Threat from a recent LL parent body disruption: The case for an Apophis sample return.

C. J. Renggli[1], M. Hilchenbach[1], O. Stenzel[1], C. R. Walton[2] and T. Kleine[1], [1]Max Planck Institute for Solar System Research, Justus-von-Liebig-Weg 3, 37077 Göttingen, Germany, renggli@mps.mpg.de, [2]ETH Zürich, Dep. of Earth Sciences, Clausiusstr. 25, 8092 Zürich, Switzerland.

Introduction: The Near-Earth Asteroid (NEA) (99942) Apophis will pass Earth on the 13th of April 2029 at a geocentric distance of only 38,000 km. The close fly-by presents a unique opportunity to study a potentially hazardous asteroid in detail without a long cruise phase. Spectral properties of Apophis suggest that the asteroid is an LL chondrite (low-Fe, low-metal) with a source region in the inner main asteroid belt [1,2].

In this contribution we argue why a sample return from Apophis as part of an ESA Ramses mission is necessary, both from a scientific and a planetary defense point of view. A key benefit of sample return missions is the direct link between remote sensing observations and subsequent laboratory analysis providing rare geological context for extraterrestrial samples. Such a context has previously only been available for lunar samples (Apollo and Luna), and the asteroid samples returned by the missions Hayabusa 1 to (25143) Itokawa (LL chondrite, JAXA), Hayabusa 2 to (162173) Ryugu (CI chondrite, JAXA), and OsirisRex to (101955) Bennu (carbonaceous chondrite, not finally defined yet, NASA). Ramses would become the first European sample return mission and pave the way for future missions.

Evidence for LL parent body disruption: Apophis is likely a LL chondrite [3]. This would suggest that Apophis originates from the same parent body as the Chelyabinsk meteorite, which is also a LL ordinary chondrite and caused a major airburst event in 2013 [3,4]. Following the initial radiogenic metamorphism caused by the decay of short-lived radionuclides [4], a major impact reset the U-Pb ages of phosphates to 4473±11 Ma [4,5]. However, fracture networks and textural evidence in phosphates show that a much more recent event resulted in the spallation of the Chelyabinsk meteorite, with an age unresolved from the present by U-Pb dating [4].

Such a recent collisional event on an LL asteroid, resulting in the formation of Chelyabinsk, would also be responsible for additional rogue bodies of LL composition. Asteroid collisions have the potential to produce a substantial population of potentially hazardous objects for Earth, within a short period of time after the collision [6]. For example, the break-up of the L-type OC parent body at ~470 Ma [7,8]

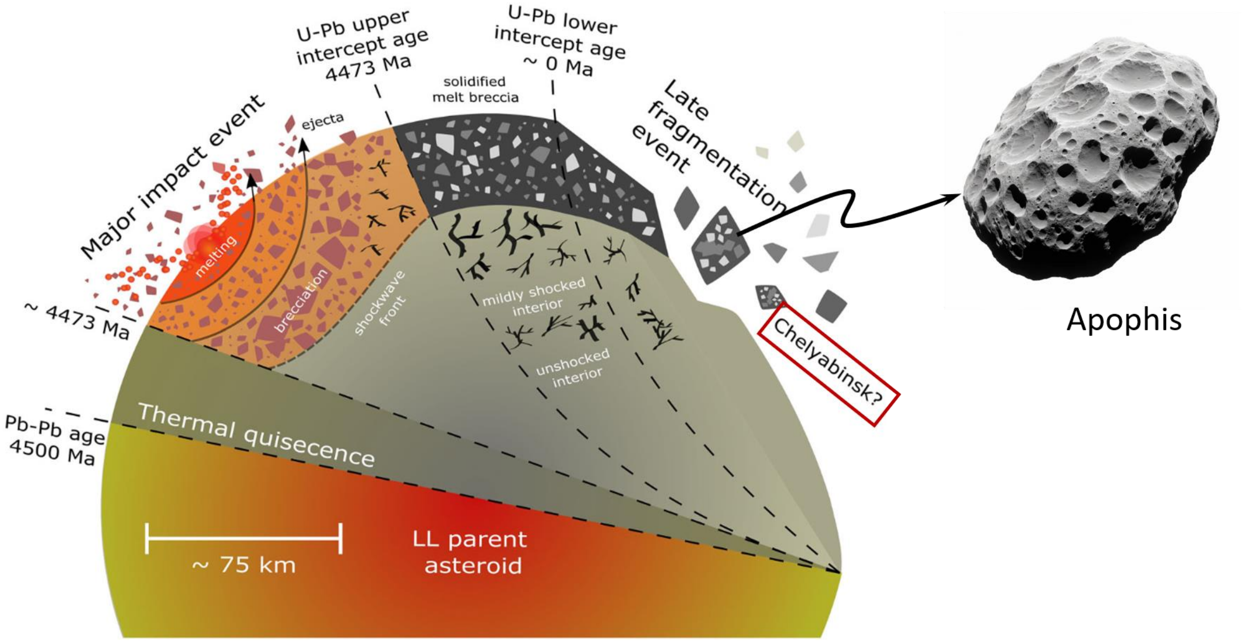

Figure 1: Schematic of the formation and evolution of the LL parent body. A recent late stage fragmentation event resulted in the formation of Chelyabinsk and possibly also the formation of (99942) Apophis. Figure modified from [3].

resulted in an exceptionally high rate of meteorite deliveries to Earth [9]. Indeed, the high number of LL-type NEAs makes them particularly important as potentially dangerous objects [10,11]. Specifically, we propose that the history of (99942) Apophis is related to this same LL parent body spallation event as Chelyabinsk. This idea will be directly tested by the detailed investigation of a returned sample from Apophis by the Ramses mission. If the materials returned from Apophis show the same evidence for a recent asteroid collision of the LL parent body, we suggest that a more detailed account of potentially dangerous LL objects is called for.

Constraints for flyby observations from returned samples: The Apophis fly-by of Earth can be understood as a unique natural laboratory. For the first time, we will be able to directly observe the interactions between an asteroid and Earth's tidal forces and the outer radiation belt in close proximity [12]. Such close planetary encounters of asteroids have been proposed to refresh their surfaces and changing the spectral properties from S-type to Q-type [13]. Dust particles from the surface of Apophis may experience charging from the interaction with both the solar wind, as previously observed at Comet 67P Churyumov-Gerasimenko [14], and Earth's radiation belt. The interactions will be observed, both by cameras onboard Ramses, and remotely from the surface of Earth. However, how do these forces act on the dust and regolith materials at a microscopic scale [15]? What are the properties of the grains that enable their interactions with Earth's environment specifically? The fundamental understanding of these mechanisms, and the scientific return from the observations of Apophis by Ramses during the flyby, will be uniquely enriched by laboratory studies of returned samples. Furthermore, the returned samples will put new constraints on the space weathering timescales of asteroids [16]. Finally, the returned samples will provide an independent test of the link between asteroid classifications based on spectral properties and ordinary chondrite meteorites.

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