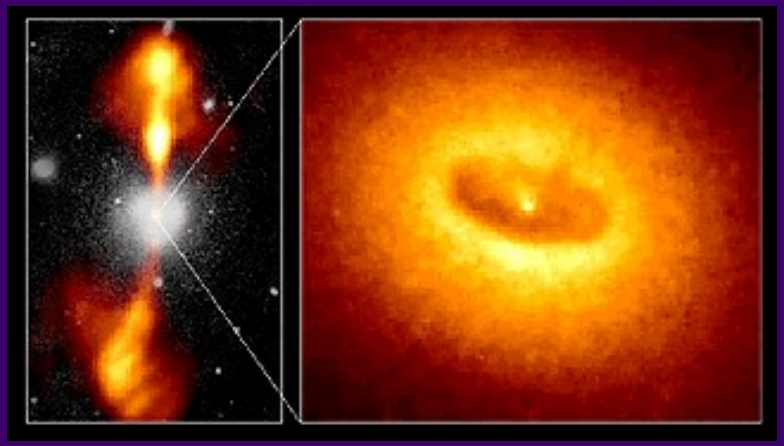
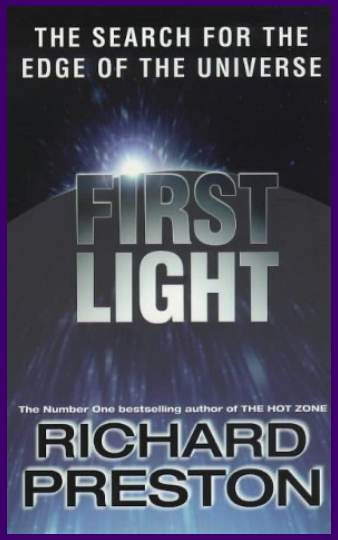


Quasars and Active Galaxies

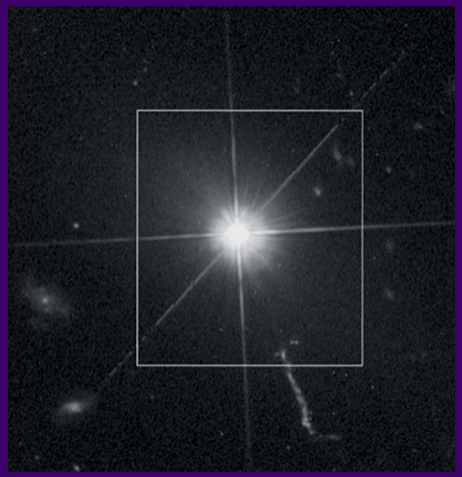
Today:

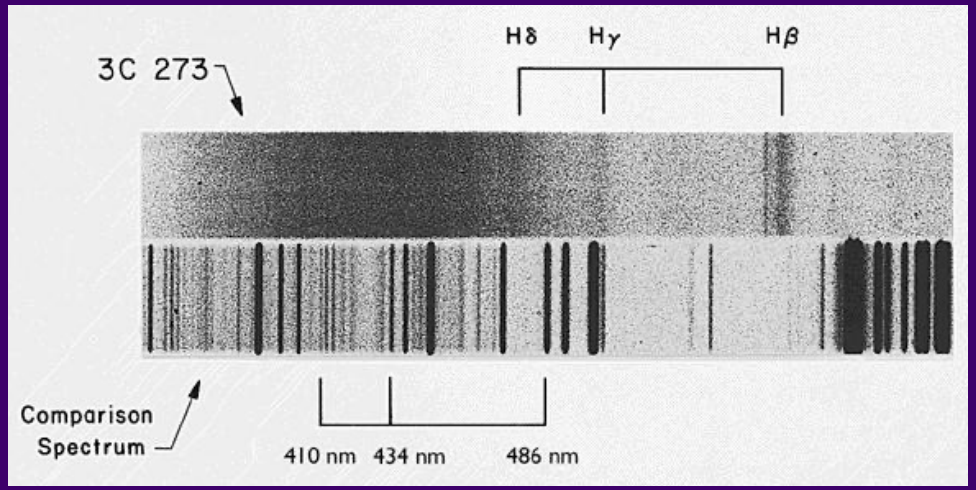
- The discovery of quasars
- What are quasars?
- Alternative cosmologies

Quasars: Quasi-stellar radio sources



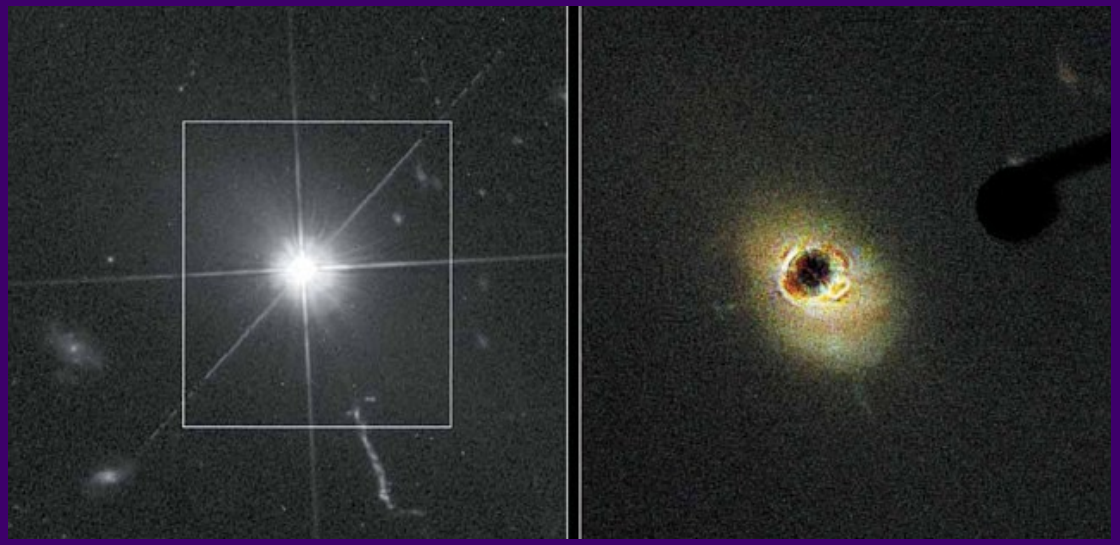
Quasars: Quasi-stellar radio sources



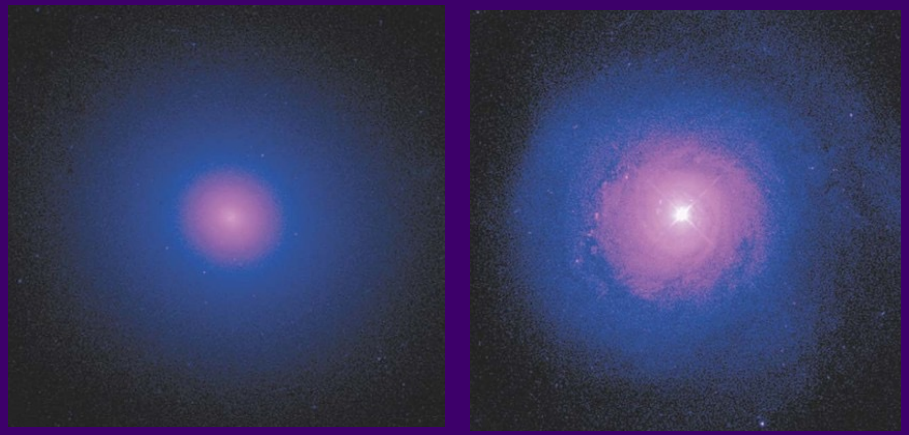


Quasars become famous!

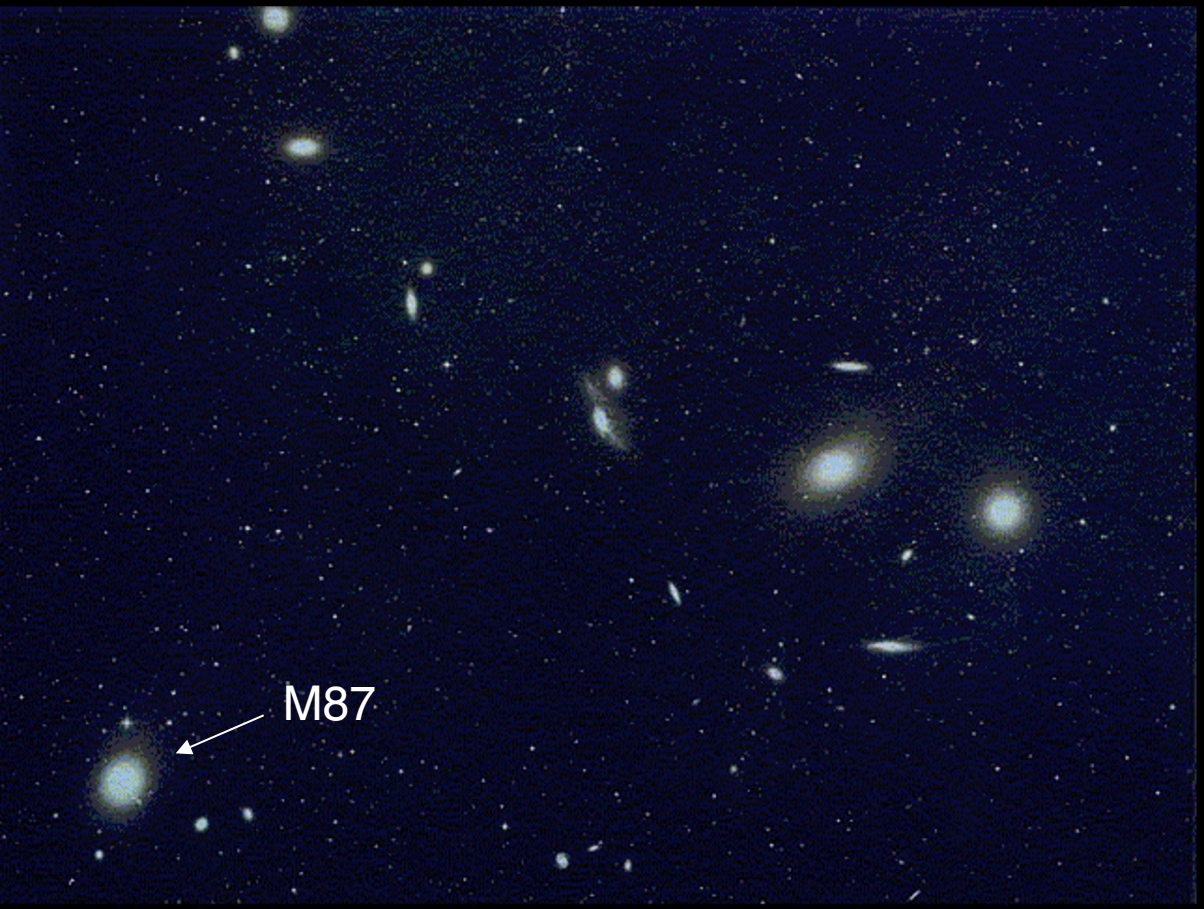
Quasars live(d) at centers of galaxies



3C 273 and
host galaxy

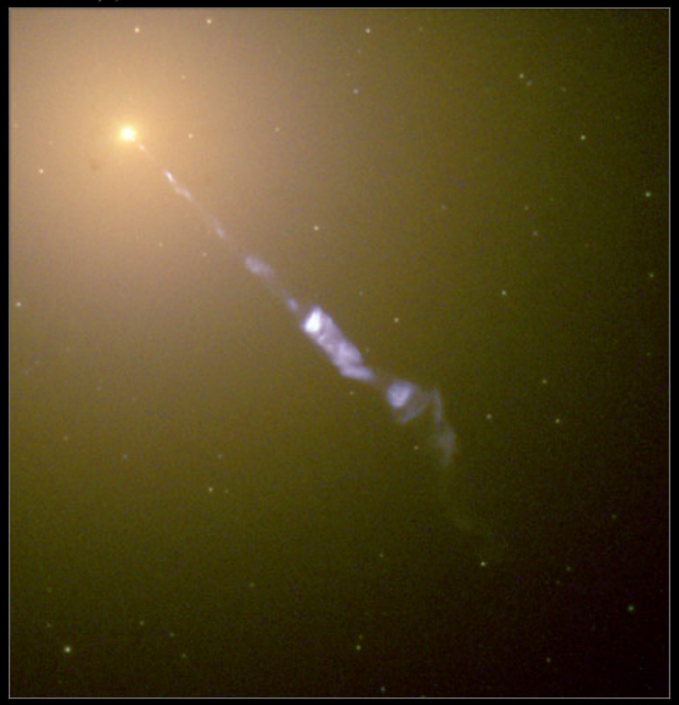


Normal galaxy and
“active” galaxy
(false color)



M84, M86, M87 © Royal Observatory Edinburgh/Anglo-Australian Observatory
Photograph from UK Schmidt plates by David Malin

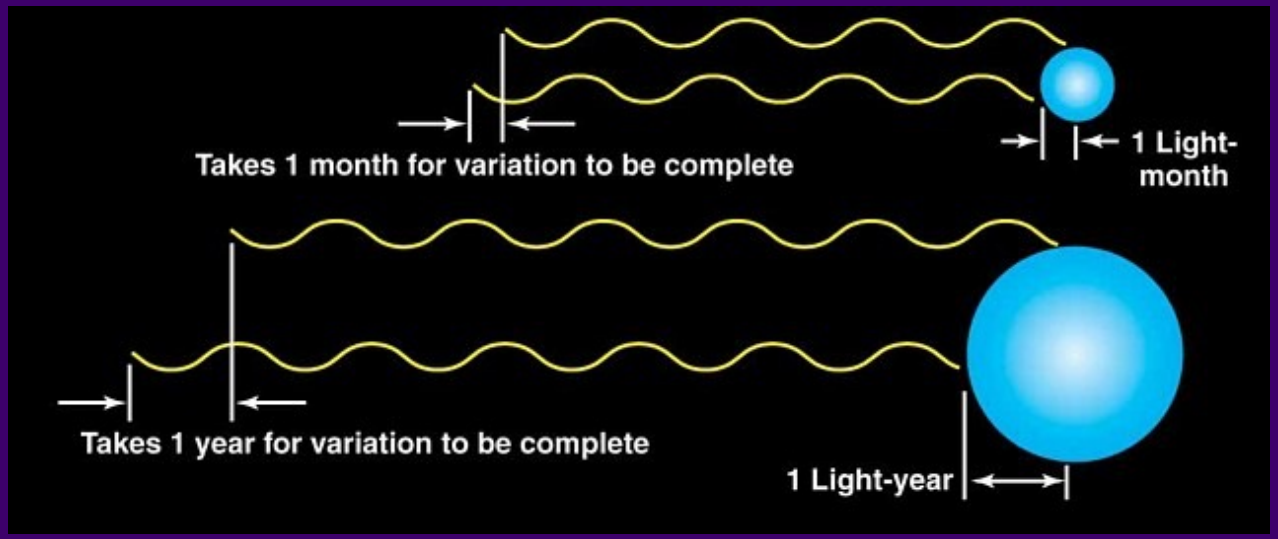
The M87 Jet



Hubble Heritage

Clues to the nature of quasars

- A quasar can be up to 1000 times brighter than its host galaxy.
- Though quasars are rare today, they were relatively common in the past (several billion years ago).
- Statistics indicate that quasars must shine for hundreds of millions of years.
- Quasars vary in brightness over time periods as short as weeks; this implies that they are quite small.



Where could all this energy come from?

Motion (“kinetic”)

Gravitational

Elastic

Thermal

Chemical

Nuclear

Electrical

Radiant (light)

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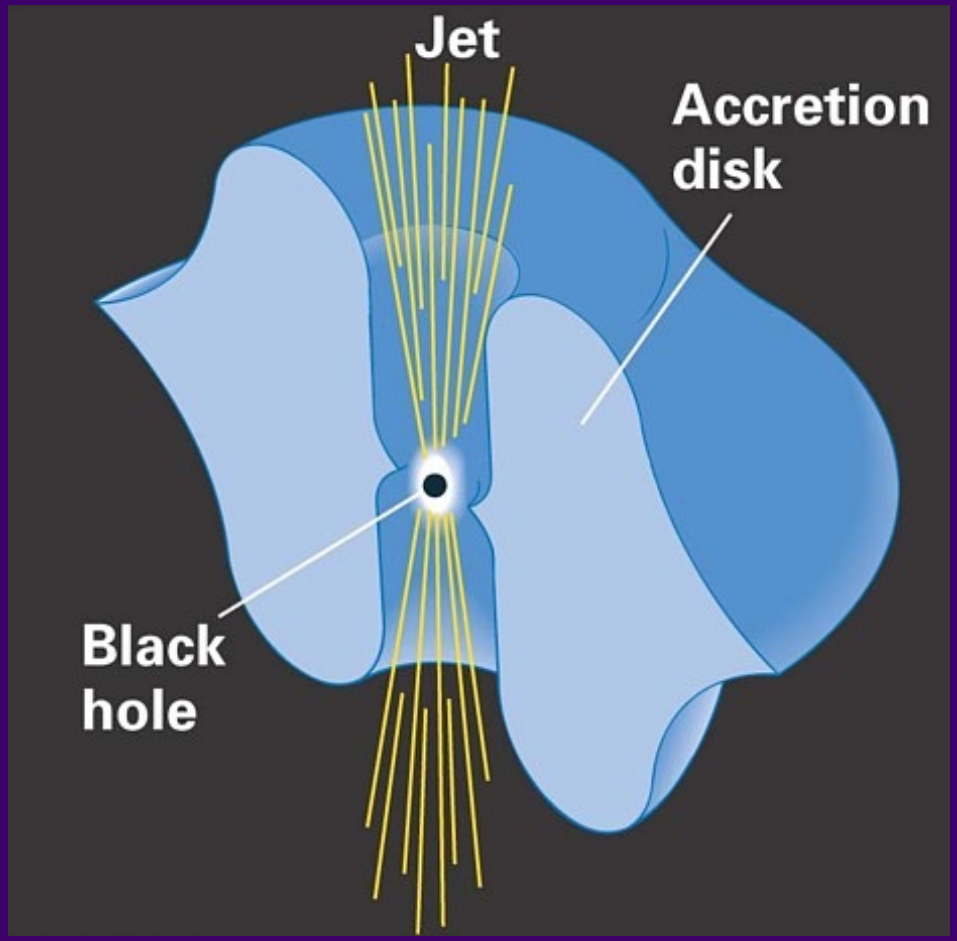
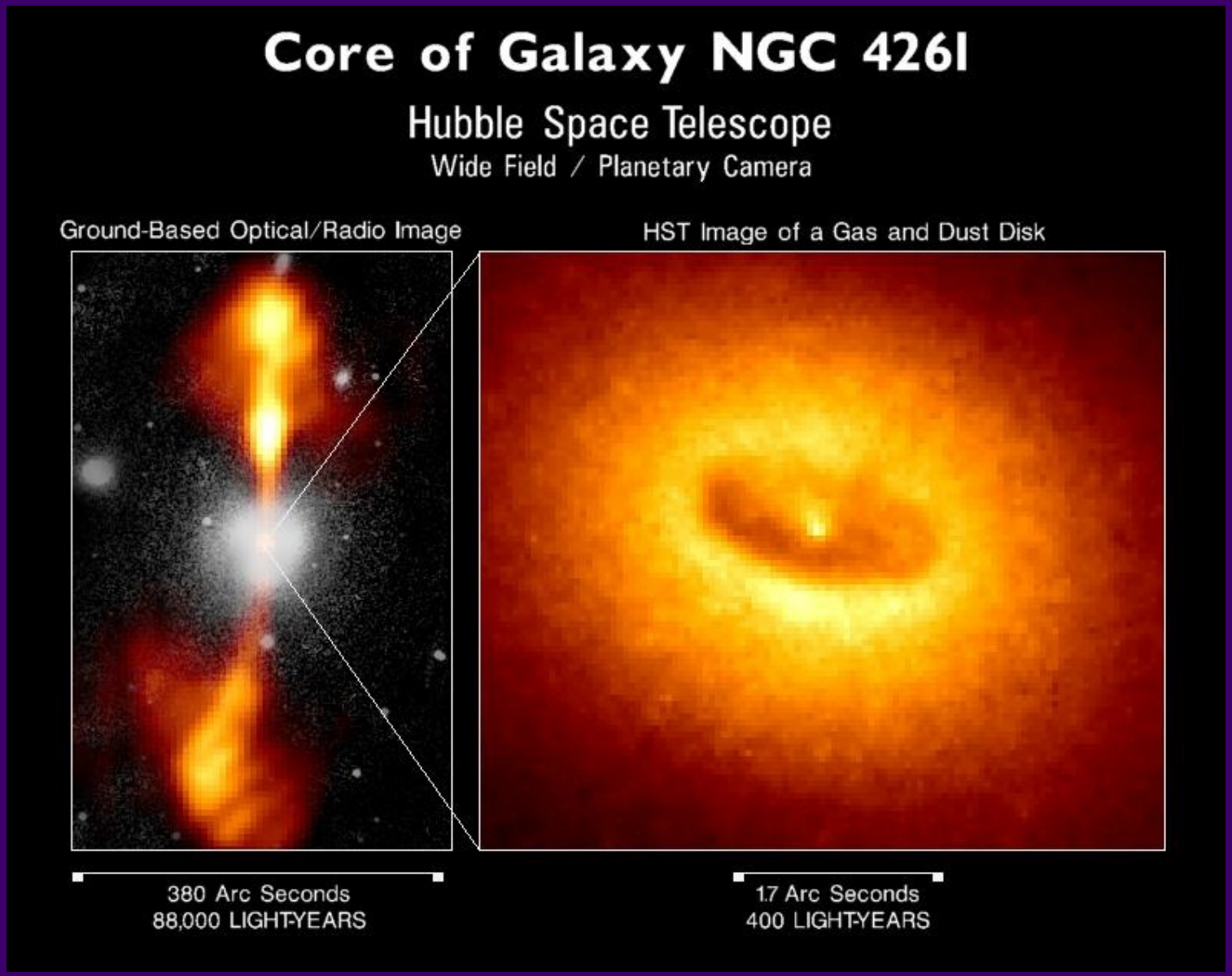
Theoretical Model of a Quasar

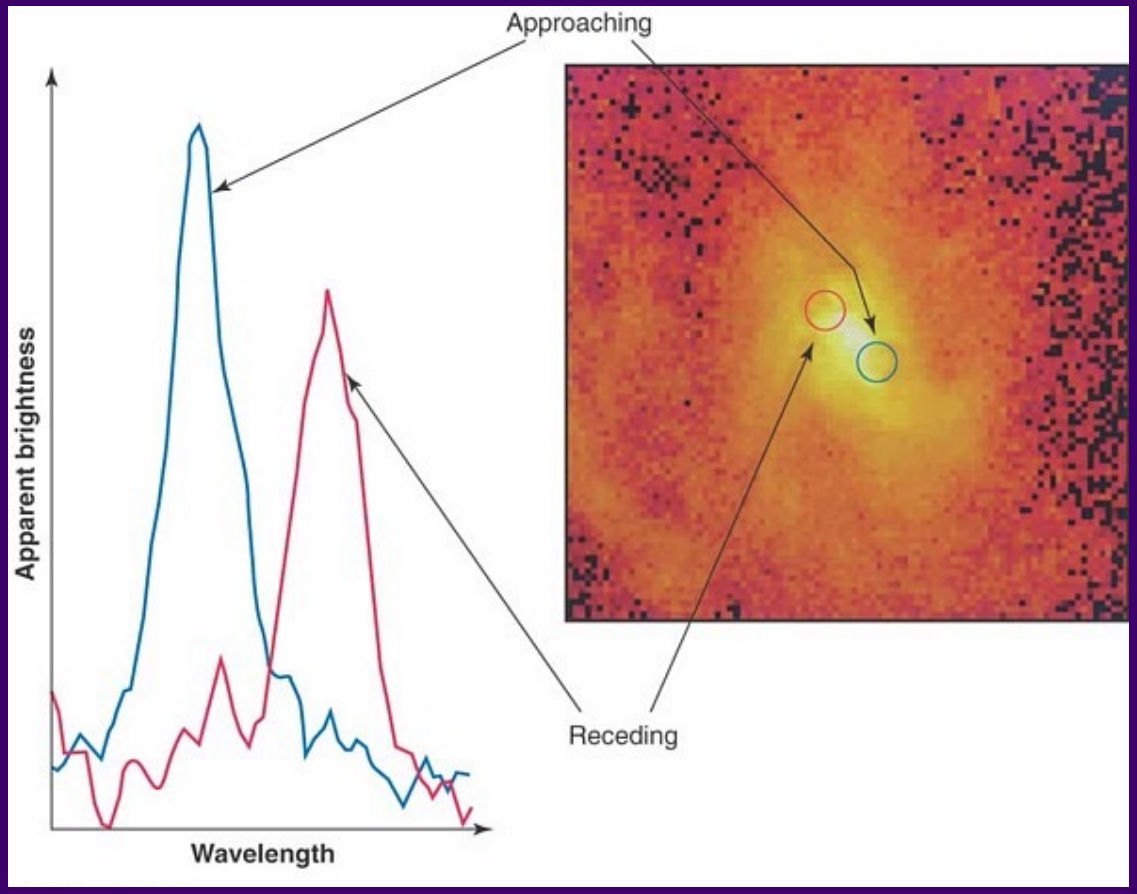


Matter falls toward a black hole, gathers into a spinning disk of hot gas, converting gravitational energy to thermal energy. Just outside the horizon, pressures are so high that some material is forced out into a jet at near light speed.

Testing the Theory



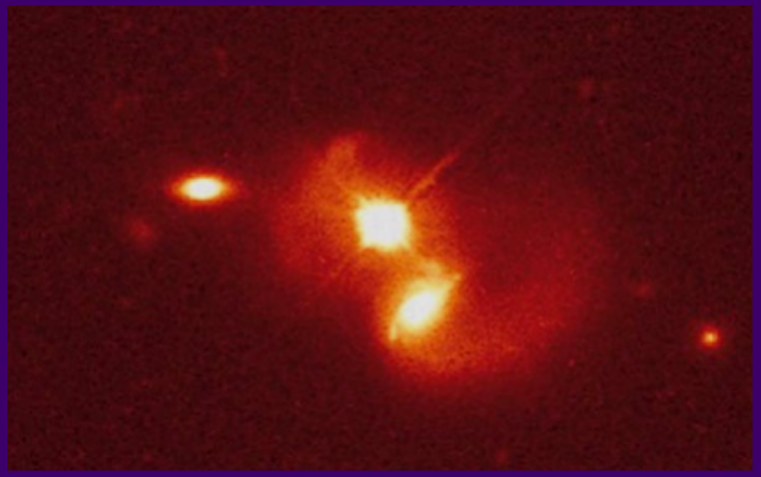
Testing the Theory



Stars near centers of all large galaxies (including our own) are orbiting VERY fast. Central masses vary from about 1 million to 1 billion solar masses.

Why are quasars rare today?

- Eventually they suck up all the nearby gas and run out of fuel.
- Stars slightly farther out are in stable orbits; they rarely collide to send material toward the black hole.
- But if another galaxy should happen to stray through, its material could reignite the quasar!



Active Galaxies bridge the energy gap between ordinary galaxies and quasars

- peculiar galaxies (pec)
  - appear to be blowing themselves apart

LINER - Low-Ionization Nuclear Emission-line Region, gaseous regions common in the centers of many kinds of galaxies. Some of these have been shown to be low-luminosity active galactic nuclei, perhaps an extension of Seyfert activity to the lowest levels and implying that the whole phenomenon of nuclear activity occurs in a significant fraction of bright galaxies.

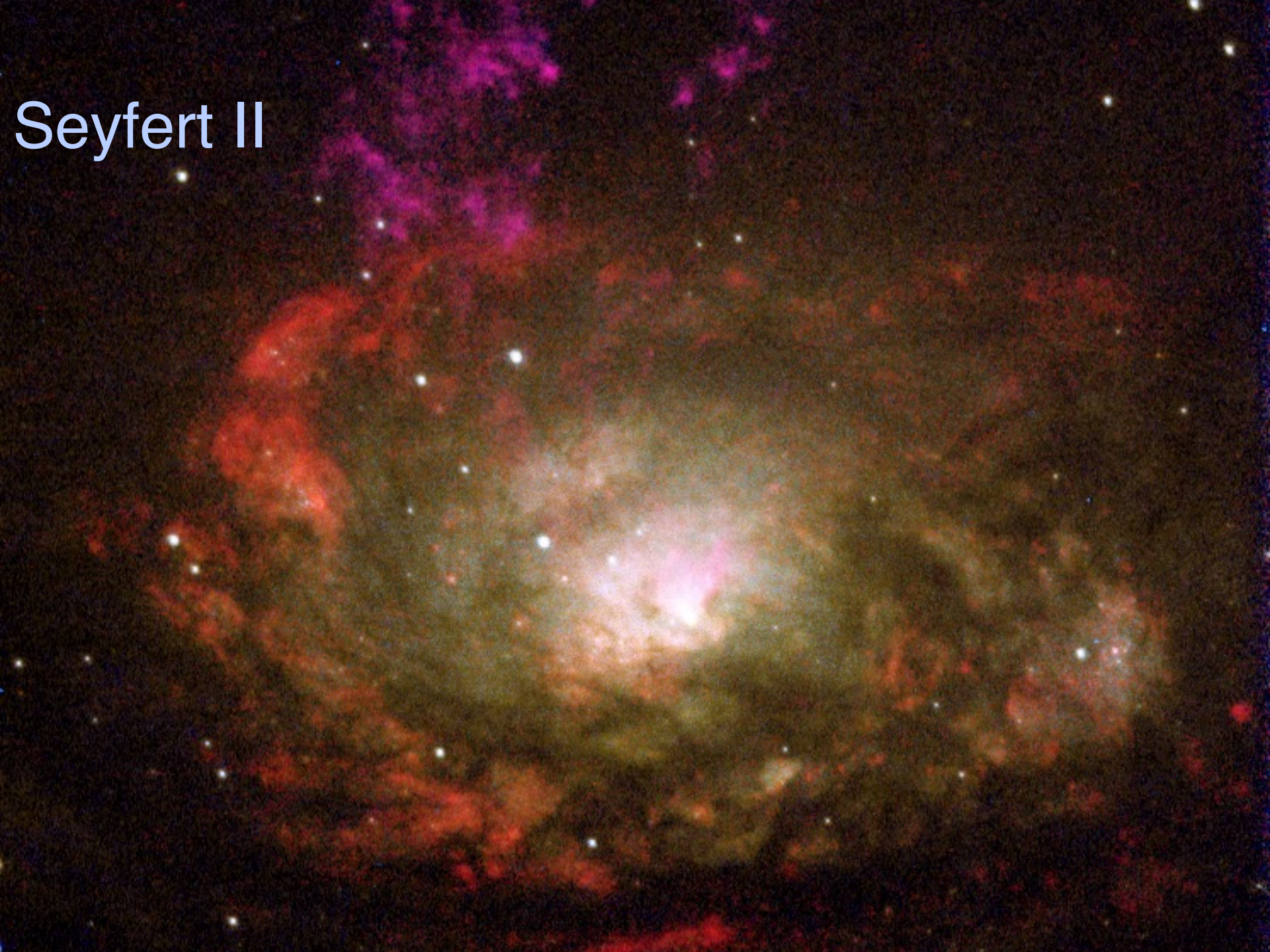
- Seyfert galaxies

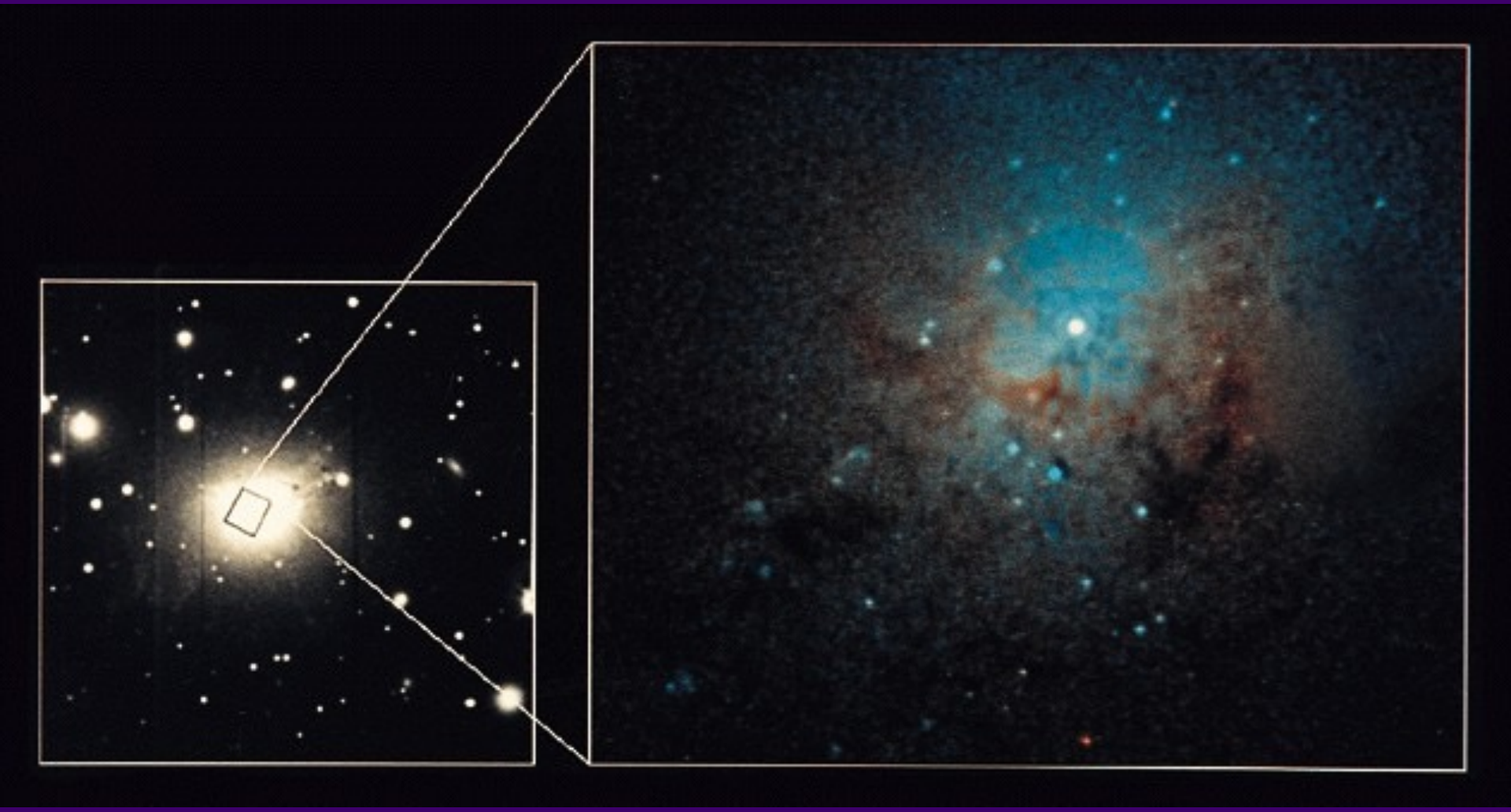
  Usually a spiral or disturbed system, whose nucleus shows strong emission lines which are too broad and of ionization too high to be produced by the galaxy's stellar population. Often, we see a bright starlike nucleus associated with this.

  In type 1 Seyferts, some of the emission lines, those that an be produced at high densities, are still broader, while in type 2 nuclei, all the linewidths are comparable.

  Seyfert nuclei are strong X-ray sources, and many show significant radio emission.

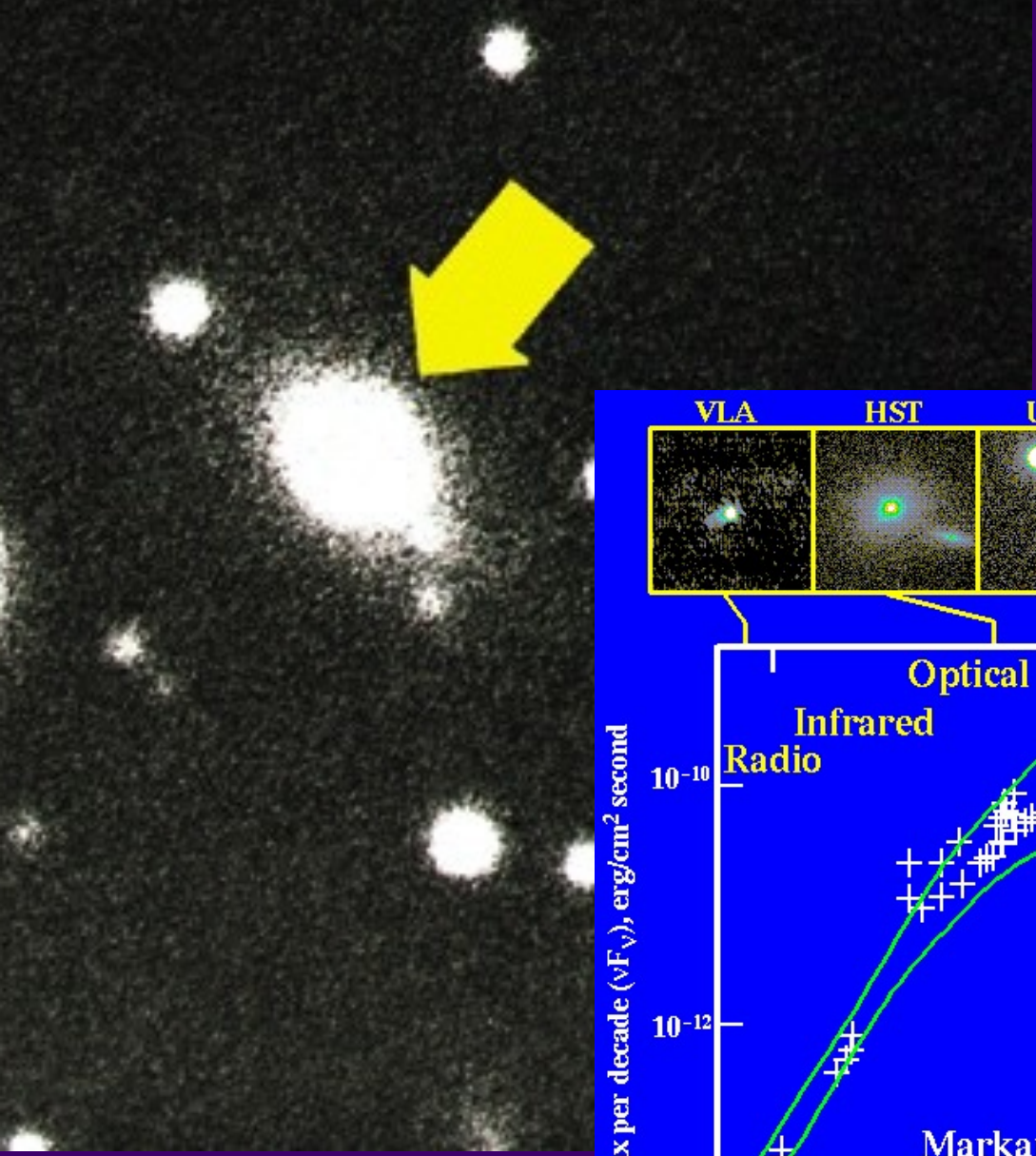
Seyfert I

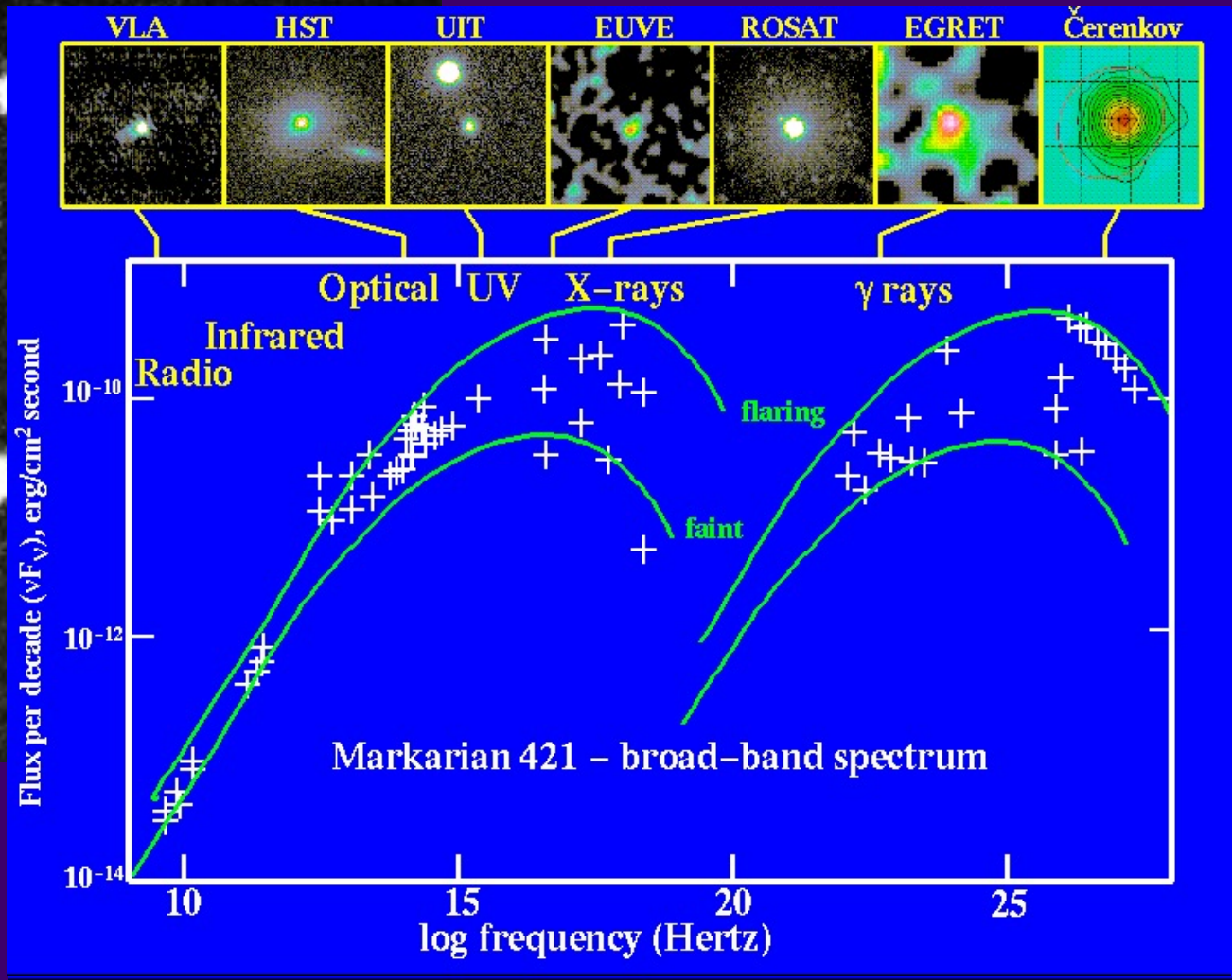

Seyfert II



Blazar - broader term including BL Lacertae objects and those quasars which share their characteristics of unusually weak spectral features, plus strong and rapid variability.

- BL Lacertae objects (BL Lacs)
  - featureless spectrum with a brightness that can vary by a factor of 15 times in a few months. These may be other kinds of radio-loud AGN seen nearly along their jets, so that the Doppler-boosted radiation from the jet overwhelms everything else.

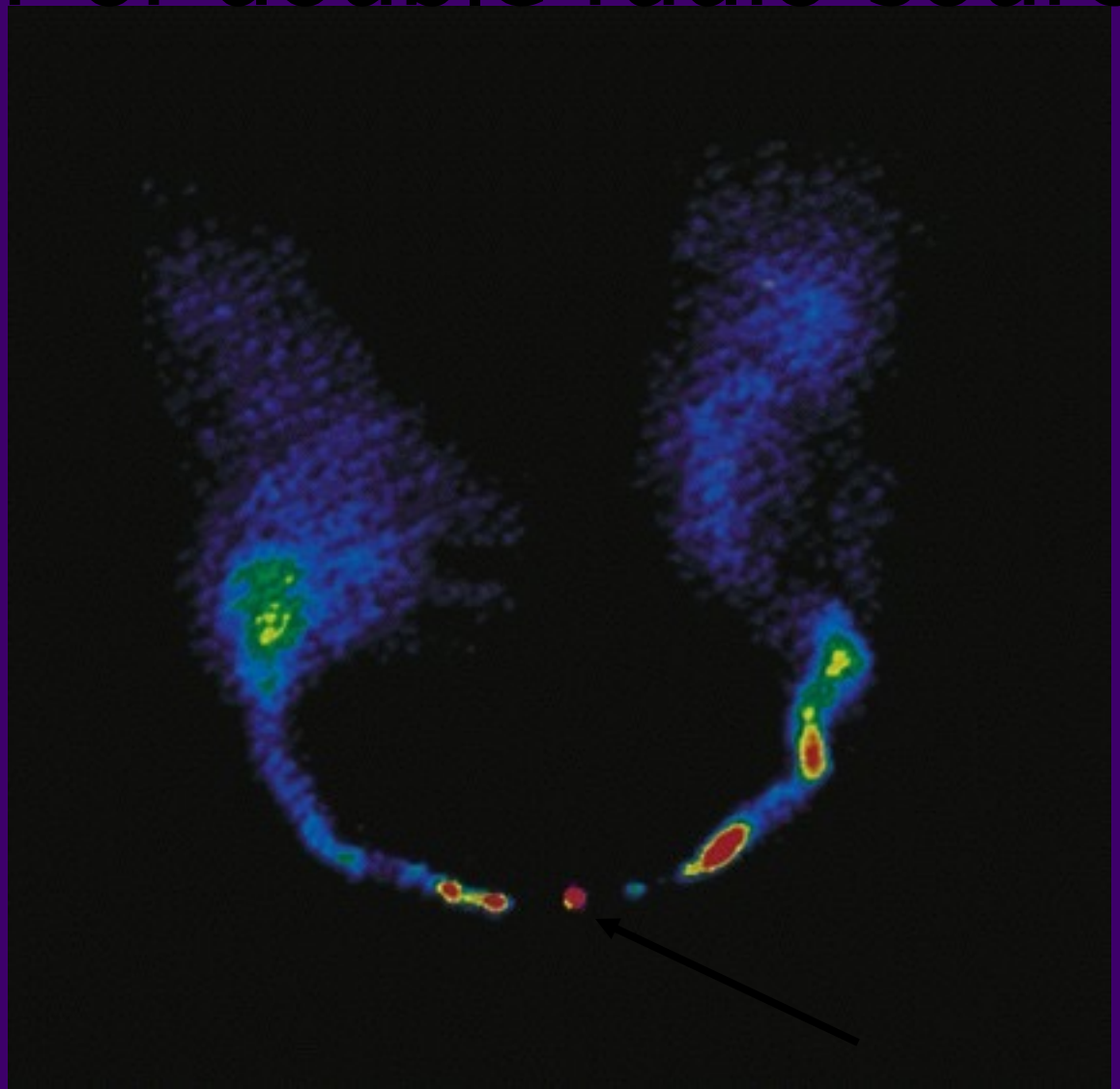


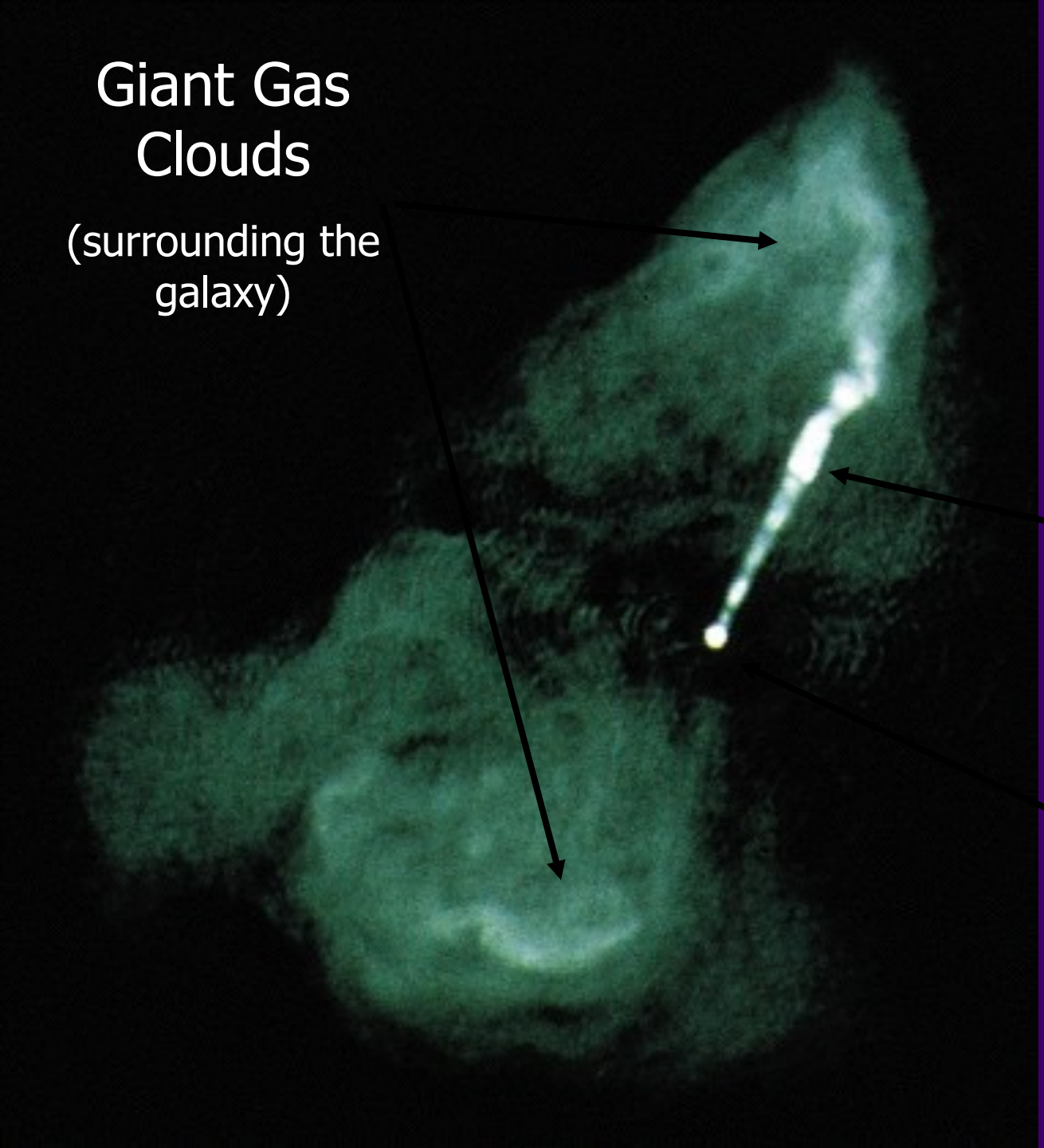

VLA
HST
UIT
EUVE
ROSAT
EGRET
Čerenkov
Optical
UV
X-rays
γ rays
Infrared
Radio
flaring
faint
Markarian 421 – broad-band spectrum
Flux per decade (νF_ν), erg/cm² second
10⁻¹⁰
10⁻¹²
10⁻¹⁴
10
15
20
25
log frequency (Hertz)

radio galaxy - a galaxy showing unusually strong radio emission, too intense to be produced by the normal processes of starbirth and stardeath. This may come only from the nucleus, or from a pair of more or less symmetric lobes stretching as far as a million light-years. Many show emission from jets connecting the nucleus to these lobes. Optical spectra of radio galaxies may show nothing unusual, but in many instances show strong emission lines, either narrow (NLRG, like type 2 Seyferts) or including broad lines of certain species (BLRG, like quasars and type 1 Seyferts).

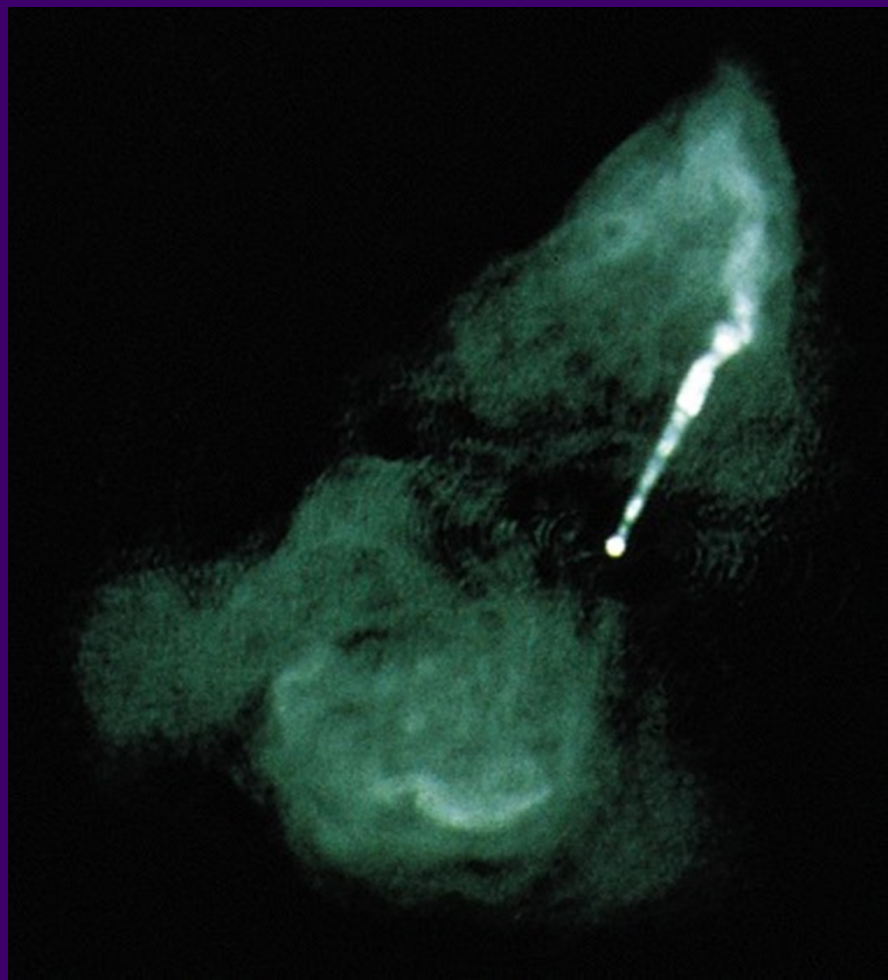
Radio image of Cygnus A showing a small but very bright radio galaxy in the middle of the 320,000 ly wide lobes

Active galaxies lie at the center of double radio sources

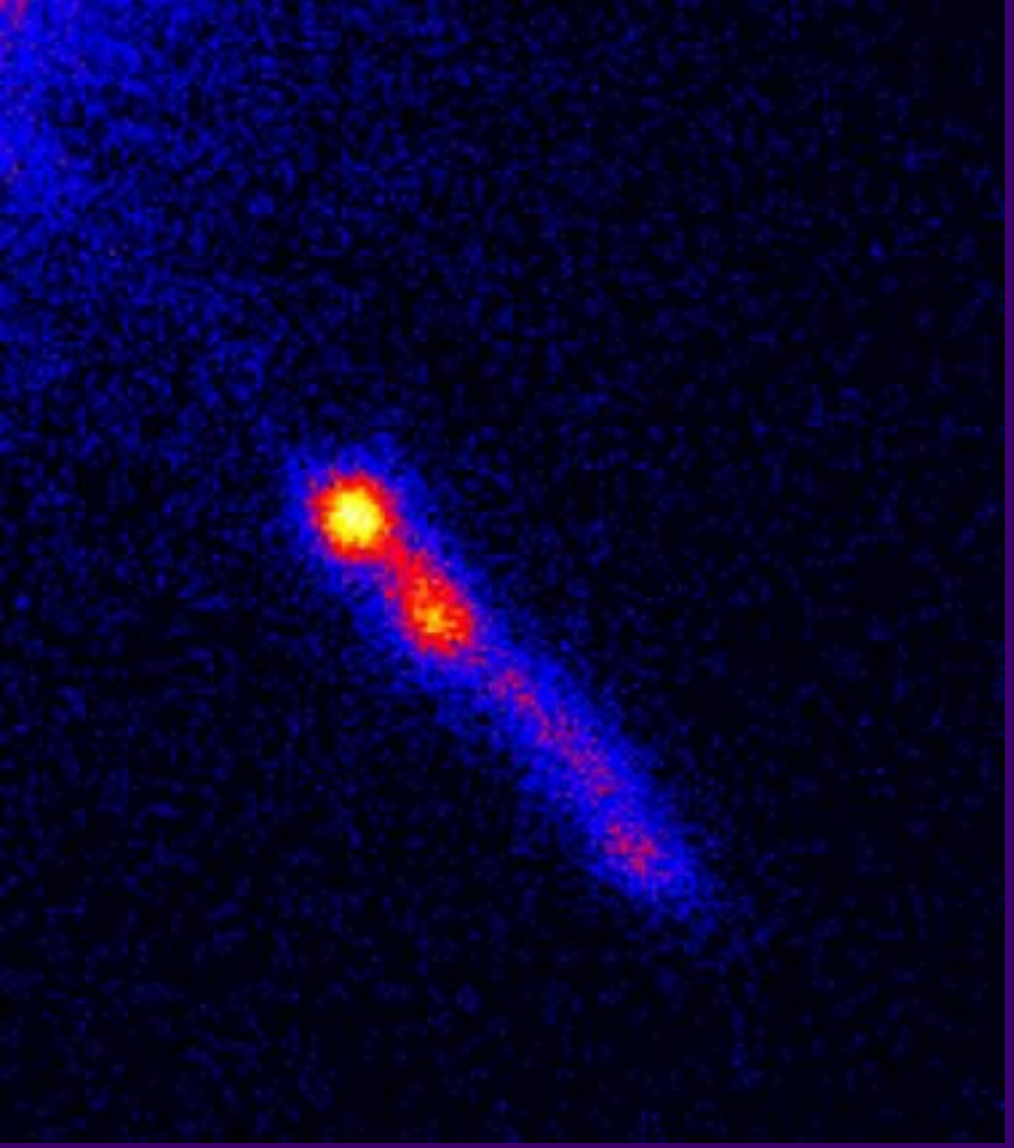



Giant Gas Clouds
(surrounding the galaxy)
Intergalactic gas jet
Galaxy
(which is actually quite large)

superluminal sources - radio sources which show internal motions (for example, increasing separation between the core and a knot in the jet) which appears faster than the speed of light in our frame of reference. The data are consistent with this being a transformation effect from seeing jets moving almost directly toward us, so that the emitting material almost catches up with its own radiation. This has the effect of compressing the scale of time that we measure for it, and so increasing the observed speed.

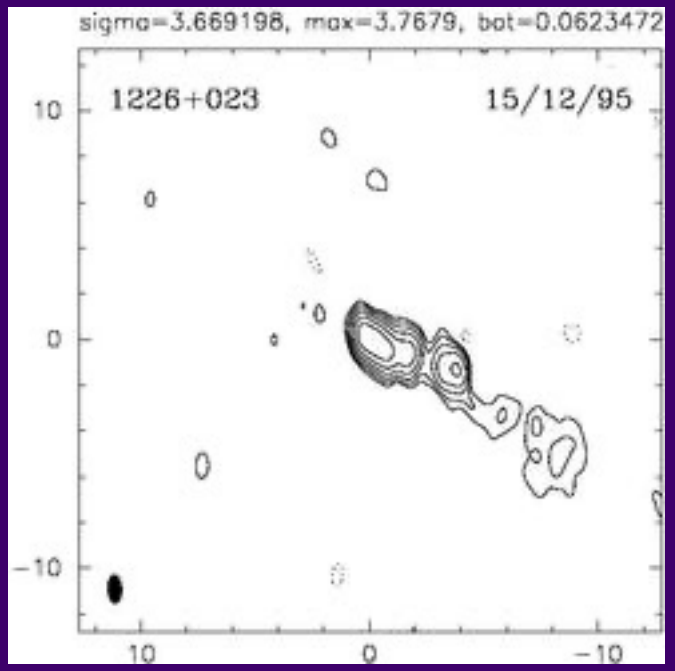


Quasistellar object (QSO) - an object with optical properties as described for quasars, but not necessarily a strong radio source. Only about 10% of QSOs are radio-loud. "Quasar" is often used more loosely to include QSOs.

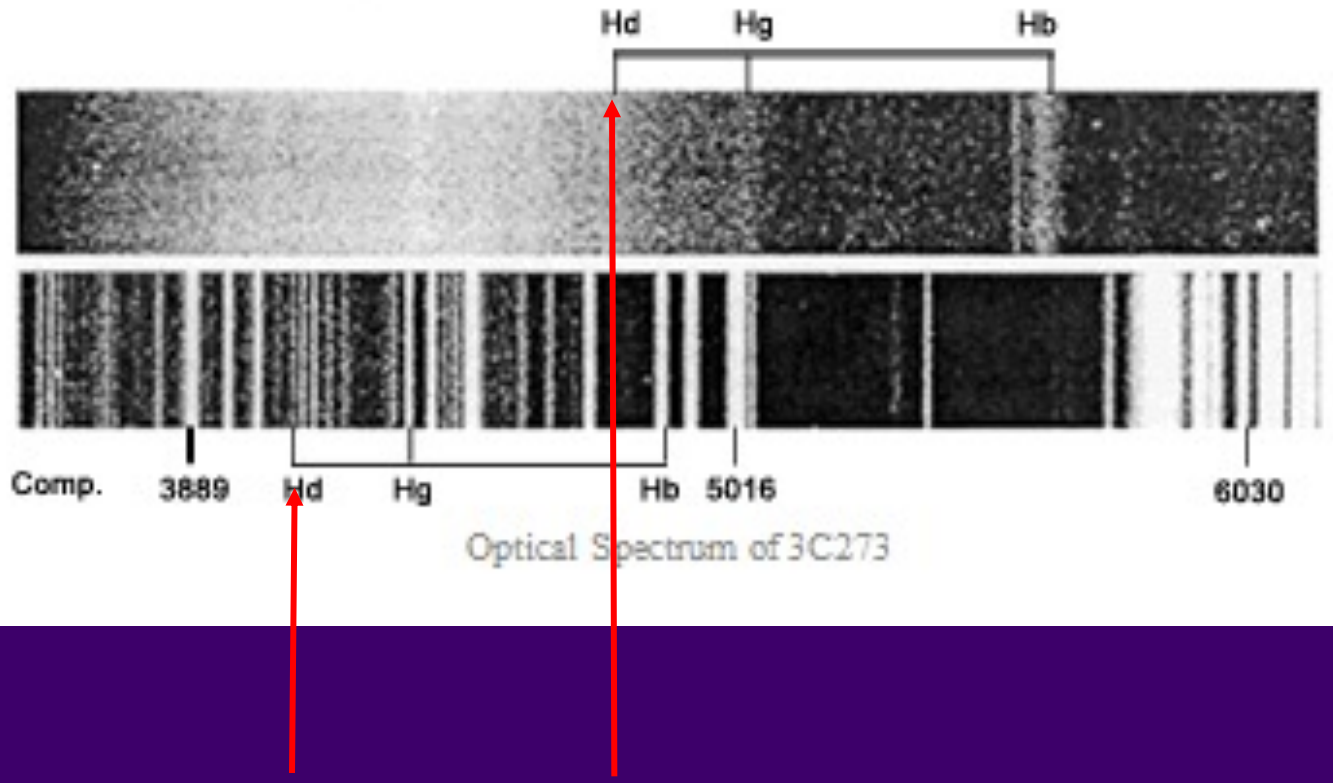


X-ray

Radio (VLA)



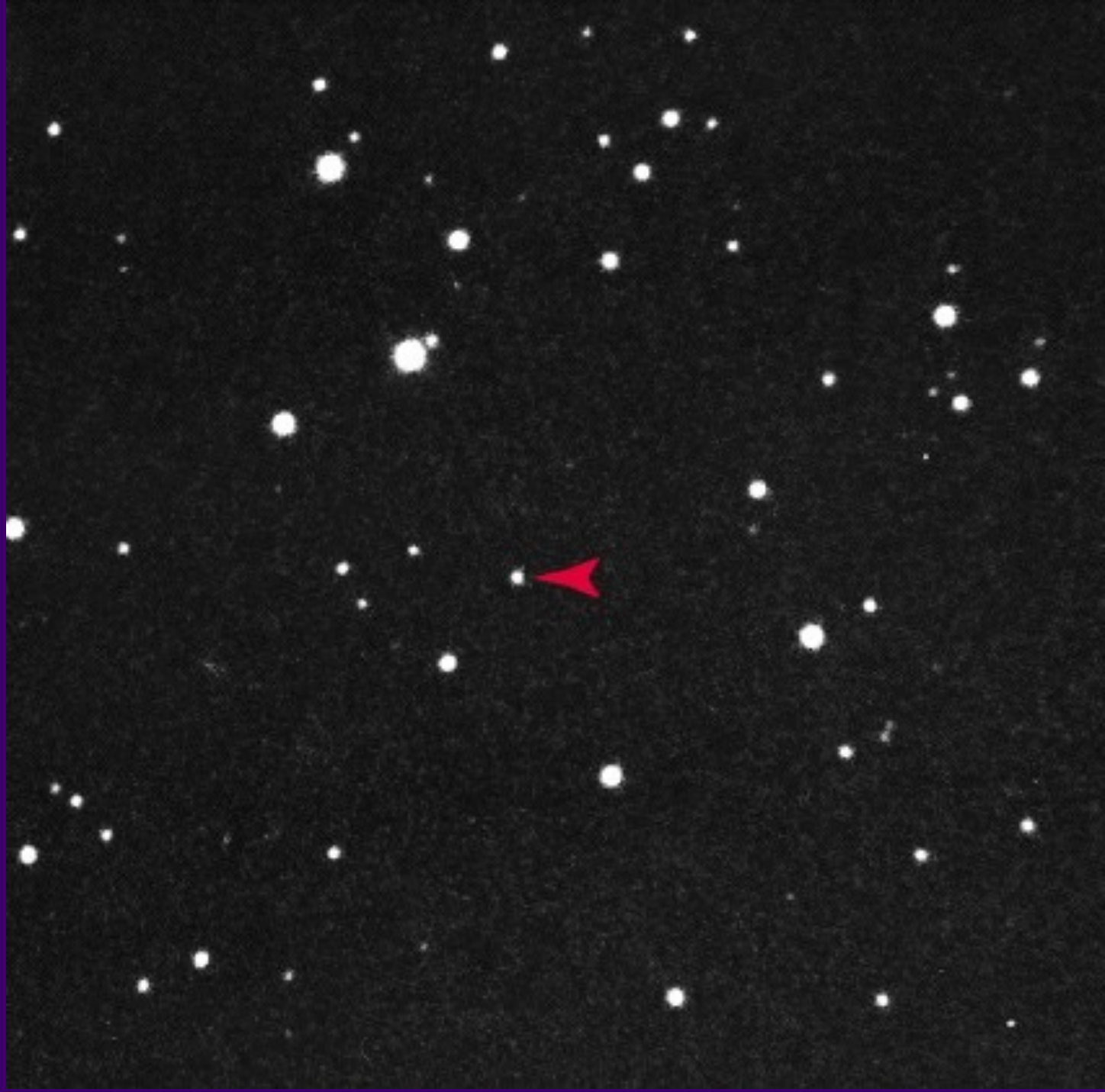
Schmidt measured the spectrum:



Optical Spectrum of 3C273

Redshift of 0.13 indicating that the object is very far away (about 2.5 billion light years) and very bright!

This object that looks like a star must be enormously luminous - its redshift indicates it is 4 billion light years away!!



Competing Cosmologies

- “Big Bang”: 10 - 20 billion years ago the universe was much more dense than today (and therefore hot and unpleasant).

- “Steady State”: As galaxies move apart from each other, new atoms are spontaneously created in empty space. These atoms coalesce to form new galaxies. The average density of the universe doesn’t change over time. There was no hot early universe.

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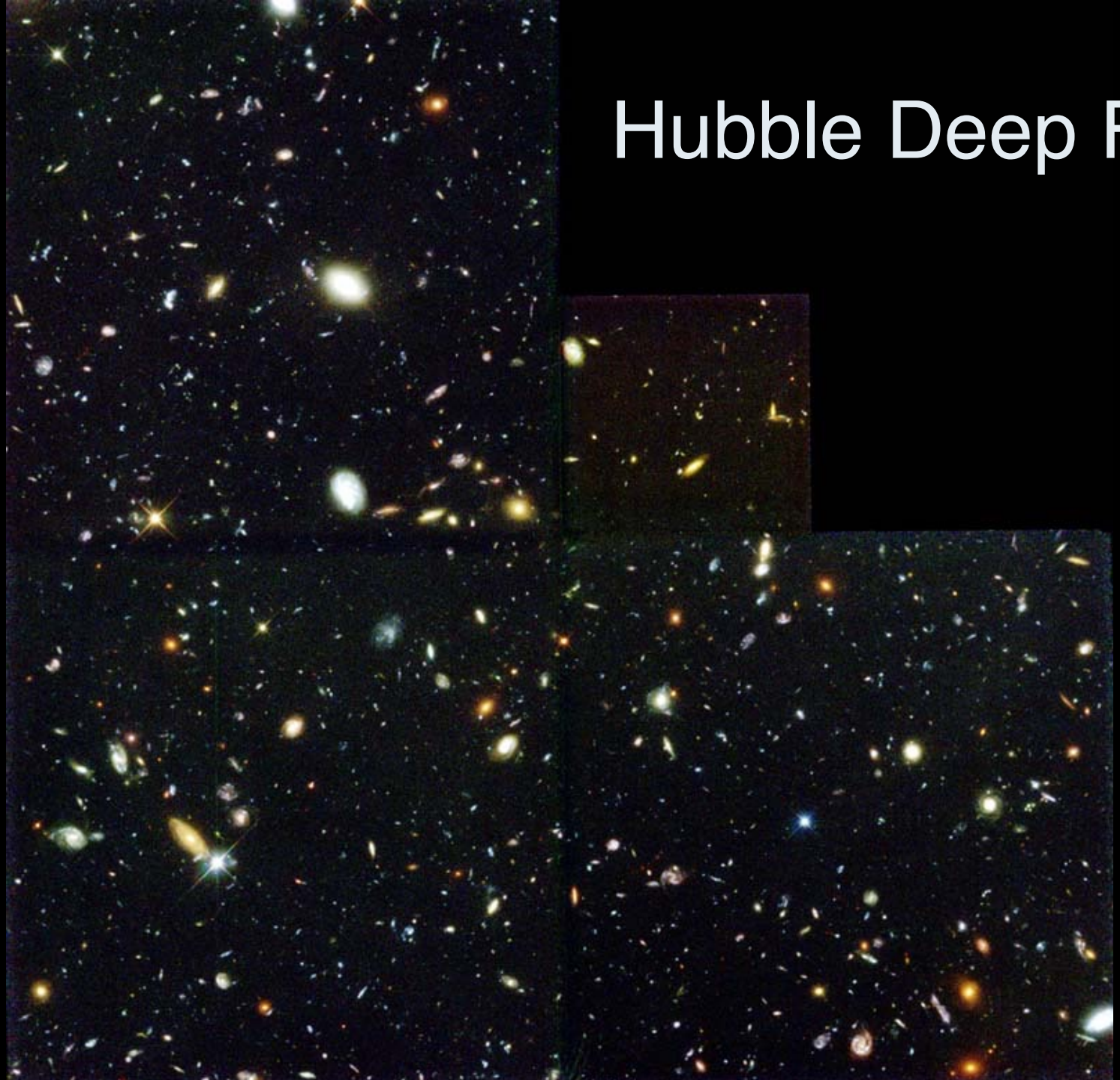
Quasars were the first evidence that the universe was much different in the past than it is today.

Hubble Deep Field



Competing Cosmologies

- Young universe: The “Hubble time” (since everything would have been in the same place, moving at current speeds) is only about 10 billion years.
- Old universe: The “Hubble time” is about 20 billion years.

Thanks to more accurate distance measurements, this dispute has been settled. The Hubble time is 13 - 14 billion years, in agreement with globular cluster ages.