STELLAR PHOTOMETRY WITH WIDE FIELD CCDs: NGC 6822

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ABSTRACT. A wide-field CCD has been used to obtain photometry of resolved stars in the main body of the Local Group Dwarf Irregular Galaxy NGC 6822. Under good seeing conditions, the relatively large pixel size of the chip produces a poor sampling of the stellar profiles. This paper discusses how this undersampling affects the quality of the photometry and shows that this problem can be overcome when the point-spread function is suitably modelled. Finally, a brief discussion of the stellar content of NGC 6822 is given in the light of the [(V-R), V] colour-magnitude diagram.

1. Introduction

It is well known that the advent of CCDs has triggered a major improvement in the photometry of bidimensional sources and, in particular, of rich star fields with major crowding, thus making it possible to obtain data of good accuracy easily. The only disadvantage of CCDs compared with photographic plates has been the small field they covered; this made them almost useless for the study of objects of large angular size. A few years ago, a new generation of large CCDs became available in most observatories. These detectors provide wide fields which, in some cases, are beginning to compare with those of the traditional photographic plates. The price to pay is the relatively large pixel size that, under good seeing conditions, produces a poor sampling of the stellar profiles. When profile-fitting photometry algorithms are used, this translates into larger photometric errors, unless an accurate point-spread function (PSF) model is used.

We are employing wide-field CCDs to study the resolved stellar population of a sample of nearby Dwarf Irregular Galaxies (DIG). Since their typical diameter is of a few degrees, most of them can be covered by a single frame. Nevertheless, the undersampling problem that usually affects these images emerges in addition to the traditional ones that have a more adverse influence when deriving photometry of stars in external galaxies, namely, the severe crowding of the stellar images and the variations in the background. Here, we will discuss the effect of the undersampling problem on the quality of the photometry obtained for the Local Group DIG NGC 6822. We show how it can be improved when suitable modelling of the PSF is applied.

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2. The Observations

UBVRI frames covering the main body of NGC 6822 were obtained in July 1992 at the prime focus of the 2.5 m Isaac Newton Telescope at the Roque de los Muchachos Observatory, La Palma (Canary Islands, Spain). The detector used was the CCD-EEV5 of 1242 x 1152 pixels which, with the configuration employed, provided a field of 11.2′ x 10.4′. In these images, the undersampling is severe (0.54″/pixel, for a seeing under 1″). The observations and data reduction are described and discussed in detail in Gallart, Aparicio & Vílchez (1994).

In short, for our main concern here, we derive the photometry of the stars following an almost identical reduction procedure with DAOPHOT II (DAOII) and an older version of DAOPHOT implemented within IRAF V2.10.2 (DAO/IRAF). A discussion on the new analytic forms allowed for the PSF in DAOII and the way they work with differently sampled images can be found in Stetson et al. (1989). Within DAOII, we used a Moffat function as PSF model, and allowed it to vary linearly with position in the frame. In the case of DAO/IRAF, a Gaussian, constant across the frame, has been used. These parallel reductions produced several good indicators that allow us to analyze the performance of both options when dealing with undersampled images.

3. Comparison between the Photometry Obtained with DAO/IRAF and DAOII

We will discuss three indicators of the photometric quality achieved with the two versions of DAOPHOT. A more detailed discussion can be found in Gallart et al. (1994).

The most direct indicator is the distribution of the standard error of the star's magnitude, σ, as given by the routine ALLSTAR. Figures 1a and 1b show this distribution for the R band when using DAO/IRAF and DAOII respectively. When using DAO/IRAF the dispersion is larger, and the distribution of σ is not as clearly dependent on brightness as for DAOII. This different behaviour occurs in all bands, although it is specially obvious in the R band. It seems that in the

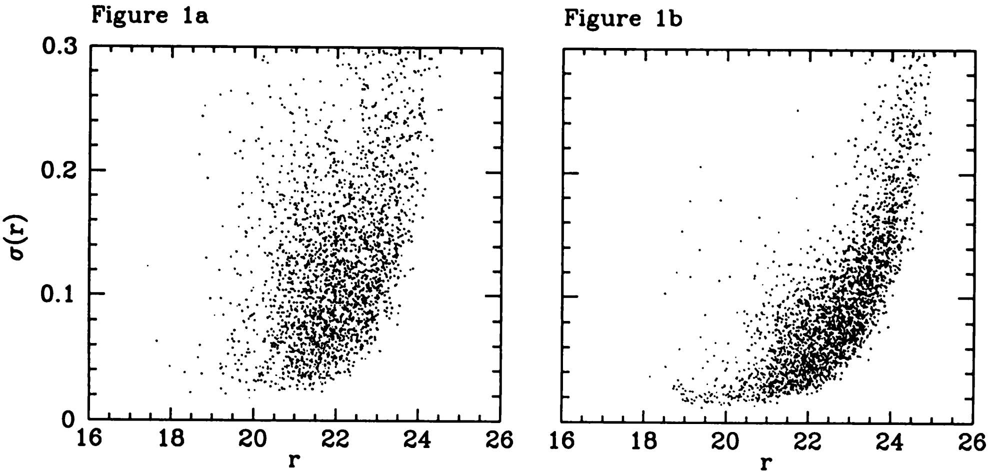

Figure 1. Magnitude errors as given by ALLSTAR obtained a) from DAO/IRAF and b) from DAOII, versus r instrumental magnitude.

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case of the R band another factor is present in addition to the better modelling of the PSF in DAOII. Since in the R band the background is more difficult to evaluate due to the inclusion of the H_α emission line, the reason for this worse behaviour is probably the more accurate estimation of the sky background by the routine ALLSTAR in DAOII. An important consequence of these different error distributions is that the number of stars that remain in the final photometry list is much larger when using DAOII, because the most restrictive criterion when removing spurious stars is their larger σ values.

Another good indicator of the photometric quality is the completeness factor, Λ, obtained from the artificial stars tests, and calculated by eye-fitting a curve to the N_{rec}/N_{inj} vs. magnitude plot, where N_{rec}/N_{inj} is the ratio of the number of artificial, recovered stars to the artificial stars injected in the images. In Fig. 2, we represent Λ as a function of magnitude, as obtained from both DAO/IRAF and DAOII. Again, the most obvious difference is seen in the R band, where the completeness factor in the photometry derived with DAO/IRAF is always under 0.5.

Finally, the most decisive indicator is the quality of the final Colour-Magnitude diagrams (CMD), and the amount of information available from them. Figures 3a and 3b show the [(V–R),V] CMD obtained with DAO/IRAF and DAOII respectively. The most obvious difference between both diagrams is the quantity of stars; but also, much narrower structures are seen in the diagram obtained with DAOII, indicating a smaller dispersion in the data points. This, of course, translates into the amount of information contained in each diagram. In particular, the blue plume from $(V - R) = 0.2$ to $(V - R) = 0.4$ corresponding to the main sequence stars is much better defined in Fig. 3b in which the large number of stars indicates a substantial star formation ongoing in the galaxy. The reddest part of this plume for $V < 21$ is also occupied by the massive stars blue loops. Also the *yellow* plume at $(V - R) \simeq 0.6$, corresponding to the

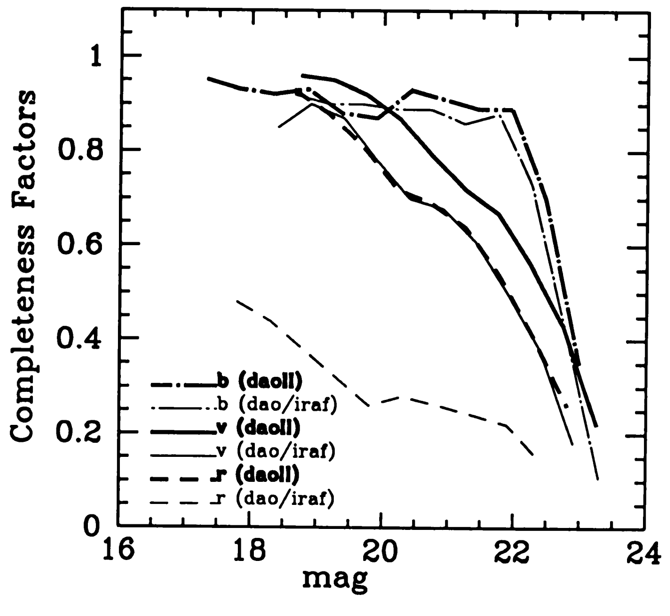

Figure 2. Comparison of the completeness factors obtained with DAOII (heavy lines) and with DAO/IRAF (thin lines), for the B, V and R bands.

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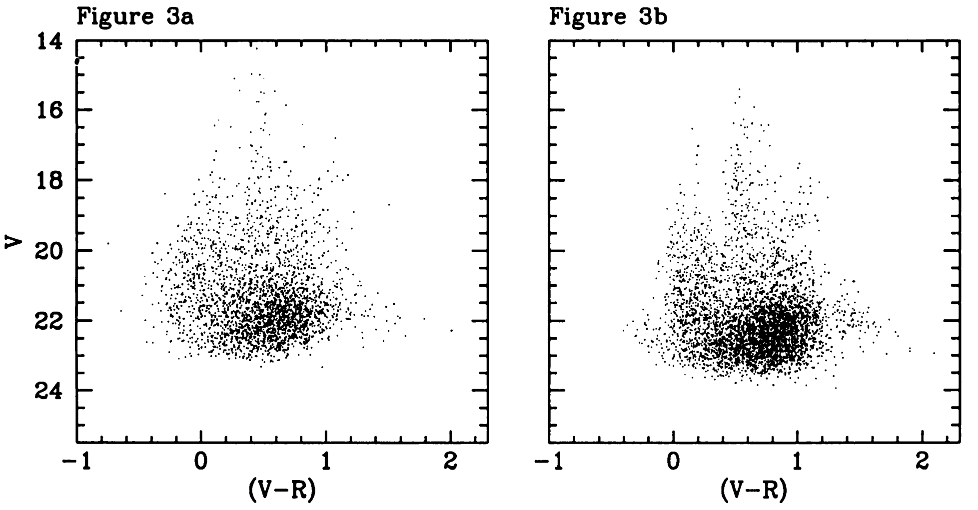

Figure 3. [(V-R), V] Colour-Magnitude diagrams of the resolved stars of NGC 6822 obtained **a)** with DAO/IRAF and **b)** with DAOII. They contain respectively 4700 and 16300 stars.

foreground Galactic stars, is better delimited in Fig. 3b. Another clear example is the feature present around $V = 22$ and $1.2 \leq (V - R) \leq 1.8$ in the CMD obtained with DAOII, which is not seen well in Fig. 3a. It corresponds to a sample of old AGB stars and will be of crucial importance in the interpretation of the star formation history of NGC 6822 at old ages. It could indicate either a burst of star formation which occurred about 1 Gyr ago, or it could reflect a combined effect on the position of the stars in the CMD due to the evolution of the metallicity with age. These two possible interpretations are explored in Gallart et al. (1993a, 1993b).

It has been shown how the use of an appropriate model for the PSF can overcome the undersampling problem that usually affects the images obtained with wide-field CCDs. This has great importance when high quality profile-fitting photometry is required. This good photometry, together with the large fields covered is producing great advances, in particular in the study of the stellar populations of nearby galaxies.

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