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A5_12 World's Greatest Pitch

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Abstract

The goal of this paper was to investigate the possibility of an ordinary human throwing a ball around a planet, as depicted in the series Invincible. It is determined that this scene would be impossible to recreate on Earth, however it could be done on a planet with a radius of 67.03 x 10^3 m, roughly 1/100th that of Earth.

Introduction

In the first episode of the animated series Invincible, two superhuman characters are shown throwing a baseball to each other around the Earth [1]. As shown in the scene, the characters are positioned no more than a couple of metres apart meaning that the ball is effectively completing a full orbit of the Earth.

On the Earth

As the feat is depicted in the episode, this scene would be impossible to recreate. This is due to the limitations of the speed with which a human can throw a baseball and Kepler's third law [2], as shown below.

$$T^2 = \frac{4\pi^2}{GM}R^3 \tag{1}$$

In this equation T is the time period of an orbit (s). G is the gravitational constant of 6.674×10^{-11} m^3 kg^{-1} s^{-2}, M is the mass of the body being orbited (kg), and R is the radius of the orbit (m).

T can be replaced using the following substitution, $V = 2\pi R/T$. Where V is the tangential velocity of the baseball as it goes around the orbit (m s^{-1}). Doing this and rearranging for V results in the following equation.

$$V = \sqrt{\frac{GM}{R}} \tag{2}$$

Using this equation with the mass and radius of the Earth results in the baseball needing to be thrown at a velocity of 7910 m s^{-1}. As shown by the world record for the fastest baseball pitch being only 105.1 miles per hour or 46.98 m s^{-1} [3], this is impossible for an ordinary human to achieve. However, there is another factor to all of this that would make this scene impossible to recreate regardless of how fast the ball is thrown. That being air resistance.

The characters in Invincible are shown to be flying during this scene but are still clearly visible from the ground. This means that they are located within Earth's atmosphere. Furthermore when the ball is thrown it is shown passing by planes and mountains meaning that it remains within the atmosphere during its orbit.

The force of air resistance on object experiences is proportional its velocity. Using the equation for drag force in [4], the acceleration experienced by the ball at the instant it is thrown can be given by,

$$a = \frac{A\rho_a C_d V^2}{2m} \quad (3)$$

Where a is the acceleration in m s^{-2}. ρ_a is the air density of 1.225 kg m^{-3}. C_d is the coefficient of drag taken from [4] to be 0.5. A is the frontal surface area of the object in m^2, and m is the mass of the object in kg. [5] provides the mass of a baseball to be 145.5 g and the radius to be 37 mm. This radius provides a frontal surface area of 4.283×10^{-3} m^2. Using these values in (3), it was found that a baseball travelling at 7910 m s^{-1} would experience an acceleration against its direction of motion of 5.640×10^5 m s^{-2}.

The drag force the ball experienced would decrease massively as it slowed down, due to the dependence on the squared velocity. However, this would still rapidly decrease it's velocity to below that which is needed to orbit the Earth. This means that as the ball travelled around the Earth its path would spiral downwards. This therefore makes the scene impossible to recreate on Earth.

On a smaller planet

While it may be impossible to recreate a world spanning throw on the Earth, it may be possible to do so around a significantly smaller object. The reason for this can be shown by making the following substitution. $M = (4/3)\pi R^3 \rho$ where ρ is the average density of the orbited object in kg m^{-3}. Using this in (2) results in the following equation.

$$R = \sqrt{\frac{4}{3} G \rho V^2} \quad (4)$$

This equation shows that, due to the reduced total mass, being on a smaller object means a baseball could complete an orbit with less velocity.

To find the largest possible object a human could throw a baseball around we used the current world record for the fastest baseball pitch of 46.98 m s^{-1}. To obtain a value for ρ we assumed that a solid body a human can stand on would have density comparable to that of Earth at 5520 kg m^{-3}.

Using these values in (4), we found that the largest object a human could throw a baseball around would have a radius of 67.03×10^3 m. Which is a little over 1/100th that of the Earth.

Within the solar system, the closest approximation to an object this size would be the asteroid 20 Massalia which possesses nearly the same radius [6]. This asteroid does not possess an atmosphere meaning that a baseball thrown on it would experience no drag force capable of slowing it down.

Conclusion

To summarise, we determined that throwing a baseball around the Earth as depicted in Invincible would be impossible. However due to the reduced radius, gravity and air resistance it would be possible to perform this feat stood on an object with a radius of 67.03 x 10^3 m and a density similar to that of Earths.

References

[1] Invincible: Episode 1 - It's About Time

[2] P. A. Tipler, G. Mosca, *Physics For Scientists and Engineers* (W. H. Freeman and Company, New York, 2008) p. 365

[3] `https://tinyurl.com/mrxn259k` [Accessed 29/11/2022]

[4] `https://www.engineeringtoolbox.com/drag-coefficient-d_627.html` [Accessed 29/11/2022]

[5] `https://img.mlbstatic.com/mlb-images/image/upload/mlb/hhvryxqioipb87os1puw.pdf` [Accessed 11/12/2022]

[6] J. Bange, Astronomy and Astrophysics, Vol. 340, (1998)