Wednesday, May 4, 2016

Fifth exam and sky watch, FRIDAY, May 6.

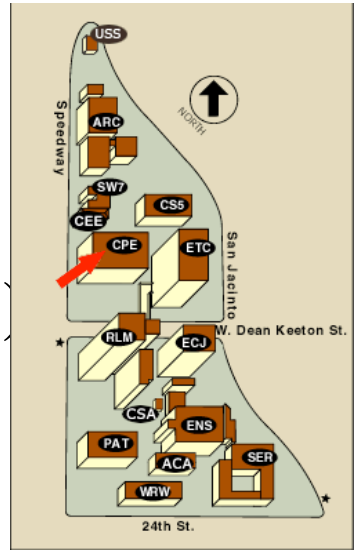
Review Th 4:30, RLM 15.216B (**or make an appointment!**)

Review Sheet

Reading for Exam 5:

Chapter 9 – Sections 9.6.1, 9.6.2, 9.7, 9.8; Chapter 10 - Sections 10.1-10.4, 10.9; Chapter 11 - all except Section 11.6 (abbreviated, focus on lectures); Chapter 12 - all; Chapter 13 (skip) - all; Chapter 14 - all

Electronic Class Evaluation now available. Please do this!



Astronomy in the news?

Yuri Milner awards a special Breakthrough Prize, $1million to the 3 founders of LIGO and $2million to the 1012 other authors of the paper announcing gravitational radiation from two merging black holes.

Goal:

To understand why we need a new theory of Quantum Gravity and the ideas involved in the attempt to construct that theory.

Goal:

To understand how string theory represents the current best candidate to be the needed theory of quantum gravity (Chapter 14)

Goal:

To understand why physicists argued that any “extra” dimensions had to be tiny and wrapped up, how that restriction was removed, and what that means for our view of the Universe.

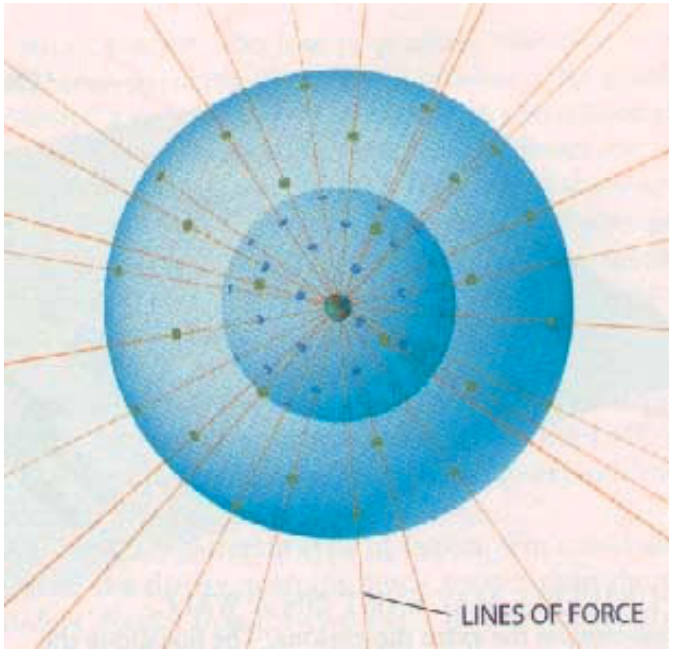
Old argument: there could ***not*** be a ***large*** 4th spatial dimension

Behavior of light, electrical force, and gravity in 3D

The luminosity or lines of force flow out through larger ***area*** at larger distance. The strength (brightness or lines of force per unit area) is thus diluted by 1/area 1/r^2 in 3D.

Area is one dimension less than volume.

The "2" in the inverse square law is exactly "1" less than the total number of large dimensions, "3"



Light and electricity might be stuck in 3D, but gravity probes all space, whatever its dimension. Gravity is a creature of space/time

Extend the argument to higher dimensions than 3.

An "area" is one dimension less than the total "volume" corresponding to a given dimension of space.

If gravity extends to a fourth dimension, where "volumes" scale like r^4 and "surfaces" scale like r^3, then gravity would be diluted in 4D by 1/ "area" 📷 $1/r^3$ in 4D.

Obviously wrong! Even Newton knew that gravity weakens as the inverse of distance squared, not as distance cubed!

Implication (it was long thought): IF there is a 4th (or higher) dimension it must be "wrapped up" so gravity has nowhere to go.

Concept check:

Can you explain what it means to have a wrapped up, closed dimension in 3D? What are examples?

Can you explain what it means to have tiny, wrapped up higher dimensions?

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, 10.

These surfaces can also wiggle and vibrate.

In analogy to membranes, they are called ***branes*** of dimension p, or ***p-branes***. A point is a zero-brane, a line a one-brane, etc.

The hyperspace "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.

New insight: (Lisa Randall 1999) - Can have ***large extra dimensions*** and gravity will still leak only a little into those extra dimensions, still weaken very nearly as $1/r^2$. Had assumed extra dimension was "flat" - it needn't be.

Leakage into higher dimensions could account for why gravity seems "weaker" than other forces.

Our 3D Universe could be a 3D brane in a large, extended, 4D bulk

There could be a real, large (infinite), four-dimensional hyperspace in which our 3D Universe is embedded.

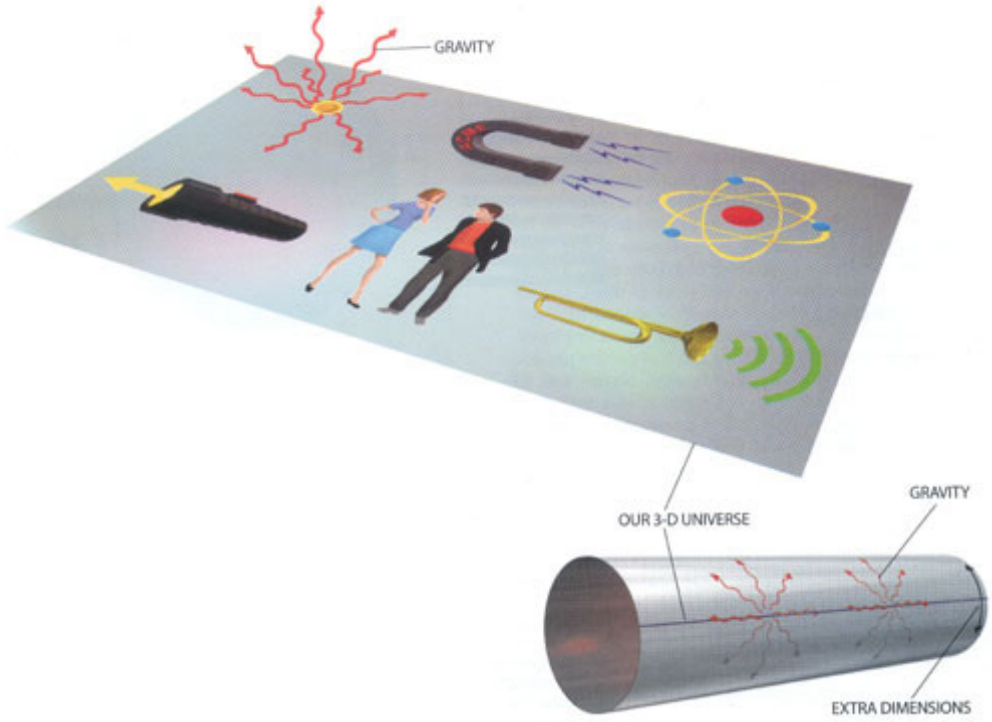
Plus tightly wrapped up dimensions.

In this picture, ordinary forces, electromagnetism, nuclear forces, correspond to "open" strings that have ends stuck on the 3D brane,

These strings cannot "go" into the 4D bulk, we cannot "see" the 4D bulk.

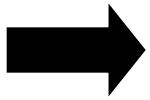
Gravity is based on "gravitons," closed loops of strings that are not stuck on the brane. They can float off into the bulk, but in a way that gravity still weakens very nearly like $1/r^2$.

Balls on 2D brane, sound into 3D bulk

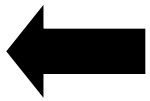


One minute exam

In string theory, our Universe is pictured as a

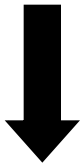


2 brane



3 brane

10 brane



3D bulk

Goal:

To understand how the notion of a large 4^{th} dimension led to notions of multiverses and what string theory has to say about black holes and information.

Brane World cosmologies: exploring the theoretical possibility that our Universe is a 3D brane floating in a 4D bulk, with 6 wrapped-up dimensions, plus time

Example: Ekypyrotic Theory (Greek *ekypyrosis* = conflagration)

Two 3D branes collide in 4D bulk

hot, dense "Big Bang" but not infinite density

no singularity

different gravitational waves than standard "inflation" theory - could be a test.

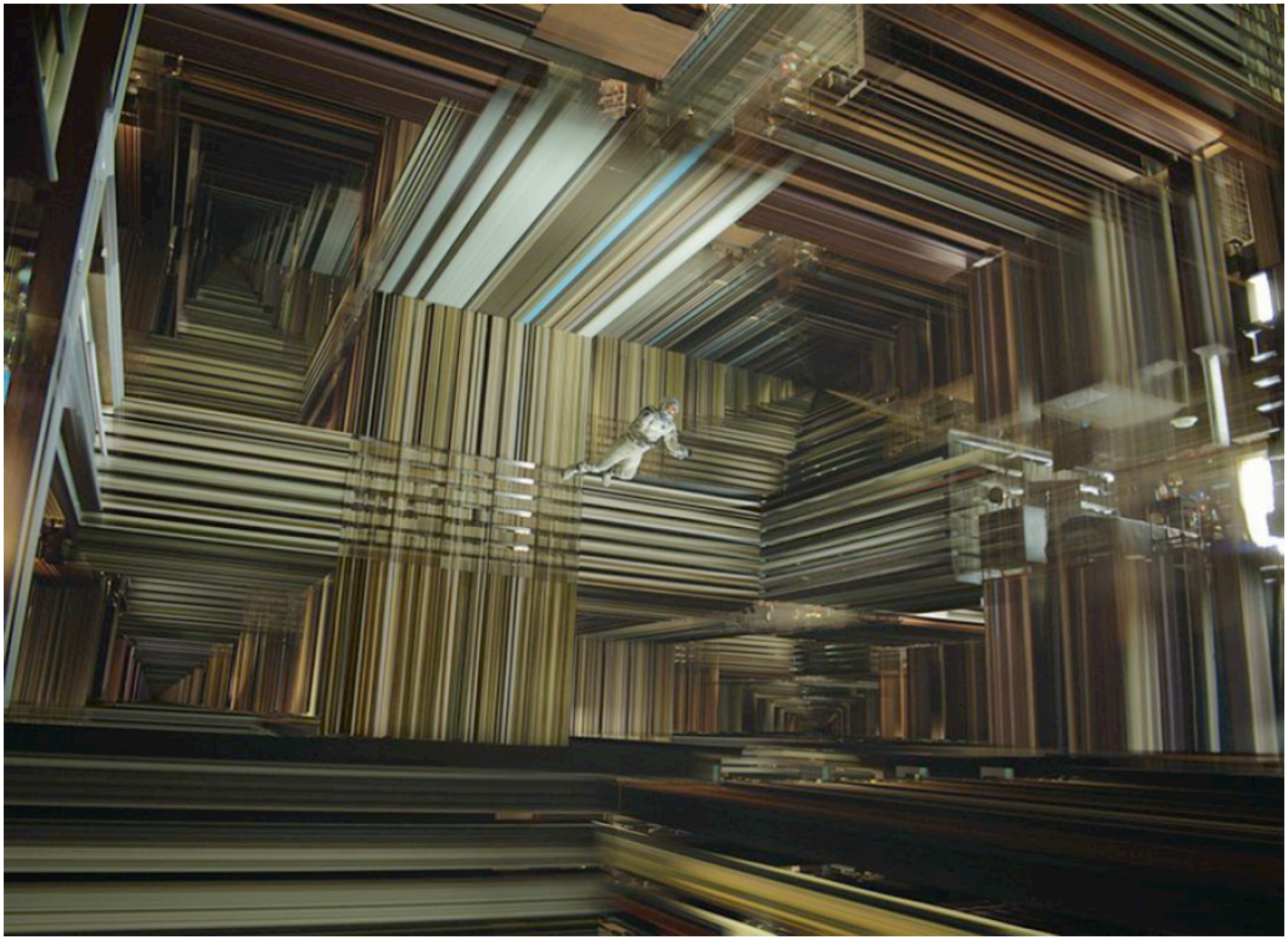
More Brane World ideas:

Singularity in black holes, quantum foam ↝ nested "loops" of strings?

The 4D Bulk: is this where our Universe curves to when it curves, expands to when it expands – Maybe…

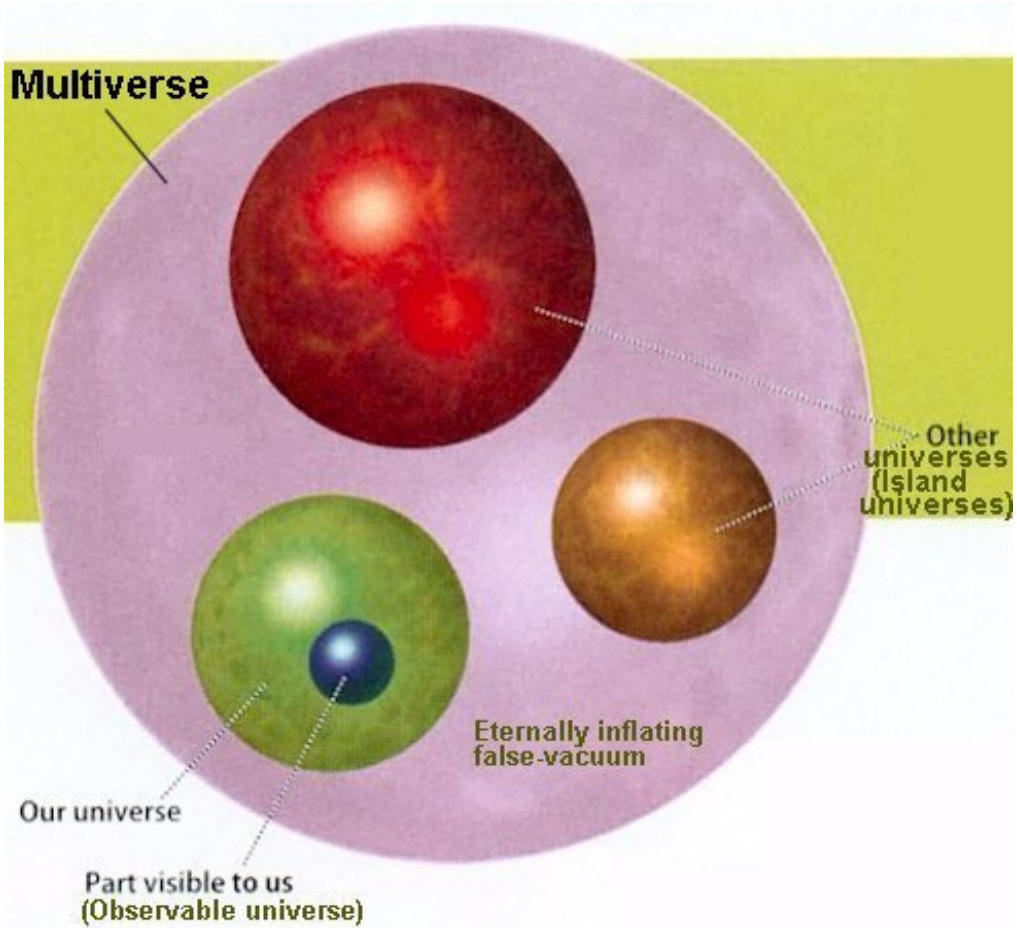
Is the Dark Energy that drives the acceleration of the Universe some manifestation of a "nearby" 3D Universe only a little distance away from our Universe in the 4D bulk?

Interstellar - McConaughey in the Tesseract (a 4D "cube") inside the supermassive black hole, Gargantua, ranging in time as well as 3D/4D perspectives. He taps out the "solution to quantum gravity." All this was based on these string theory, 4D hyperspace bulk, ideas.



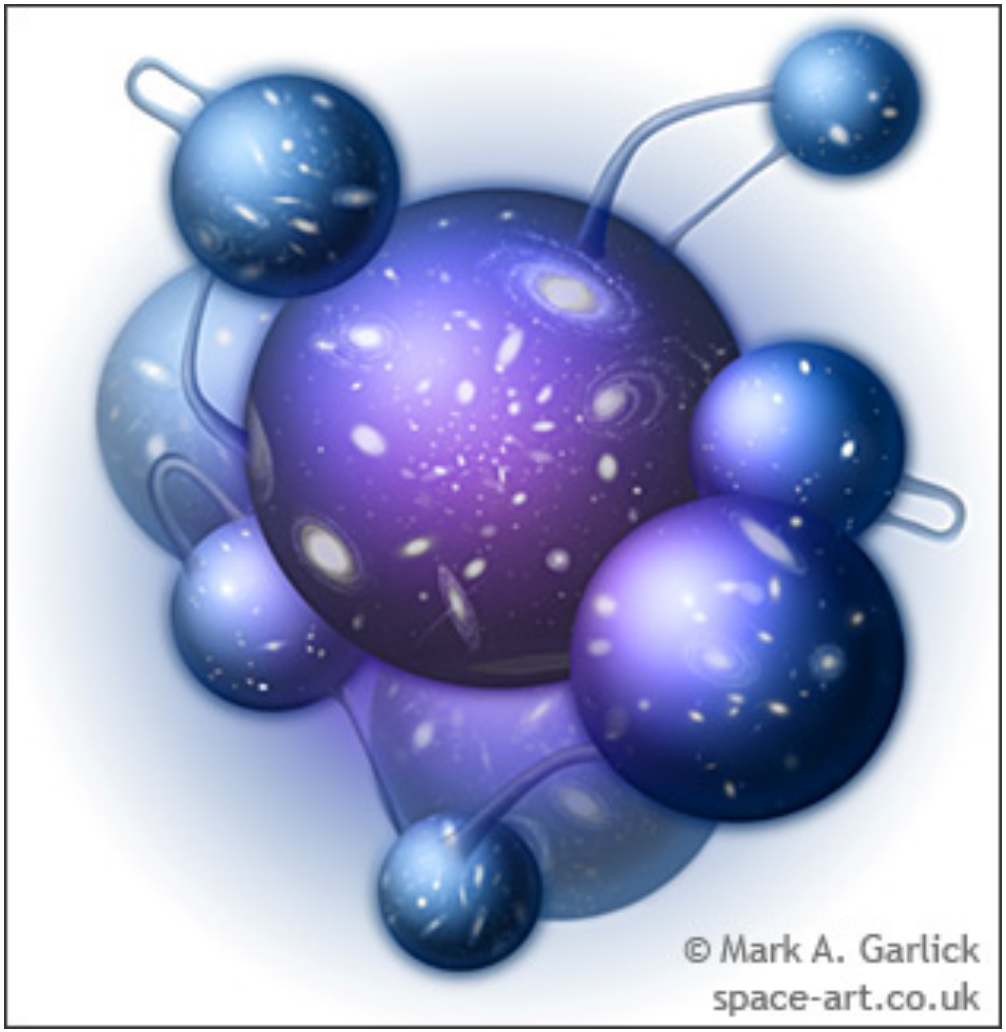
More current ideas:

The Multiverse - the idea that there could be many 3D universes separated in 4D hyperspace.



Bubble Universes - the individual universes created from the parameters of the String Landscape that populate the Multiverse.

One idea: when a black hole forms a "singularity" in one universe, a new universe is born "elsewhere" in hyperspace.



New insights into information

Derivation of the temperature of a black hole from string theory got exactly Hawking's answer.

But string theory is a quantum theory and exactly preserves information.

The implication is that Hawking was wrong that information is destroyed in a black hole and that black holes have only mass, charge and spin.

The information must be retained in string vibrations **at the event horizon** (not within the black hole).

Surfaces are the true repository of information, not volumes.

In a hologram, the information is stored as patterns on a 2D surface. With exposure to a laser, a 3D representation of the 2D information can be restored.

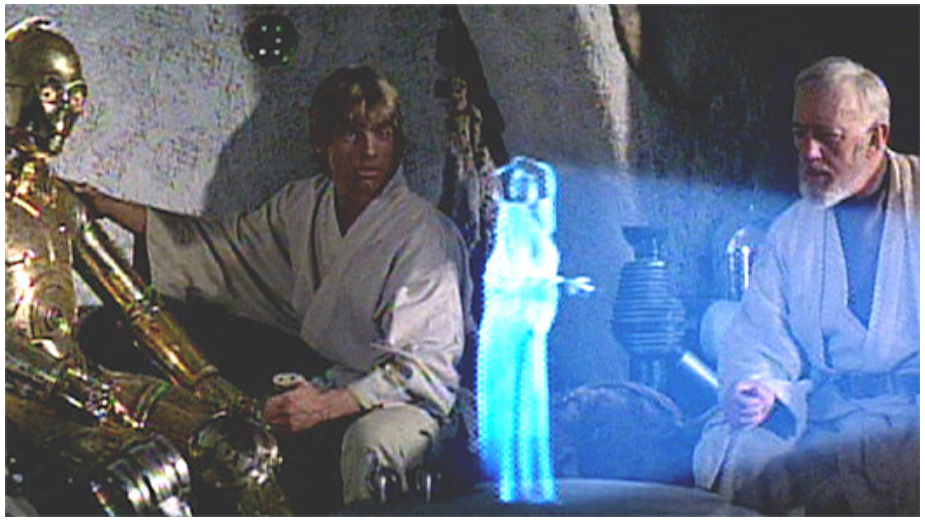
All this led to the idea that we live in a ***Holographic Universe***.

The Holographic Universe - the notion that the real information content is imprinted in quantum bits on the surface, the event horizon, of the observable universe.

What we regard as the physics (and chemistry and biology) in our 3 dimensions, is fundamentally set and controlled by information and physics on the 2D surface around us (the Big Bang is in every direction).

Closely related to the understanding that the information of what fell into a black hole is retained in string vibrations at the event horizon surface of a black hole.

We are just 3D hologram projections from the 2D surface around us.



Is this real, or just mathematical fantasy?

Must be able to test: Physicists are straining to devise such tests.

Does gravity behave a little differently than $1/r^2$, for instance like $1/r^{2.0001}$, that would be hint of higher dimensions?

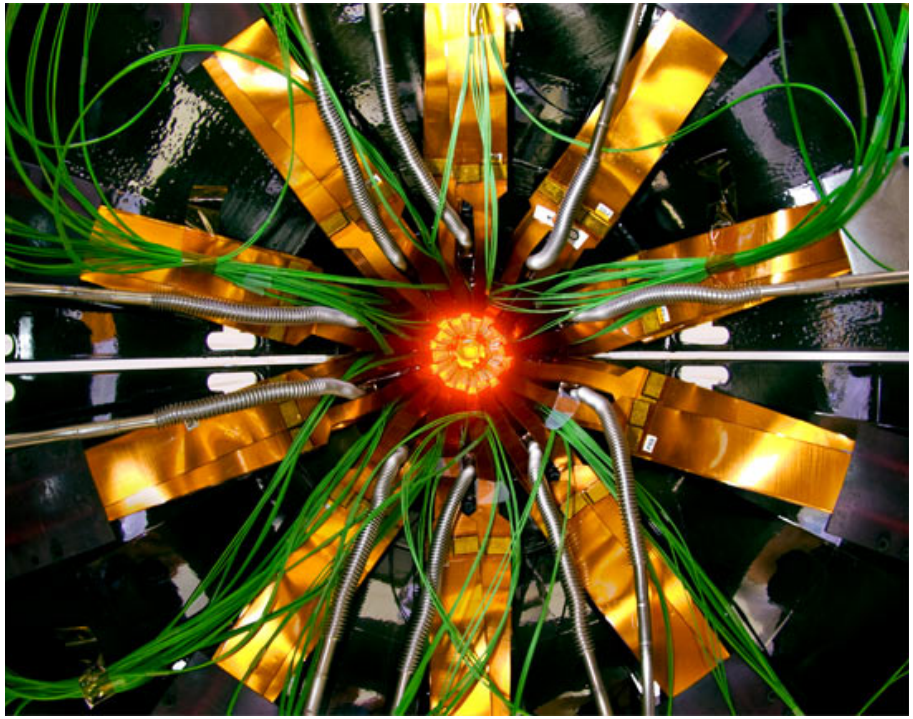
Curved space near event horizons of black holes might be different than standard Einstein gravity - can that be measured with X-rays, or, now, with gravitational waves?

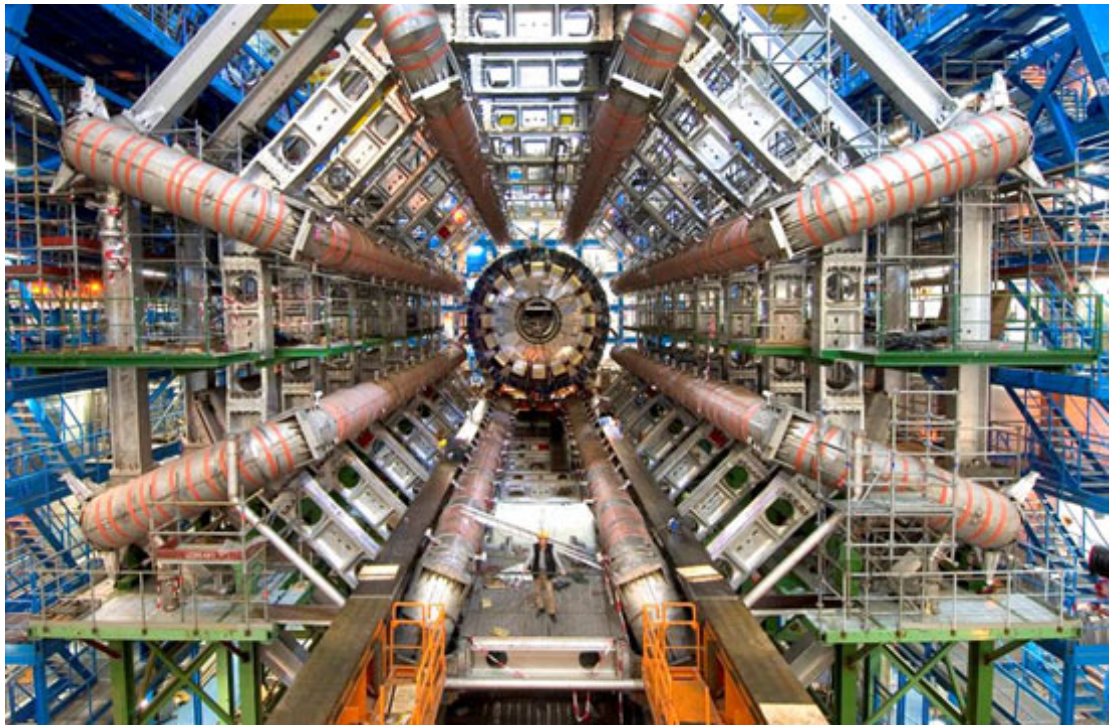
Interactions in particle accelerators could be different if some energy disappears into the 4D bulk (as closed string gravitons).

The Large Hadron Collider (LHC) at CERN, near Geneva, is operating. Strong expectation that evidence for new physics, confirming or denying string theory ideas, will be seen.

Not yet, the physics community is holding its collective breath…

The **Large Hadron Collider** at CERN in Switzerland may see the first hints of extra dimensions.





Take Away Message:

Hyperspace might be real…

Stay tuned!

(and remember to keep an eye on Betelgeuse!)