4 Calibrations

In this research, two different calibration methods were used for each observation. For the observation on the period of April, 2~3, 2006, a well observed and wide binary, Castor was used as a reference to calibrate scale and orientation of all the targets. For the period of observation of February, 9~11, 2007, a double slit mask with 60-cm interval was set in front of the telescope and point to a bright star Capella, and the produced fringe image was used to calibrate pixel scale. A drift scan image stream was taken to calibrate orientation. of each target. The double slit mask only set on February,11, 2007 to calibrate image taken on both February 10 and 11.

Calibration by a wide binary, Castor

Castor was used as a reference star for scale and orientation calibration on April, 2006. Because we have not a mask aperture of two slits for scale calibration in the observation. Furthermore, the star tracking was done in fast or slow tracking mode that is not suitable for the calibration of orientation, so we rely on observing a wide binary, Castor, with long period and good observations in the Fourth Interferometric Catalog (Harkhopf and McAlister, 1998) to calibrate the angular scale and orientation of binaries in the observation.

The angular separation and the position angle of Castor at the our observing time, 2006.652, calculated from the orbit elements taken from the Sixth Orbits Catalog of visual binaries (Hartkopf and Mason, 2003) are 4.36" and 59.62°, respectively. The separation between Castor A and B is 101.0 pixel and the angle responds to the x-axis of CCD chip is 57.20°, so that the angular scale is 0.0432 "/pixel, and the difference between the direction of north and the y-axis 2.42° (Figure 4-1)

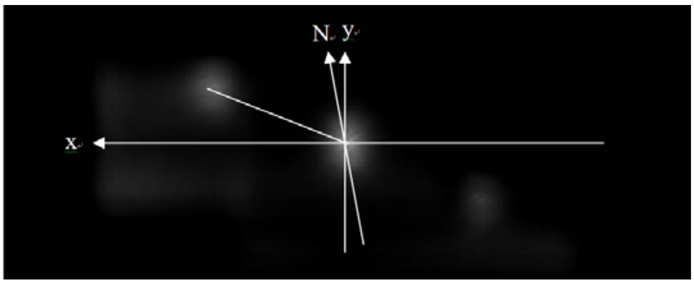

figure 4-1 The astrometry of Castor image of autocorrelation is used for the calibration of the angular separation and the orientation.

Calibration by double slits mask and drift scan images

In order to measure the pixel scale directly and precisely, a double slits is mount on the front of the telescope to produce diffracting fringe image on focal plane. The diffractive fringe images of Young's double slits are processed with autocorrelation method and taken with sum value, and a FFT analysis is used to determine the distance of the autocorrelation fringe. For Young's double slit, the equation where d is interval between two slits, λ is observing wavelength, A_{Pix} is pixel scale, and N_{pixs} is interval between measured patterns. The effective wavelength of 600 nm is chosen corresponding to the maximum quantum efficiency of CCD chip. Distance of the double slits is 60 cm.

The angle of constructing fringes is calculated in equation 4-1. n is set in 1 because the ratio of fringe interval and focal length is as small as $2*10^{-6}$ to be able to ignore the difference of each interval of the image. The calculated angle is divided by the interval length of fringe to calculate the pixel scale in unit of "/pixel (equation 4.2)

$$\sin^{-1}\theta = \frac{n\lambda}{d} \quad \ldots 4\text{-}1$$

$$A_{Pix} = \frac{1}{N_{pixs}} \sin^{-1}\frac{n\lambda}{d} \quad \ldots 4.2$$

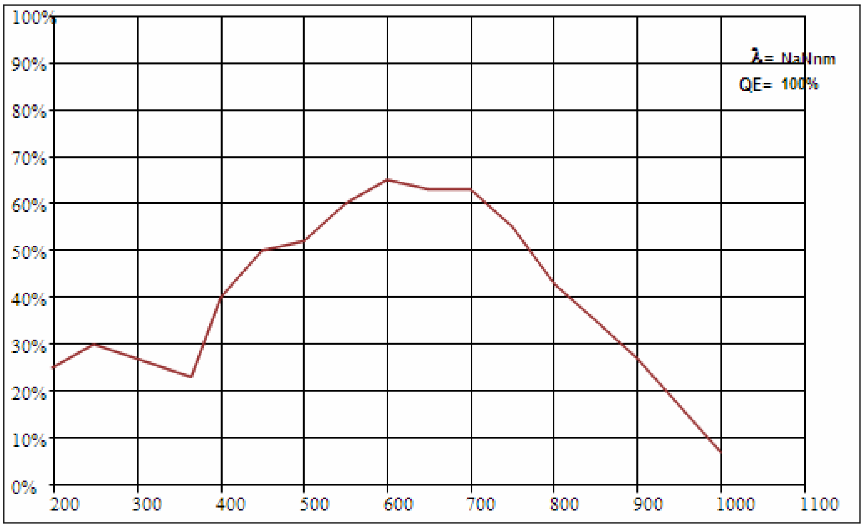

figure 4-2 QE-Wavelength response figure of iXon CCD

figure 4-3 The front face of double slits mask mount on LOT

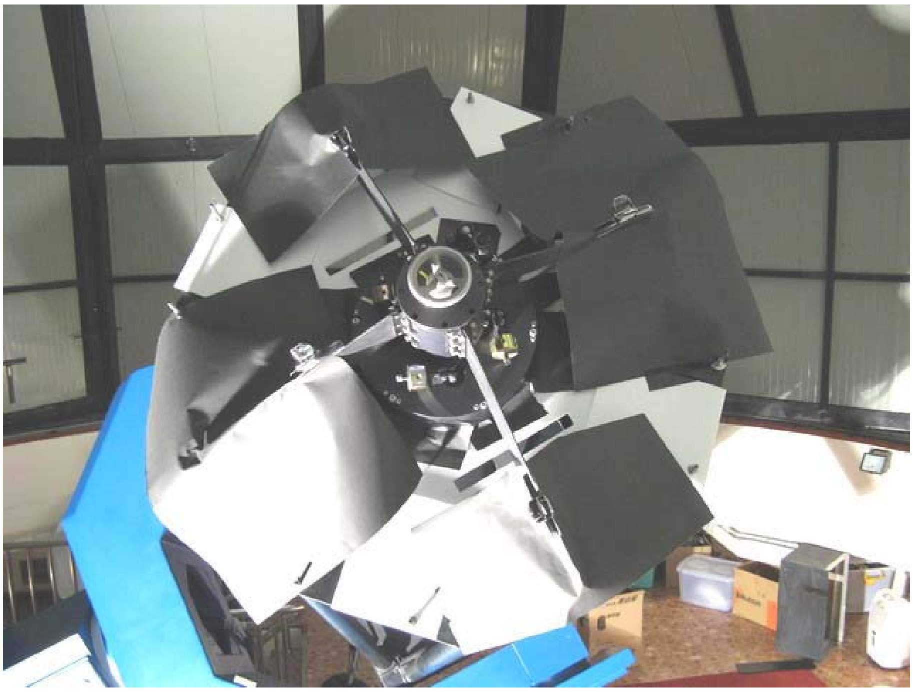

figure 4-4 The back face of double slits mask mount on LOT

The 300 frames of fringe images were processed by 2D autocorrelation function and calculated mean value for each pixels before analysis. And FFT analysis is used to measure the fringe distance in x-axis. The DC term is located on sides of x axis and the symmetric peaks 1 and 4 are the strongest response of fringe. In order to compensate the orientation of fringe, the image is rotated to clockwise direction with step 0.001 degree to find the smallest fringe interval in x-axis. And the result of 5.364 pixels is determined as the interval of fringes. And the pixel scale 0.0385"/pixel can be calculated with the equation.

$$A_{Pix} = \frac{1}{N_{pixs}} \sin^{-1} \frac{n\lambda}{d} = 0.0385\text{"/pixel}$$

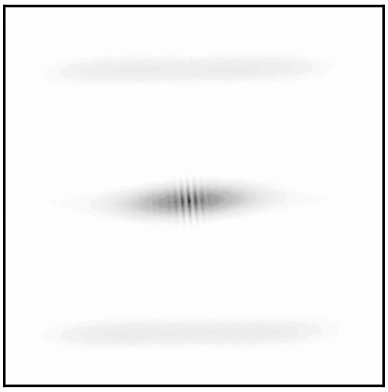

figure 4-5 Fringe image after autocorrelation process

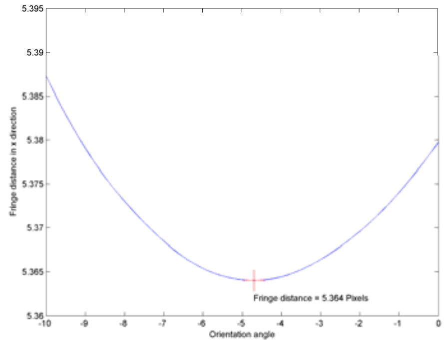

figure 4-6 The relationship of orientation of fringe distance and orientation angle

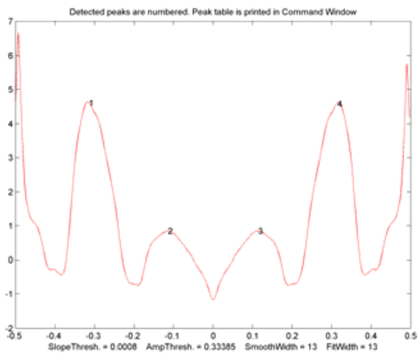

figure 4-7 The result of fft for fringe patterns of two slits.

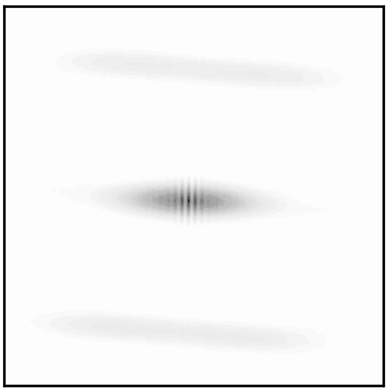

figure 4-8 Calibrated fringe shows perfect alignment with y axis.

The orientation of images on east-west direction are taken by turning off the tracking motor, and let star drifts through the whole field. More than 10 frames, the star will been seen in the field depending on its declination. The orientation of east-west is determined by linear regress of each track.

The original images recorded by iXon CCD are converted to AVI format with Andor SOLIS software, and process with autocorrelation function and boxcar cleaning using Matlab. Autocorrelation and boxcar processed Images are finally analysed by Astroart 4 software to detect the position of the stars in x-y coordinate.

Separation and position angle are finally calculated with x-y coordinate and calibration results as parameters. Where A_{pix} is pixel scale in arc second, Φ is orientation of image respond to counter clockwise direction of x-axis, ρ is separation of binary and θ is position angle of binary.

$$\rho = \sqrt{x^2 + y^2} * A_{pix}$$

$$\theta = \tan {}^{y}\!/\!{}_{x} - \Phi$$

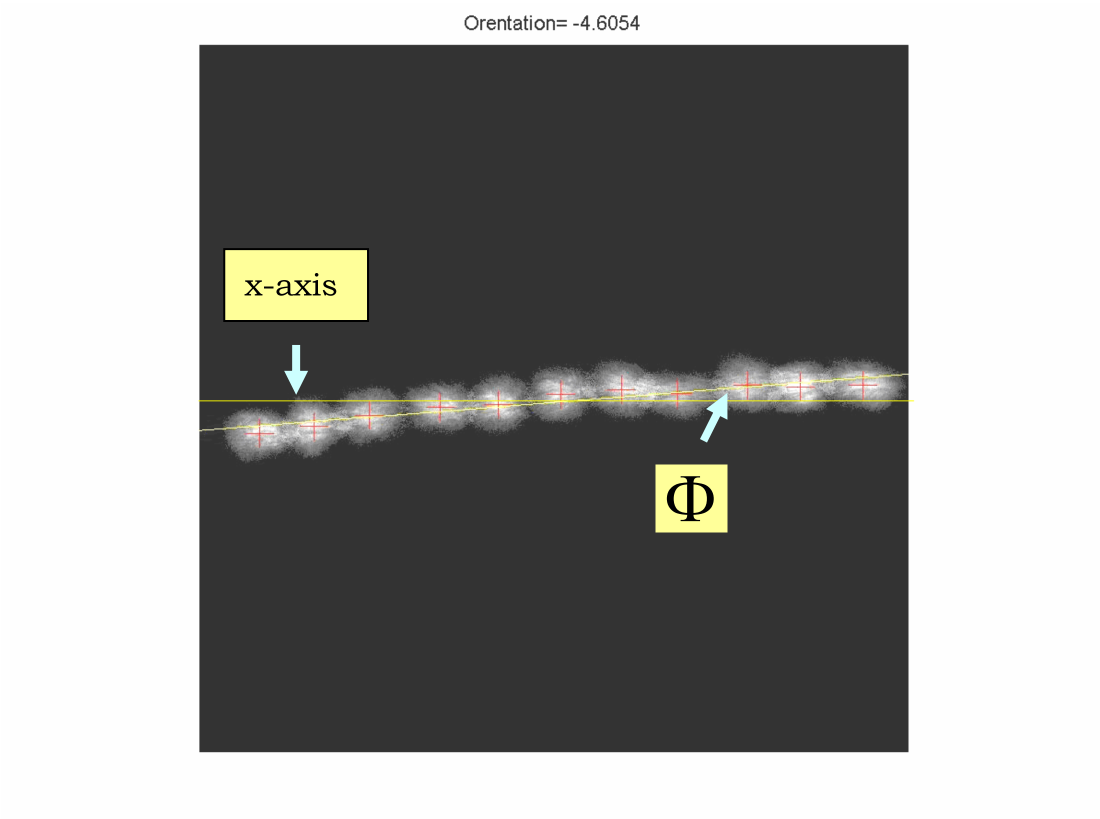

figure 4-9 Orientation calibration using drift scan images. In this example, 11 frames were analyzed (STF1555AB). Orientation Φ of each target are shown on Table 4-1.

Table 4-1 Orientation of each target

Target	Orientation Φ (°)
STF1037AB	-5.2
STF1555AB	-4.6
STF1669AB	-3.4
STF1670AB	-5.8
STF3121AB	-5.3
STT208	-5.1
STT227	-5.3
BU341	-5.2
BU612AB	-4.7
Castor	-4.8
HU879	-6.1
HU1134	-5.7
KUI48AB	-5.4
McA38Aa	-5.2
STF728	-4.6
STF1333	-5.1
STF1728AB	-5.5
STF1865	-4.9
STT163AB	-4.9
STT185	-4.5
STT187	-6.0