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Light Dispersion in the Interstellar Medium and Pulsar Distance

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Abstract – Light dispersion in the interstellar medium of our galaxy, allow us to know the exact distance of Pulsars and other variable emission objects by measuring the time delay between light of different frequencies.

From Lorentz's equations:

$$\begin{cases} x = \dfrac{x_0 + vt_0}{\sqrt{1 - v^2/c^2}} \\ t = \dfrac{t_0 + vx_0/c^2}{\sqrt{1 - v^2/c^2}} \end{cases} \quad \Leftrightarrow$$

$$\Leftrightarrow \qquad c^2t^2 - x^2 = c^2{t_0}^2 - {x_0}^2$$

For n relative frames:

$$c^2{t_1}^2 - {x_1}^2 = c^2{t_2}^2 - {x_2}^2 = \bullet\bullet\bullet = c^2{t_n}^2 - {x_n}^2 \qquad \Leftrightarrow$$

$$\Leftrightarrow \qquad c^2{t_n}^2 - {x_n}^2 = k \qquad \text{(Constant)}$$

t and x are the period and wavelength of a light wave, and k must be different from zero since we know that light speed in the vacuum of our galaxy is variable with frequency due to the existence of free electrons. c is light speed in a perfect vacuum.

Doing the propagation speed equal to:

$$w = \frac{x}{t} \qquad \text{and the frequency:} \qquad f = \frac{1}{t}$$

We get the general propagation speed formula:

$$w = \pm\sqrt{c^2 - kf^2}$$

The dispersion time delay between two different frequencies along the distance D is:

$$\Delta t = D\left(\frac{1}{w_A} - \frac{1}{w_B}\right) \qquad \Leftrightarrow$$

$$\Leftrightarrow \qquad \Delta t = \pm \frac{Dk\left(f_B^{\,2} - f_A^{\,2}\right)}{2c^3}$$

The distance of the Pulsar is:

$$D = \frac{2c^3\left|\Delta t\right|}{k\left|f_B^{\,2} - f_A^{\,2}\right|}$$

If f is the average frequency and B the bandwidth in Hertz, the distance in meter is (all S.I. units):

$$D = \frac{c^3 \Delta t}{kBf}$$

According with the data analysis we have done for a great number of Pulsars we found the relation:

$$kf^{3.7} = 3.7 \times 10^{20} \qquad \text{, so:}$$

$$D = 7.3 \times 10^4 \frac{\Delta t f^e}{B} \qquad ; \qquad (e = 2.71828)$$

This is the exact formula of the distance of a Pulsar or a variable star in our galaxy. The interstellar medium seems to be almost uniform. Outside our galaxy this formula is not correct.