HOSTS AND ENVIROMENTS OF RADIO-ACTIVE AGN

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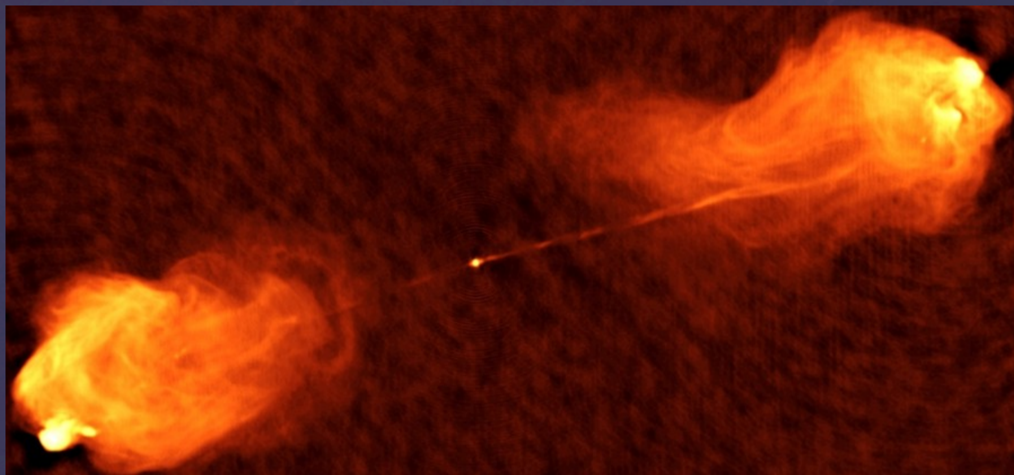
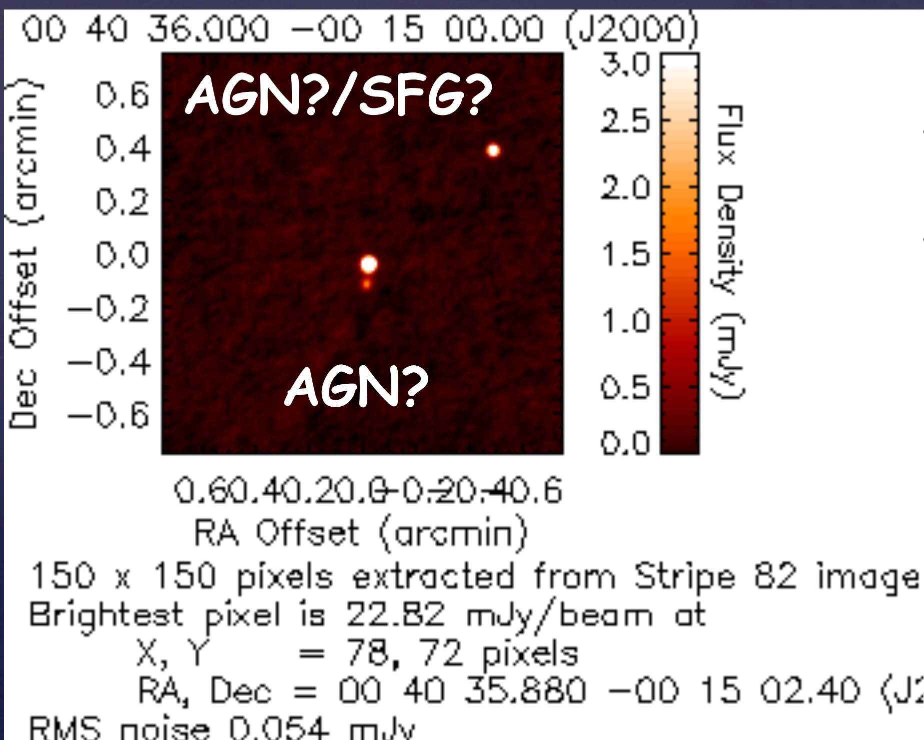
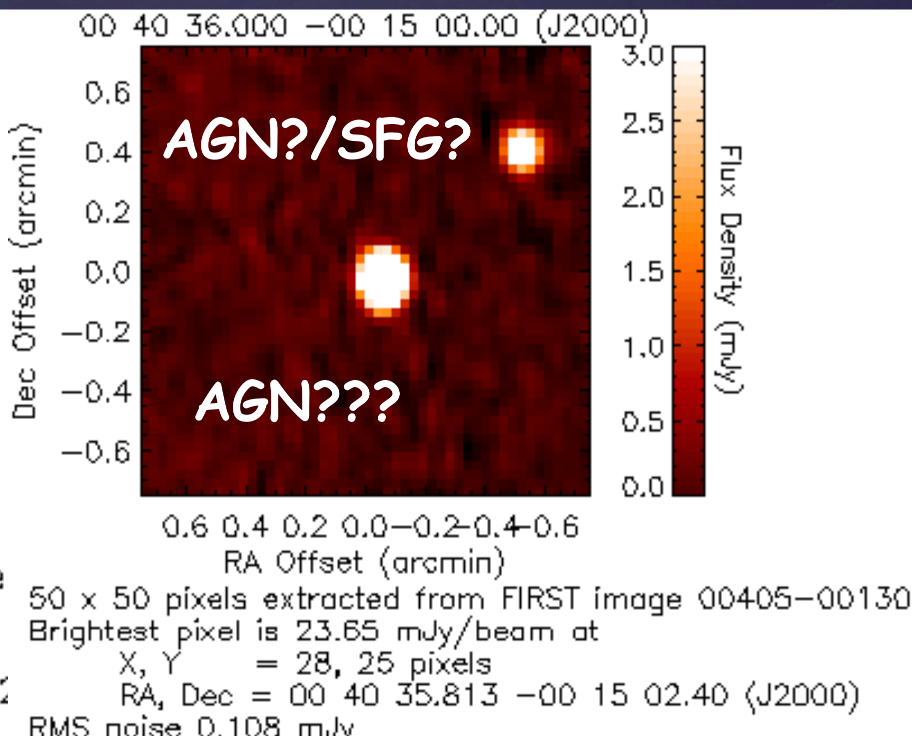
(Magliocchetti+2014;2016,2017,2018a,2018b)

RADIO-EMITTING AGN OR STAR-FORMING GALAXY?



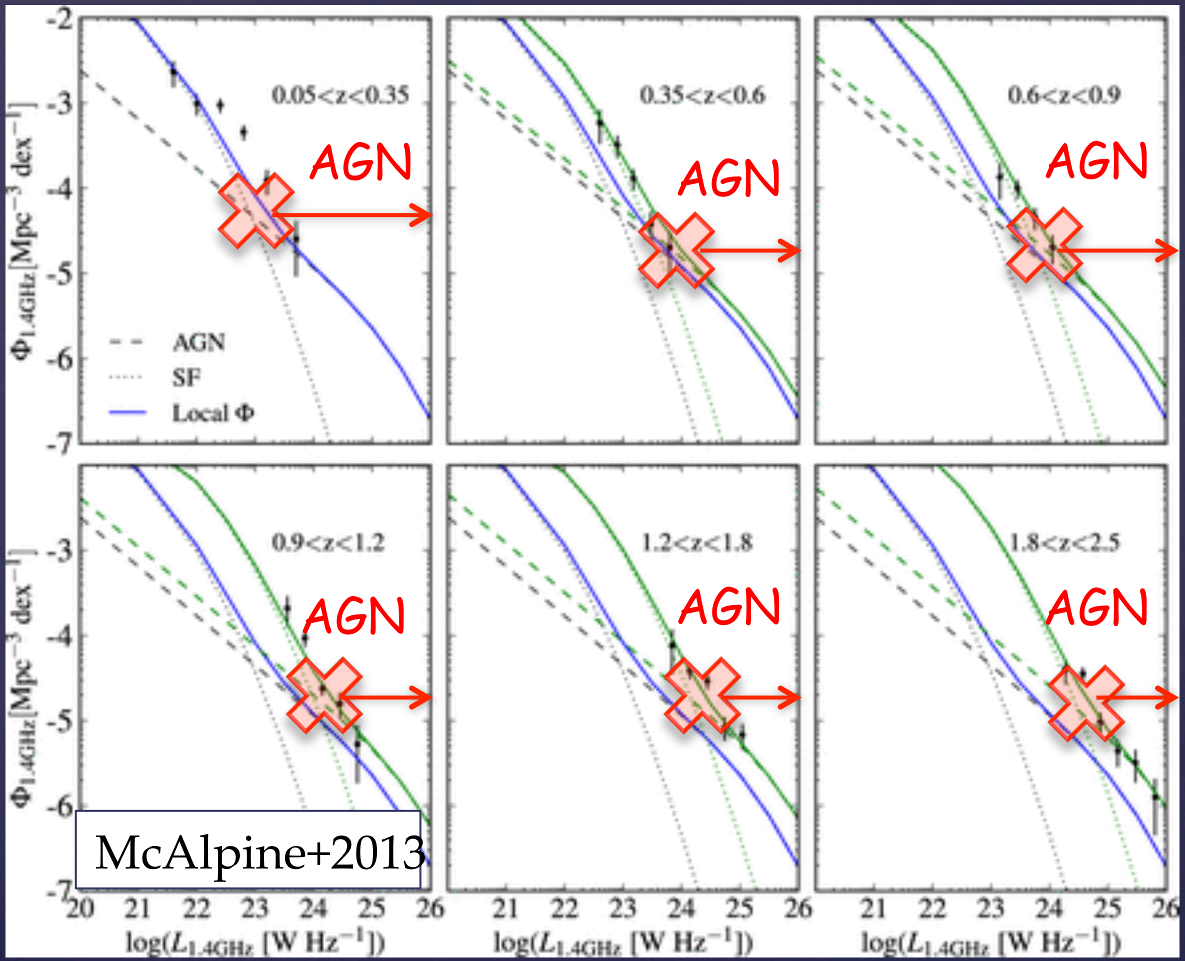
AGN!!





CRITERIA FOR AGN/SF DIVISION IN RADIO SURVEYS

(Magliocchetti+2014;2016,2017,2018a,2018b)



Radio data from VLA-VIRMOS (Bondi+ 2003). 1 deg^2 complete to 100mJy: 1054 sources

From McAlpine+13 RLF z evolution of cross-point from SF-dominated to AGN-dominated sources:

$Log_{10}P_{cross}(z)=Log_{10}P_{0,cross}+z$ @ z<1.8

$Log_{10}P_{cross}=23.5$ [W/Hz/sr] @ z>1.8

$P_{0,cross}$ break of local SF RLF (Magliocchetti+2002; Mauch& Sadler 2007)

AGN all sources with $P(z)>P_{cross}(z)$

SF all sources with $P(z)<P_{cross}(z)$ [N.B. also includes RQQ]

FIELD AND DATA SELECTION

A) COSMOS-VLA Survey (Bondi+2008)

Ntot ($F_{1.4GHz}$>60μJy): 2382
Nz($F_{1.4GHz}$>60μJy)=2123 (90%)

NAGN=704 (272 FIR) -- shallower in radio/FIR but wider area

B) GOODS-N + GOODS-S (Morrison+2010; Miller+2013)

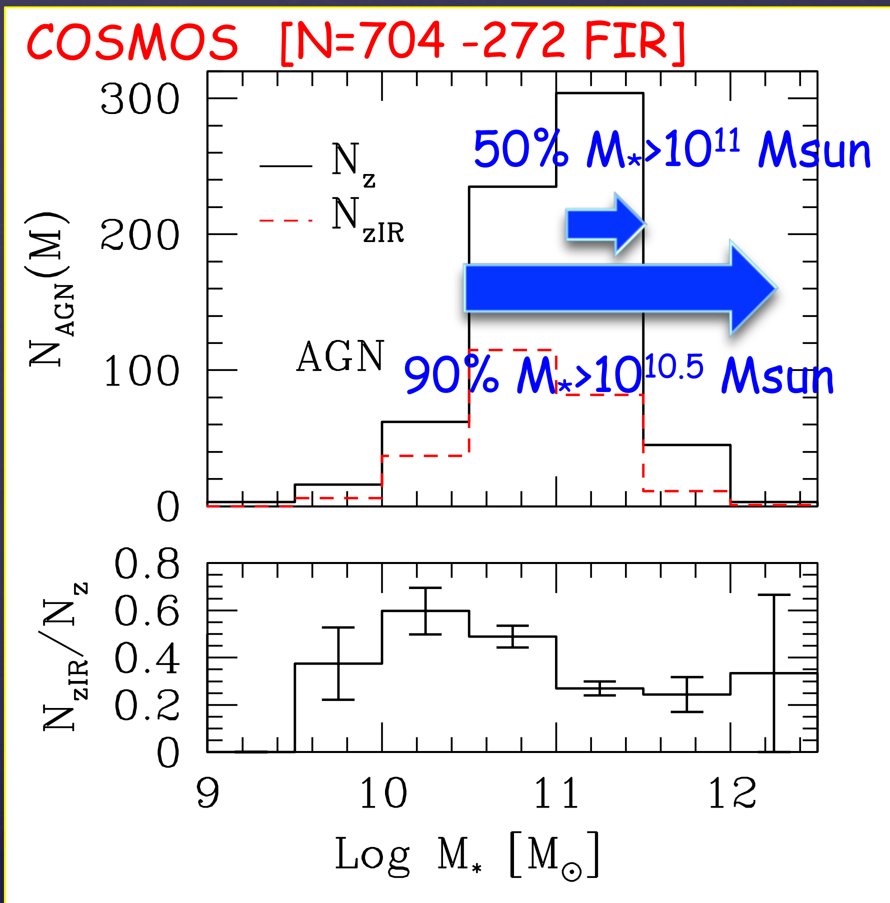
Ntot ($F_{1.4GHz}$>20μJy): 401 + 142
Nz($F_{1.4GHz}$>20μJy): 267 + 114 (≈75%)

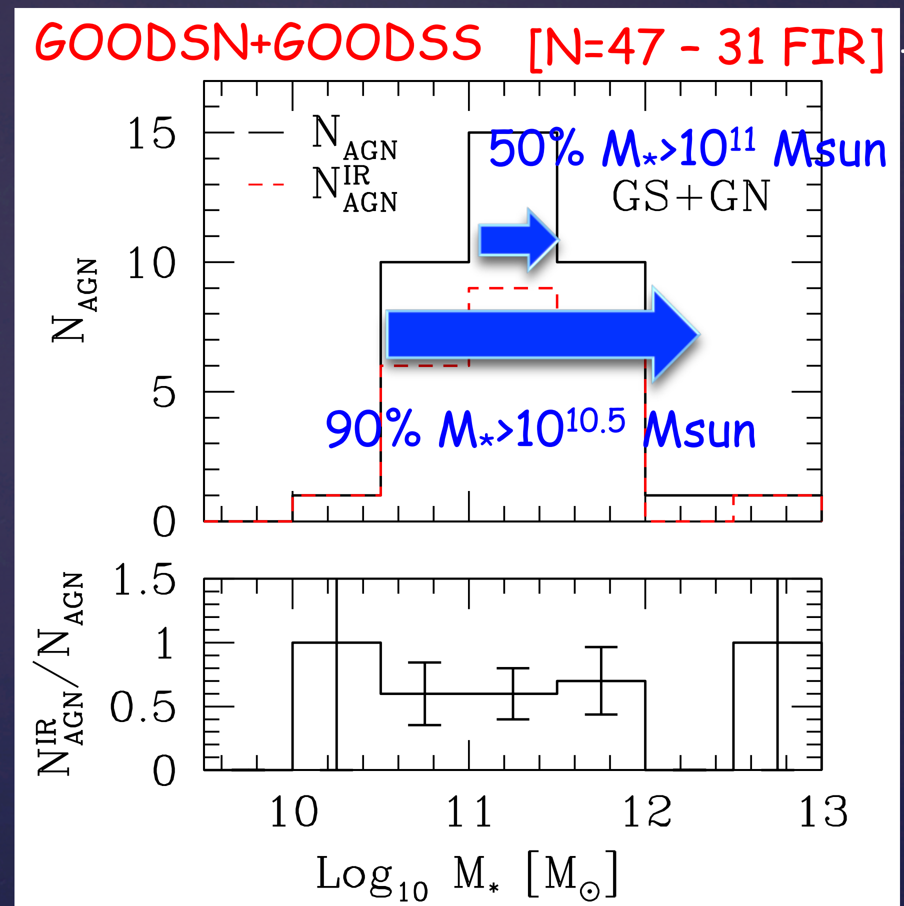
NAGN=32+15 (23+8 FIR)-- deeper in radio/FIR but smaller area

N.B. All samples complete up to z~ 3.5
Success-rate independent of radio flux (up to ~ 3 mJy) and redshift

STELLAR MASSES OF RADIO-AGN HOSTS

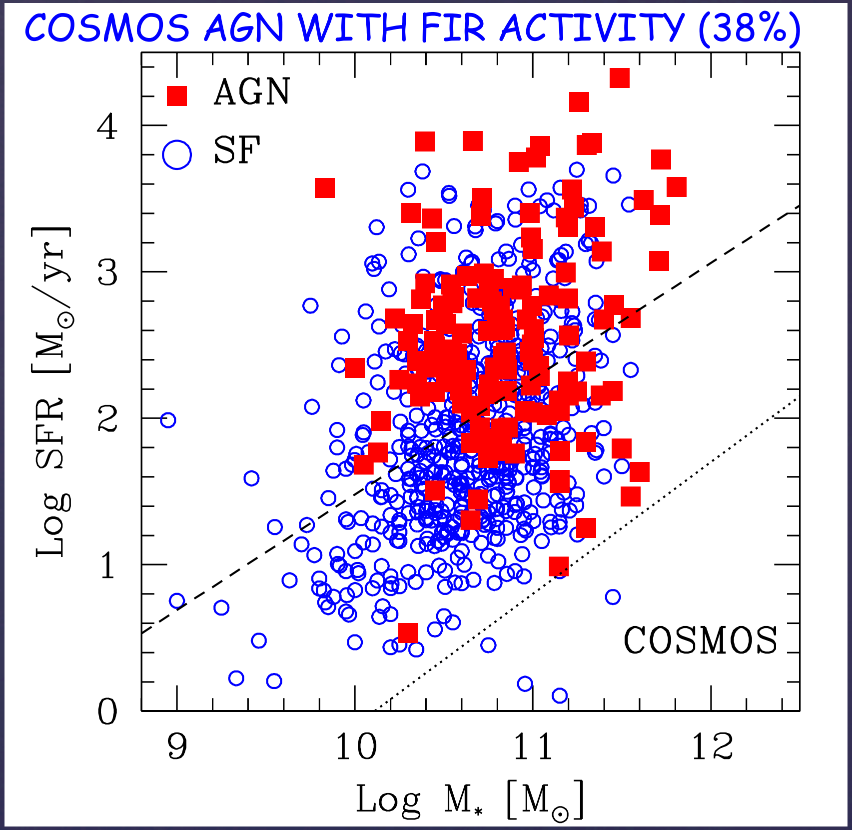
90% have $M_* > 10^{10}$ Msun. 50% $M_* > 10^{11}$ Msun

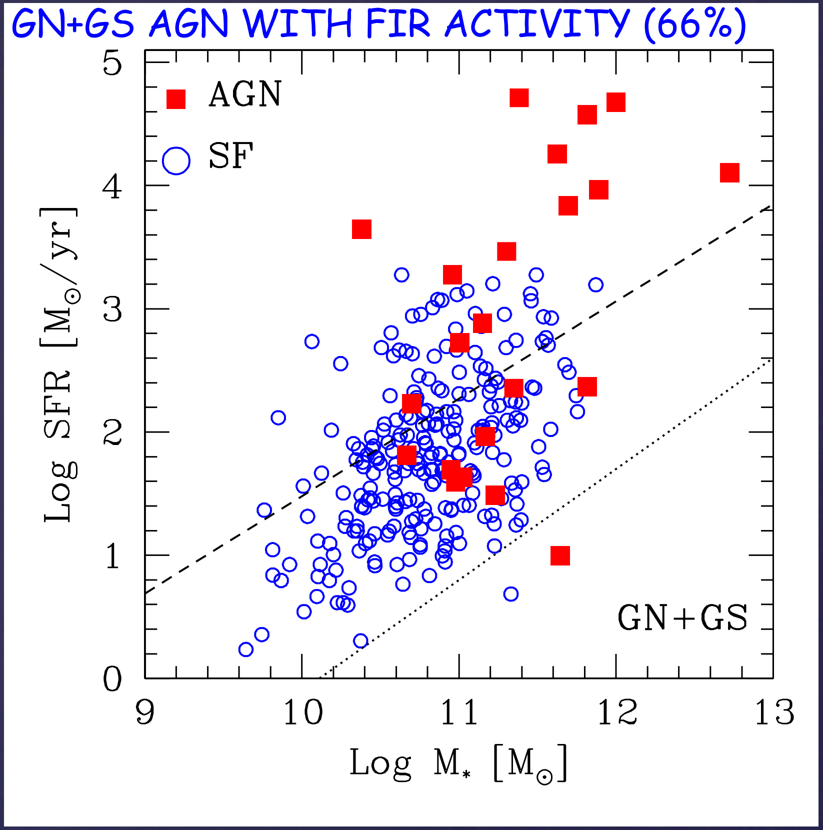




HOSTS OF RADIO AGN EXTREMELY MASSIVE GALAXIES AT ALL REDSHIFTS

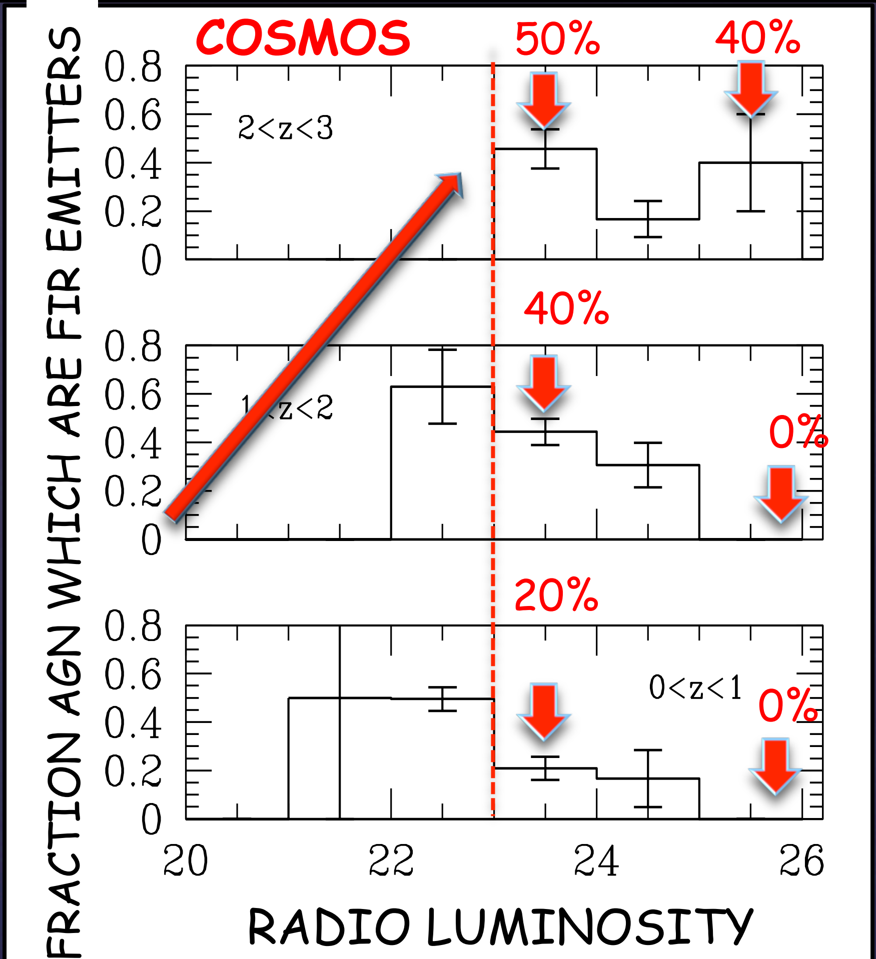
STAR-FORMING ACTIVITY WIHIN RADIO-AGN HOSTS

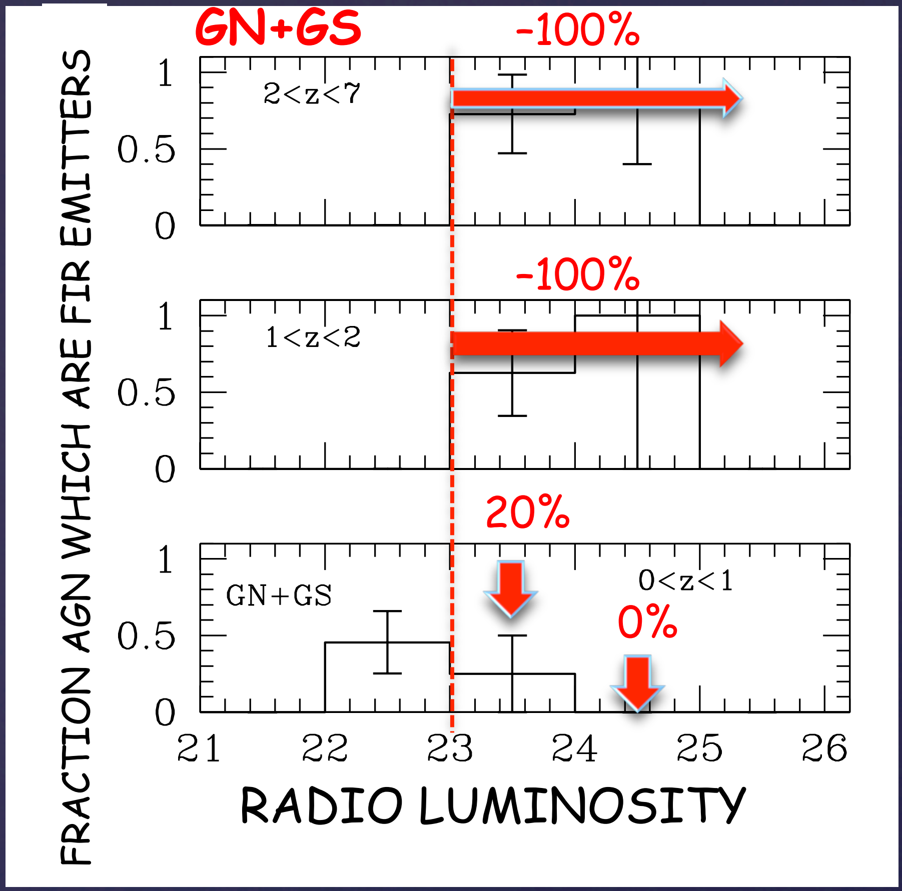




HOSTS OF RADIO EMITTING AGN NOT ONLY VERY MASSIVE BUT SITES OF INTENSE STAR FORMATION ACTIVITY, PARTICULARLY AT z>1

Fraction of FIR emitters amongst radio-selected AGN as a function of radio luminosity at different cosmological epochs





Powerful radio AGN are more likely associated to ongoing star-formation at earlier epochs. ~100% at z>1 for deep enough FIR surveys. NO SIGN OF NEGATIVE FEEDBACK only present for z<1 and only for radio-bright sources

WHAT HAVE WE LEARNED SO FAR?

1) Radio-emitting AGN are hosted by very massive galaxies at all z

2) Most of them are in the process of forming stars at very high rates

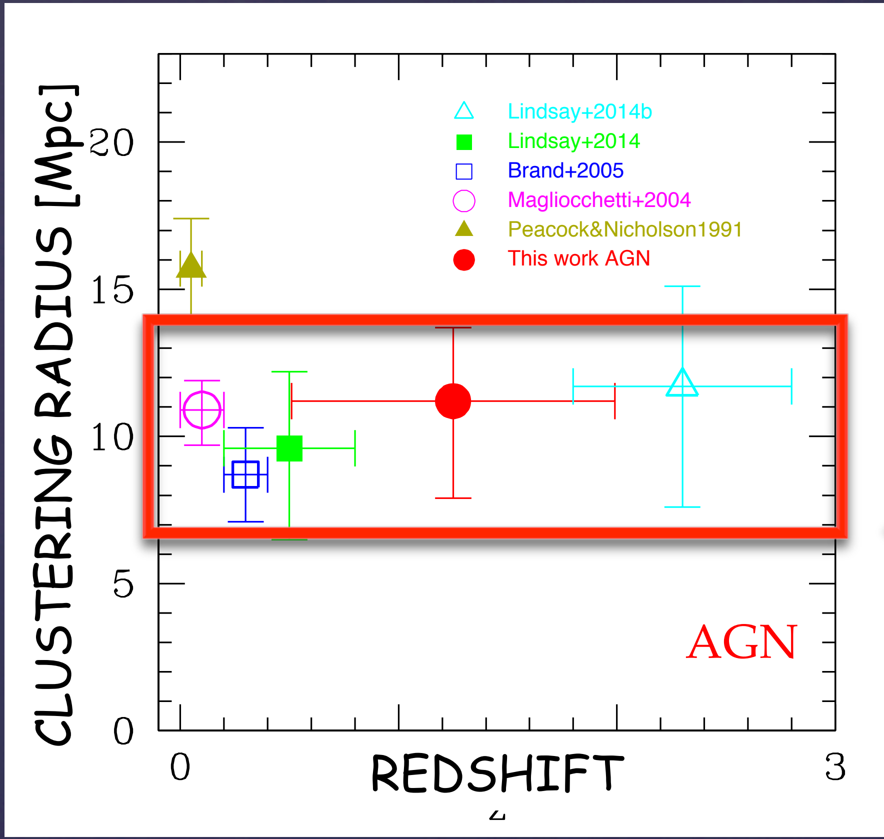
3) Such star-forming activity much more intense in the past. Deepest FIR surveys show that ~100% of high (z>~1) redshift radio-active AGN are associated to SF events
→ NO (negative) AGN-to-SF FEEDBACK at those z

4) Feedback only present in the z<1 universe and for mainly for sources which are radio-powerful

AND WHAT ABOUT AGN LARGE-SCALE ENVIRONMENT?

Investigate spatial distribution via 2ptCF and direct pinpoint on known structures (COSMOS)

CLUSTERING ANALYSIS:
COMPARISON OF AGN RESULTS WITH LITERATURE



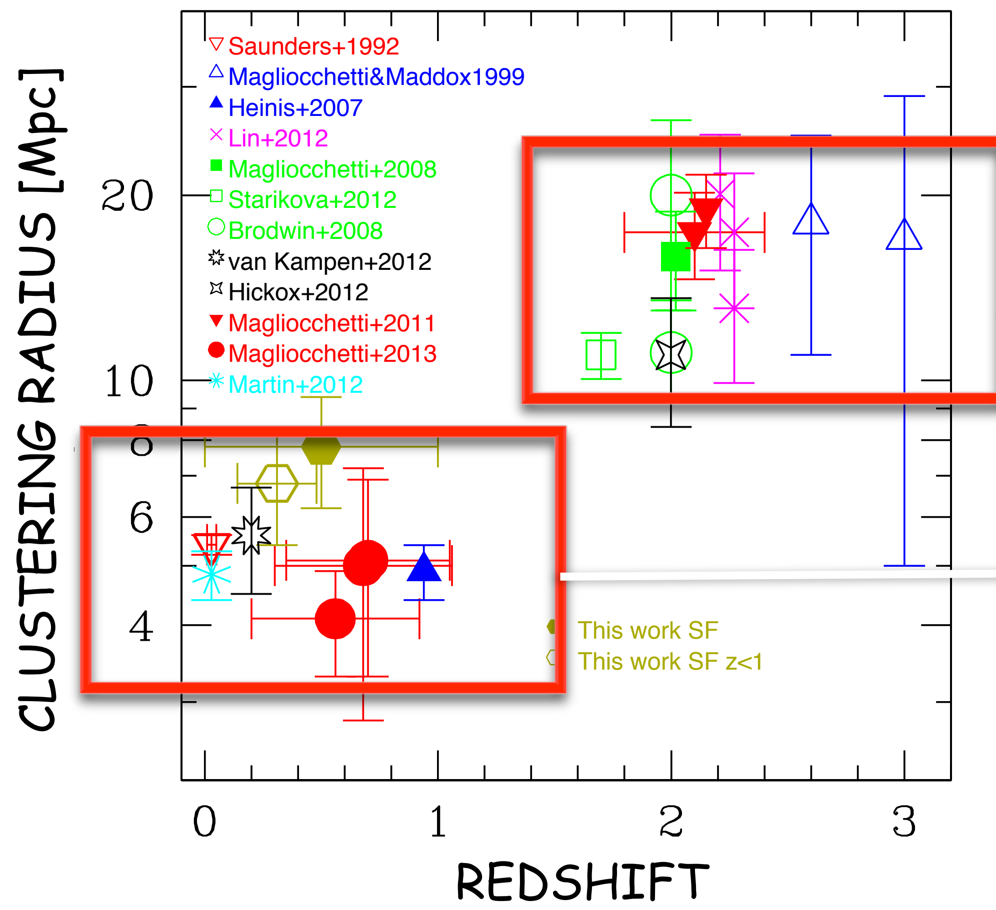
Peacock& Nicholson 1991
F>500 mJy - z<0.1
Magliocchetti+2004 -- 2dF+FIRST
F>1 mJy (AGN) -- <z>=0.1
Brand+2005 -- Texas-Oxford+NVSS
F>3 mJy -- <z>=0.3
Lindsay+2014 - GAMA+FIRST
F>1mJy -- <z>=0.5
Lindsay+2014b - VLA-VIRMOS
F>0.09 mJy -- <z>0=2.2
Magliocchetti+2016 - VLA-COSMOS
F>0.15 mJy -- <z>=1.3

$M^{HALO}_{MIN} \approx 10^{13.5}\ M_{sun}$
(groups-to-clusters of galaxies)

Except for P&N excellent agreement amongst different results →
→ INDEPENDENCE OF AGN CLUSTERING PROPERTIES ON
1) REDSHIFT and 2) RADIO LUMINOSITY ($P <\sim 10^{24.5-25}$ W/Hz)

RADIO-ACTIVE AGN RESIDE WITHIN THE SAME STRUCTURES AT ALL RADIO LUMINOSITIES $<\sim 10^{24.5-25}$ W/Hz. NO EVOLUTION IN PROPERTIES DURING COSMIC EPOCHS AT LEAST SINCE z~3! **NO DOWNSIZING**

CLUSTERING ANALYSIS: COMPARISONS OF SF RESULTS WITH LITERATURE



Adapted from Magliocchetti+2014

Red: 60mm RF selection
Blue: UV selection
Magenta: BzK selection
Green: 24mm selection
Black: 250mm (RF) selection
Cyan: HI selection
Gold: radio-SF selection (this work)

$M^{HALO}_{MIN} \approx 10^{13.5}\ M_{sun}$

$M^{HALO}_{MIN} \approx 10^{11.5}\ M_{sun}$

Peculiar trend of SF clustering. Jump in the clustering properties beyond z>1.5.
At variance with AGN
SF hosted by very massive structures only z>1.5

DOWNSIZING

RELATIONSHIP BETWEEN DARK AND LUMINOUS MATTER IN AGN

M_{min} from clustering ----- M_* from Laigle+2016 catalogue

$\langle M_* \rangle / M_{min} < 10^{-2.7}$ relatively small stellar content (large uncertainties)

DURATION OF RADIO-ACTIVE AGN PHASE

Comparison of observed space density of AGN with that expected for dark matter haloes more massive than M_{min} (from clustering results)

Fraction of haloes with $M_{min} > 10^{13.6} M_{sun}$ host of a radio-active AGN = 0.4

→ about one in two haloes observed to host radio-AGN (a lot!!)

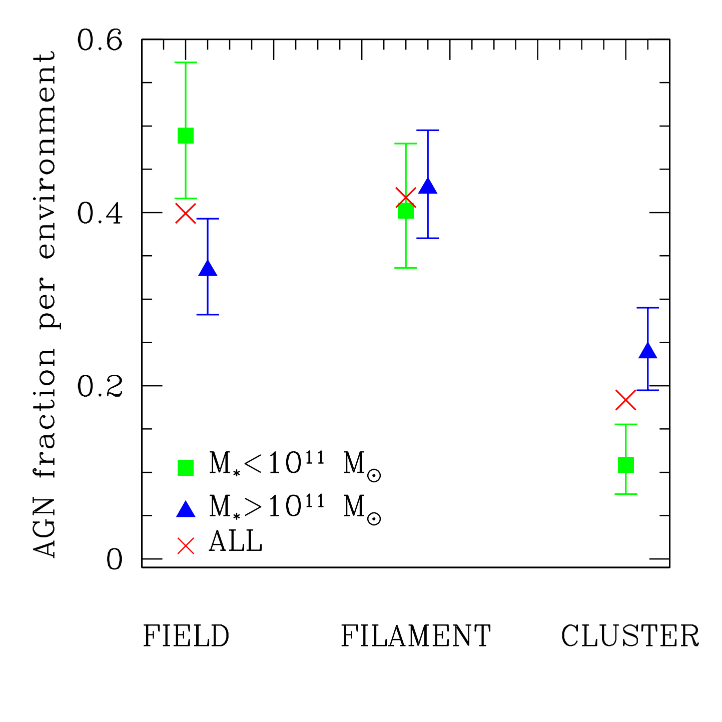
If we assume every halo with $M_{halo} > M_{min}$ hosts a black hole that at some point becomes radio-active we derive life-time of radio phase τ=1 Gyr

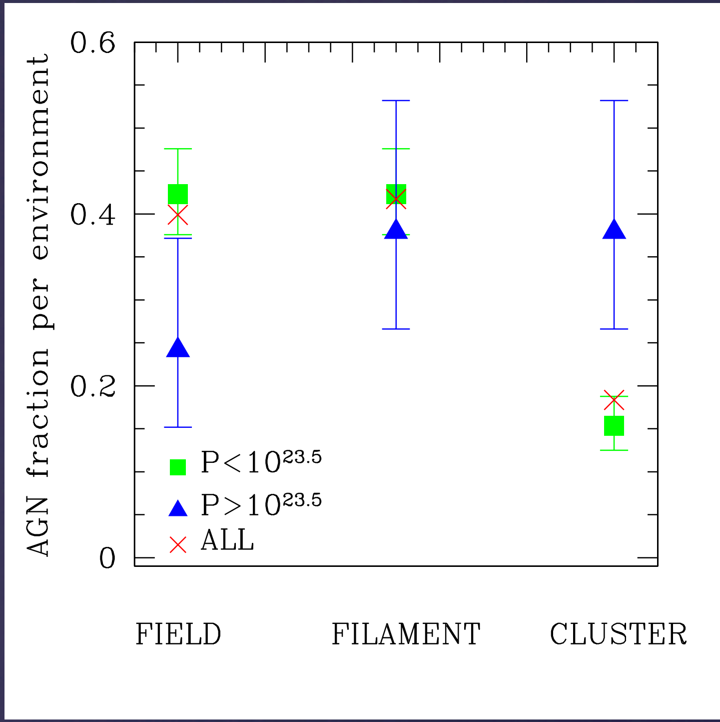
$\tau \gg$ a few x10 Myr for radio-bright phase (Blundell & Rawlings 1999) →

Radio active phase is recurrent phenomenon

DEPENDENCE OF ENVIRONMENTAL PROPERTIES ON AGN-GALAXY PHYSICS

(218 radio-AGN z<1.2 on COSMOS field. Environments from Darvish+2017)





More massive radio-AGN prefer denser environments (not only mass-segregation effect. Ask me!)

Most radio-powerful - $P > \sim 10^{24.6}$ W/Hz - AGN prefer denser environments

(cf Peacock & Nicholson clustering results)

CONCLUSIONS

1) Radio-emitting AGN are hosted by very massive galaxies at all z

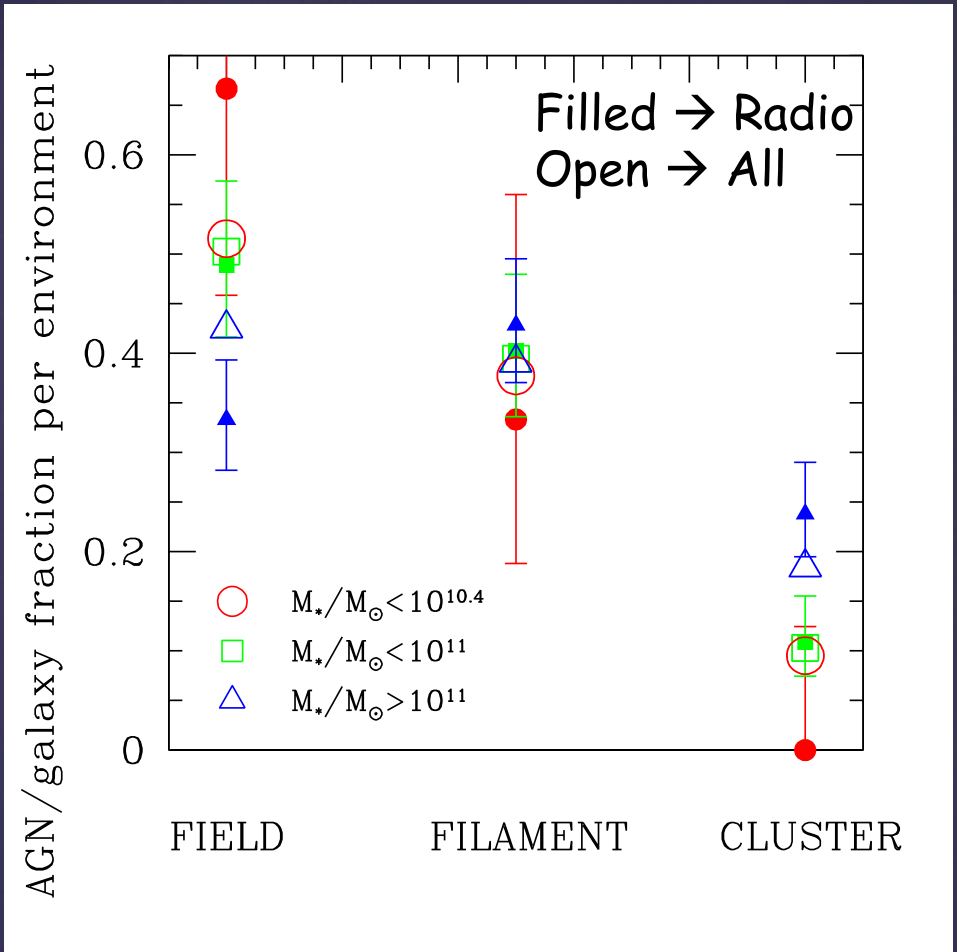
2) Most of them are in the process of forming stars at very high rates especially in the past.
Deepest FIR surveys show that ~100% of z>~1 radio-AGN are associated to SF events → NO (negative) AGN-to-SF FEEDBACK at those z
Feedback only present in the z<1 universe and mainly for sources which are radio-powerful

3) Hosted by DM halos of masses >$10^{13.5}$ M_{sun} (groups-to-clusters of galaxies)
Radio-AGN environmental properties do not depend on radio luminosity (at least up to P~$10^{24.5-25}$ W/Hz) and do not evolve with cosmic epoch

4) Stellar content relatively small $\langle M_* \rangle / M^{HALO} < 10^{-2.7}$

5) From comparison of densities 1 out of 2 massive halos host of radio-AGN
→ τ~ 1Gyr → **Radio-active phase recurrent phenomenon**

6) Dependence of environmental properties on stellar content/AGN emission at different λ/radio luminosity (only for very bright sources)
Connection between sub-pc up to Mpc behaviours?



Massive radio-AGN tend to avoid under-dense structures more than general population of galaxies of same mass

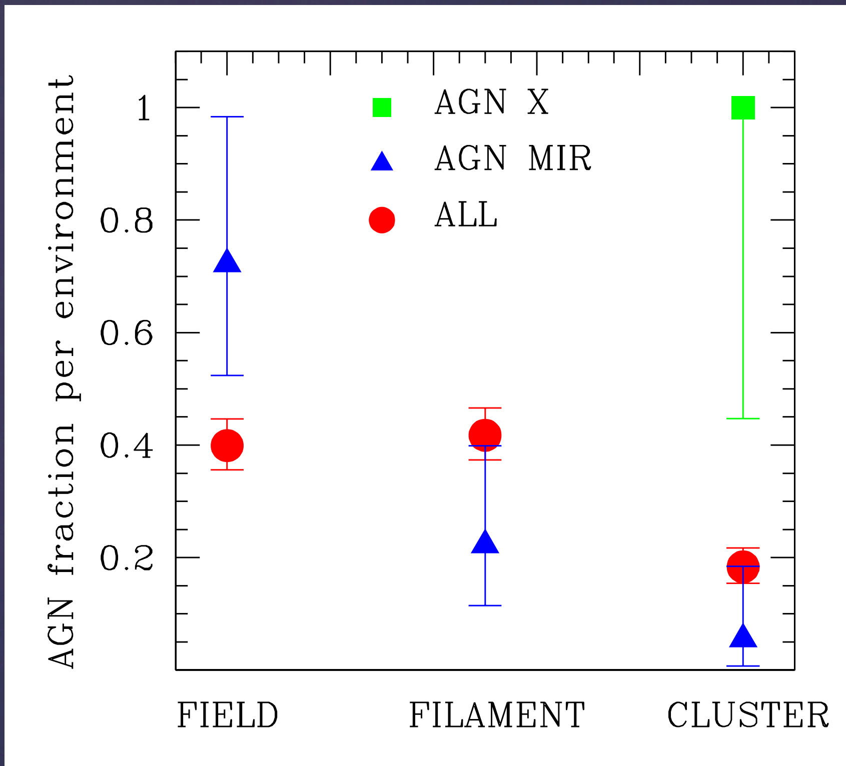
The least massive radio-AGN tend to avoid (0/15) over-dense structures more than galaxies within same mass range

DIFFERENT ENVIRONMENTAL PROPERTIES CONNECTED WITH (RADIO) AGN ACTIVITY WHICH IS FAVOURED IN HIGH-MASS SYSTEMS RESIDING IN DENSE REGIONS OR IN SMALLER ISOLATED GALAXIES.

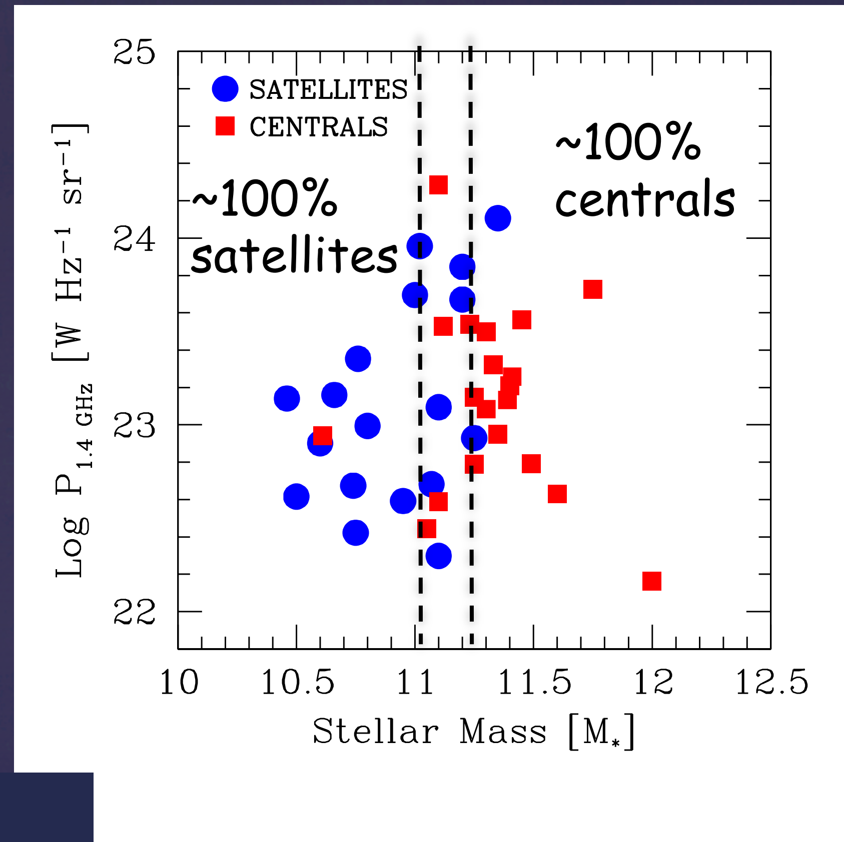
<u>DIFFERENT TRIGGERING MECHANISMS (COOLING VS MERGING – eg Tasse+2008) IN DIFFERENT MASS REGIMES?</u>

DEPENDENCE OF ENVIRONMENTAL PROPERTIES ON AGN-GALAXY PHYSICS

(218 radio-AGN z<1.2 on COSMOS field. Environments from Darvish+2017)



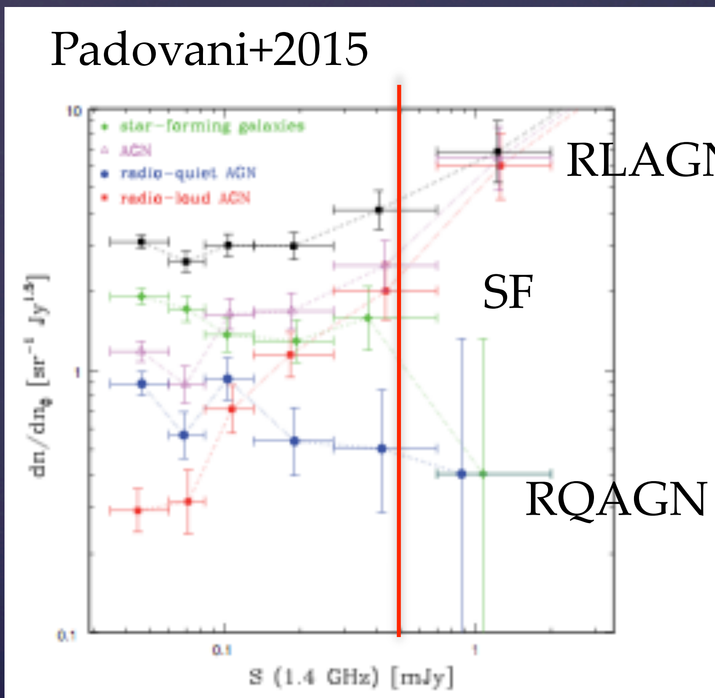
Radio-AGN which are also MIR emitters way more likely to be found within under-dense environments than X-ray emitters. Also less massive.
Different sub-populations with different triggering (accretion of hot gas vs merging) mechanisms?

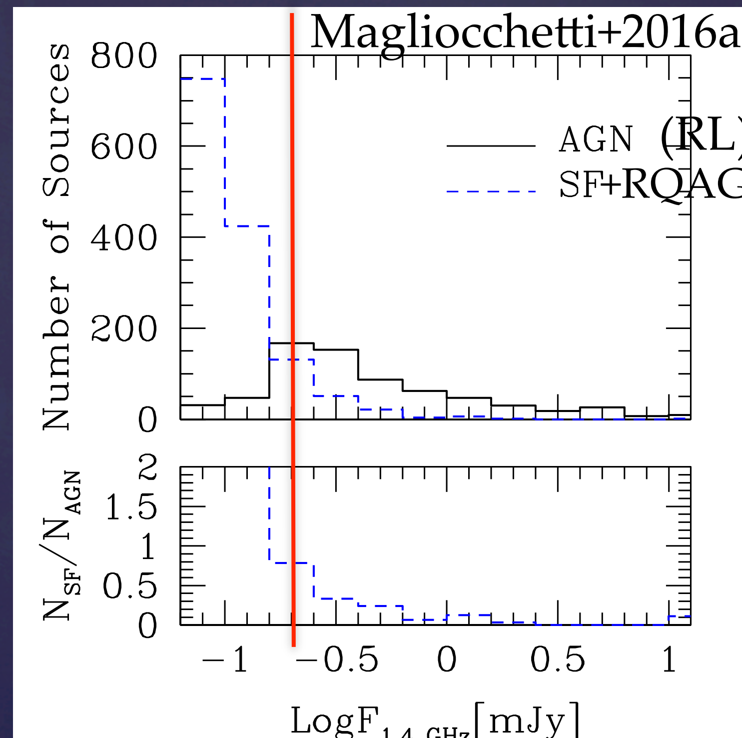


No dependence of position of radio-AGN within cluster on radio luminosity. Only dependence is on host mass (mass segregation)

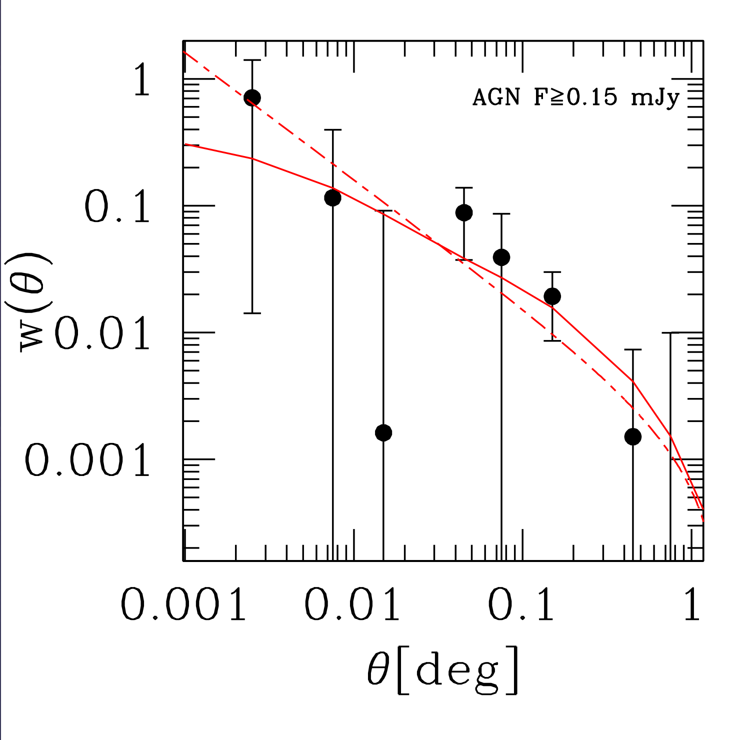
SELECTION EFFECTS

AGN sample selected only on basis of radio emission. SF RLF much steeper than AGN RLF at all z →chances of contamination of AGN sample from SF+RQAGN above luminosity threshold very limited (<~20% already at Pcross)





CLUSTERING ANALYSIS: RESULTS FOR HALO MASSES



Halo model:

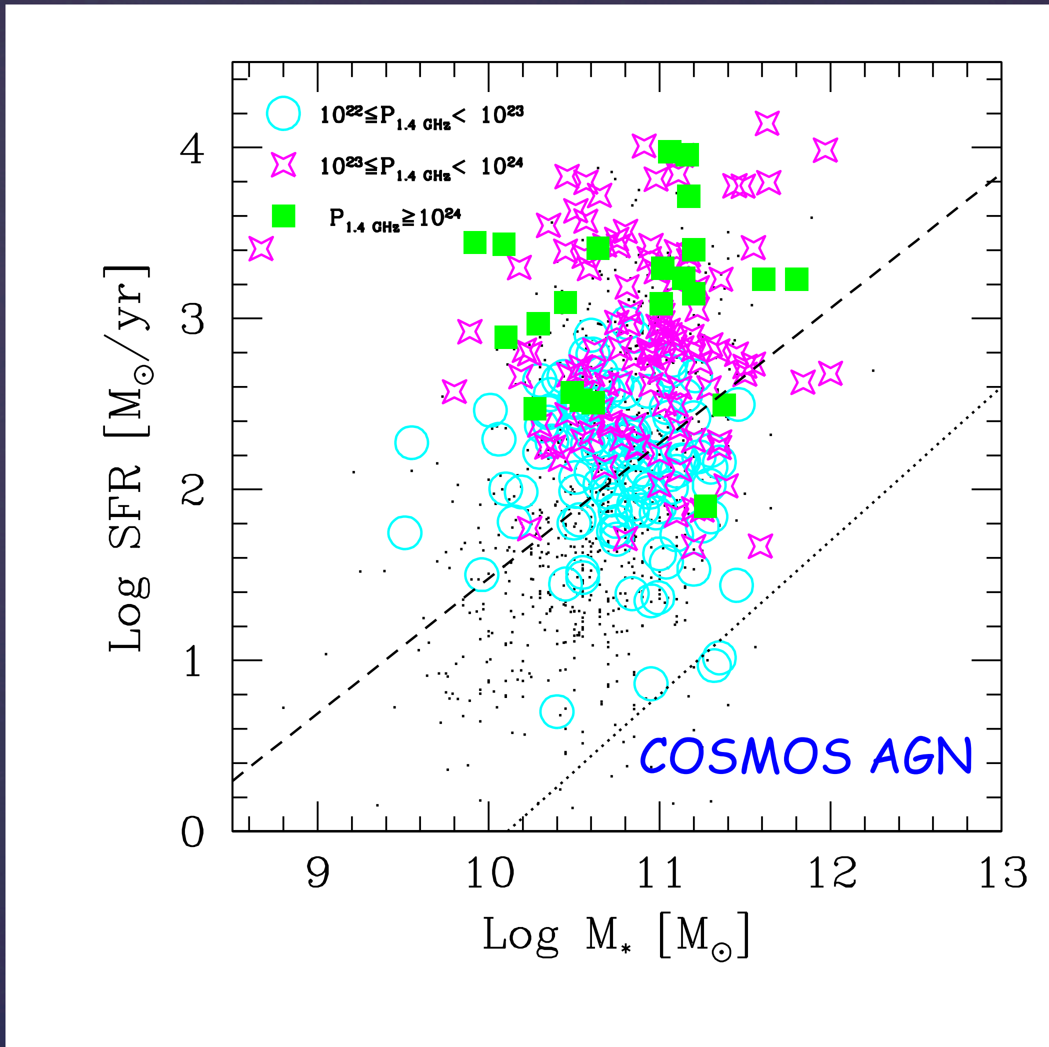
$\xi(r,z)=\xi_{DM}(r,z)\ b^2(M_{min},z)$

b → BIAS

M^{HALO}_{MIN} → minimum halo mass capable of hosting source

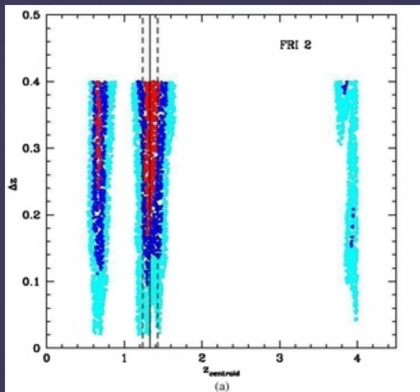
AGN: $M^{HALO}_{MIN}=10^{13.6}\ M_{sun}$

VERY MASSIVE HOSTS COMPARABLE TO THOSE OF GROUPS-TO-CLUSTERS OF GALAXIES

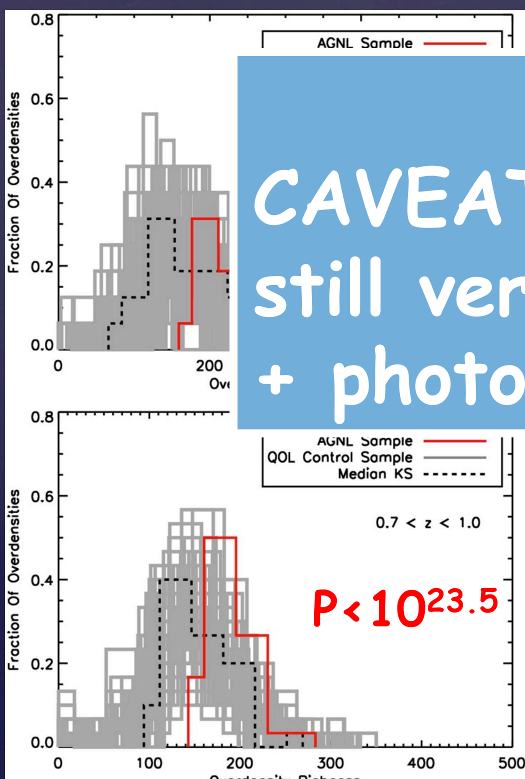


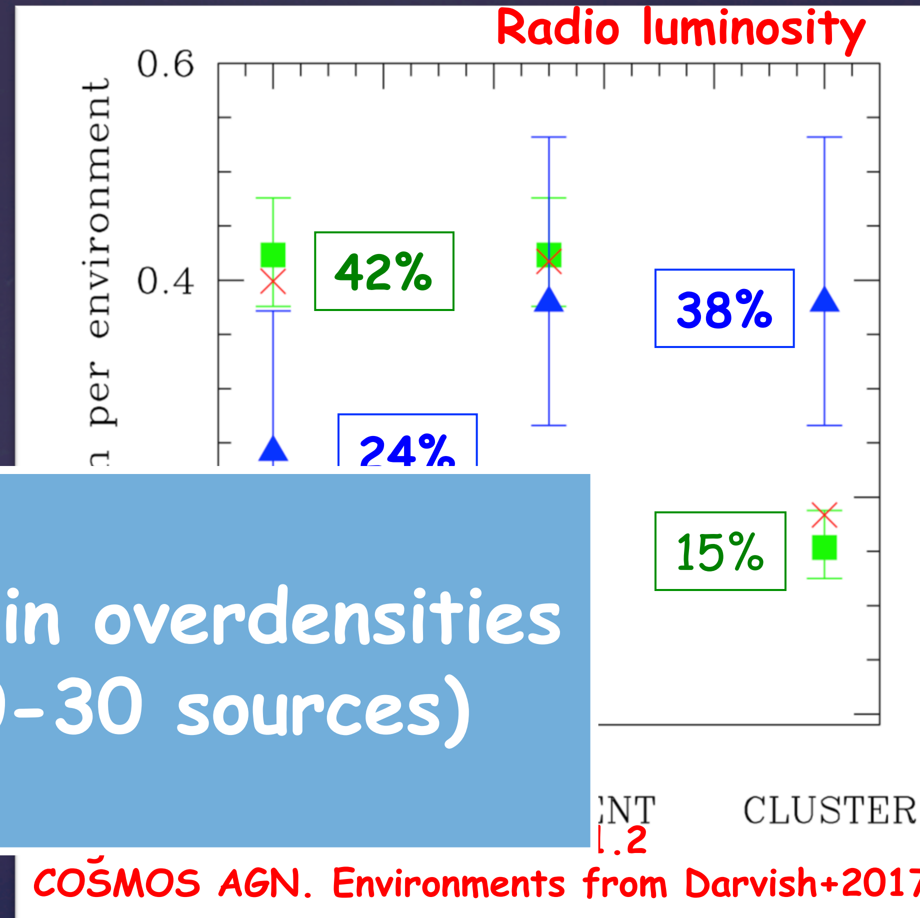
10²²≦P1.4 GHz< 10²³
10²³≦P1.4 GHz< 10²⁴
P1.4 GHz≧10²⁴
Log SFR [M⊙/yr]
Log M* [M⊙]
0
1
2
3
4
9
10
11
12
13
COSMOS AGN

ENVIRONMENT OF RL AGN at 0<z<1.5: DEPENDENCE ON RADIO LUMINOSITY - COSMOS



Castignani+2014 report 70% overdensities around RLAGN and no dependence on radio luminosity





?

CAVEAT: samples in overdensities still very small (10-30 sources) + photoz

Magliocchetti+2018:
More radio luminous sources prefer denser environments