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A1_2 Niven Rings

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Abstract

This article outlines the basic principles of a Niven Ring and with regards to harnessing a greater proportion of the Sun's energy and as a stepping stone to a Dyson sphere.

Introduction

In 1970, Larry Niven's Ringworld [1] introduced the idea of an intermediate step between planets and Dyson spheres which were in turn introduced by Freeman Dyson in 1959 [2]. The principle behind both structures is that any sufficiently advanced race will eventually require both more room and energy as their population is ever expanding, assuming all races expand in population like humans. Another assumption is that these hypothetical races will be unable to send large numbers of their populous to other planets efficiently requiring large scale structures to be built in the home system or in close proximity to the home system.

To meet energy requirements for such an expanded populous it would be logical to make use of the Sun's output, after all on Earth we can only use a minuscule amount of the solar output of the Sun. This is where Dyson proposed the idea of a spherical structure with life living on the inner surface thus utilising all of the solar output. However, the amount of materials required to build a spherical structure around the Sun are astronomical and it requires the use of artificial gravity to keep life on the surface of the sphere. Due to these constraints Niven created the idea of a spun ring around the Sun to simulate gravity via centrifugal force and being only a ring would use far less materials than a sphere yet still receive a much larger proportion of the solar output compared to a planet.

Dimensions

For the sake of simplicity we'll assume that the ring should be placed at 1 A.U. to stay in the habitable zone of the solar system. From this we can easily calculate the circumference of the ring to be approximately 9.5×10^{11}m, the height of the ring, perpendicular to the rotational plane, is dependent on the mass available but for now the figure used by Niven, 1.6×10^{9}m [1], is acceptable. So the total area available is 1.5×10^{21}m^2 which is approximately 3 million times the surface area of the Earth.

Ring Rotation

As has been mentioned, the main reason for using a ring as the structure is to simulate gravity from the centrifugal force produced from the rotation of the ring. The centrifugal force, F_{cen} is the calculable from the rotational velocity, v, the mass, m, and the radius of the ring, r, combined as in (1) below,

$$F_{cen} = m\frac{v^2}{r}. \qquad (1)$$

Since we actually want an acceleration, a, we can use Newton's second law of motion (2) to equate force and mass to find the acceleration,

$$F_{cen} = ma. \qquad (2)$$

Rearranging (2) and substituting in (1) gives us the acceleration for a given rotational velocity of the ring, however, we know the acceleration we want, $9.81ms^{-2}$, so we can find the rotational velocity for the given radius of 1 A.U. to give the answer in equation (3),

$$v = \sqrt{a.r} = \sqrt{9.81 \times 1.5 \times 10^{11}} = 1.2 \times 10^{6} ms^{-1}. \quad (3)$$

Given the rotational velocity in (3), we can calculate the tensile strength, σ, of the ring, to prevent it from snapping, from the cross sectional area of the ring, A, and the force acting on it. The force is of course the same as the centrifugal force so the minimum tensile strength of the ring can be calculated from (4)[3],

$$\sigma = \frac{F_{cen}}{A} = \frac{mv^2}{Ar}. \quad (4)$$

Equation (4) unfortunately contains two unknowns, m and A, which are dependent on the materials available to the builders. However, if, for this article, we use Niven's figures again we have a mass of 2×10^{27} kg [1] and a width of 250m [1] giving an actual cross sectional area of $4x10^{11}m^2$. These values can be substituted into (4) to give a tensile strength of $4.8x10^{16}Nm^{-2}$. Comparing this to the strongest material we have today, Carbon nanotubes, with a tensile strength of $6.2x10^{4}Nm^{-2}$ we can see that the materials we have are twelve orders of magnitude below the required tensile strength, in fact $4.8x10^{16}Nm^{-2}$ is comparable to the strong nuclear force.

Adapting the Environment for Human Life

For life to survive on a Niven Ring there needs to be an atmosphere. Compared to building the entire ring, creating an atmosphere is not too difficult. However, there needs to be some mechanism to contain the atmosphere to stop it escaping. Once again the centrifugal force helps in this respect, since the atmosphere will also be directed towards the ring's inner surface then all is needed is a wall on each rim of the ring to prevent any overspill off the sides.

The next problem is the fact that we live on a rotating planet meaning we experience a day/night cycle along with all life on Earth, whilst we could probably adapt to a continuous noon some animals may not. To this end a series of dark panels could be placed in a closer orbit around the Sun with an orbital period that causes a shadow across the ring which would be equivalent to a 12 hour night. These panels could also be used as solar panels due to their extreme size and proximity to the Sun they could produce a significant proportion of the power needed to support a Ring world civilization.

The third consideration is that of protection from the Sun, especially from UV radiation and impact from the solar wind. On Earth we have the magnetosphere to protect us from the solar wind and the radiation output of the Sun. A magnetosphere could be simulated by having a conducting web imbedded in the ring material which would induce a magnetic field around the ring thus protecting the ring from the solar wind.

Conclusion

In conclusion, a Niven Ring is ideal in theory and would indeed be able to support life. However, we have no materials with the required tensile strength, $4.8x10^{16}Nm^{-2}$, and we are a long way from being able to manipulate such large masses in the solar system.

References

[1]L, Niven (1970). *Ringworld* New York: Ballantine Books .ISBN 0-345-02046-4

[2] Freemann J. Dyson (1960). "Search for Artificial Stellar Sources of Infra-Red Radiation". *Science* **131** (3414): 1667–1668. doi:10.1126/science.131.3414.1667. PMID 17780673

[3] G. Woan (2000) The Cambridge Handbook of Physics Formulas