MASS LOADING OF THE EARTH'S MAGNETOSPHERE BY MICRON SIZE LUNAR EJECTA-- II:EJECTA DYNAMICS AND ENHANCED LIFETIMES IN THE EARTH'S MAGNETOSPHERE

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Extensive studies have been conducted concerning the individual mass, temporal and positional distribution of micron and submicron lunar ejecta existing in the earth-moon gravitational sphere of influence. Initial results of these studies have been reported/1, 2, 3, 4/ and show a direct correlation between the position of the moon, relative to the earth, and the percentage of lunar ejecta leaving the moon and intercepting the earth's magnetosphere at the earth's magnetopause surface, EMPs. The current studies reveal the following information concerning the general transport characteristics of the ejecta (lunar phase angle, LPA, defined as the angle of the moon in earth orbit with 0^o at full moon or anti-solar position):

1. The percentage of lunar ejecta entering the earth's magnetosphere varies between 65% and 85% for ejecta with radii between 0.05μ and 0.6μ and LPA between 60^o and 180^o;
2. the ejecta LPA release positions for maximum percentage flux at the EMPs varies with the particle mass;
3. the transport time of the ejecta from the lunar surface to the EMPs also varies with the particle radii; and
4. with the preceding data, the lunar ejecta cumulative flux, LECF, at the EMPs for conditions of maximum ejecta in-put during one lunar orbit is determined and the result is a lunar ejecta pulse for masses less than 10^{-9} g entering the EMPs during a time period $\leq$ 48 hours, and this represents a focusing, by a factor $\gtrsim$ 3, of the lunar ejecta flux into the earth's magnetosphere.

The pertinent data relating to LPA and % of LEF at EMPs is presented in Tables 1 and 2. The information in Table 1 shows four ejecta sizes, the range of LPA for enhanced lunar ejecta flux at the EMPs, the LPA for % Max LEF and the % Max LEF at the EMPs, but gives the range of LPA as the Max % LEF arrive at the EMPs and the LPA at % Max LEF at the EMPs.

Table 1
EJECTA AND MOON POSITION PARAMETER ASSOCIATED WITH EJECTA MOON-EARTH TRANSPORT TIMES AND POSITIONS

Particle Radii	Range of LPA	LPA at % Max	% Max LEF at EMPs
0.6μ	40^o--140^o	90^o	72
0.3μ	50^o--160^o	110^o	85
0.1μ	80^o--180^o	130^o	65
0.05μ	100^o--200^o	150^o	62

Table 2
RANGE OF LPA AND % MAX LPA AT ARRIVAL OF LEF AT EMPs

0.6μ	150^o--260^o	205^o	72
0.3μ	135^o--255^o	195^o	85
0.1μ	130^o--250^o	190^o	65
0.05μ	135^o--240^o	188^o	62

The above information uses the LPA as a time indicator. For example, the transport time for 0.6μ ejecta is 115° LPA (8.9 days); 0.3μ ejecta is 85° LPA (6.6 days); 0.1μ ejecta is 60° LPA (4.7 days); and 0.05μ ejecta is 38° LPA (2.9 days). The result is the arrival at the EMPs of the Max % LEF for each size within 32 hrs, or essentially at the same time. The LEF and Lunar Ejecta Space Density, LESD, has been estimated for the sporadic interplanetary dust particle flux and examples of the same quantities associated with two representative meteor streams /5/. Thus, a pulse of lunar ejecta into the earth's magnetosphere for each lunar cycle is indicated from these studies.

An additional factor of major importance to this work is that of lunar longitude at the time of impact of a primary particle. While the LPA is the major determing lunar position factor, the combination of LPA and longitude produces the maximum LEF onto the EMPs surface. This is demonstrated in Table 3 where all percentages are calculated for the LPA range (in 10° steps) from 10° to 160° /6/.

TABLE 3

Lunar Longitude Quarter	Average % EMPs Intercept	Max % EMPs Intercept	LPA°
1st	20	64	100
2nd	27	78	90
3rd	38	94	110
4th	33	90	110

The most important factor regarding sensitivity to longitude is the occurrance of non-random impact flux events. This is quite noticeable for the periods known as major shower periods. Initially, the LPA will determine if these ejecta will be transported to the EMPs surface. For an optimal LPA, the maximum LEF will occur when the lunar quarter (by longitude definition) is in the most favorable impact position with respect to the meteor shower radiant. From Table 3, a shower radiant that was essentially normal to the 3rd and 4th quarter with an LPA near 110°, would result in greater than 90% of the produced ejecta intercepting the EMPs surface.

When the dynamics of micron and submicron particles are being studied, several forces other than gravitational have to be considered. Radiation pressure is the major additional force which causes the lunar ejecta-magnetosphere pulse effect. The force due to convective drag becomes significant in cis-lunar space for the smallest of particles ($r \leq 0.1u$) because this is a force essentially normal to the ecliptic plane of such a magnitude (= to radiation pressure force) that many particles miss the magnetosphere even during the favorable LPA pulse portion of the lunar cycle.

The magnitudes of some of the nongravitational forces inside the earth's magnetosphere become vastly different from that of interplanetary space at 1 AU. The Lorentz type forces represent the greatest change as the radiation pressure is the same and the coulomb drag type forces are near the same because, though the velocity of the solar wind is much higher, the increase of electron densities in the magnetosphere as compared to interplanetary space effectively compensates for the velocity difference.

The Lorentz Force is much more significant inside the magnetosphere because the earth's magnetic field is greater than the magnetic field of interplanetary space and the charge on a particle is also much greater inside the magnetosphere. It is found that the Lorentz Force can be greater than the earth's gravitational force inside the magnetosphere.

Table 4 presents a comparison of gravitational and Lorentz forces inside the earth's magnetosphere. These values are calculated for spherical particles of tektite material that have been charged to a potential of -1000 volts or to the break-up potential, whichever has the lowest value. The Lorentz Force is greater than the gravitational force for particles of one micron and less radii.

Table 4 /6/

Particle	Particle	L=1.5		L=3		L=6	
Radii(u)	Mass(g)	FG (dy)	LF (dy)	FG (dy)	LF (dy)	FG (dy)	LF (dy)
10	$1.5x10^{-8}$	$6.4x10^{-6}$	$2.8x10^{-6}$	$1.6x10^{-6}$	$2.5x10^{-7}$	$4.0x10^{-7}$	$2.2x10^{-8}$
1	$1.5x10^{-11}$	$6.4x10^{-9}$	$2.8x10^{-7}$	$1.6x10^{-9}$	$2.5x10^{-8}$	$4.0x10^{-10}$	$2.2x10^{-9}$
0.1	$1.5x10^{-14}$	$6.4x10^{-12}$	$2.8x10^{-8}$	$1.6x10^{-12}$	$2.2x10^{-9}$	$4.0x10^{-13}$	$1.9x10^{-10}$

Table 5 gives the particle radii for which the Lorentz Force exceeds the gravitational force by the factor γ .

Table 5 /6/

γ = LF/FG	L=1.5	L=3	L=5
1	8.3 μ	3.9 μ	2.7 μ
10	2.1 μ	1.2 μ	0.9 μ
100	0.7 μ	o.4 μ	0.3 μ

It is seen that the Lorentz Force dominates all other forces, thus suggesting that submicron dust particles might possibly be magnetically trapped in the well-known radiation zones. For stable trapping to occur, 3 conditions must be satisfied. The Lorentz Force must be large compared to any other force acting on the particle. Second, the particle's cyclotron gyro-period must be small compared to the corotation of the earth's magnetosphere. Third, the magnetic field must be approximately constant over distances comparable to the particle's cyclotron gyro-radius. Even if these 3 conditions are not met and no durable trapping occurs, important magnetic focusing effects may still be present. Conditions do exist where micron and submicron lunar ejecta meet the three criterion; thus, magnetically trapped or focused lunar ejecta can exist. An observable enhancement of these particle fluxes with in-situ impact experiments will occur only if the spatial density of these particles is significant in comparison to the spatial density of interplanetary dust at 1 AU. This indeed appears to be true.

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