Cosmic Catastrophes | Wheeler
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Review for Test #4
Black Holes and Gamma-Ray Bursts

Nature of Time in the vicinity of a black hole. Any observer always senses his or her own time as perfectly normal. But an observer at a large distance from the black hole where the force of gravity is small sees time passing more slowly for events occurring deep in the gravitational field of a black hole. Events right at the event horizon would show no passage of time to a distant observer. A distant observer watching another person falling toward the event horizon would perceive (other effects not interfering) that this second person gradually approached but never crossed the event horizon. An observer freely falling under the influence of no forces would plunge into the black hole after a finite (and normally short) passage of their own time.

Redshift—the redshift of the wavelength of photons received at a distance gets very large as the point of emission of the photon gets deeper in a gravitational field.

"Black Hole"—the large redshift of photons emitted near the event horizon coupled with the long passage of time between the arrival of these photons at a distant observer due to the apparent slowing of time means events happening just outside the event horizon cannot, in practice, be "seen" by a distant observer, —hence, a "black hole."

Hawking Radiation—according to Stephen Hawking, if one studies the event horizon with the Quantum Theory one finds that the gravitation energy (and hence mass) of a black hole can be converted into matter and anti-matter (mostly photons) with some of this material being ejected, carrying off the mass of the hole as if the black hole had a temperature.

Black Hole Evaporation—For a black hole of ordinary stellar mass or larger the amount of mass loss is negligible in the age of the Universe and may be ignored. A black hole of less than asteroid mass could totally evaporate within the age of the Universe.

The three fundamental properties of a Black Hole are those that can be measured from a distance - mass, charge, and spin. Other properties such as size and shape are specified once these basic properties are set.

Information Loss in Black Holes – Quantum theory insists information is preserved; black holes seem to destroy it.

Normal space – can be highly curved, but is "normal" in the sense that one can navigate and return to a given point of origin.

Time-like space—interior to event horizon space drags in one direction, just as time drags you older.

Schwarzschild black hole—mass but no spin, no electrical charge. Time-like space leads to the singularity, so it cannot be avoided.

Rotating or Kerr black hole—the idealized mathematical solution of Einstein's equations developed by Kerr in which one assumes that all the mass is in the rotating singularity and that there is vacuum everywhere else.

Singularity in a rotating black hole—shaped like a ring, surrounded by "normal " space so that it can be avoided in principle.

Time-like space in rotating black hole—the "in-going" time-like space is bounded on both sides by an event horizon so that it does not extend down to the singularity. Inside the inner event horizon is "normal" space surrounding the singularity. At the same place, but in the future, there is a region of "out-going" time-like space again bounded by two event horizons leading out to a normal Universe of flat space. In the future of that Universe is another in-going time-like space.

Inner "normal" space. Inside the rotating black hole the "normal" space will be one of huge gravity and tidal forces, but they are not infinite, and one could survive in principle never emerging from the black hole, but also never hitting the singularity.

Through the singularity—passing through the ring of the singularity leads to another volume of "normal" space within the black hole surrounding the singularity, but it is not the same one that surrounds the singularity that is first encountered when entering the black hole.

Blue shift - in a real Universe matter and energy falling into a black hole will gain energy (blue shift) and that energy will probably alter the "vacuum" Kerr solution, so no extra Universes are accessible.

Clues for black holes – look for binary system where X-rays are produced in accretion disk before matter disappears down the black hole and Kepler's law helps to determine mass greater than maximum mass of neutron star.

Cygnus X-1—First candidate black hole in a binary star system. Object of 10 $M_{\odot}$ emits X-rays and orbits un-evolved star of 30 $M_{\odot}$. Astronomers worried that the 10 $M_{\odot}$ object is itself a 9 $M_{\odot}$ star transferring mass to a 1 $M_{\odot}$ neutron star. The 9 $M_{\odot}$ star could be lost in glare of 30 $M_{\odot}$ star. This was ruled out by careful observations.

Black hole candidates with low mass companion stars—for these systems the "unseen" X-ray emitting star is more massive than the un-evolved companion. No third ordinary star could remain unseen.

Milky Way Galaxy – contains a 4 million solar mass black hole as determined by orbits of stars near the center.

Galaxy/Black Hole connection – The velocities of stars that respond to the bulge mass of a galaxy are correlated with the mass of the central supermassive black hole despite the fact that they are presently much too far from the black hole to sense its gravity. The bulge mass is always about 800 times the black hole mass. This suggests that the processes that cause the development of whole galaxies are nevertheless closely linked to the growth of the black hole when both first formed.

Gamma-ray bursts – flashes of gamma-ray energy detected by satellites about once per day lasting about 10 to 30 seconds.

Distribution in space – the gamma-ray bursts occur randomly all over the sky, so they are not associated with our Galaxy.

Optical Counterparts – discovered only in 1997, these allow gamma-ray bursts to be associated with other phenomena. They are in galaxies at cosmological distances.

Afterglow – fading radiation in radio, optical, and x-ray lasting for weeks or months after main burst, collision of ejected material with matter surrounding the star.

Gamma-ray bursts occur in star-forming regions in spiral galaxies, so associated with massive, short-lived stars and hence core collapse.

The energy of a gamma-ray burst is focused in a jet moving at near the speed of light, with an energy comparable to a supernova.

GRB030329 – Gamma-ray burst in March of 2003 proved that at least this burst was associated with a Type Ic supernova. Several others have been associated with supernovae since then, all Type Ic.

GRB 080916C was 12.2 billion light years away. It was equivalent to 9000 supernovae, the brightest optical event ever recorded.

GRB090423 is the most distant object for which a spectrum has been obtained, 13.1 billion light years away, when the Universe was only 600 million years old.

The most popular idea is that gamma-ray bursts represent the birth of black holes, but the birth of magnetars is also considered.

Gamma-ray bursts and cosmology - gamma-ray bursts are so bright they might be the first objects observable as stars first began to form and die at the end of the “Dark Ages” after the Big Bang cooled off.