Effects of solar heating on asteroids

M. Delbo[1], G. Libourel[2,1], J. Wilkerson[3], N. Murdoch[4], P. Michel[1], K. Ramesh[3], C. Ganino[2], C. Verati[2], and S. Marchi[5]

[1]Laboratoire Lagrange, UNS-CNRS, Observatoire de la Côte d'Azur, Boulevard de l'Observatoire-CS 34229, 06304 Nice Cedex 4, France.
[2]Laboratoire Géoazur, UNS-CNRS, Observatoire de la Côte d'Azur, 250 rue Albert Einstein, Les Lucioles 1, Sophia-Antipolis, 06560 Valbonne, France.
[3]Hopkins Extreme Materials Institute, Johns Hopkins University, Latrobe 122, 3400 North Charles Street, Baltimore, Maryland 21218, USA.
[4]Institut Supérieur de l'Aéronautique et de l'Espace, 10 avenue Edouard-Belin, BP 54032, 31055 Toulouse Cedex 4, France.
[5]Solar System Exploration Research Virtual Institute, Institute for the Science of Exploration Targets, Southwest Research Institute, 1050 Walnut Street, Suite 300 Boulder, Colorado 80302, USA.

The surfaces of atmosphereless solar-system bodies are weathered in space by the action of several processes, such as the implantation of ions of the solar wind and the bombardment of micrometeorites. It is well known that these phenomena alter the spectroscopic properties of asteroids [1,2].

Here we describe the many effects of another process, whose importance has been neglected in the past, that can alter the original surface nature of asteroids: the radiative heating by the light from the Sun. In particular, near-Earth objects (NEOs) can easily reach temperatures >400 K, and the heat penetration depth is in the order of some centimetres [3,4]. At perihelion distances (q) of the Sun smaller than 0.5 au, temperatures can be >550 K leading to the breakup of organic components (e.g., 300–670 K [5,6,7]). The knowledge of the temperature range of materials at different depth over the orbital evolution of space mission target asteroids is important for defining sampling strategies that ensure the likelihood that unaltered and pristine material will be brought back to the Earth [8,9]. Heating of small carbonaceous meteoroids with perihelia close to the Sun can also account for the petrological features observed in CK chondrites [10]. There are also NEOs with extremely close approaches to the Sun as in the case of the asteroid (3200) Phaethon and (1566) Icarus. Temperature on these asteroids can reach 1000 K, inducing thermal fracture and/or desiccation cracking and the production of dust particles. Indeed, (3200) Phaethon is the parent body of the Geminids meteors and activity near perihelion has been detected for this asteroid [11].

Furthermore, although the fraction of NEOs with $q < 0.5$ au is as of today 10 % of the total number of known NEOs, the orbits of these bodies are not stable over their dynamical lifetime: it is known that an important fraction of NEOs have experienced low perihelion distances in the past. It is also estimated that up to ∼70 per cent of them end their orbital evolution colliding with the Sun. As a consequence, these bodies are expected to have suffered considerable Sun–driven heating, not trivially correlated to their present orbits [3].

Moreover, the surfaces of NEOs are also subject to large temperature variations (e.g., 150 K): these are due to the change of the insolation intensity caused by the diurnal cycle between day and night, by seasonal effects and by the orbital eccentricity. The surface make up and mineralogy of these asteroids is altered by these strong temperature variations.

Acknowledgements: This work was supported by the French Agence National de la Recherche (ANR) SHOCKS, the BQR of the Observatoire de la Côte d'Azur (OCA), the University of Nice-Sophia Antipolis, the Laboratory GeoAzur and the French National Program of Planetology (PNP). KTR, JW, and SM acknowledge support from the NASA SSERVI program.

References: [1] Hapke B., 2001, JGR, 106, 10039. [2] Sasaki S., Nakamura K., Hamabe Y., Kurahashi E., Hiroi T., 2001, Nature, 410, 555. [3] Marchi et al., 2009. [4] Spencer J. R., Lebofsky L. A., Sykes M. V., 1989, Icarus, 78, 337. [5] Frost, R., Ruan, H., Kloprogge, J. T., & Gates, W. 2000, Thermochim. Acta, 346, 63. [6] Kebukawa Y., Nakashima S., Zolensky M. E., 2010, Meteoritis and Planetary Science, 45, 99. [7] Huang, W. L., Bassett, W. A., & Wu, T. C. 1994, Am. Mineral., 79, 683. [8] Michel P., Delbo M., 2010, Icarus, 209, 520. [9] Delbo M., Michel P., 2011, ApJ, 728, L42. [10] Chaumard N., Devouard B., Delbo M., Provost A., Zanda B., 2012, Icarus, 220, 65. [11] Jewitt et al., 2013.