Tuesday, May 5, 2009

Fourth exam this Thursday, May 7

Review Sheet posted

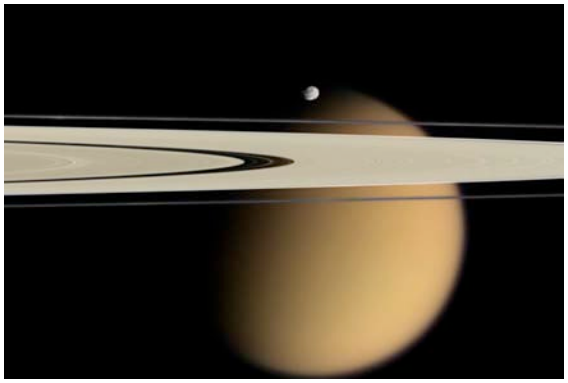
Review Session Tomorrow, RLM 15.216B, 5:00 PM

Turn in fourth Sky Watch by Sunday, May 10

Class Evaluation on Thursday before the exam. Need Volunteer.

Astronomy in the News -

Pic of the day - Cassini Mission at Saturn, rings, Titan and small moon, Epimetheus



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

Black Hole Candidates in the directions of Sagittarius, Ursa Majoris, Perseus, Scorpius, Ophiuchus, Vulpecula, Monoceros, Lupus, Cygnus (2) (Find and observe the constellations for extra credit)

AO620-00 = Nova Mon 1975 = V616 Monocerotis - one of the first and best studied with a small mass companion, black hole about 5 solar masses.

V404 Cygni - somewhat evolved companion, but one of the best cases for a black hole with "dark' mass of about 12 solar masses.

Two candidates in the Large Magellanic Cloud:
LMC X-1, LMC X-3

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.

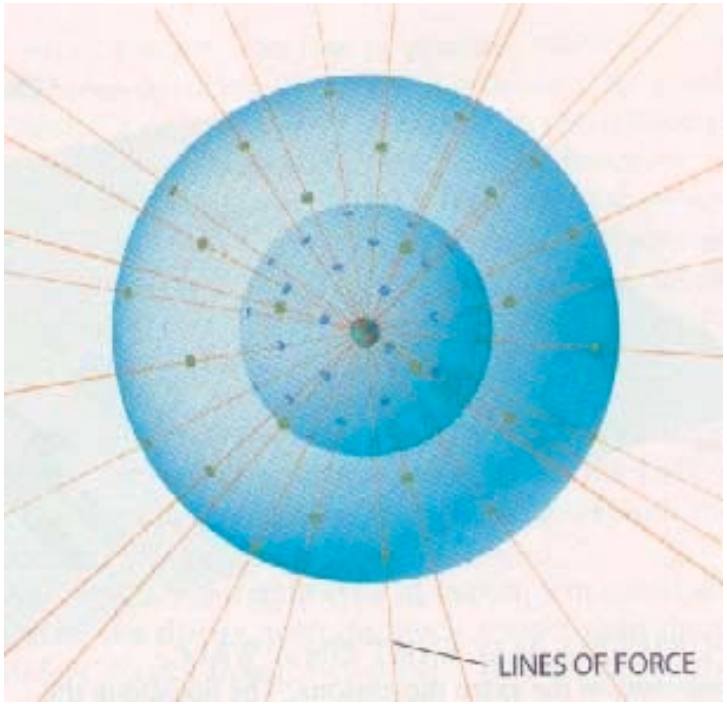
This led to a revolution in our perspective on the Universe.

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



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” $\propto 1/r^3$ 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 no where to go.

New insight: (1999) - Can have ***large extra dimensions*** and gravity will still leak only a little into that extra dimension, still weaken very nearly as $1/r^2$.

Our 3D Universe could be a 3D brane in a 4D bulk

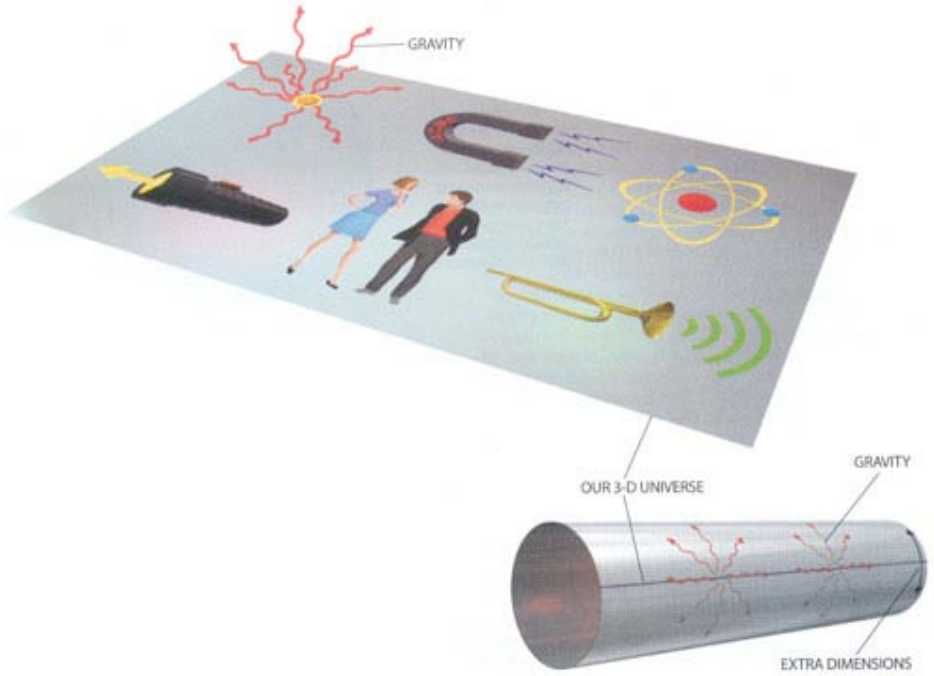
There could be a real, large (infinite), four-dimensional hyperspace in which our 3D Universe is embedded.

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.

Balls on 2D brane, sound into 3D bulk



Gravity corresponds to 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 $1/r^2$.

One minute exam

In string theory, our Universe is pictured as a

A) 2 brane

B) 3 brane

C) 10 brane

D) 3D bulk

One minute exam:

If gravity reached into the 4D bulk as easily as it penetrates our ordinary three-dimensional space, then it would get weaker with distance from the source as

A) $1/(\text{distance})^2$

B) $1/(\text{distance})^3$

C) $1/(\text{distance})^4$

D) Our 3D brane expands

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 gravity waves - could be a test.

Brane world ideas:

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

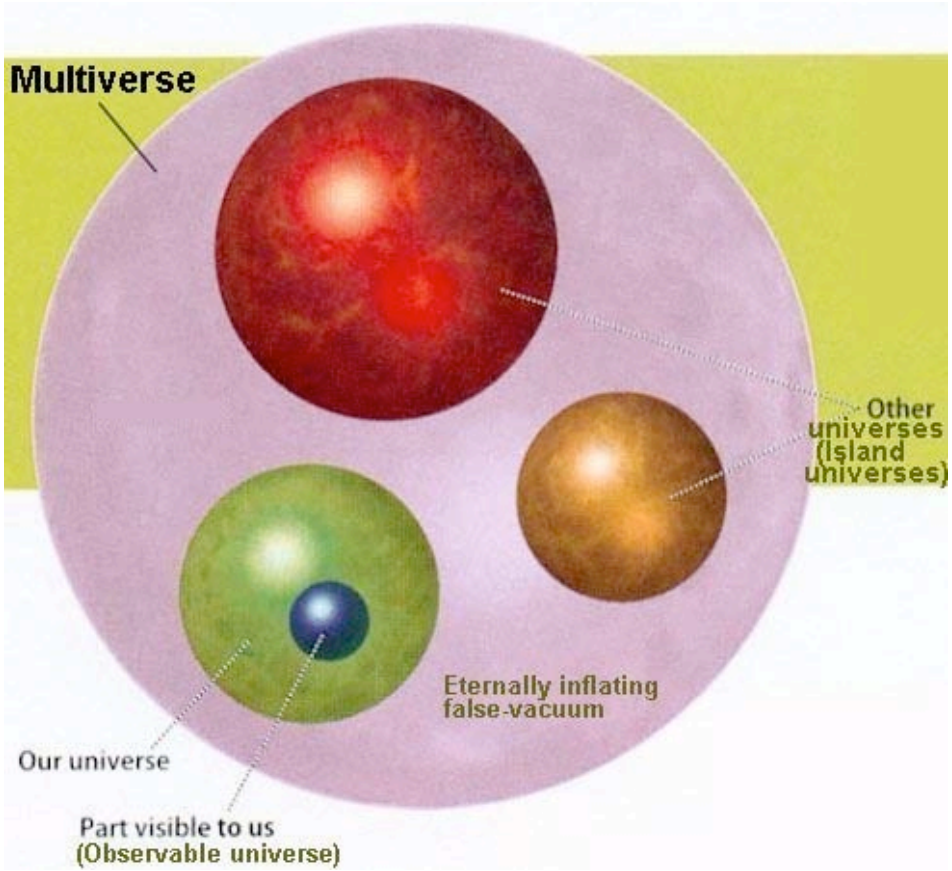
The 4D Bulk: is this where our Universe curves to when it curves, expands to when it expands - Maybe…

Bubble Universes: When a black hole forms a "singularity" does a new Universe spring into existence "elsewhere" in 4D hyperspace?

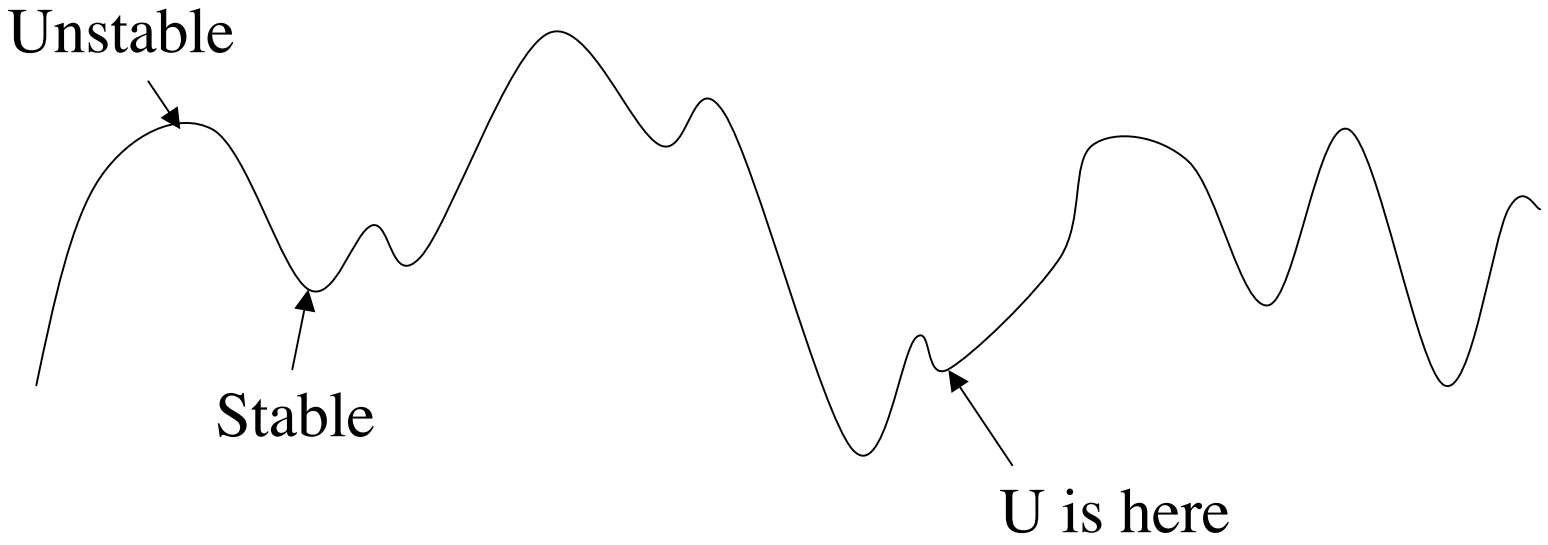
Is the Dark Energy that drives the acceleration of the Universe some manifestation of a "nearby" 3D Universe only a little distance away from our Universe in the 4D bulk?

More current ideas:

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

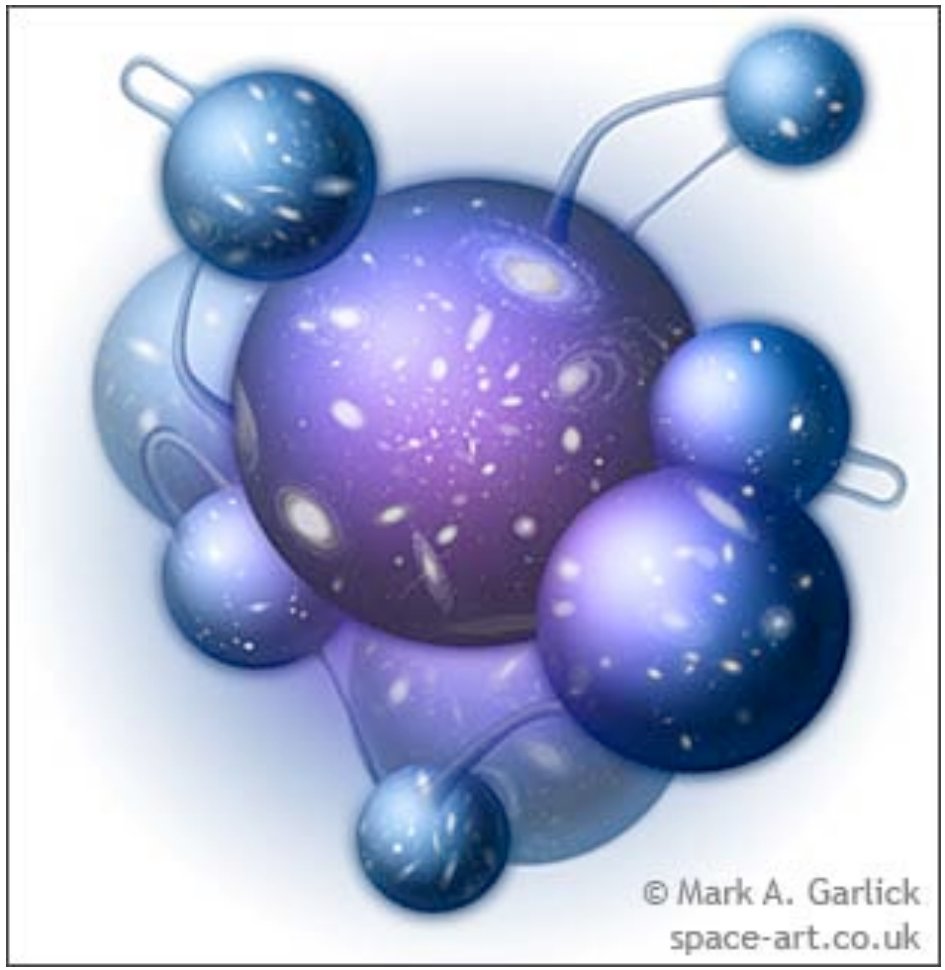


The String Landscape - current estimates are that string theory might provide 10^{500} different solutions, "universes," each with a different set of values of the physical constants, speed of light, the gravitational constant, Planck's constant that determines the size of quantum uncertainty, Einstein's Cosmological Constant, masses and charges of particles. Only some universes could make stars, galaxies, and life.



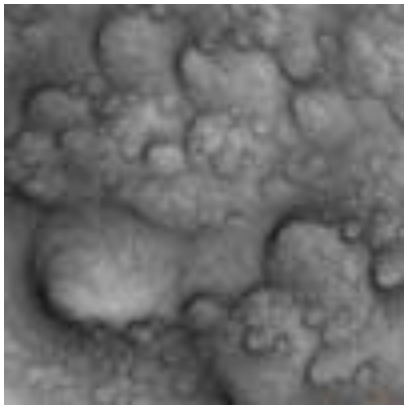
Bubble Universes - the individual universes created from the parameters of the String Landscape that populate the Multiverse.

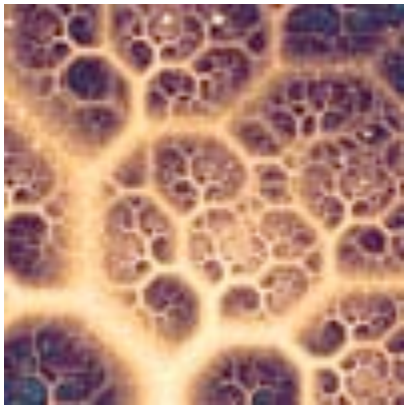
One idea: when a black hole forms a "singularity" in one universe, a new universe is born "elsewhere" in hyperspace.



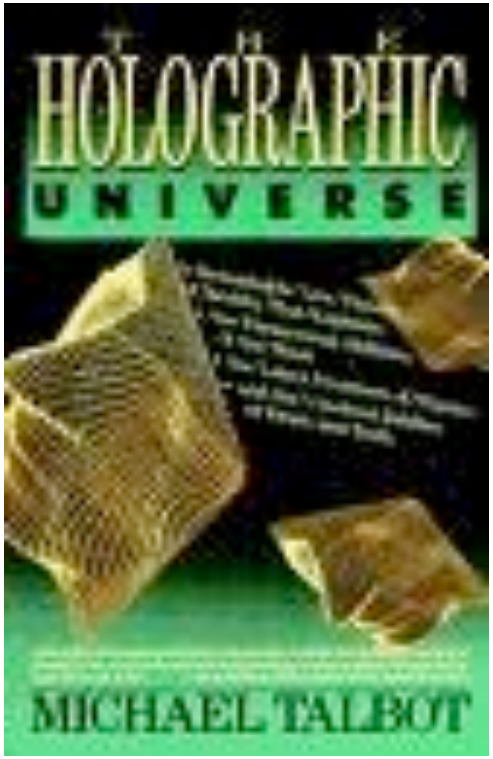
Eternal Inflation - the notion that new bubble universes are constantly being born, "inflated" from the quantum foam or stringy space-time.

Chaotic Inflation - a variation on eternal inflation in which new bubble universes are constantly being born and the multiverse is fractal on large scales.





The Holographic Universe - the notion that the real information content is imprinted in quantum bits on the surface of the observable universe (we are just 3D hologram projections from the 2D surface), or that our 3D physics is the projection of quantum gravity, string theory, from the 4D bulk (we are the hologram on the credit card).



The origin of space and time

In principle, a true “theory of everything” should tell us the nature of space and time.

String theory assumes the existence of 10 dimensional spaces and time, so the fundamental question of how and why space and time exist remains elusive.

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?

Interactions in particle accelerators could be different if some energy disappears into the 4D bulk.

The Large Hadron Collider (LHC) CERN, near Geneva, will begin to operate in 2009. Strong expectation that evidence for new physics, confirming or denying string theory ideas, will be seen.

Take Away Message:

Hyperspace might be real…

Stay tuned!

(and remember to keep an eye on Betelgeuse!)