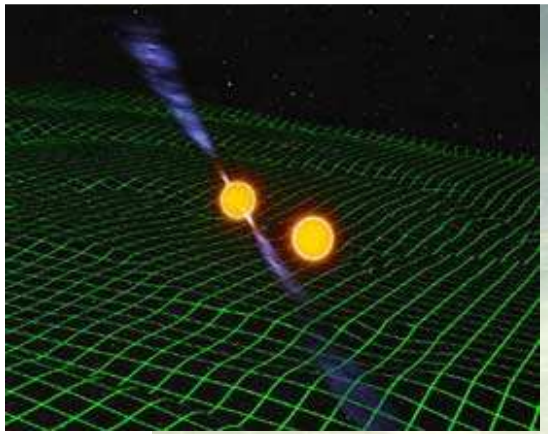

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Developing a pulsar time scale

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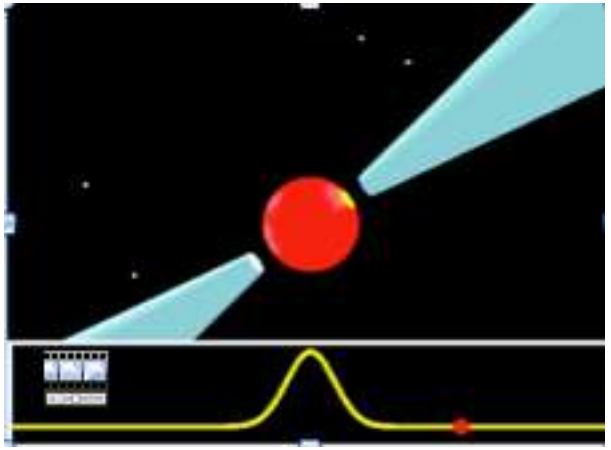
Overview

Collaborators: W. Coles (UCSD), □□ □Chen Ding) (NTSC), R. Manchester (CSIRO)

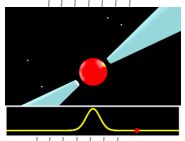
- Overview of pulsar timing
- What will irregularities in a terrestrial time standard look like in our data?
- Developing a pulsar time scale
- Initial results

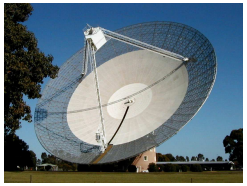


Credit: M. Kramer

Pulsar timing

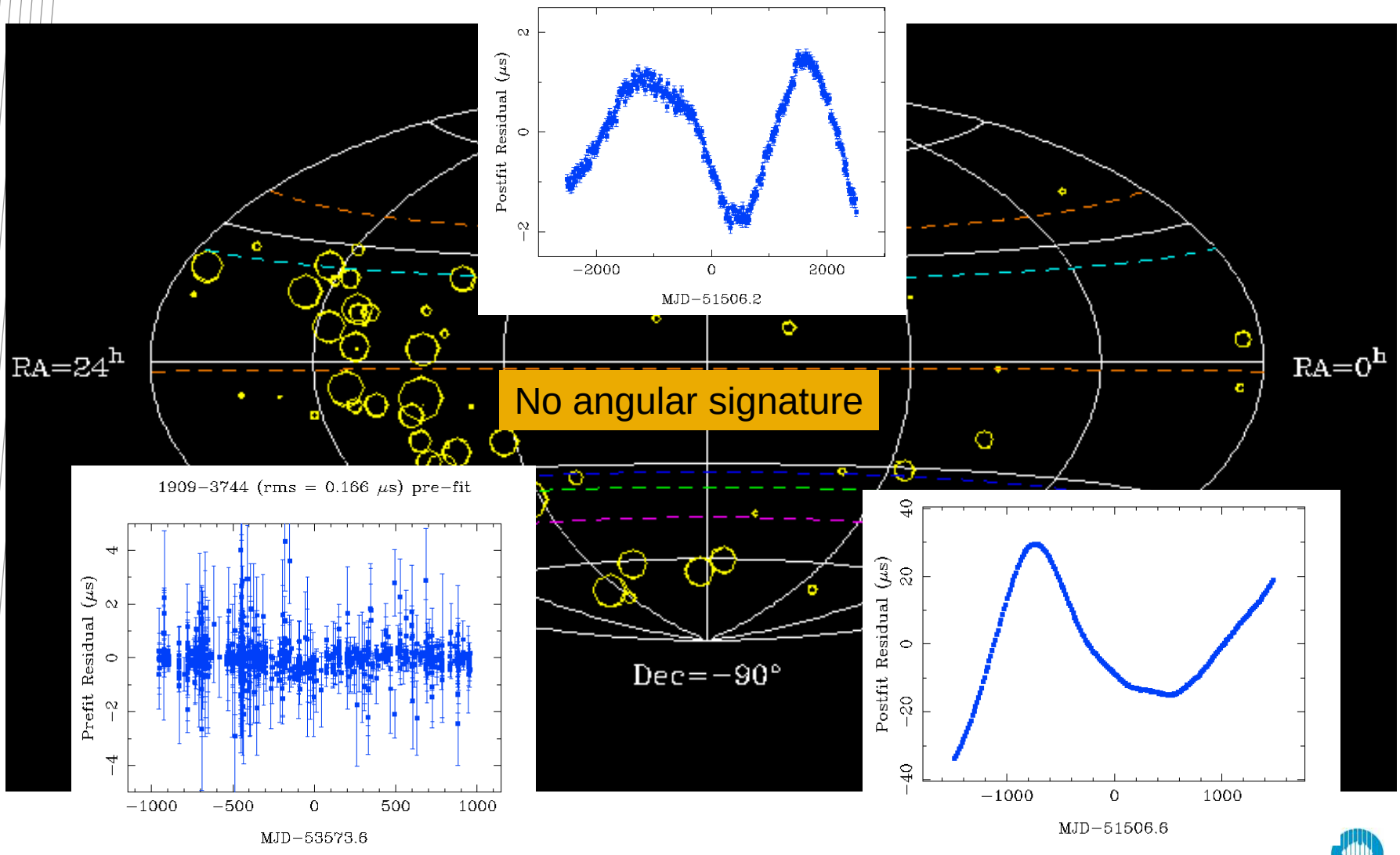
Slide from D. Champion





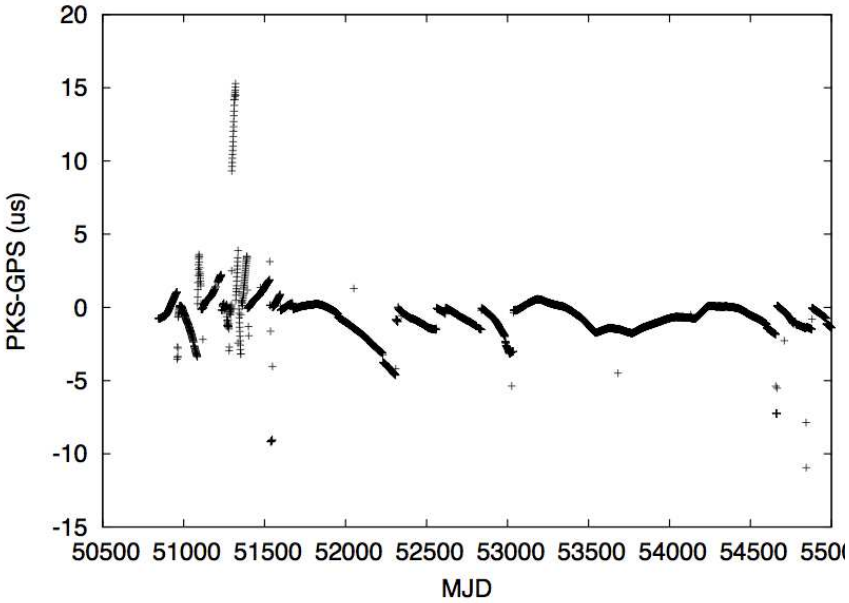
Timing residuals = unmodelled physical effects

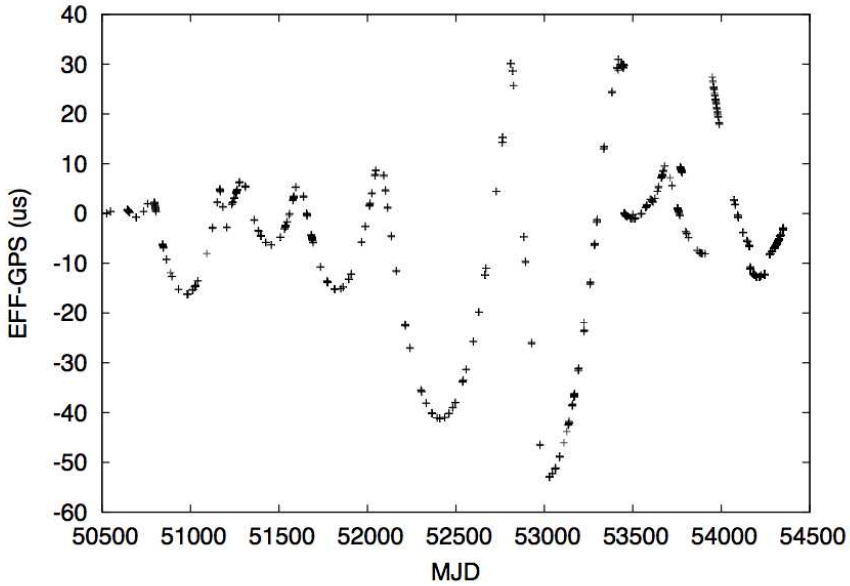
Spin-down irregularities



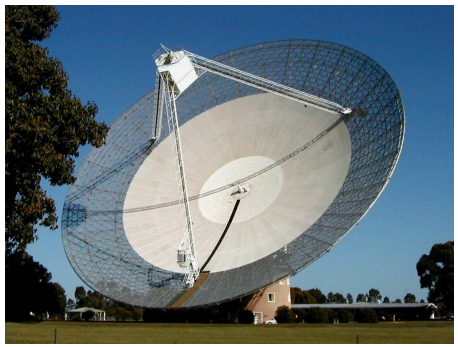
The observatory clock

- Parkes hydrogen maser -> GPS -> TT(TAI)

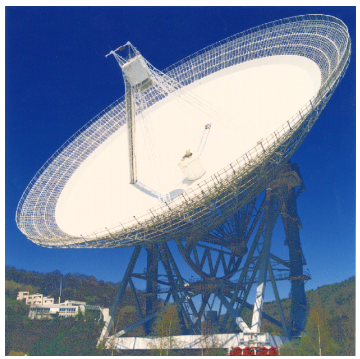




- Parkes-GPS

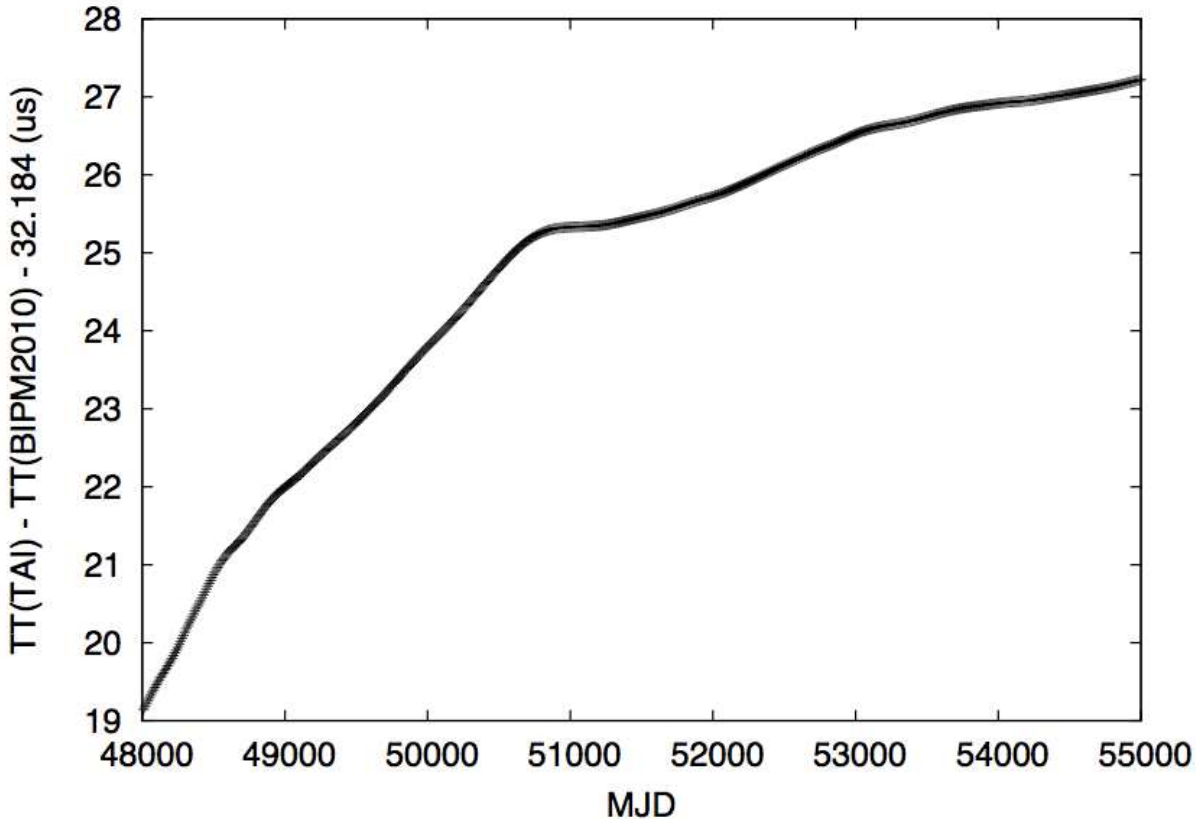


- Effelsberg-GPS

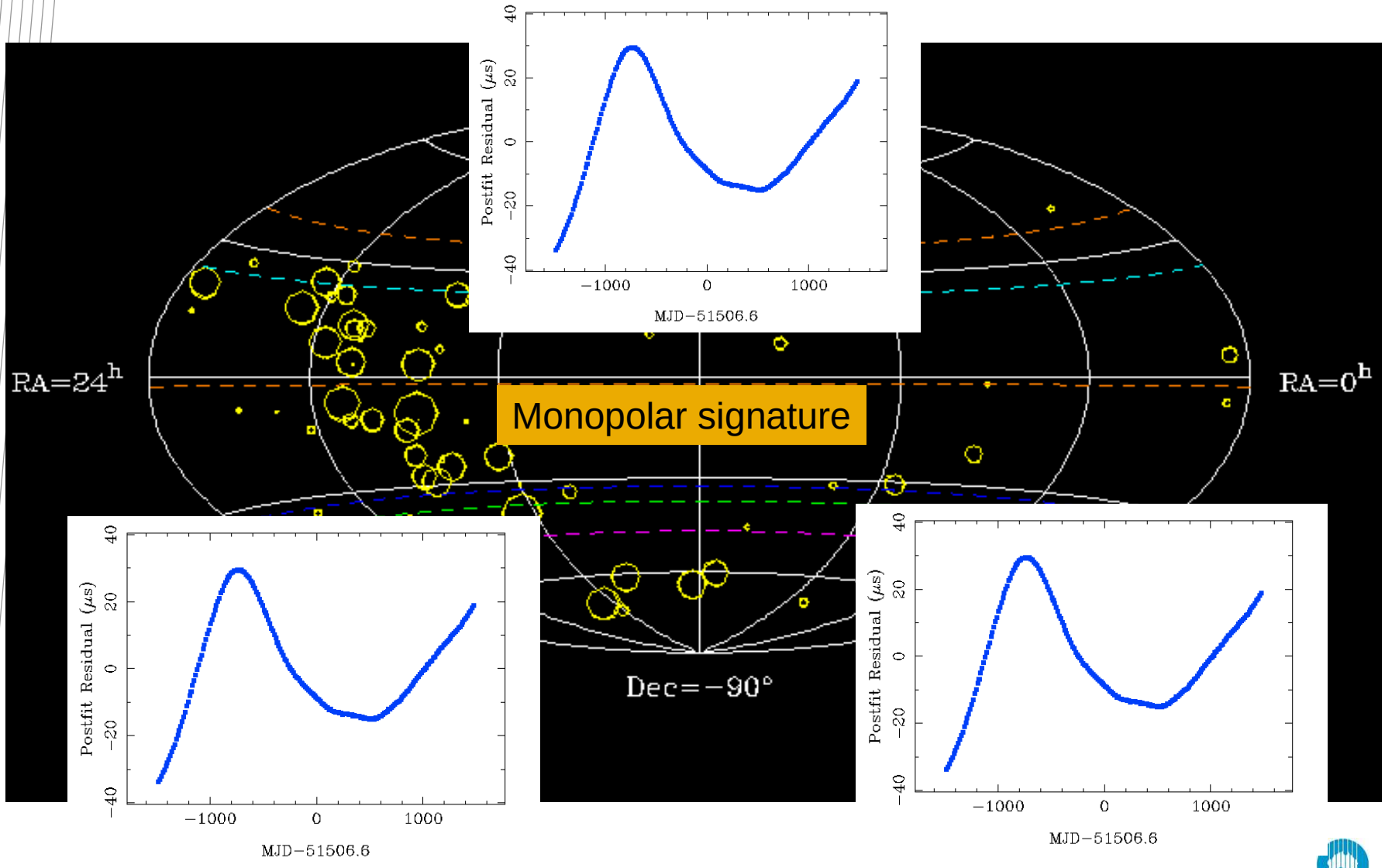


Time standards

- Most pulsar observations referred to TT(TAI)
- Post-corrected time standard TT(BIPM2010) can be used



Terrestrial time standard irregularities



Basic idea

- Irregularities in terrestrial time standards will show up as residuals that are the same for different pulsars
- Can find this correlated signal to:
  - identify any errors in the terrestrial time standards
  - correct for any such errors

What happens if irregularities exist in an Earth-based time-scale? TT(TAI)-TT(BIPM2010)

Different data spans

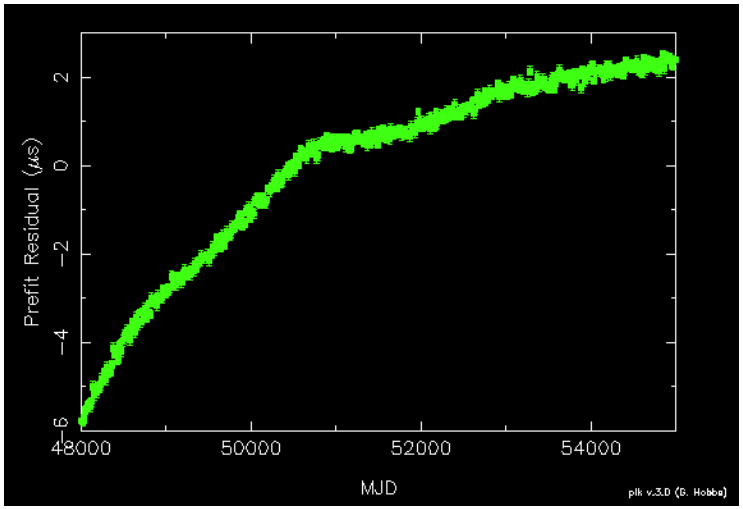
Timing model fits

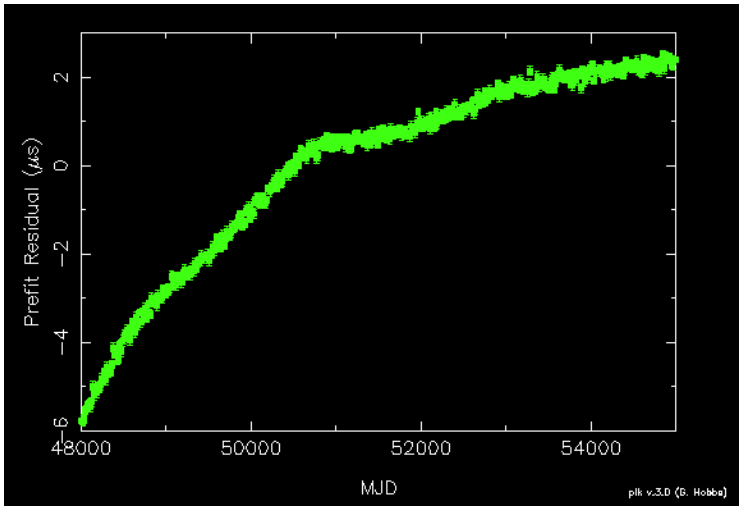
Different sampling

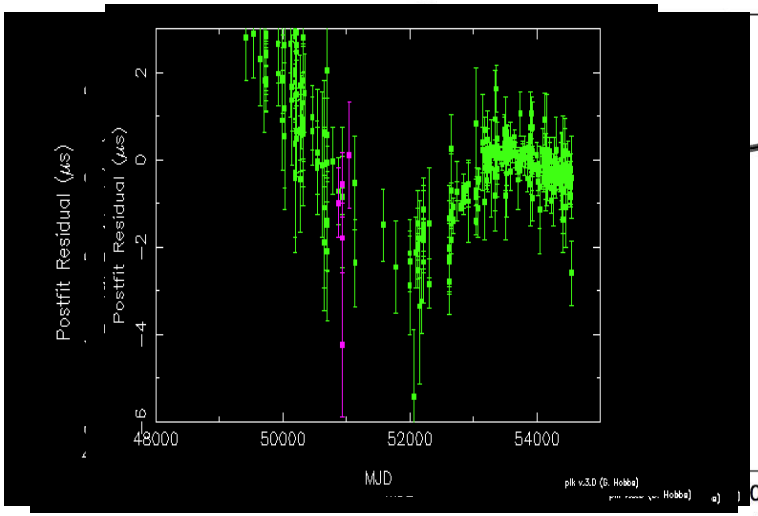
Varying error bars

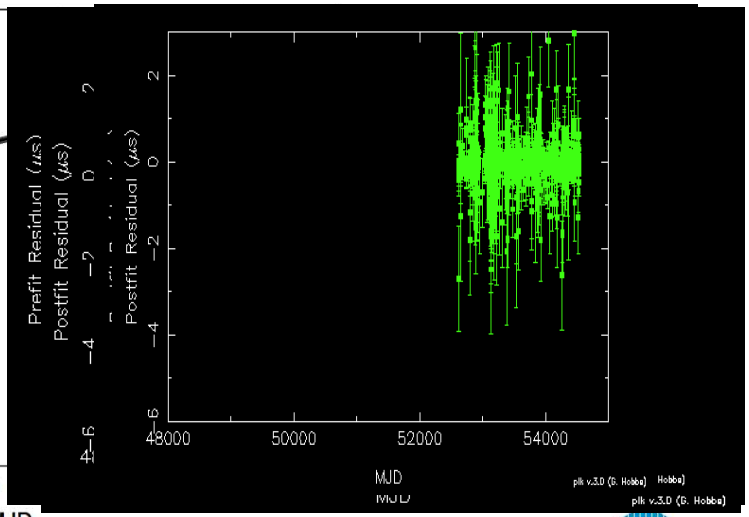
Unexplained timing noise

Note: can never recover a linear (or quadratic) drift









Technique

- Define clock function to be simple Fourier expansion:

$$f(t) = \sum A_k \cos(k\omega_0 t) + B_k \sin(k\omega_0 t)$$

(note: can use other functional forms if needed)

- Carry out a standard least-squares fit of pulsar timing model parameters + f(t) as usual, except:
- simultaneously fit to multiple pulsars
- use measurement of the covariance in the residuals for a given pulsar as part of the least-squares-fit fit (to deal with timing noise)

$$\vec{P}_{est} = (M^T C^{-1} M)^{-1} M^T C^{-1} \vec{R}$$

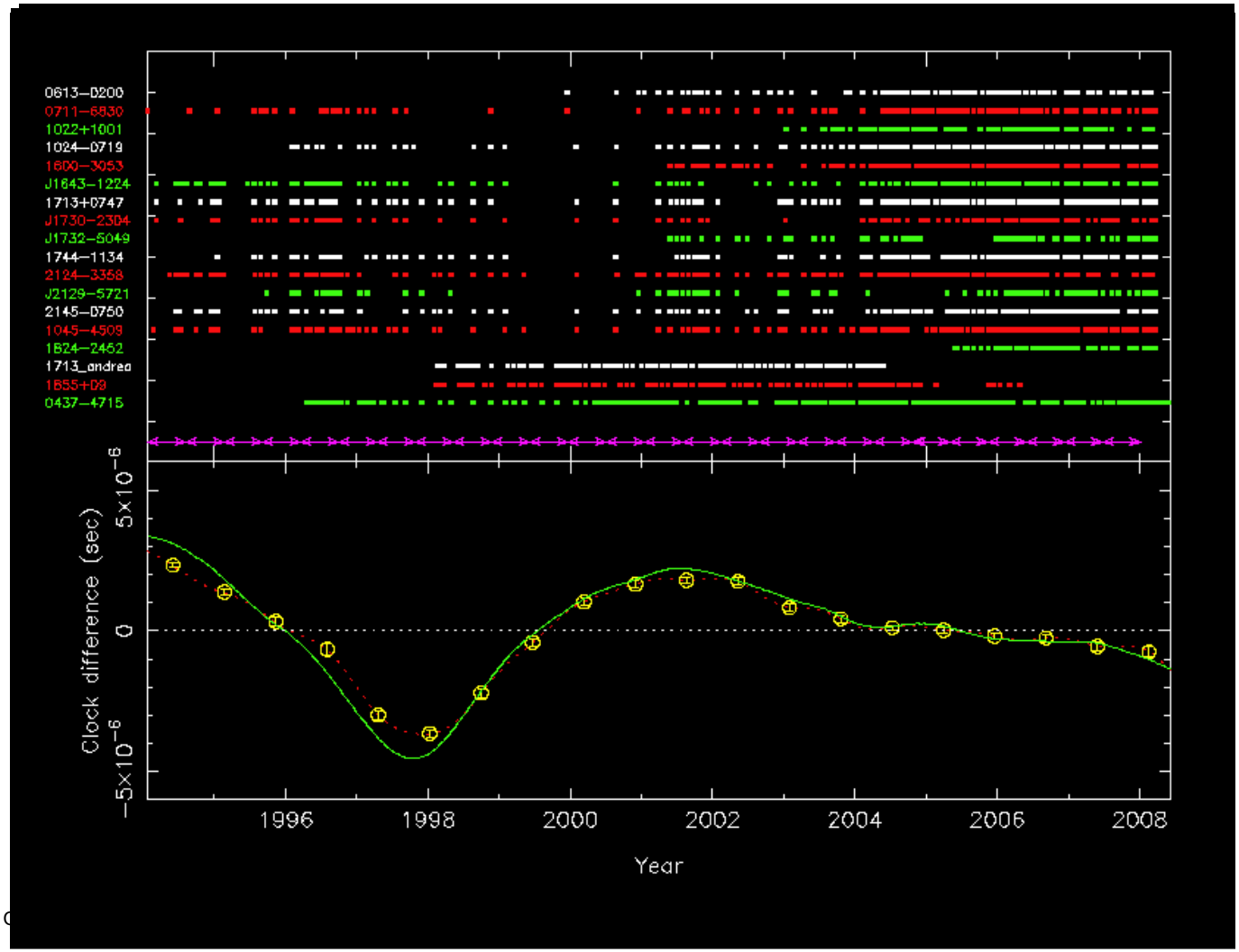
Timing residuals

Covariance matrix of the residuals

Pulsar timing model

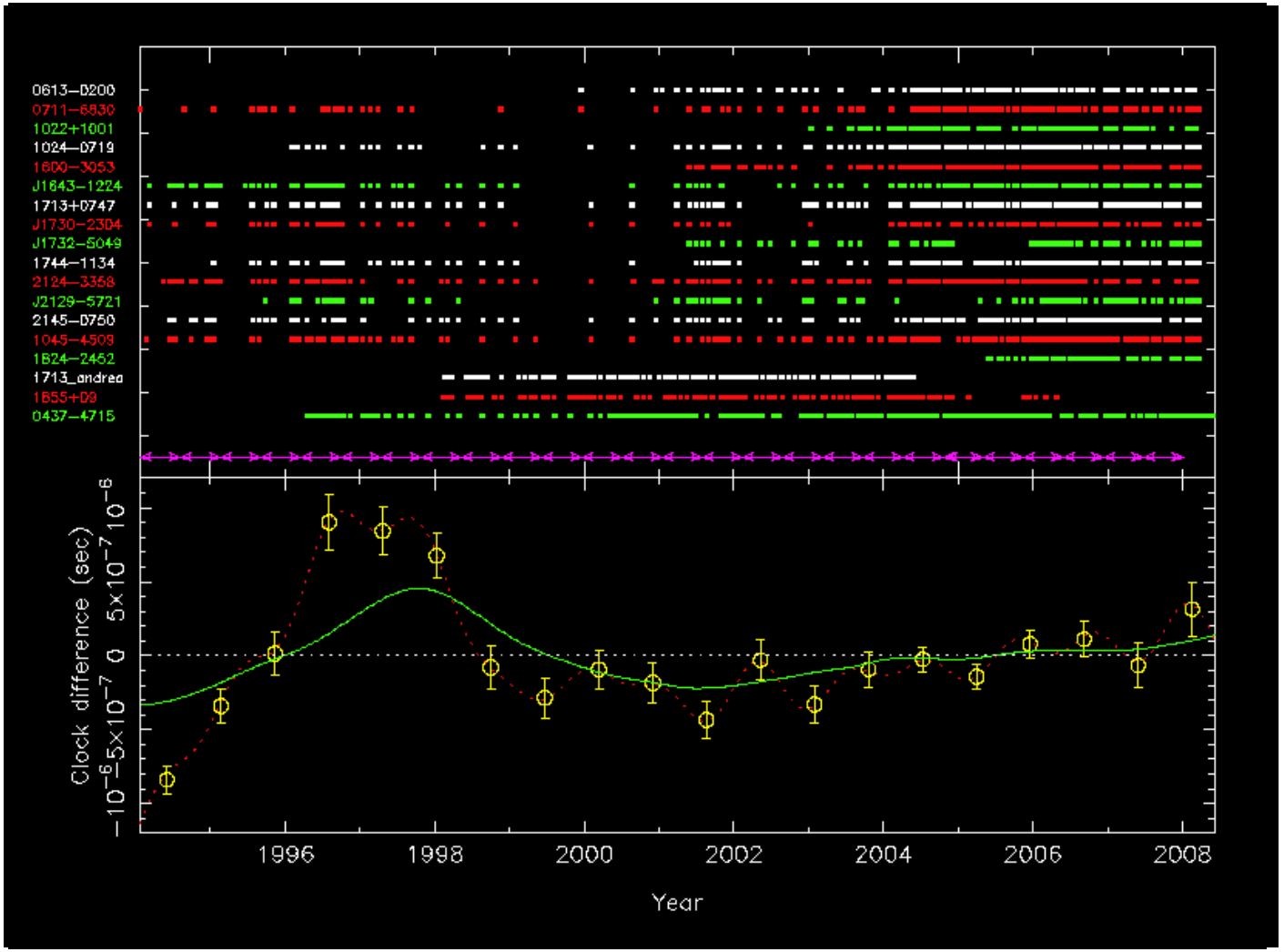
Testing: can we recover TAI-TT(BIPM2010) x 10?

- Simulate 10x expected TAI-TT(BIPM2010) in real pulsar data



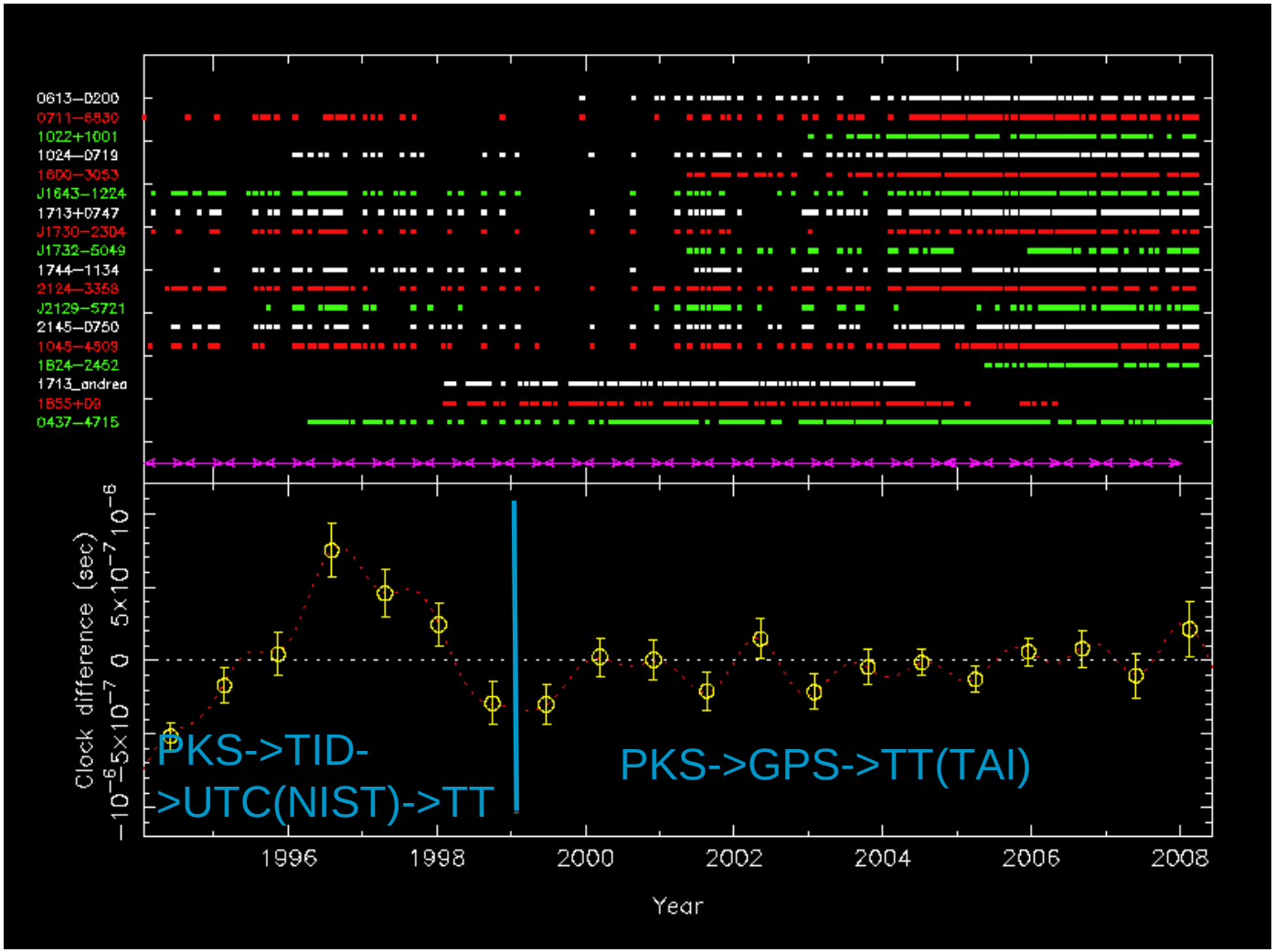
5µs

Final result (no simulations)
EPT-TT(TAI) and TT(BIPM2010)-TT(TAI)



1μs

EPT-BIPM(2010) – time transfer?



Future improvements

- Adding more data sets
- Adding more recent data
- Producing σ_y/σ_z stability plots
- Compare results from different observatories to distinguish between time transfer errors from TT(BIPM2010) errors
- Correct the pulsar timing residuals using EPT

Summary

- Can recover recent deviations between TT(BIPM2010) and TT(TAI) using pulsar observations
- Have significant deviation from TT(BIPM2010) prior to the year 1999
- Can not (currently) distinguish between errors in TT(BIPM2010) and errors in the time transfer from the Parkes observatory
- New data sets should significantly improve the results
- New pulsar discoveries and improved observing techniques are significantly improving the precision with which pulsars can be timed.
- Pulsars may be able to provide confirmation/addition to Earth-based timestandards on timescales of years and decades.

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