Far-IR observations of Titan and the kronian system with next generation spectrometers

Athena Coustenis[1], Antonella Barucci[1], Georgios Bampasidis[1], Anezina Solomonidou[1,2], F. Michael Flasar[3], John Brasunas[3]

[1] LESIA - Observatoire de Paris, CNRS, UPMC Univ. Paris 06, Univ. Paris-Diderot, 92190 Meudon, France

[2] Jet Propulsion Laboratory, California Institute of Technology, California, USA

[3]NASA/GSFC, Greenbelt, MD, USA

EWASS, Athens, Greece,
4-8 July 2016

The Saturnian system and in particular the icy moons and Titan were observed in the far-IR with the ISO SWS (Coustenis et al. 2003). Also, space missions like Voyager with IRIS and the ORS instruments on board the Cassini mission (Fig. 1) have provided far-IR spectra of Saturnian system, in particular since 2004. One of the remote instruments on Cassini is the Composite Infrared Spectrometer (CIRS, Fig. 2), which has two interferometers covering 10-600 cm^{-1}, 600-1100 cm^{-1} and 1100-1400 cm^{-1} in focal planes 1 (FP1), 3 (FP3) and 4 (FP4) respectively with spectral resolutions of 0.5, 2.5 and 15 cm^{-1} (Flasar et al. 2004, 2005, Table 1, Fig. 3).

The results from the studies of the Saturnian system using CIRS over the past 10 years or so have been published in several articles covering atmospheric structure, evolution and dynamics of the planet (Fig. 4) and active satellites like Titan (Fig. 5), as well as surface properties of the icy moons (see Flasar et al., 2005; Coustenis et al., 2016 and references therein; Carvano et al. 2007; Brucato et al. 2010). Among other, these studies pertain to the atmospheric properties of Titan's stratosphere and it evolution over the Cassini mission both in terms of temperature (Fig. 6) and of chemical composition (Fig. 7).

Figure 1

Cassini ORS instruments: Spectral coverage

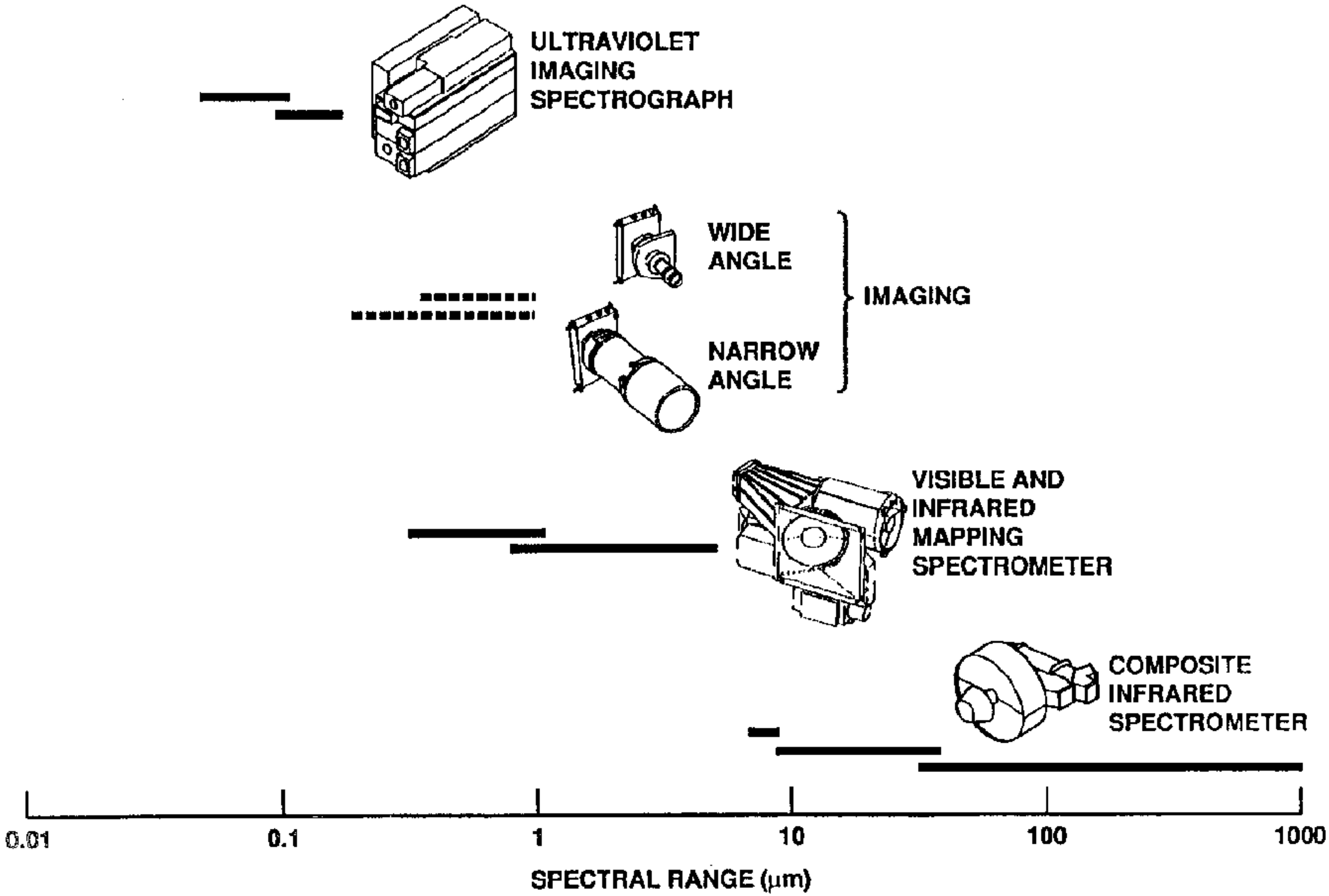
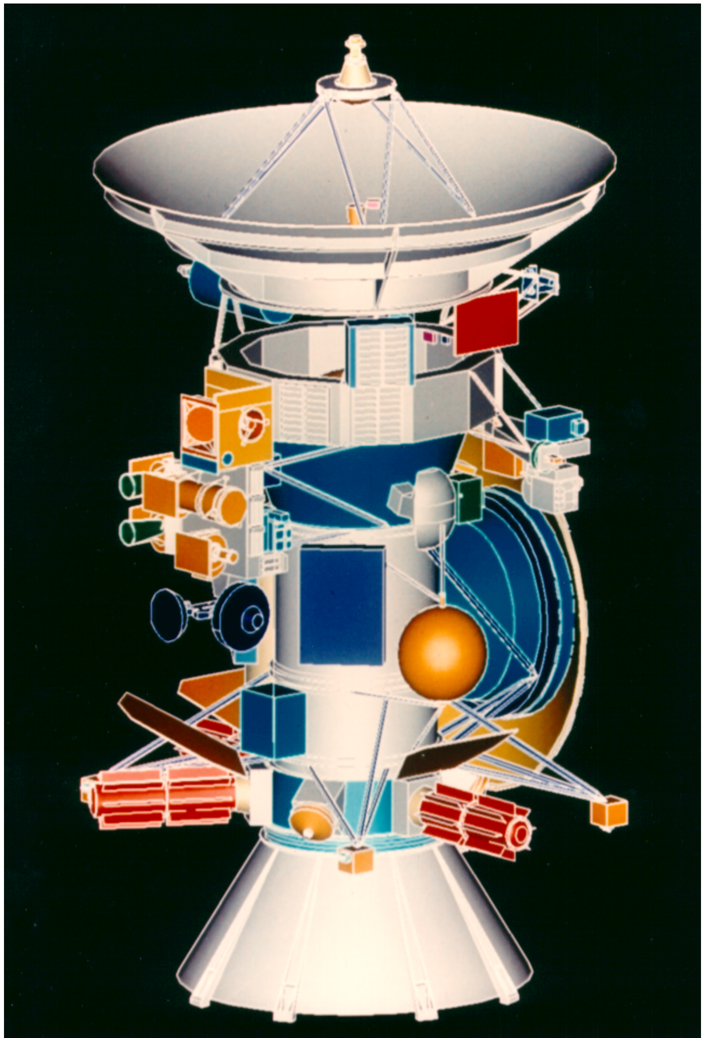


Figure 2

Cassini S/C – CIRS Location

CIRS—>



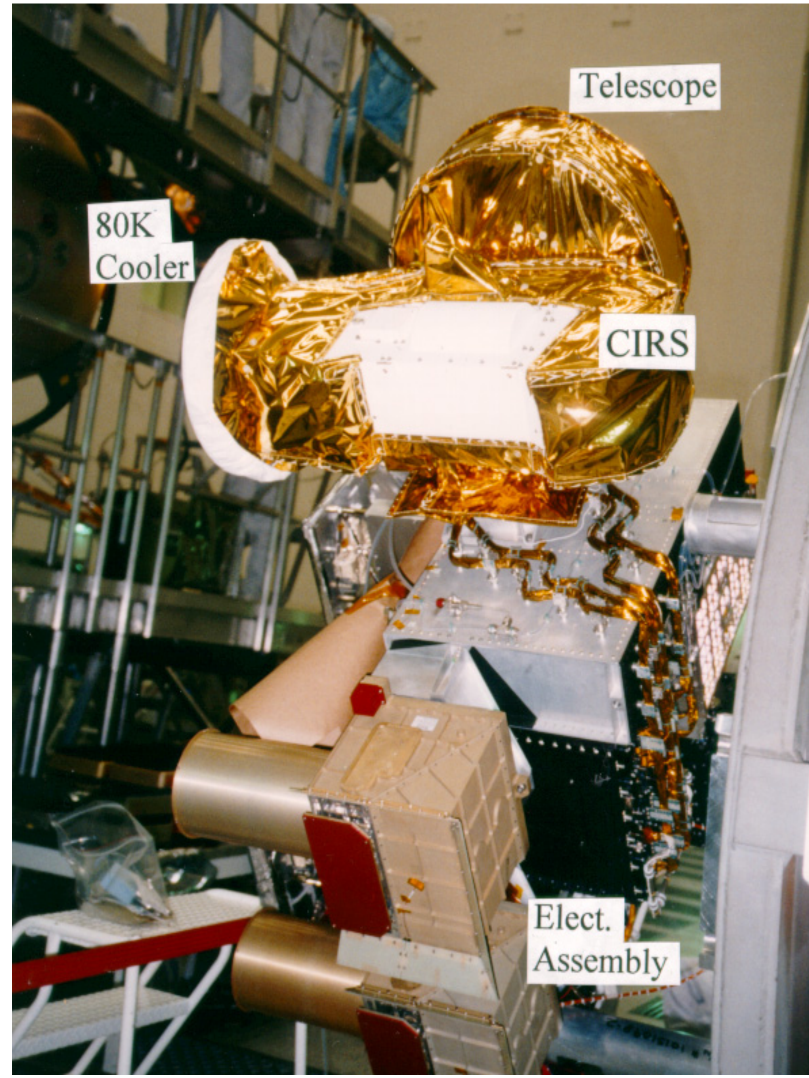


Table 1: CIRS Instrument Characteristics

Telescope Diameter (cm):		50.8	
Interferometers:	Far-IR	Mid-IR	
Type:	Polarizing	Michelson	
Spectral range (cm^{-1}):	10 - 600	600 -1400	
Spectral range (μm):	17 - 1000	7 - 17	
Spectral resolution (cm^{-1}):		0.5 to 15.5	0.5 to 15.5
Integration time (sec):	2 to 50	2 to 50	

FOCAL PLANES:	FP1	FP3	FP4
Spectral range(cm^{-1})	10 - 600	600 - 1100	1100 - 1400
Detectors	Thermopile	PC HgCdTe	PV HgCdTe
Pixels	2[*]	1 x 10	1 X 10
Pixel FOV (mrad)	3.9	0.273	0.273
Peak D*(cm $Hz^{1/2}$ W^{-1})	4×10^{9}	2×10^{10}	5×10^{11}

Data Telemetry Rate (kbs)	2 & 4
Instrument Temperature (K)	170
Focal Planes 3 & 4 Temperature (K)	75 - 90

---

[*] Single FOV, two polarizations

Figure 3

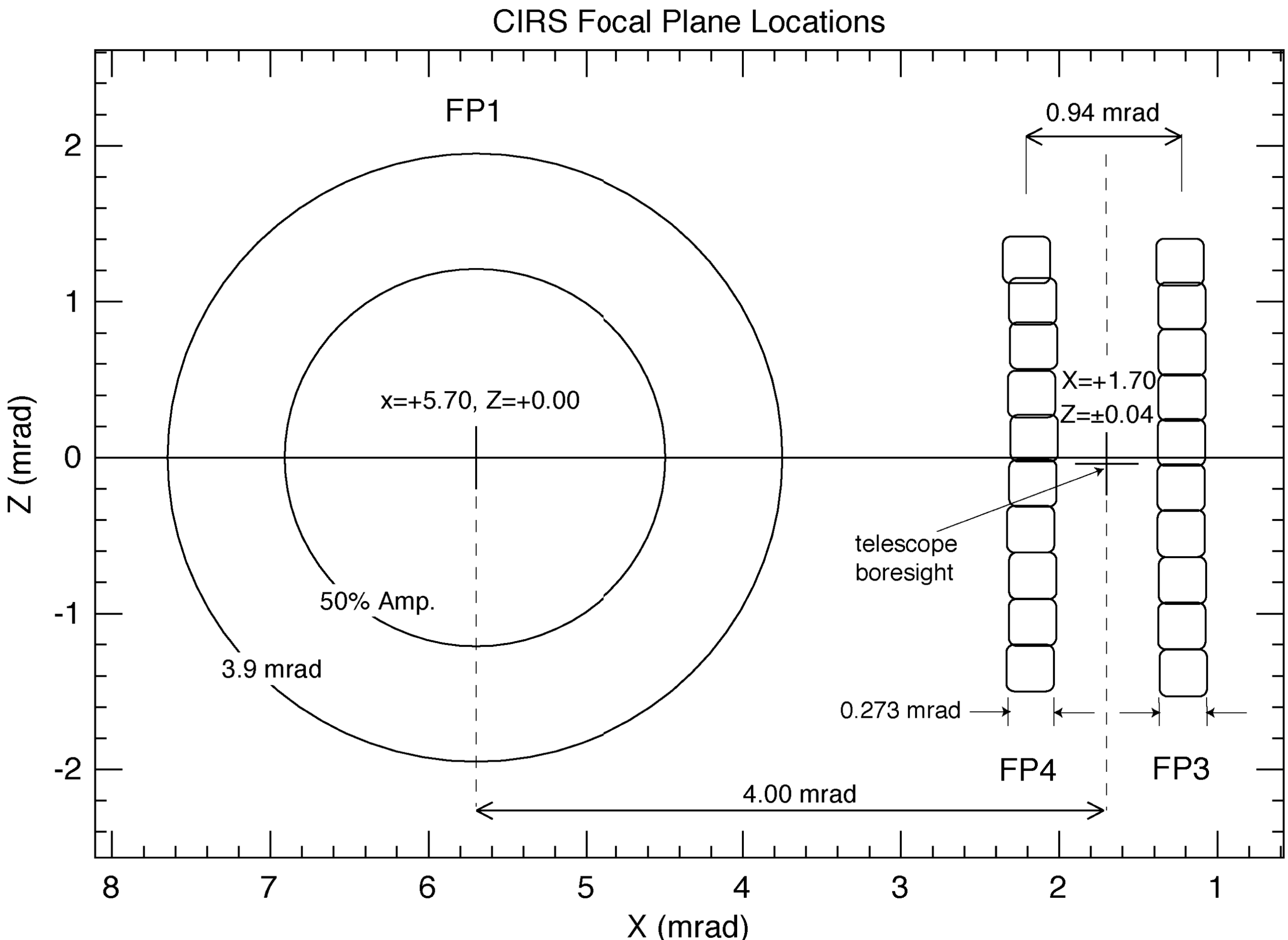
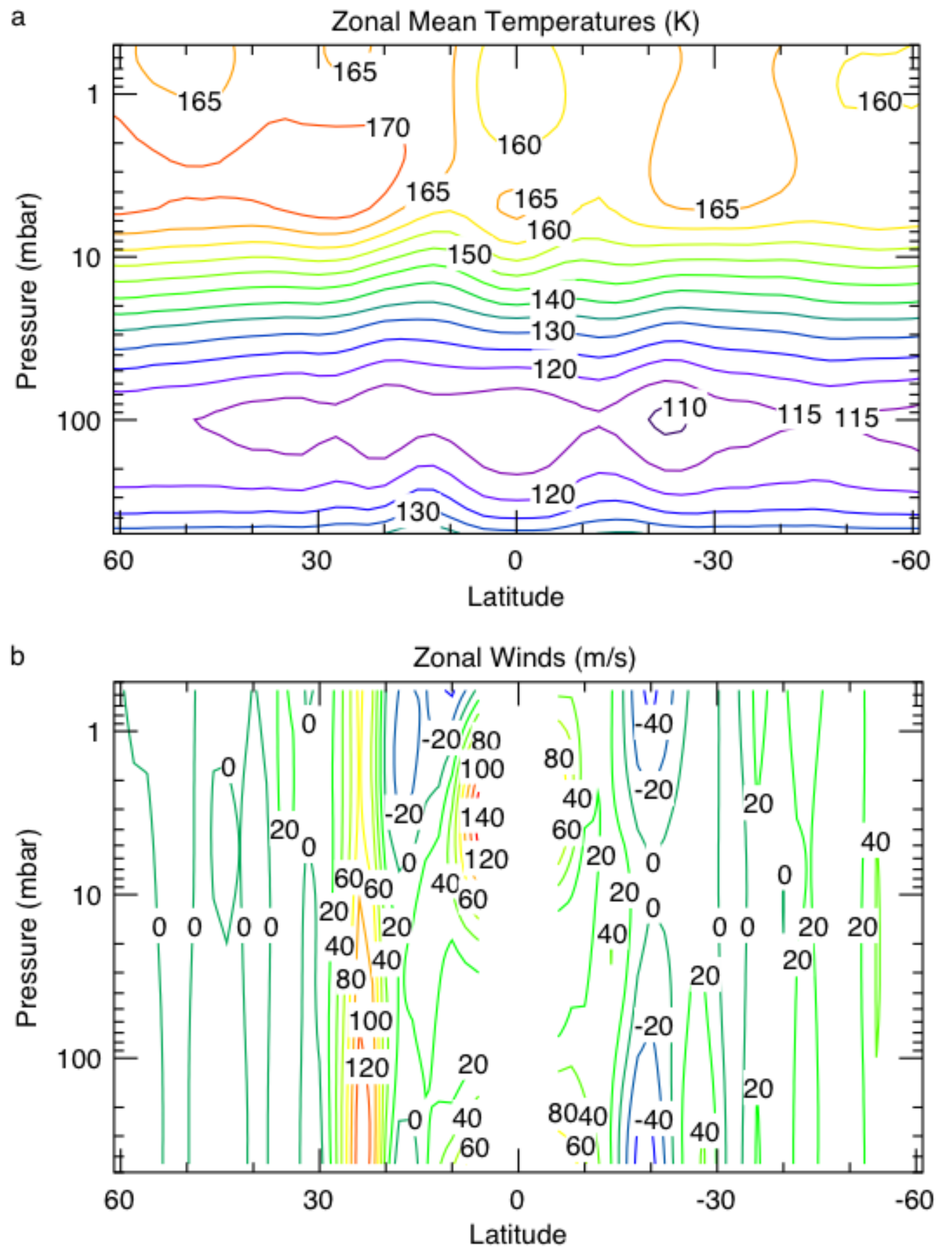


Fig. 1

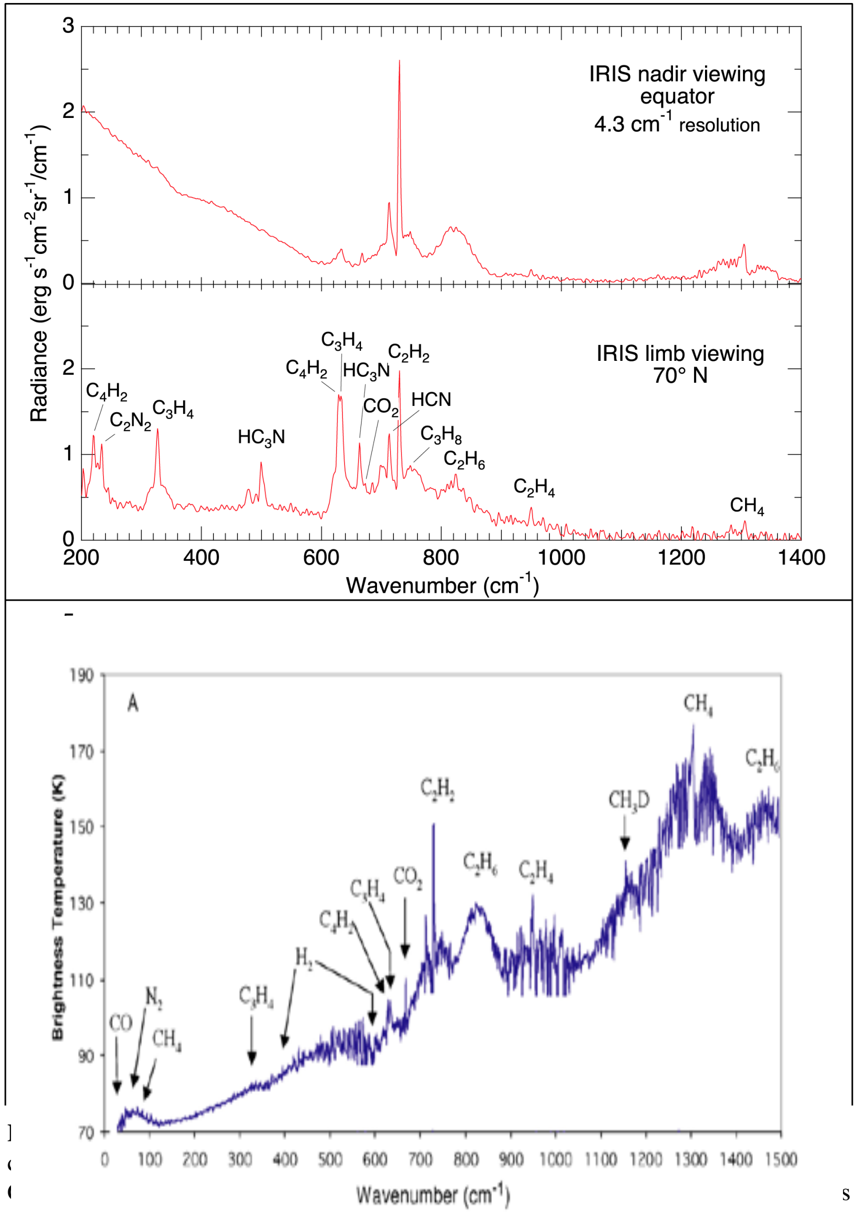
Figure 4

(CIRS at Jupiter)



Flasar et al. 2005

Figure 5



IRIS and CIRS observations of Titan

Figure 6

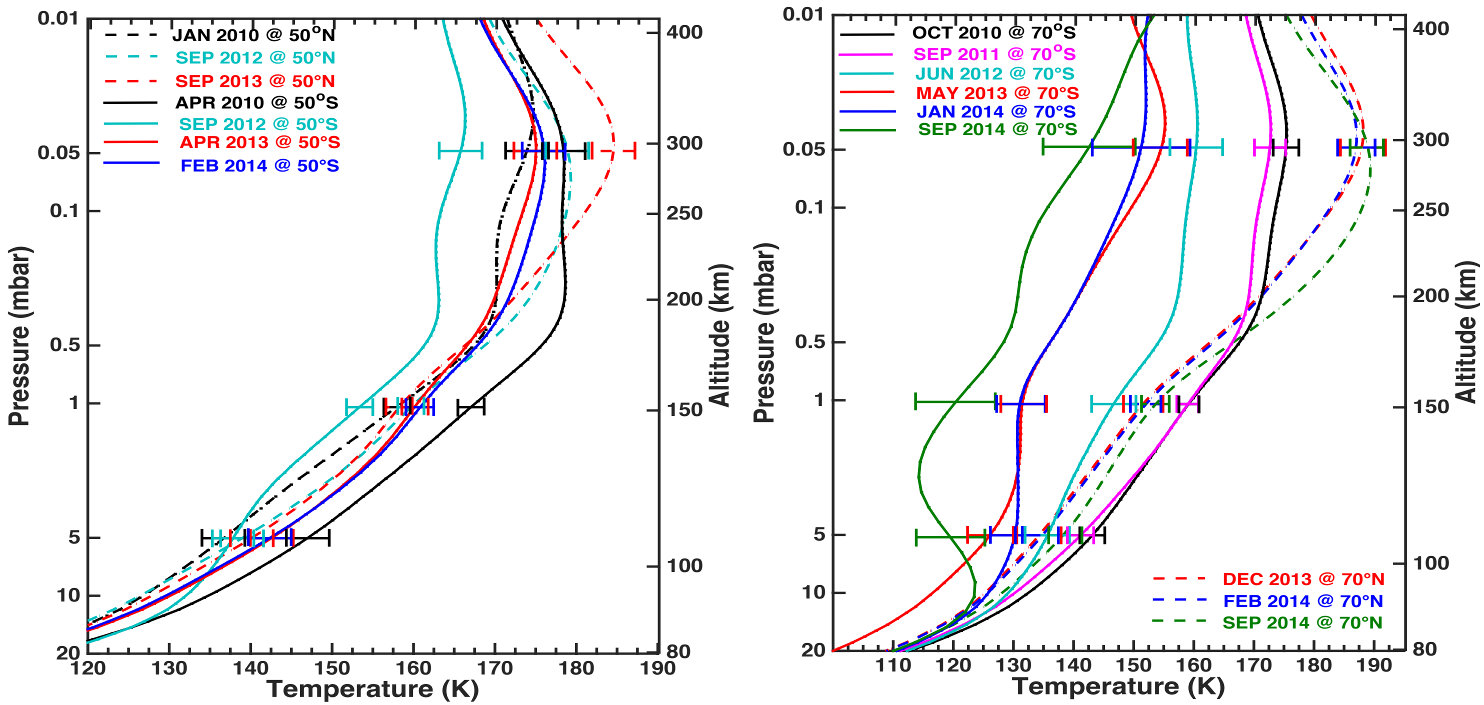


Fig. 5. (left panel) : temperature variations at 50°S (solid lines) and 50°N (dashed lines) in Titan's stratosphere from January 2010 until February 2014; (right panel) : temperature profiles of Titan at 70°S (solid lines) and 70°N (dashed lines) with dates ranging from October 2010 to September 2014, along with horizontal 3-σ error bars (from Coustenis et al. 2016, see text for details). As can be seen, the stratospheric temperatures in the 0.1 to 1 mbar pressure range dropped by about 40 K near the Southern pole within the past 4 years. At the same time, the temperatures in the North indicate rather an increase in temperature by about 6 K.

Figure 7

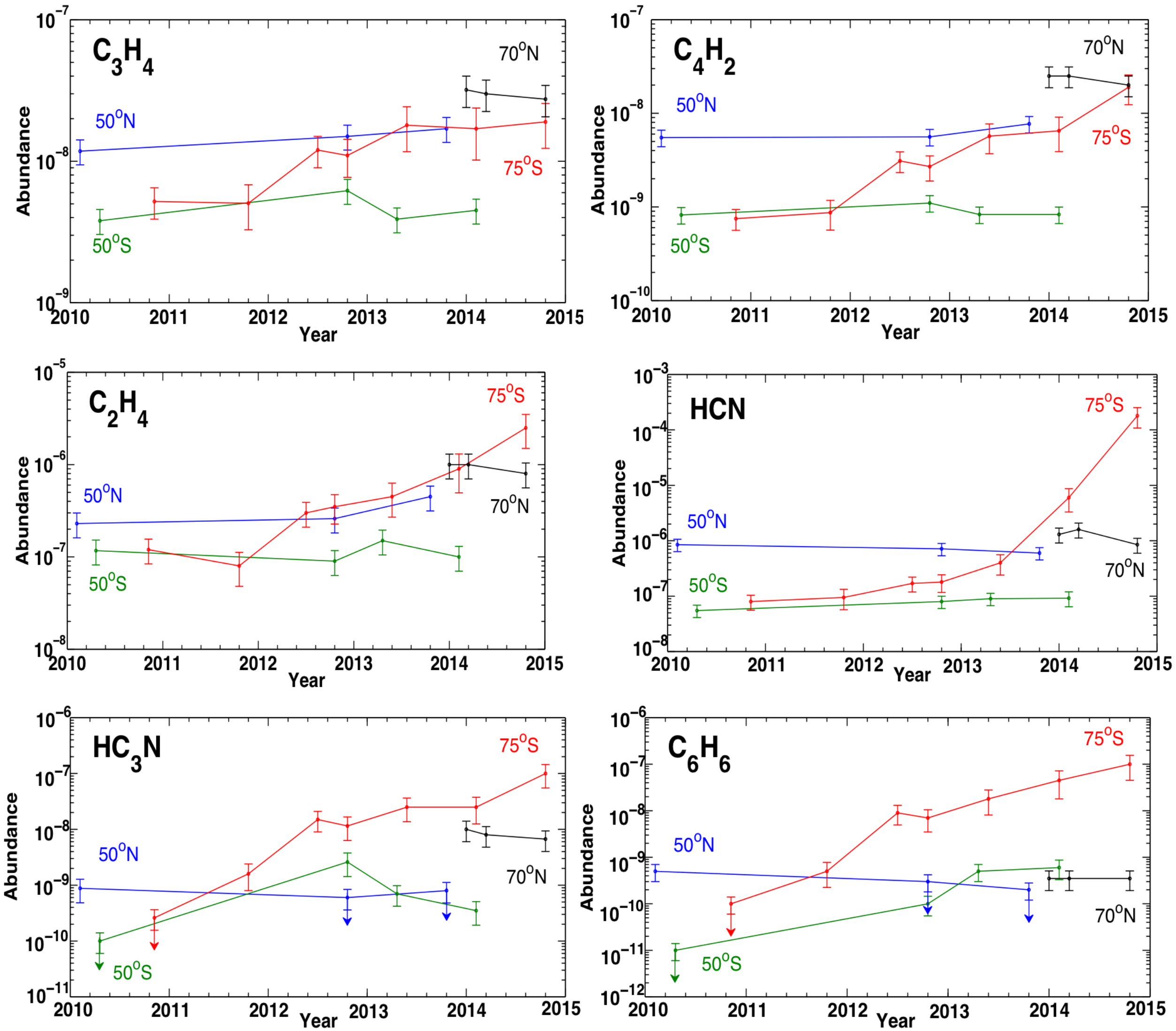


Fig. 6. Retrieved abundances in the stratosphere of Titan for C_2H_4, C_3H_4, C_4H_2, C_6H_6, HCN and HC_3N. (From Coustenis et al. 2016).

The connection with the near-IR data needs to be correctly assessed as we see from Cassini/VIMS investigations (Solomonidou et al. 2016, Fig. 9) in order to precisely infer information on the lower atmospheres and surfaces. A future instrumentation (or a "CIRS-lite" instrument, as proposed by Brasunas et al. in the study for the study of the space mission TANDEM (Coustenis et al., 2009) and TSSM (Fig. 10) would have a smaller telescope (15 cm in diameter for the primary, to keep the mass down) which would result in a similar spectral range coverage except with a lower wavenumber cutoff around 300 cm-1 (diffraction limited). Some differences include: high temperature superconductor detectors instead of the less sensitive thermopile detectors in the far IR; HgCdTe detectors in the mid-IR (FP3, 4). The spectral resolution would be 0.125 cm^{-1} apodized (Table 2). Two interferometers, like CIRS, wouldn't be required as a single CVD diamond beam splitter and compensator (60 cm in diameter) would provide similar results, with the advantage of further also reducing the mass. Optics temperature would be around 140 K vs 170 K for CIRS.

Such type of instruments would be very appropriate for future missions and would operate very well in the investigations of Saturn, icy moons and Titan, where one can get by with passive cooling. However, further out in the solar system, observations would be more challenging. Uranus is particularly so, because of its cold atmospheric temperatures which implies an active cooler. This is because a lower temperature (~35 K) superconductor is preferred in the far IR, and passively cooled HgCdTe detectors at 80 K would not even sense Uranus' stratosphere. It remains to be seen if even detectors at 35 K would be cold enough.

Table 2

CIRS-*lite* nominal design (planetary)

- spectral resolution 0.125 cm^{-1} apodized (FTS is double-passed; physical travel is 1 inch)
- spectral coverage is 7 to 333 μm, one FTS with 60 mm diamond beam splitter, no compensator
- detector arrays

TYPE	WAVELENGTH (μm)	PIXEL (mrad/μm)	EXTENT
high Tc	16+ to 333	4.3 x 4.3 / 300 x 300	1 x 4
PC HgCdTe	9+ to 16+	1.5 x 1.5 / 200x200	1 x 30
PV HgCdTe	7 to 9+	same as PC	same as PC

- telescope primary diameter is 15 cm
- there may be a point-able mirror in front of the telescope; similar to the TES design
- optics temperature is 140K (same as Voyager MIRIS)
- all detectors near 70 to 90K, with passive cooler
- collimated FTS beam ~ 3.5 cm -- need ~ 5 cm clear aperture for beam splitter at 45 degrees.

Figure 8

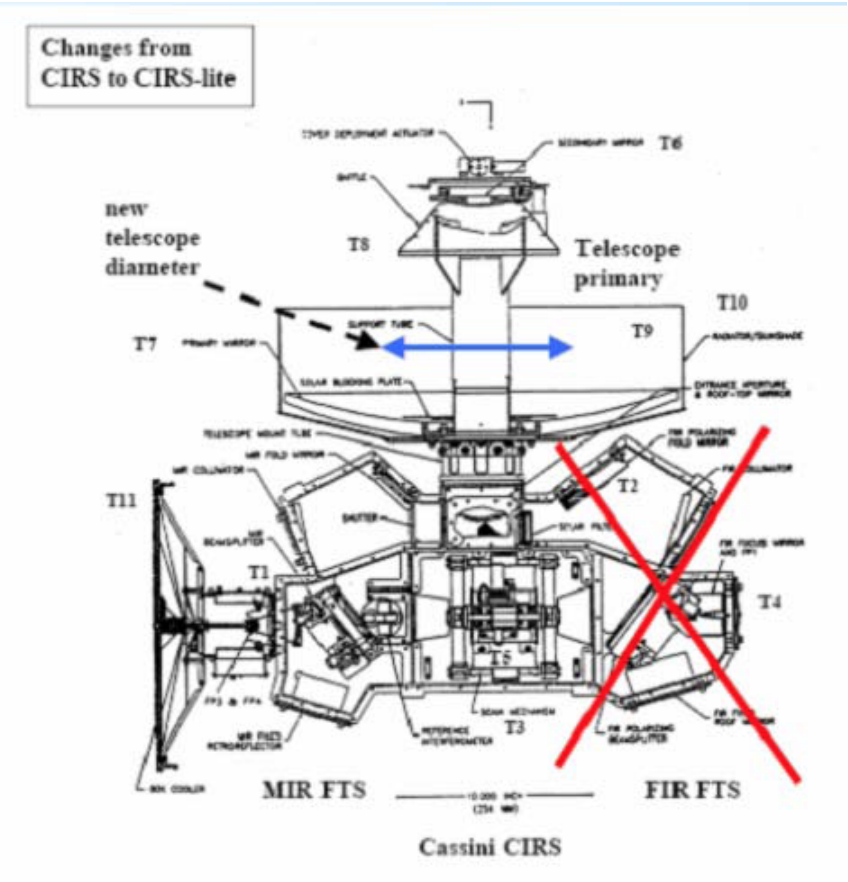
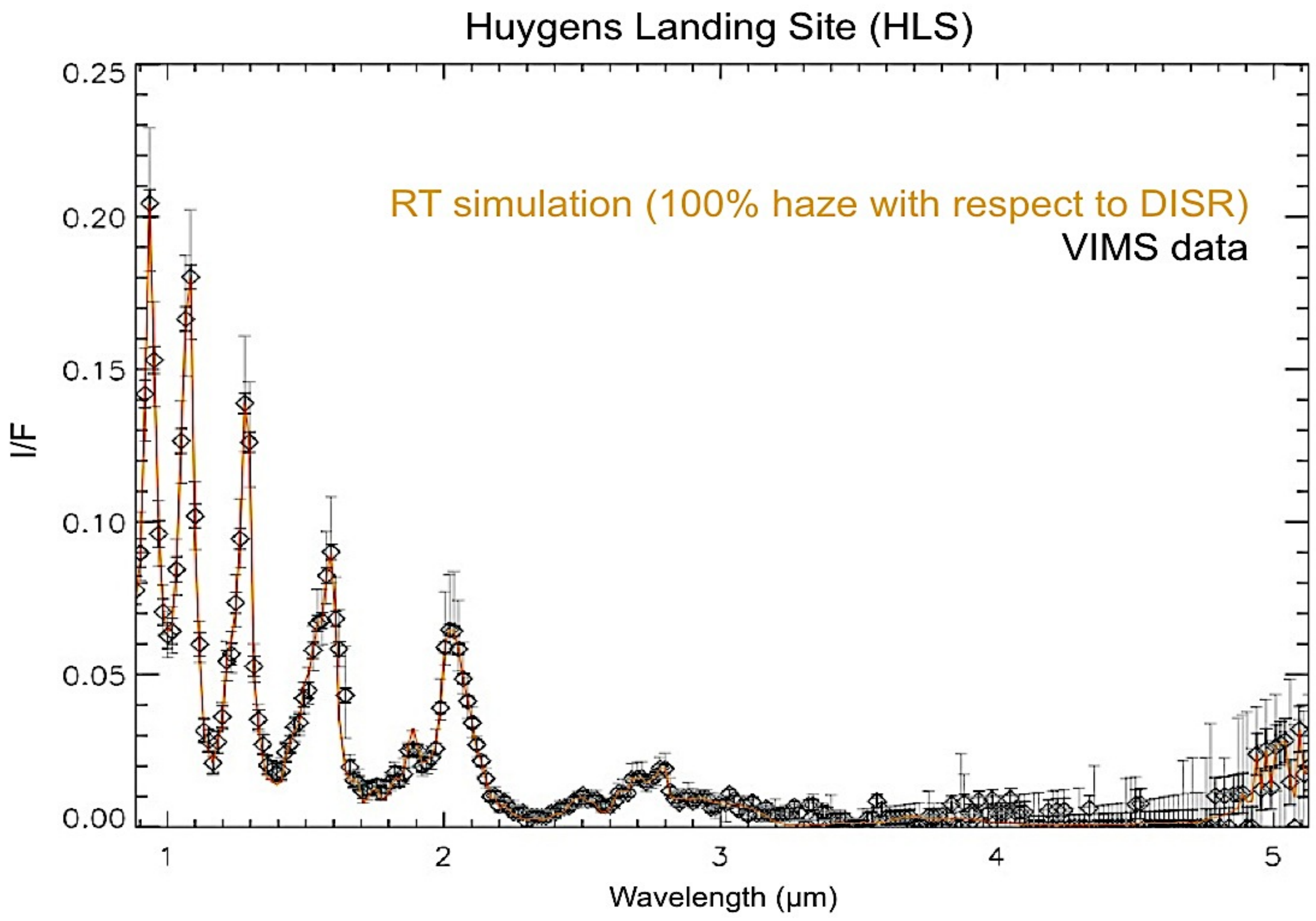

Changes from CIRS to CIRS-lite
new telescope diameter
Telescope primary
T6
T8
T7
T9
T10
T11
T1
T2
T3
T4
T5
MIR FTS
FIR FTS
Cassini CIRS

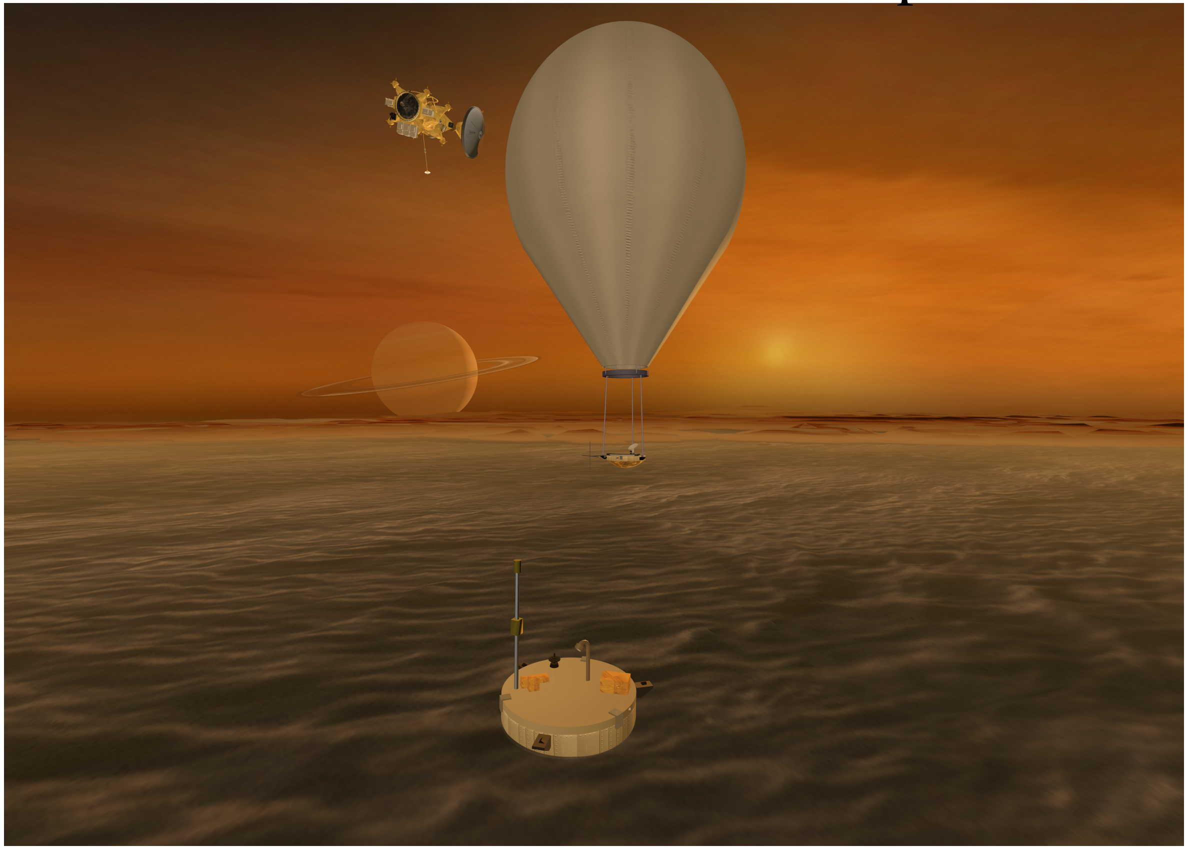
Figure 9



VIMS observations of Titan's lower atmosphere and surface in the near-IR with Cassini-VIMS: Solomonidou et al., 2016

Figure 10

The TSSM mission concept



References : Brasunas et al. 2012, *Intl Workshop on Instrumentation for Planetary missions;* Brucato et al., 2010, *A&A 516*; Carvano et al. 2007, *Icarus 187, 574*; Coustenis et al. 2003, *Icarus 161, 383*; 2009, *Exp. Astron. 23*; 2016, *Icarus, 270, 409*; Flasar et al. 2004, *Nature 427, 132*; Solomonidou et al. 2016, *270,85* and references therein.