Journal of Physics Special Topics
An undergraduate physics journal

A5 9 Stellar replacements

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December 14, 2023

Abstract

In this paper we investigated what the impact that replacing the Sun with other main sequence stars, with the same apparent bolometric magnitude, would have on the incoming radiation at the surface of the Earth. We considered the effects of atmospheric absorption on the black body radiation of the stars. We found that the relationship between star type and incoming radiation peaks at Sun-like stars and then drops off for smaller and larger classifications.

Introduction

Thousands of exoplanets have been discovered to date, in systems similar and much different than ours. One of the most defining characteristics of our planetary system is the Sun. Our paper investigates the hypothetical of having the Sun replaced several other main sequence stars, such that their apparent magnitude remains the same, and how that would affect the light that would reach the surface of the Earth. For our main sequence stars we used 19 data points ranging from an O3 to a M8 star [1].

Theory

Keeping the apparent bolometric magnitude the same for different classes of stars will alter the distance of the Earth from them but it ensures that the incoming flux is the same. As such the differences in the incoming radiation are not due to luminosity discrepancies but rather due to the different spectral distributions of the incoming radiation and how that interacts with the Earth's atmosphere.

Stars can be approximated as black body emitters and as such their spectral distributions are given by Planck's Law (Eq. 1) [2].

$$B(\lambda, T) = \frac{2\pi hc^2}{\lambda^5} \cdot \frac{1}{e^{\frac{hc}{\lambda kT}} - 1} \tag{1}$$

Where B is spectral radiance, h is Planck's constant, c is the speed of light in a vacuum, λ is the wavelength, k is Boltzmann's constant and T is the temperature in Kelvin. Given the surface temperature of a main sequence star and a wavelength range, you can model the spectral radiance of a star.

The incoming radiation from the stars would not make it to the Earth's surface unimpeded. Solar radiation looks very different at the top of the atmosphere than it does at the surface and that is due to atmospheric absorption. our atmosphere mostly consists of N_2, O_2, H_2O and CO_2 and these molecules along with others present scatter and absorb incident light according to quantum mechanical selection rules. Figure 1 shows how atmospheric absorption affects different wavelengths of the incoming radiation. In the case of the Sun, around 77% of the incoming radiation reaches the surface [3] (including ra-

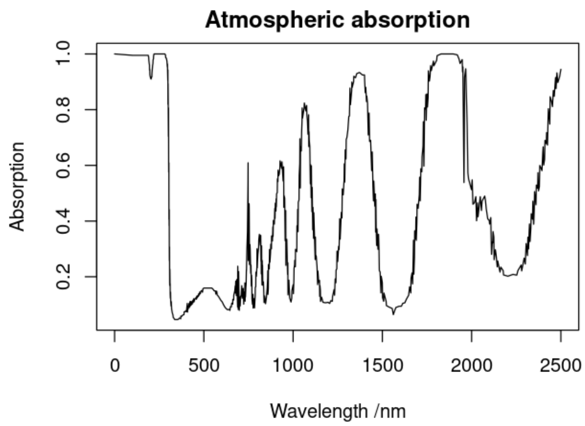

Figure 1: Atmospheric absorption of incoming radiation [4]

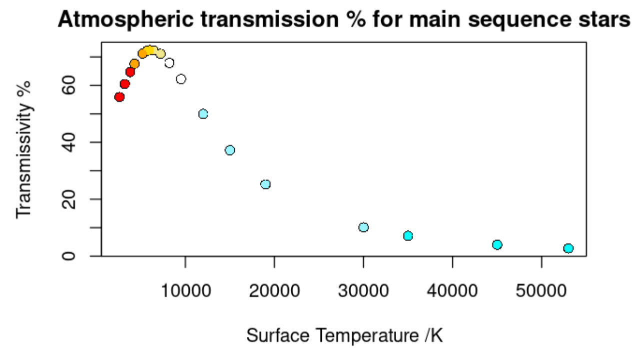

Figure 2: Solar surface temperature against transmissivity %

diation that gets reflected away at the surface). To find this percentage for the other stars we multiplied each star's black body curve by the atmospheric absorption (shown in Fig. 1) and found the ratio between the adjusted and original curve. The results have been plotted in Figure 2 with colours symbolising stellar classes.

Results and Discussion

As shown in Figure 2 the smaller, colder stars are in the 56% to 68% range of incoming radiation reaching the surface. Sun-like stars are at the maximum around 71% to 72% and the bigger, hotter stars go down to as low as 2.4%. The discrepancy between previous findings and our data can be explained by the resolution of the absorption data. Many bands are present in the range and the resolution of our data is likely not high enough to include them all. The overall trend can be explained by considering how the peak wavelength is inversely proportional to the temperature as Wien's displacement law states [2]. In Fig. 1 the UV range is highly absorbed by the atmosphere, so as the temperature increases and the peak moves further left and gets sharper, which means most of the incoming radiation is absorbed. So while you could have other main sequence stars in the centre of the Solar system, the Earth's atmosphere will only allow a smaller fraction of the incident light to reach the planet's surface. The less light received in the visible spectrum, and overall on the surface, the harder conditions would get for life on Earth as it has evolved to function and thrive in those conditions.

Conclusion

In conclusion, atmospheric transmission peaks with Sun-like stars in the main sequence, which highlights the pivotal role of the atmosphere and how it interacts with solar radiation to shape the characteristics of the Earth's surface.

References

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