Ray patterns of impact ejecta on the Moon, e.g. of the Tycho crater, used to determine ballistic parameters

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Motivation: Lunar ray patterns are material disturbances (typically observed as albedo anomalies) caused by the impact of ejecta produced during the crater formation stage following the collision of a hyper velocity bolide with the Moon. The dynamics of such collisions can be investigated in laboratory settings in the restricted domain of sub-gram particles impacting solid or granular grounds at the high end of planetary system velocities whereas more substantial projectiles can be propelled typically at Earth's escape velocity range, rarely faster. The processes involved in producing large craters are generally understood by analogy from observations of cataclysmic explosive events such as volcanic eruptions or underground nuclear bomb tests. The actual formation a large Lunar crater is so far unobserved. The intricate delineations of Lunar ray patterns will *provide a test of our understanding of impact and ejecta mechanics*.

LROC observations Recent observations by LROC [1] has resulted in detailed normalized light (643 nm) reflectance maps of the entire Moon. These maps show that several of the impact craters anchor extensive ray fans which in some cases reaches across large distances (thousands of km). The Tycho crater (43.3°S, 11.4°W) is the cardinal example for such endowments but in these global maps the Anaxgoras crater (73.4°N, 10.1°W), the Giordano Bruno crater (35.9°N, 102.8°E), the Jackson crater (22.4°N, 163.1°W), and the Copernicus crater (9.7°N, 20.1°W) are very noticeable; it is not difficult to identify twenty more such rayed craters.

Earlier work The prominence of the near side's Tycho crater (43.3°S, 11.4°W) triggered several earlier investigations including, two-body, ballistic simulations [2, 3] with a rotating spherical Moon. These were most commonly analysis of Earth based telescope studies and therefore confined to the scenes of the Moon's near side. The ejecta and impact dynamics are well understood in this approximation and may, if need arises, be supplemented by generalizations to those of *wandering* pole situations [4]; all such ballistics formulae can, nowadays, be conveniently manipulated [5].

Our approach The Tycho crater ejecta ray fan structure is the initial focus of our work and will be the testing ground for the soundness of our methodology. We use standard image analysis tools [6] in order to select sequences of locations within particular ray filaments. The resulting data set constitute the locations of one terminus of the, assumed, ballistic trajectory path. The other terminus, the initiation site, is allowed to attain a range of positions within the confines of the impact crater rim boundary. These data points are measured in a selenocentric frame and they will be converted to the corresponding set in an inertial frame and these pairs of termini are further processed so as to isolate the associated orbital elements. We will assume that the Moon is spherical in shape and that all its mass is located at the sphere's center. Fixing the value of the rotation rate of the Moon and the direction of its rotation axis will then determine a multidimensional parameter volume (i.e. value ranges of the duration of the time of flight, the initial speed, and the launching vector angles) for the Keplerian motion of the ejecta fragment. Proceeding in this fashion along a specific ray (a ray has a finite width; we will choose the lateral center point as its representative) produces a family of distinct parameter volumes. We further process these parameter volumes by searching for maximum overlap between volumes associated with pairs of adjacent impact locations on the ray of interest. Various forms of likelihood assignments can then be computed for the aggregated shape of the ejecta launching vectors. The Tycho crater ray setting is analyzed accordingly and with an added emphasis on providing plausible scenarios for the discernment of launching parameter values which would force flight trajectory paths to have antipodal reconnections.

The far side of the moon is replete with craters anchoring distinct ray patches and among these we select some of the more clearly delineated ones for launching parameter determinations analogous to that performed on the Tycho ray fan ensemble. Common features are recognized and anisotropies in ray pattern direction distributions are categorized.

References

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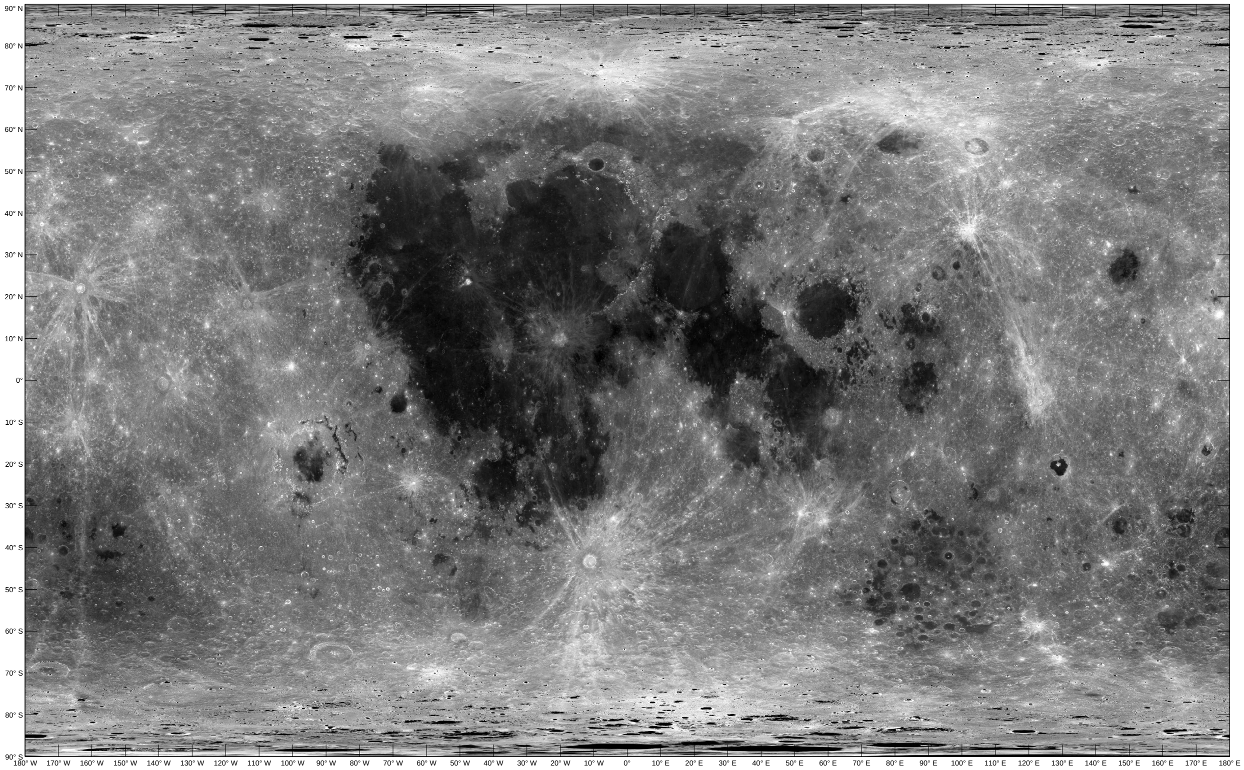

An LROC map

Courtesy Aaron K. Boyd, Research Analyst
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