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Stars in their eyes

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Abstract

Stars in their eyes is an Idiom often used to portray someone being overly optimistic. In this paper the aim was to consider the physical conditions involved in the formation of stars and decide if this idiom could represent reality here on Earth. When considering the mass and self-gravitational forces that are required to form a star, it quickly became apparent that a star could not exist extra terrestrially at a scale comparable with an eye. However, considering this idiom in the context of a model based on ICF, it was found that 72.38 potential miniature stars could be enclosed within the volume of an eye, with 5.25% of the Deuterium/Tritium fuel being available to create them.

Introduction

Stars in their eyes is a common idiom, often used to denote over optimism. This paper aims to investigate this idiom by considering the physical laws that govern our universe to reach a conclusion on whether this idiom could be based on any physical reality.

Theory

Stars form in interstellar space from dark clouds of dust and gas. These clouds contract under the vast compressive gravitational forces which build up due to their enormous coalesced mass. This creates tremendous internal pressures serving to compress the core and generate huge temperatures - more than 1.5×10^7 K [1]. At these temperatures, the fourth state of matter - a gaseous ionic plasma is formed. Here, at the centre of a newly formed protostar, enough energy is generated to drive a proton - proton chain. High energy photons vigorously collide with protons and electrons, generating sufficient energy to overcome prevailing electrostatic forces that ordinarily keep these colliding nuclei apart. Overcoming these forces (coulomb barrier) enables the fusion of hydrogen into helium - the energy source of a star. The estimated minimum protostellar mass that allows fusion to be generated by self-gravitation is believed to be approximately 0.05 – 0.10 solar masses ($M_{\odot}$)[2].

Findings

Even though 0.05 $M_{\odot}$ is the minimum mass limit estimate, currently the smallest known star discovered is EBLM J0555-57Ab, which is believed to be around 85±4 M_{Jup} (0.081$M_{\odot}$) with a radius of 58.72 km [3]. Clearly, a body the size on eye (average mass 0.0075 kg) could not exist as a star in isolation within the interstellar medium, based on these estimates; therefore, the hypothesis breaks down very quickly at this point. However, if we consider this idiom from an alternative perspective, and model the creation of a star terrestrially within the physical and dimensional constraints of an eye, then the proposition becomes at least theoretically conceivable. This is because the fusion of light nuclei has been achieved here on Earth by the process of inertial confinement fusion (ICF) [4].

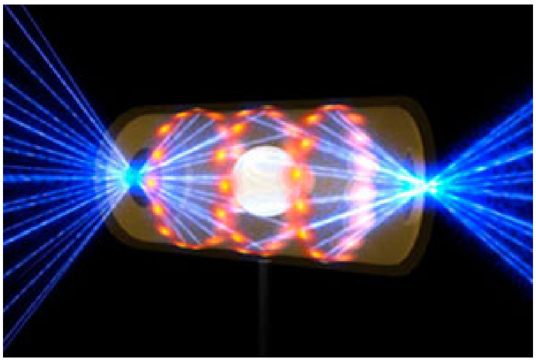

Figure 1 – Inertial confinement fusion (ICF) [4]

Using our own star – the Sun – as a comparator, the temperatures at its core is more than 1.55×10^7 K [1], these temperatures result from the enormous self-gravitational forces that build up proportional to its mass, radius, and density. Nevertheless, even these great temperatures are miniscule to those needed to initiate fusion here on Earth. This is because the mass of the fuel source used in ICF is typically measured in milligrams [4], not solar masses [1]. Consequently, to achieve the necessary temperature to initiate fusion in ICF, a rapid, vast surge of energy is delivered to the fuel source – a mixture of Deuterium and Tritium (DT). This instantaneously turns the fuel into a super-heated plasma, as the temperature approaches 2×10^{8} K – much hotter than the core of our Sun [4]. The fuel is burned so quickly that it does not have time to expand and reach the reactor walls, allowing the reactor to survive. At the heart of this technology is a miniscule centimetre-scale cylindrical gold vessel called a hohlraum. Within this miniature cylinder, the tiny fuel pellet is positioned for transformation [4].

If the hohlraum is modelled as a perfect cylinder, then by using equation (1) the volume of a single hohlraum is calculated to be 1.13×10^{-7} m^3 (where h = 0.001 m and r = 0.006 m [4]). If an average eye is modelled as a perfect sphere, then using equation (2) the volume is calculated to be 8.18×10^{-6} m^3 where r = 0.0125 m.

$$V(cylinder) = \pi r^2 h \qquad (1)$$

$$V(sphere) = \frac{4}{3}\pi r^3 \qquad (2)$$

This reveals that, the volume of a human eye could theoretically enclose 72.38 hohlraums. However, unlike stars which initially fuse hydrogen into helium, the fuel used in ICF comprises a Deuterium pellet mixed with a trace of Tritium (DT) [4]. These elements are naturally occurring within the human body – 5g of Deuterium [5] and traces of Tritium taken in through ingestion and background radiation [6]. In this model we assume that these elements are equally distributed around the body. Therefore, using equation (3) the percentage of Deuterium/Tritium within an average 70 kg human body is calculated to be 0.007%.

$$Percentage = \frac{DT\ present\ in\ the\ body}{Body\ mass} \times 100 \quad (3)$$

Thus, by multiplying the mass of an average eye (7.5 g) by 0.007 % the amount of Deuterium/Tritium present could be as much as 0.525 mg. This would represent approximately 5.25 % of the DT fuel currently used to create potential miniature stars by ICF standards.

Nevertheless, in addition to the appropriate fuel, a huge amount of instantaneous energy is required to initiate fusion by ICF. This energy is delivered to the target by multiple lasers with a combined output equivalent to 1011 kW. This is enough energy to create the vast temperatures required to overcome the coulomb barrier and initiate fusion [7] – this is equivalent to 1×10^{8} MW or the total energy consumption of 65 billion homes for a period of 10^{-9} seconds [8].

However, a star existing in the interstellar medium, self-sustains fusion through the equilibrium of gravitational forces compressing the core, and the outward pressure provided by the fusion reaction itself, facilitated by a continuous supply of fuel [1]. Conversely, in ICF, although fusion is being initiated by overcoming the coulomb barrier, this is only for a fraction of a second and the newly formed star dies almost as quickly as it was born - this is because the input energy is still greater than the net energy yield of the reaction [4]. To achieve sustainable fusion (ignition) the critical fusion temperature must be maintained at a high enough ion density for longer periods [9]. This is the current goal of researchers but has so far eluded them.

Conclusion

Although a human eye may contain approximately 5.25% of the D/T fuel required to initiate fusion by ICF standards, fusion has only been achieved here on Earth for fractions of a second - net energy yields have not currently outstripped energy inputs by this method. To achieve self-sustained fusion comparable to the stars that are known to exist within the cosmos, suitable ion density and confinement times, in relationship with colossal temperatures would need to be achieved; thus far, this goal has eluded researchers. Therefore, these creations cannot really be regarded as equivalents to stars that are known to exist extra terrestrially in much wider physical conditions; at least not until ignition and positive net energy yields has been achieved. Therefore, the inference of this idiom, where one is being overly optimistic, may yet prove to be at least contextually true until ICF researches reach their goal of 'Ignition'. Nonetheless, although these stars cannot yet be regarded to realistically occur - other than in this very limited way – currently, 72.38 of these creations could theoretically be enclosed in the volume of an eye.

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