An automatic procedure for photometry and astrometry in crowded fields

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Abstract

A number of astronomical problems require accurate measurements of the brightness of stars located in crowded fields. These include the search for extrasolar planets, gravitational microlensing amplification events, as well as the search for variable stars. In this work, we describe an automatic procedure for photometry and astrometry in crowded fields using a methodology similar to the one used in DAOPHOT, but with capability of processing a list of the images automatically.Two applications are presented: The light curve of the eclipsing binary BUL SC16 335 and the identification of the flaring components of the astrometric triple LHS 1070.

1. Introduction

ACCURATE automatic determination of the parameters of astronomical images is a fundamental problem in modern astronomy. A procedure to obtain a list with position, intensity and other information about the stellar profile is fundamental in performing elementary classification of images in stars and galaxies, to study distribution, variability, colour and proper motions of objects which are parameters useful for a wide variety of astronomical problems.

When the field is not crowded the procedure to obtain the position and the intensity is relatively easy. It does not make assumptions about the actual shape of the source PSF (Profile Stellar Function) but simply collects and sums up the observed counts within a specified aperture centred on the source, this technique is called of aperture photometry. However, when one is interested in classification of the images into stars and galaxies or if the fields are crowded aperture photometry does not work.

A procedure using PSF is a way of performing differential photometry and astrometry in crowded fields. The PSF is treated as a template for all the stars in a frame, so its knowledge is fundamental for a reliable analysis. In this work, we use Gaussian and Moffat analytical functions as a model for the PSF and use the AMOEBA routine of Press et al. (1992) for the fitting procedure.

2. Analysis procedure

IN order to present a generic analysis procedure, we describe bellow the steps involved. We divide the procedure in three parts: the input parameters, the execution and the output files.

The input parameters are as follows: a list with the images, a list with the position of the stars in the CCD, a normalized flat-field, a master median bias image and informations about the target and about the observation as, for example, right ascension, declination, day of observation, etc.

The list of stars is selected as statistically significant intensity peaks above the background. The isolated and bright unsaturated stars are used to compose the shape of the PSF. These stars must be the first objects at the list. In sequence must be listed the reference star, the targets and the comparisons. In this step, we select the best images of the night to register them and then combine them. In the resulting image we use a task that selects the stars automatically using a generic PSF and a lower limit for the counts.

In execution, our code initially subtracts a master median bias image from each program image, and divides the result by a normalized flat-field. The isolated and bright unsaturated stars are found automatically in the resulting image and then they are fitted using either Gaussian or Moffat models. The models can be elliptical or circular. The median value of the PSF shape parameters is used to fit one by one the star of the field. So, in fitting all objects, including the the star that will be used as reference, only amplitude and position are free parameters.

The code also allows to fit two or three stars simultaneously (see application section). In this case, the star positions in the list must be after the reference star position and the user must indicate how many double and triple stars will be fitted.

The output is composed of two files: one with the photometric results and other one with the astrometric results. In the file with the photometric results the name of images, the Heliocentric Julian Day (HJD), the instrumental magnitude of the reference star and the differential magnitudes of the targets and of the comparisons are listed. Besides image names and the HJD, in the astrometric file the positions in the CCD of all stars in all images are listed.

3. Applications

WE show two applications of our code. The first case is the astrometric triple system LHS 1070 (see Figure 1). The second case is a pre-cataclysmic variable located in the Galactic bulge (see Figure 5).

LHS 1070 is a triple system of low-mass stars at a distance of $7.72 \pm 0.15\,\mathrm{pc}$ (Costa et al. 2005). We observed two flare in this system. The first was an impressive 5 mag amplitude flare in the B band (see Figure 2). In the second, a descend of a long (hours time-scale) I band flare with a few tenths of mag amplitude (see Figure 4). However, as one can see in Figure 1, the three components are overlapped. So, in this case, aperture photometry would not be able to identifying which of components was the flaring object. In both case we fitted simultaneously three 2-D Moffat functions to the stellar profile leaving only the position of component A and the amplitudes of the three components as free parameters to be searched for. In Figure 3, we show the position of the flare observed in the B band together with the orbital solutions for LHS 1070 B/C and LHS 1070 A/(B+C) and conclude that component B was the flaring object. The results of the second flare is shown in Figure 4 and we conclude that component A was the flaring star (Almeida et al. 2010).

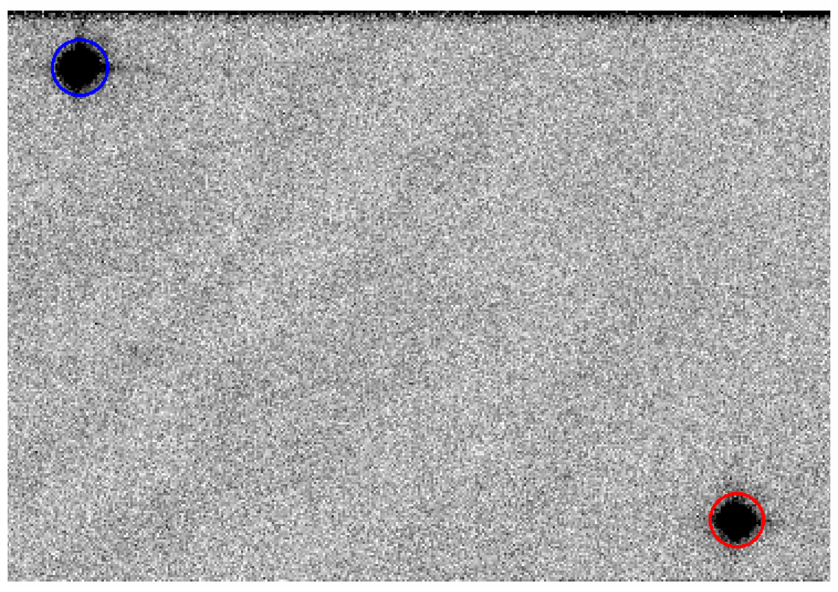

Figure 1: *Image of the astrometric triple system field LHS 1070 obtained using the Zeiss 0.6-m telescope on August 28, 2008. The reference star and LHS 1070 A+B+C are marked with blue and red circles, respectively.*

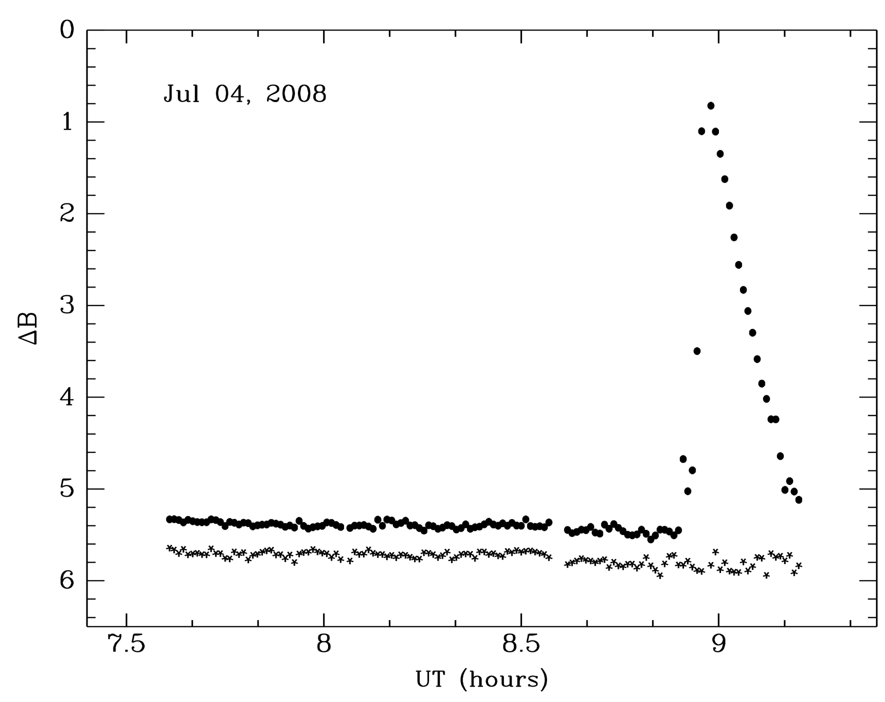

Figure 2: *B-band differential photometry of LHS 1070 on July 04, 2008. The light curves of LHS 1070 and of a comparison star are presented with full circles and stars, respectively.*

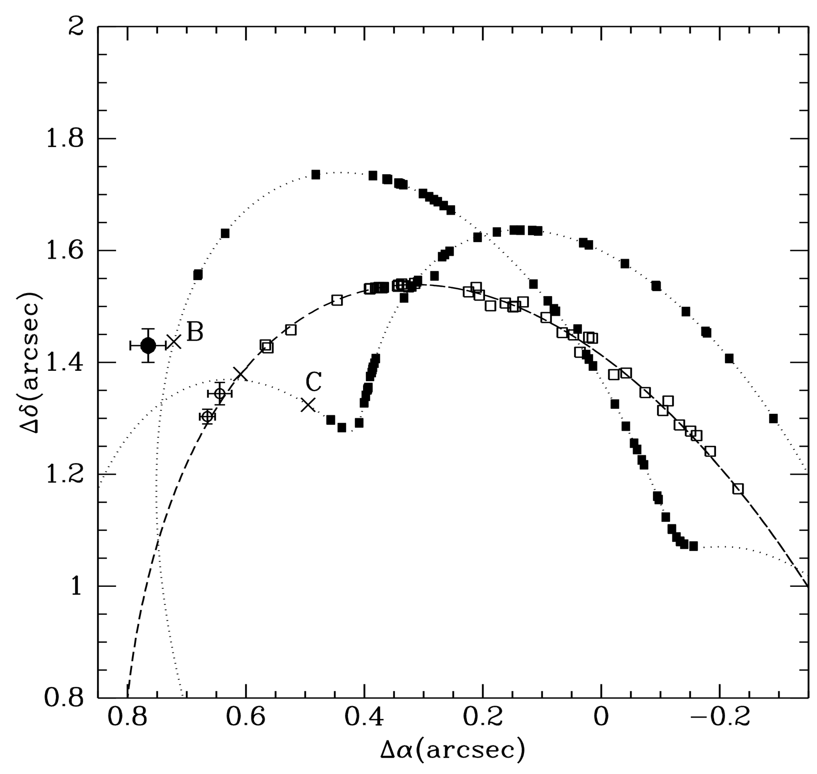

Figure 3: *Configuration of LHS 1070 on Jul 04, 2008. The dashed line represents the trajectory of the barycenter of LHS 1070 B+C around LHS 1070 A which is at the origin. The dotted lines show the trajectories of components B and C around the barycenter of LHS 1070 B+C, assuming the two components have the same mass. The positions measured by Leinert et al. (2001) and Seifahrt et al. (2008) are shown as open and full squares. Our measurements appear as open circles. The full circle shows our estimated position for the flaring object. The predicted positions of the barycenter of LHS 1070 B+C and of components B and C are marked with a "×" symbol.*

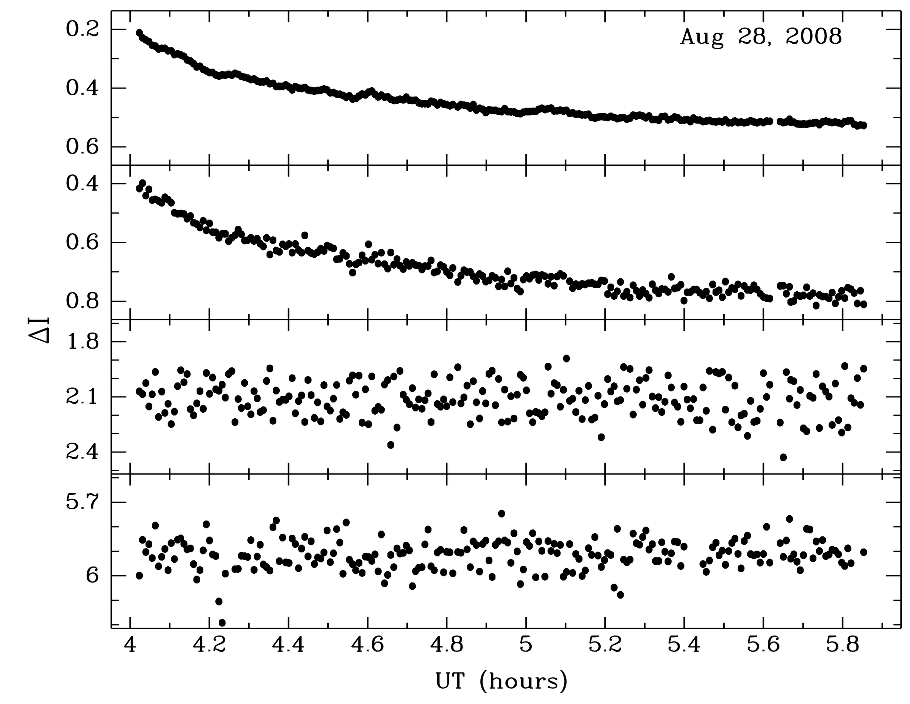

Figure 4: *I_C-band differential photometry of LHS 1070 on August 28, 2008. From top to bottom we show the aperture photometry for LHS 1070, the results of the 2-D Moffat function fitting for LHS 1070 A and LHS 1070 B+C and the aperture photometry for a comparison star.*

BUL-SC16 335 is a eclipsing pre-cataclysmic variable (Polubek et al. 2007). This object is very interesting in the evolution study of cataclysmic variables because the physical and geometrical parameters of the system can be estimated with relatively good precision. However, can one see in Figure 5, the binary is overlapped for another object. Therefore, any variation in this another object could induce errors in estimating the parameters of the system. To avoid a possible contamination from that object, we used our code to fit two 2-D Moffat functions to the stellar profile leaving only the position and amplitude as free parameters. In Figure 6 we show the results of this procedure.

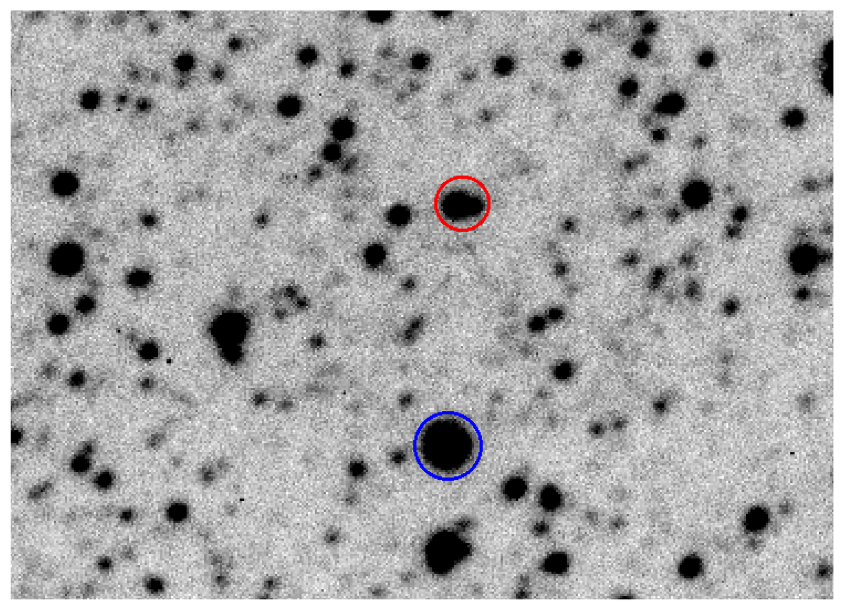

Figure 5: *Image of BUL-SC16 335 field obtained using the Perkin-Elmer 1.6-m telescope. The reference star and the system are marked with blue and red circles respectively.*

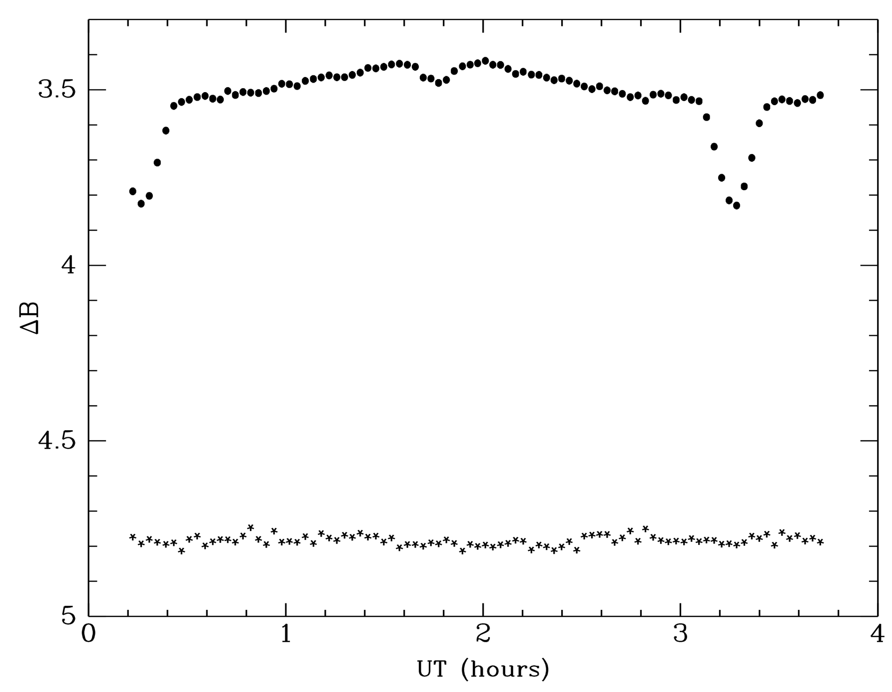

Figure 6: *B-band differential photometry of BUL SC16 335 on July 03, 2008. The PSF differential photometry of BUL SC16 335 and of the star overlapped is shown with full circles and stars respectively (see red circle in figure 5).*

References

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