Special relativity, the "margin" problem, and Doppler extinction

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Lightsignals exchanged by a pair of idealised massed particles in otherwise empty space cannot be correctly described using special relativity, because the signals must pass through regions adjacent to the particles, where gravitational and gravitomagnetic curvature effects are arbitrarily strong.

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1. Introduction

It is generally currently assumed that when two massed particles with relative motion in otherwise flat empty spacetime exchange signals, the results can be described exactly using special relativity. The purpose of this paper is to explain why this is not the case.

2. Einstein's 1905 paper

2.1 Special relativity is relativity in flat, empty space

Einstein's 1905 paper [1] starts by applying the relativity principle to empty space, the assumption being that if space is empty, its lightbeam geometry should *necessarily* be "flat", because geometrical detail does not exist without reason, and an empty region will contain *literally nothing* that can be blamed for any specific *deviation* from flatness.

The relativity principle applied to fixed flat spacetime gives us Lorentzian relativity and fixed Minkowski spacetime. [2] [3] This is a *geometry*: to convert it into a physical theory then requires a "bridging hypothesis": [4] an argument that the lightbeam geometry that we have just derived for an empty space still applies when the space is *not* empty, but populated by physical observer-masses moving with relative velocities that might be significant fractions of the speed of light. This bridging hypothesis can be considered special relativity's unwritten third postulate. [4]

To treat the geometry as physics, the SR bridging hypothesis requires either that no matter is present, [5] or that if matter *is* present, it must have inertial mass without gravitational mass. This would violate GR's "Principle of Equivalence" of inertia and gravitation.

2.2 Spacetime is not flat in the presence of massed particles

The Principle of Equivalence of inertia and gravitation ("**PoE**") says that inertial and gravitational effects are different aspects of the same fundamental property of matter. A body with inertial mass resting on a set of weighing-scales has "weight", because weight is simply the amount of upward force that the scales have to apply to prevent the body from following its natural inertial free-fall trajectory towards the Earth's centre.

Additionally, attempts to implement the **Relativity of Inertia** ("**RoI**") typically explain the inertial mass of a body as a measure of how strongly its fields couple with the background field. Eliminate the "gravitational" properties of a body and we eliminate its inertia. [i] [6]

These issues led Einstein to write in 1919 that if all massed particles had associated curvature, the existence of objects in a region must necessarily invalidate the flat-spacetime assumptions and rules of SR and Minkowski spacetime. [7] The metric's geometry is then no longer *fixed* (as with Minkowski [3]) but *dynamic*. Under a general theory, SR does not then apply to regions *containing* particles, but only to regions *between* particles.

2.3 Is space flat and empty *between* masses?

According to the usual argument, if we already know that relativity applied to flat spacetime gives SR, and a region devoid of matter is flat, then an "empty" region must be SR-compliant. By this line of reasoning, even if a region was *not* strictly empty (because it contained observer-masses exchanging signals) then since the space *between* these particles would be empty, the SR relationships would still apply. [5]

If one took an empty region and added a pair of observer-masses with relative velocity, exchanging signals, the mass-curvature aspect of the problem could be ignored. The properties of the connecting signals in the remaining region of flat spacetime would then obey the predictions of the 1905 theory.

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i This causes problems for Einstein's general theory, which is supposed to implement both special relativity ("*Inertial physics in the absence of gravitation*") **and** the PoE ("*equivalence of inertia and gravitation*"). Special relativity is generally considered to be a limiting case of general relativity, but a valid general theory has no physical limit at which gravitation disappears and inertia remains, where SR might apply.

3. Revised argument – gravitational fields

In the period from 1907 to 1911, Einstein developed an additional caveat, that since a gravitational field gradient should deflect light, the gradient must represent a *variation* in the speed and/or velocity of light, [i] [8] invalidating his 1905 assumptions of global lightspeed constancy and flat lightbeam geometry. [ii] [9] Special relativity was now only to be assumed valid in the absence of matter *and gravitational field gradients*. [iii]

This made an important change to the "rules of engagement" of special relativity, as it was no longer good enough to say that the 1905 theory applied in regions devoid of *matter* (*no gravitational field sources*): to be considered truly "empty", the region also needed to contain *no varying gravitational fields*. For SR to apply throughout a region, *the adjacent regions* must *also* contain no significant matter, otherwise the fields from this adjacent material would bleed into our region of study.

For SR to apply throughout a region, there must be no matter ***either in or adjacent to*** the region – the "flat" region needs to be surrounded by an additional empty "exclusion zone" or "**safety margin**" where matter is not allowed to intrude.

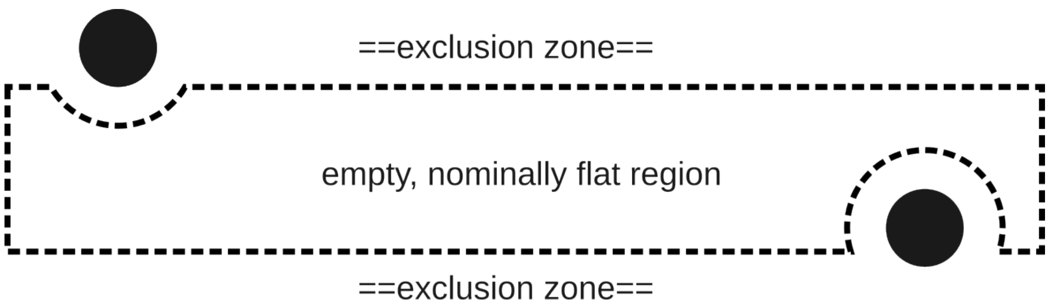

Figure 1: The "flat" region is surrounded by an exclusion zone in which matter needs to be either absent, or given a uniform spherically-symmetrical distribution to allow field-cancellation.

i A deflection of light normally represents a change in the velocity and momentum (and therefore directional energy) of the light-signal, both in the original direction of travel and in the direction being deflected towards.

ii **Einstein (1916):** [8], " *It will also be obvious that the principle of the constancy of the velocity of light* ***in vacuo*** *must be modified, since we easily recognize that the path of a ray of light with respect to K' must in general be curvilinear, if with respect to K light is propagated in a straight line with a definite constant velocity.* "

iii **Einstein (1914):** [10], " *It is the essence of the theory we derived here that the original theory of relativity holds in the infinitesimally small.* " … in other words, within empty pointlike regions that cannot contain *real* pairs of particles with relative motion, exchanging signals, and which are too small to allow meaningful field gradients. Special relativity is then assumed to correctly describe matter-physics when the size of the region is effectively zero, the field gradients are zero, the number of observer-masses with relative motion is zero, and where the number of physical observations within the region that require "relativisation" is zero. This suggests that SR is a "null solution".

4. Applicability of SR

Once we have established the “exclusion zone” principle, we see that the region of space carrying a signal passed between two relatively-moving masses cannot be modelled using SR, because the adjacency of *the particles themselves* violates the **margin condition**.

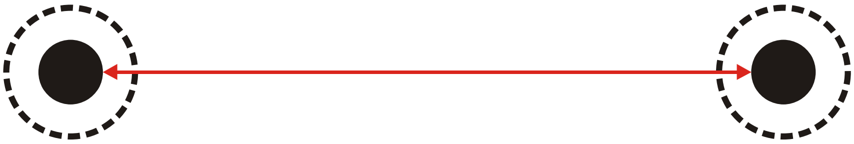

Figure 2: A signal sent between the interaction surfaces of two particles has to pass through an arbitrarily-strong region of gravitational and gravitomagnetic (“GM”) curvature adjacent to each.

A signal cannot be passed between two massed particles without also crossing the non-SR regions *adjacent* to the particles.

5. "Exclusion zone" physics

5.1 Strength of the GM effect

How badly do these regions depart from normal Minkowski spacetime? As it turns out, very badly indeed …

It has been common practice for GR researchers to model a moving massed particle as an idealised moving point-singularity of the field (*e.g.* [11] , [12]). [i] [ii] Within the context of a general theory, every *inertial* mass is also a *gravitational* mass with an associated contribution to the local field. The point-particle idealisation, combined with the inverse square law, gives an *arbitrarily-strong* curvature at arbitrarily-short distances.

Before we reach zero separation and infinite field strength, we meet a curvature horizon, which can be considered (in the absence of any conflicting information) to be the natural default interaction surface of the idealised particle. The physics of a pair of tiny idealised fundamental massed particles with relative motion exchanging signals therefore corresponds to **the absolute worst-case scenario** for SR, involving the most extreme gravitational and gravitomagnetic effects conceivable – the physics of **moving curvature-horizons** (albeit on a sub-microscopic scale).

If one of these particles *moves*, our current default expectation is that a moving segment of horizon surface should drag light along *completely*. [13] If the moving interaction surface deflects nearby light, then it also changes that light's momentum, and therefore also its detected energy and frequency, as a function of the particle's relative velocity. The Doppler relationships for a moving horizon cannot then be those of "flat" special relativity.

Even if the spatial extent of the non-SR curved-spacetime region surrounding a fundamental massed particle is considered to be *vanishingly small*, light still has to pass *through* this non-SR gravitomagnetically-warped region to reach the nominally-flat region, by which time the motion-shift relationship has already changed, and the damage is done.

5.2 Magnitude

The expected frequency-shift due to dragging effects is not insignificant – we would by default expect the full-dragging ***gravitomagnetic*** shift to be $E'/E = (c-v)/c$, which is of the same order as a conventional Doppler shift. This is also, coincidentally, the default Doppler relationship for mid-Nineteenth-Century Newtonian theory. [iii]

The default physics of the two regions that we traditionally ignore as being "too insignificant" to be worth calculating the effects for, actually create a Doppler-effect analogue every bit as strong as a conventional everyday Doppler shift, before we have even started to consider the physics of the much larger flat intervening region.

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i Einstein's writings often refer to the idea of an idealised moving point-mass (used as a purely hypothetical "building-block" entity for larger arguments), as a "***material point***".

ii Here, the point-singularity is, of course a "stand-in" for the actual unknown-and-unspecified structure of an actual fundamental massed particle. As long as the particle's properties are symmetrical, the point-idealisation would seem to work at a reasonable distance from the real particle's centre.

iii This also turns out to be the exact relationship required to bring general relativity into line with quantum mechanics regarding horizon behaviour: the redder relationship given here represents the only relativistic solution that allows gravitational horizons to be **relative** and **observer-dependent** [14] as *per* Hawking (2014) [15] Unlike Einstein-Wheeler **event horizons**, *relative* horizons allow massenergy and information to migrate outward along non-inertial paths, generating the classical "statistical" equivalent of Hawking radiation. As well as a fusion between modified GR and QM, we obtain a topological agreement with cosmological horizons (which are *necessarily* relative), and get to fully merge cosmological and gravitational theory. In this revised system, atomic emissions become Hawking radiation events.

5.3 Doppler shift extinction

Since this predicted gravitomagnetic shift is so strong, we might wonder why (if it exists) we have never noticed it. If we have a gravitomagnetic shift *and* a conventional Doppler shift, with the GM shift redder than the SR shift by an additional Lorentz factor, then surely even at low velocities, where the Lorentz factor difference between the two is minimal, we should be measuring twice the conventional Doppler effect? [i]

However, the gravitomagnetic shift ***extinguishes and replaces*** the conventional Doppler effect. If we consider a signal sent between two bodies with relative velocity *v*, and the signal rides a gravitomagnetic differential *also* of *v*, and arrives already moving at $c_{\mathrm{DESTINATION}}$, then we no longer have a rationale for the signal to undergo a conventional Doppler shift when it arrives, as the original velocity-difference has been "absorbed" by the GM field.

In a gravitomagnetic theory, the SR shift predictions for a flattish region between two particles are almost irrelevant, because it is the *gravitomagnetic* shift that gives the dominant defining physics.

i Alternatively, one might suggest that the "conventional" Doppler effect and the "gravitomagnetic" shift effect are one and the same — but this argument does not work if our "conventional" Doppler shift is the one provided by special relativity. The 1905 SR Doppler relationship, *tailored* for a perfect fit to flat spacetime, *only works* in perfectly flat spacetime, and the gravitomagnetic shift is a curved-spacetime effect.

If the GM effect *is* to be considered "dual" with a conventional Doppler effect, that "conventional" effect must be calculated within a dynamically curved spacetime, and cannot correspond to the SR Doppler relationships.

6. Conclusions

Suppose that we have a region fifty lightyears across on the *x*, *y* and *z* axes, utterly empty of matter, and effectively flat. We then introduce two idealised fundamental massed particles with significant relative motion and a separation of 25 lightyears. Such a region is *exceptionally* flat, far beyond what can be currently expected to exist in Nature. We are traditionally told to ignore the tiny local regions of strong gravitational and gravitomagnetic curvature around each particle as vanishingly insignificant, and calculate the energetics of exchanged signals purely from the relativity principle applied to the properties of the overwhelmingly-larger "flat" 25 lightyears of intervening space.

However, if we try to actually model the effects of short-range curvature, [i] we find that the reality is very different. Rather than the energetics of the problem being wholly defined by the flat region and special relativity, with no sensible contribution being made by the two tiny curved regions, the energetics are dominated and apparently *entirely defined* by the small-scale gravitomagnetic curvatures, and *not at all* by Lorentz-Einstein-Minkowski flat spacetime geometry, whose shift effects are eliminated and replaced by the gravitomagnetic behaviour. Special relativity plays no obvious part in the final calculations.

We therefore need to develop a new and more sophisticated geometrical system of physics that is not a full superset of SR: some SR relationships will turn out to be general and will survive, [16] others will turn out to be specific to flat spacetime and will need to be discarded.

We can, of course, still continue to use special relativity as useful "engineering" theory, giving an averaged and homogenised *flat approximation* of the real underlying curved-spacetime geometry, but its status *must be **understood*** to be that of a flat approximation. [16] Since the 1905 theory's "flat" definitions do not carry over into general relativity, quantum mechanics, [ii] [17] or Hubble cosmology, [18] [19] it should not be mistaken for foundation theory. [iii]

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i … instead of arbitrarily setting their effects to zero, and declaring an *assumed* insignificance as obvious …

ii In quantum mechanics, the counterpart of the **velocity-dependent gravitomagnetic field** is the **momentum probability field**, which then corresponds to a **classical momentum field**. If the gravitational field is considered to be the spatial extension of *mass*, and a moving mass has *momentum*, then classical field theory requires the *moving mass-field* to have an associated *momentum field* (the corresponding spatial extension of the particle's *momentum*). By requiring the absence of a momentum field for moving bodies, a 1916-style SR-centric general theory violates both classical and quantum field theory. [17] With the momentum field we have a relativistic light-dragging theory, and Hertzian rather than Lorentzian relativity.

iii Further study shows that the averaged SR approximation does seem to get *some* relativistic physics *exactly* right, specifically aspects of reality that depend on round-trip measurements rather than one-way descriptions, as some properties of Nature *are* actually averaged properties, and all relativistic solutions, when their forward and time-reversed predictions are averaged, will generate the SR relationships as an artificial "shell" solution. Several other aspects of special relativity, on analysis, turn out not to be specific to the theory at all, but are general results that appear in any relativistic model (*e.g.* $E_0=m_0c^2$). [20] The experimental literature has many results that are "relativistic", but largely or completely insensitive to the question of *which* relativistic system is in operation. [20]

References

1. Albert Einstein, "*Zur Elektrodynamik bewegter Körper*", **Annalen der Physik**, **vol. 322**, issue 10 (1905), pages 891-921.
https://doi.org/10.1002/andp.19053221004
translated and reprinted as:
Albert Einstein, "*On the Electrodynamics of Moving Bodies*", **The Principle of Relativity** (Methuen 1923) pages 35-65.
ISBN 0486600815

2. Hermann Minkowski, "*Raum und Zeit*", **Jahresbericht der Deutschen Mathematiker-Vereinigung vol. 18** (1909), pages 75–88.
translated and reprinted as:
Hermann Minkowski, "*Space and Time*", **The Principle of Relativity** (Methuen 1923), pages 73-91. ISBN 0486600815

3. Albert Einstein, May 1921 "Stafford Little" Princeton lectures, published as
The Meaning of Relativity (Meuthen, 1922), Third lecture, "*The General Theory of Relativity*", pages 57- .
Einstein Papers Project **7-71** https://einsteinpapers.press.princeton.edu/vol7-trans/331

4. Eric Baird, "*Einstein's Missing Third Postulate*", **ResearchGate** (July 2022).
doi: 10.13140/RG.2.2.13356.74881

5. Edwin F. Taylor, John Archibald Wheeler, **Spacetime Physics, second edition** (Freeman, 1992), page 132.
"*Box 3.1: The Principle Of Relativity Rests On Emptiness!*", Pages 56-57 ISBN 0716723271

6. Albert Einstein, **Relativity: The Special and the General Theory,** "*Appendix 5: "Relativity and the problem of space*" (added to the 1952/1954 edition).
" *If we imagine the gravitational field, i.e. the functions $g_{\mu\nu}$, to be removed, there does not remain a space of the type (1), but absolutely nothing, and also no "topological space." For the functions $g_{\mu\nu}$ describe not only the field, but at the same time also the topological and metrical structural properties of the manifold.* "

7. Albert Einstein, "*Do gravitational fields play an essential part in the structure of the elementary particles of matter?* ",
Sitzungsberichte der Preussischen Akad. d. Wissenschaften, (1919).
Einstein Papers Project **7-17**. https://einsteinpapers.press.princeton.edu/vol7-trans/97

8. Albert Einstein, "*The Foundation of the General Theory of Relativity*", **Annalen der Physik Volume 49** no. 7 (1916), "*§2: The Need for an Extension of the Postulate of Relativity*" pages 769-822 . doi: 10.1002/andp.19163540702
Einstein Papers Project **6-30** https://einsteinpapers.press.princeton.edu/vol6-trans/158

9. Albert Einstein, "*On The influence of gravitation on the propagation of light*", **Annalen der Physik Volume 35** (1911), pages 898-908 .
Einstein Papers Project **3-23** https://einsteinpapers.press.princeton.edu/vol3-trans/393

10. Albert Einstein, "*The Formal Foundation of the General Principle of Relativity*",
Königlich Preußische Akademie der Wissenschaften (Berlin). Sitzungsberichte (1914), pages 1030-1085.
Einstein Papers Project **6-9** https://einsteinpapers.press.princeton.edu/vol6-trans/42

11. Karl Schwarzschild, "*On the Gravitational Field of a Point-Mass, According to Einstein's Theory*", **Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften, S**. (1916) pages 189–196
Translated and reprinted in
The Abraham Zelmanov Journal, **vol. 1** (2008), pages 10-19. ISSN 1654-9163

12. Albert Einstein, Leopold Infeld, and Banesh Hoffmann, "*The Gravitational Equations and the Problem of Motion*", **Annals of Mathematics volume 39**, No. 1 (January, 1938), pages 65-100. doi: 10.2307/1968714

13. Dieter R. Brill, and Jeffrey M. Cohen, "*Rotating masses and their effect on inertial frames*"
Physical Review volume 143, issue 4 (March 1966), page 1011-1015.
doi: 10.1103/PhysRev.143.1011

14. Eric Baird, "*The Doppler equations of Newtonian optics as a unique solution to quantum gravity*" (May 2018).
https://doi.org/10.13140/RG.2.2.21885.67045

15. Stephen W. Hawking, "*Information Preservation and Weather Forecasting for Black Holes*" (22 January 2014).
http://arxiv.org/abs/1401.5761

16. Eric Baird, "*Special Relativity Considered as an Average of Earlier Theories*" **ResearchGate** (February 2020).
doi: 10.13140/RG.2.2.35879.70566

17. Eric Baird, "*Problems with Einstein's general theory of relativity*", **ResearchGate** (September 2024).
doi: 10.13140/RG.2.2.16665.12649

18. Eric Baird, "*Cosmological redshifts vs. gravitational redshifts*" **ResearchGate** (June 2018)
https://doi.org/10.13140/RG.2.2.26042.29128

19. Eric Baird, "*Shift Symmetry in Einstein's Universe: D: Cosmology*", **ResearchGate** (May 2024).
doi: 10.13140/RG.2.2.11760.06401

20. Eric Baird, "*Ten proofs of special relativity*", **ResearchGate** (July 2020).
doi: 10.13140/RG.2.2.30051.17441