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Abstract

Minkowski spacetime parallax uses the shifting plane of simultaneity (POS), of an accelerating inertial reference frame (IRF), while referencing a distant signal (such as a pulsar) with regularly recurring intervals. The distance of the signal's source can be derived from the Lorentz transfer equations, and the rate which the intervals are changing, due to the shifting (POS) during acceleration. The advantage of this method of measuring distance is that: Per the Lorentz transfer equations, time displacement actually increases with distance x, so using time displacement as a parallax to triangulate vast distances (approaching the cosmic microwave background) becomes feasible. The Time Dependent Hubble Parameter can be approximated, using this method. Such a method of measurement is well justified, as an alternative to conventional methods of redshift spectroscopy surveys, or CMB temperature fluctuations, with the intent of resolving the lingering "Hubble Tension".

Keywords Special Relativity · Astronomy: distance measure · Hubble Parameter · Minkowski spacetime

1 Introduction

Proposing an alternate method of measuring galactic distances is well justified, when considering that the discrepancy between the two current standard methods of determining the Hubble constant (Ho) is greater than 5%, which is equivalent to about three standard deviations. Using visible spectra redshifting of cepheid variables, the most recent calculation is $Ho = 74.03 \pm 1.42 km/sec/Mpc$ [1]. However, measurements using temperature fluctuations in the Cosmic Microwave Background (CMB) are calculated to be $Ho = 68.7 \pm 1.3 km/sec/Mpc$ [2]. Observed discrepancies between such methods might reveal insights into the nature of the dark energy used in the standard model of cosmology.

2 An Intuitive Description of this Method of Measurement

Measurement of distance involving spacetime displacement, is analogous to classic stellar parallax measurements of nearby objects [3], in which d is triangulated using the Earth's orbit mean radius of 1AU. See figure 1

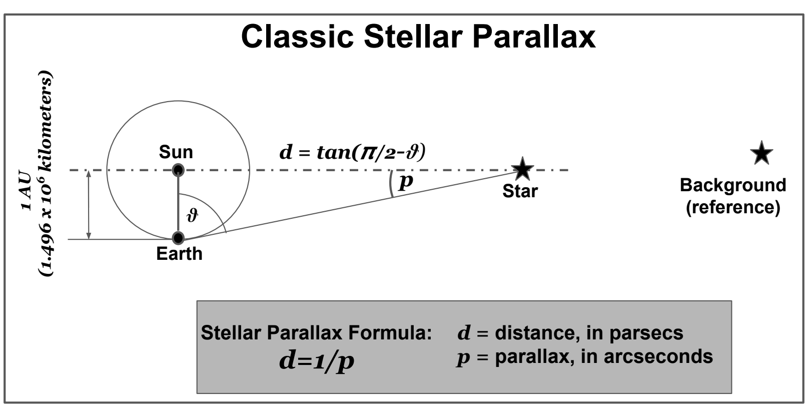

Figure 1: Classic Stellar Parallax measurement

$$d = \tan(\pi/2 - \theta) \quad (1)$$

The standard unit of distance, 1 parsec is equal to the parallax displacement of angle p, in arcseconds,

$$d_(parsecs) = 1/p \quad (2)$$

Minkowski Spacetime Parallax

Minkowski spacetime parallax uses the shifting plane of simultaneity (POS), of an accelerating inertial reference frame (IRF), while referencing a distant signal (such as a pulsar) with regularly recurring intervals. The distance of the signal's source can be derived from the Lorentz transfer equations, and the rate which the intervals are changing, due to the shifting (POS) during acceleration.

Figure 2 describes spacetime displacement, from the inertial reference frame (IRF) of stationary observer S, with respect to accelerating observer S'. The spacetime displacement of S' is indirectly measured by recording pulsar flash periods T **during acceleration** from velocity $v = 0$ to final velocity v_{fin}. Note that the (POS) is pivoting, during acceleration.

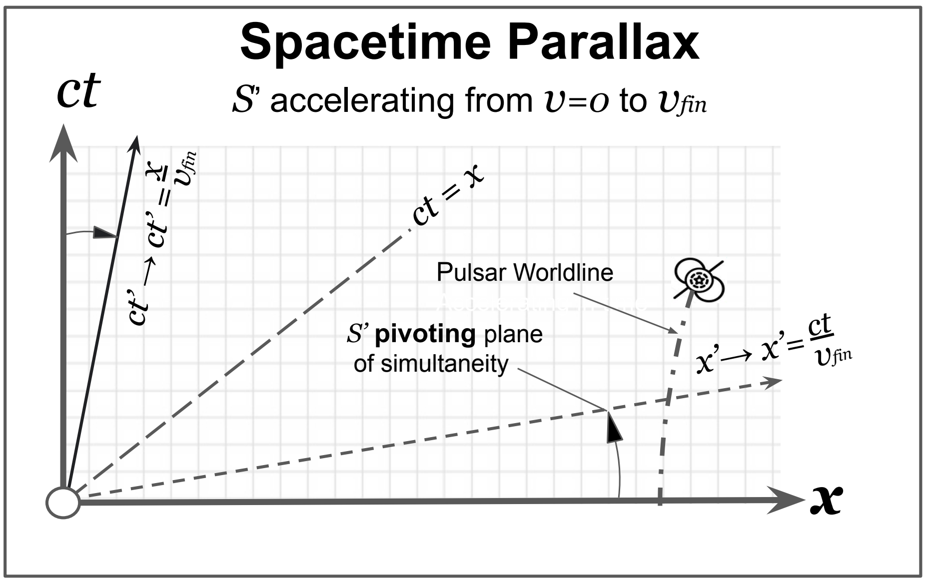

Figure 2: Spacetime Diagram

3 How the Summation of Pulsar Flashes, With respect to an Accelerating Observer, can Represent Years of Spacetime Displacement.

Figure 3 (left side) describes how detected average pulse periods T_{det} increase over time, during S' acceleration, as S' plane of simultaneity sweeps across n years of the pulsar worldline [4] .

Figure 3 (right side), shows S' pivoting plane of simultaneity, during acceleration from $v = 0$ to final velocity v_{fin}. In this example S' summed total pulsar flashes $|A'|$ represents 5 $years$ of displaced spacetime Δt. **Thus, the accelerating observer's pulsar sum $|A'|$ could be several orders of magnitude greater than the stationary observer's pulsar sum $|A|$.**

Note: T_{det} is actually a net result of combined S' acceleration, and pulsar recession velocity v_{pulsar} (which expands similar to redshifting).

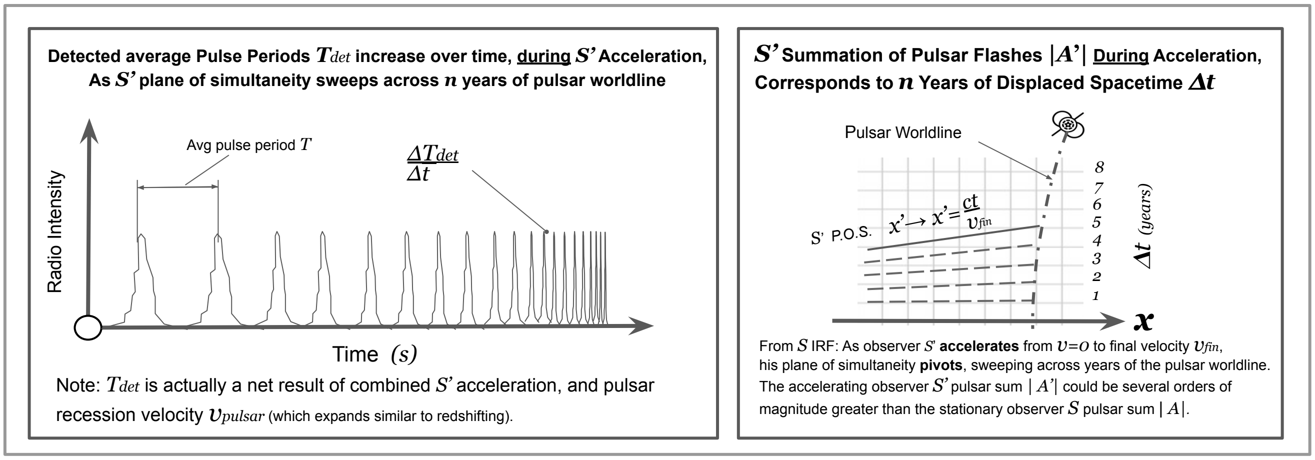

Figure 3: Left: Increasing pulsar periods. Right: Pivoting plane of simultaneity represents n years of displaced spacetime

Equation for Time Displacement

Figure 4 shows that displacement in time Δt_{pulsar}, along x', is calculated from the difference of the accelerating observer S' summed flashes $|A'|$, and the stationary observer S summed pulsar flashes $|A|$, divided by the initial pulsar period T_0

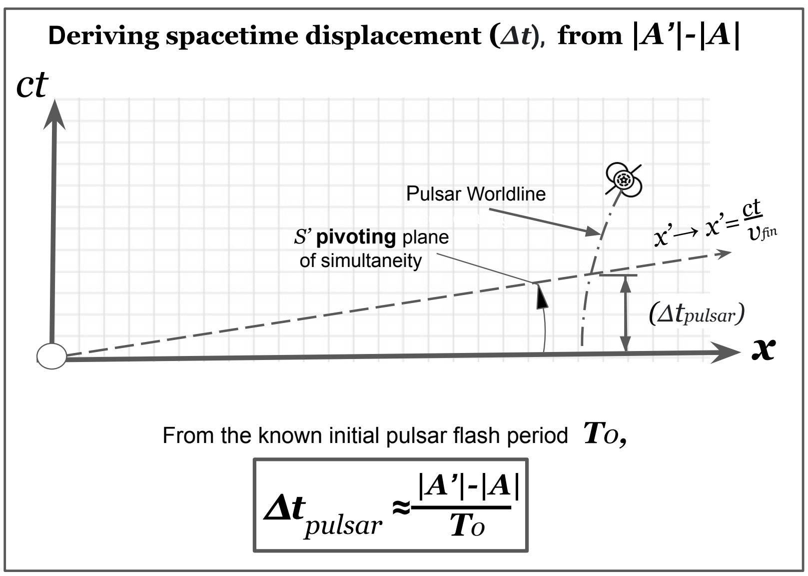

Figure 4: Deriving spacetime displacement from pulsar flashes in both IRF

With respect to S' IRF, $|A'|$ is summed empirically during acceleration, from his time $t' = 0$ to $t' = t'_{fin}$ (at final velocity), as his POS pivots across n years of pulsar world line,

$$|A'| = \sum_{i=1}^{n} 1(flash) \tag{3}$$

With respect to S IRF, $|A|$ can simply be calculated, from his time period $t = 0$ to t_{fin}, and the initial period T_0 as,

$$|A| = \frac{t_{fin} - t_0}{T_0} \tag{4}$$

Where t_{fin} is determined by the reverse Lorentz time transformation equation [5],

$$t_{fin} = \frac{t'_{fin} + \frac{vx'}{c^2}}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{5}$$

Thus, time displacement Δt is the difference between S' summation of $|A'|$, and S summation of $|A|$, over the known pulsar initial period (T_0),

$$\Delta t = \frac{|A'| - |A|}{T_0} \tag{6}$$

4 How pulsar distance can be triangulated from spacetime displacement and simultaneity plane slope.

From S IRF: Figure 5 describes how pulsar distance x_S can then be triangulated from the slope of S' plane of simultaneity (at final velocity v_{fin}) and the spacetime displacement Δt.

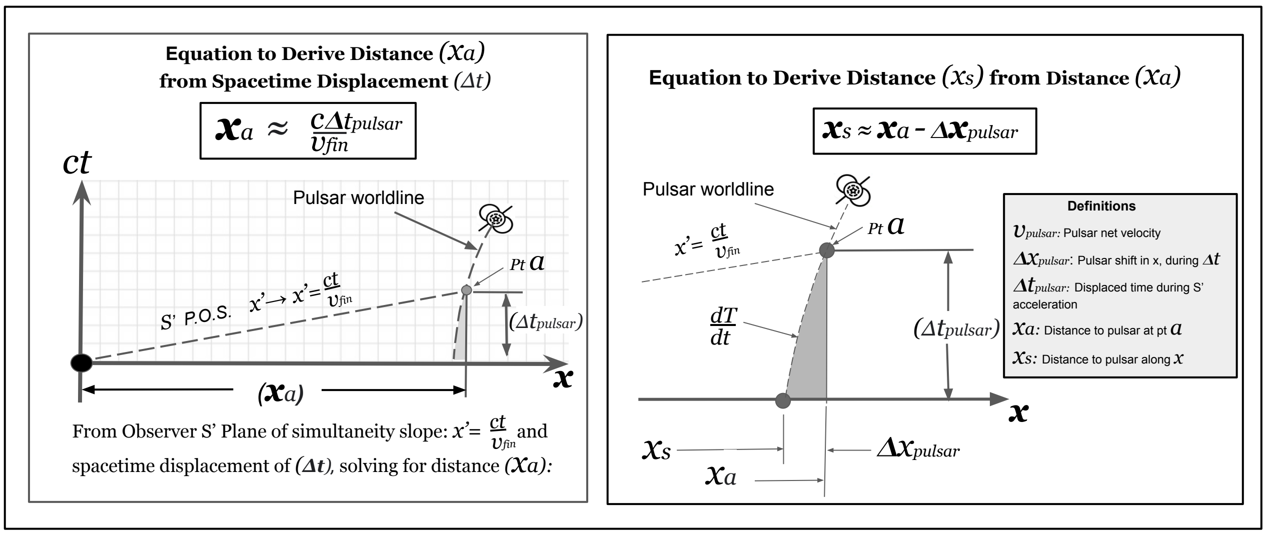

Figure 5: Deriving distance x_a from time displacement Δt_{pulsar}

As observer S' worldline accelerates to velocity v_{fin}, his plane of simultaneity pivots to a slope of:

$$x' = \frac{ct}{v_{fin}} \tag{7}$$

Substituting Δt for t, and solving for x_a,

$$x_a \approx \frac{c\Delta t_{pulsar}}{v_{fin}} \tag{8}$$

Thus, Δt_{pulsar} increases with distance x_a. Greater distances of x_a require less acceleration to triangulate.

Note that this method has a clear advantage in measurements of very remote distances, approaching the Cosmic Microwave Background (CMB).

Determining Pulsar Distance X_S, with Respect to S IRF, from Establish Distance X_a, at pt a

Equation 8 establishes distance x_a, which is the distance at point a, along x, to the pulsar in n years of time displacement Δt. However, the objective is to derive x_s, which is the measurement of the pulsar, along x, from S IRF (See figure 5, right image). In order to do so, we must subtract distance Δx_{pulsar}, which is the distance the pulsar increases over displaced time Δt, along x, from S IRF,

$$x_s \approx x_a - \Delta x_{pulsar} \tag{9}$$

Integrating Distance v_{pulsar} from Expanding Periods T_{det}

Figure 6 shows how to calculate Δx_{pulsar} by subtracting S' distance (x_{fin}) from the integration of detected periods (T_{det}), as T_{det} is a sum of both velocities ($S' + T$), during S' acceleration. Note: Although changing pulsar periods T over time are in fact discrete, they are so minute as to be considered $\frac{dT}{dt}$.

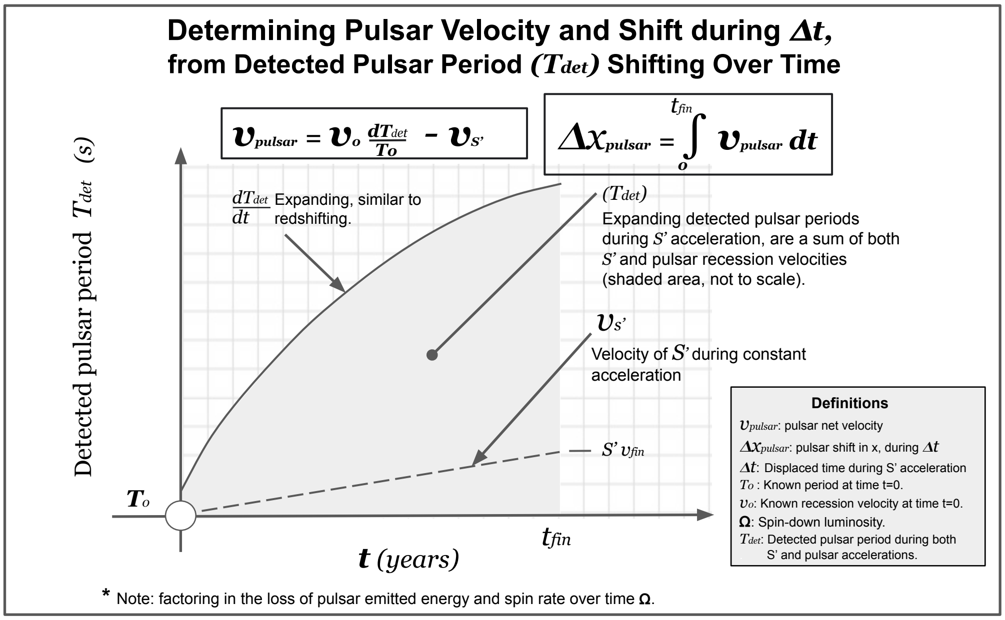

Figure 6: Deriving pulsar distance from spacetime displacement.

First, the pulsar velocity v_{pulsar} is derived from the shifting of pulsar periods T_{det} and S' velocity $v_{S'}$ is subtracted,

$$v_{pulsar} = v_0 \frac{dT_{det}}{T0} - v_{S'} \tag{10}$$

Then distance Δx_{pulsar} is integrated over time t from pulsar velocity v_{pulsar}

$$\Delta x_{pulsar} = \int_0^{t_{fin}} v_{pulsar}\, dt \tag{11}$$

Where T_0 is the known period, from the stationary observer, at time $t = 0$, and v_0 is the known initial pulsar velocity at time $t = 0$.

5 Determining the Time Dependent Hubble Parameter, from Shifted Pulsar periods

The Hubble parameter over time ($\frac{dH}{dt}$) can be approximated from the derivative of v_{pulsar} (equation 10) over time, such that,

$$\frac{dv_{pulsar}}{dt^2} \approx \frac{dH}{dt} \tag{12}$$

Figure 7 is scaled to S' constant acceleration, in order to show the change in pulsar acceleration over time. Note: factoring in the loss of pulsar emitted energy and spin rate over time (Spin-down luminosity Ω).

Determining Distance x_{fin}, and x'_{fin}

From the (IRF) of S, Distance x_fin in (of spacecraft S', at the point of final velocity), can be determined by integrating the function (Assume a constant acceleration, for simplicity), See figure 8,

$$x_{fin} = \int_0^{t_{fin}} \frac{v_{fin}}{t_{fin}}\, t\, dt \tag{13}$$

From the (IRF) of S', distance x' (at S' final velocity), is calculated using the Lorentz distance transformation equation [5],

$$x'_{fin} = \frac{x - vt}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{14}$$

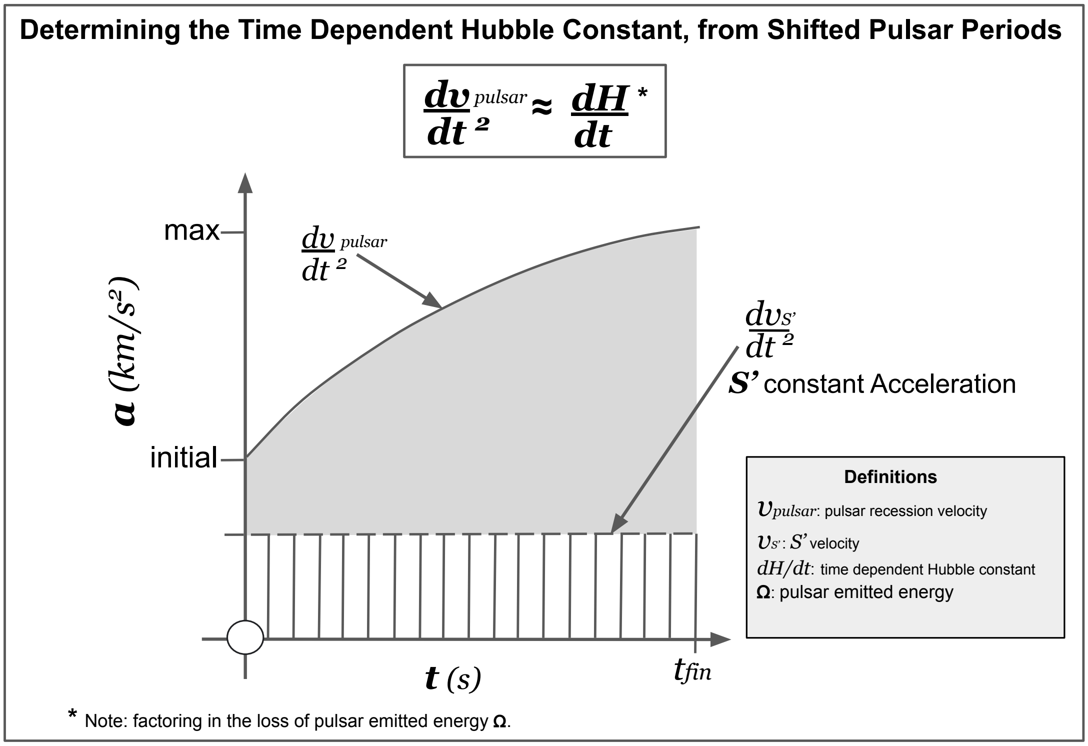

Figure 7: Determining how the Hubble Parameter changes Over time

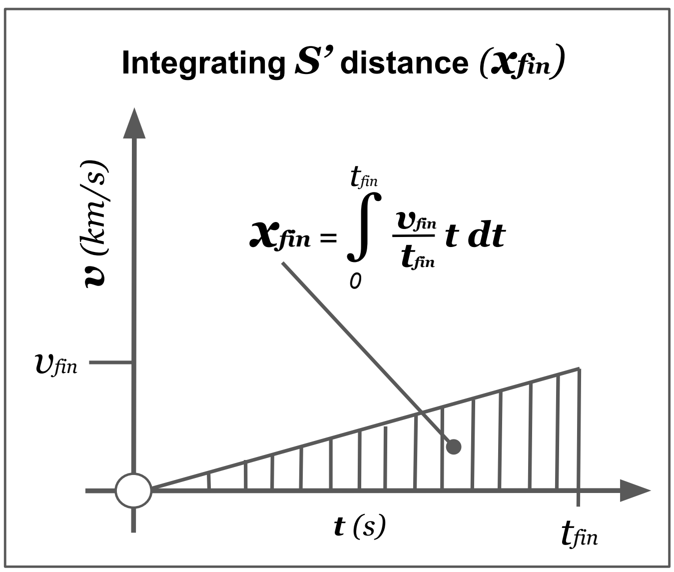

Figure 8: Integrating spacecraft S' distance x, at point of final velocity

6 Measuring vast distances, Approaching the CMB

Theoretically, this same method could also reference oscillating patterns of CMB Anisotropic Dipole Radiation (instead of pulsar flashes), to measure the most distant light of the observable universe. The spacecraft payload would include a microwave radiometer. However, would be limited by portable optical instruments, which have yet to be developed. Such instruments would require ultra an light-weight telescope with moderately good angular resolution.

7 Example Using the Vella Pulsar

For the purpose of example, the Vela Pulsar [6] (a radio, optical, X-ray- and gamma-emitting pulsar associated with the Vela Supernova Remnant in the constellation of Vela) is described. Vella period = 89.33 $milliseconds$. Note: $t(ct)$ units are in years. x units are in light years (ly). Time at final velocity t_{fin} is assumed to be $0.10ly$. Per the NASA Parker Solar Probe [7], final velocity: $v_{fin} = 150 km/s = 0.0005c$.

The total flashes $|A|$, as calculated by the stationary observer S from equation 4 (Converted to common units of seconds),

$$|A| = \frac{t}{T} = \frac{3,155,695s}{0.089s} = 35,457,247, \ or \ |3.55 * 10^7| \ flashes \tag{15}$$

$|A'|$ (the $IRFofS'$) from equation 3, is **hypothetically** assumed (as it's summed empirically, during acceleration) to be a cardinal value of,

$$|A'| = \sum_{i=1}^{n} 1(flash) = |3.68 * 10^7| \tag{16}$$

Pulsar angular time displacement Δt_{pulsar}, from equation 4,

$$\begin{aligned}
\Delta t_{pulsar} &\approx \frac{|A'| - |A|}{T} \\
&= \frac{3.68 * 10^7 - 3.55 * 10^7}{0.089s} && (17) \\
&= 1.48 * 10^7 s && (18) \\
\Delta t_{pulsar} &\approx 0.47yr && (19)
\end{aligned}$$

Pulsar distance x_{pulsar}, per equation 8, can then be determined as,

$$\begin{aligned}
x_{\Delta t} &\approx \frac{c\Delta t_{pulsar}}{v_{fin}} \\
&= \frac{c * 0.47yr}{0.0005c} && (20) \\
x_{\Delta t} &\approx 939ly && (21)
\end{aligned}$$

Note: The integration of distance Δx_{pulsar} is undetermined, as $|A'|$ and T_{det} must first be empirically established from actual measurements, during S' acceleration.

8 Practical Considerations

Some practical issues to consider, with this proposed method of measurement are listed:

- Folding analysis could not be separated into regularly spaced intervals (i) during acceleration, as the time differential decreases with velocity such that: $\frac{di}{dt} = \frac{k}{v}$.
- A reasonable final velocity v_{fin} would be similar to the NASA Parker Solar Probe, of $0.0005c$.
- Relatively strong emitting pulsars, such as the Vela Pulsar, can be detected (around the Hydrogen line frequency of 1420MHz) by amateur radio telescopes. By utilizing 5 RTL-SDRs to gather 10 MHz of bandwidth together with some processing, the minimum required dish aperture could be reduced to 3.5m, which could conceivably fit into a spacecraft Payload

9 Conclusion

The clear advantage of this alternate system of measuring galactic distances, is that the greater distance x, the less acceleration is required for measurement, as the Lorentz transfer equation for distance is a function of x, as well as velocity.

Continuous systematic development of methodology is an essential component of the scientific method. Discrepancies from such an alternative method of measuring galactic distance could reveal much about multiple parameters of Cosmology including: Dark Energy, Accelerated Universal Expansion, The Cosmic Event Horizon.

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