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A2 4 Saving the Dinosaurs

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Abstract

In this paper, we found the power and intensity required for a gamma ray laser that would slow down and stop (or destroy) the asteroid that killed the dinosaurs. We found the power and intensity to be 1.2×10^{14} W and 1.8×10^{18} W/m^2 , which allowed the laser to stop the asteroid in 1.59 years at a safe distance of Mars' orbit, assuming it to be a blackbody. Assuming not, the laser disintegrates the asteroid in $\sim$ 9 minutes.

Introduction

65 million years ago, the dinosaurs perished when a cataclysmic, $\sim$ 10 kilometer wide [1] asteroid slammed into earth, transferring huge amounts of kinetic energy in the process. They could not stop this due to their lack of anti-asteroid counter measures. In this paper we consider a situation where the dinosaurs became highly advanced, and gained access to extremely high powered laser systems. We model that the asteroid originates from the outer asteroid belt, with the laser being positioned at Lagrange point 1. In this paper estimate whether their efforts are successful, and calculate the intensity required for the laser system to be able to stop the asteroid at Mars' orbit.

Methodology and Equations

The asteroid's initial speed was $\sim$ 20 km/s, and its approximate mass was 9×10^{13} kg [1]. We started by finding its momentum, which gave the total momentum the laser needed to deplete so that it will be stationary. Next, we used the photon momentum equation:

$$p = E/c = nhf/c \tag{1}$$

Where E is the total delivered energy in terms of frequency *f*, Planck's constant h and total photons delivered n. The equation relating deceleration to distance travelled is:

$$v^2 = u^2 + 2as \tag{2}$$

Where u is the initial velocity, v = 0 is the final velocity, a is the deceleration and s is the distance travelled. Applying Newton's Second law to find the force required, given the acceleration from equation 2:

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

Using the relation for the force and the change in momentum over time, we then found the total time of the asteroids deceleration:

$$t = p/F \tag{4}$$

We decided a gamma ray laser was suitable as using the most energetic photons provided the most radiation pressure per photon. The frequency of gamma ray photons were taken to be 2×10^{28} Hz; the highest frequency of gamma ray found [2]. Combining equations 1 and 4, the power of the gamma laser was calculated using:

$$P_\gamma = Fc = nhf/t \tag{5}$$

Finally, to calculate the intensity of the laser, we divided the power by the area of the laser aperture.

Initial Conditions and Assumptions

The asteroid originates from the outer belt, and is stopped at the orbit of mars. This distance is $D_{tot} = 4.8 \times 10^{11}$ m; The mass of the asteroid is 9×10^{13} kg; Initial velocity is 20 km/s; The asteroid is on a straight path towards Earth; the laser system is at Lagrange point one so it is able to be constantly beaming the asteroid The assumptions we made are that the beam decelerates the asteroid at a constant rate; aperture and beam are circular; beam dispersion is negligible; the laser is 100 percent efficient.

Results

Using the equations and initial conditions above , we present the key values of the laser.

a	-4.17×10^{-4} m/s^2
F	-3.75×10^{10} N
t_{Stop}	4.8×10^7 s — 1.59 yr
$N_{Delivered}$	4.1×10^{31}
E_{tot}	5.4×10^{26} J
P_γ	1.2×10^{14} W
I	1.8×10^{18} W/m^2

Table 1: Table presenting deceleration, force, stopping time, total photons delivered, total energy delivered, laser power and laser intensity

Discussion

We have calculated that the intensity required by a laser to achieve a complete stop of the asteroid in the vicinity of Mars' orbit is 1.8×10^{18} W/m^2. Mars' orbit was considered a safe enough distance from Earth's gravitational influence that the asteroid would not begin travelling towards Earth again. By calculating the binding energy of the asteroid using [3], assuming the asteroid is a perfect sphere:

$$E_B = 3GM^2/5R \tag{6}$$

the binding energy is 6.49×10^{16} J, which is 10 orders of magnitude less than the total energy delivered. This leads us to believe in reality, assuming the asteroid is not a blackbody, the energy of the laser will disintegrate the asteroid in approximately 9 minutes; significantly less time then what is require to stop the asteroid. This was found by dividing the lasers power by the binding energy of the asteroid.

Conclusion

Compiling all this information we have deduced two extreme outcomes of this scenario. The asteroid is completely destroyed after 9 minutes of laser impact, causing the matter to disperse and eliminating the threat to Earth, however debris from this effect could potentially still be threatening to the dinosaurs. The other outcome is the asteroid is treated as a perfect blackbody, allowing the momentum of the photons to take effect, but not cause the asteroid to be destroyed; potentially a better option but we understand this is an ideal situation and is not possible.

References

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