

## Added in proof: reception, erratum, confirmation

*Reception.* With several thousand downloads, this paper is one of the most-read in general relativity. An early all-out criticism by the Einstein Institute [27] got subsequently replaced by a toned-down version [28]. The latter no longer repeated the first's claims that the Abraham paper contradicts both general relativity and experiment. The only relevant criticism remaining was a prediction: that *if* the gothic-R theorem were to be extended from the radial Schwarzschild metric to the full metric, it would prove incompatible with celestial mechanics. Even this prediction was laid to rest by the successful re-formulation of the full Schwarzschild metric in terms of the gothic-R variable achieved by an anonymous author signing with "Ich" [29] (see his Eq.17). No further claim at falsification has been made to my knowledge. All high-publicity claims at falsification made since by high-ranking institutions (like KET, CERN and two national parliamentary bodies) do rely on the authority of Nicolai's first paper and hence are baseless. So are the ill-fated experimental decisions made in their wake.

*Erratum.* The merits of the already mentioned anonymous author do not stop here. He also succeeded in finding a first error in the above paper – not in the gothic-R theorem proper but in the added conjecture (erroneously labeled "Q.e.d.") that the proper infalling time were *infinite*. This conjecture is false: the proper infalling time is *finite* [30]. The reasoning is based on the Rindler metric which is a valid approximation to the Schwarzschild metric [5,31]. The new result at first sight comes as a surprise from the point of view of the gothic-R theorem since the infinite distance implicit in the latter cannot be covered in finite proper time by definition – unless luminal observer speeds are involved. This appears absurd at first sight. Surprisingly, Ich's result goes hand in hand with a corollary that implies exactly this.

*Confirmation.* The new confirmative corollary follows likewise from the Rindler metric. Since the Rindler metric involves only special relativity, it can be fully understood in terms of a 2-D Minkowski diagram (the familiar x,t frame of special relativity). More specifically it refers to a long rocket in constant acceleration in outer space, with earth's gravity (1 g) reproduced at the tip. The full rocket consists of many segments each carrying its own pair of boosters on the outside. (Picture many solid hollow cylinders pairwise connected by a rubber tube.) In the x,t plane, the trajectories of all segments come to lie in between  $t = +x$  (right-hand part of first bisector) and  $t = -x$  (second bisector). This *quarter* of the full Minkowski plane is called the "Rindler wedge." Inside the quarter, we have our 1-light-year-long rocket momentarily located motionless along the x-axis while accelerating everywhere at full blast, stretching from  $x = 0$  (bottom) to  $x = 1$  (tip). In the x,t plane the trajectory of the tip rises up vertically at first in order to gently bear right along a curved line in the form of a half-hyperbola which asymptotically approaches the first bisector to coincide with it only at  $t = x = \text{infinity}$ . The lower (past) part of the same trajectory does the same thing reflected downwards, approaching the second bisector in negative infinite time. (This means, physically speaking, that the constant acceleration is superimposed on a constant negative, initially at  $t = -\text{infinity}$  luminal, speed.) The more inner segments of the rocket ( $x < 1$  on the x-axis) all do the same thing along proportionally downscaled hyperbolas with a correspondingly larger acceleration ( $g/x$ ). This principle continues right down to the 90-degree angle at  $x = 0$  where the acceleration becomes infinite ( $g/0$ ). The assumed gradient in accelerations is necessary in order for the rocket to remain connected over time – a paradoxical accepted fact in special relativity [5]. It follows that the intra-rocket times ("rocket tip times") T remain definable inside the rocket indefinitely: along straight lines through the origin. The bundle of these "T times" through the origin ranges from  $T = -\text{infinity}$  at slope  $-1$ , via  $T = 0$  at slope zero, to  $T = +\text{infinity}$  at slope  $+1$  [5]. All T-times

are on the same footing; that is, they can each be identified with the  $x$ -axis by shifting the initial condition by simply “scrolling up“ or “scrolling down.“

Now the two results announced. First, the *finite* proper infalling time result [30]: The internal observer at the tip of the rocket (at  $x = 1$  and  $t = 0$ ) lets go of his handle and simply stays put moving up in time  $t$  along the  $x = 1$  vertical. He simultaneously is “falling“ freely inside the rocket so as to leave it through an opening in the bottom at  $t = 1$  (1 year) at the point  $x = t = 1$ , only to see the rocket’s bottom depart from him at the speed of light. He at this point has effectively “fallen“ through the whole length of the rocket in 1 year’s proper time.

Second, the new *luminal-speeds* result: To see it, we assume for starters that the hole in the tail has been plugged by a trampoline (this assumption can be dropped later). The coasting passenger – assumed resilient enough – then bounces back all the way up toward the tip in another year of his proper time. In the Rindler diagram, this rebounding trajectory is again a straight line: Starting at the point  $x = t = 1$ , it continues along the first bisector in coincidence with the latter, so as to let the jumper re-catch his handle which moves along the curved hyperbola of the rocket’s tip, at  $x = t = \text{infinity}$ .

This is all. One sees that the two legs of the observer’s trip are mutually equivalent (except for orientation in time). For it is possible to “scroll down“ the initial time  $T$  when the observer lets go of his handle, all the way down from  $T = 0$  toward  $T = -\text{infinity}$ . In the new equivalent picture the observer then reaches the trampoline, not at  $x = t = 1$  but rather at  $x = t = 0$  (origin). This *symmetric* case now reveals that during either half trip (the two are now mirror images of each other), an infinite distance in outer space is being covered by the observer – in finite proper time. Thus there always exists an appropriately chosen frame in which an infinite distance is bridged by the falling (or rebounding) observer in finite proper time.

This new result is surprising since luminal speeds of massive bodies had no place in physics before. The reason they are a reality here lies in the free choice of frames that is the hallmark of the Rindler metric – the above “scrolling operation.“ For we can always make sure that the “arriving event“ at the bottom of the rocket (which is the horizon [31]) coincides with the origin of the metric (the 0,0 foot point of the Rindler wedge). This point can by definition be reached from inside the wedge (or be left into the wedge, respectively) only along one of the two 45-degree trajectories, that is, along a luminal trajectory that is coincident with one of the wedge’s boundaries.

This fact – that the origin of the Rindler metric is “nonsingular“ – comes as a surprise. But recall that the bottom of the rocket was actually reached by our first “falling“ observer on his stepping out into the light from the hole in the rocket’s bottom, at  $x = t = 1$ . This fact [30] now also means that a luminal speed is indeed accessible to a falling observer or particle inside the Rindler metric! But cannot such a speed only be reached after an infinite period of constant acceleration by definition? This is correct.

Amazingly, both seemingly contradictory facts are mutually compatible for once. For the waiting time at permanent constant acceleration inside the rocket is infinite. The handle (or a companion sitting on the neighboring seat) has to wait upstairs an infinite period of time under constant acceleration, bridging an infinite distance in outer space in the process before being at last reunited with the back-bouncing youthful observer.

More abstractly speaking, the “scrolling operation“ *includes* the two 45-degree singular limiting cases with their luminal speeds as effectively nonsingular cases. This mathematical finding is amenable to a deeper (differential-topological) explanation. Here it suffices to say that such a situation – that the singular limits are nonsingular – is so far unheard of in physics. This fact gives the Rindler metric – and its close relative, the Schwarzschild metric – a unique place in nature.

What does the effective infinite intra-rocket (and extra-rocket) distance found mean? It means that a well-known result possesses a new corollary. So far it was known that *photonic* Hawking radiation by definition takes *zero* proper time to emerge from the horizon after having covered the whole (infinite) gothic-R distance. Now *material* Hawking radiation analogously takes a *finite* proper time to come out. Similarly, *light* takes an *infinite* outside time to come out as shown in the paper. Now *material* particles take a longer (twice as long) *infinite* outside time to come out across the whole gothic-R distance. Thus we again have only reproduced a self-evident fact, it appears.

This notwithstanding, the prediction of an infinite “emerging time“ because of an infinite distance to be covered from the horizon is what gave the above paper its worldwide publicity. For this prediction implies that microscopic black holes generated on earth cannot evaporate in finite time and hence put the planet at risk if earth-bound. In this way an *ethical* dimension got suddenly attached to a pure physics result. This other dimension was interestingly not seen at the time of writing the paper. Rather it was the merit of a relativist colleague who when recommending publication jokingly asked whether there could be repercussions on the LHC experiment. Since of the latter I had not heard before, this remark eventually triggered a vain attempt at defusing the joke. When it failed, a more serious one followed so that it eventually became a sport to find a new more sophisticated argument to defuse the joke. Each floundered for a different reason. Eventually a vague hunch of a danger-conserving principle being at work developed – that all the uncanny failures may be non-coincidental. The hunch became tangible when the final unsuccessful attempt at giving the all clear had been communicated to CERN in May and published in July [33]: neutron stars seem to possess a special quantum protection against natural cosmic ray-borne very fast analogs to the miniblack holes potentially created on earth. (Superfluidity was the likely culprit.) The idea of a joke potentially played by nature on humankind – that the ultraslow human-made cousins could be *alone* in representing a danger – then befell the whole planet as a serious concern on September 10 when more than 500 newspapers across the globe referred to it in one way or the other. The joke still waits to be defused. Thinking twice – by no longer opposing the safety conference demanded on April 18 [33] – fortunately is still an option today thanks to a *fehllleistung* at CERN on September 20. The whole globe is grateful for the second chance at falsification given to it. Or is it not?

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