A1 3 Tonight We Steal The Moon!

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Abstract

In this paper, we investigate the physical consequences caused by shrinking the Moon, similar to the plot of Despicable Me. We used reference radial sizes and energy values to explore the variety of consequences caused by shrinking the Moon, given some assumptions. This resulted in a variety of outcomes, such as the Moon becoming a neutron star or black hole, due to its new, ultra-dense state.

Introduction

In the 2010 film, Despicable Me, the story's protagonist, Gru, attempts to steal the Moon by using a 'shrink ray' [1] into a size he can hold within his hand. In this paper, we investigate the impacts of the task with regards to the Moon's new form and the energy required to significantly shrink the Moon, given some assumptions.

For this investigation, we are assuming that the Moon maintains its current mass of $M_m = 7.3459 \times 10^{22}$ kg [2], and it does not undergo any fragmentation or shatter as it is being shrunk down. Additionally, we assume that the Moon is of uniform density and perfectly spherical. From this, the radius, and thus density, of the Moon are the changing physical parameters. Finally, we assume the Moon's size is reduced via quasi-static compression so the Moon stays in thermodynamic equilibrium [3]. From here, we look at what occurs to the Moon at these new densities, and its resulting physical form.

The analysis of this paper will focus on two shrinking references. **Scenario 1** will investigate reference sizes and **Scenario 2** will investigate reference energy values.

Scenario 1: Reference Sizes

In this scenario, we are giving the Moon a radius value, r, based upon a reference frame and investigating the subsequent impacts of its new density. To find the Moon's new density, ρ_{NM}, we need to relate it to the Moon's mass, M_m, and its new volume, V. For this, we use:

$$\rho_{NM} = \frac{M_m}{V} = \frac{M_m}{\frac{4}{3}\pi r^3} \qquad (1)$$

We are selecting several spherical or near-spherical objects as reference examples for radius values, which are then used to calculate the Moon's new density. These are then compared to the density of a neutron star (NS), ranging between 3.7 to 6×10^{17} kgm^{-3} [4]. At greater values than this range, it is labelled an 'ultra dense body' (UDB). After this, once the Moon's radius falls below its own Schwarzschild radius, it will collapse into a singularity under its own gravitational forces and form a black hole (BH) [5]. The Moon's Schwarzschild radius can be found [6] via;

$$r_s = \frac{2GM_m}{c^2} \qquad (2)$$

where G is the gravitational constant [7], and c the speed of light in a vacuum [8]. This gives the Moon a Schwarzschild radius of 0.000109 metres.

The results shown in Table 1 list reference sizes, their radius, the density of the Moon with that radius and a celestial comparison.

Ref. Object	Radius(m)	Dens.(kgm^{-3})	NS/UDB/BH
Las Vegas Sphere	87.5 [9]	2.62×10^{16}	N/A
Football	0.70 [10]	5.11×10^{22}	UDB
Sand Grain Min.	0.000060 [11]	8.12×10^{34}	BH

Table 1:

Reference Sizes for the new Moon and their subsequent densities, with celestial references.

Table 1 shows what would happen to the Moon given Gru shrinks it based upon these references. If he was to shrink the Moon to the minimum value for sand [11], the Moon would become a black hole, as the radius is lesser than the Moon's Schwarzschild radius.

Scenario 2: Reference Energies

In this scenario, we are selecting reference energies to apply to the Moon in quasi-static compression and find the new radius and density of the Moon. To do such, we are using the gravitational binding energy, U for a sphere of uniform density [12], which is:

$$U = -\frac{3}{5}\frac{GM_m^2}{R} \qquad (3)$$

To find the radius of the new Moon for a given energy, we need to consider ΔU, which represents the change in binding energy between the Moon and the new Moon. As the compression is quasi-static, and the binding energy is 'negative', we need to remove energy from the Moon in order to decrease its radius. This means to extract external energy from the Moon, increasing the absolute value of $|U|$, and thus decreasing the value of R. Therefore, we can set $-U$ equal to E_{remove}, and thus we can input our energy values as E_{remove} By doing this, we can rearrange Equation 3 to:

$$E_{remove} = \frac{3}{5}GM_m^2\left(\frac{1}{R_n} - \frac{1}{R_m}\right) \qquad (4)$$

where R_n is the radius of the new Moon, in metres, and R_m is the radius of the Moon; 1740 km [13].

We are aiming to find R_n, so we can rearrange Equation 4 to be equal to this, which gives us:

$$R_n = \left[\frac{5E_{remove}}{3GM_m^2} + \frac{1}{R_m}\right]^{-1} \qquad (5)$$

Again, we are using a table listing reference energies, their subsequent energy amounts, the new radius of the Moon and its comparison related to its density. These are listed in Table 2:

Ref. Energy	Energy (J)	Radius (m)	NS/UDB/BH
World Usage (2024)	6.48×10^{20} [14]	$\approx R_m$	Moon
Sun Output (Day)	3.34×10^{31} [15]	6453.31	IRWD [16]
Sun Output (Year)	1.22×10^{34}	17.75	UDB
Sun Output (165,000 Years)	2.01×10^{39}	0.00011	BH

Table 2:

Reference Sizes for the new Moon and their subsequent densities, with celestial references.

Table 2 shows the incredible amounts of energy Gru would need to shrink the Moon by even a few millimetres. The world's energy usage for 2024 had an incredibly small impact of 0.0091 metres, which demonstrates the physical improbability, even with our assumptions, of shrinking the Moon at all. Here, IRWD is the inner region of a white dwarf.

Conclusion

Throughout this paper, we showcased the densities of a shrunken Moon and the physical impacts the Moon's new density would have upon it, as well as the theoretical shrinking capabilities when selected amounts of energy are applied. Shown by the energy values in scenario 2, Gru would need unrealistic amounts of energy to have any significant shrinking impact on the Moon. For the Moon to be held in his hand, as the film depicts, he would create an object with greater density than a neutron star, leaving himself gravitationally bound to it as he holds it [17].

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