

4/25/2008

Fourth, Last Exam, Friday May 2

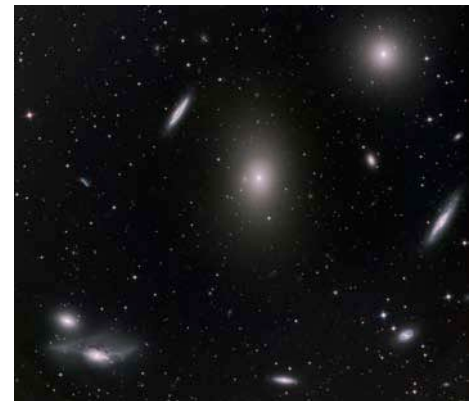
Reading

Chapter 11 - all except 11.6, 11.7

Chapters 12, 13, 14 - all

Astronomy in the News -

Pic of the day - a central piece of  
the Virgo Cluster



## 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

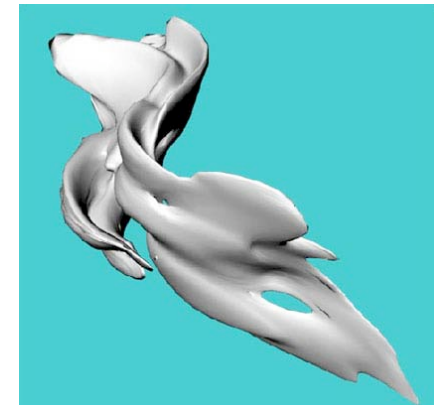
Perspective of Cubism

Picasso -



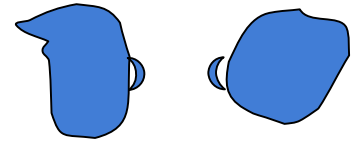
Deschamps - *Nude Descending A Staircase*

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

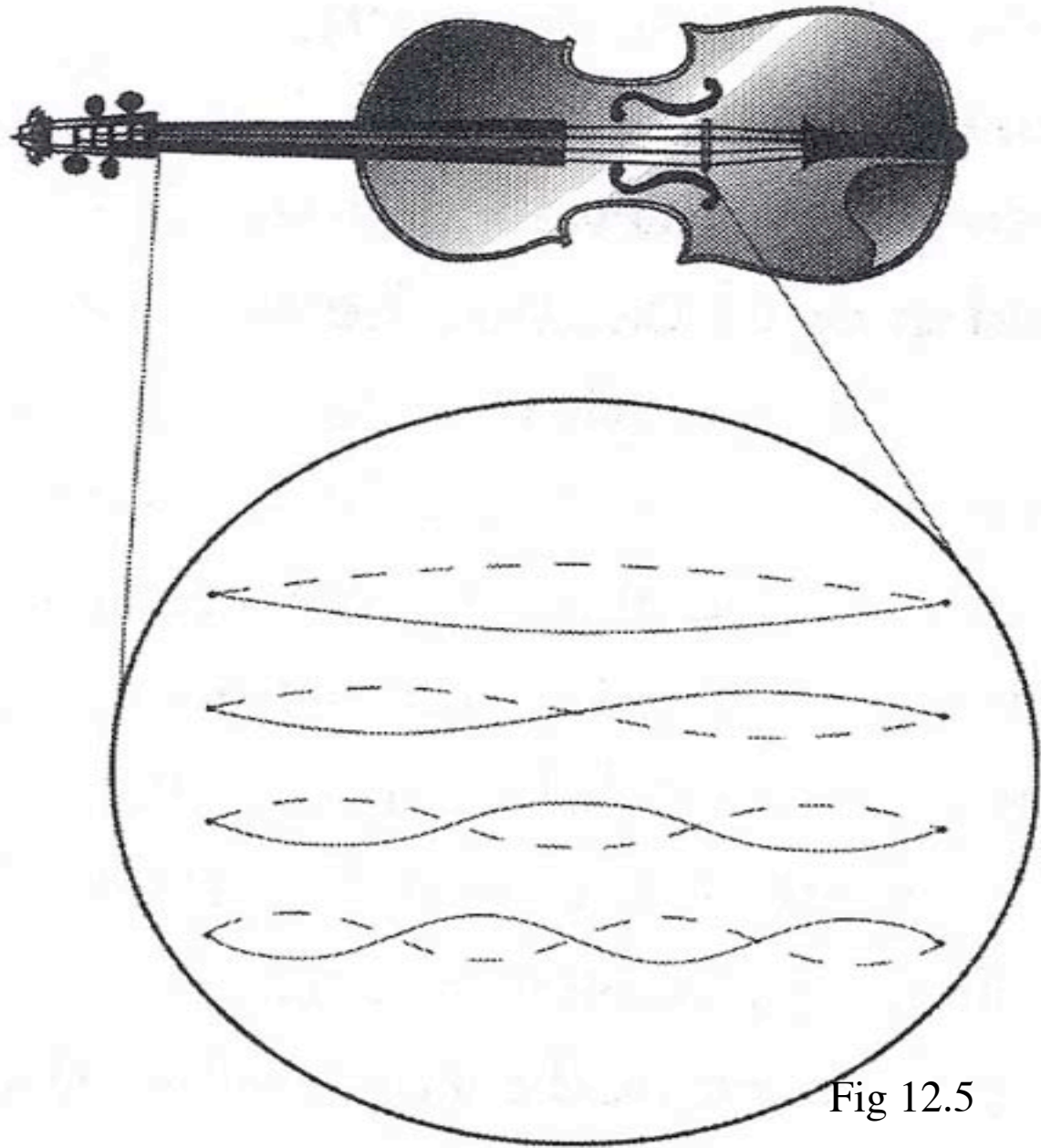
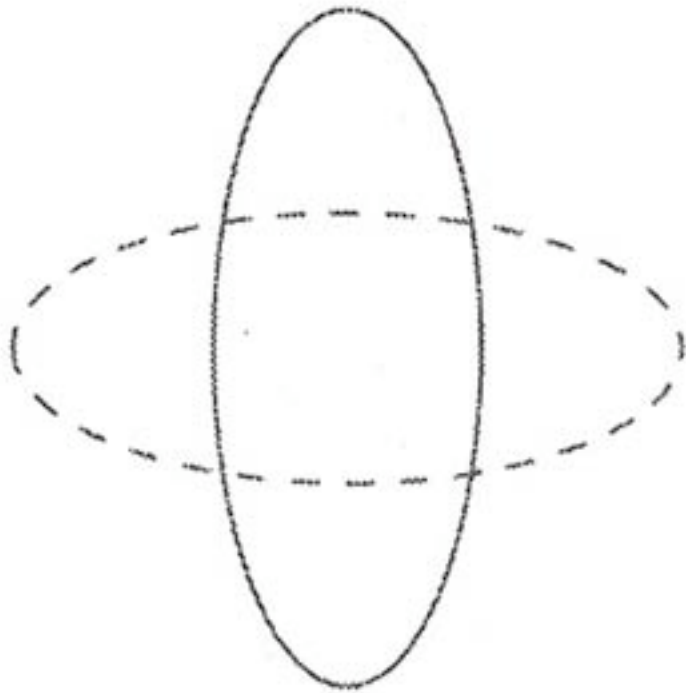


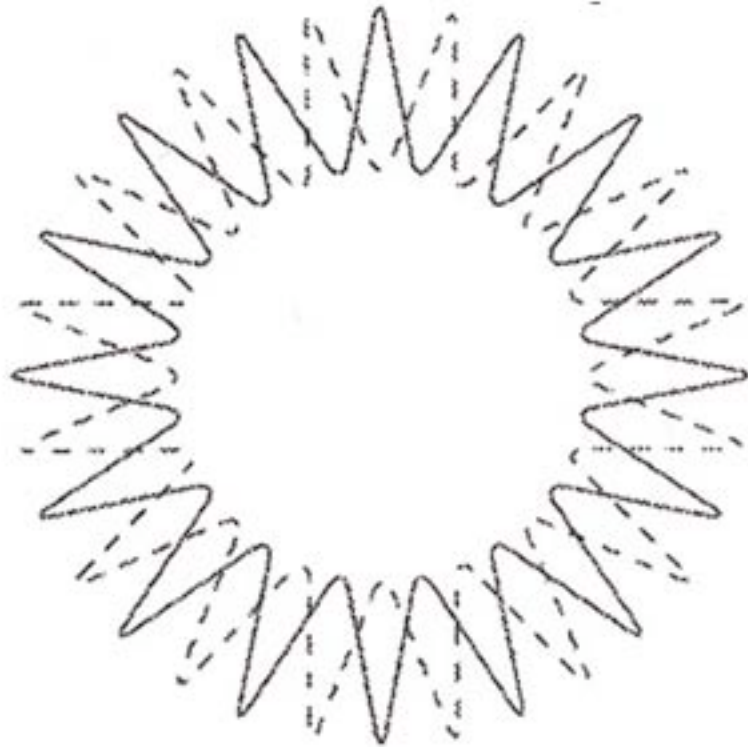
Fig 12.5

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

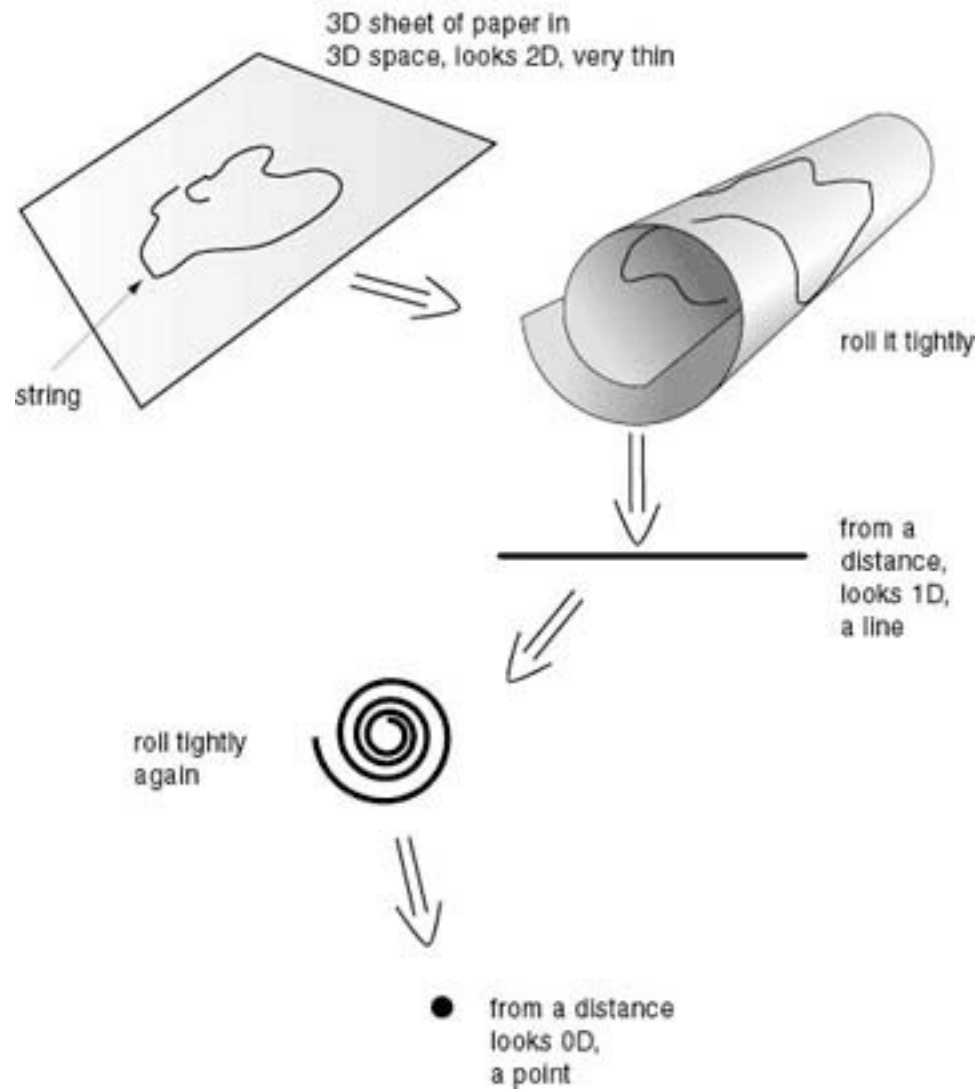
First notions:

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

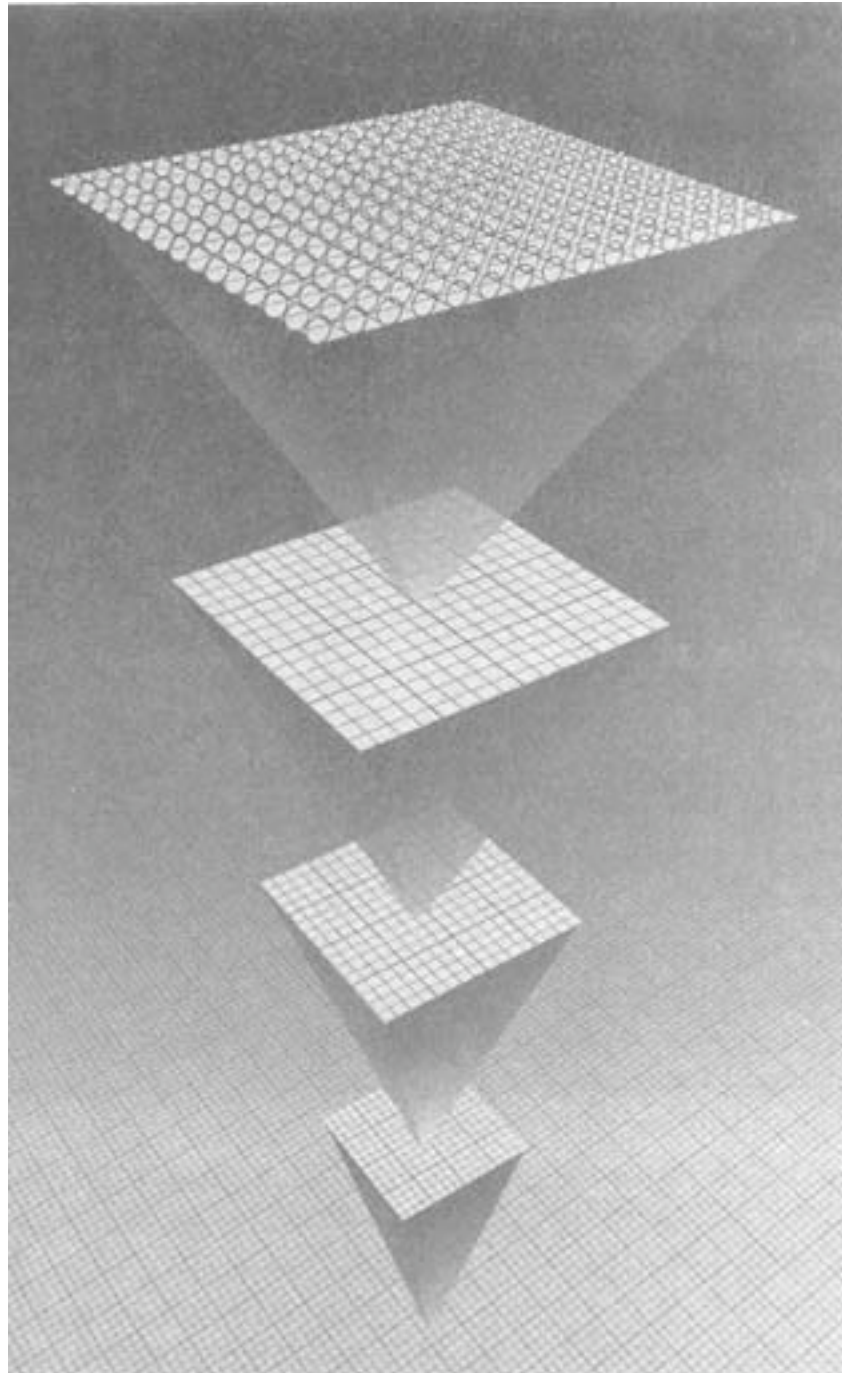
History - in 1960's physicists recognized that the equations corresponding to the strong nuclear force also described entities that could stretch and wiggle - strings

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

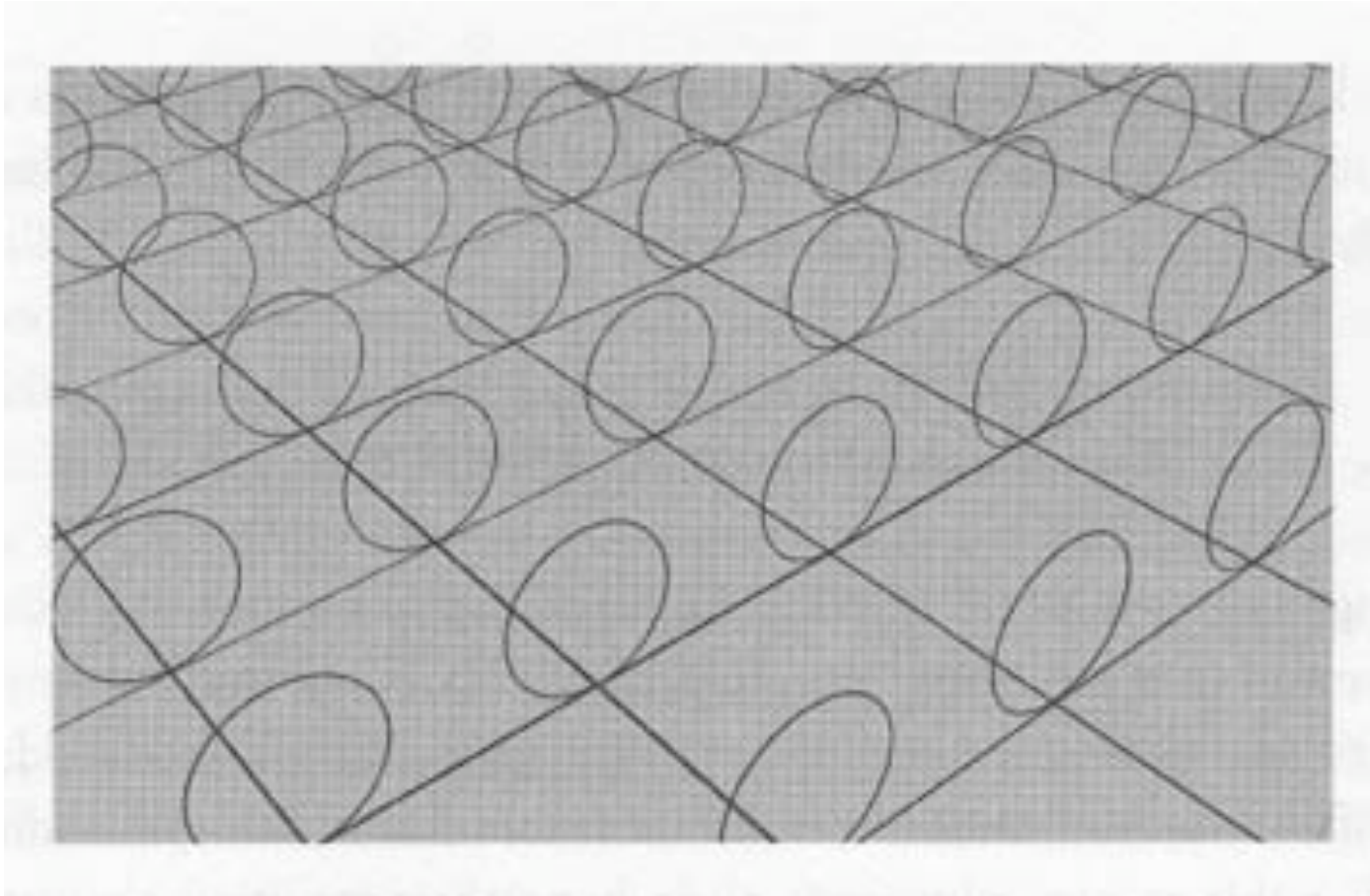
Shape of wrapped-up space determines how strings vibrate, what particles they represent.

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.

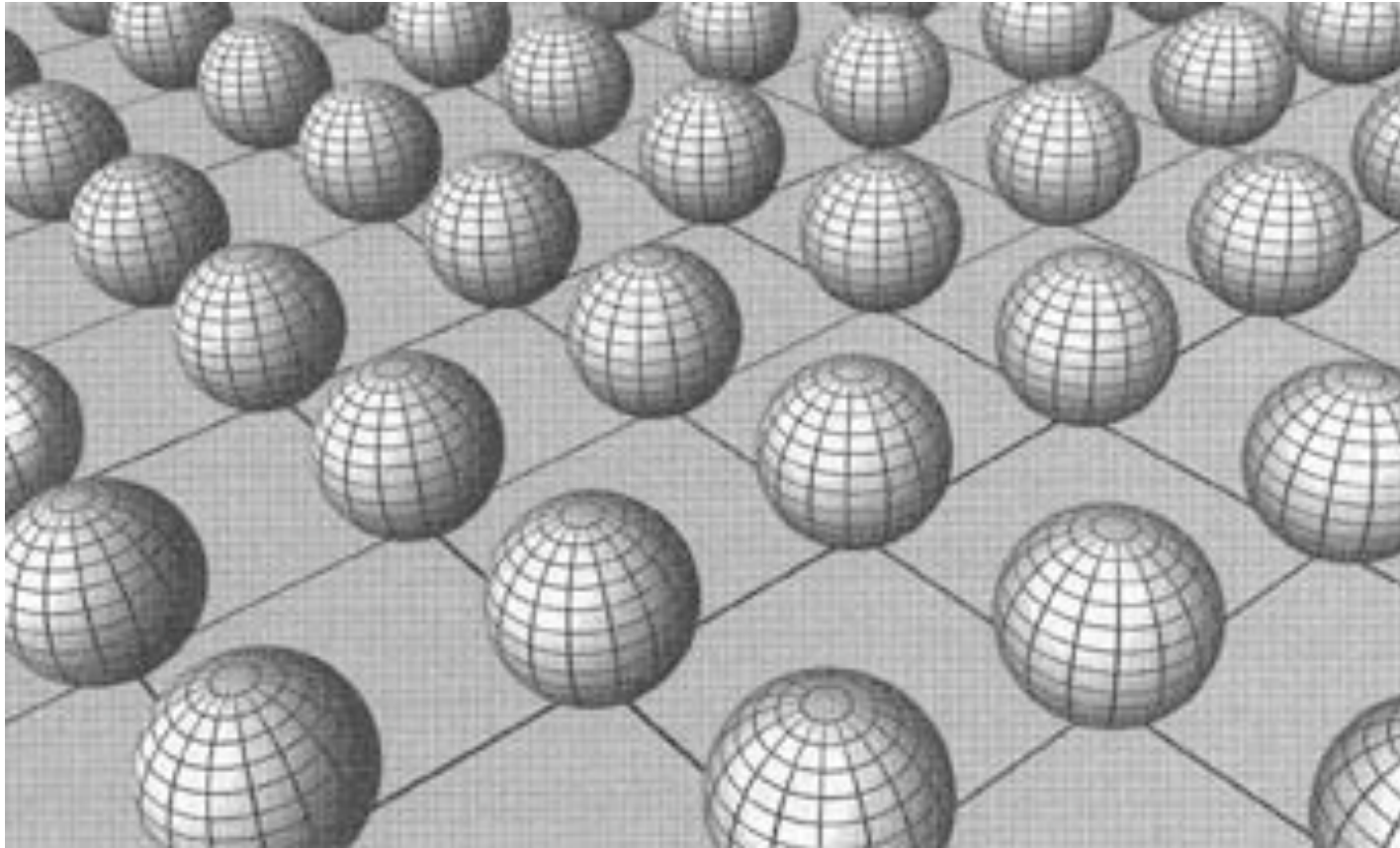
From Brian Green - The Elegant Universe



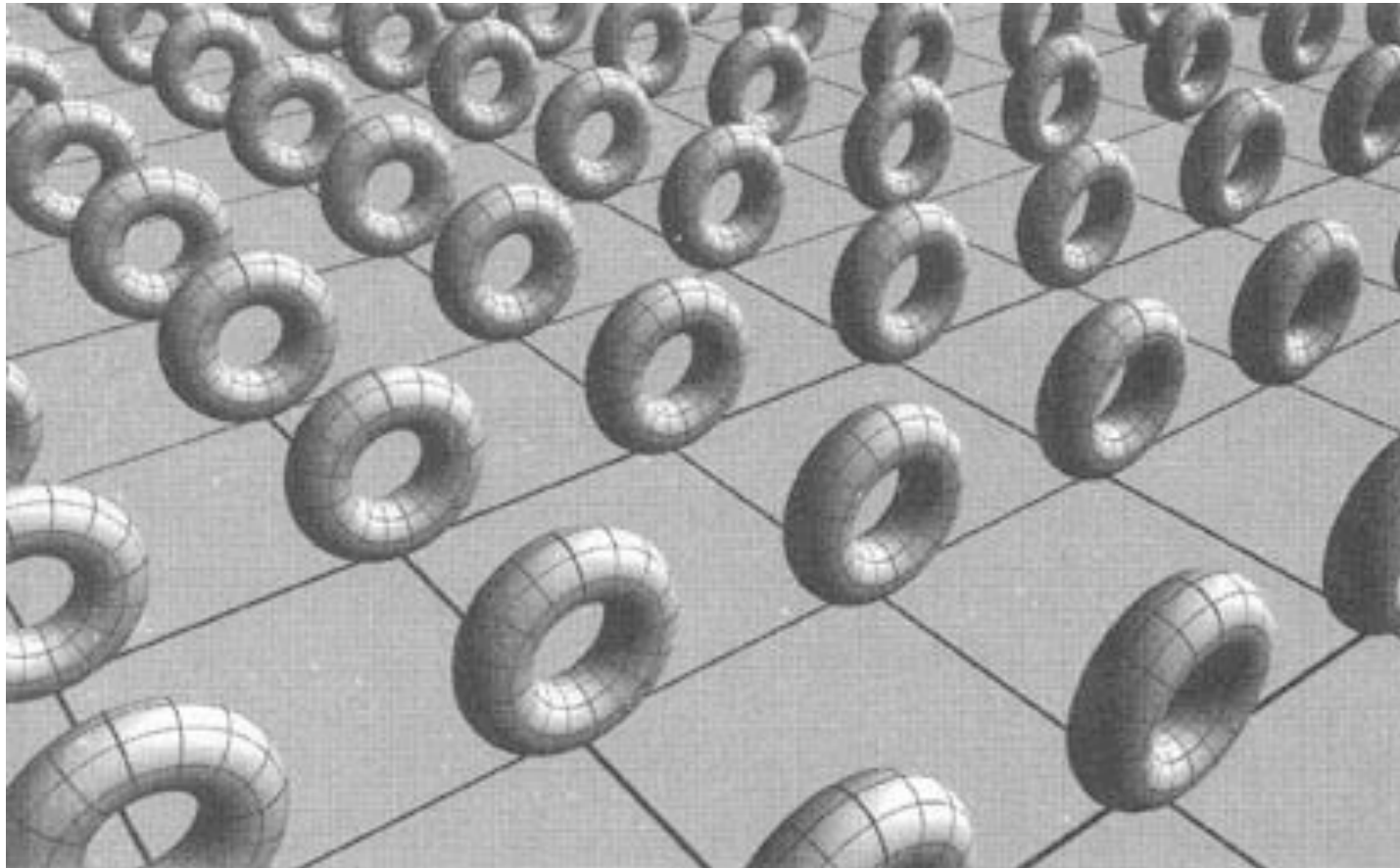




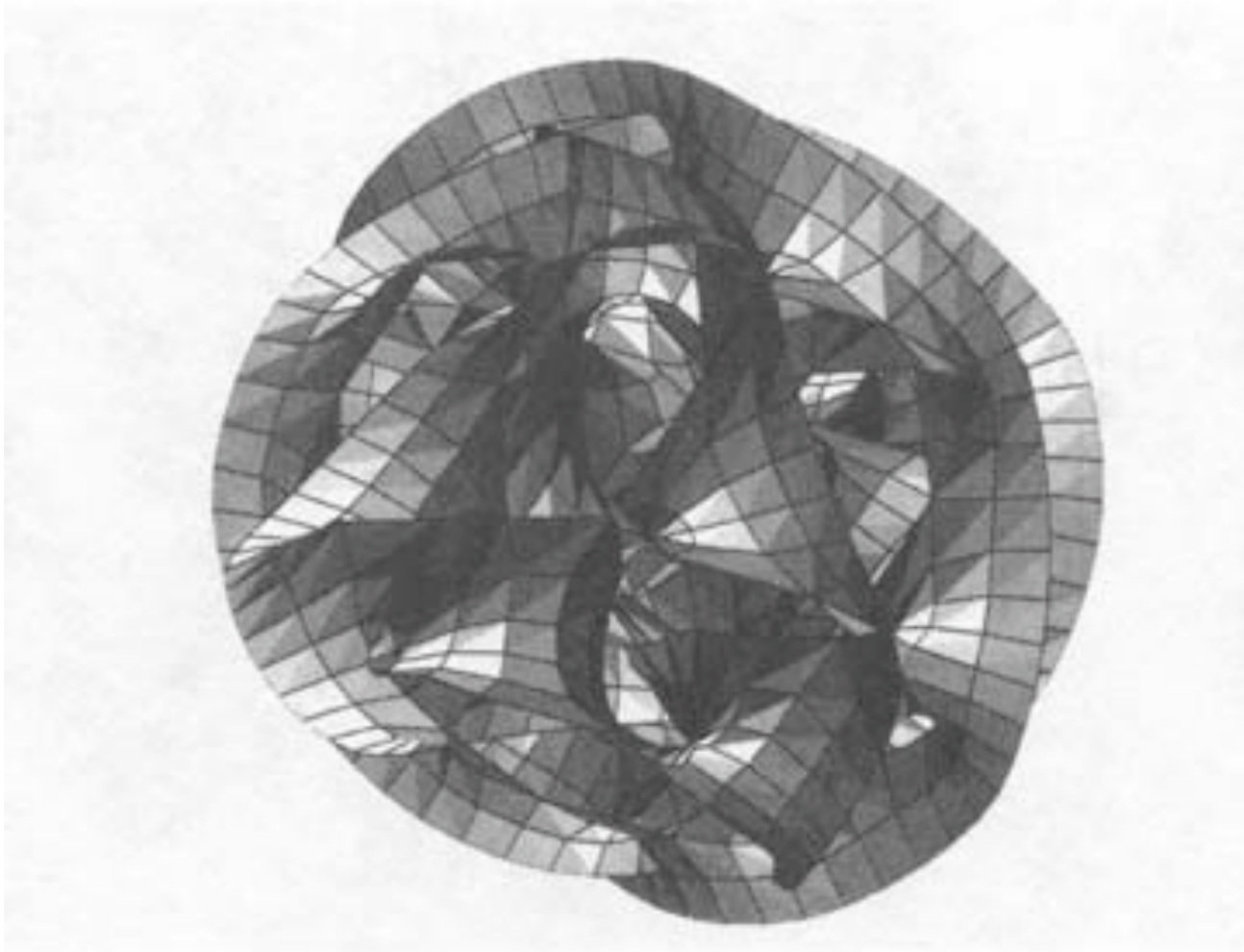
At each point in the 2D space (not just at the intersections of grid lines), there is a little 1D loop of one wrapped up extra dimension. From Brian Green: The Elegant Universe



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.

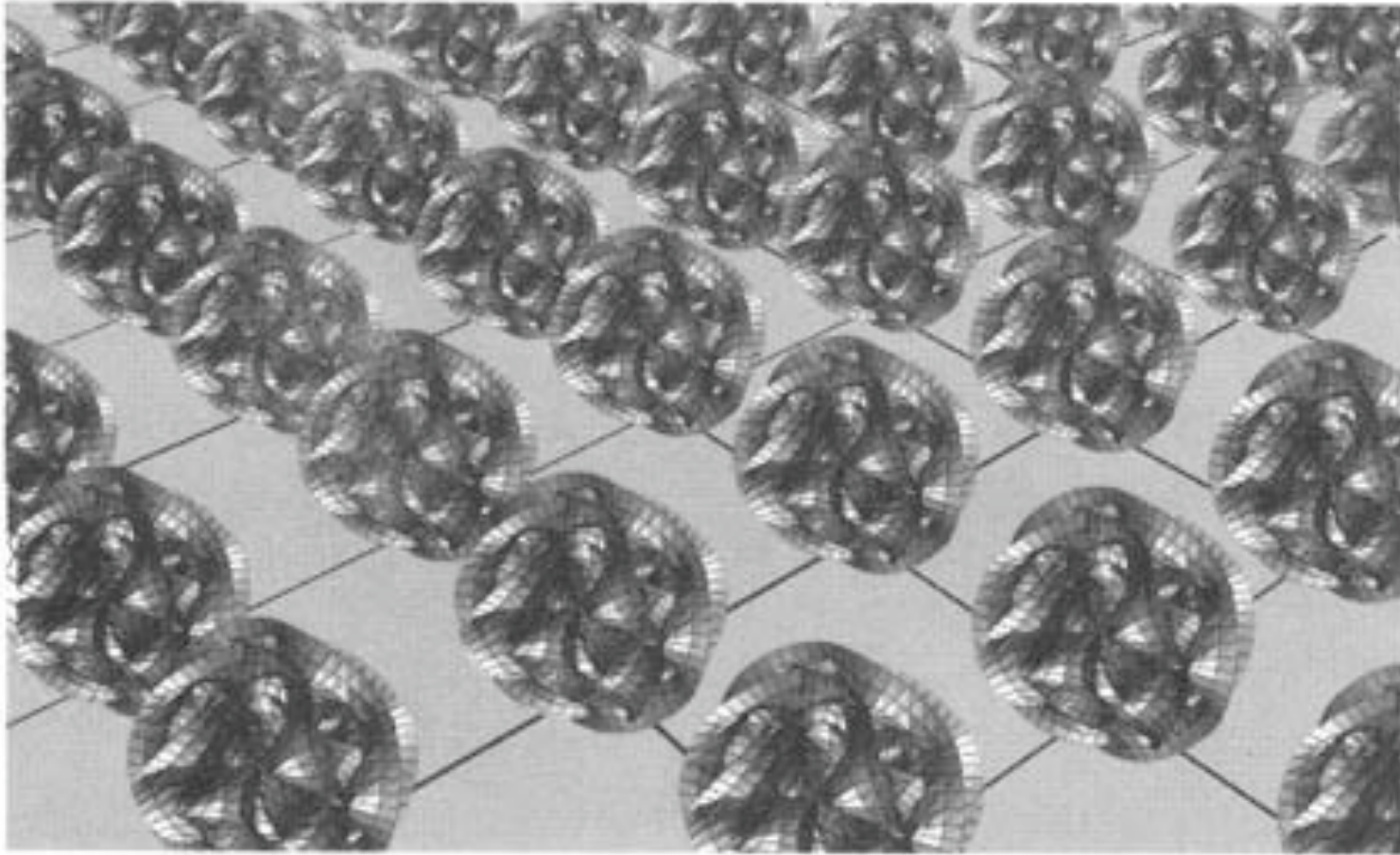


At each point in the 2D space (not just at the intersections of grid lines), there is a little 2D “torus” of two wrapped-up extra dimensions. A torus has a distinctly different “topology” or “connectedness” than a sphere. From Brian Green: *The Elegant Universe*.



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*.