An X-ray/SDSS sample: outflowing gas Electron Temperature and Density

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OUTLINE

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CONTEXT

- AGN feedback is invoked in many models of galaxy formation (e.g., Springel+05; Hopkins+08) to explain the relations observed locally between Super Massive Black Holes (SMBH) and their host galaxies (Kormendy & Ho 2013).
- Several physical processes regulating AGN feedback have been proposed (jets, winds, radiation pressure).
- AGN-driven ionized outflows extending to kpc-scales have been observed both locally (e.g Feruglio+15; Lanzuisi+15) and at high redshift (Perna+15a,b; Brusa+15,16; Cresci+15; Zakamska+16).
- Outflow energetics (mass outflow rate, kinetic power and momentum rate) are usually derived to compare observations with model predictions.

Outflow properties

outflow mass rate:

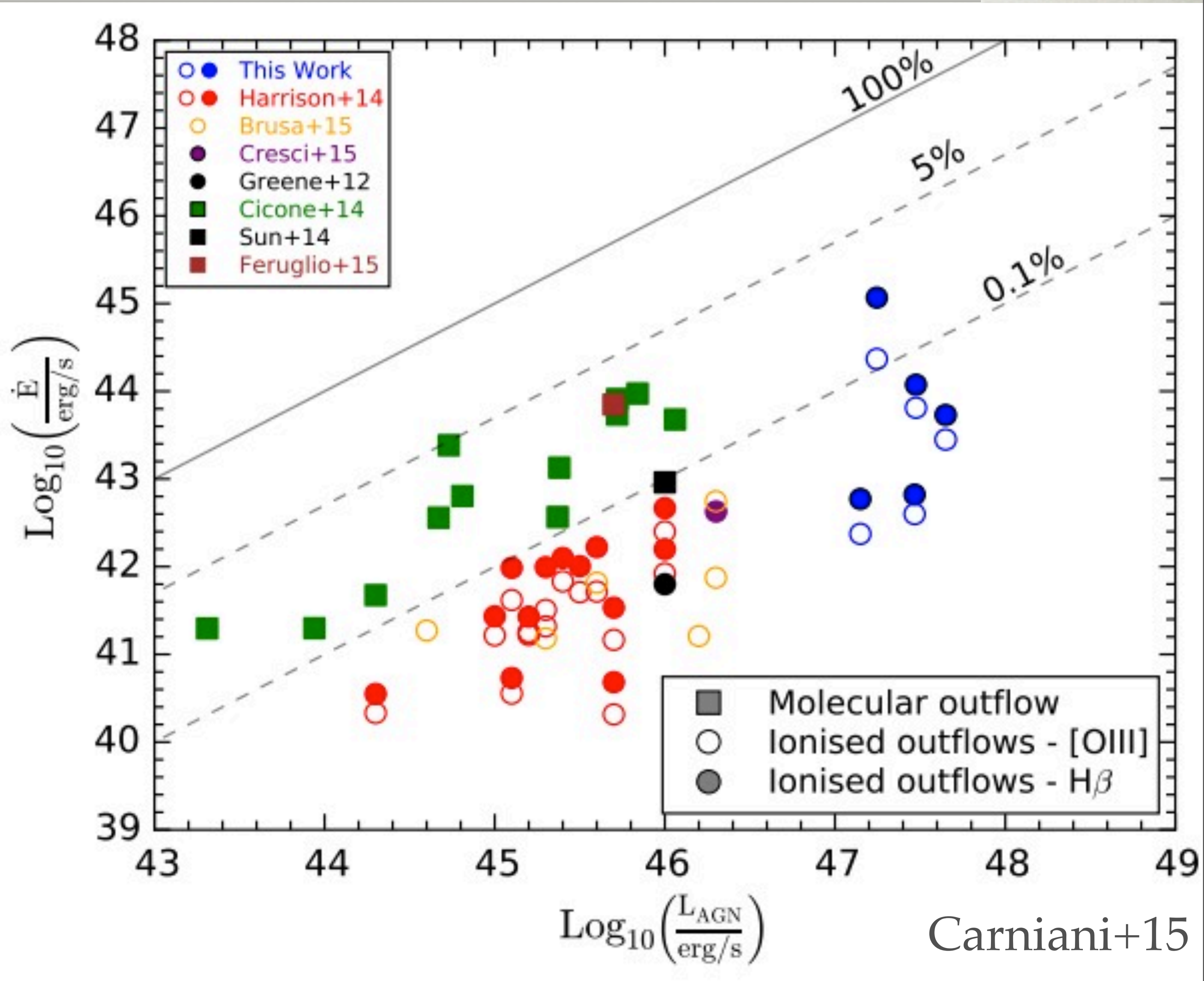
$$\dot{M}_{out} \propto M_{out} V_{out} / R$$

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*]

$\dot{E}_{out} \approx 0.05 - 0.1\%\ L_{bol}$ [*Ionised outflows*]

$\dot{P}_{out} \approx L_{bol}/c$ [*Ionised outflows*]

$\dot{P}_{out} \approx 10 - 50\ L_{bol}/c$ [*Molecular outflows*]

[OIII]5007 MASS OUTFLOW

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

- Ionized Mass Outflow estimates are commonly obtained starting from the [OIII]5007 luminosity associated to the outflow

$$M^{out}_{[OIII]} \propto \frac{L_{[OIII]}}{10^{[O/H]-[O/H]_{\odot}} j_{[OIII]} < N_e >}$$

(see, e.g., Carniani+15)

Assumptions are usually required for

- the metallicity term (see Perna+15)

- the emissivity j[OIII], weakly dependent on electron density (Ne) and electron temperature (Te) within 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 (assuming Te=10'000 K) :**

  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**

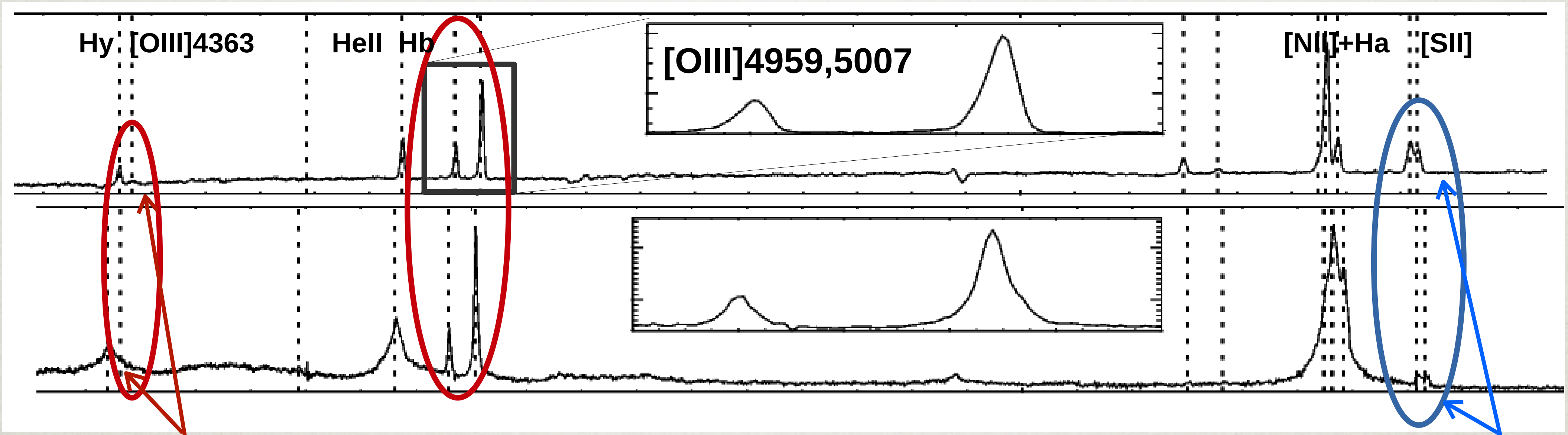
  Brusa+16 (Ne = 780 cm^{-3} ; Te = 13'000 [single obj])

  Villar Martin+14 (Ne = 800-3200 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 such as [OIII]4363,4959,5007 and [SII]6716,6731 can be used to derive outflow Te and Ne (Osterbrock & Ferland 2006), but usually great challenges preclude their adoption.



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

$$R_{[SII]} = F(\lambda 6716)/F(\lambda 6731) = 1.49\frac{1+3.77x}{1+12.8x},$$

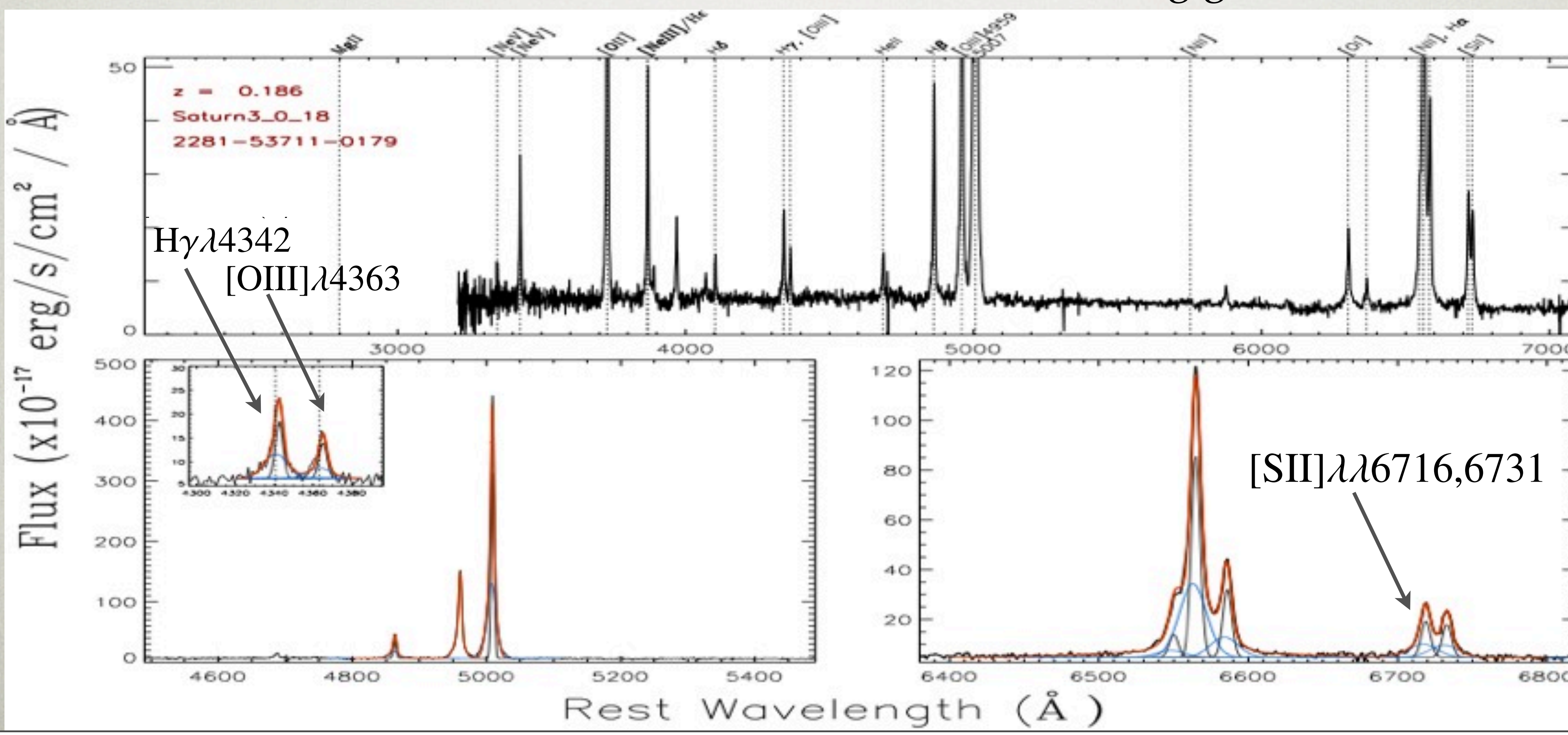
$$R_{[OIII]} = [F(\lambda 5007) + F(\lambda 4959)]/F(\lambda 4363)$$

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

The X-ray/SDSS sample

- Motivated by our recent results (see Brusa+16), we collected a sample of ~ 500 X-ray/SDSS AGNs to derive general relations between nuclear X-ray emission and outflow properties.
  Outflows are found in ~ 50% of AGNs.

- Here we present the Plasma Diagnostic analysis and the physical characterization of the NLR and ionized outflowing gas.



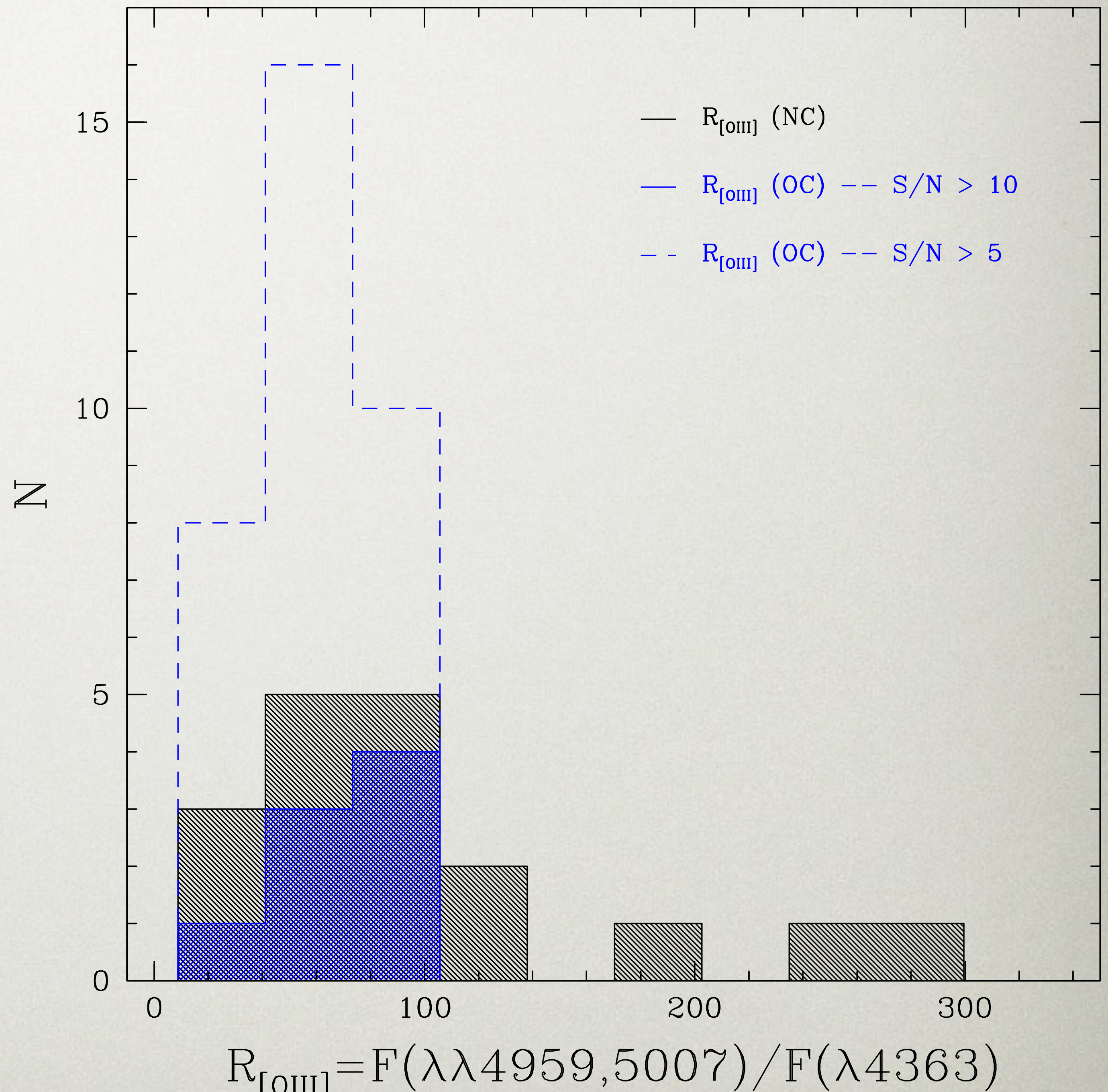
ELECTRON TEMPERATURE ESTIMATE

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.***

We derived

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



ELECTRON DENSITY ESTIMATE

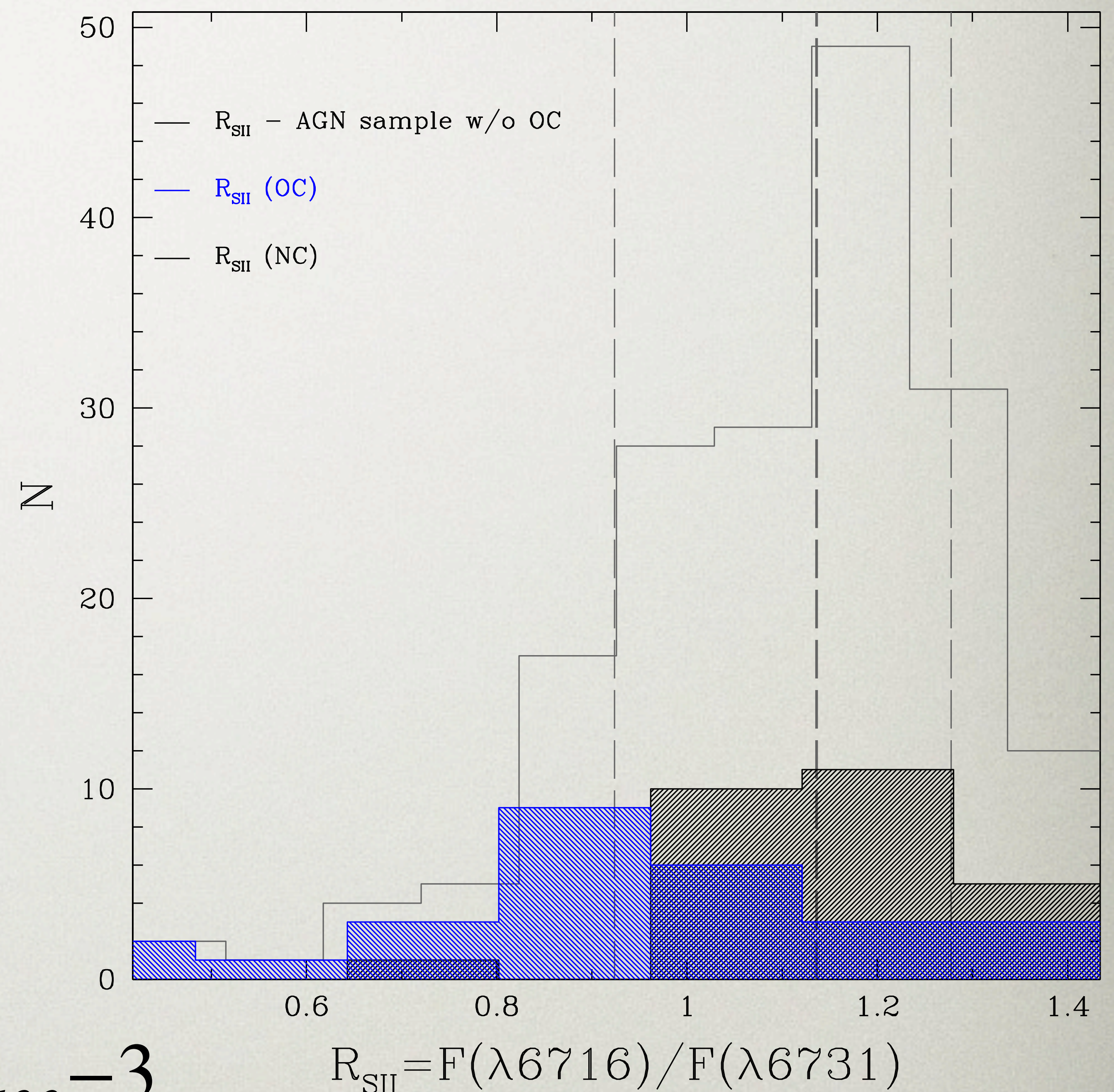
R[SII] distribution for both NLR (NC) and outflow (OC) components has been obtained selecting sources with well detected [SII] doublet.

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

We derived

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

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



Results

- We derived 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 (see, e.g., Zhang+13)