EPSC Abstracts Vol. 8, EPSC2013-72-1, 2013 European Planetary Science Congress 2013 © Author(s) 2013



First submillimeter observation of CO in the stratosphere of Uranus with Herschel-HIFI

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Abstract

Oxygen-rich deep interiors of the Giant Planets [1] cannot explain the discovery of water vapor and carbon dioxide in the stratospheres of the Giant Planets by [2] because these species are trapped by condensation around their tropopause levels (except CO_2 in Jupiter and Saturn). Therefore, several sources in the direct or far environment of the Giant Planets have been proposed: icy rings and/or satellites [3], interplanetary dust particles [4] and large comet impacts [5].

Infrared Space Observatory (ISO), Cassini, Odin and Herschel observations have proven that the Jovian stratospheric water and carbon dioxide originate from the Shoemaker-Levy 9 comet impacts in July 1994 [6, 7], while Herschel has recently shown the external flux of water at Saturn and Titan is most likely due to the Enceladus geysers and the water torus they feed [8, 9].

As for carbon monoxide (CO), the emerging picture seems to show more uniformity for its sources. Because CO does not condense at the tropopauses of Giant Planets, oxygen-rich interiors are a valid source. An internal component has indeed been observed in the vertical profile of CO in Jupiter by [10] and in Neptune by [11], while an upper limit has been set on its magnitude by [12] for Saturn. In addition to interiors, large comets seem to be the dominant external source of CO in the Giant Planets, as shown by various studies: [10] and [13] for Jupiter, [14] for Saturn and [15] for Neptune.

Despite its first detection almost a decade ago by [16], the situation has remained unclear for Uranus ever since. The (sub)millimeter domain with the use of heterodyne spectroscopy has long been considered

as promising to determine the vertical profile of CO, and thus its origin, in Uranus (e.g., [17]). However, attempts made to detect the molecule have failed so far in this spectral range, leading only to upper limits [18]. In this paper, we present the first submillimeter detection of CO in Uranus carried out with the HIFI instrument [19] onboard the Herschel Space Observatory [20] in 2011-2012. Using a simple transport model, we review the various possible sources of CO (internal and external) and constrain their magnitude. For instance, we derive an upper limit for the internal source of CO. And with the thermochemical model of [21], adapted to the interior of Uranus, we derive an upper limit on its deep O/H ratio from it.

Acknowledgements

T. Cavalié acknowledges funding from the Centre National d'Études Spatiales (CNES) and support from the European Research Council (Starting Grant 209622: E_3ARTHs).

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