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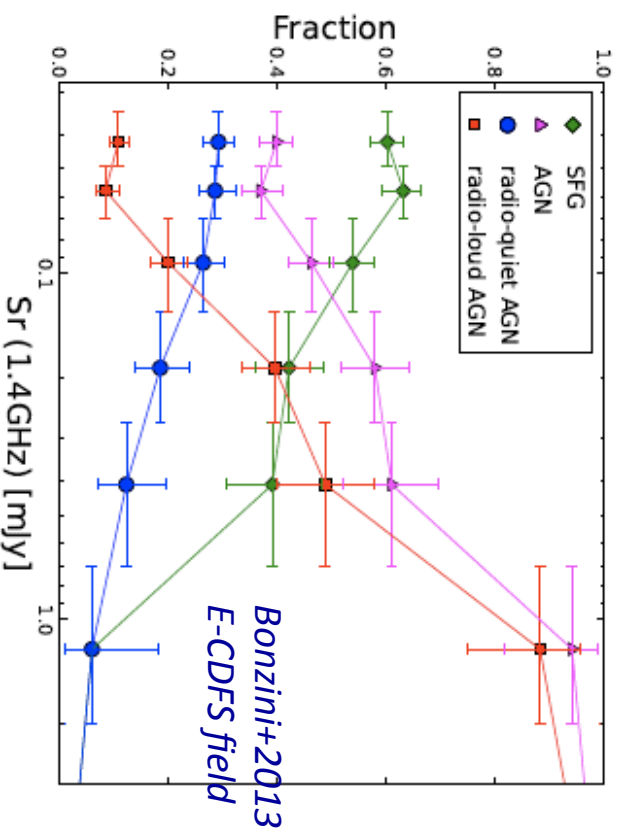
Compact Radio Cores in RQ AGNs

A pilot search in the E-CDFS

In collaboration with:

A. Maini (PhD Uni Bologna/Macquarie),
R.P. Norris, G. Giovannini, L.R. Spitler
[Maini et al. 2016, A&A Letters, 589, L3]

RQ-AGNs in deep radio surveys



Radio-selected AGN Evolution:

RL-AGN: z_{peak} at $\sim 0.5-1$

RQ-AGN: z_{peak} at $0.5-2$

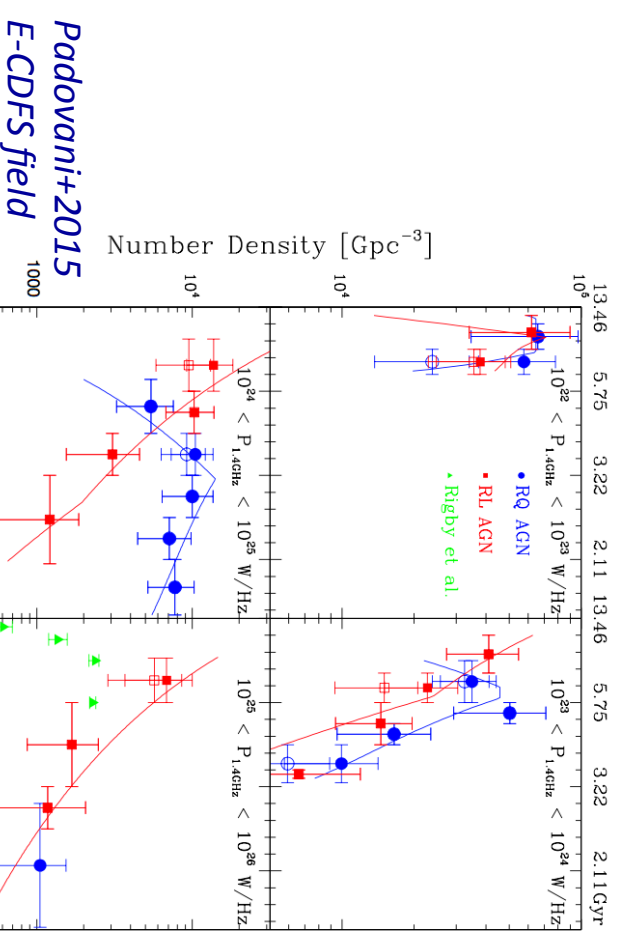
→ High- z dominated by RQ AGN & by RQ AGN related feedback ?

6/30/16

RL-AGN: Radio Excess: f.i. q_{24} → **RI AGN**

RQ-AGN: No Radio Excess; AGN signature in MIR or X-ray bands → **RE AGN**

→ complete view of AGNs/AGN feedback down to RQ regime (no dust extinction/gas obscuration)



I. Prandoni

Origin of Radio Emission in RQ AGNs

What triggers radio emission in RQ AGNs?

- pure SF in the host galaxy?
- SF and AGN related emission do co-exist?
- Incidence of embedded AGN radio cores?
- Fraction of AGN-driven radio emission?
- Mechanism responsible for AGN-driven radio emission?
- Is there any associated jet-feedback?

→ Resolved (VLBI-scale) radio imaging of RQ AGN cores

Wide-field VLBI imaging:

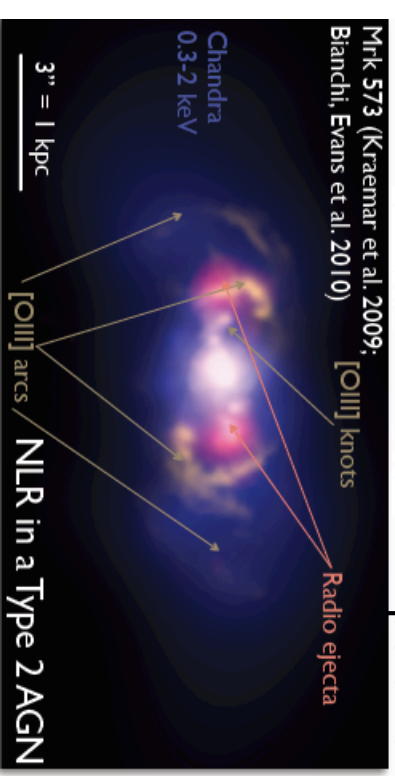
GOODS-N@EVN:

Garrett +2001; Chi+2013; Radcliffe+2016

E-CDFS@VLBA: Middleberg+2011

LH@VLBA: Middleberg+2013

<2 kpc size



Targeted VLBI observations of RQ-AGNs:

COSMOS@VLBA: Herrera-Cruz+2016

E-CDFS@LBA: Maini, IP, et al. 2016

E-CDFS: LBA follow-up of RQ AGNs

Why E-CDFS: $S_{\text{lim}} \sim 37 \text{ uJy/b; } 0.32 \text{ deg}^2$

First with complete & reliable RQ-AGN classification (Bonzini et al. 2013)

Why LBA: Decl. $\sim -28 \text{ deg}$

challenging for VLBA

(El. $\sim 20^\circ$ on average)

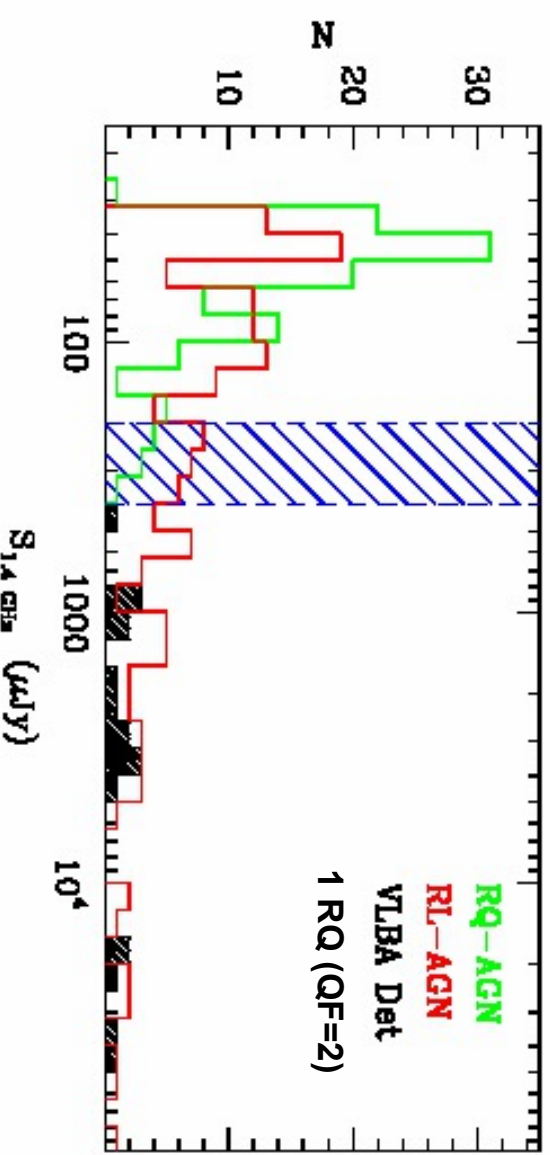
→ detections $>400 \text{ uJy}$

**Pilot study to probe
LBA feasibility:**

→ Brightest flux interval: 200-400 uJy

→ 4 RQ AGN (50%) with secure classification (QF=3), point-like

→ 4 RL-AGN (20%) with same flux and redshift distribution ($z \sim 1-3$)



E-CDFS: LBA follow-up of RQ AGNs

Observations: from March 2014 to March 2015, 51.5 hours in total

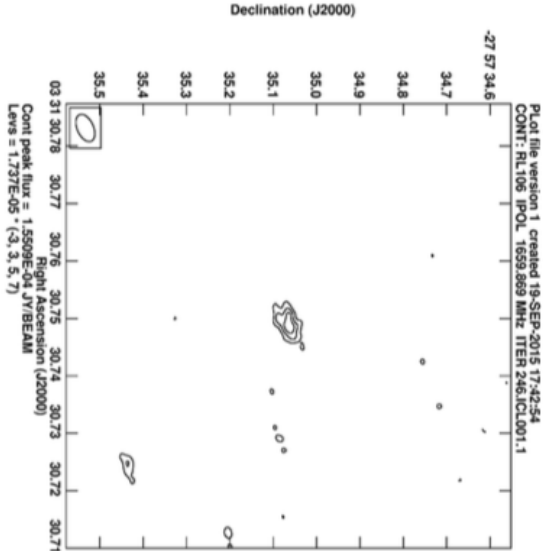
Run	Date	t_{Obs} (hrs)	ν_{Obs} (GHz)	BW (MHz)	Antennas	Target(s)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
A	09/03/2014	9.5	1.666	64	AK, AT, Cd, Ho, Mp, Pa	RQ26 RL106 RL728
B	04/06/2014	11	1.650	32	AT, Cd, Mp, Pa, Ti	RQ174 RQ851
C	26/11/2014	12	1.410	64	AK, AT, Cd, Ho, Pa, Ti	RL183 RL287
D	30/03/2015	10	1.410	64	AT, Cd, Ho, Mp, Pa	RQ851
E	31/03/2015	9	1.410	64	AT, Cd, Ho, Mp, Pa	RQ76

Data from Run C discarded

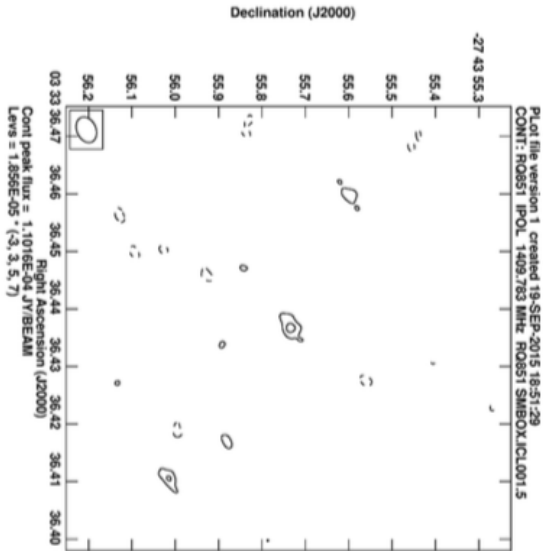
- 2 RL-AGN and 4 RQ-AGN successfully observed
- 1 RL-AGN and 2 RQ-AGN detected (50%)

E-CDFS: Radio core detections

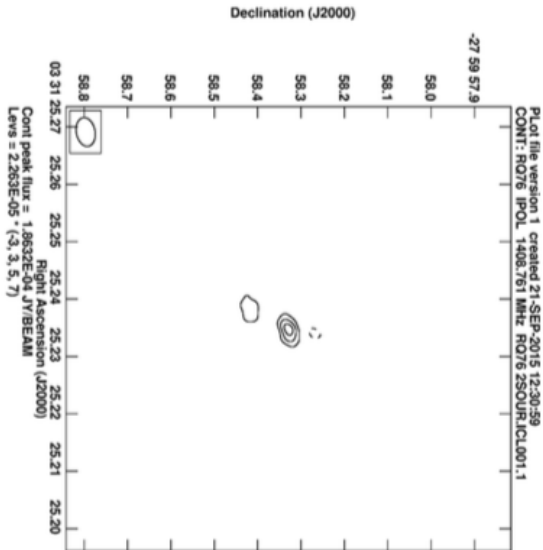
RL106



RQ851



RQ76



E-CDFS: Radio core detections

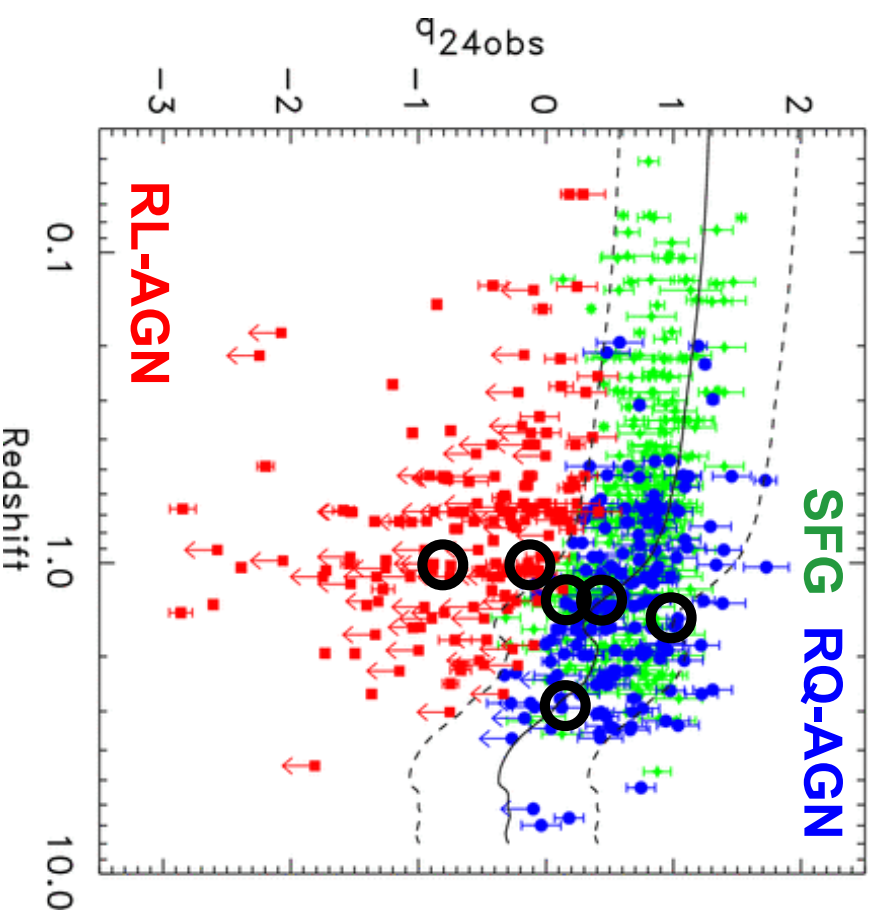
Target	S_{VLBI} (μ Jy)	S_{VLBI}/S_{VLA}	r.m.s. (μ Jy/beam)	K -corr. ^a $L_{1.4GHz}$ ($\times 10^{23}$ W/Hz)	Restoring beam (mas ²)	T_B ($\times 10^4$ K)	z	Linear Scale (pc)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
RQ26	$\lesssim 157$	$\lesssim \mathbf{0.49}$	52	...	...	...	1.59 ^b	...
RL106	155 ± 29	0.43 ± 0.08	17	$\mathbf{6.6 \pm 1.2}$	$\sim 67 \times 38$	2.7 ± 0.5	1.06 ^c	$\lesssim 544 \times 308$
RL728	$\lesssim 109$	$\lesssim \mathbf{0.33}$	36	...	...	...	1.08 ^b	...
RQ174	$\lesssim 125$	$\lesssim \mathbf{0.42}$	42	...	...	...	2.85 ^c	...
RQ851	110 ± 26	0.50 ± 0.12	20	$\mathbf{9.7 \pm 2.3}$	$\sim 62 \times 44$	2.5 ± 0.6	1.35 ^d	$\lesssim 521 \times 370$
RQ76	186 ± 36	0.69 ± 0.14	23	$\mathbf{17.2 \pm 3.3}$	$\sim 67 \times 43$	4.0 ± 0.8	1.38 ^b	$\lesssim 564 \times 362$

- rms ~ 20 -50 μ Jy/b $\rightarrow$ **1 RL-AGN and 2 RQ-AGN detected (50%)**
- resolution $\sim 60 \times 40$ mas² $\rightarrow$ **All unresolved on $\sim 500 \times 300$ pc² scales**
- **$S_{VLBI}/S_{VLA} \sim 40$ -70% (<30-50% for undetections)**
- RQ detections $\rightarrow$ similar/ larger S_{VLBI}/S_{VLA} fractions than RL
- **1.4 GHz core radio powers ~ 5 -20 10^{23} W/Hz** ($>100 \times$ compact HII regions)
- $T_B \sim 10^4$ K $\rightarrow v^{YSN} > 100$ -300 SN/yr; $v^{SNR} > 10$ -30 SN/yr (Kewley et al. 2000)

E-CDFS Target Properties

E-CDFS: 650/883 sources classified as RQ/RL AGNs or SFG

Original Classification
Bonzini et al. 2013

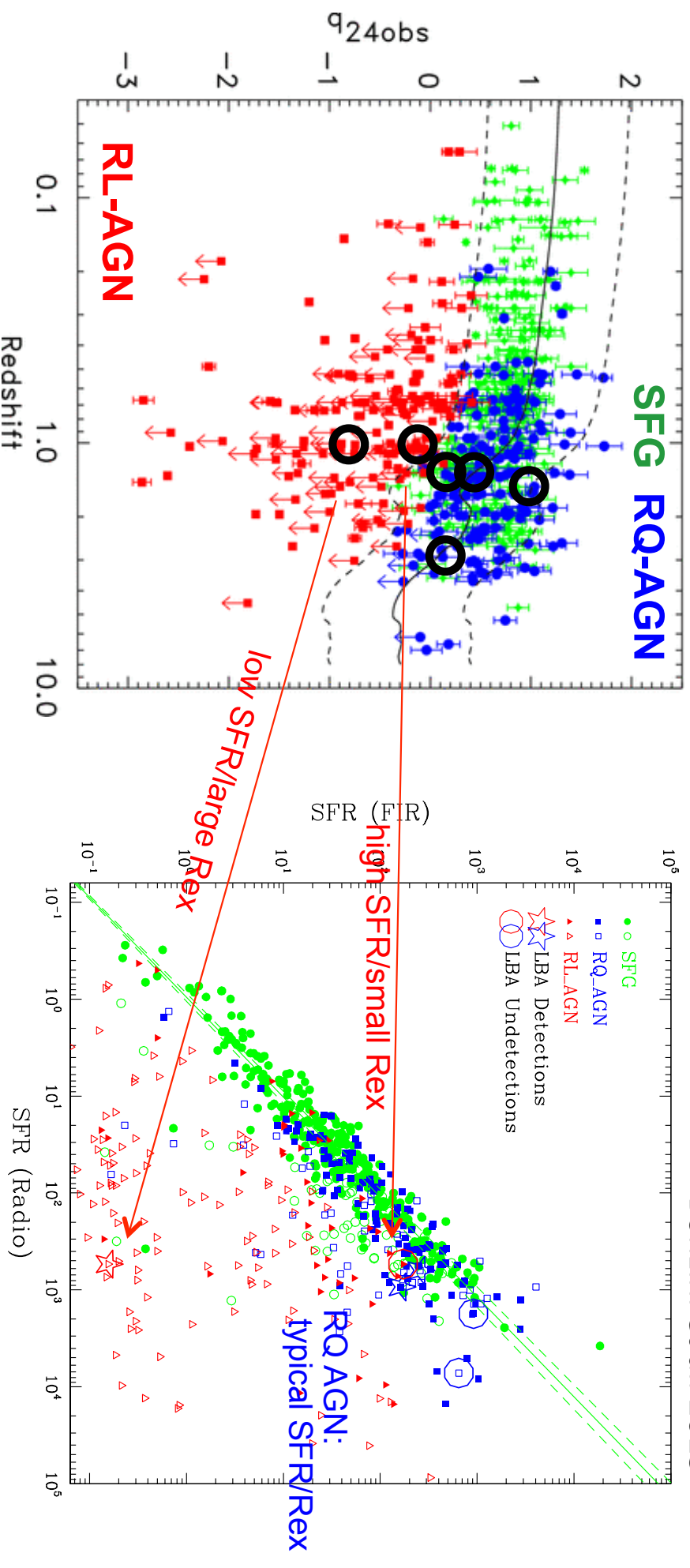


E-CDFS Taget Properties

E-CDFS: 650/883 sources classified as RQ/RL AGNs or SFG

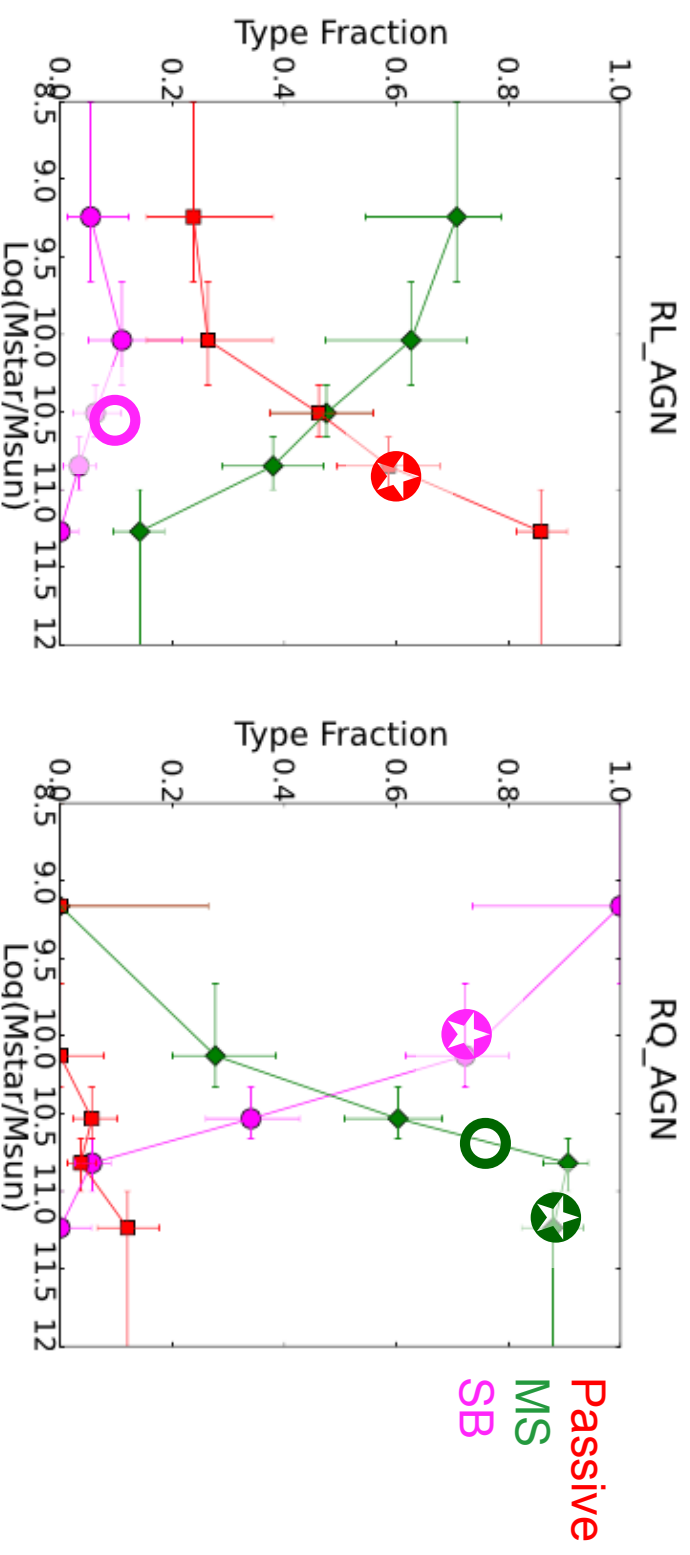
Original Classification
Bonzini et al. 2013

Based on new multi-band analysis,
including Herschel PACS data
Bonzini et al. 2015



E-CDFS: Target Properties

Based on new multi-band analysis, including Herschel PACS data [Bonzini et al. 2015]



Host types/ M_{star} :

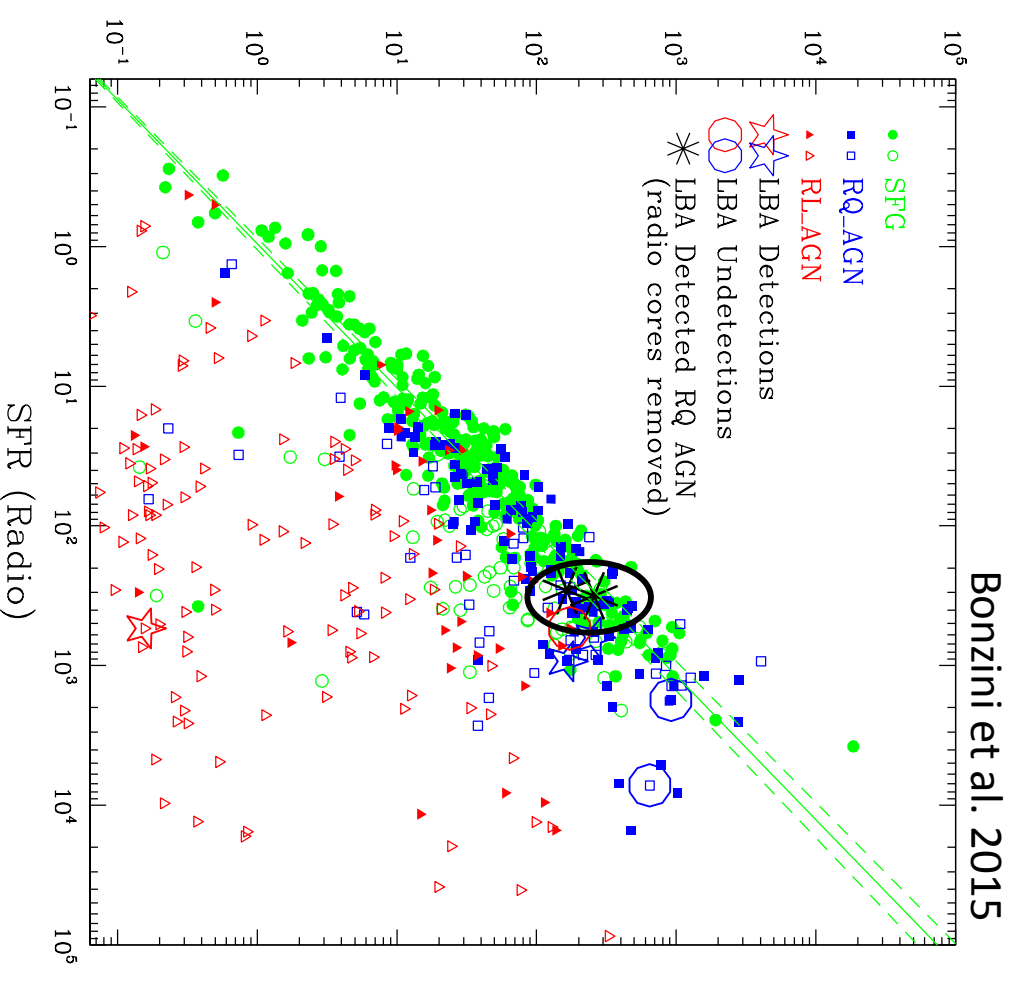
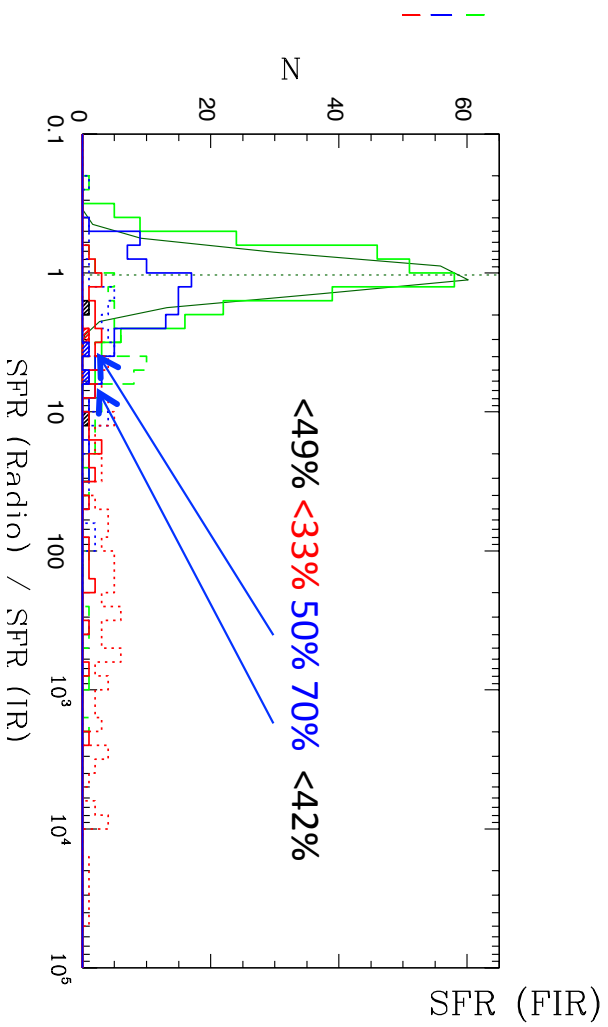
- RL AGN det. → **Passive**
- RL AGN u.l. → **SB**
- RQ-AGN det. → 1 **MS** + 1 **SB**
- RQ-AGN u.l. → **MS**

$L_X \sim 10^{43} \text{ erg/s}$

E-CDFS: Target Properties

RQ-AGN: Composite Radio Emission

→ When removing cores RQ-AGN nicely fit on the RC/FIR SFR correlation (we are likely accounting for all AGN-related radio emission)



Conclusions & Future Perspectives

- **E-CDFS** pilot LBA study: 2/4 (50%) or 2/5 (40%) RQ AGN detected
- Re-analysis of **GOODS-N**: 2/13 (15%) RQ AGN detected (but not deep enough)
 - Evidence of radio cores in (at least a fraction) of RQ AGN

What's next:

- Extending the search for VLBI cores in E-CDFS (20 RQ >100 uJy)
- Analysis of upcoming EVN data for the GOODS-N (1-4 uJy rms expected) in connection with eMERGE project (200 mas @ 1.4 GHz and 50 mas resolution @ 5.5 GHz) → **trace small-scale jets, if present**