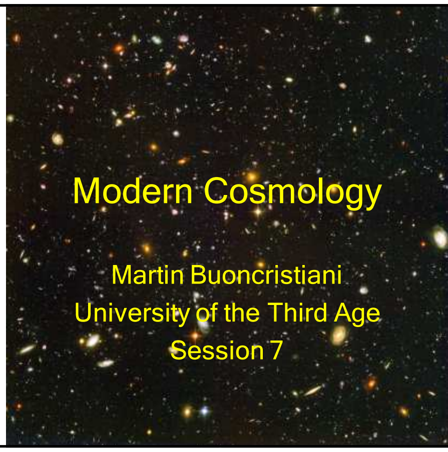
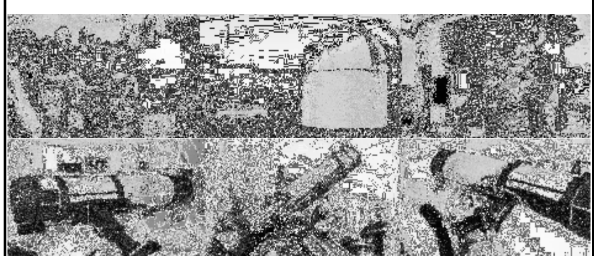


News from Mt. Burnett Observatory



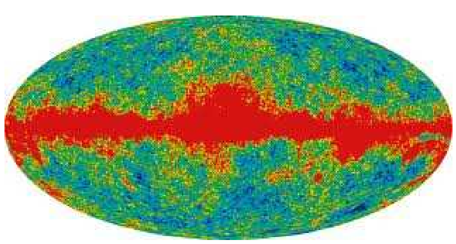
Evidence for the Big Bang

1) Expansion of the universe,

2) Abundance of light elements,

3) Cosmic Microwave Background

and … it is consistent with all current measurements



Wilkerson Microwave Anisotropy Probe

Ingredients of The Universe
Radiation Matter Energy

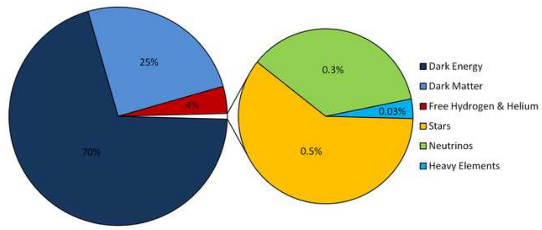
Radiation: electromagnetic radiation (light) across the spectrum.

Ordinary Matter: the matter that makes up atoms – neutrons, protons and electrons. Also called baryonic matter

Dark Matter: invisible matter whose existence inferred from the general motion of celestial objects –

(Ordinary Matter and Dark Matter: Matter)

Dark Energy: energy that is required for consistency with general relativity theory and observations.



The New Standard Cosmology

1) The universe we live in emerged from an early epoch of rapid expansion (called inflation), then slowed its expansion rate.

2) The universe today is flat and the acceleration of its expansion is increasing. (Flat refers to the fact that the universe has almost zero curvature.)

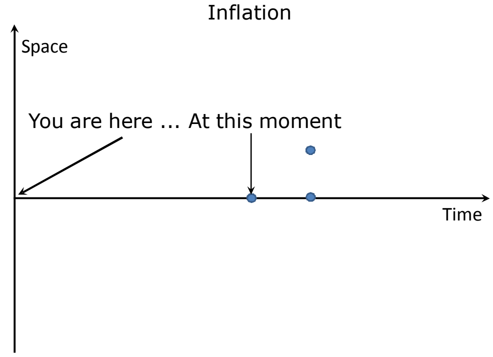
The New Standard Cosmology (2)

3) The irregularities in the universe today (galaxies, stars, and all the rest, including ourselves) resulted from quantum fluctuations during the inflationary epoch.

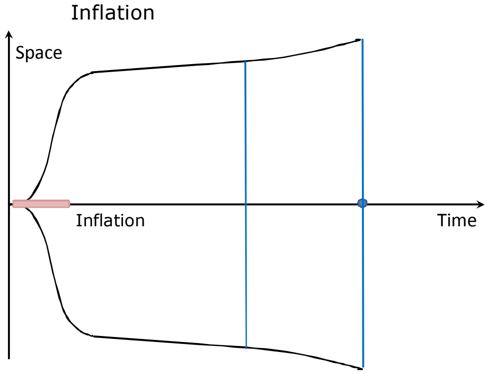
4) The universe is made up of 70% Dark energy and 30% matter.

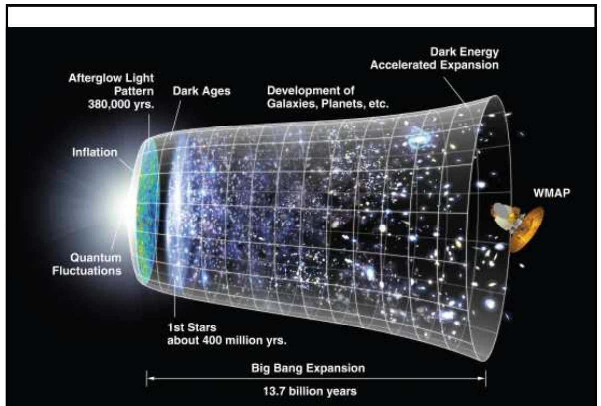
5) The matter in the universe is made up of seven times more dark matter (non-baryonic matter) than matter in the form of bright stars.

Inflation



Inflation





Three fundamental, long range forces of Classical Physics

Gravity Electricity Magnetism

Each of these forces has its own fundamental constant – a number which determines the strength of that force.

G ε_0 μ_0

These forces act the same way throughout the universe so their constants are Universal

and so are combinations of them.

For example,

$$\varepsilon_0 \mu_0 = \frac{1}{c^2}$$

Gravity	$\vec{F}_{gravitation} = G \frac{m_1 m_2}{r^2} \hat{r}$	$G = 6.673\ 10^{-11}\ m^3\ kg^{-1}\ s^{-2}$
Electric	$\vec{F}_{electric} = \frac{1}{4\pi \varepsilon_0} \frac{q_1 q_2}{r^2} \hat{r}$	$\varepsilon_0 = 8.854\ 10^{-12}$ $C^2\ s^2 / (kg\ m^3)$
Magnetic	$\frac{\vec{F}_{magnetic}}{[L]} = \frac{\mu_0}{2\pi} \frac{I_1 I_2}{r} \hat{r}$	$\mu_0 = 4\pi \times 10^{-7}$ $\approx 1.257\ 10^{-6}\ kg\ m/C^2$

Physics also deals with aggregates of particles – where it treats them statistically.

If a collection of particles is near equilibrium then, on average, their kinetic energy is distributed equally

$$Average\ Kinetic\ Energy\ of\ a\ particle = \frac{3}{2} k T$$

where T is the temperature of the collection and k is another Universal constant (Boltzmann's Constant).

Thus, we have four universal constants

G, ε_0, μ_0 and k

from classical physics

If we add the fundamental constant of quantum mechanics Planck's constant, h, we can find universal measures for all of the fundamental units in physics.

Fundamental Concepts and Their Units

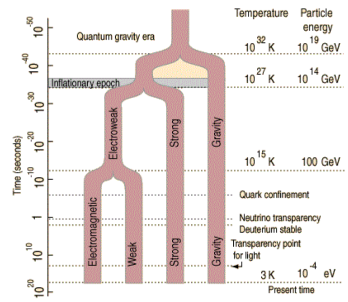
Concept	Space	Time	Inertia	Electricity	Magnetism	Thermal
Dimension	Length, L	Duration, T	Mass, M	Charge, Q	Current, I	Temperature, Θ
SI Unit	Meter, m	Second, s	kilogram, kg	Coulomb, C	Ampere, A	Degree C or K
Elementary Unit	$l_P = \sqrt{\frac{\hbar G}{c^3}}$ Planck Length 1.616 10^{-35} m	$t_P = \sqrt{\frac{\hbar G}{c^5}}$ Planck Time 5.391 10^{-44} s	$m_P = \sqrt{\frac{\hbar c}{G}}$ Planck Mass 2.176 10^{-8} kg	$q_P = \sqrt{4\pi \varepsilon_0 \hbar c}$ Planck Charge 1.875 10^{-18} C	$\mu_M = \hbar \sqrt{G \varepsilon_0}$ Magnetic Moment 2.564×10^{-45} C m^2/s	$\Theta_P = \frac{m_P c^2}{k_B}$ Planck Temperature 1.417 10^{32} K

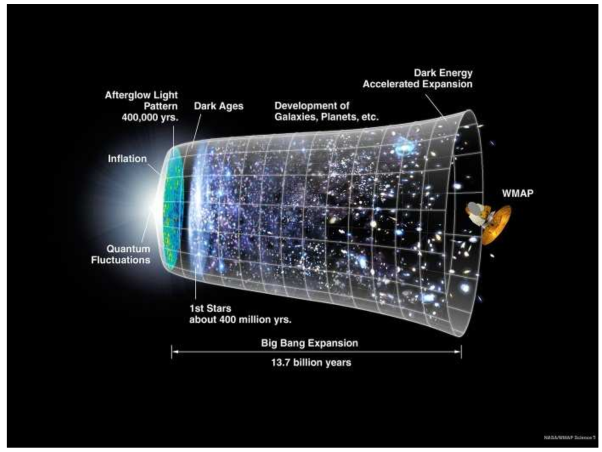
After the Big Bang

At very early moments four forces are unified

but over time the fundamental forces separate out

Gravity	10^{32} K	10^{19} GeV	10^{-43} sec	1 t_P
Strong	10^{27} K	10^{14} GeV	10^{-36} sec	10^7 t_P
Electro-weak	10^{15} K	10^2 GeV	10^{-12} sec	10^{31} t_P





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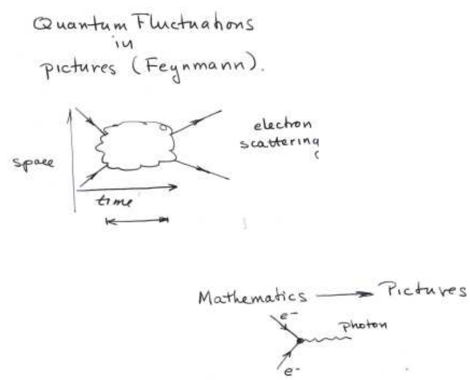
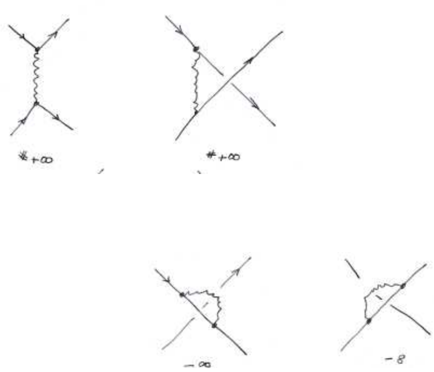
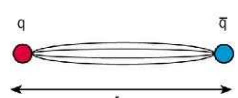




Maturity - Asymptotic Freedom

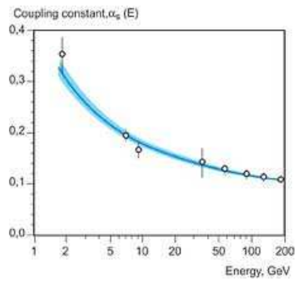
Once the particles of the standard model were identified theorists began to work out the details.

At first, they believed the quarks were bound together with super strong forces



Quark Confinement

However, when the theory was worked out it showed that as the energy increased the strength of the force got weaker ... asymptotic freedom.

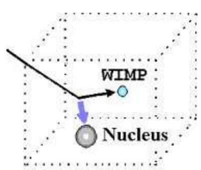


Re-normalizable gauge theory with spontaneous symmetry breaking

This meant that the universe is "a poor man's accelerator" (Yakov Zel'dovich).

Since the 1980's particle physicists and astronomers have pieced together a chronology of the universe from the big bang.

Experimental Particle Physicists turn their attention to Cosmological questions



What do you think of the "Big Bang".