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Discovering minimoons with LSST

Grigori Fedorets (1), Mikael Granvik (1,2), Lynne Jones (3), Mario Jurić (3) and Robert Jedicke (4)
(1) Department of Physics, PL 64, 00014-University of Helsinki, Finland (grigori.fedorets@helsinki.fi) (2) Department of Computer Science, Electrical and Space Engineering, Luleå University of Technology, Kiruna, Sweden, (3) DIRAC Institute, Department of Astronomy, University of Washington, Seattle, USA, (4) Institute for Astronomy, University of Hawai'i, Honolulu, USA

1 Introduction

It has been predicted that there is a transient population of small asteroids orbiting the Earth [4]. They have been temporarily captured by the Earth from the population of near-Earth objects (NEOs). Temporarily-captured orbiters (TCOs), colloquially known as minimoons, have elliptic geocentric orbits and come within 0.03 au from the Earth, making at least one revolution around the Earth. Recent results suggest that at any given time there is one 75 cm-diameter asteroid captured on an elliptic geocentric orbit within 0.03 au from the Earth [3].

2 Motivation

A continuous flow of discoveries of minimoons would allow to resolve the differences in the size-frequency distribution of 1-10 m objects, as well as provide low Δv targets for the retrieval mission of an entire metre-sized body. Alternatively, the emerging field of asteroid mining could use minimoons as testing ground at a small scale before reaching for larger objects [6]. Minimoons also serve as suitable and challenging targets for testing various LSST systems, such as fitting elongated PSFs, filtering artifacts, and testing the automatic Moving Object Processing System (MOPS).

3 Discovery of captured asteroids

The major bottleneck in studying minimoons is the difficulty of observing them. The brightest of the objects are usually visible for only a few days, and during that time, their sky velocity reaches its maximum (see Fig. 1). In addition, the detectability suffers from trailing losses.

So far, only one minimoon, 2006 RH_{120}, has been discovered while in geocentric orbit [7]. The Large Synoptic Survey Telescope (LSST) will have the highest likelihood among existing and upcoming observatories of obtaining regular detections of minimoons [1]. LSST is expected to cover the available southern sky every 4 nights for the duration of 10 years.

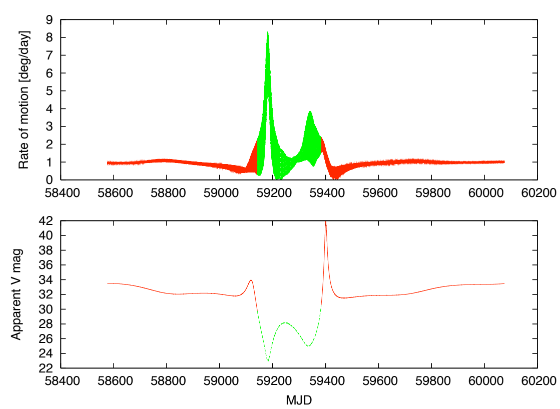

Figure 1: *Top image:* The rate of motion of a typical minimoon as a function of time. *Bottom image:* The apparent magnitude V as a function of time. The green line represents the period during which the object is captured as a minimoon whereas the red line represents the time evolution of the parameters when the object is not captured.

4 Results

We use a synthetic minimoon population with a realistic magnitude distribution, that is based on a NEO model [5] combined with a size-frequency distribution slope derived from the bolide data [2]. The synthetic population is fed to a pointing simulation of LSST.

The initial simulation yielded only 3 objects automatically discoverable by MOPS over a 5 year period. However, a substantially higher number of objects possessed the number and distribution of observations suitable for orbital linking and initial orbit determination. Orbital linking and initial orbit determination for various combinations of minimoon observations is performed, and compared to a reference population of potentially hazardous asteroids. The typical magnitudes and velocities as well as preferences for observations as a function of capture duration are also investigated.

We also assess the probability of other objects which produce elongated streaks to be confused with minimoon detections, and the means to mitigate the confusion. Initial orbit determination is a sufficient filter in most cases, but distant artificial satellites may remain a source of potential mix-up, as they currently are.

In principle, minimoons should be identifiable in LSST's data swarm, but relying solely on MOPS would leave the majority of minimoons undiscovered. A method complimentary to MOPS needs to be developed to enhance the minimoon discovery.

References

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