Binary pulsar searching with GPUs

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20th July 2011

Outline

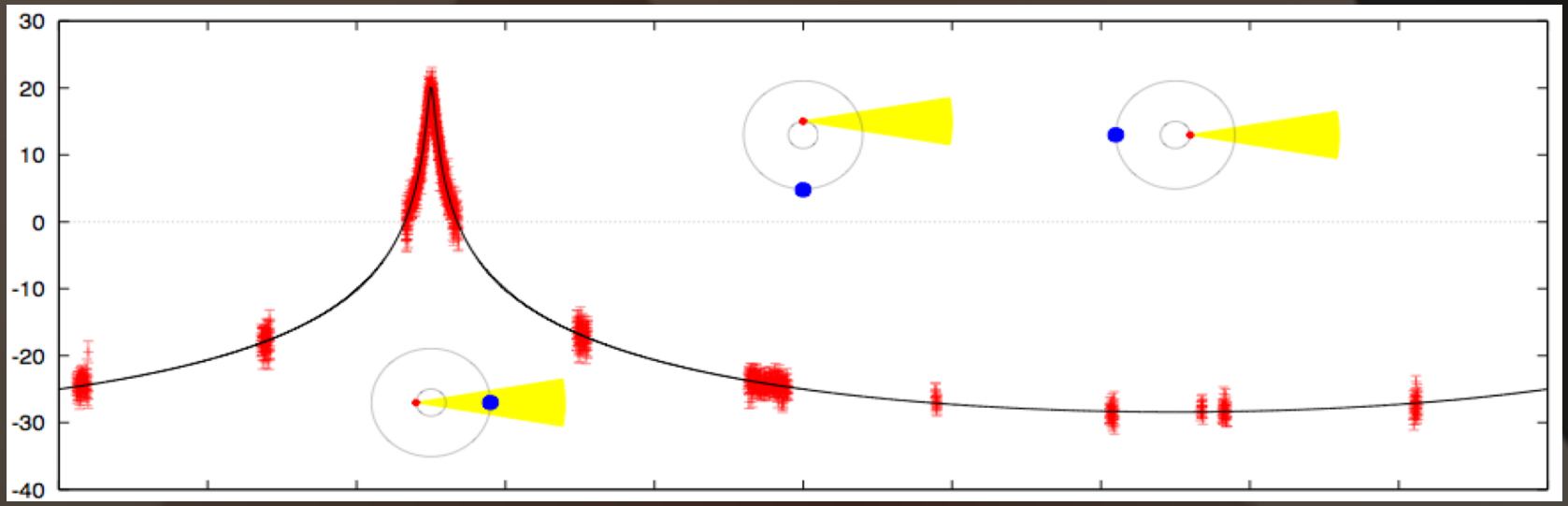
- Motivation
- Pulsar searching
  - Fourier analysis
  - Binary motion modifications
  - Revealing the pulsar
- Applications of GPUs
  - What are GPUs?
  - GPUs in searching

Motivation

- To find new pulsars!
- Particularly millisecond pulsars (MSPs)
- Mass-accretion phase to spin-up to millisecond periods
- Slowing increasing very slowly – long-lived
- GW detection-possibility improvement
- Often in binary systems (PSR-WD, PSR-NS, or PSR-PSR!)
- Timing binaries to test theories of gravity

Pulsars in binary systems

- Why are they interesting?
  - Gravitational effects (e.g Shapiro Delay)
  - Binary stellar evolution models
- Doppler effects make pulsars in binary systems difficult to detect



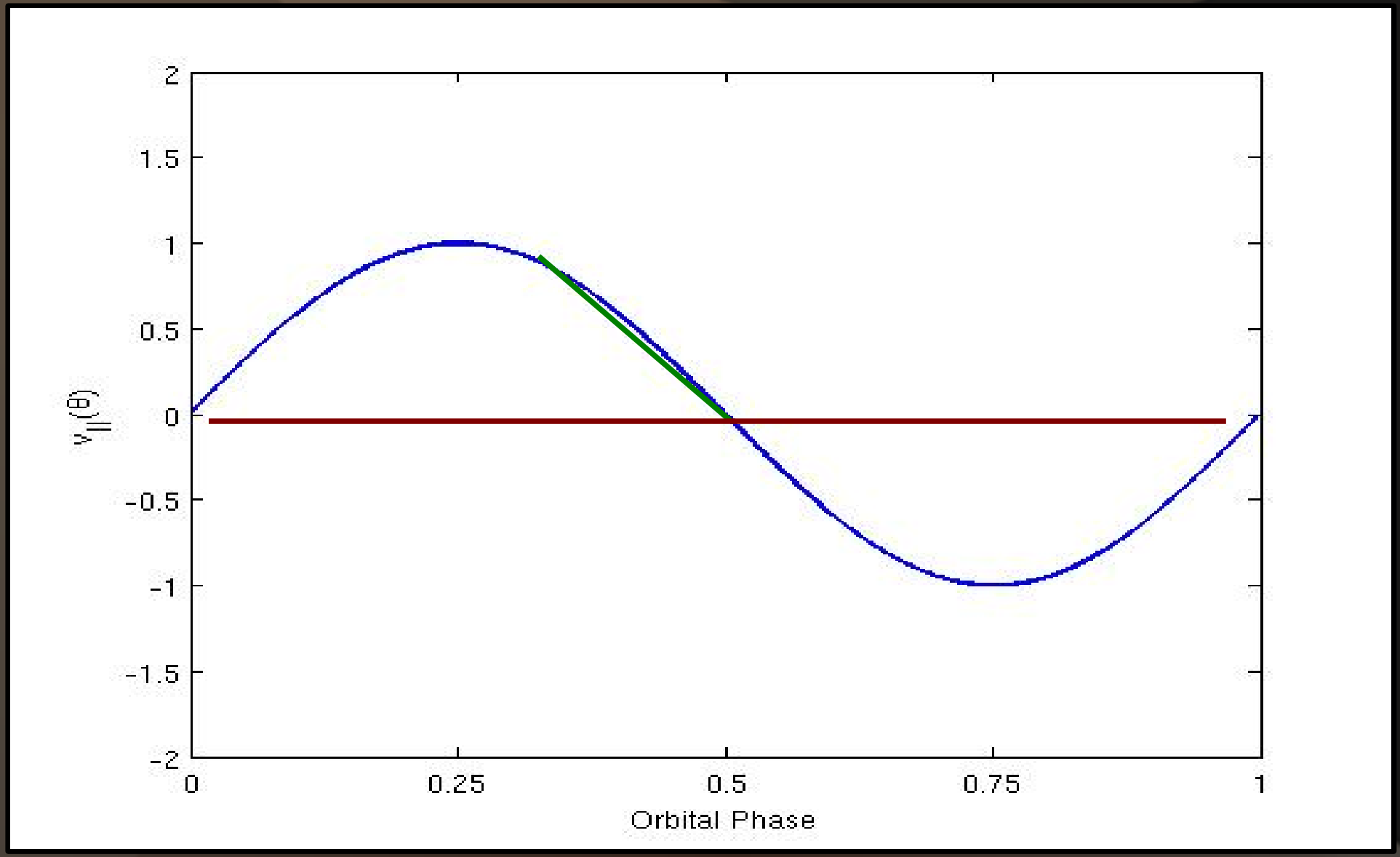
PSR J1614-2230

Demorest et al. 2010

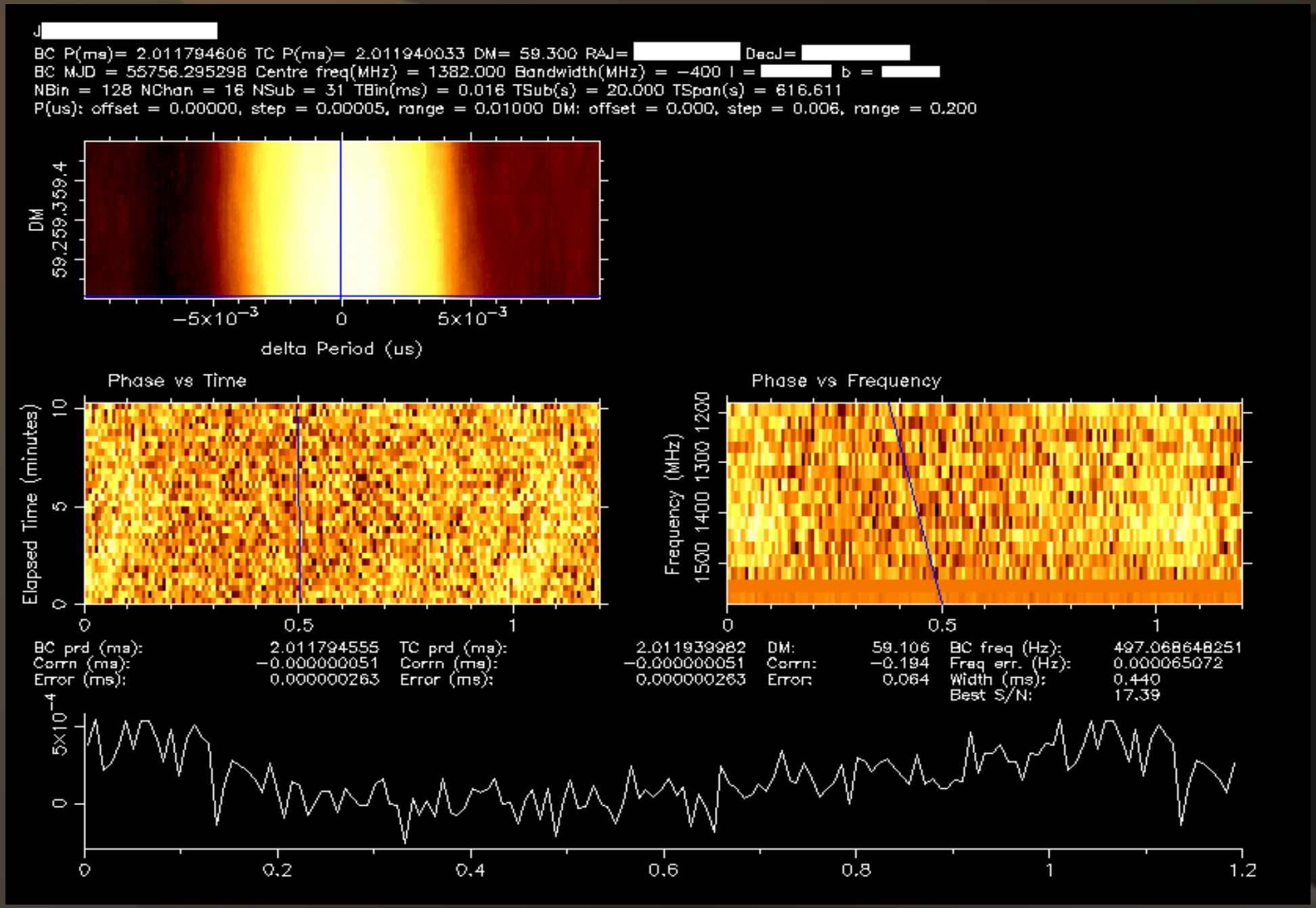
Fourier Analysis

- Pulsars are usually detected by searching for a pulsed signal at an unknown period and DM
- Dedisperse at a test DM value and fft(time_series)
- Harmonic folding
- Pick out significant peaks
- In a binary system the power in the Fourier spectrum is spread around the true pulse frequency by Doppler effect
- Need methods to restore the spread power to a single Fourier bin

Doppler effect on observed period



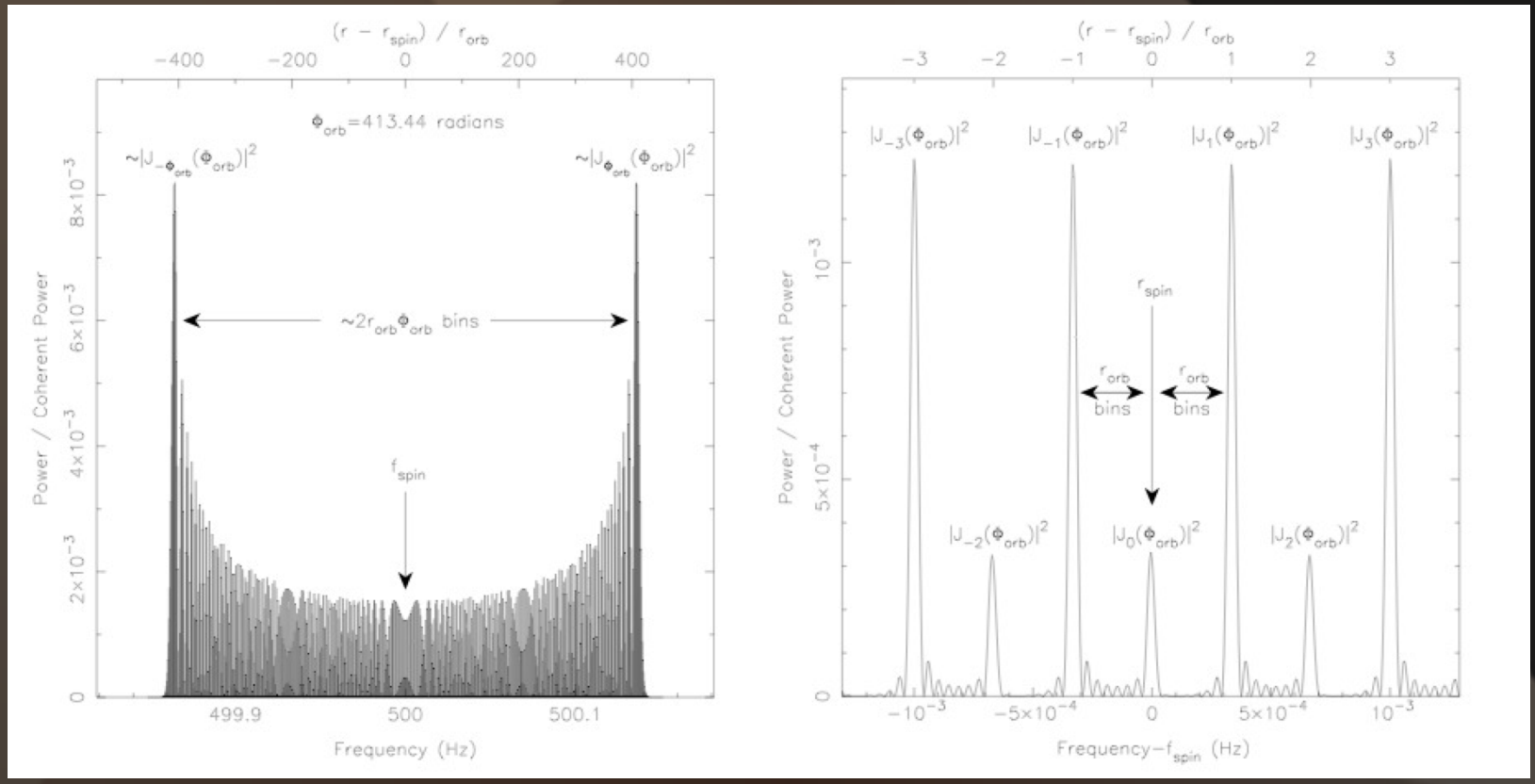
A brand new MSP



Orbital Motion Corrections

- Stretch and resample the time-series pre-FFT to apply a constant acceleration
- The signal appears to originate from a static pulsar
- Normal Fourier analysis continues on the modified time-series
- Good for long orbits relative to the observation time
- Reasonable acceleration range would take ~4 days / beam on a HTRU med-lat pointing!
- Need a faster way for the time-consuming steps
- For longer pointings, there is another method

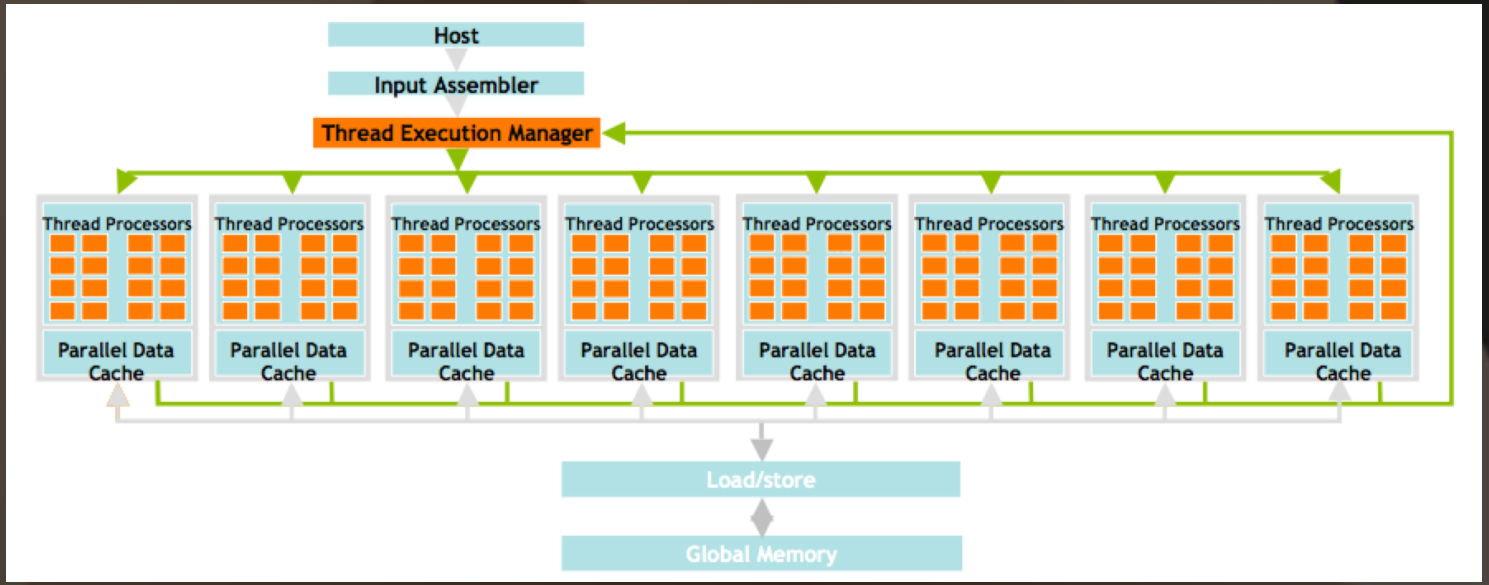
- In this case the power spectrum is affected in a known way about the true pulse frequency
- By convolving the power spectrum with an inverse of the transfer filter power is restored to a single bin
- Fourier transforming small sections of the power spectrum



Ransom, Cordes & Eikenberry 2003

What are GPUs?

- Massively parallel processing
- Can have hundreds of processing cores on a single GPU
- £/flop is lower than traditional supercomputing
- Problem must lend itself to parallelisation



NVIDIA

Acceleration on GPUs

- Current pipeline is sequential
- N acceleration test values increases time by factor N
- Already at ~4 hours for a med-lat HTRU pointing
- Dedispersion already applied on GPUs (Barsdell, 2010)
  - From 80 minutes to 5 minutes with identical results
- The time consuming steps of acceleration searching could be strongly parallel with high memory locality
  - Both creating the stretched time-series, or searching the power spectrum for modulation

Conclusion

- Pulsars in binary systems are an important tool in gravitational astronomy
- Techniques exist to find these Doppler shifted systems but are simply too time-consuming to be practical
- GPUs have already proven effective in de-dispersion, and acceleration searching also lends itself to massively parallel processing

Thank you