

Unit 1 Intro // Chapter 1: Scientific Theory and the Big Bang

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Science: an objective, logical, and repeatable attempt to understand the principles and forces operating in the natural universe

Understanding science:

Observation -> Hypothesis -> Theory -> Law (maybe)

Scientific Theory: foundation of science

Big Bang Theory: leading theory of how the Universe originated (most profound and complex of all scientific theories)

Theory vs. Law vs. Hypothesis

Hypothesis: educated guess based upon observation

- Can be supported/rejected through experimentation
- Cannot be proven to be true

Theory: summarizes a hypothesis (or a group of hypotheses) that is supported by repeating testing and observation

- Considered valid as long as there is no firm evidence to dispute it
- Can be supported/rejected
- If evidence accumulates to support, then the hypothesis becomes accepted as a good explanation

Law: explains a body of observations

- No exceptions will have been found to that law
- Laws explain things but does not describe them

- "why" it happened? -> theory
- "how" did it happen? -> law

Singularity

- No readily understood definition
- Area in space-time where gravitational force is so high that all known laws of physics break down and do not apply

Gigantic expansion

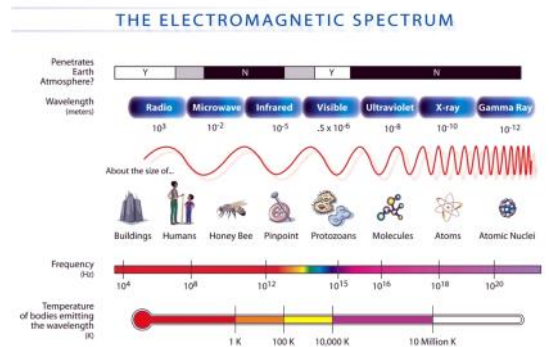
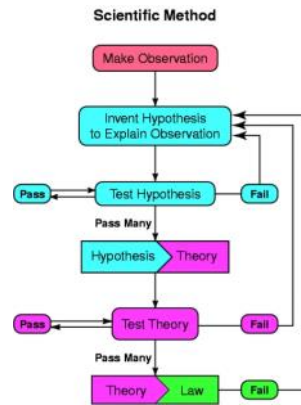
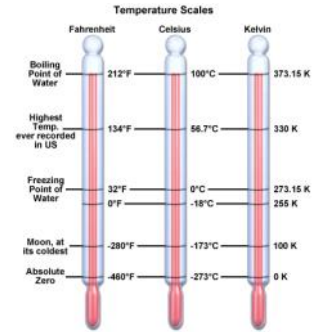
- When everything, in a fraction of time, suddenly expands in space creating the universe

Observations (the Evidence)

- Three Pillars of Proof
 - o Recession of stars/galaxies (as described by Hubble's Law)
 - o The characteristics of cosmic microwave background radiation
 - o The abundance of light elements
- Hubble fought to have astronomy recognized as belonging to the subject of physics
- Noble Prize Committee made his recognition after his death
 - o Never received the nobel price because they don't give nobel prizes to dead ppl
- 1990, NASA installed an optical telescope into the earth's orbit calling it Hubble Space Telescope in honor of Edwin Hubble

Light's Redshift and Hubble Law

- Similar to Doppler Shift/Effect for soundwaves
- Moving objects emitting light
 - o Wavelengths shorter when compressed by the motion (going forward)
 - Moving towards blue spectrum
 - o Light source moving away from reference point, wavelength lengthens
 - Moving towards red spectrum
- Faster the light-emitting object was moving, the greater the shift
- Since speed of light is fixed and can't change, and when Hubble observed the changes in the speed of light from a star with earth as a reference point, he came to the only possible conclusion that the STARS



HAD TO BE MOVING AWAY FROM THE EARTH

- Leading to the hypothesis and theory that the universe is ALWAYS EXPANDING
 - The more distant the galaxy -> the longer it takes for light to arrive -> the more red-shifted the light becomes
- THEREFORE Hubble formulated the equation
 - HUBBLE LAW:
 - ◆ $v=H_0d$
 - v = speed expressed in kilometres per second
 - d = distance in parsecs (1 parsec = 3.26x the distance light travels in one year)
 - H_0 = Hubble constant, speed of expansion of the universe

Cosmic Microwave Background Radiation

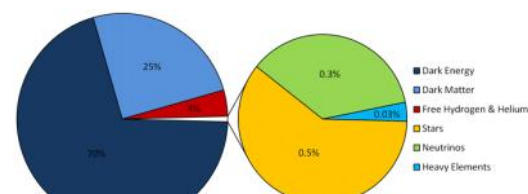
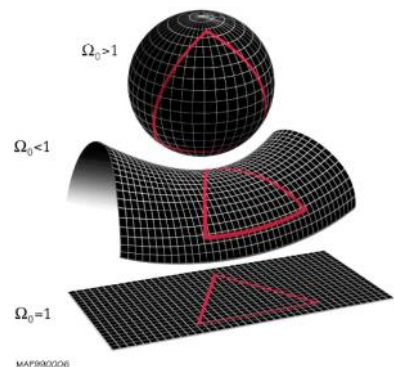
- Estimated it was really hot in the universe in the first seconds of creation and as it expanded, it cooled.
 - Hot protons produced in the early period lost its energy
 - Dropped from the visible light energy range into microwave energy range
 - Makes up the Cosmic Microwave Background (CMB)
 - ◆ CMB can be seen anywhere in the universe bc it comes from all directions, with almost the same intensity
 - CMB discovered in 1965 as 'noise' in a sensitive microwave receiver
 - ◆ Thought it was pigeons lol but that got them a nobel prize so they not rllly stupid at all
 - CMB makes space hotter
 - ◆ Space should be 0 Kelvin
 - ◆ Instead it's ~2.726K due to CMB

Abundance of Light Elements

- Third 'pillar of proof' -> ration of all various atoms of 3 lightest elements
 - Hydrogen (75%)
 - Helium (25%)
 - Lithium (trace)
- The abundance of these different types of atoms can only be explained if they originated from one single ratio of the first subatomic particles of matter

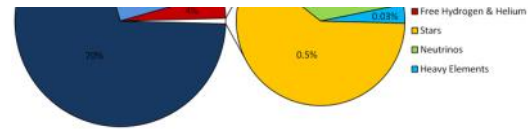
Shape of the Universe

- Sphere
 - Positive curvature ($\Omega_0 > 1$)
 - Closed universe
 - Universe finite in size but without boundary
 - Closed universes are also closed in time
 - Eventually stop expanding, then contract in a 'Big Crunch'
 - This model depends greatly on the assumption that there are sufficient matter in the Universe that gravity can eventually pull things back together
- Open
 - Negative curvature ($\Omega_0 < 1$)
 - Saddle-shaped
 - Infinite, unbounded (parallel lines eventually diverge)
 - Expand forever, expansion rate never approaching zero
- Flat
 - Infinite in spatial extent, no boundaries
 - Expand forever (parallel lines are always parallel)
 - However the expansion rate does approach zero
- Ω_0 is actually called the DENSITY PARAMETER
 - >1 , more than enough matter for universe gravity to pull everything back together
 - <1 , not enough matter
 - $=1$, at a constant, 'critical' value of matter that will prevent universe from pulling back together or from expanding indefinitely to oblivion
- WHAT AFFECTS GRAVITY?
 - Conventional matter
 - Stars, planet, asteroids, comets, etc



- WHAT AFFECTS GRAVITY?

- Conventional matter
 - Stars, planet, asteroids, comets, etc
 - Makes up only ~5% of the universe
- Dark matter
 - Matter we have never seen because it gives off no electromagnetic energy, but we know it exists because we can detect its gravitational attraction to conventional matter
 - Makes up around 27% of universe
 - If there is only dark matter, it would probably be enough total matter to slow the expansion of the Universe and pull things back into a big Crunch
- Dark energy
 - Composes 70% of the universe
 - The reason why the universe expansion is increasing instead of decreasing
 - Repels matter
 - Works in opposition to gravity
 - When it exactly counterbalances gravity, density parameter value = 1
 - As of right now the universe is almost perfectly flat, but has the slightest negative curvature
 - We'll just call that flat



Age of the Universe

- Radioactivity
 - Observe the composition of gases around old stars
 - Know the exact radioactive processes required to produce these gases around old stars
 - Know all the time factors involved in the decomposition of one component resulting in the yield of others
 - The universe age range estimates between 11.5-17.5 billion years
- Hubble's Expansion Constant
 - Hubble made many refinements to his constant
 - Based on shape/density of matters
 - The age of universe had to fall between 13-14 billion years due to radioactivity dating of some dwarf stars (cooling off)
 - Estimated to be 12-13 billion years old
 - Takes 1 billion years to cool off
- Cosmic Microwave Background Radiation
 - These signals offer the most accurate view to date of conditions in early universe
 - Using the best physics, a model of the universe from the time of the Big Bang has been produced
 - Many assumptions has had to be made when creating this model, therefore it should be nowhere near correct
 - The conclusion was that the universe is 13.80 plus/minus 0.04 billion years according to data published in 2013

Neil Turok suggest that big bang is just a part of the infinite repeated cycle of expansions of the universe