Three Micron Spectroscopy of Hydrocarbons, HCN, and Haze

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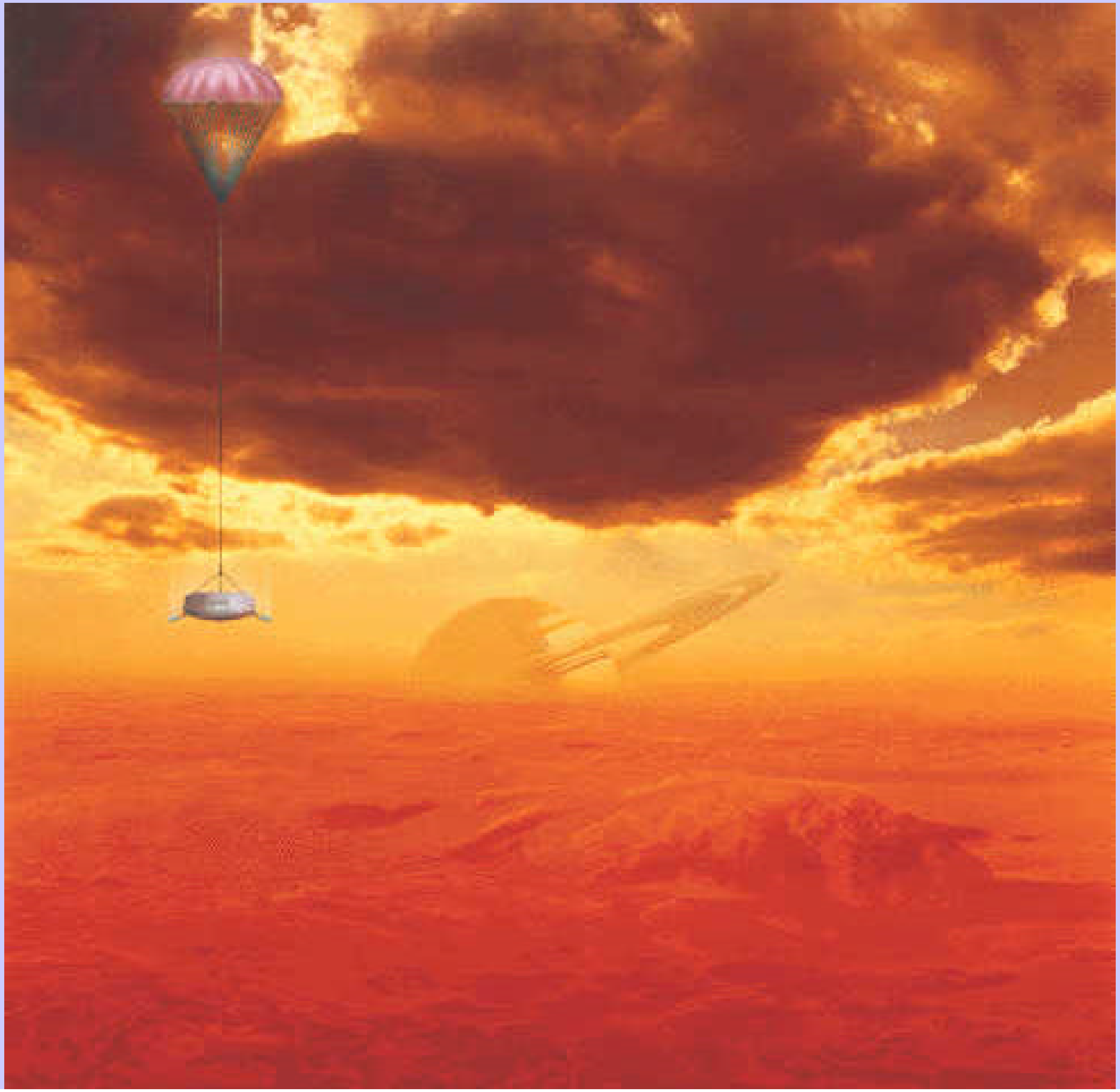
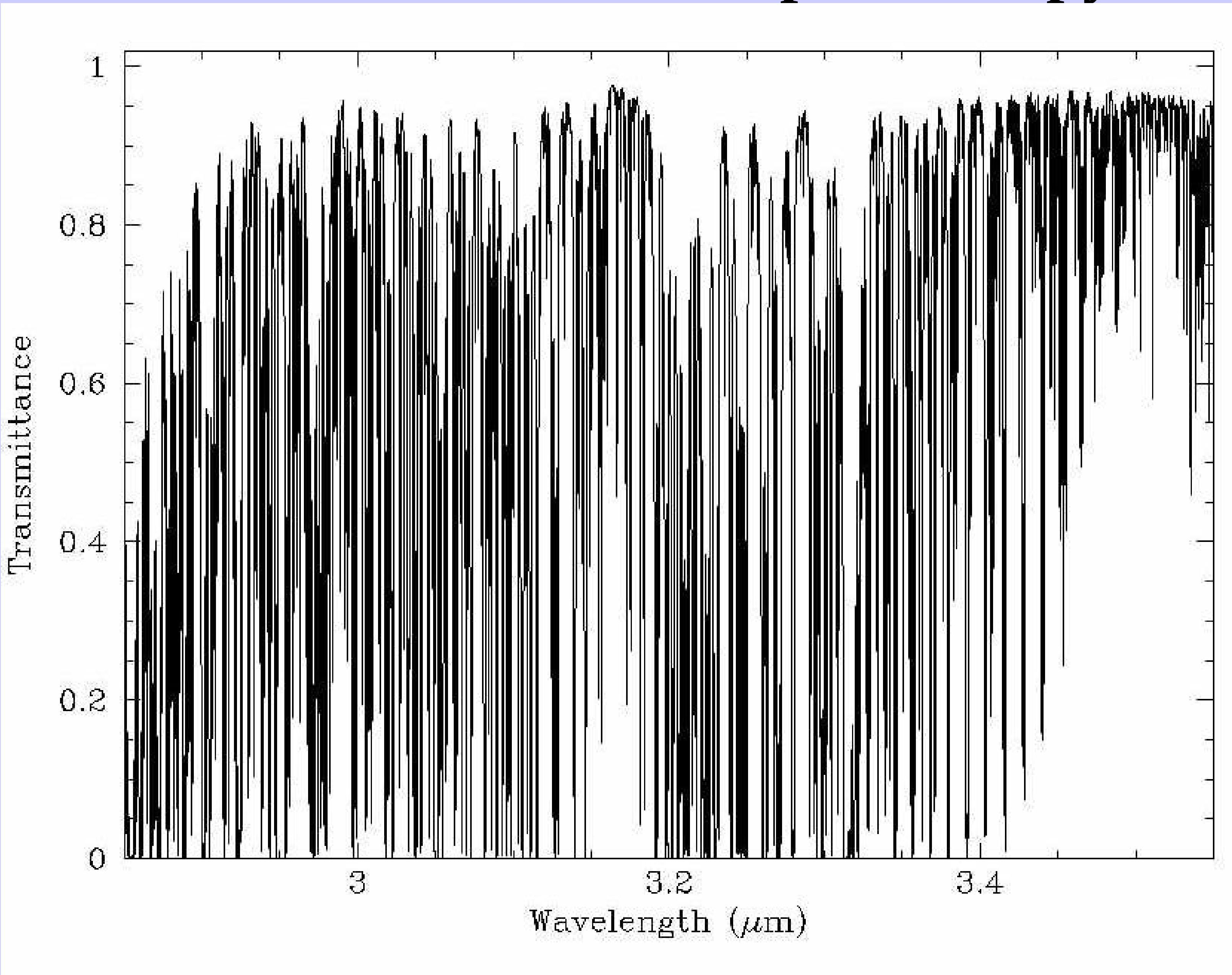
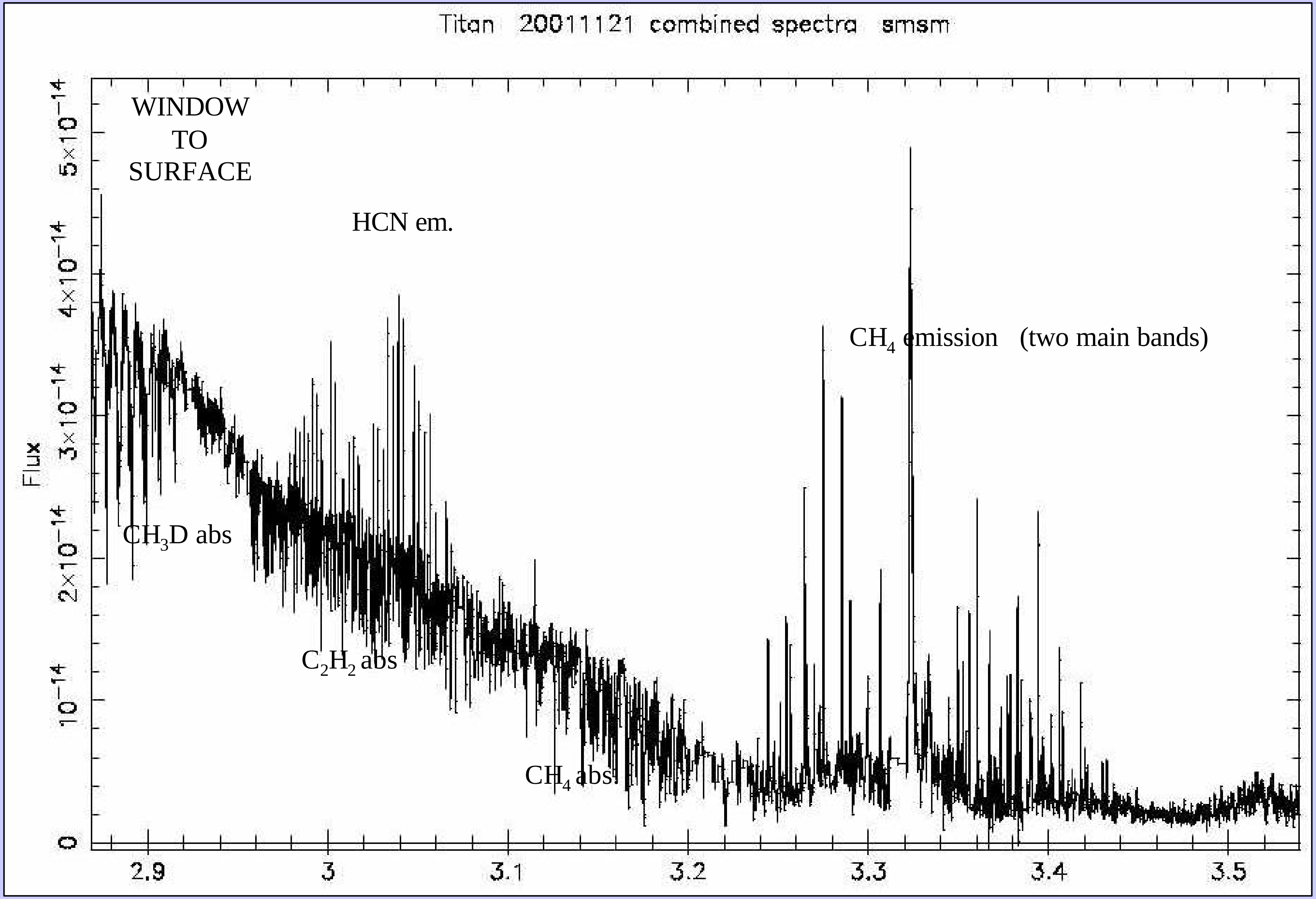


Ground-based 3mm spectroscopy

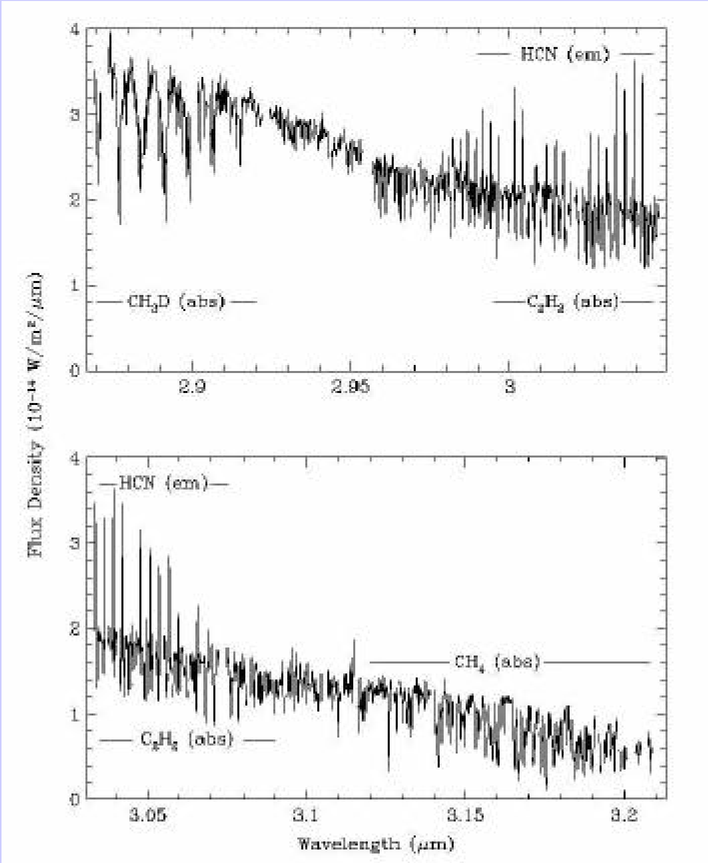


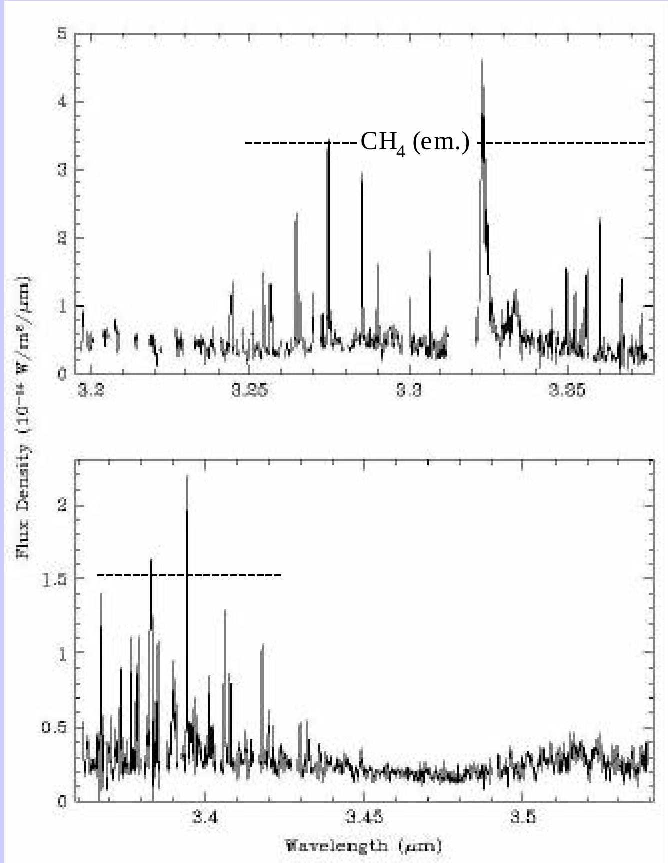
The data



Wavelength (microns)

Features formed at a variety of altitudes





- HCN and CH_4 emission is high altitude fluorescence
- CH_3D absorption forms at low altitudes
- CH4 emission/absorption lines present/absent at band center but absent/present at band edge !

Radiative Transfer Model

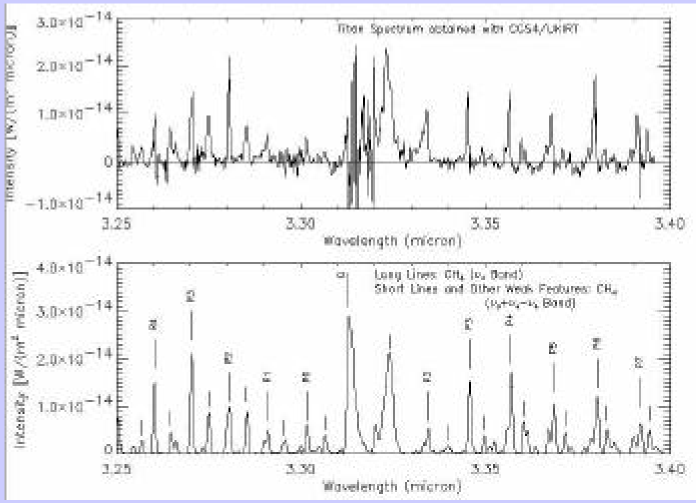
81 plane-parallel layers from surface to 10^{-10} bar

Radiative transfer adopted from Chamberlain (1987)

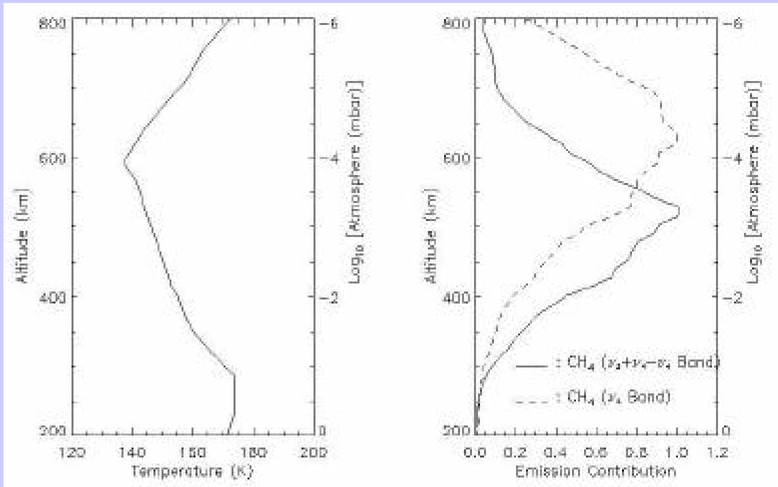
Insert clouds/haze (continuum absorbing/reflecting layers) at various altitudes (ignore multiple scattering).

Use Voyager T-P profile for low altitudes(below 1 mbar. Use high altitude profile (similar to Yelle 1991) derived from CH_4 emission spectrum (Kim Geballe, & Noll 2000) assuming constant mixing ratio at high altitude.

In each layer calculate vibrational excitation by radiation from attenuated sunlight and adjacent layers, and deexcitation by collisions and spontaneous emission. Assume pressure-broadened linewidths and include self-absorption.



KGN (2000)

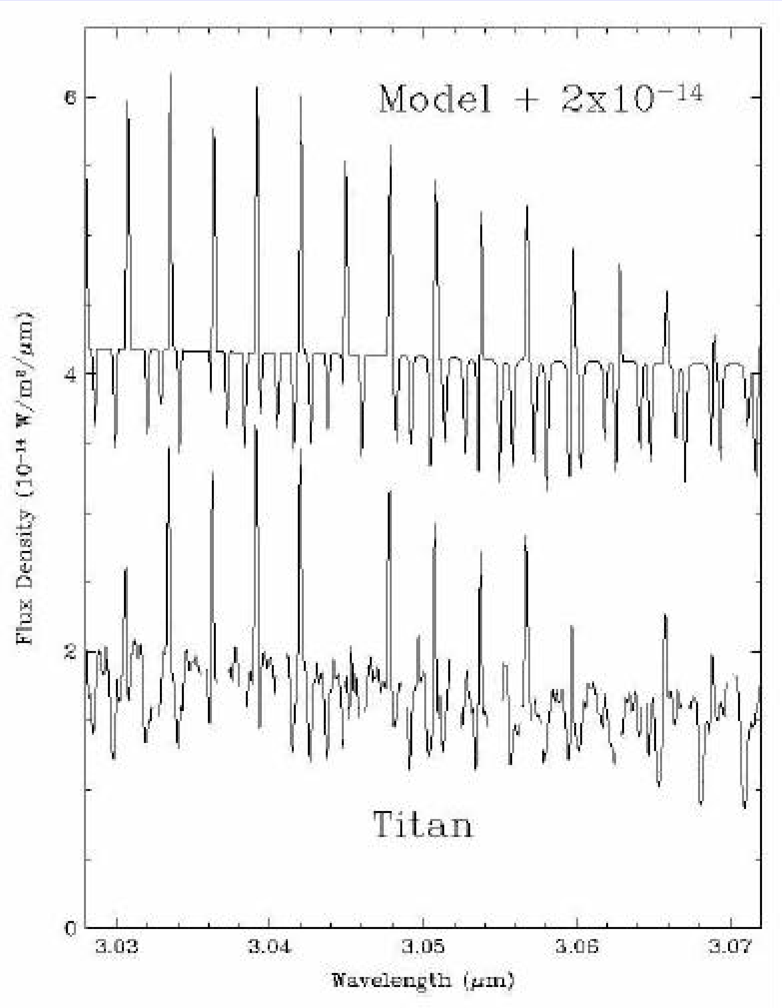


HCN emission and C_2H_2 absorption

Previous analysis by us Geballe et al. (2002) suggested that **HCN** might be highly overabundant in the mesosphere, but used far too high a collisional deexcitation rate, as pointed out by Yelle and Griffith (2003).

Our re-analysis of line intensities indicates HCN emission occurs over a temperature range of 140-180K (300-600 km).

Together, these changes yield an HCN mixing ratio consistent with previous atmospheric models and with Y&G (2003).



The stratospheric **C_2H_2** abundance must be drastically less than in most mixing ratio curves in the literature in order to reduce line emission and produce net absorption, as observed.

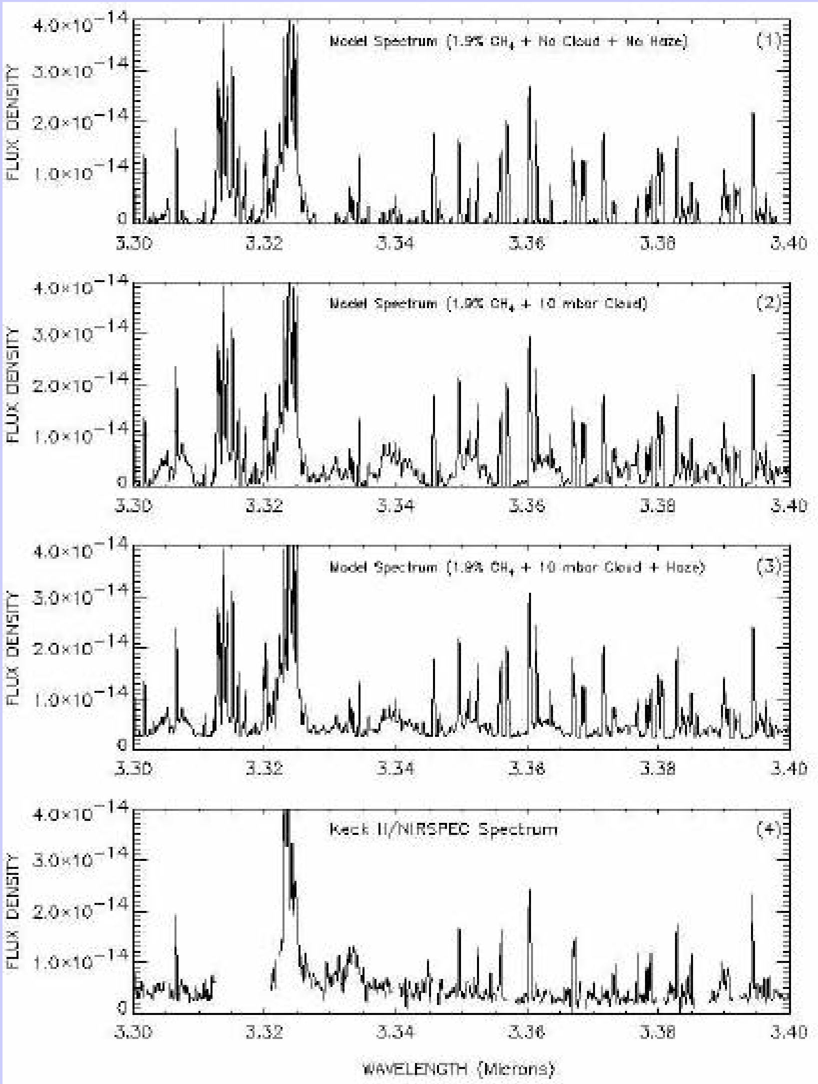
Evidence for high altitude clouds and/or haze

No clouds or haze:
absorption is totally saturated – no continuum

Opaque, partly reflecting cloud layer at 10 mbar (50 km):
still too much absorption

Opaque partly reflecting cloud layer at 10 mbar +
partly reflecting haze above 10mbar,
or extended haze optically thick below 10 mbar:

Satisfactory



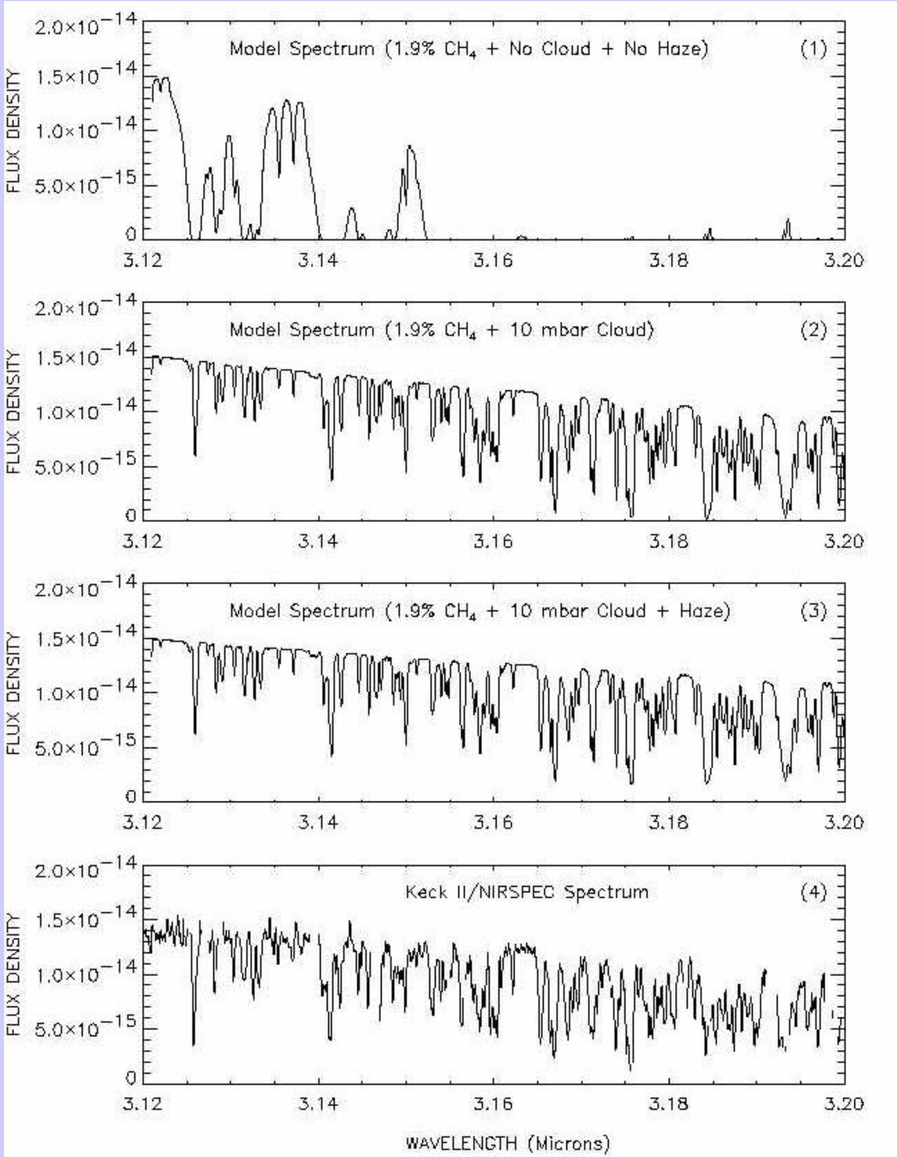
More evidence for high altitude clouds and haze

No clouds or haze

Opaque, partly reflecting cloud layer at 10 mbar (50 km)

Opaque partly reflecting cloud layer at 10 mbar + partly reflecting haze above 10mbar, or extended haze optically thick below 10 mbar

Albedo (reflectivity)of haze must be higher than at band center.



The CH_3D band and the 2.9mm window

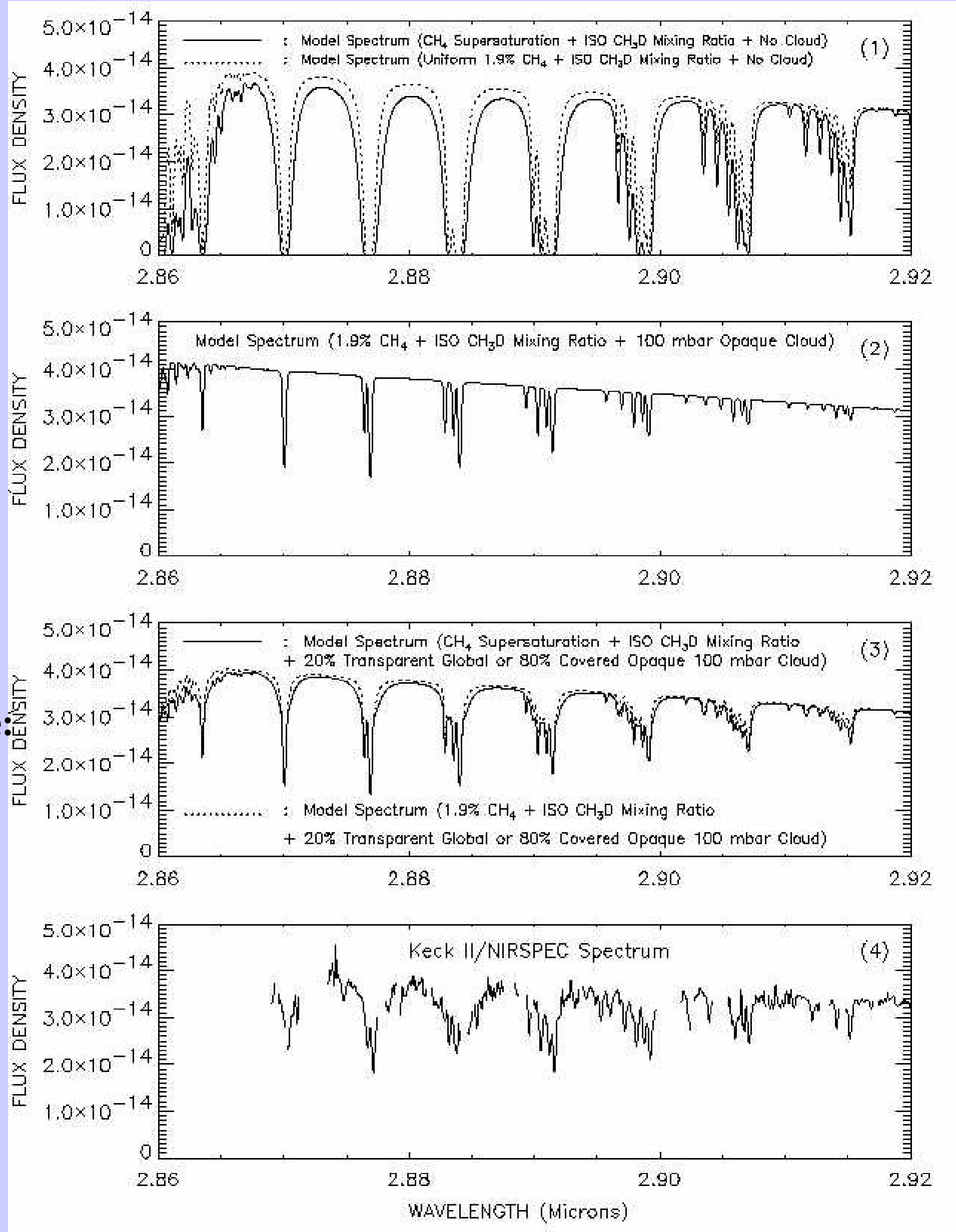
10 mbar cloud and haze must be transparent.

No clouds: absorption is too strong

100 mb opaque cloud deck:
line depths about right,
but lines are too narrow.

100 mb, 20% transparent cloud
or opaque cloud with 80% coverage of surface:

Reasonable agreement



Supports conclusion of Griffith et al. (1998) that the surface of Titan is observe at 2.9mm.

Summary

• CH_4 line emission confirms high altitude T-p profile of Yelle (1991)

• T_{rot} (HCN) ~ 140-180 K; mixing ratio is consistent with previous predictions.

• Stratospheric C_2H_2 mixing ratio is 1-2 orders of magnitudes less than previous atmospheric chemical models.

• High altitude cloud/haze layer at 10 mb (100 km) and above is identified. The wavelength-dependent albedo suggests that its particles are made of hydrocarbons.

• Second cloud layer at 100 mb (50 km) identified; it is either 20% transmitting at 2.9um and covers the disk or is opaque and blocks 80% of the surface from view.

• CH_3D line profiles confirm that the surface of Titan is observed at 2.9μm.