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A1_1 Bruce Almighty: Moon Wrangler

Harneet K. Sangha, Gregory A. Childs, Heidi B. Thiemann, Taranpreet K. Sohal

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH

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Abstract

In the film Bruce Almighty, starring Jim Carrey, as a romantic gesture he erases the clouds in the sky and draws the Moon closer to the Earth, using an invisible lasso. In this paper we have calculated 2.1x10^{21}N would be needed to pull the Moon towards the Earth. We have also discussed the ramifications of changing the Moon's distance from the Earth, finding the tides rose by 15.2m.

Introduction

Jim Carrey plays an average news man, Bruce Nolan, who feels like he's going nowhere in life. He has a bad day, goes for a drive and begs God for a miracle. He ends up receiving God's powers. He goes on to create a romantic evening for his girlfriend, Grace, by erasing clouds and pulling the Moon closer to him. We calculated the force that would be required to do this, along with the change in tidal acceleration in order to see the implications of this act.

Figure 1: The Moon enlarged by a scale factor of 3.4 [1]

Theory

In order to calculate the force that would be needed to pull the Moon closer to the Earth, the new distance between the Earth and the Moon was required. We found this by measuring the diameter of the Moon before and after it was drawn closer, calculating the scale factor in observed size. Calculating the original angular diameter, δ_1, and multiplying by the scale factor we found the new angular diameter, δ_2. We then used equation 1 in conjunction with this to find the new Earth-Moon distance, D_2.

$$D_2 = \frac{d_2}{2\tan\frac{\delta_2}{2}}, \tag{1}$$

where d_2 = actual diameter of Moon (3474km).

Calculating the difference in the forces of attraction between Earth and the Moon, equation 2, at the original and new orbital distance, we found the force required for this change.

$$F = \frac{GMm}{R^2}, \tag{2}$$

where G = gravitational constant, M = mass of the Earth (5.97x10^{24}kg), m = mass of the Moon (7.35x10^{22}kg) and R = distance between the two (384400km).

The Roche limit is the distance at which a satellite would begin to be ripped apart by tidal forces. After calculating the new orbital distance of the Moon, we checked to see whether it fell within this limit.

We calculated the tidal variations that would occur after Bruce pulled the Moon closer to the Earth. Using equation 3 we calculated the tidal acceleration, a_t, of a particle on the Earth-Moon axis, as this would give the maximum displacement of water.

$$a_t \approx \pm 2rG\frac{m}{R^3}, \tag{3}$$

where r = radius of the Earth (6371km). [2]

The actual amplitude of the oceanic tides caused by the tidal acceleration of the Moon has a maximum of 0.54m [3]. To calculate the new maximum tide, we used the equation below [4];

$$R_2 = R_1\left[\left[\frac{a_t + g}{g}\right]^{1/2} - 1\right], \tag{4}$$

where g = acceleration due to gravity, R_1 = the position of a point mass at Earth's radius (6371km) and R_2 = the position of a point mass at some height above R_1.

We can use this equation to calculate the increase in tidal height from the increase in tidal acceleration.

Results

We calculated the scale factor in the Moon's new apparent size to be 3.4 times larger than at its initial position. From this, the new distance was found to be 1.1x10^8m and the force required to achieve this move was calculated to be 2.1x10^{21}N. This is equivalent to the total thrust of 6.3x10^{13} Saturn V rockets (the most powerful machine made by man) [5], a rather godly feat.

The Roche limit for the Moon, orbiting Earth, is 18,381km [6] so Bruce would not destroy the Moon.

We found the tidal acceleration to be 4.8x$10^{-6}g$. At the current Earth-Moon distance, the tidal acceleration, a_t, is 1.1x$10^{-7}g$. With the new Earth-Moon distance, this is a factor of 44 times greater. If the Moon was as close as Bruce pulled it to Earth, high tides would increase sea levels by up to 15.2m in height.

Discussion

We made a number of assumptions during this project. One was that the Moon's new orbit was circularised. This is not entirely accurate as a single "pull" on the Moon would result in a very eccentric, elliptical orbit. This would result in the tidal acceleration changing over time as the Moon orbits, rather than a constant change.

Another assumption was that the orbit of the Earth would remain unaffected. This is a reasonable assumption as when compared to the scale of 1 AU even a change on the order of 10^3km would produce negligible short term repercussions compared to the implications in changing of the Moon's orbit.

From these calculations we can conclude that Bruce's "thoughtful" gesture would prove to have chaotic repercussions. Most low lying and coastal cities would experience flooding, the weather and tectonics of the Earth could be affected. This would cause widespread damage, significantly worse than the "freak Japanese tsunami" mentioned in a news report in the film the following day. Was Grace worth it?

References

[1] `https://www.youtube.com/watch?v=h-_sbtiQf8s` accessed on 17/10/16

[2] `https://en.wikipedia.org/wiki/Tidal_force` accessed on 5/10/16

[3] `https://en.wikipedia.org/wiki/Tide` accessed on 17/10/16

[4] `mb-soft.com/public/tides.html` accessed on 17/10/16

[5] `https://goo.gl/hEin53` accessed on 17/10/16

[6] `https://en.wikipedia.org/wiki/Roche_limit` accessed on 5/10/16