Constraints on the Composite Photon Theory

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Abstract In a 2015 paper [1], Perkins argued that based on the composite photon theory (CPT), antiphotons should not interact with ordinary matter. This implies that antiphotons are undetectable by detectors made of ordinary matter, and hence that antimatter galaxies are a possible candidate for dark matter. The purpose of this short letter is to argue that this conclusion is highly unlikely, because of cosmological constraints on the density of radiation, the distribution of dark matter, and C-symmetry.

1 Introduction

The problem of baryon asymmetry is one of the most important of modern physics. There seems to be no *a priori* reason for the big bang to produce more matter than antimatter (or vice versa). Yet if the big bang produced equal amounts of matter and antimatter, then they should have annihilated, leaving a universe with a lot of radiation but almost no matter. The fact that we observe a universe with matter therefore presents a problem.

The mainstream method for solving this problem is baryogenesis, whereby all three of Sakharov's three conditions for baryogenesis [2] are satisfied. Many different theories of baryogenesis abound; however there is as yet no widely-accepted solution.

Perkins [1] proposes a composite photon theory by which the universe is baryon symmetric and hence the baryon asymmetry problem does not arise. Perkins proposes that the antiphoton is actually a bound state of a right-handed neutrino and a left-handed antineutrino,

$$\gamma = \nu_{eL}\overline{\nu}_{eR}, \tag{1}$$

while the photon is a bound state of a left-handed electron neutrino and a right-handed electron antineutrino,

$$\overline{\gamma} = \overline{\nu}_{eL}\nu_{eR}. \tag{2}$$

This is in contrast to the Standard Model of particle physics, wherein photons and antiphotons are identical. Perkins' CPT further requires that electron neutrinos be massless [1]. Perkins proposes that this composition of the antiphoton makes it so that it does not interact with ordinary matter, and hence it cannot be detected by detectors made of ordinary matter. They are, however, still affected by gravity, and therefore may be candidates for dark matter. Perkins suggests that the clumps of dark matter that have been detected by gravitational lensing may therefore be invisible antimatter galaxies.

2 Problems

Perkins' CPT does not imply that all dark matter is antimatter in disguise. If it were, there would still be a baryon asymmetry problem, but with more antimatter than matter. Further, since the lifetime of antimatter in the Milky Ways halo is only 300 years [3], the dark matter responsible for the observed rotation curves cannot be due to antimatter. Perkins recognizes this issue, writing that the theory 'cannot explain other "dark matter effects," such as the observed galactic rotation curves'.

The question then arises, in a baryon-symmetric universe governed by Perkins' CPT, just how much of dark matter is antimatter in nature? The Planck collaboration [4] estimates that the total matter density in the universe is roughly

$$\Omega_m h^2 = 0.141, \tag{3}$$

of which baryons comprise

$$\Omega_b h^2 = 0.022, \tag{4}$$

where Ω_m and Ω_b refer to the density parameters of matter and baryons respectively, and $H_0 = 100h$ km/s/Mpc, where H_0 is the Hubble constant.

The density of baryons is measured by two main methods: Big Bang Nucleosynthesis (BBN) [5][6] and Cosmic Microwave Background (CMB) anisotropy [6][7]. The BBN bound is based on the idea that if there are more baryons, then BBN should produce more deuterium, helium, and lithium, which can then be detected. However, in a baryon symmetric universe governed by Perkins' CPT, the antimatter should form antideuterium, antihelium, and antilithium, all of which would emit antiphotons instead of photons. Since the antiphotons of Perkins' CPT cannot be detected by normal detectors, they are effectively invisible, and BBN does not constrain the theory. The other method, CMB anisotropy, also fails to constrain the theory: this method relies on oscillations in the photon–baryon fluid before the era of decoupling, and in Perkins' CPT antiphotons dont couple to baryons, only to antibaryons. Therefore, we can be fairly confident that in a baryon-symmetric universe governed by Perkins' CPT, $\Omega_{bm} h^2 = \Omega_{am} h^2 = 0.022$, where Ω_{bm} and Ω_{am} refer to the density parameters of baryonic matter and antimatter respectively, with what we currently identify as dark matter, Ω_{dm}, decreasing by $0.022/h^2$. Note that this exceeds Planck's measured value of $\Omega_{dm}$by more than 10σ; however this is not a problem because in Perkins' CPT antimatter behaves like cold dark matter.

However in a baryon-symmetric universe governed by Perkins' CPT, Ω_r doubles: there is now an"anticosmic microwave background" that falls off as a^4 where a is the scale factor, i.e. it behaves like radiation not matter. This has observable consequences—the redshift of matter–radiation equality z_{eq} changes, which in turn changes the amount of early Integrated Sachs–Wolfe effect (ISW effect) that CMB photons experience. The larger z_{eq} is, the greater the ISW effect experienced by CMB photons. This effect can be measured via the height of the third acoustic peak of the CMB power spectrum relative to the first peak.

[9][10] As such, Planck is able to constrain z_{eq} [4],

$$z_{eq} = 3371. \tag{5}$$

From this and Planck's value for the density of matter, $\Omega_m = 0.3089$, we can compute the radiation density, $\Omega_r = 9.16 \times 10^{-5}$. This can be independently matched against the energy density of the cosmic microwave background, which is where, by far, most of the photon radiation energy density is contained [11]. This turns out to be 5.0×10^{-5} from the Stefan–Boltzmann Law and the temperature of the CMB. Adding this to the calculated energy density of the cosmic neutrino background, 3.4×10^{-5} [11], yields a total radiation energy density of 8.4×10^{-5}, which is close to Planck's value of the radiation energy density. Even neglecting the cosmic neutrino background, the energy density of the CMB is already greater than half the total radiation density, leaving no room for an anti-CMB.

Another problem with a baryon-symmetric universe governed by Perkins' CPT is that, in such a universe, we would expect large voids where dark matter (in the form of antimatter galaxies) is present, but almost no visible matter can be detected (because it would have annihilated with the antimatter). This is not expected in standard cosmology, where dark matter density perturbations in the early universe collapse first. [8] Their gravitational potentials then act as "guides" for baryons to collapse. The mass map of a 139 $\deg^2$ section of the sky was recently constructed from Dark Energy Survey Science Verification data using weak lensing. [12] The overdensities in the mass map correlates well with the distribution of optically-detected galaxy clusters. This makes the existence of dark matter voids doubtful.

A final problem with Perkins' CPT can be seen from positron–electron annihilation. In the Standard Model, this reaction proceeds by

$$e^- + e^+ = \gamma\overline{\gamma}. \tag{6}$$

Since Perkins' CPT predicts that antiphotons can only be detected by detectors made of antimatter, it also predicts that we only see one photon emerge from this annihilation. This is not observed. One might postulate that electron–positron annihilation actually results in two photons and two antiphotons. This explains the two photons that we see, but it would also violate energy conservation. If Perkins' CPT holds, unless some hidden degree of freedom such as the simultaneous occurence of another process is postulated, electron–positron annihilation must result in two photons only — implying some kind of violation of C-symmetry. This is unprecedented in an electromagnetic interaction.

3 Conclusion

In this short letter we have described three observational issues with a baryon-symmetric universe governed by Perkins' composite photon theory. If the universe is baryon-symmetric, the most probable scenario is still large antimatter structures on the order of several Mpc in scale. Searches are currently ongoing for such structures by measuring the antihelium flux in cosmic rays. While collisions can produce positrons and antiprotons with non-negligible probability, the probability of antihelium production in collisions requires the simultaneous production of four nucleons that then bind together—something that is extremely unlikely. Detection of antihelium therefore implies the existence of antistars going supernovae and ejecting all the antihelium in their coronae into the universe. [13] The current upper bound on the antihelium flux is that due to the BESS collaboration, which found an antihelium flux of less than 6.9×10^{-8} [14]. This may be improved in the near future by AMS-2, which will have a flux limit of 1×10^{-9} [15]. If no antihelium is detected, this is sufficient to exclude large-scale antimatter to the edge of the observable universe.

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