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A NEO-NEWTONIAN EXPLANATION OF THE PIONEER ANOMALY

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RESUMEN

Por más de 20 años la NASA ha buscado una explicación a una aceleración débil de origen desconocido hacia el sol ($\approx 8.5 \times 10^{-10}$ m s^{-2}), detectada por las sondas espaciales Pioneer 10, 11, Galileo and Ulysses (Anderson et al. 1998, 1999; Katz 1999). No hay una explicación de consenso sobre el origen de esta anomalía, lo cual puede ser indicativo de la necesidad de nueva física para explicarla. El problema se puede entender si suponemos que c, la velocidad de la luz, no es una constante universal. Utilizando mecánica newtoniana, conjuntamente con la hipótesis de Céspedes-Curé (2002) de que el índice de refracción es una función de la densidad de energía gravitacional del espacio, se obtienen valores de c ligeramente superiores en regiones del espacio interestelar lejanas al sol, tierra y luna, dominadas por la densidad de energía ρ_* debida a estrellas lejanas y galaxias. El valor derivado del índice de refracción del espacio ($n' < 1$) implica un desplazamiento Doppler de las radio señales enviadas por las sondas que resulta en la disminución de la frecuencia recibida en la tierra e interpretada como una leve aceleración hacia el sol.

ABSTRACT

For over 20 years NASA has struggled to find an explanation for the Pioneer anomaly, an unmodelled weak acceleration towards the sun ($\approx 8.5 \times 10^{-10}$ m s^{-2}), observed in deep space probes Pioneer 10, 11, Galileo and Ulysses (Anderson et al. 1998, 1999; Katz 1999). No consensus explanation has been given since the anomaly was first announced, suggesting that new physics is involved. The riddle may be solved if we assume that c, the speed of light, is not a universal constant. Newtonian mechanics, together with the hypothesis by Céspedes-Curé (2002) that the index of refraction is a function of the gravitational energy density of space, leads to values of c slightly higher for interstellar space dominated by the primordial energy density ρ_* due to galaxies and far away stars, far from the gravitational influence of Earth, Moon, and Sun. The value derived for the index of refraction of space ($n' < 1$), implies a Doppler shift of the radio signal received from the probes which results in a decrease of the frequency received at Earth and interpreted as a weak acceleration towards the Sun.

Key Words: relativity

1. INTRODUCTION

NASA measures the speed of the Pioneer spacecraft by beaming a radio signal of frequency f_e = 2.295 GHz. The spacecraft receives and accurately divides the signal and retransmits it back. The accurately divided beamed frequency is compared to the received signal. The frequency shift

$$\Delta f = f_e - f_r = f_e(\frac{2v}{c}), \tag{1}$$

due to the Doppler effect is used to calculate the spacecraft speed v. The drift of the frequency shift gives the acceleration and the "excess Doppler drift" $E_D = (5.99 \pm 0.01) \times 10^{-9}$ Hz s^{-1}, obtained after subtracting the modelled gravitational force from the Pioneer 10 spacecraft (Anderson et al. 1998) and expressed as an acceleration (8.5×10^{-10} m s^{-2}) is the measured "anomaly".

The total energy density in the proximity of the Sun (at the surface of the Earth),

$$\rho = \rho_* + \rho_\odot + \rho_\oplus, \tag{2}$$

depends on the energy density ρ_* due to far away stars and galaxies, on the energy density due to the sun at 1 AU, $\rho_\odot$, and to the earth

$$\rho_\oplus = \frac{GM^2}{8\pi r^4}. \tag{3}$$

Following Céspedes-Curé's hypothesis that the speed of light is a function of the energy density of space

$$c' = \frac{k}{\sqrt{\rho_* + \rho_\odot + \rho_\oplus}}, \tag{4}$$

it can be seen this phenomenon affects the frequency shift detected from the Pioneer spacecraft. The in-

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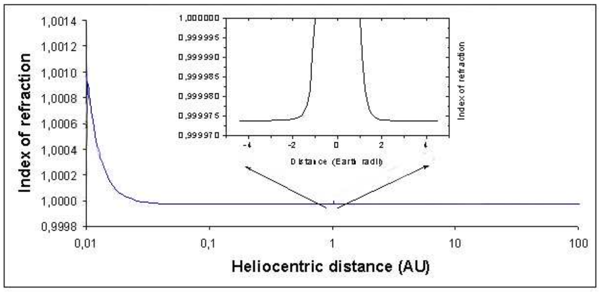

Fig. 1. Index of refraction n' as a function of the heliocentric distance. The small extent of this variation suggests that very accurate measurements are needed to verify this fundamental phenomenon.

dex of refraction of free space which is then given by

$$n' = c/c' = \frac{\sqrt{\rho_* + \rho_{\odot far} + \rho_{\oplus far}}}{\sqrt{\rho_* + \rho_\odot + \rho_\oplus}}, \quad (5)$$

from which we solve for

$$\rho_* = \frac{(\rho_{\odot far} + \rho_{\oplus far} - n'^2(\rho_\odot + \rho_\oplus))}{(n'^2 - 1)}. \quad (6)$$

These relations were used by Céspedes-Curé to obtain a value for ρ_* and an accurate Newtonian explanation of starlight deflection during eclipses. The excess Doppler shift E_D due to the effect of the energy density of space, calculated as

$$E_D = \frac{(2f_e G)}{c}(\frac{M_\odot}{r_\odot^2} + \frac{M_\oplus}{r_\oplus^2})(1 - n'), \quad (7)$$

is interpreted by NASA as an anomalous acceleration towards the Sun. However, it can also be due to the effect on the Doppler shift of the slightly higher speed of light c' in the interstellar medium as compared with the speed of light c on Earth. The anomalous acceleration is then (Greaves 2007)

$$a = G(\frac{M_\odot}{r_\odot^2} + \frac{M_\oplus}{r_\oplus^2})(1 - n'). \quad (8)$$

Examination of these relations shows that the only unknown parameter is ρ_*, the primordial energy density of space due to the stars and far away galaxies. Hence we should be able to predict the magnitude of the Pioneer anomaly with ρ_* as a single adjustable parameter. Alternatively, using one of NASA most accurately measured Pioneer anomaly values we are able to derive a value for the energy density $\rho_* = 1.0838 \times 10^{15}$ joules m^{-3} due to far away stars and galaxies, which differs in less than 1% from the value derived by Céspedes-Curé, $\rho_* = 1.09429 \times 10^{15}$ joules m^{-3}, using the bending of starlight during solar eclipses. Figure 1 shows the value of the index of refraction n' as a function of the heliocentric distance. The small extent of this variation suggests that very accurate measurements are needed to verify this fundamental phenomenon.

2. DISCUSSION

This work discusses experimental support to the hypothesis advanced by Céspedes-Curé (2002) and earlier by Einstein (1911) that the propagation of light depends on the gravitational energy density of space and that c is not quite a universal constant.

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