

Friday, April 4, 2014

Exam 4, Monday, April 14

Review Thursday, April 10 by Jacob, 5:00 PM, RLM 7.104

Wheeler expanded office hours, afternoon, Friday, April 11

Reading for Exam 4: Chapter 8 - Sections 8.1, 8.2, 8.5, 8.6, 8.10;  
Chapter 9: all except 9.6.3, 9.6.4

Astronomy in the news:

Saturn's moon Enceladus has a huge lake buried under miles of ice, but squirting plumes of water and ice into space. This might be the best place to look for life elsewhere in the solar system.

Update on new “nearby” supernova SN 2014J in M82

Nothing to Report

Lots of papers in preparation

# New Topic: Black Holes

Chapter 9

Reading, Chapter 9: all except 9.6.3, 9.6.4

## Goal:

To understand the historical roots and basic theoretical concepts behind black holes and the huge conceptual differences between Newton's and Einstein's view of gravity.

# Black Holes

Mitchell, Laplace, late 18th Century: with Newton's Gravity could have bodies with **escape velocity** greater than the speed of light => light could not get out, completely dark, *corps obscurs*.

Now know Newton was wrong.

Excellent approximation for weak gravity - “true” in that case

Conceptual problems  $F = \frac{G M_1 M_2}{r^2}$

infinite force for zero separation

instantaneous reaction => infinite speed of gravity

In physics infinity => problem

Experiment – Newton's theory predicts the wrong deflection of light.

Need Einstein and more!

# *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

## Goals:

To understand how Einstein taught us to think about space, time, and gravity.

To understand what we mean by space.

To understand how space can be curved.

# SPACE - *The Final Frontier*

***Dimensions*** - defined by the number of mutually perpendicular directions

0 D - point

1 D - line

2 D - area

3 D - volume (secret hand sign)

4 D - ?

Hyperspace - space with more dimensions than the one under consideration



# Gravity

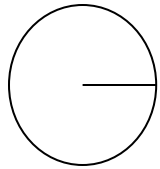
Still a deep mystery. Objects of different mass fall with the same acceleration.

Explore how Einstein taught us to think about gravity: no *force of gravity*, but the effect of *curved space*.

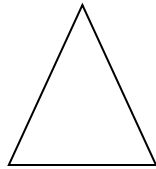
Explore the geometry of space with straight lines.

Straight line on a curved surface, possible or an oxymoron?

## Euclidian - Flat Space Geometry



$$C=2\pi r$$



$$\Sigma=180^\circ$$



never cross

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

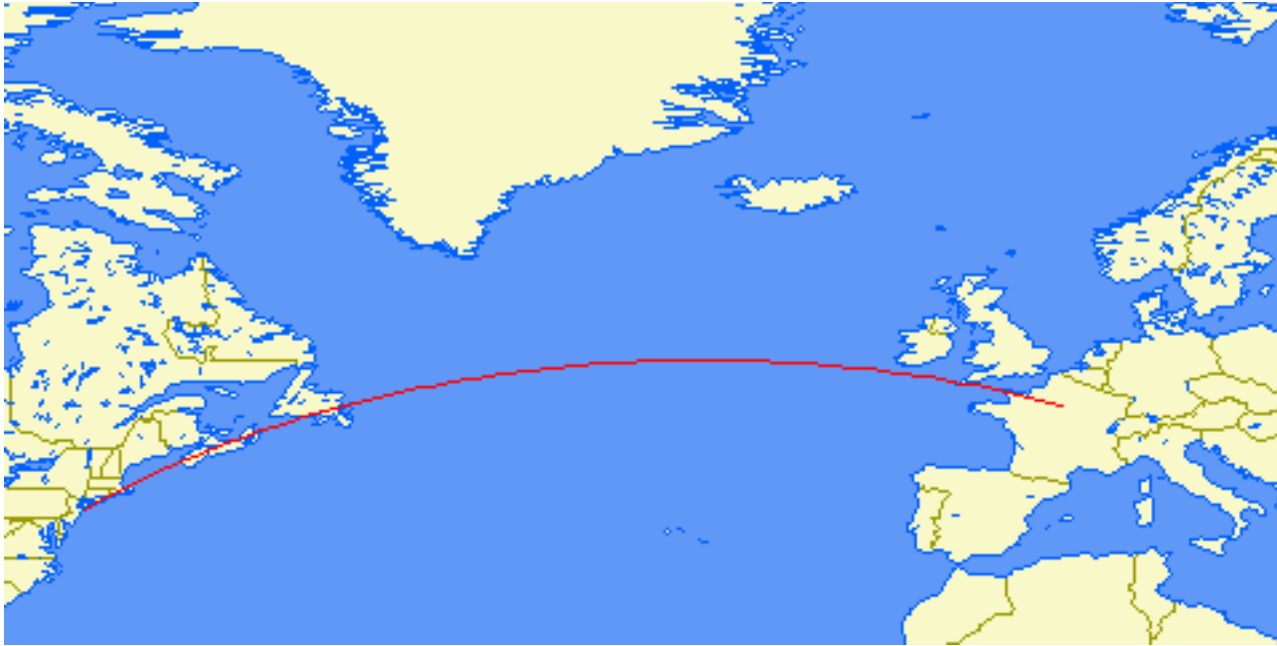
Shortest distance between 2 points - rubber band

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*.



Route from JFK airport to Paris Orly.

Is this a straight line?