Mach Effects
For
In-Space Propulsion

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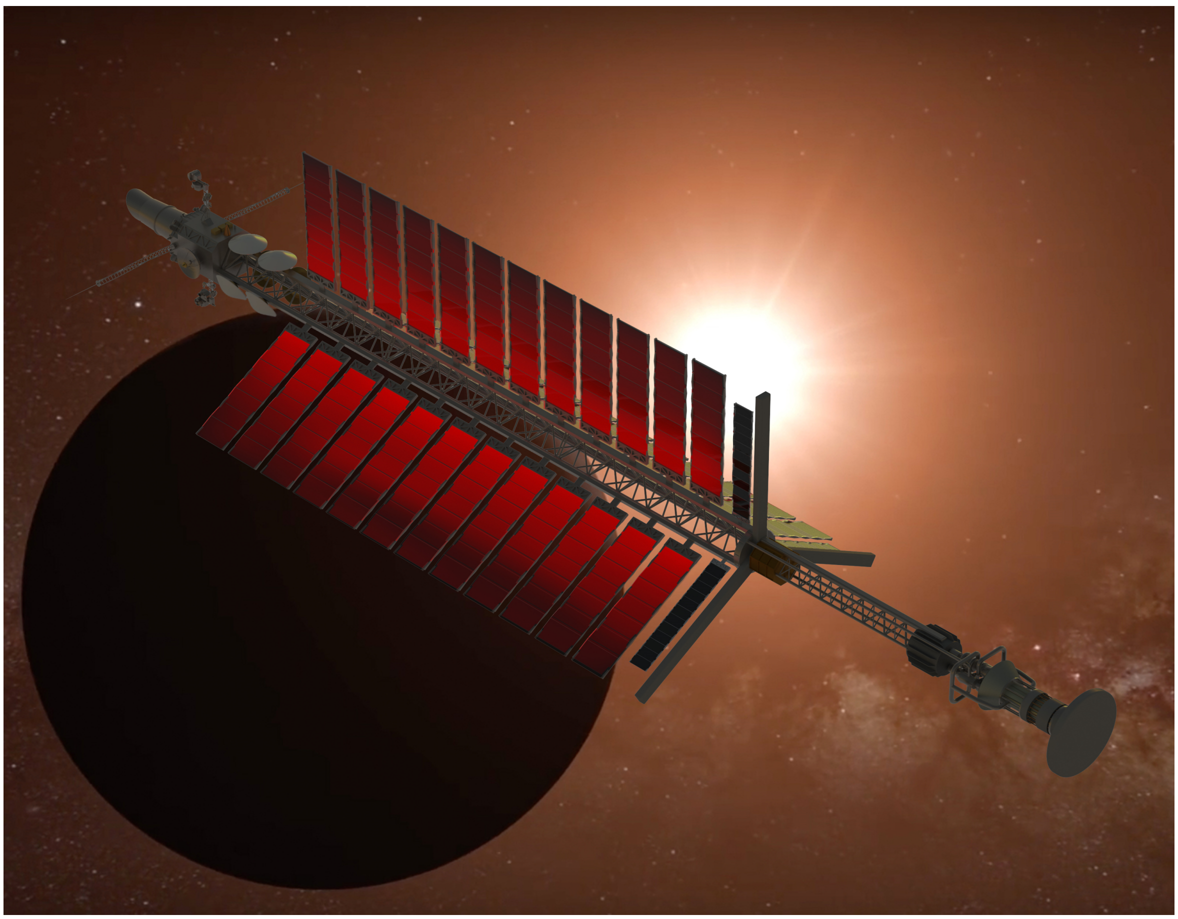

MEGA Drive Q & A

Q1. Does the MEGA drive during operation change mass, and if so, how much?

In our experiments using a device with an initial mass of 0.2 kg, the mass is calculated to fluctuate sinusoidally, at a frequency exceeding 30 kHz, with a zero to peak amplitude on the order of a Planck mass (the mass of a hypothetical black hole whose Schwarzschild radius equals the Planck length). This is a mass fluctuation per unit mass on the order of $\Delta m/m \sim 10^{-8}$.

The theoretical mass fluctuation is $\Delta m(t) = (1/(4\ \pi\ G\ \rho\ c^2))\ \partial^2 E/\partial\ t^2$, where:

> G= gravitational constant= $6.67408 \times 10^{-11}\ m^3\ /(kg\ s^2)$
> ρ = mass density (kg/m^3)
> c = speed of light in vacuum = 2.99792458×10^8 m/s

A mass fluctuation per unit mass on the order of 10^{-8} with a period of microseconds is a small variation in mass per unit time. It deserves further experimental and theoretical study. For comparison, here are some more commonly known mass changes:

(1) Combustion: decrease in mass due to combustion of methane in the gas burner of a kitchen stove: $\Delta m/m = -10^{-10}$.

(2) Change of phase: increase in mass due to melting of ice: $\Delta m/m = 3.7\text{x}10^{-12}$.

(3) Temperature change: increase in mass due to temperature increase of a flat iron by 200 K: $\Delta m/m = 10^{-12}$.

(4) Emission of solar power from our Sun: the rate at which the Sun emits energy from its surface (its luminosity), is around $3.8 \text{ x } 10^{26}$ Watts, therefore the rate at which solar mass disappears is=$4.2\text{x } 10^9$ kilograms per second. Since the total mass of the Sun is $2 \text{ x } 10^{30}$ kilograms, the change in mass of our Sun per 100 years is $\Delta m/m = 6.5\text{x}10^{-12}$.

(5) Strong nuclear force: due to the strong nuclear force, energy is required to separate a stable nucleus into its constituent protons and neutrons. The more stable the nucleus is, the greater is the amount of energy needed to break it apart (called the binding energy of the nucleus). For example, for deuterium (a stable isotope of hydrogen: the bound state of a proton and a neutron), the binding energy and hence the defect of mass is 2.2 MeV, so that $\Delta m/m = 10^{-3}$.

Q2. How does the MEGA drive move?

The minimum model of complexity to illustrate the rate of change of the center of momentum (relativistic) due to variable mass is a system of two masses m_1 and m_2 coupled by a spring k.

$$p_{COM} = \frac{\dfrac{m_1 \dot{x}_1}{\sqrt{1 - \dot{x}_1^2/c^2}} + \dfrac{m_2 \dot{x}_2}{\sqrt{1 - \dot{x}_2^2/c^2}}}{\dfrac{m_1}{\sqrt{1 - \dot{x}_1^2/c^2}} + \dfrac{m_2}{\sqrt{1 - \dot{x}_2^2/c^2}}}$$

A dashpot is also necessary for realistic modeling of the amplitude of vibration, but for simplicity, the rate of change of the **center of momentum** (COM) can be demonstrated without a damper. For this illustrative purposes the following assumptions are made:

(1) no damping
(2) very weak gravitational field
(3) uniform gravitational field with respect to the dimensions of the drive
(4) small spin and spin rates
(5) small strain

The positions of the masses from an arbitrary reference point are x_1 and x_2. Time differentiation is shown by the number of overdots (single overdot for the first derivative, etc.). Then, it can be shown that the rate of change of momentum is given by the first time derivative of the variable masses as follows:

$$\dot{p}_{COM} = \frac{\dfrac{\dot{m}_1 \dot{x}_1}{\sqrt{1 - \dot{x}_1^2/c^2}} + \dfrac{\dot{m}_2 \dot{x}_2}{\sqrt{1 - \dot{x}_2^2/c^2}}}{\dfrac{m_1}{\sqrt{1 - \dot{x}_1^2/c^2}} + \dfrac{m_2}{\sqrt{1 - \dot{x}_2^2/c^2}}} + \text{higher order terms}$$

Note that:

1. if the masses are constant, then the rate of change of momentum, of the COM, is zero;

2. if the masses are variable but equal, such that m_1=m_2, then the displacements, velocities and accelerations, due to oscillation of the masses at the natural frequency, (in reality the first eigenmode) are equal in magnitude but opposite in sign, and therefore the rate of change of momentum of the COM is zero; and,

3. to change the center of momentum it is needed to excite oscillations of unequal variable masses, their rates of change and their displacements and velocities, at two frequencies ω_1 and ω_2, with ω_2=2 ω_1. Multiplication of harmonic terms (the first

time derivative of the mass times the velocity all being harmonic functions of time) results in even terms having a non-zero time cycle average, for example: $\cos^2(\omega t) = ½ + \cos(2 \omega t)/2$. Conservation of momentum for a system of unequal masses with such a fluctuation in mass demands that the center of momentum must change with time.

Q3. Why hasn't this force shown up in experiments before now?

The force measured by experiment is due to both the piezoelectric and electrostriction effects. Piezoelecticity is only found in certain crystals in nature and is represented by a 3rd order tensor which is uncommon. There are two excitations involved the lowest 30kHz and the second at twice that frequency, which is not a common occurrence. The force measured in the current experiments is very small, microNewtons, and would be unlikely to be observed in work that was not focused on anomalous accelerations and anomalous forces.

One possible explanation, left to explore, is that the force maybe hidden by a chameleon field. A chameleon field is a massive scalar field (a "fifth force") following a Klein-Gordon equation with a field mass (and thus a group velocity and Compton wavelength) that depends on the local matter density. The chameleon field would have a Compton wavelength of order 0.1 mm or less in high density regions (such as within the Earth's atmosphere), enabling the theory to survive fifth force tests, but a much lower mass (and larger Compton wavelength) in the vacuum of space. In this theory, the chameleon field in a high-density region surrounded by a vacuum, is confined to a thin screen of order 1 micrometer in depth and thus with a high field gradient, on the surface of the massive body. The group velocity of the field in the various proposed theories would be 100's of meters per second on the surface of a massive body, and very close to the speed of light in deep space.

The test units in our experimental work, in the near vacuum of a test chamber, would have a thin screen and would be vibrating that screen at roughly the frequency ($\sim v_{group}/R$) of the first normal mode of chameleon radiation for the drive stack. These units should thus be efficient radiators of chameleon field radiation, converting acoustic oscillations to chameleon waves in a fashion analogous to how magnetoelectric antennas convert acoustic waves to electromagnetic waves. This chameleon radiation, with its low group velocity at the surface of the body, would carry away substantially more momentum per unit energy than would a photon rocket. (The wave frequency would substantially increase outside of the drive unit, but that does not change the momentum loss at the drive surface). This momentum change will cause a thrust, which should be even larger in deep space than in a vacuum chamber. In a confined vacuum chamber, it would be reasonable to expect standing chameleon waves to be set up inside the chamber, which may be detectable experimentally.

A literature search does not reveal any other search for fifth force or analogous effects at frequencies much larger than diurnal, roughly 9 orders of magnitude smaller than the 35 kHz used in our experimental work.

There is a lot of theoretical work as well as a few proposed experiments in this area (one of them is a 2017 Phase I NIAC grant by Dr. Nan Yu at JPL, "A direct probe of dark energy interactions with a solar system laboratory").

https://www.nasa.gov/directorates/spacetech/niac/2017_Phase_I_Phase_II/Dark_energy_interactions_solar_system_laboratory

Q4. Doesn't the explanation of Mach's Principle require information to propagate at greater than the speed of light if there is connection between local mass and the distant stars?

If the energy of stars 10^8 light years away were being fluctuated at consistent uniform frequencies ω and 2 ω, then the only way fluctuating stars billions of light years away would be able to affect immediately the mass of the device here, would be through a superposition of advanced and retarded waves. But what is being fluctuated in CSUF experiments is the self-energy of the device here, **at the same location as the mass of the device,** rather than 10^8 light years away. What fluctuates is the device's self-energy – it is a **self-interaction effect**. Therefore there is no need for propagation of information faster than the speed of light.

Q5. Why doesn't the MEGA drive result in free energy, and therefore used for energy generation?

The MEGA drive does not violate energy conservation. The kinetic energy comes from the gravitational field, not from the electrical power applied to the device. There is a large gravitational potential in the universe we are tapping into to gain kinetic energy of the device. If we take a small amount of energy, practically no loss will be noticed by the whole universe. There are far more efficient ways of extracting energy, for example, from nuclear or solar power. Trying to extract energy from gravitation via the Mach effect is very inefficient.

The benefit of Mach effect propulsion is to avoid carrying propellant for long space missions, particularly for interstellar missions.

Q6. Does the MEGA drive violate General Relativity?

No, the MEGA drive does not violate Einstein's general relativity.

The theory is based on Einstein's theory of gravitation. The mass change result can be obtained from general relativity.

The theory is Machian and fully consistent with Einstein's general relativity.

Q7. What natural systems might exhibit MEGA drive effects? Could these be observed, and how?

We have examined astronomical observations to see if they exhibited MEGA effects, which require two excitations (at frequencies f and 2f), but we haven't found anything yet. Such excitations do naturally occur in elliptical orbits (as one can ascertain from harmonic expansion). However, the naturally occurring frequencies (harmonics of the orbital periods) are not high enough to produce an observable effect. For example, the well-known binary pulsar PSR B1913+16 (also called the Hulse–Taylor binary after its discoverers) has an orbital period of 7.75 hours, and an eccentric orbit, resulting in totally unobservable orbital perturbations on the order of one part in 10^{30}.