Wednesday, April 9, 2014

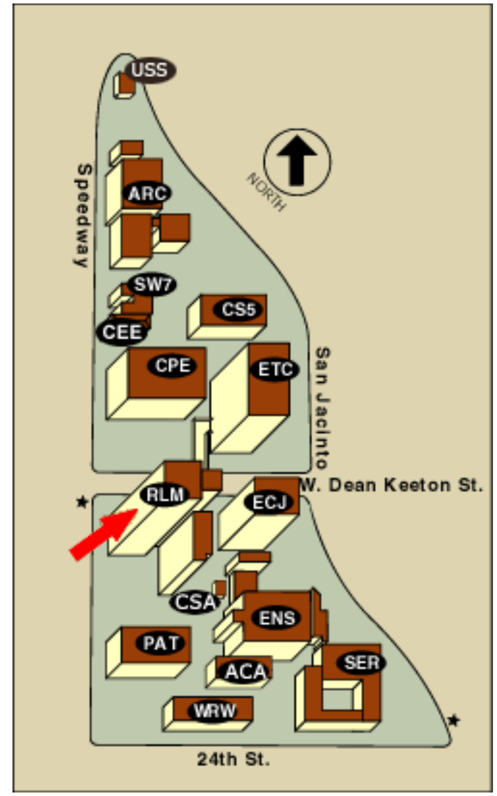
Exam 4, Skywatch 4, Monday, April 14

Review sheet posted

Review Tomorrow 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 – Sections 9.1 – 9.5 (NOTE not all of Chapter 9).



Astronomy in the news:

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

Nothing to Report

Lots of papers in preparation

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.

Embedding diagram:

Real Space	->	Embedding Diagram Space
Volume (3D)	->	Surface (2D)
Surface (2D)	->	Line (1D)
Line (1D)	->	Point (0D)

Invert balloon - 2 D embedding diagram of curved 3 D space around gravitating object

Properties of this curved space that are preserved in the embedding diagram:

$C < 2\pi r$

Sum of angles of triangle not equal 180° (can be $>$ or $<$)

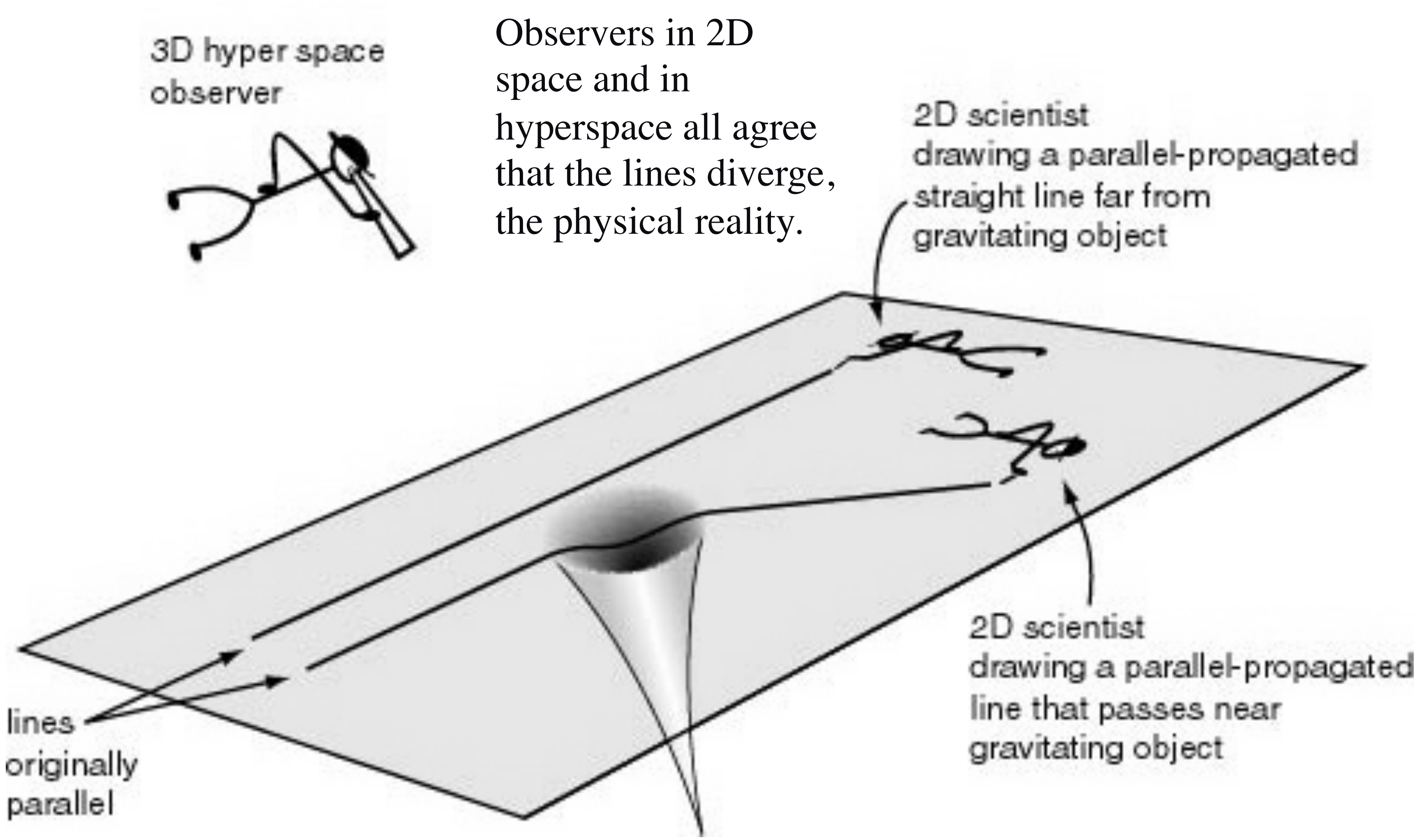
Parallel lines diverge or cross

Orbits around “cone”

Far from a gravitating object, the curvature and hence gravity, gets very weak, 3D space becomes FLAT, and the corresponding embedding diagram is a flat 2D plane (can’t show this with the balloon).

Figure 9.4

Observers in 2D space and in hyperspace all agree that the lines diverge, the physical reality.



Straight lines in the 2D embedding diagram of curved, gravitating space.

One Minute Exam

In the corresponding two-dimensional embedding diagram, the interior volume of a real, three-dimensional planet would be represented as:

➡ A point

⬅ A line

⬆ An area

⬇ A volume

One Minute Exam

In a two-dimensional embedding diagram of the Earth, the surface of the Earth would be represented by:

➡ A volume

⬅ A surface

⬆ A line

⬇ A point

Goal:

To understand what Einstein means by an orbit.

Orbit - circle around “cone”

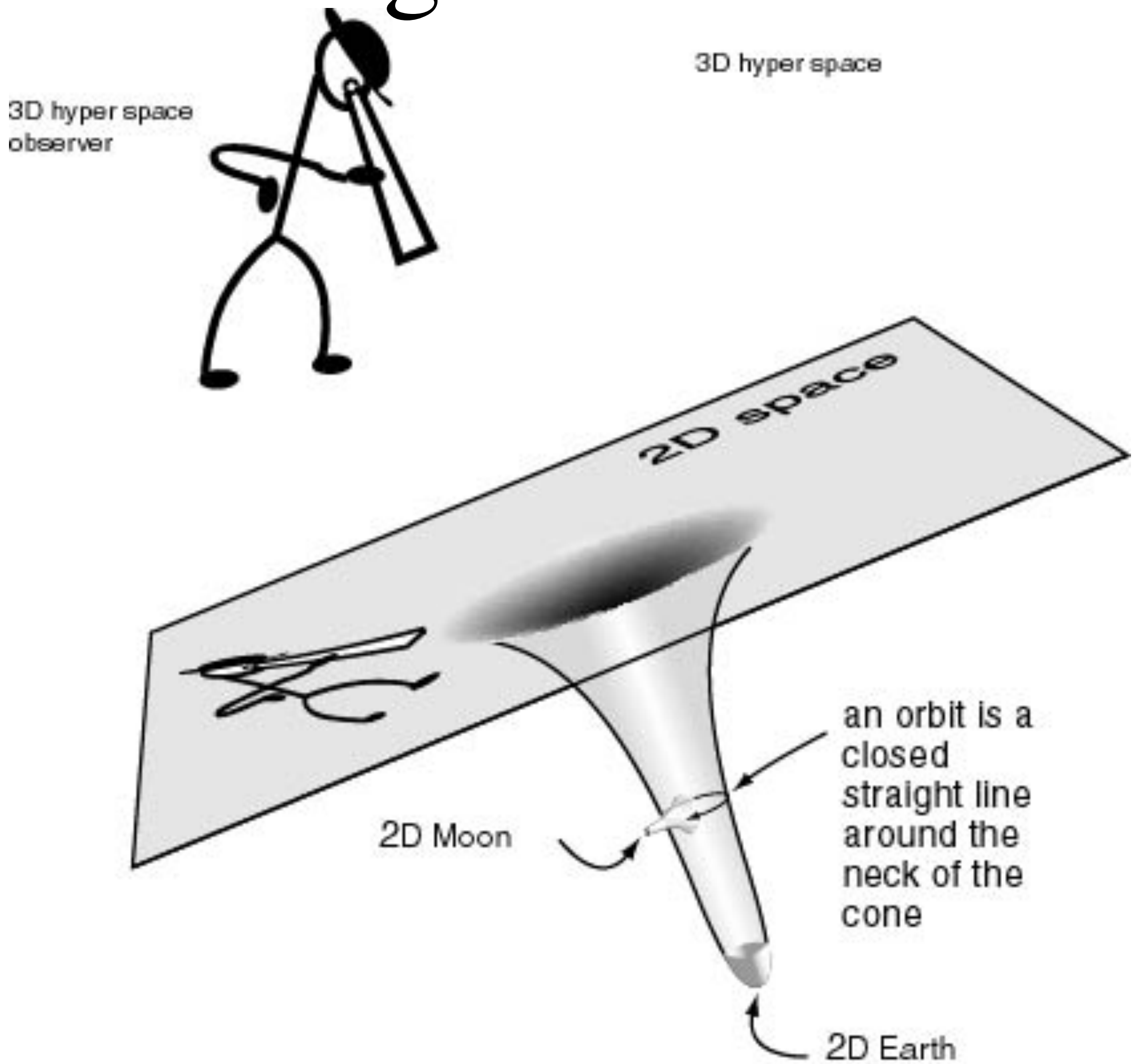
Moon is going as straight as it can in curved space around the Earth

This is how gravity works for Einstein - no Newtonian Force -

Gravitating objects curve the space around them - nearby objects move in that curved space

The parallel-propagated straight lines of their force-free motion are warped by the curved space.

Figure 9.5



Orbits in curved 2D embedding diagram of gravitating space

One Minute Exam

An astronomer fires two laser beams so they will pass near a distant black hole. The beams are initially parallel. An astronaut on the far side of the black hole tracks the two beams and finds that they are diverging, but that they never crossed. This means that:

→ one of the beams entered the black hole

← the beams passed on opposite sides of the black hole

↑ the beams passed on the same side of the black hole

↓ one of the beams had more energy than the other

Goal:

To understand the “real” curved space of a gravitating object in three dimensions

3 D gravitating space is not a "cone;" that is just an artifact of the 2 D embedding diagram.

Real 3 D space around gravitating objects has the properties:

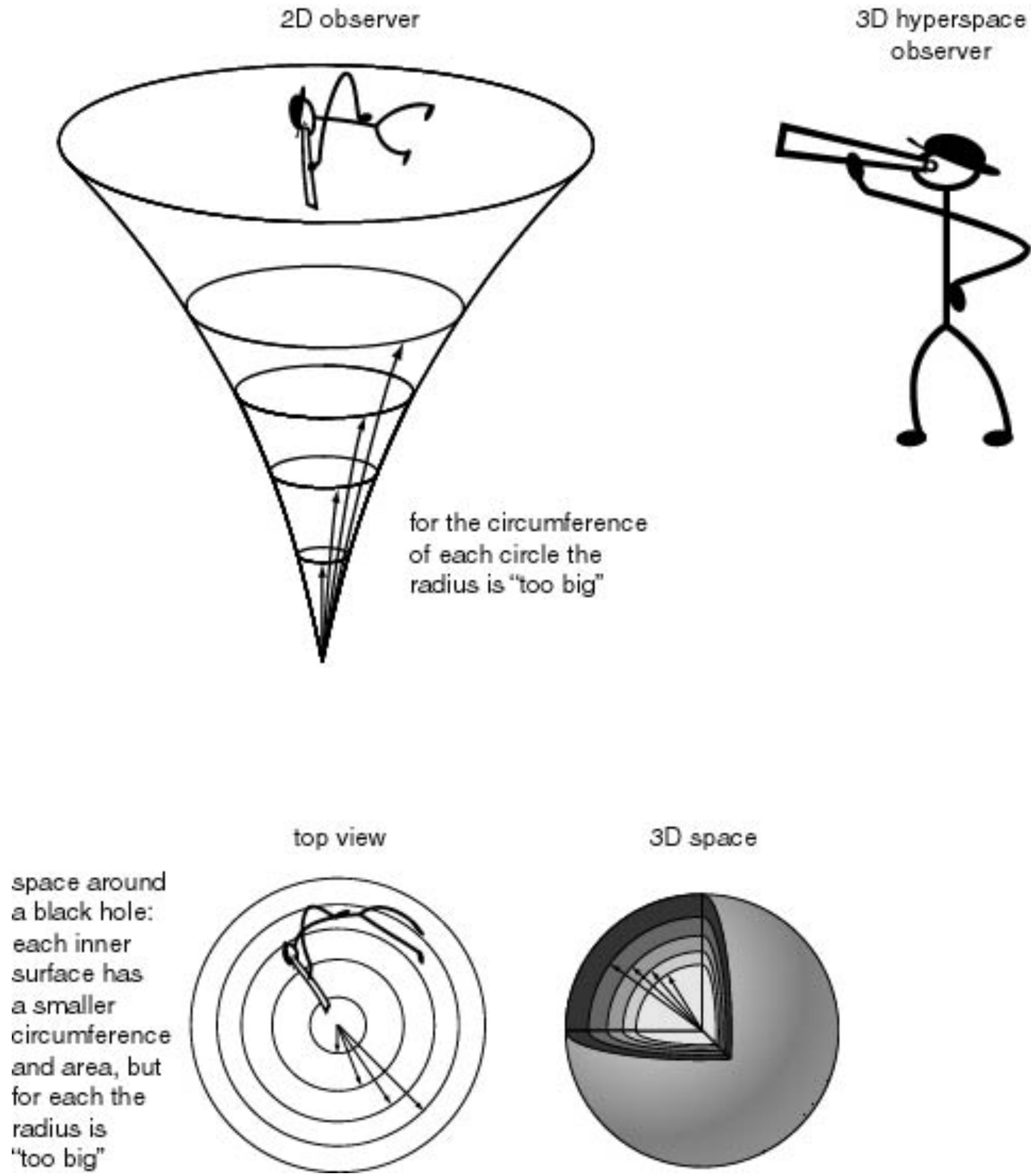
$C < 2\pi R$

Δ not equal 180°

// lines cross or diverge

light is deflected (this one has been experimentally verified)

Fig
9.6

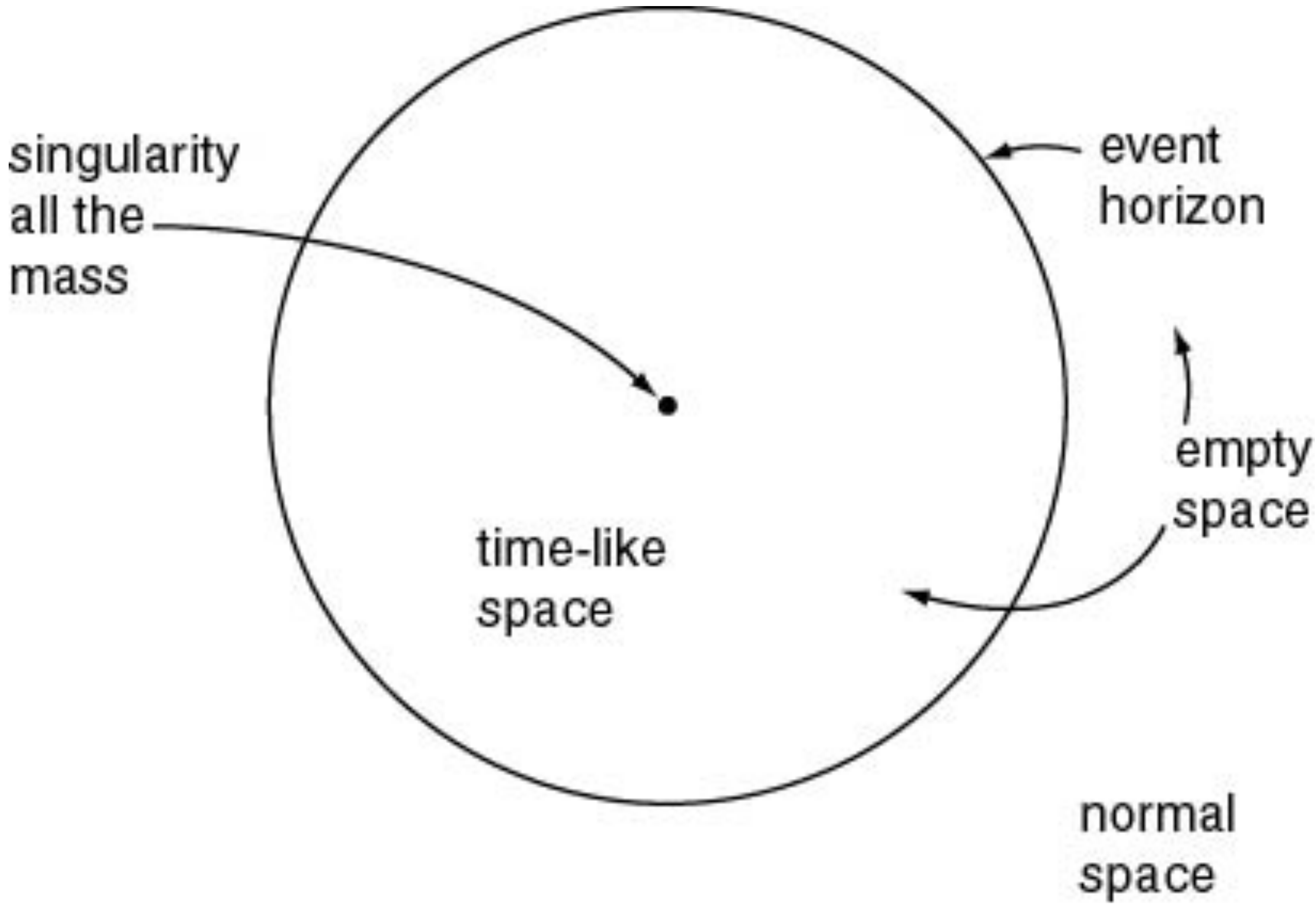


Curved
3D
space

Goal:

To understand the basic features of a black hole

Figure 9.1



Basic properties of a (non-rotating) black hole

In Einstein's theory of gravity, black holes are predicted to have an *event horizon* and a *singularity*

Event horizon: the surface within which nothing travelling at or less than the speed of light can get out.

=> No event within the event horizon can be witnessed from outside

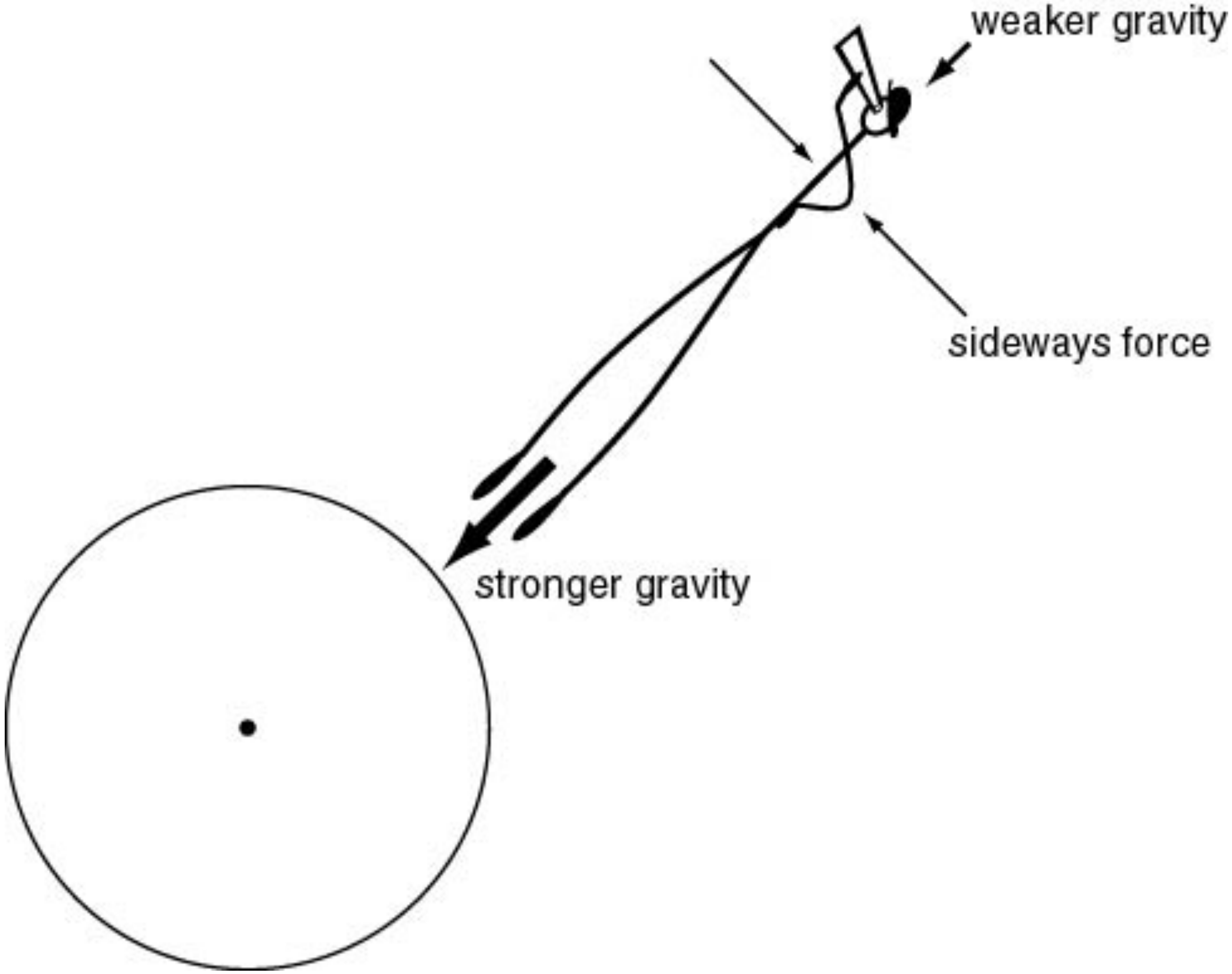
Singularity: Finite mass, zero radius, zero volume

=> infinite density, infinite tidal forces, the end of space and time.

Goal:

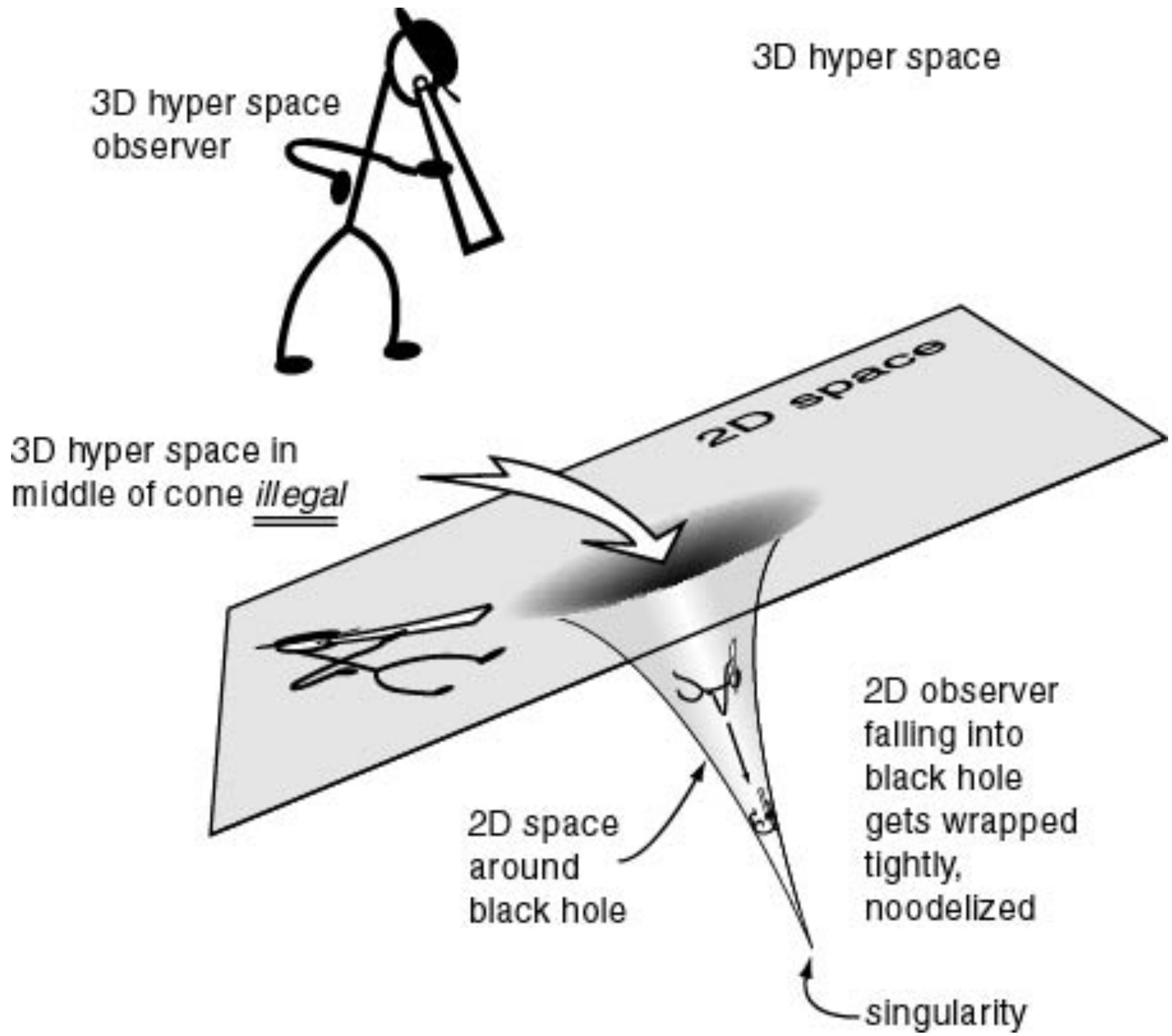
To understand what it is like to die falling into a black hole.

Figure 9.2



Tidal Forces

Figure 9.3



2D embedding diagram of 3D curved space around a black hole