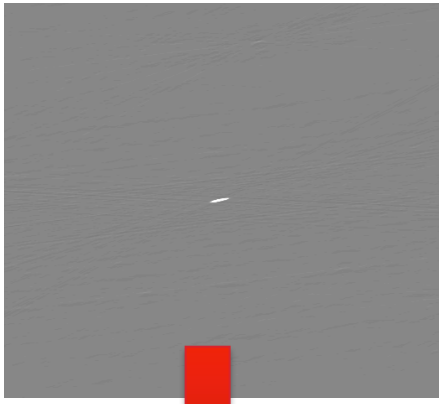
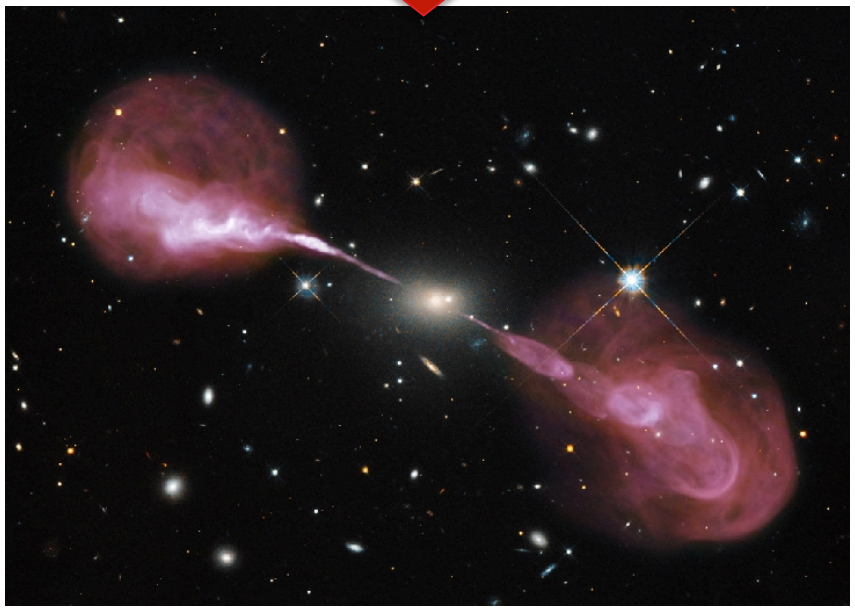
Why Study CSS/GPS Sources?





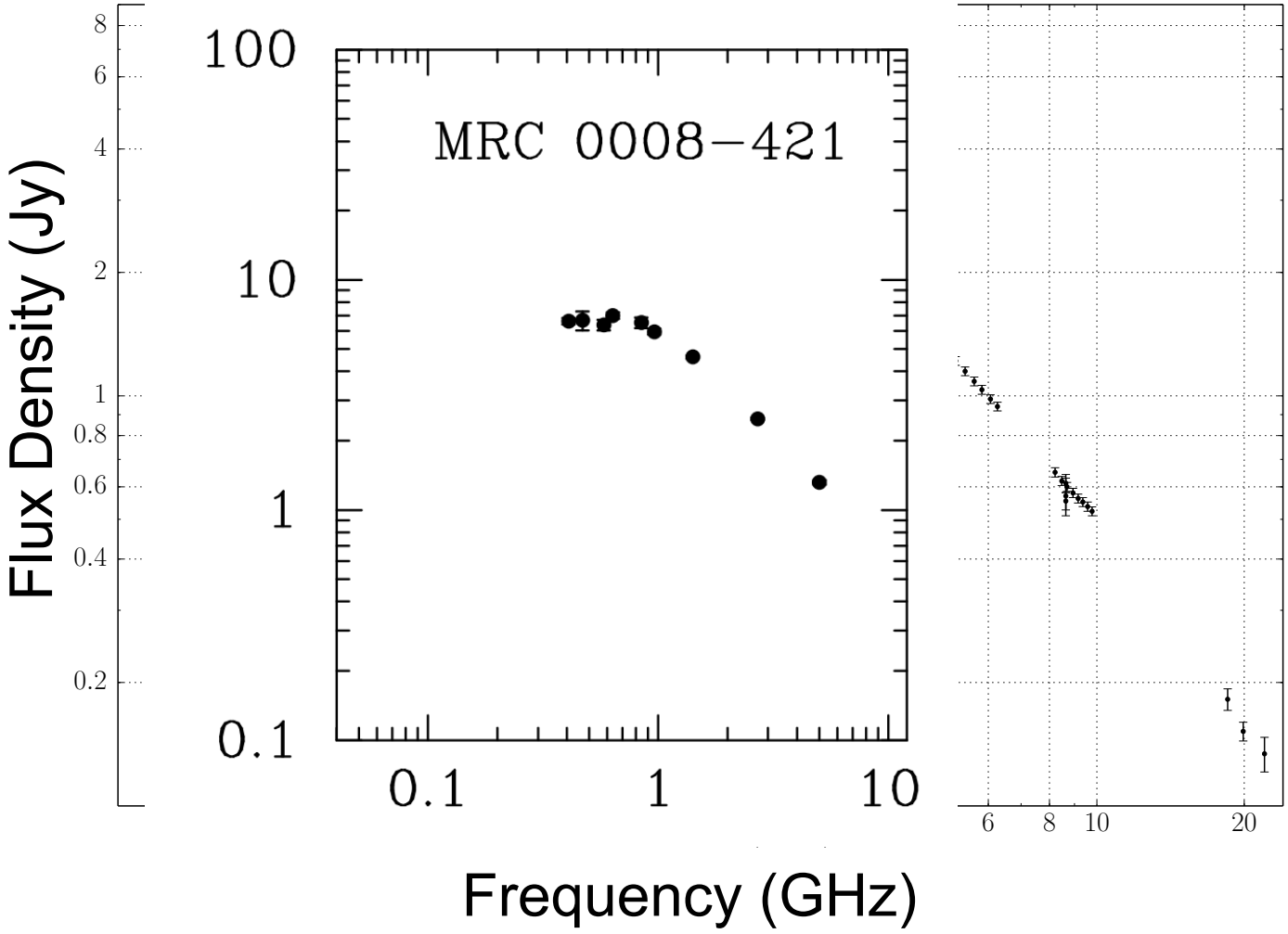
NASA, ESA, S. Baum and C. O'Dea (RIT), R. Perley and W. Cotton (NRAO/AUI/NSF), and the Hubble Heritage Team

- 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

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.
- Low radio frequency radio telescopes becoming operational.



MWA All-Sky 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 ~August 2015 with ~700,000 sources. Commissioning survey released
  Hurley-Walker et al. (2015), arXiv:1410.0790

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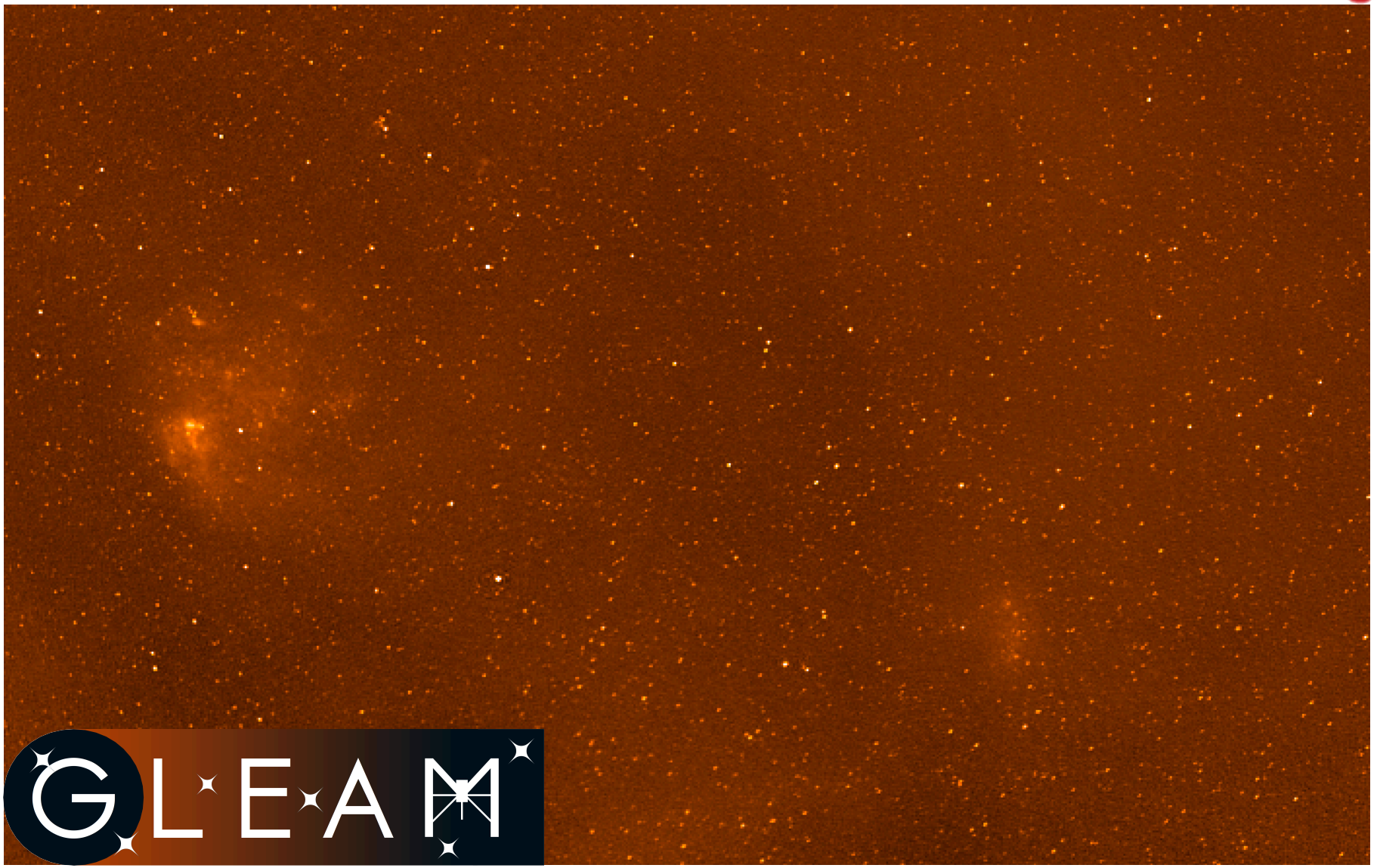
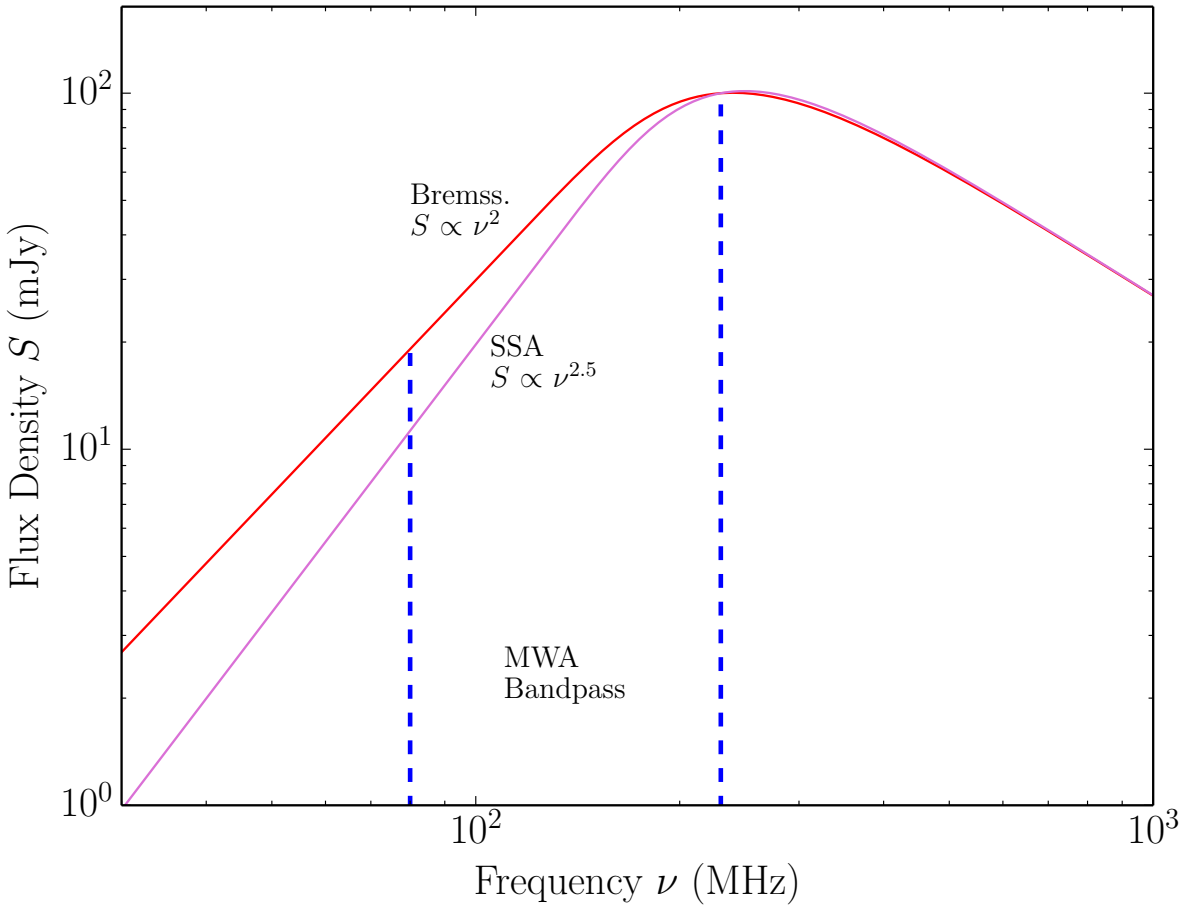
Pictures speak the loudest



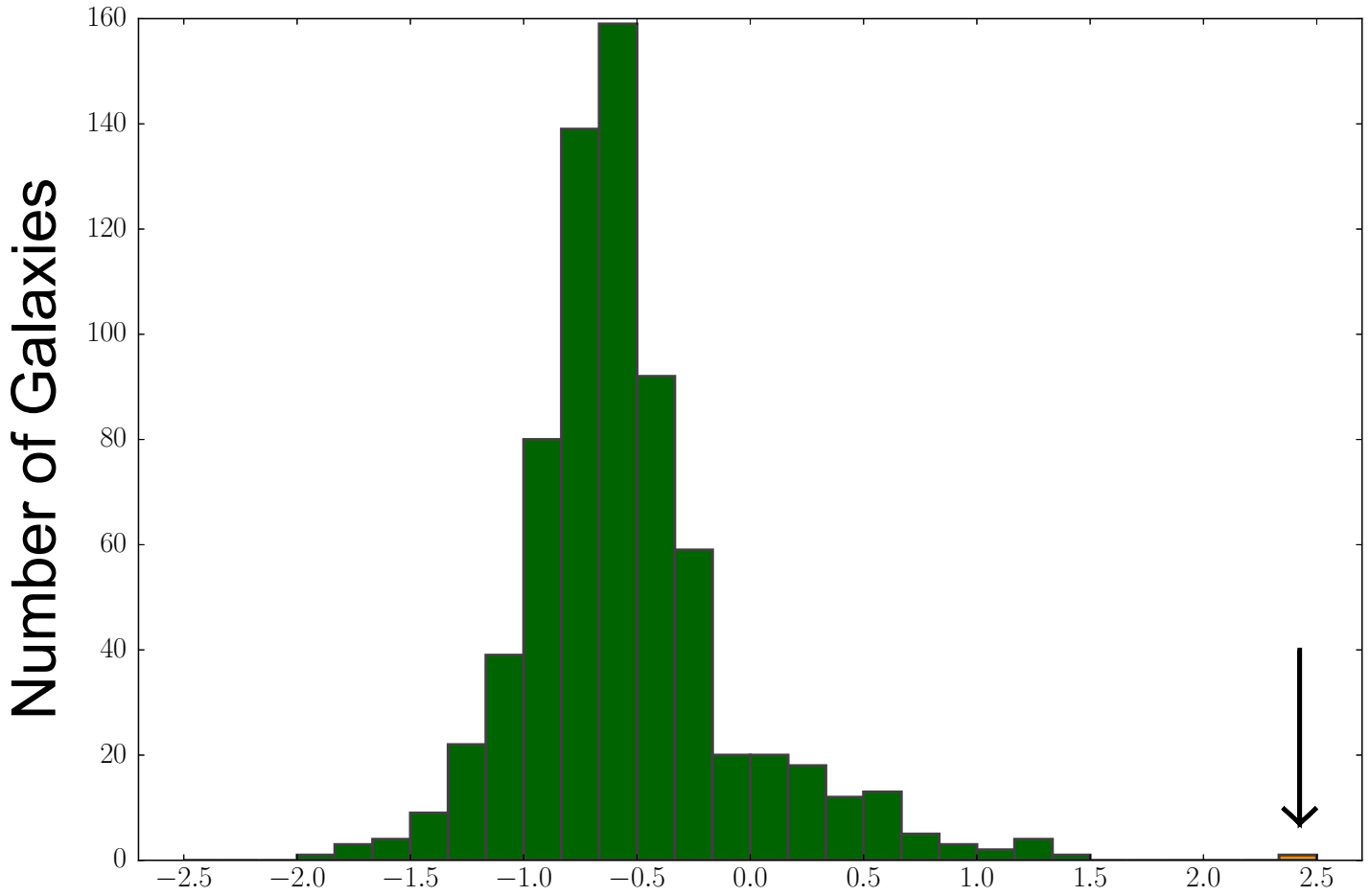
The MWA Spectral Revolution

- GPS/CSS ~10% of MWA radio population?
  - turnover solely due to synchrotron self-absorption or free-free absorption?
  - are some “frustrated” sources confined by dense gas?
- Three absorption models:
  - Homogeneous free-free
  - Inhomogeneous free-free
  - Synchrotron self-absorption



New Extreme GPS Source PKS B0008-42

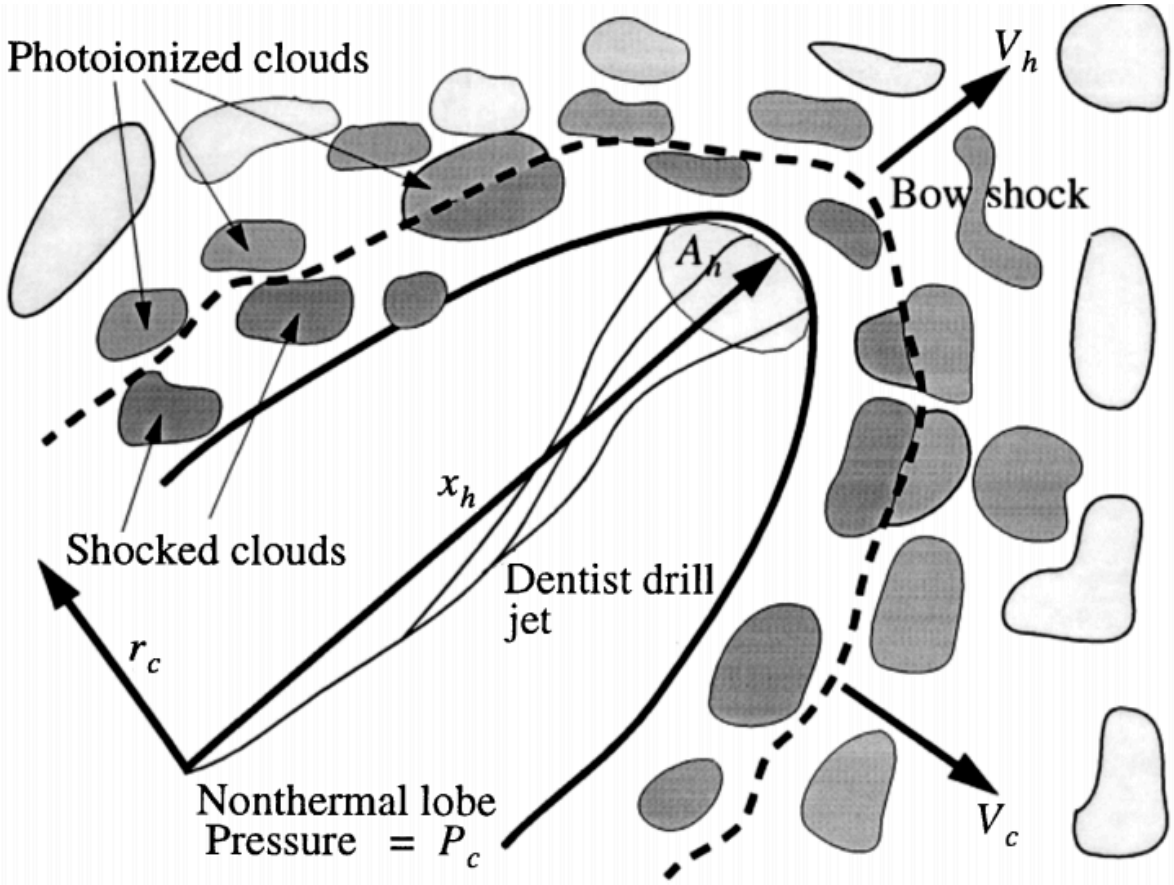
- Low frequency data has a gradient of ~2.5 – steepest known. Spectral width ~0.6 decade of freq. – smallest known.
- Test bed for models of GPS/ CSS spectra.
- ~120 mas scale, 1000 pc



Callingham et al. (ApJ, *submitted*)

Models of GPS Radio Spectra

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



$$S_\nu = a(p+1)\gamma\left[p+1, \left(\frac{\nu}{\nu_\mathrm{p}}\right)^{-2.1}\right]\left(\frac{\nu}{\nu_\mathrm{p}}\right)^{-\alpha+2.1(p+1)}$$

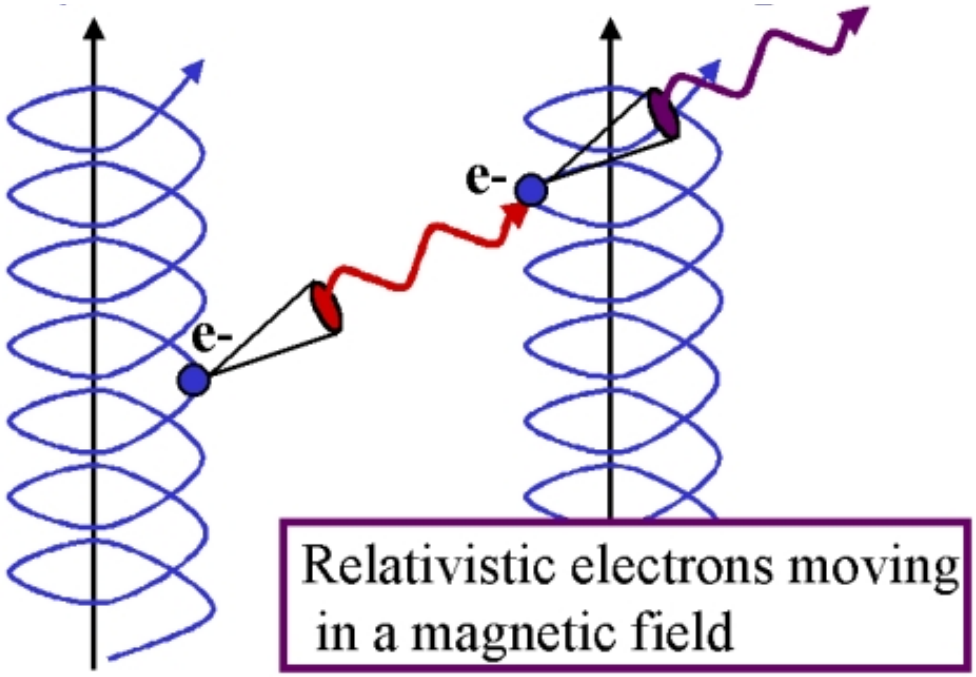
Models of GPS Radio Spectra

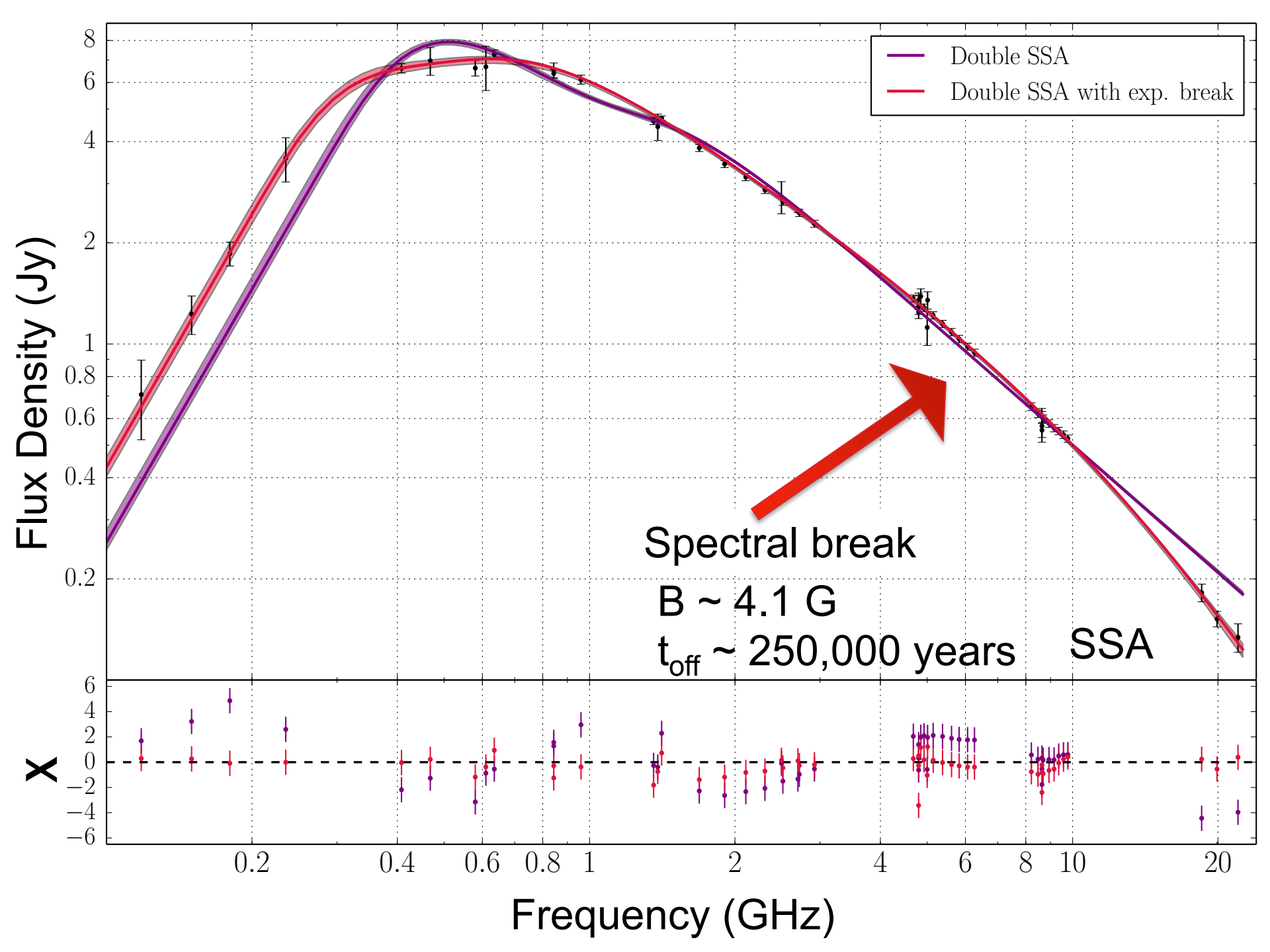
Synchrotron self-absorption (SSA) model (Kellermann 1966)

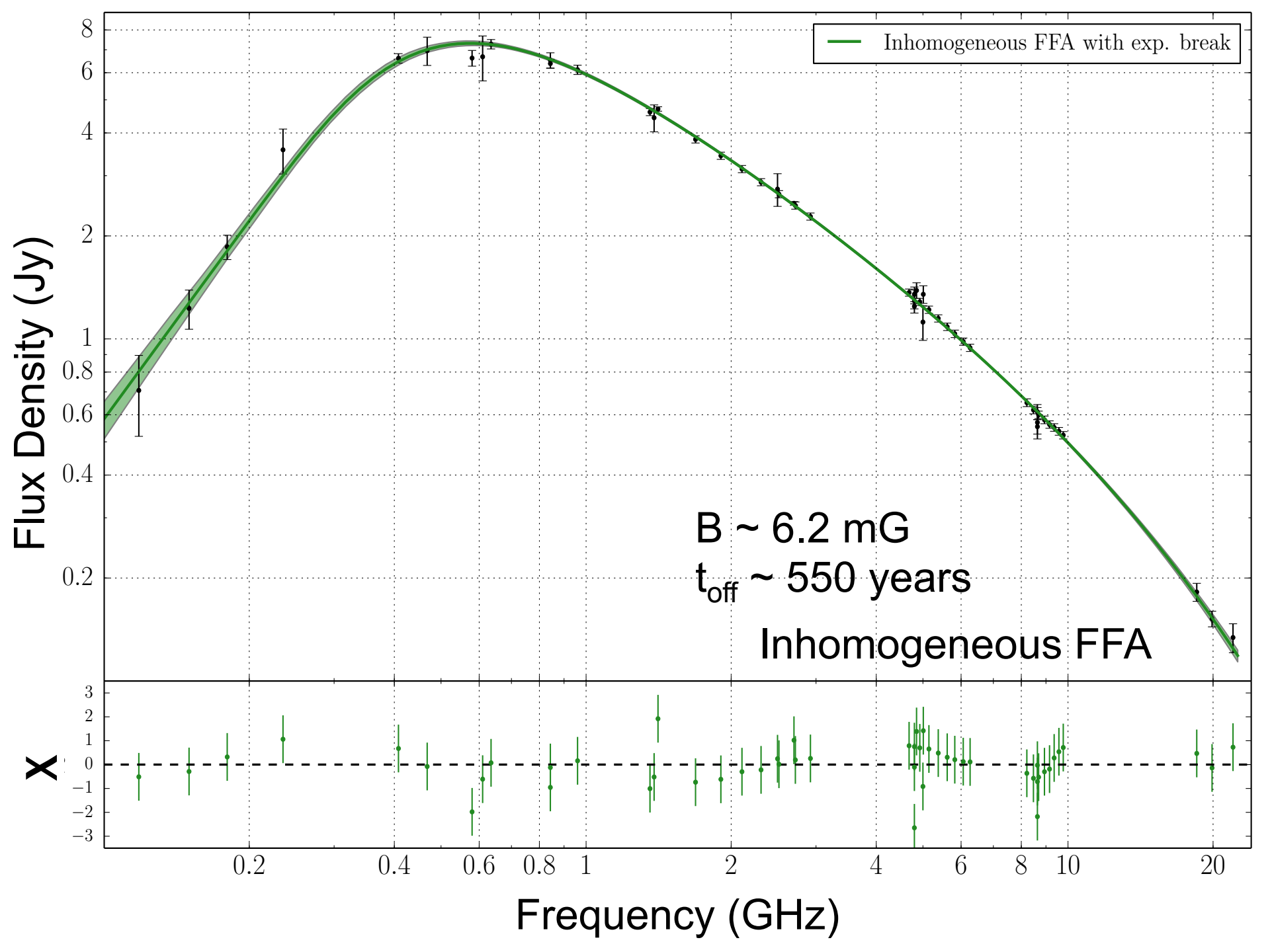
$$S_\nu = \sum_{i=1,2} a_i \left(\frac{\nu}{\nu_{\mathrm{p},i}}\right)^{-(\beta_i-1)/2} \left(\frac{1-e^{-\tau_i}}{\tau_i}\right)$$

$$\tau_i = \left(\frac{\nu}{\nu_{\mathrm{p},i}}\right)^{-(\beta_i+4)/2}$$

Prediction of 2.5 slope – never seen

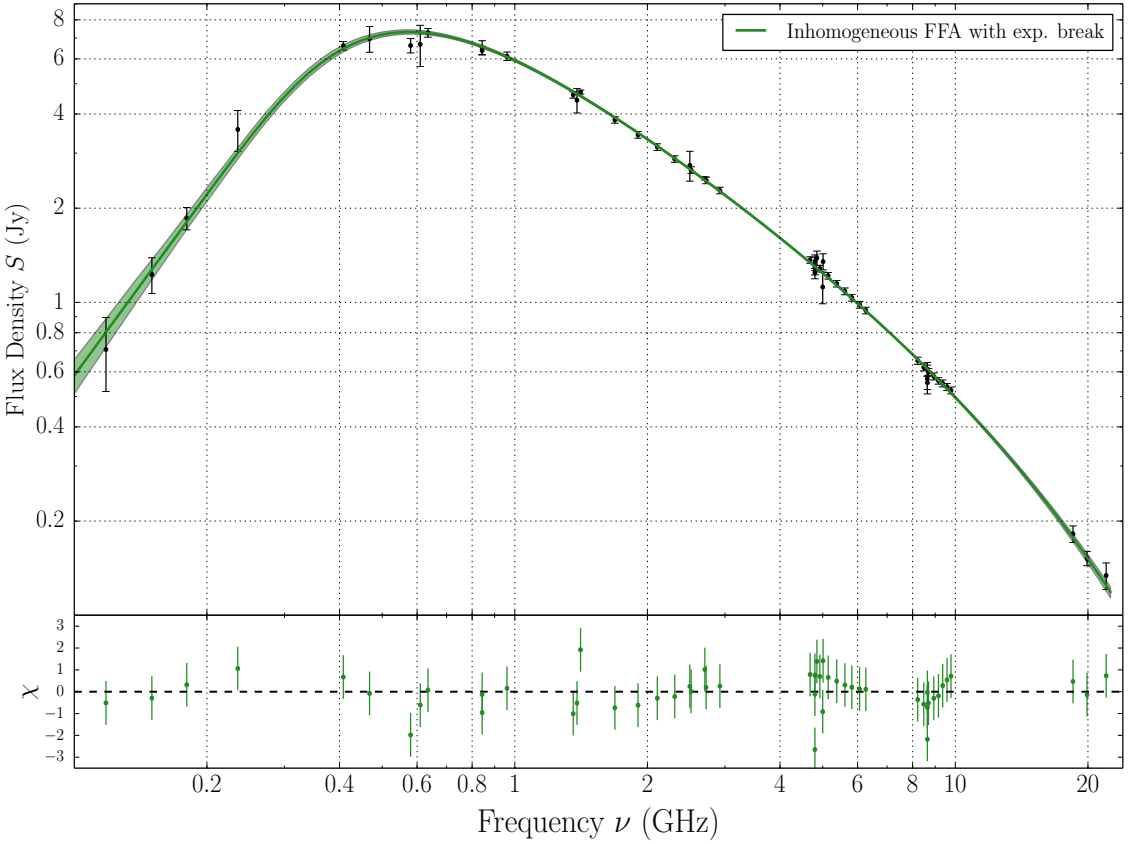



Double SSA
Double SSA with exp. break
Flux Density (Jy)
Spectral break
B ~ 4.1 G
t_{off} ~ 250,000 years
SSA
X
Frequency (GHz)


Inhomogeneous FFA with exp. break
B ~ 6.2 mG
t_{off} ~ 550 years
Inhomogeneous FFA
Flux Density (Jy)
Frequency (GHz)
X

Conclusions

- Spectral modelling of PKS 0008-42 shows power of MWA in constraining models.
- Ruling out SSA for GPS sources with CSO characteristics?
- Dying sources a new population MWA/LOFAR/ LWA will reveal?
- Rinse and repeat on large number of known GPS/CSS sources
- Nail down what the absorption mechanism - vital for evolutionary models.



Work in Progress

- WARNING – Uncertainties are underestimated
- Correlated uncertainties?
- Probably ~3% too high due to mosaicing regridding.

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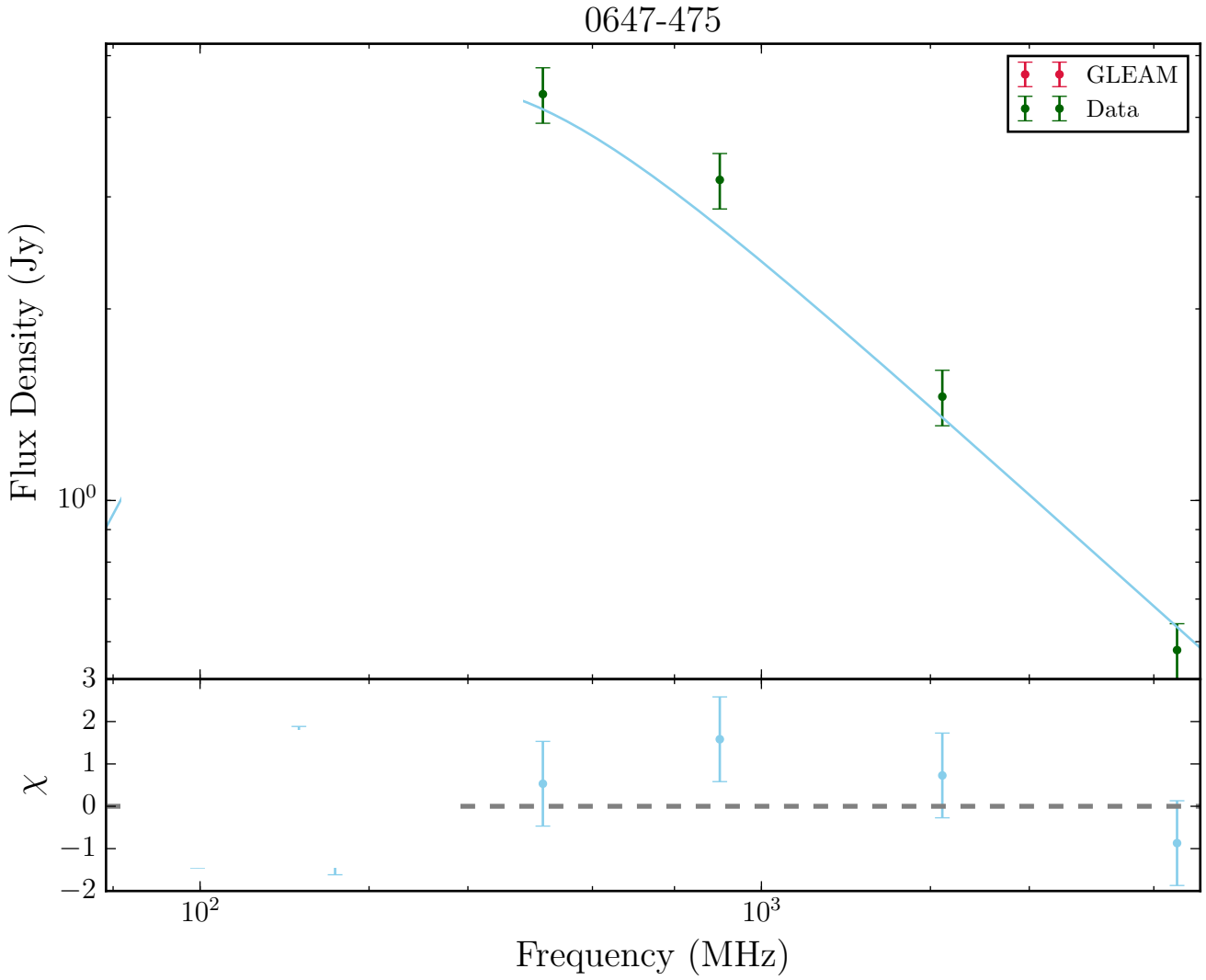
Preliminary GLEAM data



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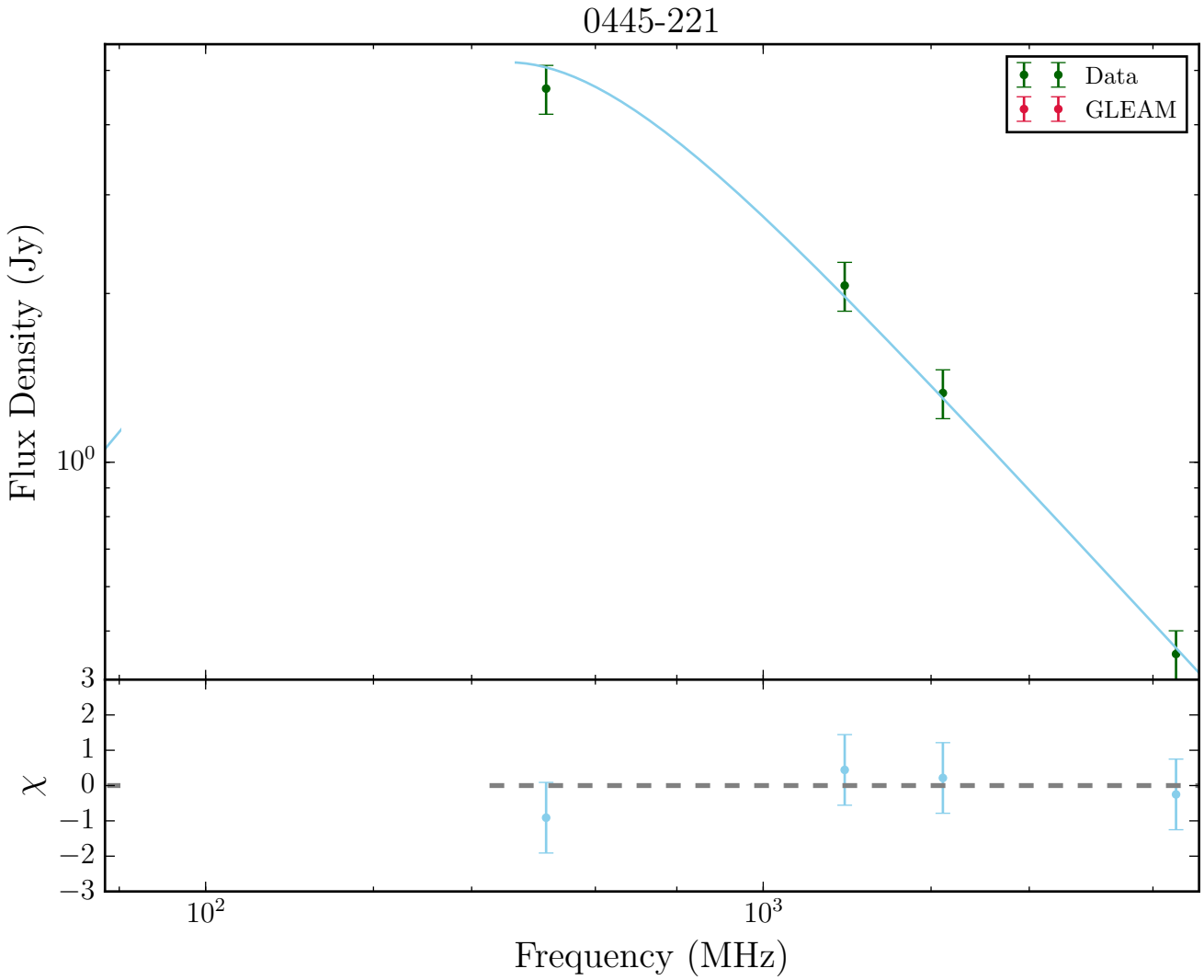

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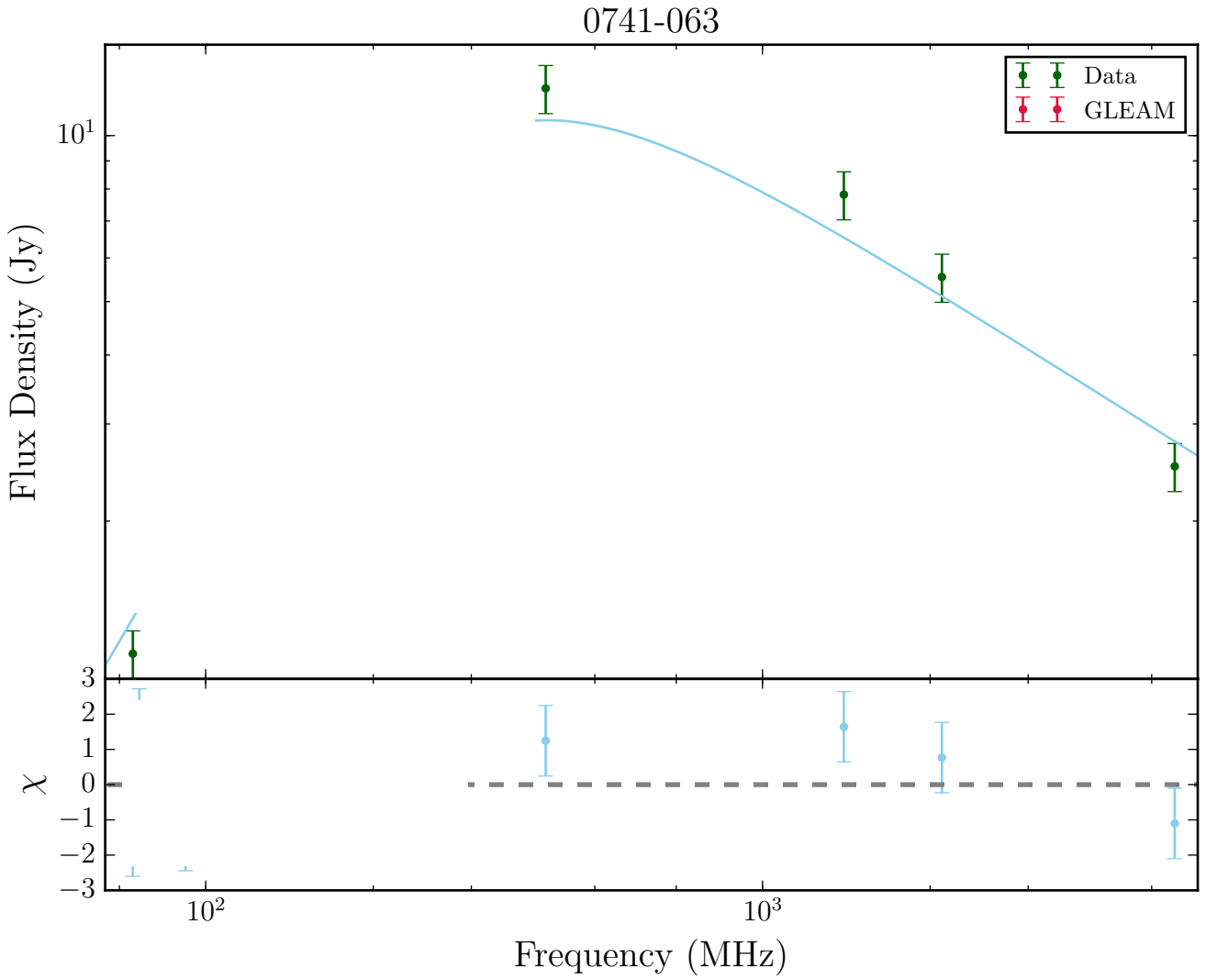
Preliminary GLEAM data



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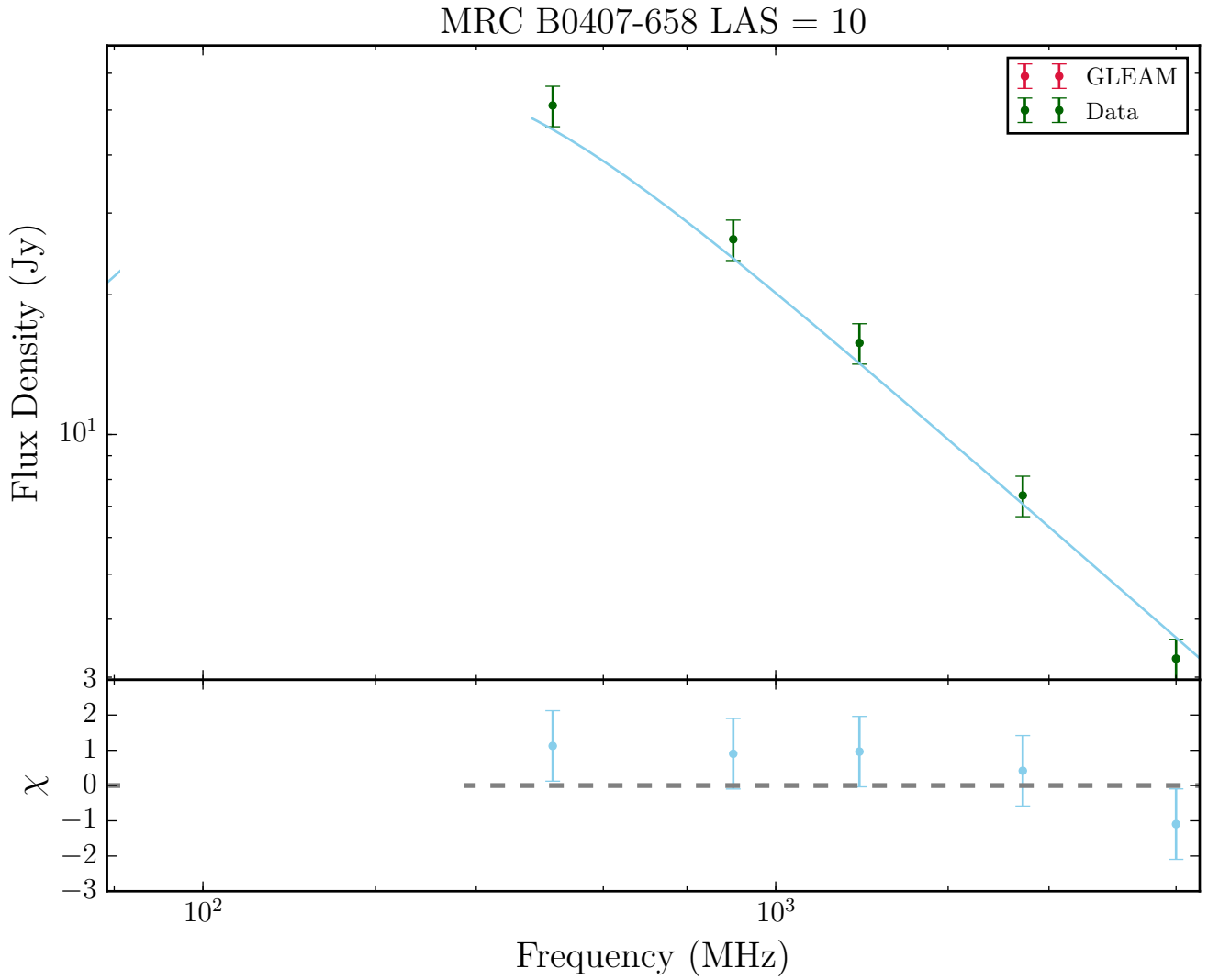
Preliminary GLEAM data



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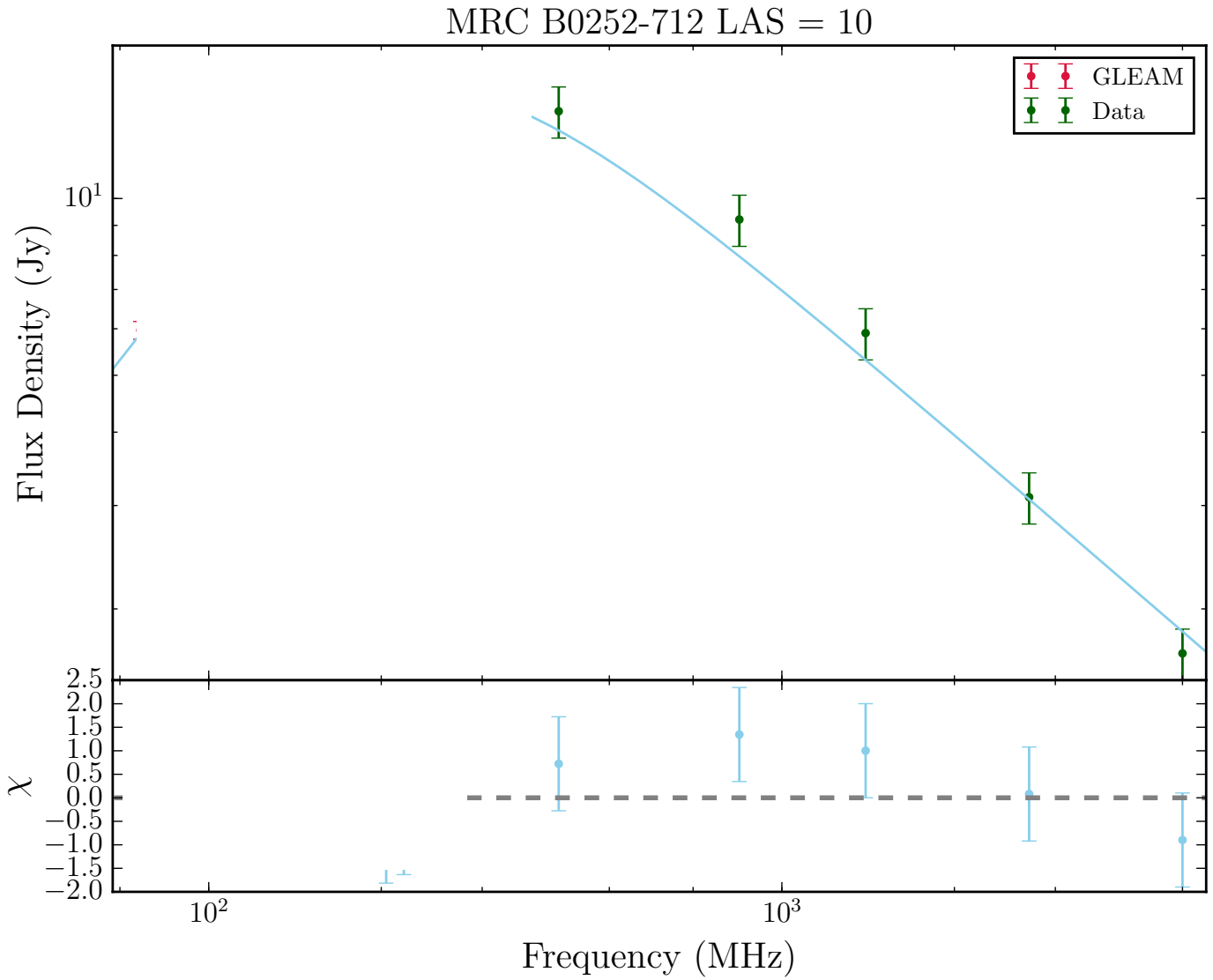
Preliminary GLEAM data



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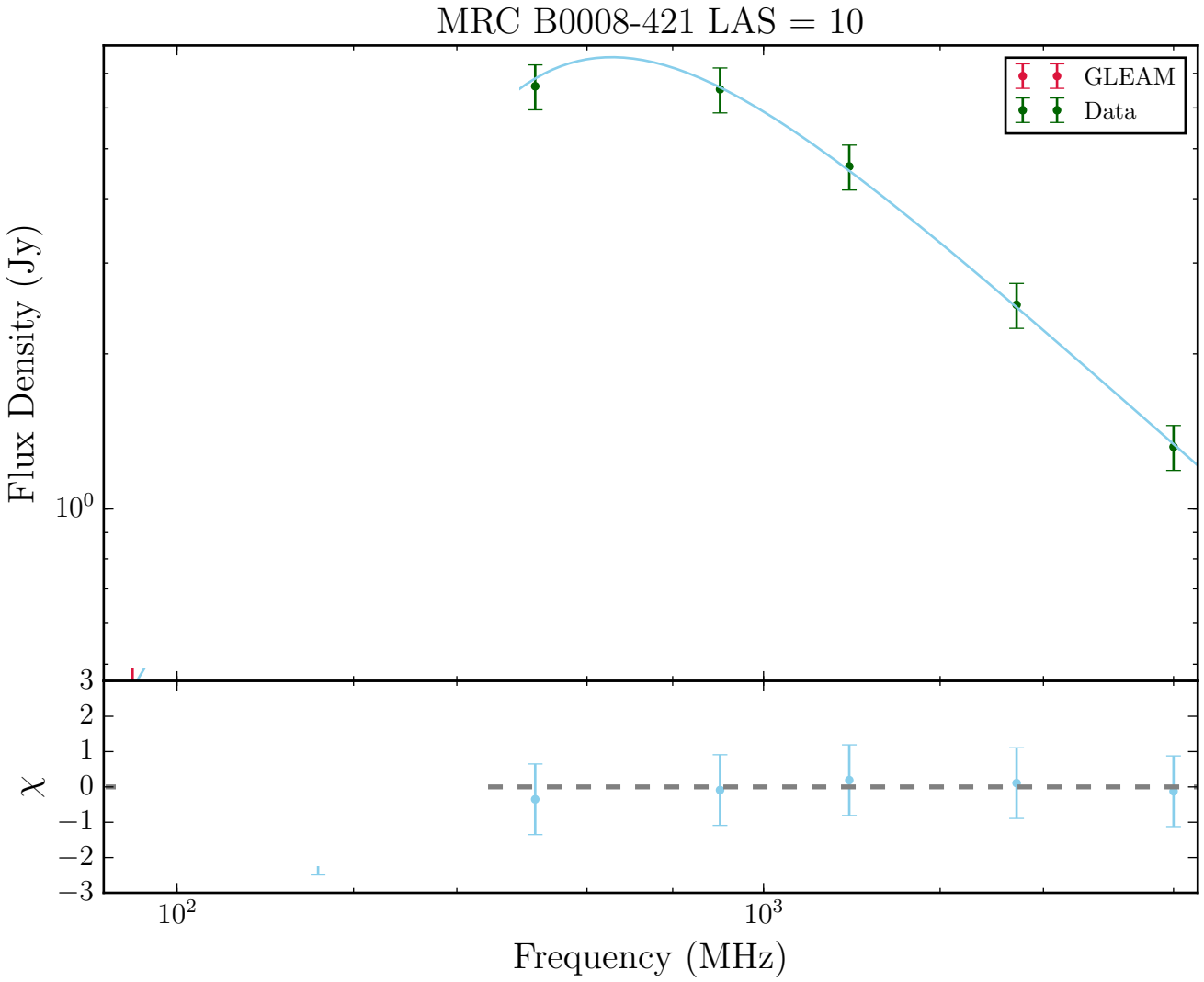
The spectral revolution is here



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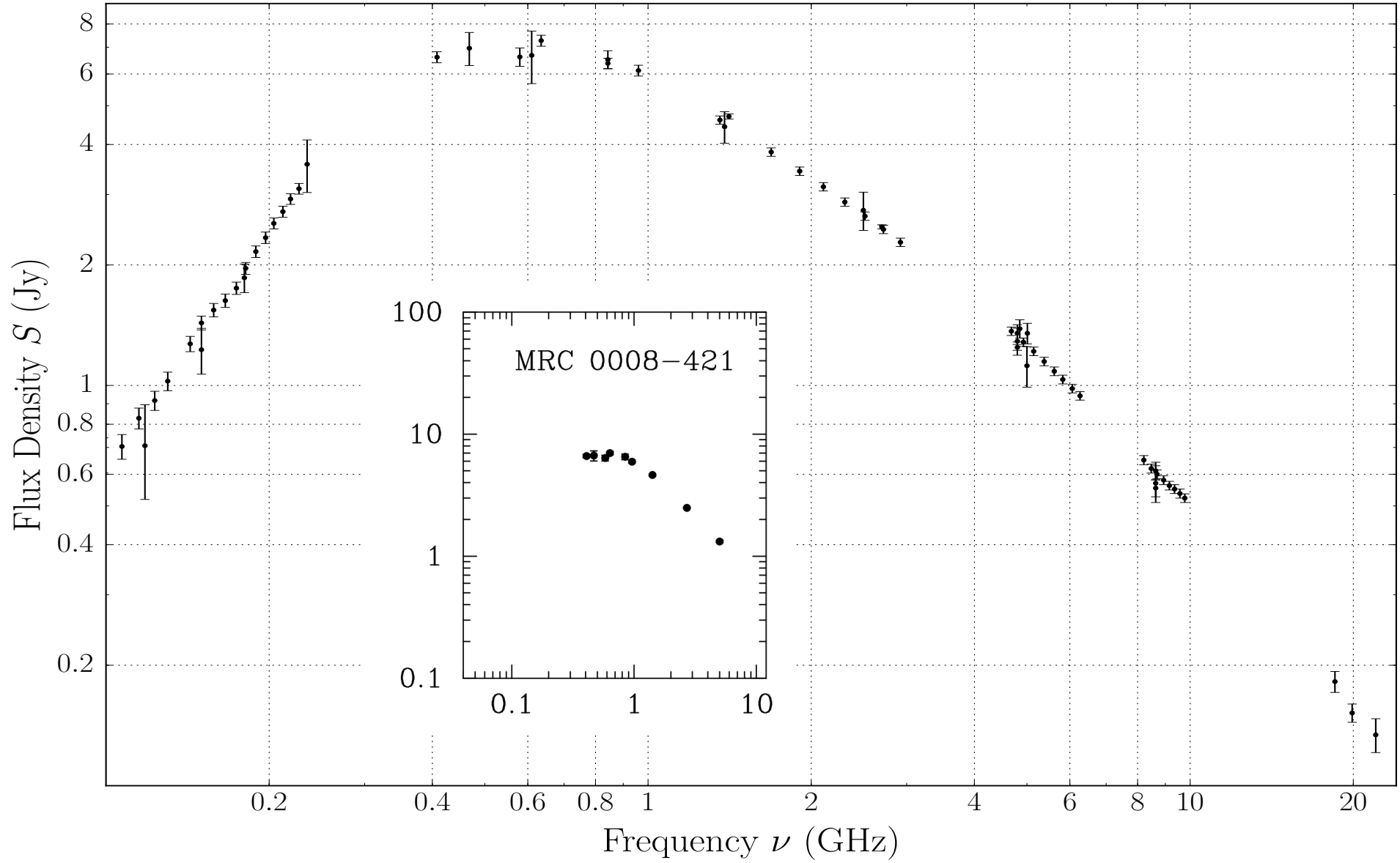
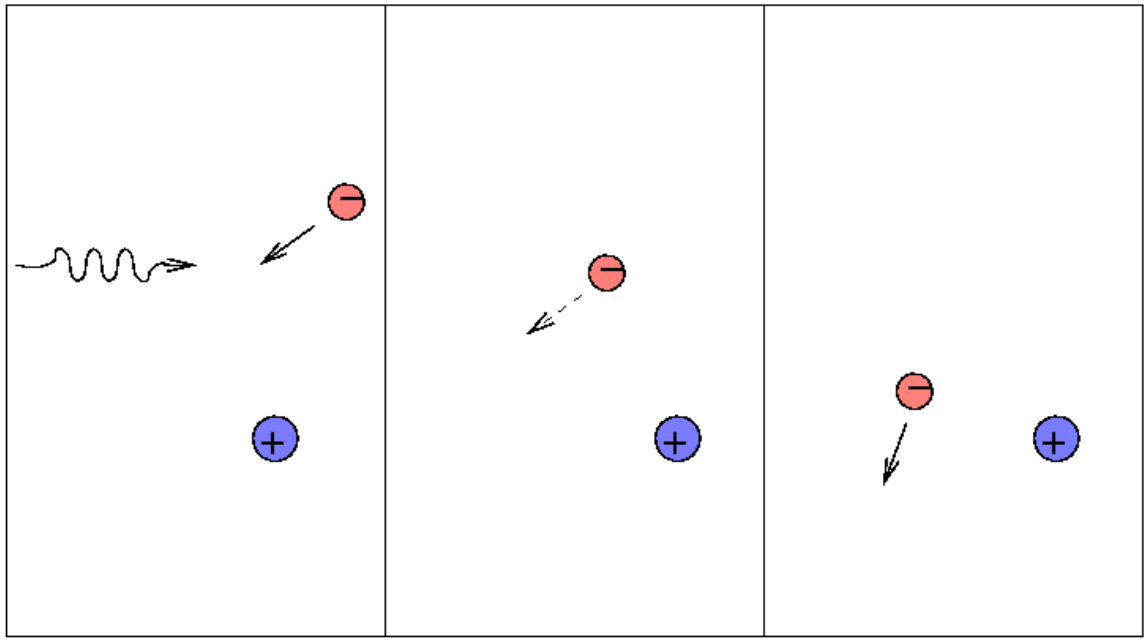
The spectral revolution is here



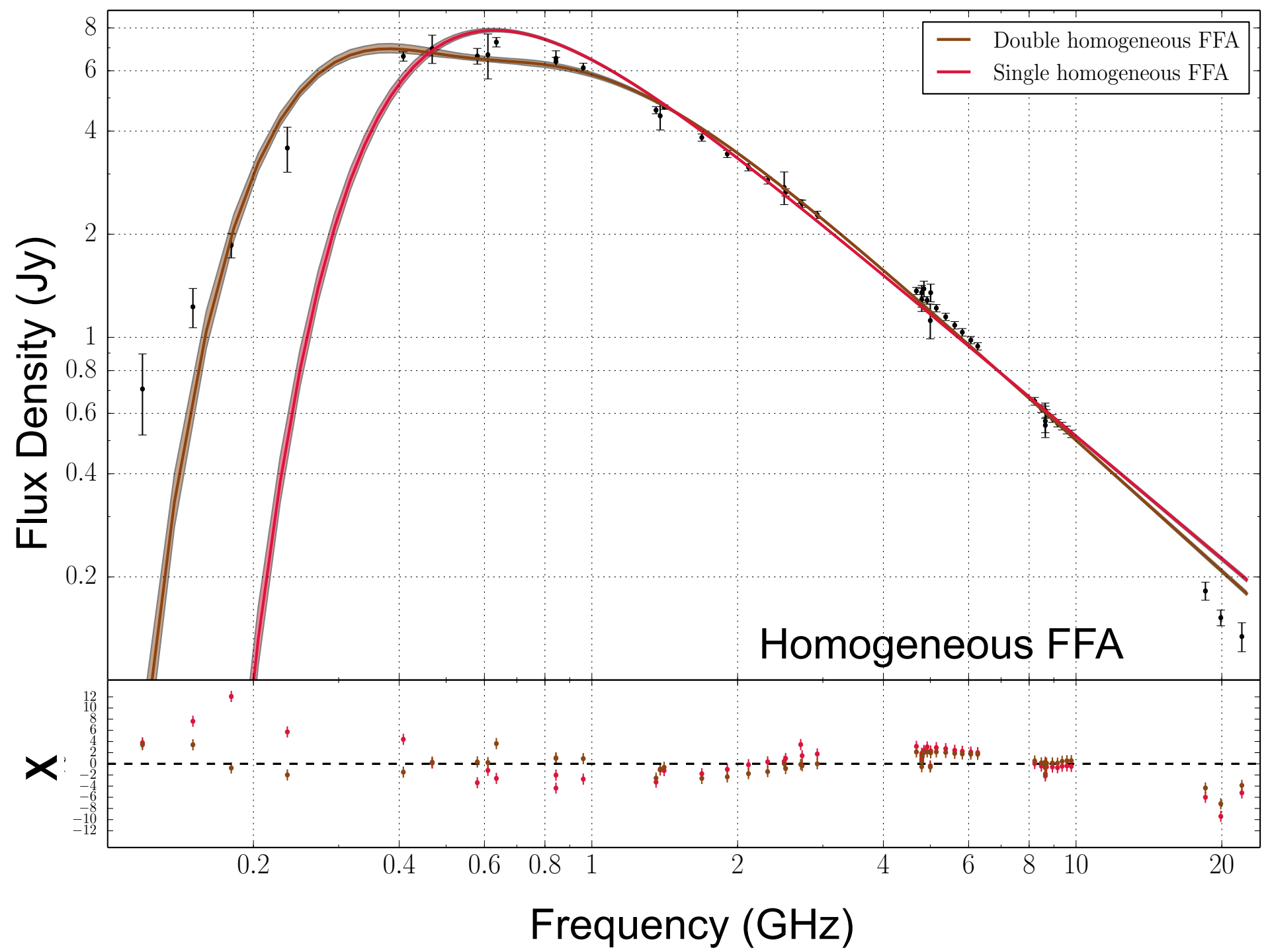
Models of GPS Radio Spectra

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)


Double homogeneous FFA
Single homogeneous FFA
Homogeneous FFA
Flux Density (Jy)
X
Frequency (GHz)

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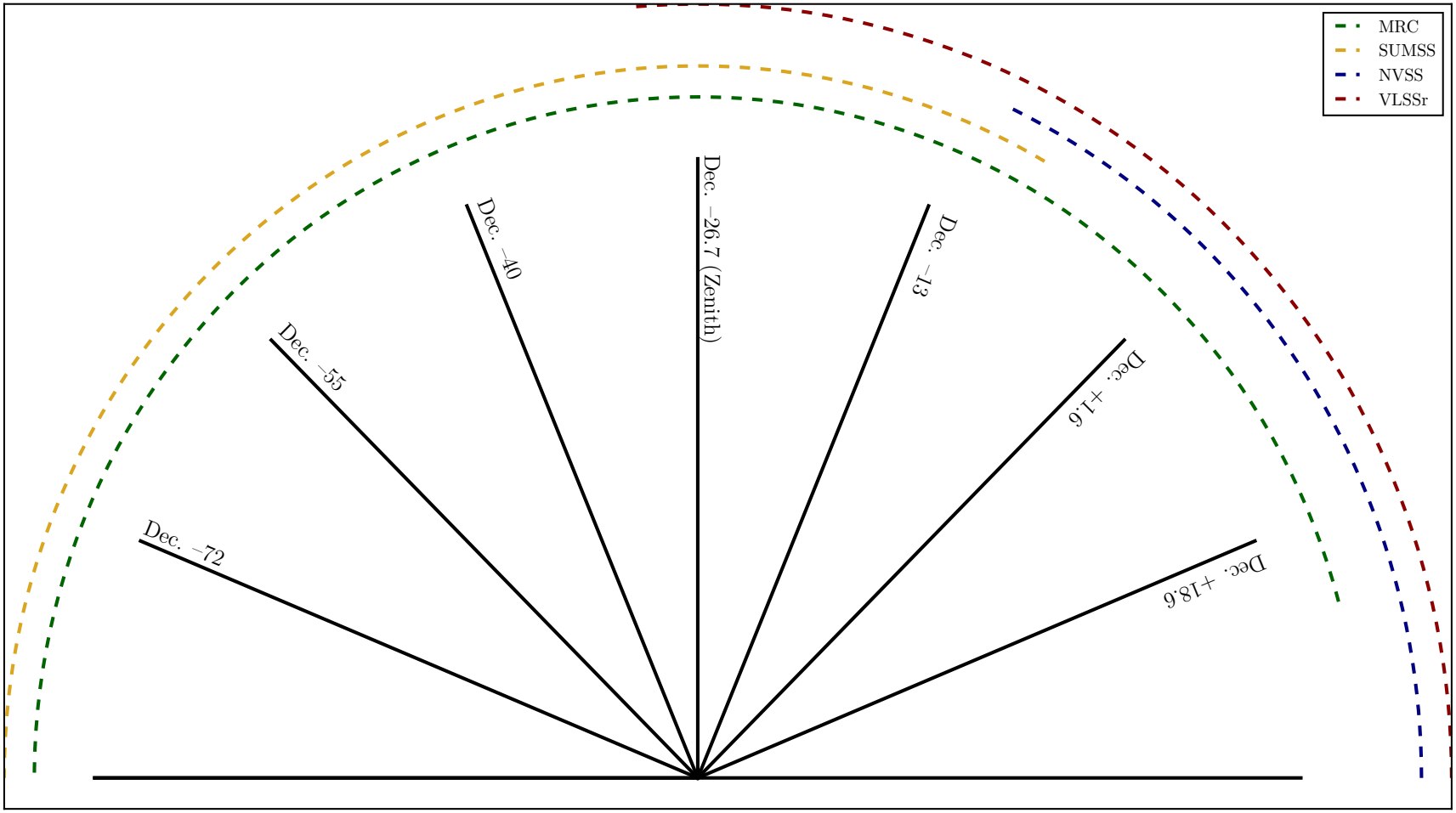
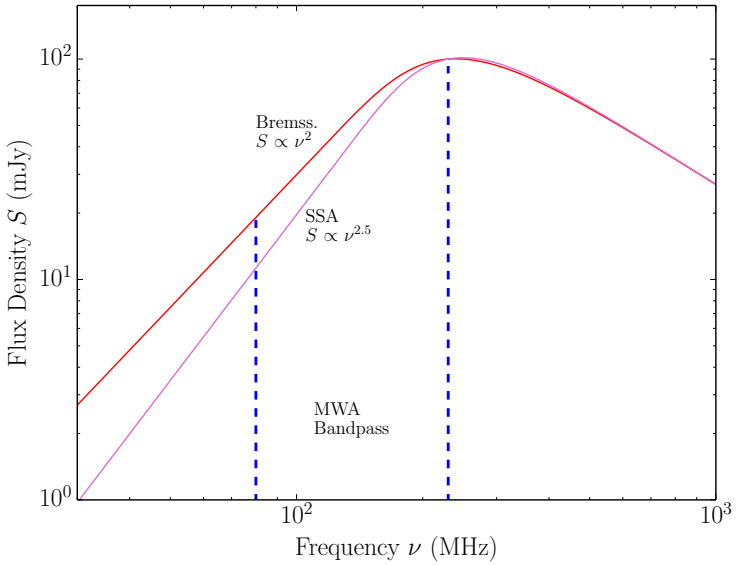
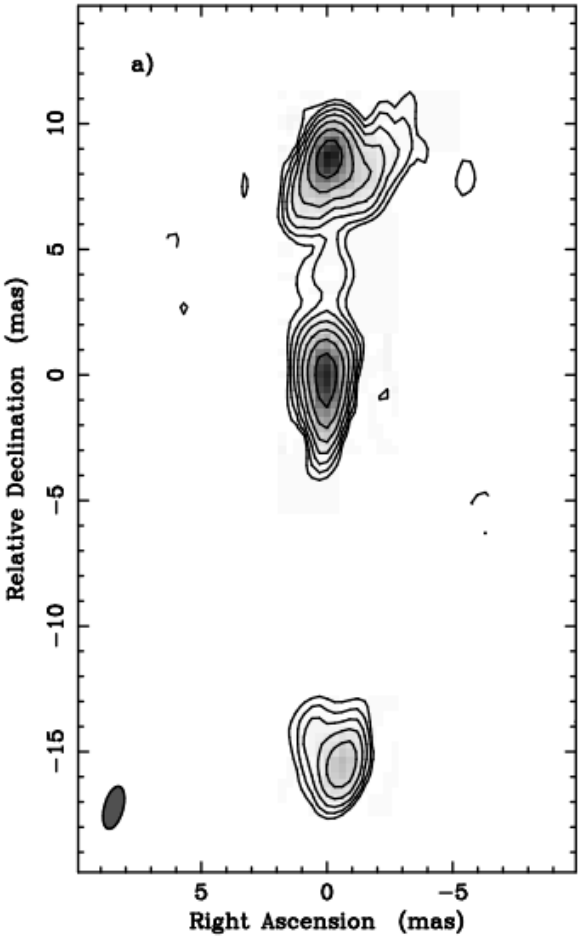
MWA All-Sky Survey



What are CSS/GPS sources?

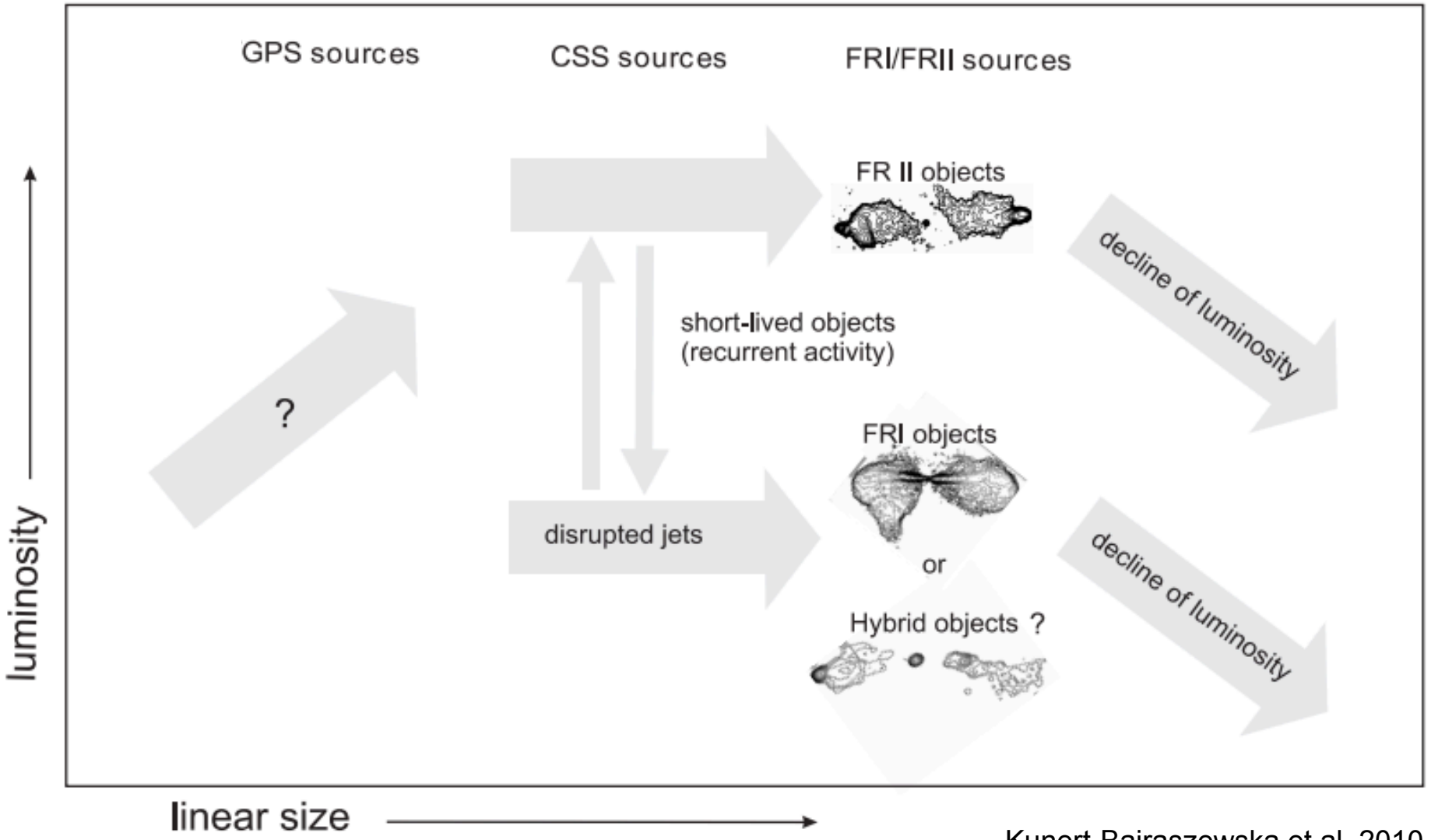
- Originally empirical classification:
  - Powerful AGN with concave spectra
  - GPS turnover ~ 1 GHz, CSS turnover ~ 150 MHz (?)
  - Small physical sizes. GPS < 1 kpc, CSS ~ 1 – 10 kpc
  - Hosts vary - quasars, radio galaxies and Seyferts





0710+439, Owsianik et al 1998

Acronym Spaghetti



Kunert-Bajraszewska et al. 2010

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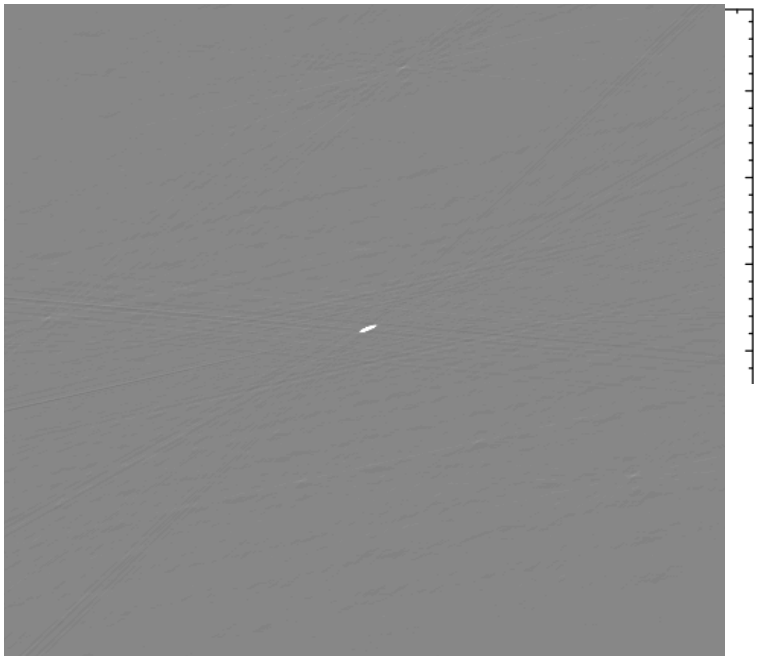
Acronym Soup

Radio-Loud galaxy



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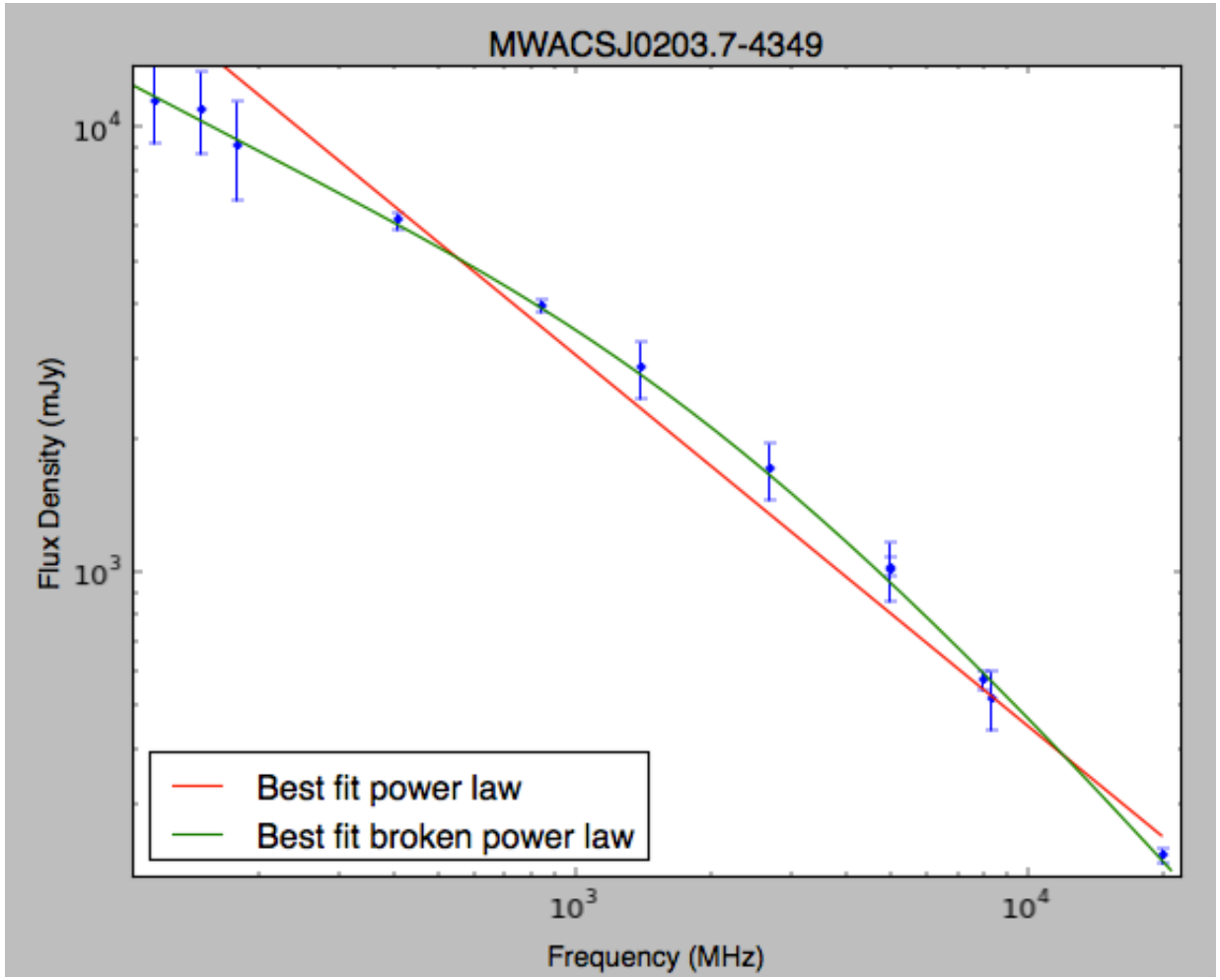
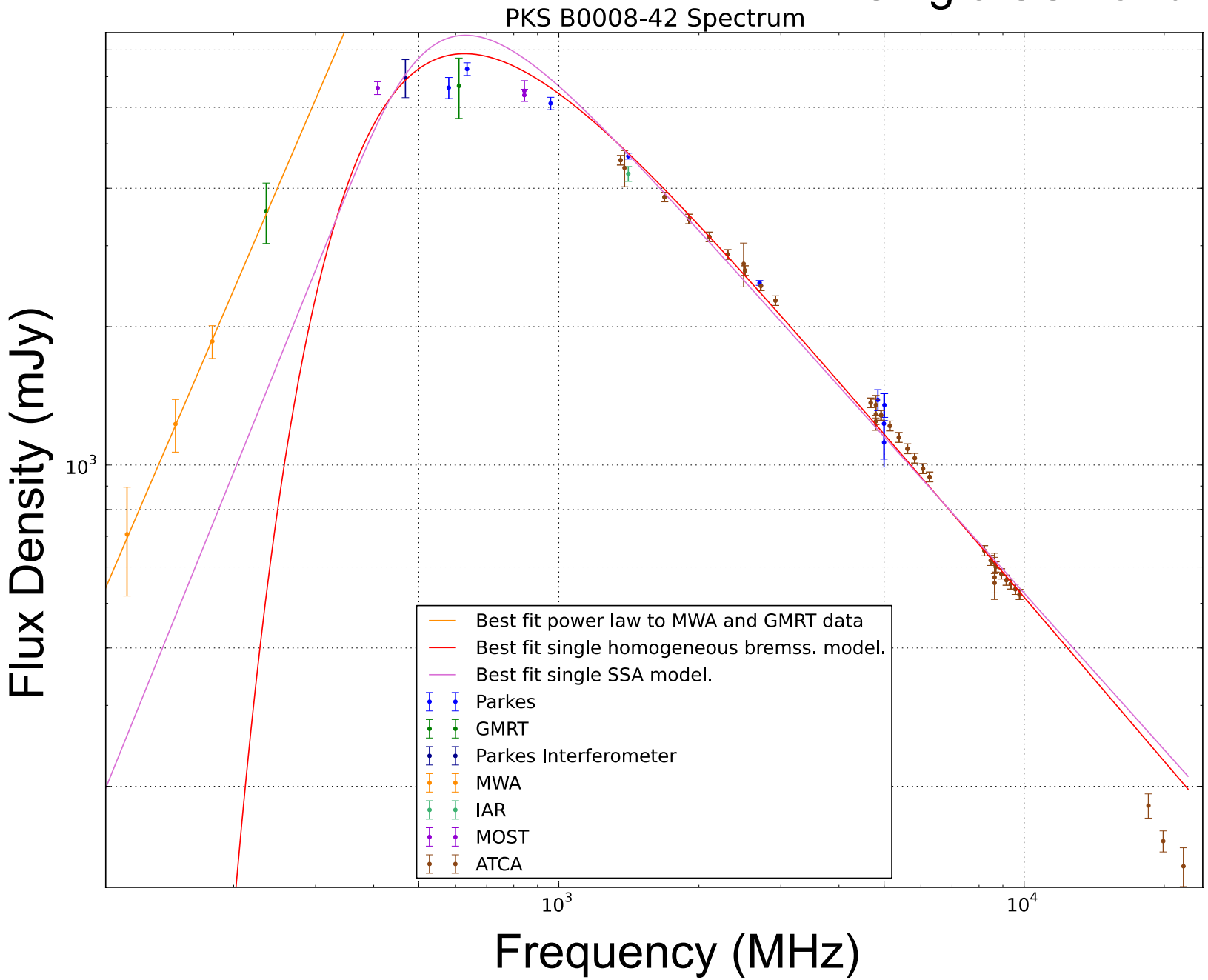
Death to the Power Law



Days of the power law are numbered!

Single SSA and FFA



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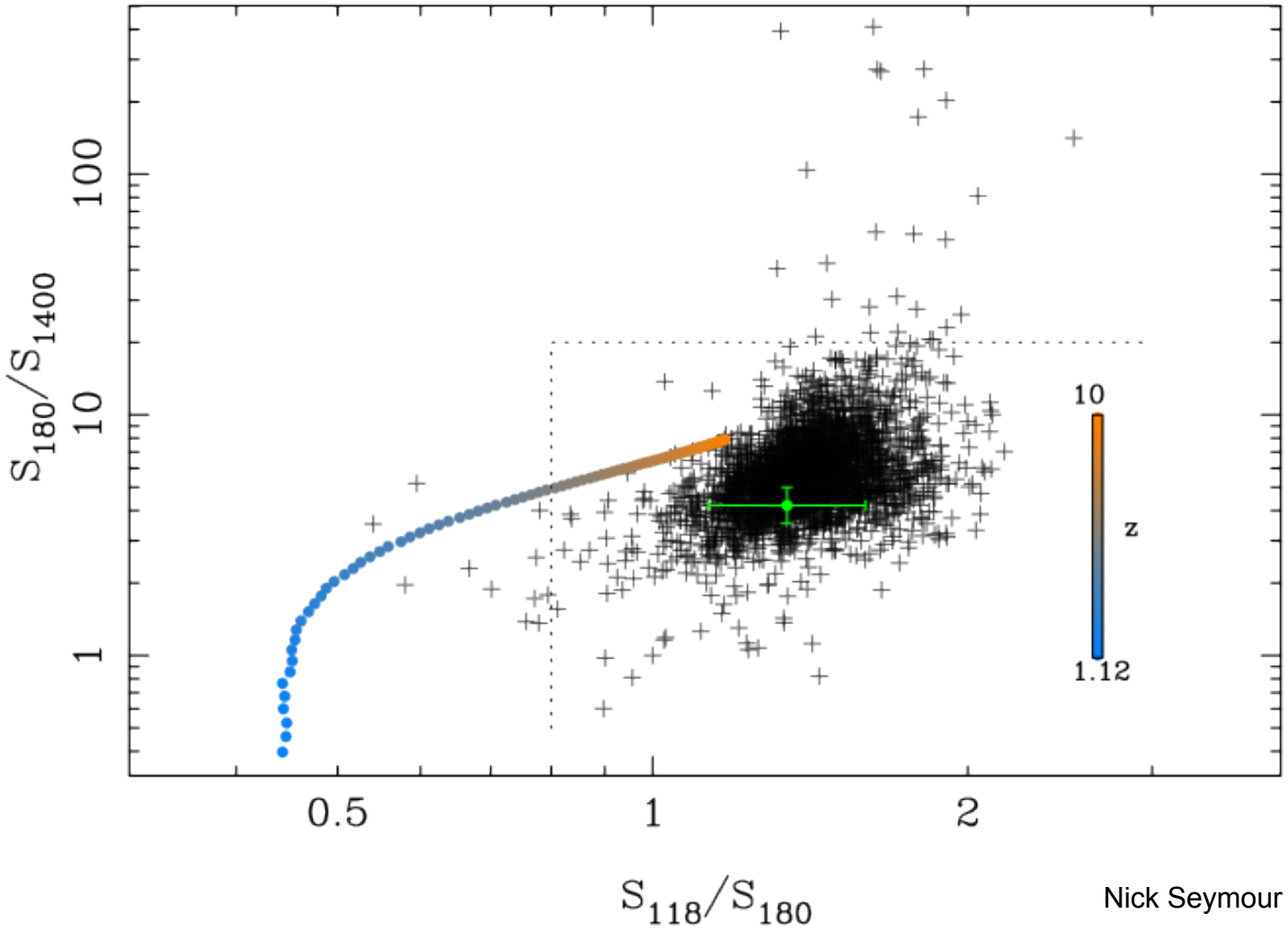
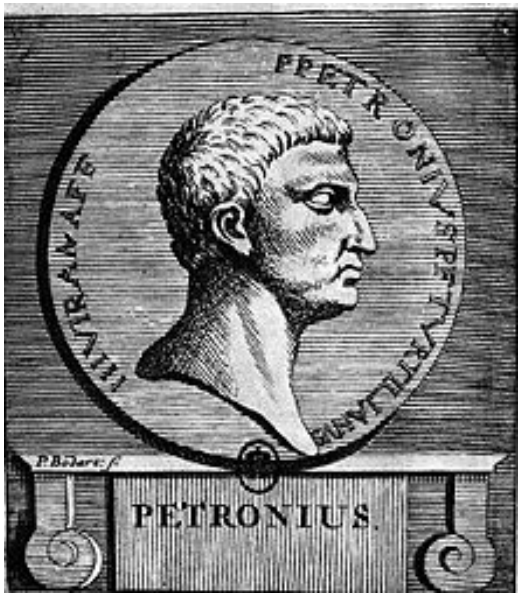
Finding high-z galaxies



Nick Seymour

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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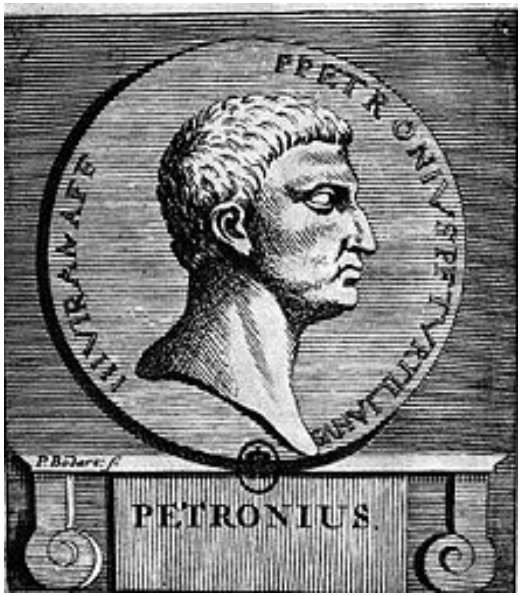
Why Bayes?



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

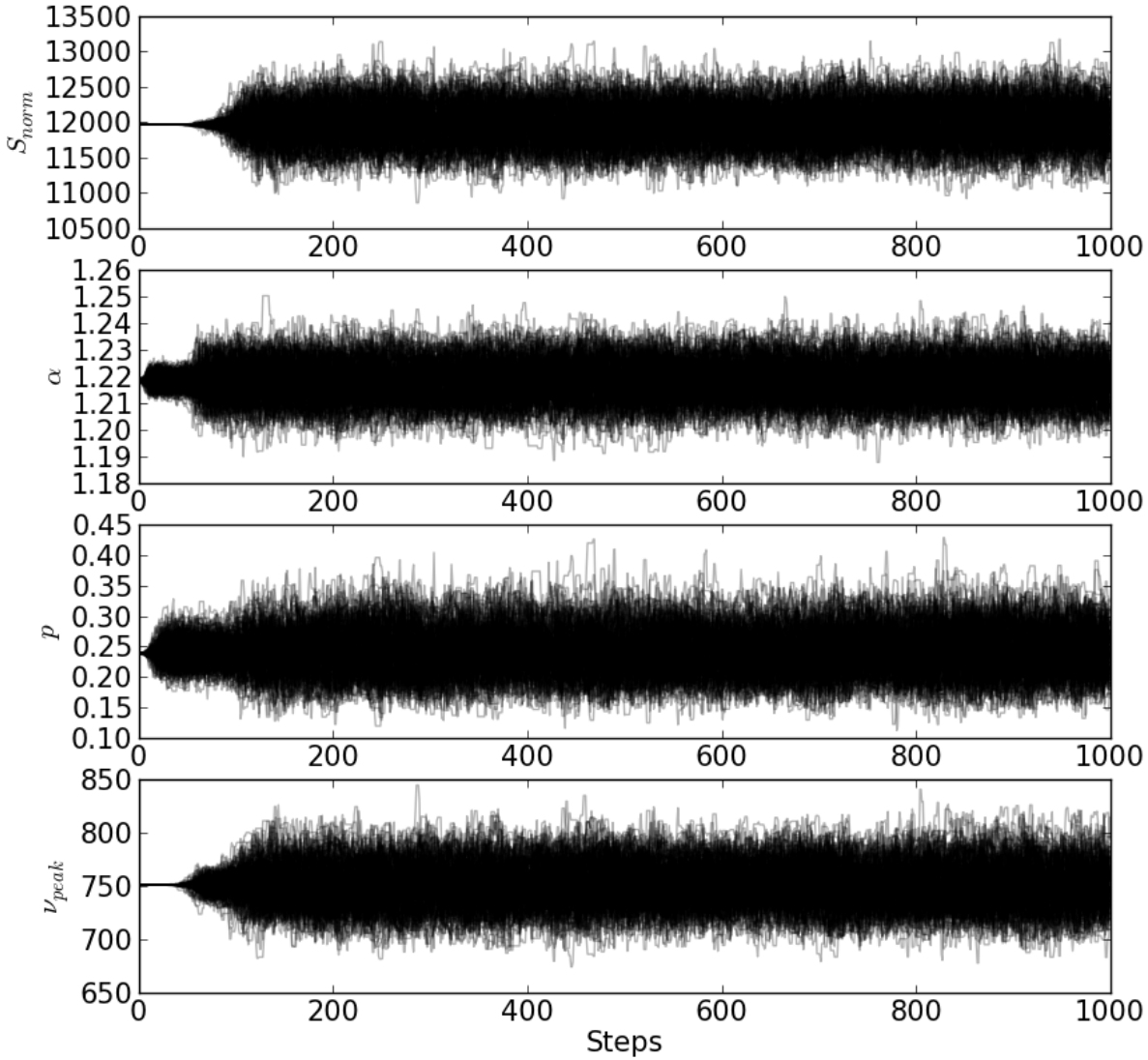
Why Bayes?

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