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Pure ice grains in the coma of 9P/Tempel 1 after Deep Impact

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Abstract

The Deep Impact (DI) spacecraft encountered comet 9P/Tempel 1 on July 4th, 2005. The spacecraft released an impactor that collided with the comet nucleus and excavated (possibly unprocessed) cometary material in a prominent ejecta plume. We report on the temporal evolution of water molecules observed with the IRS instrument on the Spitzer Space telescope after impact. We show that it can only be explained by the presence of subliming pure ice grains. The mass of water ice in subliming 0.1 - 1 μm grains is close to 2 x 10^6 kg.

1. Introduction

The NASA Discovery mission Deep Impact to the Jupiter family comet 9P/Tempel 1 provided the first opportunity to examine material from the interior of a cometary nucleus. A principal objective was to compare the composition of dust and volatiles before and after the impact. Spectral maps covering 20" x 67" (1.85"/pixel) were acquired with the IRS instrument on the Spitzer Space Telescope at different times around the DI event: twice before impact (TI-41.3hrs and TI-22.9hrs) and twelve times after impact (between TI+0.67hrs and TI+1027hrs). These IRS observations are stored in the Spitzer data archive and presented by [2]. The interpretation of the 5.2-7.6 micrometer spectra obtained in the second order of the short-wavelength module (SL2) allows us to study the temporal evolution of the number of water molecules within the field of view (FOV) by analysing the intensity of the ν_2 H_2O band.

2. Temporal evolution of the water emission

Figure 1 shows the temporal evolution of the number of molecules in 9.25" x 9.25" extraction centered on the nucleus. We have developed a time dependent model in order to interpret this temporal evolution. To fit the observational data we need a linear combination of a short duration outburst and a long-duration outburst. We deduce a number of water molecules injected by the impact equal to 2.5 $\pm$ 0.5 x 10^{32} molecules. To explain the long-term production of water vapor, the sublimation of long-lived grains can be invoked. This conclusion is consistent with [1] who suggested that the principal source of volatiles in the ejecta was sublimation from outflowing grains.

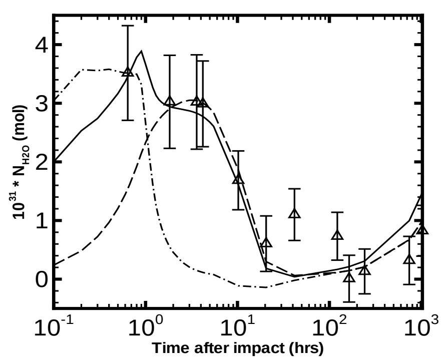

Figure 1: Number of water molecules of the ejecta in 9.25" x 9.25" FOV from the data (triangle), expected for a short-duration outburst (dash-dotted line), for a long-duration outburst (longdashed line) and for a linear combination of both (solid line).

3. Interpretation by subliming icy grains

To study this hypothesis, we have developed a model that investigates the sublimation of pure water ice grains and of three-layer grains consisting of a silicate core surrounded by an organic component, covered by a mantle of water ice. From the variation of the grain radius with time due to sublimation we determined the grain lifetime which is very dependent of the grain size and temperature (Fig.2). In our model, we supposed that the grains are moving radially with a velocity dependant of the grain radius and produce water molecules when subliming. These water molecules are moving radially once ejected from grains with a velocity equal to 0.8 km/s. We studied the evolution with time of the distribution in space for the different water molecule clouds produced by the different grain sizes. We compared this model with an approach where the grains are moving radially but the water molecules are escaping isotropically from the grains. These two models are complementary: the first one is appropriate for a dense medium where the water molecules sublimating from grains are forced to move in the same radial direction. In the second case (analogous to the vectorial model for photodissociation products) the medium is quite rarefied, collisions are less important, and the water molecules are expanding isotropically from grains. With these studies we can reproduce the temporal evolution observed in the FOV if pure water ice grains are present and the mass of water within these grains for size between 0.1 - 1 μm is close to 2 x 10^6 kg. Water ice present in grains was spectroscopically detected by the infrared DI spectrometer [3]. This work is in progress. The aim is to determine the dust-to-ice ratio in the material excavated by DI.

References

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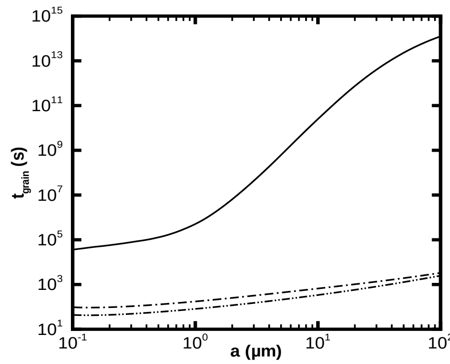

Figure 2: Lifetime of pure ice grains (solid line) and of three layers grains with fractionnal mass of water equal to 0.95 (dash-dotted line) and equal to 0.90 (dash-dotted-dotted line).

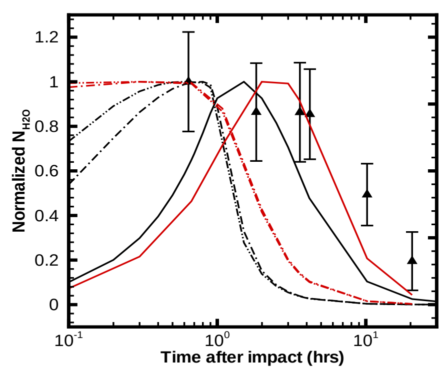

Figure 3: Time evolution of the number of water molecules released from pure ice grains (solid line) and three layers grains with fractionnal mass of water equal to 0.95 (dash-dotted line) and equal to 0.90 (dash-dotted-dotted line) in the case of a radial expansion of the molecules (dark) and in the case of an isotropic expansion of the molecules from the grains (red).