The Hunt for New Pulsars with the Green Bank Telescope

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Symposium 291
Neutron Stars and Pulsars

What we'll talk about...

- Two most recent large-area GBT pulsar surveys – the 350 MHz Drift Scan Survey and the Green Bank North Celestial Cap Survey
  - Primary science goals
  - Progress so far
  - Highlights
  - Future work
- A brief overview of some targeted pulsar searches

- Anne Archibald (McGill)
- Aaron Berndsen (UBC)
- Jason Boyles (WVU)
- Fernando Cardoso (WVU)
- Angus Cherry (UBC)
- Jason Hessels (ASTRON)
- Rick Jenet (UTB)
- David Kaplan (UWM)
- Vicky Kaspi (McGill)
- Chen Karako (McGill)
- Vlad Kondratiev (ASTRON)
- Duncan Lorimer (WVU)
- Joeri van Leeuwen (ASTRON)
- Erik Madsen (UBC)
- Maura McLaughlin (WVU)
- Christie McPhee (UBC)
- Chris Pankow (UWM)
- Tim Pennucci (UVA)
- Scott Ransom (NRAO)
- Mallory Roberts (Eureka)
- Xavier Siemens (UWM)
- Ingrid Stairs (UBC)
- Kevin Stovall (UTB)
- ARCC (UTB/UWM)

First, some motivation

- We keep finding cool new pulsars whenever we look, so keep looking!
  - High precision MSPs for PTAs
  - Gravitational laboratories (Kramer et al. 2006; Freire et al. 2012)
  - Massive pulsars (e.g. Demorest et al. 2010)
  - Radio magnetars (Camilo et al. 2006,2007; Levin et al. 2010)
  - And many, many more...
- Different surveys can be complementary

The importance of the GBT

- Largest fully steerable telescope in the world
- Can see parts of the sky that Arecibo and Parkes can't
- Relatively little RFI
- Several excellent low-noise receivers
- State-of-the art pulsar back-end

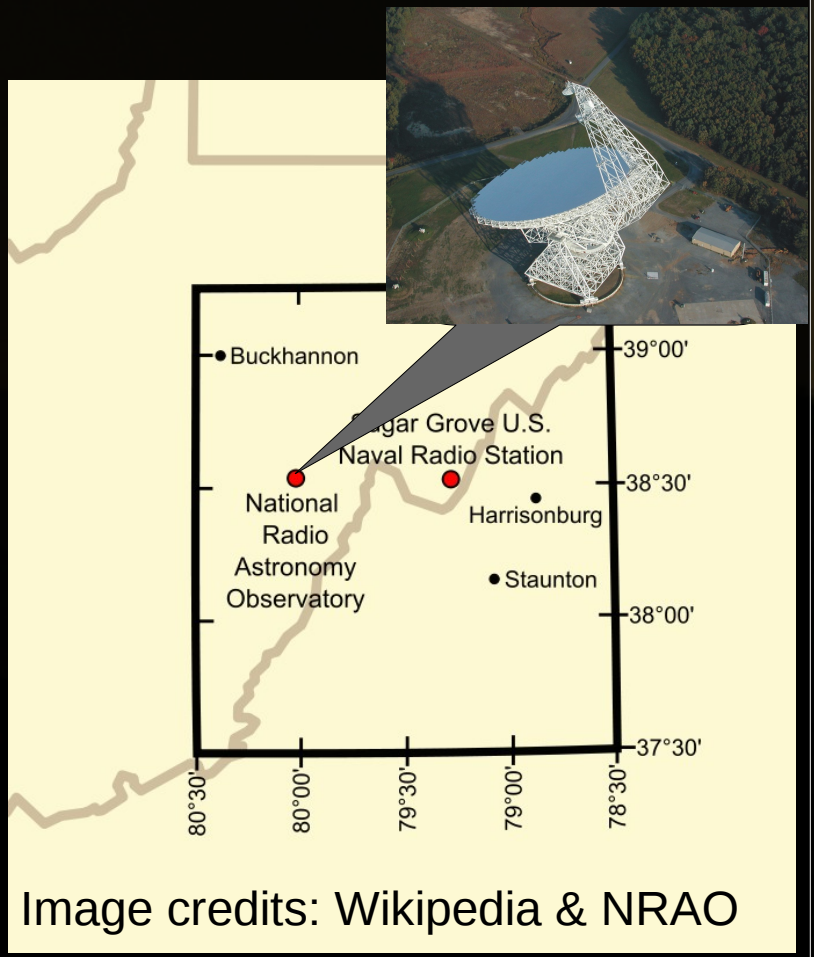


Image credits: Wikipedia & NRAO

The GBT Drift Scan survey

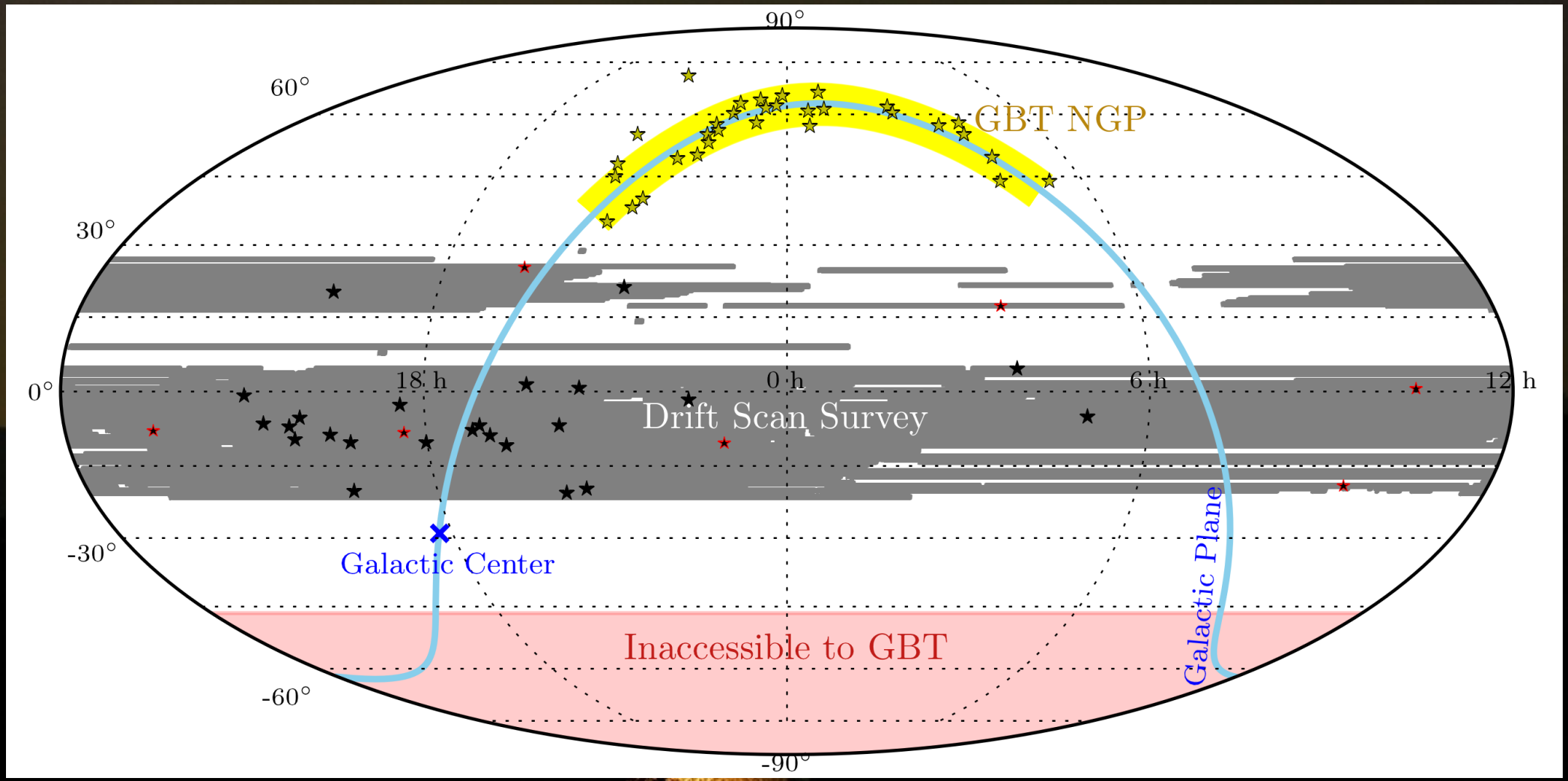
- Primary science goal: find high precision MSPs and exotic pulsars (young pulsars, RRATs, etc)
- Completed between May and August 2007 during GBT track repair shutdown
- Access to $-7.7° < \delta < 38.4°$ and $-20.7° < \delta < 38.4°$

Image credit: NRAO

The GBT Drift Scan survey

- Centered at 350 MHz with 50 MHz bandwidth
  - Most data recorded with 2048 channels
- Data analyzed in 140-s sections with 50% overlap
- 10347 sq deg, totaling 1491 hrs of observing time and 134 TB
  - 2800 sq deg reserved for Pulsar Search Collaboratory (Rosen et al. 2010)
- Data analysis now complete: 31 new pulsars including 7 MSPs ($P < 10$ ms)

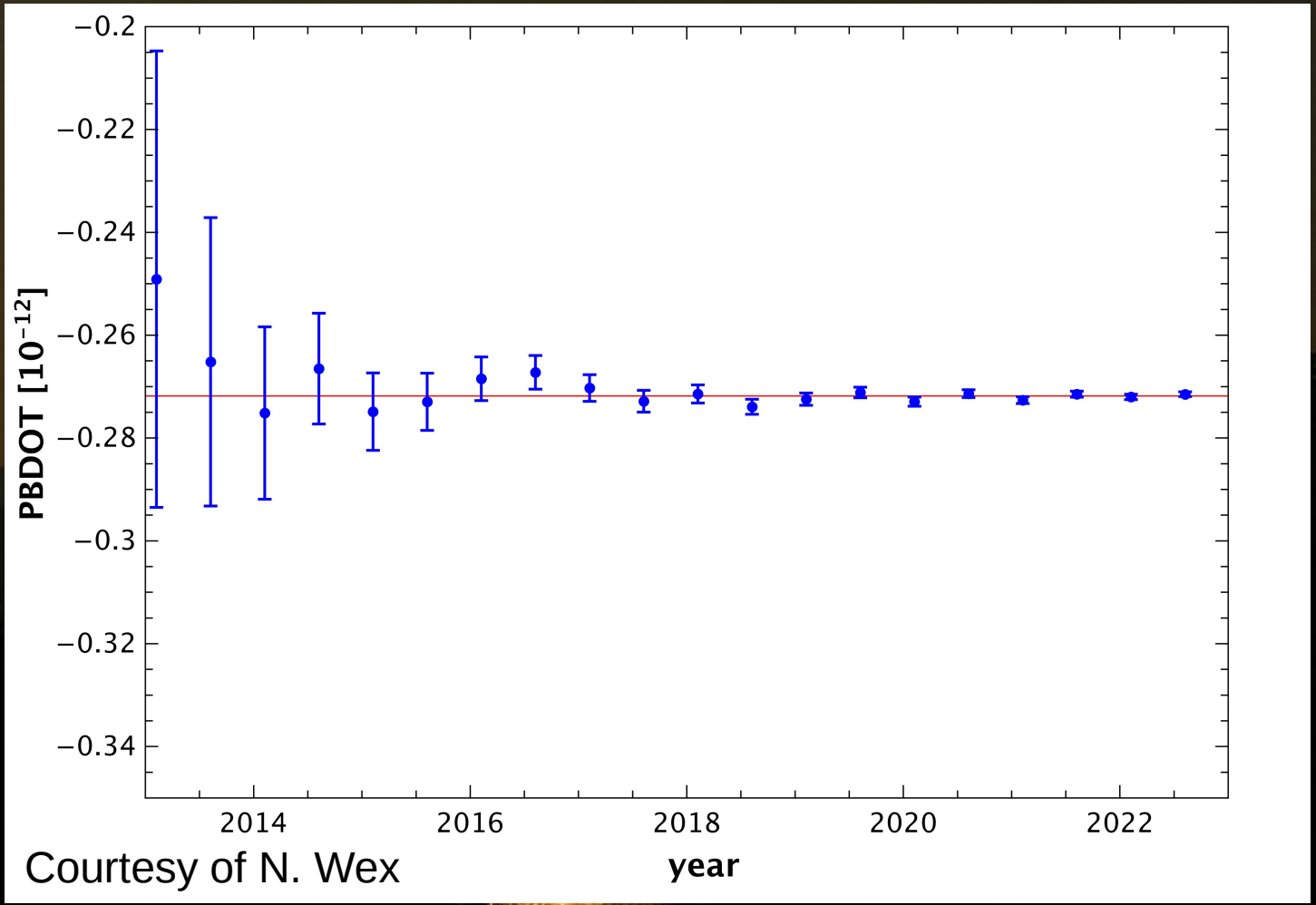
The GBT Drift Scan survey



GBT Drift Scan Highlights

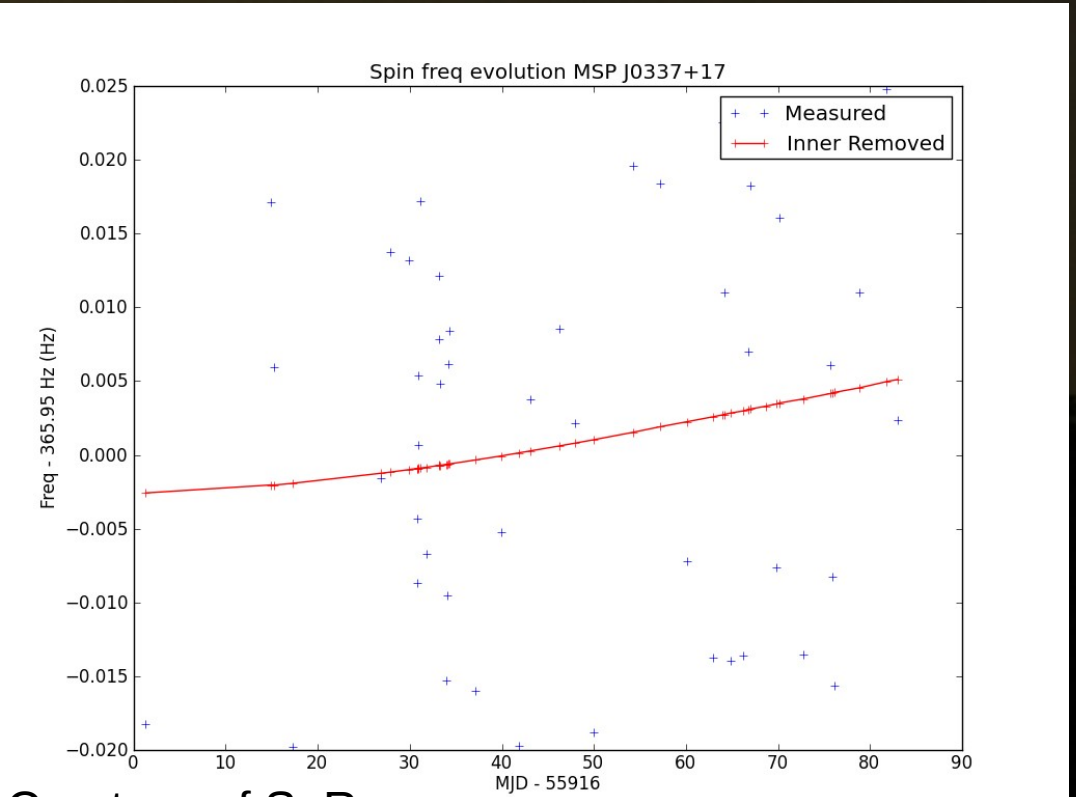
- J0348+0432 is a 39-ms recycled pulsars in a 2.4-hr orbit (Lynch et al. in prep)
  - Spectroscopic follow-up of the companion reveals a 0.17 Msun white dwarf (Antoniadis et al. in prep)
- Predicted to be a strong emitter of dipolar GWs by scalar-tensor theories of gravity
- Ongoing Arecibo timing will provide one of the most stringent tests ever of these alternative gravity theories (Antoniadis et al.)

J0348+0432 Pb-dot prediction



GBT Drift Scan Highlights

- J0337+1715 is a 2.7-ms MSP in a hierarchical triple (Ransom et al. in prep)
  - Inner companion is a WD on 1.6 day orbit
  - Outer companion on a 327 day orbit
- Already is proving to be a fantastic test-bed for 3-body dynamical theory



Courtesy of S. Ransom

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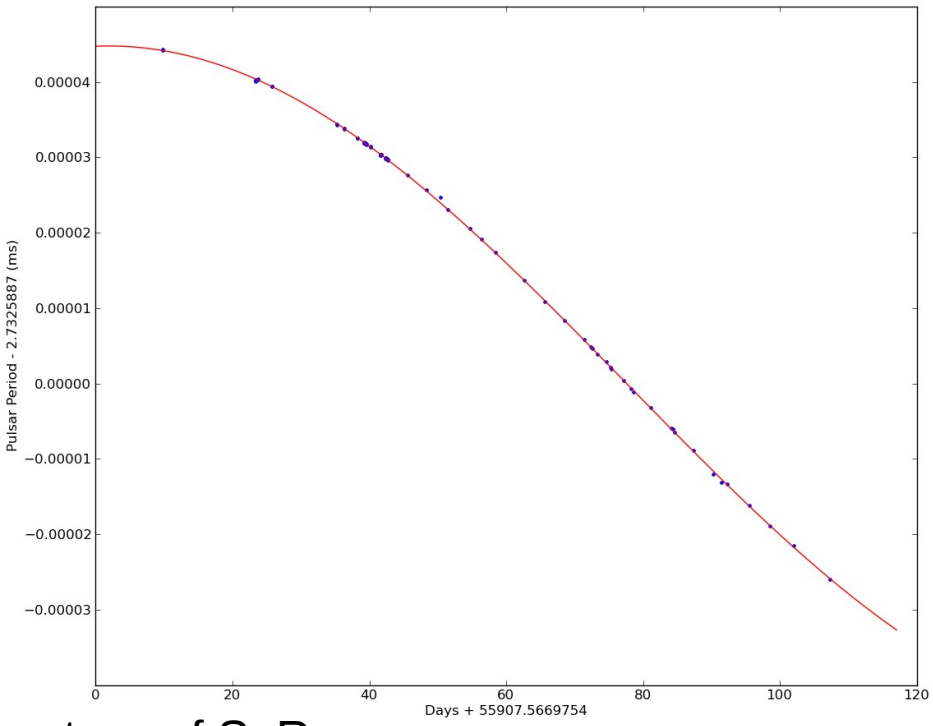


Courtesy of S. Ransom

GBT Drift Scan Highlights

- J2222-0137 (Boyles et al. in prep) is a 33-ms recycled pulsar with a > 1.1 Msun companion
  - Look for Shapiro delay measurement results soon
- J1923+2515 and J0931+1906 are 2 MSPs already included in NANOGrav and IPTA timing
- J1023+0038 (Archibald et al. 2009): The “missing link” pulsar
- 34 RRAT candidates discovered by Chen Karako (see tomorrow's talk)

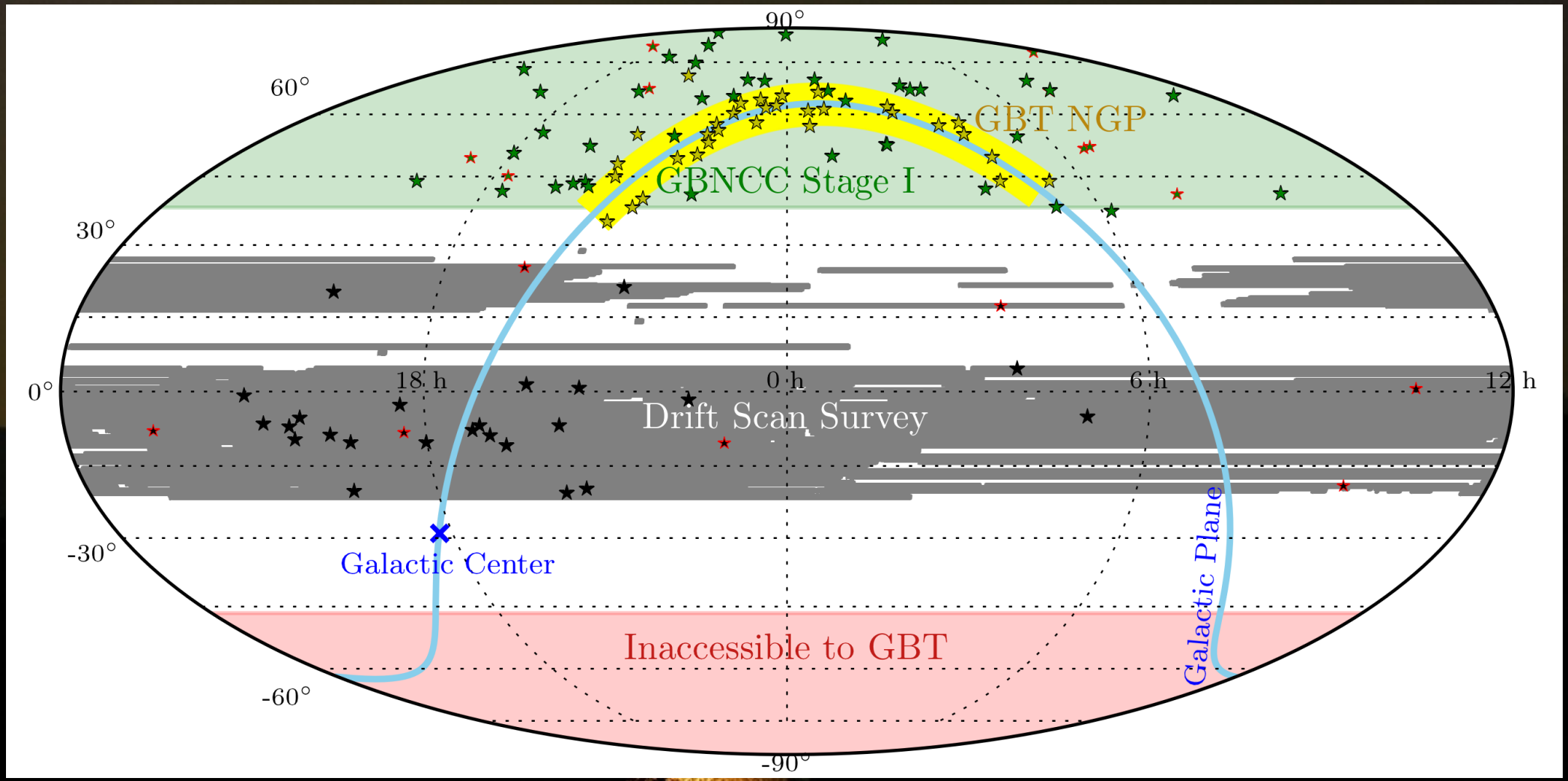
The GBNCC survey

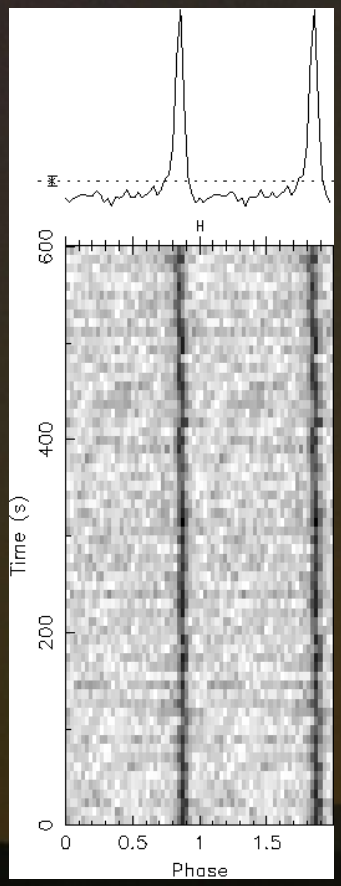
- Science goals similar to Drift Scan, but with particular emphasis on high declinations
  - More wide-separation baselines for pulsar timing arrays
  - Probe pulsar and RRAT populations in less well studied part of the Galaxy
- Data taking began in 2009 and is ongoing
  - Stage I covered $\delta > 38°$ and is now complete
  - Stage II pushing south and will cover entire sky visible from the GBT

The GBNCC survey

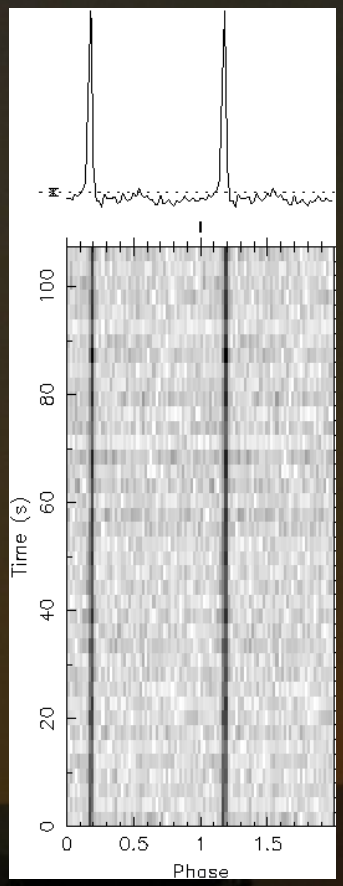
- Centered at 350 MHz using newer GUPPI back-end
  - 100 MHz bandwidth with 4096 channels
  - 120-s pointed integrations
- Will use 2030 hrs and amass ~360 TB when completed
  - Early processing by Kevin Stovall at UTB
  - Most processing now at McGill using 2048 cores on the Guillimin supercomputer
- Preliminary results: 50 new pulsars including 9 MSPs

The GBNCC survey

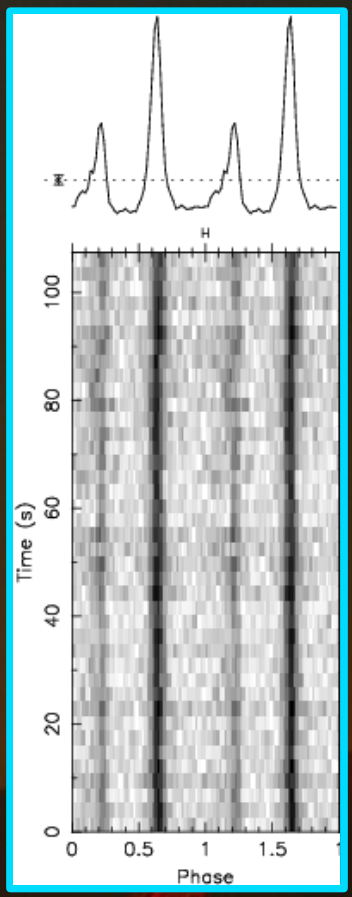




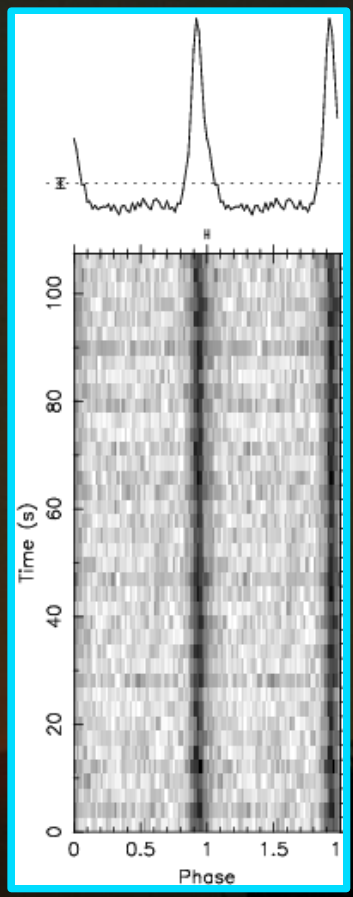
J0636+51
P = 2.86 ms
DM = 11.1 pc/cc



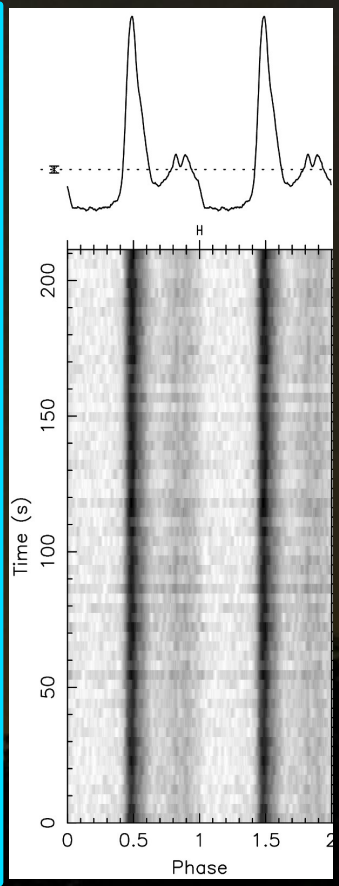
J0645+51
P = 8.85 ms
DM = 18.2 pc/cc



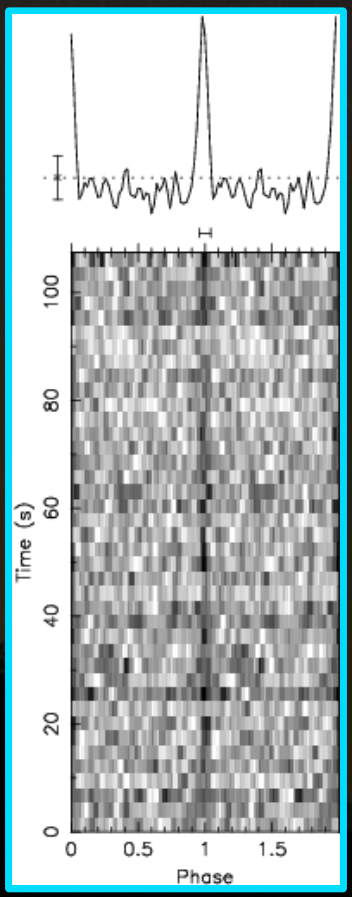
J0741+66
P = 2.88 ms
DM = 15 pc/cc



J1122+78
P = 4.2 ms
DM = 11.2 pc/cc



J1710+49
P = 3.2 ms
DM = 7.1 pc/cc



J1649+80
P = 2.0 ms
DM = 31 pc/cc

Included in
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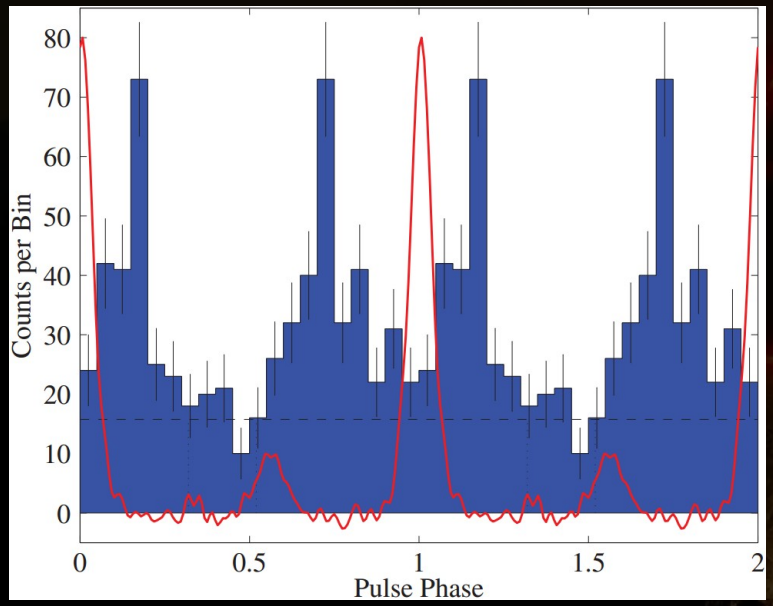
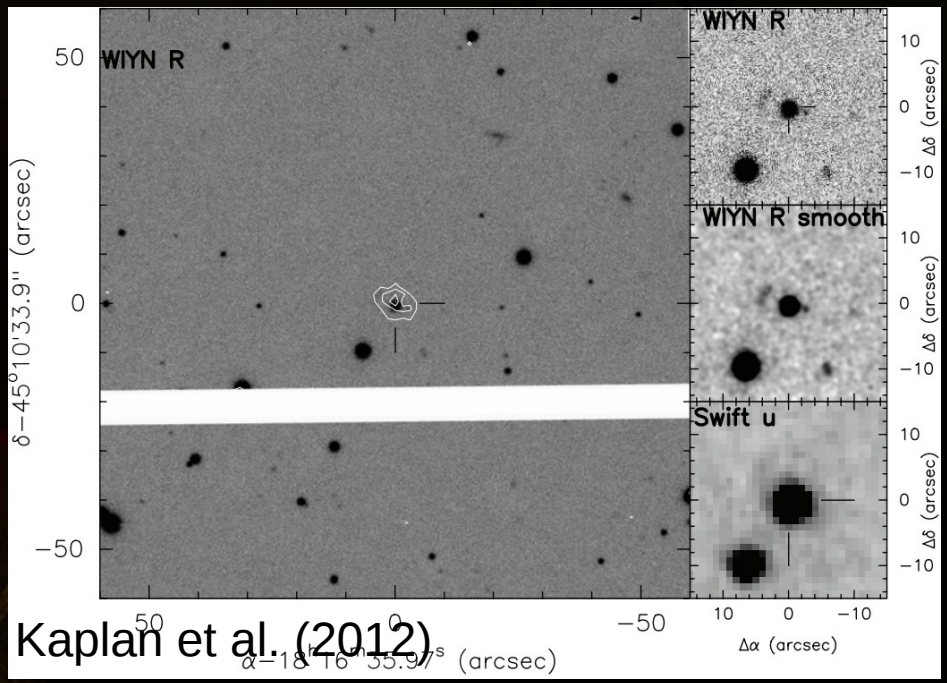
GBNCC Highlights

- J1816+4510 is a binary MSP in an 8.7-hr orbit around a > 0.16 Msun companion (Kaplan et al. 2012)
  - Detected with Fermi and has UV/optical counterpart





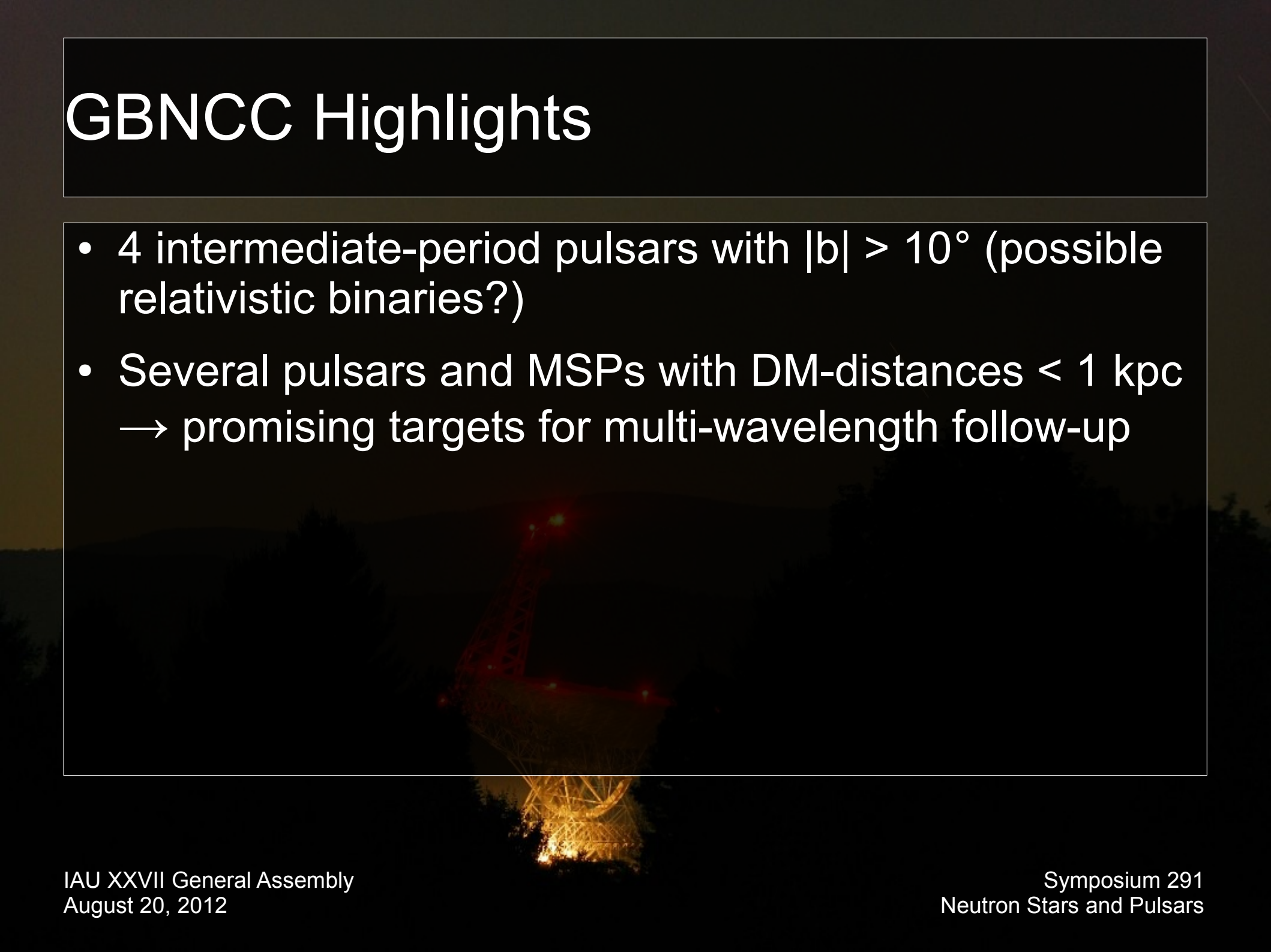
Kaplan et al. (2012)

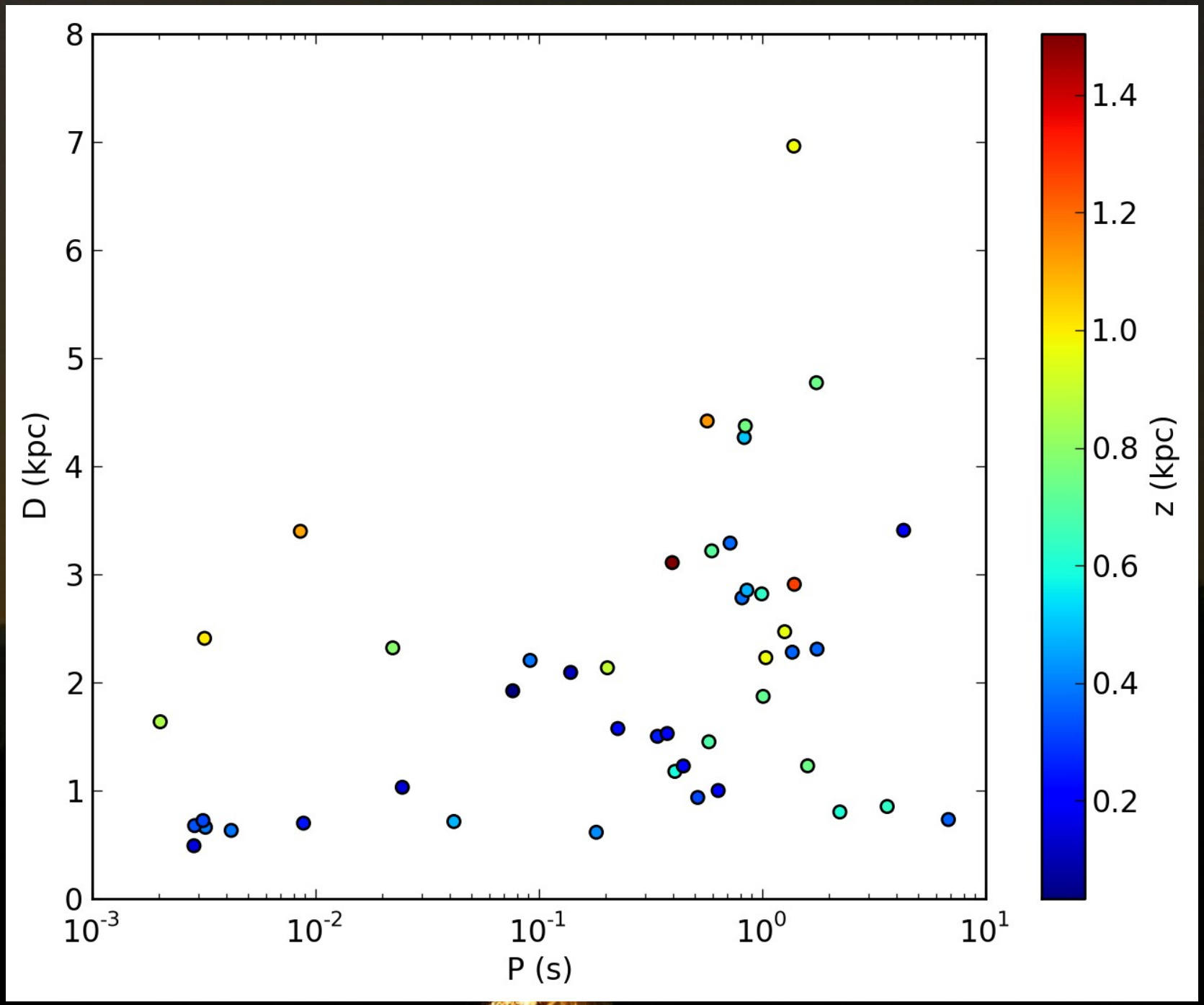
GBNCC Highlights

- J0510+38 is a 76-ms pulsars with *b*=1° (possible young pulsar?)
- J0737+69 is a 6.8-s pulsar
  - Only 6 radio pulsars with longer periods (3 are RRATs)
- J0636+51 is a 2.9-ms MSP in a 1.5 hr orbit
  - Lower limit on companion's density is 2x diamond planet (Bailes et al. 2012)

GBNCC Highlights

- 4 intermediate-period pulsars with |b| > 10° (possible relativistic binaries?)
- Several pulsars and MSPs with DM-distances < 1 kpc
  ⟶ promising targets for multi-wavelength follow-up

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0.6
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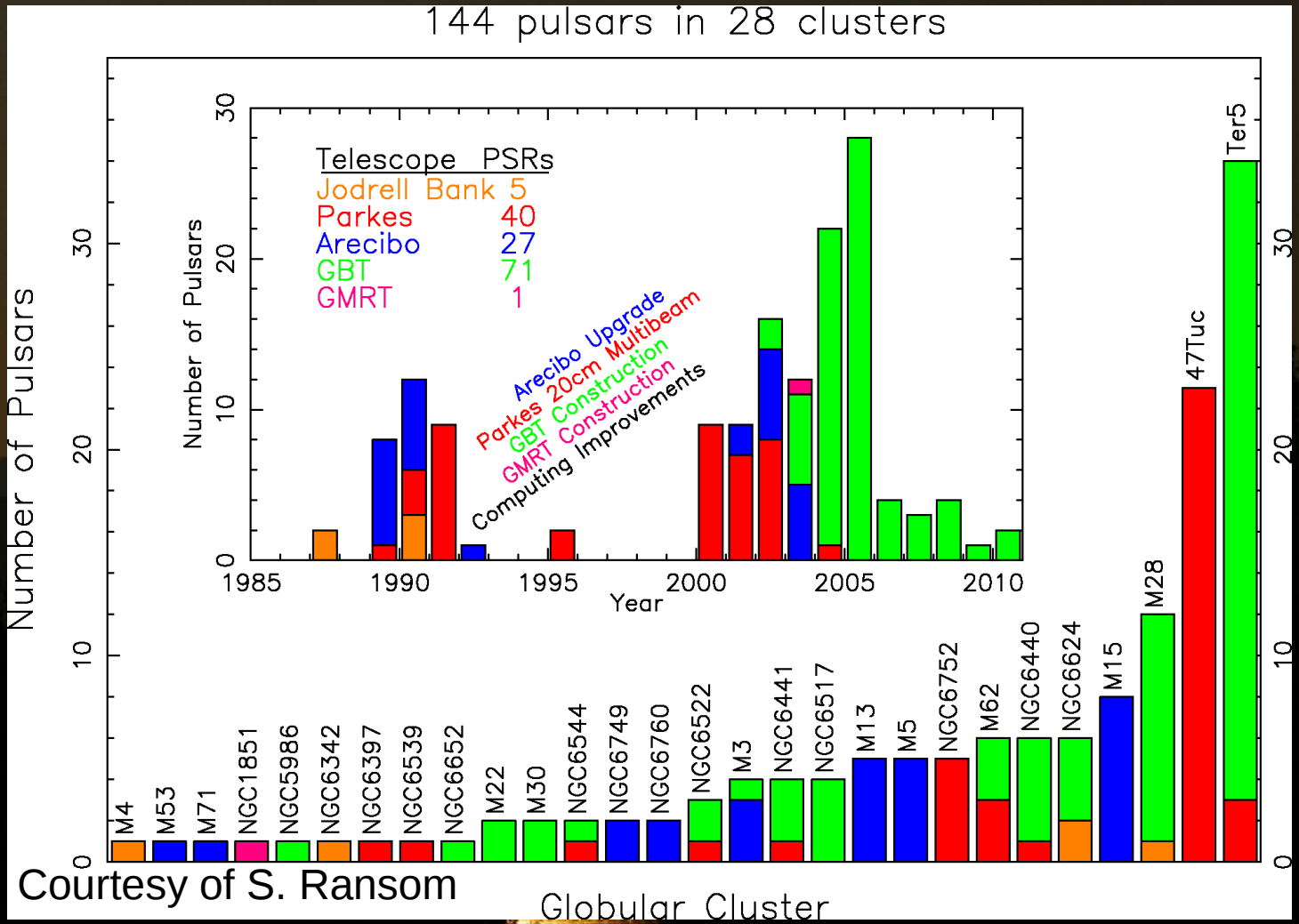
Targeted surveys: Globular Clusters

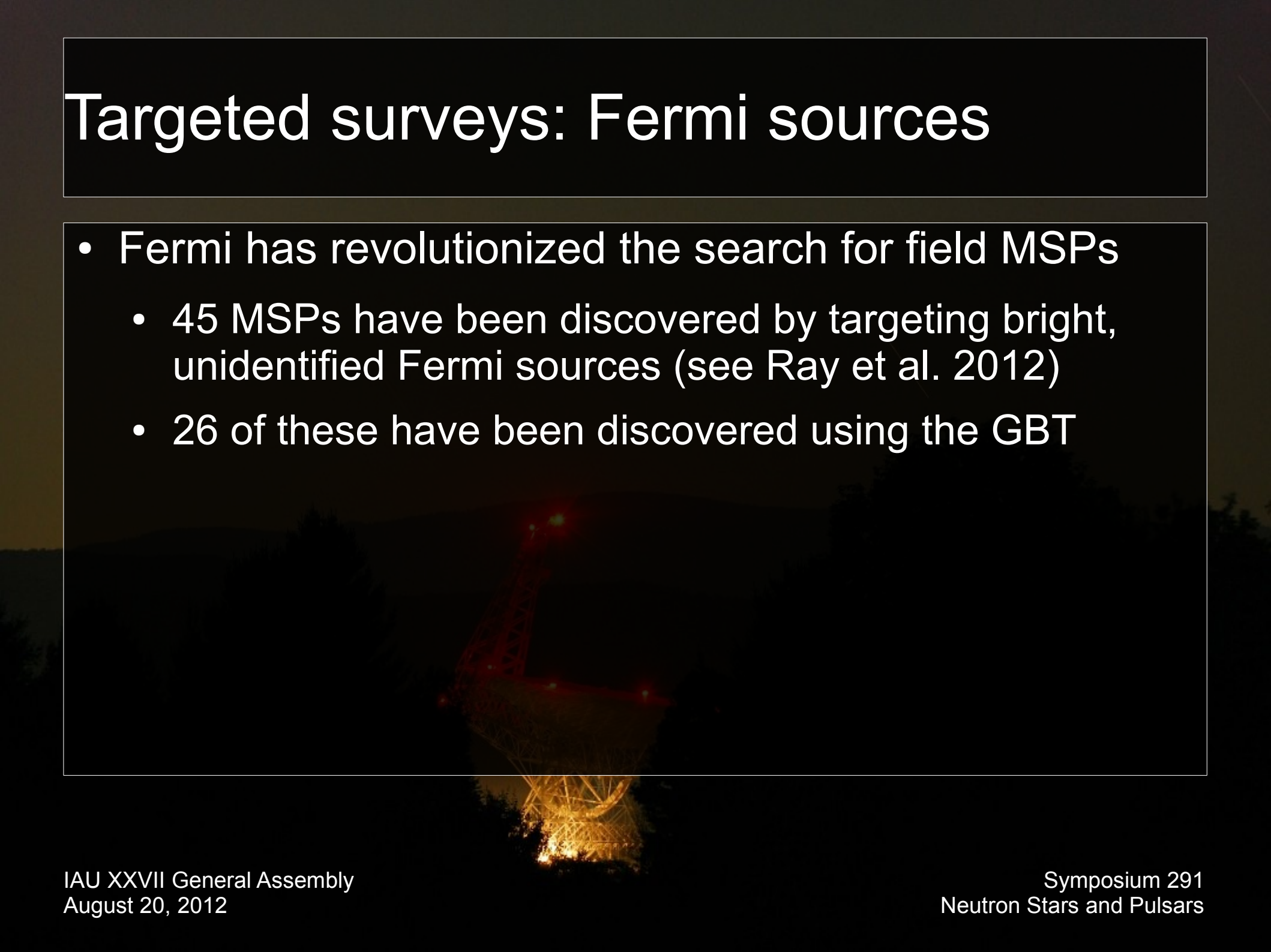
- The GBT has been amazing for finding GC pulsars
  - The most promising GCs have been deeply searched as part of several projects (Ransom et al. 2005; Freire et al. 2008; Lynch et al. 2011a/b, 2012, Stairs et al. In prep)
  - These included the fastest rotator (Hessels et al. 2006), potentially super-massive pulsars (Freire et al. 2008), and a potential double neutron star system (Lynch et al. 2012)

Targeted Surveys: Globular Clusters



Targeted surveys: Fermi sources

- Fermi has revolutionized the search for field MSPs
  - 45 MSPs have been discovered by targeting bright, unidentified Fermi sources (see Ray et al. 2012)
  - 26 of these have been discovered using the GBT



Summary and Conclusions

- There are still lots of really cool pulsars to discover!
  - Pulsar-BH binary, planet systems, bridges between magnetars and pulsars, RRATs, massive pulsars...
- The GBT is one of the best instruments in the world for finding new pulsars
- The most recent GBT surveys have combined to discover 81 new pulsars (12 MSPs)
- The ongoing GBNCC survey promises to keep increasing this number by a lot (so stay tuned)