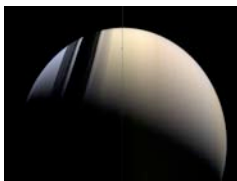


5/3/06

Reading: Chapter 12 in the Book, revised posted chapters 13 (worm holes and time machines), 14 (quantum gravity, string theory, large extra dimensions).

News: Mike Griffin, NASA Administrator: science budgets pinched until “legacy programs, Shuttle, Space Station, are dealt with.

Gravity Waves from inspiralling black holes.



Pic of the day; Saturn

Comprehensive Final

100 multiple choice questions,

Saturday, May 13, 2 - 5 PM, Burdine 106.

Extra credit sky-watch reports are due by Midnight on Friday, May 5 (RLM 17.230).

Brief descriptions of what you saw, under what circumstances, with what relevance to course.

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 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

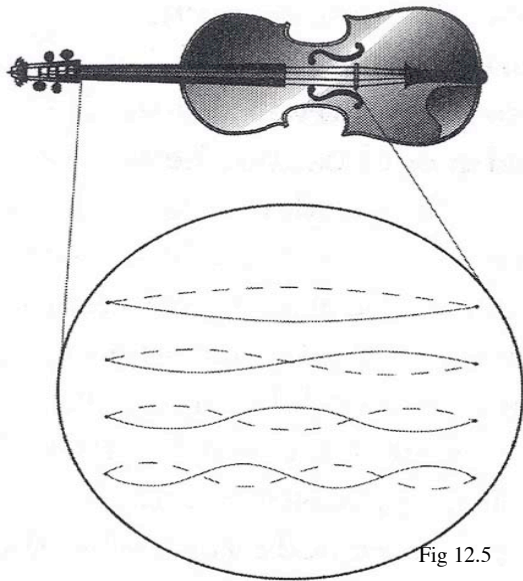
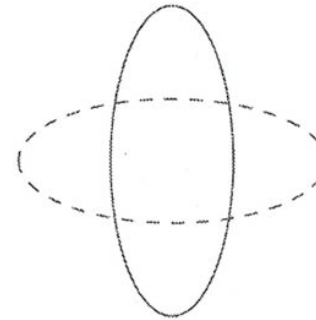


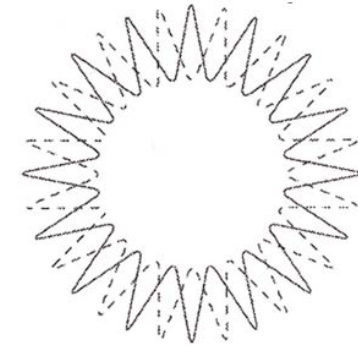
Fig 12.5

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

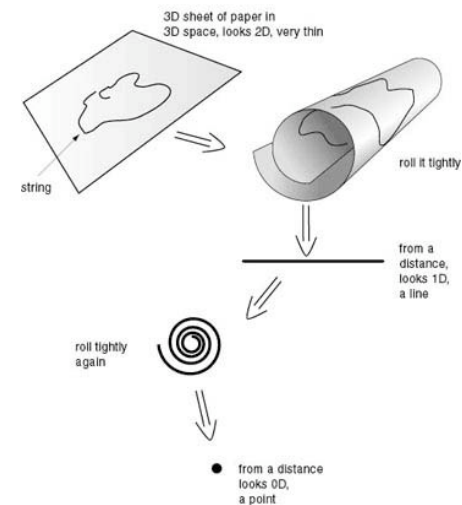
First notions:

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

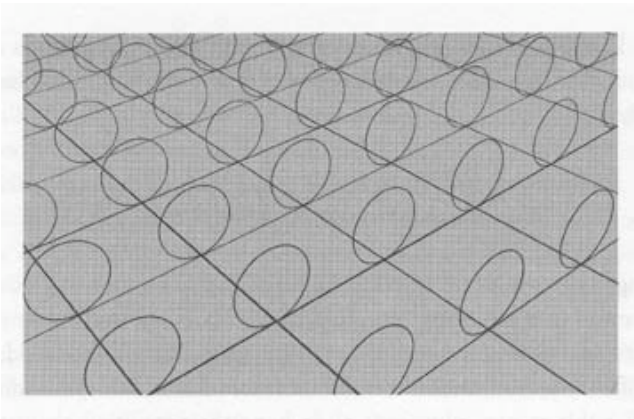


String Theory

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

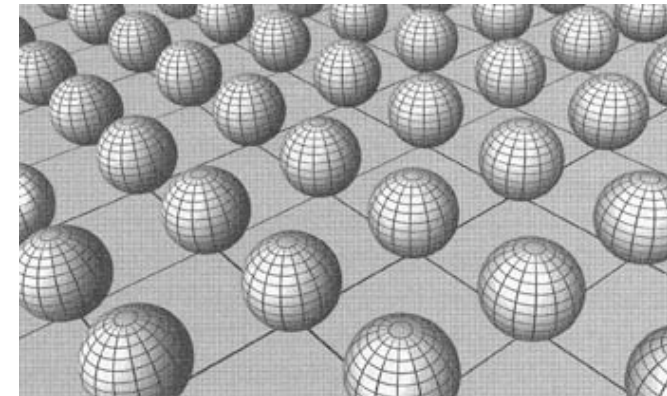
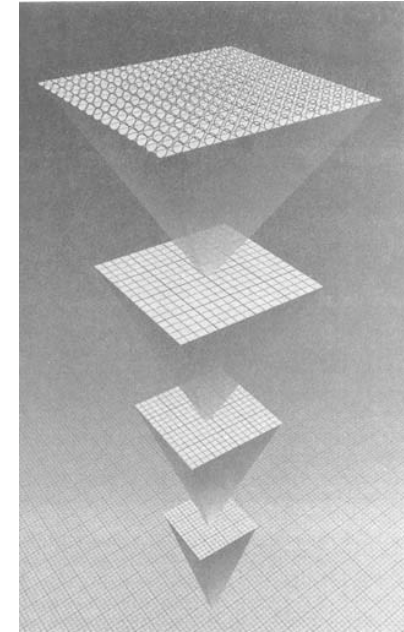
Shape of wrapped-up space determines how strings vibrate, what particles they represent.



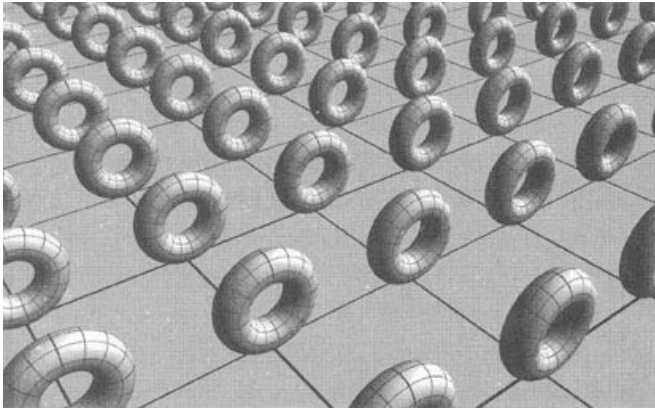
At each point in the 2D space (not just at the intersections of grid lines), there is a little 1D loop of one wrapped up extra dimension. From Brian Green: The Elegant Universe

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.

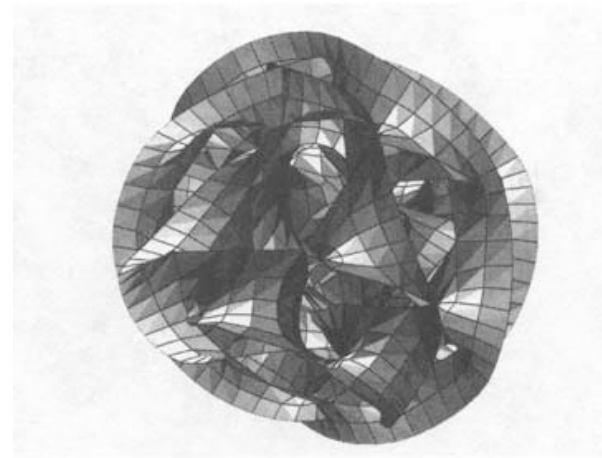
From Brian Green - The Elegant Universe



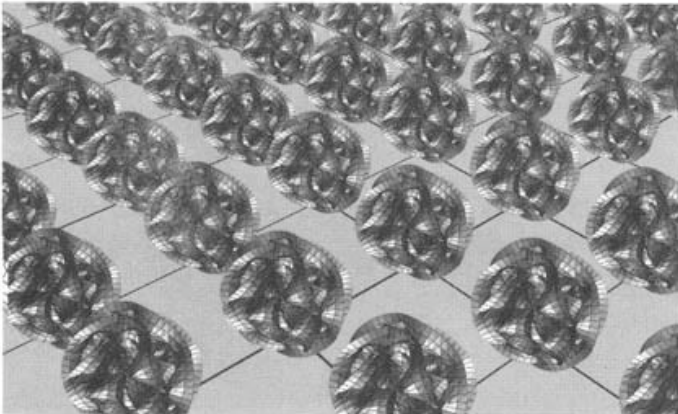
At each point in the 2D space (not just at the intersections of grid lines), there is a little 2D “sphere” of two wrapped-up extra dimensions. From Brian Green: The Elegant Universe.



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.