# Clocks around the Rock

## The search for pulsars around the SgrA* black hole


Dale A. Frail

National Radio Astronomy Observatory


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

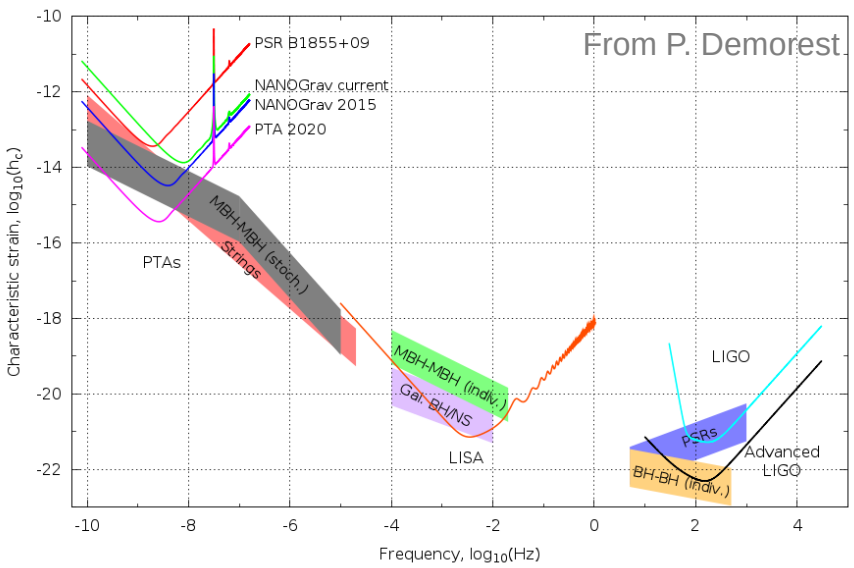
NRAO

# Talk outline

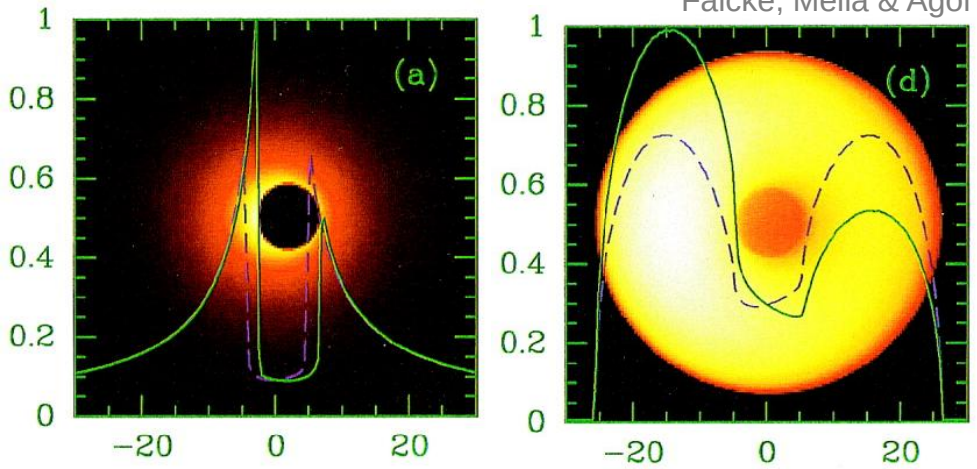
- Motivation for searching for pulsars at the galactic center
- Challenges at the galactic center and how to overcome them
- A high frequency pulsar search toward the GC with GBT
- Future prospects

Collaborators include Andy Harris (Maryland), Nissim Kanekar (NCRA), Jean-Pierre Macquart (Curtin) and Scott Ransom (NRAO)

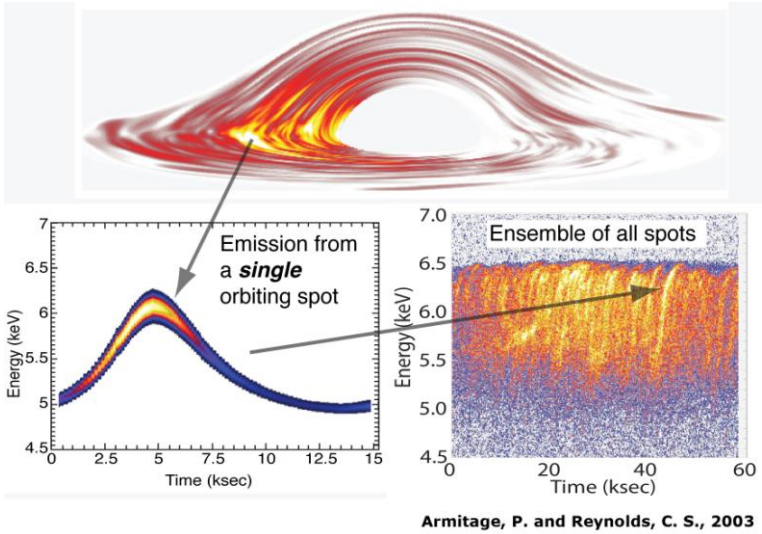
# Gravity's Rainbow – the discovery decade




Falcke, Melia & Agol

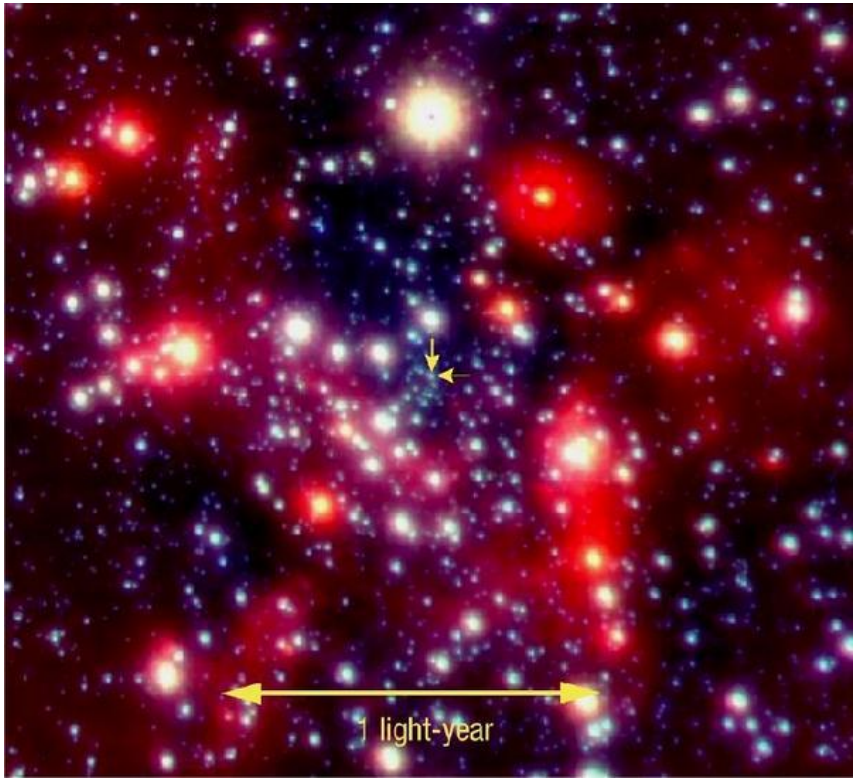



- LISA, LIGO, NanoGrav
  - direct detection of GW
- Event Horizon Telescope
  - VLBI imaging of BH environs
- IXO and GRAVITY at VLTI
  - motion of last stable orbit



# Young massive stars and PSRs in the GC

- SgrA* black hole is surrounded by young stars. Age~5 Myrs
- 200-300 early type stars inside the central parsec of the GC
- 10% of all massive stars (>20 $M_\odot$) in the Galaxy are found within the central 100 pc of the GC
  - Other massive star tracers (e.g. masers, OB associations, SNRs, etc) peak toward the inner Galaxy
- Expect significant compact remnants (BH, NS, WD) in the GC
  - Theory predicts 100-1000 PSRs
  - Observational evidence for NS from PWN and XRB 20x over-density

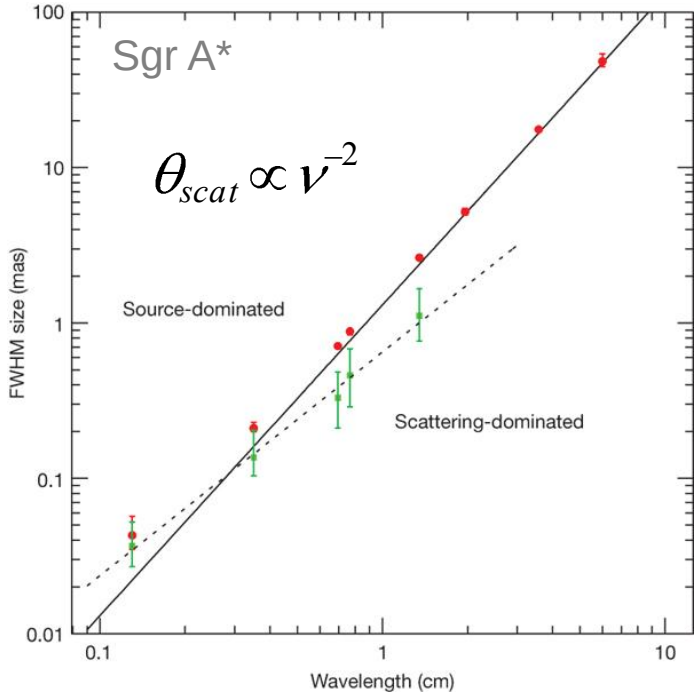



VLT Image by Genzel et al

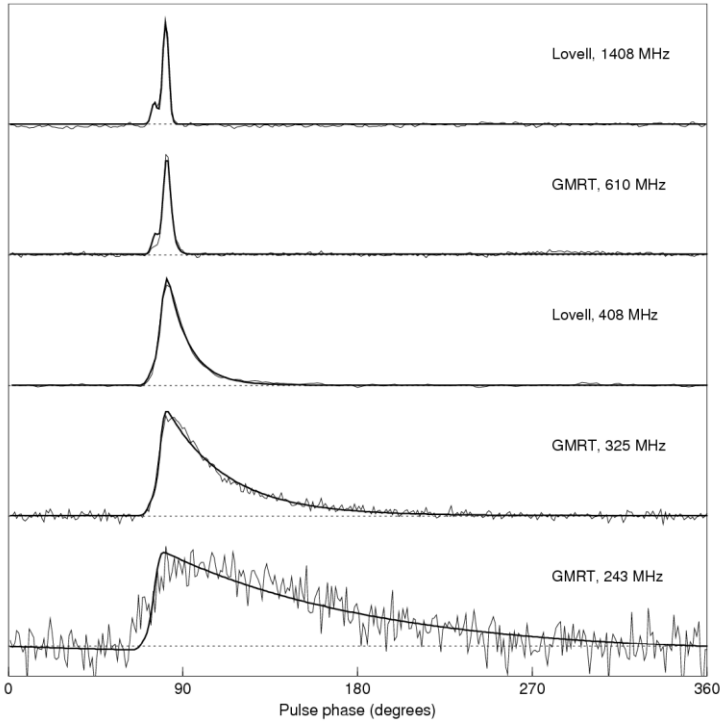
See review by Genzel, Eisenhauer, & Gillessen (2010)

# Challenges to finding pulsars at the GC

Less than 1% of all known pulsars are within one degree of GC. Why?




Doeleman et al. (2009)




Lorimer and Kramer (2005)

- Temporal and angular broadening by turbulent ionized gas
- The most scattered line of sight in the Galaxy

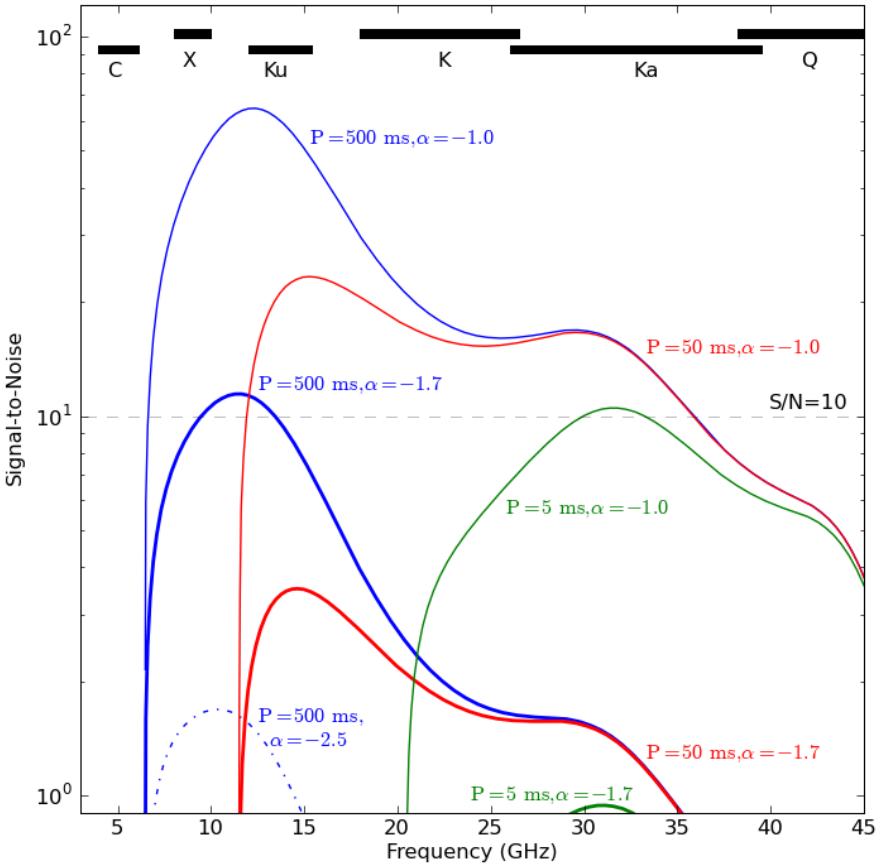
$$D_{scat} = 133^{+200}_{-80}\ \text{pc}$$

$$\tau_{\text{scat}} = 0.116 \left(\frac{D_{scat}}{100\ \text{pc}}\right)^{-1} \left(\frac{\nu}{10\ \text{GHz}}\right)^{-4}\ \text{s}$$

# What is the optimal observing frequency?

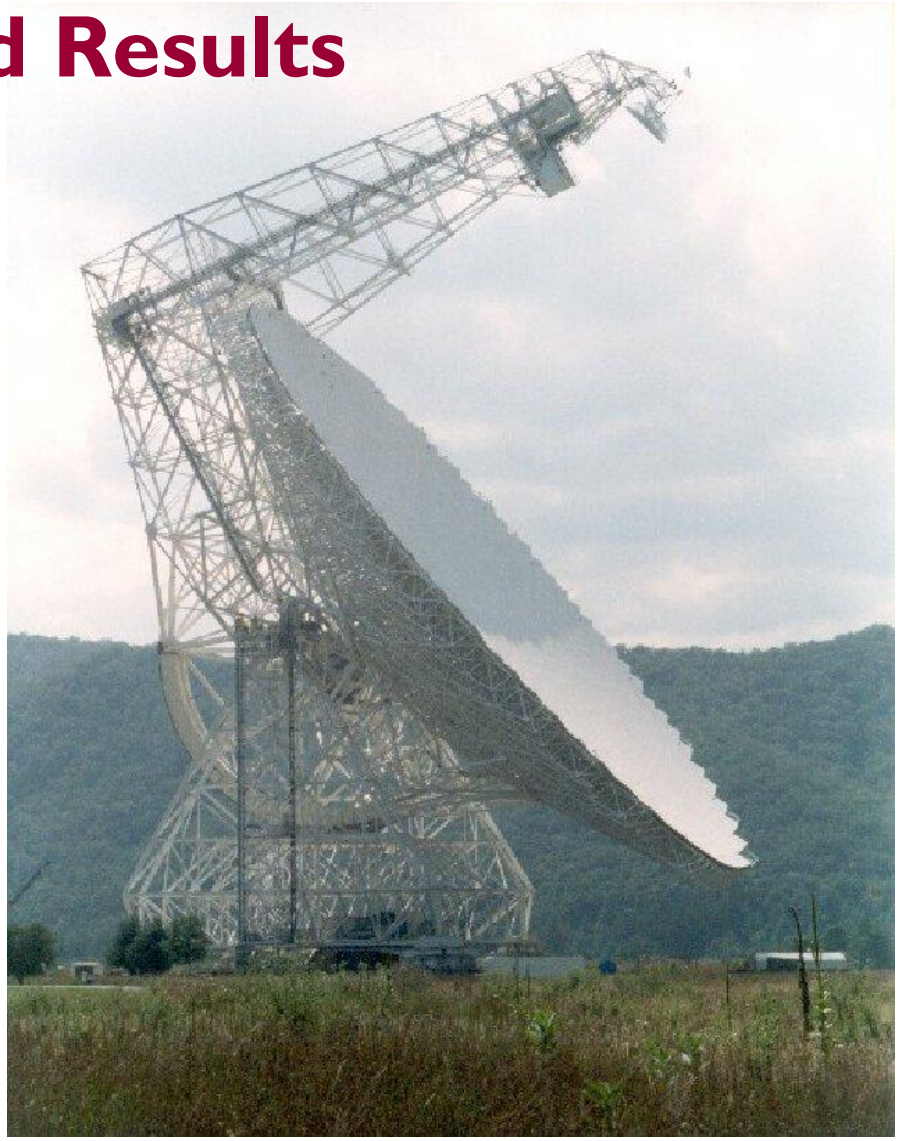
| Effects | Dependence | S/N |
|---|---|---|
| PSR | $S_{psr} \alpha \nu^{-1.7}$ | ↓ |
| ISS | $\tau_{scat} \alpha \nu^{-4}$ | ↑ |
| GC Background | $T_b \alpha \nu^{-2.7}$ | ↑ |
| Receiver + Sky | $T_r \alpha \nu^{a}$ (a>0) | ↓ |

- Normal PSRs (~500 ms)
  - 10-20 GHz. Very feasible
- Young or recycled PSRs (~50 ms)
  - 12-20 GHz. Hard.
- Millisecond PSRs (~5 ms)
  - 30-35 GHz. Needs SKA.



# GBT Experiment and Results

- Ku-band receiver (14.6 GHz)
- Pulsar Spigot (0.8 GHz)
- 50” GBT beam at 14.6 GHz is 1 pc radius at GC
- Bottom line: Deep search (10σ, 10 μJy) but no convincing candidates.
- Was our experiment sensitive enough to detect pulsars at the GC?



Macquart et al. (2010)

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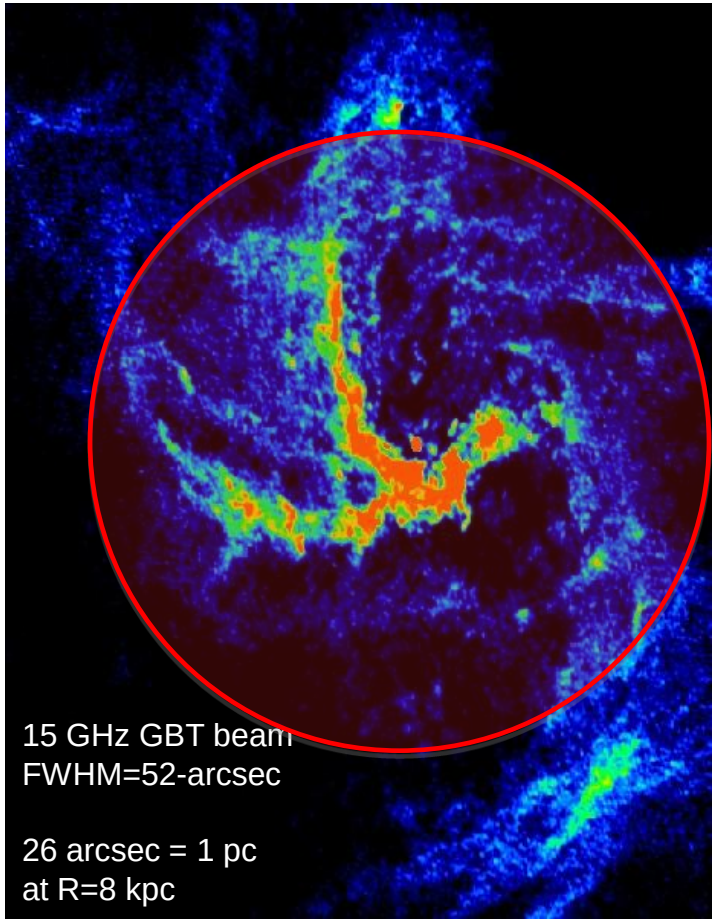
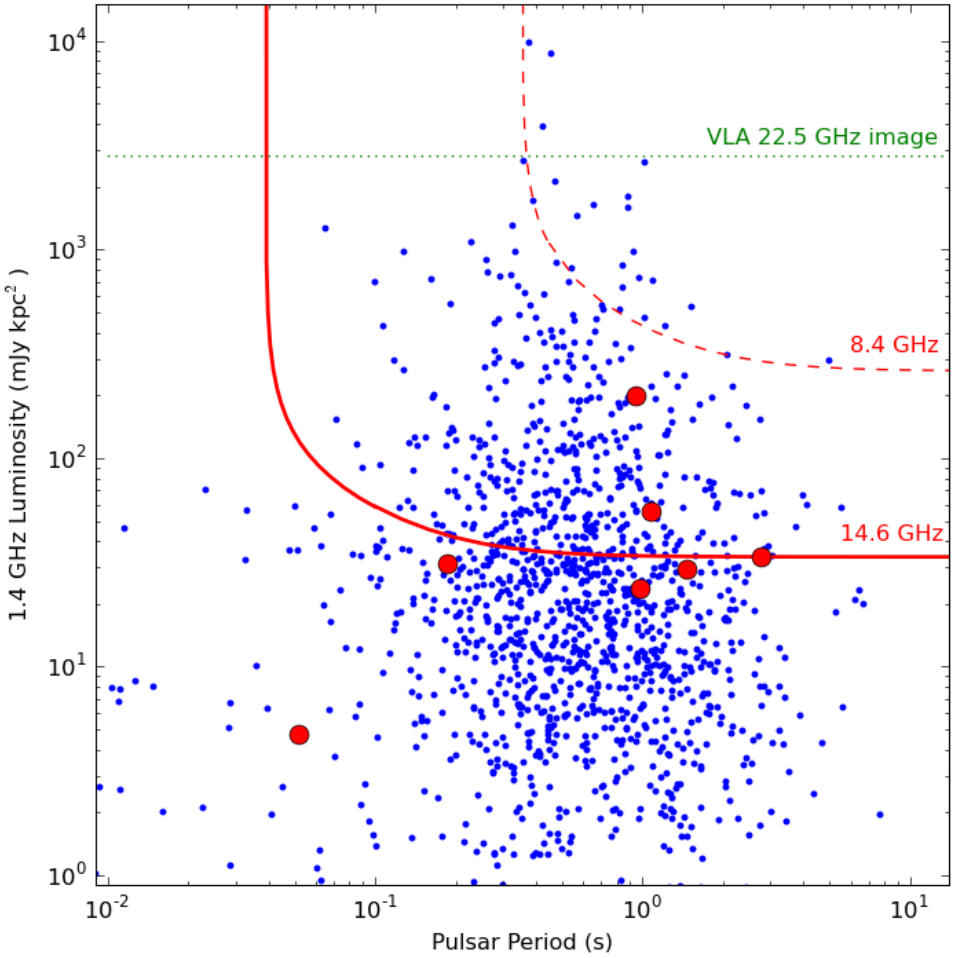


# Fraction of Pulsar Population

- First experiment capable of detecting a significant fraction of population of normal pulsars (15%)
  - a more careful analysis=5%
- The null result implies an upper limit of 90 PSRs within 1pc radius of SgrA*
- Future GBT experiments can push into the bulk of the PSR population

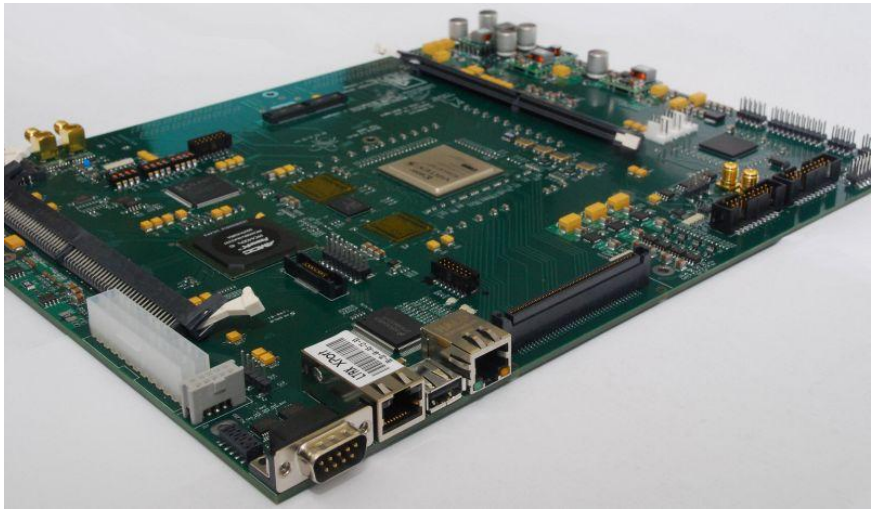


# Future GBT Experiments. Step 2

- Use Zspectrometer as backend
- Analog autocorrelation spectrometer designed for molecular line searches for high redshift galaxies
- Currently configured for Ka band (26-39.5 GHz)
- Reconfigure to Ku band (12-15.4 GHz). Gives 3.4 GHz BW.
- Tested dump rates of 5.7 using hardware flight spares from SOFIA CASIMIR experiment
- Funded. Spring 2011

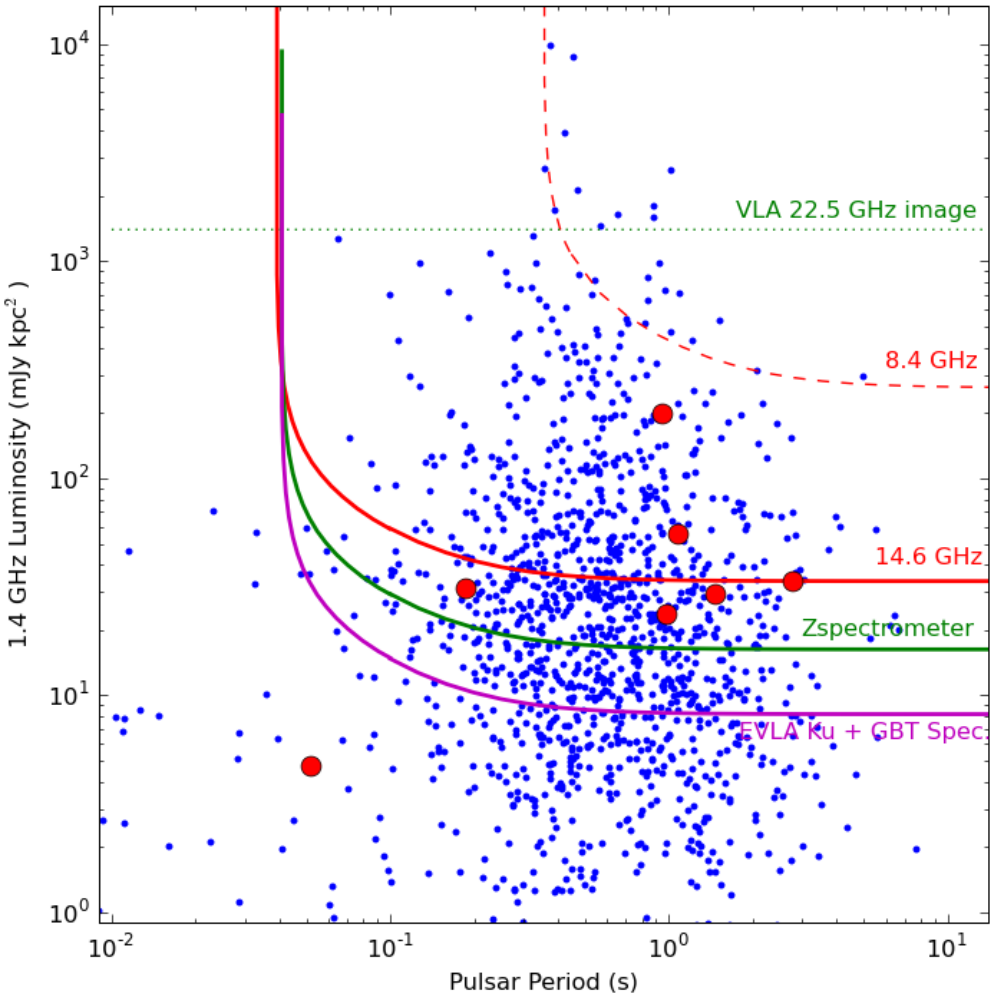
# Future GBT Experiments. Step 3

- New wide-band digital backend
- Joint CASPER (Berkeley) and NRAO (GB) ATI grant
- Uses ROACH-II FPGA boards
- 1.25 GHz x 8 spectrometers
- Basic mode for PSR/GC search available January 2012
- Replace existing Ku receiver with new EVLA Ku design
  - larger BW (12-18 GHz)
  - 1.5 to 2X better Trec
- Several groups requesting funding for EVLA Ku or more



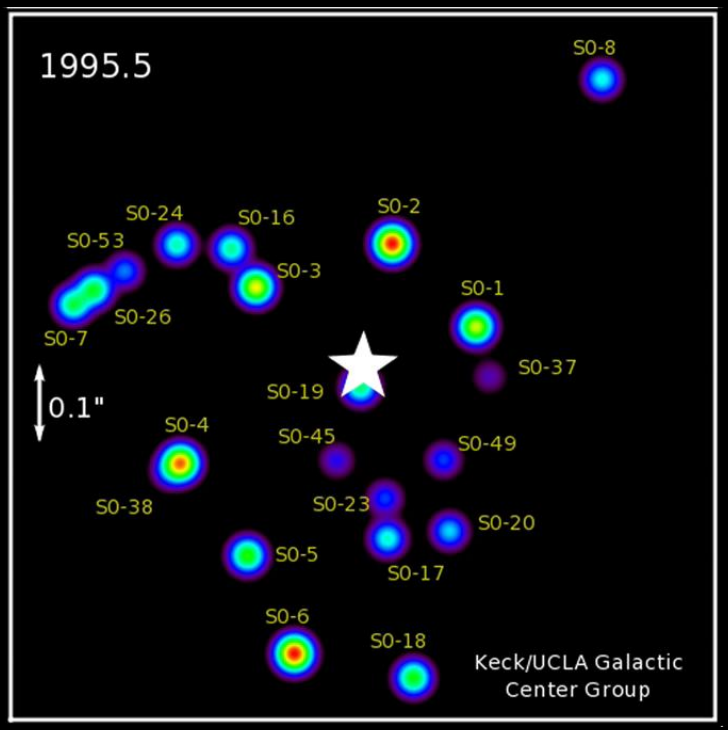
# Future GBT Experimental Capabilities

- Small increases in sensitivity result in large increase in fraction of population detectable
- 2-3 times increase
- Ultimately limited by GBT receivers.
  - or X + Ku hybrid
- Experiment pushes us into the bulk of the PSR population



# Summary

- The GBT has carried out a deep high-frequency search for pulsars within the central parsec of SgrA*
- No convincing candidates were detected
  - 10σ detection threshold of 10μJy at 15 GHz
- This survey should have been capable of detecting a significant fraction of pulsars (~5%) around SgrA*
- Either (a) turbulence at the GC has been underestimated, or (b) the number of PSRs at the GC has been overestimated
- GBT has the ability to detect and study pulsars at the GC for only a modest investment




We dance round in a ring and suppose,
But the Secret sits in the middle and knows.

- Robert Frost, *The Secret Sits*

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