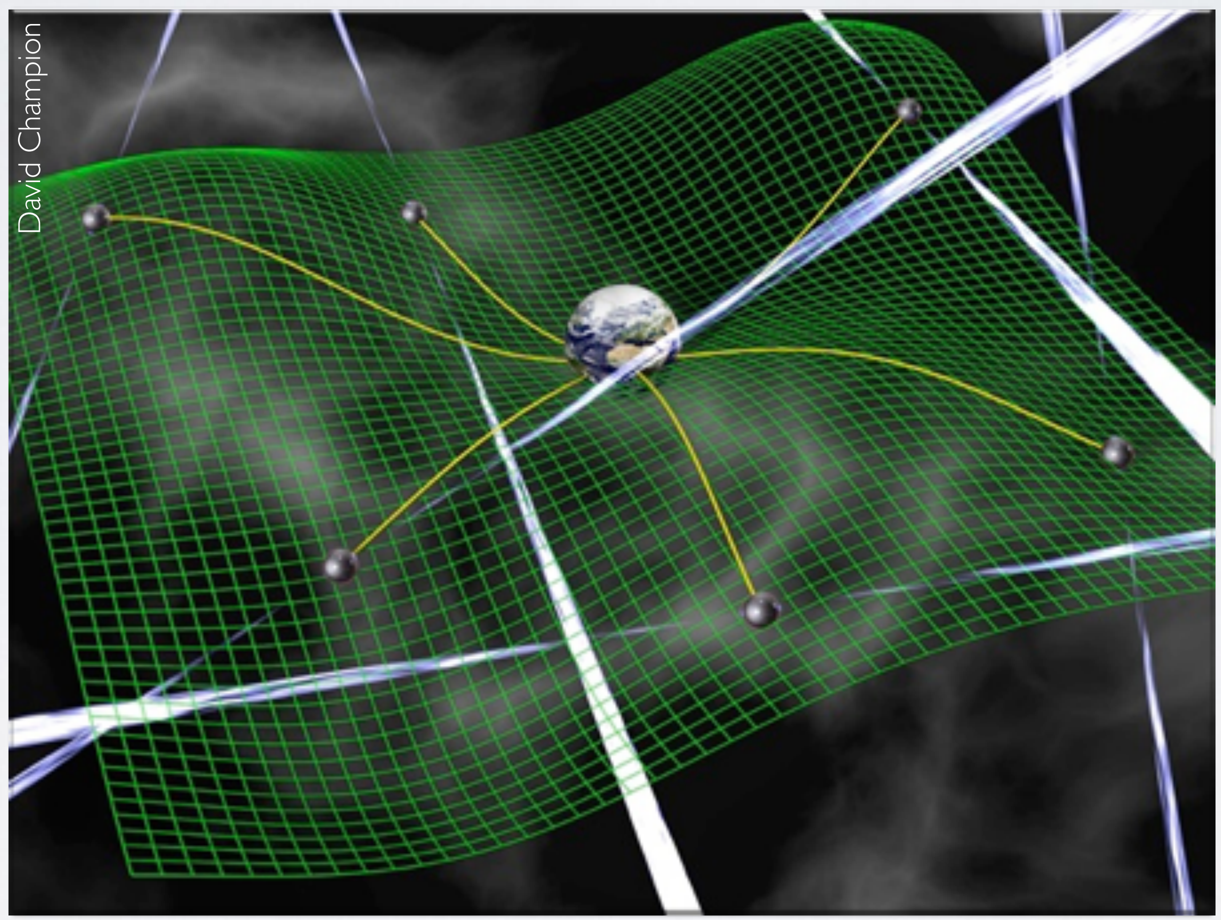
The European Pulsar Timing Array for the detection of Gravitational Waves

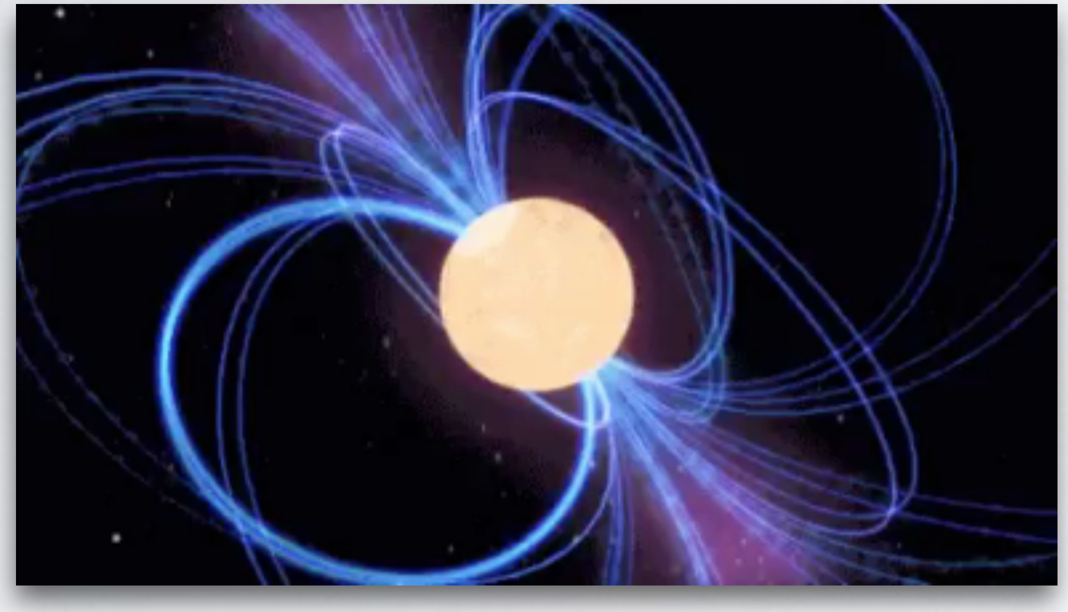


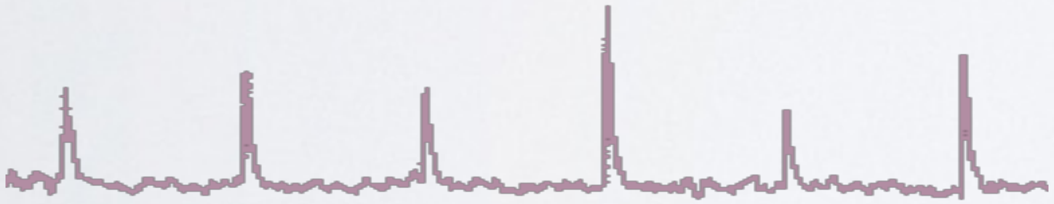
Marta Burgay (INAF Cagliari) on behalf of the EPTA collaboration

OUTLINE

- Pulsars
- Pulsar Timing method
- Detecting gravitational waves with pulsars
- EPTA & PTAs
- Future perspectives

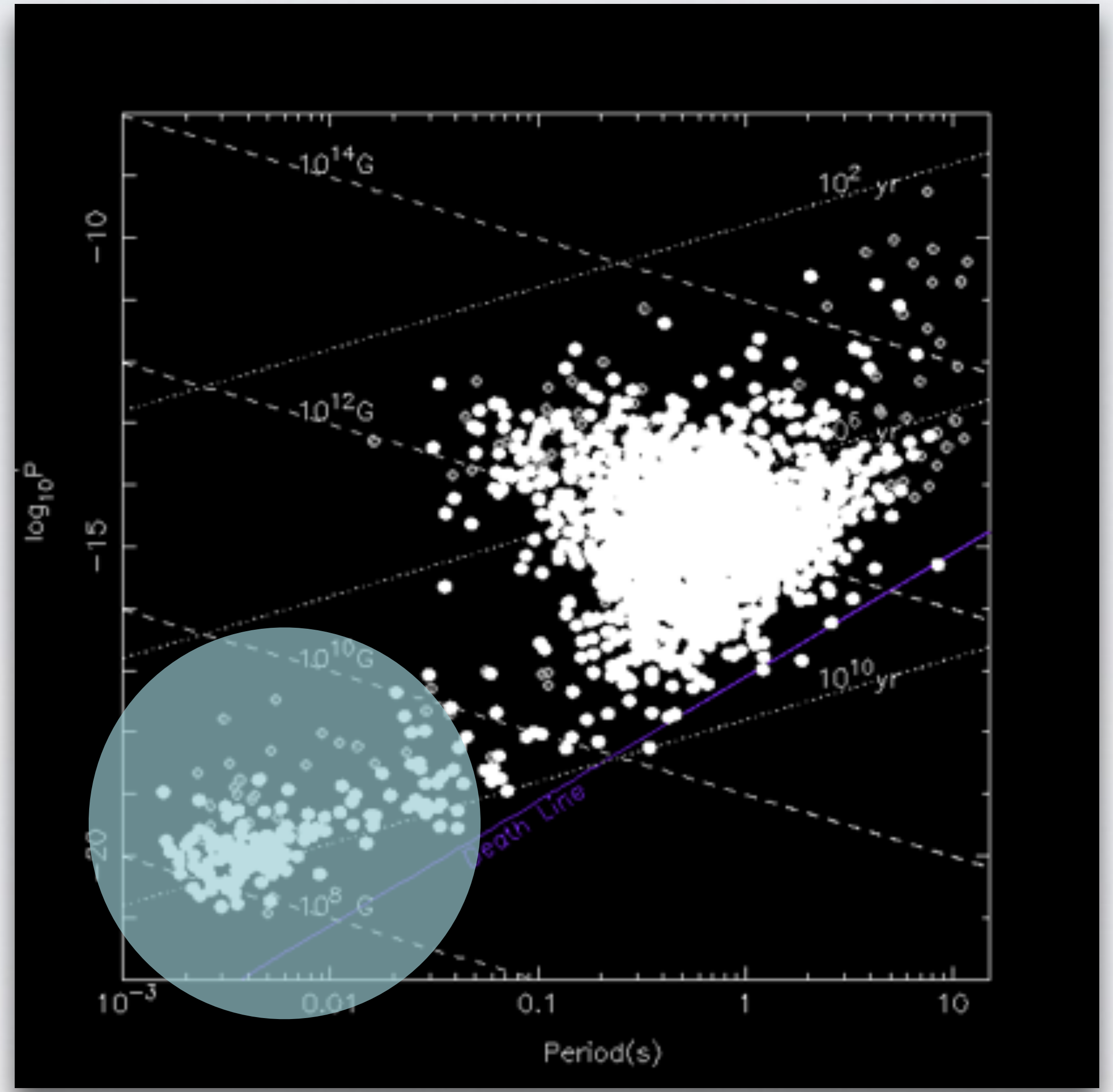
Pulsars





- Highly magnetised, fast rotating neutron stars
- Emitting beams of radio waves from their magnetic poles
- Lighthouse effect

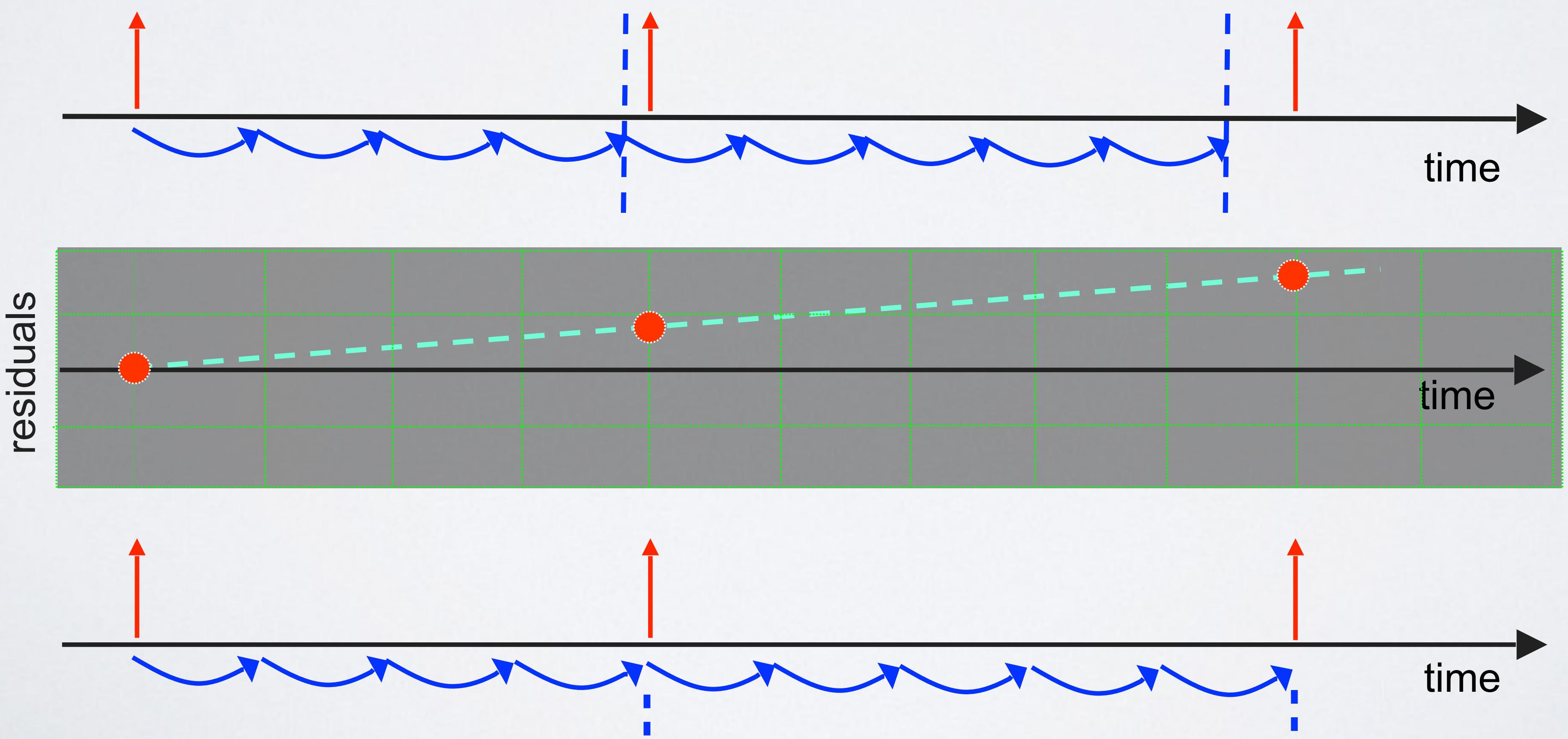
PULSAR EVOLUTION



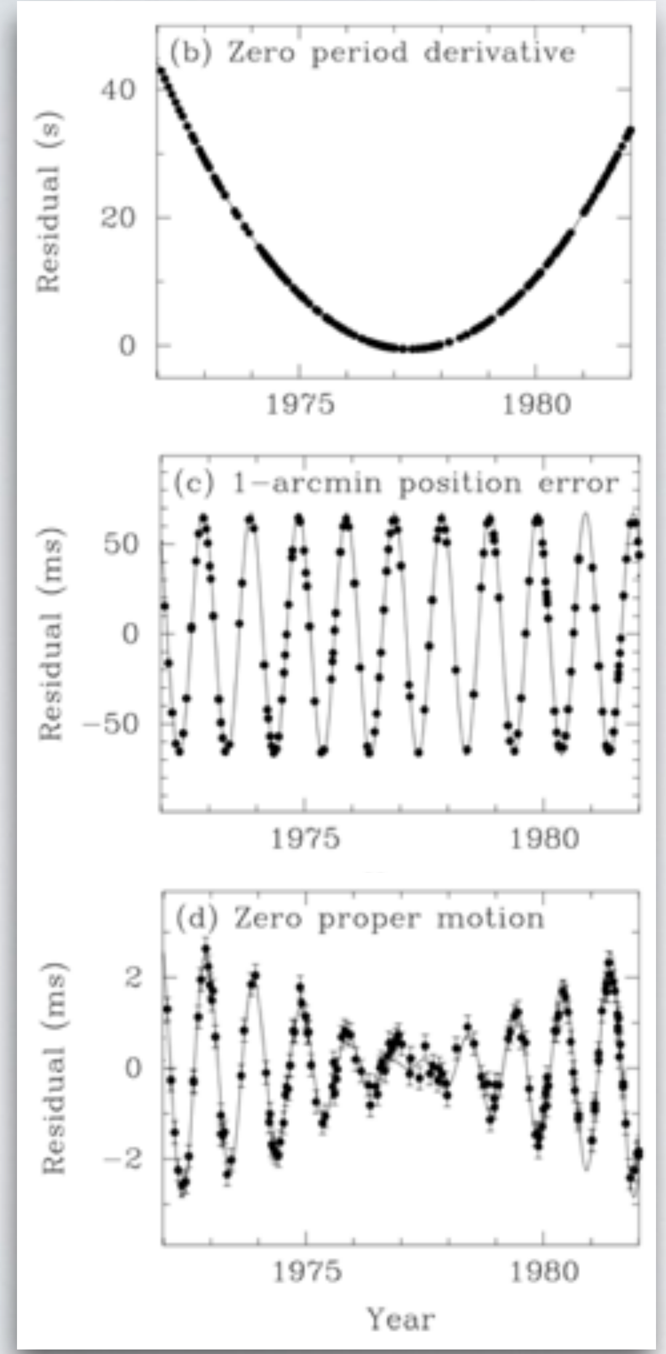
MSP
most stable clocks
testbeds for many studies

Pulsar Timing

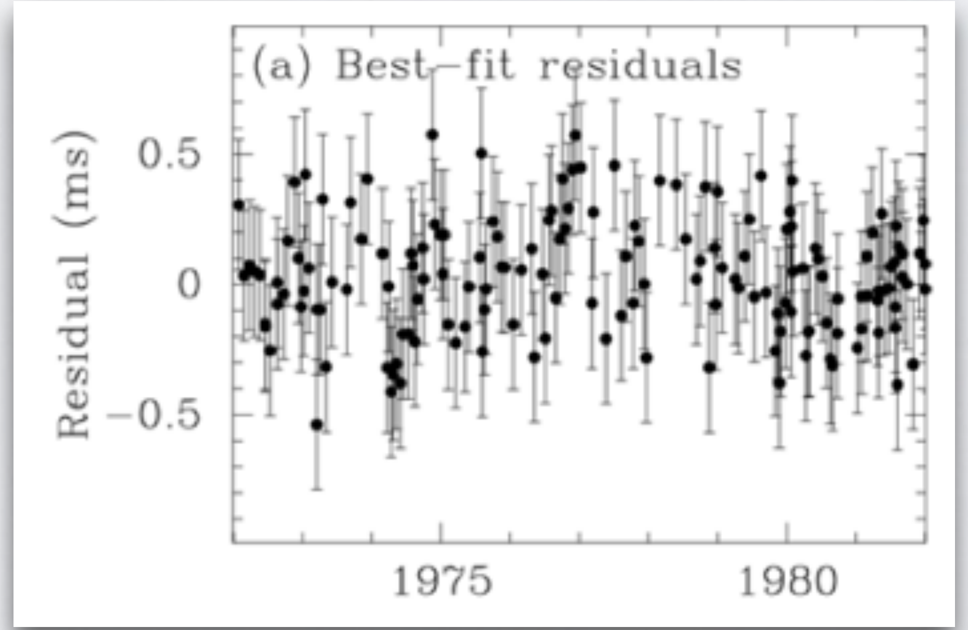
- Predicting Times of Arrival (ToAs) on the basis of a model (set of ephemeris)
- Measuring ToAs from repeated observations
- Creating timing residuals
- Fitting for model parameters to remove trends



Pulsar Timing



Correctly taking into account for all pulsar parameters (getting good pulsar ephemeris) should give us flat residuals randomly distributed around the zero

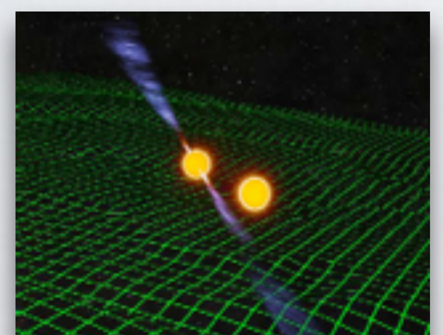


FLAT RESIDUALS

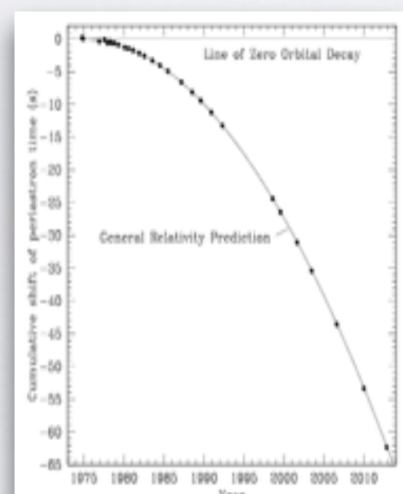
Pulsar Timing

NON FLAT RESIDUALS

Extra parameters

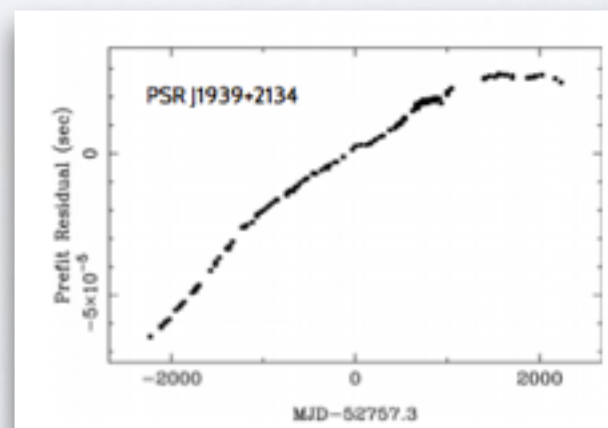


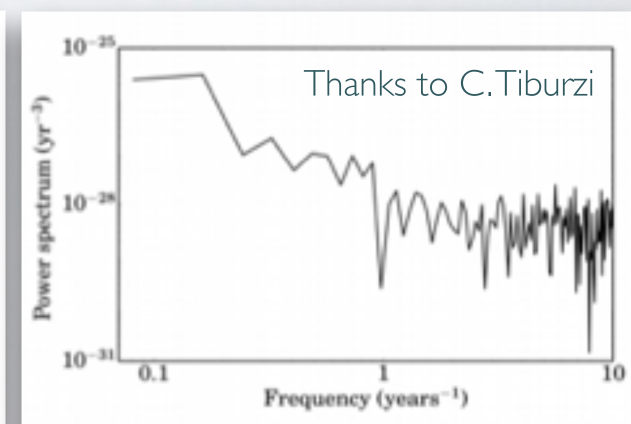
B1913+16



First *indirect* detection of ***GWs***!
Nobel prize for Taylor & Hulse 1993

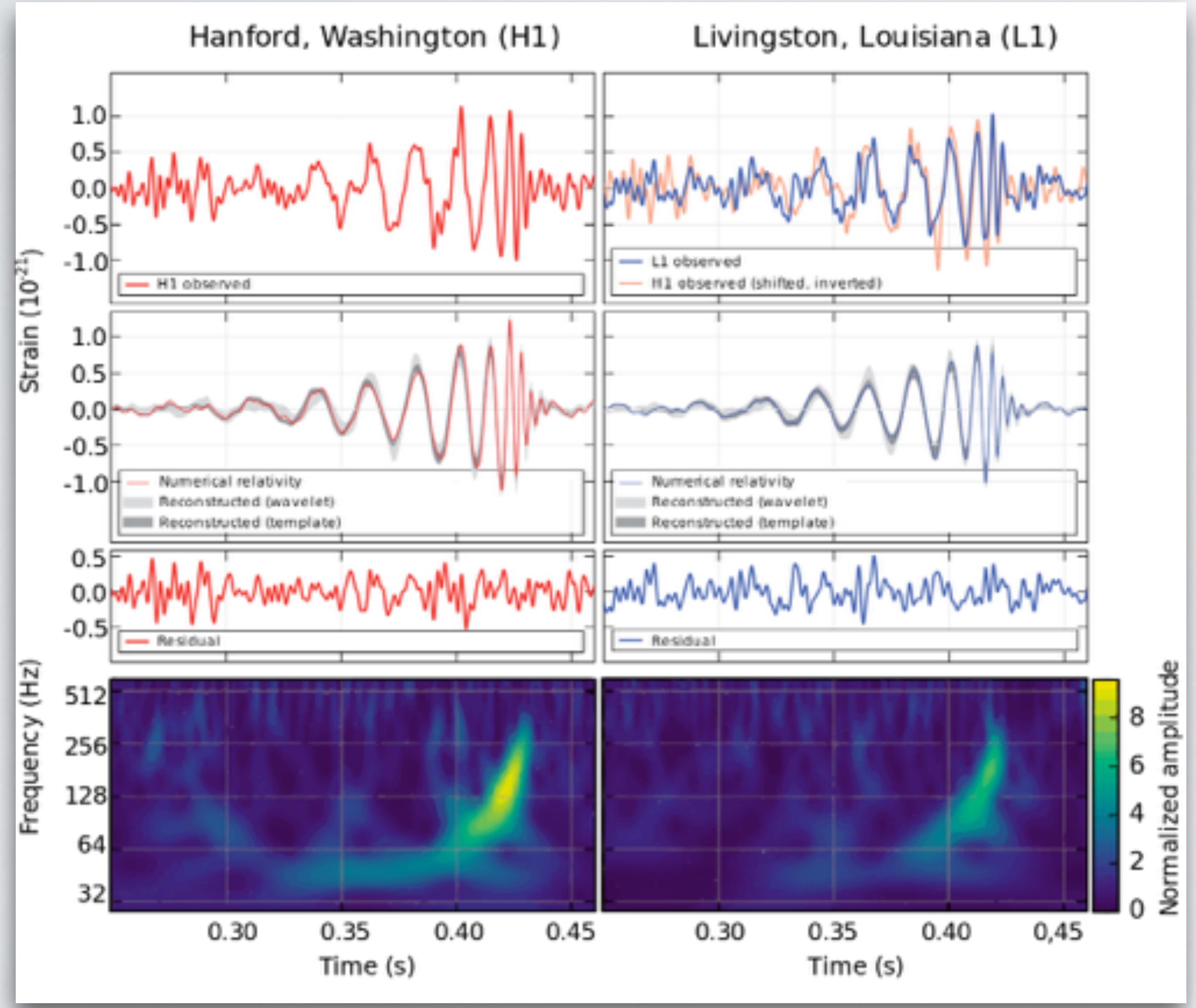
Unmodeled long-term effects





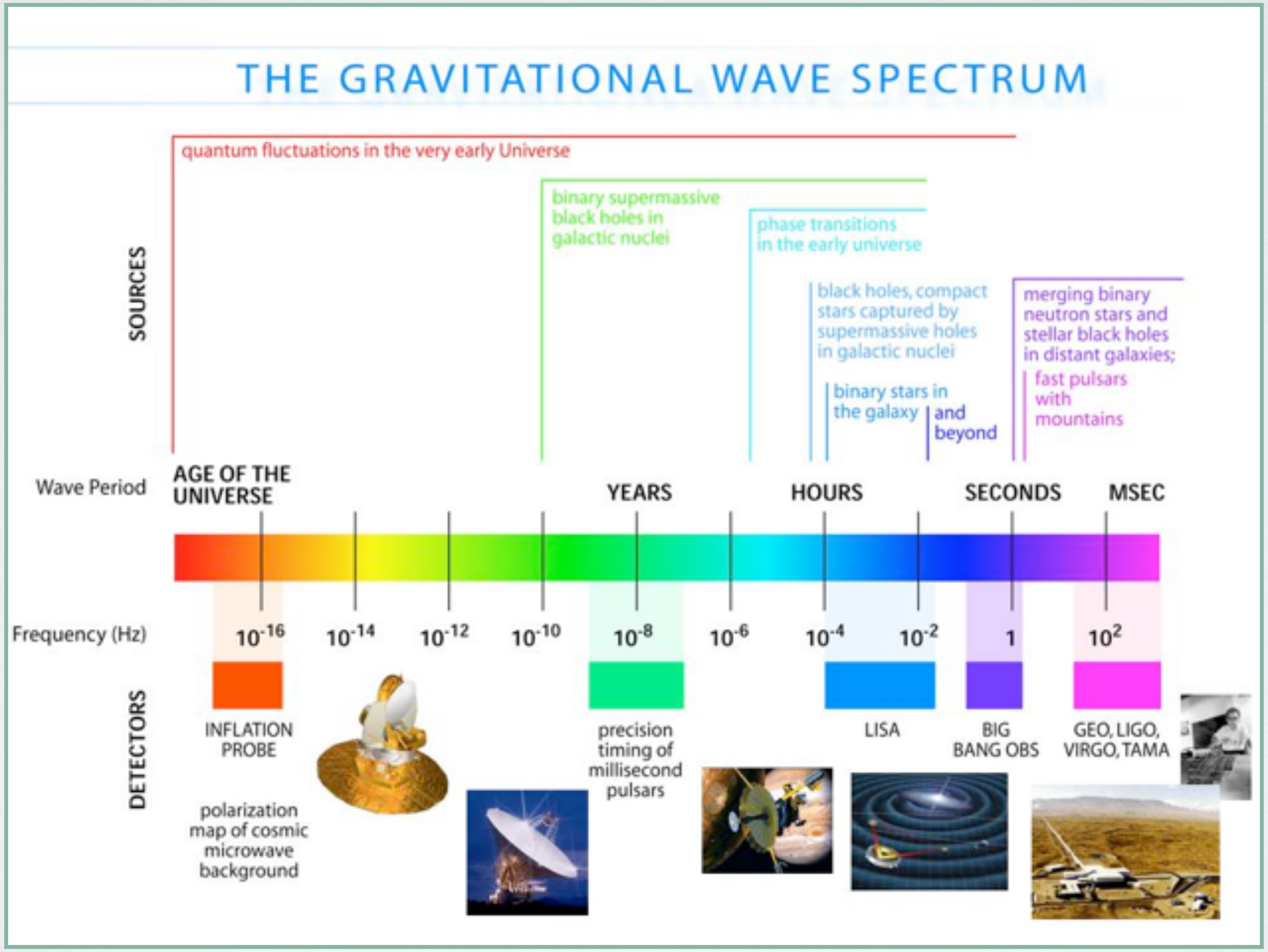
- spin noise
- turbulent ionised ISM
- instrumentation issues
- incorrect planetary ephemeris
- incorrect time standards,
- ***gravitational waves!***

Gravitational Waves



First *direct* detection of a GW from stellar-mass BH merger

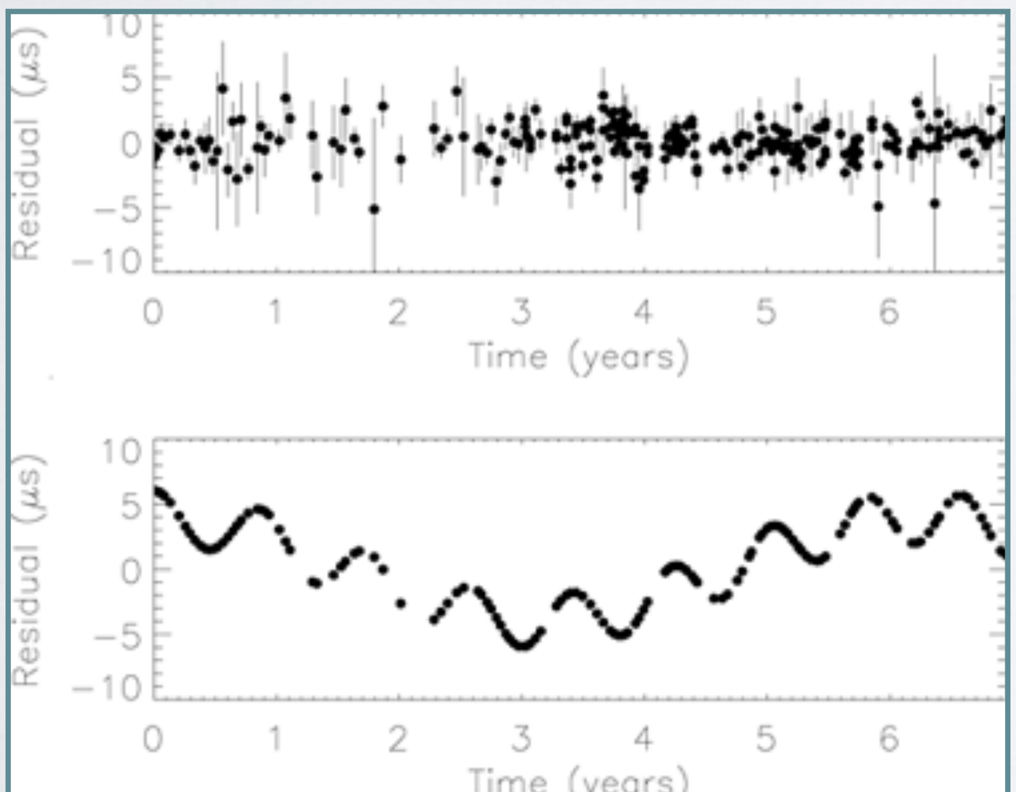
Gravitational Waves



Pulsars and GWs

An extreme example

The radio galaxy 3C66 (at z = 0.02) was claimed to harbour a double SMBH with a total mass of 5.4 x 10e10 Msun and an orbital period of order ~yr
[Sudou et al 2003]



[Jenet et al 2004]

In general, though, the blind detection of a single SMBHB is difficult, and localization requires the knowledge of the distance to the pulsar

Mergers of galaxies (with SMBH in their centres) should be ubiquitous -> plenty of SMBHB, creating a isotropic, stochastic GW background

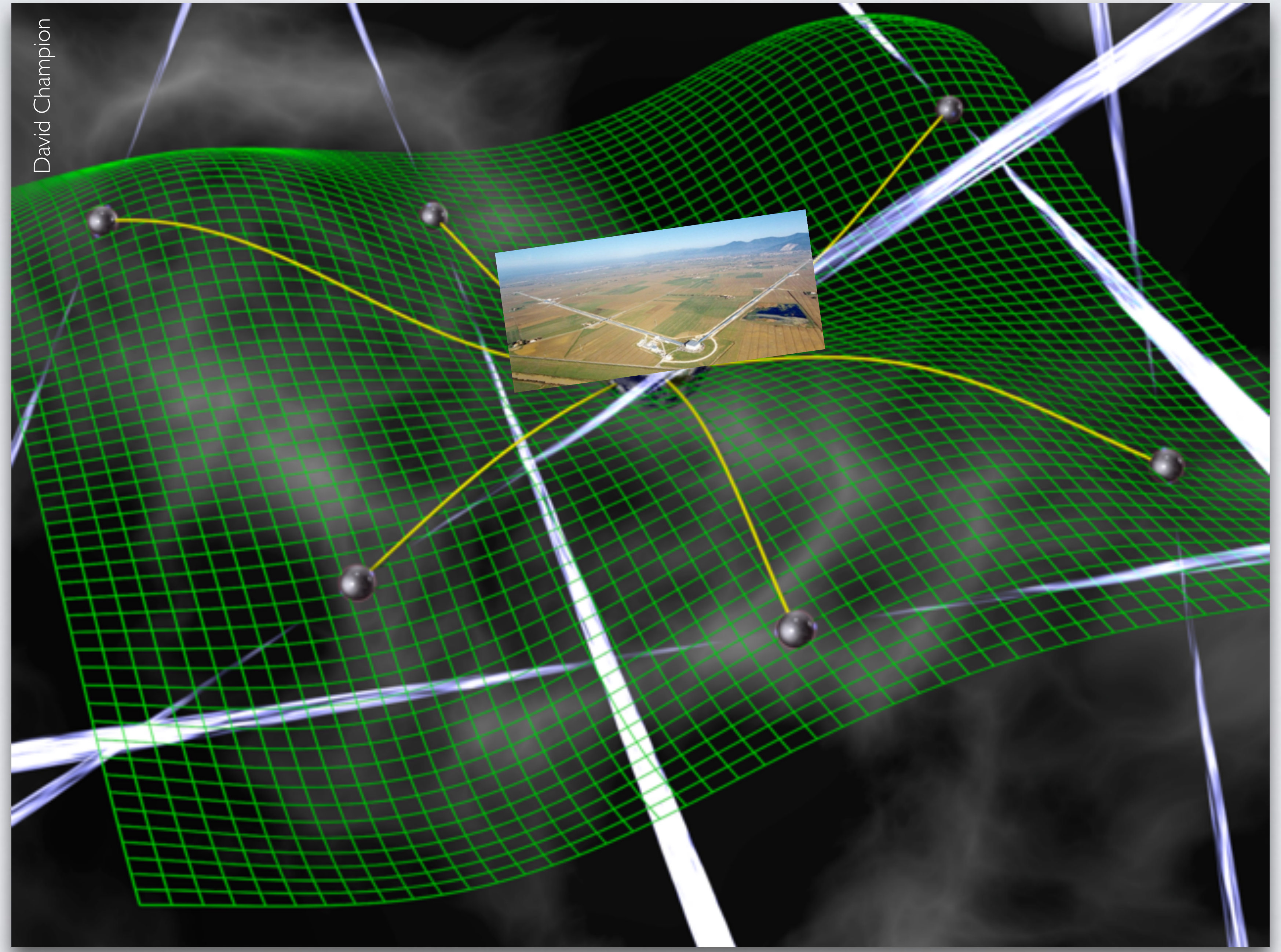
GW Background

- The expected amplitude spectrum of an isotropic, stochastic GWB from SMBHB is [e.g. Phinney 2001; Jaffe & Backer 2003], assuming a fully GW driven merger [Vigeland & Siemens 2016]

$$h_c(f) \sim f^{-\alpha}; \alpha = 2/3$$

- the power spectrum for the timing residuals affected by a GWB will be also a power law, with a spectral index of -13/3 [Detweiler 1979; Jenet et al. 2005/2006]

Pulsar Timing Arrays



PTA COLLABORATIONS

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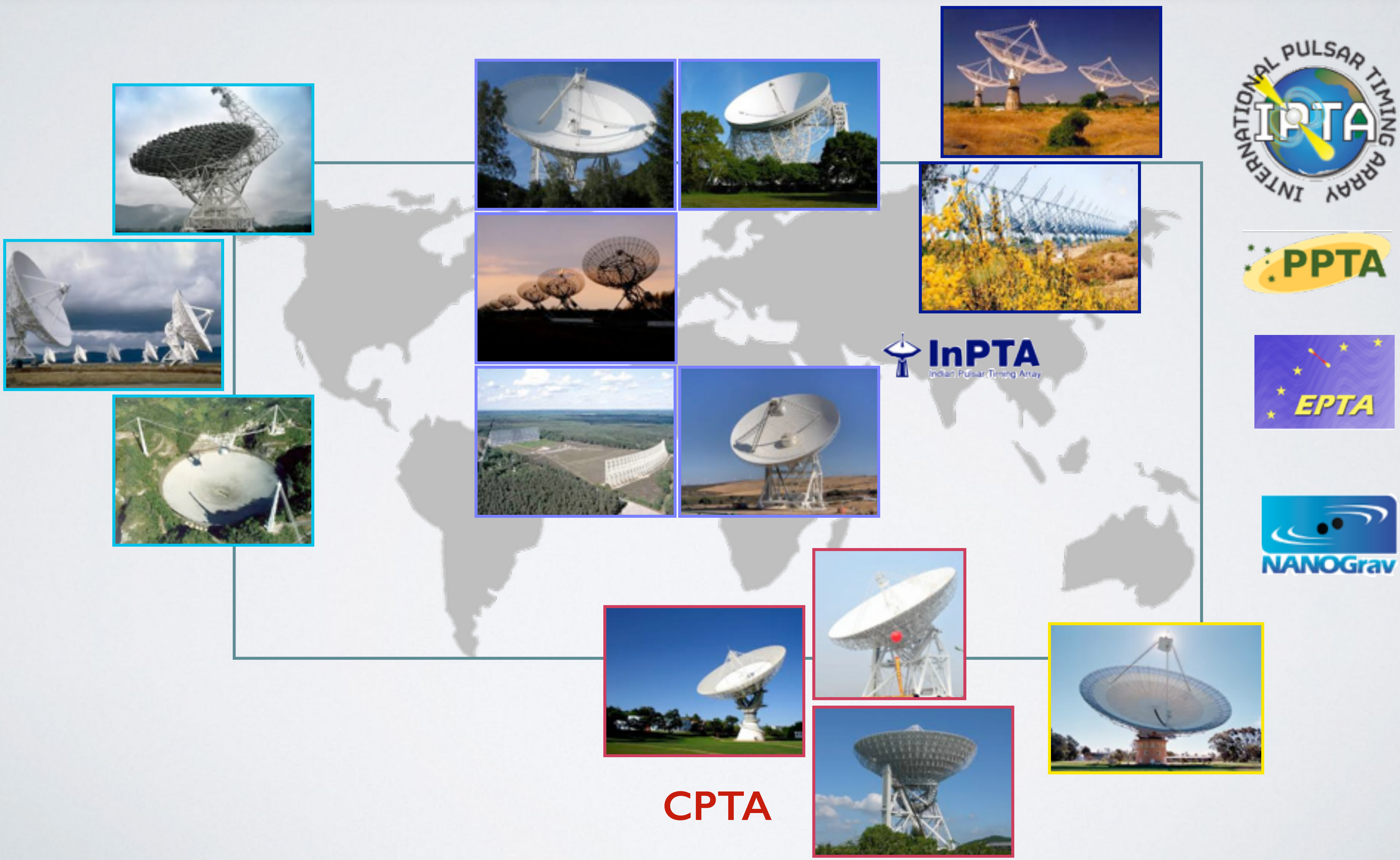
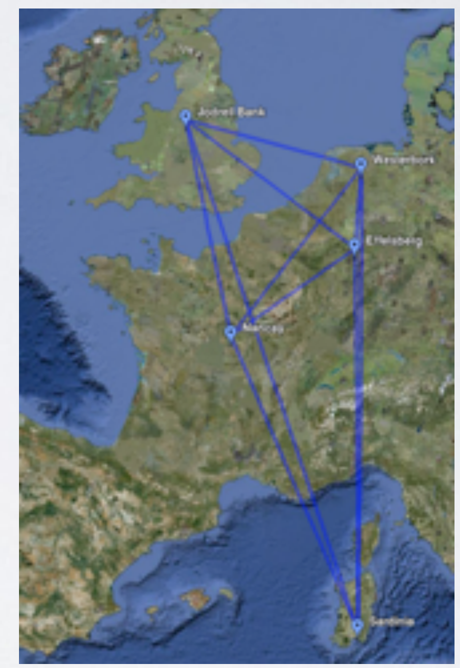


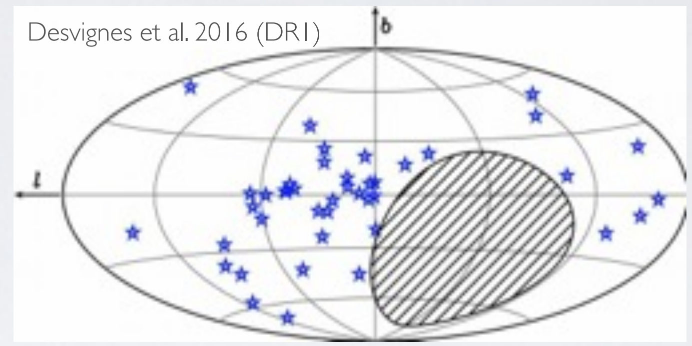
The European Pulsar Timing Array

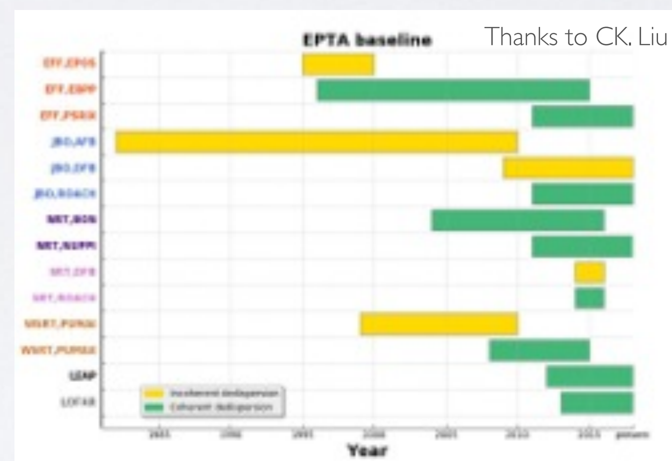
- 5 largest telescopes in Europe
- combined in the LEAP (194m)
- +LOFAR
- 10+ institutes involved

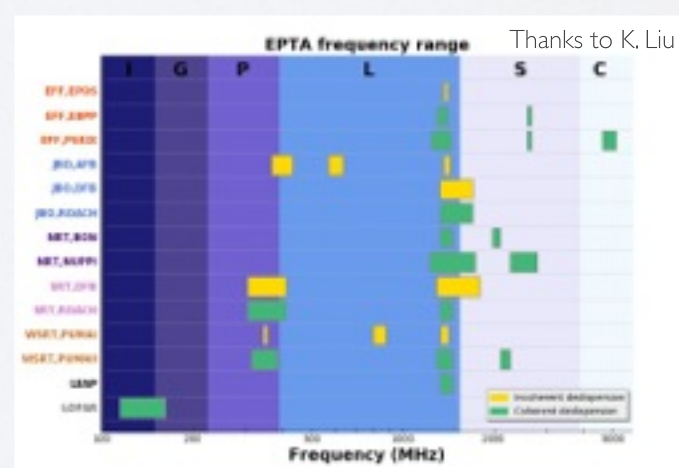


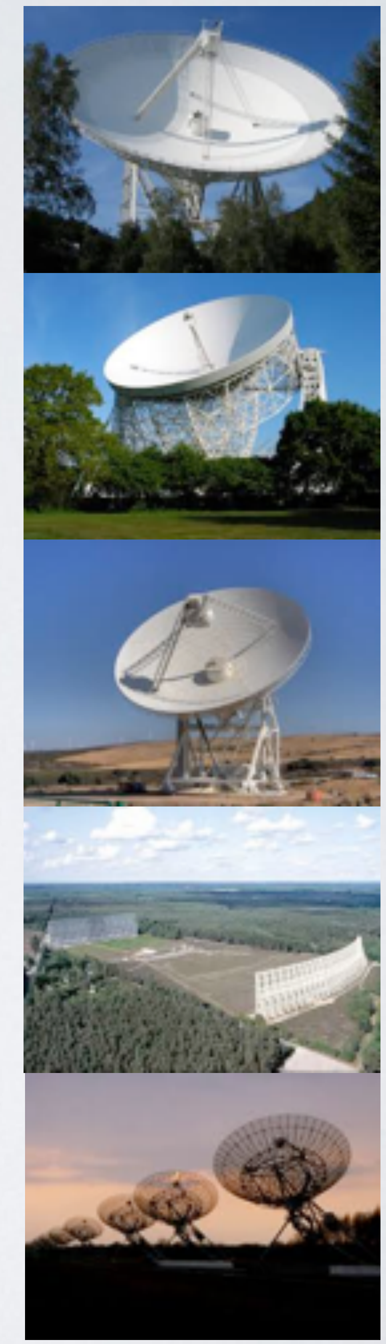
THE EUROPEAN PULSAR TIMING ARRAY

- > 42 timed MSPs
- Longest baseline
- Widest frequency coverage









(E)PTA LIMITS ON GWB

Current best limits on the amplitude of the GW background from SMBH binaries
(GW spectral idx -2/3 at fg_{GW}=2.8 nHz [P_{GW}=1 yr] for H_o = 73 km s^{-1} Mpc^{-1})

Lentati et al., 2015:

$A < 3 \times 10^{-15}$ (conservative limit, including different correlated effects; see also Tiburzi et al. 2016)

Arzoumanian et al., 2018:

$A < 1.45 \times 10^{-15}$

Shannon et al., 2015:

$A < 1.0 \times 10^{-15}$

Verbiest et al., 2016:

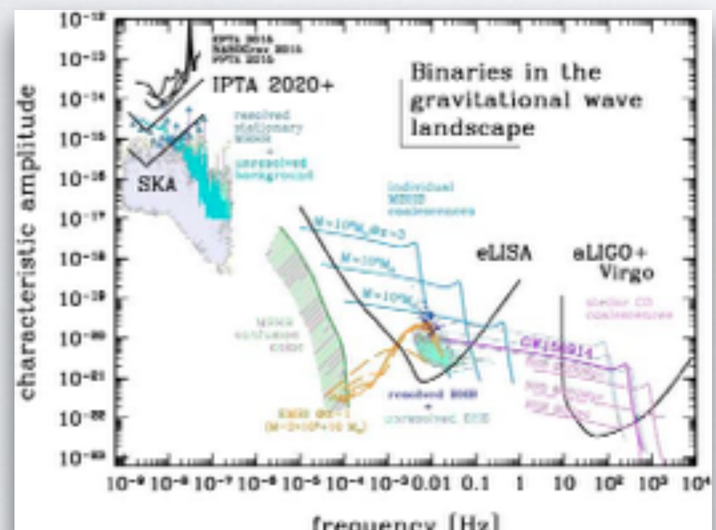
$A < 1.7 \times 10^{-15}$

Non GW EPTA studies

- Study of individual pulsars of interest (Desvignes et al. 2016; Bassa et al. 2016; McKee et al. 2016; Shaifullah et al 2016)
- Study of the Solar wind (Tiburzi & Verbiest 2018; Tiburzi et al. submitted)
- Study of the IISM (Donner et al. 2019)
- Pulsar noise characterisation (Caballero et al. 2016)
- Solar system ephemeris (Caballero et al. 2018)
- …and many more from all PTAs

Future

- New additions to IPTA
- The SKA!



Thank You!

10-21 June 2019
Pune

https://conf.ncra.tifr.res.in/event/2/

http://www.radiotelescopes.inaf.it/proposal_main.html

Observation Proposals

Regular call is open. Deadline: April 2nd, 17:00 CEST.
Proposals for ToOs and DDT can be submitted anytime.