A model of spacetime in a world with repulsive gravity

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It is widely believed that gravity is attraction only, but that has not yet been established definitely. Although it is known since the 1950s that a matter-antimatter repulsive gravity is ruled out if theories of modern physics (GR, QED, QCD) are valid beyond their established area of application [1], it is currently a hot topic in experimental physics to *directly* measure the acceleration of massive antiparticles in the gravitational field of the earth: three sizeable projects (AEGIS, ALPHA, GBAR) are going on at the AD facility of CERN using anti-hydrogen, and one (MAGE) at the PSI using muonium. The current state of affairs is that results with an accuracy of 1% can be expected in the nearby future.

That being said, the aim of this lecture is to present a model of spacetime that can be used under the condition that a massive system made up of antimatter is *repulsed* by the gravitational field of a body of ordinary matter. First the following two propositions about spacetime, which are counterintuitive for most physicists, will be proven:

(i) under the aforementioned condition, spacetime is not necessarily curved;

(ii) under the aforementioned condition, spacetime is necessarily substantival.

To prove proposition (i), it will first be proven by *reductio ad absurdum* that spacetime is necessarily curved if the equivalence principle (EP), introduced by Einstein in [2], holds; the proof is based on an argument by Susskind [3]. Next, it will be proven that the EP does not hold if a matter-antimatter repulsive gravity exists: that proves proposition (i). To prove proposition (ii), it will be shown that energy conservation is violated if spacetime is relational and if a matter-antimatter repulsive gravity exists: this is Morrison's argument against repulsive gravity [4]. Ergo, if a matter-antimatter repulsive gravity does exist then spacetime is necessarily substantival—else energy conservation would be violated. That's proposition (ii).

Having proven these propositions, a Vierbein frame will be presented: this can be used as a model for spacetime in a world with repulsive gravity [5]. This idea of a Vierbein frame boils down to the view that spacetime is characterized by two real fields: a *gravitational potential field* and a *vacuum temperature field*. These two fields are encoded in the Vierbein field $\{\vec{g}_\alpha\}$, a set of four vector fields $\vec{g}_\alpha$ on the spacetime manifold $\mathcal{M}$. The local values at a point $X \in \mathcal{M}$ form a four-element set $\{\vec{g}_\alpha^X\}$: this is the *local Vierbein*. The physical interpretation of a local Vierbein will be discussed. In an elementary process by which a gravitational interaction takes place between a massive system and its environment, the system "sees" the local Vierbein field: therein lies then the key to repulsive gravity.

References

[1] M.M. Nieto, T. Goldstein, The arguments against "antigravity" and the gravitational acceleration of antimatter. *Physics Reports* **205**, 222–281 (1991)

[2] A. Einstein, Über das Relativitätsprinzip und die aus demselben gezogene Folgerungen. *Jahrbuch der Radioaktivität und Elektronik* **4**, 411–462 (1907)

[3] L. Susskind, General Relativity: Lecture 1. Lecture for the theoretical minimum series at Stanford University (2012)

[4] P. Morrison, Approximate Nature of Physical Symmetries. *American Journal of Physics* **26**, 358–368 (1958)

[5] M.J.T.F. Cabbolet, *And now for something completely different: the Elementary Process Theory. Revised, updated and extended* 2^{nd} *edition of the dissertation with almost the same title.* Eburon Academic Publishers, Utrecht, *liv* + 581 pp. (2022)