Solar System Studies with SOFIA

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SOFIA Observers' Workshop

May 2015

Quick tour of possibilities

Terrestrial Planets

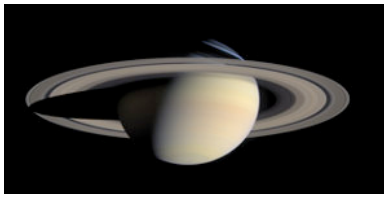
Mercury: not visible

Venus: atmosphere composition, dynamics (winds, temporal ation) [EXES]

Mars: atmosphere composition, dynamics

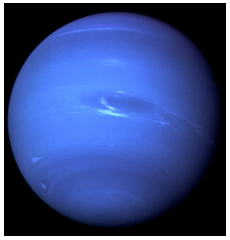
Outer Planets

Jupiter



Saturn

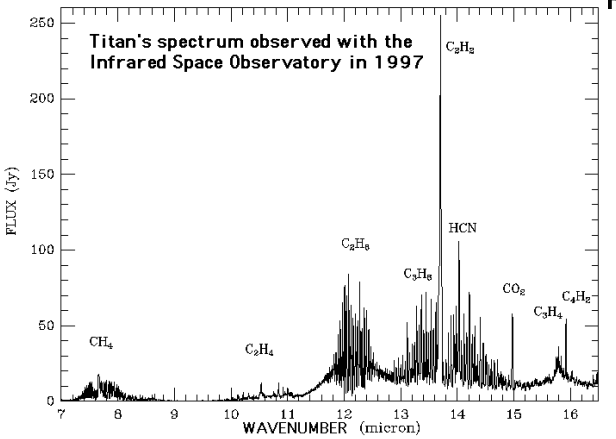
Uranus



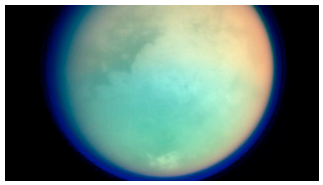
Neptune

All: Convection in tropsphere (FORCAST), convection in stratosphere (EXES), weather (FORCAST), atmosphere chemistry including exosphere (GREAT, EXES), heat output (FORCAST, FIFI LS, HAWC+)

Moons



- Titan atmosphere [EXES, GREAT]

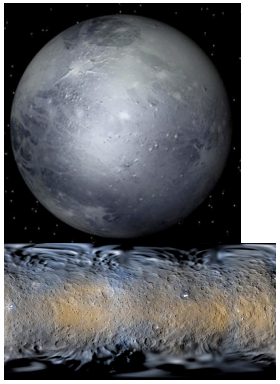


prebiotic molecules

out-of-equilibrium species tracing hot chemistry

- Moons with subsurface oceans
  - Radiometry for energy balance [FORCAST, FIFI LS, HAWC+]
  - temporal and phase-angle changes due to surface features [”]

Small Bodies

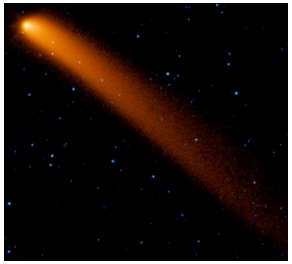


Dwarf Planets

- Occultations [HIPO/FLIPO] for diameters, rings, atmosphere search, haze
- Radiometry [FORCAST]: diameter, thermal properties
- Surface composition [FORCAST & FLITECAM grism]

Comets: like asteroids, plus dust and gas composition from outgassing [GREAT, FORCAST grism]

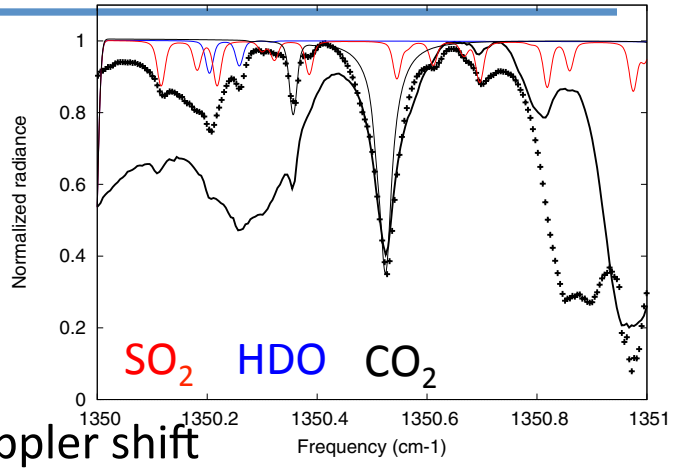
- mineralogy (Fe/Mg silicates)
- origin of terrestrial water (D/H, ortho/para)



More details on a few potential projects

Venus

- Visibility conditions on mid-Feb2017:
  - 40 degree solar elongation
  - 40” angular size
  - but only visible in early evening for <1 hr
- Molecules already observed with TEXES
  - CO_2, HDO and SO2
  - Detectability of lines depends critically on Doppler shift
- Other molecules remain uncharacterized
  - no access to infrared outside Earth’s atmosphere, while Venus has many of same gases as Earth
  - Isotopic ratios trace chemical history; why were Venus’ oceans lost?
- Dynamics
  - Vertical distribution of SO, SO_2 related to cycling
  - Winds
  - Factor of 5-10 temporal variation in SO_2 (Encrenaz et al 2012)



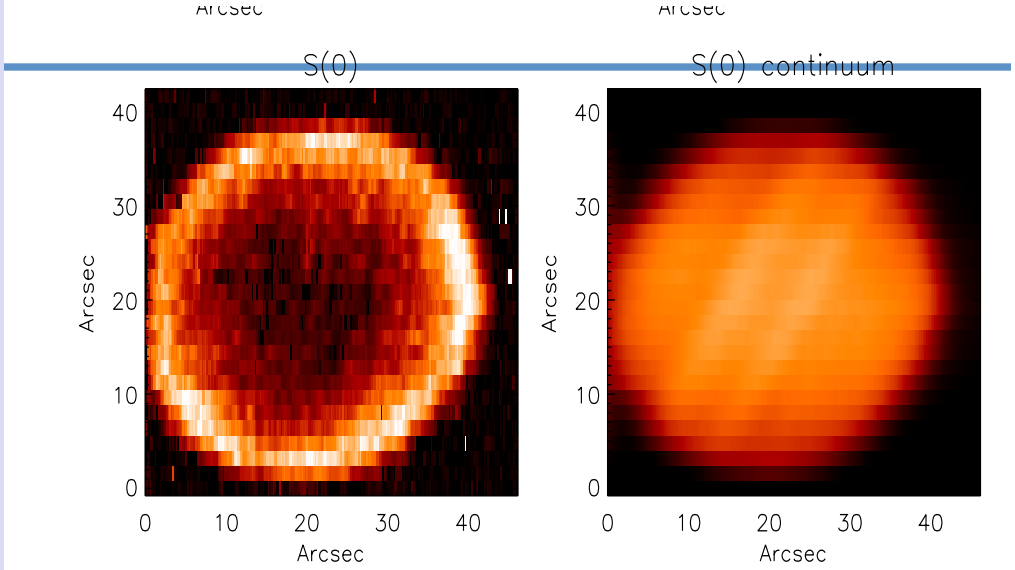
Jupiter's Stratosphere and Troposphere

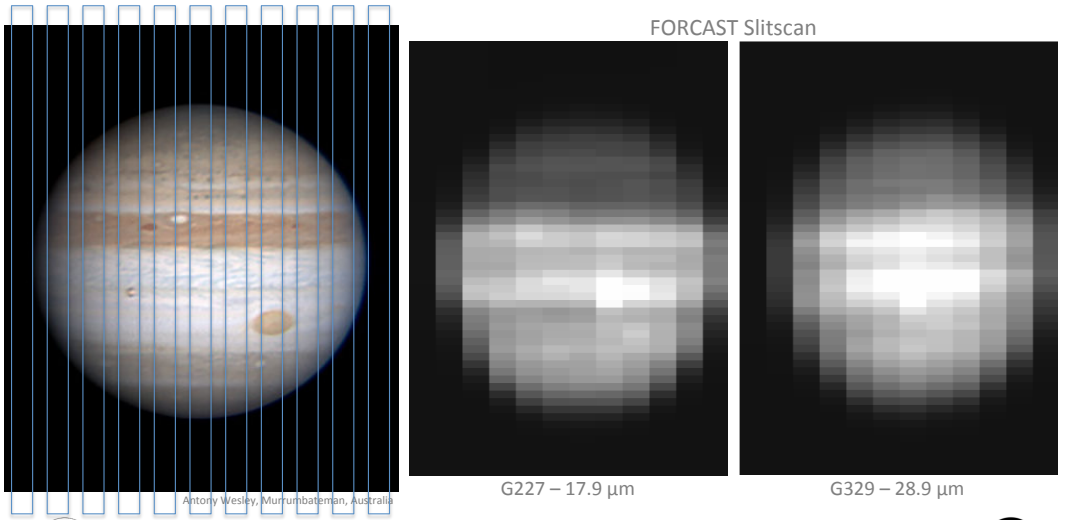
SOFIA spectroscopic slits were stepped across the disk of Jupiter to make spectral maps.

With EXES at high spectral resolution: lib-brightened, narrow, stratospheric H_2 line.

With FORCAST at moderate resolution, measure pressure-broadened H_2

Para/Ortho state ratio, paired with CH_4 temperature, measures mixing rate in the atmosphere, because the rate of para/ortho conversion is known.





Titan occultation

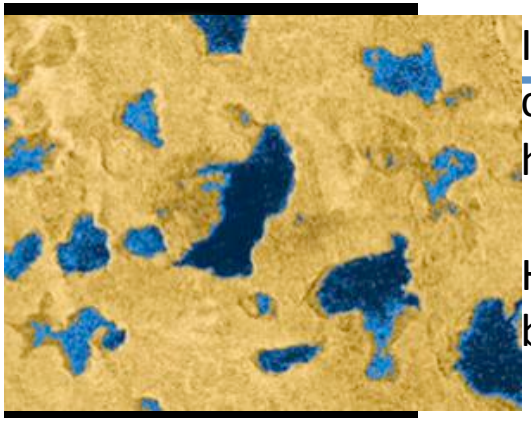
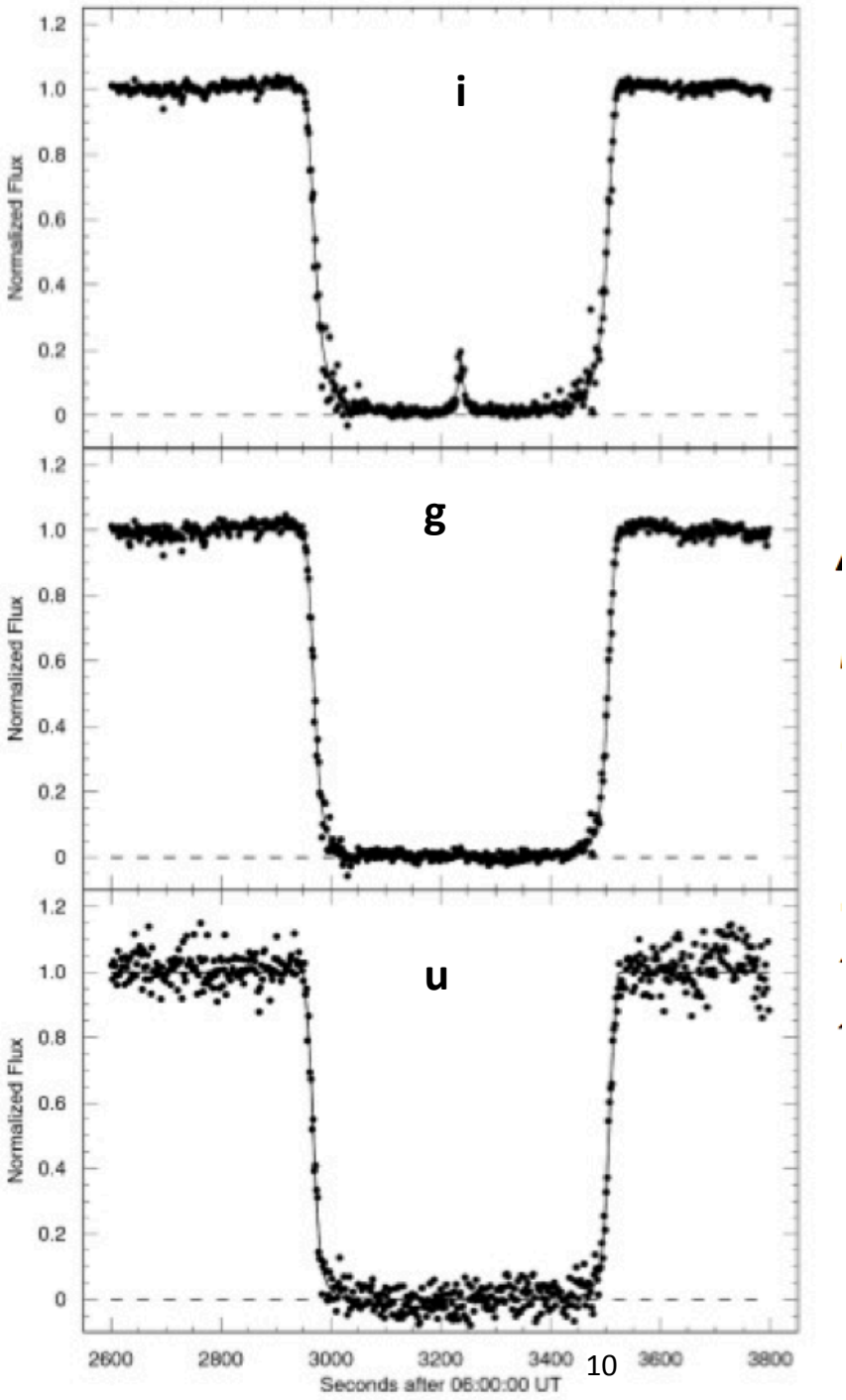


Image of Titan, which is covered in hydrocarbon haze

Hydrocarbon lakes found by Huygens spaceprobe

- Central flash only present for longest wavelength
  - Extinction and refraction can be separated because of their different wavelength dependence
  - Aerosol scattering is much stronger at shorter wavelengths, depends on $(a/\lambda)^4$

- ***Multi-wavelength observations are critical for understanding atmosphere***



Zalucha et al. (2007); from Eliot Young

Solar System Observation Notes

Tracking

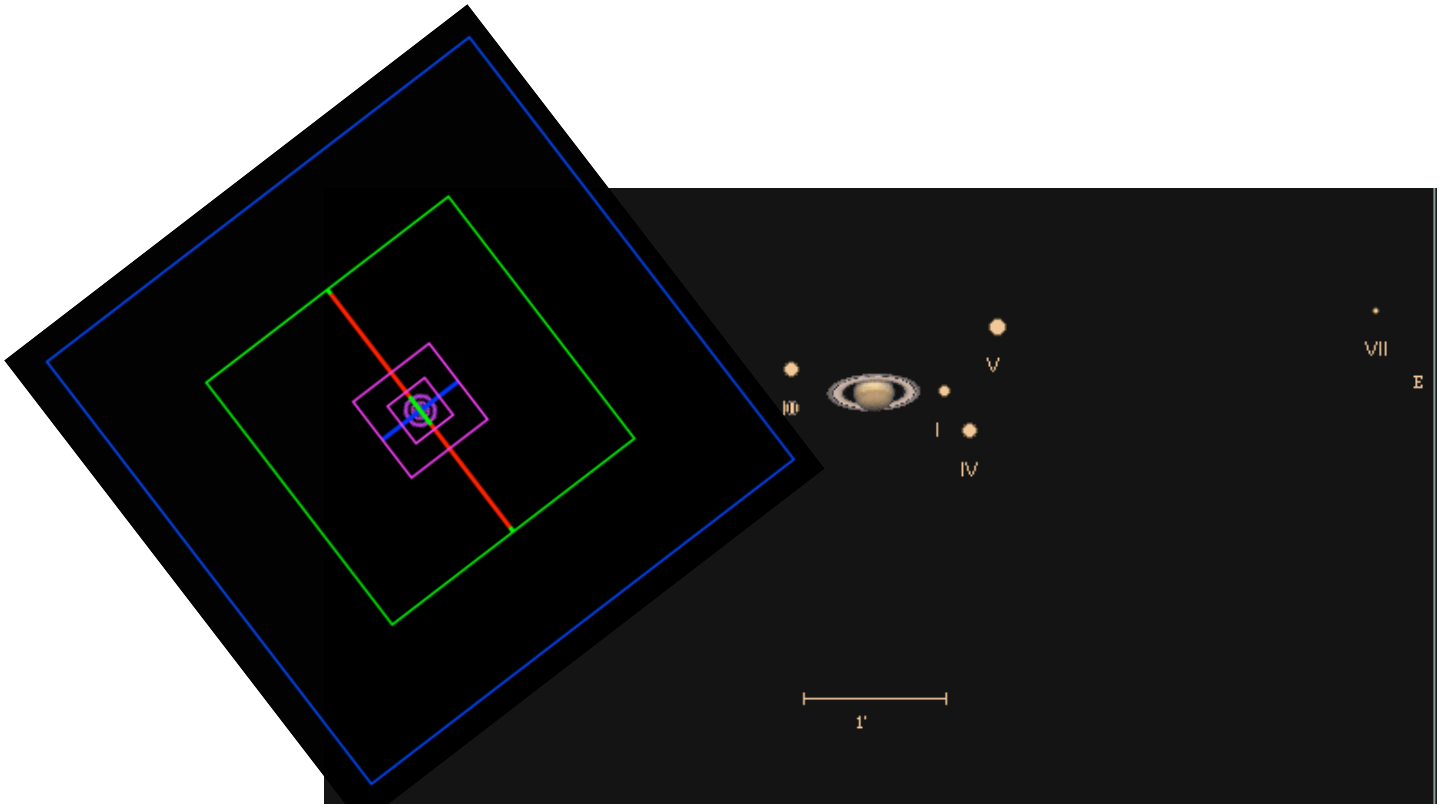
- Rate should be slower than 1”/s
- “easiest” tracking for visibly-bright objects (V<14), better than 1”
- Invisible targets possible using offset guiding on celestial source, but this is a not-well-tested mode

Elevation limits and Sunrise/Sunset

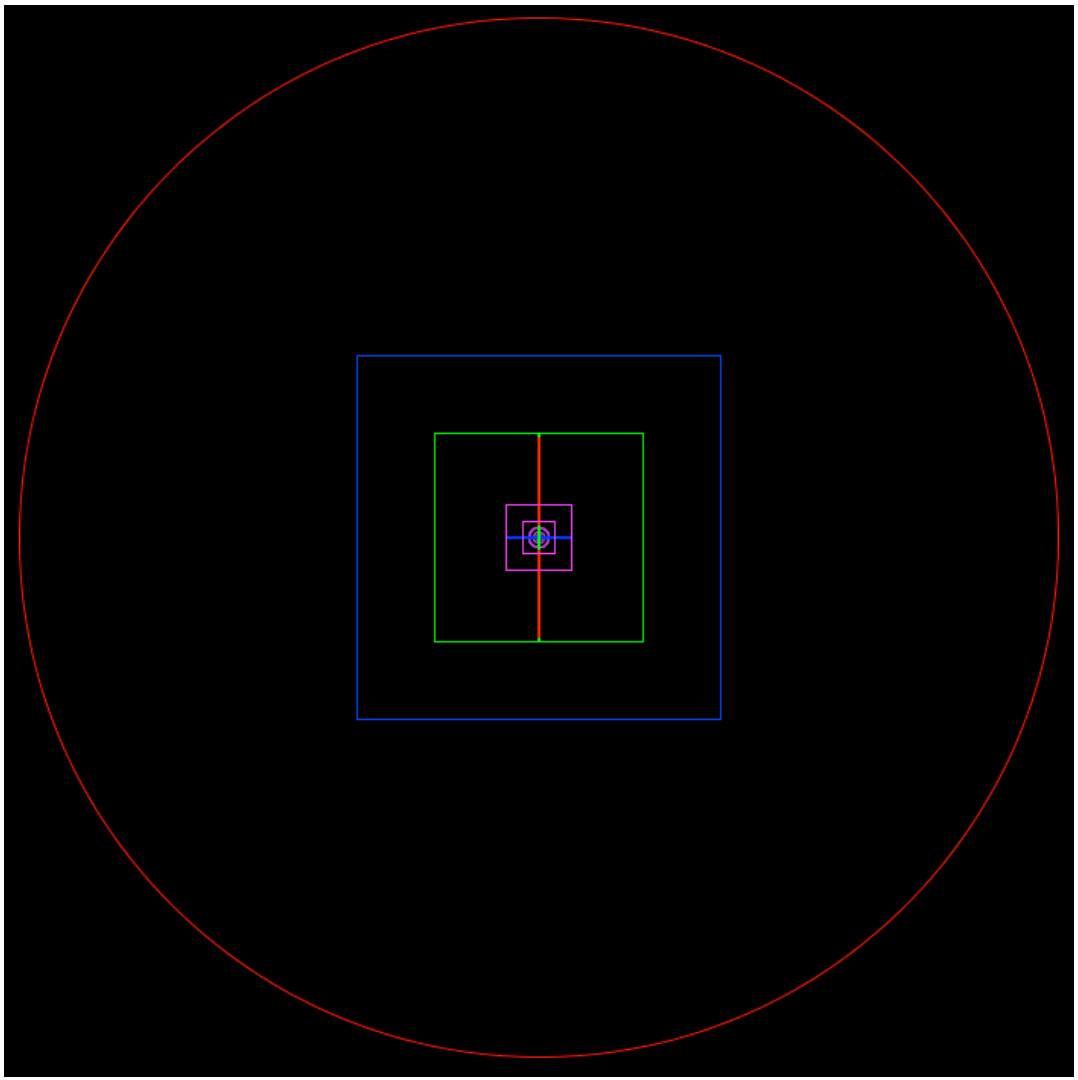
- The telescope stays in the elevation range 22-58 degrees
- Absolute minimum solar elongation is therefore 22 degrees
  - Practical limit of 25 degrees to allow time to acquire & observe
- We have flight rules to prevent sunlight on the telescope
- Observations right after sunset are possible
  - No time for initial calibration leg, so not best for 1st flight of series
  - Takeoff before sunset, door open at 10,000 feet, get on target
- Observations up to sunrise are possible but have risk
  - Need to close door and prepare alternate landing scenario such that a potentially “stuck open” door is pointed away from the Sun

Moons

- Keeping main planet off the array (or slit) is highly desirable
- Horizons and XEphem are good for visualizing orientations



SOFIA Focal Plane



- View from Spot
- EXES Medium
  - X-dispersed slits are short
- FLITECAM
  - Horizontal slit
- FORCAST
  - Vertical slit
- FIFI LS
  - Blue channel ½ area