

# Pulsar Observations with the Effelsberg 100-m: Facilities and Projects

David Champion  
Max-Planck-Institut für Radioastronomie  
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# Outline

- The Effelsberg 100-m telescope
  - The telescope
  - Receivers
  - Control software
- Pulsar backends
  - 7 beam filterbank
  - Coherent dedispersion
  - Others
- LEAP
- The local pulsar group
- Current and future projects
  - Searching
  - Timing
  - And more!
- Conclusions



# The 100-m telescope

- First light 1971
- 100 m diameter
- Gain    1.55K/Jy (21cm)  
          1.35K/Jy (3cm)  
          0.61K/Jy (6.5mm)
- 50° 31' North
- Located in a valley in the Eifel range
- Accommodation on-site
- Infrastructure recently improved

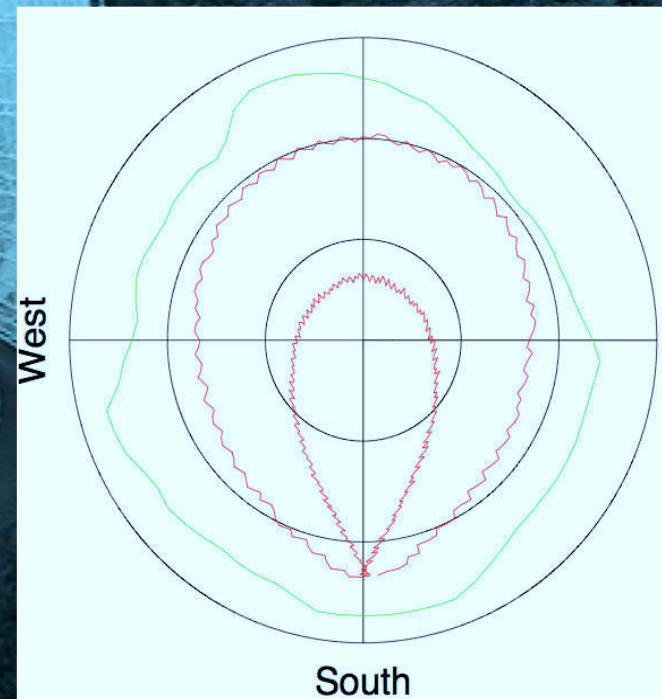




# The 100-m telescope

- Lower elevation limit is 8.6 but valley provides limit for most Az
- Valley location helps with RFI mitigation
- Valley faces south providing low decl obs
- Decl obs times:
 

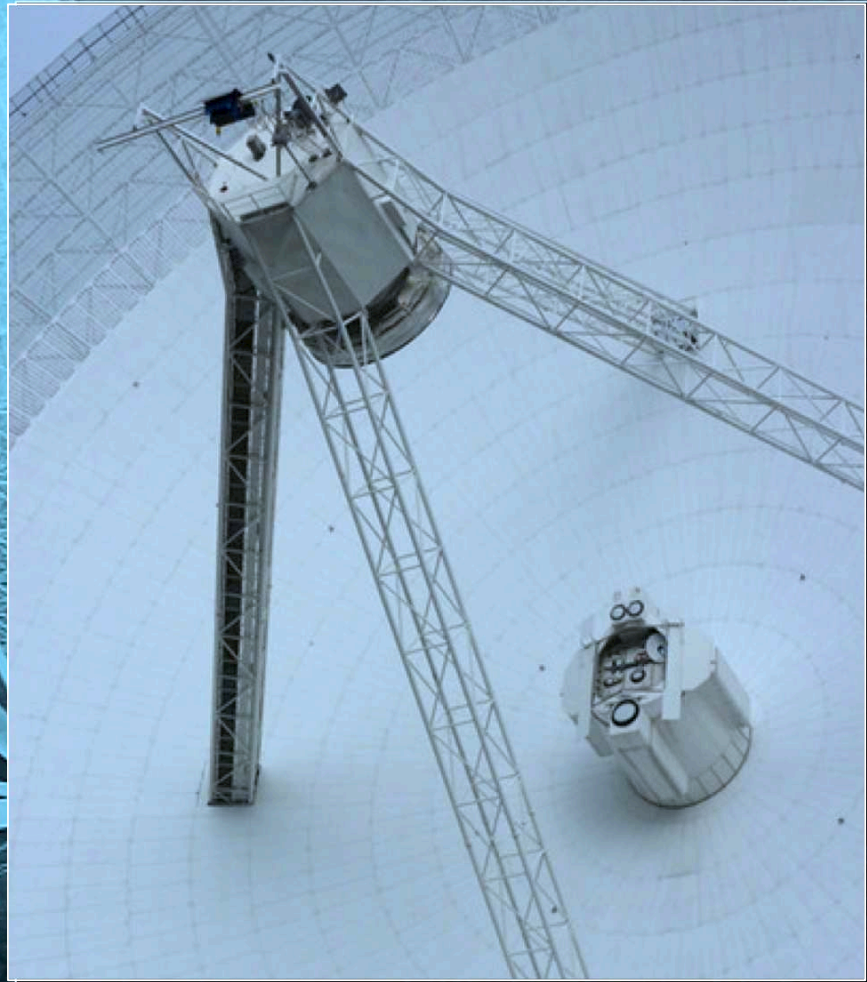
10	10hrs
0	9hrs
-15	5.5hrs
-25	4hrs
-30	2hrs
-31	1hr
- High slew-rate, 12 min for a full turn





# The 100-m telescope

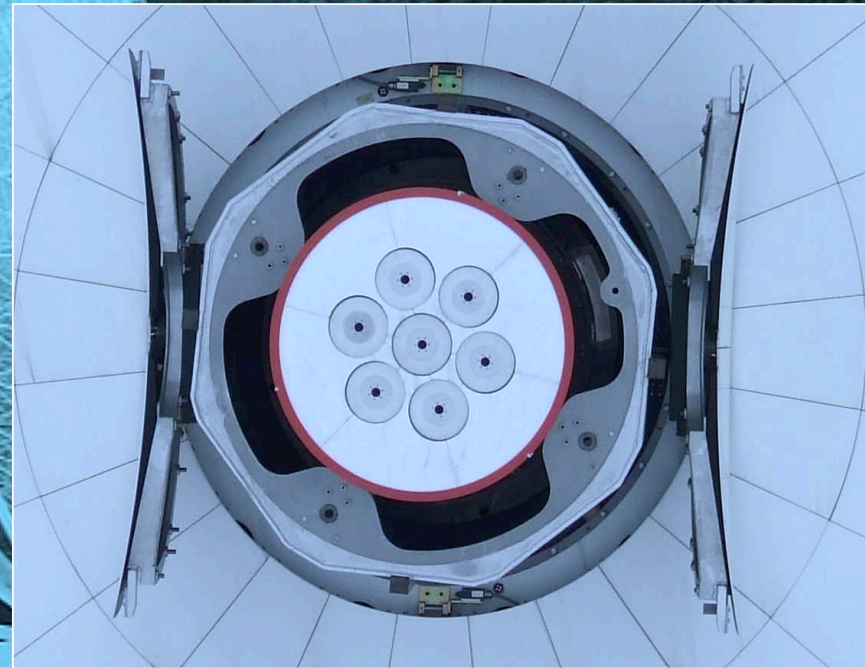
- Primary focus
  - One RX in position
  - One RX stored in cabin
  - Switching not automatic
- Secondary focus
  - RXs mounted for long term operation
  - High frequency RXs
- Switching between primary and secondary is quick





# Pulsar receivers

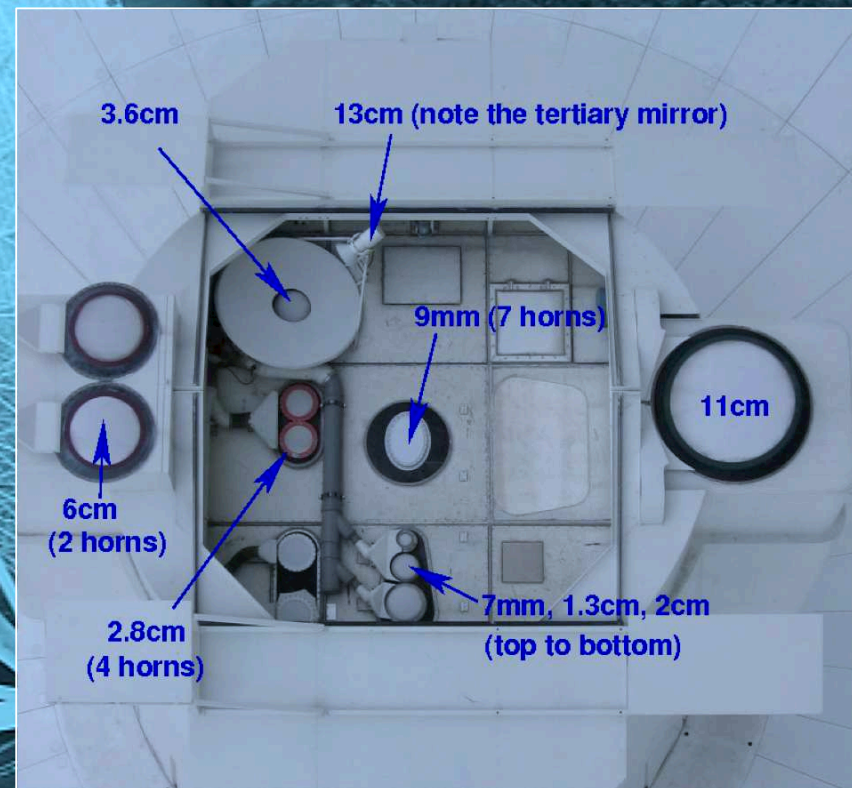
- 21-cm 7-beam
  - 300 MHz BW
  - Central beam circular pol
  - Outside beams linear pol
  - $T_{\text{sys}}$  25K
  - FWHM 550 arcsec
  - All beams have cals
- 20-cm
  - 300 MHz BW
  - $T_{\text{sys}}$  25K





# Pulsar receivers

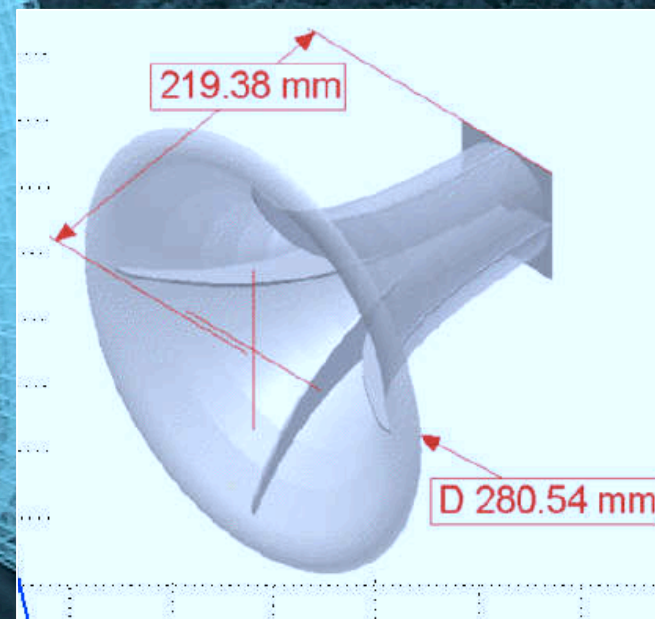
- 11-cm
  - 100 MHz BW
  - $T_{\text{sys}}$  17K
- 73-cm (temp)
  - 50 MHz BW
  - Uncooled
  - Used to assess RFI
- A suite of high frequency receivers from 9 cm to 3 mm
- Ongoing system of review, updating and consolidation





# Under development

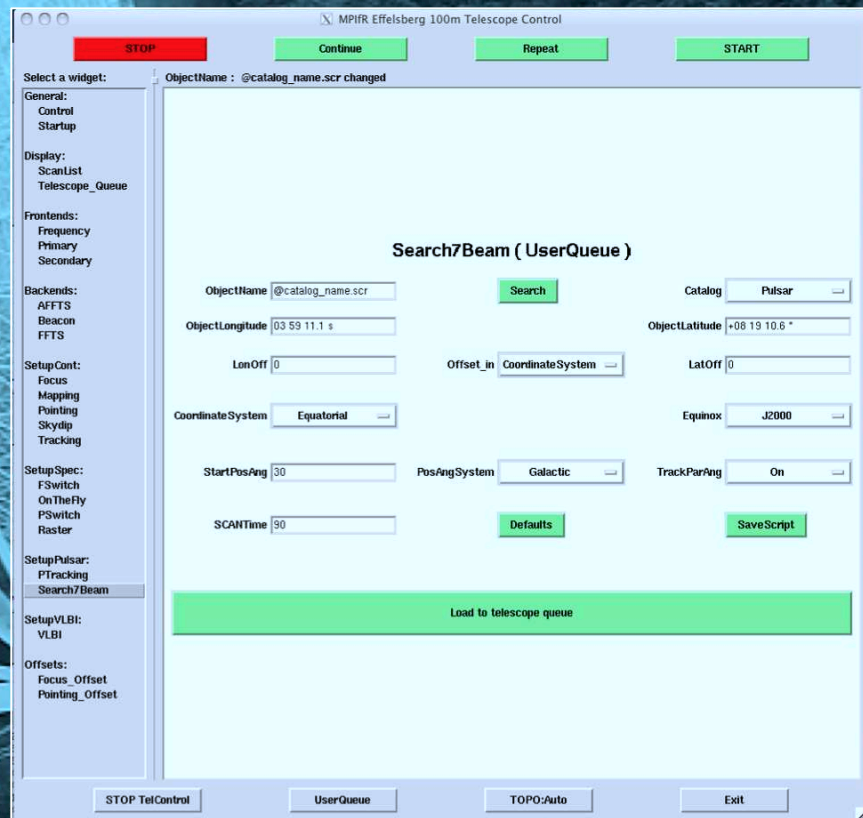
- Ultra Broad Band Receiver
  - 0.6 GHz to 3.0 GHz
  - $T_{\text{sys}}$  40K
  - RFI rejection filters required
  - >75% of band usable





# Control software

- Old text based system upgraded
- GUI system in place since summer 2010
- Full scripting and catalogue support
- Allows for remote observations
- Under continual development





# Pulsar backends

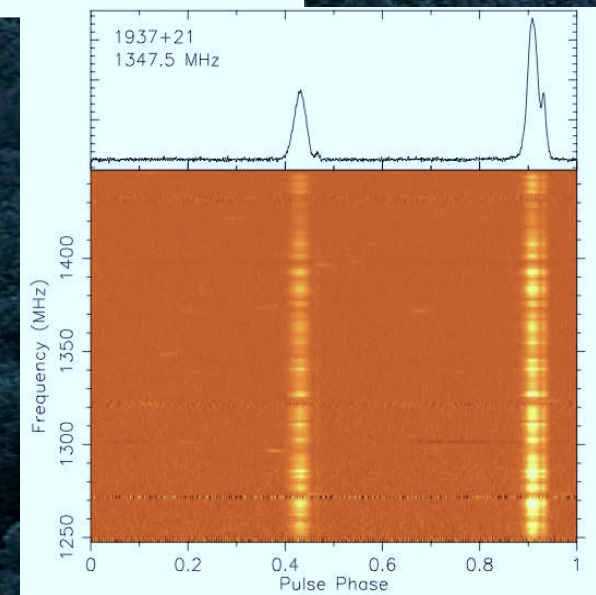
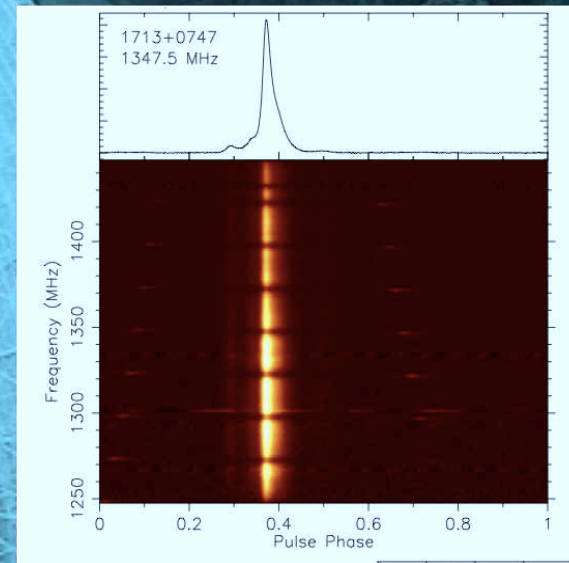
- 7-beam filterbank
  - In-house development
  - 512 frequency channels
  - 54  $\mu$ s sample time
  - Ultra-simple and stable operation
  - 32-bit data streamed directly to disk
  - Sigproc fil format used
  - Can be used for other frequencies
  - Not well suited to timing





# Pulsar backends

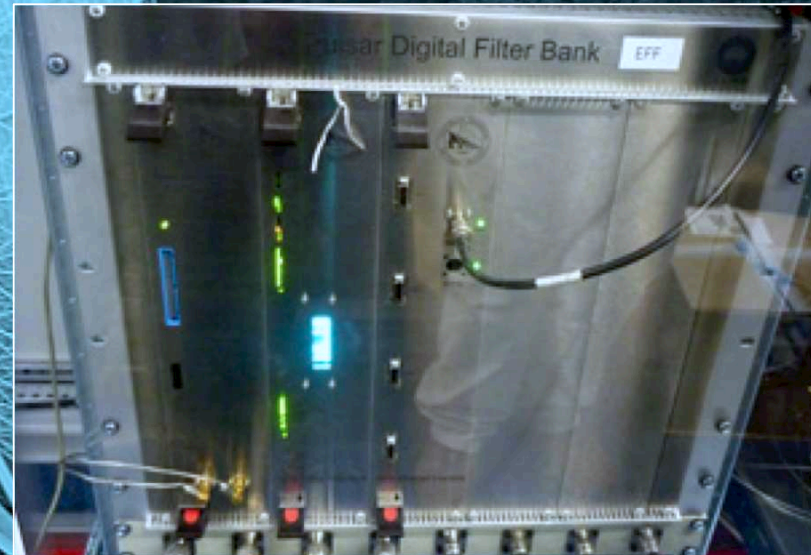
- ‘Asterix’
  - Based on ROACH boards + HP5412 switch + 16 high-performance nodes
  - Coherent dedispersion
  - 512 MHz BW
  - Best time res 31.24 ns
  - Realtime coherent dedispersion for  $DM < 200$
  - Higher DMs dedispersed off-line
  - Up to 34 hours of hard drive space
  - Can produce dedispersed, unfolded timeseries for initial timing
  - PuMa II file format





# Pulsar backends

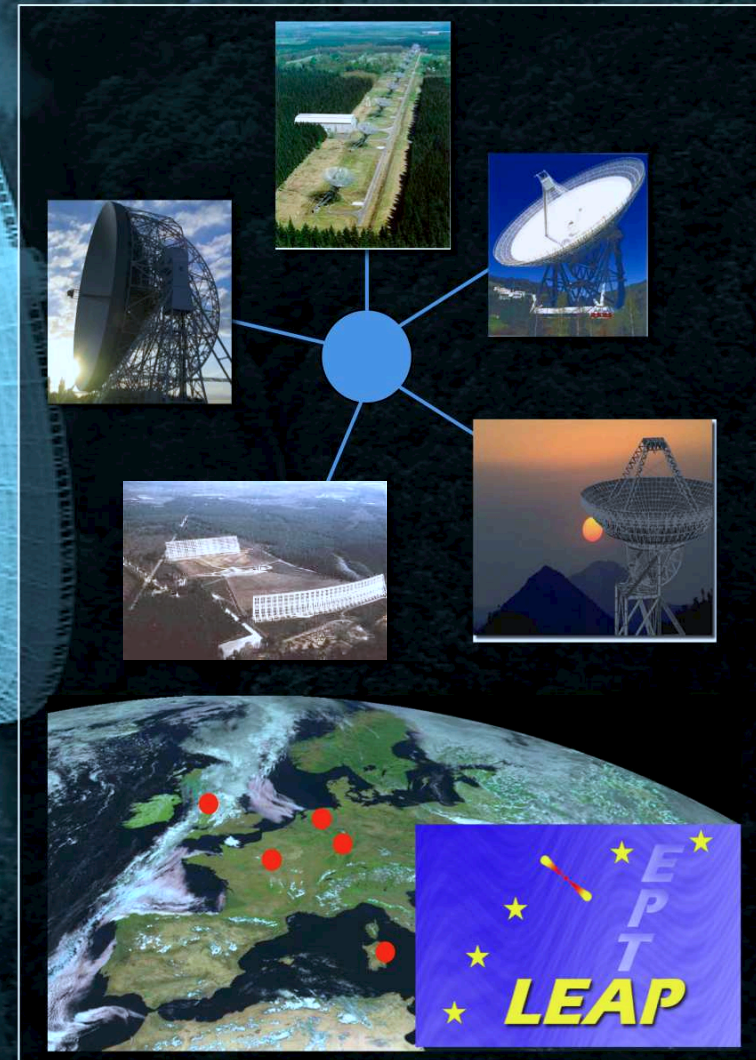
- DFB (from ATNF)
  - Digital filterbank
  - FITS format output
- EBPP
  - Coherent dedispersion
  - Very limited BW
  - Run in parallel to obtain overlap
  - Large amounts of historical data
- EPOS
  - Filterbank
  - No longer used





# Large European Array for Pulsars

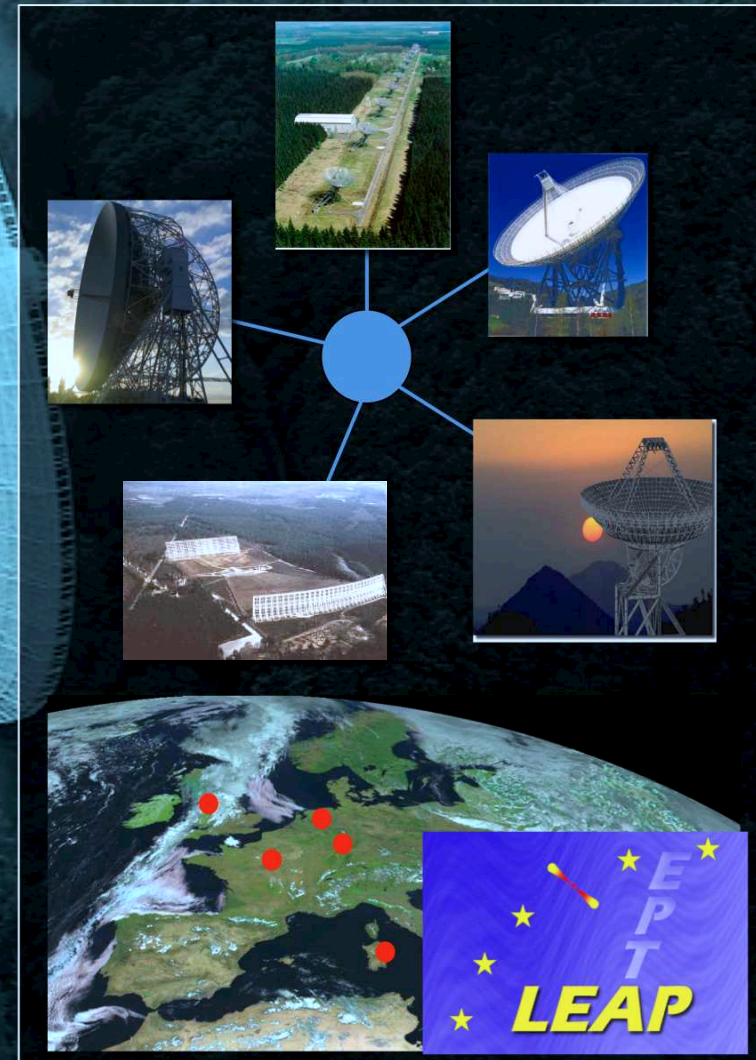
- Extension of European Pulsar Timing Array (EPTA)
- Goal to form single, Arecibo-sized dish by coherently adding signals from all big European telescope:  $\sim 200\text{m}$  dish!
- Effelsberg, Lovell, Nançay, WSRT and SRT (when completed)
- Initially at 1.4 GHz with a BW of 100 MHz





# Large European Array for Pulsars

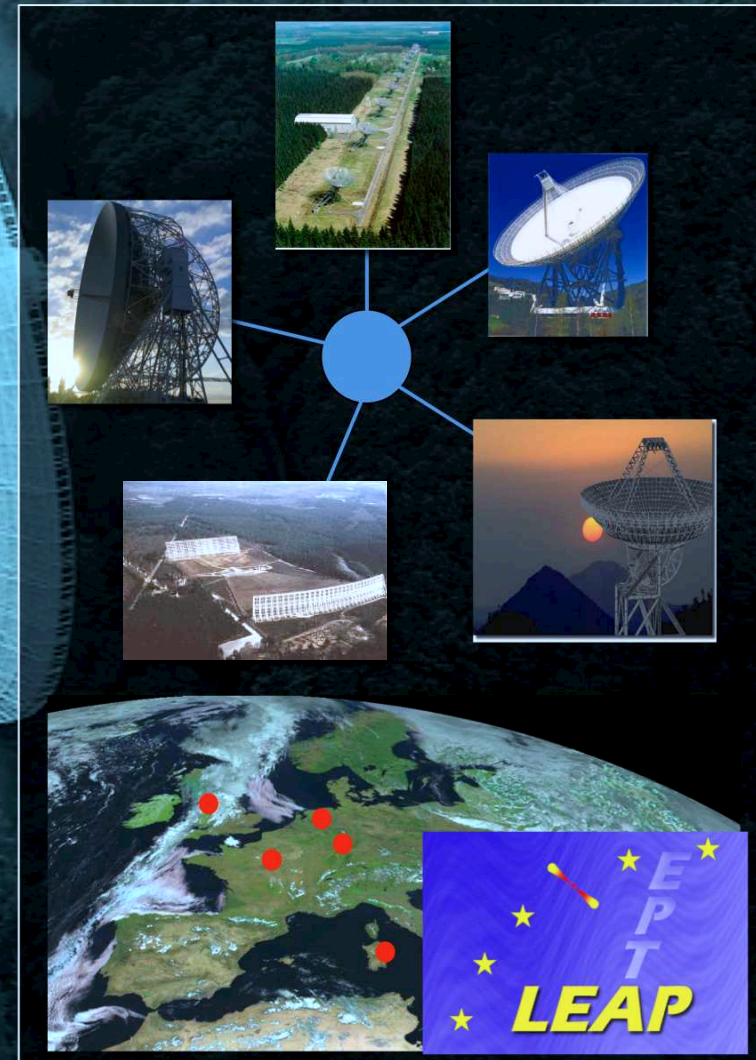
- Using the Asterix and Obelix (ROACH systems) at Effelsberg, Lovell and SRT
- PuMa II at WSRT
- GPU based system at Nançay
- Initially disks shipped to central location for correlation
- Eventually over network





# Large European Array for Pulsars

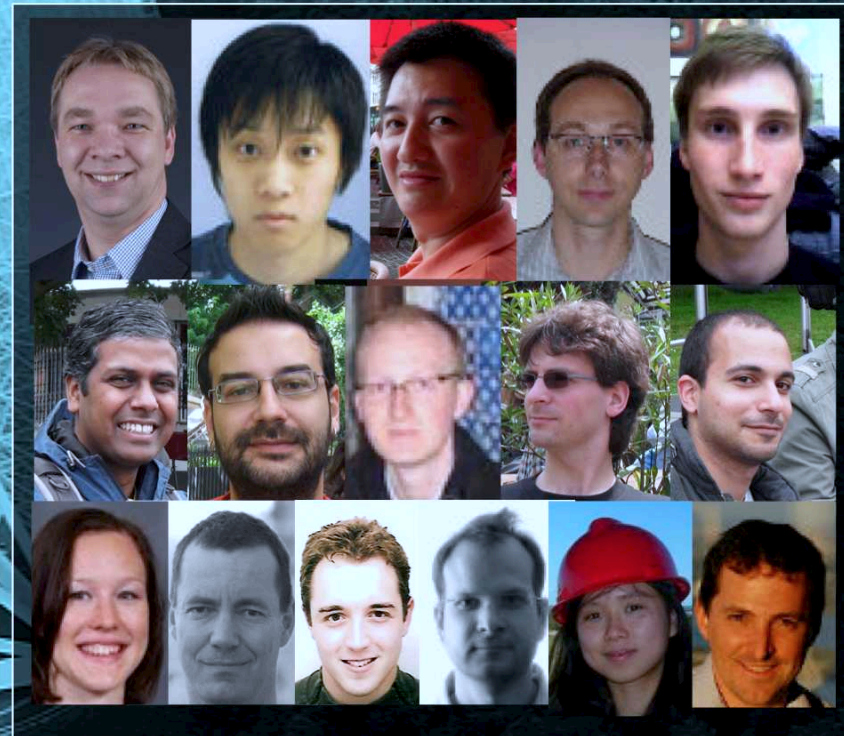
- Up to order of magnitude improvement for pulsars outside Arecibo range
- Excellent sky coverage
- Ideal test bed for SKA technology
- We have the first fringes from the telescopes in the array





# The pulsar group

- 17 members
- Lead by Michael Kramer
- 4 staff
- 7 post-docs
- 5 students (more on the way)
- Particularly close links with Jodrell Bank group





# European Pulsar Timing Array (EPTA)



University of Manchester, JBO (UK)

ASTRON (NL)

Max-Planck Insitut für Radioastronomie (GER)

Nançay Observatory (FR)

INAF Osservatorio Astronomico di Cagliari (IT)

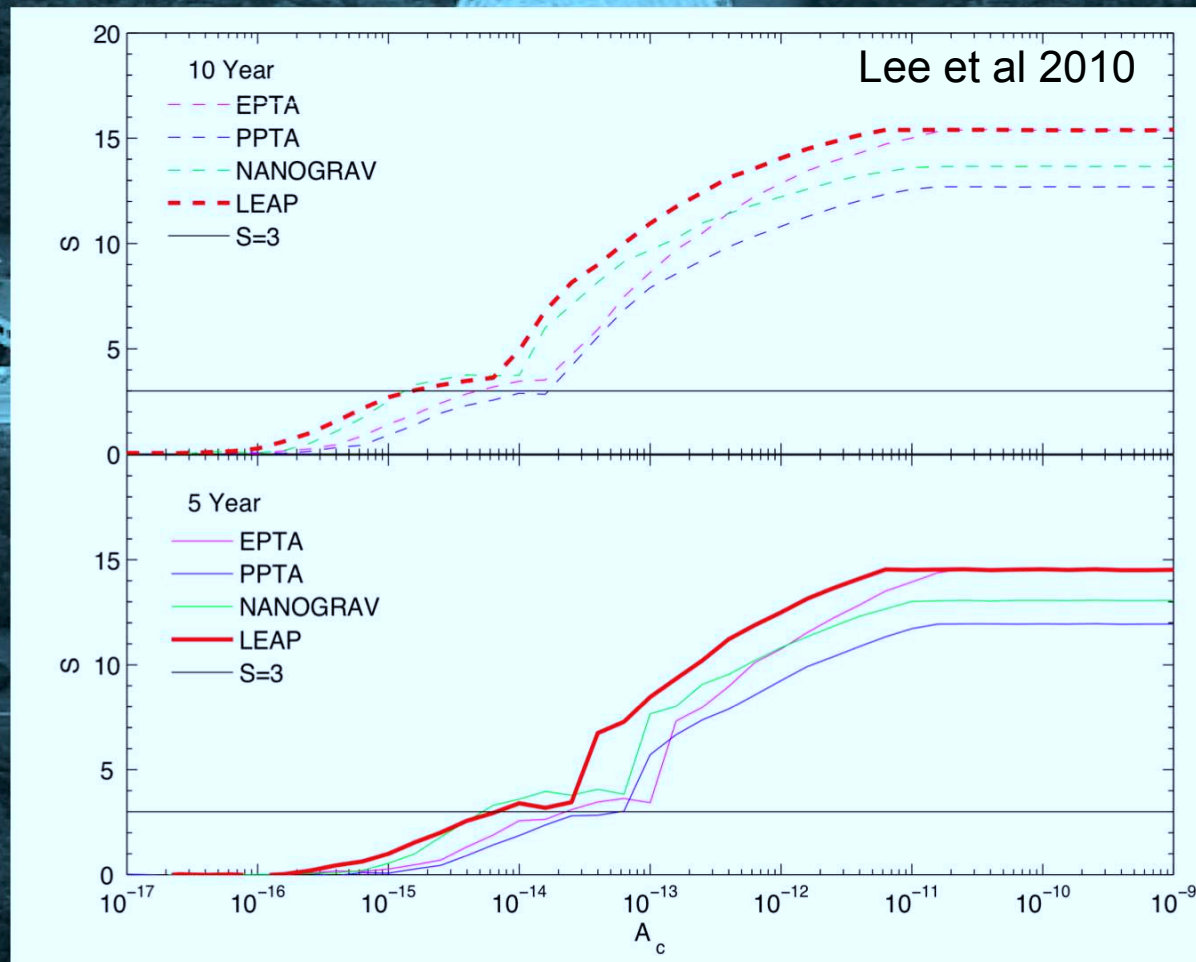
Leiden (NL): Yuri Levin & Rutger van Haasteren

Birmingham (UK): Alberto Vecchio et al.

- Good coverage in radio frequency and time
- Long time baseline (>10 years)



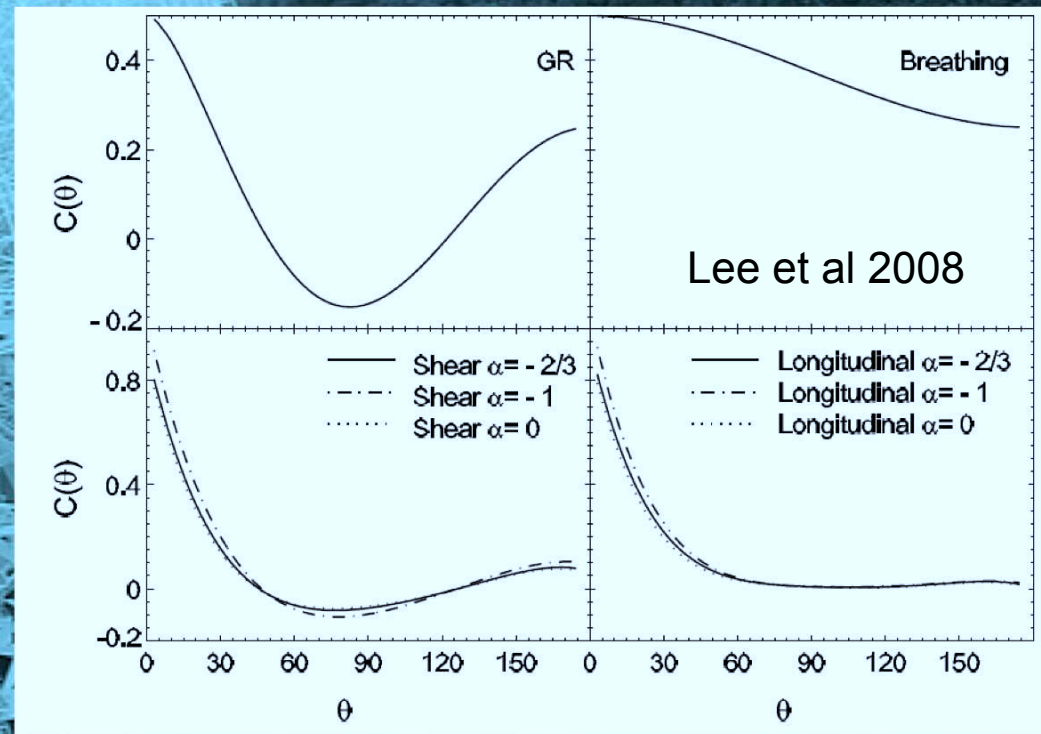
# EPTA





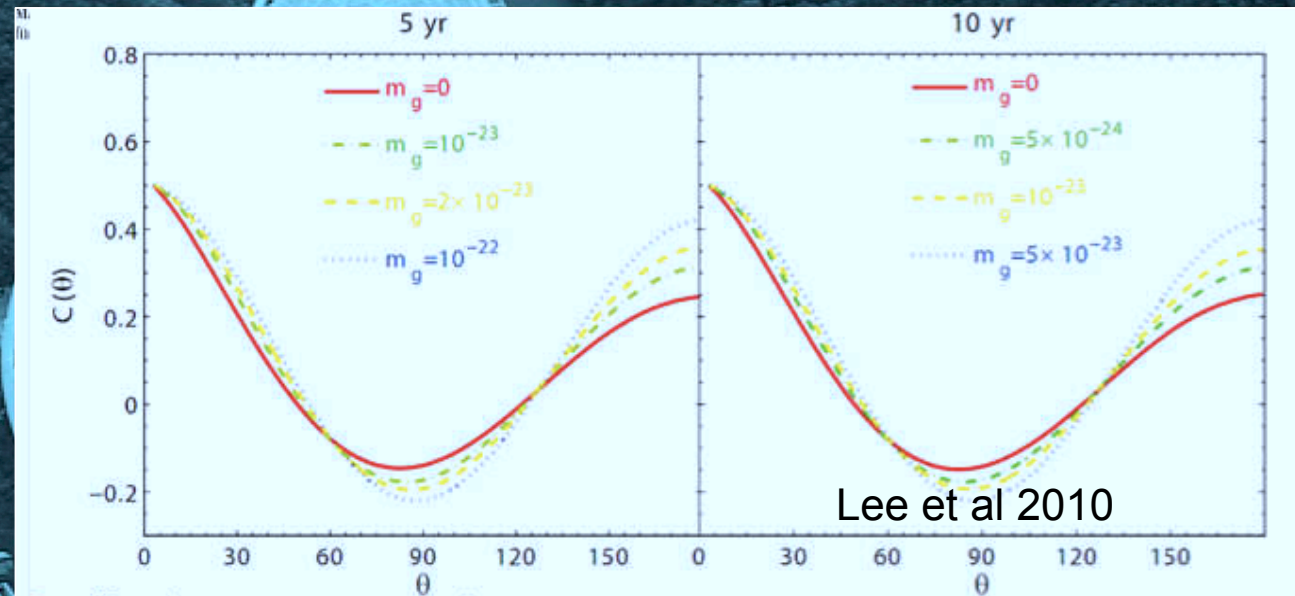
# GW science

- Shape of curve depends on GW polarisation
- Precise measurement gives test for theories of gravity!





# GW science



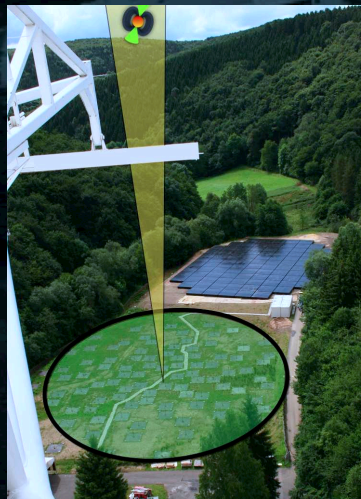
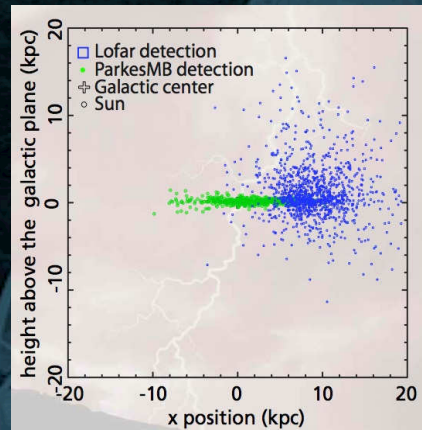
We can even give  
exciting constraint  
on graviton mass!



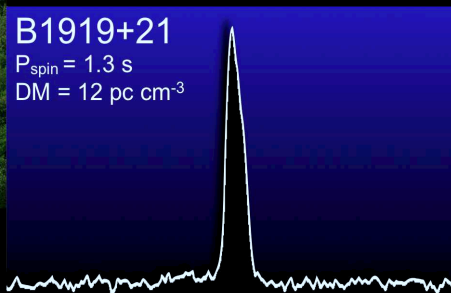
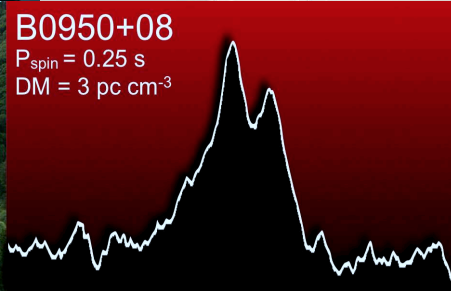
# LOFAR



Van Leeuwen & Stappers (2006)



Effelsberg (DE601)  
First Pulsar Detection



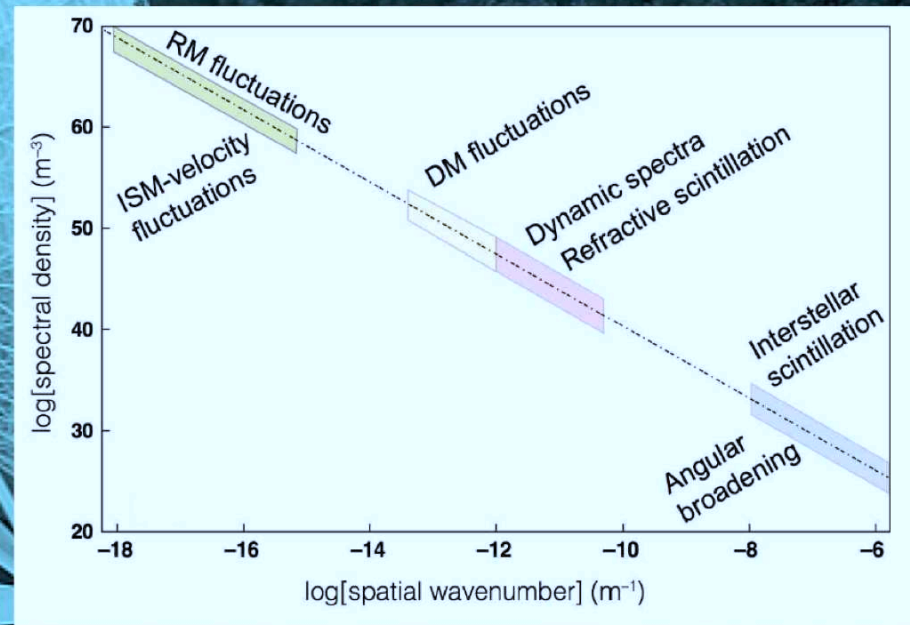
LOFAR Pulsar Science Working Group





# Galactic work

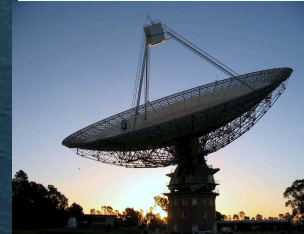
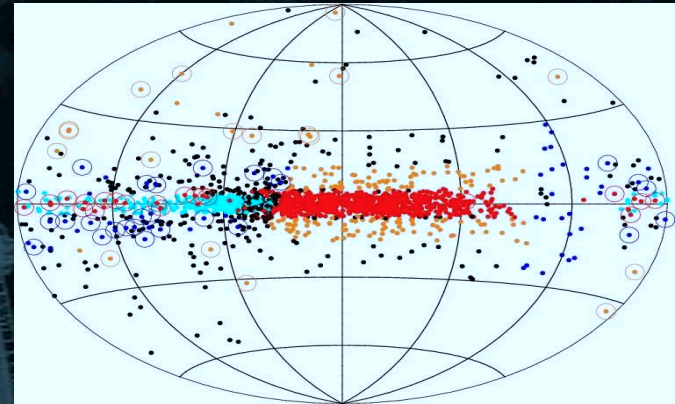
- Survey of northern pulsars to get more RMs, fill in the gaps
- Use wavelet analysis to produce Galactic model
- Combine the DM and RM information to produce a unified Galactic model





# The High Time Resolution Legacy Survey or How to get more PTA pulsars

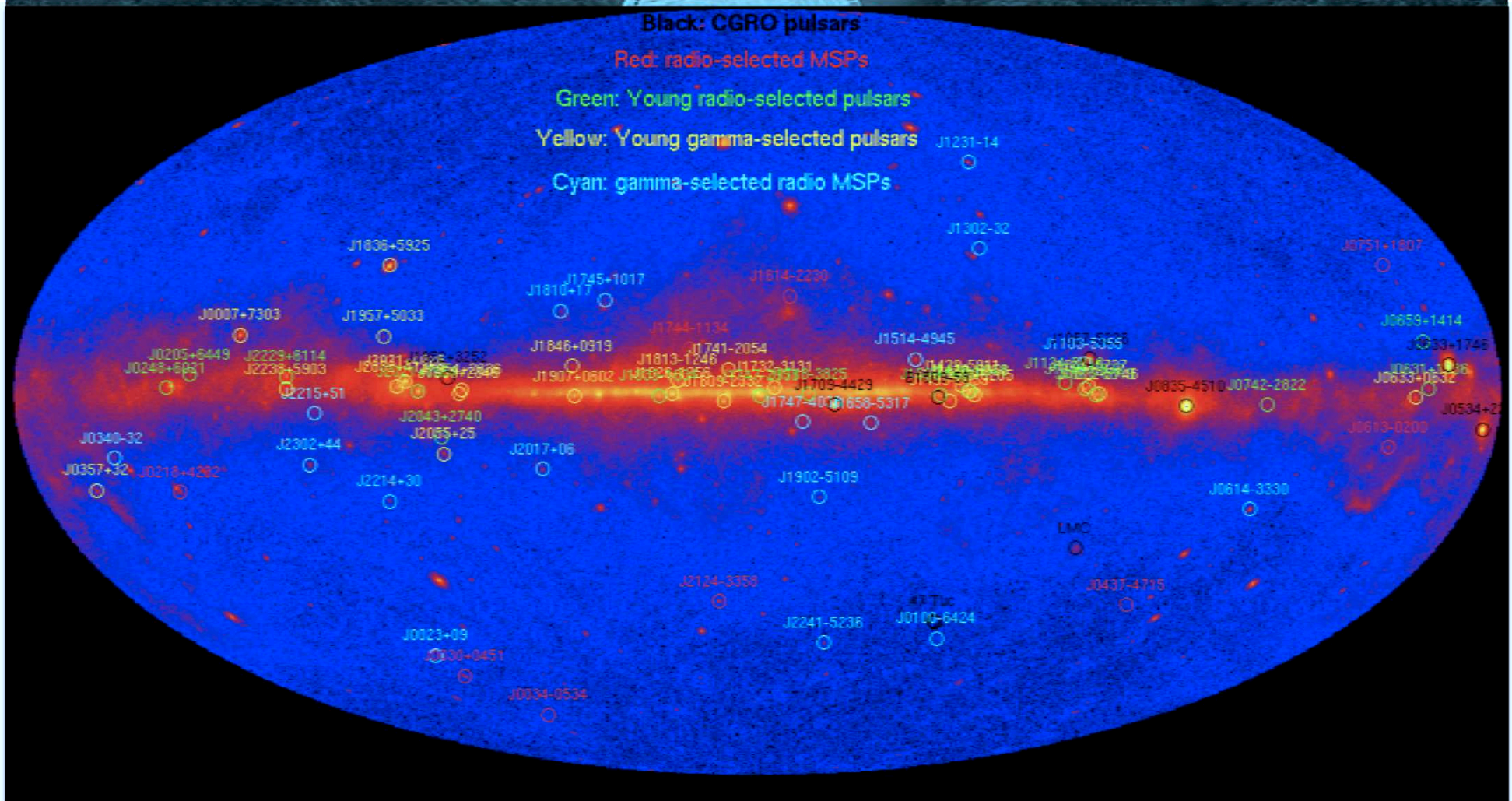
- Survey of the whole Northern & Southern sky with Effelsberg & Parkes
- Using the 7-beam & 13-beam L-band systems
- Deeper than all previous surveys
- High-time resolution ( $32\mu\text{s}$ ), fine frequency resolution (0.5 MHz) and 8 bits sampling
- Probing 8 x more volume in Galaxy!
- Up to 500/530 normal pulsars expected
- Plus 100/130 millisecond pulsars
- Combined with local LOFAR census this all-sky survey will be the defining pre-SKA survey





# A short-cut to find PTA pulsars...

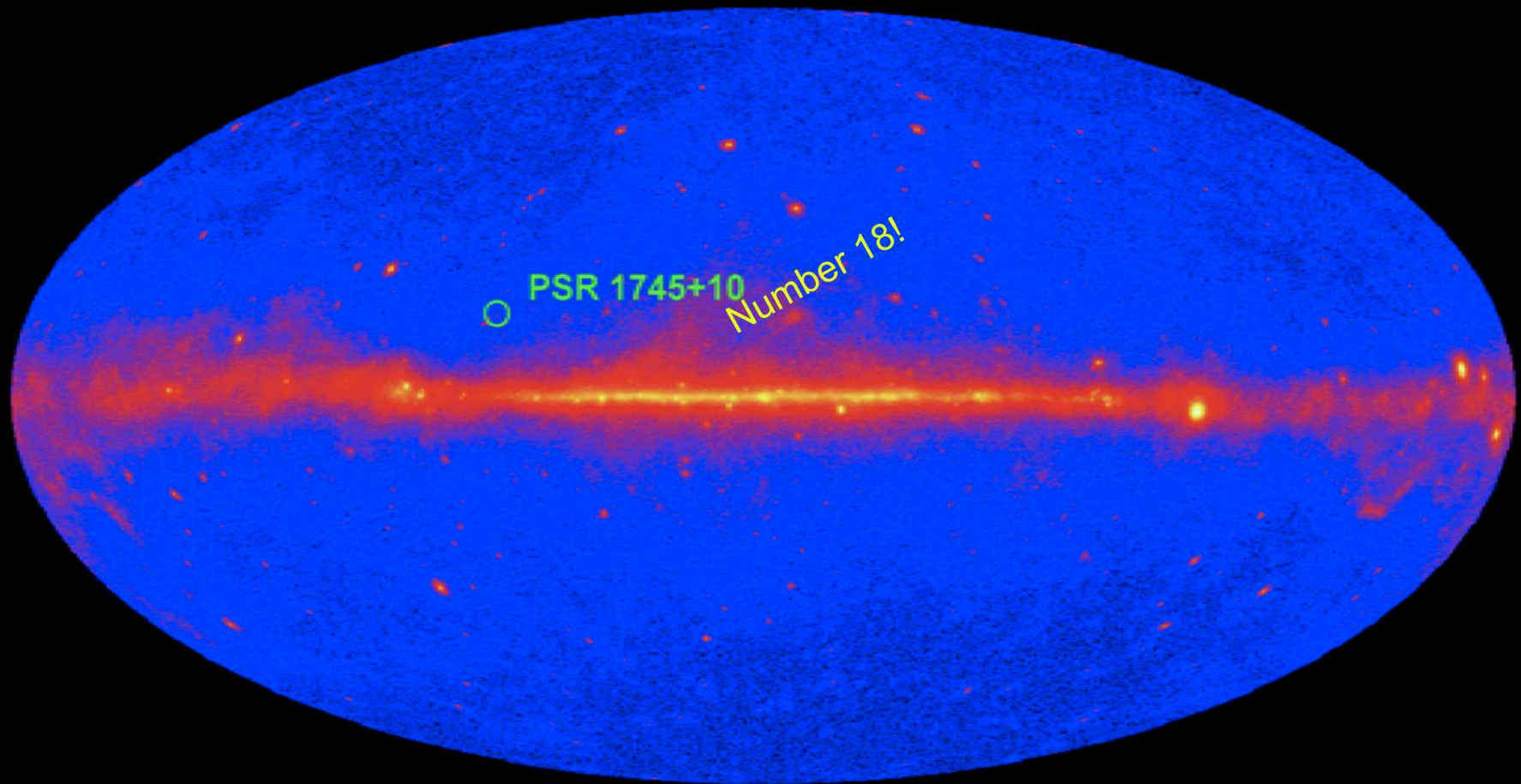
FERMI does not only detects known radio pulsars (about 50 already!)...  
But a lot of unidentified FERMI point sources are pulsars, in particular MSPs!





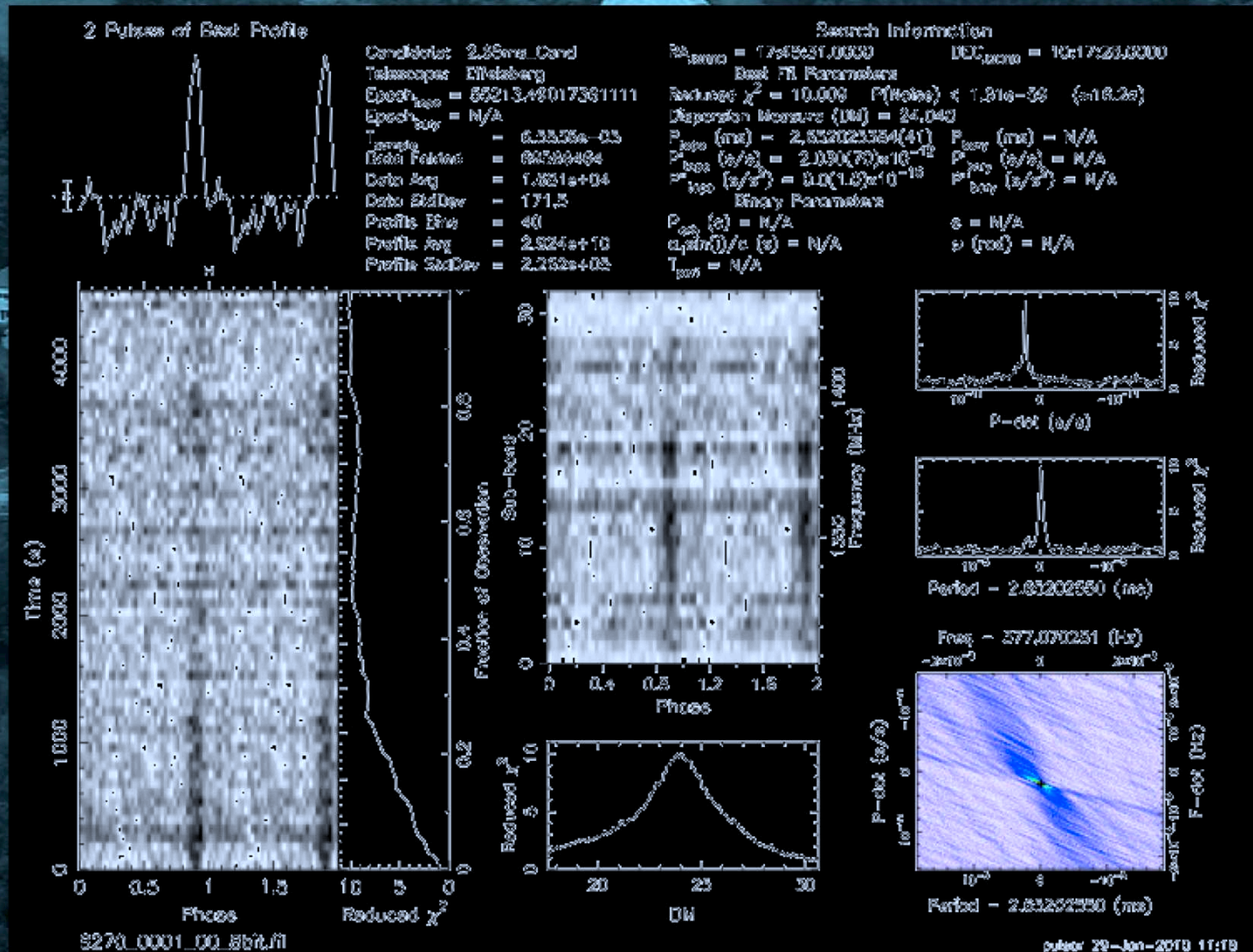
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But a lot of unidentified FERMI point sources are pulsars, in particular MSPs!





# Effelsberg's first MSP





An aerial photograph of a large radio telescope dish, likely the Effelsberg 100m telescope, situated in a dense forest. The dish is a complex lattice structure, and its base is surrounded by some buildings and a road. The entire image has a blue tint.

And many more...

The telescope and group are involved in numerous other European and international projects



# Summary

- The telescope is a powerful pulsar instrument
- Receivers and backends are under continual development
- Proposals are encouraged!
- Remote observation possible for experienced observers
- Local pulsar group has grown dramatically
- The group and telescope are involved in numerous large- and small- scale projects