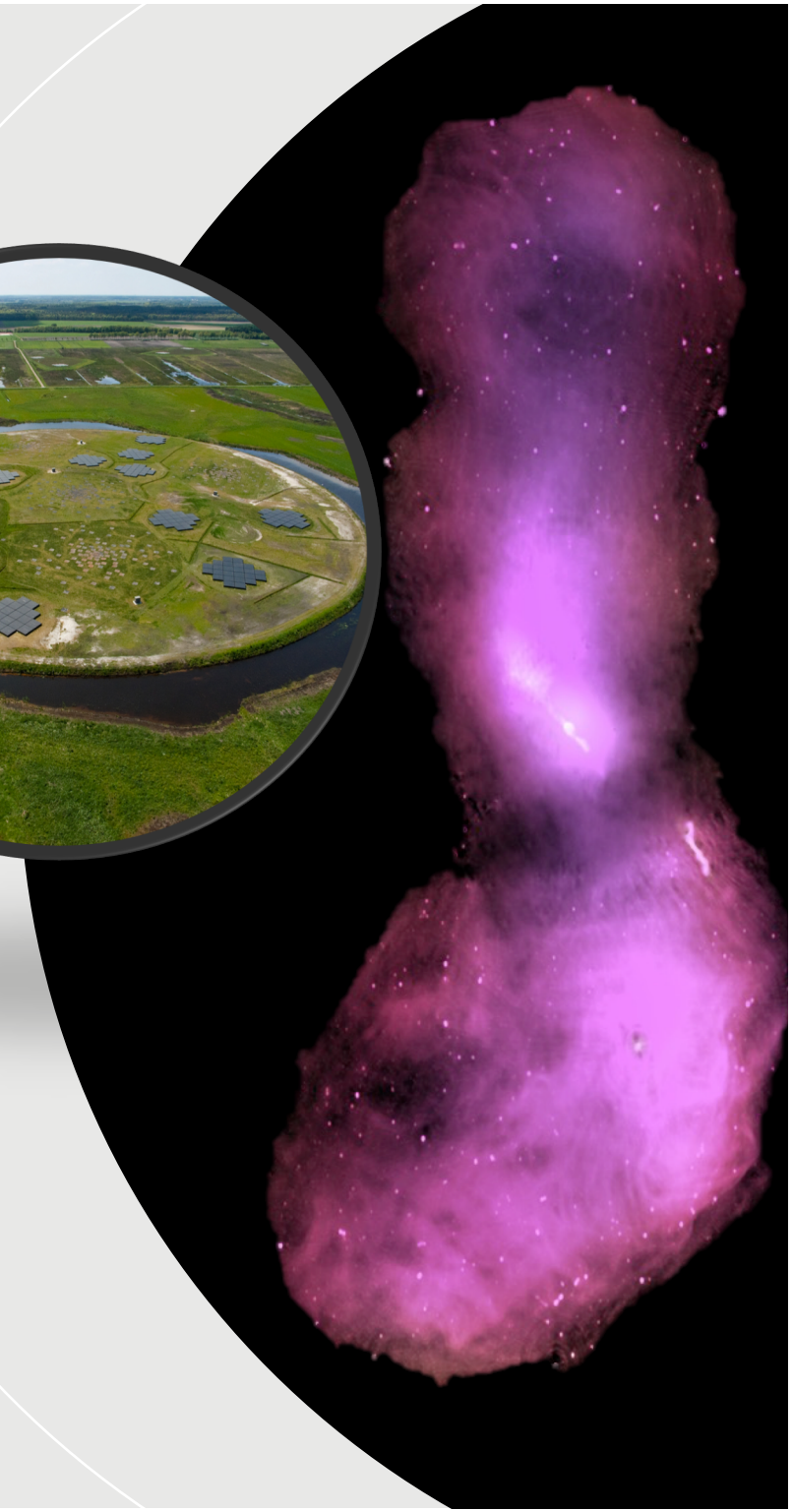
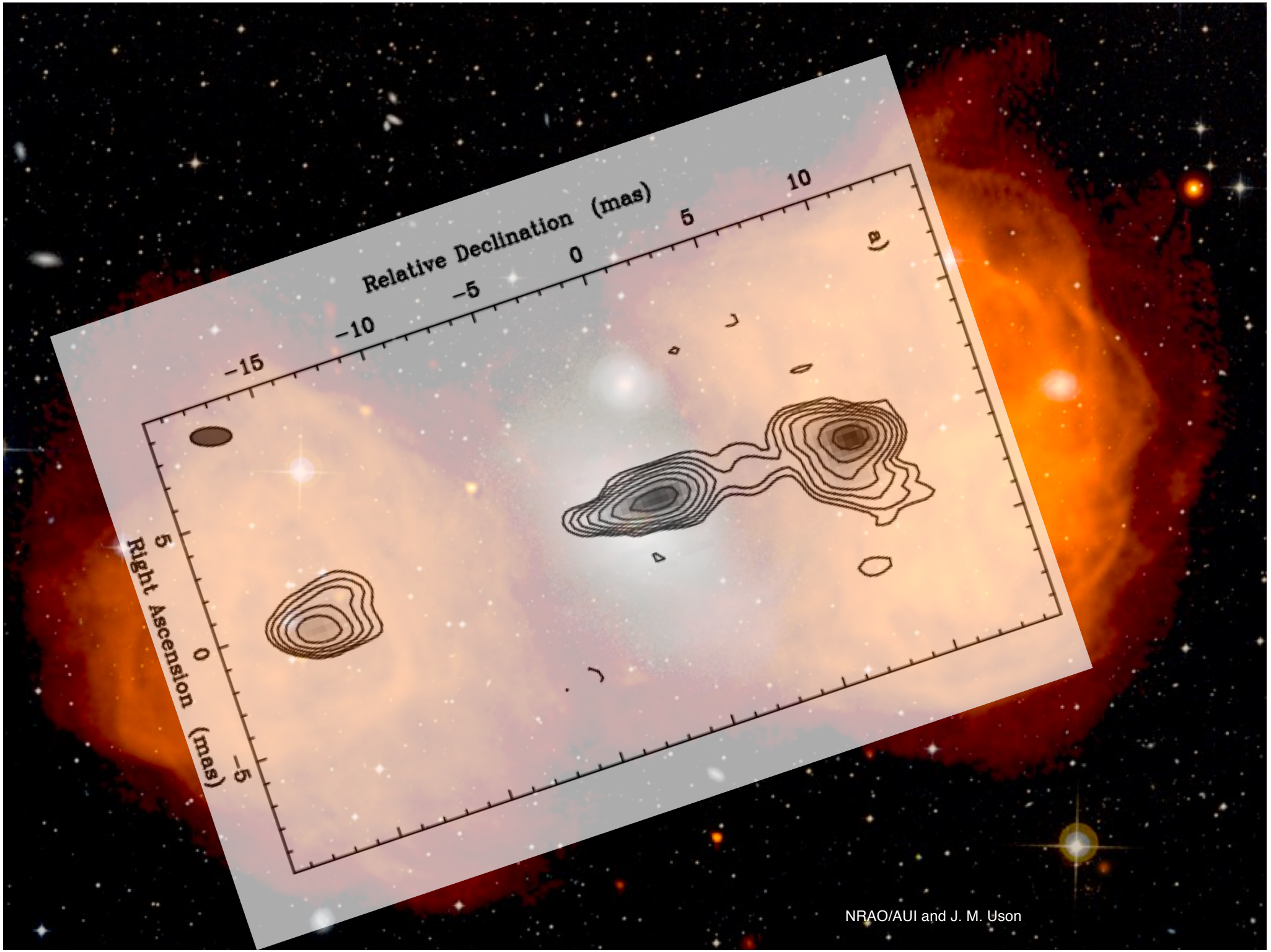
Learning lots about radio galaxy evolution from LoTSS: A low luminosity peaked-spectrum sample



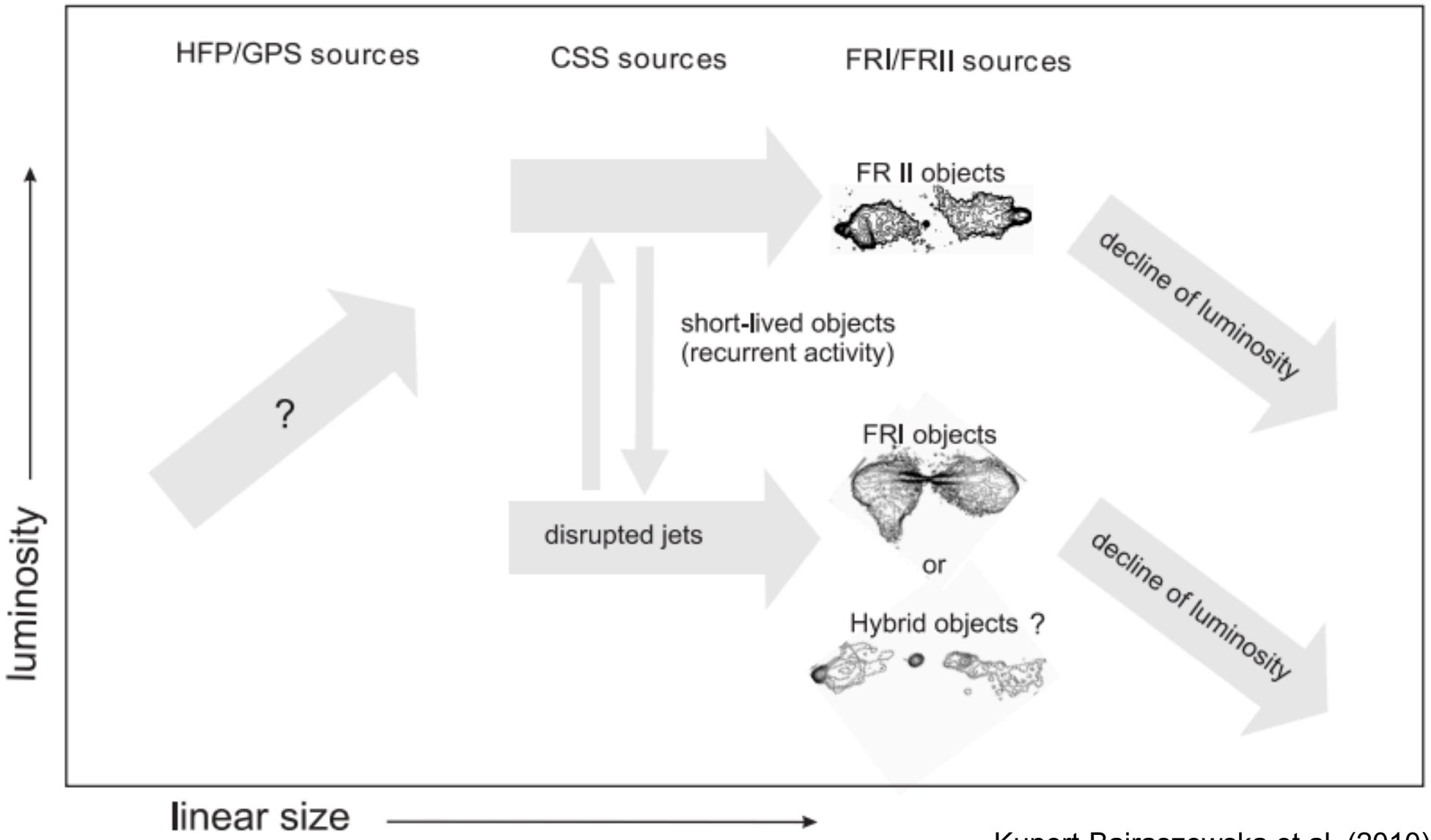
Joe Callingham
ASTRON Postdoctoral Fellow

Energetics and life-cycles of radio sources,
Dwingeloo, Netherlands
26th of March 2018



NRAO/AUI and J. M. Uson

Possible Evolutionary Picture

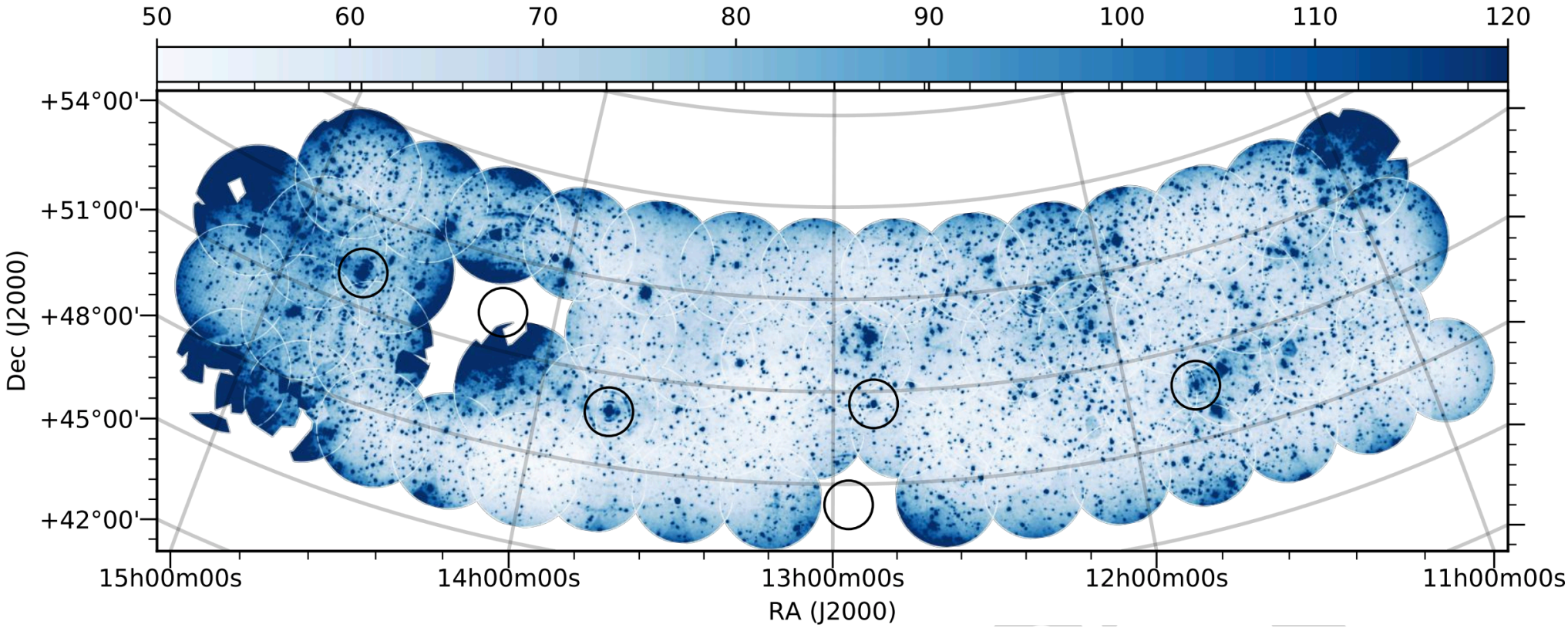


Kunert-Bajraszewska et al. (2010)

Tier-1 Survey and Hetdex

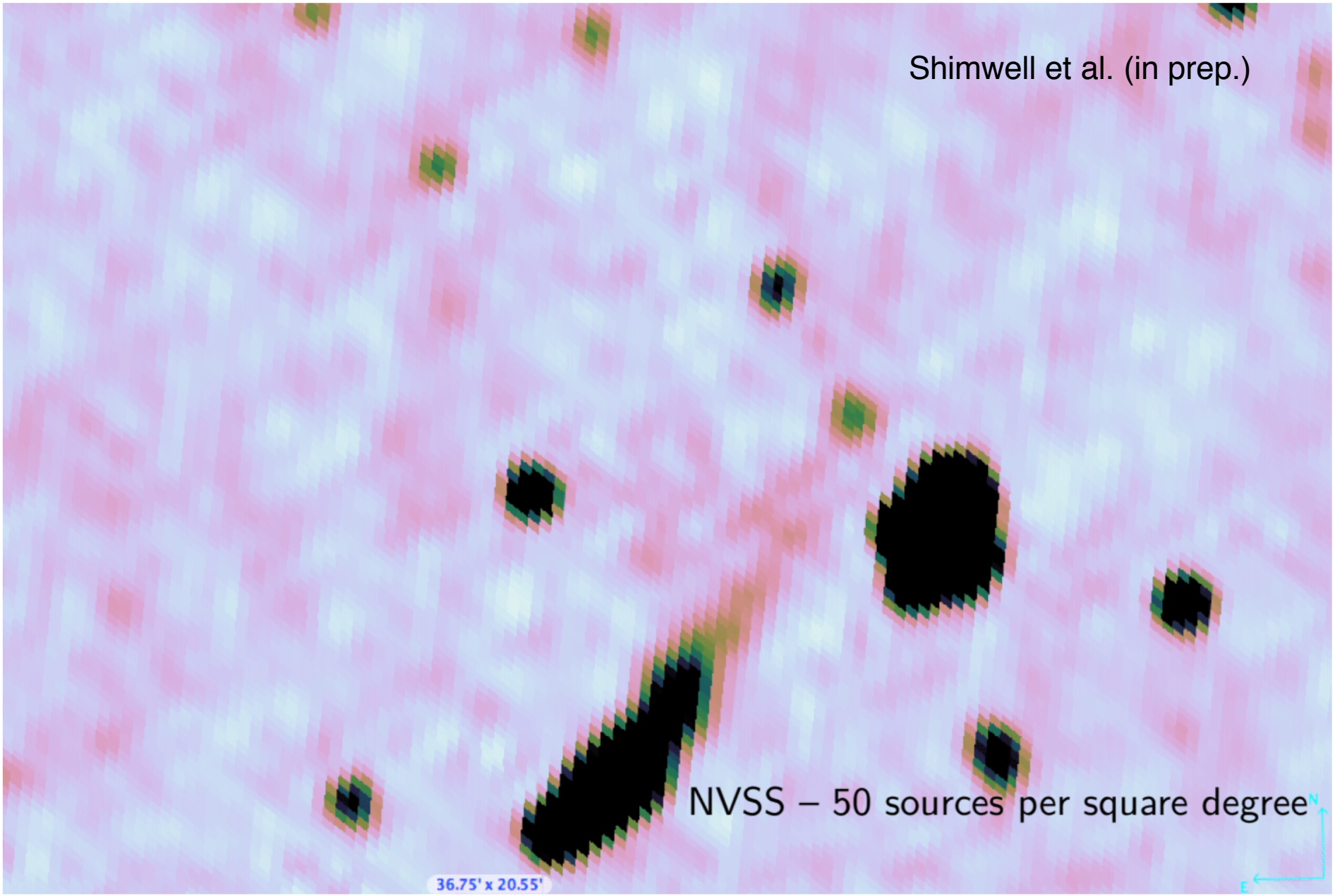
ASTRON

- ~6” resolution
- ~100 μJy/beam rms noise
- ~325,000 sources over 400 sq. deg
- Compared to 300,000 GLEAM sources over 60% of the sky

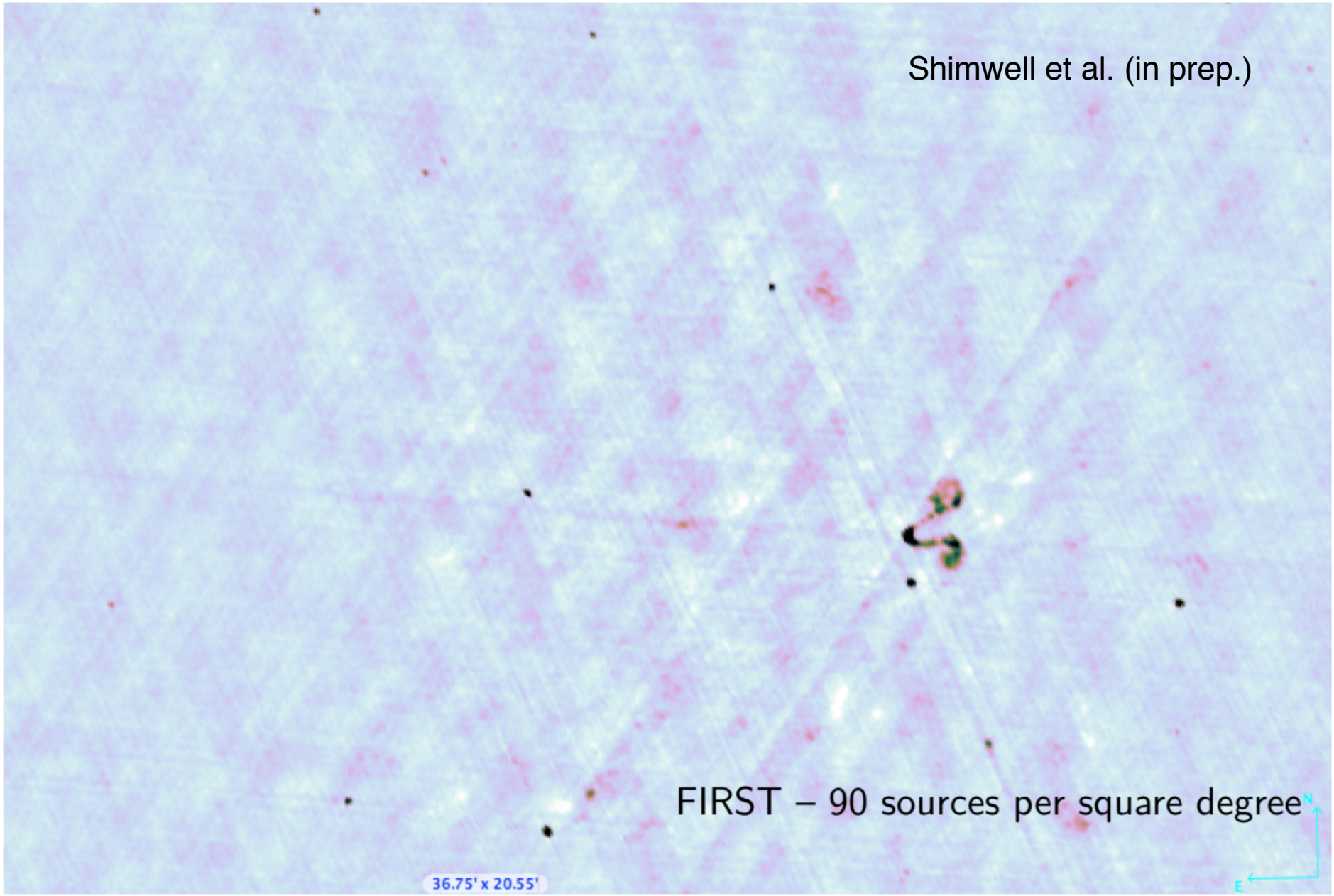


Shimwell et al. (in prep.)

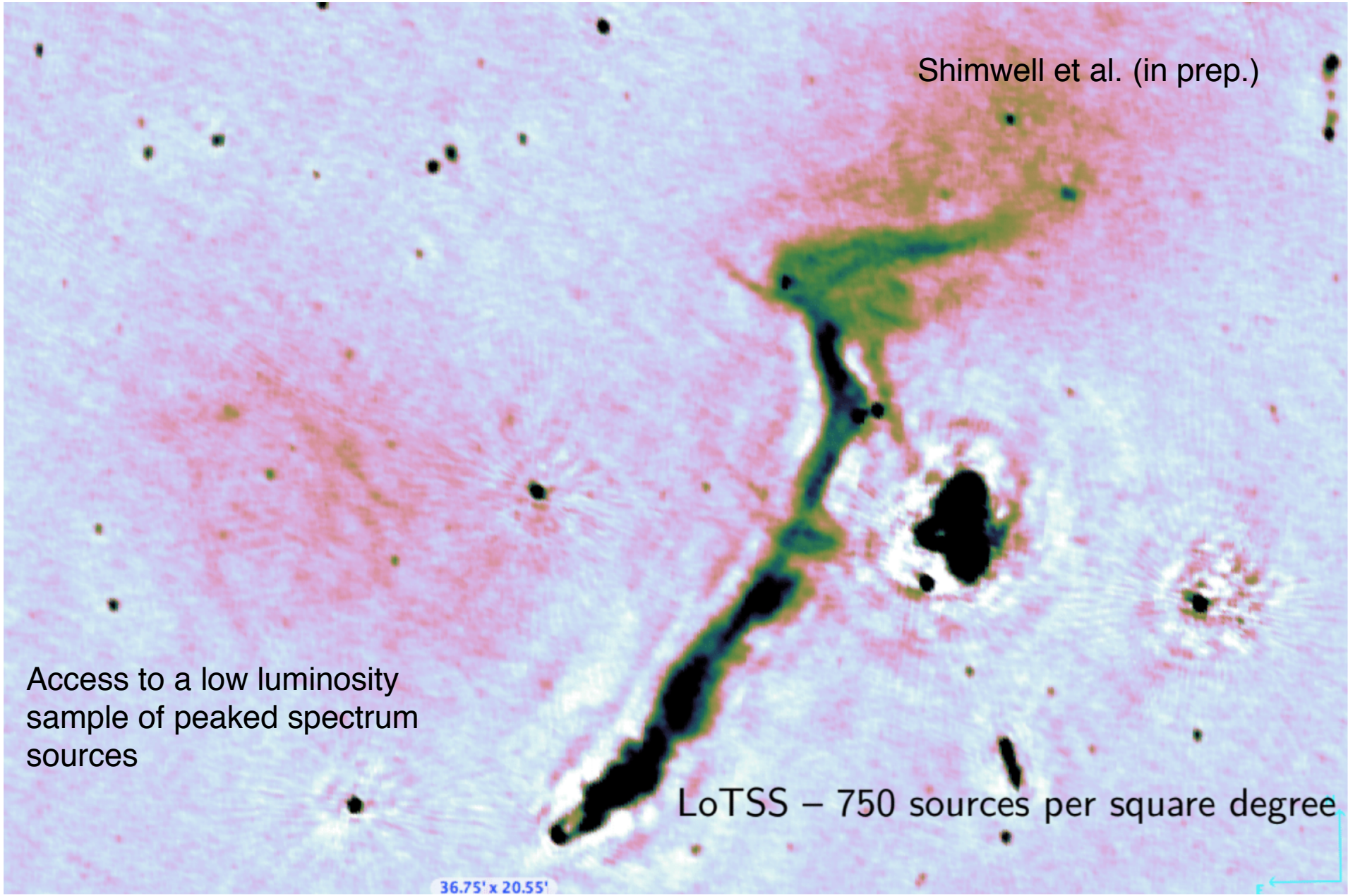
LoTSS


Shimwell et al. (in prep.)
NVSS – 50 sources per square degree
36.75' x 20.55'

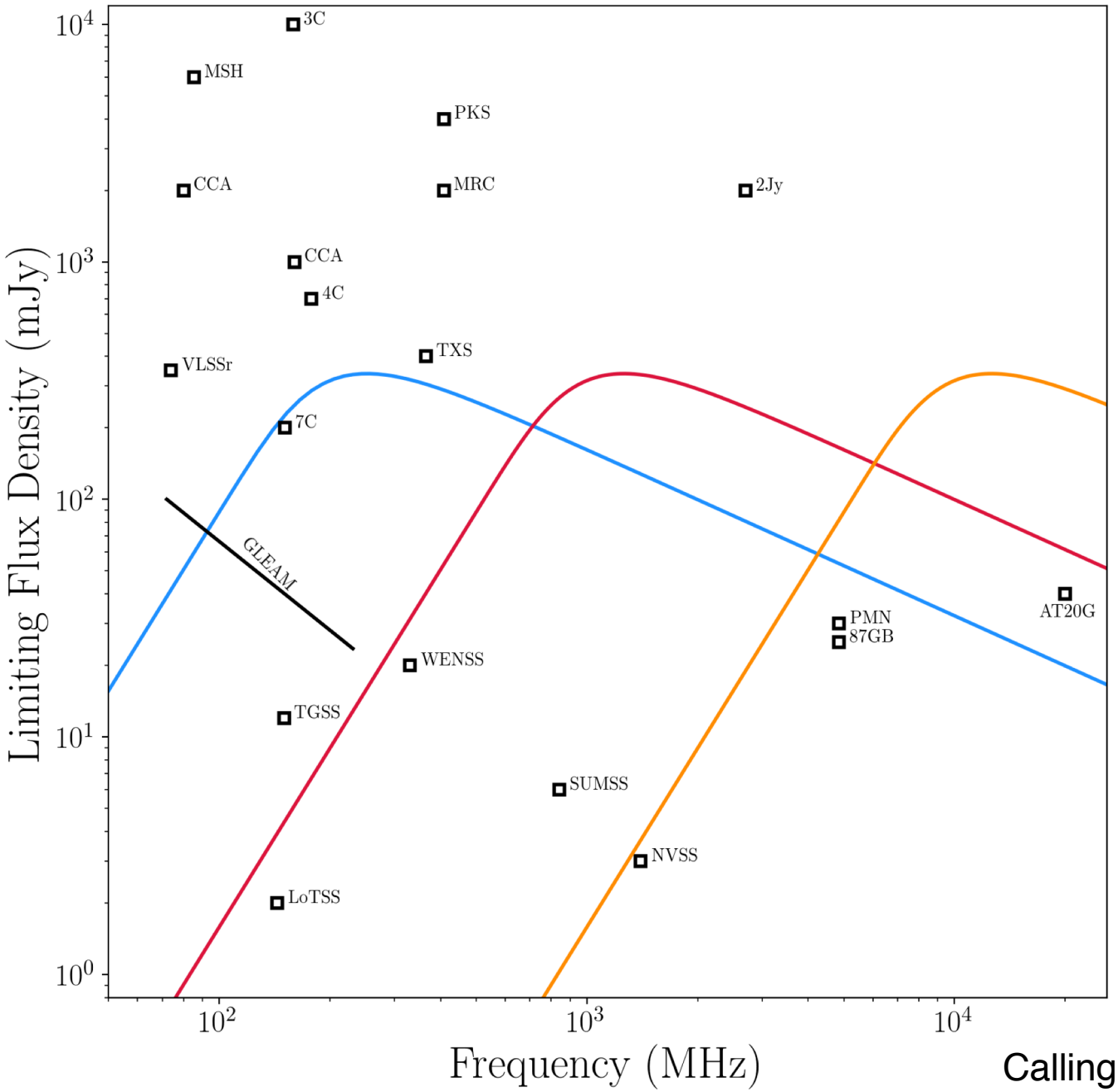
LoTSS


Shimwell et al. (in prep.)
FIRST – 90 sources per square degree
36.75' x 20.55'
N
E

LoTSS

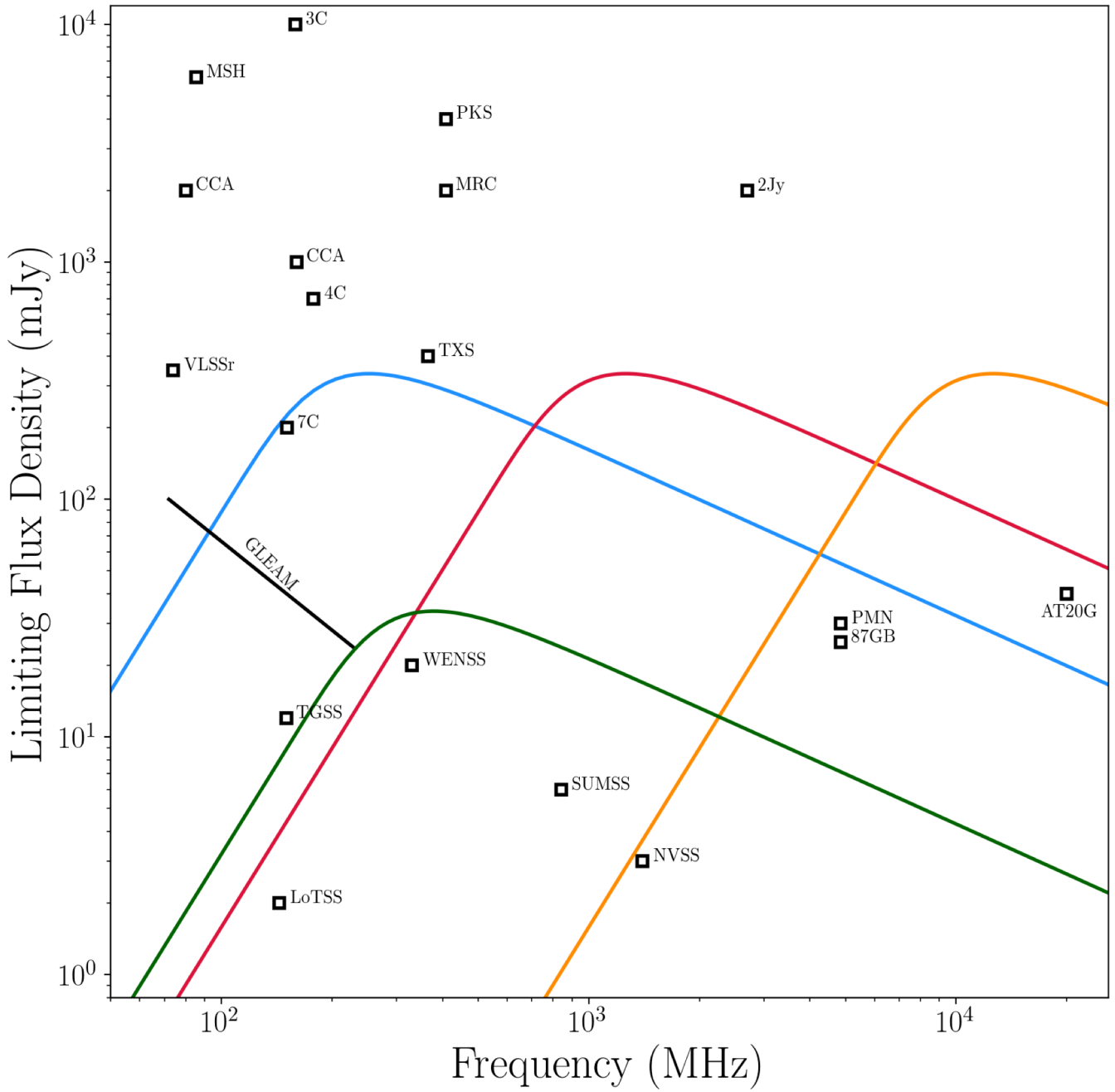

Shimwell et al. (in prep.)
Access to a low luminosity sample of peaked spectrum sources
LoTSS – 750 sources per square degree
36.75' x 20.55'

Which peaked-spectrum source?

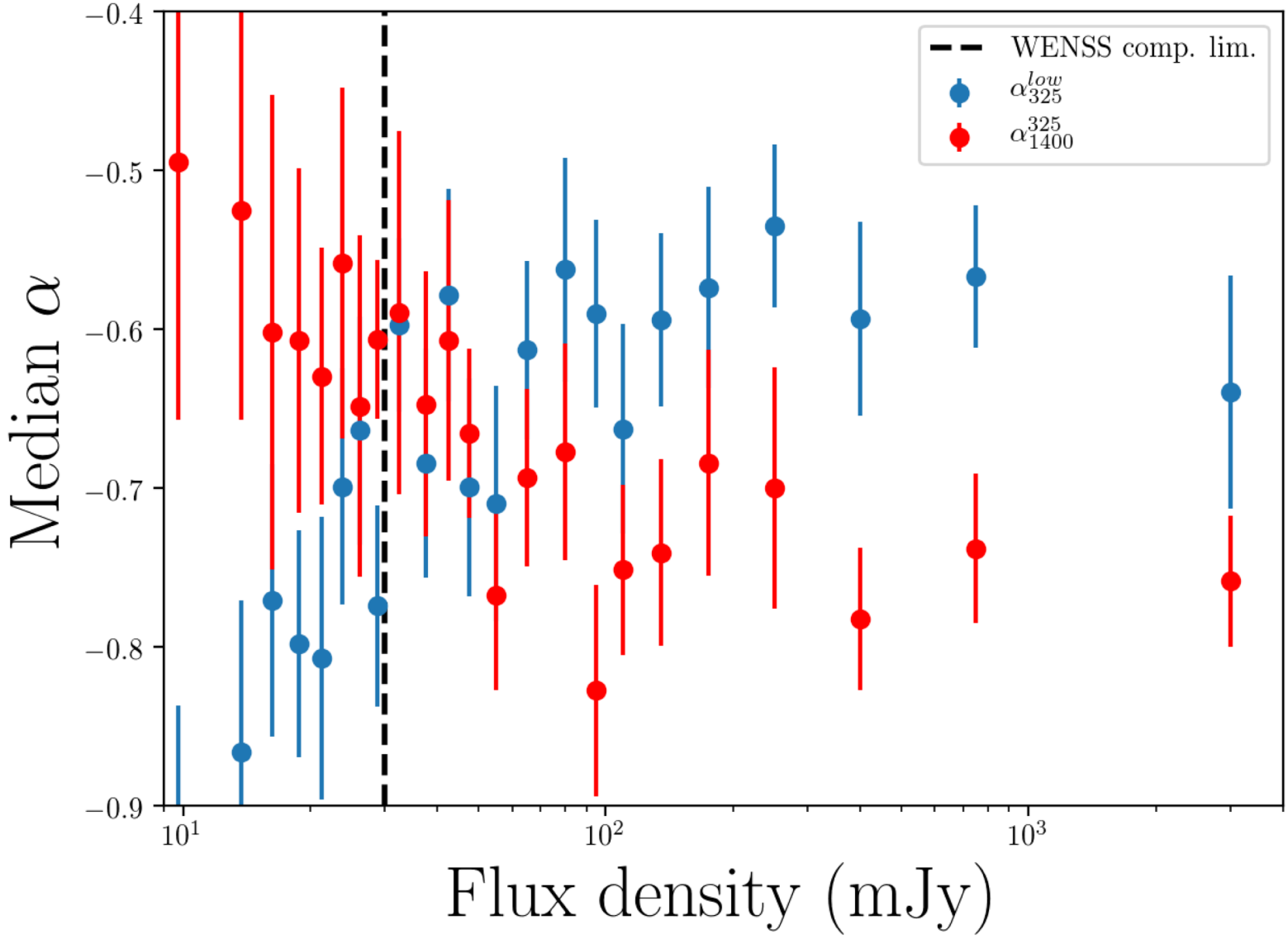


Callingham et al. (2017)

Which peaked-spectrum source?

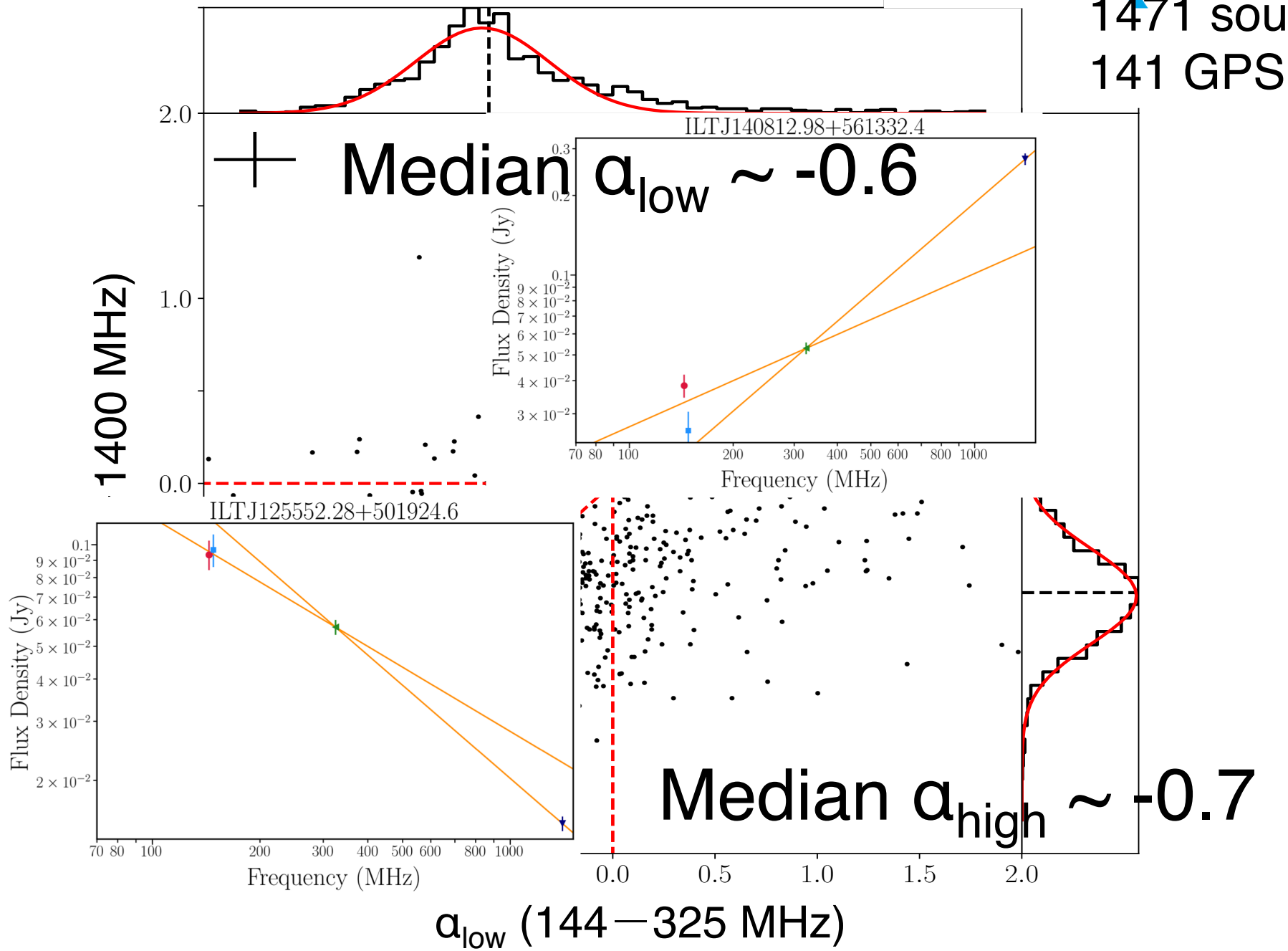


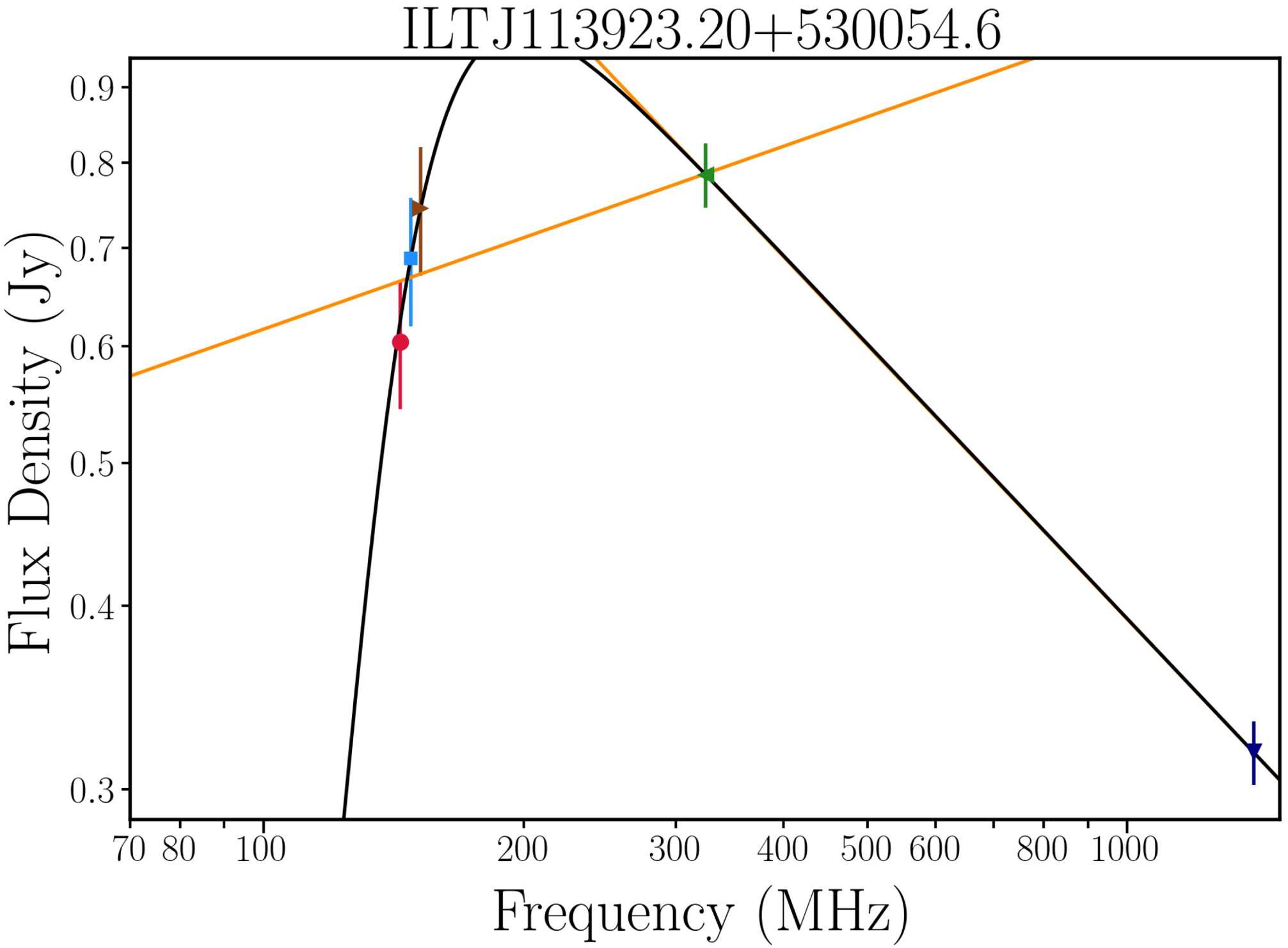
WENSS Flux Density Scale ☹

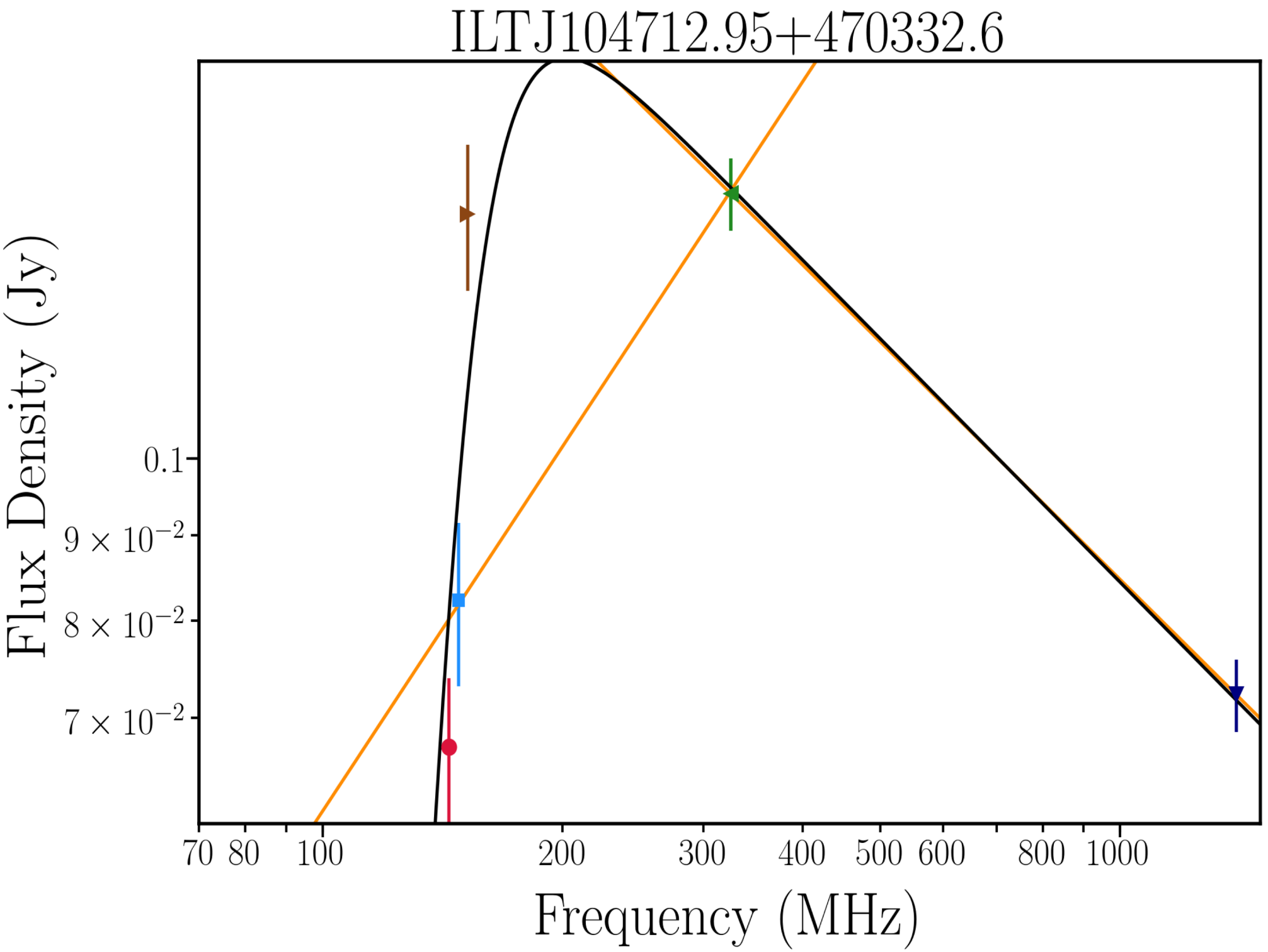


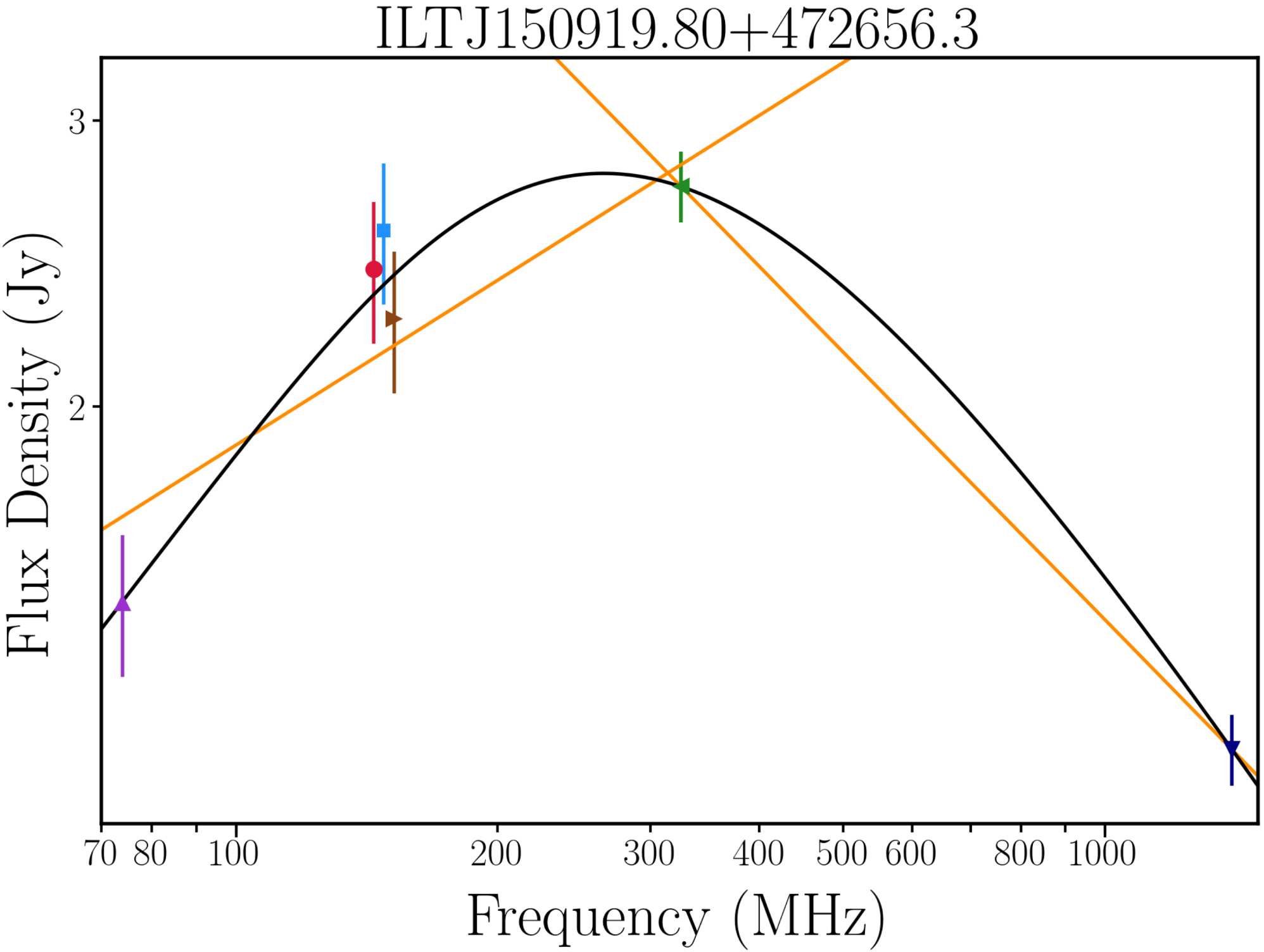
LoTSS Colour-Colour Diagram

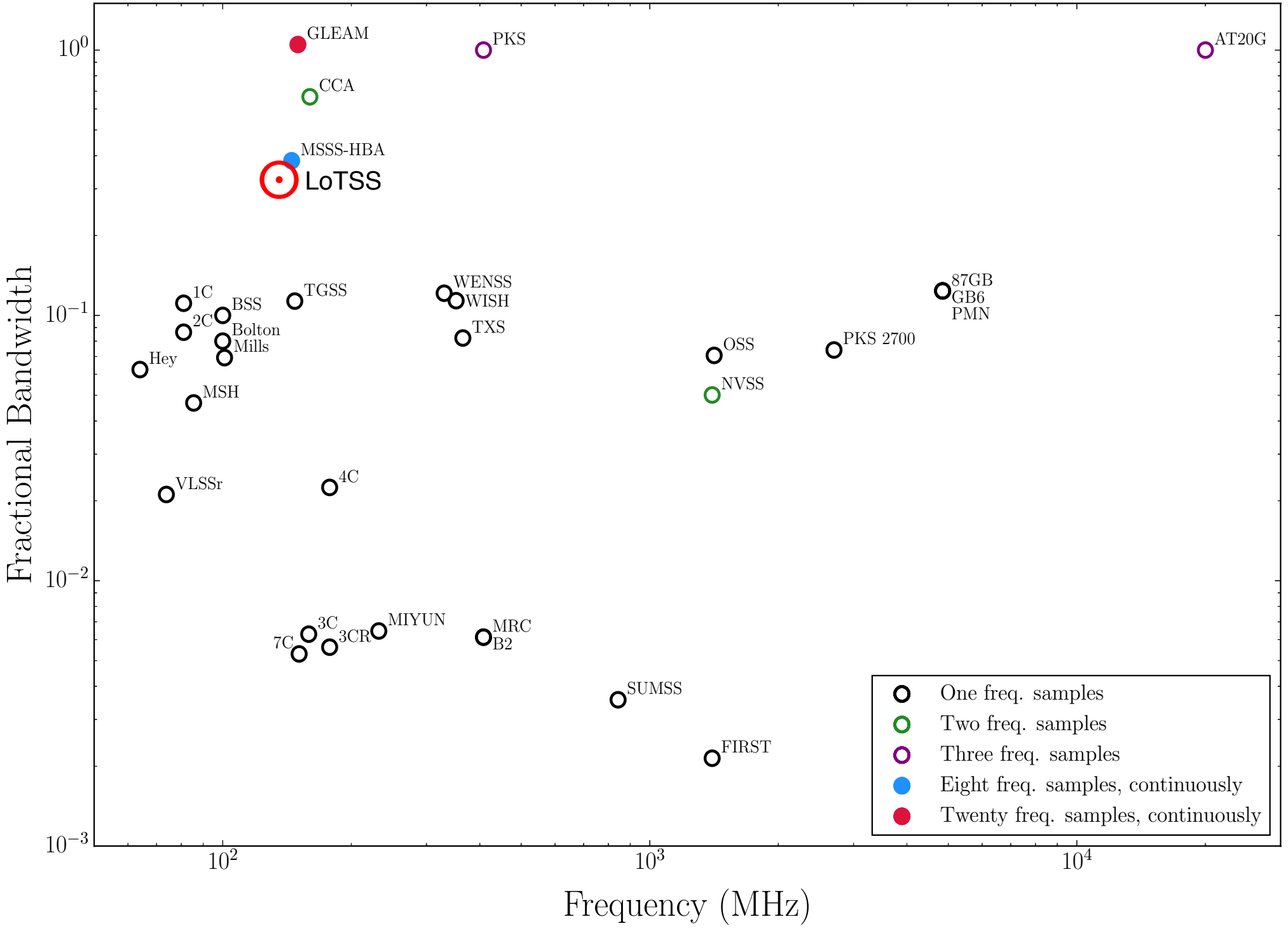
1471 sources
141 GPS

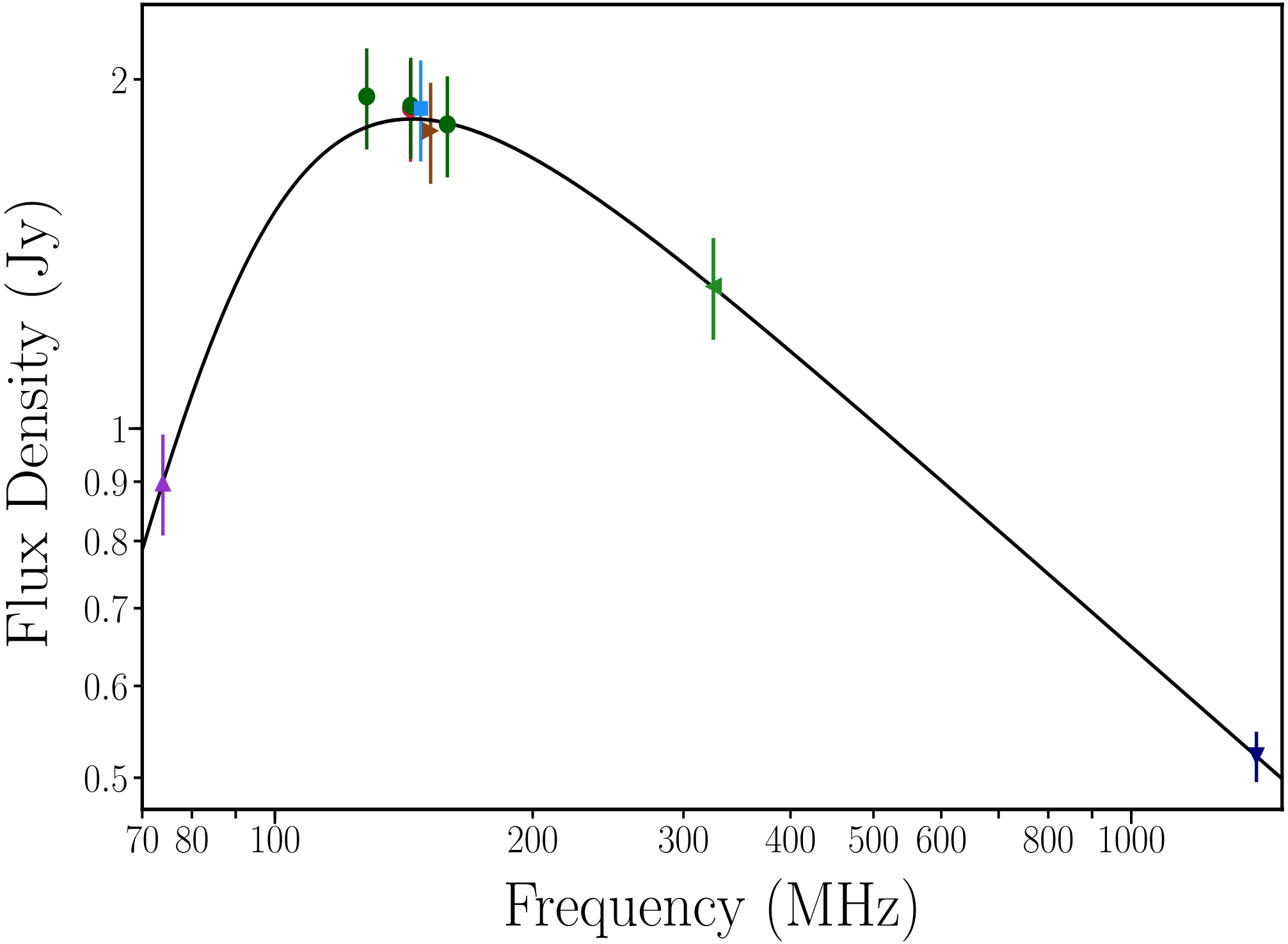



ILTJ113923.20+530054.6
Flux Density (Jy)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
70
80
100
200
300
400
500
600
800
1000
Frequency (MHz)


ILTJ104712.95+470332.6
Flux Density (Jy)
0.1
9×10^{-2}
8×10^{-2}
7×10^{-2}
70
80
100
200
300
400
500
600
800
1000
Frequency (MHz)

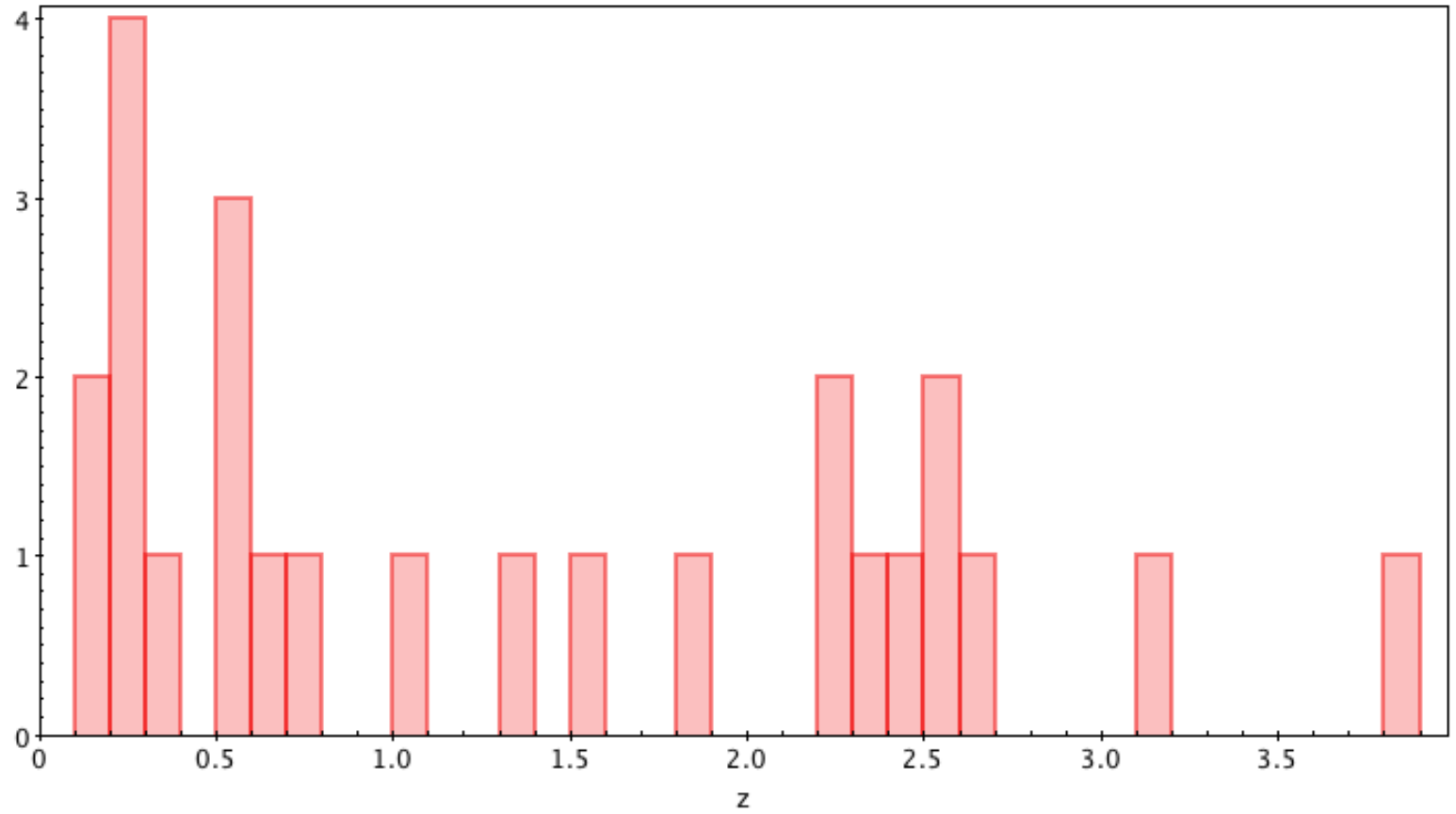

ILTJ150919.80+472656.3
Flux Density (Jy)
3
2
70
80
100
200
300
400
500
600
800
1000
Frequency (MHz)


GLEAM
PKS
AT20G
CCA
MSSS-HBA
LoTSS
1C
BSS
TGSS
WENSS
WISH
87GB
GB6
PMN
2C
Bolton
Mills
TXS
OSS
PKS 2700
Hey
NVSS
MSH
VLSSr
4C
3C
MIYUN
MRC
7C
3CR
B2
SUMSS
FIRST
One freq. samples
Two freq. samples
Three freq. samples
Eight freq. samples, continuously
Twenty freq. samples, continuously
Fractional Bandwidth
Frequency (MHz)
10^0
10^{-1}
10^{-2}
10^{-3}
10^2
10^3
10^4

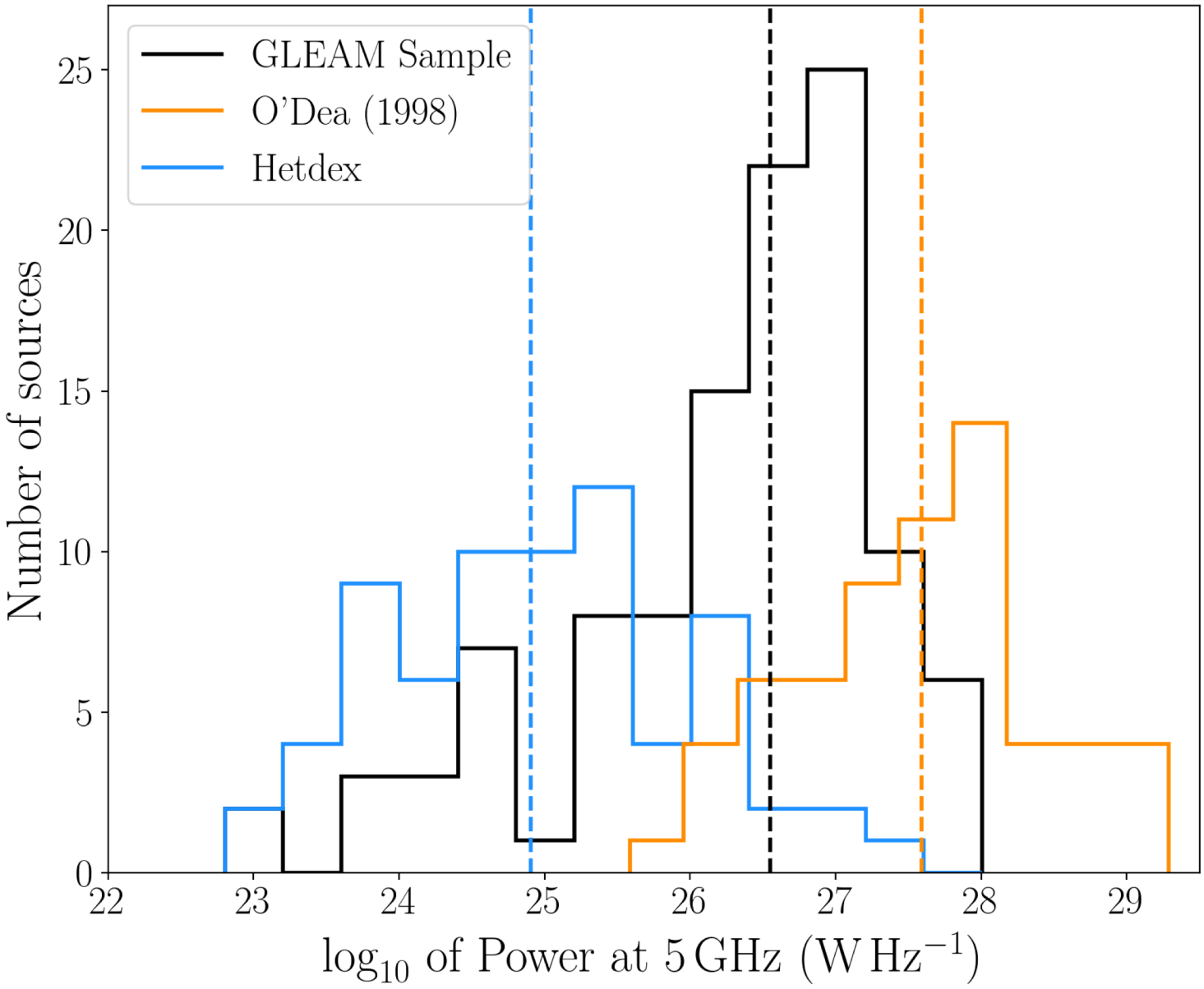

Flux Density (Jy)
2
1
0.9
0.8
0.7
0.6
0.5
70
80
100
200
300
400
500
600
800
1000
Frequency (MHz)

Too many…

- ~10 % of sources that have NVSS/WENSS counterpart are peaked-spectrum
- Obviously completeness issues but compared to complete sample with GLEAM, we have double the number of sources selected at the same frequency (~4.5%). Why?
- 25 of 144 have spectroscopic redshift (SDSS + literature/NED)



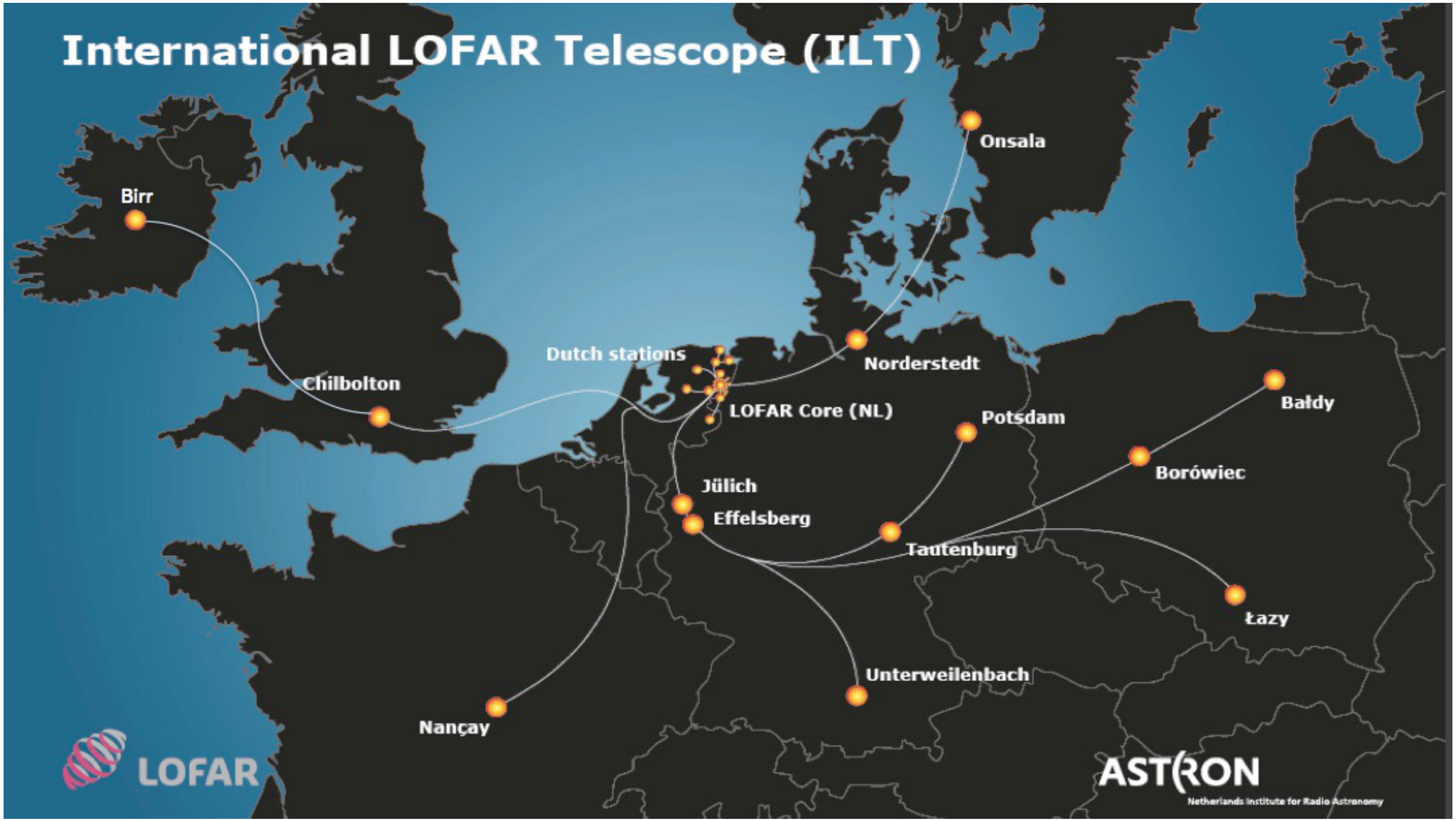
Power to the galaxies



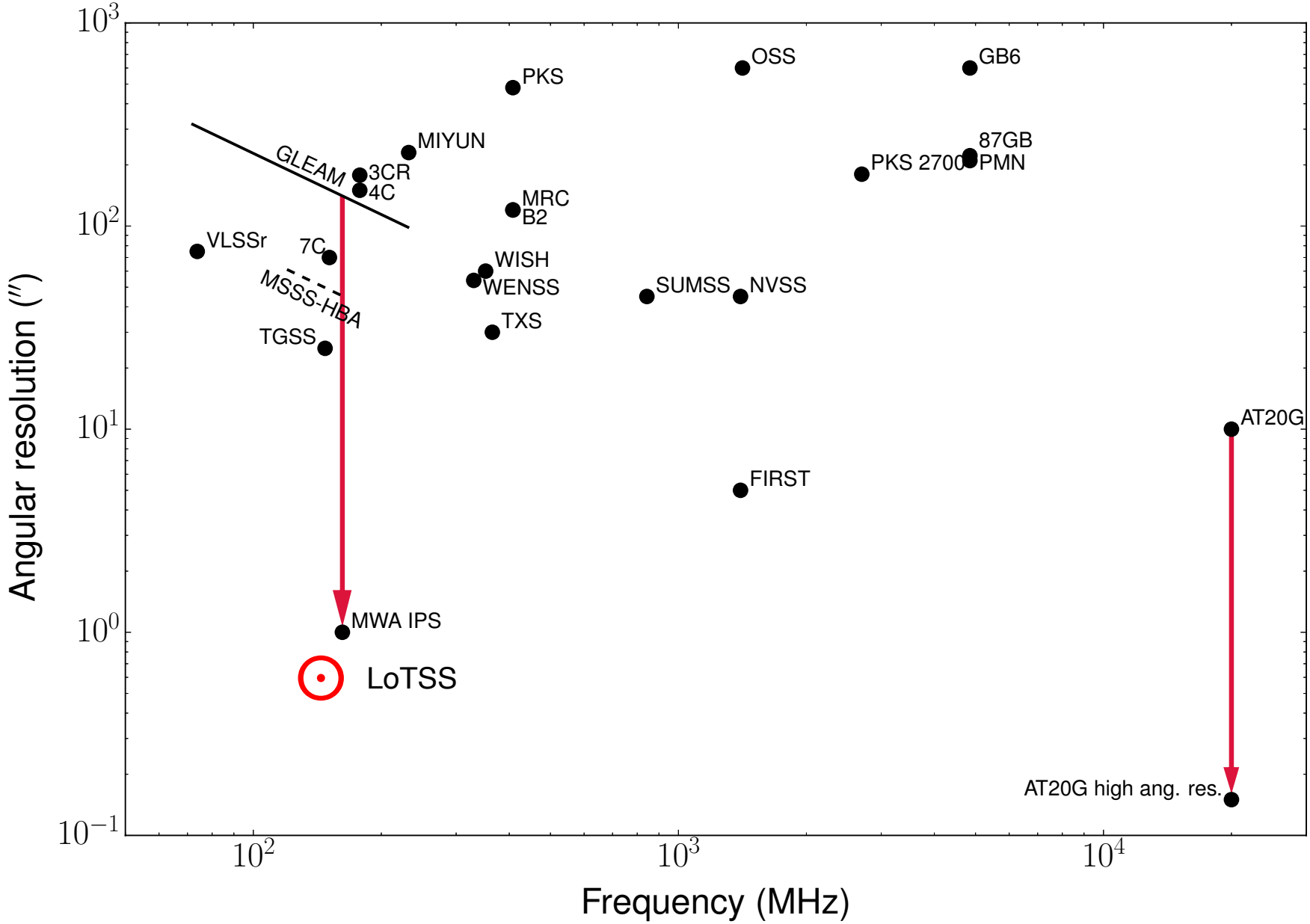
Callingham et al. (in prep.)

International baselines

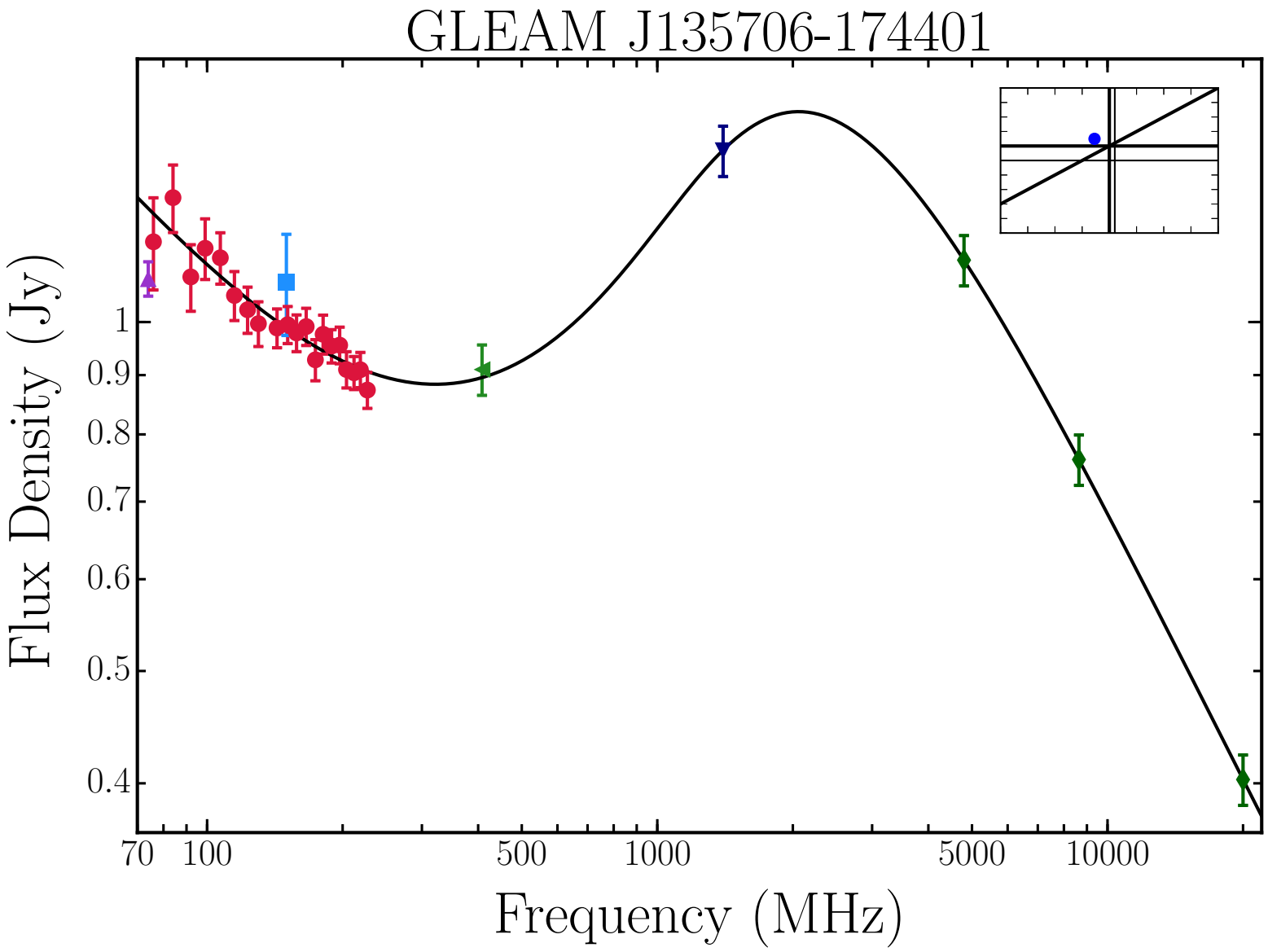
› LOFAR international baselines can achieve a resolution of ~0.5”.



IPS tricks

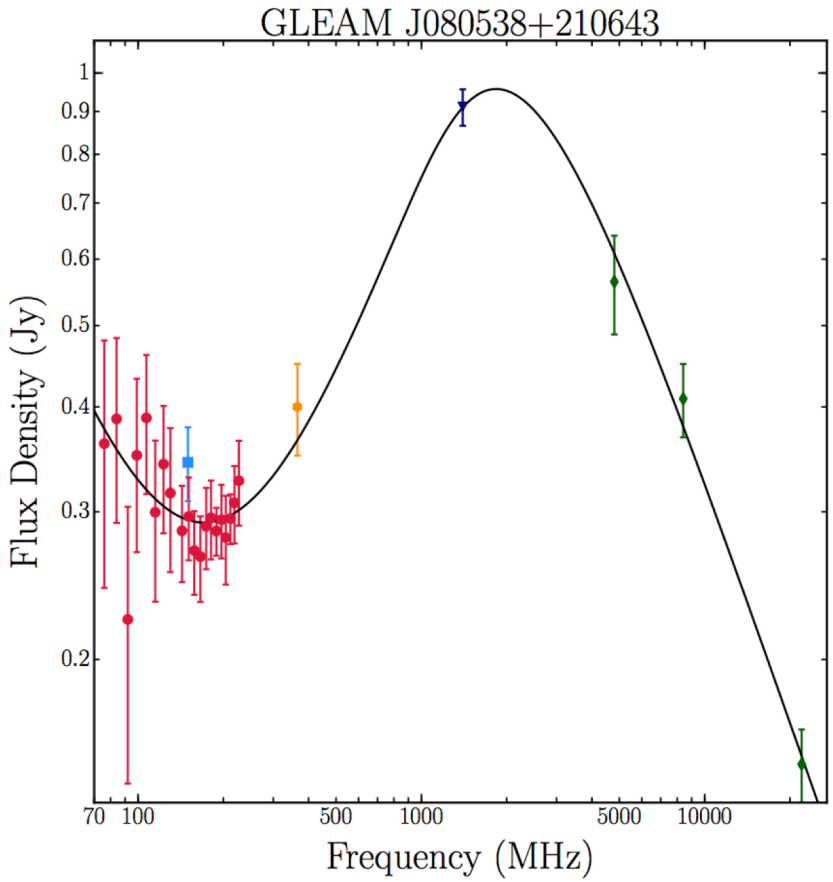

Angular resolution (″)
Frequency (MHz)
10^3
10^2
10^1
10^0
10^{-1}
10^2
10^3
10^4
PKS
OSS
GB6
MIYUN
GLEAM
3CR
4C
87GB
PKS 2700
PMN
MRC
B2
VLSSr
7C
WISH
WENSS
MSSS-HBA
SUMSS
NVSS
TXS
TGSS
AT20G
FIRST
MWA IPS
LoTSS
AT20G high ang. res.

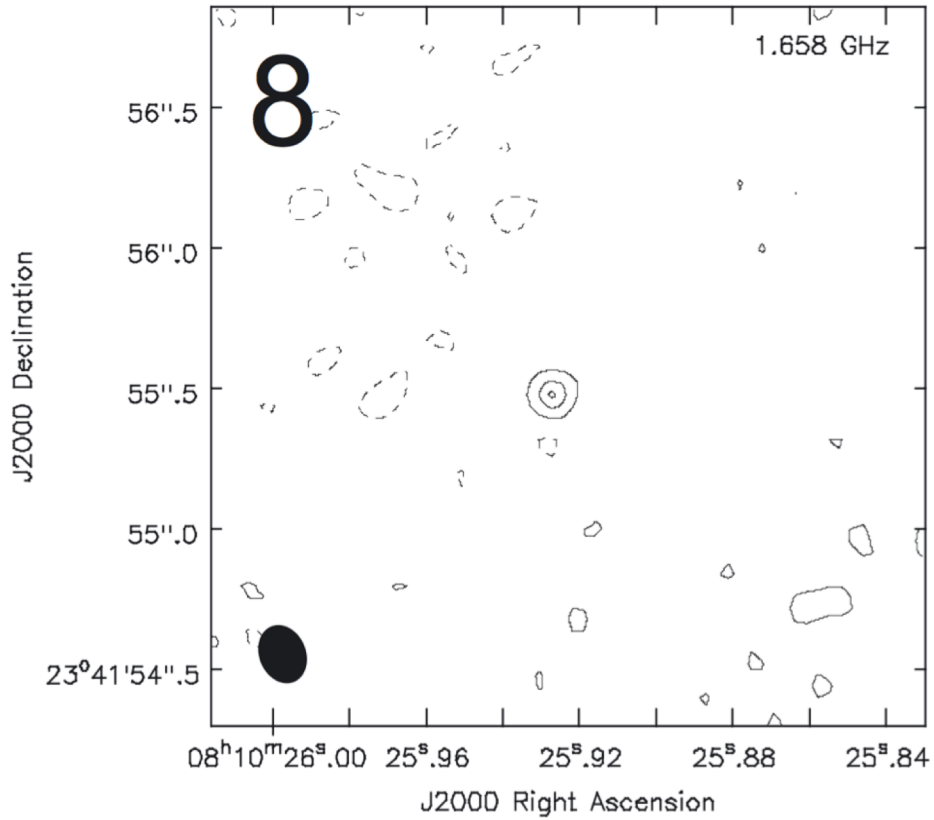
Convex Source

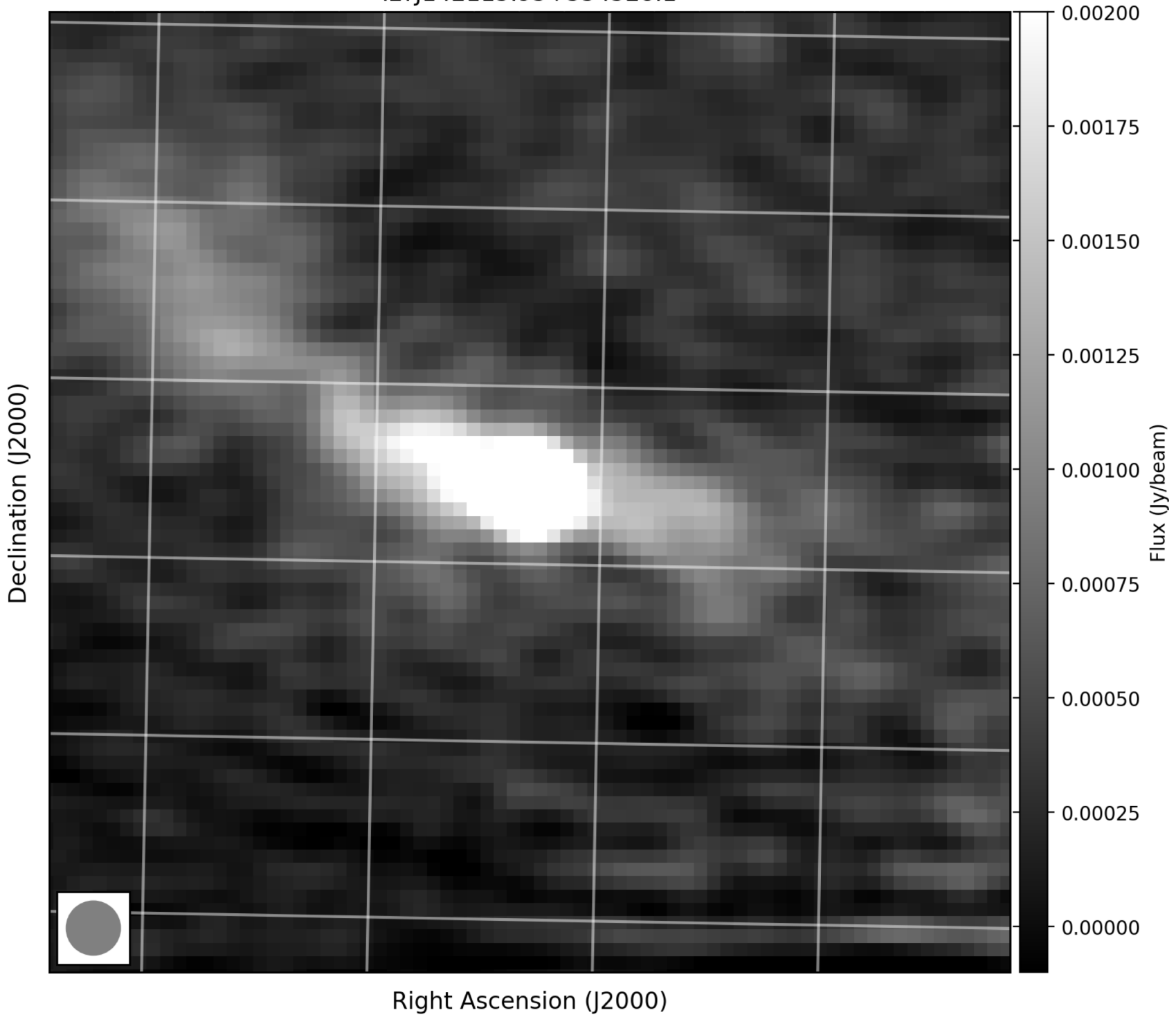


Callingham et al. (2017)

Restarted?


GLEAM J080538+210643
Flux Density (Jy)
Frequency (MHz)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
70
100
500
1000
5000
10000


8
1.658 GHz
56''.5
56''.0
55''.5
55''.0
23°41'54''.5
J2000 Declination
08h10m26s.00
25s.96
25s.92
25s.88
25s.84
J2000 Right Ascension


ILTJ142115.95+554528.1
Declination (J2000)
Right Ascension (J2000)
Flux (Jy/beam)
0.00200
0.00175
0.00150
0.00125
0.00100
0.00075
0.00050
0.00025
0.00000

Summary

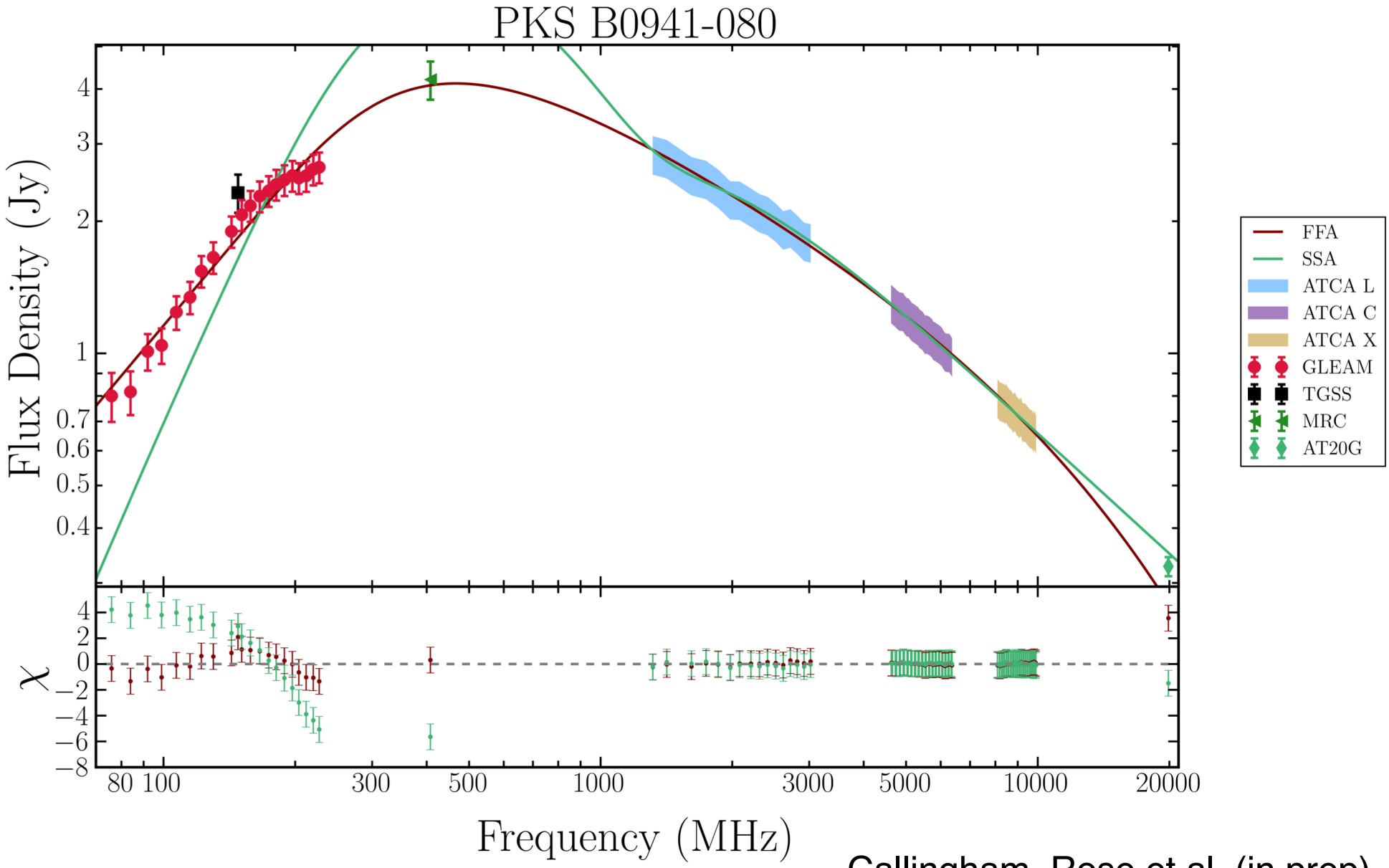
- Identified ~150 new peaked-spectrum sources in Hetdex field
- These sources are likely low luminosity counterparts to GPS sources identified at higher freq.
- Maybe dominant precursors to FR1 galaxies?
- Finding discrepancy in the number of GPS/CSS sources selected with LoTSS with those selected by GLEAM. Variability bias? Evolution?
- Using the spectra is a very useful way to find restarted GPS/CSS sources? Duty cycle?
- Question for Stas – what scale do you expect this low-surface brightness emission to be on?

MWA / Hurley-Walker

NASA, ESA, RIT, NRAO / AUI / NSF, Hubble Heritage

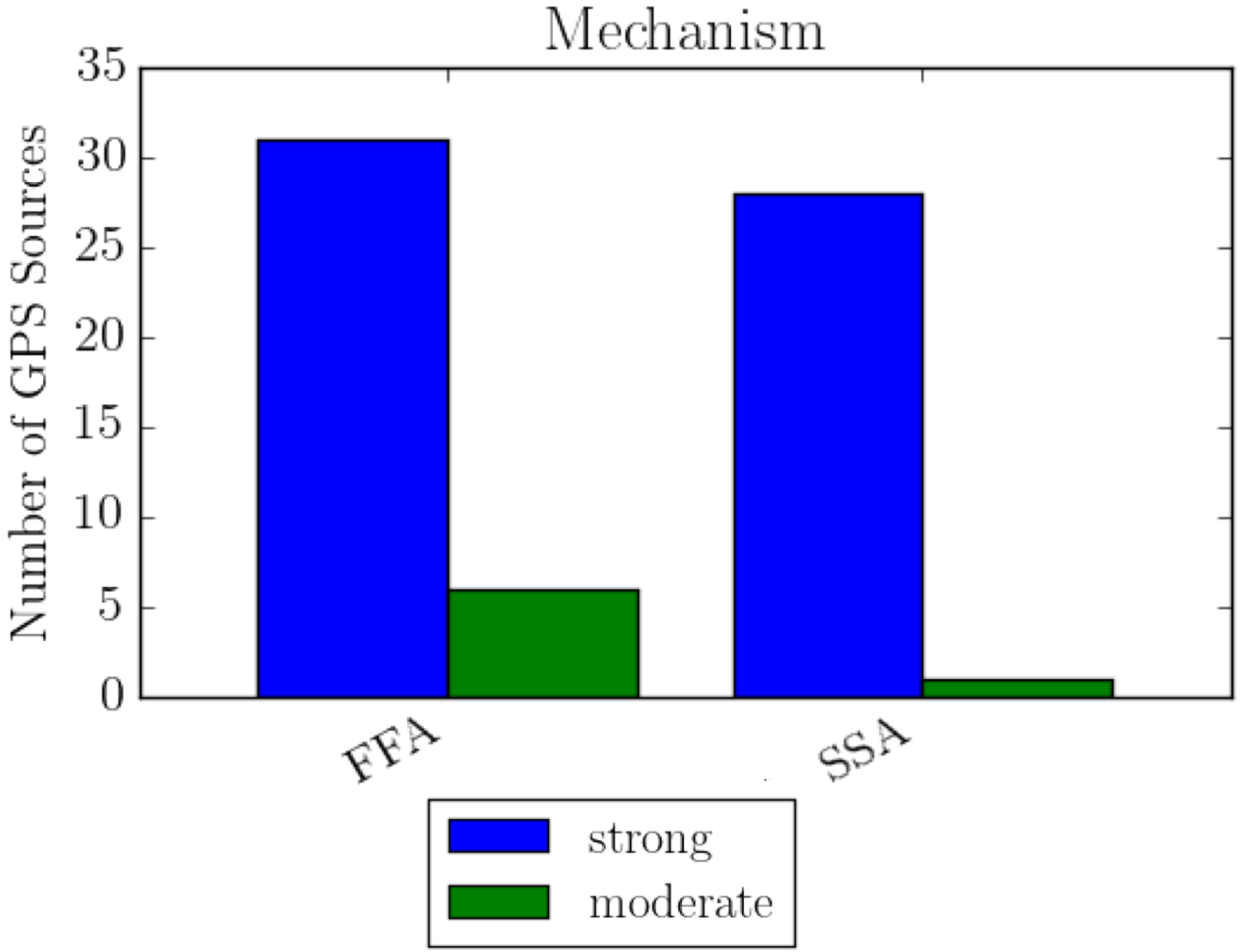
LOFAR / ASTRON

Bayesian Model Testing



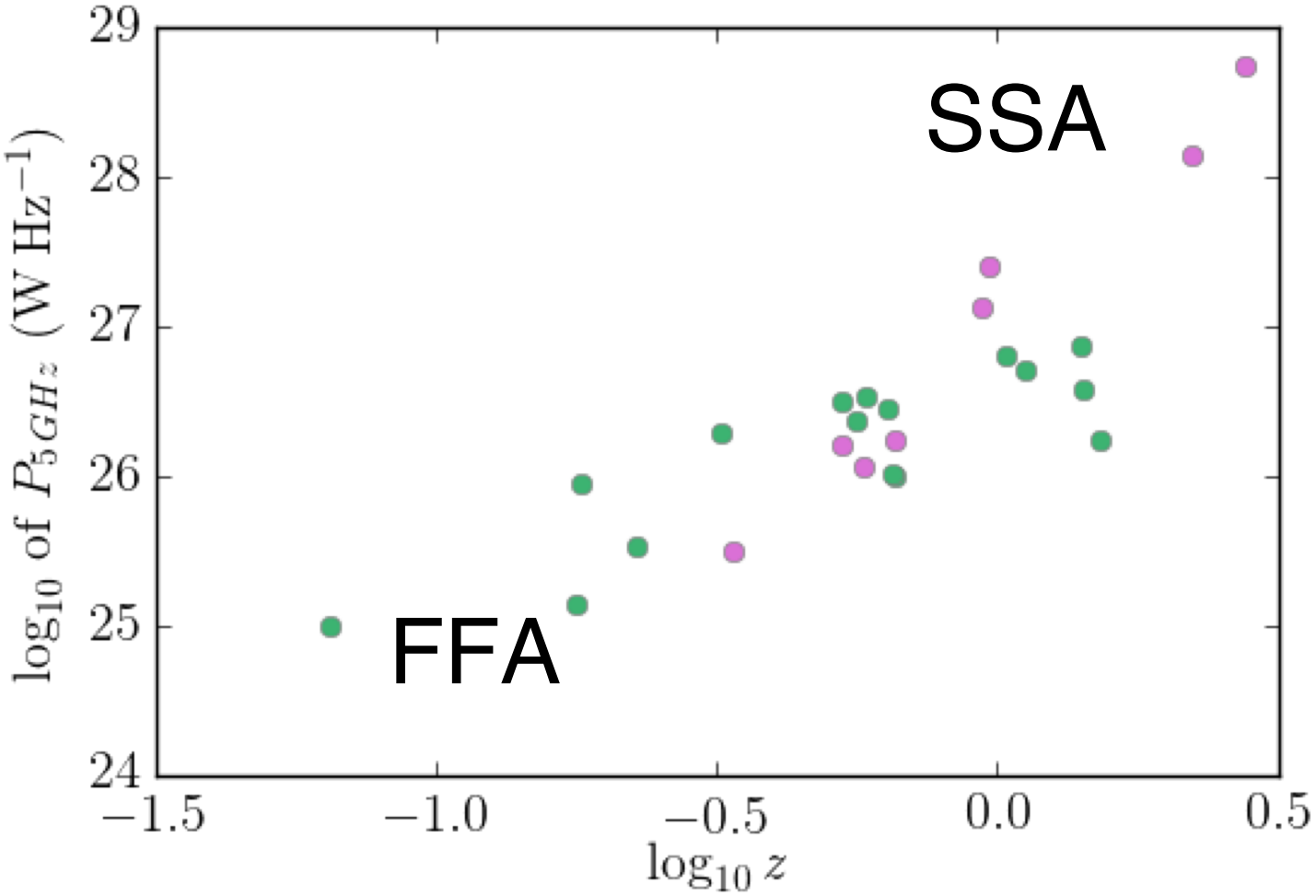
Callingham, Rose et al. (in prep).

Two populations!

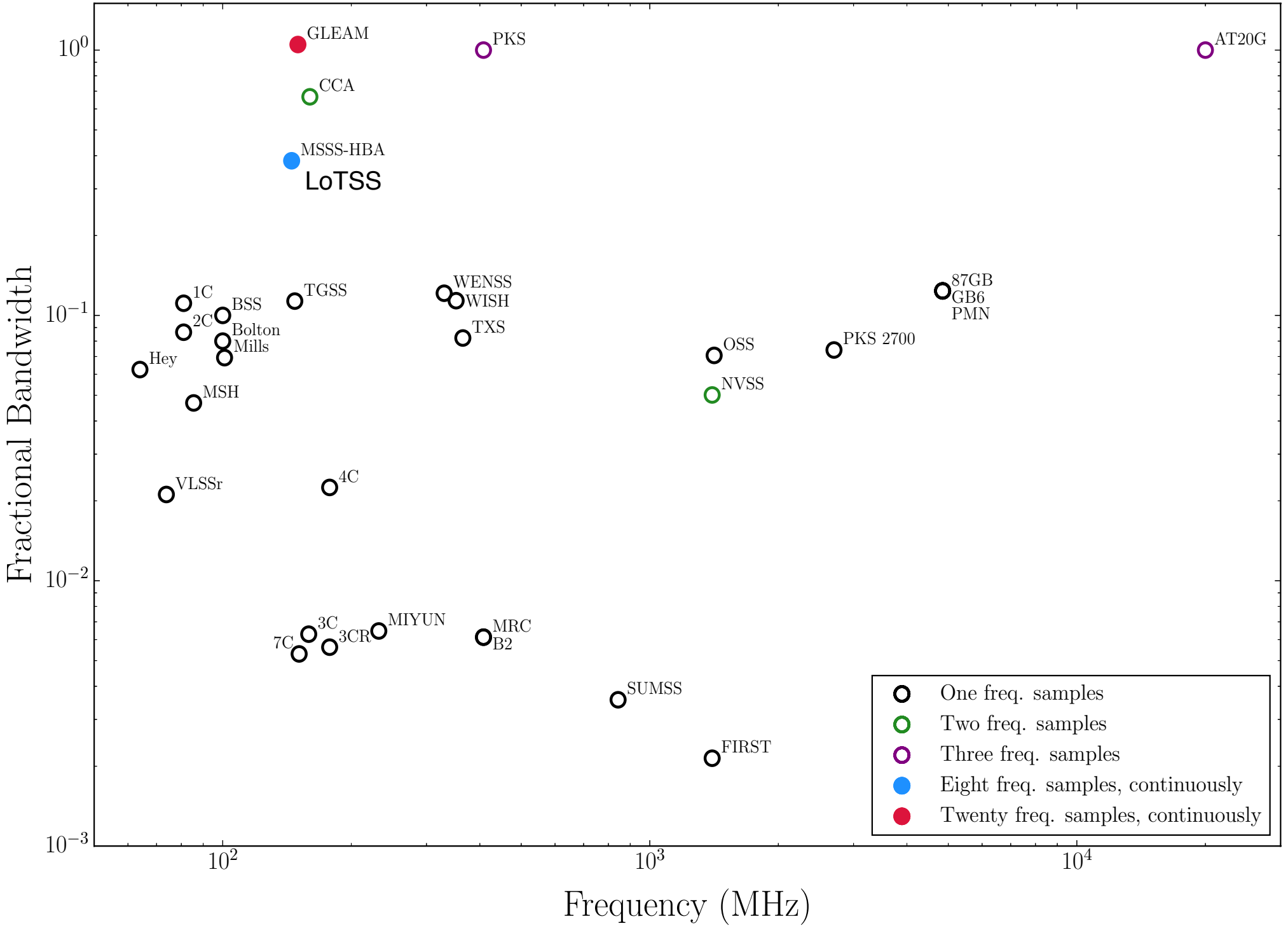


Callingham, Rose et al. (in prep).

Possible Power Dependence?

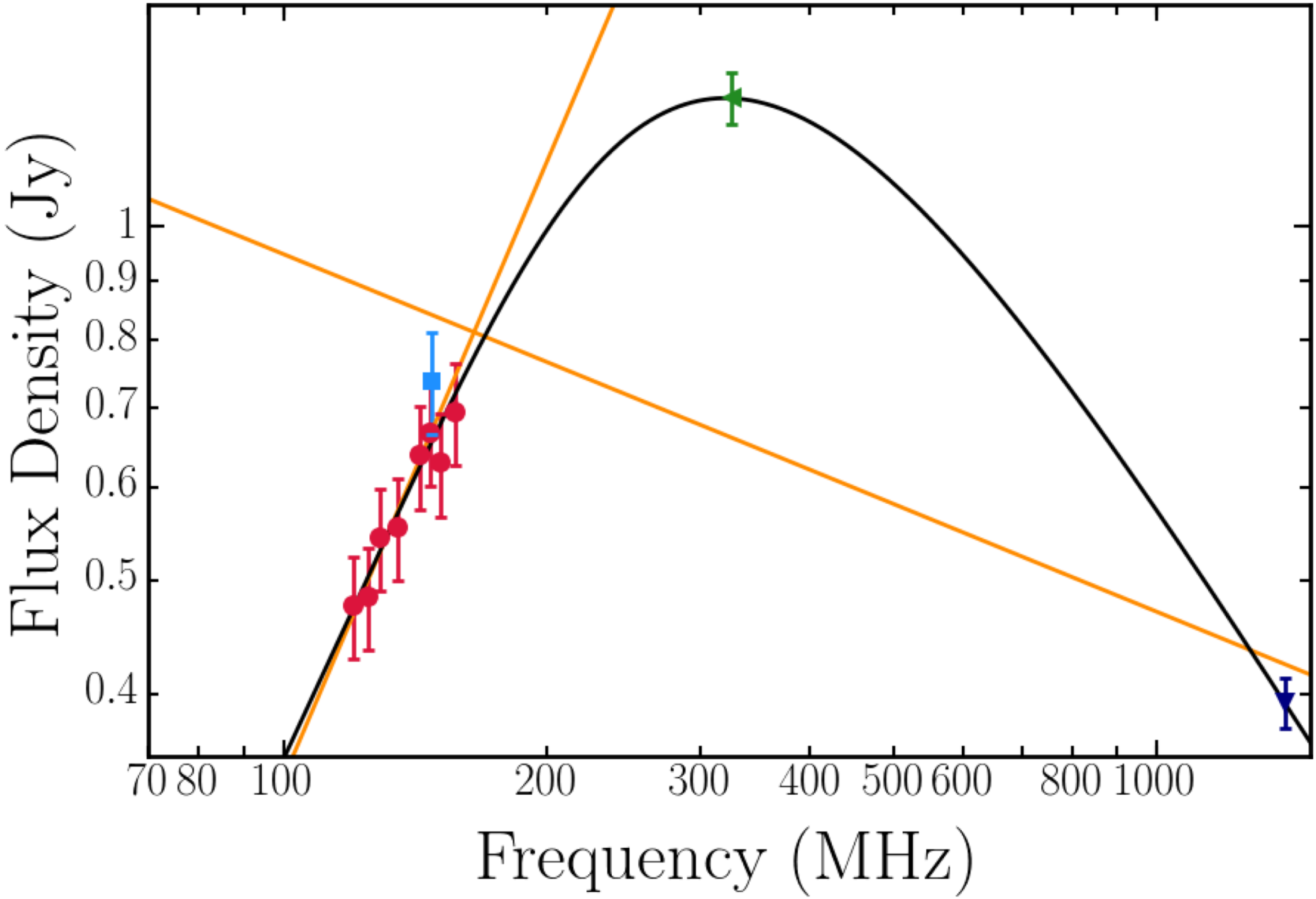


Callingham, Rose et al. (in prep).


GLEAM
PKS
AT20G
CCA
MSSS-HBA
LoTSS
1C
BSS
TGSS
WENSS
WISH
87GB
GB6
PMN
2C
Bolton
Mills
TXS
OSS
PKS 2700
Hey
NVSS
MSH
VLSSr
4C
3C
MIYUN
MRC
7C
3CR
B2
SUMSS
FIRST
One freq. samples
Two freq. samples
Three freq. samples
Eight freq. samples, continuously
Twenty freq. samples, continuously
Fractional Bandwidth
Frequency (MHz)
10^0
10^{-1}
10^{-2}
10^{-3}
10^2
10^3
10^4

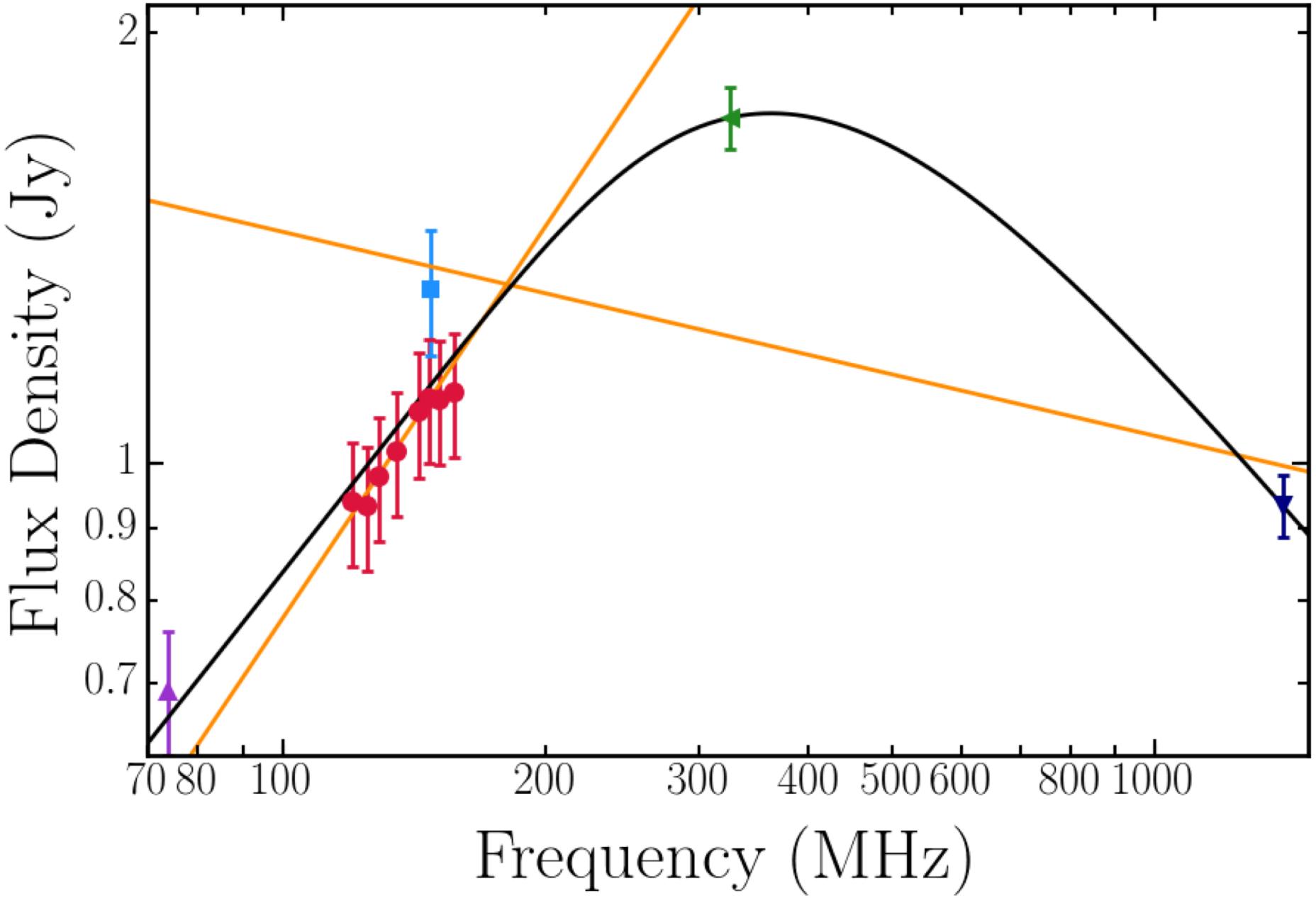
MSSS

ASTRON

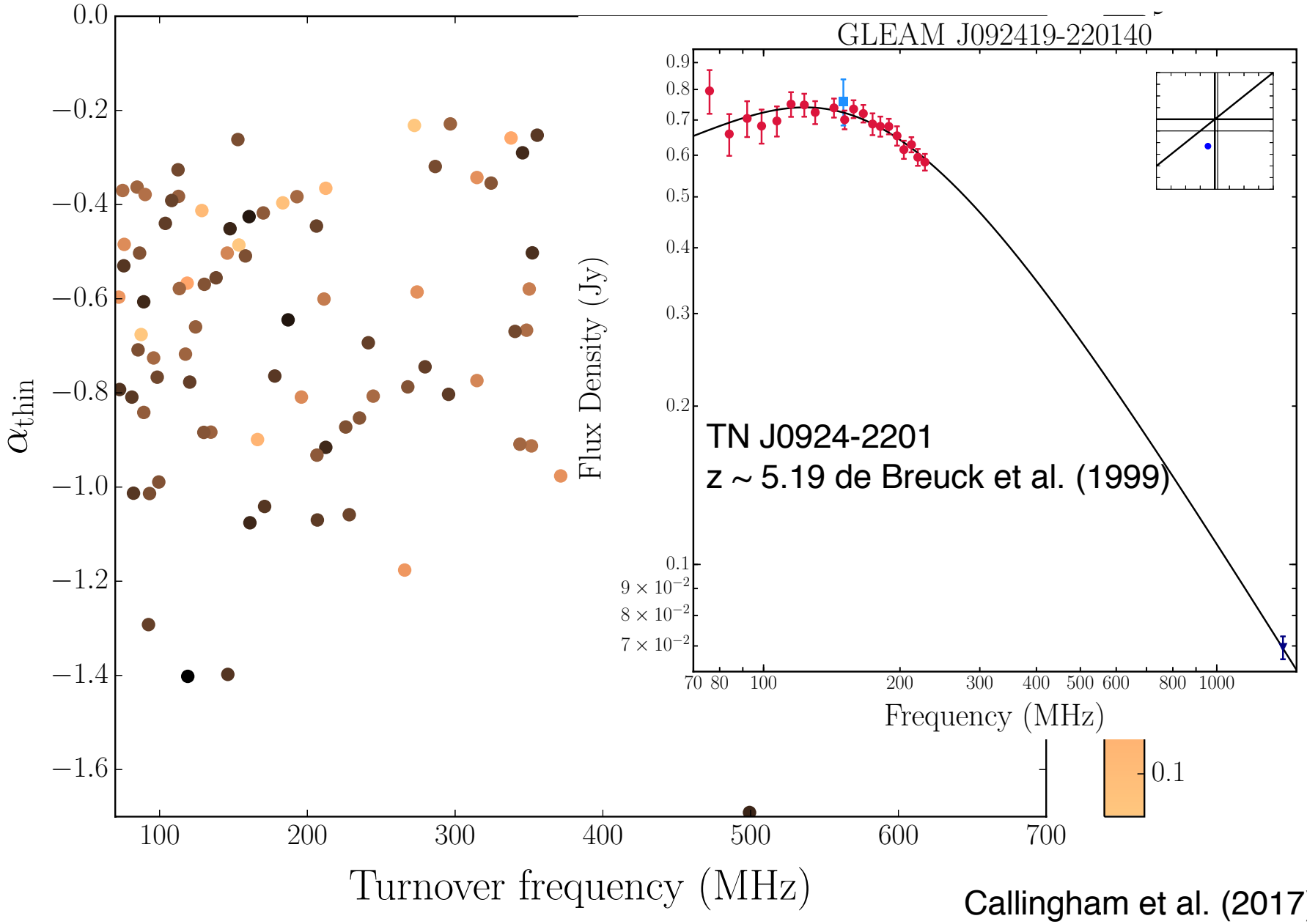

Flux Density (Jy)
1
0.9
0.8
0.7
0.6
0.5
0.4
70 80 100 200 300 400 500 600 800 1000
Frequency (MHz)

MSSS

ASTRON


Flux Density (Jy)
2
1
0.9
0.8
0.7
70 80 100 200 300 400 500 600 800 1000
Frequency (MHz)

High Redshift Universe



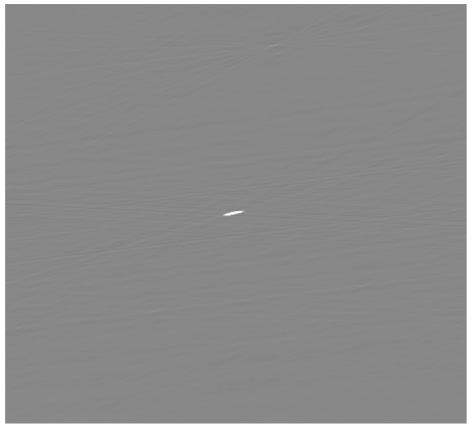
Callingham et al. (2017)

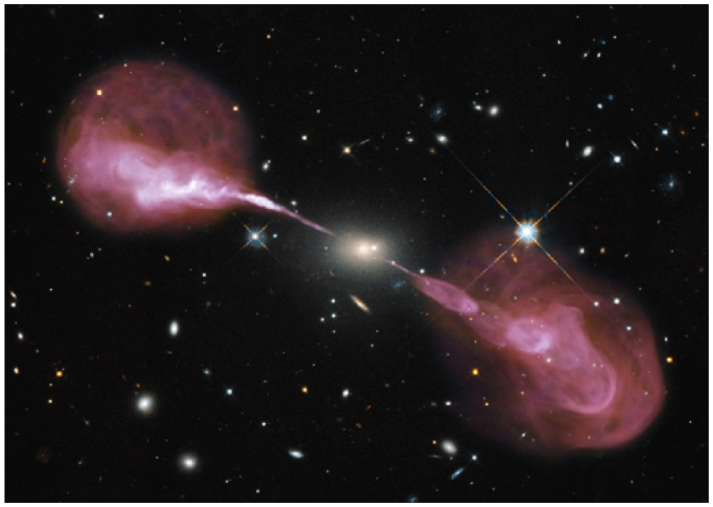
Why Study GPS/CSS Sources?

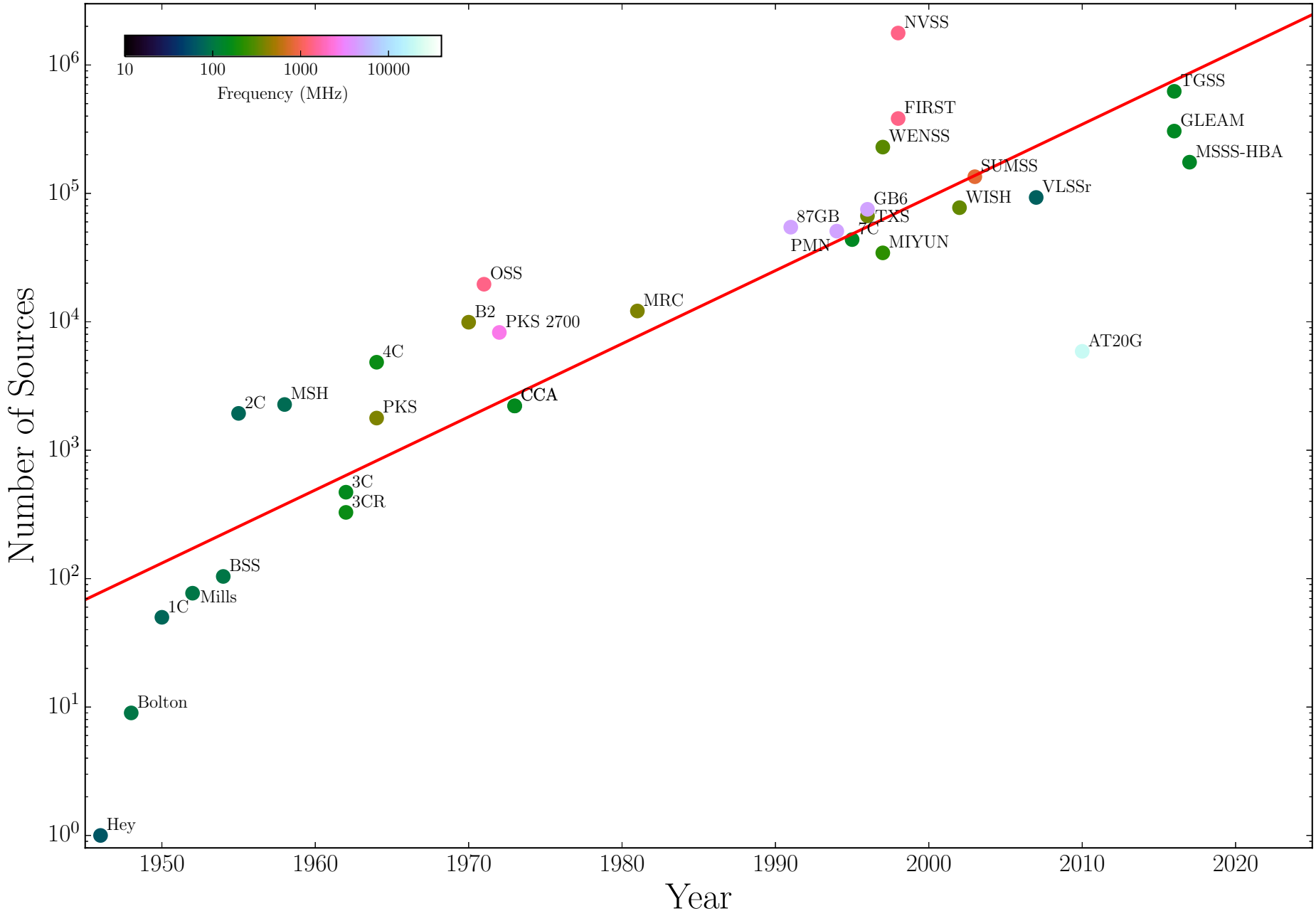
ASTRON

- Unique view of early AGN stages; probe of environment at scales of tens of pc
- Which radio galaxies evolve into "A team" sources (Cyg A, Her A, etc)?
- Are they confined to small spatial scales due to youth, frustration, or both?
- Cause of the turnover in spectrum? Free-free vs synchrotron self absorption

(see Peck et al. 1999; Kameno et al. 2000; Marr et al. 2001, 2014; Orienti & Dallacasa 2008; Tremblay et al. 2008; Tingay et al. 2015, Callingham et al. 2015)





NASA, ESA, S. Baum and C. O'Dea (RIT), R. Perley and W. Cotton (NRAO/AUI/NSF), and the Hubble Heritage Team

Widefield (continuum) survey evolution