April 4, 2011

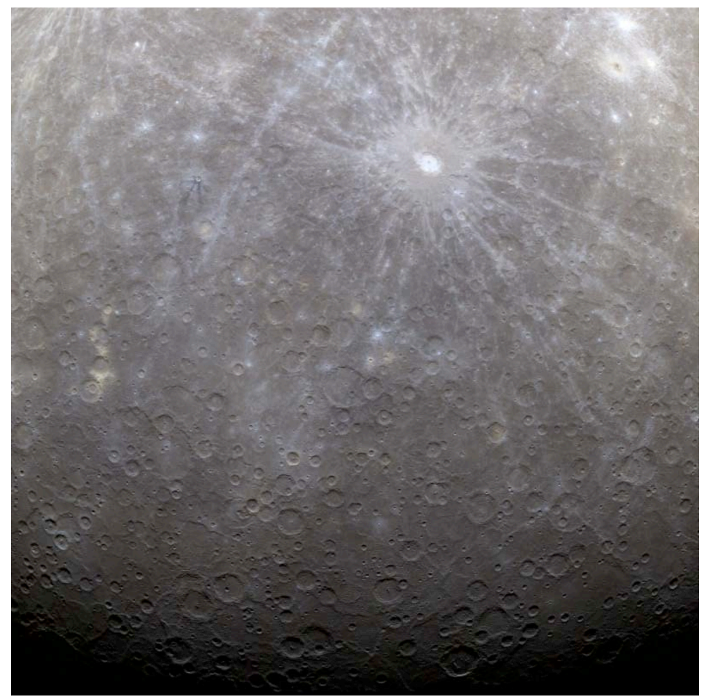
Exam 3 back Wednesday.

Reading: Chapter 9, Sections 9.5.2, 9.6.1, 9.6.2. 9.7, 9.8

Astronomy in the news? Manos in Austin American Statesman, paper on very bright supernova.

Messenger mission goes into orbit around Mercury.

Pic of the day: Messenger at Mercury, from March 31.



The story so far:

Look up at the sky and wonder about the stars.

Betelgeuse is a red supergiant about to collapse.

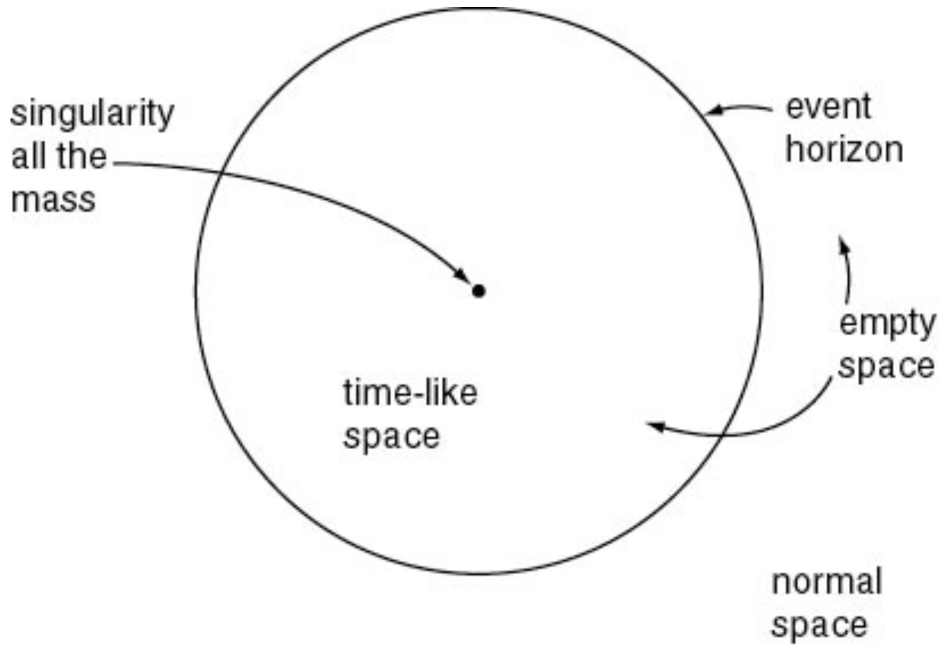
Collapse can lead to supernova explosions and the production of neutron stars, but also of black holes.

Black holes are predicted by Einstein 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.

Goal:

To understand the conflict between Einstein's theory of gravity and the Quantum theory.



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
=>affects 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 ↓ T ↑

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

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.

Neutron star + Anti-neutron star => gigantic explosion!

Black Hole + Black Hole => 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 or maybe it is still somehow in the singularity.

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: My Battle with Stephen Hawking to Make the World Safe for Quantum Mechanics, 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

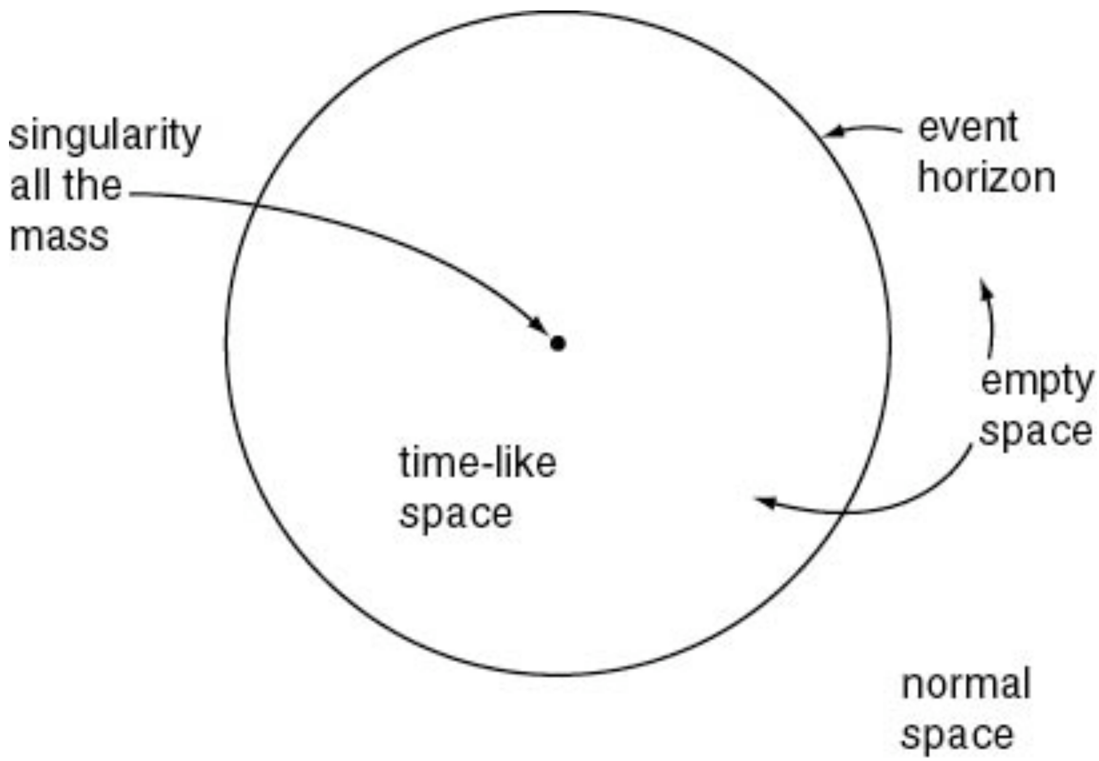
⬇ Black holes can explode

Goal:

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

§ 8 Time-like Space

Figure 9.1

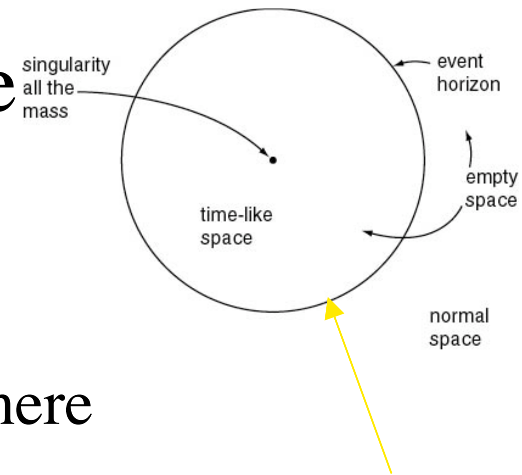


"Time-like" space forces motion in one direction. Space moves faster than the speed of light compared to a distant observer; the real reason black holes are black.

Goal:

To understand the full space-time associated with non-rotating black holes.

Non-rotating Schwarzschild Black Hole



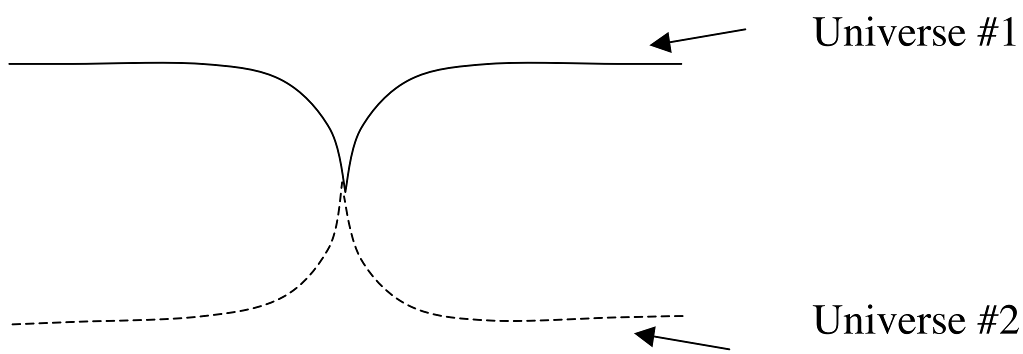
Mass, but no spin, no electrical charge

Assume all mass is in the 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 the singularity.

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



Somewhere else in hyperspace