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High precision photometry in crowded stellar fields

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A deconvolution-based method which allows to derive high precision photometry of stars in crowded fields, proves very useful for a variety of astronomical projects, including transit searches for extrasolar planets.

An increasing number of astronomical problems require to accurately measure the brightness of stars situated in crowded fields. Among those, we may mention the searches for extrasolar planets by the transit method. In this case, the low probability that a planet passes in front of its parent star implies that a large number of targets have to be monitored at the same time, hence the high degree of crowding. Other applications concern the dating of the oldest stellar clusters or the measurement of the light curves of bright variable stars in external galaxies (the *standard candles* used to determine cosmological distances).

When the fields are so crowded that the images of neigbouring stars overlap, the separation of the different images requires the knowledge of the shape of point sources, the so-called *Point Spread Function* (PSF). Most methods rely on images of sufficiently isolated stars to construct the PSF. However, in very crowded fields, no such isolated objects can generally be found and an accurate PSF cannot be constructed, which undermines the quality of the brightness measurements.

Method and results

Unlike traditional techniques, such as DAOPHOT[2], which first determine the PSF and afterwards rely on a fit of that PSF on the individual (possibly blended) point sources, our method carries out a simultaneous determination of the PSF and of the point sources positions and intensities[3]. It is based on the same principles as the MCS deconvolution algorithm[4], which seeks to improve the resolution while still conforming to the sampling theorem.

We write the solution of the deconvolution problem as an analytical sum of point sources, whose positions and intensities are unknown. The shape of these point sources in the deconvolved image is fixed by the user. We generally adopt a Gaussian of 2 to 3 pixels Full-Width-at-Half-Maximum (FWHM), so that the sampling is satisfactory. We then seek the convolution kernel (and hence the PSF) which allows to transfrom the analytical solution into the original images. The source positions and intensities are determined together with the PSF, by minimization of a χ-square merit function, which measures the agreement between the model and the observations.

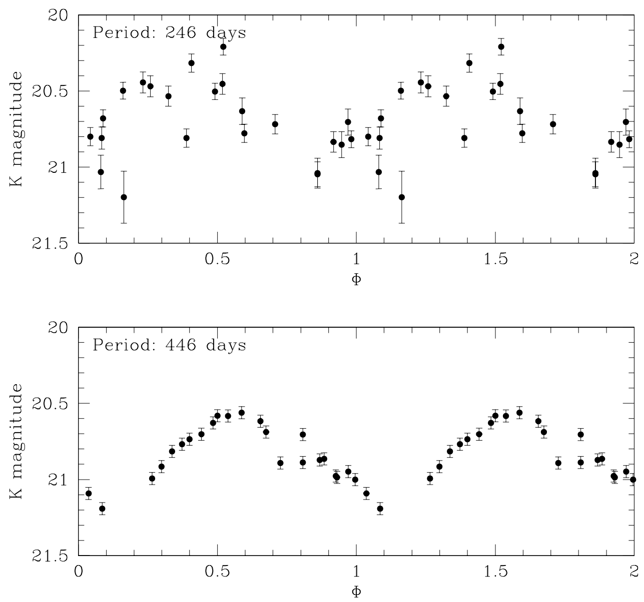

Figure 1. Top: the Mira star light curve as determined from a traditional PSF-fitting technique, which gives a 246-days period[1]. Bottom: the light curve from our method, from which a 446-days period is found.

We have tested the method on a variety of synthetic as well as real astronomical images, with varying degrees of crowding and a large range of signal-to-noise ratios. We have shown that it provides both accurate PSFs and accurate astrometry and photometry. It gives optimal results in the sense that it uses the information contained in all point sources, and not just (semi-)isolated

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ones in order to construct the PSF. An example is shown in Figure 1, which displays the light curve of a variable star in an external galaxy, as compared to the results obtained with a traditional technique.

We have also extended the method to images containing a mixture of point sources and diffuse objects (such as nebulae or distant galaxies). In this case, we use an iterative technique which, at each steps, tries to improve both the PSF and the determination of the diffuse component.

Further work

At the present stage, we have put the emphasis on accuracy rather than computing speed. Our algorithm thus gives more accurate results but is also much slower than traditional PSF-fitting methods. As such, it is not yet adapted to the processing of images containing more than a few hundred point sources. We are presently working on improvements of the processing speed, so that it can cope with images containing several thousand sources.

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