Friday, April 29, 2016

Fifth exam and sky watch, FRIDAY, May 6. Review Th 4:30

May have Review Sheet today

Reading for Exam 5:

Chapter 9 – Sections 9.6.1, 9.6.2, 9.7, 9.8; Chapter 10 - Sections 10.1-10.4, 10.9; Chapter 11 - all except Section 11.6 (abbreviated, focus on lectures); Chapter 12 - all; Chapter 13 (skip) - all; Chapter 14 - all

Electronic Class Evaluation now available. Please do this!

Astronomy in the news?

Israeli scientists have constructed a supercold liquid helium “black hole” so that sound can get in, but can’t get out. Quanta of sound, phonons, manage to do so, akin to Hawking radiation.

Goal:

To understand the nature of dark matter and how it affects the Universe.

Dark Matter

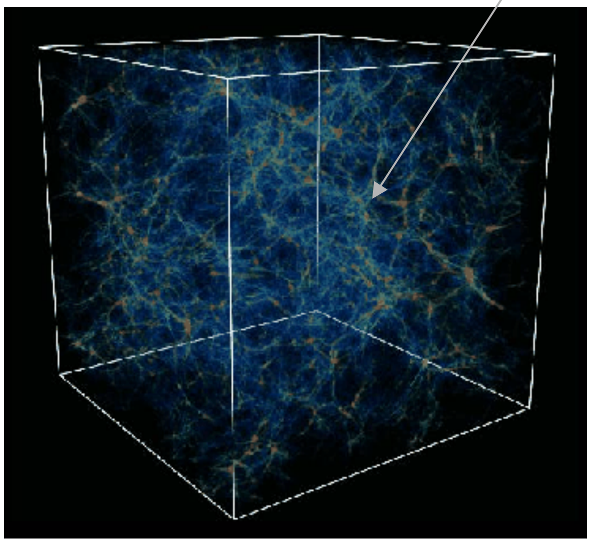
Most ***gravitating*** matter in the Universe is mysterious ***Dark Matter***

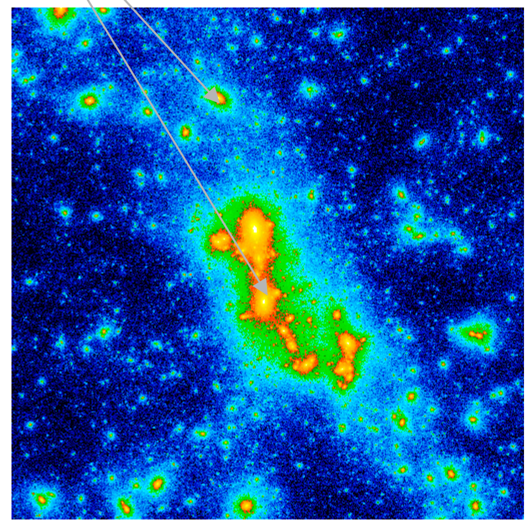
Not composed of p, n, e - the stuff of stars, galaxies, planets, and people

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:
5 × more total density and mass than "normal" stuff stars, gas, etc.

Dark Matter (false color representation)





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 supernovae 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

Density of the Universe

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

↑ High Density, closed

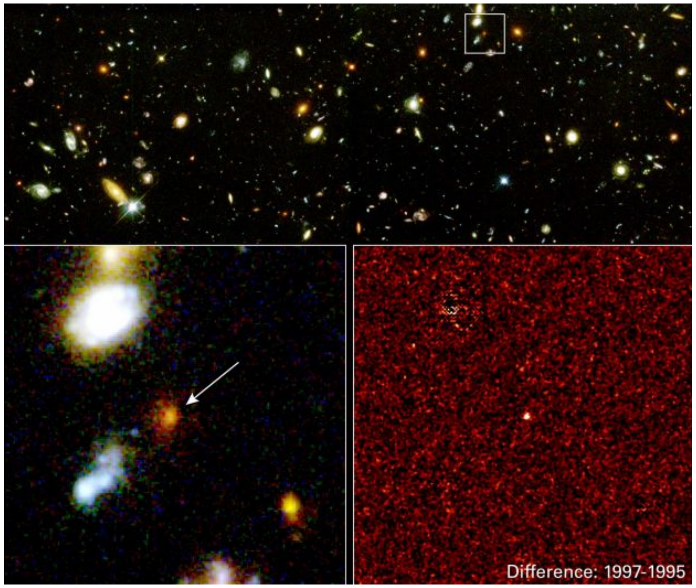
Very special density, flat

Low density, open

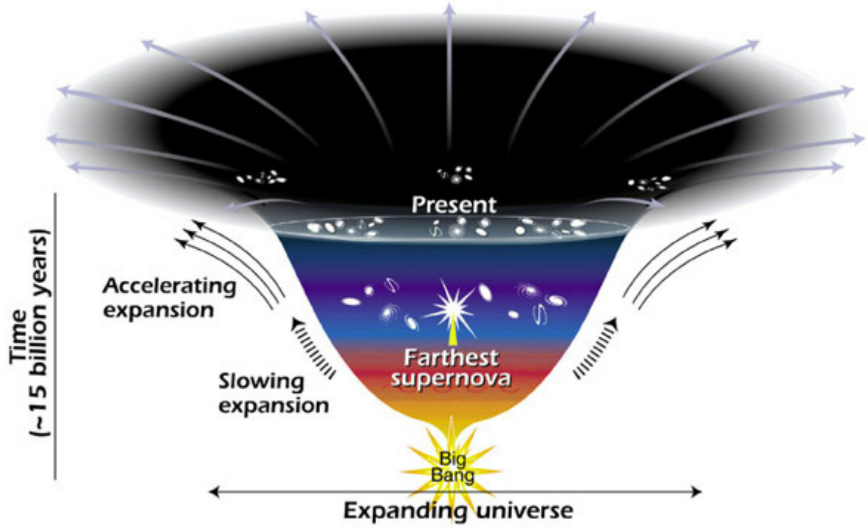
More subtle techniques than making parallel lines or drawing triangles, but still amounts to "doing 3D geometry."

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 *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.

Dark Energy Anti-gravitates: cannot be any particle, “normal” (p, n, e) or Dark Matter, that gravitates.

Dark Energy force field is not accounted for by any currently known physics.

A major challenge to fundamental physics!

And why this discovery was awarded the Nobel Prize for Physics in October 2011.

Saul Perlmutter
UC Berkeley

Brian Schmidt
Mt. Stromlo Observatory, Canberra, Australia

Adam Riess
Johns Hopkins University

One Minute Exam

The type of supernova used to discover the acceleration of the Universe was

➡ Type Ia

⬅ Type Ib

⬆ Type Ic

⬇ Type II

One Minute Exam

Dark Matter is responsible for

➡ The acceleration of the Universe

⬅ The dark space between stars and galaxies

⬆ The clumping of matter to form stars and galaxies

⬇ The Dark Ages after the initial Big Bang

One Minute Exam

Dark Energy is responsible for

→ The acceleration of the Universe

← The dark space between stars and galaxies

↑ The clumping of matter to form stars and galaxies

↓ The Dark Ages after the initial Big Bang

Goal:

To understand what the Dark Energy implies for the shape and fate of the Universe.

Add up all the normal matter (not much, about 4%), Dark Matter (about 23%) and the mass equivalent of the Dark Energy ($E = mc^2$, about 73%) and find the Universe has just the very special density to be flat!

The Universe is Flat (in 3D) on average

Still have individual stars, neutron stars, black holes, galaxies, that curve the space around them causing the small scale, local effects of gravity.

Just as a table top is composed of atoms and molecules on small scales, but is flat for all practical purposes when we sit down to eat.

The best current guess is that our real 3D Universe is essentially 3D flat - but accelerating!

Nature of Dark Energy

Energy of vacuum - quantum fluctuations, particle/anti-particle (recall role in Hawking radiation) predict an acceleration that is too large by a factor x 10^{120}. It works on Earth, but not, somehow, in deep space.

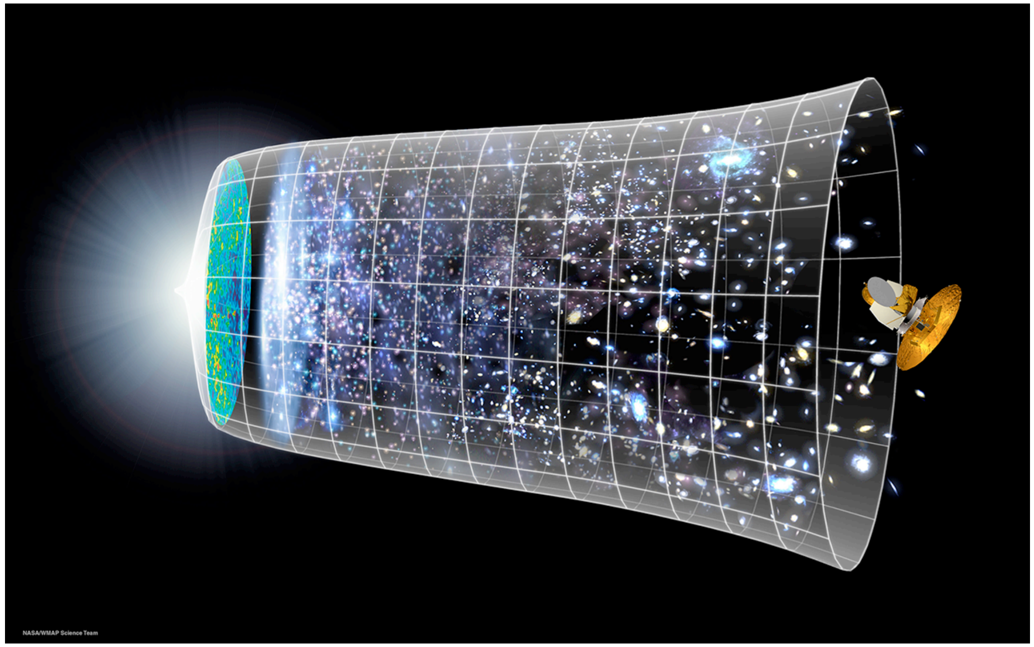
"Worst prediction ever in physics,"
Steven Weinberg (UT Nobel Laureate)

Related phase early in Big Bang, when the Universe was a fraction of a second old,

A huge "inflation" by anti-gravitating vacuum force blows the Universe so big that it is essentially flat (like the surface of the Earth appears to us, only moreso!)

Anti-gravitating energy went away - has come back gently in the last 5 billion years. ***What is it???***

“Space-time diagrams” illustrate how the Big Bang led to inflation, then deceleration, and now acceleration



At each time, the space would be flat (not shown in this type of diagram)