ORBITS OF SUBMICRON LUNAR EJECTA IN THE EARTH-MOON SYSTEM

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ABSTRACT

Flux measurements of picogram dust particles near the lunar surface and in selenocentric and cis-lunar space made by Lunar Explorer 35, HEOS, and ALSOP dust experiments all indicate, to varying degrees, ejecta from lunar impacts of interplanetary dust particles. The orbits of these submicron particles in the earth-moon system are significantly altered by radiation pressure. Recent orbit calculations show that, in favorable lunar phases, as many as 80% of the ejecta may enter the magnetosphere and 20% may enter the earth's atmosphere. The results of this analysis are presented, and their implications are discussed.

RECAP OF PAST STUDIES OF DYNAMICS OF LUNAR EJECTA ESCAPING THE MOON

Over the past two decades, numerous investigations of the dynamics of lunar ejecta escaping the gravitational sphere of influence of the moon have been reported e.g.,[1-4]. The studies in the 1960's were primarily concerned with possible hazard to astronaunts and the question of the gain or loss of lunar mass.

Until the preliminary results of the dust particle experiments on the Lunar Orbiters (LO) [5] and Lunar Explorer 35 (LE35) [3], no study was reported with a primary emphasis on the dynamics of micron size ejecta. Alexander and Corbin [4] reported the results of a study which placed an emphasis on lunar ejecta in heliocentric space. For this study, ejecta that were eliminated from closed orbits by radiation pressure or were subjected to pertubations by Jupiter determined the minimum size of the particles of interest. These ejecta were found to have a minimum mass of 4.4 pg and radius of 0.68μ (density of 3 gcm^{-3}). The emphasis for this paper is on the dynamics of the micron and submicron particles in the earth-moon system with specific attention focused on the ejecta entering the magnetosphere and finally, the atmosphere of the earth. These much smaller ejecta become very important with respect to studies of ejecta-magnetic and electrostatic field interactions within the

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magnetosphere. The major non-gravitational force experienced by the ejecta prior to entrance into the magnetosphere is the solar radiation pressure (srp) force. Ejecta that would immediately be in hyperbolic heliocentric orbits are included in these calculations because interaction of these particles with the earth's magnetosphere is of primary interest in the present work.

Previous computer simulations of ejecta orbits in the earth-moon system simply assumed an escape velocity condition above the lunar surface. This work simulates the orbits of ejecta in the earth-moon system resulting from the impact of sporadic meteors on the lunar surface. The equation of motion used is that stated by Alexander, et al.[6]. It is solved for the displacement of the ejecta in an earth centered frame of reference. For this work, a second order Numerov method was used to produce successive positions of the ejecta.

SIMULATED EJECTA ORBIT COMPUTATIONS

In the present model the lunar orbital inclination is taken to be 0°, and lunar perigee is at first quarter. References to lunar phase are with respect to the antisolar direction at the time of lunar impact, as shown in Fig. 1. An impact is simulated by randomly selecting a seleno-longitude from a uniform distribution and a seleno-latitude from a Gaussian distribution centered at the equator with a standard deviation of 20°. The equatorial biasing is based on the observation that low inclination orbits predominate among sporadic meteors [7]. Nine particles are then ejected in equally spaced azimuthal directions. The altitude angle of their initial velocity is randomly selected from a normal distribution of mean = 66° and standard deviation = 8°, in order to conform with Gault's [2] results that faster ejecta tend to leave the impact site with higher values of altitude angle. An ejectum speed of 2.35 km-sec^{-1} is assumed because the greatest number of ejecta escaping the moon's sphere of influence are expected to have speeds just greater than lunar escape velocity

Next, the numerical method mentioned above is used to calculate the orbit of each ejectum, which is modeled as a uniform spherical blackbody of density 3.0 g-cm^{-3}. The forces included in the orbit calculations are the

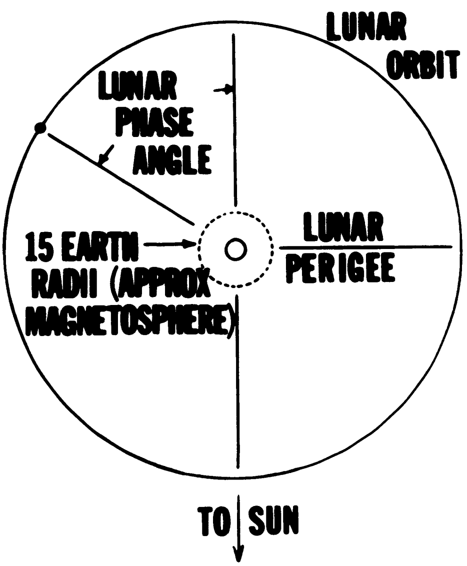

FIGURE 1. COORDINATE SYSTEM USED FOR EJECTA ORBIT CALCULATIONS

gravitational forces of the moon, earth, and sun, solar radiation pressure, and Coriolis forces.

Thirty impacts were simulated (270 orbits were calculated) for lunar phase angles in 10^{o} increments. A total of 17,010 orbits were calculated involving particles of radius 0.05um, 0.10um, 0.30um, and 0.60um. Output from the program included percentages of the ejecta of each size and for each lunar phase angle that were recaptured by the moon, that passed within 15 earth radii of earth (i.e., entered the magnetosphere), and that passed within 1.025 earth radii of earth (i.e., entered the atmophere).

RESULTS

As is shown in Fig. 2, a well defined "window" exists in the lunar phase angle during which a major portion of the submicron ejecta -- as much as 80% -- is intercepted by the earth's magnetosphere. Because of the greater effect of solar radiation pressure on the smaller ejecta, this window occurs later in the lunar cycle than for larger particles. In Fig. 3, the relationship between ejecta sizes and percent of ejecta reaching the magnetosphere and atmosphere of the earth is shown. A peak in the number of particles intercepted by the magnetosphere occurs for particles near 0.30um radius for this model (Fig. 3).

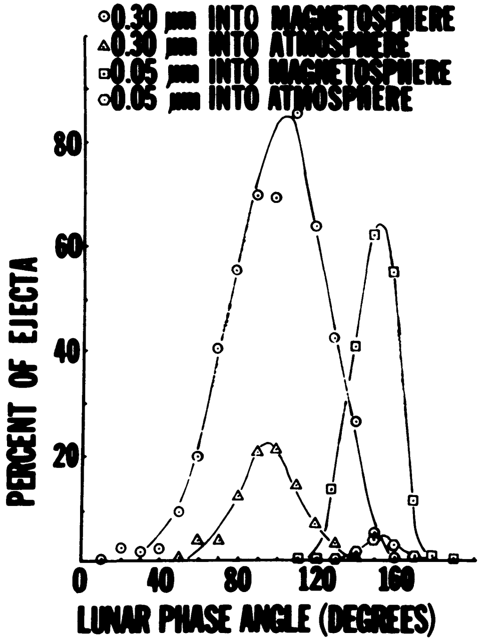

FIGURE 2. PERCENT OF EJECTA INTERCEPTED BY EARTH'S MAGNETOSPHERE AND ATMOSPHERE

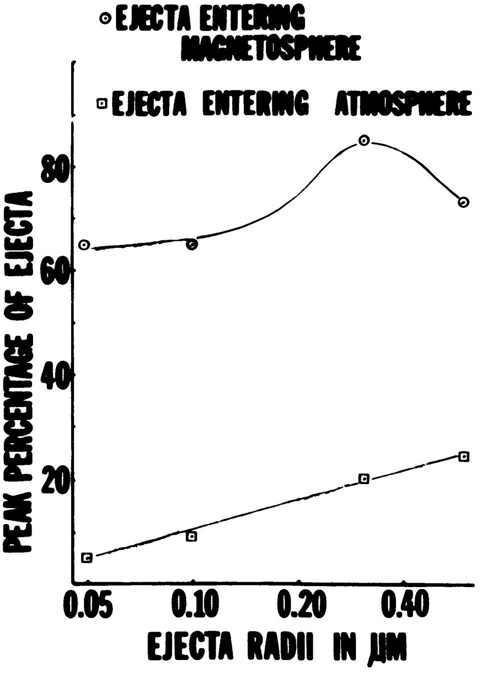

FIGURE 3. PEAK FLUX FOR VARIOUS EJECTA SIZES

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The major result of this study is the "pulse" of submicron ejecta into the magnetosphere of the earth for each lunar orbit. Since the ejecta flux considered in this work is produced only by the sporadic meteor background, monthly enhancement would be expected to follow the random variations of the sporadic flux.

Another consideration concerns the possible enhancement of this flux by major meteor showers. Since the annual periods of these showers occur during varying lunar phase angles, magnetosphere ejecta flux associated with major showers will vary depending on the coincidence of shower periods and favorable lunar phase angles. Magnetosphere ejecta flux associated with major meteor showers is the objective of a current study. Ejecta within the magnetosphere can have significant orbital perturbations and a presentation of the initial results of a study concerning these factors is presented in another paper of these proceedings [8].

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DISCUSSION

Fechtig: Did you calculate fluxes for particles coming off the surface of the moon?
Alexander: The ejecta flux compares well with the flux of sporadic interplanetary dust particles at 1 AU.

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