Thursday, April 30, 2009

Reading for Fourth exam on Thursday, May 7:
Chapter 10, Sections 10.9, 10.10
Chapter 11, Sections 11.1 - 11.5, 11.8
Chapter 12, all
Chapter 13, all
Chapter 14, Sections 14.1 - 14.5

Astronomy in the News - record distant gamma-ray burst last Thursday: GRB090423, redshift of 8.1, 13 billion light years away, when Universe was only 630 million years old, shortly after the end of the Dark Ages, and in the epoch of the first stars and first galaxies. See lecture 24, slide 16.

Pic of the day - crescent Moon

Worm Holes and Time Machines

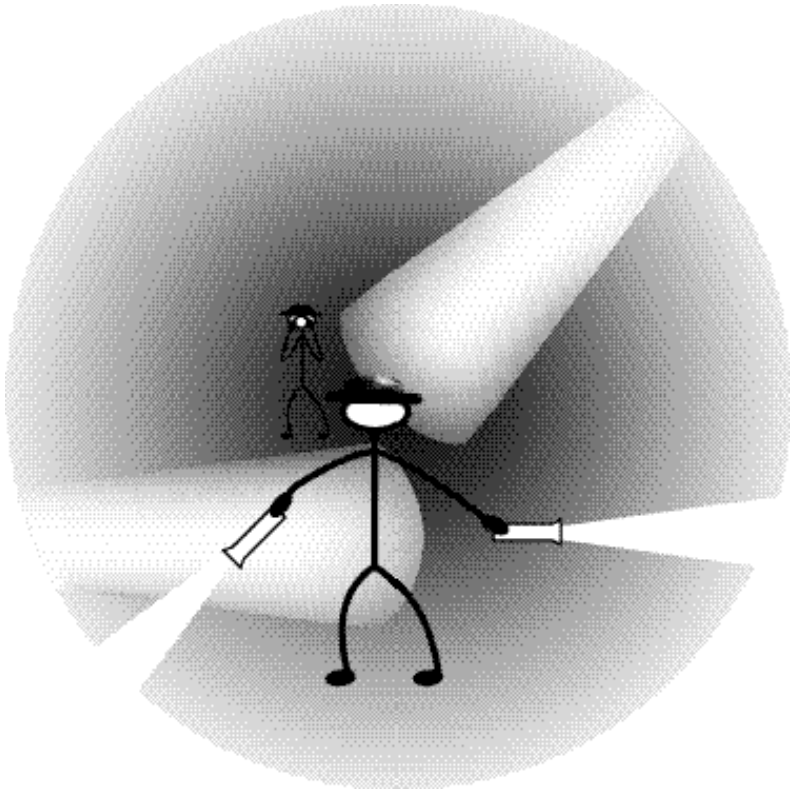
(Chapter 13)

Amazing mathematical developments in the context of Carl Sagan's ***Contact*** by Kip Thorne and Igor Novikov:

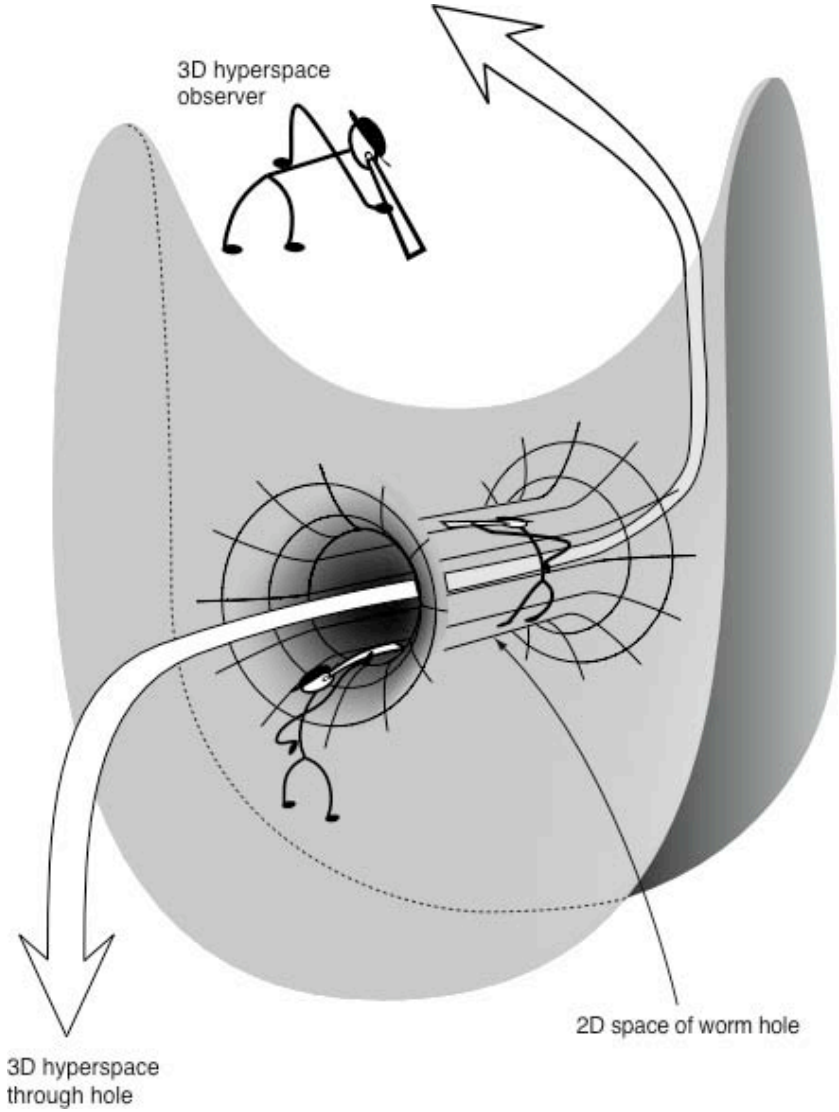
Einstein's equations allow the possibility of worm holes. To be stable, they must be held open by some imagined "substance" that anti-gravitates.

Highly curved space, but no singularity.

The Dark Energy gives a hint that such a "substance" could exist.



The mouth of a worm hole would be a 3D “object,” the space inside highly curved.



Embedding diagram of a worm hole in an “open” universe

The most amazing property discovered was that, in principle, worm holes would also be ***time machines***!

Novikov Consistency Conjecture: physics will arrange itself so that there is no time-travel paradox - you cannot travel back in time and kill yourself before you enter the worm hole/time machine.

Thorne video

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

Ultimate resolution - will not know if worm holes can be constructed, even in principle, without a theory of ***quantum gravity***.

Hawking - vacuum fluctuation energy (from uncertainty principle applied to vacuum) can go into wormhole, come out in past, pile up at mouth where began, quickly build up huge energy density, curve space, slam worm hole shut.

Maybe, but cannot actually compute that process without a theory of quantum gravity to handle the change in the "connectivity" of space time - must space time be smooth, or can it be laced with "tunnels" in space and time?

Need quantum gravity theory of singularity, quantum foam, worm holes

The best current candidate for a theory of Quantum Gravity is String Theory

See Brian Green - The Elegant Universe

(http://www.pbs.org/wgbh/nova/elegant/)

Read ***The Universe on a String*** editorial by Brian Green posted under links -> string theory

Hyperspace is an intrinsic aspect of string theory - 10 dimensions of space, plus time.

Background - pre-Einstein late 19th, early 20th Century

Where does space curve to?

Riemann (1826 -1866), Lobachevsky (1792 - 1856)

Theory of curved space, non-Euclidian geometry

Notions of 4D hyperspace affected art/culture turn of 20th century

Flatland - Edward Abbott

Tesseract - 4D hypercube (Elegant Universe link)

3D “unfolding” of tesseract in Salvadore Dali’s

Crucifixion (Corpus Hypercubas)

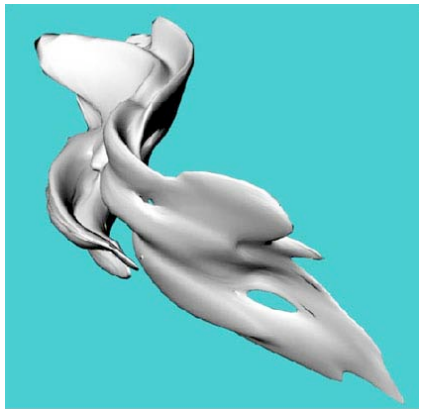
Notions of seeing from different directions at once

Perspective of Cubism

Picasso -

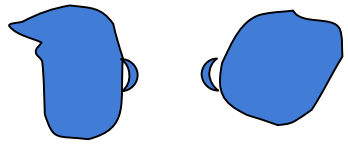
Deschamps - *Nude Descending A Staircase*

Contemporary Brazilian artist Marcos Novak -
3D projections of 4D objects



Hyperspace Perspectives (reflected in cubism?)

2D creature - another 2D creature sees the front



From 3D, we see front, back and ***inside*** simultaneously

In our 3D space we see the front of another 3D creature

A being living in a 4D hyperspace would see all of our surface, front and back, and our insides, all at once!

A 3D creature passing through a 2D Universe would start as a point, grow to a finite ***area***, then decrease to a point and disappear.

A 4D creature passing through our 3D Universe would start as a point, grow to a finite ***volume***, then decrease to a point and disappear.

One Minute Exam

A four-dimensional creature intruding into our space would appear to us to be

A) One-dimensional

B) Two-dimensional

C) Three-dimensional

D) Four-dimensional

Classic Quantum Theory

Particles are points (electrons) or are made up of point-like particles (three quarks in a proton or neutron), that also have wave-like properties.

Quantum view of forces - the quantum theory (mathematically) views all forces as resulting from an exchange of particles, with different exchange particles representing different forces.

Photons are the exchange particles for the electromagnetic force, other exchange particles account for the weak and strong nuclear forces.

String Theory

Best current candidate for a quantum gravity "theory of everything."

Particles like e-, p, n are not "points" but strings, loops 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

From Brian Green - The Elegant Universe

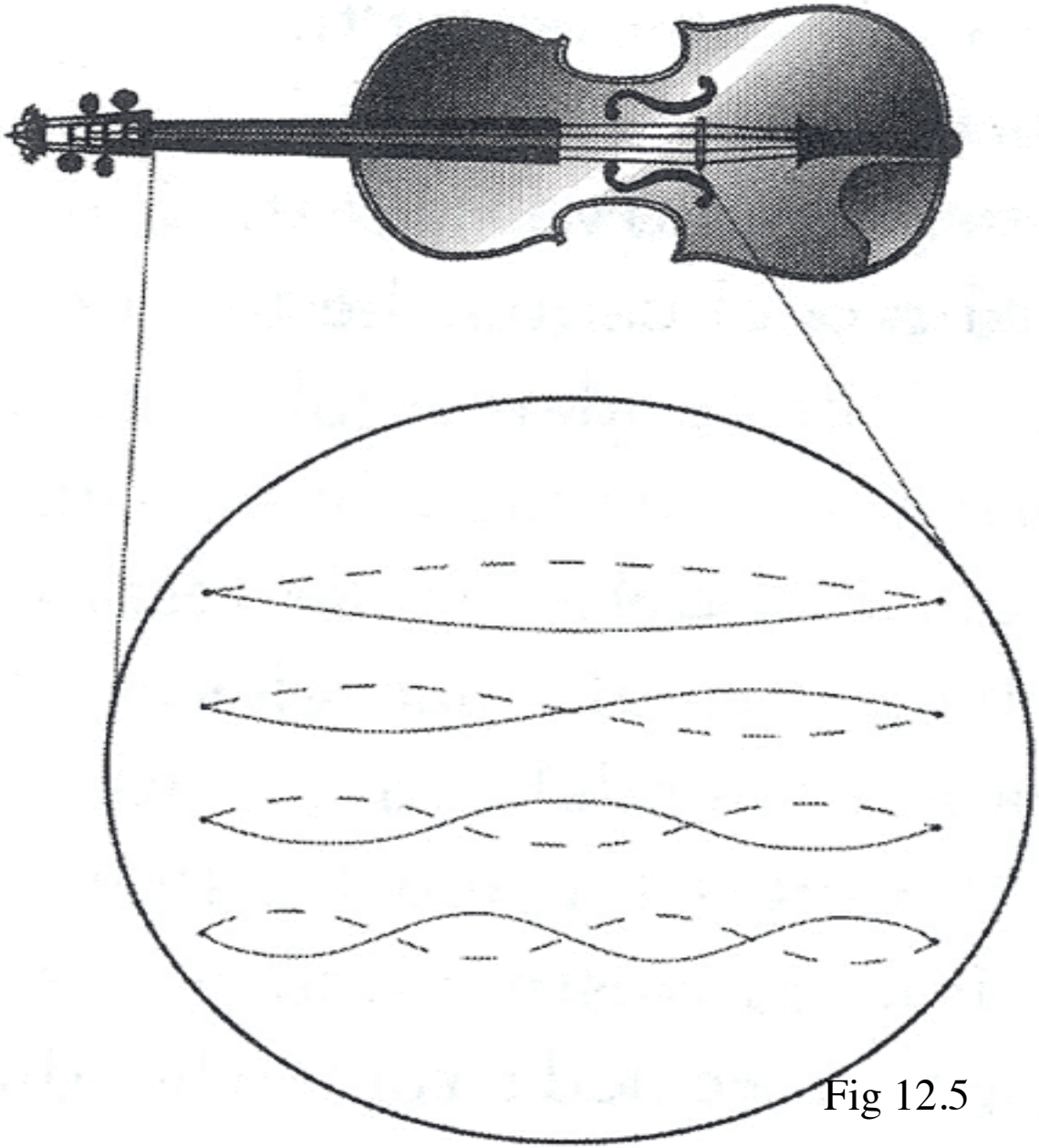
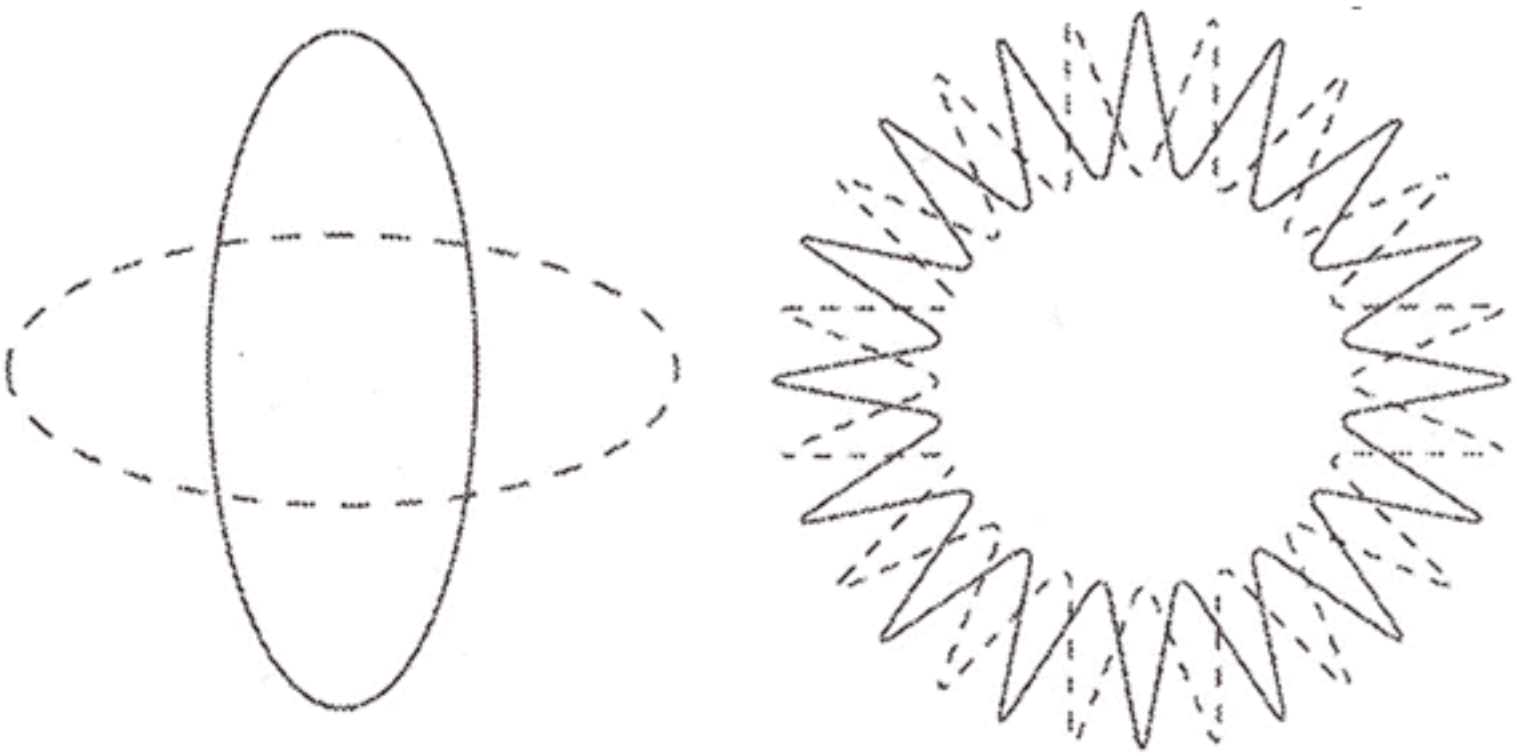


Fig 12.5

One particle

A different particle



Same fundamental loop of string

From Brian Green - The Elegant Universe

To be mathematically self-consistent

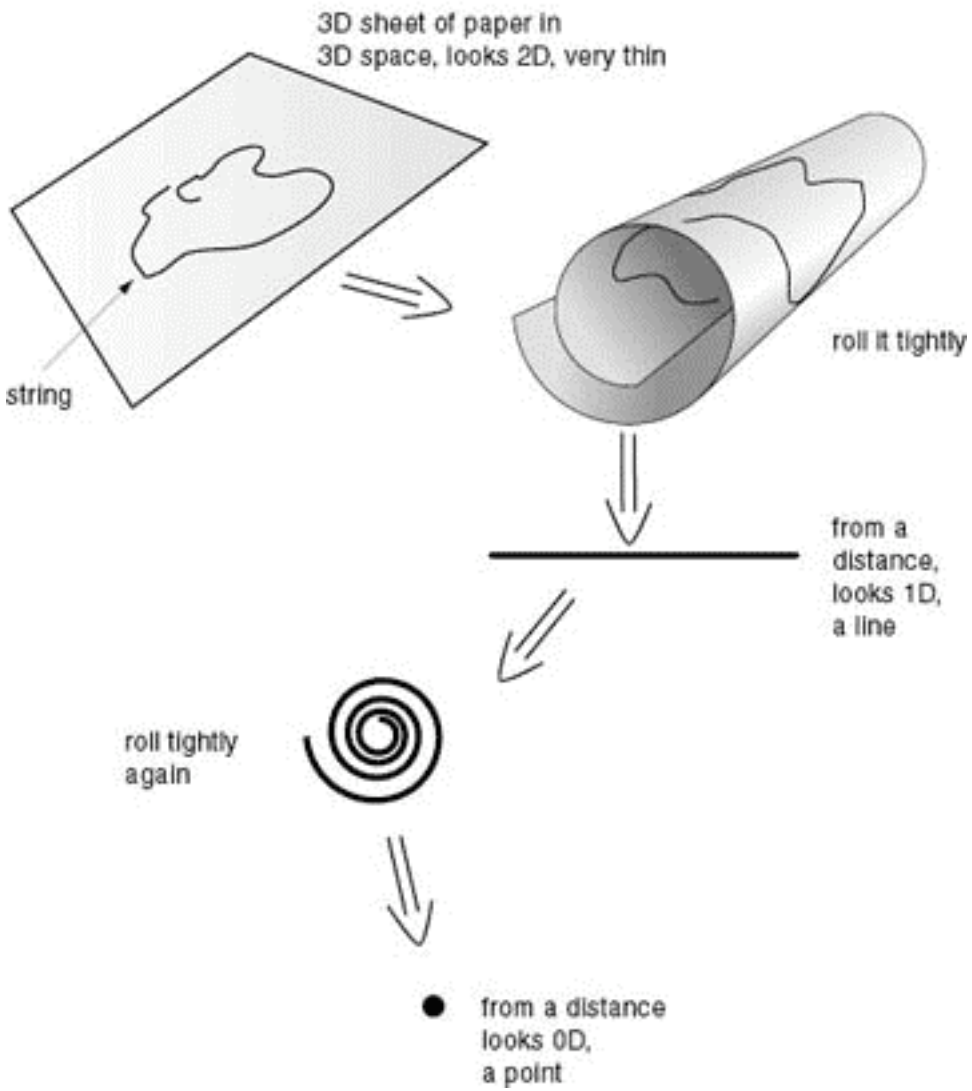
Space in which strings vibrate has ***10 space dimensions*** + time

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


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

String Theory

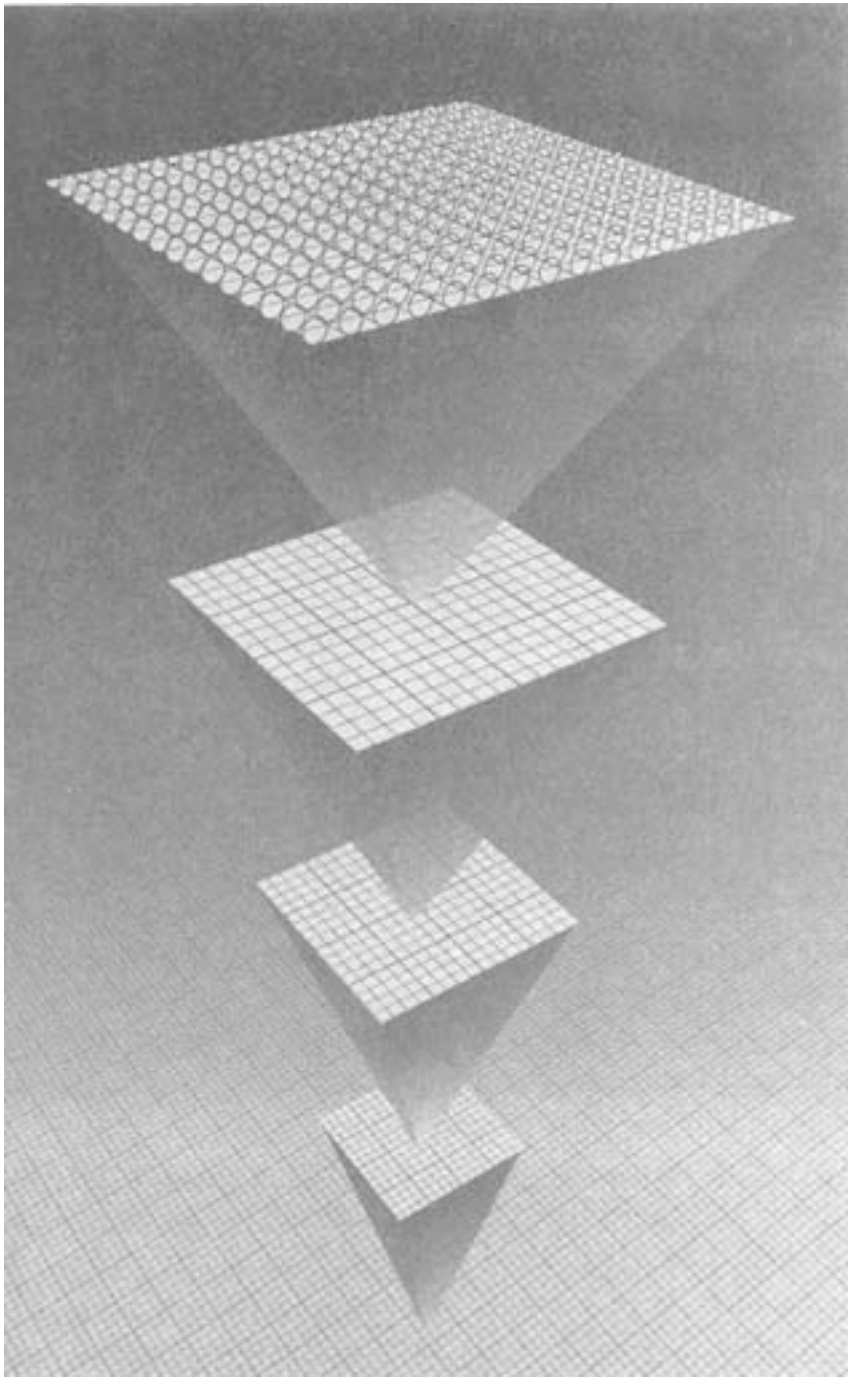
History - in 1960's physicists recognized that the equations corresponding to the strong nuclear force also described entities that could stretch and wiggle - strings

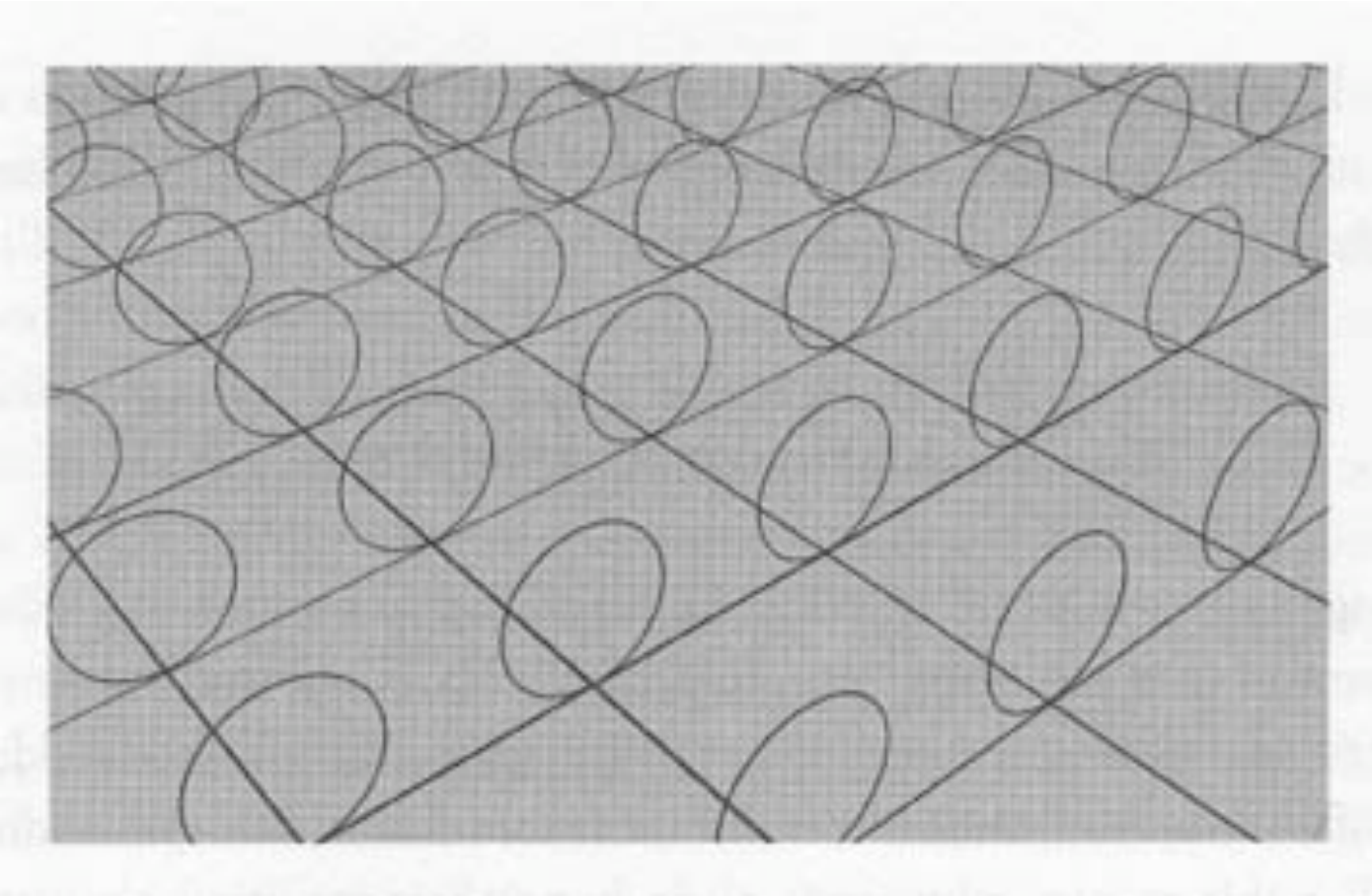
Space in which strings vibrate has ***10 space dimensions*** + time

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

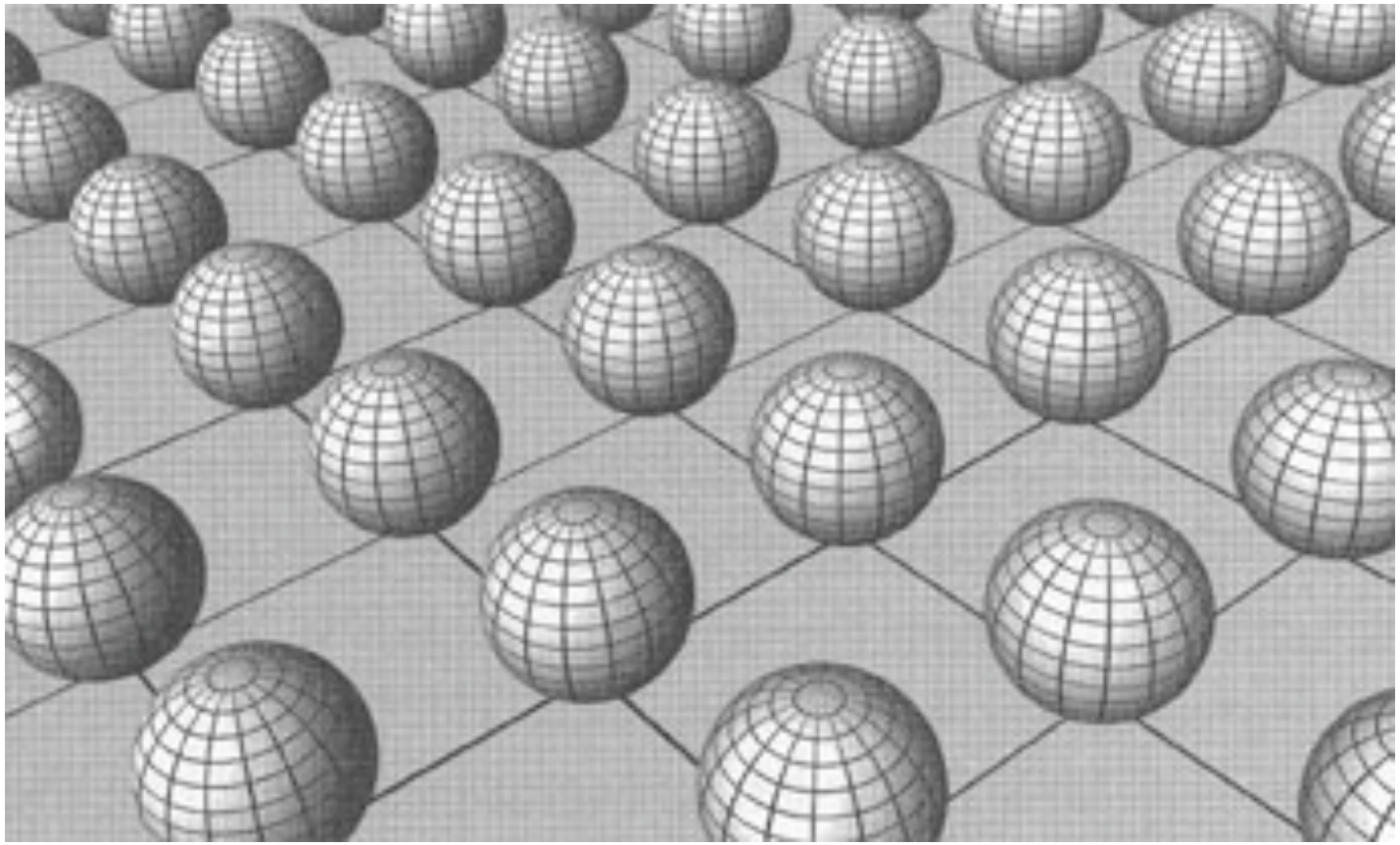
Schematic illustrations of how tiny “wrapped up” extra dimensions could be associated with our 3D space - something like an embedding diagram of the higher dimensional space, so our 3D space is reduced to 2D and the higher dimensional wrapped spaces are reduced to 3D.

From Brian Green - The Elegant Universe

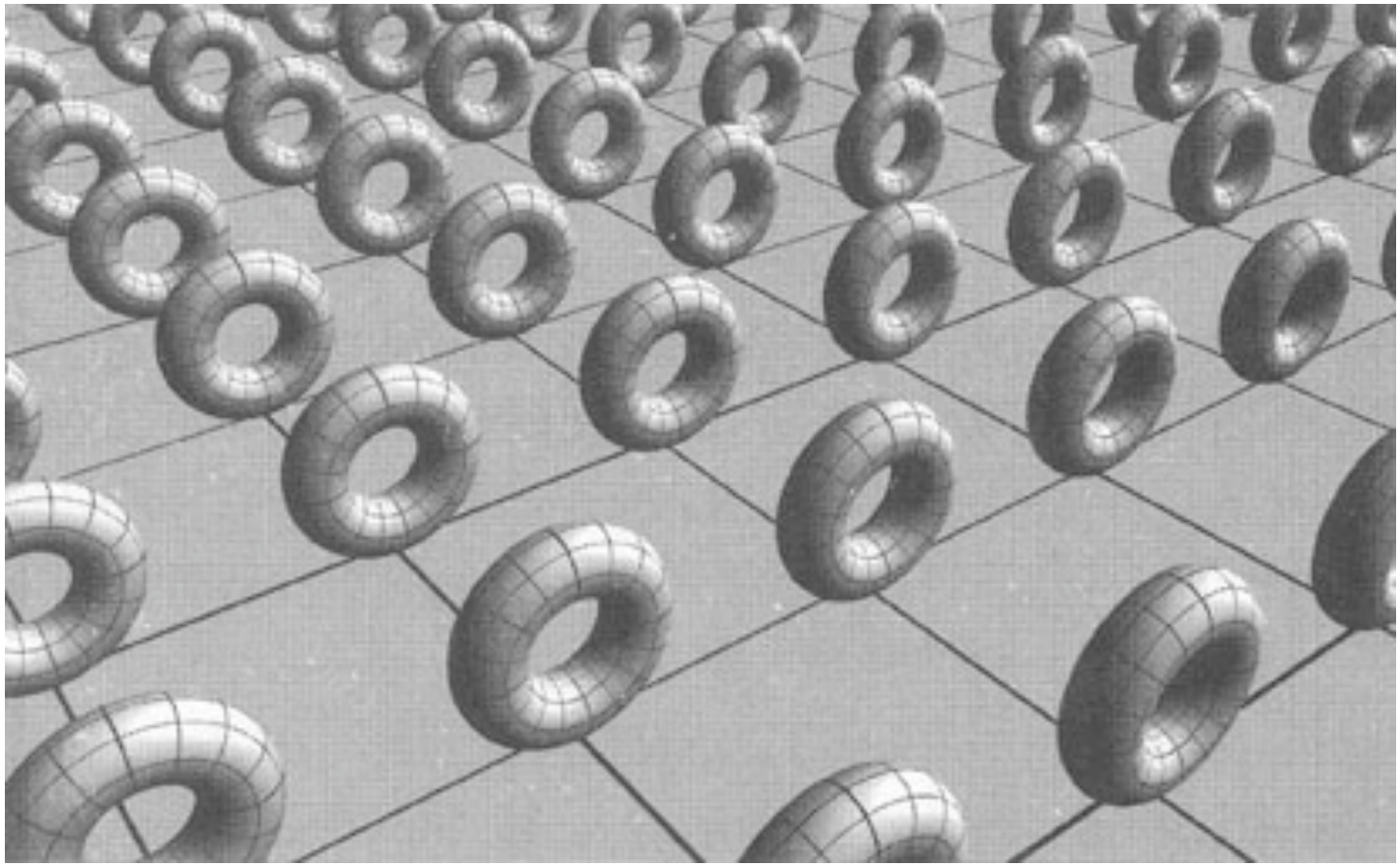




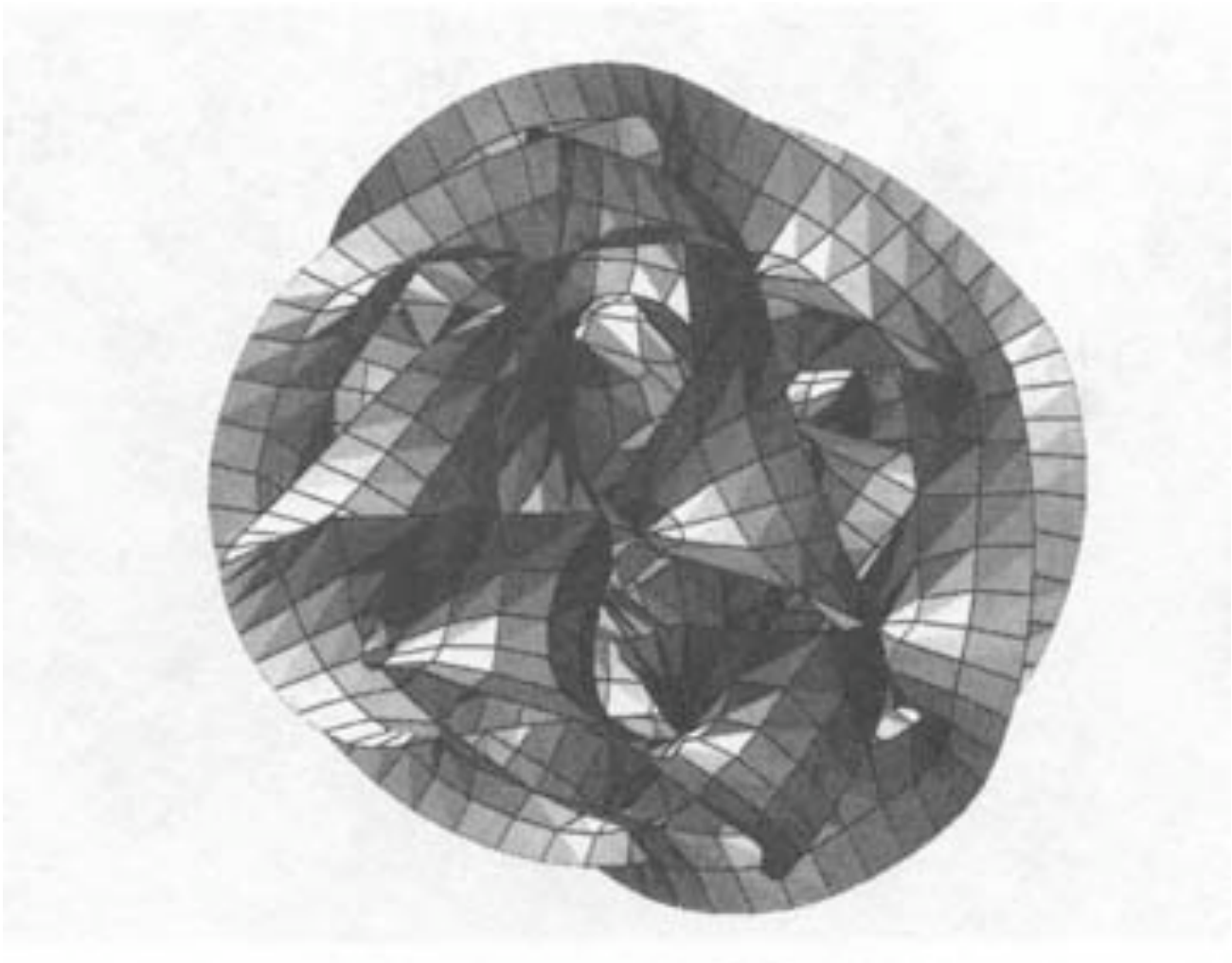
At each point in the 2D space (not just at the intersections of grid lines), there is a little 1D loop of one wrapped up extra dimension. From Brian Green:The Elegant Universe



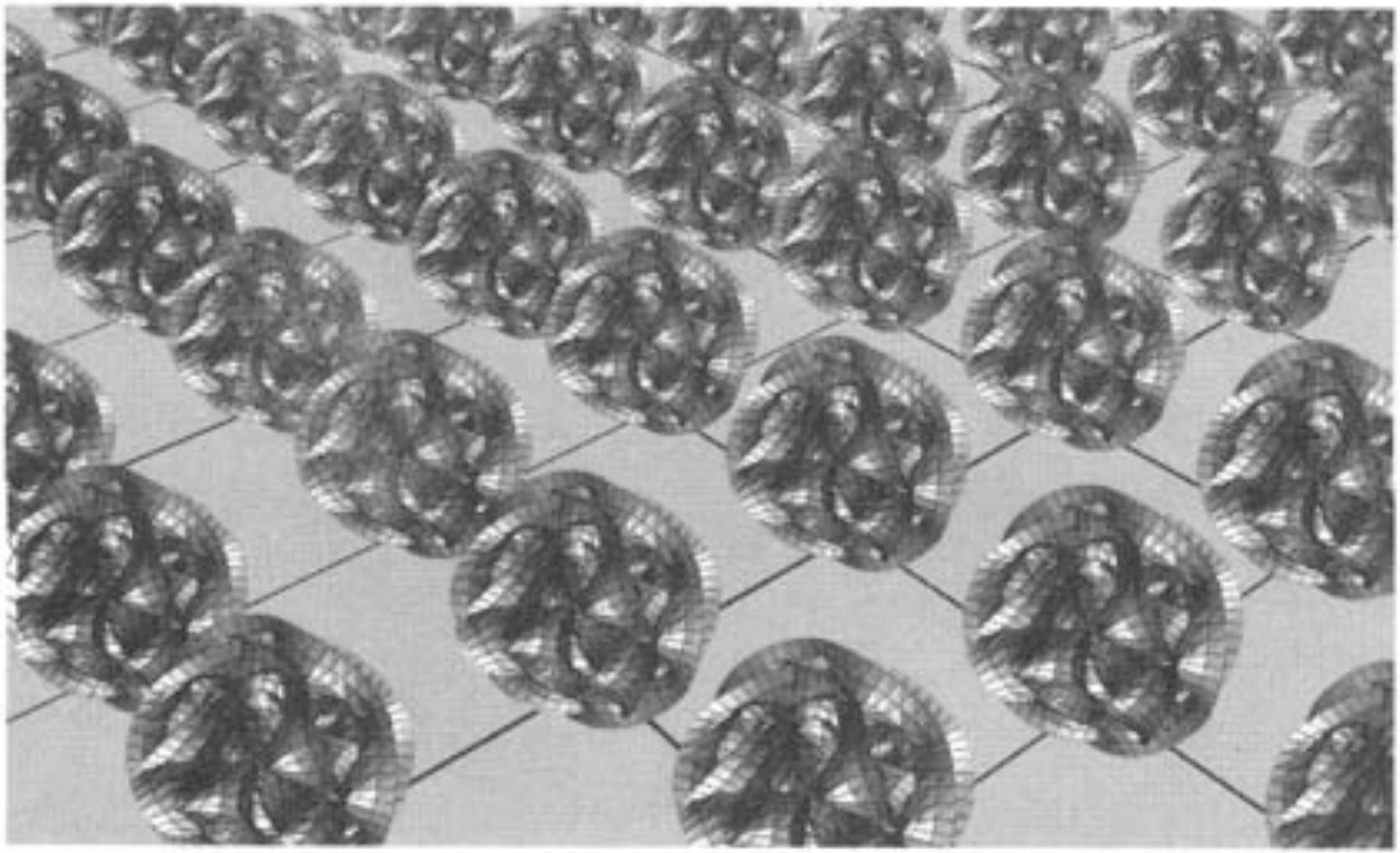
At each point in the 2D space (not just at the intersections of grid lines), there is a little 2D "sphere" of two wrapped-up extra dimensions. From Brian Green: The Elegant Universe.



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 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