Lecture #16 Thurs Mar 25 2010 The Big **BANG!**

Back to general relativity:
Experimental explainations/predictions:

(1) Perihelion shift of Mercury
(2)Gravitational redshift
(3) Gravity waves

+ (4) possible expansion/contraction of the Universe
If you write down the equations of general relativity and apply to the Universe as a whole, you find the Universe is allowed to expand or contract (and will continue to do so). To prevent this, Einstein added a term to his equations, known as the "cosmological constant" Λ. This would result in a "static universe."
In the 1920's, however, astronomers gathered evidence that the Universe *was in fact expanding!* Einstein called the cosmological constant his "biggest blunder."

The Runaway Universe
To understand the evidence for an expanding Universe, we need to understand the **Doppler effect** :
If an object is approaching, the wavelength of light (or sound) is shortened (blueshift).
If an object is receding, the wavelength of light (or sound) is lengthened (**redshift**).
Distant galaxies are **all** redshifted, and thus moving away from us.
In 1929, Edwin Hubble discovered that the velocity is proportional to the distance (Hubble's Law). (He did this using Cepheid variable stars, using the period-luminosity relation discovered by Henrietta Leavitt). If the entire universeis expanding, this is exactly what you would expect to see.
Of course, if the universe is expanding outwards, that suggests it must have started all squished together: "The Big Bang" (a derogatory term by British astronomer Fred Hoyle)

The Big Bang
Is the Big Bang (13.7 billion years ago) a "just-a-theory?"
Must distinguish between "just-a-theory:" a theory with little or no evidence, and "Theory+evidence" = theory backed up with lots of experimental/observational evidence
Evidence for Big Bang:

(1) Expansion of the Universe
(2) Primordial nucleosynthesis
(3) Cosmic Microwave background.

Alternate theory: "Steady-state" theory of Fred Hoyle

Expansion of the Universe
Redshift of distant galaxies proportional to distance (Hubble's law)
In fact, recent evidence suggests expansion is *accelerating*. This requires use of Einstein's cosmological constant, but with opposite sign
Requires a single "unexplained" event: the Bang itself
Steady-state theory: continuous creation of matter (a few atoms at a time) between galaxies: continuous unexplained events.

Primordial nucleosynthesis
ratios of light elements (deuterium, 3He, 4He, 7Li) in exactly the ratio predicted by Big Bang (also predicts 3 species of neutrinos, later confirmed by accelerator experiments)
Steady-state theory: no simple explanation

Cosmic microwave background
Originally universe was VERY HOT but eventually cooled to a low temperature 2.7 K.
1965: Penzias and Wilson accidentally discover microwaves coming from throughout the universe. Steady-state theory: not easy to explain
Small fluctuations in background temperature can tell you a lot about the details of the Big Bang---all in agreement with theory!

Current make-up of universe:
baryonic luminous matter (stars): approx 1%
baryonic dark matter: approx 5%
nonbaryonic dark matter approx 30%
"dark energy" approx 64%
"baryonic" = made up of protons and neutrons (like you and me)
"nonbaryonic" = some strange particle we don't understand
"dark energy" = source of cosmic acceleration (we think)

What "caused" the Big Bang?
We don't know! Lots of "just-a-theories"