Baryonic Asymmetry

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Abstract

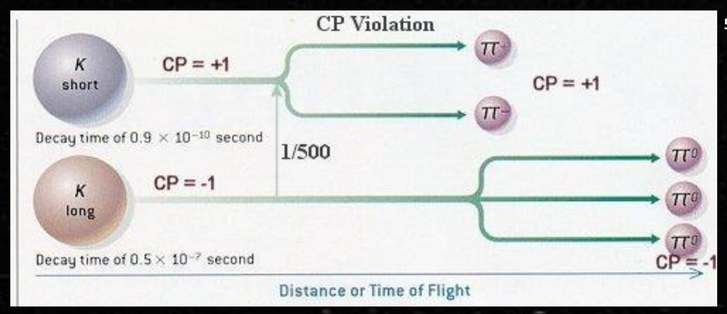
In order to analyze the apparent asymmetry of matter in the universe, multiple theories must be examined to determine the cause or un-observability of this unevenness. I have researched experiments trying to explain this phenomenon, including the CP violating decays of the neutral Kaon and B meson, the measurement of the Electric Dipole Moment of the neutron, and the analysis of cosmic rays to search for antimatter.

Introduction

Everything that we interact with in our daily lives and observe in the outer reaches of space is composed of baryonic matter. Yet in current mathematical theories, equal parts matter and antimatter should have been created in the beginning of the universe. In a universe where antimatter and matter were created in the same proportions, everything would annihilate and leave only photons. Where is all the missing antimatter? This is one of the largest unanswered questions in physics today.

CP Violation Observation

Charge Parity number is the product of a particle's quantum numbers for parity and charge, usually conserved in all interactions. However, violation of CP number has been observed in the decays of the neutral Kaon[6] and B meson. Slight evidence of CP Violation has emerged as of late for the D meson.



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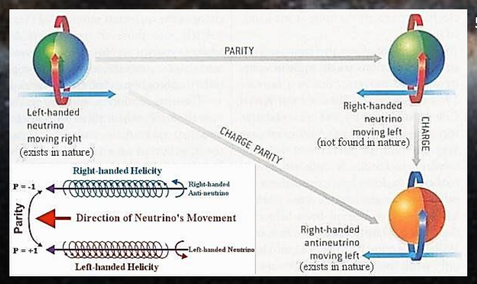
The K Long and K Short are superpositions with differing ratios of the K_1 and K_2. In all decays, the K Short flavor of the Kaon will decay to 2 oppositely charged pions. The K Long will most often decay into 3 neutral pions. Every 1/500 times, however, the K Long will decay into a π+ and π-, violating CP symmetry.[6]

Sakharov's Conditions for Baryogenesis[1]

1. Baryon Number Violation : With unequal amounts of baryons and antibaryons, baryon number must be violated.
2. CP Violation : In some reactions, there must be a preference for matter over antimatter.
3. Thermal Nonequilibrium : For an asymmetry to occur, the universe must be out of equilibrium so other reactions do not stabilize the asymmetry.

All 3 of these conditions are met in the standard model, yet there is not enough CP violation to account for the observed asymmetry.[1]



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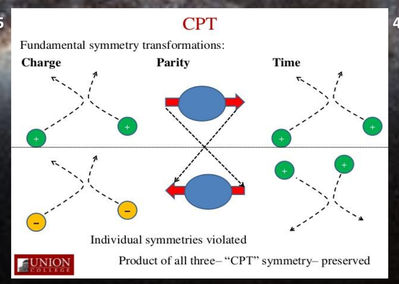
An Example of Charge Parity Transformation.
CP was thought to be preserved, but the decay of the B meson and Kaon show that CP is violated by the weak interaction.



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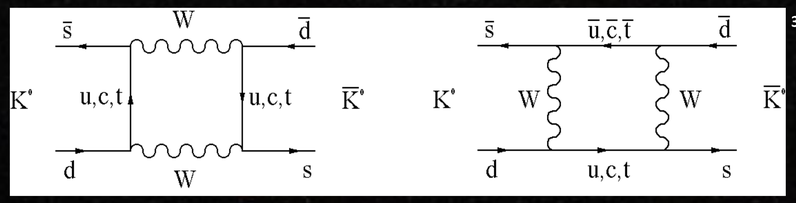
Three Fundamental Transformations.
If a universe with these transformations or a product of these behaves identically to our universe, it is said to be symmetric.
All 3 individually are observed to be violated.



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Quantum particles oscillate between matter and antimatter (above). These transformations , however, do not occur at the same rate in each direction. This imbalance causes the K_1 and K_2 mesons (below) to have a slight asymmetry and therefore causes a CP violation and preference for matter over antimatter.

$$|K_1^0> = \frac{1}{\sqrt{2}}\left(|K^0> + |\bar{K}^0>\right),$$

$$|K_2^0> = \frac{1}{\sqrt{2}}\left(|K^0> - |\bar{K}^0>\right),$$

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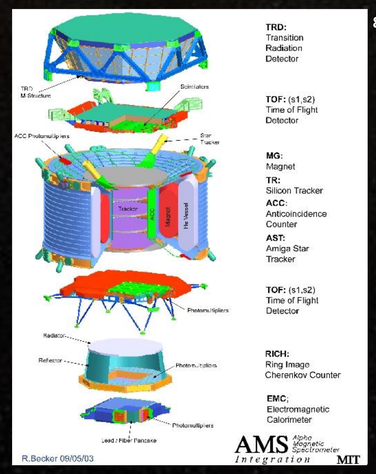
Equations describing the K_1 and K_2 mesons as superpositions of the neutral Kaon and anti-Kaon, including a normalization factor.

Leading Theories on Asymmetry[1]

1. Universe was created with unequal amounts of matter and antimatter.
2. Universe was created with equal amounts matter and antimatter, but CP violating reactions caused a preference for matter over antimatter, known as Baryogenesis.
3. Universe was created with equal amounts matter and antimatter, and there exist regions of the universe dominated by antimatter, perhaps outside of the observable universe.

The Alpha Magnetic Spectrometer[9]

The Alpha Magnetic Spectrometer (AMS) is a particle detector on the ISS, seeking to detect antimatter from deep space cosmic rays. The detection of heavy antimatter atoms such as anti-helium would provide significant evidence for the theory that regions of the universe are dominated by antimatter instead of matter, with a total net baryonic symmetry.



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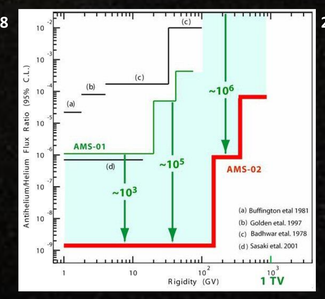

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The AMS-02 Detector (left) will analyze the helium/antihelium flux of the universe with a sensitivity of 10^{-9} (above).

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