

Astronomy 150: Killer Skies



This Class (Lecture 35):
Quasars

Next Class (Lecture 36):
Aliens

HW 11 due on Dec 5th

Exam3: Dec 8th

Music: Supermassive Blackhole – Muse

Online ICES



- Anonymous ICES forms are available online, so far 79/286 (~28%!) students have completed it.
- I **appreciate** you filling them out!
- But, we can do better than 60%!
- **Please** make sure to leave written comments. I find these comments the most useful, and typically that's where I make the most changes to the course.
- This is a newer course, so comments are especially welcomed. Keep in mind constraints of a gen-ed though.

Exam 3



- Exam 3 in this classroom on Dec 8th, regular time
- 40 Multiple choice questions
- Will cover material from Lecture 26 to last day.
- May bring 1 sheet of paper with notes
 - Both sides
 - Printed/handwritten/whatever.. I don't really care
- Major resources are lecture notes, in-class questions, and homeworks
- Created and posted a new study guide

Question



Are you going to fill out an ICES form before the deadline?

- a) Yes, I did it already.
- b) Yes, sometime today.
- c) Yes, I promise to do it before the deadline of Dec 9th!
- d) No, I have too much else to do, so I can't help you out. My facebook page is so out of date that my friends don't know what movie I saw last weekend!

Question



Do you think a required textbook would have helped you in this course?

- a) Very much
- b) A little
- c) No real difference
- d) Not at all, lecture notes are enough

Question



Do you think a required textbook would have helped you in this course? Keep in mind that astronomy textbooks (with color pictures) are easily \$75-\$100+.

- a) Very much
- b) A little
- c) No real difference
- d) Not at all, lecture notes are enough

Outline

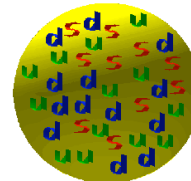


- Death Rays from the center of Galaxies.
- We see it happening.
- Are we in danger?

Stranglets



- One last thing, stranglets
 - Really just another one of those accelerator scares
- Proton = uud quarks & Neutron = udd are lowest energy (stable) particles at regular density.
- But if high density and equal large numbers of uds quarks, it might be a lower energy state



Quarks	u up	c charm	t top
	d down	s strange	b bottom

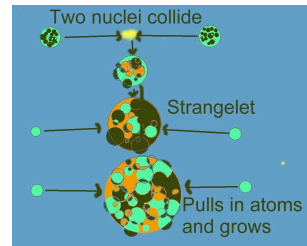
Stranglets



- Anything that contacts, drops to the lowest energy state, releasing heat.
- The world burns in strange matter

<http://www.youtube.com/watch?v=SndbB8hA0UQ> 4:32+

- But, again lack of strange neutron stars and other evidence suggests that it is very unlikely.



Top 10 Ways Astronomy Can Kill you or your Descendents



6. Rogue compact objects—White Dwarfs/Black Holes. Black Holes don't suck, but if they hit you it sucks.
7. Galaxy Collisions. Milky Way vs. Andromeda.
8. Cosmology! This is the way the Universe ends..
9. Quasars. The Monster in the Milky Way? It burnsssss...

Imagine

- After getting flung a few billion years into the future in a British police box, everything seems normal.
- Humans must have moved the Earth.
- But something isn't right.
- Suddenly, the Earth rips apart..
- Then your body rips apart.
- As your body's atoms get ripped apart, you wonder why Leslie didn't mention how painful it would be.

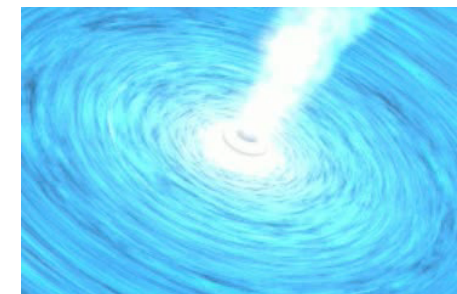
Top 10 Ways Astronomy Can Kill you or your Descendents



8. Quasars. The Monster in the Milky Way?

Right now, our supermassive black hole is quiet. But what if it starts to feed?

What about Andromeda?



Imagine

- Astronomers notice that the center of Andromeda is getting brighter. Something interesting is going on.
- Astronomers suggest that Andromeda's supermassive black hole is feeding for some reason.
- It is exciting as astronomers watch the formation of a large accretion disk, which is somewhat unexpectedly oriented perpendicular to our line of sight.

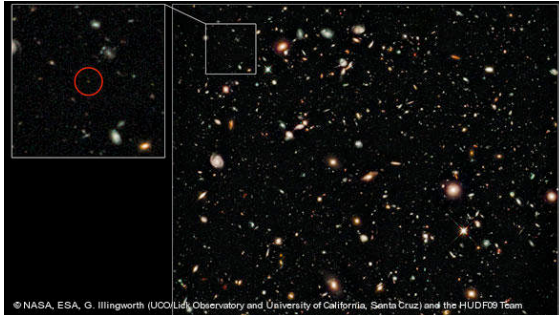
Imagine

- Without warning, a beam of energy is unleashed from the center of Andromeda.
- The gamma-ray beam has less energy/time than a gamma-ray burst, but it doesn't turn off.
- As you are fried by gamma-rays, you wonder why you didn't pay more attention to Leslie during the last week of class and why you didn't fill out your ICES form online.

The Furthest Known Galaxy



- UDFy-38135539
- This galaxy is confirmed to be 13+ billion light years away!
- That means only 700 Myrs after the Big Bang!
- If Universe had a human lifetime (say 80 years), this galaxy is from when the Universe was only 4 years old!

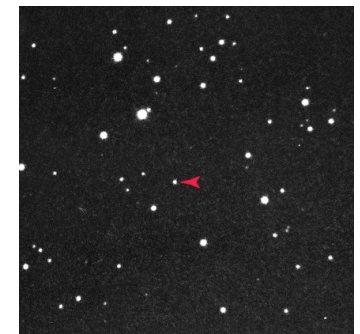


<http://www.dw-world.de/dw/article/0,,6135607,00.html>

A Very Strange Star !?!



- The first most distant galaxy (while much closer) was a shock to astronomers: tracked down a bright radio source.
- Looked like a blue star, but had very odd spectrum.
- Turned out it was simply greatly redshifted.
- 2 billion light years away!
- It must be 100 times brighter than the entire Milky Way!
- **Not** a star

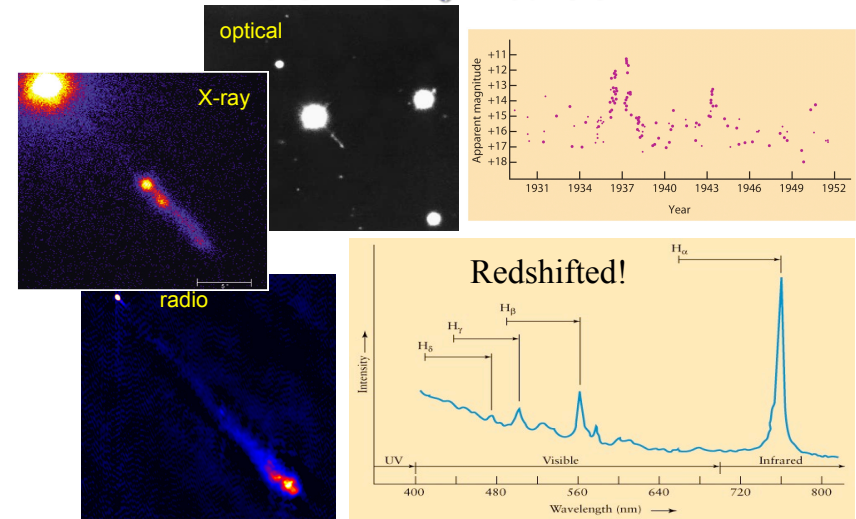


Quasars...



- These objects have a spectrum much like a dim star
 - But highly redshifted
 - Appear to 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

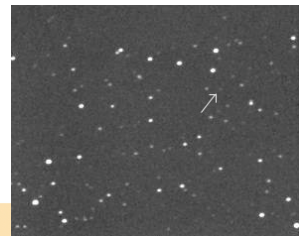
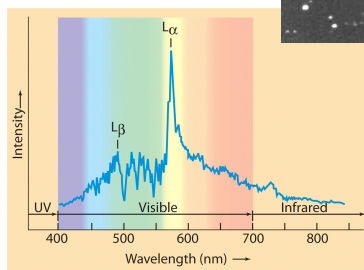
The First Quasar Discovered: 3C 273: $z = 0.158$



PKS 2000-330



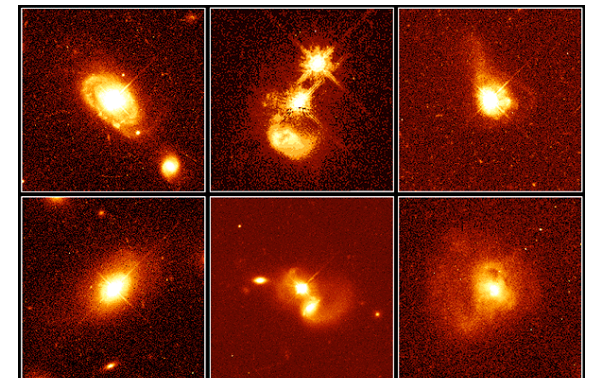
- Redshifted so much that UV emission can be seen in the optical
- This quasar appears to be moving away from us at 92% of the speed of light!



Quasar Host Galaxies

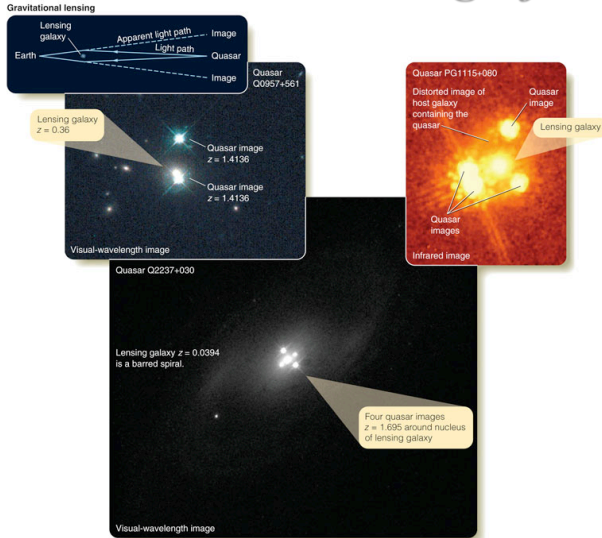


- Quasars live in **distant** galaxies
- They are *galactic nuclei!*
- *But why are these nuclei so bright?*



Quasar Host Galaxies HST • WFPC2
 PRC96-35a • ST ScI OPO • November 19, 1996
 J. Bahcall (Institute for Advanced Study), M. Disney (University of Wales) and NASA

Gravitational Magnified



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Question



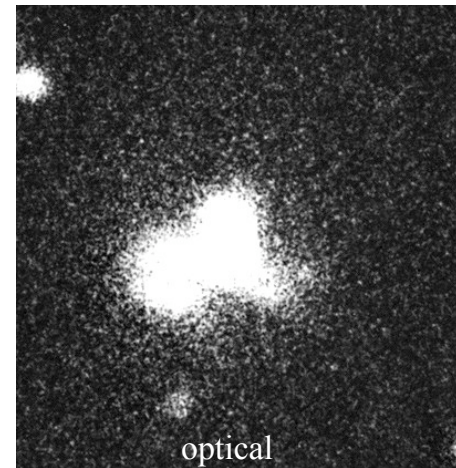
So what is a quasar?

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



Are there quasars in the nearby Universe?

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!
- Similar to a quasar, but not enough energy.

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



Seyfert Galaxies



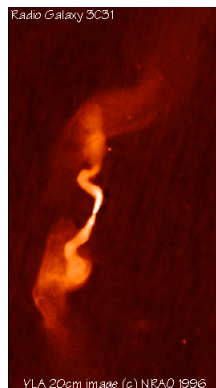
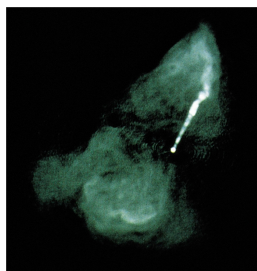
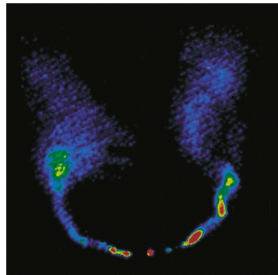
- Look like normal spiral galaxies, but with incredibly bright nuclei
- Potentially as bright as a trillion Suns!
- Brightness varies tremendously
- Over a few weeks it's brightness can change by the ENTIRE brightness of the Milky Way



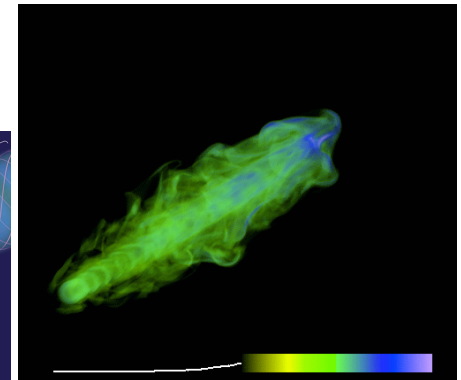
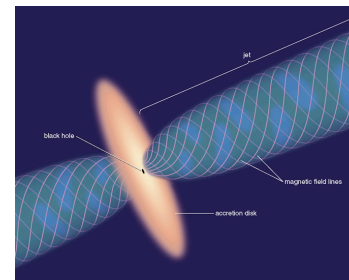
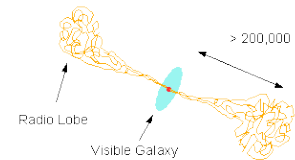
Radio Galaxies



- 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



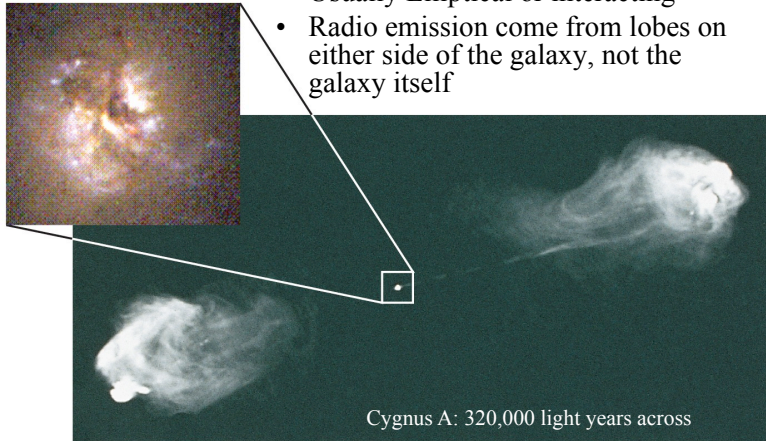
Radio Galaxy Jets



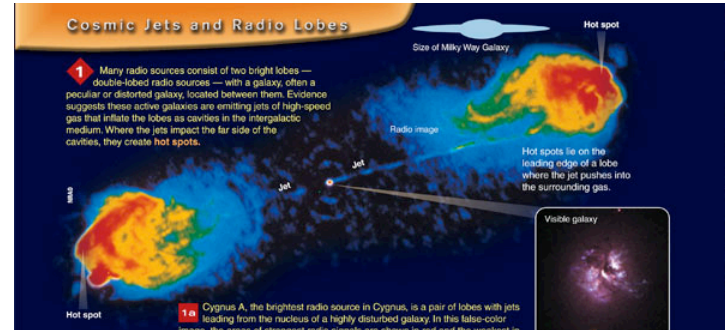
Radio Galaxies



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

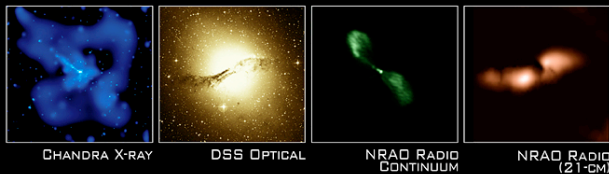


Huge

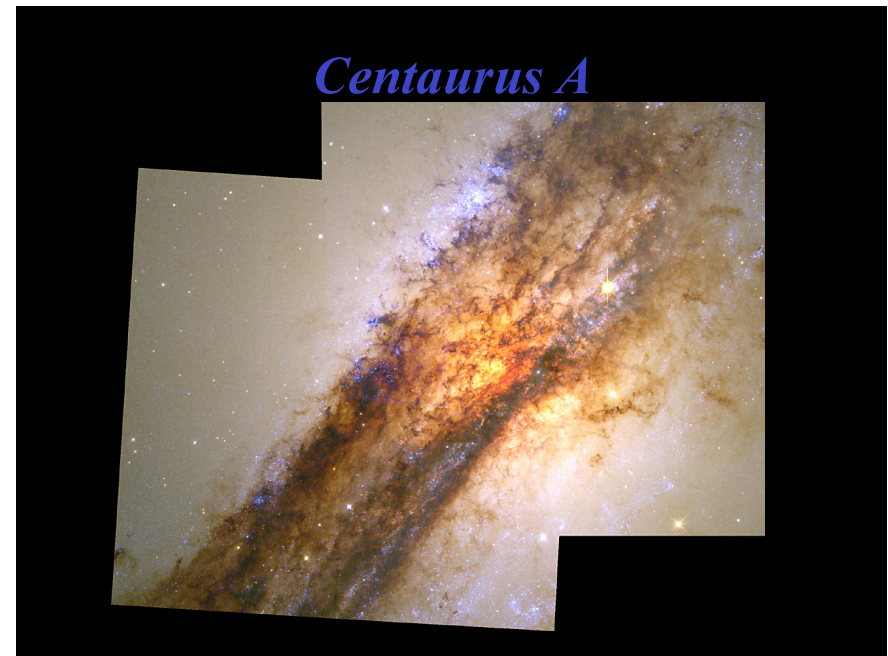


Radio Galaxies: Centaurus A

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



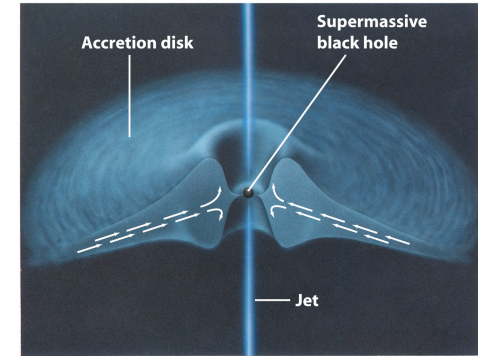


Driving Active Galaxies: The Monster Within



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

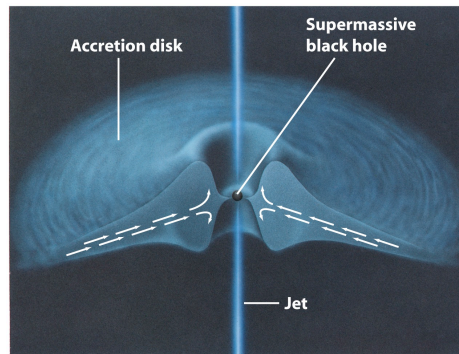
- A scary blue monster?
- Probably not



Driving Active Galaxies: The Monster Within



- Most likely - the energy source is a supermassive black hole
- Accretion disk emits tremendous amounts of energy as it falls onto the black hole
- Active nuclei are the largest reservoirs in the Universe, lasting millions of years or longer.



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
- Were very powerful active galaxies at one time quasars?
- As the Universe evolved, the quasars calmed down
 - Turned off?
 - Became today's active galaxies?
 - Why?

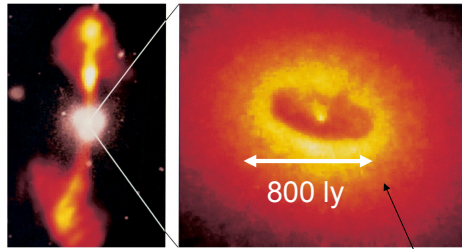
TABLE 16-1 Galaxy and Quasar Luminosities

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	$10^{38} - 10^{42}$

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



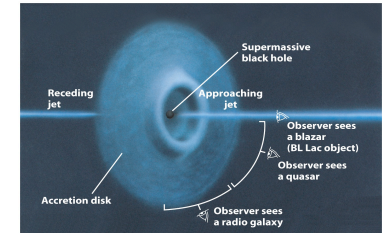
NGC 4261 in the Virgo Cluster

From velocities,
1.2 billion solar masses!

Origin of Supermassive Holes?



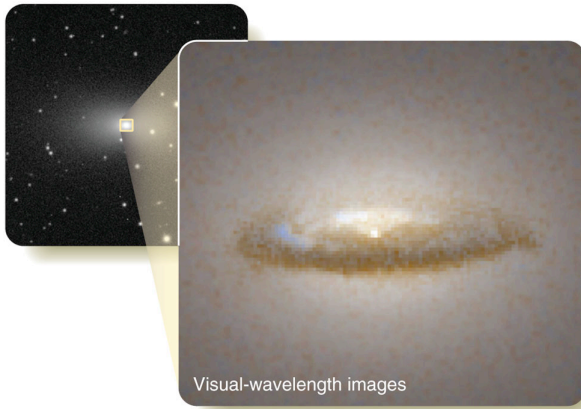
- There is a correlation between the mass of the central black hole and the bulge of the galaxy.
- Not the disk component, only the bulge.
- About 0.5% of the bulge.
- Suggests that the black hole formed earlier in the bulge formation process.



The Central Engine – Supermassive Black Holes

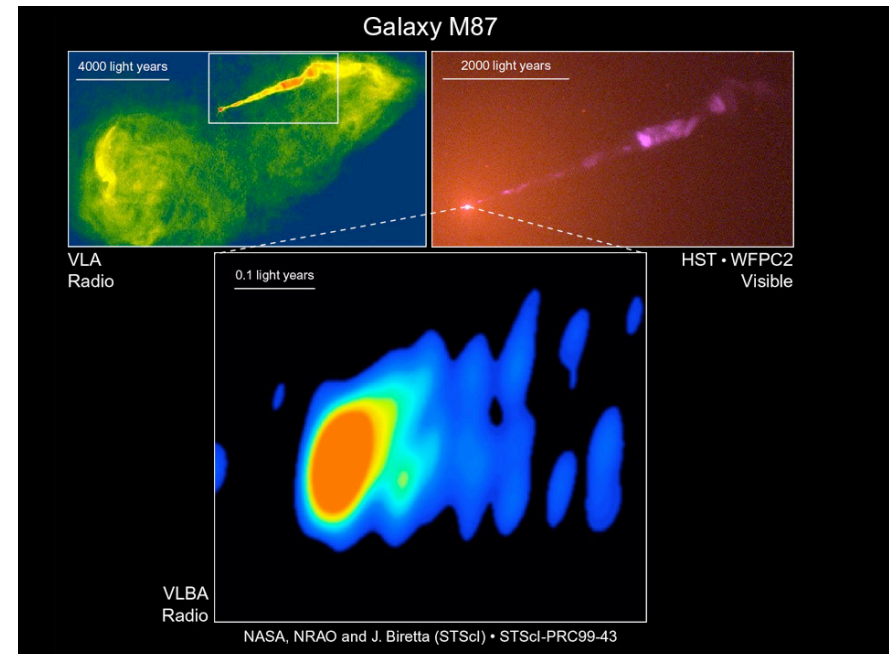


NGC 7052



Visual-wavelength images

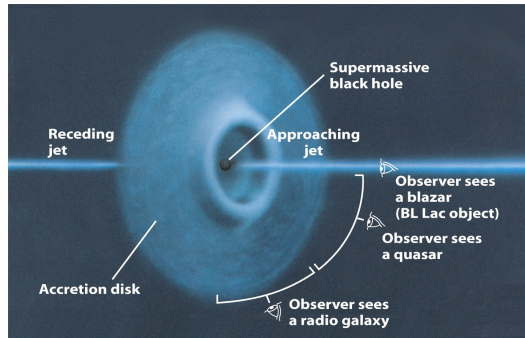
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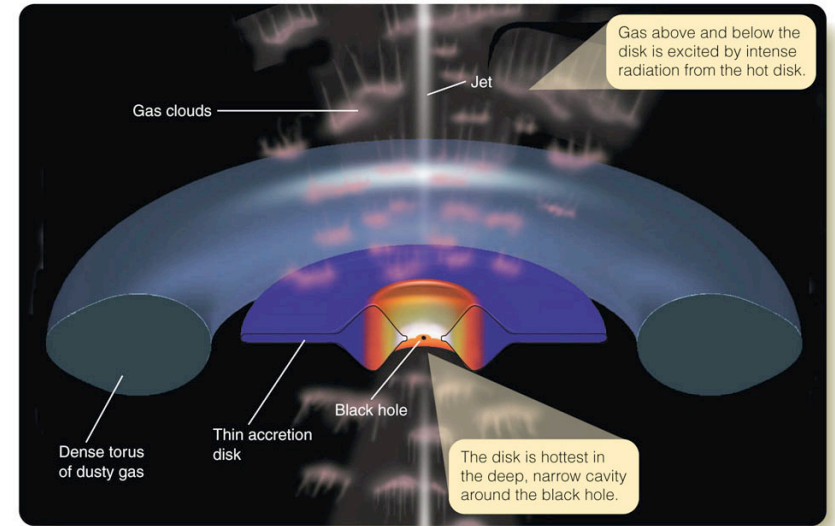
A Unified Model



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



Torus



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Question



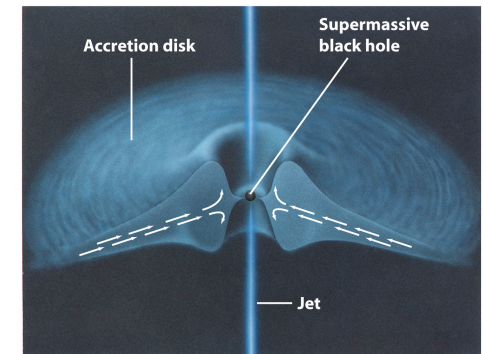
What would happen to our Galaxy if the supermassive black hole at the center were “fed”?

- Nothing
- Something

Driving Active Galaxies: The Monster Within



- The energy source is a supermassive black hole
- Accretion disk emits tremendous amounts of energy as it falls onto the black hole
- Jet is a beam of death! But typical perpendicular to Galaxy.



Quasi-Quasar Danger



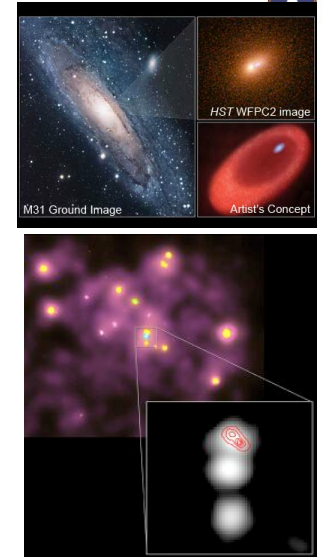
- The Milky Way has a supermassive black hole and so does Andromeda.
- They are not feeding right now, so no quasar-like energy.
- Can they every turn on?
- Yes, if material falls in (why?) and creates accretion disk.
 - We need about 0.1 solar mass of material accreted per year.



Quasi-Quasar Dangers



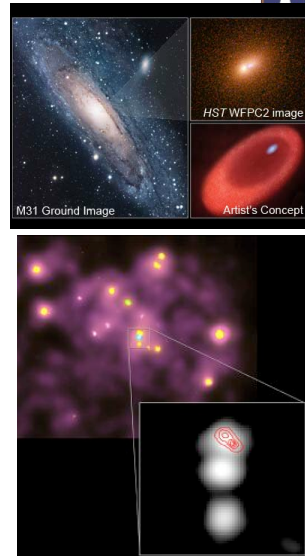
- Let's consider our near neighbor Andromeda (2 Mlyrs away).
- It has a 100 million solar mass black hole. (MW has 4 million).
- There are clusters nearby.
- Could it be about to feed?



Andromeda Danger



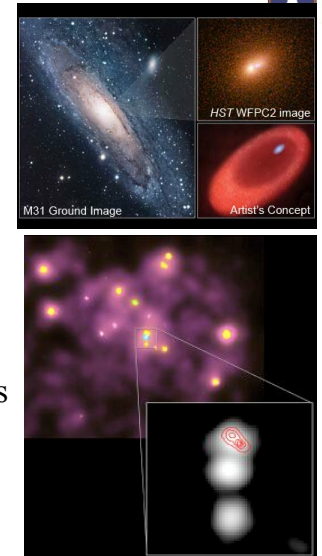
- Jet direction determined by spin of material that falls in.
- So, we don't know which way the jet would go.
- But, effects would be similar to those caused by GRB burst.
- But, Andromeda is very far away, so much less energy.



Andromeda Danger



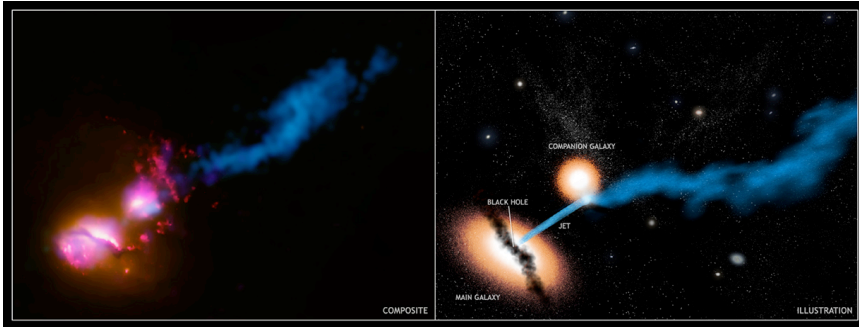
- But, this jet would stay on, not only last for ~20 seconds.
- Jet could cover large region of MW.
- Zero warning!
- Could be coming right at us right now!
- Could have started 2 million years ago!



The Death Star Galaxy



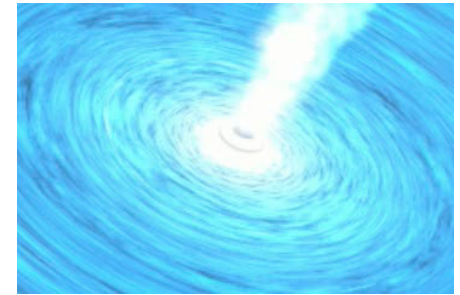
- Recent observations of a nearby galaxy (850 klyrs) show this is happening to two galaxies right now!
- Jet interacts with companion galaxy (20klyr separation)
- Any Earth-like planets getting fried?



The Death Star Galaxy



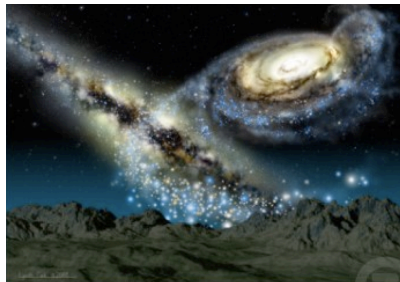
- The chances are low for Andromeda to kill us.
- Quasars are not feeding right now.
- Gas is not falling in– stable orbits?
- But it is possible.



Andromeda Future



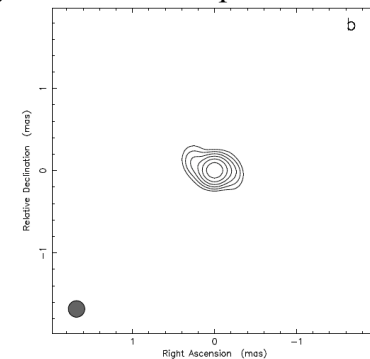
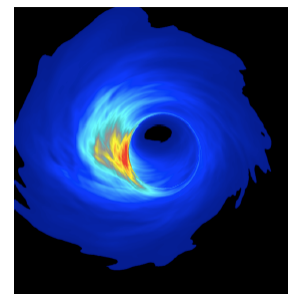
- During the creation of Milkomeda, however, all bets are off.
- Local quasar-like objects are mostly interacting galaxies.
- Gravity interaction can send material inward.
- Either black hole could feed or the new combined black hole.
- Earth location and jet direction is unknown though.



Local Danger?



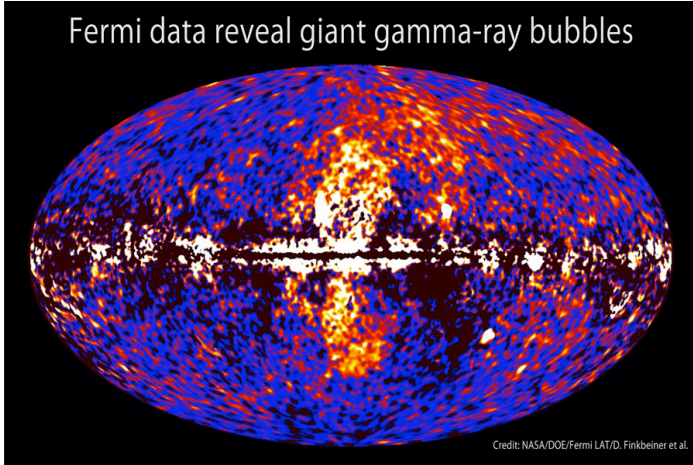
- Our black hole has a very small accretion disk.
- Not really feeding, very very light snacks at best.
 - We do see occasional flares from the center, harmless.
- No jet, but it probably had one in the past!



Remember New Bubble?



Fermi data reveal giant gamma-ray bubbles



Credit: NASA/DOE/Fermi LAT/D. Finkbeiner et al.

<http://antwrp.gsfc.nasa.gov/apod/ap101110.html>

Local Danger?



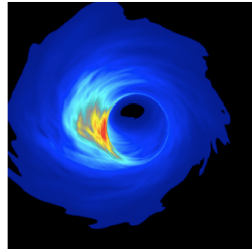
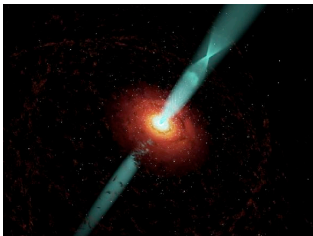
- There is a big molecular cloud nearby the center (390 lyrs), but currently in a stable orbit.
- If it fell in for some reason (cloud collisions?), we could easily create an accretion disk and jet.
- The direction of the jet will unlikely be pointed toward the Earth, but we don't know!



Mitigation



- Nope!
- Destruction on large scale of Galaxy. But beamed.
- No warning.
- Human race gone...



Imagine

- Astronomers notice that the center of Andromeda is getting brighter. Something interesting is going on.
- Astronomers suggest that Andromeda's supermassive black hole is feeding for some reason.
- It is exciting as astronomers watch the formation of a large accretion disk, which is somewhat unexpectedly oriented perpendicular to our line of sight.

Imagine

- Without warning, a beam of energy is unleashed from the center of Andromeda.
- The gamma-ray beam has less energy/time than a gamma-ray burst, but it doesn't turn off.
- As you are fried by gamma-rays, you wonder why you didn't pay more attention to Leslie during the last week of class or fill out your ICES form.

Top 10 Ways Astronomy Can Kill you or your Descendents



6. Rogue compact objects—White Dwarfs/Black Holes.
Black Holes don't suck, but if they hit you it sucks.
7. Galaxy Collisions.
Milky Way vs. Andromeda.
8. Cosmology!
This is the way the Universe ends..
9. Quasars. The Monster in the Milky Way?
It burnssss...
10. Aliens.
You're kidding right...

Top 10 Ways Astronomy Can Kill you or your Descendents



8. Aliens. Are you serious?

With 100-400 billion stars in our Galaxy, it seems likely that aliens exist. If they do exist, it takes longer to evolve than to colonize the Galaxy. Where are they? Our new alien overlords.

<http://www.youtube.com/watch?v=A8zsdIQe9UQ>