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The most dangerous IEOs in STEREO

C. Fuentes (1), D. Trilling (1) and M. Knight (2)
(1) Northern Arizona University, Arizona, USA, (2) Lowell Observatory, Arizona, USA (cesar.i.fuentes@nau.edu)

Abstract

IEOs (inner Earth objects or interior Earth objects) are potentially the most dangerous near Earth small body population. Their study is complicated by the fact the population spends all of its time inside the orbit of the Earth, giving ground-based telescopes a small window to observe them. We introduce STEREO (Solar TErrestrial RElations Observatory) and its 5 years of archival data as our best chance of studying the IEO population and discovering possible impactor threats to Earth.

We show that in our current search for IEOs in STEREO data we are capable of detecting and characterizing the orbits of 10-100 potentially dangerous IEOs. The number of expected detections by STEREO is based on the current number of known IEOs which is heavily biased by the 8 objects discovered so far [4]. STEREO is sensitive to IEOs that are not visible from the Earth and hence samples a part of the IEO population that has not been discovered yet.

1. Introduction

Near Earth Objects (NEOs) are the closest bodies to the Earth, offering an opportunity to study material from elsewhere in the Solar System as it is brought to near-Earth space. NEOs also carry significant impact risk, and the population must be catalogued and understood to quantify this risk. Interior to Earth Objects (IEOs) are a subset of NEOs whose orbits are generally inside the Earth's orbit. IEOs are therefore much harder to detect with traditional nighttime all-sky surveys, yet the IEO population may carry significant impact threat. However, very little is known about the IEO population, and only a small handful (<10) of IEOs are known at present.

Studying the orbital distribution of IEOs from the ground is very difficult due to their positions close to the Sun. However, we can use data from NASA's STEREO mission to search for IEOs. STEREO consists of twin spacecraft, one ahead of the Earth's orbit (STEREO-A) and one behind the Earth's orbit (STEREO-B) which view the Sun-Earth line using a suite of telescopes. Each spacecraft moves away from the Earth at a rate of $\sim$22.5° year^{-1} (Figure 1). Our search for IEOs utilizes the Heliospheric Imager 1 instruments on each spacecraft (HI1A and HI1B). The HI1s are centered 13.98° from the Sun along the Earth-Sun line with a square field of view 20 ° wide, a resolution of 70 arcsec pixel^{-1}, and a bandpass of 630—730 nm [3]. Images are taken every 40 minutes, providing a nearly continuous view of the inner solar system since early 2007. The nominal visual limiting magnitude of HI1 is $\sim$13, although the sensitivity varies somewhat with solar elongation, and asteroids fainter than 13 can be seen near the outer edges.

We have developed an archival search pipeline for use with data from the Hubble Space Telescope. This pipeline allows us to find moving objects in telescopic spacecraft data while measuring detection efficiency, which is key to constraining the existing population, both detected and undetected. We are now turning this pipeline and approach to STEREO data and IEOs.

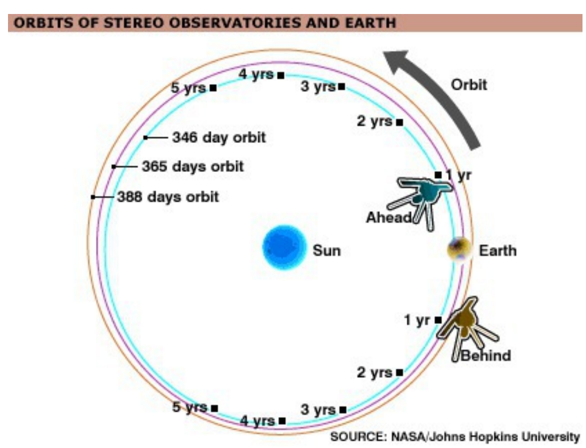

Figure 1: Trajectory of both the Ahead and Behind STEREO observatories as a function of time from launch on October 26th, 2006 . Source: NASA/Johns Hopkins University

2. Approach

A range of consecutive images where an IEO would move by several PSFs is selected. We then implant a synthetic population of IEOs to all the images in the group. Positions of detections in all the images are considered, selecting those that are consistent with an IEO orbit. Detections are then presented to a human operator to be approved.

3. Expected Results

We compute the fraction of the IEO population that STEREO should detect assuming that IEOs have the same slope for the luminosity function as NEOs [2] and the same slope parameter for the phase function. We estimate the relative number of IEOs to NEOs by also computing the expected number of objects in the field of view of ground based surveys. We also assume that Earth-based searches that have led to the discovery of known IEOs have been sensitive to objects of up to a magnitude $V\sim19$. The detection efficiency for these surveys could vary between 1% and 10%. We can then match the number of Earth detections to the eight known IEOs.

We assume a uniform distribution in $e\in[0,1]$ and $i\in[0,30]^\circ$, with a semimajor axis between $a\in[0.5, 1.0/(1+e)]$ AU (See Figure 2). For each time step in the simulation we calculate the phase function and the faintest H magnitude that would be detected by STEREO. We then use the size distribution of NEOs to find the expected number of objects detected. Almost all the objects discovered in our simulation have $H<18$ which corresponds to a diameter $D\sim$1km, and the sensitivity peaks at $H\sim$13 or $D\sim$10km.

We find that STEREO should find at least 10-100 objects. These results are based on a single STEREO telescope. Having the second telescope will increase that number of objects and will contribute more pointings for objects that are observed by both telescopes. These results are consistent with those of [1] that estimates the ratio of the IEO to NEO population is 2%, which would yield 15 objects in STEREO.

4. Summary and Conclusions

We have the necessary expertise and tools to discover IEOs in the data in an automated and calibrated survey. STEREO's location and sensitivity enable the detection of a subsample of the IEO/NEO population that is not discoverable from the ground.

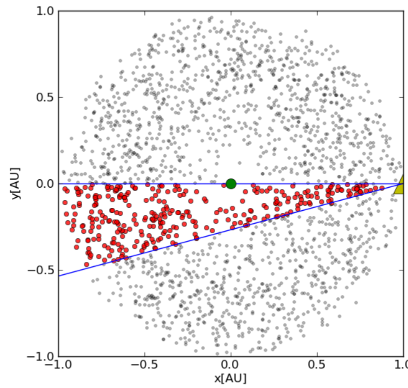

Figure 2: A single time of one simulation realization with 2,000 IEOs. The Sun (green circle) and the Solar System are observed from the ICRS North Pole to match the motion of STEREO A represented by the yellow triangle. Red and black dots represent IEO test particles that are in HI1's field of view and those that are not, respectively. We apply the NEO size distribution to all these synthetic objects. The brighness of every object in the visibility cone of STEREO is computed, such that only those with a visible magnitude V<13 will be detected in STEREO data.

We expect to discover 10-100 IEOs. The number of IEOs discovered will place a tight constraint on the total number of IEOs as well as the distribution of IEO orbits. We also expect to measure the size distribution of IEOs and compare this result to the size distribution of NEOs. These two results together will quantify the relative impact risk of IEOs compared to the entire NEO population. This description of the IEO population will also allow us to constrain the dynamical mechanisms by which NEOs become IEOs, and will be fertile input for dynamical modeling of the inner Solar System.

References

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