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P2_6 Celestial Christmas

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Abstract

Sadly, Christmas is an exclusively earthbound event and so this paper looks at the possibility of spreading the joys of Christmas across the galaxy by covering the surface of Earth with suitably festive LED lights. We found that covering the entire planet with standard LEDs would give the planet an absolute bolometric magnitude of 32.49 and could only be detectable up to 20 pc away by aliens with equivalent technology to us.

Introduction

A beloved symbol of Christmas is the humble bauble. Traditionally these objects are spherical in nature and so is the planet Earth. Naturally the next step for interstellar festivities is to turn the Earth into a giant celestial bauble. With enough LEDs, the Earth could output a sufficient luminosity such that aliens with equivalent telescope technology to us could detect the light emitted. Since LEDs have significantly different spectra to regular stars [1], any aliens should immediately recognise the difference and may come searching for the festive source.

Theory and Method

To turn the Earth into a visible beacon, a sufficient number of LEDs will need to be used. A typical LED operates at 3 V and draws 20 mA [2] resulting in a power of 0.06 W. We approximate a single LED as covering a surface area of 1mm^2. The Sun has a luminosity of $L_\odot = 3.83 \times 10^{26}$ W resulting in an absolute bolometric magnitude of 4.75. Bolometric magnitude takes into account radiation at all wavelengths and can be calculated for a different 'star' by using equation (1) [3] and this will be useful for calculating the magnitude of the Earth when covered in LEDs.

$$M_{\text{bol}\star} - M_{\text{bol}\odot} = -2.5 \log_{10}\left(\frac{L_\star}{L_\odot}\right) \quad (1)$$

In equation (1), $M_{bol\star}$ represents the absolute bolometric magnitude of the 'star' being calculated (in this case the Earth bauble), $M_{bol\odot}$ represents the absolute bolometric magnitude of the Sun and the respective L's represent the luminosity for each star.

$$m_{\text{app}} - M_{\text{abs}} = -5 + 5 \log_{10}(d) \quad (2)$$

To work out how far away our celestial bauble would be visible from, we use equation (2) [3]. This equation compares apparent magnitude (m_{app}) and absolute magnitude (M_{abs}) at a distance of d parsecs (pc). The faintest magnitude detectable by the Hubble space telescope is between 31 and 34 [4], so this is taken to be the faintest an alien civilisation could detect if they are equally as advanced as we are.

The luminosity of the LED covered Earth is calculated and then used in conjunction with

data on the Sun in equation (1). We then use the calculated magnitude with equation (2) to work out the maximum distance an alien civilisation could be at and still have a chance at detecting the Earth with a telescope.

Results and Discussion

To reach a luminosity equivalent to that of the Sun, we calculated a massive 6.38×10^{27} LEDs would need to be used and these would unfortunately cover a surface area far larger than the Earth (sphere with radius $\sim 32.3 R_{\odot}$). Limited by this factor, the number of LEDs that could fit on the surface is a mere 5.1×10^{16} (based on a unit size of 1mm^2 and a surface area of Earth of $5.1 \times 10^8 \text{km}^2$ [5]). These would collectively produce a luminosity of $L_{\star} = 3.06 \times 10^{15}$ W which is only $7.99 \times 10^{-12} L_{\odot}$, a fraction of that of the Sun.

Substituting this luminosity into equation (1), we calculated an absolute bolometric magnitude of 32.49. This is already close to the limiting magnitude of 34 stated earlier and by using equation (2) it was found that the limiting magnitude of 34 would be reached after a distance of only 20 pc. Given that the diameter of the Milky Way galaxy is in the range of 40, 000 pc across [6], the number of planets within sufficient range would not be very large when compared with the number found in the galaxy overall. To spread the joys of Christmas across the galaxy, a range of a few thousand parsecs or more would be more desirable. This could be achieved by using much more powerful LEDs or by building a structure in space with a greater surface area.

In order for the Earth bauble to be comfortably visible to the whole galaxy, we calculated that a luminosity of $3.2 \times 10^{-5} L_{\odot}$ would be required so that the limiting magnitude of 34 is only reached after 40,000 pc. Assuming the luminosity of the Earth bauble were to stay the same, an alien civilisation at the other end of the galaxy would need equipment capable of detecting a magnitude of 50.5 in order to still notice the signal.

Conclusion

In conclusion, we calculated that Earth could be covered in a maximum of 5.1×10^{16} LEDs reaching an absolute bolometric magnitude of 32.49. This results in a 20 pc visible range which is not high enough to give a reasonable chance for any alien recognition. The aliens would also require equipment capable of detecting magnitudes up to 50.5 for observers at the furthest edge of the galaxy. The consequences of covering the entire planet with LEDs would also prove quite inconvenient and would require much more energy to power than we currently produce collectively. Unfortunately, it seems unlikely we will be able to signal any aliens to come and visit for Christmas, and even if they did make the long journey, it is unlikely they would understand the concept of presents anyway.

References

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