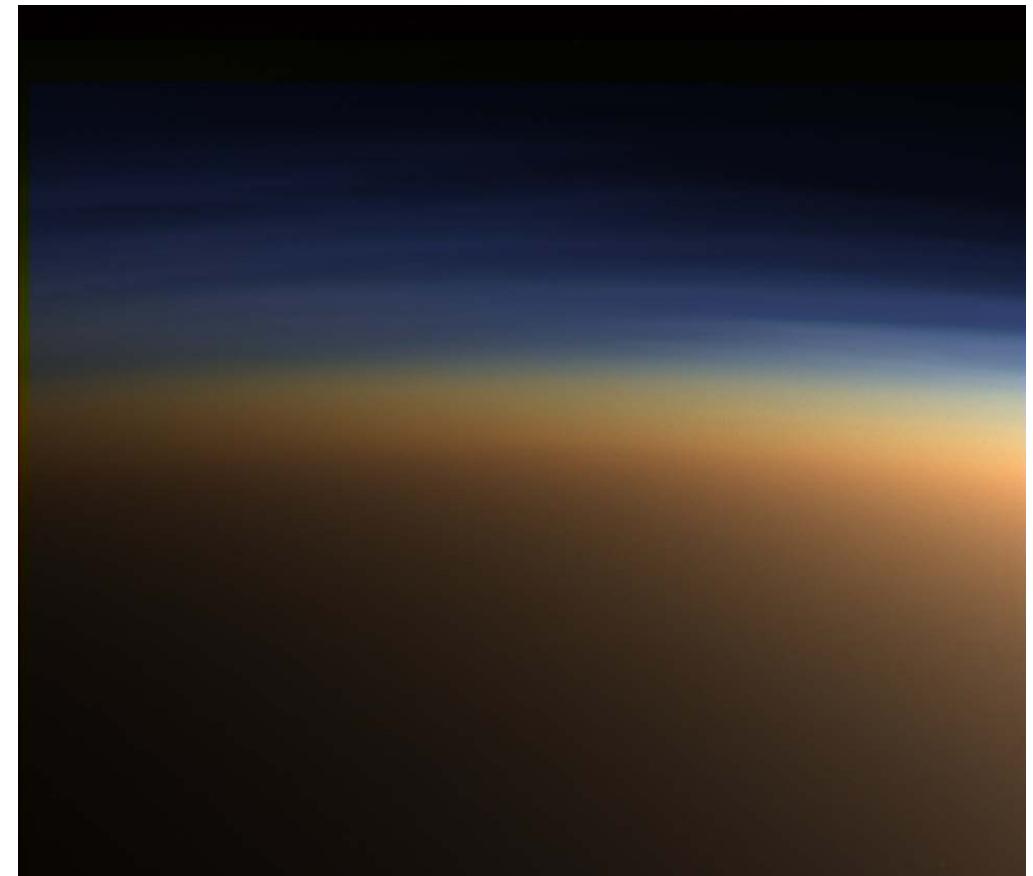
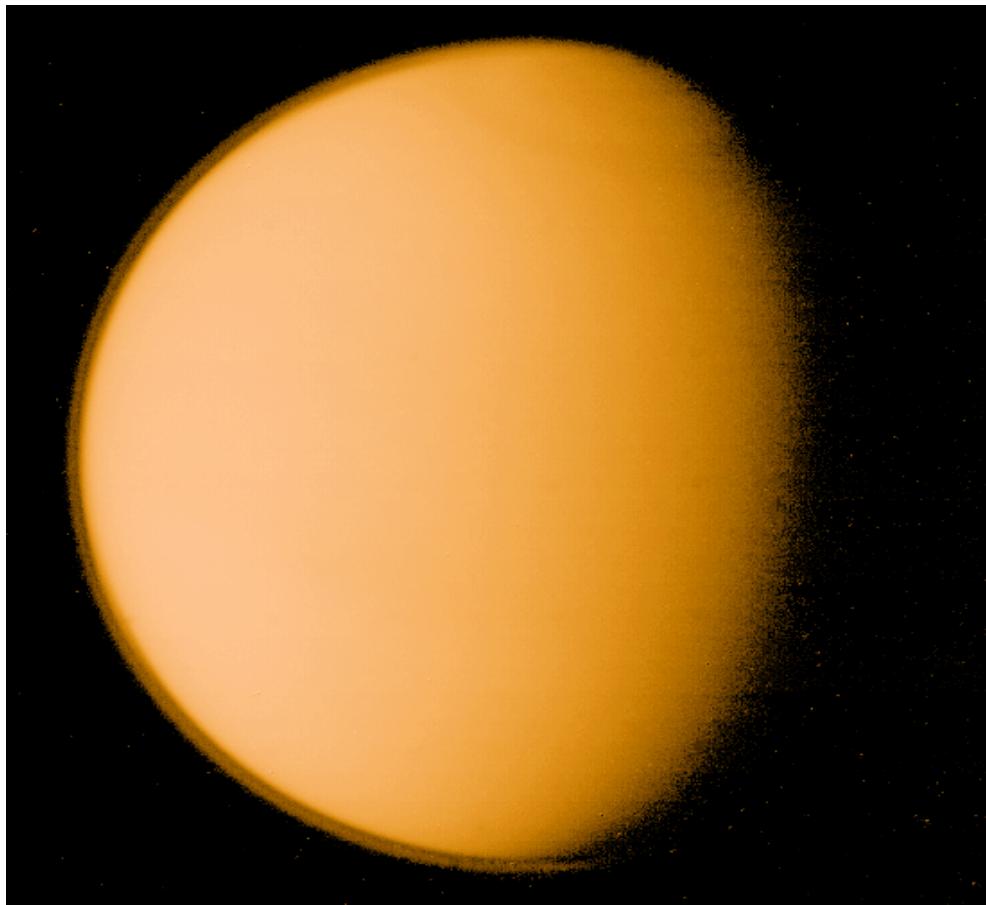


Spectroscopy of complex organic molecules on Titan



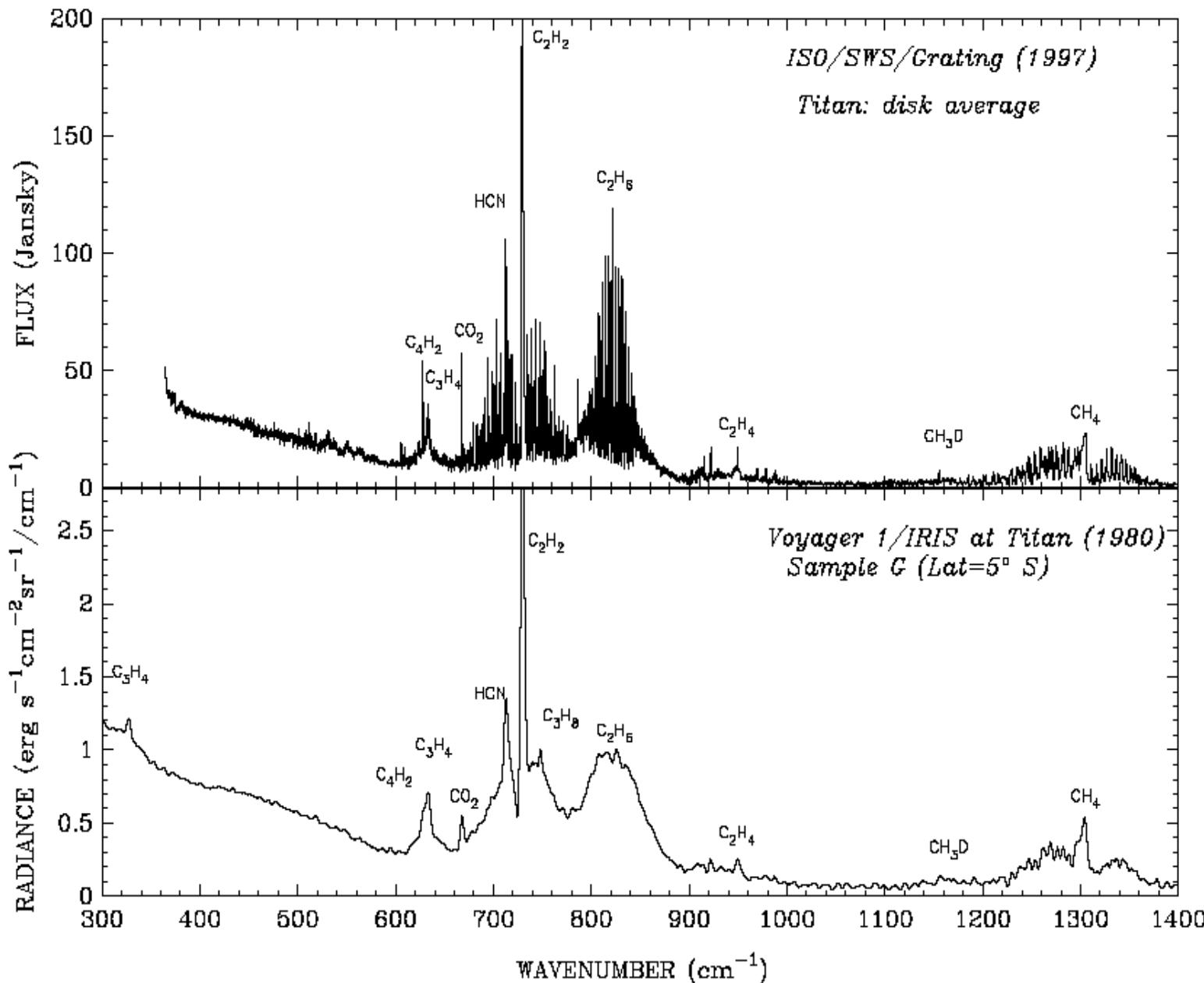
A. JOLLY

Outline of the talk

New molecules on Titan ?

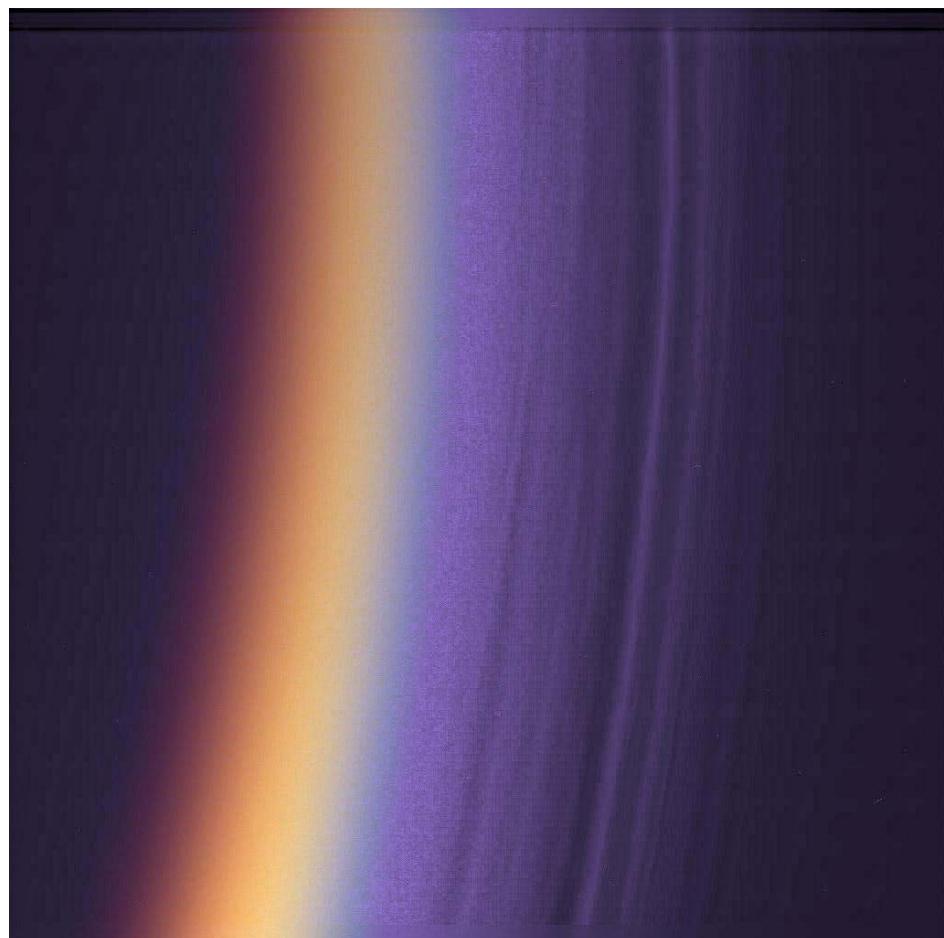
- Expected molecules from laboratory experiment
- Results from the Huygens lander
- Infrared observation from CIRS-CASSINI
- Improvement in infrared spectroscopy
- Ultraviolet observation from UVIS-CASSINI
- Improvement in ultraviolet spectroscopy

Past IR observations of TITAN

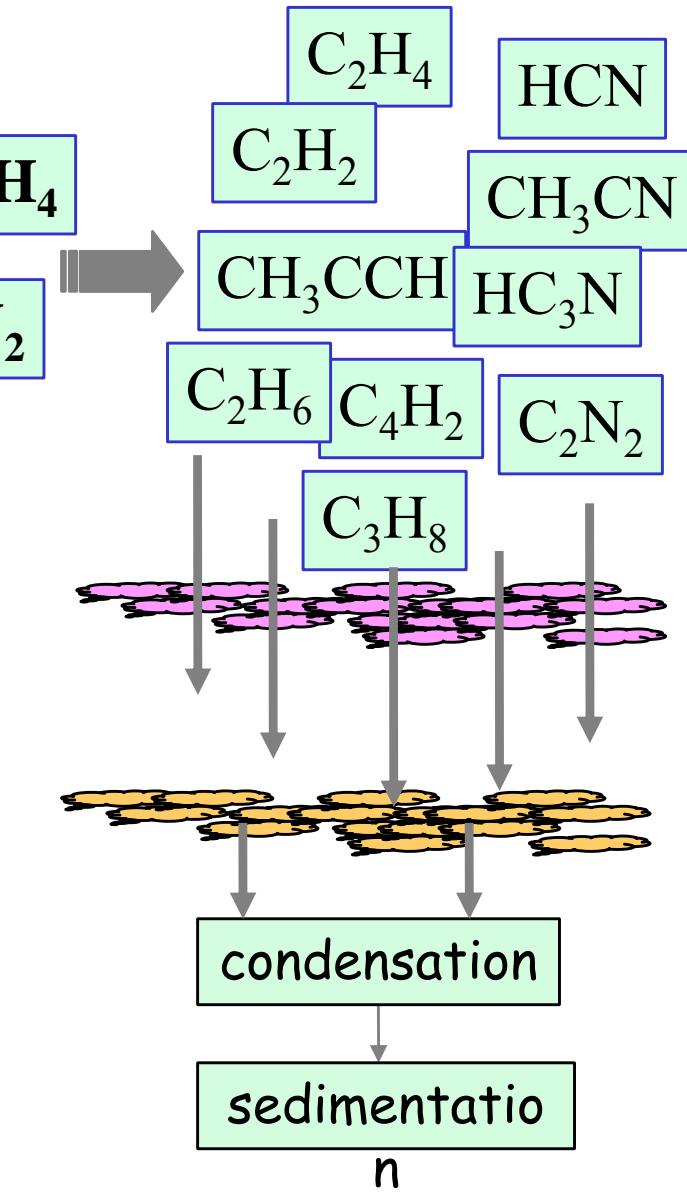
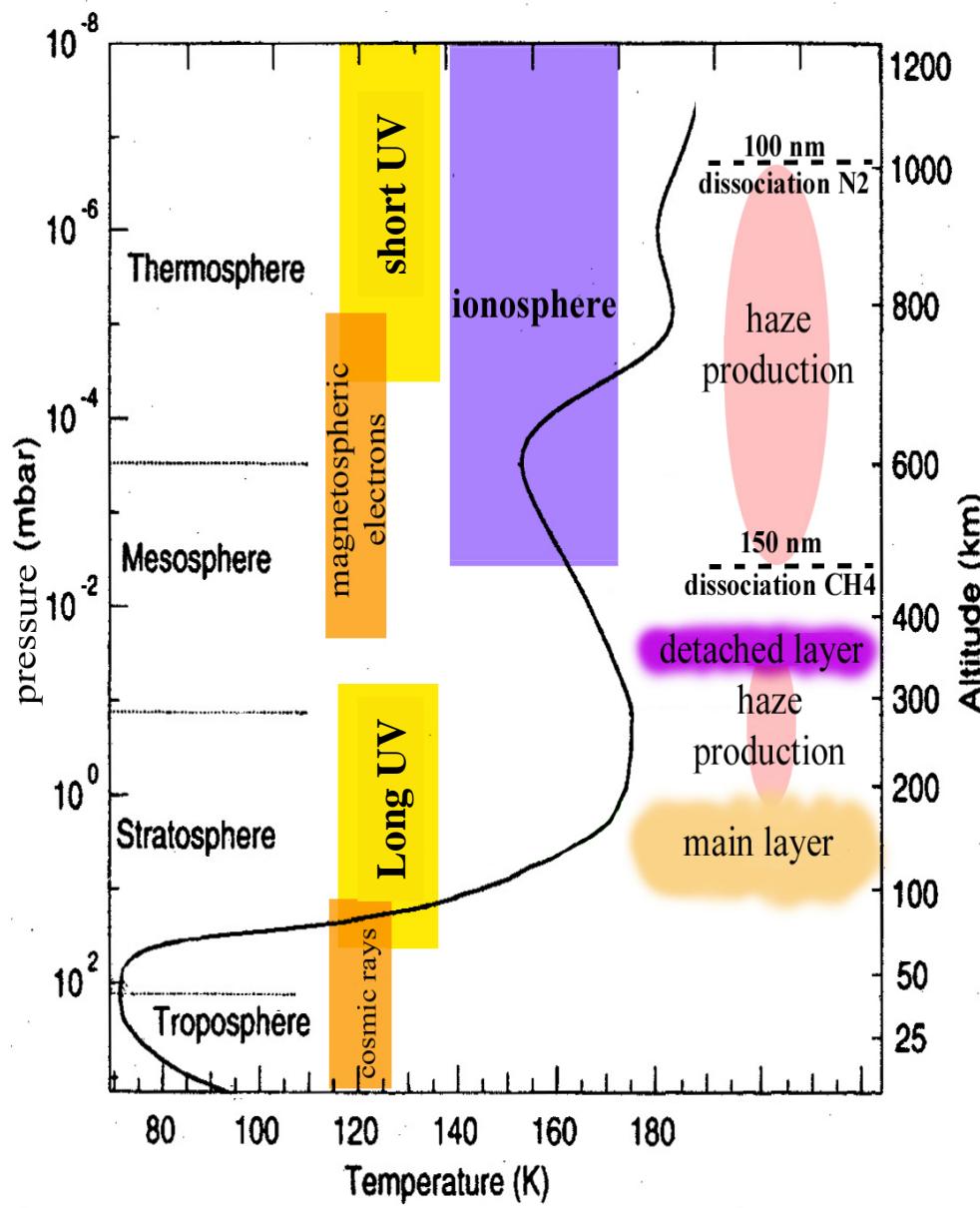


<u>Species</u>	<u>Abundances</u>
<u>Predominant species</u>	
N ₂	0.85 – 0.98
CH ₄	5.10 ⁻³ – 8,5.10 ⁻²
<u>Hydrocarbons</u>	
C ₂ H ₆	7.10 ⁻⁶ – 2,8.10 ⁻⁵
C ₂ H ₂	1,65.10 ⁻⁶ – 3,8.10 ⁻⁶
C ₃ H ₈	3.10 ⁻⁷ – 1.10 ⁻⁶
C ₂ H ₄	7.10 ⁻⁸ – 2.10 ⁻⁷
C ₃ H ₄ (propyne)	4.10 ⁻⁹ – 8,5.10 ⁻⁹
C ₄ H ₂	8.10 ⁻¹⁰ - 2.10 ⁻⁹
C ₃ H ₄ (allene)	< 10 ⁻⁹
C ₆ H ₆	1.10 ⁻¹⁰ - 7.10 ⁻¹⁰
C ₆ H ₂	?
<u>Nitriles</u>	
HCN	1.10 ⁻⁷ – 4.10 ⁻⁷
HC ₃ N	8. 10 ⁻¹⁰ – 8,4.10 ⁻⁸
CH ₃ CN	1,5.10 ⁻⁹ – 10 ⁻⁸
C ₂ N ₂	some 10 ⁻⁹
C ₄ N ₂	solid
HC ₅ N	?
<u>Oxygenated compounds</u>	
CO	3,3.10 ⁻⁶ – 6,4.10 ⁻⁵
CO ₂	9.10 ⁻⁹ – 2,2.10 ⁻⁸
H ₂ O	8.10 ⁻⁹

Titan's atmosphere

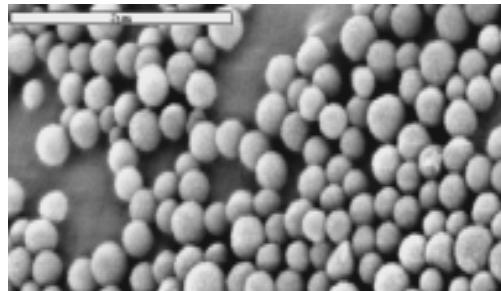


Titan's Atmospheric chemistry



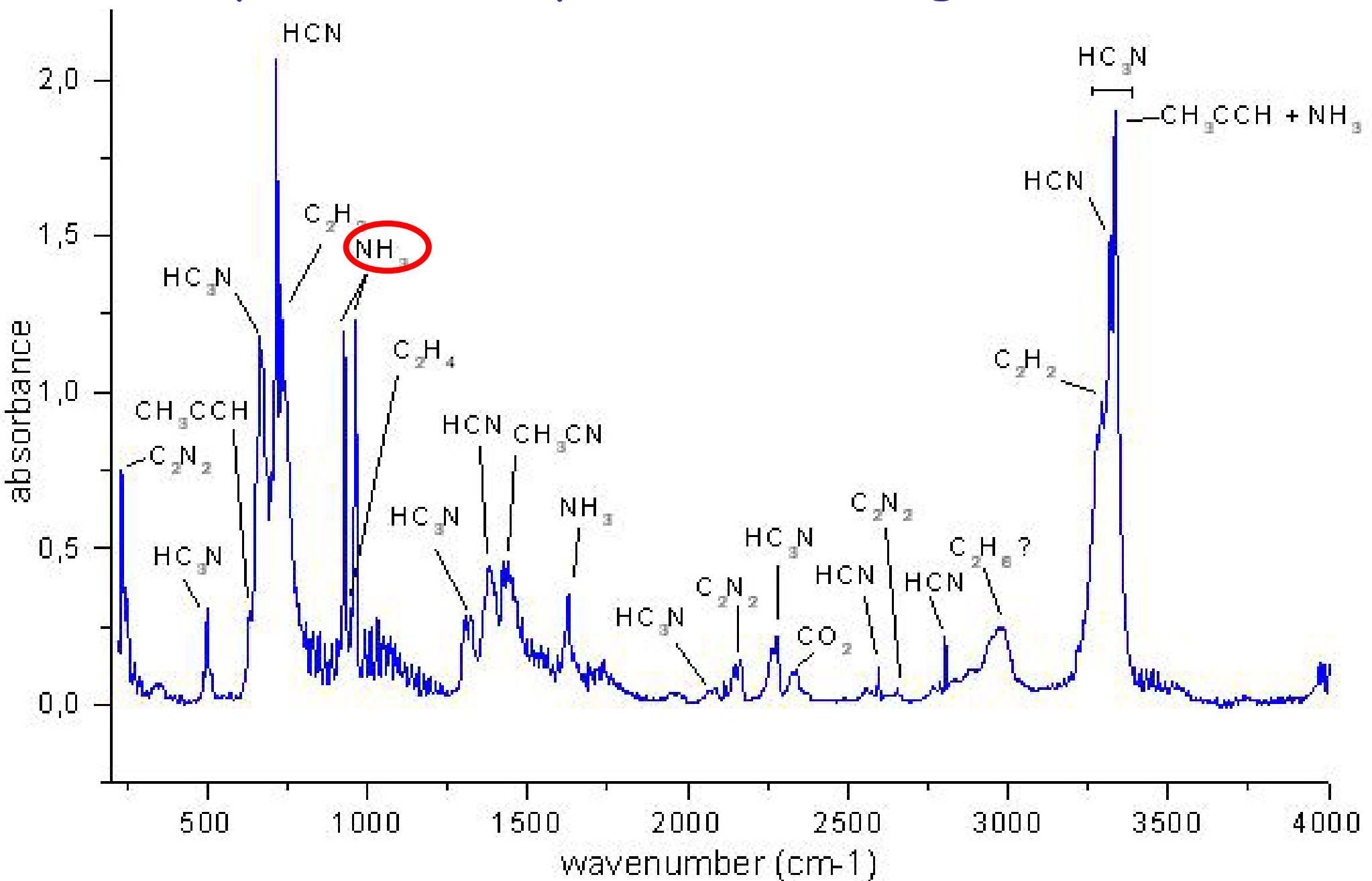
Dust formation on TITAN and in the laboratory?

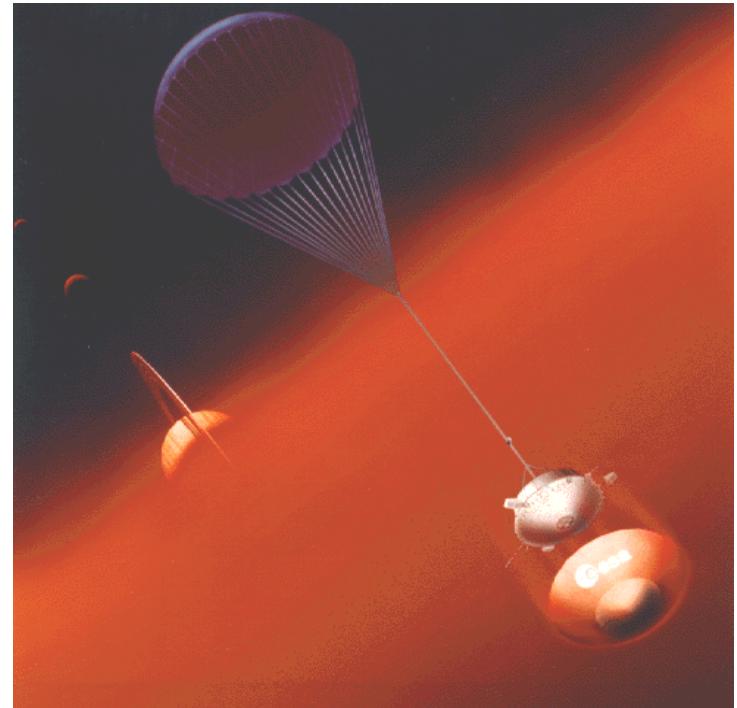
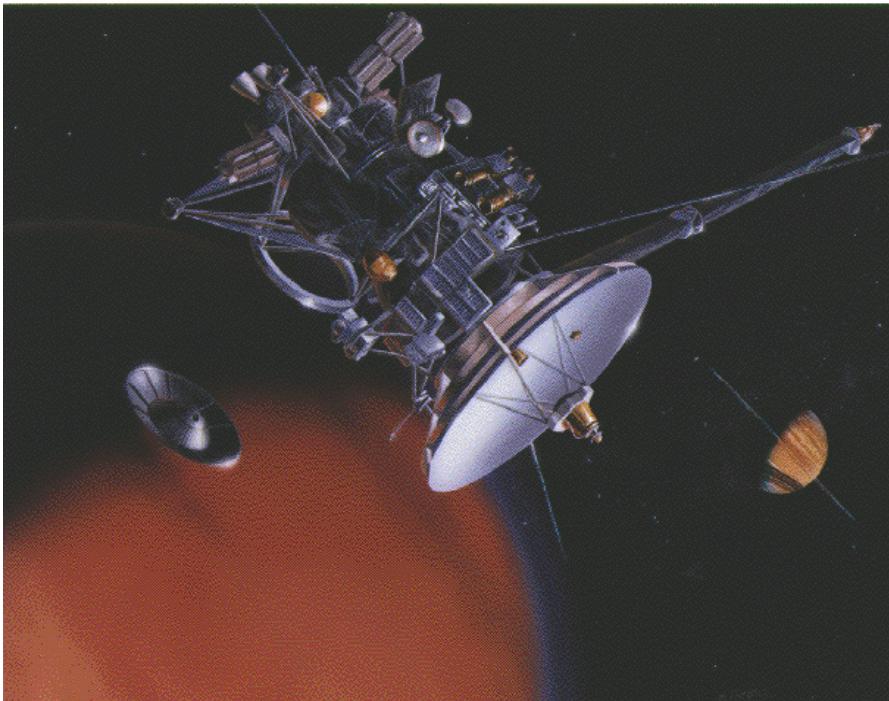
Organic particles are easily formed in a N₂/CH₄ plasma



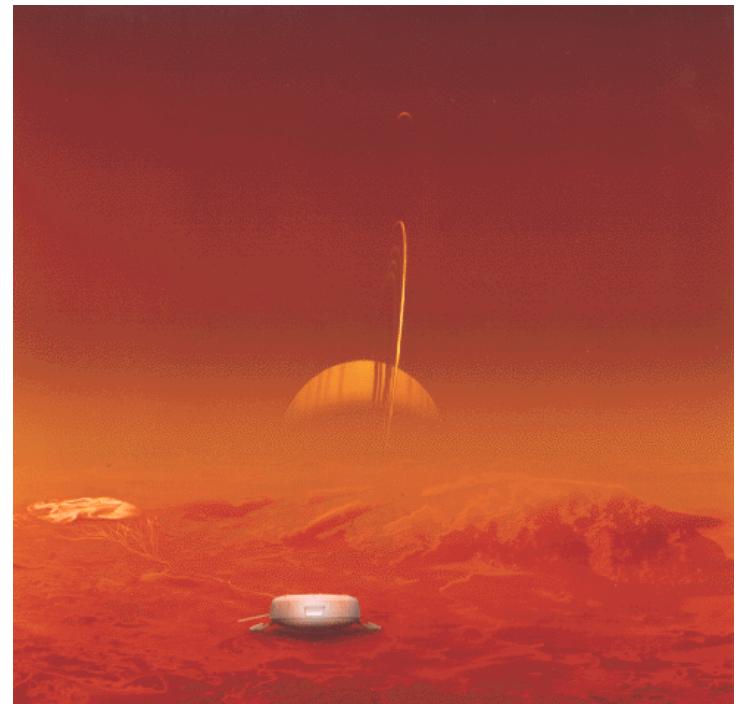
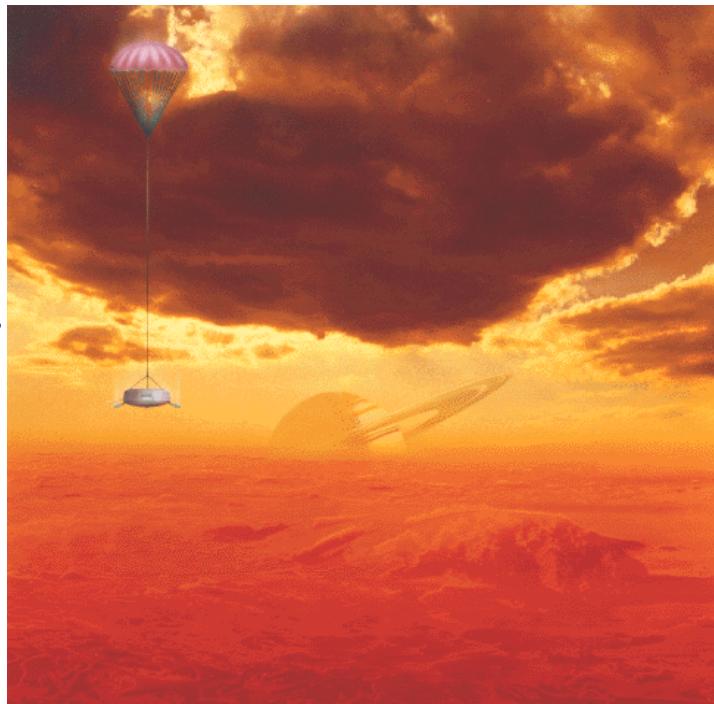
- **Characteristics :**
- molecules formed (all molecules detected on Titan and more)
- Refraction Index (compared to Titan's albedo)
- Chemical composition (C/N ratio)
- UV emission Spectroscopic analysis (radicals ; CN, NH, CH)
-

IR spectrum of a mixture produced by a N₂/CH₄ plasma discharge

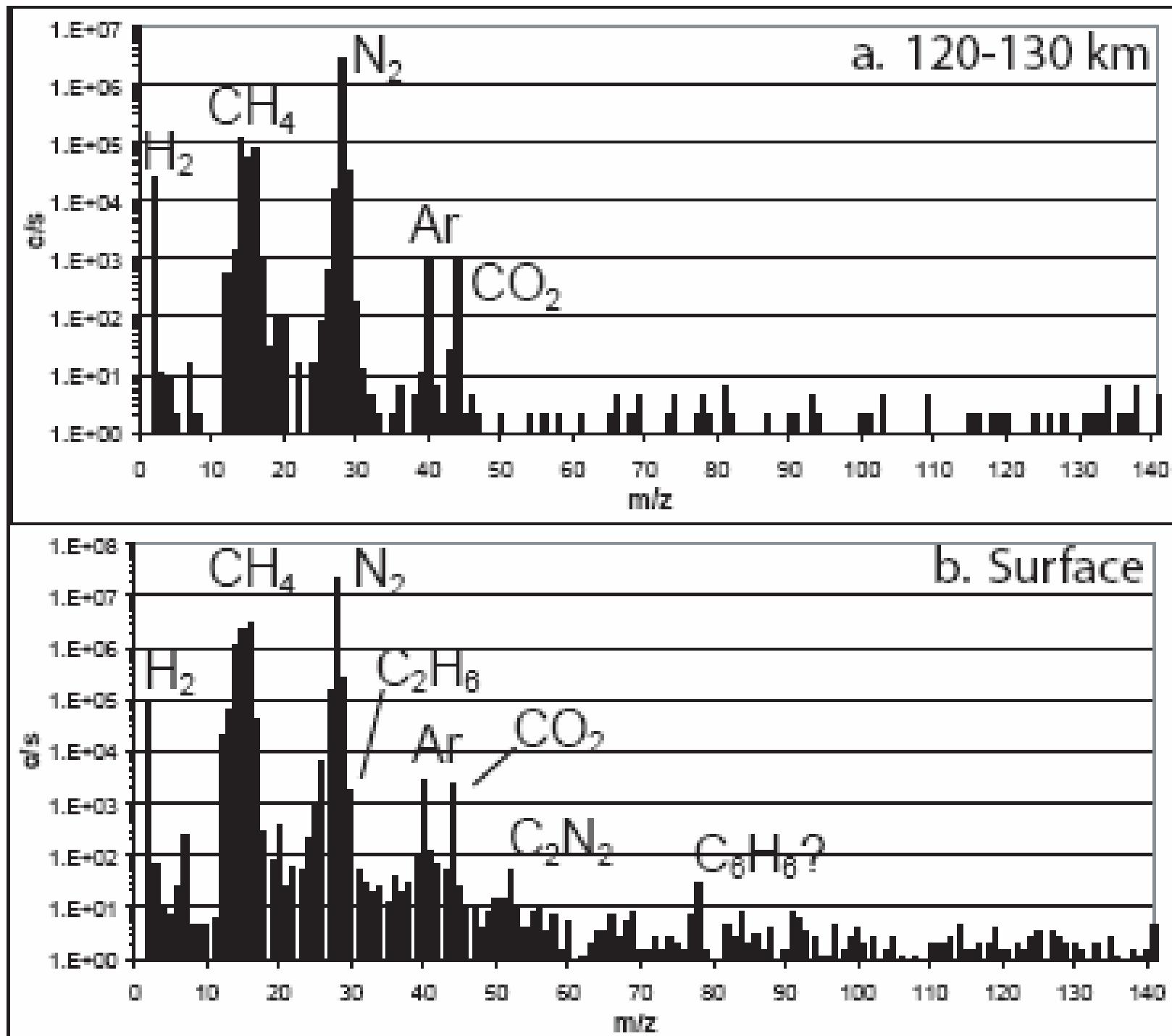




Huygens
Atmosphérique
Entry:
14-01-2005

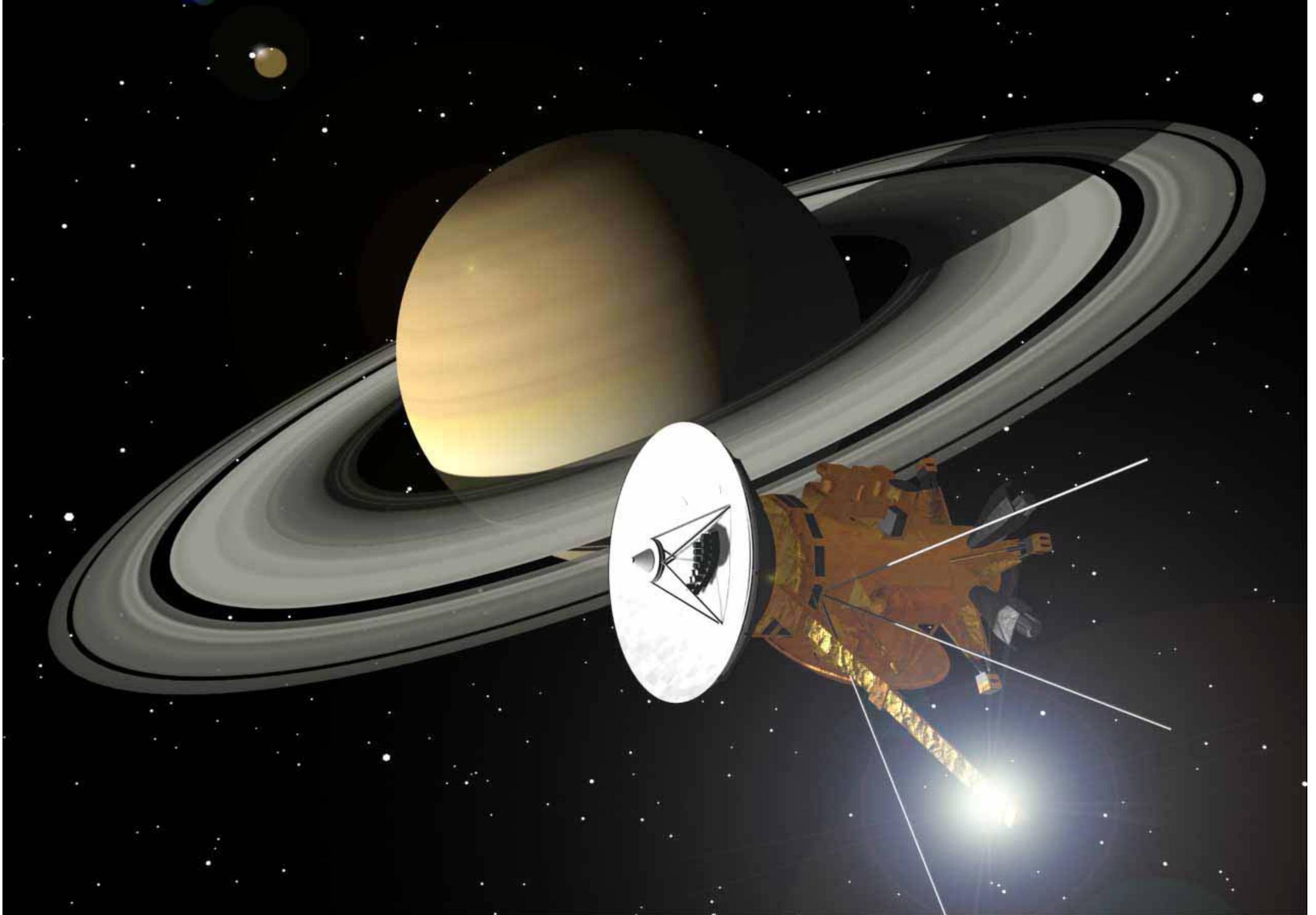


Huygens GC-MS data





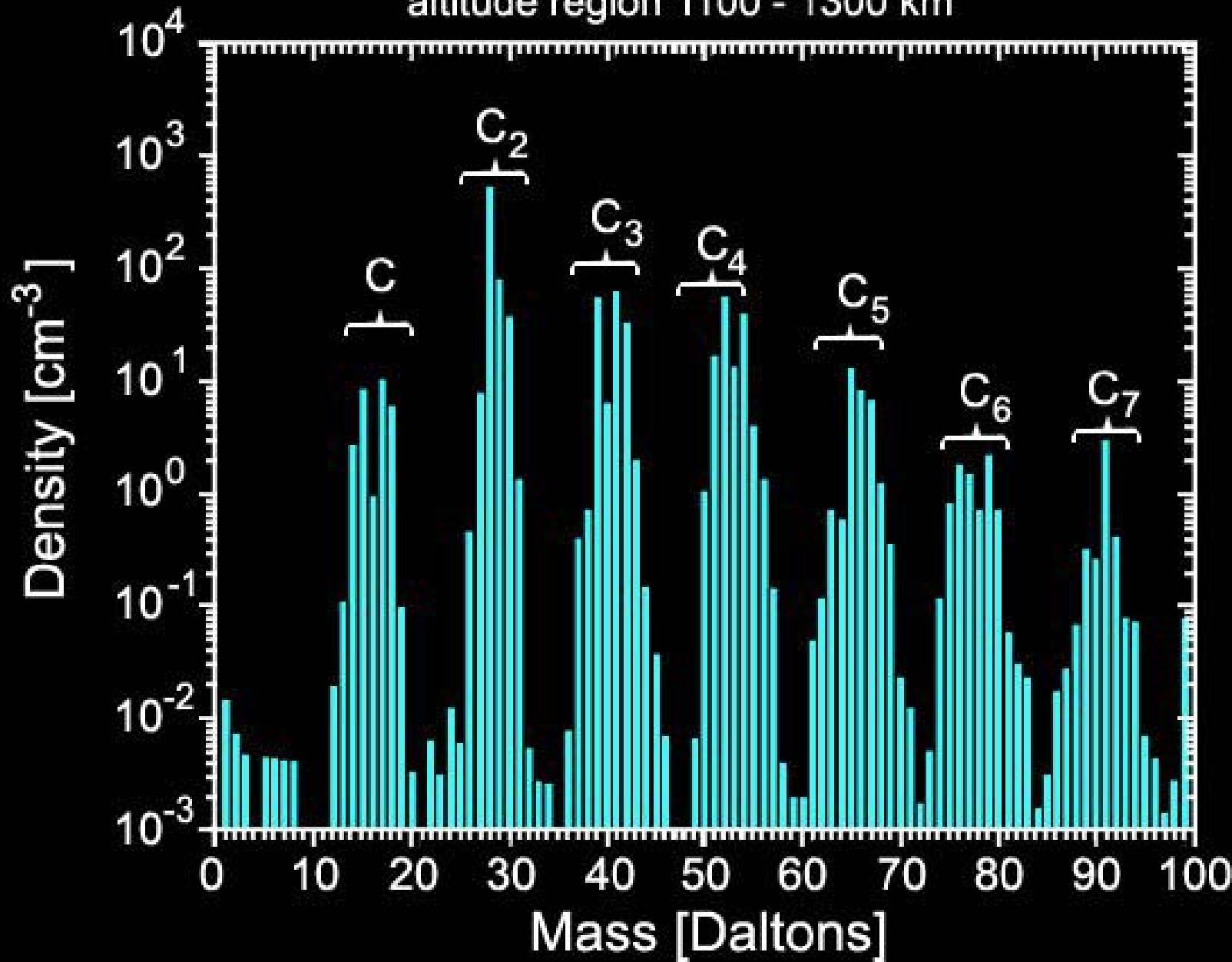




Cassini at Saturn since 1. July 2004

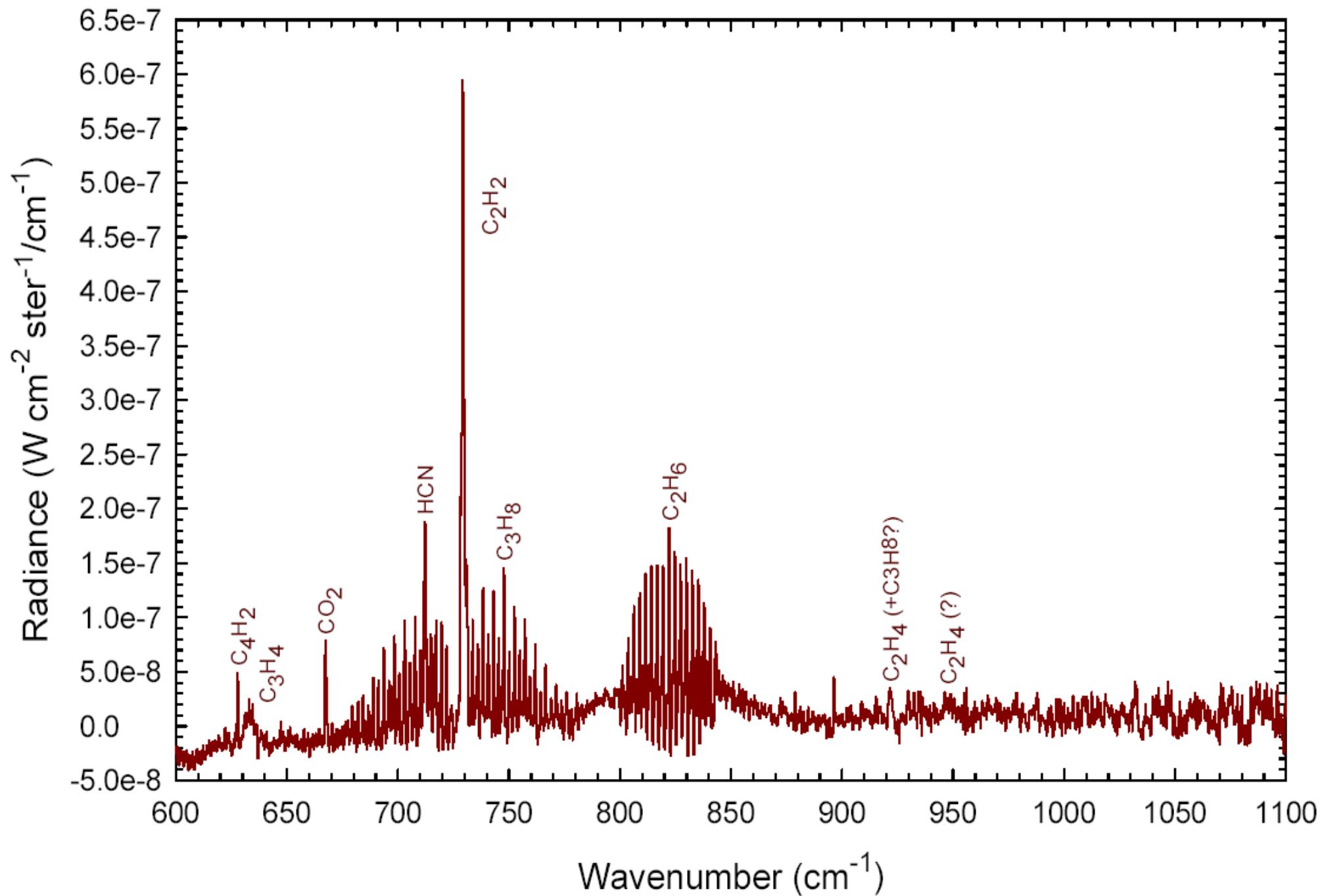
INMS

Titan's Ionospheric Density
altitude region 1100 - 1300 km

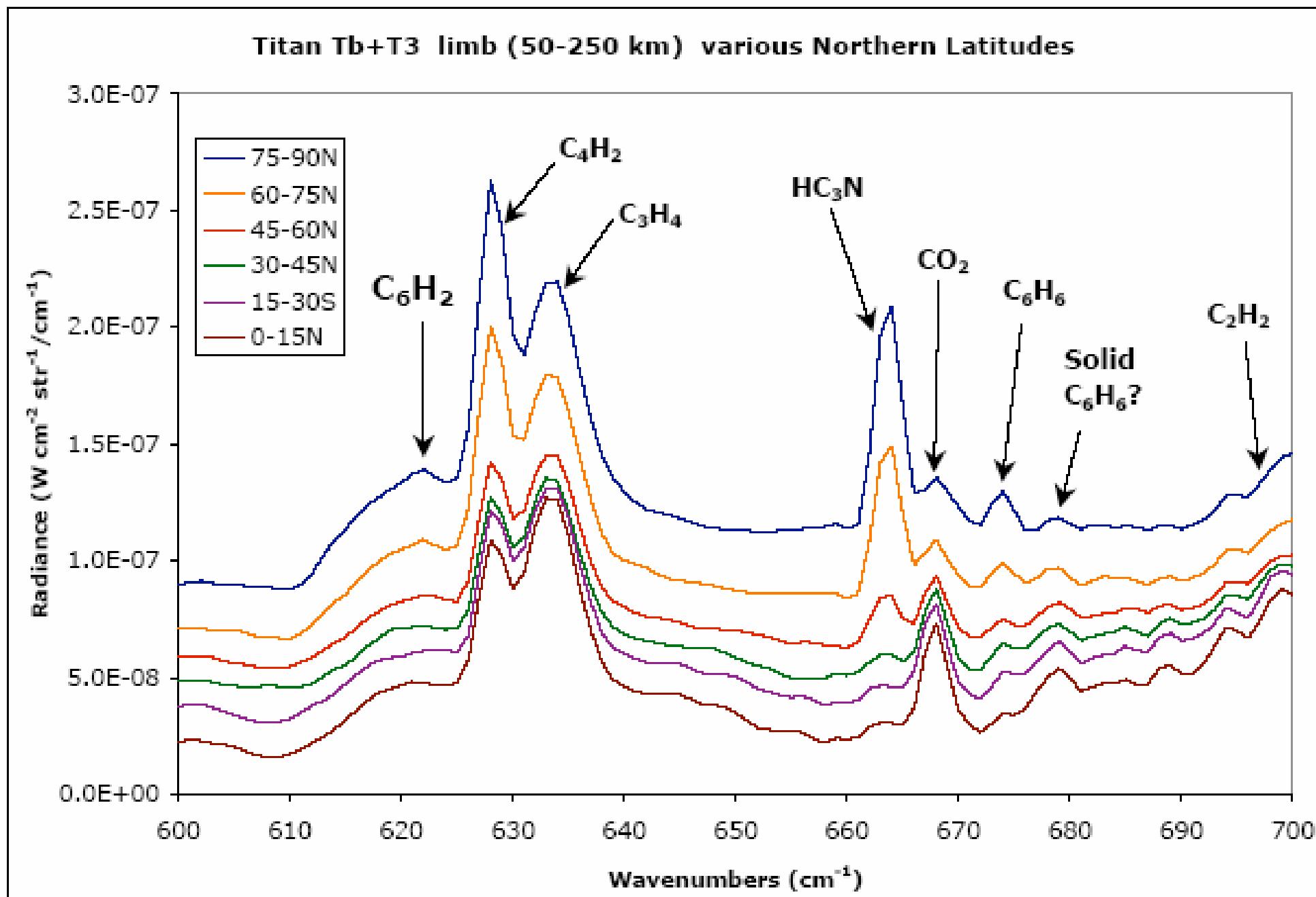


2004 Day 162: CIRS Titan Spectrum - FP3 Detector 05

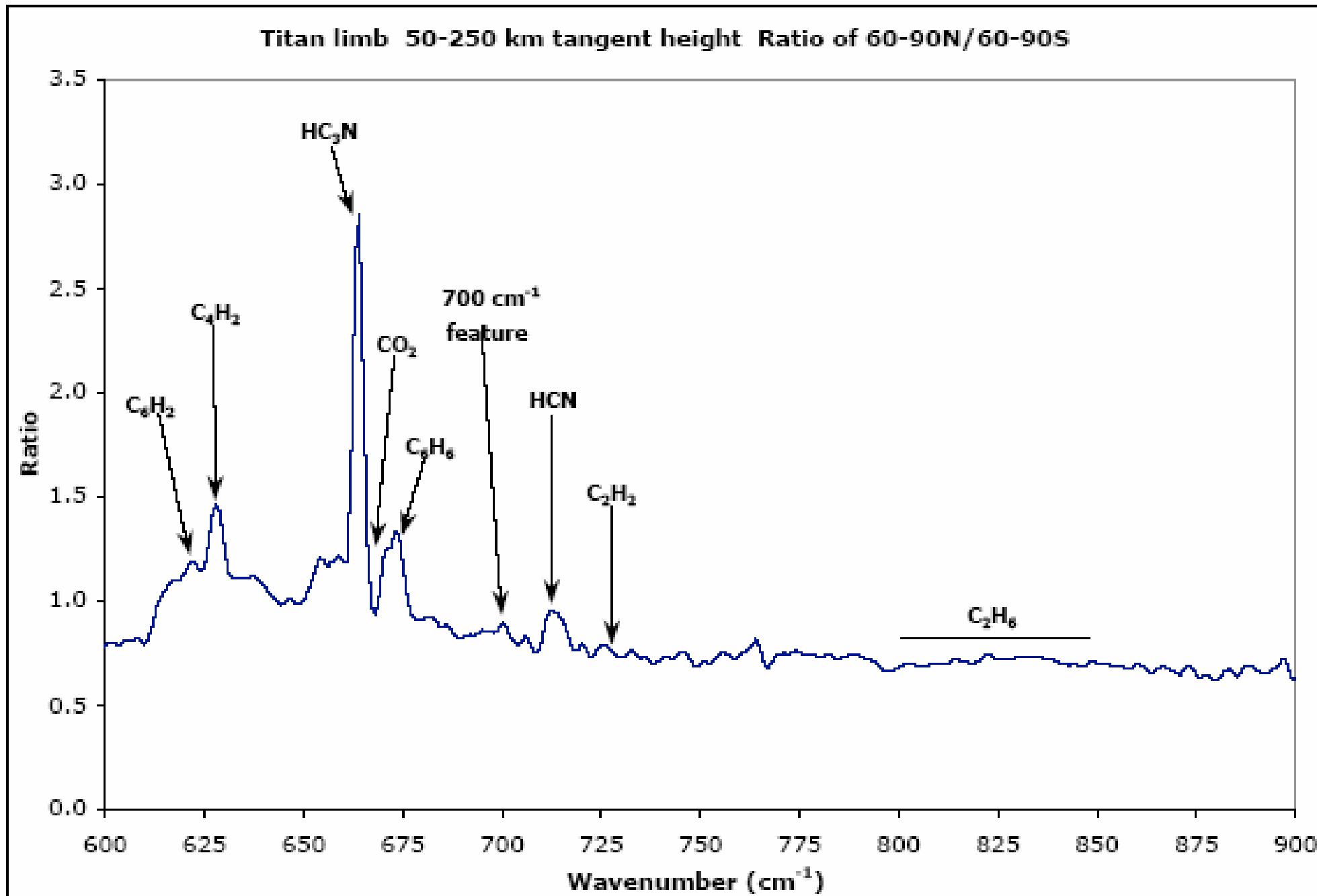
12 Coadded Scans: Spectral Resolution = 0.53 cm^{-1} Apodized

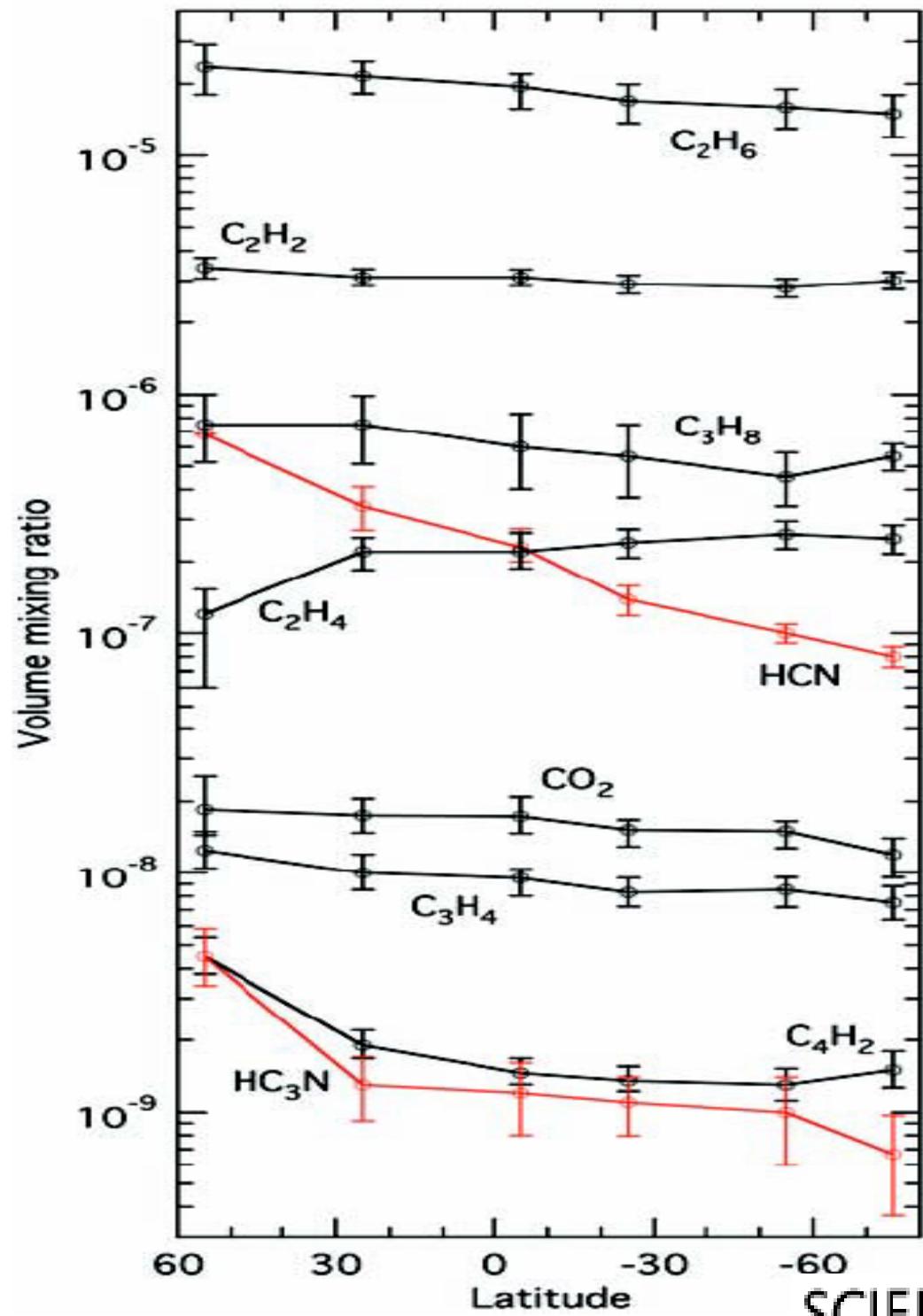


CIRS Observations of Titan : various latitudes



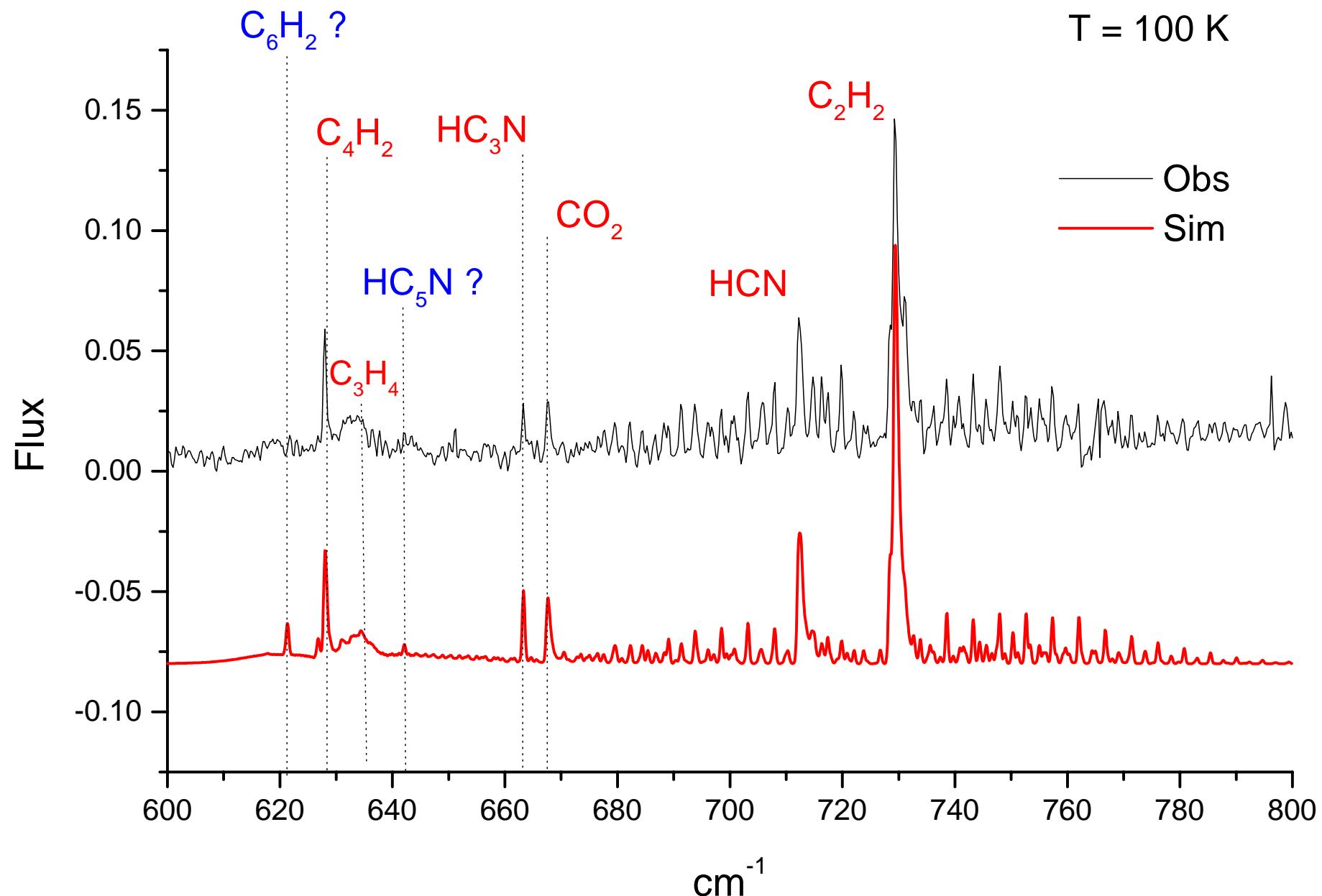
CIRS Observations of Titan : north to south ratio



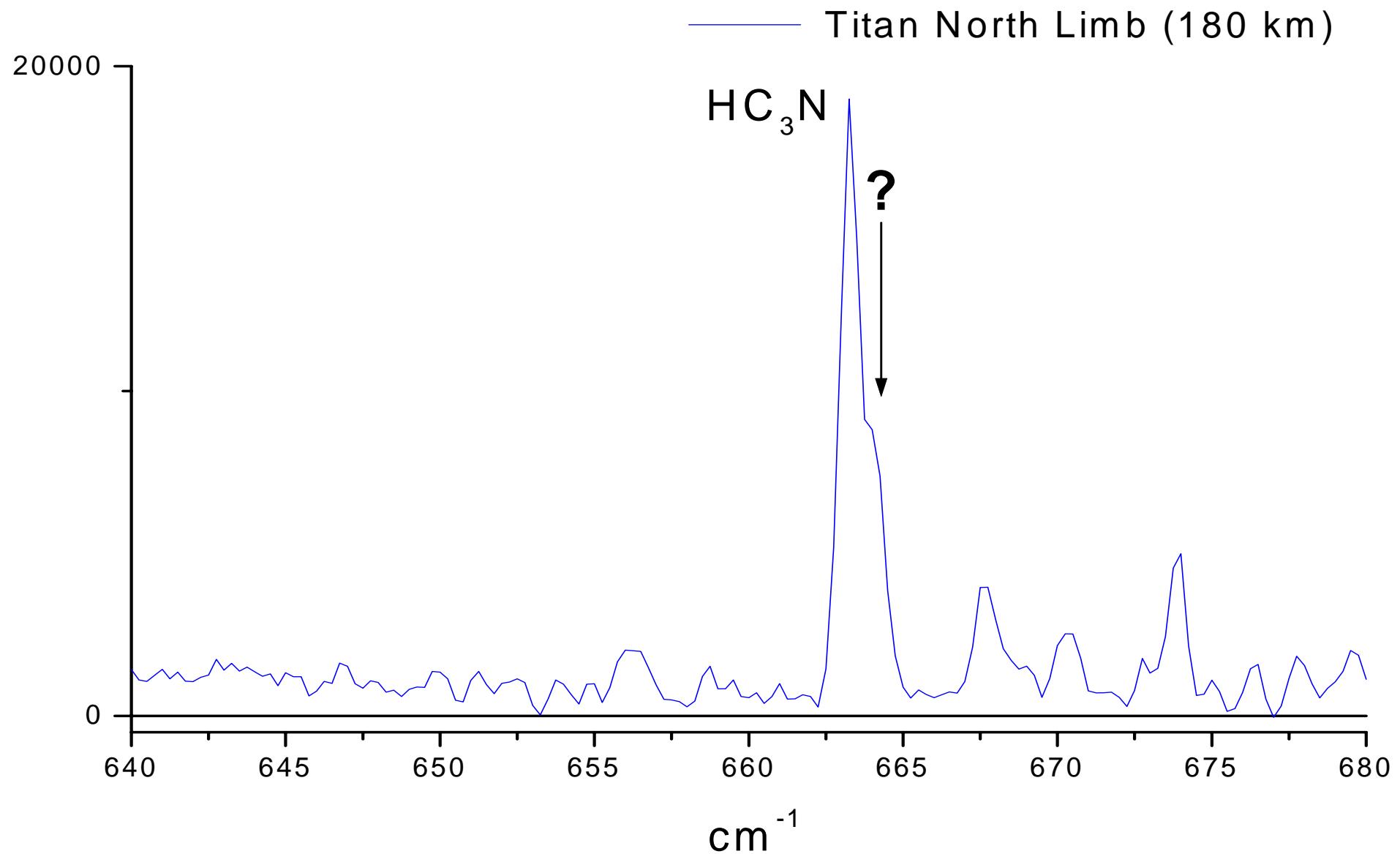


CASSINI MISSION
Composite InfraRed Spectrometer

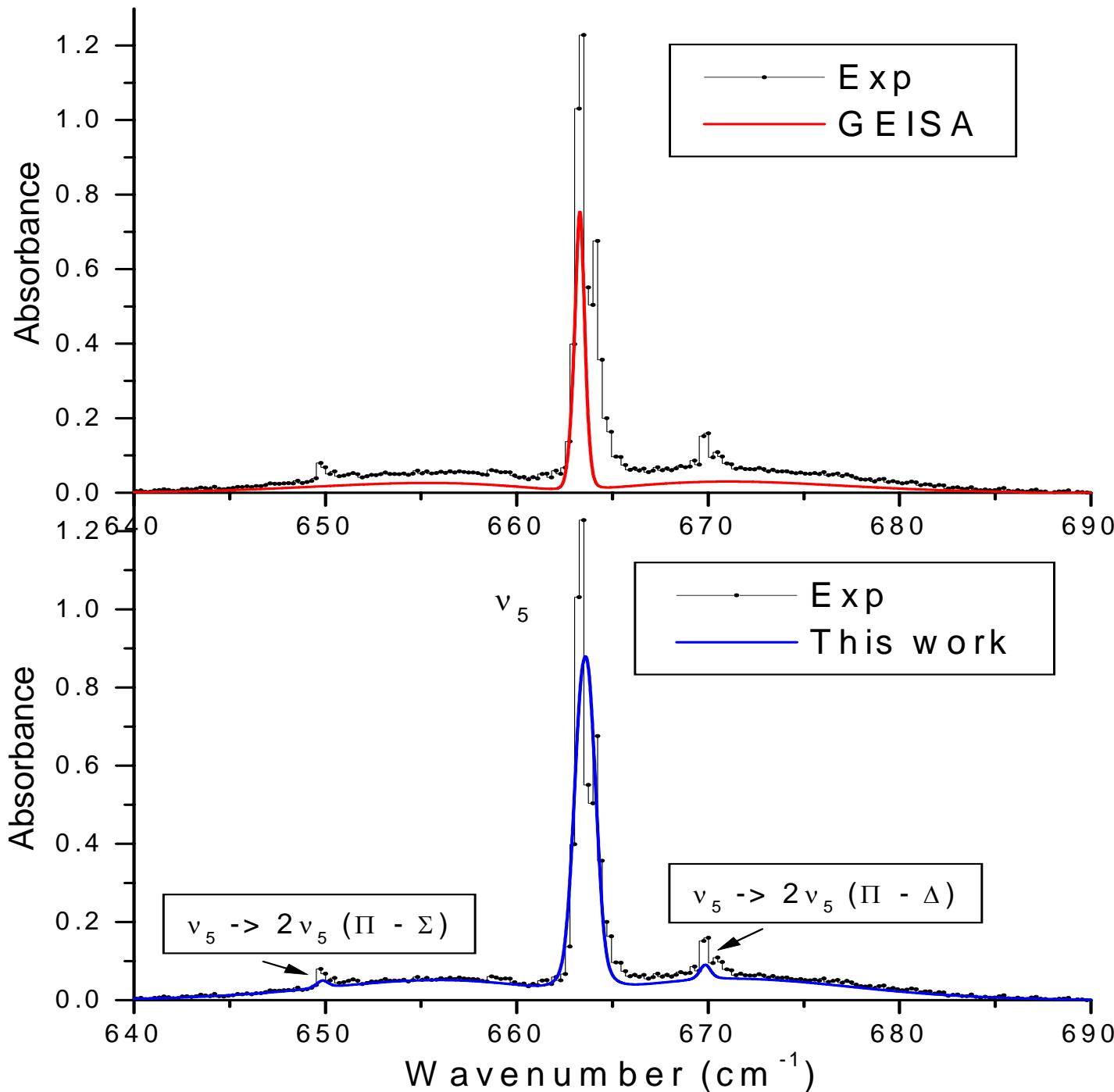
TITAN Limb Observation (CIRS)



HC_3N in Titan. Hot bands ?

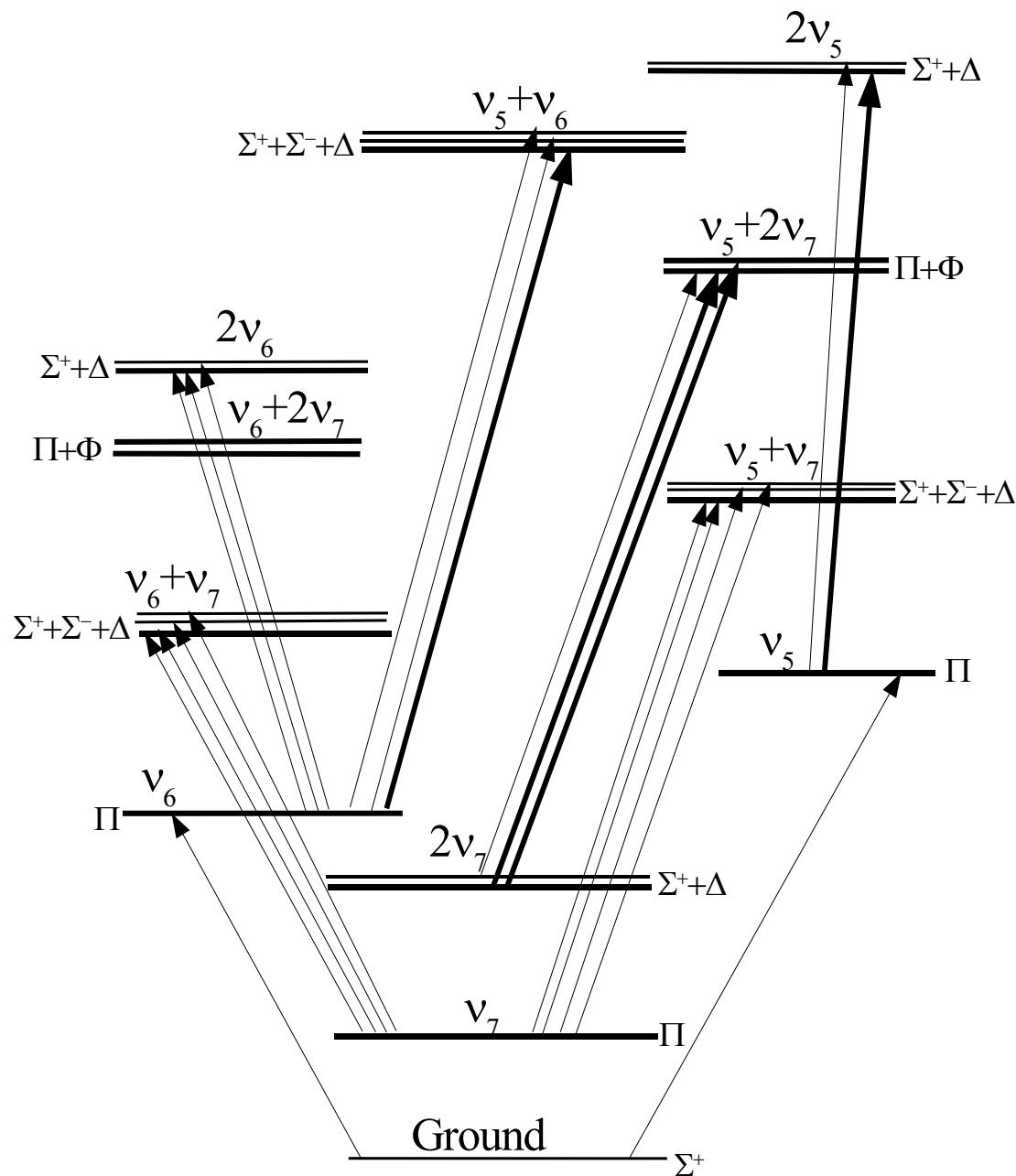


Infrared Spectra of HC_3N (resolution : 0.5 cm^{-1})



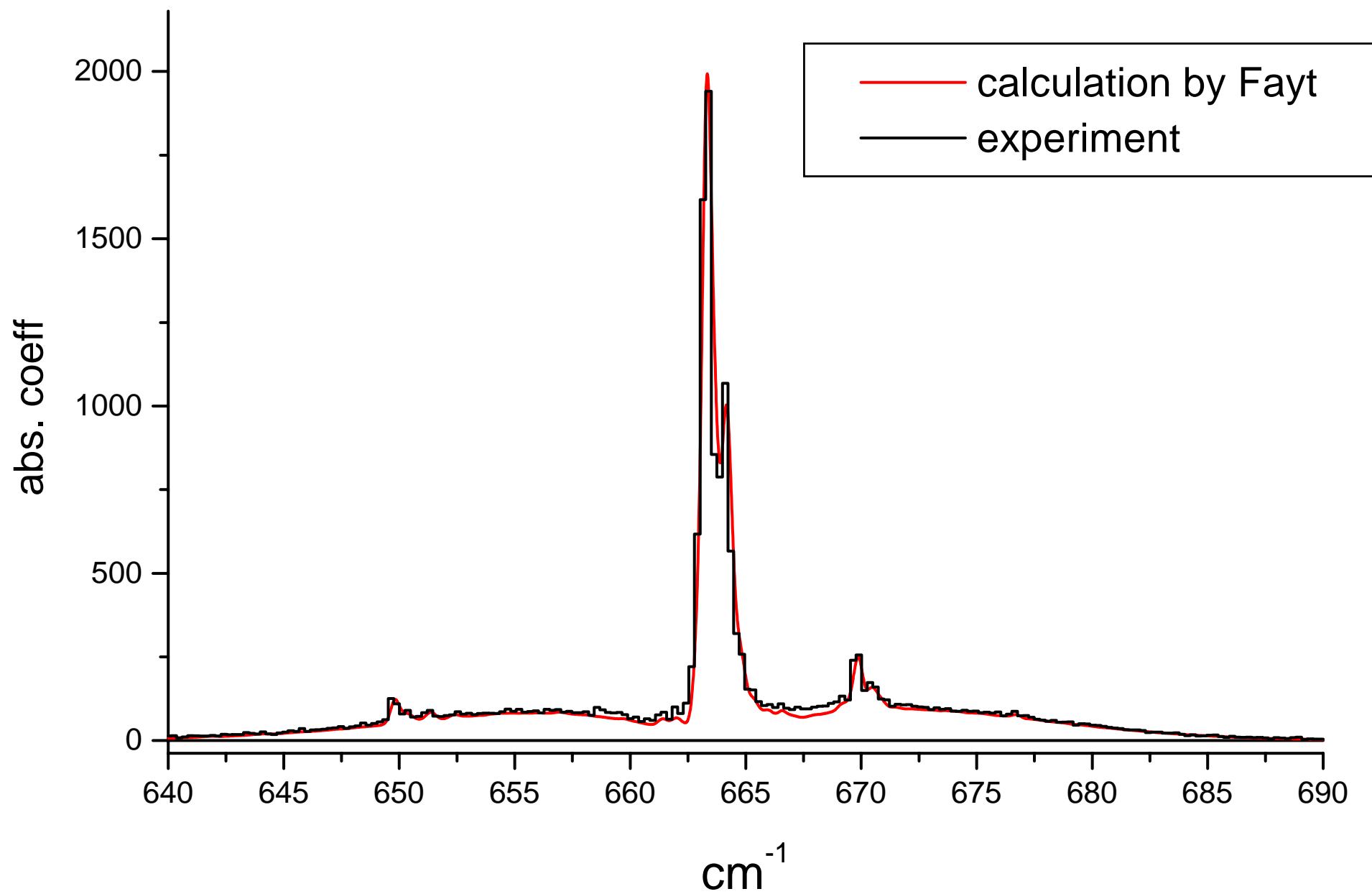
Energy level diagram : HC_3N

Hot bands in HC_3N

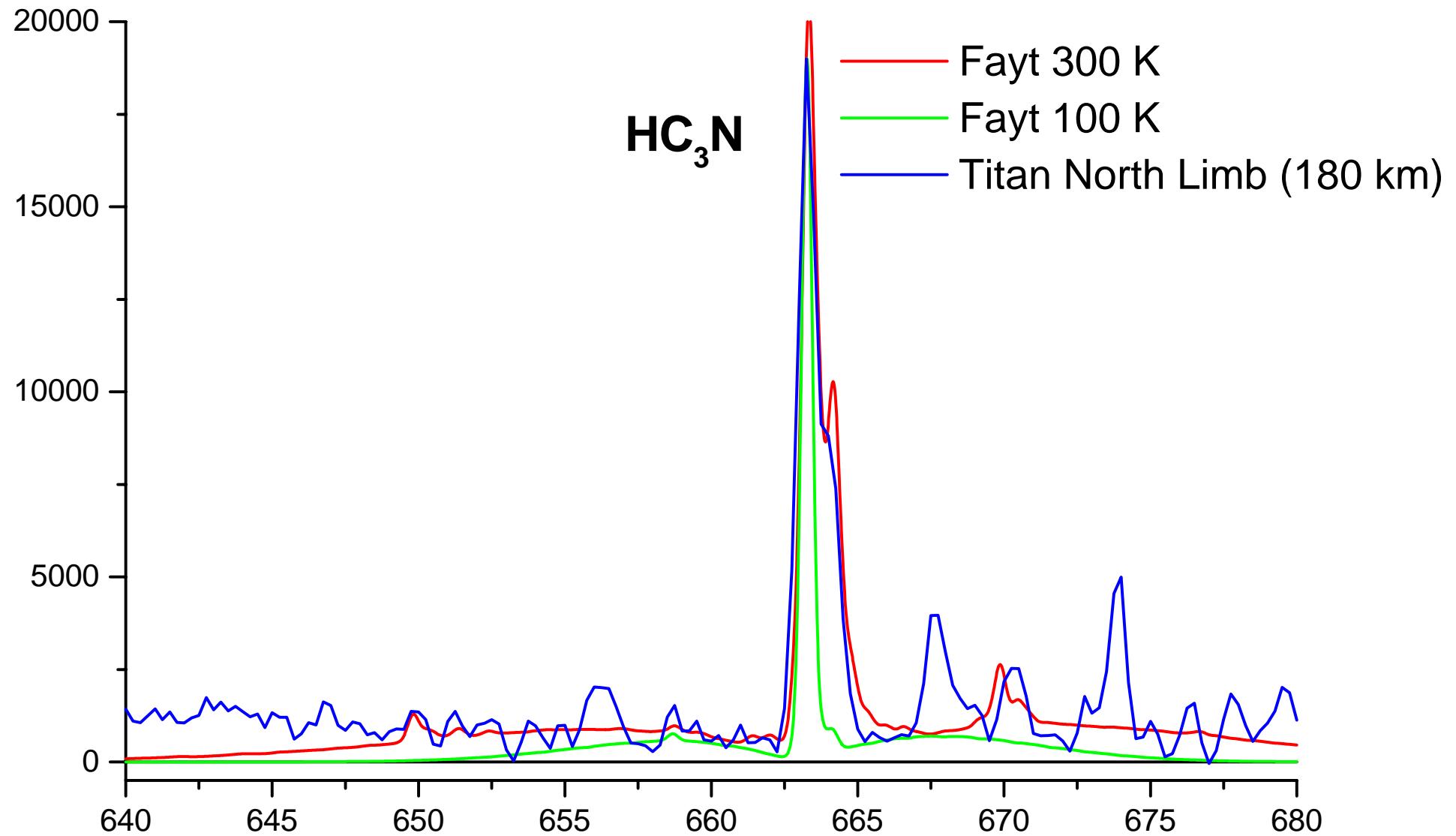


33 % of the population in
the ground level at room T

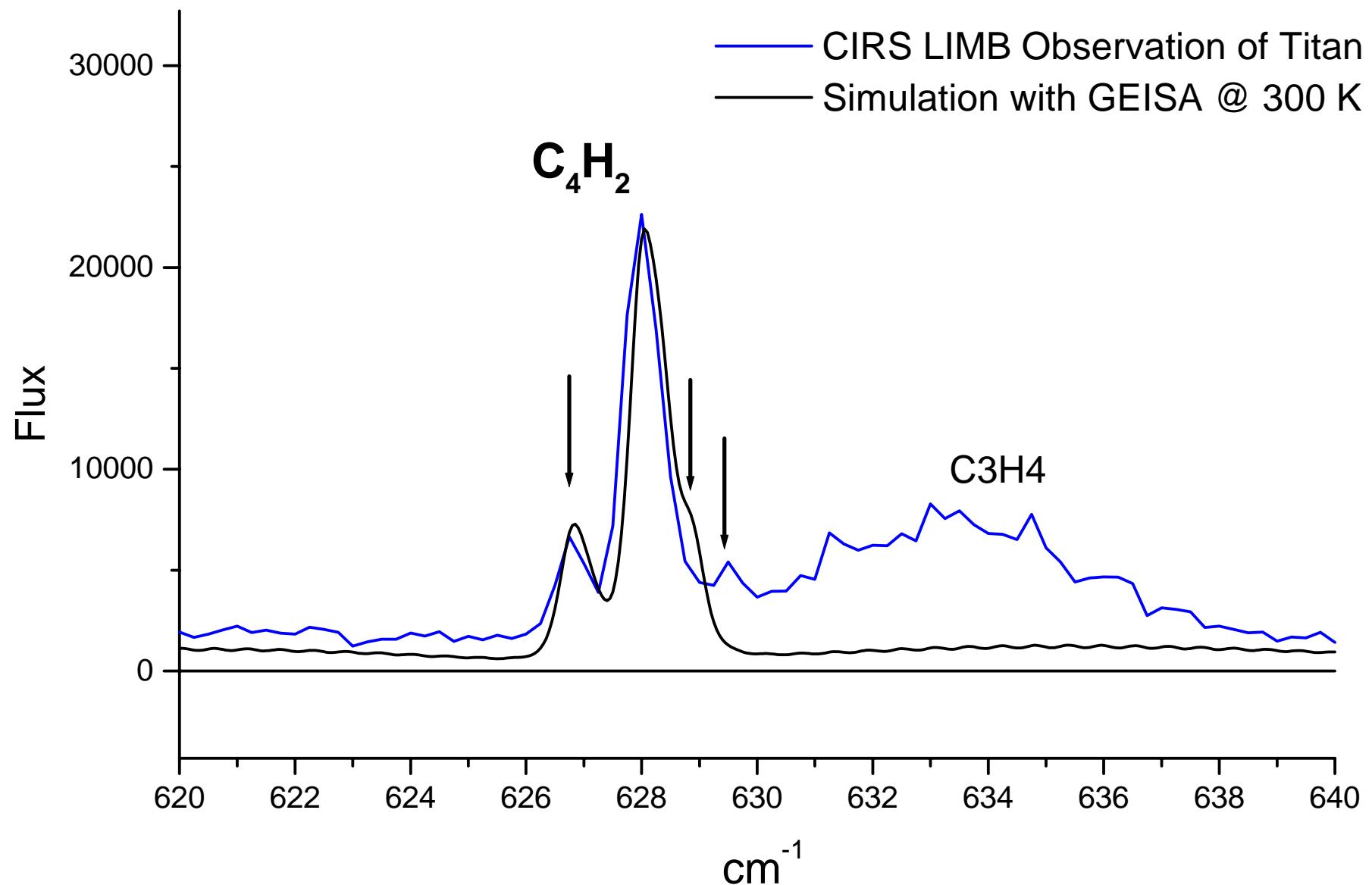
Fayt et al. (2000) 181 sublevels between 0 and 1750 cm⁻¹



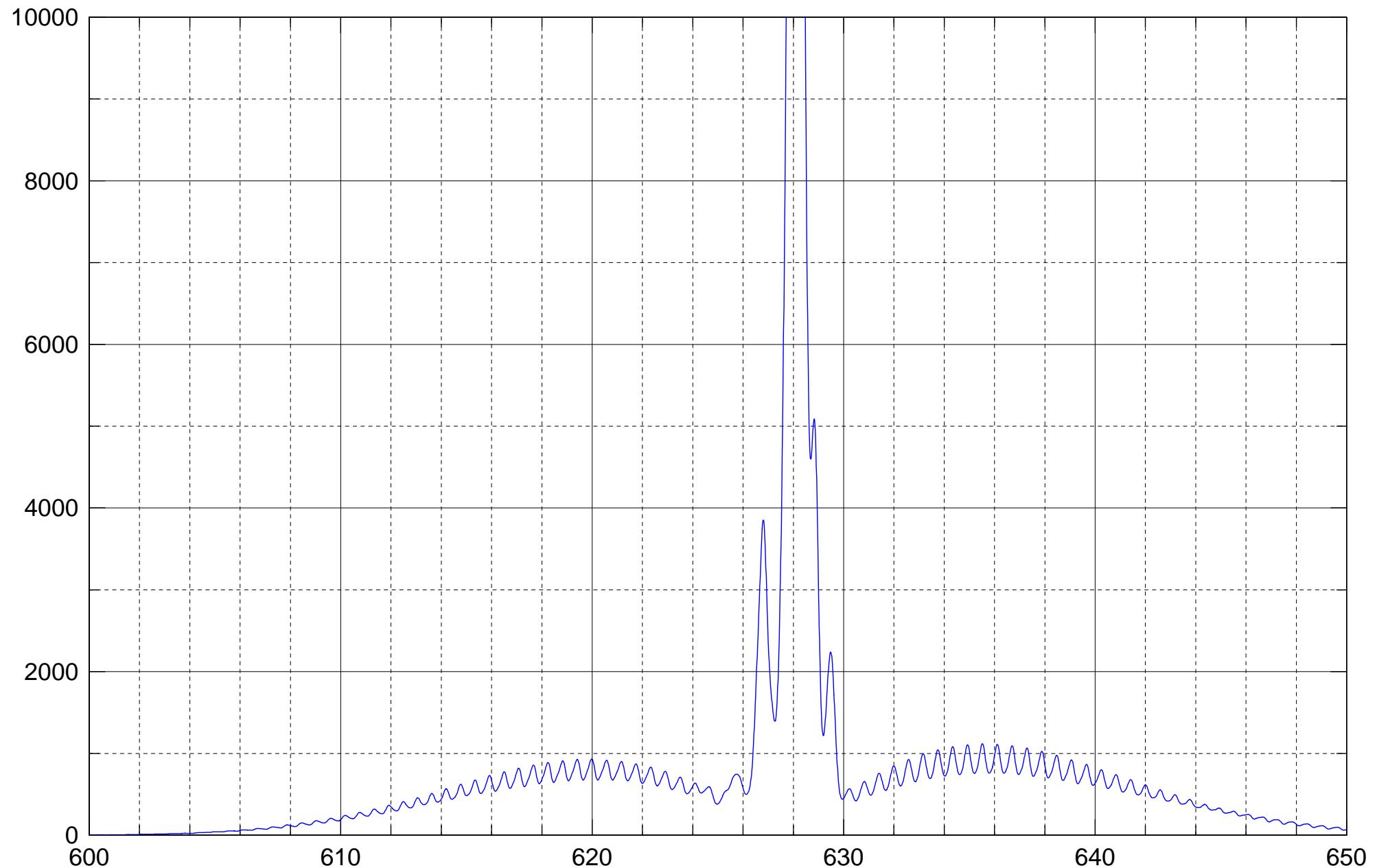
Hot HC_3N bands in Titan



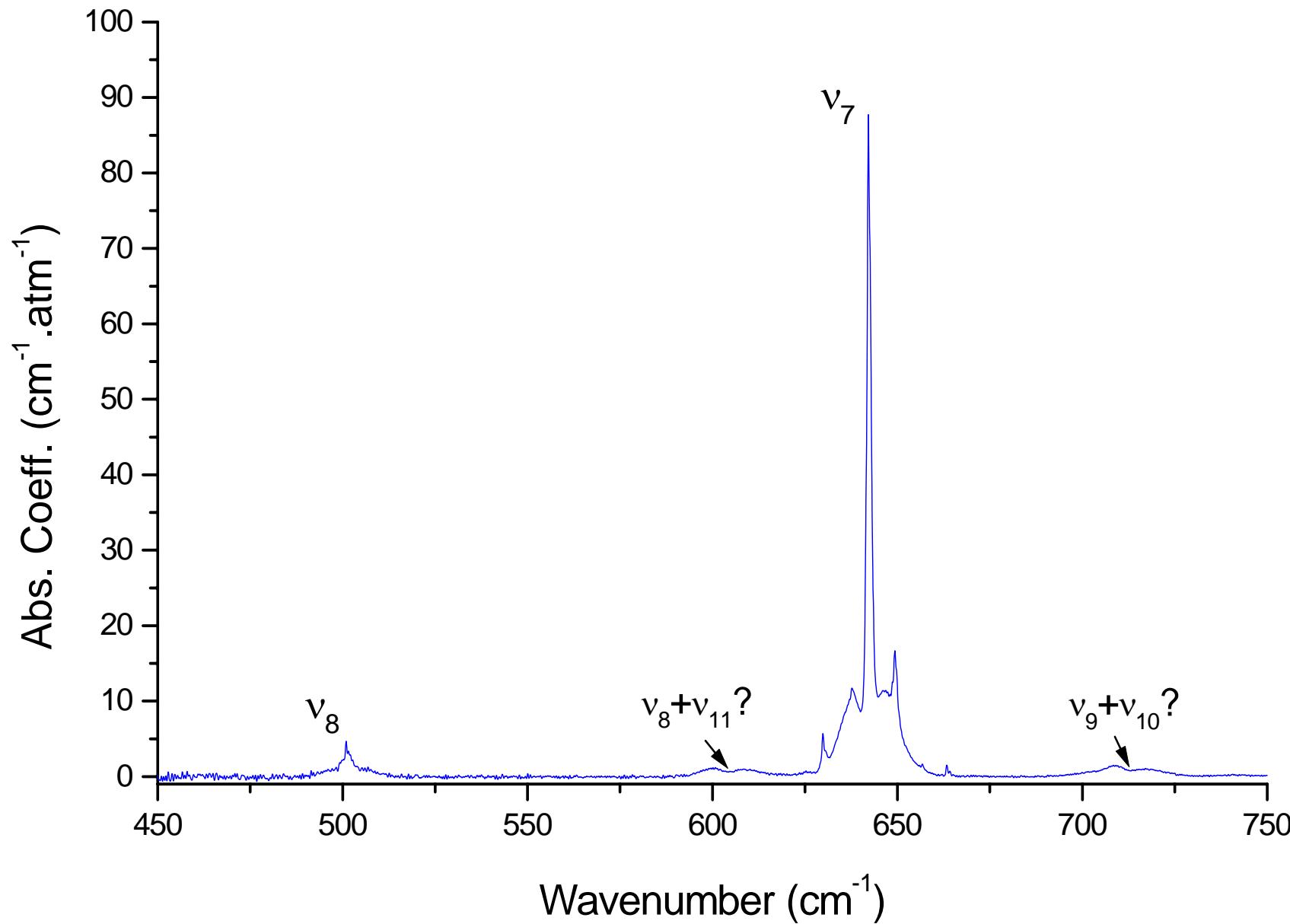
More hot bands on Titan ? YES



C_4H_2 simulation



First absolute intensity measurement for HC_5N in the infrared (resolution : 0.5 cm^{-1})



Comparison with theoretical results

HC ₅ N			Absolute Intensities (atm ⁻¹ cm ⁻²) at 296 K	
Mode	Vibration	Position (cm ⁻¹)	This work (2005)	Theoretical Results*
v ₁ /v ₃ +v ₅	C-H str.	(R) 3333 (P) 3322	167	508 ^a /362 ^b
v ₂	C=C str.	(R) 2257 (P) 2248	77.6	277 ^a /138 ^b
v ₃	C=C str.	(R) 2192.5 (P) 2182.5	17.3	1.24 ^a /22.5 ^b
v ₇	bend.	642.2	128.3	177 ^a /318 ^c
v ₈	bend.	500.9	10	7.4 ^a /55 ^c

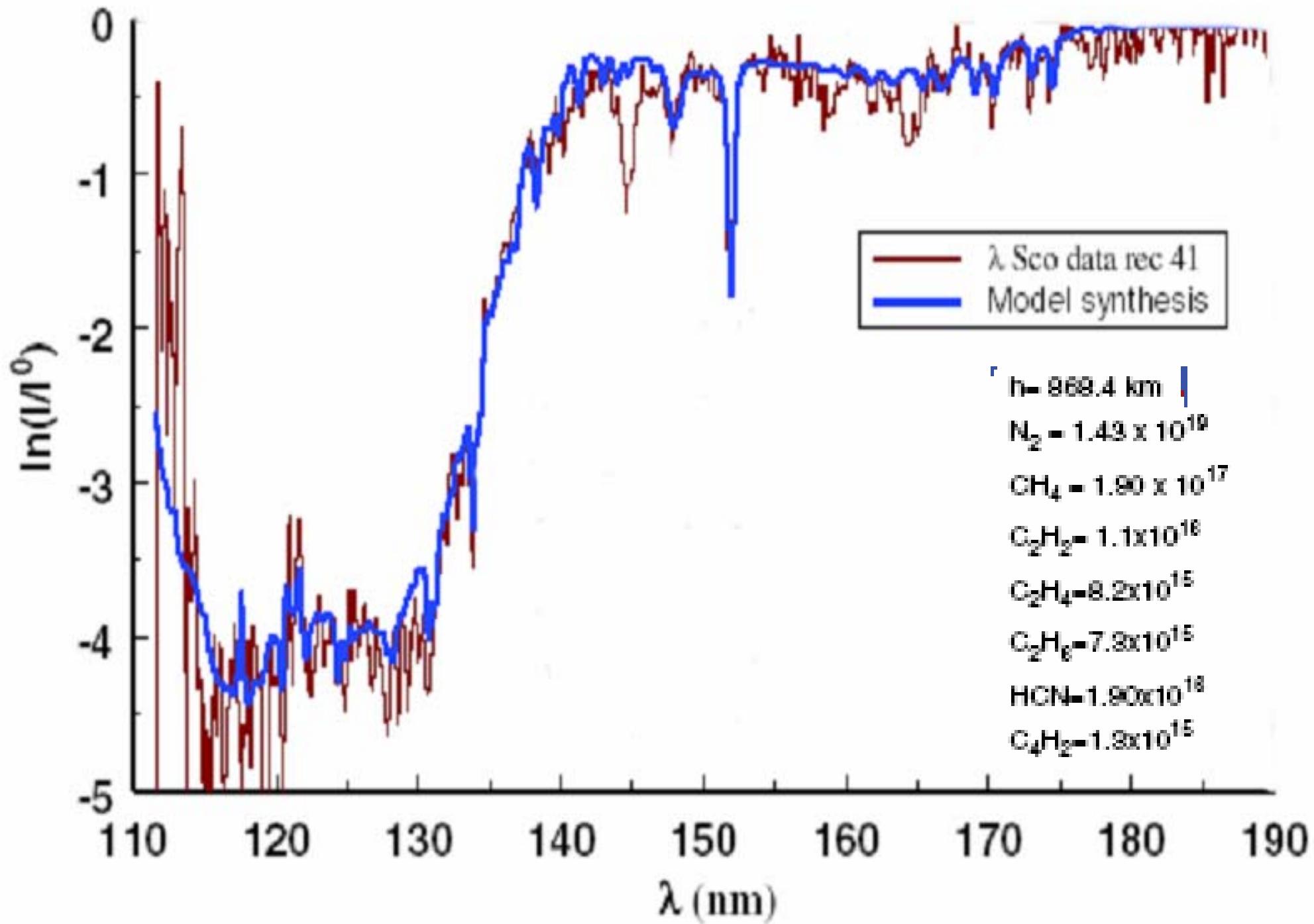
* converted from km/mol to atm⁻¹.cm⁻²

^a Scemama (2002)

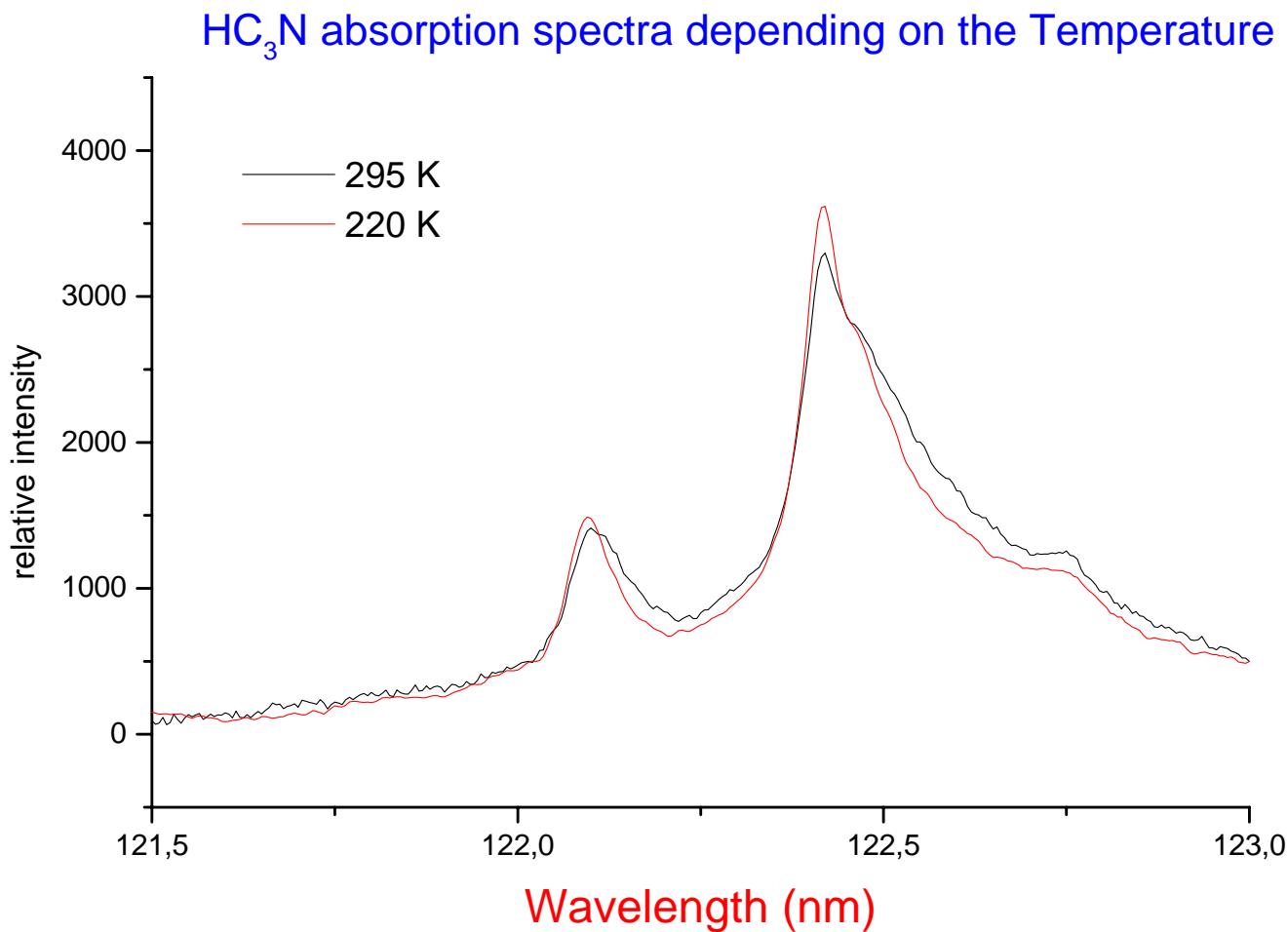
^b Botschwina (1997)

^c Deguchi (1984), Uyemura (1986)

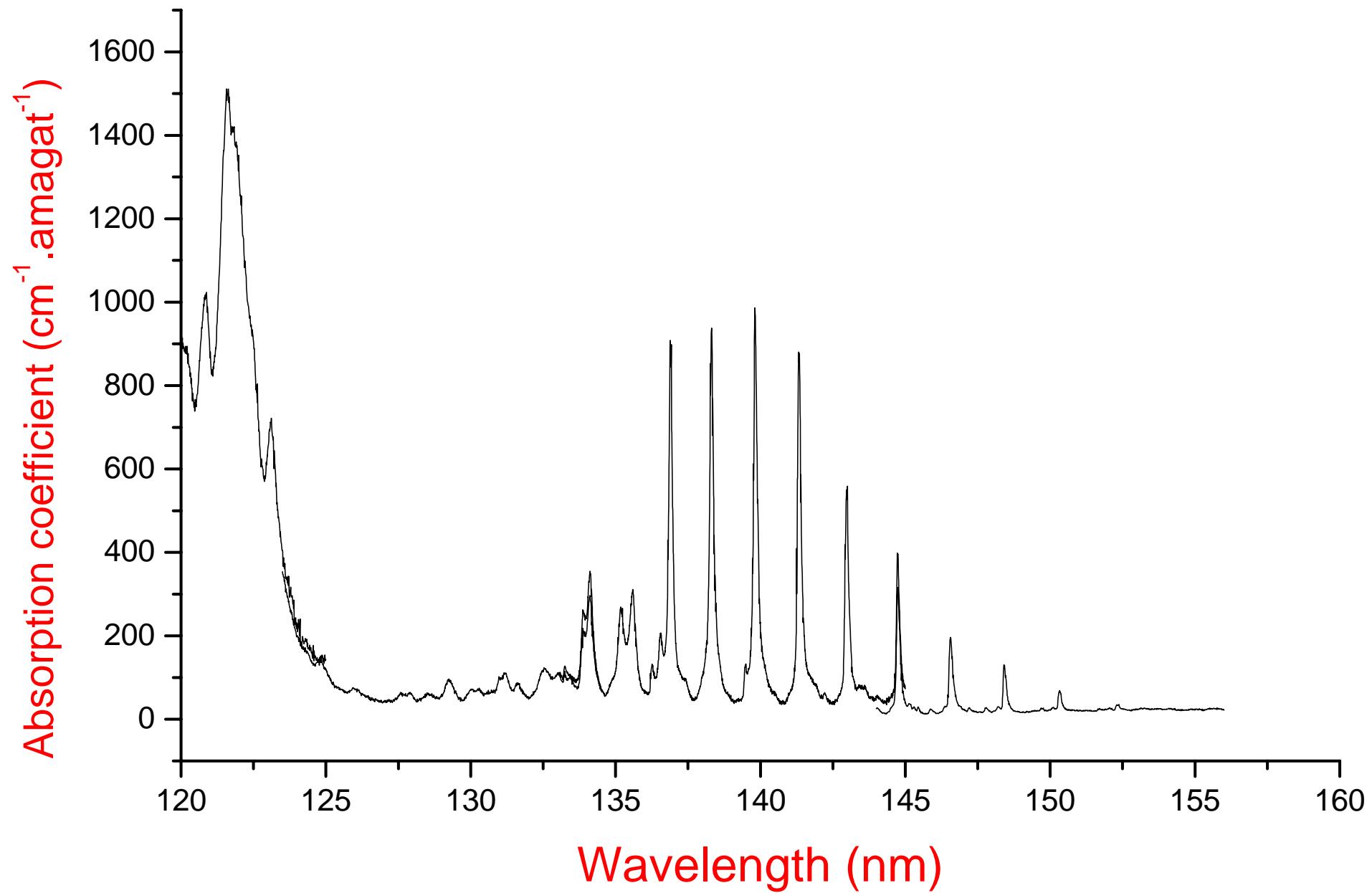
CASSINI UVIS Team, Science (2005)



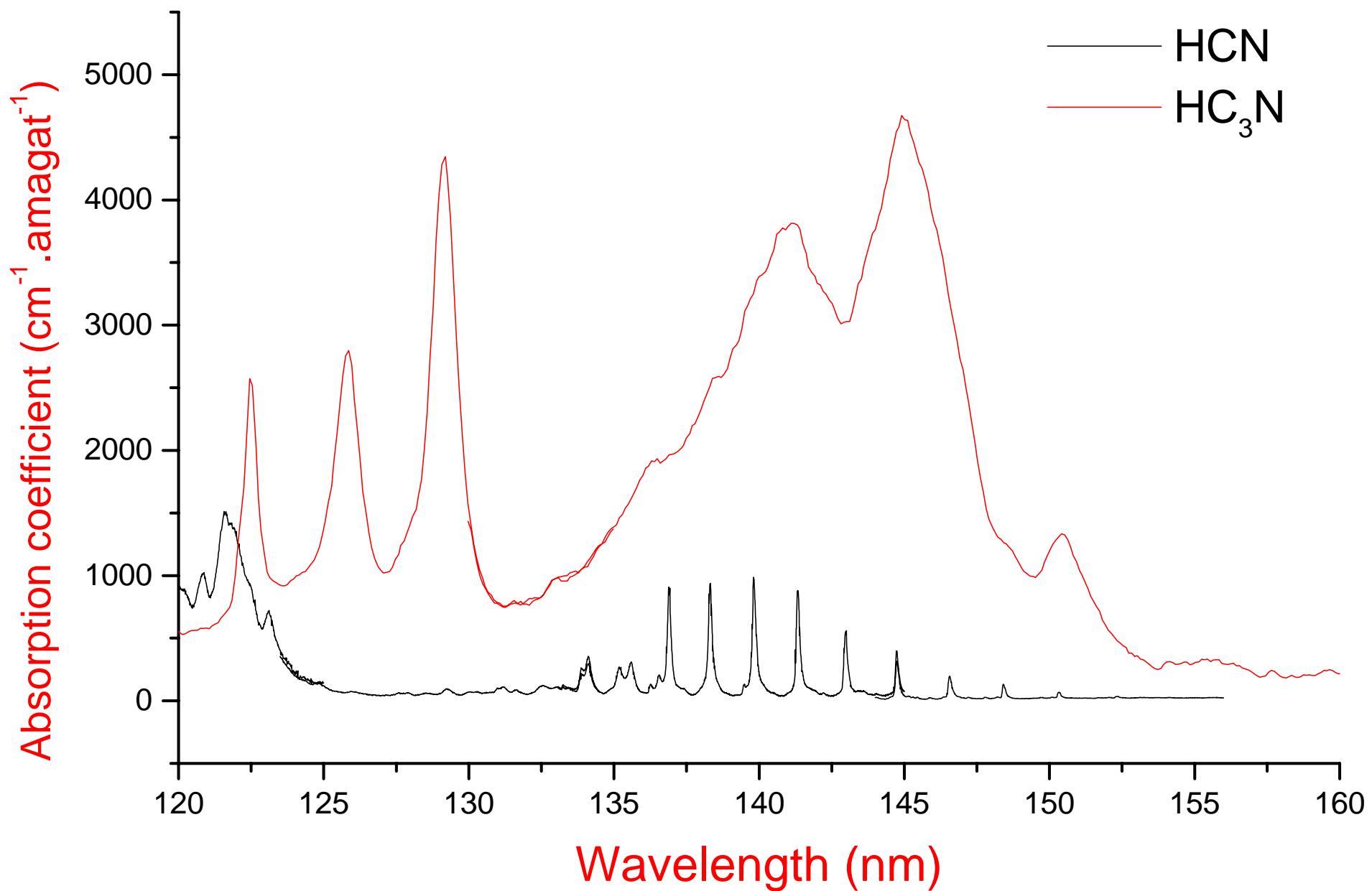
*Experimental study done at BESSY :
Berlin Synchrotron Facility (GERMANY)
April and July 2005*



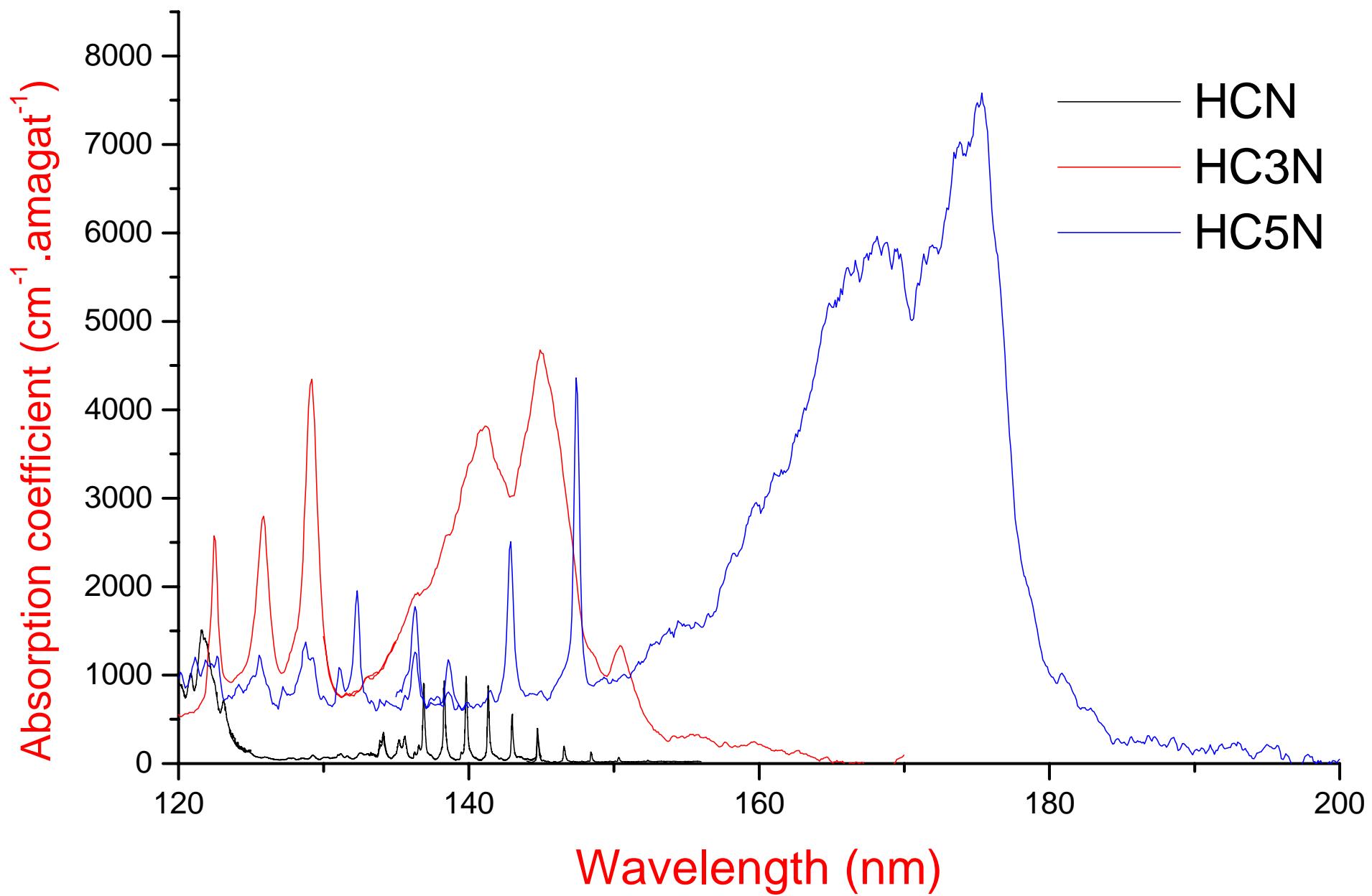
Cyanopolyynes spectra above 120 nm, HCN.....



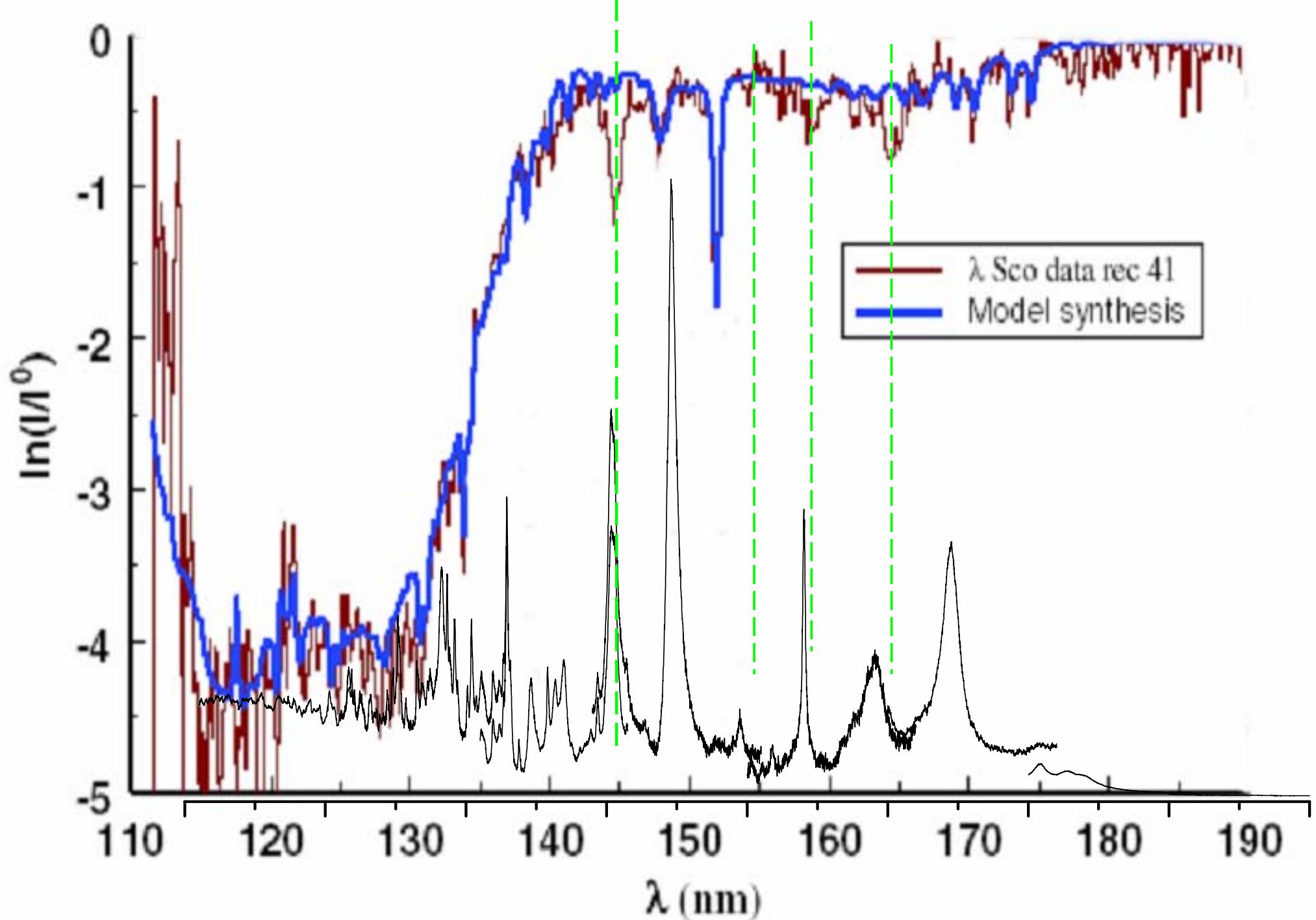
Cyanopolyynes spectra, HCN, HC₃N.....



Cyanopolyynes spectra, HCN, HC3N, HC5N....



New C₄H₂ spectra and UVIS occultation spectra



Simplified photochemical model : polymerisation

Reactions with radicals



Photodissociation :



Photodissociation rates:

$$J = \int_0^{\lambda_0} \phi(\lambda) S(\lambda) e^{-\tau(z)} \cdot \sigma(\lambda, T) d\lambda$$

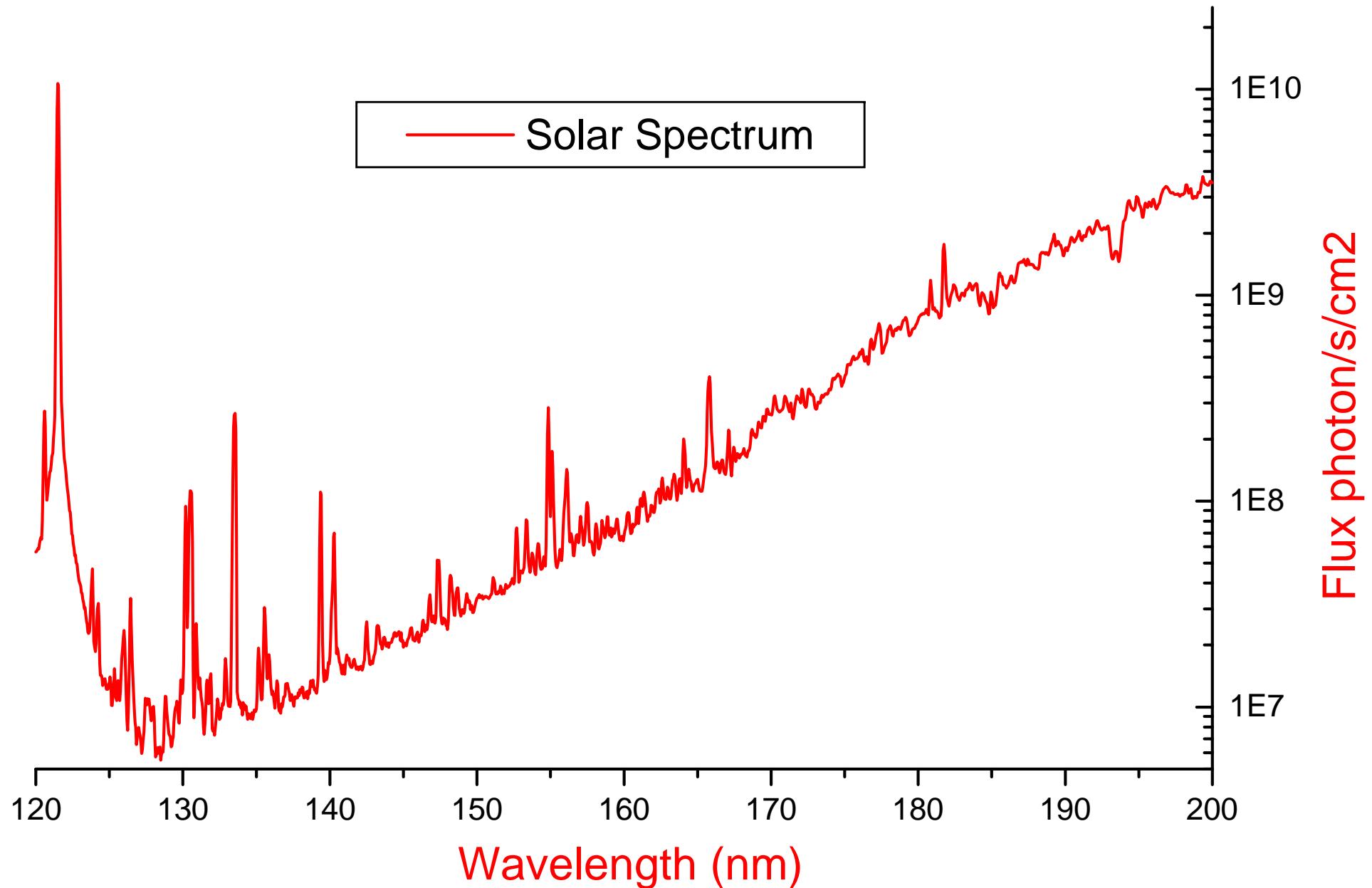
$\Phi(\lambda)$ Quantum yield

$S(\lambda)$ Solar Flux (photons.cm⁻².s⁻¹)

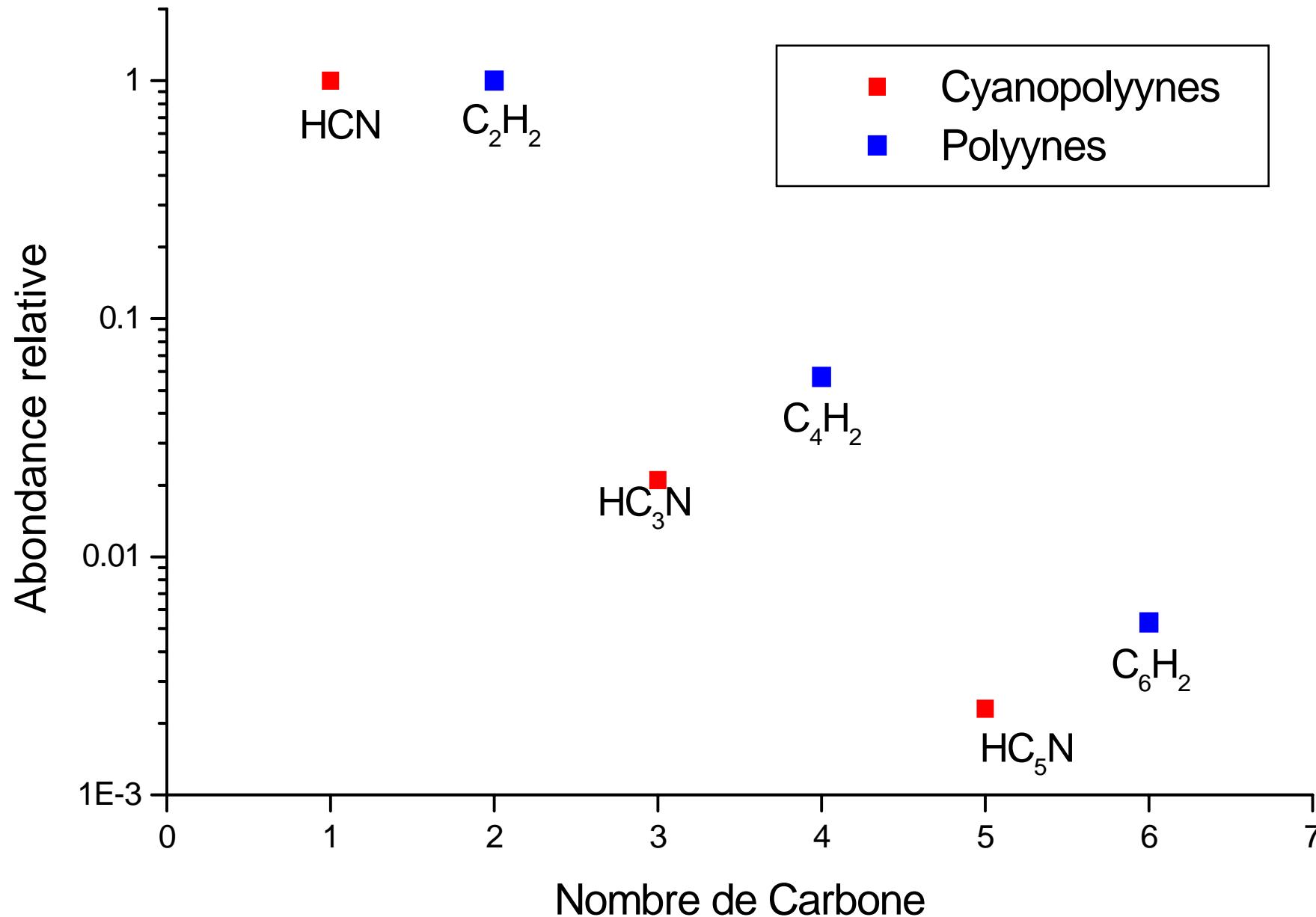
$\tau(z)$ Optical depth

$\sigma(\lambda, T)$ Absorption cross Section

Solar spectrum in the absorption domain of hydrocarbons and nitriles



Predicted relative abundance of polyynes and cyanopolyynes on Titan

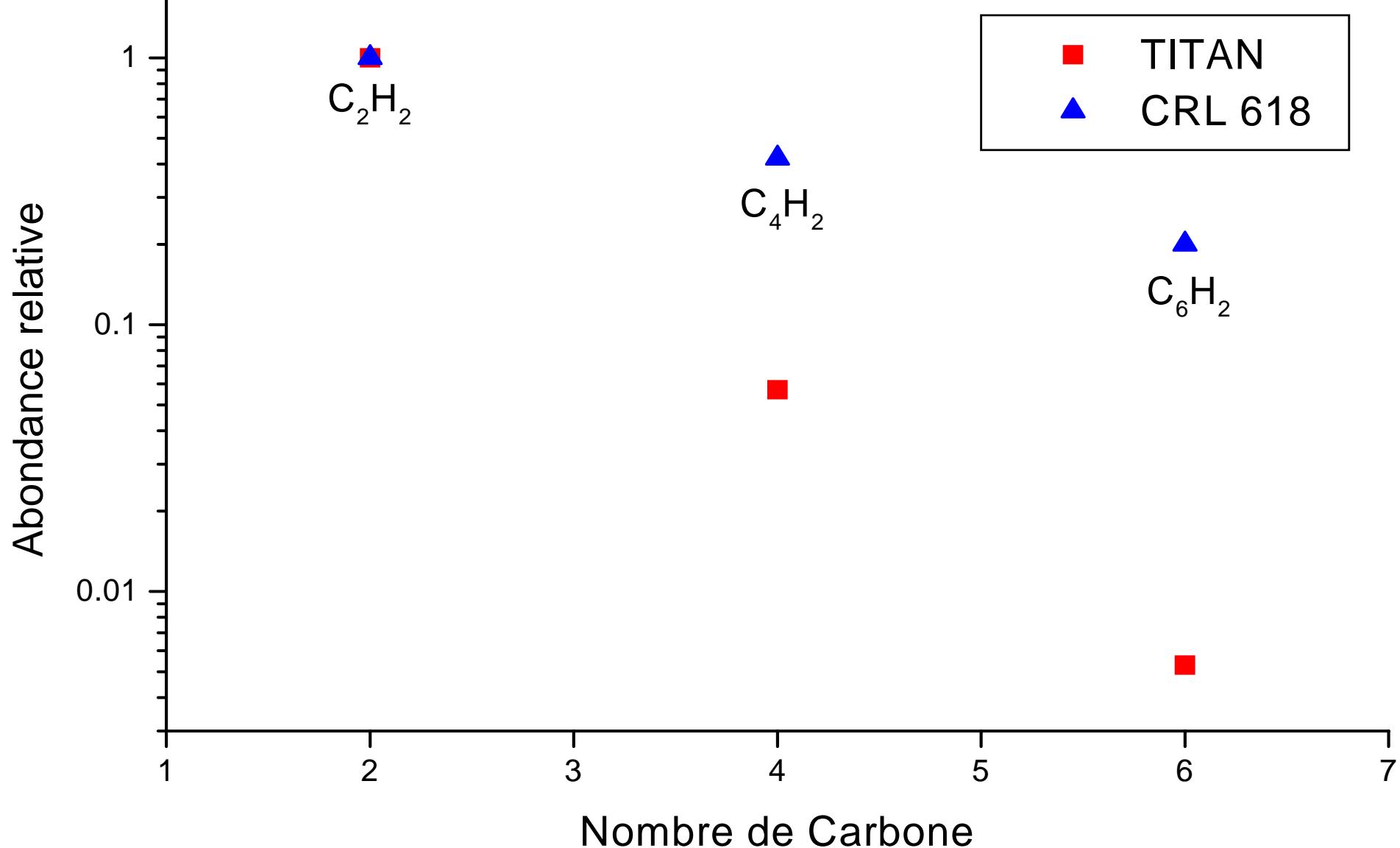


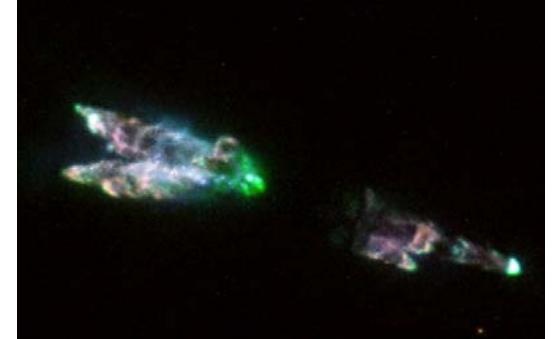
CRL 618 : Nebuleuse proto-planétaire riche en carbone





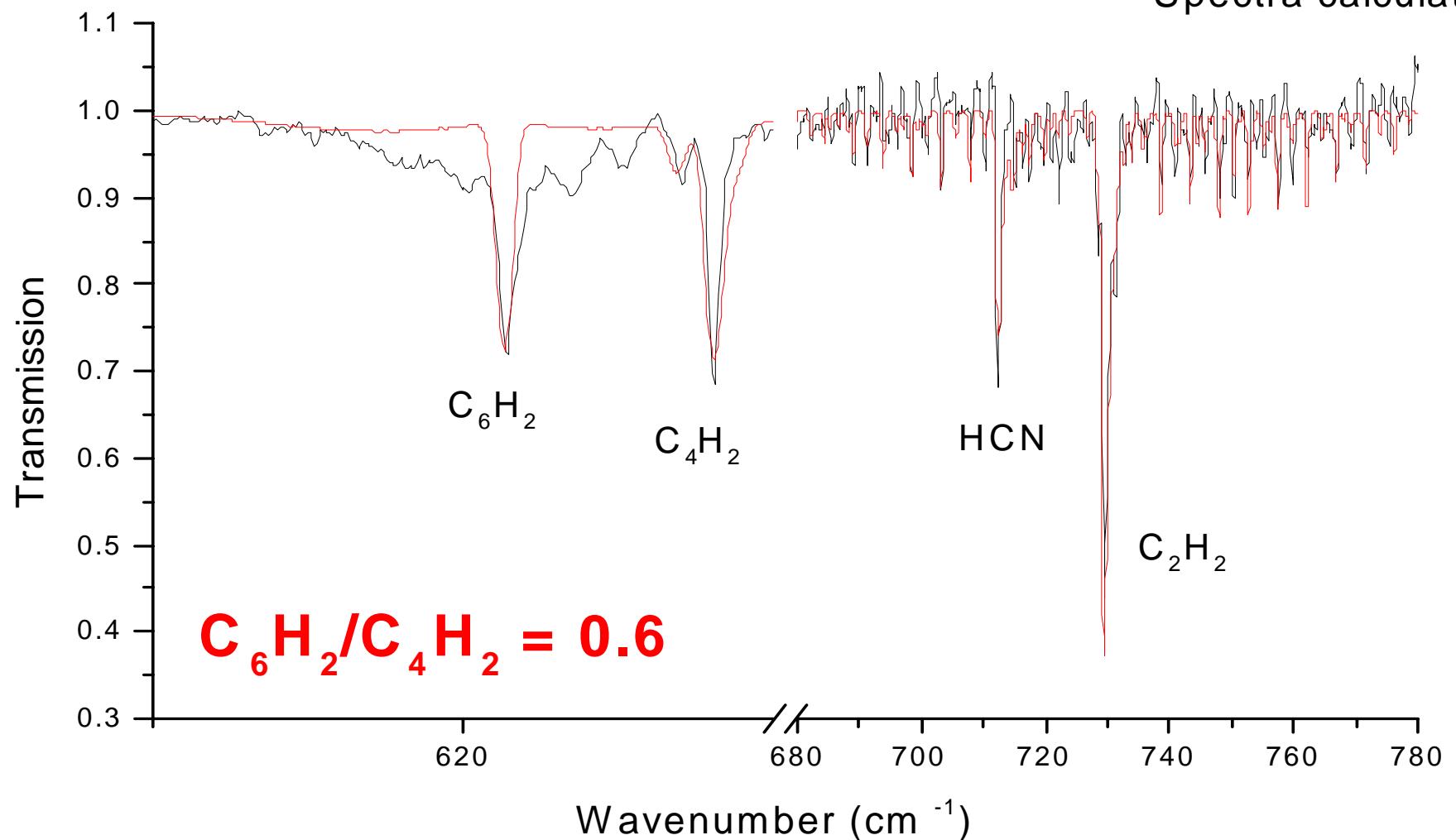
Predicted relative abundance of polyynes on Titan and CRL618





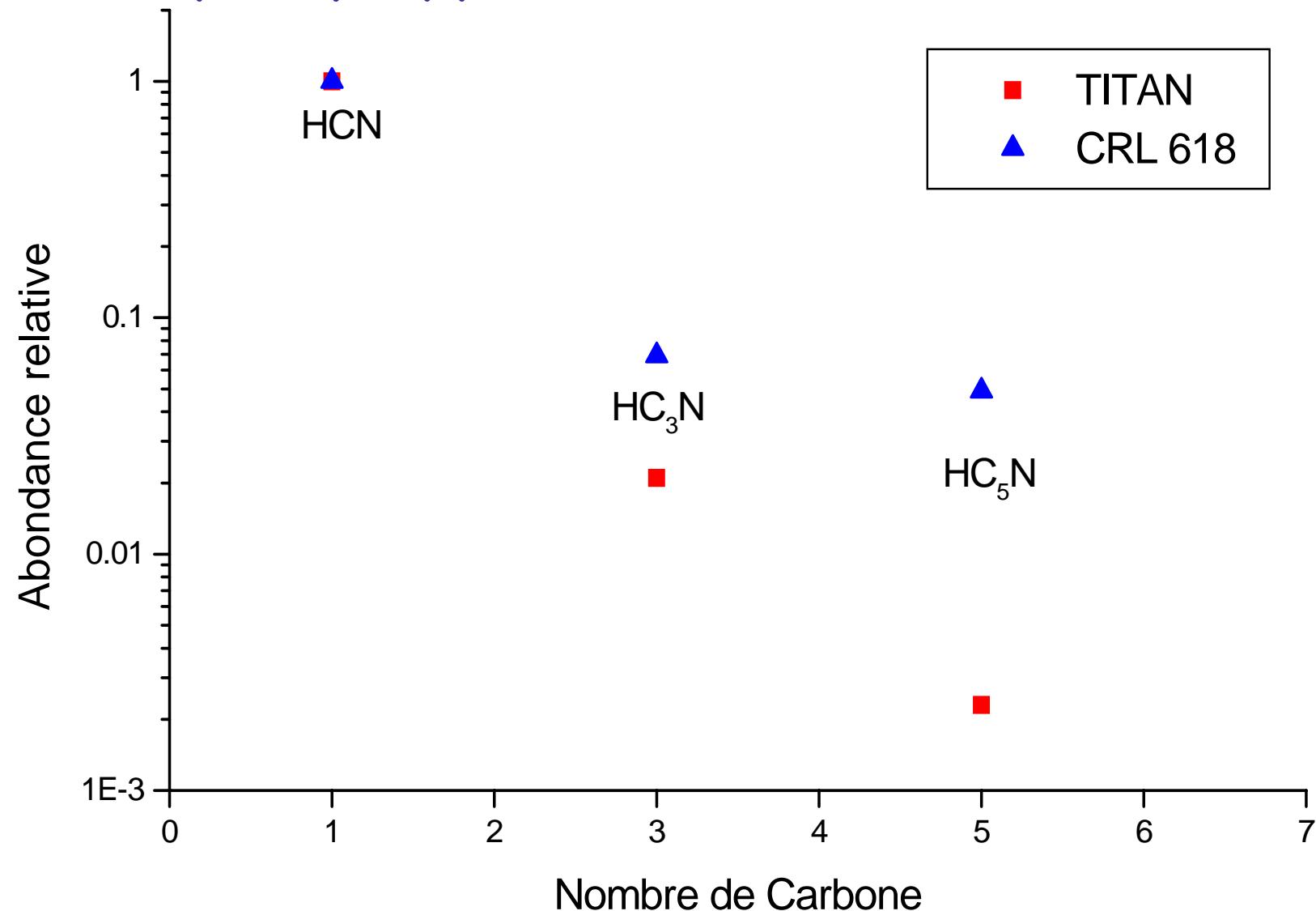
ISO Observation of CRL 618

— Observations
— Spectra calculation





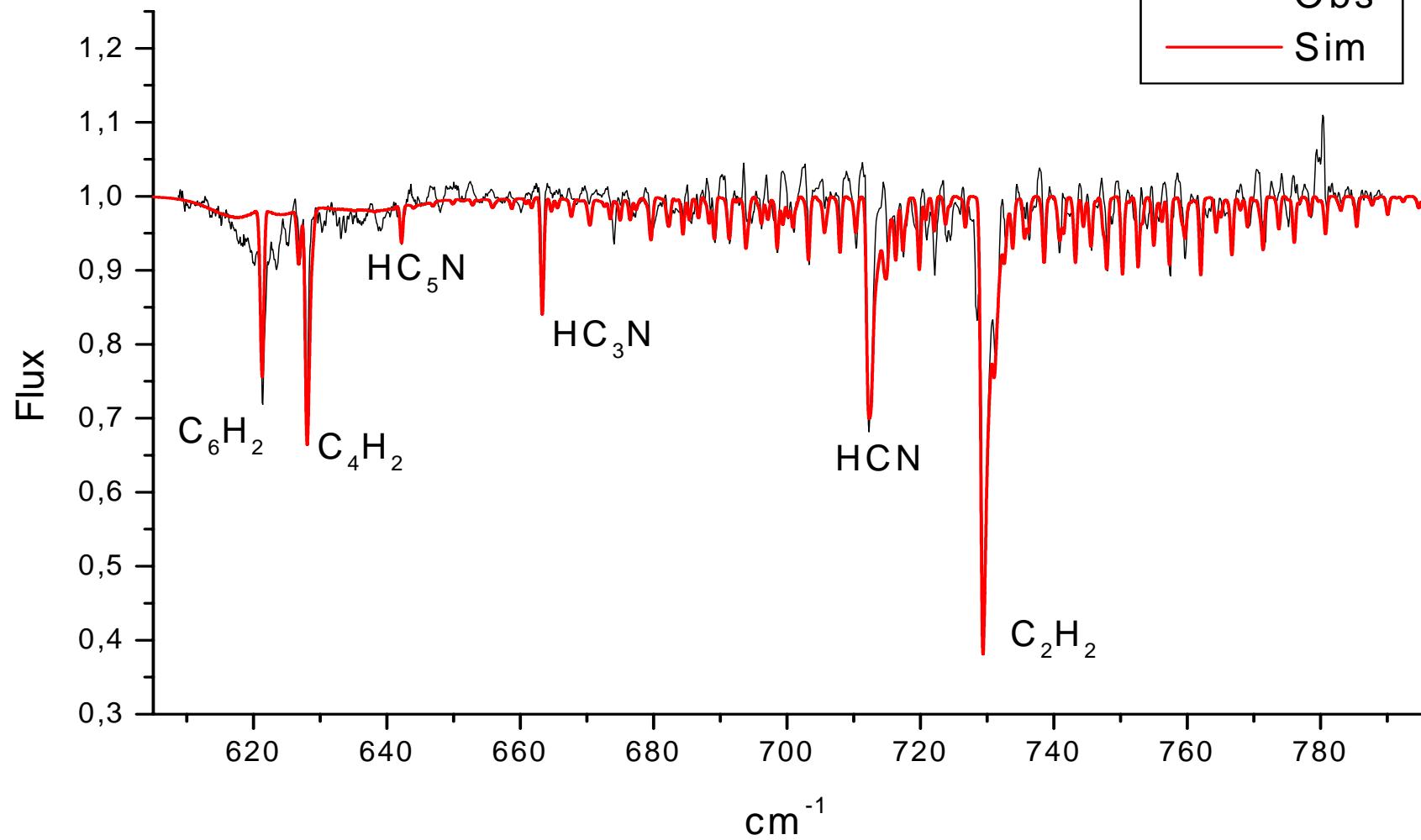
Predicted relative abundance of cyanopolyynes on Titan and CRL618





ISO Observation of CRL618

— Obs
— Sim



Titan's spectroscopic database

<http://www.lisa.univ-paris12.fr/GPCOS/SCOOPweb/SCOOP.html>

The LISA Team and collaborators

- UV spectroscopy : Yves Benilan , Thomas Ferradaz, Martin Schwell, Marie-Claire Gazeau, Nicolas Fray, Hans Jochims (Berlin)
- IR spectroscopy : Yves Benilan, Jean Claude Guillemin (Rennes), André Fayt (Louvain la neuve)