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P6_5 Matrioshka Brain

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Abstract

The Matrioshka brain is a hypothetical structure originally proposed by Robert Bradbury in 1999 [1]. It consists of layers of Dyson spheres around a star, generating energy through solar panels, to power a supercomputer. In this paper we find that the structure could generate 9×10^{18} times more power than our current most powerful supercomputer, however would require more resources than are currently available to create.

Introduction

Currently the most powerful super computer on Earth is the Chinese Sunway TaihuLight with a maximum computational power of 125.4359 [2] PetaFLOPS (floating point operations per second), which defines the amount of real number calculations that can be computed each second. How much computing power could be extracted from our star using the Matrioshka brain model?

Concept

The Motrioshka brain utilises almost all of a stars output energy, this is achieved by building layers of Dyson spheres around the star to capture all electromagnetic radiation. Each Dyson sphere is coated internally with solar panels to capture the energy output from the star. Each layer heats up as it captures energy and re-emits it isotropically, this energy is then captured by the successive layers.

Equations

To model the concept, the solar panels were assumed to be the most efficient silicon solar panels currently achieved at 26.3% efficiency [3] and the coefficient of reflection was that of silicon

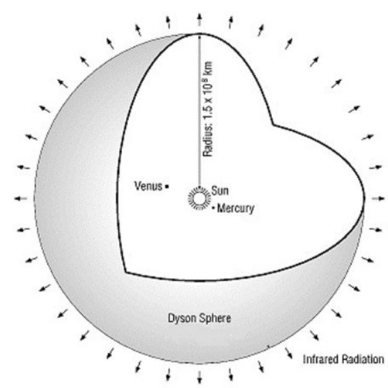

Figure 1: Diagram showing the layout and structure of a Dyson sphere, radius 1.5×10^{11}. Credit:arXiv:1503.04376

R=0.348[4]. Given that the power is being used to drive computation, virtually all of it would be re-emitted as heat. Thus assuming all energy absorbed by the shell is re-emitted isotropically from the external surface then the total power absorbed by the system can be given by;

$$P_T = \sum_{i=1}^{n} P_I \times E_{ff} \times T^n, \quad (1)$$

Where P_I is the power incident on the first shell (W), E_{ff} is the efficiency of the solar panels, T is the transmission coefficient and n is the number of shells. To achieve an efficiency of 99.9%, solving the equation for n and setting $P_T/P_I = 0.01$ gives the number of shells required to be ≈ 11.

By assuming that all incident light that is not reflected contributes to the heat of the shell, a minimum value of shell radius can be calculated to prevent the computer from overheating. This can be achieved by reverse engineering the effective temperature equation [5];

$$T_{eff} = \left[\frac{(1-a) \times A_{sun} \times T_{sun}^4}{4\pi \times D_{sun}^2}\right]^{1/4}, \quad (2)$$

to find the distance where a, A, T and D are the albedo, solar disk area (m^2), temperature (K) and distance (m) respectively.

Using this distance as the radius we can calculate the volume of a spherical shell of thickness 1m, approximating all 11 shells as having the same radius and thickness, the volume can be calculated as the surface area of a sphere multiplied by the thickness t;

$$V = 4\pi r^2 \times t. \quad (3)$$

Results

Using Eq. (1) we can calculate the total power produced by the panels to be 1.87×10^{26} W, or approximately 50% of the sun's total power output. Given the efficiency of the TaihuLight supercomputer 6 GFLOPS/W [2], this would suggest a theoretical maximum computational power of 1.12×10^{36} FLOPS, approximately 9×10^{18} times more than the TaihuLights maximum.

Using Eq. (2), simplifying the sphere to be solid silicon the albedo can be approximated as the coefficient of reflection of silicon 0.348, using an area of 1.77×10^{16}m^2, Sun temperature of 5800K and a target temperature of 300K [6] a distance of 1.06×10^{11}m from the sun is obtained. Combining this with Eq. (3) the volume of the sphere was calculated to be 1.54×10^{24}m^3. If the sphere was to be constructed solely of iron this would give a mass of 1.21×10^{28}kg, more than the mass of Iron in the solar system excluding the sun, calculated from the mass of the solar system and the mass fraction of iron in the universe [7].

Discussion

The Matrioshka brain model gives an incredible amount of computing power however the construction of the Dyson shells would prove almost impossible. Given the inefficiency of current solar cell technology and the limited resources of our solar system it may be more useful to consider different Dyson models for energy collection such as the Dyson swarm, very dense mesh of satellites in orbit around the star, or ring, a ring shaped object built around the star at a fixed distance. It would also be useful to look at different solar cell technology, making them more efficient so more energy can be captured. As the supercomputer itself would take up very little space comparatively further study should be done into the potential efficiency of these structures.

Conclusion

The Matrioshka brain concept could revolutionise computing and given the time it would take to construct a sufficient Dyson structure to support it, computer and solar cell technology would advance considerably making the structure even more efficient. The significant decrease in mass required for smaller Dyson structures, swarm or disk, would make the Matrioshka brain a much more attainable structure.

References

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[2] `https://goo.gl/TfUFQ9`[Accessed 22/11/2017]

[3] `https://goo.gl/CuyVC1`[Accessed 22/11/2017]

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[6] `https://goo.gl/XxMpvA`[Accessed 22/11/2017]

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