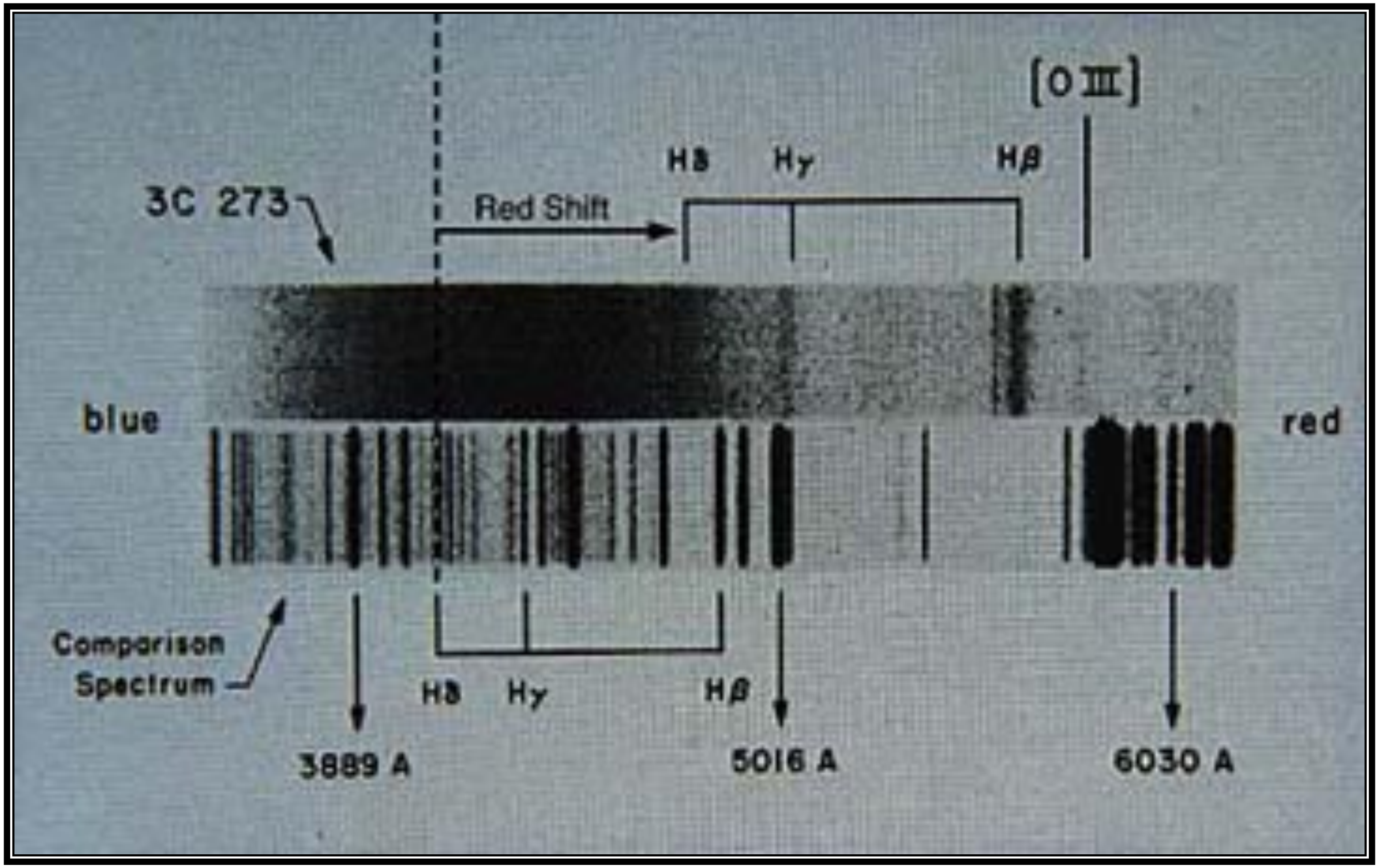
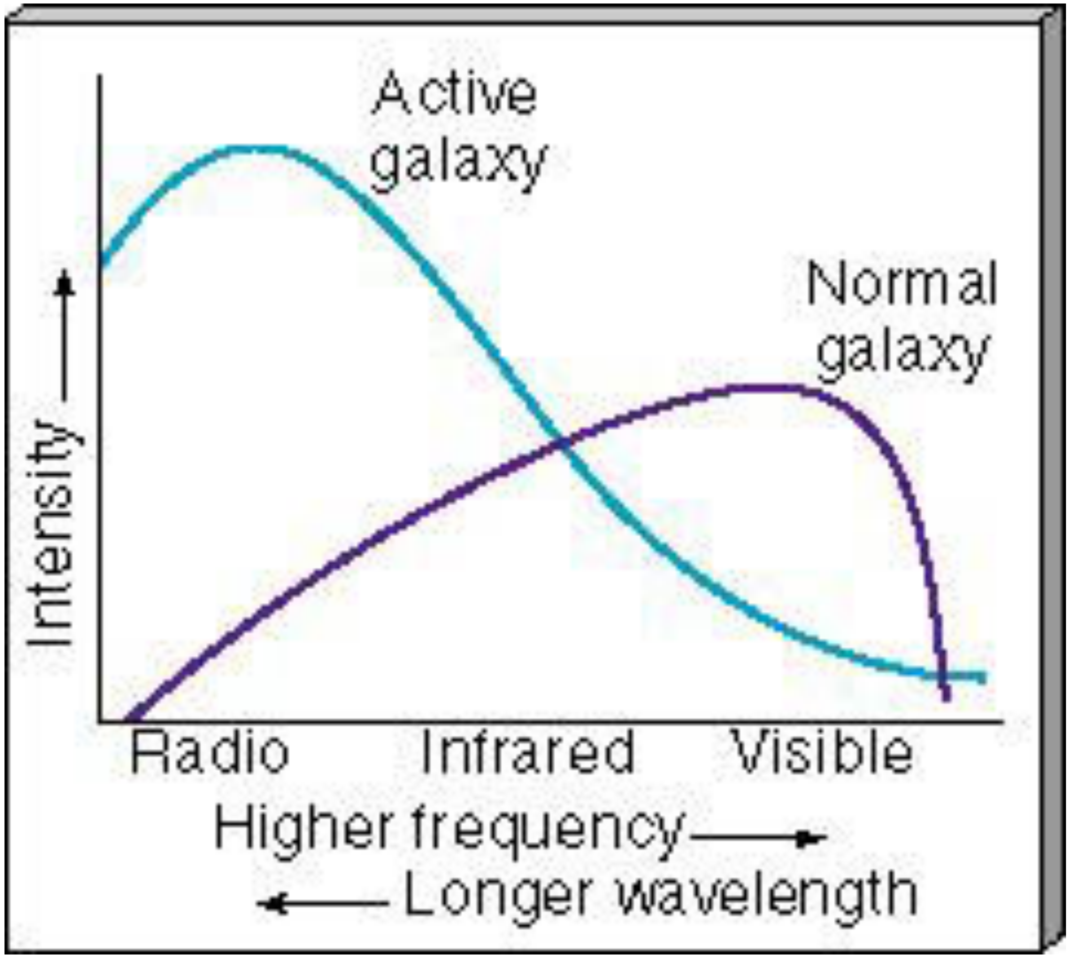
Quasi-Stellar Objects (QSOs) and Schmidt's Realization



Active Galaxies

- o Galaxies that have unusually bright nuclei
- o Can have
  - ✓ Jets
  - ✓ Strong variability
  - ✓ Strong radio emission
  - ✓ Broad emission lines (like winds)
- o Most are located large distance of millions and even billions LYs away

Comparison of Spectra



Enter the AGN Zoo

Seyfert Galaxies:

- Bright pointlike nuclei
- In spirals
- Two types –
  1) Broad lines, X-rays
  2) Narrow lines, IR
- Lower luminosity than quasars

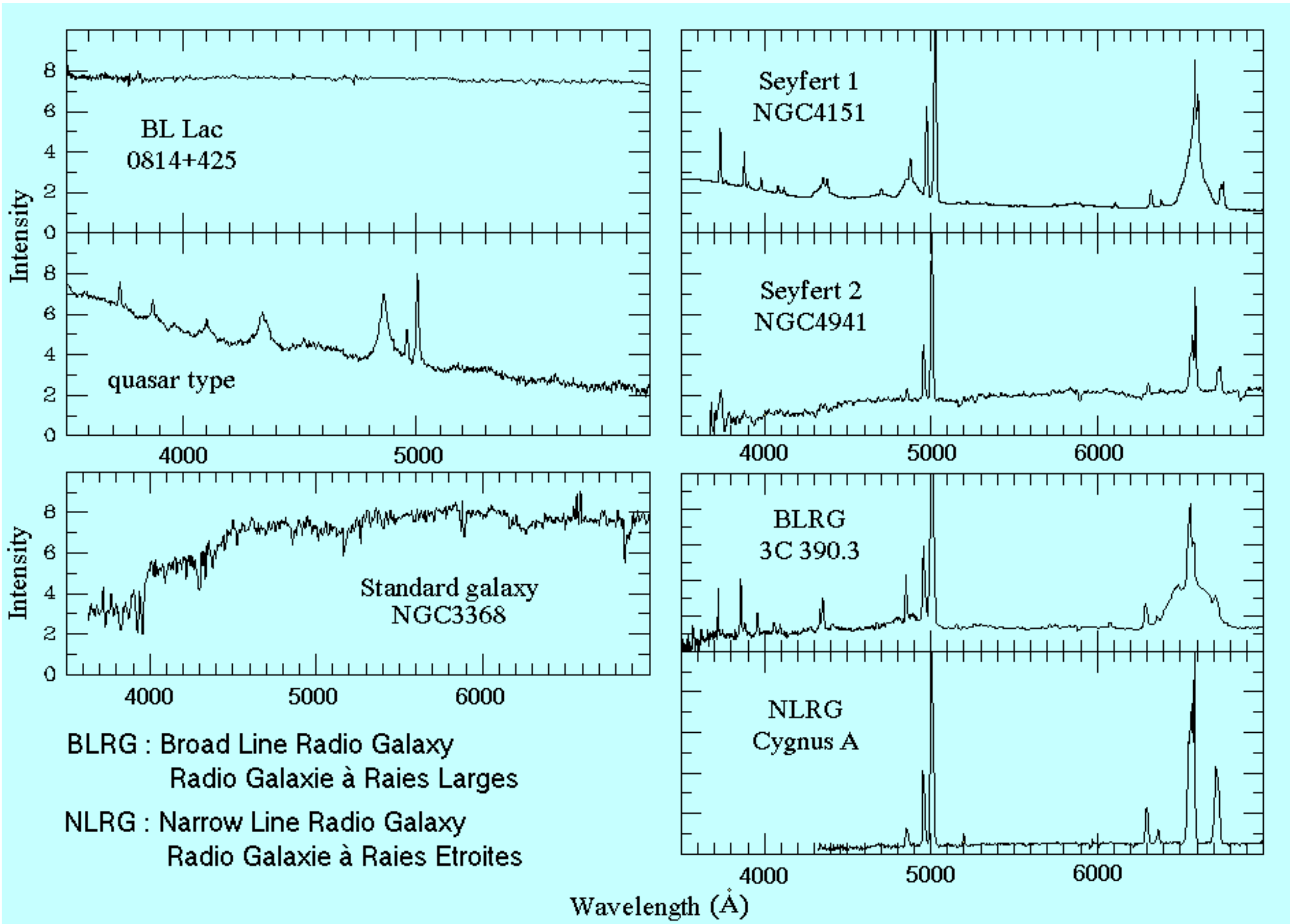
Radio Galaxies:

- In ellipticals
- Jets and large radio emitting lobes (ala synchrotron emission)

Blazars:

- Bright, extremely variable
- Little or no emission lines
- X-rays

Spectra of the Zoo Animals



Radio Galaxy Centaurus A

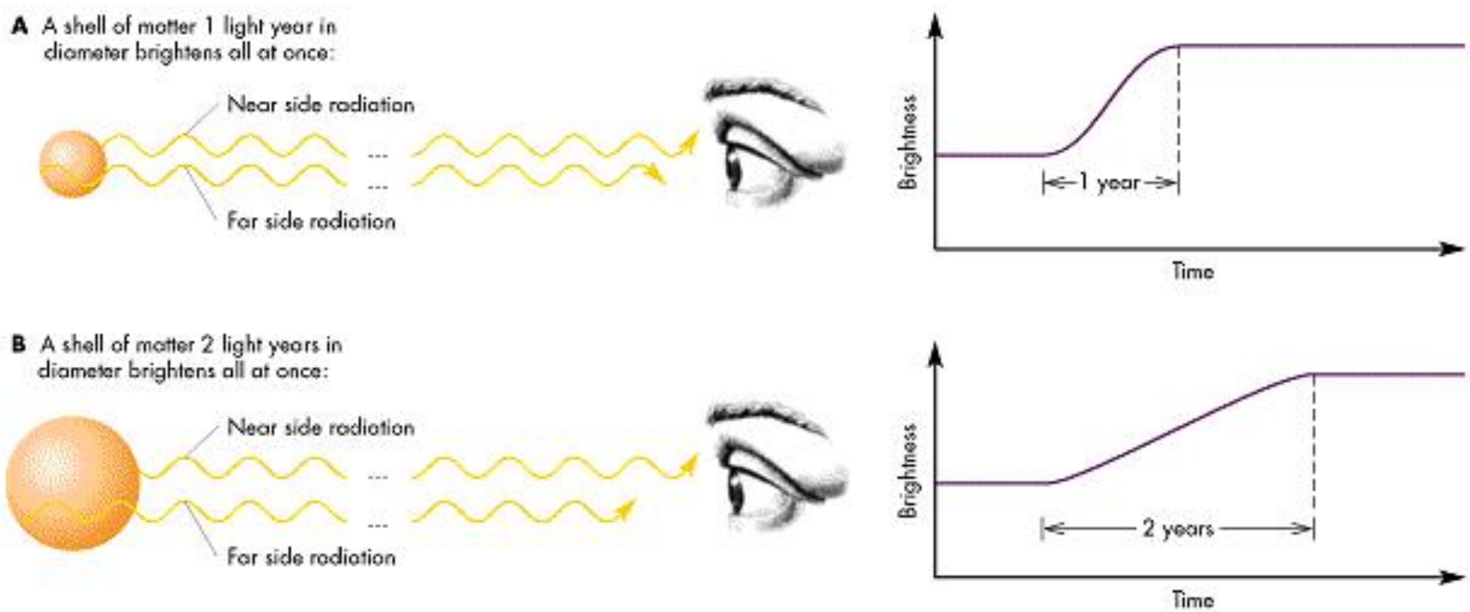
X-Ray (NASA/CXC/SAO)

Optical (AURA/NOAO/NSF)

Radio (NRAO/AUI)

Infrared (2MASS)

Sizes of AGN

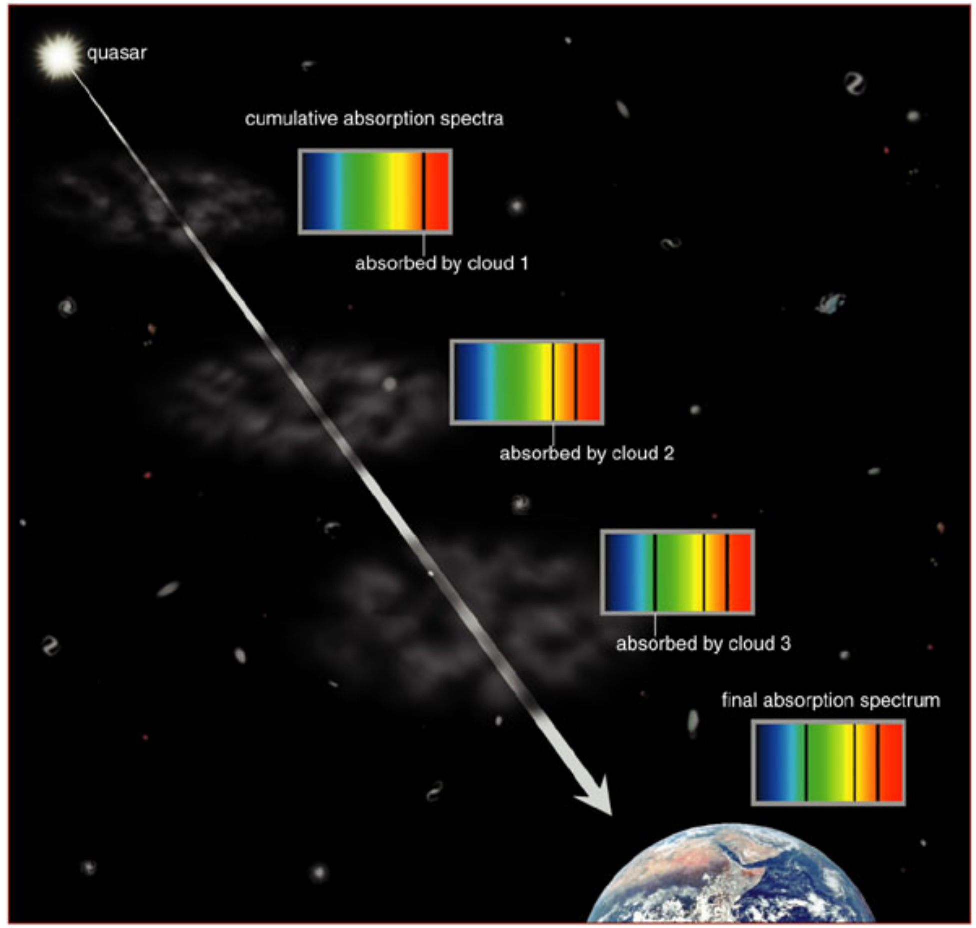

A A shell of matter 1 light year in diameter brightens all at once:
Near side radiation
Far side radiation
Brightness
1 year
Time
B A shell of matter 2 light years in diameter brightens all at once:
Near side radiation
Far side radiation
Brightness
2 years
Time

Quasars

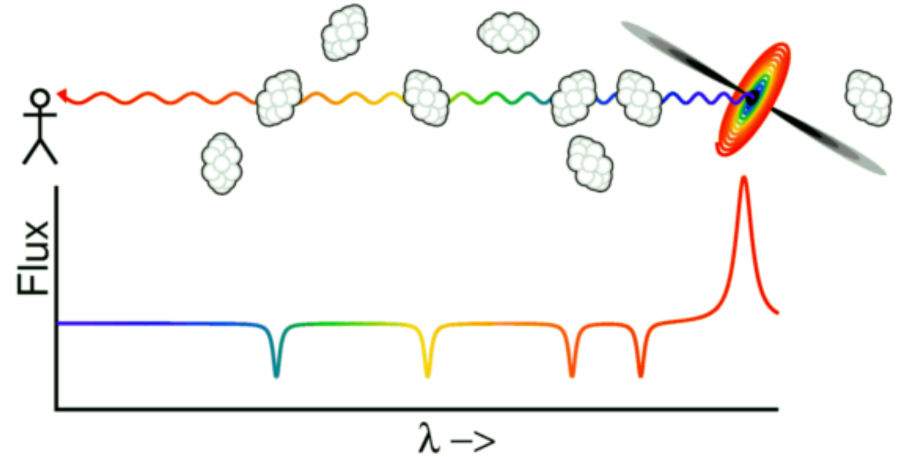
- Quasi-stellar radio sources: Radio sources that appear pointlike in visible light
- Extremely luminous at 10^{11} – 10^{15} L_o (note that L_{MW} ~ 10^{11} L_o)
- Broad and narrow spectral lines
- Lots of X-rays, UV, and blue light
- Rapid variations indicate that source size is compact (around a few pcs in extent)

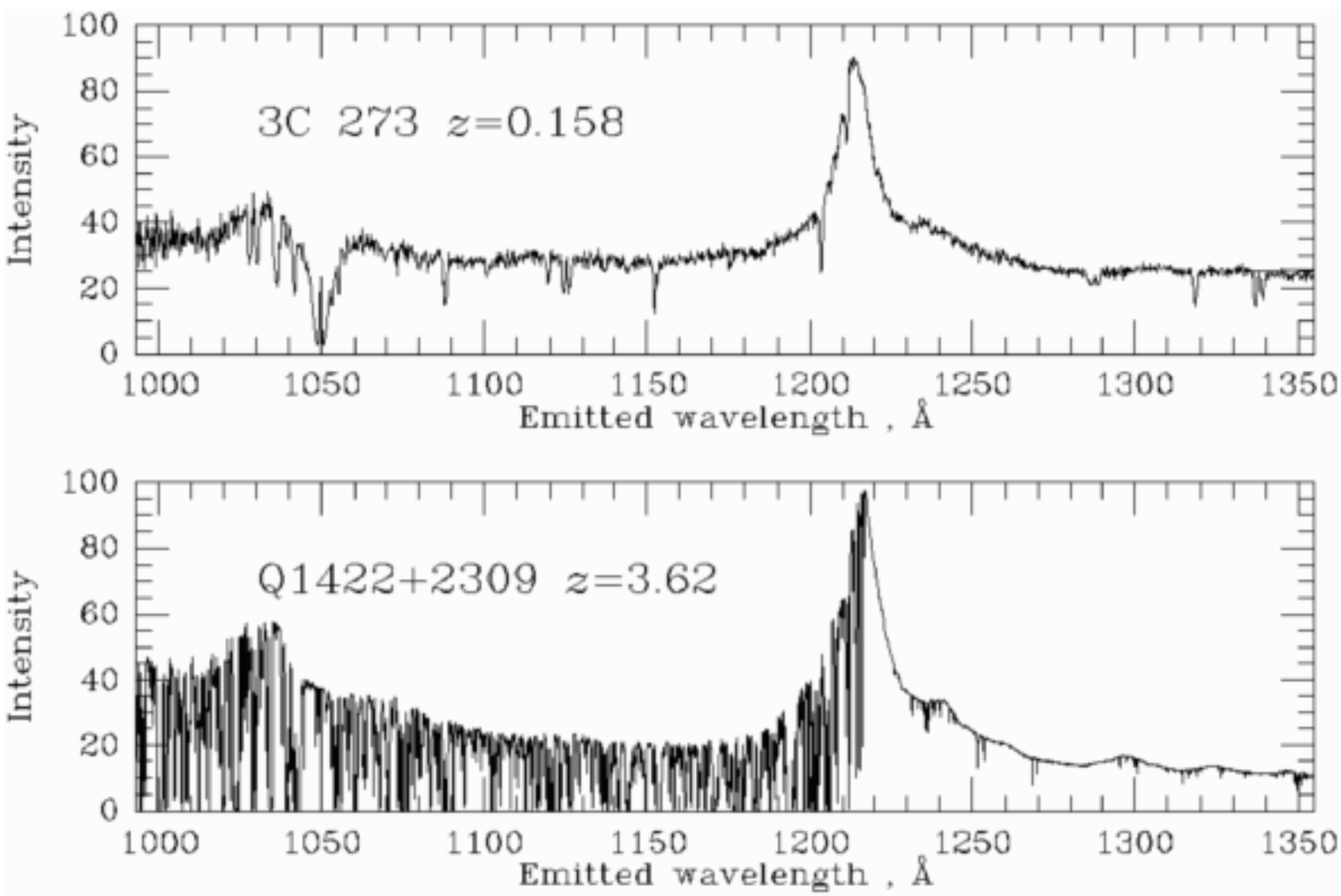
Aside on Quasars

Quasars are way super bright, and so they make excellent probes of gas throughout distant space

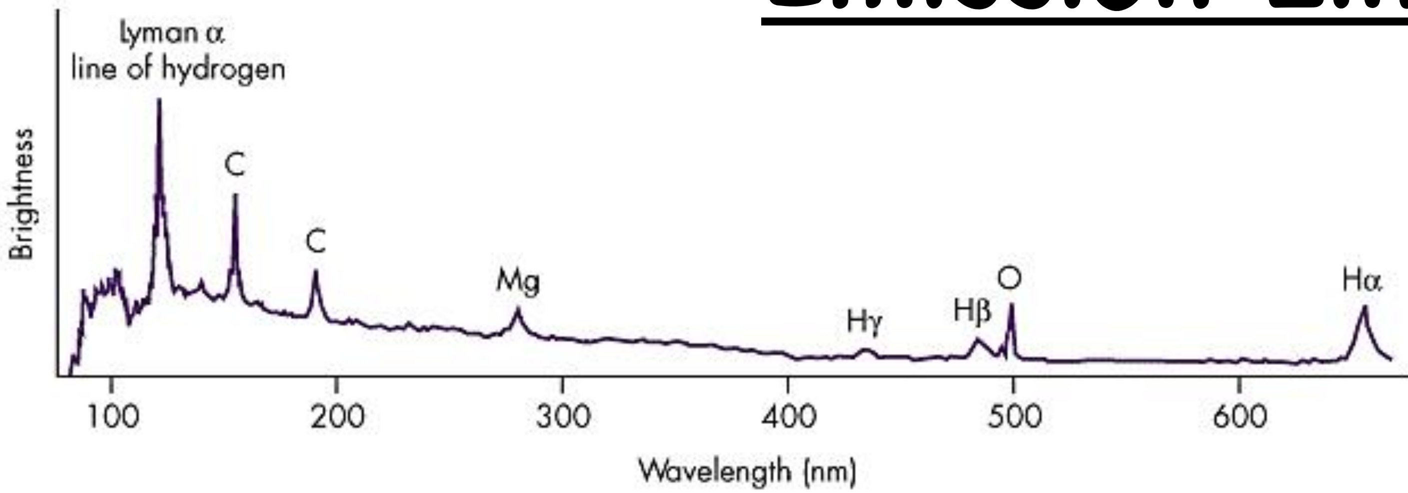


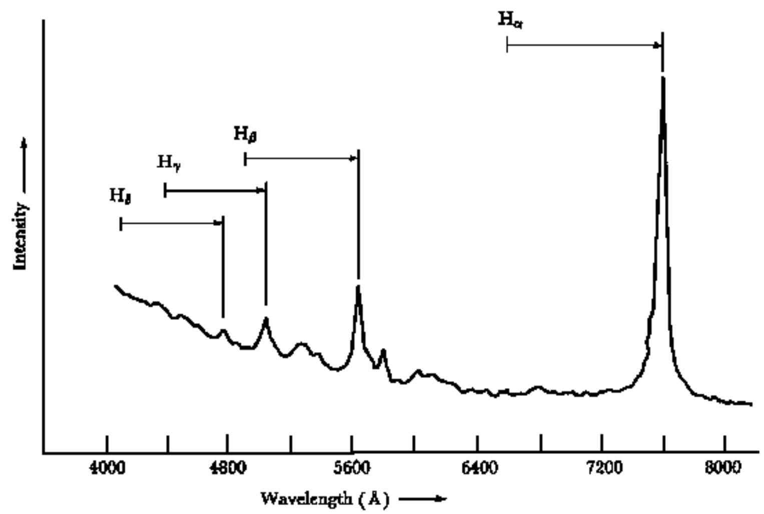
Lyman Alpha Forest



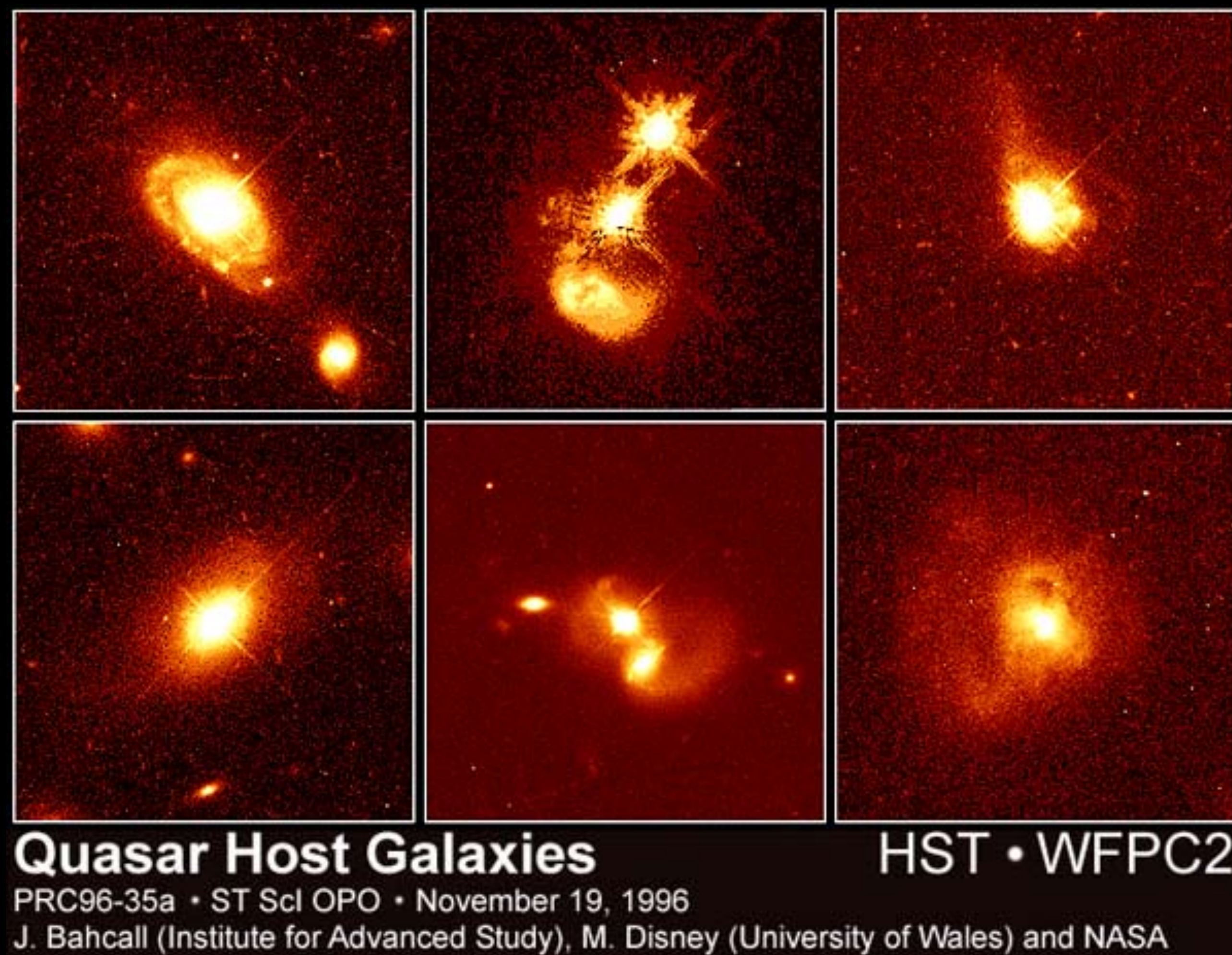


Quasar Spectra: Emission Lines





Quasar Hosts



Supermassive Black Holes

- How to get so much energy from so little space?!
- Infall of matter onto a BH can liberate gravitational energy to be emitted as light

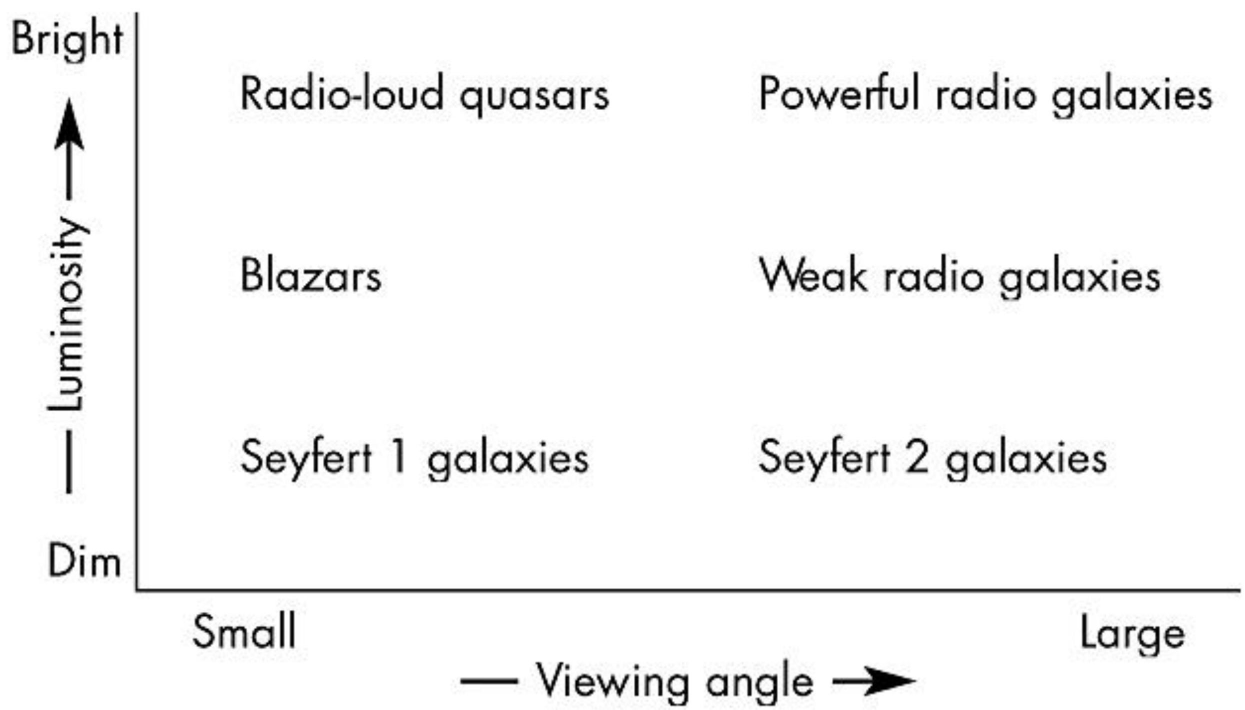
$$E = \frac{GM_{SB}m}{R_S}$$

$$L = \frac{\Delta E}{\Delta t} = \frac{GM_{SB}}{R_S} \times \left(\frac{\Delta m}{\Delta t}\right)$$

$$\text{but } R_S = \frac{2GM_{SB}}{c^2}, \text{ so}$$

$$L \approx 10^{13} L_o \times \frac{\Delta m}{\Delta t} \left(M_o / yr\right)$$

Ordering the Zoo



Getting the SBH Mass

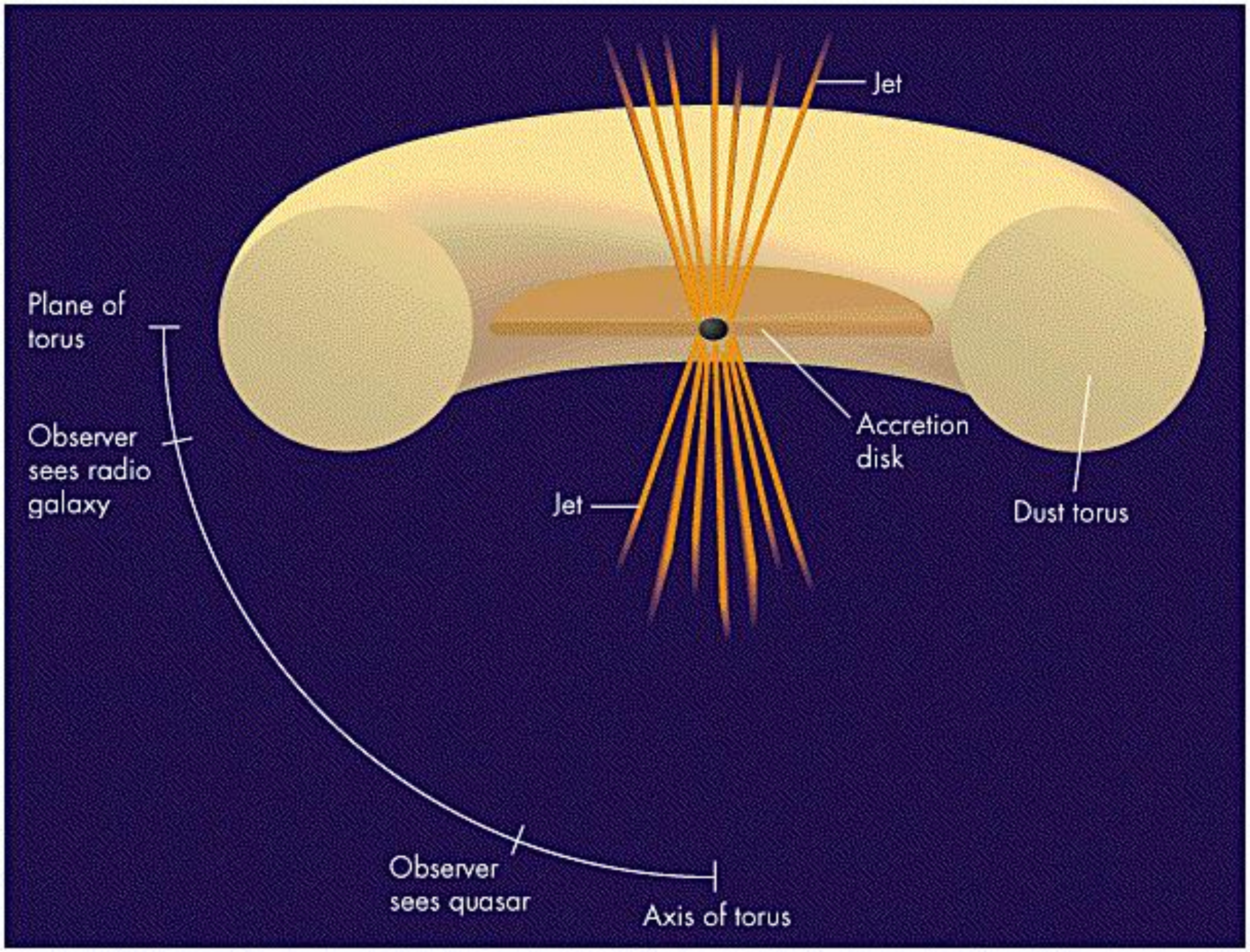
- One way to estimate the BH mass is to use the Eddington limit
- AGN are *incredibly* luminous, but the BH mass must be large enough so that gravity results in a net infall, hence the mass must exceed

$$M_{BH} \geq 30 \times 10^6 M_o \times \left(\frac{L}{10^{13} L_o} \right)$$

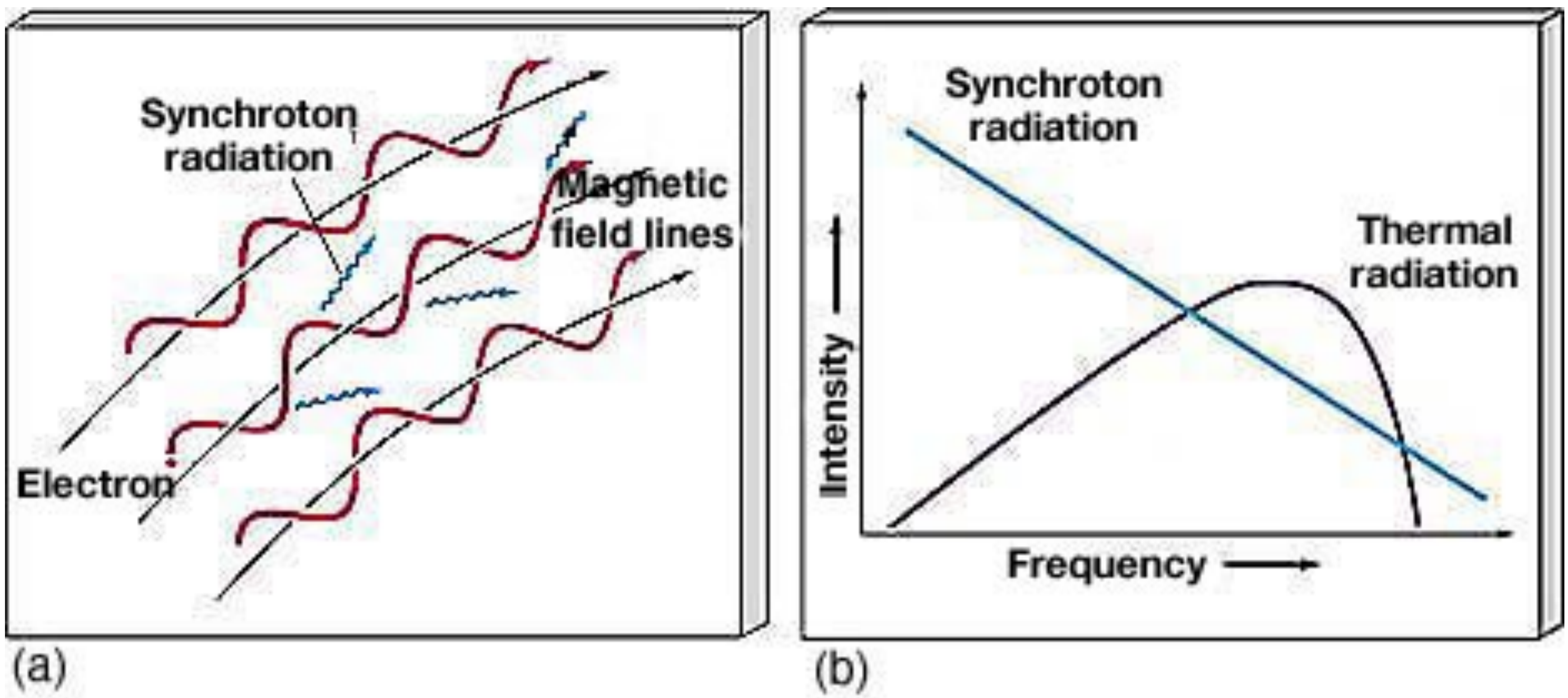
The Unified Model

- Gas material is “fed” to a central SBH by an accretion disk
- The disk glows to produce high luminosities
- Magnetic fields channel some gas along poles to make jets
- Zoo of AGN arise because of different SBH masses, feeding rates, and viewing perspectives

Illustration of AGN



Synchrotron: Magnetic Fields and Emission



How are ancient AGN related to galaxies today?