Nano-JASMINE: Simulation of Data Outputs

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Abstruct

We simulated the data outputs of the first Japanese astrometry satellite Nano-JASMINE, which is scheduled to be launched by the Cyclone-4 rocket in August 2011. The simulations were carried out using existing stellar catalogs such as the Hipparcos catalog, the Tycho catalog, and the Guide Star catalog version 2.3. Several statics are shown such as the number of stars those will be measured distances using annual aberration observations. The method for determining the initial direction of the satellite's spin axis has also been discussed. In this case, the frequency of bright stars observed by the satellite is an important factor.

I. Nano-JASMINE Project

Nano-JASMINE (hereafter, NJ) is the first Japanese astrometry satellite equipped with a 5-cm telescope made entirely of aluminum. Figure 1 shows the external appearance of NJ, which is based on a CAD image. NJ will be launched into a sun-synchronized low-Earth orbit and will perform all-sky astrometry observations of nearby bright stars during an operational period of more than 2 years. NJ aims to make direct determinations of stellar distances by performing annual parallax measurements. Figure 2 shows the system spectral response, which is the definition of the Zw-band used by NJ. NJ will be launched using the Cyclone-4 rocket developed by the Yuzhnoye State Design Office and manufactured by the Yuzhymash State Enterprise in Ukraine. It will be launched by the Alcantara Cyclone Space Binational Company; this facility was recently constructed by Ukraine and Brazil and is located near the equator in Brazil. The launch is scheduled for August 2011 and this is the maiden flight for the Cyclone-4 launcher.

Because NJ employs the same astrometry technique as was used by Hipparcos to get better astrometry performance, it is equipped with a beam combiner that enables us to observe two largely separated fields simultaneously. A field separation angle of 99.5° is adopted for NJ. We use the fully depleted CCD developed by Hamamatsu Photonics Co., which has a response in the redder wavelength region that is much better than that of a conventional CCD. A 1024 × 1024 pixel format is used for observations, out of the total of 2048 × 1024 pixels. The pixel size is 15 microns. The integration time is about 6 seconds, which is determined by the speed of the field scan and originally depends on the orbit's altitude in principle. Observations will create very long stripes of images with a width of 0.5° . Figure 3 shows a simulated image for an observation toward the Pleiades region.

II. Observation Procedure

NJ's CCD will be controlled by the time delay and integration (TDI) mode, so that the charge transfer rate of the CCD is synchronized with the velocity of NJ's field of view. Thus, we will be able to obtain very long stripes of images along great circles in the sky. The spin axis will rotate in a circle at a distance of 45° from the Sun. It will rotate at a rate of one rotation per 2 months. The spin rate depends on the orbit altitude and will be about 100 min/rot if the altitude is about 600 km. Figure 4 shows the trajectory of the Sun location and the NJ spin axis. Figure 5 shows the trajectory of the NJ field of view. Figures 6 to 9 show the observation frequencies for popular objects as examples.

III. Observation Statistics

Using cataloged stars in the Guide Star Catalog version 2.3 and the Hipparcos and Tycho catalogs, we simulated the observations of NJ. At the beginning of this procedure, we translated the photometric data from these catalogs into Zw-band magnitudes, using the color-color relations obtained from literatures. Figure 10 shows the number of stars that will be observed by NJ for every Zw magnitude. We assume that we will be able to determine the distance to a star if the accuracy of the annual parallax of the star is better than 10%. The accuracies of the annual parallax measurements depend on the distances to the stars, Zw magnitudes, and amplitude of NJ's systematic error. Figures 13 and 14 show the projected positions on the equatorial plane of stars for which distance measurements are available. Figures 11 and 12 show plots of the number of stars for which distances have been measured against the Zw magnitude.

IV. Initial Angle of Spin Axis

The spin axis of NJ rotates around the position of the Sun, keeping the distance from the Sun at a constant angle of 45° . It rotates at a rate of one rotation per 2 months. However, the initial position angle of the rotation is a free parameter. We have performed simulations to determine the number of stars that will be observed in a single rotation scan for cases with different initial position angles. Because the pointing accuracy will be worse in the initial stage of the operation, the stellar images will be elongated, requiring the detection of a brighter star. The information on the length and direction of these elongated stellar images will be used to improve the pointing accuracy. More frequent observations of bright stars will be beneficial in the initial operation. Figures 15-19 show plots of the numbers of stars that will be observed in one scan for cases with different initial angles of the spin axis.

Figure 1: The external appearance of NJ. It is about 50 cm cubic in size and weighs about 30 kg.

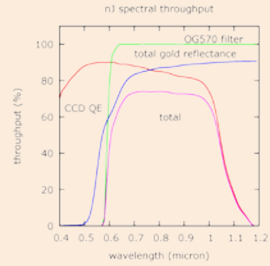


Figure 2: The spectral response of the FDCCD, telescope throughput, spectral response of the short cut filter, and system spectral response combining all of these are plotted.

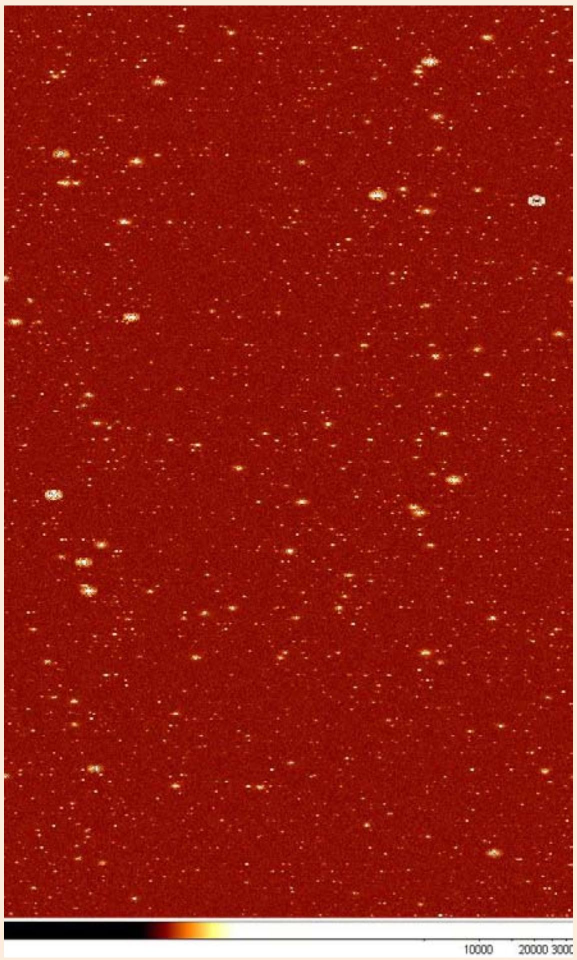


Figure 3: A simulated field image near the field of the Pleiades open cluster. It shows a 0.5 × 1.0° field. Another field at RA = 6h DEC = -36° is overlapped because of the use of the beam combiner.

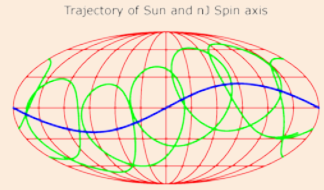


Figure 4: The trajectory of the Sun location and NJ's spin axis in the sky for a time period of one year starting from August 2011.

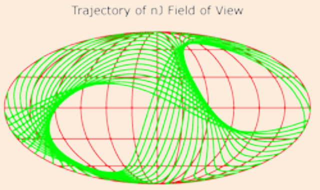


Figure 5: Trajectories of NJ's field of view for a 2-month period starting from August 2011.

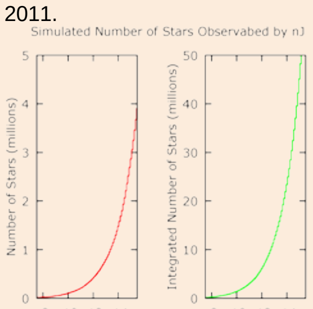
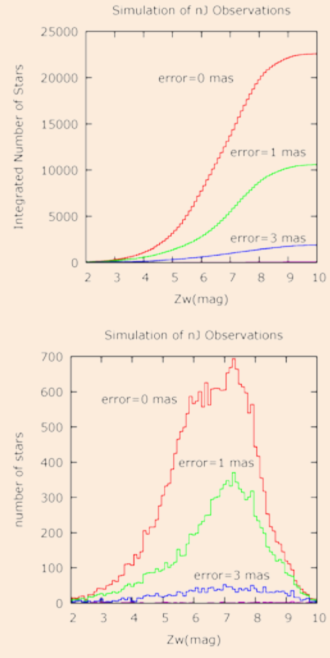
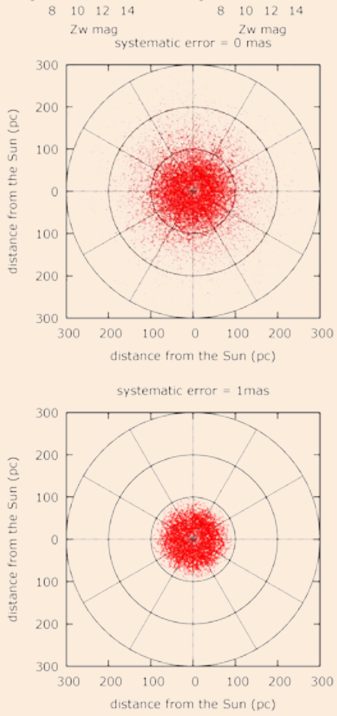


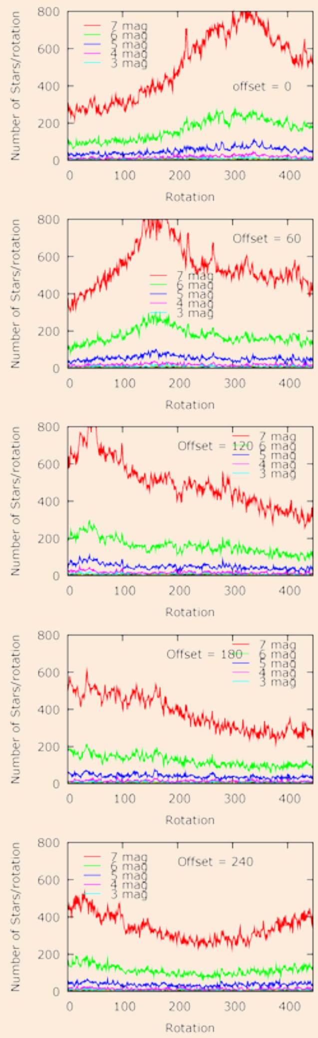
Figure 10: The number of observable stars for every Zw magnitude. The integrated numbers of stars are also shown.



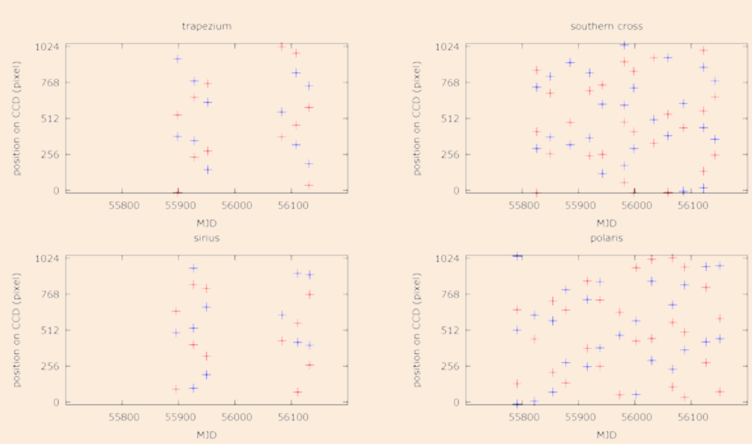
Figures 11 and 12: The dependencies of the NJ systematic error, and number of observable stars for which distances have been determined.



Figures 13 and 14: Projected star locations for stars whose distances have been Determined.



Figures 15-19: Numbers of stars observed in one revolution along a great circle plotted against the number of revolutions for a one-month period from August 1, 2011 for different offset angles. Here, the initial offset angle of the spin axis is measured from the north on August 1, 2011.



Figures 6, 7, 8, and 9: Observation frequencies for several popular astronomical objects, the polar star, the Trapezium star cluster, and the Southern Cross. The horizontal axis shows the Modified Julian Day, which matches the period from August 2011 to August 2012. The vertical scale shows the position on the CCD and the red and blue marks indicate the observation of events by the different beams.