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Dynamical investigations on the leading/trailing asymmetry of lunar rayed craters

Renu Malhotra (1), **Youngmin Jeongahn** (1) and Takashi Ito (2)
(1) Lunar & Planetary Laboratory, University of Arizona, Arizona, USA (jeongahn@lpl.arizona.edu), (2) National Astronomical Observatory, Tokyo, Japan

Abstract

We suggest that the leading/trailing asymmetry of young lunar craters can be used to constrain dynamical models of the Near-Earth Objects.

Introduction

It is generally accepted that the Near Earth Objects are the source of planetary impactors in the inner solar system at the present epoch. The size distribution of young impact craters on the Moon, Mars and Mercury are consistent with this hypothesis [7]. Our current best understanding of the orbital distribution of NEOs is constrained by the orbital distribution of observed NEOs, but are based upon assumptions about sources and estimates of observational incompleteness (e.g., [1]). It is difficult to test these models. Here we describe one novel test involving the leading/trailing asymmetry of impact craters on the Moon; the impact crater record has not yet been used to constrain models of the NEO population.

As is well known, the spin angular velocity of the Moon is synchronous with its orbital angular velocity about Earth. This results in a small but detectable difference of the density of impact craters on the Moon's leading hemisphere and its trailing hemisphere [5]. The asymmetry is roughly explained by the differential flux of NEOs [3], but [4] points out that there is systematic discrepancy between the crater densities as a function of longitude predicted by the dynamical models and the crater densities that are actually observed. This systematics offers a way to test and improve models of the NEO population because the degree of leading/trailing impactor flux asymmetry can be related to the orbital distribution of the impactors.

Dynamical investigations

We are investigating two possible reasons for the discrepancy, (i) the existence of an undetected population of co-orbital asteroids of Earth, and (ii) dynamical pathways in the known NEO orbital parameter space that lead to Earth-like orbits, both of which may enhance the population of low velocity impactors and thereby enhance the leading/trailing asymmetry of the lunar impactor flux.

For (i), we first obtain the dynamical lifetimes of asteroids in the co-orbital region of Earth's orbit. We adopt the realistic model of the eight major planets of the solar system and examine a wide range of initial orbital parameters of Earth co-orbital asteroids: semi-major axis, eccentricity, inclination, and relative longitude; we compare our results with those of previous studies [2, 8]. Then, we trace the escaping objects from the co-orbital region and determine their impact velocity and location on the Moon. We confirm that these objects have average impact velocities much lower than the average impact velocity of NEOs. We estimate the steady-state current co-orbital population that may account for the leading/trailing asymmetry of lunar rayed craters, and that may be detectable in current or future observational surveys (e.g., WISE, PAN-STARRS, LSST).

For (ii), we are analyzing the extensive numerical simulations of NEOs reported in [4] to identify any systematic differences in the NEO initial conditions which yield impactors on the leading vs. trailing hemisphere of the Moon. We will estimate the relative weighting of such parameter regions that would be needed to account for the discrepancy. This will allow for an improved NEO orbital distribution model.

Alternative explanations for the discrepancy include the following: (a) the lunar rayed crater counting is incomplete; (b) the present-day NEO orbital distribution is not representative of its distribution over the geological time interval spanned by the lunar rayed craters.

We suggest that the former can be addressed with the use of new lunar crater data sets from recent and future lunar missions (cf. [6]) . The latter is difficult to dismiss; we will discuss constraints that can derived from our studies.

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