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P4 4 Ceresian Spin Station

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Abstract

This paper investigates the feasibility of creating a station on Ceres, as seen in the book series 'The Expanse'. We calculate the required kinetic energy change of 2.4×10^{26} J to achieve a spin gravity of 0.3g on the surface of the dwarf planet, and explore how an advanced civilization might acquire such energy, along with the associated complications.

Introduction

In the science-fiction series 'The Expanse', over 300 years in the future, Humankind has colonized different parts of the Solar System. One station is on Ceres, the largest dwarf planet in the asteroid belt. The gravitational field strength on Ceres is $g_C = 0.27$ ms^{-2} [1]. The entire dwarf planet is spun rapidly to achieve an artificial gravity induced by spin equivalent to $g_s = 2.94$ ms^{-2} or 30% of Earth's gravity on the outermost layer of Ceres [2].

Theory

The spin gravity must cancel out the gravitational pull of Ceres to achieve the desired effect. The centripetal acceleration required can be expressed as:

$$a_c = g_s + g_C \tag{1}$$

In terms of circular motion, centripetal acceleration relates to angular velocity, ω, and the radius of rotation:

$$\omega^2 = \frac{a_c}{R_C} = \frac{g_s + g_C}{R_C} \tag{2}$$

As we are calculating the spin gravity immediately below Ceres' surface, the radius of curvature is the radius of Ceres, $R_C = 476$ km [1].

Ceres already rotates, and it is more efficient to increase its spin in the same direction. The current angular momentum of Ceres can be calculated from its rotational period, $T_C = 9$ hours [1].

$$\omega_c = \frac{2\pi}{T_C} \tag{3}$$

The required increase in angular velocity is the difference between the current angular velocity and ω:

$$\Delta\omega = \omega - \omega_C = \sqrt{\frac{g_s + g_C}{R_C}} - \frac{2\pi}{T_C} \tag{4}$$

The kinetic energy of a rotating body in terms of angular velocity is given by:

$$E = \frac{1}{2} I \left(\Delta\omega\right)^2 \tag{5}$$

Where I is the moment of inertia. For Ceres this can be calculated from its mass ($M_C = 9.1 \times 10^{20}$ kg [3]) and its radius.

$$I = \frac{2}{5} M_C R_C^2 \tag{6}$$

By subbing in equations 4 and 6 into equation 5 we obtain the final relation for total energy:

$$E = \frac{1}{5} M_C R_C^2 \left(\sqrt{\frac{g_s + g_C}{R_C}} - \frac{2\pi}{T_C}\right)^2 \tag{7}$$

Energy Accumulation

To determine how an advanced civilisation may accumulate enough energy to create a spin station on Ceres, we compared in situ solar energy and the equivalent number of fusion bombs if all energy was harnessed at 100% efficiency.

For the solar energy, we assumed the entire surface of Ceres was covered with solar panels, with only one hemisphere receiving sunlight at a time ($A = 2\pi R_C^2$). The solar flux at Ceres multiplied by the area of solar panels gives the power [4]:

$$P = \frac{L_\odot R_C^2}{2d_C^2} \tag{8}$$

Where, $L_\odot = 3.85 \times 10^{26}$ W is the luminosity of the Sun, $d_c = 4.13 \times 10^{11}$ m is the average orbital distance of Ceres.

To estimate the number of fusion bombs required, we used the energy yield of the largest fusion bomb ever detonated, the 243 PJ Tsar Bomba [5].

Values seen in Table 1 were calculated by dividing total energy by these respective values.

Results and Discussion

Description	Value
Total Energy (J)	2.4×10^{26}
Years of Ceresian Solar Power	29,000
Number of Thermonuclear bombs	9.7×10^8

Table 1: Energy Required with comparisons of equal magnitude

Table 1 shows the energy required to achieve the gravitational effect described in 'The Expanse'. The energy required is inconceivably high. All the nuclear warheads in the world combined would make up less than 0.1% of the energy needed [5], even if they were all as powerful as the Tsar Bomba. If solar energy on Ceres were used, it still wouldn't have been accumulated even if harvesting had begun at the end of the last Ice Age.

Harvesting energy of this magnitude is not consistent with the level of human technology shown, and the technology required would likely render a Ceresian spin station obsolete. The structure needed to harness energy at this scale would require technology approaching that of a Dyson Sphere. When considering how this may be applied, rocket powered propulsion per se, any losses or efficiencies in transmission only make this prospect more unlikely.

If such energy could be expended there would be other concerns. The entire dwarf planet would have to be significantly strengthened to even hold together.With gravity no longer holding Ceres together, the body would break apart and spread into space if not supported. This issue extends deeper into Ceres, where tidal forces from the disruption would cause friction and fault lines, threatening any station. Such a station could be torn apart or melted by the intense heat.

Conclusion

In conclusion, the existence of a spin station on Ceres, such as that seen in 'The Expanse', is only plausible in fiction. The energy required at 2.4×10^{26} J is too high to be plausible, especially at the technological level present in the series. Furthermore, the effects on the structure of Ceres would render any station built uninhabitable.

References

[1] *Ceres: Facts - NASA science*. en. `https://science.nasa.gov/dwarf-planets/ceres/facts/`. Nov. 2017.

[2] James S. A. Corey. *Leviathan Wakes*. New York: Orbit, 2011. Chap. 18.

[3] Edward F Tedesco. "Ceres". In: *Encyclopedia Britannica*. Sept. 2024.

[4] Todd A. Thompson. *Lecture 24: Atoms and Light*. `https://www.astronomy.ohio-state.edu/thompson.1847/161/lecture_24_web.pdf`. n.d.

[5] *The Soviet Weapons Program - The Tsar Bomba*. `http://nuclearweaponarchive.org/Russia/TsarBomba.html`. n.d.