Active Galaxies

Chapter 27

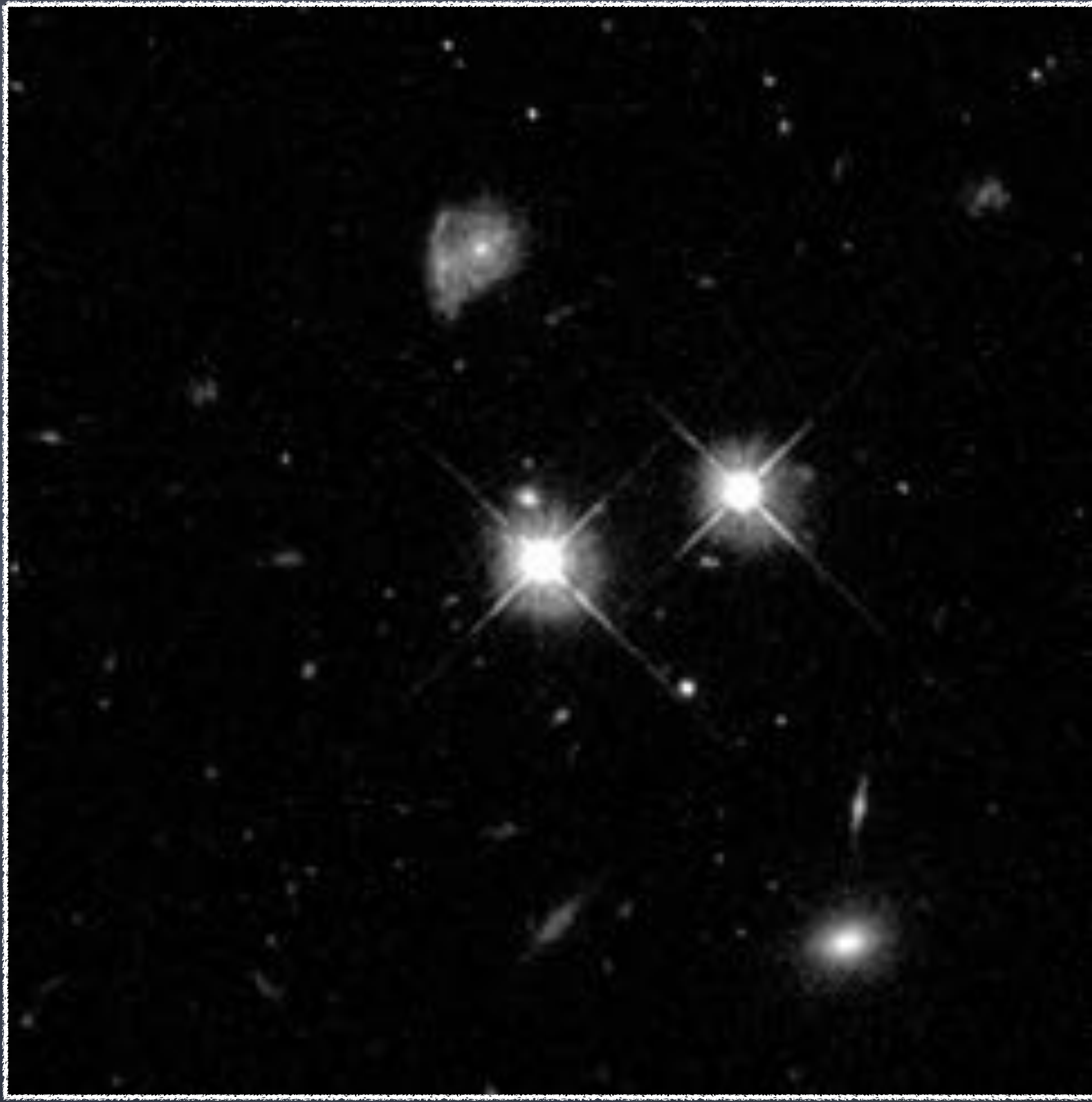
A very deep picture of the sky over a small area, 1/100 the area of the full moon. The left in visible light shows many galaxies, the right in x-ray shows point like quasars.

Quasars

- Quasar stands for quasi-stellar radio source. These are radio sources that match up with faint blue "stars", but no star is known to be such a powerful radio source.
- Spectra of quasars only increased the mystery, because the emission lines couldn't be identified. In 1963 it was realized that they were just redshifted normal lines, but the redshifts were incredible, more than 15% the speed of light.
- These could not be stars in our galaxy, but must be incredibly powerful extragalactic objects that appear point like. Quasars.

A quasar looks like an ordinary star. Only by looking at its spectra can we find that it has a very high redshift and must be very far away. Which means its luminosity is actually billions of times greater than the other stars.

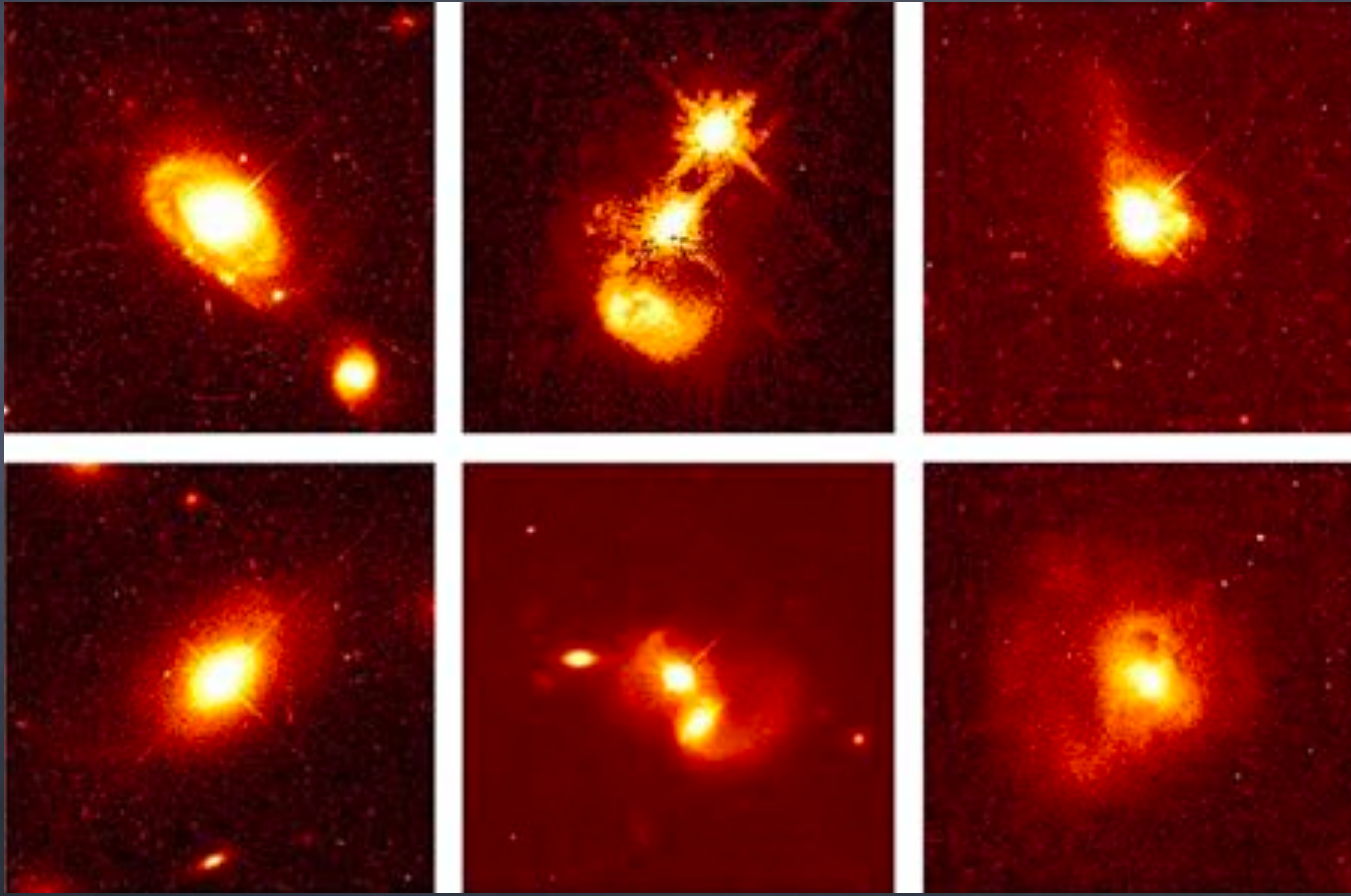
- This image shows a quasar and a star in our galaxy.
- There is no way, to tell which is which without spectra.
- Which tells us the quasar source must be very small, much smaller than a galaxy which we can easily see at this magnification.

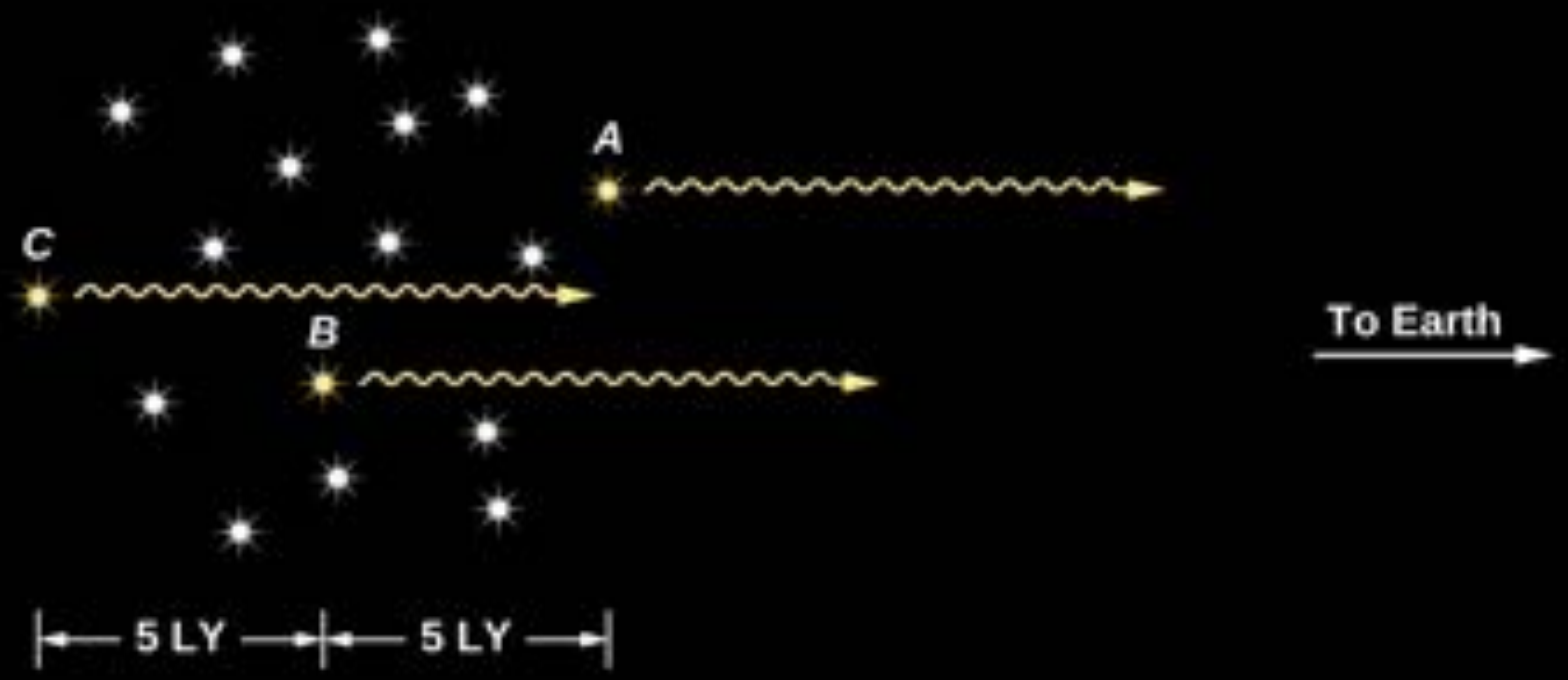


What are Quasars?

- The Hubble telescope can be used to show that quasars are inside galaxies.
- What could be powering these extremely luminous objects where the brightest ones can be a hundred trillion times as luminous as our sun?
- The brightness of quasars varies over months or even weeks. This means the size of the region creating the radiation must be around a 1/10 of a light year, because a larger region could not vary so quickly.
- There are also observations of giant jets coming from the centers of galaxies. These are called active galaxies.

Hubble images of the galaxies hosting quasars. They show quasars occur in a wide range of galaxy types.



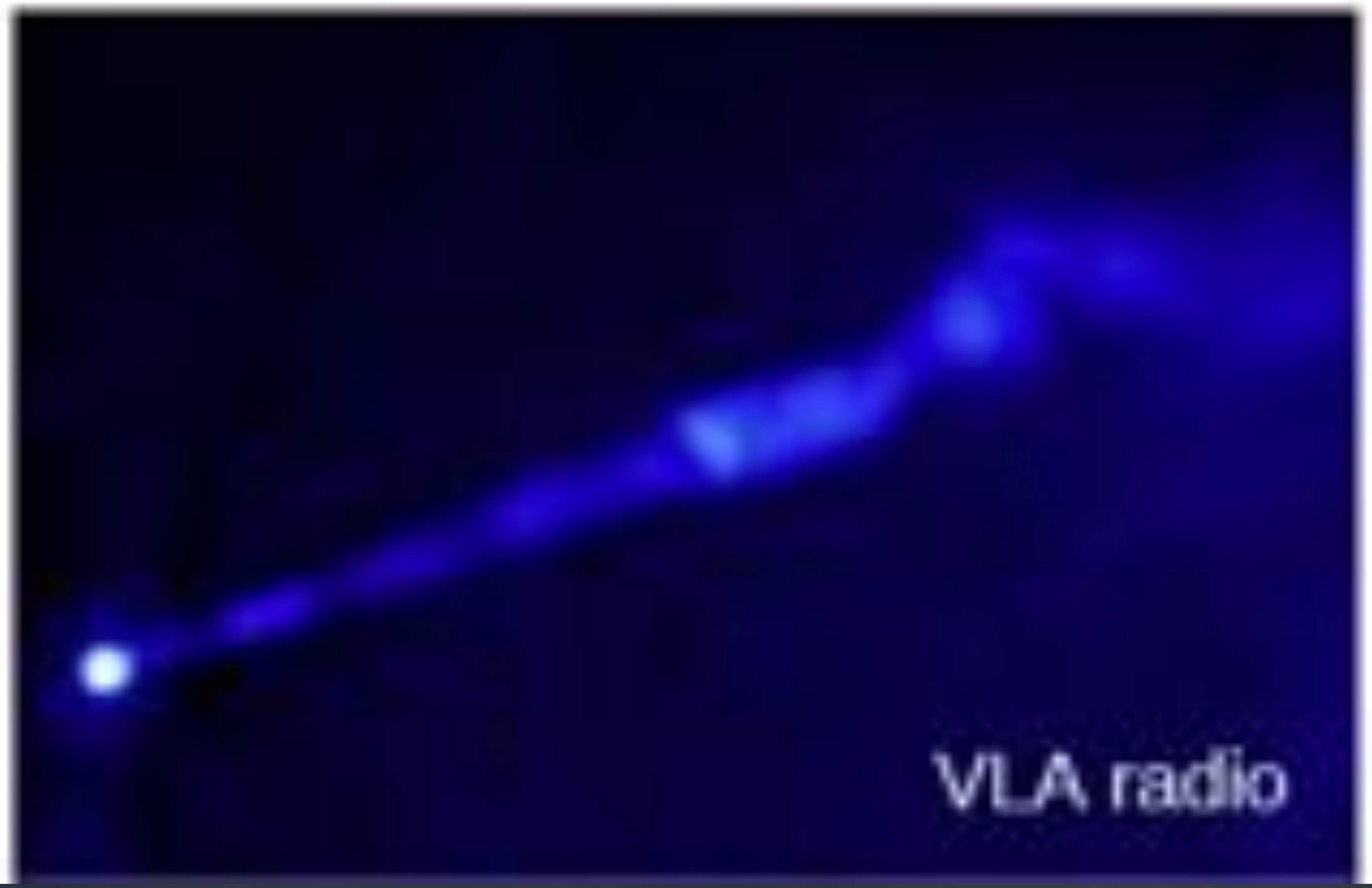


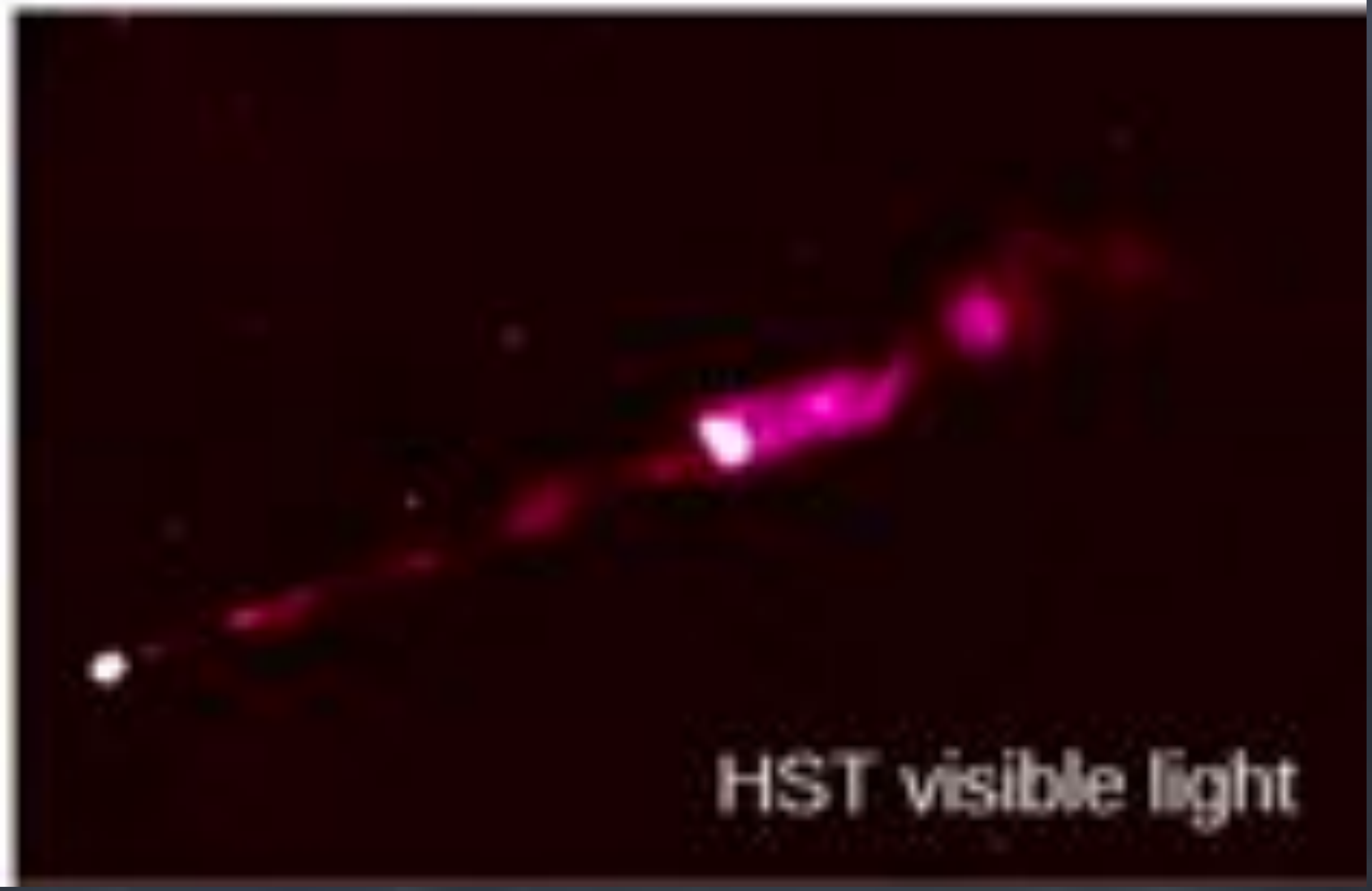
If an object was 10 light years across and it suddenly changed its luminosity, then when we see the change from the front part (A) it still takes 5 years to see the change from the middle part (B) and 5 more to see the change at the end (C). Thus the time it takes an object to change its luminosity is roughly related to its size.

Active Galaxies

A huge jet traveling at nearly the speed of light out of the center of the galaxy M87

The astronomer, Carl Seyfert, found a number of galaxies with very bright centers. Spectroscopy showed that gas was moving at 2% the speed of light in the centers of these galaxies





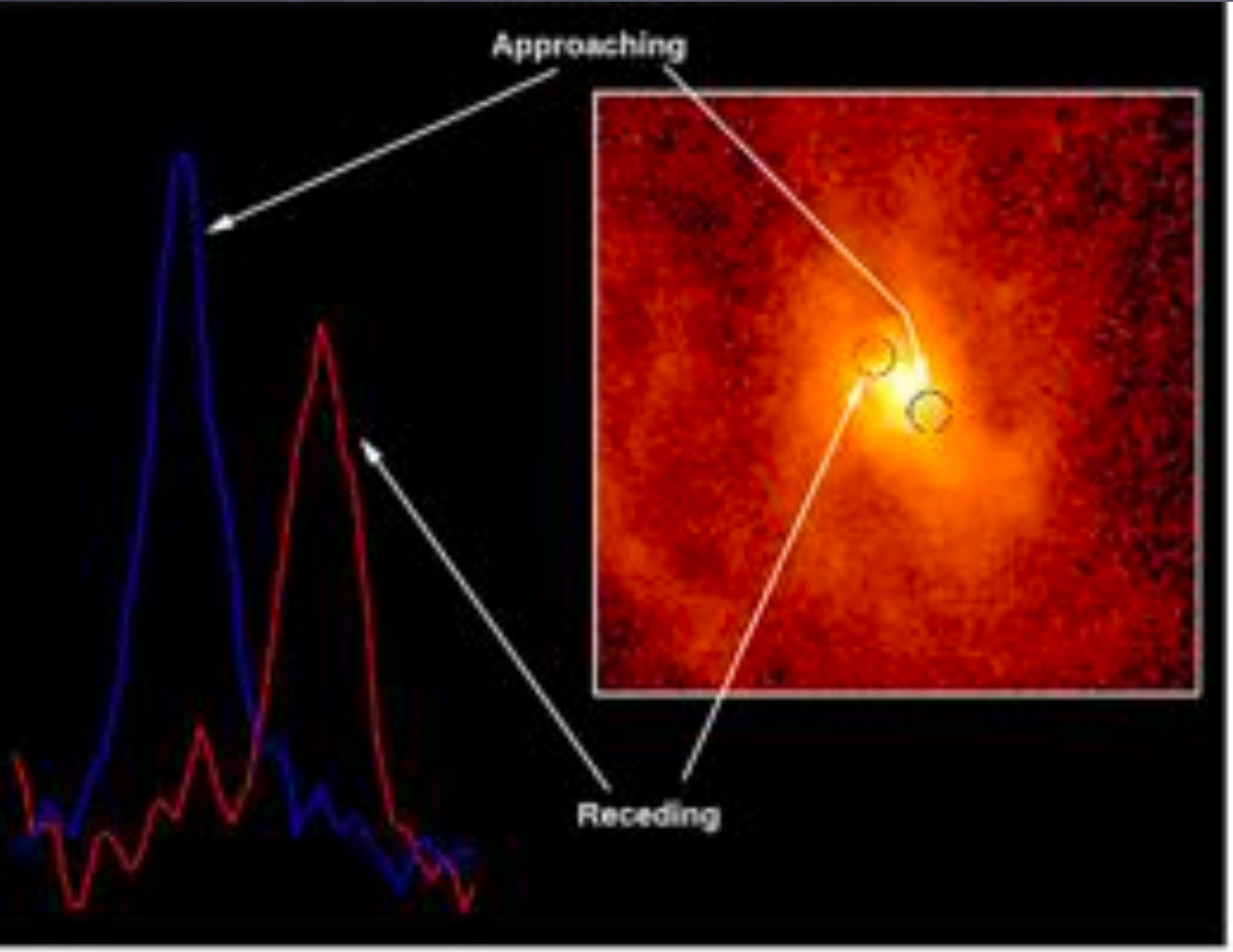
Quasars and Active Galaxies are Powered by Super Massive Black Holes

- Quasars are very luminous, as luminous as an entire galaxy.
- Quasars are very small, much smaller than the distances between stars.
- The only power source we know of that compact is a black hole, but these would need to be millions and billions of times larger than a star.
- We also know blackholes can shoot out jets like seen in the active galaxies.

Observational Evidence of Black Holes

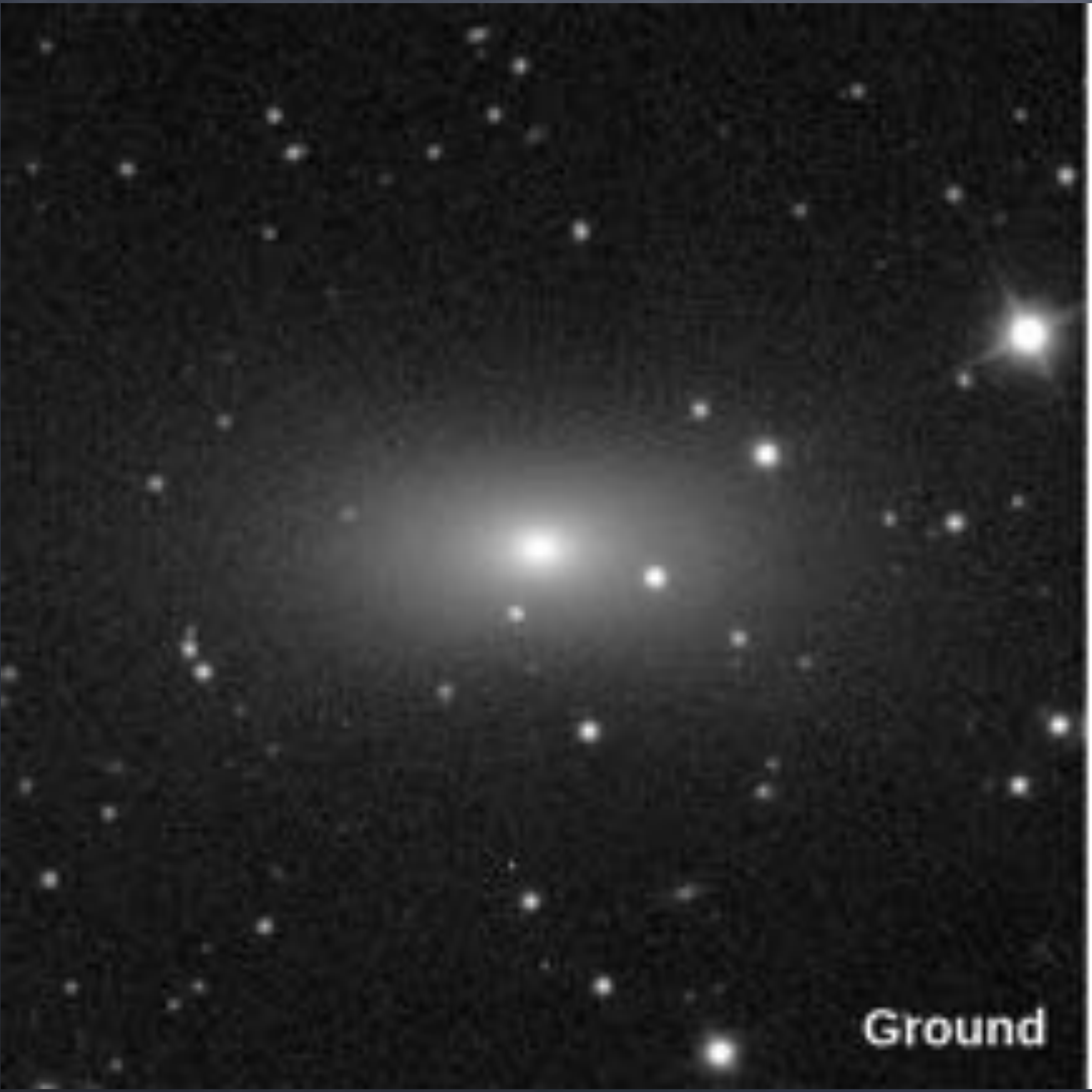
- The best evidence for mass comes from orbiting material. Unlike the Milky Way we can not image individual stars in other galaxies.
- But we can detect gas the seems to be orbiting the central object in some of these galaxies.
- Recently radio interferometers have imaged an accretion disk with such precision that the shadow caused by the black hole can be clearly seen.

Measuring the gas rotating around the center of M87 we can detect there is a massive object of at least 3.5 billion solar masses.



Recently this black hole was directly imaged in radio wave interferometers. This is close as we can get to 'seeing' a back hole.

Another image of gas circling a black hole. In this case the black hole is much smaller, only 300 million times the mass of our sun.



Gravitational Energy

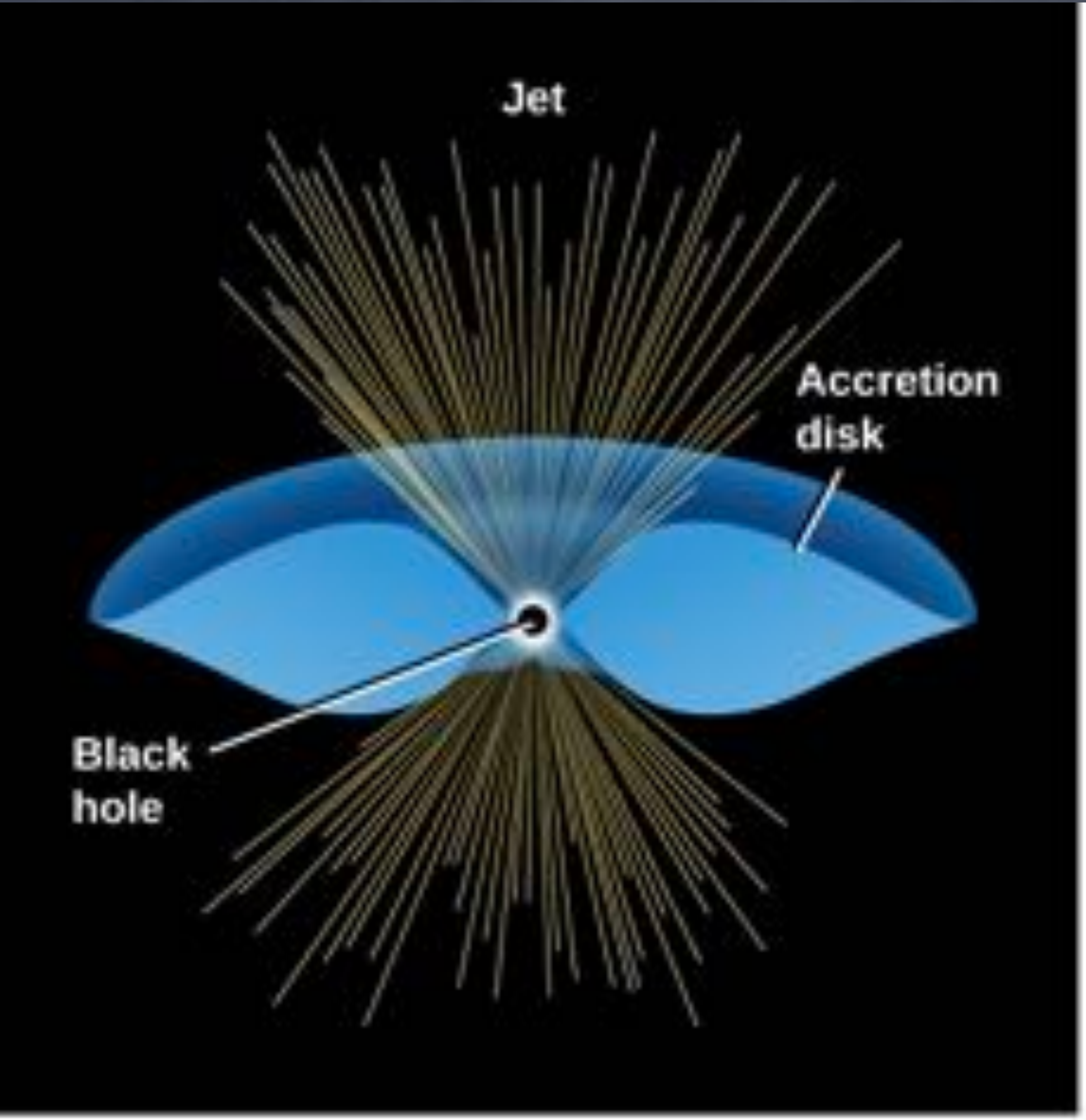
- Gravitational energy is released by friction. The same thing happens with a space craft in the Earth's atmosphere.
- Gas falling into a black hole can be accelerated to 10% the speed of light.
- This converts into temperatures of millions of degrees, emitting x-rays.
- Fusion coverts 1% of the mass to energy, gravitational energy from a black hole is more often 10% of the mass of accreting material.

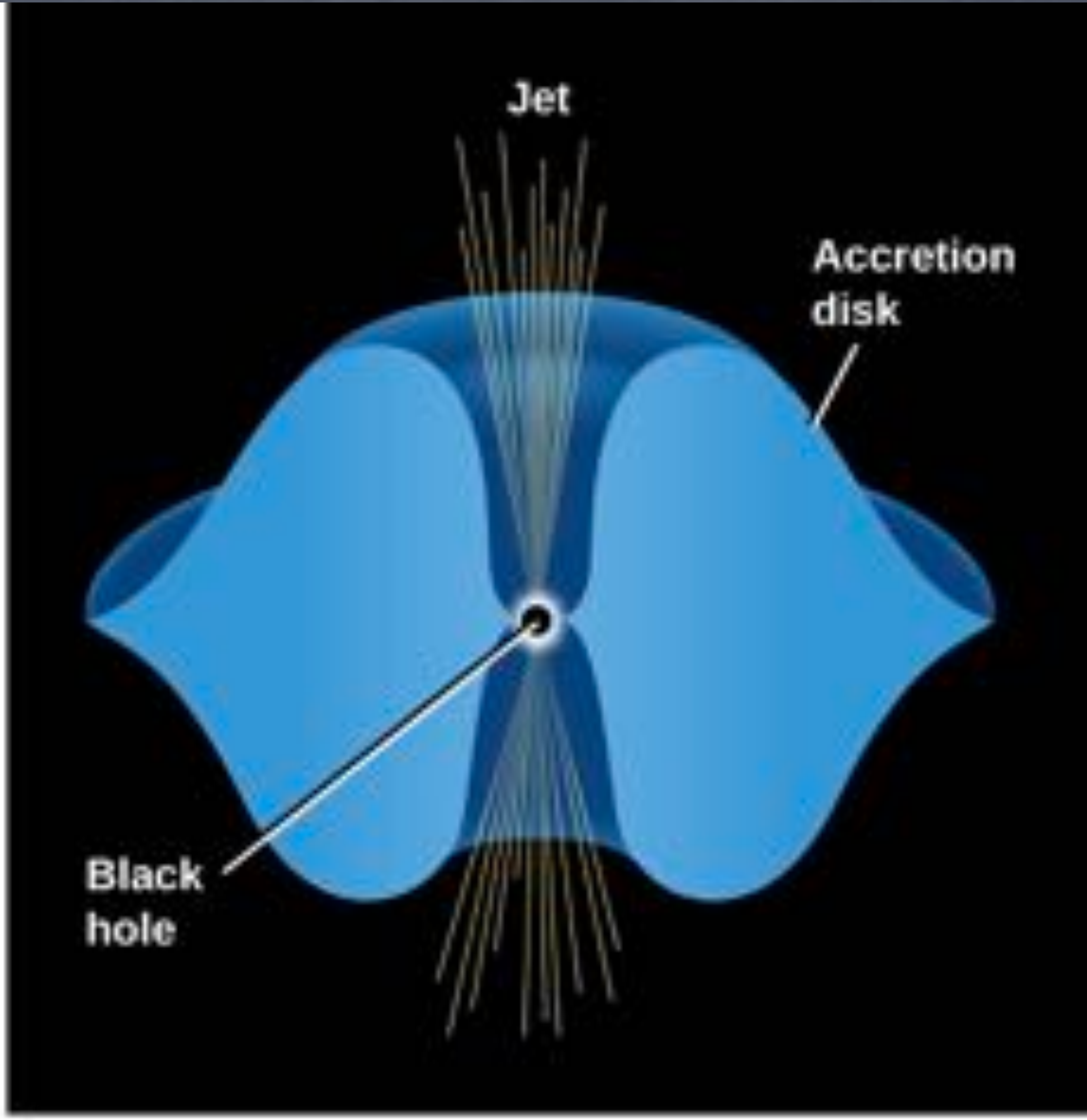
These ‘Fermi Bubbles’ are hot gas bubbles that come from the Milky Way’s center. They may suggest that our supermassive black hole was more active in the past.

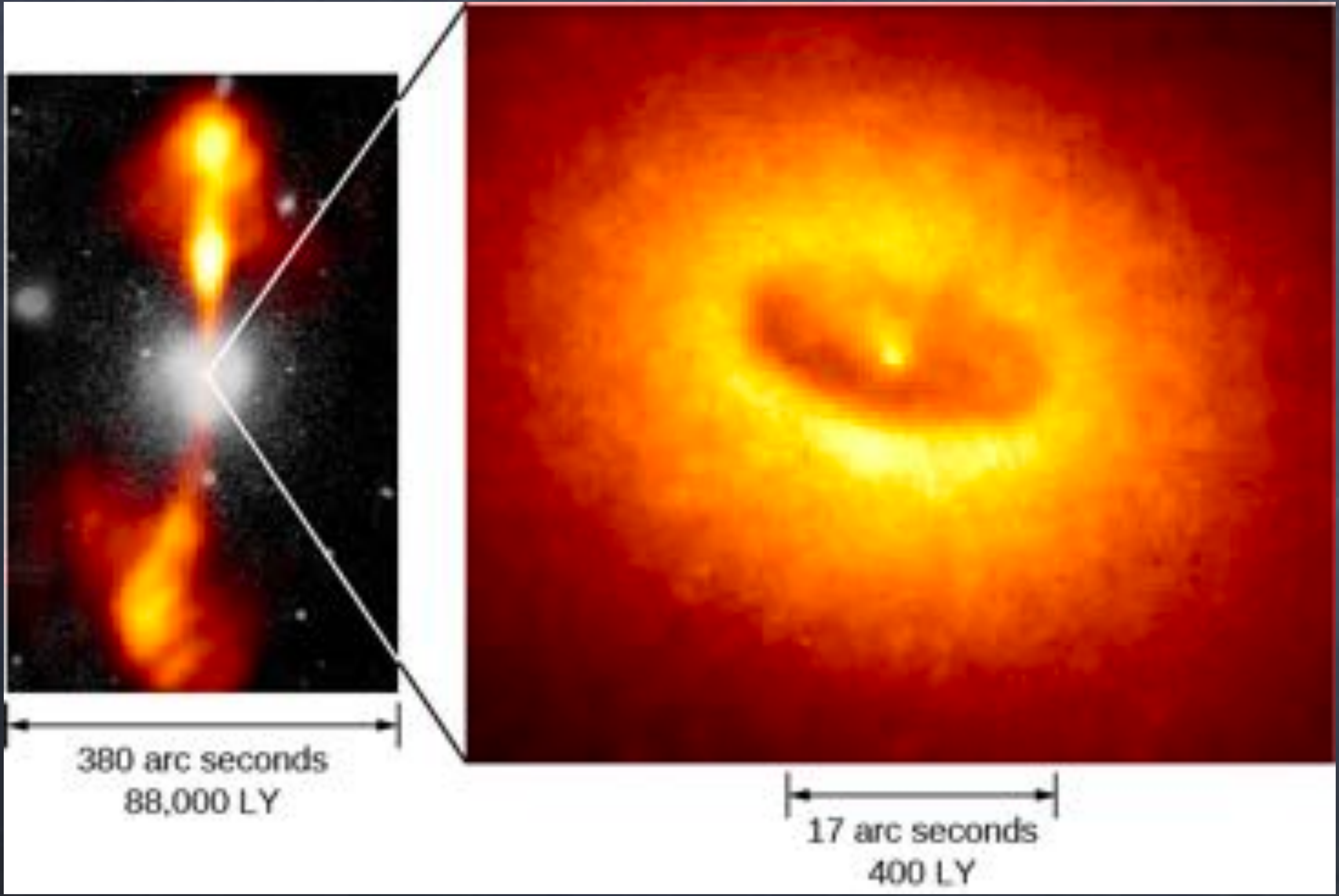
Radio Jets

- We assume that the jets of material coming out of black holes has a similar origin to the jets we see in other astronomical objects; magnetic fields.
- These magnetic fields can take hot material in the accretion disk and eject them perpendicular to the disk with close to speed of light velocities.
- The velocities are so high the jets can extend out for 100 of thousands of light years.

Model of the jets, perpendicular to the accretion disk





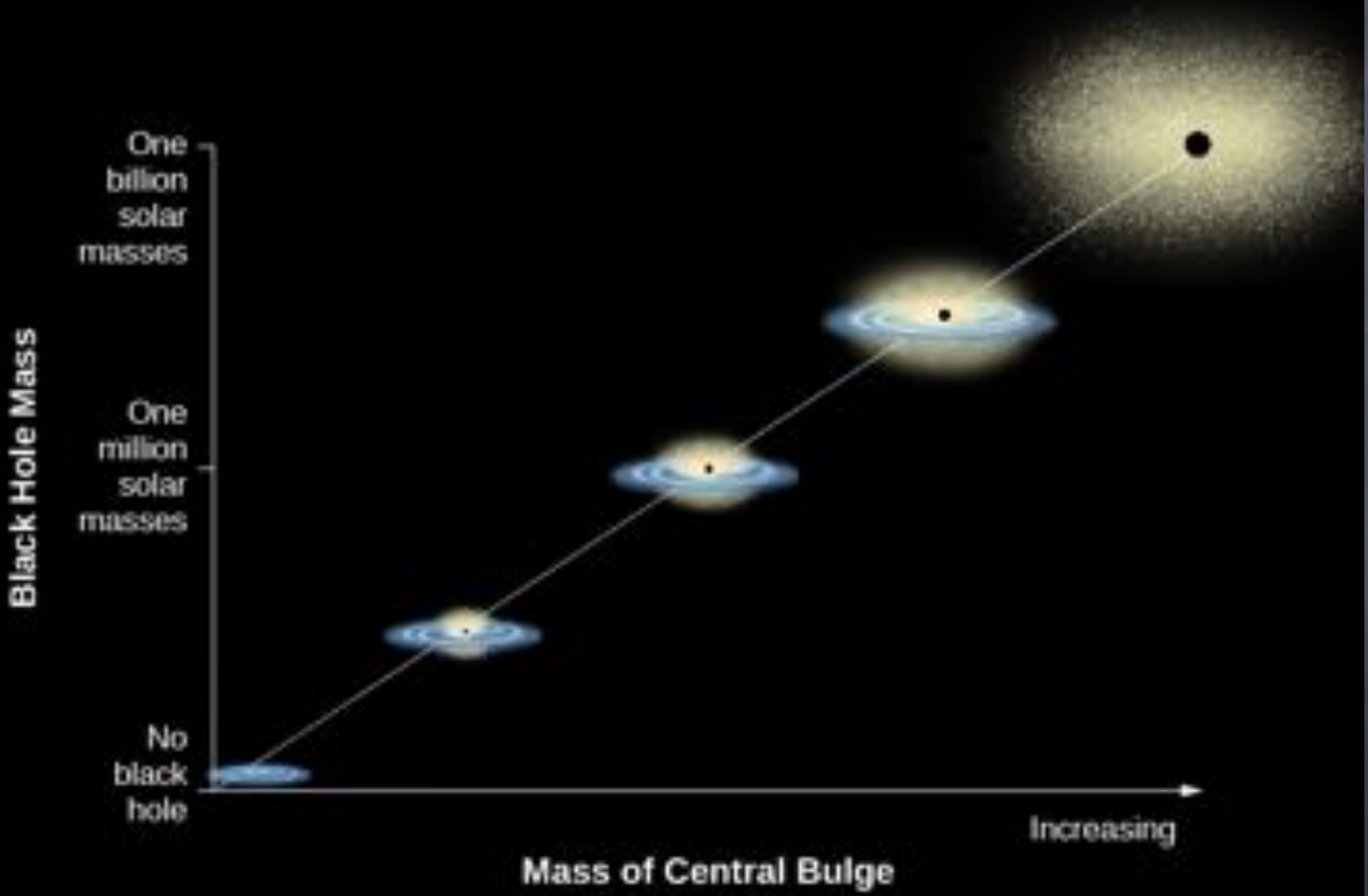


Observations of this in a galaxy with a 1.2 billion solar mass black hole. The accretion disk is perpendicular to the jets.

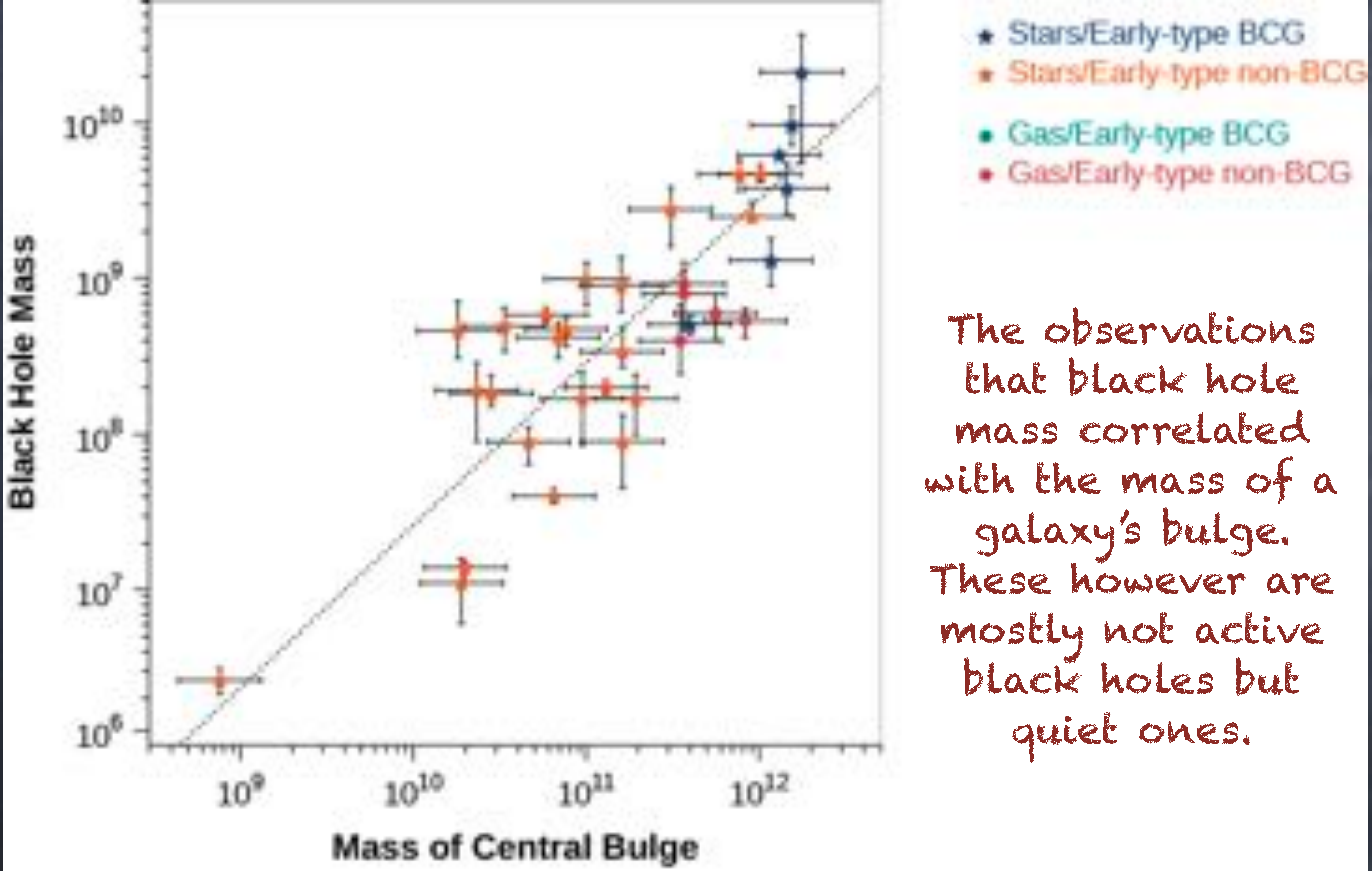
Quasars strongly show that the universe has changed with time. There are very few quasars today, but there were a thousands of times as many two billion years after the big bang. The total star formation rate shows a similar evolution.

Growth of Super Massive Black Holes

- Since quasars require accreting gas to shine, being more common in the past could mean super massive black holes were more common or the gas to feed them was more common.
- Since we know of no way for a super massive black hole to lose mass, the assumption is that all those super massive black holes are still around today, but not quasars because they don't accrete as much gas.
- For nearby galaxies we find there is a correlation between the mass of the central black hole and the mass of the galaxy's bulge.
- So quasars are somehow connected with the properties of galaxies.



Nearby we have discovered that the mass of a galaxy's supermassive black hole is closely related to the mass of the bulge part of a galaxy.



The observations that black hole mass correlated with the mass of a galaxy's bulge. These however are mostly not active black holes but quiet ones.

Even if there is no gas to make a black hole active it can still occasionally flare up by eating a star. A star will be tidal disrupted when to close to a black hole causing a flash of light. Astronomers think they have seen this.

The Galaxy - Central Black Hole Connection

- It is still unclear exactly why this connection exists, but we can hypothesis some reasons.
  - During the quasar phase a tremendous amount of energy is released. This might remove all the gas in a galaxy and end star formation.
  - Merging galaxies can funnel gas to the central regions feeding the black hole and the bulge. Mergers are also more common when the universe was younger.

This image shows the merger of two galaxies which both have central black holes. In x-ray (right) we can see the emission from both black holes.

https://www.youtube.com/watch?v=TseB5fKQlHU