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Relativistic Flyby Anomaly

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We found that the flyby anomaly of the earth orbits of satellites can be explained by a relativistic correction from The Unified Absolute Relativity Theory:

http://www.wbabin.net/saraiva/saraiva93.pdf

This anomaly consists of an increase of the speed of the satellites during earth flybys, that can't be explained with Newton's physics. As the Einstein's general relativity theory doesn't predict this correction, it is a proof that supports our theory.

Orbital motion equation from UART

$$a(1-\varepsilon^2)\frac{du}{d\theta} = \frac{3GM\theta}{c^2 a(1-\varepsilon^2)} - \theta + \frac{3GM\varepsilon\sin\theta}{c^2 a(1-\varepsilon^2)} - \varepsilon\sin\theta + 1 + C_1$$

As $\dfrac{du}{d\theta} = \dfrac{-\varepsilon\sin\theta}{a(1-\varepsilon^2)}$ and doing: $C_1 = -1$ ⇔

$$\Delta\theta = \frac{3GM\theta}{c^2 a(1-\varepsilon^2)} + \frac{3GM\varepsilon\sin\theta}{c^2 a(1-\varepsilon^2)}$$

a = major semi axis; ε = eccentricity; M = mass;

G = gravitational constant; c = light speed; θ = angle

The first correction is the geodetic effect or the perihelion precession correction. The two effects are the same.

The gravitomagnetism doesn't exist.

The second correction is the flyby anomaly. As we see the effect cancels for a complete orbit.

Mercury's Perihelion Precession

$$\Delta\theta = \frac{3GM\theta}{c^2 a(1-\varepsilon^2)} \quad ; \quad \text{For one orbit } \theta = 2\pi$$

$$\Delta\theta = \frac{6\pi.GM}{c^2 a(1-\varepsilon^2)}$$

$M = 2\times10^{30}\,kg$; $a = 5.8\times10^{10}\,m$; $\varepsilon = 0.2056$

$$\Delta\theta = 5\times10^{-7} \text{ radians/revolution}$$

The value of the shift in seconds per one hundred years is:

$$\alpha = \Delta\theta\frac{180}{\pi}3600\frac{1}{0.2408}100 \quad ; \quad 0.2408 = \text{ Revolution period in years}$$

$$\alpha = 42.94 \text{ arc seconds (The same value as Einstein)}$$

Geodetic Effect

$$\Delta\theta = \frac{6\pi.GM}{c^2 a(1-\varepsilon^2)}$$

$\varepsilon = 0.0014$; $a = 7\times10^{6}$; $M = 6\times10^{24}$; $T = 9.27\times10^{-5}$ years

$$\alpha = \Delta\theta\frac{180\times3600}{\pi.T}$$

$$\alpha = 26.6 \text{ arc seconds/year}$$

The Einstein value is $\alpha = 6.6$ $\qquad \frac{26.6}{6.6} = 4$

Flyby Anomaly

$$\Delta\theta = \frac{3GM\varepsilon\sin\theta}{c^2 a(1-\varepsilon^2)}$$

For $\theta = 2\pi \quad \Leftrightarrow \quad \Delta\theta = 0$

The effect cancels for a complete orbit.

Earth Flyby Data

Mission	Date	a (m)	ε	Δv (m/s)
Galileo	Dec90	5×10^{6}	2.47	3.92×10^{-3}
Near	Jan98	8.57×10^{6}	1.81	13.46×10^{-3}
Cassini	Aug99	1.58×10^{6}	5.8	1.1×10^{-4}
Rosetta	Mar05	2.55×10^{7}	1.33	1.82×10^{-3}

Angle for the maximum Δv

Orbital speed: $v = \sqrt{GM\left(\frac{2}{R}+\frac{1}{a}\right)}$ and $v = v\sin\theta$

$$R = \frac{a(1-\varepsilon^2)}{1+\varepsilon\cos\theta} \quad \Leftrightarrow$$

$$v = \sqrt{\frac{GM}{a(1-\varepsilon^2)}}\sqrt{3-\varepsilon^2+2\varepsilon\cos\theta}\,\sin\theta$$

$$\frac{dv}{d\theta} = 0 \quad \Leftrightarrow \quad \cos\theta = \frac{\varepsilon^2 - 3 \pm \sqrt{(3-\varepsilon^2)^2 + 12\varepsilon^2}}{6\varepsilon}$$

Galileo

$$\theta = 0.603537 rad$$

$$\Delta R = a(1-\varepsilon^2)\frac{\varepsilon \sin\theta}{(1+\varepsilon\cos\theta)^2}\Delta\theta \quad \text{and} \quad \Delta\theta = \frac{3GM\varepsilon\sin\theta}{c^2 a(1-\varepsilon^2)}$$

$$\Delta R = 2.85 \times 10^{-3} \quad ; \quad \Delta v = 3.92 \times 10^{-3}$$

The variation of R and Δv is along the same direction, and there's a direct relation between them:

$$\Delta v = \frac{\Delta R}{t}$$

We don't know how to derive the value of the time or period t.

For Galileo: $t = 0.7277$

Near

$$\theta = 0.923 \; ; \quad \Delta R = 6.36 \times 10^{-3}$$

$$t = 0.472$$

Cassini

$$\theta = 1.7441 \quad \Leftrightarrow \quad t = 26.6$$

Rosetta

$$\theta = 1.11 \quad \Leftrightarrow \quad t = 4.1$$

For Galileo and Near we found the relation:

$$t = \frac{\sqrt{a^3 / GM}.\varepsilon^4}{28000}$$

For Cassini and Rosetta:

$$t = \frac{\sqrt{a^3 / GM}.\varepsilon^4}{4300} \quad ; \qquad \frac{28000}{4300} = 2\pi$$

But the value of t must be derived.

We also think that the Pioneer anomaly is a flyby effect from the Sun, where the angle is almost 180 degrees.