The NLR in NLS1 galaxies

Dawei Xu, NAOC

(I) A zone of avoidance in density

(II) Correlation space

(III) The M-sigma relation

(IV) [OIII] blue outliers:

large scale outflows

In coll. with
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Luc Binette
……

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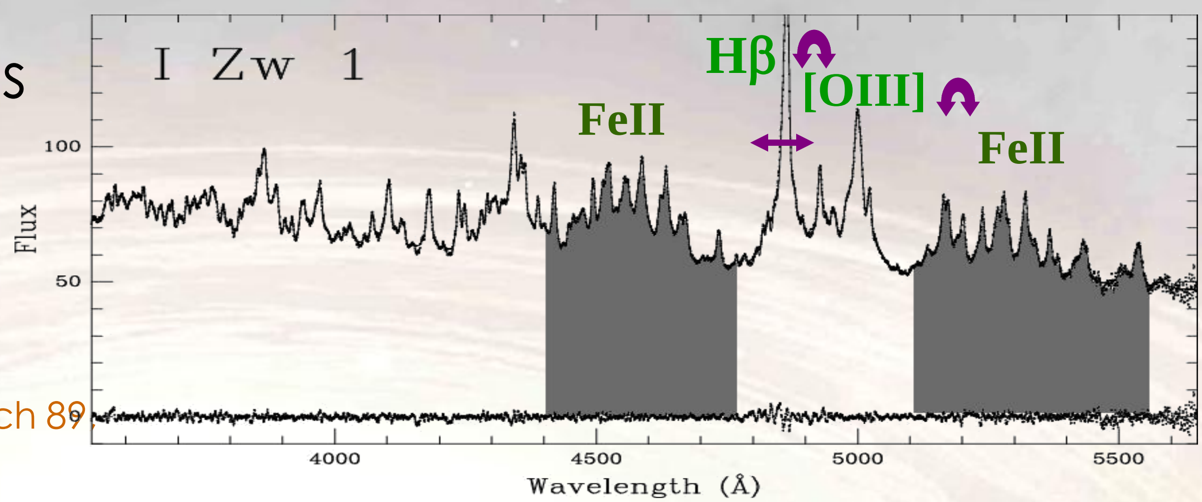
Intro: Narrow-Line Seyfert 1 galaxies

- **defi**: via optical spectral properties

$FWHM_{H\beta}$ < 2000 km/s
[OIII]/Hβ < 3
strong FeII/Hβ

[e.g.,Osterbrock & Pogge 85, Goodrich 89, Veron-Cetty & 01]



- **NLS1s at "extreme end" of correlations (`EV1´) between line/conti properties of AGNs:**

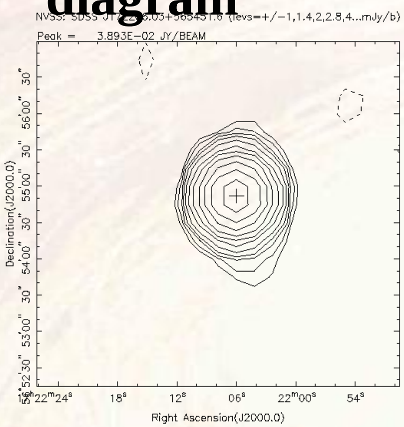
- small $FWHM_{H\beta}$
- strong FeII/Hβ
- weak [OIII]/Hβ
- strong CIV blueshifts, Hβ asym.
- *sometimes*: steep X-spectra

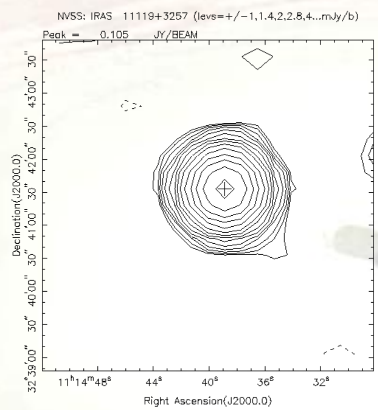
  some samples show Γ_x-$FWHM_{H\beta}$ corr., others not at all

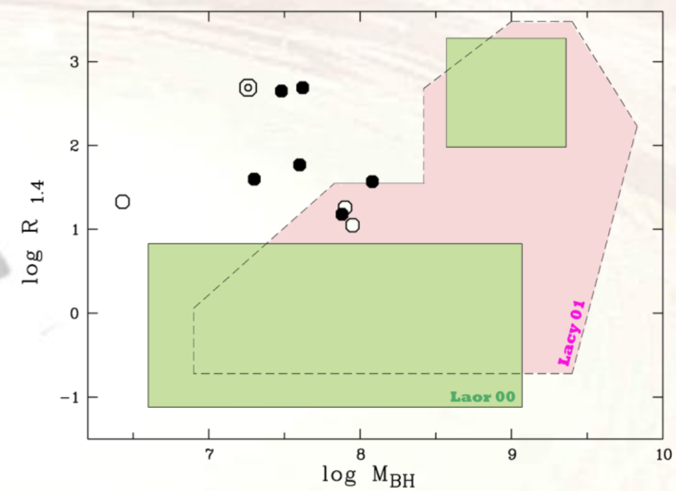
[e.g., Boroson & Green 92, Boroson 02, Osterbrock & Pogge 85, Sulentic & 00; Gaskell 85, Pounds & 95, Wang & 96, Boller et al. 96, Grupe & 97, Brandt & 97, Lawrence & 97, Laor & 97, Leighly 99, Wei & 99, Wills & 00, Veron & 01, Marziani & 01, 03, Williams & 02,04, Puchnarewicz & 02, Zheng et al. 02, Richards & 02, Shemmer & Netzer 02, Sulentic & 02, 03, Xu & 03, 07a,b, Grupe 01, 04, Bachev & 04, Netzer & 04, Fields & 04, Zhou 06]

Intro: Narrow-Line Seyfert 1 galaxies

- Systematic radio study (Komossa & 06) showed that:
  - NLS1s, as a class, are much less radio-loud than BLS1s.
  - RL-NLS1s show similarity with compact steep-spectrum sources (CSS), which might be young radio sources in dense environment;
  - BH masses in prev. rarely populated regime of $M_{\rm BH}$-radio-loudness diagram







- Among the radio-loudest NLS1s, several cases for beaming have emerged, and they share similarities with blazars (e.g., Zhou& 03, Komossa& 06, Yuan& 08).
- Some of the beamed radio-NLS1s have now also been detected in the gamma-ray regime (we'll hear more on this from Luigi...).

(I): 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; Komossa et al. 2008) 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?

(I): NLR density in NLS1s

We present for the first time a systematic study of the NLR density for a large homogeneously analyzed NLS1 sample and compare it with that of BLS1s, by using the density diagnostic [S II] line ratio: i.e., [S II]6716/6731.

We attempt to answer the following key questions:

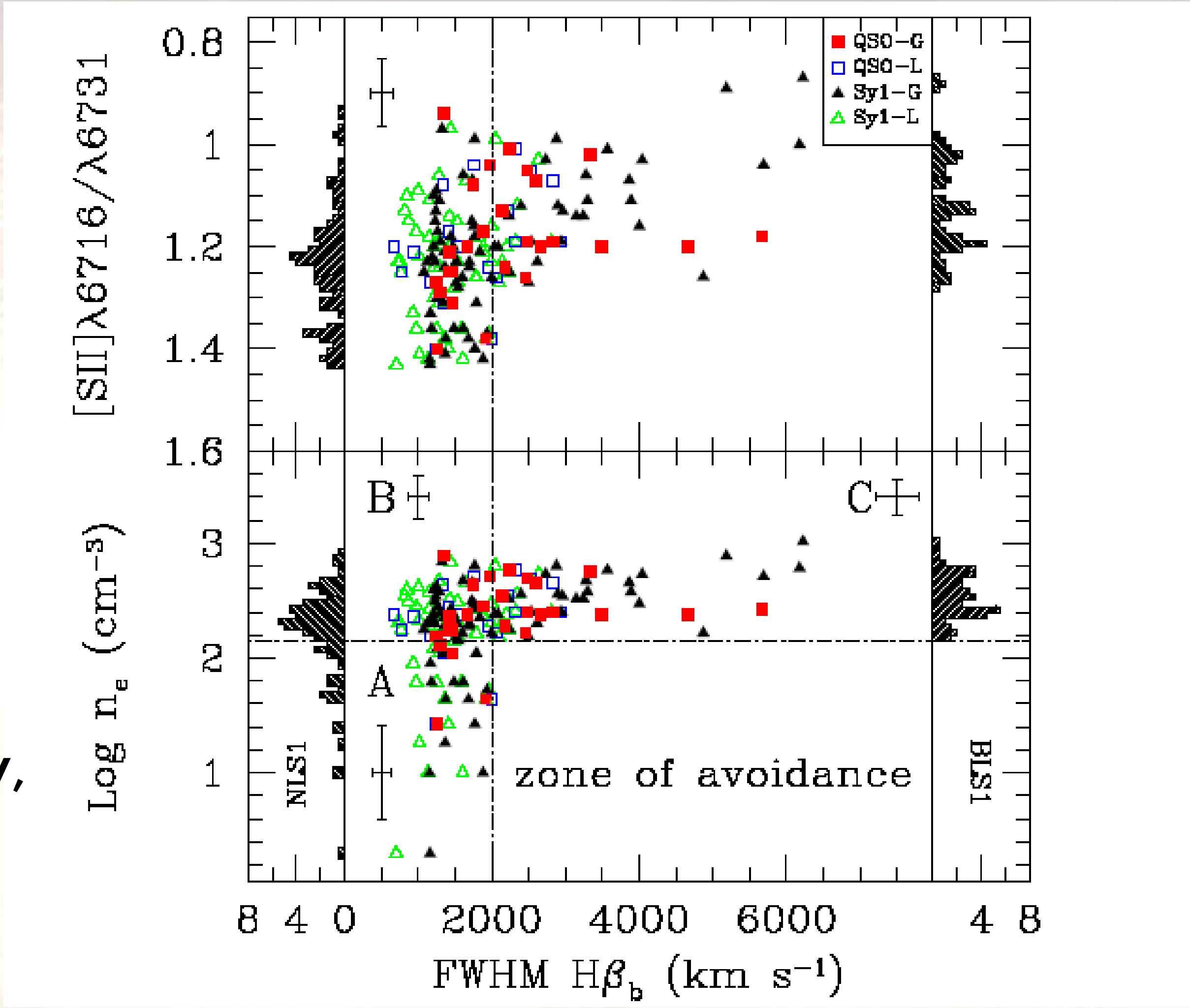
- Is there any difference in the NLR density between NLS1s and BLS1s?
- If so, do trends in density correlate with other parameters?
- What are the key physical drivers of the trends in density?

(I): Density vs FWHM ($H\beta_b$):

a zone of avoidance

Key finding:

detection of a '*zone of avoidance*' in the density—FWHM ($H\beta_b$) 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}.



Xu, Komossa+ 07

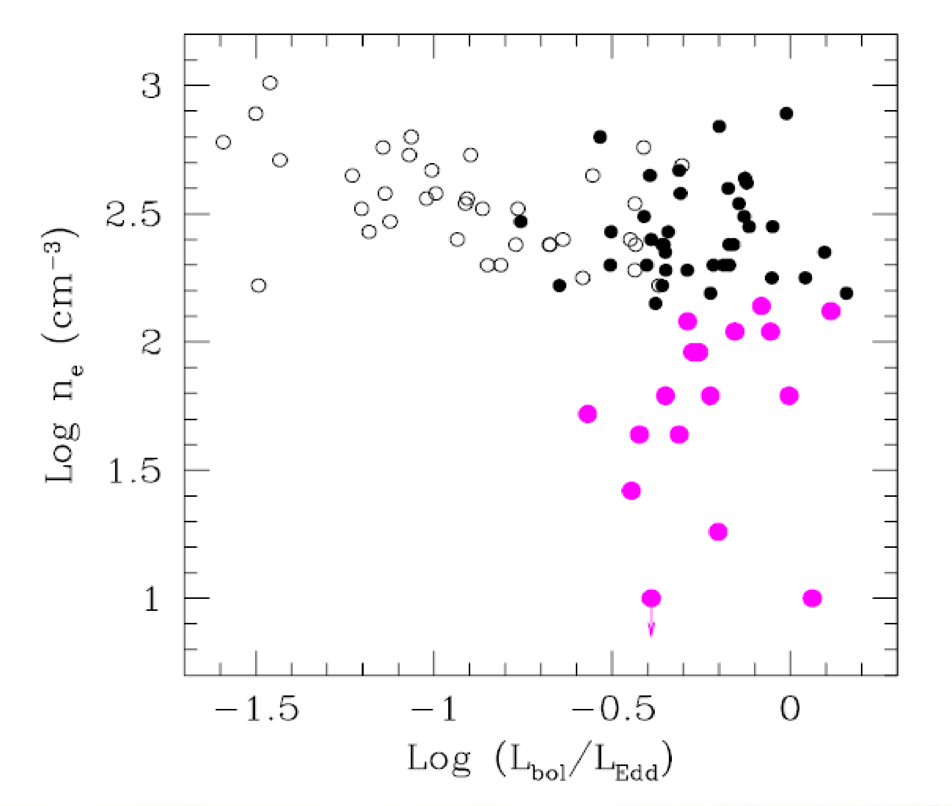
(I): On the origion of the ZOA

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} vs. density:

- Anti-correlation between density and L/L_{Edd} (rs =-0.42)
- 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?
- Low n_e NLS1s have higher-than-average L_X/L_{Edd} compared to high-n_e NLS1s.



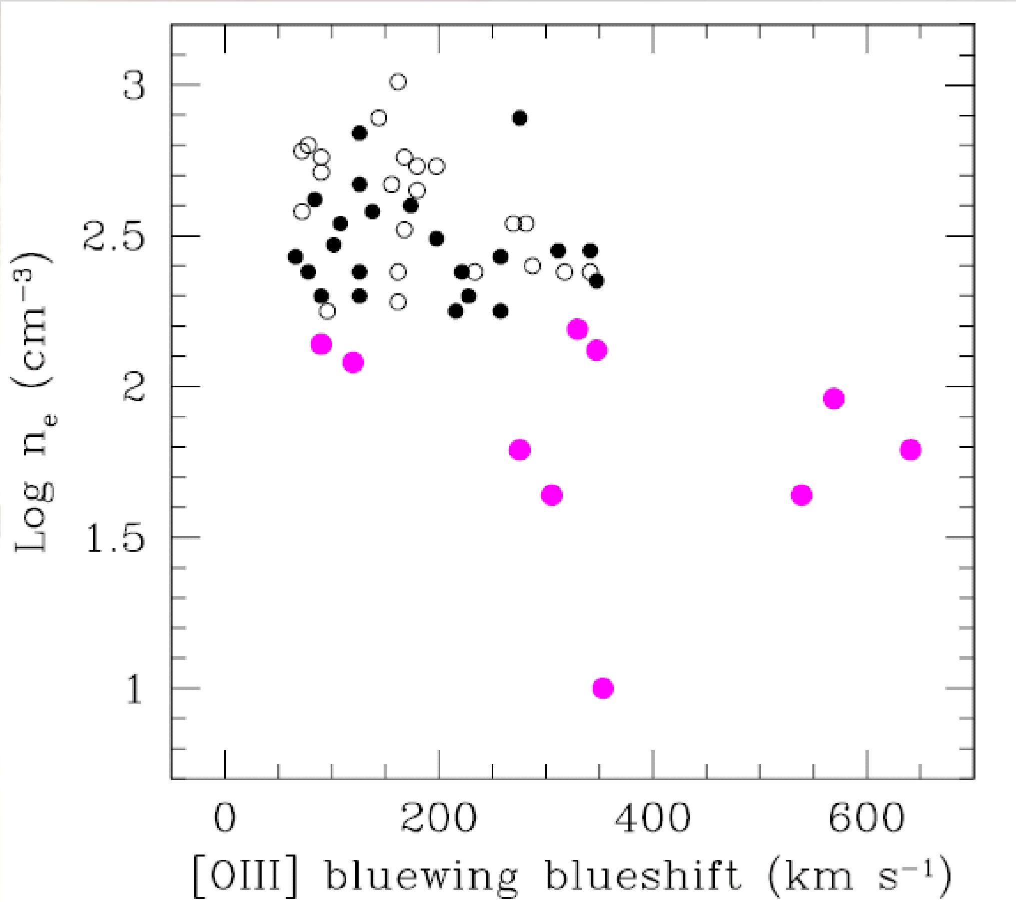
(I): On the origin of the ZOA-outflows

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

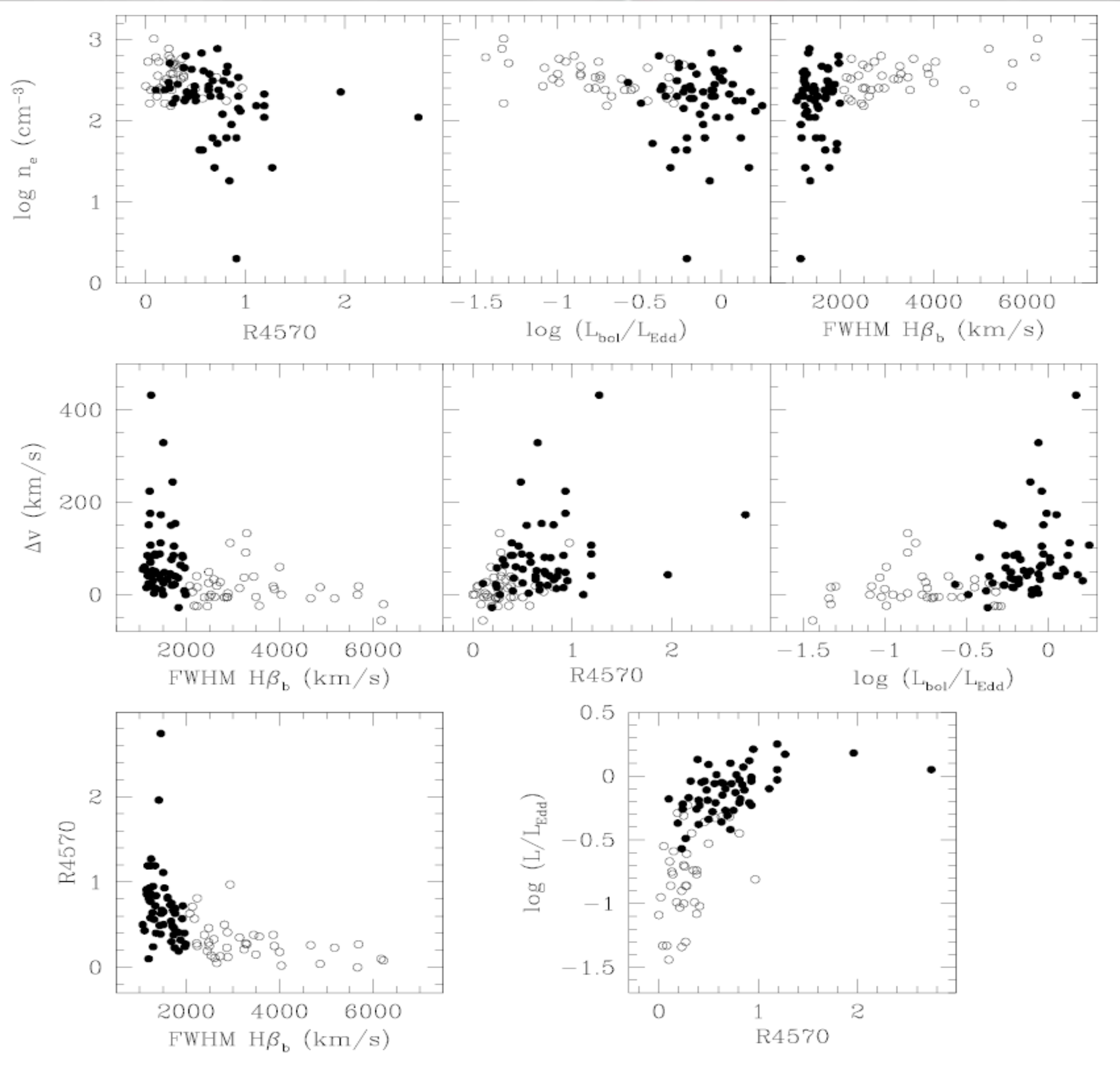
- **Only a weak correlation (rs=-0.29) exists between the density and the [OIII] peak blueshift.**
- **the [OIII] peak blueshift does strongly correlates with L/L_{Edd} .**

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

- ***A strong correlation is seen (rs=0.51)!***



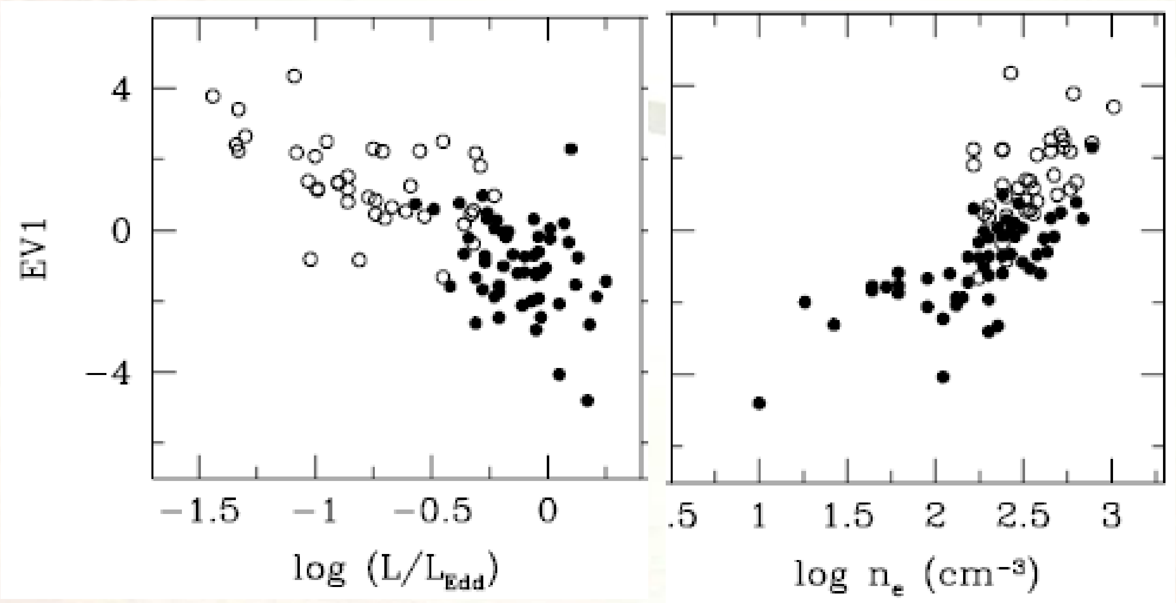
(II): Correlation Space



(II): Correlation Space

Eigenvector 1: search for physical driver of the correlation space

- **Main driver：Eddington ratio**
- **New element：the NLR density**



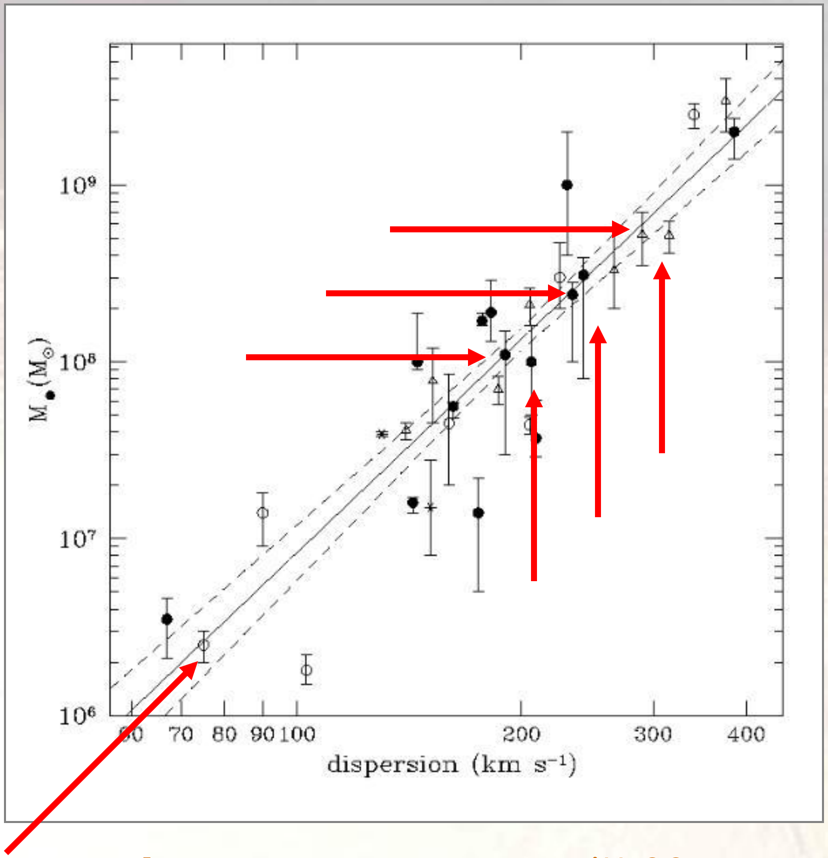
Xu & Komossa 2010

(III): The M_{BH} - σ relation

- correlation between black hole mass, M_{BH}, and bulge stellar velocity dispersion, σ_*,

$M_{BH}/(10^8 M_{sun}) = 1.7\ (\sigma_*/\sigma_0)^{4.9}$ (FF05)

→ **implies close link between BH and galaxy formation/evolution**



- do all types of galaxies, at all times, follow the M-σ_* relation ?

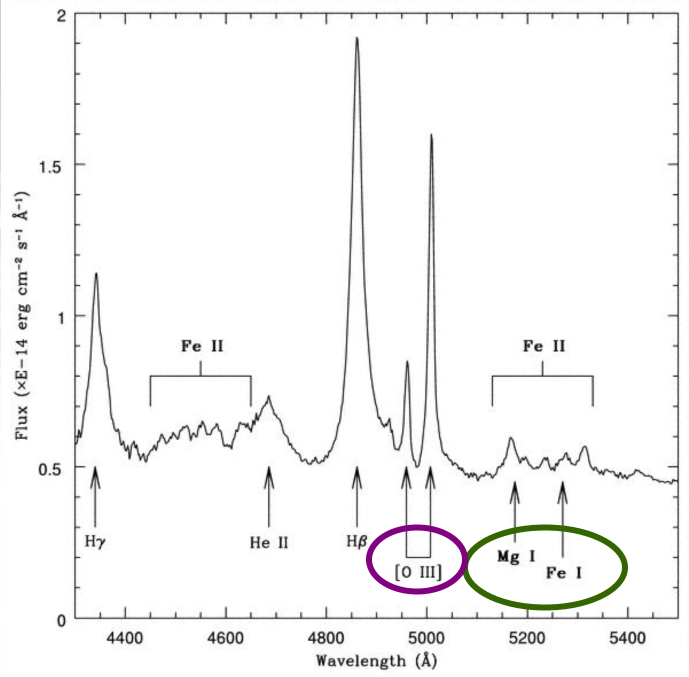
- how do objects '*move onto*' the relation ?

[M-σ: Ferrarese & Merritt 00, Gebhardt & 00, MF01, Tremaine & 02, Ferrarese & Ford 05]

[models: e.g., Silk & Rees 98, Burkert & Silk 01, Haehnelt+ 03, Springel+ 05, Hopkins+ 06, Li+ 07 ....]

(III): M_{BH} and σ measurements in AGNs

• in AGNs, an independent way to estimate *BH masses* from “reverberation mapping“ of the BLR, → R_{BLR}-L relation
[e.g., Kaspi et al. 2005, Peterson 2007]



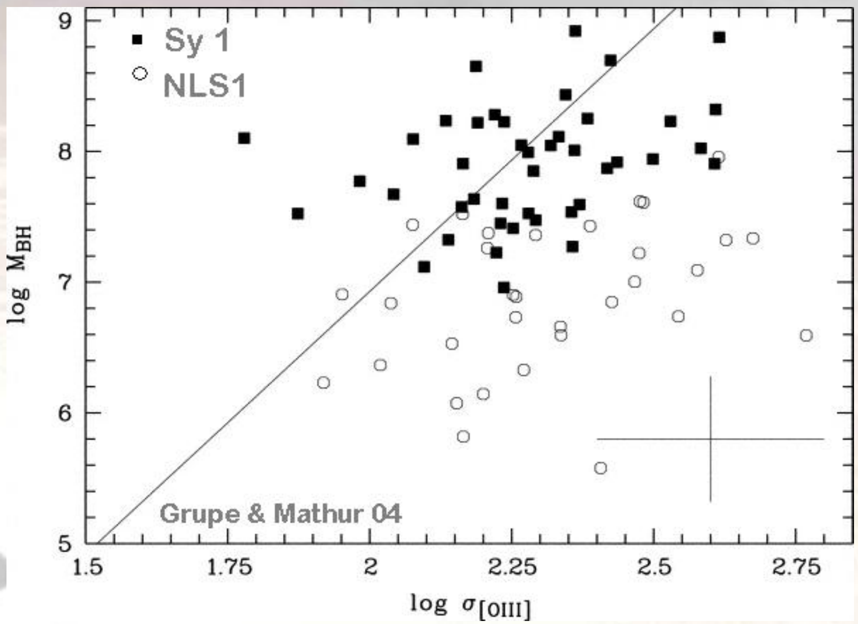
• do we also have a way to measure σ_* ?
Not really, AGN conti bright; stellar absorption features often superposed by bright conti & emission-complexes

→ use *gaseous* kinematics, traced by emission-lines, instead.
[Nelson & Whittle 96, Nelson 2000]

• nearby ‘normal‘ AGNs: agree with M_{BH}–σ_* relation if $\sigma_{[OIII]}$ is used as substitue for σ_*

(III): NLS1s on the $M_{BH} - \sigma_{[OIII]}$ planes

- original trend: NLS1s are *OFF* $M_{BH} - \sigma_{[OIII]}$ relation(Mathur+ 01), but "on" in Wang & Lu (2001)
- few real σ_* measurements (e.g., Botte+ 05: "on"; Zhou+ 06: "off"; Bian+ 08 "on" or "off")
- few L_{bulge} measurements (e.g., Botte+ 04, Bentz+ 11: "on"; Ryan+ 07, Mathur+ 11, Orban de Xivry+ 11: "off")



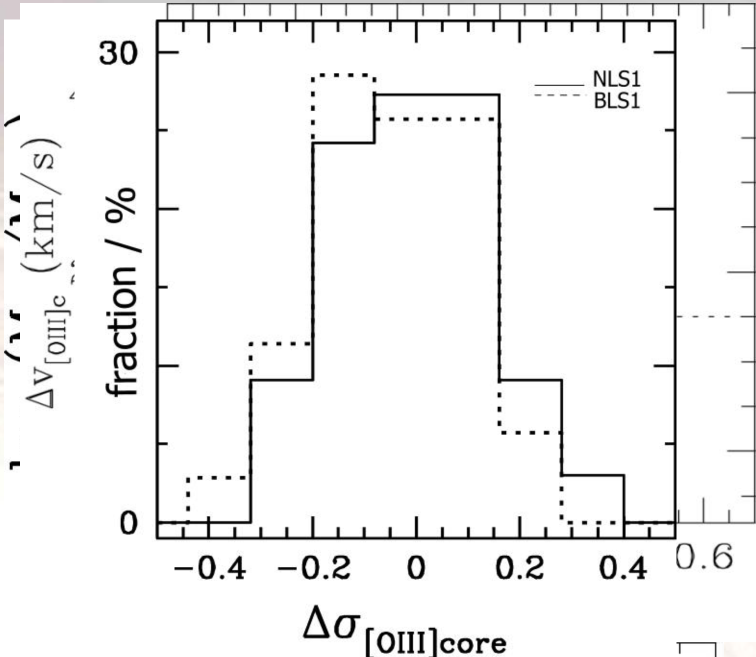
→ how reliable is [OIII] as substitute for stellar velocity dispersion ?

→ need large, independent, homogeneously analyzed samples

[Mathur & 01, Wang & Lu 01, Wandel 02, Grupe & Mathur 04, Bian & Zhao 04,06, Botte & 04, 05, Barth & 05, Mathur & Grupe 05a,b, Greene & Ho 05, Zhou & 06, Ryan & 07, Watson & 07, Komossa & Xu 07, Bentz & 11, Mathur &11, Orban de Xivry& 11]

(III): NLS1s on the M_{BH} – σ relation

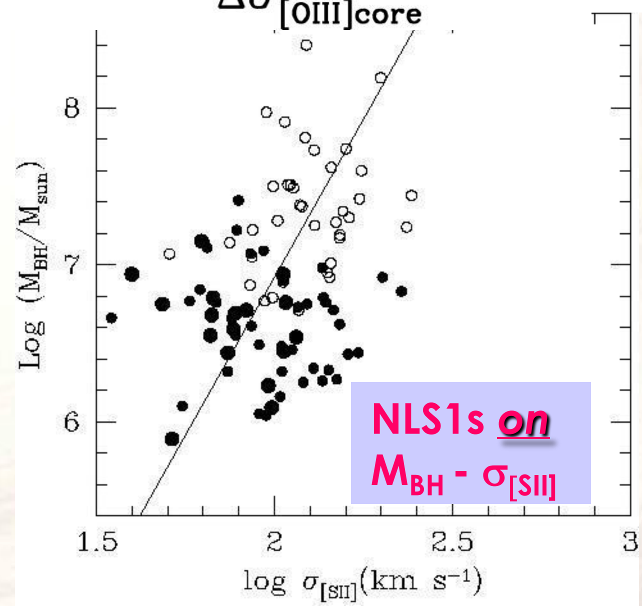
- our analysis, based on a sample of SDSS-NLS1s, plus a BLS1 comparison sample; using several NLR emission lines & decomposing complex [OIII] profile (Komossa & Xu 07)



→ NLS1s ***follow*** the M_{BH} - $\sigma_{[SII]}$ relation

→ and NLS1s follow the M_{BH} - $\sigma_{[OIII]}$ relation, *if objects with outflows in [OIII] are removed, in which velocity fields are not dominated by the bulge potential*

→ remaining scatter in the relation does not *systematically* depend on [OIII] strength, FeII, density, M_i, L/L_{edd}



(III): NLS1s on the $M_{BH}-\sigma_*$ relation

- in summary: NLS1 galaxies *do* follow M-σ, if objects dominated by outflows* are removed

→ they evolve *along* the M-σ relation

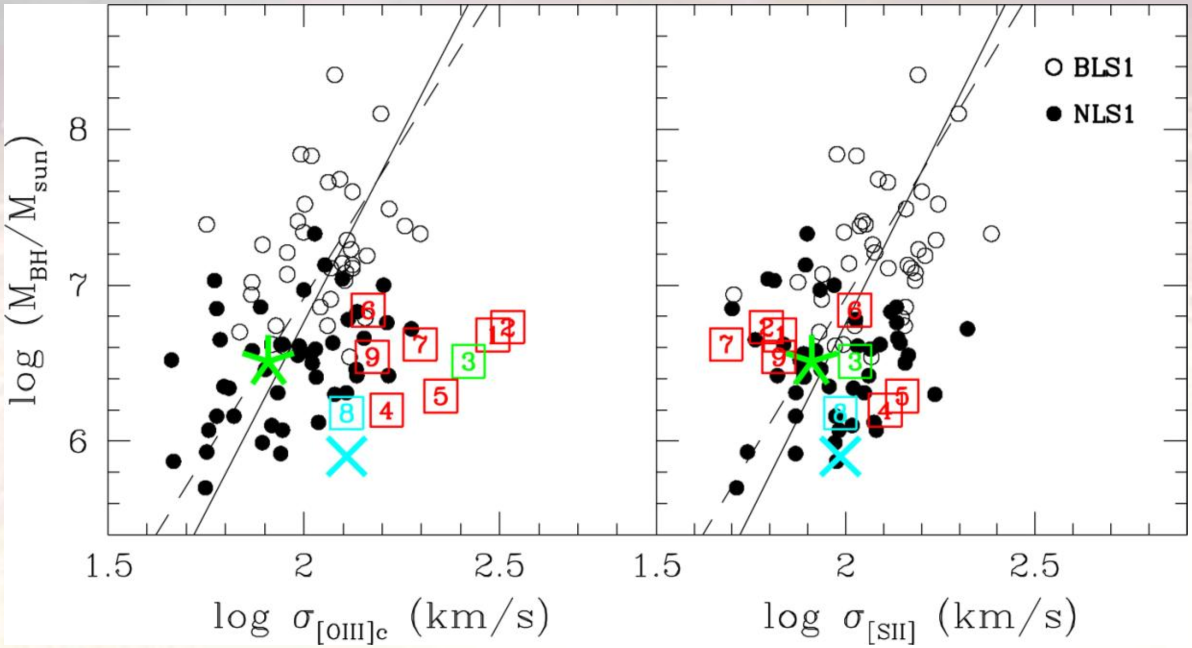
- BH mass increases by fact. 10 within 10^8 yr ($L \sim L_{edd}$), if BH keeps growing
- NLS1 hosts: no mergers, but perhaps excess of bars
- secular processes at work to adjust host properties, keeping them on the relation

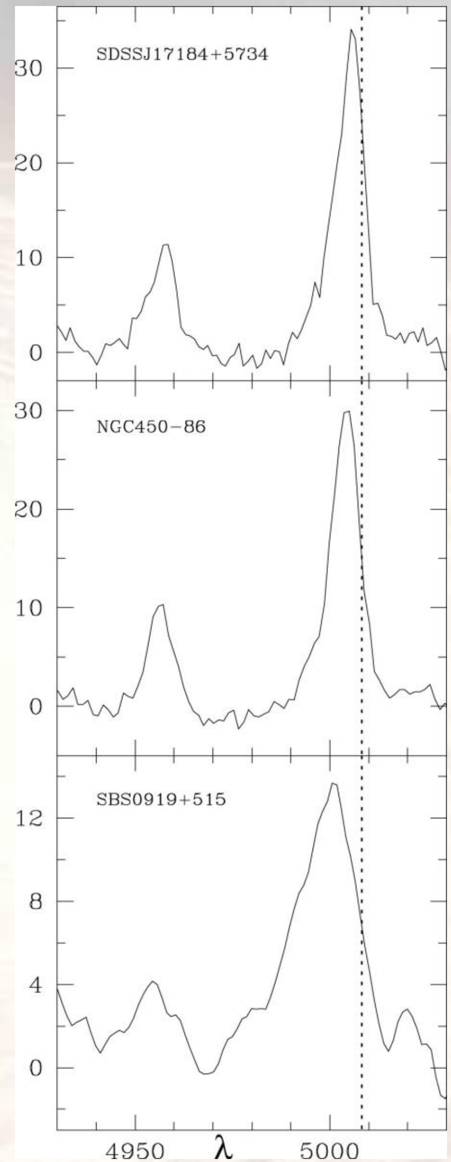
→ or they are simply low mass extensions of the BLS1 phenomenon

- high L/L_{edd} just represents a short-lived acc. phase

* NLR outflows also occur in BLS1s → studies which involve [OIII] lines as surrogate for σ_* should remove objects with strong [OIII] shifts from the sample

(IV): strong outflows in AGN: on the nature of [OIII] “blue outliers“

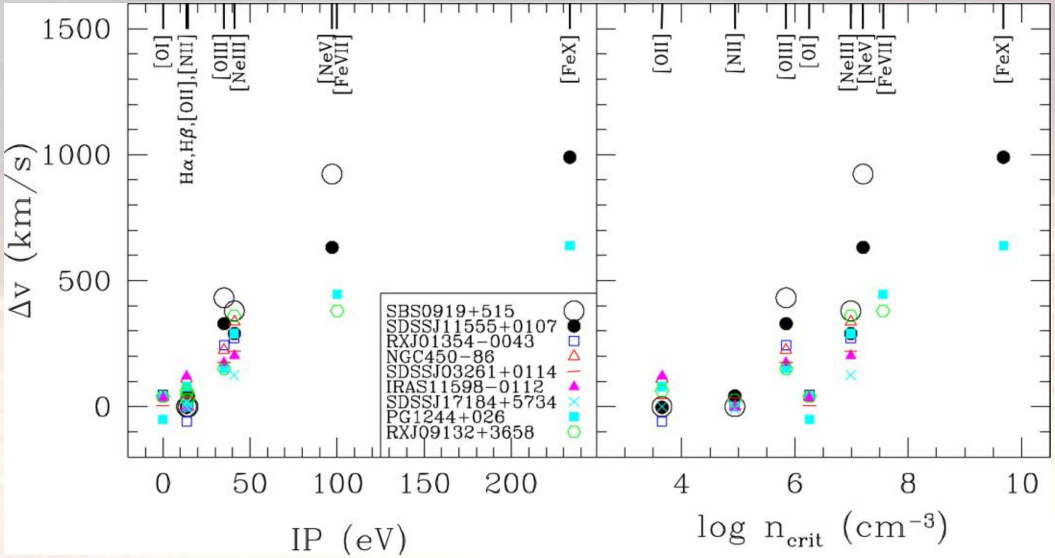


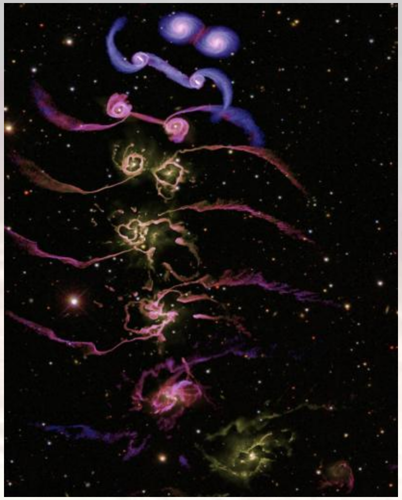


what causes the “blue outliers“, which have their whole [OIII] profile blueshifted, by up to several 100 km/s?

(IV): on the nature of [OIII] "blue outliers"

[Komossa, Xu, Zhou, Storchi-Bergmann, Binette 08]



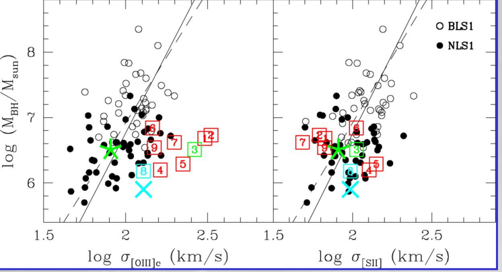


[di Matteo+ 05]

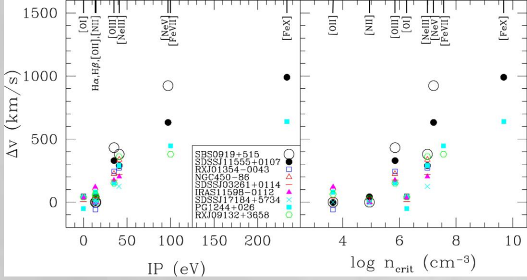
- other emi-lines show evidence for *extreme outflows* up to 1000 km/s; affecting the CLR, and large parts of the NLR - while the outer NLR is quiescent
- Scenario: the NLR clouds are entained in a decelerating wind
- driving mechanism is still being investigated -

radiation pressure on gas, cloud-entrainment in jets or thermal winds

- high *L*/*L*edd, & pole-on view into an outflow ?
- is *feedback* due to outflows at work? follow-up *HST* imaging: search for mergers *a la* Springel et al. / or bars



Summary



- A 'zone of avoidance' in the density—FWHM ($H\beta_b$) diagram is detected. Several lines of evidence show that outflows play a significant role in driving the difference in the NLR density between NLS1s and BLS1s.

- the NLR density is added as a new element to the EV1 space.

- NLS1s do follow the *M*–σrelation of BL-AGNs and normal galaxies, if [SII], $[OIII]_{core}$ are used to measure σ ; *with one exception*:

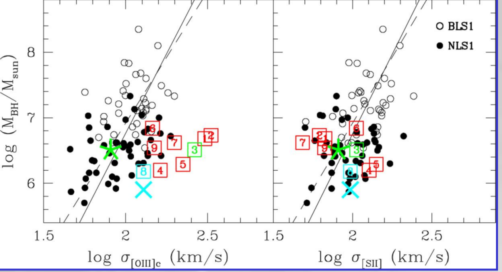
- lines with systematic blueshifts in [OIII] have anomalously broad profiles → outflows dominate → not suitable for σ_* measurements, all samples making use of [OIII] should remove 'blue outliers' ;

- these [OIII] 'blue outliers' are of independent interest because of their strong large–scale outflows (→ constraints on mechanisms to drive AGN winds on large scales).

Other recent work on NLS1s of the USTC—NAOC group

- **Largest NLS1 sample SDSS DR4, ~2000 NLS1** Zhou, Wang, Yuan & 2006
- **Radio-loud NLS1s**
  - **A new population of RL-NLS1 with jets suggested before the Fermi observations** Zhou & 2003, 2007, Yuan & 2008
  - **New region in the radio-loudness—M_{BH} diagram** Komossa & 2006, Yuan & 2008
- **X-ray property of extreme NLS1 (FWHM_Hβ<1200 km/s)**
  - **First convincing evidence for AGN accretion disk seen in X-ray in J1633+4718** Yuan & 2010
  - **The hard X-ray 2-10keV continuum slopes flatten at L/Ledd ~ 1** Ai & 2011
  - **Rapid and large variability consistent with small MBH** Ai & 2011
- **Optical/UV variability** Ai, Yuan, Zhou, &. 2010, 2011 (in prep.)
  - **NLS1 are variable and in a way similar to BLS1, *but with less amplitude***
  - **Variability inversely correlated with L/Ledd**
  - **A few NLS1 with large variability found (by a fraction of 1mag)**

Thank you for your attention!



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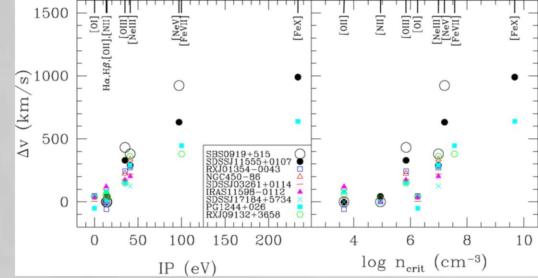

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