

A Proposal On Measurement Methods of the One Way Speed of Light

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I. Abstract

The ability to measure the exact one-way speed of light had often been thought to be impossible^[4,6]. Under most simplified theoretical conditions, there appears to be no intuitive method of measuring the strict one-way speed of light, with the main problem being the synchronization of clocks at point A and B^[4,6]. The significance proving or disproving the illusion of invariant lightspeed may shed light on the incompleteness and possible improvements of special relativity^[5]. However, as of relative recency experiments designed to measure the one way speed of light appears to still be highly limited, where special cases may give false positives^[3]. The experiment designed in this paper can provide a precise measurement, when performed under ideal conditions will produce no false positives, and taking into account special relativity. Two spacecraft launched together are sent into a stable solar orbit between the Earth and Mars, spaced out a significant distance (>10 light minutes). Both spacecraft will be synchronized to constantly observe a pulsar - counting pulses, our start signal. Upon reaching a specified number of pulses the probes send signals to each other while starting their timer, ending their timer when they receive the signal from the other side. The end difference should accurately reflect the one-way speed of light.

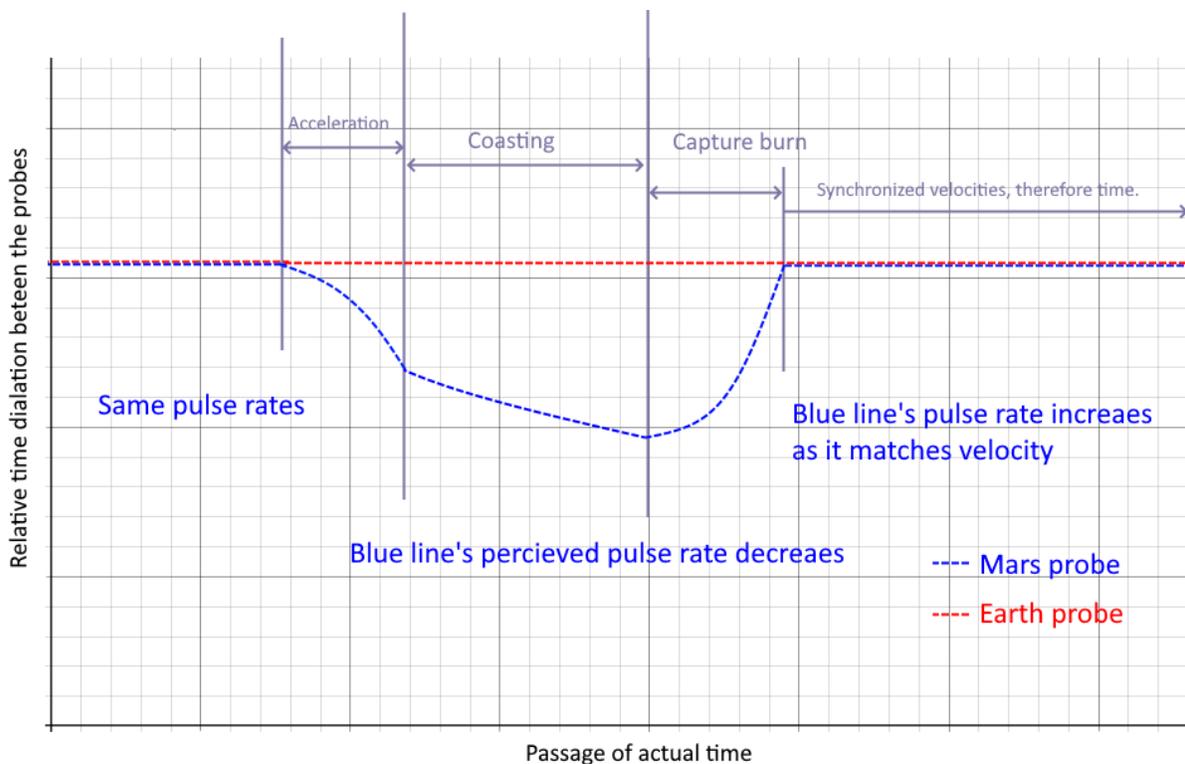
II. Introduction

The speed of light has only ever been measured with “two ways”, that is the round trip of pulses of photons towards a reflector, and back to a detector, which generally pass the photons through some sort of moving filter to calculate the time it took for light to travel the distance sum. The conundrum comes from the speculation that there is a theoretical possibility of the speed of light being different on the way to the reflector and on its way back. So far, our methods have been used to test the two-way speed of light, and there appear to be no trivial and reliable method to prove that light does actually have a constant velocity regardless of its direction^[4,6]. It’s perfectly possible that lightspeed is instant from A to B, but $\frac{1}{2}c$ from B to A^[4].

III. Proposal - Earth, Mars, and Pulsar

The one-way speed of light is generally composed of two parts: c^* and c' . $\frac{1}{2}(c^* + c') = c$, where c^* is used to refer to the speed of light from A to B, and c' is used to represent the speed of light from B to A.

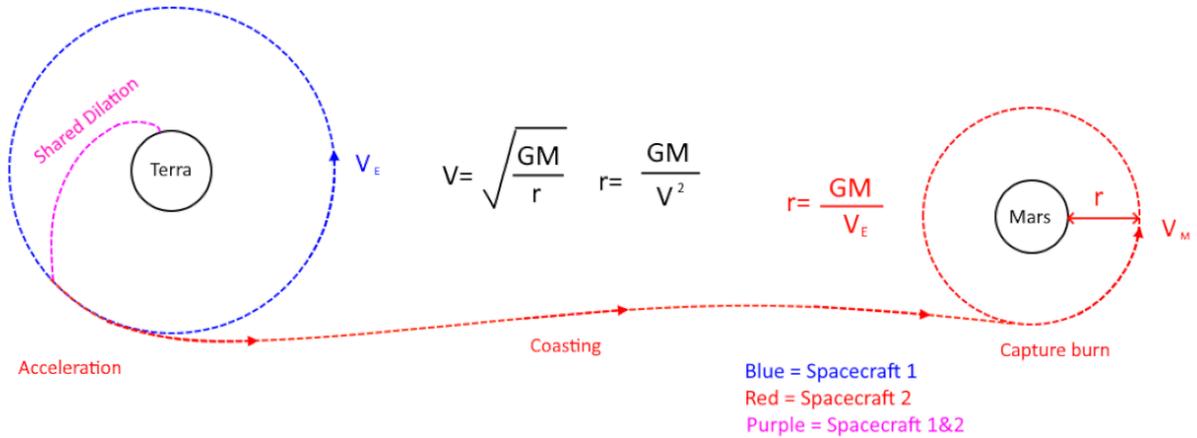
Two spacecraft are launched from Earth from the same launch vehicle, with their own internal atomic clocks. The atomic clocks are to be used as a stopwatch, and as long as the two spacecraft are travelling at the same velocities, their passage of time will be identical. ^[1]



[Fig. 3-1, Graph showing the profile of experienced time relative to pulses. Not to scale]

In this case in order to ensure the start signal is received at the correct “universal time”, we need to define what is our reference frame for time. In our case, we’ll use the source of the pulse signals (x axis grid, not to scale) as our reference, the pulsar. No matter the time dilation differences between the two probes, the number of pulses of the pulsar serves as an absolute frame of time. Experiencing time faster, the pulses will count faster, experiencing time slower, the pulses will count slower. To an outside observer the probes will simultaneously detect each pulse, therefore counting pulses eliminates the problems of time dilation.

Notice on Fig. 3-1, The length of the line is the perceived time, while the x-axis increment is actual time that is relative to the number of pulses received at any given time by some constant multiple. Therefore, as you travel faster, the pulse rate you perceive slows down, synchronizing with the perceived pulses of the the other probe or to any nearby outside observer

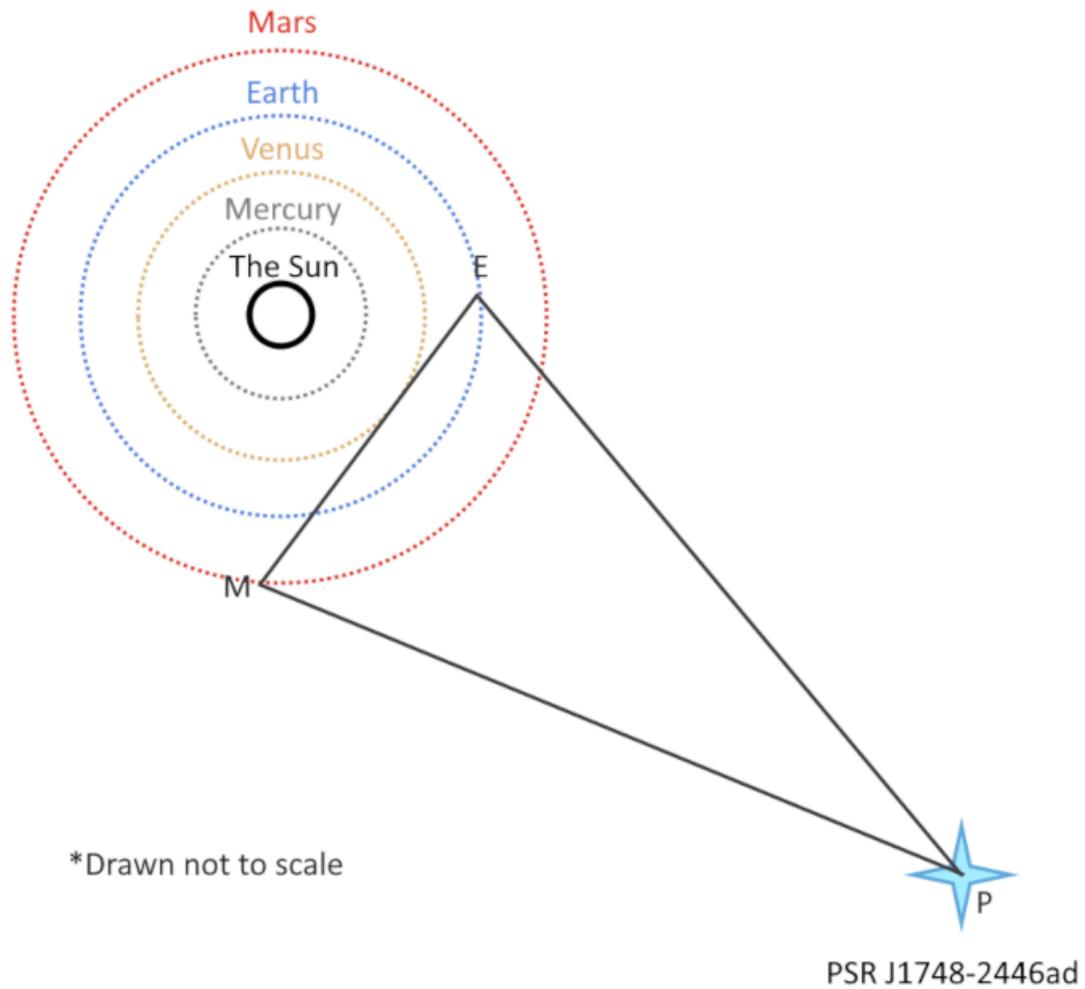


[Fig. 3-2 Mission trajectory and matching velocities.]

The mission will require us to launch two probes simultaneously, with synchronized time and synchronized counts of pulses from the pulsar. Both probes will count a specific number of pulses simultaneously. Both probes are first delivered to high Earth orbit, of which then one will separate and orient itself to constantly face the pulsar. An orbit with its axis perpendicular to the pulse source is necessary to observe the pulsar continuously. HEO is selected for the minimization of gravitational lensing messing with the path of light, and therefore its measurement.

The second probe will remain with the main spacecraft's transfer stage, which will now embark to Mars. To simplify the mission and reduce dV costs, a well-timed fly-by mission can be plotted where the relationship of geometry between point Earth, Mars, and Pulsar forms an isosceles triangle.

(Labeled E, M, and P on the following graph)



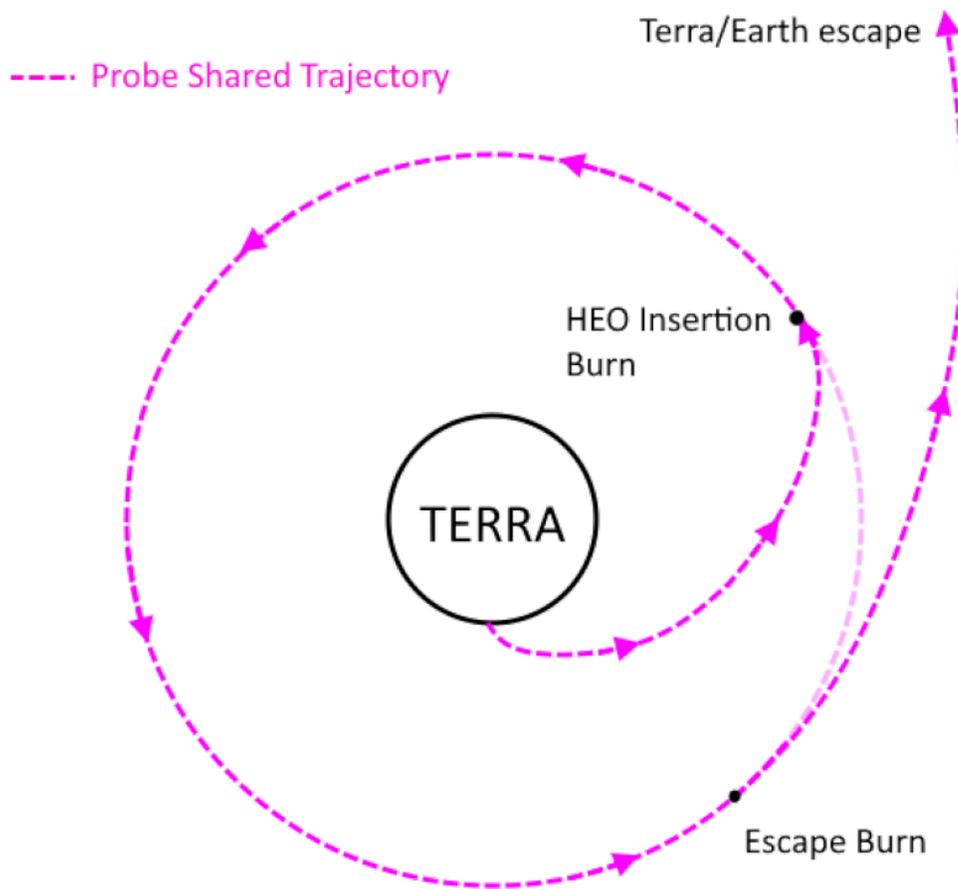
[Fig. 3-3 - Isosceles triangle formed by Earth, Mars, and PSR J1748-2336ad]

Note that the vertical location of the Pulsar does not matter, as it will form an isosceles triangle none the less. This is not the only method to form the triangle. Additionally, due to the difference in the orbital velocity of Earth and Mars, the orbits must also be oriented so that at a certain point, this difference is cancelled out. Transmissions can start near this point.

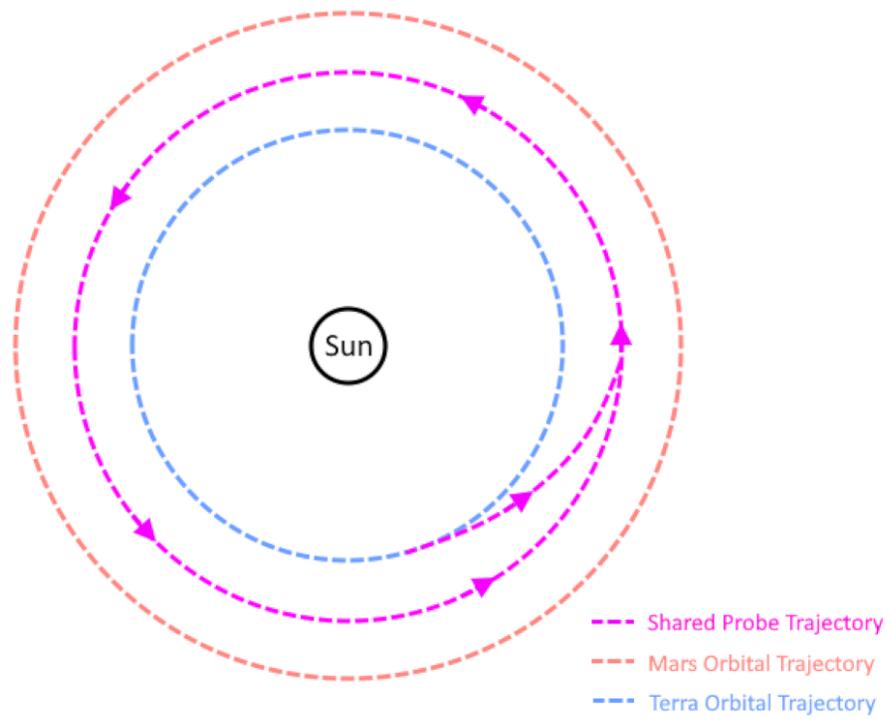
The pulsar we will use in this example will be PSR J1748–2446ad. It’s specifically chosen for its great distance from the solar system (~18,000 LY) and its high pulse rate of 716.35Hz^[2]. Both of those statistics enhance the precision of our measurements, as it minimizes the half angle of the triangle at its peak, with two base angles approaching 90°. If the one-way speed of light is truly different, the minimization of target angular difference for photons emitted during pulses should theoretically minimize the lightspeed difference caused by angular differences in space.

IV. Simplification with Sacrifices

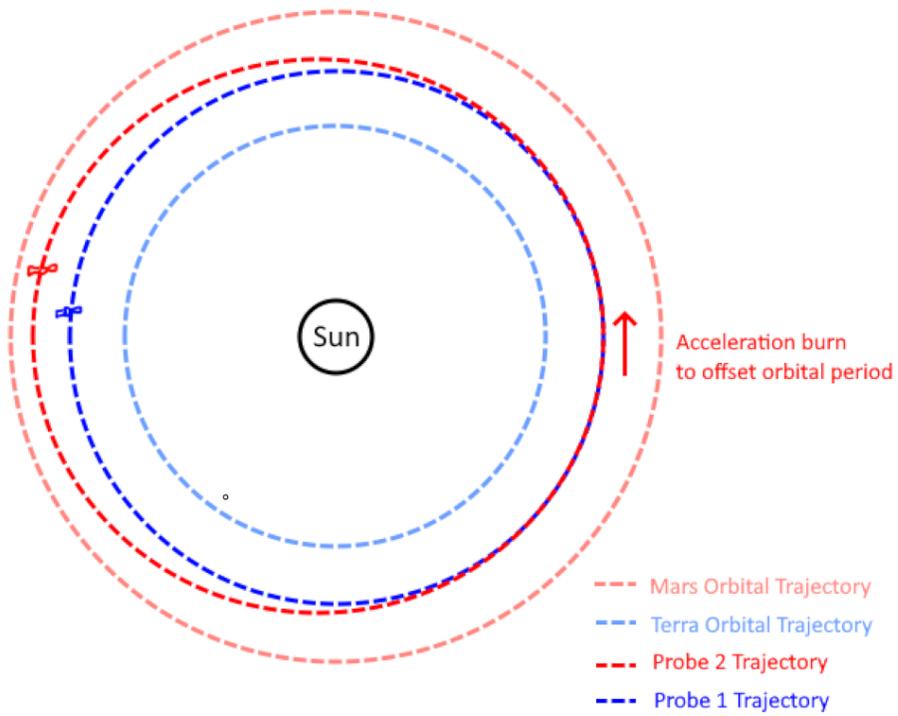
The orbits of probes from Earth and Mars complicates our problem significantly with their trajectories and orbit requirements. There's a much simpler method that can achieve a similar result: Two probes are launched simultaneously, escaping into a circular orbit between the trajectory of the Earth and Mars. Both probes will be synchronized on their count on pulses, and then one probe is accelerated into an eccentric orbit, upon completing one full revolution, the orbit is corrected back to circular, matching the other probe's orbit but offsetting themselves by ~5-10 light minutes.



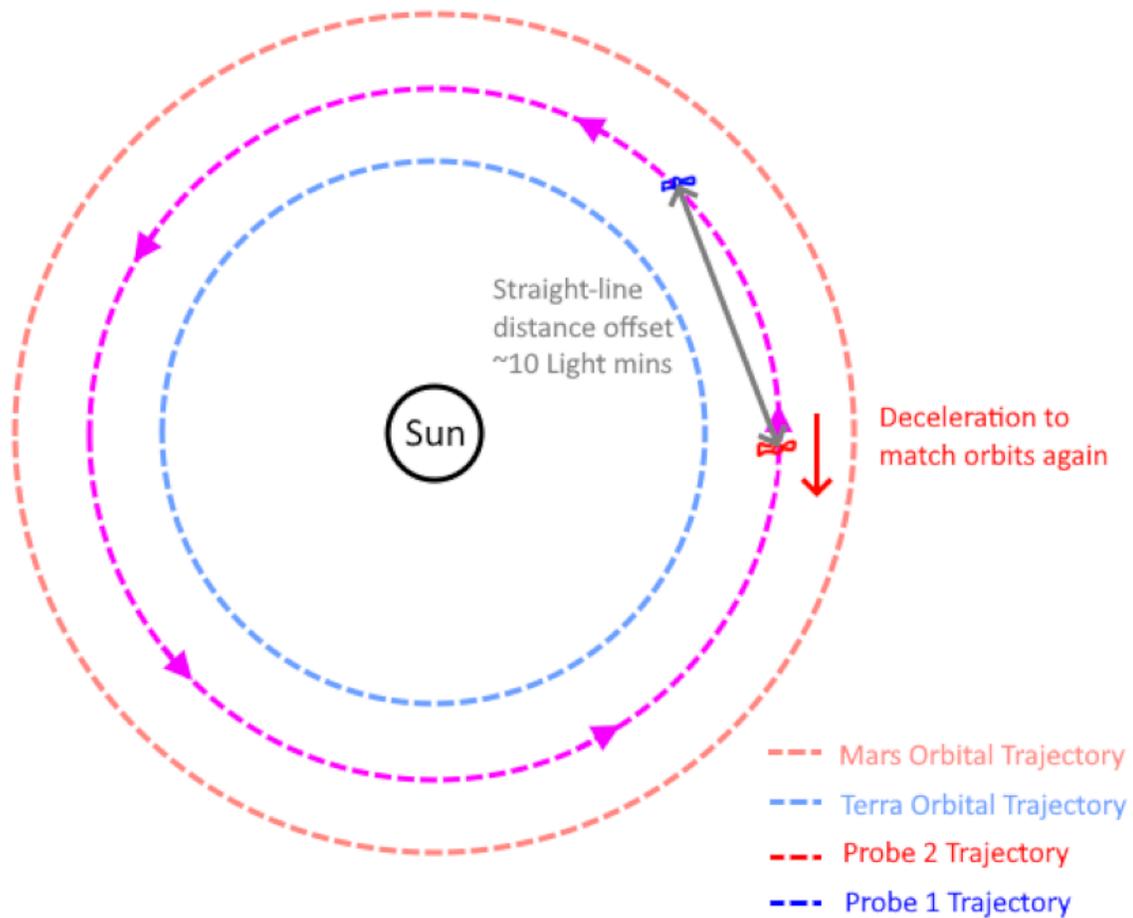
[Fig 4-1, Escape trajectory, initial orbits of the two satellites]



[Fig 4-2, Two probes are carried together to desired orbit]



[Fig. 4-3, Probe B accelerates to an elliptical orbit necessary to create an offset]



[Fig 4-4, Probe B decelerates upon completing one orbit , matching orbits and velocities with probe A.]

On a specified number of pulses, the probes will signal each other and start a local clock. The velocities of the probes are identical, therefore no time dilation differences. As the probes are travelling around the sun at a constant velocity, red/blueshifting will occur due to the doppler effect. This can be accounted for if the relative velocity difference can be calculated between the two probes, and subtracted from the leading probe while added to the trailing probe. The clock is stopped upon receiving the signal from the opposing probe.

The downside to this approach is that the experiment can be repeated only twice an orbit, and the probes will be active for > 1 year, continuously counting approximately, or over 4×10^{10} pulses with no downtime. The Earth-Mars approach can be timed to work at a specific window, and the launches can be timed to minimize equipment active time.

V. Conclusion

There are multiple setups for an experiment that will give a relatively accurate measurement of the one-way speed of light, involving the use of pulsars as absolute clocks could eliminate time dilation of probes, or synchronization issues. A setup of two probes that are travelling at identical velocities forming an isosceles triangle with a high pulse rate pulsar extremely distant from the Solar System can eliminate time variances between the two probes, effectively allowing us to measure the one-way speed of light.

VI. Acknowledgments

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