4/24/06

Exam 4, THIS FRIDAY

Chapter 9 Sections 6 - 8, Book Chapter 10, Book Chapter 11 (Revised, posted Chapters 11, 12).

Review sheet posted today

Review session Thursday, April 27, 5 PM, RLM 4.102

News:

Pic of the day; Earth clouds, Galactic clouds

All 3D space expands - carrying essentially motionless matter (galaxies)

No 3D center, no 3D edge, no 3D outside

As 3D astronomers, we don't have to ask what the Universe is expanding into, but if anything it is a 4 (or more) D hyperspace, just as a 2D balloon expands into 3D hyperspace.

Infinite flat rubber sheet could expand without expanding into any hyperspace (2D embedding diagram example).

Our Expanding Universe

Expanding ***surface*** of a balloon as an example

2D embedding diagram of 3D expanding Universe

No 2D center, no 2D edge, no 2D outside to the ***surface*** of an expanding balloon.

There is a 3D center, a 3D edge, a 3D outside, in 3D hyperspace

Einstein's theory says that for a Universe that is the same, on average, everywhere, there are only three basic shapes it can have

The 3D analog of a spherical surface - ***Closed Universe***

The 3D analog of a "saddle" or "Pringle" shape - ***Open Universe***

The 3D analog of a flat plane - ***Flat Universe***

The ***2D embedding diagrams*** of these 3D Universes are, respectively***, a sphere, an infinite saddle or Pringle, and an infinite flat plane.***

A closed universe is finite in space and time, the other two are infinite in space and time, but all must have started 13.7 billion years ago in the Big Bang.

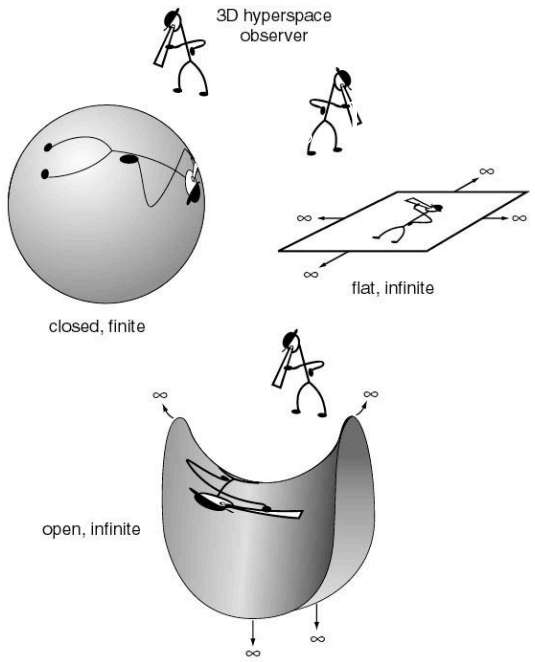


Fig. 11.1

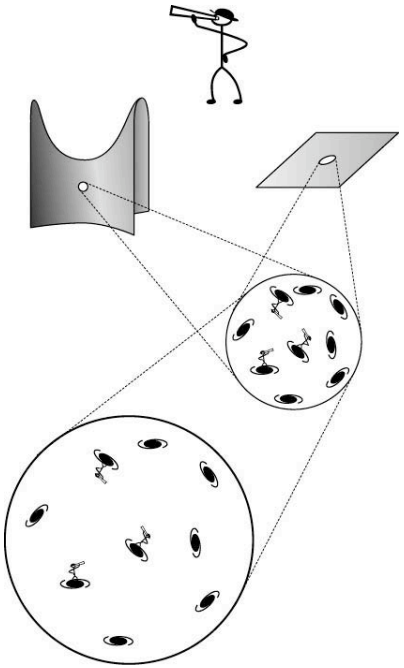


Fig 11.2

Age and Fate of the Universe

All distances between distant galaxies are proportional to the time elapsed. Distance plus Velocity from the Doppler red shift
⇒ Age of Universe ~13.7 billion years

Fate of the Universe is intimately tied to the shape (we thought!)

Simplest choices: finite age, recollapse (closed, "sphere," high density, high gravity)
expand forever, v > 0 (open, "Pringle," low density, low gravity)
Special Case: expand forever, v → 0 as reach infinity (flat, very special density and gravity)

In principle, we can figure out the shape and fate of our Universe by doing 3-D geometry in our 3-D Universe, in practice we often try to measure the density of the matter.

Dark Matter

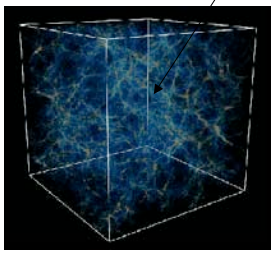
Previously known surprising result:
Most ***gravitating*** matter in the Universe is mysterious ***Dark Matter***

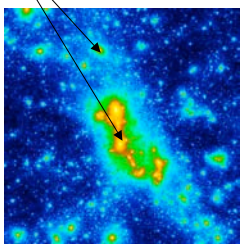
Not composed of p, n, e - the stuff of stars, galaxies, planets, and people

Dark Matter was ***never*** composed of that stuff (or would upset observed mix of hydrogen and helium from the Big Bang), so also not black holes once made from ordinary star stuff.

Some yet undiscovered particles that only interact by gravity and by the weak nuclear force, no electrical force, no strong nuclear force:***100 × more total mass than normal stuff stars, gas, etc.***

Dark Matter





Computer simulations show that from the tiniest wrinkles the Dark Matter agglomerates to form all the ***Large Scale Structure*** of the Universe

Ordinary matter, protons, electrons, settle to center of Dark Matter lumps to form galaxies and clusters of galaxies

Density of Dark Matter is not enough to close the Universe
⇒ Universe is "open?" (3D Pringle)

Marcelo movie

Nature recently threw us a curve ball

SN were the key!

Use Type Ia supernovae (brightest, ~ uniform behavior)

Carefully map ***distances*** (dimmer appearance means further away), ***velocities*** (Doppler red shifts) in all directions

Do geometry - measure curvature - "sphere", "Pringle", "flat"
closed, open, flat

More subtle techniques than making parallel lines or drawing triangles, but still amounts to "doing 3D geometry."

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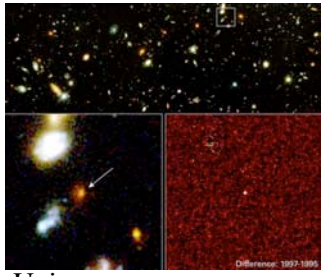
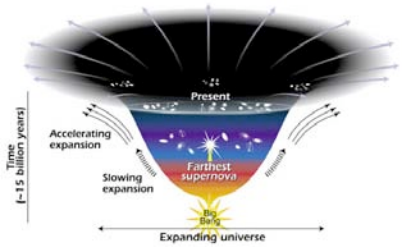
Type Ia supernovae are generally the brightest and can be seen at cosmological distances.

They were used as cosmological probes...



to discover the ***acceleration*** of the Universe...



the Science Magazine scientific Breakthrough of the Year in 1998

The supernovae were found to be a little too dim at given expansion velocity (red shift)

⇒ Further away than expected for a "normal" gravitating Universe

How do you get further away in a given time?

⇒ Universe has been *accelerating*!!

Throw ball