DIFFRACTO-ASTROMETRY MEASUREMENTS: ACCURACY OF THE MEASURING ALGORITHM

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RESUMEN

Se presenta un análisis teórico del algoritmo de medida de la Difracto-Astrometría. Se generaron funciones de esparcimiento de punto teóricas con el programa Tiny-Tim para los CCDs de la HST Wide Field Planetary Camera 2 (WFC2). Estas imágenes fueron medidas y se encontraron posiciones para cada una de las Theoretical Point Spread Functions (PSFs) simuladas. El algoritmo de medida recobra las posiciones originales razonablemente (± 0.1 a ± 0.4 pixeles). Sin embargo, existen pequeñas desviaciones con respecto de los valores originales. Se ajustaron las diferencias entre las posiciones reales y las medidas con una función cuadrática de las coordenadas. La aplicación de estas transformaciones permite determinar la posición de una imagen estelar con una precisión de varios centésimos de pixel.

ABSTRACT

We present a theoretical analysis of the Diffracto-Astrometry measuring algorithm. We generated Tiny-Tim Theoretical Point Spread Functions (PSFs) for the CCDs in the HST Wide Field Planetary Camera 2 (WFPC2). These images were then measured using only their diffraction pattern, and positions for the simulated PSFs were obtained. The measuring algorithm recovers the original positions reasonably well (± 0.1 to ± 0.4 pixels). However, slight deviations from the original values are observed. We adjust the differences between the real and the measured position with a quadratic function of the coordinates. Application of these transformations allows determination of the position of a stellar image within a few hundredths of a pixel.

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

1. INTRODUCTION

Diffracto-Astrometry is a technique developed with the intention of making high precision measurements of absolute and relative stellar positions of saturated stellar images (Sánchez et al. 2008, 2013a). To establish a position for a saturated stellar image, Diffracto-Astrometry utilises in principle both the diffraction spikes and the diffraction rings on the PSFs (Sánchez et al. 2011, Olivares et al. 2011). So far, we have only explored the use of the diffraction spikes to determine the photocentre of saturated stars on WFPC2 images of the Orion Trapezium (OT) see Sánchez et al. (2013b, in preparation).

To investigate the precision with which the measuring algorithm is able to recover the positions of saturated stars on archival observations, we study the measuring accuracy of the algorithm on WFPC2 simulated saturated images.

2. THEORETICAL POINT SPREAD FUNCTIONS (PSFS) USED TO DETERMINE THE ACCURACY OF THE MEASURING ALGORITHM

The application of Diffracto-Astrometry techniques 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, 2013b, in prep.).

In this section, we study the intrinsic errors and determine the accuracy of the measuring algorithm. We generate, using the Tiny Tim software (Krist 1993, 1995; Krist & Hook 2004; Hook & Stoehr 2008), theoretical PSFs for 9 different, regularly distributed positions on CCD 2, and for 16 positions on CCDs 1, 3, and 4 of the WFPC2.

Appropriate background and saturation levels are added to each generated image.

The simulated PSFs images for CCDs 1, 3 and 4 are similar to those presented for CCD 2.

For each one of the theoretical PSFs across the field we determined the photocentre applying our measuring algorithm. The determinations of the PSF photocentres differ slightly from the theoretical positions.

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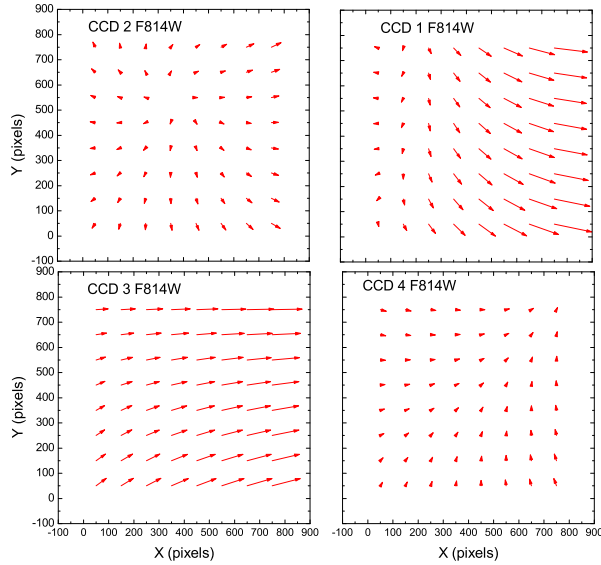[2]Instituto de Astronomía y Meteorología, Universidad de Guadalajara, 44130, Guadalajara, Jalisco, Mexico.

Fig. 1. Vector diagrams of the differences between the measured and the real positions across the surface of the WFPC2 CCDs for filter F814W. To make the differences visible, each vector is magnified by 100. Taken from Ruelas-Mayorga et al. (2011).

After having experimented with different polynomial functions, we chose to fit the differences measured for each positional coordinate with the polynomials which represent a compromise between lower residual values and polynomials that did not produce too many folds in the fitting surface (see Ruelas-Mayorga et al. 2011).

The coefficients of the transformations were found following a least-squares adjustment.

In Figure 1 we show vector diagrams made for filter F814W and for the four CCDs in the WFPC2. The vectors represent the differences we find between the theoretical positions and those measured by our algorithm. The differences (in pixels) in X are contained in the range $(0.11, 1.48)$, and in Y $(0.02, 0.48)$. The residual values (in pixels) in X are contained in the range $(0.06, 0.27)$, and in Y $(0.04, 0.40)$.

After having performed a statistical analysis, we determined that the Diffracto-Astrometry measuring algorithm is able to recover the PSF positions with an accuracy of ± 0.1 to ± 0.4 pixels both in the X and Y coordinates. The correction to the measuring algorithm presented here should improve this accuracy.

3. CONCLUSIONS

• We present an analysis of the ability of the Diffracto-Astrometry measuring algorithm for finding the position of the centre of a saturated stellar image on HST images.

• We generated Tiny-Tim theoretical PSFs

• We located these PSFs on the surface of the different CCDs and then compared their theoretical positions with those found by application of the algorithm.

• The differences between the measured and the real values are fitted to a quadratic function of the coordinates.

• The Diffracto-Astrometry measuring algorithm alone recovers the stellar positions with a precision ± 0.1 to ± 0.4 pixels, while after the application of these transformation equations the position is recovered with a precision of a few hundredths of a pixel of the real value.

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