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P5_2 Getting to Treasure Planet the Old Fashioned Way

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Abstract

In the Disney film 'Treasure Planet' all ships use a combination of rockets and solar sails to travel the universe for their missions. The aim of this paper is to examine whether the solar sails on the RLS Legacy are there for a reason or purely for aesthetics. We concluded that using the 1,022 m^2 sail area it would take the RLS Legacy ~ 0.5 years to reach 1 $m\,s^{-1}$, to reach Voyager 2's average velocity of 15 $km\,s^{-1}$ it would take $\sim 7,700$ years.

Introduction

In the popular 2002 Disney film 'Treasure Planet' the main character joins the crew of the RLS Legacy rocket-ship to find Treasure planet. In the film all ships are based off of 17th century navy ships equipped with rockets and solar sails, are the solar sails there to help the ship or just to look aesthetically pleasing? The mission for RLS Legacy is to try find treasure planet and loot it, but assuming they don't use rockets to travel the universe, how useful are their solar sails?

Using information about the ships [1] from the Disney wiki page, we find the RLS Legacy is a Galleon type ship, after some research of Galleon type ships in the 17th Century, HMS Dartmouth [2] appeared to be the most similar real life ship that best resembles RLS Legacy.

Theory

As mentioned earlier, the closest real life ship was HMS Dartmouth, it was chosen because of it being in the 17th century, being a Galleon type-ship and having only 20 guns on-board (in 1655) as well as having the least amount of crew on-board, 130 crew members [3], during an era of naval technology where bigger was better.

Thus by using HMS Dartmouth as a starting point for the ships technical details, it had a mass of 240,000 kg (including crew and guns) but RLS Legacy has only 7 crew members and 5/6 guns on board [1], thus the estimated mass of RLS Legacy is 150,000 kg. However any details about sail area isn't mentioned, hence Galleon Andalucia [4] was used for sail size assuming Galleons of that era had a similar sail size of 1,022m^2. The important assumptions for this paper are that the solar sails being used for this calculation are 100 % reflective, absorbing no energy and using it all for force to push the ship and the intensity of the Sun does not change to give the sails a chance to pick up velocity.

Equations and Results

The main principle of the physics is a photons' momentum and how the momentum is transferred to an object it reflects off. The equation below shows the momentum of a photon when reflecting off of a solar sail with 100 % [5];

$$dp = 2dE/c \tag{1}$$

Where dp is defined as the change of momentum of the photon, dE the change in energy of the photon, c the speed of light and the 2 is because the momentum from the photon is transferred twice onto the sail due to the reflectively. Equation (1) combined with $dE = IAdt$ (derived from solar energy flux equation [7]) gives us;

$$dp = 2IAdt/c \tag{2}$$

Then subbing $dp = mdv$ into equation (2) and integrating allows us to get to the equation (4);

$$\int_{v_0}^{v_1} dv \ = 2IA/mc \int_{t_0}^{t_1} dt \tag{3}$$

$$v = 2(IAt)/mc \tag{4}$$

Where v is the velocity, I intensity of the Sun, t is time, A is the area of sails and m the mass of the ship $150,000$kg, with c being the speed of light. Unfortunately in the film there were no details about any approximate star, thus I will be the Sun's intensity of $1360\mathrm{W\,m^{-2}}$, where I will be kept constant through-out the paper.

Hence using t as 60 seconds, we get the result of the ship having a velocity of 3.706×10^{-6} $\mathrm{m\,s^{-1}}$ after one minute, using equation (3).

Re-arranging equation (3) allows us to figure out how long it will take the ship to get to a velocity v. Using v as $1\ \mathrm{m\,s^{-1}}$ to find t , we find that it will take the RLS Legacy ~ 0.5 years to get to this velocity. To get to $100\mathrm{m\,s^{-1}}$, using the same formula, it would take ~ 50 years.

Using Voyager 2 as a minimum reasonable velocity to travel across space ($15\ \mathrm{km\,s^{-1}}$ [6]), it would take RLS Legacy $\sim 7,700$ years to get to Voyager 2's velocity. For RLS Legacy to reach 15 $\mathrm{km\,s^{-1}}$ in a reasonable time of 5 years it, using the equations above, the solar sails for the RLS Legacy would have to be $1,573,631\mathrm{m^2}$ in area to be able to achieve this.

Conclusion

After using estimations for the details of RLS Legacy (lower mass than a Galleon, constant Sun intensity and 100% reflectivity in solar sails), with our laws of physics the solar sails are useless and purely for aesthetics. It appears they wouldn't be able to get to 'Treasure Planet' if they didn't have rockets, due to the limited size of the sails and the limited energy the Sun provides. If they only used the solar sails, it would take thousands of years just to gain velocity to begin travelling, this would take too much time.

References

[1] https://disney.fandom.com/wiki/R.L.S._Legacy [Accessed 7th October 2020]

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[6] https://voyager.jpl.nasa.gov/news/details.php?article_id=20#:~:text=Voyager%201%20is%20traveling%20faster,of%20phenomenon%20as%20Voyager%201. [Accessed 10th October]

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