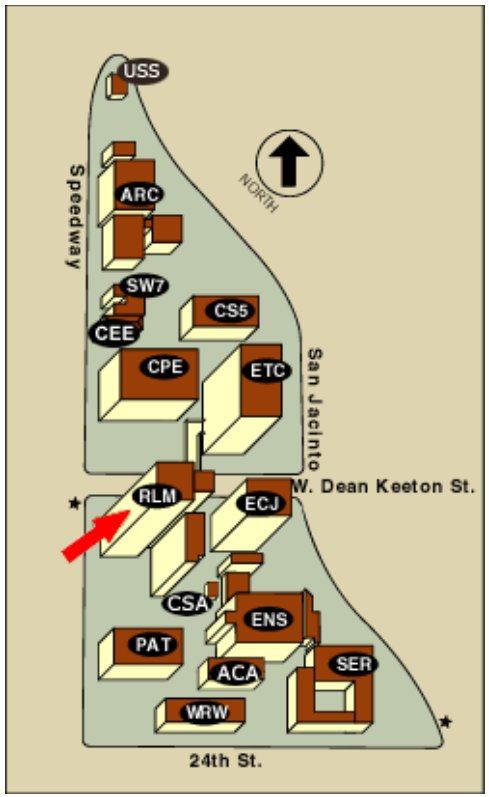
Monday, April 28, 2014

Fifth exam and sky watch, FRIDAY, May 2. Review sheet today. Review session Thursday, 5:00 PM, RLM 7.104.

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; SKIP Chapter 13; **Chapter 14 – very abbreviated version.**



Electronic class reviews now available. Please respond. We find the feedback very valuable.

Astronomy in the news: Ex-Texan Robert Quimby confirms his discovery of a Type Ia supernova 9 billion light years away, but brightened by the gravitational lensing of the dark matter in a foreground galaxy. Lensing of SN provides a new and special way to measure cosmic expansion.

Update on new “nearby” supernova SN 2014J in M82

Report from X-ray satellite of gamma-rays from the decay of 56-cobalt.

Goal:

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

Dark Matter

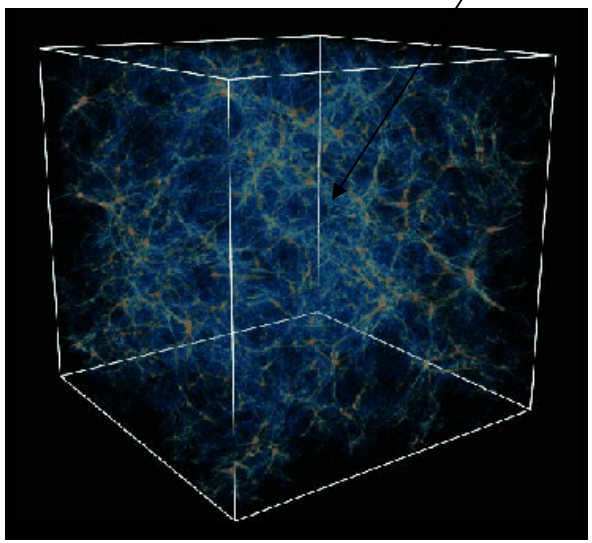
Most ***gravitating*** matter in the Universe is mysterious ***Dark Matter***

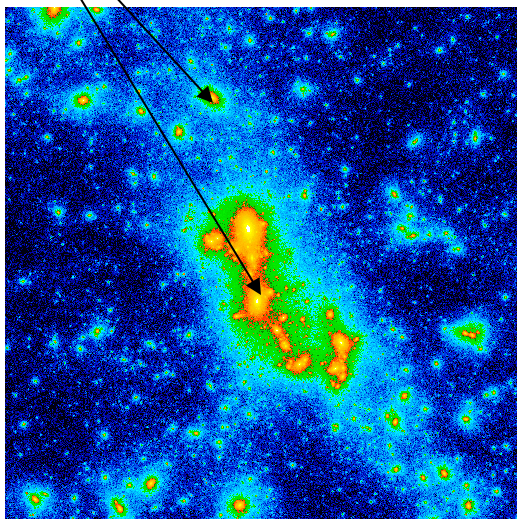
Not composed of p, n, e - the stuff of stars, galaxies, planets, and people

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





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.

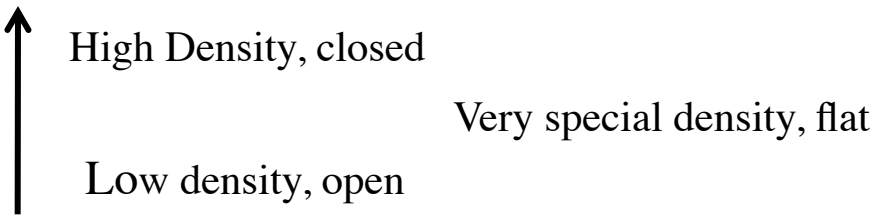
Nature threw us a curve ball

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

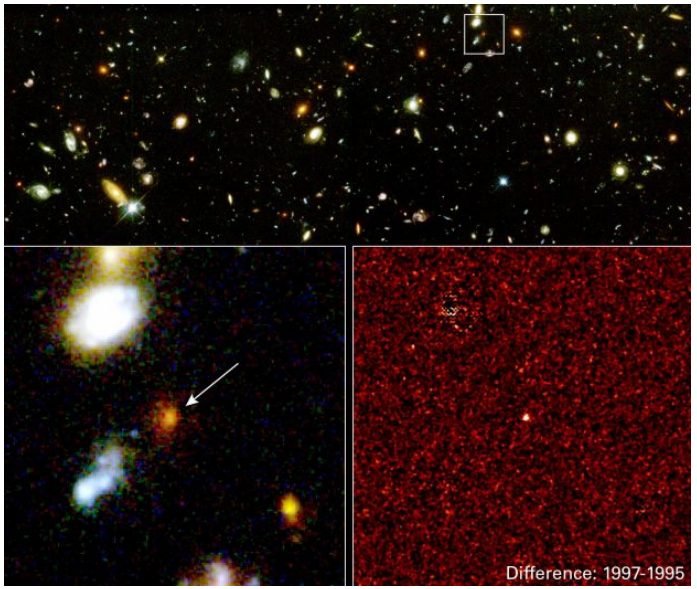
Do geometry - measure curvature – "sphere", "Pringle", "flat"
closed, open, flat



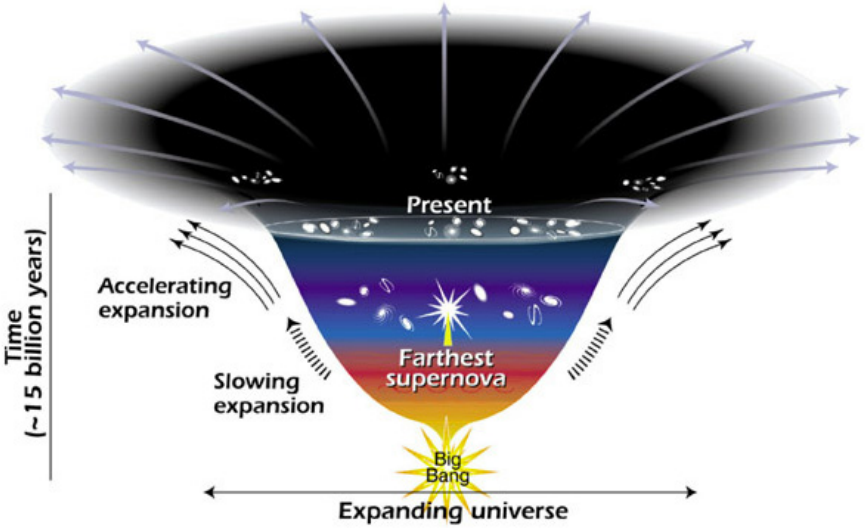
More subtle techniques than making parallel lines or drawing triangles, but still amounts to "doing 3D geometry."

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 *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.

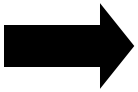
Saul Perlmutter
UC Berkeley

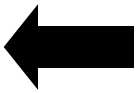
Brian Schmidt
Mt. Stromlo Observatory,
Canberra, Australia

Adam Riess
Johns Hopkins University

One Minute Exam

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

 Type Ia

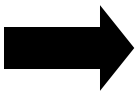
 Type Ib

 Type Ic

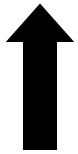
 Type II

One Minute Exam

Dark Matter is responsible for


The acceleration of the Universe

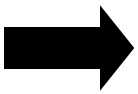

The dark space between stars and galaxies


The clumping of matter to form stars and galaxies

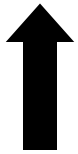

The Dark Ages after the initial Big Bang

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.

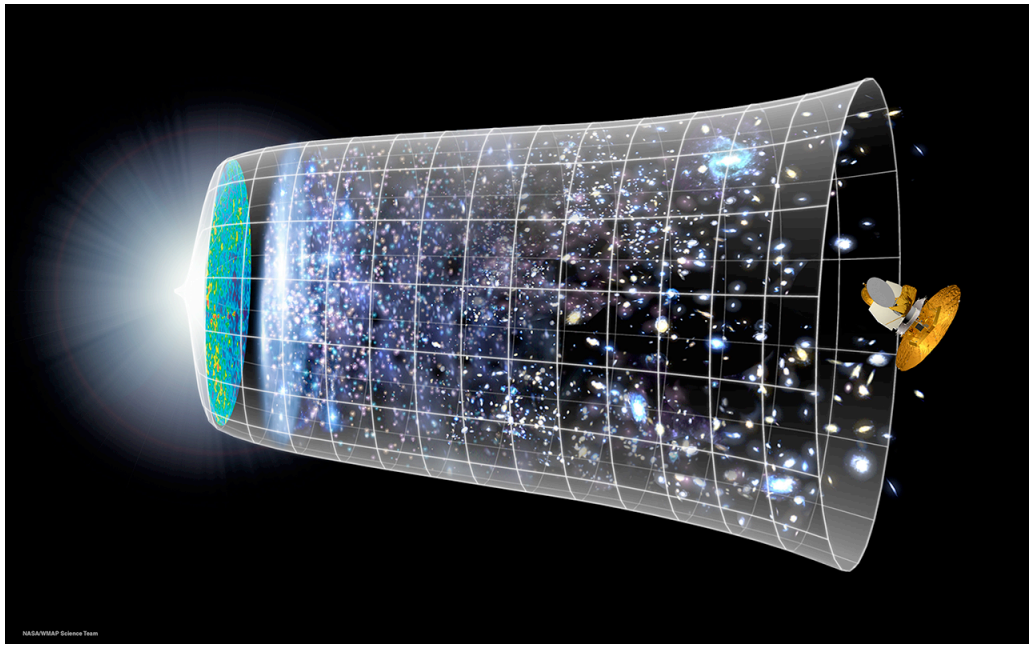
"Worst prediction ever in physics,"
Steven Weinberg (UT Nobel Laureate)

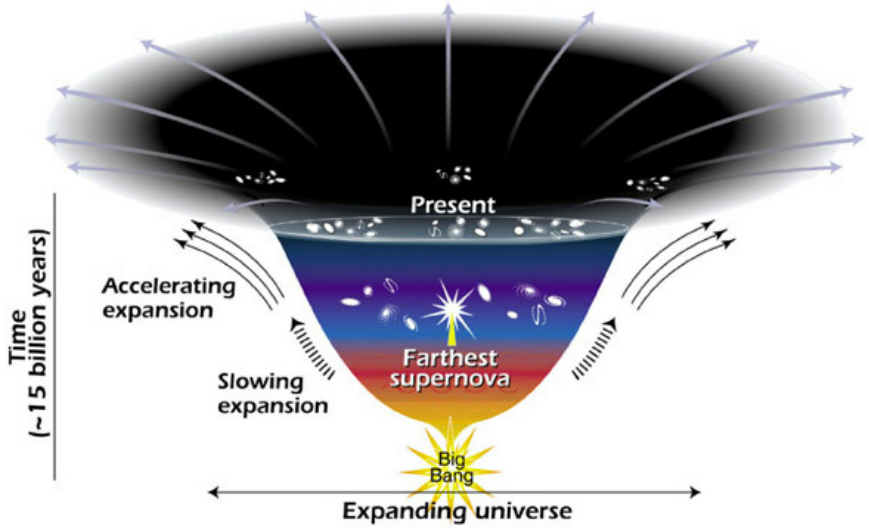
Related phase early in Big Bang, when the Universe was a fraction of a second old,

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





Goal:

To understand why we need a new theory of Quantum Gravity and the ideas involved in the attempt to construct that theory.

Chapter 14: Quantum Gravity - The Final Frontier

The remainder of the class will be spent exploring various aspects of the most fundamental issue of modern physics: reconciling ***Einstein's theory of gravity*** as curved space with the ***quantum theory*** of how things behave at a fundamental microscopic level.

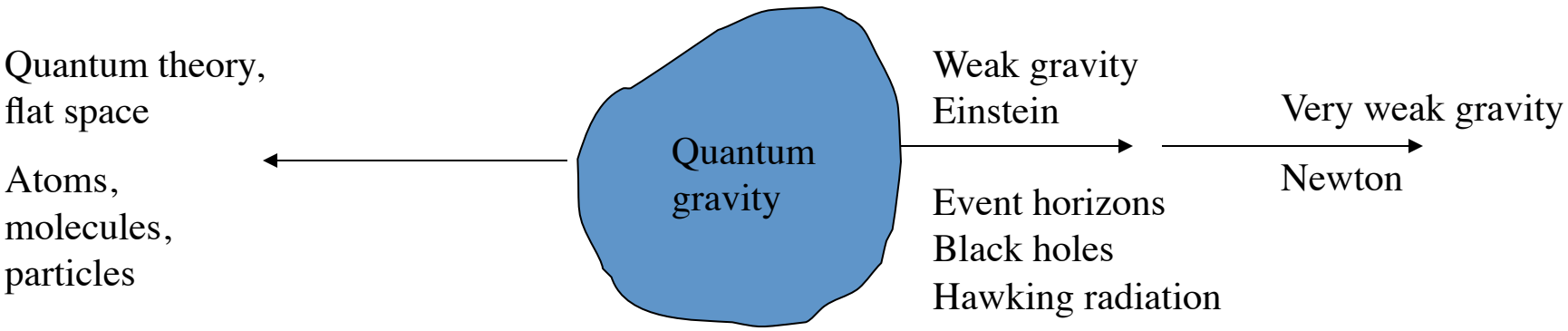
The problem - each of these great theories of 20th century physics contradict one another at a fundamental level.

Einstein's theory predicts ***singularities*** at the beginning of the Big Bang and in the centers of black holes where matter is crushed to a point with infinite density, time and space come to a halt. Quantum theory says the position of nothing, not even a singularity, can be specified exactly (the Uncertainty Principle applied to singularities).

Quantum theory is designed to work in flat, or gently curving space. It does not make sense when the curvature of space is tighter than the "wavelength," the uncertainty in position, of a particle.

Each great theory of 20th century physics contradicts the other!

We need an embracing theory of ***quantum gravity*** that will reduce to ordinary gravity and ordinary quantum theory where they work well (away from singularities and with non-severe curvature - same thing!), but will also tell us what a "singularity" really is.



The world of the small

The world of the large

Goal:

To understand how string theory represents the current best candidate to be the needed theory of quantum gravity (Chapter 14)

String Theory

Best current candidate for a quantum gravity "theory of everything."

String theory is a quantum theory, but it also intrinsically contains curved surfaces.

Particles like e-, p, n are not "points" but strings, otherwise identical loops of energy that vibrate in different modes

The different modes of vibrations give all the well-known particles and ***more***

Can't make notes with grains of sand, but with strings, you have Mozart

From Brian Greene - The Elegant Universe

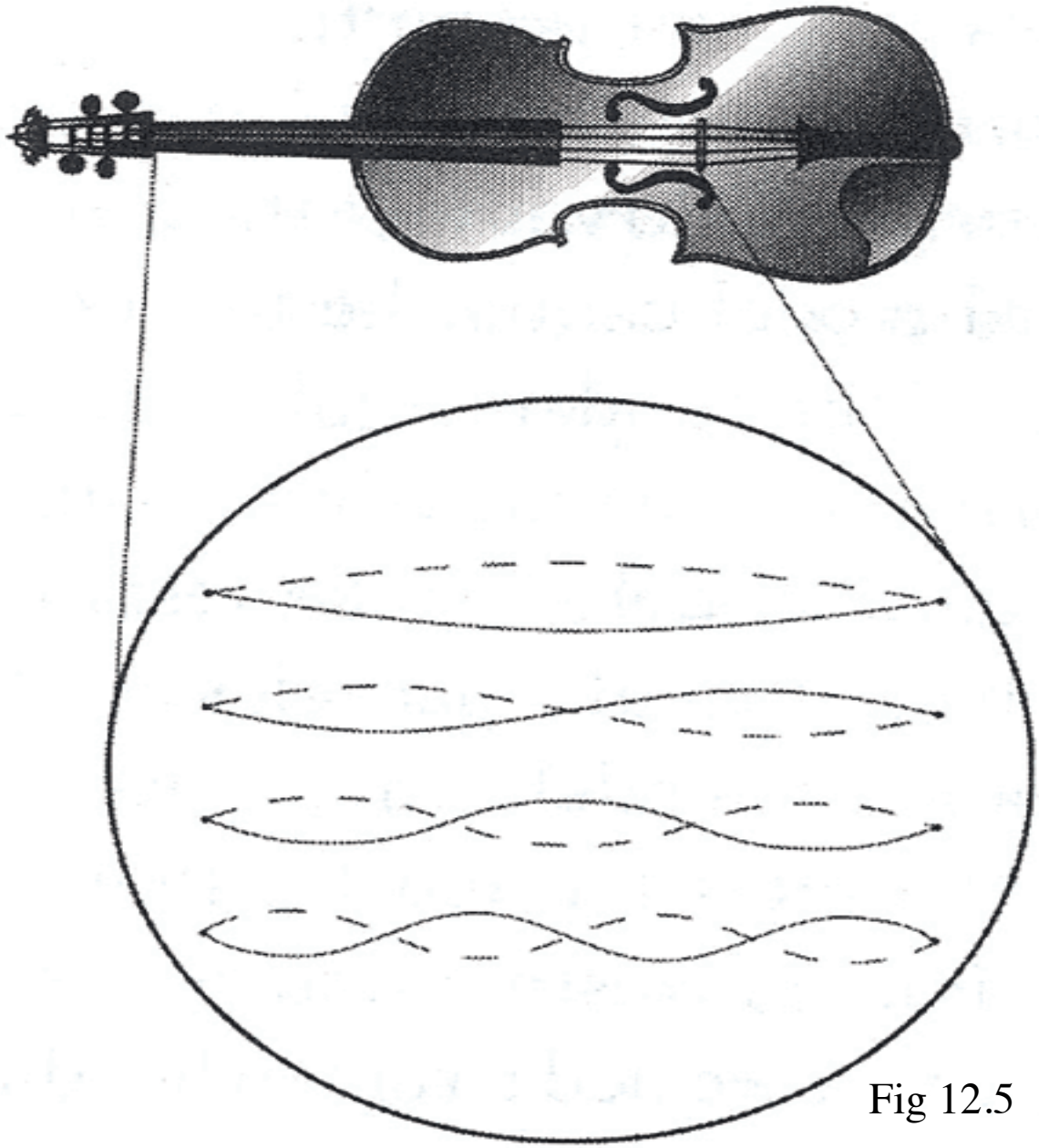


Fig 12.5