Methane Absorption Spectra by the Descent Imager / Spectral Radiometer

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In the visible and near-infrared, the spectra of the Jovian planets and Titan are dominated by methane absorption features, which allow probing a variety of levels of their atmospheres. Interpretation of most data in this wavelength range requires an understanding of methane absorption features. Methane absorption data have provided the best constraints on the vertical distribution of aerosols in the Jovian atmospheres. Methane plays an important role in the heat balance in the Jovian atmospheres. Measured methane mixing ratios have given important clues about the history of the solar system.

Above 5000 nm wavelength, methane lines are theoretically understood sufficiently well to predict methane absorption for every temperature, pressure, methane abundance, and gas composition. Toward lower wavelengths, theoretically methane data are more and more incomplete. Below 1600 nm, our knowledge of methane absorption is based on laboratory measurements.

Because the size of laboratories on Earth are measured in meters, but the scale heights of the atmospheres are measured in kilometers, laboratory measurements have to be extrapolated to be applied to planetary conditions which is intrinsically unreliable.

On January 14, 2005, we set up a kilometer-sized laboratory in the atmosphere of Titan. The Huygens probe measured temperature, pressure, methane mixing ratio, and the transmission of the atmosphere between Huygens and the sun at more than 300 wavelengths and at many altitudes. The data revealed that some of the extrapolations from laboratory conditions to Titan's conditions were quite accurate while others were off by up to a factor of 100.

The Huygens data confirmed our knowledge about methane absorption up to 850 nm wavelength. Between 850 and 1050 nm, the strongest absorptions of methane were some 30 percent weaker than the extrapolations from laboratory data. From 1050 nm to 1600 nm, the upper wavelength limit of the Huygens data, strong methane absorptions were almost as strong as expected, but the weak absorptions were up to 100 times stronger than expected.

We investigated these differences and found that the previous model of temperature dependence of methane absorption was too simple. We altered the model and eventually could fit all laboratory data and all Huygens data fairly well. We estimate that the Huygens data revealed the major flaw of previous methane band models, and that our new model provides reliable methane absorption coefficients for the conditions in the Jovian planets and Titan probed by most observations.

Some previous investigations based on the data before the Huygens descent have to be reevaluated. For example, some estimated cloud altitudes in Titan atmosphere were too low. Some estimated albedos of Titan's surface need to be revised up by 50 percent or more. Some aerosol optical depths for the atmospheres of Uranus and Neptune need to revised up by large factors.

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