Excitation of the lunar inclination via three-body interactions

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The Moon is generally thought to have accreted from an equatorial circumterrestrial disk with a primordial orbital inclination of ~1 degree relative to the Earth's equator [1]. Tidal evolution calculations suggest that every degree of primordial inclination to the Earth's equator translates to half a degree of inclination to the ecliptic plane in modern times [2,3]. Contrary to expectations from the origins theory, the modern lunar orbit exhibits a ~5 degree inclination. Such a ~10x discrepancy between expectations and observations has become known as the lunar inclination problem.

Here, we develop a new dynamical mechanism – three-body interactions – for tilting the primordial lunar orbit. We find that collisional and collisionless interactions can dynamically excite the system significantly and that the inclination of the lunar orbit is a sensitive recorder of dynamical events in the Earth-Moon (EM) system. With this mechanism, we can quantify how pristine the EM system is, limit the largest post-Moon-formation impacts with the Earth, and constraint dynamical and compositional changes to the system via interactions with remnant populations. One of the implications is that the ~5 degree modern lunar inclination is a reflection of the occurrence of the Moon-forming event towards the end of Earth's accretion. Consequences for late accretion [4] will be discussed.

References

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