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DIFFRACTO-ASTROMETRY MEASUREMENTS: THE TECHNIQUE

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RESUMEN

Investigamos la posibilidad de realizar astrometría de precisión en imágenes estelares saturadas de la Wide Field Planetary Camera 2 (WFPC2) del *Hubble Space Telescope* (HST). Obtenemos la posición de los fotocentros de éstas utilizando una técnica de centrado que usa el patrón de difracción producido por el soporte del espejo secundario. La técnica parece ser muy prometedora en el análisis astrométrico. Mediante ella logramos una precisión del orden de 10 milisegundos de arco en imágenes de la WFPC2.

ABSTRACT

We investigate the possibility of performing precision astrometry on saturated stellar images of the *Hubble Space Telescope* (HST) Wide Field Planetary Camera 2 (WFPC2). We obtain the position of the stellar photocentres by using a centring technique which utilises the diffraction pattern produced by the secondary mirror support. This technique appears to be very promising in the astrometrical analysis. It allows a precision of the order of 10 milliarcseconds in WFPC2 images.

Key Words: methods: data analysis — techniques: image processing

1. INTRODUCTION

Diffracto-Astrometry (DiAs) is a methodology developed by us with the aim of measuring relative stellar positions and displacements on diffraction-limited images such as archival HST and Adaptive Optics (AO) images. Application of this methodology is independent of whether or not the sources are saturated. Successful application of this methodology to saturated images enables us to extract valuable astrometric data from WFPC2-HST archival material (see Olivares et al. 2011, 2013).

2. THE TECHNIQUE VIEWED THROUGH THE MEASURING ALGORITHM

The application of the Diffracto-Astrometry technique to the measurement of relative stellar positions on archival HST images requires an algorithm to ensure minimum systematic errors in the results (Sánchez et al. 2008, 2011; Ruelas-Mayorga et al. 2011, 2013).

There exist a number of systematic errors associated with the WFPC2-HST measurements which have been extensively analysed in the past. The most important are caused by geometric distortion (Kozhurina-Platais et al. 2003; Anderson & King 2003), by the 34th row error (Anderson & King 1999), and by Charge Transfer Efficiency (CTE) (Holtzman et al. 1995; Stetson 1998; Whitmore et al. 1999; Dolphin 2000).

In our analysis of WFPC2-HST images, we correct for geometric distortion and for the 34th row error using the formulae given in the literature mentioned above. Since the maximum charge loss due to the CTE problem amounts to ∼2% for bright sources, CTE problems are negligible when applying the DiAs technique.

In what follows, we enumerate the steps taken by the measuring algorithm in the determination of the photocentre of a stellar object. A study of the accuracy of this technique is given in Ruelas-Mayorga et al. (2011, 2013).

1. First, we select standard pipeline-calibrated WPCF2-HST archival files (*.c0f.fits) from the Multimission Archive at STScI (MAST) according to criteria regarding astronomical object, date of acquisition, filter, exposure time and CCD (PC or WF chip).

2. We create a mask that identifies the saturated pixels.

3. The angle formed by the CCD rows and the diffraction spikes of the brightest component is measured.

4. A straight line is fitted to each pair of spikes and its intersection is taken as a first approximation to the stellar photocentre.

5. This pixel is used as the intersection point of a pair of perpendicular straight lines which are used

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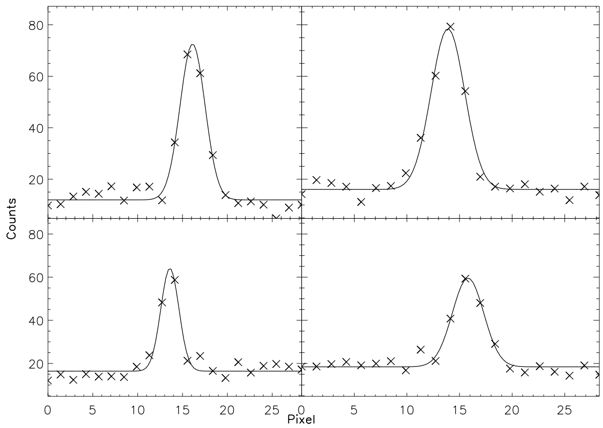

Fig. 1. Example of gaussian curves adjusted to four brightness-cuts of the diffraction spike.

as guidelines for intensity cuts along the spikes. We assume that our initial guess locates the real photocentre within a square 3×3 pixels in size.

6. Depending on the intensity modulating pattern of the spikes, the algorithm chooses to perform regularly spaced perpendicular cuts across the maximum spatial extension of the diffraction spikes.

7. To each brightness-cut the algorithm adjusts a Gaussian curve (see Figure 1) by the Levenberg-Marquardt method (Moré 1978). The central point of this Gaussian is taken as the position of the spike on that cut. The corrected central positions (Kozhurina-Platais et al. 2003) are used to generate a least-squares straight line which we consider as the best position for the diffraction spike. The intersection of the two least-squares lines fitted to both pairs of spikes provides a statistically significant position for the stellar photo-centre.

8. Steps 5 to 7 are now repeated over the 8 surrounding pixels of the point determined in the fourth step, and a new statistically significant central position is determined for each case.

9. These positions are corrected for the 34th row error following Anderson & King (1999).

10. Each one of the nine positions are finally corrected for the measuring algorithm intrinsic errors (see Ruelas-Mayorga et al. 2011, 2013).

11. The position which the measuring algorithm provides as the definitive position of a stellar image corresponds to the average of the nine central positions determined in step 10. The uncertainty of this result is given by the standard deviation.

3. CONCLUSIONS

The technique of Diffracto-Astrometry appears to be very promising for exploiting, not only the important HST public image data base, but also images obtained at telescopes using AO techniques. We have determined that our technique allows a precision of the order of 10 milliarcseconds in WFPC2-HST saturated stellar images.

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