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P1 3 Steam powered Sun

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Abstract

In this paper, we calculate the total amount of time that the oceans on Earth could fuel the Sun's luminosity via the P-P chain I fusion. Assuming that the Sun gets all its energy from the oceans, we found that each hydrogen atom produced 6.549 MeV and the hydrogen from the oceans could fuel the Sun for approximately an additional 7.7 years.

Introduction

Main sequence stars like the Sun, mainly get their energy from fusing hydrogen into helium. Approximately 99% of all the Sun's energy comes from the P-P chain [1] and thus we are assuming that all energy comes from the P-P chain in this paper. Theoretically, if the oceans were transported to the Sun, the temperature is greater than the threshold required to become a plasma (10,000 K) [2], therefore all bonds break down in the water molecules and the electrons will become free. These now ionised hydrogen atoms (protons) can then be used in the P-P chain to fuel the Sun.

Theory

The P-P chain: a sequence of three fusion reactions occurring in a star, that fuse four protons into a helium-4 ion. There are three branches of P-P chain: I, II and III. In our case we are simplifying and using only the I chain, as this dominates energy production over the other two [3] and the other chain requires heavier elements not present in ocean water, which contradicts our constraints of the oceans powering the Sun.

Using the following equation:

$$Q = (m_i - m_f)c^2 \tag{1}$$

Where Q is the left over energy (energy released) by the reaction, m_i is the rest mass of the reactants, m_f is the rest mass of the products and c is the speed of light in a vacuum. By comparing the rest energy of the particles before and after fusion, we find the energy released by the reaction.

The first step of the P-P chain is two protons fusing via the weak force, causing one of the protons to convert to a neutron. This net reaction produces deuterium, a neutrino and a positron which is immediately annihilated by free electrons in the plasma [3].

$$^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} + \mathrm{e}^- \longrightarrow {}^{2}_{1}\mathrm{H} + \nu_e + 1.442\,\mathrm{MeV} \tag{2}$$

The second step of the P-P chain is fusing deuterium with another proton, which produces helium–3 and releases gamma rays [3].

$$^{2}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \longrightarrow {}^{3}_{2}\mathrm{He} + \gamma + 5.493\,\mathrm{MeV} \tag{3}$$

The third and final step of the P-P chain fuses two helium-3 ions, producing helium–4 and releasing two protons [3].

$$ {}^{3}_{2}\mathrm{He} + {}^{3}_{2}\mathrm{He} \longrightarrow {}^{4}_{2}\mathrm{He} + 2\,{}^{1}_{1}\mathrm{H} + 12.859\,\mathrm{MeV} \quad (4) $$

The total chain requires two of the first two steps and one of the final, resulting in a total energy released 26.729 MeV. However, around 2% is lost via neutrinos [3], therefore the final energy released per P-P chain I is 26.194 MeV or 6.549 MeV (1.049×10^{-12} J) per proton as 4 protons are fused in total in this chain.

Now the total amount of hydrogen in the oceans must be calculated. There is 1.335×10^{18} m^3 of saltwater in the ocean [4] which has a density of 1030 kg m^{-3} [5] and is 96.5% water [6]. Therefore there is 994 kg of water per m^3 of saltwater. Overall, this means that there is 1.327×10^{21} kg of water in the oceans (m_W). Water has a molecular mass of 18.015 g mol^{-1} (M_W) and hydrogen is 1.008 g mol^{-1}(M_H) [7]

$$ N = N_a \times (2m_W/M_W) \quad (5) $$

Where N is number of hydrogen atoms in the ocean and N_a is Avogadro's number. Using this equation we find that there is 8.872×10^{46} atoms.

Multiply this number by the energy released per proton to get the total energy the oceans produce via the P-P chain I as 9.307×10^{34} J

Finally, we need to divide the total energy produced by the luminosity of the Sun to find how long it could be powered. The luminosity is 3.846 $\times10^{26}$ W [8], by rearranging the power equation of power equals energy over time, we find that the energy produced could fuel the luminosity for 2.420×10^{8} seconds or 7.674 years.

Discussion

In reality, the calculated value would be inaccurate. Firstly, the Sun would also undergo the P-P Chain II and III as the Sun has the extra components for them, these two processes release less energy than the P-P and would account for approximately 10% of energy released [1]. Also, this energy would be released over many billions of years as the first stage of the P-P chain I reaction takes on average 9 billion years for a given proton to fuse [1] thus the 7.674 years calculated would not be consecutive, but spread out over the Sun's lifetime. It is also assumed that all water in the ocean is normal, whereas a very small percentage of ocean water is so called "heavy water" which has two deuterium bonded to oxygen instead of just hydrogen, which would slightly increase the time. Finally, the helium produced does not disappear from the Sun and will be used later in the Sun's lifespan in other reactions such as the CNO cycle and helium fusion, which occurs when all hydrogen is fused.

Conclusion

In conclusion we find that if the entirety of Earth's oceans were transported to the Sun, the water molecules would turn into a plasma where the protons produced undergo fusion via the P-P chain I reaction, fueling the Sun for around 7.7 additional years assuming only P-P Chain I fusion is considered.

References

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