Active Galactic Nuclei (or AGN)

The spectra of these galaxies are different than "normal" galaxies.

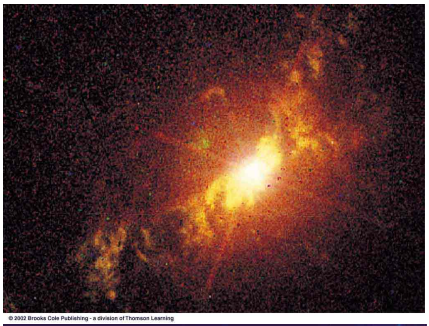
Normal galaxies have stellar like spectra (sum of all stars in galaxy), but AGN show emission lines!

This suggest very hot, low density gas and very ionized and excited atoms.

The velocity dispersion of the emission region is about 10,000 km/s

Seyfert galaxies have very small (unresolved), extremely powerful centers! The strength of the emission lines vary on timescales of a month- region is small ($R = ct$)

NGC 4151: Seyfert w/ a Black Hole



We think all Seyfert galaxies have black holes in their nuclei.

Why?

The Doppler effect strikes again!

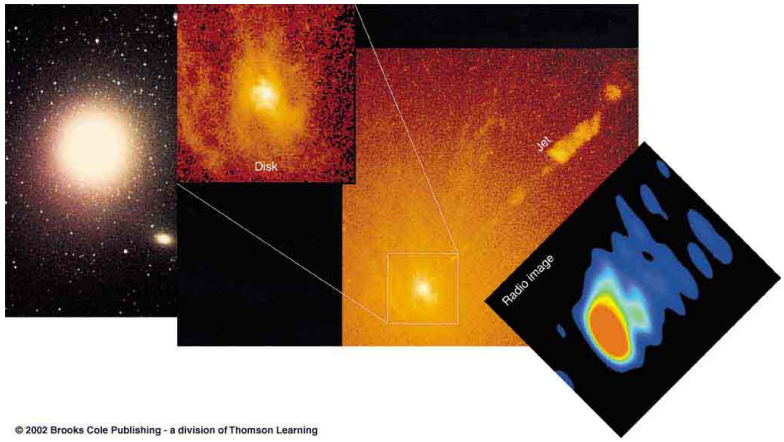
In this image, from the Hubble Space Telescope Imaging Spectrograph, we see that some of the gas is coming toward us and some is moving away.

This suggests rotation- *very rapid rotation in a small region of space*.

The only object this dense and massive can be a black hole.

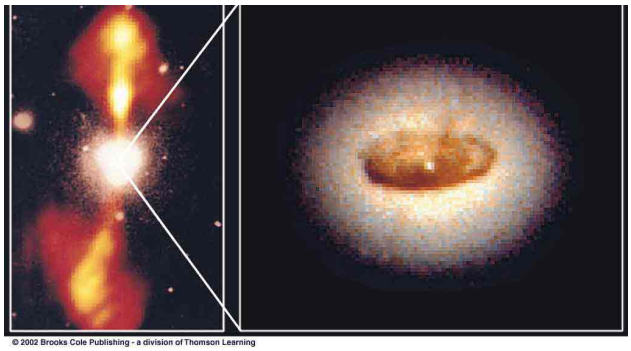
Even "normal looking" galaxies can have powerful black holes.

M87, the central giant elliptical of the Virgo Cluster of galaxies, has a small accretion disk, out which arise a jet of material. The radio image shows that it originates in a very small region (1 light week in diameter).

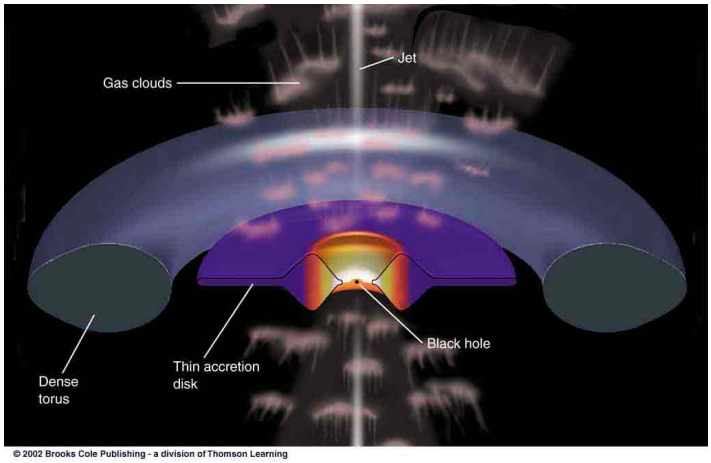


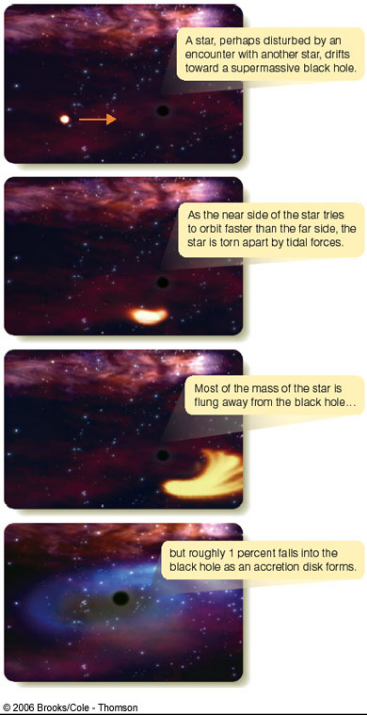
NGC 4261

(left) An optical image shows a fairly normal elliptical galaxy. A radio image overlay shows powerful jets that pile up into double radio lobes. In the center is an accretion disk (right). The rotation axis is in the direction of the jets.



Schematic of an accretion disk and its jets.



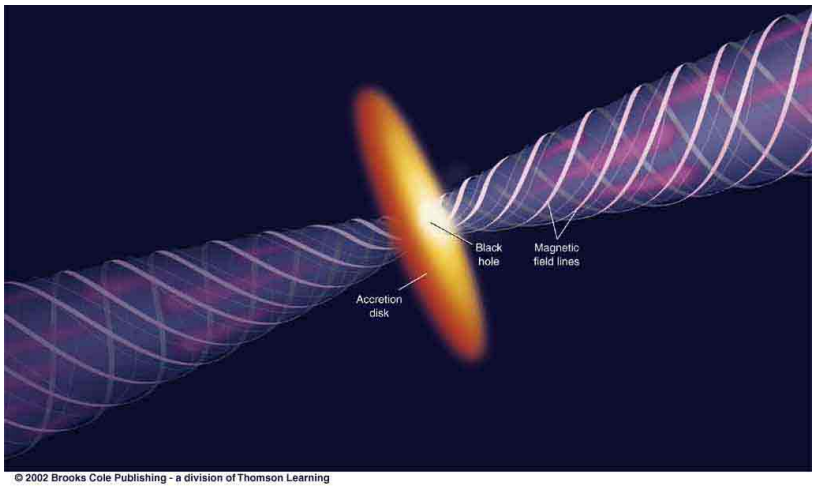


The fuel for a black hole is provided by infalling stars and gas.

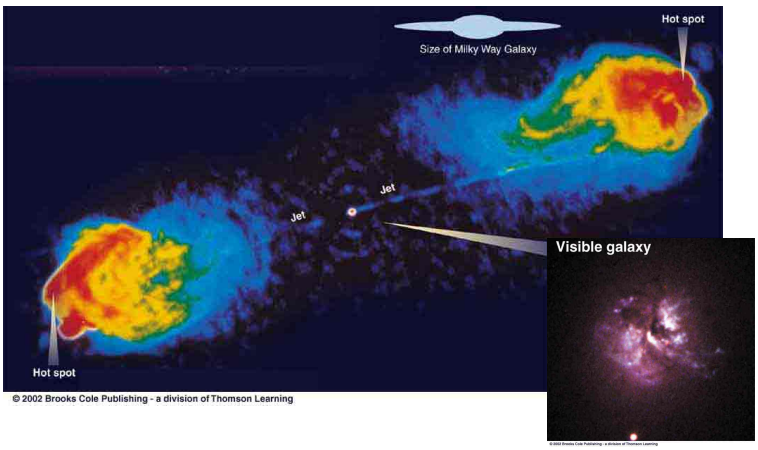
Much of the mass of each star does not fall into the black hole…

99% of each star ends up contributing material to the accretion disk and to the jets!

Channeled magnetic field lines carry the material off in the jet.

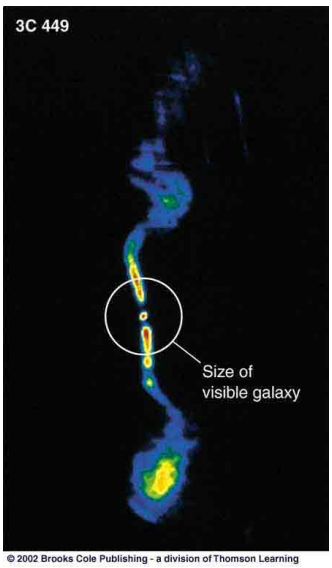


Cygnus A

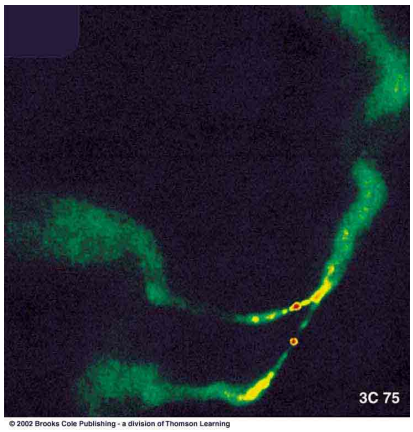


A classic example of a double radio lobe galaxy.

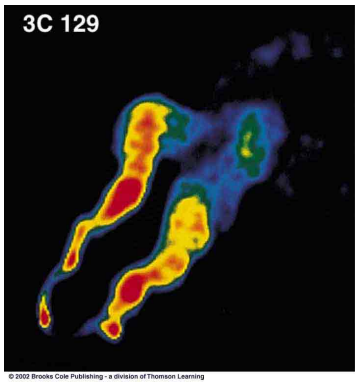
Evidence for the Intergalactic Medium

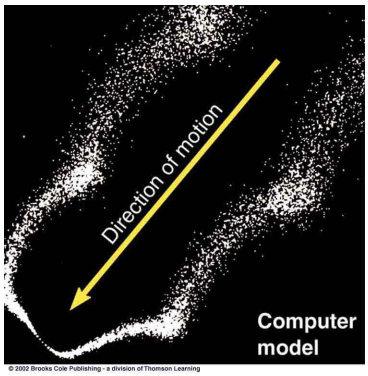


Note how the radio lobes of these jets appear to be swept by the movement of the galaxy through a medium…

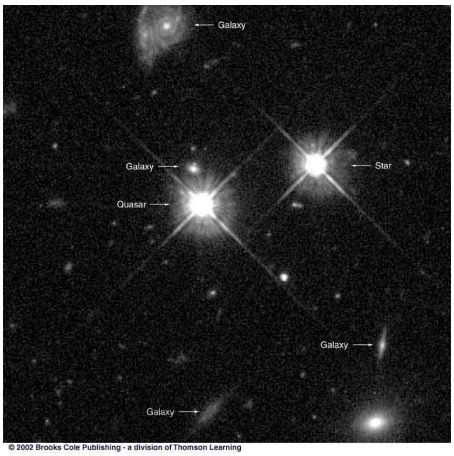


A computer model of 3C 129.





Quasars



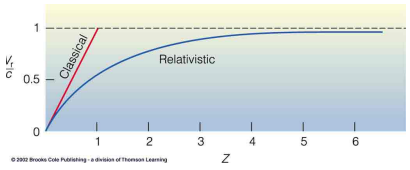
Quasar is short for Quasi-stellar object. Note how star-like this quasar appears compared to the star.

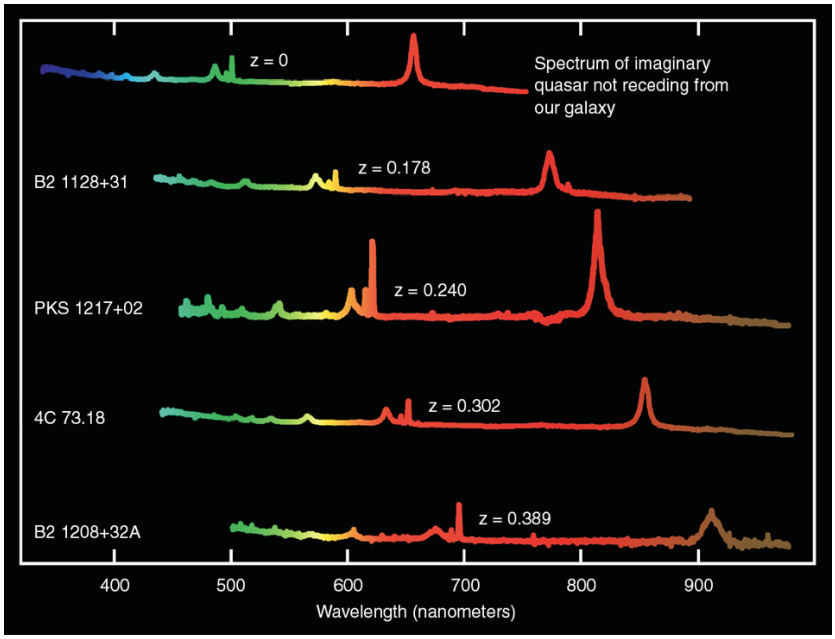
Quasars are highly redshifted, which places them at great distances.

If they are at the far reaches of the universe and are very bright, then they must be extremely luminous.

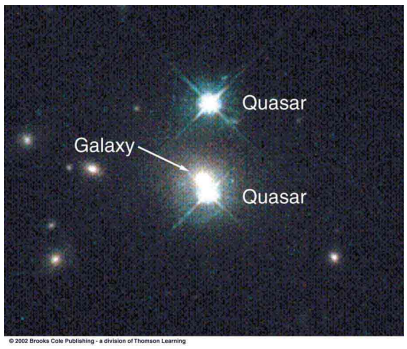
Recall Hubble's Law $v = H_0 d$

Velocity comes from the Doppler shift. But, objects cannot move faster than the speed of light… so we need to use the Relativistic Formula to convert distance, redshift, and velocity to get it correct.





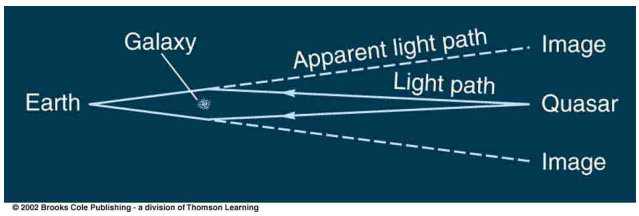
Gravitational Lens: Remember Einstein and Light Bending!



Since Quasars are so far away, there is a high probability that massive material will lie between us and the quasar.

When this happens, the light rays are bent (as shown below).

Our eyes project along two "apparent light paths", whereas the light from a single object has simply been bent.



The Einstein "Cross"