Future of US-China Pulsar Work

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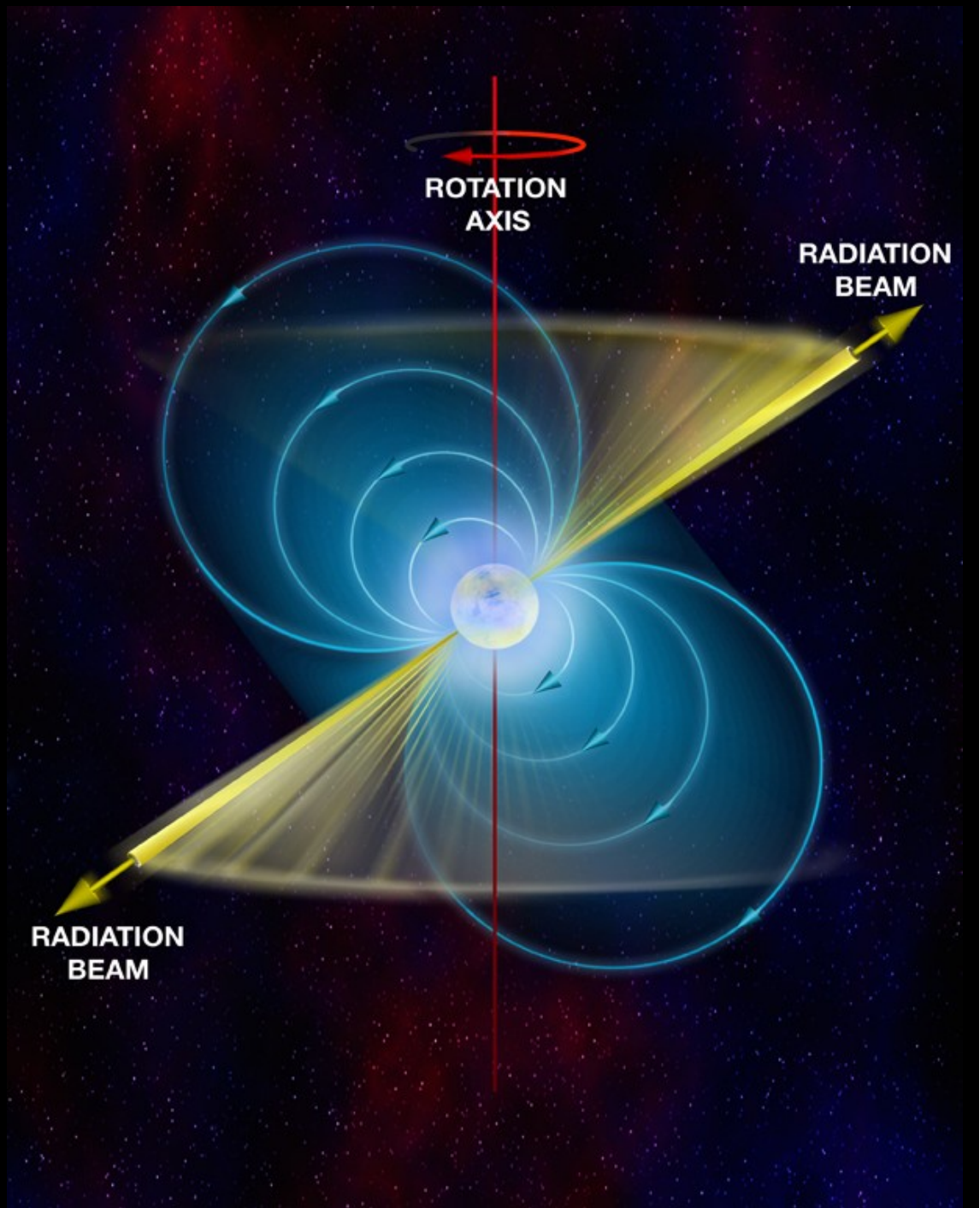
What are pulsar radio properties?

- Continuum point sources
- Quite linearly polarized
- Steep radio spectra (index ~ -2) so 0.3-3 GHz obs
- Dispersion ($\sim\nu^{-2}$) scattering ($\sim\nu^{-4}$) push to higher freqs
- Highly time variable
- No confusion or beam dilution
- Very faint average flux density ~mJy
- RFI is a big problem, affects slow pulsars much more than MSPs



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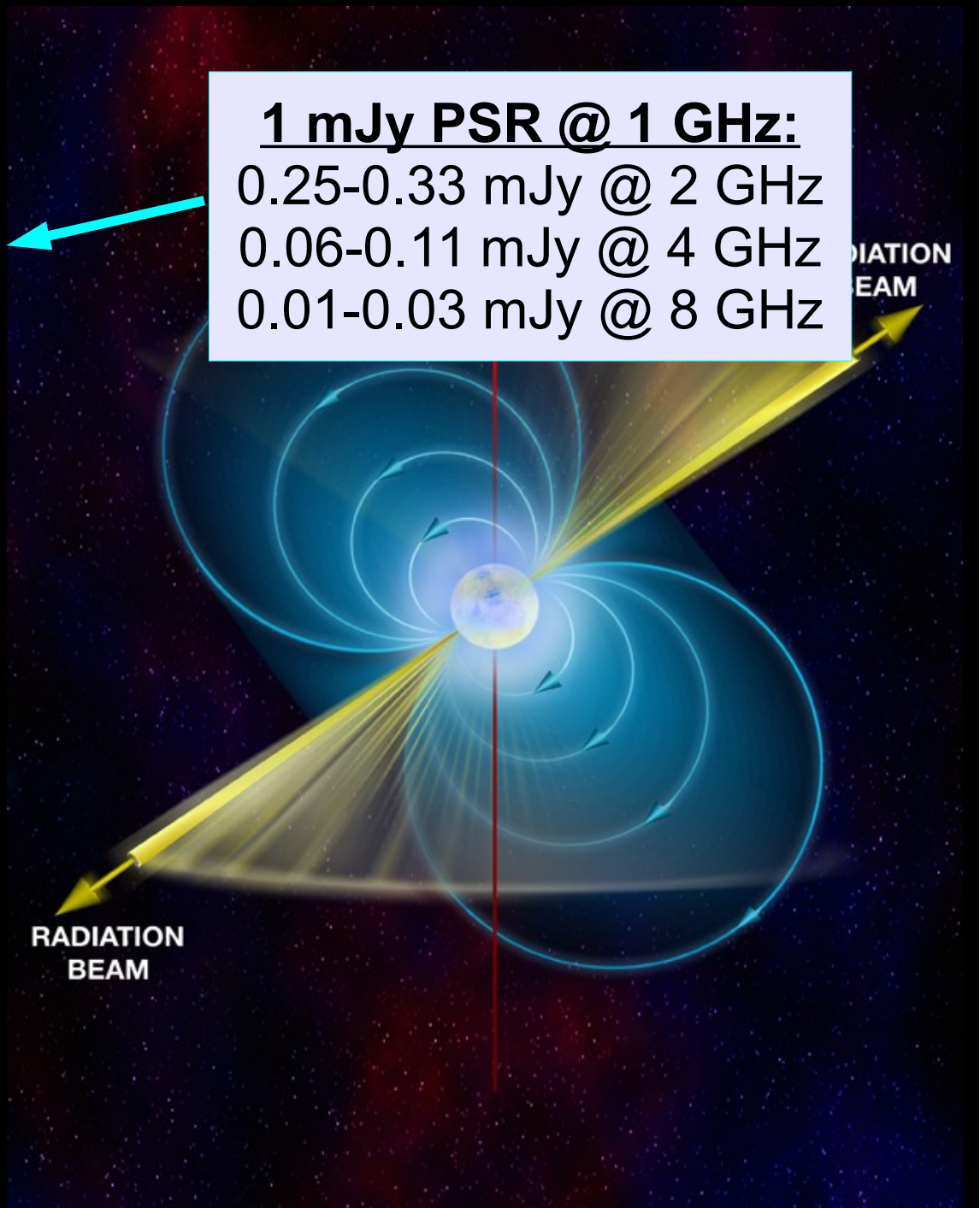

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Pulsar Population of the Galaxy

~2300 pulsars known, but the Galaxy has ~30000 (and ~10000 MSPs)

Only 2-3% of known pulsars are "interesting" for basic/astro physics individually

In Galaxy, we know:

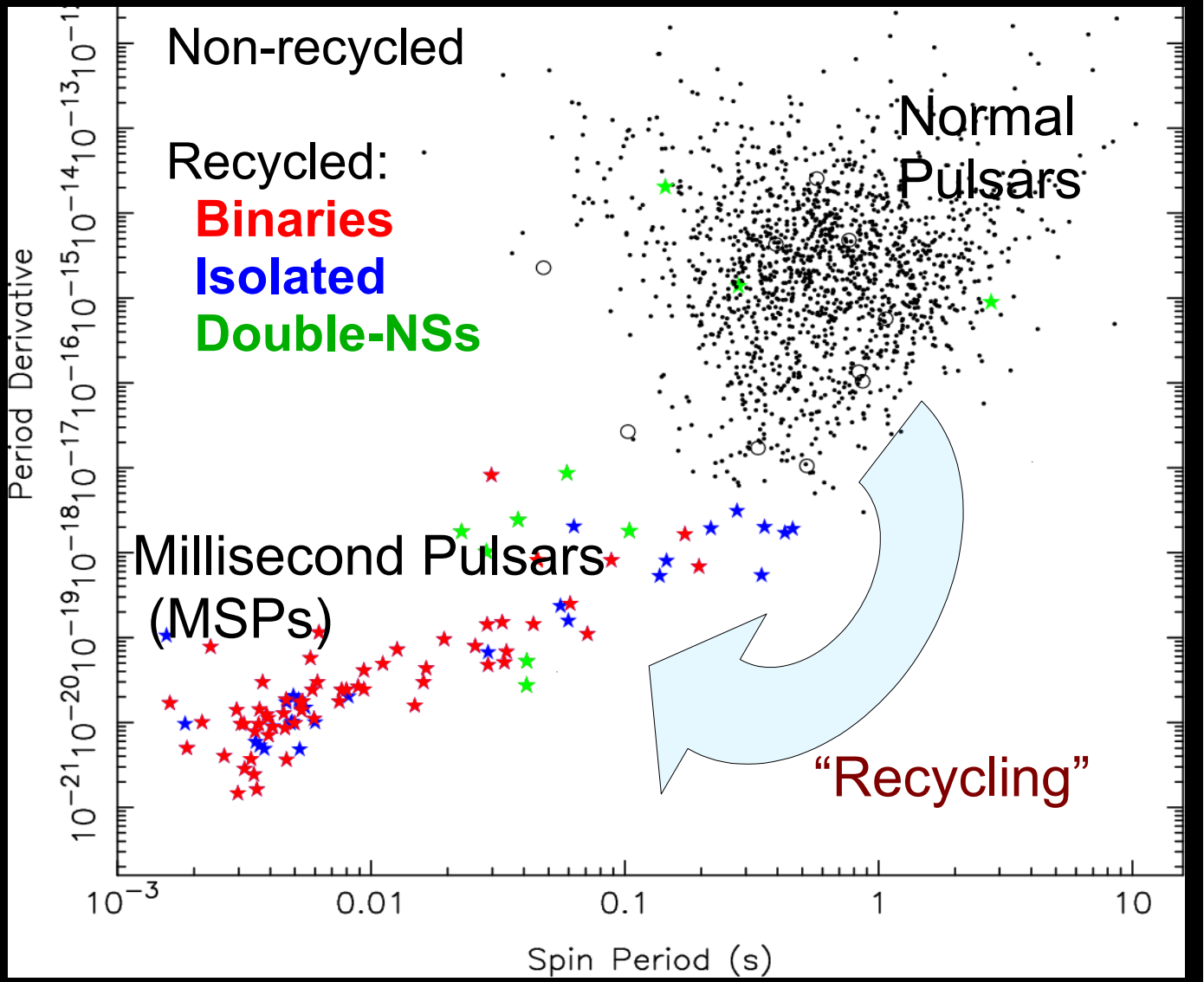
~160 binary MSPs
~40 isolated MSPs

~40 binary part-recyc
~20 isolated part-recyc

Definitions:

Part-recycled:
P > 20 ms, B < 3×10^{10} G

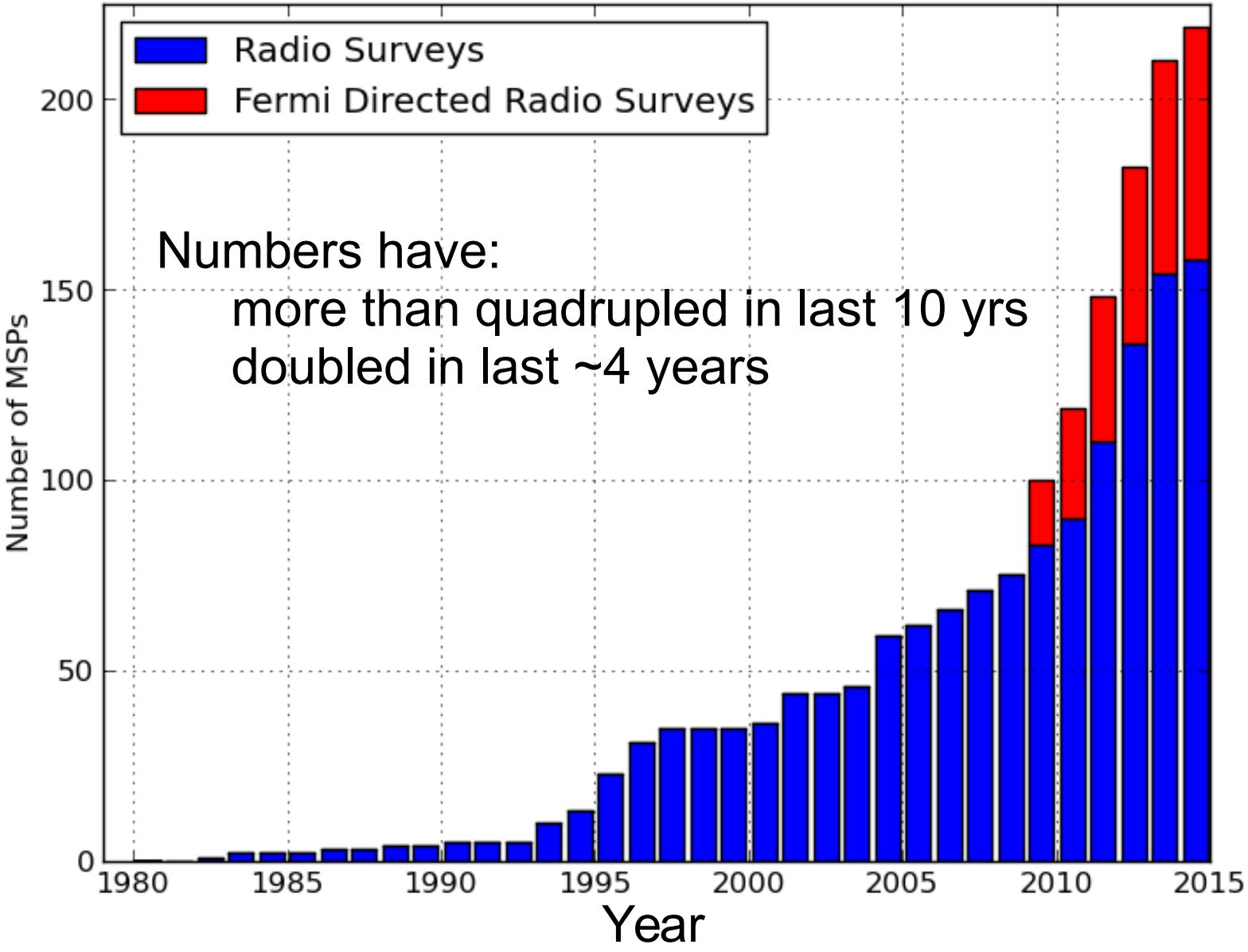
MSP:
P < 20 ms, B < 10^{9} G



Ongoing All-Sky Pulsar Surveys

- All major radio Northern scopes:
  - Arecibo: P-ALFA (7x1.4GHz) and AO-Drift (1x327MHz)
  - GBT: GBNCC (1x350MHz)
  - LOFAR: several
  - Effelsberg: HTRU (7x1.4 GHz)
- Lots of data (~50-200 MB/s)
- Millions of candidates
  - Due to big param space and RFI
- 200-300 PSRs in next few years
- *Timing (~1yr) of every pulsar is a crucial part of the survey – identifies the interesting ones!*

New Millisecond Pulsars



Crucial for Pulsar Timing Array experiments for gravitational waves

Recent exotic systems…

- Double pulsar J0737-3039 (Lyne et al., *Science*, 2004)
- Radio magnetar XTE J1810-197 (Camilo et al., *Nature*, 2006)
- P-dot changing PSR B1931+24 (Kramer et al., *Science*, 2006)
- Rotating Radio Transients (McLaughlin et al., *Nature*, 2006)
- Eccentric MSP J1903+0327 (Champion et al., *Science*, 2008)
- "Missing Link" MSP J1023+0038 (Archibald et al., *Science*, 2009)
- 2-Msun MSP J1614-2230 (Demorest et al., *Nature*, 2010)
- "Diamond Planet" J1719-1438 (Bailes et al., *Science*, 2012)
- Massive NS J0348+0432 (Antoniadis et al., *Science*, 2013)
- MSP-LMXB switching M28I (Papitto et al., *Nature*, 2013)
- MSP in triple system J0337+1715 (Ransom et al., *Nature*, 2014)
- *Future?*: MSP-MSP, PSR-BH, sub-MSP, ultra-massive, ….

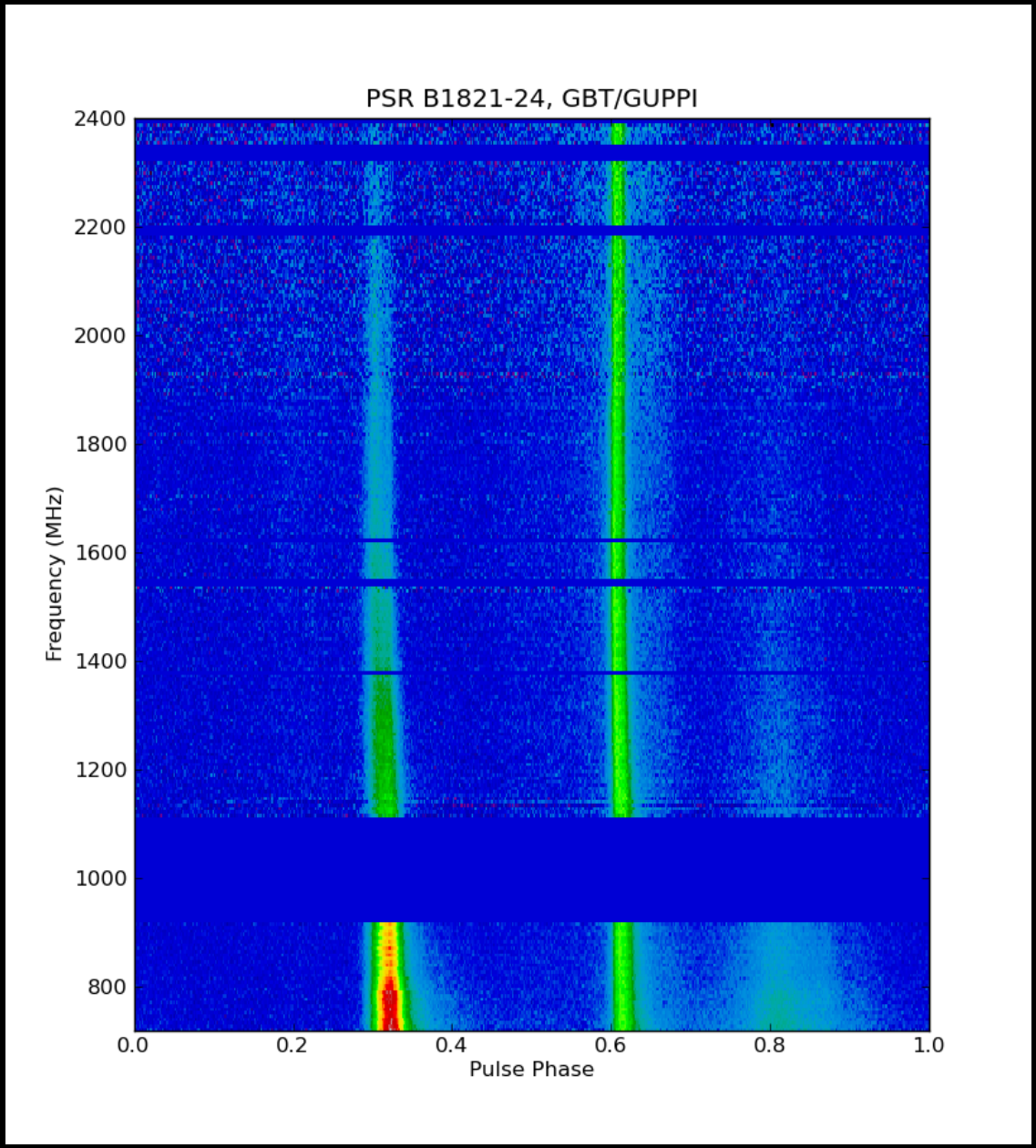
Chinese Telescopes and Pulsars

- FAST will be *fantastic* (sensitivity + sky coverage)
  - Surveys should find 1000-2000 new pulsars
    - But: if 10-min slew times, how do you time and confirm? Will be very difficult with FAST, but need its sensitivity!
    - QTT, Arecibo, GBT – but will take a lot of telescope time
    - For confirmation, maybe do full sky twice with driftscans
- QTT: will be great (sensitivity + sky coverage)
  - Excellent general-purpose pulsar telescope (like GBT)
- SHAO 65-m: probably niche uses for pulsars
  - RFI will dramatically limit use of L-band and S-band
  - C-band population studies of spectral indices

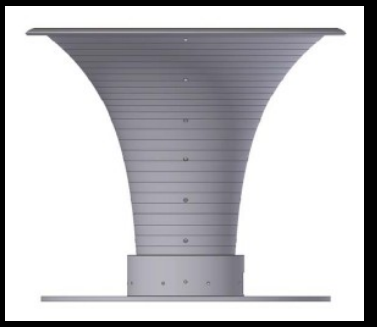
Timing: want all the useful bandwidth

0.5 – 3 GHz receiver/backend

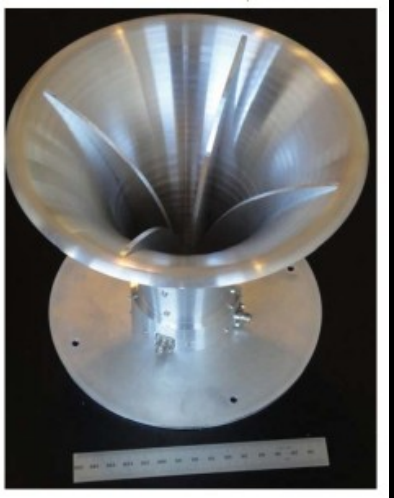
- ~40% total SNR improvement
- ~60% timing improvement from SNR and DM alone
- much better systematics
- ~2.5 GHz bandwidth sampled in one chunk
- ~GUPPI x3 (realtime dedispersion with GPUs – DIBAS modes in VEGAS)



Scaled Caltech quad-ridge feed



CIT Quad-ridge Flared Horn (QRFH)
Frequency Range: 2 – 12 GHz
Dimensions: 20 x 20 x 20 cm
(slightly bigger than 3164-05)
Mass: < 1 lbs
(less than 3164-05)

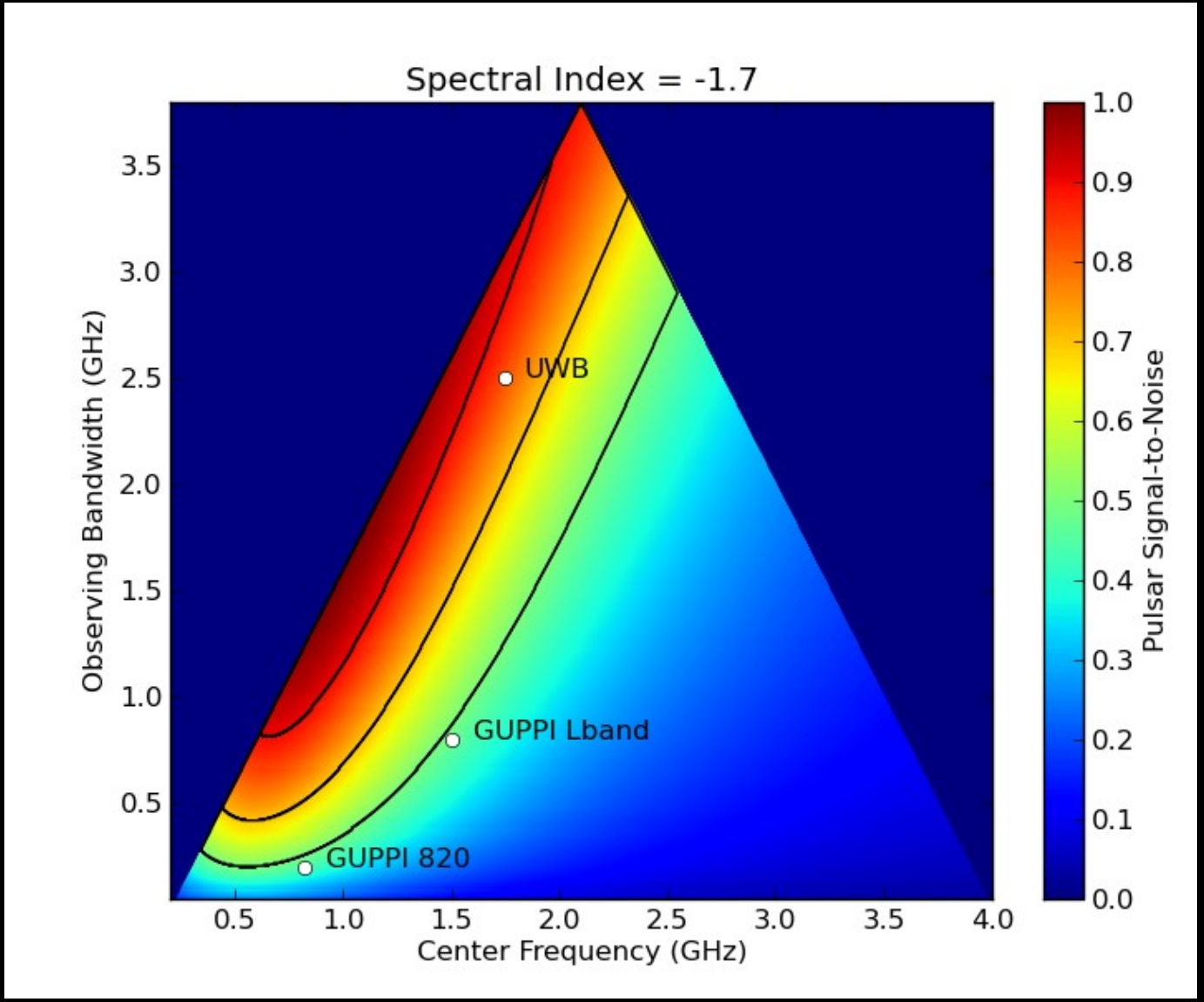


- **Ahmed Akigray** and Sandy Weinreb
- Looking for funding as part of NANOGrav's NSF MSIP proposal for GBT

Suggest design can be (easily) tweaked to achieve:

- 3% spillover noise at 1.4GHz and zenith
- 60% aperture efficiency over full band (~0.5-3 GHz)
- **Tsys ~ 29K (5K sky + 9K spill + 4K coax jct + 7K dewar jct + 3K LNA)**
- Total size is ~1m long and ~1m in diameter
- Achieving a competitive Aeff / Tsys is the key... and will be tricky!

Observations will be more efficient and have much better systematics (ISM)



Summary

- There was a pulsar renaissance in the last decade because of instrumentation
- There will be another in the next decade from new telescopes (esp FAST, MeerKAT, SKA-1)
- Current telescopes (esp GBT and Arecibo) will crucial for follow-up observations of new PSRs
- A huge amount of exciting new science to come:
  - Gravitational waves, neutron star masses, exotic systems, plasma and nuclear physics, GR tests, ...