Pulsar acceleration processing

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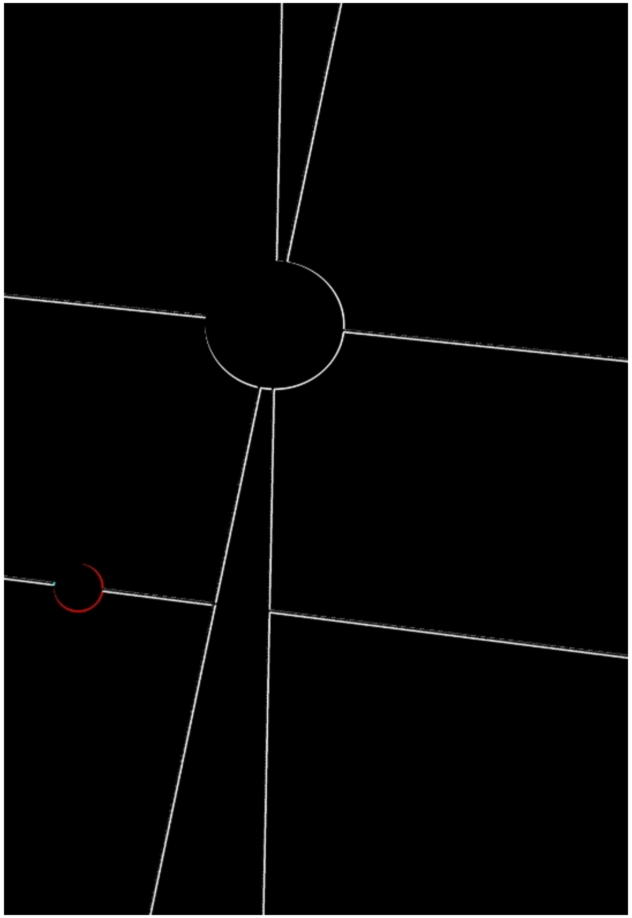
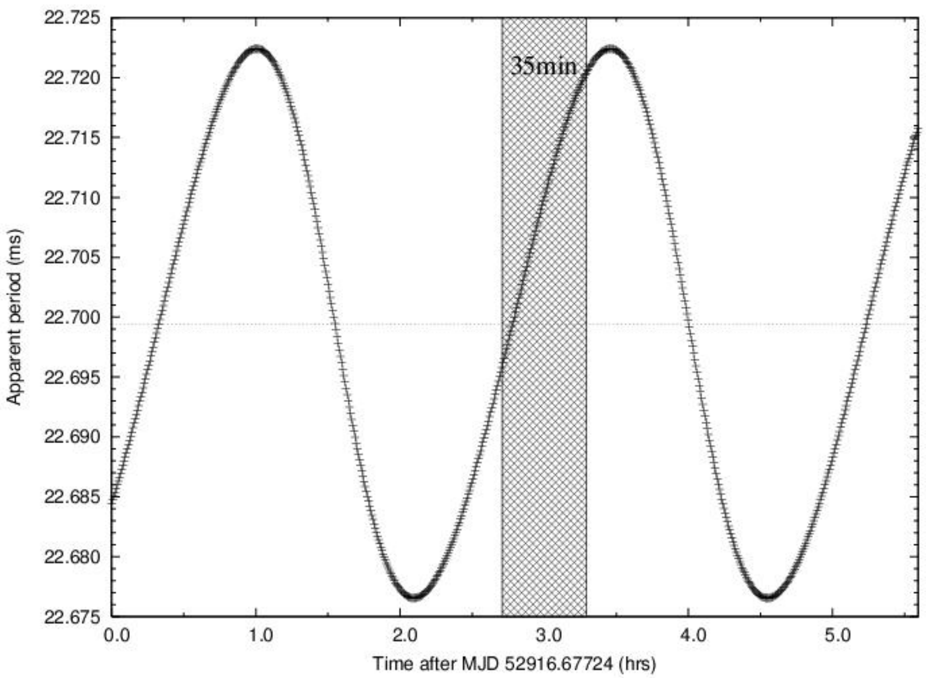
Relativistic binary pulsars

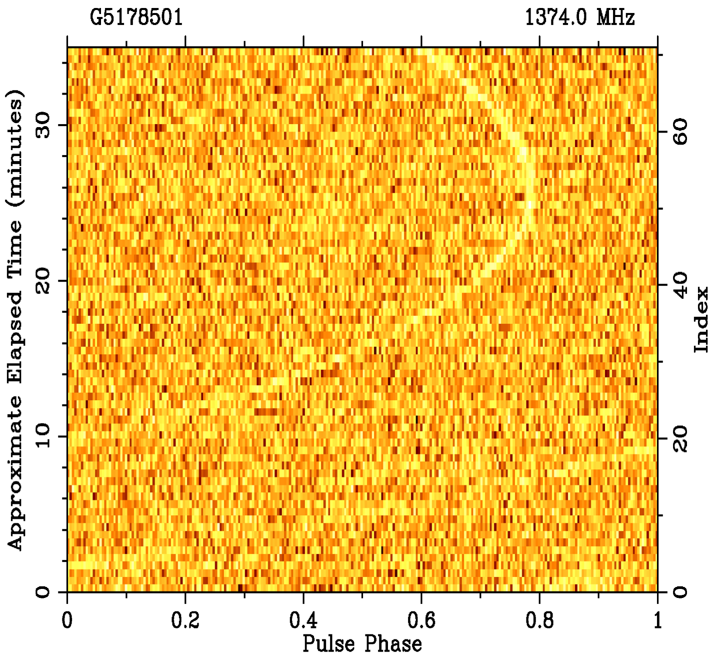
- High mass compact binary pulsar systems, e.g. pulsar mass ~ 1.4 M_{sol}, companion mass ~ 1 – 30 M_{sol}, orbital period < 10 hrs.
- Such systems would provide the most precise tests of gravity in the strong field cf. the double pulsar system now.
- In PSR-BH systems we may be able to probe the properties of the black hole directly with tests of the no hair theorem and the cosmic censorship conjecture.



The detection problem

- Pulsars in highly relativistic binary systems show periodic changes in their pulse frequency due to the Doppler effect.



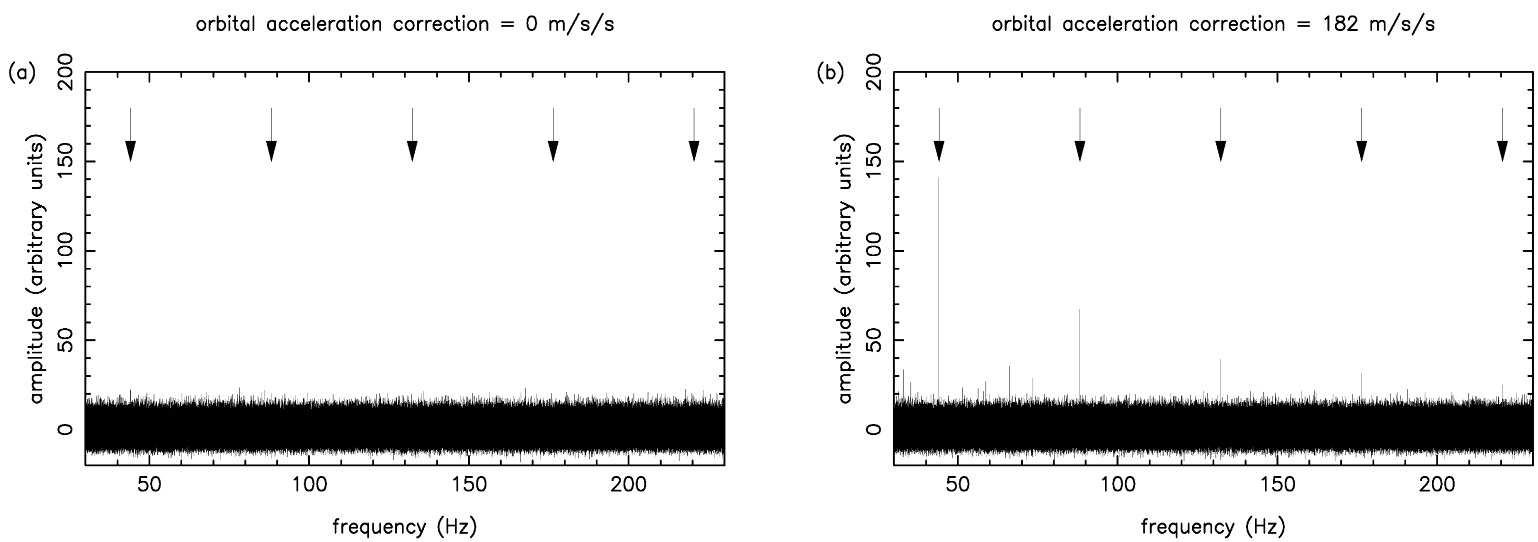


- Standard Fourier based periodicity searches are not sensitive to varying frequency signals.

The detection problem

• If the observation time is a small fraction of the orbital period we can modify the time series to remove the effects of the LOS motion on the pulsar signal assuming a constant orbital acceleration.

• Since the acceleration of any undiscovered binary pulsar is a priori unknown this must be done for all possible orbital accelerations! Increases the number of computational operations in the periodicity search by the same factor.



Current binary search algorithms

Current computational E@H limit for 4 min obs

- **Fully coherent demodulation (matched filters)** – Re-sample the time series with a search over 3 to 5 Keplerian orbital parameters.

$$T_{obs} \geq P_{orb}/2$$

- **Hough transformation** – Search dynamic spectra for faint sinusoidal tracks.

- **Phase modulation searches** – Detect periodic side-bands in power spectra.

$$T_{obs} > P_{orb}$$

- **Acceleration searches** – These can be divided into sub-categories:

  - *Stack searches*. Divide time series into many short chunks and stack resulting spectra with linear offsets. Fast but incoherent method.

  - *Time domain re-sampling.* Coherent demodulation with only one parameter, constant acceleration.

  - *Coherence recovery*. Same procedure as above, but operates in the frequency domain.

$$T_{obs} \leq P_{orb}/10$$

Current binary search algorithms

Can switch to any regime by altering T_{obs}

Current computational E@H limit for 4 min obs

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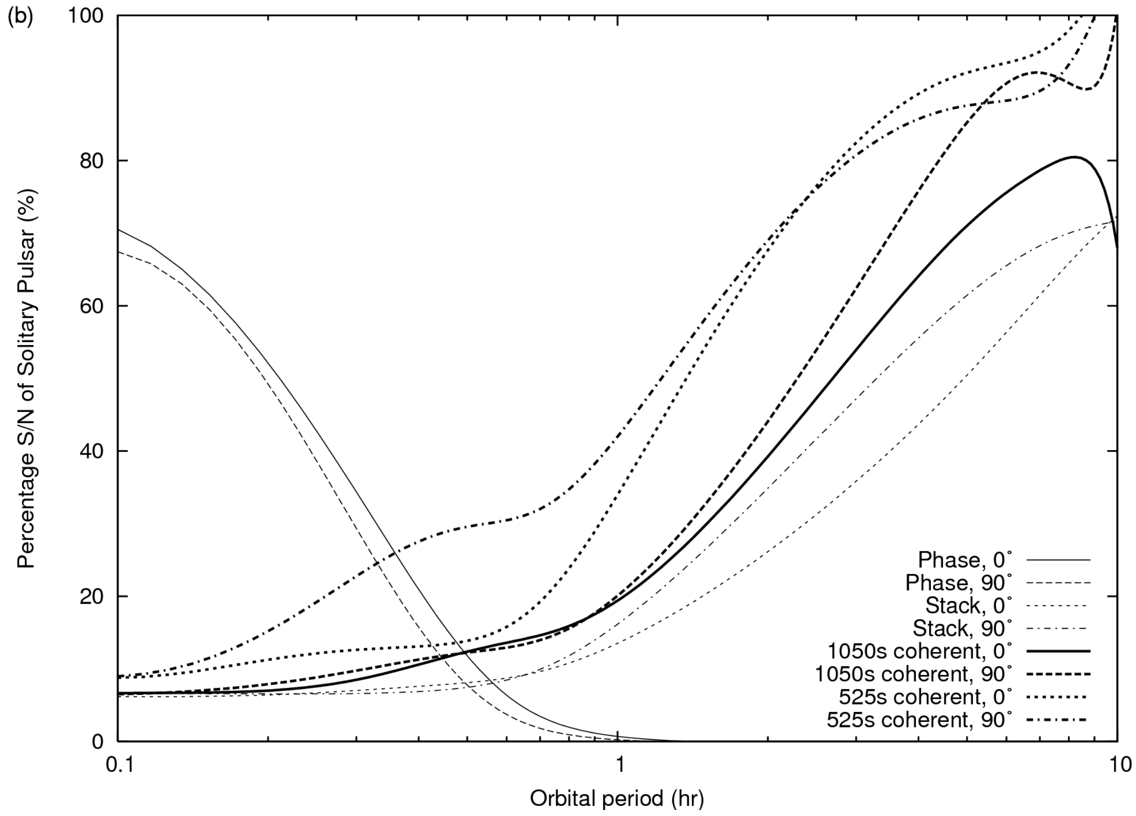
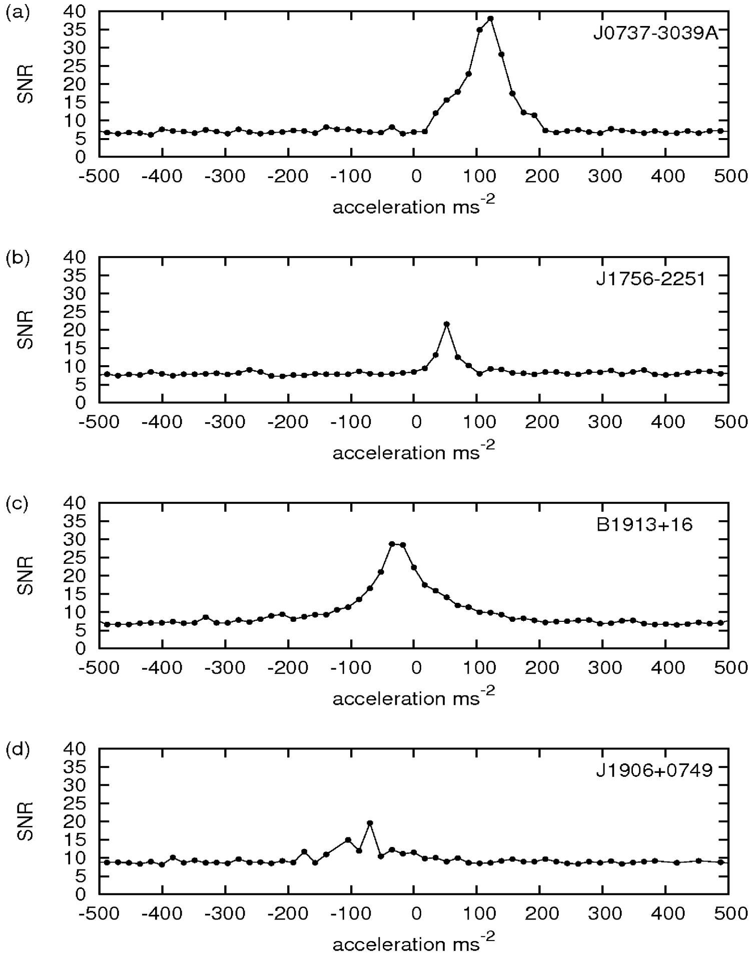
Current binary search algorithms

Methods used in re-analysis of Parkes multi-beam pulsar survey.



Current binary search algorithms

Coherent acceleration search of PMPS. Tests on known relativistic binaries.



The detection problem (revisited)

Computational costs:

• Orbital acceleration searching is typically the dominant process in pulsar searches (~ 70%), followed by dedispersion (~ 10-20%).

• Estimated processing time for last coherent acceleration search of PMPS was ~ 18 yrs with a single CPU. Analysis was performed via GRIDPP using the 1800 CPU Tier2 facility in Manchester. ~ 60 orbital acceleration trials applied.

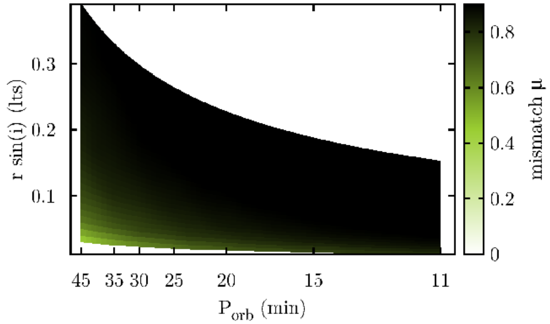
• Processing time for new fully coherent demodulation of PMPS is 370 days using 50% of Einstein@home's 100 000 volunteer computers. ~ 13 000 orbital templates applied. *We expect a factor 4 – 5 increase in speed with new GPU code.*

The detection problem (revisited)

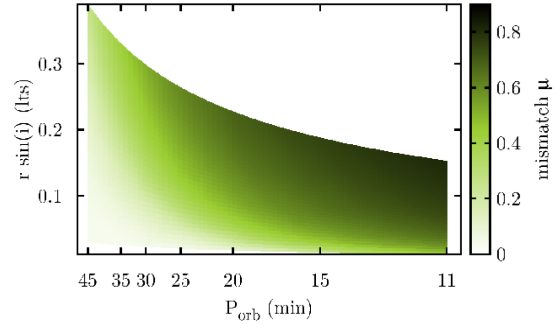
Optimal sampling of binary parameter space with Stochastic/Random template banks

T_{obs} = 268 s

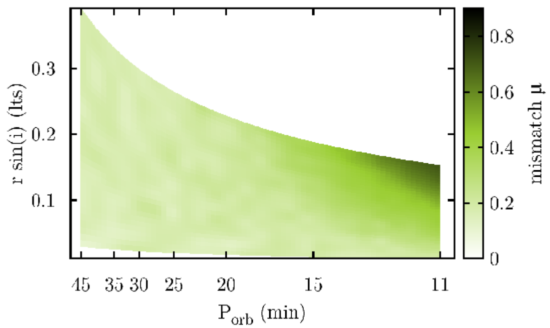
F_0 = 400 Hz



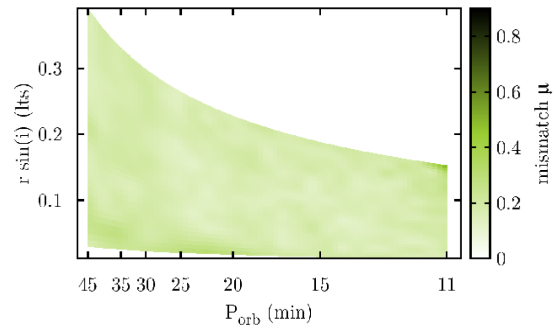
(a) Search over f only.



(b) Acceleration search over f and a.



(c) Acceleration/jerk search over f, a and j.



(d) Full orbital search over f, Ω, τ, and ψ.

B. Knispel, PhD thesis in prep.

Future acceleration searches

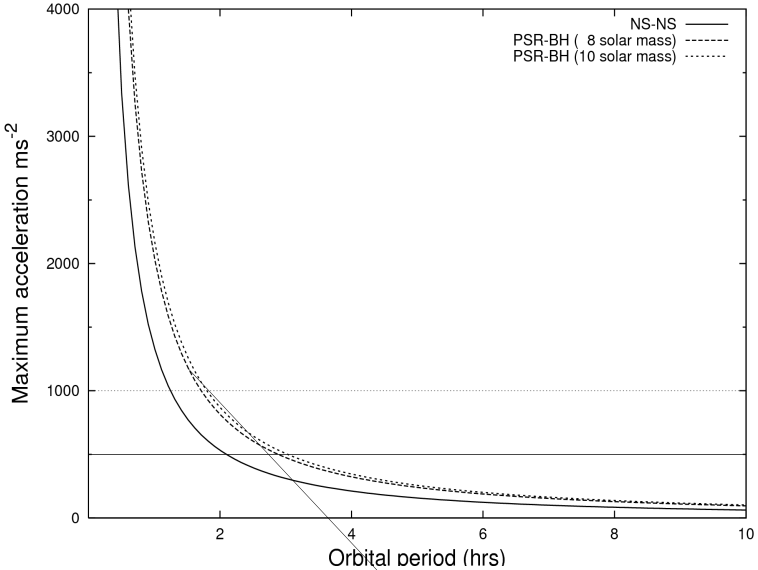
- For the expected pulsar survey integration times for Phase 1 SKA (~ 600s) acceleration searches can probe very interesting regions of binary parameter space (>1.7 hr orbits).

- Current HTRU deep binary searches (538s) will take ~ 4 days per beam. ~ 12 days per year using the ATLAS 7000 CPU cluster.

- Compensating for collecting area with increased observation length will severely hamper searches for binary pulsars.

- Orbits that can be discovered with acceleration searches become less interesting!

- However, phase modulation searches are computationally cheap. Could be applied if observation time goes up.



$$N_{drift} = aT^2 / Pc$$

$$T_{proc} \propto N_{drift}$$

Thanks!

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---------------------------------------------------------
0283_0001_00_8bit.fil was processed on pulsarsrv
Ending UTC time:  Sun Aug  1 12:30:22 2010
Total wall time:  330972.8 s (91.94 hrs)
Fraction of data masked:  2.52%
---------------------------------------------------------
          rfifind time =      0.0 sec ( 0.00%)
       subbanding time =  31337.1 sec ( 9.47%)
     dedispersing time =   3057.1 sec ( 0.92%)
     single-pulse time =  25162.4 sec ( 7.60%)
              FFT time =   4710.1 sec ( 1.42%)
   lo-accelsearch time =  31999.5 sec ( 9.67%)
   hi-accelsearch time = 224620.4 sec (67.87%)
          sifting time =    793.2 sec ( 0.24%)
          folding time =   9137.4 sec ( 2.76%)
---------------------------------------------------------
```

SKA SQUARE KILOMETRE ARRAY

Presto ACCELSEARCH run time dependence on N_{drift} (Z_{max}) parameter.