March 31, 2010

Reading: 9.5.2, 9.6.1, 9.6.2, 9.6.3, 9.7, 9.8.

Astronomy in the News? Large Hadron Collider at CERN in Switzerland fires up proton collisions. Will seek tiny black holes, the conditions in the first trillionth of a second of the Big Bang and extra dimensions. Picture above the fold on the cover of the New York Times.

Reflected light from Cas A shows that the spectrum is different from different angles - proof of non-spherical explosion

New evidence for asymmetry in SN 1987A in the flow of matter.

Pic of the Day - Globular star cluster Omega Centauri, may be left over of ancient dwarf galaxy that merged with the Milky Way.

The story so far:

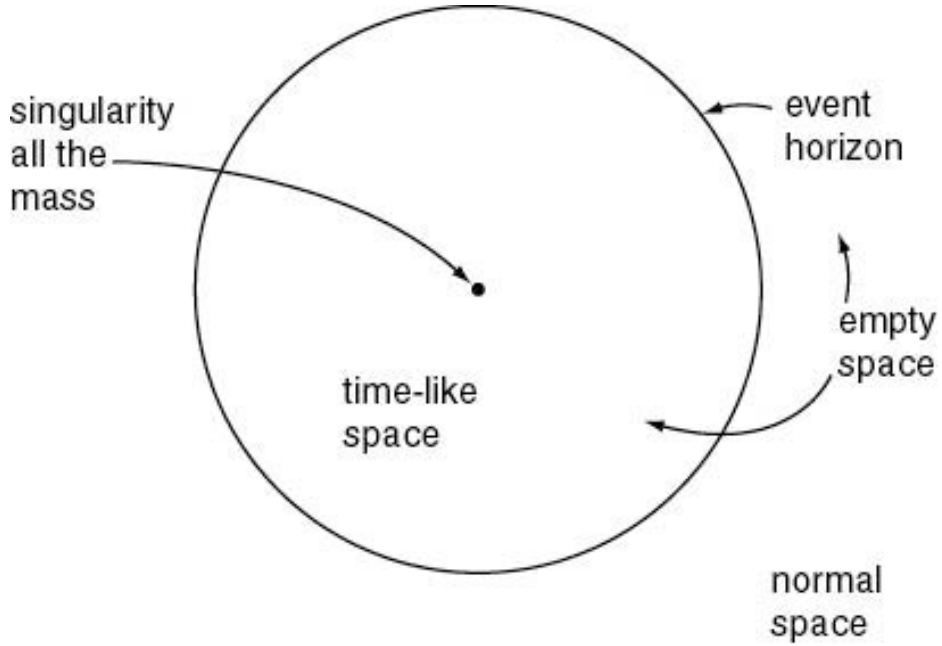
Look up at the sky and wonder about the stars.

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 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.



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

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).

Goal:

To understand the basic properties of black holes and why their simplicity is a great challenge to quantum theory.

§ 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.

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.

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

↘ 2 BH -> One large Black Hole

Black holes transcend ordinary physics of matter/anti-matter

Information Loss??

Black holes have only three fundamental properties: mass, spin, and electrical charge (= 0 in practice)

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 a theory of ***Quantum Gravity.***

New book by Leonard Susskind - Black Hole Wars, will discuss later. You may be a hologram…

One Minute Exam

According to Stephen Hawking:


Black holes are totally black


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


A singularity is a point

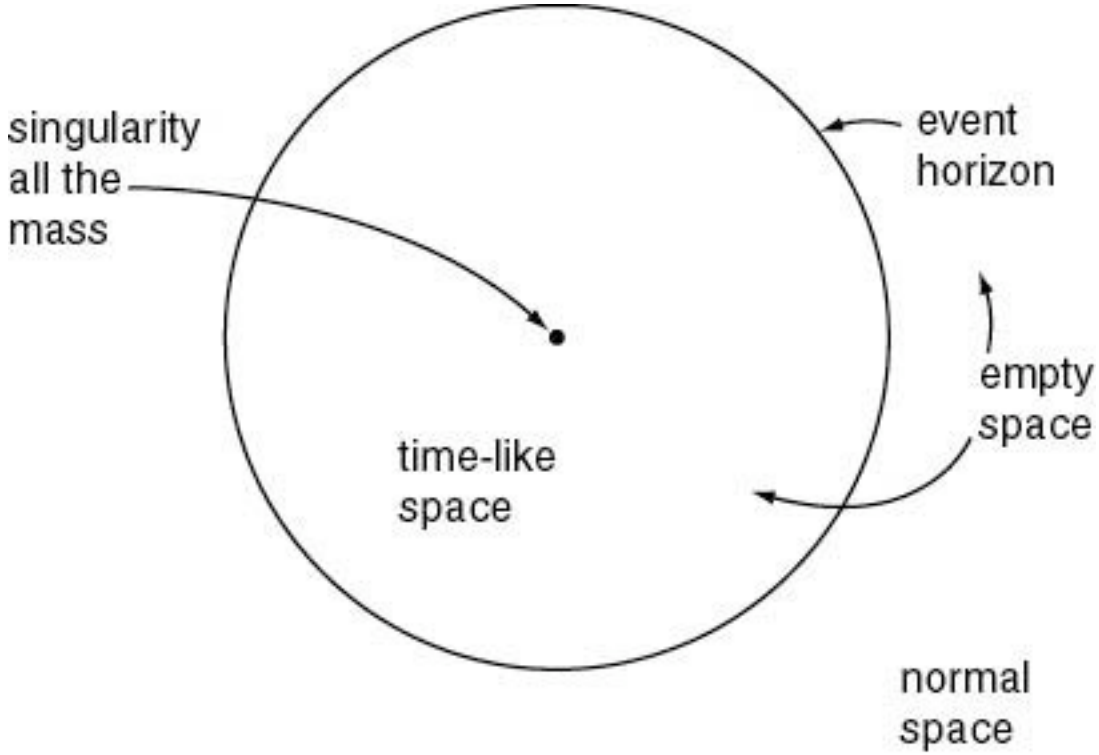

Black holes can explode

Goal:

To understand the nature of time-like space inside a black hole.

§ 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.