A Comment On arXiv:1110.2685

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This brief paper traces comments on the article arXiv:1110.2685. It seems there is an intrinsical misconception within its claimed solution, since an intrinsical proper time reasoning leads to the assumption the OPERA collaboration interprets a time variation as a proper time when correcting time intervals between a GPS frame and the grounded baseline frame.

AN INTRINSICAL PROPER TIME REASONING, MISCONCEPTED BY THE OPERA COLLABORATION?

The author of the article arXiv:1110.2685 uses the designation: *from the perspective of the clock...* Within the approach used by the author, via special relativity, the GPS frame of reference must use ***two*** distinct but synchronized clocks to tag the instants at A and B. The Eq. (2) in arXiv:1110.2685 should be obtained via the Lorentz transformation for the neutrino events of departure from A and arrival to B. Let (x_A, t_A) and (x_B, t_B) be the spacetime events of departure and arrival of the neutrino in the baseline reference frame K, respectively. The time interval spent by the neutrino to accomplish the travel in the arXiv:1110.2685 GPS reference frame K' is:

$$\delta t' = \left(1 - v^2/c^2\right)^{-1/2} \left[(t_B - t_A) - \frac{v}{c^2} (x_B - x_A) \right], \quad (1)$$

in virtue of the canonical Lorentz transformation for time in K' as a function of the spacetime coordinates in K, where v is the assumed boost of K' in relation to K in the baseline direction AB, c the speed of light in the empty space. With $\delta t = t_B - t_A$, $\delta x = x_B - x_A = S_{baseline}$, $\delta x = v_\nu \delta t$, where v_ν is the neutrino velocity along the AB direction, the eq. (1) reads:

$$\delta t' = \left(1 - v^2/c^2\right)^{-1/2} S_{baseline} \left(\frac{1}{v_\nu} - \frac{v}{c^2} \right). \quad (2)$$

With $v_\nu = c$, $\gamma = \sqrt{1 - v^2/c^2}$, $\delta t' \stackrel{!}{=} \tau_{clock}$, as defined in arXiv:1110.2685, the Eq. (2) here becomes the Eq. (2) in arXiv:1110.2685:

$$\tau_{clock} = \frac{\gamma S_{baseline}}{c + v} \Rightarrow c\tau_{clock} + v\tau_{clock} = \gamma S_{baseline}. \quad (3)$$

But:

- $\delta t' \stackrel{!}{=} \tau_{clock}$ is not a proper time (it is a time interval measured by distinct clocks at different spatial positions in K'); hence: why would the OPERA collaboration correct $\delta t' \stackrel{!}{=} \tau_{clock}$ via $\delta t = \delta t'/\gamma$, as claimed via the Eq. (5) in arXiv:1110.2685?
- Such correction would be plausible if the events of departure and arrival of the neutrino had the same spatial coordinate $x'_A = x'_B$ in the GPS K' frame of reference, but it is not the case.

Hence, putting straightforwardly, as asserted before, the claimed solution within arXiv:1110.2685 supposes an intrinsical proper time reasoning, but there is no reason for this, since the $\delta t'$ is not a proper time. Thus, the claimed solution turns out to be constructed on an erroneous correction. The correction that should be done by the OPERA Collaboration, if the arXiv:1110.2685 GPS reference frame was to be taken in consideration, would read:

$$\delta t = \left(1 - v^2/c^2\right)^{-1/2} \left[(t'_B - t'_A) + \frac{v}{c^2} (x'_B - x'_A) \right], \quad (4)$$

and this correction would read: $\delta t = \delta t'/\gamma$, with the $\gamma = \sqrt{1 - v^2/c^2}$ defined in arXiv:1110.2685, ***if and only if***: $x'_B - x'_A = 0$, but it is not the case.

Furthermore, I would like to assert, respectfully, that, related to the K' reference frame, the frame the author of arXiv:1110.2685 takes to explain the relevance of the GPS reference frame in terms of special relativity: the radio signals turn out to be irrelevant to be taken into consideration once the clocks within K' are synchronized, viz., the Lorentz transformations for events do consider radio signals intrinsically under the synchronization of clocks in a given reference frame. This said, the factor 2 the author uses to reach 64 ns seems misconcepted. Remembering, the τ_{clock} is the time interval in K', it is not a proper time interval, and this time interval totally accounts for the entire process of emission and detection of the neutrino at A and B, respectively, departure and arrival, from which there are not two corrections to be accomplished at the points A and B related to radio signals. The radio signals related to the events at A and B in the GPS reference frame in arXiv:1110.2685, K', are taken into consideration since the clocks at A and B in this reference frame tagging the events of departure and arrival are previously synchronized by the very radio signals the author refers at the final of the article arXiv:1110.2685. Hence, once the Lorentz transformations provide the τ_{clock}, one should not consider radio signals twice.

I would like to comment some misconceptions the author of arXiv:1110.2685 seems to have incurred when raising his arguments. Related to my previous comments, these ones are related to the first version of the mentioned article uploaded to arXiv. Recently, the author had uploaded an updated version, but the misconceptions seem to persist. It seems the author had in mind that the time interval to be corrected $\delta t' = \tau_{clock}$ (here, I will be considering the first version of the arXiv:1110.2685, since there are not substantial modifications throughout the updated version to avoid the criticisms raised) was a proper interval. Constructing his arguments, the author refers to what is observed in the satellite reference frame. Suppose, following the author of arXiv:1110.2685 reasonings, the satellite sends a radio signal to the event at A to see the departure of the neutrino when this radio signal turns back to the satellite. Be t'_{ESA} (E denotes emission, S denotes satellite, and A denotes the location of the CERN at the instant, read in the satellite local clock, the neutrino starts the travel to Gran Sasso) the instant this signal is sent to reach the event of the neutrino departure, t'_{RSA} (R detotes reception) the instant the signal comes back to the satellite, read in the satellite local clock. These instants are related by:

$$t'_{RSA} = t'_{ESA} + 2d'_{SA}(t'_A)/c, \tag{5}$$

where $d'_{SA}(t'_A)$ is the distance between the satellite and the CERN location at A at the instant the signal (radio signal) reaches A, at the instant t'_A the neutrino is sent to Gran Sasso in the satellite frame. Analogous reasoning related to the neutrino arrival at Gran Sasso, at B, leads to:

$$t'_{RSB} = t'_{ESB} + 2d'_{SB}(t'_B)/c, \tag{6}$$

where $d'_{SB}(t'_B)$ is the distance between the satellite and the Gran Sasso location at B at the instant another signal previously sent by the satellite at instant t'_{ESB} read in the satellite local clock (another radio signal) reaches B, at the instant t'_B the neutrino arrives to Gran Sasso in the satellite frame. The instants t'_A and t'_B are respectively given by:

$$t'_A = \frac{t'_{ESA} + t'_{RSA}}{2}, \tag{7}$$

and:

$$t'_B = \frac{t'_{ESB} + t'_{RSB}}{2}. \tag{8}$$

From these relations, the proper time interval between the instants the satellite SEES the events of departure and arrival, $t'_{RSB} - t'_{RSA}$, is given by:

$$t'_{RSB} - t'_{RSA} = t'_B - t'_A + \frac{d'_{SB}(t'_B)}{c} - \frac{d'_{SA}(t'_A)}{c}, \tag{9}$$

therefore, since $t'_B - t'_A = \delta t' = \tau_{clock}$, see my previous comments:

$$\tau_{clock} = t'_{RSB} - t'_{RSA} - \left(\frac{d'_{SB}(t'_B)}{c} - \frac{d'_{SA}(t'_A)}{c}\right), \tag{10}$$

from which: τ_{clock} DOES TAKE INTO CONSIDERATION the radio signals travelling, encapsulated within the time intervals within:

$$\tau_{signals} = \frac{d'_{SB}(t'_B)}{c} - \frac{d'_{SA}(t'_A)}{c}. \tag{11}$$

The problem within the reasonings of the author of arXiv:1110.2685 is this author was thinking that τ_{clock} would be the proper interval related to what was being seen by the satellite, $t'_{RSB} - t'_{RSA}$. Hence, at the final of his article, this author applies a correction related to radio signals to account for the time interval $t'_B - t'_A$, but this process was already done when the author obtained $\delta t' = t'_B - t'_A$, viz., as said before within my previous comments, the Lorentz transformations have got radio signals intrinsically, by construction, to deal with events in spacetime. Concluding, when the author of arXiv:1110.2685 applies the factor 2, this author seems to erroneously account for radio signals twice, and the factor 2 is misconcepted. Even if the OPERA Collaboration had done the correction the author of arXiv:1110.2685 refers to, such discrepancy would be 32 ns, but not this value twice. The factor 2 seems to have not got logical explanation within the arXiv:1110.2685 reasoning, mostly being putted a fortiori.

Concluding, it seems unlikely that the OPERA collaboration has misinterpreted a GPS time interval.

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[1] The OPERA collaboration: T. Adam et al. Measurement of the neutrino velocity with the OPERA detector in the CNGS beam http://arxiv.org/abs/1109.4897 *arXiv:1109.4897*, 2011.

[2] Ronald A.J. van Elburg. Times of Flight between a Source and a Detector observed from a GPS satelite http://arxiv.org/abs/1110.2685 *arXiv:1110.2685*, 2011.