Searching for Pulsars and Fast Transients with the SKA

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This work is a collaboration among:

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NZ Alliance

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UNIVERSITY OF OXFORD

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ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

Max-Planck-Institut für Radioastronomie

Outline

- Overview & goals
- What's new
- Challenges – acceleration search
- Solutions
- Benchmarks
- Future Work

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What is your favorite pulsar?

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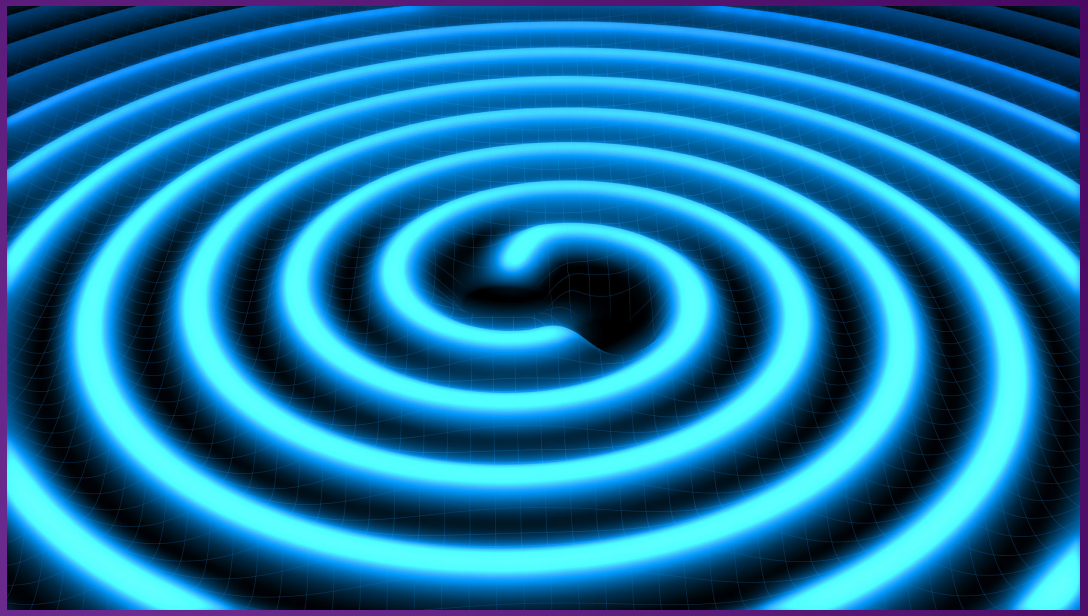
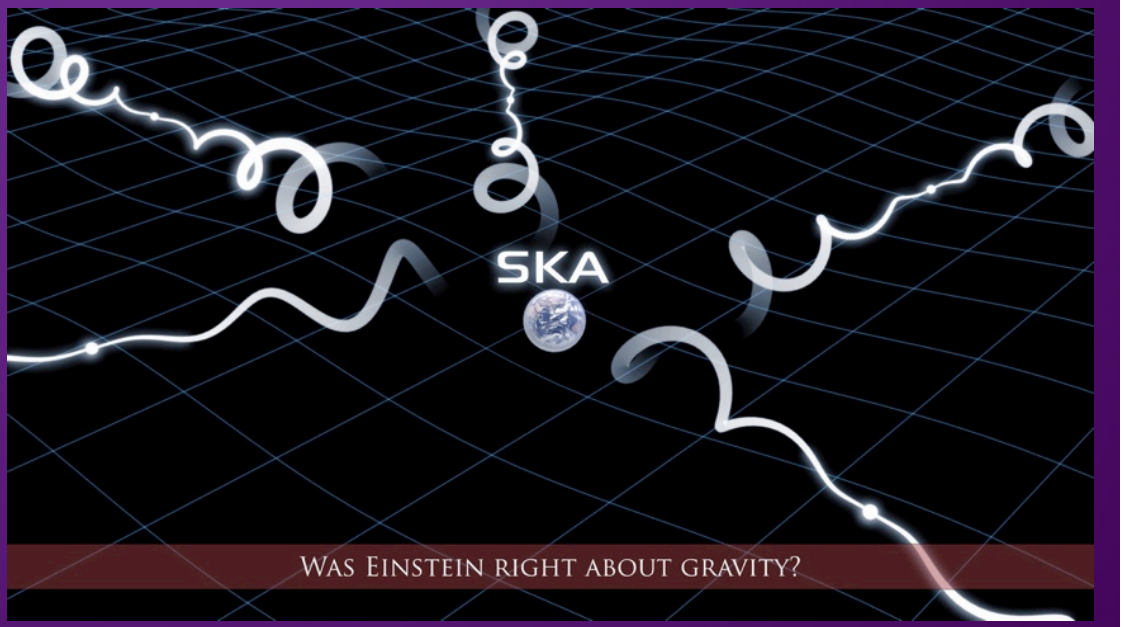
Goals of PSS

- Gravitational Waves
- Strong tests of gravity, general relativity
- Fast transients, new phenomena



SKA Organisation/Swinburne Astronomy Productions



SKA Organisation/Swinburne Astronomy Productions

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Goals of PSS

- Order of magnitude more pulsars
- Find interesting systems
- Detect transients in real time

SKA Organisation/Swinburne Astronomy Productions

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Pulsars are a key science goal for the SKA

- Key science goals of the pulsar survey with the SKA:
  - Discover pulsar/black hole binaries to perform tests of gravity
  - Discover pulsars in the Galactic centre orbiting the supermassive black hole
  - Discover millisecond pulsars to enable direct detection of gravitational waves
  - Discover sub-millisecond pulsars to constrain the equation of state of super-dense matter
- The SKA is expected to discover 14000 normal pulsar and 6000 millisecond pulsars

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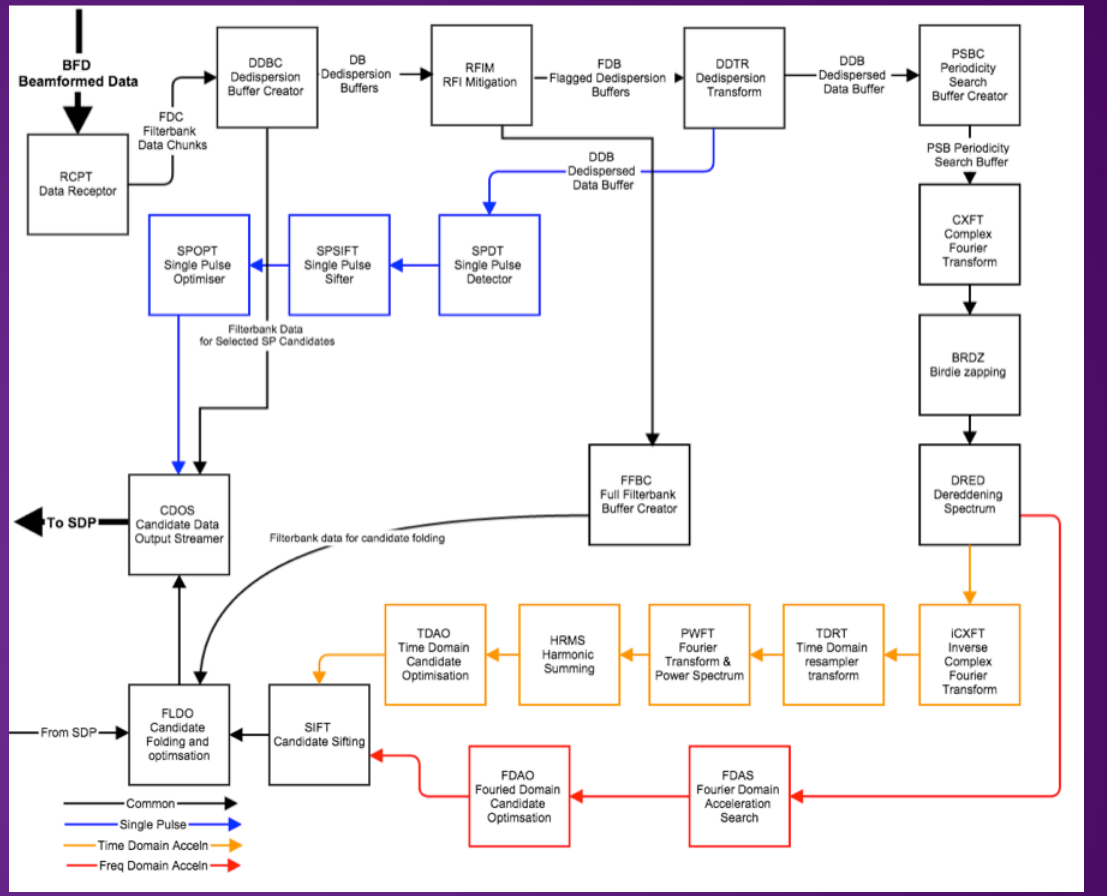
PSS overview



	Mid	Low
Sampling time (µs)	64	128
Beams	1500	500
Channels	4096	8192
Bandwidth (MHz)	320	100

Common Observing Parameters	
Observation length (s)	540
Data bit width	8
Dedispersion trials	6000
Acceleration trials	84 + 1
Harmonics summed	Up to 8

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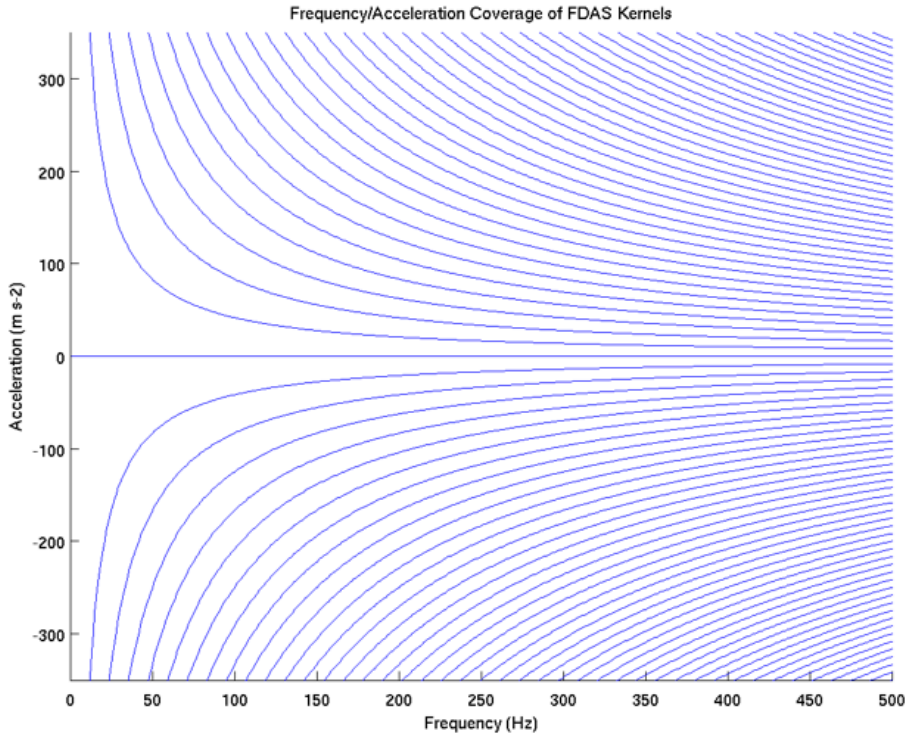
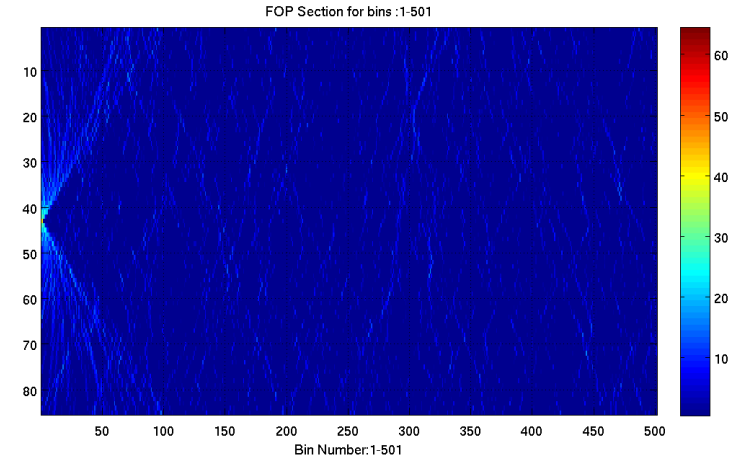
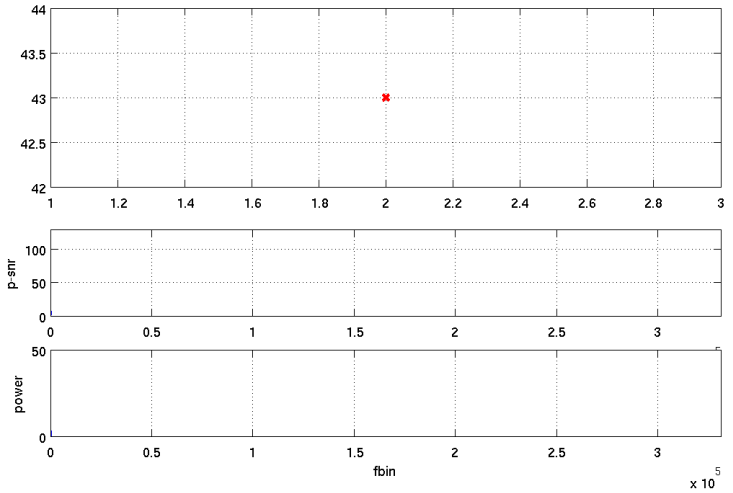
What's new?

- 6000 DMs, 6000 8Mpoint FFTs, 85 acceleration trials







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What's new?

- 6000 DMs, 6000 8Mpoint FFTs, 85 acceleration trials
- Detect, sift, and optimize transients in < few seconds
- Two orders of magnitude more beams than previous real-time searches, and those did not include acceleration searches

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Challenges, briefly

- >10 POps of processing required
- Acceleration search ~10 POps, very computationally intensive
- Entire search must be done in real time

What if we cut our acceleration phase space?

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Why do we need acceleration searches?

- Without any acceleration search, we won't find the most exciting systems

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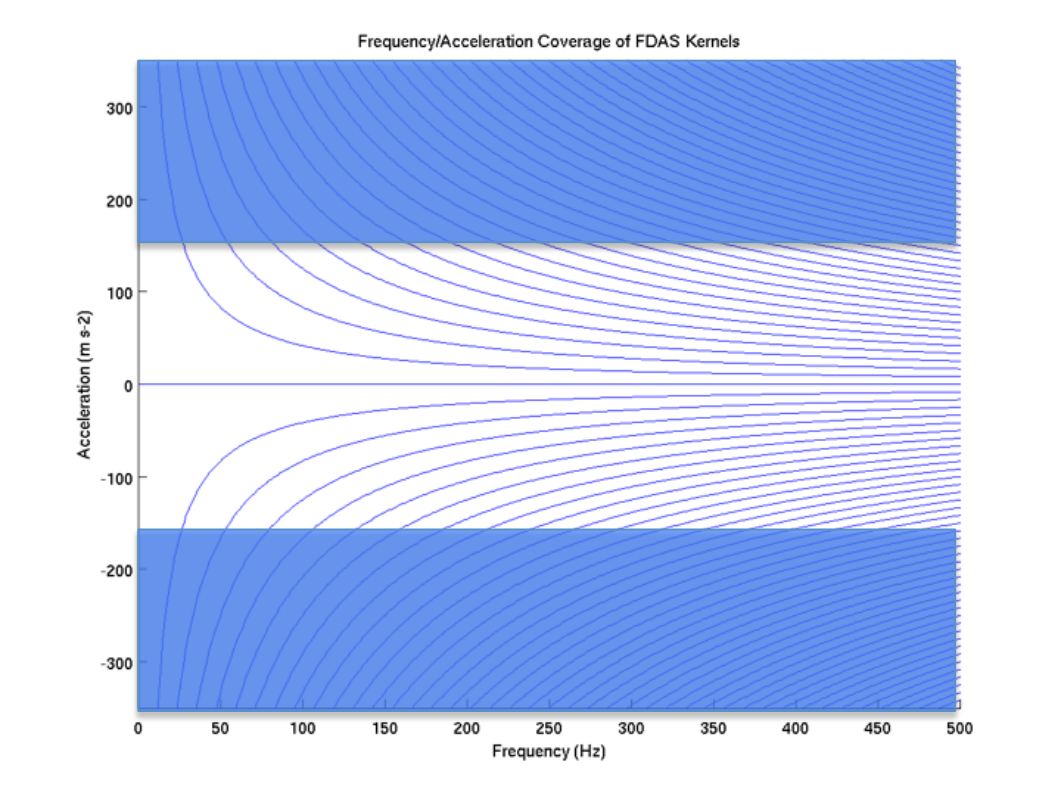

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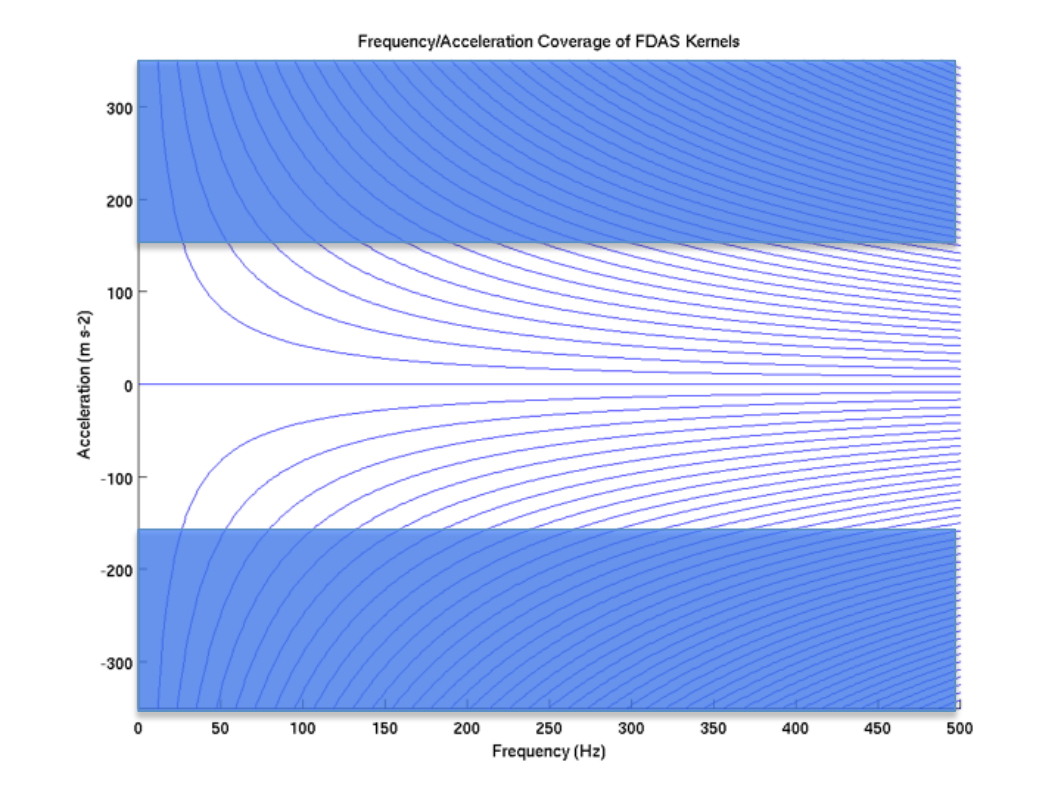
Why do we need acceleration searches?

- Interesting systems will have high acceleration and populate the corners of our phase space



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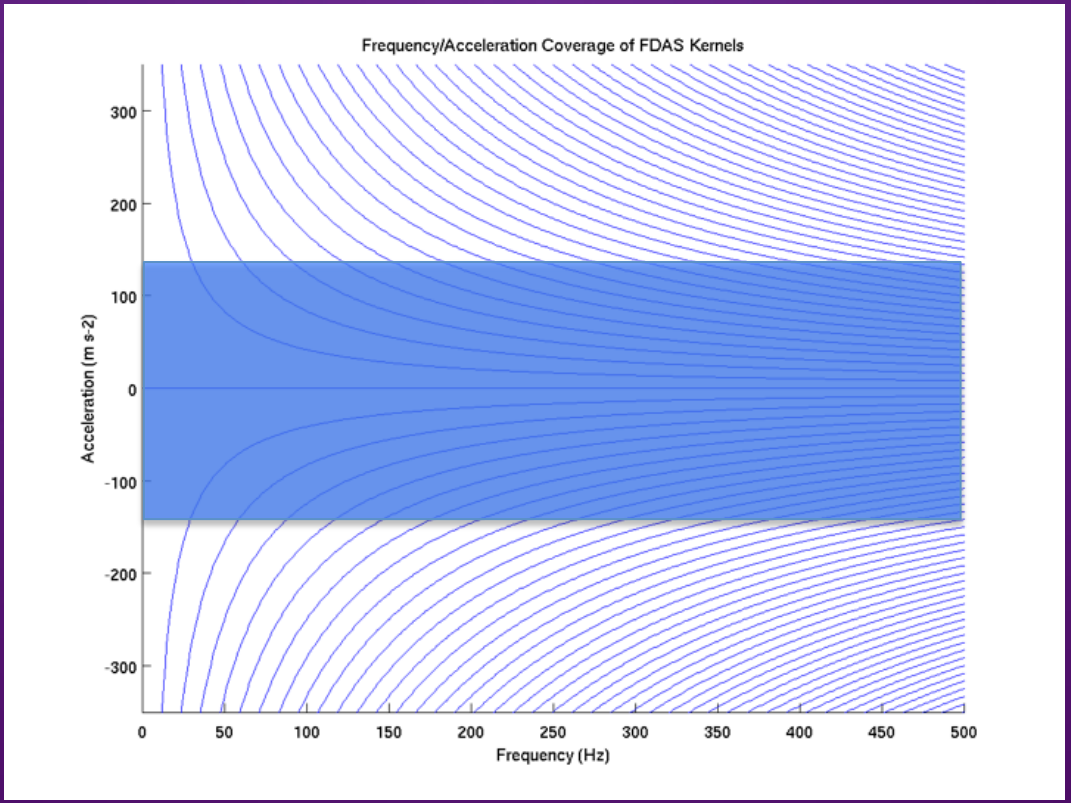

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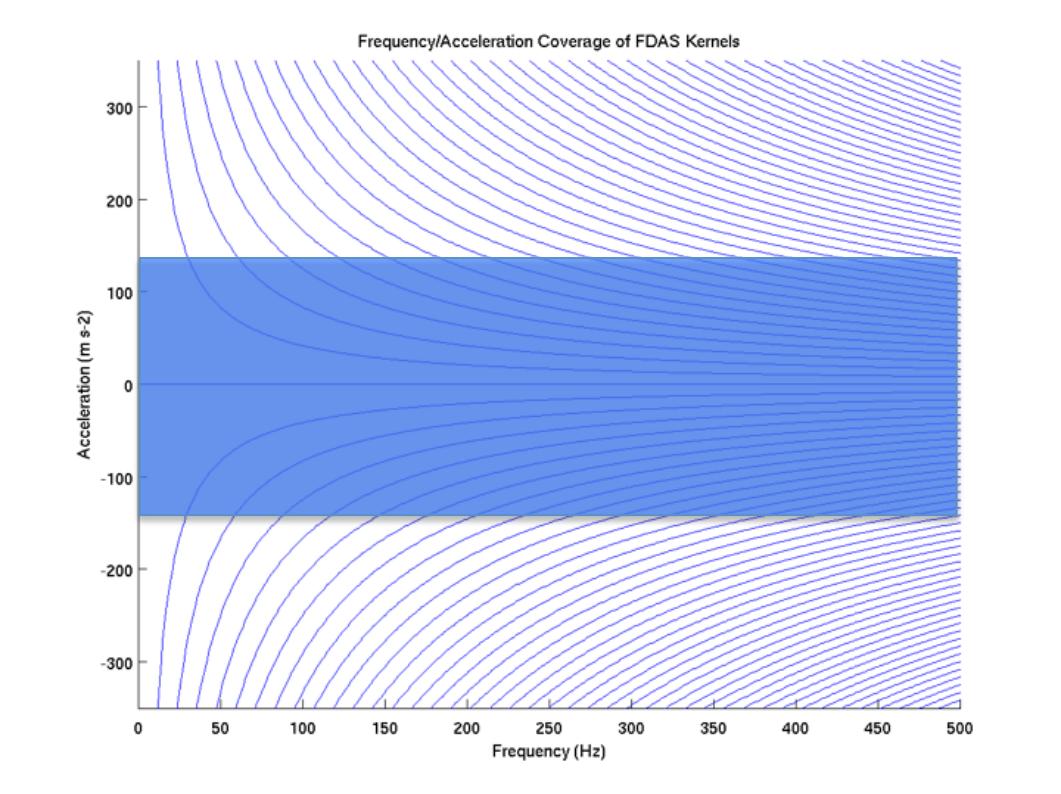
Why do we need acceleration searches?

- Can’t ignore the middle of the phase space, we will miss a lot of science



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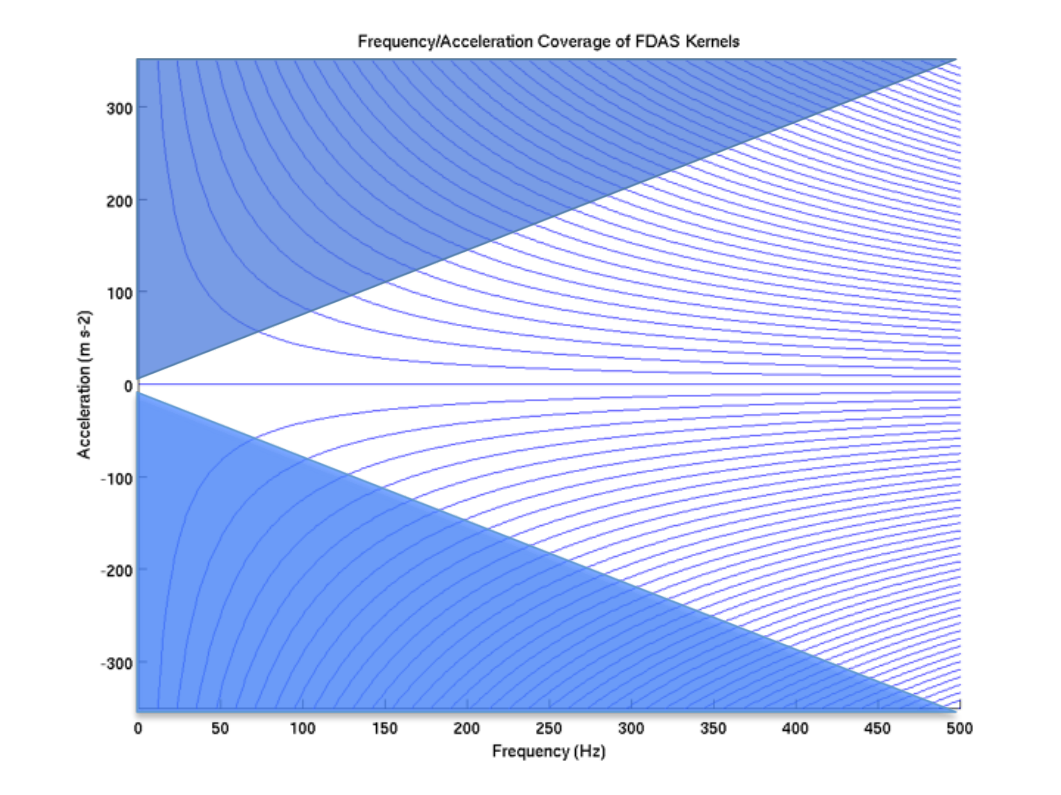

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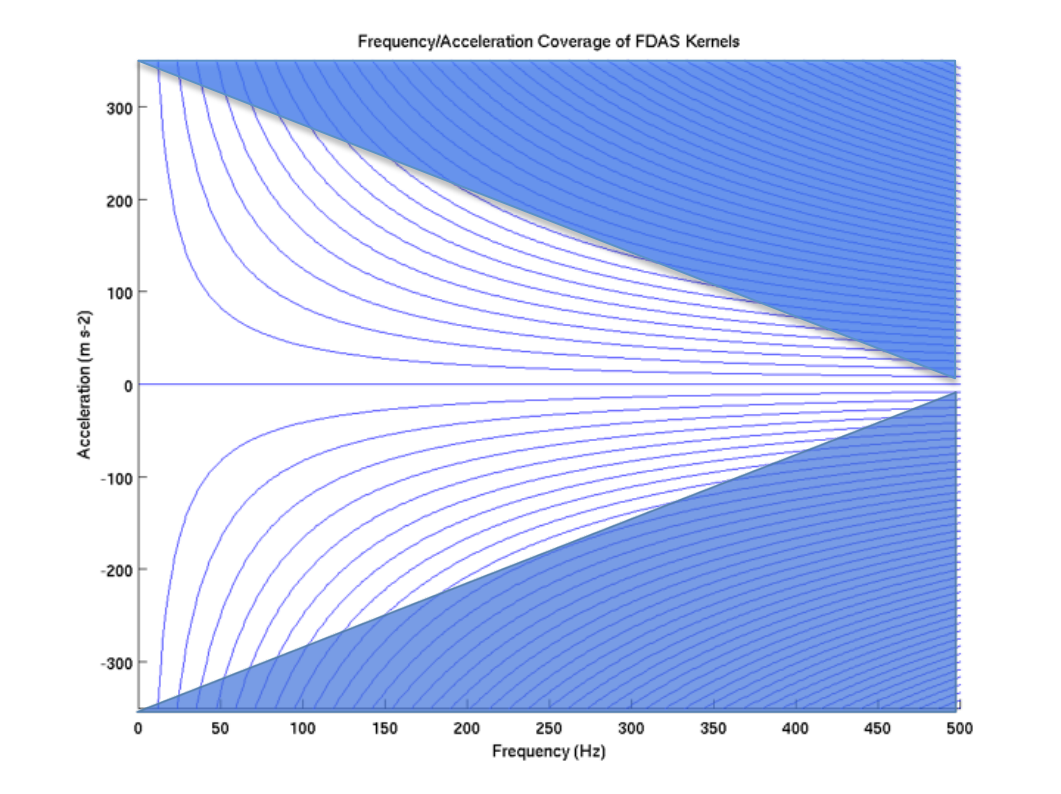

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Why do we need acceleration searches?

- Could find pulsar/black hole binary in last two scenarios
- Can’t focus on what we know we want to find

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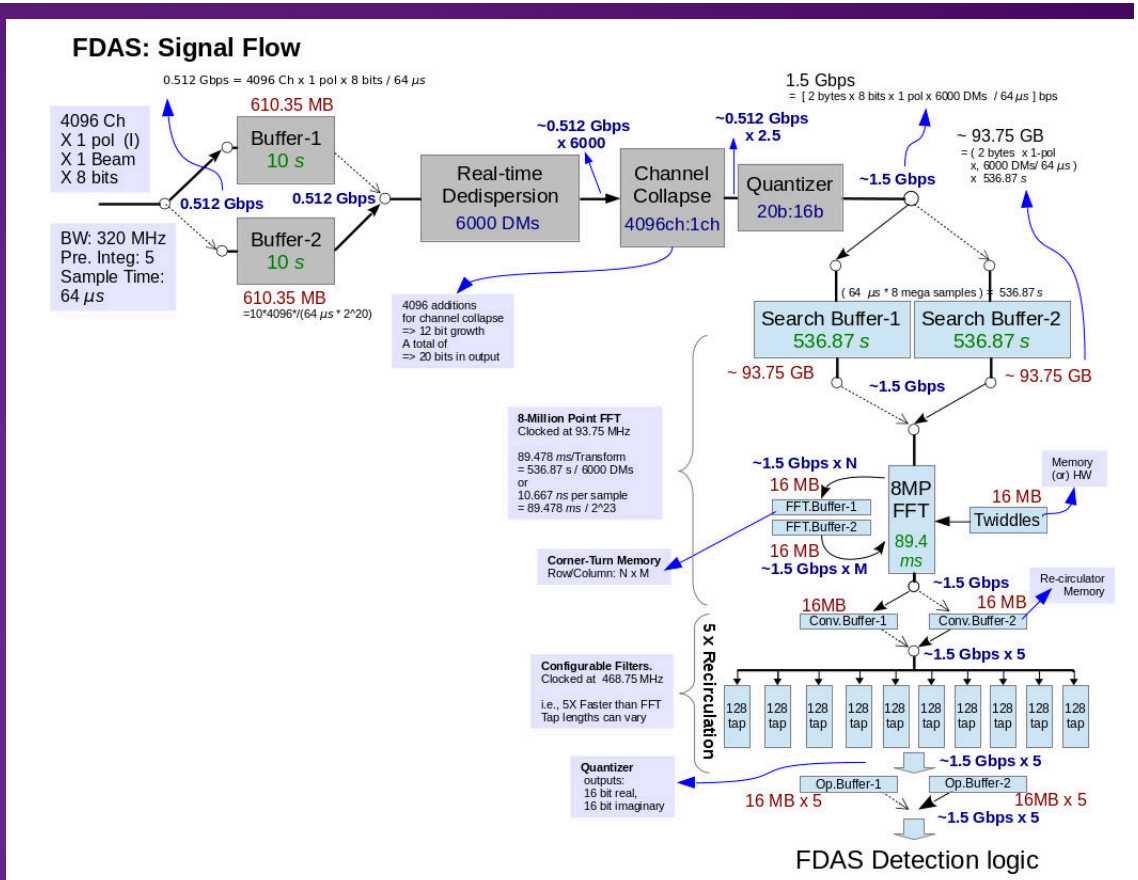
Challenges



- Complex algorithms with high computational load
- Need to have a processing rate of >10 Pflops
- Real-time processing at low power; need 25 Gflops/Watt – 5X better than current greenest computers!
- High data rate (~60 PB/day) – can't record for offline processing

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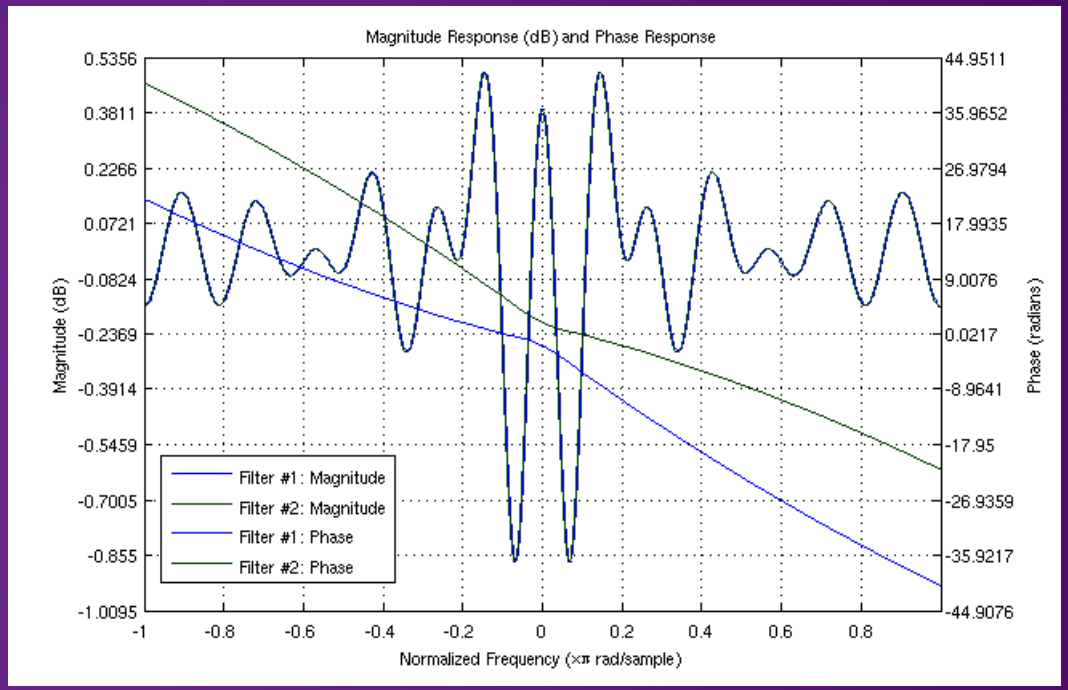
Solutions



Hardware

- GPUs
- FPGAs

Software

- Better/faster algorithms
- Innovative approaches to reduce processing times

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Solutions: Hardware

GPUs

- *Work mainly focused on dedispersion and acceleration searching*

FPGAs

- *Work mainly focused on long FFTs and convolution*

- Different architectures for different problems
- Power usage
- Mixed design – greater robustness to rapid tech change, other configurations of beams/nodes/accelerators for power use, more scope to get good deal in procurement

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Solutions: Software

- Faster algorithms – e.g. PRESTO GPU acceleration search code 30X slower than real time. Optimizing structure and execution of FFTs should increase performance by order of magnitude.

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Solutions: Software

- Innovative approaches – e.g. acceleration search done through convolution with complex templates. Can exploit conjugate symmetry and use half of the templates + their complex conjugates, reducing multiplication load by 50%.

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PSS prototype benchmarks

Current best performance of top accelerators for most computationally intensive modules reported in multiples of real time (>1 faster than real time).

	RFIM	DDTR	CXFT	FDAS	FLDO	SPS
Altera Stratix V	--	1.5	--	--	--	2.4
Altera Arria 10	14.3	0.9	3.7	0.6	1.2	2.4
Altera Stratix 10	--	--	--	--	2.4	--
NVIDIA GTX 1080	--	--	--	--	6.4	--
NVIDIA P100	--	--	--	1.3	--	6.5

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Current & future work: protoNIP

- 17 node prototype to be installed on MeerKAT
- To test density, power consumption, heat dissipation in real PSS environment
- To test reliability and maintainability of potential components
- To test logistical assumptions, further mitigate cost uncertainties
- protoNIP on site, installed soon, used to inform PSS CDR