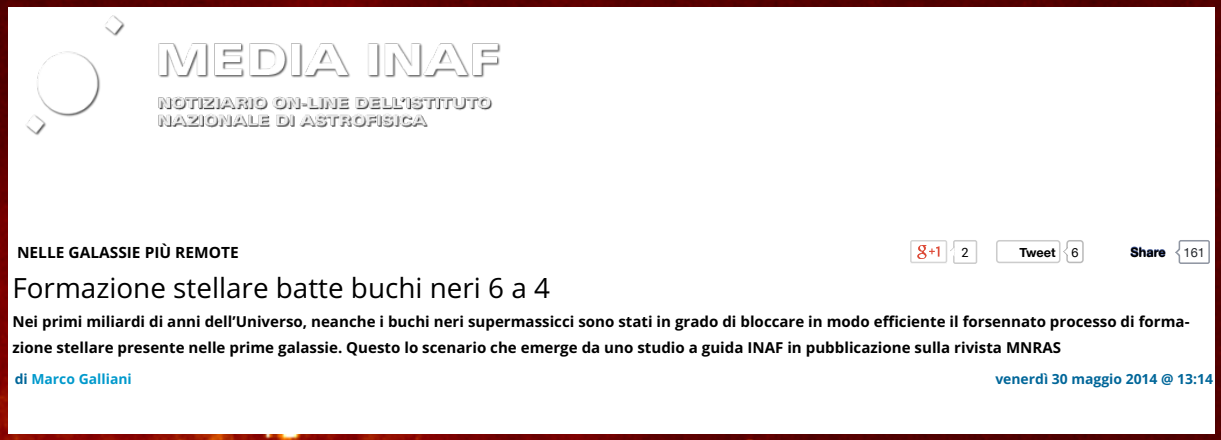
# The PEP Survey:
# Infrared Properties of radio-selected AGN



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Formazione stellare batte buchi neri 6 a 4

**Nei primi miliardi di anni dell'Universo, neanche i buchi neri supermassicci sono stati in grado di bloccare in modo efficiente il forsennato processo di formazione stellare presente nelle prime galassie. Questo lo scenario che emerge da uno studio a guida INAF in pubblicazione sulla rivista MNRAS**

di Marco Galliani venerdì 30 maggio 2014 @ 13:14


**MANUELA MAGLIOCCHETTI**
**IAPS-INAF**

Collaborators: D.Lutz, D.Rosario, S.Berta, P.Santini
& the Herschel PEP team


Credits for image: Hi-GAL

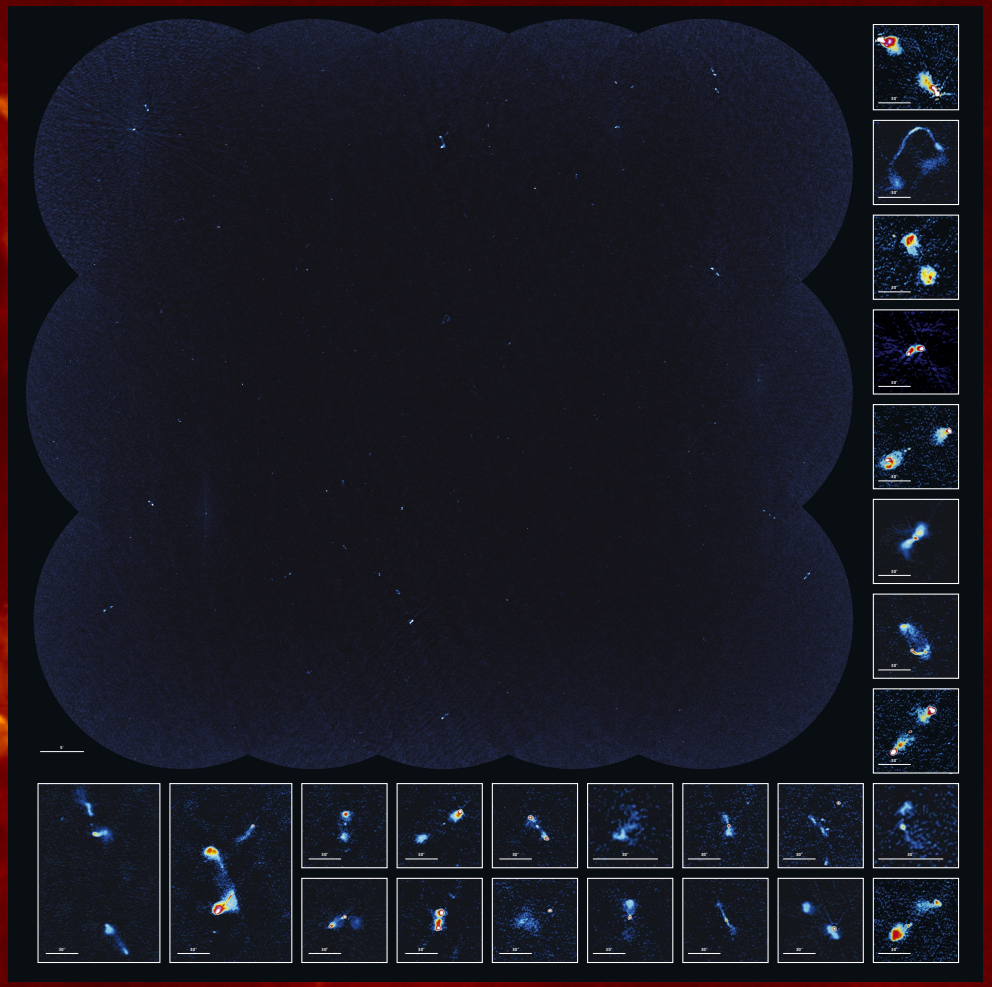
# Scientific rationale and outline

Almost general consensus on AGN selected in various bands (from optical to X-ray) to be hosts of star-forming activity.
Question: does it also hold for radio-selected AGN (generally expected to reside in "red and dead" galaxies)?

Aim: provide analysis of FIR properties of radio-selected AGN of *all* radio luminosities and at *all* redshifts.

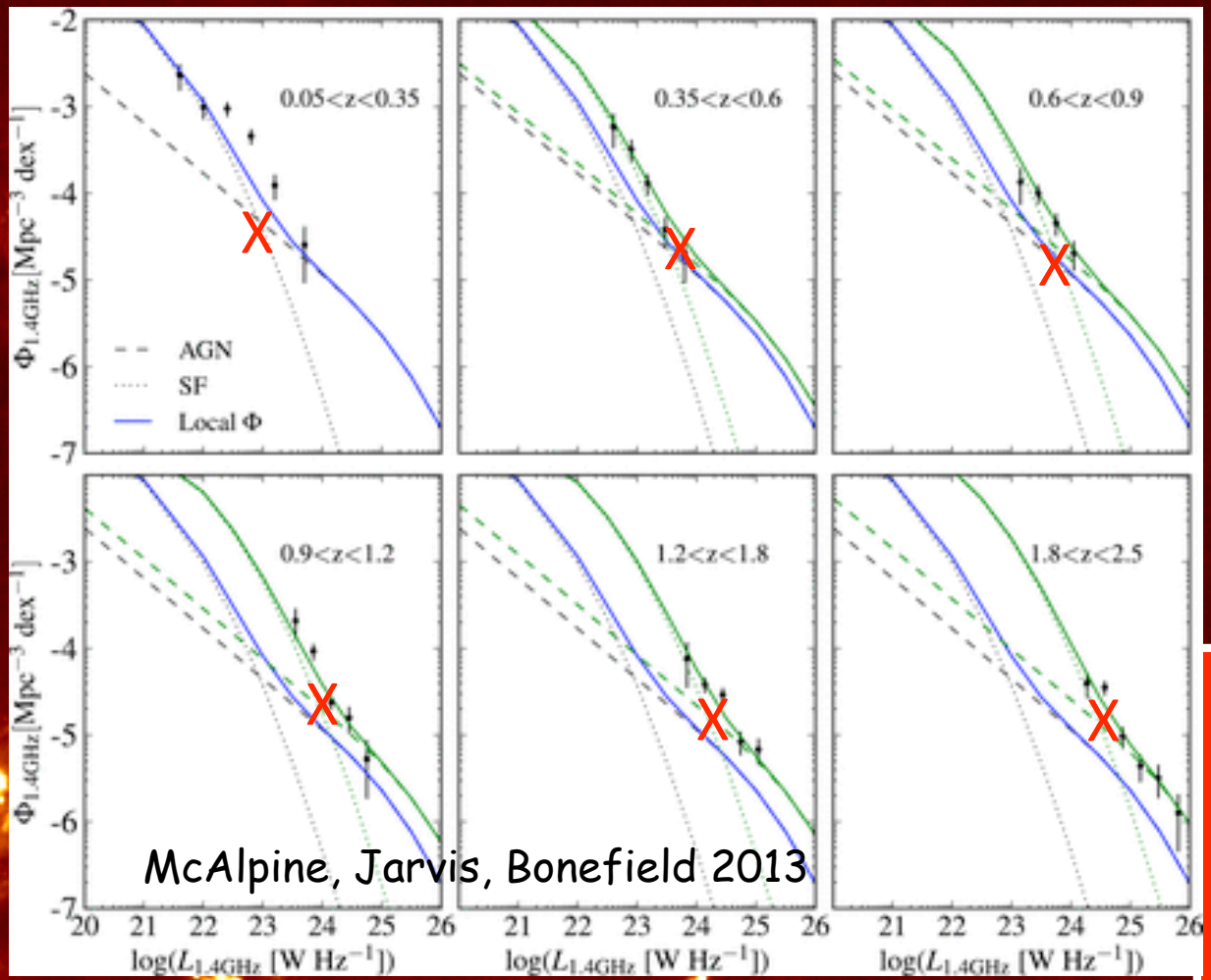
Method: adopt criterion for selecting AGN based on *radio-luminosity alone*
Apply it to the COSMOS-VLA sample of 1.4GHz-selected objects.
FIR fluxes from the PACS Evolutionary Probe (PEP, P.I. D.Lutz) survey performed with the PACS instrument onboard Herschel.

COSMOS-VLA @ 1.4 GHz
(Schinnerer+ 2004; 2007; Bondi+2008)



COSMOS-Herschel
(Lutz+2011)

# The Origin of FIR emission in radio-selected AGN: criteria for AGN selection in radio surveys

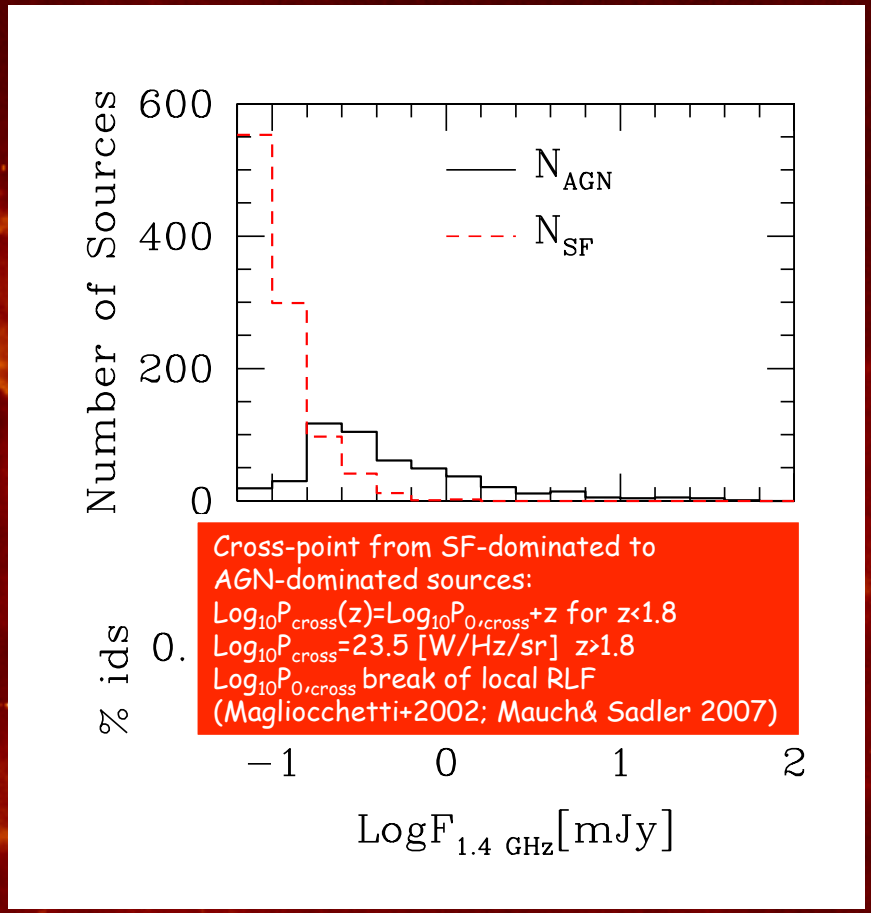



Radio data from VLA-VIRMOS (Bondi+ 2003). 1 deg$^2$ complete to 100$\mu$Jy: 1054 sources

10-band photometry via VIDEO (Jarvis+2013) and CFHTLS (Ilbert+ 2006) for 942 sources (91%).
Photo-z with $\sigma$~0.025 accuracy ($\sigma$~0.10 for QSOs above z~0.22) + SED analysis of source type

From McAlpine+13 RLF z evolution of cross-point from SF-dominated to AGN-dominated sources:
$Log_{10}P_{cross}(z)=Log_{10}P_{0,cross}+z$ for z<1.8
$Log_{10}P_{cross}$=23.5 [W/Hz/sr] z>1.8
$Log_{10}P_{0,cross}$ break of local RLF
(Magliocchetti+2002; Mauch& Sadler 2007)

# The Origin of FIR emission in radio-selected AGN: VLA-COSMOS (radio+FIR) sample




Radio data from VLA-COSMOS (Bondi+ 2008). 2 deg$^2$ complete to 60$\mu$Jy: 2382 sources.

Redshifts from Ilbert+ 2013 1537 radio sources with z (65%) independent of radio flux.

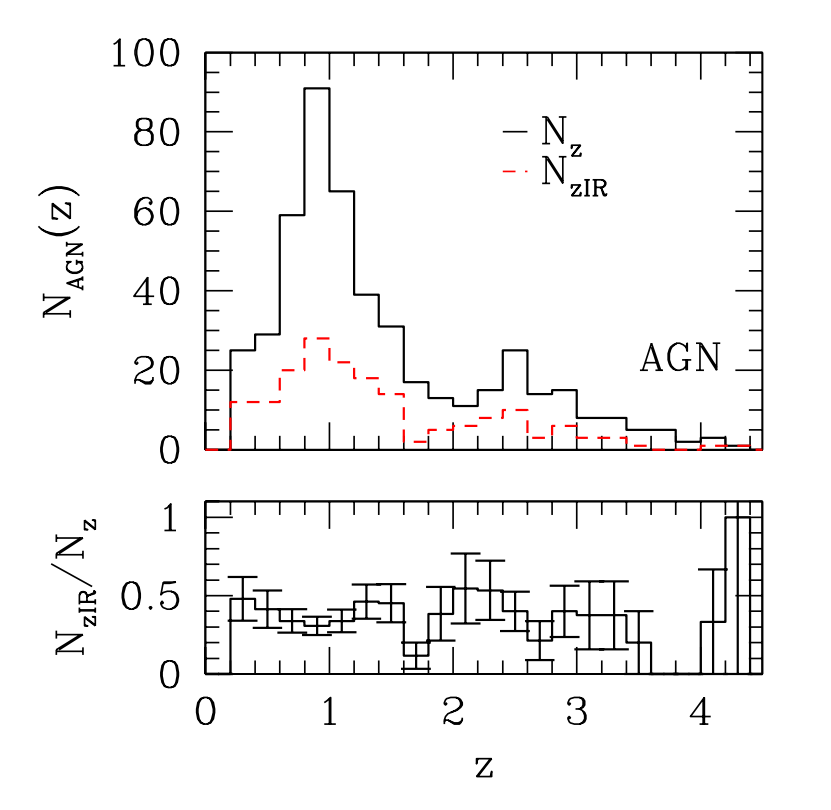
1026 sources (67%) SF.
Majority SF $F_{1.4GH}$<0.4 mJy
482 sources (32%) AGN.
Majority AGN $F_{1.4GH}$>0.4 mJy.

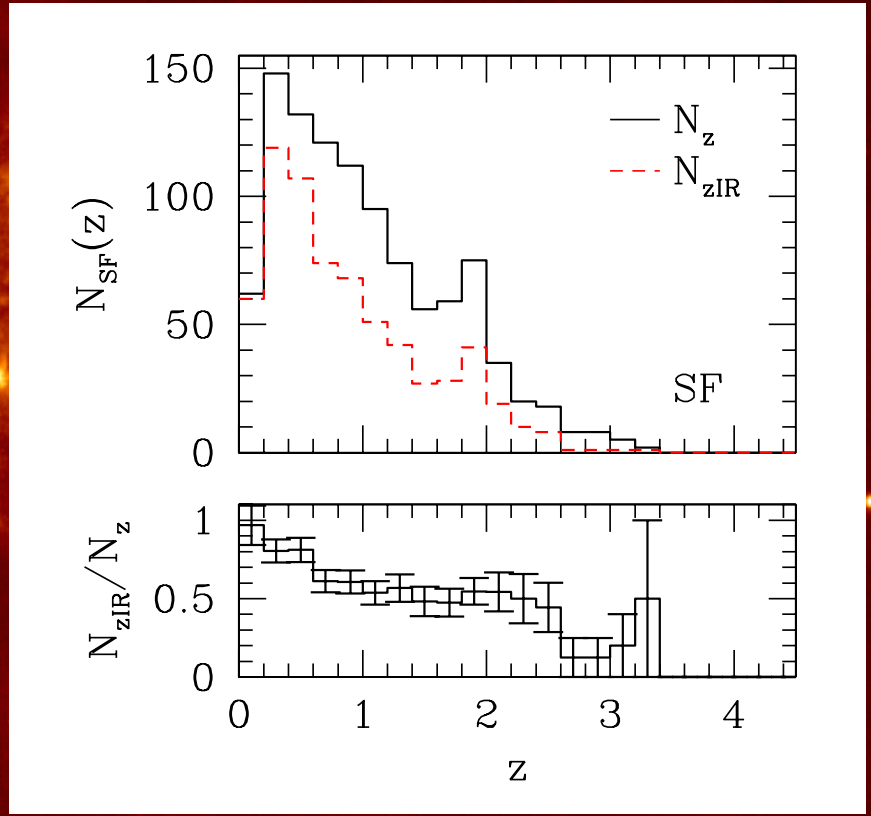
FIR fluxes from PEP Survey (Lutz+2011) down to ~4 mJy (@100$\mu$m to 4") and 7 mJy (@ 160$\mu$m to 5").

FIR ids → -657 SF have counterpart in PEP catalogues. Dependent on RF.
-175 (36%) AGN. No dependence on radio flux up to F~3 mJy.

# The Origin of FIR emission in radio-selected AGN: redshift distributions

-$F_{1.4GHz}$>0.06 mJy →$P_{min}$<$P_{cnoss}$ [W/Hz/sr] for z<3.5→ VLA-COSMOS AGN sample *complete* in radio for *all z<3.5*!

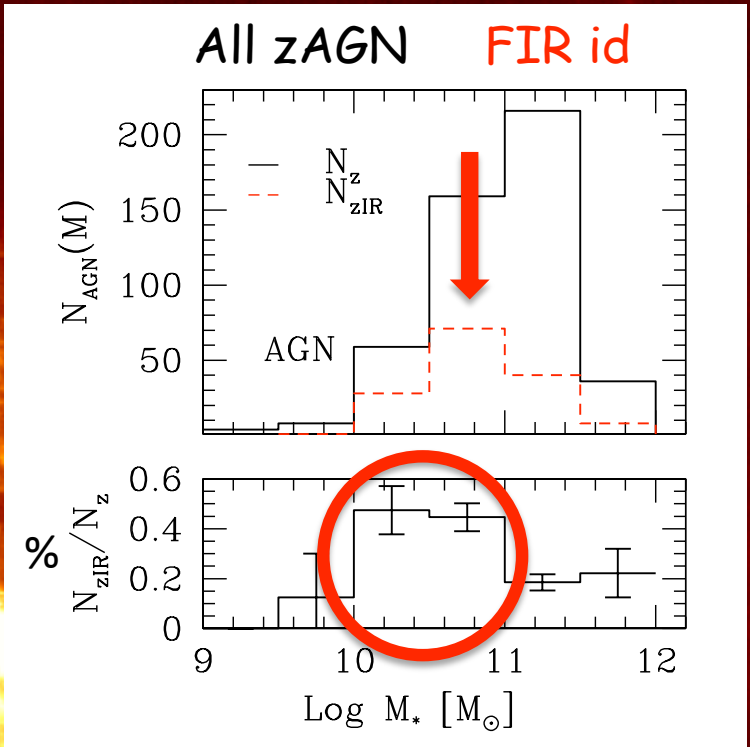


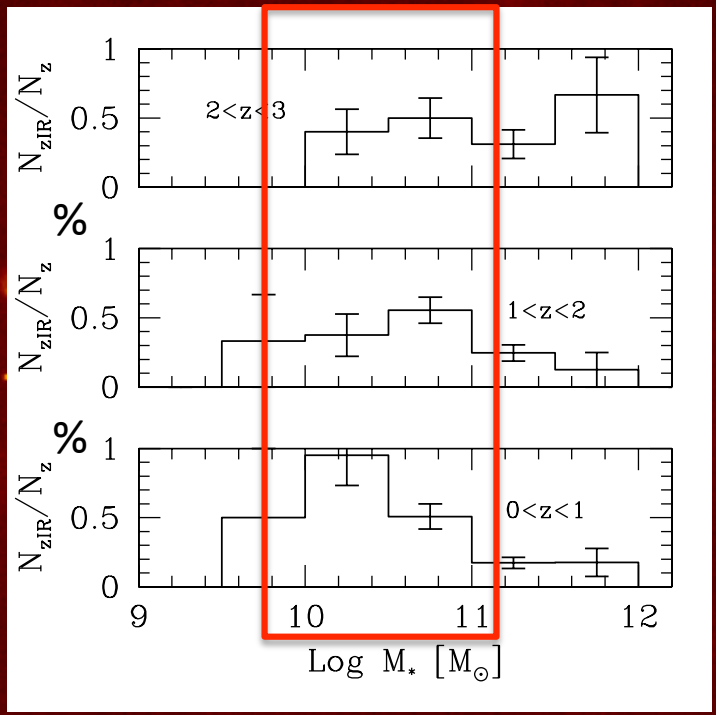




-NO dependence of FIR id success rate on z for AGN family
-FIR-id AGN same (rescaled) N(z) distribution wit marked peaks @ z~1 and z~2.5

Id-rate of SF galaxies monotonically decreases with z (incomplete sample)

# The Origin of FIR emission in radio-selected AGN: information from stellar mass $M_*$



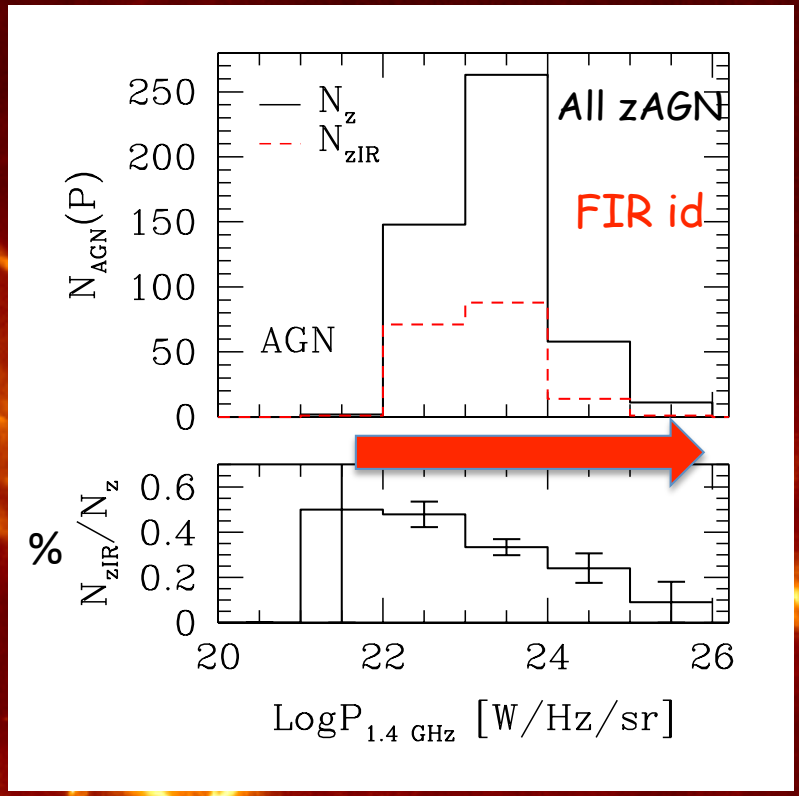



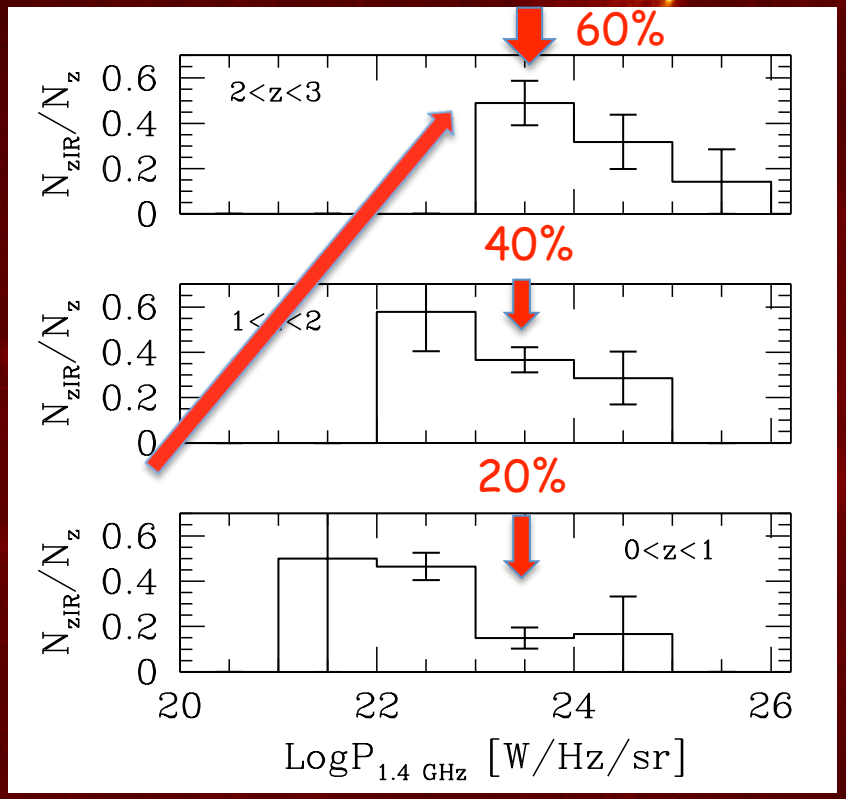

-FIR-id AGN smaller masses than whole radio-selected AGN population

-Preferential mass scale $M_*$~$10^{10}$-$10^{11}$ $M_{sun}$ maximizes chances for FIR emission

-Only true for z<2

# The Origin of FIR emission in radio-selected AGN: information from radio luminosity $P_{1.4GHz}$

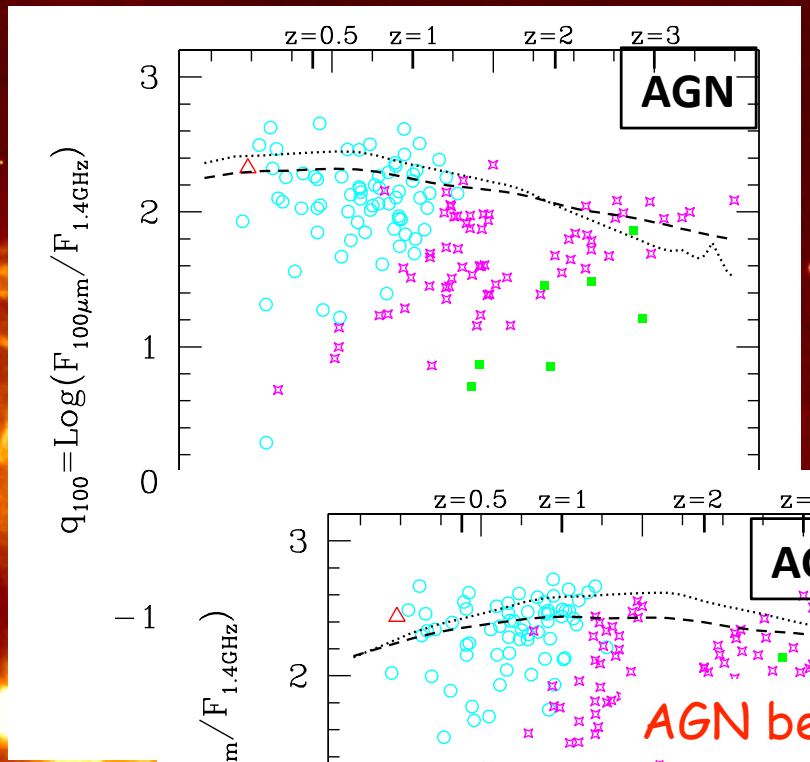


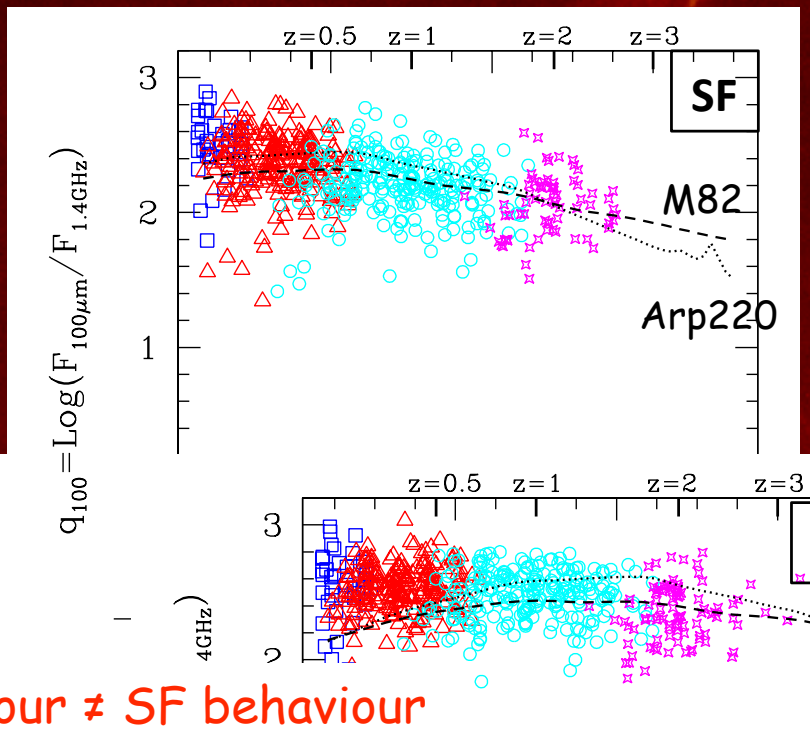




- As expected fraction of FIR emitters decreases with increasing radio luminosities
- Drop shifts to higher radio luminosities at higher zs

**Powerful radio sources are more likely to be FIR emitters at earlier epochs**

# The Origin of FIR emission in radio-selected AGN: information from $q_{100}$ and $q_{160}$ for AGN and SF of given P



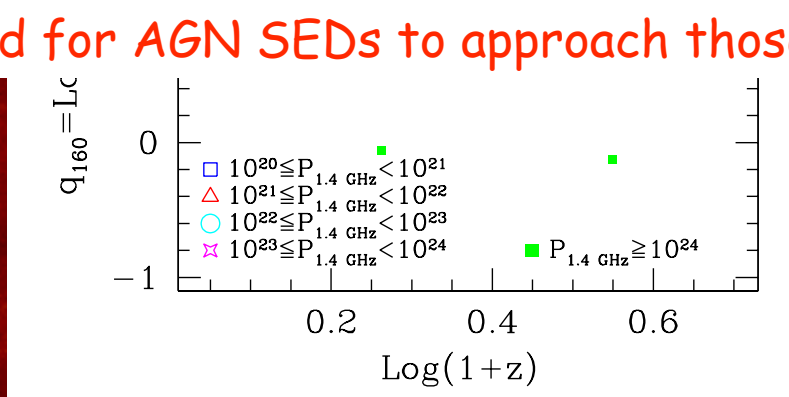


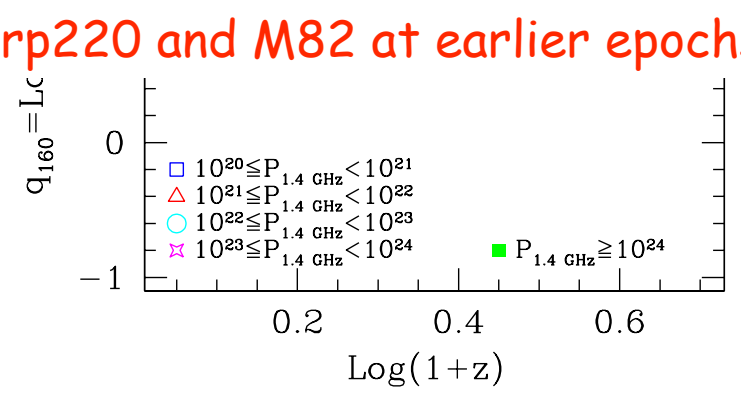




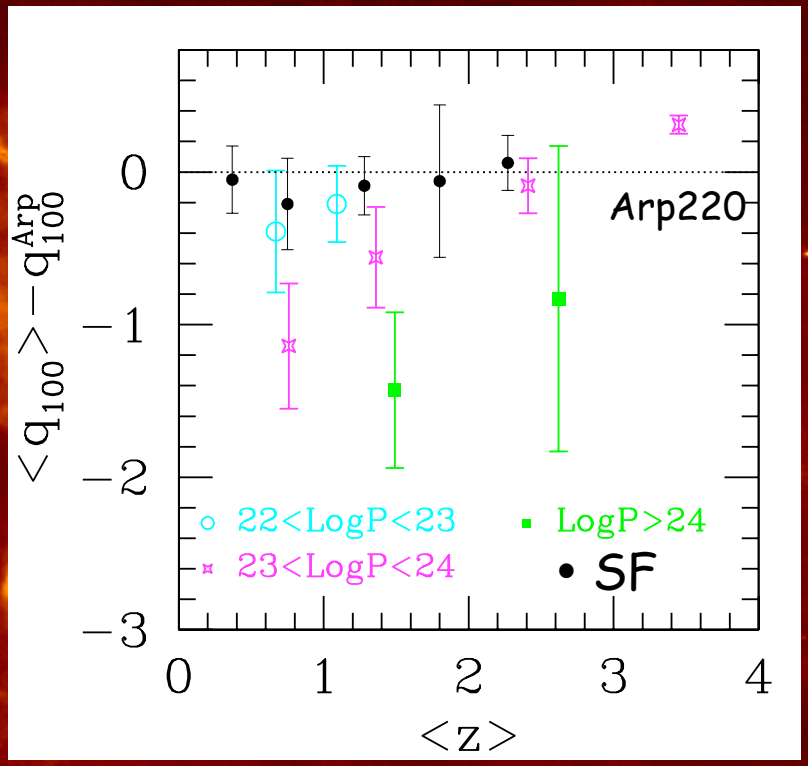

AGN behaviour ≠ SF behaviour

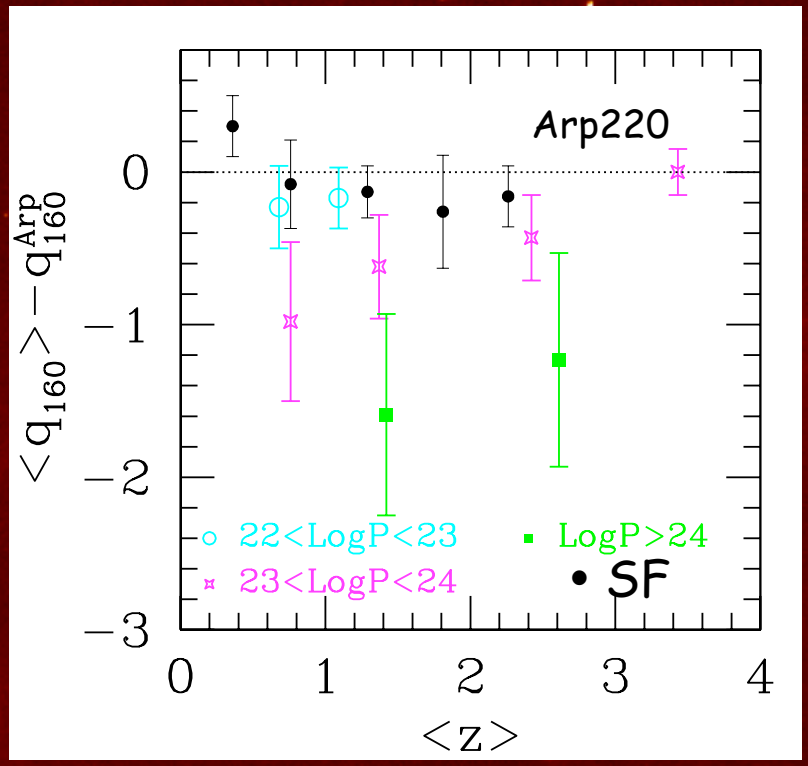
Trend for AGN SEDs to approach those of Arp220 and M82 at earlier epochs



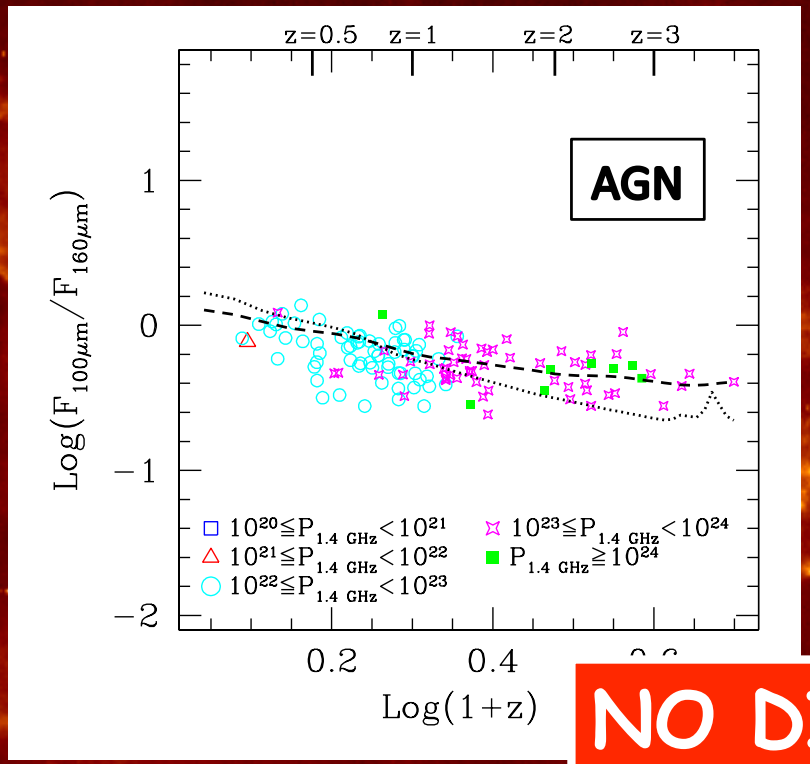
# The Origin of FIR emission in radio-selected AGN: information from $q_{100}$ and $q_{160}$ for AGN and SF of given P

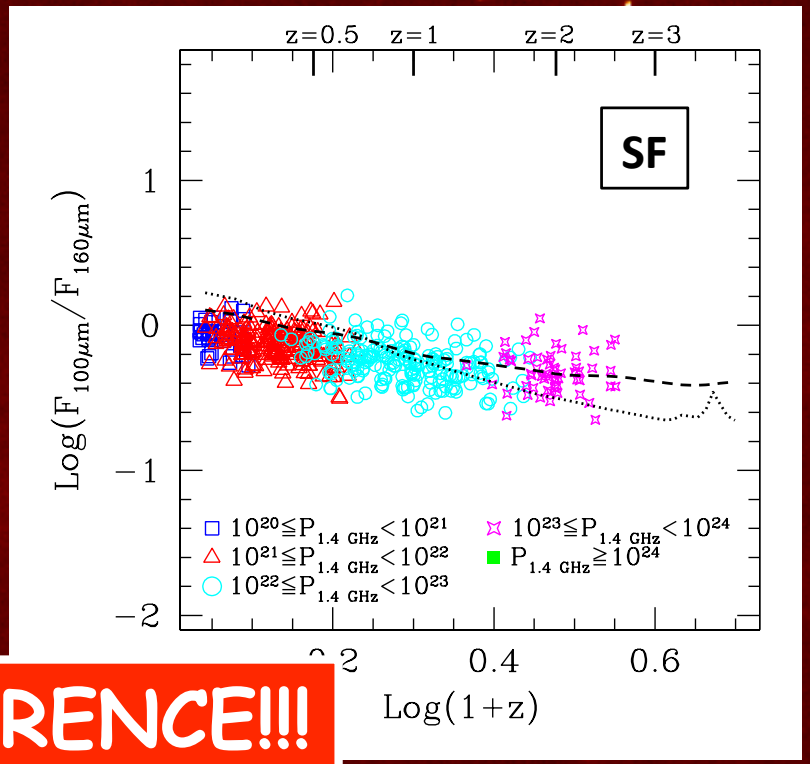



SF follow Arp220 SED at all z and P.
AGN FIR-to-radio approaches Arp220 at earlier epochs at *all* P.
Analysis performed at fixed P → enhancement of FIR activity with z

# The Origin of FIR emission in radio-selected AGN: information from FIR fluxes of AGN and SF of given P




**NO DIFFERENCE!!!**

Irrespective of radio activity and z FIR emission in radio-selected AGN indistinguishable from that produced by star-forming galaxies →

→ FIR entirely due to star forming processes within AGN host

# CONCLUSIONS

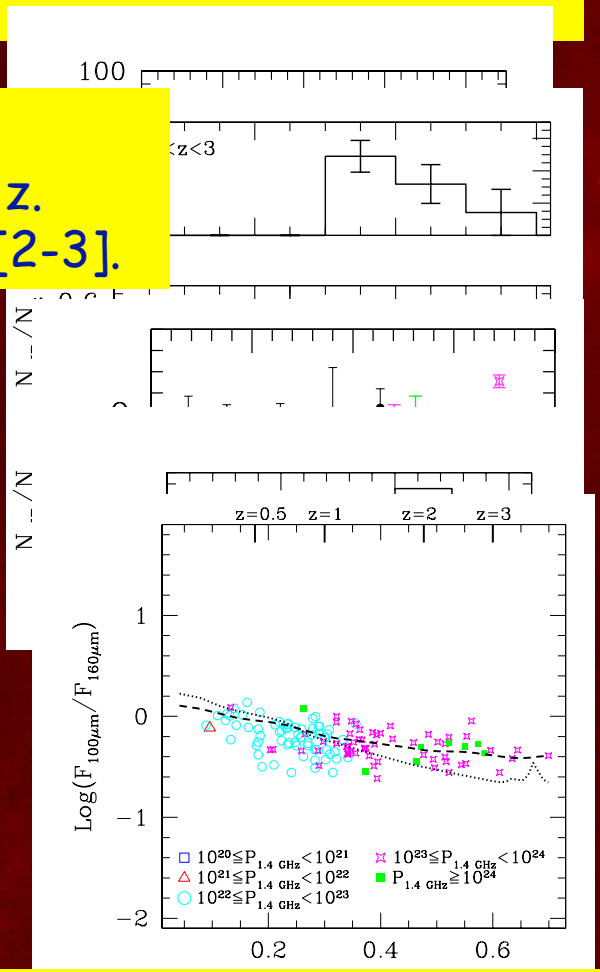
Complete catalogue (up to z=3.5) of 482 radio-selected AGN from COSMOS-VLA.
175 (i.e. 36%) with counterpart in the PEP survey either at 100 or at 160 $\mu$m.
No redshift dependence of FIR ids.

Probability for FIR emission strong function of P and z.
More powerful sources more likely FIR emitters at higher z.
$P_{1.4GHz}$~ $10^{23}$-$10^{24}$ W/Hz/sr from ~10% at z<1 to ~60% at z=[2-3].

Above phenomenon due to enhancement of FIR activity with z in AGN of all P.

Typical mass $M_*$~[$10^{10}$-$10^{11}$] $M_{sun}$ for FIR emission (up to 60%, only for z<2). Why??

FIR emission in radio-selected AGN same origin of FIR emission in SF galaxies: SF activity within host galaxy.



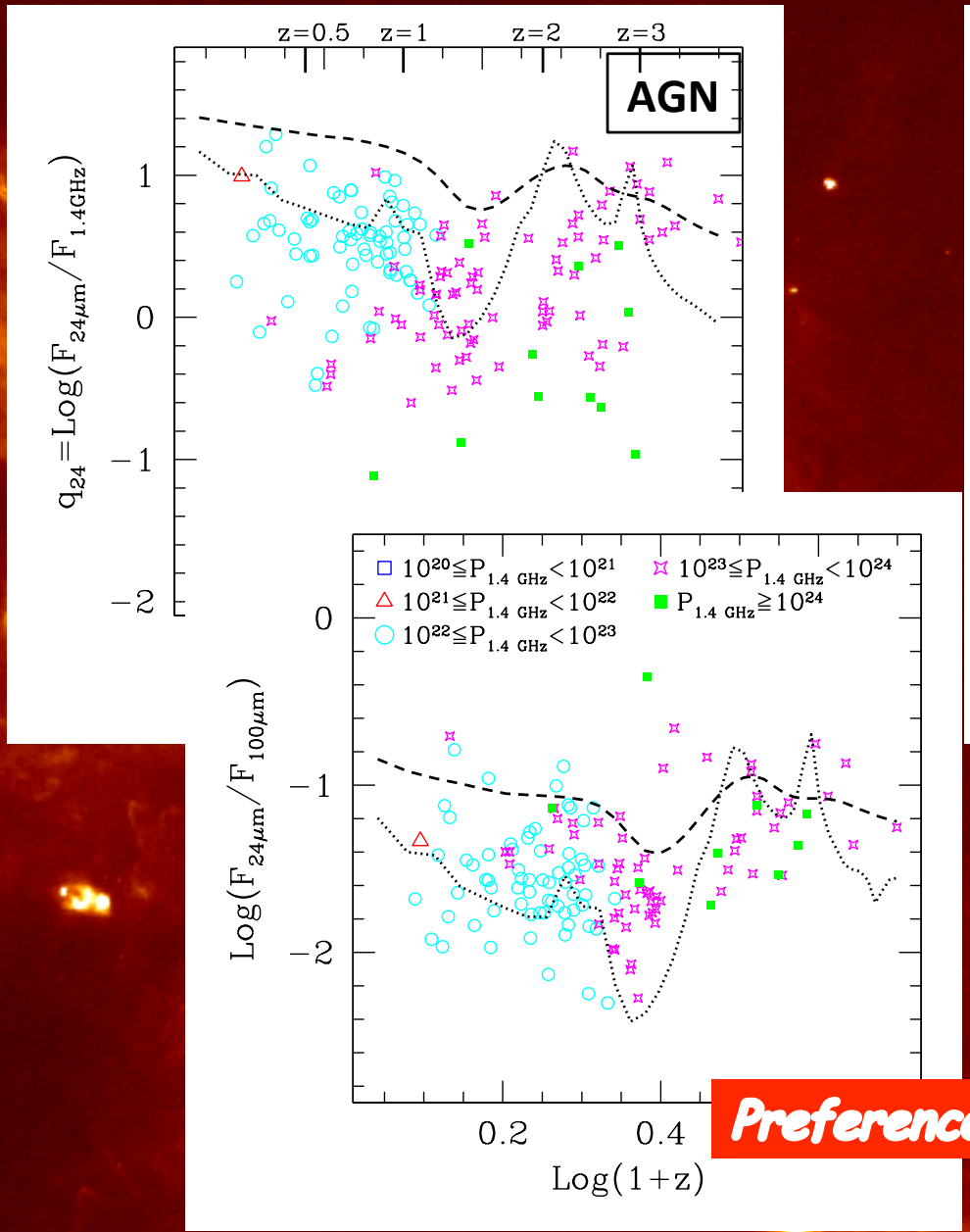

**CAUTION WHEN ASSOCIATING RADIO GALAXIES TO 'DEAD' ELLIPTICALS (RADIO MODE) AS STRONG FUNCTION OF REDSHIFT!!**

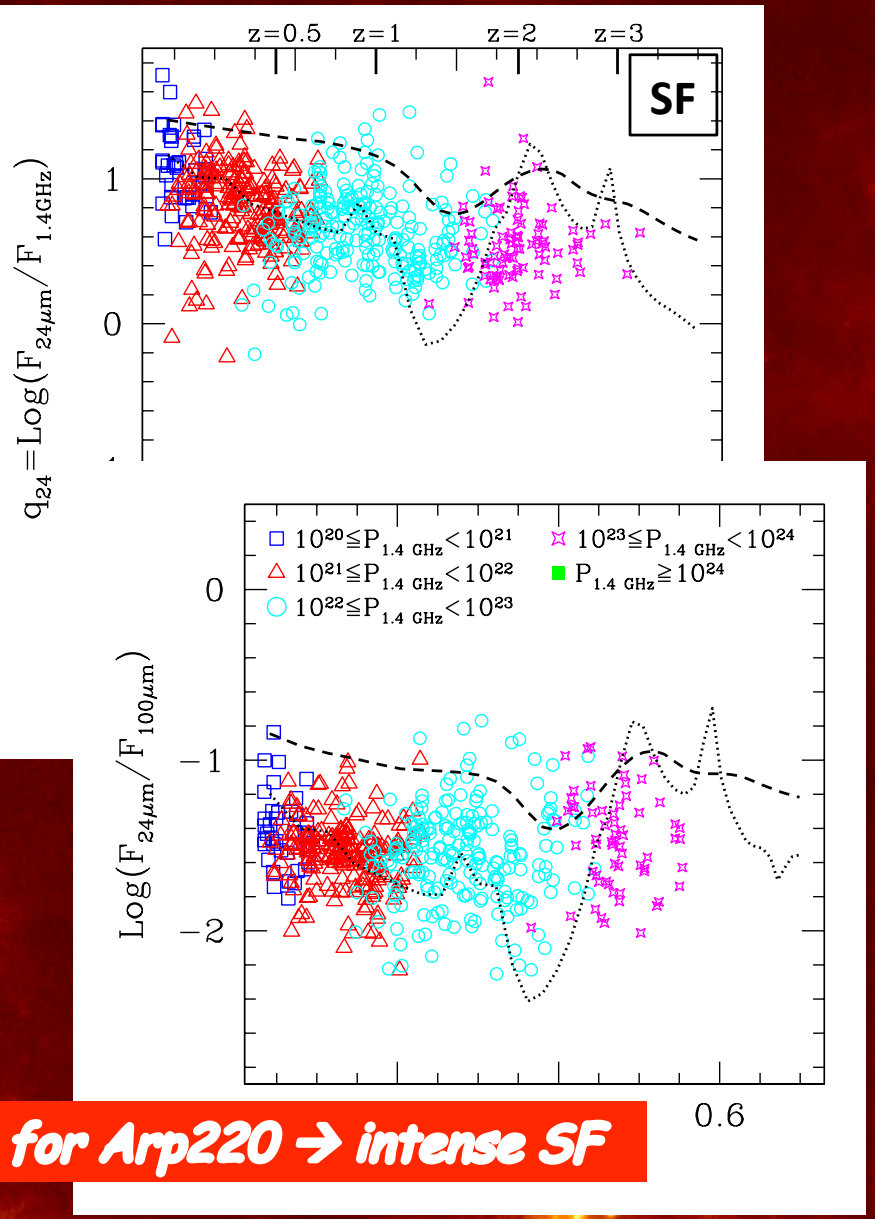
# SELECTION EFFECTS

Results refer to 36% of whole radio-selected AGN population.
However, AGN sample complete at all z<3.5. Also, FIR ids independent of both radio flux and z → Fainter FIR fluxes will merely boost the number of radio-selected AGN with FIR ids while leaving conclusions unchanged.

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 galaxies above luminosity threshold very limited.
NEW!! (from ongoing work: only 3 out of 175 based on optical-to-FIR SEDs)

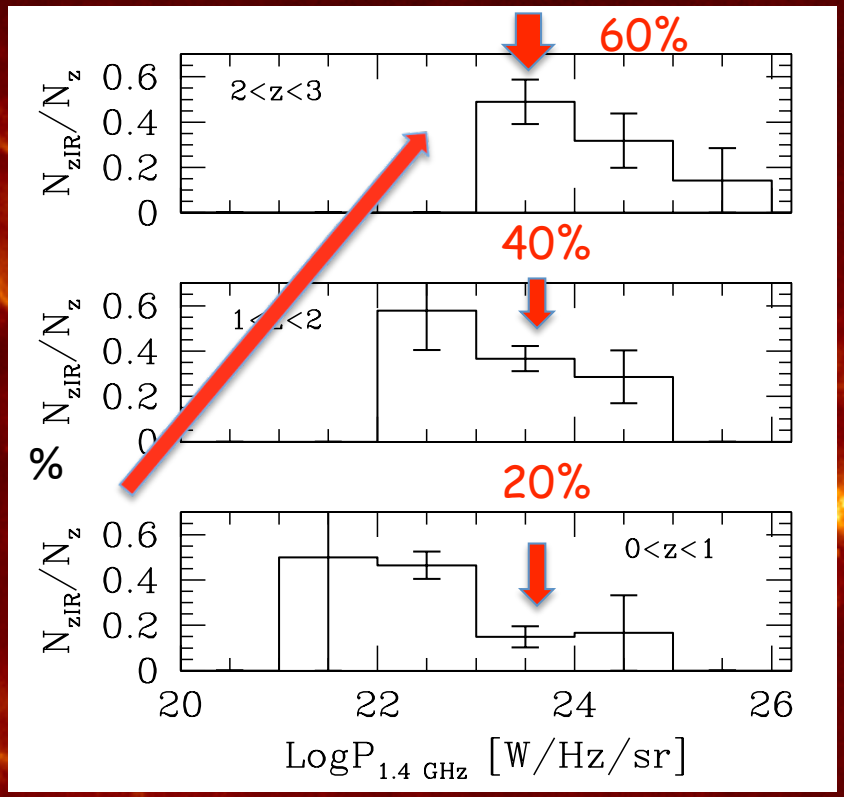
# The Origin of FIR emission in radio-selected AGN: information from MIR fluxes of AGN and SF of given P

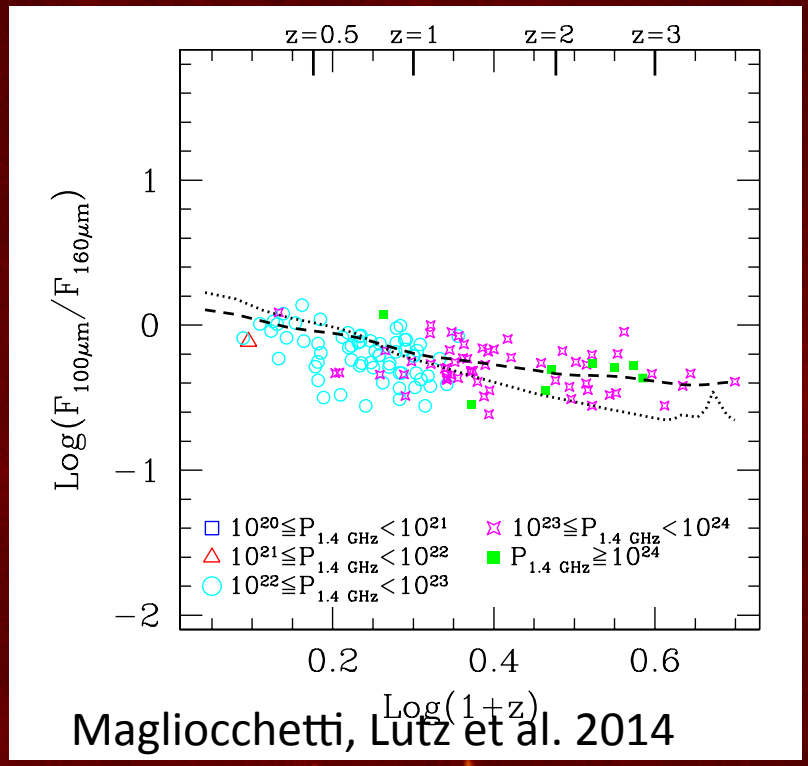



**Preference for Arp220 → intense SF**

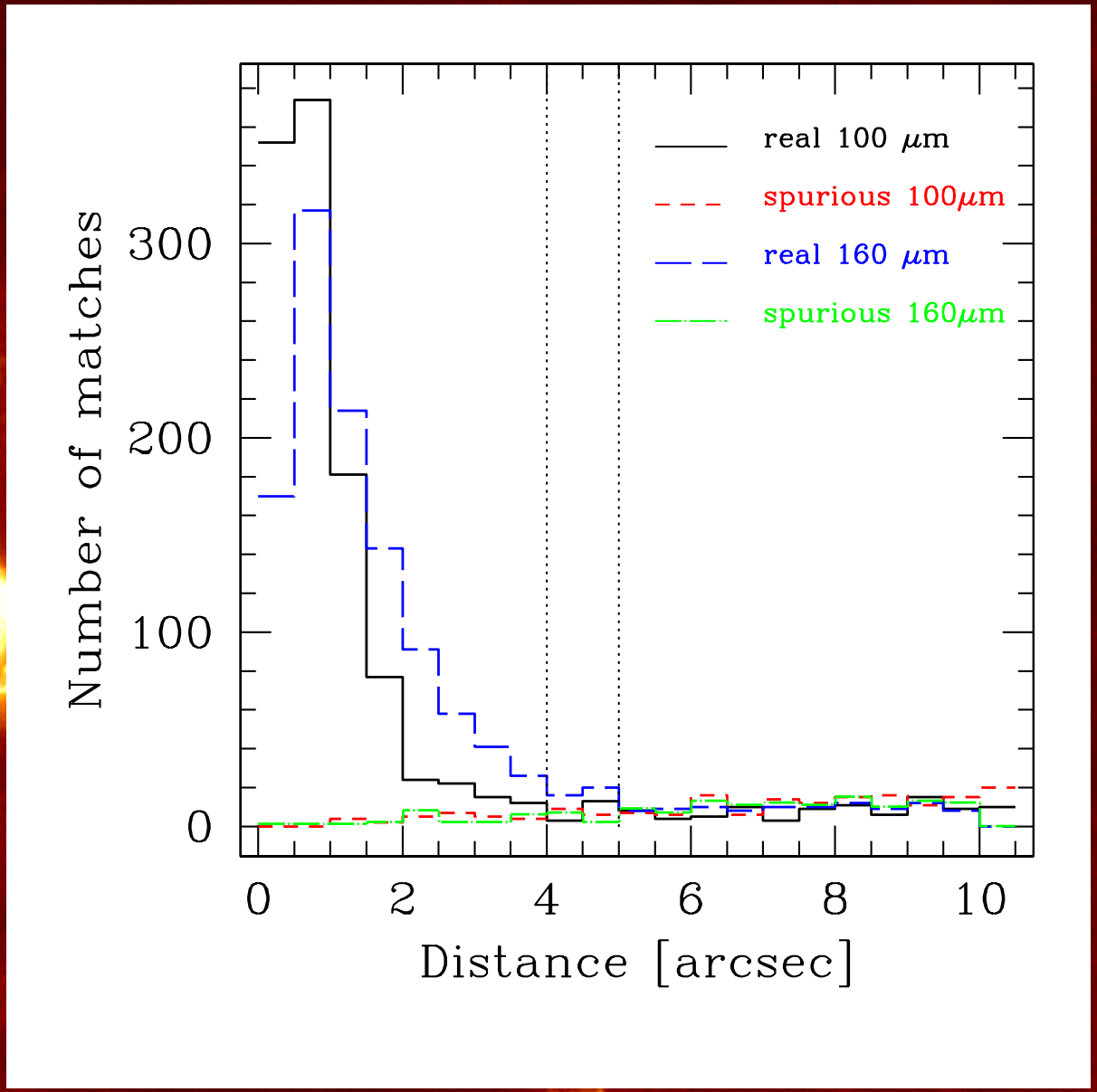
**Short answer: radio activity *does not* prevent star formation, especially at high z.**
**Caution when associating radio sources to 'dead' ellipticals (radio mode) as strong function of z!**



Magliocchetti, Lutz et al. 2014

**Powerful radio sources are more likely to be FIR emitters at earlier epochs**
**FIR emission entirely due to star-forming processes**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