

4/10/06

Exam results back Wednesday

Exam 4, Friday, April 28

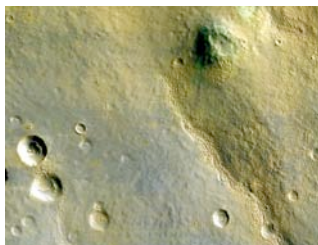
Final, Saturday, May 13, 2 - 5 PM Comprehensive

Wheeler in College Station T, Th, Cosmology Symposium,
Lisa Randall, inventor of idea of large extra dimensions

Betelgeuse

News: Venus Express, launched by
European Space Agency goes into
orbit around Venus tomorrow.

Pic of the day; **Mars: The View
from HiRISE**



Black Hole Evaporation Hawking Radiation § 6

Quantum Fuzzy Event Horizon

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

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***

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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 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

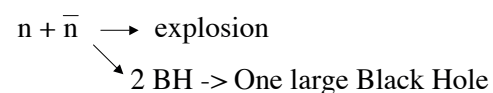
The fundamental properties of black holes are electrical charge (usually taken to be zero), mass, and spin (angular momentum).

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.



Black holes transcend ordinary physics of matter/anti-matter

Hawking Radiation

Information Loss??

Deep issue.

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

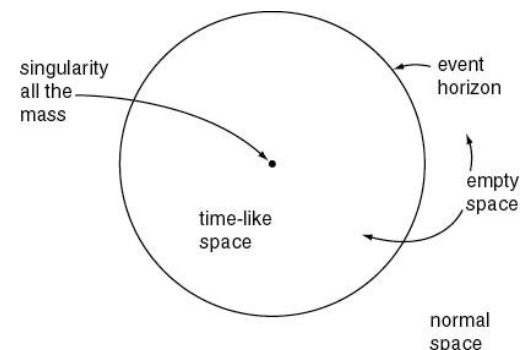
Quantum theory insists there must be no loss of information.

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**

§ 8 Time-like space

Figure 9.1



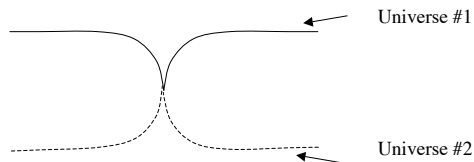
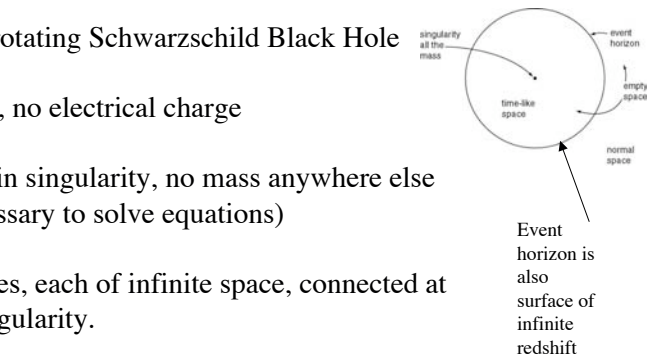
Non-rotating Schwarzschild Black Hole

Mass, but no spin, no electrical charge

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

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



Rotating Kerr Black Hole

Mass and spin, but no electrical charge

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

Find *singularity is a ring* (not a point)



0 thickness, ∞ density, still uncertainty problem

Infinite Universes!

Cross-sectional view of rotating Kerr black hole

