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A4_2 Walking on Sunshine

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Abstract

This paper investigates the solar power output necessary for someone to be supported against Earth's gravity by radiation pressure alone. By making some estimates regarding human proportions, and calculations based on known information, it shows that it is not feasibly possible to walk on sunshine as the radiation flux from the sun is around 3 billion times too small. Furthermore it would require a very large increase in solar mass to come anywhere near possible - roughly 530 times the current mass.

Introduction

In 1983 the band Katrina and the Waves released the song "Walking on Sunshine" which was successful in music charts and has gone on to become well recognised and used in multiple films, advertisements, and television shows. While the song is not literally concerned with people walking on sunshine, it raises an interesting idea: whether or not it is possible for the radiation emitted by the sun to create enough pressure to support a human. This paper looks at the theory behind this question and attempts to answer it.

Theory

All radiation has an associated energy proportional to its wavelength and given by the Planck equation. As such it also has momentum, which can be transferred via collisions, creating a force between objects. The magnitude of this radiation pressure is

$$P_{Rad} = \frac{<\boldsymbol{S}>}{c}, \tag{1}$$

where <***S***> is the time-averaged Poynting vector and *c* is the speed of light. [1] Using the relation between force and area combined with Equation (1) gives

$$<\boldsymbol{S}> = \frac{Fc}{A}, \tag{2}$$

where *A* is the area that the force *F* is applied over. In this case *F* is the force due to gravity, *mg*, with *m* being the mass of the person and *g* the acceleration due to gravity. Equation (2) therefore allows the calculation of energy per unit time and area to offset a given weight.

The sun radiates evenly outwards in a radial direction, and so the luminosity of the sun is given by the Stefan-Boltzmann equation for a blackbody

$$L = \sigma A T^4, \tag{3}$$

where σ is the Stefan-Boltzmann constant, *A* is the surface area of the source - in this case $4\pi R^2$ with *R* the radius of the sun – and *T* is the effective temperature of the blackbody [2]. As the luminosity decreases radially, the flux at a distance *r* from the source is given by

$$\Phi = \frac{L}{4\pi r^2}. \tag{4}$$

There is a way of estimating the mass of a body based on its luminosity, using the formula

$$\frac{L}{L_{sun}} = (\frac{M}{M_{sun}})^{\alpha}, \tag{5}$$

where α takes a value between 1 and 6 (3.5 when used below, as is common for main sequence stars) and M refers to the mass of the body.[3]

Discussion

First some parameters need to be defined for the human attempting to walk on sunshine. A good estimate for the mass of the person is around 70kg, and it is assumed that their feet are around a size 9 or approximately 9cm by 28cm, giving a surface area of 0.025m^2 per foot. This leads to a pressure due to gravity of 13.7KPa. The flux needed to balance such a pressure (assuming the incident radiation is all absorbed – the reflected case is mentioned later) is $4.12\times10^{12}\text{Wm}^{-2}$, from Equation (2).

To give an idea of the scale necessary for such a high flux, the value calculated is around 3 billion times larger than the flux of the sun incident on Earth, calculated using Equation (3). To meet such an output the sun would need to heat up to around 234 times its current temperature (to 1.4MK), which may not seem so much but using Equation (5) you can show it requires an additional mass of 1.1×10^{33}kg, making it around 531 times its current mass.

Conclusion

Through the calculations above it has been shown that it is certainly not possible to walk on sunshine, even if the total solar flux incident on Earth could somehow be entirely directed onto the soles of someone's feet and absorbed without harm. The case above deals with what would happen if the radiation was entirely absorbed, and shows that the temperature of the source would need to increase to 234 times its current value. If the incident radiation was instead totally reflected by some mirroring device attached to the shoes it would impart two times the radiation pressure discussed above, however even with that increased pressure the force would be insufficient – the temperature is still 197 times too low to produce enough force upwards.

References

[1] Dale A. Ostlie and Bradley W. Carroll, An Introduction to Modern Astrophysics (2nd edition), Pearson, San Francisco, CA 2007

[2] "Luminosity of Stars". Australia Telescope National Facility. 12 July 2004. http://outreach.atnf.csiro.au/education/senior/astrophysics/photometry_luminosity.html Retrieved 23 October 2012

[3] Salaris, Maurizio; Santi Cassisi (2005). Evolution of stars and stellar populations. John Wiley & Sons. ISBN 0-470-09220-3.