IPTA mock data challenge: setup and analysis

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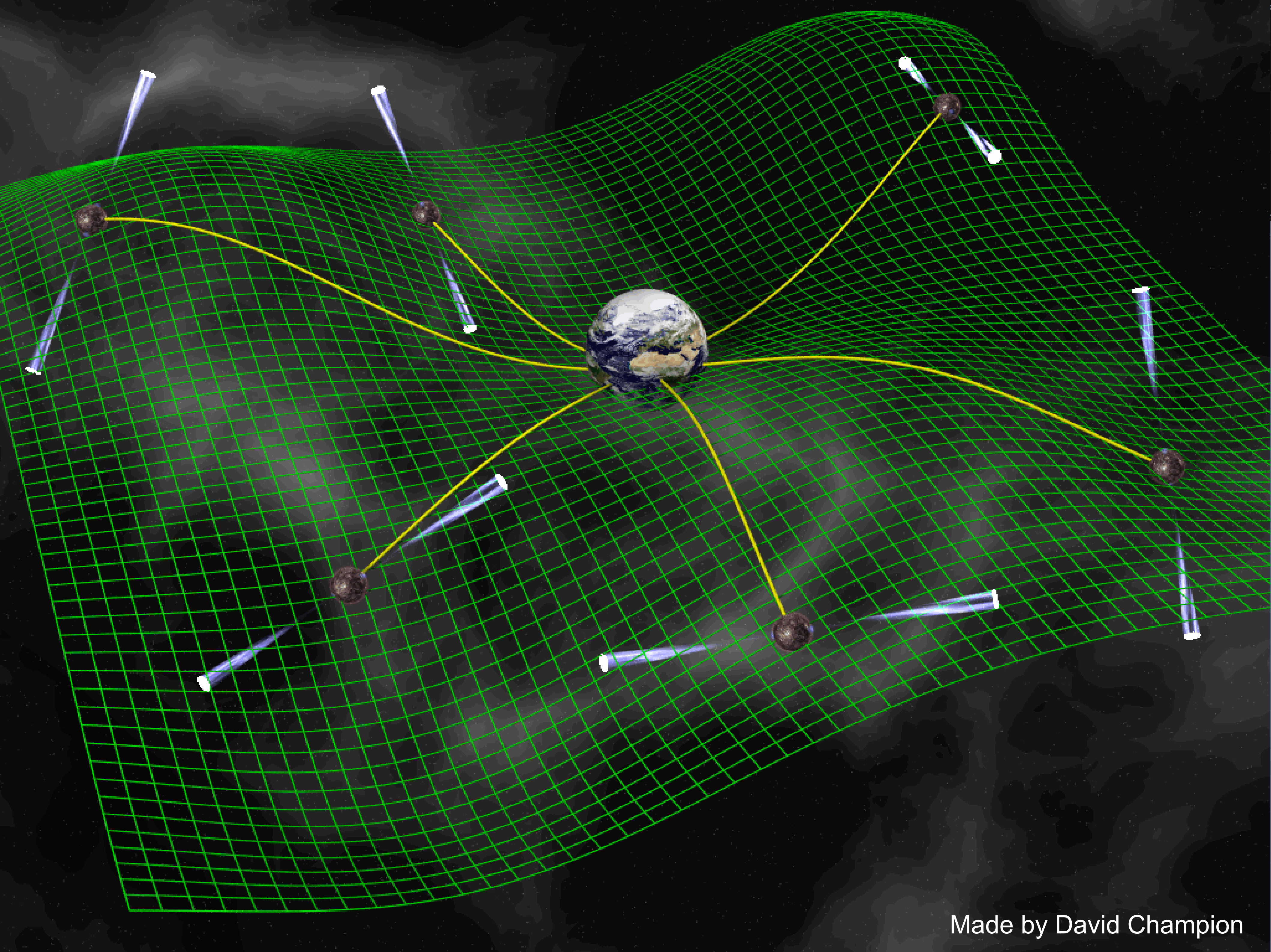
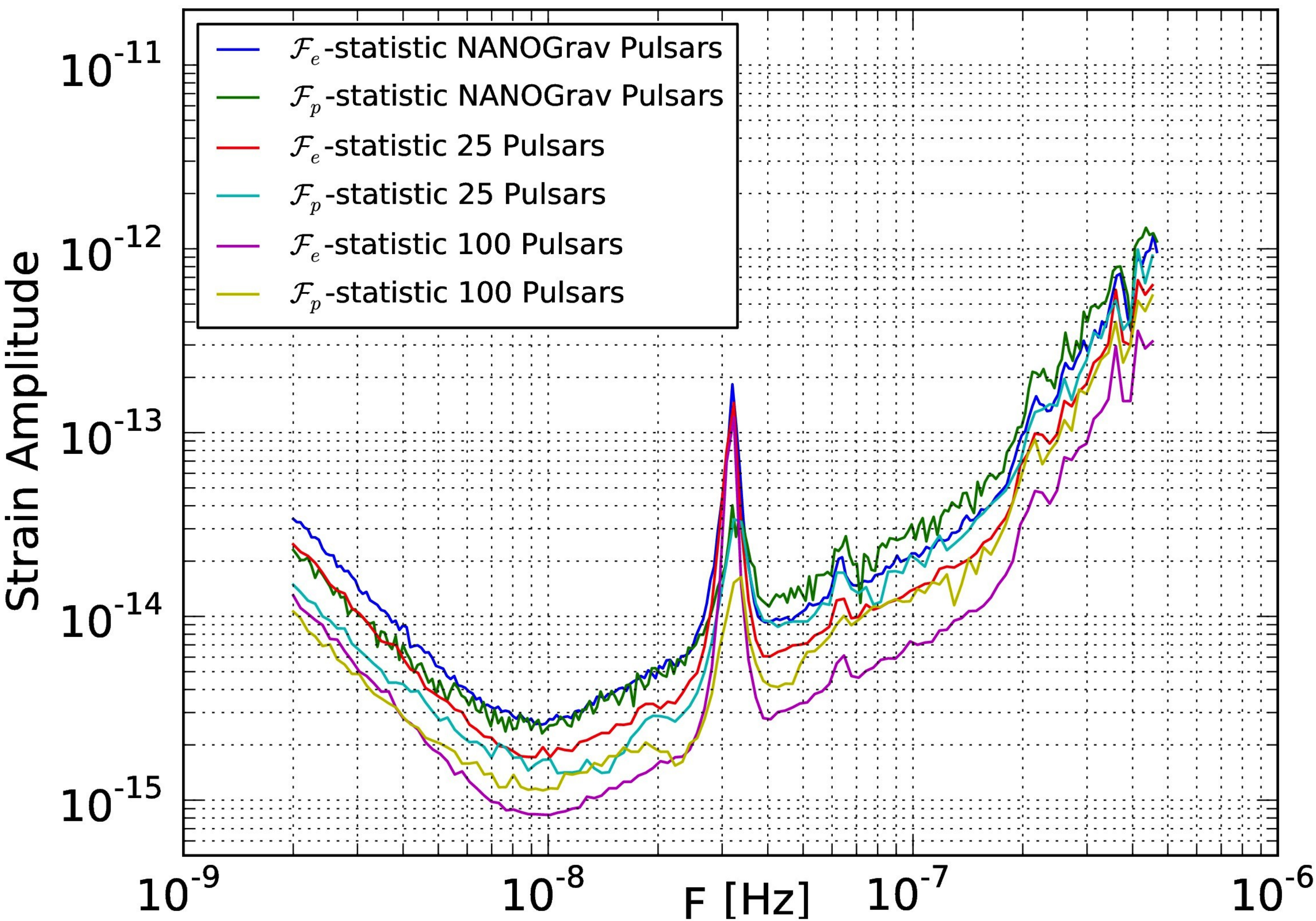
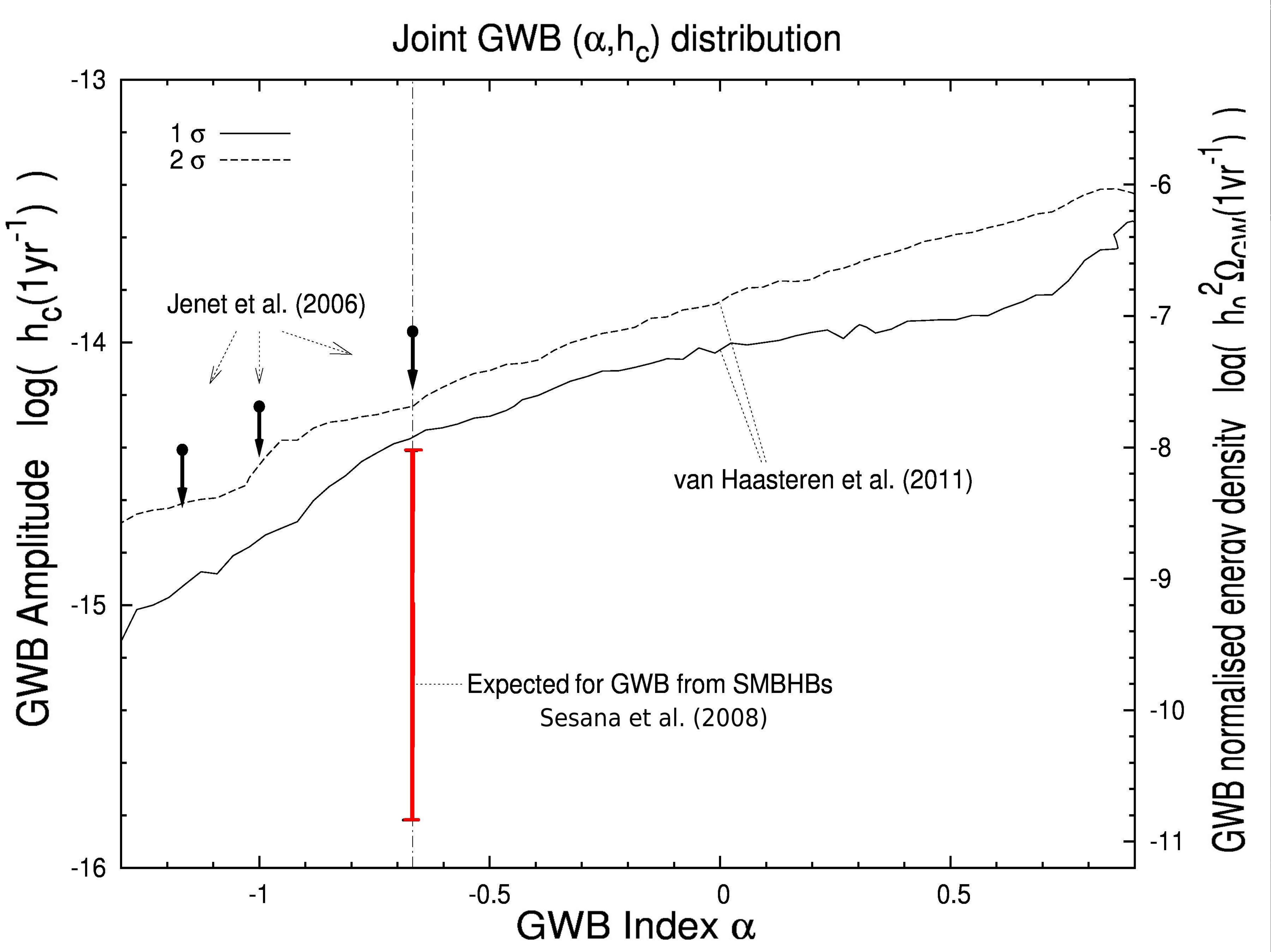
Outline

- Pulsar Timing
- Mock data challenge
- EPTA data analysis library
- EPTA approach to the MDC


Made by David Champion

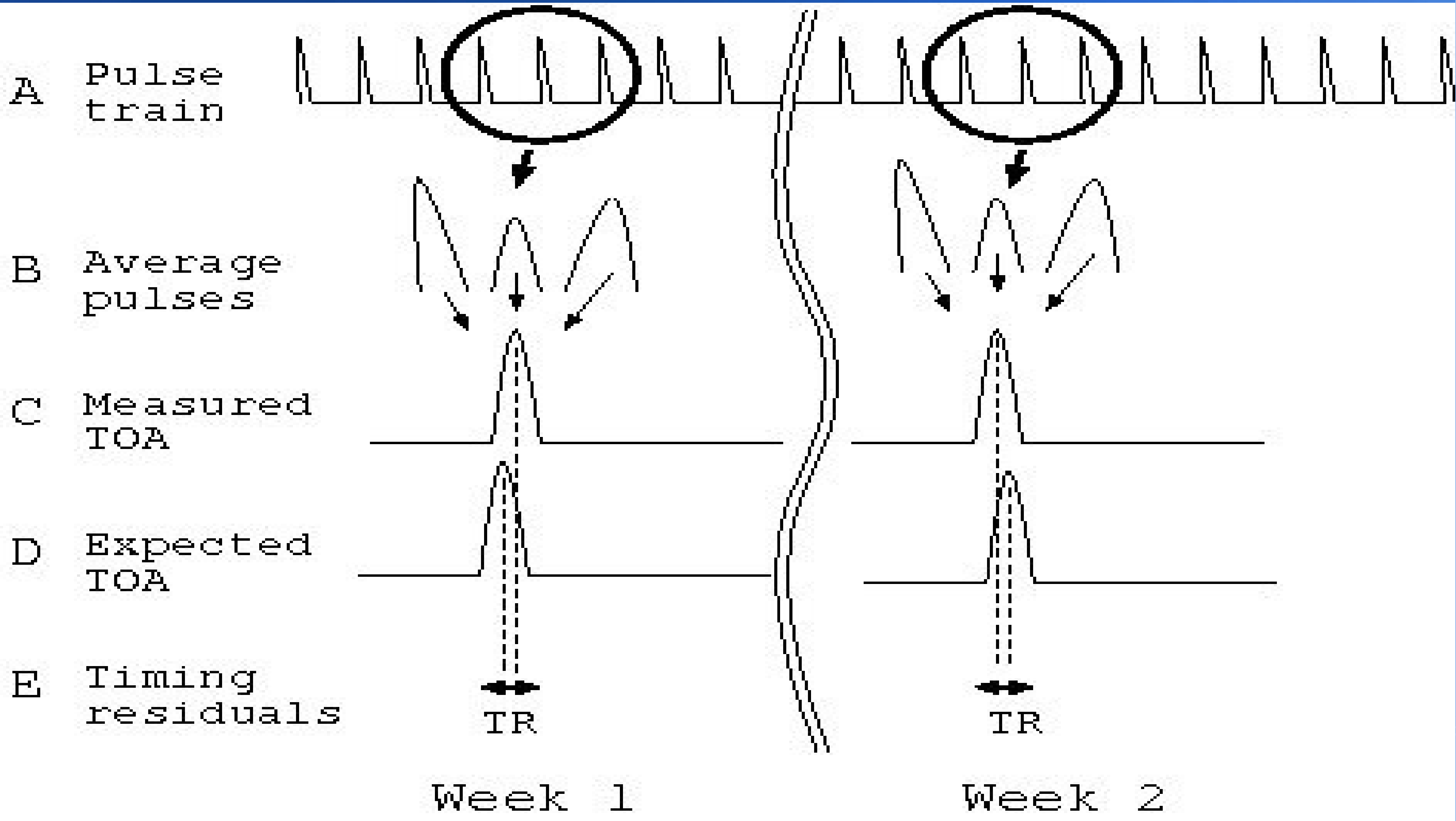


Ellis, Siemens & Creighton (2012)

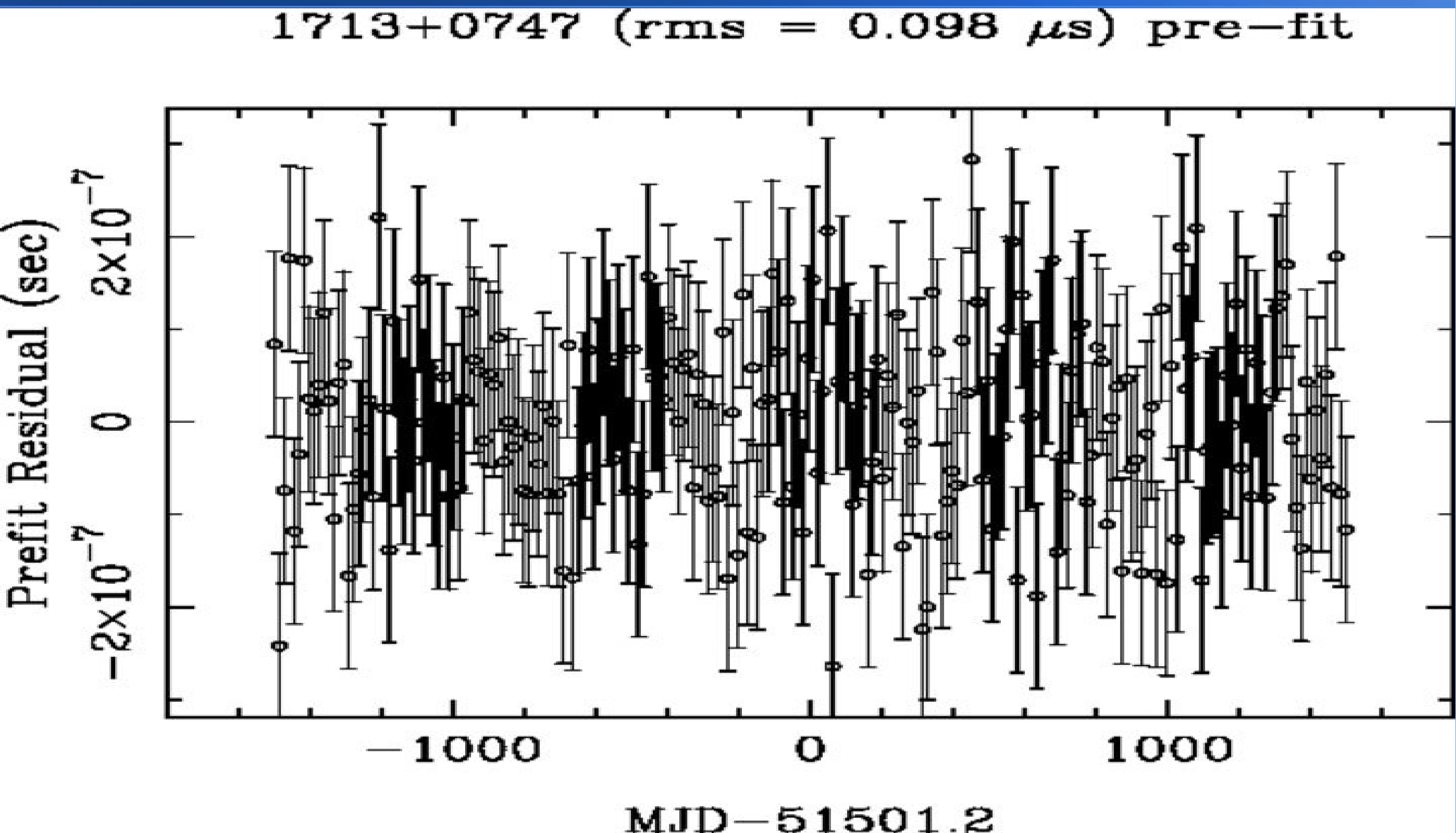


Joint GWB (α,h_c) distribution
1 σ
2 σ
Jenet et al. (2006)
van Haasteren et al. (2011)
Expected for GWB from SMBHBs
Sesana et al. (2008)
GWB Amplitude log(h_c(1yr^-1))
GWB normalised energy density log(h_0^2 Ω_GW(1yr^-1))
GWB Index α
-13
-14
-15
-16
-6
-7
-8
-9
-10
-11
-1
-0.5
0
0.5

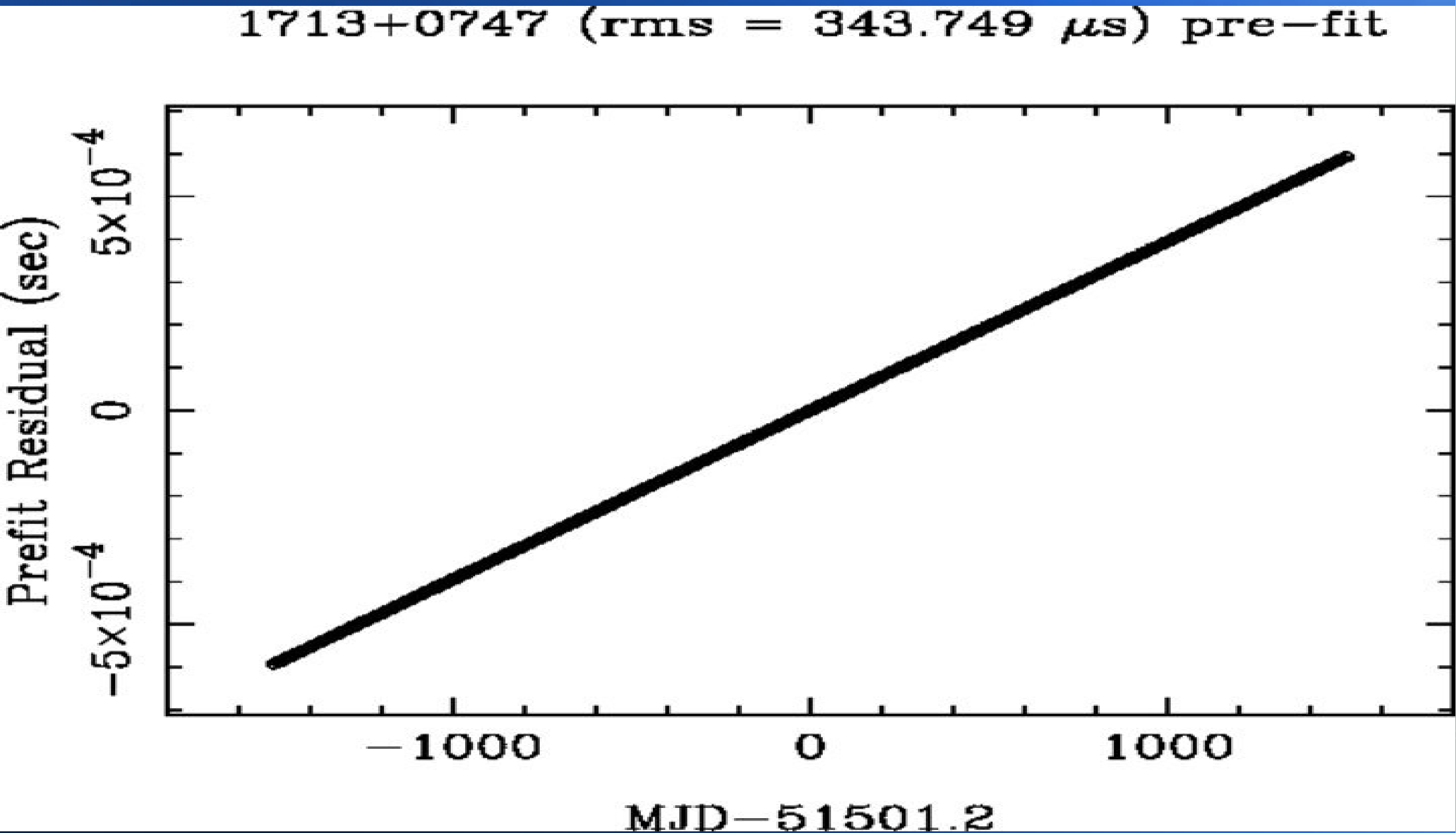
Constructing TOAs



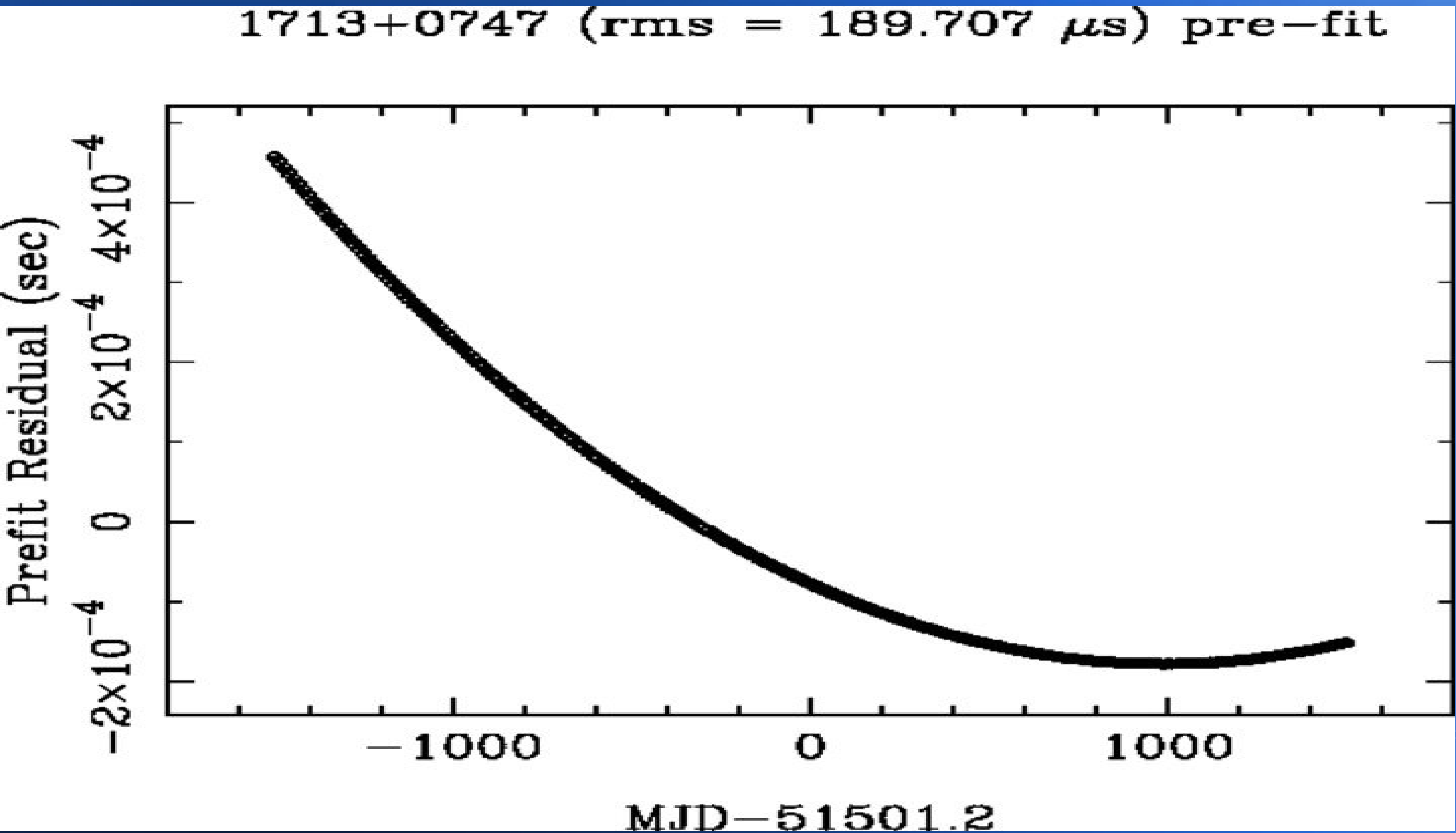
Primary data: timing residuals



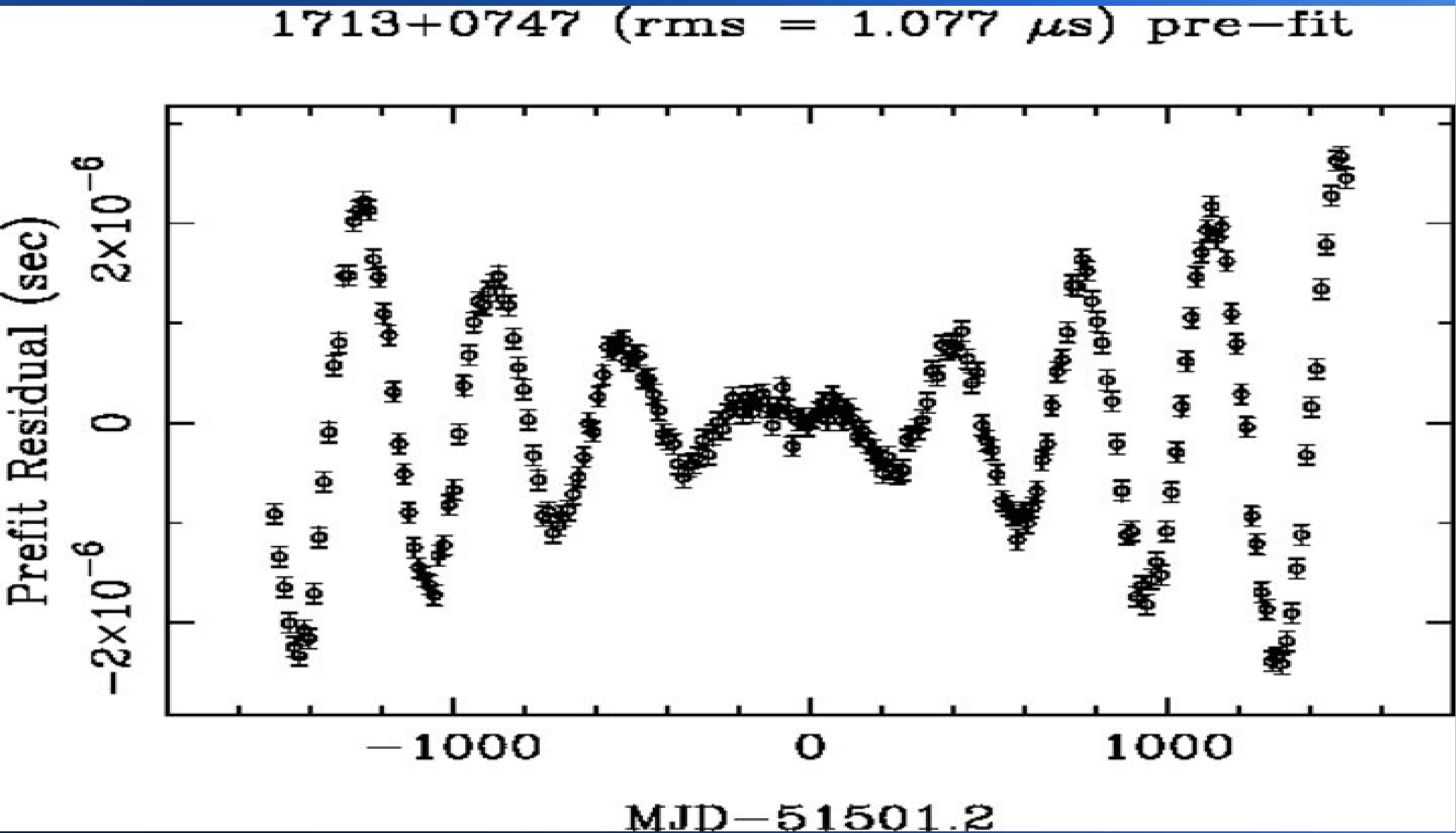
Incorrect pulse period



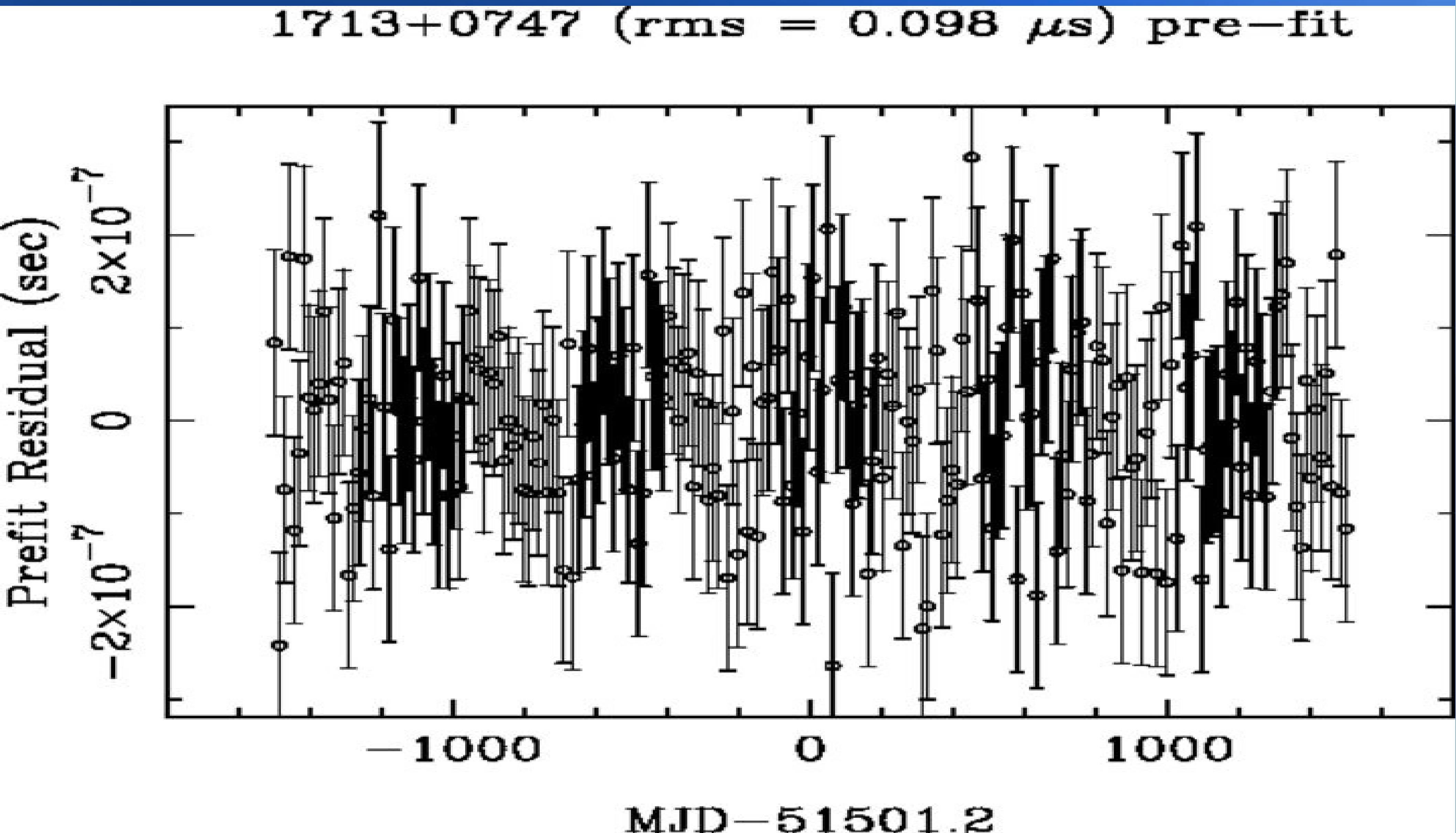
Incorrect period derivative



Incorrect proper motion



White signal



Analysis of timing data

- Non-regular sampling: big gaps in data
- Very low-frequency signals
- Time-variant linear filter applied to all data (fit timing-model parameters)
- Low-frequency timing noise (ill-modelled)

In time-domain most straight forward

First IPTA mock data challenge

(on behalf of K.J. Lee)

- http://www.ipta4gw.org/
- Simple challenge at first, subsequent challenges will be more difficult
- First true comparison of all different data analysis methods.
- All participants are invited as co-authors on the following paper discussing the results.
- PTA data analysis is a developing field. Still much to do, so everyone encouraged to join in the challenge!
- Methods for interferometers may be easily converted to PTA data analysis

First IPTA MDC release

- Data pre-release at 16th Jan, release at 24th Mar 2012.
- Deadline Sepember 28th
- Formal data release is **different** from to the pre-release, due to the feedback from R. van Haasteren, M. Keith, and X. Siemens.

Authors of data challenge (see website):

K.J. Lee, Mike Keith, Rick Jenet

More information

- Deadline for the submission of results will be September 28th, 2012.
- The submission of feedback is via a link in the page (at the bottom, a little bit hard to find) http://www.ipta4gw.org/?page_id=214
- Please take a look, see if it satisfies the requirements, especially you feel to have something extra to report.
- The open data challenge contain signal of each noise component, which can be used to compare your pipeline.

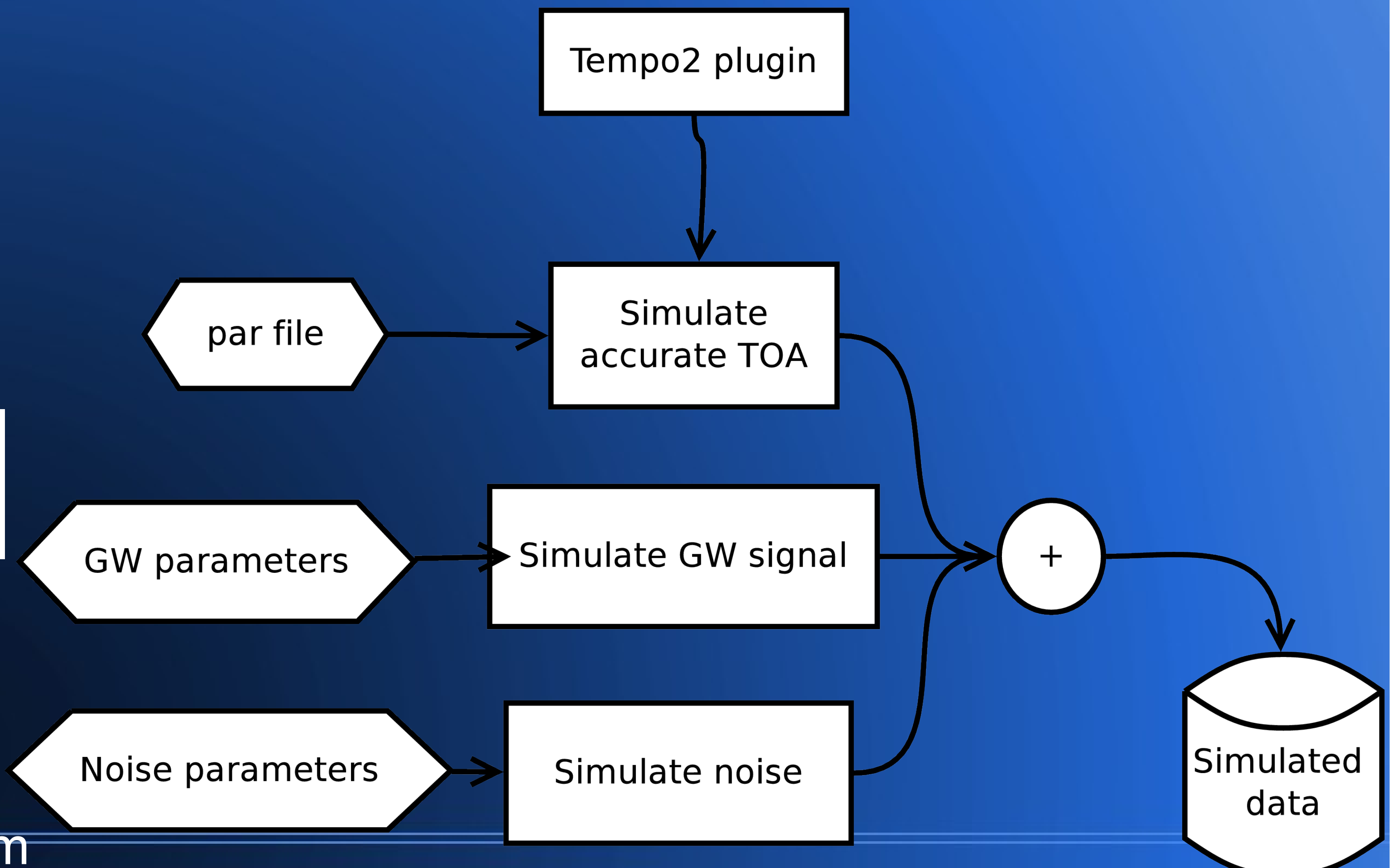
Conversions, code implementation and algorithm

$$h_c(f) = A_c \left(\frac{f}{1\mathrm{yr}} \right)^{-\alpha}$$

GW spectrum

$$P(f) = A f^{-\alpha}$$

Noise spectrum



Submission

Feed back for the results of data analysis

a) Report the value of the characteristic strain spectrum at one year and the power law index Gravitational wave stochastic background or report the uplimit

c) Any other gravitational wave signals. (e.g. continuous waves or bursts), describe them. Also could report on the properties of the noise (i.e. white, red, amplitude, etc...)

Algorithms

a) Reference for the algorithms.

b) Computational cost for the algorithm

c) Major difficulties in analyzing data

Other feedback

General comments on the data challenge and suggestions for improving the next data challenge

This first challenge may not have the power to differentiate the algorithms. Feedback will be important for following challenges

EPTA data analysis library

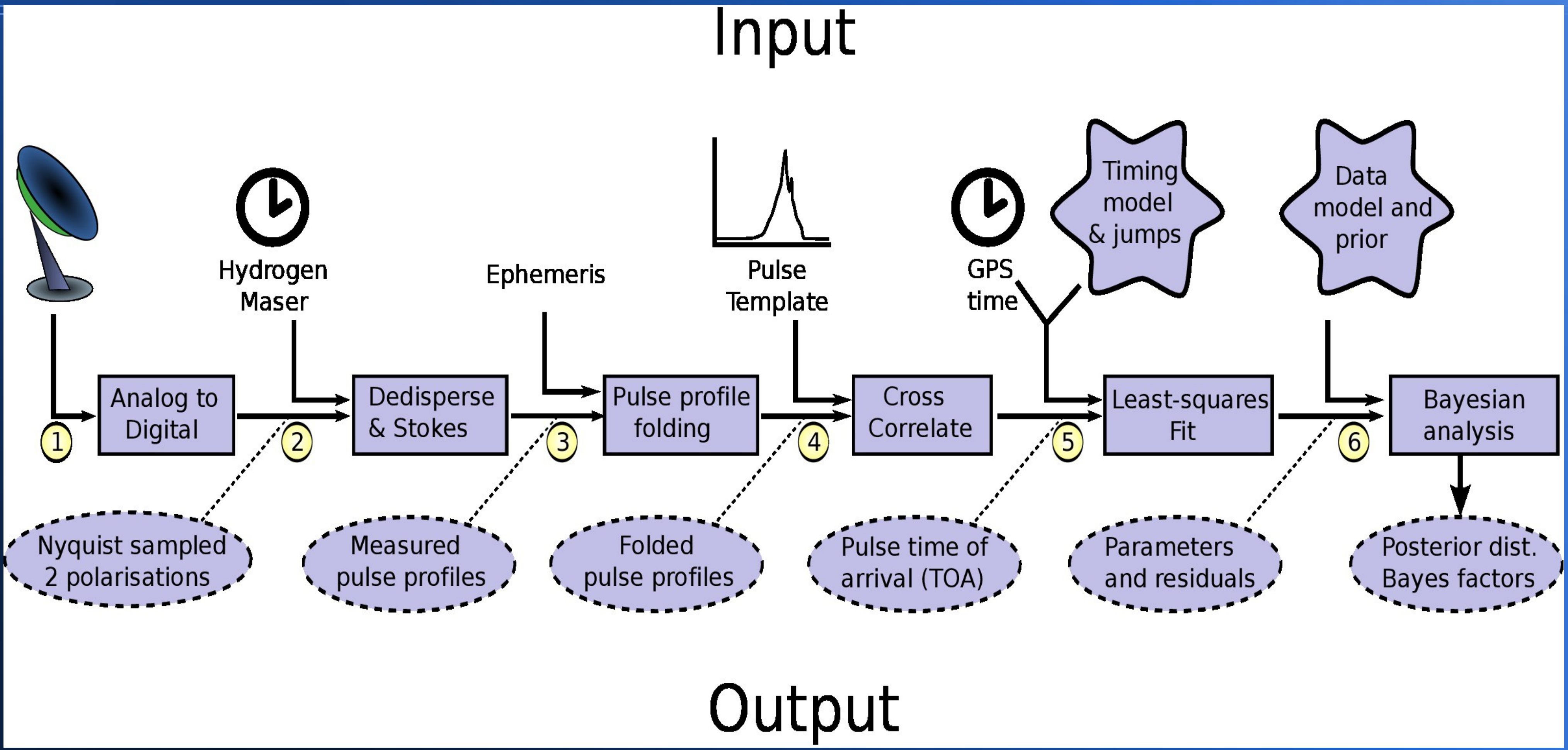
Currently no 'standard' codebase to do PTA data analysis. Project members:

K.J. Lee *Chiara Mingarelli* *Rutger van Haasteren*

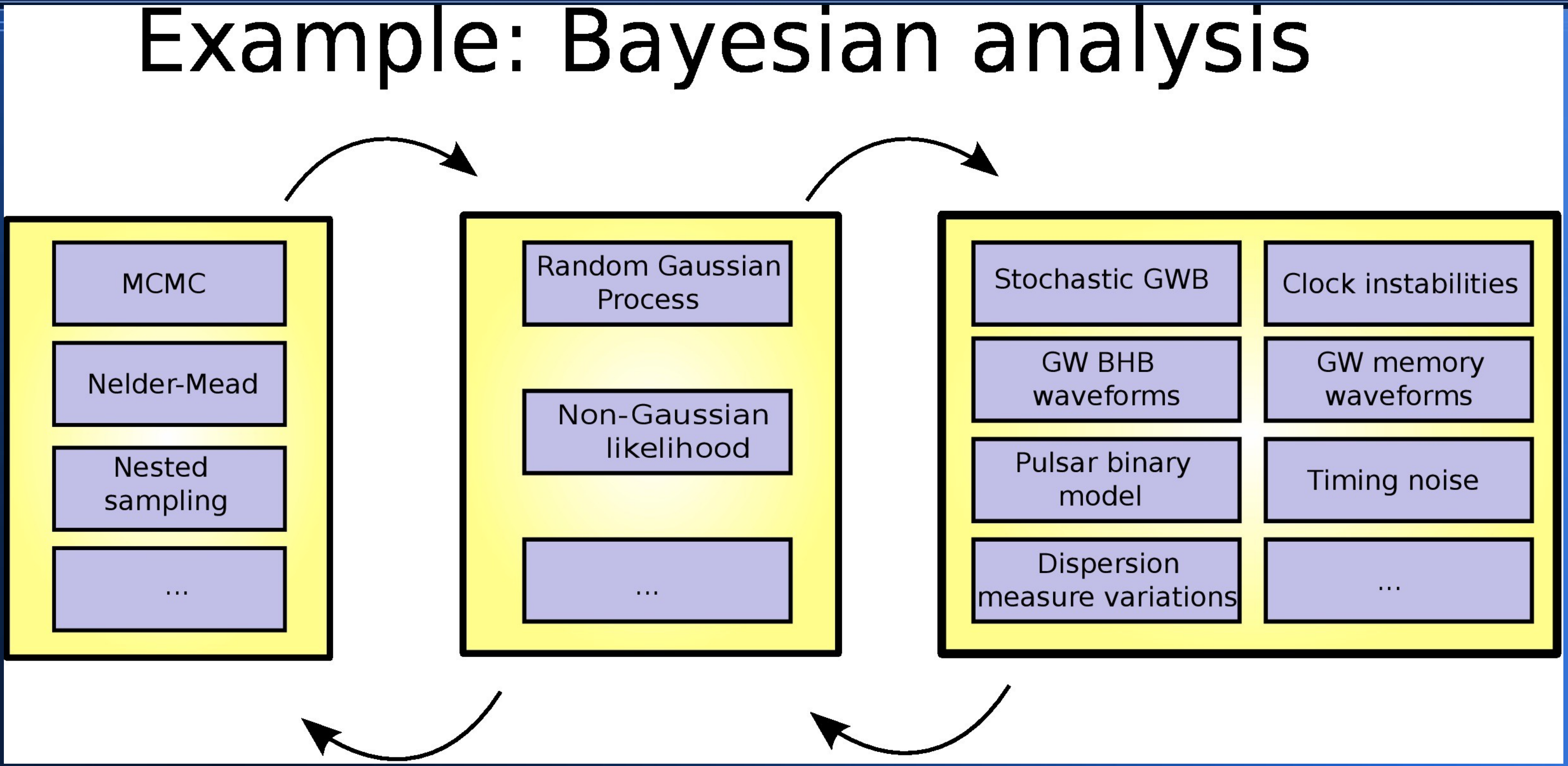
Antoine Lassus *Alberto Vecchio*

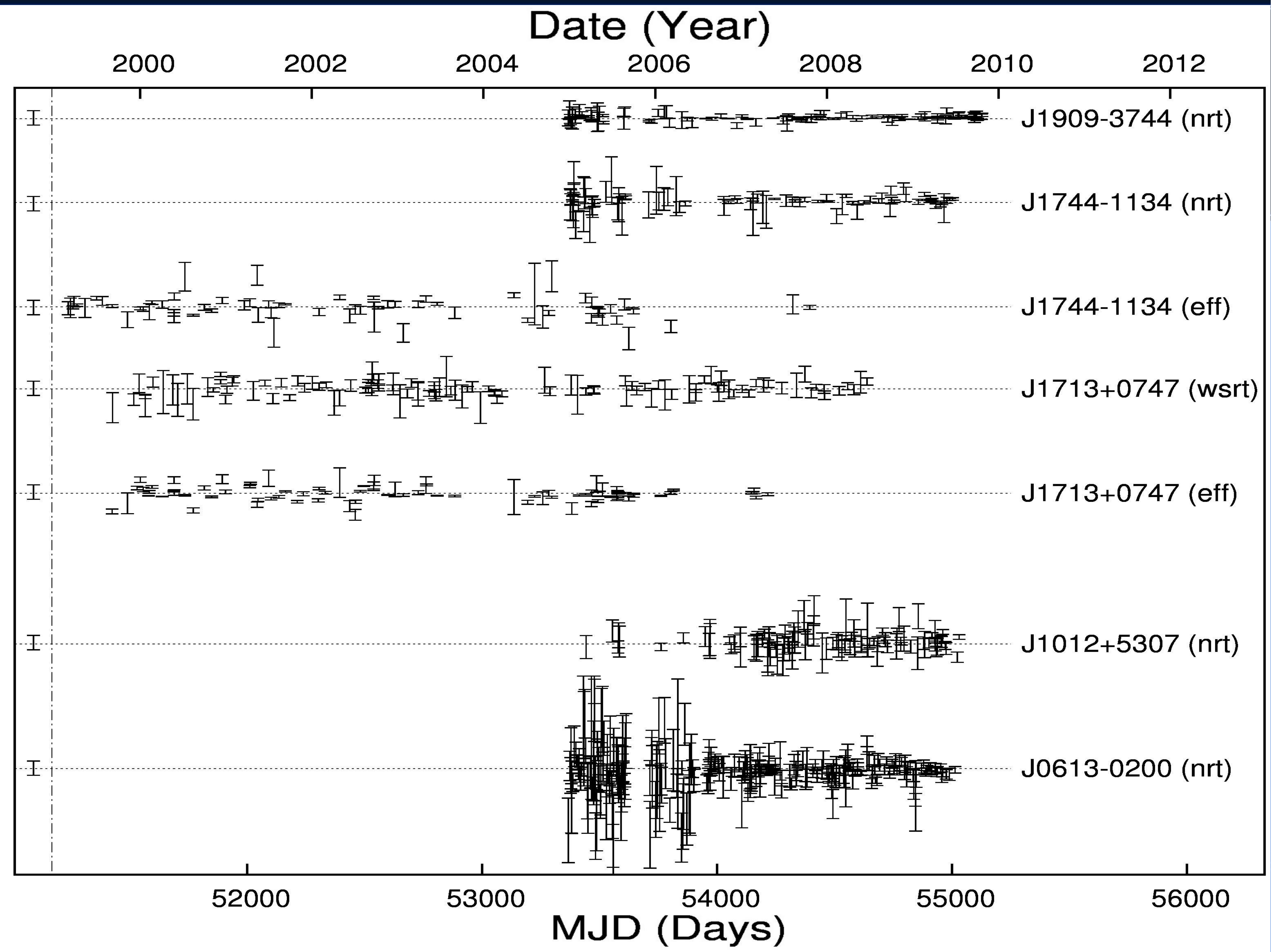
- Python library, modular in design (core stuff in C)
- Well-designed interface
- Use standard well-debugged libraries
- Unit tests
- New file format which keeps track of data transformations
- Allow fast development of new, realistic analysis methods
- ...

EPTA data analysis library

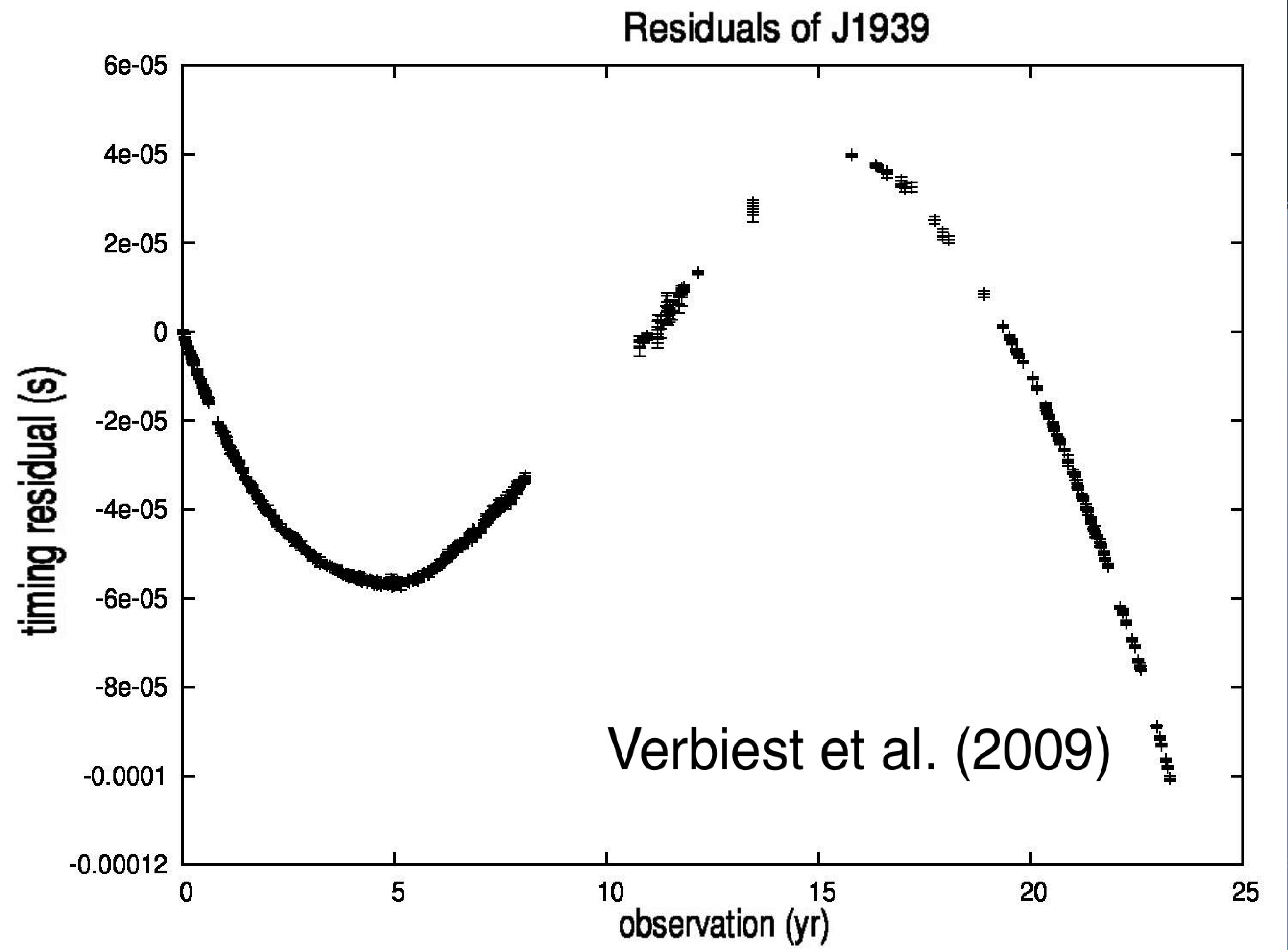


EPTA data analysis library





Date (Year)
2000
2002
2004
2006
2008
2010
2012
J1909-3744 (nrt)
J1744-1134 (nrt)
J1744-1134 (eff)
J1713+0747 (wsrt)
J1713+0747 (eff)
J1012+5307 (nrt)
J0613-0200 (nrt)
52000
53000
54000
55000
56000
MJD (Days)


Residuals of J1939
timing residual (s)
observation (yr)
6e-05
4e-05
2e-05
0
-2e-05
-4e-05
-6e-05
-8e-05
-0.0001
-0.00012
0
5
10
15
20
25
Verbiest et al. (2009)

Analysing mock data

The van Haasteren et al. (2011) approach to the MDC:

Deterministic (+/- 10 per pulsar):

- Position, proper motion, tempo2 binary model, ephemeris.. Email me if you want to know how to get tempo2 waveforms easily!

Noise (4 per pulsar):

- Error bars, red timing noise (power-law PSD)

GWB signal (2 total):

- Isotropic, correlated gravitational-wave background (power-law PSD)

Summary

- MDC deadline is September 28th.
- Data not too different from interferometers. Please try your techniques on the MDC: everyone invited to join!
- Very irregular sampling and time-varying linear filter
- EPTA will provide a data analysis library to aid this type of analysis. First application will be Bayesian analysis of MDC
- Mostly Python, with core stuff in C.
- Use new methods on real data with ease. Modular design