EARTH'S TEMPORARY NATURAL SATELLITES – TARGETS FOR ASTEROID RETURN MISSIONS?

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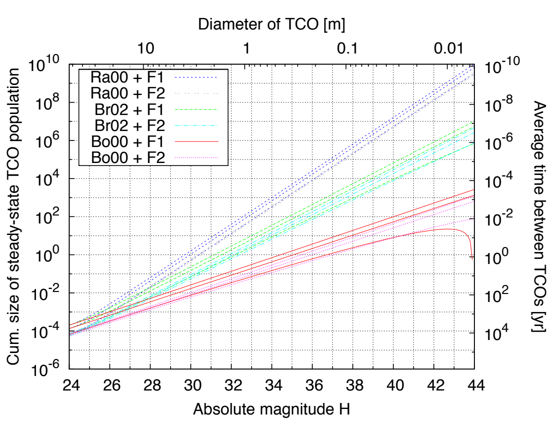
Introduction: Several space agencies, such as JAXA, ESA, and NASA, are currently planning missions to asteroids. The quest is therefore on to find suitable target candidates for these missions. The main criteria include, but are not limited to, the required Δv. The smallest Δv is required for objects on Earth-like orbits, in particular those near-Earth objects (NEOs) that are temporarily orbiting the Earth. Only one temporarily-captured natural Earth satellite (NES) – the few-meter-diameter 2006 RH_{120} – has ever been discovered, but we have recently [1] estimated that 2006 RH_{120} is just the tip of the iceberg: the largest member of the steady-state population of Earth's temporarily-captured orbiters (TCOs; captured objects that make at least one revolution around the Earth in a co-rotating frame while being within 3 Hill radii from the Earth) is about 1 meter across and there are about 10^3 natural objects larger than 0.1 m orbiting the Earth at any given time (see the "Br02+F2" curve in the figure below; Ra00, Br02, and Bo00 are different NEO size-frequency estimates, whereas F1 and F2 are alternative NES flux estimates).



Science Case: NESs open up several new possibilities in asteroid research:

Population statistics for small asteroids. NESs provide a test of the NEO population statistics in a size range that is not well-sampled by contemporary asteroid surveys. E.g., the Yarkovsky force is assumed to strongly affect the orbital distribution of small asteroids and a difference in the number of expected and observed NESs would, at least indirectly, be a verification for the assumption.

Remote laboratory for detailed long-term studies of small asteroids. Small asteroids tend to be observable for a short time only. Their physical properties are therefore not typically well constrained by, e.g., photometric, polarimetric, and spectroscopic observations. Since NESs spend months or even years orbiting the Earth there is ample time to carry out detailed observations of these objects.

Laboratory analysis of an entire asteroid. Whereas typical sample return missions bring back minute amounts of material and meteorite surfaces have been altered during the passage through Earth's atmosphere and subsequent weathering, the extremely low requirement on the Δv combined with the relatively small NES diameters would allow an entire asteroid to be brought back to Earth for laboratory analysis in a shielded spacecraft. Compared to meteorite studies and ordinary sample return missions this would open up completely new windows in several areas of asteroid research such as space weathering, interior structure, mineralogy, and maybe even astrobiology.

Challenges: There are many fundamental issues that we need to understand better before we can assess the viability of a space mission to a NES such as:

Detectability. The optimum observation strategy for discovering NESs is not currently known. Also the requirements on the hardware configuration are still unclear. It may well be that we need to wait for the LSST before NESs will be discovered in large numbers given that NESs tend to be faint and move fast.

Ephemeris prediction. At the time of the discovery of a temporary satellite the estimated duration of capture has large uncertainties due to the combined effects of the orbital uncertainty and the fractal nature of the capture properties. How soon after discovery can we typically estimate the capture duration with a given accuracy and thus decide whether a space mission is viable?

Encountering an object on a chaotic trajectory. The trajectories of temporary satellites are highly irregular and the capture events have limited duration. We expect that a spacecraft must be launched before the trajectory and encounter conditions are accurately known. How much uncertainty in the encounter conditions at the time of launch is acceptable?

References: [1] Granvik M. et al. (2012) *Icarus, 218(1),* 262-277.