Journal of Special Topics

A4_2 A Bright Night?

Barker, J.F.; Conlon, T.M.; Coxon, J.C..

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

February 1, 2011

Abstract

The gas giant planet Jupiter is often referred to as a 'failed star'. This paper investigates whether a change in brightness levels would be experienced by the Earth if Jupiter was in fact undergoing fusion and radiating. It is found that the luminosity generated by nuclear fusion within Jupiter would be a very small percentage of that produced by the Sun, even in the case where the mass of Jupiter is increased.

Introduction

The planet Jupiter has often been called a 'failed star', it is thought that Jupiter lies close to the mass required for the process of nuclear fusion to occur. Current theories suggest that Jupiter would need to be around 80 times more massive than it currently is for the core to undergo fusion. This theory has been supported by the discovery of the star OGLE-TR-122b, this is the smallest detected star. It has a mass that is 96 times that of Jupiter and is 20% larger than Jupiter [1]. It is thought that Jupiter never made it to this size due to the limitations placed on growth by the distribution of matter throughout the primordial accretion disc. This paper uses the Mass-Luminosity Relationship [2] to make estimates for the change in brightness the Earth would experience if Jupiter did shine. We will look at the luminosity generated by the Jupiter if it was of an appropriate mass to shine, 80 times larger and we will also consider the luminosity emitted by Jupiter at its current mass regardless of the fact that this mass is not considered large enough for the planet to shine. The Mass-Luminosity relationship we will be using is

$$\frac{L_{obj}}{L_{Sun}} = \left(\frac{M_{obj}}{M_{Sun}}\right)^{\alpha}, \tag{1}$$

where L is the luminosity, M is the mass, α is a constant, M_{Sun} is $1.989\text{x}10^{30}$ and L_{Sun} is $3.846\text{x}10^{26}$W. The value for α we will use is 2 as this is the number suggested for use when dealing with low mass objects [2]. This relationship can be arranged to give the Luminosity of the object,

$$L_{obj} = L_{Sun} \times \left(\frac{M_{obj}}{M_{Sun}}\right)^{\alpha}. \tag{2}$$

Analysis

If we take the two masses being considered and apply the Mass-Luminosity relationship to them we can obtain values for the luminosity of Jupiter that we could expect to see if nuclear fusion was occurring with its core. These values have been calculated for Jupiter at its current mass and at a mass that is considered to be close to the limit required for fusion to start occurring. This data can be seen in table 1, M_J from [3].

Mass (kg)	Luminosity (W)	% of Solar Luminosity
M_J - 1.8986×10^{27}	3.504×10^{20}	9.111×10^{-5}
80 M_J - 1.5189×10^{29}	2.243×10^{24}	0.583

Table 1 - Table showing the Luminosity in Watts and as a percentage of Solar Luminosity for Jupiter if it is assumed to be fusing at its core.

In order to give the values being discussed we will convert the luminosities into the apparent magnitude. We can do this by using the following relationship[4],

$$m_1 = m_2 - 2.5\log_{10}\left(\frac{F_1}{F_2}\right) \text{ where } F = \frac{L}{4\pi r^2}.$$

It follows from this that

$$m_1 = m_2 - 2.5\log_{10}\left(\frac{r_2^2 L_1}{r_1^2 L_2}\right). \tag{3}$$

In this relation *m* is the apparent magnitude and *r* is the distance to the object being observed. In this case the subscripts refer to *1* as Jupiter and *2* as the Sun. We know that Jupiter is $6.283\times10^{11}m$ from the Earth and that the Sun is $1.496\times10^{11}m$ away [4]. We know the sun has an apparent magnitude of -26.74 when observed from the Earth [5]. Using these numbers we can calculate a value for the apparent magnitude of Jupiter if it was fusing Hydrogen. The value we arrive at is -8.523 for Jupiter at its present size, for the increased mass Jupiter the apparent magnitude is -18.038.

Discussion

Table 1 shows that the luminosity generated by Jupiter assuming it is fusing at its core is much smaller than the luminosity of our sun, even if you increase the planets Mass to the limit required for fusion to happen this only increases to around 0.5%. If we convert these Luminosities to apparent magnitudes we can better compare them to other objects to discuss the affect a fusing Jupiter would have on brightness levels. After calculating the magnitudes we get -8.523 for the original mass Jupiter and -18.038 for the increased mass Jupiter. If we compare the calculated magnitudes we can see a large increase in brightness from Jupiter's current magnitude of -2.94 [5]. If we look at the magnitude for the increased mass case we can see that the magnitude Jupiter reaches under these conditions gives it approximately the same brightness as a full moon[6]. While this seems to suggest that this would have a large implication on the brightness experienced on Earth, especially at night, we must consider that Jupiter will still only appear as a small point on the night sky due to its distance from the Earth. As we do not have a similar magnitude point-like source in the night sky it is difficult to tell whether the large increase in magnitude would affect the illumination experienced on Earth.

References

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