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A5_11 Saving Alderaan 2: Momentum Strikes Back

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Abstract
This paper will look into whether a silver mirror required to successfully reflect and absorb the Death Star's laser intent on destroying Alderaan could be accelerated by the laser out of stable orbit and into the planet's surface. We will then find whether the mirror would impact with enough kinetic energy (KE) to overcome the gravitational binding energy (GBE) of Alderaan (2.03×10^{33} J) and destroy it. Without taking into account the acceleration due to Alderaan's gravity, which would only increase the KE, it was found that the mirror would have a KE of 4.40×10^{34} J which is more than sufficient to overcome Alderaan's GBE. Therefore, in saving Alderaan we doom it.

Introduction

In this paper we will look into whether a massive silver mirror could be accelerated due to the radiation pressure from a battle-station, named the Death Star (DS), sufficiently to overcome the gravitational binding energy of the planet Alderaan and destroy it. Applying physics to the Star Wars universe tends not to give good results.

Method

From the previous paper, we know that the mirror in question has a reflectance of 0.786 and the DS's laser has energy 2.03×10^{33} J[1]. This allows us to find the DS laser energy absorbed as 3.91×10^{32} J and the DS laser energy reflected back as 1.64×10^{33} J. The equations for radiation pressure from reflected and absorbed radiation, respectively, are:

$$P_{i,r} = 2\frac{I_r}{c} \quad (1)$$

and

$$P_{i,a} = \frac{I_a}{c} \quad (2)$$

Where I is the irradiance flux density (the radiant flux received by a surface per unit area) of the DS's laser, subscripts r and a refer to reflected and absorbed beams respectively, c is the speed of light - taken as 3.00×10^8 ms^{-1}, $P_{i,r}$ is the radiation pressure caused by the beam impacting and then reflecting off the mirror and $P_{i,a}$ is the radiation pressure caused by the absorption of part of the total beam by the mirror[2].

To use these equations, we must first find the area the laser covers. To do this we measure the diameter of the DS and that of the DS's main laser aperture (which we assume to be circular), find the ratio between the two and use the known value of the DS's diameter to find an estimate for the diameter of the main laser aperture. We do this by measuring the respective distances on the image shown in Figure 1. The DS has a diameter of 1.60×10^5 m[4] and a measured diameter of 4.50×10^{-2} m whilst the aperture has a measured diameter of roughly 3.00×10^{-4} m. This gives a ratio between the measured distances of $1 : 150$

(aperture : DS diameters), which in turn gives an aperture diameter of 1.07×10^3 m and thus an aperture area of 8.94×10^5 m^2. Assuming the laser remains coherent until it comes into contact with the mirror it will share this area and retain it until it has been either absorbed by the mirror, or reflected and then absorbed by the DS - destroying it. Therefore using Eqs. (1) and (2) we can find the individual pressures exerted by the two aspects of the laser interaction.

Figure 1: The image used to measure, with a ruler, the apparent diameter and apparent aperture diameter of the Death Star[5].

$P_{i,r}$ is found to be 1.09×10^{25} Pa and $P_{i,a}$ is found to be 1.30×10^{24} Pa. Taking a sum of the two values gives a total radiation pressure of 1.22×10^{25} Pa. Multiplying this value of radiation pressure by the aforementioned area of the laser aperture to find the force imparted on the mirror gives 1.09×10^{31} N. Then, using Newton's 2nd Law:

$$F = ma \tag{3}$$

where F is the force applied, m is the mass of the mirror found in the previous paper[1], as 1.36×10^{27} kg, and a is the acceleration of the object. By rearranging Eq. (3) for acceleration of the mirror towards Alderaan caused by the laser we find it to be 8.04×10^3 ms^{-2}. Assuming that the laser is interacting with the mirror over one second of time and the mirror is assumed to be in an previously stable orbit around Alderaan, we can take acceleration to be equal to the velocity post-interaction and that the initial velocity of the mirror is 0 ms^{-1}. The KE of the mirror is given by:

$$E_k = \frac{1}{2}mv^2 \tag{4}$$

Where E_k is the kinetic energy of the mirror, m is the mirror's mass and v is the mirror's velocity.

Results

We can use Eq. (4) to find the kinetic energy of the mirror post-interaction as 4.40×10^{34} J. We know that the gravitational binding energy of Alderaan is 2.03×10^{33} J[1] which is far smaller (just over 21 times smaller) than the calculated value of the KE of the mirror. It could be argued to include the gravitational acceleration due to Alderaan's gravity, but that isn't within the scope of this paper.

Conclusion

From the results in this paper, we can see that Alderaan would be destroyed by the mirror as a result of being saved.

References

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