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P3_5 ALL THESE WORLDS ARE YOURS

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Abstract

This paper investigates a plot point of the novel 2010: Odyssey Two by Arthur C. Clarke in which self replicating monoliths engulf Jupiter, increasing its density to the point when nuclear fusion can take place, giving birth to a new star. It was found that 1.629×10^{20} monoliths would be needed to trigger nuclear fusion in Jupiter's core, taking 136 hours to do so.

Mission Profile

In the second novel of Arthur C. Clarke's Space Odyssey series, *2010: Odyssey Two*, a crew was sent to discover what went wrong with an earlier mission to investigate a monolith (figure 1) in orbit around Jupiter. Shortly after they arrived, the crew were told to leave as "something wonderful" was going to happen. The monolith disappeared from orbit and a dark spot appeared on Jupiter and began to grow. The spot was a population of monoliths that were self replicating exponentially and consuming the planet. Eventually, the monoliths were so vast in number that they had increased the density of Jupiter enough for it to begin nuclear fusion, and a new star was born to support aquatic life-forms on Europa.

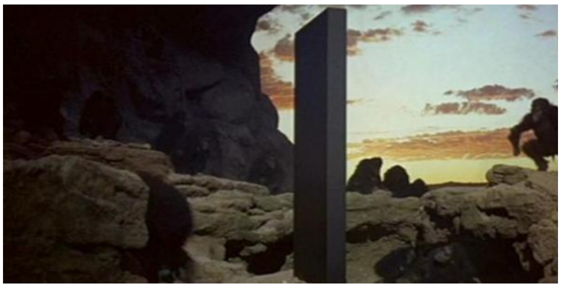

Figure 1: A monolith that appeared on Earth three million years B.C. [1].

Big Brother

The first monolith discovered by humans was found buried beneath the surface near the Tycho crater on Earth's moon. This monolith, designated TMA-1 (Tycho Magnetic Anomaly 1) was stated as being 11 feet tall (3.35m) with dimensions in the exact ratio of 1:4:9 (the squares of the first three integers) for depth, width and height respectively [2]. The monolith found orbiting Jupiter, designated TMA-2 (doubly inaccurate since it was neither discovered in the Tycho crater nor did it give off any magnetic signal), had dimensions in the exact same ratio, but was 718 times bigger than TMA-1 [3]. This enabled us to calculate the dimensions of TMA-2 as 267.5x1070x2407m with a volume of $0.6889 km^3$.

The crew were able to calculate the mass of TMA-2, which was found to be 950,000 tons [4]. It was assumed they were using long tons, as was used in the United Kingdom. This gave a mass equal to 9.652×10^8kg, corresponding to a density of $1.401 kg/m^3$.

Fire in the Deep

In the book the monoliths consumed the atmosphere of Jupiter, increasing their own density and subsequently the density of Jupiter. This increase in density was what triggered nuclear fusion. However, the lowest mass stars that have been observed are red dwarfs, with masses ranging from 0.08 to 0.7 solar masses [5]. For this paper it was assumed that, being alien technology, the monoliths could siphon matter from another dimension for example, instead of using Jupiter's atmosphere. The fusion was then triggered when the additional mass of the monoliths was sufficient enough to reach the lower limit for a red dwarf.

Jupiter's mass is shown in table 1. It is equal to $9.546\times10^{-4}M_{\odot}$, where $M_{\odot}$ is one solar mass. Therefore, the monoliths had to increase Jupiter's mass by $7.905\times10^{-2}M_{\odot}$, over 80 times its original mass, to reach the lower limit for a red dwarf.

Property	**Value**
Mass (10^{24} kg)	1898.6
Volume (10^{10} km^3)	143128
Mean density (kg/m^3)	1326

Table 1: Properties of Jupiter [6].

As a side note, it should be noted that for planets with masses much greater than 500 Earth masses ($1.502\times10^{-3}M_{\odot}$) degeneracy pressure of free electrons balances gravity in hydrostatic equilibrium [7]. So if more mass were added to Jupiter, it would actually shrink. Eventually however, the volume of the added monoliths would overtake the volume of Jupiter's degenerate atmosphere and the radius would begin to increase again as more monoliths were added.

Each monolith had a mass of $4.853\times10^{-22}M_{\odot}$, so to increase Jupiter's mass by $7.905\times10^{-2}M_{\odot}$ needed 1.629×10^{20} monoliths.

Devourer of Worlds

After vanishing from orbit around Jupiter, the monolith started acting as a von Neumann machine; autonomously replicating itself. The rate of replication was stated in the book as every two hours [8]. It was assumed that it took two hours after disappearing from orbit for the monolith to perform its first replication. The number of monoliths N after time t measured in hours was given by equation (2),

$$N = 2^{0.5t}, \qquad (2)$$

when $t = 0$ was set to when the monolith first disappeared from orbit.

Rearranging equation (2), the time it takes to replicate enough monoliths to ignite nuclear fusion could be found, as shown in equation (3),

$$t = 2\log_2 N = 2\left(\frac{\ln N}{\ln 2}\right). \qquad (3)$$

Substituting the value obtained earlier for the number of monoliths needed N, the time taken to reach that many monoliths was 134.3 hours. Since the monoliths can only replicate once every two hours, the actual time before nuclear fusion ignited within Jupiter would be 136 hours.

It has been shown by Marshall *et al.* [9] that the increase in mass of Jupiter would cause Europa to collide with the new star, due to the increased gravitational pull.

Epilogue

It was found that to ignite nuclear fusion in Jupiter, a minimum of $0.079M_{\odot}$ would need to be added, corresponding to 1.629×10^{20} monoliths. Because of the exponential replication of the monoliths, it would only take 136 hours to create enough to cause fusion.

In the book, this new star was created to support aquatic life on Europa. However, it has been shown that the increased gravitational force from the star would in fact cause Europa to collide with the star. The gravitational effects on Earth have yet to be investigated.

References

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