EPSC Abstracts
Vol. 10, EPSC2015-323, 2015
European Planetary Science Congress 2015

A possible water ice cloud in Jupiter's stratosphere

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Abstract

Jupiter's atmosphere has been sounded in transmission from UV to IR, as if it were a transiting exoplanet by observing one of its satellites, Ganymede, while passing through Jupiter's shadow during a solar eclipse from Ganymede. The spectra show strong extinction due to the presence of aerosols and haze in the atmosphere and strong absorption features from CH_4. In addition, the spectra show two broad features near 1.5 and 2.0 μm that we tentatively attribute to a layer of H_2O ice in Jupiter's stratosphere. While the spectral signatures seem to be unequivocally attributed to crystalline water ice, to explain the strong absorption features requires a large amount of water ice.

1. Introduction

In the search for the characterization of exo-planets atmospheres, there has been recently put emphasis on observing planetary transits in our own solar system [4, 3]. These, in addition of providing insights for future exoplanet characterizations, also serve for exploring our planetary atmospheres themselves.

Here we report on the limb transmission spectra of Jupiter's atmosphere obtained by using ground-based observations of Ganymede, which is in synchronous rotation around Jupiter, when crossing Jupiter's shadow. During the eclipse, the spectral features of the Jovian atmosphere are imprinted in the sunlight that, after passing through Jupiter's planetary limb, is reflected from Ganymede toward the Earth (see Figure 1). The ratio spectrum of Ganymede before and during the eclipse removes the spectral features of the Sun, of the local telluric atmosphere on top of the telescopes, and the spectral albedo of Ganymede. The spectra cover from UV to near-IR and have a high spectral resolution and high signal-to-noise ratio. The highlights of the observations have been reported by Montañes-Rodríguez et al. [3]. Here we focus on a detailed analysis of the spectral region from VIS to near-IR and particularly on the signatures of water ice.

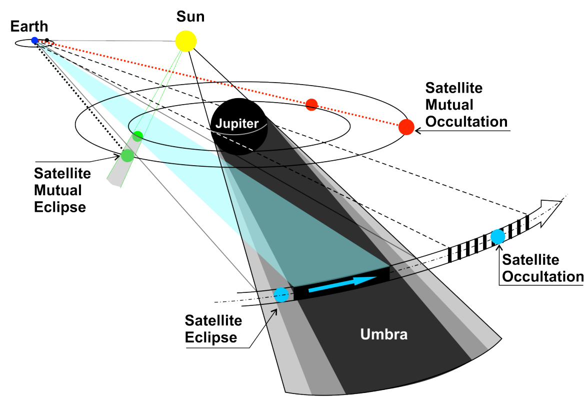

Figure 1: A diagram (not-to-scale) showing the orbital geometry of the Jovian System during the observations [3].

2. Observations

An eclipse of Ganymede was first observed on 06/10/2012 using LIRIS [2] at WHT in La Palma Observatory, Spain. The experiment was repeated later by observing a second eclipse with XSHOOTER [6] at VLT in Paranal Observatory, on 18/11/2012. This work focus on the analysis of VLT data, due to their higher signal to noise ratio, although the WHT observations exhibits essentially the same spectral features.

3. Analysis and Results

Transmission spectra of the occultation of the Sun through Jupiter's atmosphere as observed from

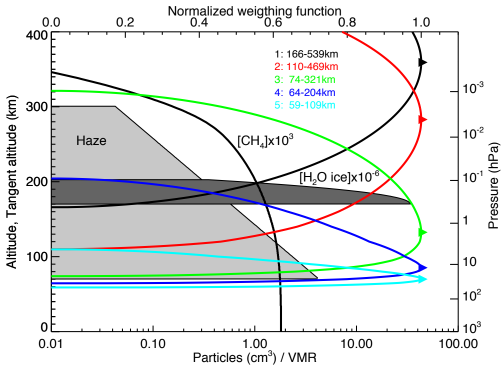

Figure 2: The distribution of haze, CH_4, and H_2O ice used in the simulations of the transmission spectra (see Fig. 3), together with the tangent altitudes covered in each of our simulations corresponding to the mean times when the (umbra)-penumbral spectra were taken. Altitude is taken as zero at the 1 bar pressure level. Over-plotted are the profiles of the concentrations of aerosols and of the water ice particles cloud [3].

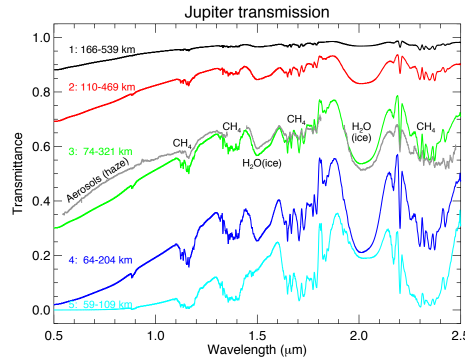

Figure 3: Transmission spectra of Jupiter calculated for the early phase of the penumbra and during the umbra over the $0.5-2.5$ μm spectral region. The grey line is one of the observed penumbral spectra [3].

Ganymede have been simulated for the observations of the eclipse in the penumbra and within the first stages of the umbra by using the Karlsruhe Optimized and Precise Radiative Transfer Algorithm (KOPRA; [5]). Besides the CH_4 absorption, the simulations also include: Rayleigh scattering by molecular hydrogen and helium, collisions induced absorption (CIA) for H_2-H_2 and H_2-He, and Mie scattering by water ice and aerosols. The distribution of CH_4, haze, and H_2O ice used in the simulations are shown in Fig. 2, and the simulated spectra together with one of the penumbral observed spectra are shown in Fig. 3.

The spectra show the most prominent CH_4 bands, the extinction of the aerosol particles (haze), and two distinct absorption features of water ice at 1.5 and 2.0 μm. All major features of the measured spectra are simulated. The absorption spectral features at 1.5 and 2.0 μm can be very well reproduced in our model with crystalline water ice at 150 K, but needs a total vertical column of about 10^{13} particles/cm^2 with a size of $\sim$0.01 μm located near the 0.5 mbar level (see Fig. 2). If sublimated, this leads to a much larger water amount (about a factor of 500) than that measured by HERSCHEL [1] at and above that pressure level. While the spectral features fit perfectly to those of water ice, the required large amount of water ice to reproduce the spectra is still not understood.

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