Jupiter: Cloud Chemistry Revealed

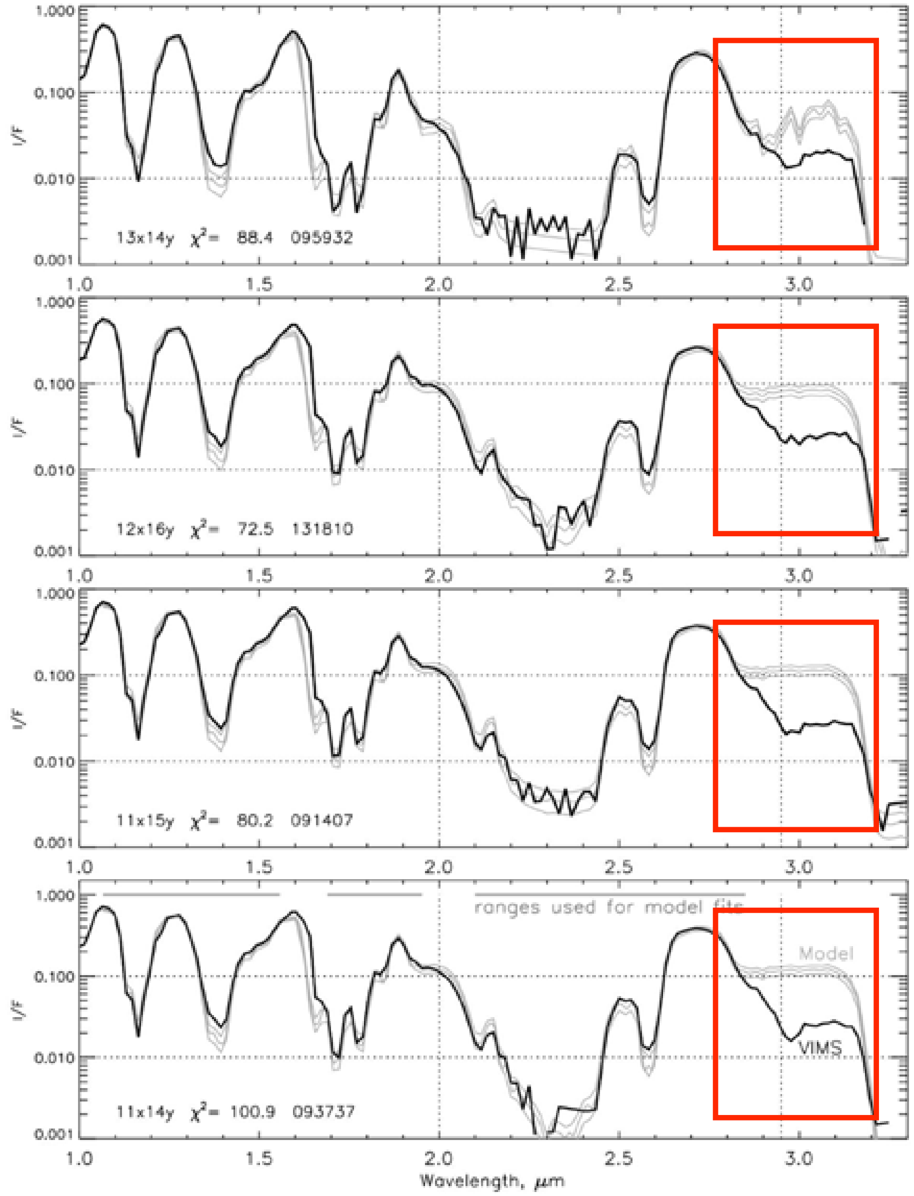
The Cassini flyby of Jupiter in 2000 provided spatially resolved spectra of Jupiter's atmosphere using the Visual and Infrared Mapping Spectrometer. A prominent characteristic of these spectra is the presence of a strong absorption at wavelengths from about 2.9 µm to 3.1 µm, previously noticed in a 3-µm spectrum obtained by the Infrared Space Observatory (ISO) in 1996.

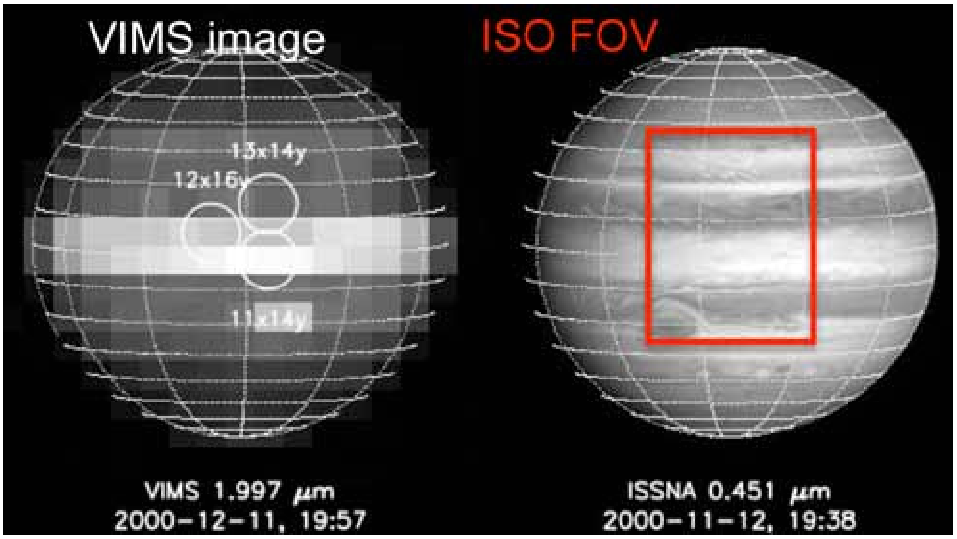
Ammonia ice was a prime candidate as the sole source of particulate absorption. But Irwin et al. 2001 identified a flaw in this explanation: if the absorption is provided by 10-µm NH_3 ice particles, there should also be absorption evident at 2-µm where NH_3 has a sharp feature.

Calculations for a cloud model (as described in Brooke et al. 1998) show the 2-µm feature, but the Near Infrared Mapping Spectrometer spectral measurements do not show it.

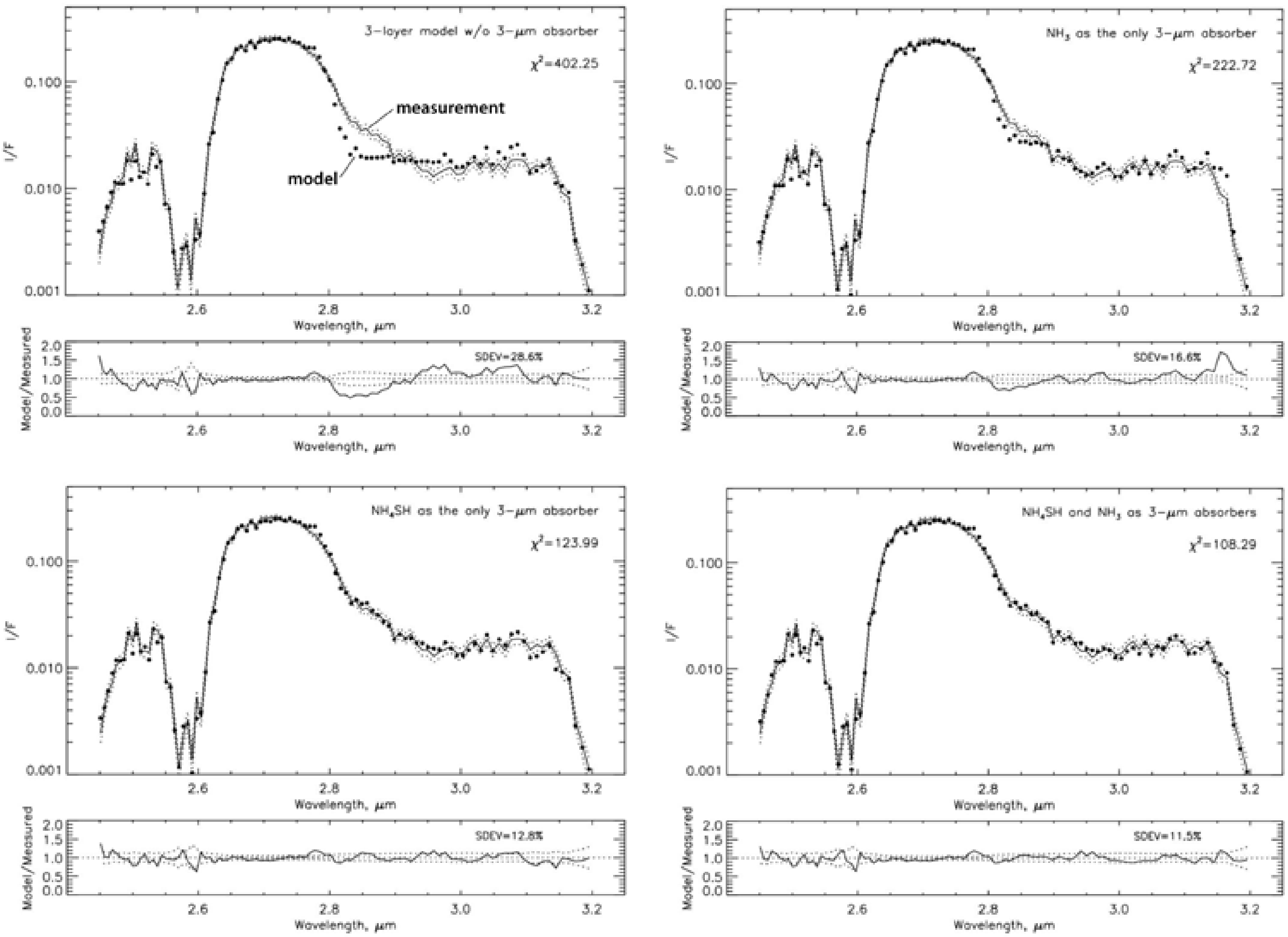
SSEC planetary scientists Larry Sromovsky and Pat Fry, using significantly revised NH_3 gas absorption models, showed that ammonium hydrosulfide (NH_4SH) provided a better fit to the ISO spectrum than NH_3, and that the best fit was obtained when both NH_3 and NH_4SH were present in the clouds.

The 3-micron absorber is present throughout the observable atmosphere of Jupiter, unlike the spectrally identifiable ammonia clouds (SIAC)





The need for a 3-µm absorber is most obvious when trying to fit VIMS spectra (black curves) with grey cloud particles. Such models (grey curves) result in excessive model absolute reflectivity values near 3 µm (the defect is worse for the brightest clouds). The need for absorption is evident in spatially resolved NIMS and VIMS spectra as well as large-FOV ISO spectra and seems to be present everywhere on Jupiter.



For a single 3-μ absorber, the best fit to the ISO spectrum is provided by NH_4SH, in the form of large particles (r = 15-20 μ) near a pressure of 450 mb.

previously studied, which are present over less than 1% of Jupiter. These clouds seem to be made of pure NH_3 and do show a 2-μm absorption feature (as identified by Kevin Baines of SSEC in 2002).

Sromovsky and Fry evaluated seven candidate materials for the 3-micron absorbing layer using improved models for methane and ammonia gas absorption that were not available at the time of previously published work on this issue.

For a single 3-micron absorber, the best fit to the ISO spectrum is provided by ammonium hydrosulfide, in the form of large particles (r = 15-20 microns) near a pressure of 450 millibars. Ammonia is a 7-sigma second best fit among substances thought to be present in Jupiter's atmosphere, with water ice an 11-sigma third place.

Better fits can be obtained by two-absorber models with ammonia contributing a minor fraction either as a population of particles just above or mixed with the ammonia hydrosulfide particles, or as a coating on the small particle layer near 320 millibars.

Strong vertical convection would seem to be needed to transport ammonium hydrosulfide particles to the level that is implied by these results. Such transport would likely result in composite particle composition with NH_3 condensed on top of NH_4SH cores.

Saturn's spectra do not exhibit the broad 3-μm absorption feature characteristic of Jovian spectra, perhaps because the cloud layer containing that absorber is obscured by the moderately thick tropospheric haze that overlies it. However, Saturn spectra do exhibit a small absorption feature near 2.965 μm, which is qualitatively consistent with NH_3 absorption when diluted by combining NH_3 with a substantial conservative core or shell.

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