Journal of Physics Special Topics
An undergraduate physics journal

A4_4 Adventure Time: A Terrible Fate

Thomas, E.M., Ballantine, K.M. and Pain, C.T., Ward, K.E.

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

November 4, 2016

Abstract

The theory of *Adventure Time* suggests that a nuclear bomb's blast provides enough energy to push the Earth into the path of a nearby comet. With the use of astro-dynamics and nuclear physics we find that a Uranium-235 bomb with a mass of 8.73×10^{14} kg $\pm$ 97.63 % would need to be "detonated" on Earth to successfully accelerate it into the path of the *Adventure Time* comet.

Introduction

Within the television series *Adventure Time*, the Earth has a giant crater due to a comet collision. The favoured fan theory for this crater [1], suggests that the Earth was ejected from its own orbit by the force of a nuclear bomb and intercepted the path of a nearby comet.

We ask how much Uranium-235 would be required to eject our own Earth into a similar comet.

Theory

The closest comet to have passed Earth was Lexell's Comet in 1770 which passed the Earth (only once) at 0.0151 AU [2]. We assume that the comet in *Adventure Time* passes the Earth at the same distance as Lexell's Comet. We also assume that Earth's orbit is circular (but use perihelion and aphelion values as the errors in this assumption). Hence the path that the Earth must take to intersect the orbit of the *Adventure Time* comet is shown in Fig. 1, where we suggest that the Earth takes a trajectory similar to a Hohmann transfer orbit [3]. A process used to transfer satellites from one orbit to another via a change in velocity, except a second change in velocity would not occur in this situation.

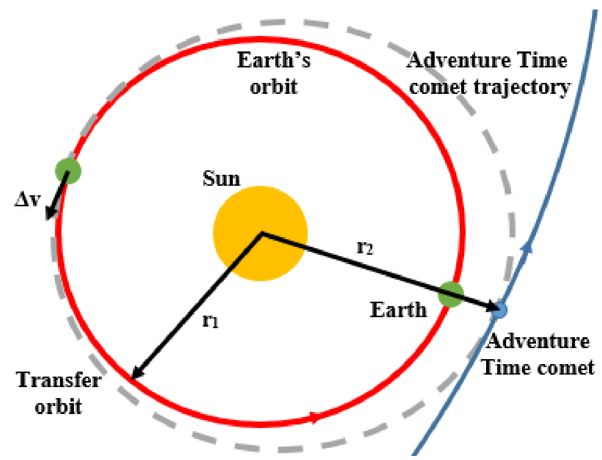

Figure 1: The orbits of Earth and Lexell's Comet, including the transfer orbit of Earth to intercept the comet. Not to scale.

To calculate the energy required to move the Earth out of our current orbit and into an elliptical orbit, the required change in velocity at perigee can be found with Eq. 1 [3].

$$\Delta v = \sqrt{\frac{\mu}{r_1}}\left(\sqrt{\frac{2r_2}{r_1+r_2}}-1\right) \tag{1}$$

where Δv is the change in velocity of the Earth, μ is the product of the mass M_s of the Sun and the gravitational constant G, r_1 is the radius of the Earth's semi major axis. r_2 is the radius of the comet from the Sun, at its point of closest approach to Earth. In the above equation, the mass of Earth is neglected when compared to the mass of the Sun.

To provide an increase in velocity, energy is required to move the Earth into its transfer orbit. For a nuclear detonation, only 50% [4] of the energy is converted into the blast force, and so twice the energy would be needed. The required energy E can then be found in Eq. 2.

$$E = M_e \Delta v^2 \tag{2}$$

where E is the energy required for a change in velocity of Earth, and M_e is Earth's mass. To find the number of Uranium-235 atoms required to produce energy E we used Eq. 3.

$$N_o = \frac{E}{E_{U235}} \tag{3}$$

where N_o is the number of Uranium-235 atoms required to produce energy E. E_{U235} is the energy released by the fission of a single Uranium-235 atom. The number of atoms is converted into a Uranium-235 mass with Eq. 4 [5].

$$M_{U235} = \frac{N_o M_r}{N_A} \tag{4}$$

where M_{U235} is the Uranium-235 mass needed for the transfer orbit. M_r is the molar mass of Uranium-235 and N_A is Avagadro's constant. Combining Eq. 1, 2, 3 and 4 produces Eq. 5 which is used to find the mass of Uranium-235 needed including its errors.

$$M_{U235} = \frac{\mu M_e M_r}{r_1 E_{U235} N_A} \left(\sqrt{\frac{2r_2}{r_1 + r_2}} - 1 \right)^2 \tag{5}$$

Discussion

We used Eq. 5 to calculate the Uranium-235 mass required to accelerate the Earth. The variables used are defined below: μ is 1.33×10^{20} $\mathrm{m^3 s^{-2}}$; M_r is 0.235 $\mathrm{kgmol^{-1}}$ [6]; E_{U235} is 215 MeV [7]. Lastly r_1 is 1.496×10^{11} m $\pm$ 2.510 $\times 10^9$ m (error is equal to half the difference between perihelion and aphelion [8]), and r_2 is r_1 plus 0.0151 AU which equals 1.519×10^{11} m.

Substituting the variables into Eq. 5, the mass of Uranium-235 needed to push the Earth into the orbit of *Adventure Time*'s comet is $8.73 \times 10^{14} \pm 2.07 \times 10^{13}$ kg. The errors in this result arise from the error analysis of r_1.

Conclusion

The mass of Uranium-235 required to push the Earth into the path of the comet is 8.73×10^{14} kg $\pm$ 97.63 %. However the Earth only contains 5.20 $\times 10^{12}$ kg of identified Uranium [9], and so our Earth would avoid the same fate as *Adventure Time*'s Earth.

References

[1] `http://adventuretime.wikia.com/wiki/Earth` accessed on 15/10/16.

[2] `http://neo.jpl.nasa.gov/ca/historic_comets.html` accessed on 15/10/16.

[3] Widnall, S. and Peraire, J., *16.07 Dynamics*, (Massachusetts Institute of Technology, 2008), p. 3.

[4] `https://www.remm.nlm.gov/nuclearexplosion.htm` accessed on 15/10/16.

[5] Tipler, P.A. and Mosca, G., *Physics For Scientists and Engineers*, (W. H. Freeman, New York, Sixth Edition, 2008), p. 570 and 573.

[6] `https://pubchem.ncbi.nlm.nih.gov/compound/61784#section=Top` accessed on 19/10/16.

[7] `http://hyperphysics.phy-astr.gsu.edu/hbase/nucene/u235chn.html` accessed on 19/10/16.

[8] `http://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html` accessed on 19/10/16.

[9] Nuclear Energy Agency, *Uranium 2014: Resources, Production and Demand*, (Issy-les-Moulineaux, France), p. 9.