

Astronomy 122



This Class (Lecture 25):

Active Galaxies &
Quasars

Next Class:

The Big Bang

HW10 due on Sunday

Music: Space Oddity – David Bowie

Apr 17, 2008

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Final Exam



- In this classroom, May 6th from 1:30-4:30pm
- Multiple choice.
- Can bring a sheet of notes
- Will be cumulative (80% new material)
 - If 60 questions, 48 from the new and 12 from the old.
 - The old parts should be relevant to new discussions.

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Final Exam



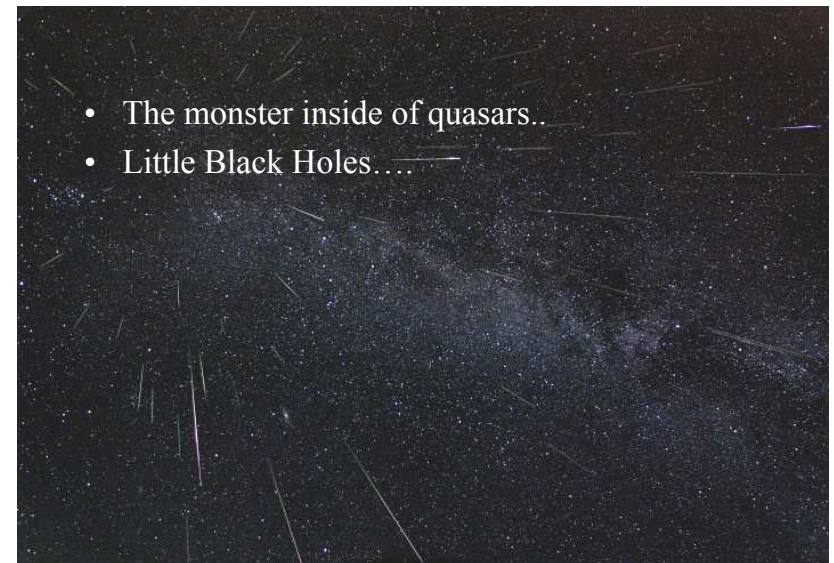
How many questions should we have for the 180 minutes?

- a) 50
- b) 60
- c) 70
- d) 80
- e) 90

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Outline



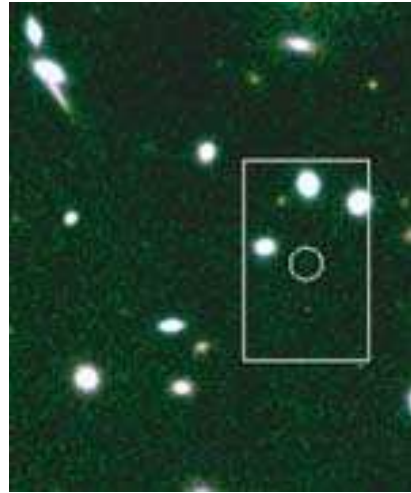
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The Furthest Known Galaxy



- Although under some debate, this galaxy is thought to be at $z=10$!
- 13,230 million light-years away
- That means only 470 Myrs after the Big Bang!
- If the Universe had the lifetime of a human (say 80 years), this is like a galaxy from when the Universe was only 2 years old!



<http://www.universetoday.com/2004/03/01/record-for-furthest-galaxy-is-broken-again/>

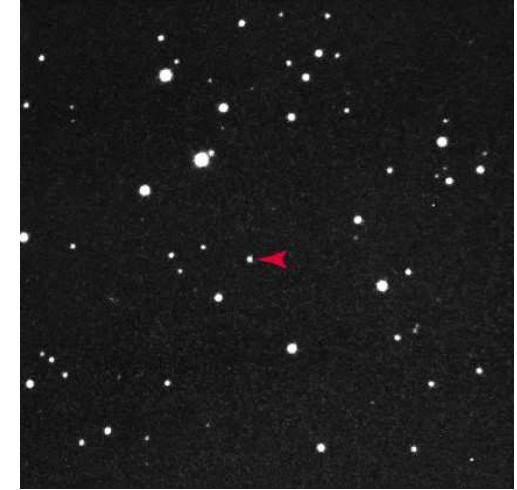
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A Very Strange Star !?!



- Looked like a blue star, but had very odd spectrum lines
- Turned out it was simply greatly redshifted $\Rightarrow z = 0.16$
- That's 2 billion light years away!
- It must be 100 times brighter than the entire Milky Way!
- **Not** a star



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Quasars...



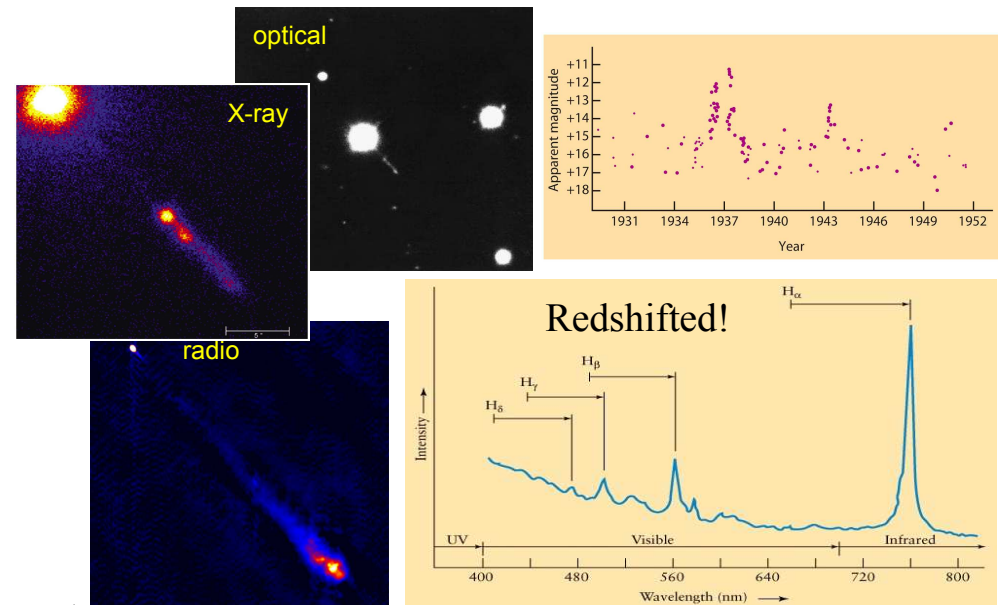
- These objects have a spectrum much like a dim star
 - But highly redshifted
 - Appear to be moving away from us very fast!
- Dubbed **quasars** (quasi-stellar radio sources)
- Hubble's Law tells us that they are at "astronomical" distances
 - Up to 13 billion light years away!
- Great distances - must be very bright
 - Some 1 million times the brightness of our Galaxy!
- Highly variable
 - Emission region must be small - about the size of our Solar System

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The First Quasar Discovered:

3C 273: $z = 0.158$



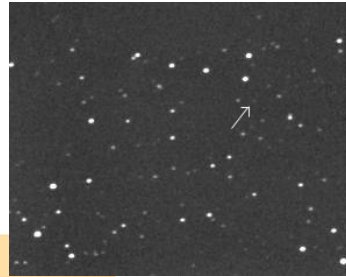
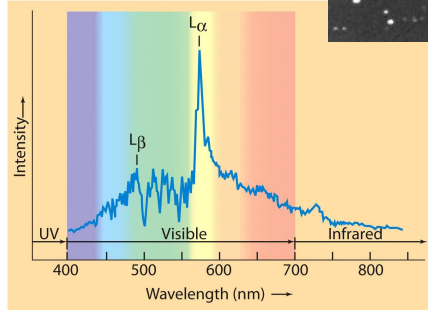
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PKS 2000-330



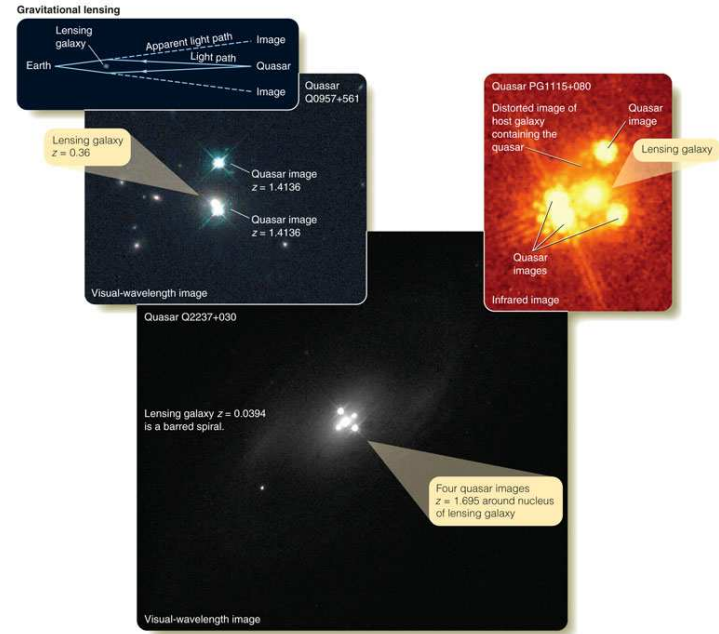
- Redshifted so much that UV emission can be seen in the optical
- This quasar appears to be moving away from us at 92% of the speed of light!



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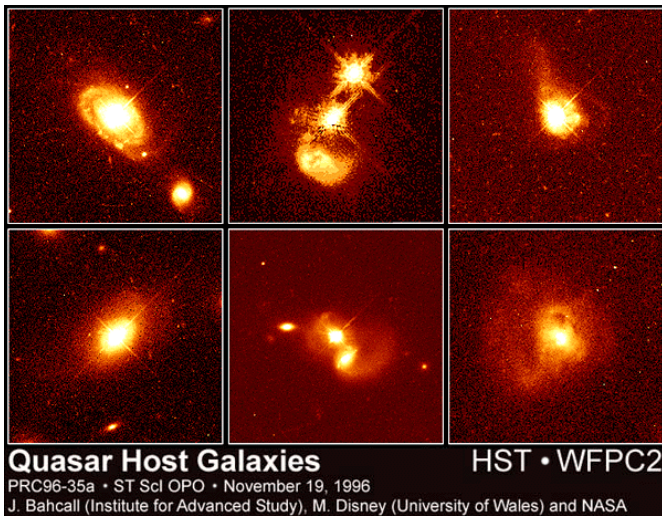
Gravitational Magnified



Quasar Host Galaxies



- Quasars live in distant galaxies
- They are *galactic nuclei!*



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Question



So what is a quasar?

- The nucleus of a galaxy far away.
- A tasty treat.
- A star with high velocity.
- A quasi-static nebula that is bright in the radio.

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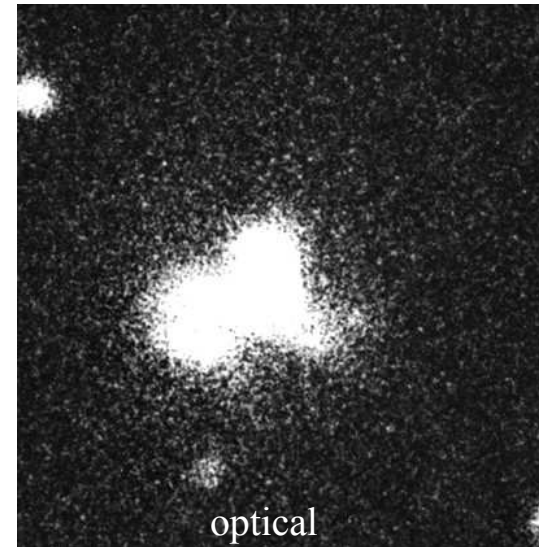


Are there quasars in the nearby Universe?

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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.
- Similar to a quasar??

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Active Galaxies



- There are no quasars in the nearby Universe *now*
- But there are some very energetic galaxies (about 1% of all galaxies)
 - Very bright, star-like nuclei
 - Often, energetic outflows of matter from the nucleus
- Called **active galaxies**
- Types of active galaxies
 - **Seyfert galaxies**
 - **Blazars**
 - **Radio galaxies**
- Like quasars, but not as energetic



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Seyfert Galaxies



- Look like normal spiral galaxies, but with incredibly bright nuclei
- Potentially as bright as a trillion Suns!
- Brightness varies tremendously
- Over a few weeks it's brightness can change by the ENTIRE brightness of the Milky Way



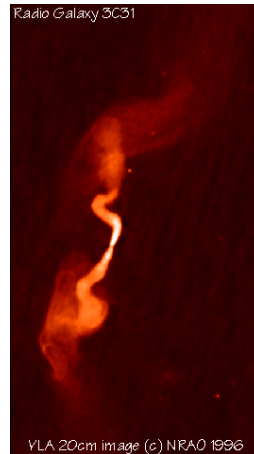
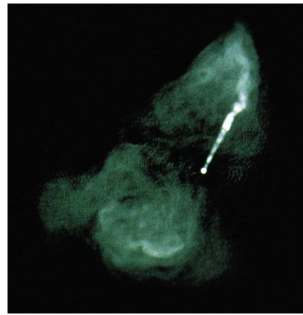
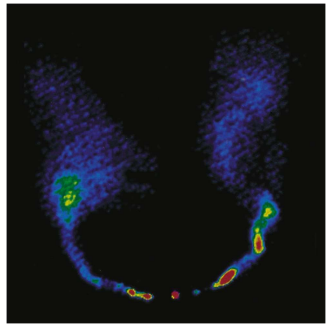
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Radio Galaxies



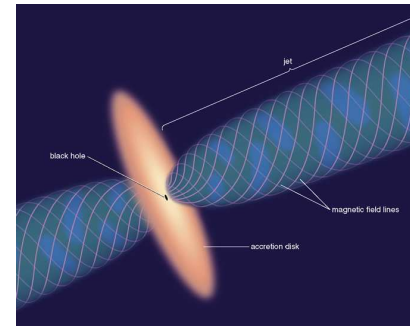
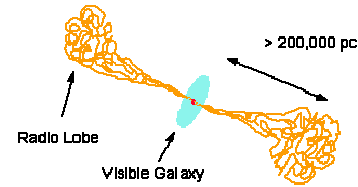
- There are varying types of radio galaxies
- Called *radio loud* as they can be 10 million times as bright as the Milky Way at radio wavelengths



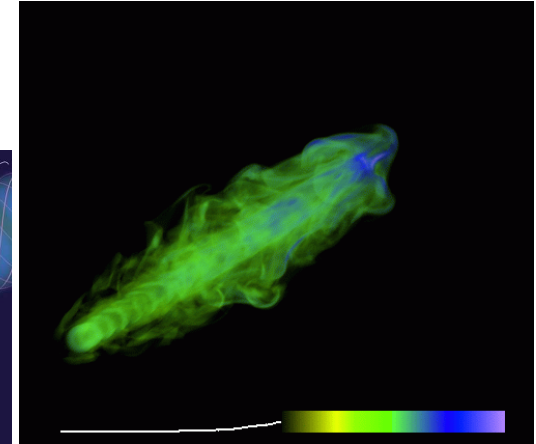
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Radio Galaxy Jets



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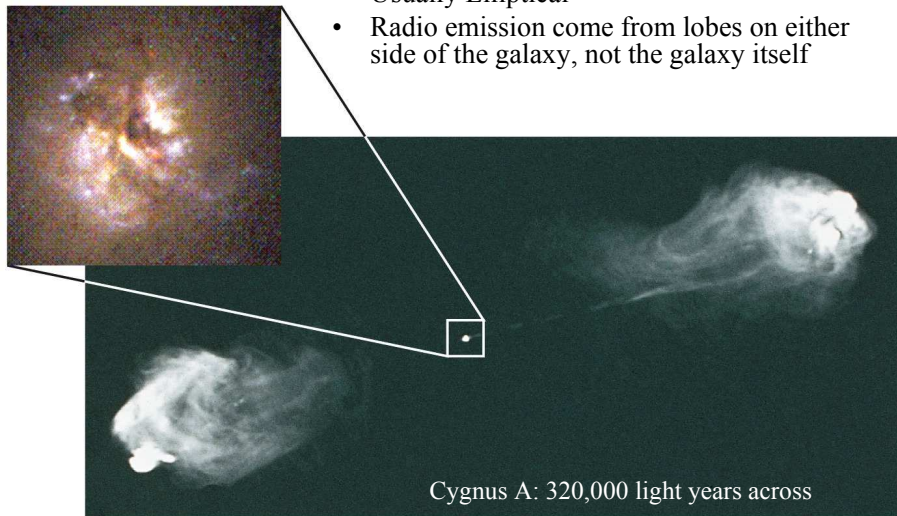
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Radio Galaxies

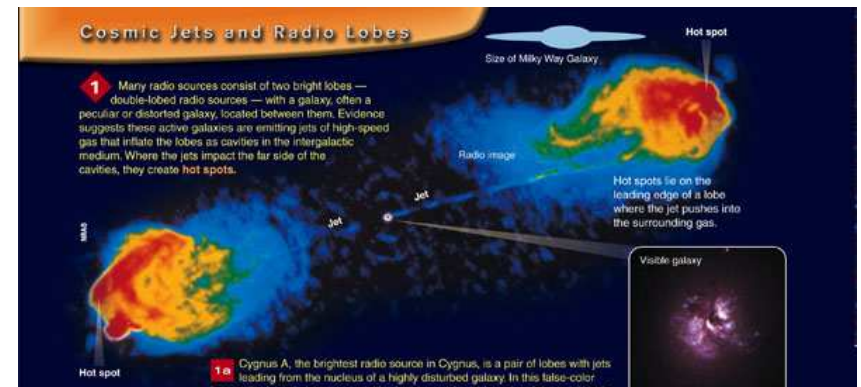


- Galaxies that emit large amounts of radio waves
- Usually Elliptical
- Radio emission come from lobes on either side of the galaxy, not the galaxy itself



Cygnus A: 320,000 light years across

Huge

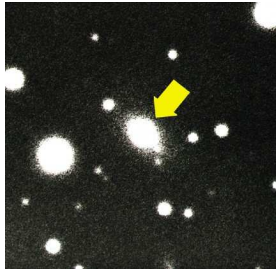


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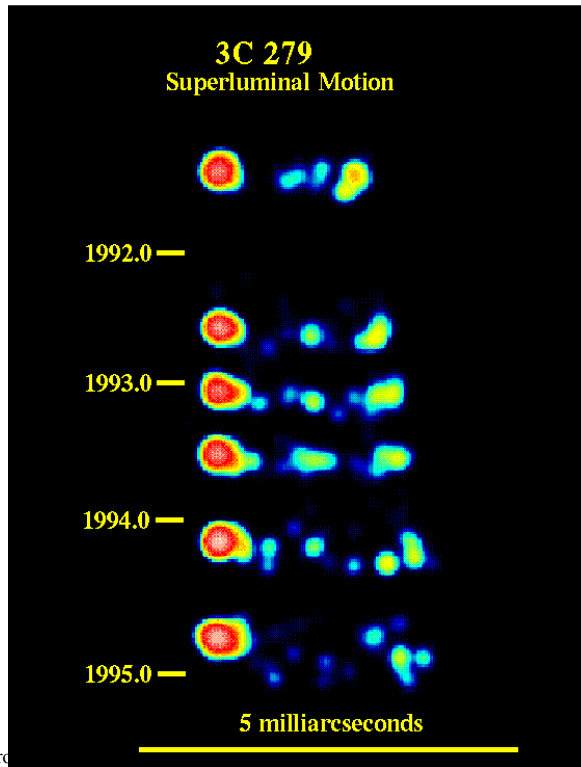
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Blazars

- Bright nuclei with almost completely featureless spectrum.



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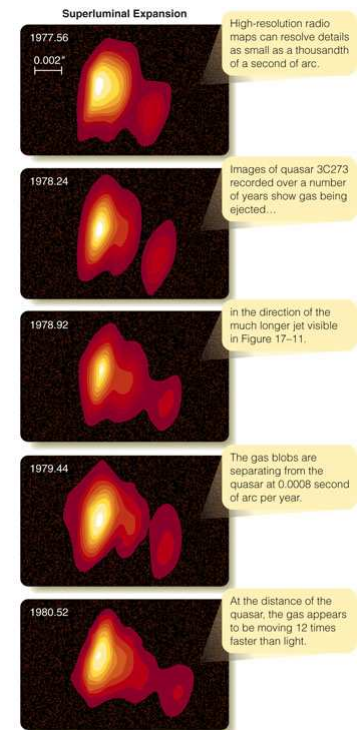
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Superluminal?

- We can see blobs of gas that appear to be moving faster than light!
- Since the jets are moving so fast 99% the speed of light, we have two effects
 - Light travel time
 - Blob travel time

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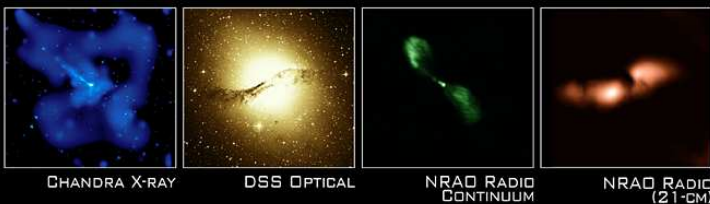
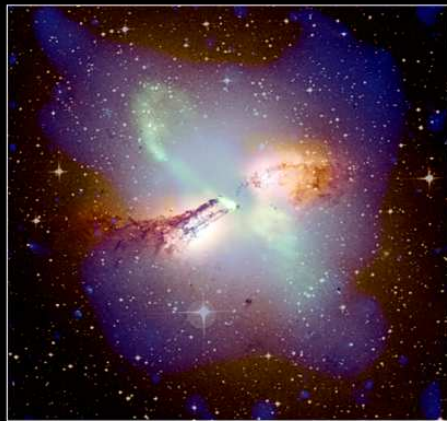
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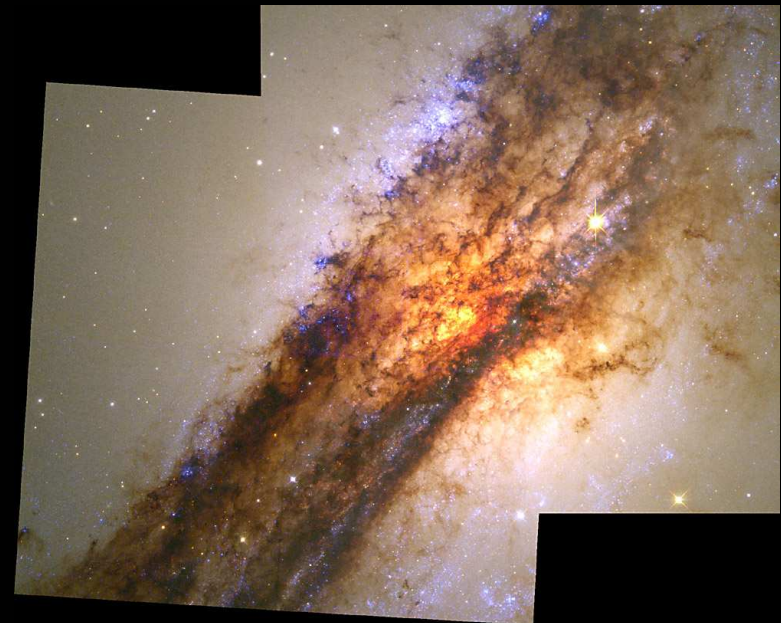
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Radio Galaxies: Centaurus A

If you could see the lobes of the jet with your naked eyes, it would be 10 times bigger than a full moon!



Centaurus A





What is the power source for quasars and other active galaxies?

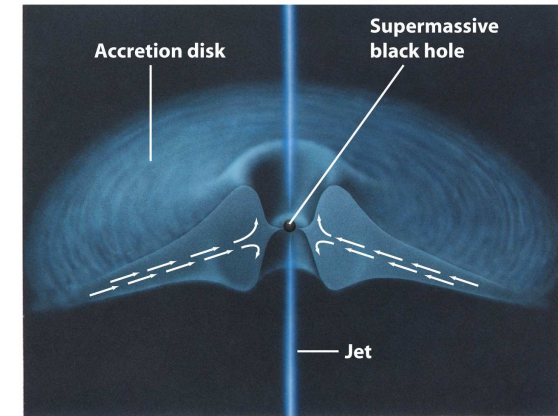
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Driving Active Galaxies: The Monster Within



- A scary blue monster?
- Probably not
- Most likely - the energy source is a supermassive black hole
- Accretion disk emits tremendous amounts of energy as it falls onto the black hole



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Quasars and Active Galaxies



- Supermassive black holes probably exist in most if not all galaxies' cores
- In the past, active galaxies were more common than now
 - Peaked at $z=2$, none past 2.7
- Were very powerful active galaxies at one time quasars?
- As the Universe evolved, the quasars calmed down
 - Turned off?
 - Became today's active galaxies?

TABLE 16-1 Galaxy and Quasar Luminosities

Object	Luminosity (watts)
Sun	4×10^{26}
Milky Way Galaxy	10^{37}
Seyfert galaxies	$10^{36} - 10^{38}$
Radio galaxies	$10^{36} - 10^{38}$
Quasars	$10^{38} - 10^{42}$

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The Central Engine



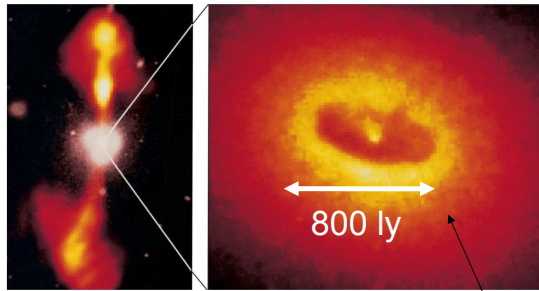
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The Central Engine – Supermassive Black Holes



- Energy source for active galaxies
- Only thing compact enough and energetic enough
- Material falling into the black hole compresses and heats up
 - Emits tremendous amounts of energy
 - Some gas escapes via high-speed jets



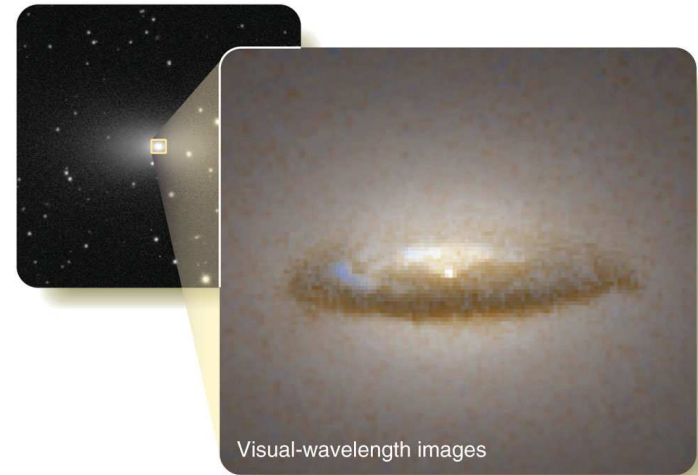
NGC 4261 in the Virgo Cluster

From velocities,
1.2 billion solar masses!

The Central Engine – Supermassive Black Holes

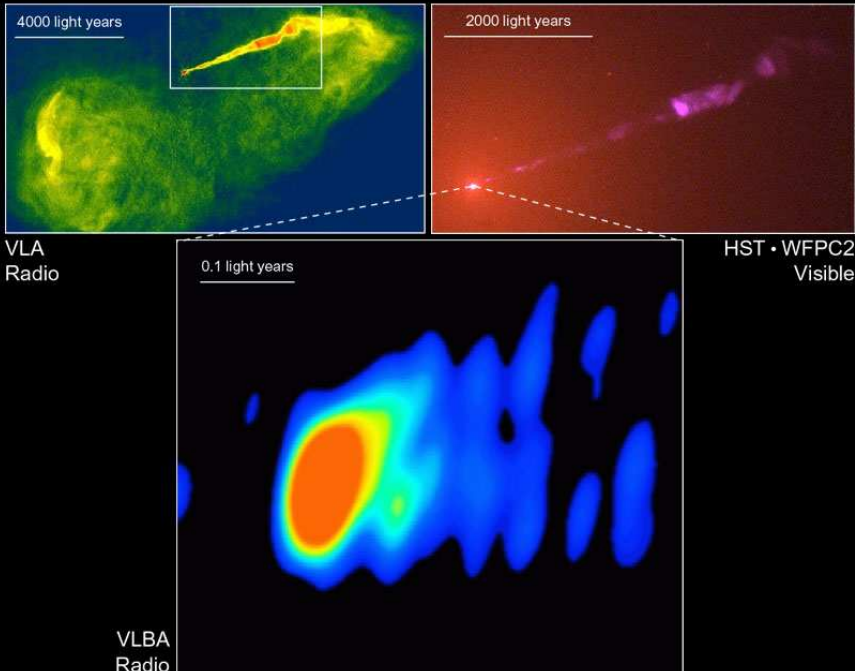


NGC 7052



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Galaxy M87

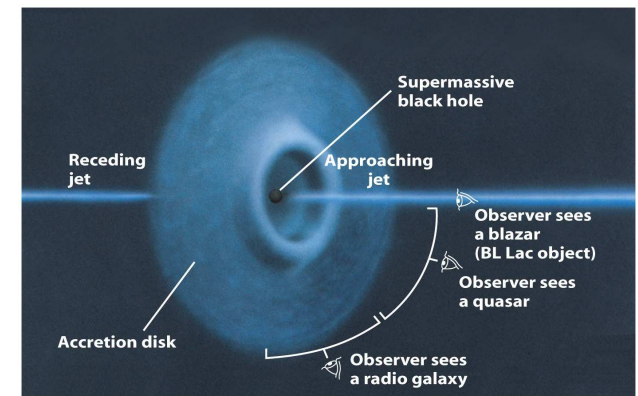


NASA, NRAO and J. Biretta (STScI) • STScI-PRC99-43

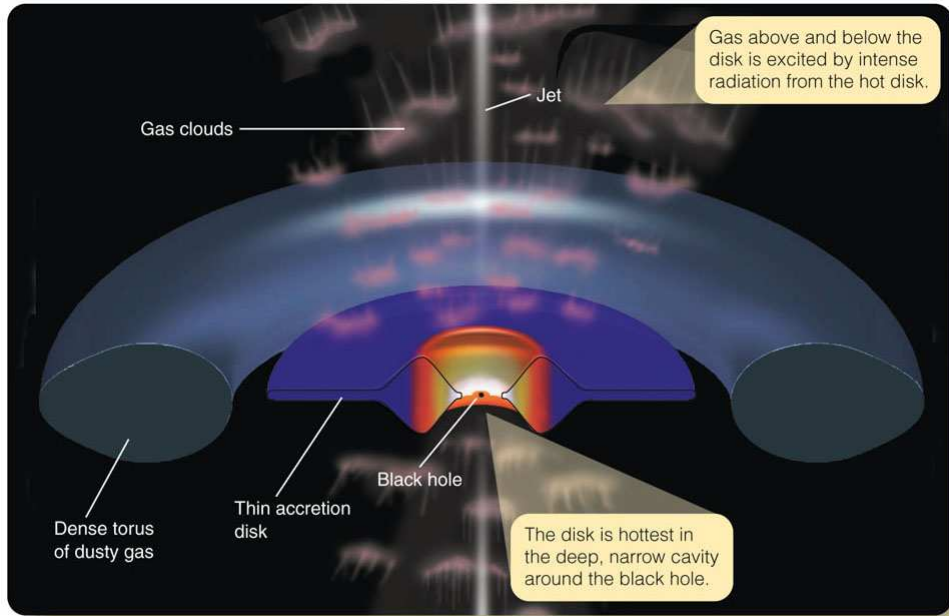
A Unified Model



- Active galaxies and quasars have the same energy source (supermassive black holes)
- Orientation matters!



Torus



Question



What would happen to our Galaxy if the supermassive black hole at the center were “fed”?

- a) Nothing
- b) Something

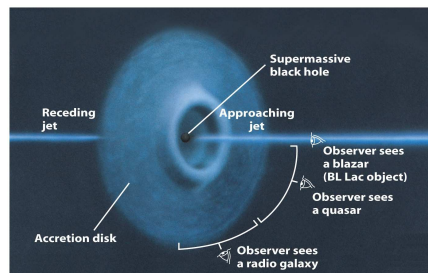
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Origin of Supermassive Holes?



- There is a correlation between the mass of the central black hole and the bulge of the galaxy.
- Not the disk component, only the bulge.
- About 0.5% of the bulge.
- Suggests that the black hole formed earlier in the bulge formation process.



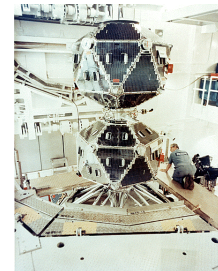
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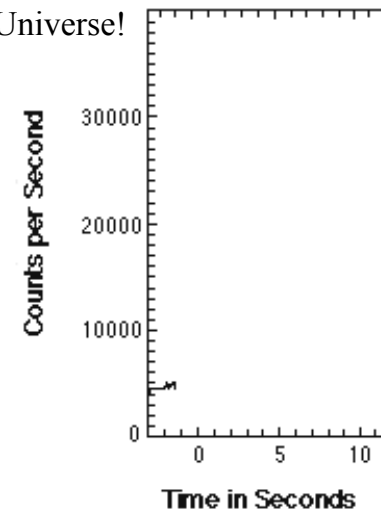
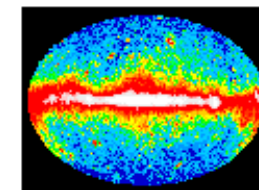
Gamma Ray Bursts



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



Vela Satellites

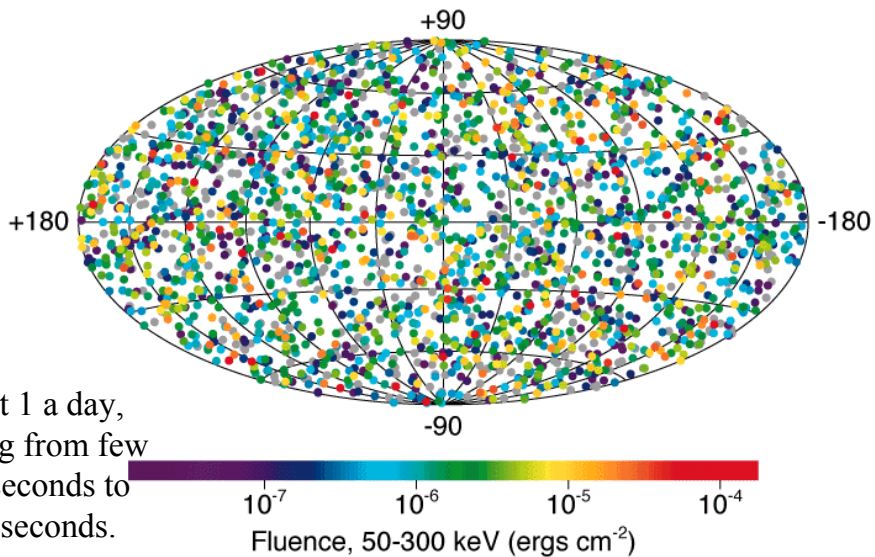


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Gamma Ray Bursts



2512 BATSE Gamma-Ray Bursts



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

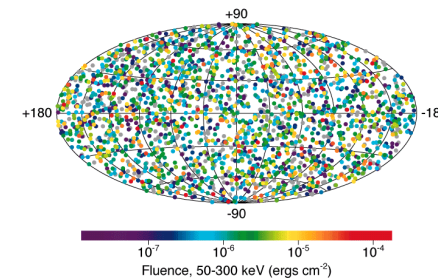
Question



Based on the image, where do you think gamma ray bursts come from?

- a) Far away
- b) Milky Way
- c) Local

2512 BATSE Gamma-Ray Bursts



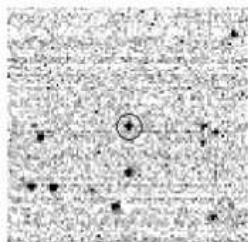
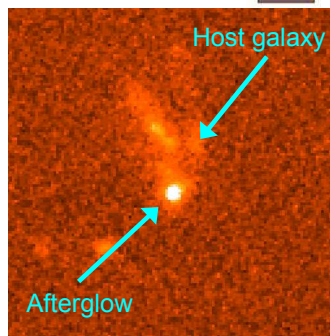
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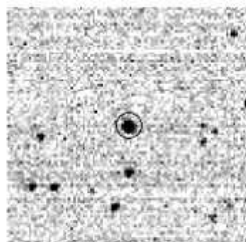
Gamma Ray Bursts



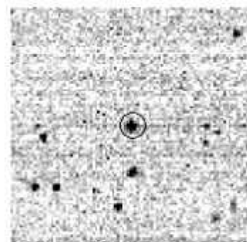
- Recent observations confirm they are very energetic (*as much energy in 100 seconds as the Sun over its entire life!*) and very distant ($z = 4$).
- Energized by either the merging of neutron stars or, more likely, hypernovae (> 40 solar mass star)



22 seconds



48 seconds



73 seconds

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