ARTSSCI 2D06 – Outline of missing lectures on General Relativity (GR)

(Cf. Giancoli, Section 44-4)

(*Note*: Inquiry questions will not be handed in or marked)

Einstein's motivation for GR

Extension of Special Relativity to non-inertial frames

Starting point: Equivalence Principle

Connection between gravity and accelerated reference frames

Prediction: Light travels along curved paths

Cf. Newtonian gravity: Light/photon travels in straight lines since it's massless

In GR: A new "visual metaphor" for gravity

Einstein:

Equivalence Principle leads to the mathematical requirement that space is "curved" by a source of gravity (e.g., Earth). (Technically, it's space-time that's curved.)

➔ "Space is a flexible fabric" curved by matter; objects – and light – respond by moving along curved paths, or "contour lines" of curved space.

To help with visualization: https://www.youtube.com/watch?v=uwtJaQyXpQs

Compare with Newtonian "metaphor": gravity as force between objects with mass

How to test GR's bending-light prediction?

Inquiry question: Estimate how much the light beam falls as it crosses the width of an elevator. Is this measurable? (Assume that the light is shone horizontally and then "falls" with an acceleration of *g*.)

Inquiry question: How would you increase this effect to measure it?

Prediction verification (1919):
https://www.aps.org/publications/apsnews/201605/physicshistory.cfm

https://www.youtube.com/watch?v=vF4DENWd_ts

Another GR prediction: Black holes

GR: Object's path curves more strongly if it passes closer to mass M and if M is made more massive

If M is very large and if light passes by very closely, the latter can get trapped.

From GR, one can derive an equation for the black hole's Event Horizon: $R_s = 2\ G\ M / c^2$

G is Newton's gravitational constant and c is the speed of light.

No escape from black hole if $r < R_s$

R_s also known as the Schwarzschild radius of the black hole of mass M.

Implications:

A mass compressed down to within its Schwarzschild radius becomes a black hole

Inquiry question: Calculate the Schwarzschild radii for the earth and the sun.

What's your own R_s?

The mass itself collapses into a point called the "singularity" of the black hole.

Nothing inside can escape – not even light!

Do black holes exist? If so, where? If light can't escape from them, how do we "see" them?

e.g., check out: https://chandra.harvard.edu/blackhole/

https://www.youtube.com/watch?v=S_GVbuddri8

Another GR prediction, recently verified: Gravitational Waves

Check out:

https://perimeterinstitute.ca/videos/janna-levin-black-hole-blues-and-other-songs-outer-space

https://www.youtube.com/watch?v=iphcyNWFD10

GR has passed every experimental test to date!