11/5/07

Exam 3 this Friday, November 9, Chapters 8 and 9

Review sheet posted

Review session, Thursday, November 8, 5:00 PM
Room CPE 2.220 NOTE DIFFERENT ROOM!!

Reading:Chapter 8, Sections 8.1, 8.2, 8.5, 8.6, 8.7, 8.10, Chapter 9

Astronomy in the News - successful Space Station solar panel repair

Pic of the day - Comet Holmes grows a tail - wafted in solar wind.

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

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

One particle in pair can be swallowed, 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.

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 ↓ T ↑

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

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

Theories that mini-black holes might be created in the Big Bang (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, DNA,

Not even 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

$\searrow$ 2 BH -> One large Black Hole

Black holes transcend ordinary physics of matter/anti-matter

Information Loss??

Deep issue.

What happens to the ***information*** about all the stuff that fell into the black hole?

Quantum theory insists there must be no loss of information.

Maybe it is in the radiation (Hawking) or maybe it is still somehow in the singularity (string theory).

Does the singularity evaporate and disappear? Don’t know in absence of theory of ***Quantum Gravity***

One Minute Exam

According to Stephen Hawking:

A) Black holes are totally black

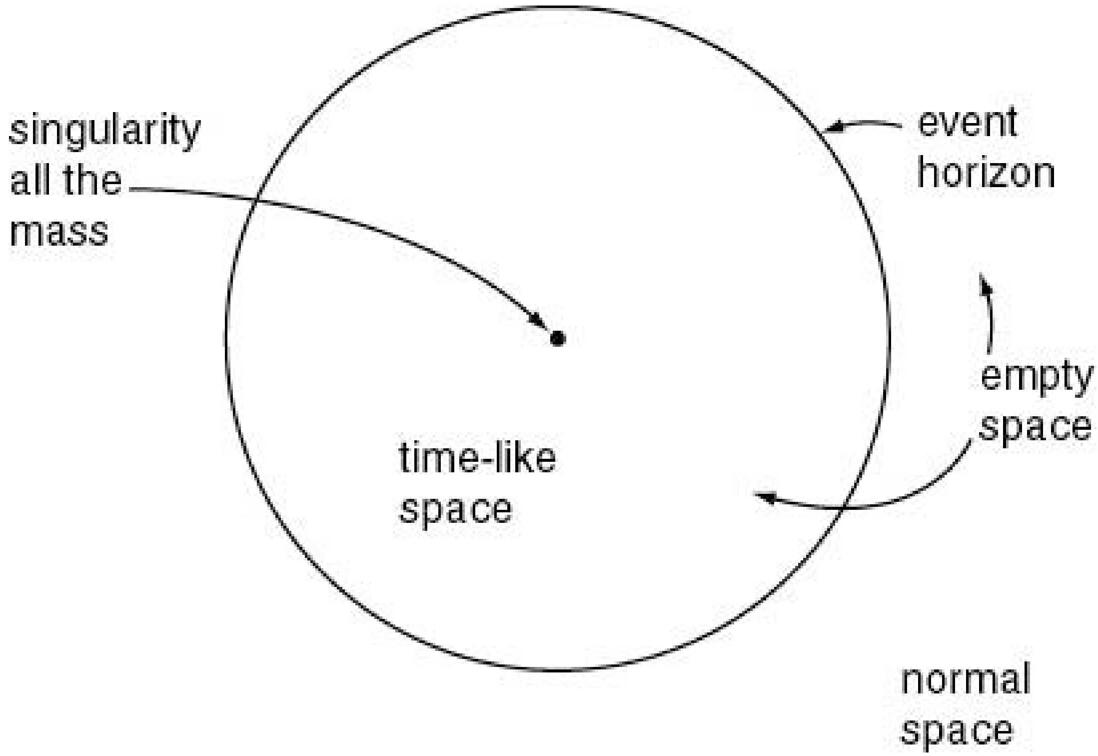
B) Combining a neutron star and an anti-neutron star will make a black hole

C) A singularity is a point

D) Black holes can explode

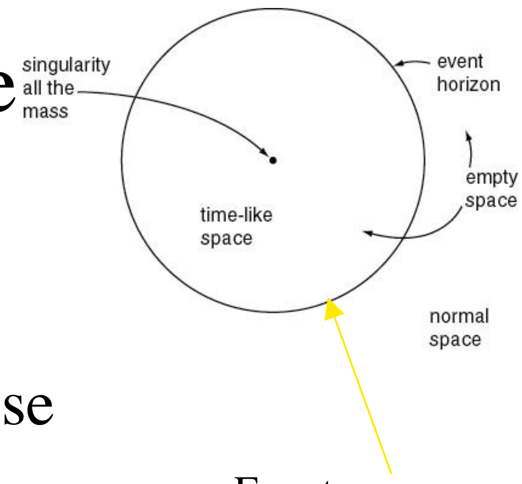
§ 8 Time-like Space

Figure 9.1



"Time-like" space forces motion in one direction. Space moves faster than the speed of light compared to a distant observer; the real reason black holes are black.

Non-rotating Schwarzschild Black Hole



Mass, but no spin, no electrical charge

Assume all mass in singularity, no mass anywhere else (assumption necessary to solve equations)

Event horizon is also surface of infinite redshift

Find two Universes, each of infinite space, connected at one instant by singularity.

Cannot pass from one to the other if travel at less than the speed of light