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Detection of water vapour around dwarf planet (1) Ceres

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Abstract

We report the detection of water vapour on (1) Ceres, the first unambiguous discovery of water on an object in the asteroid main belt. Most of the water vapour stems from localized regions at low latitude, possibly from surface features known from adaptive optics observations. We suggest either cometary-type sublimation from the near surface or cryovolcanism as the origin of the waver vapour [1].

1. Introduction

The snowline conventionally divides Solar System objects into dry bodies, ranging out to the main asteroid belt, and icy bodies beyond the belt. Recently, the detection of dust emission from "main-belt comets" [2] and of hydration features and possible water ice absorption on some main-belt asteroids [3] together with theories of migration of small bodies in the solar system [4] cast some doubts on the classical picture.

Ceres is thought to be differentiated into an icy core and a silicate mantle [5] and hydrated minerals were found on infrared spectra of its surface [6]. A marginal detection of OH, a photodissociation product of water was reported in 1991 [7], but questioned by later, more sensitive observations [8].

2. Observations and results

We observed Ceres with the Heterodyne Instrument for the Far Infrared (HIFI) [9] on the Herschel Space Observatory [10] in the context of the MACH 11 guaranteed time program and with a follow up DDT program. The observations took place in Nov. 2011, Oct. 2012 and March 2013. We searched for the signature of water in the ground state line of ortho-water at 556.936 GHz. After a non- detection in the first observation, an absorption line is clearly visible in all other observations. Figure 1 shows the time-averaged spectra taken on 6 March 2013, normalized to the continuum of Ceres. In March 2013 water is detected in emission as well (at 3 sigma level). Water molecules outflowing towards the observer causes the absorption line to be blue-shifted. The emission line is from water molecules on the limb.

The spectrum was analysed using DMSC calculations of Ceres's exosphere, and state-of-the-art excitation models. From these models, the production rate of water on Ceres is estimated to 2.10^{26} s^{-1} (6 kg s^{-1}).

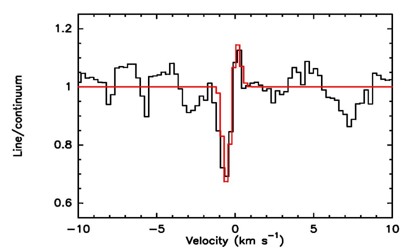

Figure 1: Spectrum of the water 557 GHz line observed in Ceres on 6 March 2013 (black), and model fit (red). Figure from [2].

The water signal varies on time scales of hours (Fig. 2). We interpret this variation as localized sources on Ceres surface rotating into and out of the hemisphere visible by Herschel. As seen on Fig.2, the time variability is consistent with those sources being known dark features known from ground-based adaptive optics observations [11].

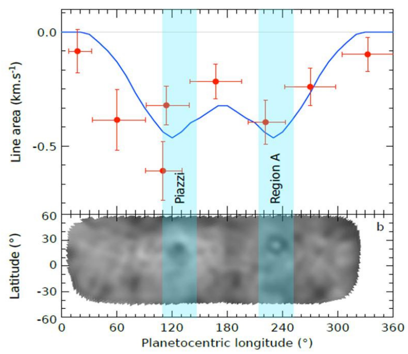

Figure 2: Variability of water absorption on 6 March 2013 as a function of the longitude of the sub-observer point. Top: Data are in red; the curve in blue is from a gas-dynamic model where water is released from regions Piazzi and A. Bottom : map of Ceres. Figure from [1].

2. Discussion

The water vapour on Ceres may be either produced by near surface ice heated by sunlight (cometary activity) or by cryovolcanoes or geysers getting their energy from Ceres' interior. In the first case the production rate is expected to peak around perihelion, while for volcanic the time variations are expected to be more stochastic. The existing observations appear consistent with the cometary hypothesis, but do not allow to clearly distinguish between those possibilities. Upon its arrival at Ceres in 2015, the DAWN spacecraft [12] may provide insight into the sources and mechanisms of water production at Ceres.

Acknowledgements

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