RevMexAA (Serie de Conferencias), **25**, 99–100 (2006)

ASTROMETRY WITH OPTIC AT WIYN

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The astrometric precision of Orthogonal Transfer CCDs (OTCCDs) is investigated by using OPTIC camera at the WIYN 3.5-m telescope. The precision of the positions, determined by the Yale image-centering code, will be used to establish astrometric design requirements for the anticipated WIYN One Degree Imager Camera that will use similar technology.

1. OPTIC CAMERA

Orthogonal Transfer CCDs (OTCCDs) are able to electronically compensate for real-time image motion and provide tip/tilt corrections without additional optics or moving parts (Tonry, Burke, & Schechter 1997). The Orthogonal Parallel Transfer Imaging Camera (OPTIC) consists of two 2K by 4K OTCCDs arranged in a single dewar mounted adjacent to each other with a small gap between the chips. Each OPTIC OTCCD is electronically divided into two 2048 × 2048-pixels regions, each of them further subdivided into two parts: a guide region and a science region. The guide regions sit at the top and bottom of each CCD and are 2048 × 516 pixels each, while the science regions are 1536 × 2048 pixels. Pixel size of the CCD is 15 micron. When the camera is mounted on the WIYN 3.5 m telescope, the image has a scale of 0.14 ″/pixel, yielding an approximate 10 ′× 10 ′total field of view. OPTIC has a read noise $< 4\,e^-$ when read at its normal rate of 160 kpix/sec and a nominal gain of 1.45 e^-/ADU.

2. OBSERVATIONS

To test the astrometric performance of OPTIC, we have imaged the open cluster NGC 188 using both Johnson-V and Gunn-i filters. A total of 65 dithered 5-minute exposures in the V-band and 71 dithered 1 to 5-minute exposures in the i-band were taken during the nights of 2003 October 20-26. The seeing ranged from 0.6 ″< FWHM < 3 ″. For the purposes of this investigation only nights with seeing $< 2''$ were considered.

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3. ASTROMETRIC REDUCTION

A complete astrometric reduction must model the Optical Field-Angle Distortion introduced by the optical system, as well as treat any systematic effects that alter the centroid of the images. The so-called *Magnitude Equation* due to imperfect Charge Transfer Efficiency (CTE) in CCDs, and the *Color Equation* related to differential atmospheric refraction, can be listed as systematic sources of errors.

By using both preliminary centroids found through `SExtractor` (Bertin & Arnouts 1996) and the astrometric catalogue of NGC 188 by Platais et al. (2003), a first astrometric reduction was made to match the stars on the different frames and then assign a unique identification number for each star. Afterwards, a more careful analysis is made using the Yale image-centering code (2D Gaussian fitting).

We selected pairs of frames with the same filter and similar hour angle to avoid effects of differential refraction. Coordinate differences of the (x,y) image centers of the stars on the two frames are fitted by a least-squares polynomial. Since each quadrant has its own guiding region, each quadrant was reduced separately. Magnitudes and colors were placed on the system of von Hippel & Sarajedini (1998) by using the instrumental magnitudes estimated by the Yale image-centering code and their standard stars. The internal errors of our photometry are approximately 0.02 mag for V<19.5 and 0.03 for i<18.5.

4. RESULTS

The results shown in Figures 1 and 2 are based on a linear reduction of the same pair of frames. No higher order terms were required for most of the pairs of frames which means that OPTIC has a very stable performance in terms of imaging.

Figure 1 shows the residuals in the x-coordinate versus position along the x-axis. There are no obvious non-linearities in the OPTIC frames down to the level of 1 micron. Based on probability plots made from the residuals of a large number of reductions, we estimate that OPTIC achieves a precision of the order of milliarcseconds over the dynamical range of the CCDs. For example, the residuals in Figure 1 for stars with S/N > 40, i.e. those considered of good quality for astrometry, represent a Gaussian distribution with standard deviation of 0.25 microns,

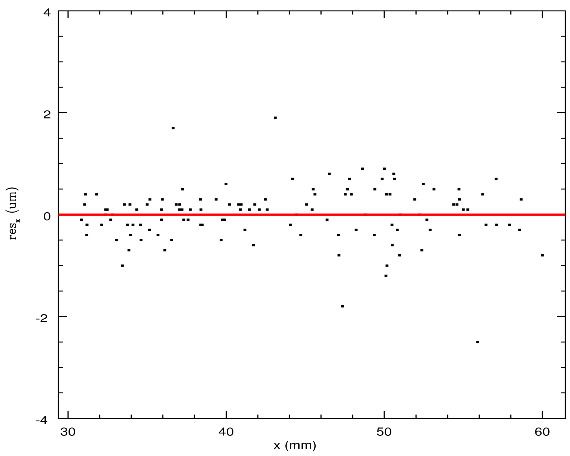

Fig. 1. Residuals in the x-coordinate vs. the x-coordinate. Residuals in the y-coordinate show a similar behavior. These data correspond to a reduction of two same-night V-frames (seeing ∼0.6 ″). Only stars within the dynamic range of the CCDs were considered in the reduction.

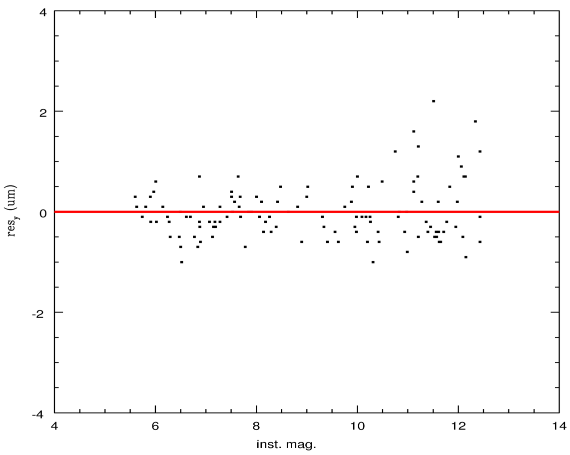

Fig. 2. Residuals in the y-coordinate vs. instrumental magnitude. No differential magnitude equation is observed. The point at which signal-to-noise becomes important is easily seen at around m∼11. The dynamic range of the OPTIC CCDs is 5 magnitudes.

which corresponds to 2.5 milliarcseconds at OPTIC's scale.

For most of the frames analyzed, the precision of a single measurement in a single frame ranges from 2 to 4 milli-arcseconds for well-measured images. The precision in position is obviously affected by the stability of the atmosphere. Consequently, these results demonstrate that the unique charge transfer done by OPTIC, which tracks the motion of each quadrant's corresponding guide star, is able to stabilize the field within the atmospheric isokinetic region to the level of a few milliarcseconds.

Figure 2 shows the residuals in y-coordinate versus instrumental magnitude. No differential magnitude equation is detected. It means that neither guiding nor charge transfer systematic errors changed between the exposures. Signal-to-noise effects start to be noticed for stars fainter than instrumental mag ∼11. The dynamic range of the OPTIC camera extends up to 5 magnitudes. No color terms were required except when reducing two (same filter) frames separated by 10 deg or more in hour angle (differential atmospheric color refraction). We are planning a more detailed analysis of these data to properly model the atmospheric refraction and then pre-correct the OPTIC frames. These data will also be used for a further analysis of the membership and proper motions in the open cluster NGC 188.

We thank Dana Dinescu of the Yale Astrometry Group for her useful observations and recommendations, Steve Howell from the WIYN Observatory and NOAO for helping us with technical issues related to the OPTIC camera and Nick Morgan (now at Ohio State University) for sharing the telescope time with us. This research was supported in part by a grant from the National Science Foundation.

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