Trans-dimensional signal modeling in PTA data

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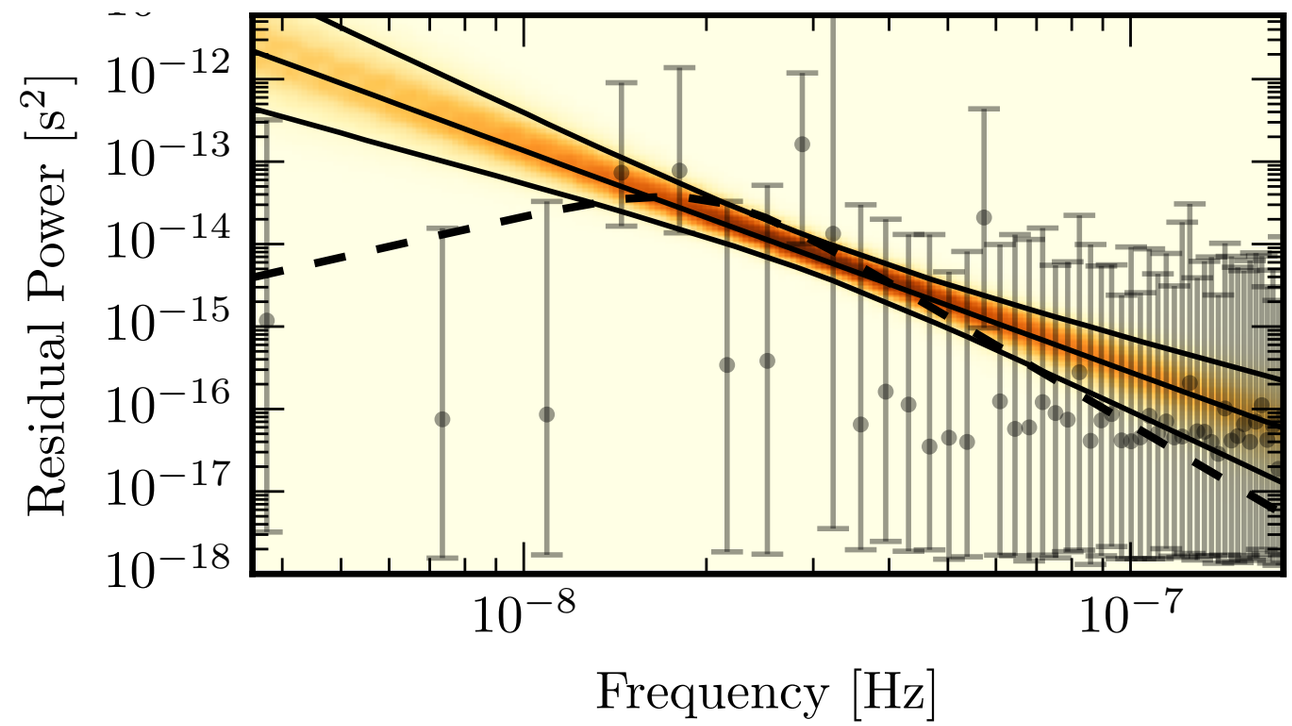
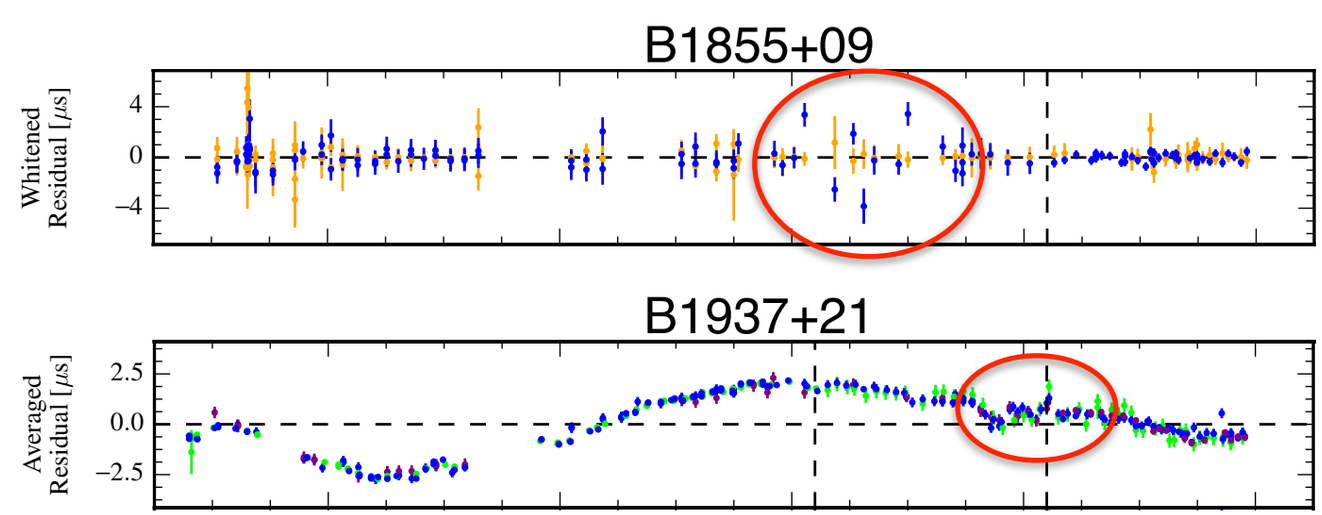
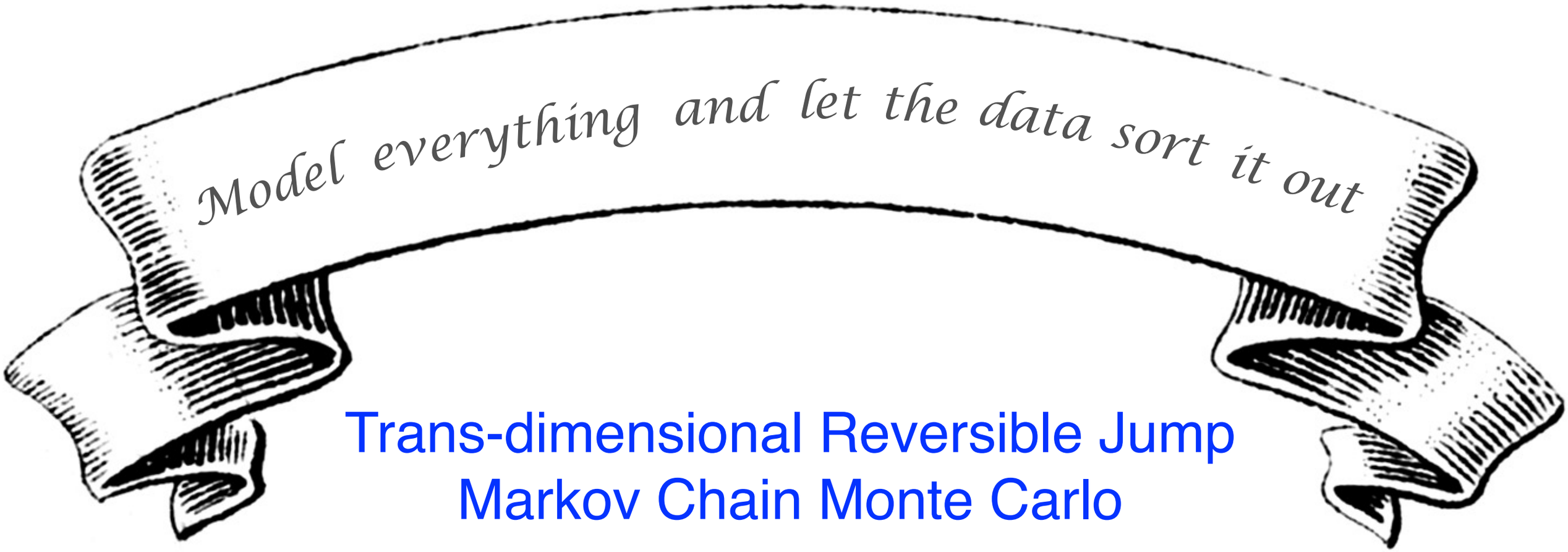
Motivation

- Spectral modeling of red noise. Power-law = 2 parameters. Free spectrum > 30 parameters. Which is “better”?
- Would like a way to use free parameters where they are needed.
- Some pulsars show transient noise events. How do we model them?
- Would like a way to model them without a-priori choosing number of basis functions.







Trans-dimensional Reversible Jump Markov Chain Monte Carlo

- Similar to standard MCMC but now the model is another parameter
- Let the data pick the best model.
- Marginalize over models and their parameters.

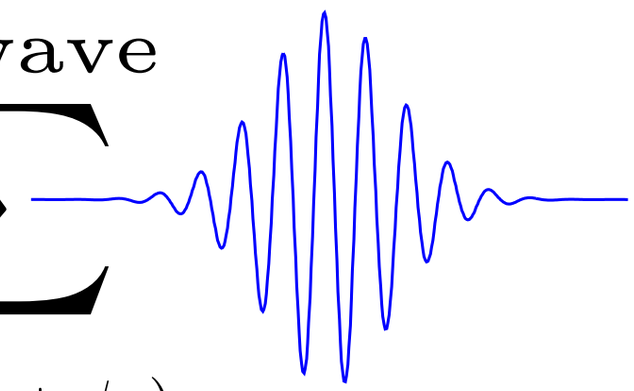
BayesWave: Cornish & Littenberg, CQG 32, 135012 (2015)

BayesLine: Littenberg and Cornish, PRD 91, 084034 (2015)

BayesWavePTA: Ellis & Cornish, arXiv:1601.00650 [in press PRD] (2016)

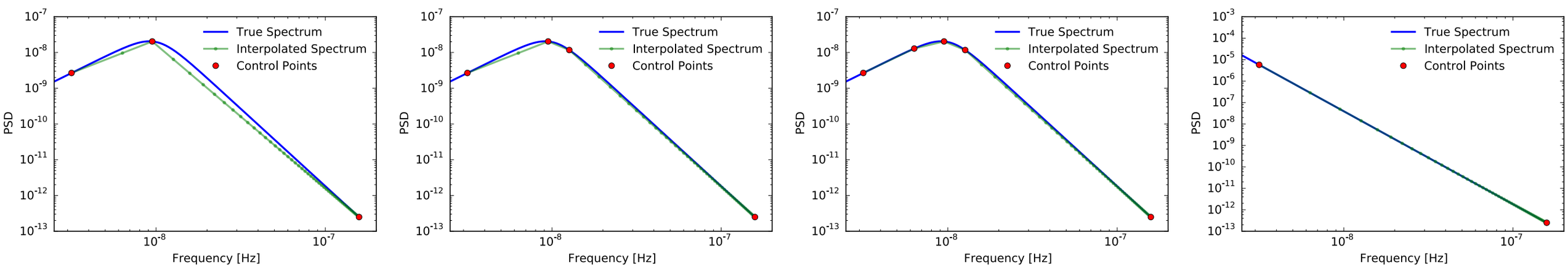
Modeling

Model Transient signals with sum of Morlet-Gabor Wavelets $\sum^{N_{\mathrm{wave}}}$



$$\Psi(t; A, f_0, Q, t_0, \phi_0) = Ae^{-(t-t_0)^2/\tau^2} \cos(2\pi f_0(t - t_0) + \phi_0)$$

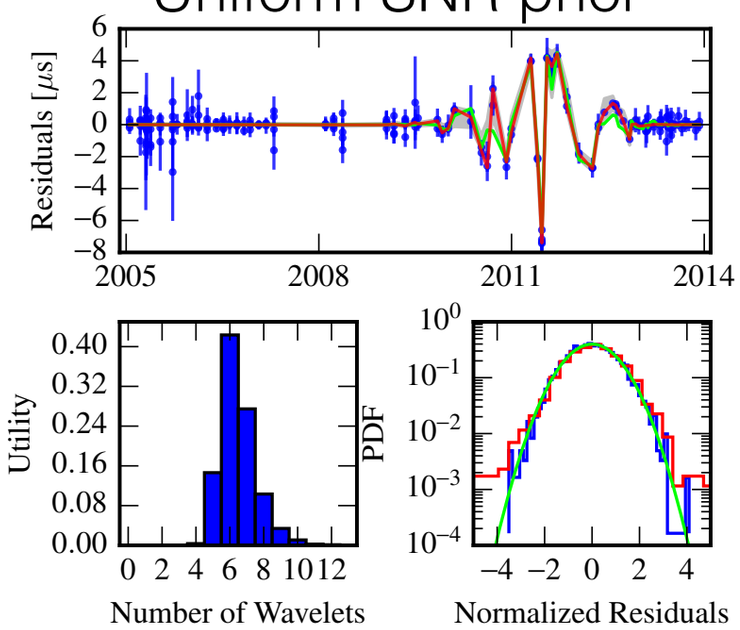
Model red spectrum with free control points and linear interpolation in log-space.



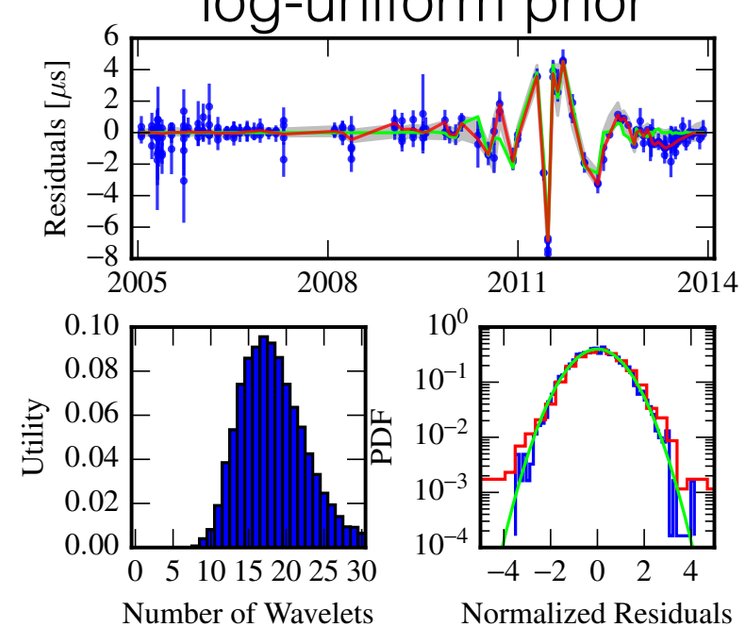
Transient Noise Event Simulation.

- B1855+09 TOAs with simulated white noise burst.
- Test model with uniform SNR prior and log-uniform amplitude prior
- Signal recovered well in both cases.
- Model much simpler with uniform SNR prior.

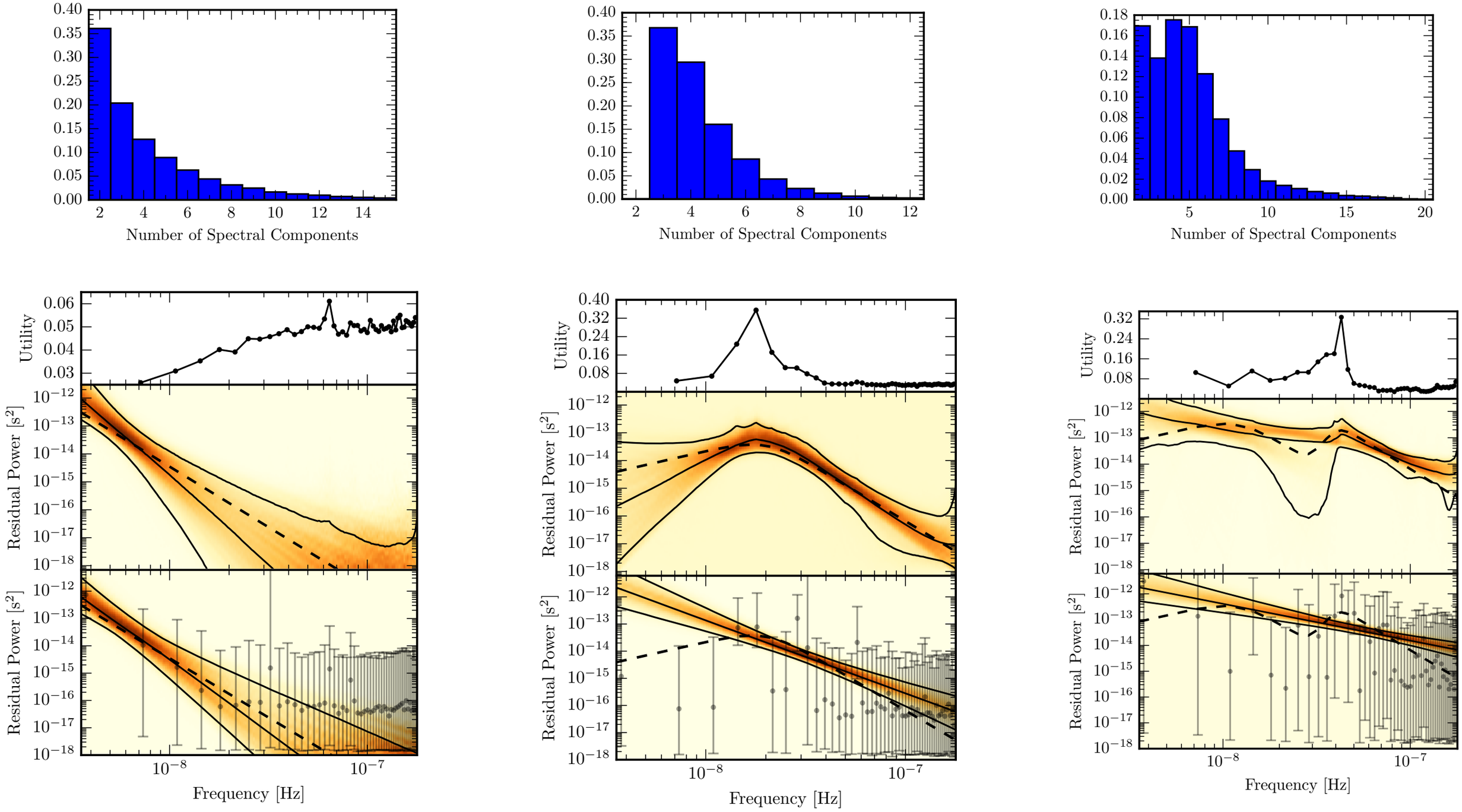
Uniform SNR prior



log-uniform prior

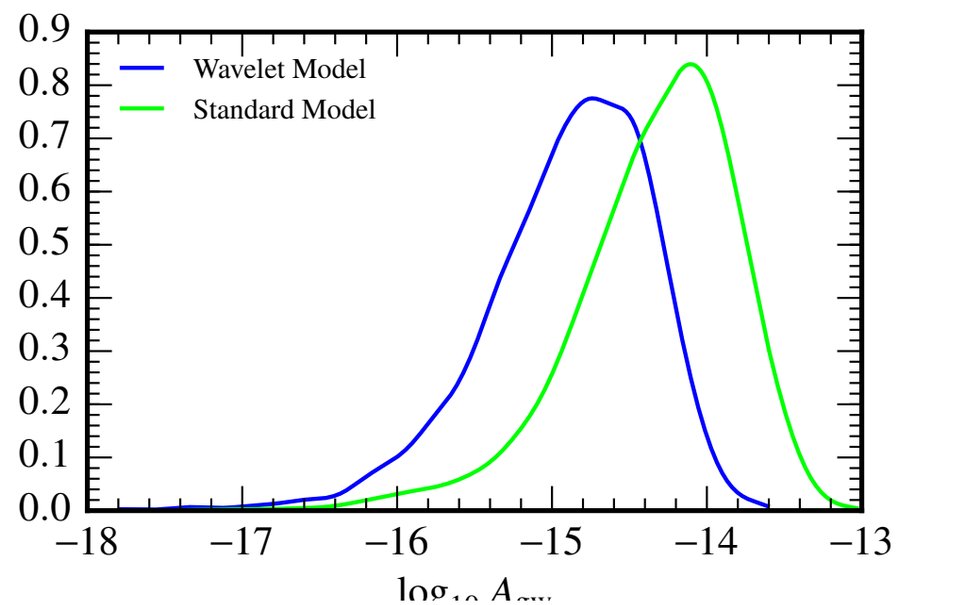


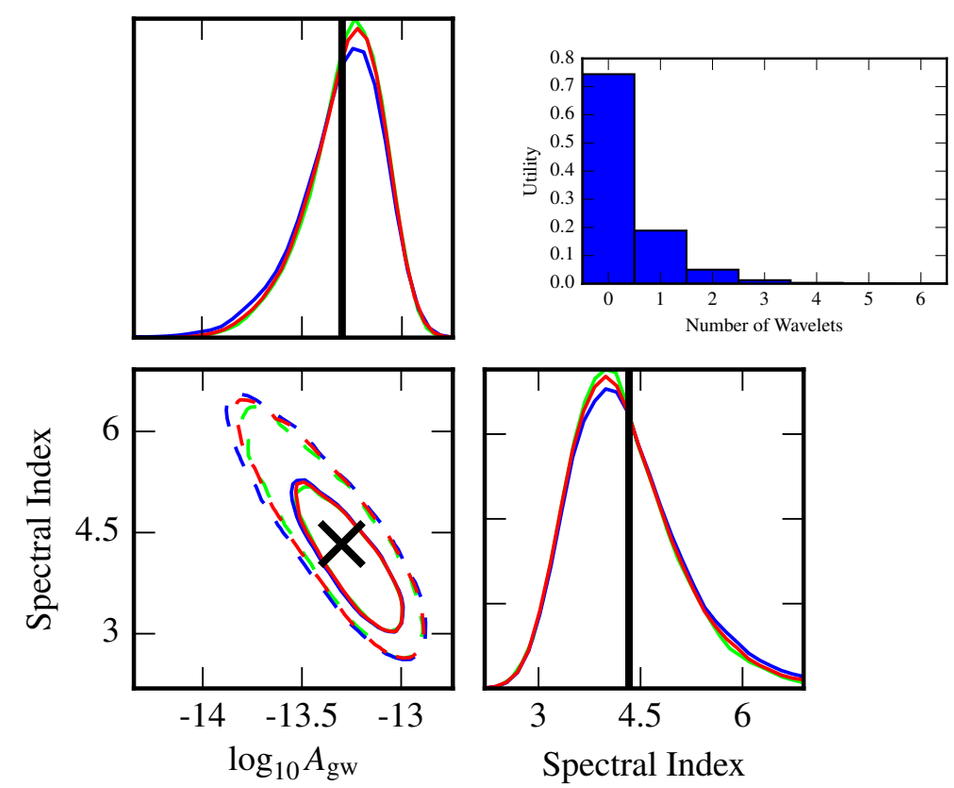
Adaptive PSD estimation



Improvement of GW limits

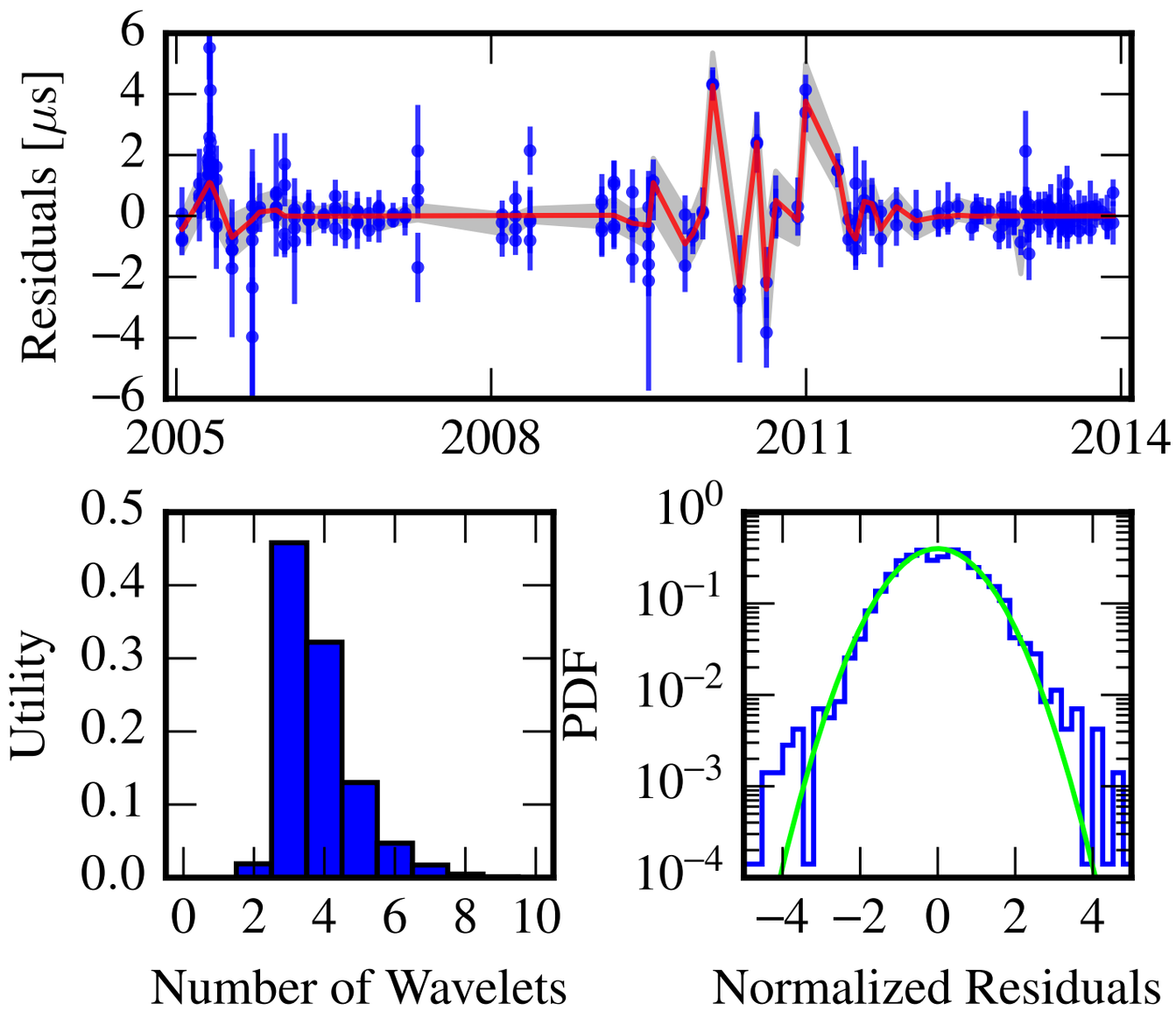
- If transient noise event is present and not modeled, GW limits could suffer severely
- Wavelet model does not absorb GW power in the absence of a transient signal
- Plan to use this method for upcoming GW limits.





Analysis on B1855+09

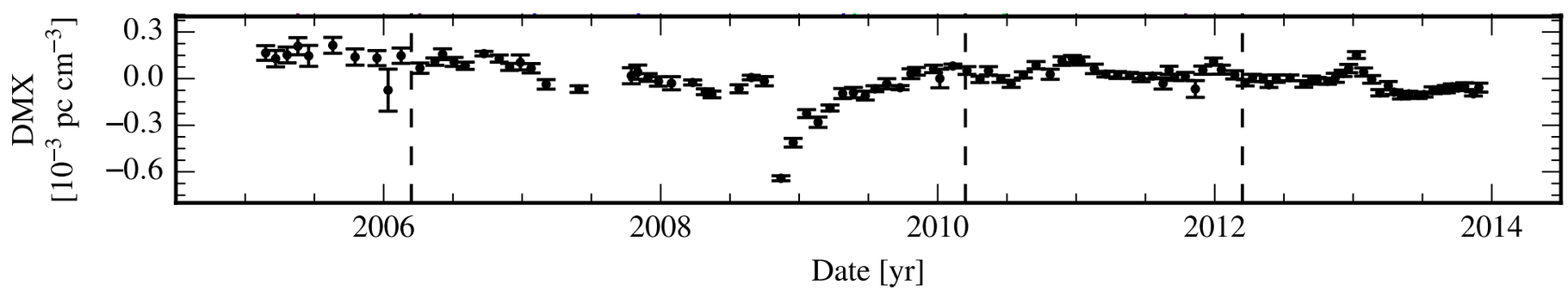
Bayes factor for > 0 wavelets is ~exp(13)

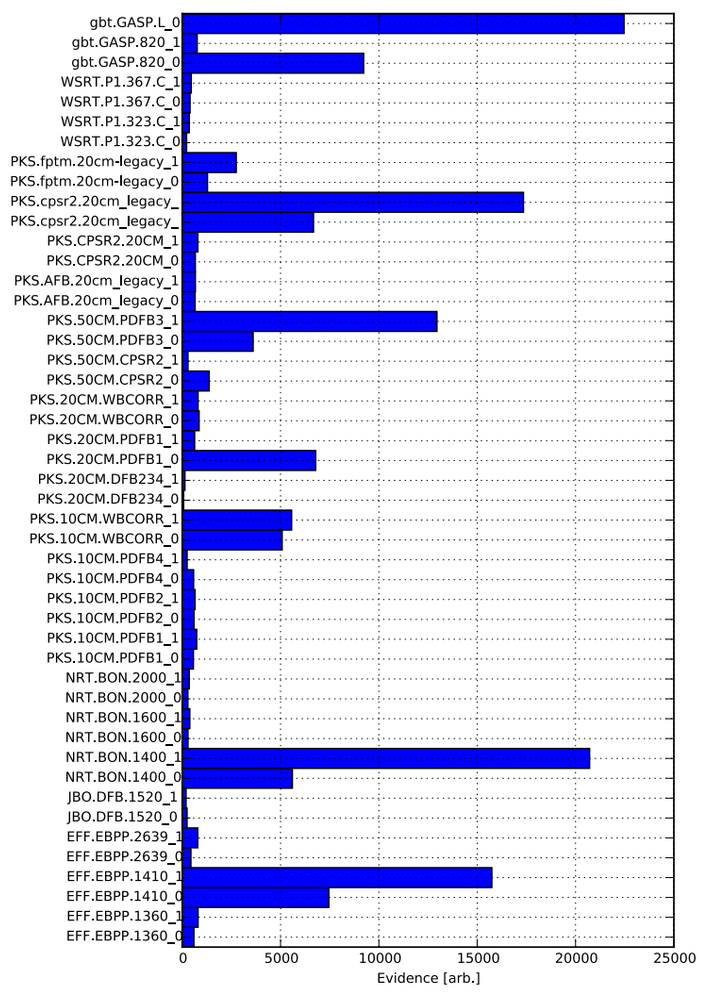


- Real B1855+09 data shows a very significant transient noise event
- Corresponds to observation run in which half of observing bandwidth data was corrupted
- Plan to carry out this analysis on all NANOGrav pulsars in the future

Future Directions

- Apply to Dispersion Measure as well as TOAs





- Use wavelets per observing backend to model systematics
- Quite a difficult sampling problem