.019 ± 0.002.

Recently, Meisel (1973) has extended the Fourier transform analysis to include a central obstruction in the entrance pupil. His results indicate that for the "average secondary size" the aperture correction should be 30% to 40% that of the same size refractor. This theoretical result is in good accord with the present empirical study.

The significance of the resulting aperture corrections can be seen in the following example, displayed in Table IV, in which 31 magnitude estimates (listed in Table V) of P/Giacobini-Zinner 1972 *d* made by members of the Comets Section of the Association of Lunar and Planetary Observers (Milon 1973) were reduced using three different methods. In the first case no aperture correction was applied, in the second the aperture correction for reflectors was applied, and in the third the Bobrovnikoff aperture correction was applied. In each case, the observed magnitude was corrected to a standard aperture of 6.78 cm. The values of H_0, the absolute magnitude, and *n*, a number which determines how the comet's brightness varies with heliocentric distance, were then determined. The results of these reductions are given in Table IV.

It can be seen from this example that the value of the aperture correction used has a large effect on the resulting values of H_0 and *n*. Thus, it is important to use the correct aperture cor-

TABLE II

COMPARISONS — REFRACTORS

Delta Aperture (cm)	*Delta Magnitude*	Number of Comparisons
1.52	0.12	268
3.07	0.18	127
5.51	0.31	67
8.48	0.27	18

TABLE III

COMPARISONS — REFLECTORS

Delta Aperture (cm)	*Delta Magnitude*	Number of Comparisons
0.64	0.00	1
3.66	0.17	14
5.08	0.23	9
8.51	0.08	113
10.59	0.35	6
13.61	0.31	31
16.08	0.28	12
18.62	0.26	8
24.10	0.51	33

TABLE IV

EXAMPLE OF EFFECT OF APERTURE CORRECTIONS

Aperture Correction	H_0	n
0	9.81 ± 0.10 (p.e.)	4.81 ± 0.44
0.019	9.57 ± 0.08 (p.e.)	4.22 ± 0.37
0.066	8.97 ± 0.06 (p.e.)	2.78 ± 0.28

rection if one is to obtain meaningful results. In the above example the "correct" result is the one in which the aperture correction for reflectors was applied to the observations since all the magnitude estimates were made with reflectors.

It was stated earlier that the values of $APCOR_1$ and $APCOR_2$ obtained in this study were average values. By this it is meant that these aperture corrections will work for an average observer estimating the magnitude of an average comet. The fact that different observers have different aperture corrections can be seen by examining Table V. On 5 and 6 September 1972, J. E. Bortle and the author estimated the magnitude of P/Giacobini-Zinner 1972*d* using the same telescope and comparison stars. In both cases, there is about half a magnitude difference in the estimates. Bortle (1972) has determined his personal aperture correction for reflectors to be 0.018, whereas the author's has been found to

TABLE V

OBSERVATIONS OF P/GIACOBINI-ZINNER 1972*d*

Date (UT)	Observer	Observed Magnitude	Corrected Magnitude*	Instrument
1972 June 8.30	Bortle	10.2	10.04	15-cm refl.
11.30	Bortle	10.2	10.04	15-cm refl.
July 5.31	Seslar	9.5	9.34	15-cm refl.
20.83	Kleine	9.4	9.31	11.3-cm refl.
26.30	Bortle	9.7	9.54	15-cm refl.
Aug. 5.33	Bortle	9.5	9.34	15-cm refl.
10.33	Bortle	9.6	9.44	15-cm refl.
19.37	Seslar	9.3	9.14	15-cm refl.
20.35	Bortle	9.7	9.54	15-cm refl.
21.32	Bortle	9.7	9.54	15-cm refl.
Sept. 5.37	Morris	10.4	9.93	32-cm refl.
5.37	Bortle	9.9	9.43	32-cm refl.
6.37	Morris	10.6	10.13	32-cm refl.
6.37	Bortle	10.2	9.73†	32-cm refl.
6.37	Bortle	10.0	9.84	15-cm refl.
10.73	Jones	11.4	10.93	32-cm refl.
11.71	Jones	11.4	10.93	32-cm refl.
12.71	Jones	11.4	10.93	32-cm refl.
15.36	Bortle	11.2	10.73	32-cm refl.
17.72	Jones	11.6	11.13	32-cm refl.
18.36	Bortle	11.3	10.83	32-cm refl.
19.70	Jones	11.5	11.03	32-cm refl.
20.72	Jones	11.5	11.03	32-cm refl.
29.69	Jones	12.0	11.53	32-cm refl.
Oct. 3.40	Bortle	11.4	10.93	32-cm refl.
4.69	Jones	11.9	11.43	32-cm refl.
9.38	Bortle	11.7	11.23	32-cm refl.
10.38	Bortle	11.7	11.23	32-cm refl.
14.68	Jones	11.9	11.43	32-cm refl.
17.67	Jones	12.1	11.73	32-cm refl.
18.39	Bortle	11.8	11.33	32-cm refl.
Nov. 16.39	Bortle	13.1	12.63	32-cm refl.

*Aperture corrected to 6.78 cm using the aperture correction derived for reflectors.
†Not used in the reductions.

be closer to 0.03. Another example can be seen by comparing the observations by J. E. Bortle and A. Jones. The estimates by Jones are always a few tenths of a magnitude fainter than those by Bortle.

The fact that different observers have different aperture corrections does not appear to become significant unless the aperture of the instrument exceeds 20 cm. If magnitude estimates are used in which the aperture exceeds 20 cm then one should check, if possible, and see if there are deviations from the average value of the aperture correction in question.

In the process of doing this study it was noted that different comets have different average aperture corrections. Although the data are sketchy it appears as if the value of the average aperture correction depends upon the degree of condensation of the comet as predicted by the Fourier transform analysis (Meisel 1970). In other words, if the comet is very diffuse the aperture correction will be large, whereas if the comet is highly condensed it will be small. From the data at hand it appears that this relationship will have little effect on the reduction of comet magnitude estimates except in a few extreme cases.

It is recommended that separate, effective aperture corrections for refractors and reflectors be calculated for any comet with a sufficient number of observations (usually over 100). In cases where the observations are too few to permit the derivation of the required aperture corrections for the individual observer and/or comet, the values 0.066 magnitude centimeter^{-1} (refractors) and 0.019 magnitude centimeter^{-1} (reflectors) are recommended.

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