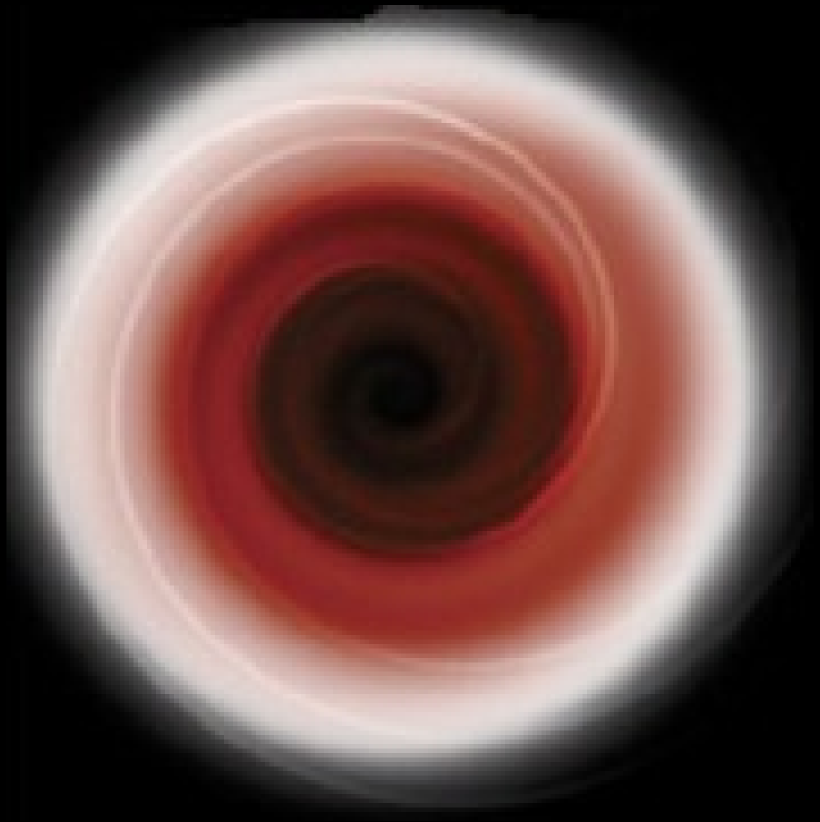
Super Massive Black Holes

A Talk Given By:

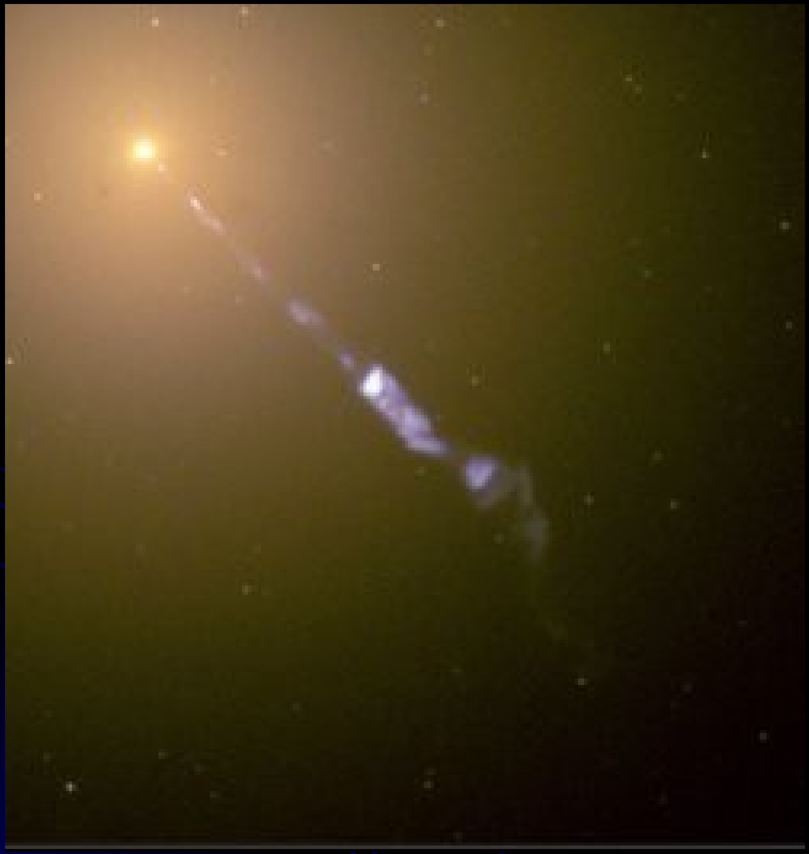
Mike Ewers

Black Holes: A Theoretical Definition (A Review)

- An area of space-time with a gravitational field so intense that its escape velocity is equal to or exceeds the speed of light.
- The Important thing is that this area can be of any size.



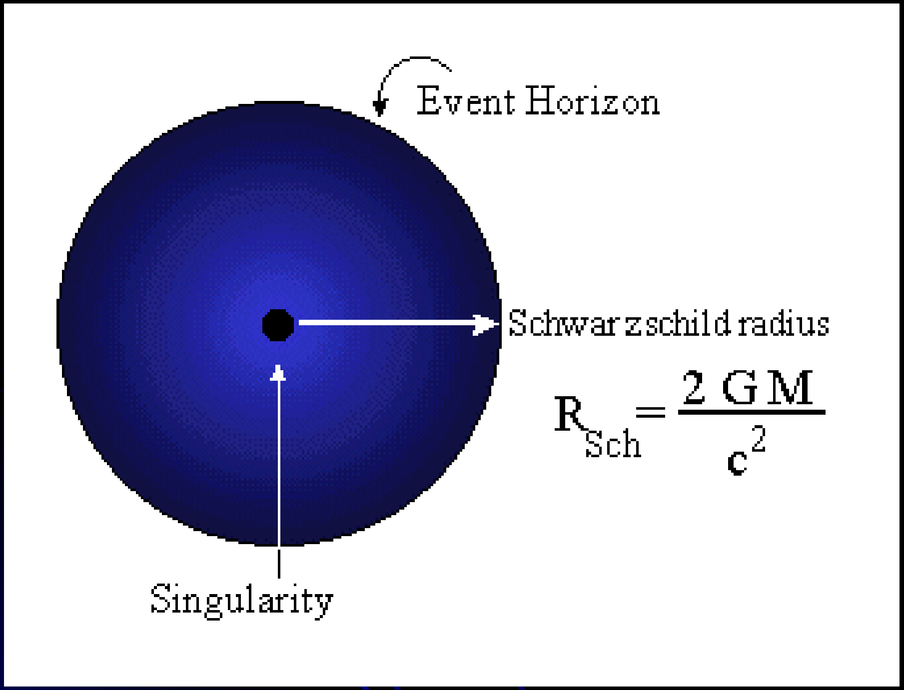
The Finite Speed of Light



- As you all know (especially Contemporary people), That the speed of light is a finite value in a vacuum.

(A black-hole-powered jet of sub-atomic particles traveling at nearly the speed of light out of the M87 galaxy)

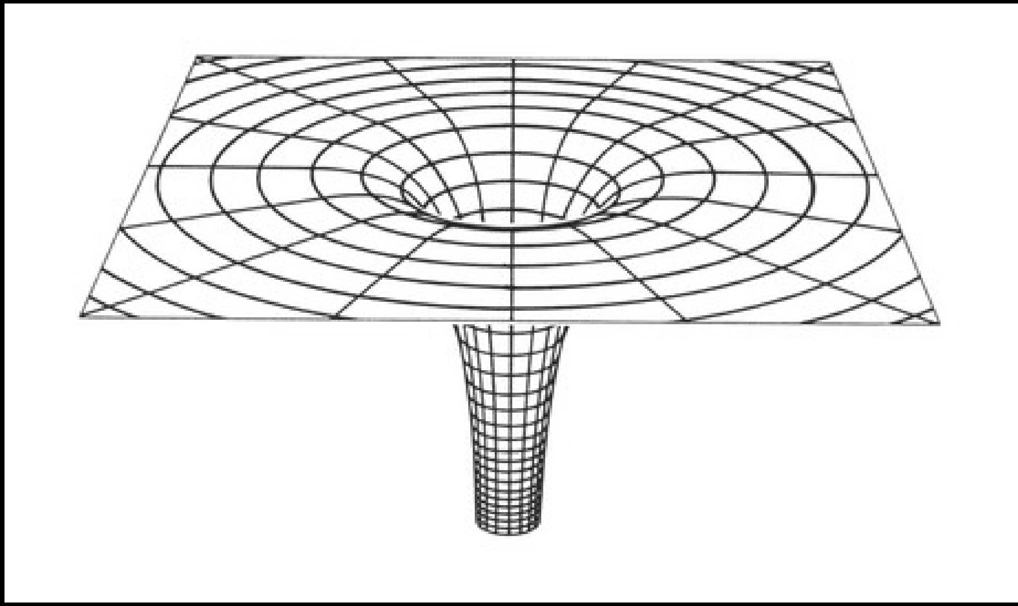
Escape Velocity, Density, and Schwarzschild Radius



- In terms of gravitational force, every object has an escape velocity as
- v_{esc} = **Sqrt**[*(2 G M)/r*].
- From that Schwarzschild Radius can be easily found.
- All comes down to a matter of density.

Thinking in Terms of General Relativity

- Einstein's Theory of General Relativity basically says that gravity warps space time.
- Rubber Sheet analogue
- Down, up, and through the funnel. An embedding diagram is generally a good representation of a black hole's warping of nearby space-time. But such 2-dimensional illustrations can also cause conceptual problems.

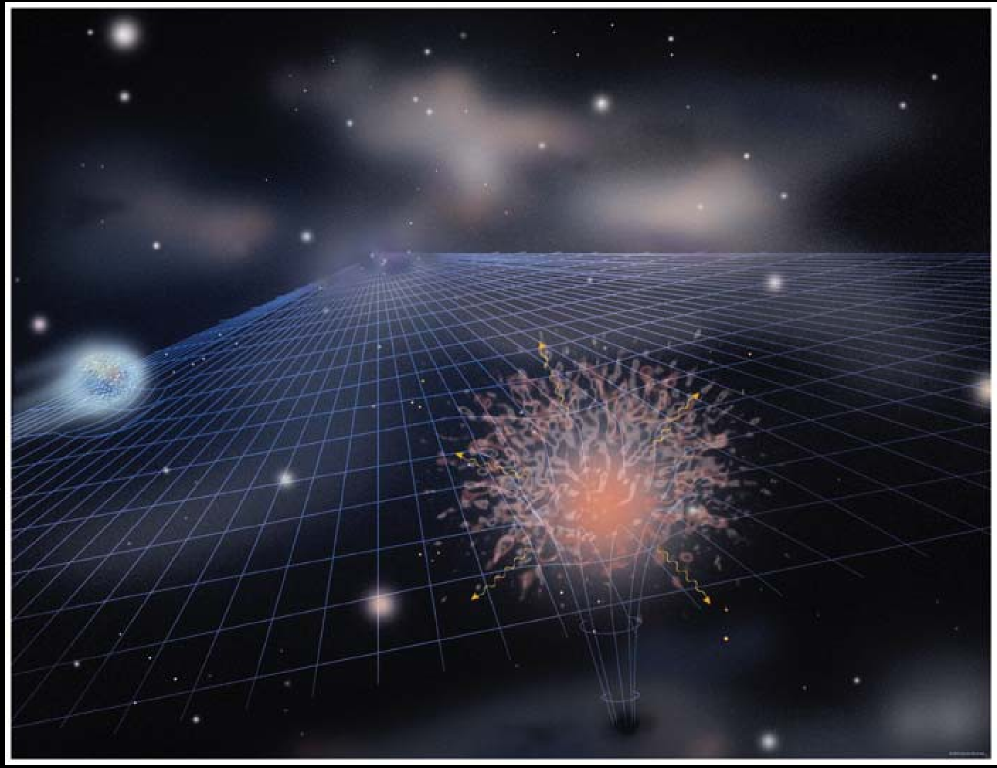


This is a simplified model

- The black hole no hair theorem shows that mass, charge, and angular momentum are the only properties a black hole can possess

Types of Black Holes

- “Normal Sized” Black Holes
- Microscopic (Primordial) Sized
- Super-Massive Black Holes (On the order of millions to billions of Solar Masses)
- (Estimated 3 million solar masses for Milky Way Black Hole)



How Normal Black Holes Come About (A Review)

- Most Black Holes are believed to come about from the death of massive stars.

Stellar Evolution (Brief)

- Star (Mass of Hydrogen) is massive enough ($M > 0.1\ M_{sun}$) to ignite fusion
- Star performs stable core fusion (first H->HE)
- Cycle repeats if star is big enough until the core is Fe.
- Star is in a kind of onion peel structure of elemental layers

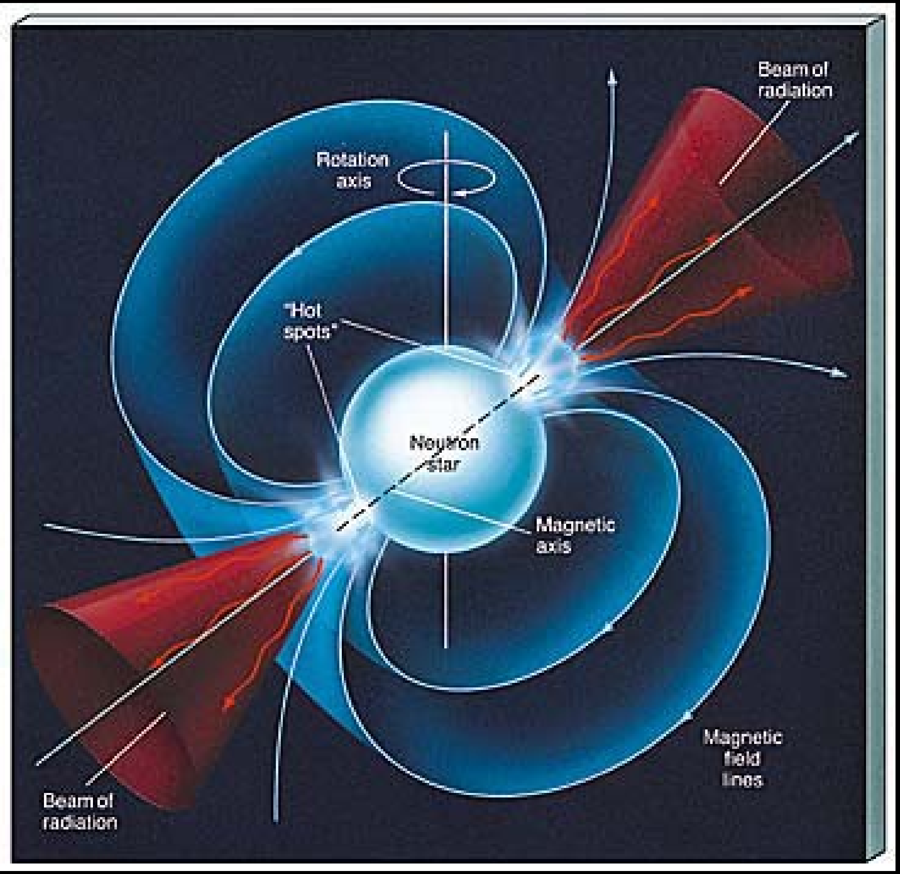
Supernovas!?

- After fusion cycles through and star's core is Fe, if the star now is $M < 1.4\ M_{sun}$, the star will supernova as a Type II supernova. Otherwise, it becomes a white dwarf, supported by degenerate electron pressure.
- This mass limit for supernovas is the Chandrasekhar limit.

Black Hole or Neutron Star?

- If the star the went supernova was between 1.4 and 3 M_{sun} , then the remnant will be a Neutron Star supported by degenerate neutron pressure (Pulsar).
- Otherwise,

  $M_{final} > 3M_{sun}$, and the result is a black hole because the is no source of outward pressure strong enough.



Where Could Super-Massive Black Holes Exist?

- The only known places in the Universe where there could be enough mass in one area is in the center of massive galaxies
- Not believed to be anywhere else

Quasars: What are They?

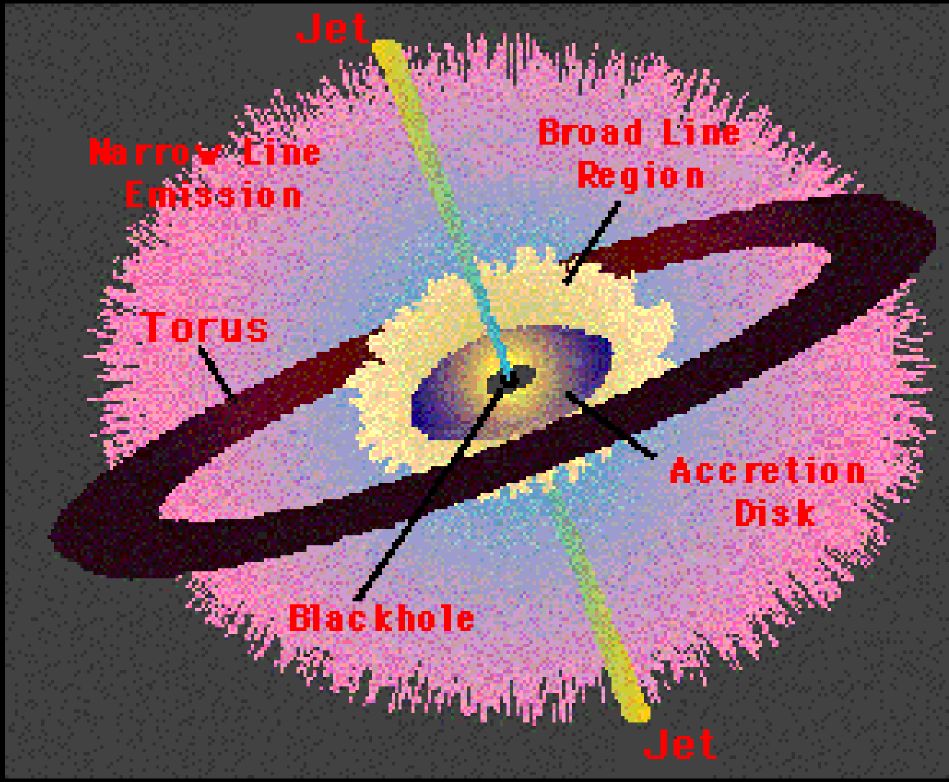
- In some places where point sources of radio waves were found, no visible source other than a stellar-looking object was found (it looked like a point of like --- like a star does). These objects were called the "qausi-stellar radio sources", or "quasars" for short.
- Later, it was found these sources could not be stars in our galaxy, but must be very far away --- as far as any of the distant galaxies seen. We now think these objects are the very bright centers of some distant galaxies, where some sort of energetic action is occurring.

Active Galactic Nuclei

- In some galaxies, known as "active galactic nuclei" (AGN), the nucleus (or central core) produces more radiation than the entire rest of the galaxy! Quasars are very distant AGN - the most distant quasars mark an epoch when the universe was less than a billion years old and a sixth of its current size.

Brief Review of case for Super-Massive Black Holes in these observed AGN

- The Time Variation of AGN
- The Eddington Luminosity Argument
- The Motion of broad line emission medium around the central core



How did Super-Massive Black Holes come about?--theories

- From “Lumps” in the early universe
- The “Stellar Seed” Model
- Collapse of a whole star cluster

Lumps from the early Universe

- In the “Big Bang” the whole universe was in a really dense state. So much that perhaps lumps could have formed and of matter dense enough that a black hole was formed.
- There was enough surrounding matter that galaxies formed around the lumps
- Could explain why pockets of interstellar gas never became galaxies

The Stellar Seed Model

- Provided that the surrounding environment is sufficiently rich in matter, a giant black hole could result in an initial “stellar seed” of 10 M_{sun} produced during a supernova.

Collapse of a whole cluster

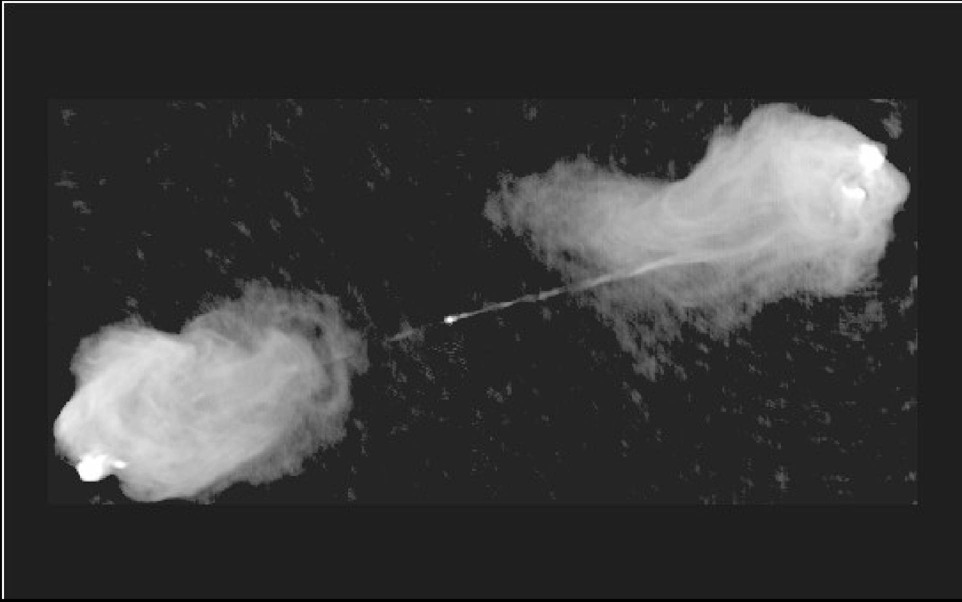
- If the stars of a tight knit cluster of the moderately young Universe had all relatively the same size stars (above the Chandrasekhar Limit), there would be quite a few Black Holes forming simultaneously causing smaller stars to be absorbed, and black holes to combine.
- NGC 1850 to the right

Some Characteristic of AGN

- Super Bright: AGN 3C273 (an extreme example) is L = 4.8*10^12 L_{sun} .
- Cosmic Optical Jets
- Tidal forces
- Cannibalism—they do eat, the source of energy

Optical Jets—Why?

- The magnetic fields around a black holes that are thought to produce the spectacular jets of high-energy particles rushing away from black holes come from the disk of hot gas around the black hole, not the black hole itself.
- The jets are made by the Magnetic field of the matter before it goes in the Black Hole.
- Emit Synchrotron radio signals
- Cygnus A



Tidal forces stretch farther, but are weaker

$$F \propto \frac{M}{r^3}$$

- The tidal force is proportional to the mass of the black hole. In other words, as the object gets more massive, the force should get bigger too. But the force is also *inversely* proportional to the *cube of the object's radius*. As the hole gets more massive, its size increases, but because of the cube factor, the force *decreases* much faster than any possible mass increase can account for. The result is that big black holes have weak tidal forces, and small ones have strong tidal forces.
- Frames from a NASA computer animation depict one possible cause of gamma ray bursts. A star orbiting a black hole spirals in as it is shredded by tidal forces, generating an intense burst of gamma and other radiation as the its matter is compressed and super-heated on its way to oblivion.

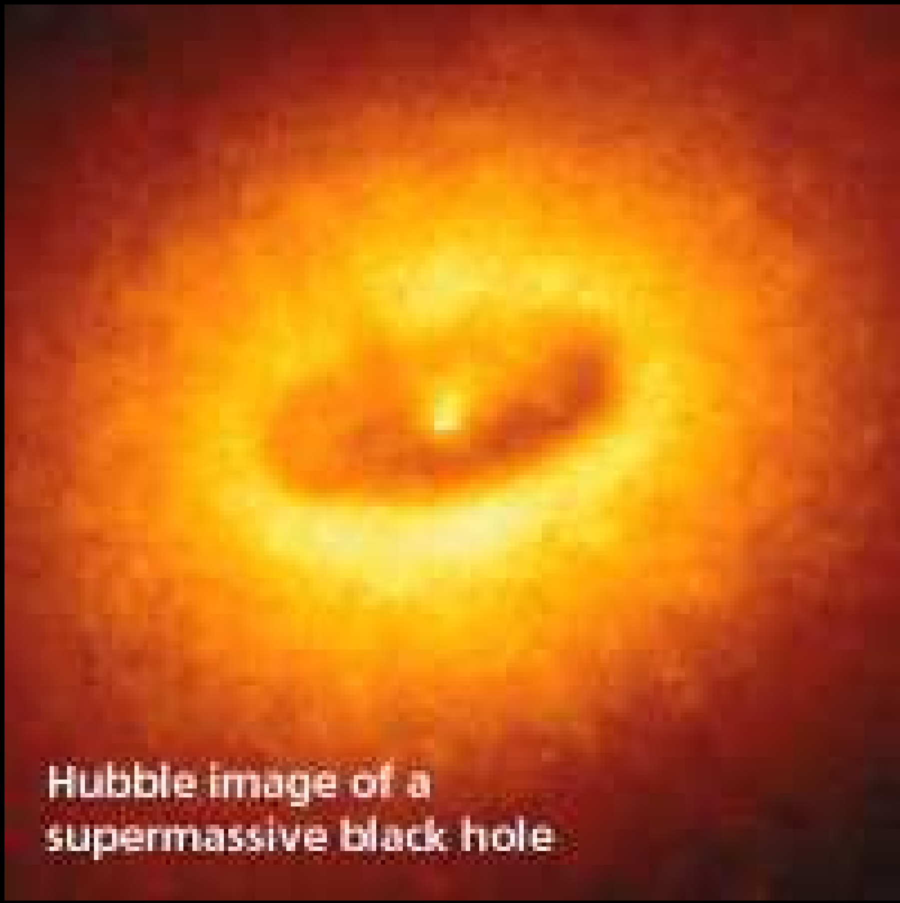
Cannibalism

- Apparently, Quasars are only active on order of 100 million years
- A dead quasar could be revived with a new source food—by colliding galaxies
- Proof—elliptical galaxies have been found to be active in radio transmissions as well.
- Collision Galaxies NGC 2207 & IC 2163

Observations of Super Massive Black Holes

- Radio observations at various radio telescopes
- X-ray observations from the orbital Chandra Observatory
- Optical Observations from Hubble Space Telescope

Pictures



NGC4261

Fate of Universe?

- All Black Holes Evaporate over time due to Hawking Radiation
- Eventually the Universe will have no matter in a cold dark death and all there will be left is radiation.
- Evaporation Time:

1 * 10^-7 (M/M$_{sun}$)^3 Years

On order of 1* 10^20 years

Picture Resources

- **www.usatoday.com/.../wonderquest/ 2001-08-22-black-holes.htm**
- www.astronomynotes.com/gravappl/s8.htm
- astrosun.tn.cornell.edu/courses/astro201/bh_structure.htm
- **www.aspsky.org/mercury/mercury/ 9802/lockwood.html**
- **www.abc.net.au/science/slab/ wormholes/default.htm**
- **www.glyphweb.com/esky/ concepts/stars.html**
- http://heasarc.gsfc.nasa.gov/docs/objects/agn/agntext.html
- **www.nature.com/nsu/020603/ 020603-1.html**
- http://www.linnaeus.uu.se/online/fysik/makrokosmos/gifs/bigbangsmall.jpg
- **www.astrographics.com/GalleryPrints/ GP0053.html**
- **www.abc.net.au/science/news/ stories/s71464.htm**
- http://imagine.gsfc.nasa.gov/docs/science/know_l2/active_galaxies.html
- **www.scs.gmu.edu/~tle/ galaxy_galery.html**