35 Astro notes 2018/11/19 - Mon - Active Galactic Nuclei - as observed

35.1 Disk temperature

By using the efficiency parameter we were able to write the luminosity of the disk as

$$L_{\text{disk}} = \eta \dot{M} c^2$$

But what about the temperature of the disk? Paradoxically, AGN actually have lower temperature disks than neutron stars or stellar mass black holes. The reason for this can be seen by first assuming that the characteristic disk size is R_S. Then the disk energy balance:

$$2\pi R^2 \sigma T_{disk}^4 = \frac{GM\dot{M}}{R} \quad \Longrightarrow \quad T^4 \propto \frac{M\dot{M}}{R^3}$$

becomes

$$T^4 \propto \frac{\dot{M}}{M^2} \quad \text{for } R = R_s \propto M$$

Then if we assume that the accretion rate is some fraction of the edddington accretion rate $L_{disk} = f_{ed} L_{Ed}$ where

$$L_{Edd} = \frac{4\pi Gc}{\kappa} M$$

then we can form the eddington accretion rate:
(Student: equate and solve form $\dot{M}$)

$$\dot{M}_{Edd} = \frac{f_{\text{Edd}}}{\eta} \frac{4\pi G}{\kappa c} M$$

where κ is the average opacity, related to the amount of photon pressure on a g/cm^2 of material. This then gives

$$T_{disk}^4 \propto \frac{1}{M}$$

so that the disk temperature actually decreases with increasing black hole mass.

Supermassive black hole accretion disks tend to have temperatures around 10^5 so that emission peaks in the UV.

35.2 The Unified Model

While this gives us a central engine, we still need to explain how it can lead to the variety of phenomenology that is seen. Most notably the narrow/broad line dichotomy, and the correlation of broad lines with bright objects. This is explained by the so-called "Unified Model", which basically says that most AGN are surrounded by a dusty torus at large radii that can obscure the AGN, so that the accretion disk is only visible from certain angles.

AGN that show broad lines are ones for which we can actually see the disk, with its large range of orbital speds.

AGN that only show narrow lines are ones for which the accretion disk itself is obscured. However, gas at high distances that is ionized by the AGN is still visible, and gives the narrow emission lines.

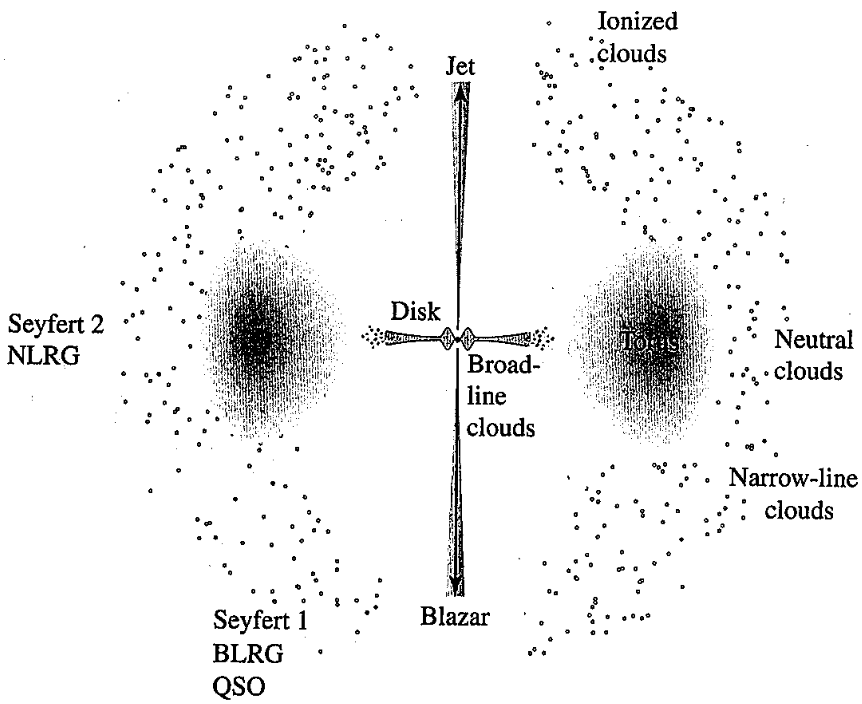


FIGURE 28.25 A sketch of a unified model of an active galactic nucleus. The jets would be present in a radio-loud AGN. A typical observer's point of view is indicated for AGNs of various types.

35.3 The broad view of AGN spectra

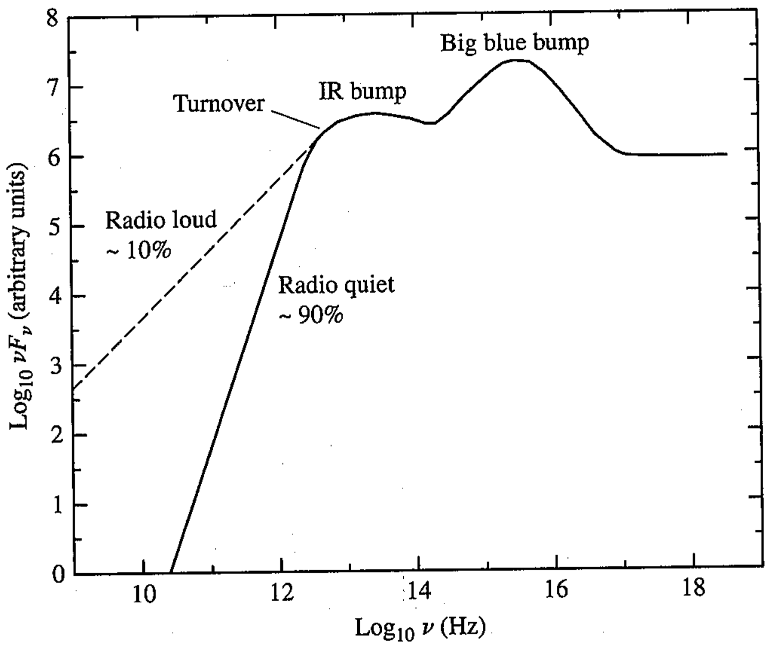


FIGURE 28.4 A sketch of the continuum observed for many types of AGNs.

AGN spectra are typically plotted in νF_ν vs $\log \nu$. This is done because it allows integration by eye:

$$L_{interval} \propto \int_{\nu_1}^{\nu_2} F_\nu d\nu = \int_{\nu_1}^{\nu_2} \nu F_\nu \frac{d\nu}{\nu} = \ln 10 \int_{\nu_1}^{\nu_2} \nu F_\nu d \log_{10} \nu$$

The major features in the spectrum include:

- The big blue bump, from the accretion disk (most likely)
- The IR bump, from the dust torus
- The underlying continuum from synchrotron emission

Syncrotron emission, powering the underlying continuum, comes from high energy (high speed) electrons spiralling in a magnetic field. The power-law slope of the spectrum is derived from the power-law distribution of electron energies.

35.4 Jets and Radio Lobes

AGN accretion disks or black holes appear capable of accelerating particles to relativestic speeds in the form of jets. These then interact with the intergalactic medium to create huge radio lobes. Sizes can range up to thousands of kpc or nearly a Mpc.

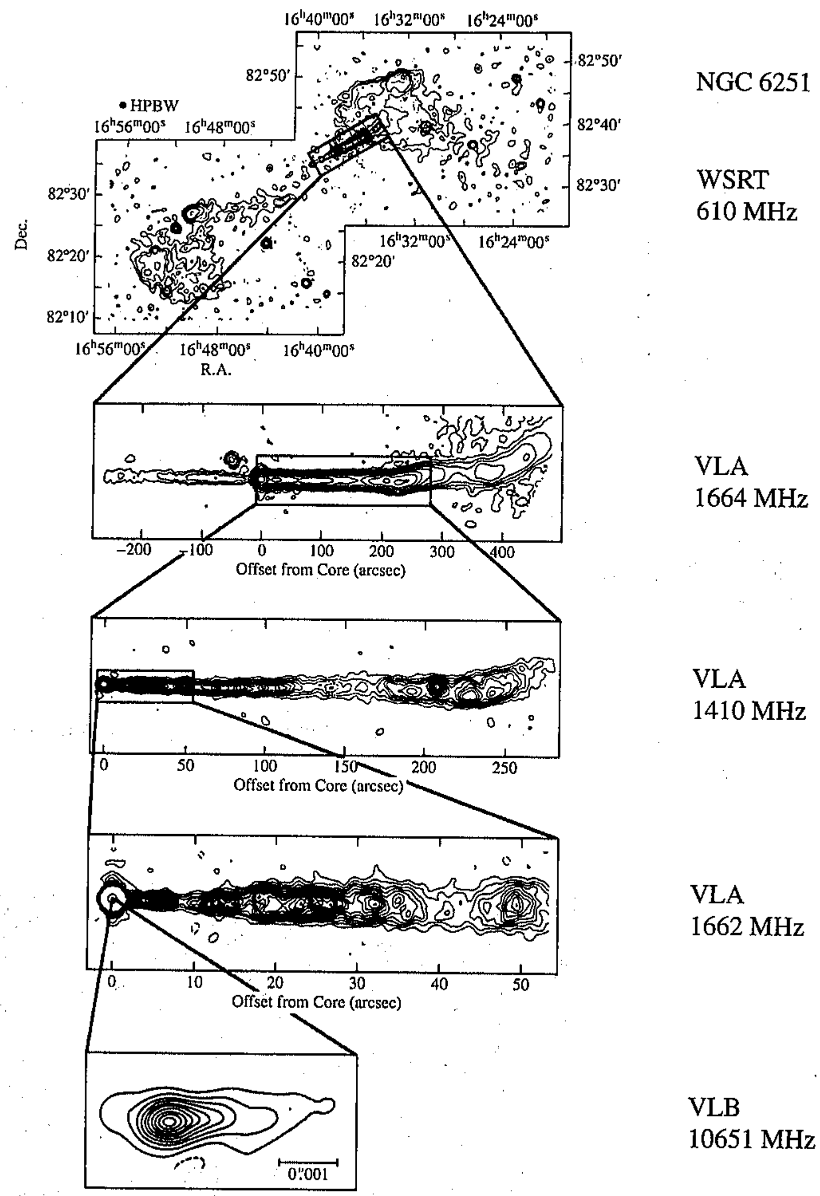


FIGURE 28.8 The jet and counterjet (second panel) of the radio galaxy NGC 6251. (Figure adapted from Bridle and Perley, *Annu. Rev. Astron. Astrophys.*, *22*, 319, 1984. Reproduced by permission from the Annual Review of Astronomy and Astrophysics, Volume 22, ©1984 by Annual Reviews Inc.)

The mechanism of launching these jets and accelerating the particles in them is not well understood.

The high speeds of the outflows are confirmed by superluminal motion of knots in the jets of some sources. This is caused by material moving at relativistic speeds toward the observer such that the projected motion on the sky is higher than c.

35.5 Quasars and the mass structure of the universe

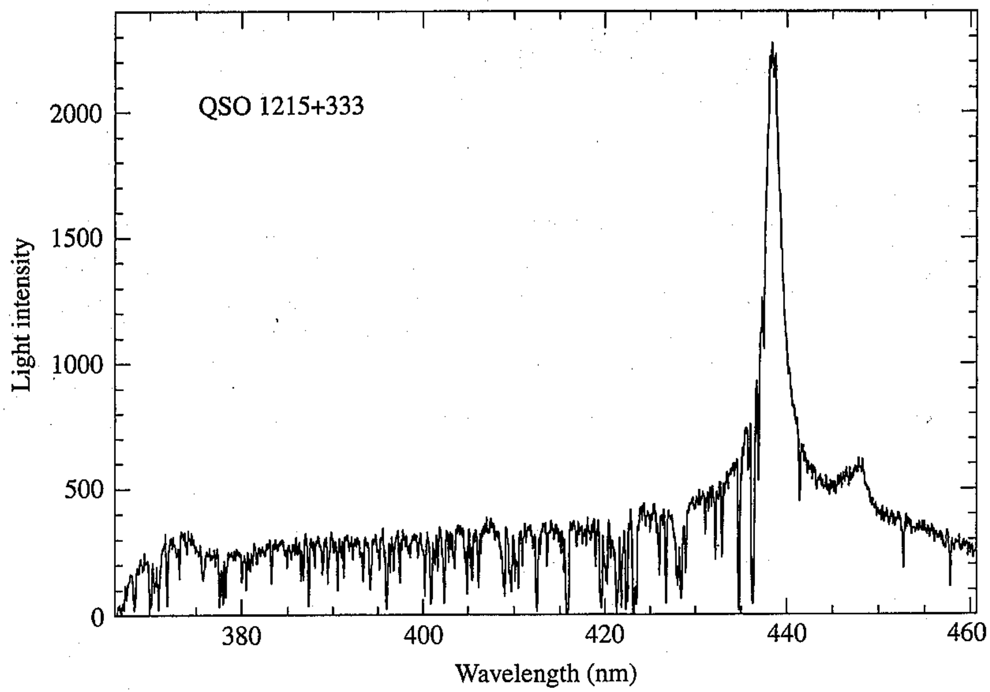
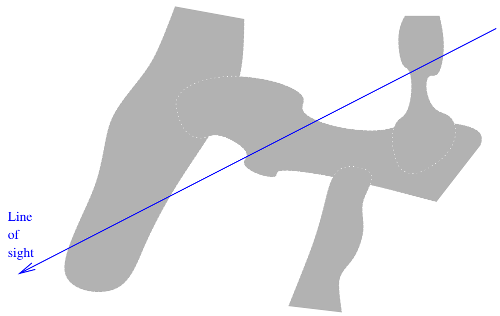


FIGURE 28.41 The strong Lyα emission line in the spectrum of QSO 1215+333, with the Lyα forest of absorption lines at shorter wavelengths. (Adapted from a figure courtesy of J. Bechtold, Steward Observatory, University of Arizona.)

The spatial structure of gas in the universe can be inferred partially from the absorbtion features in the spectra of distant quasars. The large emission feature here is a broad Lyman α emission line. As this light passes through the universe between the quasar and us, if the gas density is high enough it will absorb some light at the wavelength corresponding to the redshift of the absorbing cloud. Since Ly α is very easily obsorbed, this provides a sensitive probe of the structure (spatial distribution) of gas along the line of sight to the quasar.

This can also be extended to metal species (carbon, magnesium) to understand which parts of the intergalactic medium have been "polluted" by outflows from places where stars have formed. This provides an ongoing puzzle since the metal-enriched regions extend much farther than was expected, but modern simulations are improving the match.



Light records th expansion factor (R) at the time of passage through the absorbing gas in the redshift of the line.