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A4_3 All Aboard the RLS Legacy - Sailing the Stars!

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Abstract

In this paper we reviewed the feasibility of using a galleon-style ship in space, replacing the canvas sails with solar sails as seen in Walt Disney Studios' Treasure Planet. We considered the solar radiation force on the solar sails, and incorporated gravitational influences and spectral classifications of the host star. We found that the gravitational force always dominates, and the ship would spiral into the star. Furthermore, we discuss the ship riding a supernova shock wave, subjected to a net force of 6.34×10^7N, yet the crew and ship still come to a fiery end.

Introduction

Treasure Planet is an animated motion picture released by Walt Disney Pictures in 2002. It follows a young Jim Hawkins on a quest to find the legendary Treasure Planet with the help of his crew-mates aboard the RLS Legacy, a solar powered galleon. We investigate the feasibility of such a contraption; what kind of star could allow this ship to traverse the solar system? [1]

"Loose All Solar Sails"

In the motion picture, the RLS Legacy launches from the Montressor Spaceport, a crescent-shaped artificial moon. We made the assumption that this is equivalent to our own moon, so is located 1AU from its parent star. For the purposes of this investigation, we applied a perpendicular sail-wind configuration so that the radiative force of the sun upon the galleon is maximised. We treat all masses as point masses.

We also considered perfectly flat, non-billowing sails so we can ignore any reduction in solar pressure. Typically, the sails are made with a 2μm aluminised Kapton film; a polymer sheet for flexibility and support, and a thin aluminium coating for the reflectivity. [2]

$$P = \frac{(1+R)I}{c} = \frac{(1+R)L}{4\pi r^2 c} \quad (1)$$

Using Eq. 1 [3], we determined the solar radiation pressure P at the radial distance r of 1AU. The luminosity L varies according to the spectral class of the star [4] and we use a luminosity of 1.92×10^{36}W for the supernova [5]. I is the stellar intensity, c is the speed of light and the reflectivity R is 0.9 (aluminium) [6].

We then determined the force upon each of the sails by substituting Eq. 1 in to Eq. 2 and summed them together to get the resultant force upon the ship.

$$F = PA \quad (2)$$

where F is the force and A is the sail area. The RLS Legacy has fourteen sails; nine semi-circular sails on the main masts and five triangular sails. Using geometry and size comparison of the human Jim Hawkins (assumed 1.75m) with the sails we estimate the area of each of the semi-circular sails as 120m^2 and the area of the triangular sails as 76m^2, giving a combined area A of 1465m^2.

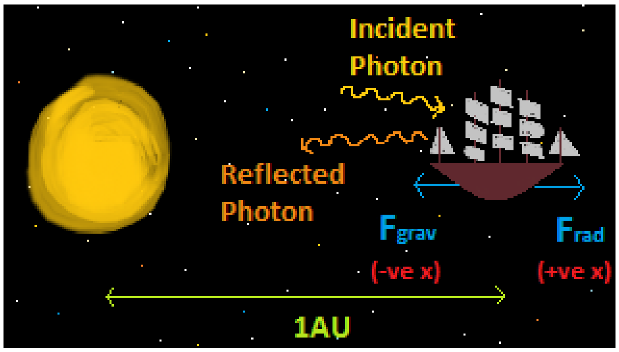

Figure 1: Forces upon the RLS Legacy (not to scale).

Fig. 1 shows a diagram of the forces we considered. Neglecting perturbations from other gravitating bodies, we calculated the gravitational force upon the solar galleon from the parent star using Eq. 3.

$$F = \frac{GMm}{r^2} \tag{3}$$

where G is the gravitational constant, m is the mass of a galleon (1×10^6kg [7]) and M is the stellar mass according to spectral class [4]. We find the net F by subtracting Eq. 3 from Eq. 2.

Results and Conclusion

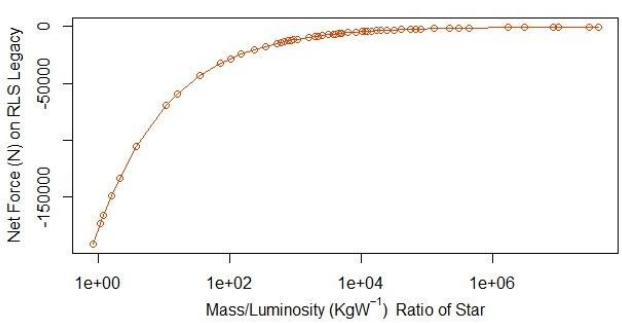

Figure 2: Mass to light ratio versus the resultant force. On the left are Type O stars which are massive and luminous. The stars decrease in mass and luminosity until on the far right are Type L stars.

Fig. 2 shows the relationship between the net force upon the galleon and the mass to light ratio of the star. The stars range from Type O to Type L, from giant radiant stars to barely visible stars. We can see that the lower the M/L ratio, the more the galleon is pulled towards the star. So despite the more massive stars having a larger luminosity it is not enough to overcome the gravitational forces, since the galleon has a large mass. The galleon appears to fare better in systems with low mass, barely visible stars. So what happens to our galleon when near a type 1a supernova? In the film, the RLS Legacy is able to outrun a supernova. We assume the lower mass limit is equal to 1.44 solar masses and the luminosity is 1.92×10^{36}W [5]. This gives an outwards net force of 6.34×10^7N.

$$L = 4\pi r^2 \sigma T^4 \tag{4}$$

However, using Eq. 4, we show that this luminosity corresponds to a radiation temperature T of 1×10^5K at 1AU where σ is the Stefan-Boltzmann constant. We conclude that the galleon would not escape and would be vaporised.

References

[1] Treasure Planet 2002 Walt Disney Studios.

[2] G. A. Landis, *Advanced Solar- and Laser-pushed Lightsail Concepts* Page 5, (1999).

[3] `http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20030093608.pdf`. [17/10/16]

[4] `http://www.uni.edu/morgans/astro/course/Notes/section2/spectralmasses.html` [17/10/16].

[5] `https://en.wikipedia.org/wiki/Type_Ia_supernova` [17/10/16].

[6] "Researchers produce strong, transparent carbon nanotube sheets" Ch 4 (2005).

[7] `http://www.cindyvallar.com/galleons.html` [17/10/16].