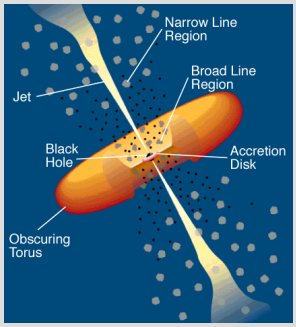
Introduction Active Galactic Nuclei

Lecture -2- Taxonomy & Unification

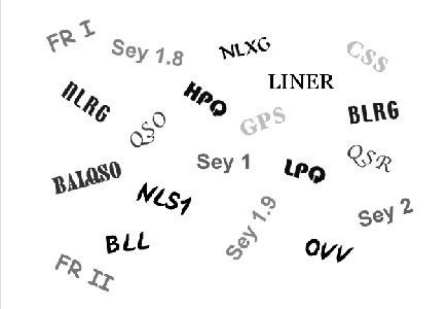


This Lecture

Give a general overview of different types of AGN and some ideas on their unification

Read Chapt.2 & 7 of Peterson
Read Chapt.1.3 of Krolik (optional)

Different types of AGN !

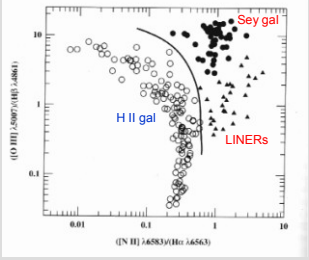


(The incomplete) AGN taxonomy

- Seyfert Galaxies
- Quasars & QSOs
- BAL QSO
- BL Lacs/OVV -> Blazar
- LINERS
- Radio Galaxies
- FRI
- FRII

(Read Chapt.2 of Peterson for completeness!)

AGN diagnostic diagrams



The BPT diagrams are used in narrow-line emission systems, to distinguish between hard and soft radiation (Balwin, Phillips & Terlevich 1981, Veilleux & Ostrebrock 1987), which is usually ascribed to non-stellar and stellar activity, respectively.

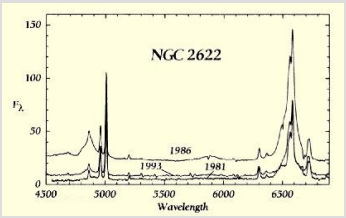
AGN taxonomy: Seyfert galaxies

Seyfert types: depends on width of the optical emission lines

- Sy 2: narrow emission lines of FWHM ≤ few x 100 km s^{-1}
- Sy 1: broad permitted emission lines (Ha, He II, …), of FWHM ≤ 10^4 km s^{-1} that originate in a high-density medium ($n_e \geq 10^9$ cm^{-3}), and narrow-forbidden lines ([OIII], [N II], …) that originate in a low-density medium ($n_e \approx 10^3$–10^6 cm^{-3}).
- Sy1.x (1.9, 1.8, …): increase with the width Ha and Hβ lines.
- NL Sy1: subclass of Sy 2 with X-ray excess and optical Fe II in emission.

AGN taxonomy: Seyfert galaxies

But the classification for a single object can change with time, due to AGN variability!



AGN taxonomy: Quasars & QSOs

Quasar/QSR = Quasi Stellar Radio-source,
QSO = Quasi-Stellar Object

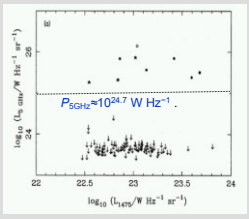
- Scaled-up version of a Seyfert, where the nucleus has a luminosity $M_B < -21.5 + 5 \log h_0$ (Schmidt & Green 1983).
- Morphology is, most often, star-like.
- Optical spectra similar to Sy 1 nuclei, with the exception that the narrow lines are generally weaker.

Two varieties:
- Radio-loud QSOs (Quasars or RL QSOs)
- Radio-quiet QSOs (or RQ QSOs)

Transitions at $P_{5GHz} \approx 10^{24.7}$ W Hz^{-1} sr^{-1} / RL QSOs are 5–10% of the total of QSOs

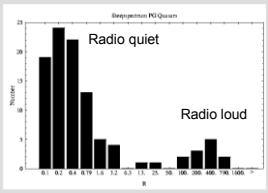
AGN taxonomy: Quasars & QSOs

There is a big gap in radio power between RL and RQ varieties of QSOs (Kellerman et al. 1989, Miller et al. 1990)



(Miller et al. 1990)

Only Steep-Spectrum PG Quasars!



R=radio/optical flux

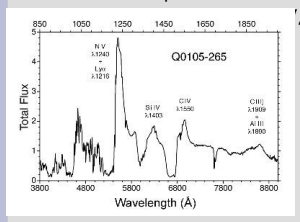
Falcke, Sherwood, Patnaik (1996)

AGN taxonomy: BAL QSO

BAL QSOs = Broad Absorption Line QSOs

Otherwise normal QSOs that show deep blue-shifted absorption lines corresponding to resonance lines of C , Si IV, N V.

All of them are at $z \geq 1.5$ because the phenomenon is observed in the rest-frame UV. At these redshifts, they are about 10% of the observed population. BAL QSOs tend to be more polarized than non-BAL QSOs.



(Ogle et al. 1999)

AGN taxonomy: Radio Galaxies

Strong radio sources associated with giant elliptical galaxies, with optical spectra similar to Seyfert galaxies.

Sub-classification according to:

- Optical spectra: NLRG = narrow-line radio galaxy, and BLRG = broad-line radio galaxy, with optical spectra similar to Sy 2 and Sy 1, respectively.
- Spectral index: At v=1 GHz: steep or flat separated by a=−0.4
- Radio morphology: Fanaroff & Riley (1974): measured by the ratio of the distance between the two brightest spots and the overall size of the radio image.
FRI with R<0.5 and FRII with R>0.5

AGN taxonomy: LINERS

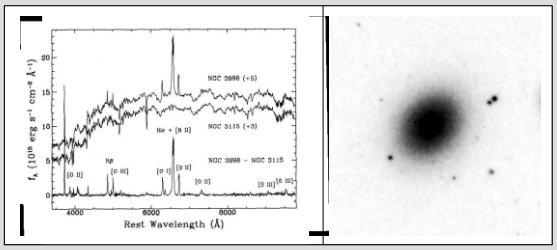
LINER = Low-Ionization Narrow-Line Region

They are characterized by [O II] λ3727Å / [O III] λ5007Å ≥ 1
(Heckman 1980) [O I] λ6300Å / [O III] λ5007Å ≥ 1/3

- Most of the nuclei of nearby galaxies are LINERs.
- A census of the brightest 250 galaxies in the nearby
- Universe shows that 50–75% of giant galaxies have some weak LINER activity
- They are the weakest form of activity in the AGN zoo.
- One has to dig into the bulge spectrum sometimes to get the characteristic emission lines.

AGN taxonomy: LINERS

LINER Spectrum

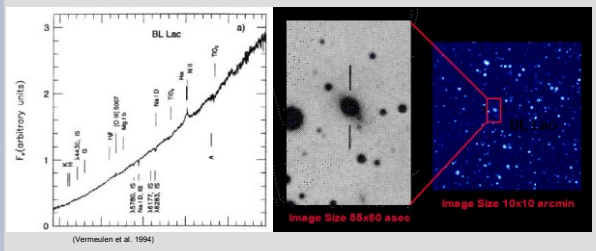


AGN taxonomy: BL Lac

BL Lac: Is the prototype of its class, an object, stellar in appearance, with very weak emission lines and variable, intense and highly polarized continuum. The weak lines often just appear in the most quiescent stages.

Blazars: Encompass BL Lacs and optically violent-variable (OVV) QSOs. These are believed to be objects with a strong relativistically beamed jet in the line of sight.

AGN taxonomy: BL Lac



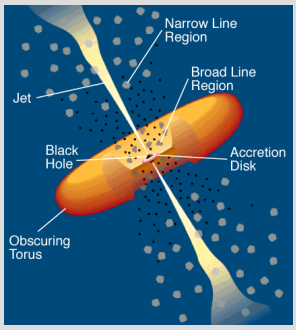
(Vermeulen et al. 1994)

How can we bring all of these types of AGN into a (single) framework?

- We "postulate" a standard model for the structure of AGNs
- Different AGN-types result from different viewing angles (and maybe some different phycial conditions) ⟶ Unification
- Evidence for unification?

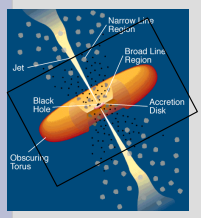
The Unified Model of AGNs

- Radio galaxies, quasars, QSOs, Seyferts, etc. are the same type of object viewed from different angles.
- Centre of a galaxy is a black hole surrounded by an accretion disk, clouds of gas and a dusty torus.
- The energy output comes from accretion of material onto the black hole.

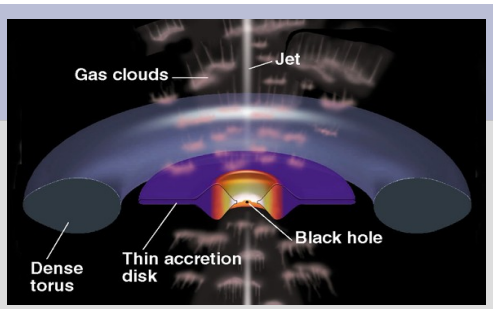


The standard model of AGN

Components:

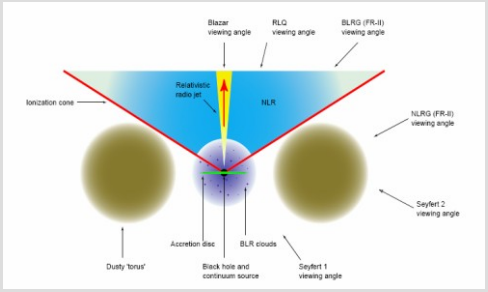


- Accretion disk:
  $r \sim 10^{-3}$ pc, $n \sim 10^{15}$ cm^{-3}, $v \sim 0.3c$
- Broad Line Region (BLR):
  $r \sim 0.01 - 0.1$ pc, $n \sim 10^{10}$ cm^{-3},
  $v \sim$ few x 10^3 km s^{-1}
- Torus:
  $r \sim 1 - 100$ pc, $n \sim 10^3 - 10^6$ cm^{-3}
- Narrow Line Region (NLR):
  $r \sim 100–1000$ pc, $n \sim 10^3 - 10^6$ cm^{-3},
  $v \sim$ few x 100 km s^{-1}

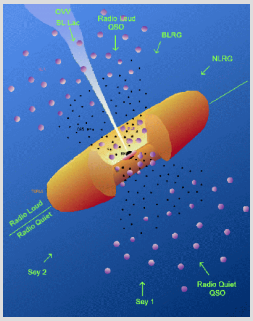


Model for the central region of an active galaxy. A super-massive black hole in the center of the galaxy is surrounded by an accretion disk of infalling material. If conditions are right, the galaxy may also possess a magnetically-confined jet which could be the source of radio emission.

Effects of the orientation to AGN



Unification in AGN



All AGN-type are the same but looked at from a different point of view

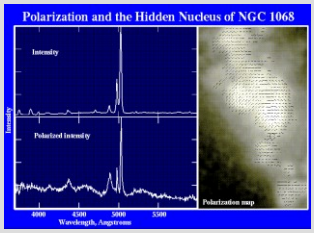
	Face-on	Edge-On
Radio-Quiet	Sy1	Sy2
	QSO	FIR Galaxy?
Radio-Loud	BL Lac	FR-I
	BLRG	NLRG
	Quasar	FR-II

This idea dates back to, at least, Rowan-Robinson (1977), and became popular in the mid-80s (reviews by Lawrence 1987, Antonucci 1993, Urry & Padovani 1997, Goodrich 2001).

Support for unification: hidden emission lines

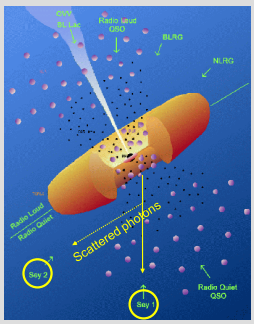
Some Sy2s show broad lines in polarized light:

The fraction is still unclear since the observed samples are biased towards high-P broad-band continuum objects.



(Bill Keel s web page with data from Miller, Goodrich & Mathews 1991, Capetti et al. 1995)

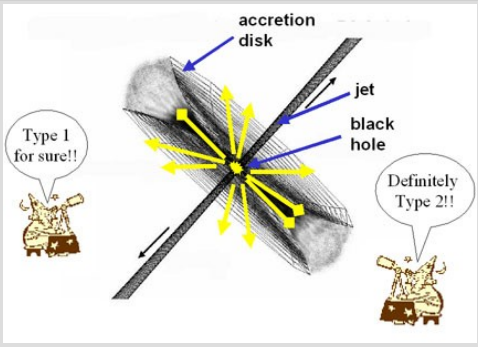
Support for unification: hidden emission lines



Hot electrons scatter photons from the BLR near the nucleus to the observer. Dust torus shield direct line-of-sight to the nucleus

Hence, Sy2 look a bit like Sy1 in polarised light

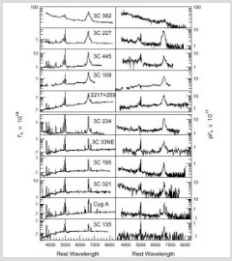
Support for unification: hidden emission lines

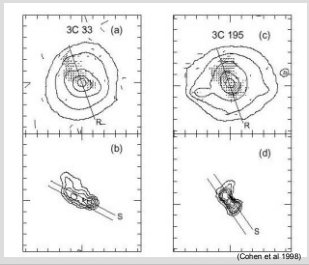


Support for unification: hidden emission lines

NLRGs behave like Sy 2s:

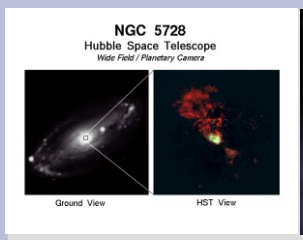
Some NLRGs have hidden broad lines (Goodrich 2001). Polarized light aligns with the radio-axis, and the direction of polarization is perpendicular to it.

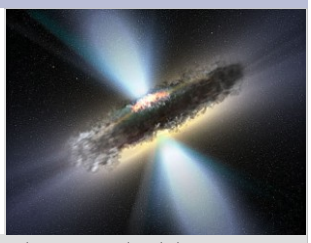




(Cohen et al. 1998)

Support for unification: ionization cones



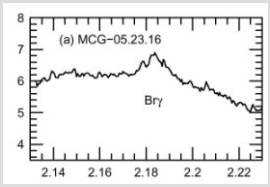


The ultraviolet emission comes from the accretion disk, lighting up a cone of glowing gas in the galaxy to the left. Only the cone of ultraviolet light can escape from the cavity in the accretion disk where the black hole lies; in other directions, the light is absorbed by the disk. (From STScI, modified by G. Rieke)

Support for unification: broad IR lines

25% of Sy2s show some broad component in the IR

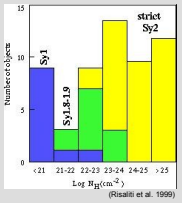
There are searches for broad-recombination lines in the near-IR spectrum of Sy 2s, where the extinction affects the emitted spectrum less. They will be detectable if $A_V \leq 11$ mag for Paβ, $A_V \leq 26$ mag for Brγ and $A_V \leq 68$ mag for Brα. (Goodrich et al. 1994).



(Veilleux, Goodrich & Hill 1997)

Support for unification: IR and N_H excess

The column of neutral H that absorbs the soft X-rays emitted by the nucleus is associated with the dust in the molecular torus, and thus provides a rough estimate of the dust content and the attenuation this provides.



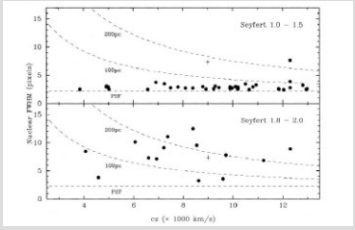
(Risaliti et al. 1999)

Sy2s have the largest absorption columns:
The medium is Compton thick, so that X-rays are suppressed below 10 keV (Mushotzky 1982, Risaliti et al. 1999, Bassani et al. 1999).

Sy 2s also have colder IR colours than Sy1s:
Explained if the torus is partially thick at mid-IR wavelengths. (Pérez-García et al. 1998): T_{Sy2}=112 – 136 K $T_{Sy1} \approx$ 150 K

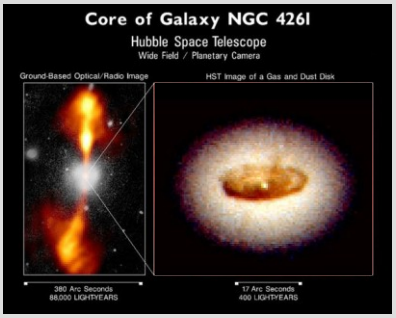
Support for unification: other statistical tests

- The continuum is stronger in Sy 1s than in Sy 2s (Lawrence 1987)
- All Seyfert galaxies have a NLR with very similar properties (Cohen 1993)
- Variability differs between different types (Lawrence 1987)
- The size of the Sy 1 continuum emitting regions are smaller than those of Sy 2s in HST images (Nelson et al. 1996)

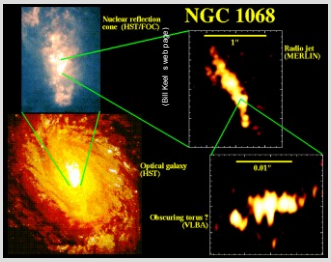


(Nelson et al. 1996)

Support for unification: direct imaging of torus?



Support for unification: direct imaging of torus?



(Gallimore et al. 1997)

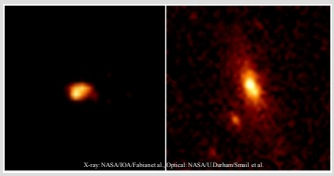
VLBA observations of the nucleus of NGC1068 (Sy 2) at 8.4GHz reveals a small elongated structure, probably an ionized disk of ~1.2pc at $T \geq 10^{6.5}$ K that radiates free-free continuum or scattered light.(Gallimore, et al. 1997).

Additional Evidence for the Unified Model

- Quasar host galaxies:
  - RLQs have the same types of hosts as FRII radio galaxies.
- Number Counts:
  - A simple relationship is expected between the number of RLQs and FRII radio galaxies based on the obscuring angle of the torus.
- Environments (next lecture):
  - RLQs and FRII radio galaxies occupy the similar (poor cluster/group) environments.

Where are the Type II Quasars?

- Only recently have we gained the technology to find these "hidden" quasars.
- Sensitive X-ray telescopes look for high energy photons penetrating the dust torus.
- Mid-IR observations: torus is transparent.



General Summary

- AGN come in many forms and shapes. However some of their properties cross AGN-type "boundaries"
- This has led to a "Standard Model" of AGN

→ In the centre of the AGN host is a black hole surrounded by an accretion disk, clouds of gas and a dusty torus, from which (sometimes) a jet eminates.

- AGN types are the results of mostly their orientation but also different physical circumstances (why a jet?)