How a Strong Solar Coronal Mass Ejection can Eject Dust from the Moon's Surface to the Earth's Atmosphere

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A solar coronal mass ejection (CME) is a massive ejection of plasma from the Sun to the space. In this article it is shown how a strong solar coronal mass ejection can eject *dust* from the Moon's Surface to the space. If this ejection occurs when the Moon is in specific regions of its trajectory around the Earth, then this lunar dust can be gravitationally attracted to the Earth, forming a dust shell at the Earth's atmosphere, which can block the sunlight for some days.

Key words: Gravity, Coronal Mass Ejection, Electromagnetic Waves, Radiation Pressure.

1. Introduction

Electromagnetic waves transport energy as well as linear *momentum*. Then, if this *momentum* is absorbed by a surface, pressure is exerted on the surface. Maxwell showed that, if the incident energy U is totally absorbed by the surface during a time t, then the total *momentum* q transferred to the surface is $q = U/v$, where v is the velocity of the photons [1]. Then, the pressure, p (defined as force F per unit area A), exerted on the surface, is given by

$$p = \frac{F}{A} = \frac{1}{A}\frac{dq}{dt} = \frac{1}{A}\frac{d}{dt}\left(\frac{U}{v}\right) = \frac{1}{v}\frac{(dU/dt)}{A} \qquad (1)$$

In a previous paper [2], we have shown that this pressure has a *negative* component (*opposite to the direction of propagation of the photons*) due to the existence of the negative linear *momentum* transported by the photons, shown in the new expression for *momentum* q transported by the photon, i.e.,

$$\vec{q} = \left(1 - \frac{1}{2}\frac{f_0}{f}\right)\frac{hf}{c}\vec{n}_r \qquad (2)$$

where f is the frequency of the photon and f_0 is a limit-frequency, which should be of the order of *10Hz* or less; n_r is the index of refraction of the mean.

Equation above shows that for $f > f_0/2$ the resultant *momentum* transported by the photon is *positive*, i.e., If this *momentum* is absorbed by a surface, pressure is exerted on the surface, in the same direction of propagation of the photon. These photons are well-known. However, Eq. (2) point to a new type of photons when $f = f_0/2$. In this case $q = 0$, i.e., *this type of photon does not exert pressure when it incides on a surface*. What means that it does not interact with matter. Obviously, this corresponds to a special type of photon, which we will call of *neutral photon*. Finally, if $f < f_0/2$ the resultant *momentum* transported by the photon is *negative*. If this *momentum* is absorbed by a surface, pressure is exerted on the surface, in the *opposite direction of propagation of the photon*. This special type of photon has been denominated of *attractive photon*.

2. Theory

It is known that the lunar dust results of mechanical disintegration of basaltic and anorthositic rock, caused by continuous meteoric impact and bombardment by interstellar charged atomic particles over billions of years [3].

Dust can be ejected from the Moon's surface to the space when *attractive photons* strike on it. In order to surpass the Moon's gravity the power dU/dt absorbed by a dust particle with inertial mass m_{i0} must be, according to Eq. (1), given by

$$\frac{dU}{dt} > g_{moon} c m_{i0} \qquad (3)$$

where $g_{moon} = 1.622 m.s^{-2}$.

Assuming that the dust grains are *submicron* particles (size of the order of $10^{-7} m$), then we can write that $m_{i0} = \rho_p V_p \cong \rho_p \left(\frac{4}{3}\pi r_p^3\right) \cong 4\times10^{-18} kg$. Substitution of this value into Eq. (3) shows that, in order to surpass the Moon's gravity, the power absorbed by the particle must satisfy the following condition:

$$\frac{dU}{dt} > 10^{-9} watts \qquad (4)$$

Since the power absorbed by the particle is only a fraction of the power transported by the radiation, then it follows that the radiation must have a power density D, greater than $dU/A_p\,dt$ (A_p is the area of the cross section of the dust particle). Thus, we have

$$D > \frac{dU}{A_p dt} \approx 10^5 watts/m^2 \qquad (5)$$

Besides this, the photons must have $f << 10 Hz$ in order to be *attractive photons*.

When occurs a solar Coronal Mass Ejection, the plasma ejected from the Sun *interacts with the Sun's magnetic field* and *cyclotron radiation* is emitted from the particles of the plasma. Most of this radiation has frequency f expressed by the following equation [4, 5]

$$f \cong \frac{qB}{2\pi m} \qquad (6)$$

and, the intensity, I, radiated from *each particle*, given by

$$I = \frac{\mu_0 q^4 B^2 V^2}{6\pi m_{i0}^2 c\left(1 - V^2/c^2\right)} \qquad (7)$$

where q is the charge of the particle; V is its velocity and m_{i0} is its inertial mass at rest; B is the intensity of the magnetic field.

Assuming that, $q = e$ and $m \cong m_{proton}$, then Eqs. (6) and (7), give the following values

$$f \cong 1.5\times10^7 B \qquad (8)$$

and

$$I = 5.2\times10^{-38} \frac{B^2V^2}{\left(1 - V^2/c^2\right)} \qquad (9)$$

Thus, the *total intensity*, I_{total}, of the radiation at the frequency f is

$$I_{total} = nI \qquad (10)$$

where n is the number of particles with $m \cong m_{proton}$, which can obtained by the following expression

$$n \approx \frac{M_{CME}}{m_{proton}} \qquad (11)$$

M_{CME} is the mass of the solar CME.

Substitution of Eqs. (11) and (9) into Eq. (10), gives

$$I_{total} \approx 5.2\times10^{-38}\left(\frac{M_{CME}}{m_{proton}}\right)\frac{B^2V^2}{\left(1 - V^2/c^2\right)} \qquad (12)$$

The *solar surface magnetic field* is around $1 Gauss = 10^{-4} T$, about twice as strong as the average field on the surface of Earth (around $0.5 Gauss$). Thus, when the plasma is ejected from the Sun, the frequency f of the emitted radiation, according to Eq. (8), is $f \cong 1.5\times10^3$. These photons are not attractive, because as we have already seen, attractive photons must have frequency $<< 10 Hz$. However, after some time of propagation the ejected plasma reaches a region where the intensity of the Sun's magnetic field is about $10^{-7} T$ *. At this place
the frequency f of the emitted radiation, according to Eq. (8), is $f \cong 1.5 Hz$ (See Fig.1). If the solar CME occurred at the direction of Earth, then a flux of these attractive photons will strike on the Earth and also on the Moon. But, in the case of Earth, it will be absorbed by the Earth's atmosphere (mainly at the regions with high electrical conductivity; Van Allen belts, Ionosphere.). This, obviously does not occurs at the Moon atmosphere, and the flux arrives at the Moon's surface with a power density D_s, which according to Eq. (12), is given by

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* The intensity of the solar magnetic field reduces with the inverse-cube of the distance to the Sun's center (r^{-3}). Thus, the intensity I (See Eq. (7)) reduces with r^{-6}. This means that after the region where B≅ 10^{-7} *T*, the intensity of the *attractive radiation* becomes much smaller than in the mentioned region.

$$D_s \sim 10^{-25} \frac{M_{CME} V^2}{\left(1 - V^2/c^2\right)} \qquad (13)$$

If $D_s = D > 10^5 \, watts/m^2$ (See Eq. (5)), then *the incidence of these attractive photons upon the Moon will eject dust from the Moon's surface to the space*, i.e., according to Eq. (13), this will occur if

$$\frac{M_{CME} V^2}{\left(1 - V^2/c^2\right)} > 10^{30} \qquad (14)$$

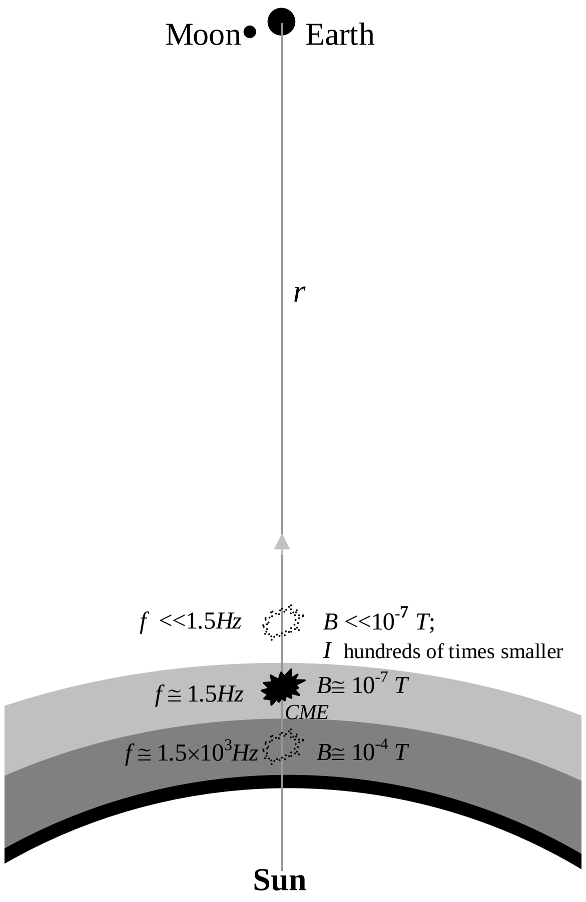

Fig. 1 – *Schematic diagram showing a Solar Coronal Mass Ejection at the direction of the Earth.* The intensity of the solar magnetic field reduces with the inverse-cube of the distance to the Sun's center (r^{-3}). Thus, the intensity I (Eq. (7)) reduces with r^{-6}.

A *large* solar CME can expel more than $10^{13} kg$ of matter with speed over $3{,}000 km.s^{-1}$ [6, 7]. In the case of a solar CME with $V \cong 10{,}000 km.s^{-1}$, Eq. (14) gives

$$M_{CME} > 10^{16} kg \qquad (15)$$

A solar CME with the values of V and M_{MCE} above mentioned can be considered a *very large* solar CME.

There is no record if this type of solar CME occurred in the past. However, if to occur in the future, and if the ELF radiation ($f \cong 1.5Hz$) emitted from the CME to hit the Moon when it is traveling in specific regions of its trajectory (See regions AB and CD in Fig.2), then *the dust ejected from the Moon's surface to the space will be gravitationally attracted to the Earth*, forming a dust shell at the Earth's atmosphere, which can block the sunlight for some days.

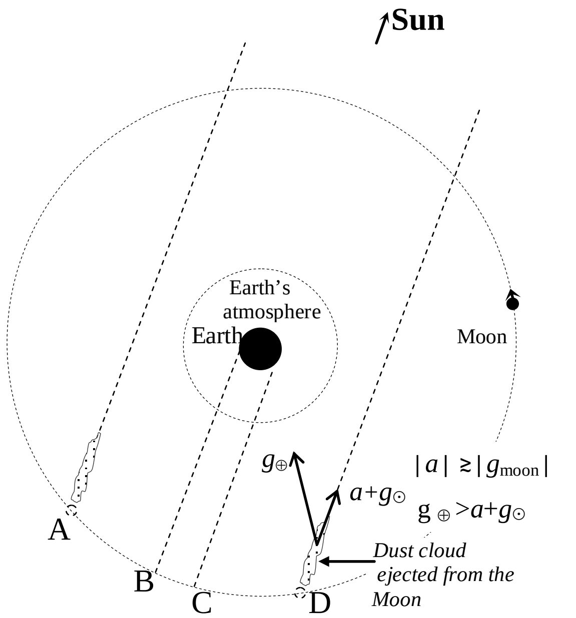

Fig. 2 – If the ELF radiation emitted from the CME to hit the Moon when it is traveling in the regions AB and CD, then *the dust ejected from the Moon's surface to the space will be gravitationally attracted to the Earth*, forming a dust shell at the Earth's atmosphere, which can block the sunlight for some days.

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