Thermal and Geophysical History of Vesta.

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Introduction:

4 Vesta is one of the large asteroid of Main Belt and probably it is the parent body of the HED meteorites [1]: as a consequence we know it was one of the first bodies to have formed and differentiated in the Solar System.

It represents the key to understand the first stages of the evolution of the terrestrial planets and of the Solar System in general.

We analyze the thermal and geophysical history of Vesta by using an improved version of our 1D model developed to study the heating history of asteroids (4) Vesta and (21) Lutetia ([2],[3]).

The Model:

We developed a 1D model ([2],[3]) for the contemporary solution of the heat equation with radiogenic heat source and the advection equation, which controls the percolation of the metals inside the asteroid. A parametrized convection is introduced in order to reconstruct the heating and cooling history of (4) Vesta in a timespan of 100 Ma starting from the condensation of CAIs.

We investigate the link between the evolution of the internal structure and thermal heating due to short and long-lived radionuclides, taking into account the chemical differentiation of the body and the affinity of ^{26}Al with silicates.

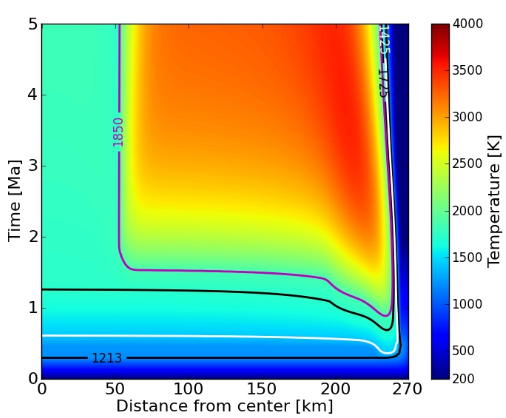

Figure 1: An example of geophysical history in case of instantaneous accretion.

We considered Vesta as a spherical body with a fixed radius (270 km) and an initial homogeneous composition similar to H-chondrites. We explored several scenarios differing in the available strength of energy due to the radiogenic heating.

Results:

We depicted several geophysical scenarios and we constrained the accretion and differentiation time of (4) Vesta as well as the size and the formation time of the core, by comparing our results to Dawn's estimate and to the constrains provided by the HED's. The cooling time and the chondritic crust evolution are also evaluated. In Fig.1 it is shown an example of geophysical history map of (4) Vesta. Our results show that Dfferentiation takes place in all scenarios in which Vesta completes its accretion in <1.4 Ma after the injection of ^{26}Al into the solar nebula. In all those scenarios where Vesta completes its formation in <1 Ma from the injection of ^{26}Al, the degree of silicate melting reaches 100 vol% throughout the whole asteroid. If Vesta completed its formation between 1 and 1.4 Ma after ^{26}Al injection, the degree of silicate melting exceeds 50 vol% over the whole asteroid, but reaches 100 vol% only in the hottest, outermost part of the mantle in all scenarios where the porosity is lower than 5 vol%. If the formation of Vesta occurred later than 1.5 Ma after the injection of ^{26} Al, the degree of silicate melting is always lower than 50 vol% and is limited only to a small region of the asteroid. The radiation at the surface dominates the evolution of the crust, which ranges in thickness from 8 to about 30 km after 5 Ma: a layer about 3–20 km thick is composed of primitive unmelted chondritic material, while a layer of about 5–10 km is eucritic.

References:

[1] De Sanctis M.C., et al. (2012), Science, 336,697; [2] Formisano M. et al. (2013), Meteoritics & Planetary Sci., 1-17,doi:10.1111/maps.12134; [3] Formisano M. et al.(2013), ApJ, 770, 50