

12/5/07

Fourth and last SkyWatch extra credit anytime before end of classes, December 7.

Reading: Chapter 13 (worm holes and time machines), 14 (quantum gravity, string theory, large extra dimensions).

Final Review Sheet posted

Final Exam Information: FRIDAY, DECEMBER 14, 9-12 N
ART 1.102

News:

Pic of the day; Another view of
Comet Holmes



Special Office Hours: RLM 15.216B

Monday, December 10, 12 - 1

Thursday, December 13, 12 - 1

One Minute Exam

The Novikov Consistency Conjecture says:

- A) Worm holes cannot lead to the future
- B) Worm holes cannot lead to the past
- C) Worm holes cannot exist
- D) Worm holes cannot lead to time travel paradoxes

String Theory

Best current candidate for a quantum gravity “theory of everything.”

Particles like e⁻, p, n are not “points” but strings, loops of energy that vibrate in different modes

The different modes of vibrations give all the well-known particles
and *more*

Can't
make
notes
with
grains
of sand,
but with
strings,
you
have
Mozart

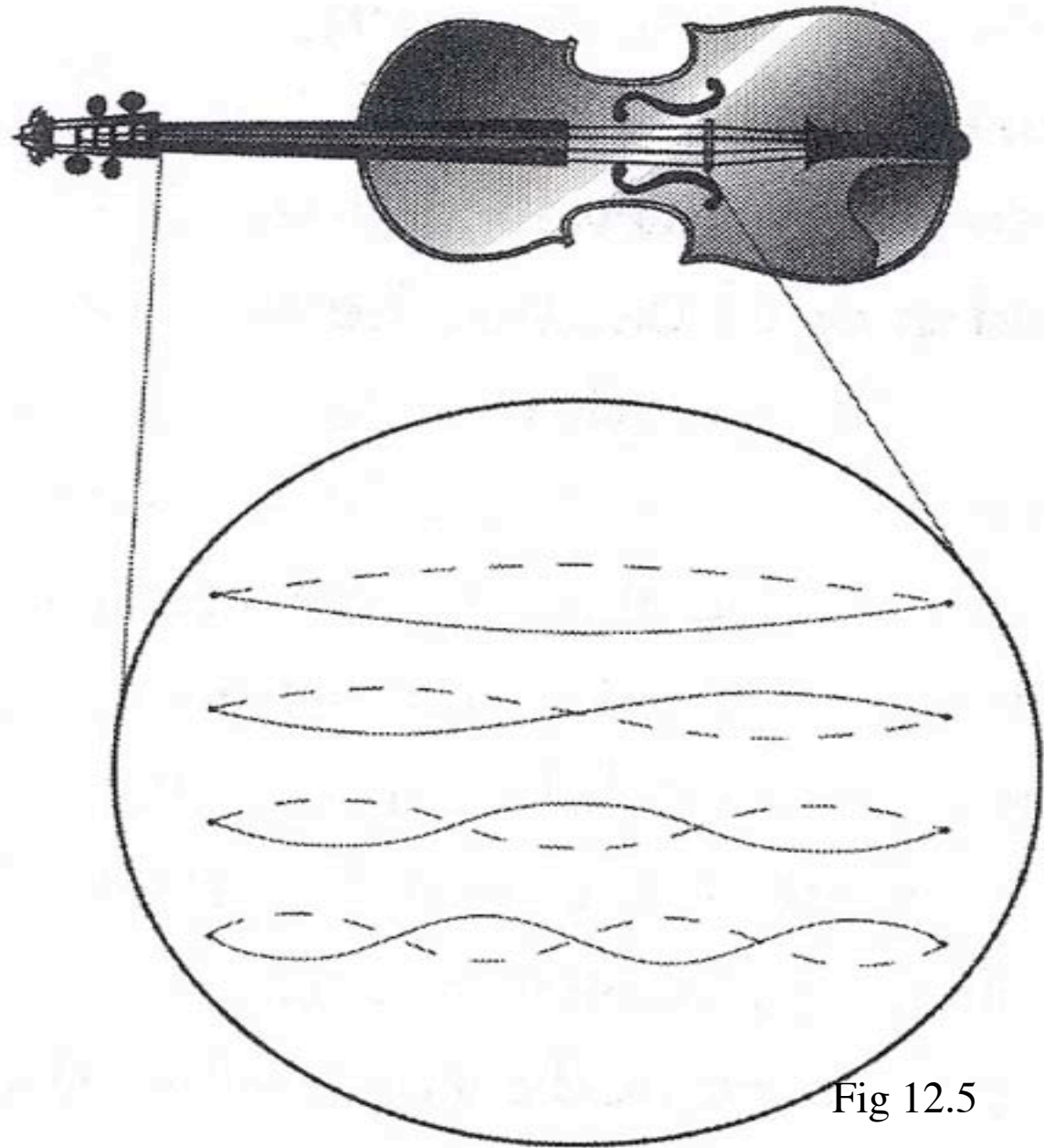
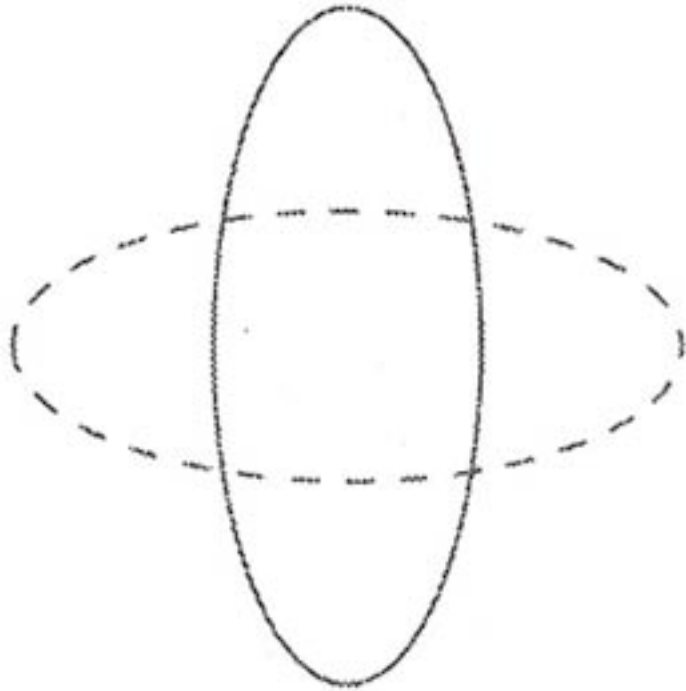


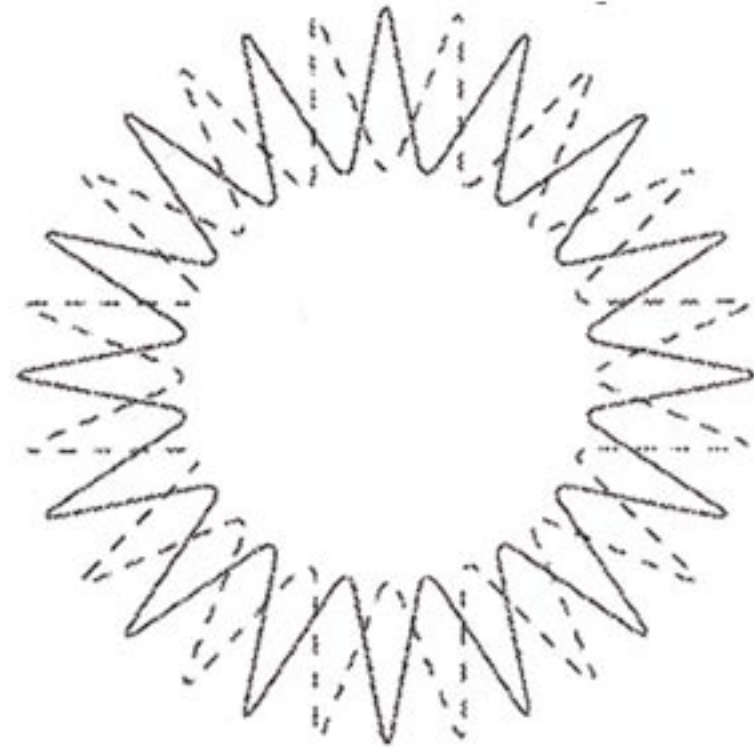
Fig 12.5

From Brian
Green - The
Elegant
Universe

One particle



A different particle



Same fundamental loop of string

From Brian Green - The Elegant Universe

To be mathematically self-consistent

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

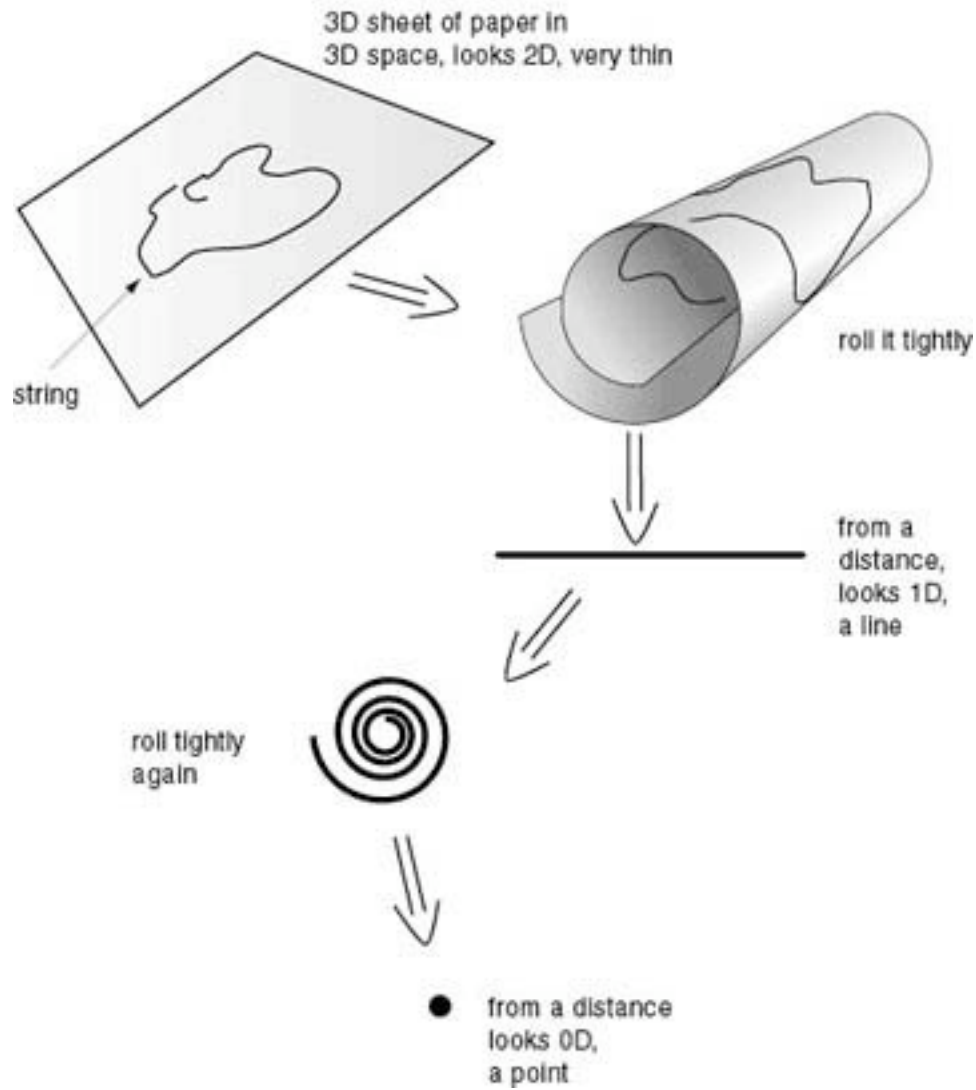
First notions:

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.”

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

Fig 12.3



String Theory

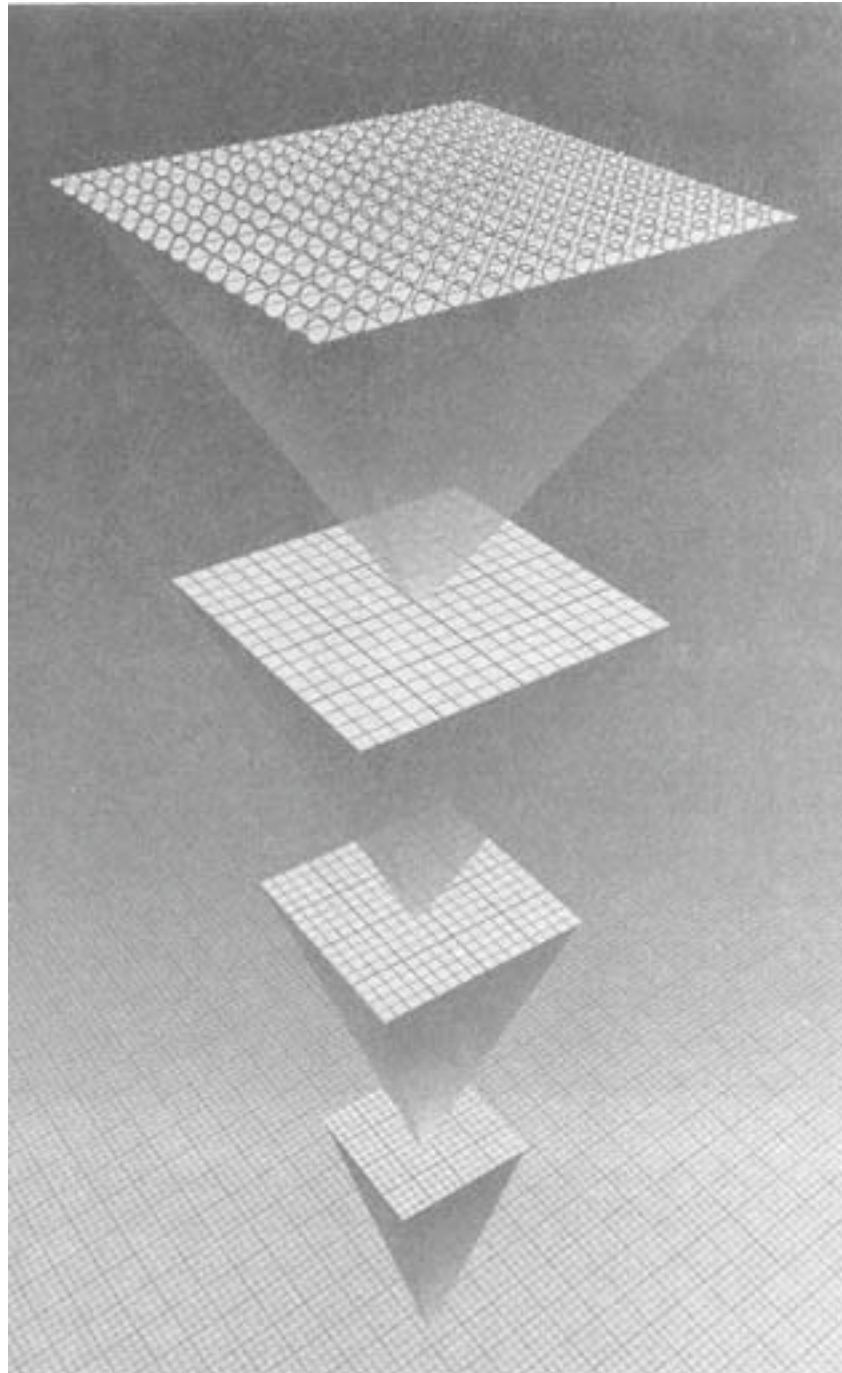
History - in 1960's physicists recognized that the equations corresponding to the strong nuclear force also described entities that could stretch and wiggle - strings

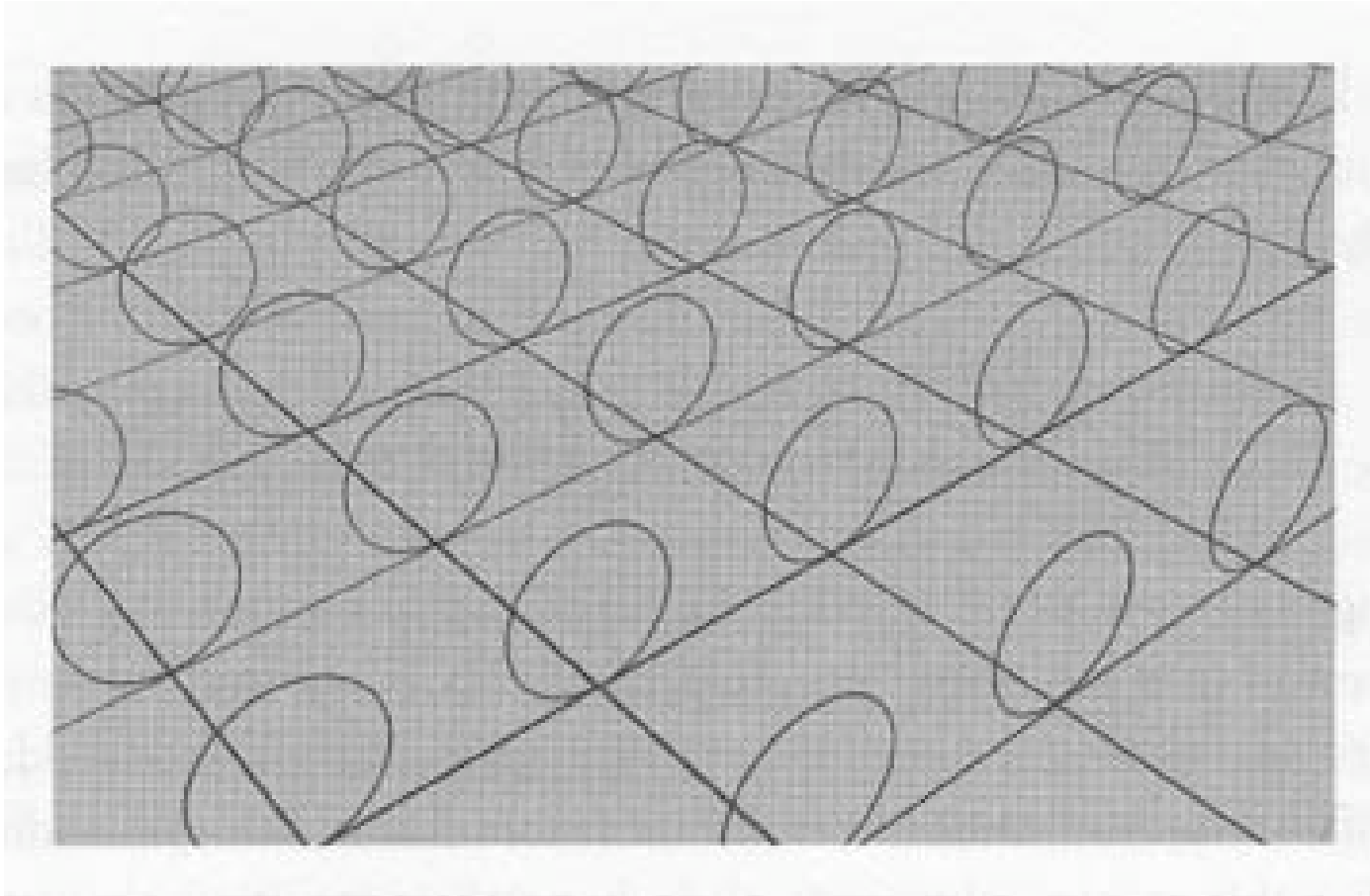
Space in which strings vibrate has *10 space dimensions* + time

Shape of wrapped-up space determines how strings vibrate, what particles they represent.

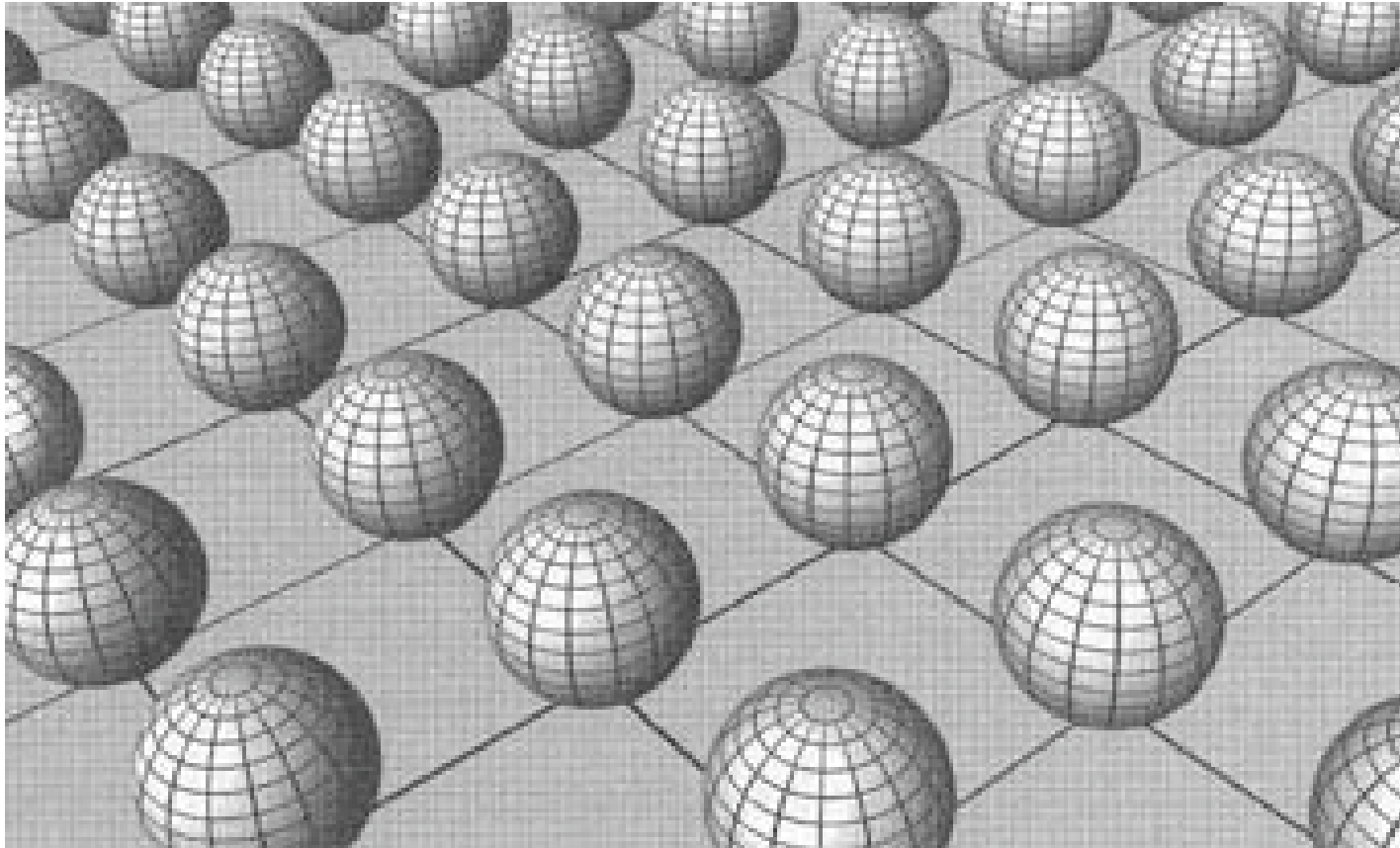
Schematic illustrations of how tiny “wrapped up” extra dimensions could be associated with our 3D space - something like an embedding diagram of the higher dimensional space, so our 3D space is reduced to 2D and the higher dimensional wrapped spaces are reduced to 3D.

From Brian Green - The Elegant Universe

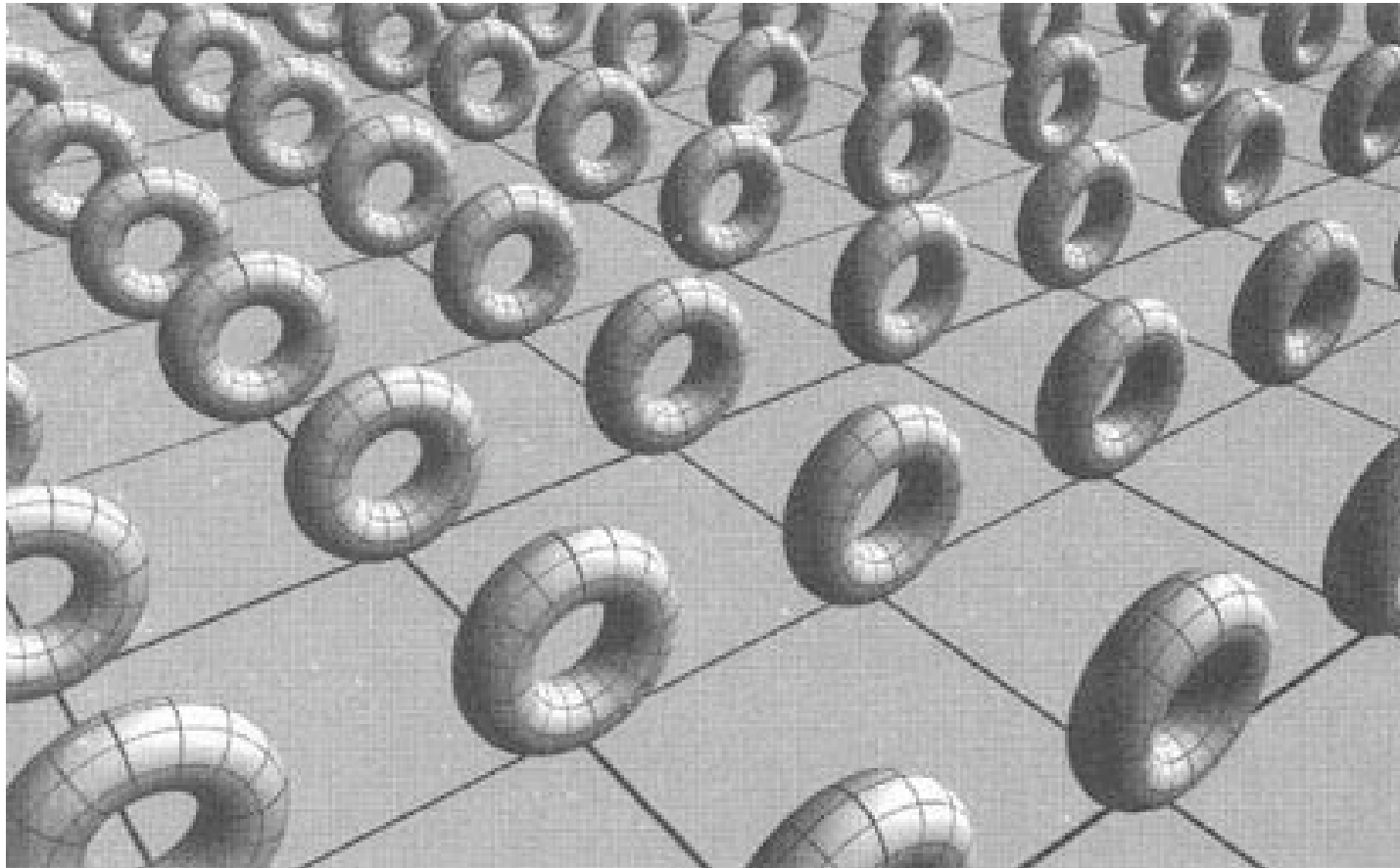




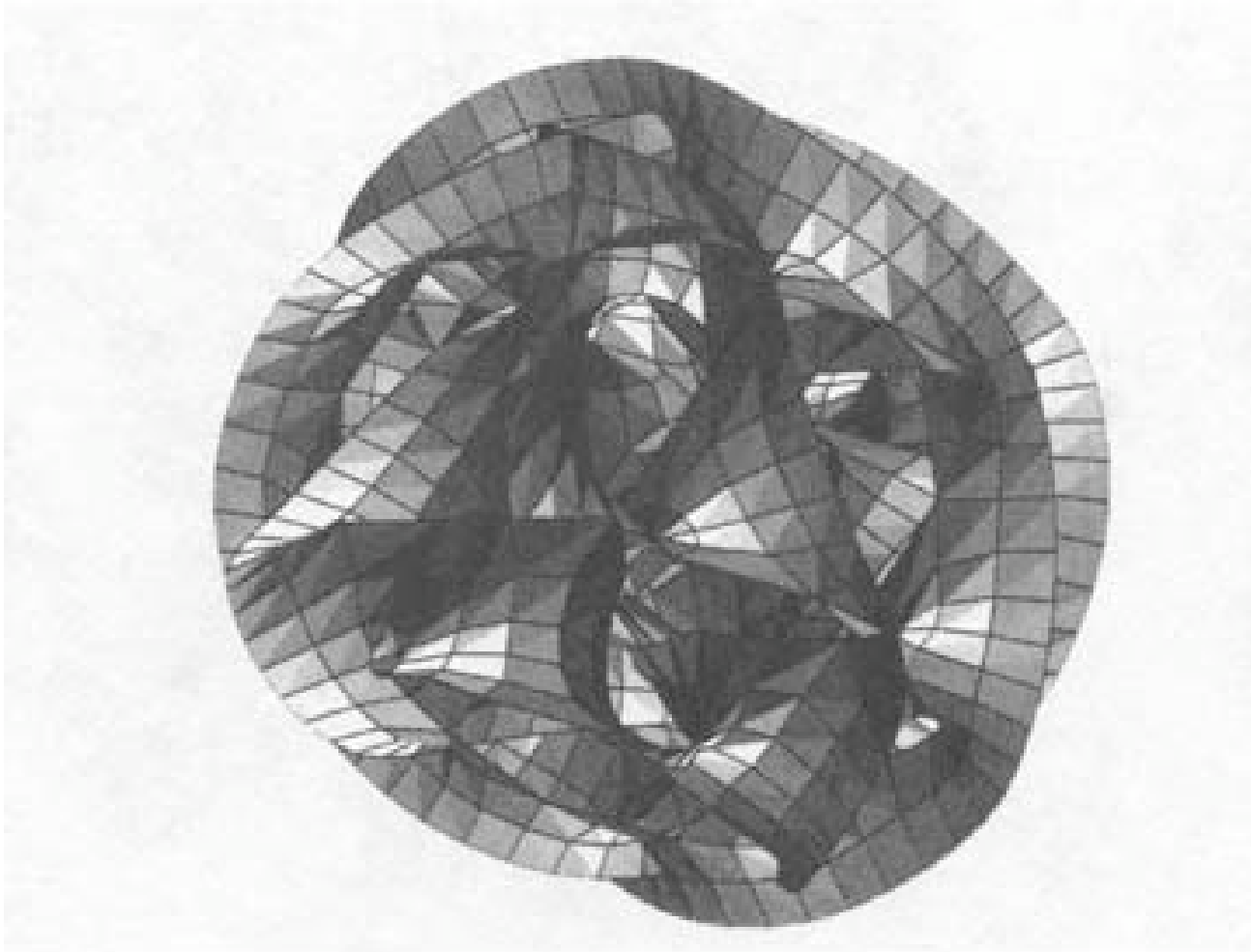
At each point in the 2D space (not just at the intersections of grid lines), there is a little 1D loop of one wrapped up extra dimension. From Brian Green: The Elegant Universe



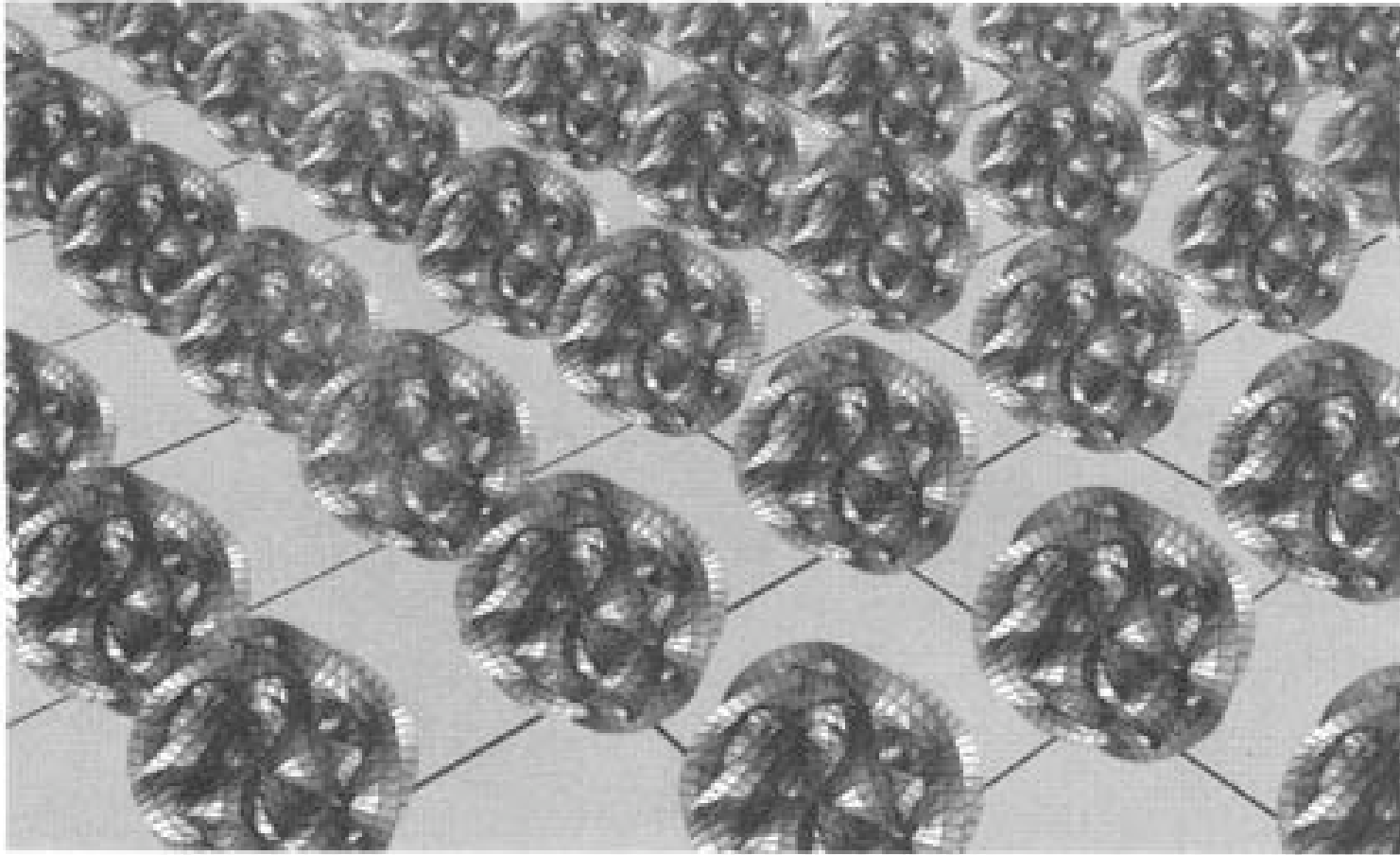
At each point in the 2D space (not just at the intersections of grid lines), there is a little 2D “sphere” of two wrapped-up extra dimensions. From Brian Green: *The Elegant Universe*.



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 Green: *The Elegant Universe*.



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 Calabi-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.