Astronomy Bizarre
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Review for Test #3
BLACK HOLES (continued)

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

Information Paradox – what happens to information about what fell into a black hole, especially if the black hole evaporates?

Fuzzball black hole – wigging strings may continue to record information of what fell into a black hole (press release).

Schwarzschild black hole—mass but no spin, no charge. Idealized mathematical solution (all mass in singularity, vacuum elsewhere) predicts two universes that contact only at a single moment. Cannot pass between if speed less than light.

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.

Ergosphere – region between outer surface of infinite redshift and event horizon where everything is forced to rotate with the hole. Objects can escape from the ergosphere with more energy than they entered, the Penrose Process.

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 event horizons so that it does not extend down to the singularity. Inside the inner event horizon is “normal” (although highly-curved) 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 curvature 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, and it anti-gravitates.

Penrose singularity theorem – if an event horizon forms, then a singularity forms. Problem of a singularity, need for a quantum gravity, is very general.

Penrose diagram – mathematical means to map whole space times. Vertical represents time, horizontal represents a single spatial dimension (dimensions 2 and 3 are suppressed). Regions of infinite time and space are brought into vertices. Light travels on 45° lines, things moving slower than light must travel more nearly vertically. Empty, flat space is represented as ◇

Penrose diagram for Schwarzchild black hole – two separate universes; a past singularity (white hole) and a future singularity (black hole) at the same place, traveling with speed less than light cannot enter event horizon without hitting singularity. Cannot access other universe.

Penrose diagram for Kerr black hole – infinite nested universes separated by time-like spaces and normal spaces within the interior of the black holes.

Blue sheet – in a real Universe matter, radiation will fall in. For external observer the energy will pile up, change mathematical solution, eliminating other universes.

Clues for black holes—look for binary system where X-rays are produced in accretion disk before matter disappears down the black hole. Kepler's law helps to determine mass greater than 3 $M_{\odot}$, the limit for a neutron star

Cygnus X-1—First candidate black hole. Object of 10 $M_{\odot}$ emits X-rays and orbits unevolved star of 33 $M_{\odot}$ Small probability that 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 33 $M_{\odot}$ star.

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

BBC Video on Black Holes – How to find a black hole. V404 Cygni, excellent candidate for binary black holes. Roger Penrose. Kip Thorne/Stephen Hawking bet. Gravitational lensing. What do you see when you fall in? Supermassive black holes.