AGN

1.2 - AGN Classification and Unification

(Netzer chapter 6)
Questions to be considered for AGN classification

Group 1

• What is the power-house of the source?
• What is the SED of the source?
• What are the properties of the host galaxy?
• What is the inclination of the source to the observer’s line of sight?
• What is the phase of activity and the amount of gas supply to the center?
Group 2

- What is the BH mass?
- What is the spin of the BH?
- What is the accretion rate?
- What is the gas and dust content, and the metallicity, in the nuclear region?
- What are the properties of the host galaxy?
Group 3

• What is the intensity and EW of the observed emission lines?
• What is the typical width of the observed emission lines?
• What is the level of ionization of the line-emitting gas?
• How strong is the radio source?
• Can we see beamed, nonthermal radiation, and at what energies?
• Is there evidence for central obscuration?
• What are the variability amplitude and time scale?
1.2.1 – Diagnostic Diagrams
The AGN family

- Seyfert Galaxies
- Star-forming Galaxies
- LINERs
1.2.2 - Type I and Type II AGNs

- Spectropolarimetry
- X-ray absorption
- Ionization cones
- Real type-II?
Figure 6.2. Spectropolarimetry of the type-II source NGC 2110 (from Tran, 2010; reproduced by permission of the AAS). The top panel shows the “normal” spectrum of a typical type-II AGN with strong narrow emission lines. The central panel shows the percentage polarization, and the bottom panel is the polarized light obtained only by multiplying the two upper panels by each other at every wavelength. The bottom panel is the angle of polarization. The polarized light shows a typical type-I spectrum with a broad, double-peak Hα line confirming the presence of a continuum source, and broad emission lines, behind the obscuring material.
X-Ray absorption

Figure 6.3. X-ray spectra of two type-II AGNs with very large obscuring columns (from Winter et al., 2009; reproduced by permission of the AAS).
Ionization cones
NGC 5252 position 1, FOS 0.26" aperture

Flux, $10^{-16}$ ergs cm$^{-2}$ s$^{-1}$ Å$^{-1}$

Wavelength, Å

Figure 1.3. The spectrum of the low-luminosity, low-redshift type-II AGN NGC 5252 (courtesy of Zlatan Tsvetanov).
While most AGNs show some radio emission, there seems to be a clear dichotomy in this property. It is therefore customary to define the “radio loudness” parameter, $R$, which is used to separate radio-loud from radio-quiet AGNs. $R$ is a measure of the ratio of radio (5 GHz) to optical (B-band) monochromatic luminosity,

$$ R = \frac{L_v(5 \text{ GHz})}{L_v(4400 \text{ Å})} = 1.36 \times 10^5 \frac{L(5 \text{ GHz})}{L(4400 \text{ Å})} . $$

(1.6)
where $L(5 \text{ GHz})$ and $L(4400 \text{ Å})$ represent the value of $\lambda L_\lambda$ at those energies. The dividing line between radio-loud and radio-quiet AGNs is usually set at $R = 10$. Statistics of a large number of AGNs show that about 10 percent of the sources are radio loud, with some indication that the ratio is decreasing with redshift.

Much of the radio emission in radio-loud AGNs originates in a pointlike radio core. The spectrum of such core-dominated radio sources suggests emission by a self-absorbed synchrotron source (Chapter 2). Except for the self-absorption low-frequency part, the spectrum is represented well by a single power law, $F_\nu \propto \nu^{-\alpha_R}$. Sources with $\alpha_R < 0.5$ are usually referred to as flat-spectrum radio sources, and those with $\alpha_R > 0.5$ are steep-spectrum radio sources. There is a clear connection between the radio structure and the radio spectrum of such sources. Steep-spectrum radio sources show lobe-dominated radio morphology and are also less variables.
Another energy spectral slope, $\alpha_{\alpha}$, is used to compare the optical–UV and X-ray luminosities of type-I AGNs. For historical reasons, the energies of comparison were chosen to be at 2500 Å and at 2 keV. The definition is

$$\alpha_{\alpha} = -\frac{\log L_\nu(2 \text{ keV}) - \log L_\nu(2500 \text{ Å})}{2.605}.$$  

(1.4)

Studies show that $L_X/L_{UV}$ is luminosity dependent such that $\alpha_{\alpha}$ increases with $L_\nu(2500 \text{ Å})$. The approximate relationship is

$$\alpha_{\alpha} \simeq 0.114 \log L_\nu(2500 \text{ Å}) - 1.975.$$  

(1.5)
Figure 6.6. (left) Radio luminosity vs. optical (B-band) luminosity for various types of AGNs. (right) The radio loudness parameter $R$ vs. $\lambda$ ($L/L_{\text{Edd}}$) (from Sikora et al., 2007; reproduced by permission of the AAS).
Figure 6.5. The $z = 0.458$ FRII radio galaxy 3C 200 (from Worrall, 2009; reproduced by permission of the Astronomy and Astrophysics review). The blue color is the smoothed 0.3–5 keV Chandra image, and the contours are the 4.86 GHz VLA radio map. Nuclear and extended emission are seen at both wavelength bands.
1.2.4 Lineless AGNs
Figure 6.7. The composite spectrum of 15 lineless AGNs with large X-ray-to-optical luminosity (from Trump et al., 2009; reproduced by permission of the AAS). The top panel shows the composite of the 15 sources (top curve) and compares it with the spectrum of a red galaxy. The bottom panel shows the stellar subtracted continuum alongside a composite type-I spectrum.
1.2.5 – Low luminosity AGN (LLAGN) and LINERs
LINER
NGC 1052

Ca II H&K
L_G band
Mg I b
Hβ
Na I λλ.5890, 5896
[S II] λλ.6716, 6731

Wavelength (Å)
1.2.6 – Narrow and broad absorption-line AGNs
Figure 6.8. Spectra of BAL AGNs showing broad absorption troughs in the (rest) UV part of the spectrum (from Capellupo et al., 2011; reproduced by permission of John Wiley & Sons Ltd.). Velocities relative to the peak emission of the C iv λ1549 line are indicated on the top. Each panel shows two observations of the same source separated by a few months to a few years. In some cases, the spectra are identical, e.g., 1232 + 1325. In others (e.g., 1303 + 3048), there is a very big difference indicating either a change in ionization of the absorbing gas or a motion across the line of sight resulting in a change in column density. The long horizontal lines indicate the boundary of the trough. The thicker, shorter bars indicate the wavelength range where variability is evident.
1.2.7 – AGN Unification
Figure 6.9. A side view of AGNs showing the main ingredients of a unification scheme that does not include LINERs and WLRGs. Strong radio and/or $\gamma$-ray jets are present in some 10 percent of all powerful AGNs. Blazars are those objects where the line of sight is along the central jet direction. Radio-loud type-I AGNs are those objects where the line of sight is at some angle to the jet direction, and radio-loud type-II AGNs are those objects where the observer's line of sight to the source is blocked by a large, dusty torus. The cone of ionizing radiation illuminates some, but not all, gas clouds around the source. Radio-quiet type-I sources are situated in the same sector as radio-loud type-I sources, but in this case, the central radio source is much weaker. The same is true for radio-quiet type-II sources. The torus is quite thick, at least in low- to intermediate-luminosity sources, such that the type-II sector subtends a larger solid angle than the type-I and blazar sectors together.
AGN Unified Model

Figure 2  Spectropolarimetry of NGC 1068 by Miller et al 1991. The flux spectrum (top) indicates a Type 2 classification, while the polarized flux (bottom) is indistinguishable from the flux spectra of Type 1 Seyferts.
The AGN zoo:

- QSO
- Quasar
- Radio-galaxy
- NLRG
- NLXG
- Blazar (BL Lac object)
- OVV
- Seyfert Galaxy (type 1 and type 2)
- LINER