Supermassive Black Holes

Quasars, Blazars, Seyferts, Radio Galaxies ...

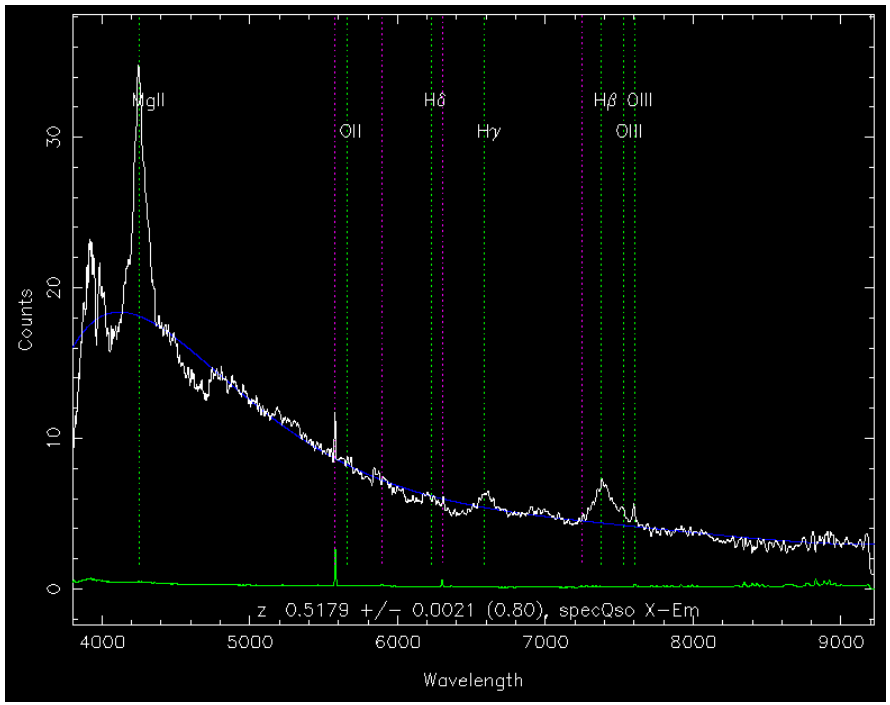
The Variety of AGN

- Active Galactic Nuclei show up in a many different forms:
  - Blazars/BL Lacs: starlike objects, high polarization, rapid variability, featureless spectrum
  - Seyfert Type I/II: spiral galaxies with abnormal emission lines and lots of gas in their nuclei.
  - Quasars: starlike objects, broad emission lines
  - Radio Galaxies: huge radio lobes emerging from a galaxy (often ellipticals)

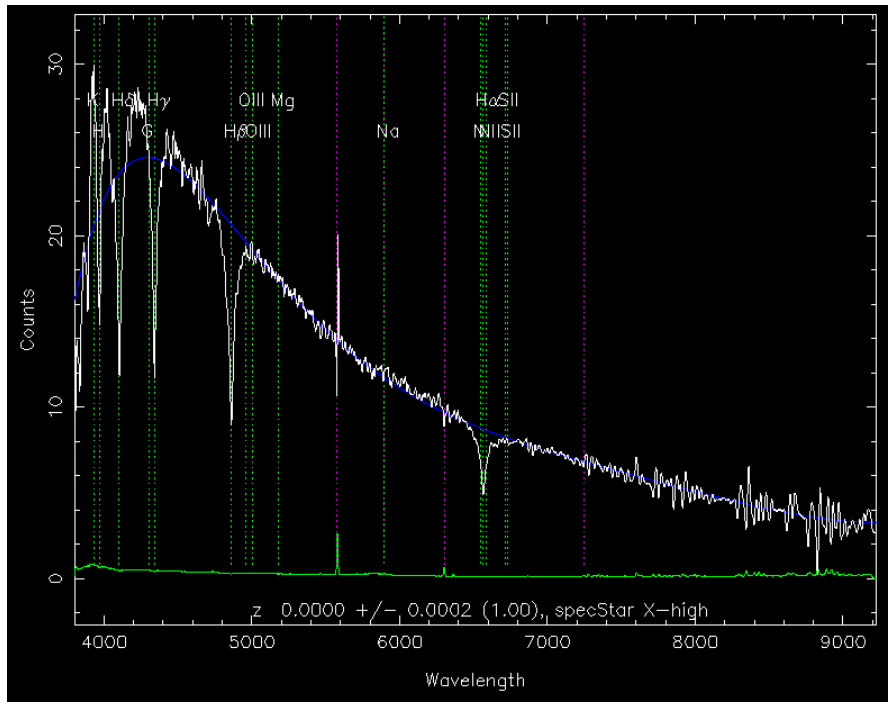
The Moieties of AGN

- Broad emission lines (~5000 km/s) in all AGNs
- Broad absorption lines (~30000 km/s) in 10% of quasars
- Highly ionized outflow (~1000 km/s) narrow absorption lines in 50% of Seyferts
- Featureless, highly polarized, “synchrotron” emission in blazars
- Polarized broad emission lines in Seyfert 2
- Scattered x-ray emission in iron lines with widths similar to the broad absorption lines

The Emissivities of AGN (1)



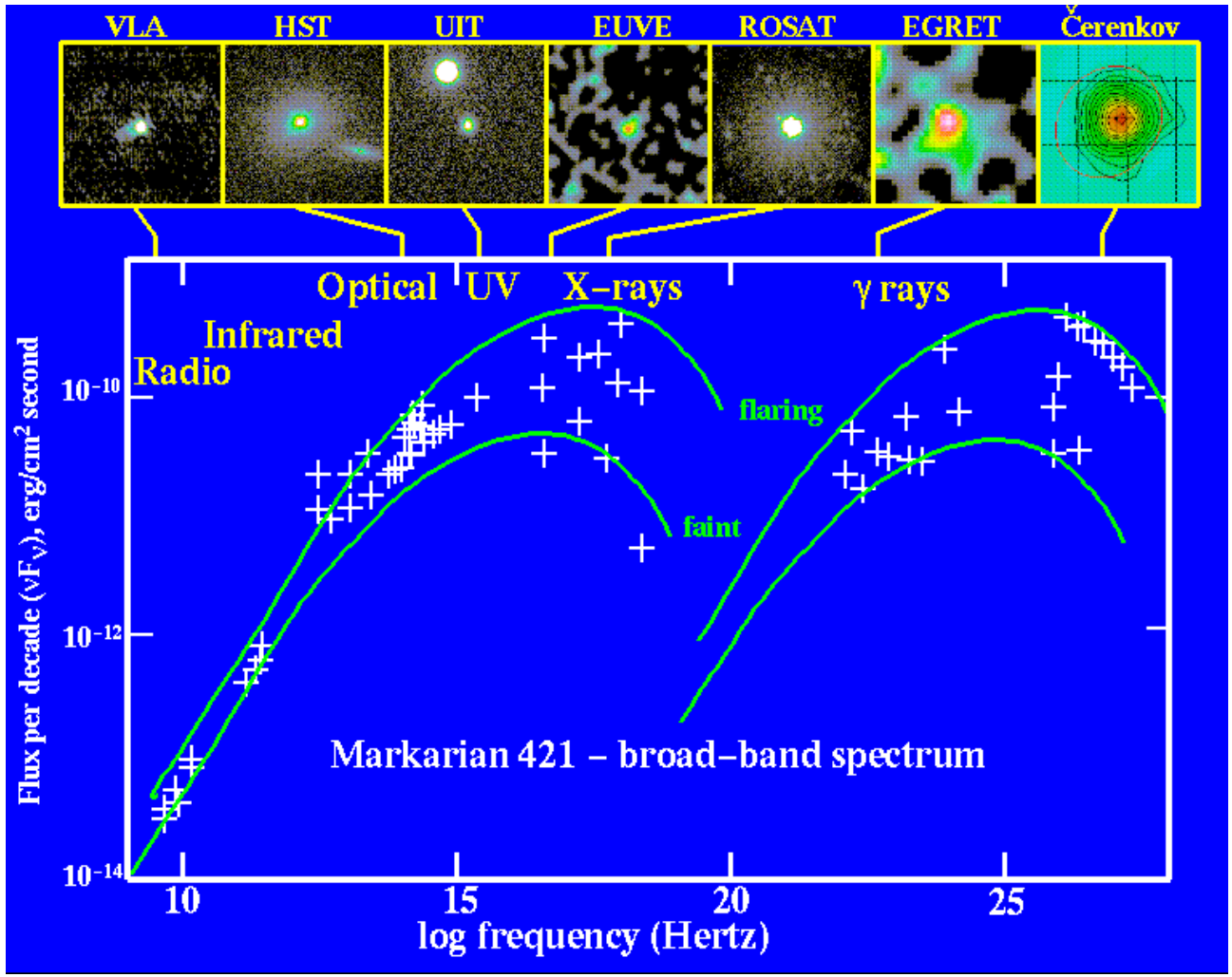
Quasar



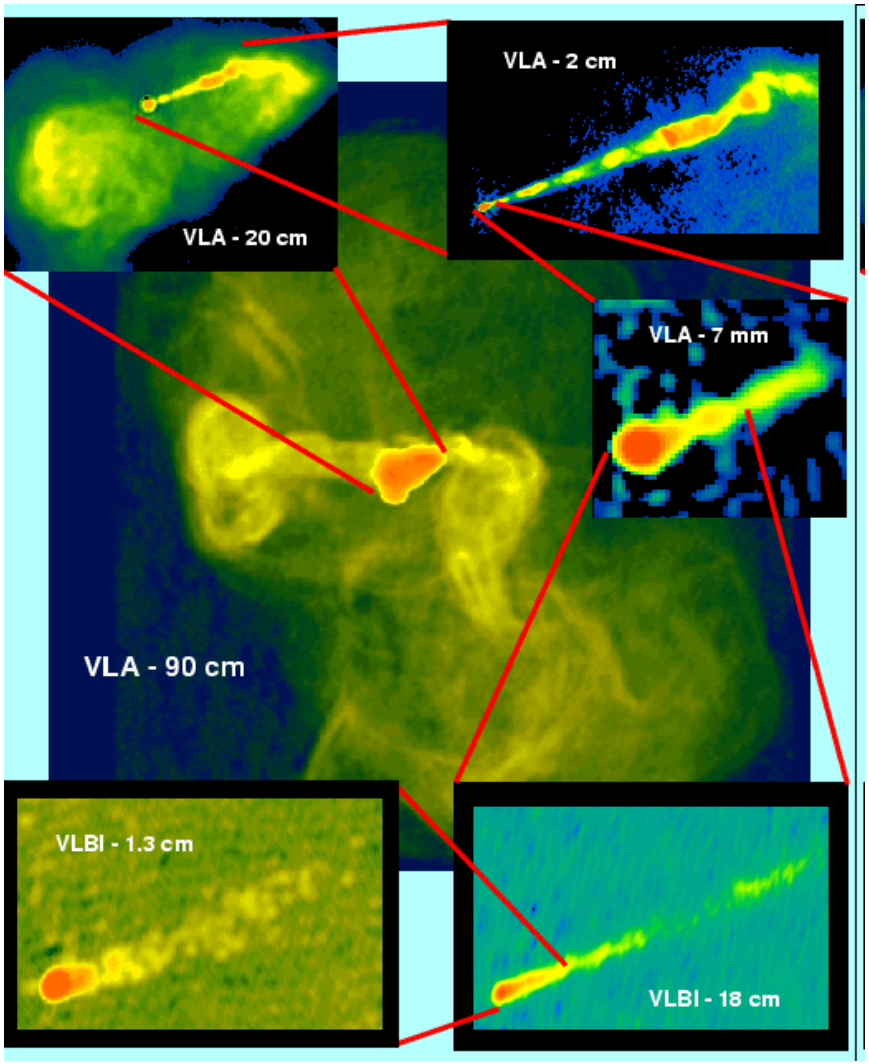
Star

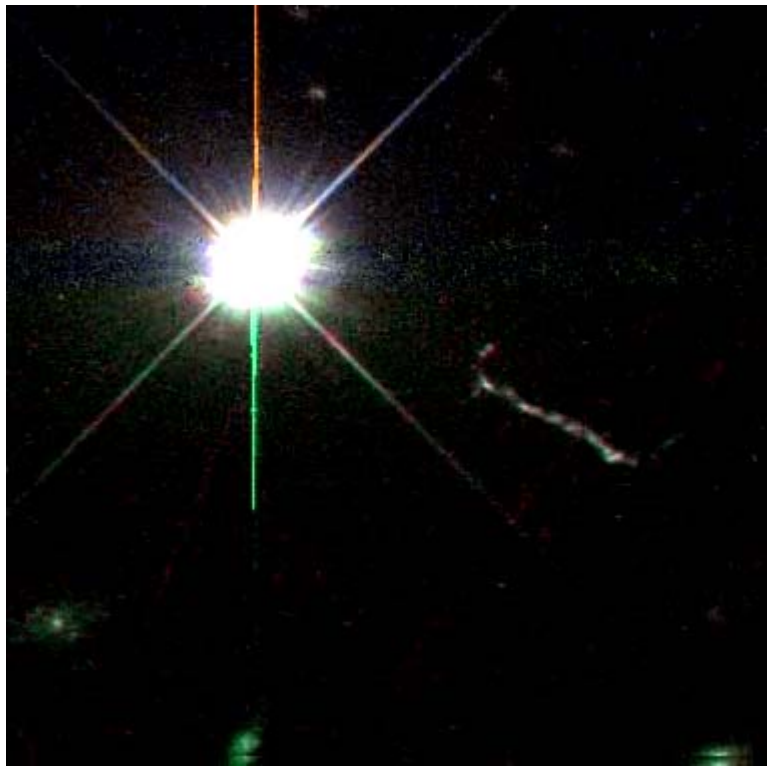
The Emissivities of AGN (2)

The nearby Blazar Markarian 421 emits lots of radiation at every energy that we have looked!



The Emissivities of AGN (3)





3C 273 - the first quasar

M87 - a nearby radio galaxy in Virgo

The Propensities of AGN

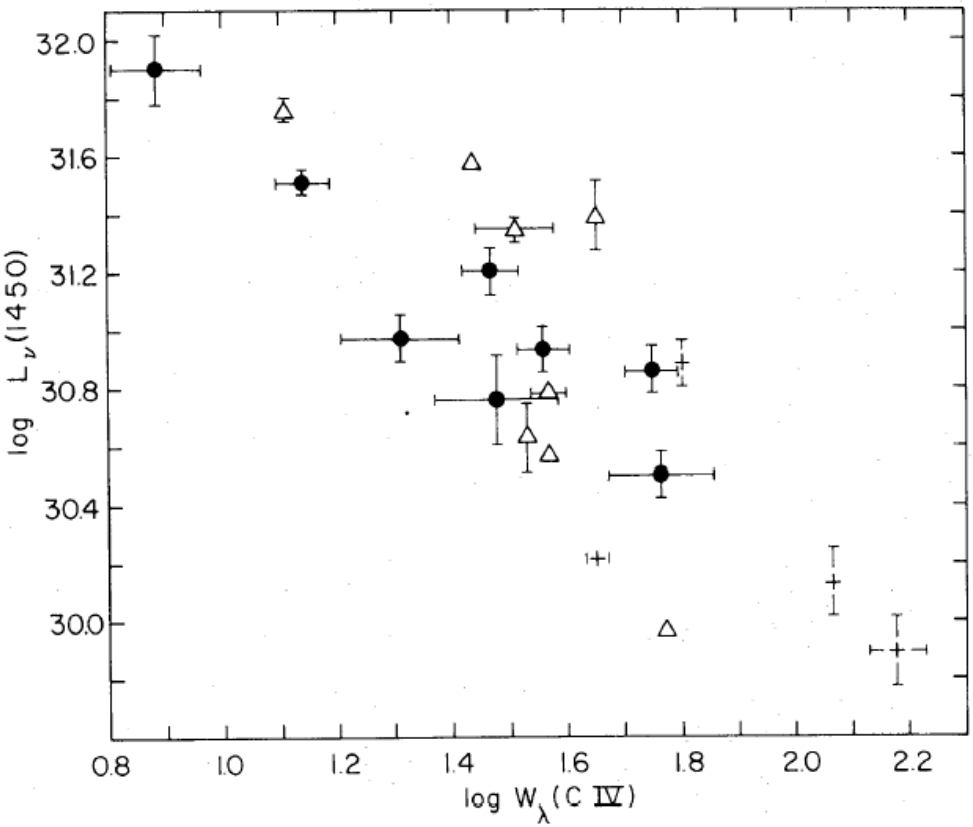
- No objects exhibit all of these features.
- AGN do follow certain trends that cause astrophysicists to believe that they are comprehensible.
  - The proportions of the different behaviors indicate a geometric explanation.
  - Baldwin Effect

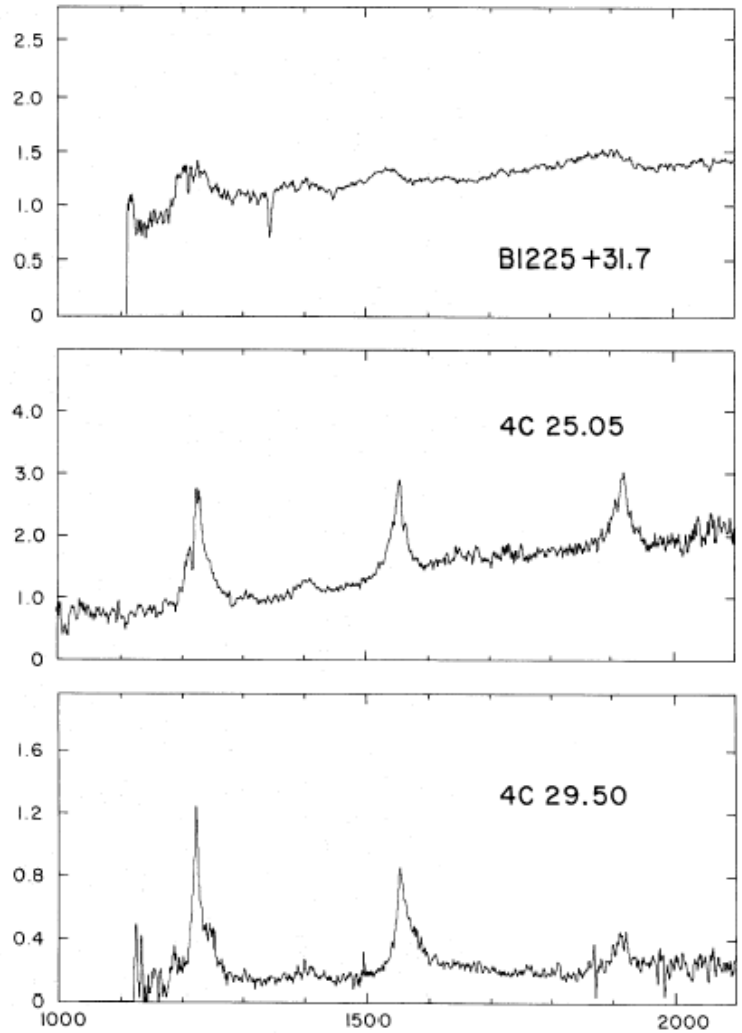
The Baldwin Effect (1)

Increasing Luminosity (UV)

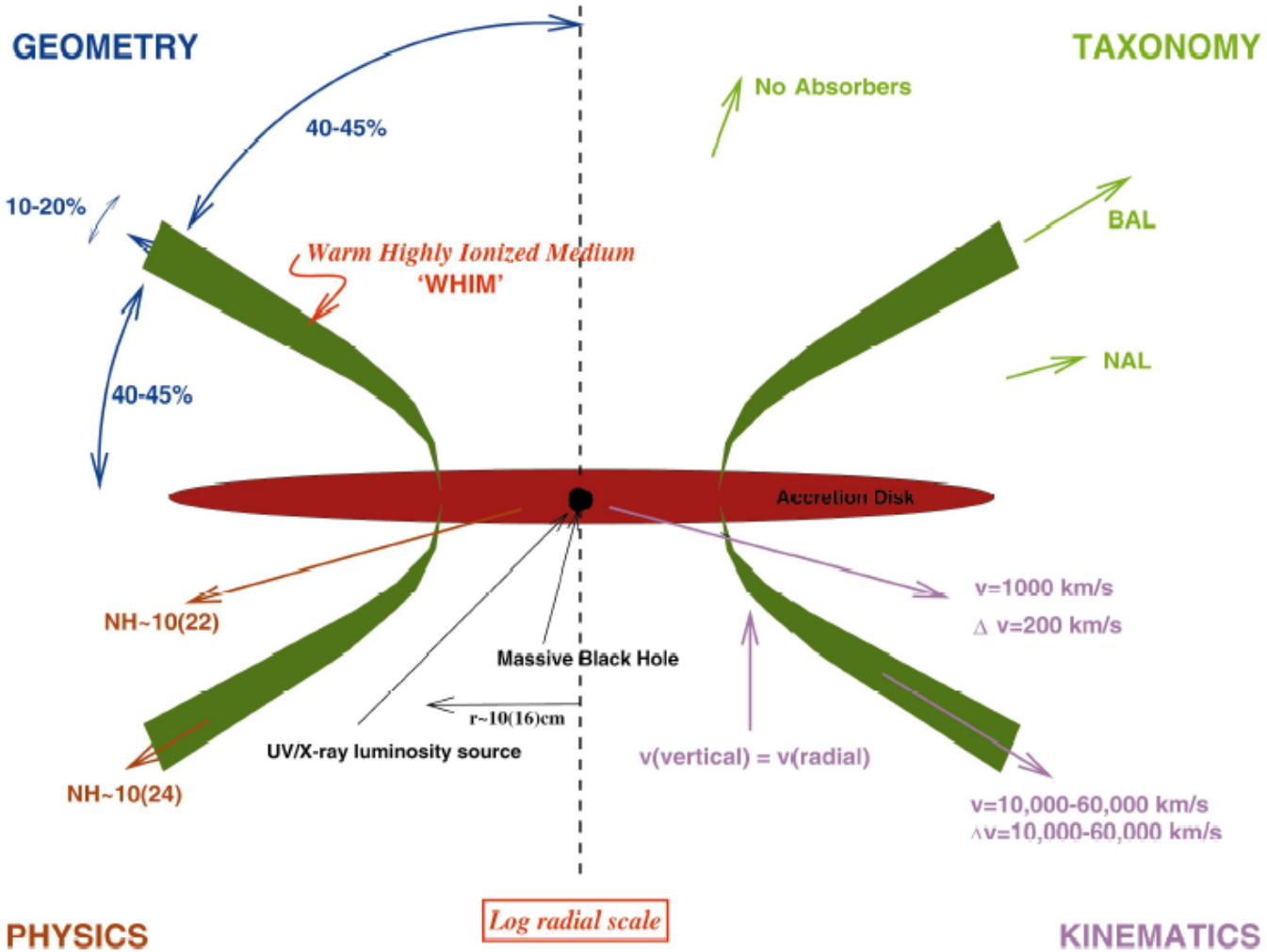
~~Increasing Age~~ Decreasing CIV Equivalent Width

The Baldwin Effect (2)

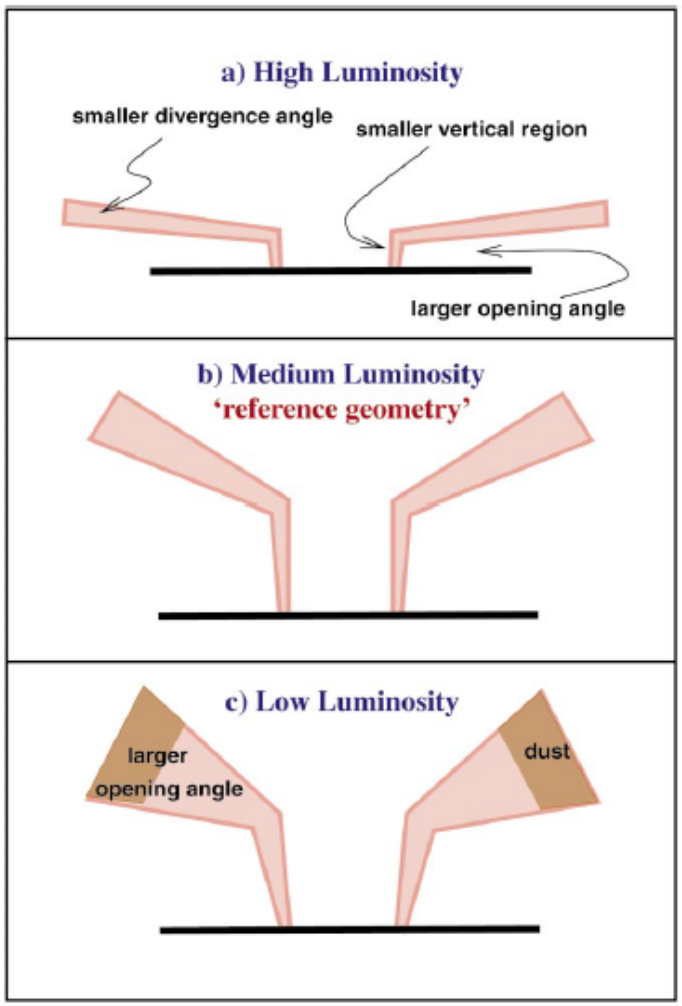


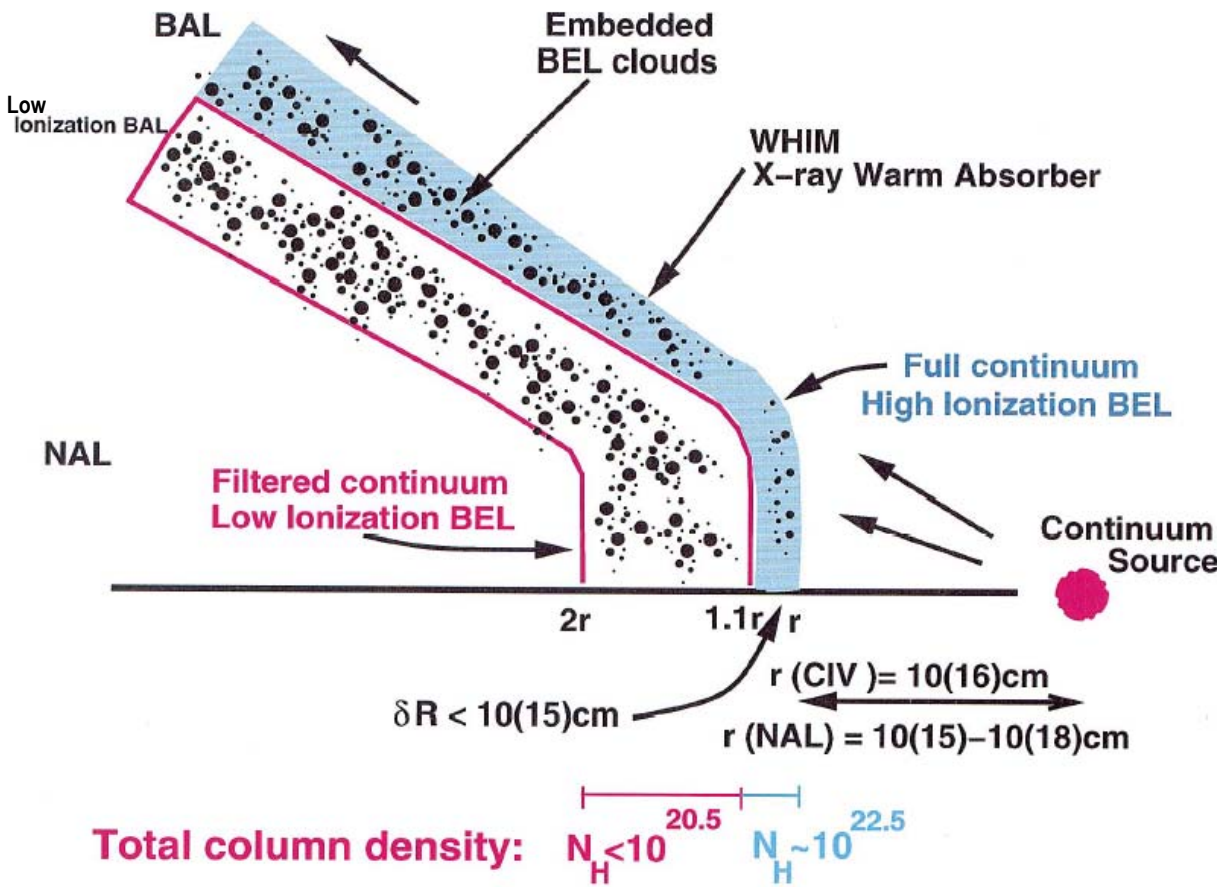


The Totality of AGN (1)



The Totality of AGN (2)



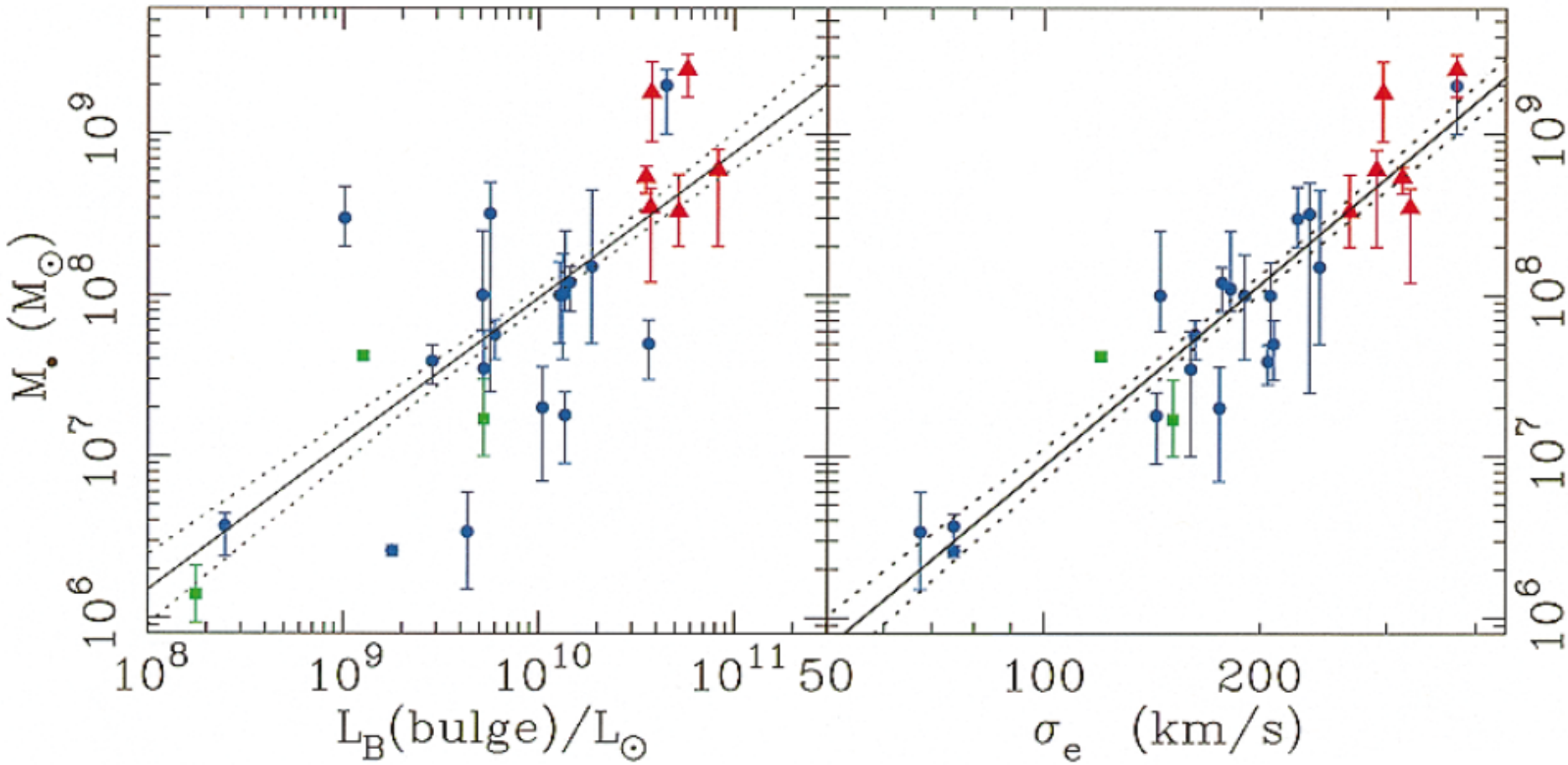


The Ubiquity of AGN (1)

- Big black holes seem to be in nearly every decent-sized galaxy but only a smaller fraction are getting fed at any time. This fraction was larger in the past.
- If central black holes are so common in galaxies, maybe they have something in common with galaxies.

The Ubiquity of AGN (2)

- Black-Hole-Bulge Relation

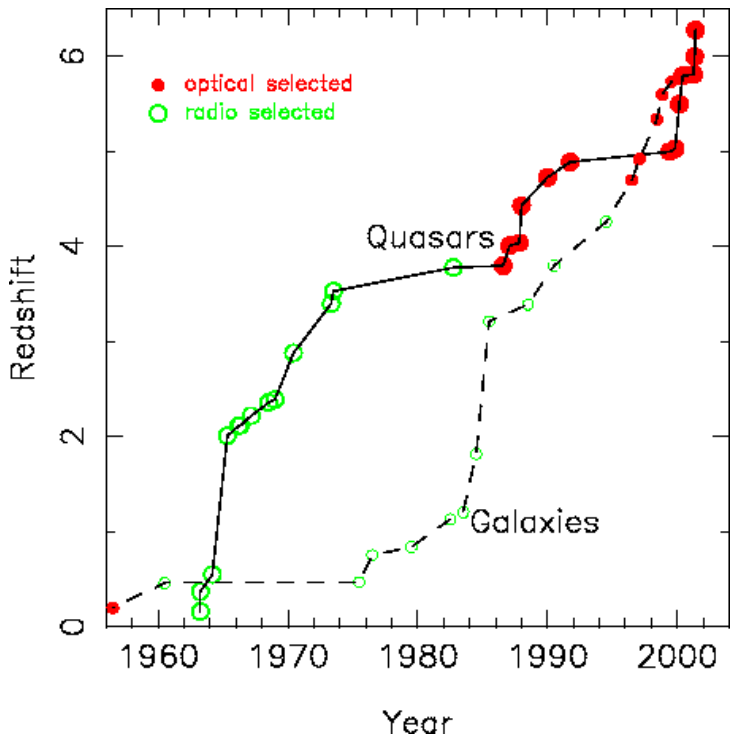


The Ubiquity of AGN (3)

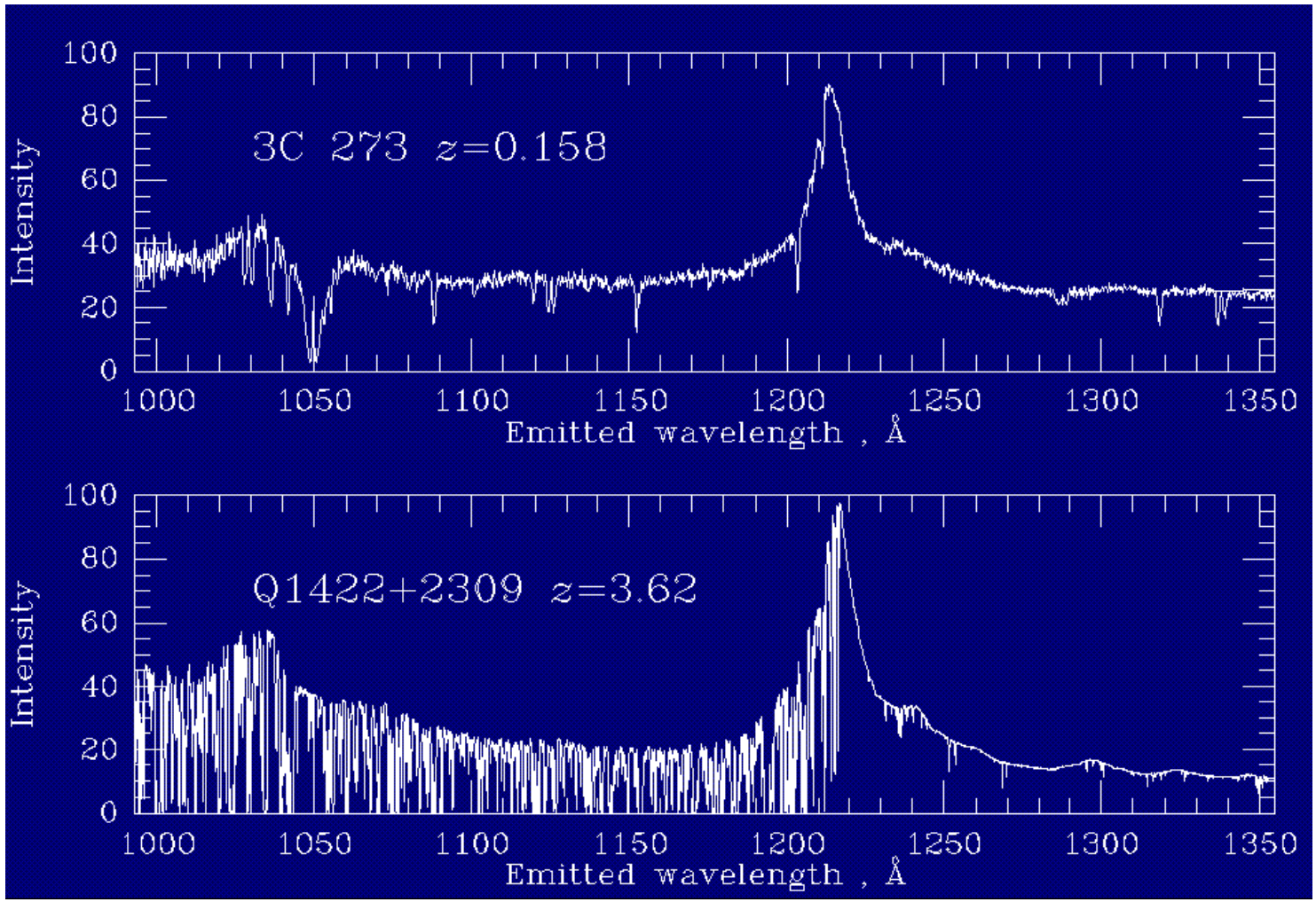
- The relationship between the black-hole mass v. bulge velocity dispersion is tighter than other galaxy scaling laws:
  - Faber-Jackson relation
  - Tully-Fisher relation
  - Fundamental plane
- How black holes are fed, grow and merge is inexorably connected with galaxy formation.

The Commodities of AGN (1)

- AGN are the most consistently bright objects in the universe. They probe what's happening in their vicinity and along the line of sight.
- The Gunn-Peterson Effect
  - "It is observed that the continuum of the source continues to the blue of Ly-α (in 3C9, z=2.01)"
  - "only about one part of 5×10^6 of the total mass at that time could have been in the form of intergalactic neutral hydrogen "

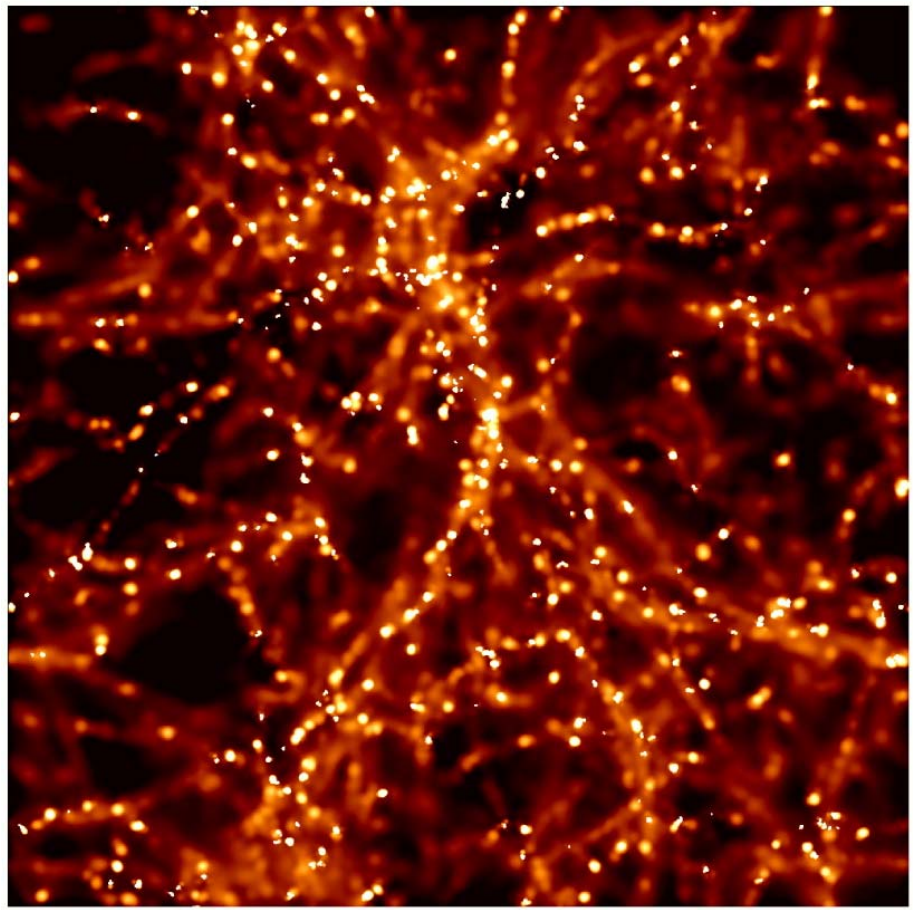


The Commodities of AGN (2)



The Commodities of AGN (3)

- Absorption lines in QSO spectra
  - Damped-Lyman Alpha Systems: ($N_H > 10^{20.3}$ cm^{-2})
  - Lyman Limit Systems: ($N_H > 10^{17.2}$ cm^{-2})
  - Lyman-Alpha Forest: ($N_H < 10^{17}$ cm^{-2})



The Commodities of AGN (4)