First Light of Tohoku 60-cm Telescope at Haleakala Observatory in Hawaii

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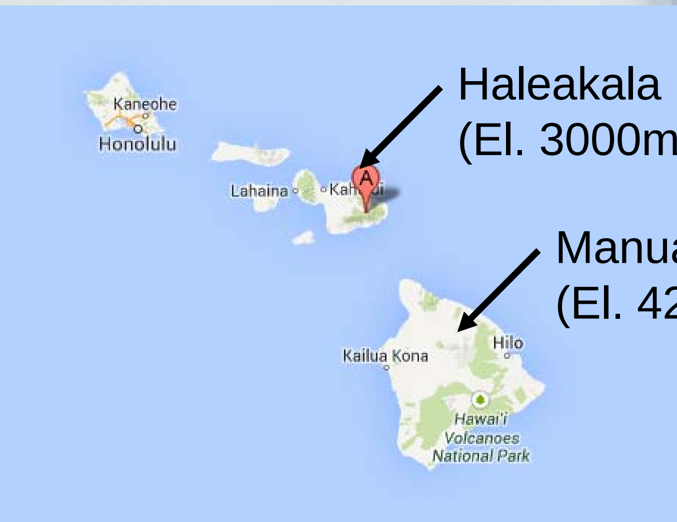
Purpose of Tohoku 60-cm (T60)

- **Flexible** - Conjugated operations with **space missions** & **large telescopes**
- **Continuous monitoring** - **Temporal variabilities** in diurnal, seasonal solar cycle
- **Unique instrument** – including IR and visible high-resolution spectroscopy

- **Mid-Infrared LAser Heterodyne Instrument (MILAHI)**:
  8–10μm, λ/δλ ~ 10^6-7^
- **Filter Imager / Spectrograph with coronagraph**:
  0.4–0.9μm, λ/δλ ~ 1000, FOV~10' / **λ/δλ ~ 50000,**
- **Double image high-precision polarimeter (Dipol-2)**:
  BVR, high-precision polarimetry (DoLP~10^{-6})

[Future plan]
- Near-Infrared Echelle spectrometer (ESPRIT): 1-5μm λ/δλ ~ 20000

T60 Opening Ceremony - 8 Sep. 2014



- **Dec 2011**: Dr. Günther Hasinger(IfA Director) accommodated a request for relocation of Iitate 60cm telescope as a part of assistance for quake disaster.
- **July 2013**: construction permitted
- **Dec 2013**: construction started
- **Sep 2014**: the opening ceremony

Tohoku 60-cm Telescope (T60)

Tab. 1 Specifications of T60

Entrance Pupil Diamter	**600 mm**
Focal length	**7200mm (F12) at Cassegrain (Cs) 14400mm (F24) at Coude (Cd)**
Instruments / Foci	Dipol2 / Cs MILAHI / Cd Coronagraph / Cs+Cd Filter Imager / Cs+Cd Visible Spectrograph / Cd

- Remote control
- 85%: Tohoku, 15%: IfA/UH

Ultra high-resolution spectroscopy of Martian atmosphere --- MILAHI (next presentation)

High-dynamic range observation close to planets

High-precision Polarimetry of exoplanets

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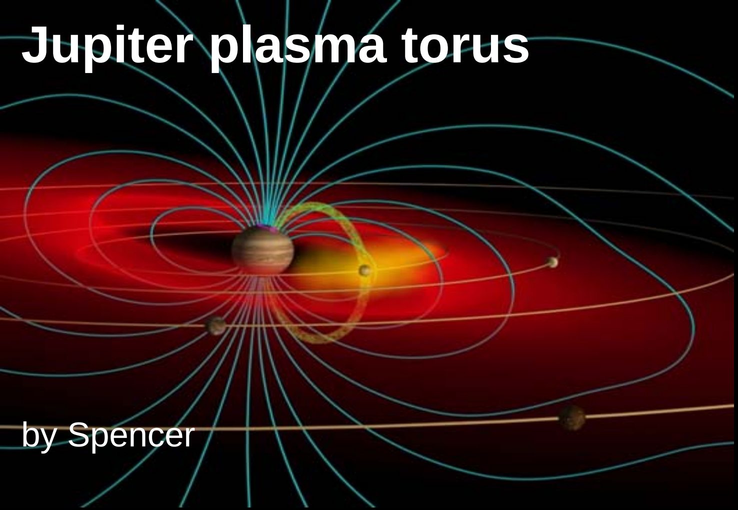
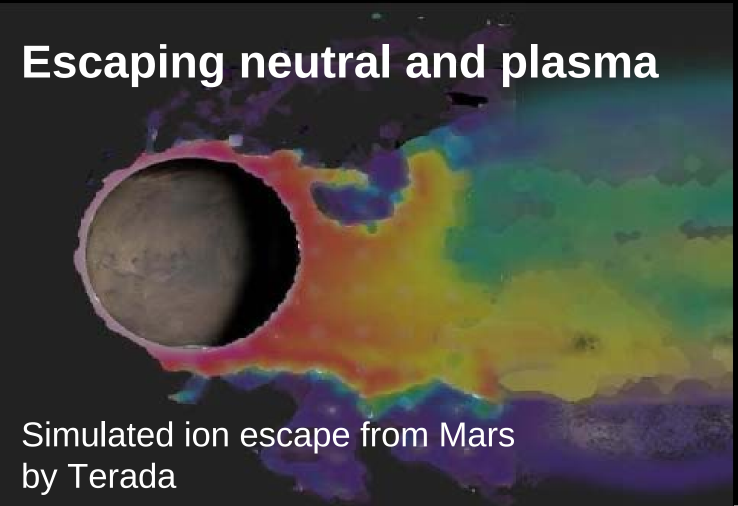




High-dynamic range observation close to the planets

Continuous monitoring of faint emissions from plasma and neutrals in planetary magnetosphere helps us to understand dynamics and energy balance, e.g. Jupiter's plasma torus, Saturn's Enceladus torus, and so on.

When we observe faint emissions close to the planets, diffracted side-lobes and scattering prevent us from getting high S/N measurements

Dynamic range of targets

Tab. 1 Brightness of targets and contamination sources in visible (0.4-1um)

Targets	Brightness of targets	Brightness of bright objects	**Brightness ratio Bright obj. / target**	**Separation from bright objects**
Jupiter plasma torus	S+, S++ 500 R	50MR/nm	**10^5**	**50-100”**
Enceladus torus	O, H_2O^+ 5 R	20 MR/nm (Ring) 15 MR/nm (Disk)	**>10^6**	**5” from Rings 15” from disk**
Escaping spices from Venus	CO^+ 1-100 R	>500/nm MR	**>10^6**	**10-100”**

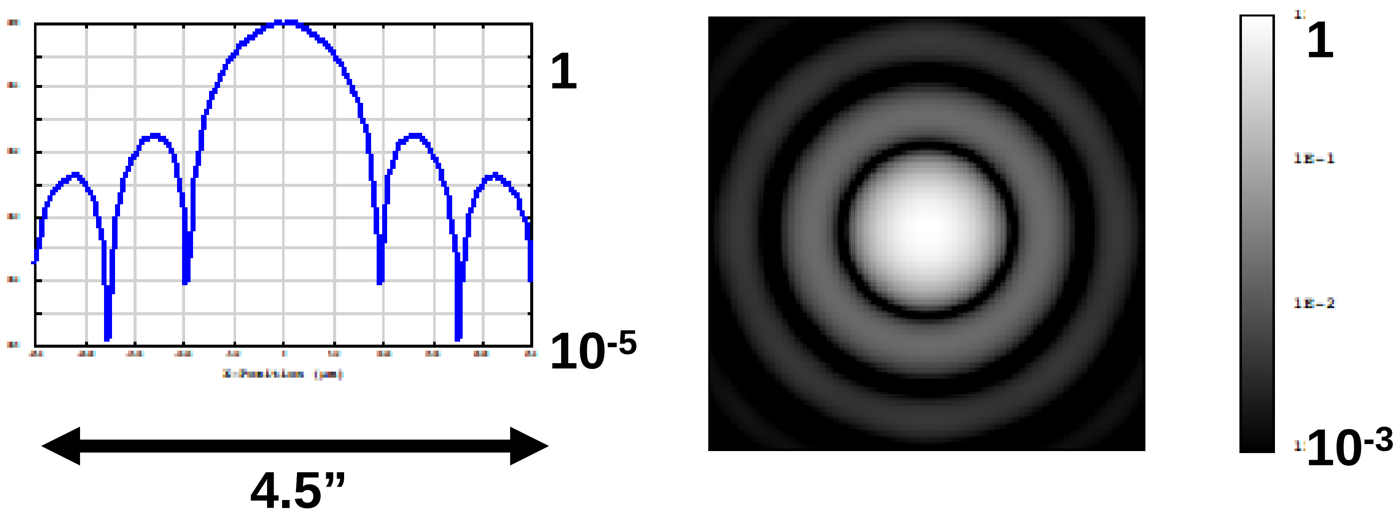


Fig. Circular aperture diffraction (D=600mm, λ=650nm)

Fig. Diffraction by secondary support structure

Reducing diffraction using a Lyot stop

Secondary support structure (spider) produces cross-shaped diffraction pattern which is the most critical for detecting fain emission spreading around the bright body.

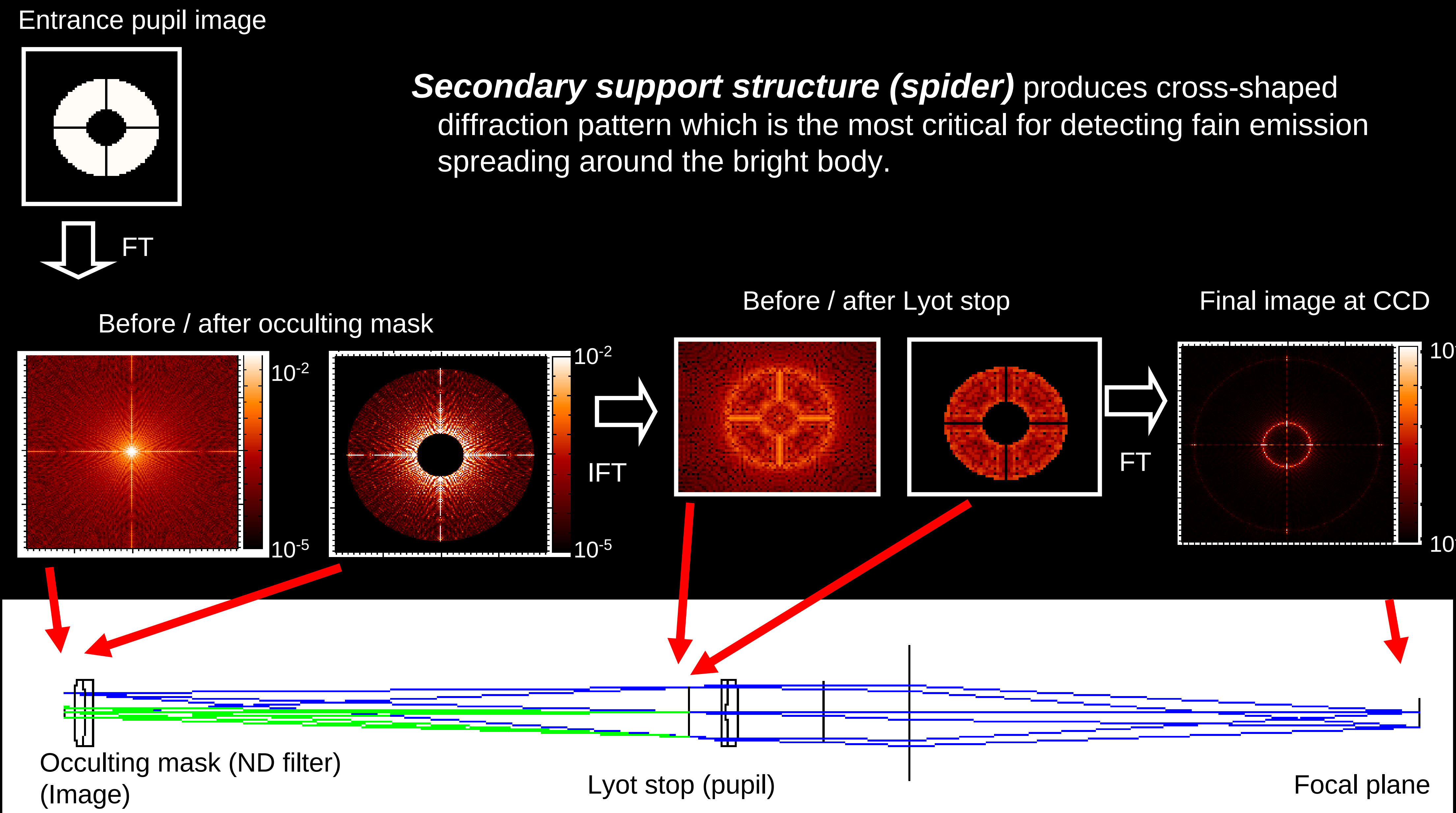


Fig. Model calculation of diffraction pattern using an occulting mask and a Lyot stop

Advantage of Lyot stop

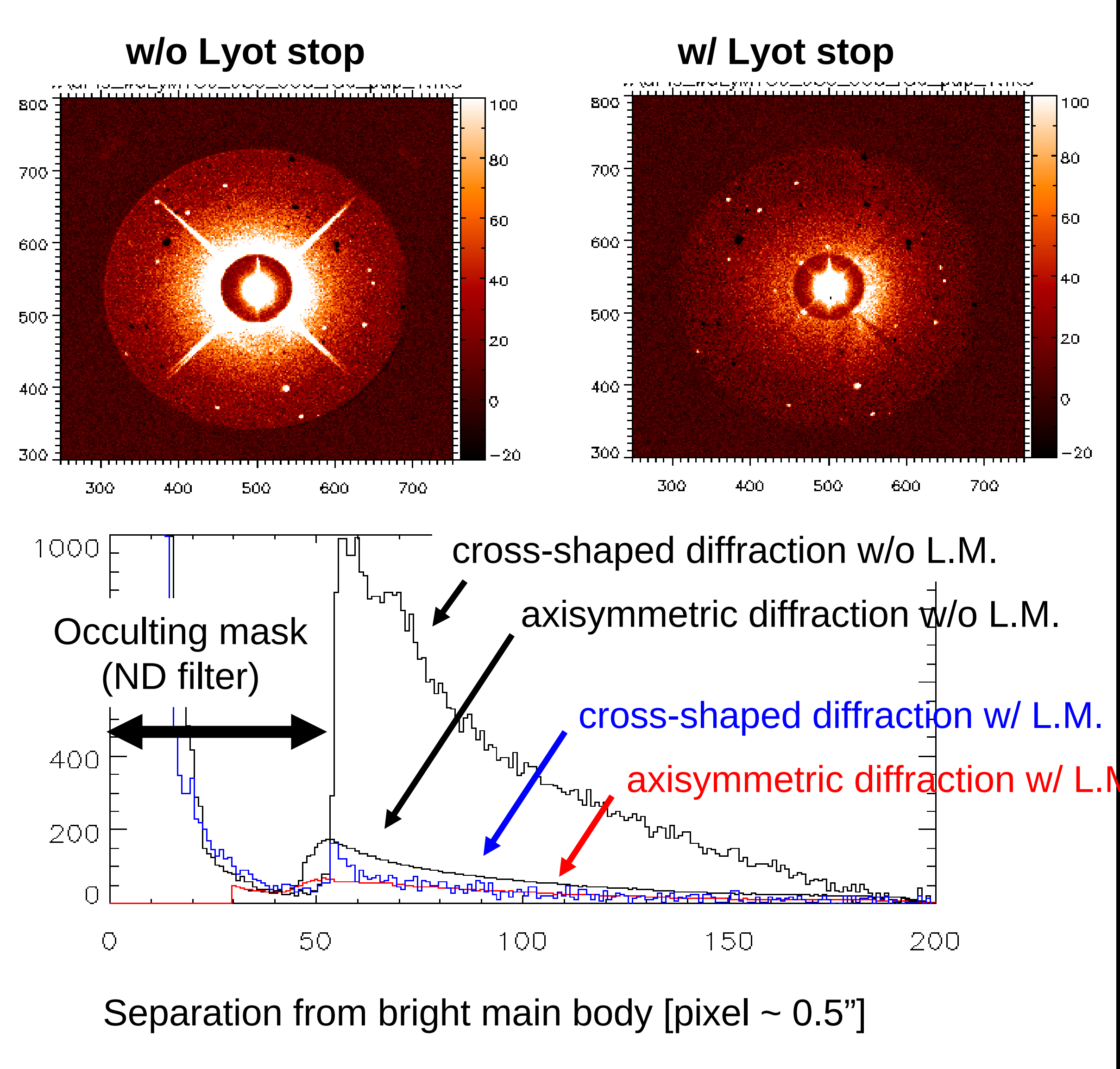


Fig. Top left: image w/o Lyot stop, Top right: image w/ Lyot stop

An Lyot stop reduces

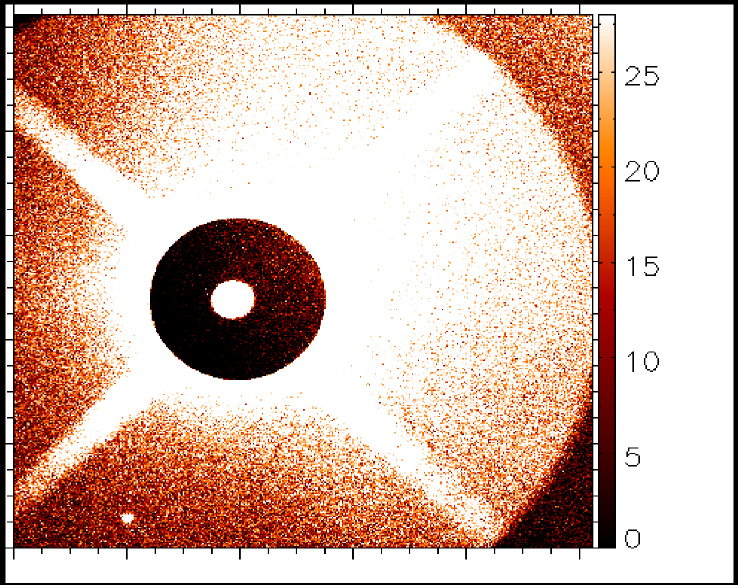
- ***axisymmetric diffraction by factor of 2-3***, as well as
- ***cross-shaped diffraction by order of 1***

at a distance of 30” apart from center of bright object.

Fig. Occulting masks in the turret

Application for Jupiter plasma torus observation

w/o Lyot stop



w/ Lyot stop

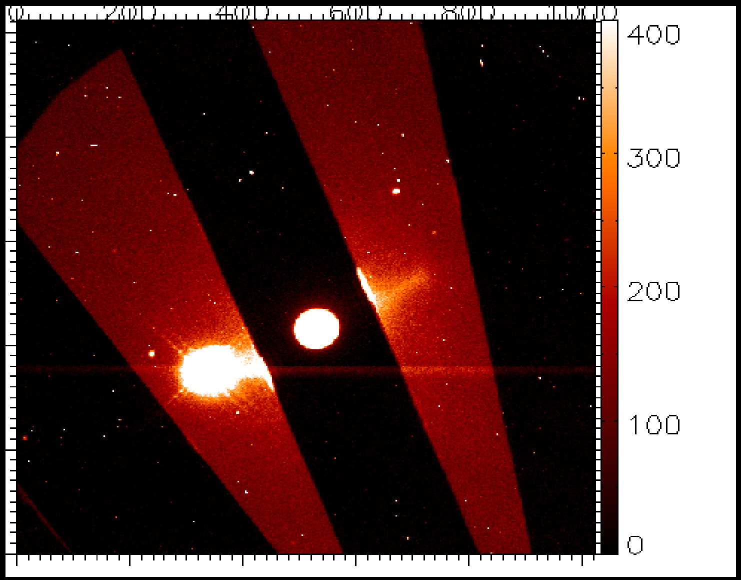


Fig. [SII] 6716A image of Jupiter plasma torus. left: w/o using Lyot mask, right: w/ using Lyot mask. Color scale is adjusted using Jupiter disk brightness.

Preliminary result of Jupiter plasma torus observation

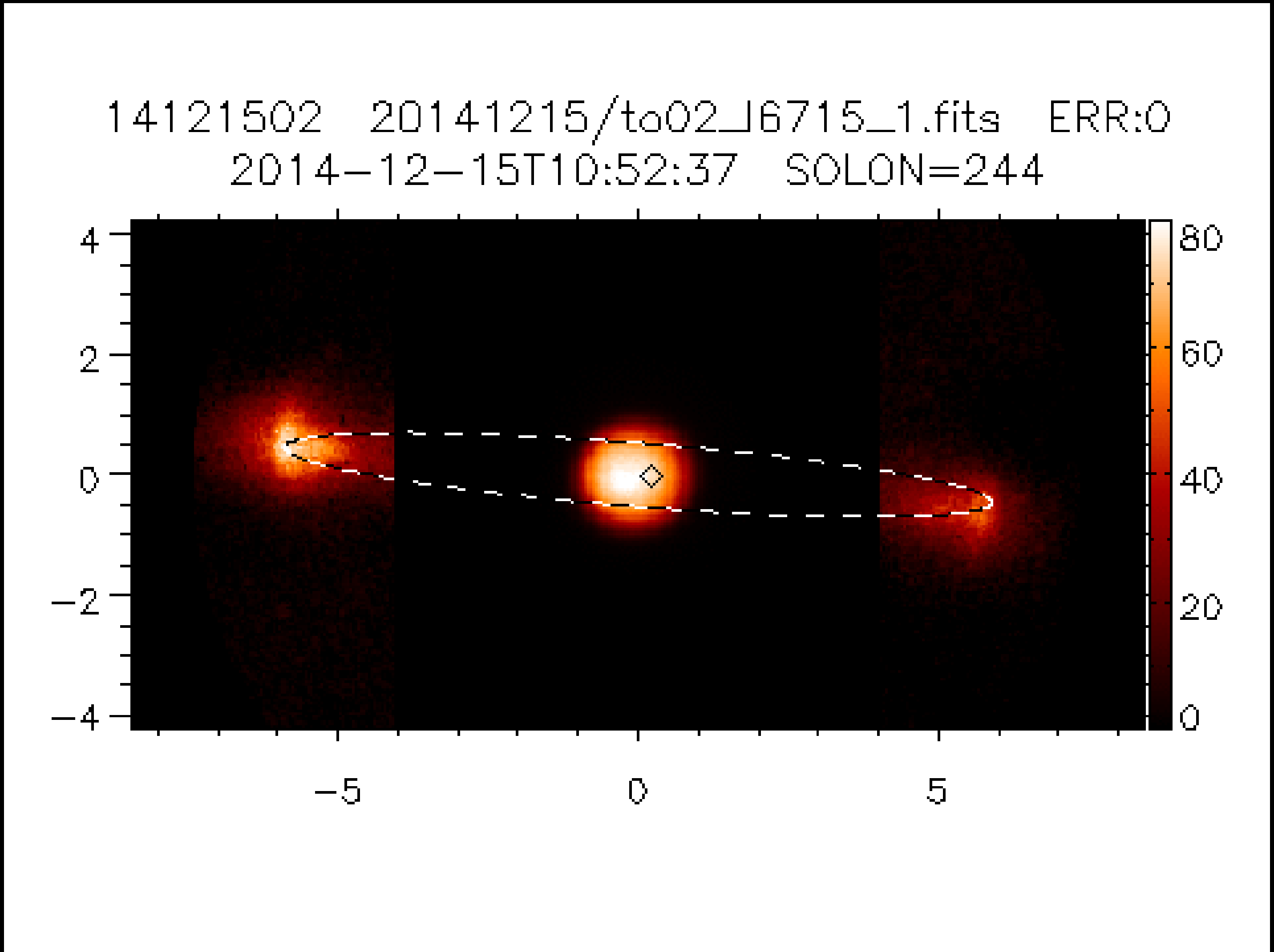


Fig. a series of [SII] 6716A images of Jupiter plasma torus on Dec. 2014 – Jan. 2015. Exposure time is 20-min. 2x2 binned (~1"/bin).

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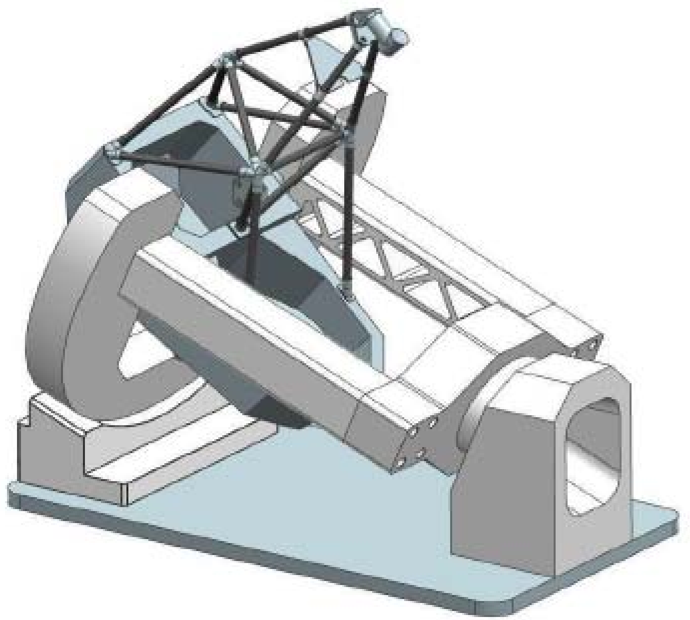
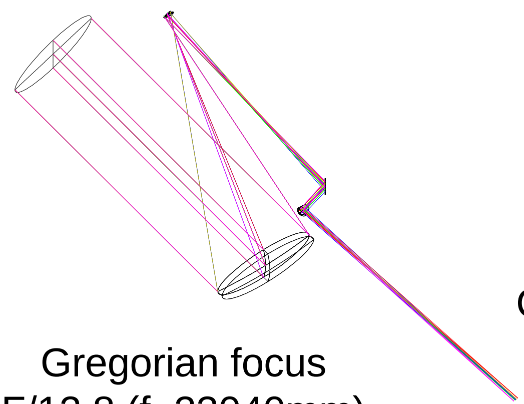
Haleakala 2m telescope (PLANETS, Polarized Light from Atmospheres of Nearby ExtraTerrestrial Systems)

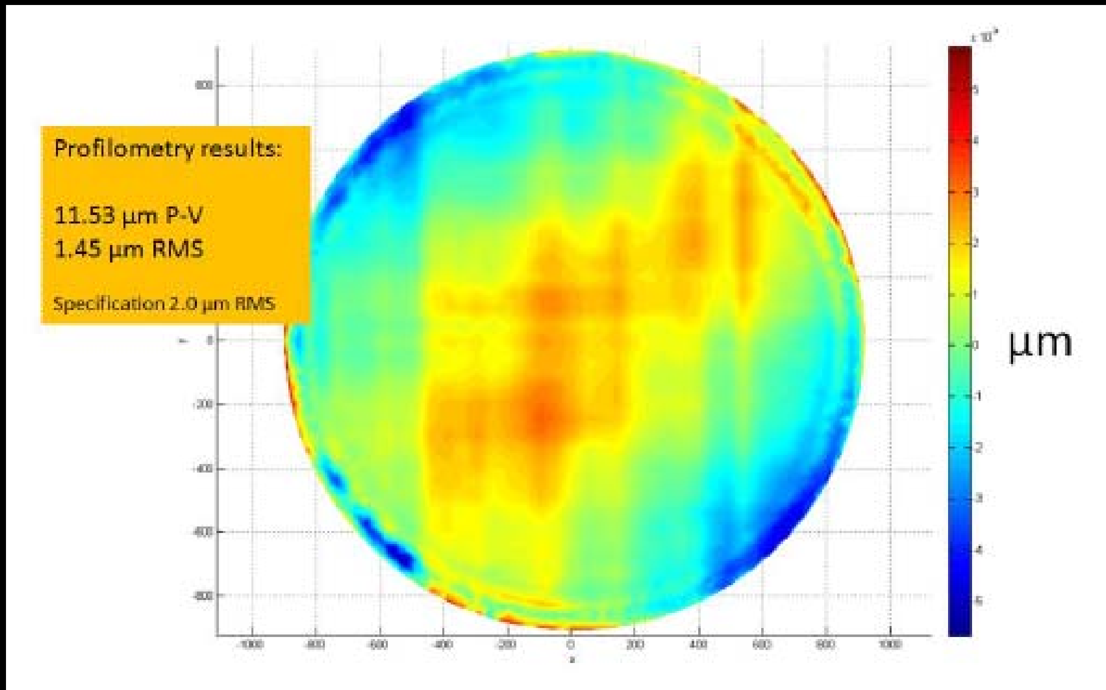


-Collaboration with IfA/UH and KIS(Germany),
- First light: end of 2016 (fastest case)



Coude (F/50)

Gregorian focus F/12.8 (f=23040mm)



Summary

- T60 was installed on Sep. 2014 at Haleakala Observatory in Hawaii.

- MILAHI ($\lambda/\delta\lambda$~10^6, 8-10μm) , Visible Imager and Spectrograph with Coronagraph ($\lambda/\delta\lambda$~10^3~10^5, 0.4-0.9μm), and Dipol2 (DoLP~10^{-6}, BVR) have gotten first-light fed to T60.

- We are starting
  - Jupiter observation using Visible Imager with Coronagraph for support observation of HISAKI/EXCEED.
  - Martian observation using MILAHI from March through September 2015 for the monitor of lower atmosphere just below MAVEN observations.
  - Exoplaents observation using Dipol2