May 3, 2010

Last exam Friday, Review Sheet posted

Small Review Wednesday, 5 PM, my office RLM 17.230

Regular Review, Thursday 5-6 PM, ECJ 1.202 *Note diff bldg!!!!!*

Reading - Chapters 12, 13, 14.

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? New Hawking's Universe episode on Discovery Channel. Stellar evolution, SN asymmetric, but only bagel, Gamma-ray burst had bagel and breadstick.

Pic of the Day - nearly edge-on spiral galaxy with dust lanes, central bulge.
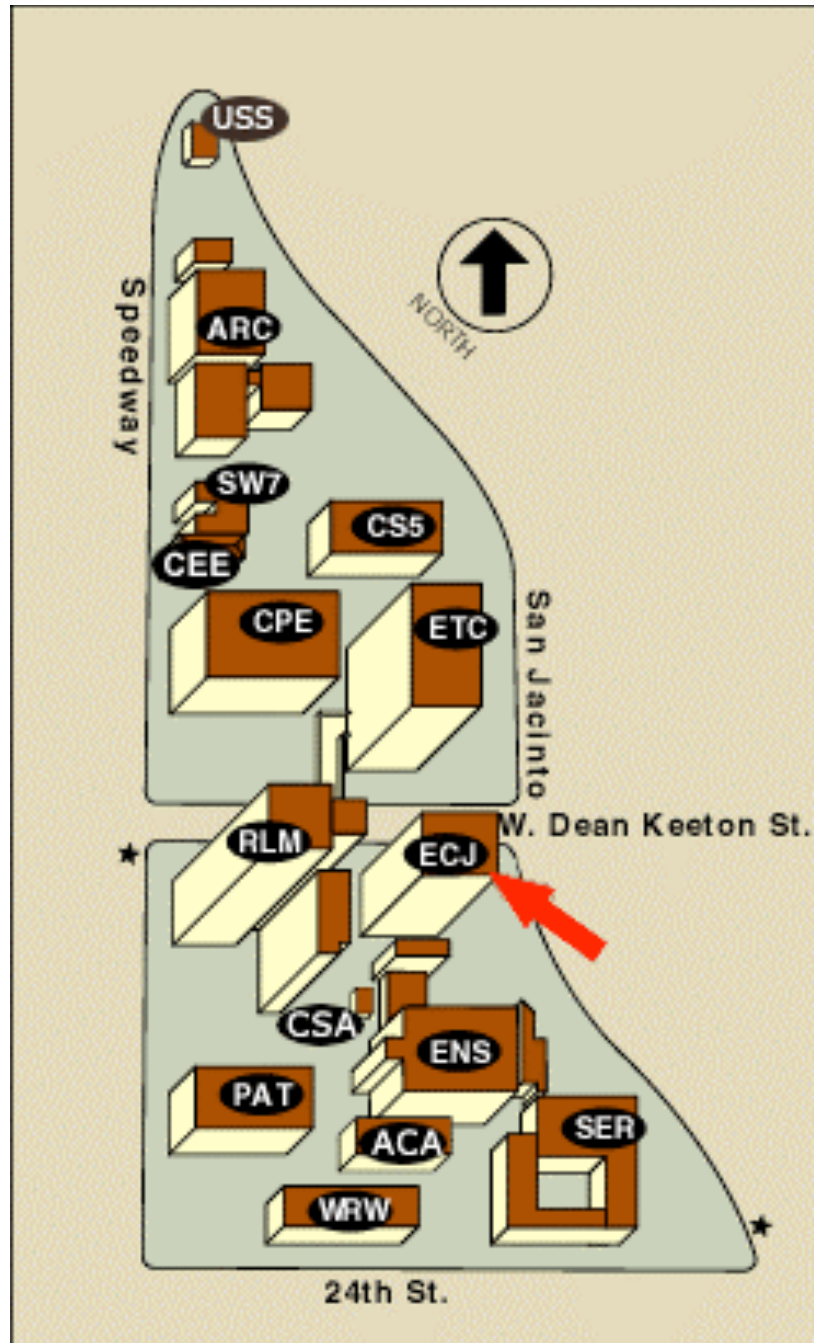
Thursday Review

ECJ 1.202, East of RLM

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.

One minute exam
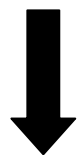
In string theory, our Universe is pictured as a

➡ 2 brane

⬅ 3 brane

⬆ 10 brane

⬇ 3D bulk

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

LINES OF FORCE
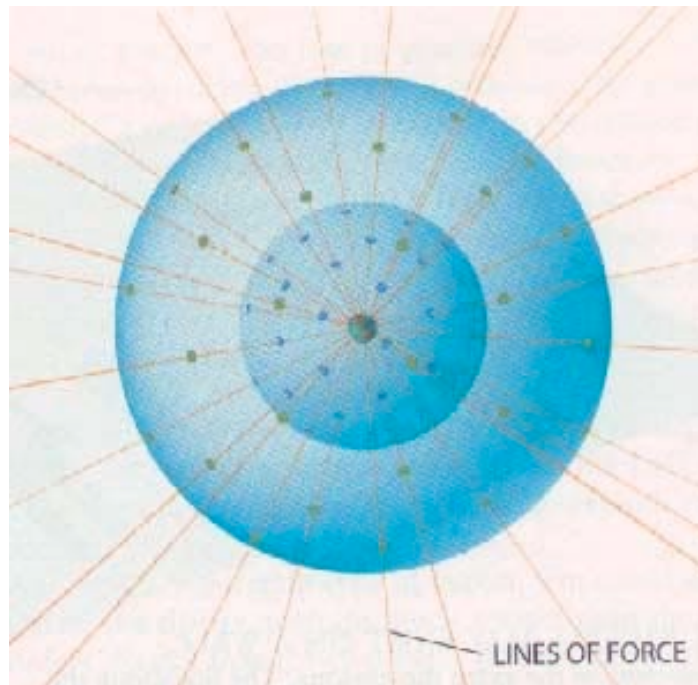
Extend the argument to higher dimensions than 3.

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.

In this picture, ordinary forces, electromagnetism, nuclear forces, correspond to "open" strings that have ends stuck on the 3D brane,

These strings cannot "go" into the 4D bulk, we cannot "see" the 4D bulk.

Balls on 2D brane, sound into 3D bulk
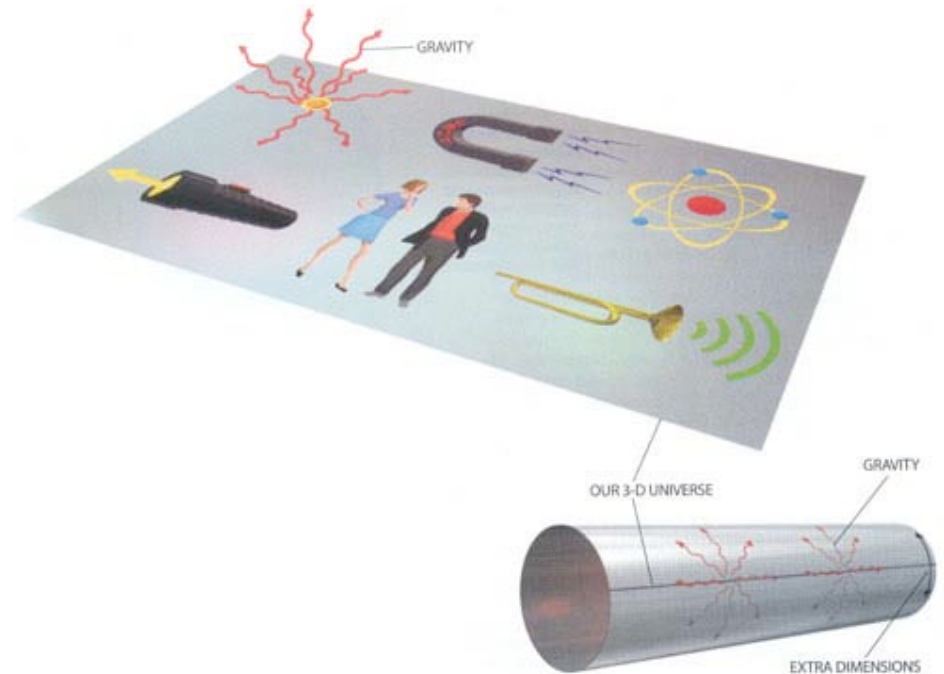
Gravity corresponds to closed loops of strings that are not stuck on the brane, they can float off into the bulk, but in a way that gravity still weakens very nearly like $1/r^2$.