PPTA

Gravitational waves from binary supermassive black holes missing in pulsar observations

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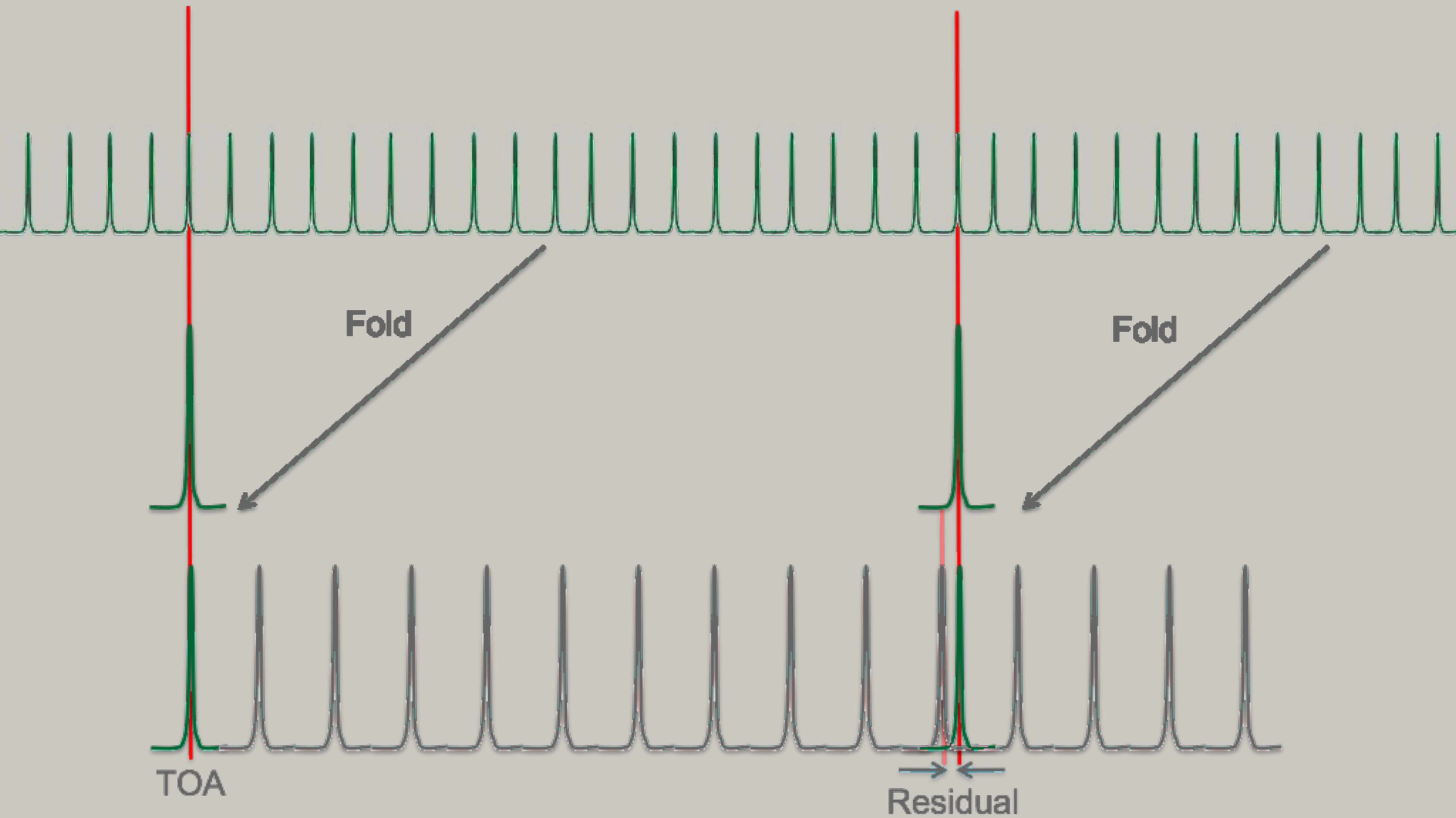
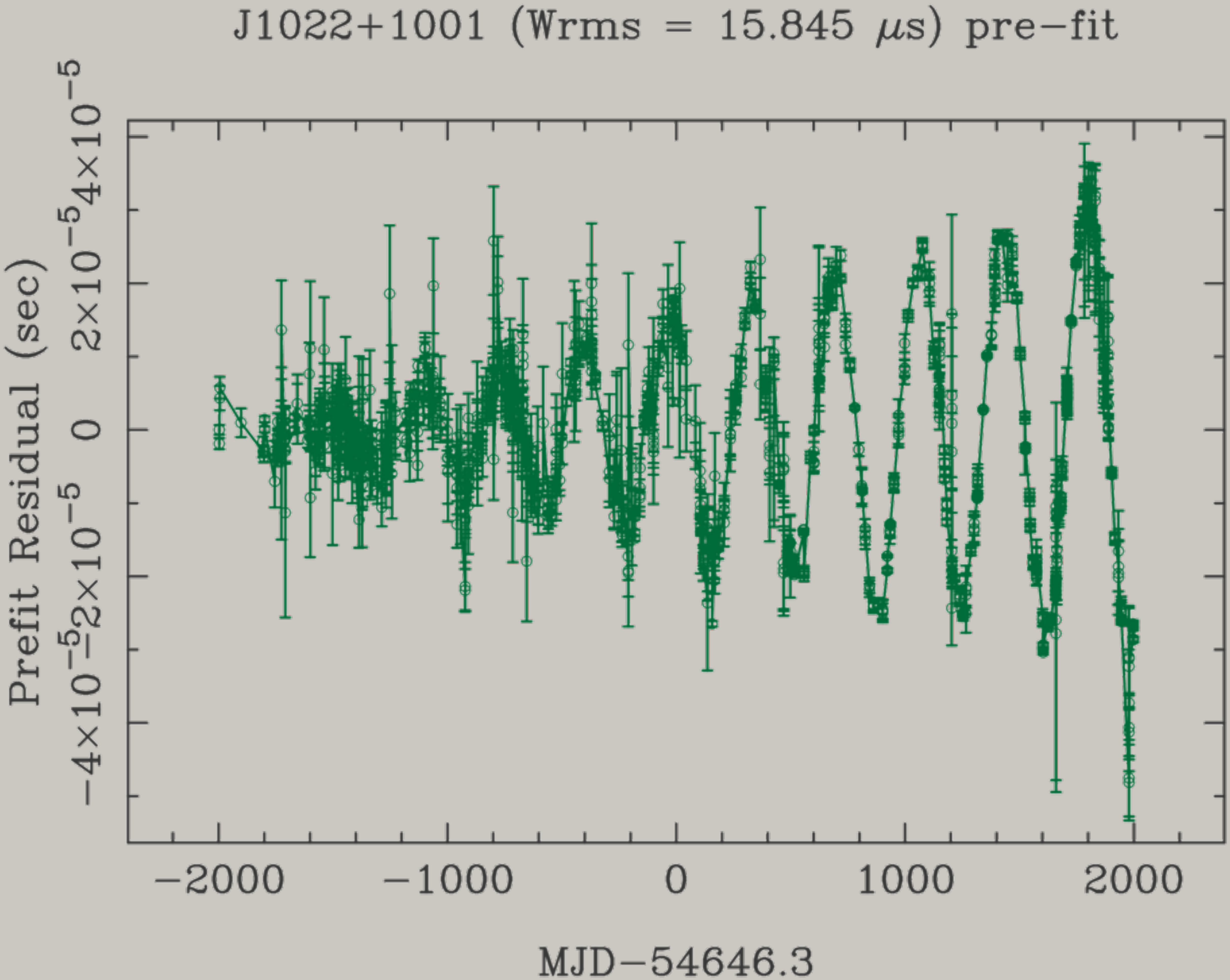
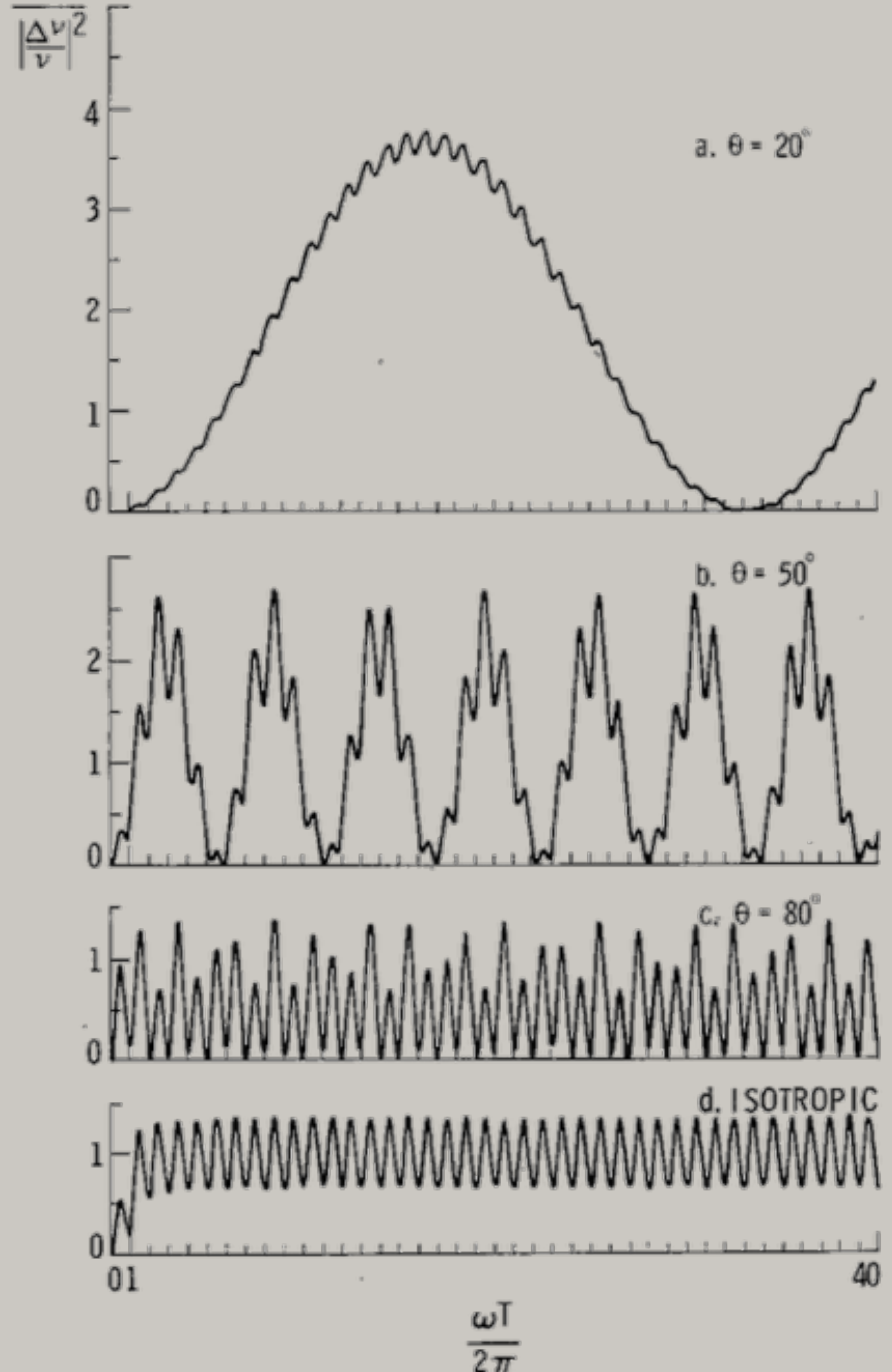
slide from D. Champion




J1022+1001 (Wrms = 15.845 μs) pre−fit
Prefit Residual (sec)
−4×10^−5
−2×10^−5
0
2×10^−5
4×10^−5
−2000
−1000
0
1000
2000
MJD−54646.3



Credit: Estabrook & Wahlquist 1975

Figure 2 - Spectral response to plane waves incident at: (a) θ = 20°; (b) θ = 50°; (c) θ = 80°; or (d) isotropically.

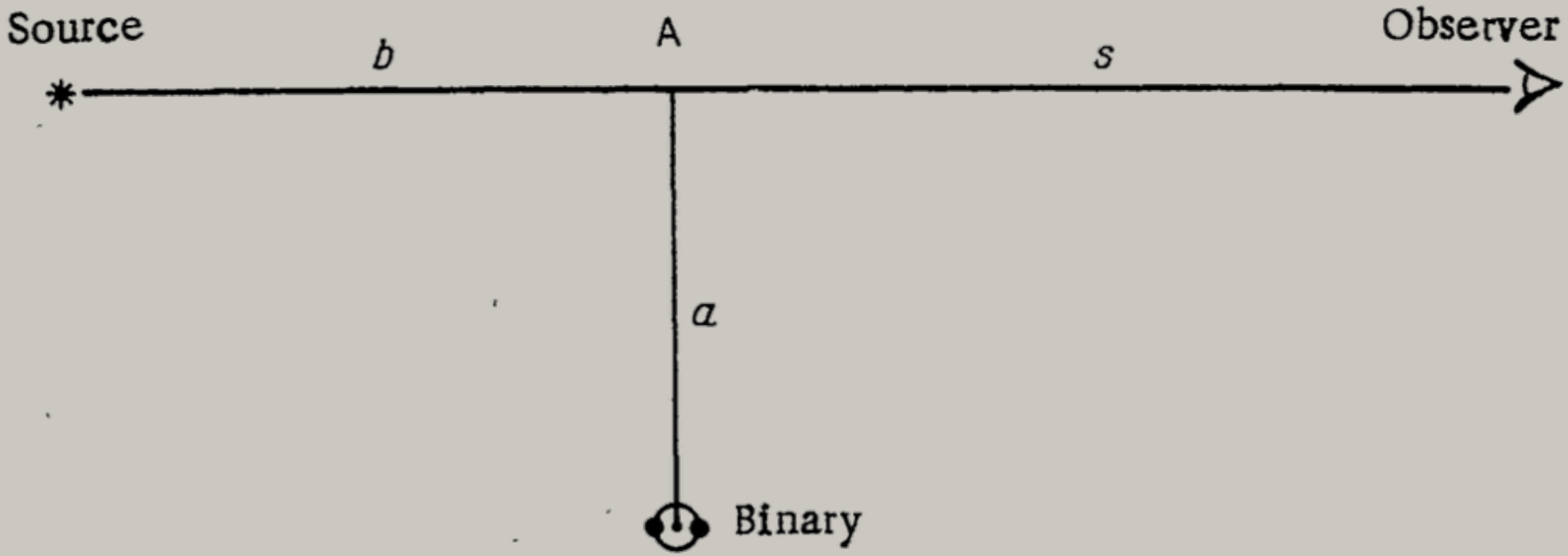


FIG. 1. Relative arrangement of the source of electromagnetic pulses, the observer, and the binary star.

Clearly the detection of gravitational waves [...] still lies well outside the realm of possible.

Credit: Sazhin 1978

PULSAR TIMING MEASUREMENTS AND THE SEARCH FOR GRAVITATIONAL WAVES

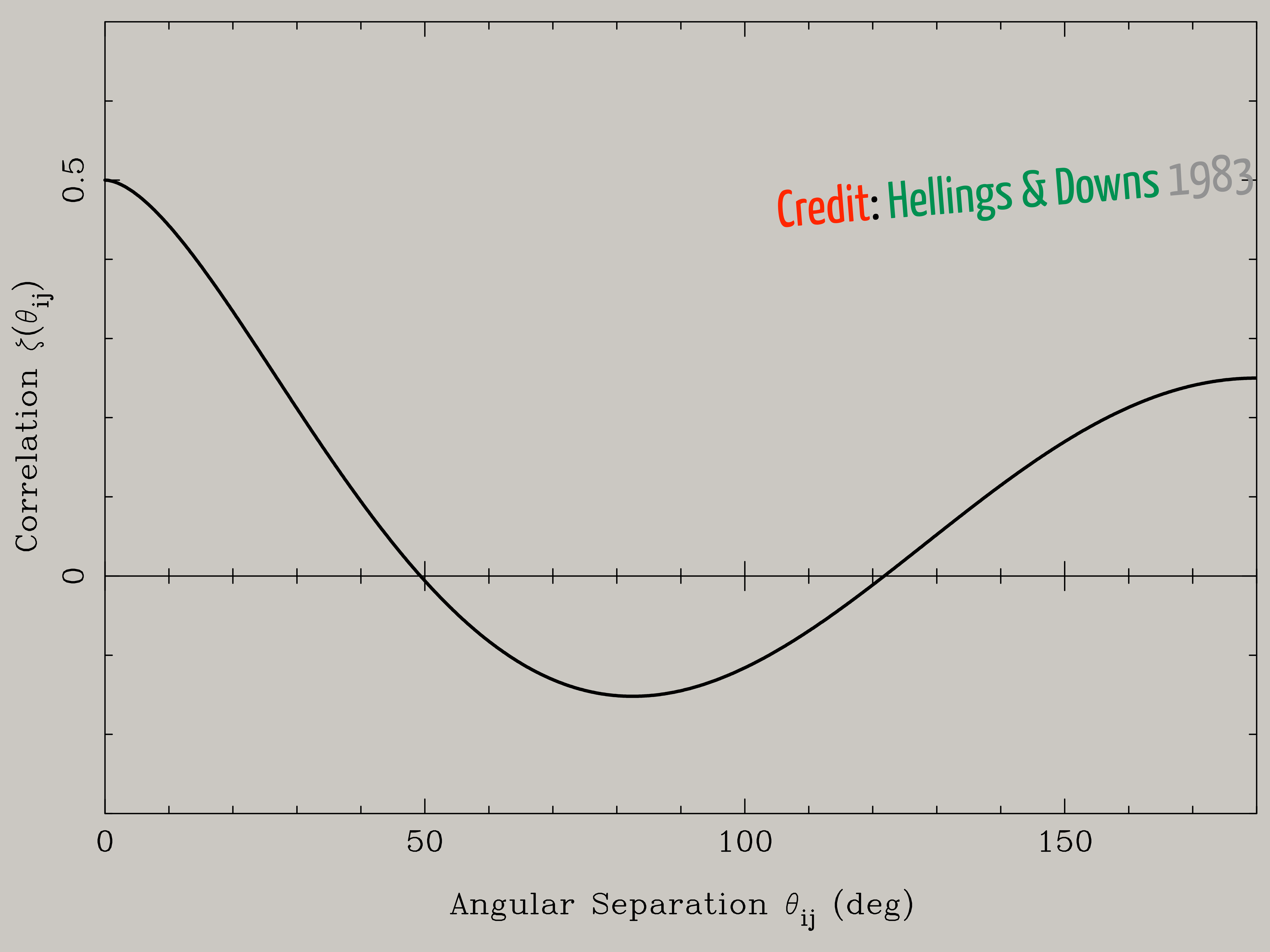
STEVEN DETWEILER
Department of Physics, Yale University
Received 1979 June 4; accepted 1979 July 6

ABSTRACT

Pulse arrival time measurements of pulsars may be used to search for gravitational waves with periods on the order of 1 to 10 years and dimensionless amplitudes $\sim 10^{-11}$. The analysis of published data on pulsar regularity sets an upper limit to the energy density of a stochastic background of gravitational waves, with periods ~ 1 year, which is comparable to the closure density of the universe.

Subject headings: cosmology — gravitation — pulsars — relativity

Credit: Detweiler 1979



Credit: Hellings & Downs 1983
0.5
0
Correlation $\zeta(\theta_{ij})$
0
50
100
150
Angular Separation θ_{ij} (deg)

CONSTRUCTING A PULSAR TIMING ARRAY

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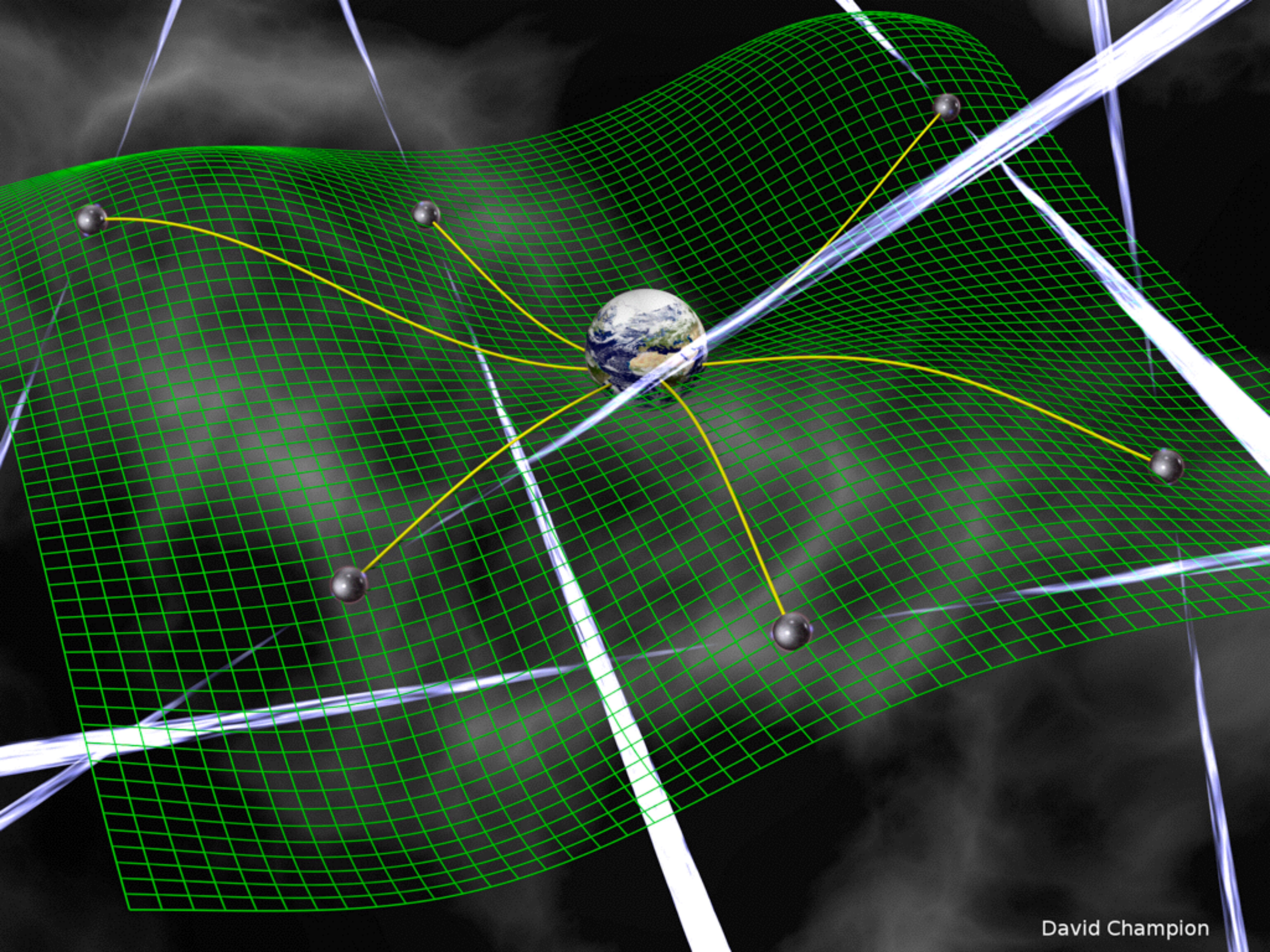
Astronomy Department, Radio Astronomy Laboratory, and Center for Particle Astrophysics, University of California at Berkeley
Received 1989 October 23; accepted 1990 March 21

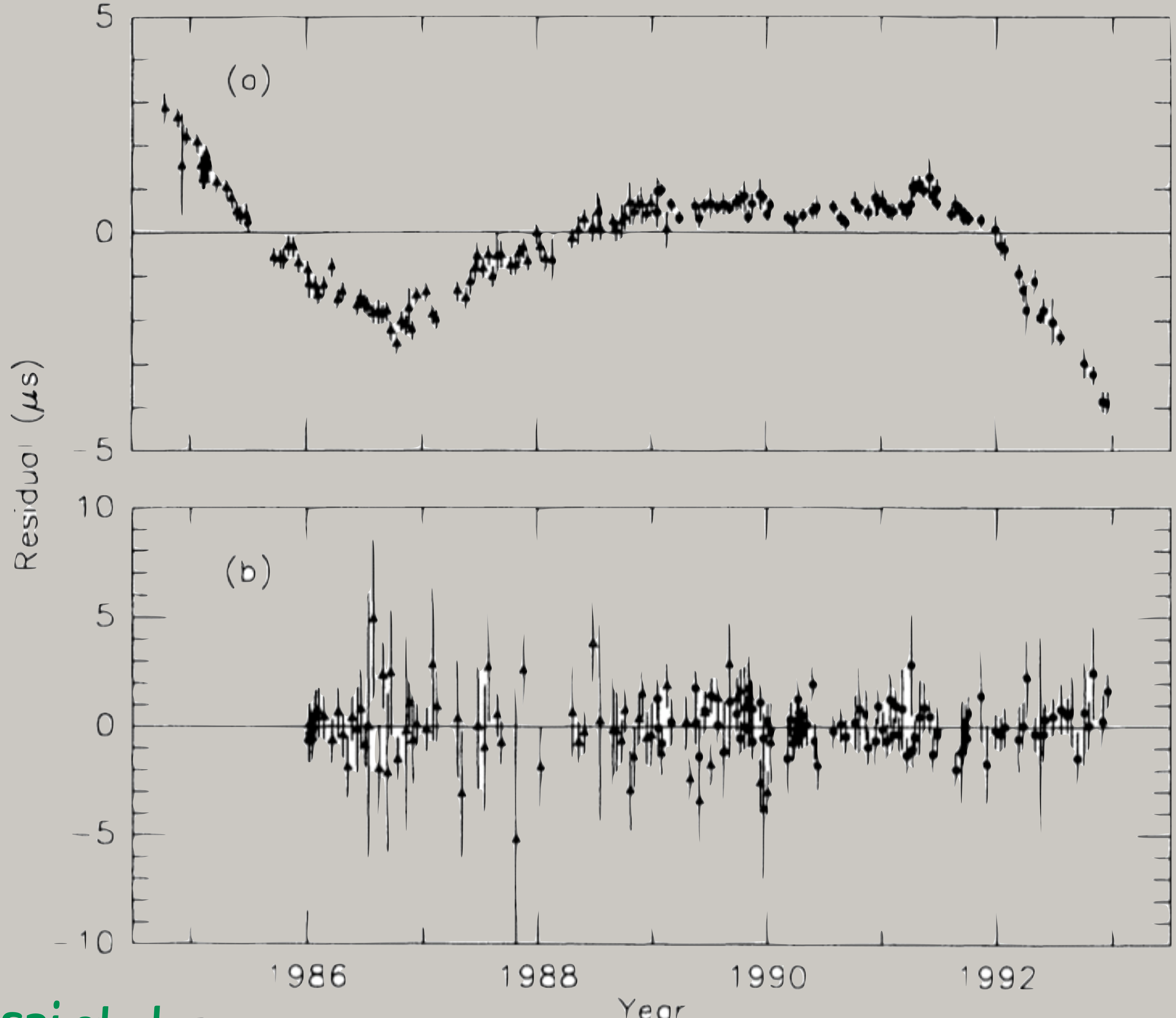
ABSTRACT

Arrival time data from a spatial array of millisecond pulsars can be used (1) to provide a time standard for long time scales, (2) to detect perturbations of the Earth's orbit, and (3) to search for a cosmic background of gravitational radiation. In this paper we first develop a polynomial time series representation for these three effects that is appropriate for analysis of the present data with its limited degrees of freedom. We then describe a pulsar timing array program that we have established at the National Radio Astronomy Observatory 43 m telescope with observations of PSR 1620−26, PSR 1821−24, and PSR 1937+21. The results presented in this paper cover a 2 yr period beginning in 1987 July. Individual parameters of these objects are compared to previous measurements. The influence of global parameters—clock, Earth location, and effects of gravitational radiation—on our data is discussed in the context of our polynomial model. Improvements in the data-gathering hardware and the inclusion of data from other observatories will lead to a significant increase in the sensitivity of this effort in the near future.

Subject headings: instruments — pulsars

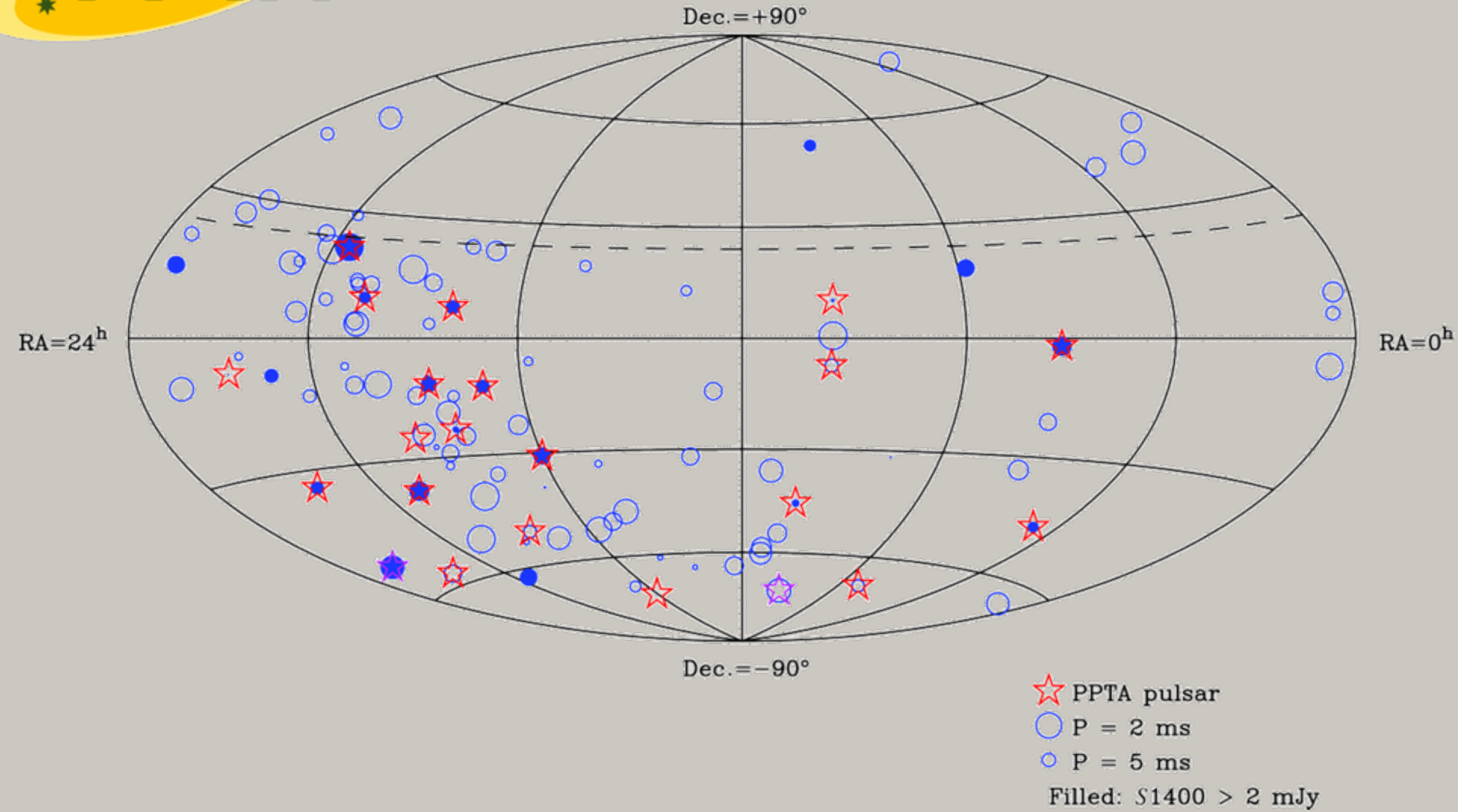
Credit: Foster & Backer 1990


David Champion



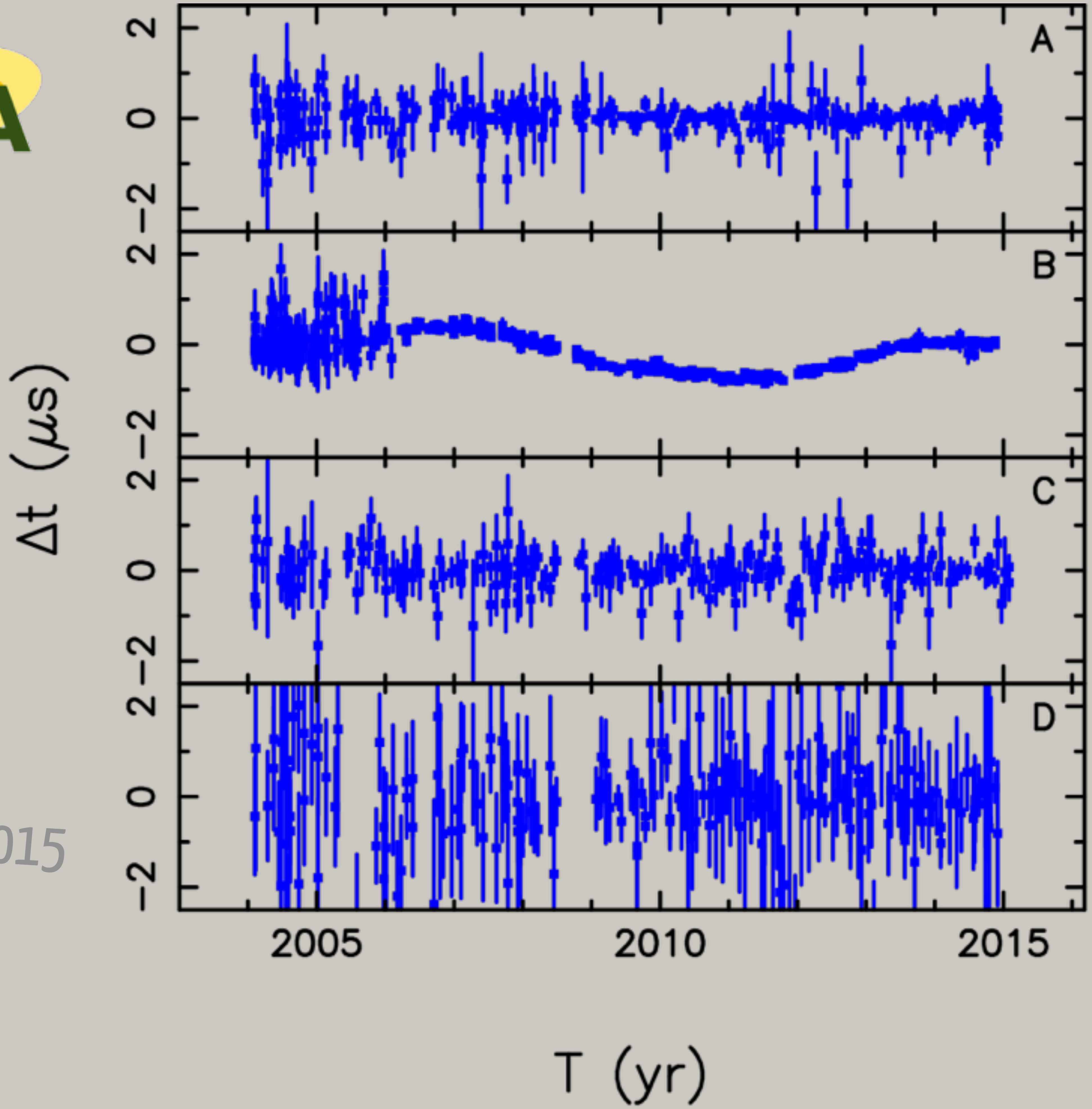
Credit: Kaspi et al. 1994

PPTA



Credit: Manchester et al. 2013

PPTA



Credit: Shannon et al. 2015

PPTA

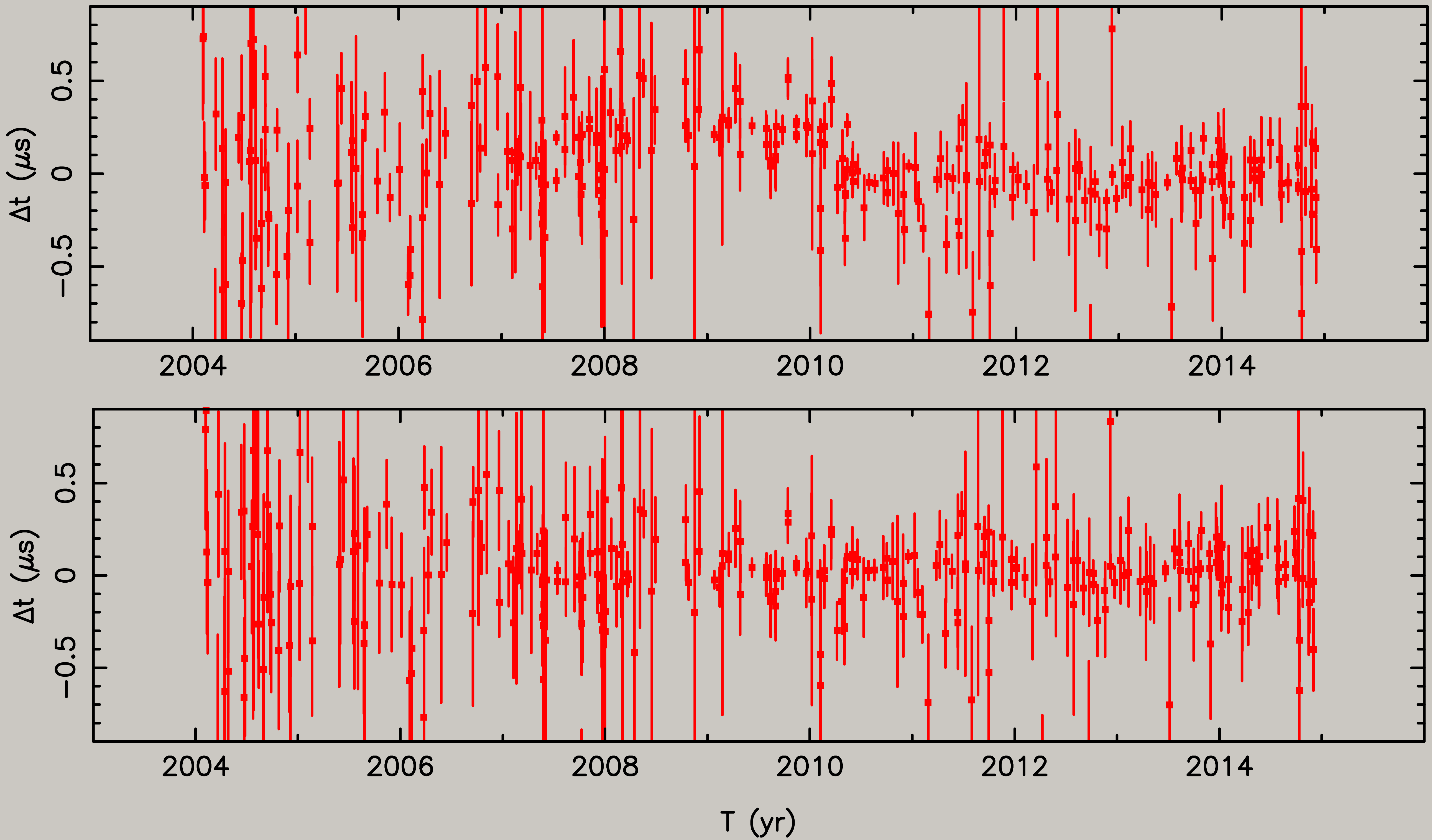
Current PPTA limit

$A_c < 1.0 \times 10^{-15}$ (95% CL)

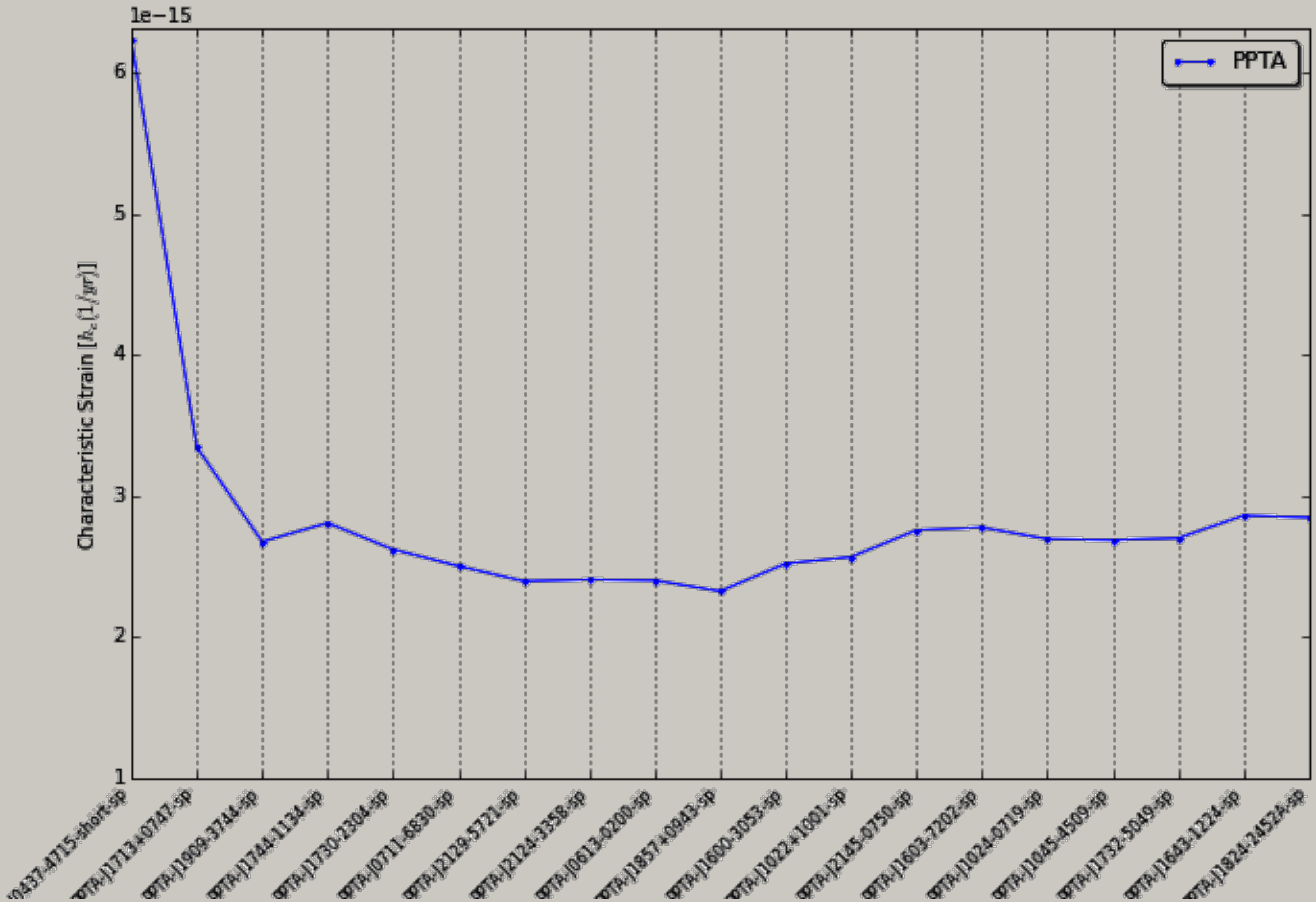
Limit calculated as per Lentati et al. 2014

and confirmed using van Haasteren & Vallisneri 2015

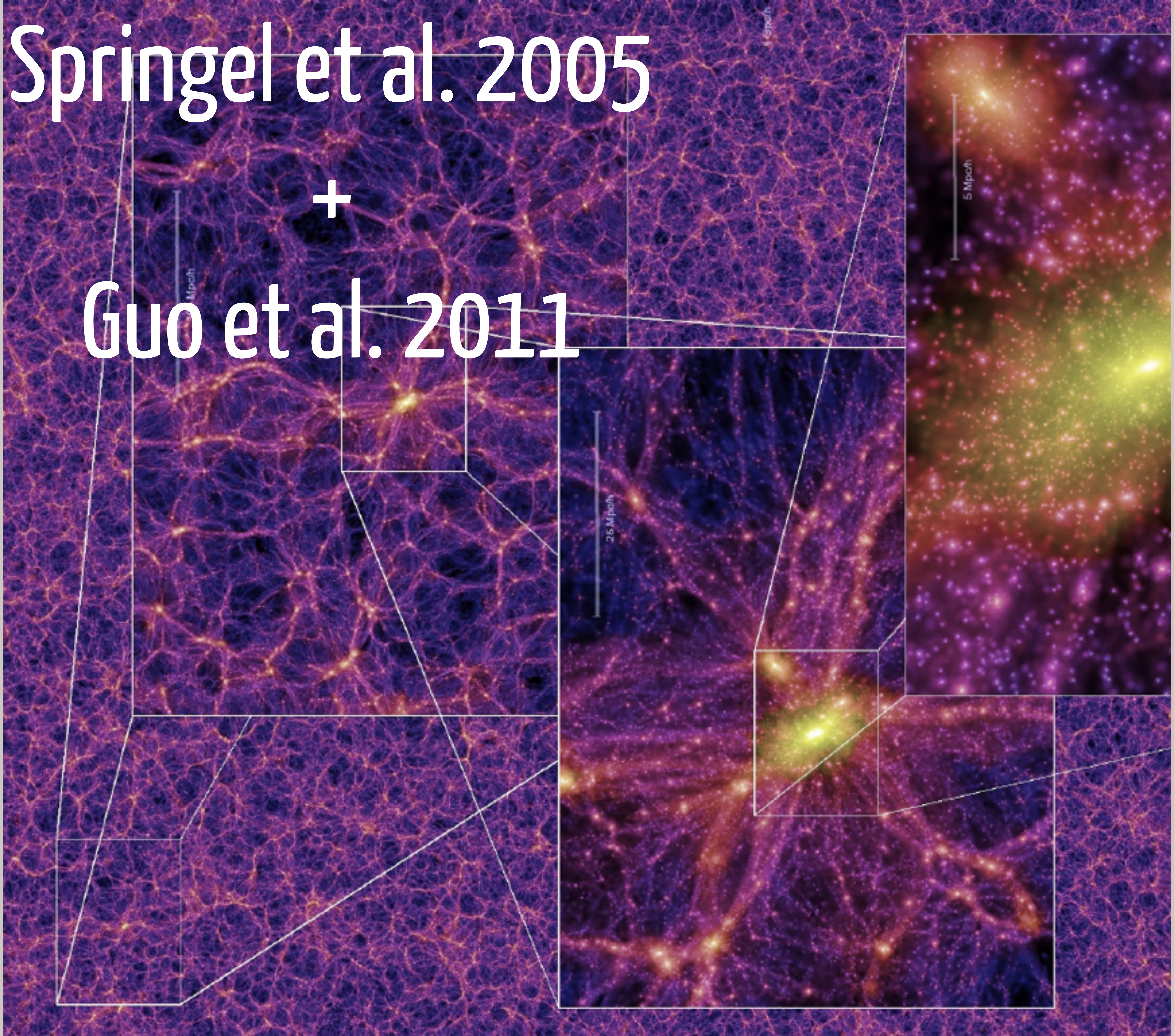
PPTA

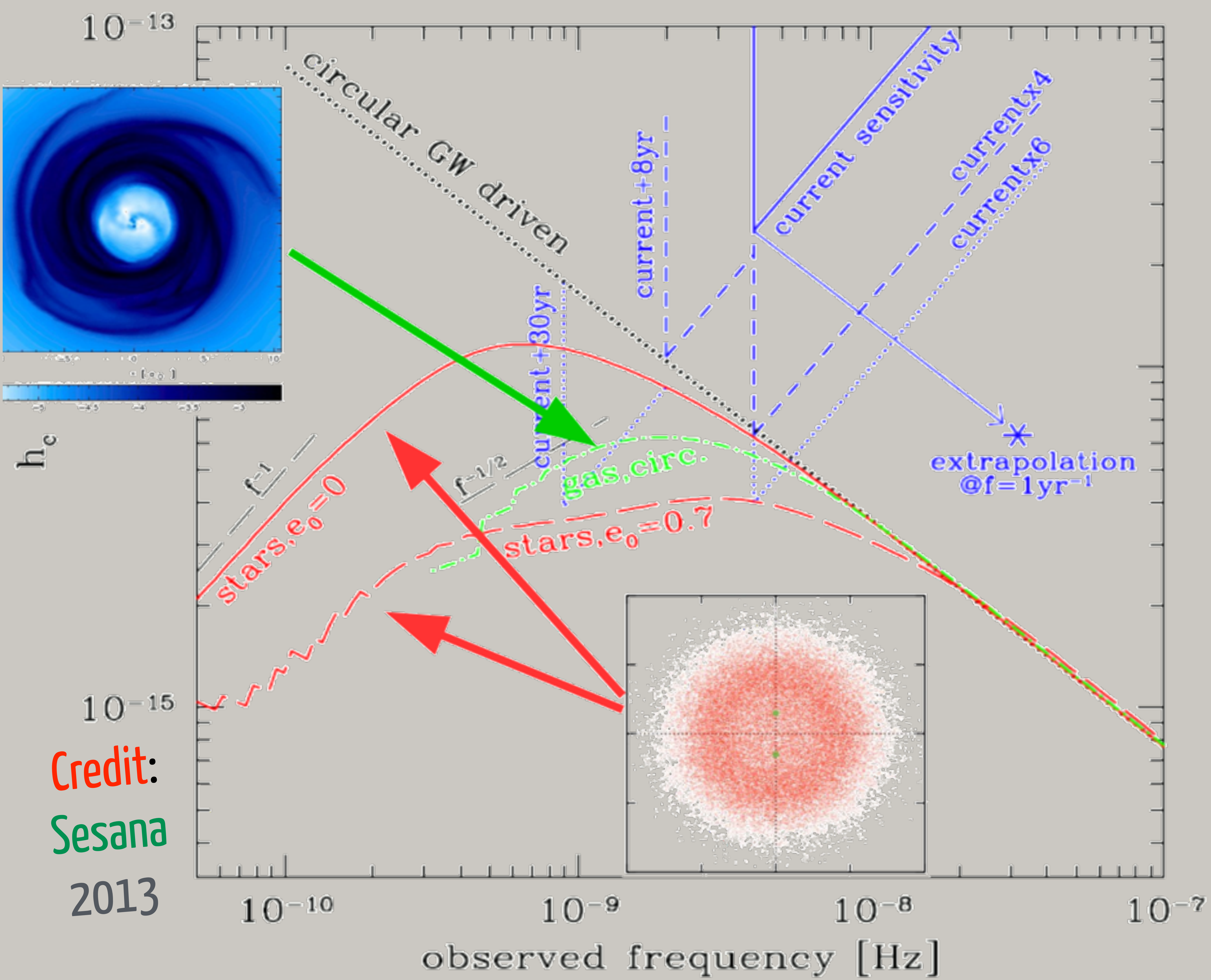


0.5
0
−0.5
Δt (μs)
2004
2006
2008
2010
2012
2014
0.5
0
−0.5
Δt (μs)
2004
2006
2008
2010
2012
2014
T (yr)

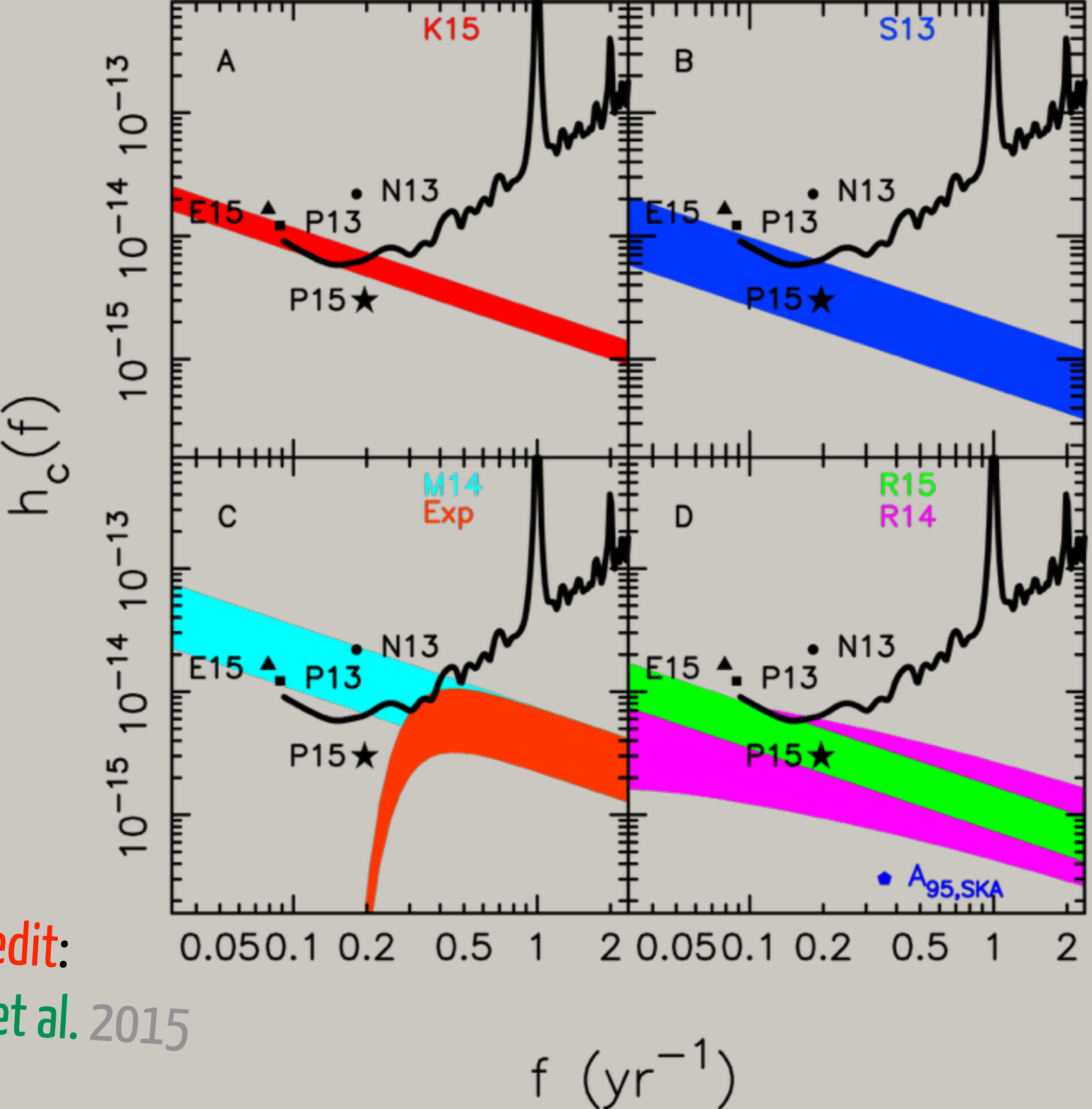


plot from R. van Haasteren


Springel et al. 2005
+
Guo et al. 2011
25 Mpc/h
5 Mpc/h



Credit: Sesana 2013



Credit: Shannon et al. 2015

PPTA Conclusions

- Simplest models of galaxy evolution excluded by PTA limits
- new models predict weaker background (see talk by E. Roebber)
- Possible we need higher cadence of observations
- Might detect single sources before stochastic background
- Need to improve sensitivity further

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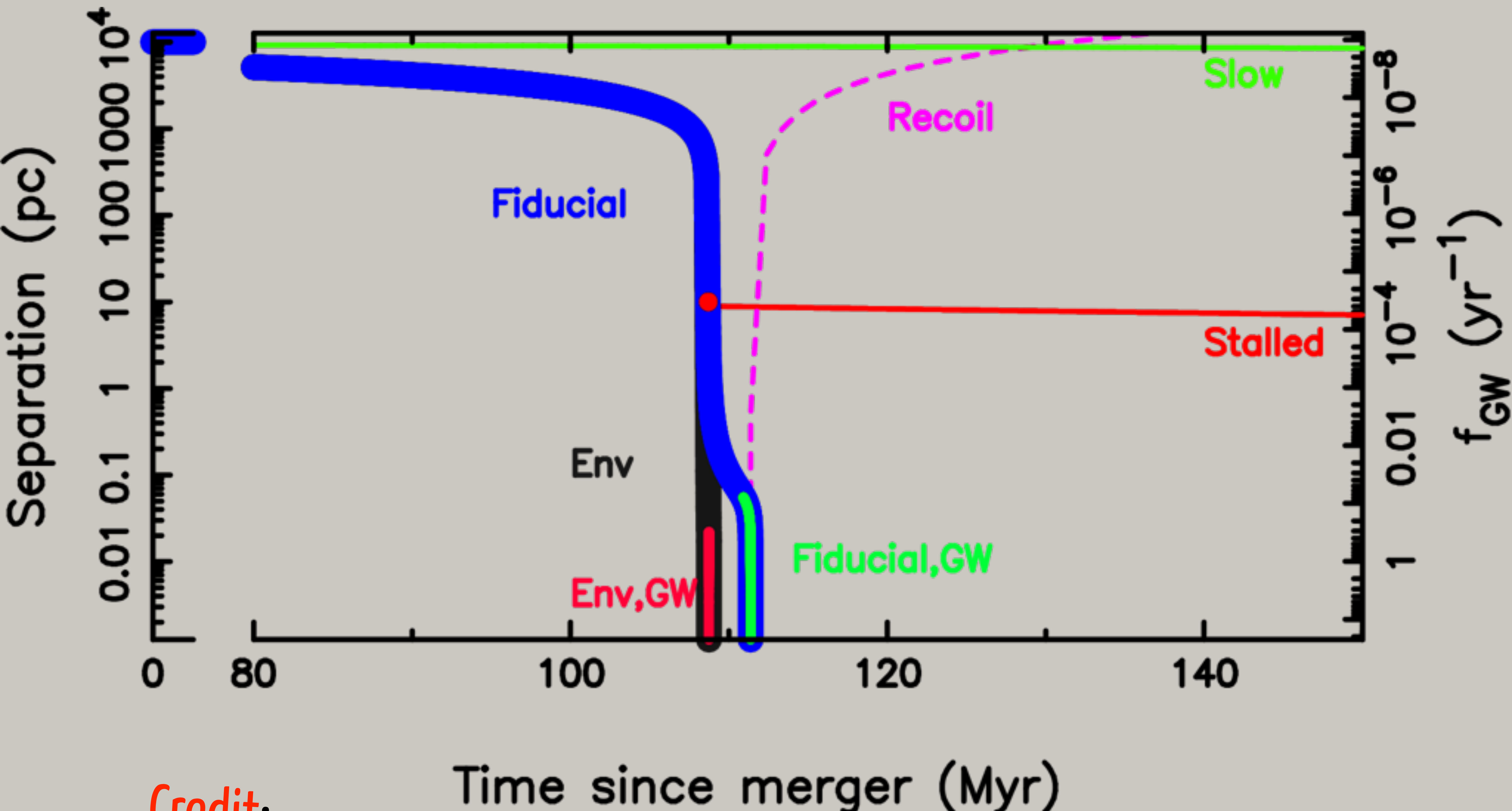
Thank you!



Credit:
Shannon et al. 2015