

**WATER D/H RATIO IN COMET C/2009 P1 (GARRADD) FROM HERSCHEL.** D. Bockelée-Morvan<sup>1</sup>, B. Swinyard<sup>2</sup>, N. Biver<sup>1</sup>, P. Hartogh<sup>3</sup>, M. de Val-Borro<sup>3</sup>, S. Szutowicz<sup>4</sup>, J. Crovisier<sup>1</sup>, D.C. Lis<sup>5</sup>, R. Moreno<sup>1</sup>, E. Lelouch<sup>1</sup>, E.A. Bergin<sup>6</sup>, M. Küppers<sup>7</sup>, M. Kidger<sup>8</sup>, M. Emprechtinger<sup>5</sup>, R. Courtin<sup>1</sup>, M. Rengel<sup>3</sup>, and G. Blake<sup>5</sup>. <sup>1</sup>LESIA, Observatoire de Paris, 5 place Jules Janssen, F92195, Meudon, France (dominique.boekelee@obspm.fr), <sup>2</sup>Rutherford Appleton Laboratory, Oxfordshire, UK, <sup>3</sup>Max-Planck-Institut für Sonnensystemforschung, Katlenburg-Lindau, Germany, <sup>4</sup>Space Research Centre PAS, Warsaw, Poland, <sup>6</sup>California Institute of Technology, Pasadena, USA, <sup>5</sup>Astronomy Department, University of Michigan, USA, <sup>7</sup>Rosetta Science Operations Centre, ESA, Madrid, Spain, <sup>8</sup>Herschel Science Center, ESA, Madrid, Spain.

**Introduction:** Measurements of isotopic ratios in comets provide key information about the formation of cometary materials and possible links with other Solar System primitive bodies and the interstellar medium. The D/H ratio in water was measured in several Oort cloud comets (OCC) using different techniques, with most measurements agreeing with a value of  $\sim 3 \times 10^{-4}$  [1]. The Herschel observatory allowed us to measure for the first time the D/H ratio in a Jupiter family comet (JFC) presumably formed in the Kuiper Belt, comet 103P/Hartley 2 [2]. The D/H ratio was found to be  $(1.6 \pm 0.24) \times 10^{-4}$ , i.e., a factor of 2 lower than the earlier measurements in Oort cloud comets and the same as the Earth's oceans value.

According to the most accepted theories, OCCs and JFCs come from the same population of objects formed in the Uranus-Neptune zone, or Oort cloud comets formed on average closer to the Sun. However, the deuterium enrichment has been predicted to increase with increasing heliocentric distance [3]. Hence, contrary to the available measurements, JFCs were expected to exhibit a D/H ratio similar or higher than that in OCCs. The discrepancy between measurements and expectations leaves us with two options: 1) the dependence of the water D/H ratio on heliocentric distance is not as expected from current models investigating deuterium fractionation in the Solar Nebula and further processing; or 2) the main source regions of JFCs and OCCs need to be revisited. Alternatively, it is also possible that each population has a distribution of D/H ratios spanning high to low values. Indeed, the distribution of planetesimals in the early Solar System underwent large-scale mixing during the stages of planetary migration [4],[5].

**New measurements in comet C/2009 P1 (Garradd):**

Further D/H measurements are essential to explore the diversity of D/H ratios in cometary water, and to confirm or disprove the suggested dichotomy between JCCs and OCCs. Since measurements in JFCs have only been acquired with Herschel, it is important to acquire a suite of measurements for OCCs with the same instrumentation.

Comet C/2009 P1 (Garradd) is a long-period comet from the Oort cloud which passed perihelion on

23 December 2011 at 1.55 AU from the Sun. We observed it with the Heterodyne Instrument for the Far Infrared (HIFI) onboard Herschel on 6 October 2011 when it was at 1.88 AU from Sun and 1.76 AU from Herschel. We used the same observing strategy as for comet 103P/Harley 2, alternating H<sub>2</sub>O, H<sub>2</sub><sup>18</sup>O and HDO observations. HDO was detected with a signal-to-noise ratio of 18 on the line area, providing the best HDO detection ever obtained in a comet from remote sensing.

We will present the D/H ratio measured in comet C/2009 P1 (Garradd) and discuss the results in the context of previous measurements in OCCs and JFCs and current dynamical models of the early Solar System.

**References:** [1] Jehin E. et al. (2009) *EM&P*, 105, 167-180. [2] Hartogh P. et al. (2011) *Nature*, 478, 218-220. [3] Mousis O. et al. (2000) *Icarus*, 148, 513. [4] Walsh K.J. et al. (2011) *Nature*, 475, 206-209. [5] Tsiganis K. et al. (2005) *Nature*, 435, 459-461.