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Detection of the Zeeman effect in atmospheric O_2 using a ground-based microwave radiometer

Francisco Navas-Guzmán (1), Niklaus Kämpfer (1), Axel Murk (1), Richard Larsson (2), Stefan A. Buehler (3), and Patrick Eriksson (4)

(1) Institute of Applied Physics, University of Bern, Switzerland (francisco.navas@iap.unibe.ch), (2) Division of Space Technology, Department of Computer Science, Electrical and Space Engineering, Luleå University of Technology, Box 812, SE-98128 Kiruna, Sweden, (3) Meteorological Institute, Center for Earth System Research and Sustainability, University of Hamburg, Germany, (4) Department of Earth and Space Sciences, Chalmers University of Technology, SE-41296 Gothenburg, Sweden

In this work we study the Zeeman effect on stratospheric O_2 using ground-based microwave radiometer measurements. The Zeeman effect is a phenomenon which occurs when an external magnetic field interacts with a molecule or an atom of total electron spin different from zero. Such an interaction will split an original energy level into several sub-levels [1]. In the atmosphere, oxygen is an abundant molecule which in its ground electronic state has a permanent magnetic dipole moment coming from two parallel electron spins. The interaction of the magnetic dipole moment with the Earth magnetic field leads to a Zeeman splitting of the O_2 rotational transitions which polarizes the emission spectra.

A special campaign was carried out in order to measure this effect in the oxygen emission line centered at 53.07 GHz in Bern (Switzerland). The measurements were possible using a Fast Fourier Transform (FFT) spectrometer with 1 GHz of band width to measure the whole oxygen emission line centered at 53.07 GHz and a narrow spectrometer (4 MHz) to measure the center of the line with a very high resolution (1 kHz). Both a fixed and a rotating mirror were incorporated to the TEMPERA (TEMPERature RAdiometer) radiometer in order to be able to measure under different observational angles. This new configuration allowed us to change the angle between the observational path and the Earth magnetic field direction.

The measured spectra showed a clear polarized signature when the observational angles were changed evidencing the Zeeman effect in the oxygen molecule. In addition, simulations carried out with the Atmospheric Radiative Transfer Simulator (ARTS) [2] allowed us to verify the microwave measurements showing a very good agreement between model and measurements. The incorporation of this effect to the forward model will allow to extend the temperature retrievals beyond 50 km. This improvement in the forward model will be very useful for the assimilation of brightness temperatures in numerical weather prediction (NWP) models.

References

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