Tuesday, April 7, 2009

Third Exam, Thursday, April 16. Neutron Stars and Black Holes

Astronomy in the News:

International Year of Astronomy, 100 hours of astronomy

Pic of the Day - colliding spiral galaxies in the Virgo cluster of galaxies. Black holes in their centers may merge.

Falling According to Einstein

According to Einstein - curved space around gravitating objects "flows" inward - ***inward escalator.***

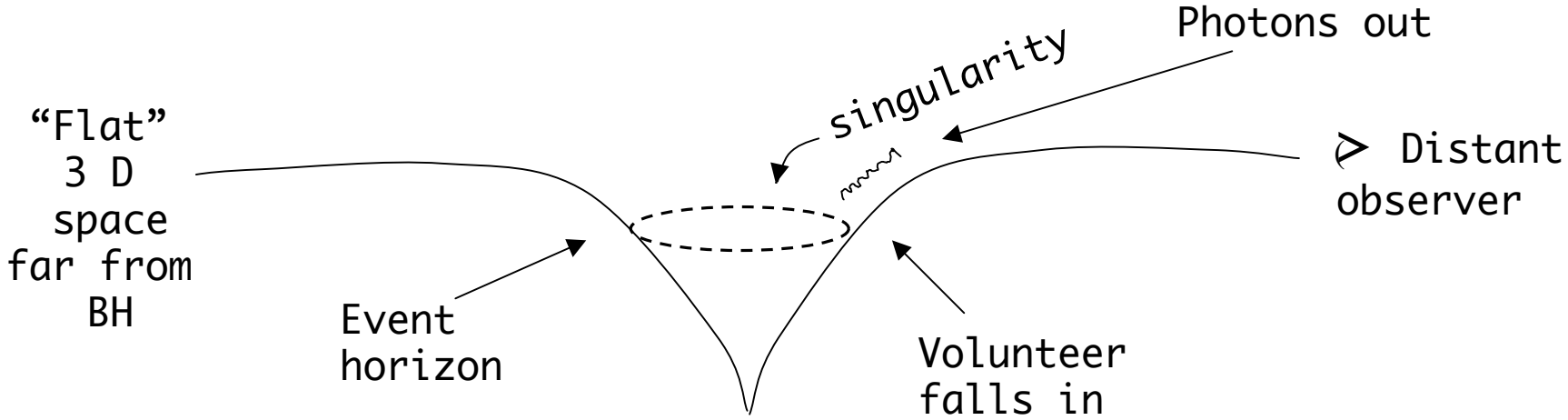
If an object floats with ***no force*** in space (free fall), it will move toward the center of gravitation

$\Rightarrow$ falling - all objects respond to the same curvature, have the same acceleration

Like water down a drain - sit still in the water, but go down the drain.

Must exert a force to resist, to avoid free fall, to avoid the flow of space inward toward the center of the gravitating object.

Specifically for Black Holes



Volunteer finds herself rapidly falling through event horizon, noodleized, dies

Distant observer sees Doppler and gravitational redshifts

Received photons get longer, longer wavelength

Time between photons gets longer and longer

Infinite time for last photon emitted just as volunteer reaches the event horizon; space is moving inward at the speed of light compared to distant observer

⇒***Distant observer never sees volunteer cross the horizon***

⇒***Photons get undetectable, very long wavelength, most of the time is between photons - absolutely black*** **- why black holes are black.**

One Minute Exam

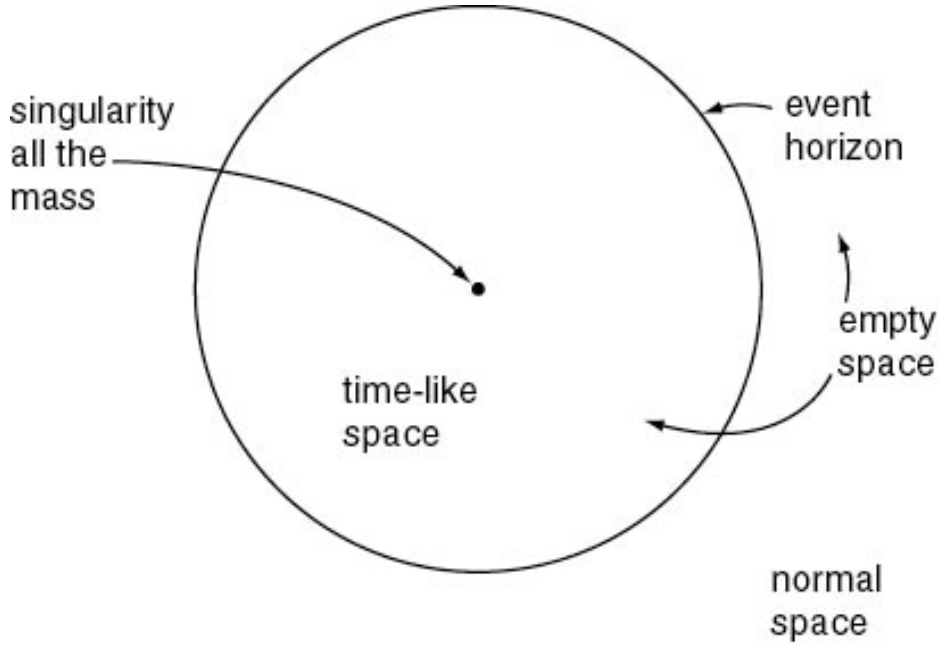
From the point of view of a distant observer, a volunteer who falls into a black hole

A) Will be noodleized and die

B) Will turn black before arriving at the event horizon

C) Will age more rapidly

D) Will shrink to a point



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**.

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

affect 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 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 comes out in a very precise form…

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 (13.7 billion years).

As mass $\downarrow$ T $\uparrow$

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

Small mass black holes can explode, disappear within the age of the Universe.

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

§ 7 Fundamental Properties of Black Holes

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.

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.

$n + \bar{n} \longrightarrow$ explosion

↘ 2 BH -> One large Black Hole

Black holes transcend ordinary physics of matter/anti-matter