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A5_5 Saving Alderaan: A Star Wars Story

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Abstract

This paper looks into whether or not the fictional planet of Alderaan in the Star Wars universe could be saved from the Empire and their Death Star. This is done by looking at reflecting the laser used to destroy Alderaan back at the Death Star. It was found that the mass of a mirror made of Silver required to reflect and absorb the laser's energy was around 227 times more massive than the Earth. It was, thus, deemed unfeasible to undertake such a task and therefore Alderaan could not be saved.

Set-up

From Wookieepedia, a fan-made Wikipedia for the Star Wars universe, we find that Alderaan has an effective diameter of $12,500\ km$[1], but it doesn't tell us the mass so we assume Alderaan and Earth are similar in their compositions to one another and thus that Alderaan has an average density of $5,510\ kgm^{-3}$[2]. After calculating the volume of Alderaan to be $3.07 \times 10^{21}\ m^3$, we can calculate the mass of Alderaan (by multiplying volume by density) as $1.69 \times 10^{25}\ kg$.

The equation to find the Gravitational Binding Energy (GBE) of a uniformly dense sphere is given by[3][4]:

$$U = \frac{3GM^2}{5R} \tag{1}$$

where G is the Gravitational Constant, taken to be $6.67 \times 10^{-11}\ m^3kg^{-1}s^{-2}$, M is the mass of the sphere in kilograms and R is the radius of the sphere in metres.

Using Eq. (1), for Earth's values, gives a value of $2.49 \times 10^{32}\ J$. This takes into account that the Earth isn't a uniformly dense sphere - as given by the Preliminary Reference Earth Model [5]. Taking a fraction of this value and the value one would get, without taking into account this lack of uniformity, we find a ratio of expected to real planetary GBE of 1.11, and after finding the expected GBE of Alderaan to be $1.83 \times 10^{33}\ J$ we can calculate the real GBE value for Alderaan to be $2.03 \times 10^{33}\ J$.

Method

Now that we know the energy required to destroy Alderaan, and therefore the minimum energy released by the Death Star, we can start the process of figuring out how to actually save Alderaan.

In Star Wars there are planetary energy shields. However, if one were to model such a thing as an EM field then it would not be able to refract the Death Star's laser to a degree wherein it becomes harmless. That is unless the light wave was totally internally reflected. Ruling this out as an effective possibility we must, instead, reflect the laser using some form of mirror.

With this in mind, and keeping to realistic

methods of reflection - rather than a massive lightsaber as this is Star Wars, we start by finding the most reflective metal known to mankind, since metals are often used in mirrors: Silver[6].

We will assume that the Death Star's laser has the standard green laser wavelength of $532nm$, this gives the Silver a refractive index of approximately 0.06[7].

From Fresnel's equation for reflectance:

$$R = \frac{n_1 cos\theta_i - n_2 cos\theta_t}{n_1 cos\theta_i + n_2 cos\theta_t} \tag{2}$$

where n_1 is the refractive index of the initial medium, which is the vacuum of space so we will assume $n_1 = 1$, and n_2 is the refractive index of the medium the light is incident upon, θ_i is the angle of incidence and θ_t is the angle of transmittance.

Assuming that the laser is incident on the mirror perpendicularly, we can use the case of normal incidence wherein $\theta_i = \theta_t = 0^o$. This simplifies Eq. (2) to:

$$R = (\frac{n_1 - n_2}{n_1 + n_2})^2 \tag{3}$$

which allows us to find the reflectance, R, as being 0.786. Multiplying this by the real GBE of Alderaan we find the energy of the laser not reflected to be 3.91×10^{32} J. With this we can then find the mass of the mirror required to absorb the remaining energy using the specific heat capacity of Silver [8] 233 $Jkg^{-1}K^{-1}$, rearranging the equation for temperature increase of a material to find the mass required yields:

$$m = \frac{Q}{c\Delta T} \tag{4}$$

where Q is the thermal energy in Joules, c is the specific heat capacity in $Jkg^{-1}K^{-1}$ and ΔT is the change in temperature of the material in Kelvin. The melting point of Silver is assumed to be 1230 K[9], the Silver is assumed to be heated uniformly and the temperature of space is assumed to be 2.70 K. From this ΔT becomes 1230 K, to 3 significant figures, and substituting all values in gives a mass of 1.36×10^{27} kg.

Conclusion

From this value of mass required to 'soak' up the remaining energy of the Death Star's laser we can see that this is an unfeasible method of defending Alderaan. Primarily because the amount of Silver is roughly 228 times more massive than the Earth. Though this doesn't begin to account for the possibility of the silver vaporising (the combination of silver's latent heat of fusion, its boiling point and then its latent heat of vaporisation). This would most likely reduce the mass required to absorb the remaining energy but that is beyond the scope of this paper.

Thus we deem it unrealistic to defend Alderaan from the Empire's wrath via reflection by a giant mirror made of Silver.

References

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