THE ESCAPE OF NATURAL SATELLITES FROM MERCURY AND VENUS

(Letter to the Editor)

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Abstract. It is suggested that the slow rotations of Mercury and Venus may be connected with the absence of natural satellites around them. If Mercury or Venus possessed a satellite at the time of formation, the tidal evolution would have caused the satellite to recede. At a sufficiently large distance from the planet, the Sun's gravitational influence makes the satellite orbit unstable. The natural satellites of Mercury and Venus might have escaped as a consequence of this instability.

1. Introduction

Venus and Mercury are slowly spinning planets with rotation periods of 243 days and 59 days, respectively. In fact, they have the longest rotation periods of all the planets in the solar system. It is unlikely that their rotations were so slow at the time of their formation. They most probably had rotation periods similar to the present periods for the other planets in the solar system. The rotation periods for Earth, Mars, Jupiter, Saturn, Uranus and Neptune lie in the range 9h–25h and it is reasonable to assume that Mercury and Venus have been slowed down to their present levels as a result of evolutionary effects. For example, the tidal interaction between the Sun and Mercury (or Venus) may cause the planet's rotation to be slowed down (Jeffreys, 1970).

Venus and Mercury are two of the three planets in the solar system which do not possess any known natural satellites. While the slow-down of Venus and Mercury may have been caused by the Sun, it is not clear that the Sun is entirely responsible for this effect. Which additional cause could account for the slow-down, and does it have anything to do with the absence of natural satellites around Venus and Mercury? We should like to propose here that the slow rotations of Venus and Mercury may be connected with the absence of natural satellites around them.

2. The Escape Mechanism

Let us start with the hypothesis that Venus and Mercury possessed one satellite each some time in the past. We may further say that each planet possessed one satellite at the time of formation. 4.6 \times 10^9 yr ago. Let \( M_s \) be the mass of a satellite moving around
Mercury or Venus with a mean distance of $a_{ps}$. If $M_p$ is the mass of the planet (Mercury or Venus), then the gravitational force acting on the satellite due to the planet is

$$F_{ps} = \frac{GM_p M_s}{(a_{ps})^2}. \tag{1}$$

The gravitational force due to the Sun on the satellite is

$$F_{os} = \frac{GM_\odot M_s}{(a_{os})^2}, \tag{2}$$

where $M_\odot$ is the mass of the Sun and $a_{os}$ is the distance of the satellite from the Sun. It is reasonable to assume that

$$a_{os} \simeq a_{op}, \tag{3}$$

where $a_{op}$ is the mean distance of the planet from the Sun.

From Equations (1), (2), and (3), we obtain

$$\frac{F_{os}}{F_{ps}} = \left(\frac{M_\odot}{M_p}\right)\left(\frac{a_{ps}}{a_{op}}\right)^2. \tag{4}$$

If the force acting on the satellite due to the Sun is much greater than that due to the planet, then we may say that the satellite's orbit will become unstable. Therefore, we may adopt as a criterion for instability the condition that

$$\left(\frac{M_\odot}{M_p}\right)\left(\frac{a_{ps}}{a_{op}}\right)^2 \gg 1. \tag{5}$$

The condition (5) can be written in the form

$$a_{ps} \gg a_{op}\left(\frac{M_p}{M_\odot}\right)^{1/2}. \tag{6}$$

If this condition is satisfied, the satellite might escape from the planet. This is not the only form of instability that could possibly take place, but we shall restrict our discussion to the escape of the satellite.

3. Application to Mercury and Venus

The criterion (6) will now be applied to Mercury and Venus. In the case of Mercury, $M_\odot/M_p = 6.0 \times 10^6$ and $a_{op} = 0.39$ AU $= 5.8 \times 10^7$ km. For a satellite around Mercury to escape, we require from (6) that

$$a_{ps} \gg 2.4 \times 10^4 \text{ km}. \tag{7}$$

The present Earth–Moon distance is $3.8 \times 10^5$ km and the Moon is currently receding from the Earth due to the tidal evolution of the Earth–Moon system. The tidal evolution of the Mercury–satellite system will also cause the satellite to recede from Mercury, and it is not unreasonable to suppose that the distance of the satellite could have