Monday, May 4, 2015

Exam 5, Sky watch 5 on Friday, May 8.

Review sheet posted today.

Review Session Thursday 5 – 6 PM, RLM 6.104



**Electronic class reviews now available.** Please respond. We find the feedback very valuable.

Fifth exam and sky watch, FRIDAY, May 8. 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 (abbreviated); Chapter 14 - all

Astronomy in the news?

After four years of improving our understanding of the planet closest to the sun, on April 30 NASA's MESSENGER probe smashed into Mercury's surface.

### 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 Einstein's theory predicts worm holes and time machines and how we need a theory of quantum gravity to understand if those are really possible.

# Wormholes (Chapter 13)

Serious physics lesson - leads to need for quantum gravity

Wormhole - connection from one place in 3D space to another (through hyperspace? Do not need to know to construct 3D solution to Einstein's equations, but implicitly, yes)

Result - highly curved space, but no event horizon, no singularity

Use 2D Embedding Diagram to help picture what is going on in 3D space (balloon: but can't connect, would need to tear rubber and reconnect)

Backstory: Sagan/Thorne CONTACT

Carl Sagan wanted "connection" through Einstein-Rosen Bridge



Kip Thorne - Jodie Foster will die a screaming death by noodleization in singularity - no good. He worked out a new theory.



Could open a "mouth" to make a worm hole, but would be unstable, would slam shut.

In principle, could stabilize with "Exotic Matter," anti-gravity stuff like Dark Energy.

Not ruled out by physics - good enough for Sagan, book and film

Thorne teamed up with producer of Contact, Lynda Obst, on *Interstellar*, that invoked a wormhole.





2D Analogy -Embedding Diagram

Can go "through" wormhole, but also once deep inside can turn "sideways," parallel propagate return to point of origin



Figure 13.1 In principle, a light beam would travel "around" the interior of a worm hole. You could also see through the wormhole.

One Minute Exam

If I flew straight into a worm hole and once inside turned at 90 degrees and kept flying as straight as I could, I would

Emerge from the other mouth of the worm hole

Run into myself

Be in hyperspace

return to the point where I made the turn

# Goal:

To understand how Einstein's theory predicts worm hole time machines.

Thorne went on to study worm holes (Thorne - Black Holes and Time Warps: Einstein's Outrageous Legacy)

#### Worm holes are automatically time machines!

Igor Novikov elaborated (Novikov - The River of Time)

Twin paradox - twin who accelerates out and back in space will be younger than the twin who stays behind (special relativity).

Do this (conceptually) with one mouth of a worm hole or lower one mouth into strong gravity where time runs slower.

Time "connects" differently through the wormhole and in the surrounding space - one mouth is "younger"

Can, in principle, travel back in time (but not before the time the machine is constructed)

Go in one mouth, come out in the past, go around in normal space, meet yourself before you go in.

Time travel paradoxes - Grandfather Paradox, Self-suicide

Pool Ball Paradox (purely mechanical, get people, intention, and will out of the analysis) - fire pool ball through time machine to deflect itself before it went in so could not have deflected

Novikov - there is no paradox - Physics always works out so that a paradox is avoided

Pool ball just nicks, Grandfather ducks.

*Novikov Consistency Conjecture:* physics will arrange itself so that there is no time-travel paradox - you cannot travel back in time and kill yourself before you enter the worm hole/time machine. You cannot change the future.

Back to the Future films

Terminator films

Consistent or not with the Novikov Consistency Conjecture?

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?

One Minute Exam

The Novikov Consistency Conjecture says:



Worm holes cannot lead to the past

Worm holes cannot exist



Worm holes cannot lead to time travel paradoxes

# Goal:

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

#### String Theory

Best current candidate for a quantum gravity "theory of everything."

String theory is a quantum theory, but it also intrinsically contains curved surfaces.

Particles like e-, p, n are not "points" but strings, otherwise identical loops of energy 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

From Brian Greene - The Elegant Universe





#### A different particle



#### Same fundamental loop of string

From Brian Greene - 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 spatial dimensions "wrapped up" on "string length scale," not known precisely, somewhat larger than the Planck scale on which Einstein's gravity and quantum theory contradict one another, but very tiny (vastly smaller than a proton) so we cannot easily "see."



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 Greene - 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 Greene:The Elegant Universe