Intrinsic Brightness Temperatures Of Blazar Jets At 15 GHz

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The Innermost Regions of Relativistic Jets and Their Magnetic Fields
June 10-14, Granada, Spain

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Monitoring
Of
Jets in
Active Galaxies with
VLBA
Experiments

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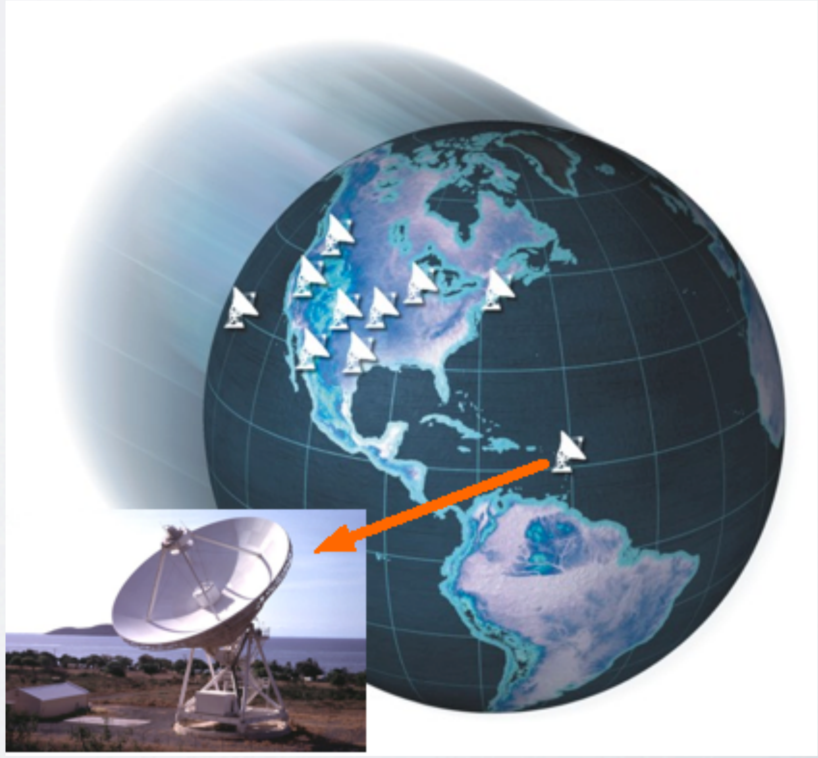
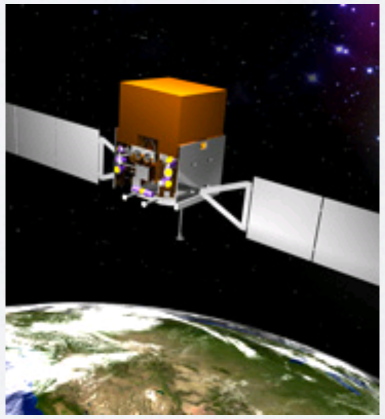




Outline

- Introduction
- New method to fit radio light curves
- Brightness temperatures from VLBA data
- Intrinsic brightness temperatures
- Caveats of the method and future work

The OVRO 40-m Monitoring Program

http://www.astro.caltech.edu/ovroblazars/

- Observations at 15 GHz
- 1158 sources from the CGRaBS (The Candidate Gamma-Ray Blazar Survey)
- All AGN associations from the 1FGL catalog (=221 new sources)
- All AGN associations from the 2FGL catalog (=241 new sources)
- + additional interesting sources from CRATES, MOJAVE etc.

→ ~ 1810 sources in total

- Observations started in 2007
- All sources observed twice per week

Motivation

- Why are brightness temperatures interesting?
  - Can be used to study if the jet is in equipartition
  - One of the few ways to easily estimate the Doppler boosting factors in the jet

Brightness Temperature Observations

- There are two commonly used methods to estimate the observed brightness temperature of blazars:

1. Assuming that a flare rise time corresponds to the light travel time across the emission region and estimating the size of the emission region using the variability timescale (e.g. Lähteenmäki et al. 1999)

    - converts to the source frame as $T_{b,var} = \delta^3 T_{int}$

2. Measuring the intensity and size of the emission region directly from VLBA images (e.g. Kovalev et al. 2005)

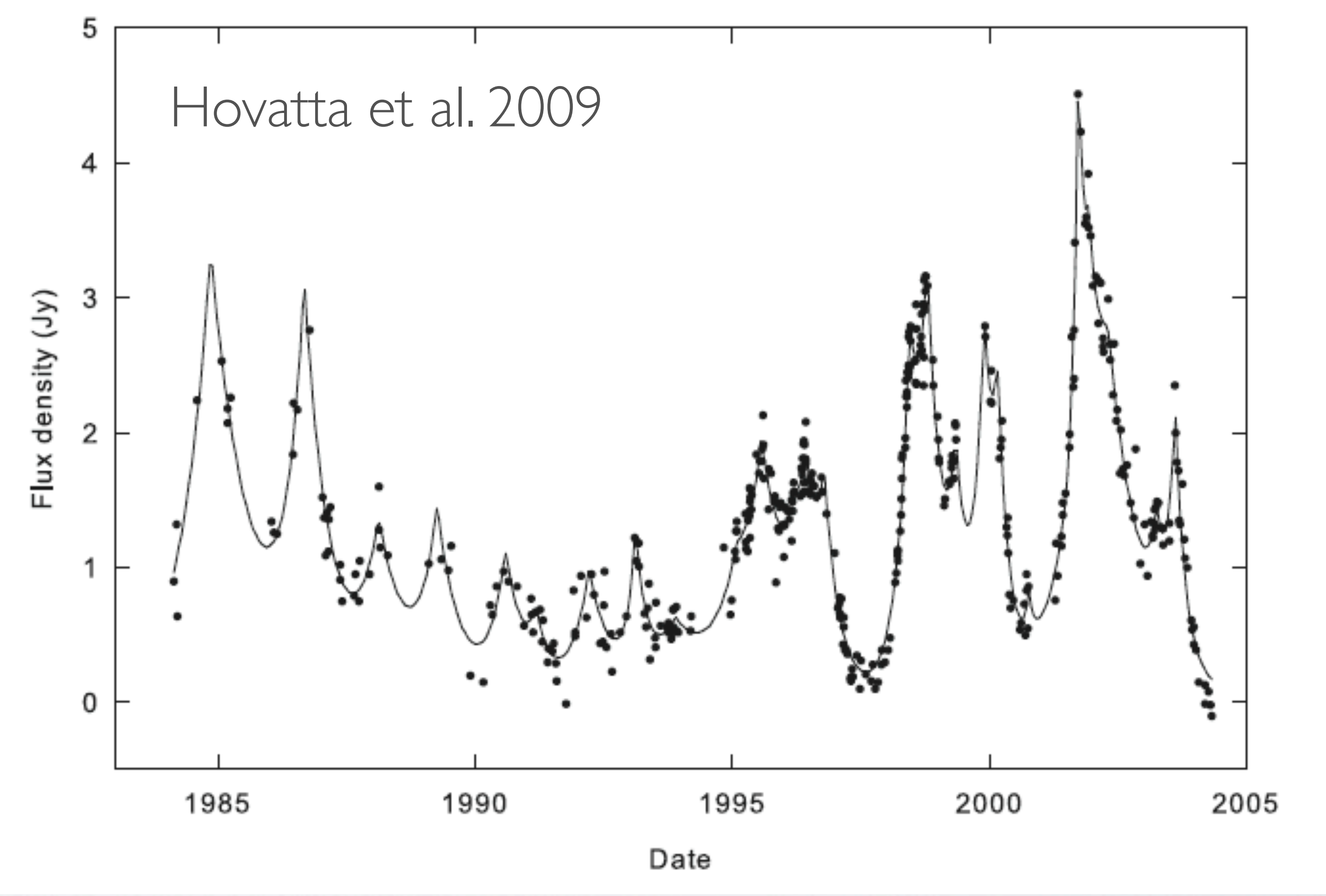
    - converts to the source frame as $T_{b,VLBI} = \delta T_{int}$

→ We can solve for $T_{b,\mathrm{int}} = \sqrt{\dfrac{T_{b,\mathrm{obs}}(\mathrm{VLBI})^3}{T_{b,\mathrm{obs}}(\mathrm{var})}}$

Variability Brightness Temperatures

- Logarithmic variability timescale stays constant during flares (Teräsranta & Valtaoja 1994)

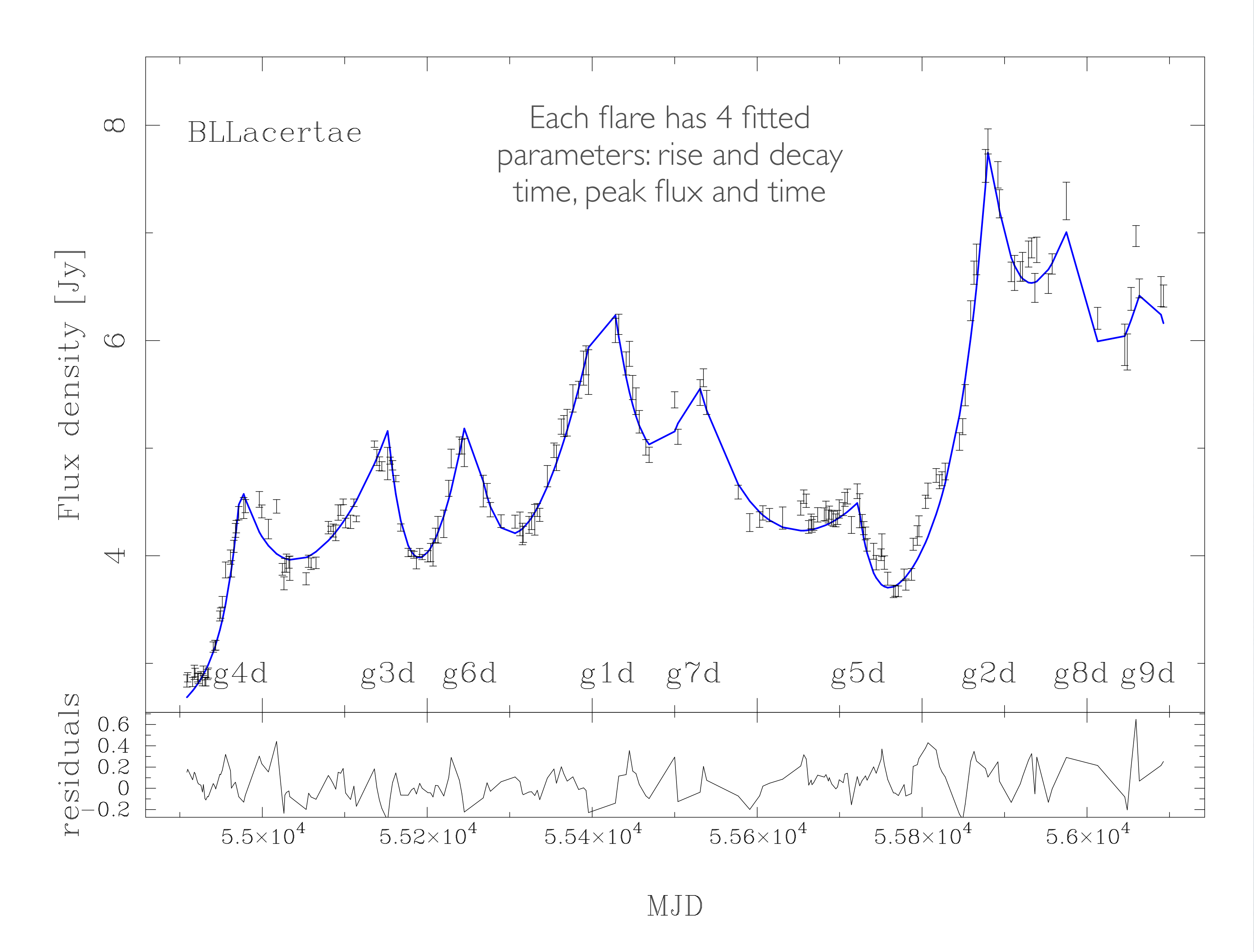
$$\tau_{\text{obs}} = \frac{dt}{d(\ln S)}$$



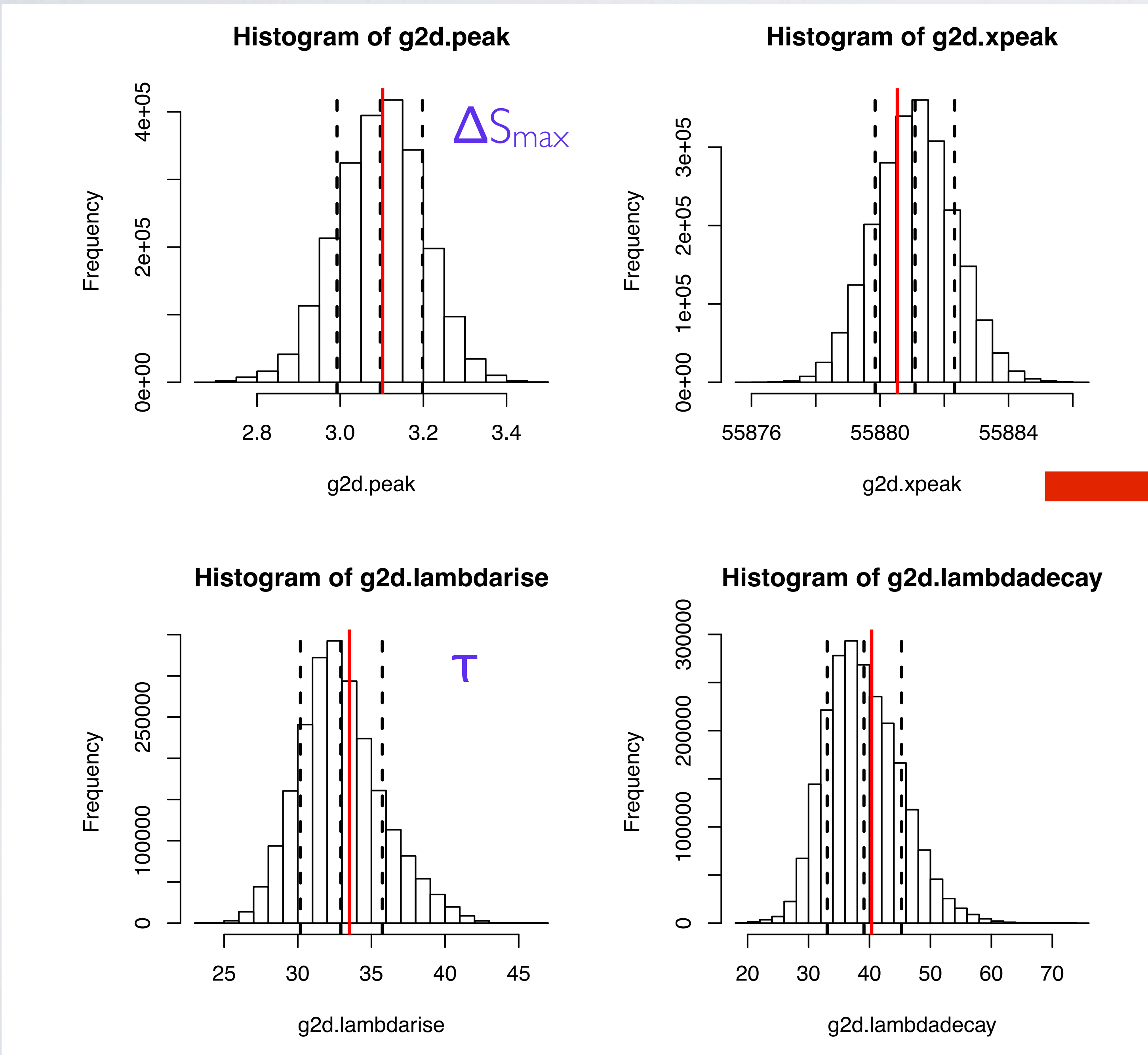
→ Total flux density variations can be fit with exponential flares (Valtaoja et al. 1999)

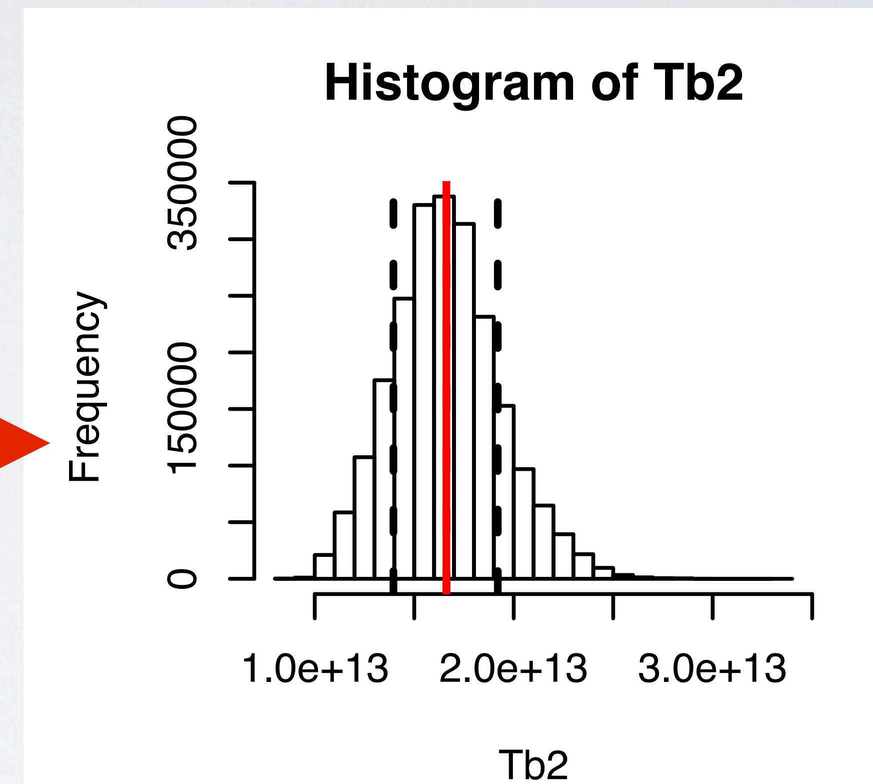
Light Curve Fitting With Markov Chain Monte Carlo

- Start by fitting one flare to the light curve
- Add more flares based on the χ^2 of the fit and the residuals
- Run several MCMC chains to check global convergence
- End product is a posterior distribution for the fit parameters of each flare



Posterior Distribution For The Flare Parameters

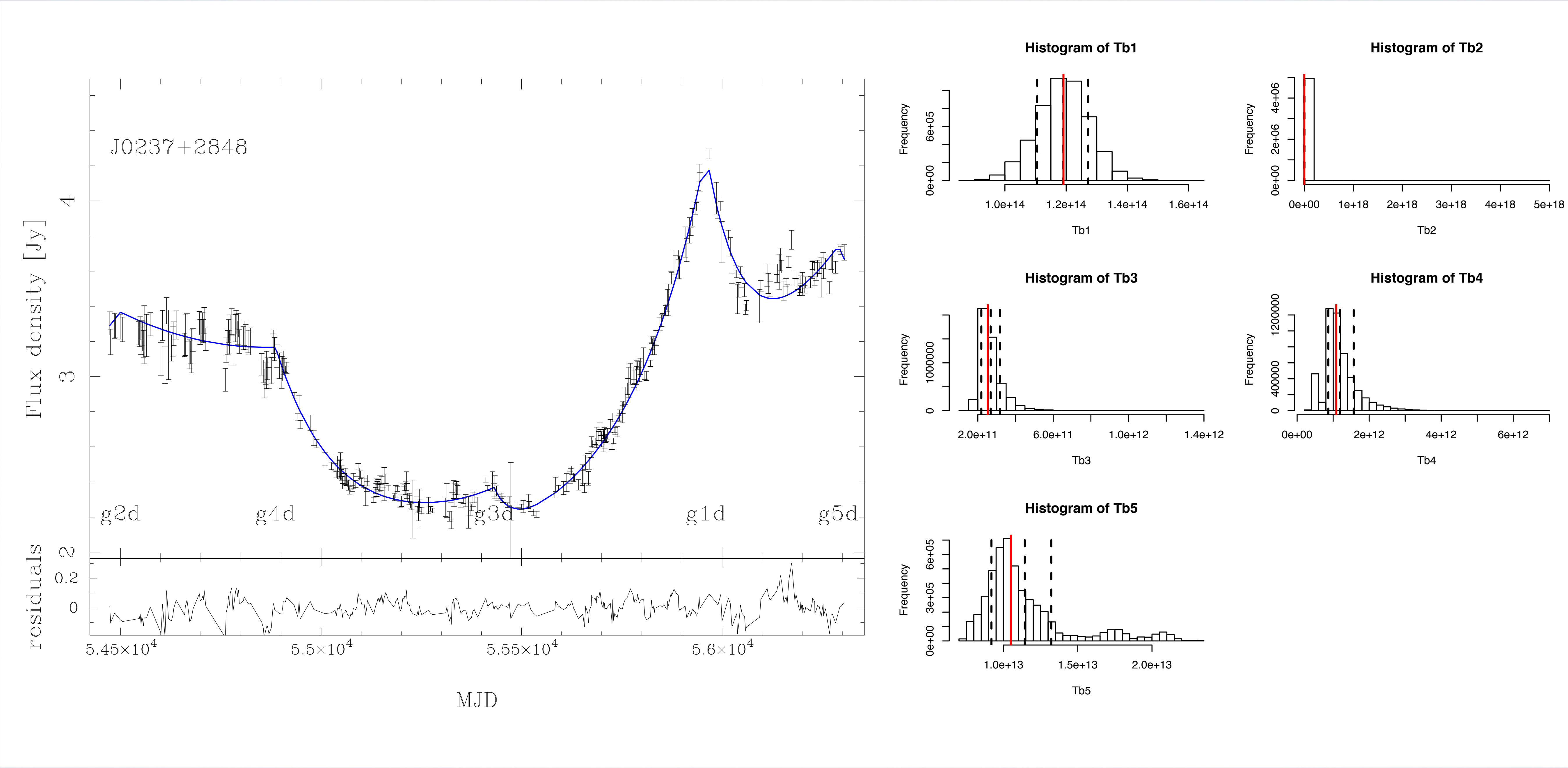




mean $T_{b,obs,var} = 1.7 \pm 0.3 \times 10^{13}$ K

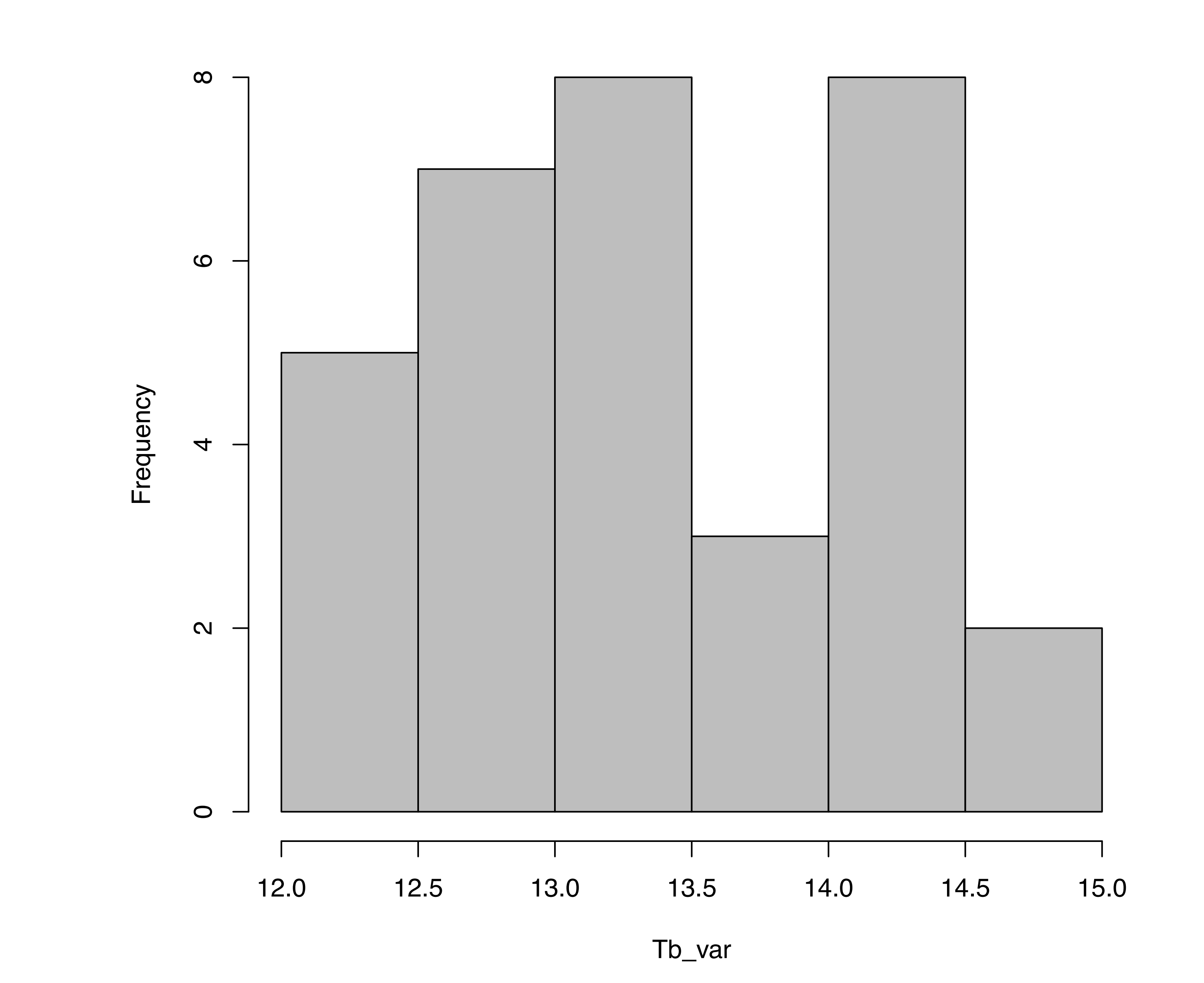
$$T_{\rm b,var} = 1.548 \times 10^{-32} \frac{\Delta S_{\rm max} d_{\rm L}^2}{\nu^2 \tau^2 (1+z)}$$

Another Example



Preliminary Observed Variability Tb

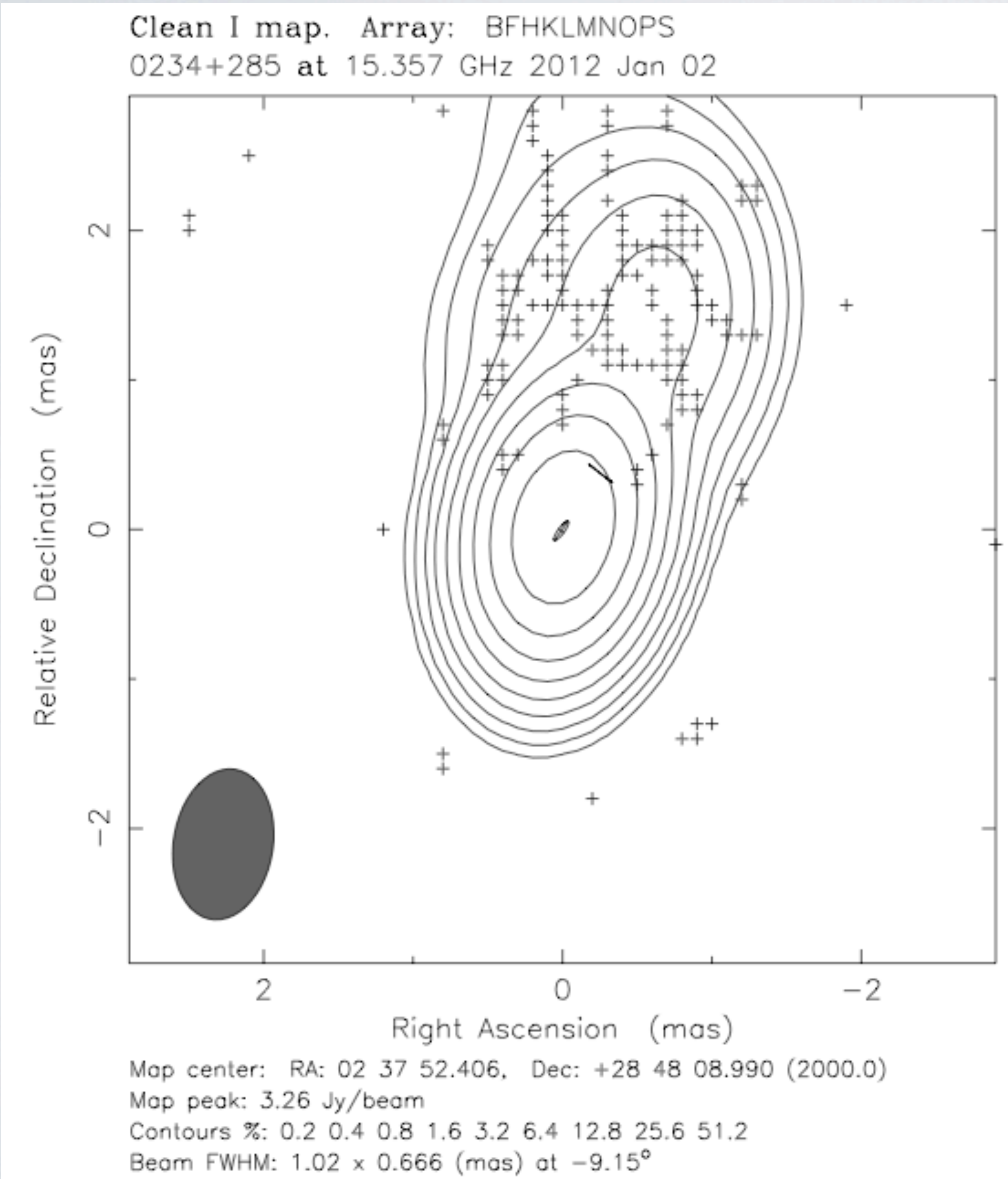
- 33 flares in 20 sources
- All above 10^{12}K
- Doppler boosting evident

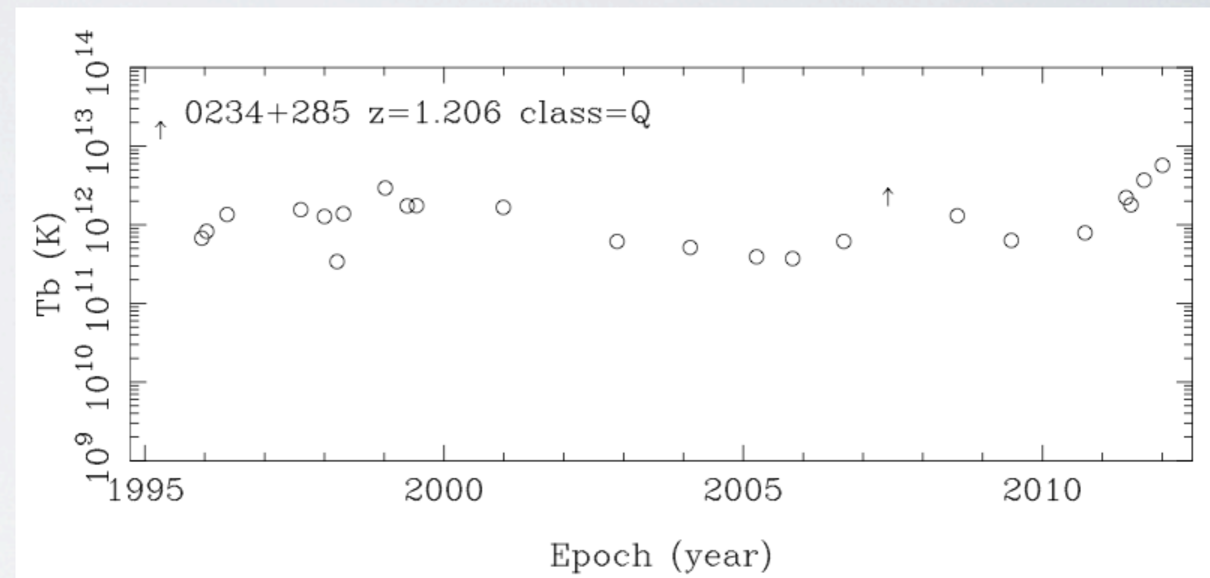


Brightness Temperatures From VLBA Data

1. Take the image of the source and identify the peak
2. Delete all clean components in locations where the map brightness is > 30% of the peak brightness and save this as a template model
3. Add a single gaussian at the peak to the template and modelfit
4. Same as above, but use 2 gaussians
5. Evaluate the 1 and 2 Gaussian models to determine which is better
6. Calculate the Tb for the preferred model from step (5). If the preferred model is the 2 component case, compute both of them, but only use the value for the component closest to the map peak location.

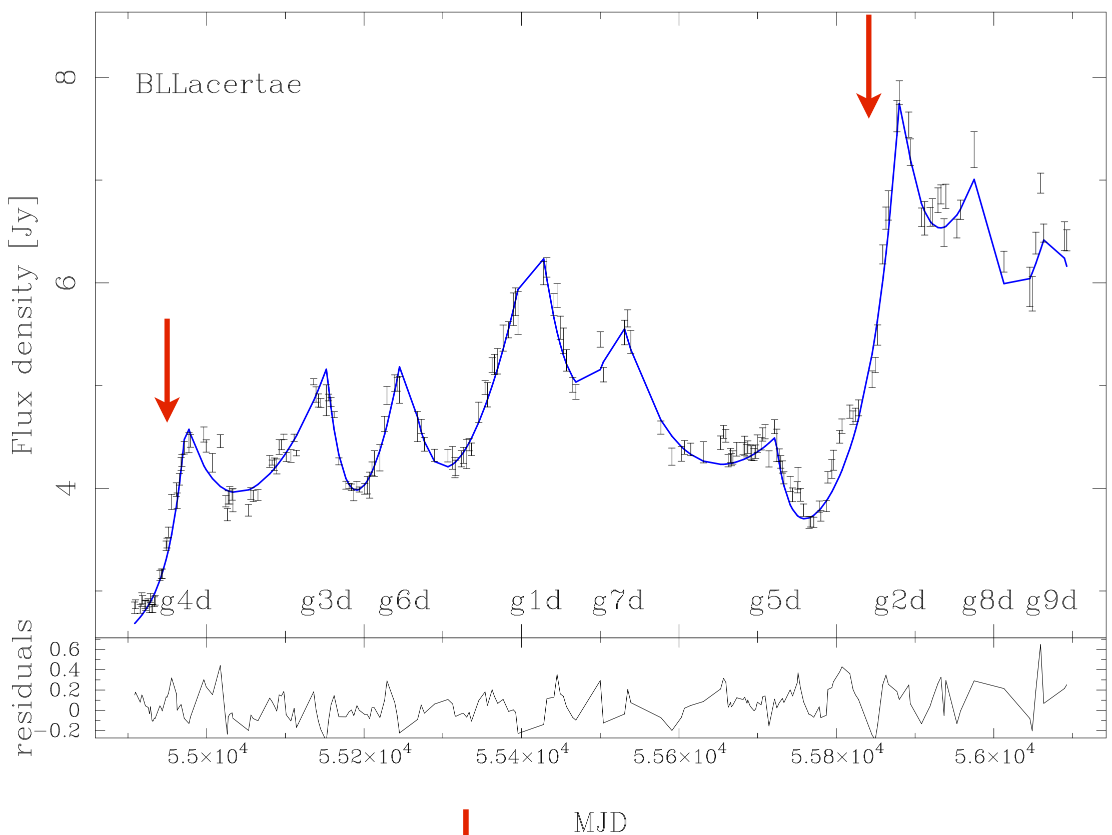
MOJAVE Tb Example

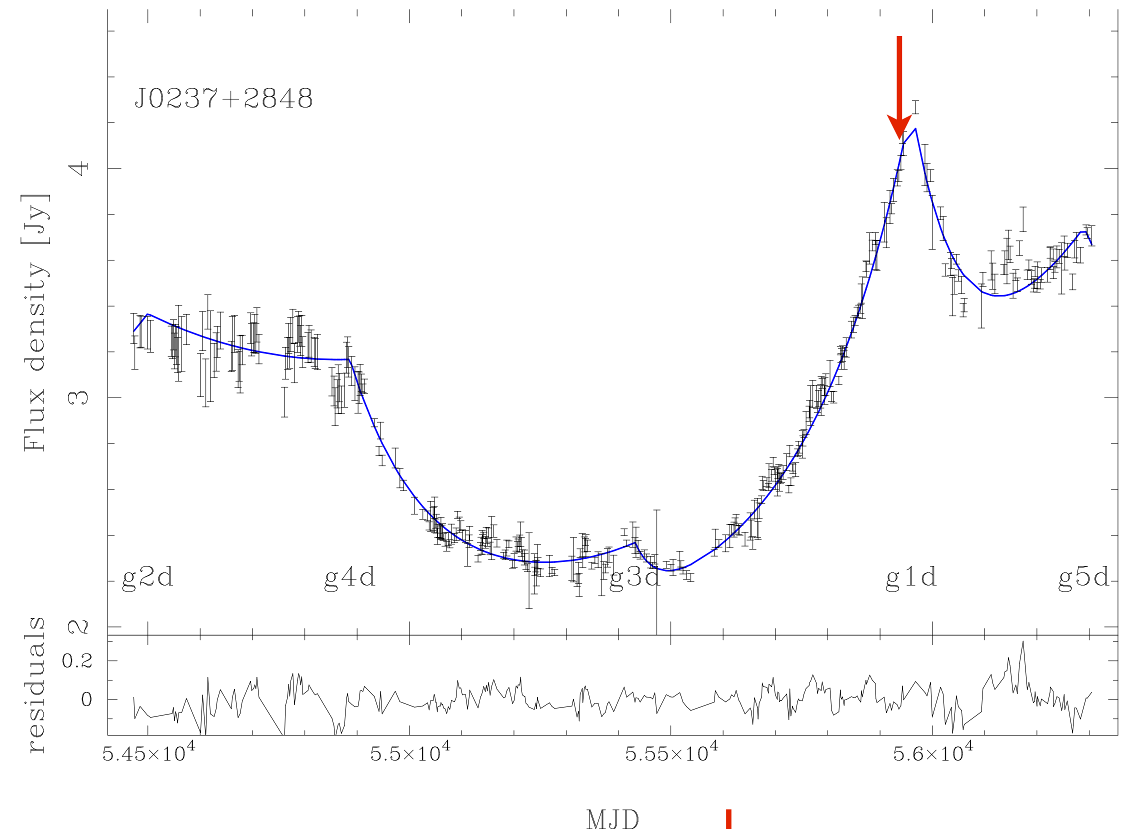


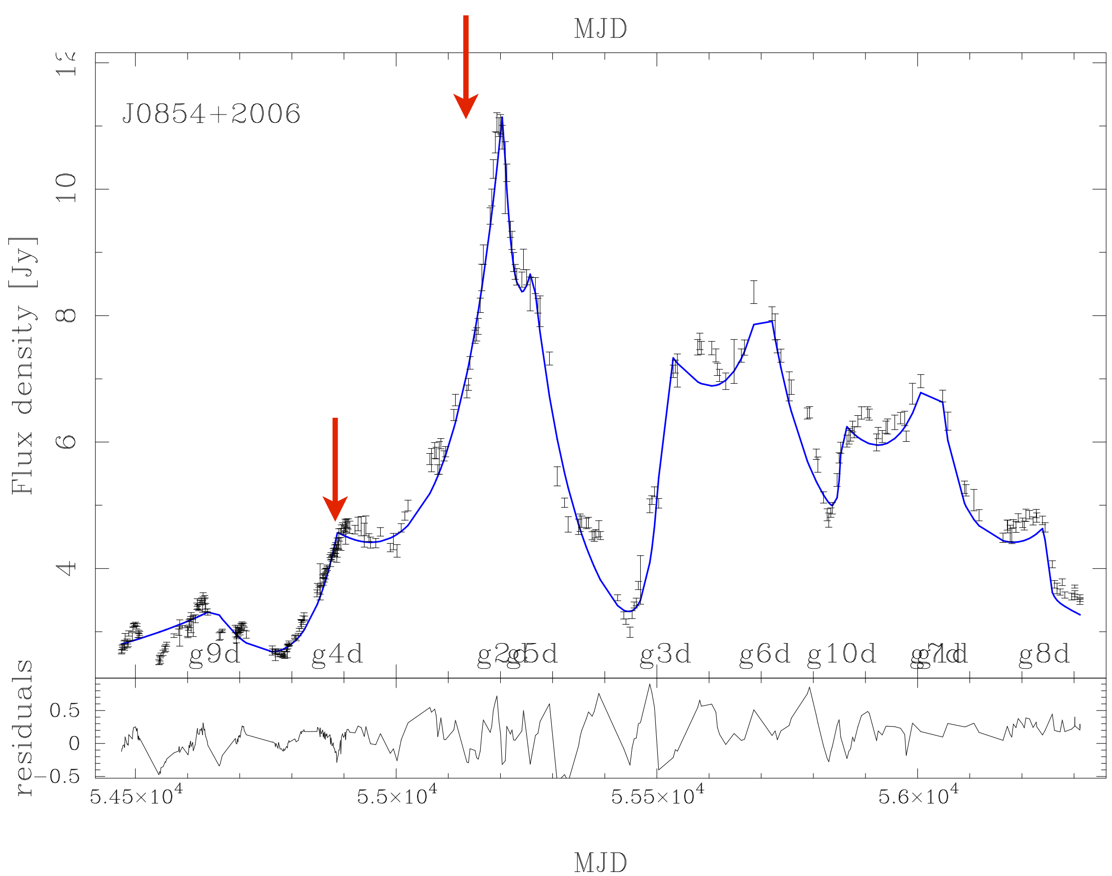


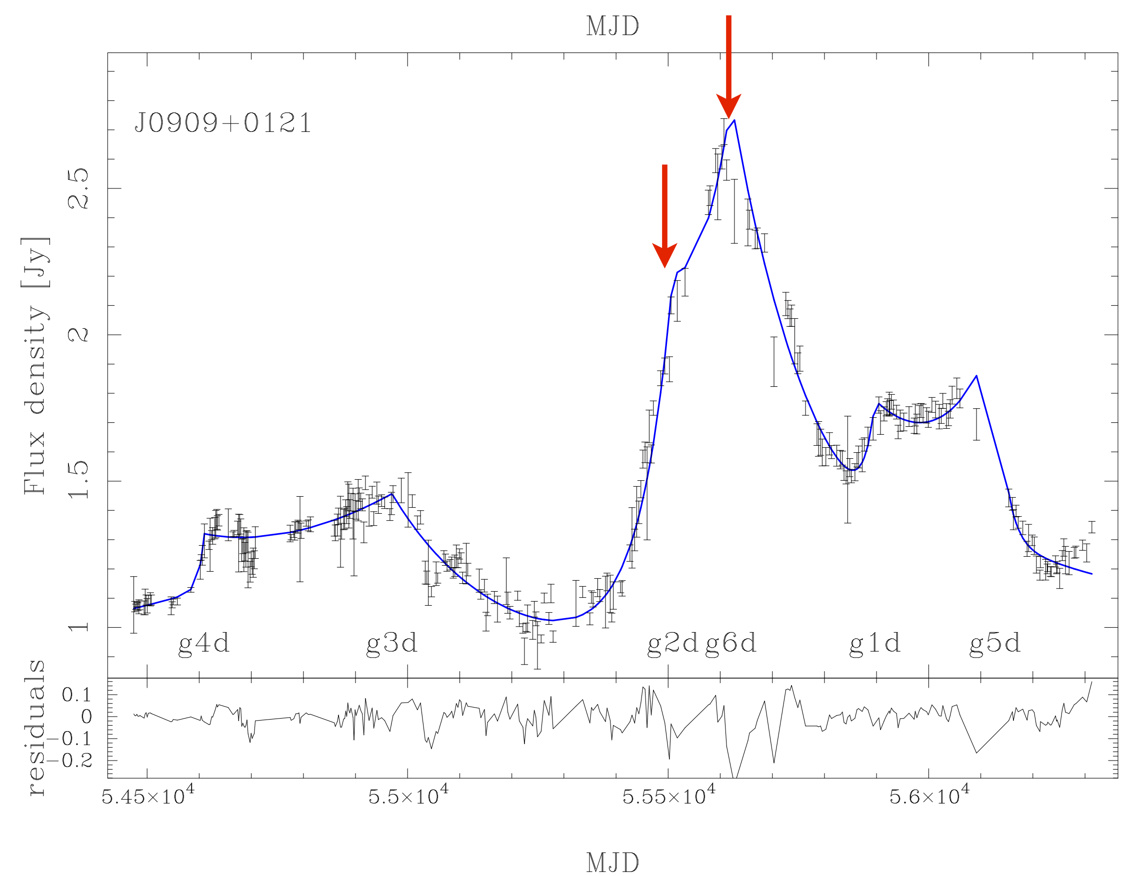
Homan et al. in preparation

Combining The Results







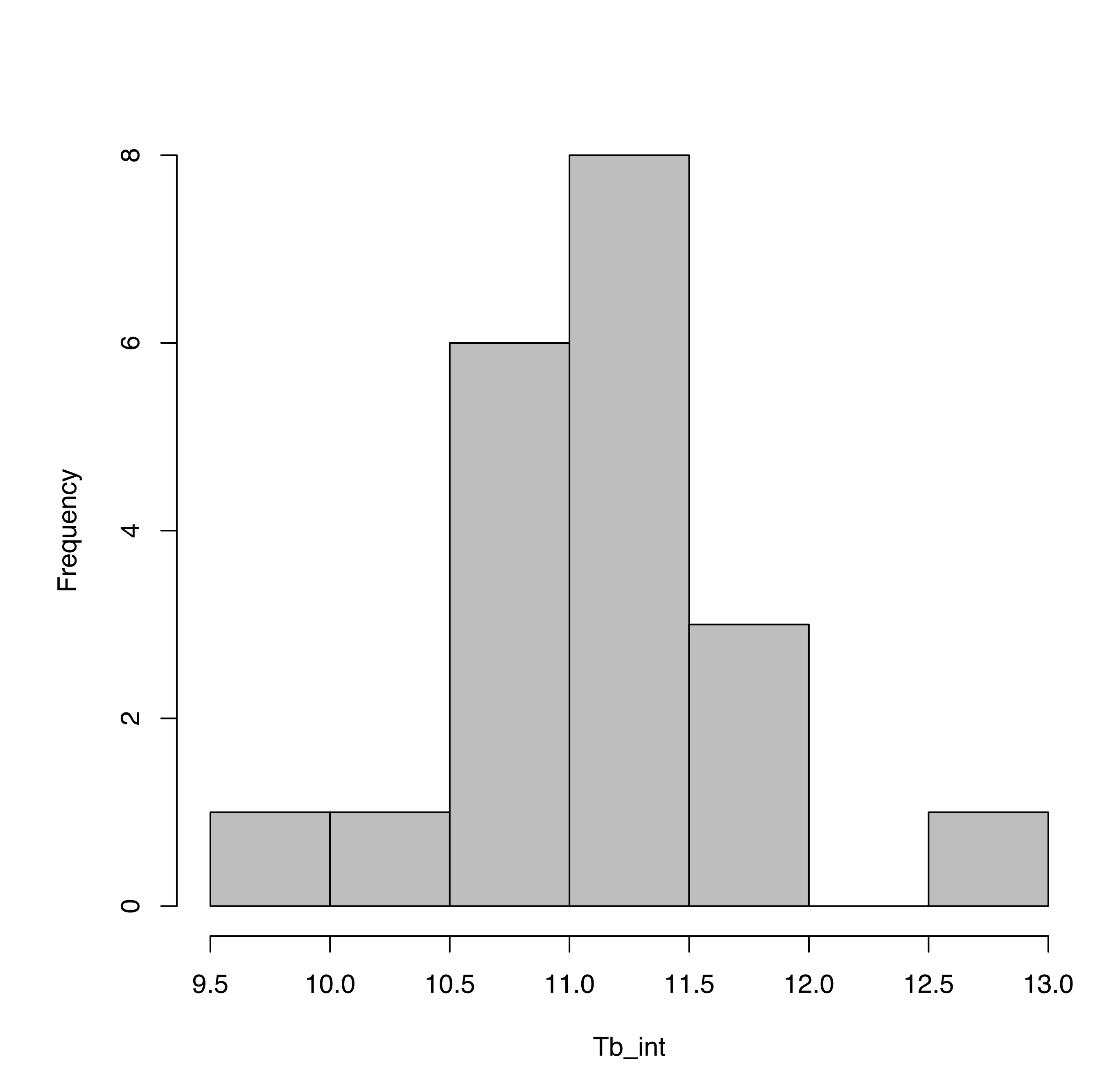


Preliminary Intrinsic Brightness Temperatures

- 20 well-defined flares in 14 sources have a VLBA epoch within 2 months of the peak

- Peak very close to Homan et al. 2006 and Lähteenmäki, Valtaoja & Wiik 1999 value of 1×10^{11}K

- Same as the equipartition Tb of Readhead 1994



$$T_{b,\mathrm{int}} = \sqrt{\frac{T_{b,\mathrm{obs}}(\mathrm{VLBI})^3}{T_{b,\mathrm{obs}}(\mathrm{var})}}$$

Caveats

- Only a very small and very biased sample studied so far!!
- $T_{b,var}$ calculation assumes a uniform disk while $T_{b,VLBI}$ assumes a Gaussian component
- Relies on the assumption that the rise time corresponds to the light travel time across the emission region.
    - method will not give correct Tb values but lower limits.
- MCMC does not yet include full model selection
    - working on a global optimizer method to achieve that
- MCMC fit does not usually converge to a global maximum
    - seems like the maximum is very broad and longer chains should be run which at the moment is not feasible

Future Work

- Improve the MCMC method to work more automatically
- Fit all the flaring OVRO sources in the MOJAVE sample to determine the intrinsic brightness temperature at 15 GHz
- Fit all the flaring OVRO sources (several hundred) and determine the Doppler boosting factors