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Transient atmospheres of dwarf planets and large asteroids

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Dwarf planets (Ceres) and large asteroids (Vesta, Pallas) have several features suggesting that low density atmospheric envelopes could have been formed around their surfaces. These atmospheres should have survived for a time ranging from several hours to few months, depending on the mass of the central body, the amount of gas released around the central body itself, and also on the mechanism and on the speed of the gas release. Besides, local temperature, i.e. distance from the Sun, and gas mean molecular weight may affect the survival timescale of the atmospheric envelope.

Recent direct measures by the Herschel Mission (Kuppers et al., 2014) suggest the presence of water vapor around Ceres, and that a surface emission of this gas could be present eventually triggered by the transit to perihelion. The permanence of gas around these bodies could be favored by the fact that their gravitational escape velocity (300-500 m/s) is comparable with thermal velocity (400-600 m/s for H2O). All the other asteroids, except perhaps Hygeia, have a very fast gas loss, due to the low or extremely low values of the escape velocity and to the small dimension of their gravitational influence region (Hill Lobe). For the largest bodies, conversely, a great part of the gas molecules has velocities and orientations that produce closed orbits for a significant fraction of molecules, and even molecules faster than the escape limit may have curved trajectories that enhance the collisions with other molecules, increasing their permanence in proximity of the central body or inside the Hill Lobe. The formation and permanence for a reasonable time of these envelopes, that are in any case isothermal and optically thin, and fill at nearly constant density the whole Hill Lobe, strongly depends on the process of gas production: an envelope that can survive by collisional self-shielding (the molecules at the base of the envelopes have to experience too many collisions in order to escape) and subjected to the ordinary hydrodynamical and Jeans thermal escape mechanisms, requires a mass of H_2O+CO_2 gas greater than 10^{11} kg and a release timescale up to 1-2 days. A natural source of volatile gas could be a cometary impact, that could have directly delivered volatiles on the surface or could have exposed a previously quiescent icy layer. This is particularly interesting for Ceres, the next target of the DAWN mission. Another interesting effect of a fast gas release in these objects could be the interaction among the gas and the dust particles that should have been released by an impact on the surface. A significant fraction of dust particles moving inside a Hill Lobe filled by gas could have slowed down their initial velocity and eventually circularized their orbits around the central body. Moreover, part of the icy vapor could have recondensed, increasing the fraction of solid matter orbiting around the central body itself. Remembering that the maximum velocity dispersion, for a diffuse cloud of dusty particles orbiting around Vesta or Ceres cannot exceed probably 100 m/s , anelastic non destructive collisions could have been able to produce relatively thin rings, having low (few meters per second) mean collisional velocities, a situation promoting accretion processes whose final result could has been rubble pile transient aggregates and/or permanent satellites.

The large amount of physical, morphological an spectroscopical data collected by the DAWN mission during the past exploration of Vesta, and the similar large harvesting of information expected from the next year encounter with Ceres, will give presumably a great observative support in order to verify these hypothesis.

In order to study the formation and the evolution of a gaseous envelope, it has been developed an SPH (Smoothed Particle Hydrodynamics, Monaghan, 1992,2005) code that allows to study the time evolution of a mixture of H_2O and CO_2 gases, initially released from a compact spherical configuration upon the Ceres and Vesta surface. All the significant local physical parameters, like density, pressure and temperature, and the velocity field where followed in time, during the persistence of the envelope, and at the same time global parameters as total mass, abundance ratios H_2O over CO_2, and optical depth were computed (Figs. 1 and 2). As a second step, the evolution of a dusty component mixed with gas and a first order computation of their mutual interactions have been studied. The role of the time evolution of this mixture of gas and dust on the formation of transient aggregates and/or satellites can be better studied through a generalized multicomponent SPH approach (dust treated as a gas), and this work is actually in progress.

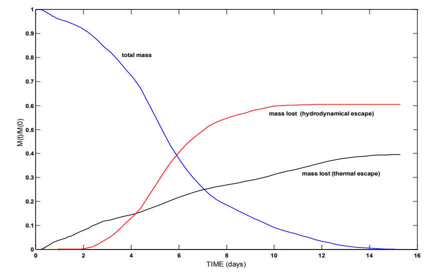

Fig.1 Time evolution of the total mass of the envelope and of the mass lost by hydrodynamical and thermal escape for Ceres and an envelope initial mass of 10^{12} kg

Conclusions

SPH simulations of the dynamical behaviour of gas inside the Hill lobe confirm that an important fraction of it may survive for several days around largest asteroids and dwarf planets, with densities probably too low for chemical direct interaction with the surface, but large enough to affect the evolution of the dust. A detailed treatment of this interaction requires the development of the general SPH multicomponent (dust+gas) model.

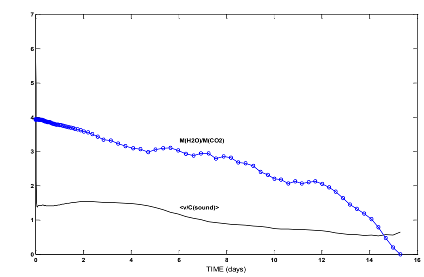

Fig.2 Abundance ratio H_2O/CO_2 and (mean velocity/sound velocity) ratio versus time for Ceres and an envelope initial mass of 10^{12} kg

References

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