Wednesday, April 13, 2016

4th Exam, Skywatch, Friday, April 15

Review sheet posted

Review Session Thursday, 4:30 – 5:30 PM, RLM 15.216B

Reading for 4th exam:

Chapter 8 Neutron Stars - Sections 8.1, 8.2, 8.5, 8.6, 8.10

Chapter 9 Theory of Black Holes: 9.1 to 9.5

Office hours at 3 and 5.

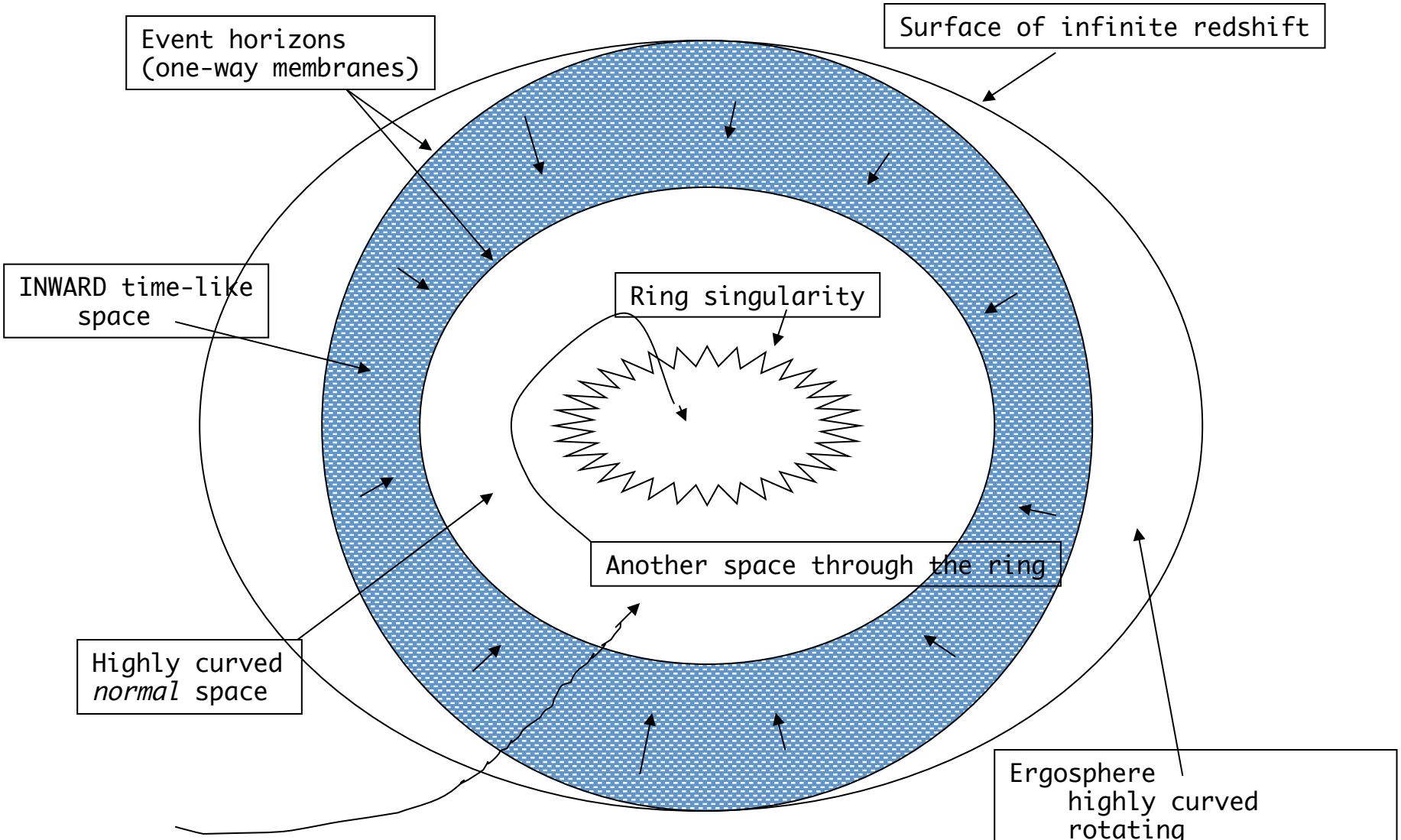
Astronomy in the news?

Russian billionaire, Yuri Milner, Stephen Hawking, and others propose swarm of small, light weight satellites powered by lasers to explore interstellar space. Laser reflection to reach 1/5 the speed of light in 2 minutes! Iphone brains. Laser needs some work…

Goal:

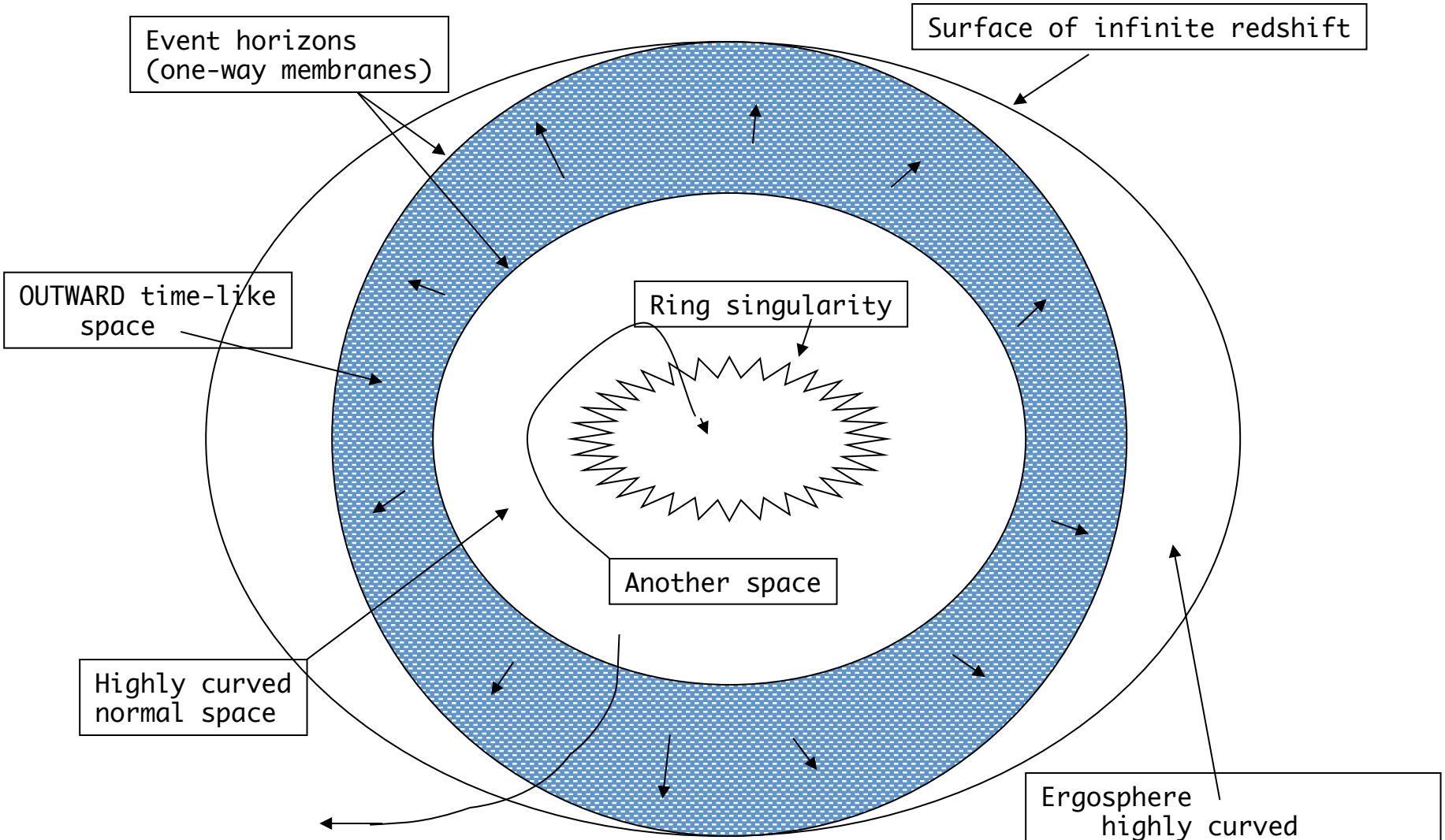
To understand the full space-time associated with rotating black holes.

Cross-sectional view of rotating Kerr black hole



Fly in, never to return

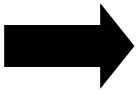
In future



Access to Universe different
than original one

One Minute Exam

In the mathematical solution for a rotating black hole:



The surface of infinite redshift is identical to the event horizon.

You can escape the black hole back to the universe from which you entered.

There are exactly two universes.

The space entered through the ring singularity is different than the space surrounding the singularity.

Are different universes in Schwarzschild and Kerr solutions to non-rotating and rotating black holes real?

In Real Universe:

Light (at least!) falls into the black hole

Photons are Doppler blue shifted, accelerated to higher energy, =>the energy/mass warps the space and changes the mathematical, hence the physical solution

So, probably not in this case, but stay tuned…

The story so far:

Look up at the sky and wonder about the stars.

Betelgeuse is a red supergiant about to collapse.

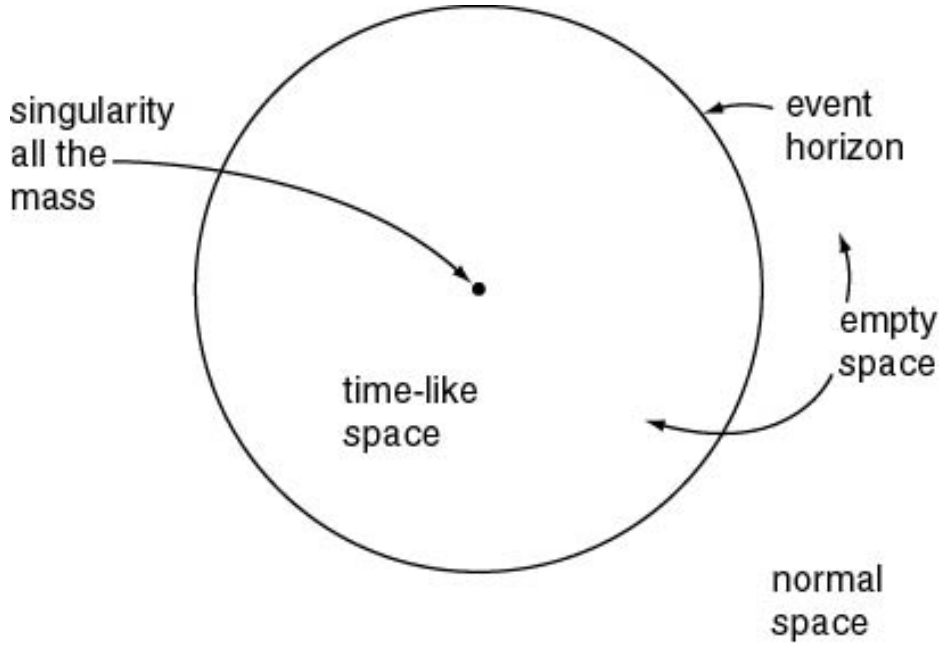
Collapse can lead to supernova explosions and the production of neutron stars, but also of black holes.

Black holes are predicted by Einstein to have a singularity, infinite density, infinite tidal forces, the end of space and time.

We need a new all-embracing Quantum Gravity to know what the “singularity” really is.

Goal:

To understand the conflict between Einstein's theory of gravity and the Quantum theory.



Einstein's theory does not incorporate any of the tenets of the quantum theory.

Singularity - all the mass is in a zero volume point in Einstein's theory.

Violates the Uncertainty Principle of Quantum Theory: cannot specify the position of anything exactly.

Need theory of ***Quantum Gravity*** to rectify, to understand what the "singularity" really is. **Deepest issue in modern physics**.

Goal:

To understand how Stephen Hawking added some quantum theory to Einstein's theory and revolutionized our understanding of black holes.

Black Hole Evaporation
Hawking Radiation - Chapter 9 § 6

Nature of vacuum in Quantum Theory - cannot specify the energy of anything precisely, even "zero" in a vacuum:

Vacuum "boils" with creation/annihilation of particles/anti-particles
easiest to make photon = anti-photon (no mass)
but also $e^- e^+$, $p^+ p^-$, neutron anti-neutron, neutrino anti-neutrino
=>affects behavior of electrons in atoms - *measured to high accuracy*

Quantum Fuzzy Event Horizon - at the event horizon, the position of the event horizon and of particles is *quantum uncertain*

One particle in a pair can be swallowed, the other escapes - carries off mass, energy - pure quantum effect.

Black holes are not just one-way affairs, with quantum effects they will lose mass and energy - Stephen Hawking's dramatic discovery.

Hawking Radiation

Loss of energy is not arbitrary, it may come out in a very precise form…

According to Hawking, Black Holes radiate *Hawking radiation* as if they had a precise temperature that depends (inversely) on the mass.

Black holes are not totally black

Given enough time, black holes will evaporate!

Hawking Radiation

If the black hole has the mass of a star, the time to evaporate will be ***much*** longer than the age of the Universe, so unimportant in practical terms.

If the black hole has the mass of a mountain or asteroid, it can evaporate in the age of the Universe (13.8 billion years).

As mass $\downarrow$ T $\uparrow$

With energy loss, less mass, hotter, more radiation. Runaway process.

Small mass black holes can disappear within the age of the Universe, ending in a final explosion of gamma-ray radiation.

Theories that mini-black holes might be created in the Big Bang (but no hint in any observation).

§ 9.7 Fundamental Properties of Black Holes

According to Einstein, the fundamental properties of black holes are electrical charge (usually taken to be zero), mass, and spin (angular momentum).

All other properties, radius of event horizon, Hawking temperature, come from that.

They have no other properties like mountains, structure, chemical composition, DNA,

Not even the number of protons, electrons and neutrons that fell in
=> *profound information loss*.

Thought experiment: one neutron star, one anti-neutron star.

Neutron star + Anti-neutron star => gigantic explosion!

Black Hole + Black Hole => One large Black Hole

Black holes transcend ordinary physics of matter/anti-matter