Andromeda's New Clothes: Revealing the Causality Hidden in the Paradox

YARON SHEFFER
Astronomy Postdoc Emeritus
Previously at the University of Maryland at College Park, MD 20742
yaron42sheffer@gmail.com

Submitted to RNAAS, 2021 August 13

ABSTRACT

The Andromeda paradox is a popular version of the Rietdijk-Putnam argument based on unobservable spacetime events along planes of simultaneity. We show and prove that an extrapolation of the motions of frames of reference in a manner consistent with special relativity leads to a physically meaningful interpretation of the paradox in terms of future light-cone observables. The unobservable time shifts in the Andromeda paradox are thus found to be predictors of light travel time differences between moving observers upon the arrival of light from an event in that galaxy. This discovery of eventual causality not only undermines metaphysical arguments that rely on relative simultaneity to promote four-dimensionalism, but is also a timely contribution to counter recent claims in physics literature that imply the existence of rather exotic astronomical phenomena not yet observed by scientific means.

Keywords: Andromeda paradox—Causality—Four-dimensionalism—Simultaneity—Spacetime—Special relativity (1551)

1. INTRODUCTION

The Minkowski diagram of special relativity (hereafter SR) includes the non-causal Elsewhere, where the plane of simultaneity of the "now" time of an observer's reference frame is found. Relative to a reference frame at rest, the Lorentz transformation of a moving frame tilts its plane of simultaneity, generating a time shift away from "now" for any "current" event. This relativity of simultaneity was employed in philosophical arguments constructed as proofs of four-dimensionalism by Rietdijk (1966) and Putnam (1967). According to them, the temporal shift of a "current" event of an observer at rest into the past of a moving observer predetermines the future for the former. These physically unobservable temporal shifts ostensibly demonstrate

that we live in a 4-dimensional universe, although philosophical counter-arguments were quick to appear, e.g., Stein (1968).

The Rietdijk-Putnam argument was popularized and endorsed by Penrose (1989), who described two Earthlings passing each other while sporting opposite velocity vectors with respect to the Andromeda galaxy (hereafter Andromeda). Their tilted planes of simultaneity shift the "current" purported launch event of a space force from Andromeda in opposite sense: into the past (or future) of the Earthling moving toward (or away from) that galaxy, thus yielding the Andromeda paradox (AP). Moreover, Penrose employed the "certainty" of shifted events as an argument in support of four-dimensionalism.

A recent contribution from D'Abramo (2020) not only adopts the non-causal scenario of the AP, but concludes that our astronomical observations of the universe have yet to uncover a multitude of SR phenomena within the non-relativistic regime of very slow relative motions between reference frames. Here, we report the discovery and mathematical proof of a physical interpretation of the AP, which explains the "current" unphysical temporal shifts in terms of future light-cone observables. This physical explanation demonstrates the close Lorentzian affinity between the tilt of the plane of simultaneity and the relative velocity of a moving frame upon which it is based, while implying that the employment of unphysical temporal shifts in arguments that support four-dimensionalism is, in all likelihood, an unproductive endeavor.

2. NO MOTION? YES PROBLEM!

The temporal shift of a plane of simultaneity on the Minkowski diagram owing to the Lorentz transformation is $\Delta y = vx/c^2$, where v is the instantaneous relative velocity, x is the distance to a "current" event, and c is the speed of light. We shall assume a walking speed of v = 1 m s^{-1}, while x is the distance to Andromeda of 2.5 million light years (Li 2021) or 2.4 x 10^{22} m. Thus walking toward (or away from) Andromeda "shifts" any event there by Δy = 2.6 x 10^5 s = 3.0 days into the past (or future).

The dependence of Δy on instantaneous relative velocity is an SR defining feature which is very critical to the argument. Elsewhere time shifts cannot become observable unless instantaneous planes of simultaneity are kept tilted for the entire duration of the light travel time from the event, and hence only by moving observers preserving their relative motions uninterrupted indefinitely.

Therefore, we must strongly disagree with D'Abramo (2020), who allows his 'observer A' to not only walk toward Andromeda and then perform a U-turn, but also to stop moving altogether while waiting for events from Andromeda to unfold. This arrangement throws the unaware Andromeda into a reversing time loop, which then is discarded altogether owing to removal of relative motion. Thus the D'Abramo AP scenario *cannot* be realized. Likewise, Penrose (1989) treats the AP scenario as a short, discontinued affair, saying that observers may

compare notes in the far future. Alas, the de-tilted planes of simultaneity would provide no future effects whatsoever for said comparison.

3. GOOD THINGS COME TO THOSE WHO WALK (WHILE WAITING)

The two requirements of (i) waiting for the light travel time from an event to elapse, and (ii) while maintaining constant relative motions for the duration of (i), imply the following proper procedure to conduct the AP experiment: *all moving observers should maintain their motion uniformly for 2.5 million years after passing each other*. Upon finally observing the light from an Andromeda event, the (very old and tired) observers may then sit down.

However, at that time, there would be one causal difference between them. Instead of remaining at the nominal distance from Andromeda, any moving observer, after walking for 2.5 million years toward (or away from) Andromeda, would surely be found nearer to (or farther from) that galaxy. At the aforementioned velocity of 1 m s^{-1}, and keeping the walk for t = 2.5 million years, or 7.9 x 10^{13} s, any observer will have covered $\Delta x = vt$ = 7.9 x 10^{13} m, or about 530 AU.

Consequently, the nearer (farther) observer will see the Andromeda event earlier (later). Upon conversion, we find that each observer will contribute $\Delta t = \Delta x/c$ = 3.0 days of light travel time. This time interval is *identical* to Δy, the Elsewhere temporal shift of a plane of simultaneity at Andromeda 2.5 million years before (see §2). Thus the causal physical meaning of the Andromeda paradox as ultimately revealed by observation is this: *as long as relative motions are maintained unchanged, the time difference between planes of simultaneity for any "current" event simply predicts an eventual light travel time difference between moving observers once that event can be finally observed*.

4. NON-PARADOXICAL PHYSICS

In hindsight, the algebraic equality between Δt and Δy can be easily proved: $\Delta t = \Delta x/c = vt/c = vx/c^2 = \Delta y$, where we used the definition for light travel time from the event, $t = x/c$. Our physical result may be interpreted as a manifestation of clock synchronization between moving frames. Consequently, the unphysical nature of the original AP renders any Rietdijk-Putnam-Penrose type of argument about SR four-dimensionalism moot, if we accept the conclusion that any "current" temporal shift has no additional physical meaning beyond numerically representing the *future* separation between moving frames.

The metaphysical aspect of the AP, namely, whether the future of one observer is predetermined by the past of the other, now has input from causality. The event's light cone will intersect the world line of the nearer observer first, a few days before it encounters the world line of the farther observer. Thus the first observer may reliably predict that the more remote observer

will have the option of detecting the same event pending additional light travel time. In this sense, the future of the latter observer is, indeed, "fixed". However, they surely have the free will to not watch the event for which they have been waiting for 2.5 million years and a few days more...

5. CONCLUSION

We have shown that a relativistically consistent treatment requires keeping all relative motions unchanged for the entire duration of the 2.5-million-year-long "Andromeda walkathon." Consequently, the paradox is found to have a physical solution in terms of future light-cone observables, namely, differences in light arrival times between moving observers. Rather than shifting an unobservable event into the past or the future, tilts of planes of simultaneity mathematically predict the physical separation between observers upon eventual observation of said event. This causal ordering of actual observables should take precedence over unobservable time shifts of "current" events on the plane of simultaneity, thus helping unchain the Andromeda argument from the paradoxical rock of Elsewhere.

REFERENCES

D'Abramo, G. 2020, Annales de la Fondation Louis de Broglie 45 (1), 87, https://arxiv.org/abs/1711.03833v6
Li, S. 2021, ApJ, accepted, https://arxiv.org/abs/2107.08029
Penrose, R. 1989, The Emperor's New Mind (Oxford), pp. 303-304
Putnam, H. 1967, The Journal of Philosophy 64 (8), 240, doi: 10.2307/2024493
Rietdijk, C. W. 1966, Philosophy of Science 33 (4), 341, doi: 10.1086/288106
Stein, H. 1968, The Journal of Philosophy 65 (1), 5, doi: 10.2307/2024512