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Global circulation in the stratosphere of Jupiter: ultraviolet observations of acetylene and ethane

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Abstract

The abundances of acetylene and ethane are tracers of the global circulation pattern present in the stratosphere of Jupiter. We present an analysis of Cassini Ultraviolet Imaging Spectrograph (UVIS) observations of Jupiter from the flyby in early 2001. This analysis required the development of our atmospheric retrieval and radiative transfer code to include UV absorption by a number of species, including acetylene, ethane, phosphine, and ammonia. The Cassini UVIS spectral range only allows for the retrieval of acetylene and ethane, whilst the longer wavelength coverage of Juno/JUICE UVS also allows us to accurately retrieve of the abundances of phosphine and ammonia. We retrieve abundances of acetylene and ethane that are consistently lower than those observed by Cassini CIRS, however, the two instruments sample different altitudes in the stratosphere, and these ultraviolet observations can contribute with important high-altitude constraints on these distributions. Finally, we discuss the implications that the observed abundances have for the global circulation in the stratosphere.

1. Overview

Acetylene (C_2H_2) and ethane (C_2H_6) are both photochemical products of methane, and are produced in the stratosphere of Jupiter. Once produced, these species are re-distributed by global circulation patterns, and therefore we expect them to have very similar zonally averaged meridional distributions, yet they been observed to be very different: acetylene has the highest abundance about the equator, and ethane has an abundance that increases towards the poles (e.g. Melin et al., 2018). The reason for this remains a mystery.

1.1 Modelling

The NEMESIS retrieval and radiative transfer code (Irwin et al,. 2008) has been used extensively to retrieve the vertical distribution of abundances and temperatures from infrared spectra. However, ultraviolet absorption spectrum offers an additional window that can provide constraints on the abundances of species in the troposphere and stratosphere of Jupiter.

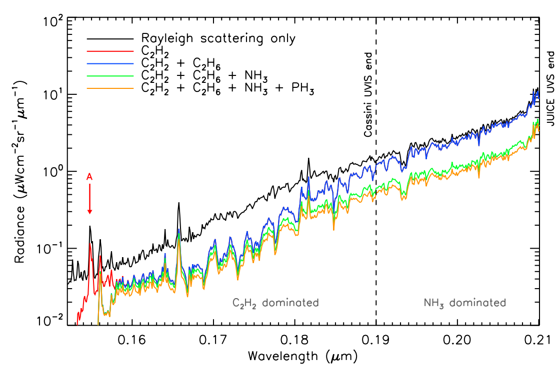

Figure 1: *Forward models of the ultraviolet reflectance spectra of Jupiter with different absorbers added in as indicated. At wavelengths lower than 0.19 microns, the absorption spectrum is dominated by acetylene absorption, whilst at longer wavelengths it is dominated by ammonia absorption.*

The ultraviolet wavelength range is dominated by Rayleigh scattering of the incident solar spectrum. This is attenuated by absorptions by different species, predominantly acetylene, ethane, phosphine, and ammonia. This is illustrated in Figure 1, showing the wavelength covered by both Cassini UVIS and Juno/JUICE UVS. The longer wavelength range of the latter allows for the retrieval of phosphine and ammonia, in addition to acetylene and ethane.

1.2 Observations

The Cassini spacecraft flew past Jupiter in late 2000/early 2001 with a minimum distance of 137 R_J. The Cassini UVIS instrument performed scans of the planet providing a low spatial resolution view at high phase angles – the wavelength integrated UVIS view of Jupiter is shown in Figure 2, along with NEMESIS forward-models with different absorptions turned on. We used the vertical profiles retrieved by Cassini CIRS as the priors (Fletcher et al., 2016). Figure 2b shows that the forward model using the CIRS profiles produce a good prediction of what is actually observed in the ultraviolet.

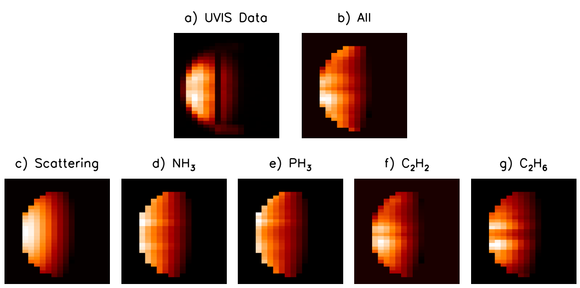

Figure 2: *The Cassini UVIS scan of Jupiter (a) and NEMESIS forward models with different ultraviolet absorptions enabled, using the Cassini CIRS profiles as the input abundance and temperature profiles.*

1.3. NEMESIS Retrievals

Figure 1 illustrates that the ultraviolet spectrum observed by the UVIS instrument (up to 0.19 microns) is dominated by the absorption of acetylene and ethane (feature A), and so abundances of these species can be retrieved from the UVIS spectra. Figure 3 shows an example of retrievals of the data shown in Figure 2. The retrieved abundances are consistently lower than those retrieved by CIRS, but whilst CIRS has a sensitivity that peaks at about 10 mbars, UVIS is sensitive to pressures between 1 and 0.01 mbars, so the two measurements are likely to be consistent with each other, indicating that the upper stratosphere is less abundant in both acetylene and ethane than the CIRS priors suggest. The different structures observed at the equator may be because UVIS is sensing a different region of the Quasi-Quadrennial Oscillation (QQO) at higher altitudes than CIRS. In addition, the latitudinal asymmetry is less pronounced in the UVIS data, suggesting that vertical mixing has less of an effect in the upper stratosphere compared to the lower stratosphere sounded by CIRS.

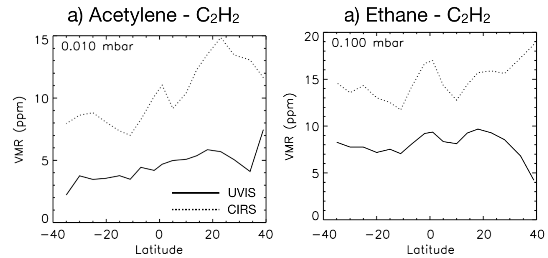

Figure 3: *The retrieved volume mixing ratio (VMR) as a function of latitude at 0.1 mbar for acetylene and ethane as observed by both Cassini CIRS and UVIS. Whilst the UVIS observations retrieve lower VMRs, they are likely sampling different altitudes.*

Acknowledgments

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