

Symmetry Breaking Equivalence Principle  
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The equivalence principle has been hypothesized as strong, weak, symmetric and so forth. Clear understanding of the equivalence principle is necessary to develop quantum gravity theory. This brief paper sheds light upon the conundrum of the equivalence principle and offers a Symmetry Breaking Equivalence Principle interpretation of the CERN AEGIS antihydrogen gravitational experiments.

**Experimental prologue:**

“In recent years, first ALPHA <sup>[1][2]</sup> and then ATRAP <sup>[3]</sup> have trapped antihydrogen atoms at CERN; in 2012 ALPHA used such atoms to set the first free-fall loose bounds on the gravitational interaction of antimatter with matter, measured to within  $\pm 7500\%$  of ordinary gravity<sup>[4]</sup>, not enough for a clear scientific statement about the sign of gravity acting on antimatter. Future experiments need to be performed with higher precision, either with beams of antihydrogen (AEGIS or GBAR) or with trapped antihydrogen (ALPHA).” Wikipedia

This result shows that  $g$  between an antiparticle and the earth is

$$g(\text{earth, antihydrogen atom}) = 9.8 \text{ m/s} \pm 750 \text{ m/s.}$$

Given the experimental difficulty, this result is astounding. But the interpretation is too timid. This result is equivalent to saying that

$$g(\text{earth, antihydrogen atom}) = 0 \text{ m/s} \pm 750 \text{ m/s.}$$

Hence, not only can we not tell whether

$$g(\text{earth, antihydrogen atom}) \text{ is positive or negative}$$

But it really looks like  $g(\text{earth, antihydrogen atom})$  is ZERO!!! i.e.

$$F_{\text{gravity}}(\text{matter earth, antimatter antihydrogen}) = 0 \pm$$

A very nice NULL experimental result.

**Theoretical prologue:**

Feynman famously described antimatter as matter travelling backward in time. Of course, the visible universe consists primarily of entropically time forward matter. Whereas the backward in time antimatter idea is a metaphorical or calculational shortcut at best. Or is it? This is a first principle question that is difficult to focus upon through the fractal maze of subspecialized physics (ditto astrophysics).

**Gedanken Experiment**

Particles  $a$  and  $b$  gravitationally attract in our time forward visible universe. Gedanken: we turn both particles  $a$  and  $b$  into their respective antiparticles; they now reverse their previous path of attraction, i.e. antiparticles  $a$  and  $b$  gravitationally repel as if moving backward in time, in our time forward visible universe, from our time forward point of view. Note:  $a$  and  $b$ , whether particle or antiparticle, are electromagnetically neutral

## Analysis of Gedanken Experiment using Newton's Law of Gravity

$F_{\text{gravity}}(a, b \text{ both matter}) = + \in \mathbf{R}$ , Force<sub>gravity</sub> is a positive number, attract

$F_{\text{gravity}}(a, b \text{ both antimatter}) = - \in \mathbf{R}$ , Force<sub>gravity</sub> is a negative number, repel

But IF:

$F_{\text{gravity}}(a, b \text{ both antimatter}) = G m_a \mathbf{i} m_b \mathbf{i} / r_{ab}^2 = - \in \mathbf{R}$

(i.e.  $F_{\text{gravity}}(a, b \text{ both antimatter})$  is a **negative** real number)

THEN

$m_{a \text{ antimatter}} \mathbf{i}$  and  $m_{b \text{ antimatter}} \mathbf{i}$  must each have an imaginary number gravitational mass values; since  $G$  and  $R_{ab}$  are both **positive** real numbers. So all antimatter must have an **imaginary number** gravitational mass value in our time forward visible universe. (Notation alert: specific imaginary number quantities will be noted explicitly, e.g.  $m_{gb} \mathbf{i} \in \mathbf{I}$  while as  $m_{gb} \in \mathbf{R}$ .)

But experiment show antimatter to have **real number** inertial mass values.

Thus this, **Symmetry Breaking Equivalence Principle** is necessary

$m_{\text{gravity of antiparticle } b} \mathbf{i} \in \mathbf{I}$ , the gravitational mass value of any antiparticle  $b$  is an imaginary number as calculated in our time forward visible universe.

### Detail Hypotheses

The equivalence principle applies only to matter (not to antimatter) in our time forward visible universe.

There is no free fall for antimatter particles in our time forward visible universe.

All antimatter is electromagnetically constrained or it will rotate out of our time forward visible universe, into a time backward T-duality curled multiverse

*matter*

$m_g \in \mathbf{R}$ , gravitational mass of a particle has a real number mass value in our time forward visible universe. And

$m_{ia} = m_{ga}$ , the inertial mass of a particle  $a$  equals the gravitational mass of particle  $a$  in our time forward visible universe.

*antimatter*

$m_{gb} \mathbf{i} \in \mathbf{I}$ , the gravitational mass of an antiparticle  $b$  has an imaginary number mass value, in our time forward visible universe. Whereas:

$m_{ib} \in \mathbf{R}$ , the inertial mass of an antiparticle  $b$  has a real number mass value, in our time forward visible universe.

## **CERN ALPHA experiment NULL result reinterpreted**

The CERN ALPHA antihydrogen experiment described itself thus  
“The primary scientific goal of the Antihydrogen Experiment: Gravity, Interferometry, Spectroscopy (AEGIS) is the direct measurement of the Earth's gravitational acceleration,  $g$ , on antihydrogen... to measure the strength of the gravitational interaction between matter and antimatter to a precision of 1%... The AEGIS experiment will represent the first direct measurement of a gravitational effect on an antimatter system... Now we are in a position to test Einstein's equivalence principle with antimatter by directly measuring the free fall of antiatoms on Earth. The equivalence principle is the keystone of general relativity and states that all particles with the same initial position and velocity should follow the same trajectories in a given gravitational field. On the other hand, quantum theories such as supersymmetry or superstrings do not necessarily lead to an equivalent force on matter and antimatter (technically, the terms related to gravity in the Lagrangians are not bound to be the same for matter and antimatter)... Any difference seen in the behaviour of antimatter and matter with respect to gravity would mean that the equivalence principle is not perfect and force us to understand quantum effects in the gravitational arena... Any difference would probably not change anything in the observable universe, but it would point to the necessity of having a quantum theory of gravity... it is extremely unlikely that antimatter experiences an opposite gravitational force to matter and therefore “falls” up. “

But CERN Earth/antihydrogen null gravitational force neither up nor down needs to be interpreted. Thus

$$F_{\text{gravity}}(\text{matter earth, antimatter antihydrogen}) = 0 \pm , \text{ i.e. CERN null result}$$

Due to Symmetry Breaking Equivalence Principle

$m_{\text{gravity of antiparticle } b} \mathbf{i} \in \mathbf{I}$ , the gravitational mass value of any antiparticle  $b$  is an imaginary number as calculated in our time forward visible universe.

The force of gravity between the earth and an antihydrogen atom must have an imaginary number force value

$$F_{\text{gravity}}(\text{earth, antihydrogen}) = G m_{\text{g earth}} m_{\text{g antihydrogen}} \mathbf{i} / r_{ab}^2 = \mathbf{Fi} \in \mathbf{I}$$

Because the gravitational mass of antihydrogen is  $m_{\text{g antihydrogen}} \mathbf{i} = m \mathbf{i} \in \mathbf{I}$ , whereas All other elements in the equation are real positive numbers.

$$F_{\text{gravity}}(\text{earth, antihydrogen}) = \mathbf{Fi} \in \mathbf{I} \text{ means that}$$

$\mathbf{Fi}$  as an imaginary number force is not observed locally in our three real spatial dimensions visible universe. In other,

$$F_{\text{gravity}}(\text{earth, antihydrogen}) = \mathbf{Fi} \in \mathbf{I}$$

Is observed as real number component of the complex number

$$F_{\text{gravity}}(\text{earth, antihydrogen}) = 0 + \mathbf{Fi} \in \mathbf{C}$$

Which has the real number force value of

$F_{\text{gravity}}(\text{earth, antihydrogen}) = 0 \in \mathbf{R}$  which agrees precisely with the observed CERN AEGIS value of

$$F_{\text{gravity}}(\text{matter earth, antimatter antihydrogen}) = 0 \pm$$

(See discussion of nonlocal interpretations of an imaginary number value gravitational force in previous paper, [A Simple Toy Universe](#))

## **Conclusion/Discussion**

Details of CPT symmetry have been carefully omitted from considerations for the antimatter in this Gedanken; so they do not change the conclusion that:

$m_{ib} = |m_{gb}i| = m_{gb} \in \mathbf{R}$ , the inertial mass of an antiparticle b is equal to the **absolute value** of the imaginary number gravitational mass value of antiparticle b in our time forward visible universe; **hence,  $m_{ib}$  has a real number value**. Thus the Symmetry Breaking Equivalence Principle.

Some advanced experiments and theories will need slight terminology changes, re-explaining, and/or reinterpretation (see my two previous papers).

However, much practical physics calculations and terminology will not change.

The value of this Symmetry Breaking Equivalence Principle regarding antiparticles is that it removes a major conceptual roadblock that has prevented proper theorizing and experimental design to achieve new insights regarding quantum gravity, time, T-duality, energy, bosons, dark matter, dark energy, and so on. My two previous papers suggest theoretical, experimental and observational directions as a result of this Symmetry Breaking Equivalence Principle interpretation of the CERN AEGIS antihydrogen experiments.

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