Looking for Pulsars in a Parallel World

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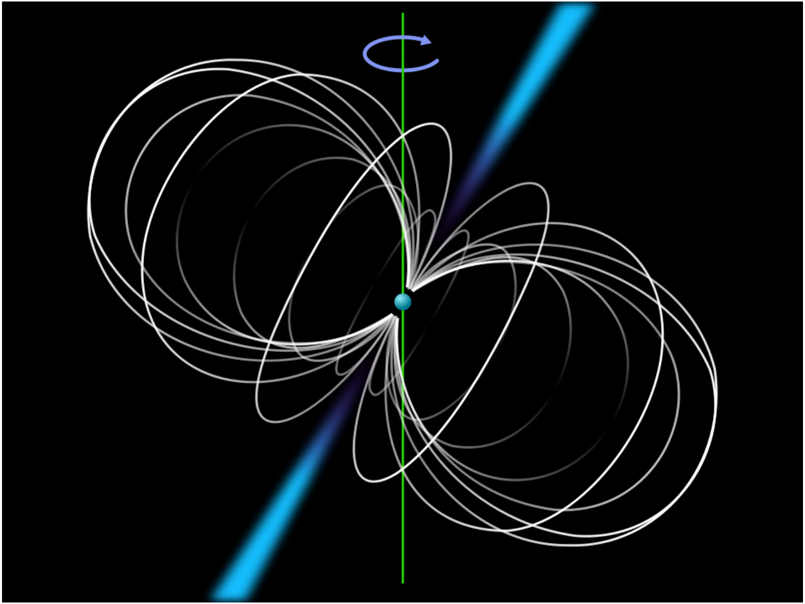
Pulsars (1/3)

- A pulsar is a highly magnetized, rapidly rotating neutron star
- If its magnetic axis lies on Earth's line of sight we perceive a pulse
- The effect is similar to a lighthouse

Pulsars (2/3)



Pulsars (3/3)

Why are pulsars so important for scientists ?

- They are high resolution clocks in space
- A precise clock and gravity: test for general relativity
- Understand the equation of state of neutron stars
- Measure the effect of gravitational waves
- Measure distances in space
- Probe the interstellar medium

Pulsars are labs with conditions impossible to recreate on Earth

Challenges

There are many challenges in the search for pulsars

- Radio frequency interference
- Dispersion, scintillation, scattering
- Binary systems
- Fast periods: millisecond pulsars
- Faint signals: long integration time

Searching Process

- Collect and store the received signals

Searching Process

- Collect and store the received signals
- Dedisperse using tentative dispersion measures

Dedispersion

Dispersion is one of the most serious problems

- A Signal does not propagate uniformly in the ISM[1]
- The speed depends on the frequency of the signal
- The lower the frequency, the more the delay
- $\Delta t \simeq 4.15 \times 10^6 \times (\frac{1}{f_1^2} - \frac{1}{f_2^2}) \times DM$

Need to compensate for this delay for every possible DM[2]

[1] Inter Stellar Medium
[2] Dispersion Measure

Searching Process

- Collect and store the received signals
- Dedisperse using tentative dispersion measures
- Perform period analysis

Period Analysis

There are two classical approaches to perform period analysis

- Search in the “frequency domain”
    - Fourier transform
    - Search for peaks
- Search in the “time domain”
    - Fold the time series
    - Search for high S/N ratio

- The frequency domain search is less computational intensive
- It is the current standard approach

Searching Process

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Searching Process

- Collect and store the received signals
- Dedisperse using tentative dispersion measures
- Perform period analysis
- Integrate over time
- Test for statistical relevance

Parallelizing the Process

Today’s world of high performance computing: many-core

1. GPUs
2. Multi-core CPU nodes
3. AMD Fusion
4. Intel Ivy Bridge
5. Intel MIC
6. etc.

“Brute forcing” in the time domain looks feasible now

GPU Dedispersion

Dedispersion

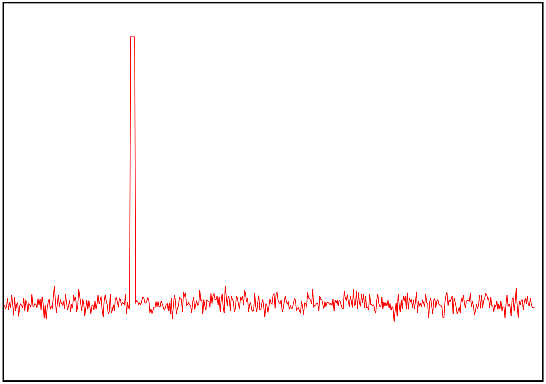
- Shift the input time series
- Brute force: try different DMs
- No inter-DM dependencies

Performance (so far)

- 156 GFLOP/s
- GPU: NVIDIA GTX580
- Frequency channels: 512
- Samples per second: 12288
- Trial DMs: 2048

GPU Folding

- Millisecond pulsars: maximum period of 1 second
- Two algorithms: naive and tree



What's Next ?

- Improve the kernels' performance
- Discuss with domain scientists
- Research new algorithms
- Parallelize the statistical relevance test
- Optimize the whole pipeline
- Use multi-GPU nodes