The promise of next-generation RC surveys

Revealing the physics and evolution of galaxies and AGN

Isabella Prandoni

INAF - IRA

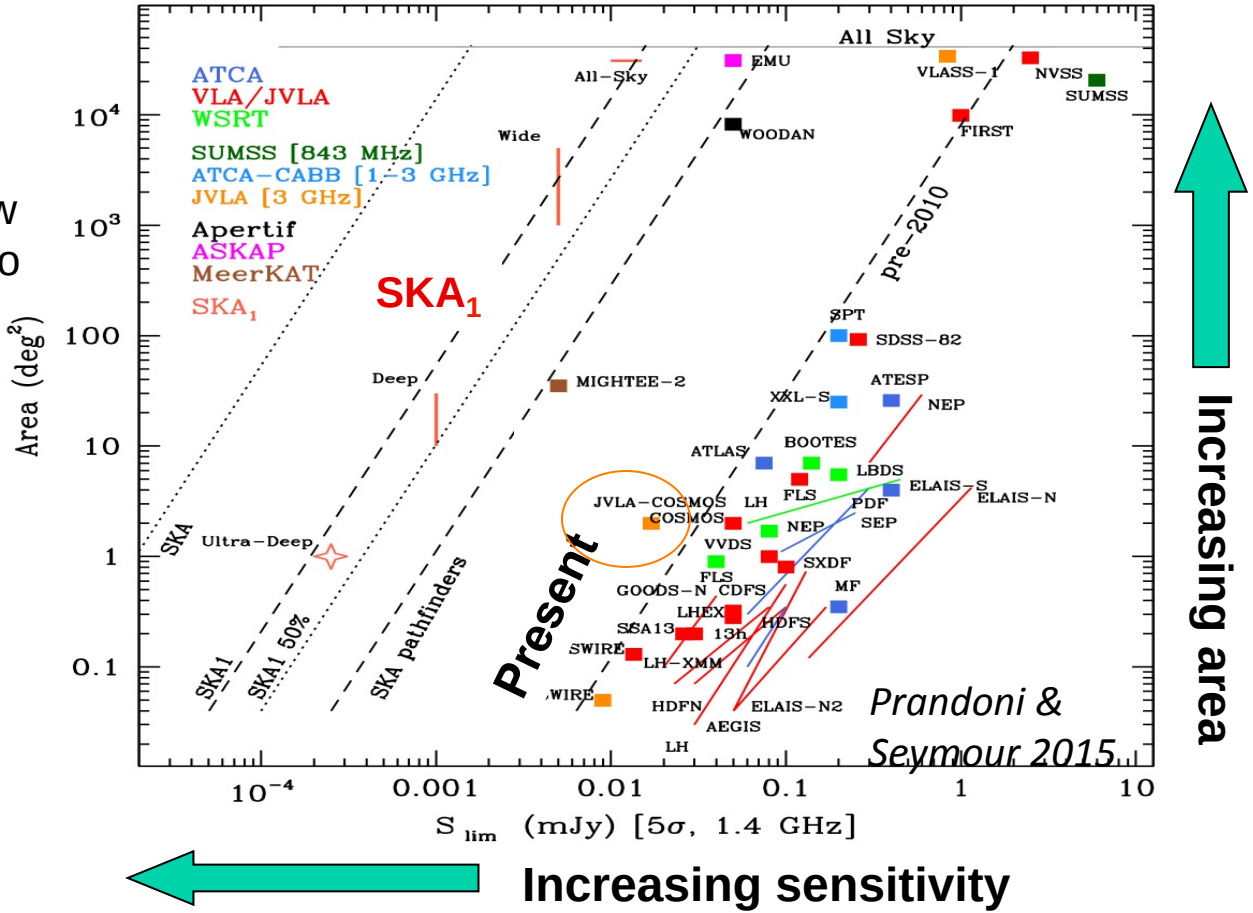
Next Generation RC Surveys

1-3 GHz surveys

RC surveys will probe from few sq. deg. (at sub-uJy rms) to all-sky (at uJy rms)

➔ representative volumes at all redshifts

- Inform about source demographics & evolution at matched res. & depth



The multi-frequency radio sky

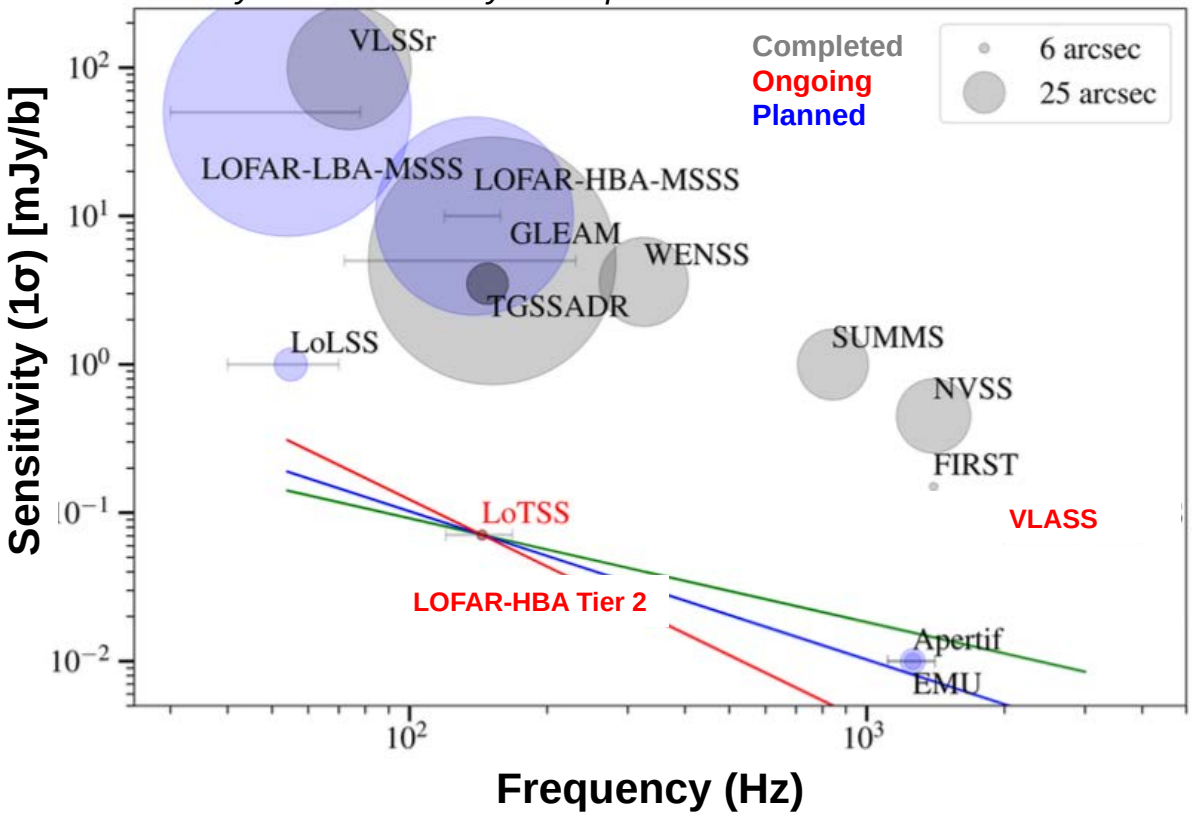
Tier 1 LOFAR Surveys:
- **All-sky; 100 uJy/b rms**

HBA: LoTSS
(Shimwell+2017; 2018)

LBA: LoLSS
(de Gasperin+2018)

Tier 2 LOFAR surveys:
- **25 extragal. fields**
- **25 uJy/b rms**

All sky/wide area surveys - adapted from Shimwell+2018



LH @ LOFAR HBA

10h: ~150 uJy rms @ 15”

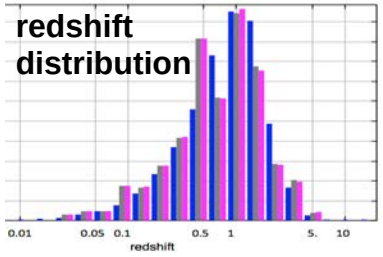
48h: ~40 uJy rms @ 6”

Dense multi-frequency coverage:

60 MHz – 15 GHz

Tier 2 Fields:

- millions SFG and AGN
- variety of environments
- 0<z<6



48h: ~40 uJy rms; 6” res.
Mandal et al. in prep.

Lockman Hole @ HBA ~ 30 deg^2

Mahony, Morganti, IP et al. 2016;

I. Prandoni - IAUGA 2018

LH @ LOFAR HBA

10h: ~150 uJy rms @ 15”

48h: ~40 uJy rms @ 6”

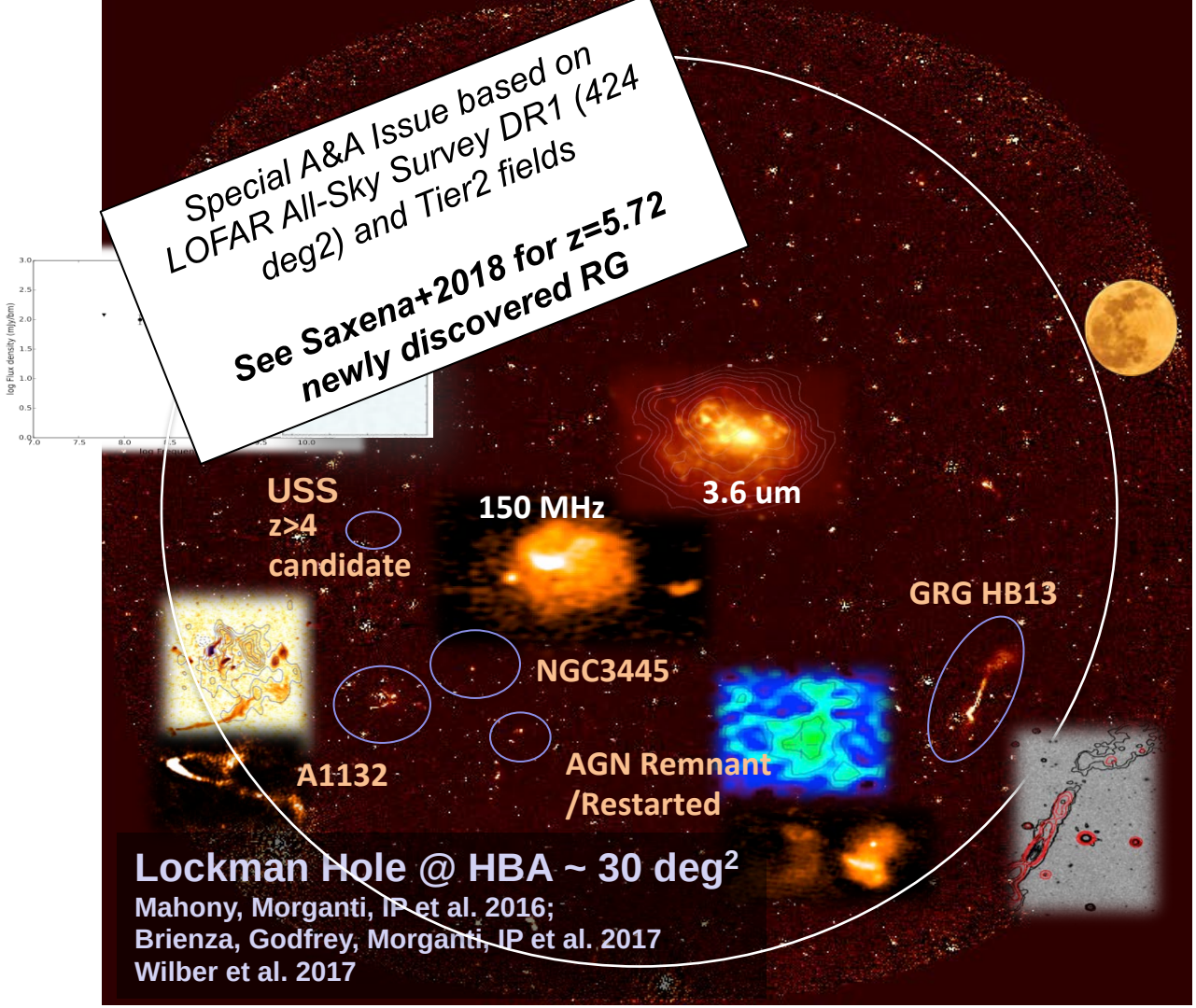
Dense multi-frequency coverage:

60 MHz – 15 GHz

Rare populations:

- 1 GRG (1.6 Mpc)
- 1 Abell cluster
- 13 peaked (incl. MHz-peaked)
- 23 AGN remnants/restarted candidates
- 1 nearby galaxy (20 Mpc)
- 20 USS *z* > 4 candidates

Transversal science!



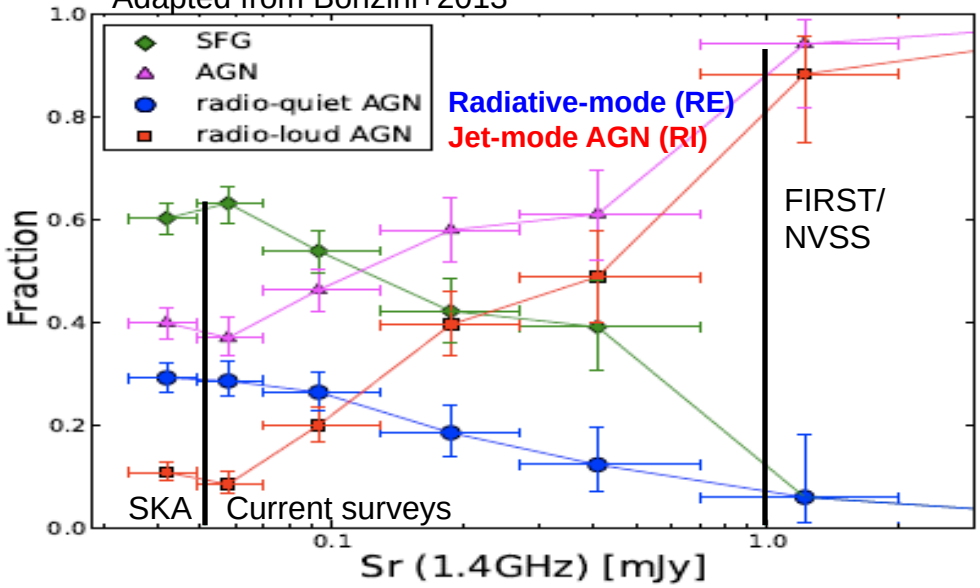
Talk Focus

Galaxies/AGN:

- demography & evolution – the benefit of large deep samples
- AGN feedback - the added value of spatial resolution

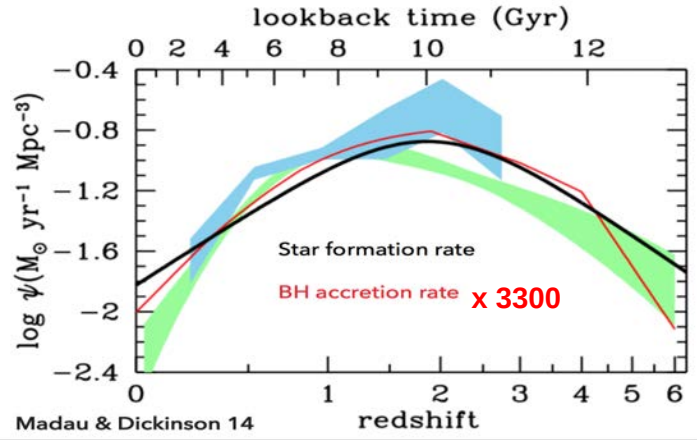
The promise of next-generation RC surveys

ECDFS S>40 uJy (→ 200 uJy @ 150 MHz)
Adapted from Bonzini+2013

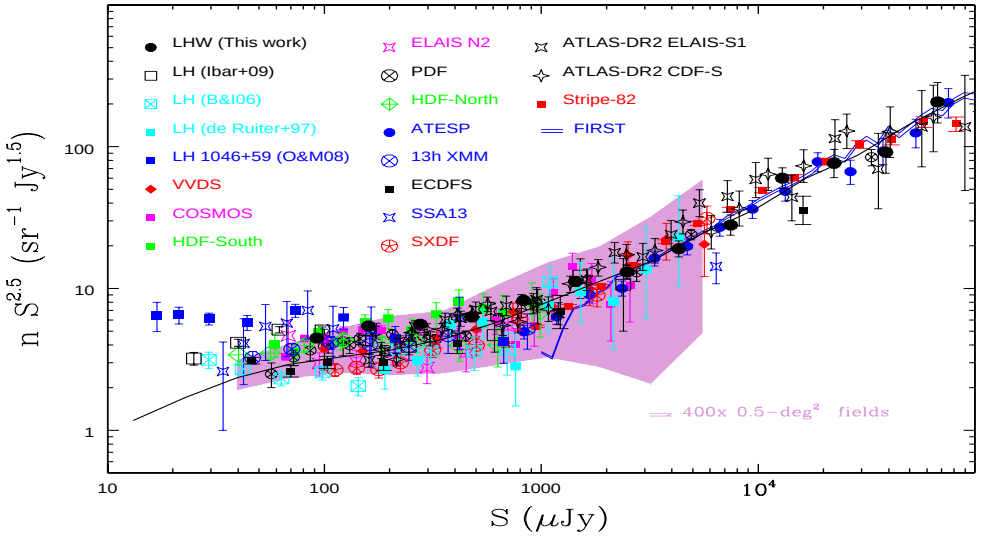


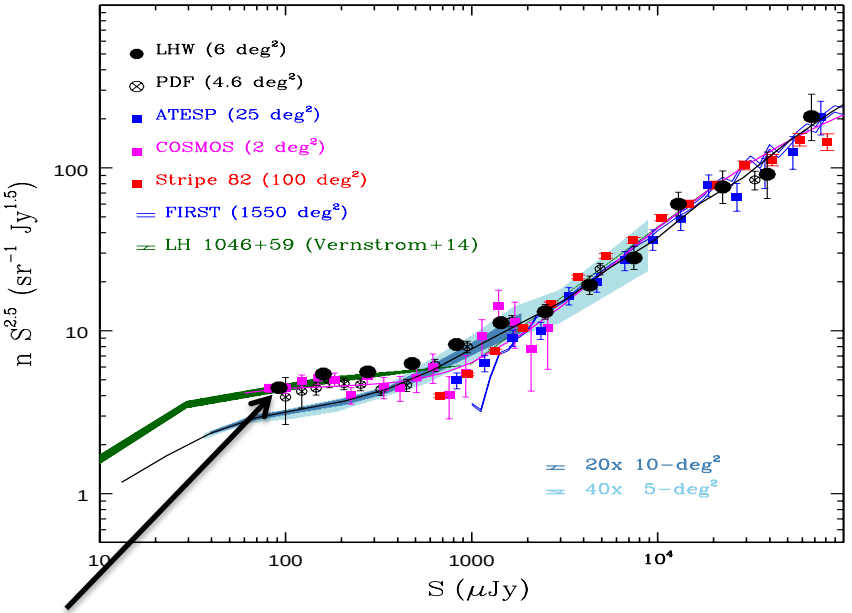
- Complete census of SF, AGN activity, up to high-z and down to RQ regime

- Co-evolution of SF AND AGN
- Role of AGN feedback [QSO winds & radio jets]
- not dust extinction/gas obscuration effects



The quest for new evolutionary models



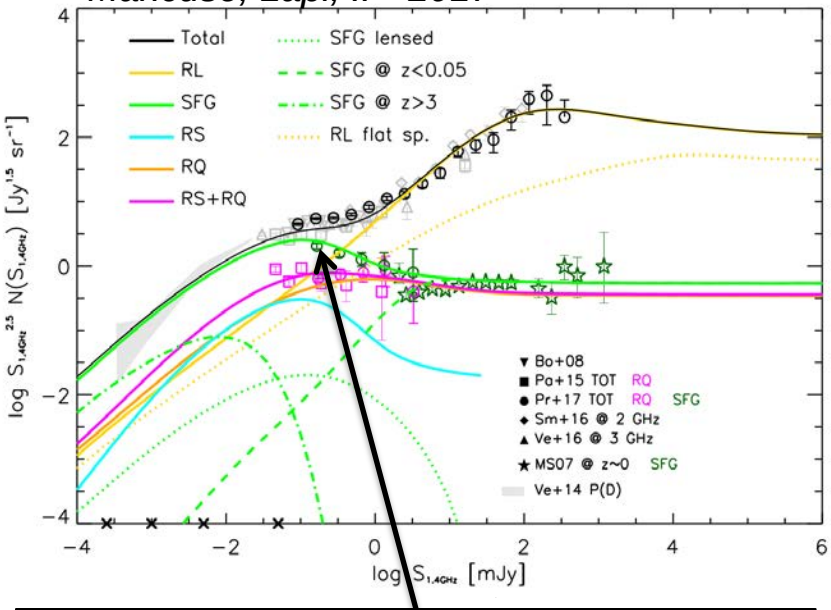


Prandoni+2018

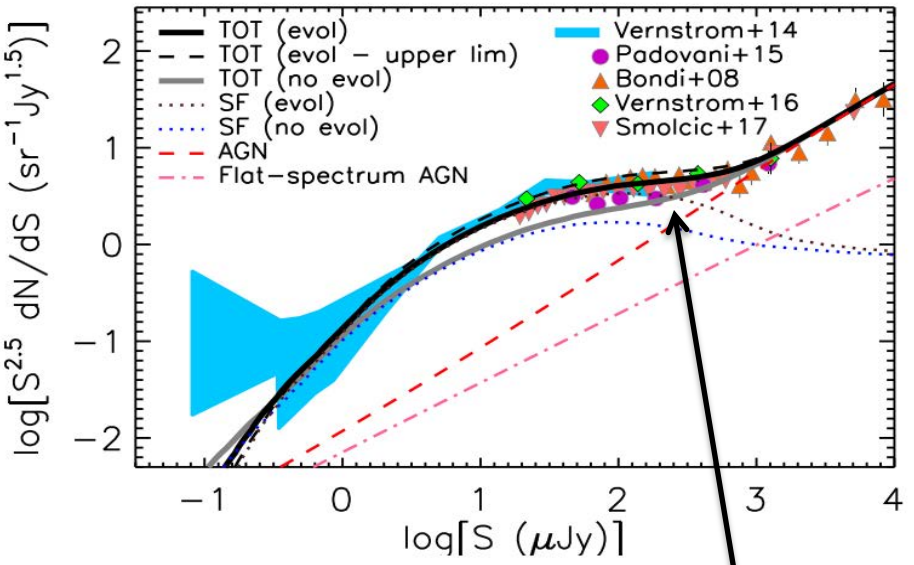
1.4 GHz Large fields point toward an excess wrt S3-SEX models at S<400 uJy

The quest for new evolutionary models

Mancuso, Lapi, IP+2017



Bonato+ 2017

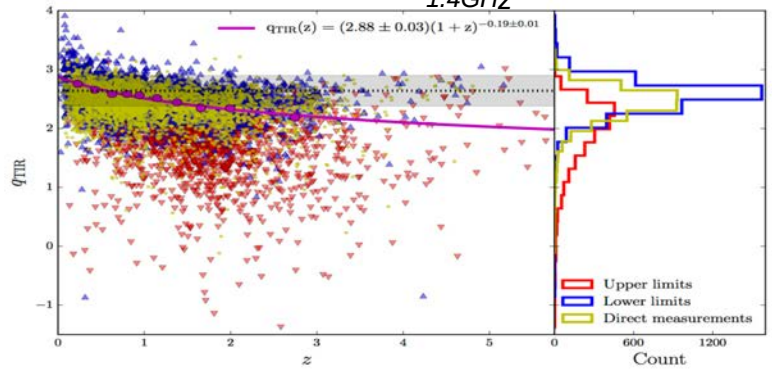


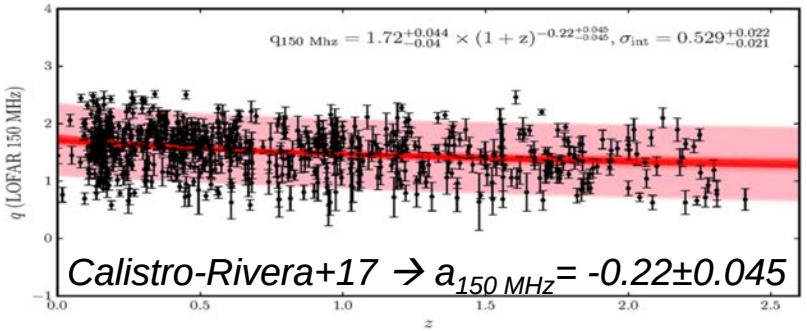
RL RQ SFG → 3 component modeling:
high-z heavily dust-obscured SB population

SFG(+RQ) RL AGN 2 component modeling:
mild L_{synch}/SFR evolution $(1+z)^{a}$; a<~1.1

The quest for new evolutionary models

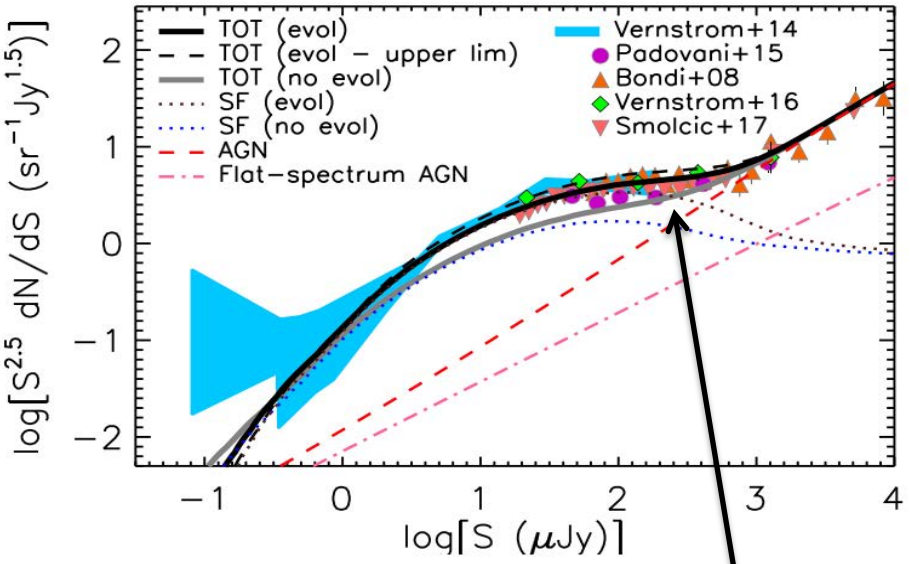
Delhaize+ 2017 → $a_{1.4GHz}$= -0.19±0.01





Calistro-Rivera+17 → $a_{150\ MHz}$= -0.22±0.045

Bonato+ 2017



SFG(+RQ) RL AGN 2 component modeling:
mild L_{synch}/SFR evolution $q\sim(1+z)^a$; a<~1.1

SKA perspectives: Unbiased census of SF

Sensitivity is key

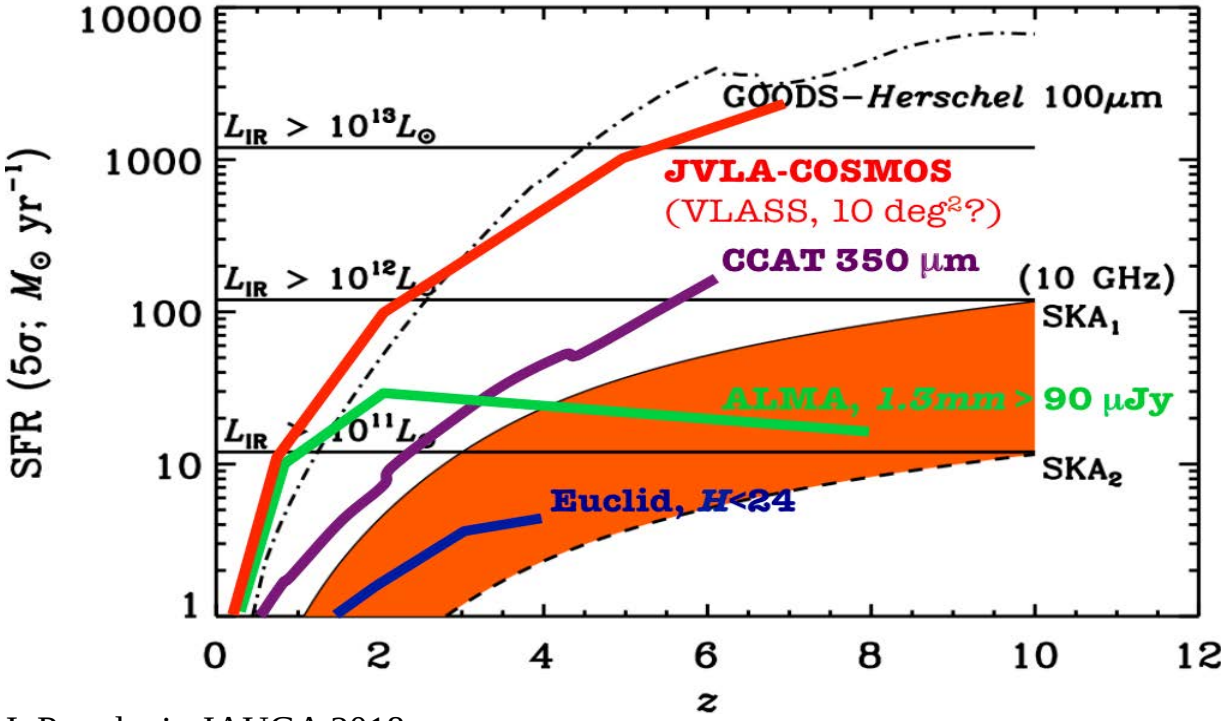
uJy → ULIRGs @ z>1.5-2 (Novak+2017)

Requirement:
→ **sub-uJy rms**

SKA unmatched sensitivity to **10 M_{sun}/yr out to z~4**

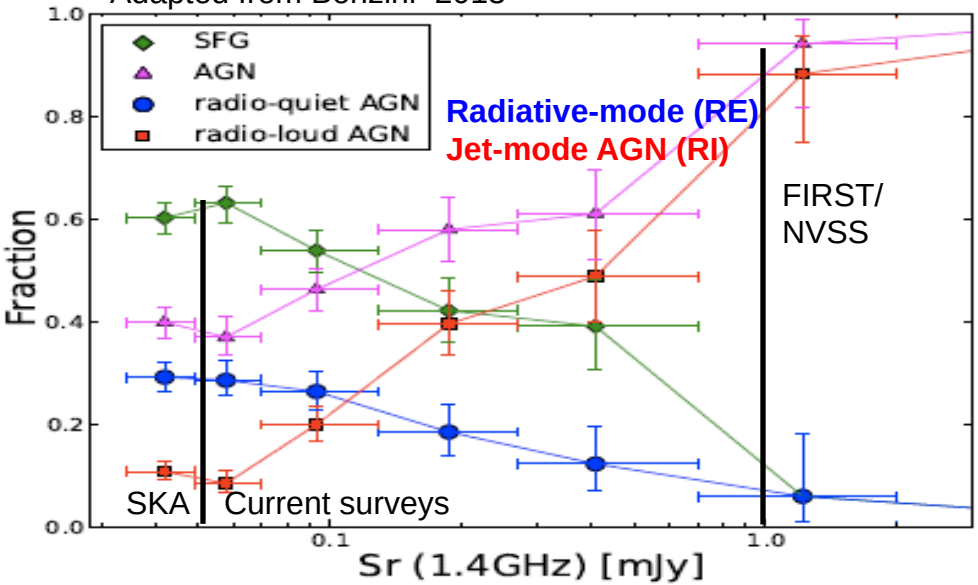
Band 5: 0.05-0.1" res. Resolved **kpc/sub-kpc imaging** of star forming disks **out to z~1**

Murphy+ 2015: SKA Science Book



The promise of next-generation radio surveys

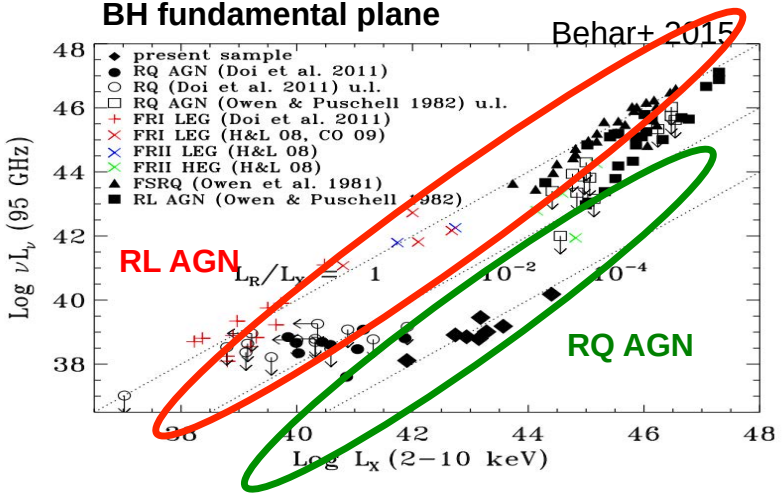
ECDFS S>40 uJy (→ 200 uJy @ 150 MHz)
Adapted from Bonzini+2013



Physics of radio emission

- RQ/RL dichotomy;
- Origin of radio emission in RQ AGN
- radio duty cycles/feedback physics

BH fundamental plane



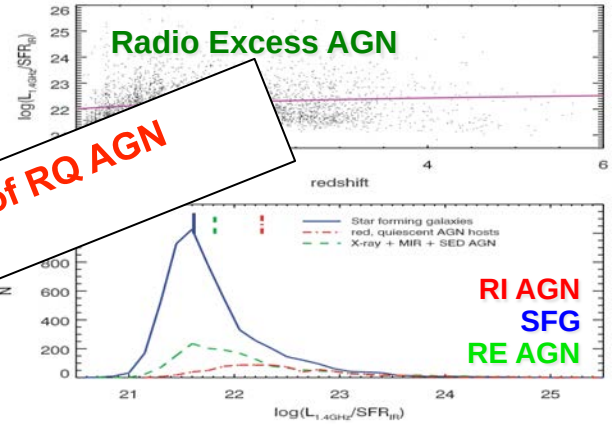
The Origin of Radio Emission in RQ AGN

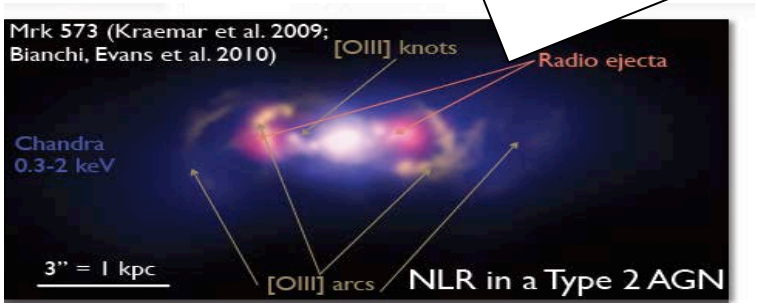
•What triggers radio emission in RQ AGN?

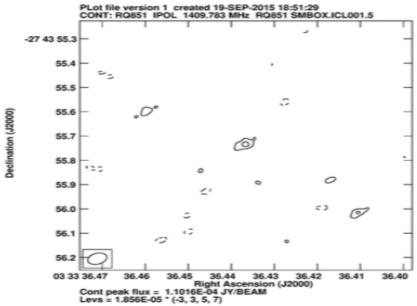
- pure SF in the host galaxy?
- **SF and AGN related emission do co-exist?**
- **In which proportions?**

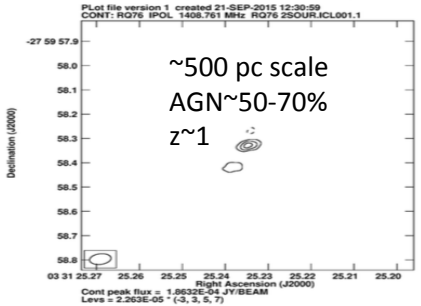
VLBI studies of deep radio fields:
GOODS-N@EVN: Garrett+2001; Chi+2013; Radcliffe
E-CDFS@VLBA: Middleberg+2011
LH@VLBA: Middleberg+2013
E-CDFS@LBA: Maini+2016
COSMOS@VLBA: Herrera-C

Evidence of radio excess in ~30% of RQ AGN (Del Vecchio+ 2017)









ECDFS – *Maini, IP+ 2016*

The role of high-resolution RC Surveys

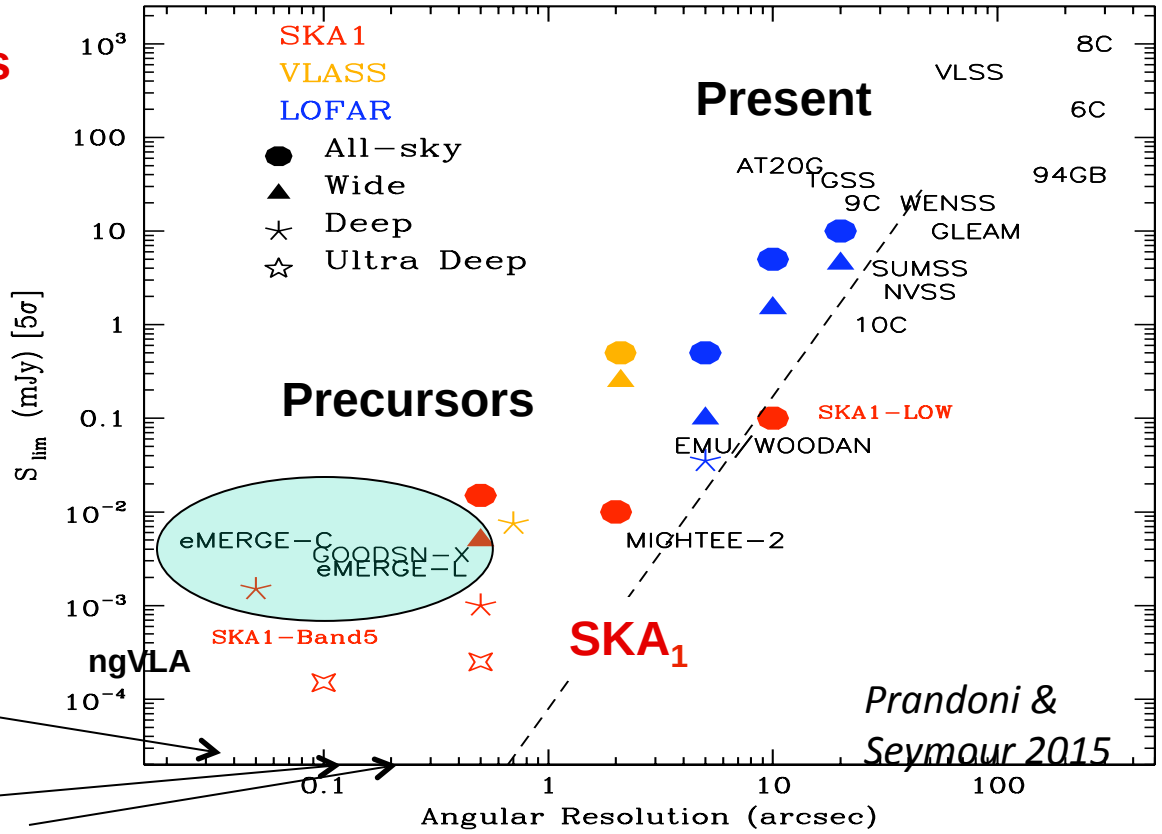
Resolved astrophysics out to high redshift

Radio surveys will probe down to mas resolution (ngVLA)

➔ multi-scale census of sources/processes

➔ Physics of RQ AGN:

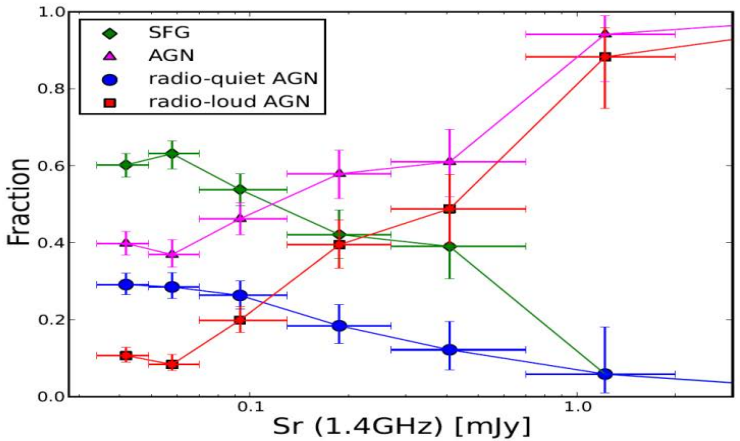
- incidence of radio jets
- SF

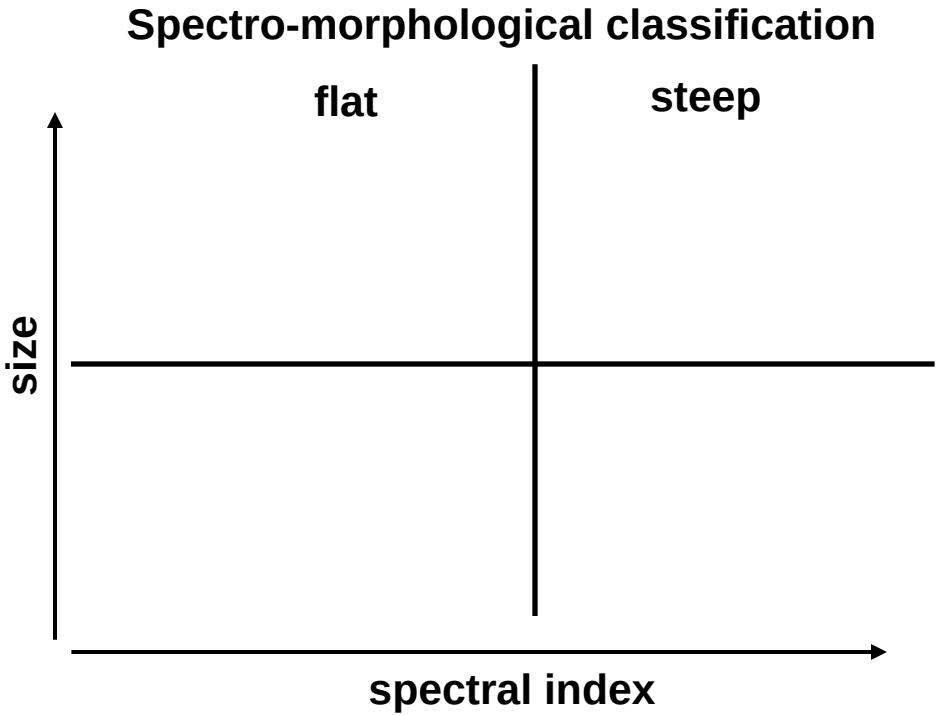


Increasing sensitivity

Higher resolution

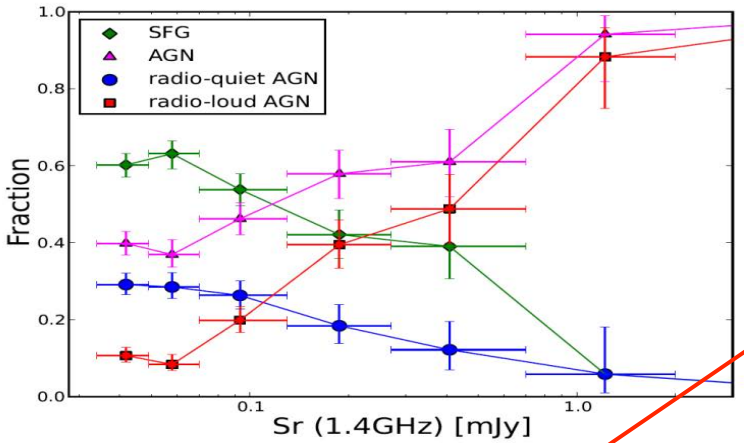
eMERGE: Resolving the radio sky

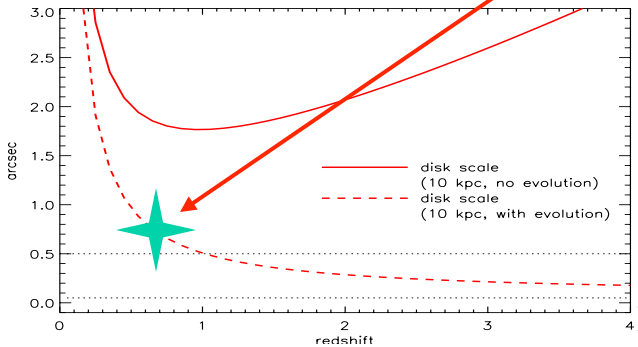




GOODS-N: VLA-C band 3 uJy rms; 0.5” res.
Guidetti,Bondi, IP + 17

eMERGE: Resolving the radio sky





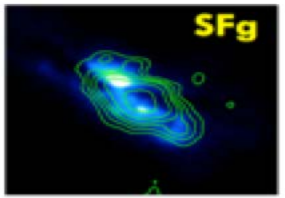
0.8”
5 kpc

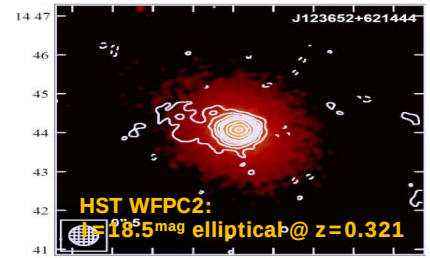
0.3”

Spectro-morphological classification

flat **steep**

z~0.5
5.5 GHz contours
HST I-band image



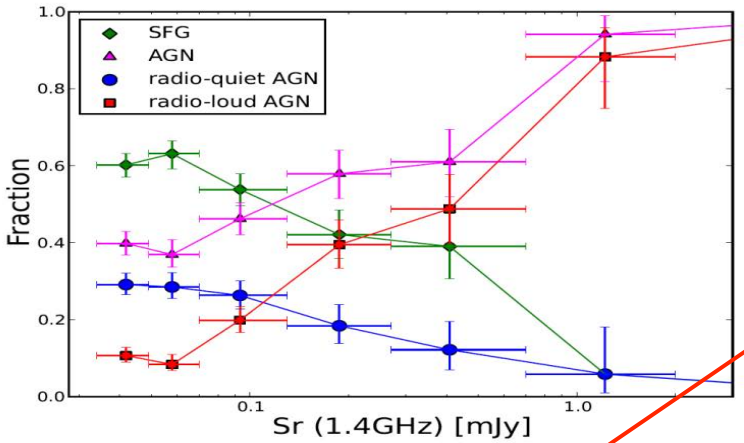


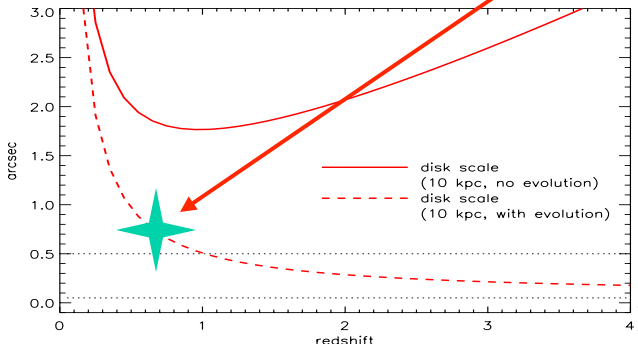
size

0.3 **spectral index** **0.7**

GOODS-N: VLA-Cband 3 uJy rms; 0.5” res.
Guidetti,Bondi, IP + 17

eMERGE: Resolving the radio sky





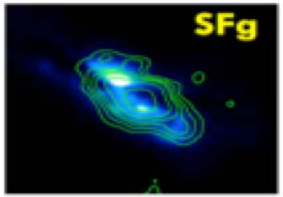
0.8”
5 kpc

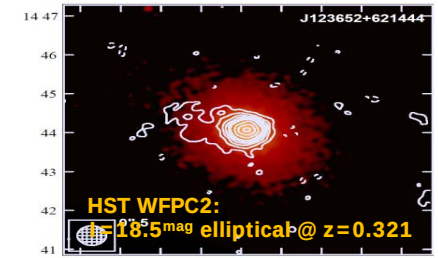
0.3”

Spectro-morphological classification

flat | **steep**

z~0.5
5.5 GHz contours
HST I-band image





size

0.3 **spectral index** **0.7**

GOODS-N: VLA-Cband 3 uJy rms; 0.5” res.
Guidetti,Bondi, IP + 17

ngVLA perspectives: jet-mode feedback

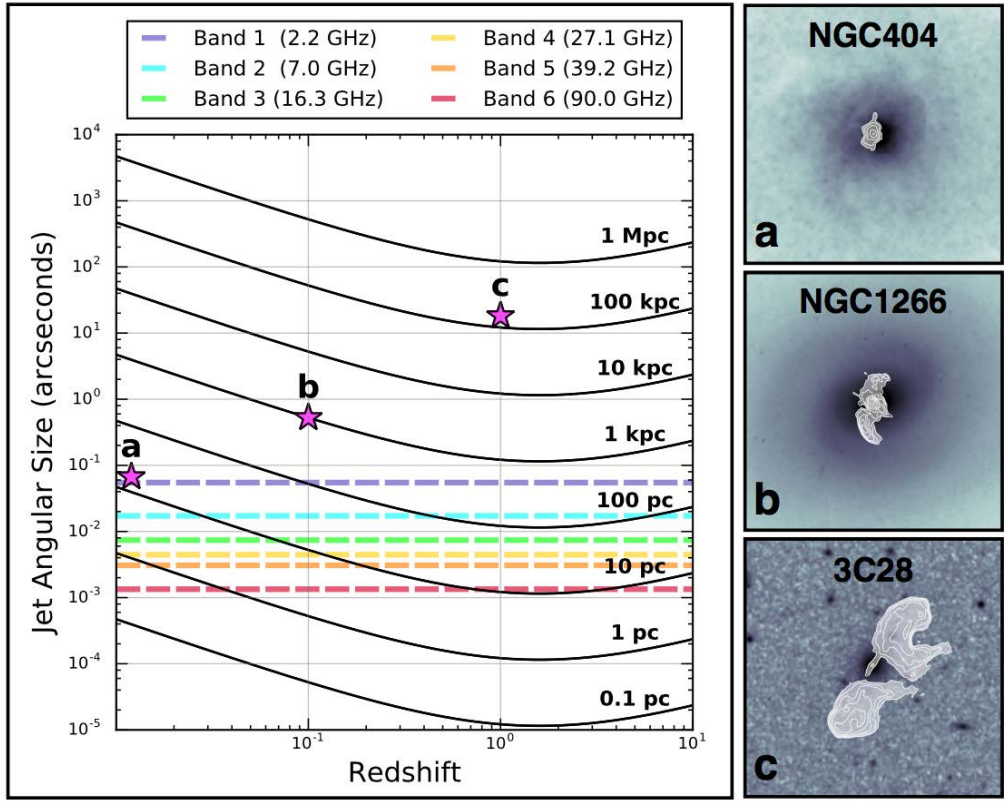
Resolution is key

ngVLA: down to mas resolution
→ **10 pc jets out to z~1-3**
(i.e. epoch of SF/AGN peak)

Role of jet-driven feedback in galaxy evolution

SKA Band 5 → 100 pc

Nyland et al. 2018
ngVLA Science Book



Summary

Ongoing surveys are revolutionizing our knowledge of radio source populations

Deep RC surveys

→ valuable dust-extinction/gas-obscuration-free t study thermal and non -thermal emission in galaxies and AGN

- Low-nu surveys can now compete with 1-3 G urveys (non thermal emission)
- **multi-frequency surveys → radio SED**

→ provide unique insights for aspe at arise at radio band

- RQ/RL AGN dichotomy
- Physics and evolution of SFG o-FIR correlation
- low E/old electron populati radio AGN life cycle

Deep high-res. RC surveys → resolved studies of the high-z Universe

- Composite (AGN+SF) sources at peak of activity z~1-3
- Role of jet-mode AGN feedback vs redshift

More expected in the next future… stay tuned!