Monday, November 28, 2011

Fifth Exam, Friday, December 2. Review sheet posted.

Fifth sky watch due. You can do any object mentioned throughout the term that you have not done before.

Review Thursday, 5 – 6 PM, RLM 4.102

Reading: Chapter 12, Chapter 13, **Chapter 14**

Electronic class evaluations. Please respond. This feedback is very valuable to me and to the TAs.

Astronomy in the news? Mars science lab with car-sized rover, Curiosity, launched Saturday, will arrive at Mars in August.

The Fabric of the Cosmos, last installment, Universe or Multiverse, infinite universes, we live in a habitable one, all represented as "spherical."
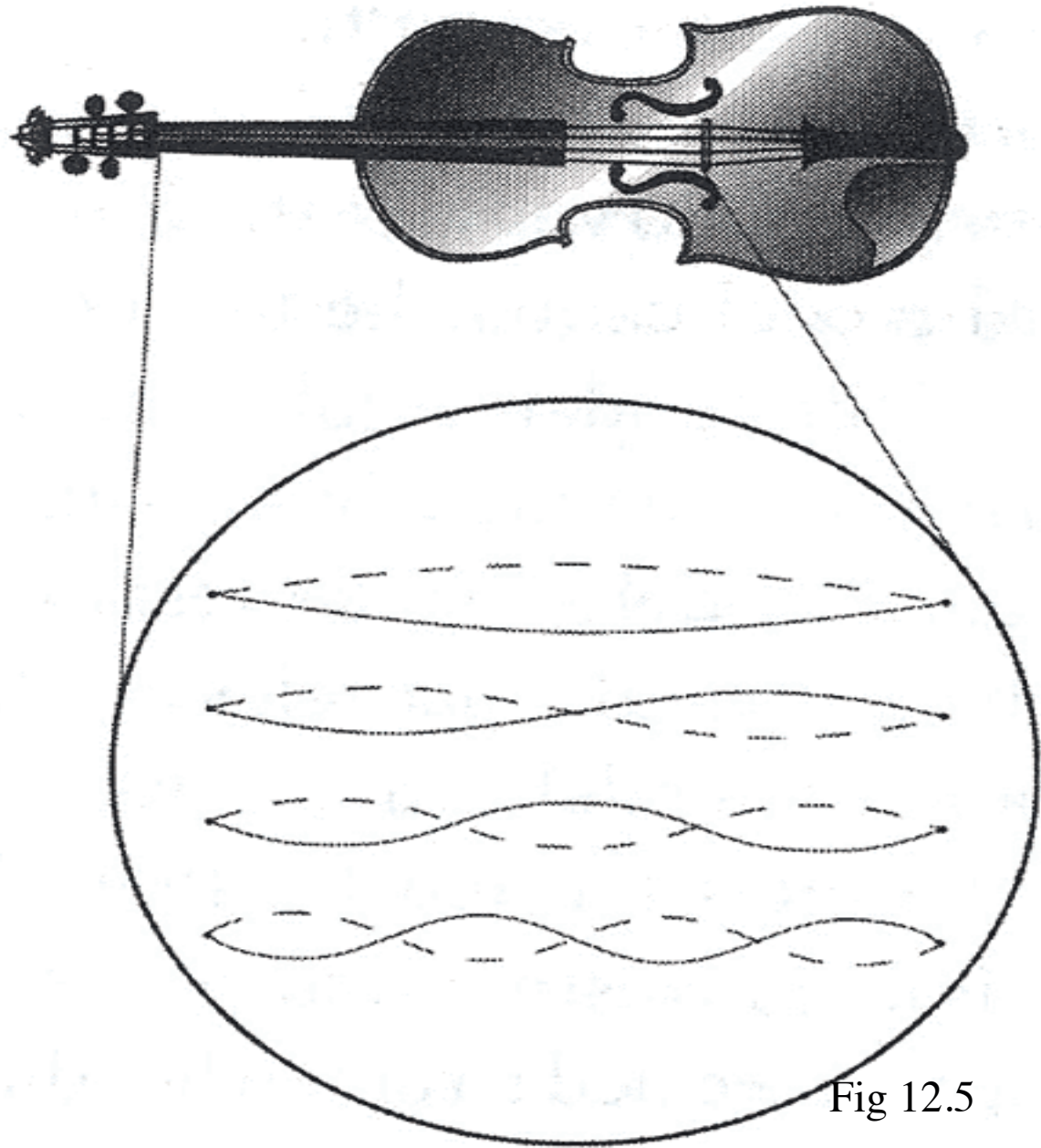
Pic of the day: asteroid Vesta
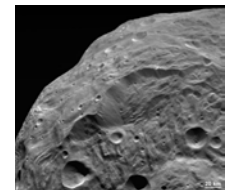
Goal:

To understand how string theory represents the current best candidate to be the needed theory of quantum gravity
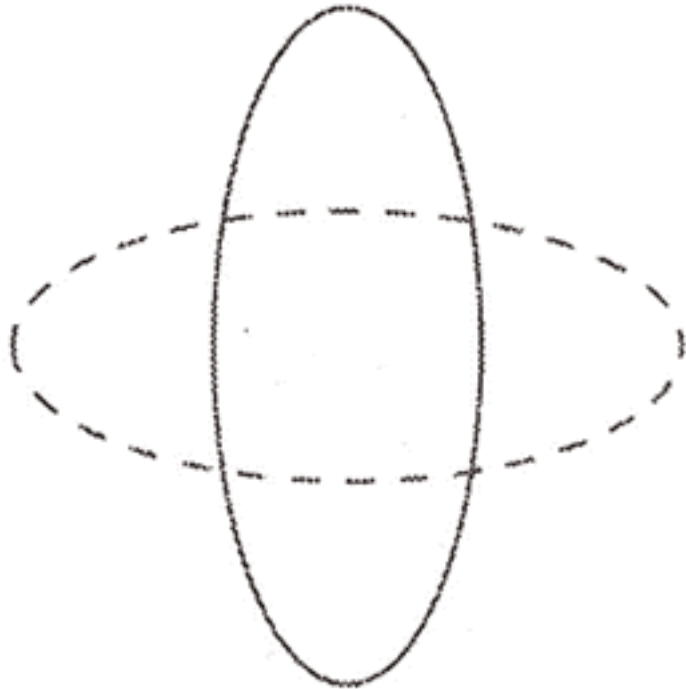
Can't
make
notes
with
grains
of sand,
but with
strings,
you
have
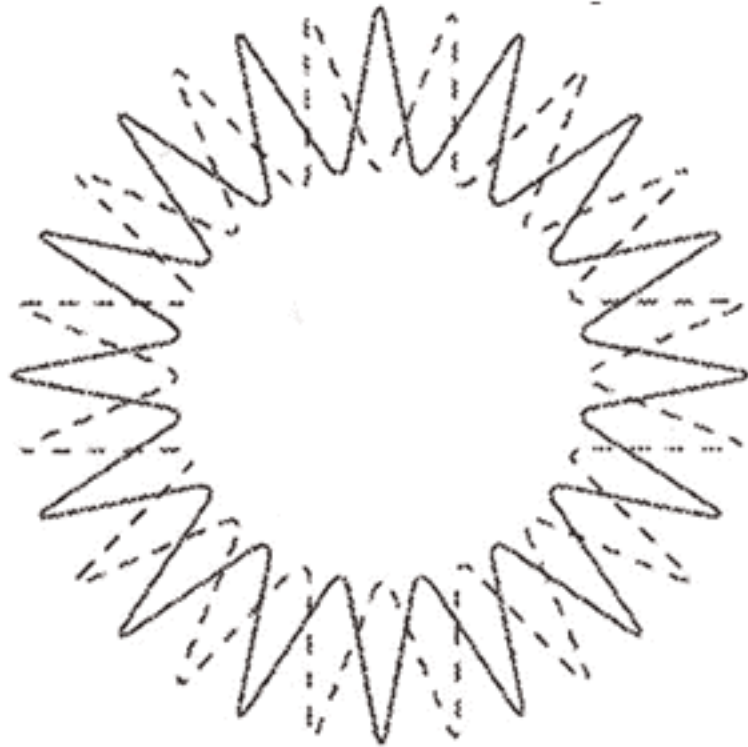Mozart

From Brian
Greene -
The Elegant
Universe

Fig 12.5

One particle   A different particle

Same fundamental loop of string

From Brian Greene - The Elegant Universe

To be mathematically self-consistent

Space in which strings vibrate has ***10 space dimensions*** + time
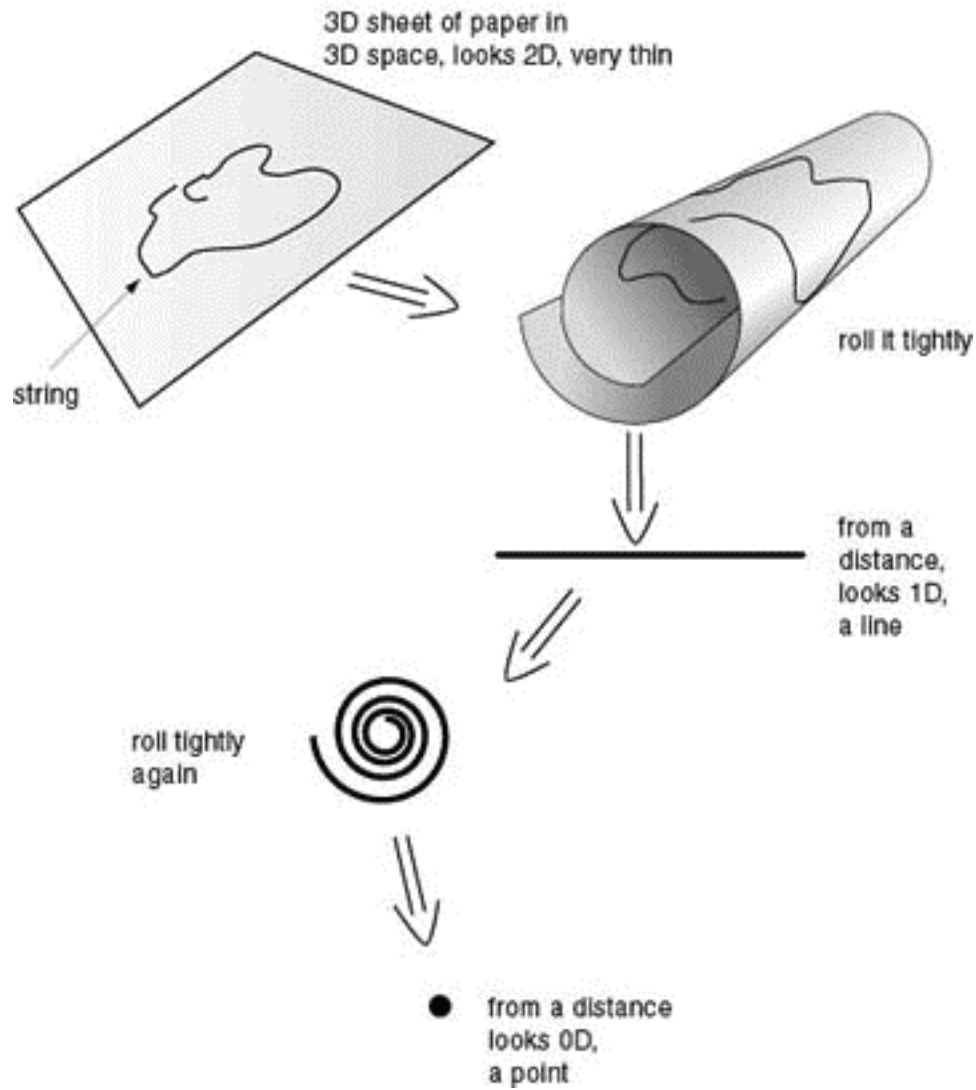
First notions:
3 big space dimensions + time

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."

Dimensions of rubber band, sheet of paper.

Rubber band - 1D, paper - 2D (wrap rubber band in paper, make 1D, 0D spaces still containing the rubber band)

Fig 12.3

3D sheet of paper in 3D space, looks 2D, very thin

string

roll it tightly

from a distance, looks 1D, a line

roll tightly again

from a distance looks 0D, a point
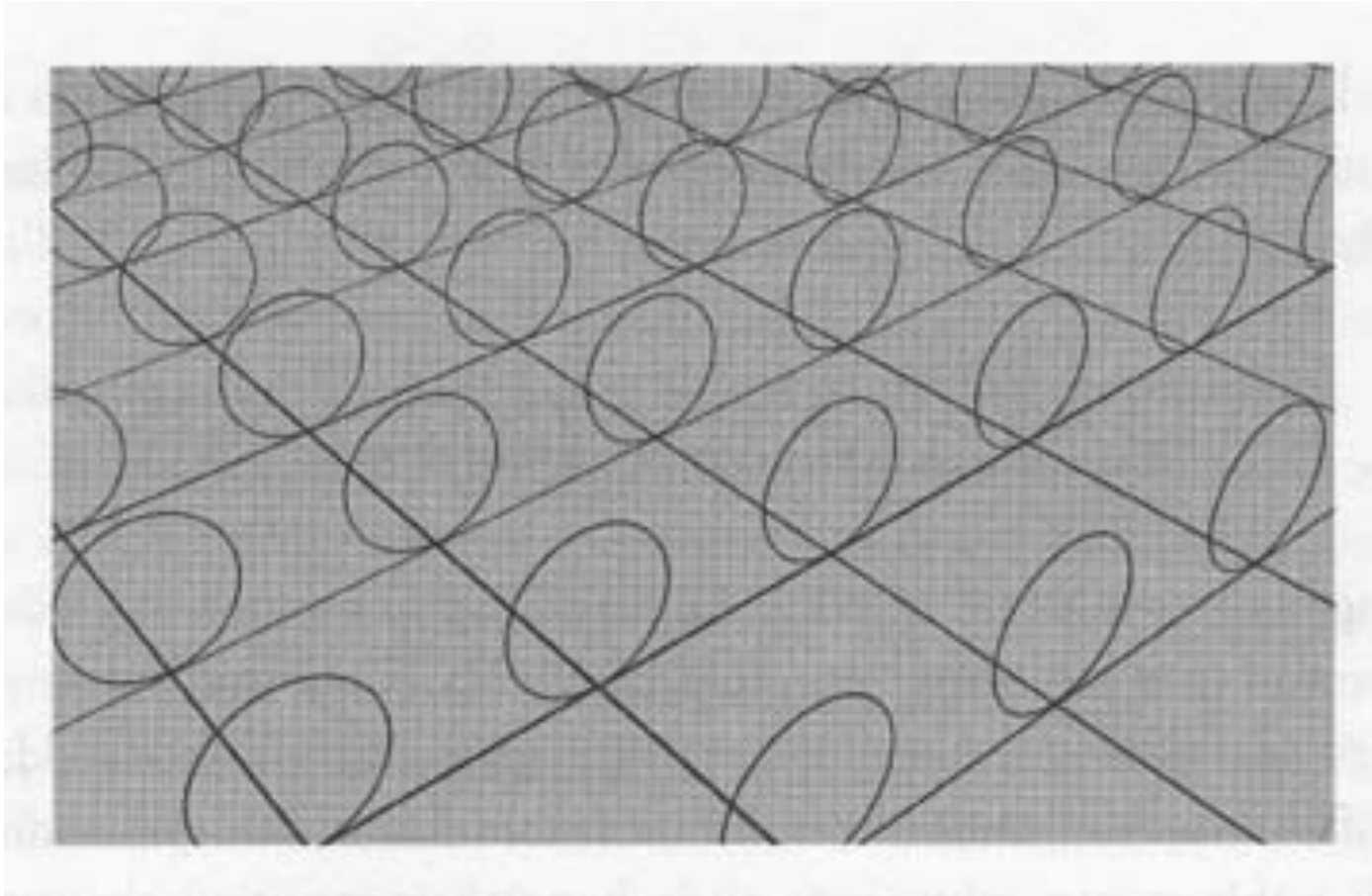
Schematic illustrations of how tiny "wrapped up" extra dimensions could be associated with our 3D space - something like an embedding diagram of the higher dimensional space, so our 3D space is reduced to 2D and the higher dimensional wrapped spaces are reduced to 3D.

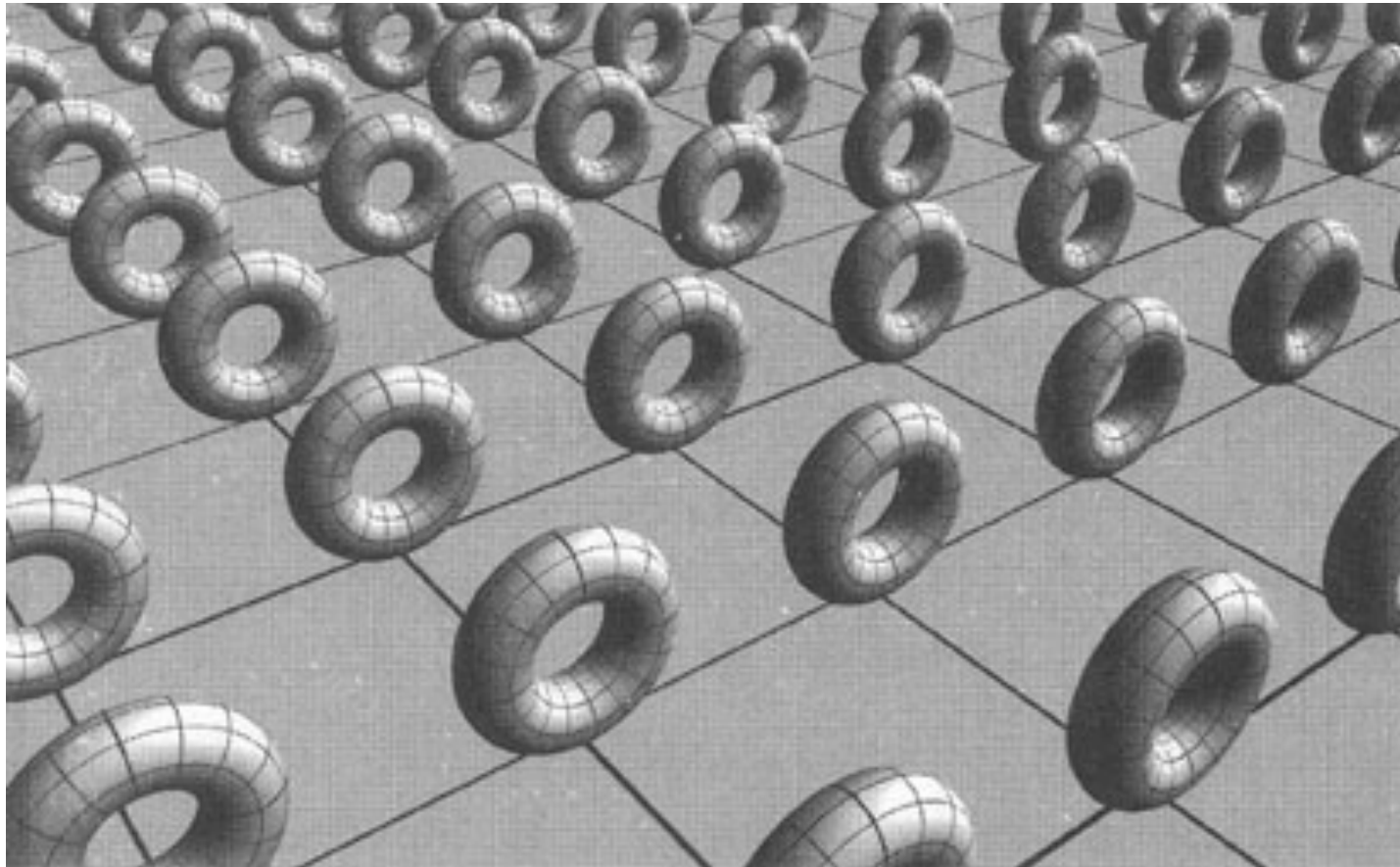From Brian Greene - The Elegant Universe
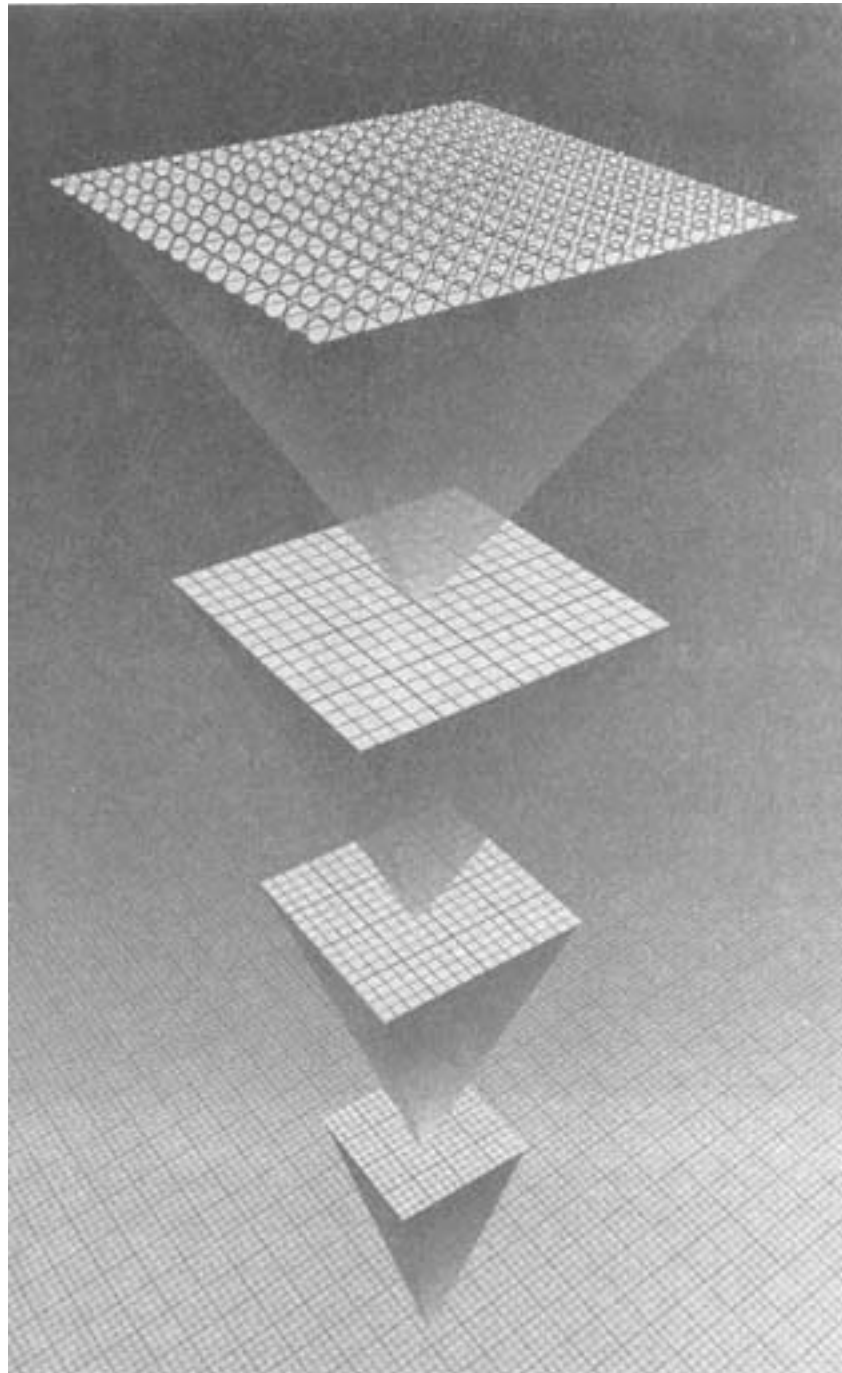
At each point in the 2D space (not just at the intersections of grid lines), there is a little 1D loop of one wrapped up extra dimension. From Brian Greene:The Elegant Universe
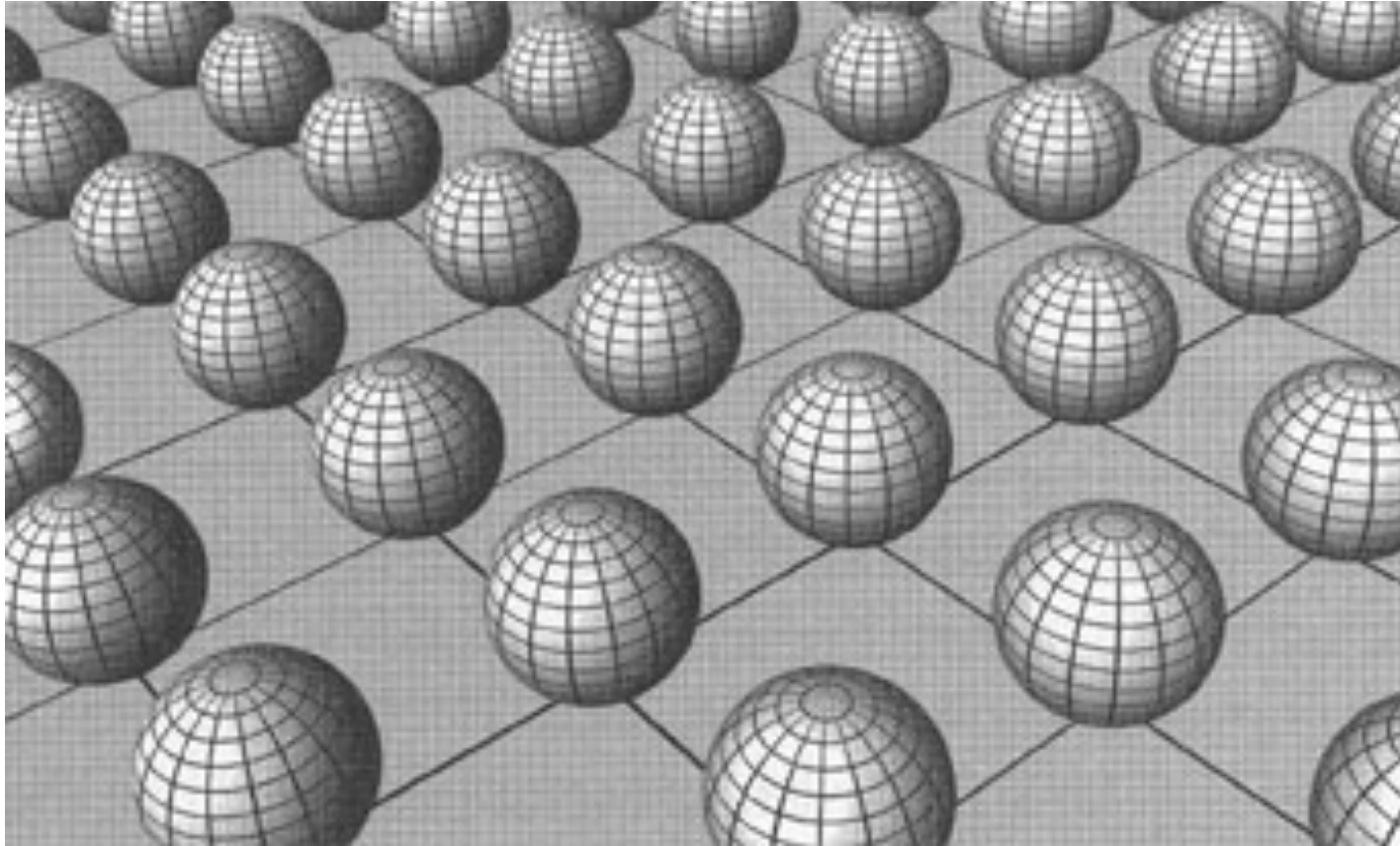
At each point in the 2D space (not just at the intersections of grid lines), there is a little 2D "sphere" of two wrapped-up extra dimensions. From Brian Greene: The Elegant Universe.

At each point in the 2D space (not just at the intersections of grid lines), there is a little 2D "torus" of two wrapped-up extra dimensions. A torus has a distinctly different "topology" or "connectedness" than a sphere. From Brian Greene: The Elegant Universe.

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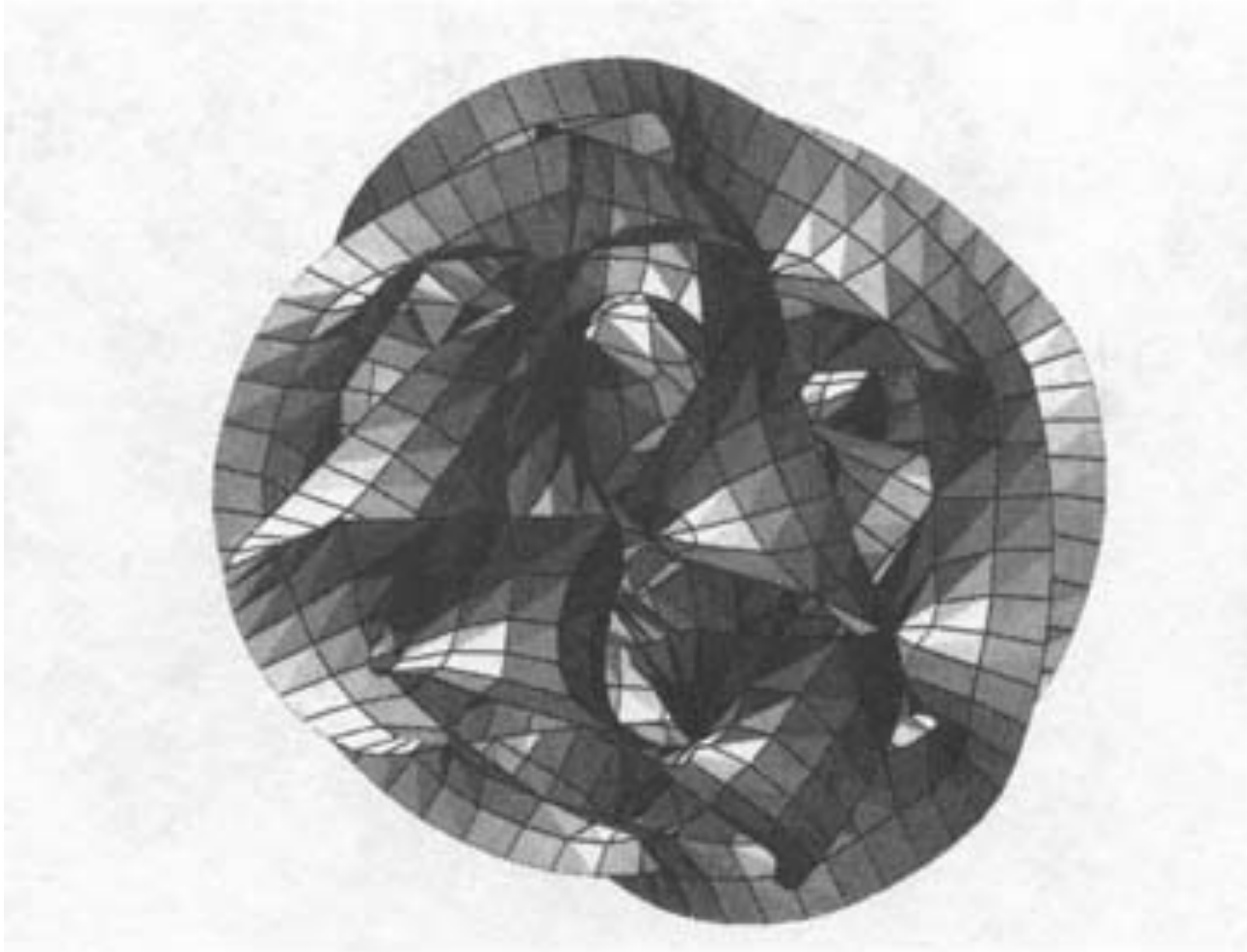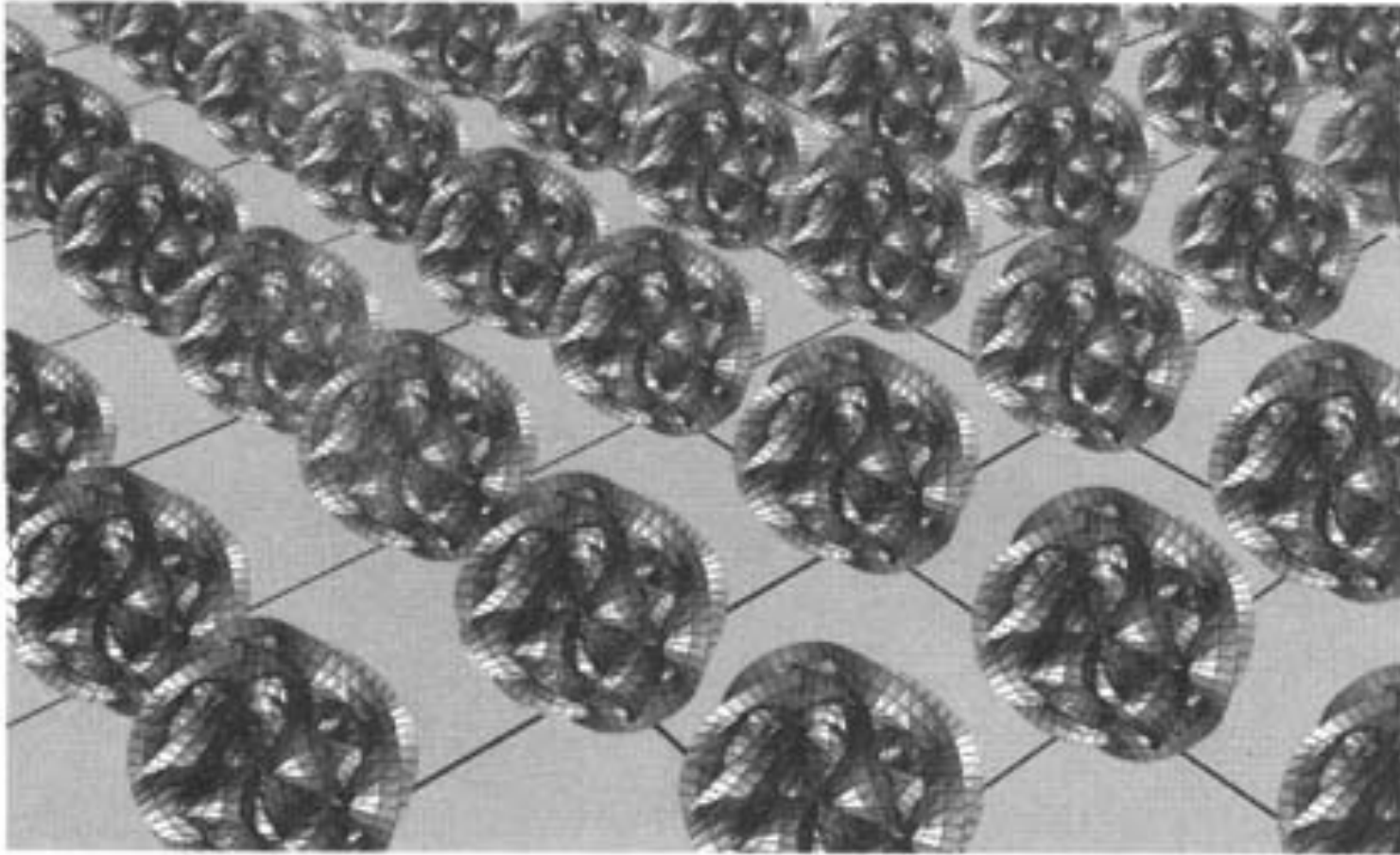
At each point in the 2D space (not just at the intersections of grid lines), there is a little 6D Calibi-Yau space of six wrapped-up extra dimensions.

From Brian Greene: The Elegant Universe.

Mathematics of string theory is complex.

Only approximate solutions so far, but:

String theory "contains" Einstein's Theory mathematically on large enough spatial scales that string "loops" are tiny, just as Einstein's theory "contains" Newton's mathematical theory of gravity on length 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).

Reprise – Newton, Einstein, and String Theory

Newton had the concept of a "force" of gravity.

Einstein's theory had the concept of gravity as curved space.

When gravity is weak, the mathematical description of gravity in Einstein's theory is exactly the same as the mathematics of Newton. The concept is different.

String theory is a quantum theory. String theory has the concept of gravity as a quantum force for which the messenger particles are "gravitons" propagating in 10 spatial dimensions.

For safe distances from a singularity (where the full string theory would be needed and remains unsolvable), the mathematical description of gravity is exactly the same as the mathematics of Einstein. The concept is different than both Newton and Einstein.

Although string theory is a quantum theory, it is built on concepts of curved space.

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, 10.

These surfaces can also wiggle and vibrate.

In analogy to membranes, they are called **branes** of dimension p, or **p-branes**. A point is a zero-brane, a line a one-brane, etc.

"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 $1/\text{area} \propto 1/r^2$ in 3D. Area is one dimension less than volume; the "2" is exactly "1" 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
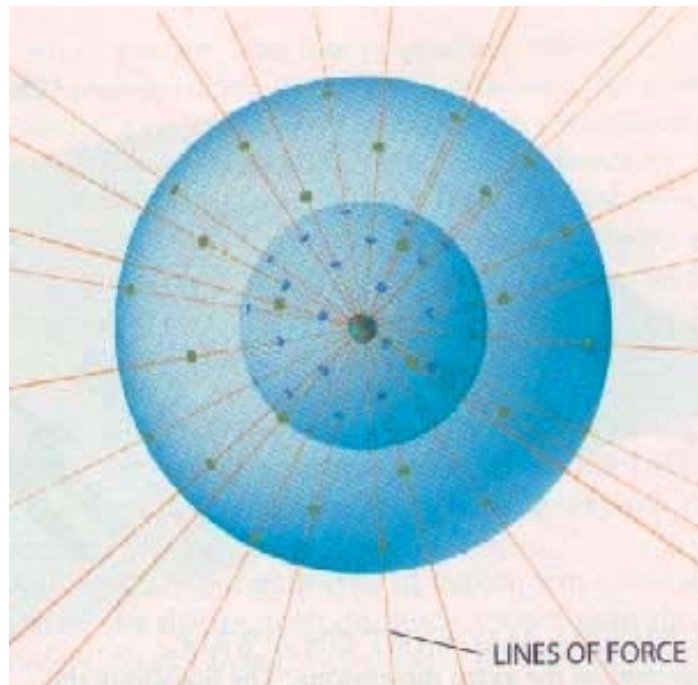
Extend the argument to higher dimensions than 3.

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 nowhere to go.