November 15, 2010

Reading: Chapter 12

Exams back Wednesday.

Astronomy in the News? James Webb Space Telescope (JWST), planned replacement for Hubble Space Telescope, goal to look back to the end of the dark ages at the first stars and galaxies. Projected budget just ballooned from $5B to $6.5B, delayed from 2014 to 2015. Disaster for NASA astronomy budget.

Pic of the Day – view of Earth from International Space Station

Goal:

To understand the origin, shape, and fate of the whole Universe and how Type Ia supernovae have helped to revolutionize that understanding.

Age and Fate of the Universe

All distances between distant galaxies are proportional to the time elapsed. Distance divided by the Velocity from the Doppler red shift
$\Rightarrow$ Age of Universe ~13.7 billion years

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

Simplest choices:

finite age, re-collapse (***closed***, "sphere," **high density**, high gravity)expand forever, $v > 0$ (***open***, "Pringle," **low density**, low gravity)
Special Case: expand forever, $v \rightarrow 0$ 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.

One Minute Exam

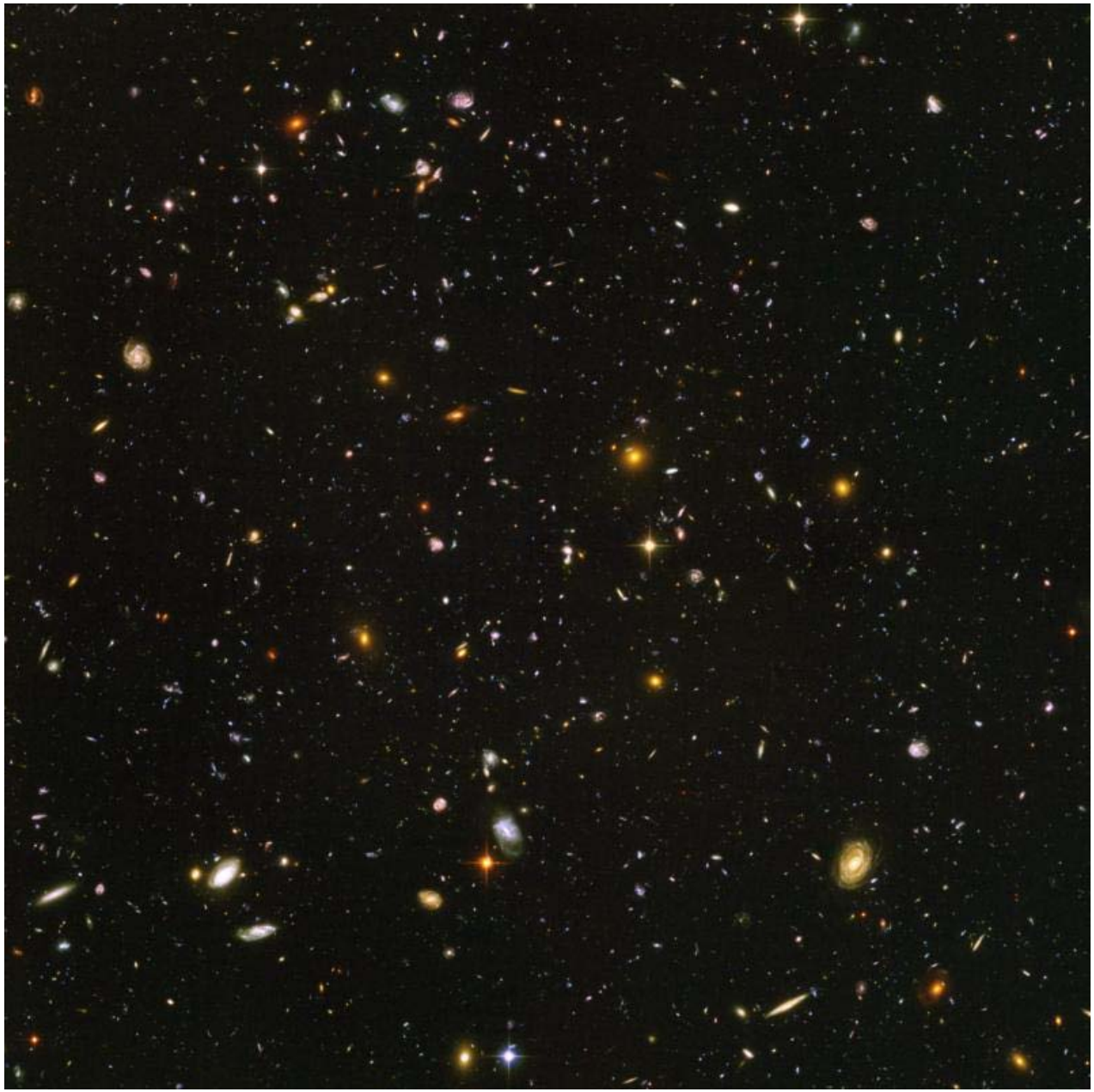
Einstein says that more distant galaxies move away from us more rapidly because:

The Earth is in the center of the Universe.

The Universe blew up in the Big Bang like a bomb blowing up in three-dimensional space.

Our 3D Universe expands into a 4D hyperspace.

Space expands, carrying all distant galaxies further apart from one another.



Dark Matter

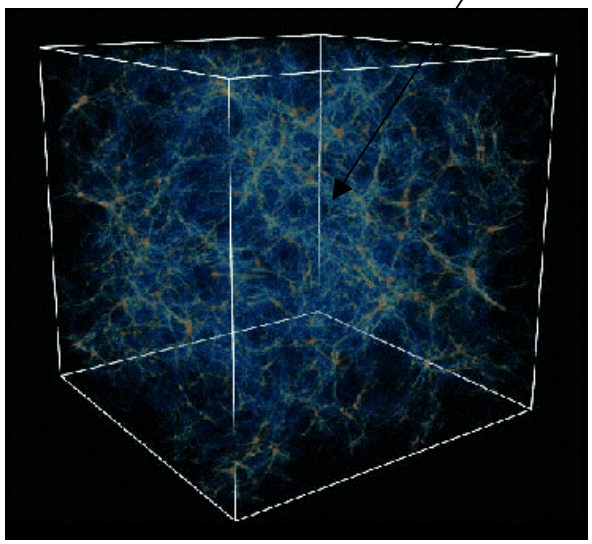
Previously known surprising result:
Most ***gravitating*** matter in the Universe is mysterious ***Dark Matter***

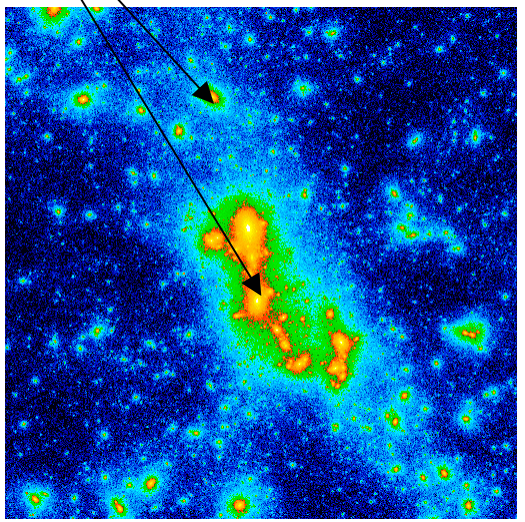
Not composed of p, n, e - the stuff of stars, galaxies, planets, and people

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:
10 × more total mass than "normal" stuff stars, gas, etc.

Dark Matter





Computer simulations show that from the tiniest wrinkles of quantum uncertainty in the Big Bang, the Dark Matter agglomerates to form all the ***Large Scale Structure,*** galaxies, clusters of galaxies of the Universe.

Ordinary matter, protons, electrons, settles to center of Dark Matter lumps to form galaxies and clusters of galaxies. Our familiar Universe of stars and galaxies would not exist without the Dark Matter.
Density of Dark Matter is not enough to close the Universe
$\Rightarrow$ Universe is "open?" (3D Pringle).

Goal:

To understand how Type Ia supernova taught us a dramatic new lesson about the Universe and what that lesson was.

We thought we were trying to determine the density of the Universe to determine how strongly it was **decelerated** by gravity and hence whether it were open, closed, or flat.

Nature threw us a curve ball

SN were the key!

Use Type Ia supernovae (brightest, ~ uniform behavior)

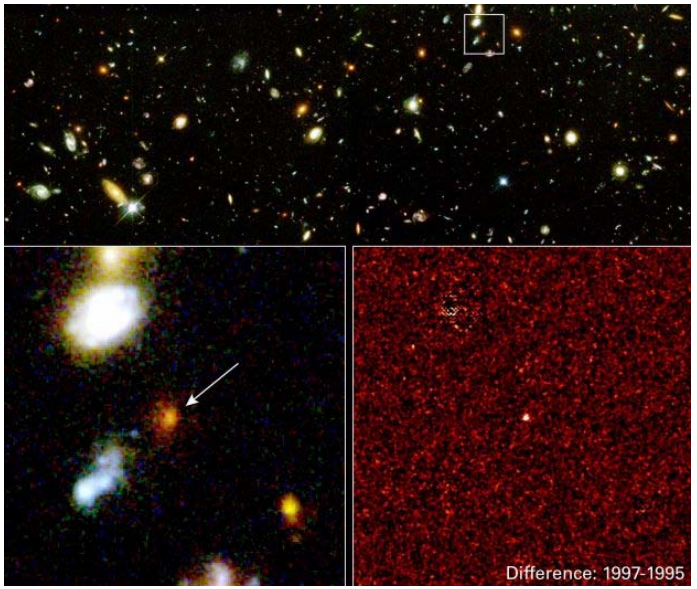
Carefully map ***distances*** (dimmer appearance means further away), ***velocities*** (Doppler red shifts) in all directions

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

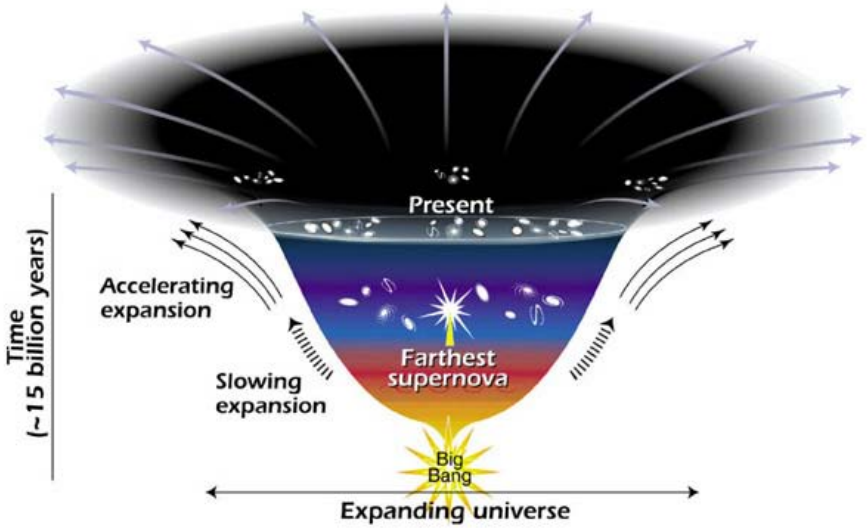
More subtle techniques than making parallel lines or drawing triangles, but still amounts to "doing 3D geometry."

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 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 at a given current velocity?

⇒ Universe has been *accelerating*!! (and it is somewhat older than a coasting Universe would have been)

Throw ball

Other arguments, especially careful study of the small irregularities of the temperature of the cosmic background radiation left over from the Big Bang, confirm the evidence from supernovae

=> Accelerating Universe - confirmed by all tests applied so far.

⇒ Universe is filled with an even more mysterious ***Dark Energy***,

The dark energy seems to be some sort of force field (like a magnetic field, only different), that permeates the vacuum, empty space, and that that *pushes*, ***anti-gravitates!***

As space expands there is just more vacuum filled with this force field, so the effect is not diluted by the expansion.