Investigation of the interior of primordial asteroids and the origin of the Earth's water: The INSIDER space mission

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Today's asteroid belt may not only be populated by objects that formed in situ, typically between 2.2 and 3.3 au, but also by bodies that formed over a very large range of heliocentric distances. It is currently proposed that both the early (<5 Myrs after Solar System formation) and late (>700 Myrs after Solar System formation) dynamical evolution of the Solar System was governed by giant planet migrations that led to the insertion of inner (1–3 au) as well as outer (4–13 au) small bodies in the asteroid belt. Taken altogether, the current dynamical models are able to explain many striking features of the asteroid belt including i) its incredible compositional diversity deduced mainly from spectroscopic observations and meteorites measurements, and ii) the evidence of radial mixing experienced by the various asteroid classes (e.g., S-, C-types) after their formation. In a broad stroke, the idea that the asteroid belt is a condensed version of the primordial Solar System is progressively emerging. The asteroid belt therefore presents the double advantage of being easily accessible and of offering crucial tests for the formation models of the Solar System by exploring the building blocks predicted by models of i) the telluric planets, ii) the giant planet cores, iii) the giant planets' satellites, and iv) outer small bodies such TNOs and comets. It also appears as an ideal place to search for the origin of Earth's water.

Up to now, only a few asteroid classes (e.g., several S-types) have been visited by spacecraft and the focus of these in situ measurements has been mainly to give a geological context to ground based observations as well as strengthen/validate their interpretation. Most of the tantalizing discoveries of asteroid missions have been realized via images of the objects surfaces. Time has come for asteroid space science to reach a new milestone by extending the reconnaissance of the Belt's diversity and addressing new science questions.

The scientific objectives of the INSIDER mission, to be proposed in response to the 2014 ESA call for an M-class mission, require the exploration of diverse primordial asteroids — possibly the smallest surviving protoplanets of our Solar System — in order to constrain the earliest stages of planetesimal formation thus avoiding the effect of destructive collisions, which produce extensively processed rubble piles. Our science objectives that justify in situ measurements in the context of an M-class mission and that are expected to lead to significant breakthroughs include:

1. The exploration of the diversity of the asteroid belt
2. The first investigation of the internal structure of asteroids
3. The origin of water on Earth

The proposed mission scenario consists in i) successive rendez-vous followed by orbit insertion of two and possibly three large ($D > 100$ km) objects, ii) one or two small landing modules (MASCOT type) to perform cosmochemical measurements (D/H ratio, O isotopes). The potential targets would include 24 Themis and 10 Hygiea.

Meeting our science objectives requires instruments (such as radar, seismometers to be dropped to the surface, magnetometer, high resolution laser-desorption-ionization mass spectrometer to analyse the surface samples) not flown so far during past asteroids missions along with the traditional powerhouses, such as cameras and spectrometers.