EPSC Abstracts
Vol. 6, EPSC-DPS2011-1422, 2011
EPSC-DPS Joint Meeting 2011

The case for a compact methane cloud on Uranus based on reanalysis of the Voyager 2 radio occultation and STIS spectra

L. A. Sromovsky, P. M. Fry, and J. H. Kim
Space Science and Engineering Center, University of Wisconsin - Madison, Madison, Wisconsin (USA)
(larry.sromovsky@ssec.wisc.edu, pat.fry@ssec.wisc.edu, joohyeon.kim@ssec.wisc.edu / Fax: 608 262-5974)

Abstract

A localized refractivity slope variation near 1.2 bars in the Voyager 2 radio occultation profile of Uranus was interpreted by Lindal et al. [4] to be the result of a condensed methane cloud layer. However, models fit to near-IR spectra found particle concentrations much deeper in the atmosphere, in the 1.5-3 bar range [5, 6, 2] and a recent analysis of STIS spectra argued for a model in which aerosol particles formed diffusely distributed hazes, with no compact condensation layer [3]. To try to reconcile these results, we reanalyzed the occultation observations with the He volume mixing ratio reduced from 0.15 to 0.116, which is near the edge of the 0.033 uncertainty range given by Conrath et al.[1], then also applied constraints provided by STIS spectral observations [3].

1. Introduction

Recently, a serious challenge to the existence of the methane cloud layer on Uranus was made by Karkoschka and Tomasko [3], which will be referred to as **KT2009** in the following. They based on their analysis of spatially resolved CCD spectra obtained from the Hubble Space Telescope STIS instrument in 2002. They concluded that the most significant cloud opacity concentration was in a layer from 1.2-2 bars, with particles uniformly mixed with the gas in this layer, which had optical depths between 1.2 and 2.2. They argued for no localized CH_4 condensation layer at all, but instead for the existence of a global thick and diffuse tropospheric haze similar to that observed on Titan. This seemed to confirm the analysis of near-IR spectral observations, which had already questioned the existence of a methane ice cloud near 1.2 bars.

2. Occultation Analysis

Following the basic approach of [4], we recreated the refractivity profile from the published temperature and methane structure for their model D, then inverted the refractivity to different temperature and methane profiles using different assumptions about the methane constraints and considering different He/H_2 mixing ratios within the approximate range of its uncertainty. By reducing the mixing ratio of He slightly we were able to increase the mixing ratio of methane enough to yield methane saturation in the region of the putative cloud layer, and to have a higher methane mixing ratio above the cloud layer that was in better agreement with the rather high mixing ratio profile assumed by KT2009. We created a suite of solutions with different He mixing ratios and used STIS spectra to constrain the results.

3. STIS Spectral Modeling

We used the radiation transfer code that includes Raman scattering and an accurate approximation for polarization effects. To characterize methane absorption at CCD wavelengths we used the coefficients of KT2009. We considered two models of vertical aerosol structure. The diffuse model has the KT2009 structure which provides a fitting standard of comparison. The compact model, the main feature of which is the splitting of the middle tropospheric layer of KT2009 into two layers, allows us to see if a compact layer of methane particles can provide good fits to the observed spectra, and which occultation-derived profiles of temperature and methane mixing ratio provide (1) the best fit to the spectra and (2) the best agreement between the fit pressure for the middle tropospheric layer and the pressure inferred from the occultation analysis. Hopefully, the best spectral fit would occur for the same profile that provided the best pressure match. As shown in the following figure, that is roughly what happened. The best overall spectral fit covers wide range of 2.9-4.9% CH_4, while the best fit in the spectral region near 0.825 μm, where H_2 collision induced opacity is important favors 3.8-4.9% CH_4. The best match between putative methane cloud pressures inferred from spectra and from occultation analysis is for 3.5-4.5% CH_4.

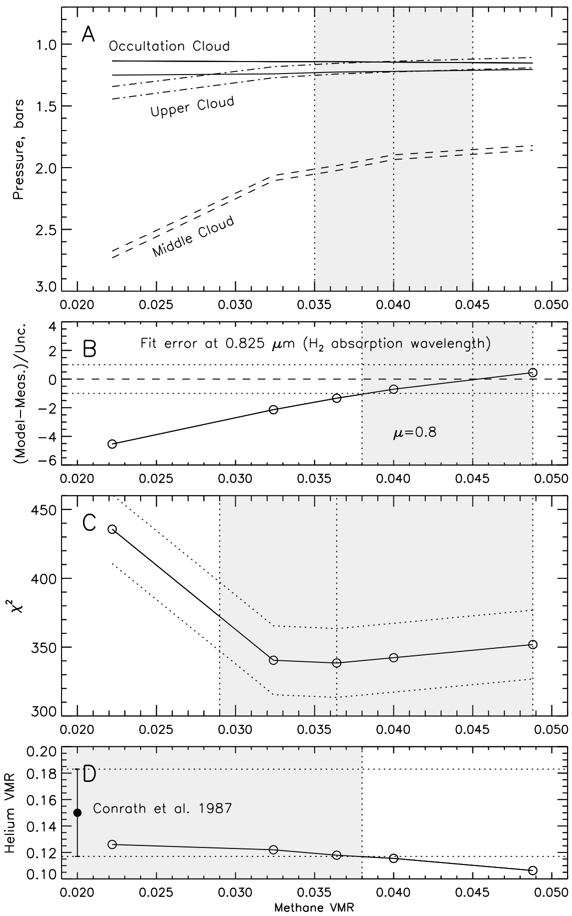

Figure 1: A: The upper two compact layers inferred from fitting STIS spectra as a function of CH_4 mixing ratio (dashed and dot-dash) compared to the methane cloud boundaries inferred from occultation analysis. B: Fit error at 0.825 μm, where CIA is dominant. C: overall spectral fit quality for the 0.6-1 μm spectral range. D: The He volume mixing ratio compared to the Conrath et al. value and its uncertainty. Figure taken from [7].

4. Summary and Conclusions

By decreasing the stratospheric He mixing ratio from its nominal value of 0.15 by 1-1.3 times its uncertainty it is possible to achieve methane saturation within the layers suspected to have condensation and to achieve increased methane humidities above the condensation level.

A five-layer cloud model in which the bottom two diffuse layers of the KT2009 model are split into three compact layers, when constrained by STIS spectra at 5° S, yield best-fit pressures for the top compact layer in excellent agreement with the location of the occultation cloud layer for profile models with deep CH_4 mixing ratios between 3.2 and 4.5%, with the best compromise fit being obtained at 4% (for our Model F1). The putative methane cloud is relatively thin, with an optical depth of $\sim$0.3 at 0.5 μm , only about 1/4 of that of the more prominent layer near 2 bars.

Acknowledgements

This research was supported by NASA Outer Planets Research Grant NNG05GG93G and Planetary Atmospheres Grant NNX09AB67G. We thank E. Karkoschka and M. Tomasko for making their calibrated STIS data cubes available to the community.

References

[1] Conrath, B., Hanel, R., Gautier, D., Marten, A., Lindal, G., 1987. The helium abundance of Uranus from Voyager measurements. J. Geophys. Res. 92 (11), 15003–15010.

[2] Irwin, P. G. J., Teanby, N. A., Davis, G. R., 2010. Revised vertical cloud structure of Uranus from UKIRT/UIST observations and changes seen during Uranus' Northern Spring Equinox from 2006 to 2008: Application of new methane absorption data and comparison with Neptune. Icarus 208, 913–926.

[3] Karkoschka, E., Tomasko, M., 2009. The haze and methane distributions on Uranus from HST-STIS spectroscopy. Icarus 202, 287–309.

[4] Lindal, G. F., Lyons, J. R., Sweetnam, D. N., Eshleman, V. R., Hinson, D. P., 1987. The atmosphere of Uranus - Results of radio occultation measurements with Voyager 2. J. Geophys. Res. 92 (11), 14987–15001.

[5] 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.

[6] Sromovsky, L. A. and Fry, P. M., 2008. The methane abundance and structure of Uranus' cloud bands inferred from spatially resolved 2006 Keck grism spectra. Icarus 193, 252–266.

[7] Sromovsky, L. A., Fry, P. M., and Kim, J. H., 2011. Methane on Uranus: The case for a compact CH_4 cloud layer at low latitudes and a severe CH_4 depletion at high latitudes based on re-analysis of Voyager occultation measurements and STIS spectroscopy. Icarus, submitted.