

To verify the time-stamp accuracy of the DATE-OBS header keyword recorded in the fits header for images captured by Mookodi we make use of the procedure suggested by Project Pluto as described [here](#).

Method

The method entails observing a fast moving Global Navigation Satellite Systems (GNSS) satellite has a have very accurately known sky-coordinate for a given time. By comparing the observed sky-coordinate of the satellite in your images (after doing astrometric calibration of your images) to the predicted sky-coordinate of the satellite at the respective header time (and knowing the sky-rate of the satellite) it is possible to determine the accuracy of the time-stamps in your image headers.

Results

Figure1: Shown is an animated gif of 50 frames @ 2x2 binning, fast (5 MHz) readout rate, and 100ms exposure time per frame of an observation of a GNSS satellite moving through the FoV. Note the readout smear, which is particularly apparent for bright stars, due to the shutter set to the "https://topswiki.sao.ac.zaALWAYS OPEN" mode. **NB. This mode is MANDATORY for continues fast imaging.** Approximate time between each frame is ~400ms (i.e., ~300ms dead-time between each frame due to image readout time, header information collection + population into fits header, and file written to disk). The CCD is flushed to clear any charge collected on the chip during dead-time before next frame is taken. The blue circles show the auto-detection of sources and which are used for astrometric calibration. The red cross shows the predicted position of the satellite at the header time (keyword=DATE-OBS) + half the exposure time (in this case 50us) by querying an independent external satellite database. The green cross shows the position of the auto-detected source extracted that is closest predicted position

Figure2: (a) Plotted in purple symbols is the offset in predicted vs. observed sky-coordinate of the GNSS satellite (i.e. the difference between the red and green cross location in Figure 1 above). It is about 2 arcseconds for each frame which is close to the detectability limit at 2x2 binning which corresponds to a plate-scale of 1.2 arc-seconds/px (b) Plotted in orange symbols is the calculated time difference between real-time and our fits-header time using the sky-rate of the particular satellite (in this case at this observed time 30.55 arcseconds/s)