

12/3/07

Fourth and last SkyWatch extra credit anytime before end of classes, December 7.

Class evaluation Wednesday - need volunteer

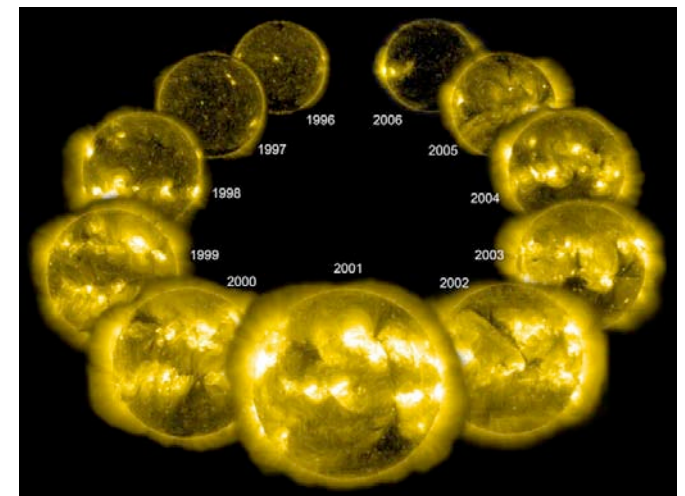
Reading: Chapter 13 (worm holes and time machines), 14 (quantum gravity, string theory, large extra dimensions).

Final Review Sheet

Final Exam Information: FRIDAY, DECEMBER 14, 9-12 N
ART 1.102

News:

Pic of the day; solar cycle



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 smaller 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!

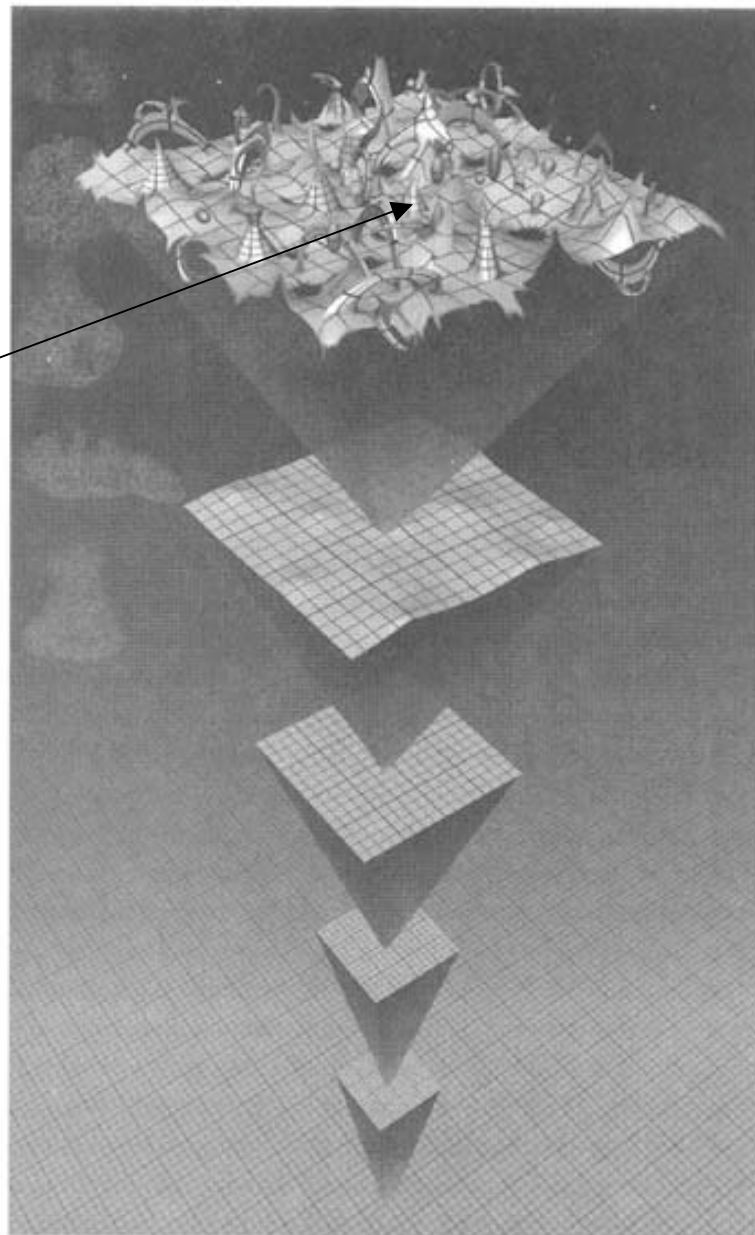
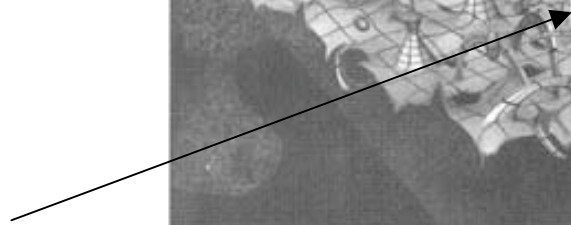
Planck density - about 10^{93} grams/cubic centimeter, huge, but not infinite!

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

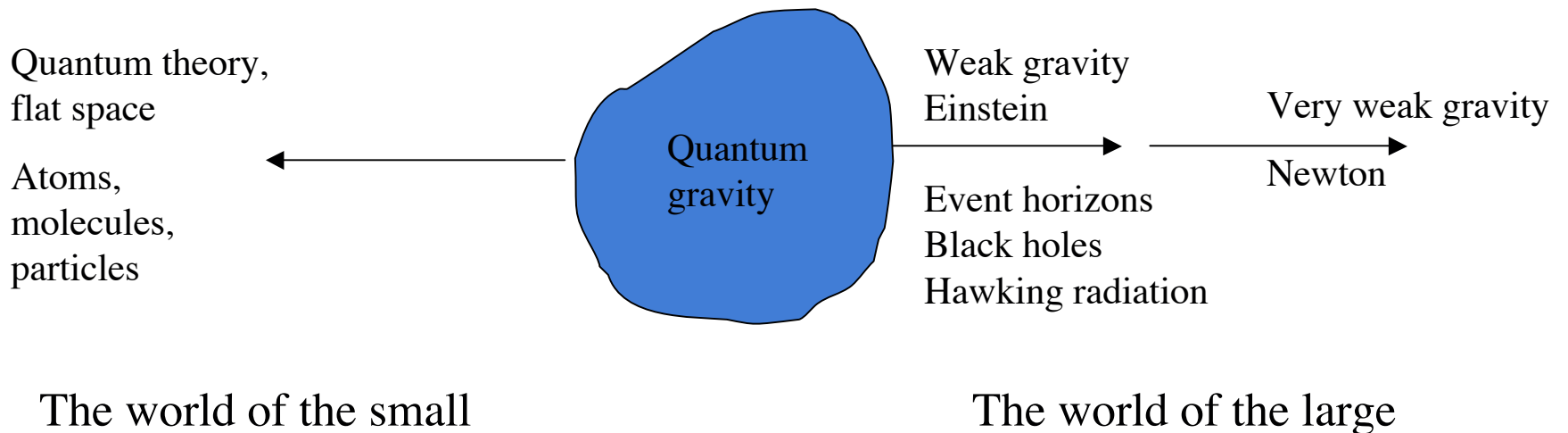
At the Planck length scale



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.



Worm Holes and Time Machines

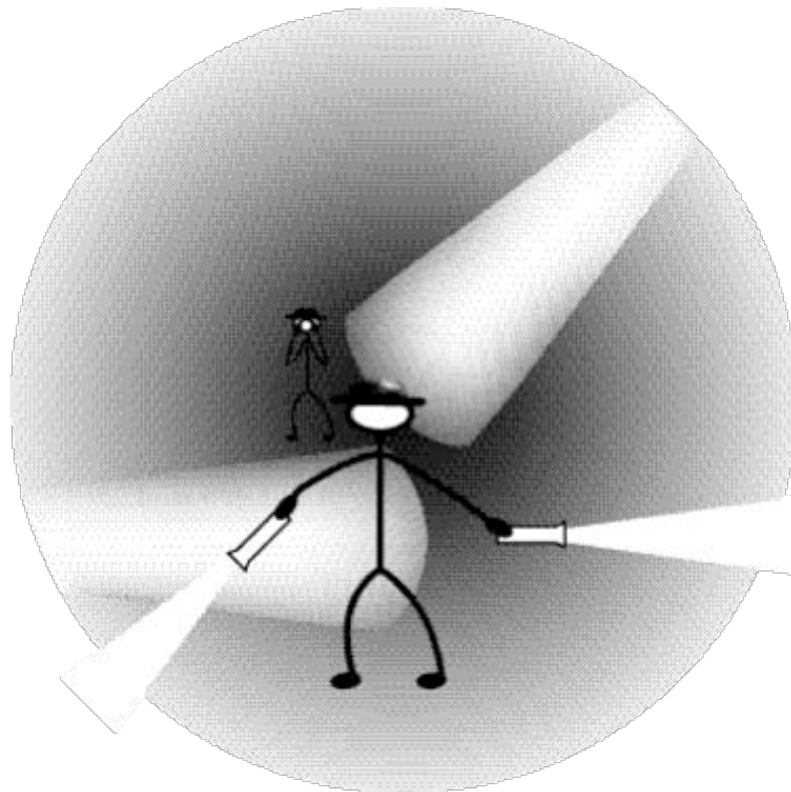
(Chapter 13)

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

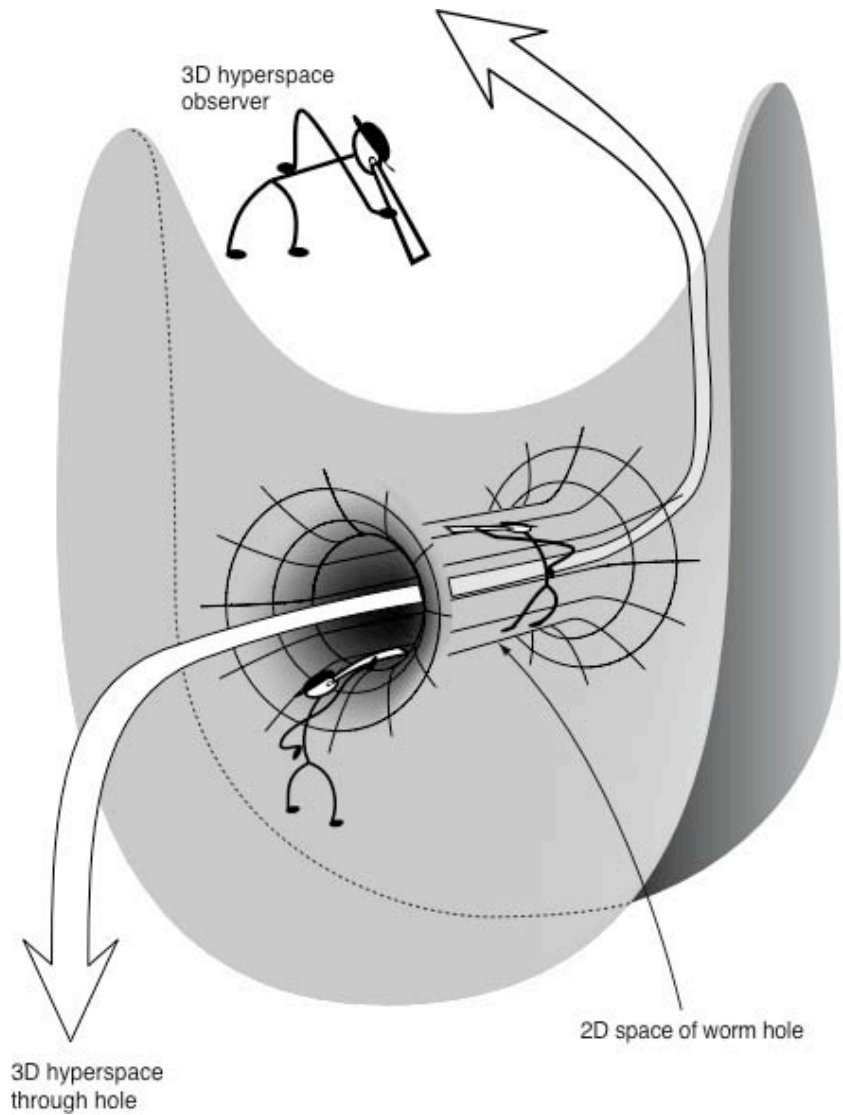
Einstein's equations allow the possibility of worm holes. To be stable, they must be held open by some imagined "substance" that anti-gravitates.

Highly curved space, but no singularity.

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



The mouth of a worm hole would be a 3D “object,” the space inside highly curved.



Embedding diagram of a worm hole in an “open” universe

The most amazing property discovered was that, in principle, worm holes would also be *time machines*!

Novikov Consistency Conjecture: physics will arrange itself so that there is no time-travel paradox - you cannot travel back in time and kill yourself before you enter the worm hole/time machine.

Thorne video

Ultimate resolution - will not know if worm holes can be constructed, even in principle, without a theory of *quantum gravity*.

Hawking - vacuum fluctuation energy (from uncertainty principle applied to vacuum) can go into wormhole, come out in past, pile up at mouth where began, quickly build up huge energy density, curve space, slam worm hole shut.

Maybe, but cannot actually compute that process without a theory of quantum gravity to handle the change in the “connectivity” of space time - must space time be smooth, or can it be laced with “tunnels” in space and time.

Need quantum gravity theory of singularity, quantum foam, worm holes

The best current candidate for a theory of Quantum Gravity is String Theory

See Brian Green - The Elegant Universe

(<http://www.pbs.org/wgbh/nova/elegant/>)

Read ***The Universe on a String*** editorial by Brian Green posted under links -> string theory

Hyperspace is an intrinsic aspect of string theory - 10 dimensions of space, plus time.

Background - pre-Einstein late 19th, early 20th Century

Where does space curve to?

Riemann (1826 -1866), Lobachevsky (1792 - 1856)

Theory of curved space, non-Euclidian geometry

Notions of 4D hyperspace affected art/culture turn of 20th century

Tesseract - 4D hypercube (Elegant Universe link)

3D “unfolding” of tesseract in Salvadore Dali’s

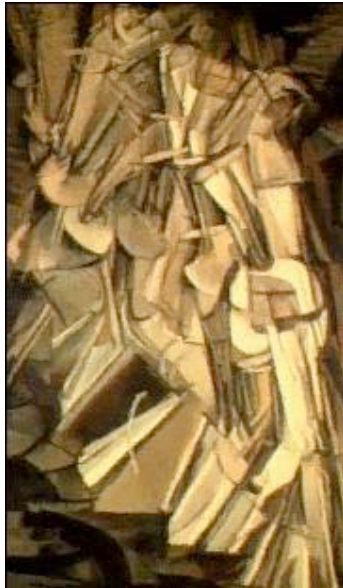
Crucifixion (Corpus Hypercubas)



Notions of seeing from different directions at once

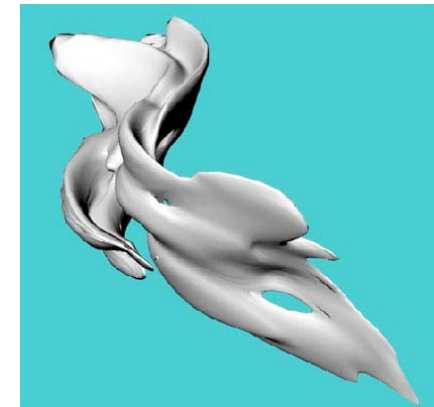
Perspective of Cubism

Picasso - Les Demoiselles d'Avignon



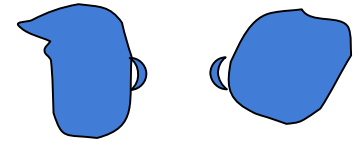
Deschamps - *Nude Descending A Staircase*

Contemporary Brazilian artist Marcos Novak -
3D projections of 4D objects



Hyperspace Perspectives (reflected in cubism?)

2D creature - another 2D creature sees the front



From 3D, we see front, back and *inside* simultaneously

In our 3D space we see the front of another 3D creature

A being living in a 4D hyperspace would see all of our surface, front and back, and our insides, all at once!

A 3D creature passing through a 2D Universe would start as a point, grow to a finite *area*, then decrease to a point and disappear.

A 4D creature passing through our 3D Universe would start as a point, grow to a finite *volume*, then decrease to a point and disappear.



Classic Quantum Theory

Particles are points (electrons) or are made up of point-like particles (three quarks in a proton or neutron), that also have wave-like properties.

Quantum view of forces - the quantum theory (mathematically) views all forces as resulting from an exchange of particles, with different exchange particles representing different forces.

Photons are the exchange particles for the electromagnetic force, other exchange particles account for the weak and strong nuclear forces.

String Theory

Best current candidate for a quantum gravity “theory of everything.”

Particles like e-, p, n are not “points” but strings, loops that vibrate in different modes

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

Download from “links” the recent editorial by Brian Greene on the status of string theory: The Universe on a String