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A3_11 Rudolph the Red Shift Reindeer

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Abstract

This paper explores the physics behind Rudolph's red nose, by investigating how fast he would have to travel for a brown nose to appear red to an observer due to red shift. We found that Rudolph would have to travel at a speed of 0.153 c for this to occur. We also found that at this speed, Santa's original green coat would appear orange, and that a speed of 0.271 c is required for the green coat to appear red. We also found that moving at a speed of 0.153 c, Santa would have an extra 22 minutes to deliver his presents. We conclude that we cannot answer some of the mysteries of Santa and his reindeer by applying the principles of red shift.

Introduction

When Santa is out delivering his presents on Christmas Eve, he does so with the help of nine reindeer. They magically pull his sleigh at great speeds through the air, allowing Santa to make millions of deliveries in one night. The most noticeable of these reindeer is Rudolph, famed for his red nose. This paper explores the possibility of his nose being the typical brown colour, with it just appearing red to observers due to red shift, a relativistic phenomenon that alters the wavelength and frequency of fast moving sources of light.

Theory

When objects travel towards an observer at considerable speeds, the observer notices a decrease in the wavelength of the source. When objects are moving away from an observer at a considerable speed, the observer will notice an increase in the wavelength they see from the source [1]. The colour of light depends on the wavelength, so by the modification of the wavelength due to the speed, we will see a different colour of the spectrum.

To find the velocity required for a source's wavelength to go from brown to red, we shall apply the principles of a relativistic longitudinal Doppler effect, given by Equation (1). We have the wavelength observed by the receiver (λ_r), wavelength from the moving source (λ_s), the accociated frequencies (f_s and f_r) and $\beta = \frac{v}{c}$, where v is the velocity of the source relative to the observer and c is the speed of light in a vacuum.

$$\frac{\lambda_r}{\lambda_s} = \frac{f_s}{f_r} = \sqrt{\frac{1+\beta}{1-\beta}} \tag{1}$$

For our purposes we need this equation in terms of v, and so we have rearranged it into the form presented in Equation (2).

$$v = \frac{(\frac{\lambda_r}{\lambda_s})^2 - 1}{(\frac{\lambda_r}{\lambda_s})^2 + 1}\ c \tag{2}$$

We take the wavelength of red light (λ_r) to be 700 nm [2], and the wavelength of brown light (λ_s) to be 600 nm [3]. Once we have found the speed at which brown light appears

red, we can then evaluate all the colours that the different components of Santa and his sleigh will appear when moving at this speed.

We can also work out the time dilation that Santa would experience whilst moving at this speed, from Equation (3).

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

Where T is from the point of view of the observer, and T_o is from Santa's rest frame.

Results & Discussion

From our values of wavelength, we find that Rudolph would have to travel at a speed of 0.153 c for his brown nose to appear red. This is a relativistic speed, but not unrealistic, considering he is a magical being and it is only 15 % the speed of light.

Rudolph's nose would not be the only thing to change colour. Santa's coat colour has been often debated, as to whether it is green or red [4]. A speed of 0.153 c is not large enough to allow a green coat to appear red when moving at speed. A green coat (530 nm [2]) would actually emit a wavelength of 618 nm at this speed, which is an orange/yellow colour [2]. For a green coat to appear red, using Equation (1), we find he would have to travel at a speed of 0.271 c. At this speed however, the reindeer and anything else that is brown when stationary would now emit a wavelength of 792 nm, which is not within the visible spectrum.

If they travelled at a speed of 0.153 c, everything that was brown when stationary would also appear red and so all of the reindeer, including their coats, would appear red. All of the source wavelengths would be increased by a factor of 1.167. We do not believe that Rudolph's nose is due to the effects of red shift, as it is only his nose that is known to be red, not his entire body.

From Equation (3) we find that Santa's time is dilated by a factor of 1.012. In essence, every second in the observers frame is equal to 0.988 seconds in Santa's frame. It is suggested that Santa has 31 hours to deliver presents, thanks to various time zones [5]. Therefore from Santa's point of view he will have 31 hours and 22 minutes, which is still nowhere near enough time to deliver all the presents.

Conclusion

We found that in order for Rudolph's nose to appear red, he would have to travel at a speed of 0.153 c towards the observer. At this speed Santa would have an extra 22 minutes due to time dilation, which would not buy him enough time to deliver all of his presents in time. We conclude that Rudolph's red nose is not due to the observers seeing the effects of red shift, as all the components of Santa and his sleigh would also change colour, which is not an effect that is mentioned in any myths or stories.

References

[1] http://hyperphysics.phy-astr.gsu.edu/hbase/Relativ/reldop2.html

[2] https://en.wikipedia.org/wiki/Color

[3] https://www.britannica.com/science/brown-color

[4] https://www.ibtimes.com/was-santa-claus-green-find-out-whether-christmas-figure-was-always-red-suit-2460936

[5] http://www.daclarke.org/Humour/santa.html

All websites were last accessed on 27/11/2019