Journal of Physics Special Topics

P3_12 Saving the Dinosaurs

Ashley Clark, Kate Houghton, Jacek Kuzemczak, Henry Simms

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

November 20, 2012

Abstract
An investigation was conducted to find out if a passing alien spacecraft could have saved the dinosaurs by firing a laser at the asteroid as it was about to collide with the Earth. It was found that a beam intensity of 2.02×10^{18} Wm^{-2} would be required.

Introduction

Investigations into the cause of the extinction of the dinosaurs show that they were most likely wiped out by a large asteroid impact with the Earth [1]. It was not the impact itself that caused the extinction but the huge amount of dust that was released into the atmosphere, drastically affecting the climate and food chain. It is investigated how plausible it would have been for a passing alien spaceship to save them.

To prevent the asteroid hitting the Earth its path needs to be changed, in the simplest form this means that it has to be moved perpendicular to the direction of travel. A more complex model would consider the orbital path of the asteroid. The simpler system is first assessed before a method of applying this force is considered.

Theory

To simplify the calculations a number of assumptions are made. First that the passing spaceship does not become aware of the impending collision until very late on, this means that they would not have the chance to exploit the orbit of the asteroid and would instead have to move it directly. Second it is assumed that the asteroid strikes the planet at the equator, this is done so that an approximate distance can be calculated that it would need to be moved to avoid colliding. Finally it is assumed that the asteroid does not speed up as it moves closer to the Earth. In reality it would accelerate, given the high velocity this can be neglected.

The asteroid would need to be deflected by a distance equal to the radius of the Earth plus its own radius to avoid a collision, with this it would still graze the surface of the planet and would be likely to collide due to the effects of atmospheric drag. Here the radius of the Earth plus the radius of the asteroid and the height of the atmosphere is used as as the distance that it would need to be moved, this means that it will never enter the atmosphere which then means that the drag does not need to be considered.

If it is assumed that the asteroid is only detected as it passes geostationary orbit, then the velocity required to push it off course can be found and an acceleration calculated using

$$v_p = u_p + at \quad , \qquad (1)$$

where v_p is the final velocity of the asteroid, u_p is the initial velocity (zero in this case since it is assumed that the asteroid is travelling directly towards the equator), both perpendicular to the original direction of travel, a is the acceleration and t is the time it is accelerating for.

The mass, m, can be estimated based on the size and composition, combined with the acceleration a force, F, can be calculated using

$$F = ma \quad . \qquad (2)$$

A number of methods of delivering this force were discussed, it was decided that the most realistic way, without being able to prepare, would be to use an intense beam of radiation such as a very powerful LASER.

The force exerted by a LASER can be found from its radiation pressure which is given by

$$P_{rad} = \frac{F}{A} = \frac{I}{c} \quad , \qquad (3)$$

where A is the area of the beam, I is the intensity of the radiation and c is the speed of light. This can be rearranged for F to give

$$F = \frac{IA}{c}(1+R) \quad , \tag{4}$$

where the additional factor, R, is the reflectivity of the material. The composition of the asteroid is clearly very important, however they are very varied [2]. It has been assumed that it is a perfect sphere made up of an unknown rock.

Assuming that the spaceship flies at a constant distance from the asteroid and also that it fires its beam perpendicular to the asteroid's original direction of travel, equations 2 and 4 can be equated and rearranged for the intensity

$$I = \frac{mac}{A(1+R)} \quad . \tag{5}$$

The distance the asteroid has to be moved is

$$x = R_{\mathrm{E}} + R_{\mathrm{A}} + H \quad , \tag{6}$$

where R_E is the radius of the Earth, R_A is the radius of the asteroid and H is the height it passes above the surface. To move this distance in the time, t, it must maintain an average velocity, v_{av}, since it is initially at rest in this direction and with the assumption of constant acceleration v can be found to be

$$v_{\mathrm{p}} = 2\mathrm{v}_{\mathrm{av}} = \frac{2\mathrm{x}}{t} \quad . \tag{7}$$

Combining this with equations 1 and 5 gives the final equation used to calculate the intensity,

$$I = \frac{2\mathrm{mxc}}{At^2(1+R)} \quad . \tag{8}$$

As the asteroid is moved from its initial path it will experience an acceleration that opposes this motion due to the gravitational pull of the Earth. This acceleration is assumed to be much smaller than that being applied by the spacecraft for simplicity, it was later calculated to be close to 350g affirming that this is a reasonable assumption.

Discussion

Geostationary orbit is 35786 km above the surface of the Earth and given that the asteroid in question is thought to have been travelling at 19.96 kms^{-1} [3] this gives a time to impact of 1792 seconds (~30 minutes). Since this time is so short the asteroid and Earth can be considered to be moving in a straight line. Assuming that the spaceship is able to fire its LASER as soon as the asteroid is detected this is also the amount of time that is available for it to be moved.

Previous studies have shown that the asteroid had a radius of approximately 7.5 km [1]. The constraints of modern technology cannot be applied to this situation since a fictional alien species is being considered, because of this it is assumed that the area of the beam can be matched perfectly to the size of the asteroid.

The average density of rock is roughly 2500 gcm^{-3} [4], with the radius this gives a total mass of 4.42×10^{15} kg. Using equation 8 it was found that an intensity of 2.02×10^{18} Wm^{-2} would be required to provide the acceleration. The reflectivity was assumed to be 0.15 which is comparable to certain types of rock.

Conclusion

The intensity of the beam found is far greater than anything that could be produced with today's technology, however these constraints do not apply. This means that providing the ship is capable of generating this huge amount of energy it would be a possible solution.

The assumptions made here break down at very high energies since the surface of the asteroid will be heated so rapidly that it blows off. This in will provide a thrust acting in the desired direction of travel and could be a subject for further study.

References

[1] www.sciencedaily.com/releases/2010/03/100304142242.htm accessed on 20/11/2012.

[2] www.esa.int/esaSC/SEM044W4QWD_index_0.html accessed on 20/11/2012.

[3] www.guardian.co.uk/science/2010/mar/05/dinosaurs-asteroid-science-climate-change accessed on 20/11/2012.

[4] geology.about.com/cs/rock_types/a/aarockspecgrav.htm accessed on 20/11/2012.