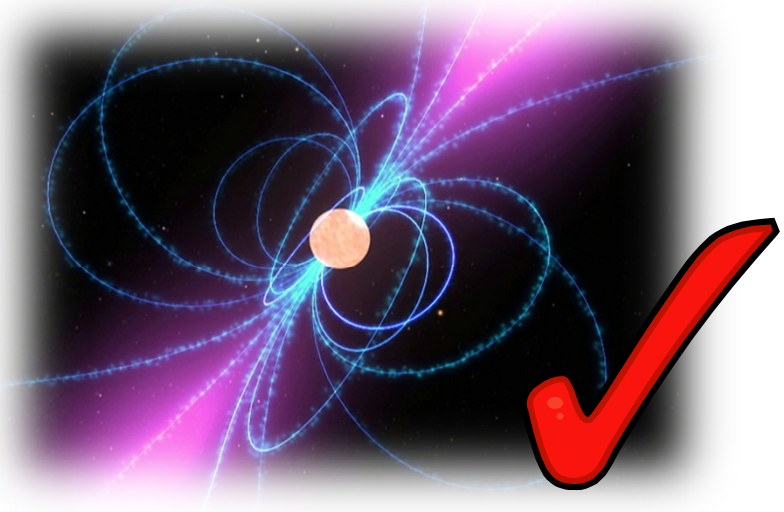
Pulsar Rotation Measures

and the

Magnetic Structure of the MW



Charlotte Sobey

Supervisors: Dr. Aris Noutsos, Prof. Michael Kramer

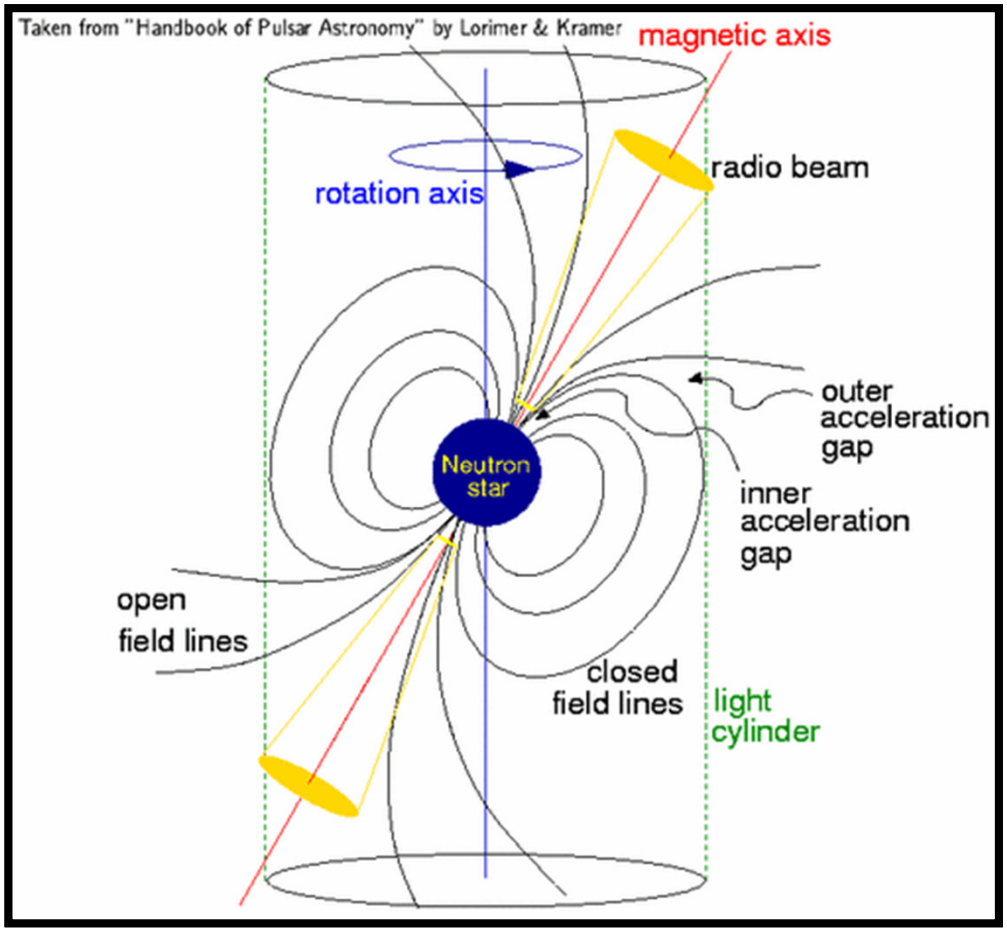
Max-Planck-Institut für Radioastronomie

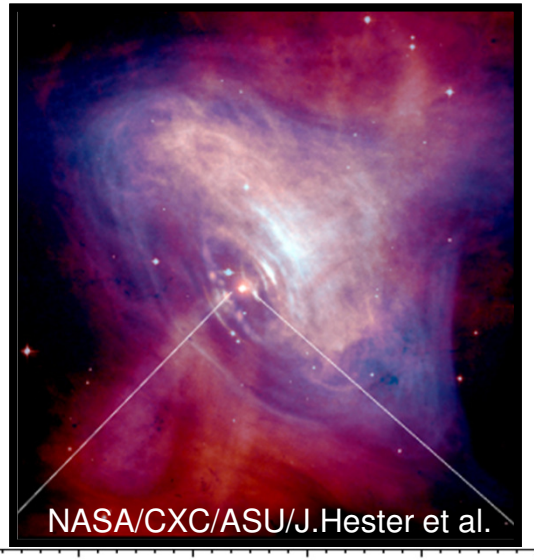
Outline

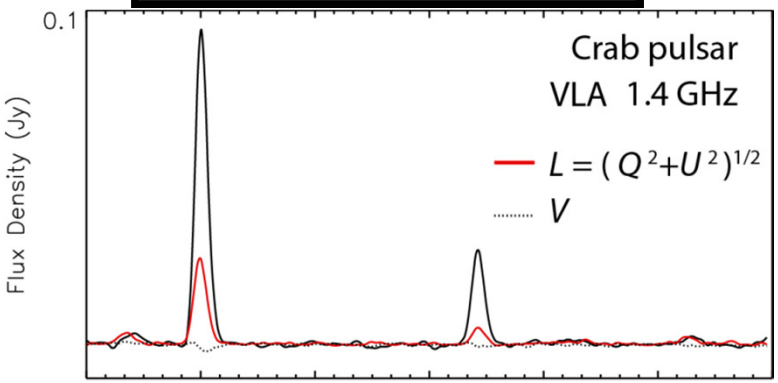
- Pulsars & related research
- The Galactic Magnetic Field (GMF)
- Pulsar Rotation Measures
- Wavelet Analysis – large-scale
- Future prospects i.e. LOFAR
- Conclusions

Pulsars…

- Theory: 'toy model' Observed: pulses







..Why they're less boring than you think!

Pulsars as objects:

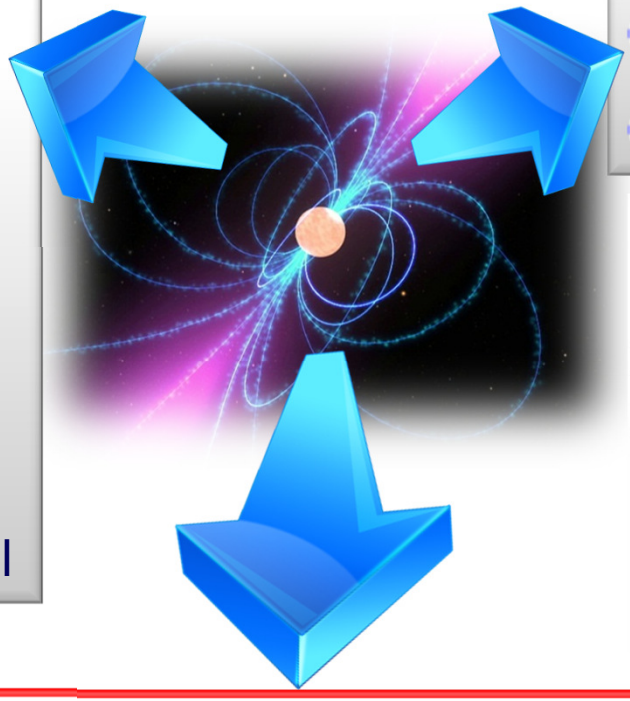
- Stellar evolution
- Equations of state
- Plasma physics

Intervening ISM:

- Scintillation

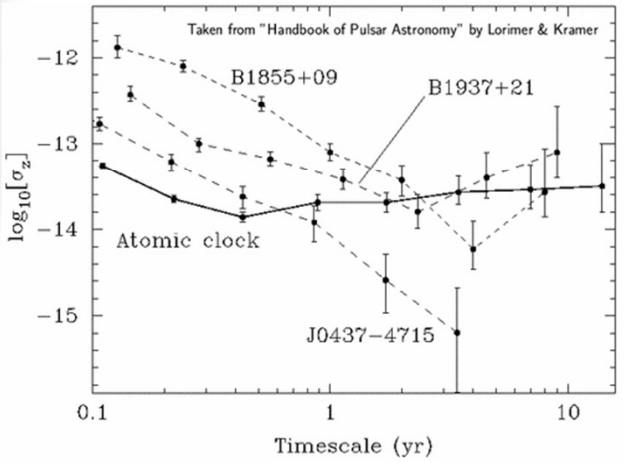
Galaxy:

- Gravitational potential



Timing:

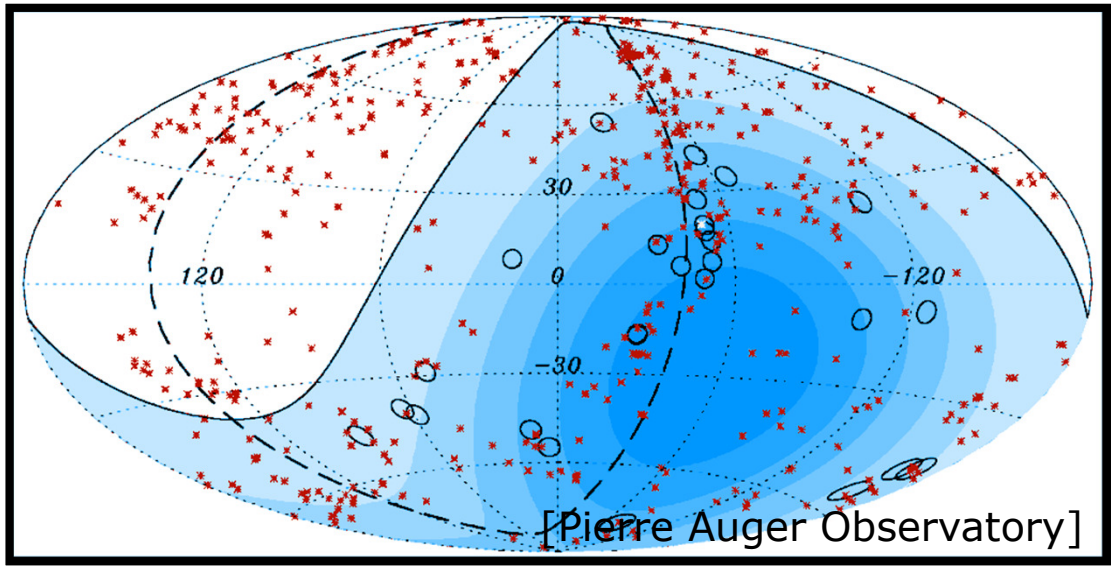
- Accurate clocks
- Theories of gravity
- Gravitational waves



Measuring the magnetic structure of the MW!..

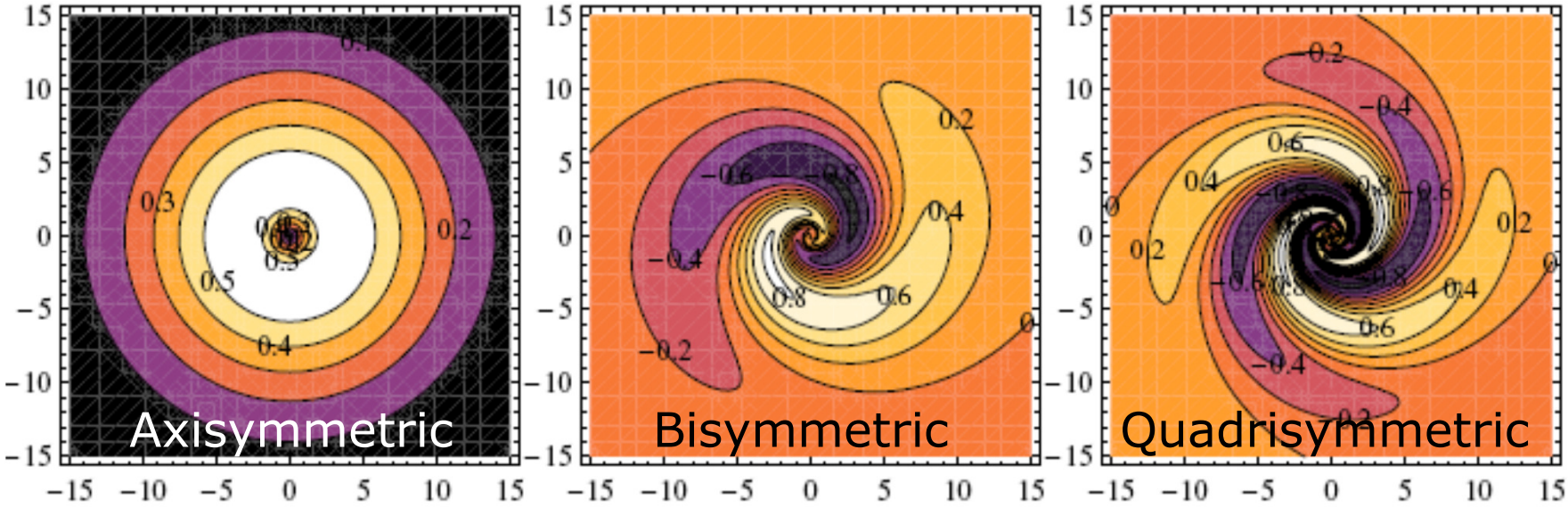
The Galactic Magnetic Field

- Crucial role in many interesting astrophysical processes:
  - Deflection of High Energy Cosmic Rays
  - Star formation and evolution of molecular clouds
  - Hydrostatic balance in the ISM



GMF components

- Modelled:
  - Turbulent, small-scale fields (10-100 pc) i.e. SNR
  - Regular, large-scale fields (> 1 kpc)



[Stepanov et al. 2008]

Pulsar Rotation Measures: Theory

- Faraday rotation of plane of linear polarisation occurs when emission traverses the cold, magnetised ISM
- Magnitude of rotation dependant on RM and wavelength:

$$\Delta PA = RM\ \Delta(\lambda^2)$$

  - RM related to magnetic field and electron density:

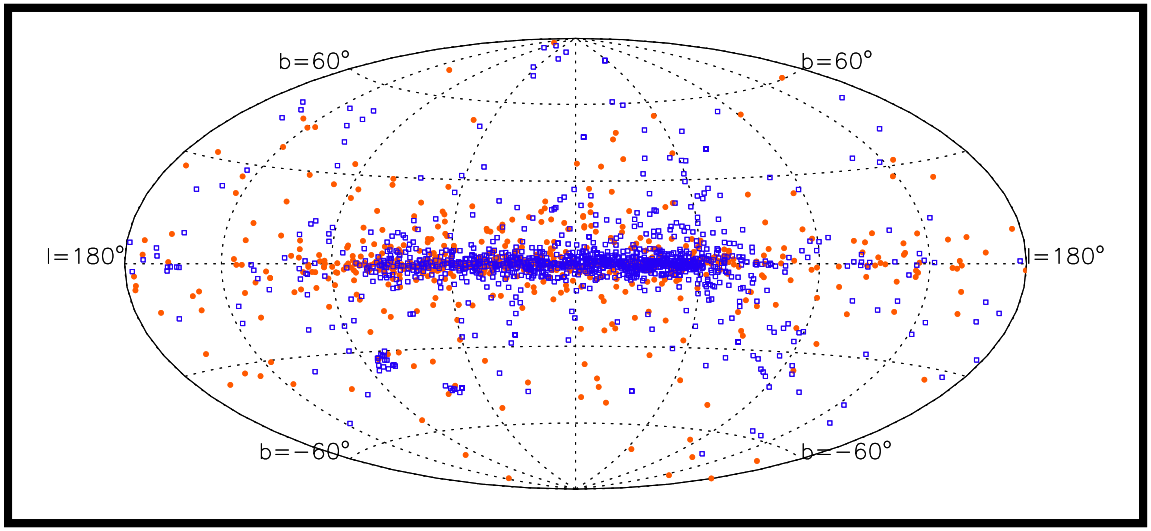
$$RM = 0.810 \int_0^d n_e(s)\ \mathbf{B}(s) \cdot d\mathbf{s}$$

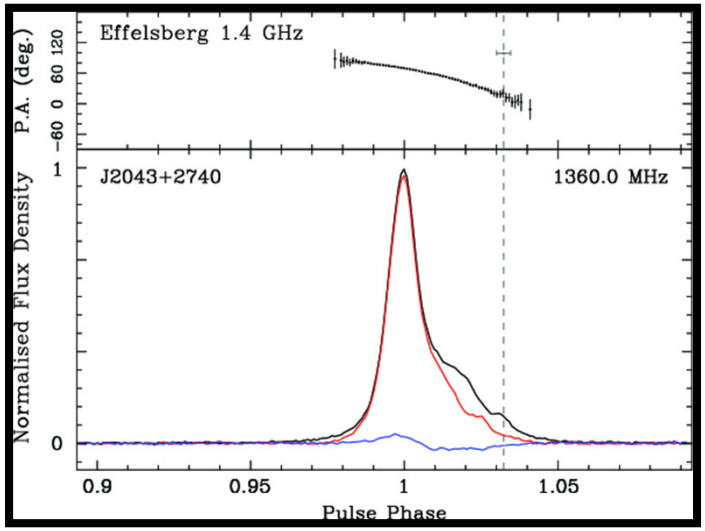
  - Combining with DM gives parallel component of B:

$$\langle B_{||} \rangle = 1.232\ \ (RM/DM)$$

Pulsar RMs: Advantages

- Magnetosphere contributes zero net Faraday rotation
- Distributed throughout Galaxy
- Many are highly linearly polarised
- Combining Dispersion Measure with n_e model -> distance

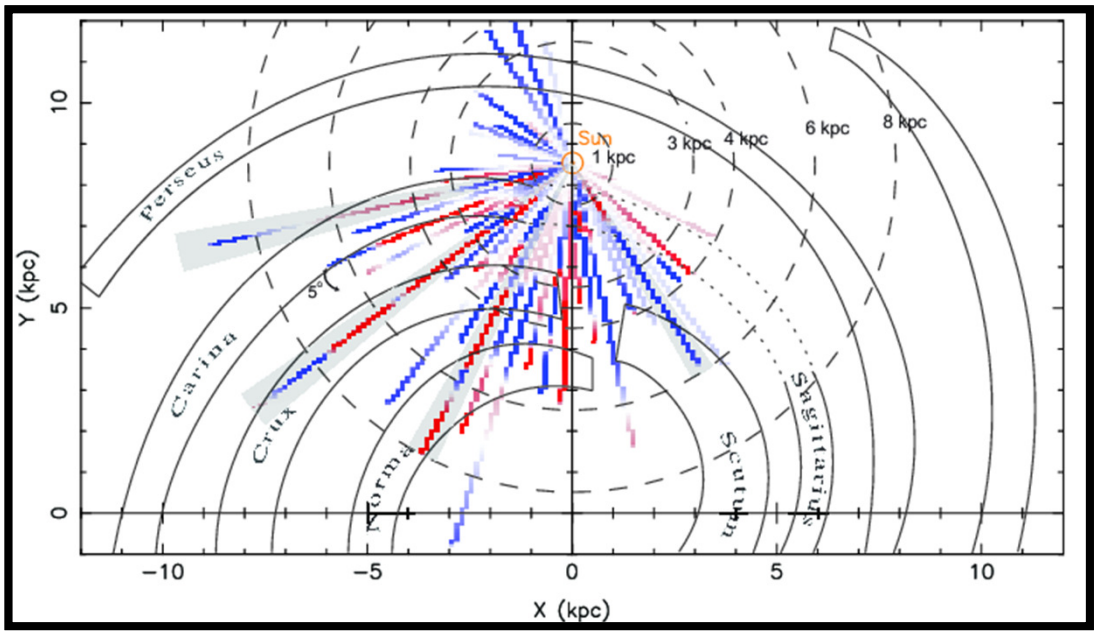




[A. Noutsos]

Pulsar RMs: Latest results

- Fitting latest results to GMF models (i.e. Nota & Katgert 2010):
  - Related to optical spiral arms
  - Most closely resembling QSS of Stepanov et al. ’08
  - Each Arm-Interarm interface shows clear field reversals…



[Noutsos et al. 2008]

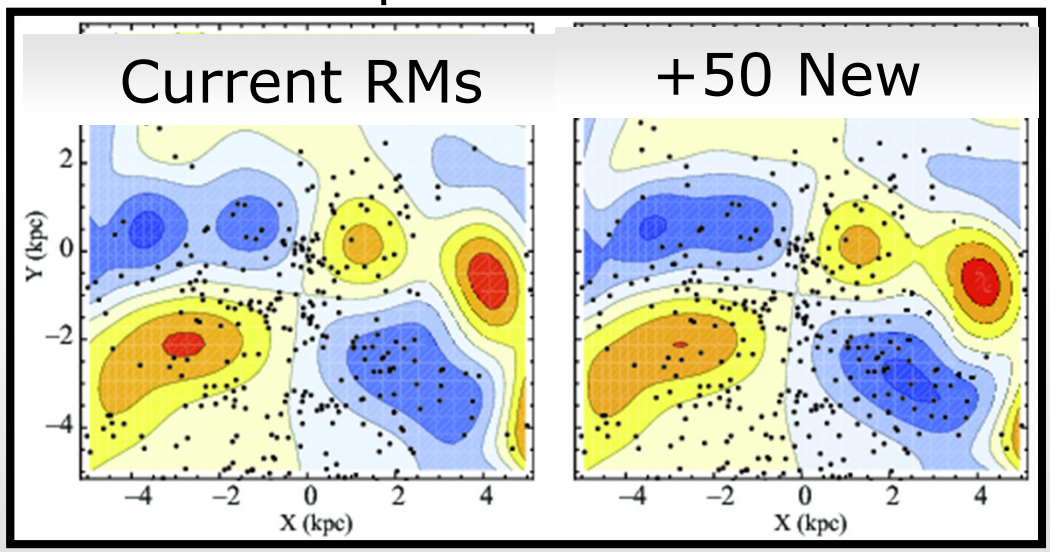
Pulsar RMs: Improvements

- Limitations of the method:
  - Simplistic to assume average $<B_{||}>$ and n_e
  - Distances from DM may introduce 10-20% errors
  - Turbulent fields (e.g. HII regions, SNRs)
  - Amplification of noise – integral quantities

How can this be improved?...

Wavelet Analysis

- Filter noise due to small-scale fluctuations
- Minimise noise amplification

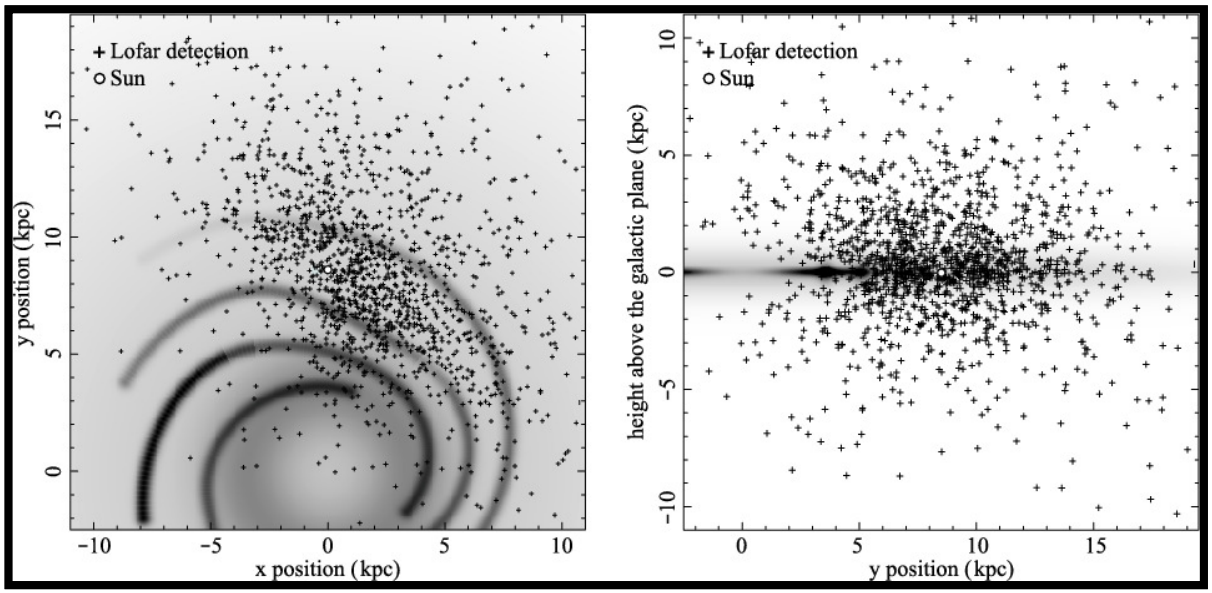


[R. Stepanov]

- Works well with regularly OR randomly distributed data where gaps do not exceed ½ wavelet scales…
  - Combine with extragalactic sources...
  - Increase number of known pulsars with RM data

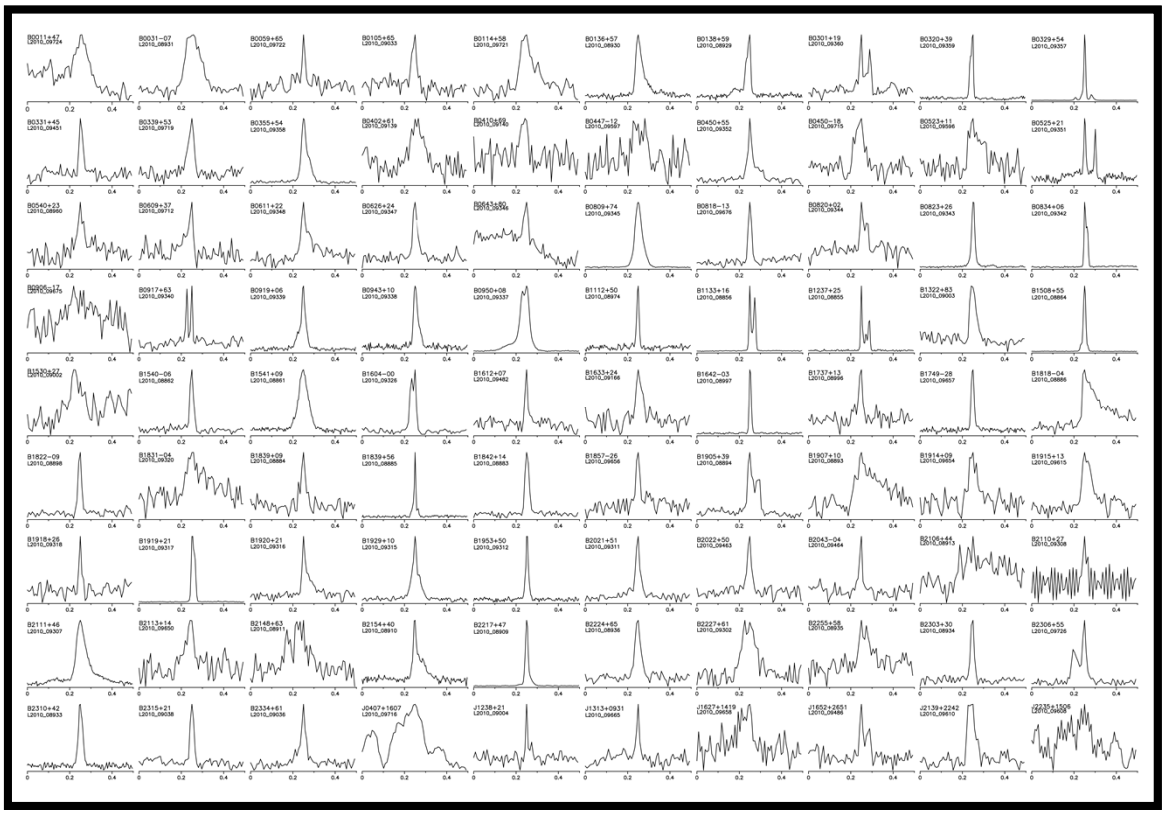
Future Prospects…

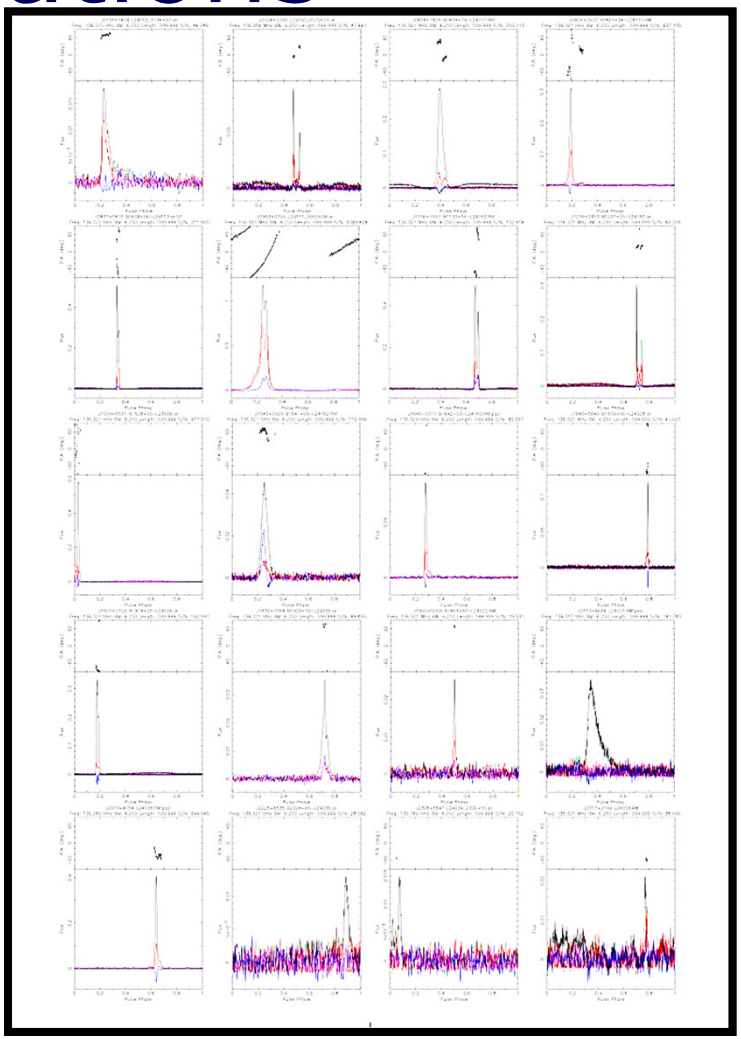
- Short-term: Observations with Effelsberg
- Long-term: Discover more pulsars – follow up with polarisation
- HTRU survey underway – galactic disk, shorter λ
- LOFAR survey to begin soon… - higher latitudes, longer λ



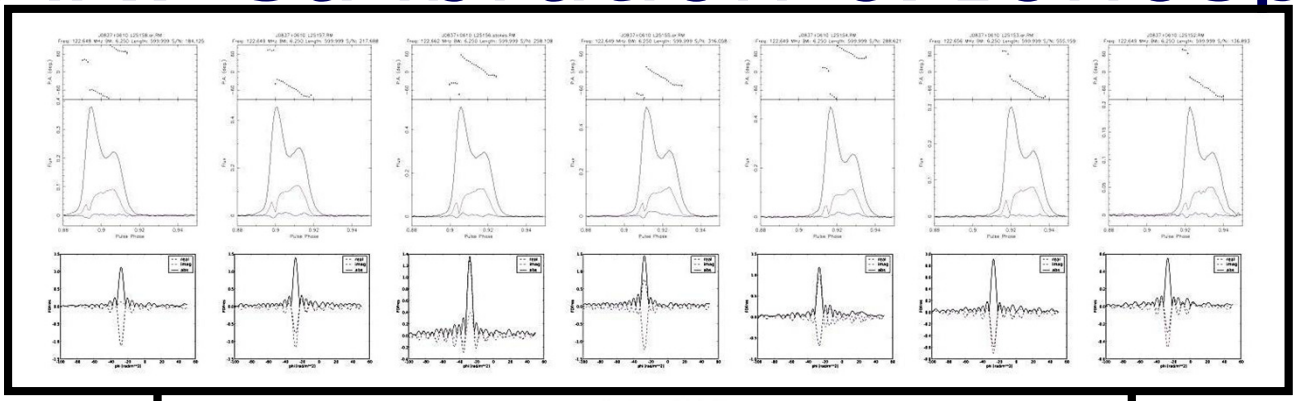
[van Leeuwen & Stappers 2010]

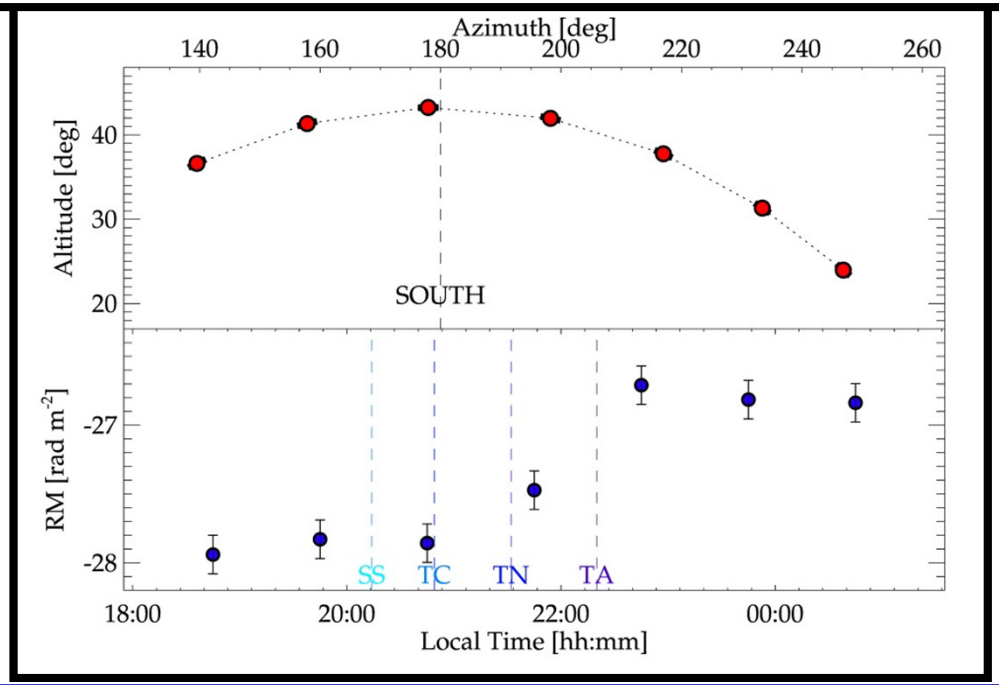
LOFAR Observations





LOFAR: Calibration & Ionosphere





Conclusions

- Measuring Galactic Magnetic Field (GMF)
- Pulsar Rotation Measures are efficient method
- Wavelet Analysis used to deconvolve large-scale
- Future: Observing known pulsars: Effelsberg, LOFAR
- Future: Discovering new pulsars, obtaining RMs

Thanks for listening!!