TESTING MODELS OF LUNAR ORIGIN

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The widely accepted canonical giant-impact model for the origin of the Moon [1] fails to account for the isotopic similarity of Earth and the Moon unless the target and impactor were isotopically ~identical. Even if the lunar disk and Earth's mantle contained similar proportions of the colliding bodies [2, 3] similar tungsten isotopes would require special circumstances. Alternatively, mixing during and after a high-energy, high-angular momentum giant impact could explain the oxygen and tungsten isotopic similarity of Earth and the Moon and mitigate the need for an impactor with identical stable isotopes [4]. The model predicts that the impact transforms the post-impact system into a state that exceeds the corotation limit, called a ***synestia***. In the hot vapor of the synestia, metal derived from the impactor is dissolved into the silicate vapor, forming a well-mixed continuous structure that extends beyond the Roche limit. Upon cooling, the synestia forms the Earth-Moon system. The model predicts high temperatures (>3000-4000 K) for the growing Moon, and the volatile element depletion in the Moon (K and Na ~0.1-0.2×Earth; Zn, Cd, Pb, Bi and Tl ~0.01×Earth) is explained by partial condensation from bulk silicate Earth vapor [4]. Such depletions, in turn, may result in isotopic mass-dependent fractionations of volatile elements in the Moon, with the Moon expected to be isotopically heavier in these elements compared to the Earth. Recent high-precision K isotope data reveal that the Moon is isotopically heavier than Earth [5]. Thus, the synestia model can account for the major constraints on the origin of the Moon: i) the volatile element pattern, ii) the non-mass dependent oxygen isotope similarity and iii) the direction of K isotope fractionation. Detailed calculations of the magnitude of isotopic fractionation will test and constrain the synestia model for lunar origin.

[1] Canup & Asphaug (2001) Nature; Canup R. (2004) Icarus [2] Canup R. (2012) Science [3] Čuk M. & Stewart S. (2012) Science [4] Lock S. et al. (2018) JGR [5] Wang K. & Jacobsen S.B. (2016). Nature.