The Solution of Flyby Anomaly

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Abstract
In this paper we shall explain the solution of the flyby anomaly basis on special relativity theory SRT is conformally invariant. We found the 4-dimensional conformal transformation can solve all the problems related to SRT and general relativity.

Theory
An empirical equation for the anomalous flyby velocity change was proposed by J. D. Anderson et al [1,6]

$$\frac{dV_\infty}{V_\infty} = \frac{2\omega_E R_E}{c} = \frac{1}{2}\frac{\Delta E}{E} = K(cos\delta_i - cos\delta_o) \qquad (1)$$

V_∞ is asymptotic velocity and dV_∞ is the asymptotic velocity difference between the incoming asymptotic velocity $V_{\infty i}$ and outgoing asymptotic velocity$V_{\infty o}$ of the spacecraft where they differed in magnitude not only by direction. δ_i andδ_o are the initial (ingoing) and final (outgoing) declination angles, analogous to Earth's latitude but measured on the celestial sphere; ω_E is Earth's angular velocity of rotation; R_E is its radius; and c is the speed of light.

$$K = \frac{2\omega_E R_E}{c} = 3.099 \times 10^{-8} \qquad (2)$$

Where $\omega_E = 7.292115 \times 10^{-5}\ Rad/s$ and $R_E = 6371\ km$ and c is the speed of light in vacuum.

In my paper [2,3] I derived the new 4-dimensional transformation equations

$$x' = \gamma^2(x - vt)$$
$$t' = \gamma^2\left(t - \frac{vx}{c^2}\right)$$
$$y' = \gamma y$$
$$z' = \gamma z$$

Where γ is the Lorentz factor, where

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Sagnac effect can be explained according to my transformations by considering the t-term in my transformations.

$$t' = \gamma^2\left(t - \frac{vx}{c^2}\right)$$

And by considering

$$t'^{-} = \gamma^2\left(t - \frac{vx}{c^2}\right)$$

And

$$t'^{+} = \gamma^2\left(t + \frac{vx}{c^2}\right)$$

From that we get the difference in time is given as

$$\Delta t = \gamma^2 \frac{2vx}{c^2} \qquad (3)$$

Now when we consider $x = ct$, from that we get

$$\Delta t = \gamma^2 \frac{2vct}{c^2}$$

Thus

$$\frac{\Delta t}{t} = \gamma^2 \frac{2v}{c}$$

Since in the case of low velocities comparing to the speed of light $\gamma^2 \approx 1$, from that we get

$$\frac{\Delta t}{t} = \frac{2v}{c} \qquad (4)$$

Which leads to eq. (2) by considering $v = \omega_E R_E$

Eq. (4) is used also in the case of Pioneer anomaly where in [5,6]

$$\frac{[\Delta v_{obs} - \Delta v_{model}]_{DSN}}{v_0} = \frac{2a_p t}{c} \qquad (5)$$

We can reach to eq.(5) by considering in eq. (4)

$$\frac{\Delta t}{t} = \frac{2\left({}^{v}/_{t}\right)t}{c}$$

Where $\left({}^{v}/_{t}\right)$ is the acceleration a_p and from that we get

$$\frac{\Delta t}{t} = \frac{2a_p t}{c}$$

And if we consider $t = {}^{r}/_{c}$, we get

$$\frac{\Delta t}{t} = \frac{2a_p r}{c^2} \qquad (6)$$

In my solution of the Pioneer anomaly [4] r is the distance of the spacecraft from the Sun and from that I got

$$a_p = -\frac{GM}{r^2} \frac{\sqrt{\frac{2GM}{r}}}{c} \qquad (7)$$

Now by considering $G = 6.67 \times 10^{-11} m^3/kg.s^2$, $M = 1.99 \times 10^{30} Kg$ are respectively the gravitational constant and the mass of the Sun. Nasa data [13] show that in the very middle part (1983-1990) of the whole observation period of Pioneer 10, its radial distance from the Sun changes from $r \cong 28.8\ AU = 4.31 \times 10^{12} m$ to $r \cong 48.1\ AU = 7.2 \times 10^{12} m$. Thus by computing a_p from eq. (7), we get the Pionner anomaly $a_{p10} = -1.8 \times 10^{-10} m/s^2$ and $a_{p10} = -0.52 \times 10^{-10} m/s^2$. We have seen that the deceleration of the pioneer 10 anomalies is decreased depending on the distance from the Sun as from eq. (7) according to my transformation, and that what is causing the varying behavior of the Pioneer anomalies according to Turyshev [13]. According to the period of observation 7 years from (1983-1990) as noted by Anderson [11], we find for the Pioneer 10 $\dot{a}_{p10}$ is given as

$$\dot{a}_{p10} = \frac{0.52 \times 10^{-10} - 1.8 \times 10^{-10}}{7} = -1.8 \times 10^{-11}\ m/s^2.year$$

Markwardt [8] obtained an improved fit of Pioneer 10 data when estimating a jerk of $\dot{a}_{p10} = -1.8 \times 10^{-11}\ m/s^2.year$ which is exactly same as in my calculations. Also Toth [9] obtained $\dot{a}_{p10} = -2.1 \times 10^{-11}\ m/s^2.year$ which is in full agreement with my calculations.
Now there is another term must be added to the Pioneer anomaly in eq. (7). This term is related to the Hubble's law. We have from Hubble's law this acceleration is given according to the equation

$$a_H = -Hc \tag{8}$$

Where H is the Hubble's constant. An estimate of the Hubble constant, which used a new infrared camera on the Hubble Space Telescope (HST) to measure the distance and redshift for a collection of astronomical objects, gives a value of H= 73.8 ± 2.4 (km/s)/Mpc or about H = 73.8 ± 2.4 $(km/s)/Mp$ [10]. Where a_H is the deceleration is caused by the Hubble Law, where is this case since the spacecraft is going far away from the Sun, in this case it is observed for an observer on ground, there is a slight blue-shift given according to the Eqs. (7)&(8). According to that we get the full Pioneer anomaly is given according to

$$a = -Hc - \frac{GM}{r^2}\frac{\sqrt{\frac{2GM}{r}}}{c} \tag{9}$$

Figure (2) illustrates the predicted Pioneer 10 anomaly versus distance from the Sun according to eq.(9).

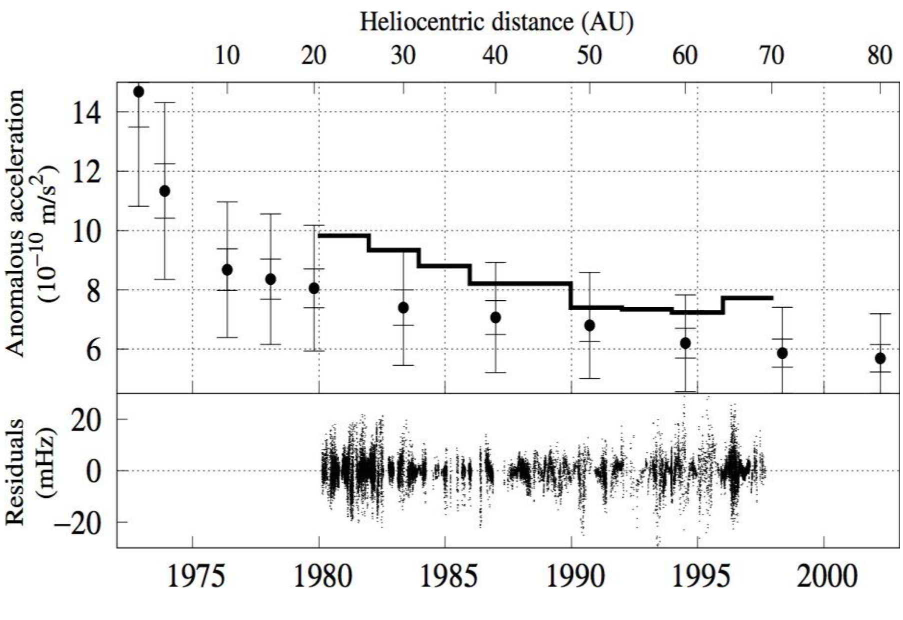

Fig. (1): Comparison of the thermally induced and anomalous accelerations for Pioneer 10. The estimated thermal acceleration is shown with error bars [7]

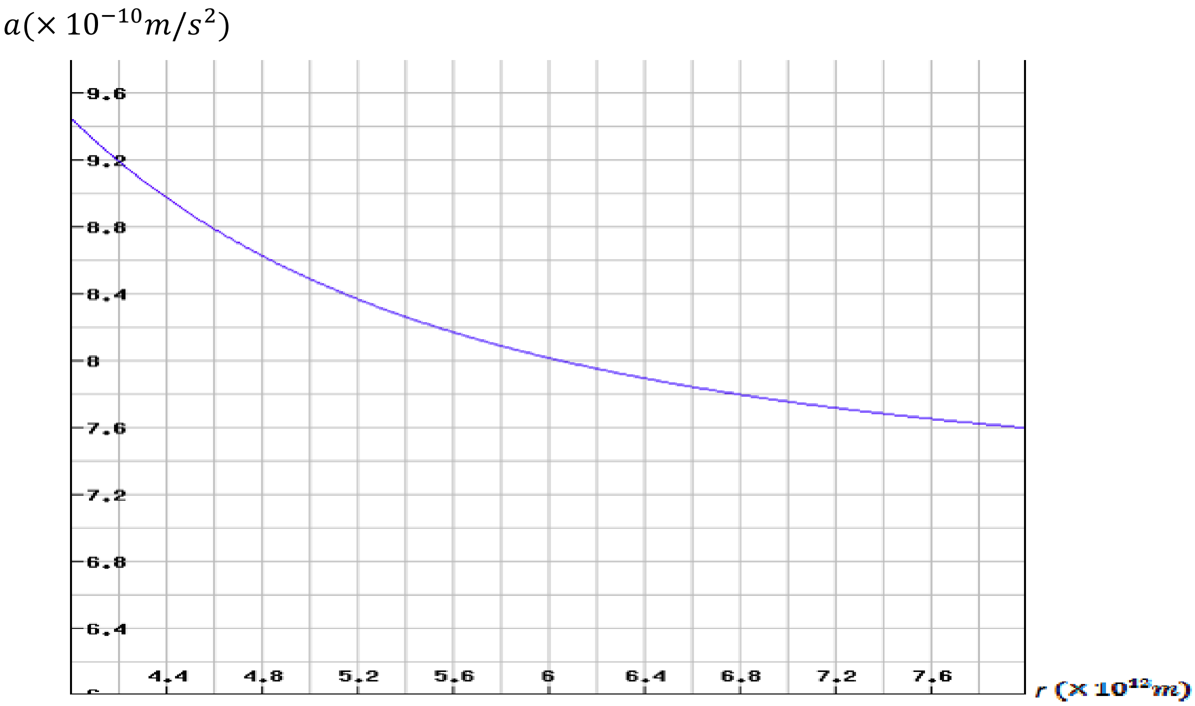

Fig. (2), the predicted Pioneer 10 anomaly versus distance from the Sun according to my solution.

References

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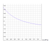
$$H = 73.8 \pm 2.4\ (km/s)/Mpc, \qquad a_p = Hc + \frac{\sqrt{2}}{rc}(GM/r)^{3/2}$$

$a_{10}(\times 10^{-10}\ m/s^2)$,



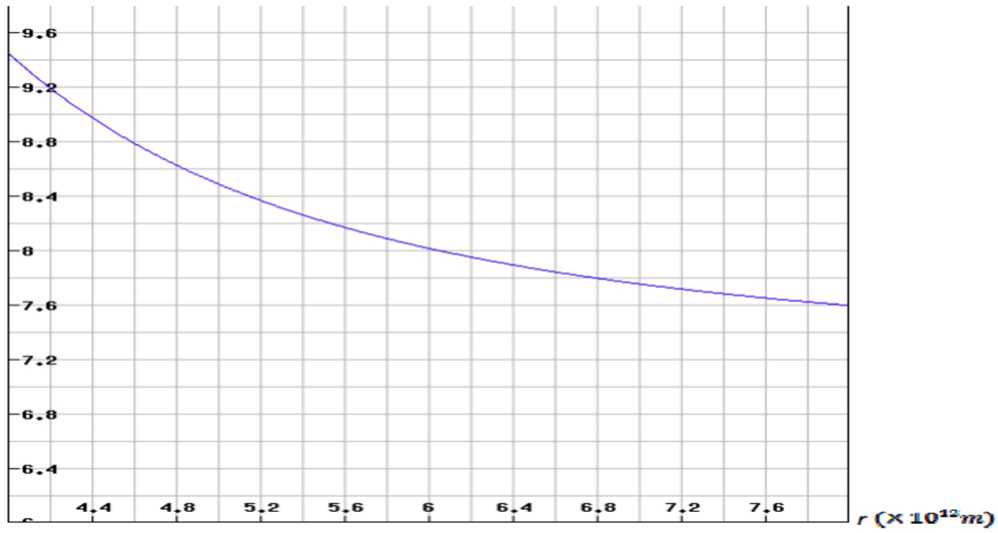


Fig. (3), the predicted Pioneer 10 anomaly versus distance from the Sun according to my solution.