OFF-CENTERING ERRORS IN MULTIAPERTURE PHOTOELECTRIC PHOTOMETRY OF GALAXIES

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Abstract

Described are numerical experiments on photometric errors that would be produced on sample galaxies by off-centering of the photometer diaphragm under different seeing conditions.

1. Introduction

Multiaperture photoelectric photometry (hereafter MPP) is still one of the main sources of information about the overall photometric properties of galaxies. Carefully made MPP is indeed one of the easiest ways to obtain total magnitudes, color profiles, and integrated colors for large samples of objects (de Vaucouleurs *et al.* 1976; Capaccioli 1988; Longo and de Vaucouleurs 1983, 1985). Furthermore, MPP is useful for the calibration of CCD images on an absolute photometric scale.

As already pointed out by Capaccioli and de Vaucouleurs (1983), the main sources of error may be identified as off-centering errors and seeing effects. The random and unpredictable off-centering errors are due to the observing procedure, which does not guarantee that the visually centered diaphragm coincides with the actual center of the image of the galaxy. Due to the outward-decreasing brightness of galaxies, off-centering errors result in a systematic underestimate of the magnitude of the inner and nuclear regions. Seeing effects, on the other hand, smooth out the bright nuclear regions and redistribute the light over the outer parts of the galaxy.

As a first step towards the reduction to a standard system of the whole bulk of MPP data available in the literature, we carried out a numerical simulation of the off-centering and seeing effects.

2. The Simulations

To estimate the effects of off-centering errors in MPP, we performed a numerical experiment on four synthetic galaxies. The light distribution of these galaxies was assumed to be the weighted sum of the two basic standard photometric components: a spheroid represented by the de Vaucouleur's $r^{1/4}$ law, and an exponential law for the disk.

In order to make our models as realistic as possible, we used the photometric parameters of three galaxies (E, Sa, Sc) taken from the sample by Kent (1985). In order to evaluate the influence of inclination, we used the parameters for the Sc galaxy to model a face-on Sc galaxy. (In Table 1, the columns give, respectively: object, distance in Mpc, photometric parameters of bulge and disk component (Kent 1985) , and ratio of the bulge to total luminosity.) The four images were first degraded with an artificial sky level arbitrarily put at 22 mag/arcsec^2 ± 2% noise and then convolved with the point-spread function (PSF) given by Capaccioli and de Vaucouleurs (1983). The convolution of the images with the PSF was performed for two different seeing conditions: seeing discs of 1" and 2" radius, respectively.

The degraded images were used to simulate MPP through circular apertures. For a given aperture, off-centering errors were introduced by moving the centers of the diaphragms with respect to the center of the galaxy at 1" steps. In each position, the flux through the aperture was integrated and then corrected for a sky background computed according to the same procedure.

Table 1. Data for Sample Galaxies

Identification	*Type*	*d(Mpc)*	μ_e	r_b*(Kpc)*	e_b	μ_o	*h(Kpc)*	e_d	*B/T*
G1	Sc	32.3	23.42	2.35	0.00	21.02	4.37	0.00	0.10
G2 (NCG 680)	E	30.8	21.78	3.69	0.27				0.00
G3 (NCG 697)	Sc	32.3	23.42	2.35	0.34	21.02	4.37	0.72	0.10
G4 (NCG5614)	Sa	39.5	20.90	2.58	0.01	21.67	4.52	0.39	0.71

3. Discussion

Figure 1 shows the growth curves for a 1" seeing disc as a function of the off-centering. The upper curve corresponds to zero off-centering, and the others to off-centering increasing with a 1" step. From these growth curves it is possible to derive estimates of the total magnitude B_T and of the effective radius r_e. Due to the redistribution of energy, the effective radius is also a function of the seeing. The values obtained are listed in Table 2.

Table 2. Total magnitudes and effective radii corresponding to two seeing values for the four galaxies.

Identification	B_T	r_e*(1")*	r_e*(2")*
G1	11.702	51.950	52.808
G2	11.261	23.000	25.813
G3	11.642	42.429	46.130
G4	11.401	21.320	29.923

Figure 2 gives the estimated error of the magnitude Δm for the galaxy G1 as a function of the aperture radius and of the off-centering. The errors are quite sensitive to the value of Δr. For example, for an r = 2" diaphragm (corresponding to the smallest aperture available at the ESO 3.6-m telescope), an error as small as 1" in centering the galaxy leads to underestimating the central magnitude by 0.15 magnitude, while an error of 3" results in an error of about 1 magnitude.

Figure 3 shows the same quantities as in Figure 2 for a 2" seeing disc. A larger seeing disc implies a larger spread of the central brightness peak (Figure 2), and therefore, especially at small apertures or large off-centerings, magnitude errors decrease for increasing seeing values. For example, using the above 2" diaphragm, an off-centering error of 1" leads to an error of 0.015 magnitude, while a 3" off-centering results of an error of 0.75 magnitude.

The errors due to "reasonable" off-centering become less dramatic for apertures larger than 10", where off-centering errors may contribute 0.05 magnitude at most. The sharp increase observed in Δm at small apertures is clearly due to the central peak in the luminosity distributions.

One final relation to be investigated is the dependence of Δm on the morphological type of the galaxy. Figure 4 plots Δm against the normalized off-centering $\Delta r/r_e$ for a normalized aperture $r/r_e = 0.2$. No clear dependence of Δm on the morphological type or on inclination can be inferred from the present results.

References

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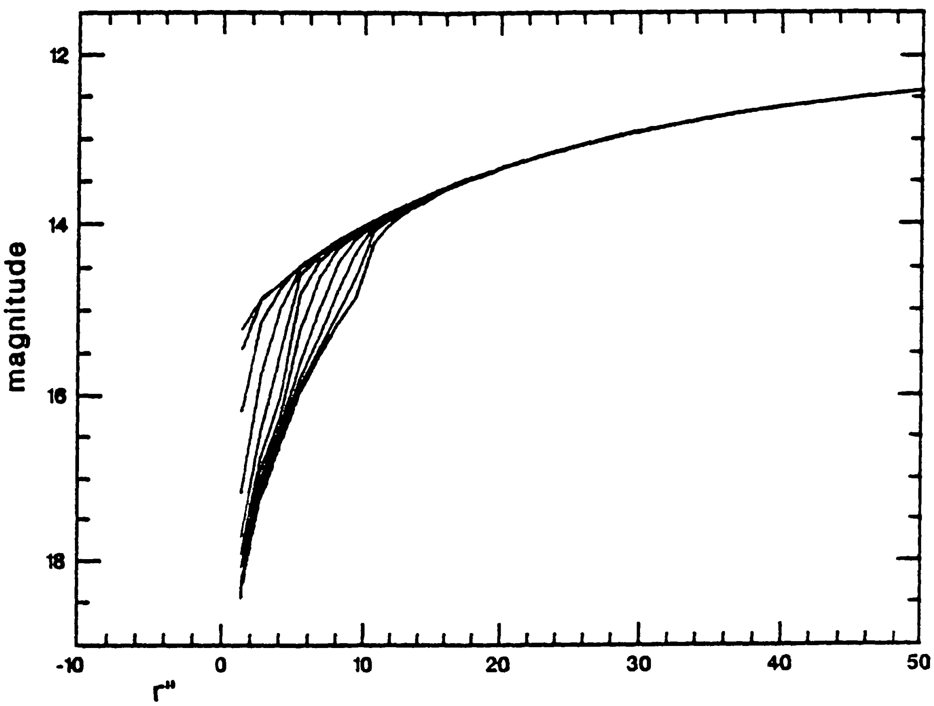

Figure 1. Luminosity multiaperture profiles for G3 for different values of the off-centering going from 0" (upper curve) to 10" (lower curve).

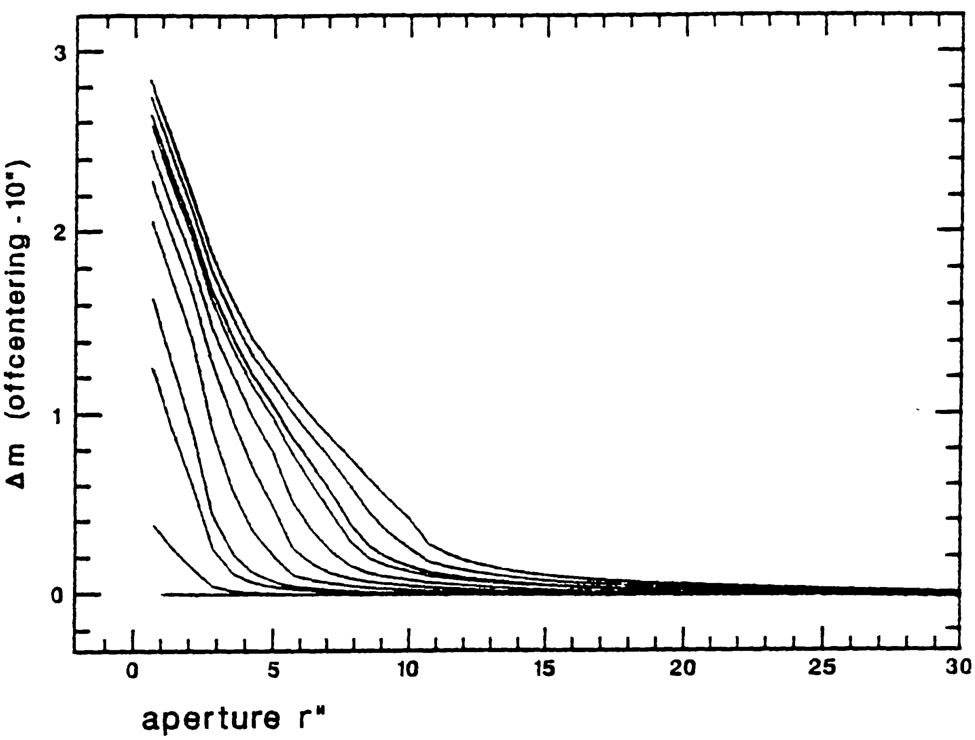

Figure 2. Error in magnitude estimate Δm for the galaxy G1 as a function of the diaphragm aperture r. The curves correspond to different values of the off-centering, from Δr = 0" (lower curve), to Δr = 10" (upper curve). Seeing disc is 1" radius.

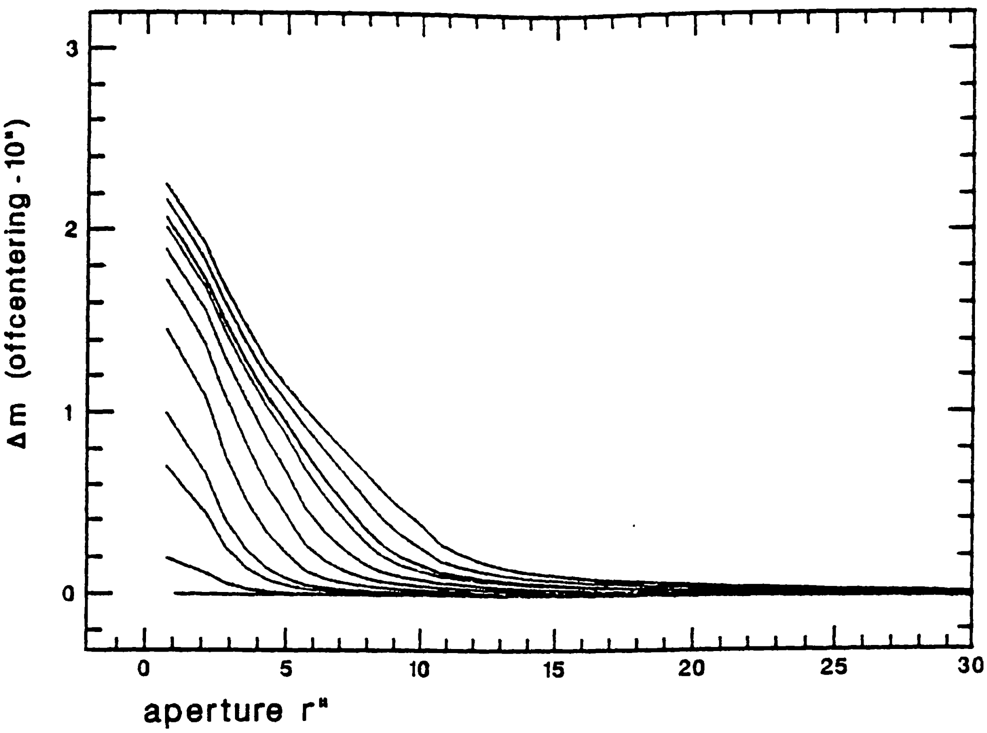

Figure 3. The same as in Figure 2 but for a seeing disc of 2" radius.

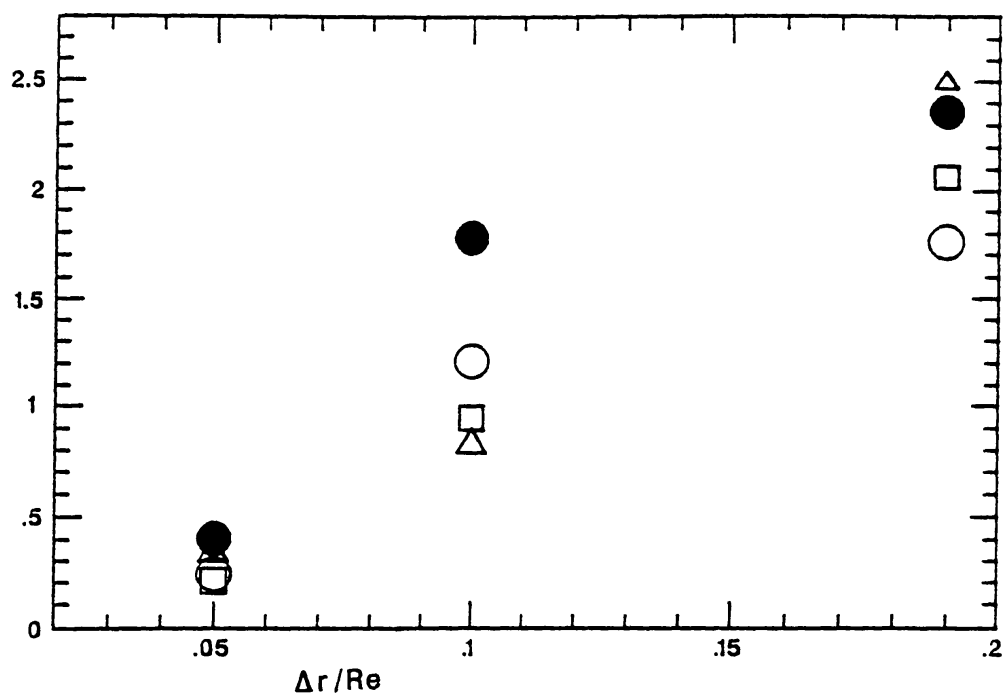

Figure 4. Magnitude estimate error against normalized off-centering for the four galaxies. The four galaxies are marked as follows: open circles, Sc pole-on (G1); filled circles, Sc inclined by 60^{o} (G3); squares, E (G2); triangles, Sa (G4).