2.16 Spectroscopic Investigation of Uranian Cloud Structure

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Planetary Atmospheres Workshop, Tuesday November 6, 2007, 4:00-5:00 pm

Introduction

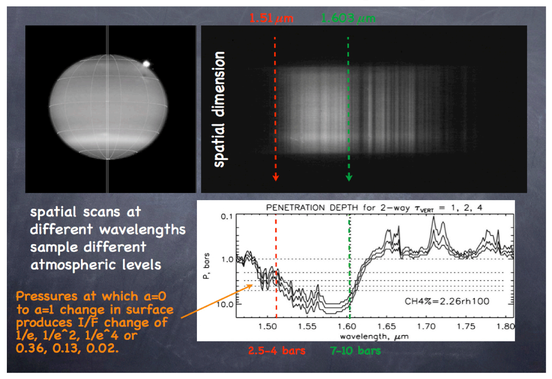
We use spectrally varying absorption of methane and hydrogen to probe varying depths of Uranus' atmosphere from the stratosphere to about the 10-bar level, using CCD and near-IR wavelengths and CH4 abs coeff from [1] and [2] respectively, the latter having been improved by low-temperature measurements [6] and new T-dependence models [5].

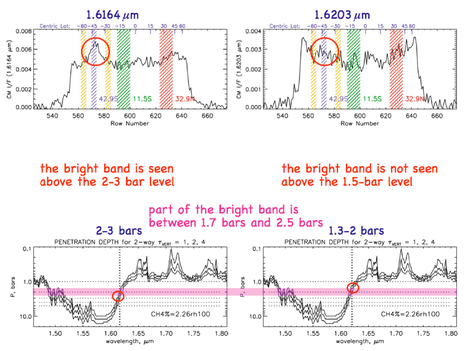
Instead of assuming cloud boundaries and methane mixing ratios inferred from Voyager radio occultation observations [10], we try to derive these parameters from the spectral observations.

From Keck and NICMOS near-IR observations [7, 8] and ACS and STIS observations at CCD wavelengths [9] we find consistent but unexpected results.

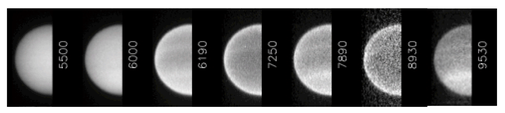
Observations:

Keck II NIRC2 Grism Spectra [8,11]

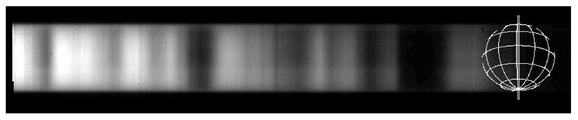


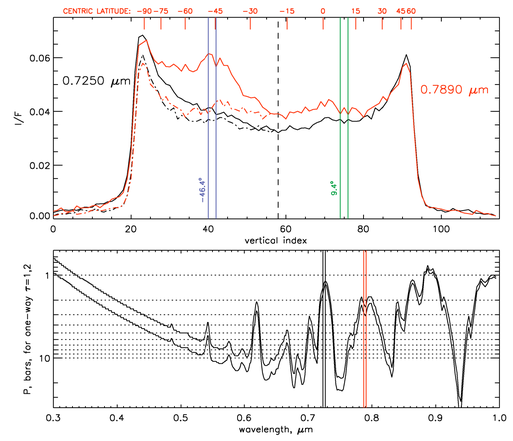


Space Telescope Imaging Spectrograph (STIS)

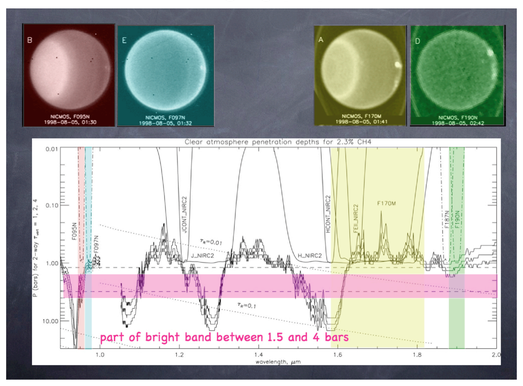


Central meridian spectrum

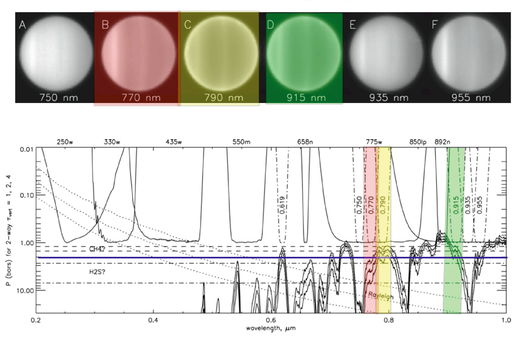




HST NICMOS Imaging [11]



HST ACS Ramp Filter Imaging



The bright band is mainly deeper than the 2-bar level.

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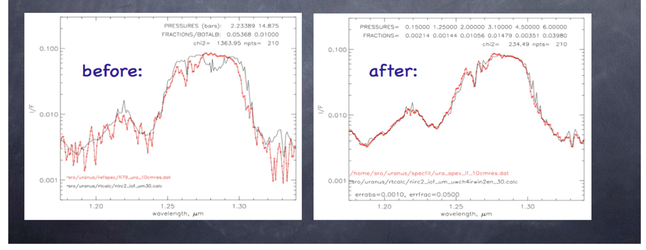
Modeling Tools

Near-ir methane absorption models

Recent improvements in modeling methane absorption:

Sromovsky, L.A., Irwin, P.G.J., Fry, P.M. 2006 Near-IR methane absorption in outer planet atmospheres: Improved models of temperature dependence and implications for Uranus cloud structure. Icarus 182, 577-593.

Irwin, P.G.J., Sromovsky, L.A., Strong, E.K. Sihra, K. Bowles, N. Calcutt, S. B. Remidios J.J. 2006, Fry, P.M. Improved near-infrared methane band models and k-distribution parameters from 2000 to 9500 cm-1 and implications for interpretation of outer planet spectra. Icarus 181, 309-319.



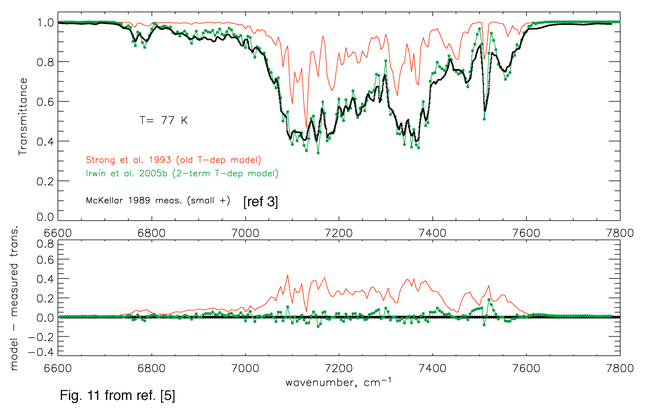
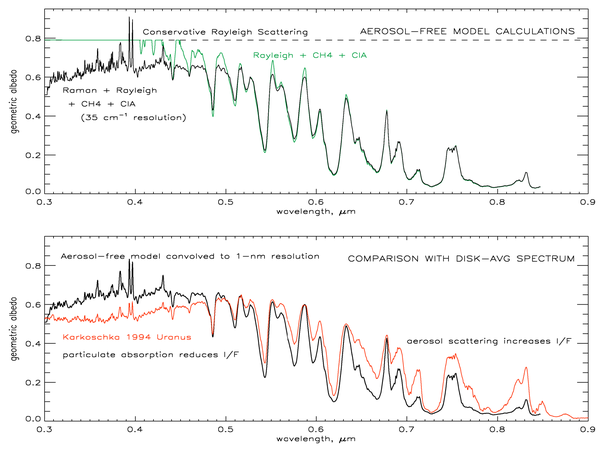


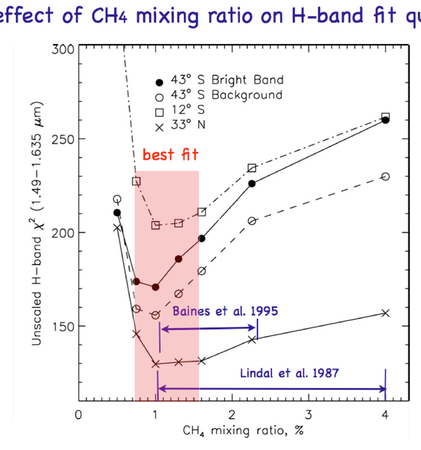
Fig. 11 from ref. [5]

Raman scattering and polarization codes

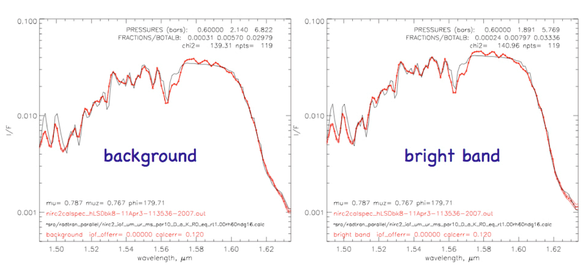


Fits to Near IR Spectra [8]

effect of CH4 mixing ratio on H-band fit quality



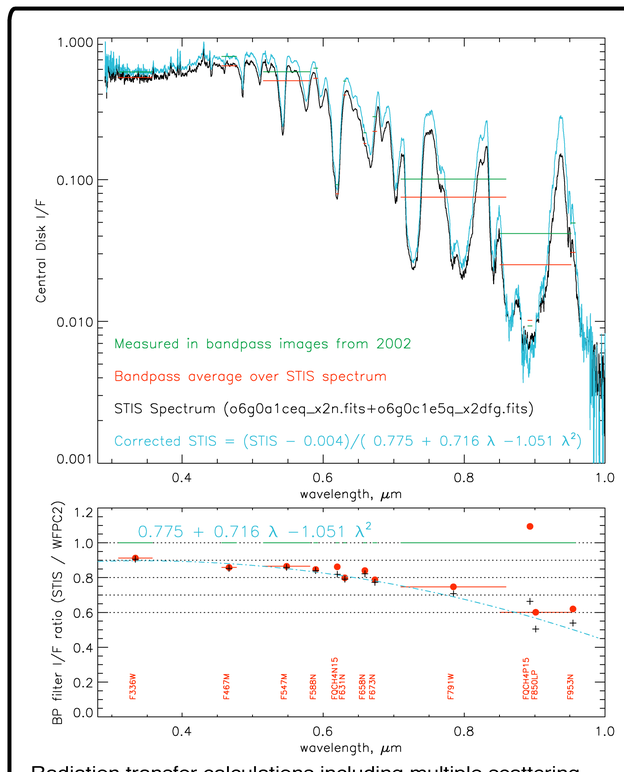
sample fits for 1% CH4

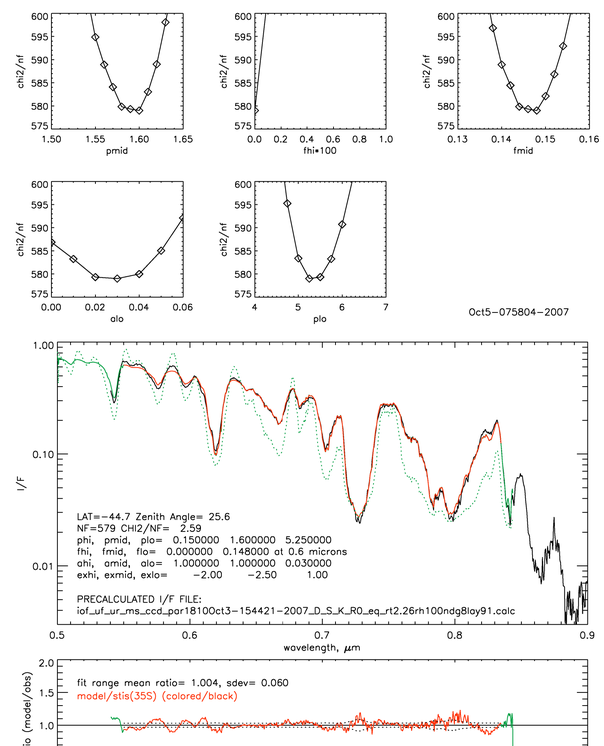


Pmid = 2.1 bars
Pbot = 6.8 bars
fmid = 0.006
abot = 0.030

Pmid = 1.9 bars
Pbot = 5.8 bars
fmid = 0.008
abot = 0.033

Fits to STIS CCD Spectra [9]





Radiation transfer calculations including multiple scattering and polarization were used in a simple 3-layer cloud model to fit spectra at 45° S, 19° S, and 8° N. These fits find the main cloud layers at pressures of 1.6 - 2 bars and 5-8 bars, with the lower pressures applying to the region of the bright band.

Results

Methane mixing ratios near 1% provide best agreement with H-band spectra.

In spite of the relatively high abundance of methane, there seems to be very little methane ice on average.

The main cloud features seem to reside near the 2-bar level and deeper (6-8 bars), suggesting H2S as a plausible constituent.

There is a large north-south asymmetry in cloud properties, with the north containing less cloud reflectivity than the south.

A large north-south contrast is expected for a long time constant response to solar forcing, and as equinox approaches, the contrast seems to be on its way to reversal (Keck observations confirm this).

References

[1] E. Karkoschka. Icarus, 111: 174-192, 1994. [2] P.G.J. Irwin et al. Icarus, 181: 309-319, 2006. [3] A. R. W. McKellar. Can. J. Phys. 67: 1027-1035, 1989. [4] P.G.J. Irwin et al. Icarus, 101: 26137-26154, 1996. [5] L.A. Sromovsky et al. Icarus, 182: 577-593, 2006. [6] K. Sihral PhD Thesis, Univ. of Oxford, 1998. [7] L.A. Sromovsky and P. M. Fry, Icarus, in press [doi:10.1016/j.icarus.2007.07.017], 2007 [8] L.A. Sromovsky and P. M. Fry, Icarus, in press [doi:10.1016/j.icarus.2007.08.037], 2007 [9] P.M. Fry and L. A. Sromovsky, Bull.Am. Astron. Soc., 39: 526, 2007 [10] G. F. Lindal et al., J. Geophys. Res. 92(11): 14987-15001, 1987. [11] L. A. Sromovsky and P. M. Fry, Bull. Am. Astron. Soc., 39: 424, 2007.