Journal of Physics Special Topics

An undergraduate physics journal

P2_3 Explaining Venus' Retrograde Rotation

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November 7, 2018

Abstract

Venus is the only planet in the solar system that has a retrograde rotation. We investigated the idea of an asteroid colliding with a young Venus, that had a rotational period similar to Earth's, with enough kinetic energy to cause it to reverse direction. Taking the velocity of 2002 VE68 (a quasi-satellite of Venus), we found the required asteroid's mass to be 3.1×10^{20} kg, comparable to that of Vesta.

Introduction

Every planet in the solar system rotates anticlockwise with the exception of Venus. The early stages of the solar system were very chaotic with many collisions that would have affected the orbits and rotations of objects within the solar system.

We thought about whether one of such collisions could have caused Venus' unique rotation. To do this, we assumed that a young Venus used to rotate with the same rotation period as modern Earth, due to the similarities between them, such as mass and radius.

We assumed that the asteroid had a perfectly elastic collision with Venus, exactly along the planet's rotational axis. As a result of this collision, it is worth noting the change in mass and radius of Venus is negligible.

Method

To start with we calculated the angular velocities, ω, of a young Venus and a modern day Venus,

$$\omega = 2\pi/T, \tag{1}$$

where T is the time period of one day [1]. For young Venus we used the length of a day on Earth, which gave us $\omega_1 = 7.3\times10^{-5}$ rad/s. And for modern Venus, where T = 243 days [2], we got $\omega_2 = 3.0\times10^{-7}$ rad/s.

Next we calculated the inertia, I, of Venus (taking it to be a solid sphere),

$$I = \frac{2}{5} M_V R_V^2, \tag{2}$$

where M_V is mass of Venus and R_V is radius of Venus [1][3]. This gave us a value of $I = 7.1\times10^{37}$ kg/m^2.

Inputting these values into Eq. (3) below, we then calculated the rotational kinetic energy, E_K, of Venus both before and after the collision.

$$E_K = \frac{1}{2} I\omega^2, \tag{3}$$

[1]. This gave us E_{K1} to be 1.9×10^{29} J before the collision, and E_{K2} to be 3.2×10^{24} J after the collision. The total change in kinetic energy was calculated by adding these two values together. This gave us $E_{Ktot} \approx E_{K1}$.

Looking at Eq. (5) we saw that in order to find the mass there was an unknown velocity. So, we looked at the orbit of Venus' quasi-satellite 2002 VE68 [4] (because it is in an orbit that could potentially collide with Venus) to calculate a realistic velocity for our potential asteroid, v, using the following equation [5]:

$$v = \sqrt{\mu \left(\frac{2}{r} - \frac{1}{a} \right)}, \qquad (4)$$

where $\mu = GM_{Sun} = 1.33{\times}10^{20}$ m^3/s [6], r is radius from the Sun at the point of collision [7], a is semi-major axis of object's orbit [4]. We found v to be 35 km/s.

From this we could then use Eq. (5) to calculate the required mass, m, to change Venus' rotation to what it is today. [1]

$$m = 2E_{Ktot}/v^2, \qquad (5)$$

The final mass we calculated for the asteroid was $m = 3.1{\times}10^{20}$ kg.

Conclusion

In this report, we investigated how large an asteroid would have to be in order to have sufficient kinetic energy to reverse the direction of Venus' rotation.

From our results, we found that an asteroid moving at 35 km/s with a mass of $3.1{\times}10^{20}$ kg would produce enough kinetic energy to overcome Venus' rotational kinetic energy, and reverse the planet's rotation.

This mass is comparable to the asteroid Vesta ($2.7{\times}10^{20}$ kg) located inside the asteroid belt [8]. Which indicates that this scenario is somewhat plausible, because both the masses of our proposed asteroid and Vesta are similar to that of proto-planets (early solar system objects) [9].

References

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