The Particle Annihilation Paradigm

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To my daughter

Abstract. The aim of this article is to show that the annihilation paradigm in Standard Theory does not reconcile with classical electrodynamics, which in turn predicts the existence of electromagnetically opaque matter.

1. Preliminaries

Particle annihilation is defined as the process of collision of particle and antiparticle which results into an electromagnetic radiation of energy that is equal to the total sum of energy of the colliding particles. So, the evident conclusion is that, since the energies match, the particles must have been converted into photons.

2. The Problem

As to electrons and positrons, this annihilation process has been measured many times. However, the detection of the electromagnetic radiation takes place over meters, not within nanometers. So, the electromagnetic radiation is a macroscopic event, therefore at least partly falling into the realm of classical electrodynamics. And classical electrodynamics is governed by Maxwell's equations. Hence, annihilation should reconcile with Maxwell's equations. (It should be said that this large scaled particle annihilation has not been observed directly for massier charged particles like protons or pions, which "almost instantly" decay into other particles, so, the annihilation into an electromagnetic field would be a very short ranged intermediary, if detectable at all.)

3. The Classical Side of Annihilation

For that reason I am mainly focussing on electrons/positrons colliding overhead, but the argumentation will apply to any charged particle/antiparticles that upon collision decay into photons. Irrespective of their opposite charges, both, particle and antiparticle have a positive nonzero (equal) mass, because of the force of inertia, which is opposite to the acceleration. So, both have a positive free energy, which is defined as the geometric mean of rest mass and momentum (with $c := 1$, where c is the velocity of light). Now, Maxwell's equations are given in covariant form as $\Box A = j$, where left and right hand side are 4-vectors, and their forward propagating solution is - modulo plane waves - given by

$$A(x_0, \mathbf{x}) = \int \frac{\delta(x_0' + |\mathbf{x} - \mathbf{x}'| - x_0)}{|\mathbf{x} - \mathbf{x}'|} j(x_0', \mathbf{x}') dx_0' d^3x',$$

in which δ is the (1-dimensional) Dirac distribution. This is nothing but the relativistic form of Poisson's equation and its solution.
Applying Gauß theorem along with $\nabla^2 \frac{1}{|\mathbf{x}|} = 4\pi\delta(\mathbf{x})$ on each of of the 4 components of the above equation gives for a 2-dimensional sphere S surrounding a ball $B(r)$ of radius $r > 0$ in the 3-dimensional space at time x_0:

$$\int\int_S \nabla A^\mu(x_0, \cdot) \cdot \mathbf{n} dS = 4\pi \int\int\int_{B(r)} j^\mu(x_0 - \mathit{dist}(\mathbf{x}, S), \mathbf{x}) d^3x,$$

where $0 \leq \mu \leq 3$ and $\mathit{dist}(\mathbf{x}, S)$ is the (Euclidian) distance of $\mathbf{x}$ to the sphere S. That is: The flux of every A^μ through a sphere S at a given time x_0 is 4π times the integral of $j^\mu(x)$ in the interior of S at the retarded local time. I denote these integrals by $Q^\mu(x_0)$. They represent charge and charge flow within $B(r)$ at those retarded, local times, that contribute to the flow through $S(r)$ at time x_0.

Therefore, if an overhead collision of an antiparticle with a particle is to result into a gamma ray spreading from the collision point, then particle and antiparticle cannot just add up to zero at the collision point, since zero charge and flux within $B(r)$ will result in a zero electromagnetic field.
In fact, the Lorentz condition

$$\partial A^0(x)/\partial x_0 + \partial A^1(x)/\partial x_1 + \partial A^2(x)/\partial x_2 + \partial A^3(x)/\partial x_3 \equiv 0$$

tells the energy that is created at the spacetime of collision to be equal to the energy of the emitted electromagnetic field.

In other words: According to Maxwell's theory, particle and antiparticle cannot purely dissolve into only electromagnetic energy, but it predicts the creation of a neutral massive particle as the outcome of a particle annihilation. So standard theory, which holds a complete elimination of particle and antiparticle, is in major conflict with Maxwell's theory. And the question is, which one is correct.

The good thing about that problem is that it can be experimentally decided upon:
Assuming that Maxwell's theory holds, the particle-antiparticle collision will result into a massive, neutral particle with rest mass equal to the the energy of collision. That formidable mass must therefore have observable gravitational effects on electromagnetically active matter like charges or atoms: For instance, a container, into which annihilating particles an antiparticles are injected from the outside, will become heavier (unless the particle antiparticles tunnel out of that container); likewise, the cross section of particle anti-particle creation through a scattering gamma ray will increase with the the number of particle-antiparticles present.

The race between both conceptions is open.
What speaks in favour of Maxwell's theory is that it is well-settled and checked, plus, it may readily explain the missing dark matter within black holes: Because of the abundance of electrons in the universe and the charge inversion symmetry, it is to be expected that a large fraction of matter in galaxies is made of electron- positron pairs. And, because of their electromagnetic inactivity, being responsive only to gravitation, they will be expected to aggregate far more densely than any other known matter. Moreover, accumulation of these particle-antiparticles should occur right at the galaxy's center of mass. We would see these centers as "black holes".

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