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IS ASTEROID 2002NY40 A RUBBLE PILE GRAVITATIONALLY DISRUPTED?

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Introduction: The existence of meteoroid streams containing meter-sized meteoroids capable of producing meteorites after atmospheric interaction was proposed quite recently [1]. Their existence has important implications because they can be naturally delivering to the Earth different types of rock-forming materials from Potentially Hazardous Asteroids (PHA).

The recent identification of Near Earth Object (NEO) asteroid 2002NY40 as source of meteorite-dropping bolides [2] opens new questions on the nature of this asteroid, and the physical process that originated the fireballs detected in 2006 August. Two of the fireballs exhibited a clear similarity with the orbit of 2002NY40, while a third meteoroid was having an orbit close to NEO 2004NL8. In fact, these five bodies would be related by the close similarity among their orbits (Figure 1, and Table 3 of [1]). We try to focus here on the possible origin of this complex of bodies on the basis of our present (little) knowledge on the structure and orbital evolution of asteroids 2002NY40 and 2004NL8.

Methods: The identification of fireball activity from 2002NY40 was achieved during 2006 by the Finish Fireball Network (FN) and the Spanish Meteor Network (SPMN). The locations of FN and SPMN stations, trajectory and orbital data of the three fireballs were already given in [1]. Astrometric reduction was performed by using the common software that we are using for trajectory and orbital determination of meteoroids. We also studied the fireball spectra of two of the bolides following the procedures described in [3]. From such approach we estimated the expected mineralogy of the fireballs, that was compared to the reflectance data obtained for NEO 2002NY40.

The theoretical probability of collision with an asteroid during one of the objects' enters into the main belt has been calculated. The fraction of D > 1 km NEOs that disrupt by hitting a main belt object is a few percent. A relatively small, but not negligible value that we prefer to keep for a more detailed study.

Results and discussion: Due to the relative low population of the NEO region, a collision among asteroids is an unlikely, but not negligible process for producing the observed asteroidal fragments. In any case, we have searched for alternative processes capable of producing the meteoroid stream. *a)* One option would be that the meteoroids were ejected by a fast rotator, unlikely according to the present spin of both asteroids, but not taking into account the YORP effect. We should remark that the original spin of the progenitor asteroid would have been very different. *b)* Another possibility for the origin of this complex would be a catastrophic disruption where typically the escape velocity is considerably smaller than the orbital velocity, producing a large amount of the mass being ejected away [4]. In this sense, a gravitational-induced disruption during a close approach of a progenitor asteroid to the Earth. In fact, both NEOs are approaching significantly to the Earth, and Mars. In support of this idea, the structure of 2002NY40 has been recently reconstructed during its last approach to the Earth, just revealing an irregular triangular shape [5]. Would be this asteroid a reaccumulated rubble pile?. If so, the weakness of such structure under a close approach to the Earth or Mars may lead to disruption. Such mechanism would link the two NEOs to a larger progenitor, and the fragments would be small pieces released during the encounter. The orbital elements of both NEOs would support such a picture. 2002NY40 and 2004NL8 asteroids have very close values of argument of perihelion (5.884º and 4.93º, respectively), and eccentricity (0.7098 and 0.7203). Moreover their orbits (and those of the identified meteoroids) are almost coplanar. We plan to check these possibilities by mean of a N-body code-based simulations. *c)* A collisional fragmentation of a progenitor with a main belt asteroid is also possible, due to the high eccentricity of both objects that drive them inside that region periodically.

From the point of view of the mineralogy of 2002NY40, spectrophotometric data of this asteroid has recently revealed its possible mineralogical link with LL ordinary chondrites [5,6]. In this sense, we measured from fireball video spectra (Fig. 1) the chemical abundances of the main elements of the two bolides [2]. Quite interestingly, we found relatively high Mg/Fe ratios (Mg/Fe=1.2±0.1), and Na/Fe=0.05±0.01 that are close to the LL chondritic mineralogy [7]. This suggests that the 2002NY40 complex (including perhaps 2004NL8) would be one of the present sources of LL chondritic meteorites that we find in terrestrial collections.

Interestingly, many objects coming out of the inner main belt (already in the NEO population) appear to have this taxonomic type. These objects are probably part of a "train" of objects coming out of the ν_6 secular resonance or other small mean motion resonances in the inner main belt. Consequently, such mechanism would be an efficient source of LL-chondrites to the Earth.

In conclusion, we think that the present case deserves a future detailed study that is in progress. In any case, this is a nice example that the orbital evolution of meteoroids, and their chemical composition can provide interesting clues on the evolution of NEO objects in the Earth's vicinity (Fig. 2). In this case, three bright bolides have pointed this out. We plan to perform additional modelling in order to better explain the origin of this interesting complex of minor bodies.

References: [1] Halliday I., Griffin A.A., and Blackwell A.T. (1996) *Meteorit. & Planet. Sci.* **31**, 185-217. [2] Trigo-Rodríguez J.M., et al. (2007) *Mon. Not. R. Astron. Soc.* **382**, *1933-1939.* [3] Trigo-Rodríguez J.M., J. Llorca, J. Borovička and J. Fabregat (2003) *Meteorit. & Planet. Sci.* **38**, 1283-1294. [4] Bottke W. et al. (2005) *Icarus* **175**, 111-140. [5] Roberts L.C. et al. (2007) *Icarus* **192**, 469-474. [6] Rivkin A.S. et al. (2003) *LPSC XXXIV*, abst. #1722. [7] Jarosewich E. (1990) *Meteoritics* **25**, 323-337.

Figure 1. The order zero image and spectrum of the Sept. 10, 2006 Finish fireball (FN100906). Its heliocentric orbit suggests the origin of this rock in NEO 2004NL8 [2].

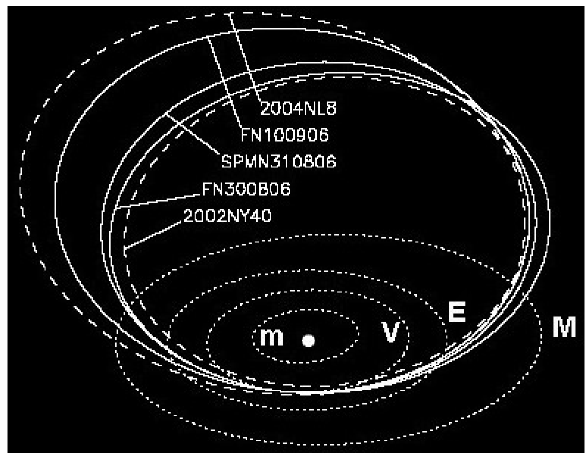

Figure 2. The orbits of NEOs 2002NY40 and 2004NL8, showing their close similarity with the three bolides recorded by the Finish Network and the Spanish Meteor and Fireball Network (SPMN). The orbits of the terrestrial planets are shown for comparison.