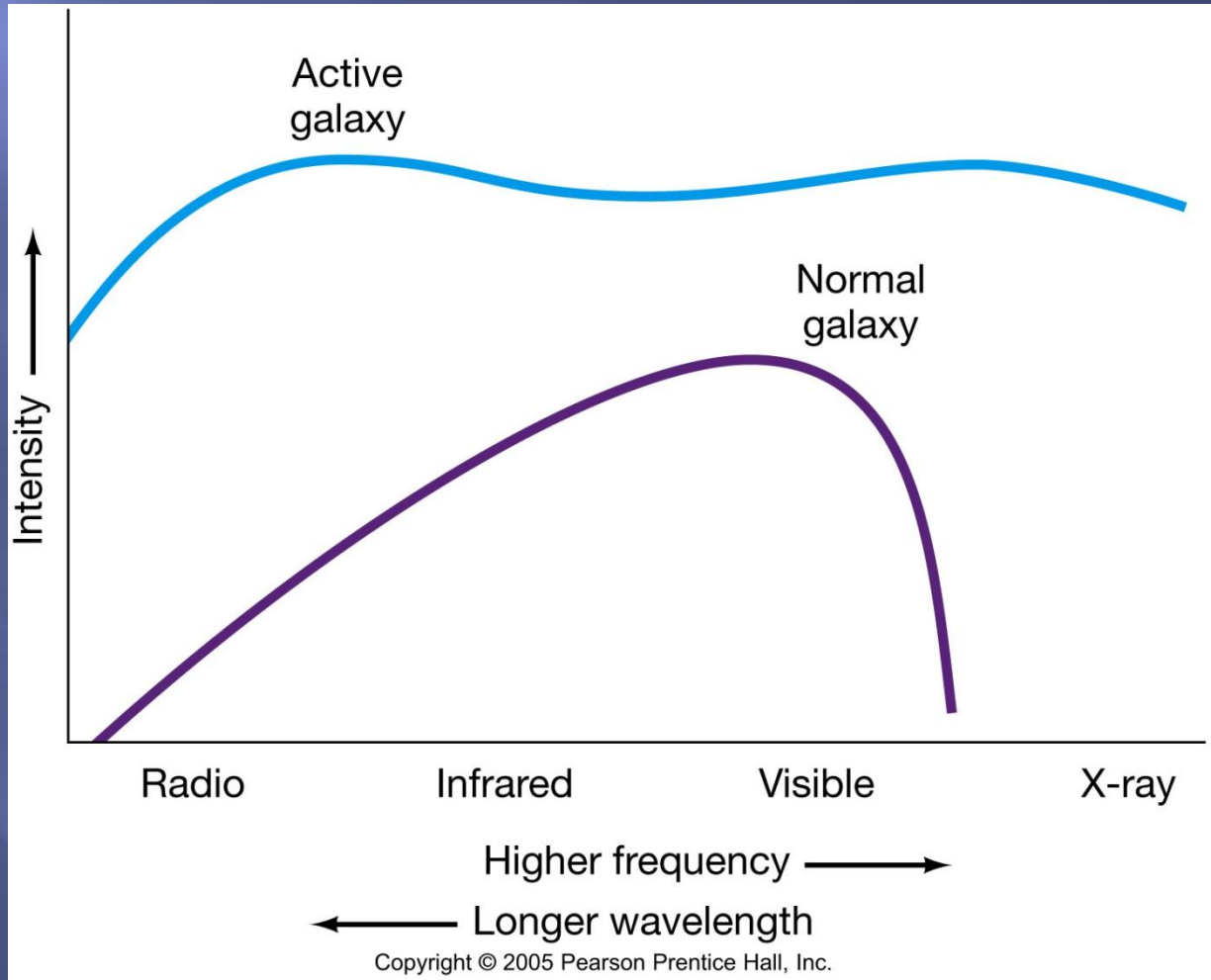
Galaxies with Active Nuclei

Active Galactic Nuclei
Seyfert Galaxies
Radio Galaxies
Quasars
Supermassive Black Holes

Active Galactic Nuclei

About 20–25% of galaxies do not fit well into Hubble categories– they are far too luminous.

Such galaxies are called active galaxies. They differ from normal galaxies in both the luminosity and type of radiation they emit.



Active Galactic Nuclei

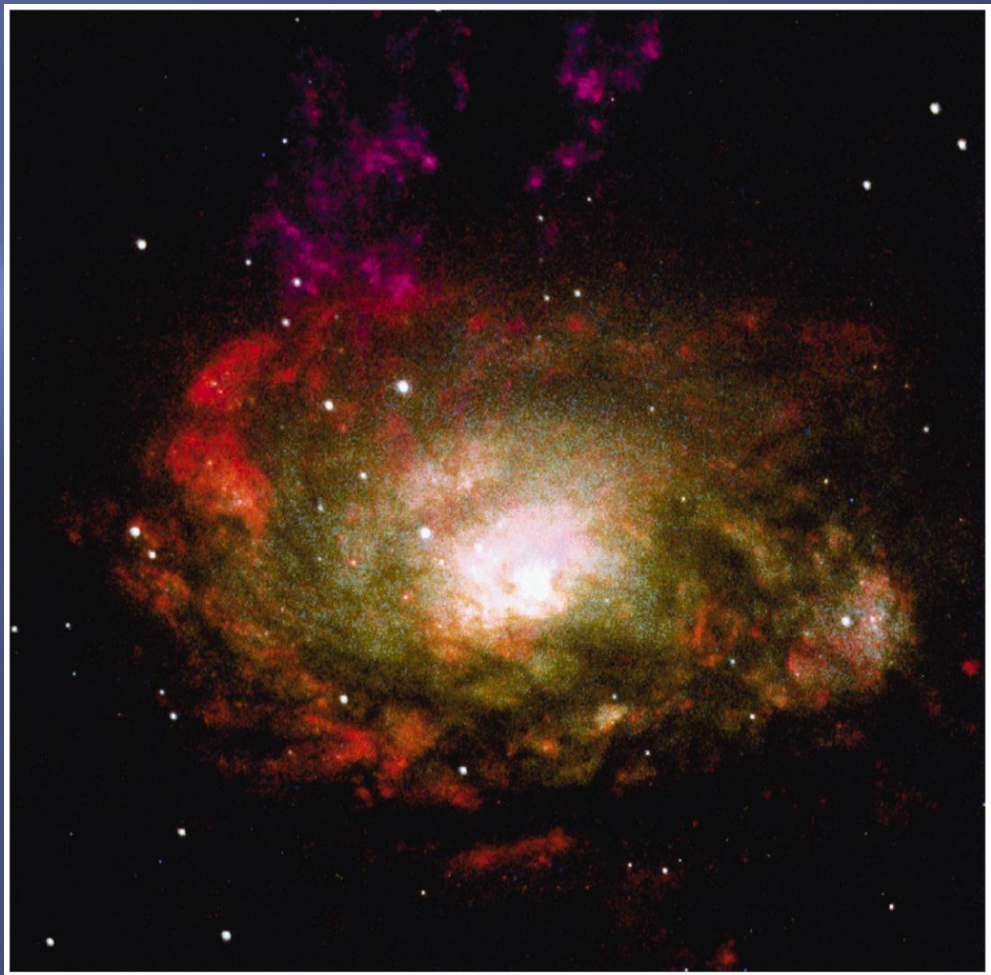
Luminous galaxies appear to be of two types:

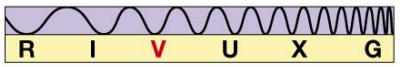
1. Many luminous galaxies are experiencing an outburst of star formation, probably because of interactions with a neighbor. These galaxies are called **starburst galaxies**, and we discussed them in the last section.
2. The galaxies we will discuss now are those whose activity is the result of events occurring in and around the galactic center. They are called **active galaxies**. The radiation from these galactic centers is **non-thermal radiation**.

Active Galactic Nuclei

Active galaxies are classified into three types: Seyfert galaxies, radio galaxies, and quasars.

Seyfert galaxies resemble normal spiral galaxies, but their cores are thousands of times more luminous.





Seyfert Galaxies


NGC 1566

They are unusual spiral galaxies:

- Very bright cores
- Emission line spectra.
- Variability: ~50% in a few months

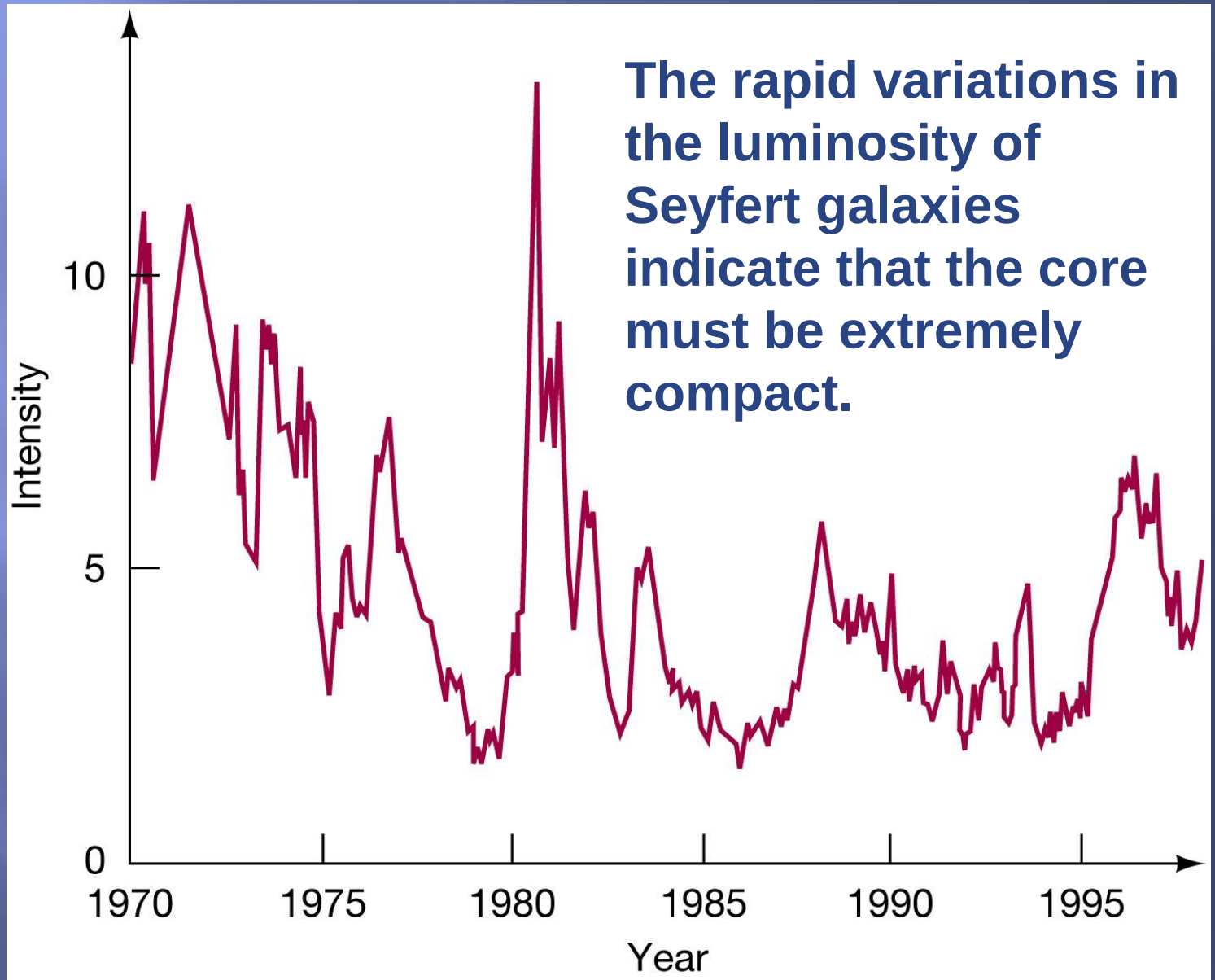
Most likely power source:

Accretion onto a supermassive black hole (~10^7 – 10^8 $M_\odot$)


Circinus Galaxy

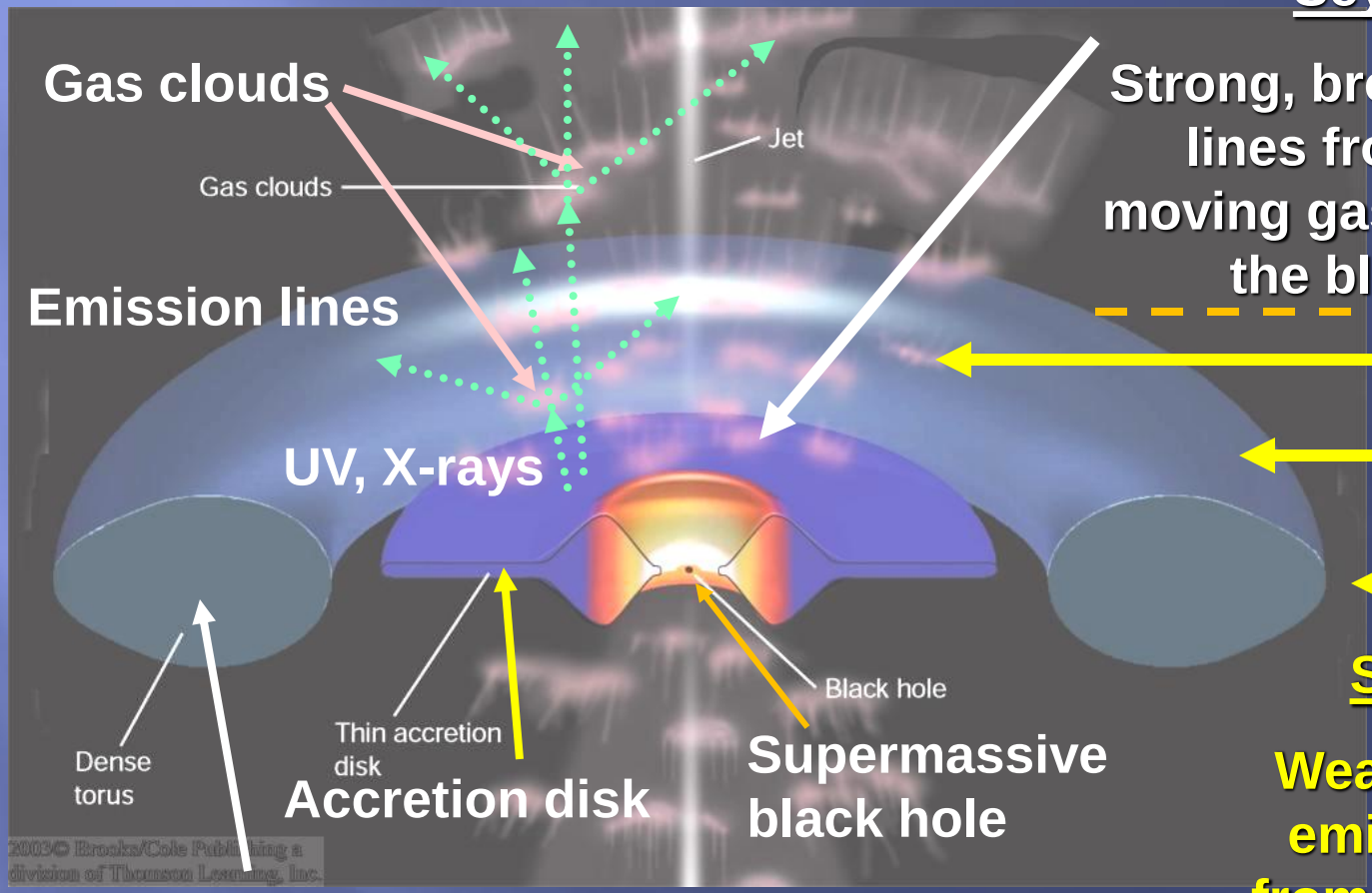

NGC 7742

Seyfert Galaxies



The rapid variations in the luminosity of Seyfert galaxies indicate that the core must be extremely compact.

Model for Seyfert Galaxies



Seyfert I:

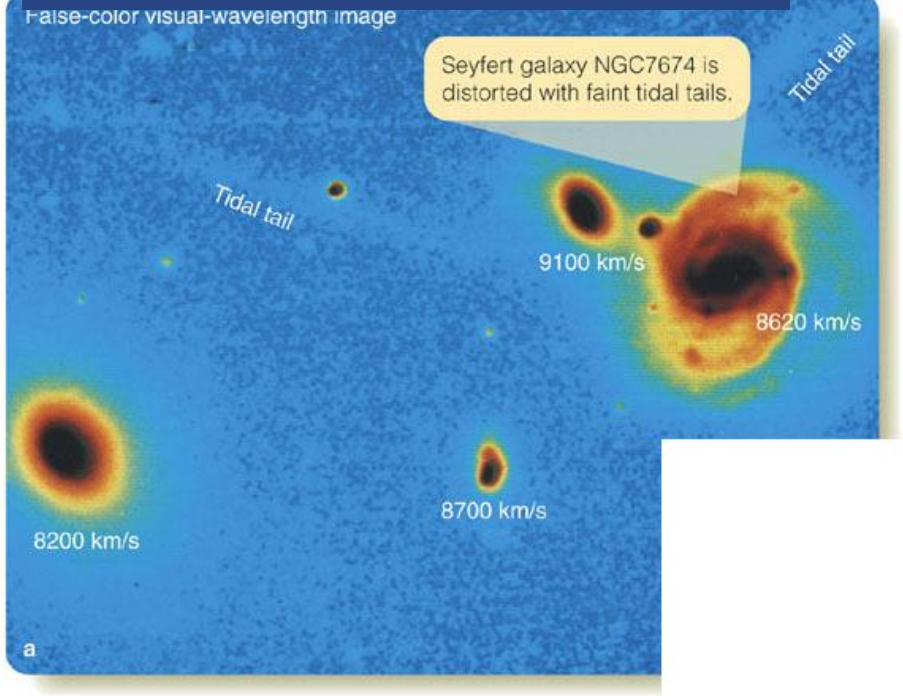
Strong, broad emission lines from rapidly moving gas clouds near the black hole

Seyfert II:

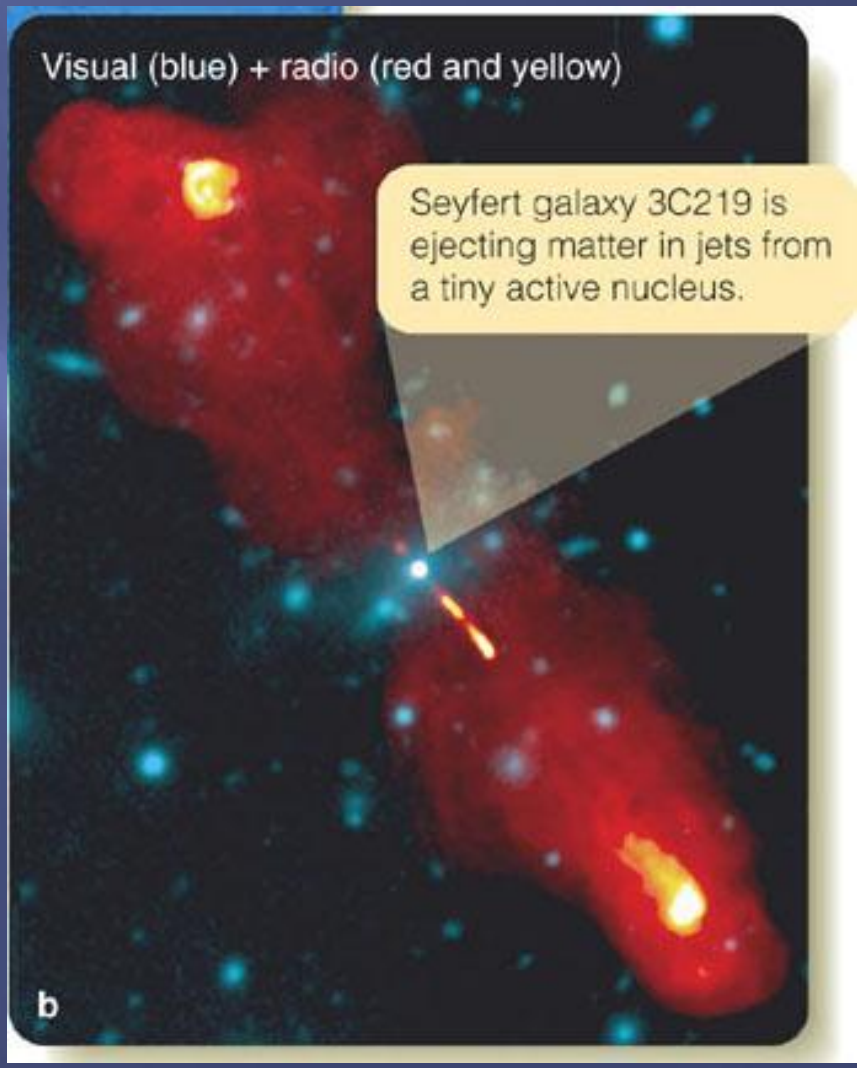
Weaker, narrow emission lines from more slowly moving gas clouds far from the black hole

Interacting Galaxies

Seyfert galaxy NGC 7674



Seyfert galaxy 3C219



Active galaxies are often associated with interacting galaxies, possibly as a result of recent galaxy mergers.

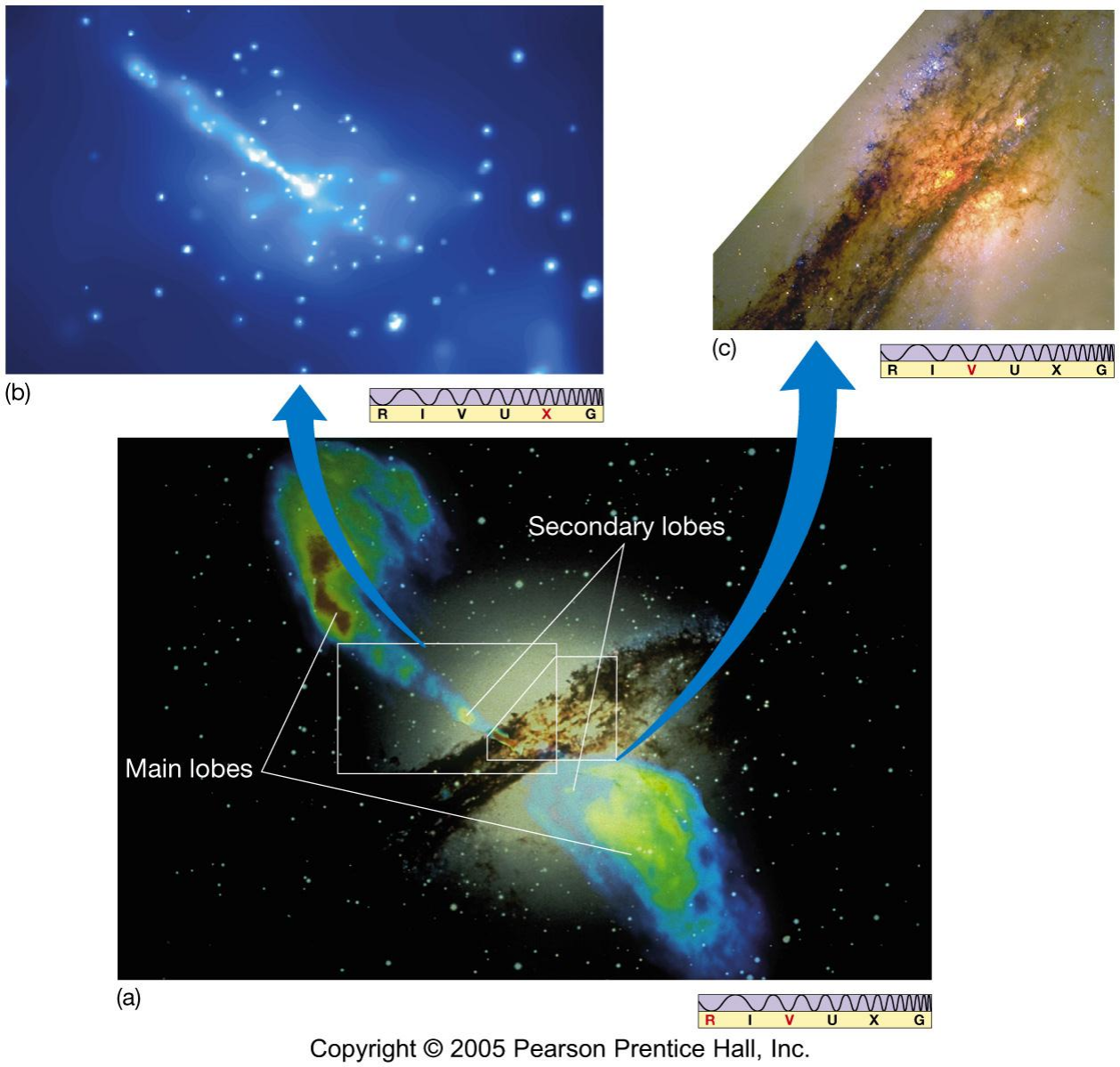
Often there is gas flowing out at high velocities, in opposite directions

Radio Galaxies

Radio galaxies emit very strongly in the radio portion of the spectrum.

Some others have enormous **lobes**, invisible to optical telescopes, perpendicular to the plane of the galaxy.

Some radio galaxies are core dominated.



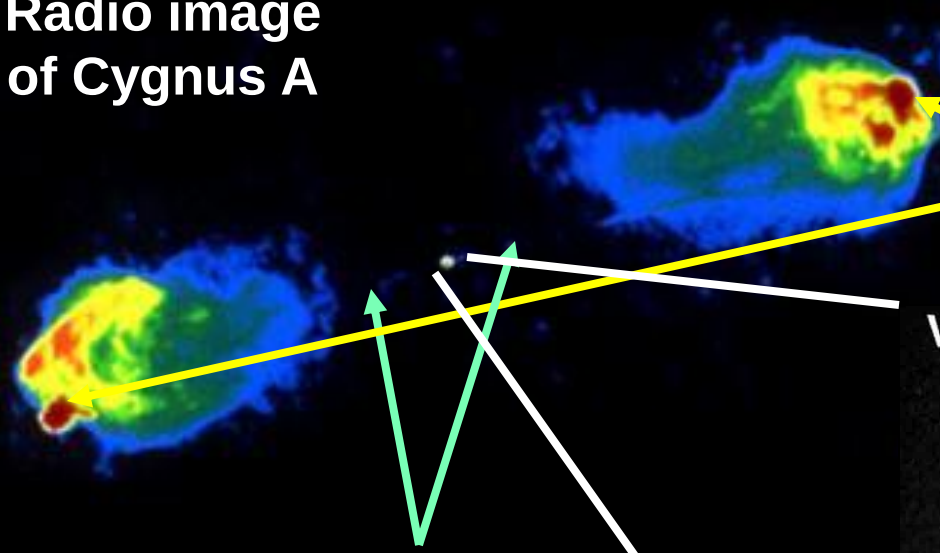
Cosmic Jets and Radio Lobes

Many active galaxies show powerful radio jets

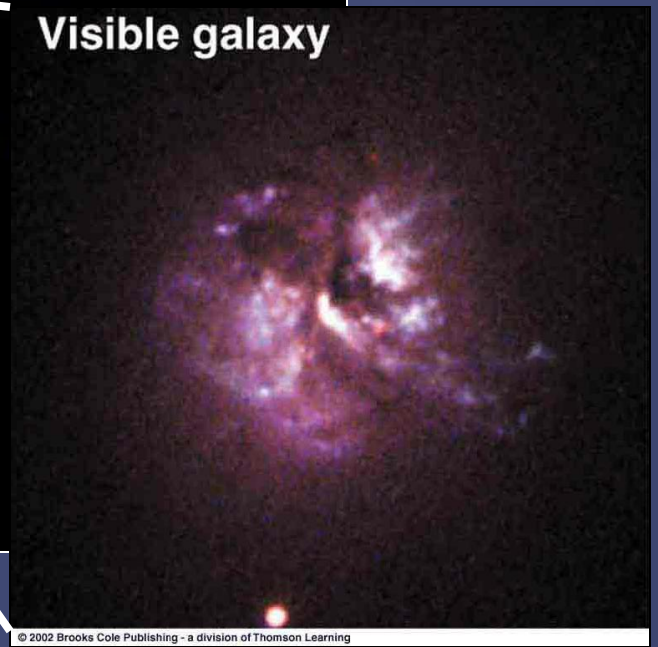
Hot spots:

Energy in the jets is released in interaction with surrounding material

Radio image of Cygnus A

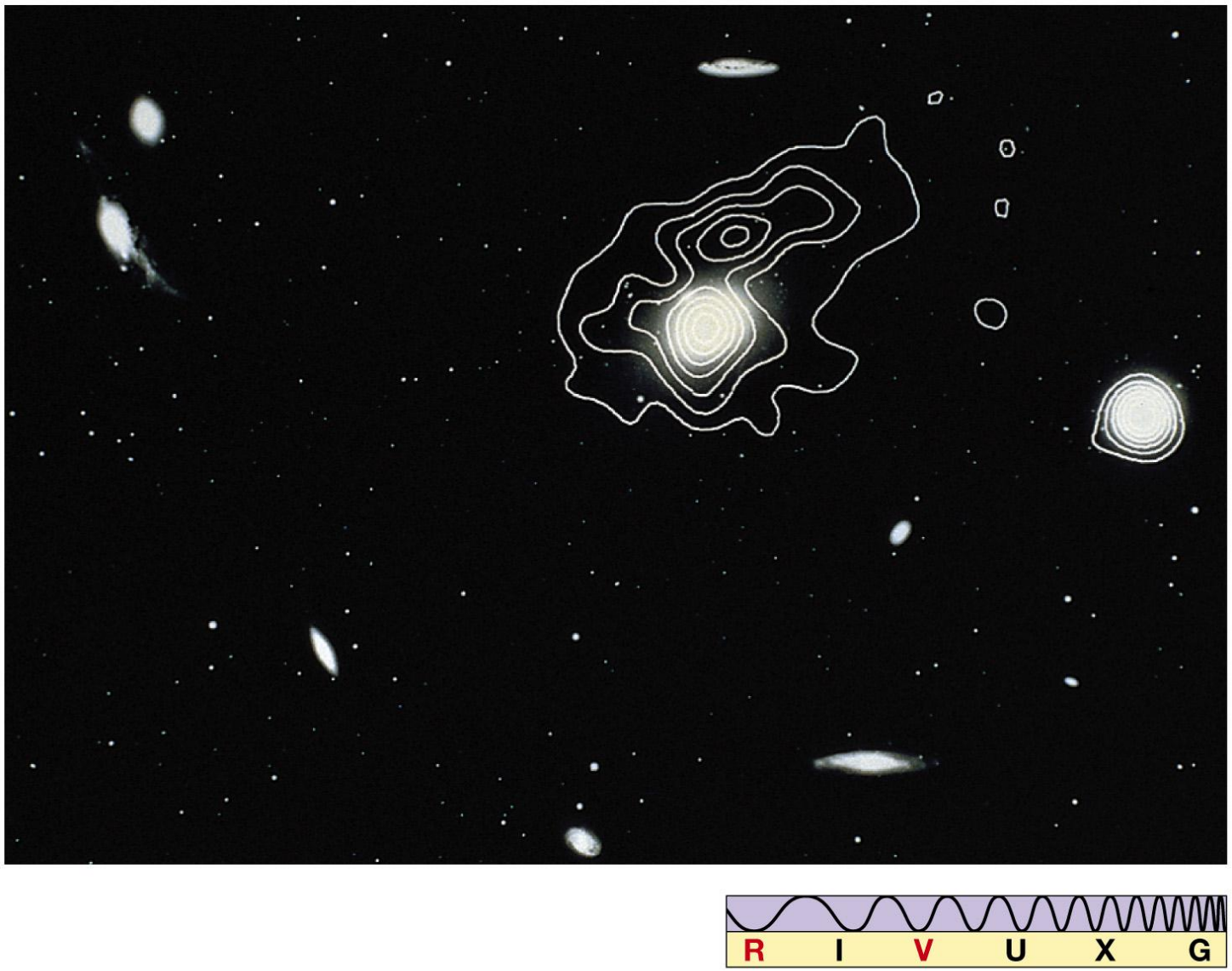


Material in the jets moves with almost the speed of light ("relativistic jets").



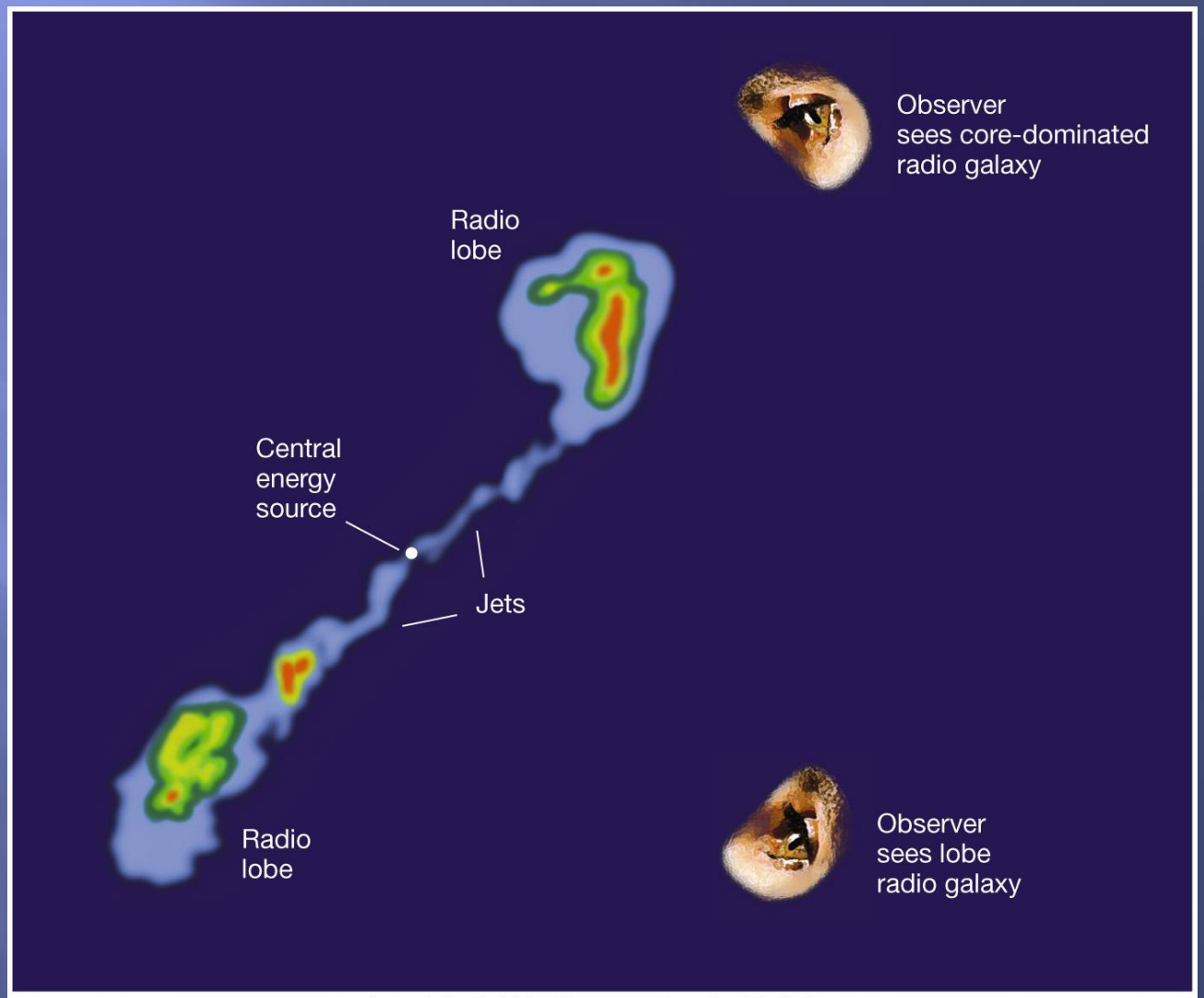
Radio Galaxies

Radio galaxies may also be core-dominated



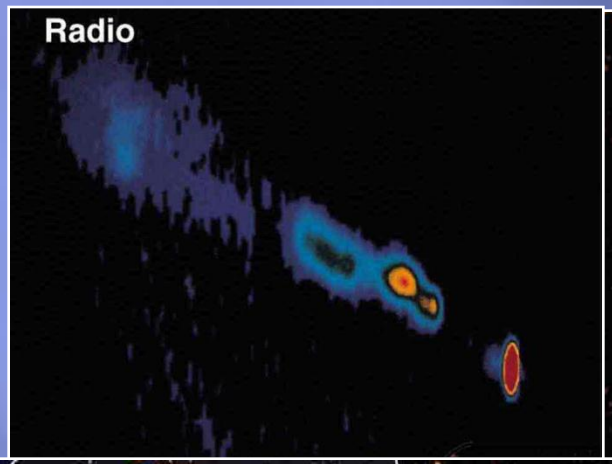
Radio Galaxies

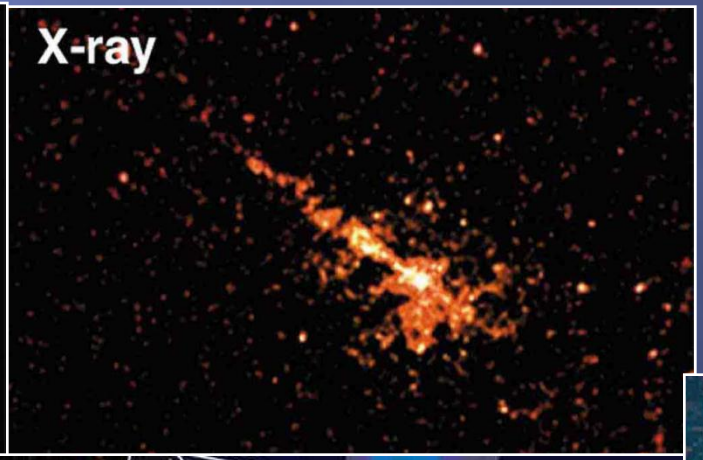
Core-dominated and radio-lobe galaxies are probably the same phenomenon viewed from different angles



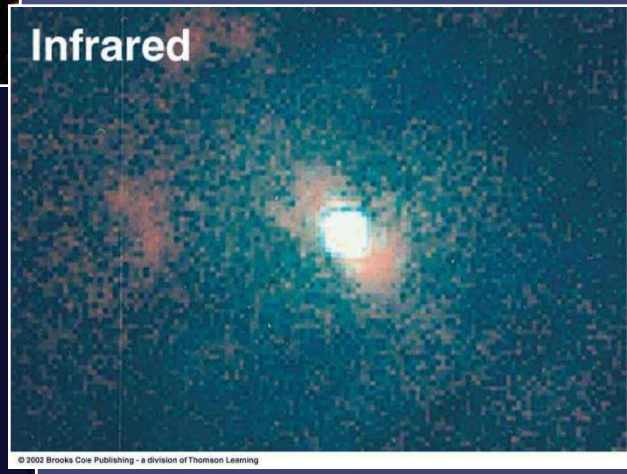
Radio Galaxies

Centaurus A ("Cen A" = NGC 5128) is the closest AGN to us.

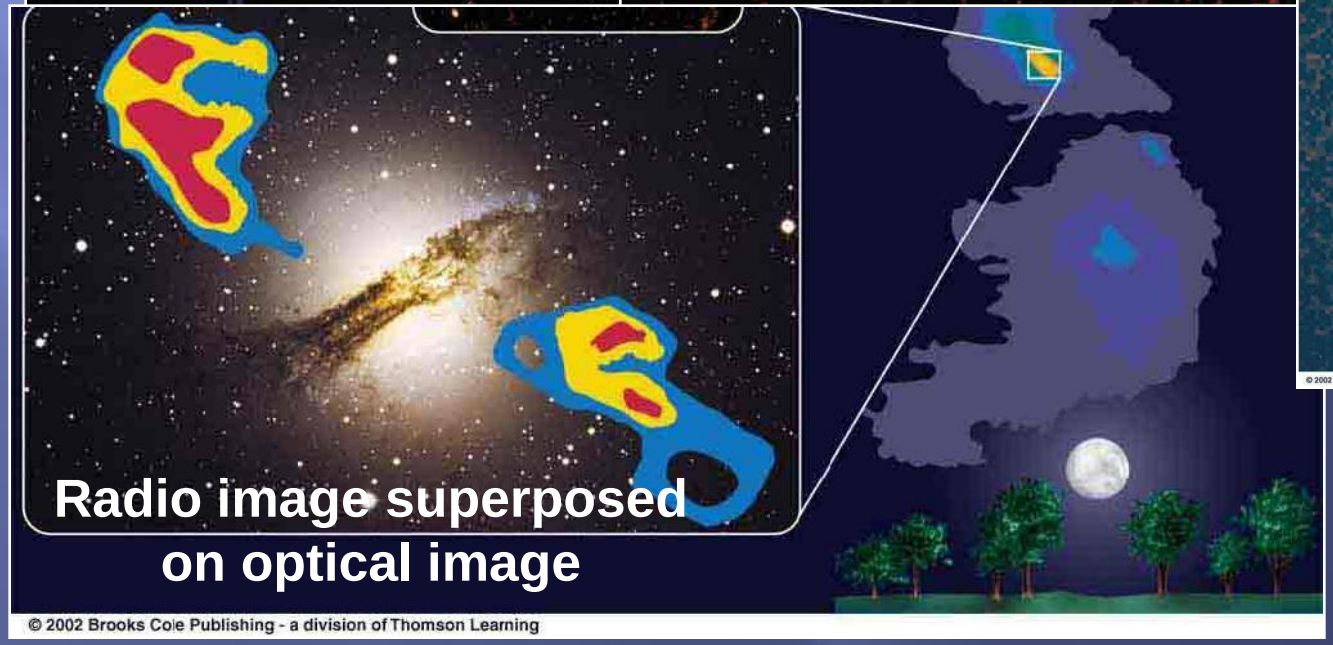




Jet visible in radio and X-rays; show bright spots in similar locations.

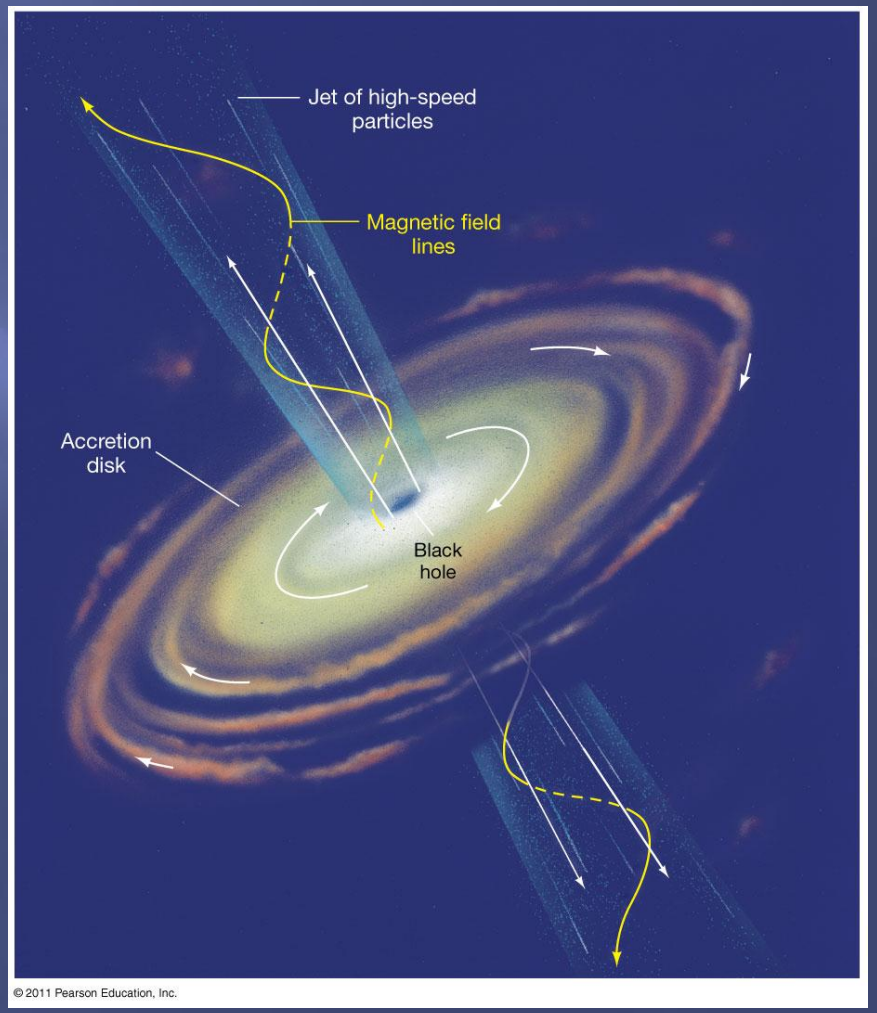


Infrared image reveals warm gas near the nucleus.

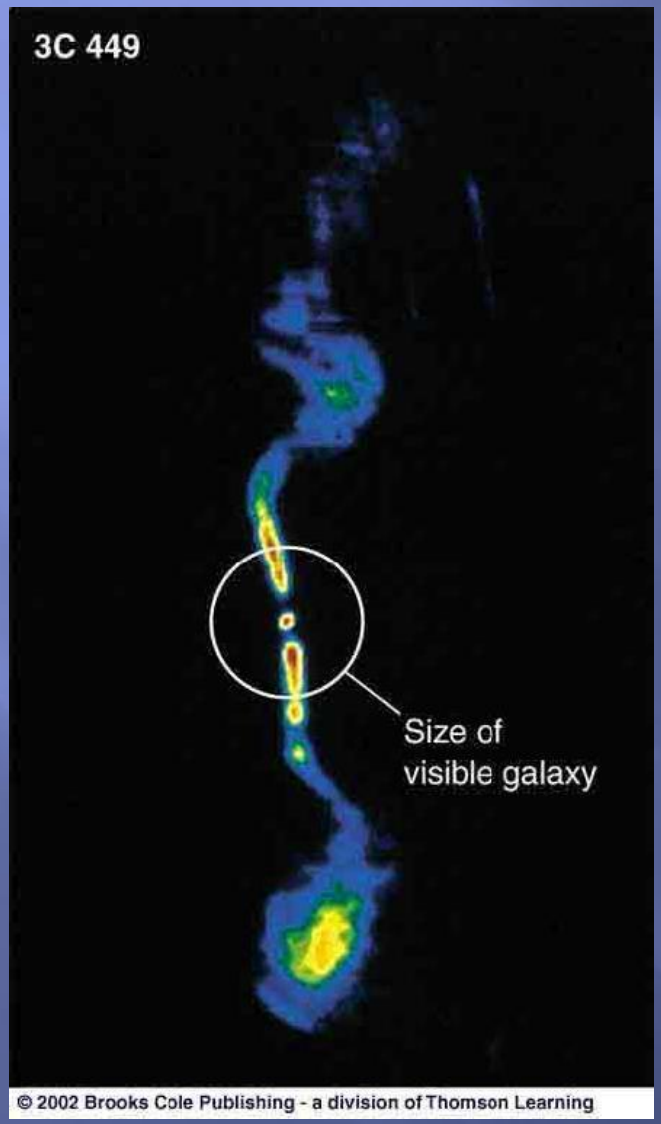


The Central Engine of an Active Galaxy

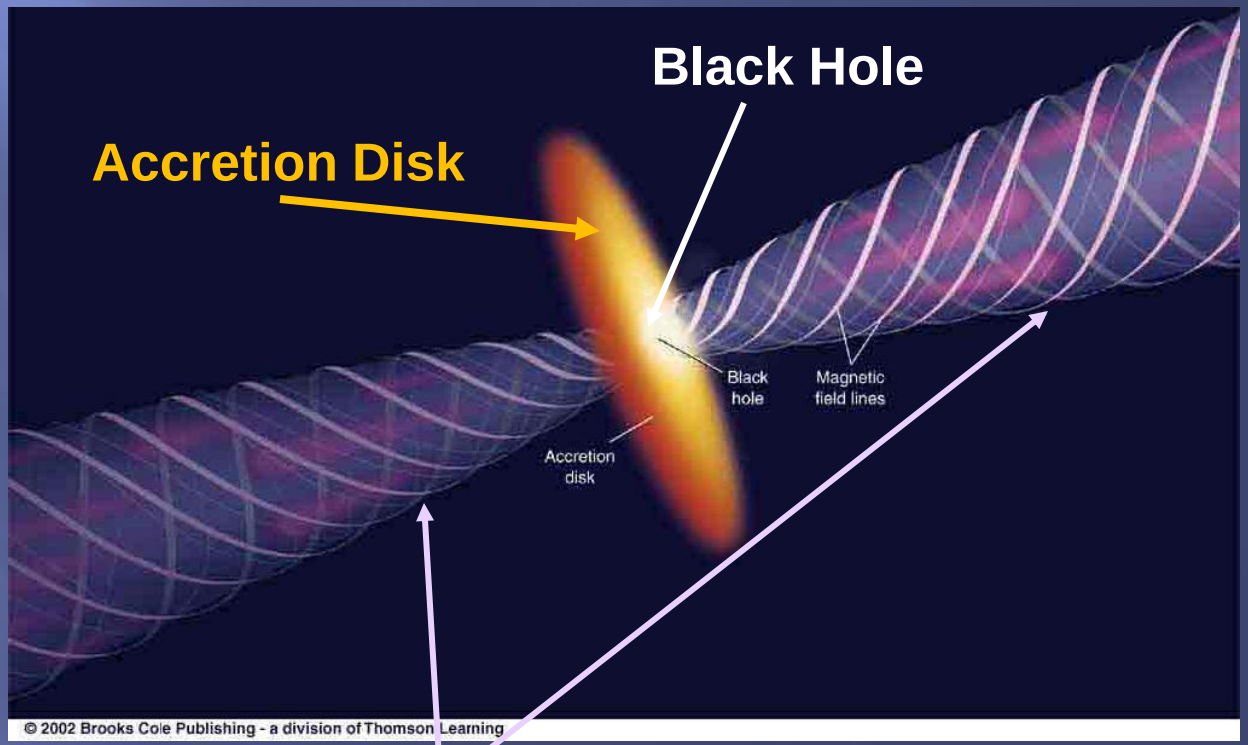
- The leading theory for the energy source in an active galactic nucleus: a black hole, surrounded by an accretion disk.
- The central black hole may be > 10^9 of solar masses.
- The accretion disk is interstellar gas and dust; it may radiate away as much as 10–20% of its mass before disappearing.
- The strong magnetic field lines around the black hole channel particles into jets perpendicular to the magnetic axis.



Formation of Radio Jets



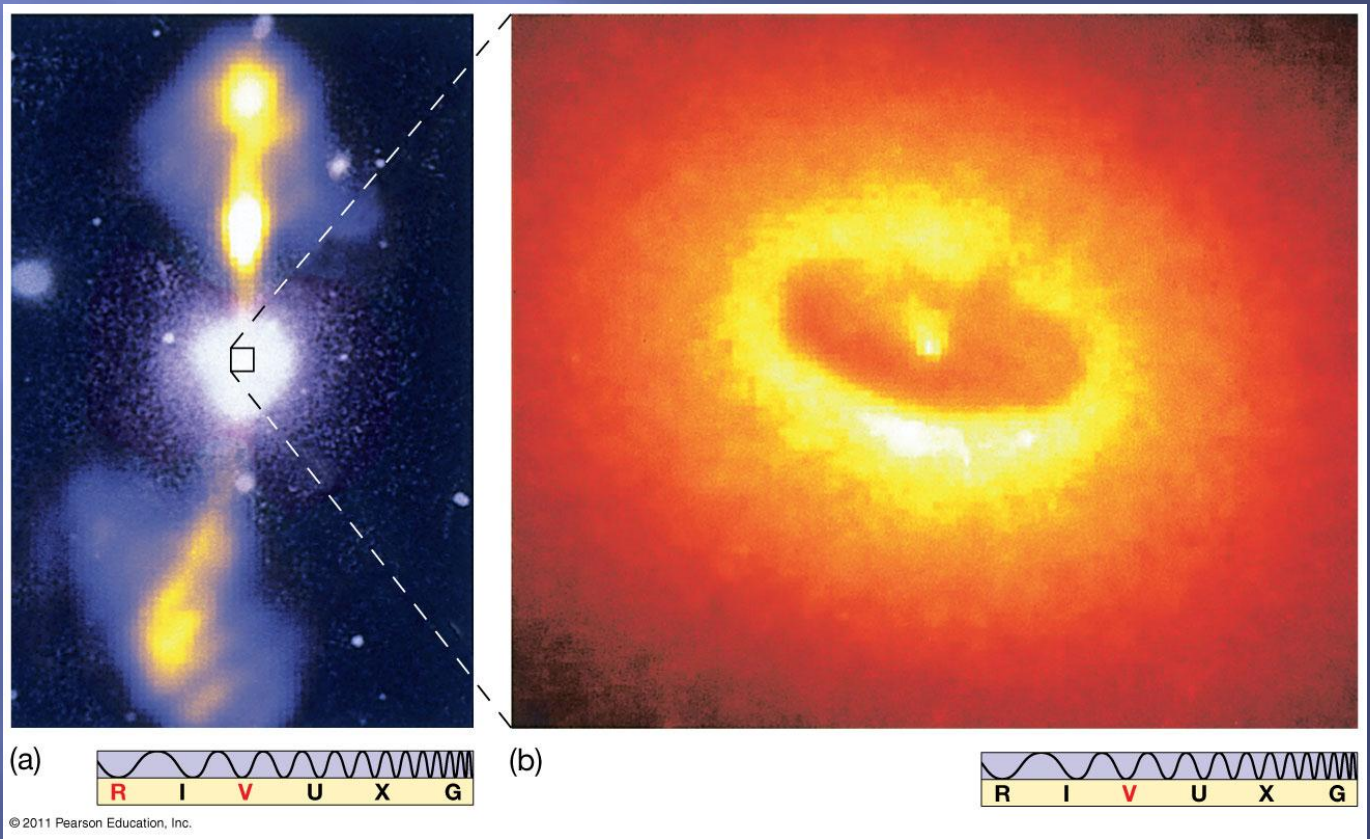
Jets are powered by accretion of matter onto a supermassive black hole.



Twisted magnetic fields help to confine the material in the jet and to produce synchrotron radiation.

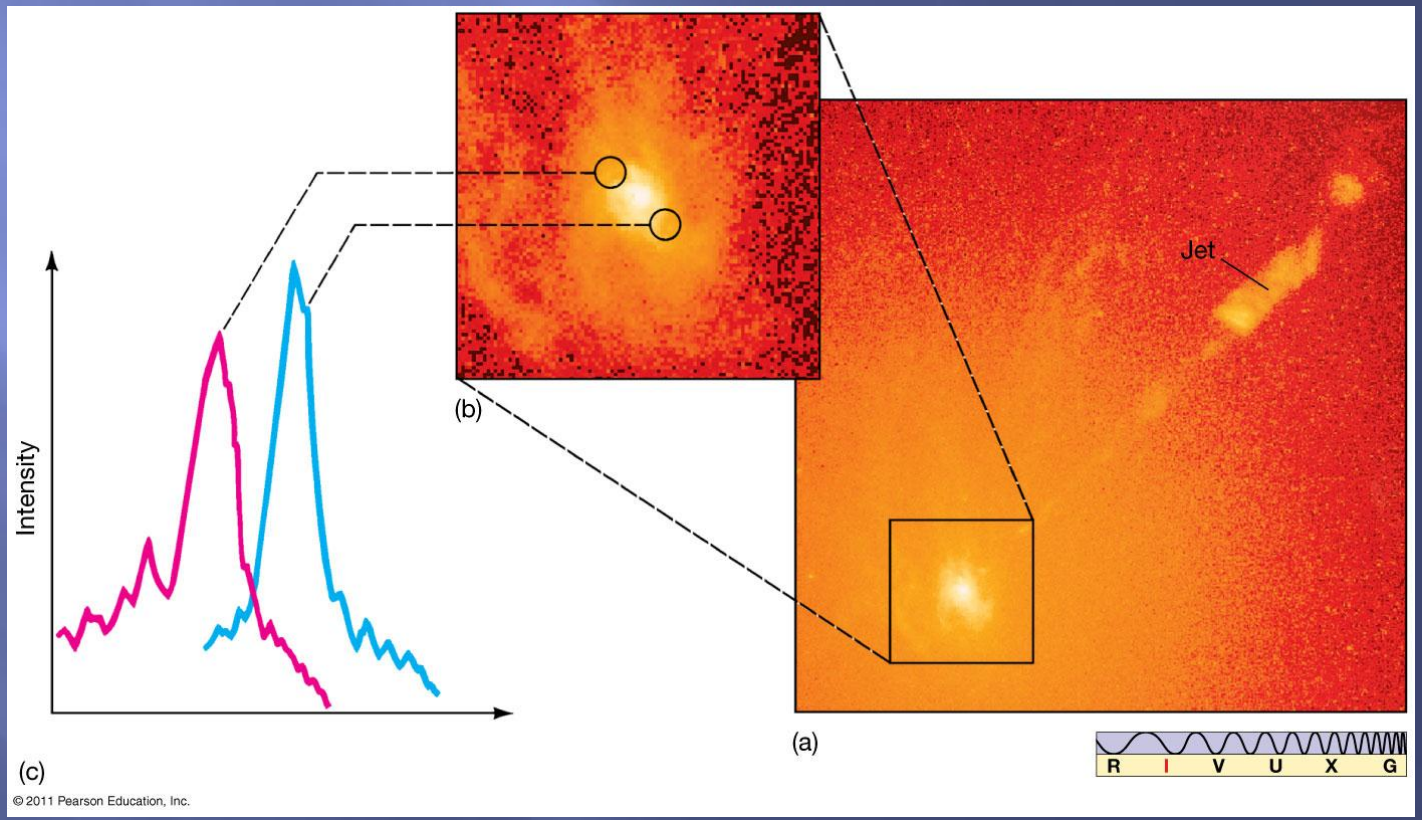
The Central Engine of an Active Galaxy

This pair of images shows evidence for a black hole at the center of NGC 4261.



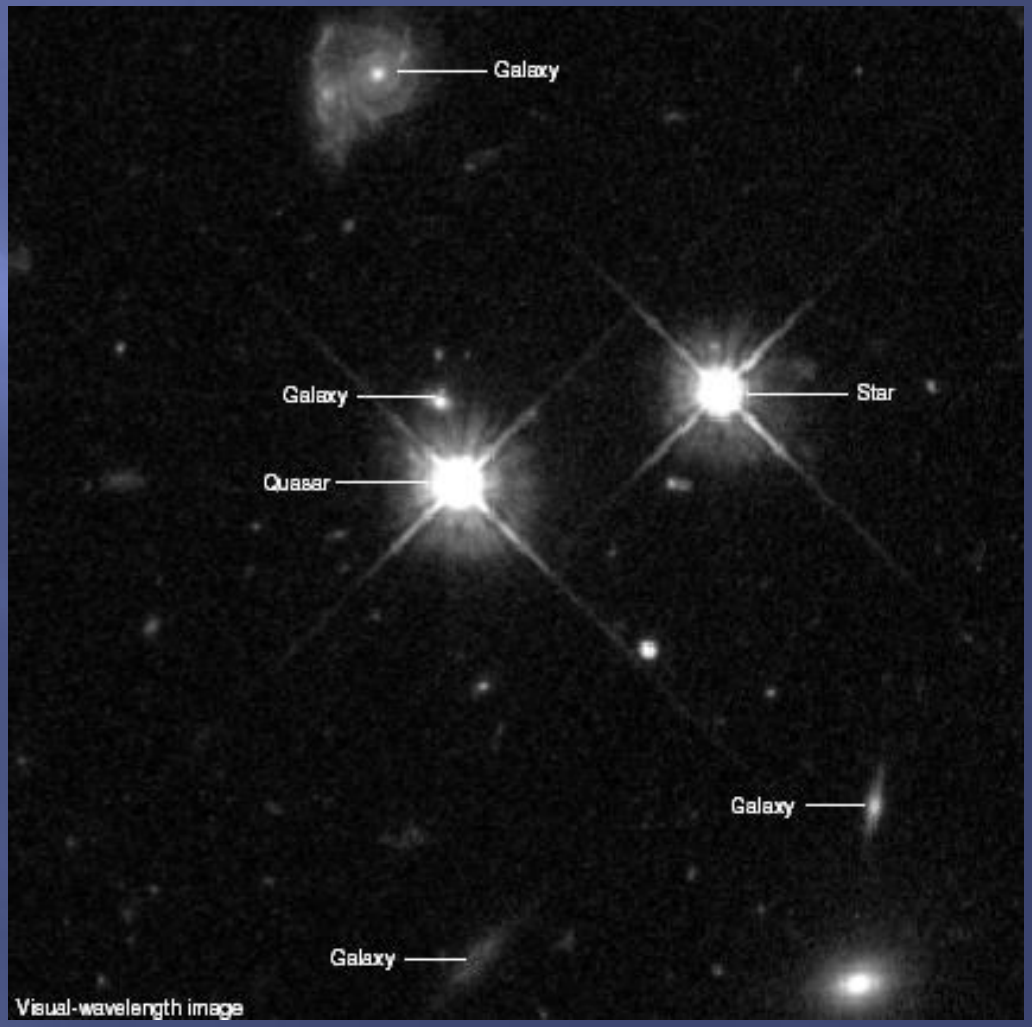
The Central Engine of an Active Galaxy

The central portion of M87 shows rapid motion and jets characteristic of material surrounding a black hole.



Quasars

- Active nuclei in elliptical galaxies with even more powerful central sources than Seyfert galaxies.
- Show strong variability over time scales of a few months.
- Show very strong, broad emission lines in their spectra.

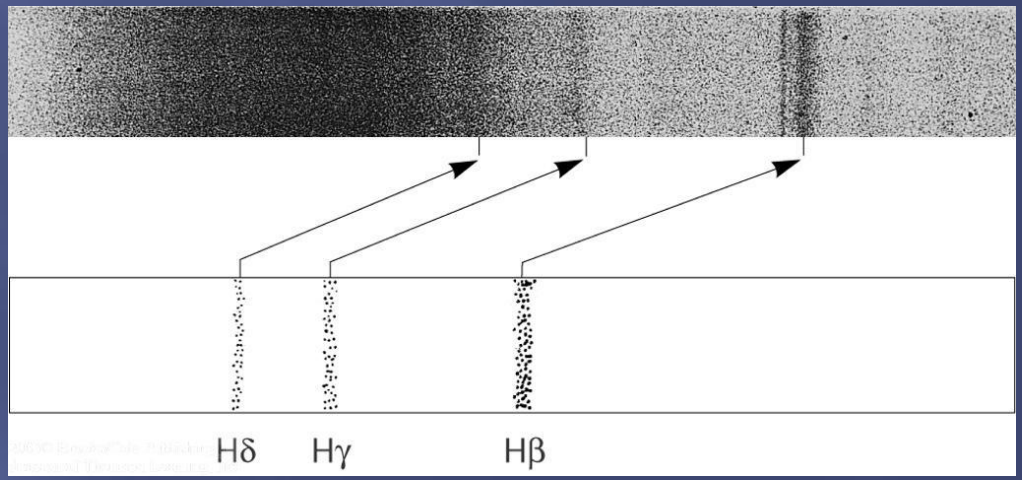


The Spectra of Quasars

Quasar 3C273

Spectral lines show a large redshift of

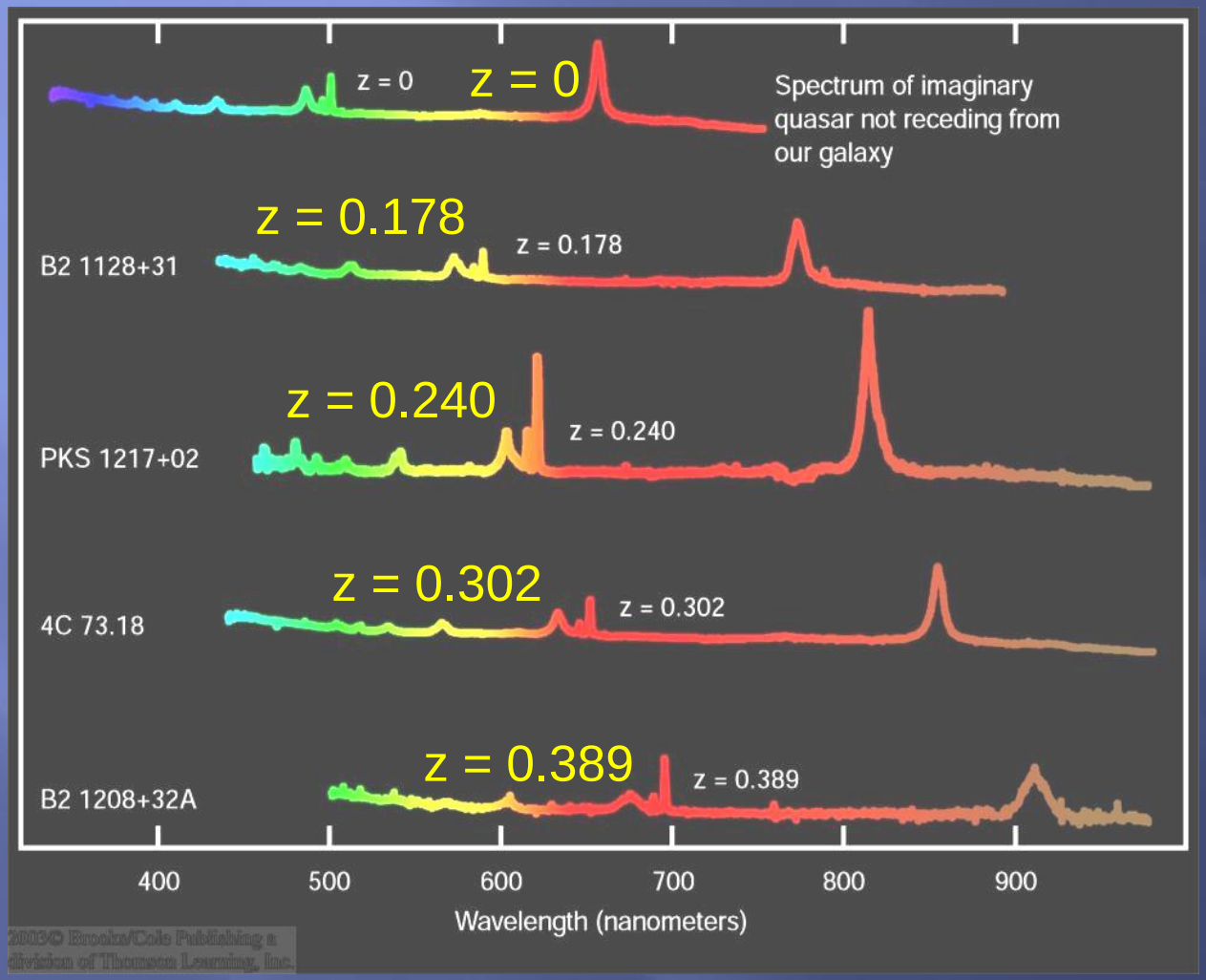
$$z = \Delta\lambda/\lambda_0 = 0.158$$



Relativistic Redshifts and Look-Back Time

- The redshift of a beam of light is its fractional increase in wavelength. Redshifts are measured directly; distances are calculated from them using Hubble's constant, which is uncertain. Astronomers therefore prefer to quote redshifts rather than distances.
- The look-back time is the time when light was emitted from a distant object; for very distant objects it is less than the redshift would indicate, as the object has receded in the meantime.

Quasar Red Shifts



Quasars have been detected at very high redshifts, up to $z \sim 6$ where

$$z = \Delta\lambda / \lambda_0 \ .$$

The simple formula

$$\Delta\lambda / \lambda_0 = v_r / c$$

is only valid in the limit of low speed,

$$v_r << c$$

Large redshifts require a formula derived from the Special Theory of Relativity

Studying Quasars

The study of high-redshift quasars allows astronomers to investigate questions of

1) **Large scale structure of the universe**
2) **Early history of the universe**
3) **Galaxy evolution**
4) **Dark matter**

Observing quasars at high redshifts

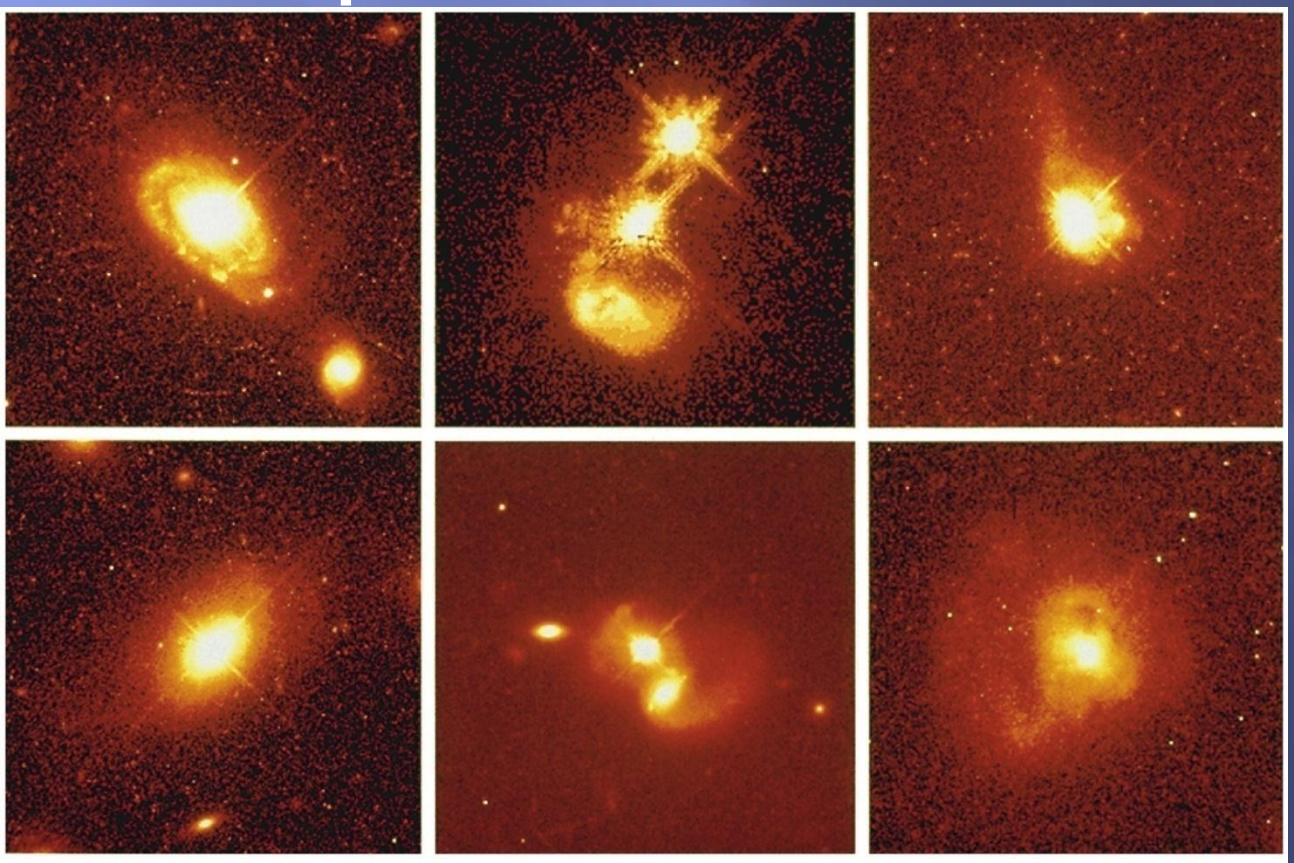
⇒ **Distances of several Gpc**

⇒ **Look-back times of many billions of years**

⇒ **Universe was only a few billion years old!**

Black Holes and Active Galaxies

The quasars we see are very distant, meaning they existed a long time ago. Therefore, they may represent an early stage in galaxy development.



The quasars in this image are shown with their host galaxies; many appear to be involved in collisions.

Black Holes and Active Galaxies

The end of the quasar epoch seems to have been about 10^9 years ago; all the quasars we have seen are older than that.

The black holes powering the quasars do not go away; it is believed that many, if not most, galaxies have a **supermassive black hole** at their centers.

Black Holes and Active Galaxies

This figure shows how galaxies may have evolved, from early irregulars through active galaxies, to the normal ellipticals and spirals we see today.