5/6/05

Final Review Sheet.

Chapter 12 - Omit worm hole, time machines Sections 1, 2, some new material - Braneworlds in higher dimensional space

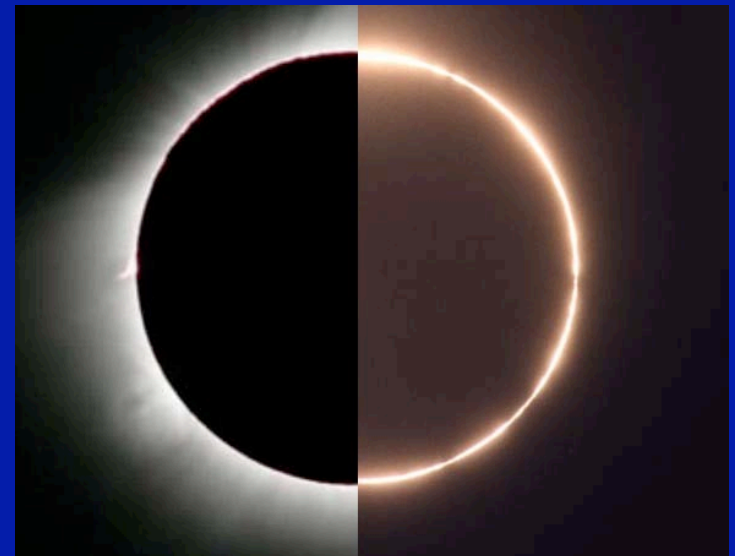EXTRA CREDIT SKY REPORTS DUE TODAY

Comprehensive Final - 100 multiple choice questions,

Wednesday, May 11, 2 - 5 PM here in Welch 3.502.

News:

Pic of the day:

Solar eclipse

*Special Office Hours: RLM 15.216B*

*Tuesday, May 10 4 - 6 PM*

Jen: 4 - 5

*Wheeler: 5 - 6*

Or make appointment with either of us.

Schematic illustrations of how tiny "wrapped up" extra dimensions could be associated with our 3D space - something like an embedding diagram of the higher dimensional space, so our 3D space is reduced to 2D and the higher dimensional wrapped spaces are reduced to 3D.

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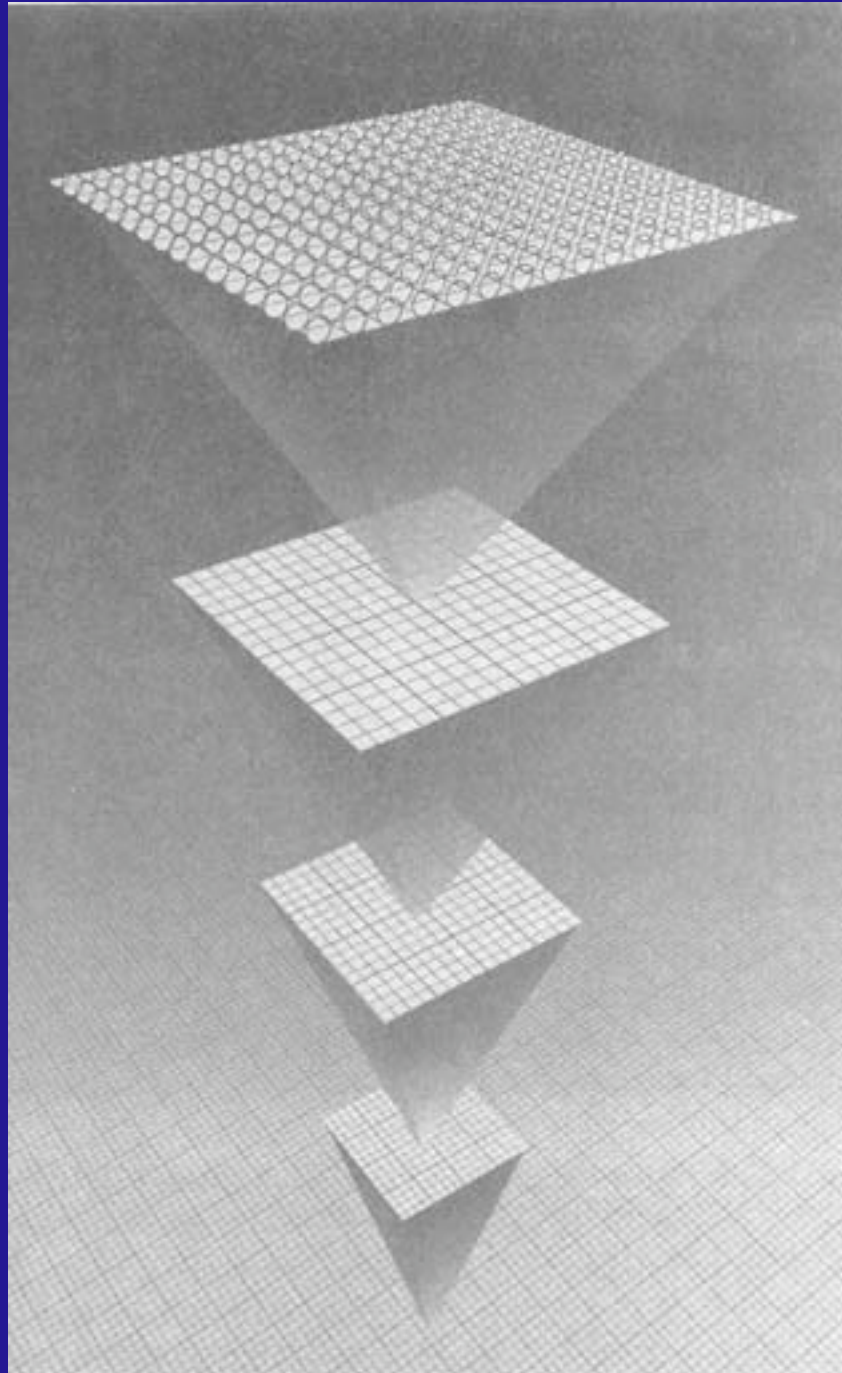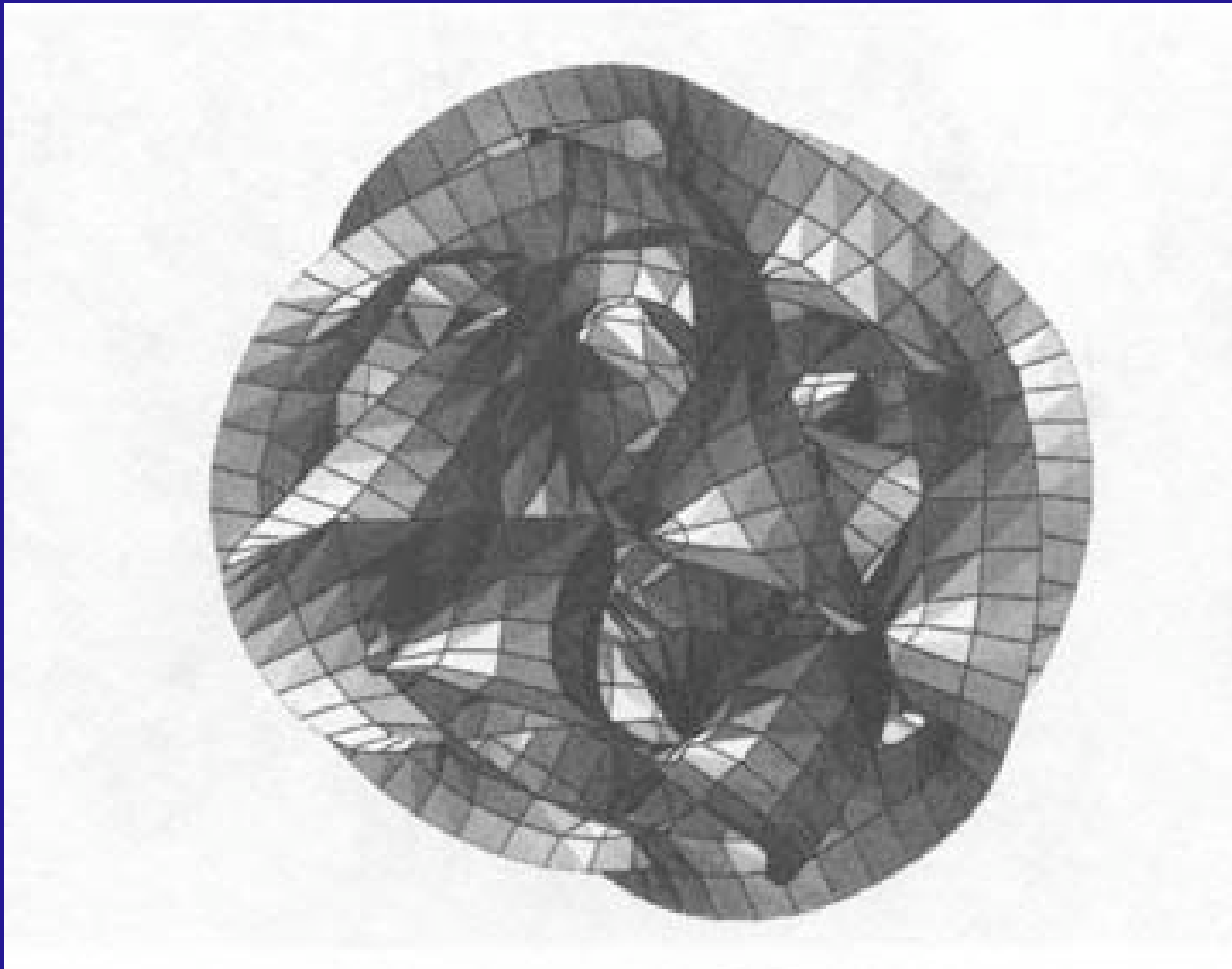
Representation of a Calabi-Yau space, with 6 wrapped-up extra dimensions
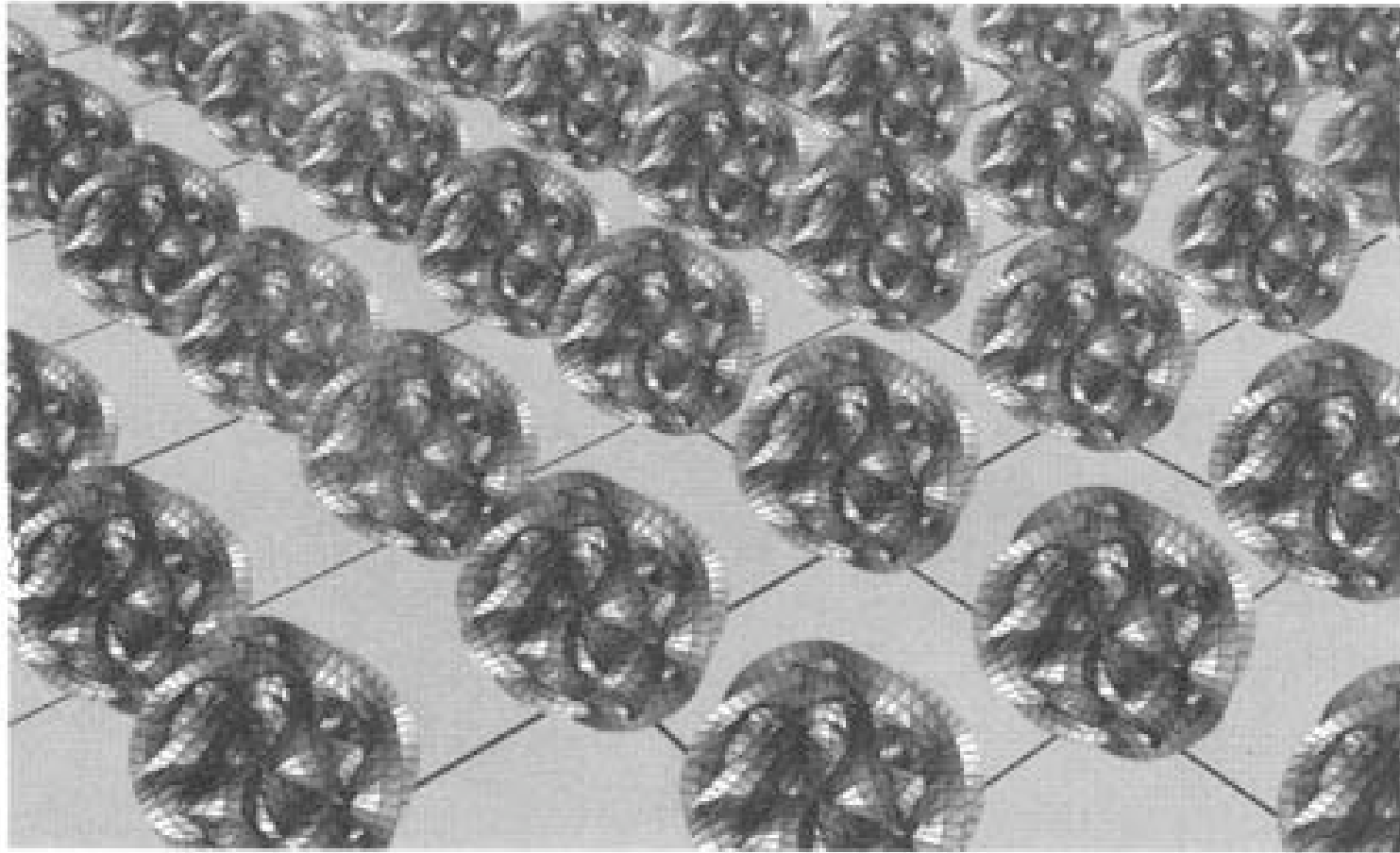
At each point in the 2D space (not just at the intersections of grid lines), there is a little 6D Calibi-Yau space of six wrapped-up extra dimensions.

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.

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.

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

Gravity probes all space, whatever its dimension, gravity is a creature of space/time

Behavior of light and gravity in 3D
    lines of force flow out through larger area at larger distance,
    the strength (lines of force per unit area) is thus diluted by
    $1/\text{area} \propto 1/r^2$ in 3D

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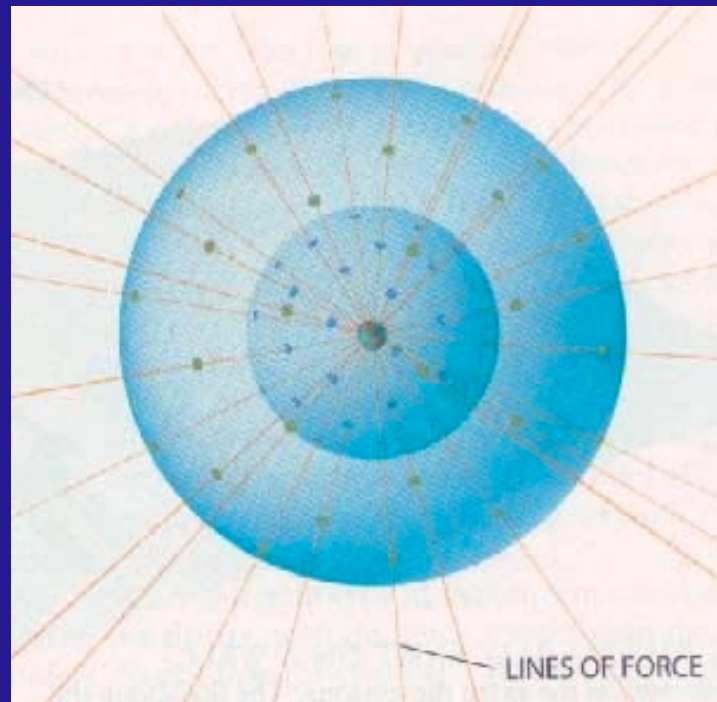
Extend the argument to higher dimensions than 3.

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, still weaken very nearly as $1/r^2$.


Our 3D Universe could be a 3D brane in a 4D bulk
> *There could be a real, large (infinite), four-dimensional hyperspace in which our 3D Universe is embedded.*

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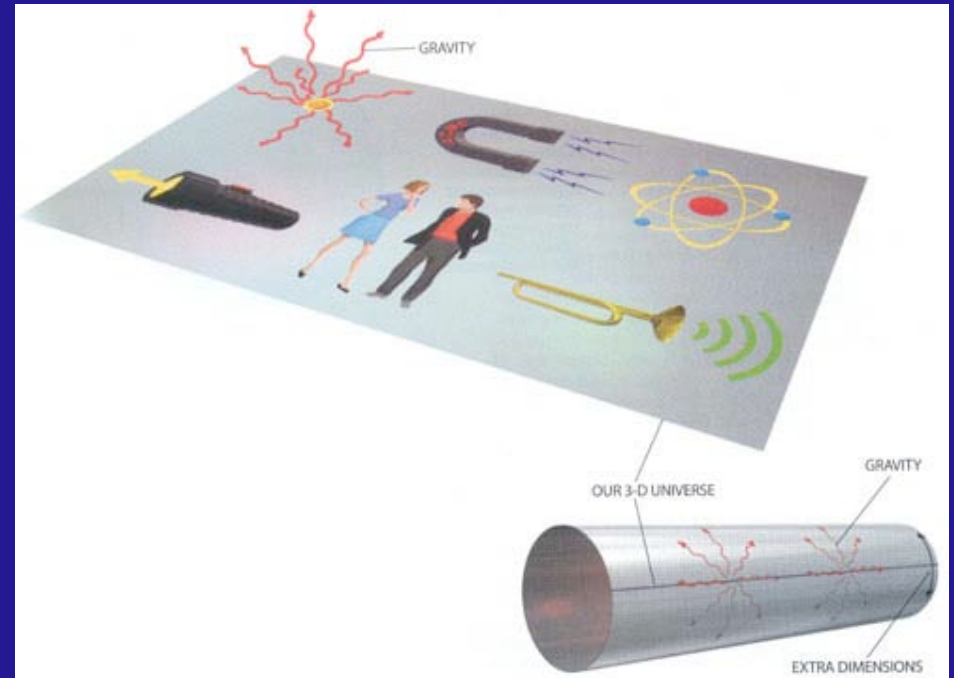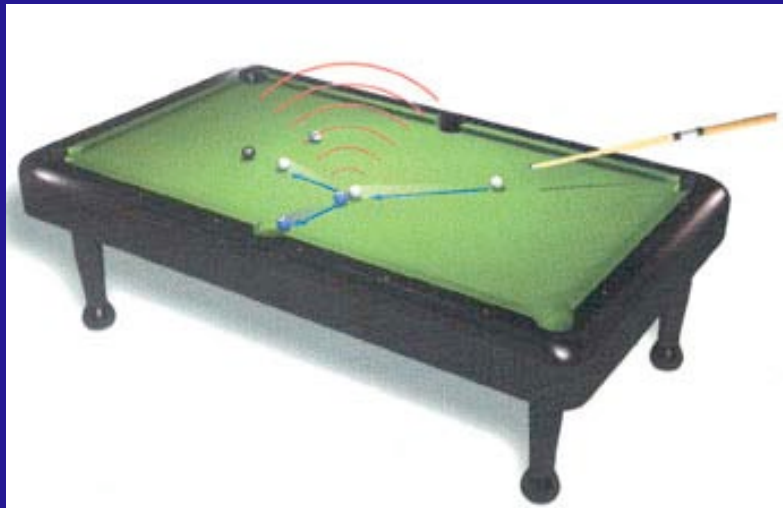
Gravity corresponds to closed loops of strings that are not stuck on the brane, they can float off into the bulk, but in a way that gravity still weakens very nearly like $1/r^2$.

Brane world cosmologies: exploring possibility that our Universe is a 3D brane floating in a 4D bulk, with 6 wrapped-up dimensions plus time

Example: Ekypyrotic Theory (Greek *ekypyrosis* = conflagration)

       Two 3D branes collide in 4D bulk
       hot, dense "Big Bang" but not infinite density
       no singularity
       different gravity waves - could be a test.

Brane world ideas:

Singularity in black holes, quantum foam $\Rightarrow$ nested "loops" of strings?

The 4D Bulk: is this where our Universe curves to when it curves, expands to when it expands - Maybe…

Bubble Universes: When a black hole forms does a new Universe spring into existence "elsewhere" in 4D hyperspace?

Is this real, or just mathematical fantasy?

Must be able to test: Physicists are straining to devise such tests.

Does gravity behave a little differently than $1/r^2$, for instance like $1/r^{2.0001}$, that would be hint of higher dimensions?

Curved space near event horizons of black holes might be different than standard Einstein gravity - can that be measured with X-rays?

Anti-protons emitted from primordial black holes?

Is the Dark Energy that drives the acceleration of the Universe some manifestation of a "nearby" 3D Universe only a little distance away from our Universe in the 4D bulk?

Take Away Message:

Hyperspace might be real…

Stay tuned!