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SOFIA Pointing and Optimization Team (SPOT): Recent Results and Plans

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SCTF

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Outline of Material

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SPOT Charter

- SPOT issues recommendations on the TA pointing improvements to the Program Office during 3 years of Observatory development (from now)

Members of the SPOT

- Eric Becklin
- Ted Dunham
- Steve Jensen
- Hans Kärcher (chair)
- Thomas Keilig
- Alfred Krabbe (ass.)
- Ulrich Lampater
- Temi, Pasquale
- Jörg Wagner
- Jürgen Wolf

Image Quality

Image Quality

- Image Quality was discussed extensively in our last two SPOT meetings. (For most astronomers, it is those frequencies above ~few Hz in the pointing)
  - Telescope jitter at frequencies from 1 to 100 Hz was the dominate term for FORCAST image quality. (2-3 arcsec FWHM)
  - Diffraction was important for wavelengths greater than 25 microns.
  - There was a report of ~ 10 arcsec low level extensions in the some images in the elevation direction, thought to be sticktion in the bearing drive due to a seal. This was fixed!
  - Visible shear lever seeing was reported by the FDC team in Nov. (About 4 arcsec FWHM). These measurements were repeated in June using HIPO and the FDC with similar results.
- GREAT has no problems with Image Quality with Beams greater than 10 arcsec FWHM

Image Quality (Cont)

- A plan has been put in place to improve the image quality due to Jitter over the next 3 years. This was discussed by Pasquale Temi. The goal is 0.5 arcsec rms jitter at all frequencies above ~1 Hz. The present value is about 1.5 arcsec rms (2.5 arcsec FWHM) and depends on aircraft height, telescope elevation and a few other parameters.

- The primary method of correction will be Active Mass Dampers, which I will discuss later.

Pointing and Image Improvement Timeline relative to Requirements

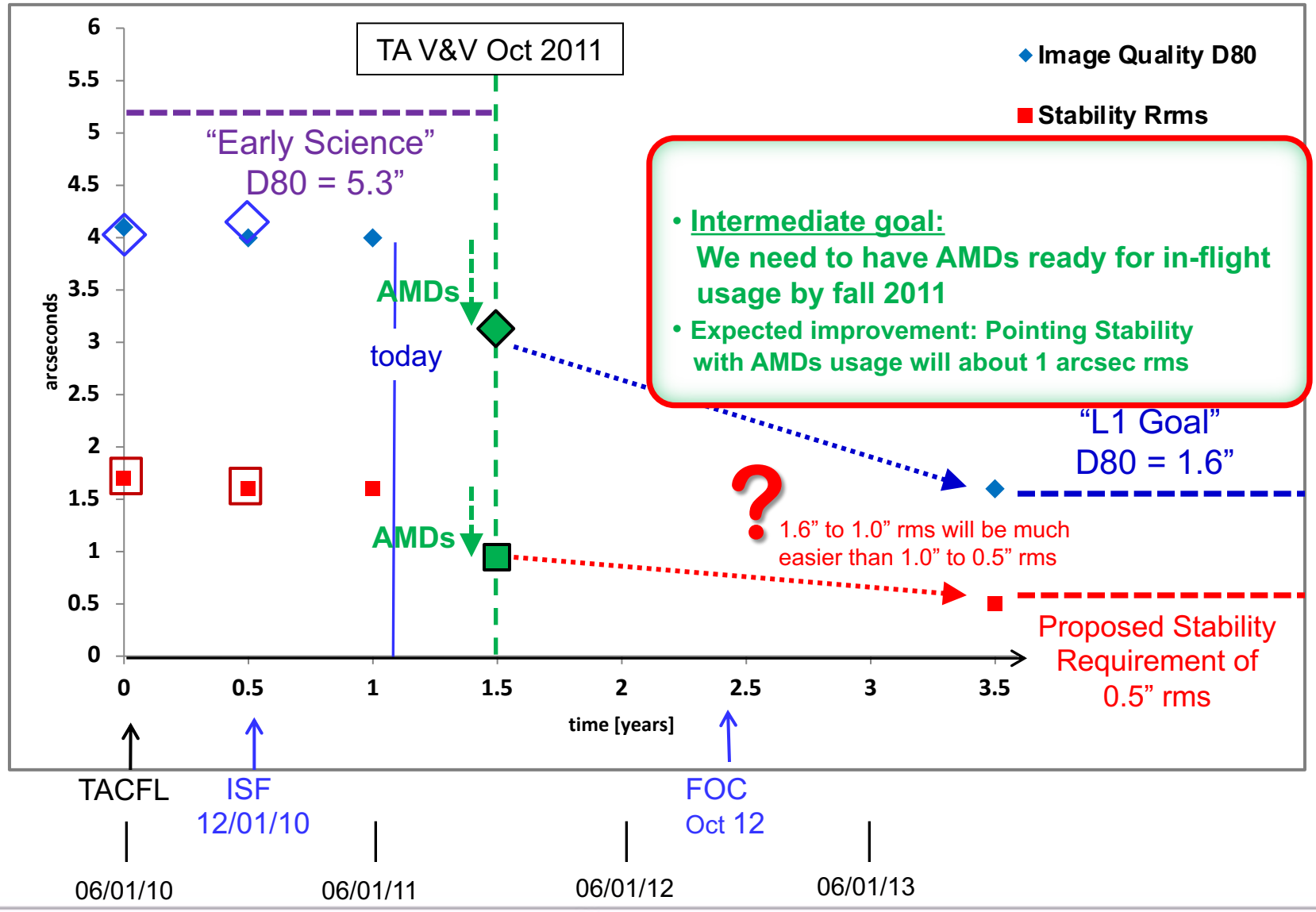


Image Quality (Cont)

- Focus could be a problem for some observations, especially if we do not implement a focus correction for temperature.
- Chopper jitter also needs to be watched.
- Results from recent engineering flights (SCAI #1 and #2) indicates a possible high frequency jitter at >200Hz. Will be measured with a faster camera in SCAI #3 and #4 later this month.
- The shear layer and cabin “seeing” will be further characterized with HIPO (blue and red) and FliteCam (1-5 microns) on SCAI #3 and #4. Minimum “seeing” expected at 5 microns.

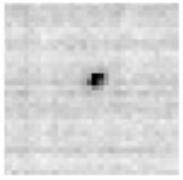
Active Mass Dampers

- The SOFIA program (Science Project, Telescope/DSI/DLR, and Platform Project) now has a program to put Active Mass Dampers on the telescope to remove jitter.
- Active Mass Dampers will be placed behind the Primary (6), behind the secondary(2) and on the baffle plate(2).
- Accelerometers are in a control loop with the Active Mass Dampers.
- They will be installed in Oct and tested on the ground.
- They will tested in flight in late Oct.

Results with FORCAST

PSF comparisons

Short term

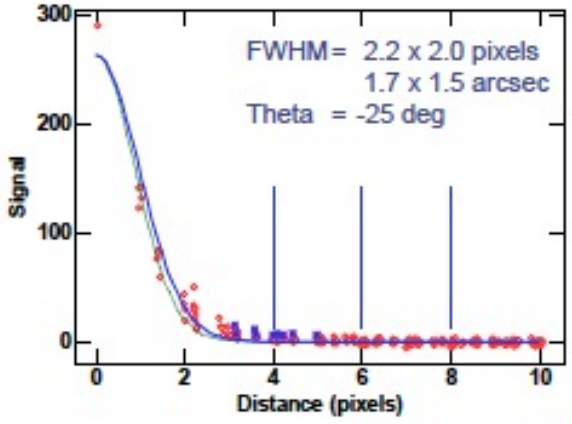


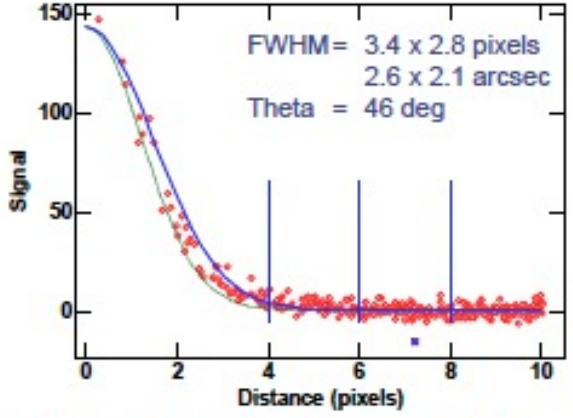
align & add

Long term

straight addition

Scale same as short term





From 500 Hz sampling at 11.1 µm, coadded 2500 exposures, from OCF#3

Science Impact of Image Quality

- For FORCAST we are presently diffraction limited beyond 25 microns. It would be better to be diffraction limited through out the FORCAST wavelengths (5 to 40 microns)
- FORCAST GRIMS will need good image quality to get and keep the objects on the slit. This is especially important for the higher resolution modes.
- FLITECAM needs good images at all wavelengths to get the best signal to noise and science. FLITECAM GRIMS need good images to get and keep the objects on the slits (1 arcsec for the highest resolution.)
- EXES must have good images to get and keep the objects on the small slits (1-2 arcsec)
- HIPO will have somewhat better S/N with smaller images.
- GREAT, FIFI-LS and HAWC are okay with the present image quality.
- Future instruments??

Tracking

Tracking

- To date SPOT has not discussed tracking to any great extent. (For most astronomers, it is those frequencies below ~few Hz or times in the pointing of between 1 sec and 20,000 sec)
- SOFIA tracking is accomplished by a combination of 3 Optic Fiber Gyros and three guide cameras. (FPI, FFI, WFI)
- On axis tracking (When your science target in the IR or submillimeter can be seen in the FPI, FFI or WFI).
- On axis tracking with the FPI appears quite good. < 1 arcsec for times up to minutes or longer? (It should be limited by differential flexure between the IR focal plane and the FPI and differential refraction)

Tracking (Cont)

- Off set tracking using a star in the FPI should also be almost as good as on axis tracking.
- It has the added tracking error created by error in the LOS gyro.
- The amount of error depends linearly on the gyro error and the distance from the guide star to the science target
- A more sensitive FPI will allow smaller distances between the guide star and the science target. (There is very good news discussed in the next slide with regards the Fast Diagnostic Camera (FDC) and its use for guiding.)
- No reported smearing of FORCAST images in Orion, would indicate this effect is smaller than 1 arcsec for integrations as long as 30 sec for a distance of 1 arcmin.

Tracking: Update on the FDC

- Juergen Wolf and his team put the FDC on the telescope this past June for the SCAI #1 and #2 flights, that included the successful Pluto Occultation.
- Working with KT, they were able to implement guide star tracking with the FDC.
- During the line operations and the flights, the team demonstrated successful tracking of the telescope
- The sensitivity was about 100 times (5 mag) better than the FPI. Allan Meyer reported easily tracking on Pluto with 0.25 second read out after the occultation was complete.

Tracking (Cont)

- Tracking using a guide star in the FFI has indicated real problems, at least for the use of GREAT. (Problems were also noted for FORCAST when they used the FFI, but they would restack their images for most observations.)
- The Guide stars are now much further from the Science target. (~15 arcmin rather than few arcmin)
- Reports of errors of up to 10 arcsec have been noted for times of a science leg ~ 1 hour. This is a real problem for GREAT with its L2 beam of 16 arcsec FWHM.
- Equally important, GREAT does “on the fly mapping” which requires the knowledge of beam relative to the background stars.
- For the Mid frequency channel (110 microns) with a 10 arcsec beam it is a problem even if the drift is a few arcsec.

Tracking (cont)

- There is an indication that some of this problem is a result of poorly determined LOS gyro drift. This is not part of the normal continuous tracking updates as with the EL and XEL corrections.
- Note: The line of site (LOS) motion is controlled mainly by the LOS gyro.
- Updates of the LOS drift, using two widely separated stars in the FFI or WFI is possible and will be tried in the SCAI 3 and 4 and their ground ops.
- It was tried to some extent during the later parts of the Basic Science 2 flights using the FFI (I think). The results were mixed, but seemed somewhat promising.

Tracking

- It has been suggestion on the short term we should try to implement continuous LOS gyro corrections using the FFI or WFI cameras. It has also been suggested that we can use two star tracking especially if there continues to be problems with the LOS gyros.

- Just as with EL and XEL corrections, this would not be possible during “on the fly mapping” or other telescope moves.

- There is also the potential for flexure between the focal plane and the FFI. However, most of this correction should be taken out by the static FBC. Flexure in the Secondary mirror might also be a problem.

Science Impact of Tracking

- GREAT is one beam on the sky, so that good tracking is important for them, especially with the smaller beams. They also do “on the flying mapping” that requires knowledge of the telescope position.

- FORCAST needs good tracking for faint objects and long integrations. (This was a problem for some Basic Science programs)

- FORCAST GRIMS will need good tracking to keep the objects on the slits.

- FliteCam needs good tracking especially for GRIMS. (Imaging can be stacked using background stars.)
- HIPO will be more efficient with good tracking.

Absolute Pointing

Absolute Pointing

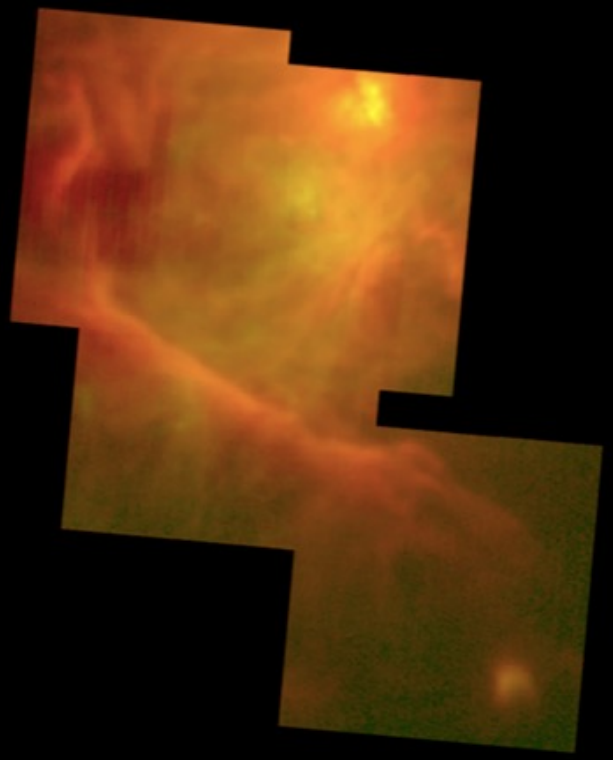
- Presently Absolute Pointing is done with the respect to visible stars.
- For many applications it has the same problems as tracking, so without an upgrade could be as bad as 10 arcsec or more.
- Both the Gyro calibration upgrade and the FDC should put this down in the 1 arcsec or better range.
- Absolute Pointing in the daytime may be a bigger challenge in the future, but will be important for SOFIA of its 20 year life.

First Science with SOFIA

20 (Green) and 37 (Red) Micron Data of Orion Nebula

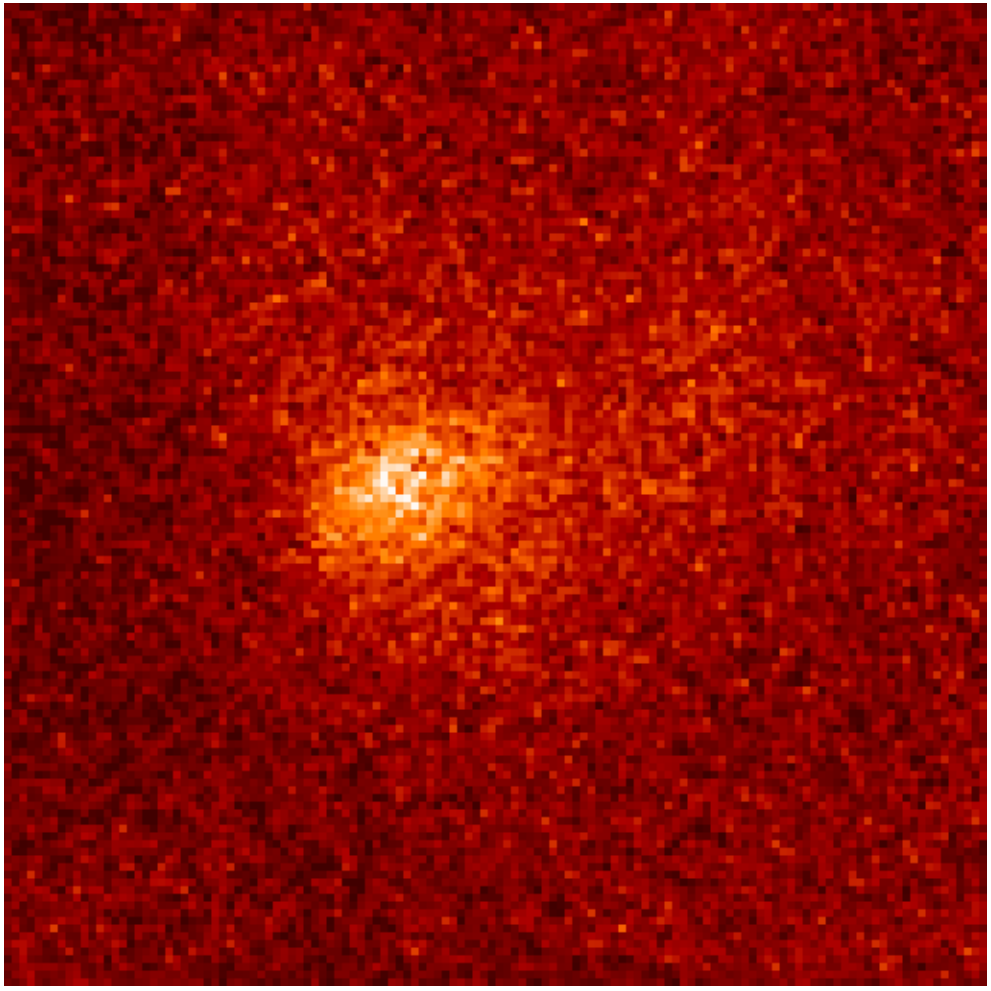
Visible light
(HST, C. O'Dell and S. Wong)

Near infrared
(ESO, M. McCaughrean)



SOFIA mid infrared
(SS02)

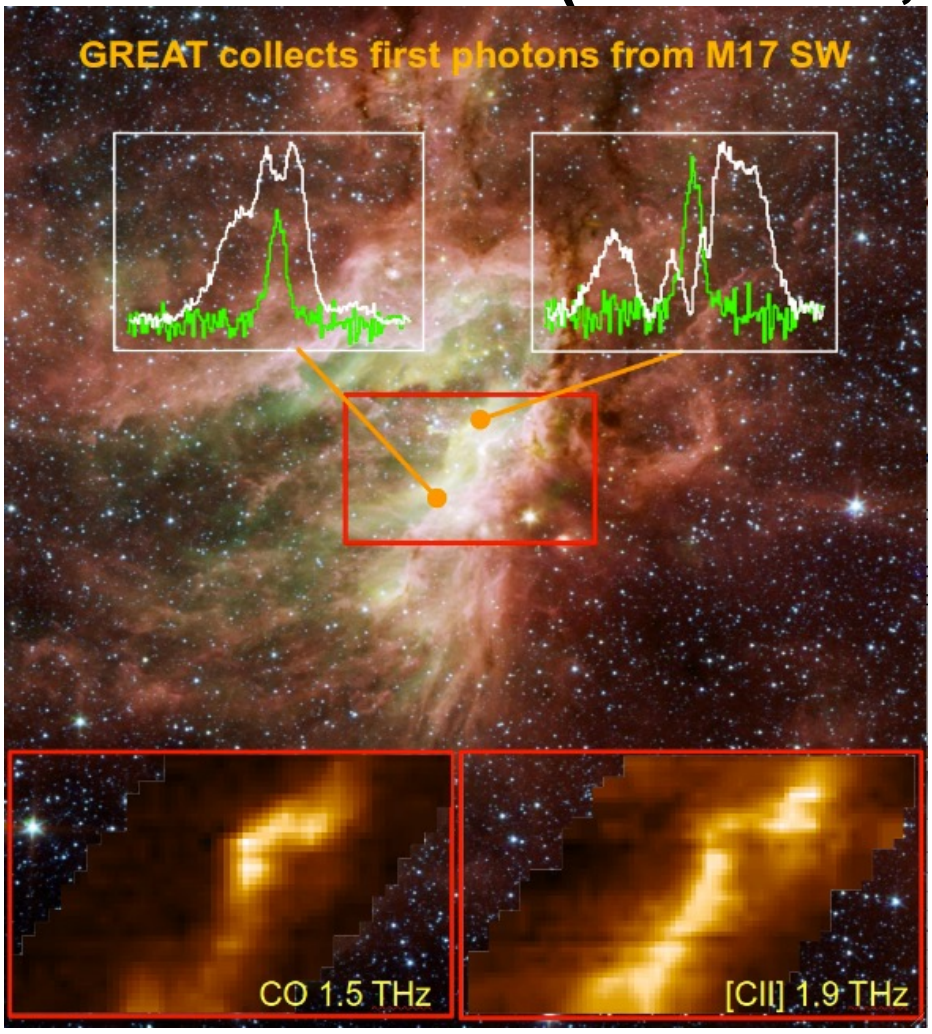
Comet Hartley 2



31.4 microns

- 31 and 37 Micron data of Comet that had a fly by in Nov.

First Science with GREAT (White CII, Green CO)



Pluto Occultation: 3 hours before, just before, during and just after.