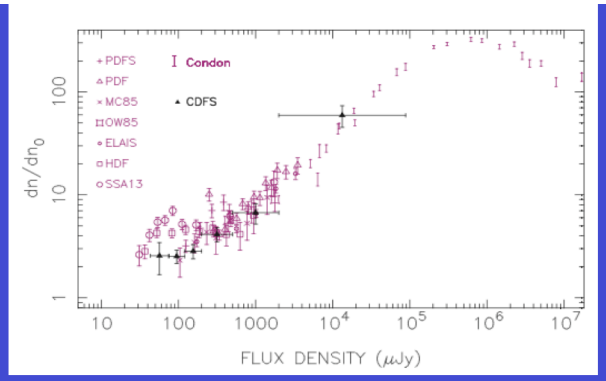


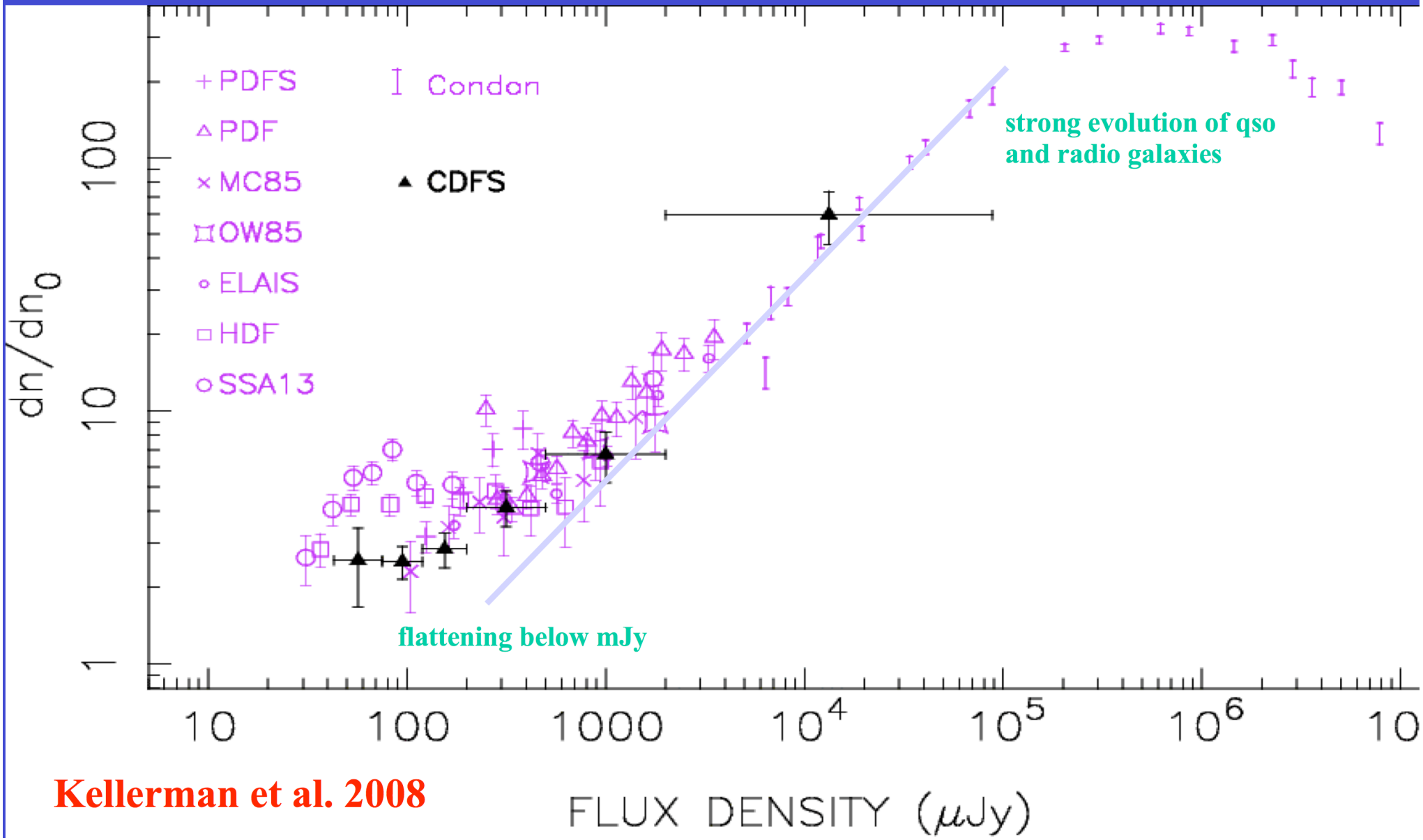
Constraints on the μJy radio source population from the VLA CDFS survey

Paolo Padovani, ESO

V. Mainieri (ESO), P. Tozzi (INAF), K. Kellermann, E. Fomalont (NRAO), N. Miller (JHU), P. Rosati, P. Shaver (ESO)

- Chandra Deep Field South (CDFS) area has great multi-wavelength coverage: *Chandra*, *HST*, ESO, Spitzer, VLA, etc.
- VLA CDFS sample: 266 radio sources (198 in complete sample) down to 42 μJy at 1.4 GHz

Radio (1.4 GHz) number counts



Kellerman et al. 2008

VLA-CDFS: main ancillary data

1. Reliable optical/near-IR IDs for 94% [94%]* of the radio sources
2. Optical morphological classification for 61% [68%]* of the sample: 39% Sp+Irr, 19% Ell+Lent, 3% compact (plus Sersic index)
3. Redshift information for 73% [77%]* (186) of the objects: 108 spectroscopic (42%), 78 photometric [COMBO-17 + GOODS-MUSIC] (31%); <z> = 0.8 [0.04 - 3.7]
4. X-ray detections for 33% [38%]* of the objects, upper limits for all the others

*complete sample

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One of the largest and most complete published sample of μJy sources in terms of redshift information

3.7]

4. X-ray detections for 33% [38%]* of the objects, upper limits for all the others

*complete sample

Selecting star-forming galaxies (SFG) candidates

Most of our sources are too faint for optical classification (limited!); therefore we need alternative criteria. Namely:

1. SFGs at our redshifts are typically NOT hosted by ellipticals or lenticulars
2. SFGs have relatively low radio powers [locally $P_r < 10^{24}$ W/Hz]: $P_r < 10^{24.5}$ W/Hz
3. SFGs have relatively low radio-to-optical luminosity ratios [locally $R = \log(P_r/L_{opt}) < 1.4$]: $R < 1.7$
4. SFGs have relatively low X-ray powers: $L_x < 10^{42}$ erg/s (detections only, no limit otherwise)

RQ AGN were defined by $R < 1.4$ (classical definition converted from 5 GHz and B-band) and $L_x > 10^{42}$ erg/s

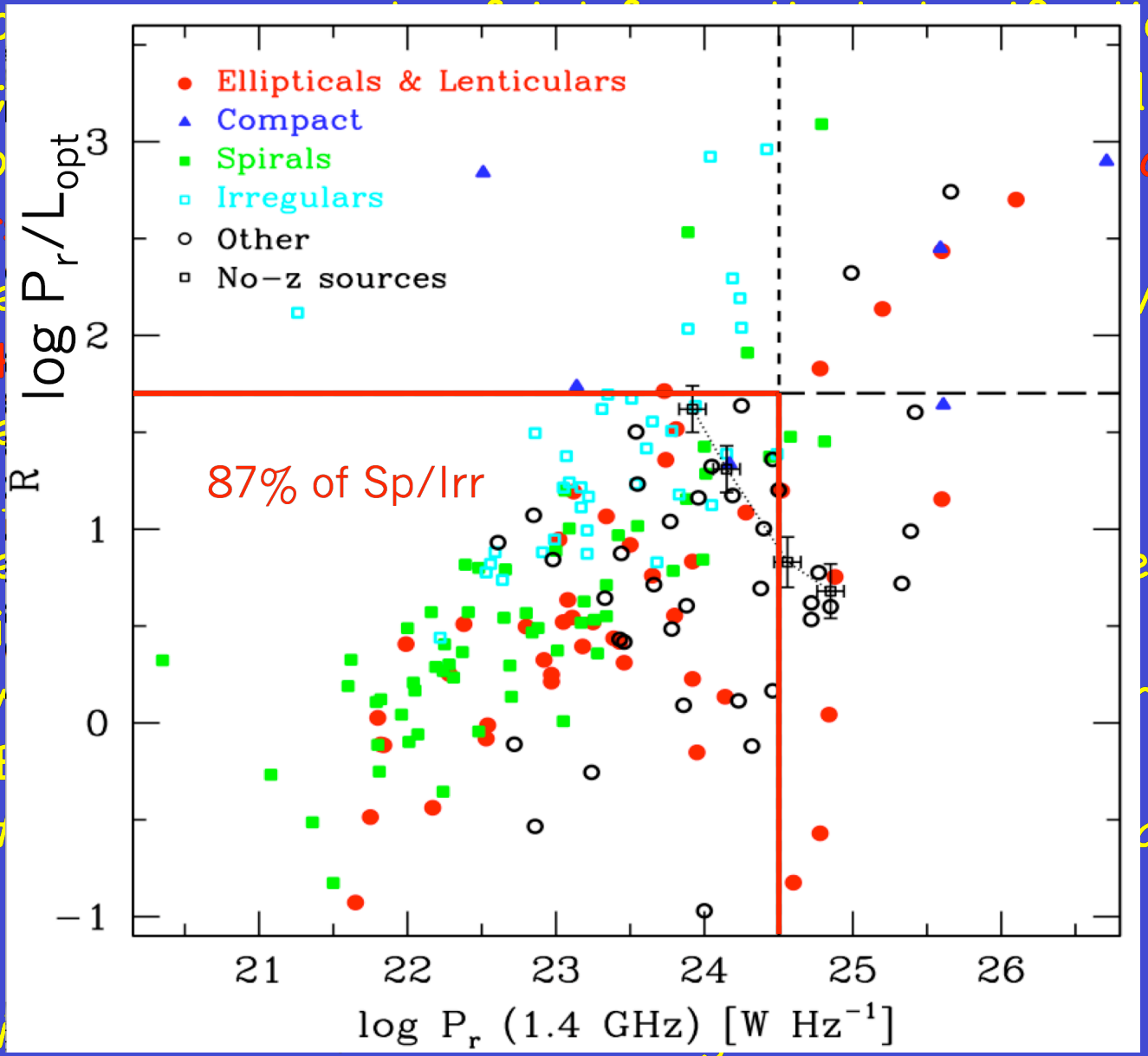
These criteria were applied conservatively; perturbations around these values do not change our results significantly

$z = \langle z \rangle = 0.8$ was assumed for the 23% of the complete sample without redshift; other choices give similar results

Selecting star-forming galaxies (SFG) candidates

Most of c… on (limited!); …y:

1. SFGs at o… …als or lenticular…
2. SFGs have… …/Hz]: P_r < $10^{24.5}$ W/H…
3. SFGs have… [locally R = log(P_r/L_{op}…
4. SFGs have… …etections only, no li… RQ AGN w… …rted from 5 GHz and E… *These crit… …around these values do… z = <z> = … sample wi…*



Selecting star-forming galaxies (SFG) candidates

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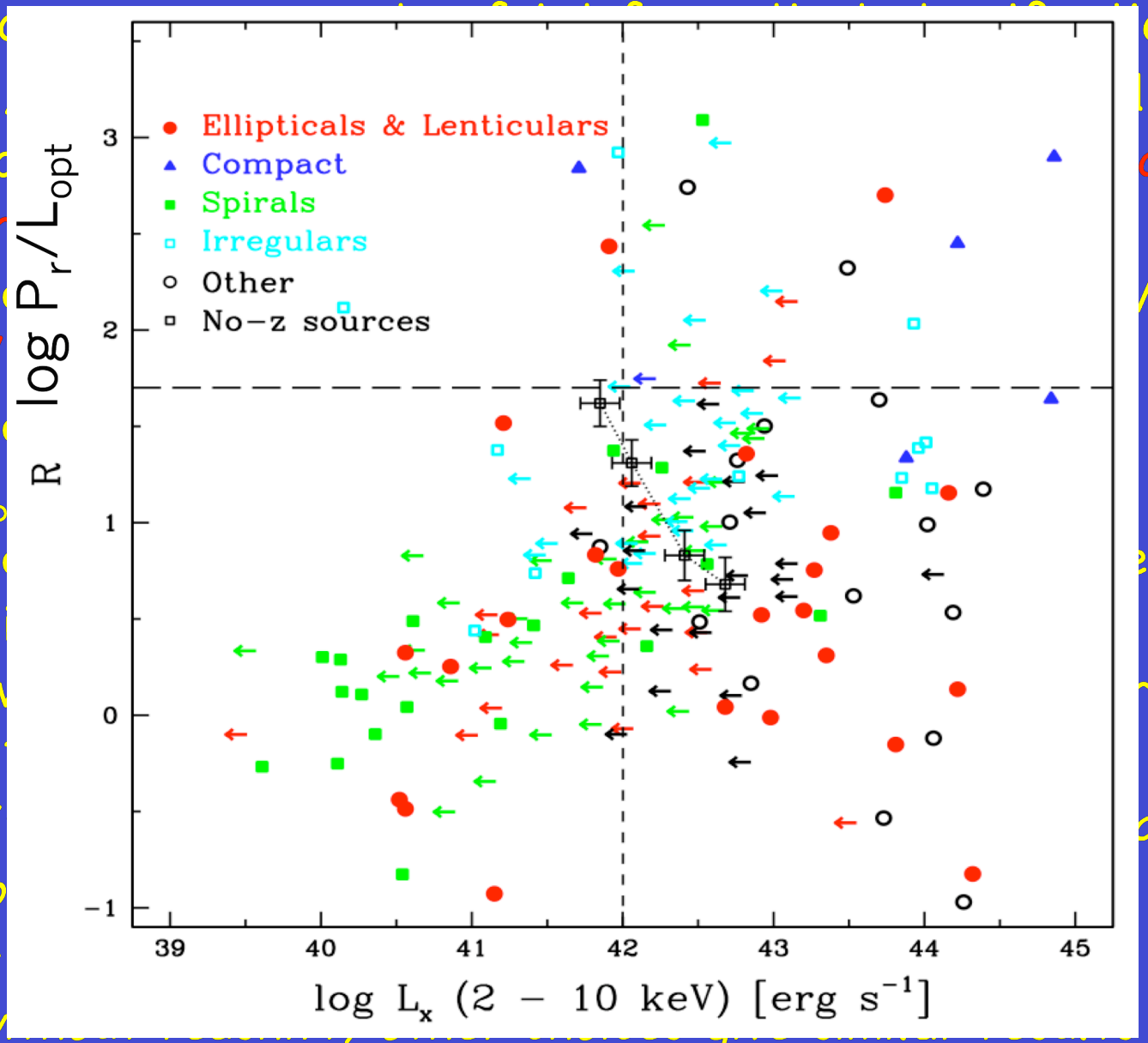
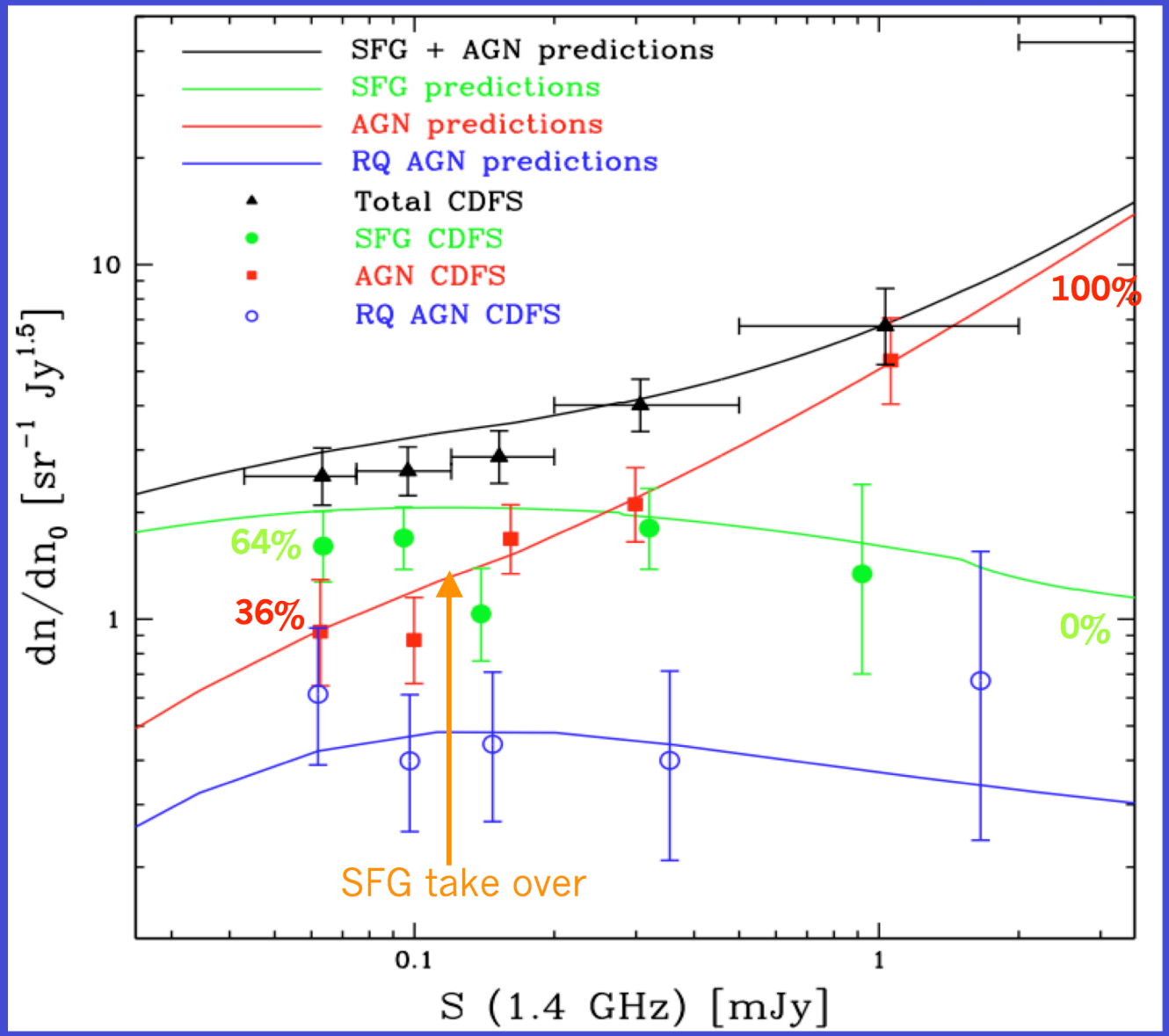
These cri… around these values do… z = <z> = … sample w…



Number counts for SFG and AGN



Sub-mJy sources:
< 57±8% SFG >
41±6% AGN
19±5% RQ AGN
(46% of all AGN)

≈1/2 SFG
≈1/2 AGN
≈1/2 RL
≈1/2 RQ

What are the sub-mJy radio-loud AGN?

- Radio-loud quasars disappear below ≈ 1 mJy (being beamed high-power [FR II] radio galaxies)
- Similarly, high-power FR II radio galaxies should reach only ≈ 0.5 mJy
- BL Lacs can reach lower flux densities but are rare: ≈ 10 - 15% of all sub-mJy AGN
- Most sub-mJy radio-loud AGN are then low-power FR I radio galaxies

Main Results

- VLA-CFDS sample: 266 sources (198 complete) down to 42 μJy (1.4 GHz); large amount of ancillary data, especially redshifts
- Sub-mJy flattening of radio number counts mostly due to star-forming galaxies (< 60% of sub-mJy sources), which are absent above ≈ 2 mJy but become dominant below ≈ 0.1 mJy
- AGN counts are driven by the fall of radio-loud sources, mostly low-power radio galaxies
- Radio-quiet AGN make up ≈ 1/2 of all AGN and ≈ 1/5 of sub-mJy sources (very "clean" selection!)
- Our main results differ with the MANY papers, which have suggested a large dominance of star-forming galaxies at sub-mJy levels, but are in agreement with a few recent papers (Ciliegi et al. 2003, Smolčić et al. 2008, Seymour et al. 2008)
- Implications for star-formation history in the Universe

Based on the following VLA-CDFS papers:

- *The VLA Survey of the CDFS. I. Overview and the radio data,* Kellermann, Fomalont, Mainieri, Padovani, Rosati, Shaver, Tozzi, Miller, 2008, ApJS, 179, 71
- *The VLA Survey of the CDFS. II. Identification and host galaxy properties of sub-mJy sources,* Mainieri, Kellermann, Fomalont, Miller, Padovani, Rosati, Shaver, Silverman, Tozzi, Bergeron, Hasinger, Norman, Popesso, 2008, ApJS, 179, 95
- *The VLA Survey of the CDFS. III. X-ray spectral properties of radio sources,* Tozzi, Mainieri, Rosati, Padovani, Kellermann, Fomalont, Miller, Shaver, Bergeron, Brandt, Brusa, Giacconi, Hasinger, Lehmer, Nonino, Norman, Silverman, 2009, ApJ, in press (arXiv:0902.3365)
- *The VLA Survey of the CDFS. IV. Source Population,* Padovani, Mainieri, Tozzi, Kellermann, Fomalont, Miller, Rosati, Shaver, 2009, ApJ, 694, 235

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- *The VLA Survey of the CDFS. II. Identification and host galaxy properties of sub-mJy sources,* Mainieri, Kellermann, Fomalont, Miller, Padovani, Rosati, Shaver, Silverman, Tozzi, Bergeron,

Stay tuned for more results on the evolution and luminosity functions of the VLA-CDFS sample!

Fomalont, Miller, Shaver, Bergeron, Brandt, Brusa, Giacconi, Hasinger, Lehmer, Nonino, Norman, Silverman, 2009, ApJ, in press (arXiv:0902.3365)

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