Dying Young and Frustrated: A study of GPS and CSS sources with the MWA

Joe Callingham

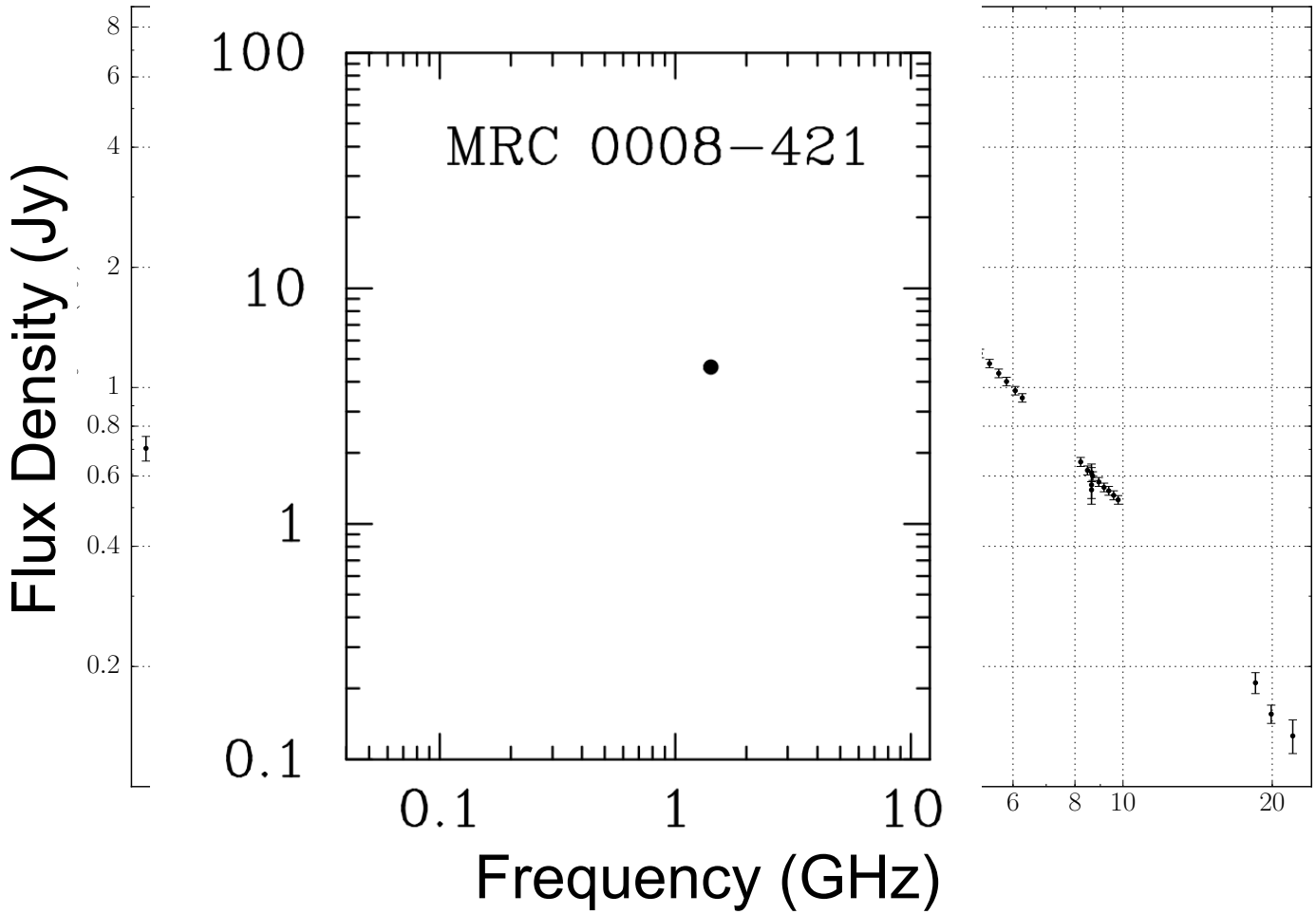
The University of Sydney / CASS

Science at Low Frequencies II, UNM, NM, 3rd December 2015

http://bit.do/gpscss

The spectral revolution has begun!

- Sampling the spectra above and below the turnover at an unprecedented level.
- New wide bandwidth backbends on the ATCA and VLA.
- MWA and LOFAR becoming operational.

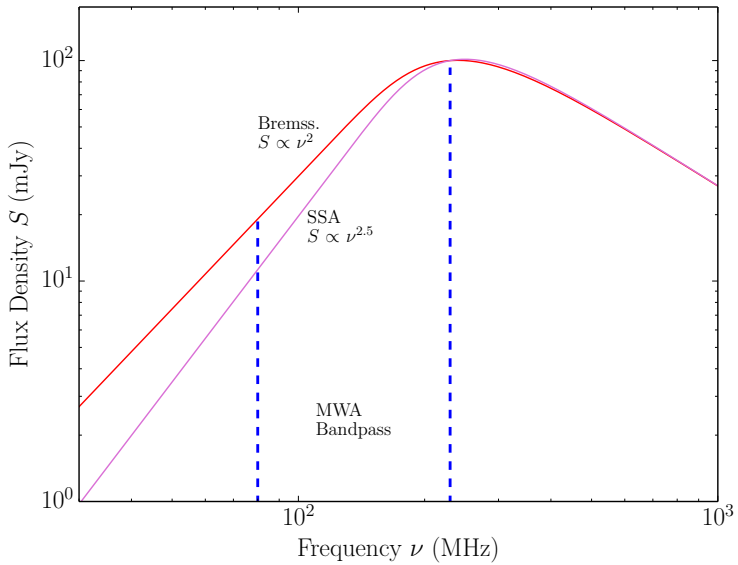


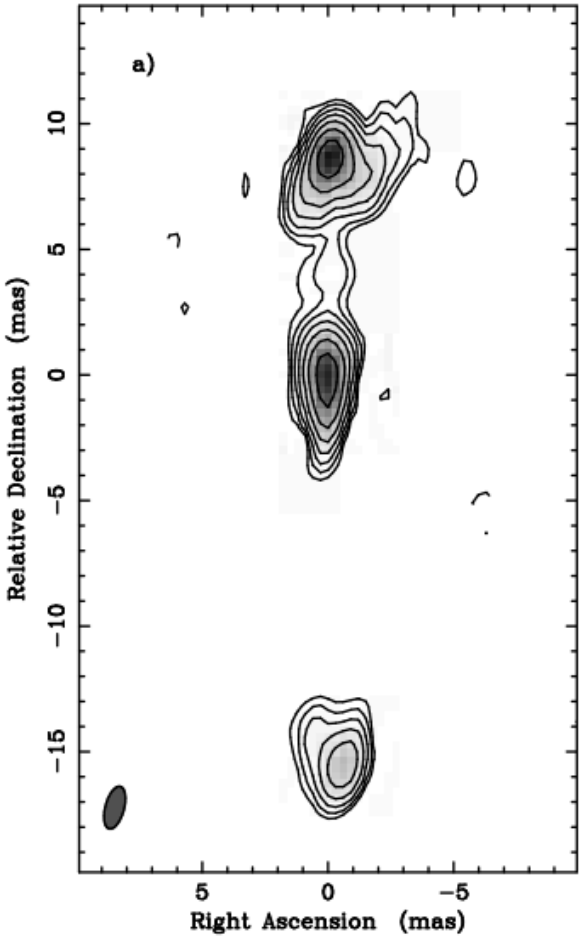
GLEAM Survey

- GaLactic and Extragalactic All-Sky MWA (GLEAM) survey:
  Randall et al. (2015), arXiv:1505.06041
- Declinations -90° to +30°
- 72-230 MHz, 8 MHz bandwidth
- Resolution ~3' at 72 MHz, ~1' at 200 MHz
- Confusion limited (~20 mJy) survey
- Release ~early 2016 with ~320,000 sources. Commissioning survey released
  Hurley-Walker et al. (2015), arXiv:1410.0790

What are CSS/GPS sources?

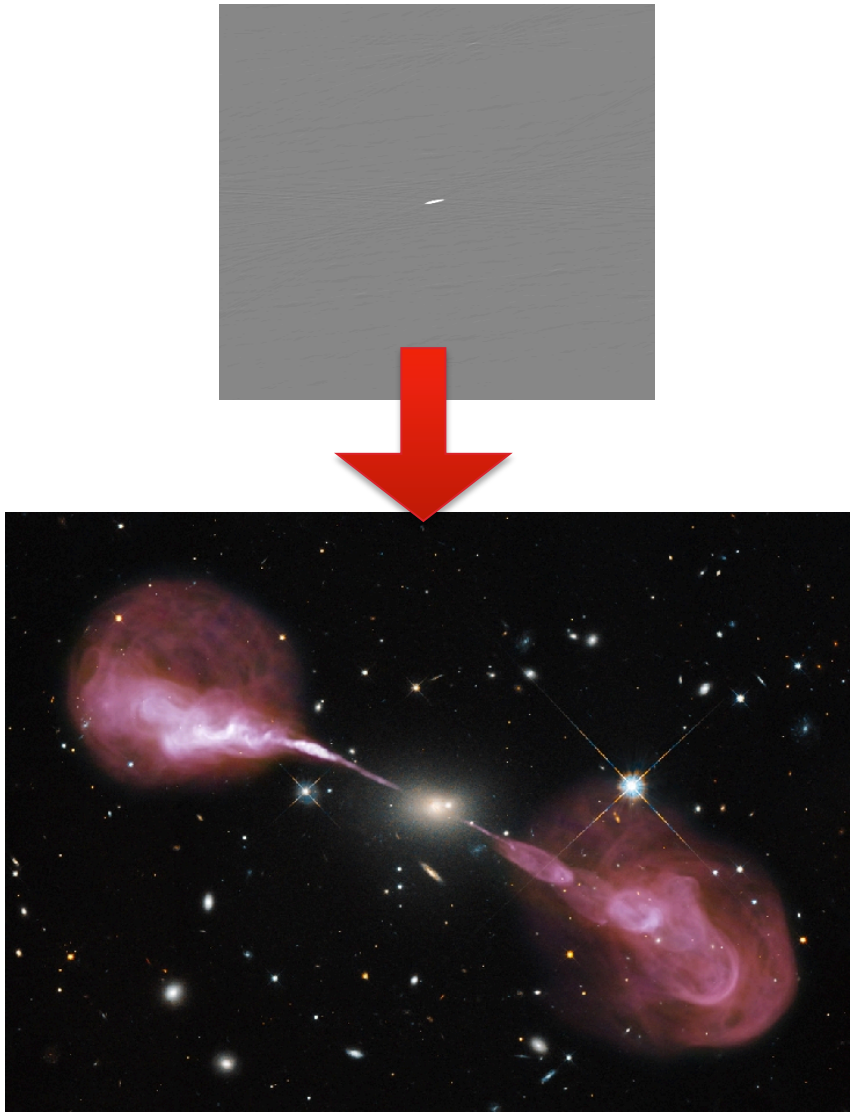
- Originally empirical classification:
  - Powerful AGN with concave spectra
  - GPS turnover ~ 1 GHz, CSS turnover ~ 150 MHz (?)
  - Small physical sizes. GPS < 1 kpc, CSS ~ 1 – 10 kpc
  - Hosts vary - quasars, radio galaxies and Seyferts





0710+439, Owsianik et al 1998

Why Study CSS/GPS Sources?



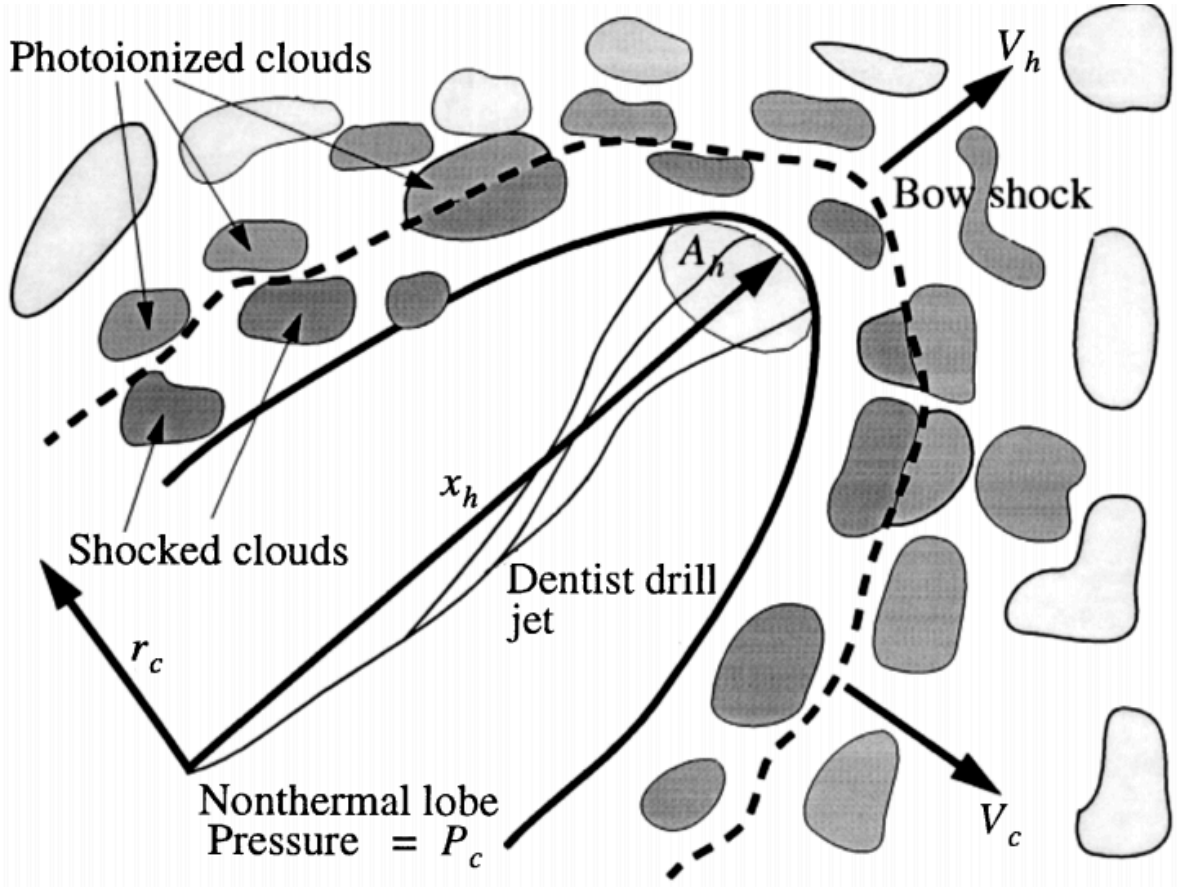
NASA, ESA, S. Baum and C. O'Dea (RIT), R. Perley and W. Cotton (NRAO/AUI/NSF), and the Hubble Heritage Team

- Unique view of early stages of AGN activity. Probe of environment to tens pc scale.
- How many sources go from birth to A team sources (Cyg A, Her A etc)?
- Are they confined to small spatial scales due to 'youth' or 'frustrated' or **both**?
- Cause of the turnover in spectrum? Vital for accurate evolutionary models

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

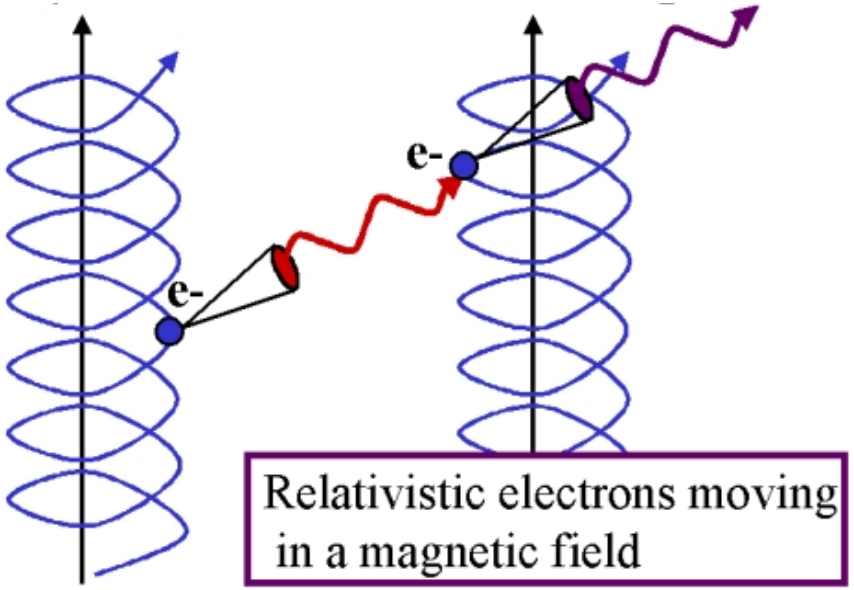
Models of GPS Radio Spectra

Inhomogeneous free-free model (Bicknell et al. 1997, Begelman 1999)



Models of GPS Radio Spectra

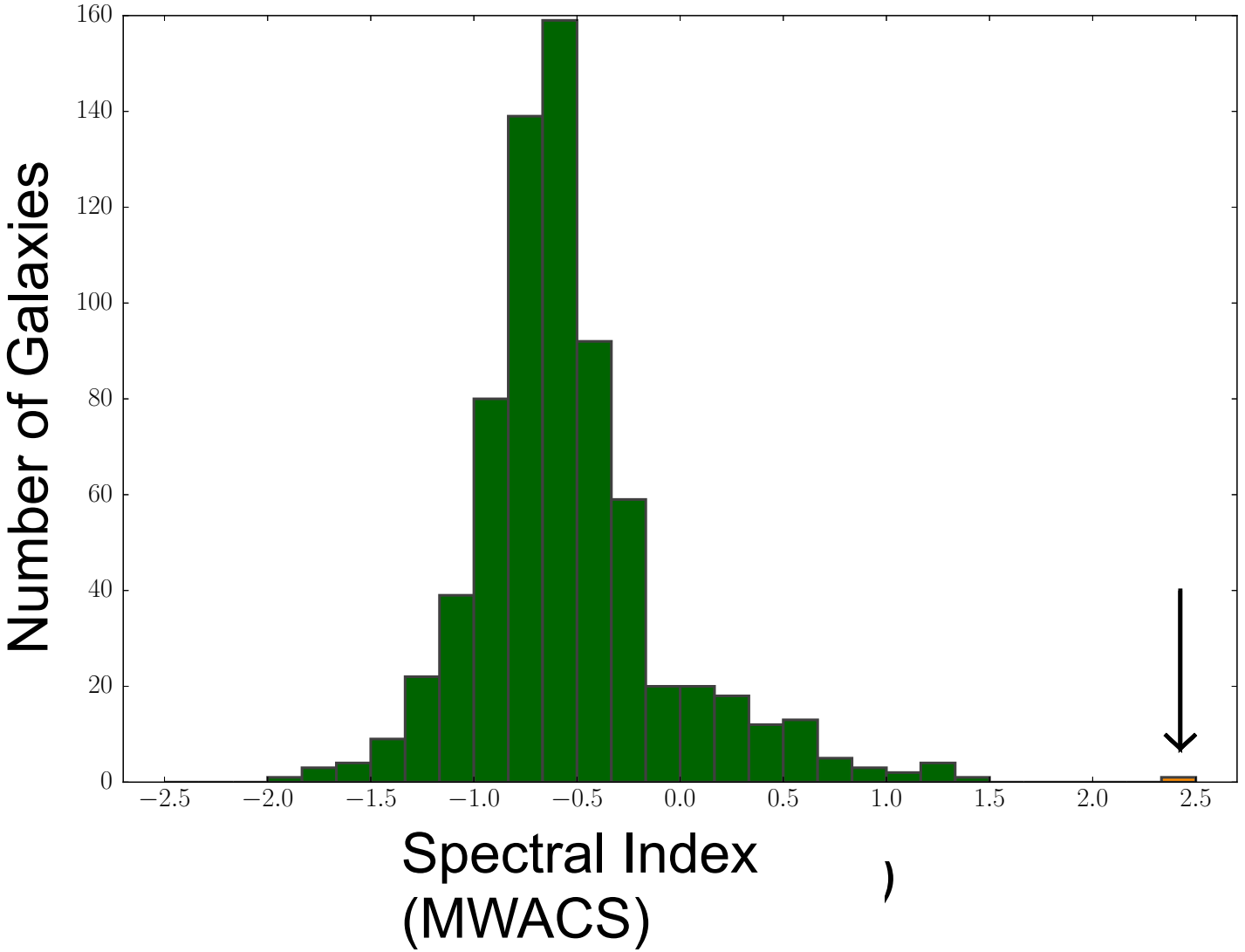
Synchrotron self-absorption (SSA) model (Kellermann 1966)

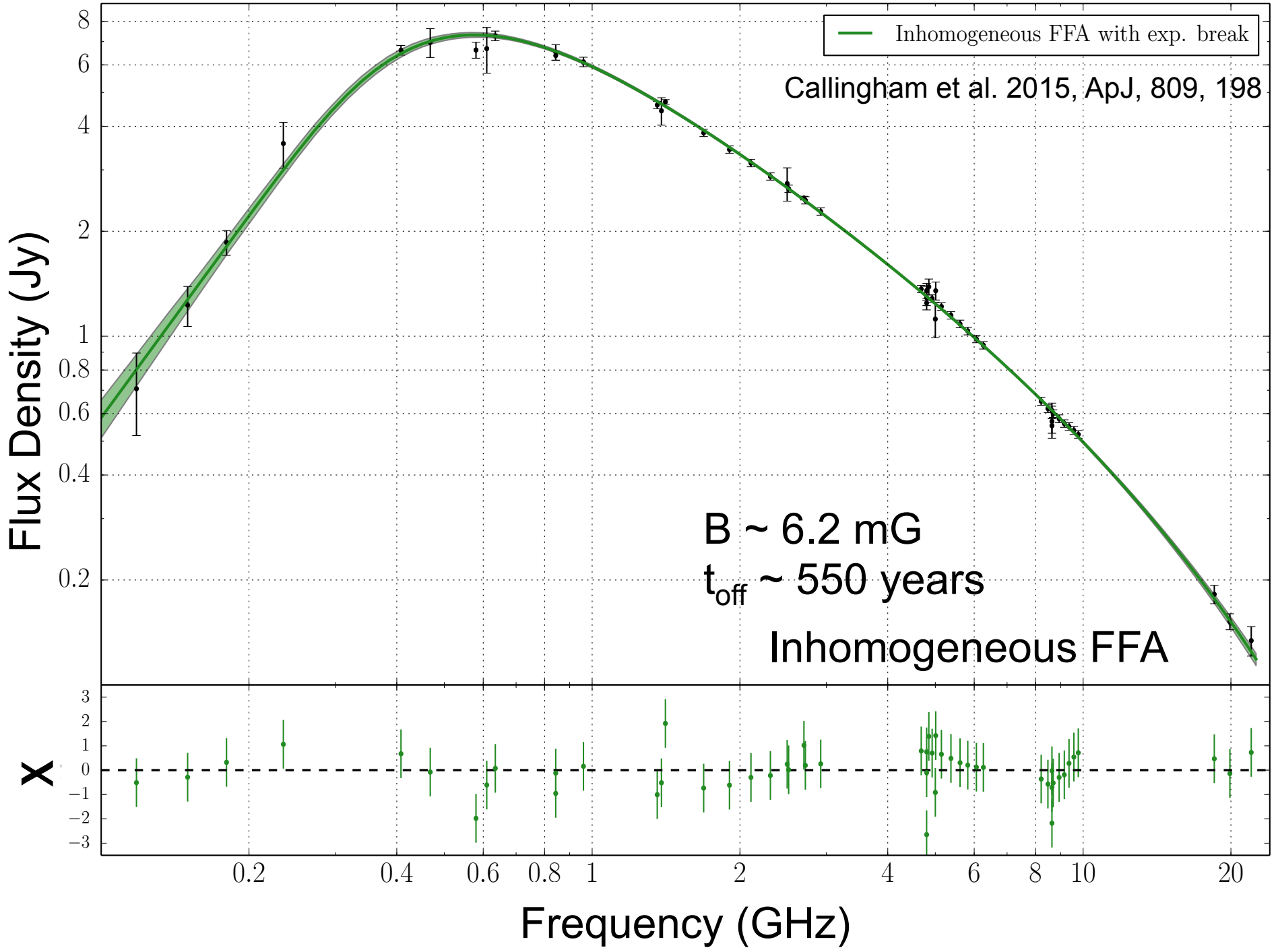


Prediction of 2.5 slope – never seen

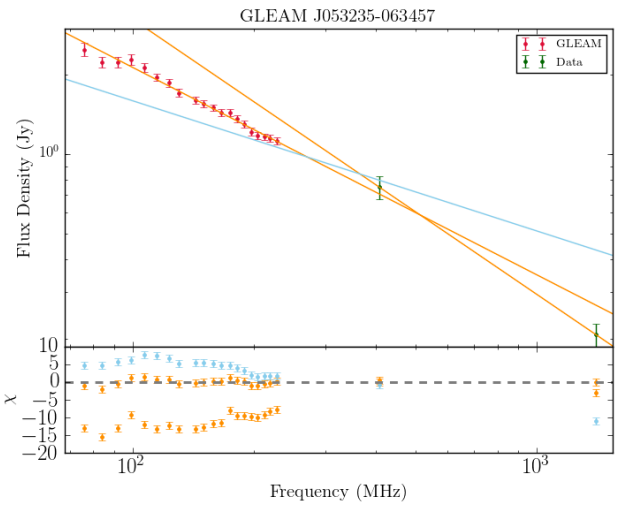
New Extreme GPS Source PKS B0008-42

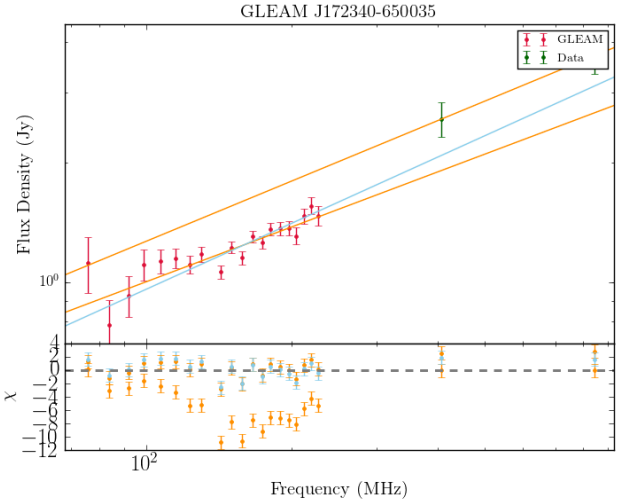
- Low frequency data has a gradient of ~2.5 – steepest known. Spectral width ~0.6 decade of freq. – smallest known.
- Test bed for models of GPS/ CSS spectra.
- ~120 mas scale, 1000 pc

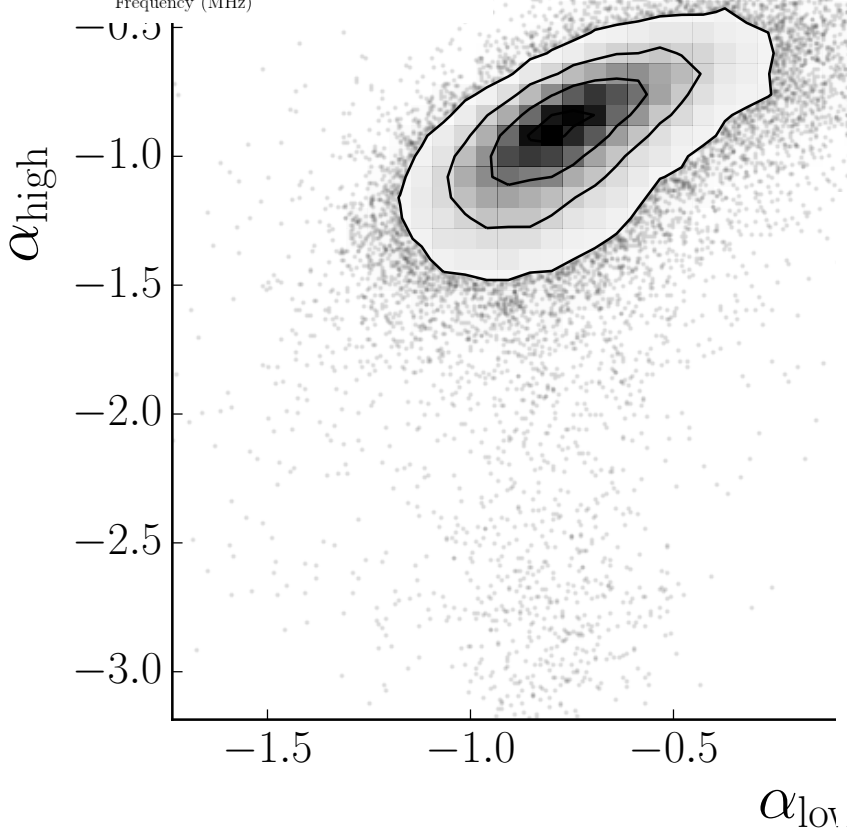


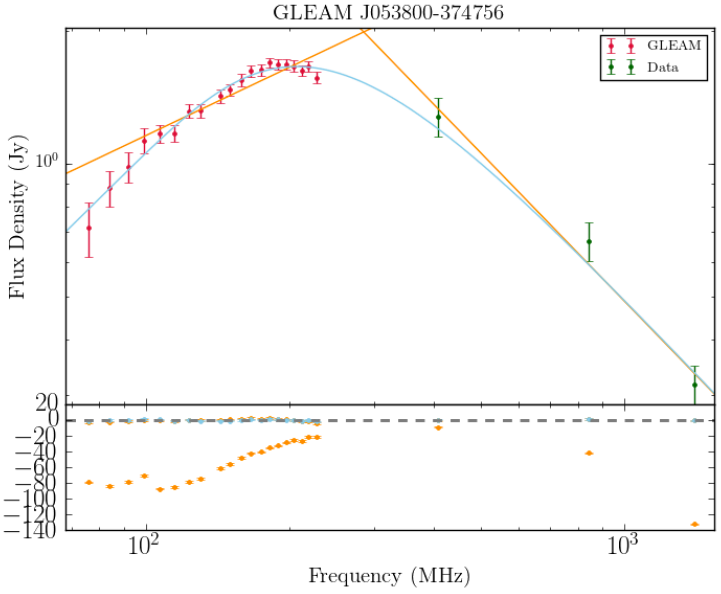

Inhomogeneous FFA with exp. break
Callingham et al. 2015, ApJ, 809, 198
B ~ 6.2 mG
t_{off} ~ 550 years
Inhomogeneous FFA
Flux Density (Jy)
Frequency (GHz)
X

sky is pr


GLEAM J053235-063457
GLEAM
Data
Flux Density (Jy)
Frequency (MHz)


GLEAM J172340-650035
GLEAM
Data
Flux Density (Jy)
Frequency (MHz)


$\alpha_{\rm high}$
$\alpha_{\rm low}$


GLEAM J053800-374756
GLEAM
Data
Flux Density (Jy)
Frequency (MHz)

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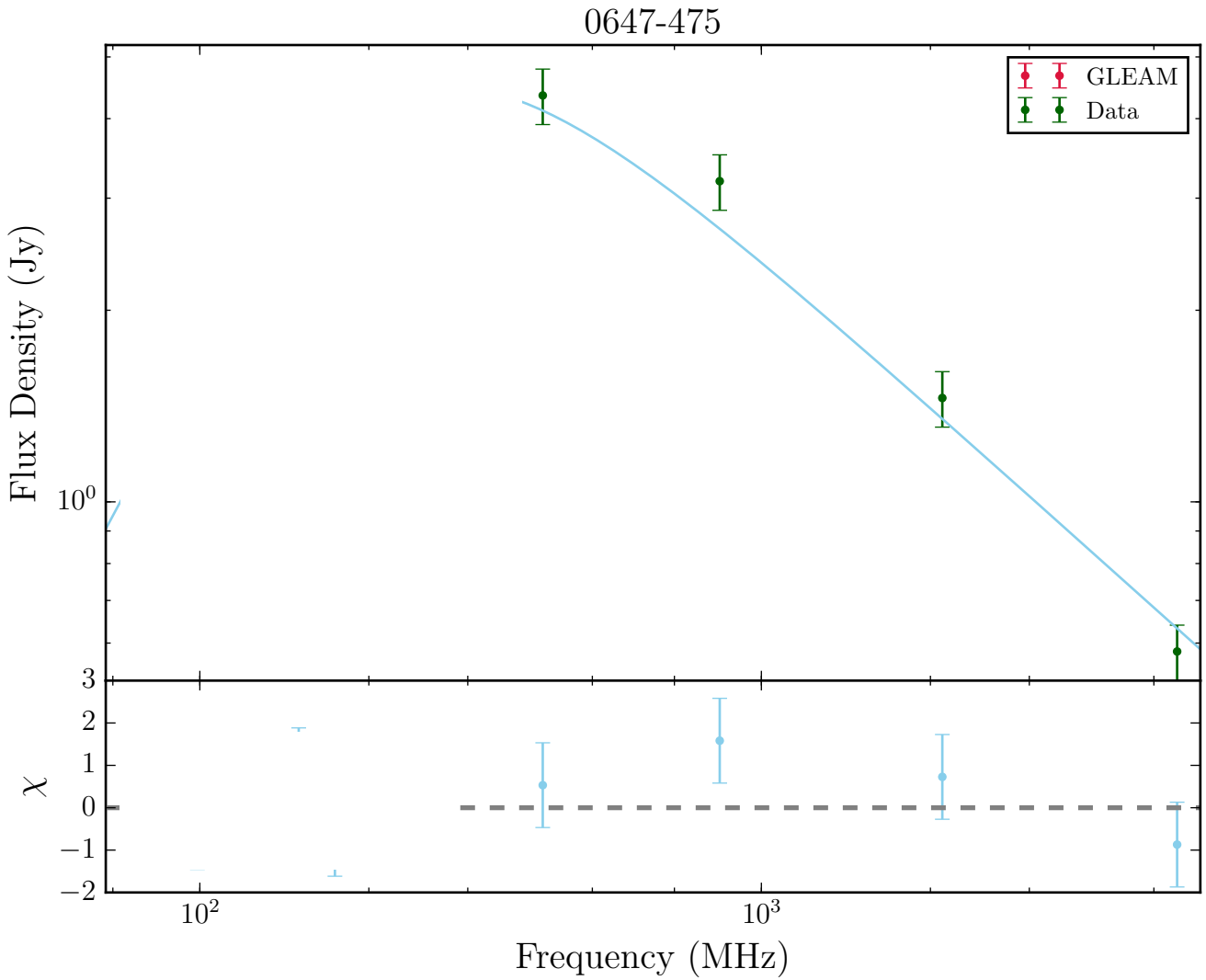
ARC CENTRE OF EXCELLENCE
FOR ALL-SKY ASTROPHYSICS

Preliminary GLEAM data



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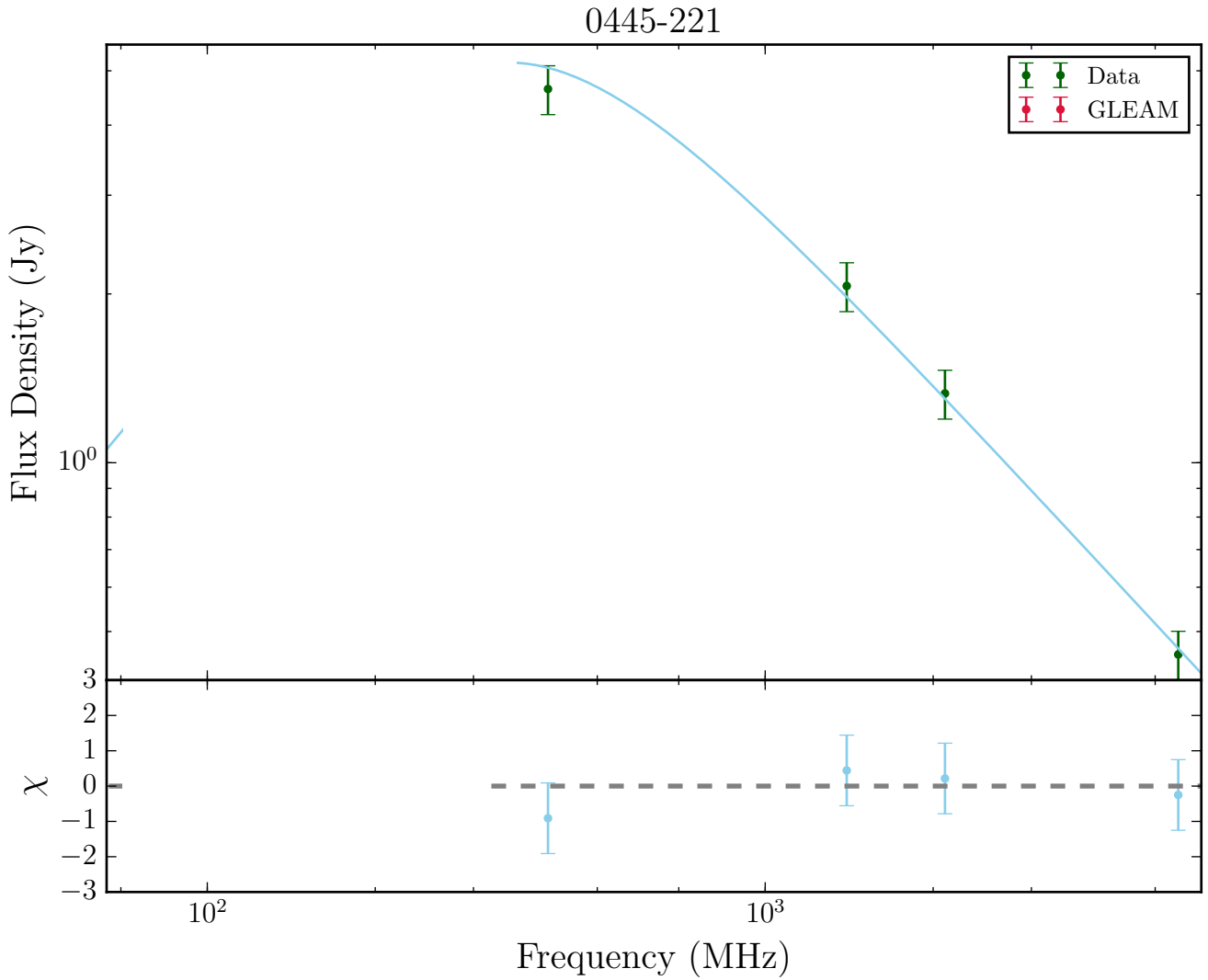

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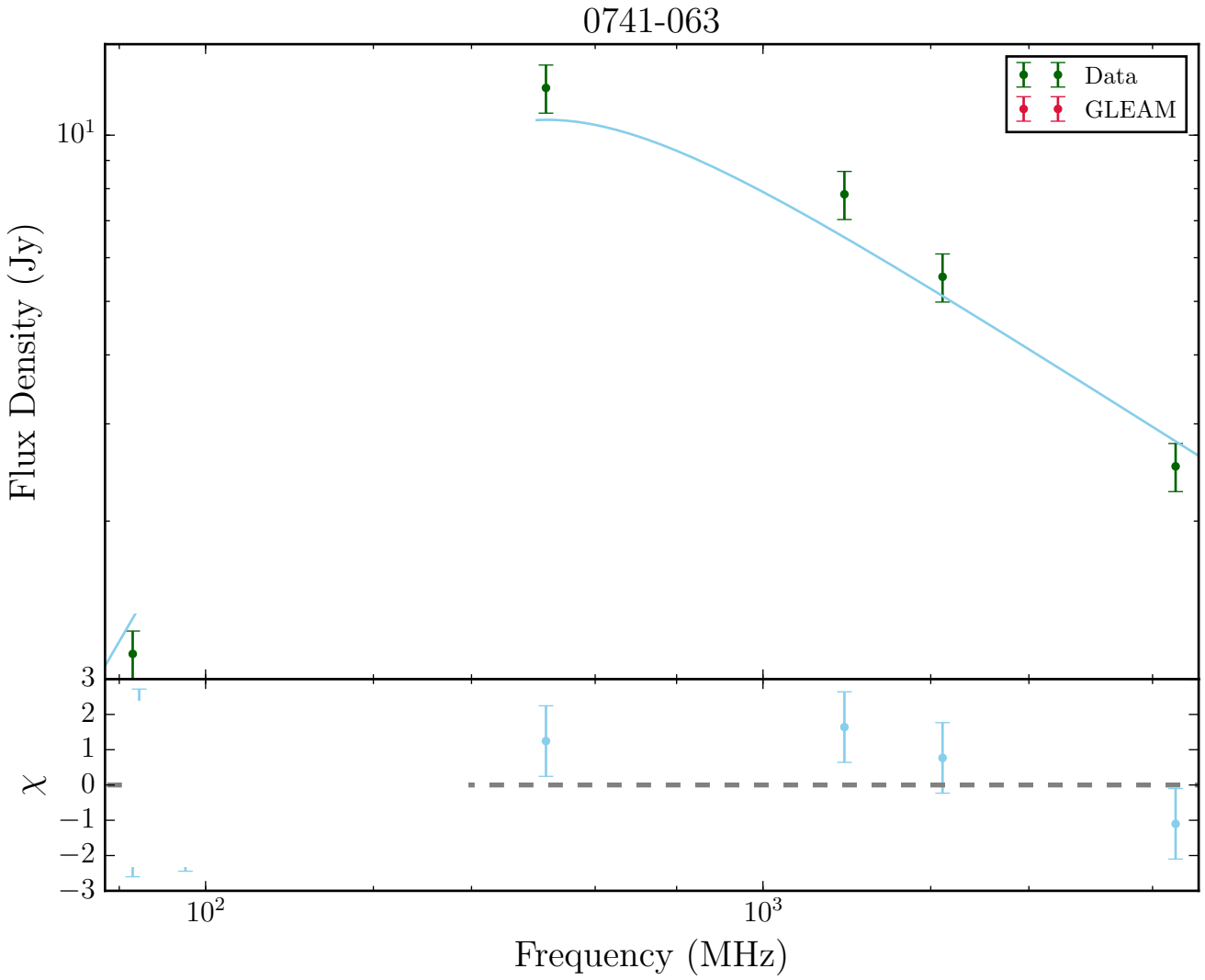

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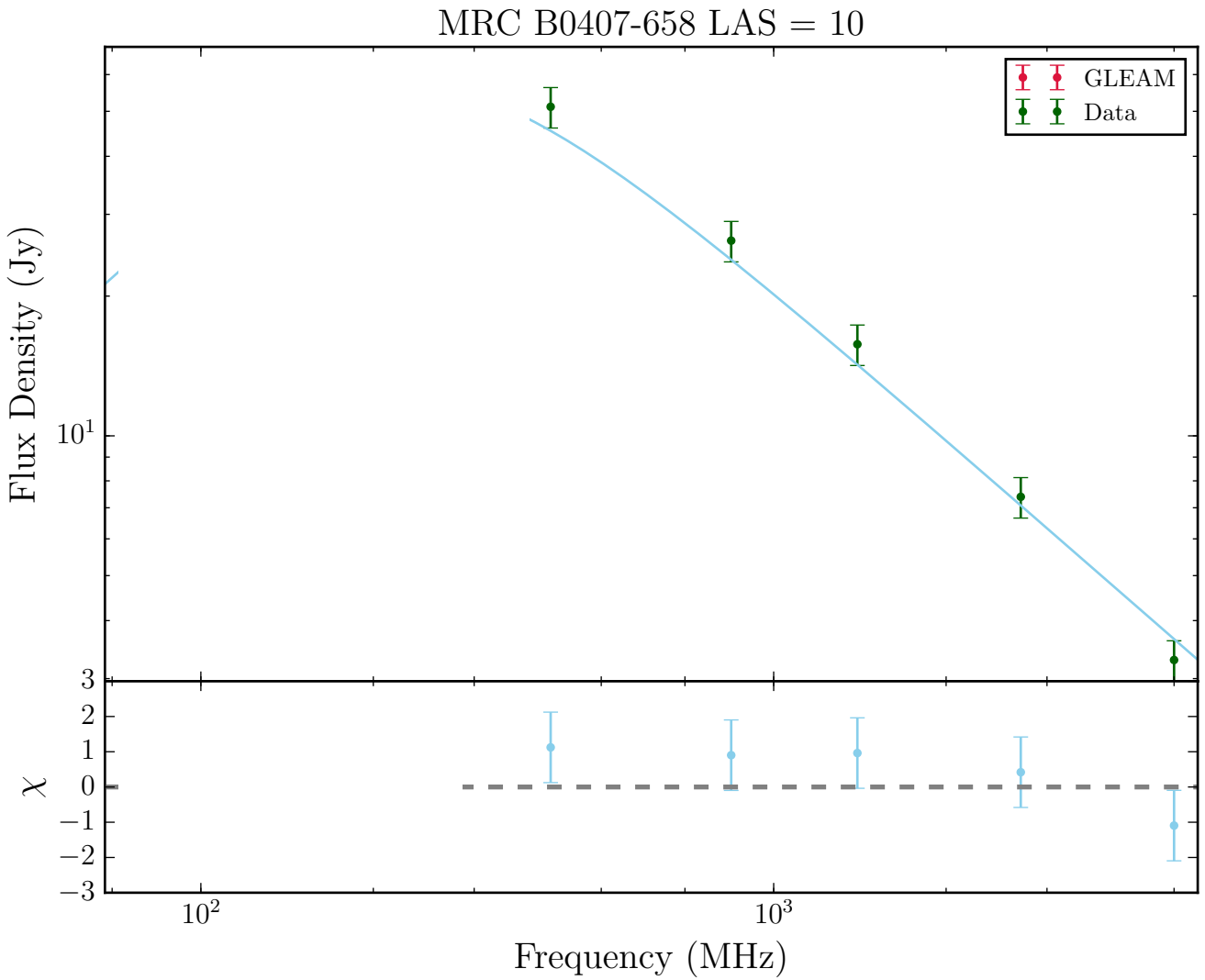
Preliminary GLEAM data



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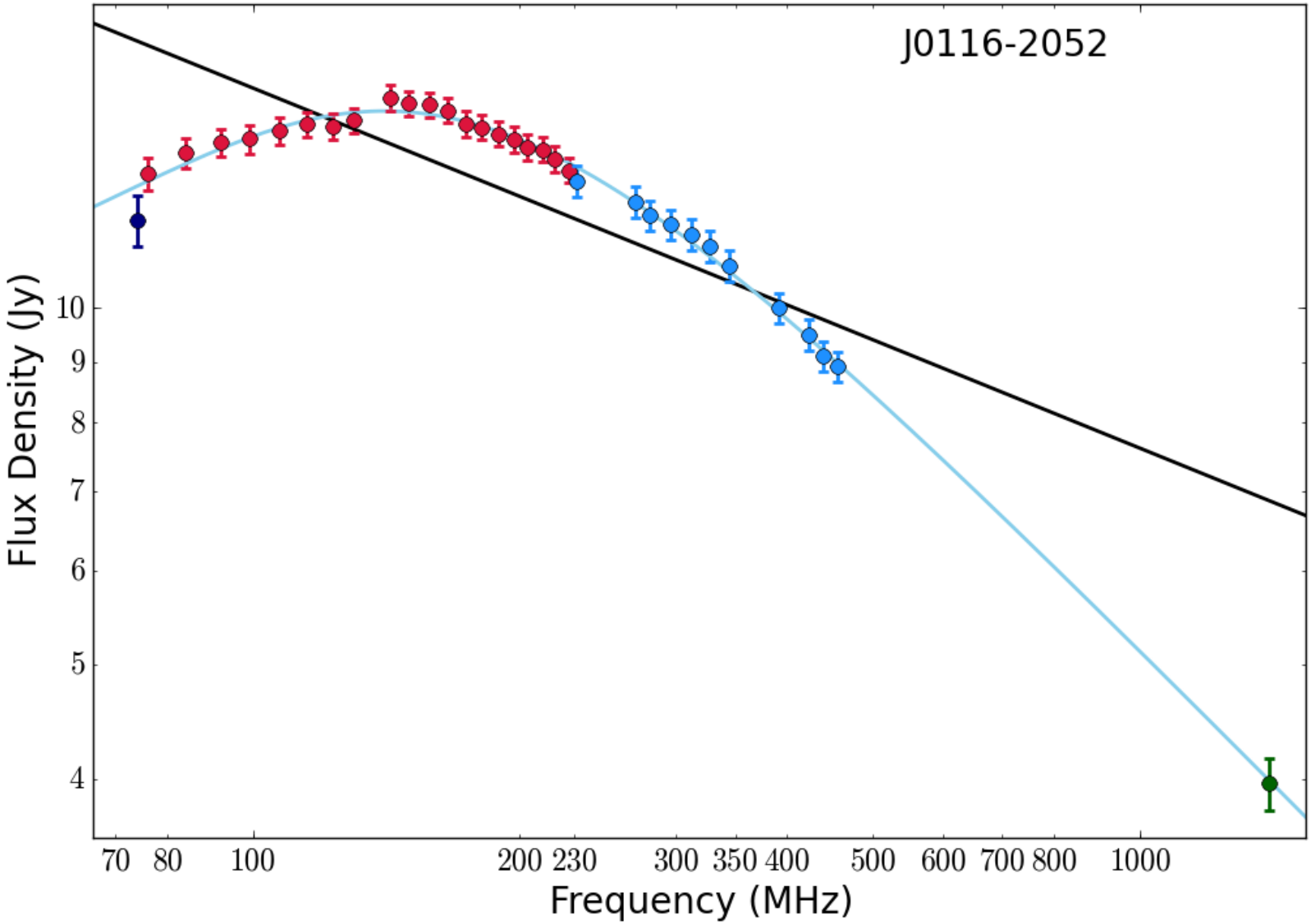
Preliminary GLEAM data



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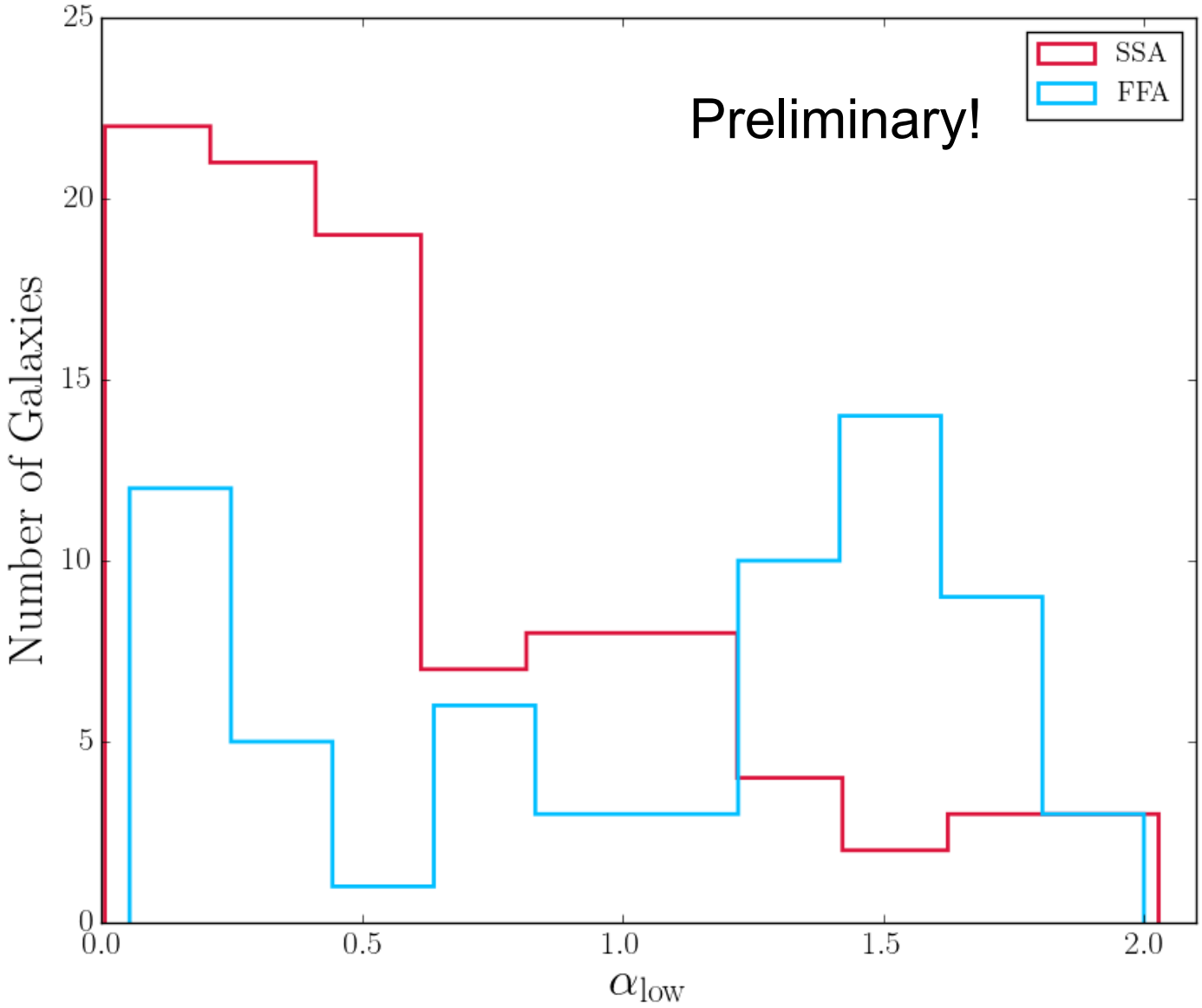
Bi-modal?



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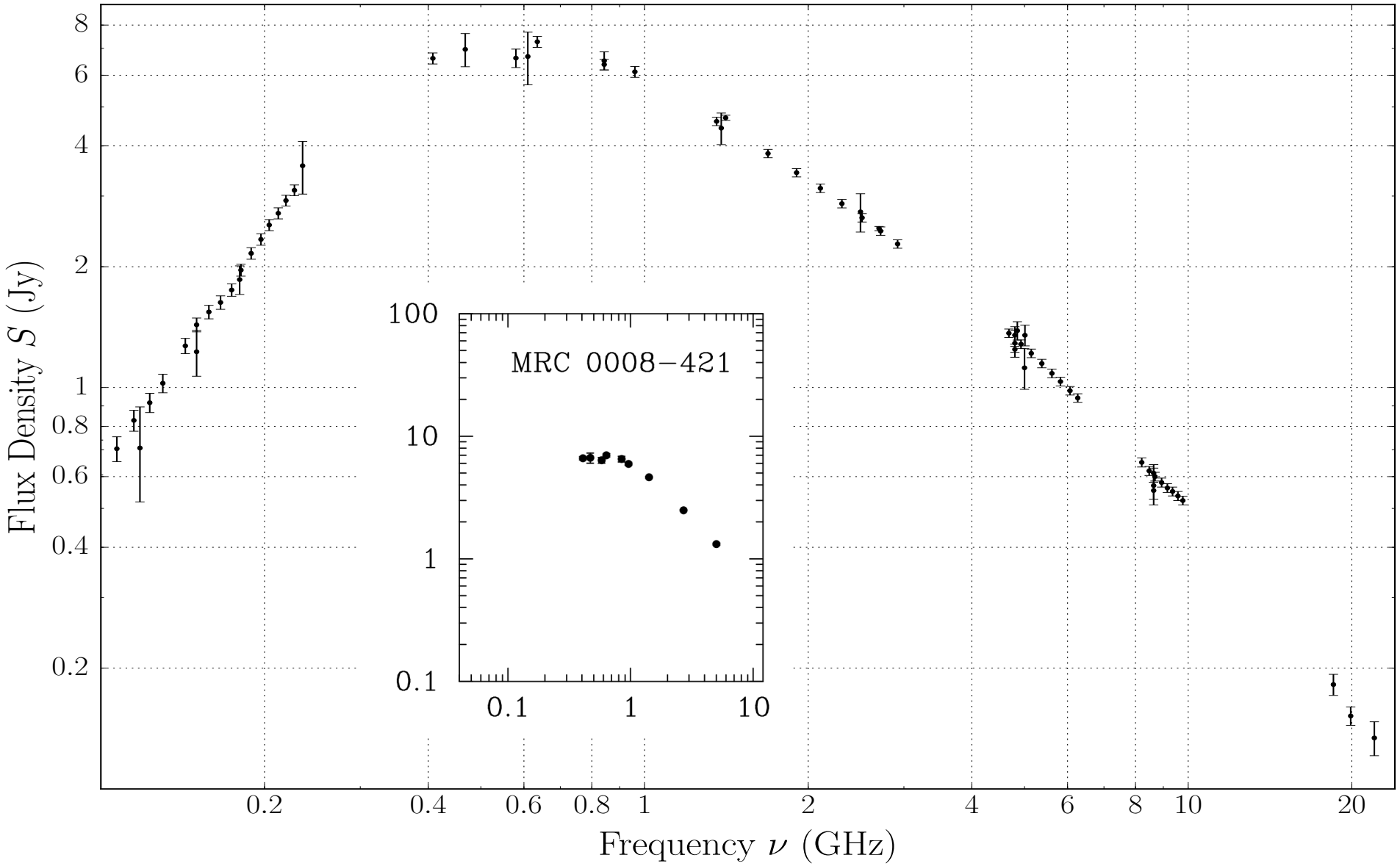
The spectral revolution is here



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Pictures speak the loudest

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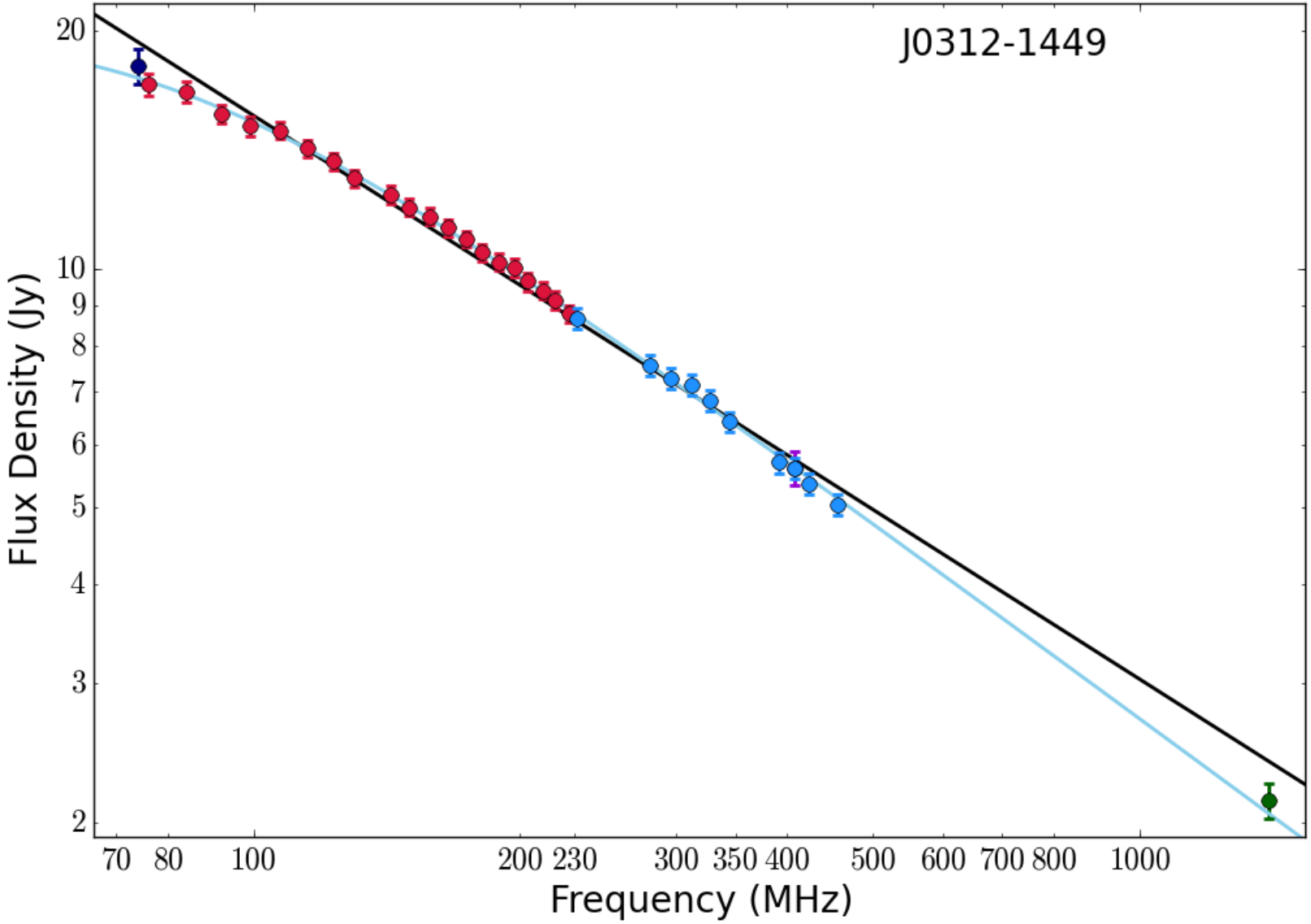
Preliminary GLEAM data



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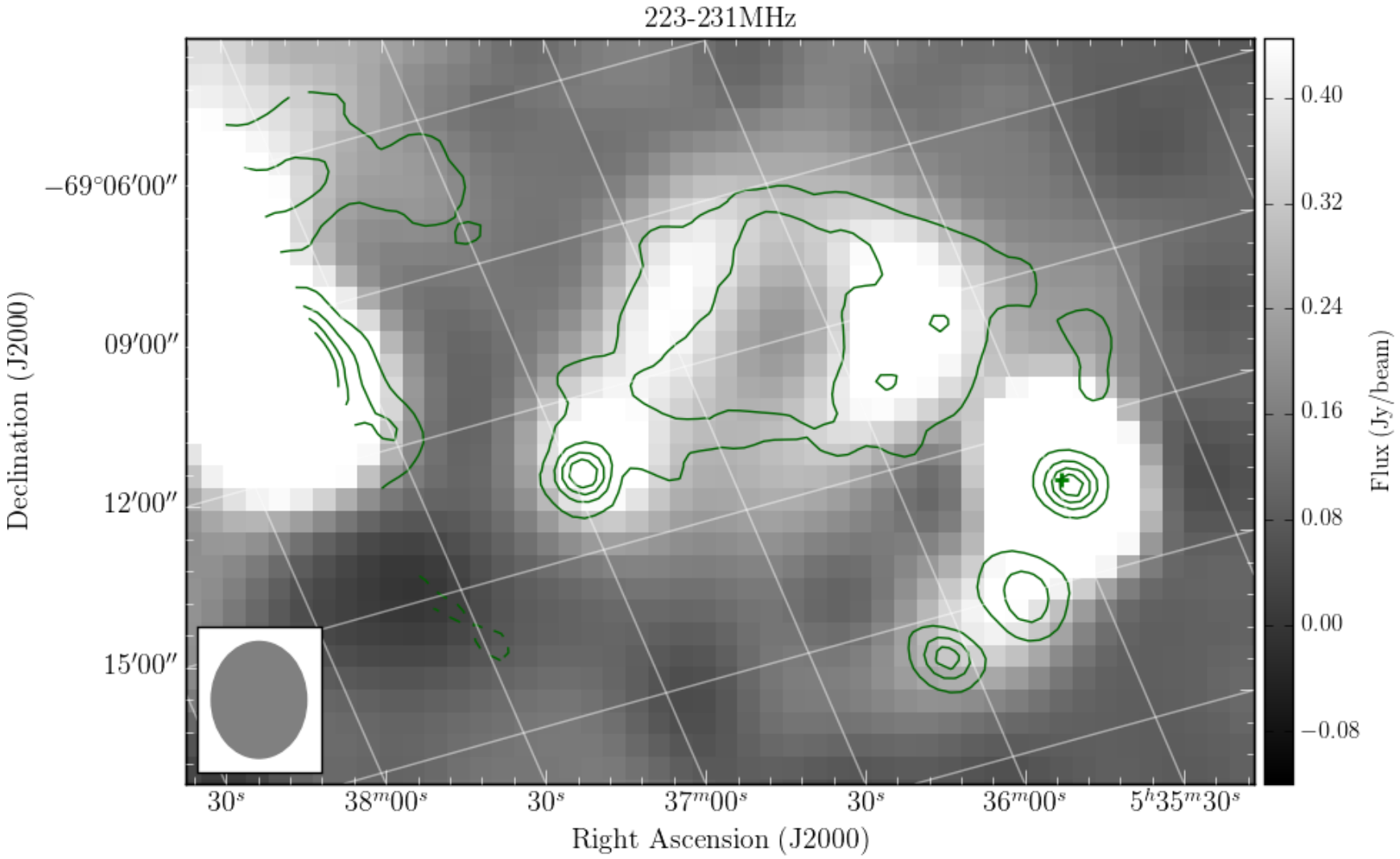
SNR 1987A



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Snazzy movie!

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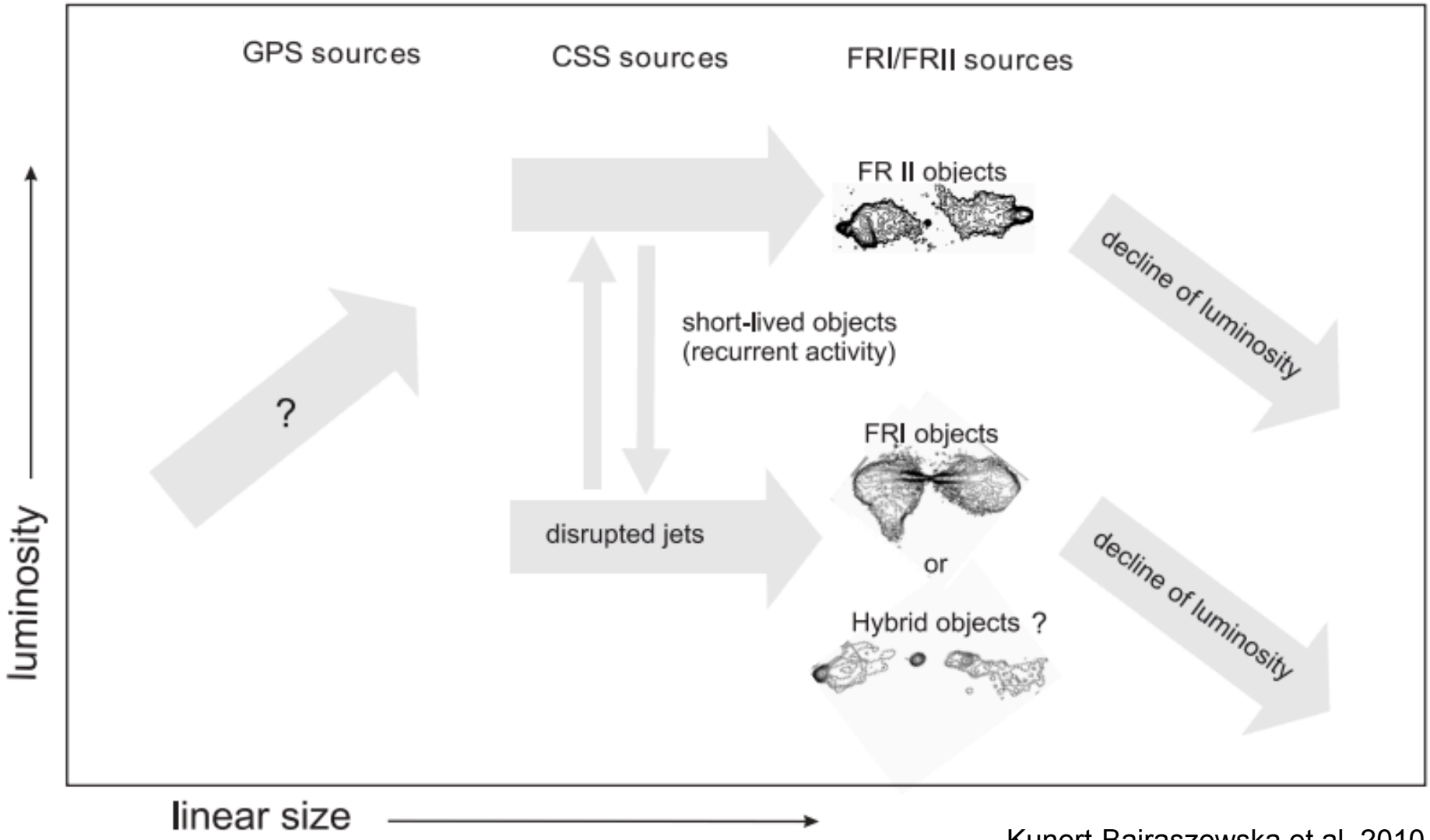
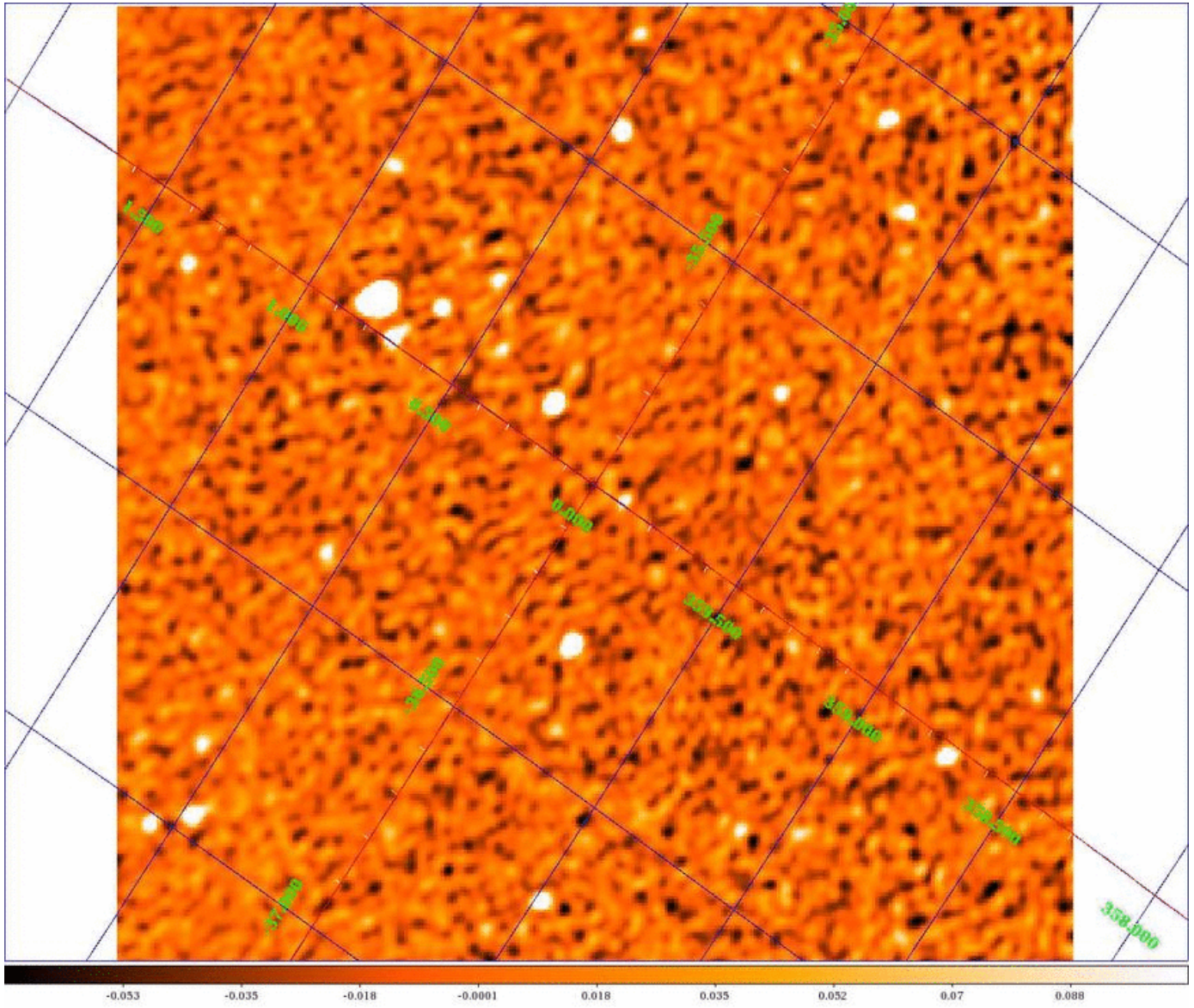
Acronym Spaghetti



Kunert-Bajraszewska et al. 2010

New (old!) problems

- Confusion
- Ionosphere
- Flux density scale
- Primary beam model
- Source association



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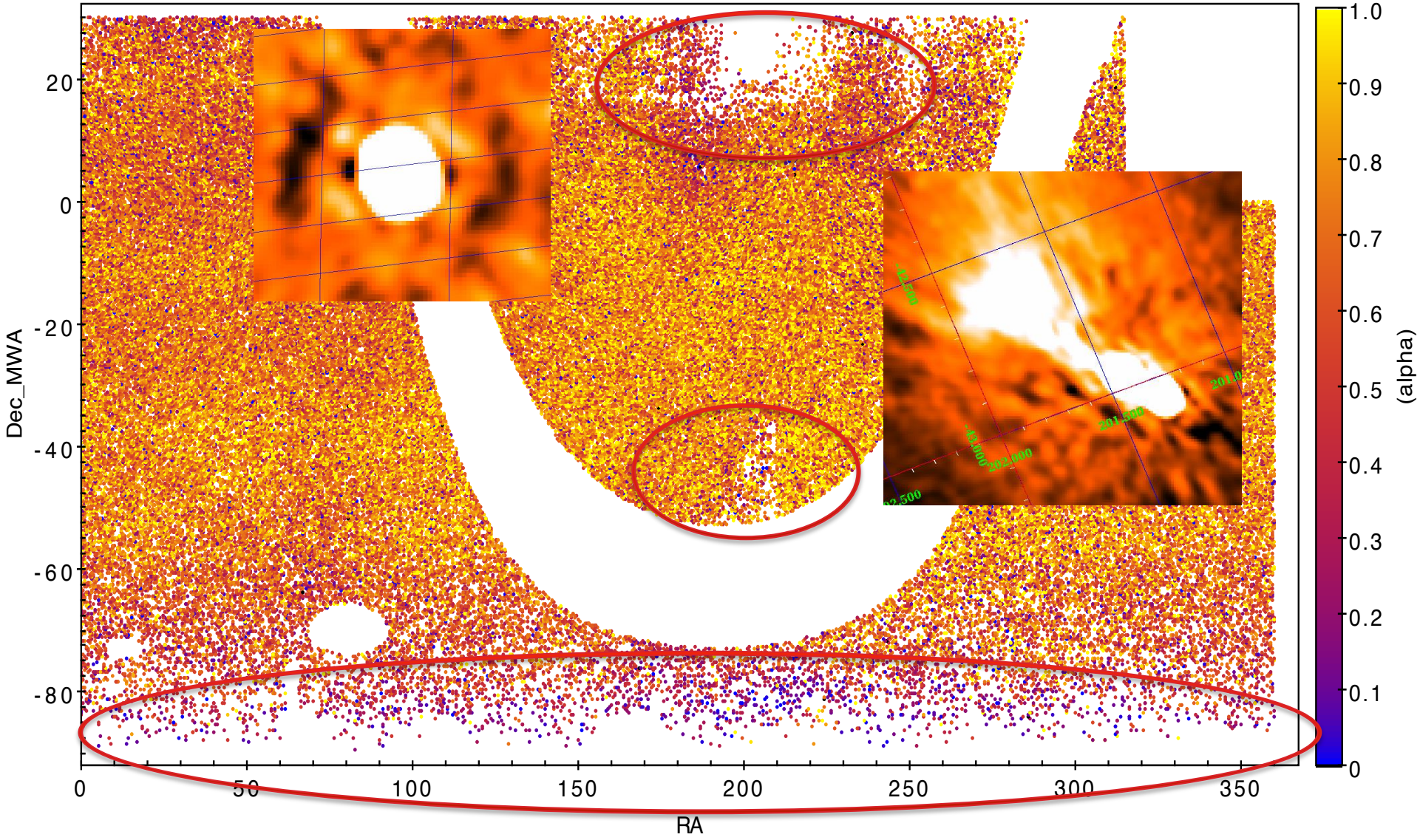
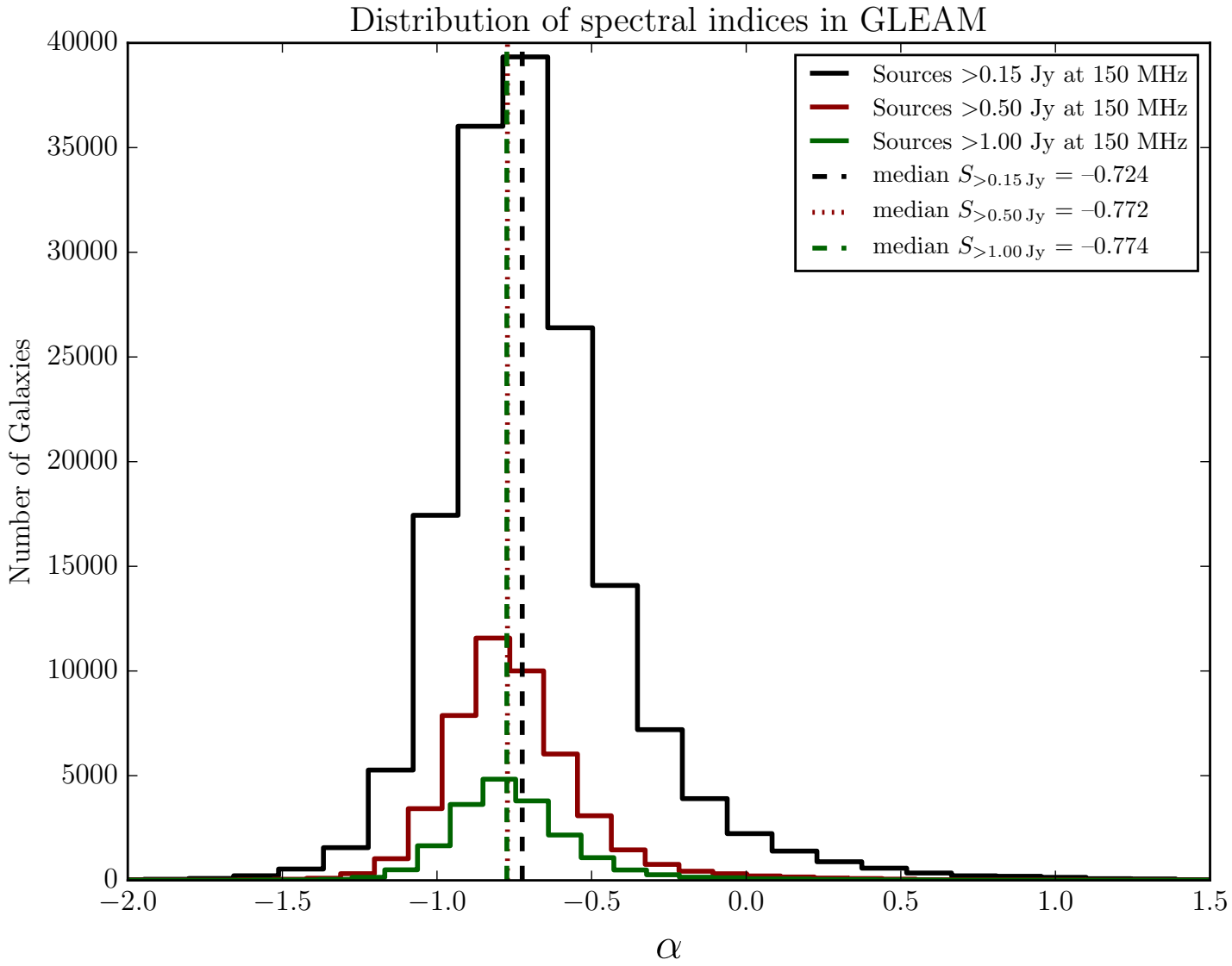
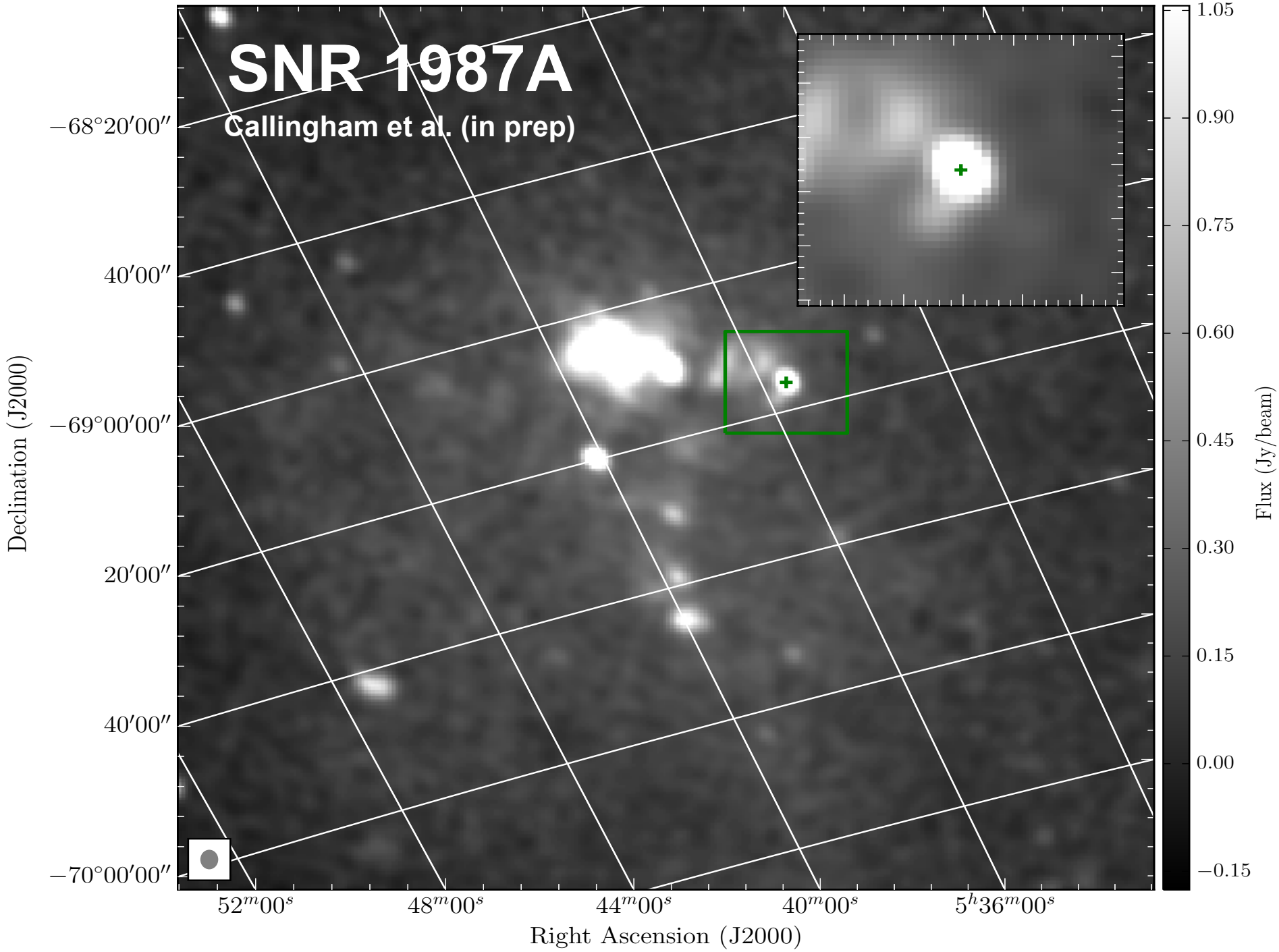
Pick the problem areas!



GLEAM – IDR2

- Intermediate data release to the consortium
- Find all the problems!




SNR 1987A
Callingham et al. (in prep)
−68°20′00″
40′00″
−69°00′00″
20′00″
40′00″
−70°00′00″
Declination (J2000)
52m00s
48m00s
44m00s
40m00s
5h36m00s
Right Ascension (J2000)
1.05
0.90
0.75
0.60
0.45
0.30
0.15
0.00
−0.15
Flux (Jy/beam)

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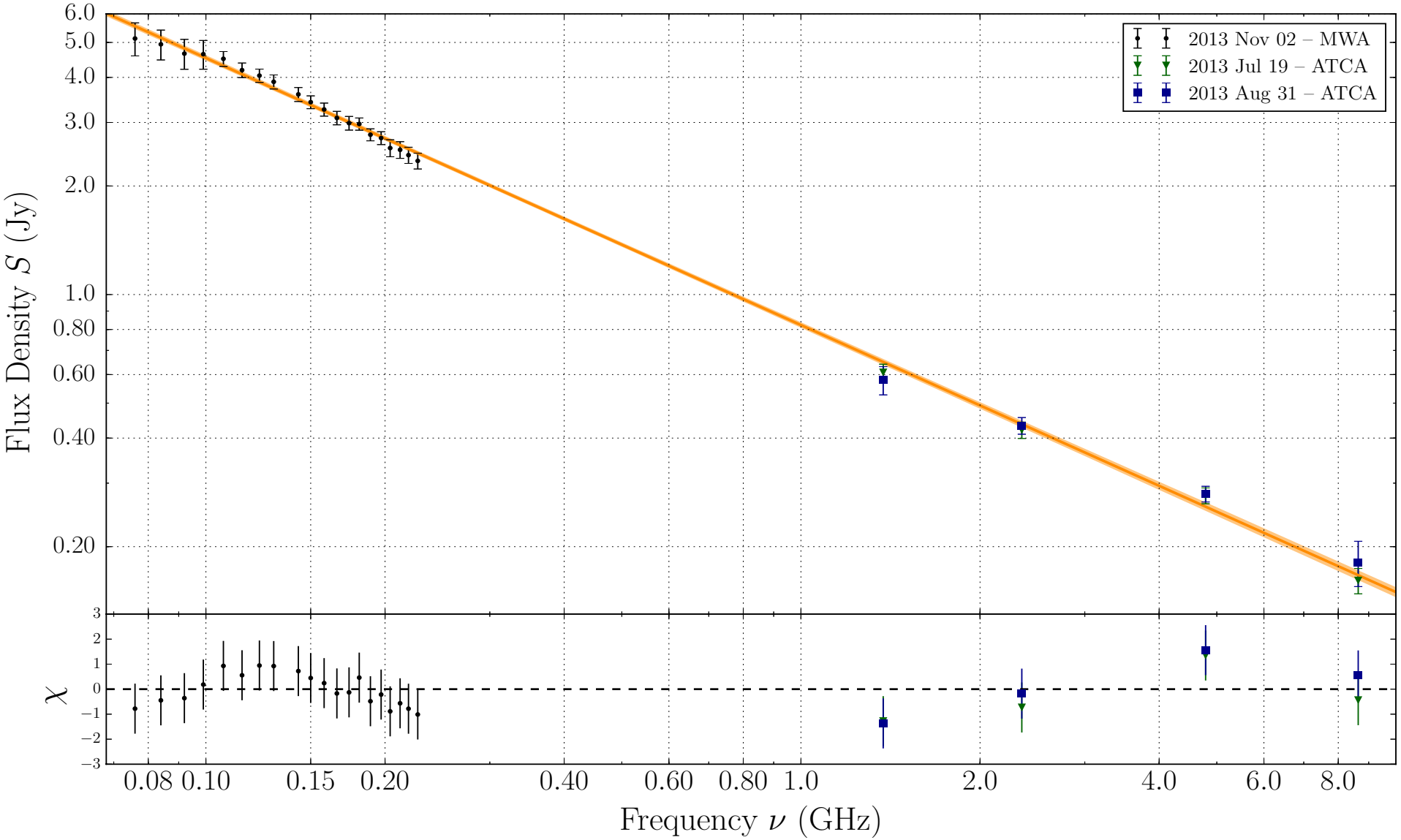
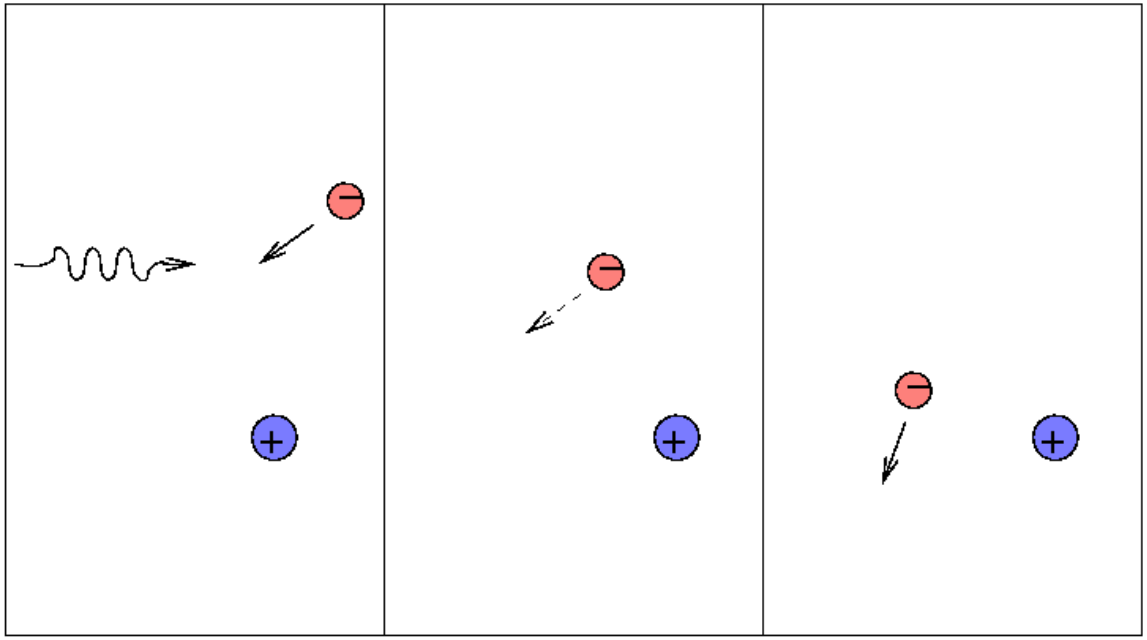
SNR 1987A



Models of GPS Radio Spectra

Homogeneous free-free model



$$S_\nu = \sum_{i=1,2} a_i \nu^{-\alpha_i} e^{-(\nu/\nu_{\mathrm{p,i}})^{-2.1}}$$

Tingay & De Kool (2003)

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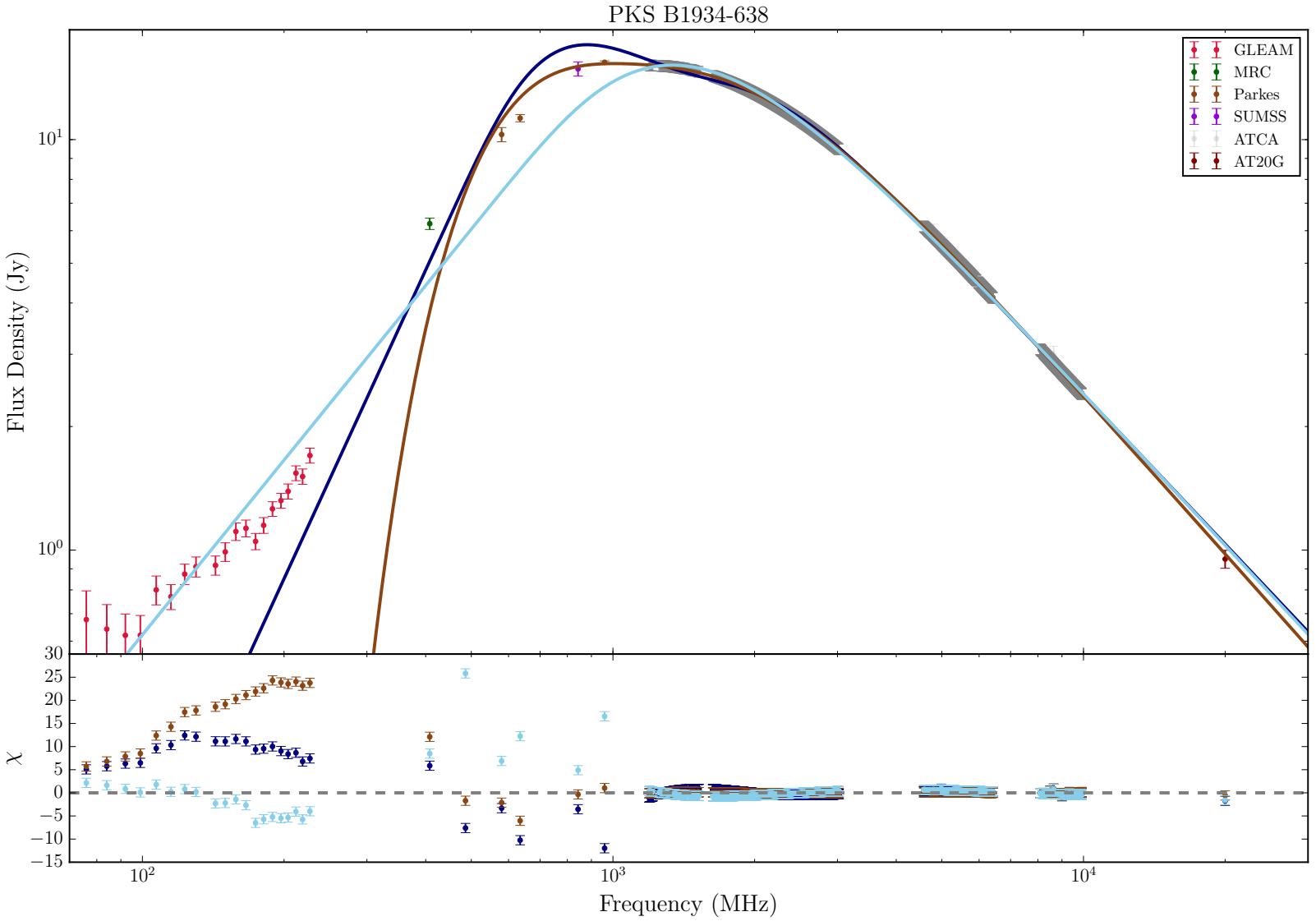
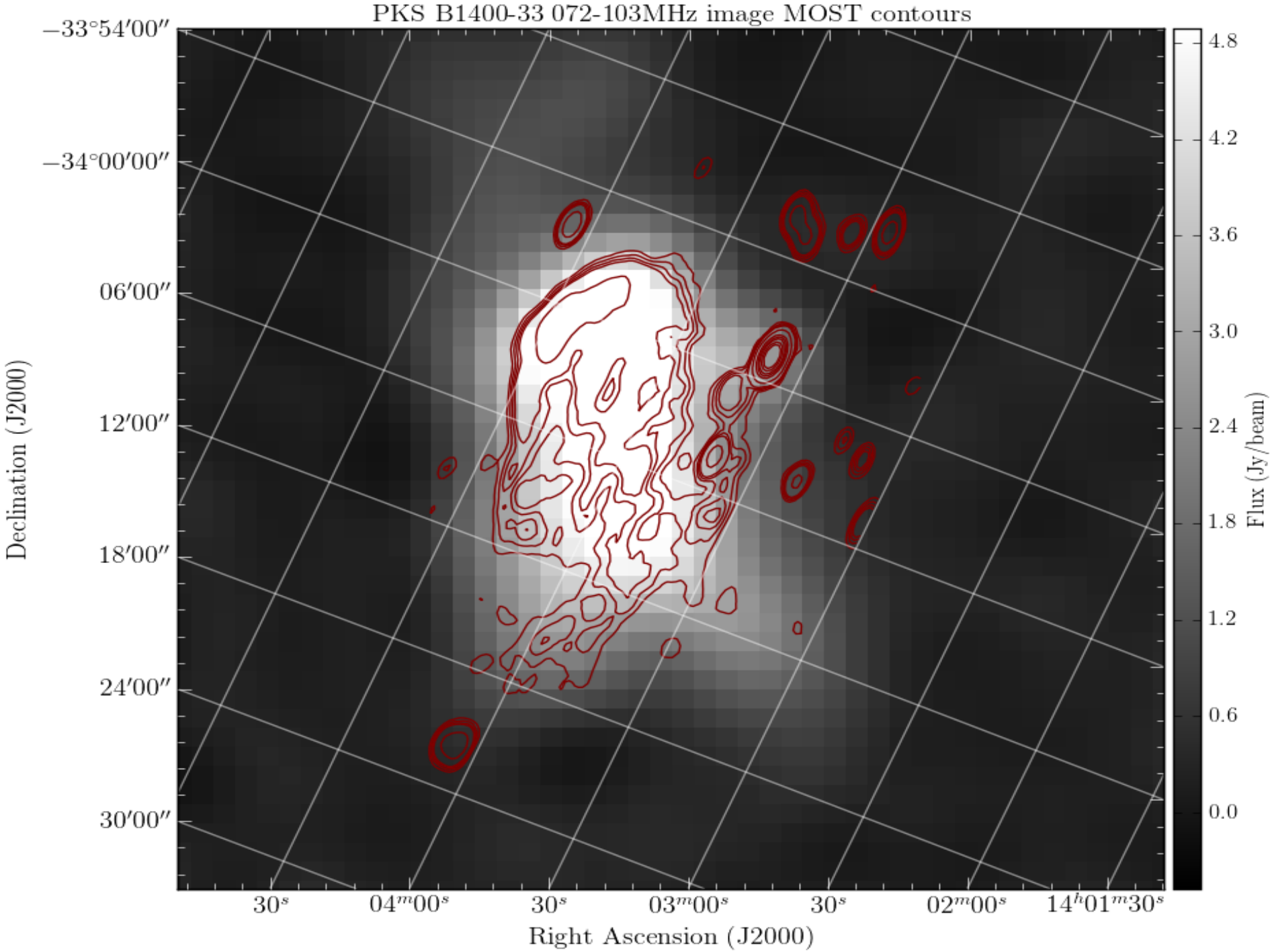
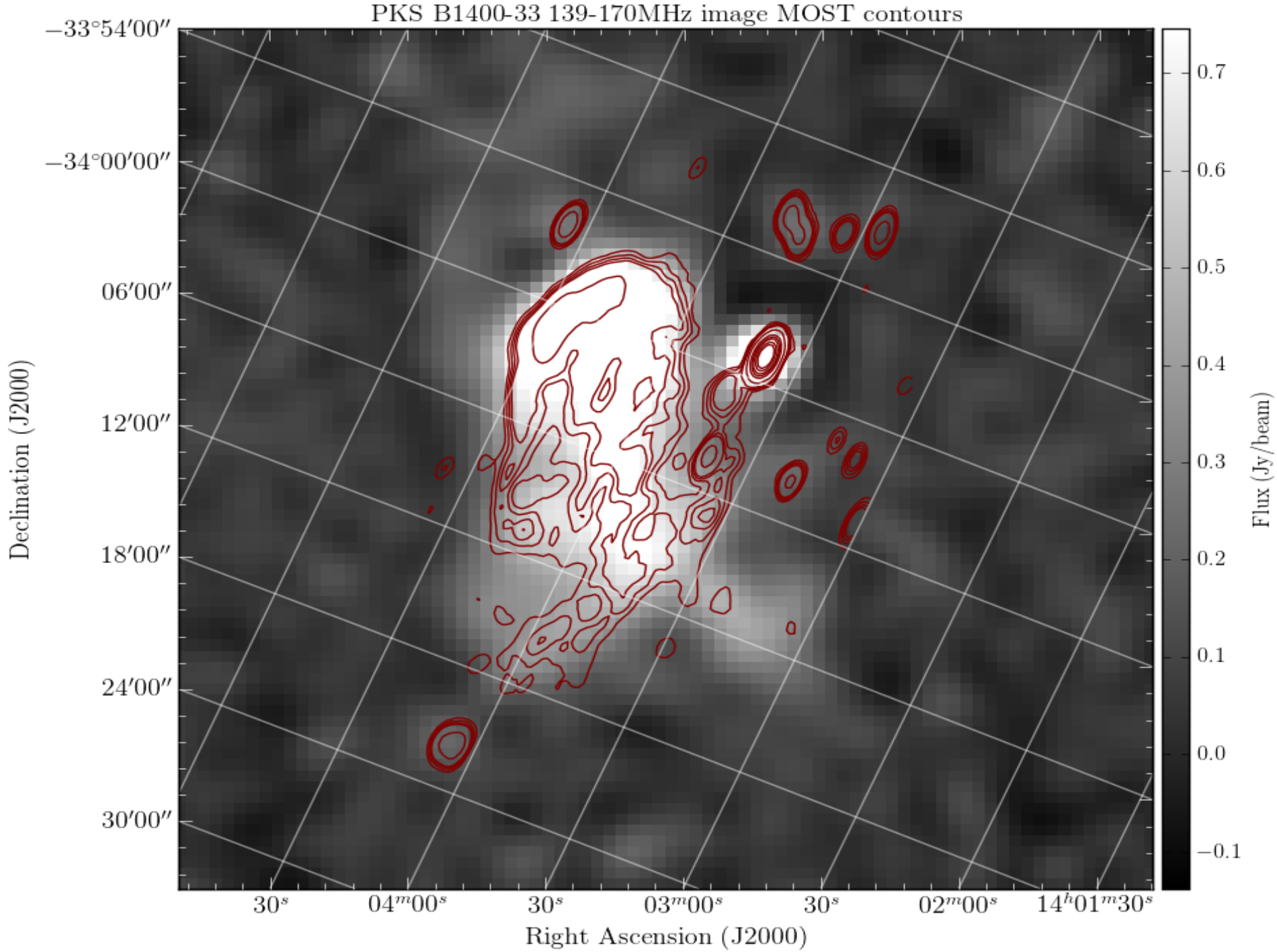
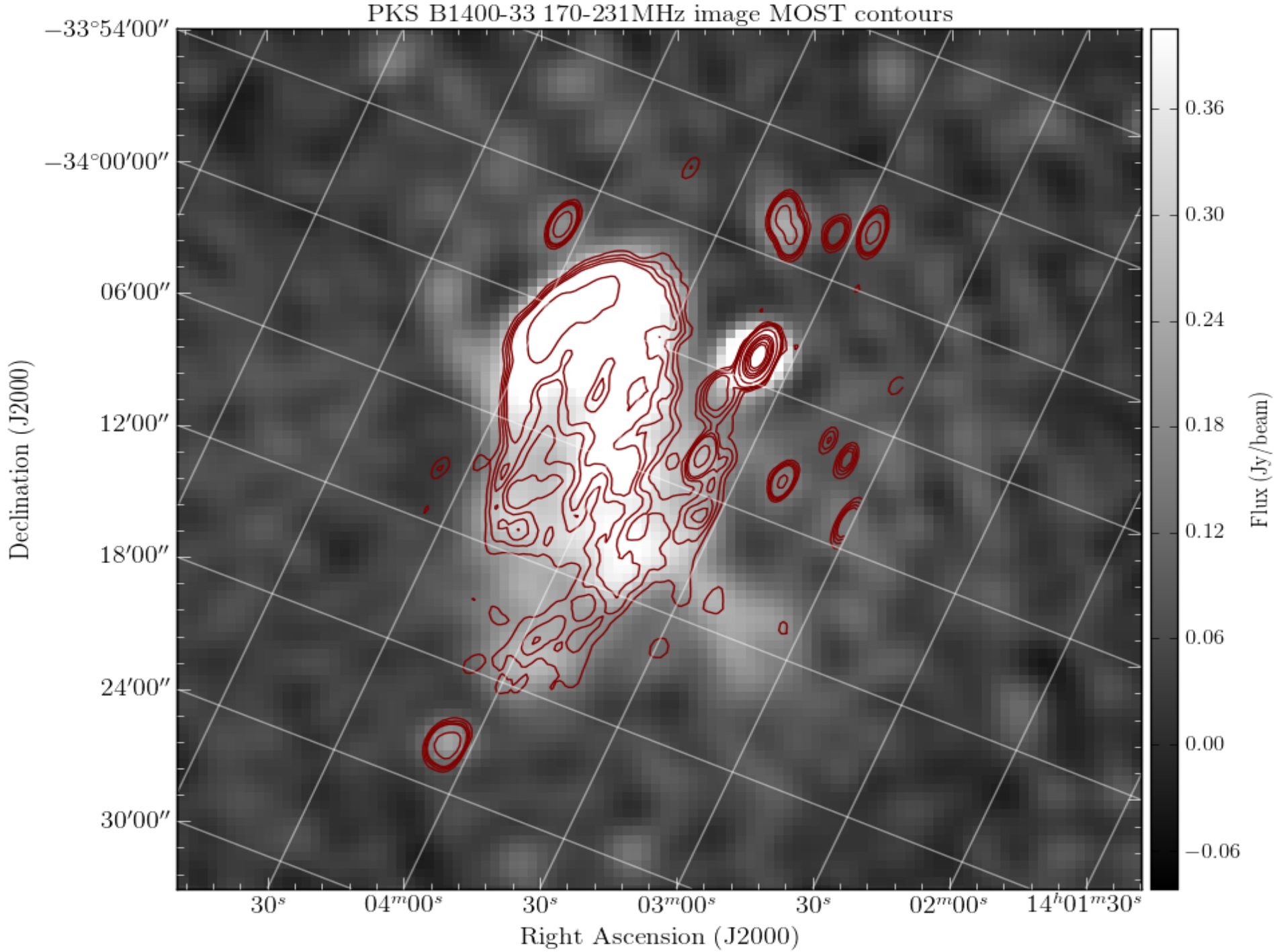
PKS B1934-638




PKS B1400-33 072-103MHz image MOST contours
−33°54′00″
−34°00′00″
06′00″
12′00″
18′00″
24′00″
30′00″
Declination (J2000)
30s
04m00s
30s
03m00s
30s
02m00s
14h01m30s
Right Ascension (J2000)
4.8
4.2
3.6
3.0
2.4
1.8
1.2
0.6
0.0
Flux (Jy/beam)


PKS B1400-33 139-170MHz image MOST contours
−33°54′00″
−34°00′00″
06′00″
12′00″
18′00″
24′00″
30′00″
Declination (J2000)
30s
04m00s
30s
03m00s
30s
02m00s
14h01m30s
Right Ascension (J2000)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
Flux (Jy/beam)


PKS B1400-33 170-231MHz image MOST contours
−33°54′00″
−34°00′00″
06′00″
12′00″
18′00″
24′00″
30′00″
Declination (J2000)
30s
04m00s
30s
03m00s
30s
02m00s
14h01m30s
Right Ascension (J2000)
0.36
0.30
0.24
0.18
0.12
0.06
0.00
−0.06
Flux (Jy/beam)

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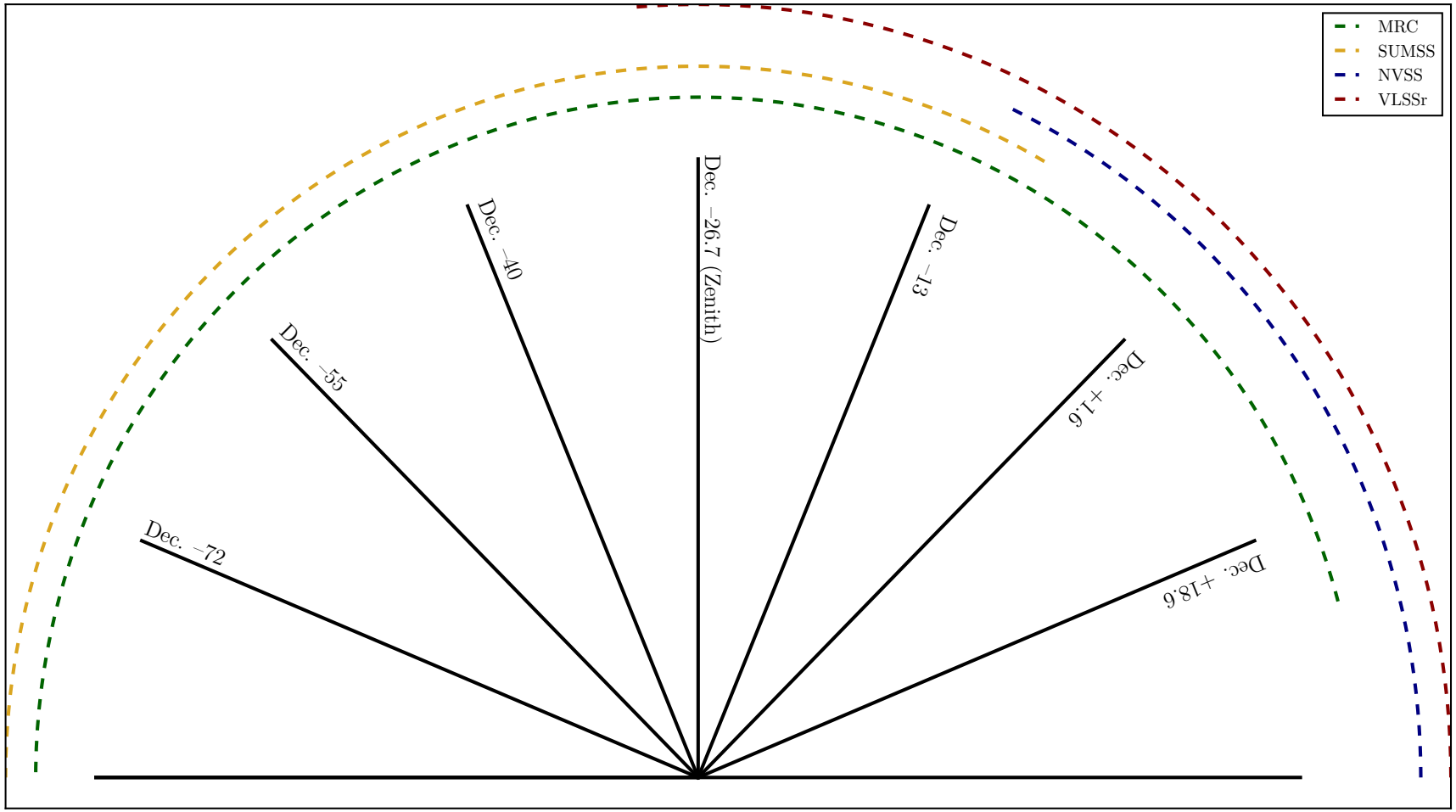
MWA All-Sky Survey



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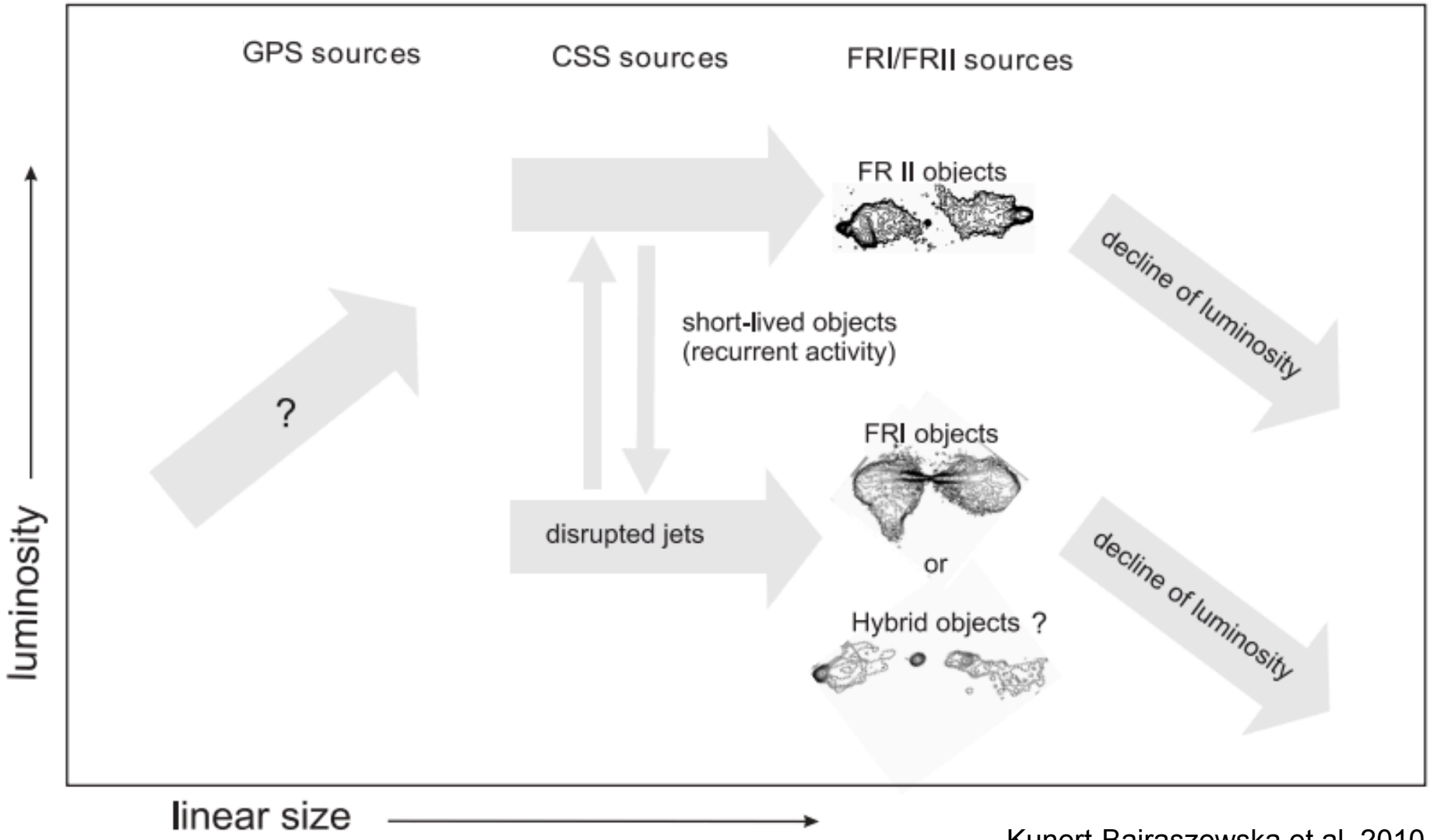
Acronym Spaghetti



Kunert-Bajraszewska et al. 2010

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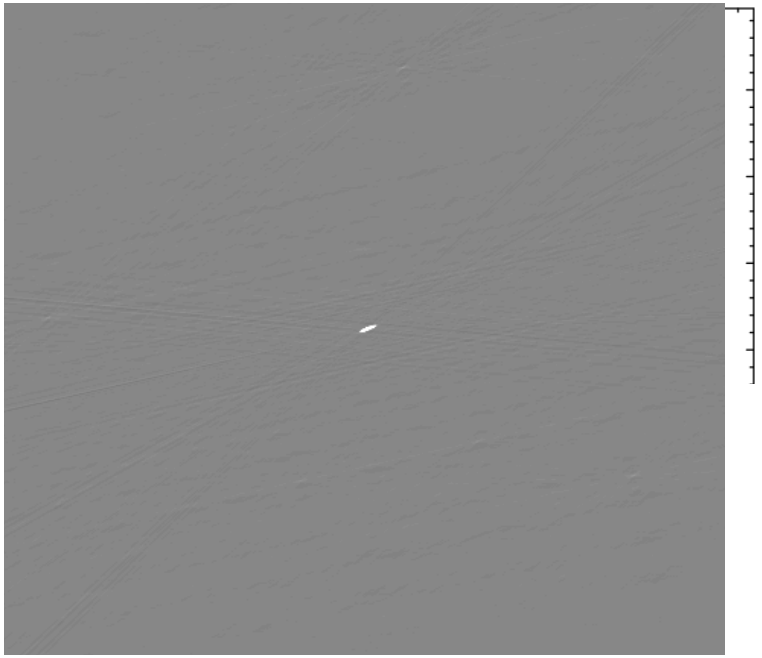
Acronym Soup



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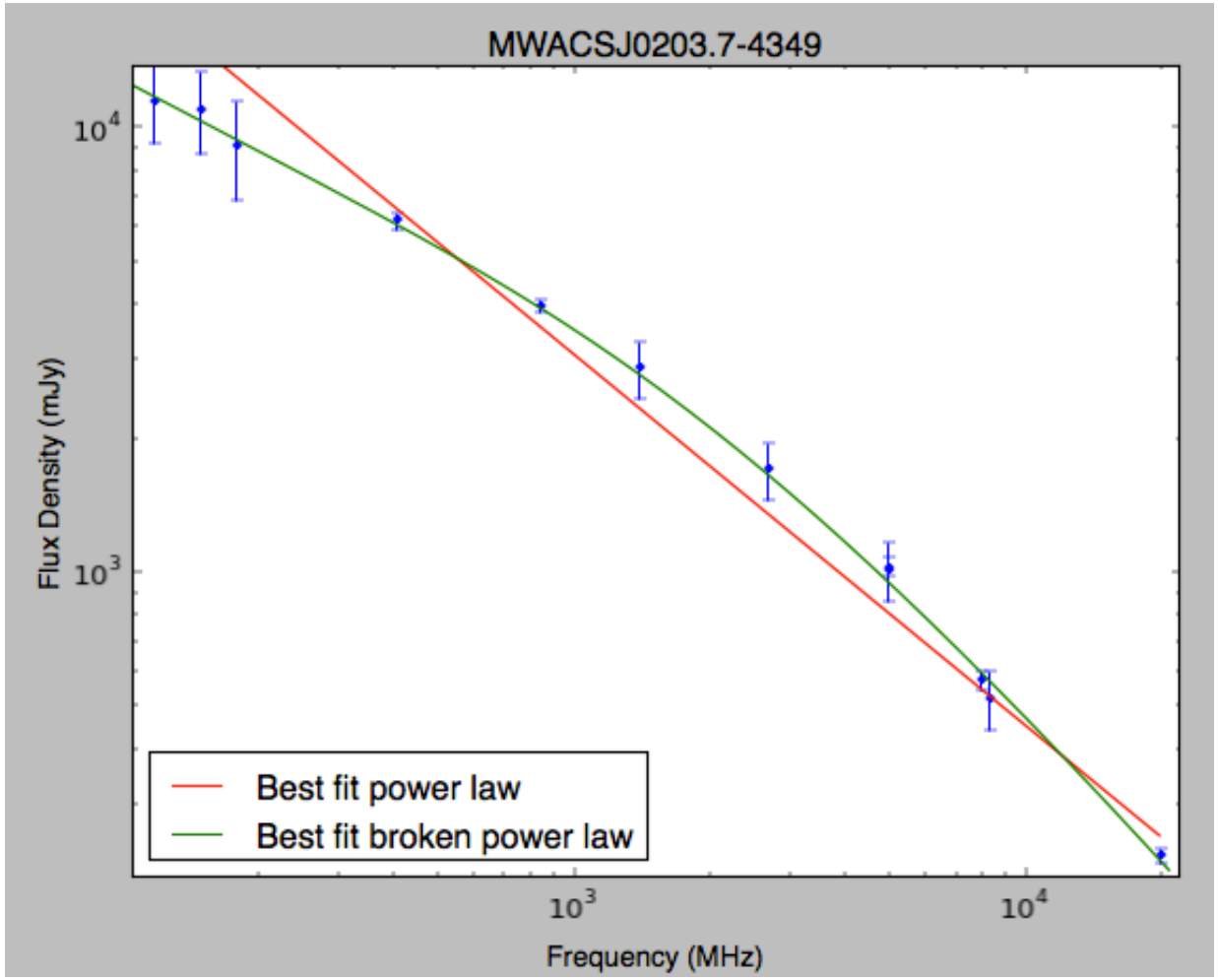
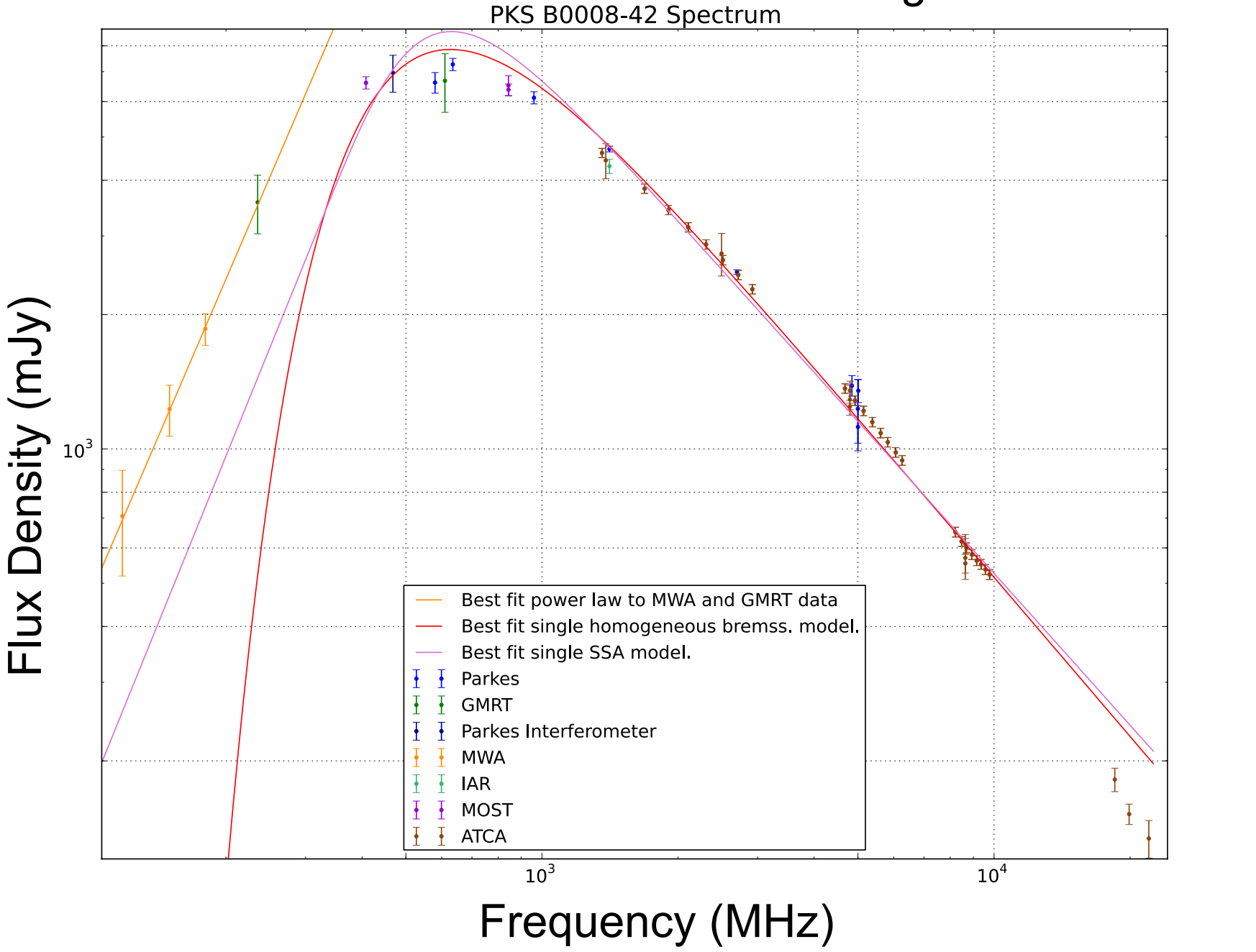
Death to the Power Law



Days of the power law are numbered!

Single SSA and FFA



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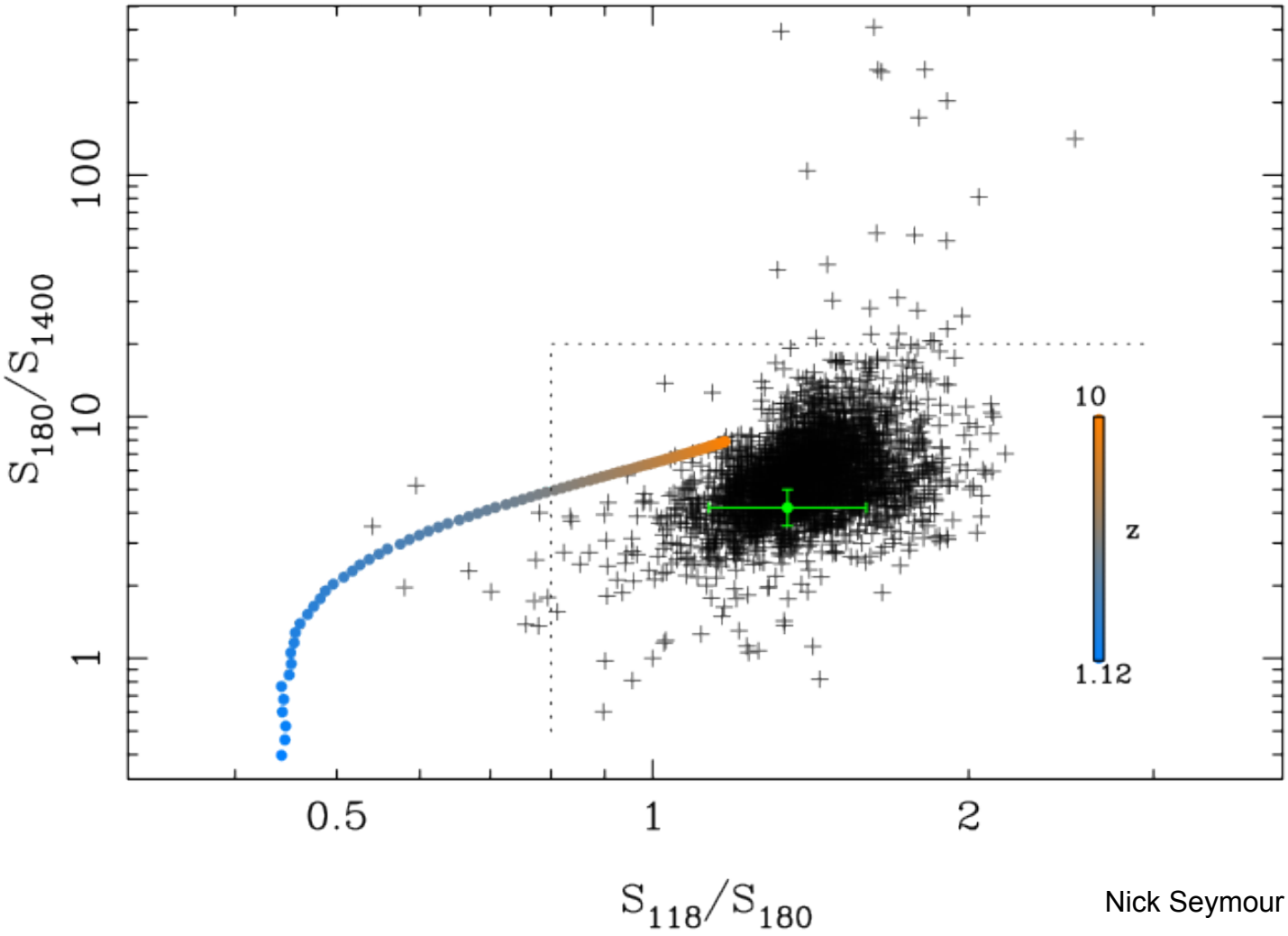
Finding high-z galaxies



Nick Seymour

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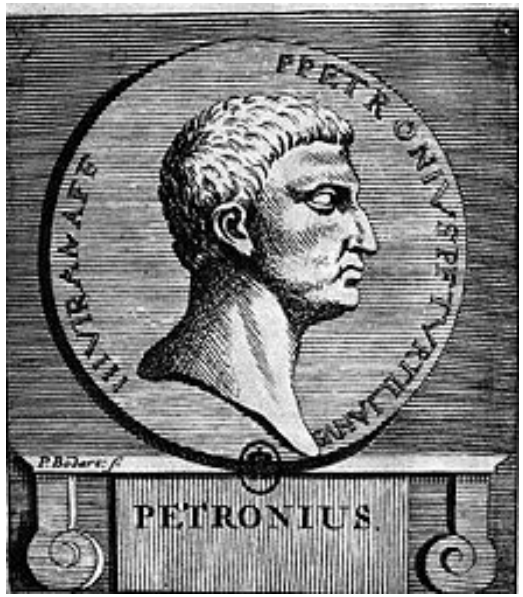
Why Bayes?



Aesthetics:

- Philosophy – accepting a theory rather than rejecting a hypothesis.
- Chi-squared evaluates the significance of the *mismatch* between theory and experiment, not whether the hypothesis is true.
- Rigorous theoretical framework

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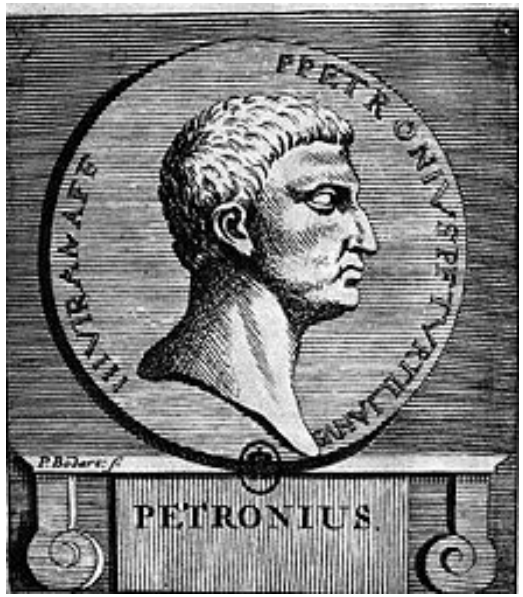
FOR ALL-SKY ASTROPHYSICS

Why Bayes?



Positives - Practical:

- Full PDFs for each model parameter
- Prior knowledge can be used to get a more accurate result and place physical constraints.
- Can deal with non-Gaussian uncertainties (e.g. calibration errors)
- Marginalise over nuisance parameters (e.g. noise floor.)
- Objective model selection more robust than reduced chi-squared.
- Less likely to get stuck in a local minimum due to implementation.
- Hyperparameters

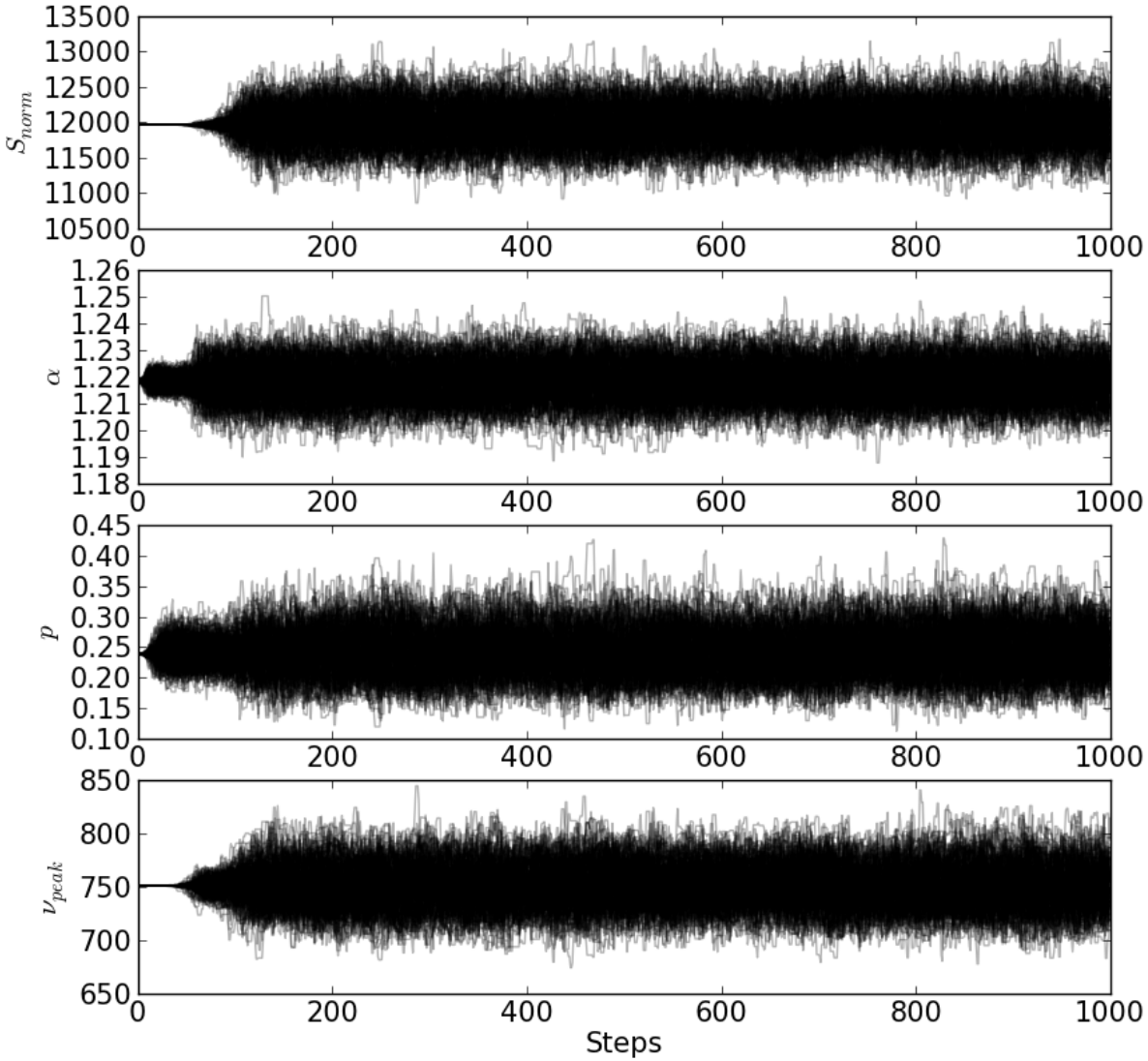
Why Bayes?

Negatives:

- Less ‘natural’ to think about – integrals, baggage of another statistical language etc.
- More computationally expensive
- In simple cases, often converges to the same parameter values as less computationally expensive methods do.
- More difficult and time consuming to code.
- Can be influenced by prior knowledge.

Application on PKS 0008-42

Inhomogeneous free-free model (Bicknell et al. 1997)



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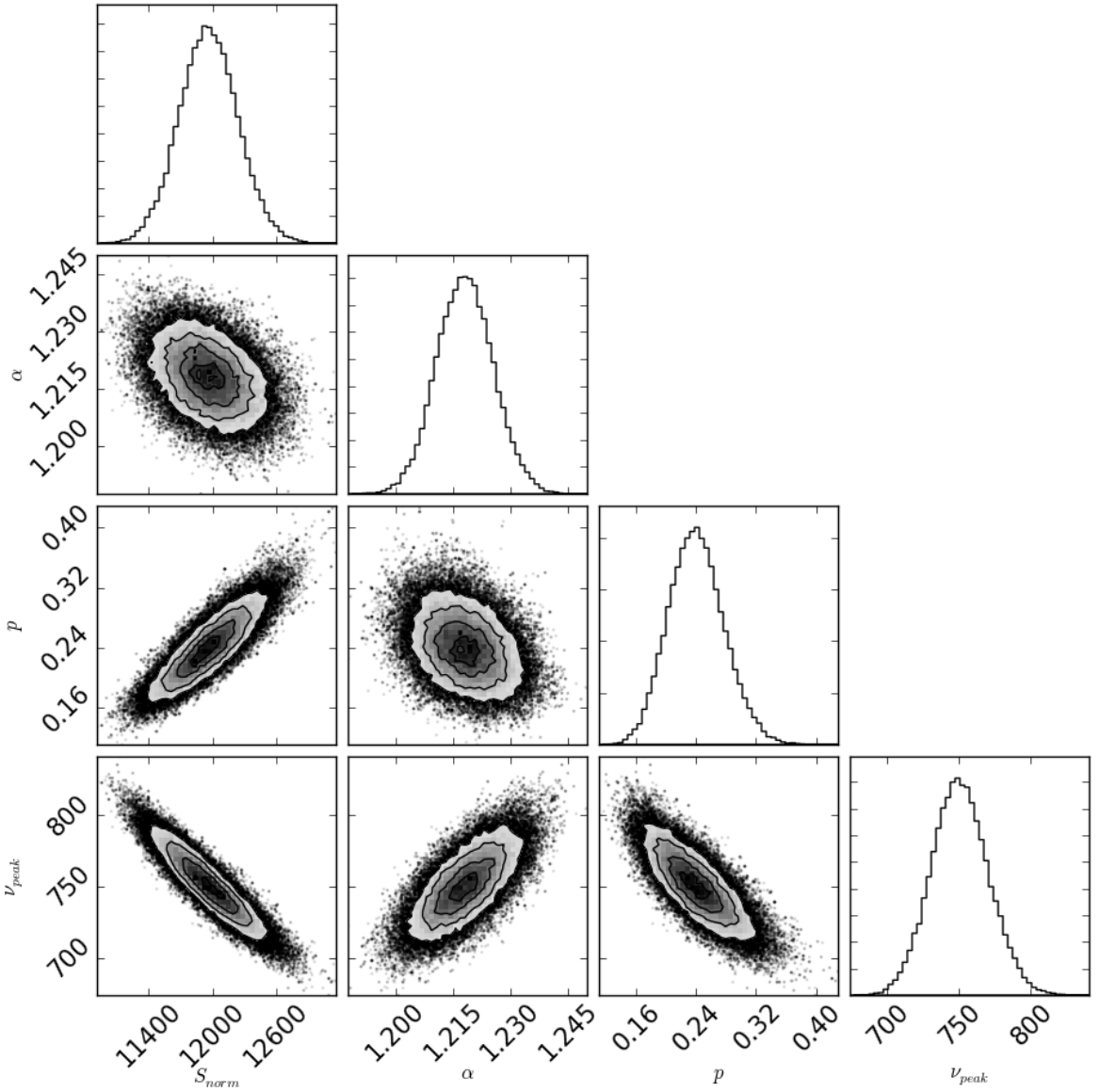
PKS 0008-42