Gravitational wave searches from noisy neutron stars

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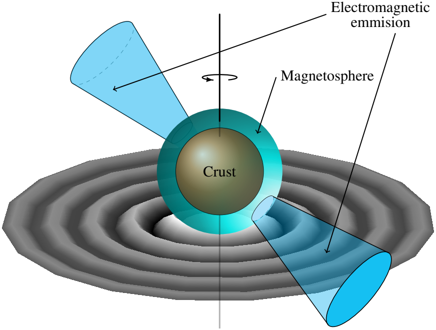
Introduction to the model

- Some neutron stars are observed to periodically pulse
- Neutron stars may emit CGWs due to non-axisymmetric distortions supported by elastic strains in the crust
- What sort of signal do we expect?
- Assume the crust is phase locked to the pulse producing magnetosphere
- Then we expect $f_{GW} = 2f_{EM}$

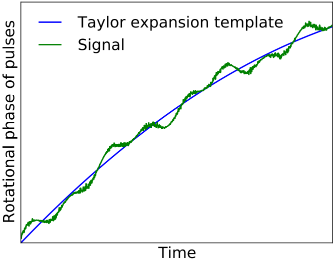


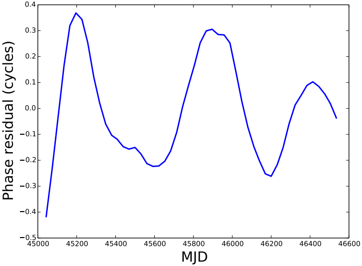
Phase models from electromagnetic observations

- The rotational phase may be modelled to within a rotation by a Taylor expansion:

$$\phi(t) \sim \phi_0 + f_{EM} t + \frac{\dot{f}_{EM}}{2!} t^2 + \ldots$$

- Deviations exist, those associated with the spindown of the star itself are labelled *timing noise*
- The deviations are typically larger in younger, more rapidly spinning pulsars[a]



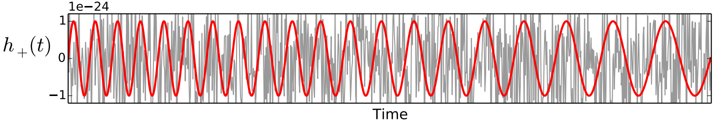


[a] Hobbs et al. 2010 MNRAS

CGW searches from neutron stars

The GW signal as written in the reference frame of the source is:

$$h_+ \sim \sin(\phi(t)), \qquad h_\times \sim \cos(\phi(t)).$$



The signal to noise ratio scales as

$$\rho_0 \propto h_0 \sqrt{T_{\rm obs}}$$

So do we always want to maximise the observation time?

Types of searches

Different types of searches:

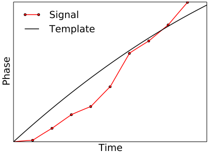
- **Targeted search**: known neutron star with known phase model so we're able to account for timing noise
- **Narrow band search**: known neutron star with poor knowledge of phase
- **Blind all sky search**: unknown neutron star, unknown phase

What effect will our ignorance of phase deviations (timing noise) have on a fully coherent gravitational wave search?

Signal injections

Jodrell Bank regualy observes the
Crab pulsar and maintains the Crab ephemeris
`jb.man.ac.uk/pulsar/crab`

This gives a phase solution
including timing noise



Inject signal into CGW
detection software (`LALapps`)

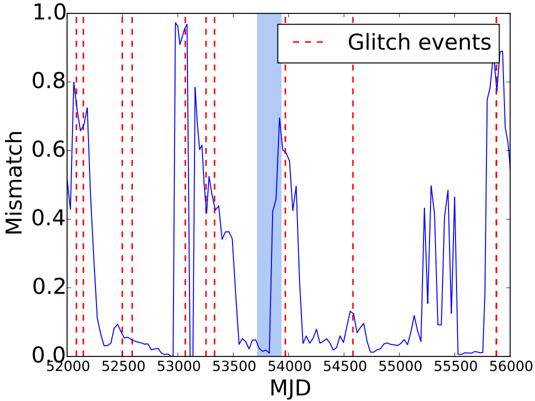
$$m = 1 - \frac{\rho^2|_{\mathrm{Injection}}}{\rho_0^2}$$

Measure the mismatch

- Use the Crab pulsar a test candidate: it is reguarlyl observed and the subject of a narrow band LIGO search [*Abbot et al. 2008 APJ "Beating spin down limits on GW emmisions from the Crab pulsar*"]

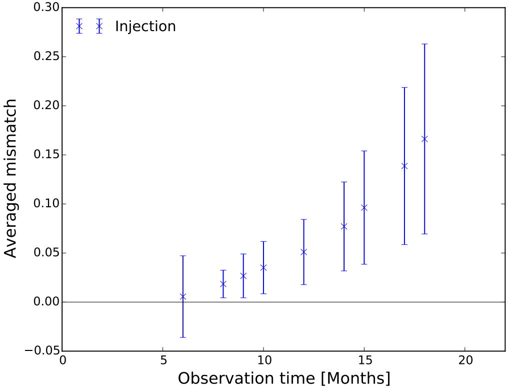
Source: `jb.man.ac.uk` & `ligo.org`

Results



- Sliding window of 10 months duration measuring the minimum mismatch over the Crab history
- Glitch events are phase disconected so expect large mismatch
- Lower threshold results from timing noise, during S5 search $m \approx 0.01$

Results



- Measure the average mismatch inbetween glitches as a function of the observation time
- Longer observation are more vulnerable to timing noise

Conclusion

- Timing noise encodes our ignorance of the real phase evolution
- Young rapidly spinning pulsars, the most probable sources for the detection of CGW, display the largest amount of timing noise
- The Crab pulsar is used to test the effect on a narrow band search
- Over short observation times (~ 10 months) the mismatch is small enough to be neglected
- Over longer periods this is no longer the case, this should be considered in future narrow band and blind all sky searches