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Oxford RAL Terahertz-Infrared Sensor - ORTIS

P.G.J. Irwin (1), B.N. Ellison (2), S.B. Calcutt(1), N.E. Bowles(1), N.A. Teanby (1), R. de Kok (3), B Alderman (2)

(1) Atmospheric, Oceanic, and Planetary Physics, University of Oxford, Clarendon Laboratory, Parks Rd, Oxford, OX1 3PU, UK, (2) Rutherford Appleton Laboratory, Didcot, OX11 0QX, UK, (3) SRON Netherlands Institute of Space Research
(irwin@atm.ox.ac.uk / Fax: +44-1865-272923)

Abstract

The sub-millimetre wave spectra of the outer planets are rich in absorption line features that can be measured with extremely high spectral resolution ($\sim10^6$) with sub-millimetre wave heterodyne technology to determine temperature, winds and composition in the stratosphere. To measure stratospheric temperature requires the observation of the absorption of a well-mixed gas such as methane and while there is a methane absorption feature near 1.2 THz that is measurable with current solid-state receiver technology, this feature is relatively weak. Methane absorption lines become stronger at increasing frequency and the feature at 2.2 THz is particularly attractive as there is a strong water line lying ~2GHz from the line centre that could be measured simultaneously with the methane absorption line (Fig.1).

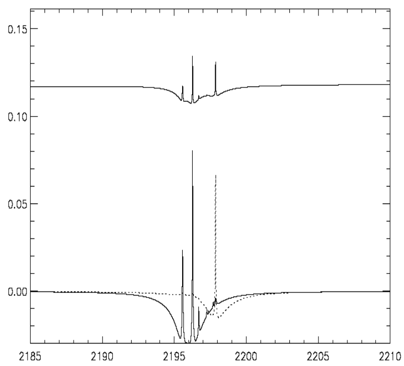

Fig. 1 Close-up of methane absorption feature in Jupiter spectrum near 2.2 THz region (top plot). The vertical scale is radiance (W m^{-2} sr^{-1} $(GHz)^{-1}$). The plots at the bottom show the sensitivity to changes in abundance of methane (solid line) and water vapour (dotted line). The close proximity between the CH_4 and H_2O lines is clear.

The technology for sub-millimetre wave spectroscopy at this frequency has advanced very considerably in recent years and we believe that observation of this feature will be technically feasible from a highly efficient and integrated payload. The advantages of this observation scenario over lower frequency measurements are numerous and include: 1) the methane absorption line is stronger, allowing sounding to higher altitudes; 2) the field-of-view is smaller for the same antenna size allowing the instrument to observe smaller features and also making limb-sounding easier; 3) it is easier to determine the Doppler shifting of lines due to winds at these higher frequencies; and 4) the instrument payload is more compact.

A sub-millimetre wave device would provide valuable information Jupiter's stratosphere, but the radiance away from the line centres is governed by the temperature in the upper troposphere and also by the abundance of ammonia, which is very variable. We propose to combine the sub-millimetre wavelength device with a far-IR channel radiometer, bore-sighted with the sub-millimetre wave spectrometer with channels spread over the 200 – 650 cm^{-1} range. The far-IR radiometer would be able to measure the upper tropospheric temperature profile in the H_2-H_2, H_2-He collision induced continuum, which is not affected by ammonia. Such an addition would very simply extend the vertical coverage of temperature of the combined instrument from the tropopause right down to the cloud tops and also return the para-H_2 fraction, which is an indicator of vertical motion. This addition would also mean that the sub-millimetre wave continuum measurements could then be used to determine the variable abundance of ammonia and allow the combined device to probe temperature, dynamics and abundances in the upper troposphere as well as in the stratosphere.