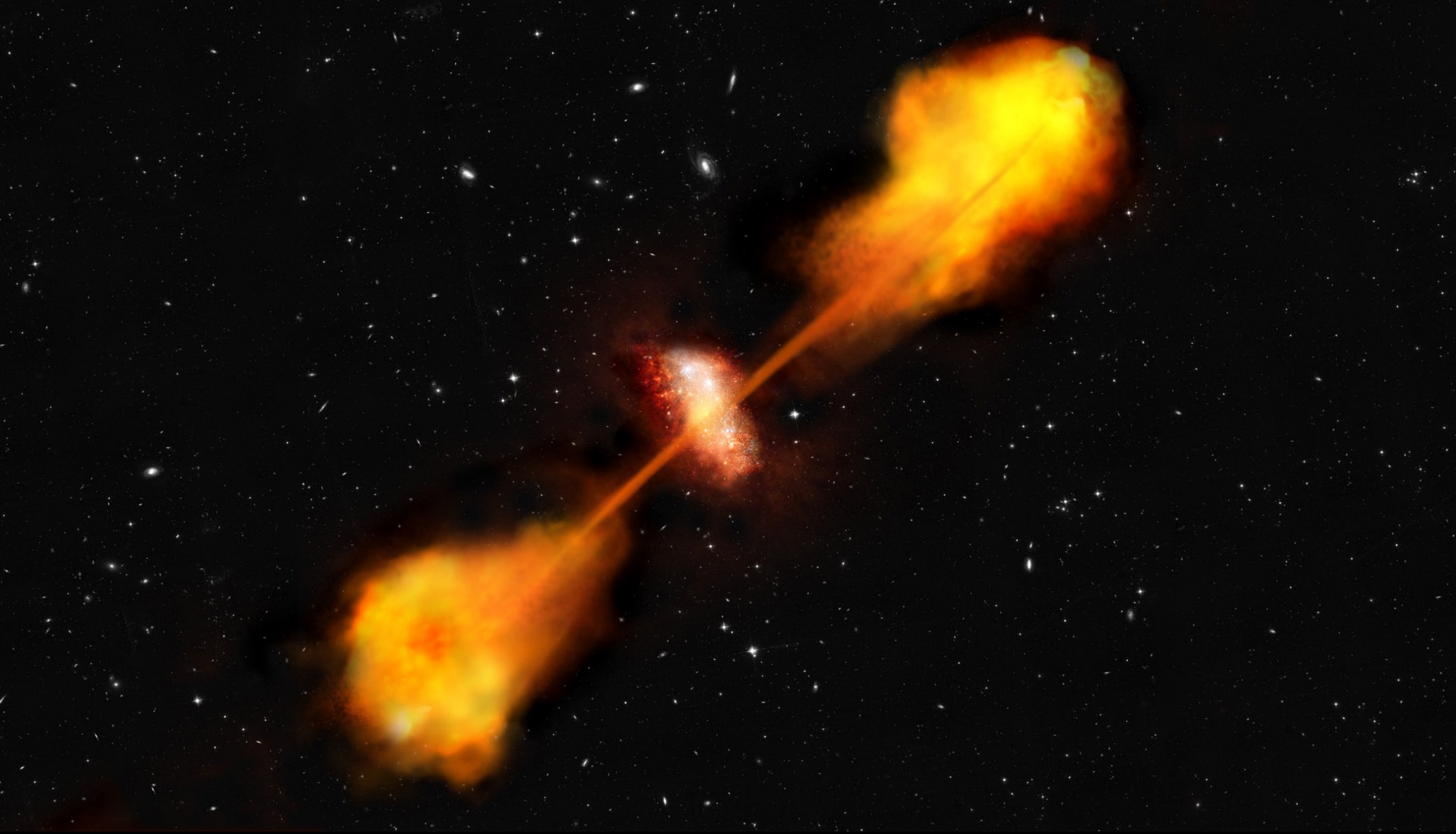
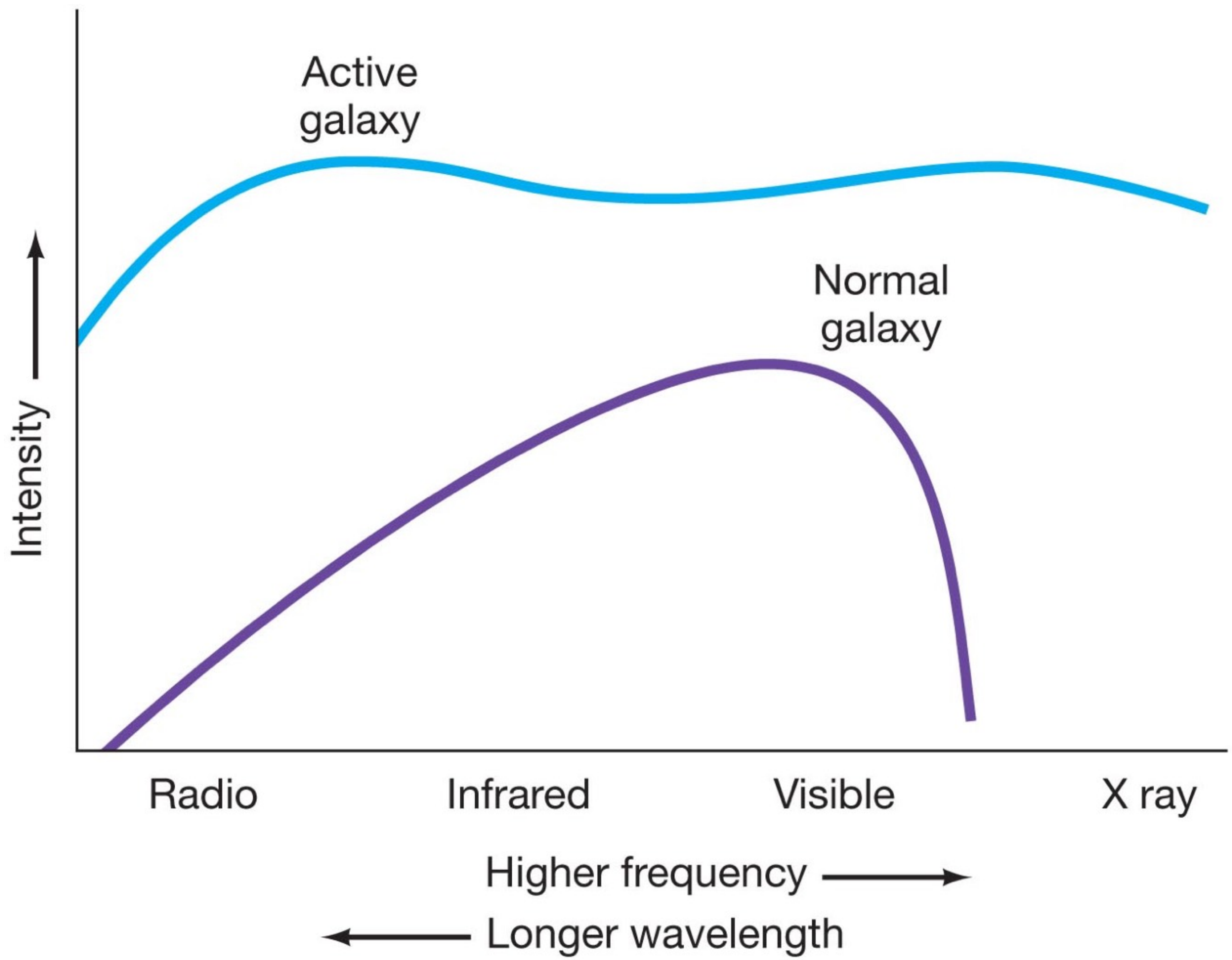


Active Galaxies

Astronomy 401/Physics 903

Characteristics of active galaxies

- Large amounts of nonstellar emission, some of it nonthermal in origin. Active galaxies produce more X-ray and radio emission than would be produced by their stars



Characteristics of active galaxies

- Large amounts of nonstellar emission, some of it nonthermal in origin. Active galaxies produce more X-ray and radio emission than would be produced by their stars
- Much of the light is concentrated in a small, central region called an active galactic nucleus, **AGN**
- Light from AGNs is variable on short timescales, at virtually all wavelengths. Timescale for variability depends on luminosity and wavelength, with most rapid variability seen at short wavelengths and low luminosities. X-rays in low luminosity AGNs can vary on timescales of minutes
- Some active galaxies have jets detectable at X-ray, visible and radio wavelengths. The jets contain ionized gas flowing outward at relativistic speeds
- The UV, visible and IR spectra of AGNs are dominated by strong emission lines

Synchrotron radiation

- Non-thermal emission, i.e. not produced by stars
- Common in AGN
- Electrons in a magnetic field spiral along magnetic field lines, continually accelerated by Lorentz force
- Accelerated charges emit radiation: these electrons emit synchrotron radiation
- Power law continuum, $F_\nu \propto \nu^{-\alpha}$
- Spectral index α depends on energy distribution of electrons

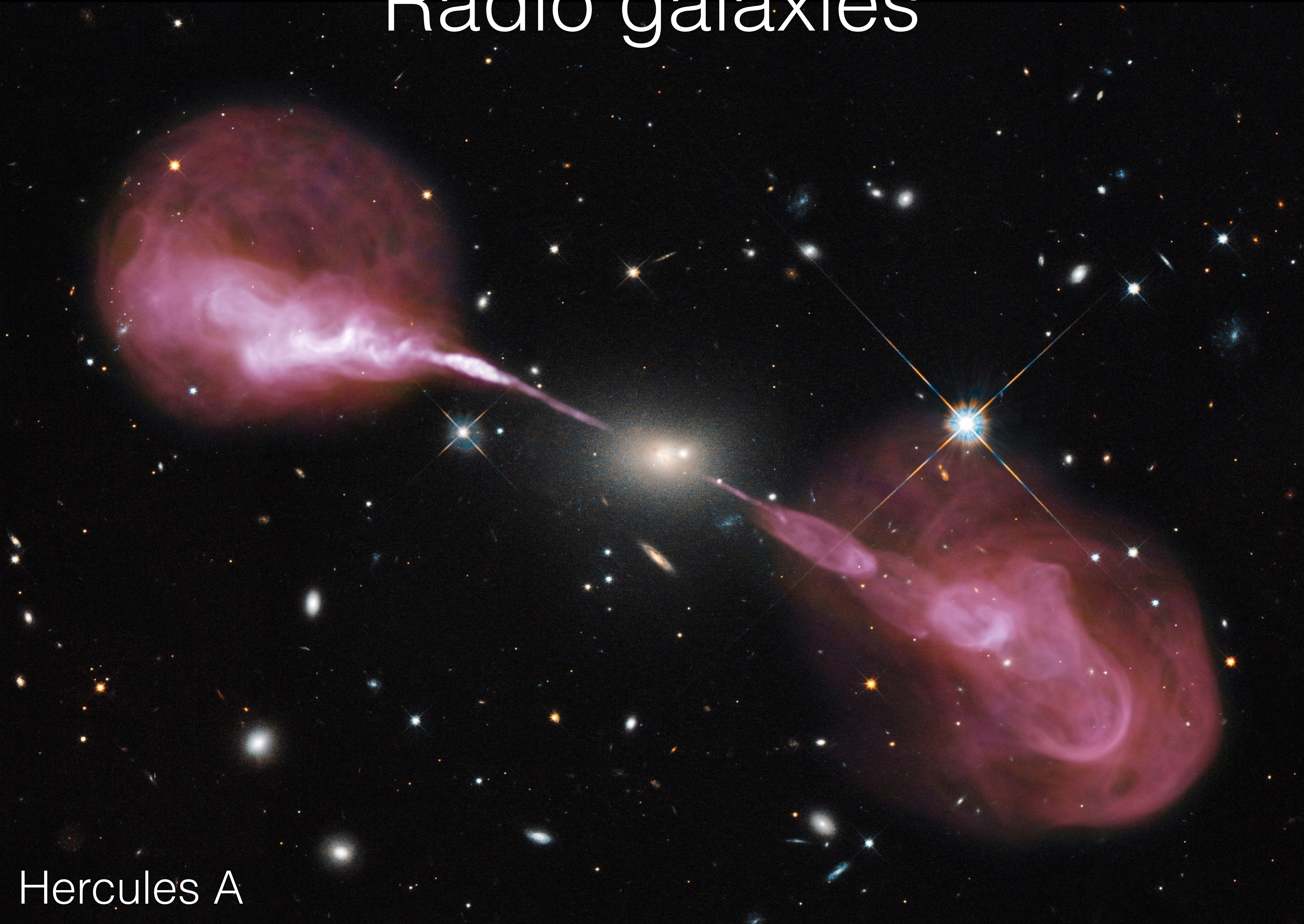
Powered by accretion onto massive black holes

- Most bright galaxies have black holes in their centers, but not all bright galaxies are active galaxies
- To be an active galaxy, the central black hole must be accreting gas rapidly enough to produce luminosity as bright or brighter than the galaxy's stars

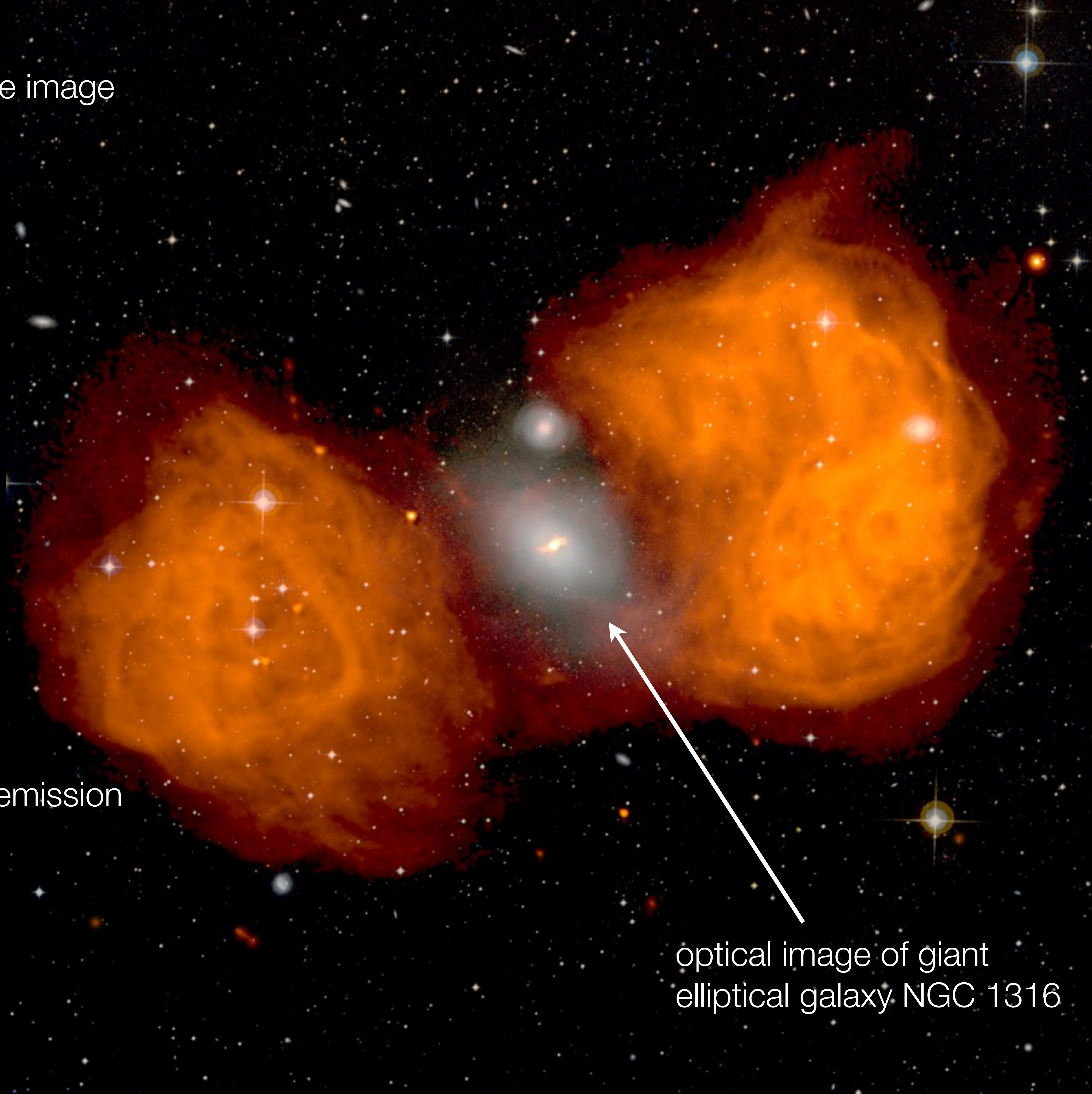
Types of AGN: Seyfert galaxies

- Galaxies with broad (500-5000 km/s) emission lines discovered by Carl Seyfert in 1943
- Emission lines come from center of galaxies
- ~0.5% of galaxies are Seyfert galaxies
- 95% of Seyferts are spirals
- In addition to broad emission lines, center often has a power law continuum excess of light, so blue compared to normal galaxies

Radio galaxies

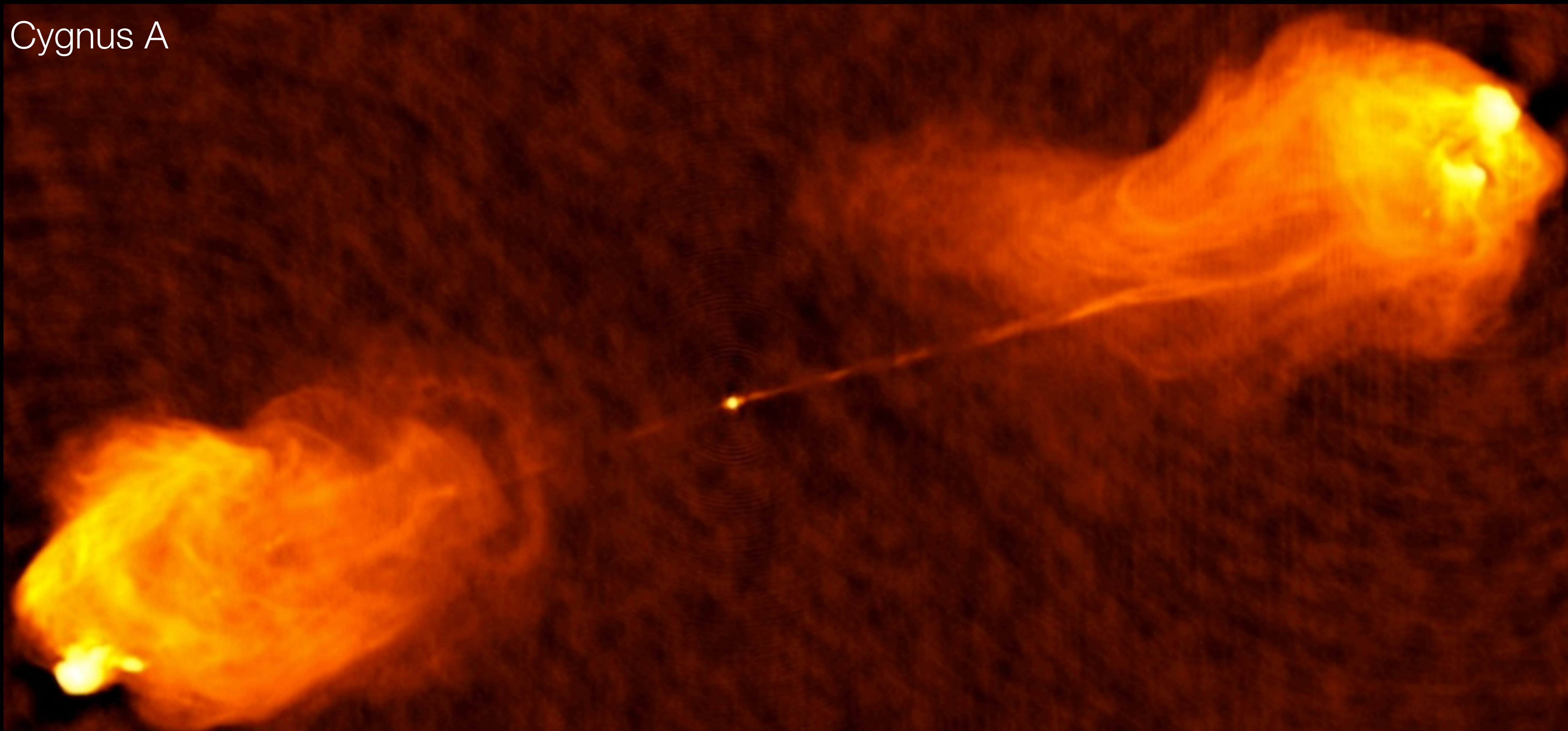


Hercules A


Fornax A
Composite image
radio emission
optical image of giant
elliptical galaxy NGC 1316

Radio galaxies

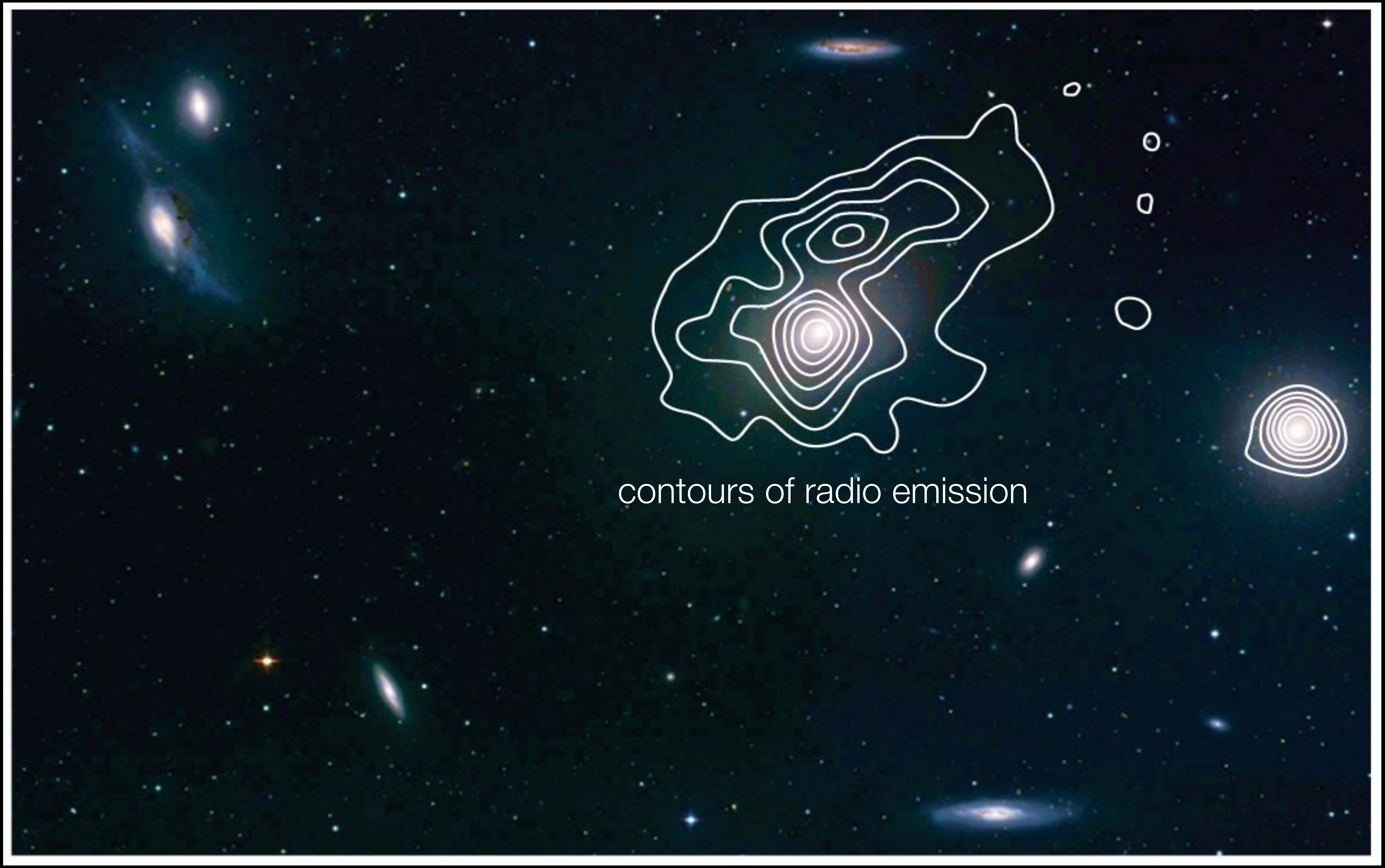
- History: sky studied at radio wavelengths after WWII
- 1946: discovery of discrete radio source Cygnus A — poor resolution, no optical counterpart found
- 1949: positions to 10 arcmin achieved (still not very good!). M87 and NGC5128 found to be associated with double radio sources
- 1951: optical counterpart to Cygnus A found to be peculiar galaxy at $z = 0.06$ (~240 Mpc! the only brighter radio sources are the Sun and the nearby supernova remnant Cas A, at 3 kpc)
    - Cyg A is 106 times more powerful at radio wavelengths than the Milky Way
- 1953: Cyg A resolved as double radio source



Radio emission is **synchrotron emission**: produced by electrons spiraling in a strong magnetic field

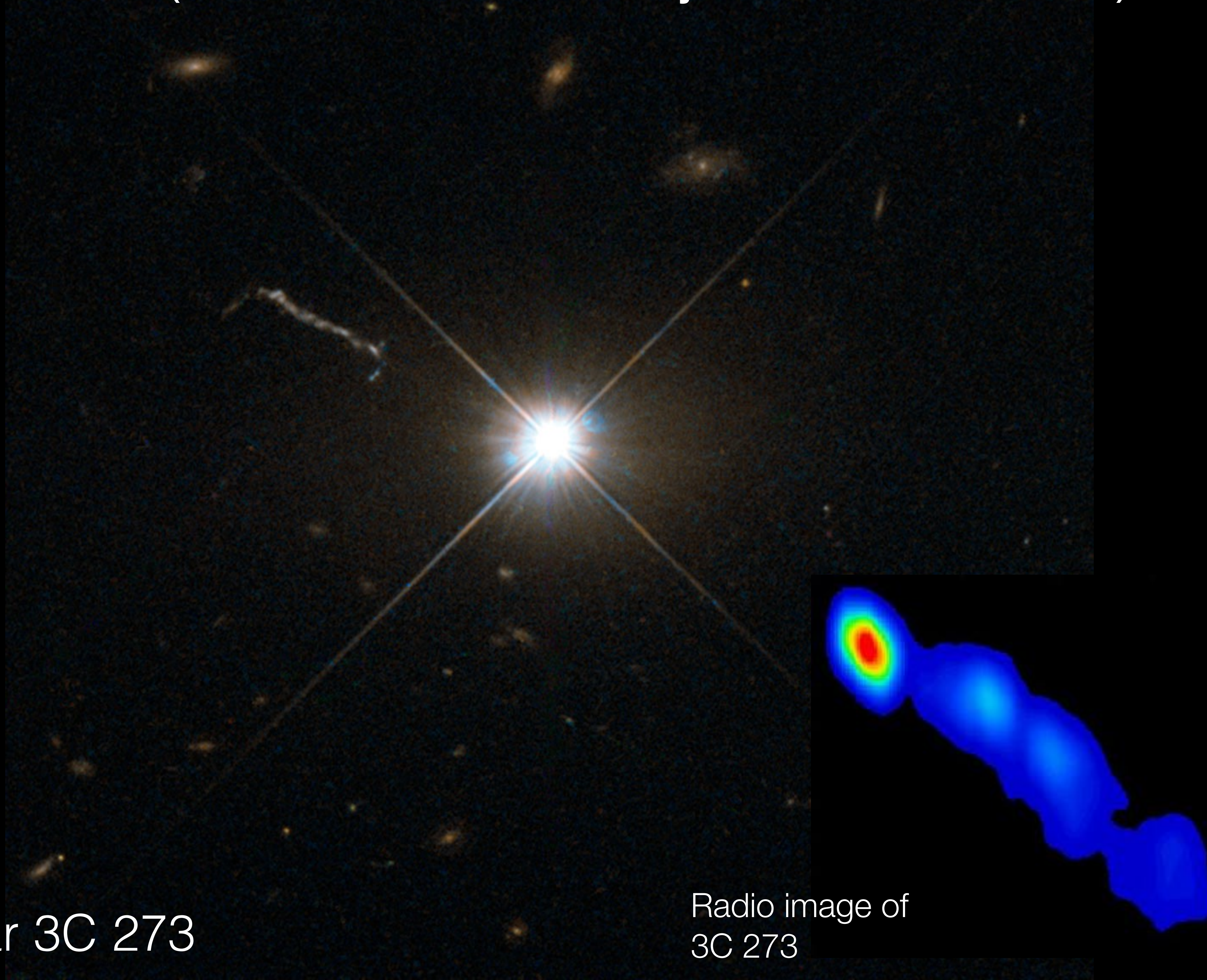
Radio galaxies

- Usually elliptical
- Non-thermal power law spectrum in radio
- Optical spectra of nucleus similar to Seyferts. Distinguish broad line radio galaxies (BLRGs) and narrow line radio galaxies (NLRGs)
- $\sim$100 times less abundant than Seyfert galaxies
- May have extended jets and lobes



Radio galaxies may also be **core-dominated**

QSOs (Quasi-Stellar Objects, Quasars)



Quasar 3C 273

Radio image of
3C 273

QSOs (Quasi-Stellar Objects, Quasars)

1960: 3C 48 (#48 in the Third Cambridge catalog of radio sources) identified with star-like object (quasi-stellar). Thought to be a star, but spectrum very weird

1963: Maarten Schmidt recognizes the spectrum of another "radio star" (3C 273) as Balmer lines redshifted to $z = 0.158$. Then 3C 48's spectrum understood as redshifted to $z = 0.367$ (these objects weren't expected to be so far away because they are so bright)

QSOs (Quasi-Stellar Objects, Quasars)

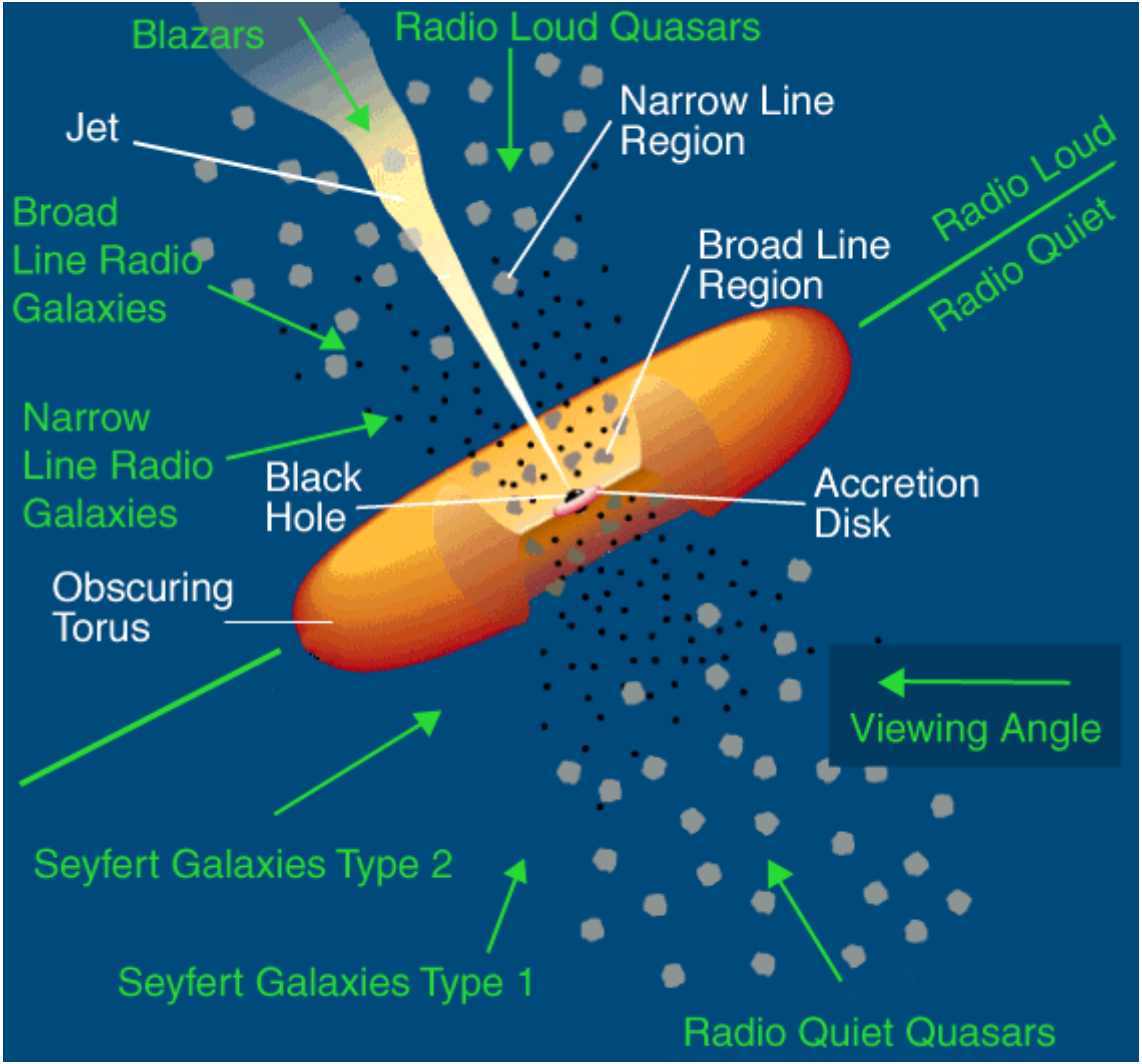
- Most radio quiet
- Look like stars. Some have optical jets, and some are the very bright nuclei of fuzzy-looking host galaxies
- Blue. UV excess called the “blue bump”
- Optical fluxes often variable on timescales of years
- Broad emission lines resemble Seyfert I galaxies
- Almost always strong X-ray emitters
- Very bright! can be detected to high redshifts
- Radio-quiet QSOs found by looking for extremely blue stars. Followup spectroscopy needed for confirmation

Major components of an AGN

- **Supermassive black hole**. Suspected for many years based on arguments of energetics and time variability, more recent evidence from high speed motions of stars and gas in galactic nuclei
- **Accretion disk**. Surrounds the black hole, responsible for the UV and visible continuum emission of AGN
- **Jets**. Ionized gas is ripped from the accretion disk by electromagnetic fields, and spirals along magnetic field lines away from the disk, producing a jet. Accelerated electrons in the ionized gas emit synchrotron radiation, accounting for the radio emission from the jet

Major components of an AGN, cont'd

- **Broad-line region.** Size is measured by timing the delay between flux variations in the UV and visible continuum and the response of the emission lines. The delay is due to the light travel time across the broad line region. This is called *reverberation mapping*.
- **Obscuring torus.** Outer edge of the broad-line region is defined by the dust sublimation radius, the closest point to the continuum source (i.e. the accretion disk) where dust grains can survive the UV radiation
- **Narrow-line region**. At about the same radius as the obscuring torus, but can extend out to hundreds of pc along the jets



Blazars
Radio Loud Quasars
Jet
Narrow Line Region
Broad Line Radio Galaxies
Broad Line Region
Radio Loud
Radio Quiet
Narrow Line Radio Galaxies
Black Hole
Accretion Disk
Obscuring Torus
Viewing Angle
Seyfert Galaxies Type 2
Seyfert Galaxies Type 1
Radio Quiet Quasars

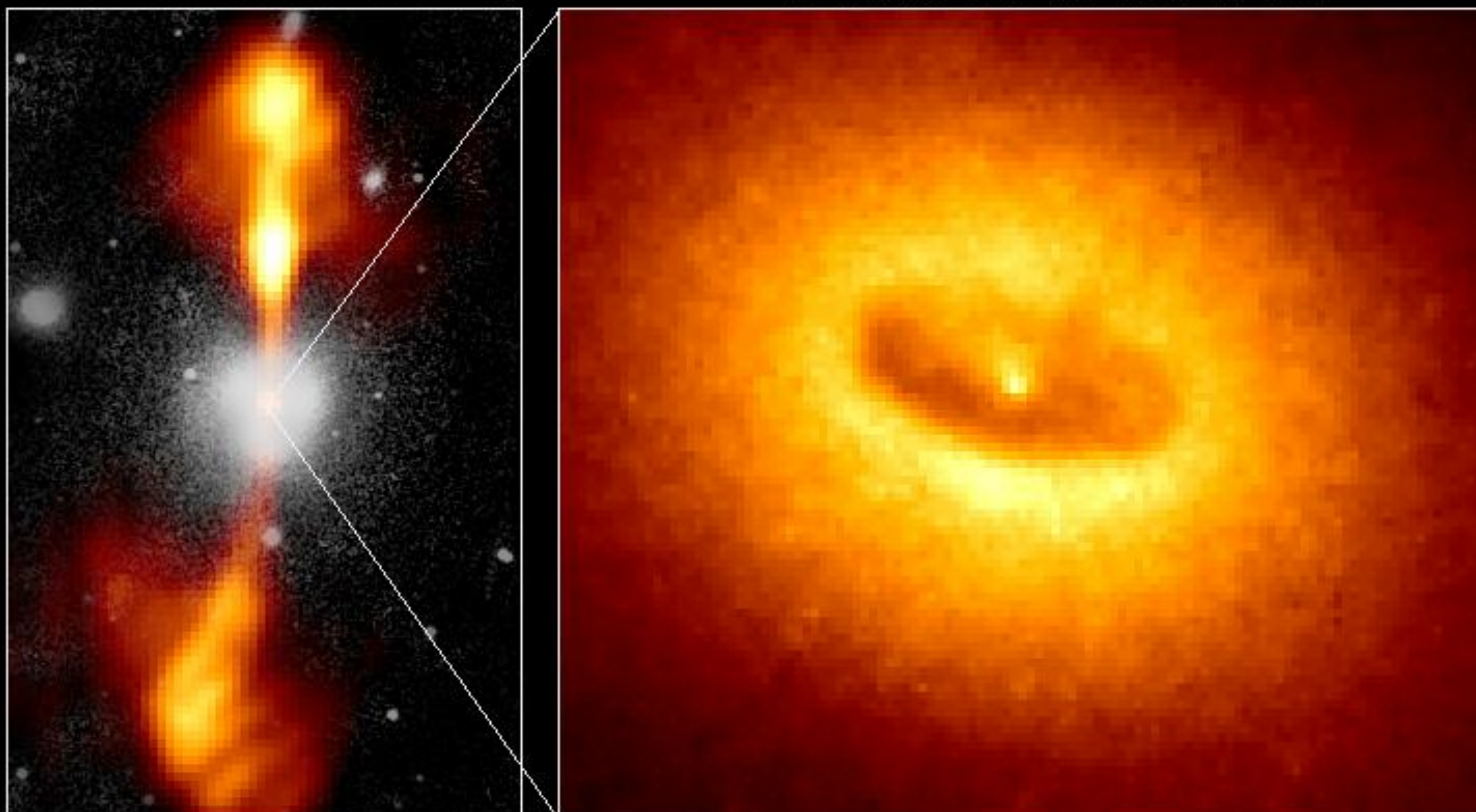
Core of Galaxy NGC 4261

Hubble Space Telescope

Wide Field / Planetary Camera

Ground-Based Optical/Radio Image

HST Image of a Gas and Dust Disk



380 Arc Seconds
88,000 LIGHT-YEARS

1.7 Arc Seconds
400 LIGHT-YEARS