The Electromagnetic Drive: an equilibrium between forces at the geostationary orbit of Jupiter

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Abstract: In this research note it is proposed how the equilibrium between the Lorentz force and the centrifugal force in a crewed spacecraft acting as a tidally stabilised skyhook, and orbiting the geostationary orbit of Jupiter, could prevent the spacecraft form deorbiting and reaching unbearable accelerations. A pair of superconducting electromagnetics would produce a constantly-increasing Lorentz Force, which would cancel the centrifugal force while producing a constant acceleration of 4 g, the limit that a crew could withstand during long periods of time.

Key-words: Lorentz force, centrifugal force, electromagnetic propulsion, skyhook, space tether, interstellar travel, speed of light.

Space tethers are long cables which can be used for propulsion, momentum exchange, stabilization and attitude control, as well as maintaining the relative positions of the components of a large dispersed satellite or spacecraft sensor system.

One type of space tether is the skyhook. Specifically, a non-rotating skyhook is a vertical gravity-gradient stabilized tether.

Here I wish to discuss how a balance between the Lorentz force (which would act as the centripetal force) and the centrifugal force could provide a high yet bearable acceleration to a crewed skyhook-style spacecraft orbiting Jupiter at geostationary altitude.

The escape velocity of Jupiter is 59.5 km/s. Any spacecraft orbiting at a higher speed would leave the geostationary orbit, and the Lorentz force would gradually weaken to the point of disappearing.

A possible balance between forces could be achieved with the proper configuration of a system formed by a pair of superconducting electromagnets, one on each side of the spacecraft. These elements would provide the Lorentz force to the spacecraft while cancelling the centrifugal force.

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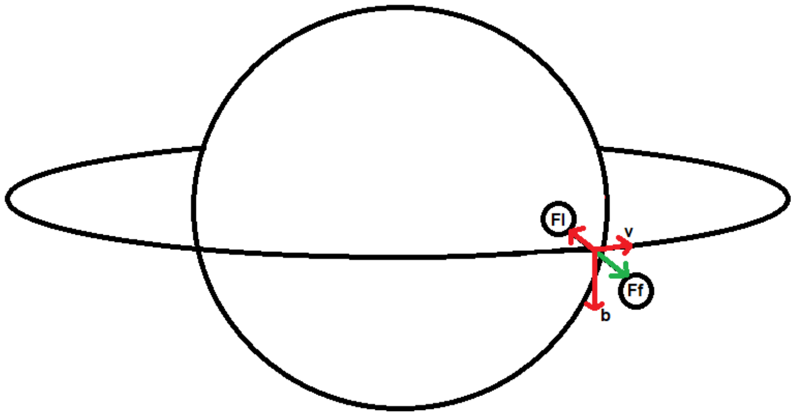

Figure 1: Balance between the Lorentz force (Fl) and the centrifugal force (Ff)

The electromagnetic system would constantly increase the Lorentz force in order to both prevent the spacecraft from deorbiting while it is being accelerated, and from producing an unbearable G-force to the crew. In theory, if the spacecraft is kept under a controlled constant acceleration, relativistic speeds could fall within the realm of plausibility.

Current flux would need to be adjusted once the speed of 42,5 km (first cosmic velocity of Jupiter) is reached, in order to balance the forces and produce a constant acceleration. At this point, if we have a spacecraft with a mass of 1,000 tons at the geostationary orbit of Jupiter, the centrifugal force would be the following:

$$\mathrm{F = m \cdot v^\wedge 2/r}$$
$$\mathrm{F = 1,000,000 \cdot 42,500^\wedge 2/159,722,000}$$
$$\mathrm{F = 11,308,711\ N}$$

Now, to calculate the Lorentz force needed to keep the spacecraft in orbit and produce the accelerate desired, we first need to determine the field strength at the geostationary orbit. Considering that Jupiter's Magnetic Dipole Moment is 1.55e+20 T.m^3, we obtain the following field strength:

$$\mathrm{B = M/R^\wedge 3}$$
$$\mathrm{B = 1.55e + 20/159,722,000^\wedge 3}$$
$$\mathrm{B = 3.8e - 5\ tesla}$$

So, for example, at 0.5c, the centrifugal force would produce an unbearable acceleration of 14.3 million g's. To cancel this, the electromagnetic system would have to produce an opposite Lorentz force equally strong.

However, the Lorentz force has to be higher than the centrifugal force in order to produce the constant acceleration desired. Considering that the crew could withstand a maximum of 4 g during a prolonged period of time (Poljak, 2018), the Lorentz force would be the following:

$$\mathrm{F} = \mathrm{q} \cdot \mathrm{v} \cdot \mathrm{B} \cdot \sin(\alpha)$$
$$\mathrm{F} = 6,865,000 \cdot 150,000,000 \cdot 3.8\mathrm{e} - 5 \cdot \sin(90)$$
$$\mathrm{F} = 1.4\mathrm{e} + 14\ \mathrm{N}$$

If we used batteries with a power output equivalent to those on board the ISS (around 7.68 Kw/h), a voltage of around 0.001 V could produce a charge of 6.8 million Ah.

Considering an initial speed of 10,000 m/s, the amount of time that the crew would have to spend orbiting Jupiter in order to reach the speed of light is the following:

$$a = \frac{v_1 - v_0}{t}$$
$$\mathrm{t} = 300,000,000 - 10,000/39.2$$
$$\mathrm{t} = 7,652,806\mathrm{sec} = 2.9\mathrm{months}$$

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