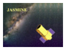
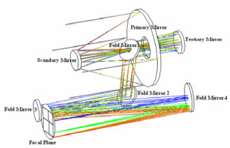
CCD Centroiding Experiment for JASMINE and ILOM



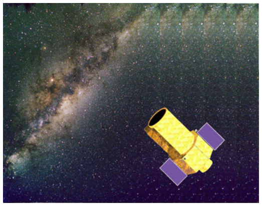
Taihei Yano, Hiroshi Araki, Naoteru Gouda, Yukiyasu Kobayashi, Takuji Tsujimoto, Tadashi Nakajima, Nobuyuki Kawano, Seiichi Tazawa (National Astronomical Observatory, Japan), Yoshiyuki Yamada(Kyoto University), Hideo Hanada, Kazuyoshi Asari, Seiitsu Tsuruta (National Astronomical Observatory, Japan)

Abstract

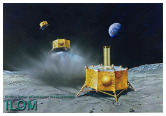
JASMINE and ILOM are space missions which are in progress at the National Astronomical Observatory of Japan. These two projects need a common astrometric technique to obtain precise positions of star images on solid state detectors to accomplish the objectives. We have carried out measurements of centroid of artificial star images on a CCD to investigate the accuracy of the positions of the stars, using an algorithm for estimating them from photon weighted means of the stars. We find that the accuracy of the star positions reaches 1/300 pixels for one measurement. We also measure positions of stars, using an algorithm for correcting the distorted optical image. Finally, we find that the accuracy of the measurement for the positions of the stars from the strongly distorted image is below 1/150 pixels for one measurement.



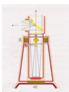
Optics of JASMINE(3mirror system)



An artist's impression of JASMINE



An artist's impression of ILOM



PZT (Photographic Zenith Tube) for ILOM

JASMINE and ILOM

JASMINE is the acronym of the Japan Astrometry Satellite Mission for INfrared (z-band :0.9 μ m) Exploration.
JASMINE will measure trigonometric parallaxes, positions and proper motions of stars, with a precision of 10 microarcsec at z =14mag.
The diameter of the primary mirror (75cm), its focal length (22.5m), wavelength (0.9 μ m).
JASMINE will take overlapping fields of view without any gaps to survey an area of about 20° × 10° around the Galactic bulge.
ILOM is the acronym of In-situ Lunar Orientation Measurement.
The objective of ILOM is to study lunar rotational dynamics by direct observations of the lunar physical libration and the free librations from the lunar surface in order to investigate the lunar mantle and the liquid core.

EXPERIMENTAL EQUIPMENT

The schematic design of the centroiding experiment is shown in Figure 1.
Overview of the experimental equipment is also shown in Figure 2.

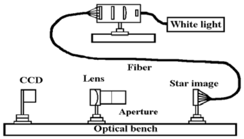


Fig. 1 Schematic of the Experimental Equipment

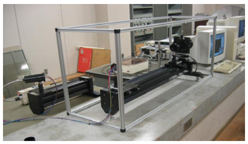


Fig. 2 View of the Experimental Equipment

Centroiding Experiment

We pick up a square subset of 5 × 5 pixels around the peak pixels of two star images.
The photon weighted means (xc, yc) are derived from the square subsets.
The photon weighted means (xc, yc) are different from the real positions (xa, ya).
We assume that the difference between (xc, yc) and (xa, ya) is proportional to the deviation of (xc, yc) from the center of the pixel as follows,

$$xa = xc + k\, xc$$

We take many images for these two stars.
We derive the parameter k using a least square method.

Result

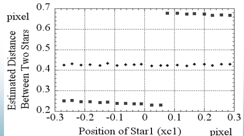


Fig 3

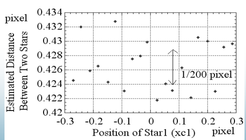


Fig 4

The results for our experiment are shown in Figure 3. The squares show only the separations between photon-weighted means of two stars, that is, no correction is performed. On the other hand, the diamonds are the estimated distances between two stars by using the algorithm. These estimated distances (the diamonds) are shown again in Figure 4. As we see, the variance of the estimated distances of two stars is about 1/300 pixel.

Centroiding Experiment for Distortion

In addition to the above procedure, we assume that the value of distortion at a certain point on the frame is proportional to the cube of distance from the position of the optical axis on the CCD array as follows,

$$\delta r = \varepsilon\, r^3$$

We derive the parameter k and parameters for the distortion using a least square method.

Result

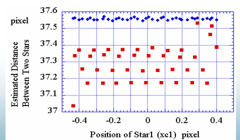


Fig 5

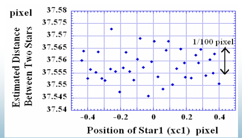


Fig 6

The squares show only the separations between photon-weighted means of two stars, that is, no correction is performed. On the other hand, the diamonds are the estimated distances between two stars by correcting the optical distorted image on a CCD plane in addition to the linear correction. The dispersion of the distance of two stars, the error of the estimation is about 1/150 pixel for one measurement.