



Planetary Science with SOFIA

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SOFIA Community Day
University of Arizona
May 2016





Quick tour of possibilities





Terrestrial Planets



Mercury: not visible

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

Mars: atmosphere composition (methane, D/H); dynamics

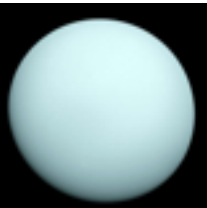
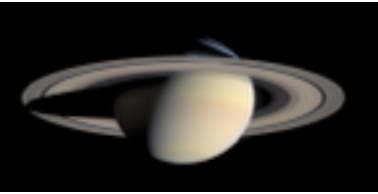




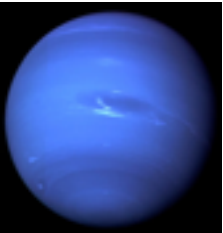
Outer Planets



Jupiter



Uranus



Neptune

All:

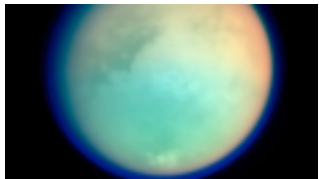
Convection in troposphere (FORCAST),
convection in stratosphere (EXES),
weather (FORCAST),
atmosphere chemistry including exosphere (GREAT,
EXES),
heat output (FORCAST, FIFI LS, HAWC+)





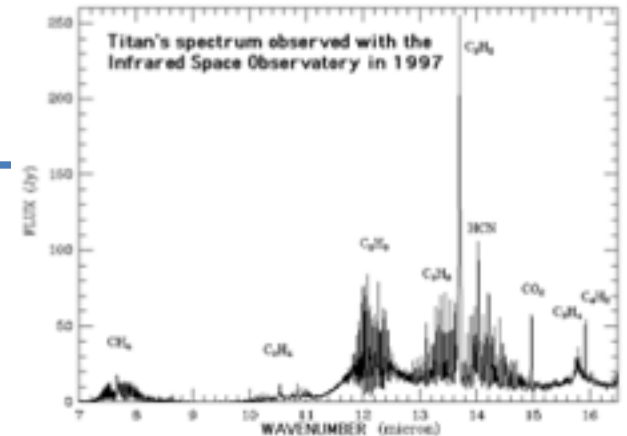
Moons

- Titan atmosphere [EXES, GREAT]



prebiotic molecules

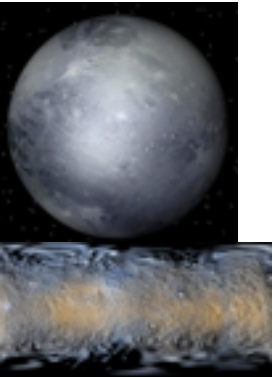
out-of-equilibrium species tracing hot chemistry



- 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



- dust and gas composition from outgassing [GREAT, FORCAST]
- mineralogy (Fe/Mg silicates) [FORCAST grism]
- origin of terrestrial water (D/H, ortho/para) [GREAT]

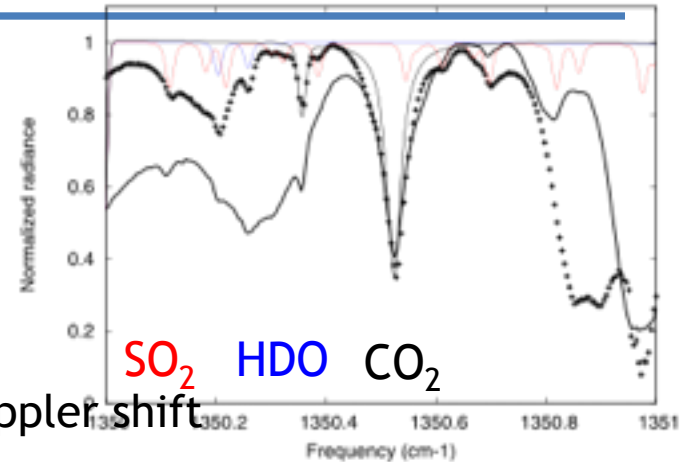


More details on a few potential projects



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
 - CO₂, 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, SO₂ related to cycling
 - Winds
 - Factor of 5-10 temporal variation in SO₂ (Encrenaz et al 2012)
- CYCLE 4 project accepted
 - Constantine Tsang (SWRI) "Venus Atmosphere: D/H Ratio from H₂O and HDO Measurements"





Jupiter's Stratosphere and Troposphere

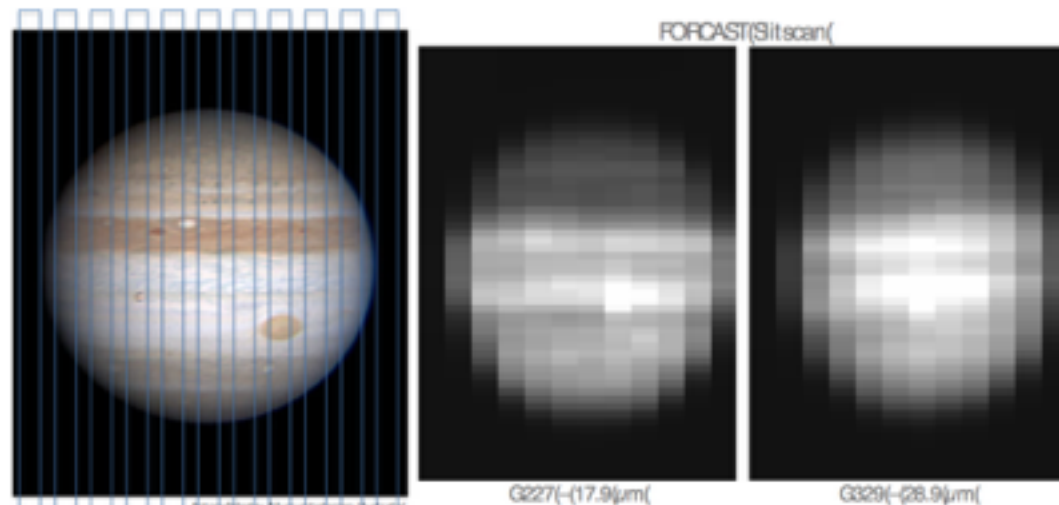
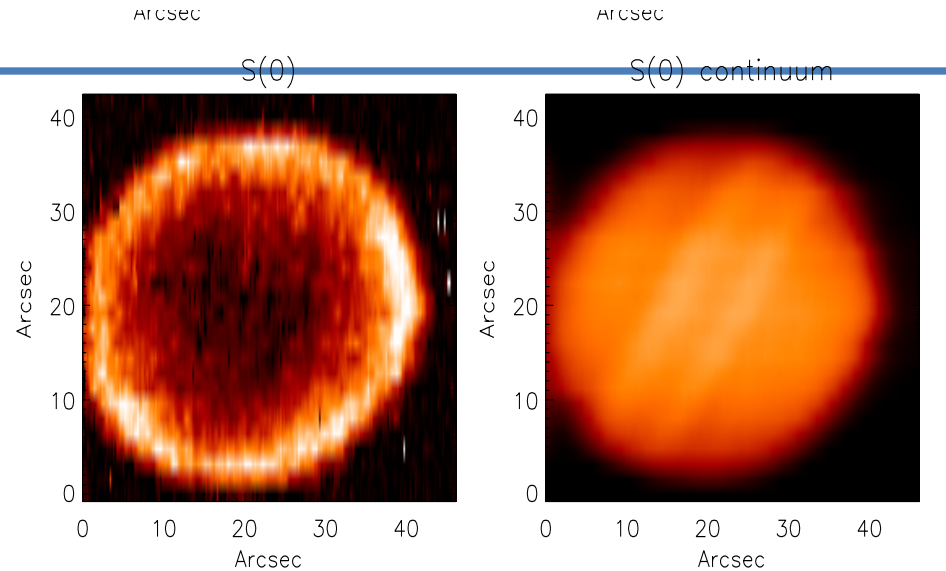


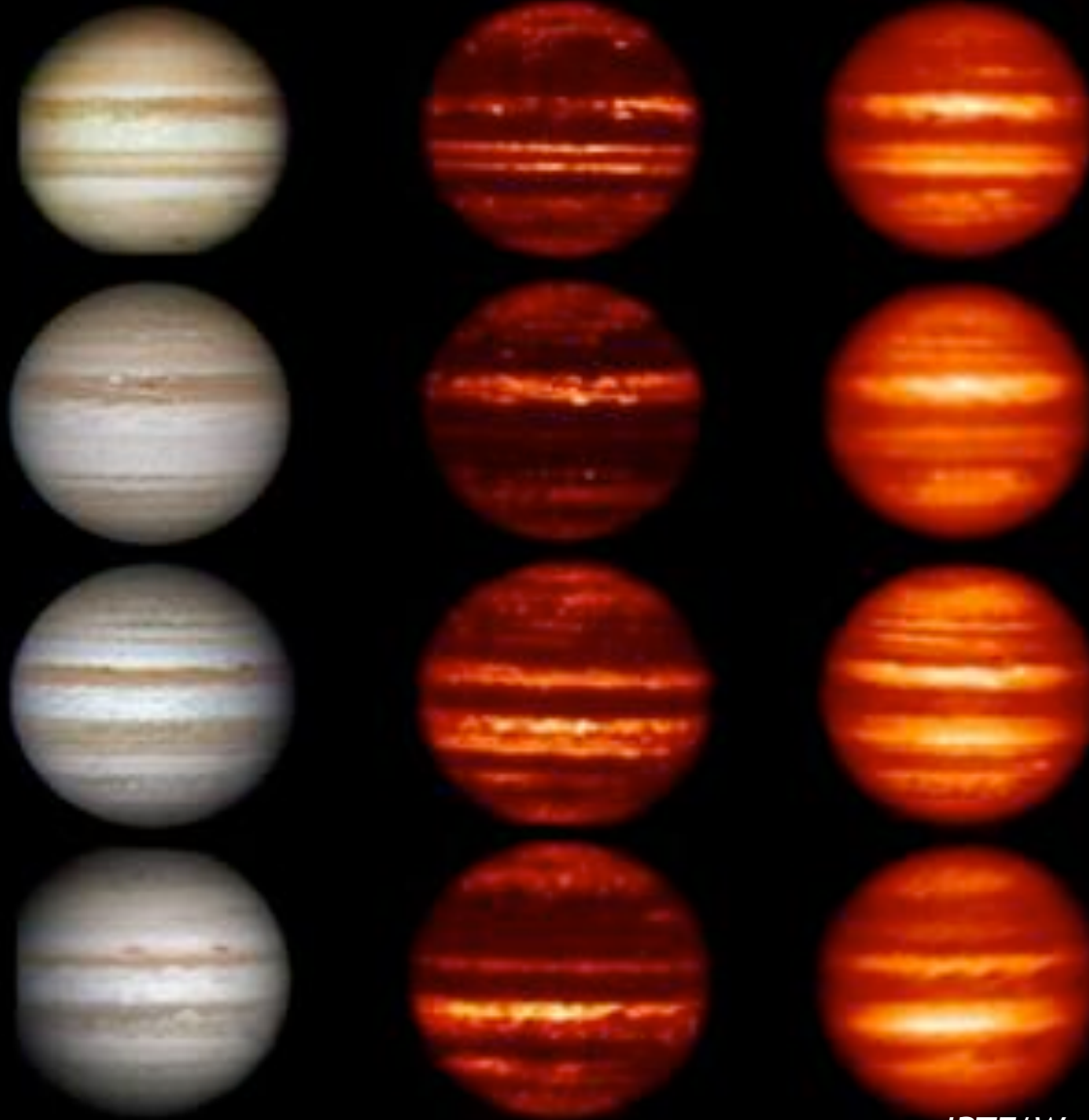
SOFIA spectroscopic slits were stepped across the disk of Jupiter to make spectral maps.

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

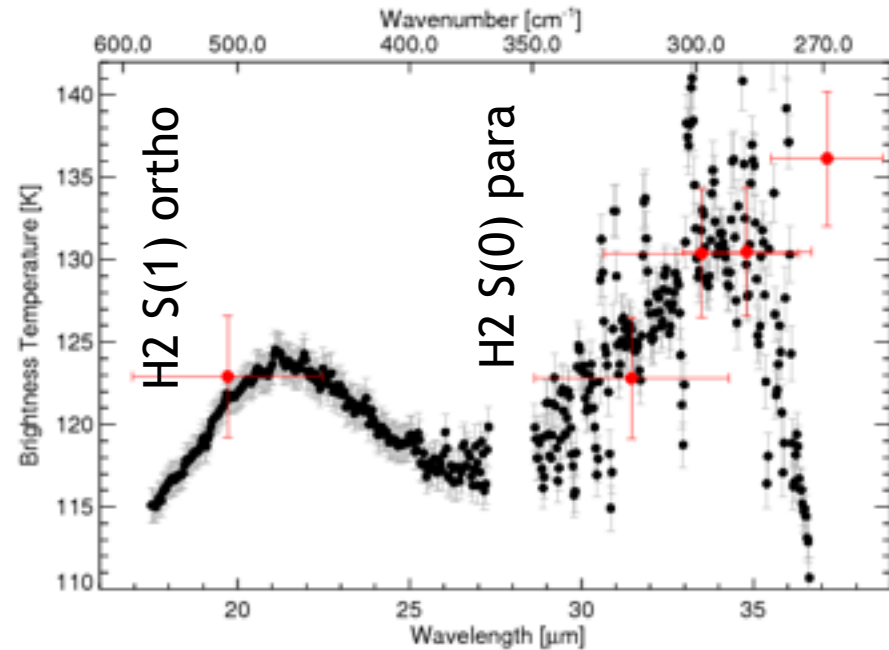
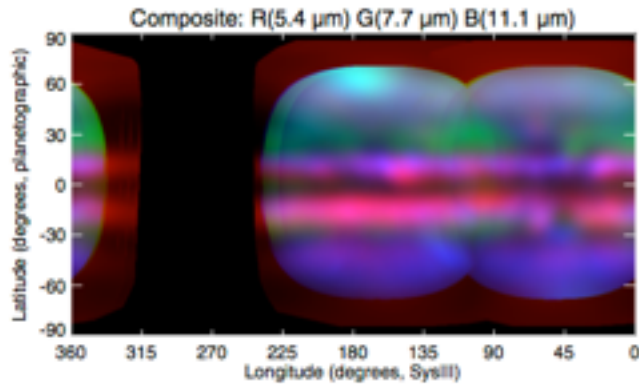




IRTF/Wesley/Kazumoto/Go



Jupiter's Para-H₂ Distribution from SOFIA/FORCAST and Voyager/IRIS 17-37 μm Spectroscopy (*Fletcher w/Reach*)



- Mid-infrared spectral maps of Jupiter for ortho/para H₂
- Equatorial/high-lat para fraction is below/above equilibrium value
- Low-para H₂ from depth is upward transported to equator
- Low-para H₂ rapidly equilibrates on aerosols at high-latitude, and sinks back

Submitted to Icarus

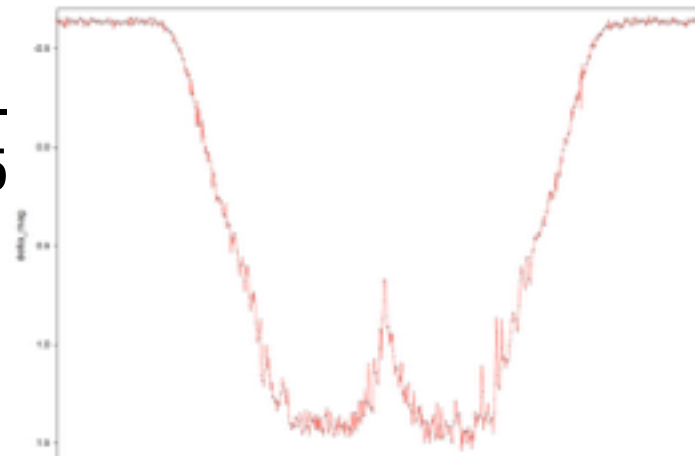
Pluto's Atmosphere

2015 Jun 29 event

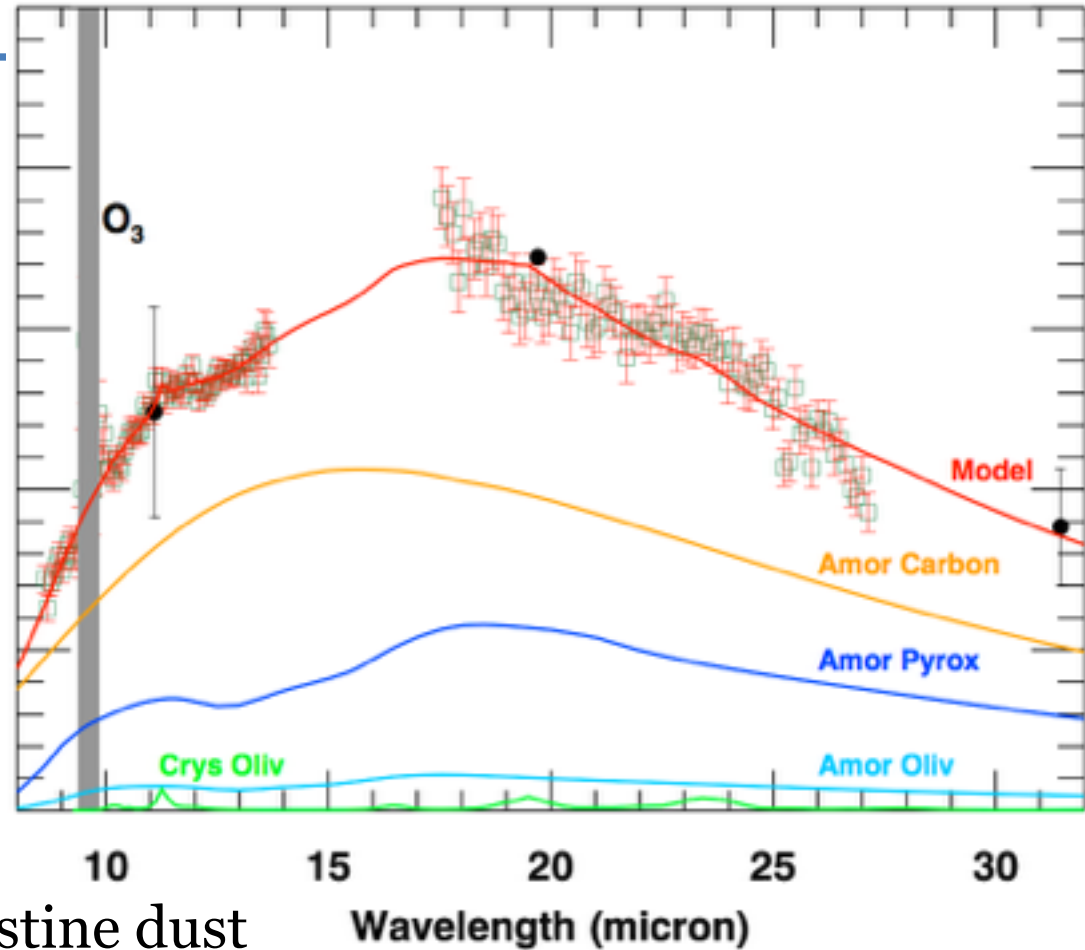


A. Bosh (Monday 4pm)

- Haze in Pluto's atmosphere:
Results from SOFIA and ground-based observations of the 2015 June 29 Pluto occultation



SOFIA Spectrophotometry of Comet C/2012 K1 (Pan-STARRS) (Woodward *w/Reach*)



- Oort cloud comet, pristine dust
- Weak silicate feature (in contrast to Hale-Bopp), carbon-rich

[2015ApJ...809..181W](#)

2015 Aug



Guest Investigator	Proposal Title	Instrument
Glenn Orton (JPL)	17- to 37-micron Photometry and Spectroscopy of Uranus and Neptune	FORCAST
Glenn Orton (JPL)	Jupiter's Stratospheric HCN, Hydrocarbon and Temperature Fields	EXES
Charles Woodward (U. Minn.)	A Tale of Two Comets - The FORCAST Story	FORCAST&FPI+
Kate Su (U. Arizona)	Mineralogical Evolution in Extreme Debris Disks	FORCAST
Therese Encrenaz (Paris Obs)	A map of D/H on Mars using EXES aboard SOFIA	EXES
Andrew Rivkin (JHU/APL)	Characterization of OH and H ₂ O in Asteroids	FLITECAM
Carl Melis (UCSD)	Unusual material orbiting the dustiest main sequence A-type stars	FORCAST
Joseph Adams (SOFIA/USRA)	The Dust Production Rate in the Fomalhaut Debris Disk	FORCAST&HAWC+
Kate Su (U. Arizona)	Structure of the Iconic Vega Debris Disk	FORCAST
Constantine Tsang (SWRI)	Venus Atmosphere: D/H Ratio from H ₂ O and HDO Measurements	EXES
Shohei Aoki (IAPS Italy)	Verification of CH ₄ on Mars and investigation of its temporal and spatial variations by SOFIA/EXES	EXES
Miriam Rengel (MPIfSS)	Investigating the composition of Titan's stratosphere with SOFIA: time variability & intriguing unidentified signatures	FIFI-LS
Inseok Song (U. Georgia)	Characterizing the Warm Disk with FORCAST Photometry for the Dustiest Debris Disk	FORCAST
Juergen Wolf (DSI/SOFIA)	Stellar Occultations by Trans-Neptunian Objects and Centaurs	FPI+



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



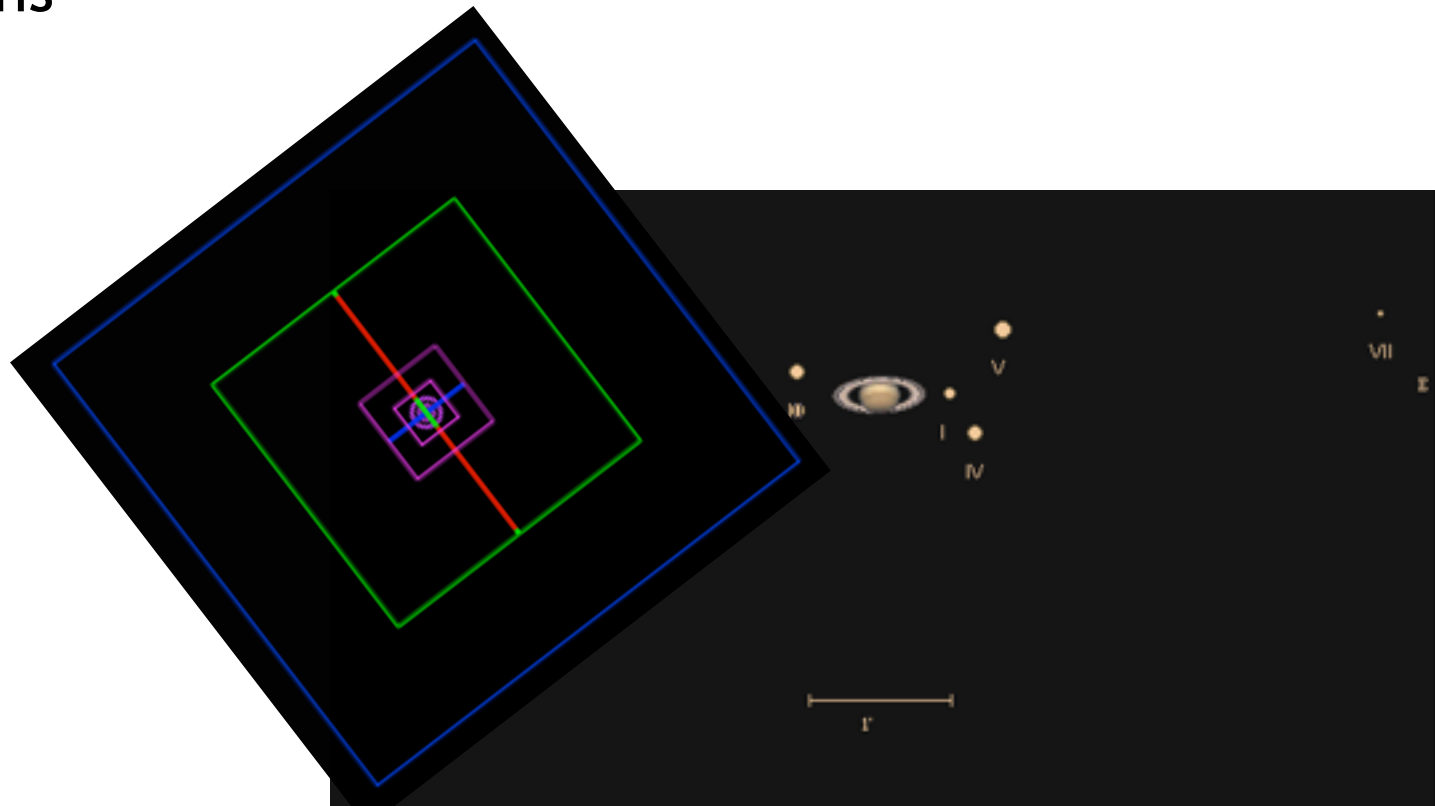


Elevation limits and Sunrise/Sunset

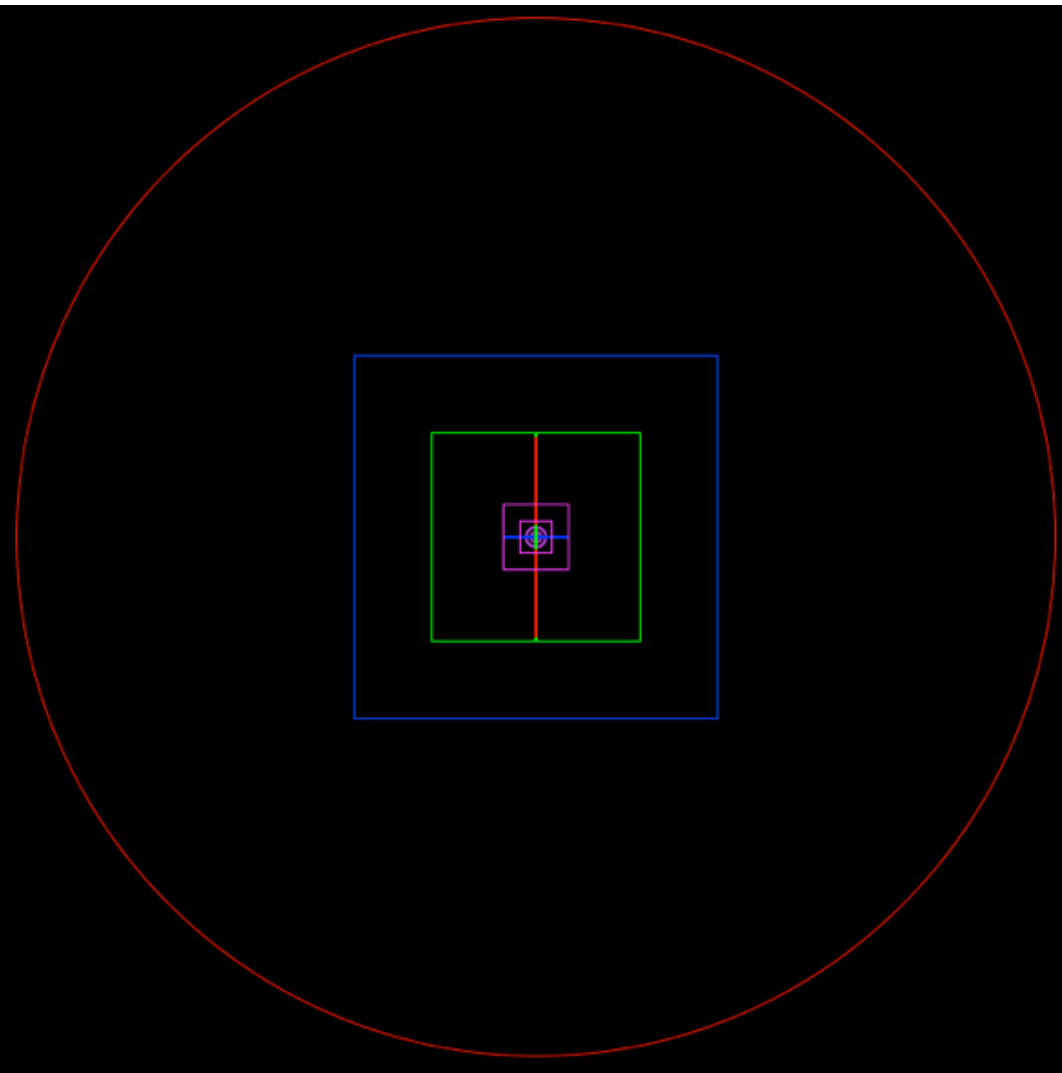
- The telescope stays in the elevation range 22-58 degrees
- Absolute minimum solar elongation is therefore 22 degrees
 - Practical limit of 25 degrees to allow time to acquire & observe
- We have flight rules to prevent sunlight on the telescope
- Observations right after sunset are possible
 - No time 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 $\frac{1}{2}$ area