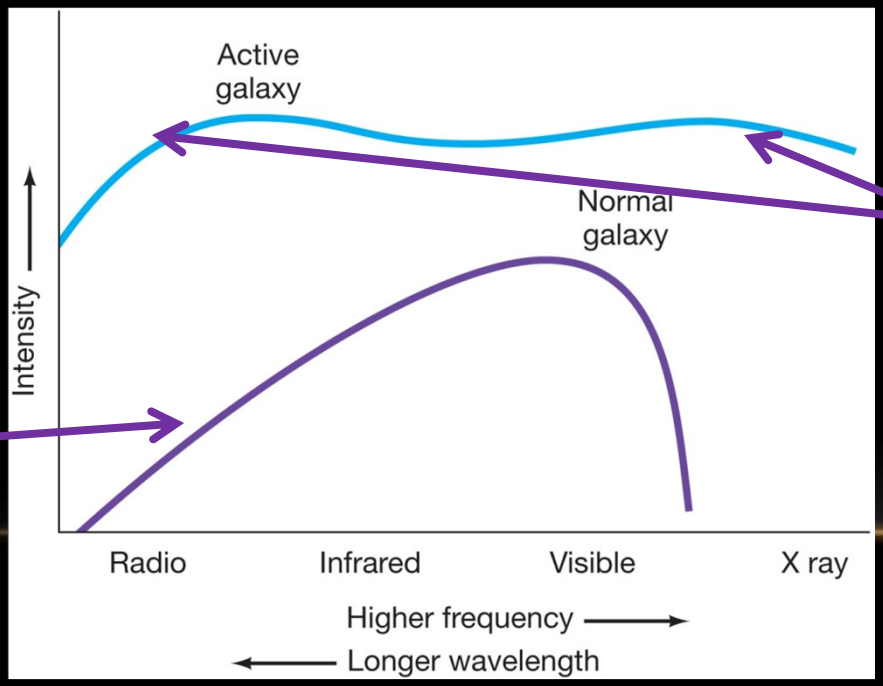
ACTIVE GALAXIES

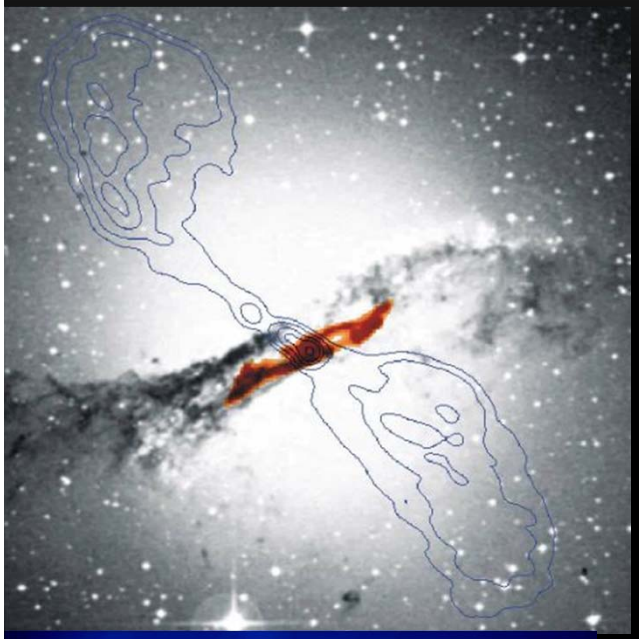
- About a quarter of galaxies are way more luminous than most
  - Also emit different wavelengths



Not Blackbodies; not stars

Mostly stars – Blackbodies

Cen A in visible, radio, and IR by I.F. Mirabel & O. Laurent



CENTAURUS A

- A nearby “Active Galaxy”
- A big elliptical
- Large radio-wave emitting jets
- Hot dust being gobbled up in the middle
  - X-rays
  - Supermassive black hole
  - Jets, accretion disk

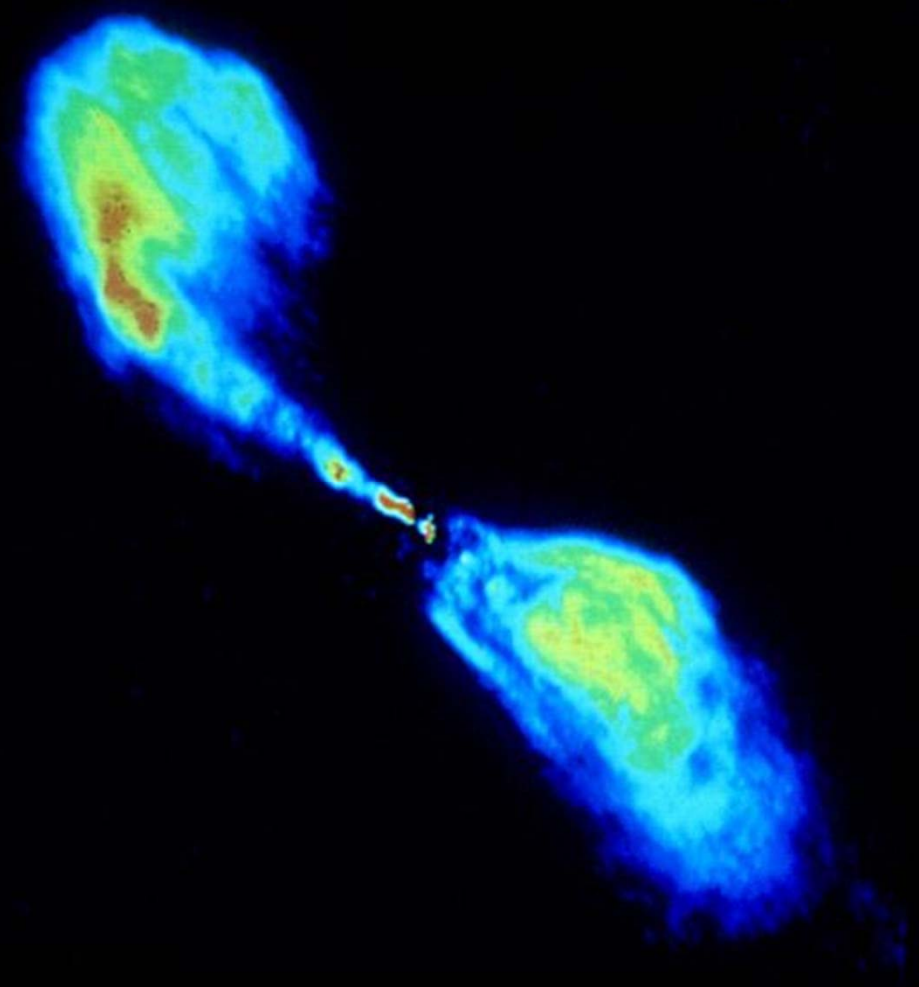
Core of Cen A in X-Rays
Chandra image by R.Kraft et al

CENTAURUS A

HST image by
E.J. Schreier *et al*

- Close-up of Cen A by HST in Visible
- Big dust lane

RADIO LOBES

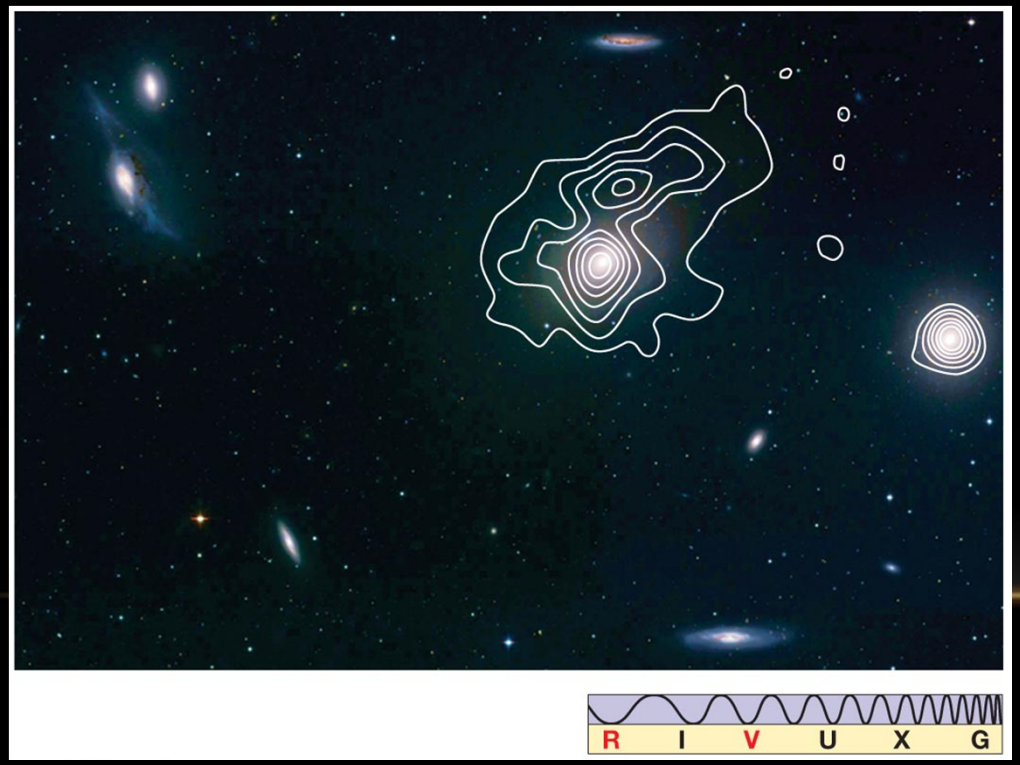


- Centaurus A's "radio lobes"
- Gas squirting out of core in jets crashes into intergalactic medium
- Emits radio waves
- Often many times larger than the galaxy itself

VLA Image by Burns & Price

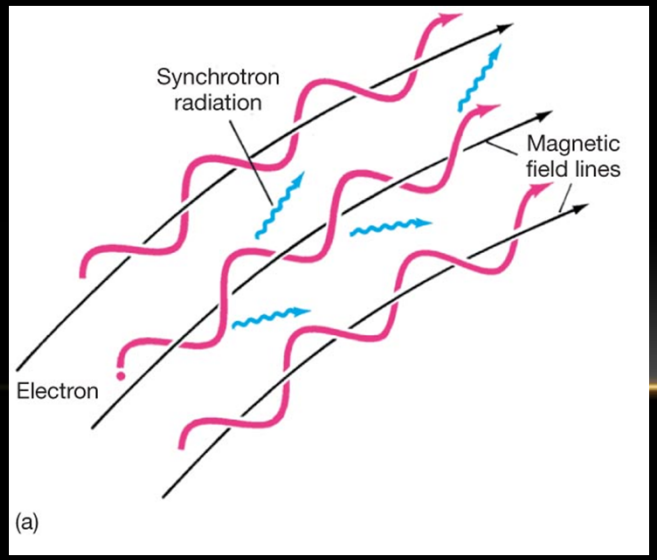
CORE-DOMINATED

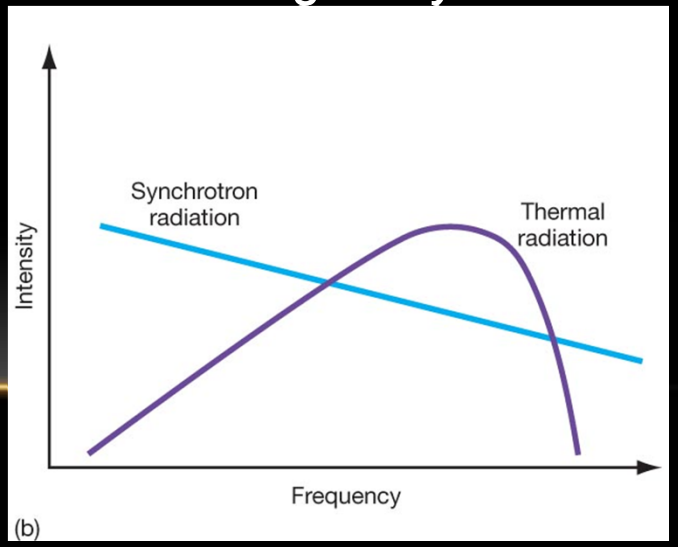
- Some galaxies are radio-loud
  - But no jets!



RADIO?

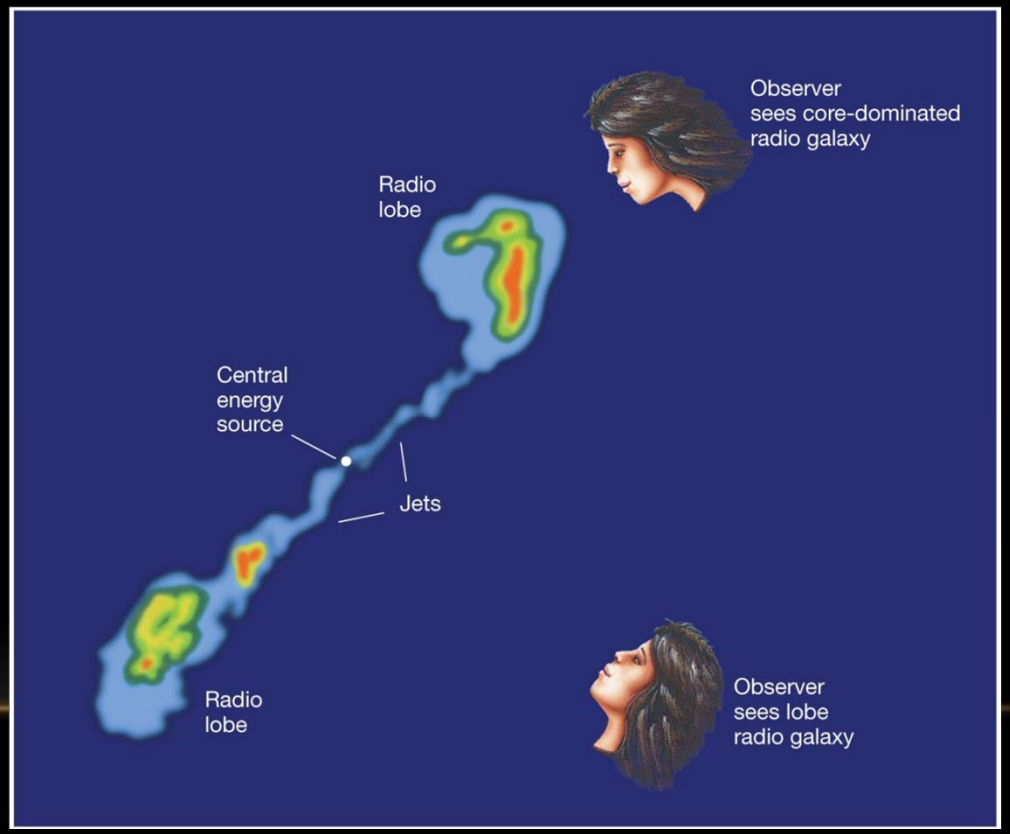
- The radio emission seems to come from "Synchrotron Emission"
  - Electrons moving in magnetic fields
  - This makes sense with jets
  - So what could a core-dominated radio galaxy be?





POINT OF VIEW!

- Which way are we looking at the galaxy?



OTHER ACTIVE GALAXIES

- Many “Radio Galaxies” have evidence of such jets
  - Very bright things in radio telescopes
  - Millions of times more than the actual galaxy itself
- “Seyfert Galaxies”
  - Very luminous nucleus, can be radio-loud
- Quasars, Blazars
  - “Quasi Stellar Object” (QSO)

SEYFERT GALAXIES

- Not too distant spiral galaxies
- Bright, variable nucleus
  - Core is thousands of times brighter than normal galaxies
- Have emission lines
  - again, not a Blackbody
- Sometimes are radio loud

A CLUE AS TO WHAT'S GOING ON

- They are variable
  - And change rapidly
  - So the bright bit must be pretty small

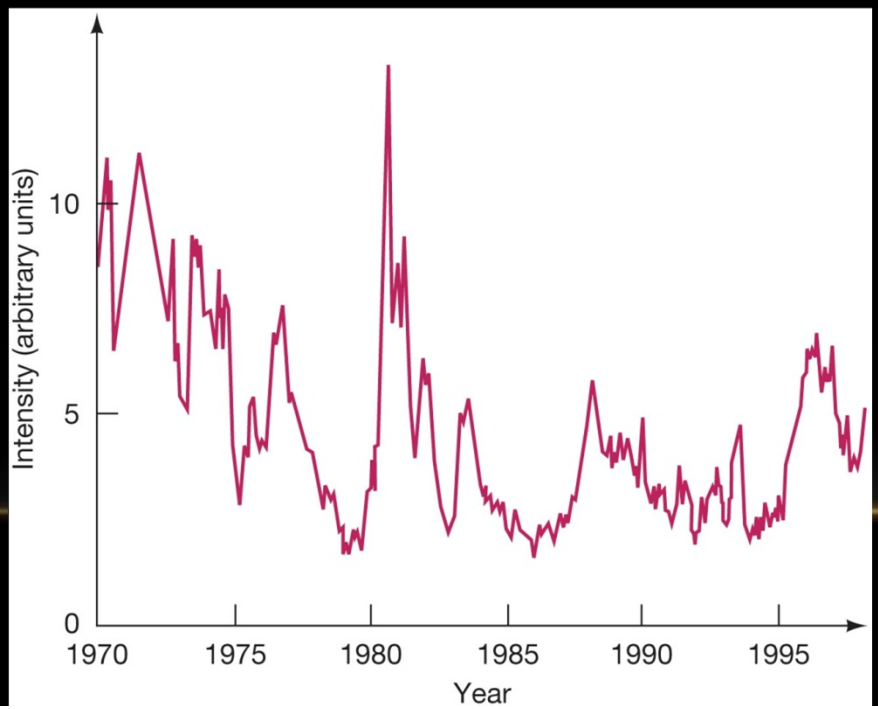
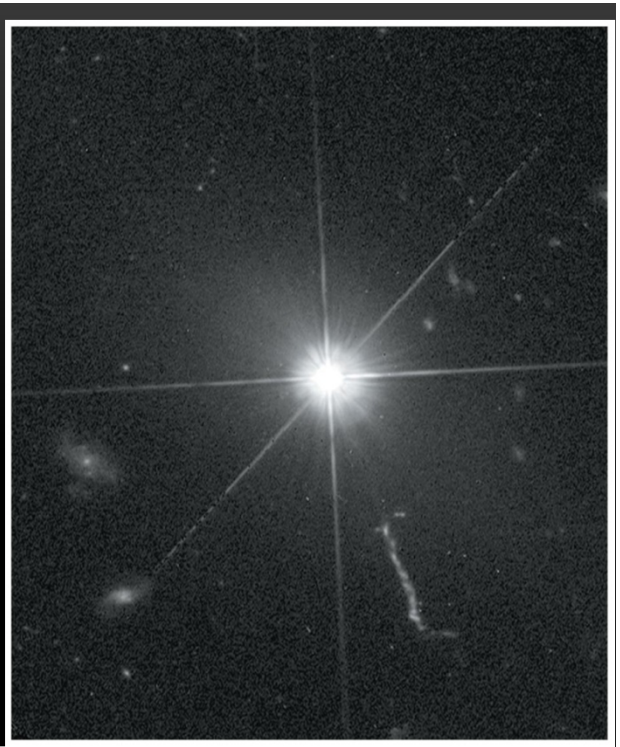
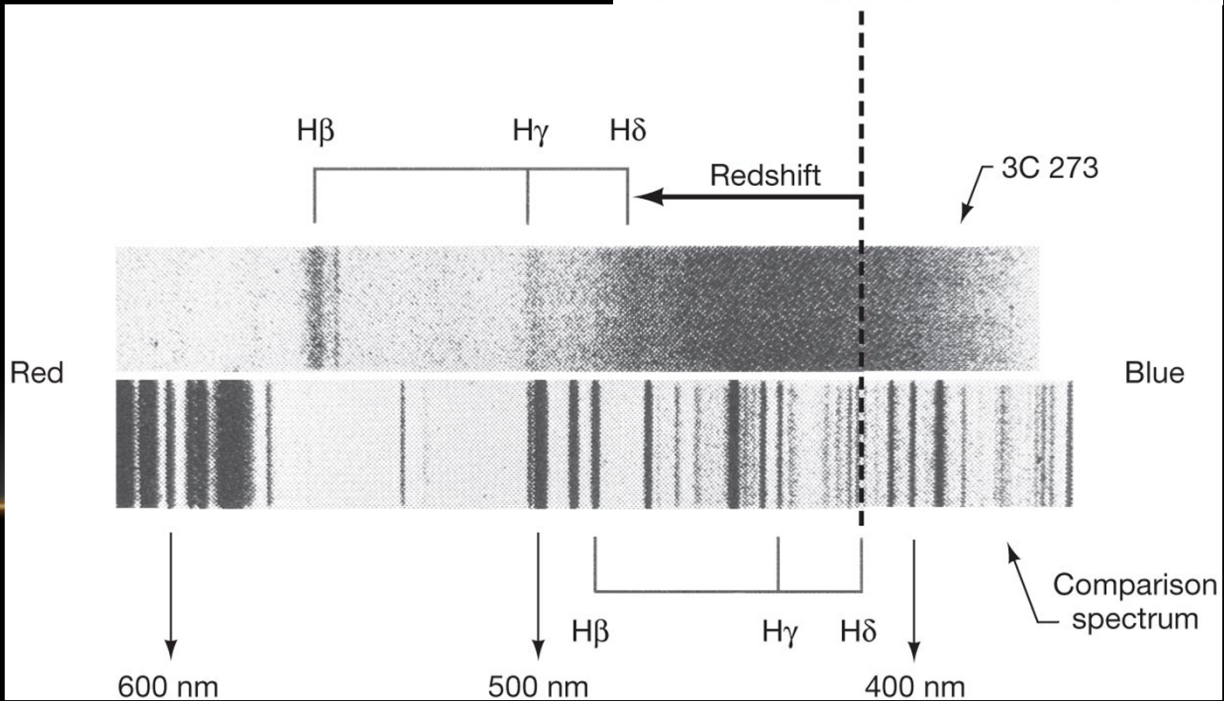


Fig.16.32

QUASARS

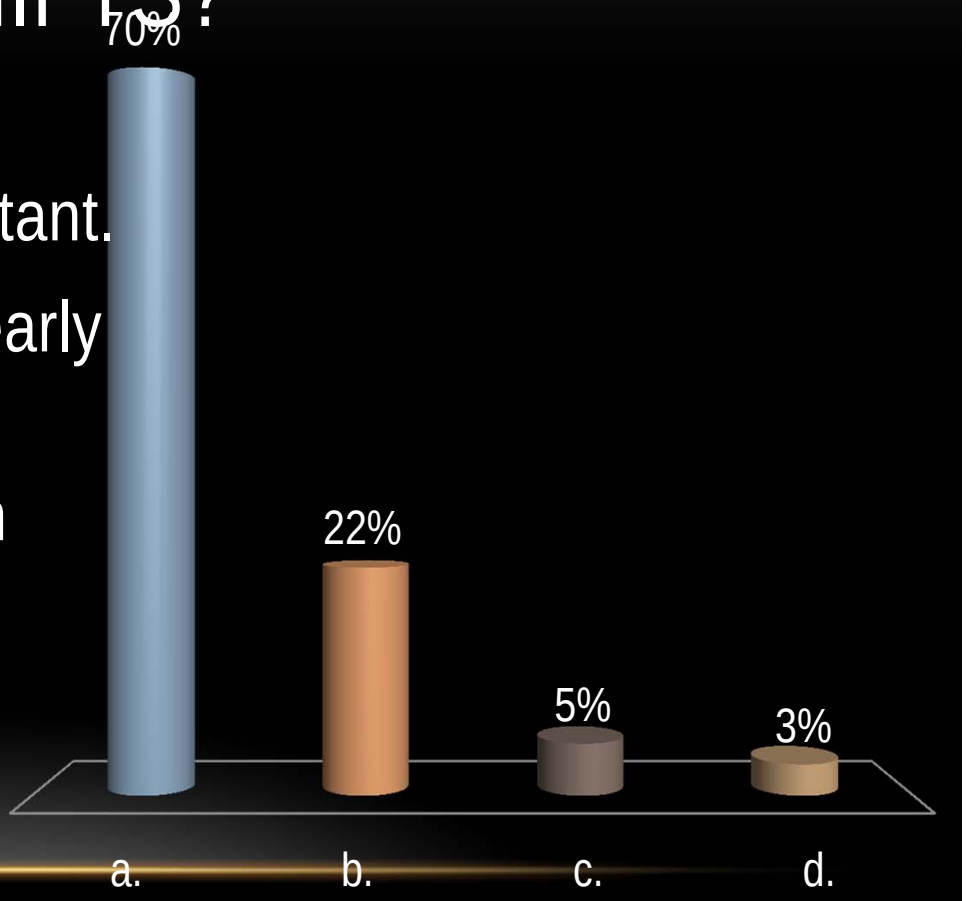
- First seen as star-like (point) objects
  - Very large redshifts
  - Some are radio loud, with lobes
  - Have emission lines, like Seyferts
    - But really weird spectra!





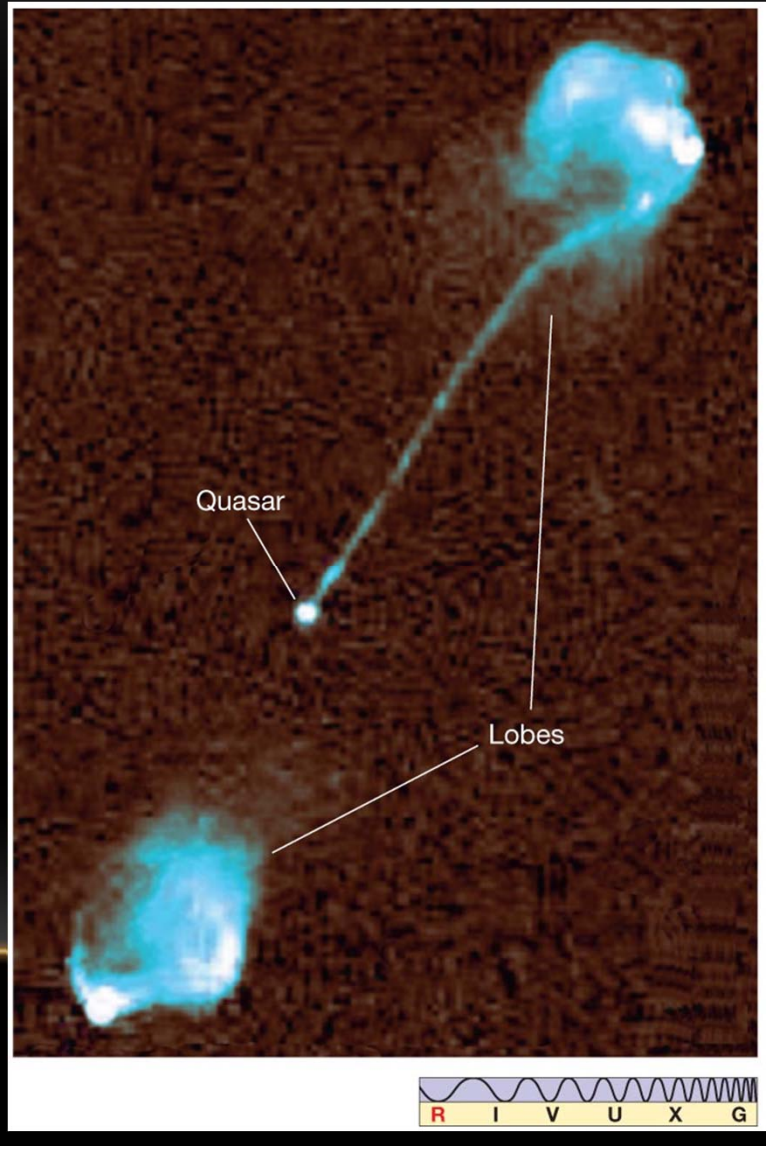
WHAT CAN YOU CONCLUDE FROM THE FACT THAT QUASARS USUALLY HAVE VERY LARGE REDSHIFTS?

- ✔ a. They are generally very distant.
- ✔ b. They were more common early in time.
- ✔ c. Galaxy collisions might turn them on.
- ✔ d. Nearby galaxies might hold dead quasars.

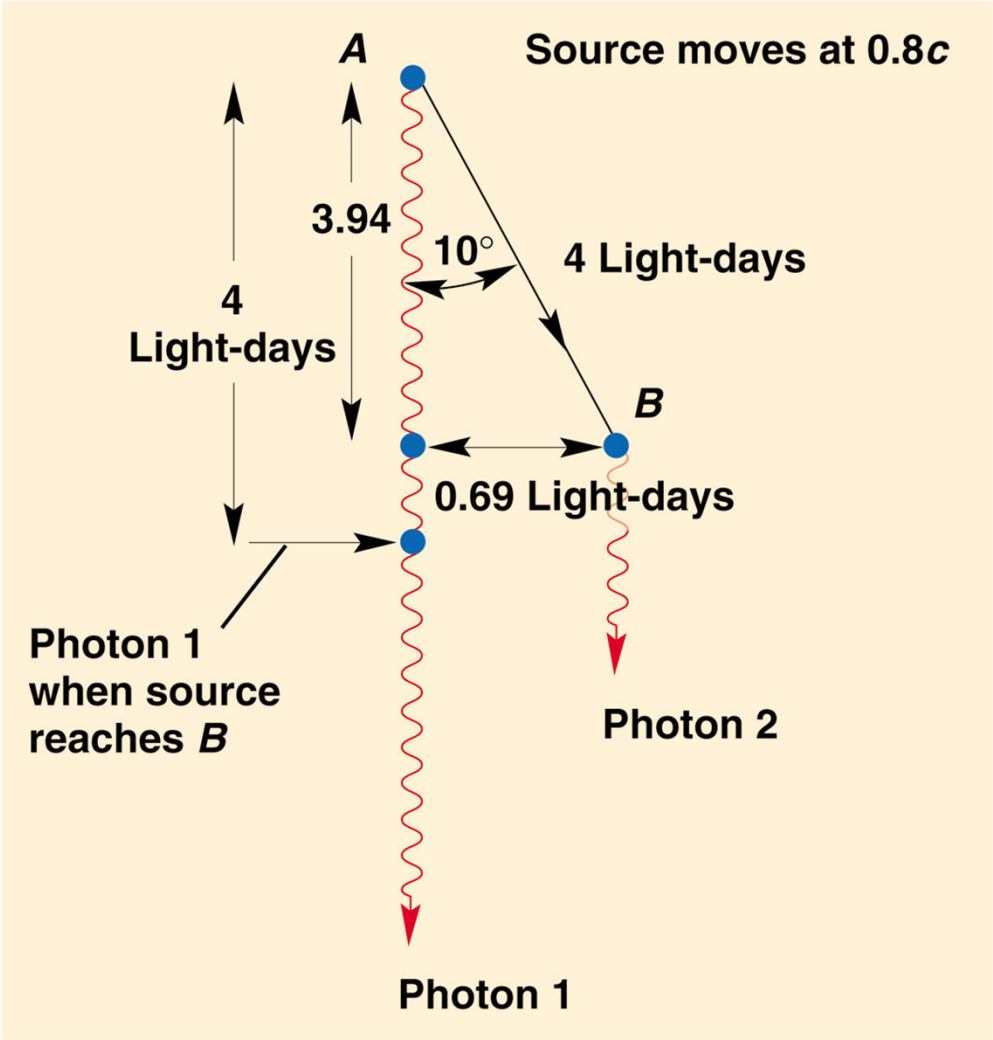


SO FLYING AWAY REALLY FAST

- From Hubble's law, they must be very far away
  - But very bright, considering
- Variable brightness on the order of hours or days
  - So the bright thing must be fairly small (solar-system sized) to change that rapidly
- Very bright, very small?
  - And also have jets



SUPERLUMINAL MOTION



- We see proper motion of some radio lobes which is apparently greater than the speed of light!
- But it is just a trick of projection – since things are moving at nearly the speed of light at an angle towards us

LOCAL QUASARS?

- Could they be close by, in our galaxy's halo?
  - Then they wouldn't need to be so bright
  - Could be moving really fast, make large redshifts not associated with Hubble Law
- Problems
  - We see no blueshifted Quasars
  - We do not see them in other galaxies

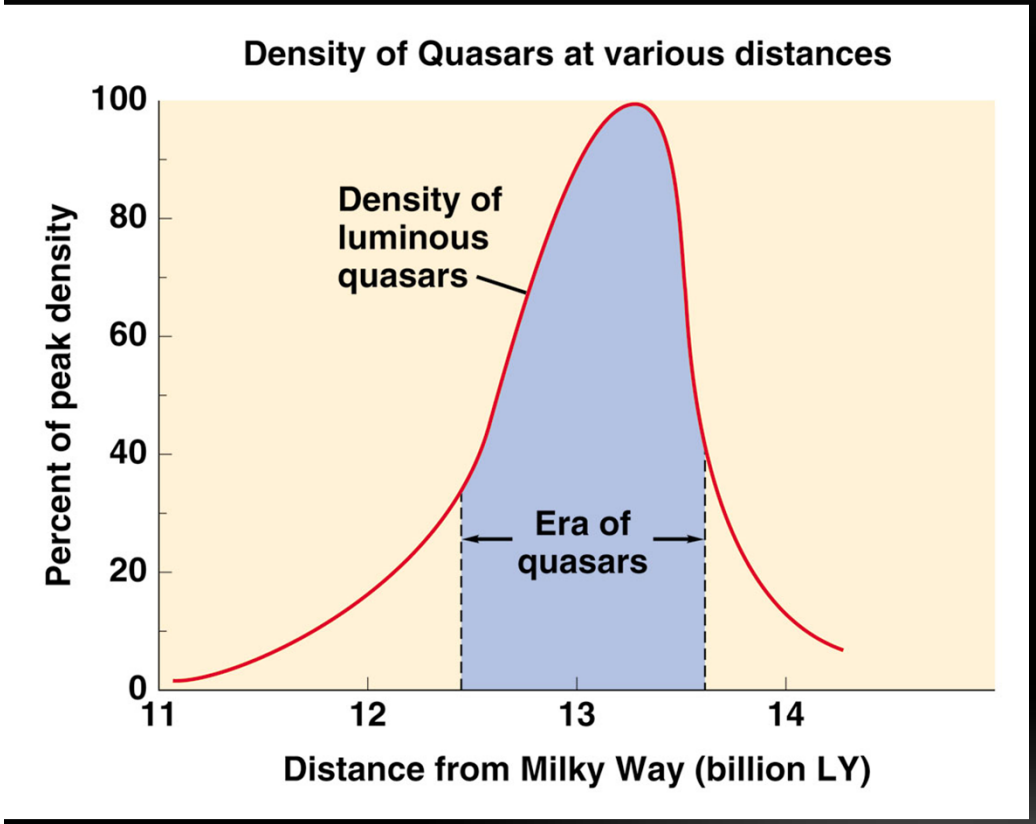
BLAZARS

- Star-like, luminous
  - Like Quasar
- Large redshifts
- Very variable, very rapidly
- Some radio emission around bright core
- Often have "*Superluminal Motion*"
  - Also seen with radio-lobed quasars

AGNS

- AGN = Active Galactic Nuclei
- Something is going on in the middle of Radio & Seyfert galaxies, and quasars
  - Something very energetic
  - In a very small space
  - Squirts out jets
  - High energy radiation also seen

ALL FAR AWAY AND LONG AGO

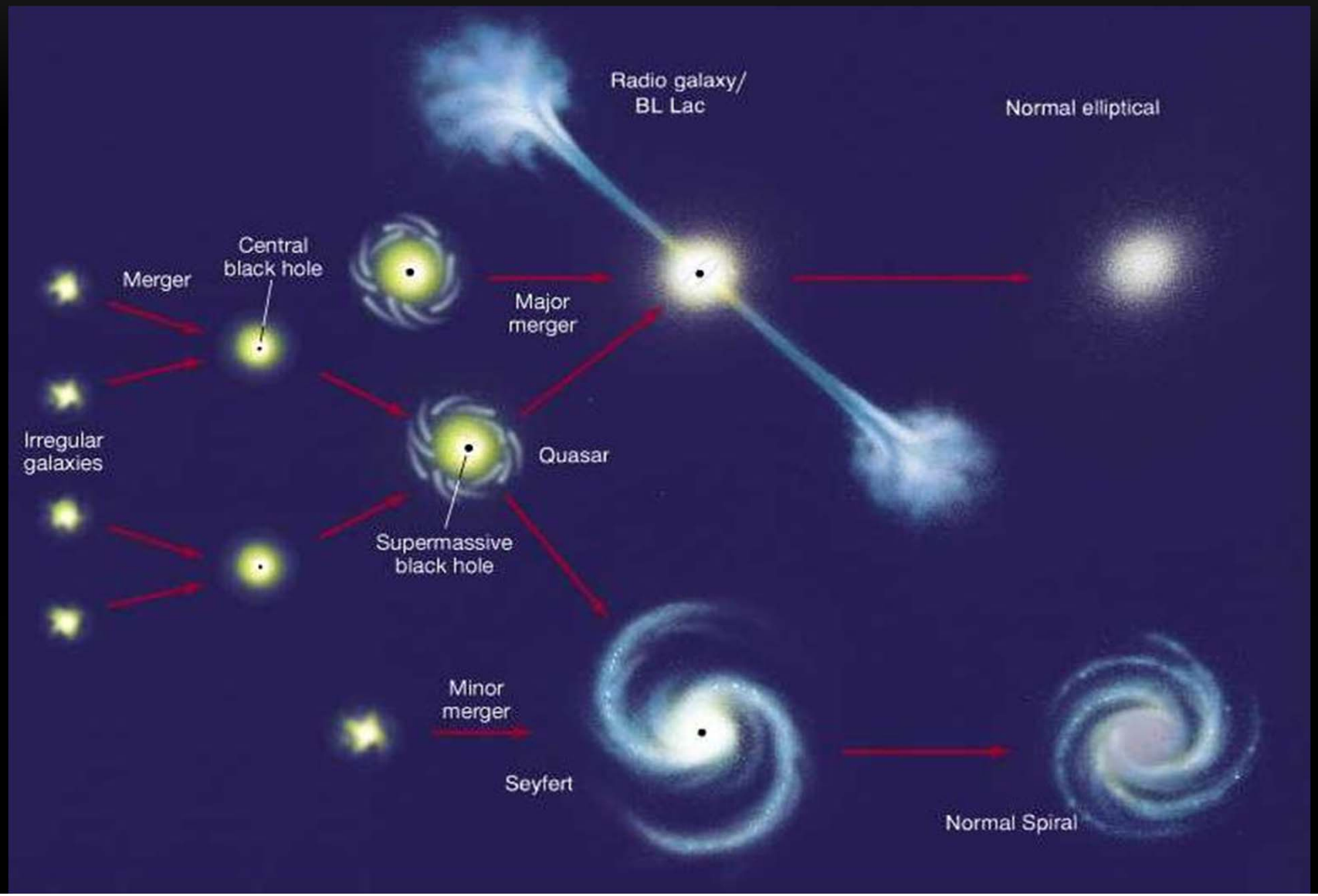


- No quasars are observed near by
- So they all stopped being quasars long ago
- Seyfert Galaxies similar but closer – like run-down versions of quasars

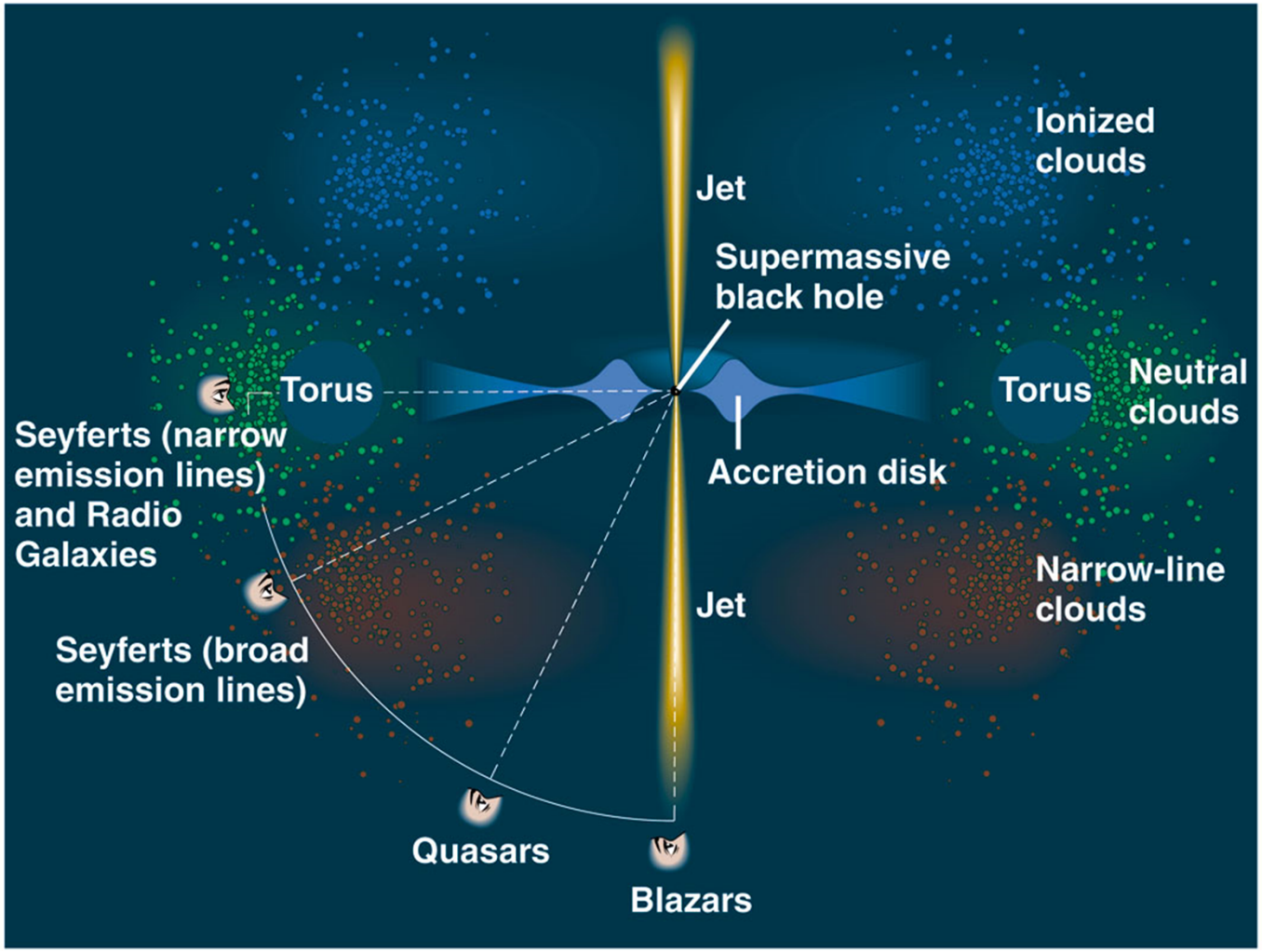
SUPER-MASSIVE BLACK HOLES?

- Many million mass black holes eating up gas and dust at the centers of galaxies could power AGNs
- Would have swept up available fuel long ago – “the quasar era”
- Less stuff to consume is handy these days
  - Radio, Seyfert galaxies

GALACTIC EVOLUTION

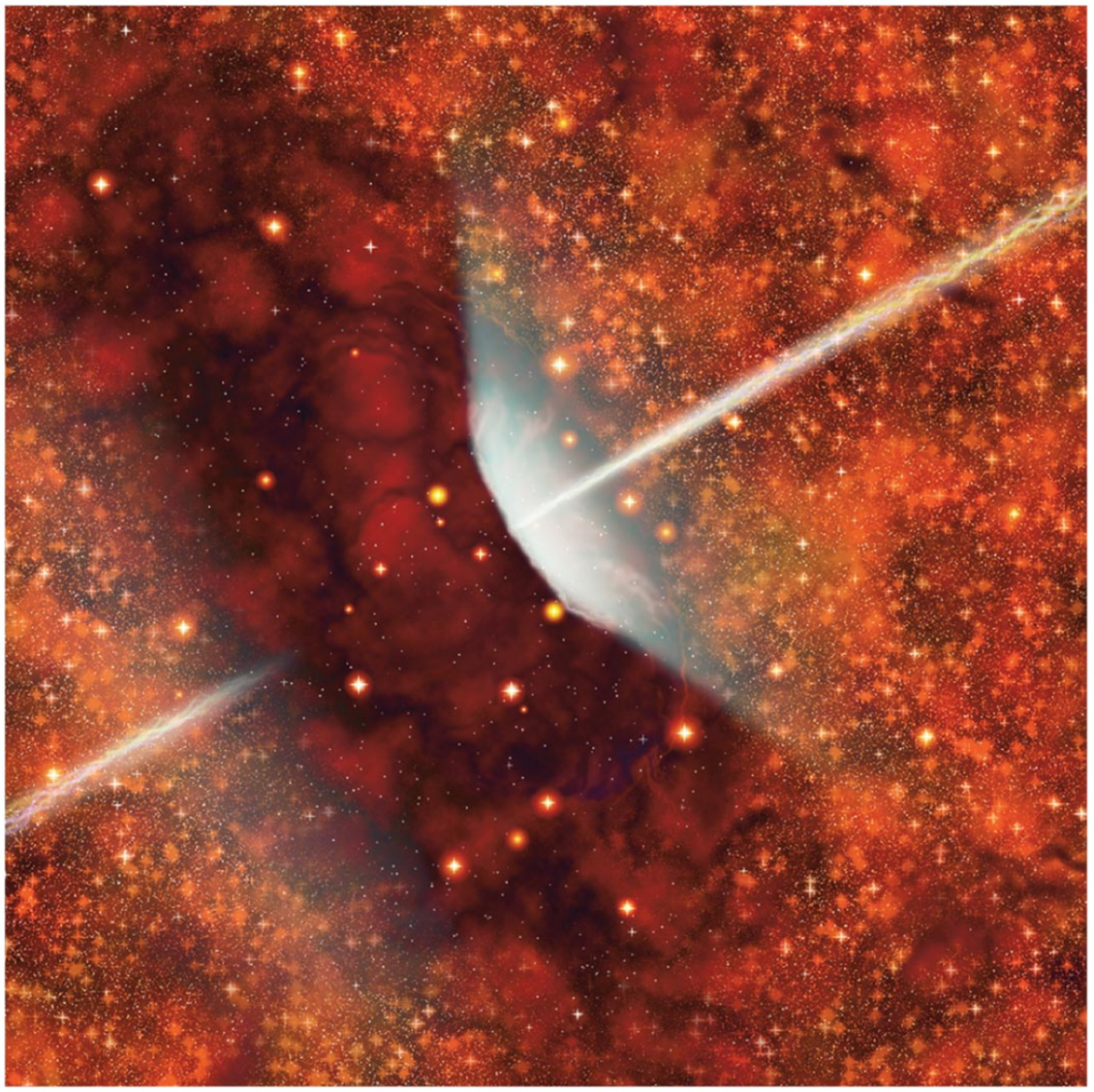


MANY WAYS TO LOOK AT THE SAME THING

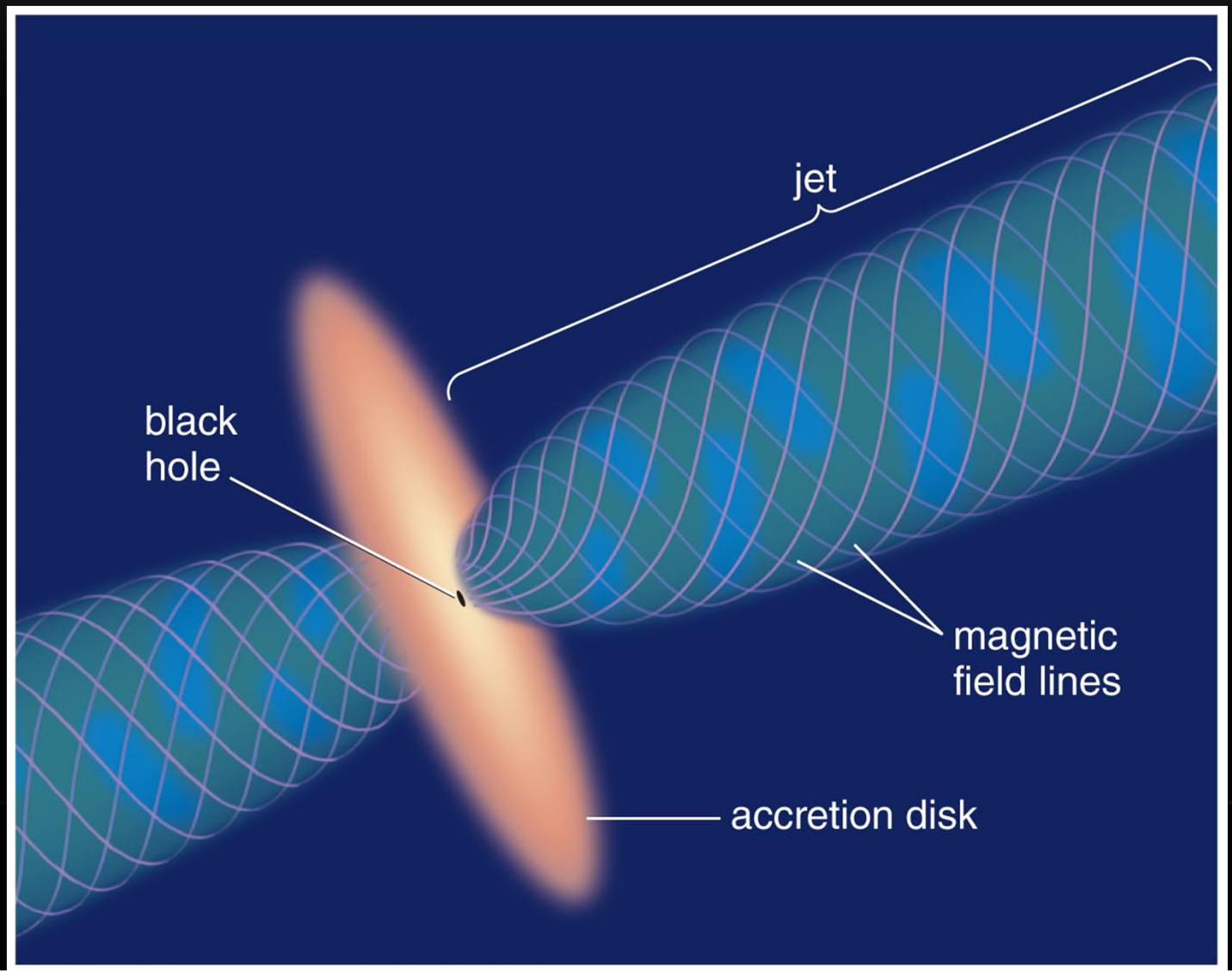


PERSPECTIVE

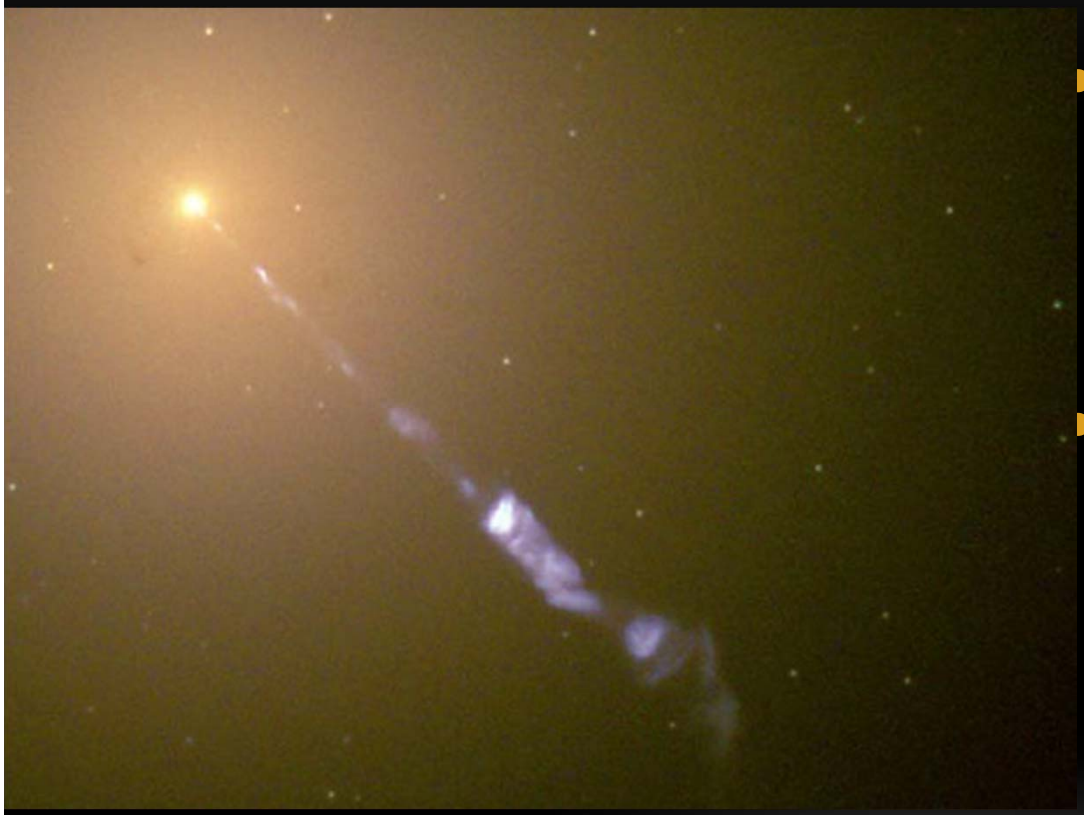
- If we're looking at one of these edge-on, gas and dust clouds block our view of the hot accretion disk in the middle
  - All we see are the jets, call it a Radio Galaxy



BLACK HOLES AND JETS?



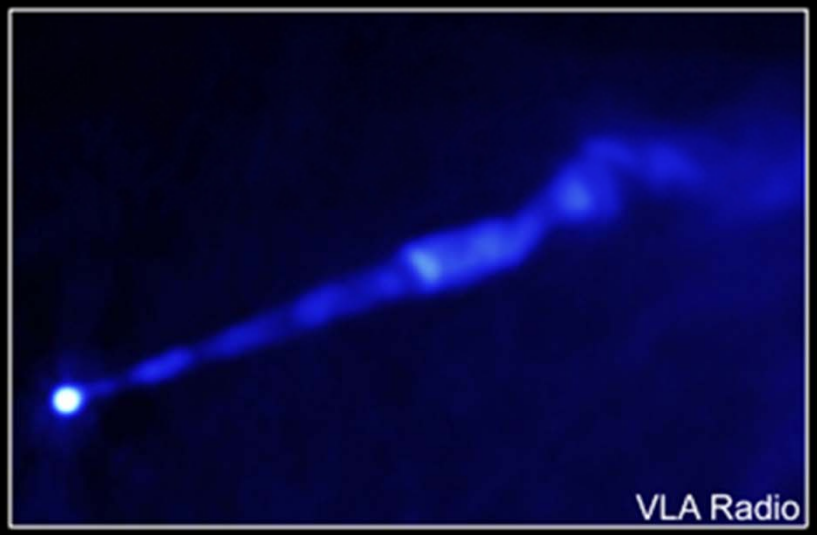
M87 AGAIN

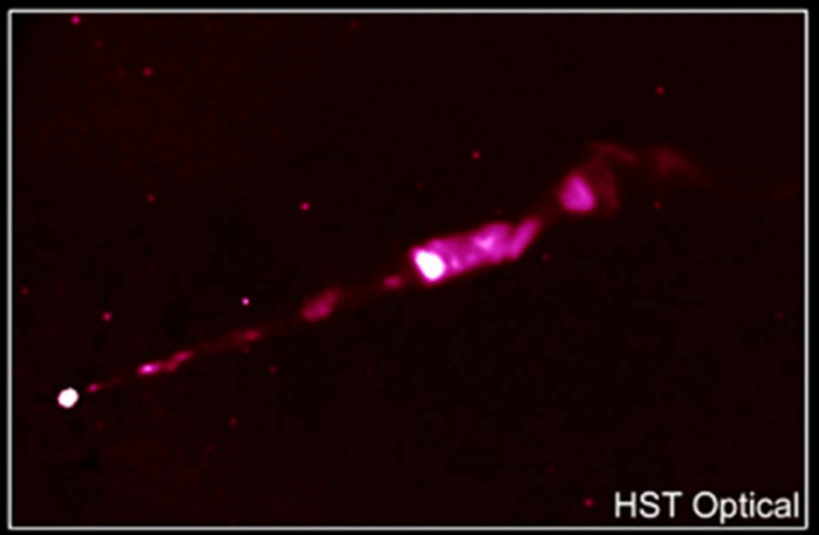


- That huge elliptical at the middle of the Virgo Cluster
- Has a jet coming from the middle of the core

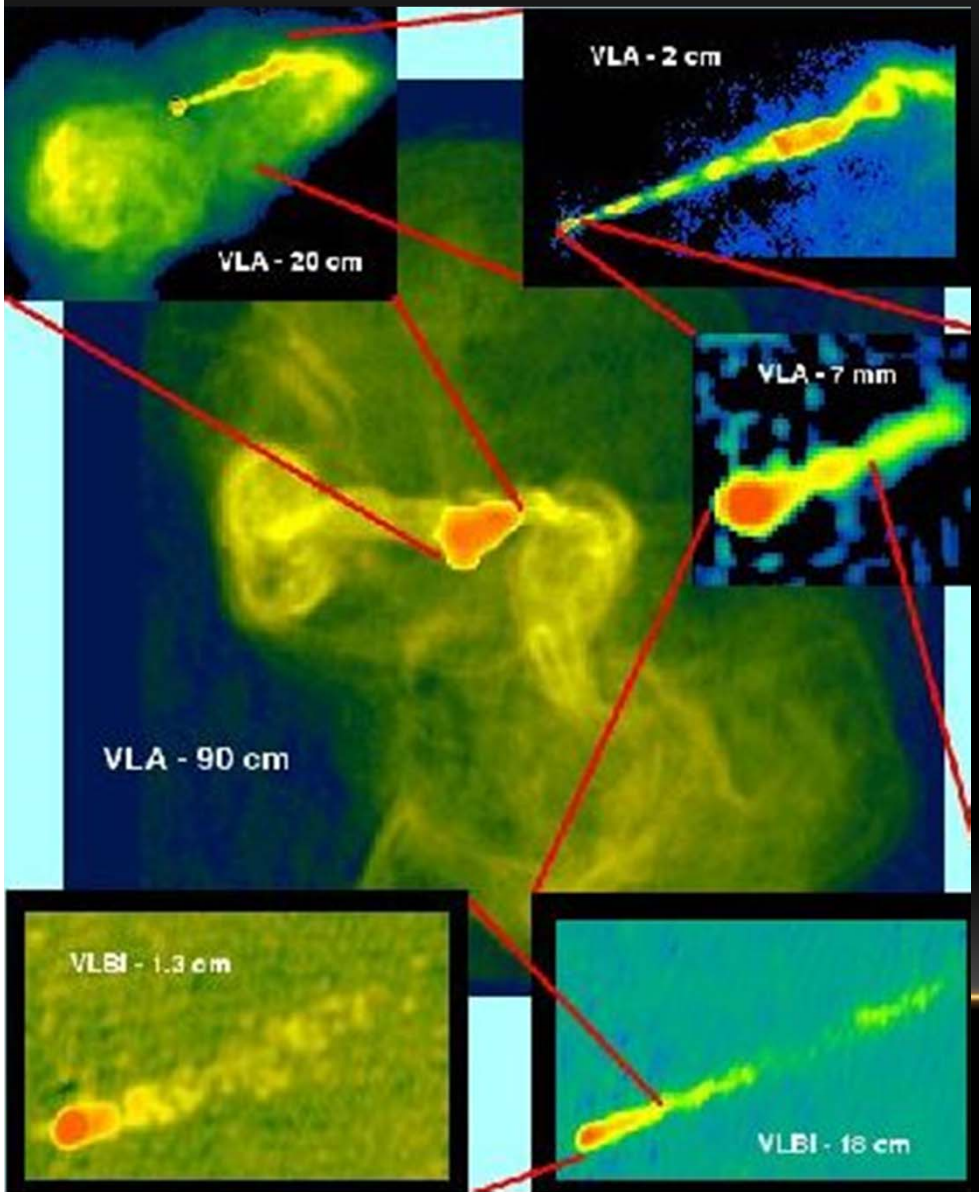
HST Image by
J.A. Biretta *et al*

M87 AT VARIOUS ENERGIES





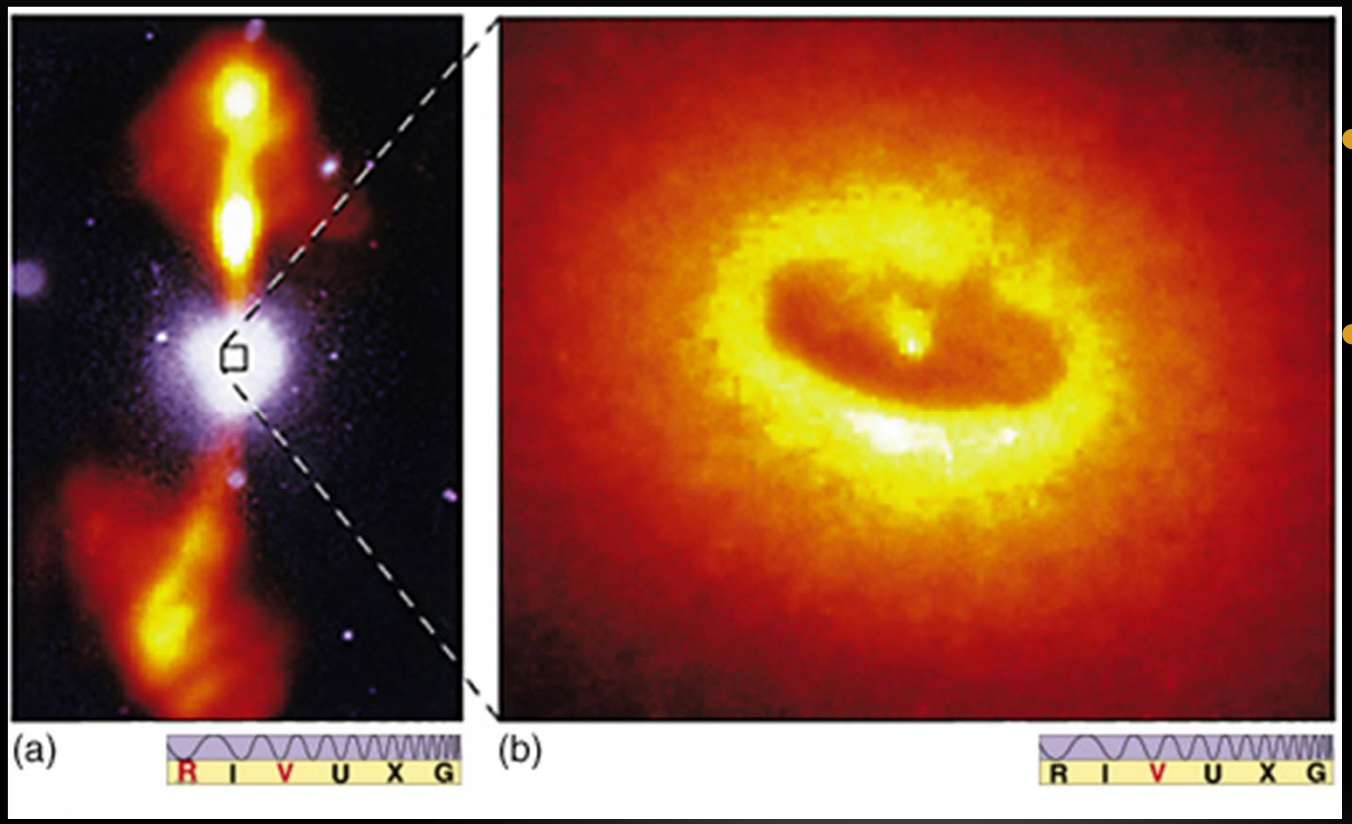
M87 IN DETAIL



- Using huge radio telescope conglomerations to get good detail, the jet can be zoomed in on
- High orbital speeds near the core indicate a super-massive black hole

VLA Radio Image by
F.N. Owen *et al*

RIGHT IN THE MIDDLE



- In M87, we see the disk
- Picture is of inner 100 pc
- Bright spot in middle – the final plunge into a black hole?

ORBITS AGAIN

- Take doppler shift measurements of the inner 60 ly of M87
- That stuff is going around fast in a small chunk of space
- Need millions of solar masses of stuff to make enough gravity to do that
  - A big Black Hole (even bigger than the one in the Milky Way)

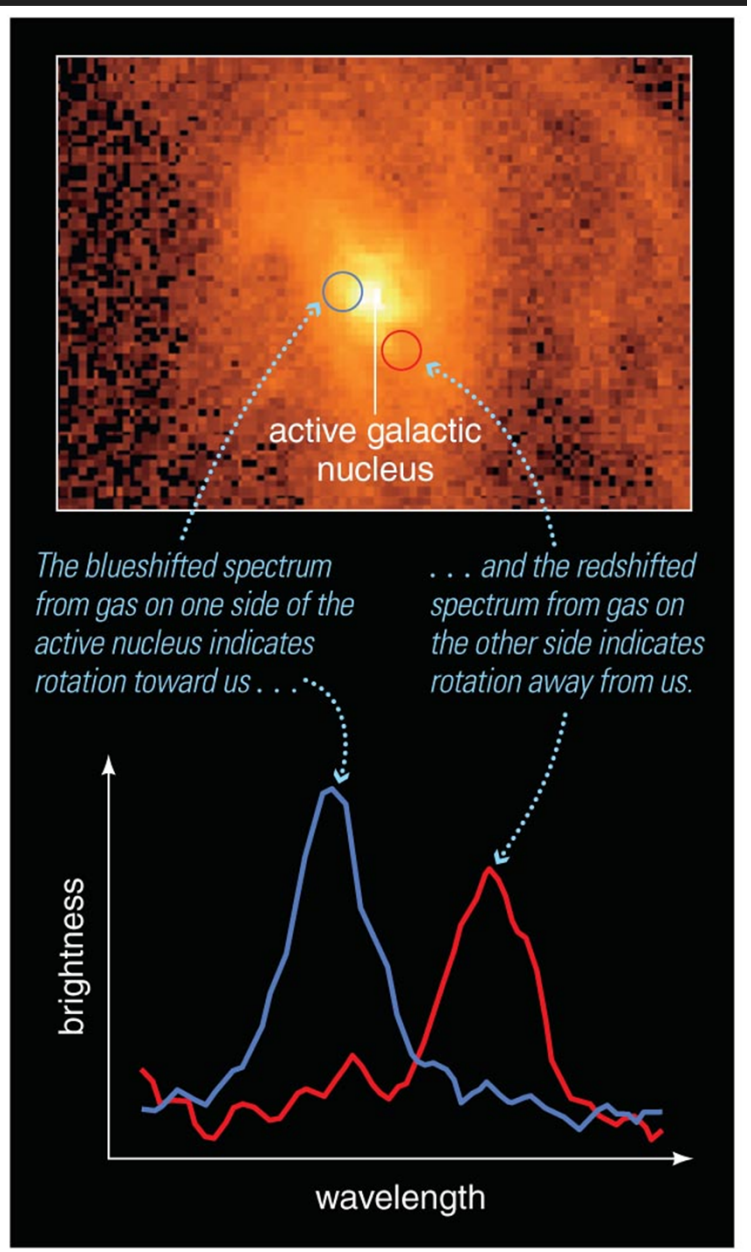


Fig.16.34

QUASARS CLOSE-UP

HST Images by
John Bahcall & Mike Disney

- Close ups confirm quasars as very-active AGNs
- Some are even seen being fueled by galaxy collisions
- Today, would they look like Cen A or M87?
  - Large ellipticals with active cores