Dust Measurements in the Coma of Comet 67P/Churyumov-Gerasimenko Inbound to the Sun Between 3.7 and 3.4 AU.

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Introduction: Comets are the most primitive bodies in the solar system. They retain a cosmo-chemical record of conditions in the solar nebula when the planets were forming, 4.5 billion years ago. While accurate measurements of the gas loss rate from comets are possible under favorable conditions even from Earth, estimates of the dust loss rate so far have been much more uncertain. Multi-parametric models are needed to extract global dust parameters from the dust features of comets (e.g. coma, tails and trails) observed from ground and Earth orbiting telescopes, and it is often difficult to establish the uniqueness of these model results. Past space missions had on board instruments devoted to the measurement of the dust flux. Since all these missions were fast flybys, it was impossible to disentangle the dust grains coming directly from the nucleus from those reflected back by solar radiation pressure [1,2]. The latter component could explain all or part of the excess of mm-sized particles observed during flybys at 1P/Halley [3] and at short-period comets 26P/Grigg-Skjellerup, 81P/Wild 2 and 9P/Tempel 1 [4-6].

An even more severe bias could affect all estimates of dust to gas (d/g) ratio obtained so far in comets. The d/g measured in 1P/Halley was close to 2 [5], but this number is valid up to the largest mass of about 1 g observed by the DIDSY detector (actually, this largest mass grain was invoked to explain the spacecraft precession-inducing impact that occurred just before closest approach). We expect that 1P/Halley was then ejecting much larger masses, and the d/g ratio strongly depends on the actual largest grain ejected in the coma. Since it was impossible to fix the size distribution between 1 g and the unknown largest ejected mass, we cannot exclude d/g values higher than 10 or even 50. In this paper we show that for comet 67P/CG we can disentangle the two families of ejected grains (direct and reflected), and extract the dust size distribution up to the largest ejected grain, obtaining for the first time an accurate estimate of the total dust loss rate from the nucleus.

Methods: Critical measurements for understanding the process of accretion and the refractory to volatiles ratio in the solar nebula are being obtained by the Grain Impact Analyzer and Dust Accumulator (GIADA) experiment onboard ESA's Rosetta spacecraft, now orbiting comet 67P/Churyumov-Gerasimenko (67P/CG). GIADA measures the mass, momentum and velocity of individual grains, providing the dust loss rate over three orders of magnitude in mass for grains from tens to hundreds of microns in diameter. GIADA consists of three subsystems: 1) the Grain Detection System (GDS) to detect dust grains as they pass through a laser curtain, 2) the Impact Sensor (IS) to measure grain momentum derived from the impact on a plate connected to five piezoelectric sensors, and 3) the MicroBalances System (MBS); five quartz crystal microbalances in roughly orthogonal directions providing the cumulative dust flux of grains smaller than 10 microns. GDS provides data on grain speed and its optical cross section. The IS grain momentum measurement, when combined with the GDS detection time, provides a direct measurement of grain speed and mass [7, 8]. These combined measurements characterize single grain dust dynamics in the coma of 67P/CG.

Results: The first grain was detected on 1 August 2014 at 814 km from the comet nucleus. Between then and 13 September 2014 GIADA detected 35 grains ranging in mass from ~ 5 x 10^{-10} to 8 x 10^{-8} kg. Including complementary data from the OSIRIS narrow angle camera, the dust mass loss was calculated over an additional three orders of magnitude in mass, extending the ejected dust grain sizes up to 2 cm. Combined with data from the MIRO and the ROSINA instruments onboard Rosetta we find a dust/gas mass ratio of 4 +/- 2 averaged over the sunlit nucleus surface. The dust to gas ratio may change as the comet approaches closer to the Sun.

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