Analyzing the Performance of the SOFIA Airborne Infrared Telescope

National Aeronautics and Space Administration

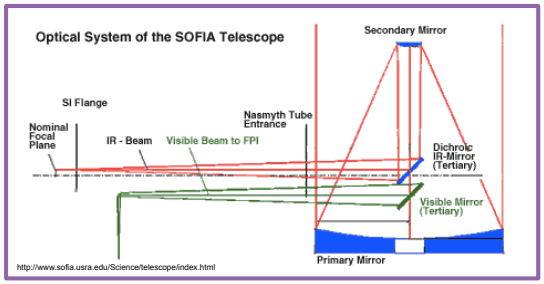
Sarah Bass[1], Jeffrey Van Cleve[2], and Zaheer Ali[3]

[1]San Jose State University San Jose, CA 95112, USA [2]USRA/NASA Ames Research Center Moffett Field, CA 94035, USA
[3]USRA/NASA Dryden Aircraft Operations Facility 2825 E. Ave P Palmdale 93550, USA

Abstract

The Stratospheric Observatory for Infrared Astronomy (SOFIA) is an airborne near-space observatory onboard a modified Boeing 747-SP aircraft, which flies at altitudes of 45,000 ft., above 99% of the Earth's water vapor. SOFIA contains an effective 2.5 m infrared (IR) telescope that has a dichroic tertiary mirror, reflecting IR and visible wavelengths to the science instrument (SI) and focal plane imager (FPI), respectively. After finishing renovations on the aircraft and software in 2013 and installing the FPI guide camera, the focus remains to determine how well the telescope pointed, whether it stayed there over the course of the observation, whether it was in focus, and what the pointing and tracking configuration and state of the telescope was. Through the use of bash scripts, and MATLAB routines, analyses of the telescope performance based on housekeeping time series- in particular centroid plots- and guide camera images will be used to determine the observatory performance.

Telescope Optical System



Light hits the primary mirror, is then reflected to the secondary mirror, and is again reflected to the dichroic tertiary mirror, which sends the light rays to the science instrument and to the FPI camera. SOFIA is an alt-az telescope, so the field rotation is compensated for by rotating the line of sight (LOS) from time to time (rewind).

Chopping, Nodding, and Dithering

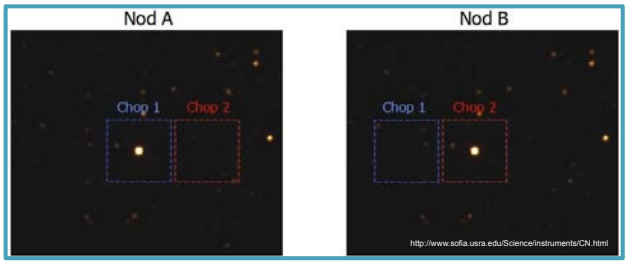
Observing the sky in the IR is like looking for stars in the daylight. Therefore the following techniques are needed to cancel the background light from the sky and telescope, and emphasize the signal of interest.

Chopping:
- Oscillating the telescope's secondary mirror between 2 positions (Chop1 and Chop2) at 1-20 Hz
- Chop1 is on source (containing the observation) and Chop2 is off source (pointing at a field of blank sky).

Nodding:
- Moving the telescope 2-4 times per minute
- Performed to remove remaining thermal telescope background emission

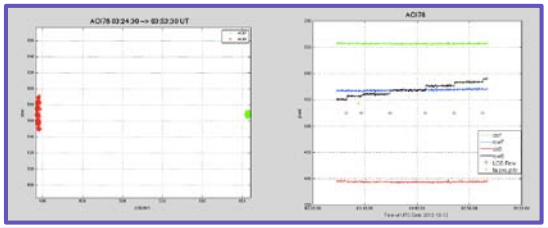
Dithering:
- Performed when the telescope is staring at an observation to facilitate background subtraction of point sources or mapping extended objects.
- Usually in a 5-point dither or 9-point dither pattern.

Example Nodding and Chopping

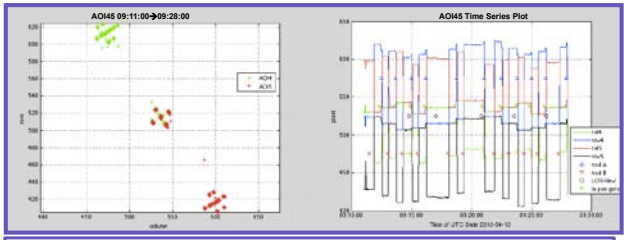


Net Signal = (NodAChop1 – NodAChop2) - (NodBChop1 – NodBChop2)

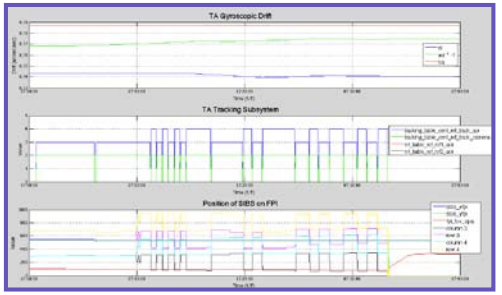
How Well Is The Telescope Pointing?



Left: Image of row vs. column plot showing target star (AOI 7) fixed during LOS rewinds. Beam 1 of the chop is fixed and the beam 2 moves when the LOS is reset.*
Right: Time series plot of rows, columns, LOS rewinds, and TA positions commands.*



Example of successful simultaneous execution of chop match nod, 5 point dither, and LOS rewind motions.
Left: Row vs. Column Plot.* Right: Time series plot of row vs. column. *



Tracking summary plot, generated by S. Bass's MATLAB script, showing whether tracking is on, which guide camera is in use, and where the guide star is with respect to the science instrument boresight (SIBS) (place where light from the target best enters the instrument).*
This information is essential for interpretation of the plots shown above.

**All plots produced using MATLAB scripts.*

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