

Journal of Physics Special Topics

An undergraduate physics journal

A5_4 Burning Giants

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December 10, 2017

Abstract

In this article we aim to investigate the plausibility of using a neutron star to raise the mass of a gas giant to the point where fusion reactions will begin to take place, creating a star. We shall also determine if this could be used on Jupiter to produce additional habitable planets in our solar system. We find that while a neutron star can turn Jupiter into a small star it will not produce any new planets in the habitable zone.

Introduction

In the science fiction novel *Hidden Empire*, the first book in the *Saga of Seven Suns* series, the expanding *Terran Hanseatic league* uses a piece of recovered ancient technology to transport a neutron star into the centre of a gas giant through wormholes. The intention behind this was to create 4 new habitable planets from the gas giant's moons.

In this article we shall determine if this method could be used on Jupiter to produce habitable planets within our own solar system.

Theory: Neutron star

A neutron star is an incredibly dense body made of neutrons, formed when stars with a large enough mass die. Neutron stars normally have a mass greater than that of the sun [1], however theoretically they can be less massive. In order to have moons of Jupiter in the habitable zone of the newly formed star, the star must have as small a mass as possible. We shall estimate the lowest possible mass of a neutron star by using the semi empirical mass formula (1) [2] and model the neutron star as a large single nucleus

made entirely of neutrons. This is a suitable model as a neutron star is made entirely of sub-atomic particles, in the same way a nucleus is, therefore it's minimum size can be estimated as the mass at which forming a stable nucleus becomes energetically favorable.

$$E_B = a_V N - a_S N^{\frac{2}{3}} - a_A \frac{(A - 2Z)^2}{A} - a_C \frac{Z(Z - 1)}{A^{\frac{1}{3}}} + \delta(A, Z) \quad (1)$$

Where; E_B is binding energy, A is the number of nucleons, Z is the number of protons, N is the number of neutrons, a_V is the volume constant, a_S is the surface constant, a_A is the anisotropy constant, a_C is the Coulomb constant and $\delta(A, Z)$ is the pairing term [2].

For a neutron star we can assume $Z = 0$, $A = N$ and $N \gg 1$ therefore $\delta(A, Z)$ and $a_S N^{\frac{2}{3}}$ are negligible. We must also add in a gravitational term to account for the large mass of the object. This leaves us with,

$$E_B = (a_V - a_A)N - \frac{3GM_n^2}{5r_n} N^{\frac{5}{3}} \quad (2)$$

where G is the gravitational constant, M_n is the mass of a neutron and r_n is the radius of the neutron star. To get the minimum mass we assume $E_B = 0$ J and that $r_n = r_o N^{\frac{1}{3}}$ where $r_o = 1.2 \times 10^{-15}$ m [2] giving us,

$$N^{\frac{1}{3}} = \frac{5(a_V - a_A)r_o}{3GM_n^2} \quad (3)$$

which gives us a minimum mass of $M = 0.067 M_{sun}$.

Theory: Star habitable zone

Using the minimum mass of a neutron star would raise Jupiter's mass from $M_J = 0.001 M_{sun}$ to $M_J = 0.068 M_{sun}$.

If we model this as simply changing Jupiter into a star of this mass and we assume it begins life as a main sequence star then we can use the relationship between mass and luminosity of stars to find its luminosity.

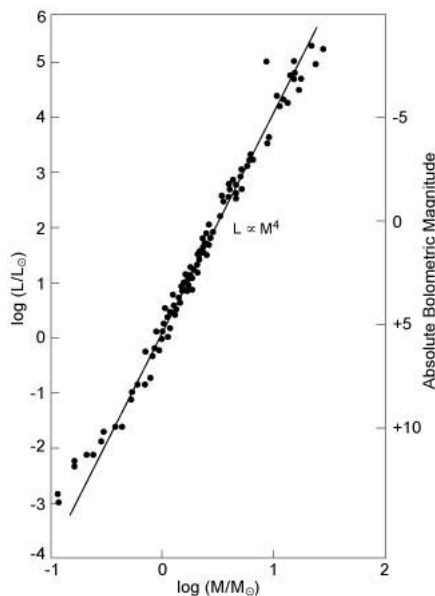


Figure 1: Graph of the relationship between the mass and luminosity of stars [3]

Using this relationship we approximated the luminosity of Jupiter as $L = 0.03 L_{sun}$.

Using the Luminosity of the star, we calculated that the habitable zone around Jupiter would be between $r = 0.14$ AU and $r = 0.378$

AU [4], where r is the orbital radius. The 4 main moons of Jupiter: Io, Europa, Ganymede and Callisto, do not lie within this region. The furthest out of the major moons is Callisto, with an orbital radius of $r = 0.012$ [5] au. There are several moons in the habitable zone, however there mass is too small to apply this habitable zone model to, intended for planets of

$0.1 M_{earth} < M < 10 M_{earth}$ [4] with the largest being $M = 50 \times 10^{-9} M_{earth}$ [5].

conclusion

We have found that, while it is possible to turn Jupiter into a small star using a neutron star, it is not a practical way to increase the number of habitable planets in the solar system. This is due to the minimum mass of a neutron star being too large to produce a star with a habitable zone close enough to Jupiter to allow one of its major moons to become habitable.

References

- [1] R. Naeye, https://www.nasa.gov/mission_pages/GLAST/science/neutron_stars.html [Accessed 10 October 2017]
- [2] <http://www.hep.ph.ic.ac.uk/~dauncey/will/lecture19.pdf> [Accessed 10 October 2017]
- [3] Kenneth R. Lang, http://ase.tufts.edu/cosmos/view_picture.asp?id=562 [Accessed 10 October 2017]
- [4] *Habitable Zones Around Main-Sequence Stars: New Estimates* by Kopparapu et al.(2013), *Astrophysical Journal*, 765, 131 [Accessed 10 October 2017]
- [5] David R. Williams, <https://nssdc.gsfc.nasa.gov/planetary/factsheet/joviansatfact.html> [Accessed 10 October 2017]