Pulsars with MeerKAT

Scott Ransom
NRAO, Charlottesville

Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array
Basic Pulsar Notes...

• All pulsar science is sensitivity limited
  – MeerKAT's improvement over Parkes will be excellent for Southern PSRs
  – Large sky coverage and similar capabilities to GBT make it very complementary to the GBT
  – If Arecibo or FAST can see a pulsar they will win

• Timing is much easier than searching (even for targeted searches)
  – Can start this right away (i.e. Bailes et al proposal)

• Large-scale surveys generate a lot of data, require a lot of computing, and will need a lot of manpower

• Pointed surveys (GCs, SNRs, Fermi sources) and high-precision timing campaigns make excellent early science
MeerKAT can be one of the best pulsar telescopes in the world

• Need excellent **receivers** (wide band and low Tsys)...
  – **Timing:**
    • ~200MHz BW single pixel at ~800MHz *(most PSRs)*
    • ~1-2 GHz of BW from 1200-3000MHz *(high-precision)*
  – **Searching:**
    • ~100 MHz BW single pixel at ~400 MHz *(all sky)*
    • Low Tsys L-band multi-beam system *(galactic plane)*
• ...and excellent **backends**
  – Pulsar observations have been limited by the backends
  – But today they are limited by the receivers *(bandwidth)*
  – Search backends are different from timing backends
Pulsar Backends

- Should cover the full bandwidth of the receiver
- Use at least 8-bit sampling and Polyphase FBs for RFI rejection
- **Acquire them as late as possible! (they are computing)**
- FPGAs (and GPUs?) are key for near future (i.e. CASPER)
- **Search Backends:**
  - Sampling rates of ~50us for millisecond pulsars
  - 512-4096 channels output with ~4bits
  - These are now simple and cheap (combine in future?)
- **Timing Backends:**
  - Need one (or 2 for simultaneous feeds)
  - Full-Stokes
  - Coherent Dedispersion (required for ultra-high precision)
  - These are becoming much easier...
GUPPI: GBT's Pulsar Backend

- High dynamic range (8-bit sampling) with Full Stokes
- "CASPER" FPGA-based technology from Berkeley
- 9x more BW ~ 3x more sensitive than GASP
- Large improvement in timing precision and "control" of ISM effects
- Ransom, Demorest, Ford, McCullough, Ray, DuPlain, Brandt

e.g. Parsons et al 2006; http://seti.berkeley.edu/casper/

CASPER “iBob” with 2xADC boards (2Gspfs each)

CASPER “BEE2” compute board with 5 fast FPGAs
GUPPI's Coherent Dedispersion

- BEE2 feeds 8 gaming systems w/ NVIDIA GPUs (programmed by Paul Demorest)
- Large improvement in timing precision (i.e. for NANOGrav)
- Clone for Arecibo and software version for EVLA this year....

~1 TFLOP in real-time!
An example: MSP J1614-2230

- 3.15 ms in 8.7 day binary
- Gamma-ray pulsar
- >0.4 Msun companion
- Orbital timing systematics from past years?

Coherent GUPPI at Lband
An example: MSP J1614-2230

Mwd = 0.500(6) M⊙

Mpsr = 1.97(4) M⊙!

Inclination = 89.17(2) deg!

Demorest et al 2010, Nature
Green Bank North Celestial Cap Survey

Same basic cast as driftscan survey (PI Ransom)
1300 hrs @50 MB/s, 100MHz BW @ 350MHz, ~19% of sky!
Expect 100+ new pulsars and more than a dozen MSPs
Radio Searches of Fermi UnIDd Sources
International “Pulsar Search Collaboration” with Fermi team

23 New MSPs so far... Expect many more.
Will likely be a boon for MeerKAT High Precision Timing
NANOGrav

- nanograv.org
- About 22 members from North America
- Observing ~20 MSPs
- Using Arecibo and the GBT via 2 large projects (PI Paul Demorest)
- 2 obs freqs at GBT, 2-3 at Arecibo per PSR
- ~7 MSPs with RMS residuals ~40-200 ns
- Recently awarded a 5-yr $6.5M PIRE Grant
- Highly ranked by Astro2010

Some interesting thoughts for the future...

- From Astro2010 Main panel:
  - 1 of 9 projects suggested to compete for new $10-100M NSF ground-based funding line
  - That line was the #2 ground-based recommendation
- This may allow funding to do something special
  - Additional collecting area for MeerKAT?
  - Additional instrumentation or improvements for MeerKAT?
  - Any other ideas?