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# Brief Review of the Evolution and Nature of the Universe

**Leonard S Kisslinger***

Department of Mechanical Engineering, Kanad Institute of Engineering and Management, India

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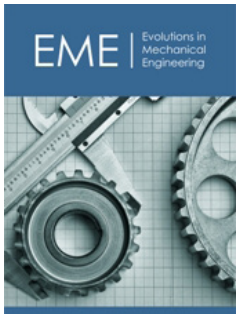


***Corresponding author:** Leonard S Kisslinger, Department of Physics, Carnegie Mellon University, Pittsburgh PA 15213, Pennsylvania, USA

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**Abstract**

First there is a review of the Cosmic Microwave Background (CMBR) estimate of ordinary matter, dark matter and dark energy in the universe. Then there is a review of the evolution of the universe with two important cosmological events reviewed.

**Keywords:** Evolution of the Universe; Matter in the Universe

## Introduction

In section 2 the Microwave Background Radiation (CMBR) experiments which estimates the types of Matter in the Universe is reviewed.

In section 3 the evolution of the universe with cosmological events as time increases and temperature declines is reviewed.

Note that the elementary particles are quarks, photons which create electromagnetic interactions and gluons which couple to quarks and antiquarks with a strong interaction that creates mesons (quarks and antiquarks) an baryons (three quarks).

## Cosmic Microwave Background Radiation (CMBR)

There have been many CMBR experiments, such as Refs [1-4] which have estimated the total density of the present universe, Dark Matter density, dark energy density, etc.

With Ω the density of the Universe and Ω=1.0 for a flat Universe, recent results from CMBR observations [5] are:

$$\Omega=1.0023+0.0056-0.0054$$

Dark Energy Density (vacuum energy)=0.703±0.025

Dark Matter Density=0.273±0.019

Baryon (Normal Matter) Density≃0.04

Age of the Universe≃1.37 billion years (1)

Therefore about 27% of the Universe is Dark Matter. About 70% of the universe is dark energy, which is anti-gravity. Dark Energy (Quintessence) is antigravity and produced inflation at a very early time, which is why we now have an almost homogeneous universe. Only about 4% of the universe is normal matter.

## The Evolution of the Universe

The evolution of the Universe is shown in the figure below. The time goes from the Big Bang at $t=10^{-35}$ seconds to 14 billion years when we have our present Universe (Figure 1). An important Cosmological events is the Electroweak Phase Transition (EWPT) at $t=10^{-11}$

seconds when all elementary particles except the photon received their mass. A second important Cosmological event is the QCD Phase Transition (QCDPT) at $t=10^{-5}$ seconds. Just before the QCDPT the Universe consisted of elementary particles. During the QCDPT quarks and antiquarks interacting via gluons formed mesons and baryons.

| t = Time | T = Temperature | Events |
|---|---|---|
| $10^{-35}$ s | $10^{14}$ GeV | Big Bang, Strings, Inflation Very early. Current particle theory no good |
| $10^{-11}$ s | 100 GeV | Electroweak Phase Transition Particles (Higgs) get masses. Particle theory ok. |
| $10^{-5}$ s | 100 MeV | QCD (quark-hadron) phase transition Quarks(elementary) condense to Protons |
| 1-100 s | Nucleosynthesis: Helium, light nuclei formed | $1.0 \times 10^{9}$ °K Superconducting Universe |
| 380,000 years | 0.25 ev, 3,000 °K | Atoms (electrically) neutral Last scattering of light (electromagnetic radiation) from big bang: Cosmic Microwave Background |
| 1 billion years | | Early Galaxies Form |
| 14 billion years | 2.7 °K | Now |

**Figure 1:** The evolution of the universe (overview).

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