



<b><i>Publication Year</i></b>	2018
<b><i>Acceptance in OA</i></b>	2022-02-28T15:37:14Z
<b><i>Title</i></b>	Hosts and environments of radio-active AGN
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<b><i>Publisher's version (DOI)</i></b>	10.5281/zenodo.1472829
<b><i>Handle</i></b>	<a href="http://hdl.handle.net/20.500.12386/31503">http://hdl.handle.net/20.500.12386/31503</a>

# HOSTS AND ENVIROMENTS OF RADIO-ACTIVE AGN

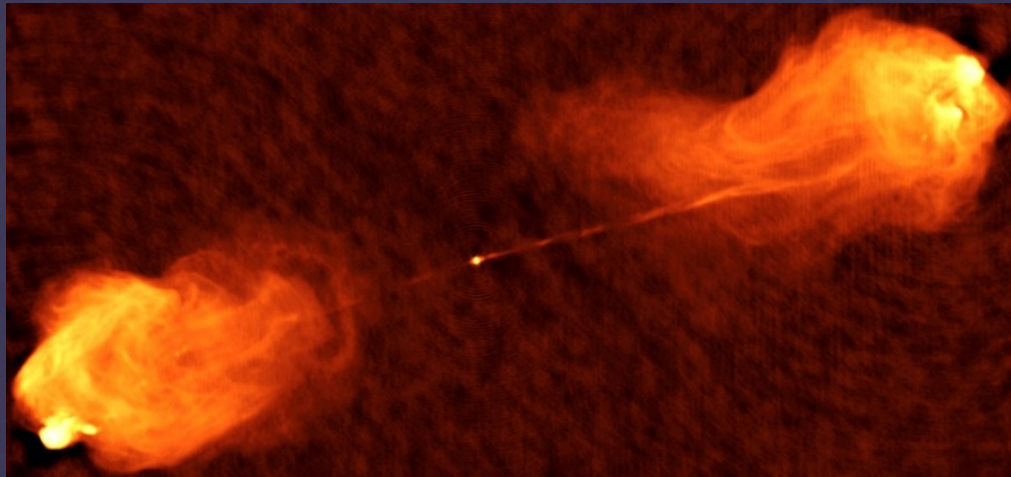
Manuela Magliocchetti  
IAPS-INAF

P.Popesso - M. Brusa - M.Salvato

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

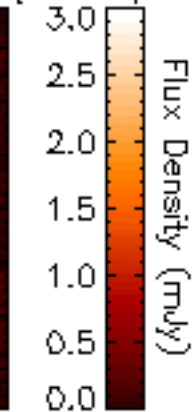
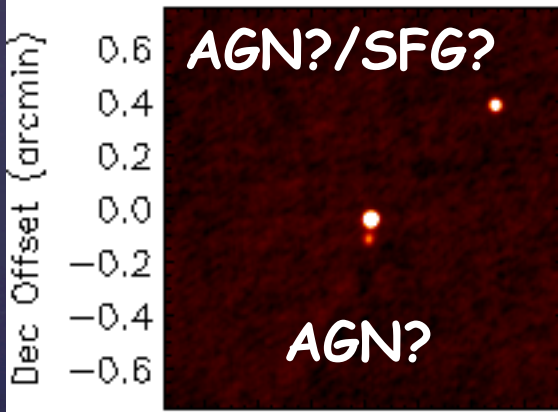


# RADIO-EMITTING AGN OR STAR-FORMING GALAXY?



**AGN!!**

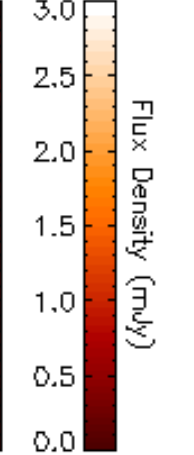
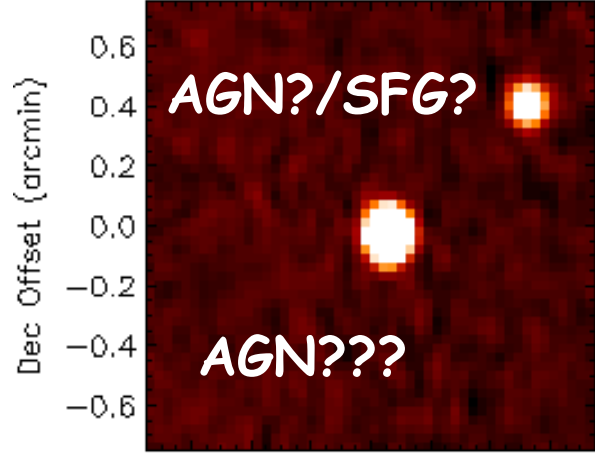
00 40 36.000 -00 15 00.00 (J2000)



0.60.40.20.0-0.20.40.6  
RA Offset (arcmin)

150 x 150 pixels extracted from Stripe 82 image  
Brightest pixel is 22.82 mJy/beam at  
X, Y = 78, 72 pixels  
RA, Dec = 00 40 35.880 -00 15 02.40 (J2000)  
RMS noise 0.054 mJy

00 40 36.000 -00 15 00.00 (J2000)

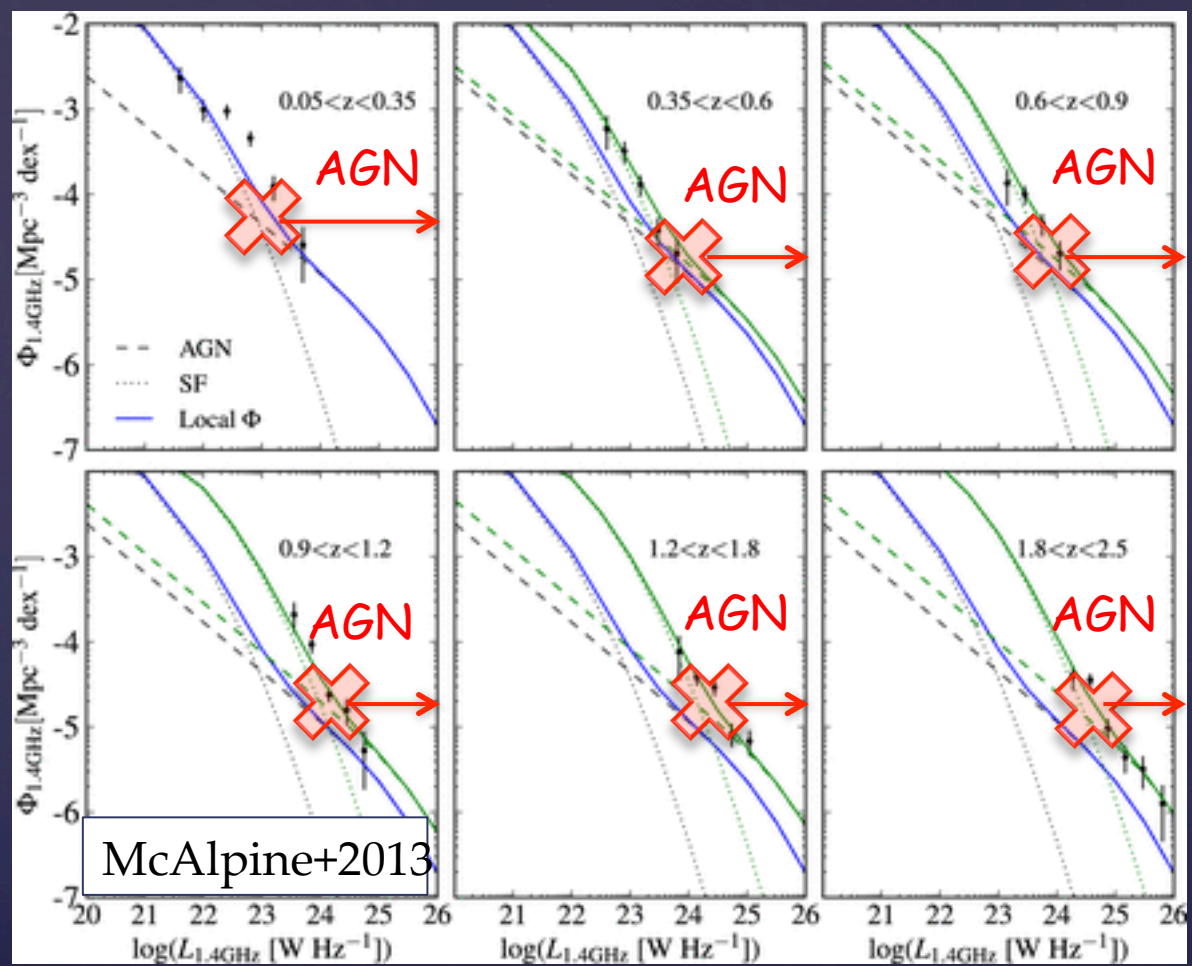


0.6 0.4 0.2 0.0 -0.2 -0.4 -0.6  
RA Offset (arcmin)

50 x 50 pixels extracted from FIRST image 00405-00130Z  
Brightest pixel is 23.65 mJy/beam at  
X, Y = 28, 25 pixels  
RA, Dec = 00 40 35.813 -00 15 02.40 (J2000)  
RMS noise 0.108 mJy

# CRITERIA FOR AGN/SF DIVISION IN RADIO SURVEYS

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



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

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

$$\text{Log}_{10} P_{\text{cross}}(z) = \text{Log}_{10} P_{0,\text{cross}} + z \quad @ \quad z < 1.8$$

$$\text{Log}_{10} P_{\text{cross}} = 23.5 \text{ [W/Hz/sr]} \quad @ \quad z > 1.8$$

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

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

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

# FIELD AND DATA SELECTION

## A) COSMOS-VLA Survey (Bondi+2008)

$N_{\text{tot}} (F_{1.4\text{GHz}} > 60 \mu\text{Jy}): 2382$

$N_z (F_{1.4\text{GHz}} > 60 \mu\text{Jy}) = 2123 \text{ (90\%)}$

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

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

$N_{\text{tot}} (F_{1.4\text{GHz}} > 20 \mu\text{Jy}): 401 + 142$

$N_z (F_{1.4\text{GHz}} > 20 \mu\text{Jy}): 267 + 114 \text{ (\approx 75\%)}$

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

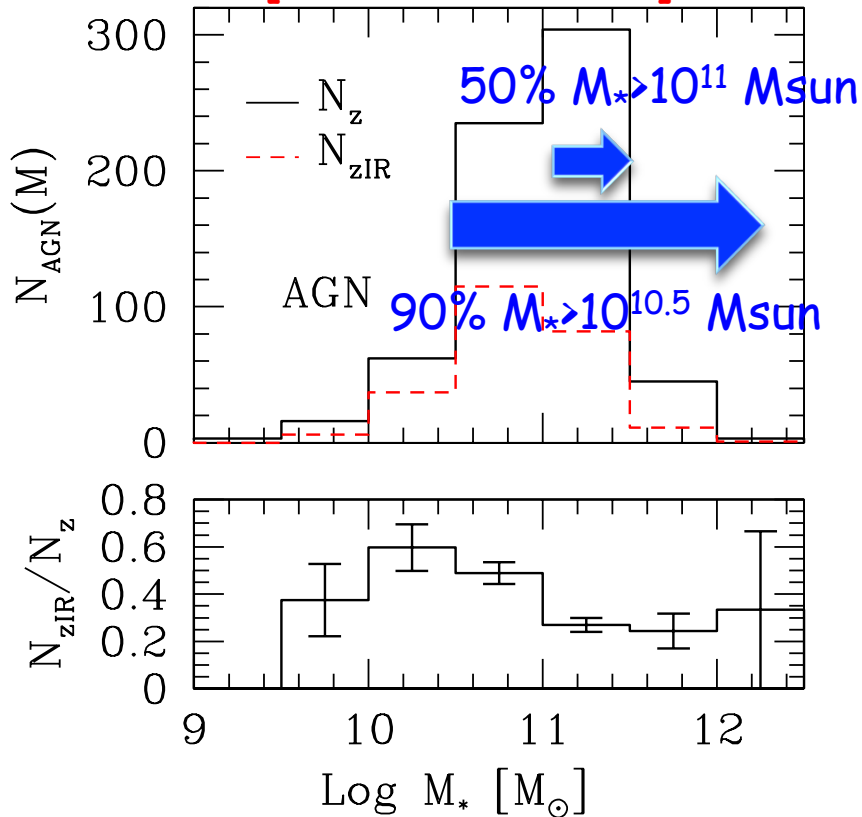
N.B. All samples complete up to  $z \sim 3.5$

Success-rate independent of radio flux (up to  $\sim 3 \text{ mJy}$ ) and redshift

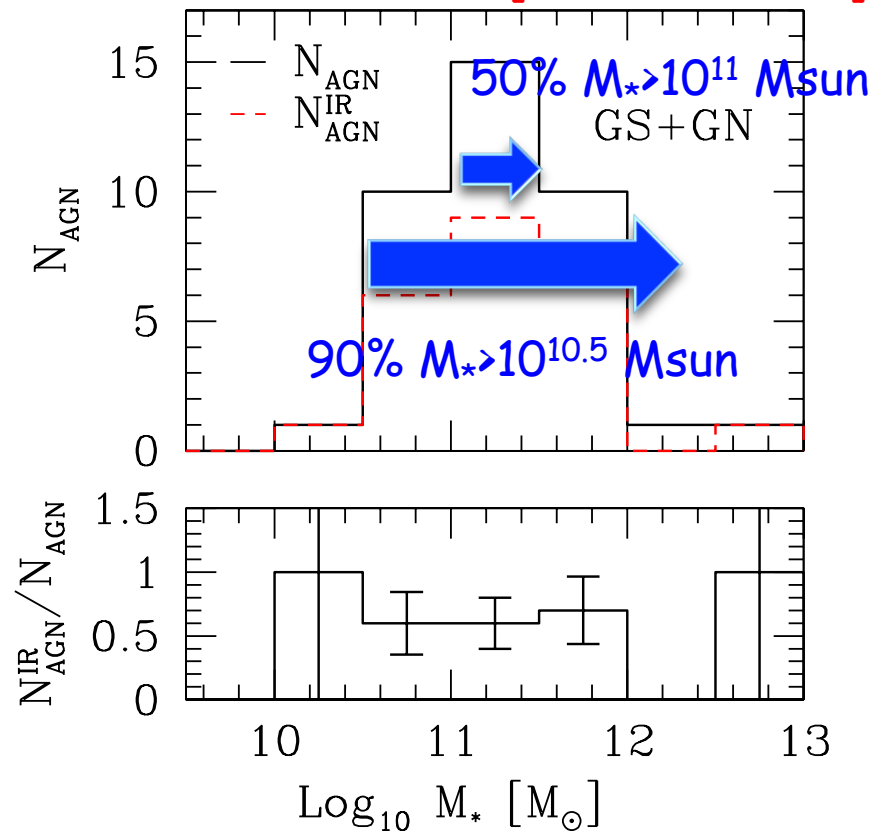
# STELLAR MASSES OF RADIO-AGN HOSTS

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

COSMOS [N=704 - 272 FIR]

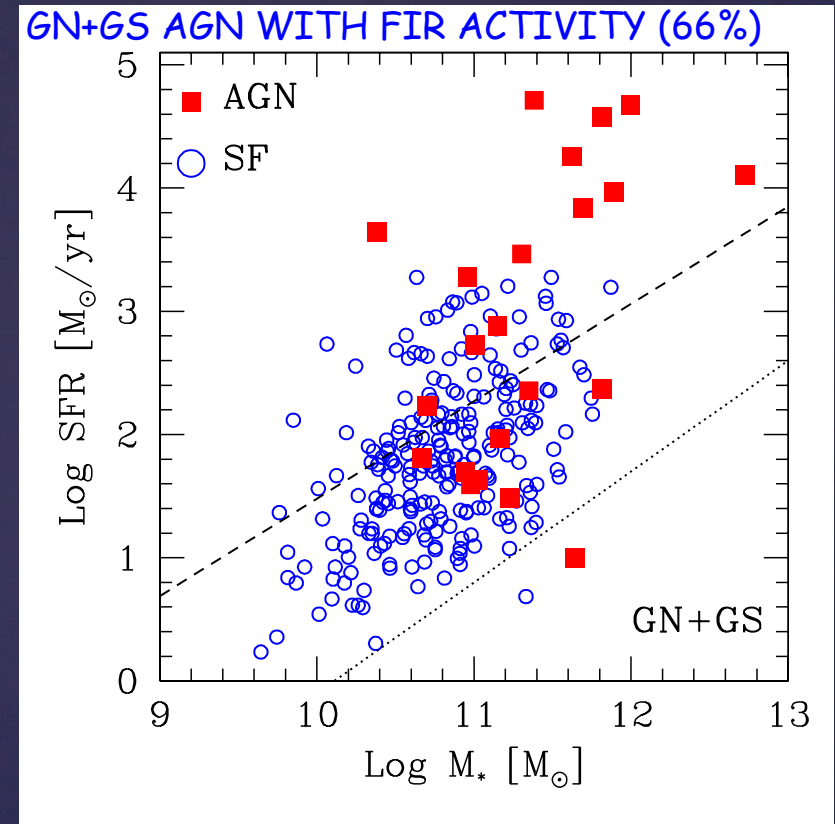
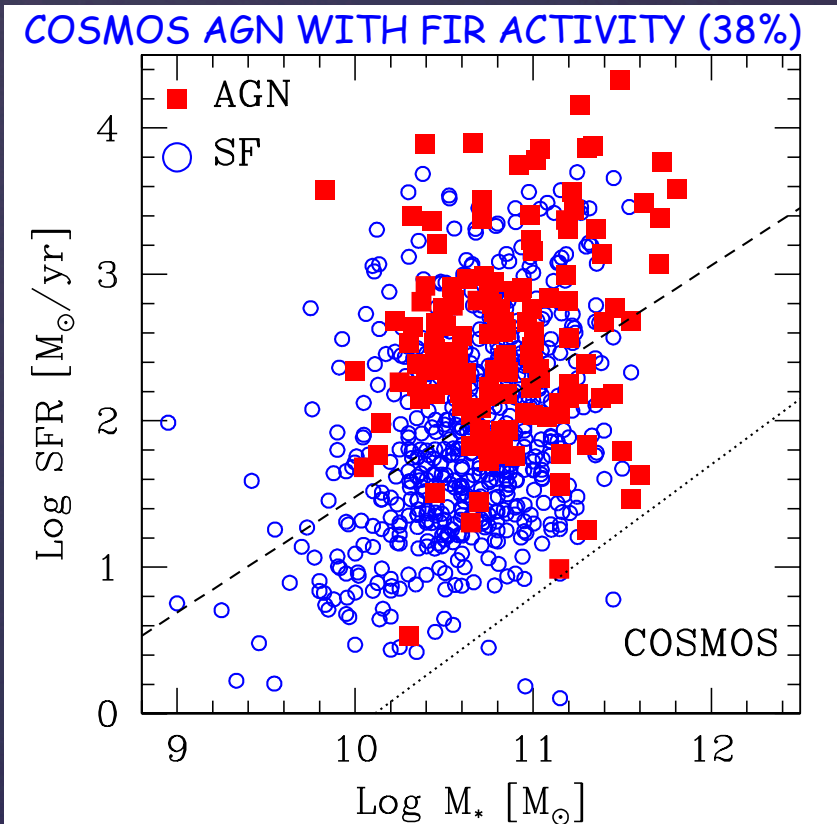


GOODSN+GOODSS [N=47 - 31 FIR]



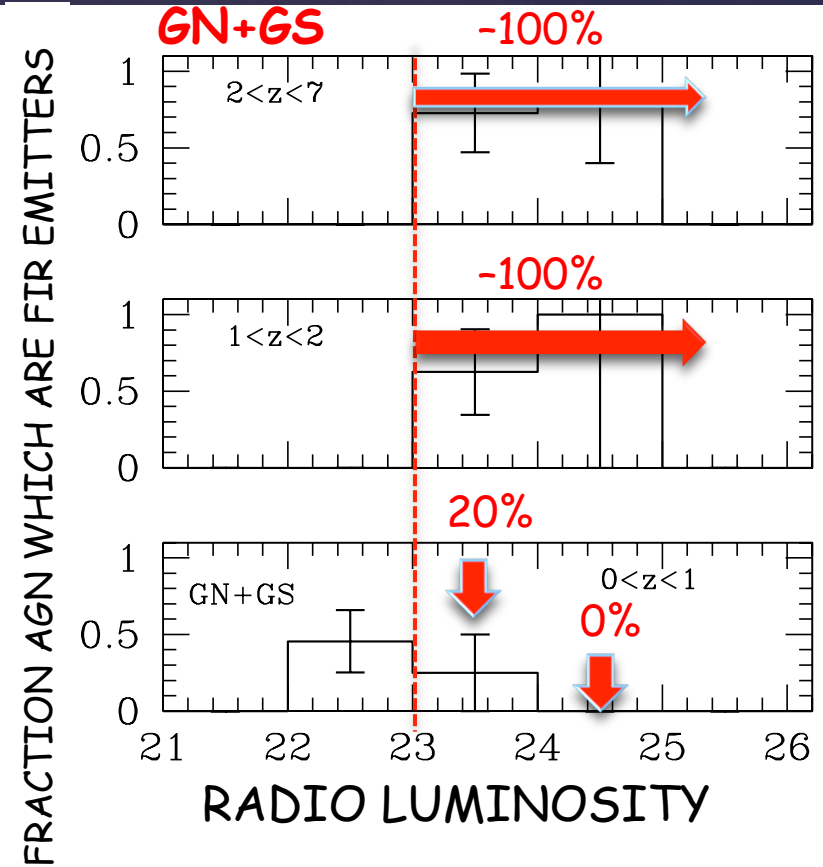
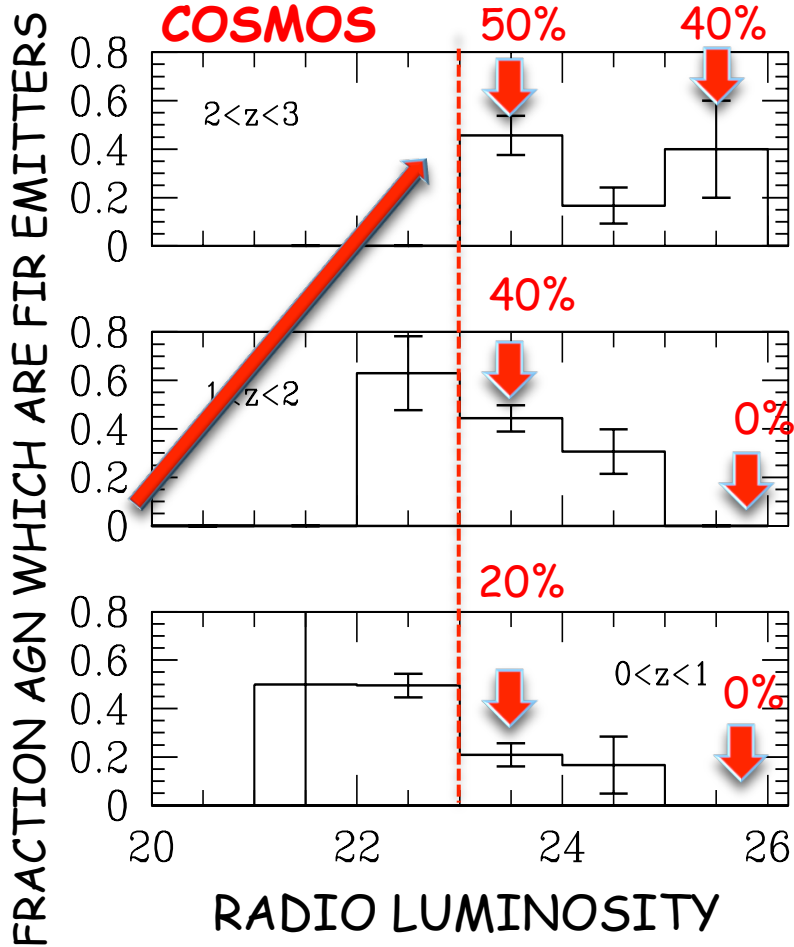
HOSTS OF RADIO AGN EXTREMELY MASSIVE GALAXIES AT ALL REDSHIFTS

# STAR-FORMING ACTIVITY WITHIN 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

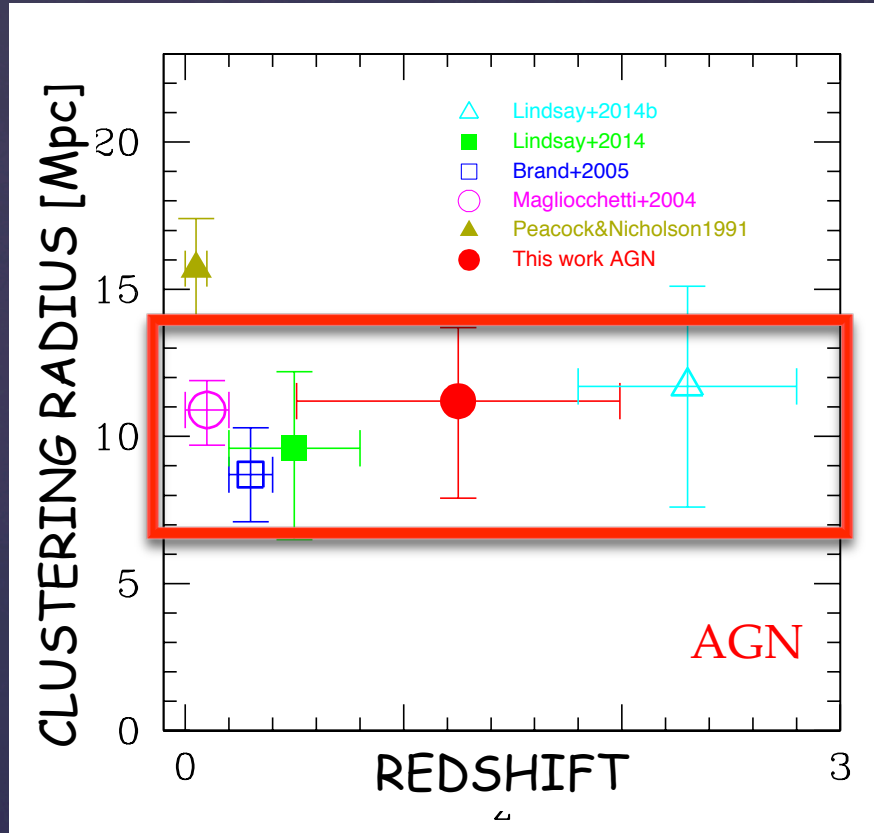
# WHAT HAVE WE LEARNED SO FAR?

- 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  $\sim 100\%$  of high ( $z > \sim 1$ ) 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



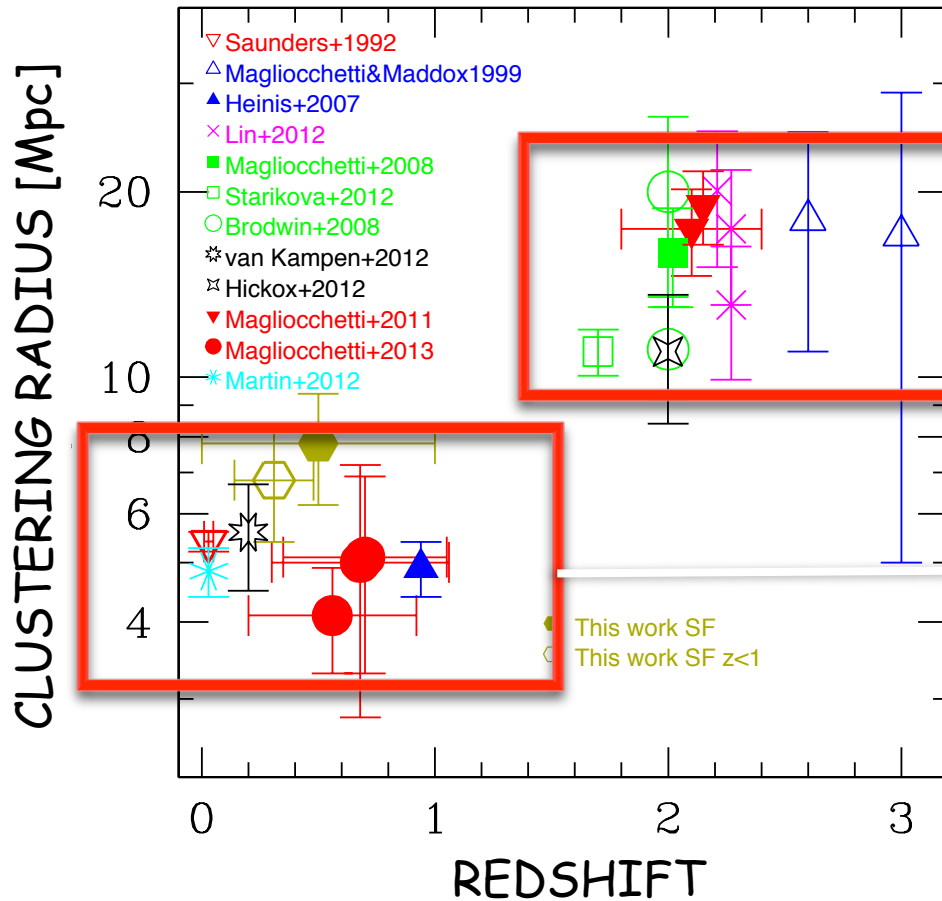
Peacock& Nicholson 1991  
 $F > 500$  mJy -  $z < 0.1$   
 Magliocchetti+2004 -- 2dF+FIRST  
 $F > 1$  mJy (AGN) --  $\langle z \rangle = 0.1$   
 Brand+2005 -- Texas-Oxford+NVSS  
 $F > 3$  mJy --  $\langle z \rangle = 0.3$   
 Lindsay+2014 - GAMA+FIRST  
 $F > 1$  mJy --  $\langle z \rangle = 0.5$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

←  $M^{\text{HALO}}_{\text{MIN}} \approx 10^{13.5} M_{\text{sun}}$   
 (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  $z \sim 3!$  NO DOWNSIZING

# CLUSTERING ANALYSIS: COMPARISONS OF SF RESULTS WITH LITERATURE



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)

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

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

**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  $z > 1.5$**

Adapted from Magliocchetti+2014

**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  $M_{\min} > 10^{13.6} M_{\text{sun}}$  host of a radio-active AGN = 0.4  
→ about one in two haloes observed to host radio-AGN (a lot!!)

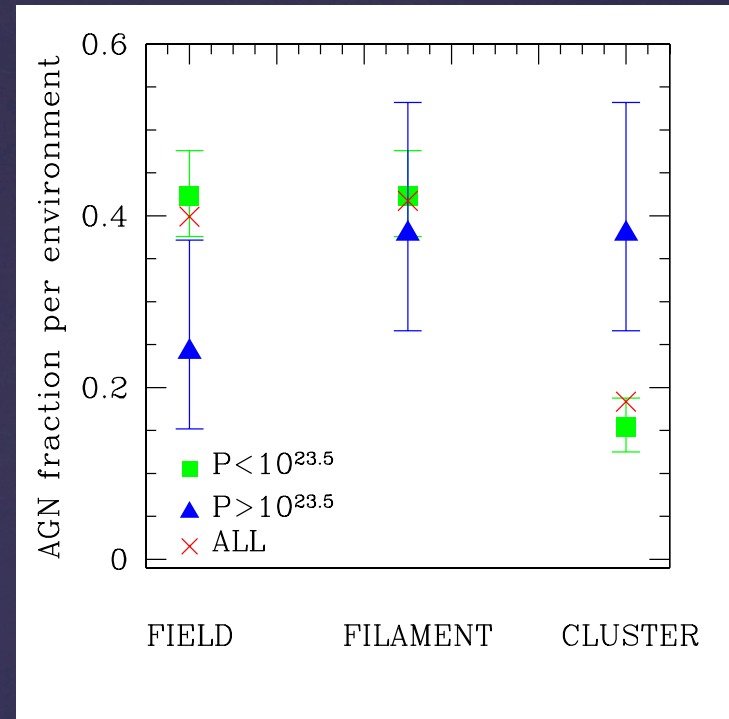
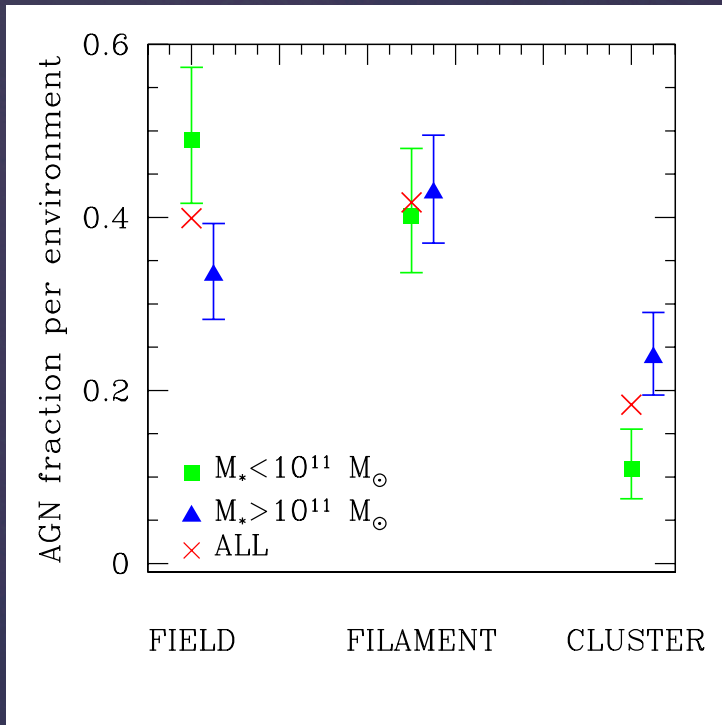
If we assume every halo with  $M_{\text{halo}} > M_{\min}$  hosts a black hole that at some point becomes radio-active we derive life-time of radio phase  $t = 1 \text{ Gyr}$

$t \gg$  a few  $\times 10 \text{ Myr}$  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  $\sim 100\%$  of  $z > \sim 1$  radio-AGN are associated to SF events  $\rightarrow$  **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  $> 10^{13.5} M_{\text{sun}}$  (groups-to-clusters of galaxies)  
**Radio-AGN environmental properties do not depend on radio luminosity (at least up to  $P \sim 10^{24.5-25}$  W/Hz) and do not evolve with cosmic epoch**
- 4) Stellar content relatively small  $\langle M_{\star} \rangle / M^{\text{HALO}} < 10^{-2.7}$
- 5) From comparison of densities **1 out of 2 massive halos host of radio-AGN**  
 $\rightarrow \tau \sim 1 \text{Gyr} \rightarrow$  **Radio-active phase recurrent phenomenon**
- 6) Dependence of environmental properties on stellar content/AGN emission at different  $\lambda$ /radio luminosity (only for very bright sources)  
**Connection between sub-pc up to Mpc behaviours?**