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Evan's story

Astronomy in the News - astronauts add DEXTRE to International Space Station



Pic of the day - Ice Moon Enceladus of Saturn



Great conceptual differences between Newton and Einstein on the Nature of Gravity

Newton - Force between two objects

Einstein - Mass curves space, objects move *with no force* in curved space

Need to explore curved space - use geometry in multiple dimensions

Euclidian - Flat Space Geometry



Answers only good in *flat space*: operational definition of flat space *NOT necessarily two-dimensional!*

Non-Euclidian geometry - curved space

Both flat space and curved space use concept of "straight line"

Curved Space - explore with straight lines

Definition of straight line

Shortest distance between 2 points - rubber band

Draw a free hand straight line

Parallel propagation - rulers

Parallel propagation will give the shortest distance between two points without necessarily knowing where the two points are in advance.

Parallel propagation works easily, even when the space is *curved*.

Balloon

Surface is curved 2 D space

3 D space around the balloon, inside the balloon is *hyperspace* with respect to the 2D surface

Imagine a 2 D creature that can only perceive 2 D space.

2 D creatures can learn all about the curvature of the space they inhabit by doing geometry in 2 D - they never need to know about or care about "hyperspace."

That's us in 3 D! There might be 4D (or higher!) hyperspace around us, but we don't perceive it.

We can, in principle, learn everything we need to know about our 3D Universe by doing 3D observations and experiments in the confines of our own dimensionality, just as 2D creatures could learn of their universe, the surface of the balloon. Geometry on the 2D surface of the balloon

Exercises of drawing straight lines

Surface of the Balloon -

What is a straight line, what is not?

What is "inside?" What is "outside?"

Where is the "center?"

What does it mean to go from surface point to surface point "through" the balloon interior?

Real 3 D curved space (for us!!) might curve in a 4 D "hyperspace," but we do not directly perceive that hyperspace.

Can determine curvature, shape of 3 D real space by doing 3 D geometry.

Do not need to ask about 4 D (but will!)

Check out

Dr. Quantum in Flatland

Right in spirit, wrong in some essential details. See if you can figure out what those are.

http://youtube.com/watch?v=KhbGYn7aAUk

Embedding diagram - 2 D "shadow" of 3 D curved space, preserves basic aspects of geometry, whether curved or not, and, if curved, how.

Meaning of *flat space* in 3 (or higher) dimensions

If 3 D space is flat: C= $2\pi r$; sum of angles of triangle = 180° ; parallel beams of light never cross *in 3D*.

The embedding diagram of 3D flat space is a flat 2D plane

In curved 3D space, the flat space answers will be wrong: 2D embedding diagram will help to illustrate that.