Food for thought - WV pulsar research

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• Introduction to pulsars
• Pulsar Searching/Timing
• GBT drift-scan survey
• Pulsar Search Collaboratory
• The future
Pulsars are rotating neutron stars

Neutron stars are compact remnants of supernova explosions supported by neutron degeneracy pressure.

Radius ~ 10 km
M ~ 1.4 x Sun
Neutron stars are extreme ...

- Extremely dense objects
  - $100,000,000,000,000,000,000 \text{ kg m}^{-3}$
- Extremely rapid rotators
  - Spin rates up to 719 Hz currently known
- Extremely high magnetic fields
  - $<10,000,000,000,000 \times \text{Earth’s field}$
- Extremely fast moving stars
  - Up to and beyond 1000 km/s
Neutron stars pop up all over the place
Pulsar searching

Then search for faint dispersed periodic pulses...
Example periodicity search output

2 Pulses of Best Profile spigot_54225_0003_0195.fil

Search Information

Pulse Parameters

- R_pulse = 18:31:50.2508
- DEC_pulse = -63:29:00.6353

Folding Parameters

- Reduced \chi^2 = 7.307
- \chi^2 (Hz) < 0.03x274 (w35.3c)

Dispersion Measure (DM)

- DM = 234.328

Timing Parameters

- P = 686.666(16) ms
- P = 0.0(5.1)x10^-10 (s/s)

Binary Parameters

- E = N/A
- \omega (rad) = N/A
- \Theta_{ph} = N/A

Pdot

- P-dot = -9.927e-11 (s/s)

Period

- Period = 686.66623604 ms

Frequency

- Freq = 1.45630 Hz

Reduced \chi^2

- Reduced \chi^2 = 0.8
Example single-pulse search output
By incorporating a model for the motion of the Earth around the Sun, our telescope’s location and the pulsar properties, we can effectively count every NS rotation!

This results in astonishing precision measurements of a wide variety of parameters relevant to the star...
Timing model residuals

(a) Best-fit residuals

(b) Zero period derivative

(c) 1-arcmin position error

(d) Zero proper motion
In the summer of 2007, we carried out a large-scale survey during GBT track repair at 350 MHz.

40.96 us sampling
2048 channels over 50 MHz
Data rate of 90 Gbyte/hr
150-s “pointings”

Over 30% of sky visible from GB covered.

25 new pulsars found so far (~100 expected in total)
Millisecond pulsars are recycled to superfast spin periods through accretion of material and angular momentum from a companion star.

During accretion, binary is visible as a low mass X-ray binary (LMXB) and radio emission is quenched.

Credit: Bill Saxton (NRAO)
PSR J1023+10 - the missing link!

P=1.69 ms

Very bright!

Signal is eclipsed at random times throughout orbit!
Some interesting history...

Associated with known variable VLA (radio) source.

1999 optical observations show spectrum consistent with G star and Doppler shifts consistent with 4.7 hour orbit.

Szkody et al. 2003

Becker et al. 1995
In 2000, this source showed optical emission lines and flickering $\rightarrow$ accretion disk!

But obs in 2001 and 2002 show return to quiescent G-star state (Homer et al. 2006).
Some interesting history...

2004 XMM-Newton observation shows power-law spectrum consistent with quiescent LMXB. Optical obs at same time show quiescent state. Our 2008 SOAR observations confirm quiescence.

Homer et al. 2006
Radio properties

Companion mass of 0.1-0.4 solar masses!

Lots of eclipses, minieclipses and DM variations.

Orbital period measured from timing seals the link... providing new insights into pulsar evolution!
Some of these data are being analyzed by WV/VA high-school students!

http://pulsarsearchcollaboratory.com
PSC student interface

http://psrsearch.wvu.edu
First PSC discovery - Lucas Bolyard

http://www.nrao.edu/pr/2009/pulsarstudent/
Holy grails for the near future

• More discoveries by students
  - Career changing implications

• A pulsar-black hole binary
  - Amazing new test of Einstein

• A pulsar spinning at >1000 Hz!
  - Physics at super high densities

• Many millisecond pulsars
  - Search for low-f GWs
  - Complement the LIGO experiment