Exploring X-ray and radio connection of type 1 AGN up to z ~ 2.3

L. Ballo

F.J. H.Heras, X. Barcons, F.J. Carrera

IFCA (CSIC-UC), Santander, Spain

OUTLINE

- Introduction
- Sample selection & properties
- M_{bh}, L_{bol} & Eddington ratios
- Radioloudness & SED

Introduction (I)

- **AGN emission:** X-ray ↔ disk; jet contribution ?
  optical ↔ mainly reprocessing
  radio ↔ jet; reprocessing ?
- **Dichotomy in radioloudness $\mathcal{R}$:**
  - real: fundamental physics ?
    evolution ?
  - unreal: incompleteness of small samples ?
- **Relevant observables: M_{bh}, λ_{Edd}, $\mathcal{R}$, and spin (?)**
  - $\mathcal{R}$ vs M_{bh} : still debated
  - λ_{Edd} vs $\mathcal{R}$: changes in accretion mode (*Ho 02*); parallel track (*Sikora+07*)
  - spin paradigm: intermittent radio emission (*Sikora+07*) vs prograde/retrograde systems (*Garofalo+10*)

Introduction (II)

- **Deep multiwavelength catalogues to investigate**
  - **origin of radio emission**
  - **interplay between radio & X-ray**
  - **SED, $\mathcal{R}$ as function of L (eg, the study of X-ray properties of RL & RI QSOs presented by *Miller+11*)**
  - **the origin of the local dichotomy RL/RQ**
- **<u>Next step</u>: understanding physical properties & accretion regimes**

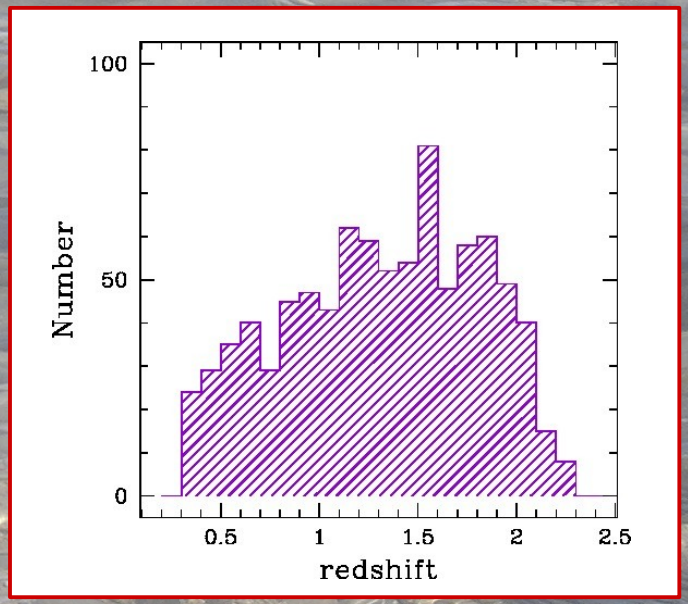
Main sample

- 2XMMi-SDSS DR7 cross-correlation *(Pineau+11)*
- with optical spectra
- classified as QSO or GALAXY
- FWHM of MgII@λ2799Å > 900 km/s (BLR)

⇒ **878 type 1 AGN with 0.3 < z < 2.3**

- cross-correlation with FIRST

⇒ 837/878 AGN covered by FIRST – **100 detections**



Control sample

SDSS + FIRST

- **same optical constraints**
- ***NOT* in the 2XMMi (ie, not covered or not detected)**

⇒ 5700 type 1 AGN

(only 11 observed but not detected)

- **X-ray counterpart → cross-correlation with RASS**

⇒ 768/5700 AGN detected with ROSAT

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- **main sample & RASS**

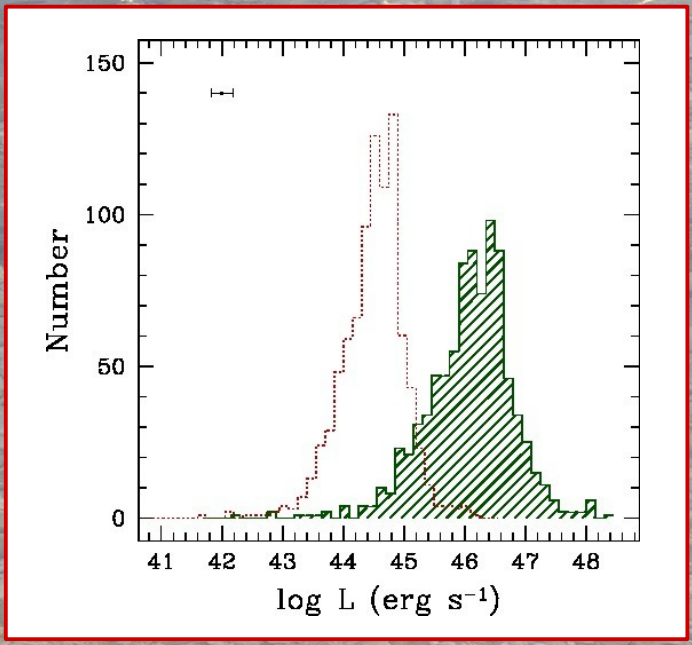
⇒ 78/878 AGN in RASS - 22 radio-detected

Nuclear properties: L_{bol}

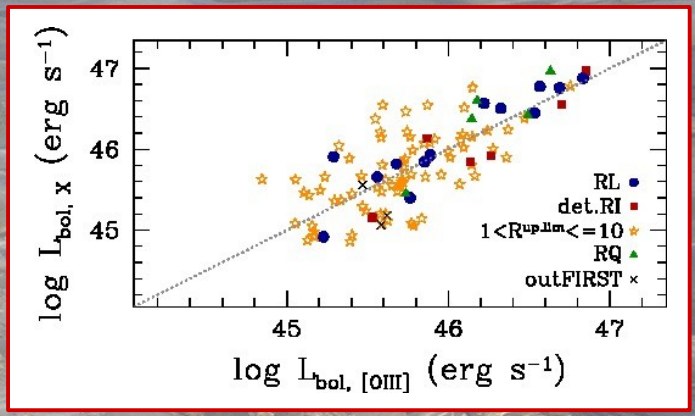
1. 2XMMi F(0.2-12 keV) → $N_{H,gal}$-corrected L(2-10 keV)
2. L(2-10 keV) → L_{bol} ($k_{X,bol}$ from *Marconi+04*)

intrinsic N_H? HRs analysis → mean correction factor:

$$L_{bol}^{abs.PL}/L_{bol}^{PL} \sim 1.2$$



CHECK: L_{bol} from [OIII] (*Lamastra+09*)
– 135/878 AGN ($0.35 \leq z \leq 0.83$)



Nuclear properties: M_{bh}

- M_{bh} for 864 QSO (cross-correlation with *Shen+10*)

$$M_{bh} = 10^{6.86} [\mathrm{FWHM(MgII)}_{1000}]^2 [\lambda I_{\lambda}(3000\text{Å})_{44}]^{0.5}$$

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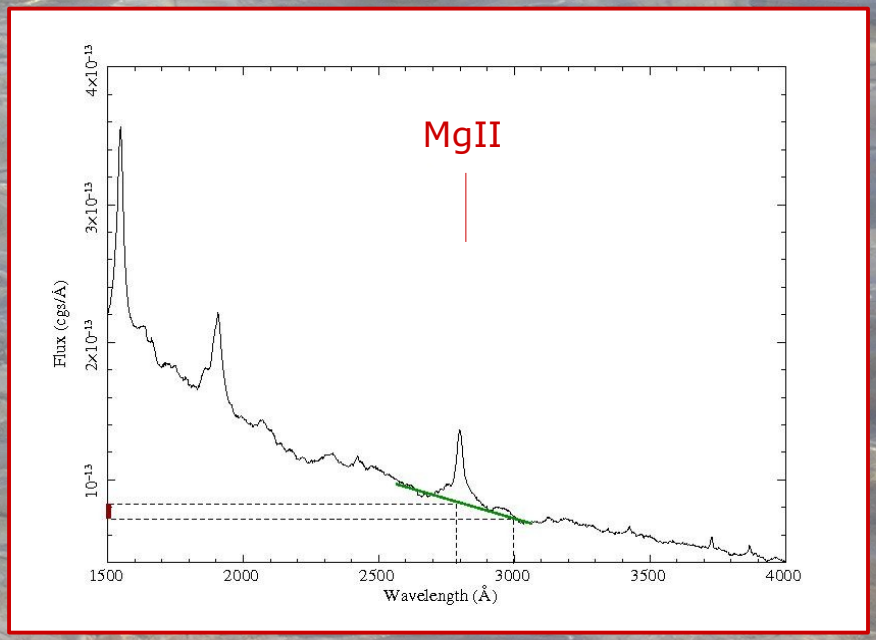
14 Seyfert-like AGN:

- **FWHM[MgII(2799Å)]**
- **from $F_{\lambda,cont}$@2799Å + template of QSO to $L_{\lambda,cont}$@3000Å**



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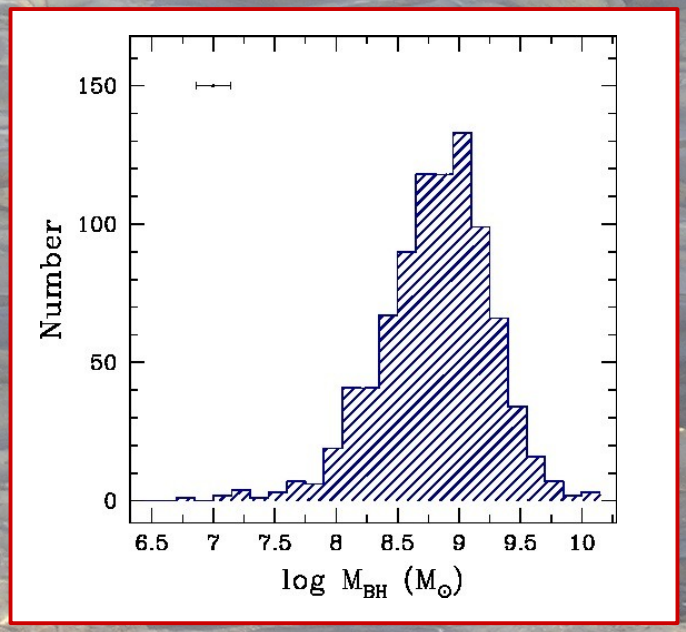
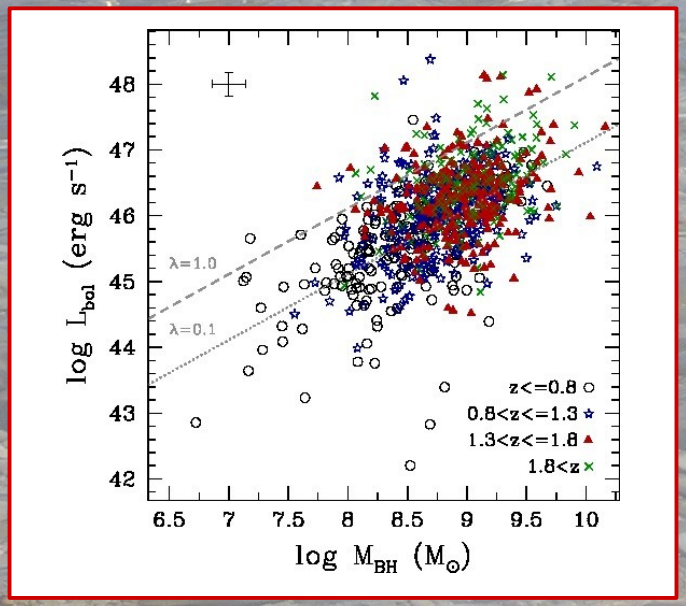
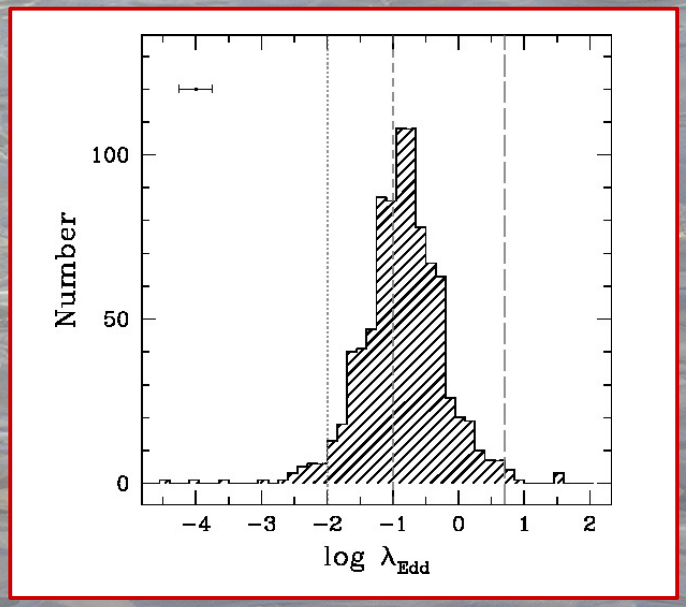


Nuclear properties: λ_{Edd}

- from L_{bol} (X-rays) & M_{bh} (optical data) to Eddington ratios (λ_{Edd})





$$\lambda_{Edd} = L_{bol}\ [\mathrm{erg\ s^{-1}}]/(1.3 \cdot 10^{38}\ M_{bh}/M_{sun}[\mathrm{erg\ s^{-1}}])$$

Radioloudness (I)

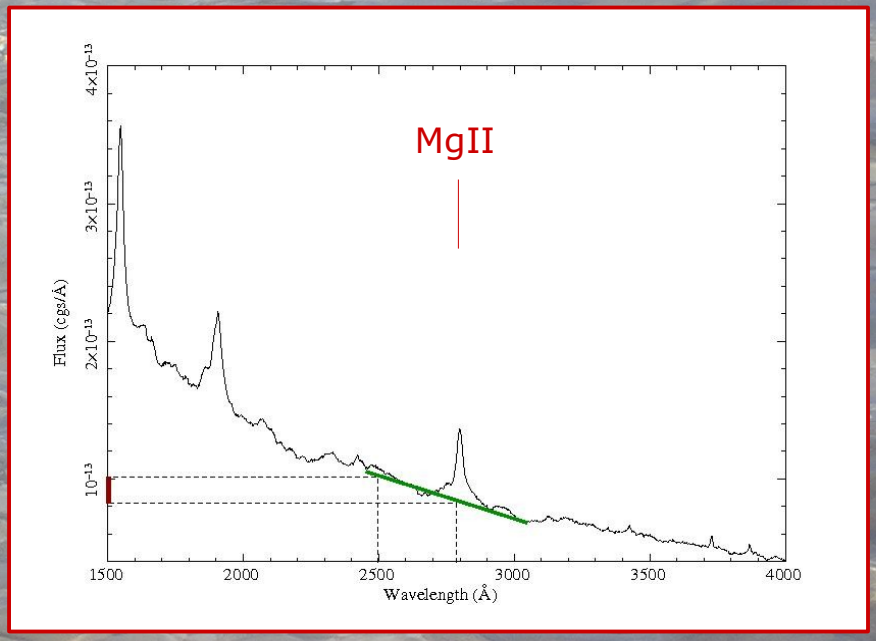
837 AGN in FIRST:

$$\mathcal{R} \equiv F@5GHz/F@2500Å$$

OPT:

- F_λ@2500Å from

  $F_{\lambda,cont}$@2799Å
  + QSO template

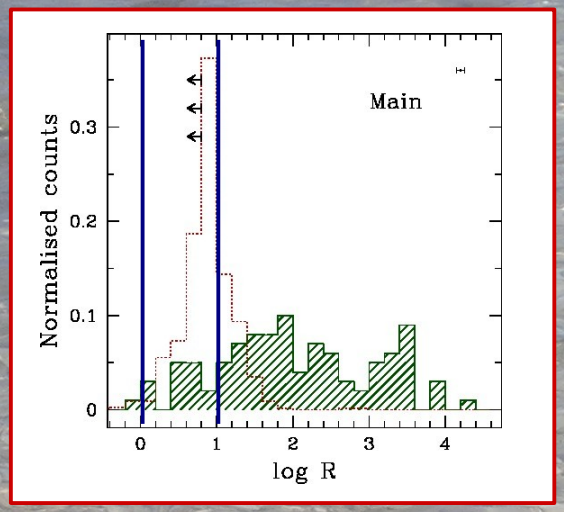


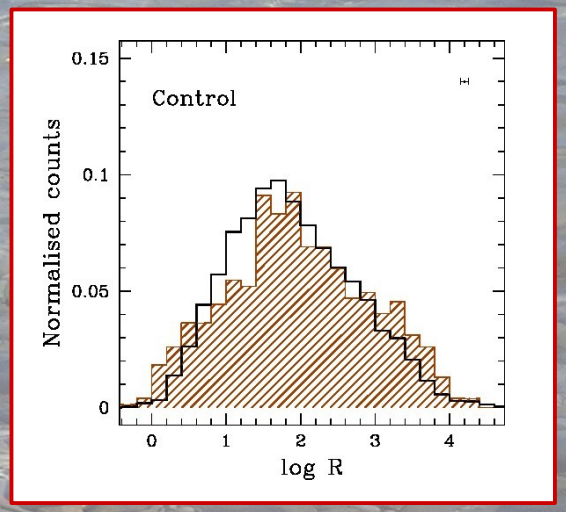
RADIO:

- 100 detected sources:
  FIRST *F*@1.5GHz,obs
- 737 undetected AGN:
  FIRST UL $F^{u.l}$@1.5GHz,obs

$F_\nu \propto \nu^{-\alpha R}$ $\alpha_R = 0.8$ from *F*@1.5GHz observed frame to *F*@5GHz rest frame

Radioloudness (II)





84 RL
15 det. RI
515 $1<\mathcal{R}^{u.l.}\leq 10$
12 RQ (det. & undet.)
211 n.c.

768 ROSAT-det.
4931 ROSAT-undet.

NO statistical difference:
KS-probability ~ 0.11

NO clear dichotomy (BUT: high number of UL!) - see also *Miller+11*

Rather high $<\mathcal{R}>$ ~ 86 (radio-detected) - possible selection bias

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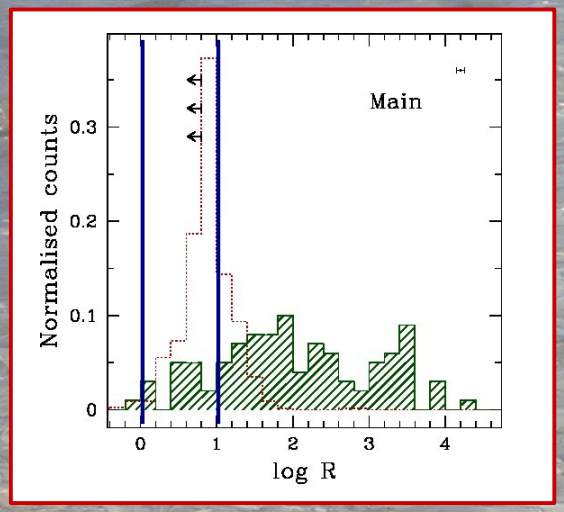

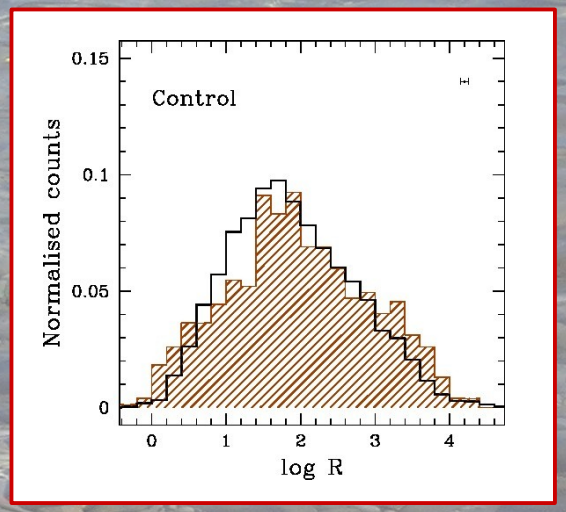

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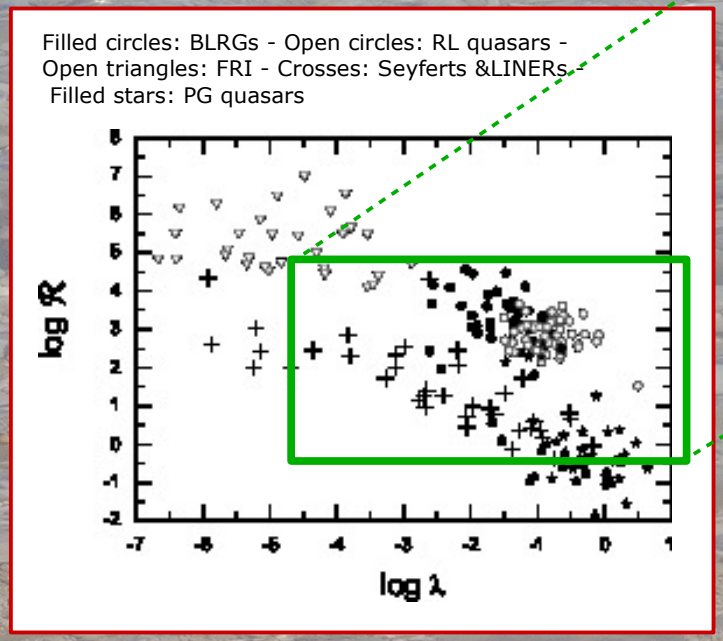
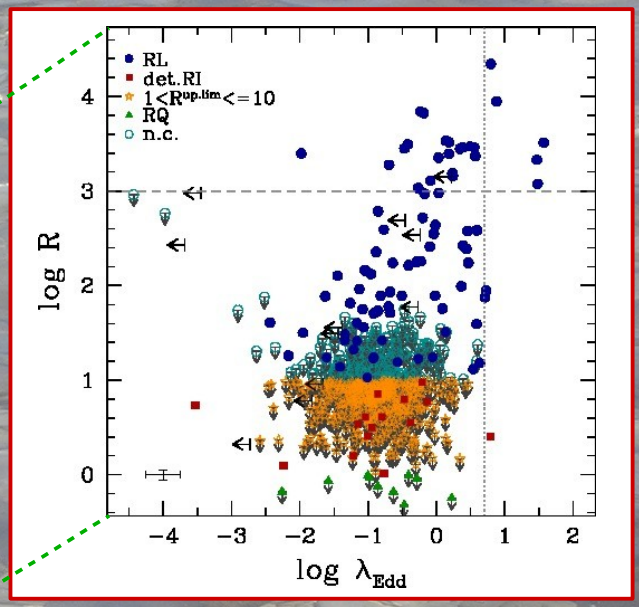
<u>Evolutionary effects?</u> splite sample in 5 *z* bins: same distribution– again: UL!

$\mathcal{R}$ vs λ_{Edd} (I)

- apparent trend of increasing of $\mathcal{R}$ with λ_{Edd}
- $P < 0.1\%$ of correlation due to chance (survival analysis)
- at odds with previous results

NOTE the different range covered





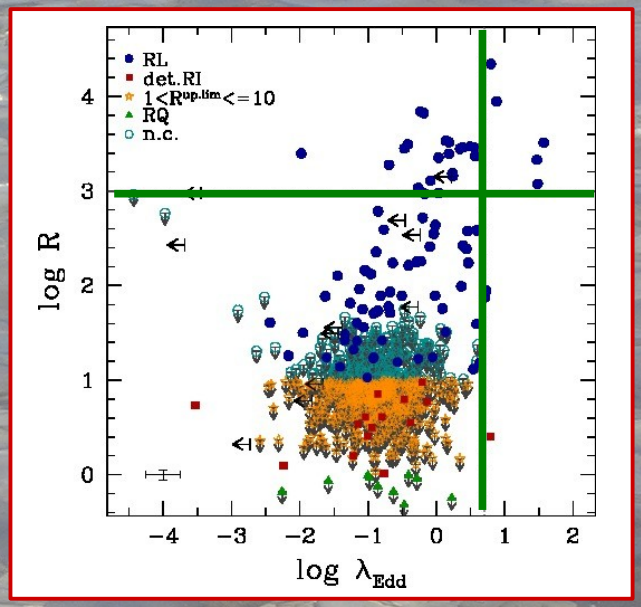
Sikora+07

$\mathcal{R}$ vs λ_{Edd} (II)

Higher λ_{Edd} for higher $\mathcal{R}$:

- **contribution of nuclear L_X due to jet contamination ?**

  ***NO*: excluding blazar-like sources (most estreme in λ_{Edd} and $\mathcal{R}$), correlation still present**



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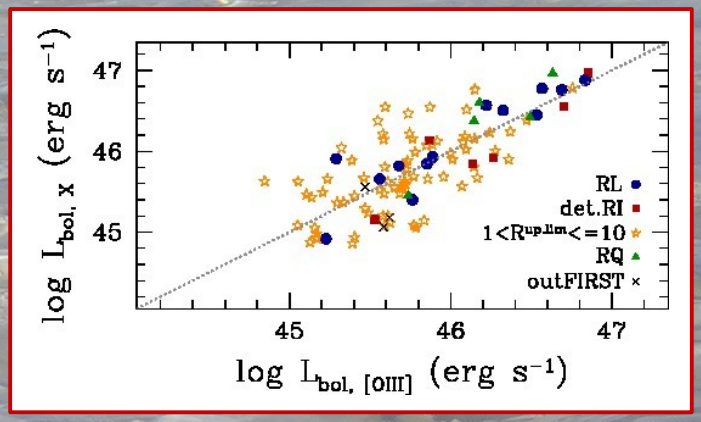
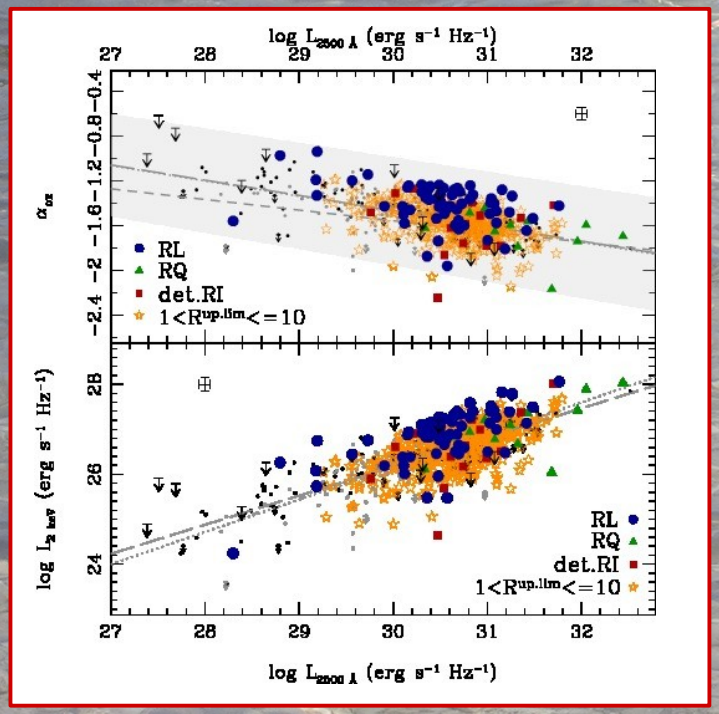


- **overestimated $k_{X,bol}$ due to different SEDs in RL & non-RL ?**

  ***NO*: L_{bol} from [OIII] vs L_{bol} from X-ray ⇒ unlikely different SEDs**

$\mathcal{R}$ vs SED & L (I)



Vignali+03, Strateva+05, Steffen+06, Just+07, Gibson+08

$L_{2500Å}$ vs L_{2keV} & a_{OX}

$[a_{OX} \equiv \log(F_{2keV}/F_{2500Å})/\log(\nu_{2keV}/\nu_{2500Å})]$

Excluding most extreme sources:

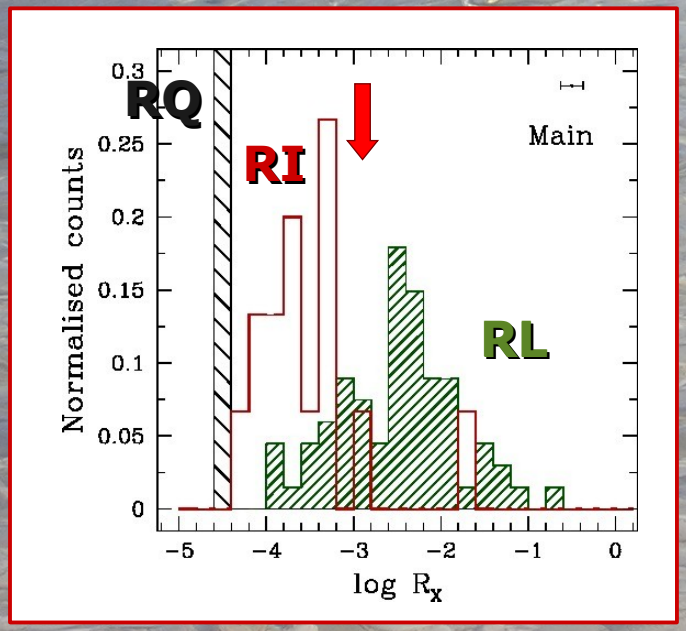
- **follows the (anti-)correlations – scatter consistent with spread**
- **RL show higher a_{OX} than expected; RI lie around the regression line.**

⇒ **different spectral shape ?**

$\mathcal{R}$ vs SED & L (II)

$\mathcal{R}_x \equiv \nu L$@5GHz,rf/$L$(2-10 keV)

Terashima&Wilson03



- gap at log $\mathcal{R}_x$ ~ -3?

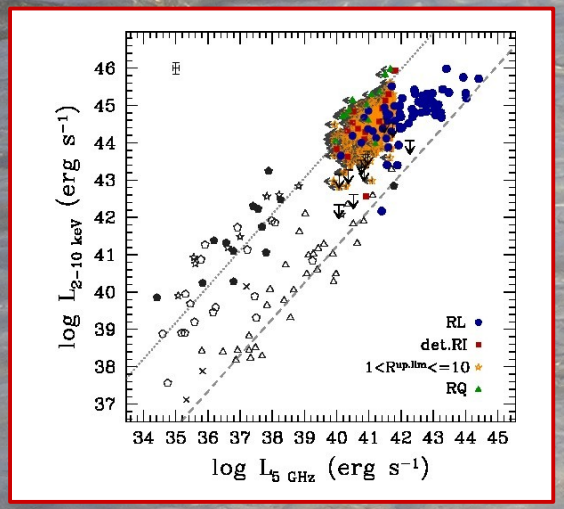
  Effects of distribution of undetected sources !

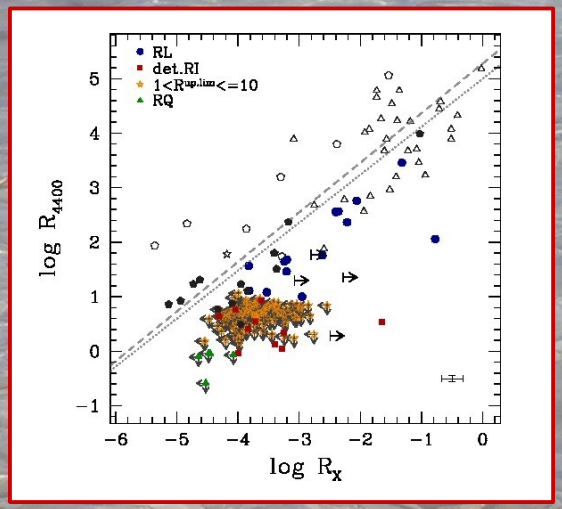
- distinction between RL & RI tends to desappear.

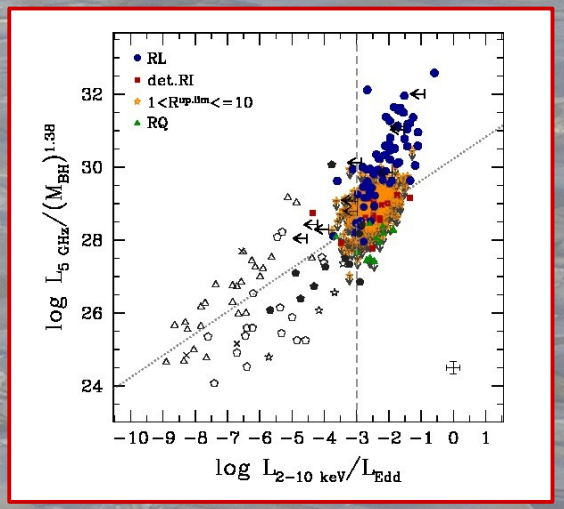
  Dependence of boundaries between RL/RI/RQ with *L* ?

$\mathcal{R}$ vs SED & L (III)

cf Panessa+07, Terashima&Wilson03







$\mathcal{R}_{4400Å}$ ⇒ **only 193 sources**

- at intermediate *L*, sources follow the Seyfert track;
- at higher *L*, RL show a sort of "saturation"

- L_X & L_{radio} proceed in a linked way;
- L_{opt} changes independently

- different accretion regime wrt lower *L* sample – see "fundamental plane" *(Merloni+03)*

X-ray NO jet-dominated; both jet (radio) and X-ray connected to accretion power

SUMMARY

- X-ray vs radio emission in ~ 800 X-ray selected type 1 AGN with $0.3 \leq z \leq 2.3$ (from 2XMMi & SDSS crosscorrelation + radio information from FIRST)
- M_{bh} from optical & L_{bol} from X-rays ⇒ λ_{Edd}
- High accretion rate $\lambda_{Edd} > 0.01$ (possible bias due to X-ray selecion)
- **NO anticorrelation** $\mathcal{R}$ vs λ_{Edd} (possible limited ranage covered)
- **NO bimodality** in $\mathcal{R}$ ⇒ due to the size and z coverage of the sample more than cosmic evolution
- L_{radio} vs L_X vs L_{opt} ⇒ radio emission linked to the accretion disk regime and not to larger scale phenomena.

(Ballo+,submitted)