GN12

XII Congresso Nazionale sui Nuclei Galattici Attivi

AGN12 - a Multi-Messenger perspective 27/09/16

An X-ray/SDSS sample: Observational characterization of the outflowing gas

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MARIE CURIE ACTIONS

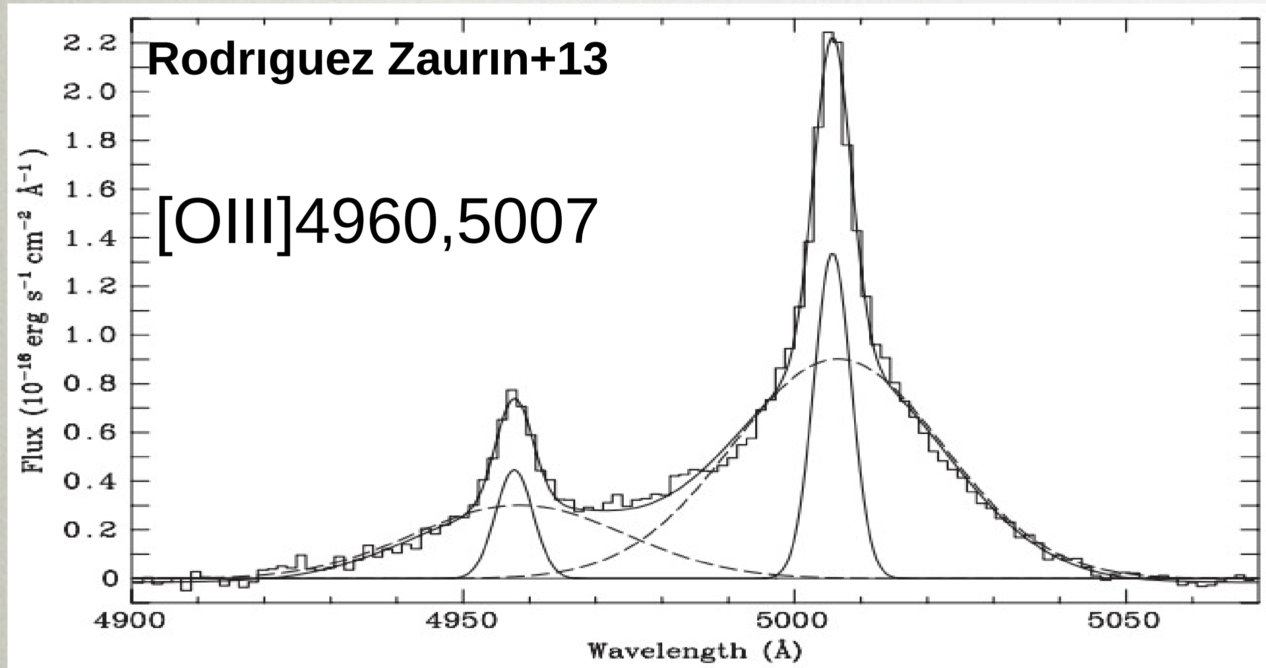
SEVENTH FRAMEWORK PROGRAMME

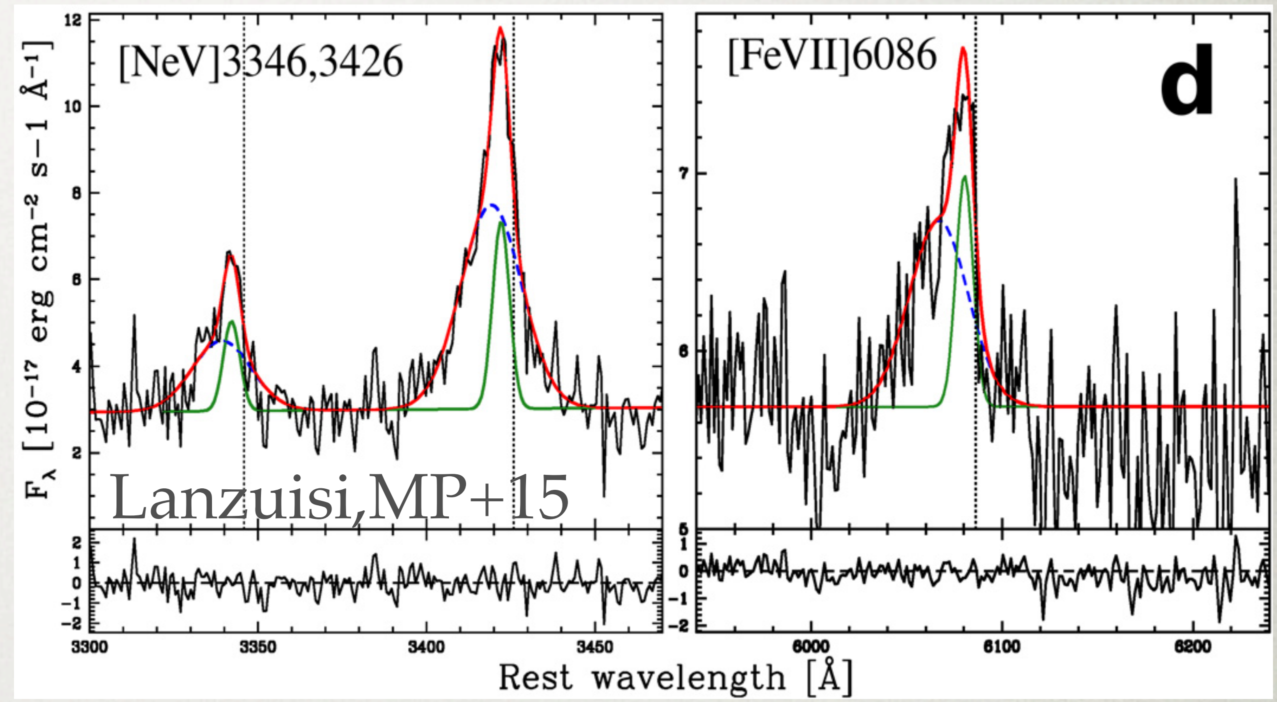
CIG grant (eEASy)

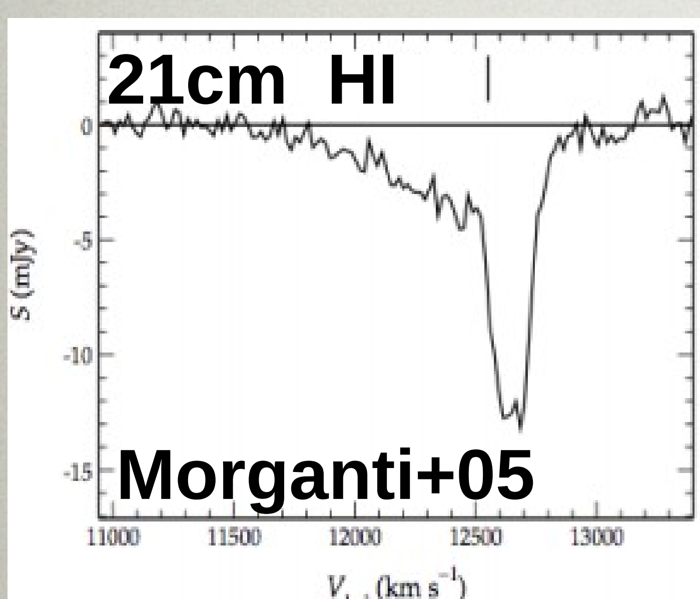
Istituto Nazionale di Astrofisica INAF

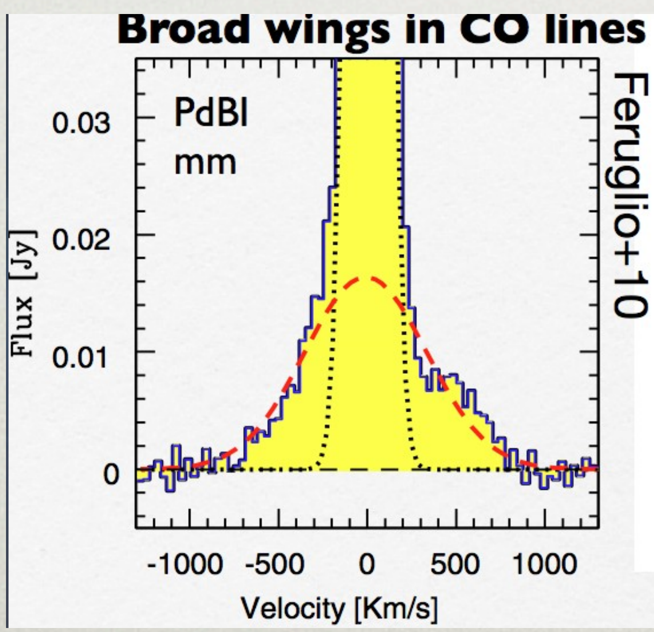
Alma Mater Studiorum Università di Bologna A.D. 1088

Feedback - gas flows





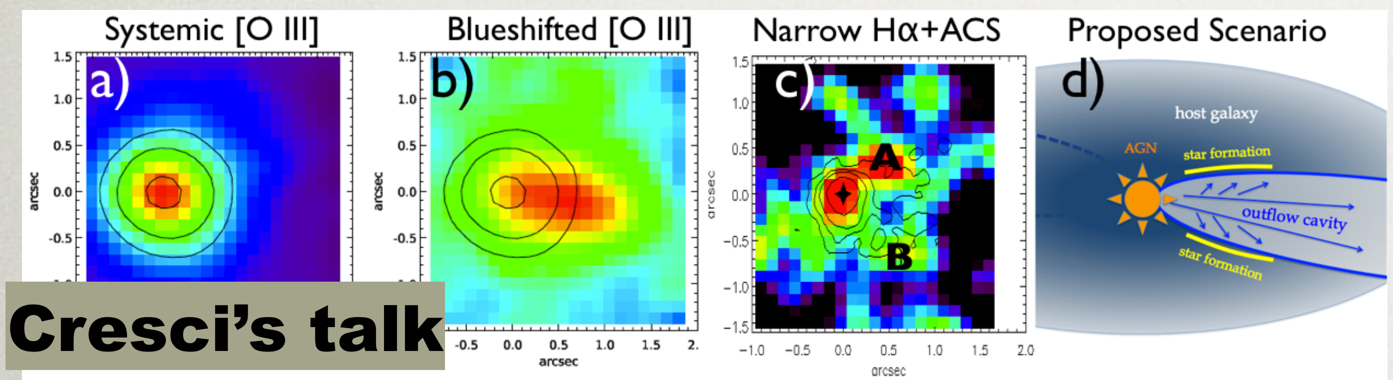


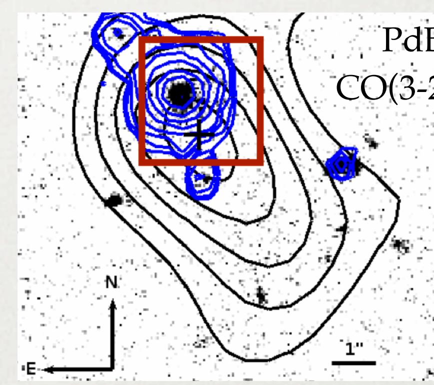


broad (and shifted) wings in ionized, atomic and molecular features

OUTFLOW CHARACTERIZATION

- major facilities synergy to study the multiphase wind / ISM interactions in individual objects

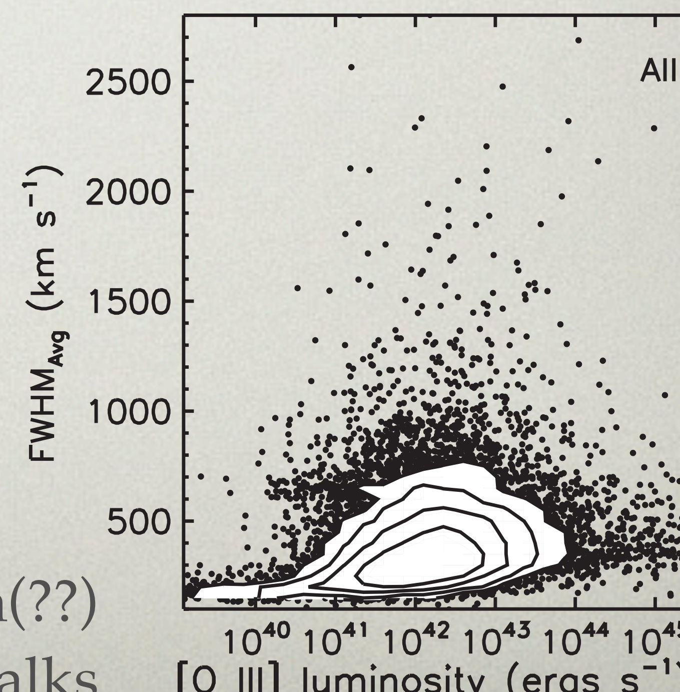




XID2028
Brusa+10;15a,b
Cresci+15
MP+15

- large samples to connect the presence of outflows with AGN & host properties

e.g., L(1.4GHz), L([OIII]), SFR, sSFR, BHAR, ...
(see Wylezalek&Zakamska16; Balmaverde+16; Zakamska+16; Woo+16; Chen+15; Banerji+15; Mullaney+13;...)
see Bongiorno's & Rodighiero's talks

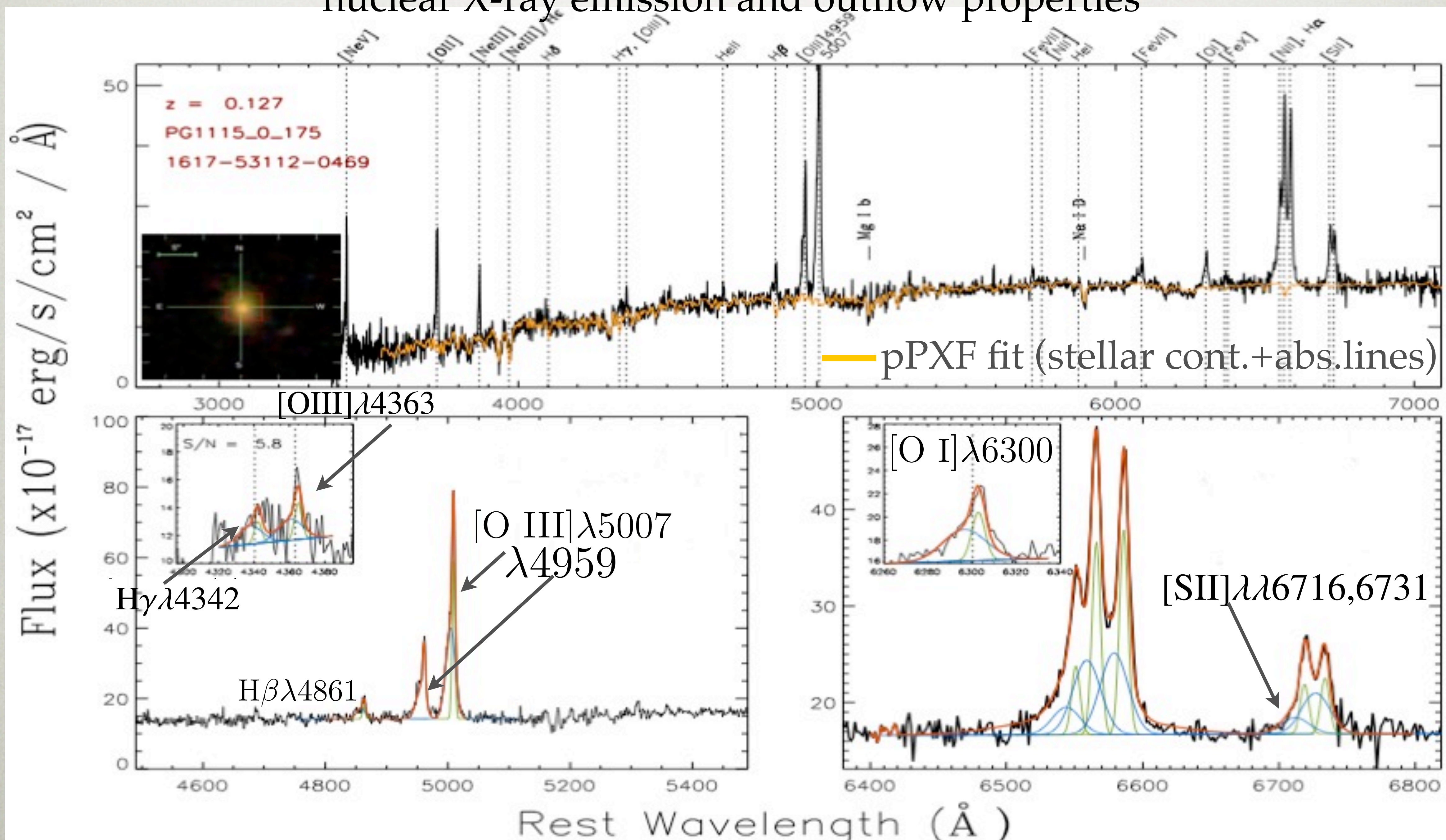


Mullaney+13

AGN / SF division(??)
Magliocchetti's & Padovani's talks

The X-ray/SDSS sample

~ 500 X-ray selected [*from Georgakakis+11; Jin+12; Wang+12; Trichas+13*] type 1 & type 2 AGNs with z < 0.8 and SN(OIII) > 10 to derive general relations between nuclear X-ray emission and outflow properties



X-RAY/SDSS SAMPLE- OUTFLOW INCIDENCE

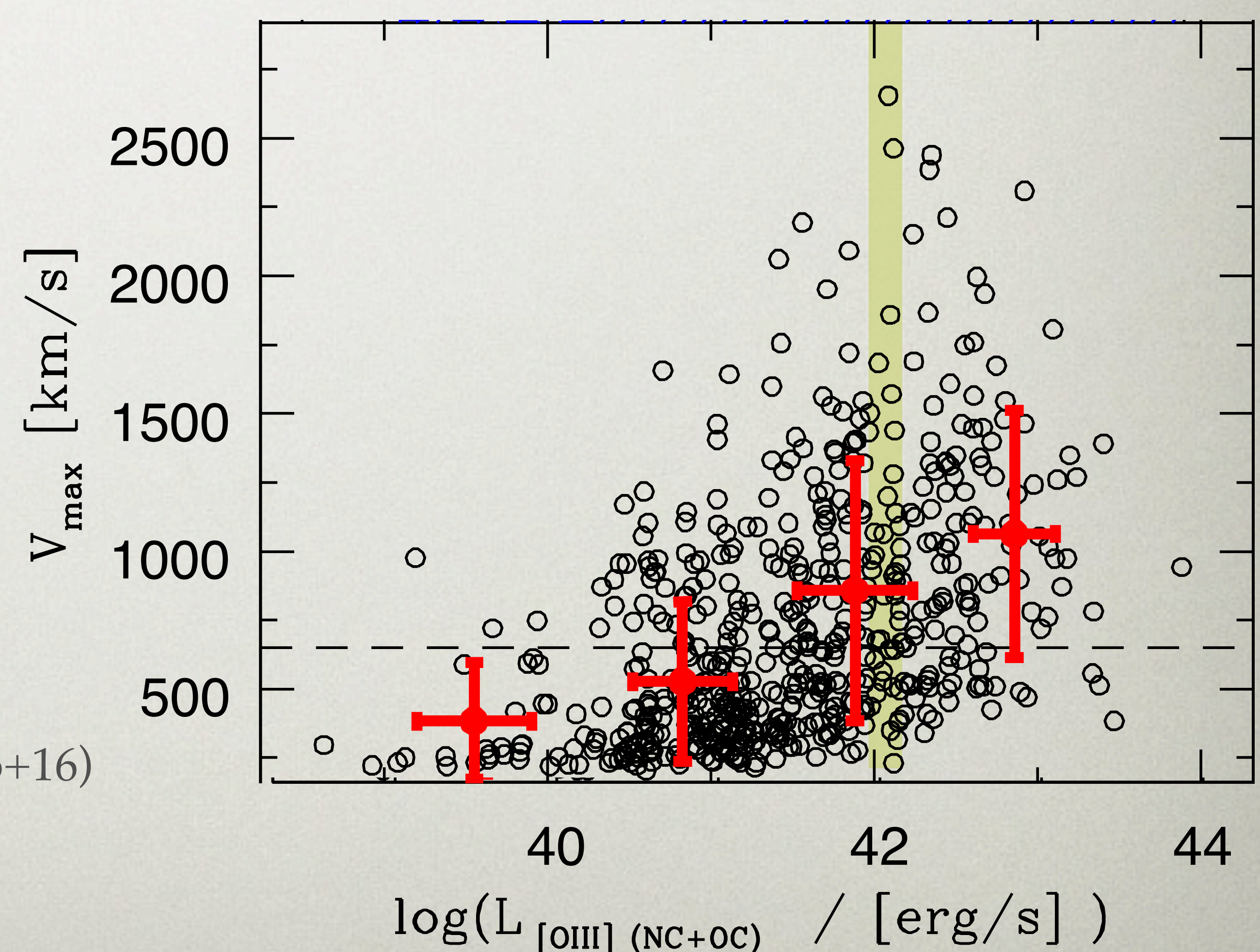
ionized component - [OIII]5007 line

- **~ 40 % shows signature ionized outflows**

  32% blue wings - approaching flows
  7% red wings - receding flows
  (same fraction in Veron-Cetty+2001; Woo+16; ...)

- **Outflow fraction increases w/ Luminosity**

- **Fraction > 50 % in QSO-Luminosity regime**
  $L_{[OIII]} \approx 10^{42}$ erg/s, i.e. $L_{bol} \approx 10^{45}$ erg/s
  (same threshold in Veilleux+13; Zakamska & Greene 14; Woo+16)



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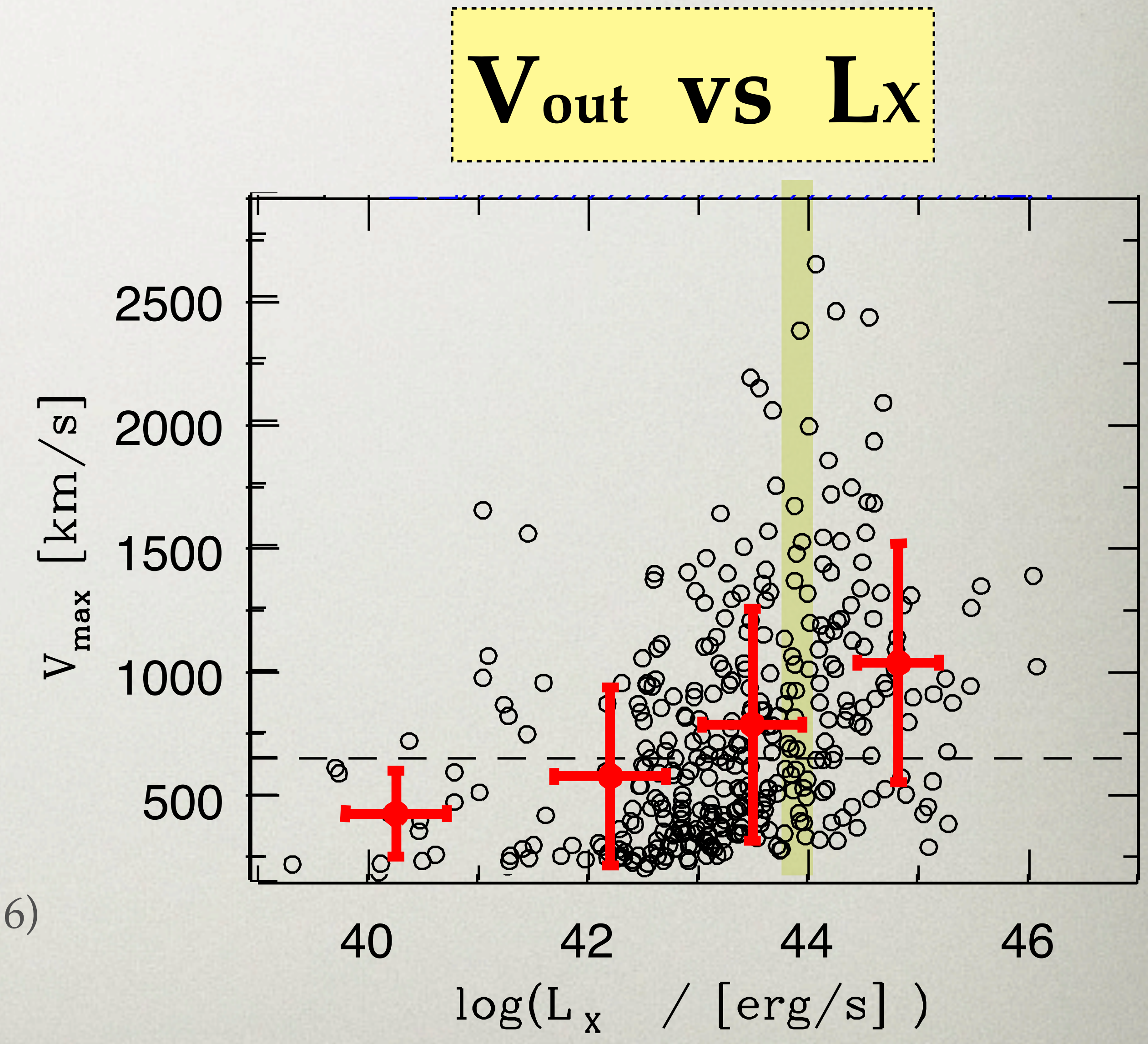
- Outflow fraction increases w/ Luminosity

- Fraction > 50 % in QSO-Luminosity regime

  $L_X \approx 10^{44}$ erg/s, i.e. $L_{bol} \approx 10^{45}$ erg/s
  (same threshold in Veilleux+13; Zakamska & Greene 14; Woo+16)



X-RAY/SDSS SAMPLE-OUTFLOW INCIDENCE

ionized component - [OIII]5007 line

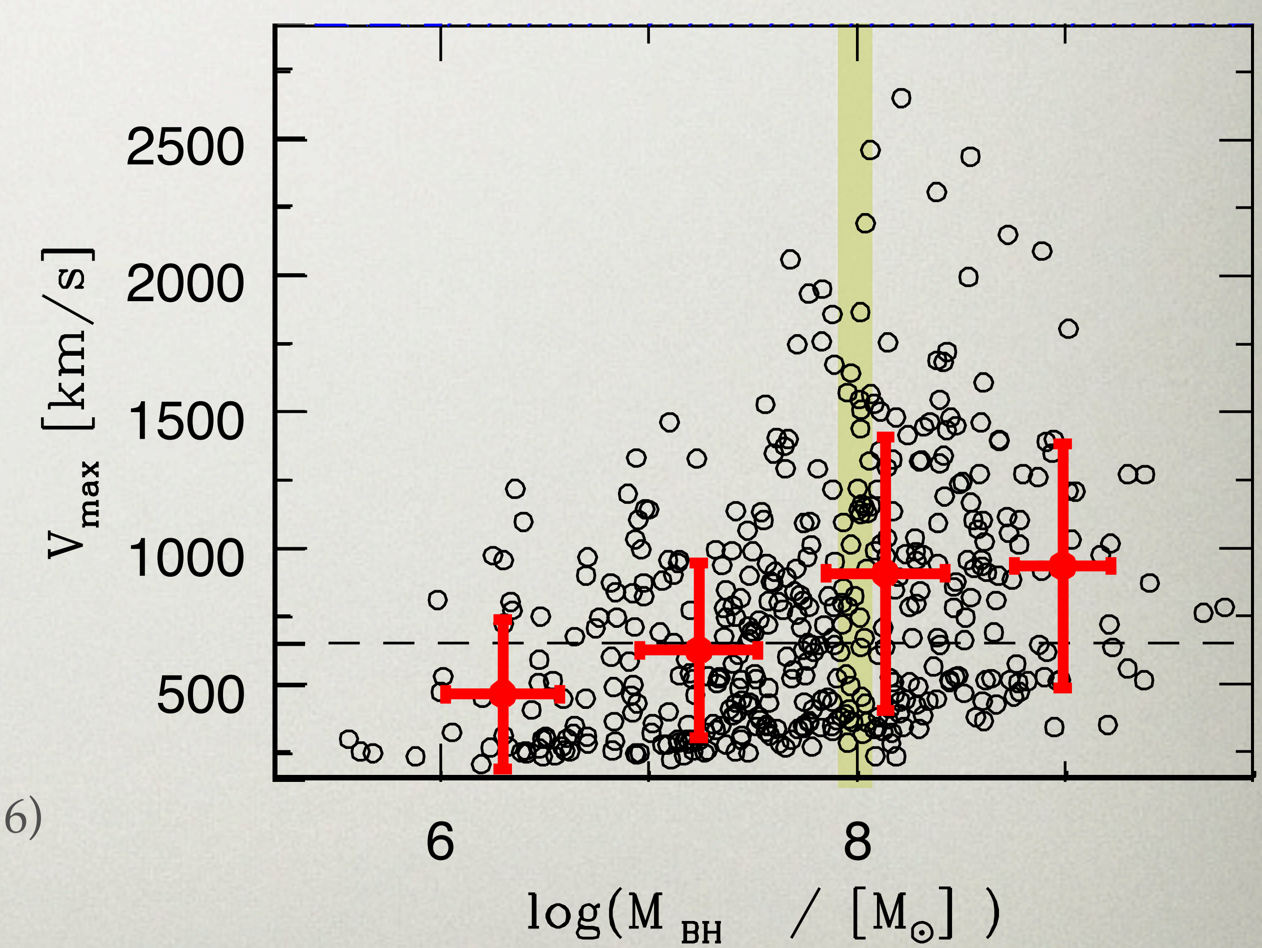
- ~ 40 % shows signature ionized outflows

  32% blue wings - approaching flows
  7% red wings - receding flows
  (same fraction in Veron-Cetty+2001; Woo+16)

- Outflow fraction increases w/ BH mass

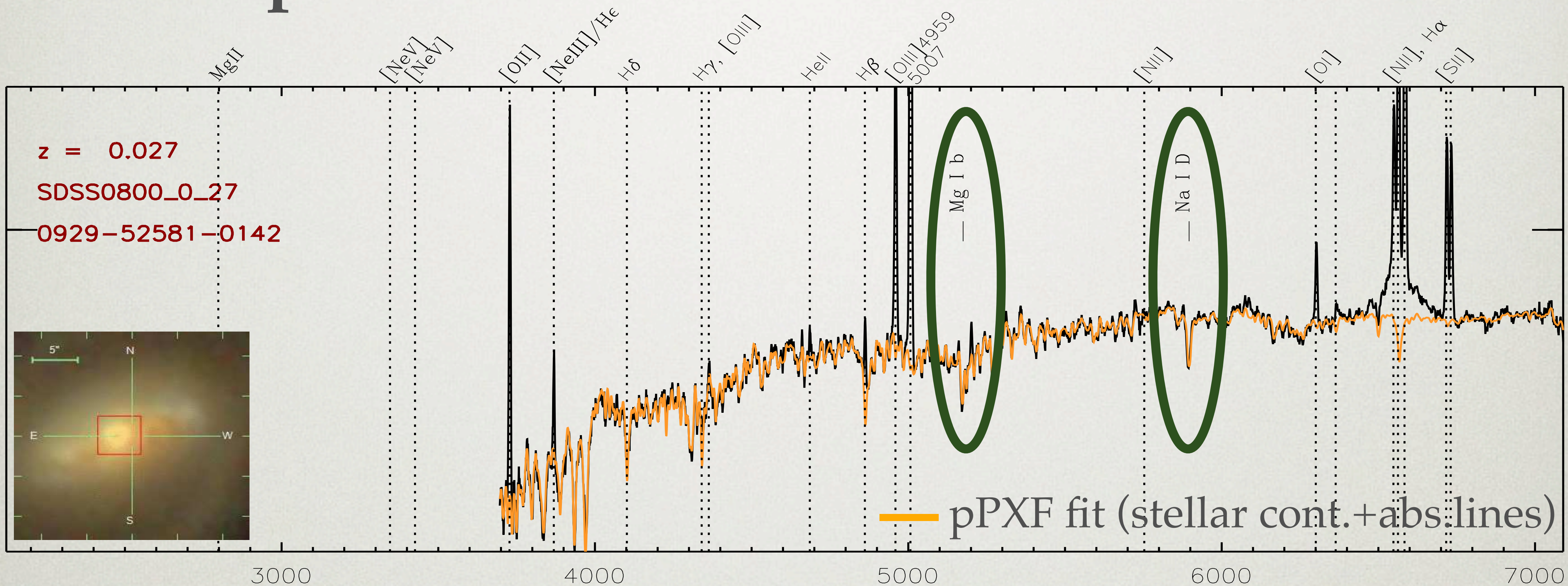
- Fraction > 50 % in more massive BHs
  $L_X \approx 10^{44}$ erg/s, i.e. $L_{bol} \approx 10^{45}$ erg/s
  (same threshold in Veilleux+13; Zakamska & Greene 14; Woo+16)

Vout vs MBH



X-RAY/SDSS SAMPLE-OUTFLOW INCIDENCE

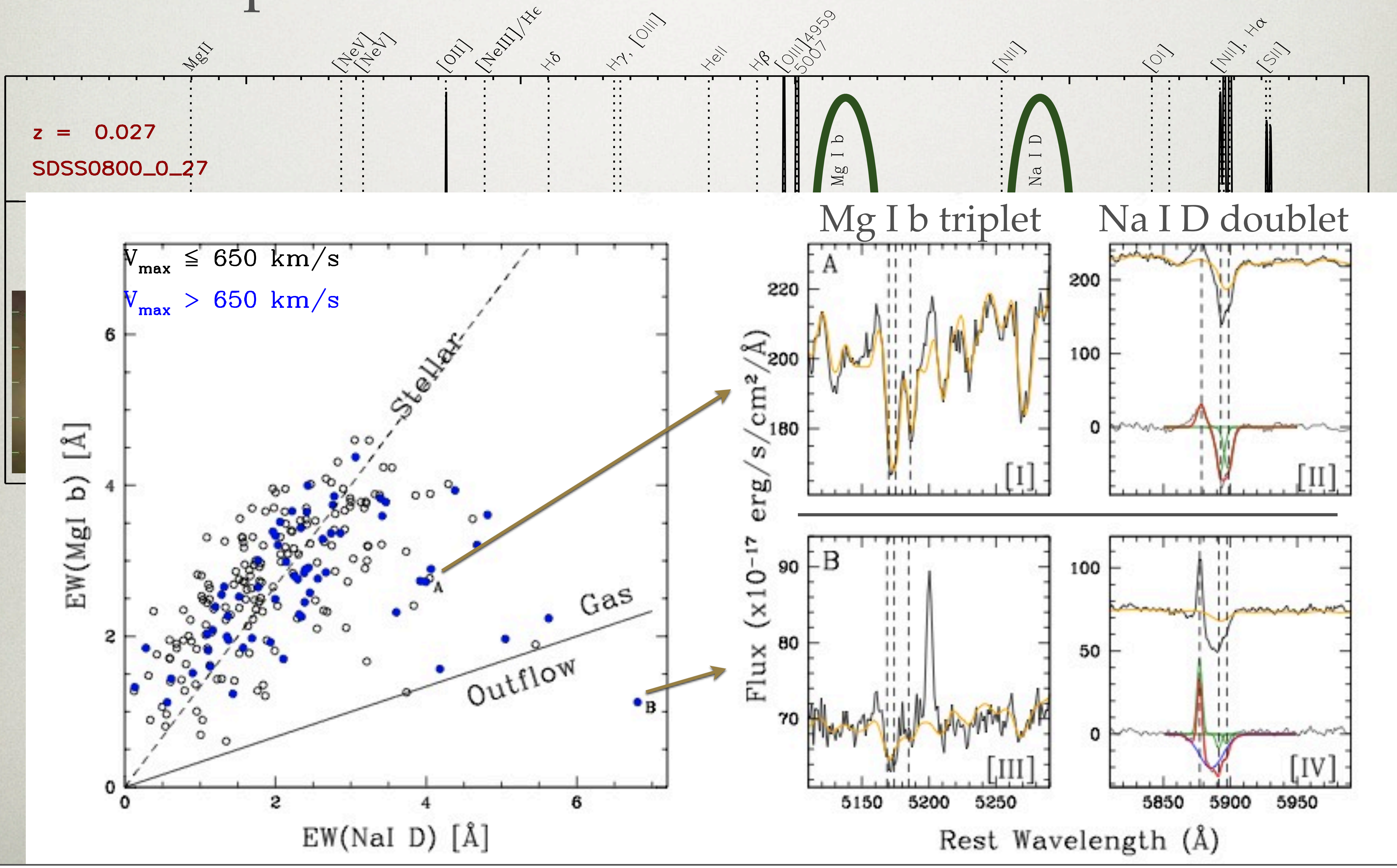
neutral component - **Na I D** abs.line



- observed in high S/N spectra of low-luminosity /obscured AGNs
- AGN radiation can easily ionize the neutral gas
- both ISM and stars contribute to NaID abs. line

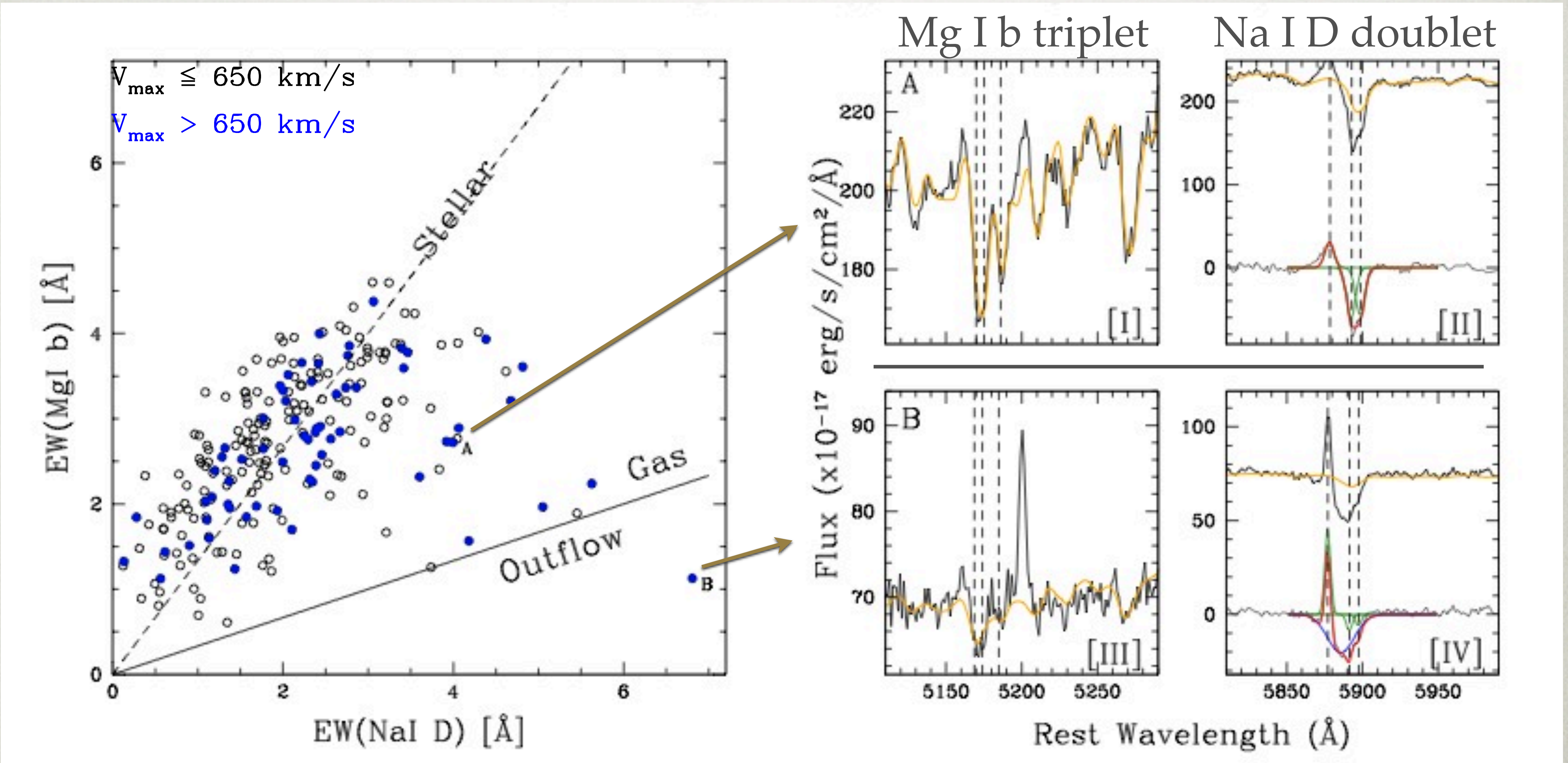
X-RAY/SDSS SAMPLE- OUTFLOW INCIDENCE

neutral component - Na I D abs.line



X-RAY/SDSS SAMPLE-OUTFLOW INCIDENCE

neutral component - Na I D abs.line



<1 % shows signature of neutral outflows (see also Sarzi+16)

Outflow properties

outflow mass rate:

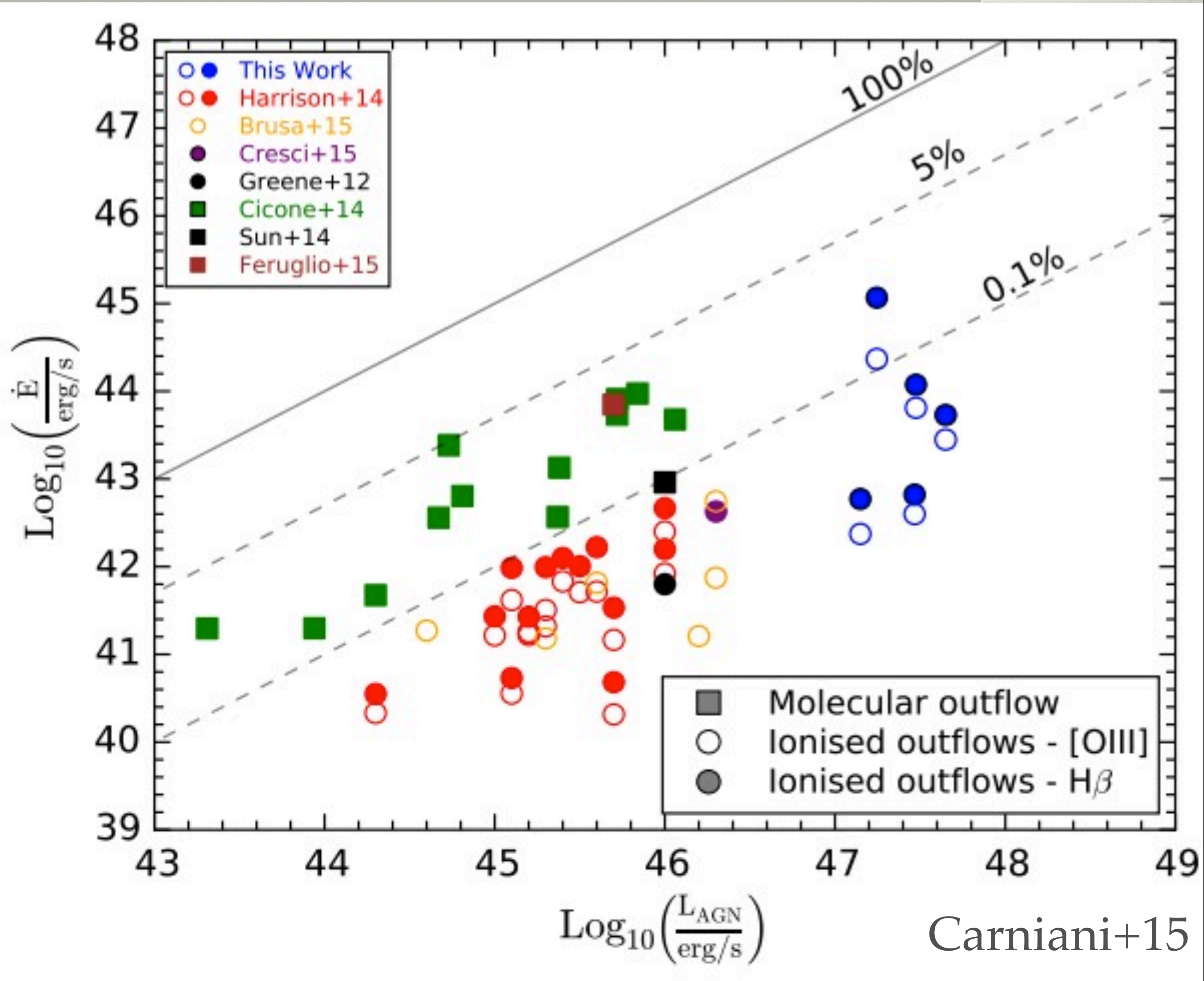
$$\dot{M}_{out} \propto M_{out} V_{out} / R$$

kinetic power:

$$\dot{E}_{out} \propto \dot{M}_{out} V_{out}^2$$

momentum flux:

$$\dot{P}_{out} \propto \dot{M}_{out} V_{out}$$



Carniani+15

Empirical relations:

$$\dot{E}_{out} \approx 1-5\% L_{bol}\ [Molecular\ outflows] \qquad \dot{P}_{out} \approx L_{bol}/c\ [Ionised\ outflows]$$

$$\dot{E}_{out} \approx 0.05-0.1\%\ L_{bol}\ [Ionised\ outflows] \qquad \dot{P}_{out} \approx 10-50\ L_{bol}/c\ [Molecular\ outflows]$$

IONIZED MASS OUTFLOW

- To derive outflow energetics, several critical assumptions are required, making the comparison with model predictions very difficult.

$$M_{ion}([OIII]) = 1.7 \times 10^3 \frac{m_p C L_{[OIII]}}{10^{[O/H-[O/H]_\odot} j_{[OIII]} < N_e >} \; M_\odot,$$

$$M_{ion}(H\beta) \approx 0.8 \frac{m_p C L_{H\beta}}{j_{H\beta} < N_e >} \; M_\odot$$

(see, e.g., Cano-Diaz+12; Carniani+15; Cresci+15)

Assumptions are usually required for

- the metallicity term (see Perna+15)
- the emissivity j, weakly dependent on Ne and Te in the outflowing regions
- the average Ne

ELECTRON DENSITY AND TEMPERATURE ASSUMPTIONS

- Different assumptions for Ne and Te are used in the literature to derive mass outflow, mostly based on few estimates.

Ne measurements (<u>assuming Te=10'000 K</u>) :

Rodriguez-Zaurin+13 (Ne > 4'000 cm^{-3})

Harrison+12 (Ne = 500 cm^{-3} [ULIRGs staked spectrum])

Harrison+14; Westmoquette+12 (Ne = 200-1000 cm^{-3})

Genzel+14 (Ne = 80 cm^{-3} [SF-ionized gas])

Perna+15 (Ne = 120 cm^{-3} [single obj])

...

Ne + Te measurements

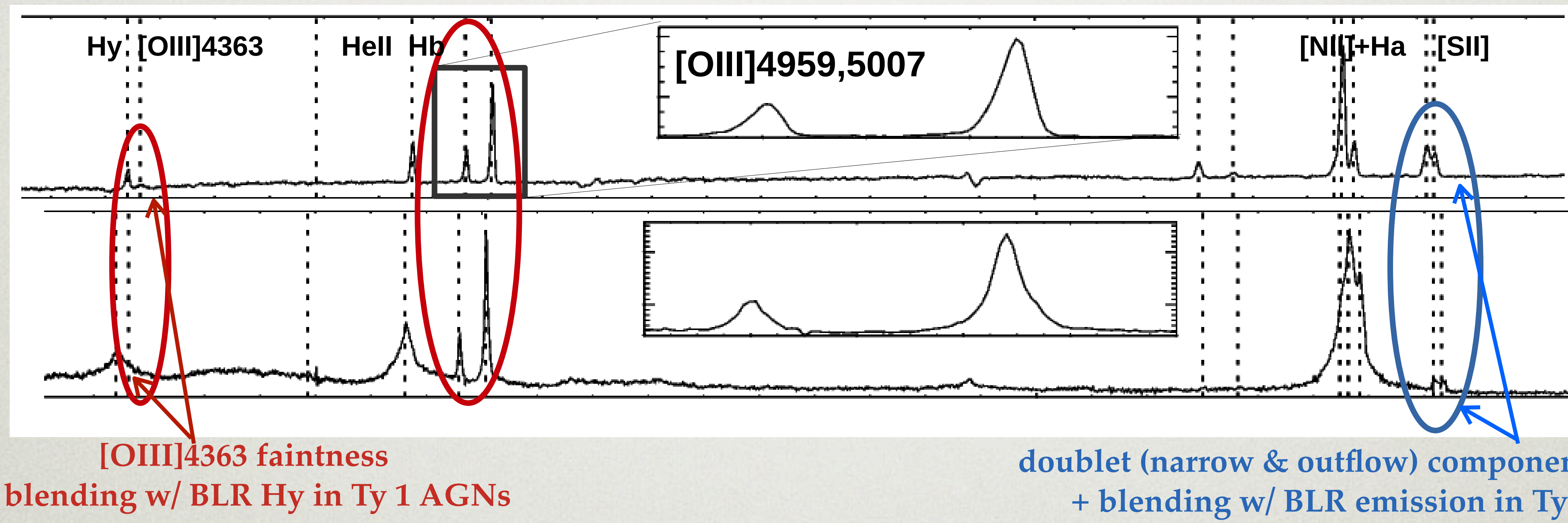
Brusa, MP+16 (Ne = 780 cm^{-3} ; Te = 13'000 [single obj])

Villar Martin+14 (Ne = 800-3’200 cm^{-3} ; Te ≈ 16'000 [4 obj])

Nesvadba+08 (Ne = 500 cm^{-3} ; Te ≈ 11'000 K [single obj])

Electron Density and Temperature Assumptions

- Plasma diagnostics can be used to derive outflow Te and Ne (Osterbrock & Ferland 2006), but great challenges preclude their adoption.



$$T_e = 32900/ln(R_{[OIII]}/7.9)$$

$$R_{[OIII]} = [F(\lambda5007) + F(\lambda4959)]/F(\lambda4363)$$

$$R_{[SII]} = F(\lambda6716)/F(\lambda6731) = 1.49\frac{1 + 3.77x}{1 + 12.8x},$$

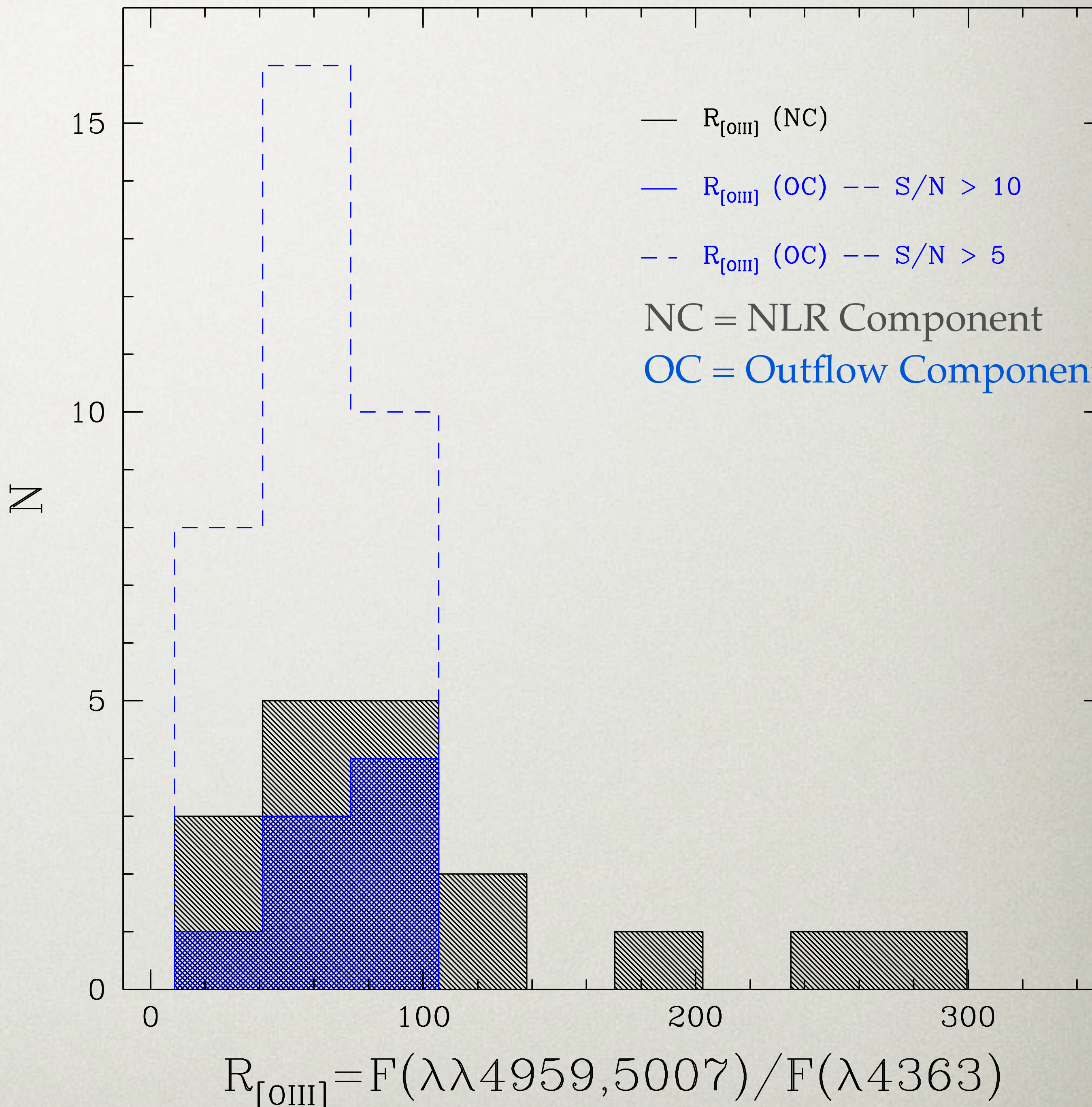
$$x = 0.01 N_e/\sqrt{T_e}$$

ELECTRON TEMPERATURE ESTIMATE

R[OIII] distribution for both NLR (NC) and outflow (OC) components has been obtained selecting sources with well detected [OIII]4363.

The analysis results suggest that, on average, ***NC and OC share similar Electron Temperatures.***

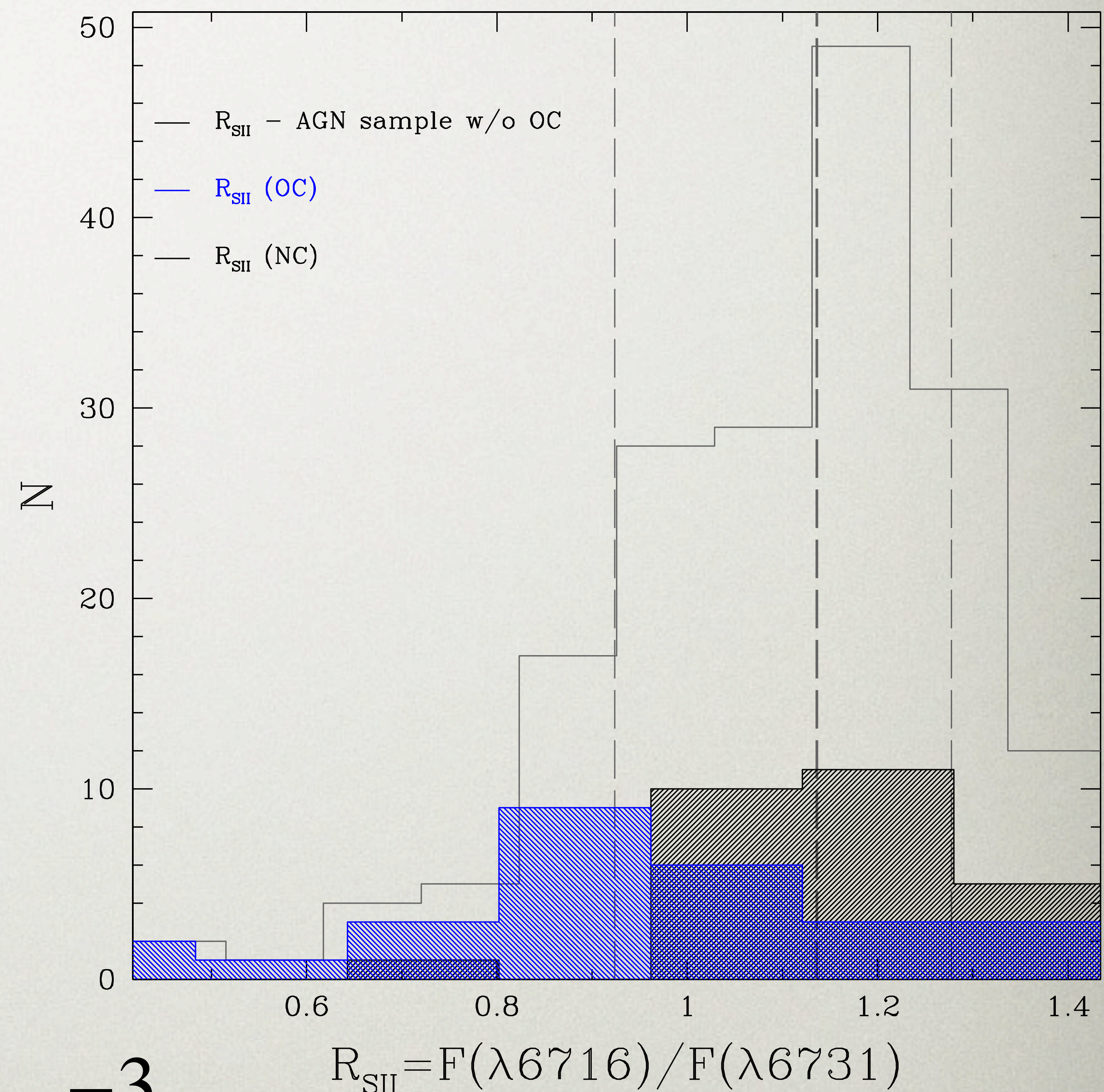
$$T_e = 1.7^{+1.1}_{-0.3} \times 10^4 \text{ K}$$



ELECTRON DENSITY ESTIMATE

R[SII] distribution for both NC and OC has been obtained selecting sources with well detected [SII] doublet.

The analysis results suggest that, on average, ***Outflow regions are characterized by higher electron densities than NLR.***



$$N_e(NC) = 500^{+400}_{-300} cm^{-3}$$

NC = NLR Component

$$N_e(OC) = 1000^{+2000}_{-700} cm^{-3}$$

OC = Outflow Component

Results

- We found signature of ionized outflows in 40% of X-ray selected AGNs.
- The fraction of outflows is > 50% in the QSO-luminosity regime
- The almost total absence of neutral outflows may be due to observational limitations / the presence of high ionized radiation from AGNs (see also Villar-Martin+14 {1/22 shows neutral outflow}).
- We derive the first average estimates of outflowing plasma properties, for a medium size sample (~ 40 targets).
- We suggest that similar electron temperatures could be present in NLR and outflowing regions (Te[OC] ~ Te[NC] ~ 17'000 K).
- Outflowing gas is characterized by electron densities ~ 2 times those of the NLR (Ne[OC] ~ 1'000 cm^{-3})
- NLR estimates are consistent with previous results (Xu+07; Zang+13; Vaona+12)