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P4 5 Roses are blue, violets are red: Stellar edition.

M'Barki, W., Tambyrajah, M., Spanswick, W. and Ali, H.

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

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Abstract

In this paper, we test the speed required to invert the visible wavelengths of a red dwarf and blue giant, causing the red dwarf to appear blue and the blue giant to appear red. This is achieved by travelling towards the red dwarf at a relativistic speed, yielding a blue shifted light, whilst travelling away from the blue giants yields a red shifted light. We calculate that this requires the observer to travel at a speed of $(1.04 \pm 0.37) \times 10^8$ m s^{-1}. Uncertainties arise from the wavelengths picked, and assumptions for the setup of this thought experiment are discussed.

Introduction

When travelling at relativistic speeds, the wavelengths of electromagnetic waves experience the Doppler effect, which changes the frequency and thus the colour of the light observed. In this paper, we test this by setting up a thought experiment where the observer travels towards a red dwarf while simultaneously travelling away from a blue giant. This motion would result in the light observed from the red dwarf blue-shifting so it would appear the same colour as the blue giant, whilst the blue giant's light would be red-shifting to appear the same wavelength as a red dwarf.

Results

We assume the red dwarf and blue giant are many light years apart and have negligible relative motion, so we work in a common stellar rest frame. The spaceship moves relative to that frame, and the Doppler factors for light from each star are computed from the spaceship's velocity relative to that star. In the stellar frame, the stars are stationary and only the spaceship is moving.

The following equations (1 to 4) are retrieved from [1]. For the appropriate colour changes to occur, the observer would be approaching the red dwarf to experience a blueshift,

$$\lambda_{\text{obs, RD}} = \lambda_R \sqrt{\frac{1-\beta}{1+\beta}} \quad \text{(approaching)}, \tag{1}$$

whilst simultaneously travelling away from the blue giant so it experiences a redshift,

$$\lambda_{\text{obs, BG}} = \lambda_B \sqrt{\frac{1+\beta}{1-\beta}} \quad \text{(receding)}. \tag{2}$$

λ_R and λ_B are the rest wavelengths for the red dwarf and blue giant respectively, and β is the velocity ratio to the speed of light,

$$\beta = \frac{v}{c}\,. \tag{3}$$

If we let,

$$k = \sqrt{\frac{1+\beta}{1-\beta}}\,, \tag{4}$$

equations 1 and 2 will become

$$\lambda_{\text{obs,RD}} = \frac{\lambda_R}{k} \tag{5}$$

and

$$\lambda_{\text{obs,BG}} = \lambda_B k\,. \tag{6}$$

For the red dwarf to appear blue, we require

$$\lambda_{\text{obs,RD}} = \lambda_B\,. \tag{7}$$

Substituting equation 5 into 7, we find that

$$k = \frac{\lambda_R}{\lambda_B}\,. \tag{8}$$

The same value for k is found when considering the blue giant to appear as red i.e.,

$$\lambda_{\text{obs, BG}} = \lambda_R\,. \tag{9}$$

In other words, one speed would result in the correct Doppler shift for both of these stars. This speed is calculated by replacing k in equation 8 with equation 4 and rearranging for β giving,

$$\beta = \frac{\lambda_R^2 - \lambda_B^2}{\lambda_R^2 + \lambda_B^2}\,. \tag{10}$$

Therefore, using equation 3, the speed can be calculated,

$$v = \frac{\lambda_R^2 - \lambda_B^2}{\lambda_R^2 + \lambda_B^2} \cdot c\,. \tag{11}$$

The error in this speed arises from the range of red and blue wavelengths that could be emitted by the stars, λ_R = 620-750 nm and λ_B = 450-495 nm [2]. Our thought experiment is only concerned with how the stars would appear to the human eye, therefore we only consider the Doppler shifting in the visible wavelength range. The minimum possible speed can be calculated using the shortest red wavelength and the longest blue wavelength and vice versa for the maximum possible speed. This gives a central estimate for the speed at which red dwarf is blue and blue giant is red,

$$v = (1.04 \pm 0.37) \times 10^8 \text{ m s}^{-1}\,.$$

Discussion and Conclusions

Our thought experiment finds that an observer spaceship must travel at $(1.04\pm0.37)\times10^8$ m s^{-1} ($\sim$0.35c) for a red dwarf to appear blue and for a blue giant to appear red. This is far beyond the speeds capable by modern spacecrafts (fastest speed of 1.92×10^5 m s^{-1} by Parker Solar Probe [3][4]). Therefore, this phenomenon would not be possible using contemporary technology.

Our model requires both stars to be perfectly aligned with the spaceship's direction of motion, with the red dwarf in front and the blue giant behind, as well as both stars being within our Galaxy to be observed. It also assumes the distance between the stars is sufficient to allow the spacecraft to accelerate to these speeds and maintain the viewing geometry.

References

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