Active Galaxies and Quasars

Normal Galaxies

Dominated by thermal emission

- starlight
- thermal radio
- thermal IR from dust

$L \approx 10^{35}$ W

Active Galaxies

Non-thermal emission
- synchrotron radiation

Strong emission lines (sometimes very broad)

Prominent across EM spectrum

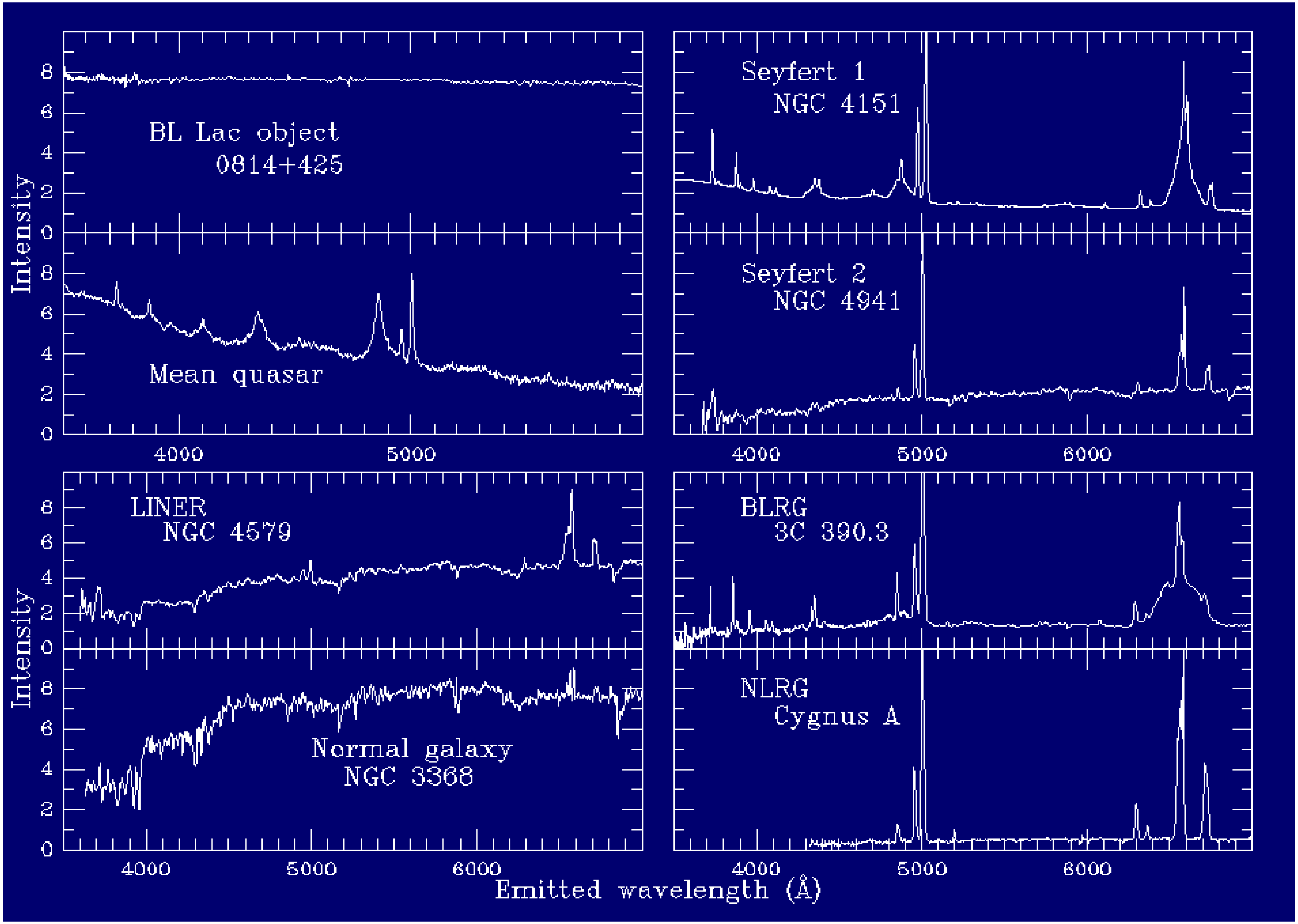
Bright central nucleus

$L > 10^{37}$ W

Rapid variability near center

Jets and outflows

Comparative Spectra



courtesy Bill Keele, U. Alabama

Emission Lines

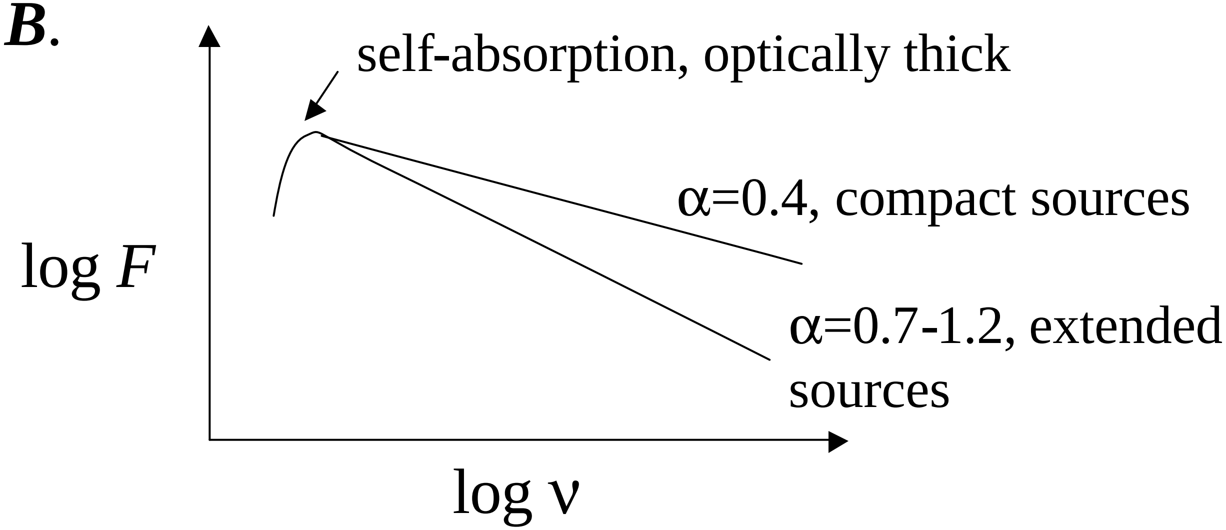
Requires highly excited or ionized atoms. What creates this?

(1) collisions between clouds or other mechanism to produce shock waves

(2) excitation or ionization by high energy photons from synchrotron radiation or tail of high temperature BB emission
=> similar effect as in emission nebulae.

Synchrotron radiation - from spectrum of high energy electrons spiraling around ***B***.

$$F = F_0 n^{-a}$$



Types of Active Galactic Nuclei (AGN's)

(1) Seyferts:

· bright central nucleus, outshines rest of galaxy

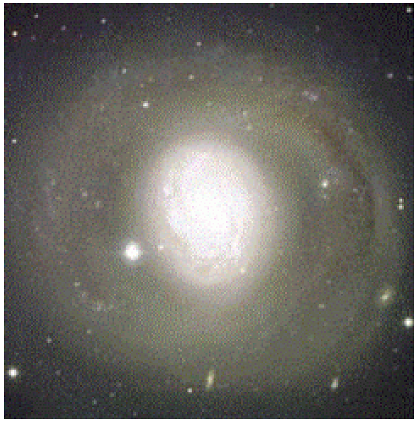
· variability on Δt < 1 yr

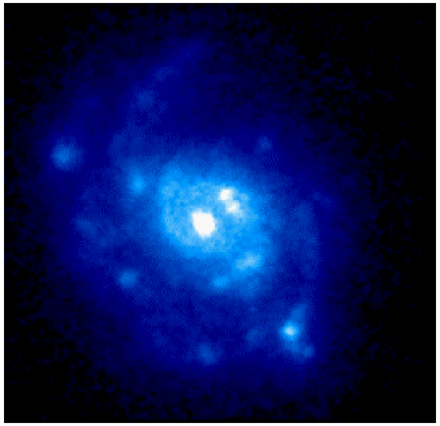
· broad emission lines

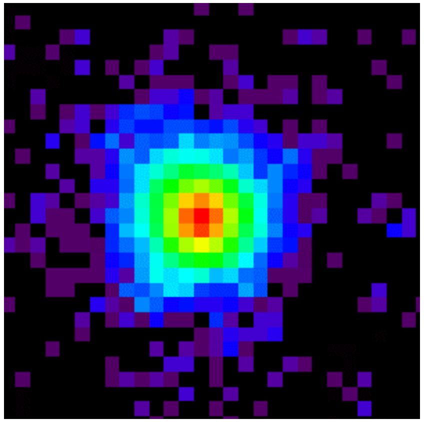
· nonthermal synchrotron radiation

· almost all are spirals (~1% of all spirals are Seyferts)

· not strong radio sources







M77 in optical, UV, and x-ray.

AGN Types

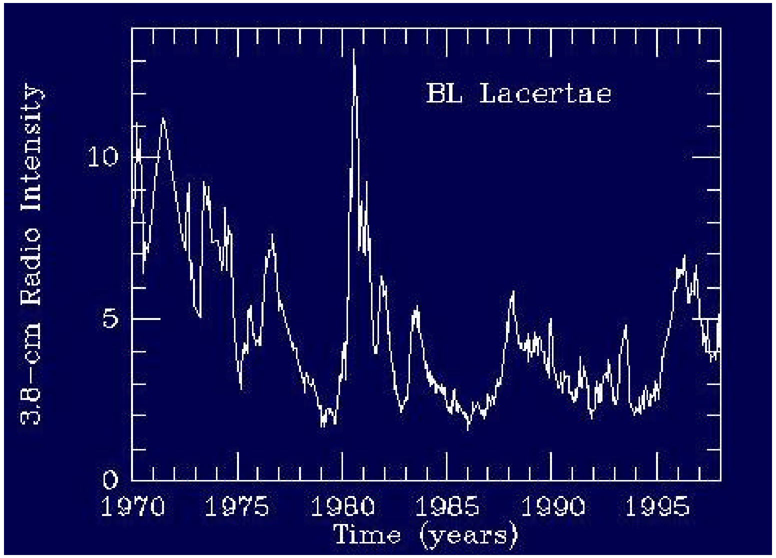
(2) BL Lac Objects:

• extremely rapid variability, Δt ~ 1 day!

• strong and erratic luminosity variations; factor ~20 overall , and 10-30% over one day

• bright, small nucleus; extended structure rarely visible

• no emission lines



courtesy Bill Keele, U. Alabama

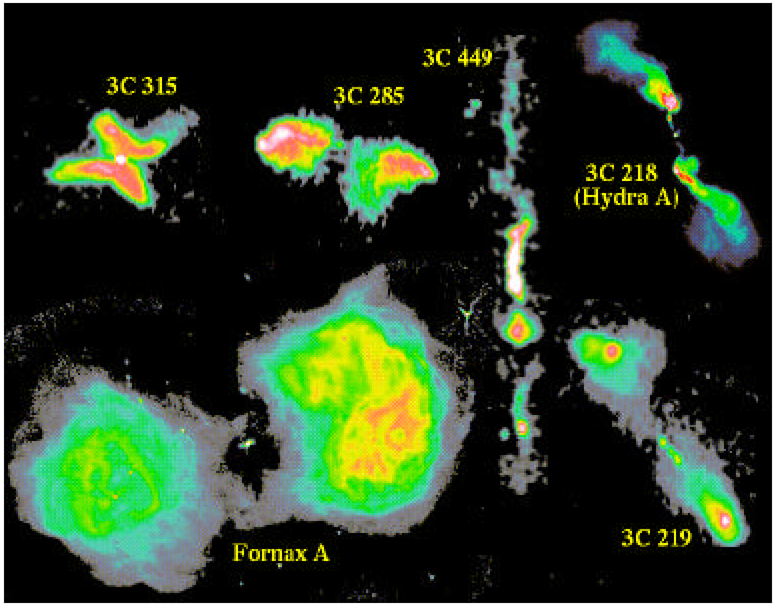
AGN Types

(3) Radio Galaxies:

· strong radio emission, primarily from synchrotron radiation

· compact sources: only a small (nuclear) source

· extended sources: emission region > optical size; often a giant double lobe. A jet emerges from the core. Lobes reveal evidence for intracluster gas.



A collection of VLA images of extended radio sources

Quasars

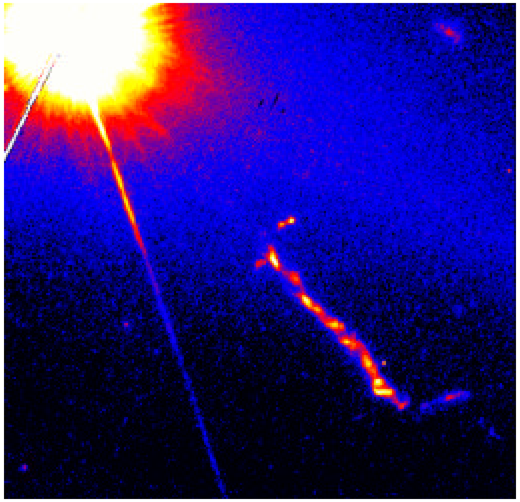
Quasi-stellar objects - first seen in radio (1950's), then optical (1960's). Looks like star in optical, but broad emission lines and more UV emission than MS star. Also characterized by

· very bright nucleus; outer galaxy not seen

· very large redshifts, up to z ~ 5 => very large distances and expansion velocities => extremely large luminosities

$$z = \frac{\Delta l}{l} = \begin{cases} \frac{v}{c} & \text{nonrelativistic,} \quad \left[\frac{1+v/c}{1-v/c}\right]^{1/2} - 1, \ \text{relativistic} \end{cases}$$

e.g., $z = 2 \Rightarrow v/c = 0.8$.



Quasar 3C273 in optical - note the jet

$z = 0.16 \Rightarrow d > 450$ Mpc

$\Rightarrow L > 10^{40}$ W.

Variability

Δt = days - weeks- years

Allows an estimate of the size of emitting region

$$\Delta t \approx \frac{R}{v} \geq \frac{R}{c} \quad \Rightarrow \quad R \leq c\Delta t$$ for coherent motions.

$$\Delta t = 1\,\text{year} \quad \Rightarrow \quad R = 1\,\text{light year} \approx 10^{16}\,\text{m} < 1\,\text{pc},$$

$$\Delta t = 1\,\text{day} \quad \Rightarrow \quad R = 1\,\text{light day} \approx 10^{13}\,\text{m} << 1\,\text{pc}.$$

<u>Fundamental question</u>: How to generate > 100 times the energy of a normal galaxy in a region < 1 pc across?

Current (unified) model for AGN's and Quasars

Energy source: release of gravitational PE of matter falling onto a supermassive black hole, $M \sim 10^7$-10^9 M_{sun}.

Size of region is small: $$R_{Sch} = 3\left(\frac{M}{M_{Sun}}\right)\text{km} = 3\times10^8\,\text{km} \approx 2\text{ AU}$$

for $M = 10^8$ M_{sun}. Can explain rapid variability.

$$L = \frac{GM}{R}\frac{dM}{dt}$$ is sufficiently large, assuming dM/dt ~ 1 M_{sun}/yr.

A scaled up version of binary x-ray source models.

Current model for AGN/Quasars

Scenario:

· supermassive BH pulls in material, tidally disrupting stars

· infalling material heats up and radiates => yields required luminosity

· high energy electrons => synchrotron radiation

· an outflow (jet) is launched perpendicular to the disk, along rotation axis

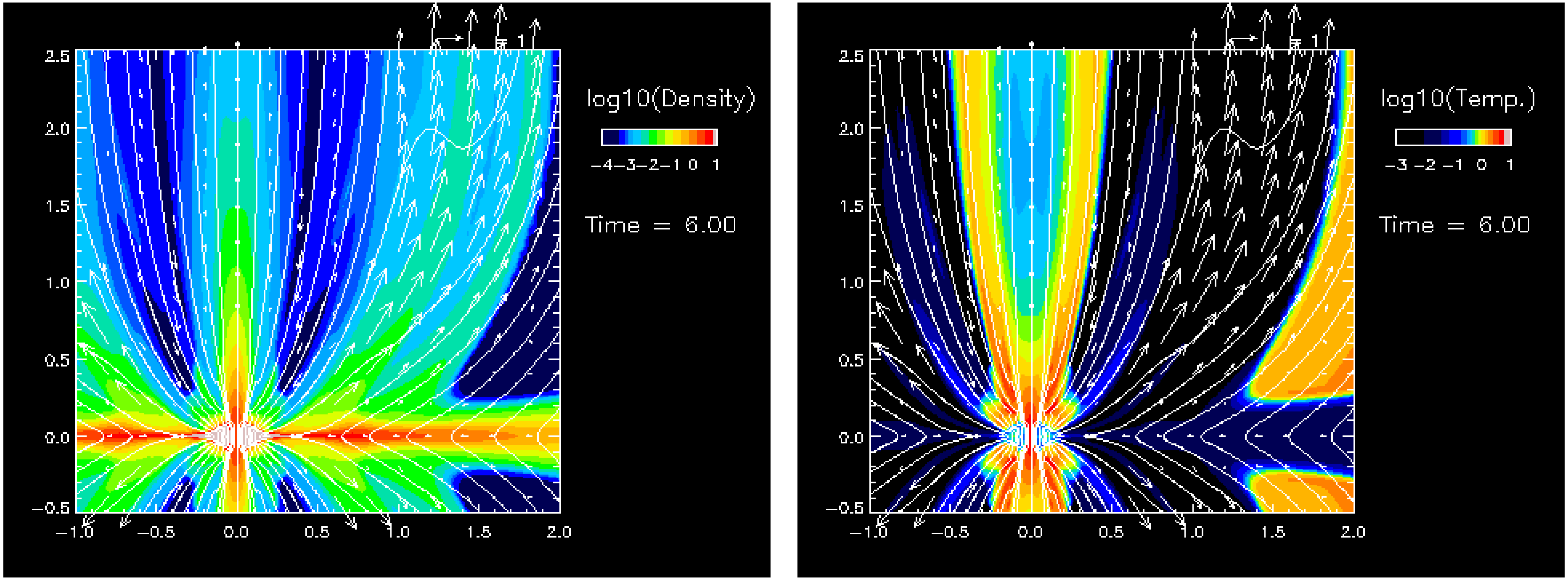
· emission lines due to gas ionized by central continuum source

· different AGN/quasar types may have to do with

  - viewing angle, i.e., the orientation of disk and jet to line-of-sight

  - amount of gas and dust near the nucleus

AGN/Quasar Jet Model



Kato, Kudoh and Shibata 1999

Magnetic field along rotation axis helps to launch jets.