The hosts and environmental impact of local radio-loud AGN

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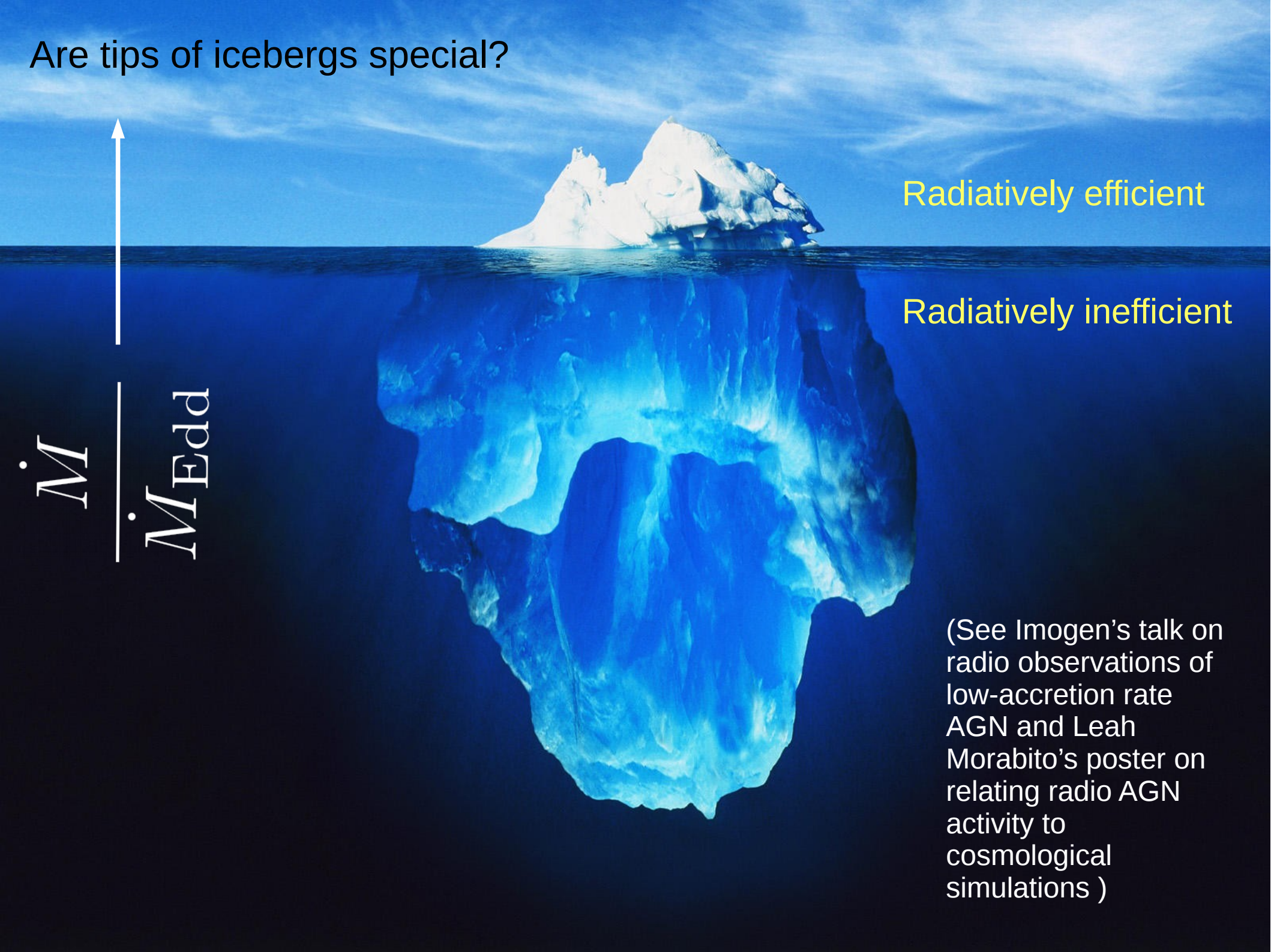
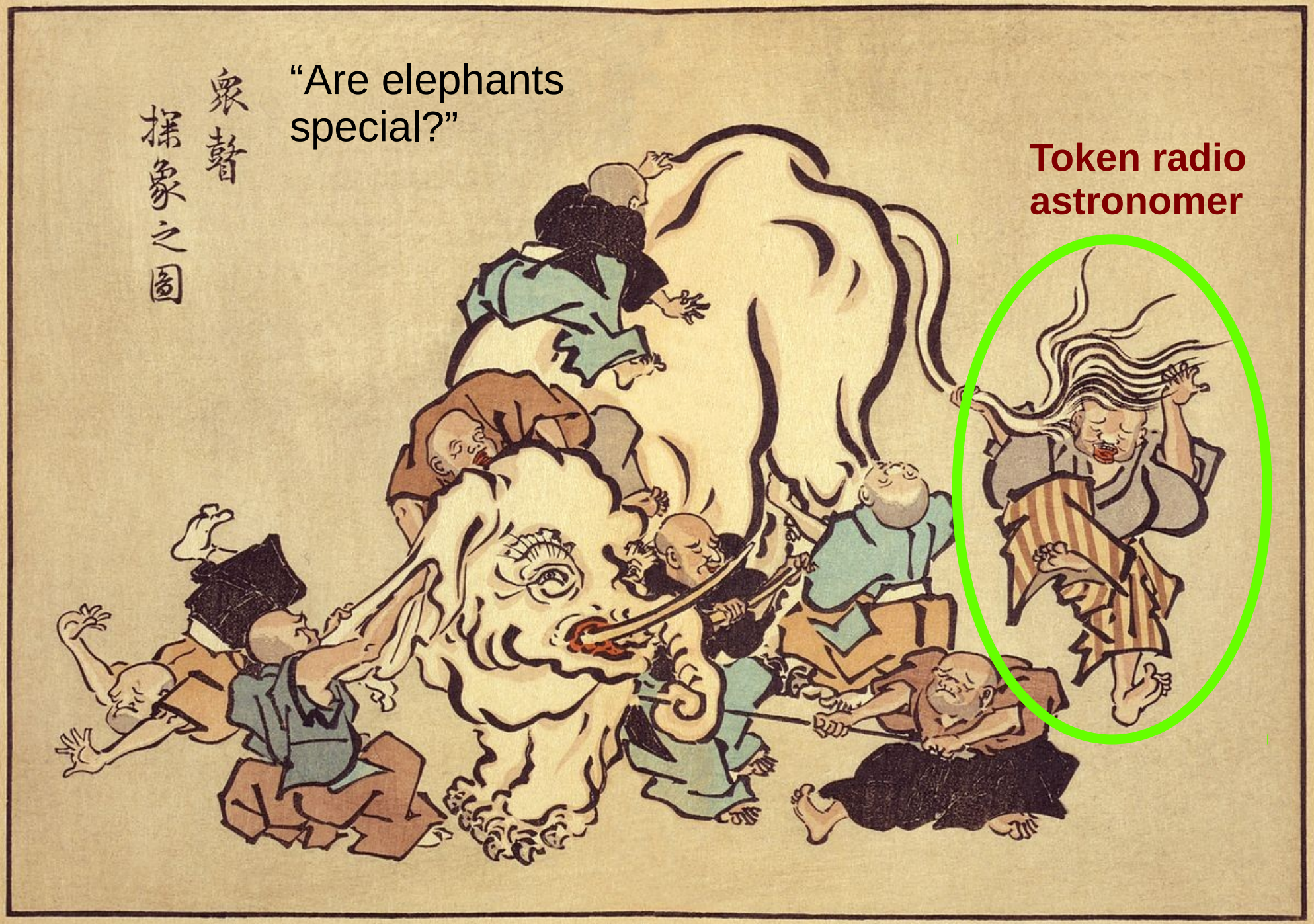
Credits:
LOFAR surveys – Tim Shimwell, Cyril Tasse, Huub Röttgering ++
Radio AGN ID/selection: Wendy Williams, Judith Croston, Ken Duncan
AGN hosts/SFRs: Gulay Gurkan, Philip Best, Pepe Sabater

Are tips of icebergs special?



(See Imogen's talk on radio observations of low-accretion rate AGN and Leah Morabito's poster on relating radio AGN activity to cosmological simulations)


“Are elephants special?”


衆聾
探象之圖
“Are elephants special?”
Token radio astronomer

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LoTSS: the most important radio survey you've never heard of

- LOFAR 'Tier 1' survey of the whole northern sky
- 6 arcsec resolution, typically 100 microJy/beam sensitivity at 145 MHz (~ 150 MHz) – comparable resolution but 10 times deeper than FIRST & with short baselines
- Precursor surveys in Boötes (Williams+16) and H-ATLAS NGP area (Hardcastle+16)
- Data release 1 will be ~420 sq. deg in HETDEX Spring field, located in SDSS/FIRST area at dec ~50 (Shimwell+18, Williams+18, Duncan+18 submitted…) w/ 70 microJy/beam sensitivity
- 320,000 radio sources in DR1 + opt ids with WISE, PanSTARRS + SDSS spec z + phot-z + ...
- 10,000 sq. deg allocated or awarded time over the next 2 years, will give ~8-9 million sources. WEAVE-LOFAR follows up with spectra.

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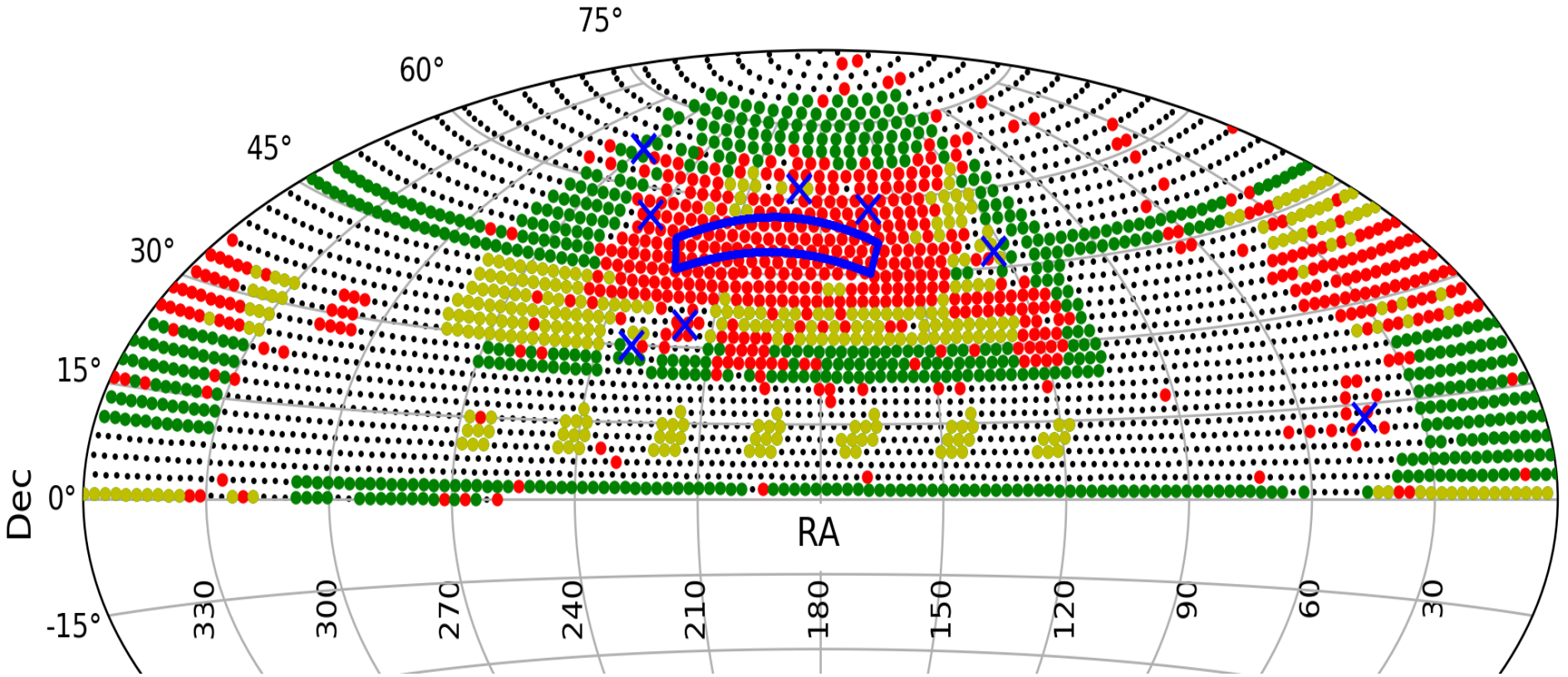
LoTSS sky coverage (now-2020)



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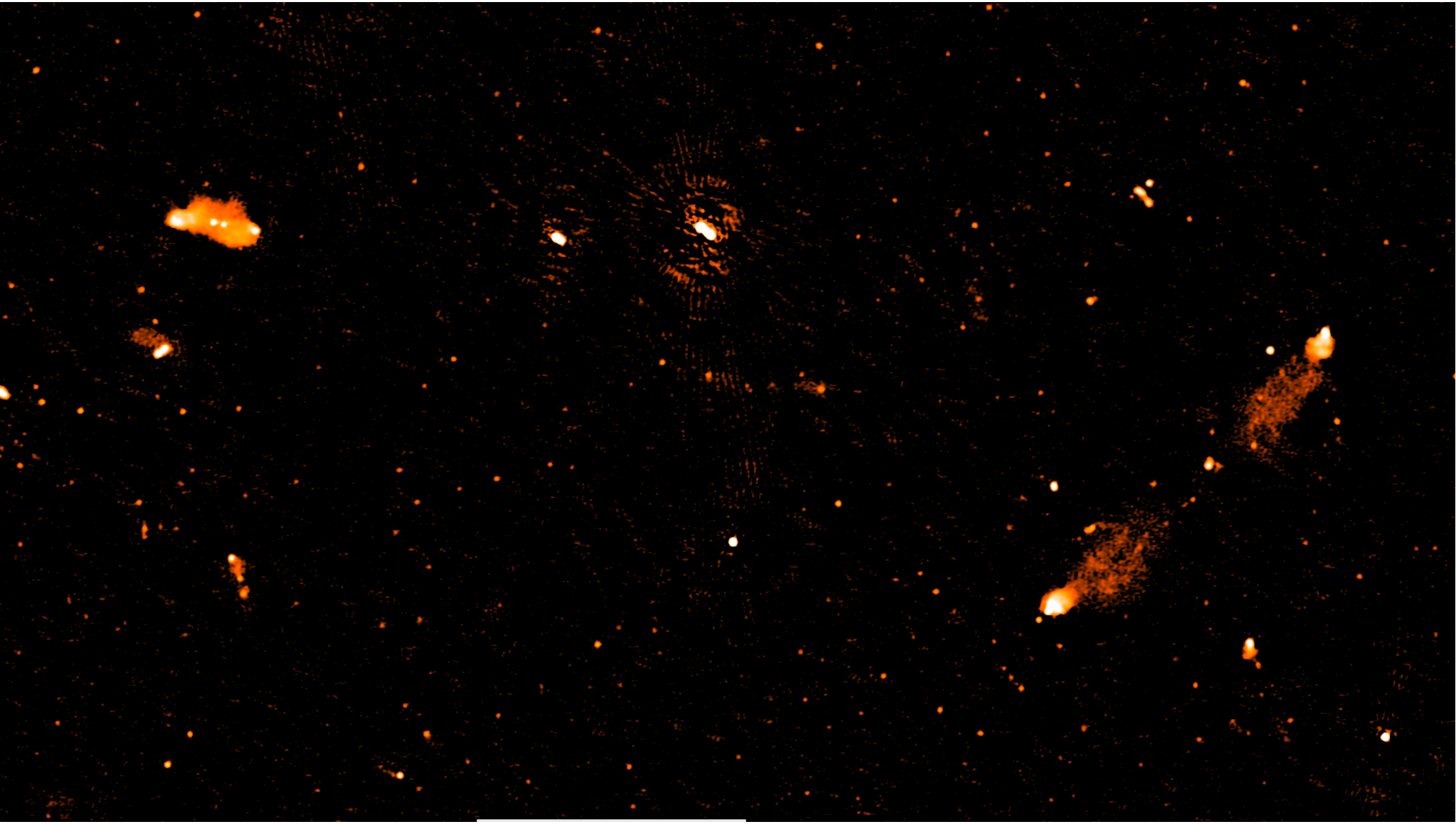
LOTSS (DR2)



0.7 deg

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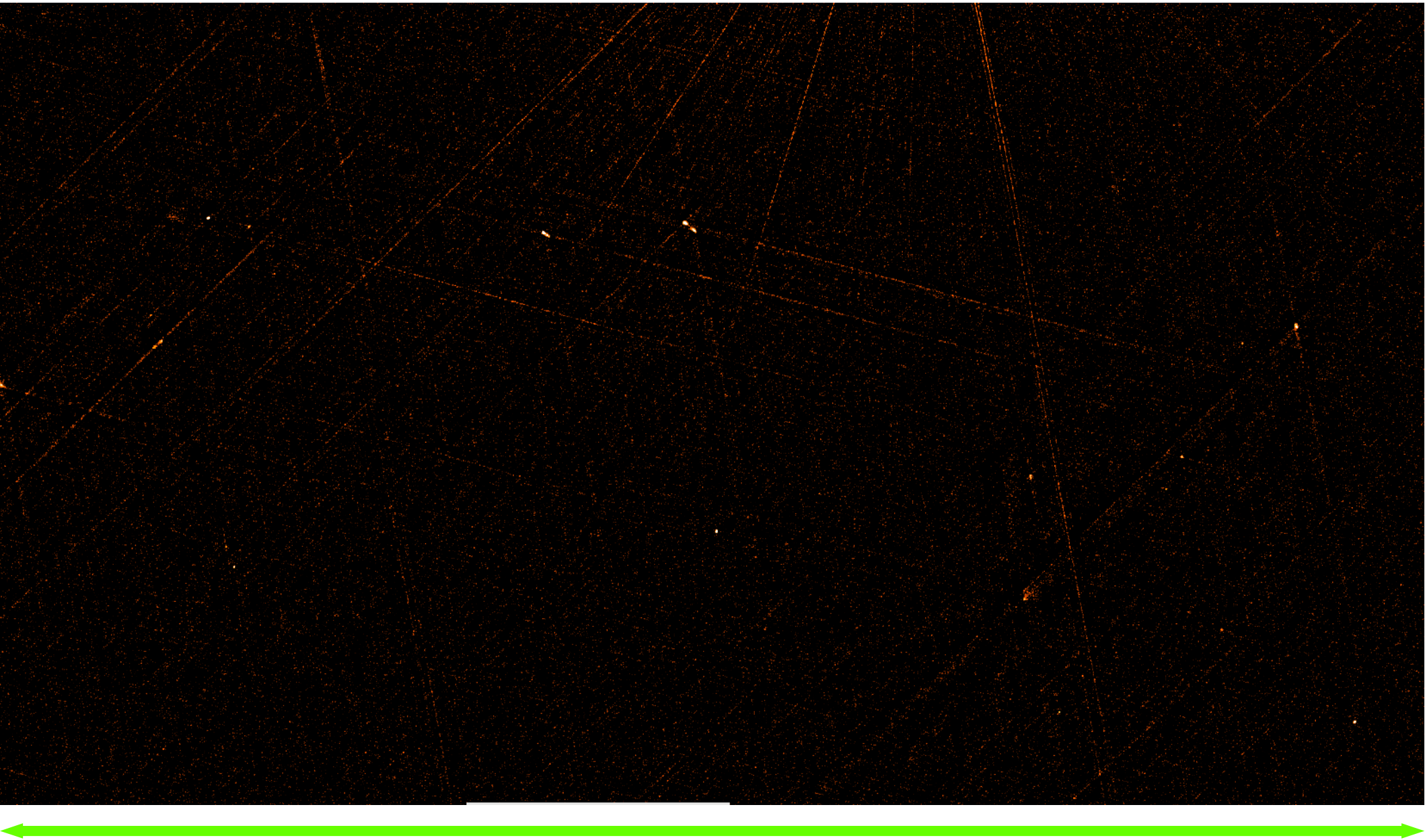
VLASS (quick look!)



0.7 deg

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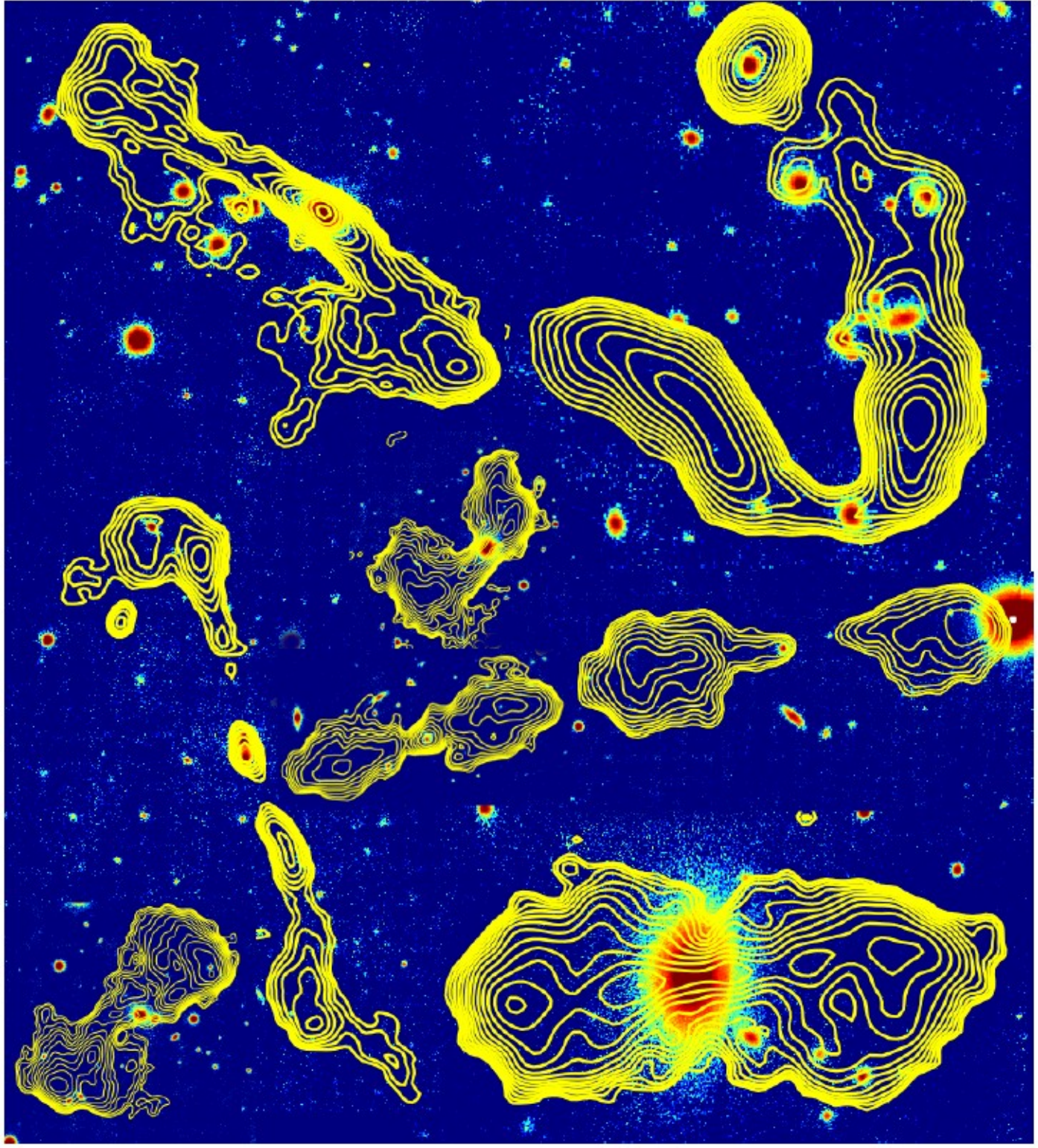
LoTSS

Montage of a few (of around 30,000) extended sources from LOFAR survey of HETDEX field on Pan-STARRS optical images



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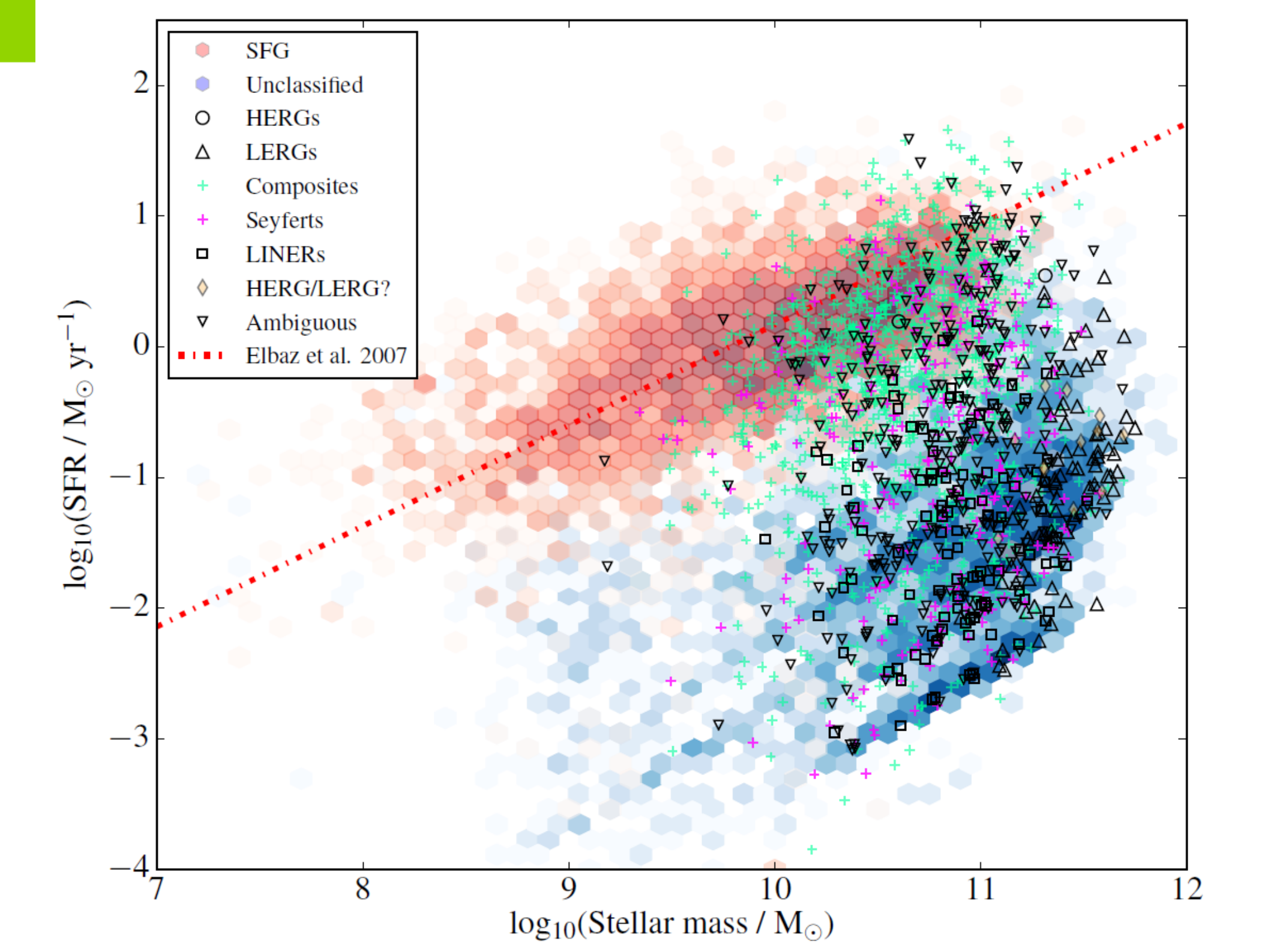
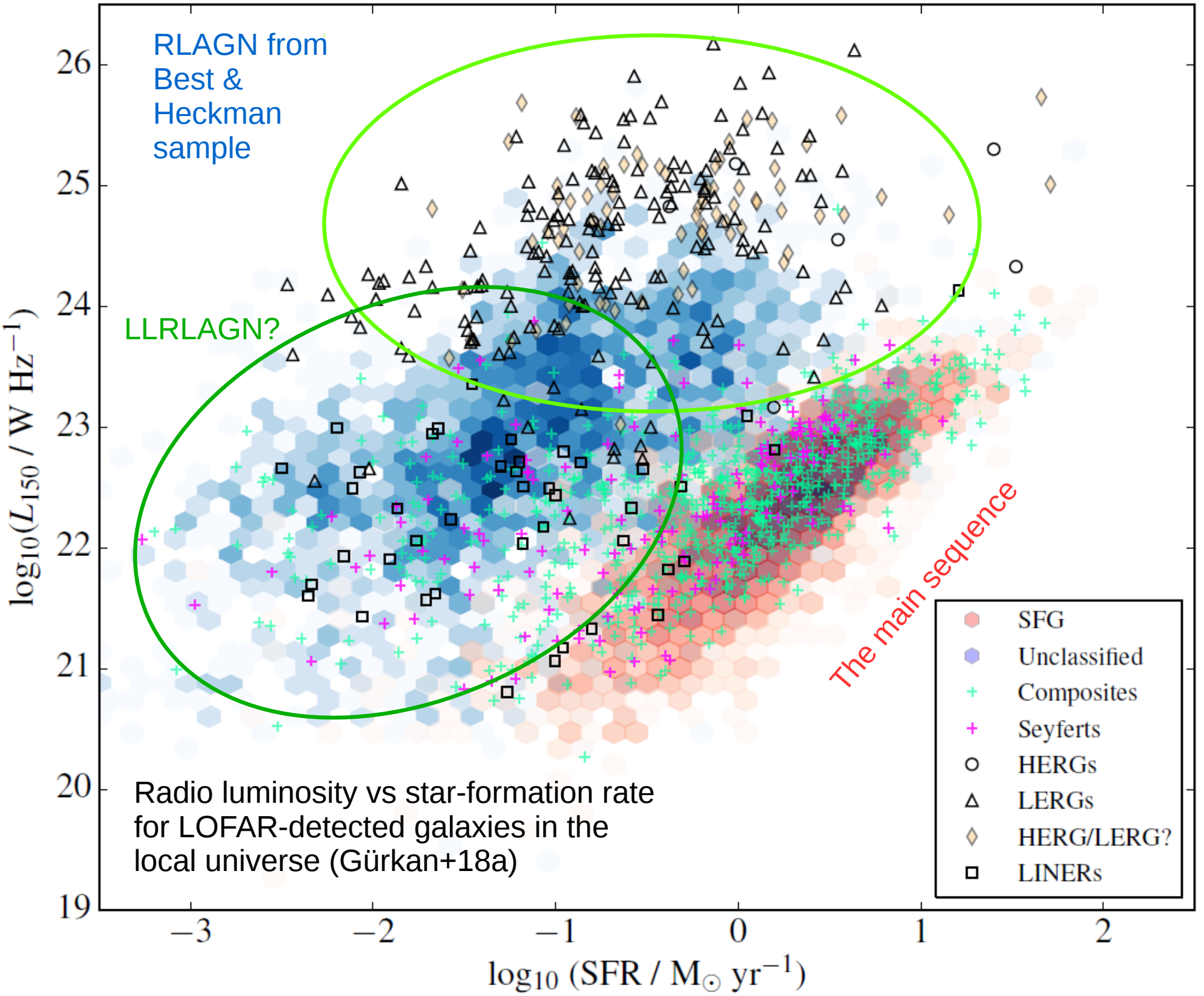
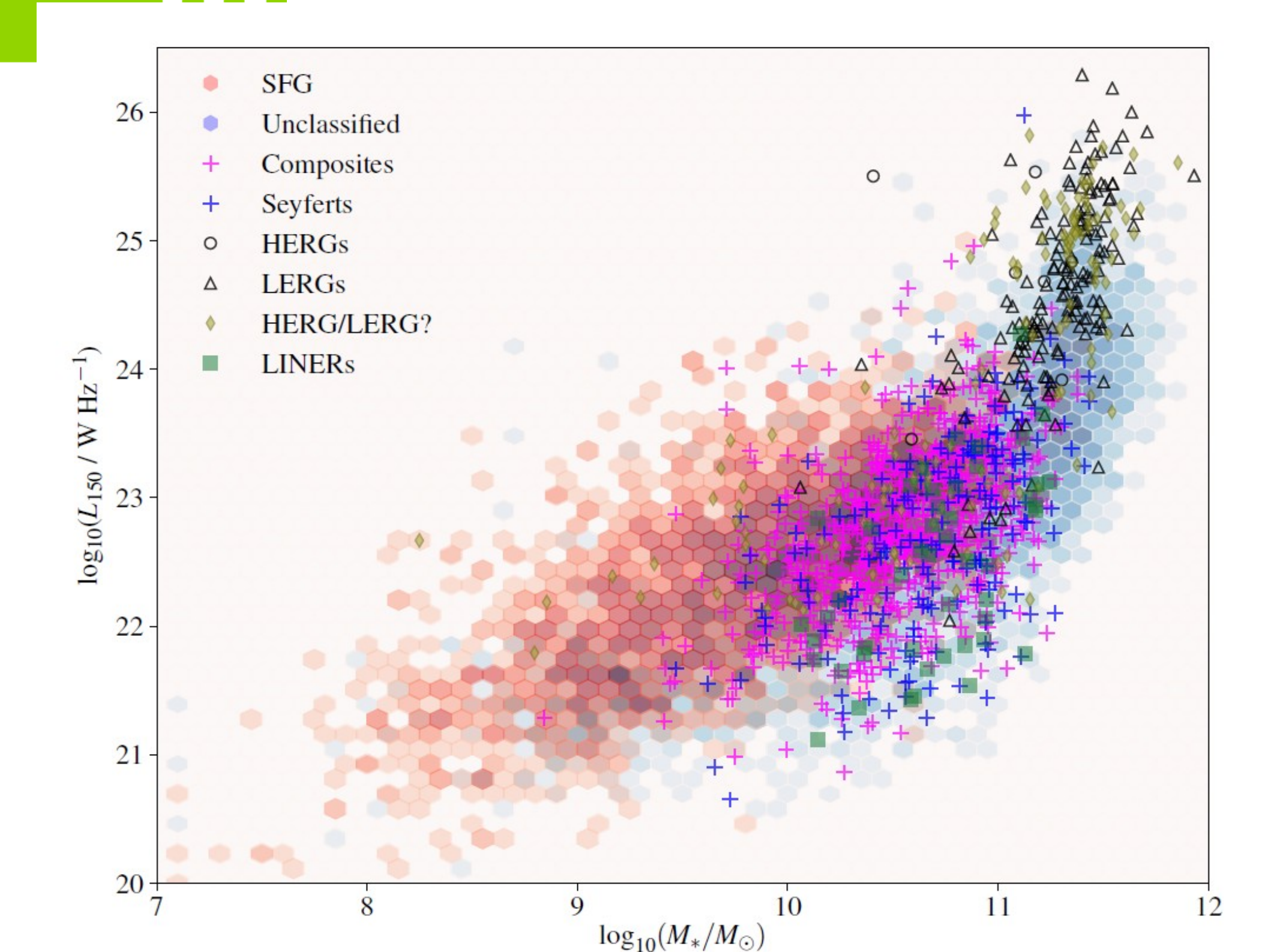
(1) SDSS galaxies from H-ATLAS

- Gürkan+18 (published)
- ~13,000 MPAJHU galaxies with spec-*z* from SDSS
- Classified by BPT
- SFR + mass from MAGPHYS modelling of SDSS, WISE, Herschel
- About 7,500 galaxies detected by LOFAR


SFG
Unclassified
HERGs
LERGs
Composites
Seyferts
LINERs
HERG/LERG?
Ambiguous
Elbaz et al. 2007
2
1
0
−1
−2
−3
−4
7
8
9
10
11
12
log10(SFR / M⊙ yr−1)
log10(Stellar mass / M⊙)


RLAGN from Best & Heckman sample
LLRLAGN?
The main sequence
Radio luminosity vs star-formation rate for LOFAR-detected galaxies in the local universe (Gürkan+18a)
SFG
Unclassified
Composites
Seyferts
HERGs
LERGs
HERG/LERG?
LINERs
$\log_{10}(L_{150}$ / W Hz$^{-1})$
$\log_{10}$ (SFR / M$_\odot$ yr^{-1})
26
25
24
23
22
21
20
19
−3
−2
−1
0
1
2


SFG
Unclassified
Composites
Seyferts
HERGs
LERGs
HERG/LERG?
LINERs
26
25
24
23
22
21
20
7
8
9
10
11
12
$\log_{10}(L_{150}$ / W Hz$^{-1})$
$\log_{10}(M_*/M_\odot)$

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Summary (part 1)

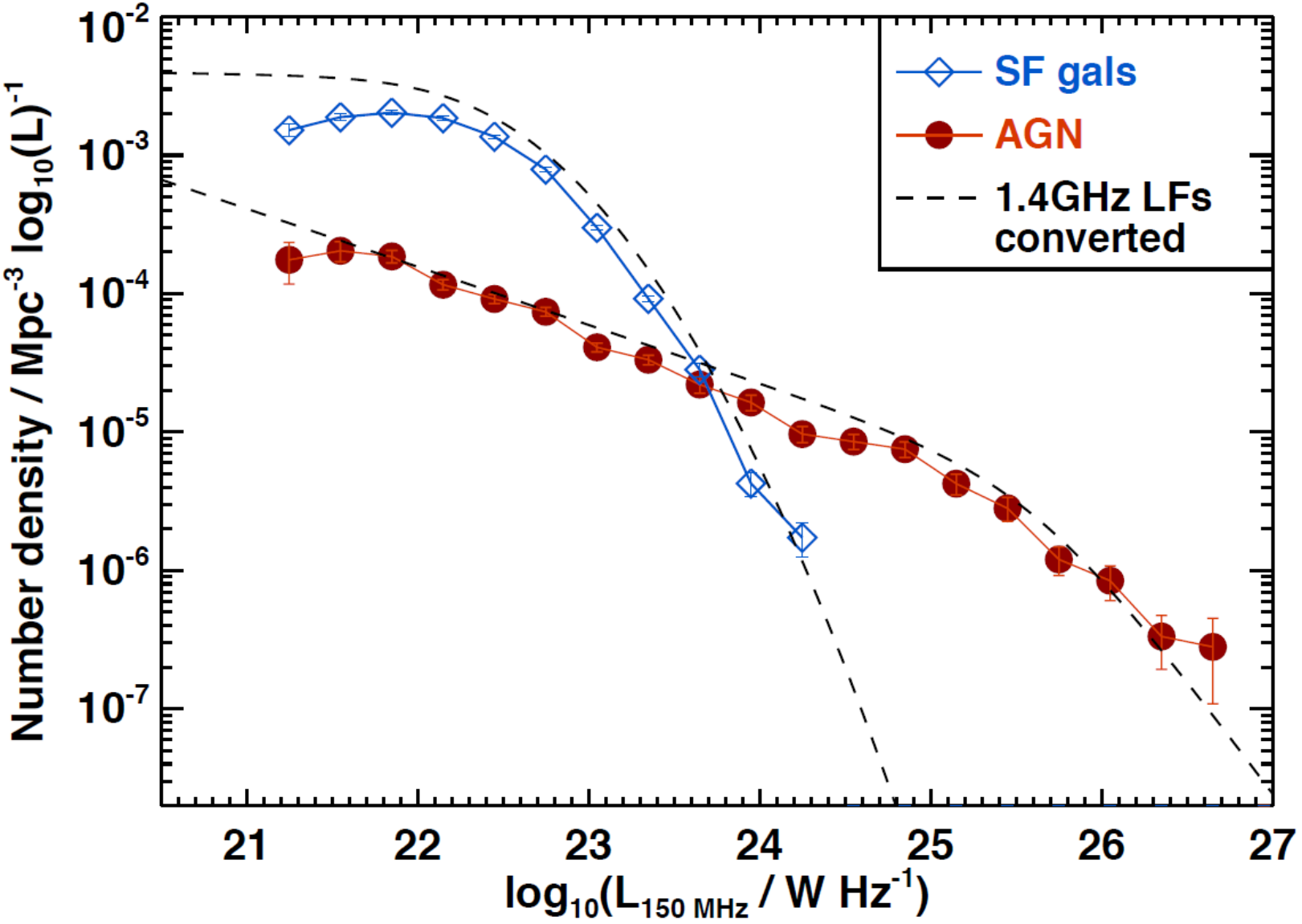
- Can select radio-loud AGN (RLAGN) by excess radio emission over star-formation expectation
- Very large population of high-mass, low-SF, low-luminosity RLAGN (see also Lofthouse+ 18)
- These would not be selected as AGN by BPT, WISE colour, X-ray (unless v deep)

- See Gürkan+18 MNRAS 475 3010 (don’t be put off by ‘star formation’ in the title)

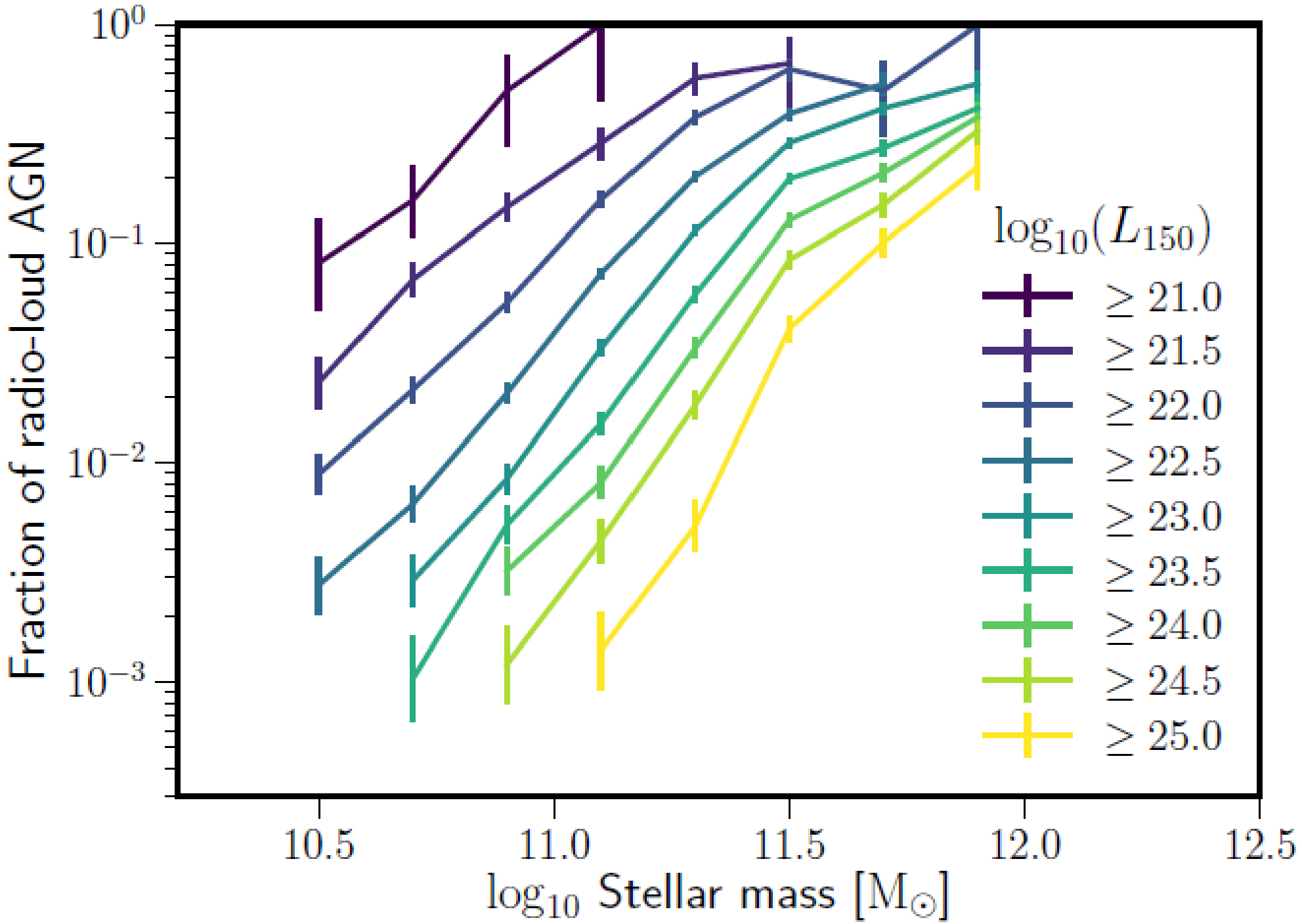
(2) LOFAR sources in HETDEX with SDSS spectroscopy

- Sabater+18 submitted
- Select MPA-JHU galaxies with catalogued LOFAR detections: about 10,000
- AGN-SF separation using the method of Best+05 refined & revised (and calibrated against the Gürkan+ sample)

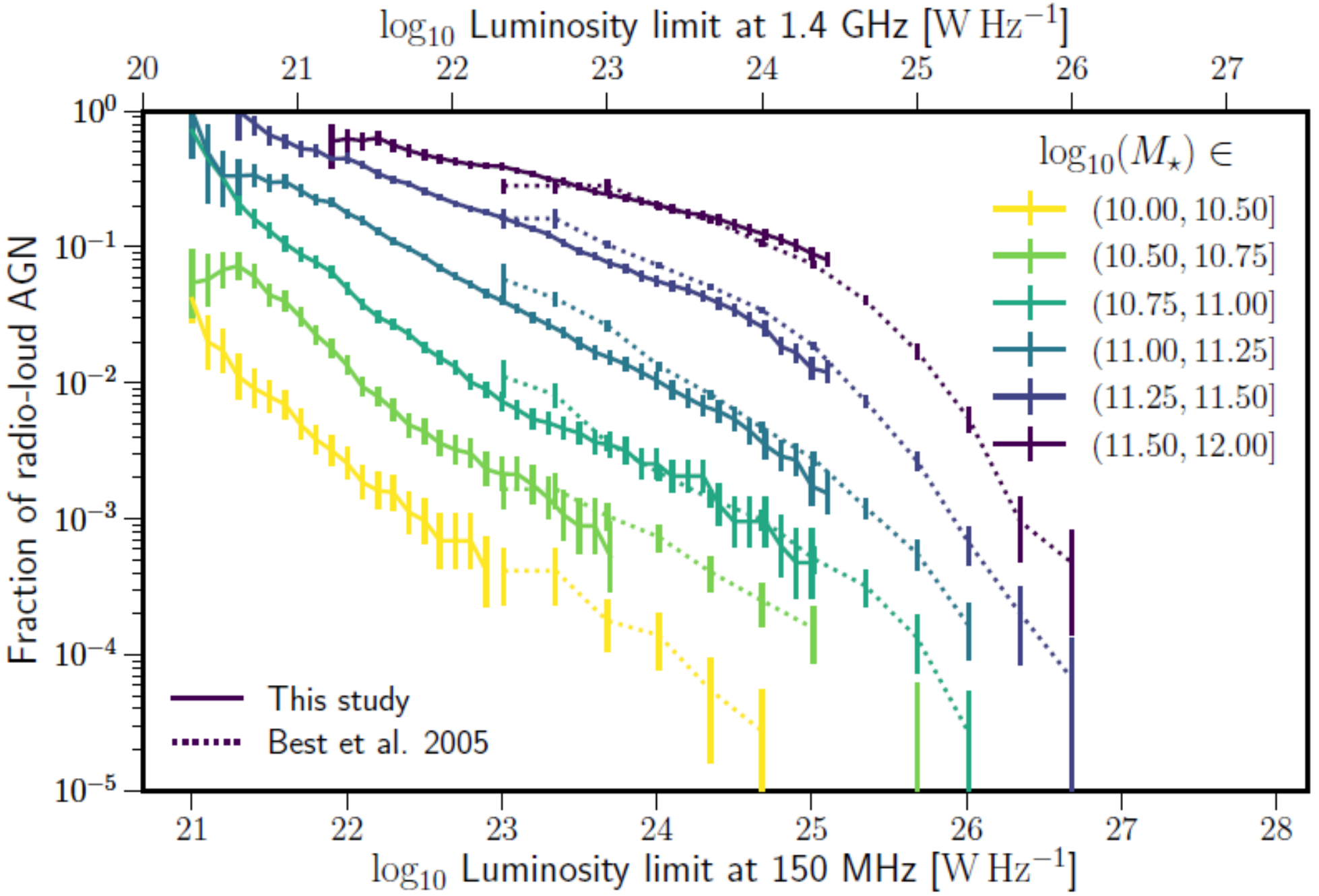
150-MHz luminosity function



Sabater+ 18


Fraction of radio-loud AGN
10^0
10^{-1}
10^{-2}
10^{-3}
10.5
11.0
11.5
12.0
12.5
$\log_{10}$ Stellar mass [$M_\odot$]
$\log_{10}(L_{150})$
≥ 21.0
≥ 21.5
≥ 22.0
≥ 22.5
≥ 23.0
≥ 23.5
≥ 24.0
≥ 24.5
≥ 25.0

Sabater+ 18


log10 Luminosity limit at 1.4 GHz [W Hz−1]
20
21
22
23
24
25
26
27
Fraction of radio-loud AGN
10^0
10^−1
10^−2
10^−3
10^−4
10^−5
log10(M⋆) ∈
(10.00, 10.50]
(10.50, 10.75]
(10.75, 11.00]
(11.00, 11.25]
(11.25, 11.50]
(11.50, 12.00]
This study
Best et al. 2005
21
22
23
24
25
26
27
28
log10 Luminosity limit at 150 MHz [W Hz−1]

Summary (2)

- RLAGN know about their host galaxies
- For low enough radio luminosities RLAGN activity is *ubiquitous* in massive galaxies
- Consistent with ideas proposed by Best+05, Hardcastle+07… on fuelling of RLAGN by cooling of the hot phase of IGM

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(3) LOFAR sources in HETDEX

- Hardcastle+18 submitted
- 320,000 radio sources in HETDEX
- 172,000 optical ID + flux-complete
- 72,000 good z (spec or photo)
- 23,000 ‘RLAGN’ selected by Sabater method/colour – exclude RQQ

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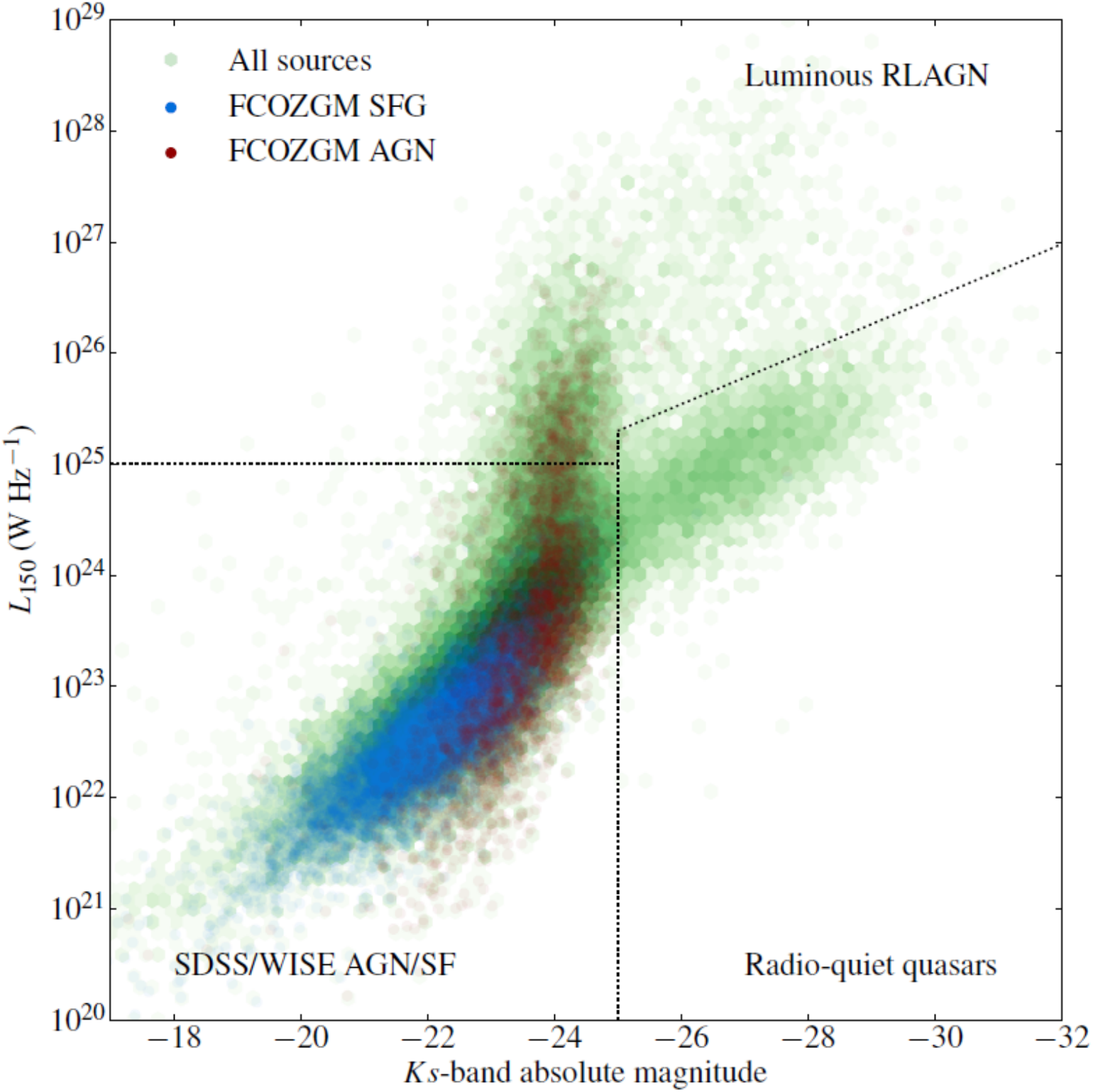
72,000 sources with good z



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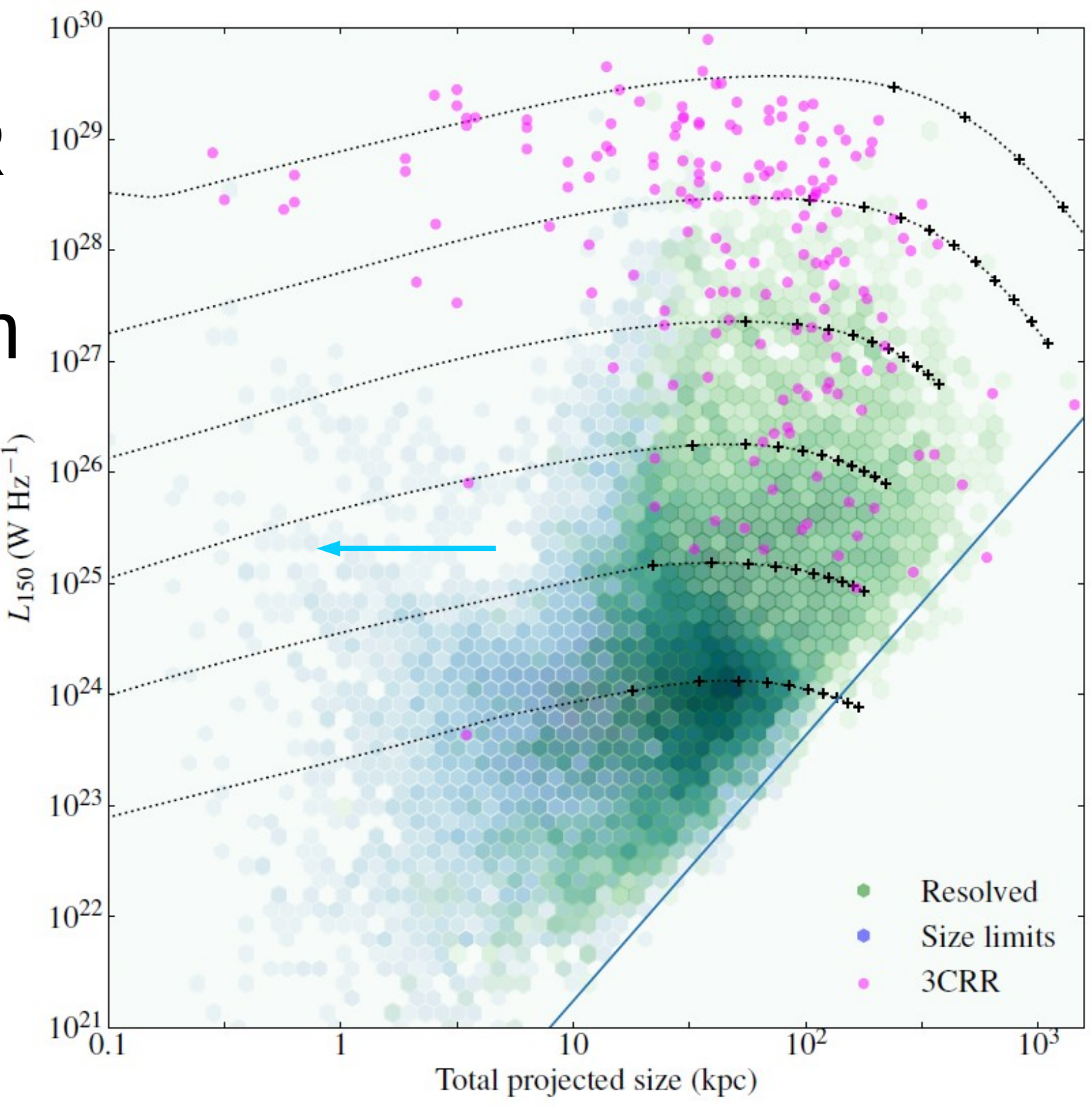
LOFAR P-D diagram

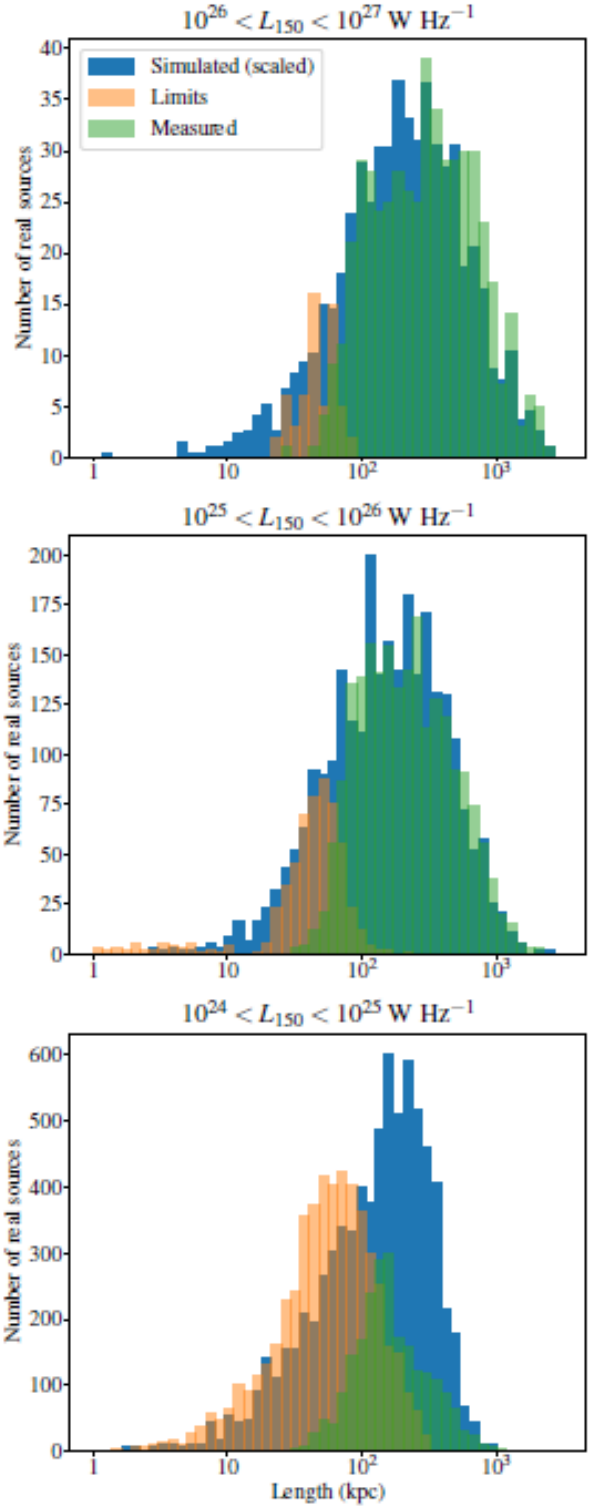


z=0 tracks for Q=10^{35} … 10^{40} W, kT=1-keV group environment; 23,000 AGN with good z

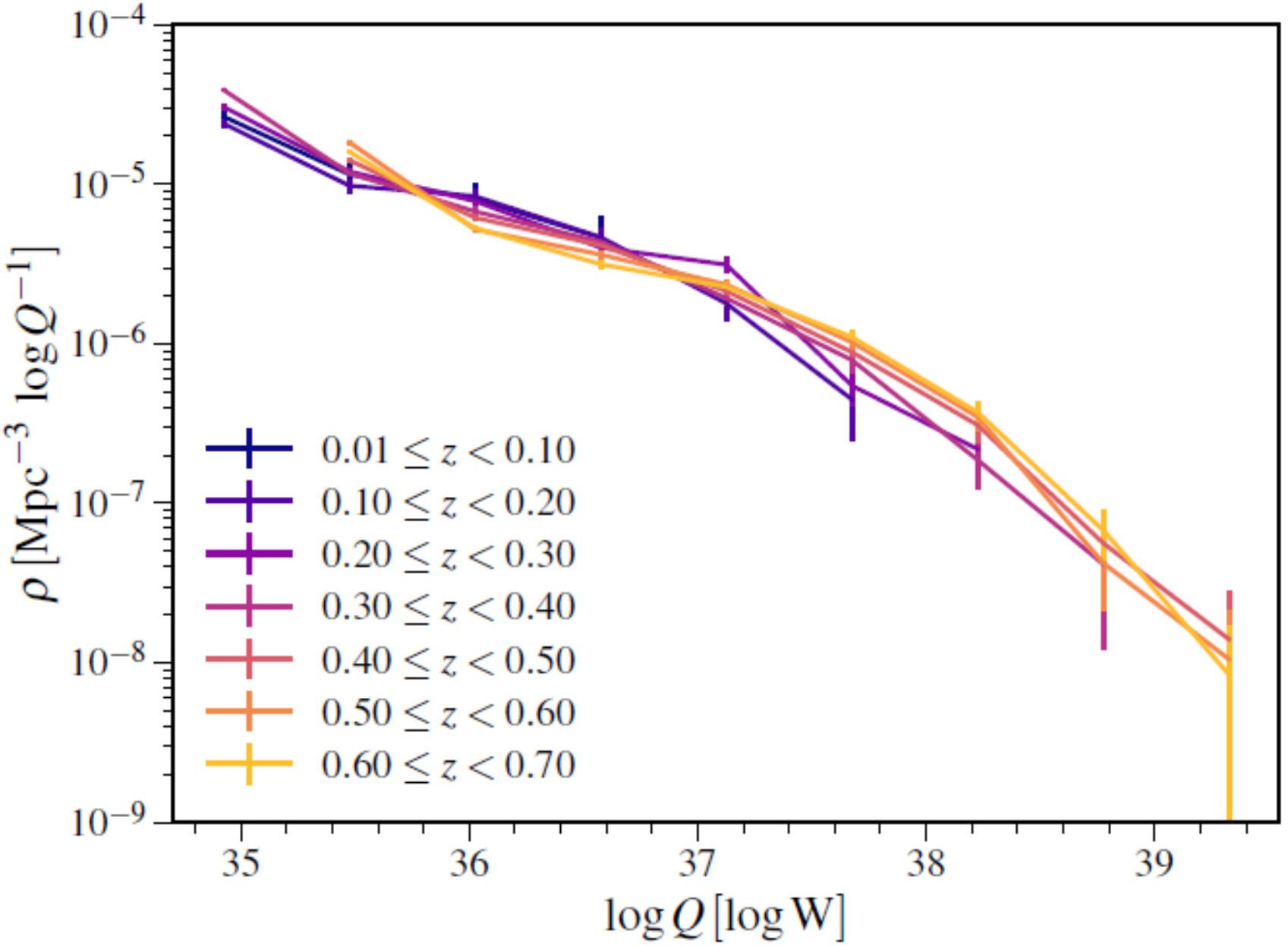
Theoretical models from Hardcastle 18

Model/real comparison

- Crucial to comparison with real distributions is the lifetime function – what is the distribution of ‘on’ times of jets
- Uniform lifetime function in range 0 – 1000 Myr provides excellent description of powerful objects
- At low radio luminosities there are way too many small sources
- Either lifetime distribution is different or there is a contaminating population: what are they?
- ‘Failed’ RLAGN where the jet is quenched by entrainment?



Inference of jet powers



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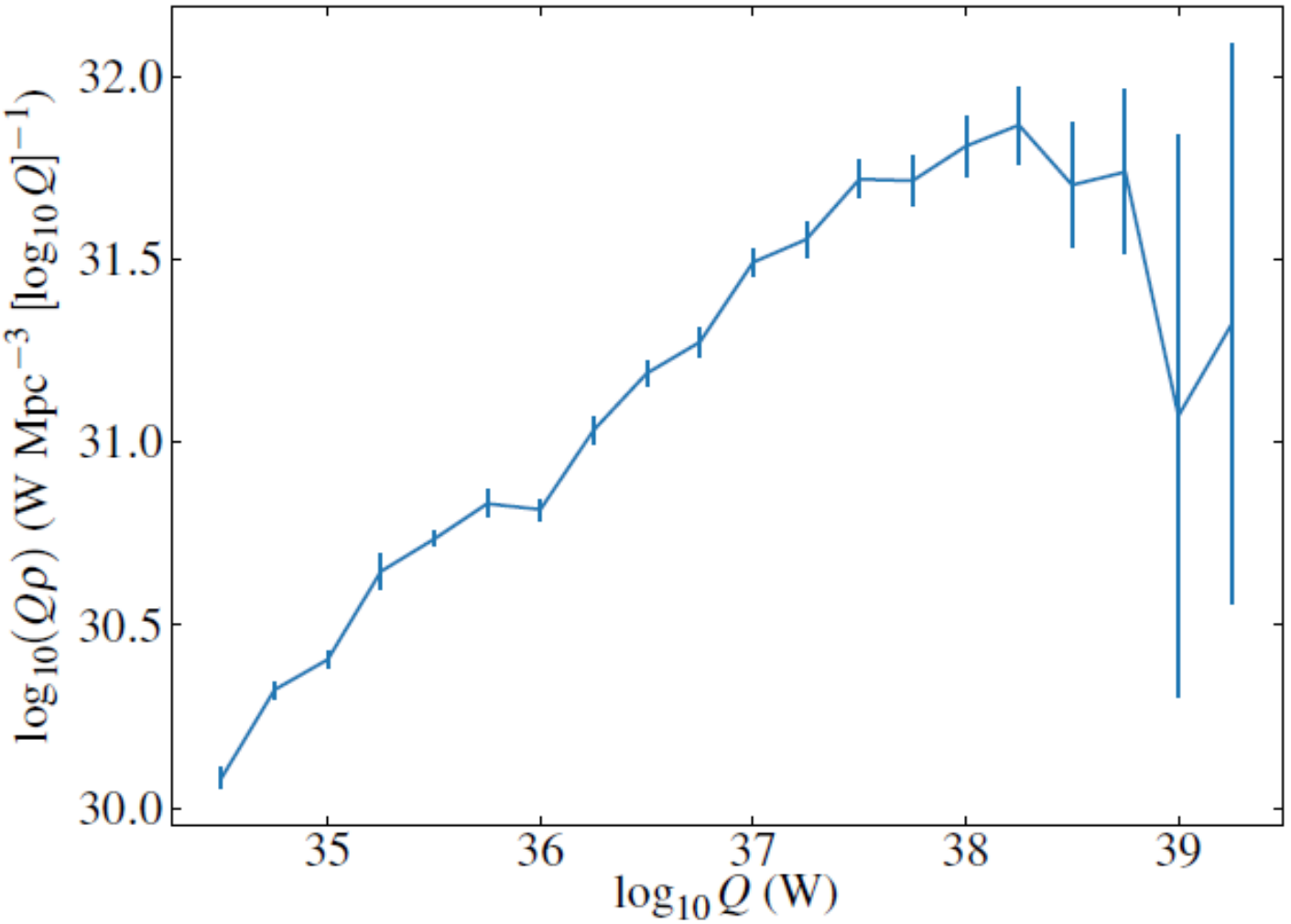
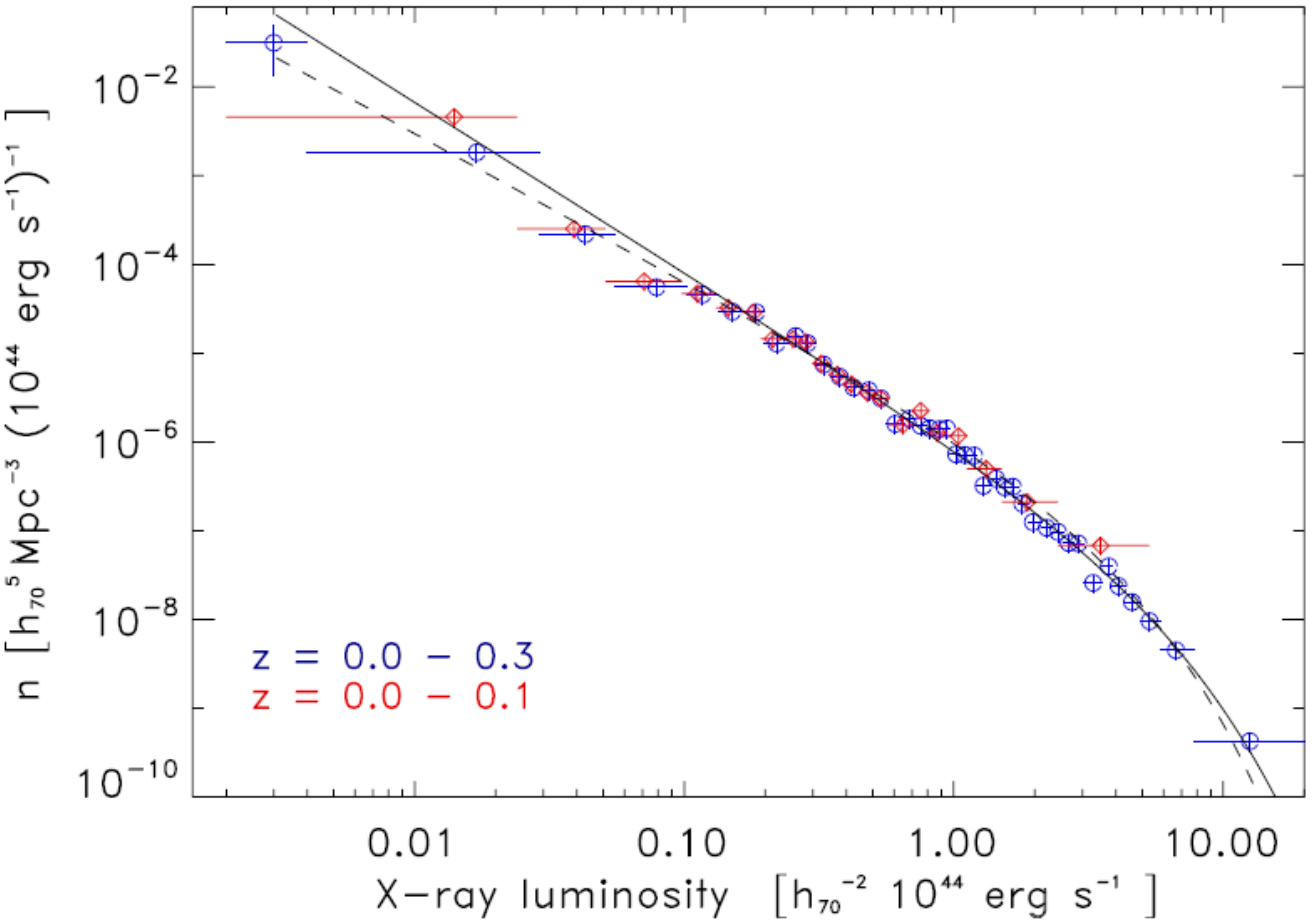
Kinetic luminosity function



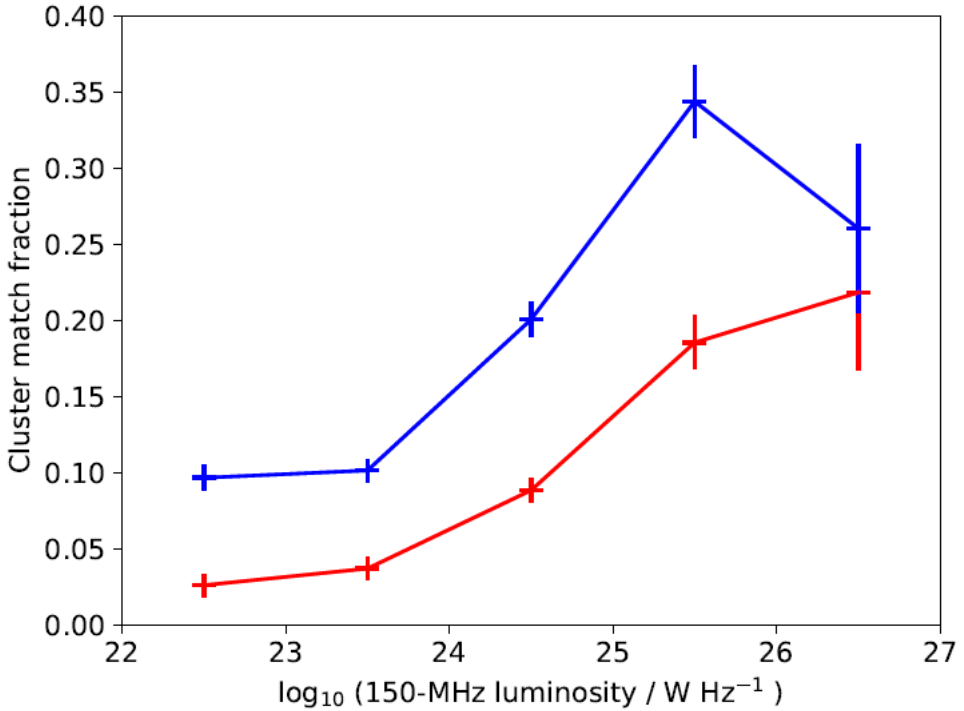
$$\int Q\rho(Q)\mathrm{d}Q = 7 \times 10^{31}\ \mathrm{W\ Mpc^{-3}}$$

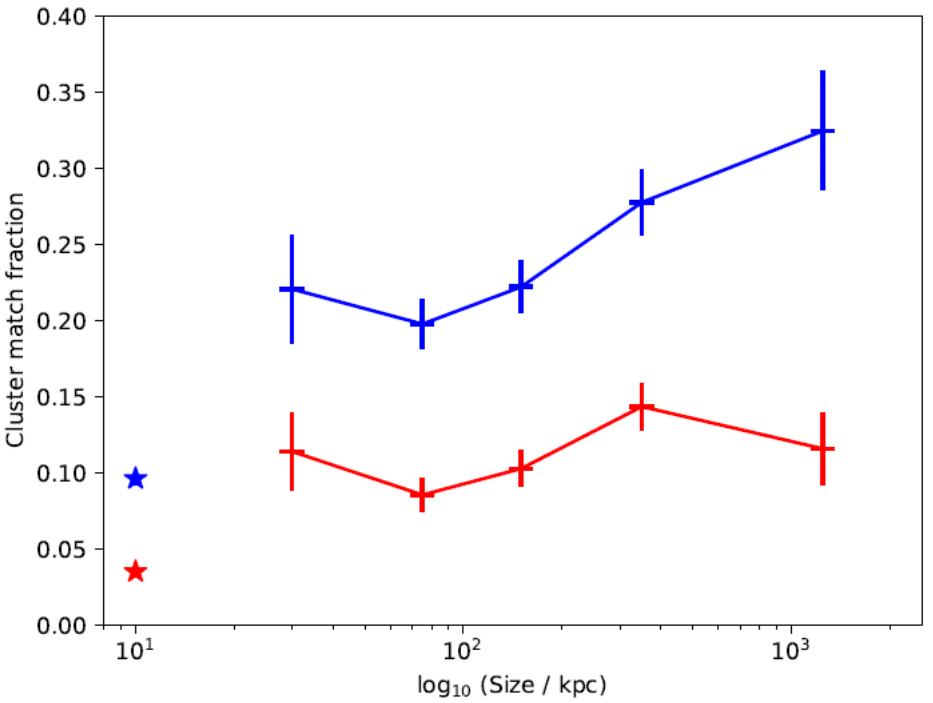
Compare to cluster luminosity fn



$$\int Ln(L)\mathrm{d}L = 4 \times 10^{31}\ \mathrm{W\ Mpc^{-3}}$$

Environments





Crossmatch to SDSS group/cluster catalogues
Red = Rykoff+14 (RedMapper)
Blue = Wen+12

Croston+ 18 in prep

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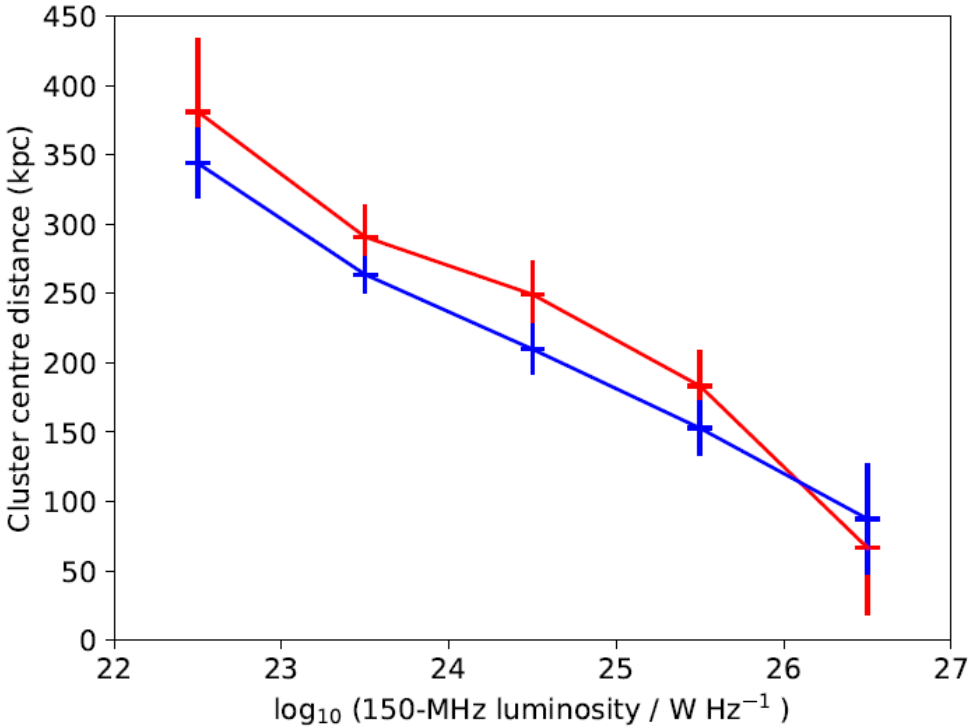
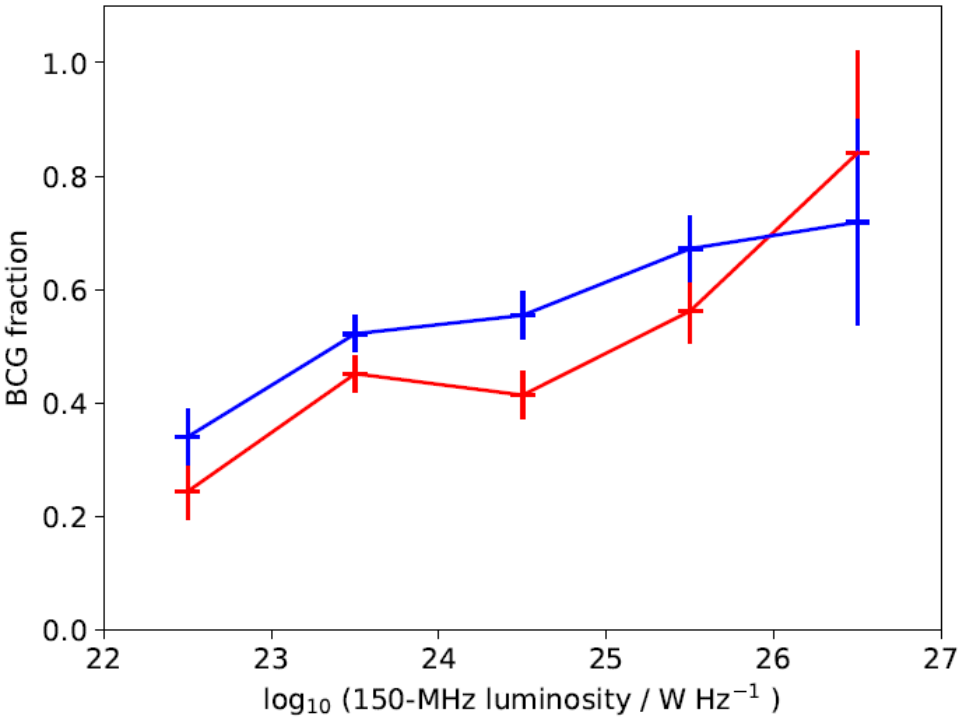
Environments





Croston+ 18 in prep

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Summary (3)

- Can model the dynamics & energetics of large, luminous RLAGN
- These objects tend to live in the centres rich environments (but better measures necessary)
- They provide the energy needed to offset cluster cooling.

- But we need to understand the numerous, small, low-luminosity objects better

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Are RLAGN special?

- No – this is just what massive galaxies do
- Low-luminosity radio in excess of star formation expectations is ubiquitous and presumably fuelled by the cooling of hot gas
- We don’t really understand the population of low-luminosity, compact objects in field environments and how it connects to more powerful jetted sources
- How does this relate to radiative AGN activity?

Are RLAGN special?

- Yes – they have a special job (keeping the hot gas from cooling)
- Powerful RLAGN do most of the work
- They appear to live just where they're needed in the centres of clusters
- Their energetic output is in remarkably good agreement with what's needed
- See Vernesa's talk