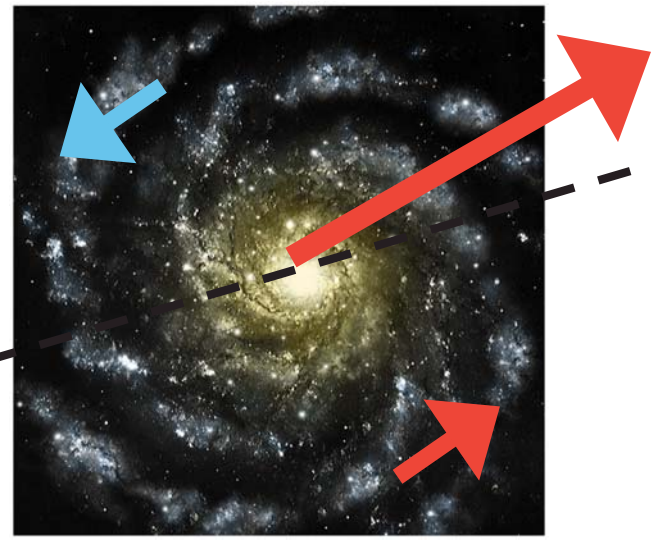
- Homework due on Friday– 11:50 am
- Honor credit– need to have those papers soon!
- THE FINAL IS DECEMBER 15th: 7-10pm!

Outline

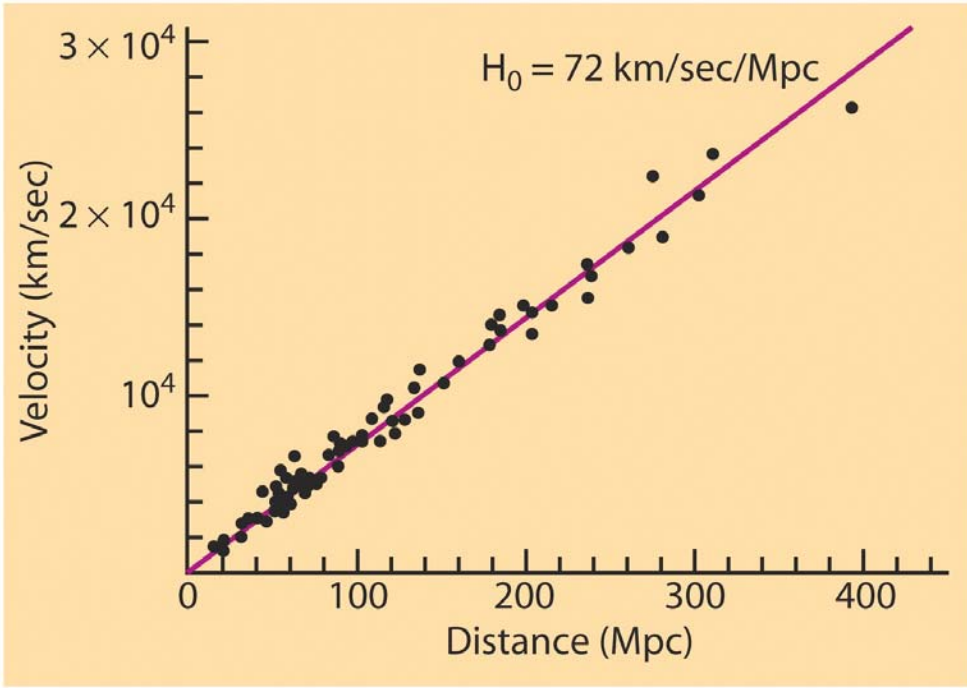
- Hubble's Law
- Active Galactic Nuclei– Quasars, BL Lac, Radio Galaxies, and Seyfert Galaxies.
- The monster within: Supermassive blackholes
- The AGN Unified Model
- Gamma ray bursts

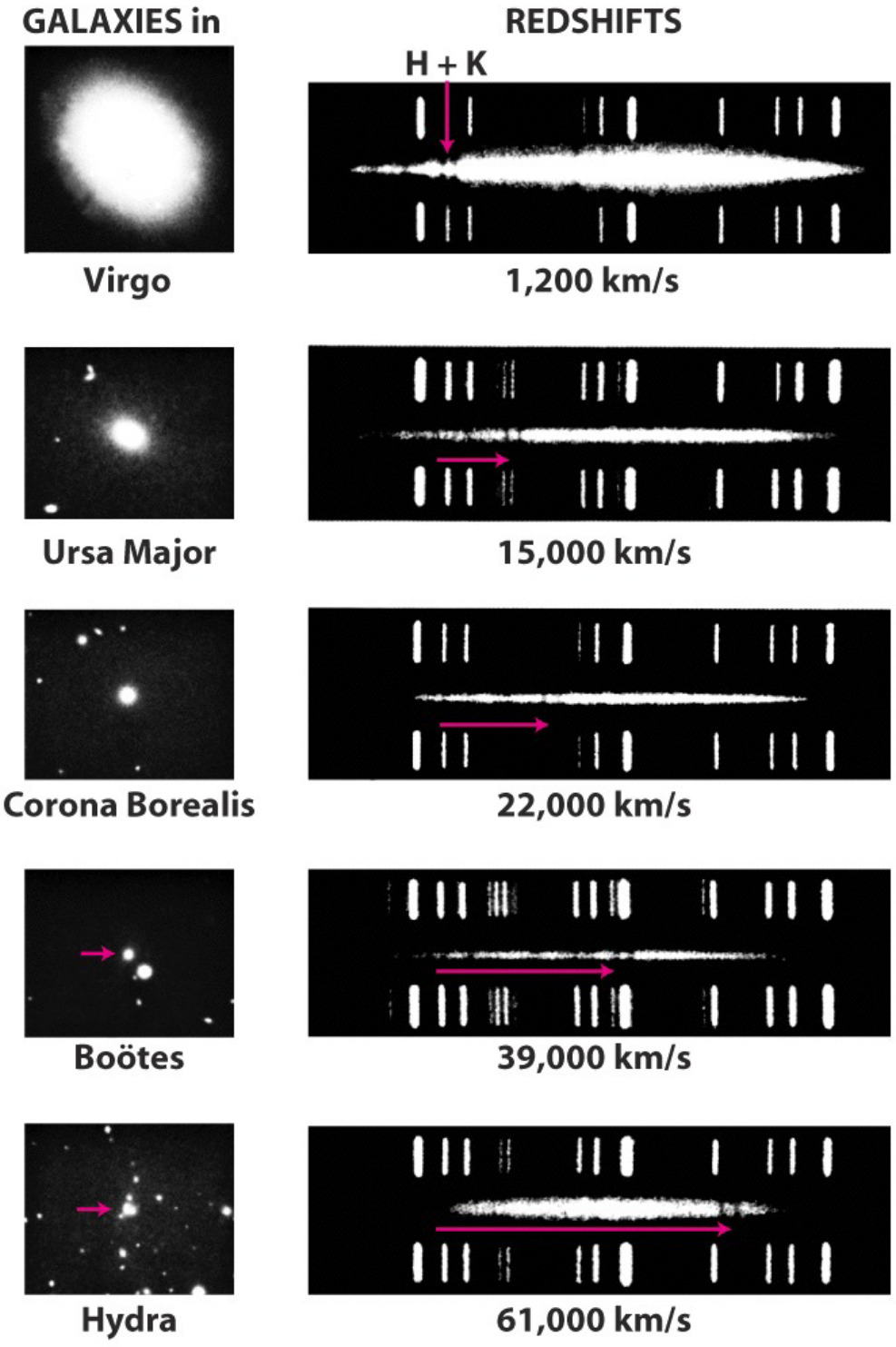
Redshift of Galaxies

- Most Galaxies are moving away from us.
- The farther away, the faster they are moving away.
- Or $V = H_o \times D$
- So, as the Doppler effect tells us, the emission from the Galaxies are redshifted.



Hubble's Law



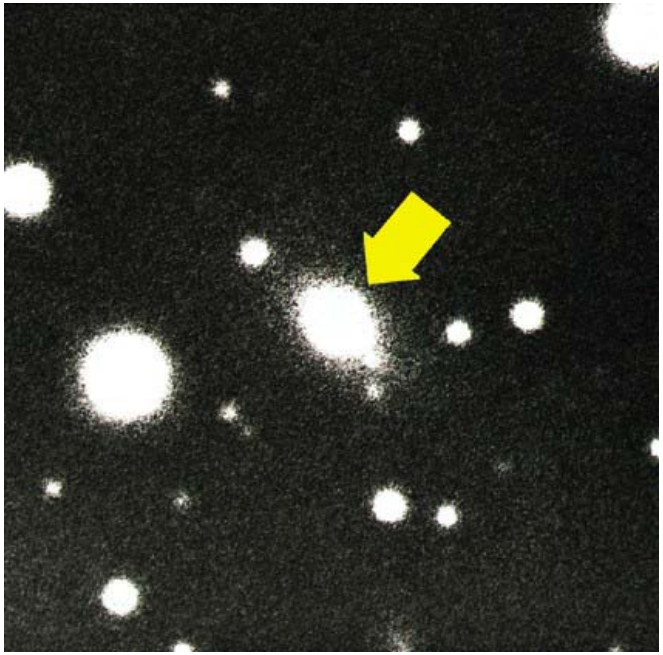


Redshift $z = (\lambda_{obs} - \lambda_{em})/\lambda_{em}$

At low redshift $z = v/c$

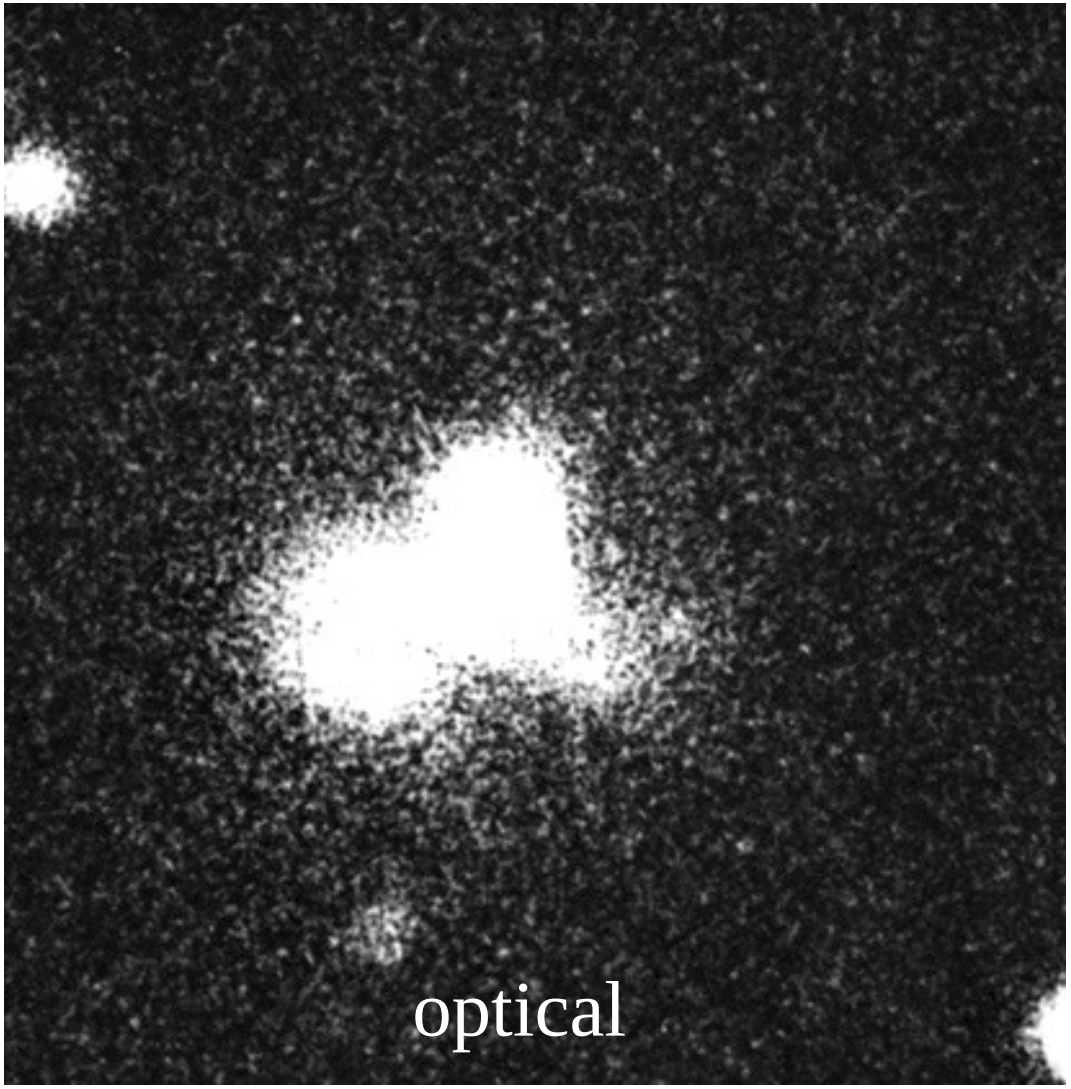
Active Galactic Nuclei

- Keep in mind that most galaxies are normal.
- But there are some weird galaxies (about 1% of all galaxies) that are unusually bright (about 10-1000 times more than the MW).
- They are also variable.
- Also called
  - Quasars
  - Radio Galaxies
  - Blazars (BL Lac)



BL Lac

The Cygnus A Galaxy



- Looks like a star
- But bright in the radio
- And it's moving away from us fast!
- Moving away at 14,000 km/s.
- That's about 5% the speed of light!
- 635 million light years away! Or 194 Mpc.

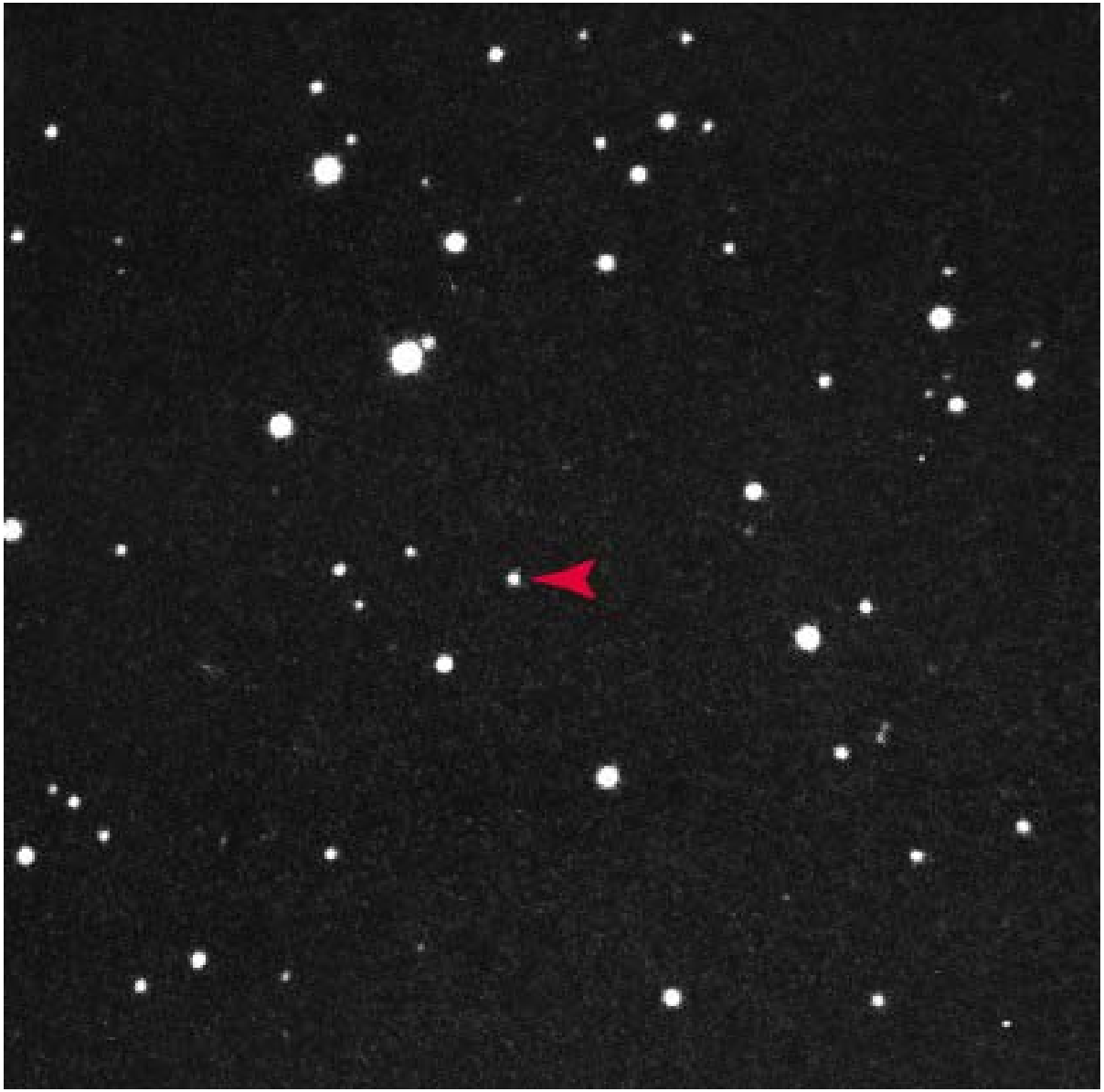
Quasars…But It looks like a Star

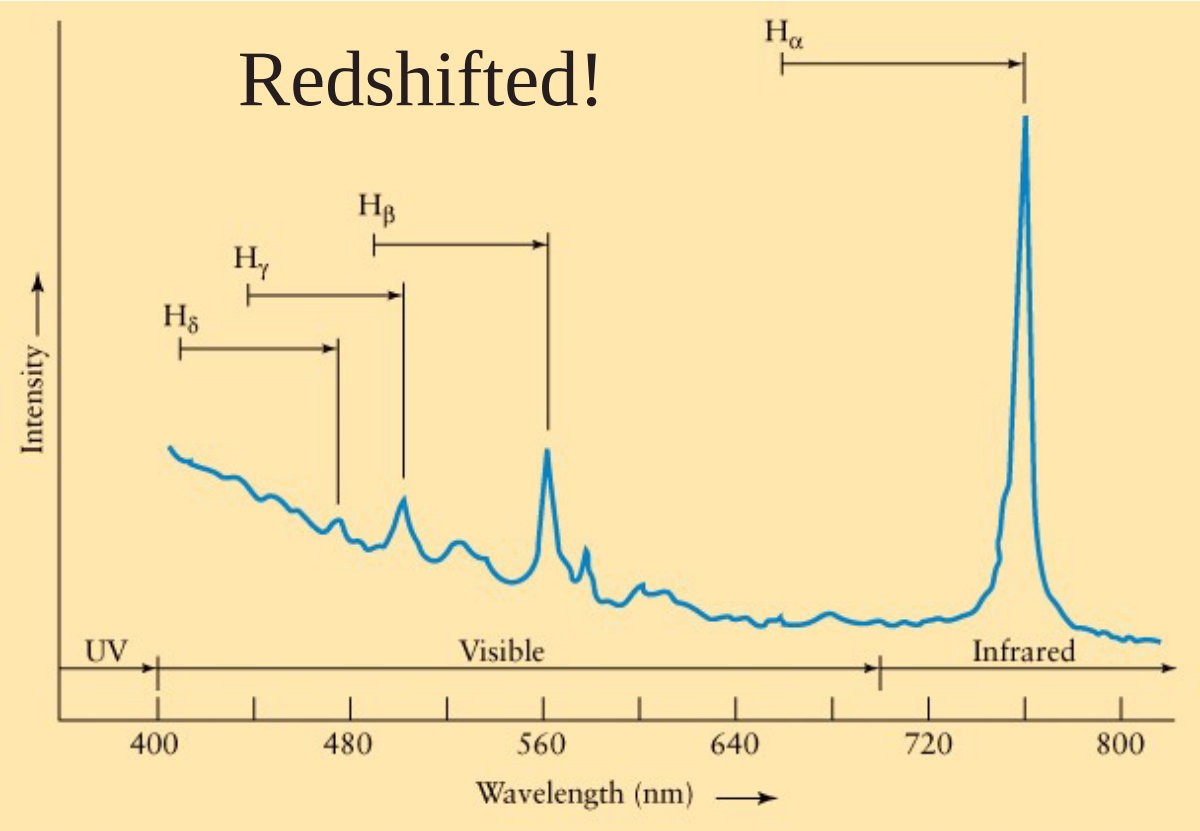
- These objects have a spectrum much like a dim star.
- But highly redshifted.
- Enormous recessional velocity.
- So, Hubble's Law tells us that they are at "astronomical" distances.
- Must be very bright to be visible at such a great distance.
- They are also very variable– emission from small region.
- Called a Quasi-stellar object, QSO, or ***Quasar.***

Quasars: 3C273

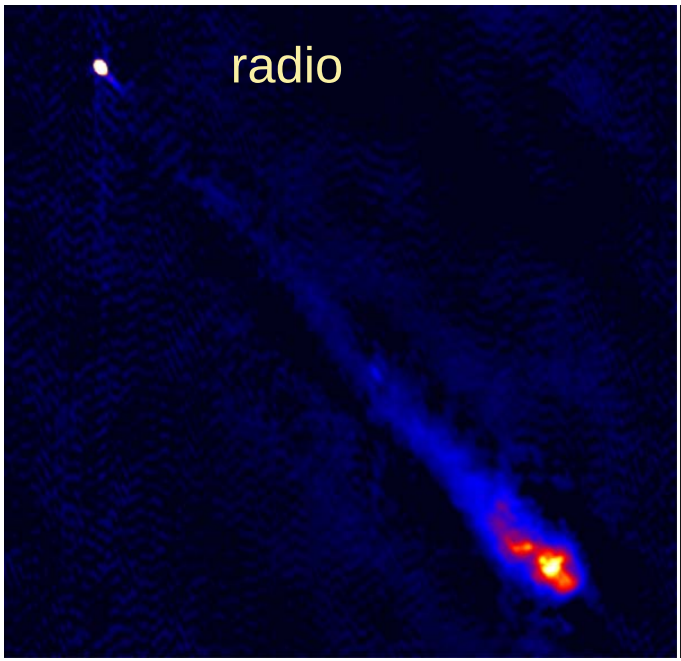
- Really looks like a star.
- But greatly redshifted–

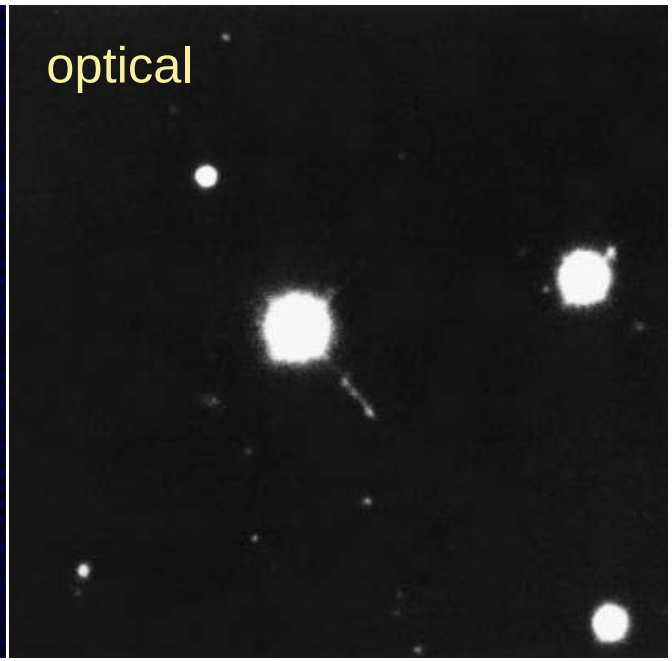
  z = 0.16
- That's 2 billion light years away.

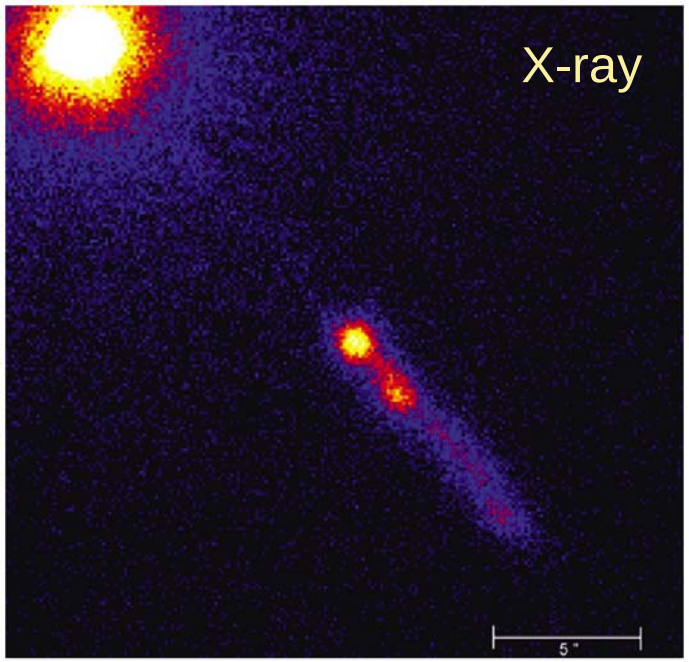




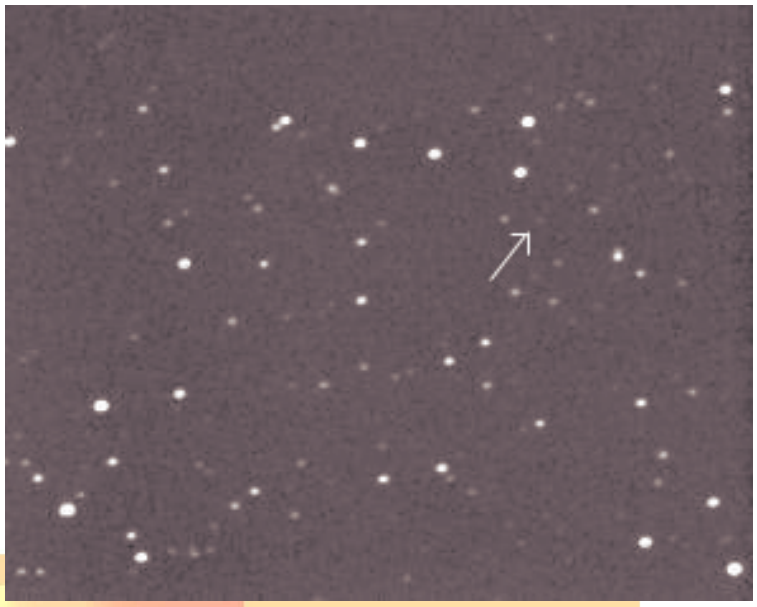
Quasars: 3c273



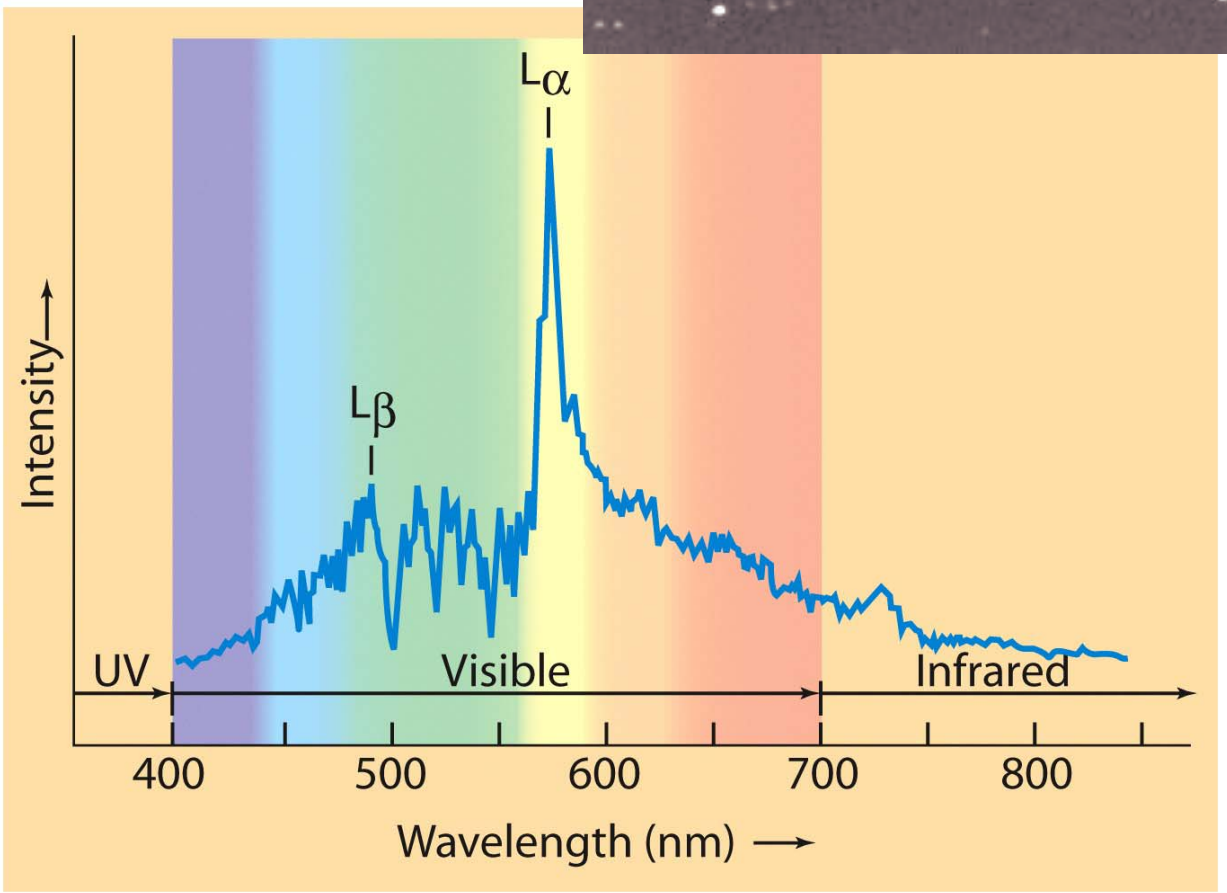




PKS 2000-330

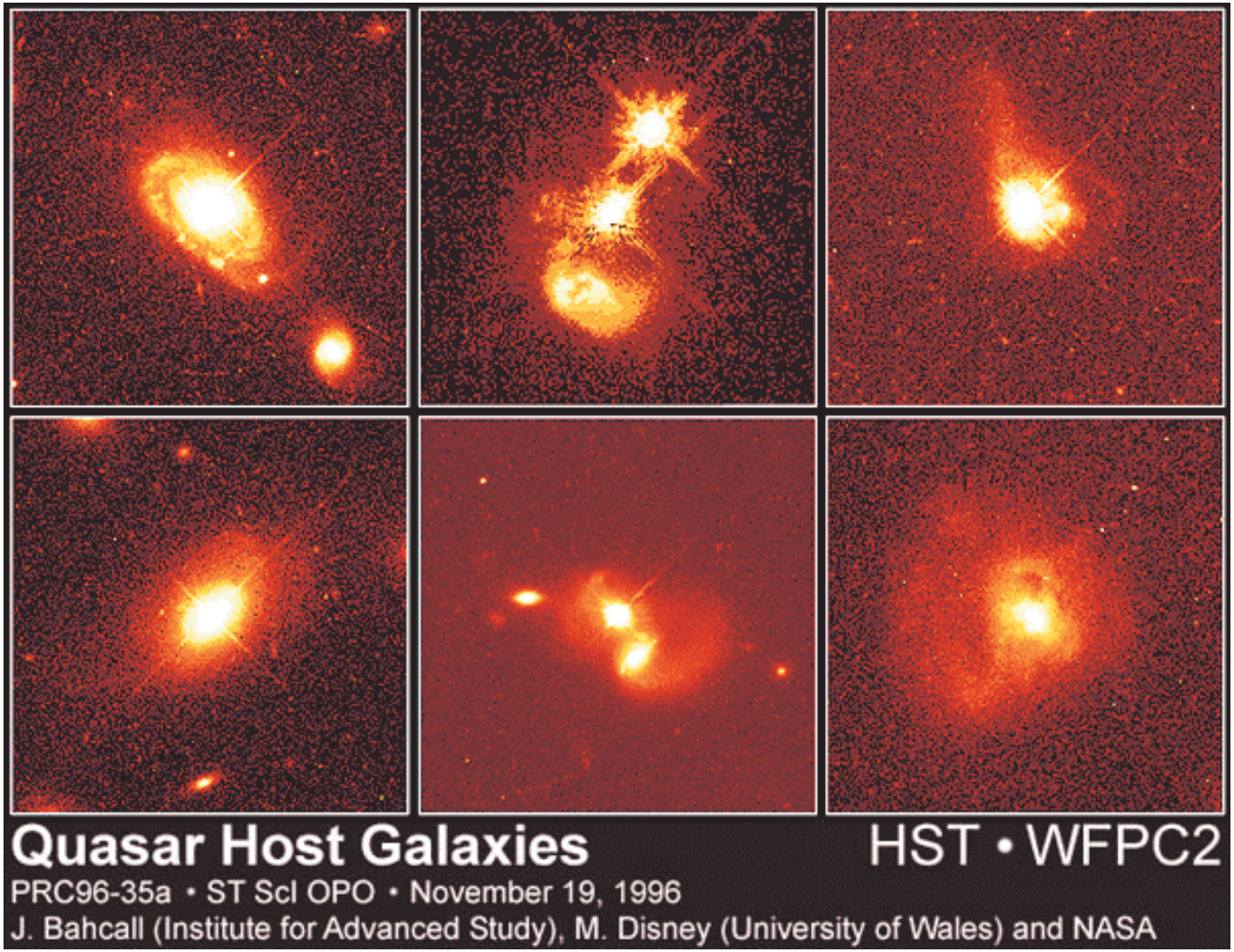


- Redshifted so much that UV line emission can be seen in the optical.
- This Galaxy is moving away from us at 92% the speed of light.
- Distances for Quasars can be as much as 10 to 13 billion light years away.



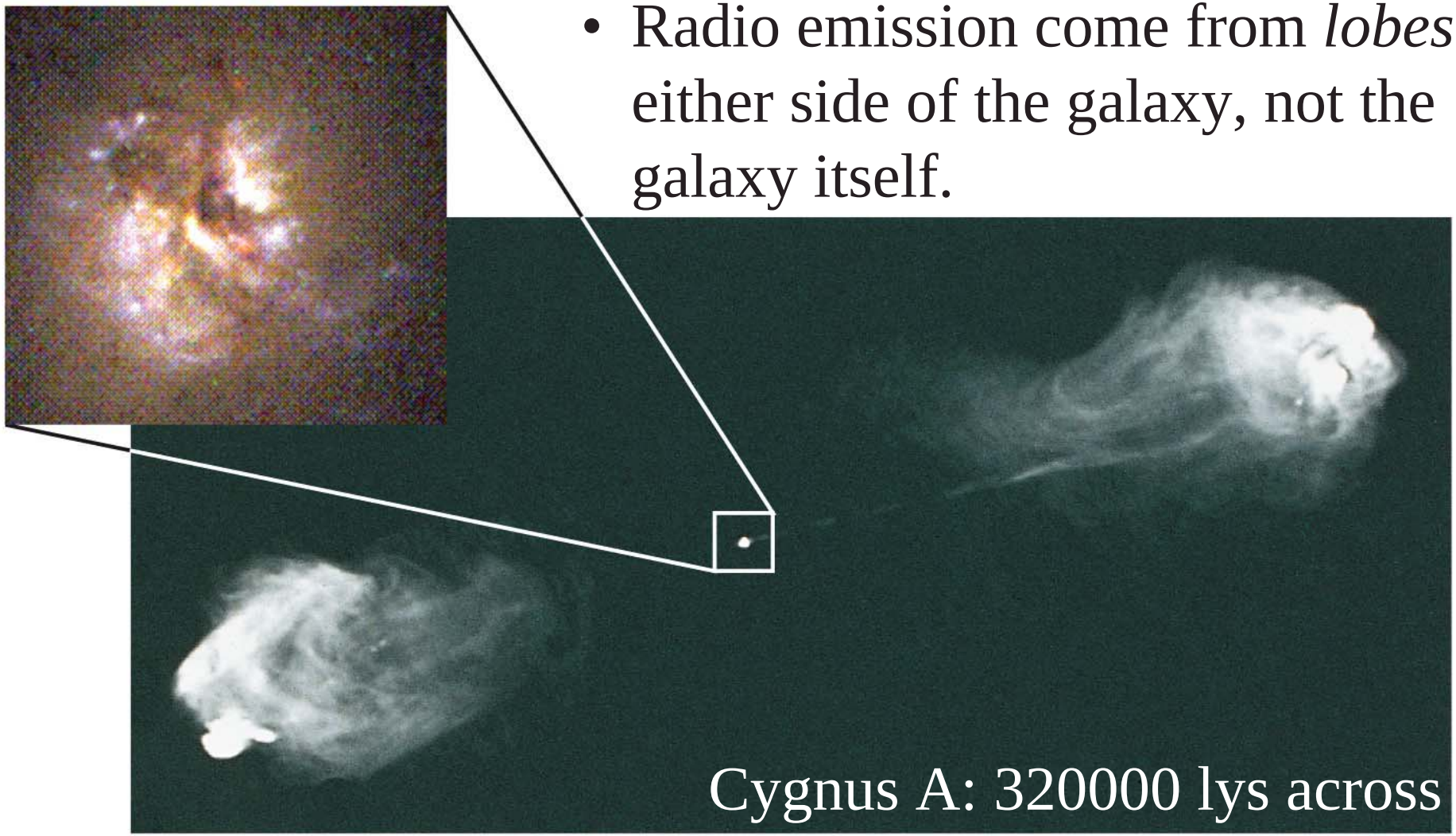
Quasar Host Galaxies

Quasars live in galaxies. They are Galactic Nuclei!

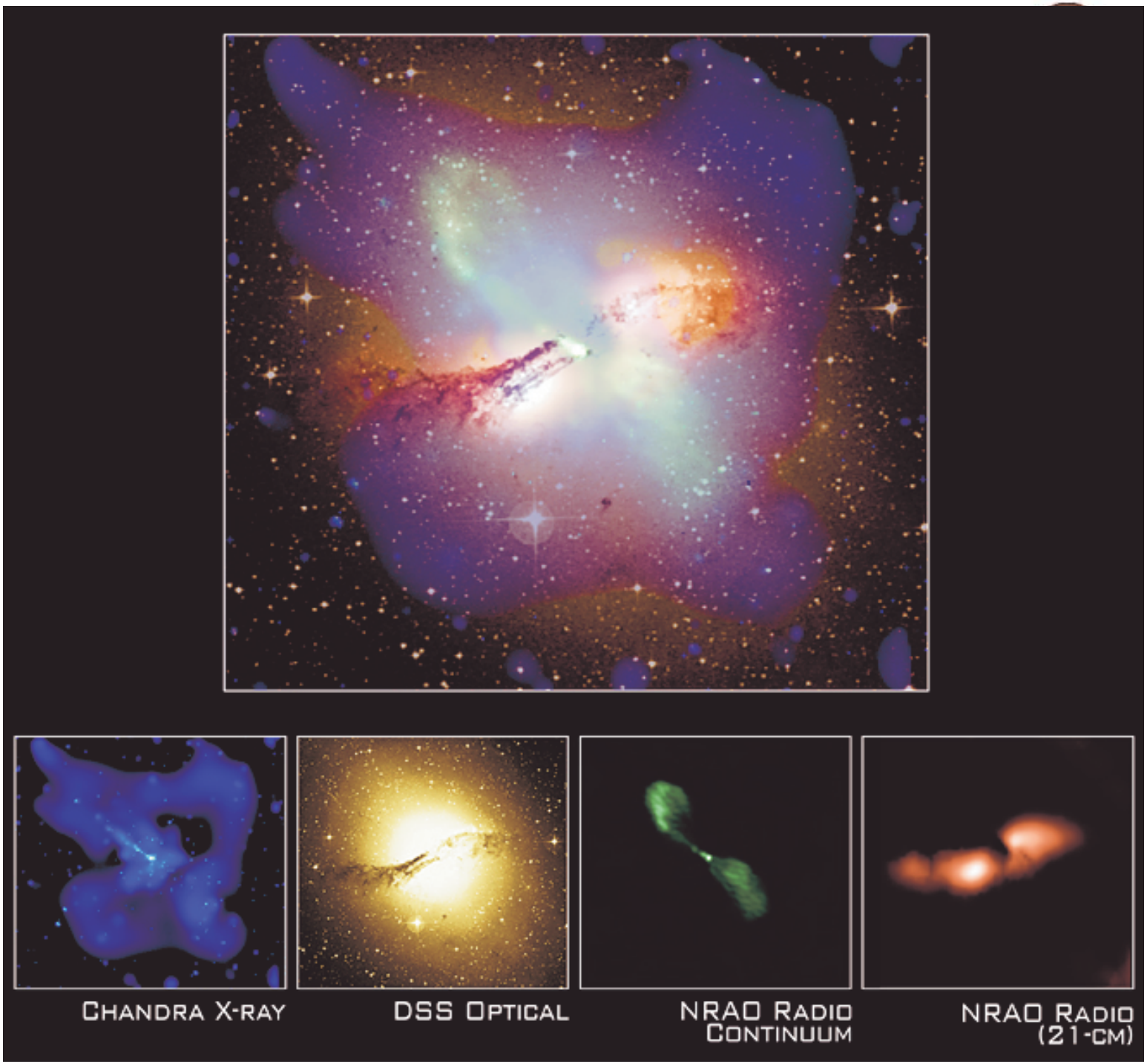


Radio Galaxies

- Galaxies that emit large amounts of radio waves
- Radio emission come from *lobes* on either side of the galaxy, not the galaxy itself.



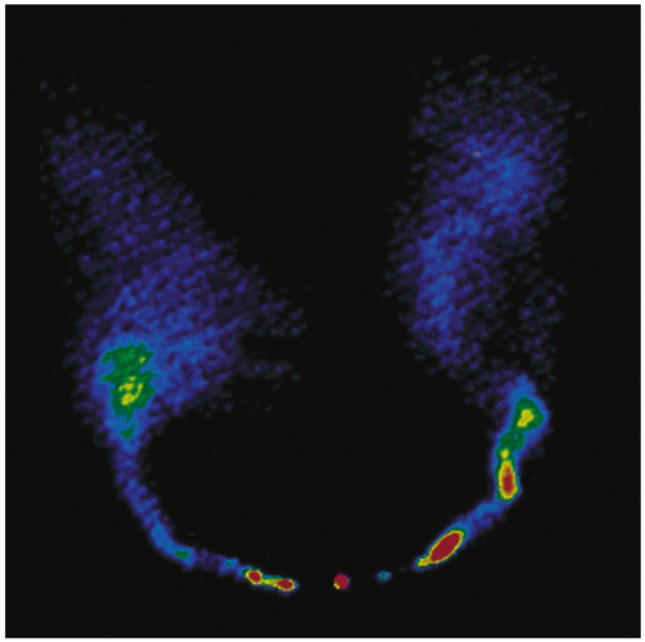
Radio Galaxies: Centaurus A

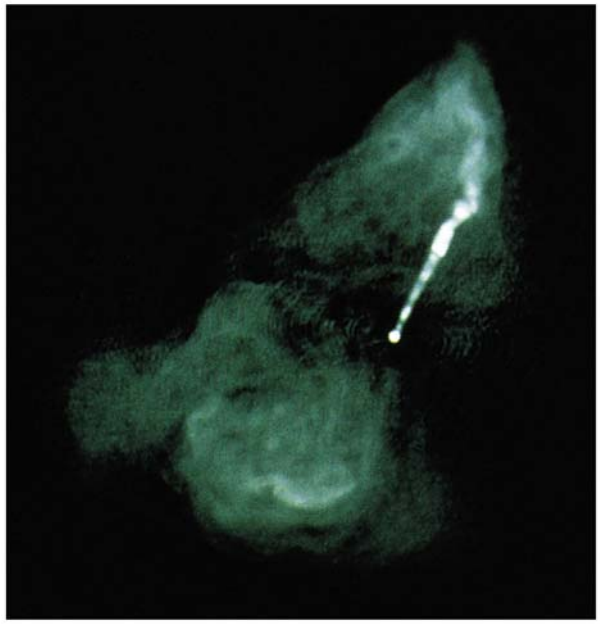


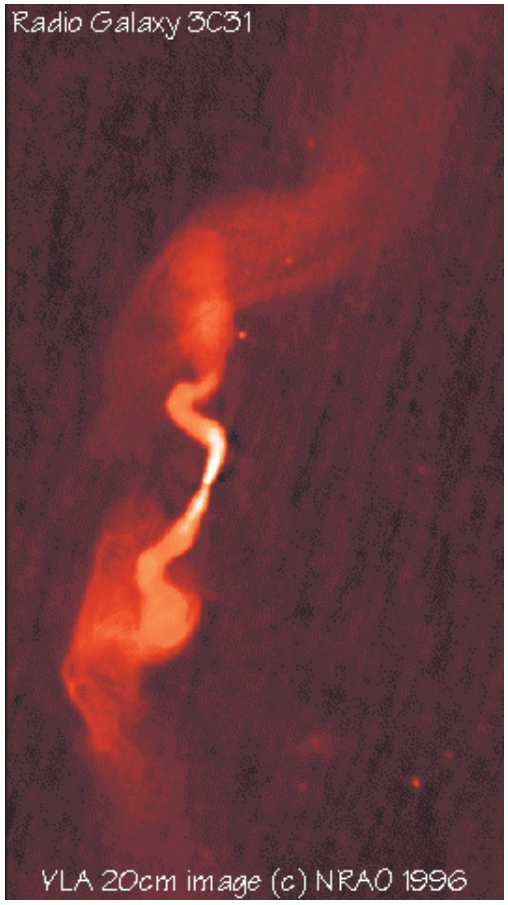
Centaurus A

Radio Galaxies

- There are varying types of radio loud galaxies.
- Called radio loud as they can be 10 million times as bright as the MW at radio wavelengths.







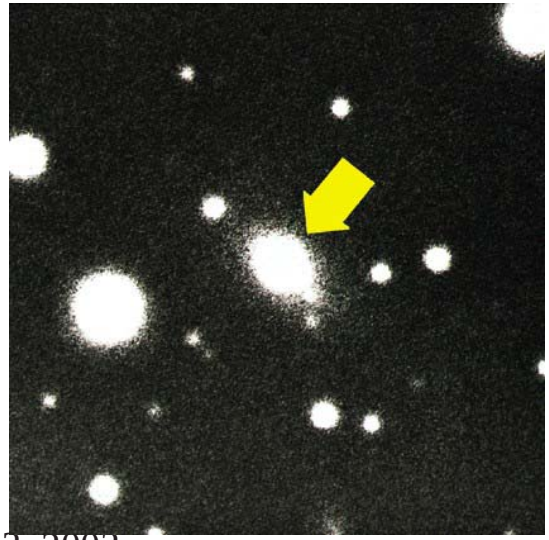
Seyfert Galaxies

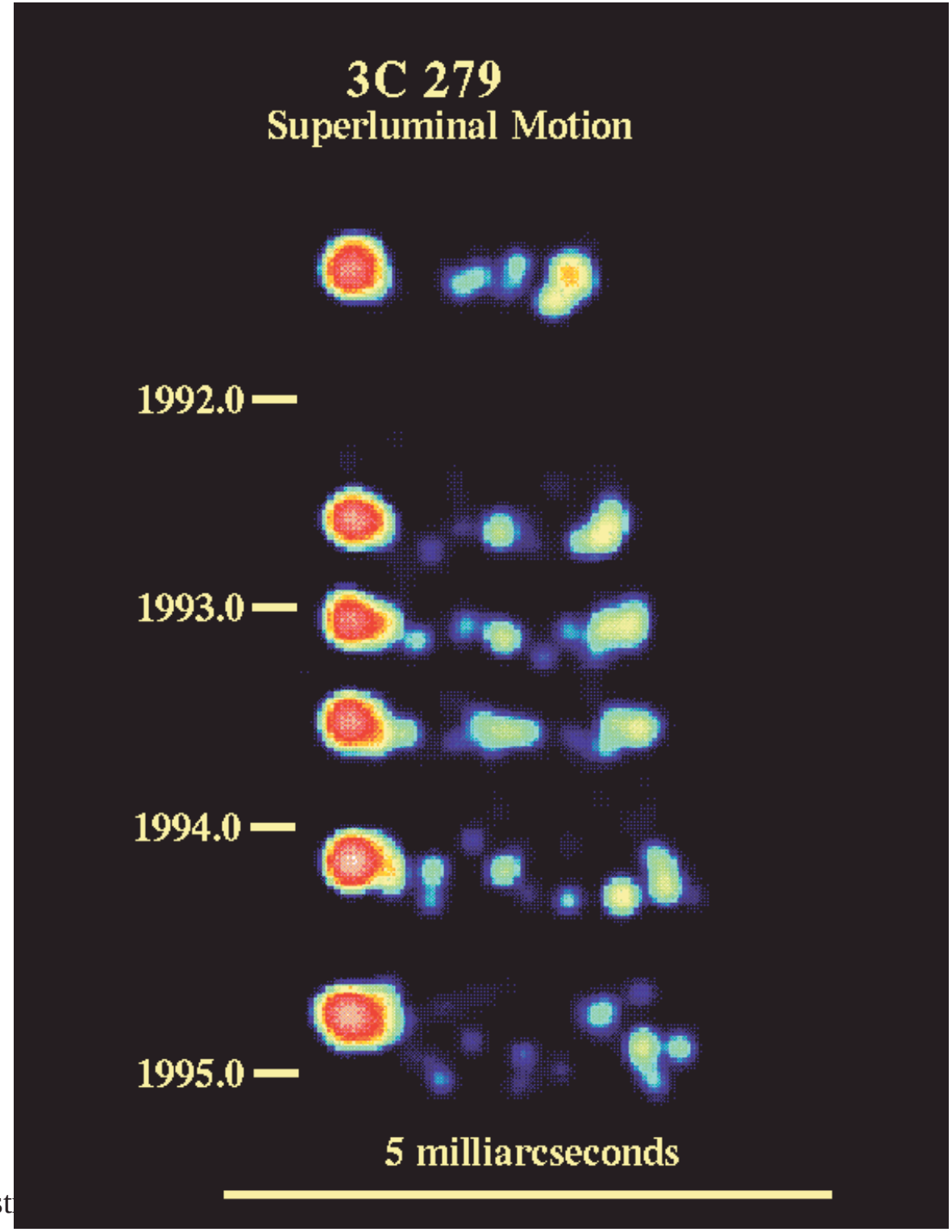
- Look like normal spiral galaxies, but with radio loud nuclei.
- This galaxy varies tremendously. Over a few weeks it's brightness can change by the ENTIRE brightness of the Milkyway.

NGC 1566

Blazars

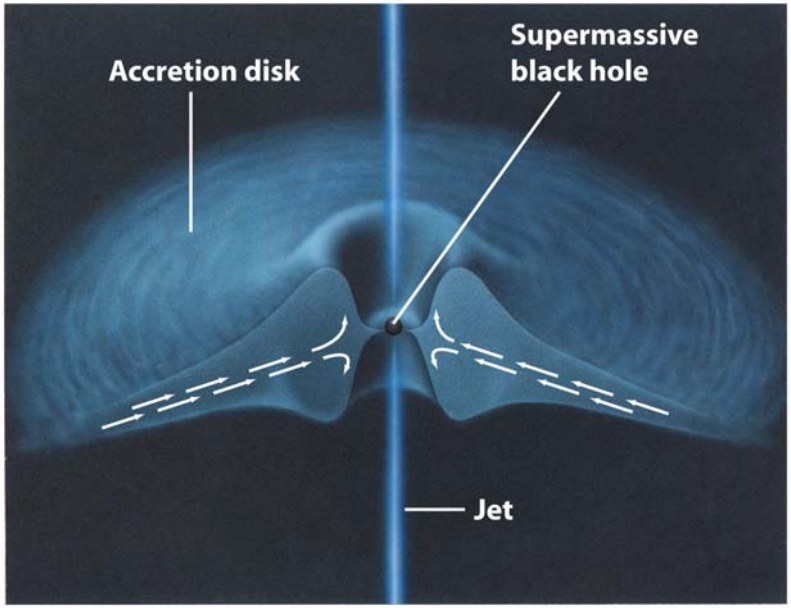
- Bright nuclei with almost completely featureless spectrum.





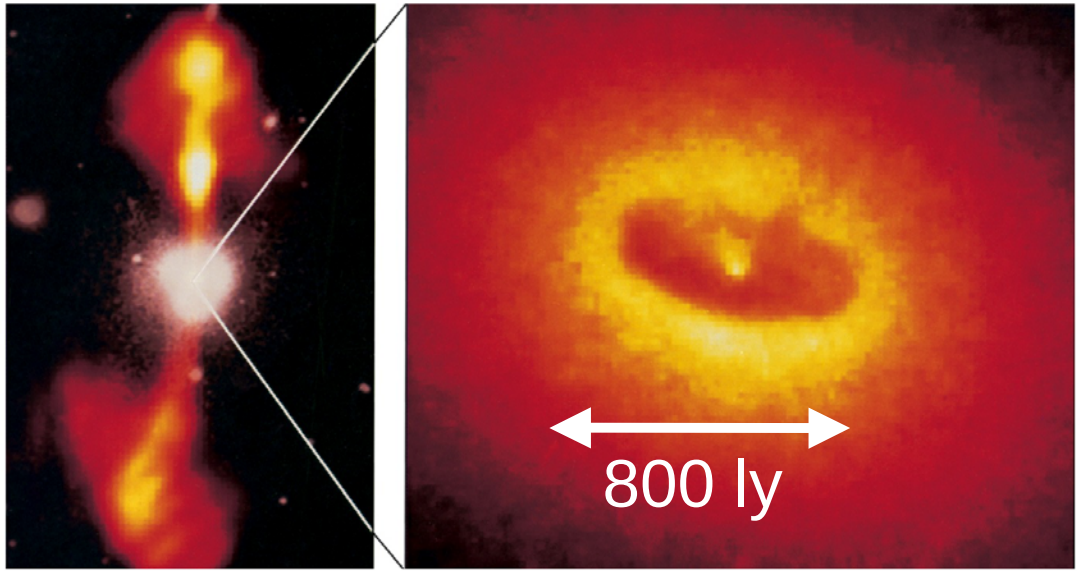
Driving the Galaxies: The Monster Within

- Probably not a scary blue monster.
- But probably the energy source is a supermassive blackhole.



Supermassive Blackholes

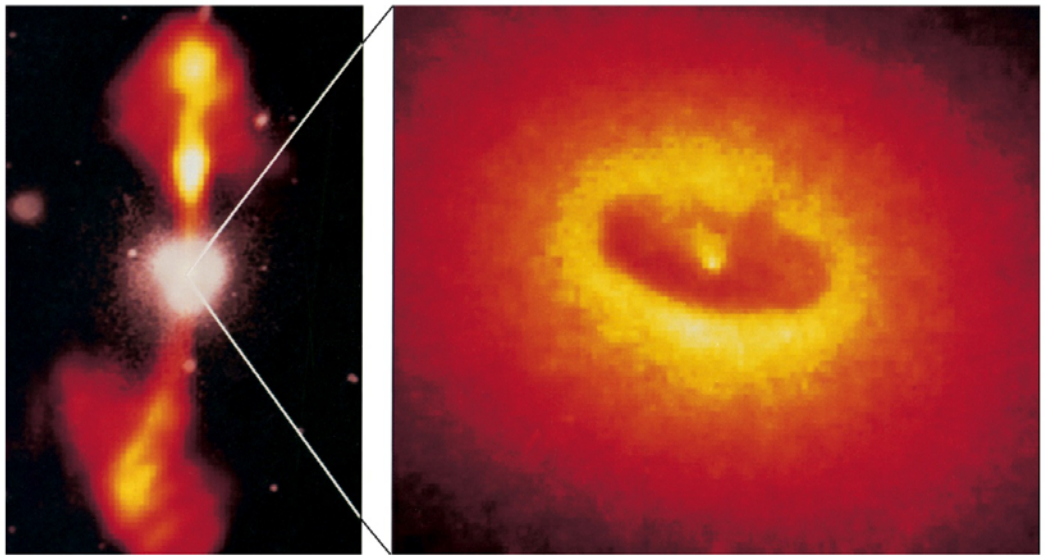
- Energy source for these active galaxies.
- Only thing compact enough and energetic enough.
- Blackholes > 1 billion solar masses
- Compression of material falling into blackhole heats it up and forces some into jet



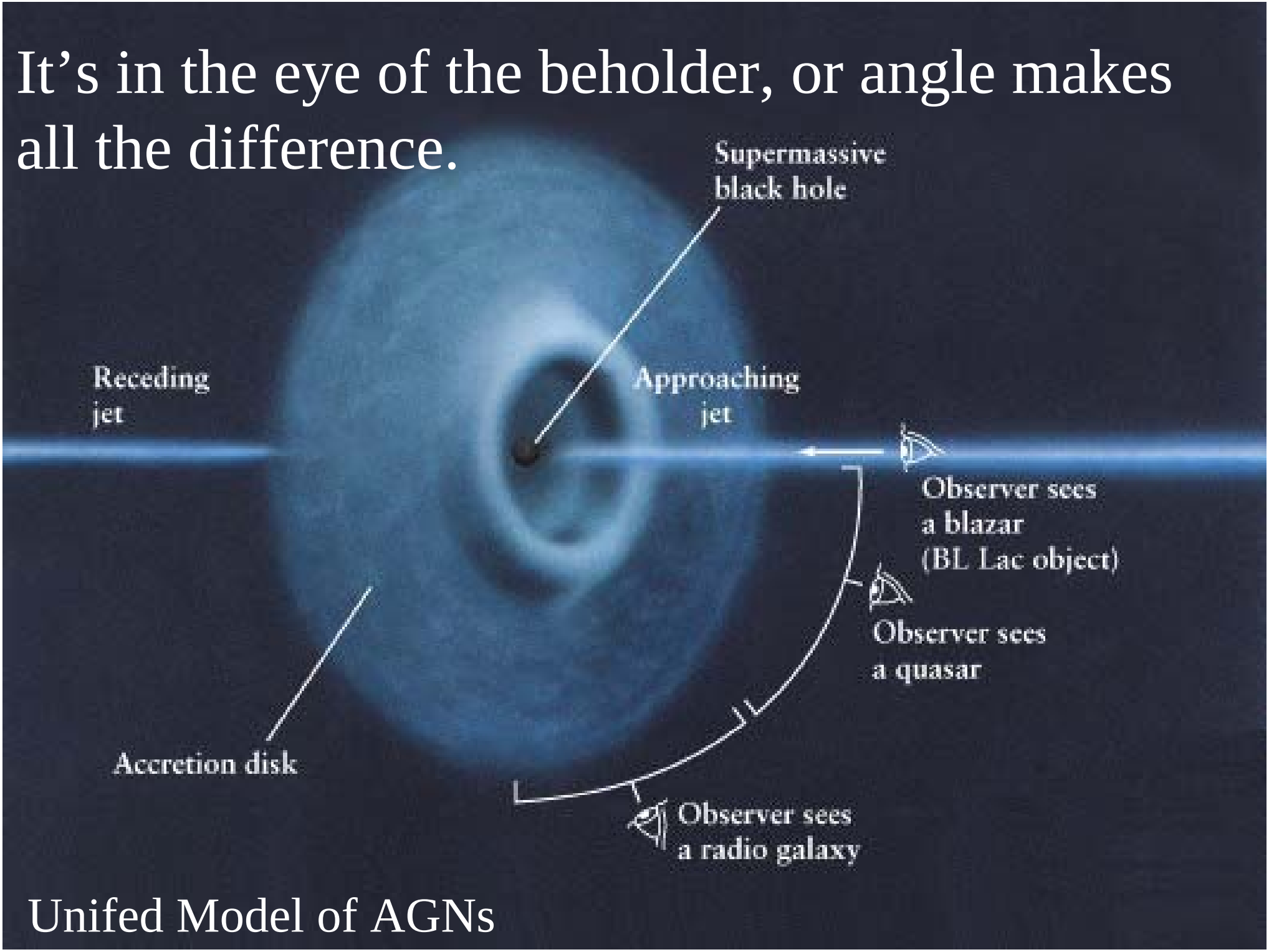
NGC 4261 in the Virgo Cluster

Supermassive Blackholes

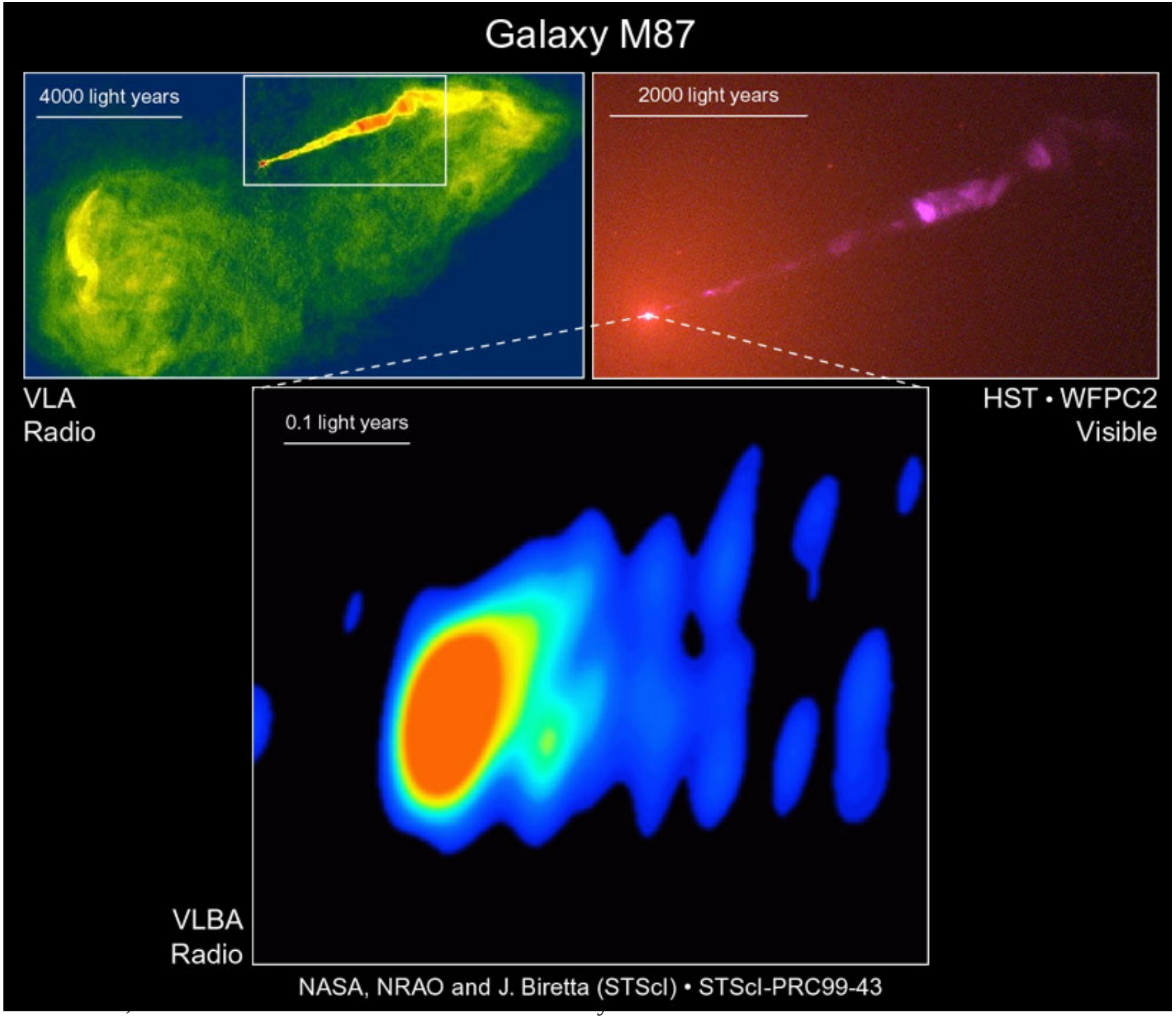
- Supermassive blackholes probably exist in most if not all galaxies cores.
- In the past, active galaxies were more common then now.
- If our galaxy's blackhole were fed, would it turn into an active galaxy?



It’s in the eye of the beholder, or angle makes all the difference.

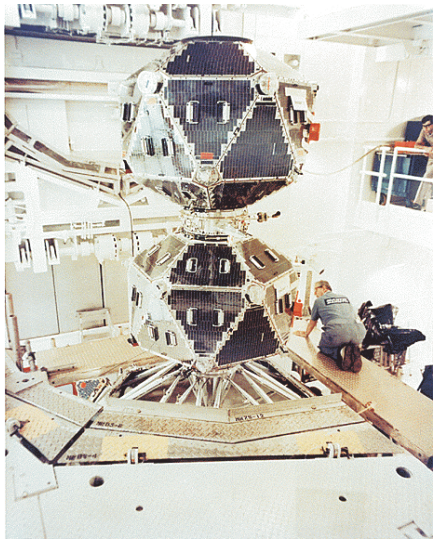


Unifed Model of AGNs

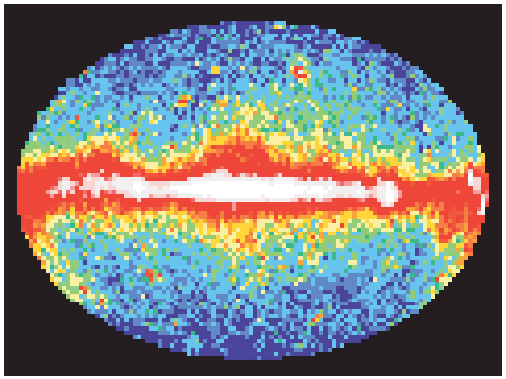

Galaxy M87
4000 light years
2000 light years
VLA
Radio
HST • WFPC2
Visible
0.1 light years
VLBA
Radio
NASA, NRAO and J. Biretta (STScI) • STScI-PRC99-43

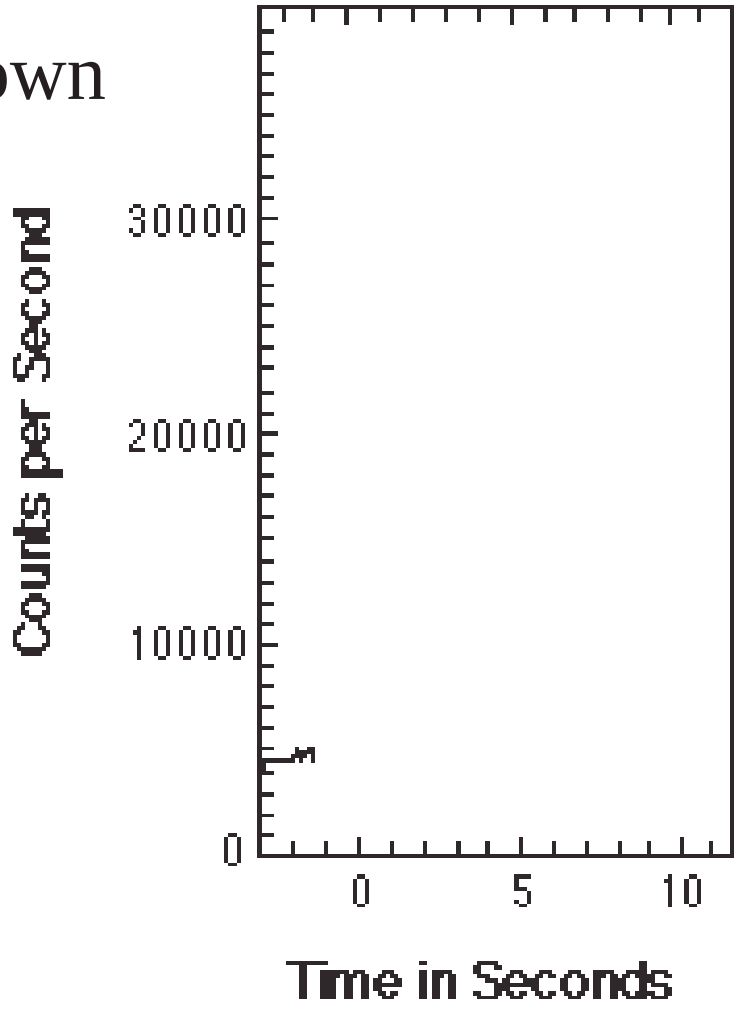
Gamma Ray Bursts

- First detected in 1967 by arm control satellites. First reported in 1973.
- Most powerful explosion in the known Universe!

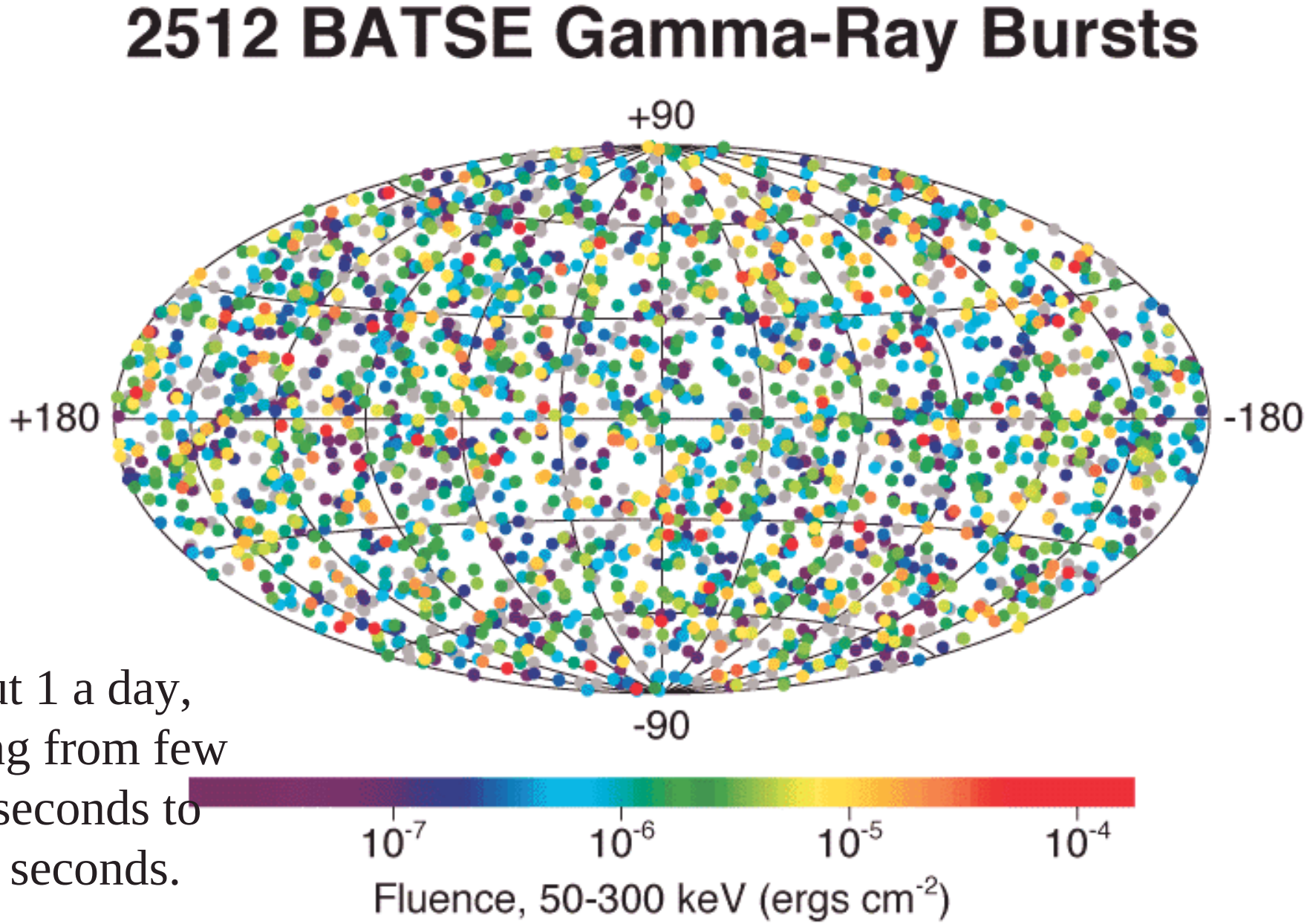


Vela Satellites





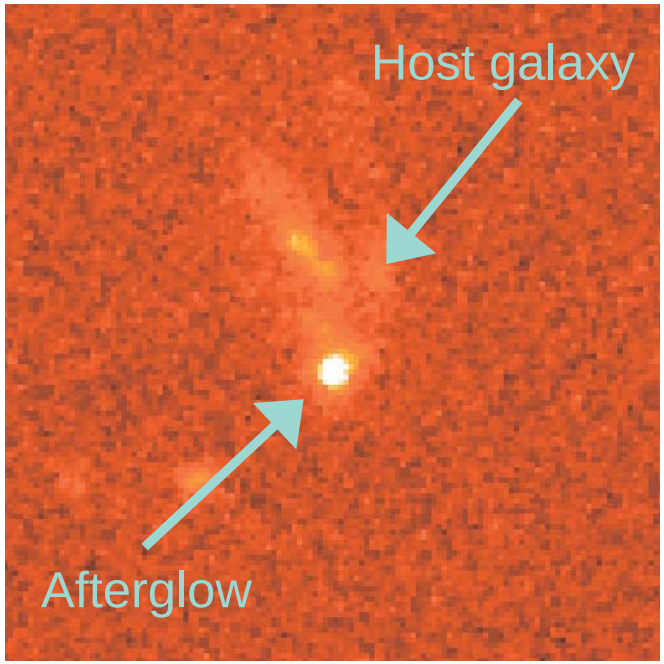
Gamma Ray Bursts

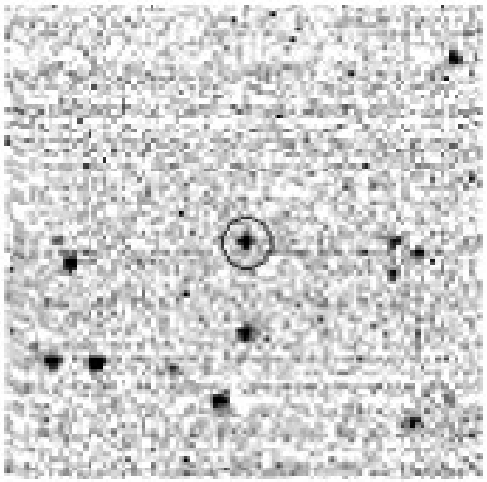


About 1 a day, lasting from few milliseconds to 1000 seconds.

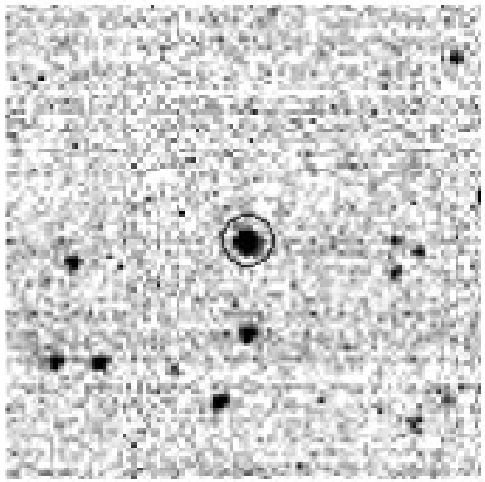
Gamma Ray Bursts

- Recent observations confirm they are very energetic *(as much energy in 100 seconds as the Sun over its entire life!*) and very distant (z = 4).
- Energized by either the merging of neutron stars or, more likely, hypernovae (> 40 solar mass star)

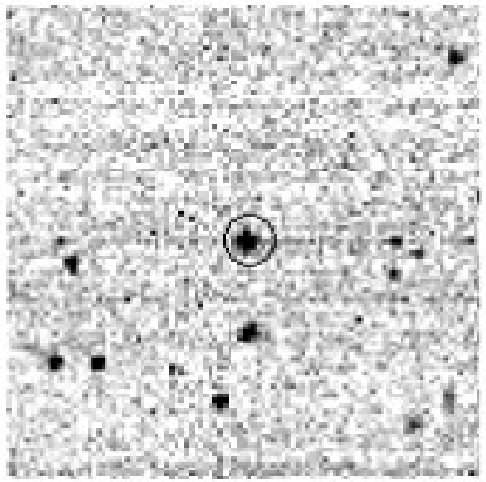




22 seconds



48 seconds



73 seconds