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P4_5 Pandora's Box

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Abstract

In this paper, we aim to investigate the effects of time dilation and how it affects the perception of time on the voyage to Pandora in the well-known franchise Avatar [1]. It was found that the time experienced on the Venture Star Interstellar Spaceship, travelling at a speed of $0.7c$ [2], was 4.71 years compared to the time experienced on Earth of 6.60 years. This meant that the ageing of the crew was 29% slower than if they had stayed on Earth.

Introduction

The Interstellar Spacecraft Venture Star is a spacecraft sent from Earth to Pandora in the franchise Avatar. Pandora is a moon of the fictional planet of Polyphemus and this planet is located around the real star of Alpha Centauri A. The spacecraft makes this journey from Earth to Pandora at a speed of 0.7c and is manned by a crew of four people [2].

Theory

Travelling this close to the speed of light causes a difference in how the crew observe the passage of time on their journey and how people on Earth observe the time of their journey. This is due to the change in acceleration of the crew when they reach Pandora and is in accordance with the theory of time dilation which states: at relativistic speeds time is distorted. To calculate the difference in the time experienced from the ship's perspective and the Earth perspective a few assumptions have been made.

The spaceship is constantly in motion either going from Earth to Pandora or vice-versa and the time taken for the ship to decelerate and accelerate is negligible, this is assumed to be near instantaneously to simplify the problem. The fictional moon of Pandora has been assumed to be at the location of the star that Polyphemus orbits. The practicality of sending a large space vessel like the Interstellar Spacecraft Venture Star to a distant star at near the speed of light is not explored in this paper nor is the effects on the crew besides the effects due to time dilation.

Equations

To find the difference in time between these two frames of reference, the distance between the Earth and the star in question must be calculated. This allows for the calculation of the time taken for the trip from the Earth's frame of reference. The distance between Earth and Alpha Centauri A can be calculated by looking at the brightness of the star and using the following equation [3]:

$$d = 10^{\frac{M_{app}-M_{abs}+5}{5}} \tag{1}$$

Where the apparent magnitude (M_{app}) is 0.137, the absolute magnitude (M_{abs}) is 4.38 and the distance (d) is given in parsecs [4]. The speed of the ship is given as 0.7c where c is the speed of light in a vacuum. This gives a time of 6.60 years. Calculating the time experienced from the perspective of the crew members on the ship can be achieved by using the following equation for time dilation [5]:

$$\Delta t = \Delta t' \gamma \tag{2}$$

Where Δt is the time experienced by an observer on Earth, $\Delta t'$ is the time experienced by the crew members on the ship and γ is the Lorentz factor given by [5]:

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{3}$$

Where the velocity of the spacecraft (v) is 0.7c and c is the speed of light in a vacuum. In this case, the Lorentz factor (γ) is 1.40. The Lorentz factor is a measure of how much time is shifted between each frame of reference.

Results

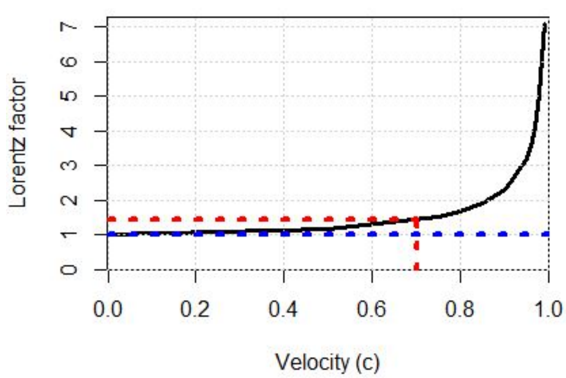

Figure 1: As the velocity increases, the Lorentz factor increases exponentially. The blue line is the time taken according to classical mechanics. The red line shows the Lorentz factor of the ship.

Fig. 1 shows that the closer that the speed of the spacecraft is to the speed of light the more extreme the effects of time dilation are. This means that the gap between the perceived time for the crew members and the observers on Earth increases as the speed of the spacecraft increases.

The distance between the Earth and Pandora was calculated to be 4.62 light-years. The time taken for the ship to reach Pandora from the Earth's perspective is 6.60 years. The time experienced from the ship's frame of reference, calculated using the time dilation equation, was 4.71 years. This results in the crew of the ship being 1.89 years younger than if they had stayed on Earth. The ship is said to have been in operation for 77 Earth years which means that under the assumptions outlined in the introduction it would have made 11.7 trips in its lifetime [2]. This means that if the same crew served on the ship throughout all its voyages, then they would be 22.0 years younger than if they had stayed on Earth.

Conclusion

The crew will experience the effects of time dilation since they are accelerating and decelerating to and from relativistic speed. This time dilation effect means that the crew would be 1.89 years younger for a single trip, 3.78 years younger for a round trip (to Pandora and back) and if they served on the ship over its entire lifetime they would be 22.0 years younger than if they had stayed on Earth. If decelerating and accelerating were considered, the resulting time difference between the two frames of reference would be less as it would take longer to reach near light speeds would be less.

References

[1] `https://bit.ly/2ZSnVKF` [Accessed 1 November 2021]

[2] `https://bit.ly/3byuFzz` [Accessed 1 November 2021]

[3] `https://bit.ly/3EF6vAb` [Accessed 1 November 2021]

[4] `https://bit.ly/3GGBKMZ` [Accessed 1 November 2021]

[5] P. A. Tipler, G. Mosca, Physics for Scientists and Engineers. 6th edition, p. 371, (2007).