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On the importance of short-perihelion approaches in the surface thermal processing of NEOs

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Introduction

We know that the NEO population is integrated by objects that have suffered a complex collisional history. It is certainly interesting identify new processes shaping the surfaces of these bodies, that are often exhibiting complex reflectance spectra. Reflectance dissimilarities with meteorites are often interpreted as consequence of space weathering [1], being consequence of different physical processes, not only associated with impact gardening. The surfaces of near-Earth asteroids (NEAs) are subject to large temperature variations: these are due to the change of the insulation intensity caused by the diurnal cycle between day and night, by seasonal effects and by the orbital eccentricity. At 1 AU from the Sun, typical temperatures at the subsolar point are of about 400 K, whereas nighttime estimated temperatures are below 200K. However, about hundred of the known NEAs have perihelion distances that bring these bodies at distances from the Sun below 0.3 AU where the surface temperature can rise above 800 K, in particular within craters. Moreover, the orbits of NEAs are not stable over their dynamical lifetime [2]: we know that a fraction of these bodies is likely to have experienced low perihelion distances in the past [3]. The composition of NEO surfaces, and the amount of regolith that is participating in thermal properties needs to be better explored [4]. We discuss here some of the physico-chemical processes going on in such extreme environment, and particularly discussing how the surface mineralogy of these bodies can be altered.

Physical processes participating

The surface processing induced by the different processes that are affecting the surface of a body exposed to the harsh space environment is known with the term of space weathering. Asteroidal surfaces experience significant chemical changes that alter the reflectivity of the body in each wavelength [5]. Among them we should mention ion-sputtering (IS), photon stimulated desorption (PSD), thermal desorption (TD), and micrometeoroid impact vaporization (MIV) [6]. For simplicity we will deal with thermal heating induced by solar irradiation, particularly important for NEOs approaching the Sun below 0.1 AU. These bodies enter in an interplanetary region where solar heating and irradiation become extreme. At that "threshold" heliocentric distance their surfaces are heated over 1200 K (see Fig. 1).

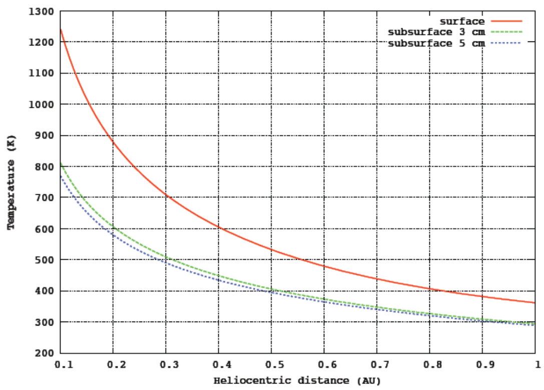

Figure 1: Temperature above a 50% fraction of the surface (and subsurface) area of a NEO is heated to.

Note that surface temperatures inside 0.1 AU are clearly over the melting point of the main minerals that are composing the chondritic asteroids: olivine $(Fe,Mg)_2SiO_4$, pyroxene $(Ca,Mg,Fe)SiO_3$,

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and plagioclase of intermediate composition $Na[AlSi_3O_8]$ to $Ca[Al_2Si_2O_8]$ [7, 8]. These minerals are distributed in different units, because chondritic meteorites contain fine grained components that form the so-called *matrix*, together with much larger components: glassy pseudo-spherical *chondrules*, and *refractory inclusions*. The number and extent of matrix, chondrules, and matrix components are variable among chondrite groups. Important mineralogical variations also are observed in ordinary chondrite groups [9].

Conclusions

Above 1000 K heat will induce a change in the grain lattice of surface minerals from chaotic to regular ordering in a process called thermal annealing. Such process leads to the transformation of amorphous silicates into crystalline ones. On the other hand, a sustained temperature T>1200 K for most crystalline silicates induces melting and vaporization, processes that can play a role in the transformation of the surface mineralogy of chondritic asteroids. Solar-induced heating together with a plasma-rich environment where other processes (like e.g. IS, PSD, and TD [6]) are playing a role is playing an important role in processing the surfaces of NEAs experiencing short-perihelion approaches. To know how these processes affect asteroidal surfaces depending of their mineralogy is an important point to look for asteroidal targets of the future Marco Polo mission.

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