Velocity Dependent Inertial Induction: Explanation of the Observed Anomalous Acceleration of Spacecraft

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An apparently anomalous, weak, long-range acceleration of the Pioneer 10/11, Galileo and Ulysses spacecraft has been reported recently. In this paper we show that this observation points to the existence of a velocity dependent inertial interaction which should be included in the theory of gravitation.

It has recently been reported [1] that the Pioneer 10, Pioneer 11, Galileo and Ulysses spacecraft show an anomalous systematic acceleration of approximately 8.5×10^{-8} cm/s^2, directed towards the sun. If some yet unmodelled force is responsible for producing the observed acceleration of the spacecraft, it is difficult to believe that it would not have any effect on other bodies in the solar system and would go unnoticed for so long. On the other hand, if such a force acts on Earth and Mars, the resulting acceleration would contradict the Viking ranging data. Therefore, what really demands an explanation is not the inferred acceleration, but the raw information behind the above observation Doppler data of the signals emitted by the spacecraft showing a frequency drift of -6×10^{-9} Hz s^{-1}. In this Letter we propose a mechanism that can produce the observed frequency drift in electromagnetic signals coming towards the sun.

This involves a slight modification of the Newtonian Law of gravitational interaction[2] so that the total force on a mass A due to a mass B can be expressed as:

$$\mathbf{F} = -\frac{Gm_A m_B}{r^2}\hat{\mathbf{u}}_r - \frac{Gm_A m_B}{c^2 r^2} v^2 f(\theta)\hat{\mathbf{u}}_r - \frac{Gm_A m_B}{c^2 r} af(\phi)\hat{\mathbf{u}}_r, \quad (1)$$

where m_A and m_B are the gravitational masses of A and B respectively, v and a are the magnitudes of the relative velocity and acceleration of A with respect to B, $\hat{\mathbf{u}}_r$ is the unit vector along $\mathbf{r}$, $f(\theta)$ and $f(\phi)$ (with $\cos\theta = \hat{\mathbf{u}}_r \cdot \hat{\mathbf{u}}_v$ and $\cos\phi = \hat{\mathbf{u}}_r \cdot \hat{\mathbf{u}}_a$) represent the inclination effects. $f(\theta)$ is assumed to be symmetric, satisfying the conditions (a) $f(\theta) = 1$ for $\theta = 0$, (b) $f(\theta) = -1$ for $\theta = \pi$, and (c) $f(\theta) = 0$ for $\theta = \pi/2$. $f(\phi)$ is assumed to have the same functional form as $f(\theta)$. The first term in (1) represents the "static" interaction of Newtonian gravitation, the second term represents a dynamic velocity dependent inertial induction and the third term represents an acceleration dependent inertial induction.

The direct effect of the velocity dependent term on the Pioneer 10 spacecraft (when it is at 25AU from the sun) can be estimated by putting $v = 12.5$ km/s, $GM_\odot/c^2 = 1.5$ km, $c = 3 \times 10^5$ km/s and 1 AU = 1.5×10^8 km. This gives the value of the additional acceleration as 1.66×10^{-12} cm/s^2, which is many orders of magnitude smaller than the reported anomalous acceleration. The effect of the acceleration dependent term is even smaller. Likewise, it can be shown that the effect of the additional terms on the motion of planets is also negligible.

It is known that gravity can cause frequency drift in electromagnetic radiation. This has been experimentally verified by means of Earth-based experiments [3,4]. We therefore assume that the frequency drift expected from Newtonian gravity is accounted for in the computer programs used in [1]. We now estimate the additional frequency drift due to the velocity dependent term in the gravitational law (1).

Suppose a photon of energy ε is coming from the Pioneer spacecraft towards the sun (Fig.1). Substituting $m_B = \varepsilon/c^2$ and $v = c$, we find that the signal will be subjected to an additional drag force of magnitude $(GM_\odot\varepsilon)/(r^2c^2)$ when the photon is at a distance r from the sun. When the photon travels a distance dr, the change in energy is given by

$$d\varepsilon = \frac{GM_\odot \varepsilon}{r^2 c^2} dr .$$

The solution of this differential equation is

$$\ln\left(\frac{\varepsilon_e}{\varepsilon_0}\right) = \frac{GM_\odot}{c^2}\left(\frac{1}{r_1} - \frac{1}{r_e}\right)$$

for signals coming from position P(t_1), where ε_0 is the energy of the photon at the source and ε_e is the energy on arrival at the Earth. We assume $r_e << r_1 < r_2$ so that the angle between the lines PE and PS is very small. Expressing the left hand side in terms of the frequency drift $\Delta\nu(t_1)$ and the emitted frequency ν_0, and after neglecting the higher order Taylor terms we obtain

$$\frac{\Delta\nu(t_1)}{\nu_0} = \frac{GM_\odot}{c^2}\left(\frac{1}{r_1} - \frac{1}{r_e}\right).$$

A similar expression is obtained when the spacecraft moves to position P(t_2). Thus when the spacecraft travels from P(t_1) to P(t_2), the drift in frequency as observed from Earth is given by

$$\Delta\nu(t_2) - \Delta\nu(t_1) = \nu_0 \frac{GM_\odot}{c^2}\left(\frac{1}{r_2} - \frac{1}{r_1}\right).$$

According to available data for Pioneer 10, the craft moved a radial distance from $r_1 = 40$ AU to $r_2 = 56.01$ AU over a period of 6 years from 1st January 1987 to 1st January 1993, and ν_0 was 2292 MHz. Substituting these values we get the rate of frequency drift as -8.875×10^{-10} Hz s^{-1}. We propose that this is one of the factors contributing to the observed frequency drift.

Moreover, the signal coming from the spacecraft has to graze past the sun for some part of the year. According to the conventional theory (both Newtonian and Einsteinian), no net redshift is expected when a photon grazes past a massive body. However, since the velocity dependent inertial

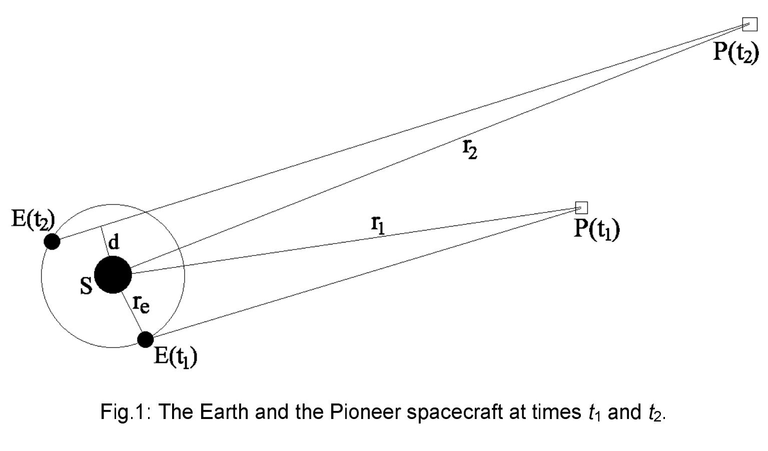

Fig.1: The Earth and the Pioneer spacecraft at times t_1 and t_2.

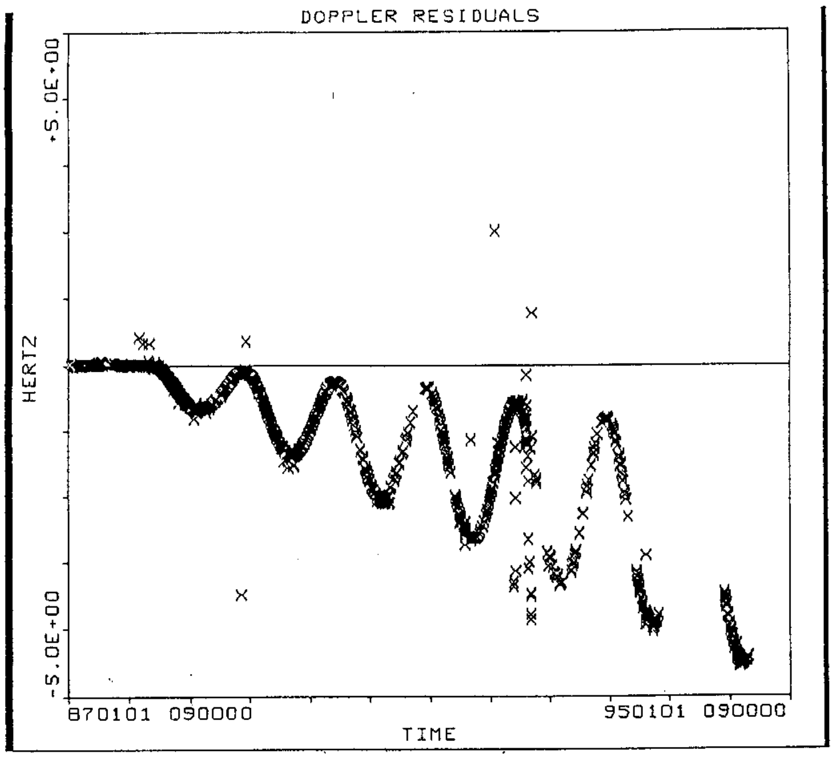

Fig. 2. Observed fluctuations in the frequency drift for Pioneer 10 (from Laing and Liu [5]).

induction is a drag, this effect will cause a photon to undergo a resultant redshift when it grazes past the sun. If the mass of the sun is assumed to be concentrated at its center, it can be shown that the fractional redshift is given by

$$z = \frac{\Delta\lambda}{\lambda} \approx \exp\left(\frac{4G_0 M_\odot}{3c^2 d}\right) - 1 \tag{2}$$

where d is the perpendicular distance of the center of the sun from the path of the photon.

This effect will cause an additional frequency drift which will have a yearly cycle. Calculation of the magnitude of this drift requires the value of d at various times of the year over the period of observation. This data not being available, we only point out that the theory of velocity dependent inertial induction predicts a frequency drift which is dependent on the distance of the spacecraft and the grazing distance. This has a steady component and a component with a periodic fluctuation with an annual cycle. It is interesting to note that such a yearly fluctuation in the frequency drift has indeed been observed [5] (see Fig. 2).

We therefore believe that the observed “anomalous acceleration” is due to a tired light effect which can be understood in the light of the theory of velocity dependent inertial induction.

We would like to point out that inclusion of the inertial induction terms in the gravitational law has many other consequences of astrophysical and cosmological significance [6]. First, it predicts a redshift higher than the conventional value GM/c^2r in the radiation emitted by a gravitating body, thus providing a quantitative explanation of the excess redshift at the solar limb and the discrepancy between the astrophysical mass and relativistic mass of white dwarfs. Second, it predicts a net redshift when photons graze massive objects, which explains the observed excess redshift of Taurus A near occultation position with the sun. Third, it anticipates a variation of G with distance as $G = G_o \exp[-(k/c)r]$, where $k = \sqrt{\chi G_o \rho}$, with $\chi = 0(\pi)$. Fourth, it explains why the gravitational mass of a body is the same as the inertial mass. Fifth, it requires that there be a small drag term proportional to v^2 associated with any movement of a particle [$\mathbf{F} = (k/c)mv^2\mathbf{u}_o - ma$]. Sixth, it predicts that photons moving over long distances in a steady state universe will be subjected to a cosmological redshift given by $z = \exp[(k/c)x] - 1$. This gives an analytical value of the Hubble constant: for $kz/ \ll 1$, we get $z \approx (k/c)x$, hence $V = kx$. Seventh, it provides a mechanism for the transfer of angular momentum from a central body to the orbiting objects and explains the transfer of solar angular momentum. The theory further predicts a secular retardation of Earth's spin at a rate of -5.5×10^{-22} rad s^{-2} (observed value is -6×10^{-22} rad s^{-2}), a secular acceleration of Phobos at a rate of $.46 \times 10^{-3}$ deg yr^{-2} (observed value is $.6 \times 10^{-3}$ deg yr^{-2}) and a secular retardation of the spin of Mars (which has not been measured as yet).

References

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Editor's note: The present paper is published here without full review in order to stimulate discussion of what would appear to be a very important development in experimental physics. Drs. Ghosh and Banerjee suggest a single explanation for the anomalous frequency drift. While their model seems plausible as a source of the annual fluctuation in the frequency drift, the energy depletion they propose is not consistent with the sign of the overall frequency residual.

NASA scientists believe the effect to be due either to an anomalous force acting to decelerate the spacecraft at a constant rate, or to a uniform slowing down of all (atomic) clocks. In the former case, the frequency drift is interpreted as a Doppler effect only. In the latter instance, however, an intrinsic change of frequency is posited, an effect which may take other forms (*e.g*., unilateral rather than global clock drift, energy gain by photons). That some factor other than an acceleration acting on the spacecraft is implicated in this phenomenon is strongly suggested by the rate of (clock) deceleration required to account for the anomalous frequency drift: -2.8×10^{-18} s/s^2. This factor is virtually identical in magnitude and of the same dimensions as a familiar constant of nature: the Hubble constant.

Readers of this journal will recall that a fundamental frequency of this magnitude has been discussed by many researchers in the past, some of whose work has been published in *Apeiron*. The appearance of the same unit of frequency in the context of local spacecraft kinematics is perhaps the first experimental confirmation that the Hubble constant has no role in a putative expansion of the universe, and is instead a constant of nature at the quantum level. It is my hope that *Apeiron* readers will be encouraged to investigate the physics behind this new experimental evidence.