November 29, 2010

Reading: Chapter 14

Exam 5, Friday, Dec 3 ***Review Sheet posted***. Review Thursday, 5 – 6 PM, TBD

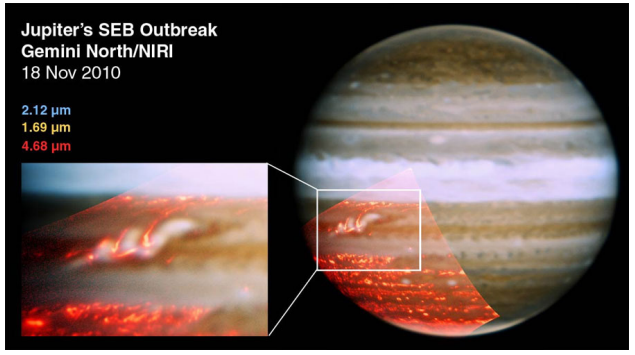
Electronic Course Instructor Survey, now until 12/3/10.

https://utdirect.utexas.edu/ctl/ecis/..

Last sky watch - you cannot make up any missed sky watch, but you can report on any object you have not yet used, or find new examples of objects we have done, red giants, white dwarfs, neutron stars, etc.

Astronomy in the News?

Pic of the Day – changes in Jupiter's cloud belt



Goal:

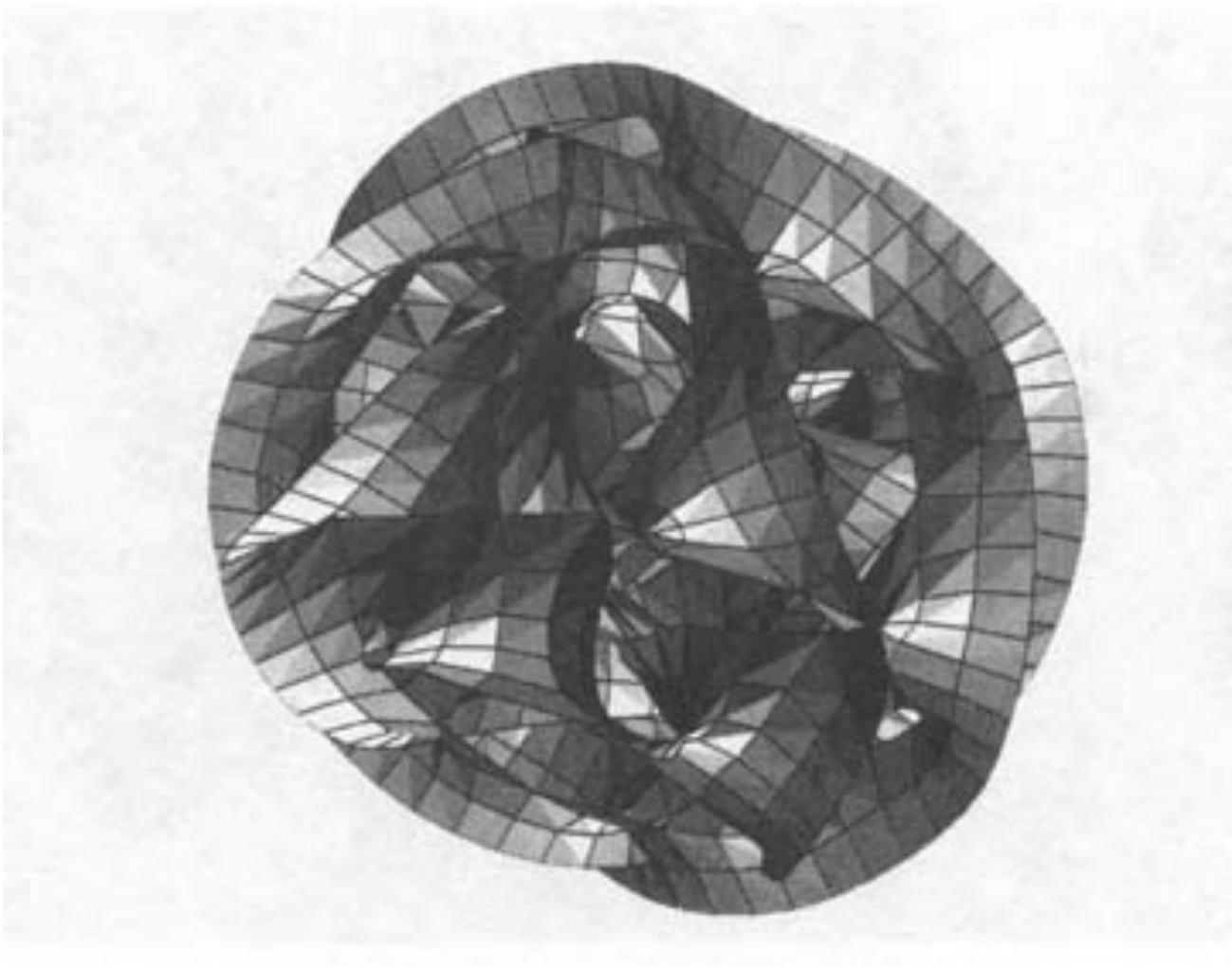
To understand how string theory represents the current best candidate to be the needed theory of quantum gravity

To be mathematically self-consistent

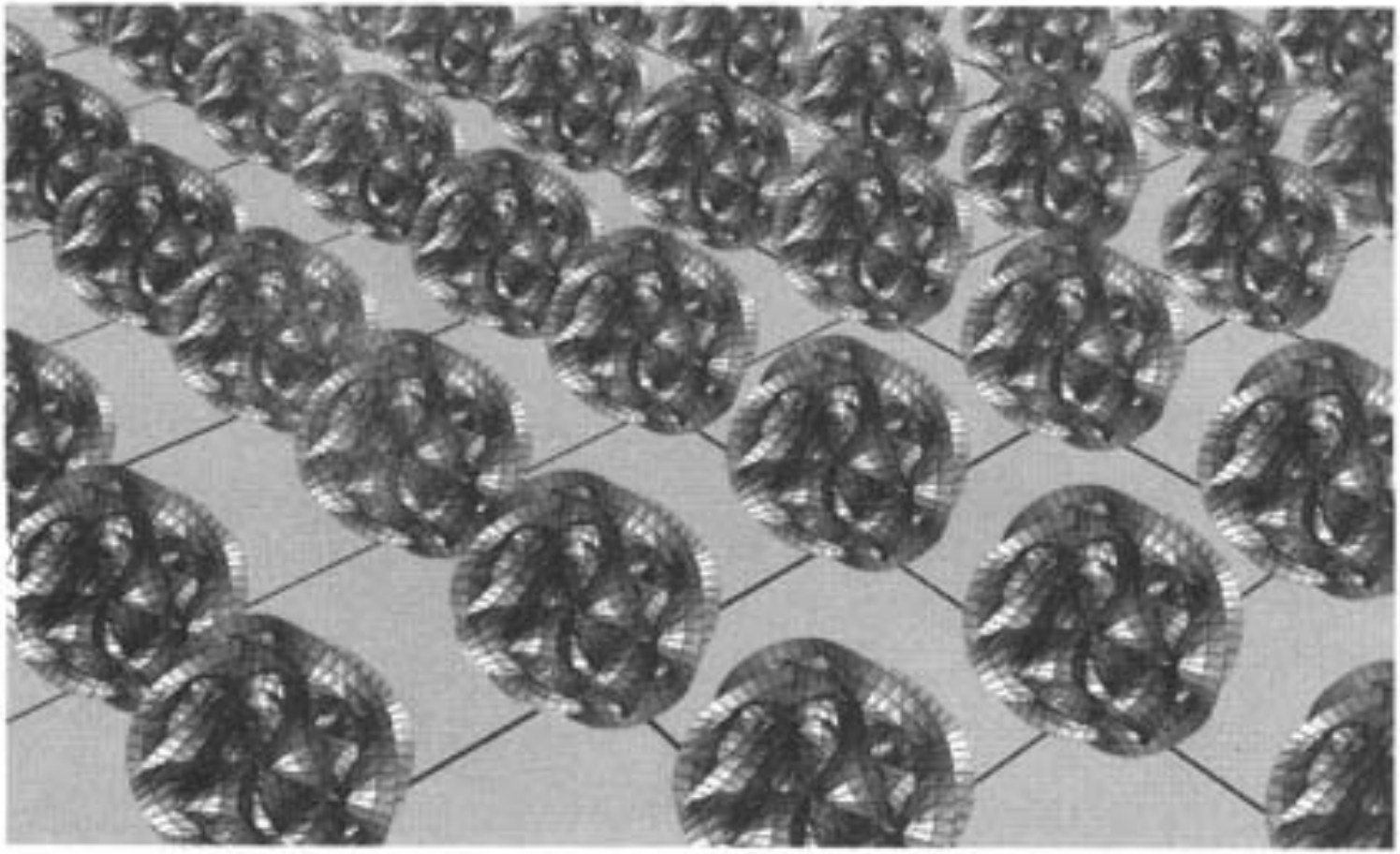
Space in which strings vibrate has ***10 space dimensions*** + time

First notions:
3 big space dimensions + time

Other 7 dimensions "wrapped up" on "string length scale," not known precisely, somewhat larger than the Planck scale, but very tiny so we cannot easily "see."



Representation of a Calabi-Yau space, with 6 wrapped-up extra dimensions. From Brian Green: The Elegant Universe.



At each point in the 2D space (not just at the intersections of grid lines), there is a little 6D Calibi-Yau space of six wrapped-up extra dimensions.
From Brian Green: The Elegant Universe.

Mathematics of string theory is complex.

Only approximate solutions so far, but:

String theory "contains" Einstein's Theory mathematically on spatial scales where string "loops" are tiny, just as Einstein's theory "contains" Newton's theory of gravity on scales where gravity is weak.

Can solve string theory near the event horizon (much larger than string scale) to determine the temperature of a black hole, get exactly Hawking's answer - deep connection between string theory and black holes.

Cannot yet solve for "singularity," but prospect to do so. Singularity would not be zero size and infinite density, but some behavior on the string length scale, not quantum foam, but some "stringy" nature.

Information fallen into black holes could be retained in string vibrations (or radiated away in Hawking radiation).

In the 1990's, physicists discovered that the equations of string theory predict not only 1D strings, but "surfaces."

These surfaces can be of any dimension less than the total of the space containing them.

In analogy to membranes, they are called ***branes*** of dimension p, or ***p-branes***.

"Volume" in which a brane is immersed is known as the ***bulk***.

Some strings are loops with their ends attached to branes; other strings are closed loops that can float off away from the brane, into the bulk.

This led to a revolution in our perspective on the Universe.

Concept check:

Can you explain what it means to have a wrapped up, closed dimension in 3D? What are examples?

Can you explain what it means to have tiny, wrapped up higher dimensions?

Goal:

To understand why physicists argued that any “extra” dimensions had to be tiny and wrapped up, how that restriction was removed, and what that means for our view of the Universe.

Concept check:

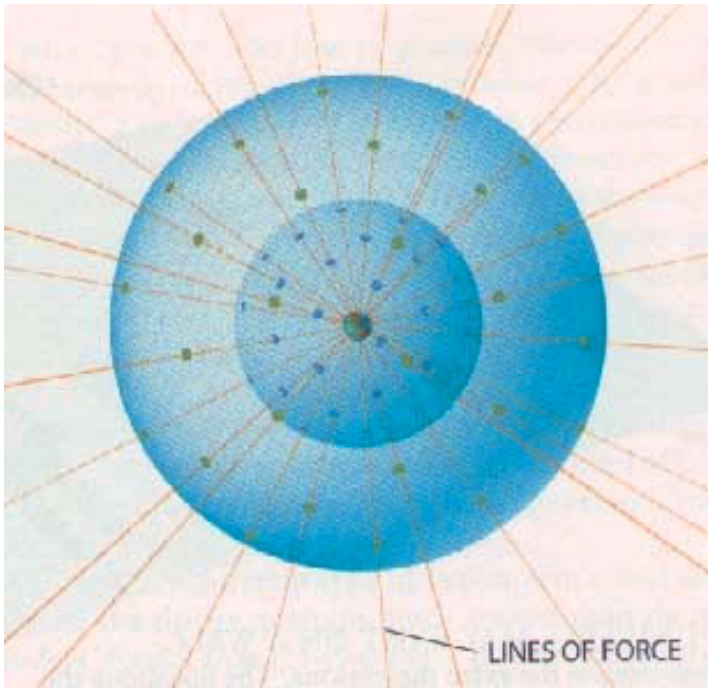
What is the “inverse r-squared law?”

Old argument: there could ***not*** be a ***large*** 4th spatial dimension

Behavior of light, electrical force, and gravity in 3D

The luminosity or lines of force flow out through larger ***area*** at larger distance. The strength (brightness or lines of force per unit area) is thus diluted by 1/area $\propto 1/r^2$ in 3D. Area is one dimension less than volume; the "2" is exactly one less than the total number of large dimensions, "3"

Light and electricity might be stuck in 3D, but gravity probes all space, whatever its dimension. Gravity is a creature of space/time



Extend the argument to higher dimensions than 3.

An “area” is one dimension less than the total “volume” corresponding to a given dimension of space.

If gravity extends to a fourth dimension, where “volumes” scale like r^4 and “surfaces” scale like r^3, then gravity would be diluted in 4D by 1/”area” $\propto 1/r^3$ in 4D.

Obviously wrong! Even Newton knew that gravity weakens as the inverse of distance squared, not as distance cubed!

Implication (it was long thought): IF there is a 4th (or higher) dimension it must be “wrapped up” so gravity has no where to go.

New insight: (1999) - Can have ***large extra dimensions*** and gravity will still leak only a little into that extra dimension, still weaken very nearly as $1/r^2$.

Our 3D Universe could be a 3D brane in a large, extended, 4D bulk

There could be a real, large (infinite), four-dimensional hyperspace in which our 3D Universe is embedded.

Plus tightly wrapped up dimensions.