The NLR of NLS1s

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in collaboration with

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Outline

- Introduction
- Sample selection
- Optical spectral analysis

Subtraction of starlight and nuclear continuum

Decomposition techniques

- Sample re-classification and selection bias

Luminosity and redshift distributions

Optical FeII emission versus [OIII] emission

- A *zone of avoidance* in the NLR density

Measurement of density

Density versus FWHM (Hβ_b): a zone of avoidance

[OI] emission versus FWHM (Hβ_b)

- Reality of the *zone of avoidance*
- On the origin of the *zone of avoidance*

NLS1 models

Main driver:

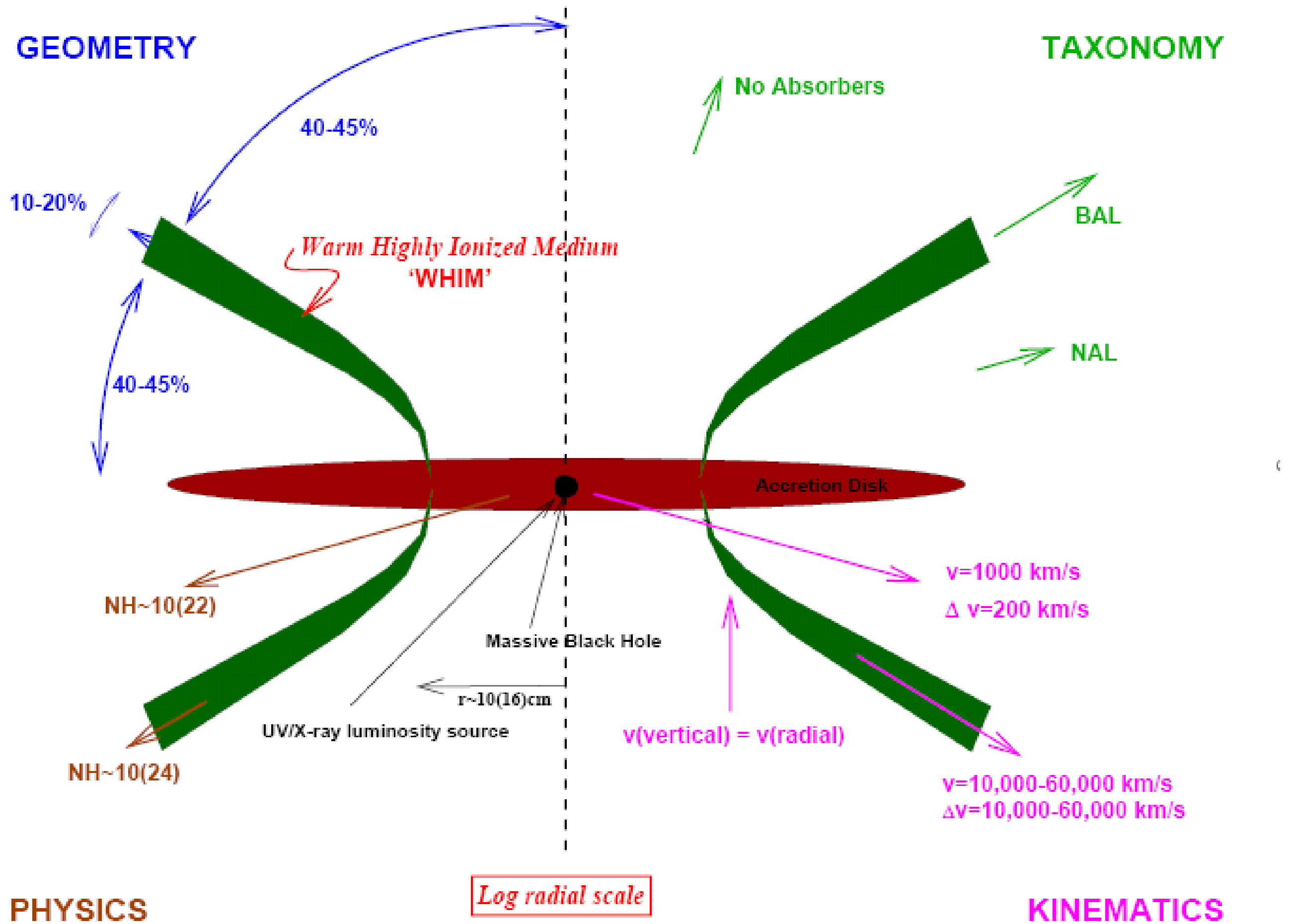
High Eddington ratio L/L_{Edd} and/or small black hole mass
(e.g. Boroson & Green 1992; Sulentic, Marziani & Dultzin-Hacyan 2000; Boroson 2002)

Other key parameters:

- **Winds and density effects** (e.g. Gaskell 1985; Lawrence et al. 1997; Wills et al. 2000; Xu et al. 2003; Bachev et al. 2004): the density of outflowing wind was speculated to be a prominent driver of EV1 (Lawrence et al. 1997).
- Age (e.g. Mathur et al. 2000, 2001; Mathur & Grupe 2005)
- Orientation (e.g. Osterbrock & Pogge 1985; Puchnarewicz et al 1992; Sulentic, Marziani & Dultzin-Hacyan 2000)
- The physics behind radio properties (e.g. Komossa et al. 2006)
- Metallicity (e.g. Mathur 2000; Komossa & Mathur 2001; Nagao et al. 2002; Shemmer & Netzer 2002; Romano et al. 2004; Fields et al. 2005)
- Absorption (e.g. Komossa & Meerschweinchen 2000; Gierlinski & Done 2004)

Winds are important

Elvis (2000)



Winds may have an important impact on the gas densities in the emission-line regions, in enriching the nuclear environment with matter from the central region.

Outflows and density effects in NLS1s

high Eddington ratios are likely particularly efficient in driving outflows

Observational evidence for outflows:

e.g., the large [OIII]5007 blueshift (e.g., Zamanov et al. 2002; Aoki et al. 2005; Boroson 2005) and blueshifted UV absorption lines (e.g., Laor et al. 1997) and UV emission lines (Leighly & Moore 2004).

Density measurements: conflicting results

- *High density BLR* based on the large Si III]1892/C III]1909 ratios from UV spectra (e.g. Kuraszkiewicz et al. 2000; Wills et al. 2000; Marzianie et al. 2001, Bachev et al. 2004) and high density NLR of I ZW 1 (Laor 1997; Veron-Cetty, Joly & Veron 2004).
- *Low density BLR* from UV spectroscopy (e.g., Rodriguez-Pacual et al. 1997) and low average density in NLR using optical and near-IR spectroscopy (Rodriguez-Ardila et al. 2000).

Moreover, there are indications that the density of [OIII]5007 decreases with steeper soft X-ray slope (Baskin & Laor 2005)

Is the density low or high in NLS1s?

Motivation

We present for a study of the NLR density for one of the largest homogeneously analyzed NLS1 sample to date and compare it with that of BLS1s, by using the density diagnostic line [S II] ratio: [S II]6716/6731.

We attempt to answer the following key questions:

- *Is there any difference in the NLR density between NLS1s and BLS1s?*
- *If so, do trends in density correlate with other parameters?*
- *What are the key physical drivers of the trends in density?*

The sample

- NLS1 sample

  "Sy1n" in 11th edition of the "Catalogue of Quasars and AGN" (Veron-Cetty & Veron 2003)
- BLS1 sample

  107 low-redshift AGN from Boroson (2003)

Selection Criteria:

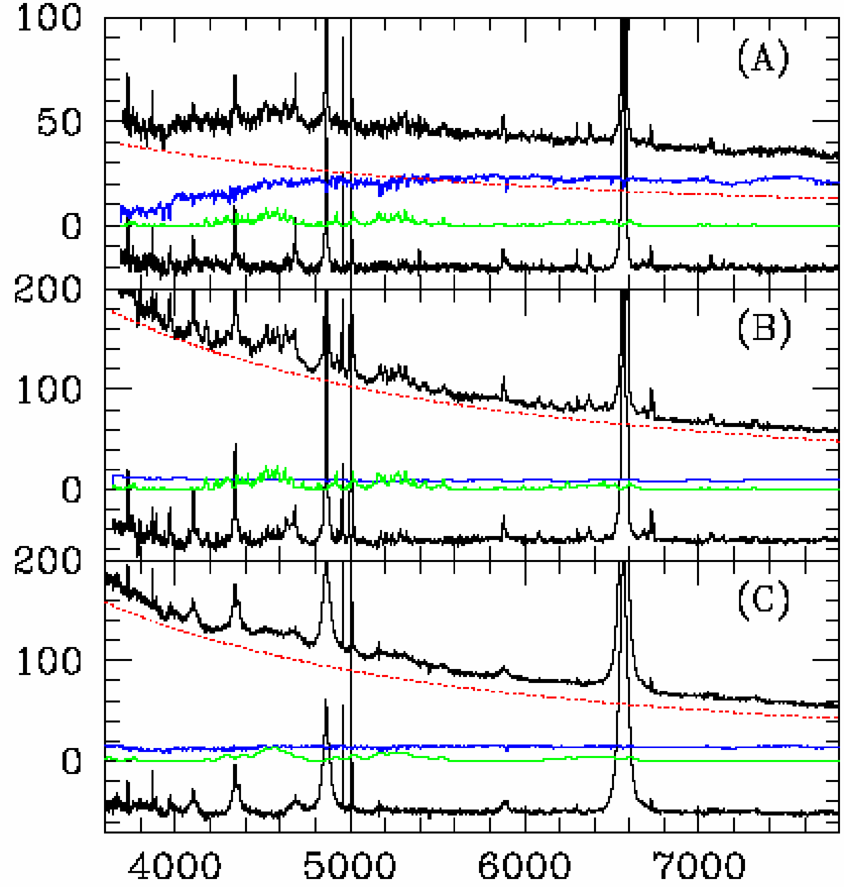
Cross correlated with SDSS DR3 spectra

Redshift < 0.3

S/N ([S II]6716,6731) > 5

→ In total, 94 objects survive

Subtraction of starlight and nuclear continuum

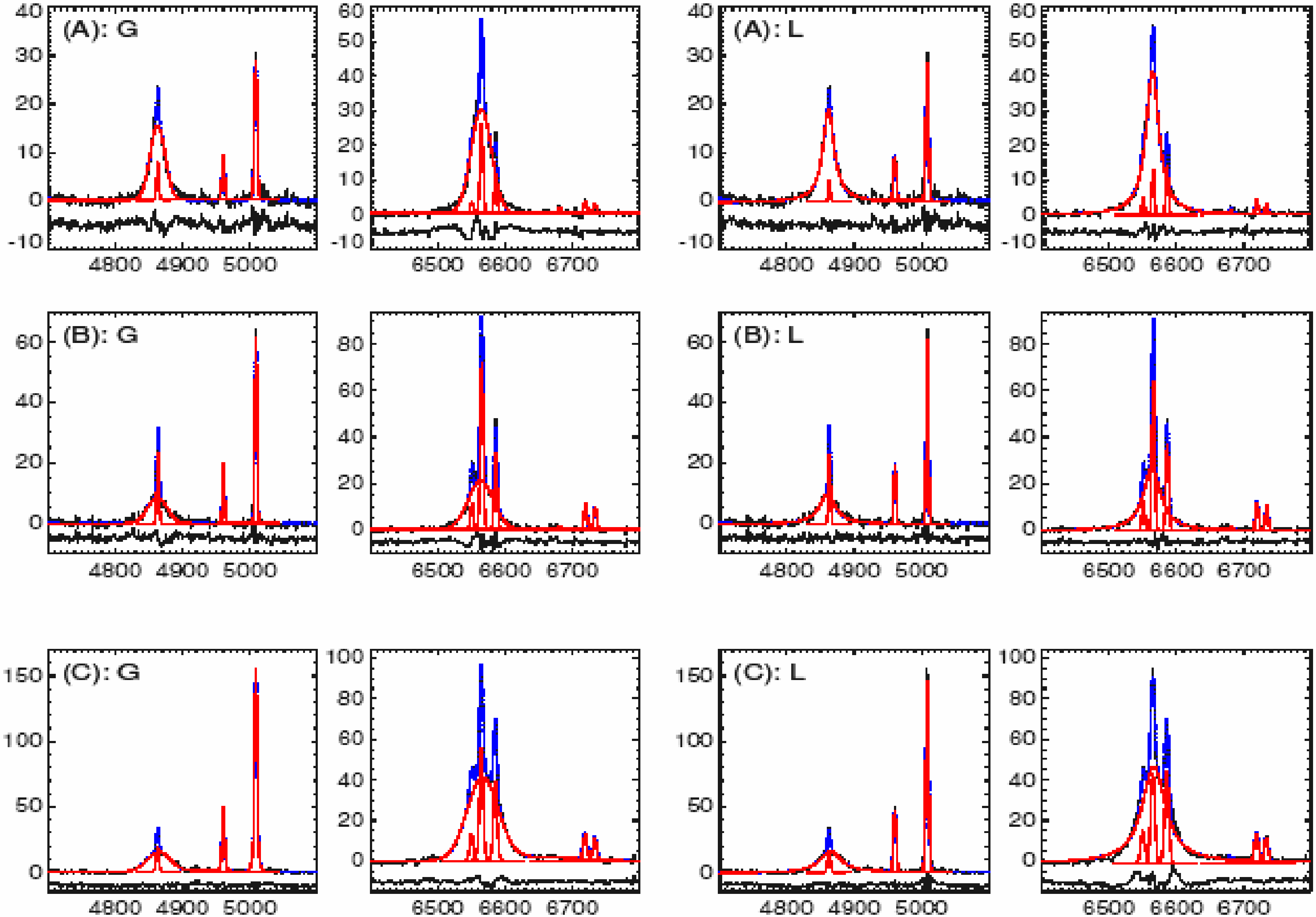


Independent Component Analysis (*ICA, Lu et al. 2006*)

- A starlight component modeled by 6 synthesized galaxy templates
- A power-law continuum of the active nucleus
- A FeII template
- A Balmer continuum generated in the same way as Dietrich et al. (2003)

→ **residual spectrum**

Optical measurements



Sample re-classification

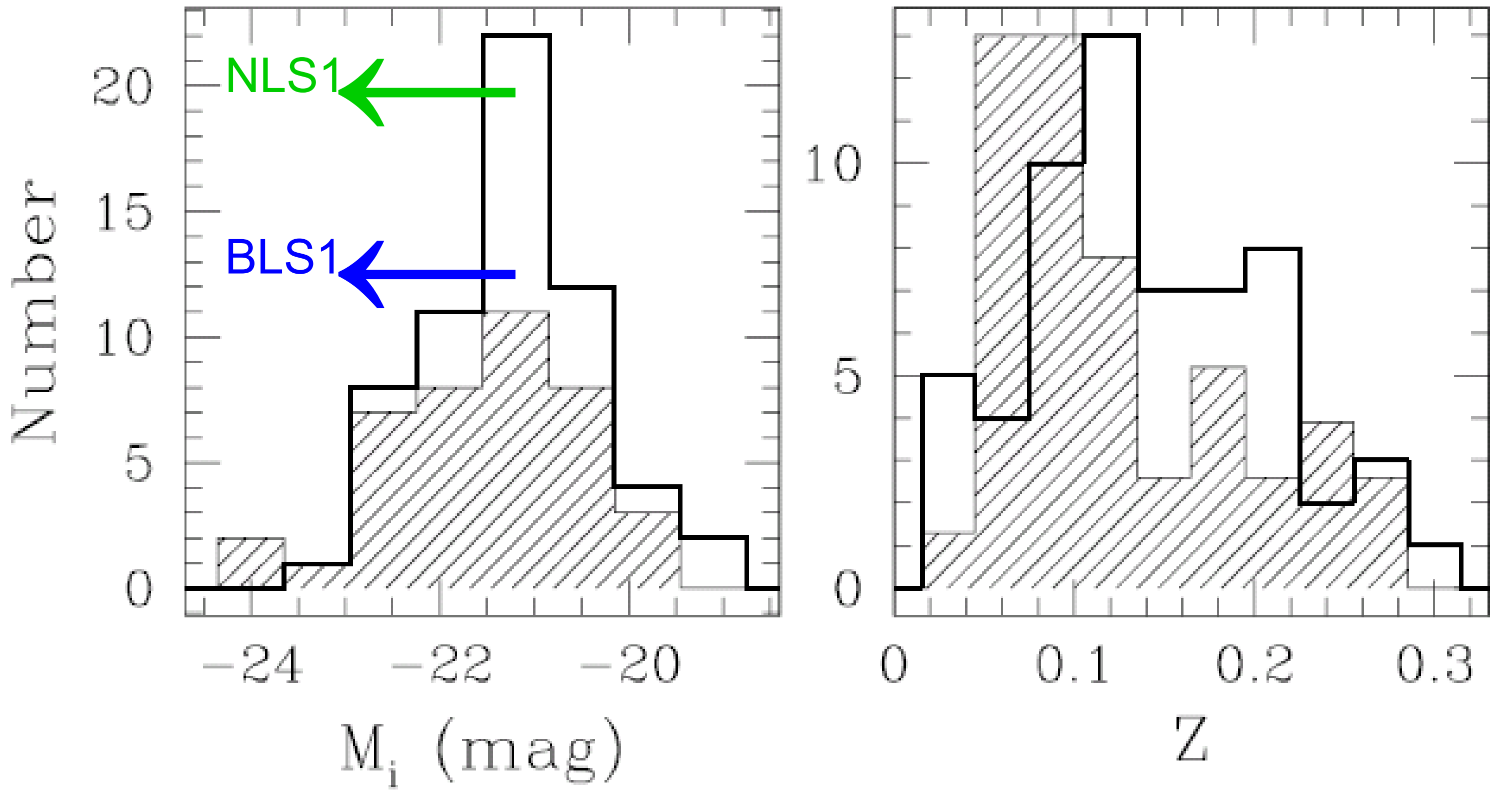
NLS1s:

55 objects: FWHM(Hβ_b) ≤ 2000 km/s

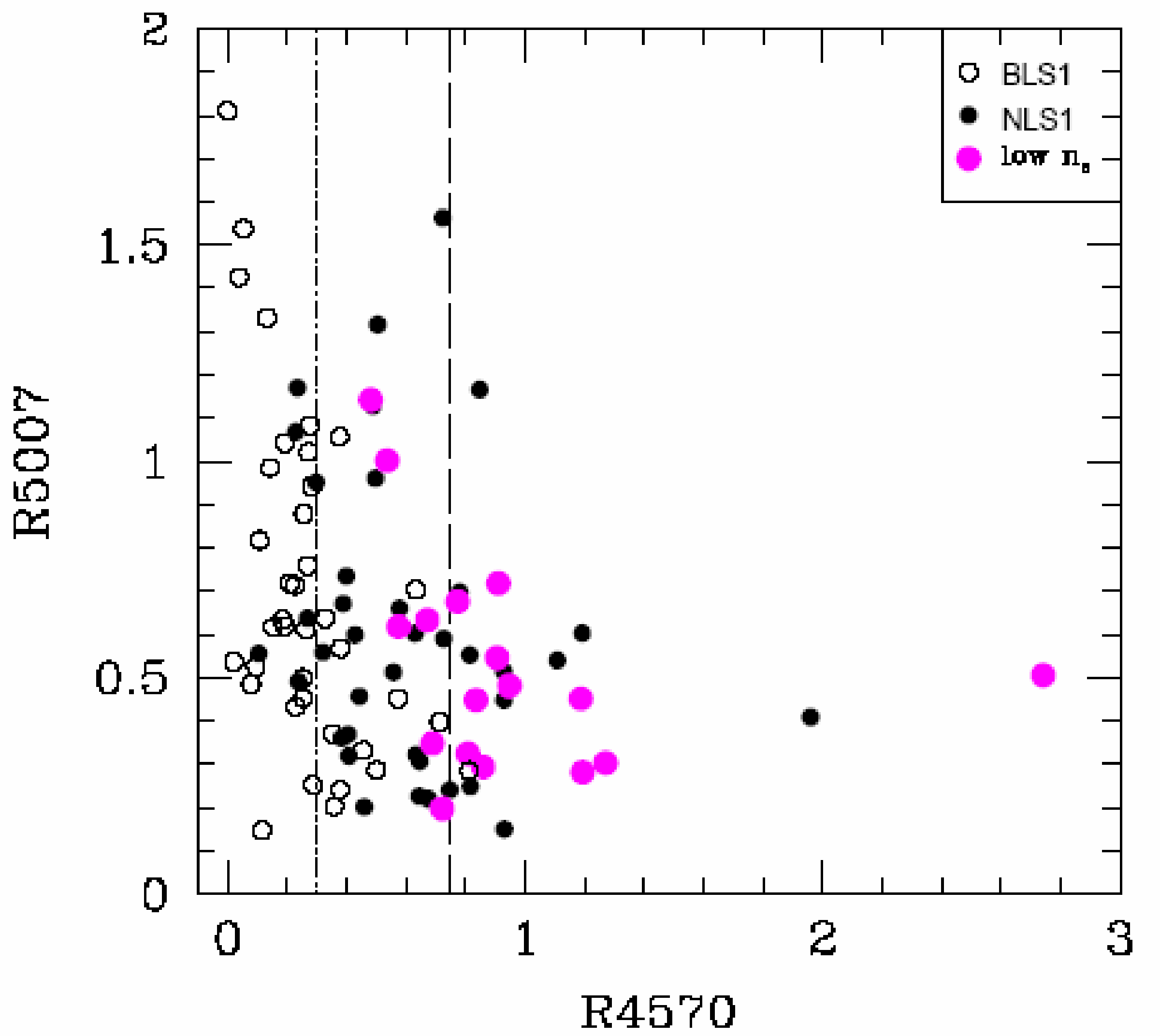
BLS1s:

39 objects: FWHM(Hβ_b) □2000 km/s

Luminosity and redshift distributions



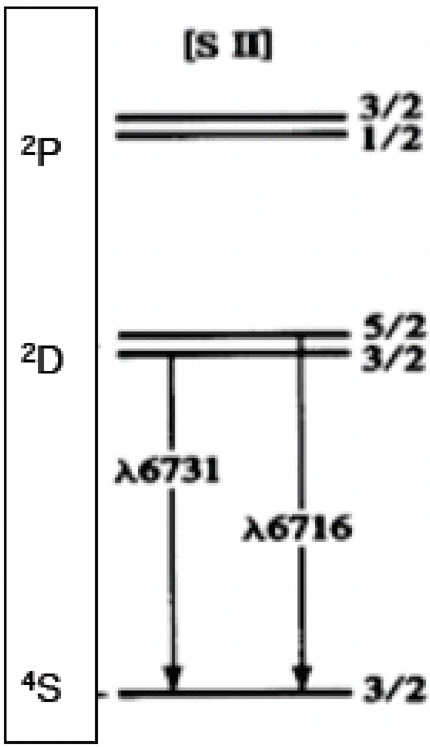
Optical FeII emission versus [OIII] emission



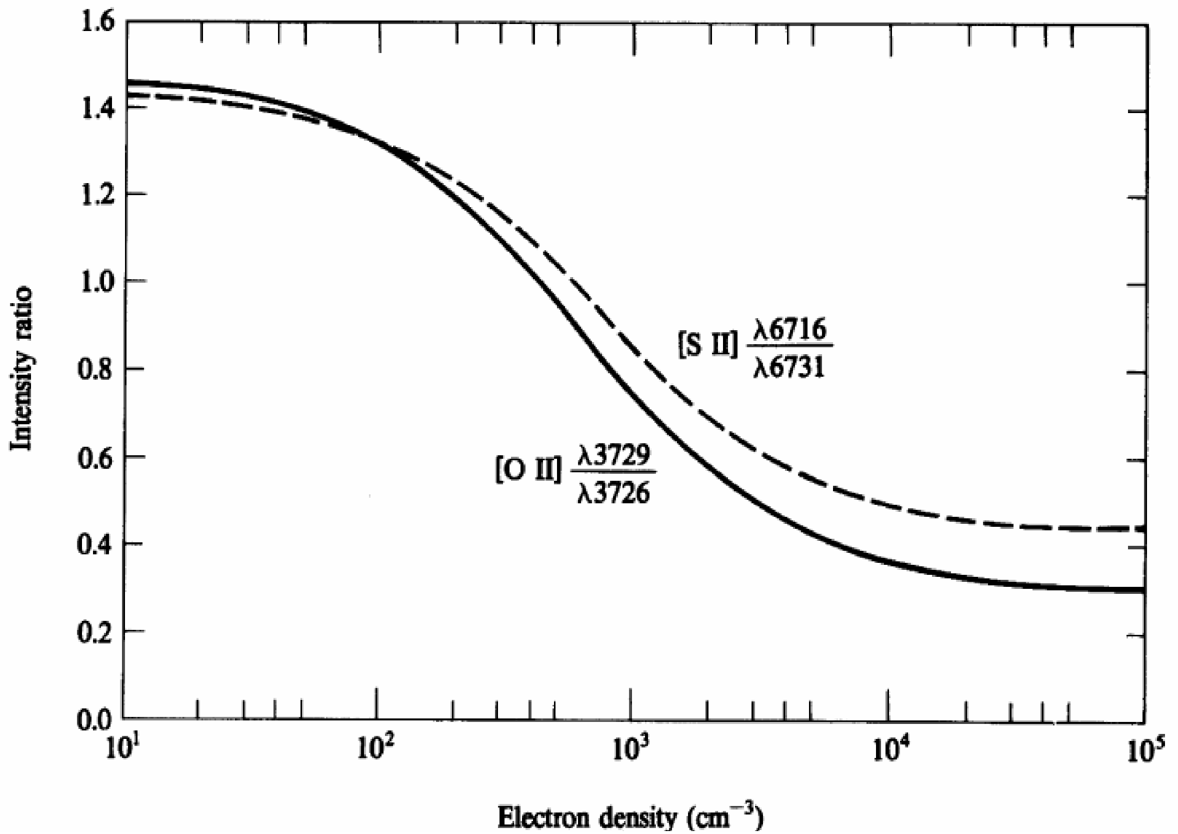
Measurement of density

The powerful n_e diagnostic

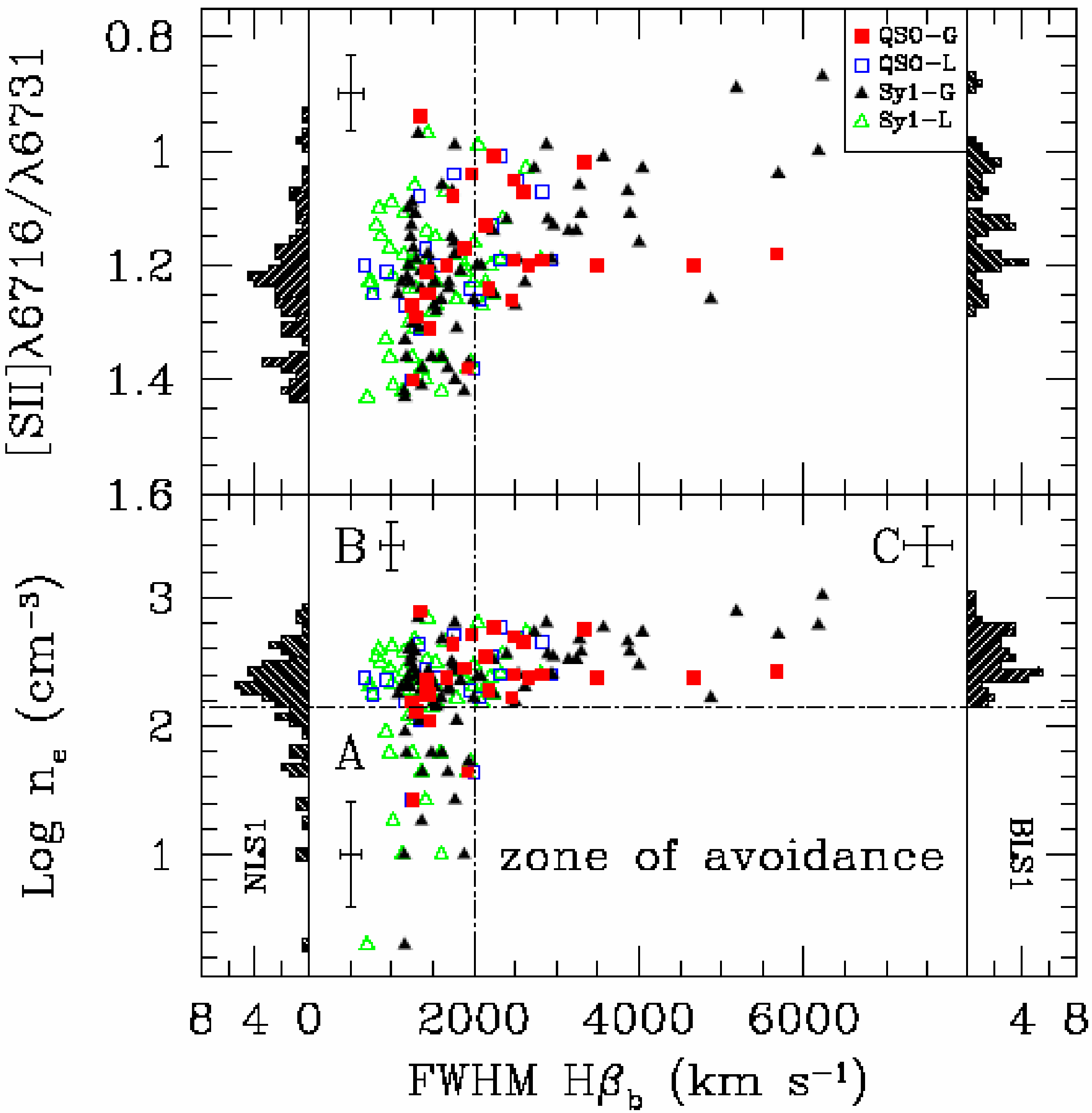
Osterbrock 1989



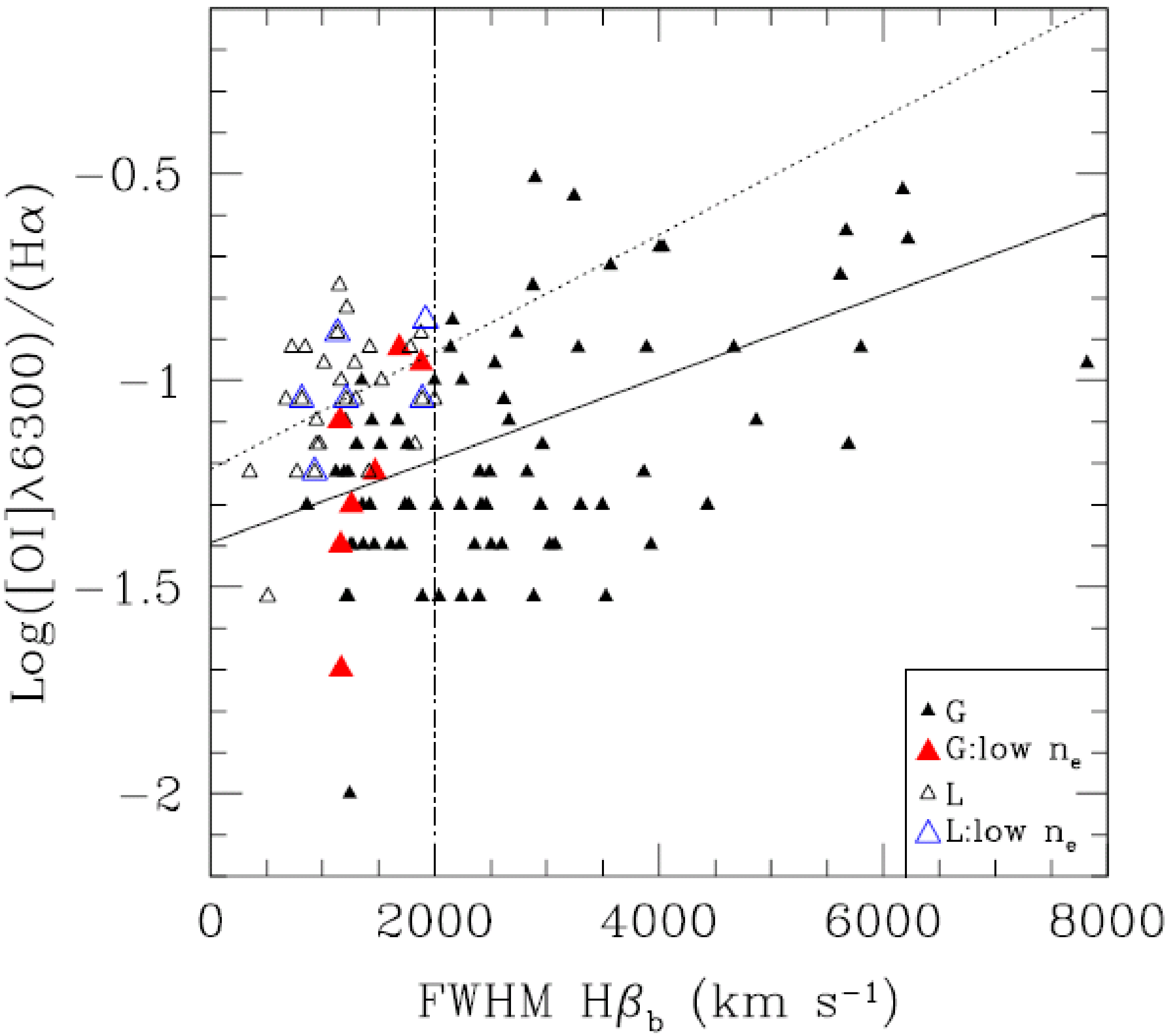
[SII]6731/6716



Density versus FWHM ($H\beta_b$): *a zone of avoidance*



[OI] emission versus FWHM ($H\beta_b$)



Supplement to the density ([SII])—FWHM(Hβb) at high density regime: higher n_e will boost [OI]
(Komossa & Schulz 1997)

Result:
BLS1s show, on average, higher [OI] than NLS1s.

Reality of the *zone of avoidance*

Is there any data analysis or selection effect that could mimic the ZOA in the BLS1 regime or a larger scatter in the NLS1 regime?

- Magnitude distribution
- Profile shape

The results are robust, independent of profiles, either a Lorentzian profile or a combination of two Gaussian profiles

- Atmospheric absorption effects
- Line de-blending

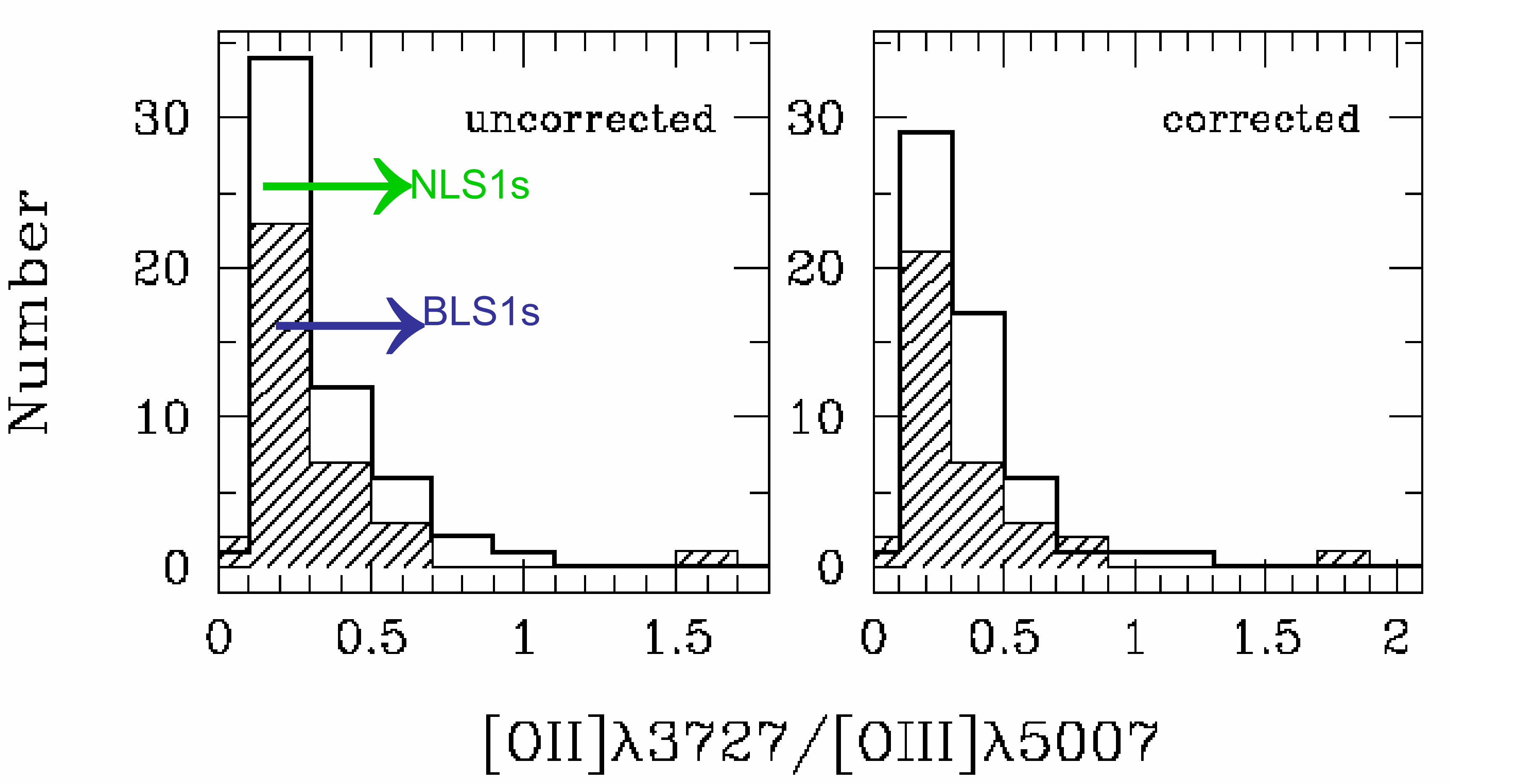
[SII] lines and Hα are well separated in most of our sources

- High and low density limits
- Influence of temperature
- Spatially resolved NLRs and viewing angle effects
- Starburst contribution

Star-forming indicator [OII]3727/[OIII]5007 are indistinguishable

[OII]3727/[OIII]5007 distribution

prior to reddening correction and after reddening correction



On the origin of the *zone of avoidance* - I

- **Coupling between NLR and BLR?**

  High density BLR (e.g. Gaskell 1985; Kuraszkiewicz et al. 2000; Wills et al. 2000; Marzianie et al. 2001, Bachev et al. 2004)

  Low density BLR (e.g., Rodriguez-Pacual et al. 1997)

- **Supersolar metallicities and temperature effects?**

  (e.g. Mathur 2000; Komossa & Mathur 2000; Nagao et al. 2002)

  increase in metals, leads to increase/decrease in temperature;

  but temperature sensitivity [OIII]4363 of low-n_e objects do not deviate from high-n_e objects.

- **Starburst contribution?**

  NLS1s are "young" AGN (e.g., Mathur 2000). NLS1s do not show strong starburst contribution to their optical emission lines.

- **NLR extent?**

  Density declines in dependence of cloud distance from the center; L[OIII] increases with NLR extent (Bennert et al. 2002, Schmidt et al. 2003)

  ➔ compact NLR and thus weaker L[OIII] in BLS1s? BLS1s do not show weaker L[OIII]

On the origin of the *zone of avoidance* - II

- **Fraction of matter-bounded clouds?**

[SII] is produced in the partially ionized zone. A larger scatter in the number of MB low-density clouds in NLS1s would lead to a larger scatter in their average densities.

No direct measurements of the fraction of MB clouds; different photoionization models make different predictions.

→ *spatially resolved long-slit spectroscopy of NLRs of nearby NLS1s needed*

- **ISM of the host galaxy?**

NLS1s host a larger fraction of barred galaxies (e.g., Crenshaw, Kraemer & Gabel 2003; Ohta et al. 2006) and nuclear star-forming rings (e.g., Deo,Crenshaw & Kraemer 2006);

NLS1s reside in galaxies with smaller diameters than BLS1s (Krongold et al. 2001);

Previous studies of mass-luminosity/sigma relation led to conflicting possibilities (e.g., Mathur et al. 2000, 2001, 2004; Wang & Lu 2001; Botte et al. 2004, 2005).

is bar driven gas flow the cause?

→ *ISM properties of NLS1s and BLS1s on sub-kpc scales needed.*

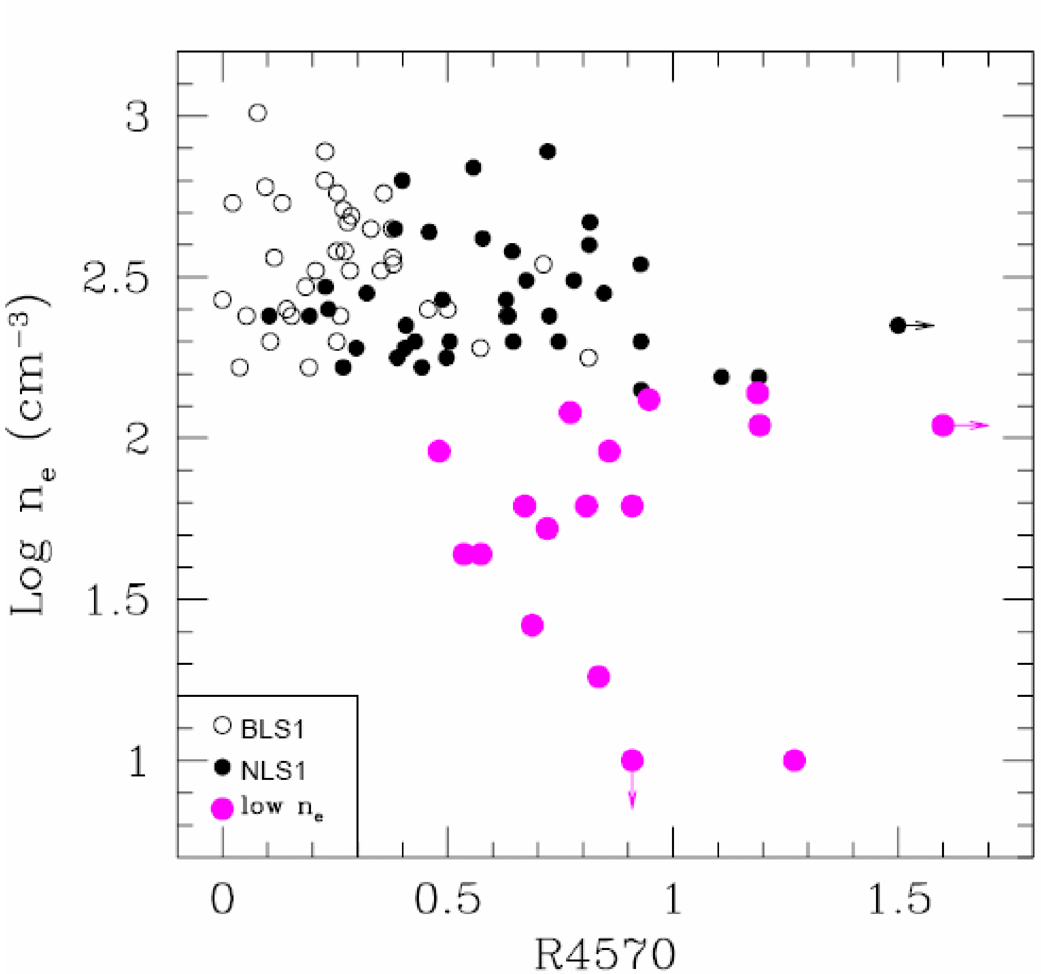
Outflows-I

- The density of the outflowing wind is an important parameter in understanding the correlations in AGN. Strong FeII emitters have denser winds (e.g., Lawrence et al. 1997).

However,

n_e anti-correlated with R4570

The low n_e objects show larger- than-average R4570



Outflows-II

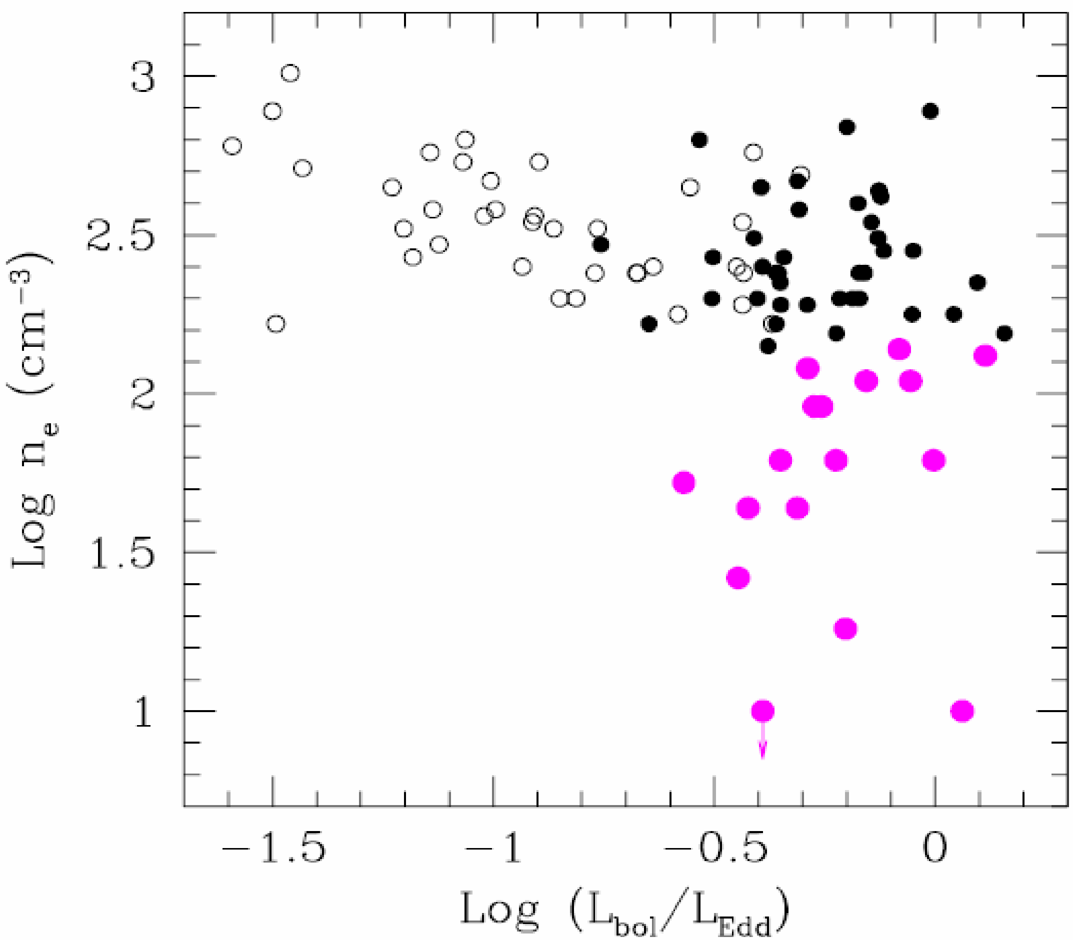
Many NLS1s accrete close to or even above the Eddington limit

Higher L/L_{Edd} —> stronger outflow

➔ more tenuous, low-density NLR in objects with higher L/L_{Edd}

L/L_{Edd} versus density:

1. ***Anti-correlation between density and L/L_{Edd}*** **(r_s =-0.42)**
2. **L/L_{Edd} of low- and high – density NLS1s are indistinguishable. Is higher L/L_{Edd} only a necessary but not a sufficient condition to lower density?**
3. ***Low n_e NLS1s have higher-than-average L_X/L_{Edd} compared to high-n_e NLS1s.***



Outflows-III

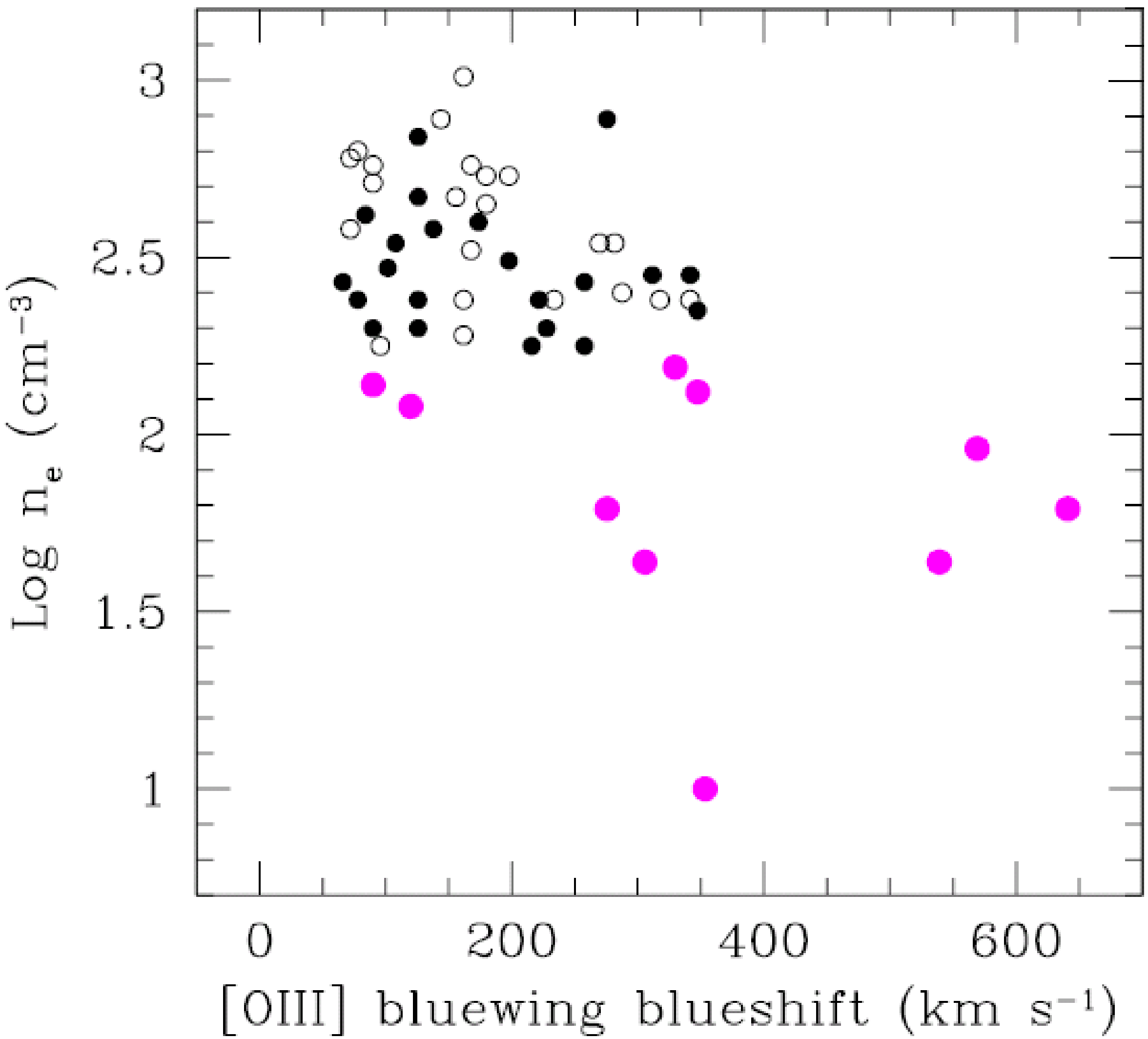
Does the density scale with the [OIII] outflow velocity (blueshift)?

- *Only a weak correlation (r_S=-0.29) exists between the density and the [OIII] peak blueshift.*

- *the [OIII] peak blueshift does strongly correlates with L/L_{Edd} (r_S=0.51)*

[OIII] bluewing: the existence of outflows (or inflows) combined with viewing angle effects (e.g. Boroson 2005)

A correlation is seen (r_S=0.51)!



Summary - I

- **Key finding**: detection of a *'zone of avoidance'* in the density—FWHM (Hβ_b) diagram: BLS1s avoid low average densities, and all show density > 140 cm^{-3}, while NLS1s show a larger scatter in densities, including a significant number of objects with low density, i.e., < 140 cm^{-3}.

- We checked whether the '*zone of avoidance*' in the BLS1 regime or the larger scatter in the NLS1 regime, could be mimicked by any data analysis and/or selection effects. We reject several possibilities, and confirm the existence of the *'zone of avoidance'* in the density—FWHM (Hβ_b) diagram.

Summary - II

We investigate a number of different models for the ***'zone of avoidance' in density***

- ***Supersolar metallicities*** and ***temperature effects***, ***a strong starburst contribution in NLS1s***, ***different NLR extents*** are unlikely;
- Possible differences in ***the fraction of matter-bounded clouds*** and ***differences in the ISM of the host galaxies*** of NLS1s and BLS1s can only be tested with future observations;
- We find several lines of evidence that ***outflows*** play a significant role in driving the difference in the NLR density between NLS1s and BLS1s. We tentatively favor ***the effects of winds/outflows*** to explain the observed trends.

Xu, Komossa, Zhou, Wang & Wei, 2007, ApJ submitted

Happy birthday Deborah!

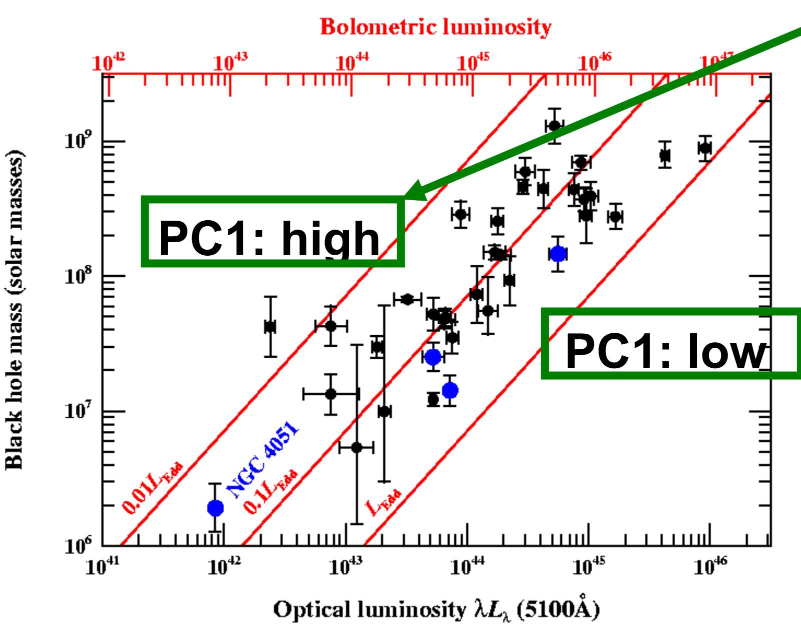
Backup slides

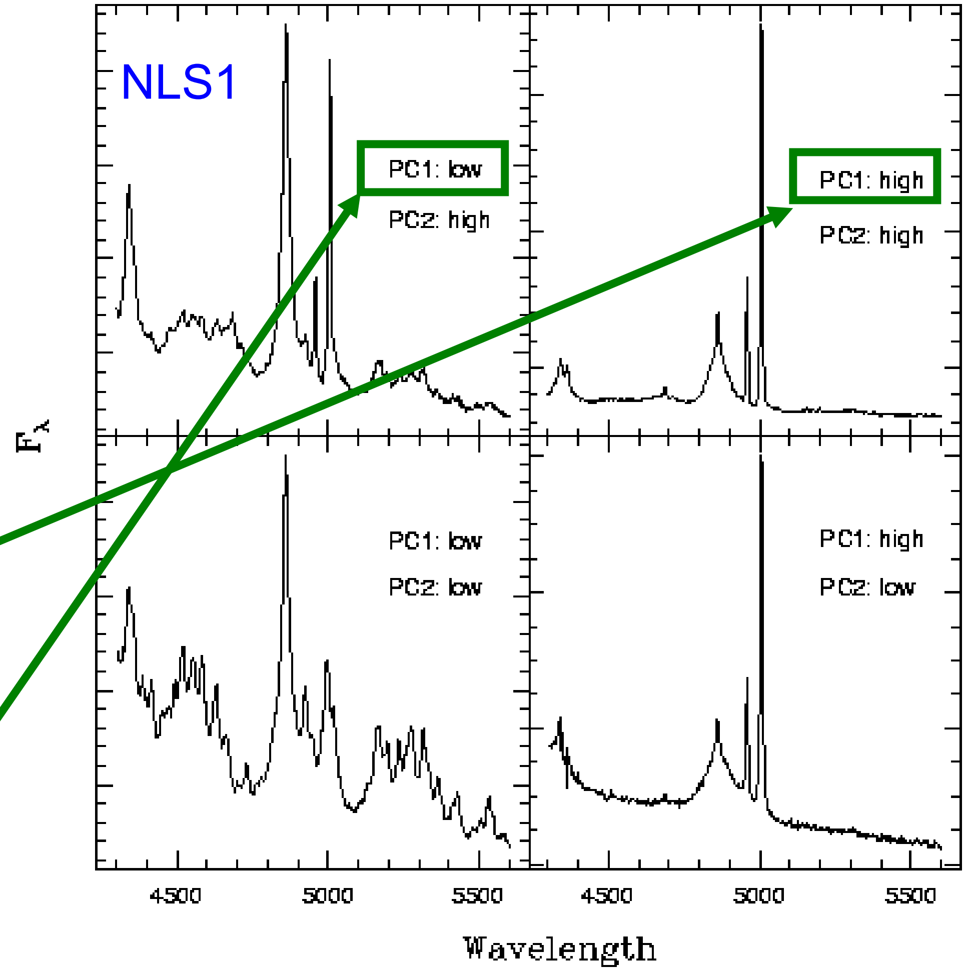
Eigenvector 1

- Principal component analysis reveals a set of correlated properties called "Eigenvector 1" or "PC1"

- NLS1s have high Eddington ratio

Peterson et al. (2005)

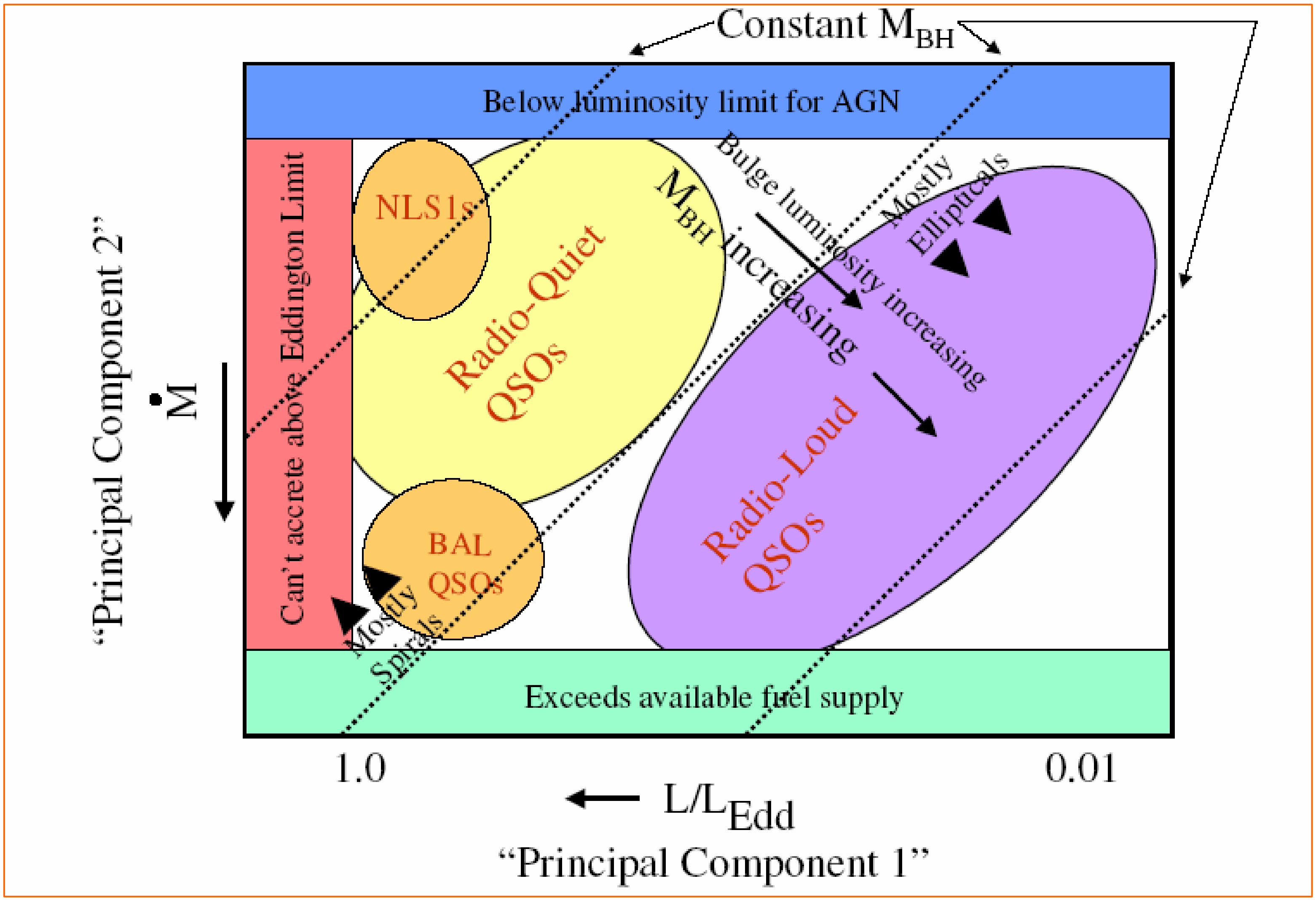




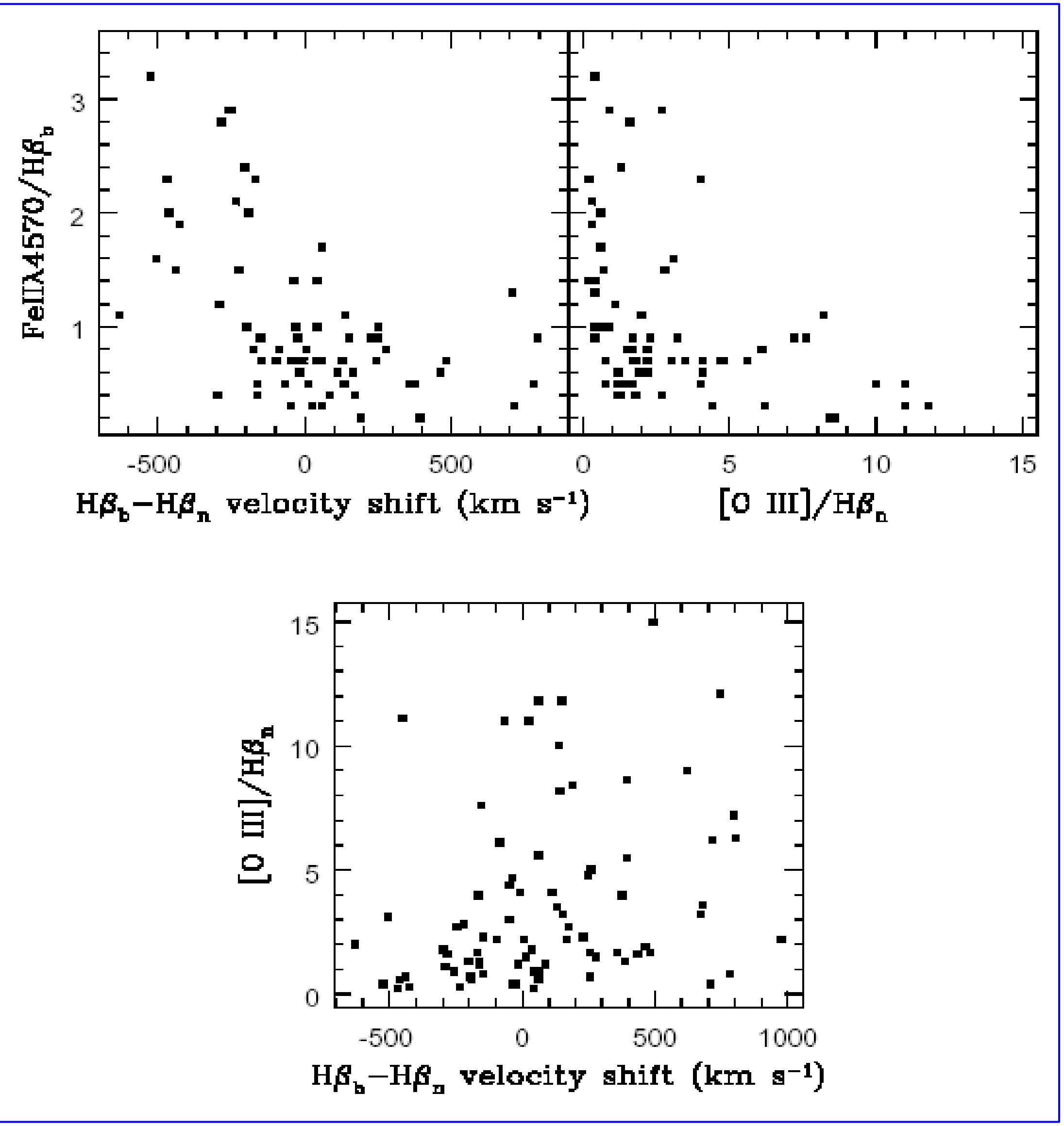
Boroson (2002)

Why are NLS1s peculiar

Boroson (2002)



Correlations between FeII4570/ Hβb, [OIII]/Hβn and Hβ blueshift: a link of kinematics and ionization in BLR/NLR



The result is consistent with previous correlation studies (e.g., Boroson & Green 1992; Laor 1997; Sulentic & 2000; Boroson 2002)

Eigenvector 1 (EV1):

FeII	strong
[OIII]	weak
Hβb	narrow
Hβ asymmetry	blue
X-ray spectrum	steep

Xu, Komossa,Wei et al (2003)

Is L/L_{Edd} underlying driver for correlations between FeII4570/Hβ_b, [OIII]/Hβ_n and Hβ blueshift?

[OIII] strength vs. hydrogen density

Hβ blueshift ⇐ strong outflow

⇐ High L/L_{Edd}

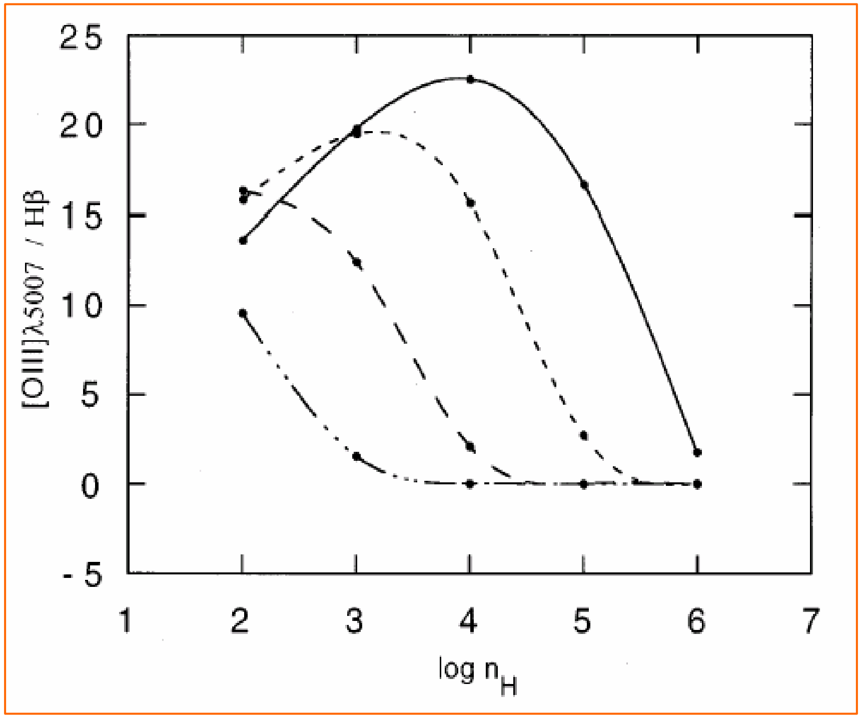
Strong FeII/Hβ_b ⇐thick BLR

⇐steep X-ray spectrum

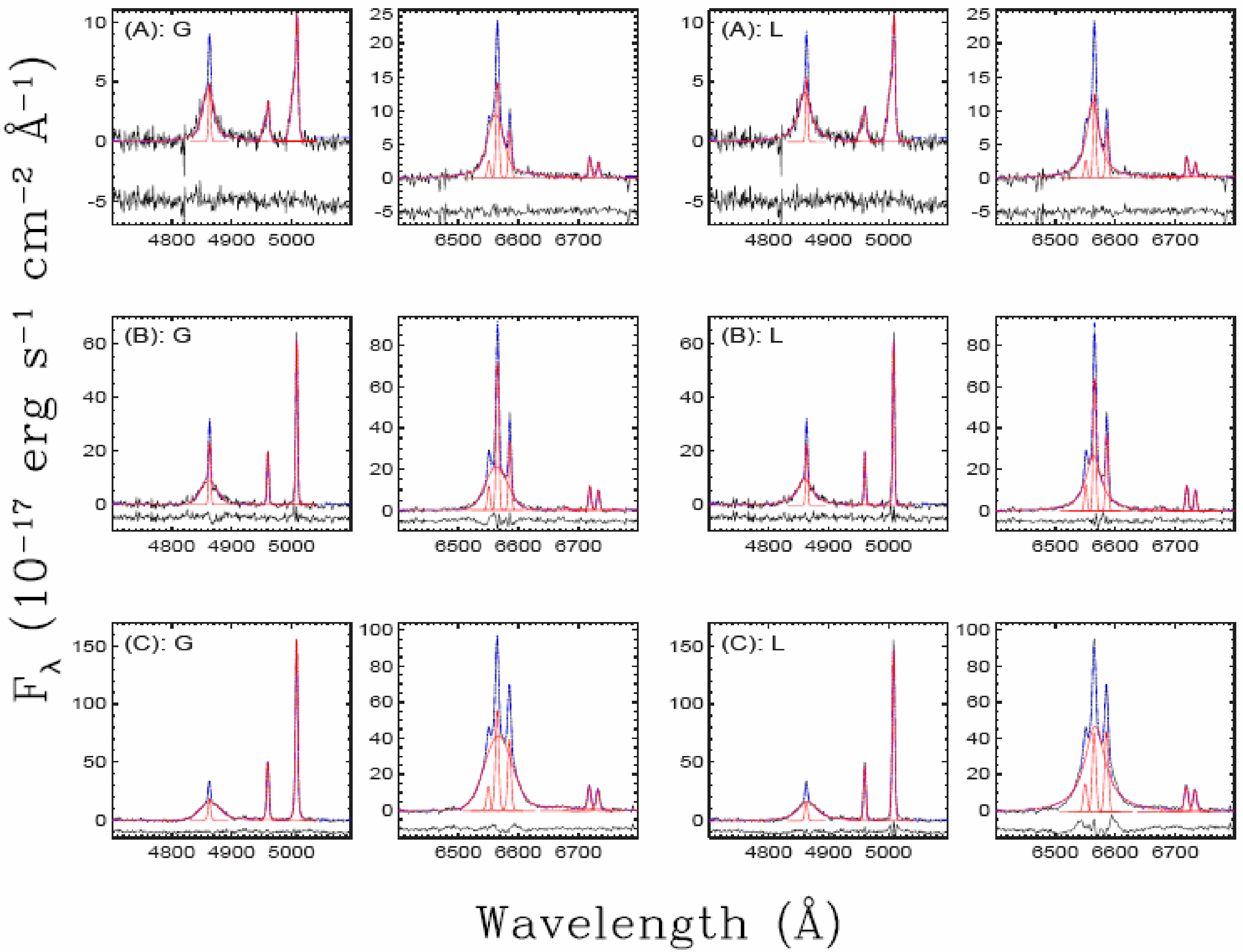
⇐high L/L_{Edd}

Weak [O III]/Hβn ⇐ dense NLR

Weak [O III]/Hβn ⇐ low-density NLR ?



Komossa & Schulz (1997)


(A): G
(A): L
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(C): L
F_λ (10^{-17} erg s^{-1} cm^{-2} Å^{-1})
Wavelength (Å)