EPSC Abstracts
Vol. 8, EPSC2013-62-4, 2013
European Planetary Science Congress 2013

Spatial distribution of water in the stratosphere of Jupiter from observations with the Herschel Space Observatory

T. Cavalié (1,2), H. Feuchtgruber (3), E. Lellouch (4), M. de Val-Borro (5,6), C. Jarchow (5), R. Moreno (4), P. Hartogh (5), G. Orton (7), T. K. Greathouse (8), F. Billebaud (1,2), M. Dobrijevic (1,2), L. M. Lara (9), A. González (9), H. Sagawa (10)
(1) Univ. Bordeaux, LAB, UMR 5804, F-33270, Floirac, France (cavalie@obs.u-bordeaux1.fr), (2) CNRS, LAB, UMR 5804, F-33270, Floirac, France, (3) Max Planck Institut für Extraterrestrische Physik, Garching, Germany, (4) LESIA–Observatoire de Paris, CNRS, Université Paris 06, Université Paris–Diderot, 5 place Jules Janssen, 92195 Meudon, France, (5) Max Planck Institut für Sonnensystemforschung, Katlenburg-Lindau, Germany, (6) Department of Astrophysical Sciences, Princeton University, Princeton, NJ 08544, USA, (7) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, USA, (8) Southwest Research Institute, San Antonio, TX 78228, USA, (9) Instituto de Astrofísica de Andalucía (CSIC), Granada, Spain, (10) National Institute of Information and Communications Technology, 4-2-1 Nukui-kita, Koganei, Tokyo 184-8795, Japan.

Abstract

Water in the atmospheres of the outer planets has both an internal and an external source (e.g., [1] and [2] for Jupiter). These sources are separated by a condensation layer, the tropopause cold trap, which acts as a transport barrier between the troposphere and the stratosphere. Thus, the water vapor observed by the Infrared Space Observatory (ISO) in the stratosphere of the giant planets has an external origin [3]. This external supply of water may have several sources: (i) a permanent flux from interplanetary dust particles produced from asteroid collisions and from comet activity [4], (ii) local sources from planetary environments (rings, satellites) [5], (iii) cometary "Shoemaker-Levy 9 (SL9) type" impacts [6]. In the past 15 years, several studies suggested that water in the stratosphere of Jupiter originated from the SL9 comet impacts in July 1994, but a direct proof was missing.

We will report the first high S/N spatially resolved mapping observations of water in Jupiter's stratosphere carried out with the Heterodyne Instrument for the Far Infrared (HIFI) [7] and Photodetector Array Camera and Spectrometer (PACS) [8] instruments onboard the ESA Herschel Space Observatory [9]. These observations have been obtained in the framework of the Guaranteed Time Key Program "Water and related chemistry in the Solar System", also known as "Herschel Solar System Observations" (HssO) [10]. In parallel, we have monitored Jupiter's stratospheric temperature with the NASA Infrared Telescope Facility (IRTF) to separate temperature from water variability.

We will present the results recently published by our team [11]. Water is found to be restricted to pressures lower than 2 mbar. Its column density decreases by a factor of 2-3 between southern and northern latitudes (see Fig. 1), consistently between the HIFI and the PACS 66.4 μm maps. Latitudinal temperature variability cannot explain the global north-south asymmetry in the water maps. From the latitudinal and vertical distributions of water in Jupiter's stratosphere, we rule out interplanetary dust particles as its main source. Furthermore, we demonstrate that Jupiter's stratospheric water was delivered by the SL9 comet and that more than 95% of the observed water comes from the comet according to our models.

On the longer term, this study can be regarded as a preparation of the observations to be performed by the Submillimetre Wave Instrument (SWI) [12]. SWI is an instrument proposed for the payload of the Jupiter Icy Moon Explorer (JUICE). This instrument will observe water and the other SL9-derived species in Jupiter with a higher spatiotemporal resolution than Herschel to constrain its 3D stratospheric circulation.

Acknowledgements

T. Cavalié acknowledges funding from the Centre National d'Études Spatiales (CNES).

References

[1] Larson, H. P., Fink, U., Treffers, R., and Gautier, III, T. N., 1975. Detection of water vapor on Jupiter. ApJ, 197, L137.

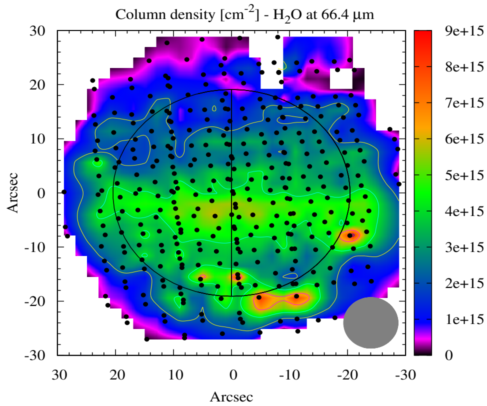

Figure 1: Column density of water (in cm^{-2}), as derived from the 66.4 μm map. Jupiter is represented by the black ellipse, and its rotation axis is also displayed. The beam is represented by the gray filled circle in the lower right corner. In the southern equatorial region (0-25°S), the emission maximum identified in this map is most probably caused by a temperature effect and not by a local maximum of the column density. Taken from [11].

[2] Lellouch,E., Bézard,B., Moses,J.I. et al., 2002. The origin of water vapor and carbon dioxide in Jupiter's stratosphere. Icarus, 159, 112-131.

[3] Feuchtgruber, H., Lellouch, E., de Graauw, T. et al., 1997. External supply of oxygen to the atmospheres of giant planets. Nature, 389, 159-162.

[4] Prather, M.J., Logan, J.A., McElroy, M.B., 1978. Carbon monoxide in Jupiter's upper atmosphere-an extraplanetary source. ApJ, 223, 1072-1081.

[5] Strobel, D.F., Yung, Y.L., 1979. The Galilean satellites as a source of CO in the Jovian upper atmosphere. Icarus, 37, 256-263.

[6] Lellouch, E., Paubert, G., Moreno, R. et al., 1995. Chemical and thermal response of Jupiter's atmosphere following the impact of Comet Shoemaker-Levy-9. Nature, 373, 592-595.

[7] de Graauw, T., Helmich, F. P., Phillips, T. G. et al., 2010. The Herschel-Heterodyne Instrument for the Far-Infrared (HIFI). A&A, 518, L6.

[8] Poglitsch, A., Waelkens, C., Geis, N., et al., 2010. The Photodetector Array Camera and Spectrometer (PACS) on the Herschel Space Observatory. A&A, 518, L2.

[9] Pilbratt, G.L., Riedinger, J.R., Passvogel, T. et al., 2010. Herschel Space Observatory. An ESA facility for far-infrared and submillimetre astronomy. A&A, 518, L1.

[10] Hartogh, P., Lellouch, E., Crovisier, J. et al., 2009. Water and related chemistry in the solar system. A guaranteed time key program for Herschel. Planet. Space Sci. 57, 1596-1606.

[11] Cavalié, T., Feuchtgruber, H., Lellouch, E. et al., 2013. Spatial distribution of water in the stratosphere of Jupiter from Herschel HIFI and PACS observations. A&A, 553, A21.

[12] Hartogh, P., Barabash, S., Bolton, S., et al., 2009. Submillimetre Wave Instrument for EJSM. EPSC Abstracts, 4, EPSC2009.