Median stacking of serendipitous radio observations of SDSS AGN

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M87

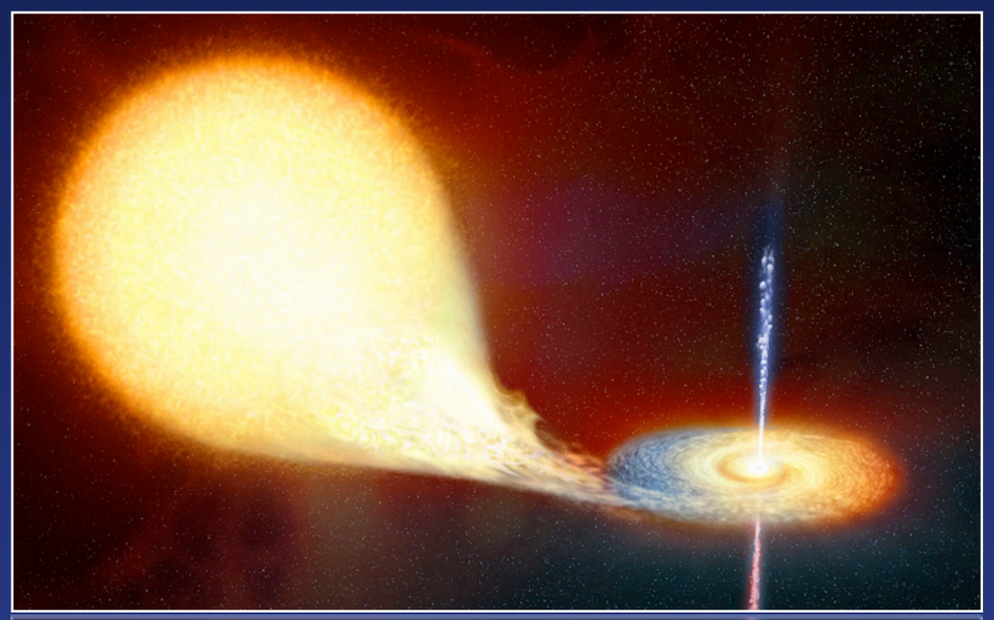
Credit: STScI/AURA and NASA/ESA

Cen A

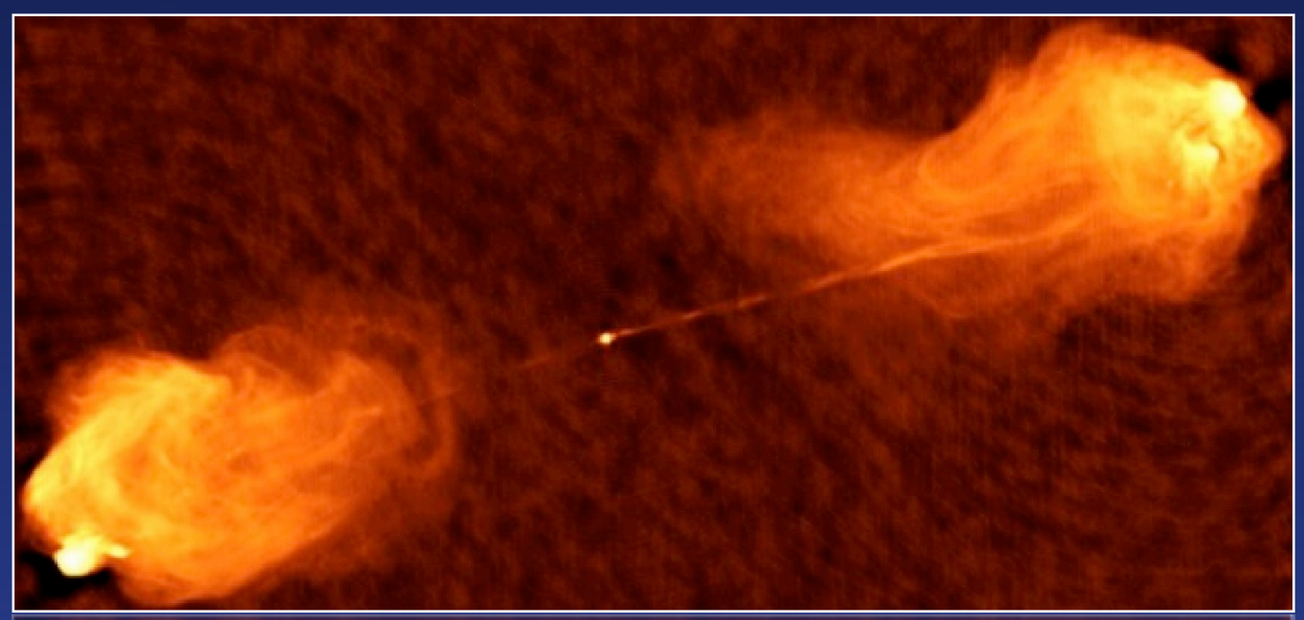
Credit: ESO

Microquasars & AGN

- Black Holes are found in systems varying hugely in mass, from microquasars (μQ) to Active Galactic Nuclei (AGN)
- Exact physical properties vary hugely, but parameters usually show simple scaling with mass
- Why are some sources radio-loud and others not?



Artist's impression of a μQ
Credit: ESA / Hubble



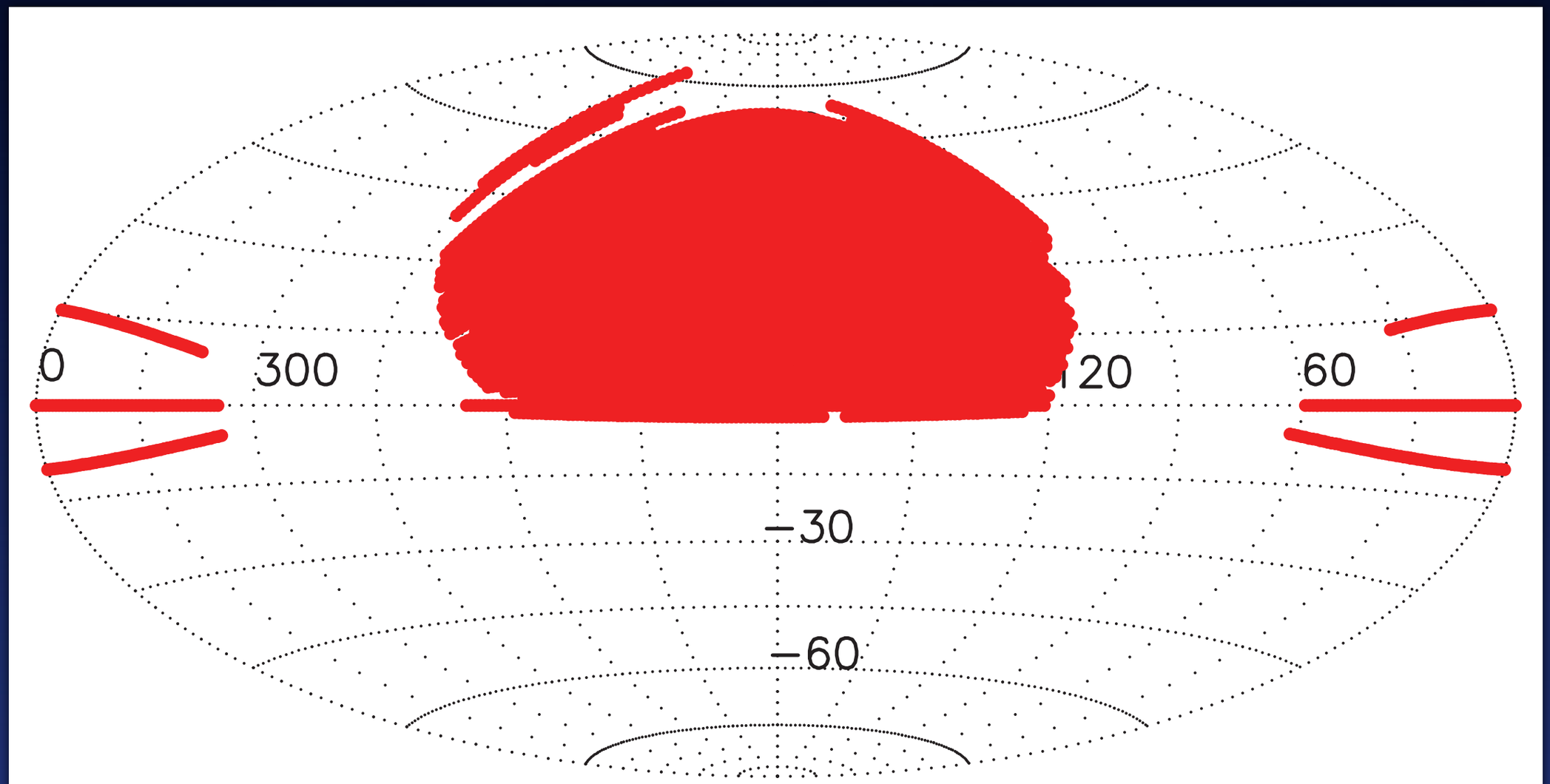
AGN: Cyg A in radio
Credit: NRAO / AUI

Problems and Biases selecting an AGN sample

- Samples selected for observation
- Black hole mass
- Host galaxy
- Environmental

Possible Solution: Do we see a clear effect at the transition accretion rate if we have a clean sample?

Optical: SDSS DR7



comprises spectroscopy of nearly 10^6 galaxies,
10^5 QSO mainly located in northern hemisphere

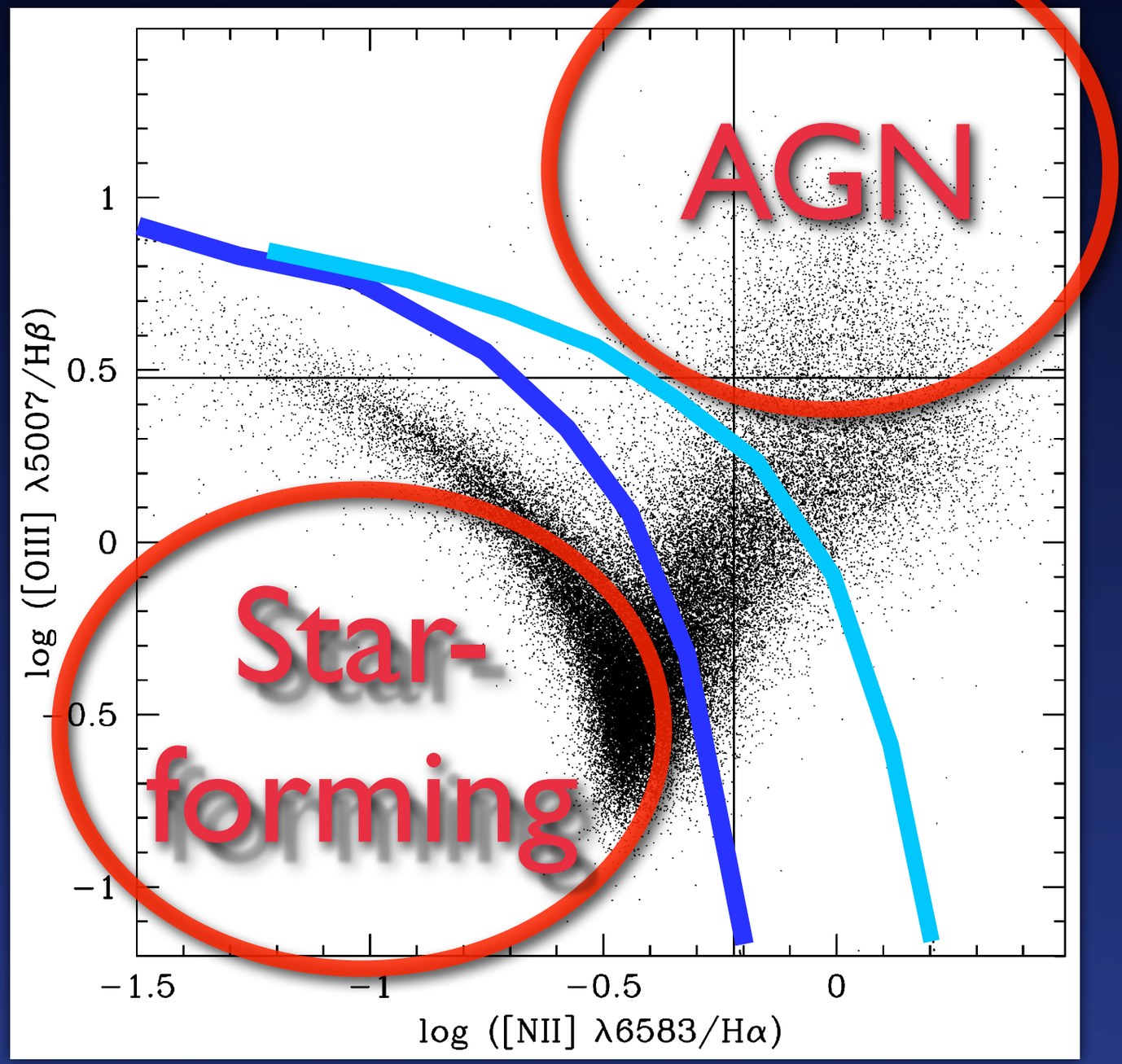
SDSS sample selection

- Galaxies: selection based mainly on extended emission, r band magnitudes
  - ☑ $\mathbf{r}_{PSF}$ - $\mathbf{r}_{cmodel}$ >= 0.24
  - ☑ Petrosian magnitude limit $\mathbf{r}_P$ = 17.77
  - ☑ Surface brightness cuts
- QSOs: complex selection algorithm based on colours to distinguish these point sources from stars

Finding the AGN: BPT diagram

- Baldwin, Phillips & Terlevich (1981) devise first empirical classification scheme, using optical line flux ratios, to remove star-forming regions that also ionise those lines

- Main line ratios: [OIII]/Hβ vs [NII]/Hα



(Kauffmann+ 2003)

Creating our AGN sample

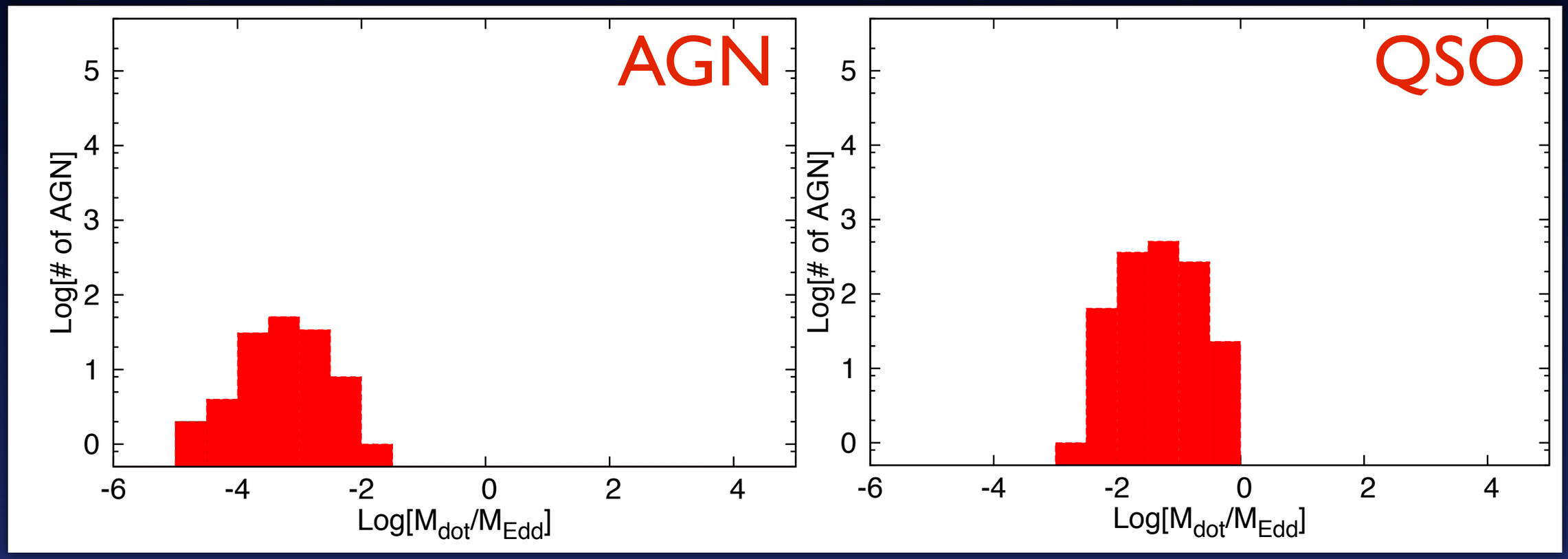
- For galactic AGN use only high-quality DR7 SDSS spectra (S/N in main lines > 3), AGN mass from M-σ relation; Tremaine+ 2002.
- For QSOs use lines and masses available from Shen +2008 and update to DR7 on website.

Selection Criteria

	AGN	QSO
Starting number	86214	94999
Mass (Msol)	7.0<Log[BH Mass]<9.5	
S/N ([OIII], Hβ)	> 3	
Hα/Hβ	>3 sigma , < 10 , > 2.86 - 2 sigma	
z	>0.04	0.04<z<0.8**
resulting number	48796	3603

** : S/N constraint on [OIII] limits QSO redshift range

Exploring the transition accretion rate



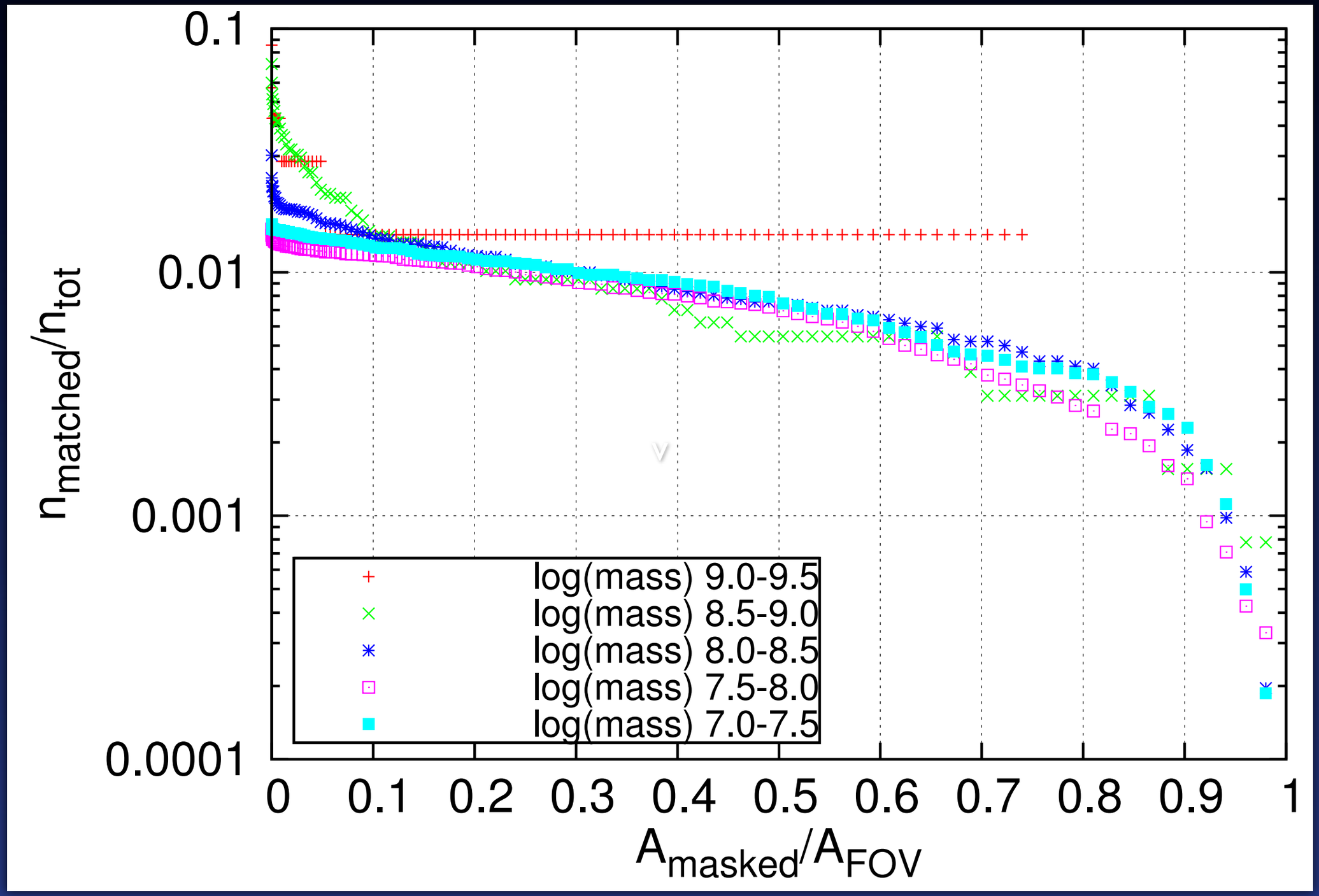
9.0<Log[BH Mass]<9.5

- Estimate accretion rates from [OIII] 5007 flux (Netzer 2009) for AGN and Lbol (estimated by Shen+ 2008) for QSOs

Serendipitous observations: SDSS DR7 and VLA

- Match optical sources to radio
- Use only higher frequency VLA to focus in on core emission (X band, 8 GHz) to examine possible state transitions
- $>10^5$ VLA observations in >30 yr

Serendipitous?



- Result: mask inner 10% of FOV (radius 0.85' ~ 50")

Matching SDSS DR7 with VLA, results

	serendipitous		non-serendipitous		Total	
	optical AGN	X band obs	optical AGN	X band obs	optical AGN	X band obs
galactic AGN	614	1716	397	843	977	2558
QSO	51	105	157	961	202	1065
Total	665	1821	554	1804	1179	3623

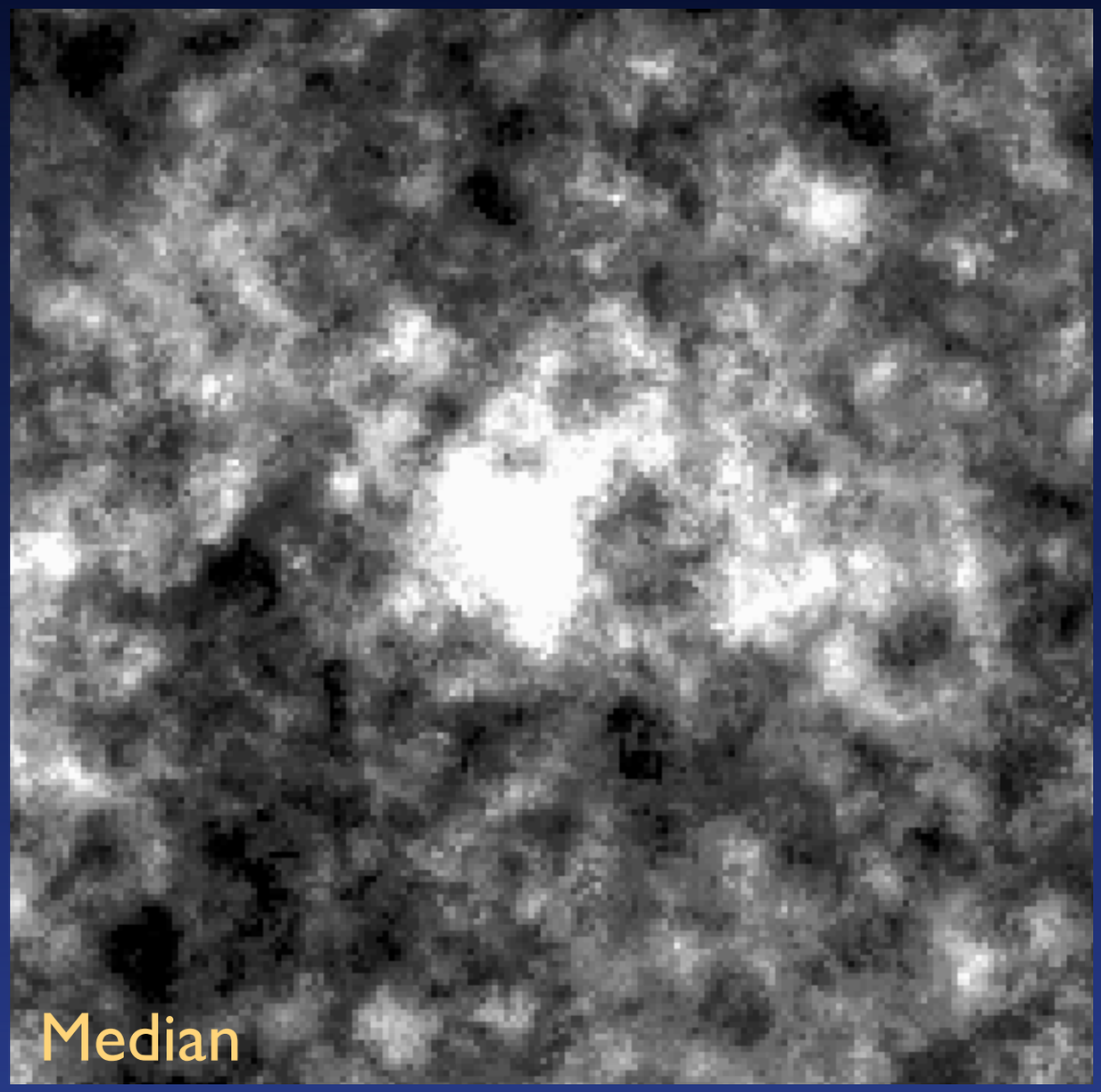
(34 gal AGN and 6 QSOs are serendipitous in some obs while not in others)

Median vs Mean Stacking

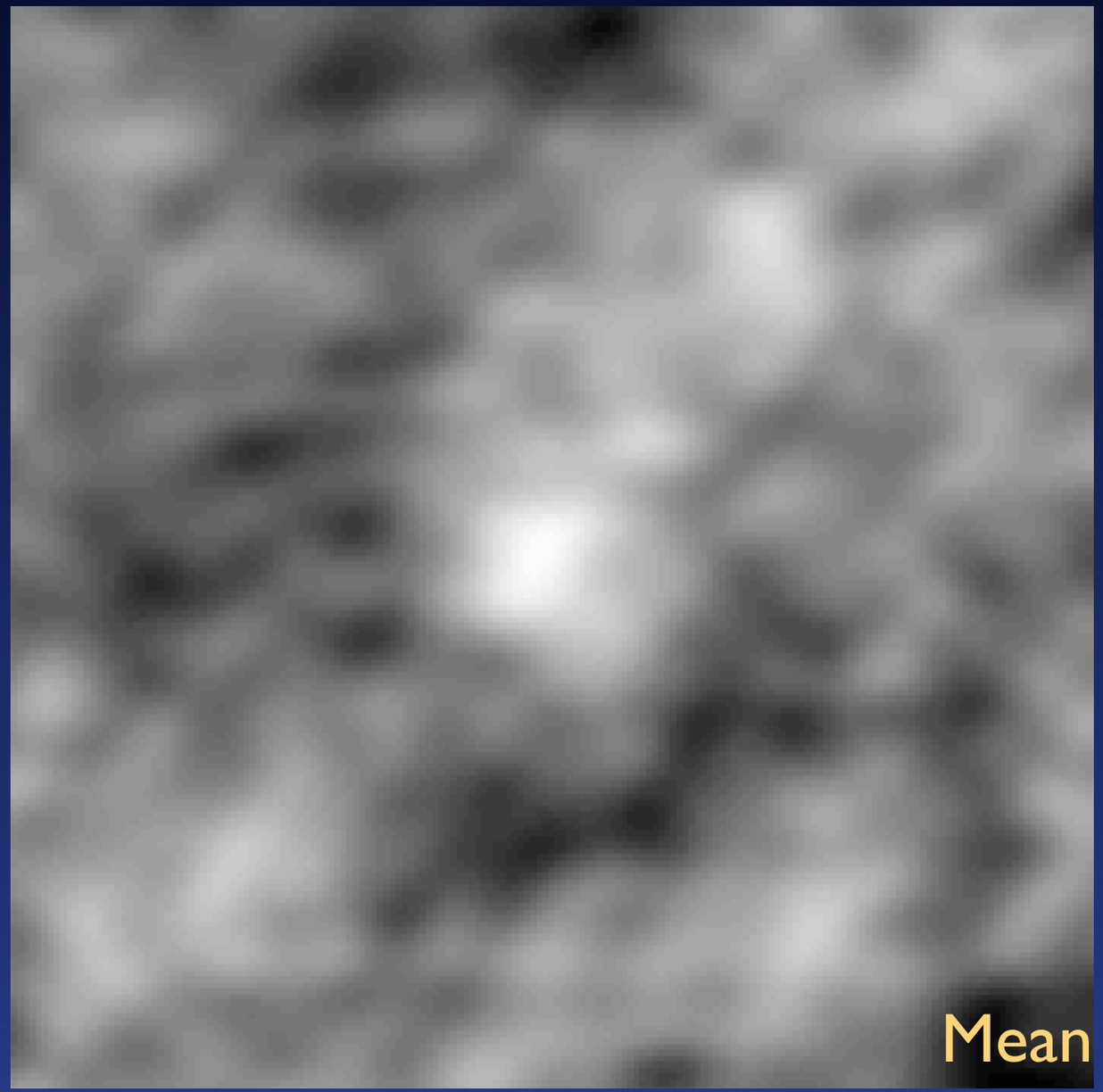
- sub-detection limit radio fluxes expected, so need stacking method (per mass bin) => statistical study
- median preferred: less sensitive to outliers

Median vs Mean
7<Log[M]<9 Msol

377 images

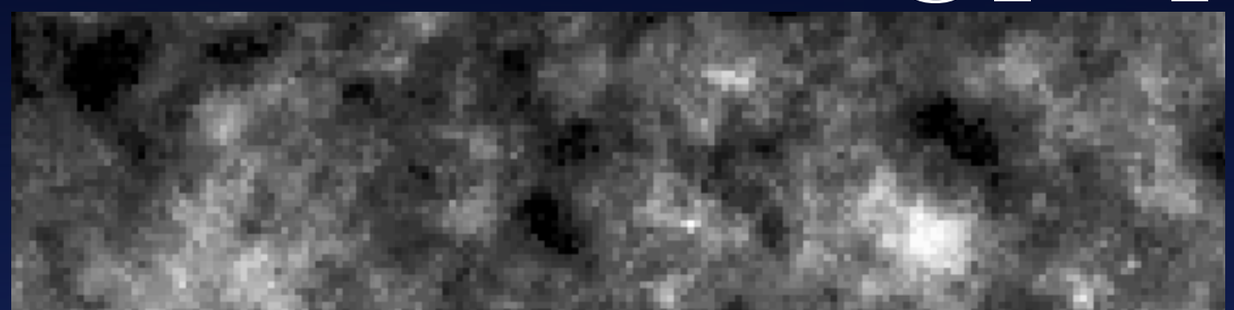


377 images



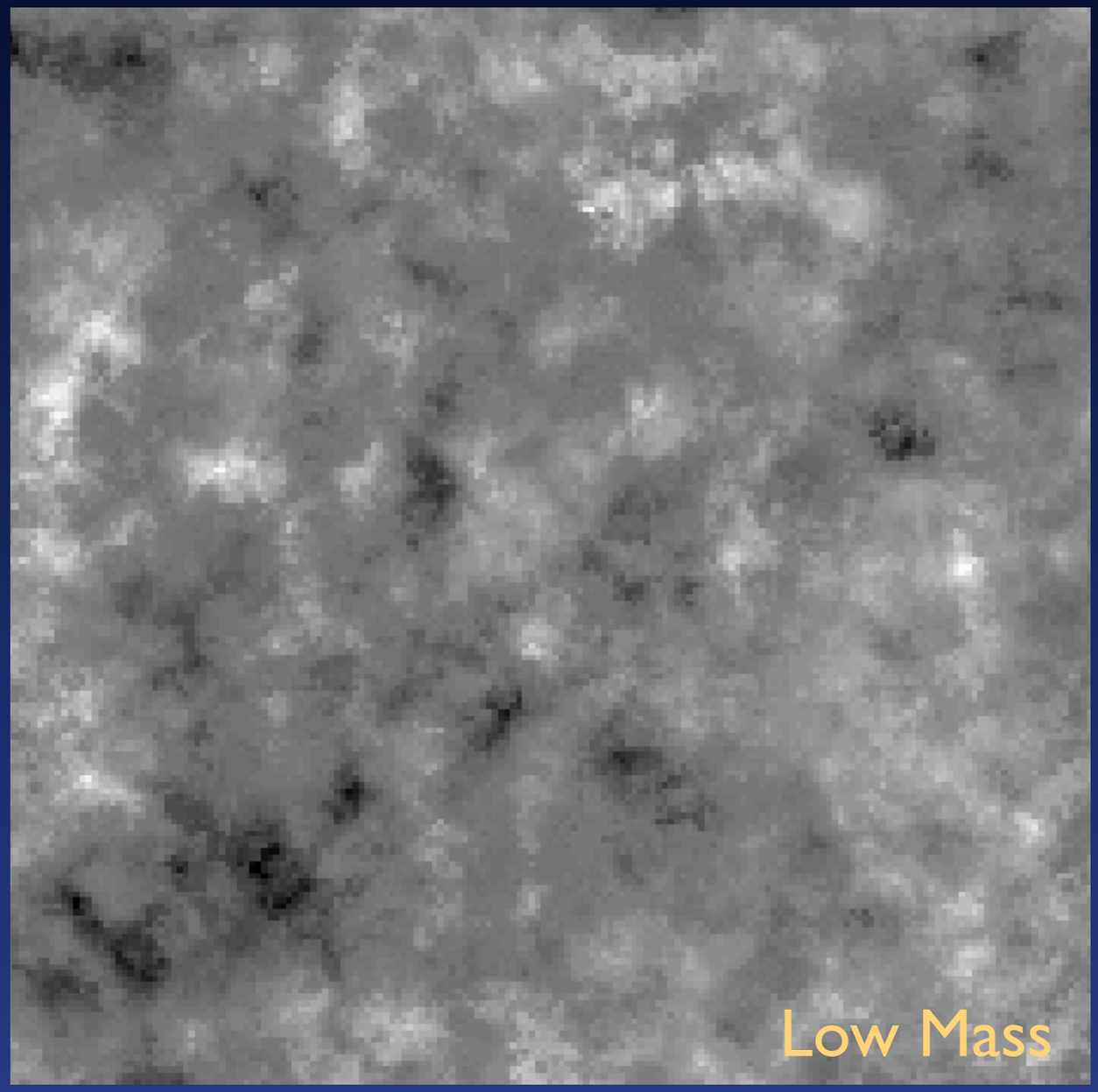
Median images: total sample and low-mass comparison 7<Log[M]<7.5 Msol

377 images



Total

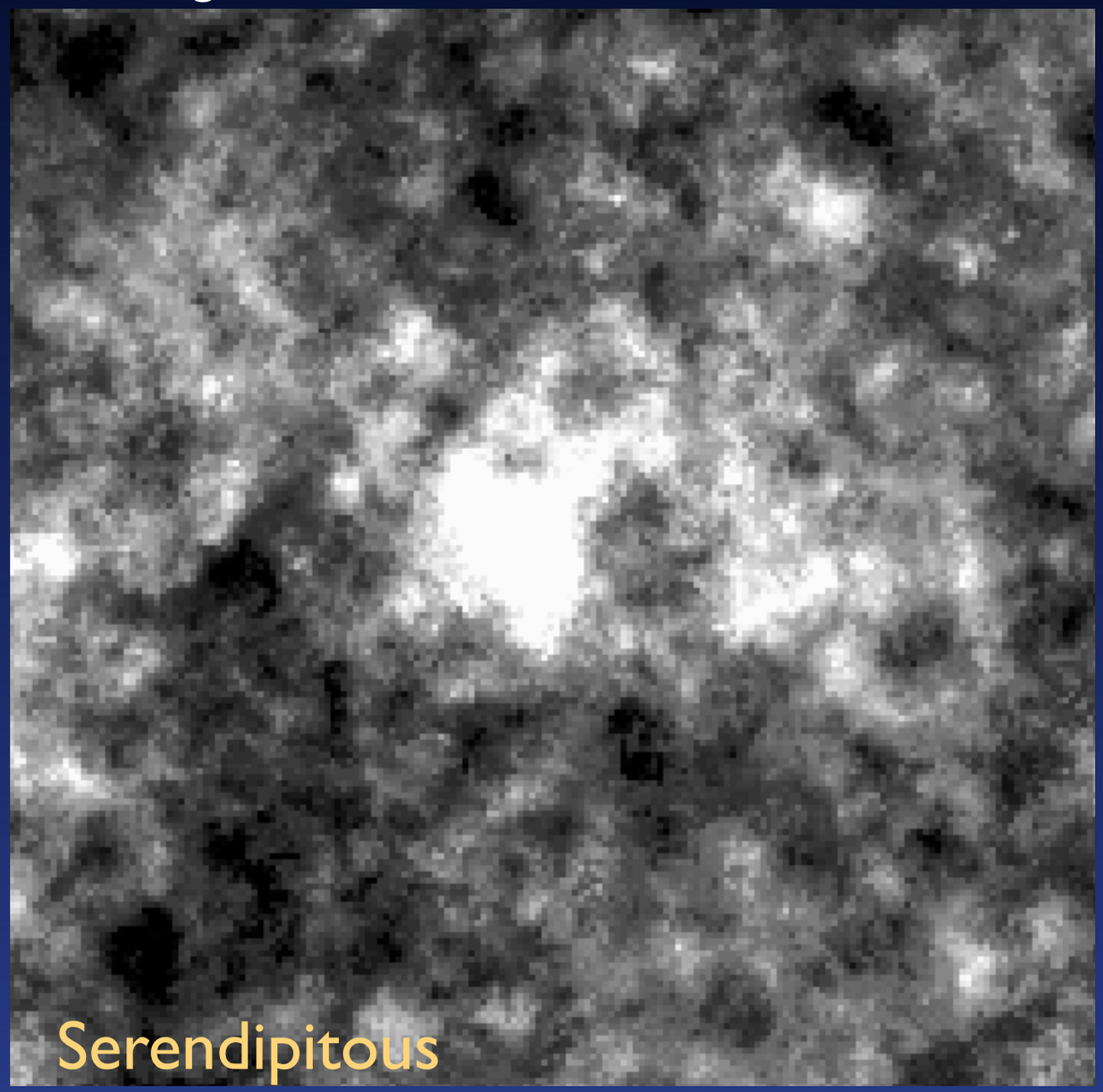
126 images



Low Mass

Serendipitous vs non-...

377 images



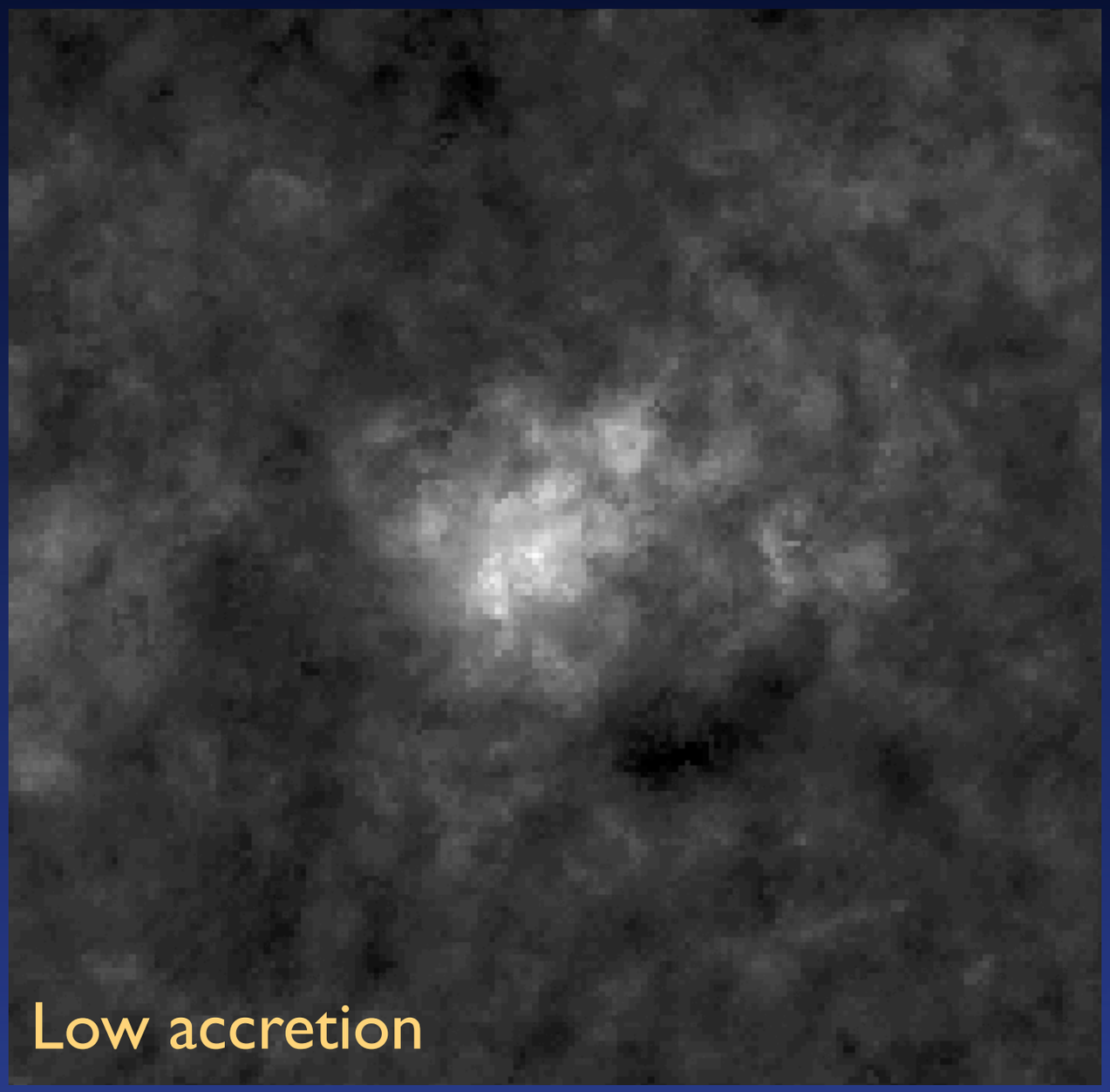
Serendipitous

291 images

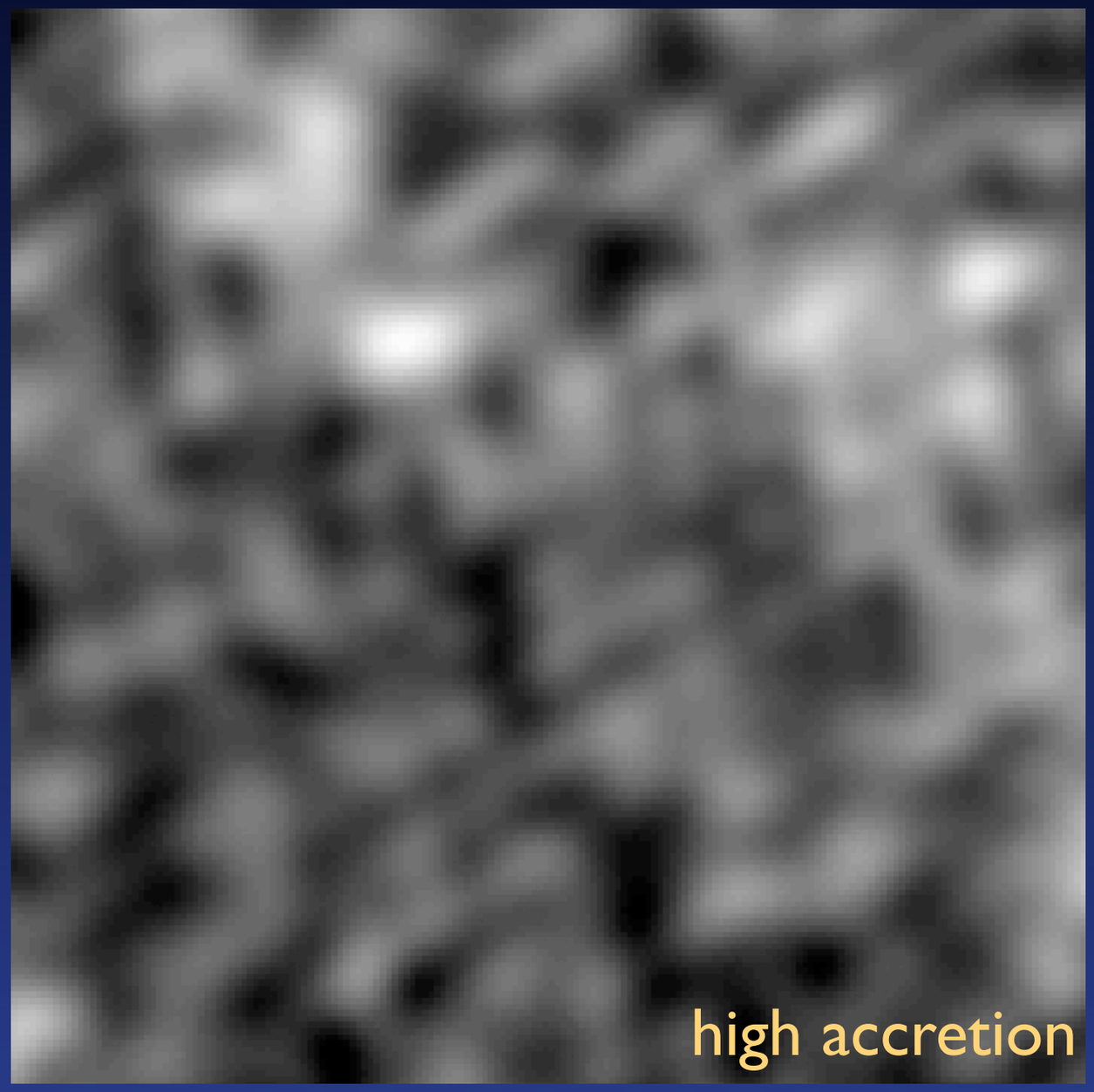
Non - Serendipitous

low vs high accretion

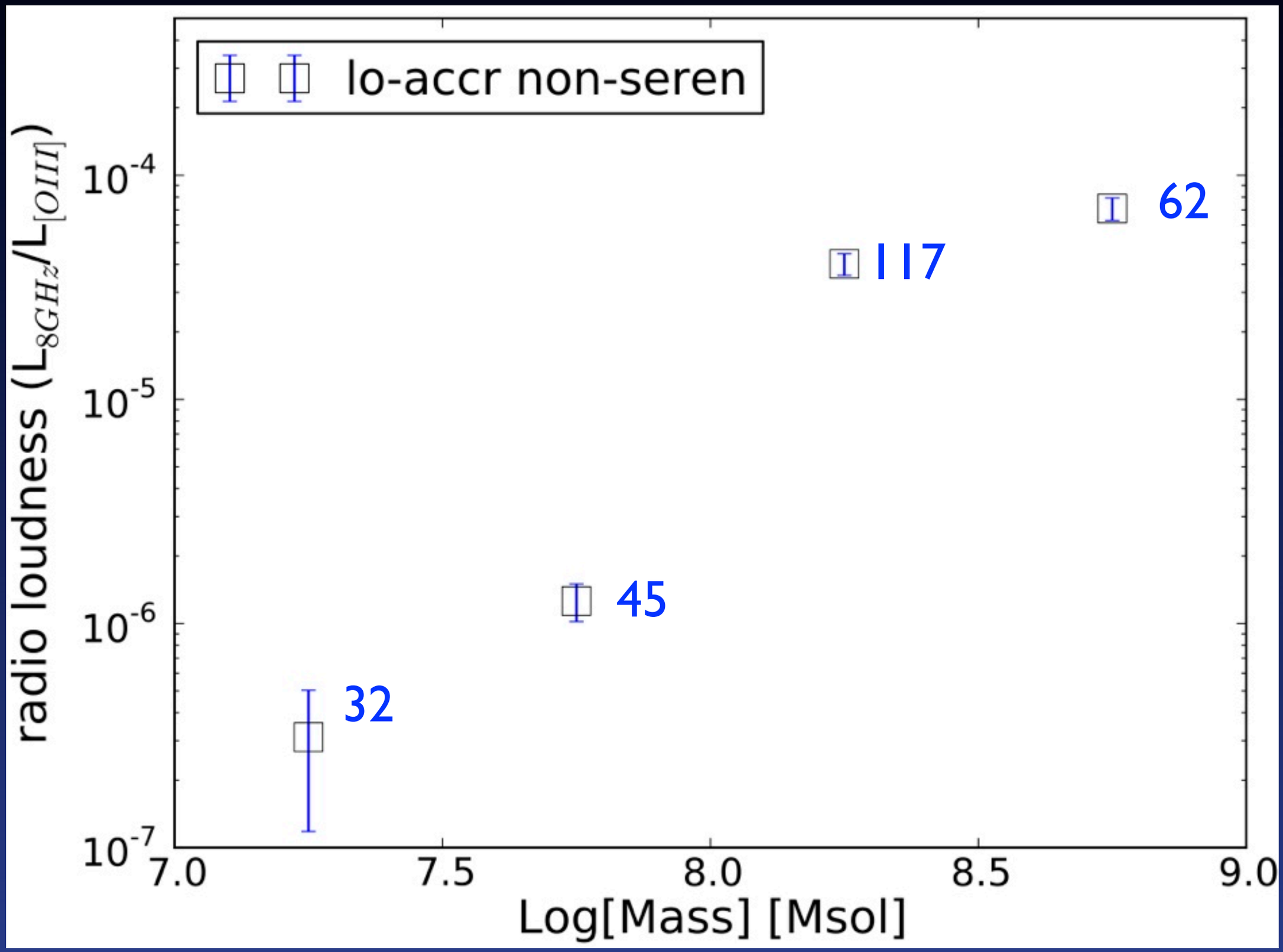
102 images



2 images



Median Radio-loudness



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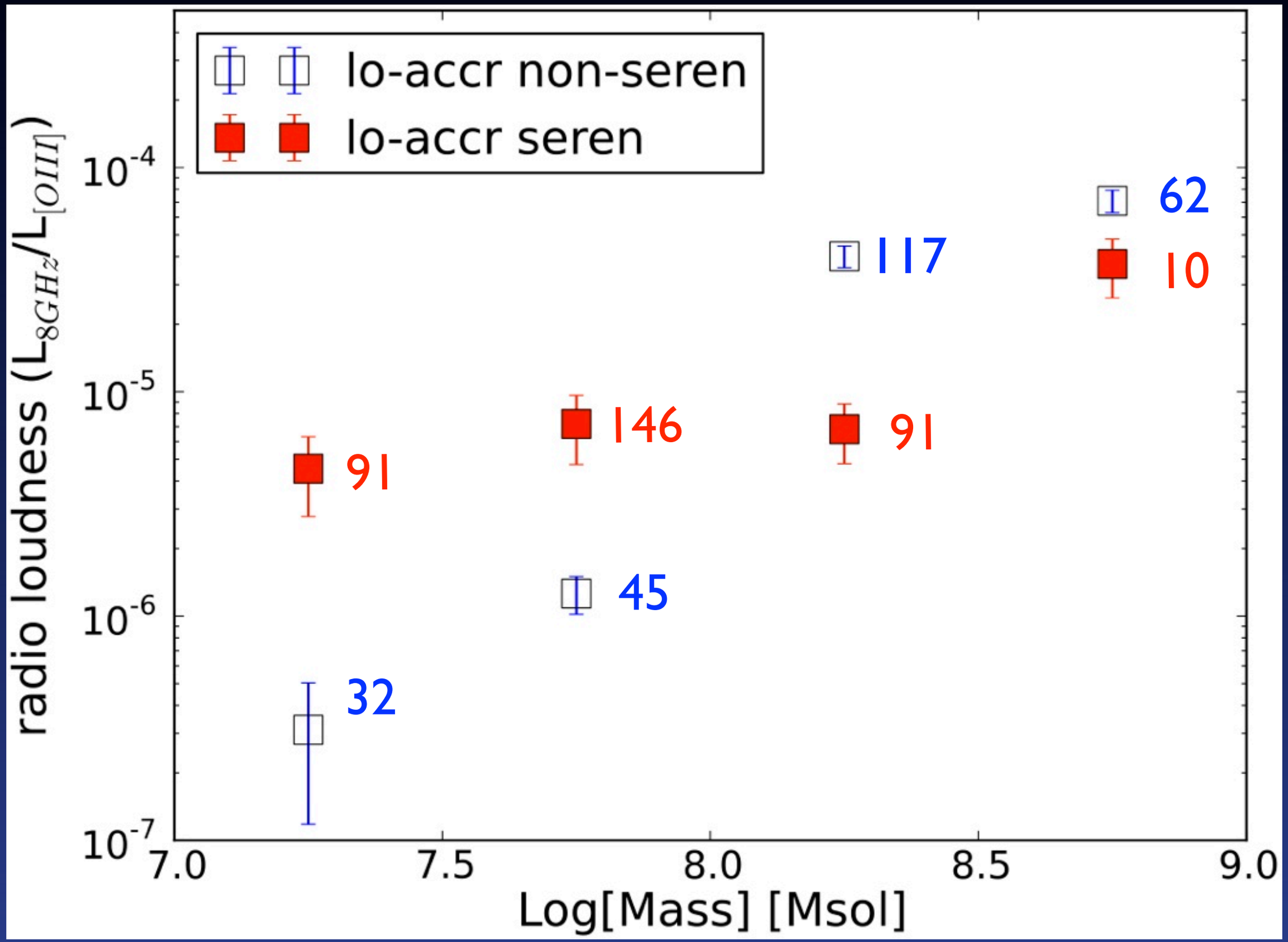

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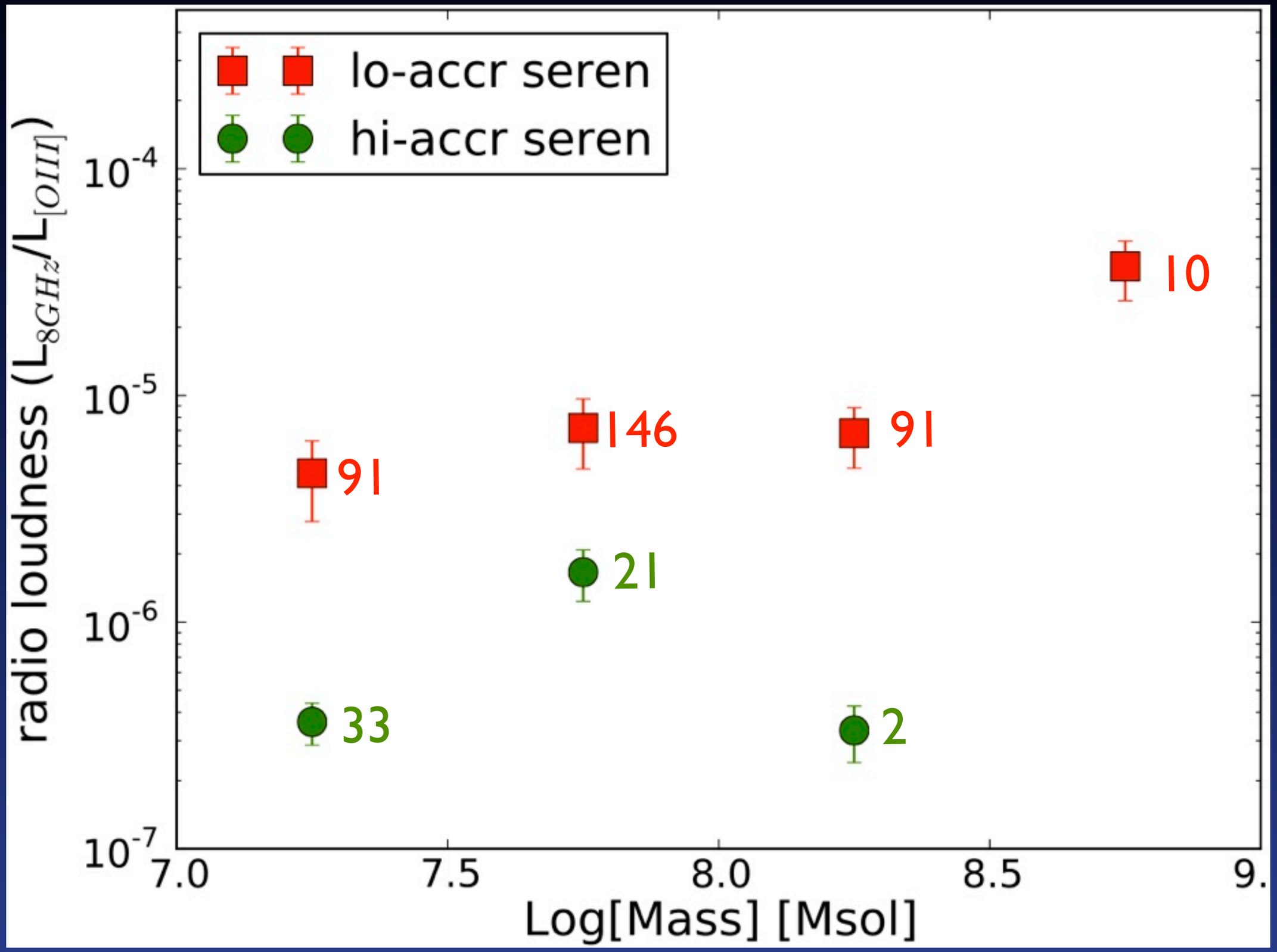

Summary

- Method allows detection detection of sources below limit
- Significant differences between serendipitous and non-serendipitous sources: No evidence for mass-dependence of radio loudness
- Interesting results, although even bigger dataset would give much better results
- Ideally use high frequency complete survey. High frequency with large FOV: SKA?

Future work

- Use similar procedure to obtain average AGN X-ray luminosity
- Use results to build average AGN SED templates. Compare with XRB SEDs.