4/28/2008

Fourth, Last Exam, This Friday May 2

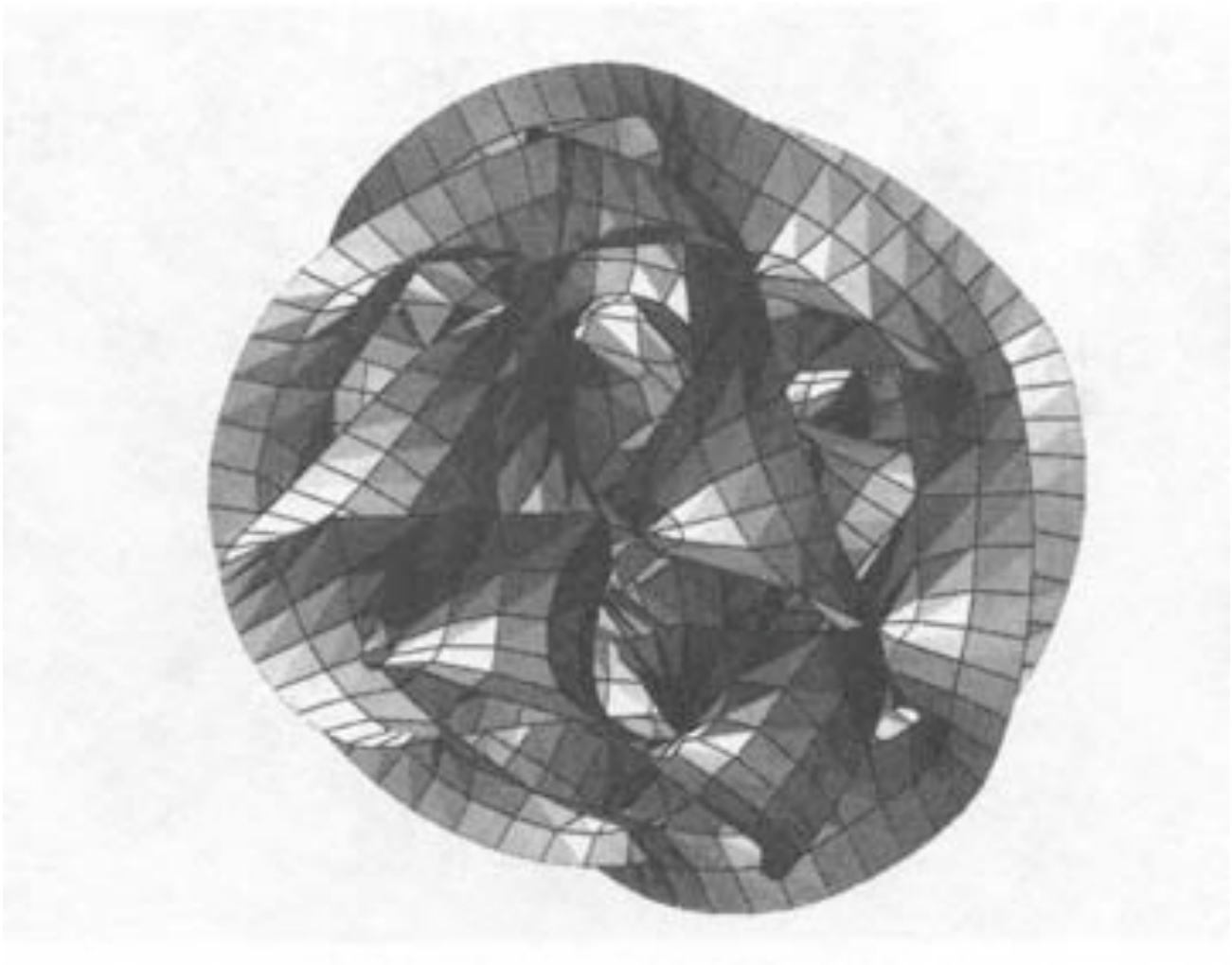
Review sheet posted today, reviewThursday, 5 PM RLM 15.216B

Reading: Chapter 11 - all except 11.6, 11.7, Chapters 12, 13, 14 - all

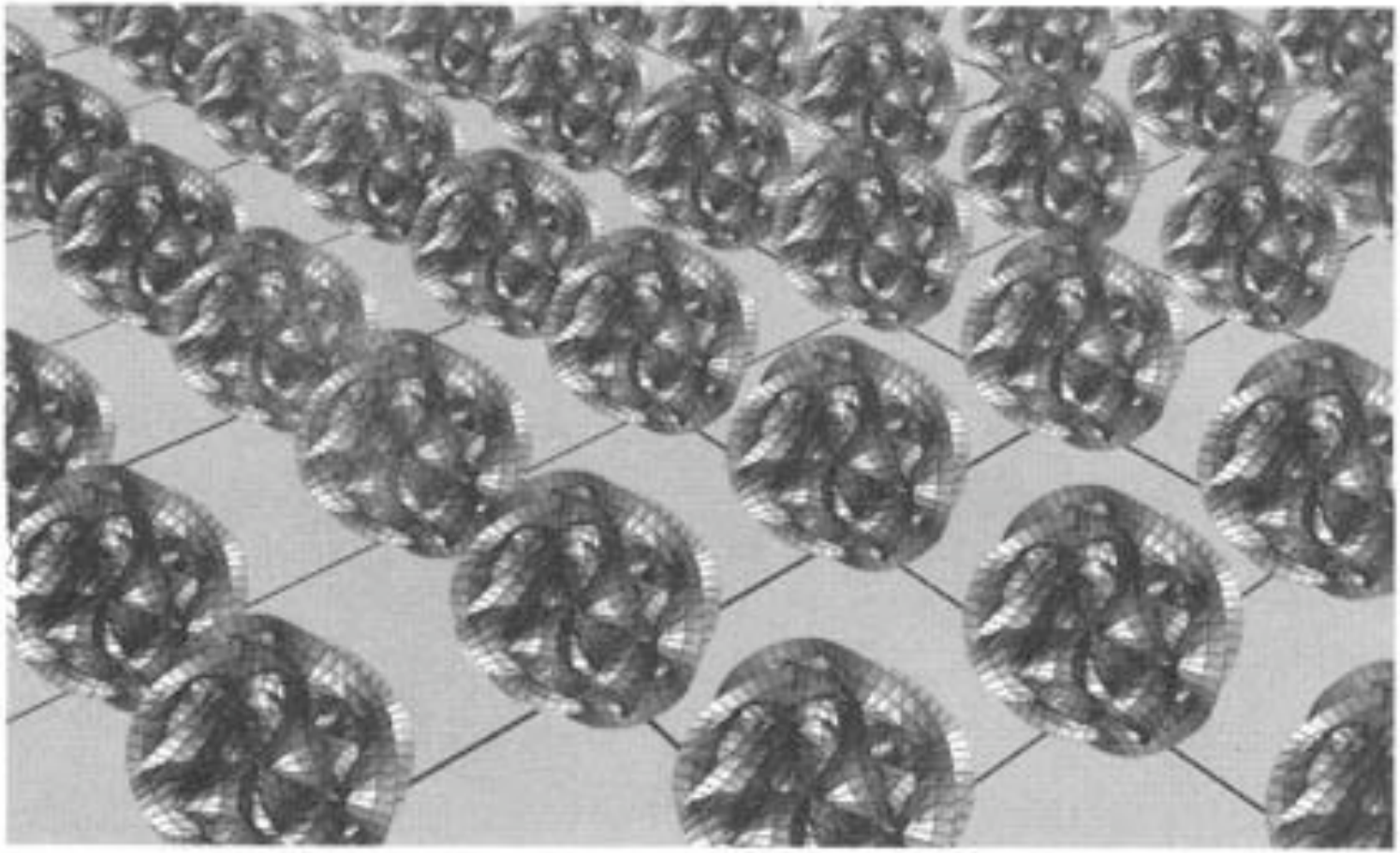
Fourth and last SkyWatch extra credit due by Sunday midnight.

Astronomy in the News - Friday, 3:00 P.M. WEL 2.224, Kip Thorne, Feynman Professor of Theoretical Physics, California Institute of Technology "The Warped Side of the Universe: From the Big Bang to Black Holes"

Pic of the day - star forming region



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.

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.

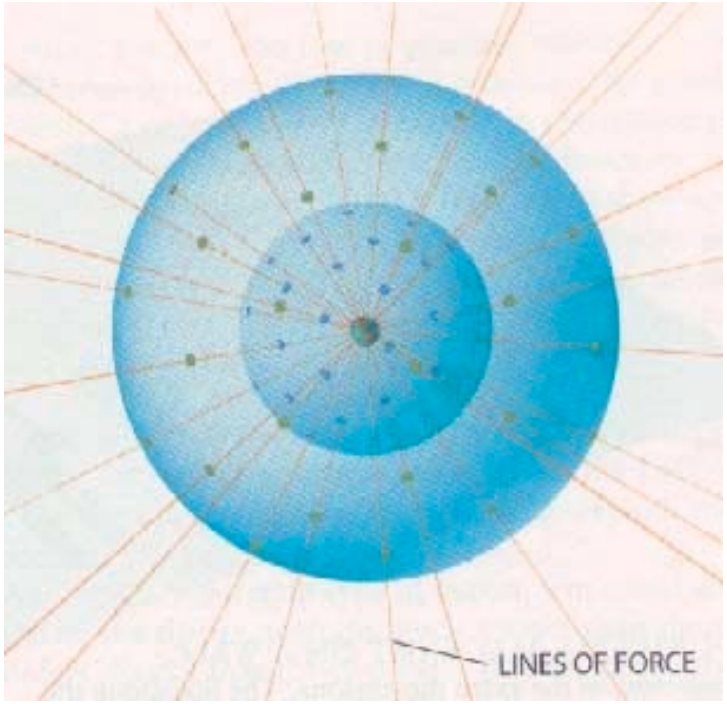
This led to a revolution in our perspective on the Universe.

Old argument: there could ***not*** be a ***large*** 4th spatial 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/area $\propto 1/r^2$ in 3D



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 4D bulk

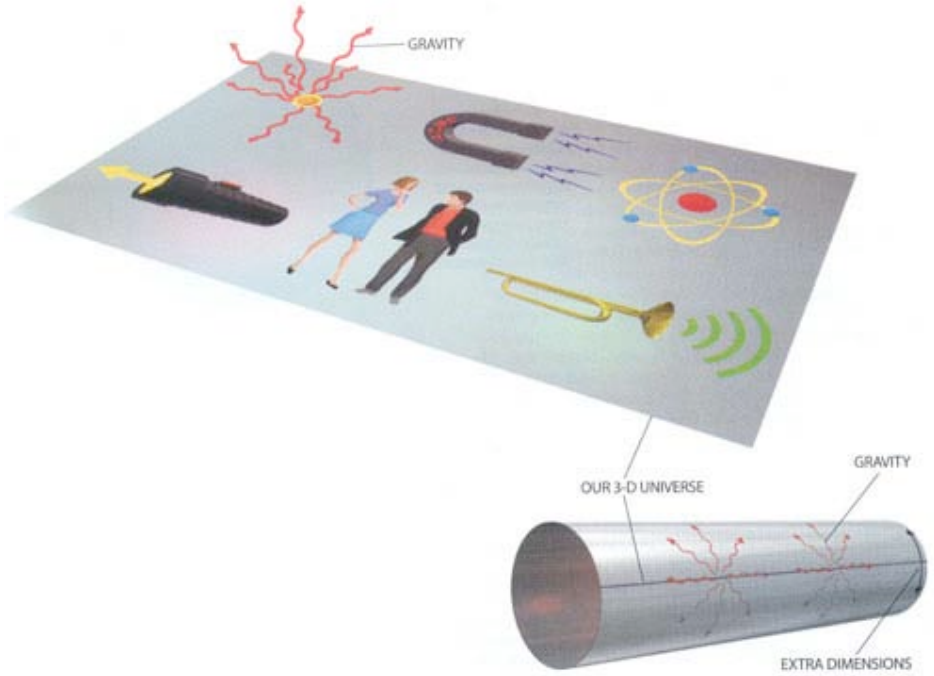
There could be a real, large (infinite), four-dimensional hyperspace in which our 3D Universe is embedded.

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 $1/r^2$.