Extragalactic Astronomy II

Lecture 12

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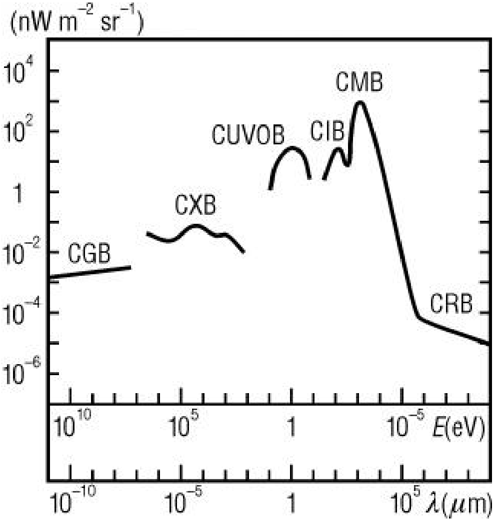
Apr-June 2021

Diffuse Extragalactic background



Course seminars- date to be fixed

- Papers listed on the website. **Email me your choice of paper on or before Friday, 4 June.**
- You will each have 17 minutes to speak with 3 minutes for questions.
- You will be graded on:
  - Content (15 marks): Did you place the talk in context? Did you read and understand your paper and auxiliary papers? Did you answer the questions well?
  - Presentation (10 marks): Were the slides well ordered? Was text legible? Were figures readable? Did you not rush through the presentations? Was your speech clear and confident?
  - Timeliness (5 marks): full marks for going -3 to +2 of specified time. Strong penalties outside this range.
- **Pitch your talk at a level at which your classmates can understand.**

Term *clouds* is misleading

We may picture the clouds as distinct entities having some random velocities. This picture is quite misleading; the BLR probably consist of a turbulent gas, with a large-scale velocity field (called AGN Winds), in which higher density condensations are present. These condensations then take the roles of the *clouds* in the simple picture.
Picture of *monsoon clouds* in turbulent motion with a net velocity field is a much better picture.

Broad line clouds

- Doppler width of $1000 - 25000$ km/s
- relative strength of emission lines in AGN spectra indicate that we are observing gas in **photoionisation** equilibrium at $\sim 10^4$ K.
- observed EWs of emission lines imply a global covering factor of 10-20%
- Abundances about solar even at fairly high redshifts!
- Gas density is $n_e \sim 10^9 - 10^{11}$ cm^{-3} as determined by strengths of [OIII] and [CIII] lines

$H - \alpha$ line is invariably broad in AGN spectra. Does it mean that this transition does not occur in narrow line clouds?

Some properties of broad lines

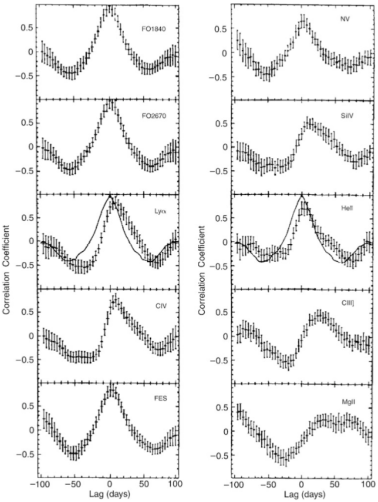
- Broad-line profiles are non-Gaussian. Sometimes fit with 2-3 Gaussian components, or Gaussian + Lorentzian.
- In a single source, the profiles of different broad lines show diversity; lines of more ionized species tend to be broader.
- Some lines, particularly those of high ionization (e.g., C IV), can show significant blueshifts (indicating outflows) in the AGN rest frame (defined using [OIII] line).

Reverberation mapping

- heating and ionization of the gas in the BLR are both caused by the central continuum source of the AGN.
- Since the UV radiation of AGNs varies, we expect corresponding variations of the physical conditions in the BLR. A decreasing UV continuum flux should then lead to a lower line flux.
- the observed variability in the lines will be delayed in time compared to the ionizing continuum. This delay Δt can be identified with the light travel time to the BLR, $\Delta t = r/c$. The BLR feels the variation in the continuum source only after a delay of Δt.

Why is reverberation mapping very difficult to do?

Reverberation mapping



No microstructure seen in broad lines

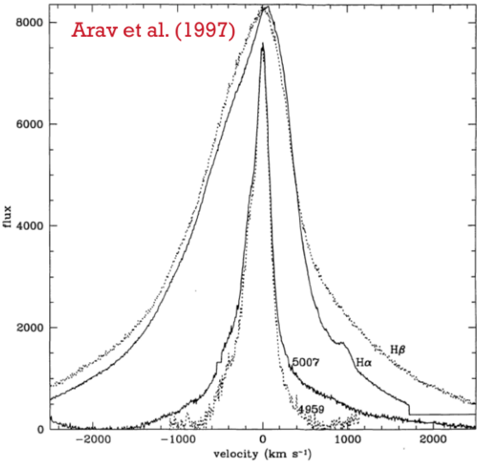


Figure 1. The observed line profiles of Mrk 335 (continuum subtracted) in arbitrary scaling that matches the peaks of Hα and Hβ, and separately the peaks of the O III lines (5007 and 4959 Å). The profiles of the 5007 and 4959 Å lines do not match owing to blending with Hβ.

Extremely high resolution and high S/N observations are needed.

Insights from BLR studies

Unfortunately, modeling the profiles usually does not strongly constrain how the BLR gas is moving, owing to modeling degeneracies. Infall? Outflow? Orbital motion? We simply don't know.

But constraints upon the microstructure in line profiles suggest the number of discrete clouds must be large, more than $\sim 10^6 - 10^8$.

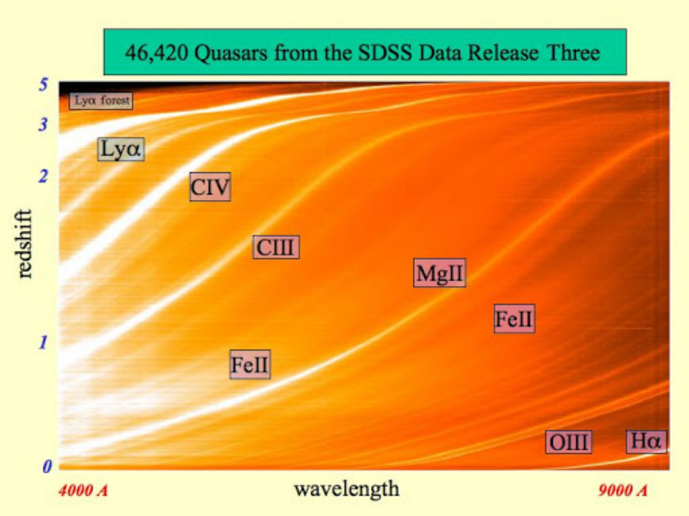
Suggests that there may well not be *clouds* at all, but rather a continuous structure. Word *region* is more appropriate than clouds.

Nature of BLR

After a lot of research over the last two decades, it is appearing increasingly likely that the BLR itself has a composite nature:

1. Moderate-ionization and high-optical-depth region
   - largely responsible for the Balmer-line emission and Mg II
   - accretion disk itself?
   - a disk with a large line-emitting region can make single-peaked profiles consistent with most objects
2. High-ionization and moderate-optical-depth region
   - largely responsible for the high-ionization lines
   - accretion-disk wind?
   - helps explain blueshifts of high-ionization lines and blueward line asymmetries

Stack of quasar spectra



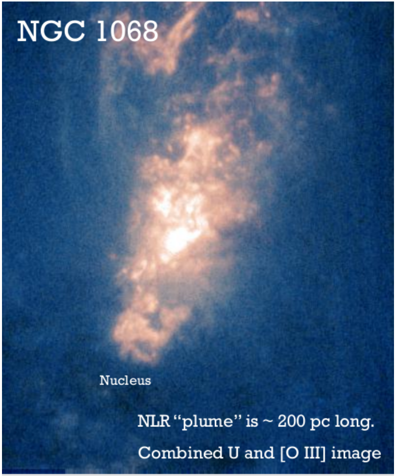
Narrow line clouds

- Doppler width of < 900 km s^{-1}
- Electron density $n_e \sim 10^3$ cm^{-3}

Some basic properties of the NLR

- Largest spatial scale where ionizing radiation from the AGN dominates.
- NLR can be spatially resolved in the optical; has sizes of $\sim$ 100+ pc in local Seyferts (and even larger in quasars).
- Can map out physical and kinematic properties directly to some extent.
- NLR is clearly not spherically symmetric, but rather is roughly axisymmetric.
- NLR axis generally coincides with radio axis in cases where extended linear radio emission is detected.

NGC 1068 NLR Plume



Macchetto et al. (1994)

NLR Properties

FWHM values are 200-900 km s^{-1}, with line profiles varying across NLR. Since BLR is not resolved, we can't determine this for the BLR.

See a wide range of ionization states:

- Low ionization (e.g., [O I] λ6300)
- High ionization (e.g., [O III] λ4959,5007)
- Sometimes even very highly ionized species (e.g., iron coronal lines)

From line ratios, infer that the NLR is mostly photoionized by the AGN continuum (with some likely additional ionization happening due to shocks from radio jets, if they exist).

Seyfert 2 Spectrum - only narrow lines seen

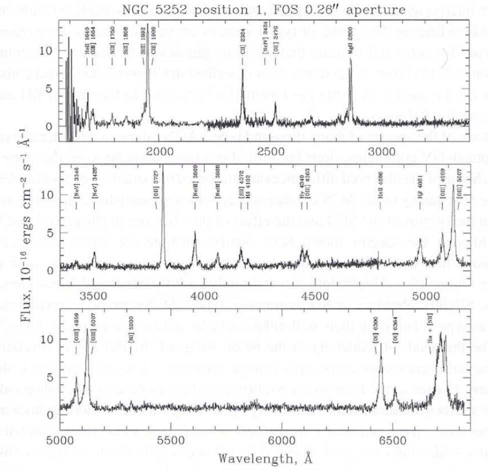


Figure 1.3. The spectrum of the low-luminosity, low-redshift type-II AGN NGC 5252 (courtesy of Zlatan Tsvetanov).

NLR density and temperature

- Density is sufficiently low to allow forbidden transitions. Varies from $10^2 - 10^5$ cm^{-3} across the NLR.
- From line ratios, infer temperatures of $\sim 10000 - 25000$ K, again varying across the NLR.
- At these temperatures and low densities, dust can survive without getting ablated in the NLR and cause self-extinction
- Estimated total mass of the NLR in Seyferts is $\sim 10^6$ solar masses.

Insights from studying the NLR

- Line peaks provide useful systemic redshifts for AGNs.
- Useful spectral calibrator since NLR lines should not vary.
- Useful as a bolometer for inferring AGN total power.
- Dynamics tells us about AGN fueling and/or outflows.
- Anisotropic illumination provides clues about AGN geometry and orientation.