

Galaxies and Black Holes

- Red shifts of quasars
- Active galactic nuclei
- Black holes in normal galaxies

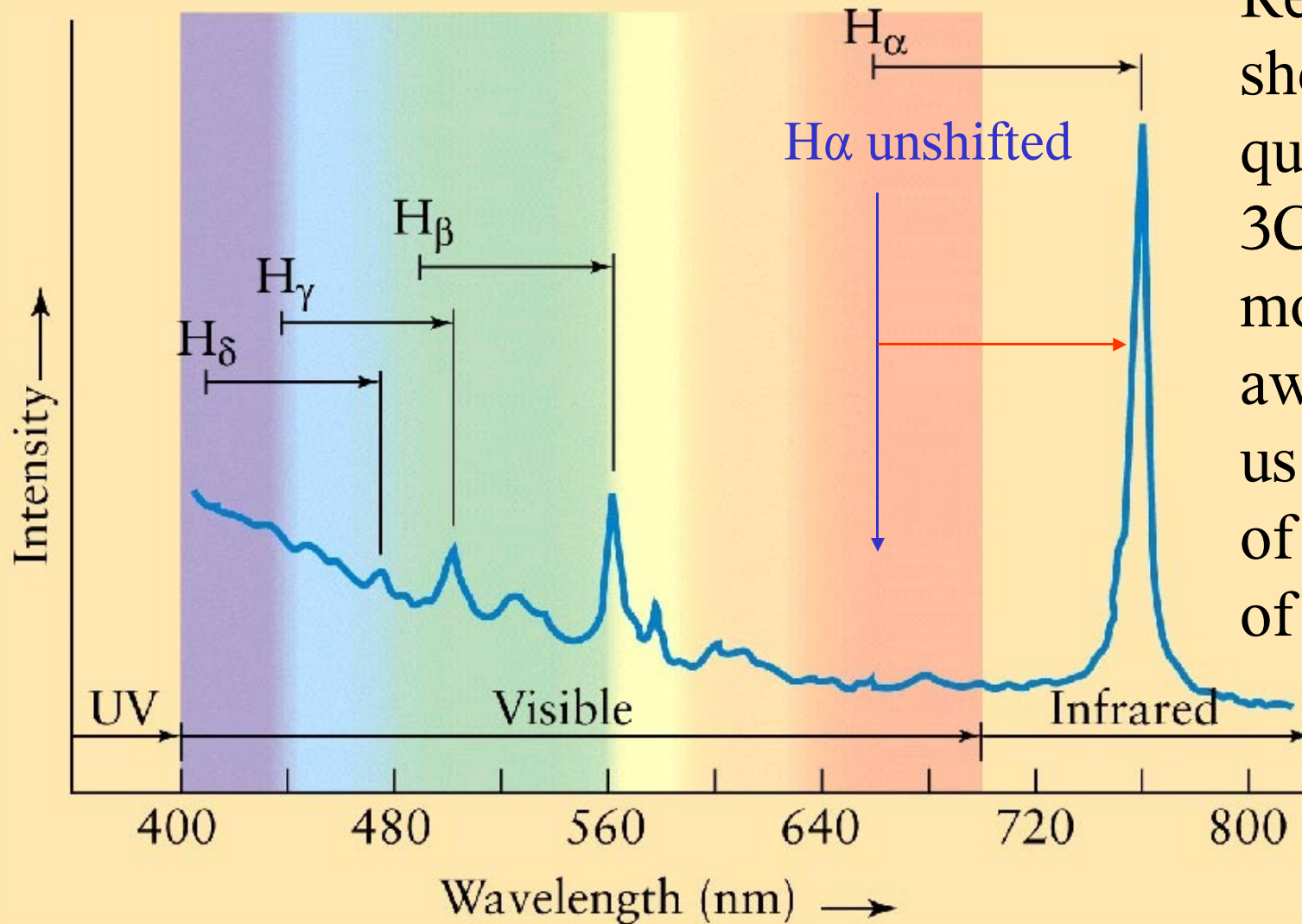
There is often a giant elliptical galaxy at the center of a cluster of galaxies. Such galaxies are thought to arise from

- A) Large amounts of gas collecting in the core
- B) A collection of black holes at the center of the cluster
- C) Interactions and collisions among cluster members
- D) A giant spiral galaxy

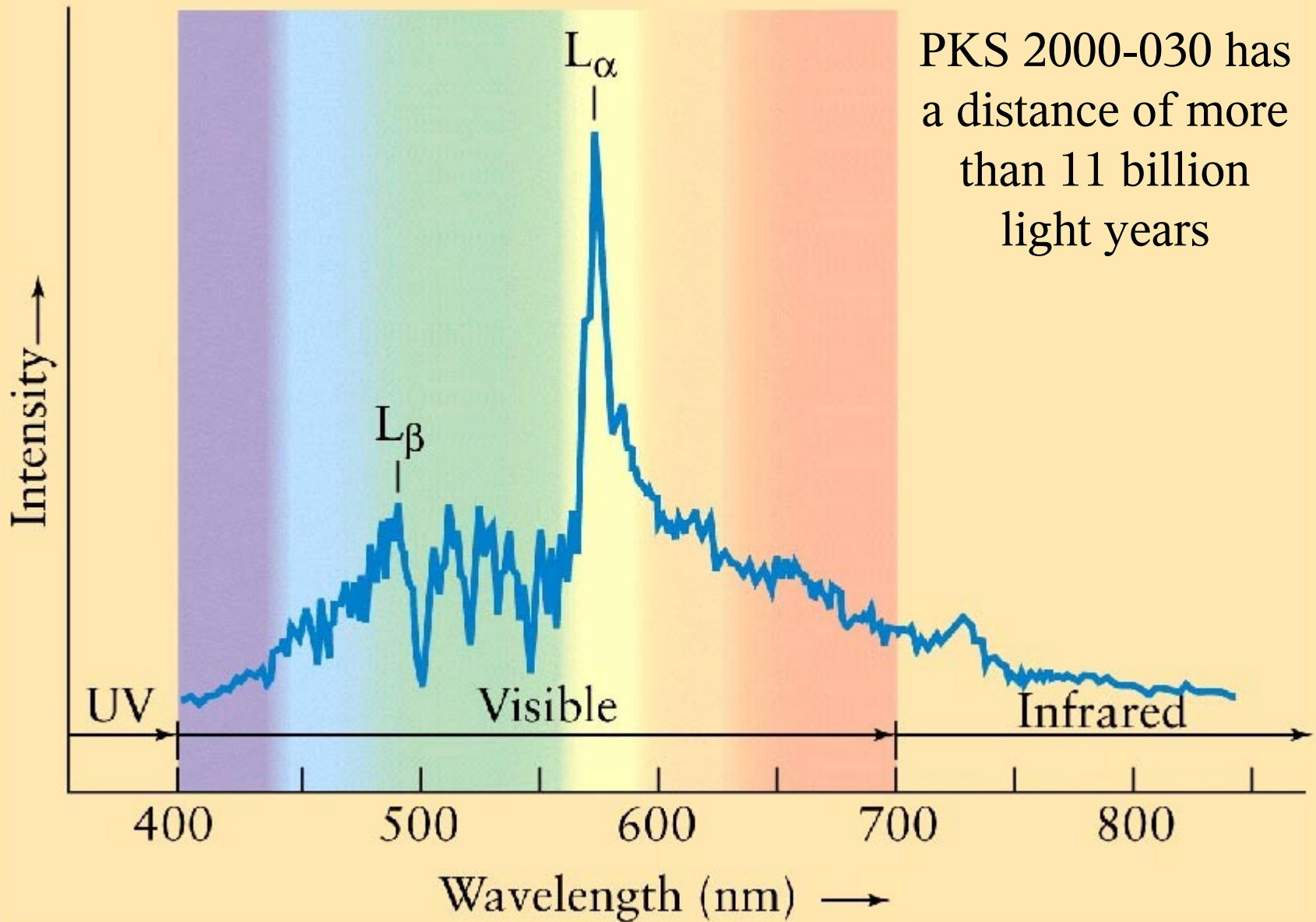
If Hubble's constant were twice as large as we now think it is, our estimate of the age of the universe would

- A) be unchanged
- B) increase by a factor of 2
- C) increase by a factor of 4
- D) decrease by a factor of 2
- E) decrease by a factor of 4

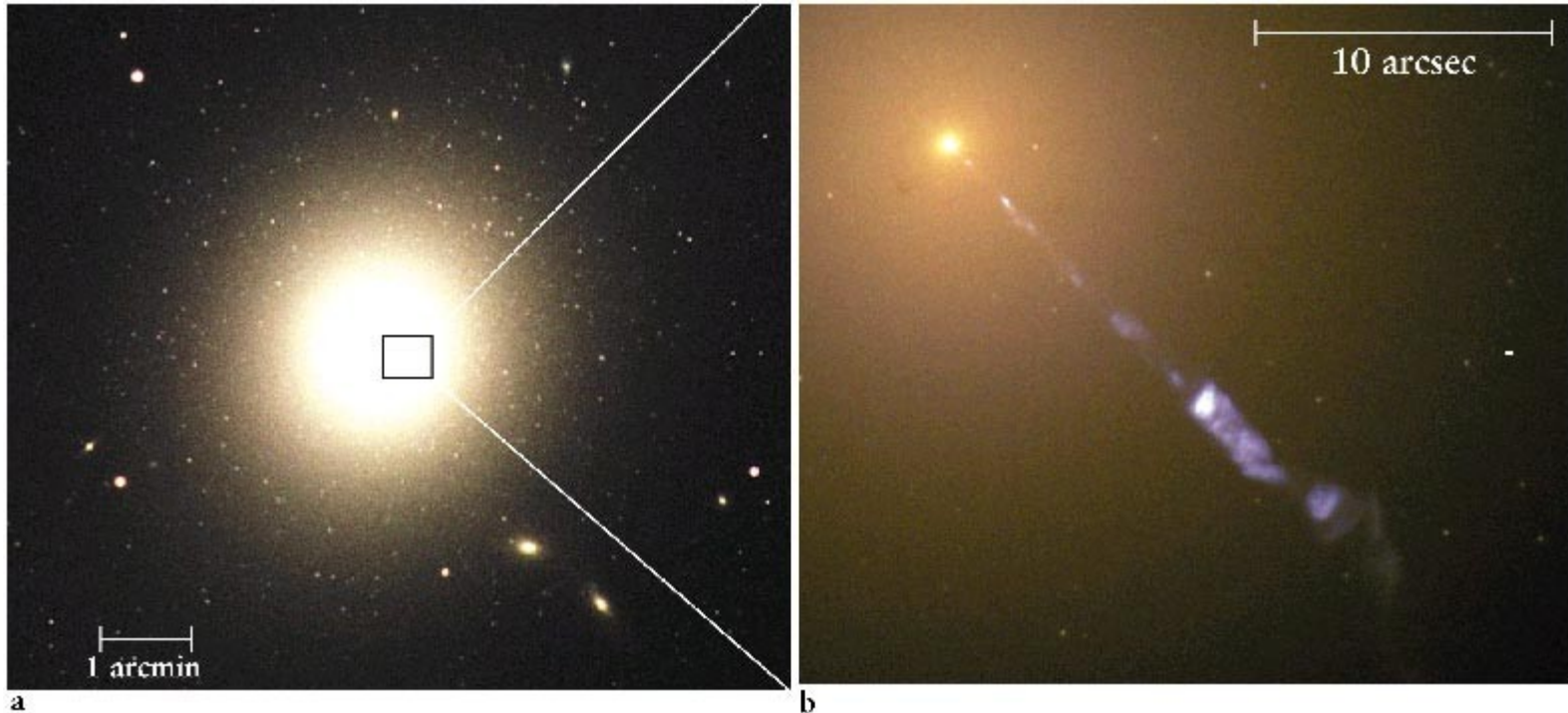
Quasar optical spectrum



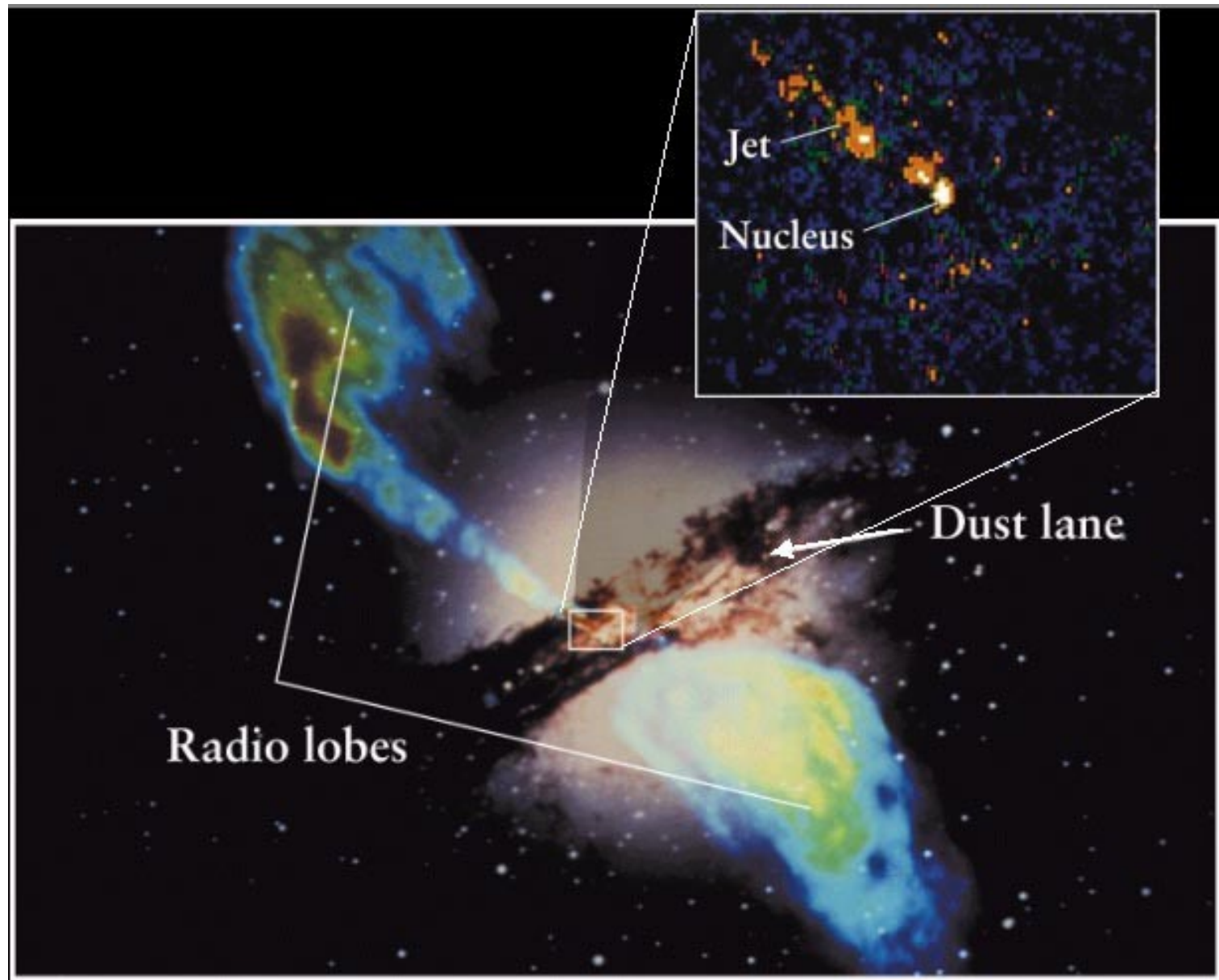
Redshift shows this quasar, 3C273, is moving away from us at 16% of the speed of light



Quasars are the most extreme of a class of galaxies known as active galaxies



M87 appears as an elliptical galaxy in visible light, but like a dim quasar in radio. The nucleus of the galaxy contains a weak quasar. This means that the galaxy harbors a supermassive black hole.

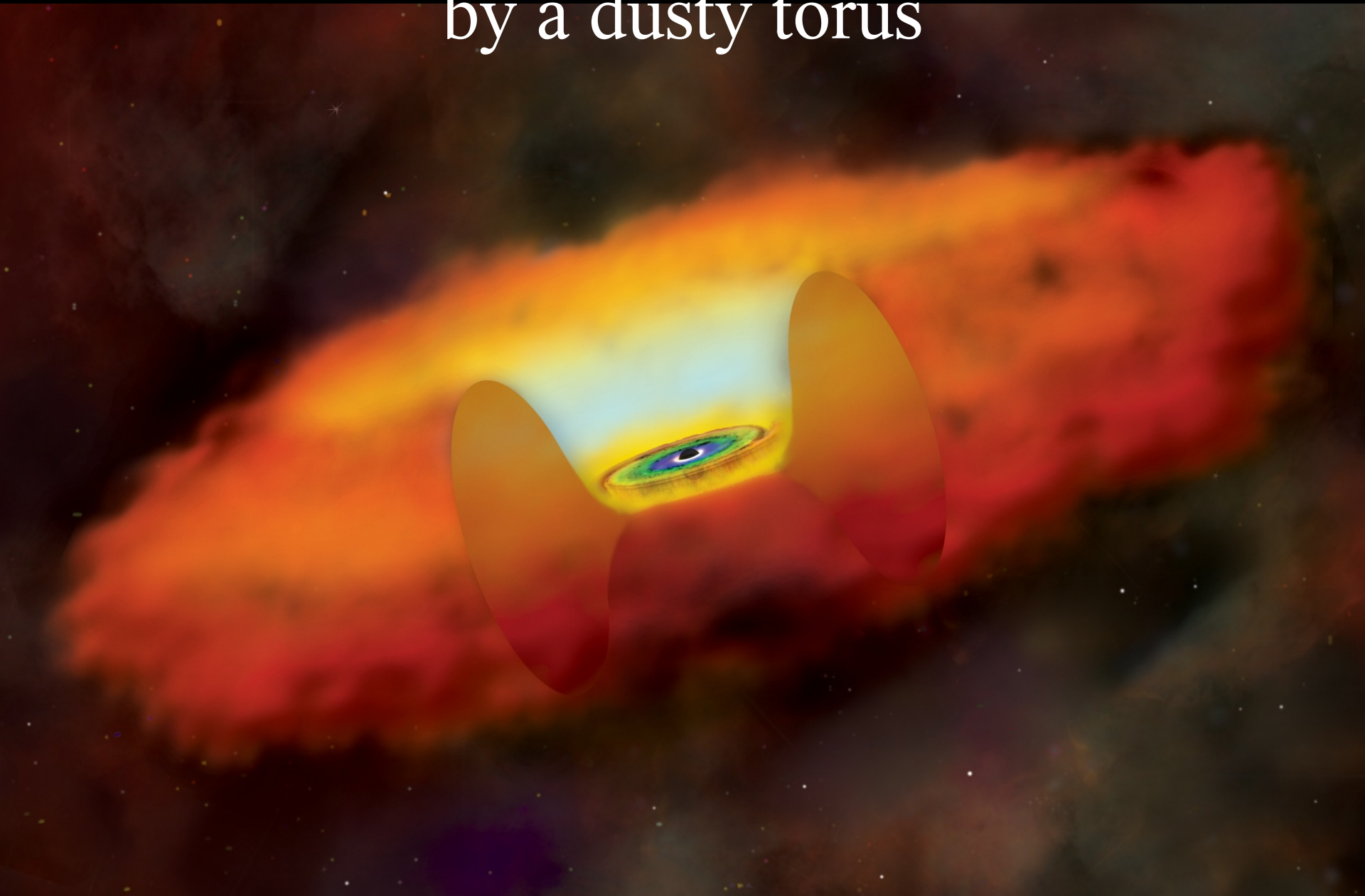


Active galaxies lie at the center of double radio sources.

Active Galaxies come in several varieties

- Quasars
- Seyfert galaxies
 - luminous, star-like nuclei with strong emission lines.
- BL Lacertae objects (BL Lacs)
 - featureless spectrum with a brightness that can vary by a factor of 15 times in a few months.
 - Most commonly known as a Blazar.
- All contain supermassive black holes

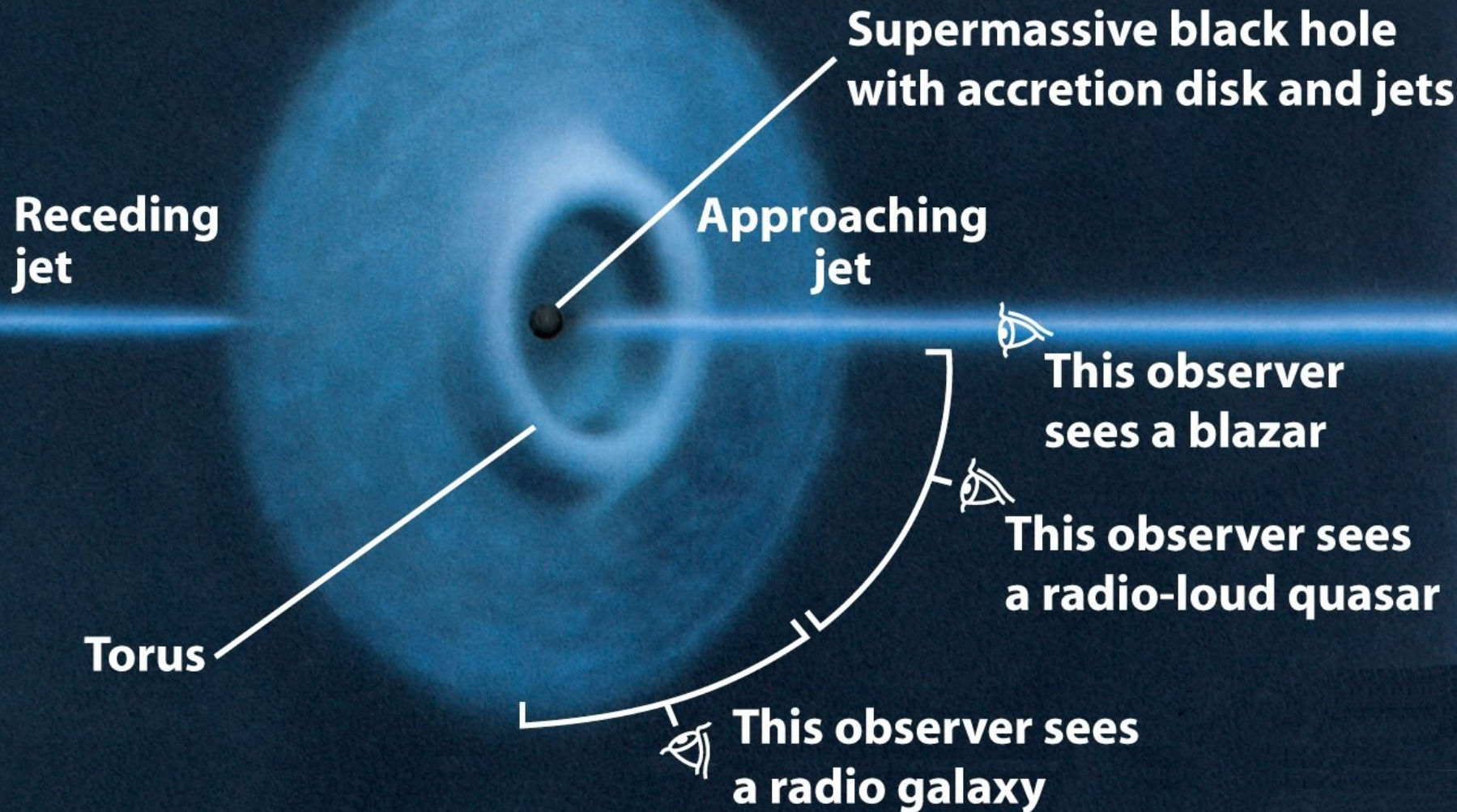
In Active Galaxies the disk is surrounded
by a dusty torus



Varieties of Active Galaxies

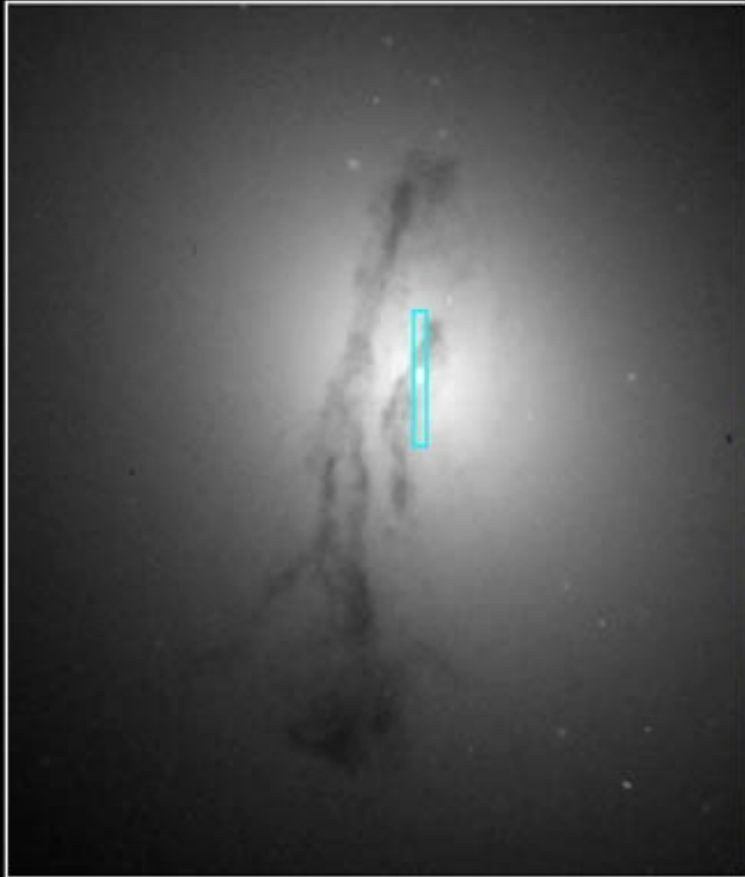
- Radio Galaxies – big jets, no obvious BH
- Quasars – jets and BH
- Blazars – mainly see the jet

Orientation



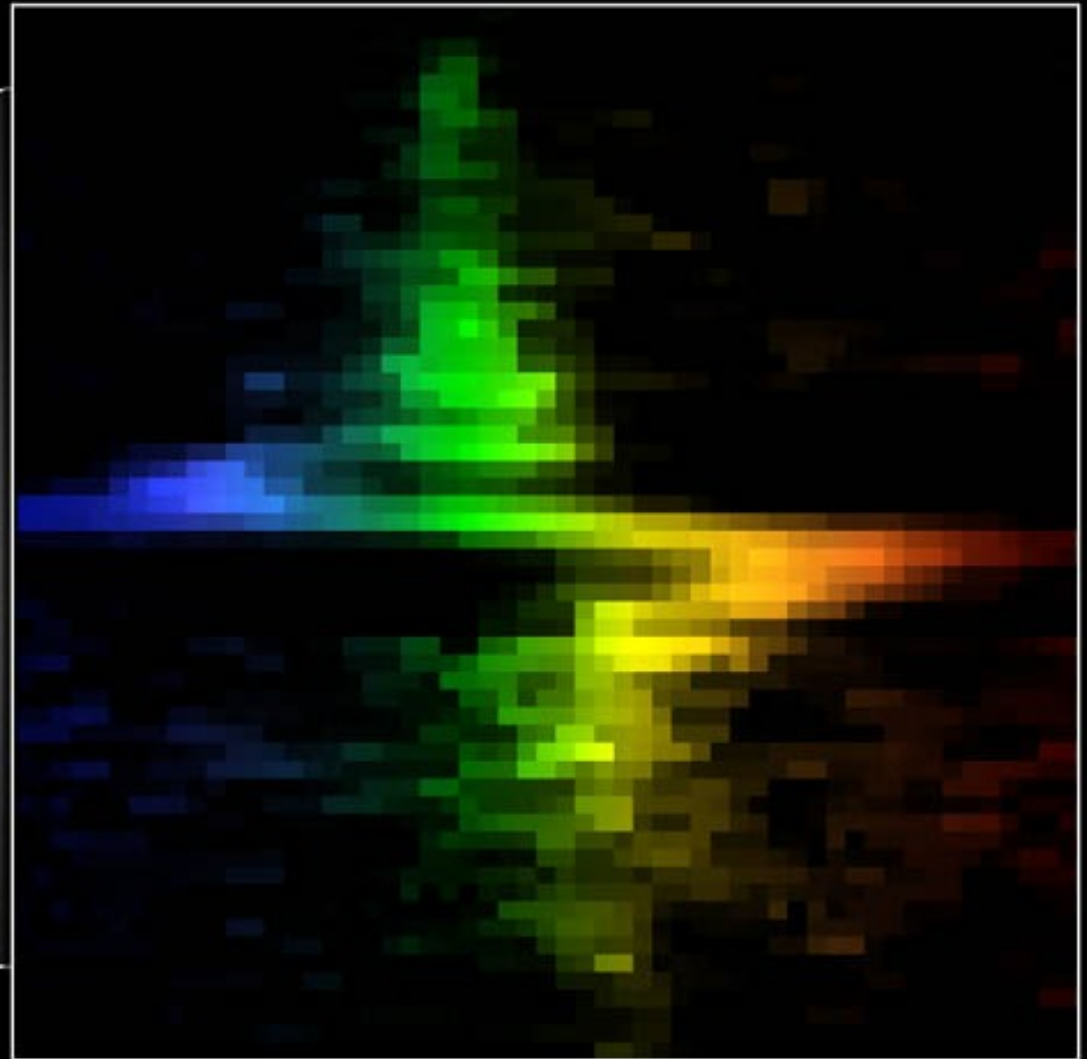
Black holes in normal galaxies

Galaxy M84 Nucleus



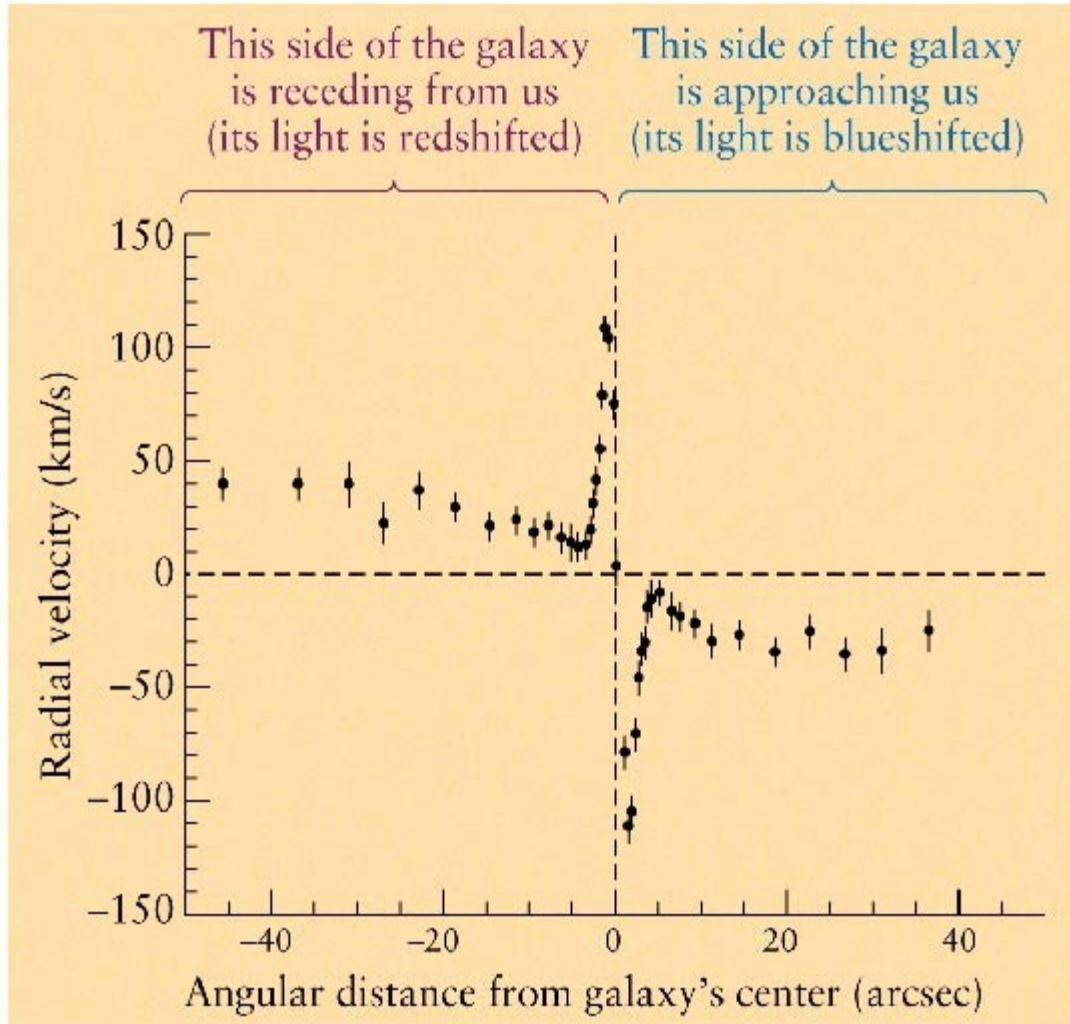
WFPC2

Hubble Space Telescope



STIS

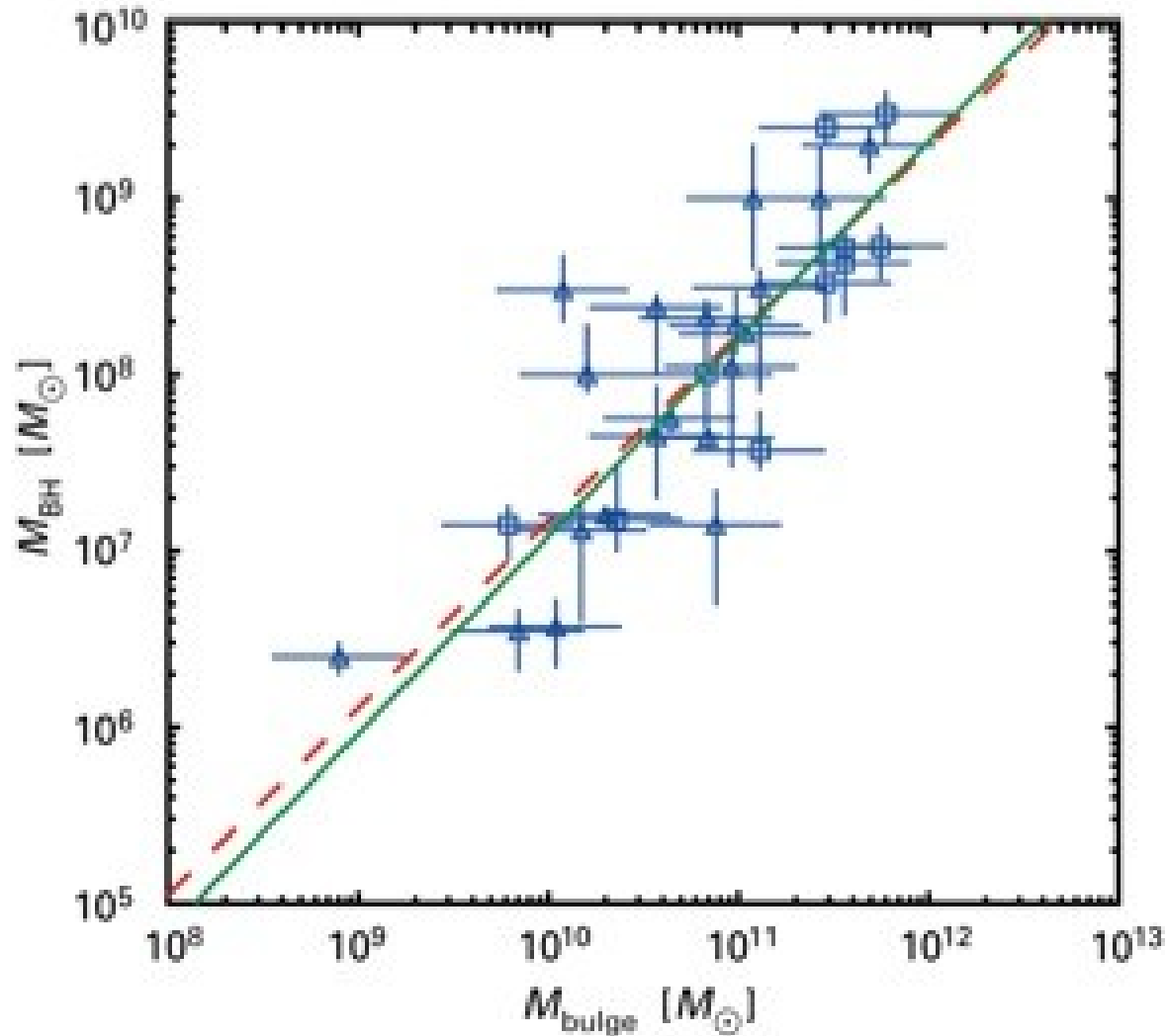
Black holes in normal galaxies



Rotation curves of stars near the centers of most galaxies show the presence of supermassive black holes with mass ranging from 10^6 to 10^9 solar masses.

Essentially all galaxies contain supermassive black holes and were likely active galaxies at some point in their lives.

Black holes related to galaxy formation



The mass of the central black hole is correlated with the mass of the bulge of the galaxy.

This implies a link between black hole formation and galaxy formation.

Quasars are receding from us at high velocities because

- A) matter in black hole jets moves at close to the speed of light
- B) matter moves rapidly when close to a black hole
- C) quasars are at large distances
- D) we smell bad

The variety of different active galaxies
can be explained as due to

- A) different orientations of the accretion disk
- B) different forms of matter being accreted
- C) different shapes of black holes
- D) different velocities of black holes