



### Origin of the Universe

Big Bang
 occurred 15 billion years ago
 model for the beginning of the universe

## Building a Universe



 infinitely dense point not governed by our physical laws or time

- all matter and energy contained in one point

http://rainbow.ldeo.columbia.edu/courses/v1001/7.html

### Building a Universe



- instantaneous filling of space with all matter

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#### Edwin Hubble

Universe is continuously expanding

Galaxy's velocity is proportional to its distance (galaxies that are twice as far from us move twice as fast)
 taken every galaxy the same amount of time to move from a common starting position to its current position

### Hubble's Evidence

- Doppler shifting wavelength emitted by something moving away from us is shifted to a lower frequency
- Sound of a fire truck siren pitch of the siren is higher as the fire truck moves towards you, and lower as it moves away from you
- Visible wavelengths emitted by objects moving away from us are shifted towards the red part of the visible spectrum
- The faster they move away from us, the more they are redshifted. Thus, redshift is a reasonable way to measure the speed of an object (this, by the way, is the principal by which radar guns measure the speed of a car or baseball)
- When we observe the redshift of galaxies outside our local group, every galaxy appears to be moving away from us - universe is expanding.

### Evidence for Big Bang

- Red shift as light from distant galaxies approach earth there is an increase of space between earth and the galaxy, which leads to wavelengths being stretched
  - In 1964, Arno Penzias and Robert Wilson, discovered a noise of extraterrestrial origin that came from all directions at once radiation left over from the Big Bang
  - In June 1995, scientists detected primordial helium in the far reaches of the universe consistent with an important aspect of the Big Bang theory that a mixture of hydrogen and helium was created at the beginning of the universe

# Building a Universe



•10<sup>-43</sup> s - gravity separates from other forces -  $10^{-28}$  centimeters

•10<sup>-35</sup> to 10<sup>-32</sup> s - fundamental particles

- quarks and electrons softball
- •10<sup>-6</sup> s quarks combine into protons and neutrons - <u>solar system</u>

•1 s - electromagnetic and weak nuclear forces separate

•3 minutes - protons and neutrons combine into atomic nuclei

10<sup>5</sup> years - electrons join nuclei to make atoms; light is emitted
10<sup>5</sup>-10<sup>9</sup> years - matter collapses into clouds, making galaxies and stars

## When Did the Universe Form?



10 to 20 billion years ago (15)

How do we know?

spreading (Red Shift)

know distances, rates of retreat, relative positions

pervasive background radiation

Orion Nebula - http://stardate.utexas.edu/resources/ssguide/planet\_form.html

#### How old is the universe?

- Speed x time = distance
- (distance of a particular galaxy) / (that galaxy's velocity)
   = (time)
  - or or
- 4.6 x 10^26 cm / 1 x 10^9 cm/sec = 4.6 x 10^17 sec
  - ~ 15 billion years