Killer Skies

- Homework 9 due Monday
- Asteroid Lab and Night Obs due now
- Solar Obs due next Friday
- Last time: Center of the Milky Way
- Today: Beams from the Galactic Center

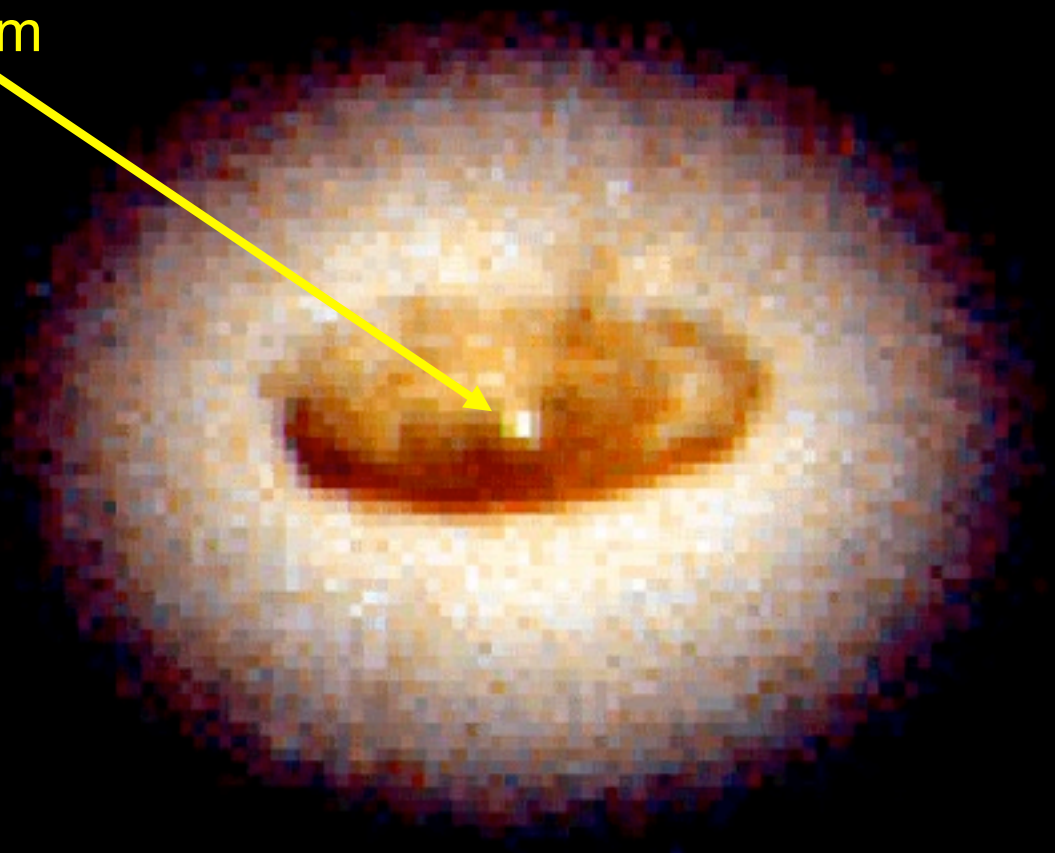
Music: *Under the Milky Way*– Church

The Monster in the Center

http://www.youtube.com/watch?v=duoHtJpo4GY

1.2 billion solar masses within region the size of the Solar System

MW not special in this



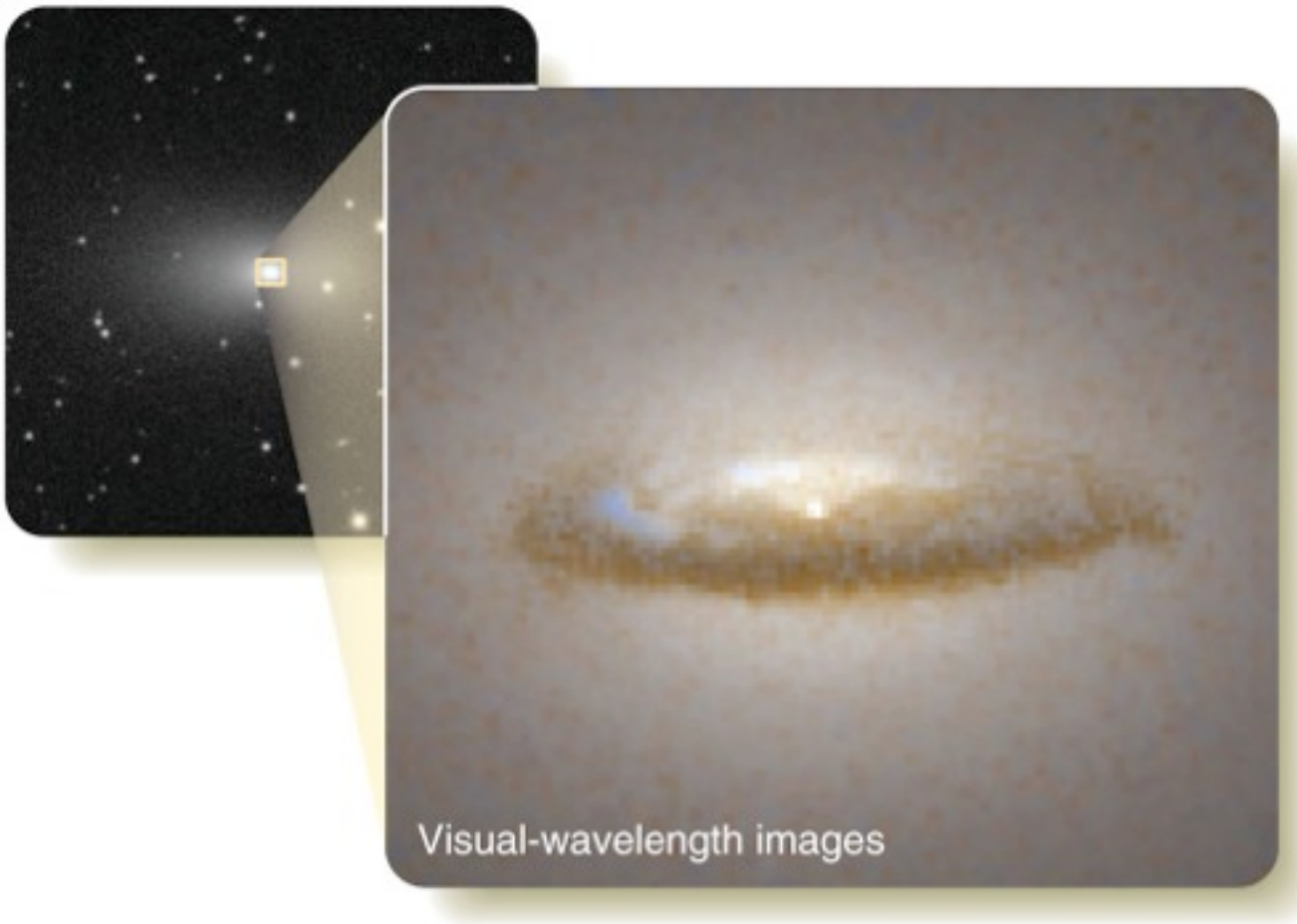
~ 800 ly

Core of Galaxy NGC4261 HST · WFPC2

PRC95-47 · ST ScI OPO · December 4, 1995
H. Ford and L. Ferrarese (JHU), NASA

Supermassive Black Holes

NGC 7052



The Center of the Galaxy

What is at the center of the Milky Way

A. Nothing
B. A large very massive star
C. A few thousand solar mass black hole
D. A few million solar mass black hole
E. A few billion solar mass black hole

Supermassive Black Holes in Context

Supermassive black holes live in the centers of galaxies containing billions of stars (and other stuff)

And despite the impressive black hole masses, they are dwarfed by their host galaxies

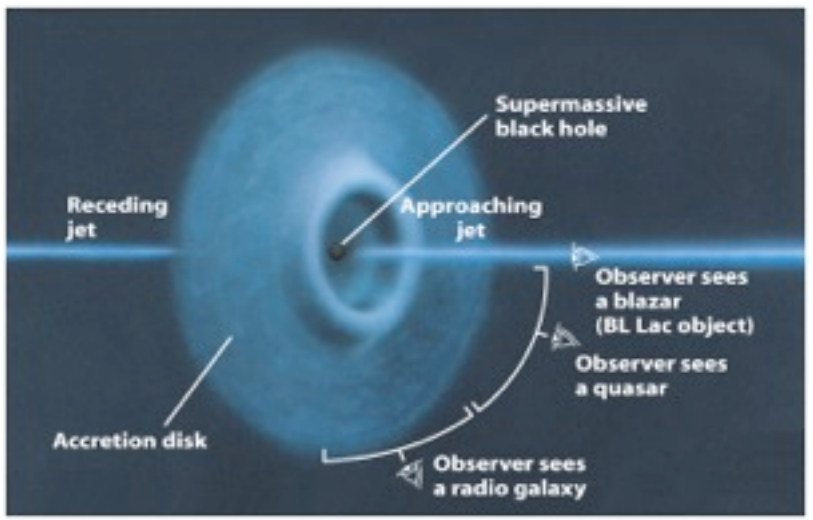
- supermassive BH mass:
  up to 10^9 M_{sun}
- host galaxy mass:
  up to 10^{13} M_{sun}!
- supermassive BH size:
  R_{Sch} up to 100 AU or about 0.03 lyrs
- host galaxy size:
  up to 100,000 lyrs!

Galaxy gravity drives black hole to center

Black hole gravity is not what holds galaxy together!

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.



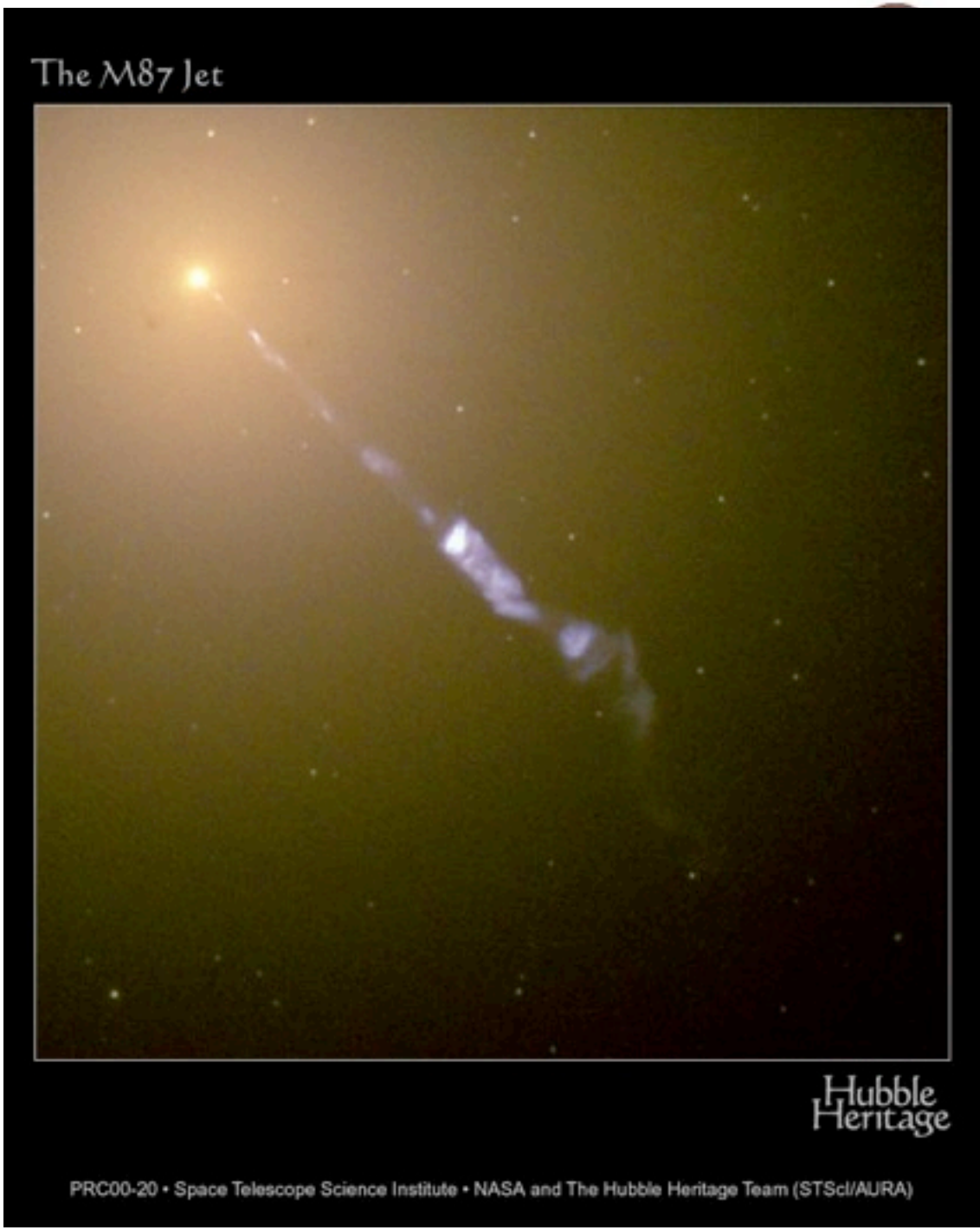
The Jet of M87

Huge jet from the center of this galaxy (50 Mlyrs away).

5000 light years in length!

What causes this?

The monster hidden at the center of the Galaxy, of course



The Central Engine – Supermassive Black Holes

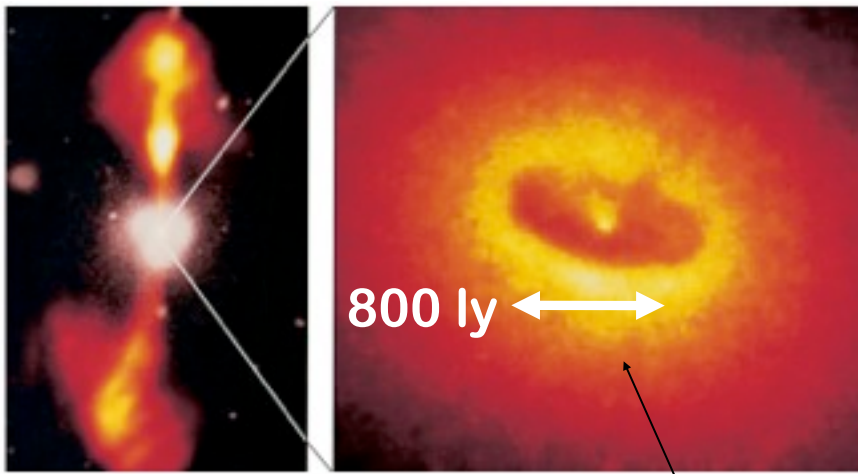
Supermassive black holes are energy source for active galaxies

- 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
- the more the black hole eats, the more powerful the jet

  i.e., accretion rate sets jet power



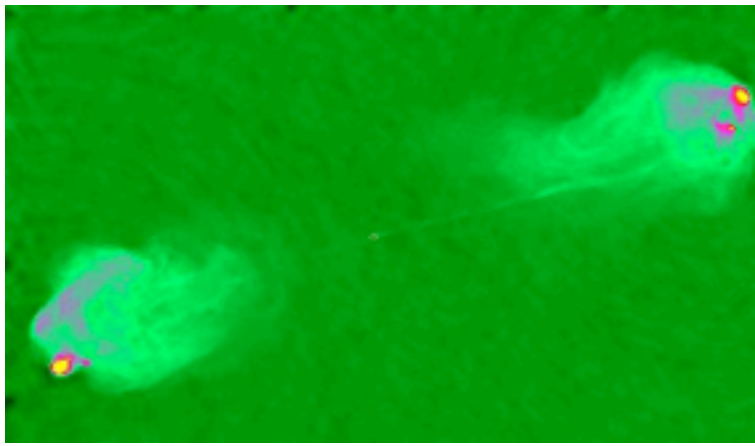
NGC 4261 in the Virgo Cluster

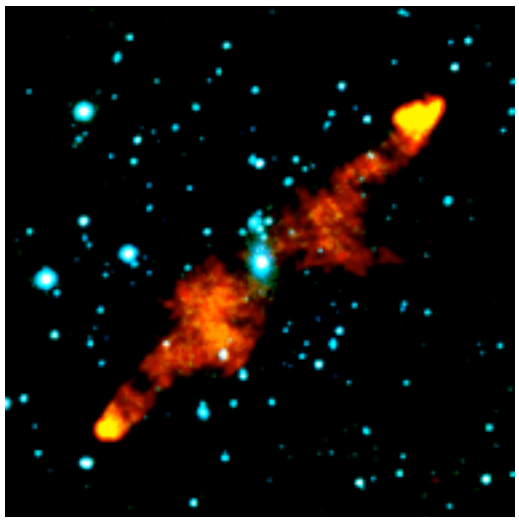
From velocities, 1.2 billion solar masses!

Supermassive Black Hole Jets

Every (?) galaxy has a supermassive black hole at its center

- most on a diet, not feeding, not dangerous (except nearby)
- when they do feed, not all matter falls in
- some matter ejected at speeds >99% c
- forms back-to-back "jets"

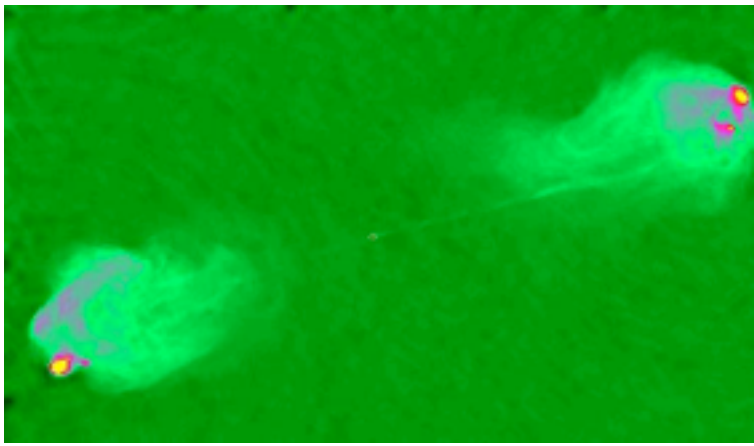


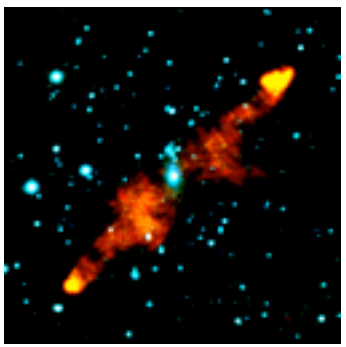


Supermassive Black Hole Jets

Relativistic Jets from Active Galactic Nuclei

- stretch from black hole to far beyond the host galaxy
- Jets are among largest structures in the Universe
- carry enormous energy

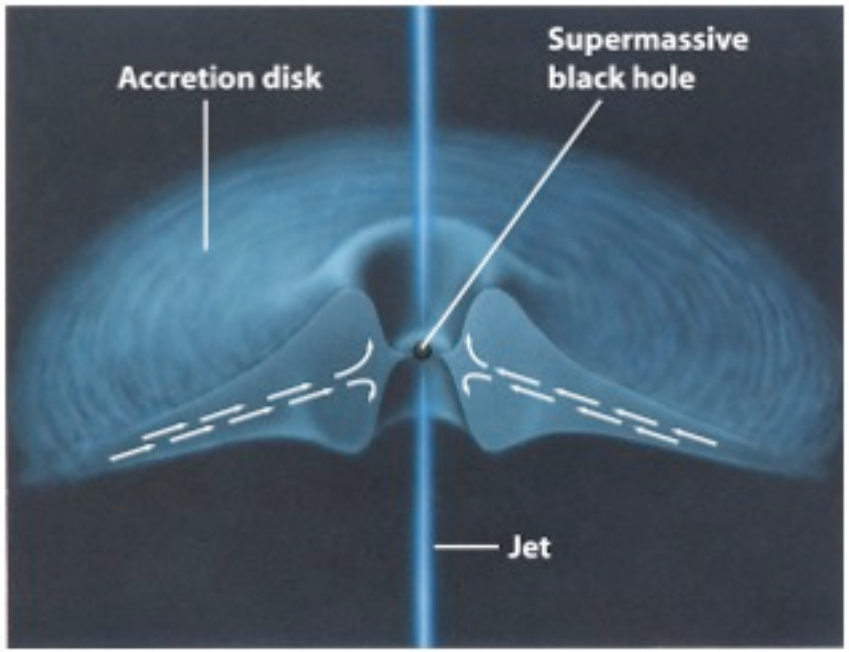




Driving Active Galaxies: The Monster Within

The jet energy source is a supermassive black hole

Accretion disk emits tremendous amounts of energy as it falls onto the black hole



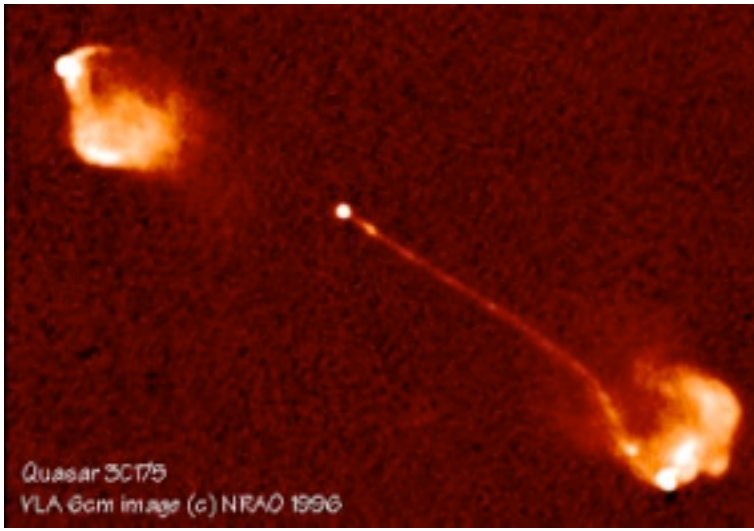
Jet is a beam of death!

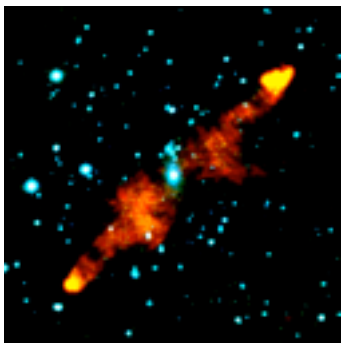
But only dangerous if you are caught in the beam

Crucial question: where does the beam point?

Supermassive Black Hole Jets
Cosmic Blowtorches

- We have seen that black holes are messy eaters
- undigested matter ejected at high speed
  - can be deadly even from “small” stellar mass black holes
  - this was the Gamma-Ray Burst threat
- but supermassive black holes also eject huge amounts of matter
- What if we are in the beam?



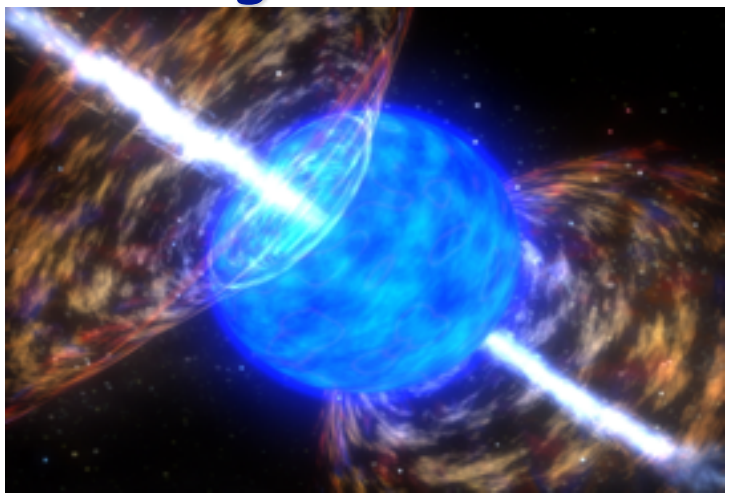


IClicker Question

What might cause our Galaxy to emit an energetic relativistic beam of death?

A. Nothing
B. Super massive black hole
C. Accretion of smaller black holes
D. Accretion of material (non-black hole)
E. Hawking Radiation

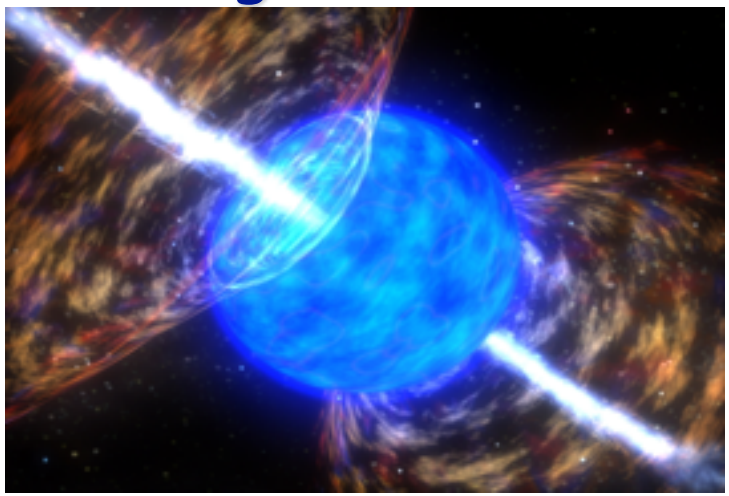
AGN Jets vs Gamma-Ray Bursts



In many ways, AGN jets are similar to GRBs

- both are created by black holes
- both are material ejected at huge speeds
- both eject matter in a narrow beam
- both are directed along the poles of a spinning black hole
- both generate ionizing radiation which is very dangerous if you are in the beam

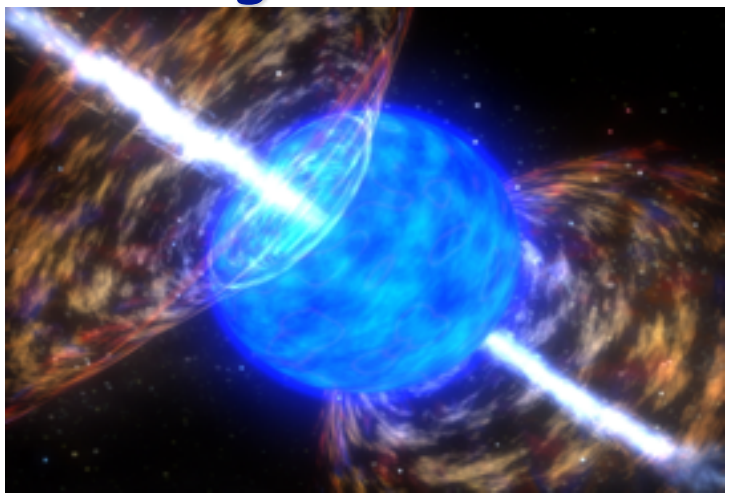
AGN Jets vs Gamma-Ray Bursts



but important differences

- GRB outflows
  - created by stellar-mass black holes, say 1-10M_{sun}
  - ejected matter has small mass, <M_{earth}
  - blast is very short-lived, dies off in days
  - blast material stopped well within galaxy hosting the GRB

AGN Jets vs Gamma-Ray Bursts



but important differences

- AGN outflows
  - created by supermassive black holes >$10^6 M_{sun}$
  - ejected material unknown, but carries huge energy
  - blast sustained for possibly millions of years
  - blasts stretch far beyond host galaxy

Lesson: AGN jets are GRBs on steroids!

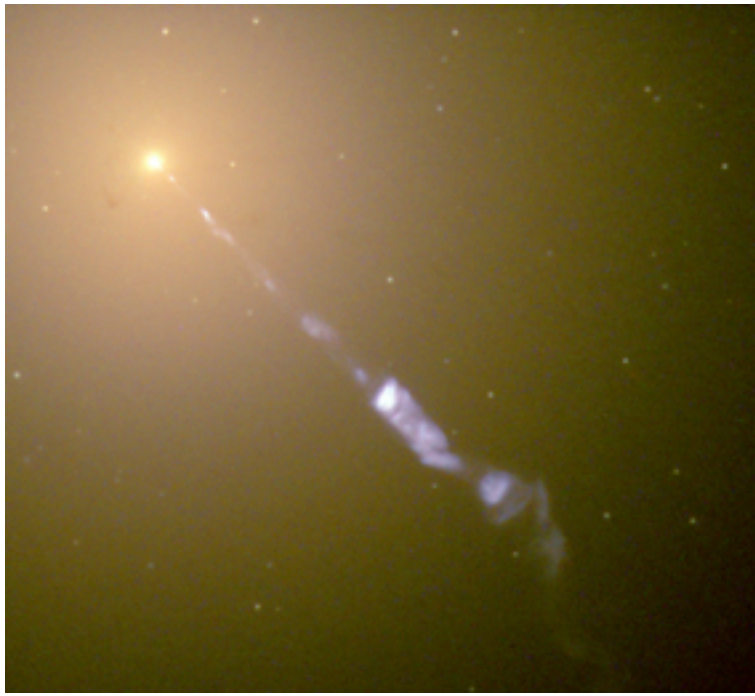
Jet Threat

Many similarities between active galaxy jets and gamma-ray burst properties

- particularly the emission of enormous amounts of ionizing radiation (X-ray, gamma-ray)

Threats are thus similar as well

- ionizing radiation destroys Earth's ozone layer
- Sun's UV unfiltered, destroys food chain from bottom up



Jet in huge galaxy M87
>100 million stars are in the beam

Jet Threat

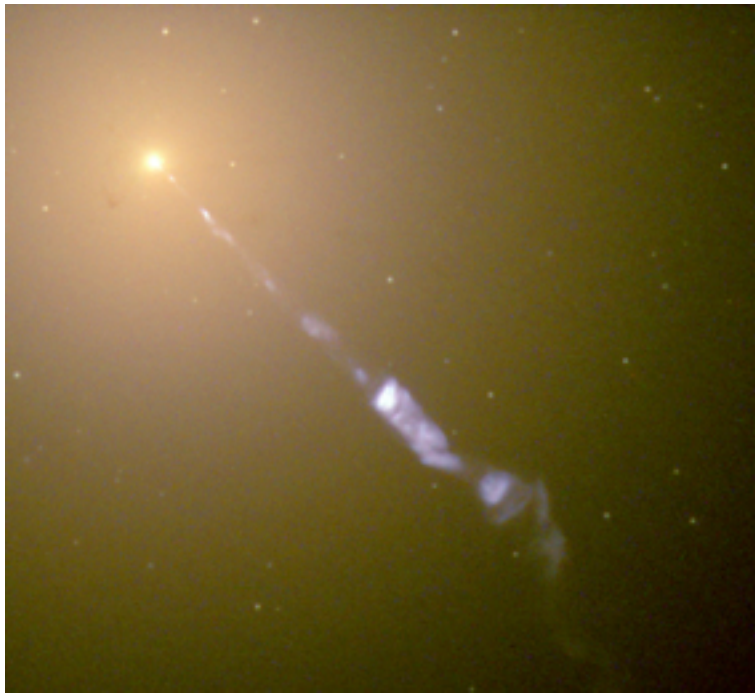
Good news:

- the GRB actually has a higher luminosity
- more energy emitted per second
- so initially the Sgr A* jet will be less harmful than a GRB

Bad news:

- the GRB lasts only seconds and then stops forever
- but the AGN goes on for millions of years!
- and worse: **Earth could be engulfed by the jet itself**

  not sure what made of but likely highly energetic electrons and positrons

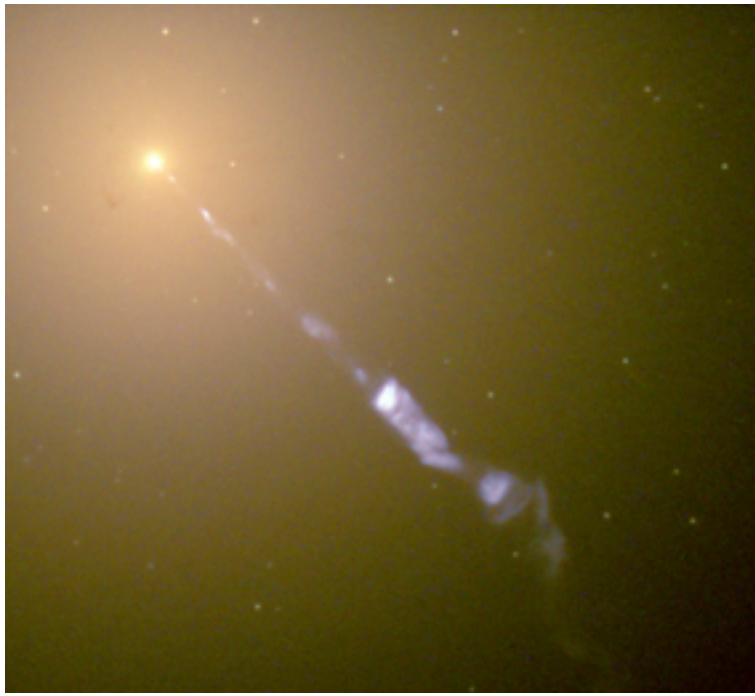


Jet in huge galaxy M87
>100 million stars are in the beam

Jet Threat

Radiation and particles will continuously fry Earth's atmosphere

- ozone layer will be totally stripped clean
- if any life survives, it will have to be highly radiation resistant



Jet in huge galaxy M87
>100 million stars are in the beam

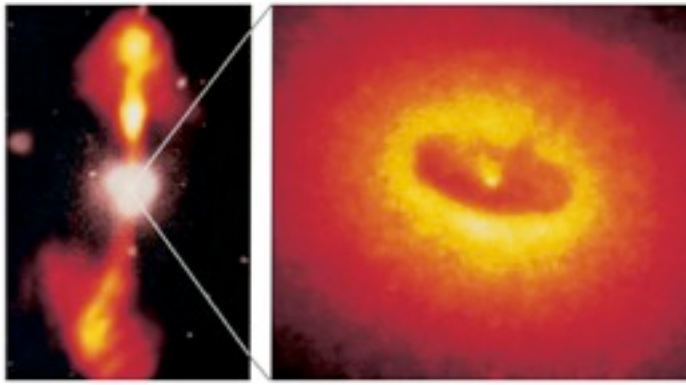
Where does the Beam Point?

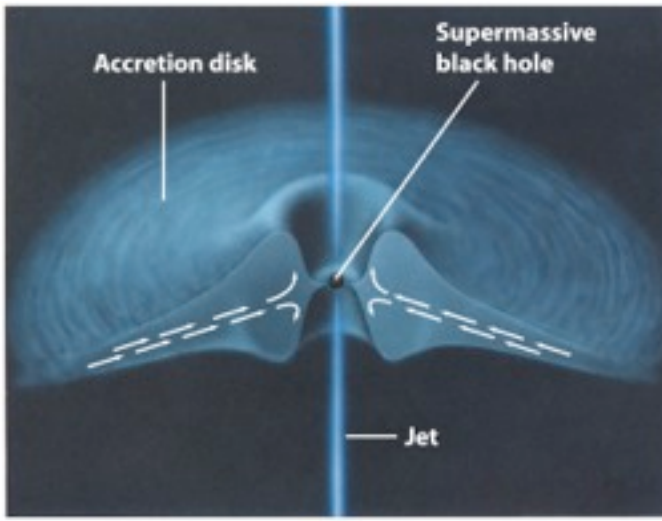
When black hole feeds, spins up

- accretion disk determines equator of spin
- Jet ejected along poles of spin

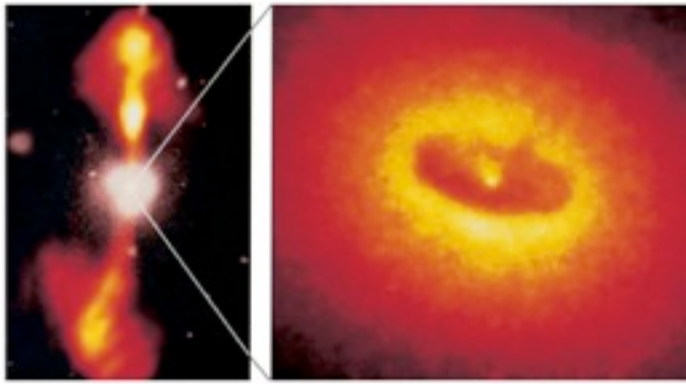
Really there are two back-to-back jets

- one from north pole, one form south





Pointing the Death Ray



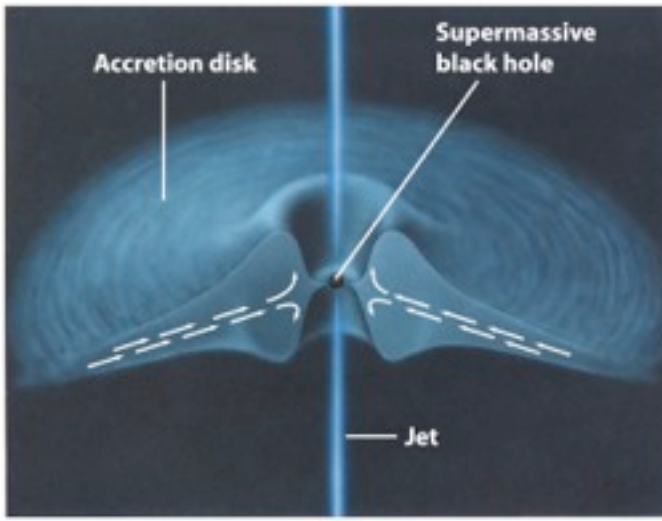
So accretion disk plane sets jet direction

- What sets disk plane?

  Orientation of infalling material

- but only accrete from region very near black hole
- direction of infalling matter depends on orbit directions of nearest stuff
- not clear what sets that,

  but could very well be random



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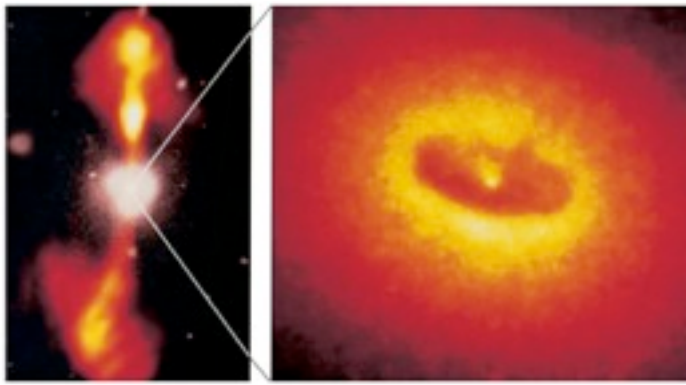
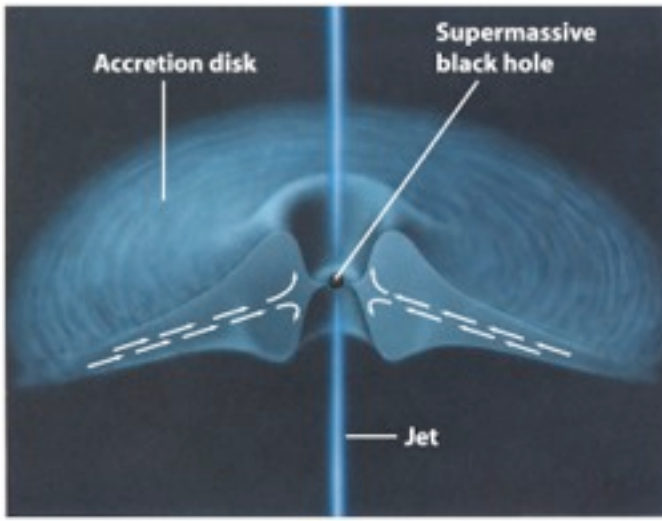


Bottom line: disk and jet directions could well be "unaware" of nature of larger galaxy

- if so: jet direction cannot be predicted by looking at host galaxy
- jet direction could be random!
- if so---nobody can feel safe!



IClicker Question

What will be the main effect from a relativistic beam from the center of the Galaxy?

A. Earth ripped apart
B. Pretty aurorae
C. Obliteration of the ozone layer
D. Sterilization of the Earth's surface
E. Trigger the Sun to become a Red Giant

Local Danger?

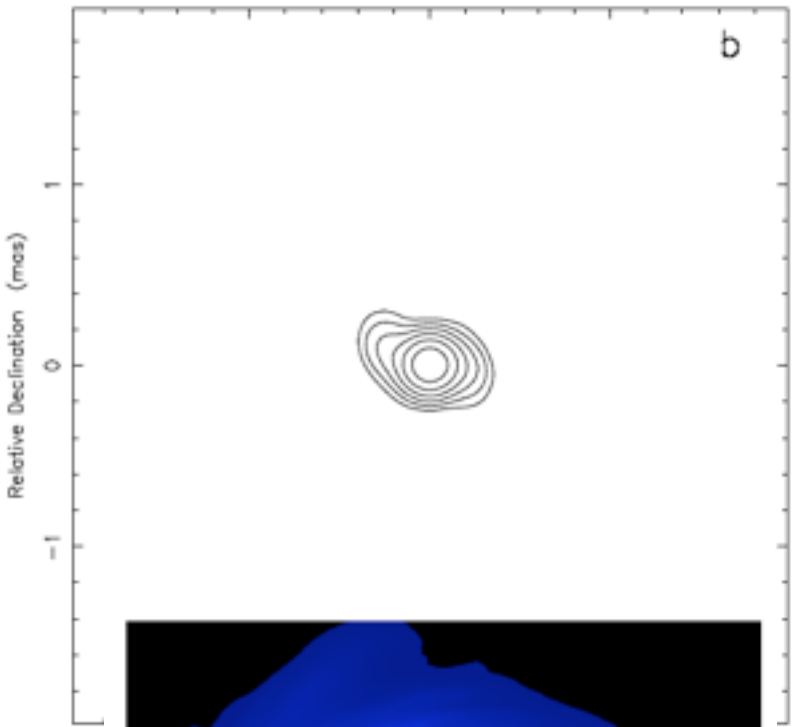
Our own Galaxy's supermassive black hole is Sagittarius A*

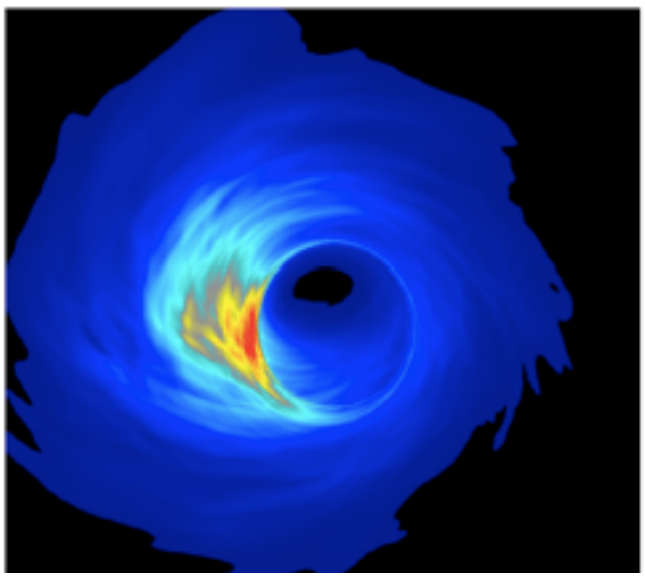
Today: Sgr A* has a very small accretion disk.

Not really feeding, very very light snacks at best.

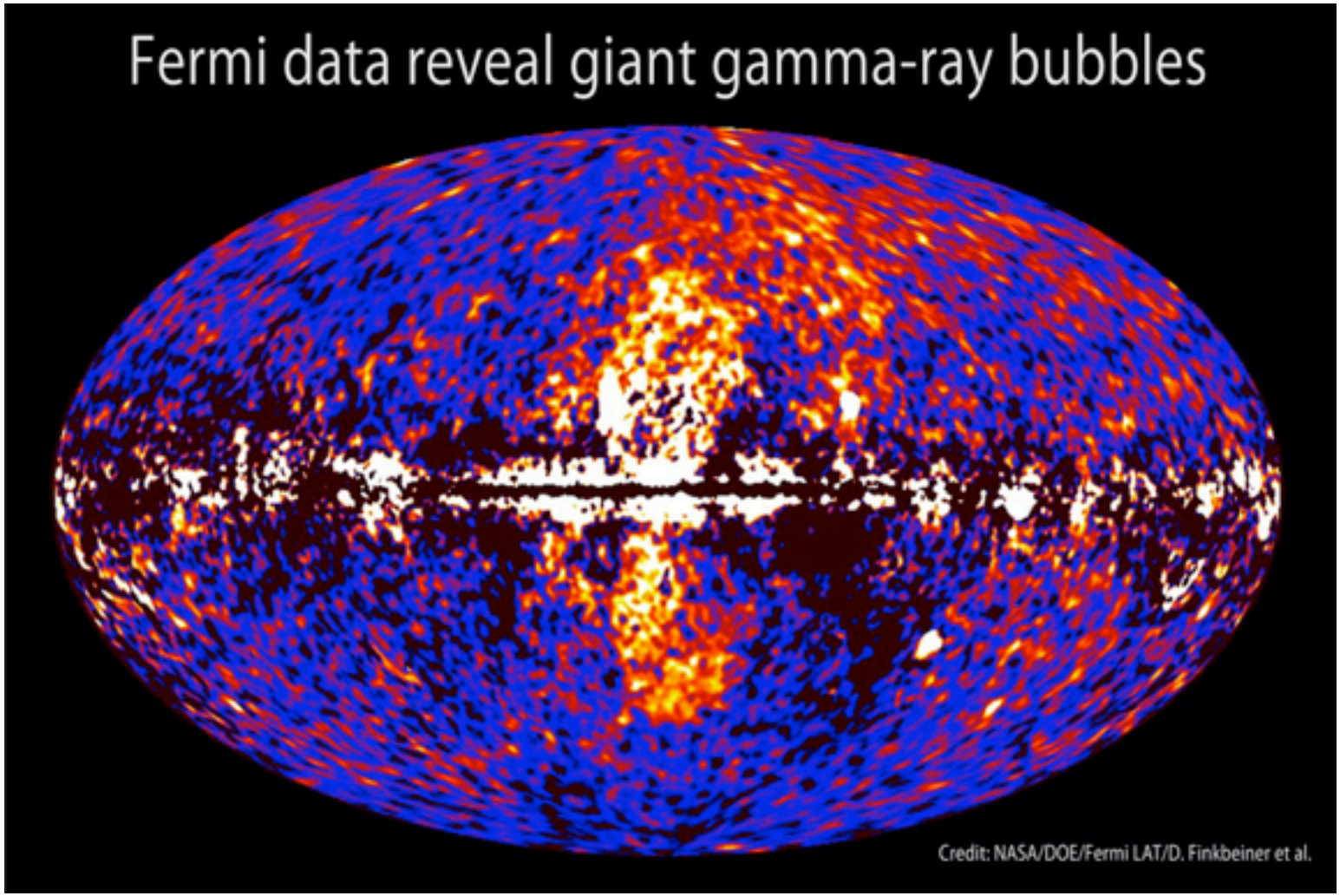
We do see occasional flares from the center, harmless.

No jet, but it probably had one in the past!





Large Bubble



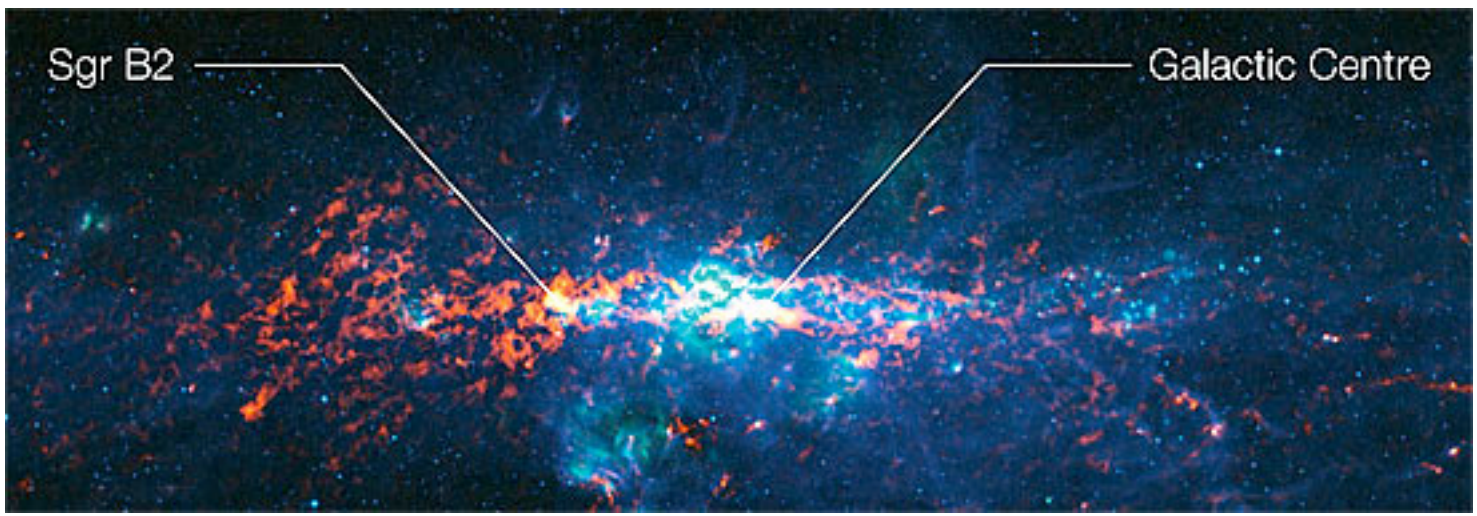
http://antwrp.gsfc.nasa.gov/apod/ap101110.html

In the Crosshairs?

There is a big molecular cloud nearby the center (390 lyrs), but currently in a stable orbit.

so no evidence right now that a harmful jet could happen soon

… but if it grows larger..



In a few million years....

http://www.youtube.com/watch?v=zgAdDDdNOqO

In the Crosshairs?

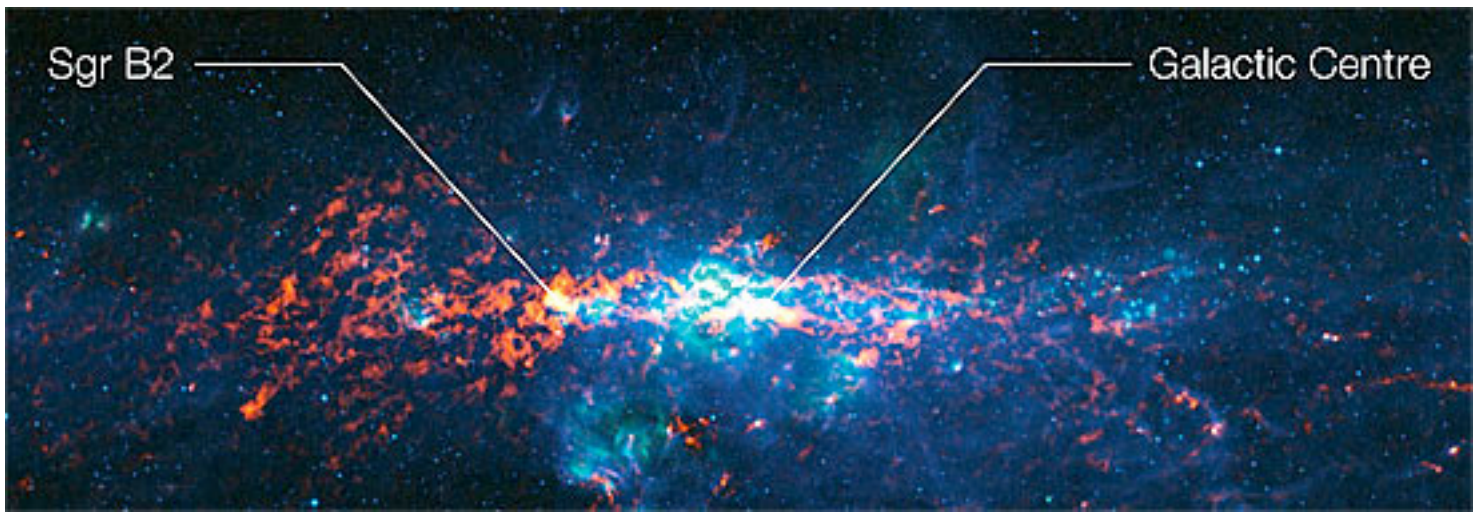
The jet will be beamed, and could be randomly oriented

- **If so, then no direction is safe for sure**
- **but like throwing one dart at dartboard:**

  most regions going to be missed
- **probably at worst a 0.1% (1 in 1000) chance of being aimed at us**

good odds…

- **but sort of disturbing given that we have no defense**



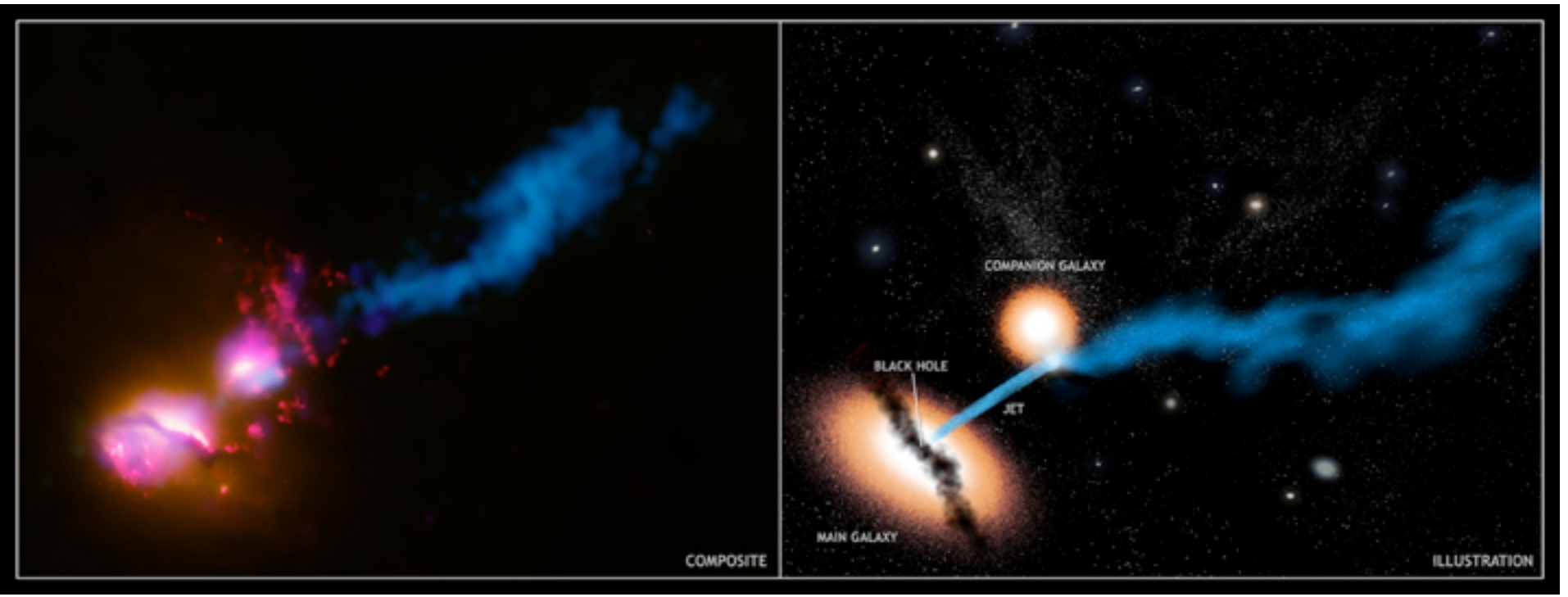
New Development: G2 Incoming!

www.eso.org

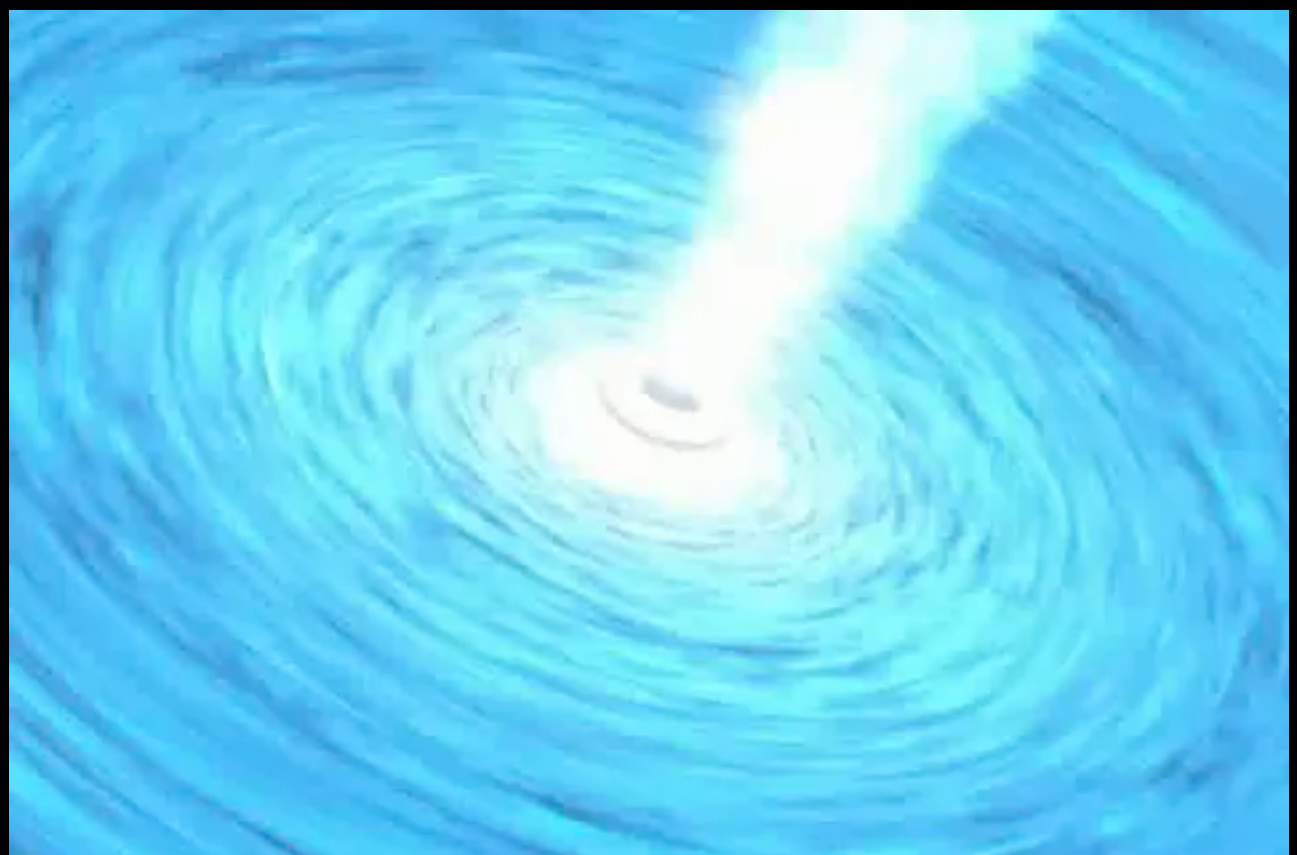
http://www.eso.org/public/images/eso1151a/

The Death Star Galaxy

- Recent observations of a galaxy (1.2 billion lyrs) show this is happening right now!
- Jet interacts with companion galaxy (20 klyr separation)
- Any Earth-like planets getting fried?



Death Star Galaxy



http://www.youtube.com/watch?v=cpLgEayf9wc

Mitigation

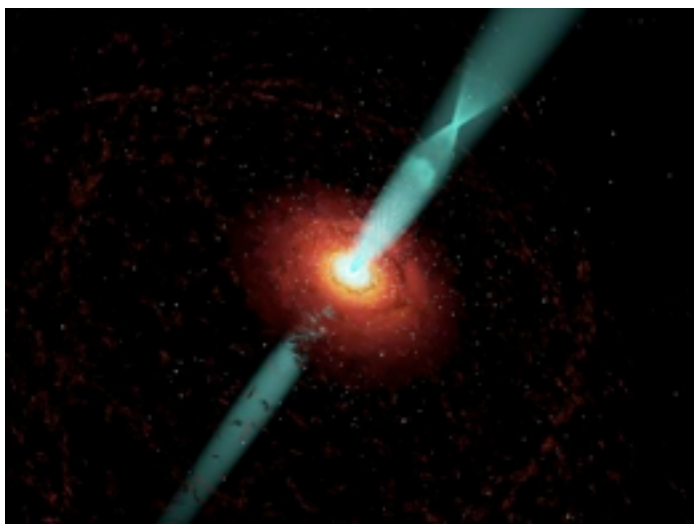
Nope!

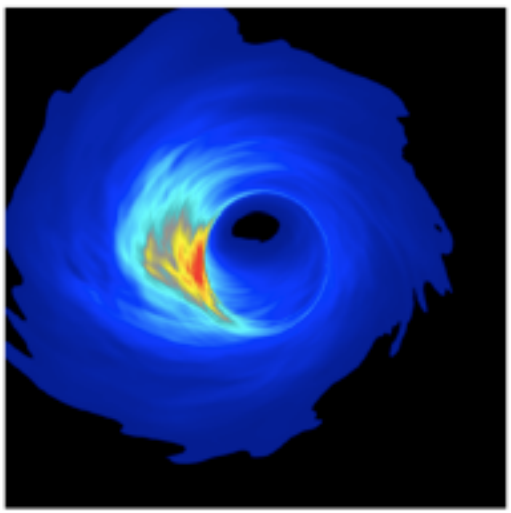
Destruction on large scale of Galaxy.

No warning.

Human race gone…

…but beamed, so the odds of this happening are small





Imagine

Radio and X-ray astronomers notice something odd

Sagittarius A* is getting brighter

And bigger: appears as an expanding blob

High-energy gamma rays turn on next, along with high-energy neutrinos

The blob starts to appear in visible light

Doppler shifts show that it is made of matter traveling at huge speeds >99% c

Eventually it fills half of the night sky

Imagine

- The UV, X-rays and gamma-rays become ever more intense
- The Earth's ozone layer is totally stripped clean
- The Sun's UV rays destroy the food chain and initiate a mass extinction
- Finally, the solar system is engulfed in the blast of a plasma filled with positrons
- The blast pushes back the solar wind, possibly inside 1 AU
- The Earth will be bathed by intense cosmic rays for thousands of years
- As you die in pain, you wonder if this is what Leslie meant by a relativistic jet.

Top 10 Ways Astronomy Can Kill you or your Descendants

1. Impacts! Splat.. Boom… Watch out for space rocks!
2. Solar storms - Magnetic bubble, coil, and trouble
3. Death of the Sun - Burn the land and boil the sea
4. Nearby Supernova - Sirius danger?
5. Gamma Ray Bursts - Cosmic Blowtorches

Top 10 Ways Astronomy Can Kill you or your Descendants

6. Rogue compact objects - Black holes don't suck, but if they get too close it sucks
7. Relativistic beam - the Galaxy is trying to kill us?
8. Galaxy Collisions - Milky Way vs. Andromeda

Our sibling galaxy Andromeda is heading right for us, on a collisions course at 120 miles/second! In about 2 billion years, they will collide. Train wreck!

Remember Galaxies mostly empty space, so stars will not impact.

Imagine

After getting flung 1 billion years into the future in a DeLorean, you notice that the sky is different.

The sky is full of a galaxy, up close and personal.

As you keep traveling into the future, you notice that it is changing position as it interacts with the Milky Way.

You sigh in hope as you notice that the Earth and Sun are fine.

Actually, the sky is prettier than before. This ain't so bad!

Imagine

But, in a few million years you realize that the Solar System has been knocked out of its usual Galactic orbit.

And the Solar System is headed straight for the center of the Galaxy….. And there are many dangers there..

As you die from lethal amounts of UV radiation, you wonder why Leslie didn't mention the beauty of the event.