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

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**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 \( \downarrow \) \( T \uparrow \) 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.

\[ n + \bar{n} \rightarrow \text{explosion} \]

\[ 2 \text{BH} \rightarrow \text{One large Black Hole} \]

**Black holes transcend ordinary physics of matter/anti-matter**

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**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

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§ 8 Time-like space

Figure 9.1

**Black holes transcend ordinary physics of matter/anti-matter**
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)

Singularity is a ring (not a point)

0 thickness, \( \infty \) density, still uncertainty problem

Infinite Universes!