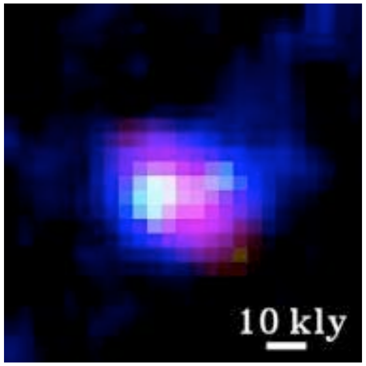
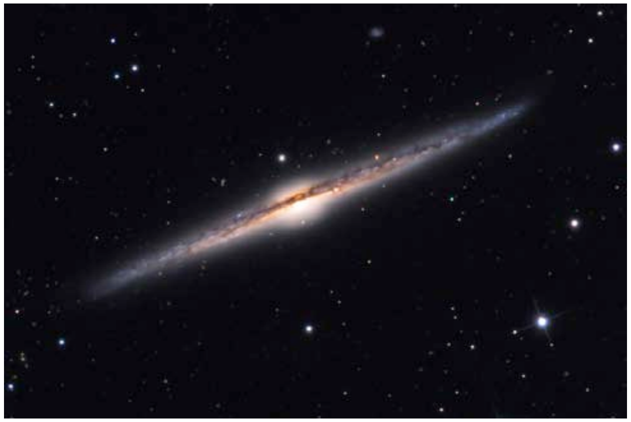
Tuesday, April 28, 2009

Fourth, and last, noncumulative exam on Thursday, May 7. Remainder of book. No Final.

Astronomy in the News - False-color image is of Himoko, a giant blob of glowing hydrogen gas at the “edge of the Universe” when the it was only 800 million years old. The blob is 1/2 the size of our Galaxy. It may be the earliest snapshot of a galaxy growing by gobbling up gas.



Pic of the day - edge-on spiral galaxy. Note the central bulge where the supermassive black hole sits.



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!

Pressure Gravitates	Tension Anti-Gravitates
Dark Matter Gravitates	Dark Energy Anti-Gravitates
1/3 of that needed to be flat (3D)	2/3 of that needed to be flat (3D)

Total 1/3 + 2/3 = 1 just the right total mass/energy to be flat (3D) within observational uncertainty of 10 - 20%.

The stuff that we and the Sun and stars are made of is essentially irrelevant to this argument, there is too little of it in the Universe.

Most of the stuff of which the Universe is composed is substances, Dark Matter, Dark Energy, completely unlike us.

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

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.

We are in one of those concentrations of dark matter, our time passes more slowly than the average place in the Universe - does that make a difference to the analysis? Some claims that data can be fit without Dark Energy. Need to be evaluated.

One Minute Exam

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

A) Type Ia

B) Type Ib

C) Type Ic

D) Type II

One Minute Exam

Dark Matter is responsible for

A) The acceleration of the Universe

B) The dark space between stars and galaxies

C) The clumping of matter to form stars and galaxies

D) The Dark Ages after the initial Big Bang

One Minute Exam

Dark Energy is responsible for

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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}

"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???***

Einstein’s theory of the behavior of the Universe contained a “Cosmological Constant,” that could be positive, negative, or zero.

Einstein first argued it was positive in order to provide an anti-gravitating force to counteract gravity to keep the Universe from expanding or contracting, but then the expansion of the Universe was discovered and he called it a “blunder.”

Current results on the expansion are consistent with the Dark Energy being just the value set by Einstein.

Even if true, we still need to know what it is, physically! Why does this “constant” have the value it does?

Theories of quantum fields suggest that the Dark Energy could or should vary with time and space.

One theory called “quintessence” (the fifth essence, after the Greek earth, air, fire, and water) would have that property.

Other theories call for interaction with other 3D Universes “elsewhere” in hyperspace.

The race is on to determine whether the Dark Energy is constant or not.

The Fate of the Universe?

If the acceleration stays constant, the fate is rather dismal: galaxies will be pulled infinitely far apart, then even small mass, long-lived stars age and die, protons, neutrons and electrons will decay to photons, black holes will evaporate by Hawking radiation.

The result would be an empty Universe filled with dilute radiation.

We know so little about the Dark Energy, that it could do other things.

It could get stronger, leading to a ***Big Rip*** with atoms and the very fabric of space being pulled apart (most physicists think this unlikely)

It could reverse sign and gravitate, leading to the recollapse of the Universe in a ***Big Crunch***.

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.

Can use current theories to “predict” where the theoretical collision occurs, where the theory of quantum gravity is most crucially needed, effectively the scale of length where quantum uncertainty and space-time curvature are equal.

Planck length - about 10^{-33} centimeters, vastly smaller than any particle, but still not zero!

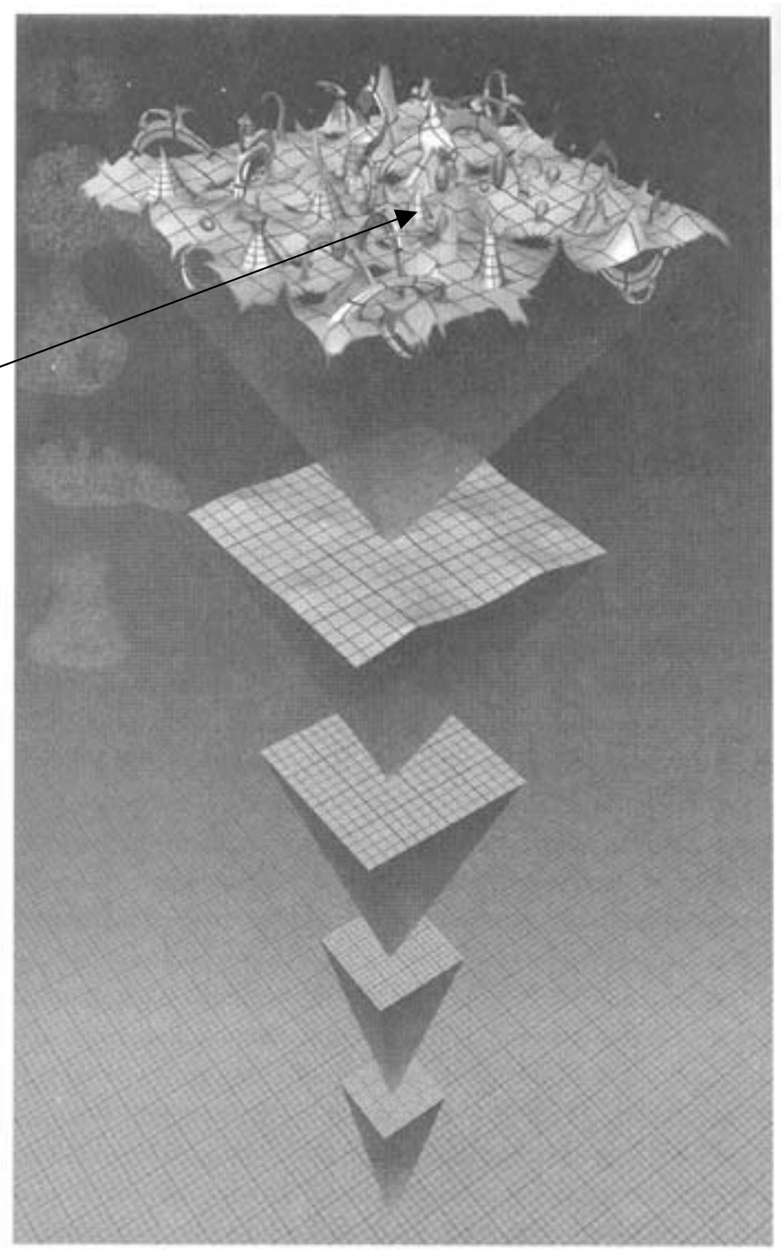
Planck density - about 10^{93} grams/cubic centimeter, huge, but not infinite!

On the Planck scale, space and time themselves would be quantum uncertain, “up” “down” “before” “after” difficult if not impossible to define.

Spacetime becomes a “quantum foam” (a poetic concept without a mathematical/physical framework).

Quantum Foam

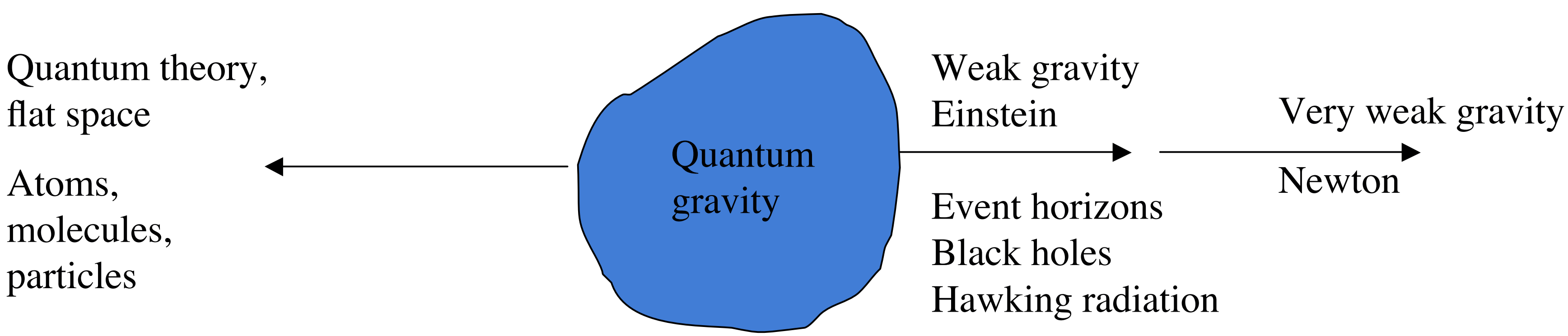
At the Planck length scale



From Brian Green

The Elegant Universe

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

Worm Holes and Time Machines

(Chapter 13)

Amazing mathematical developments in the context of Carl Sagan’s ***Contact*** by Kip Thorne and Igor Novikov:

Einstein’s equations allow the possibility of worm holes. To be stable, they must be held open by some imagined “substance” that anti-gravitates.

Highly curved space, but no singularity.

The Dark Energy gives a hint that such a “substance” could exist.

String Theory

History - in 1960's physicists recognized that the equations corresponding to the strong nuclear force also described entities that could stretch and wiggle - strings

Space in which strings vibrate has ***10 space dimensions*** + time

Shape of wrapped-up space determines how strings vibrate, what particles they represent.