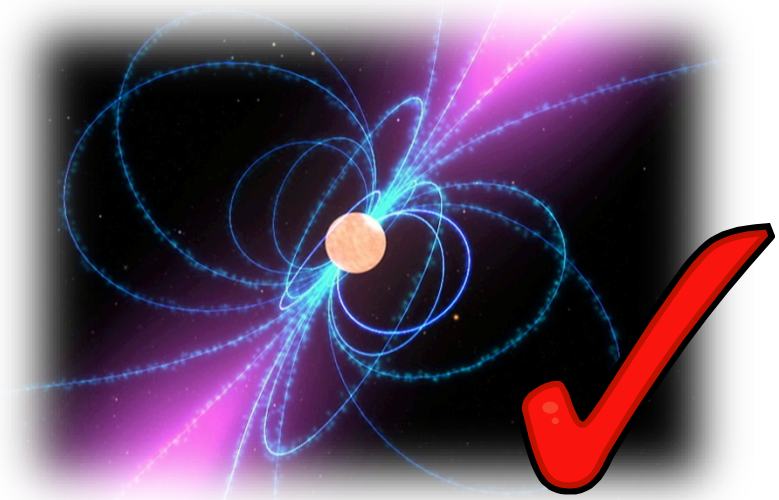


Polarised pulsars: Observations & Applications



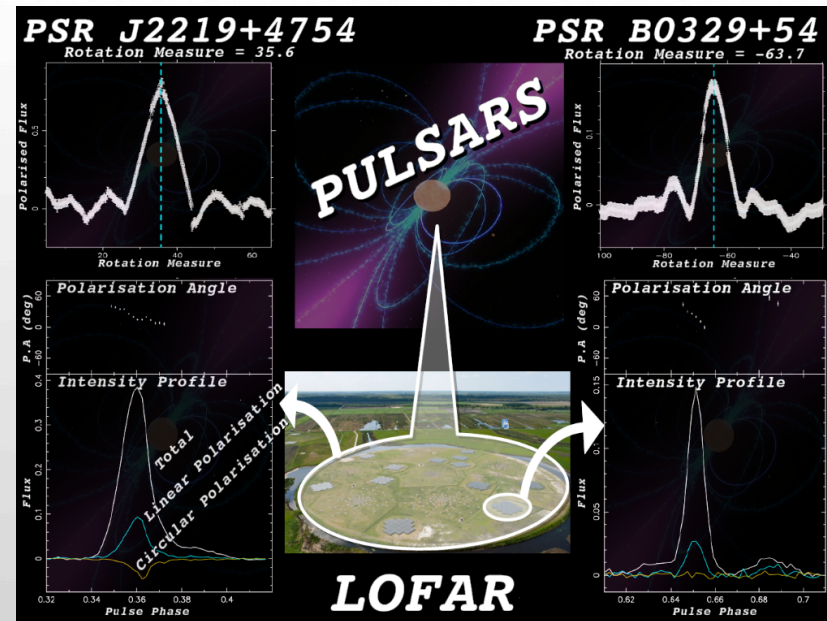
Charlotte Sobey

Dr. Aris Noutsos & Prof. Michael Kramer



Outline

- ④ First polarisation profiles of pulsars with LOFAR HBA
- ④ Why? Polarisation and pulsars
- ④ Observation details
- ④ Resulting profiles
- ④ Application of RM Synthesis
- ④ Investigation of current data
 - ④ including Ionosphere



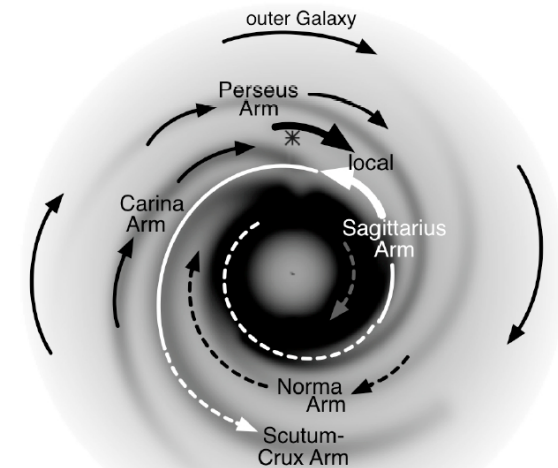
ASTRON Daily Image 16th February 2011

Pulsars and polarisation...

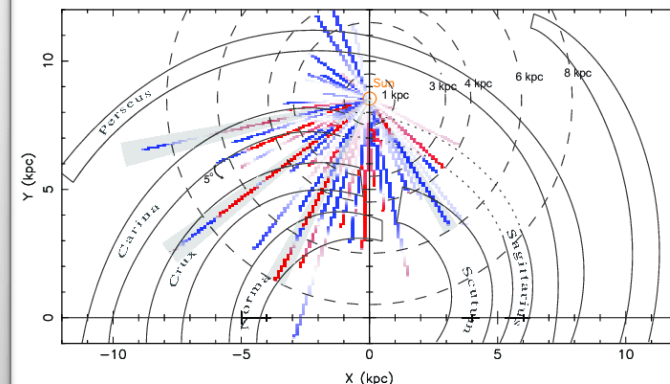
- @ Important for many areas of research:
 - @ Determining Faraday Rotation, RM
 - @ Magnetic field structure of M.W

$$RM = 0.810 \int_{\text{receiver}}^{\text{source}} n \mathbf{e} \cdot \mathbf{B} \, ds$$

- @ Fractional polarisation increase at low f
- @ Emission mechanism
- @ Pulsar orientation
- @ Scattering
- @ Scintillation...



[Van Eck et al. 2010]



[Noutsos et al. 2008]

RM Synthesis... Quick intro...

- Plane of linear polarisation modified by Faraday rotation, $\chi(\lambda) = \chi_0 + RM \lambda^2$
- But PA known to modulo π radians...

RM synthesis first shown by Burn (1966):

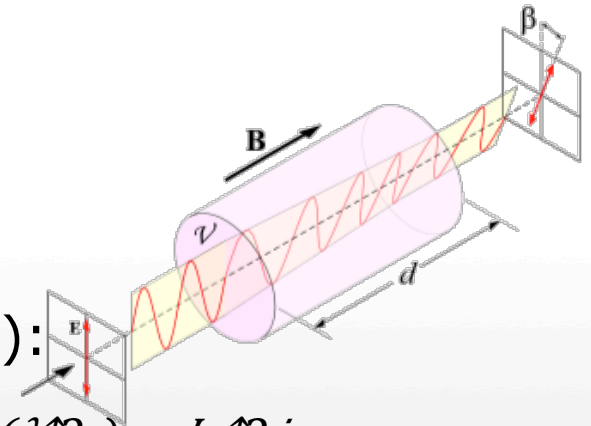
Observed complex polarisation vector: $P(\lambda^2) = p e^{i\chi}$

Substitute χ for Faraday depth (ϕ): $P(\lambda^2) = \int_{-\infty}^{+\infty} F(\phi) e^{i\phi \lambda^2} d\phi$

Fourier transform inverted: $F(\phi) = \int_{-\infty}^{+\infty} P(\lambda^2) e^{-i\phi \lambda^2} d\lambda^2$

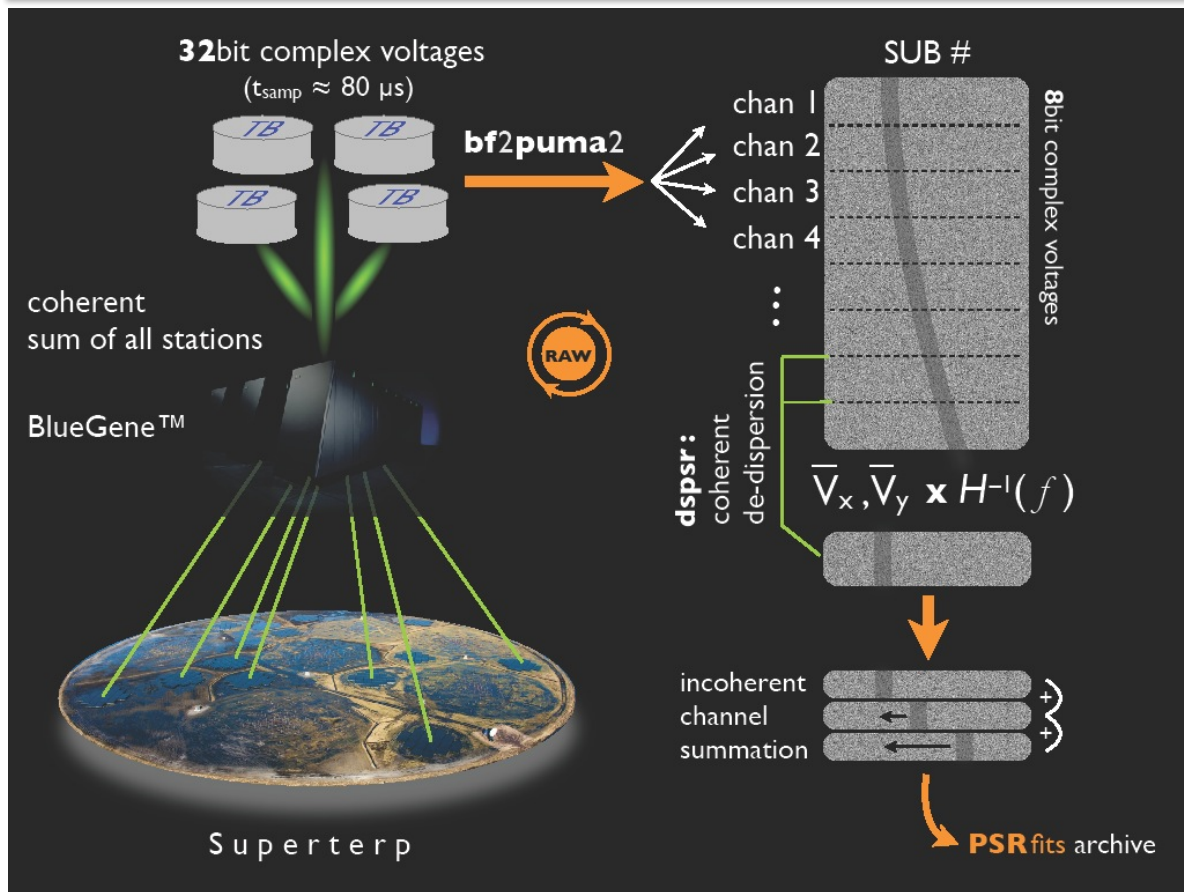
Practically, $FWHM = 3.8 / \Delta \lambda^2$ hence BW determines accuracy...

LOFAR: Low frequency and large bandwidth!



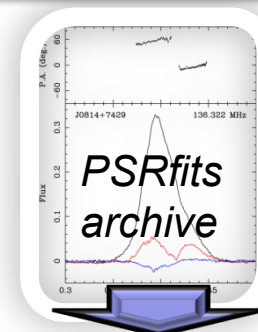
RAW Voltages to RMs...

@ Coherent dedispersion with Stokes

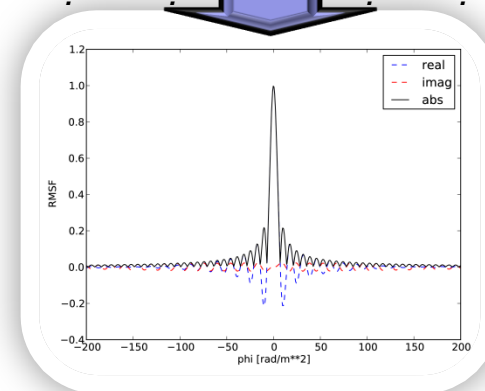


[A.Noutsos]

@ RM synthesis

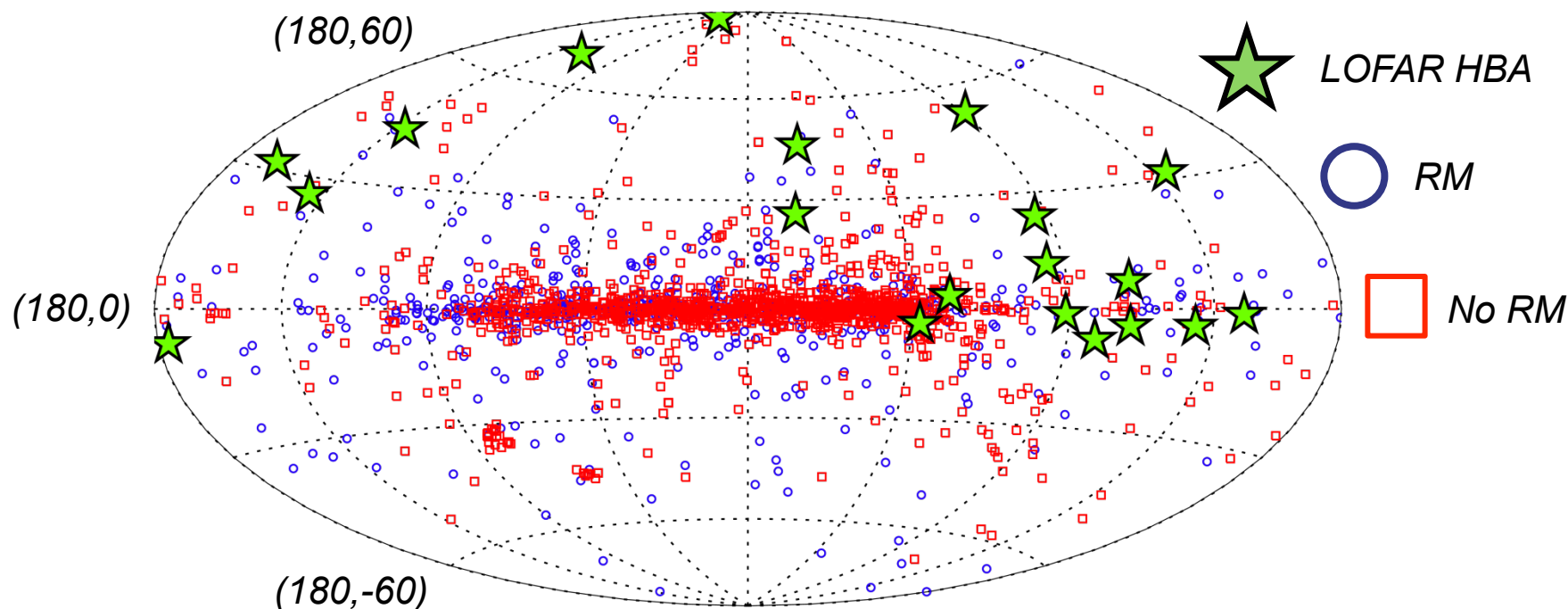


Freq	I	Q	U	V
112.0	1.2	0.3	-0.6	0.1

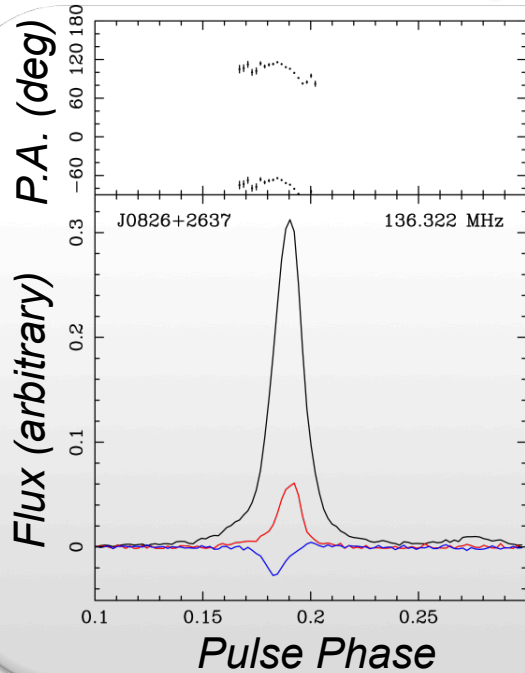


Polarisation observations – ‘survey’

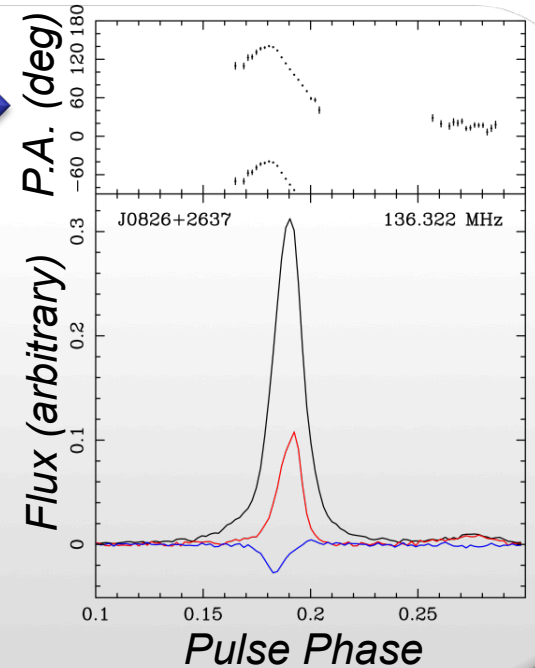
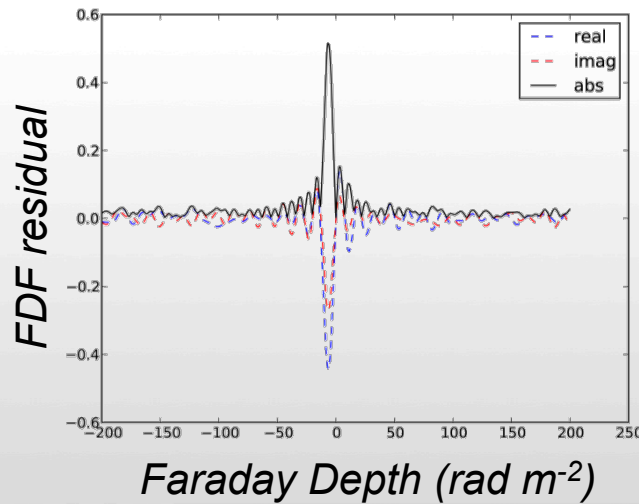
- @ ‘Survey’ of bright pulsars in raw voltage mode...
 - @ Coherent addition of Superterp 12 Core Stations
 - @ Frequency = 136.322 MHz
 - @ Bandwidth = 6.250 MHz



Example Profile... B0823+26

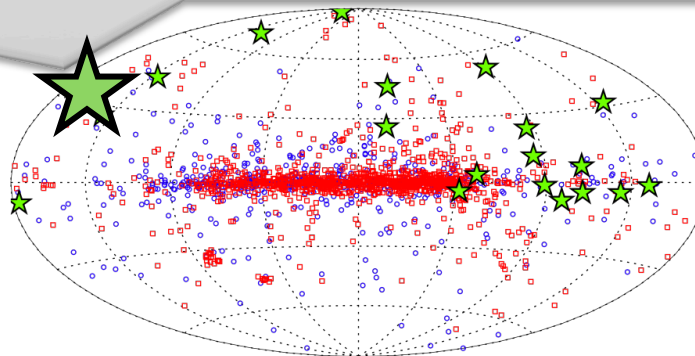


RM Synthesis



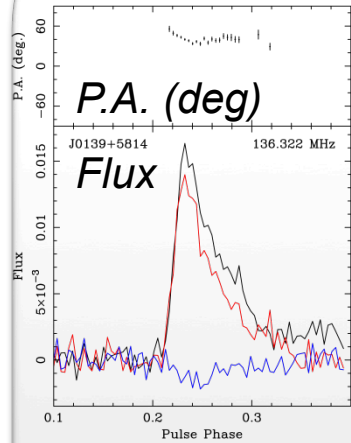
Before RM

After RM

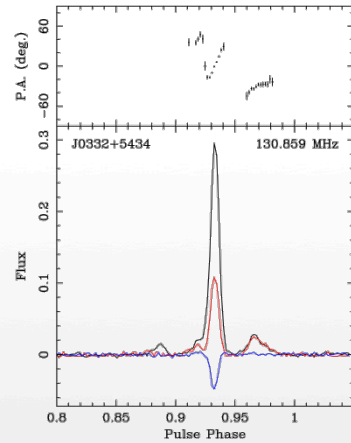


LOFAR Observations

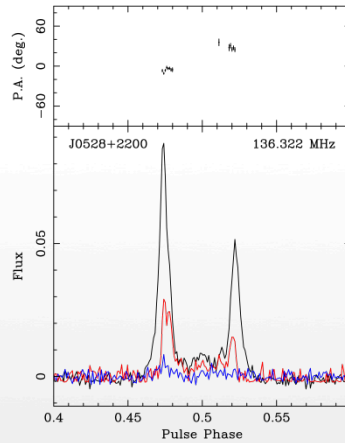
B0136+57



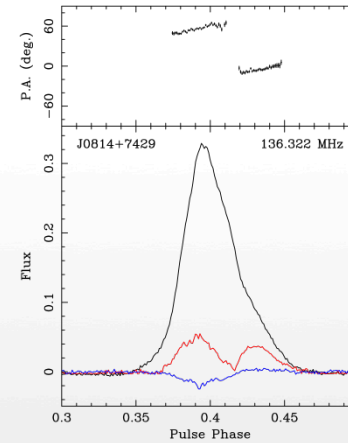
B0329+54



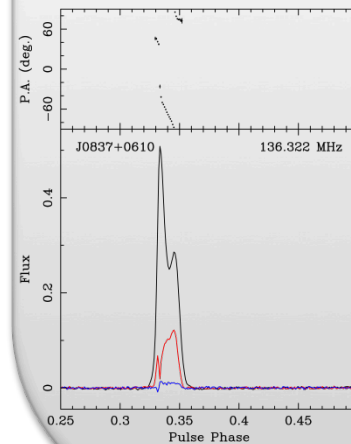
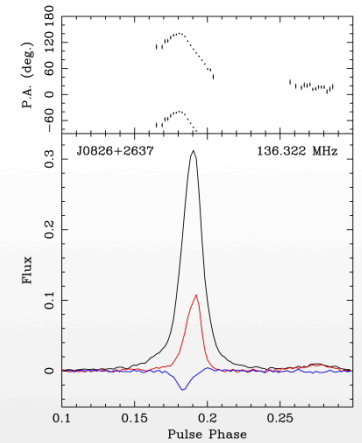
B0525+21



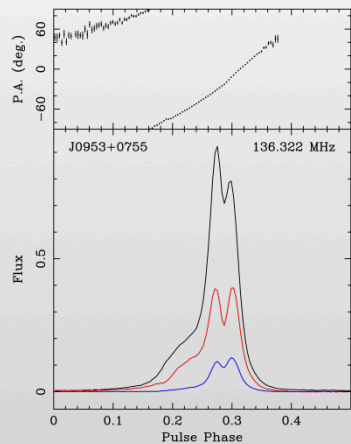
B0809+74



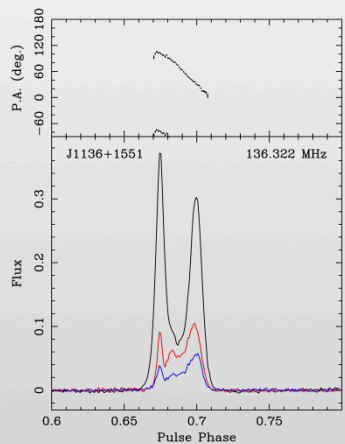
B0823+26



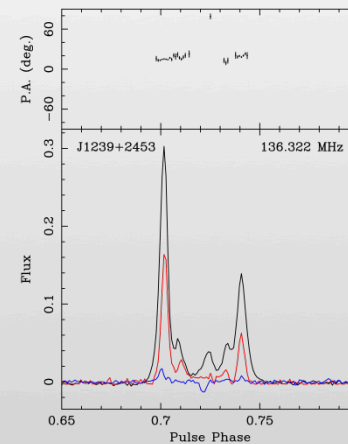
B0834+06



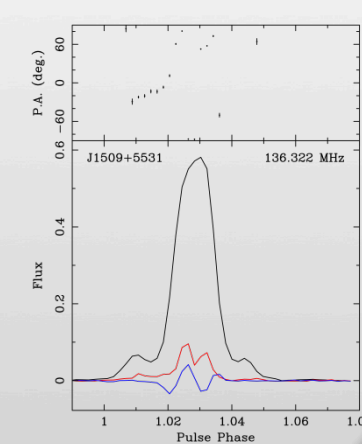
B0950+08



B1133+16



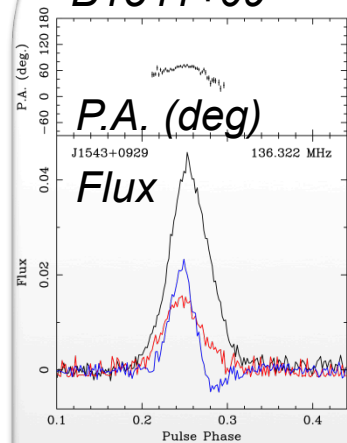
B1237+25



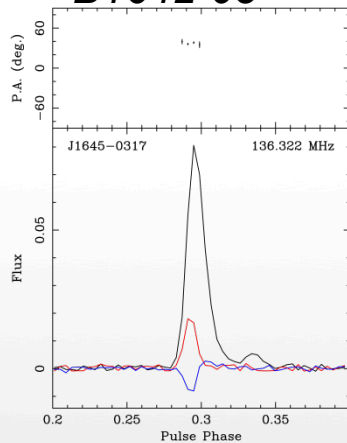
B1508+55

LOFAR Observations

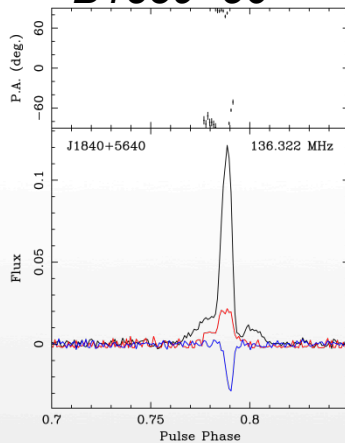
B1541+09



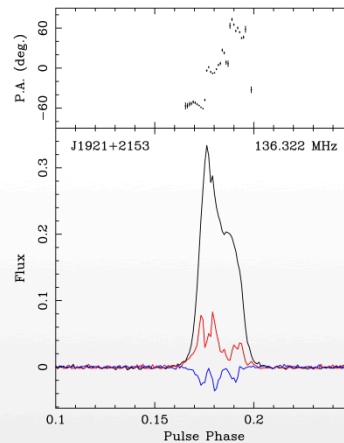
B1642-03



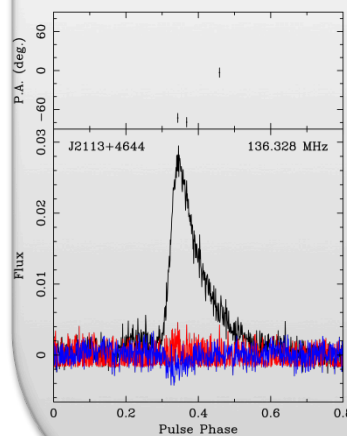
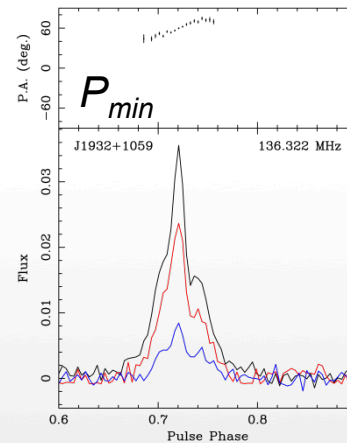
B1839+56



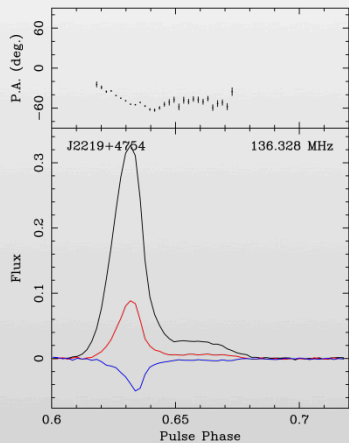
B1919+21



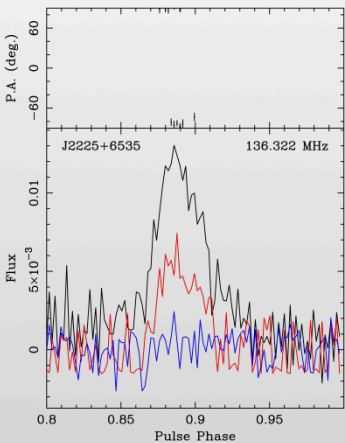
B1929+10



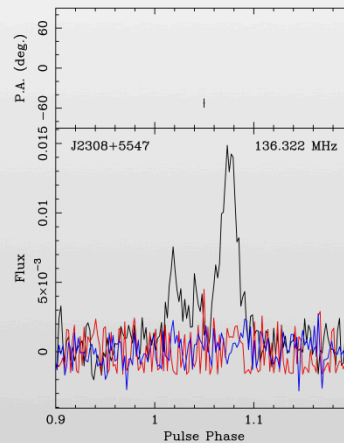
B2111+46



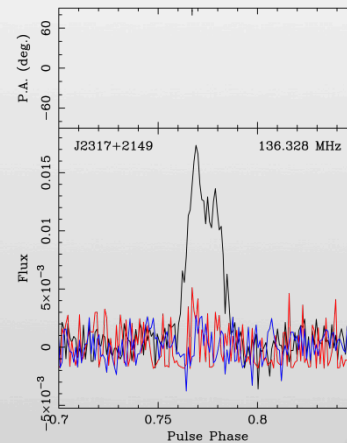
B2217+47



B2224+65



B2306+55

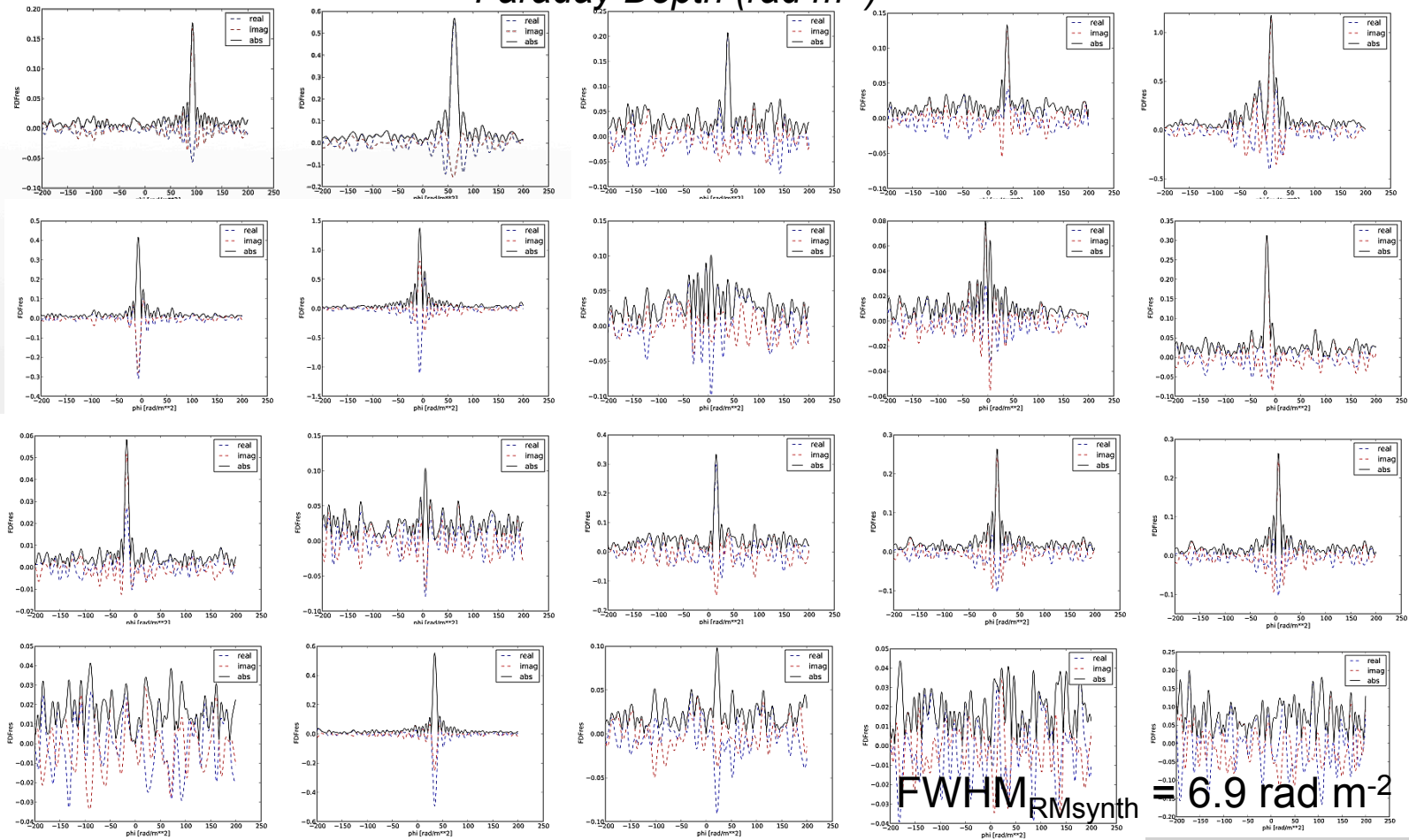


B2315+21

RM synthesis

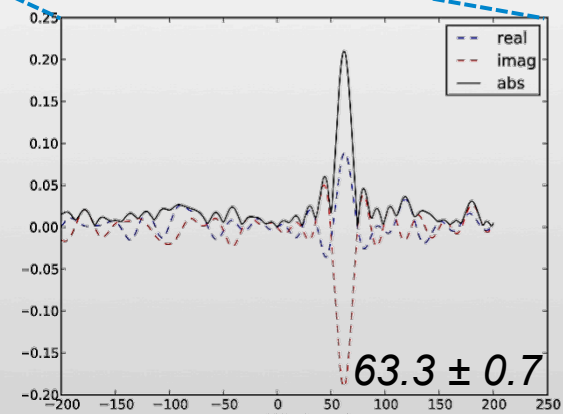
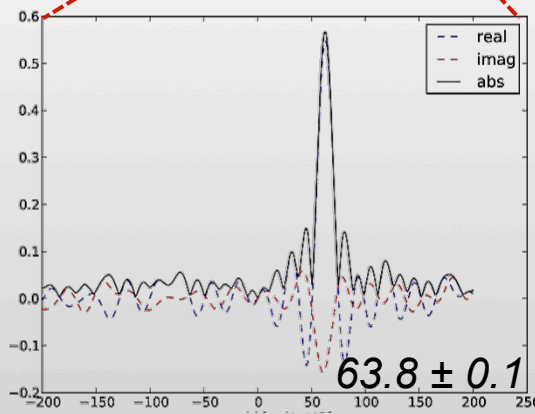
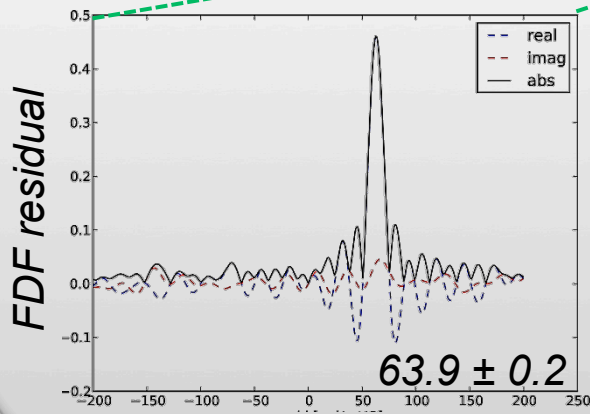
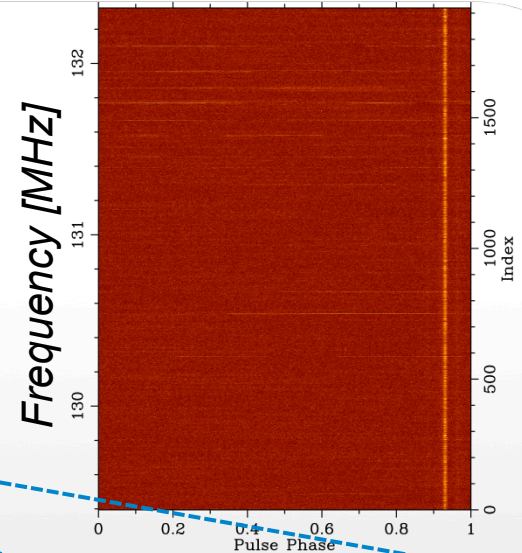
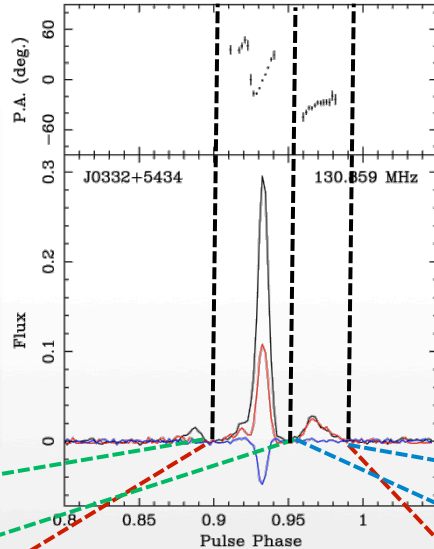
Residual Faraday Dispersion Function (Normalised)

Faraday Depth (rad m^{-2})



RM and pulse phase... B0329+54

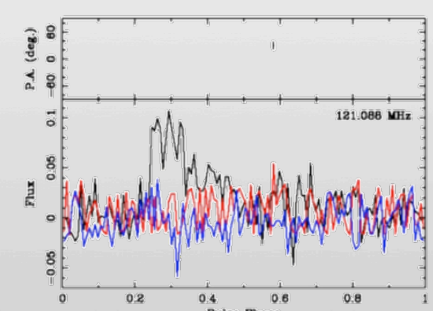
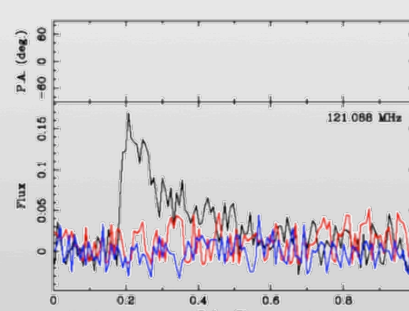
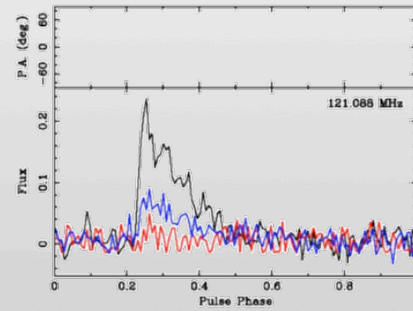
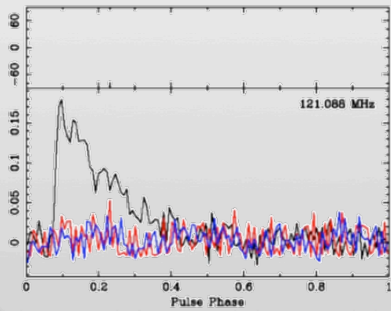
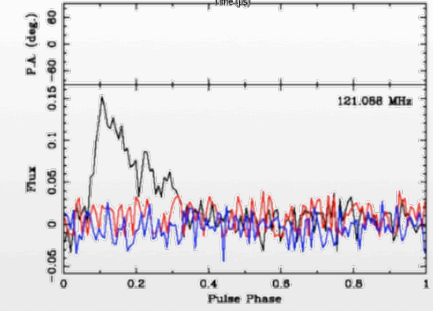
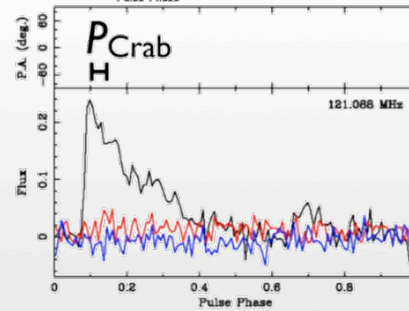
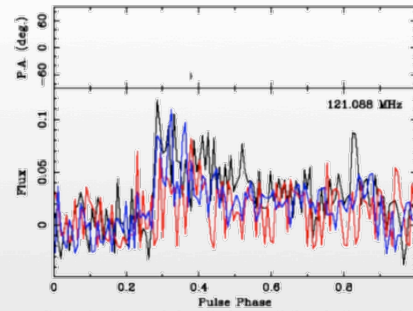
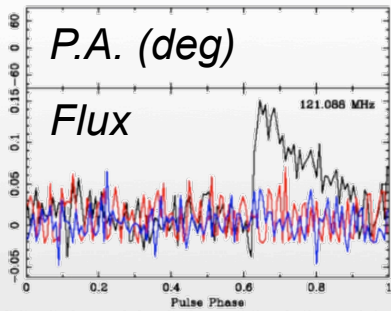
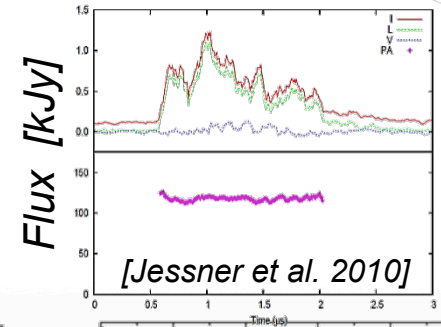
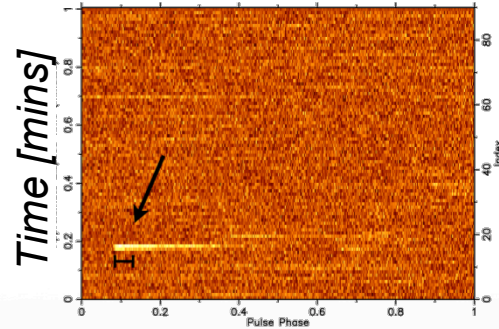
- 10 CS (CEPII)
- Freq = 130.859 MHz
- BW = 2.930 MHz
- FWHM = 13.8 rad m⁻²



Faraday Depth (rad m⁻²)

Crab Pulsar Giant Pulses

- ⊙ 6 CS, 10 min
- ⊙ Freq = 121.08 MHz
- ⊙ BW = 3.125 MHz
- ⊙ dt = 82 μs



$Pulse\ phase = 20 \times P_{Crab} (673\ ms)$

[A. Noutsos]

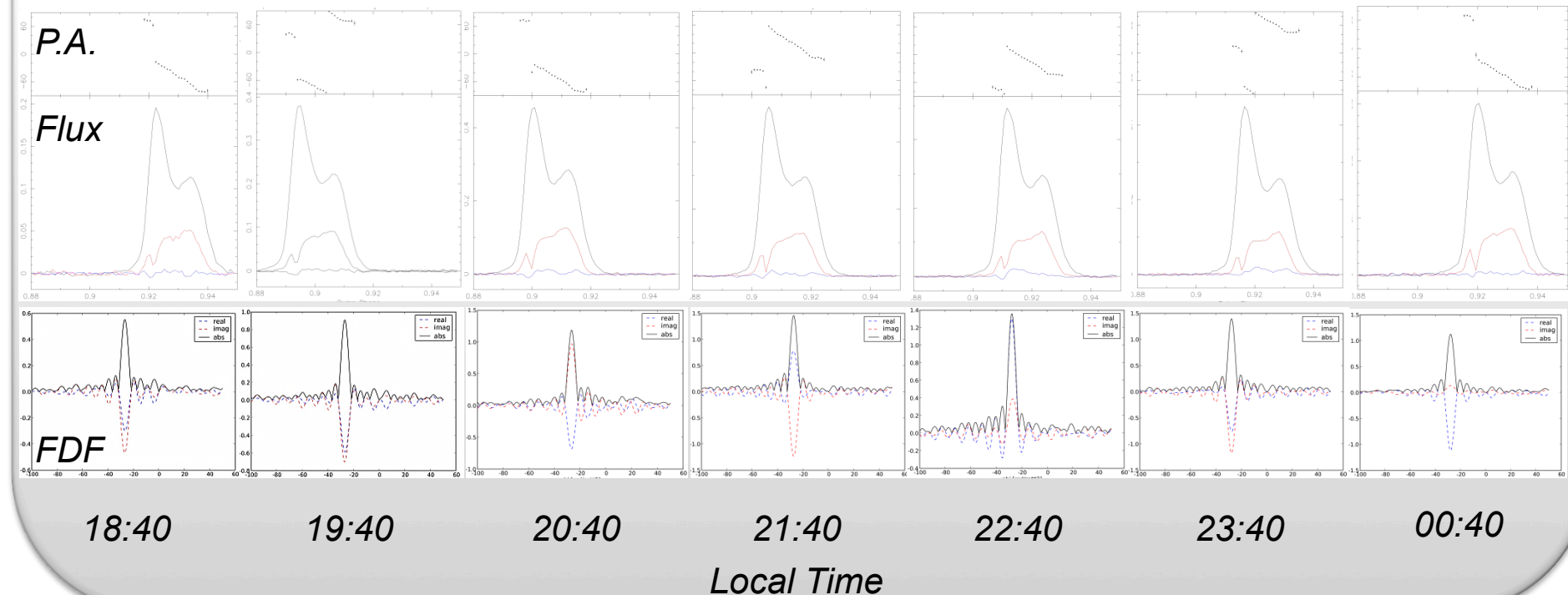
RM stability... B0834+06

12 CS, 10 min

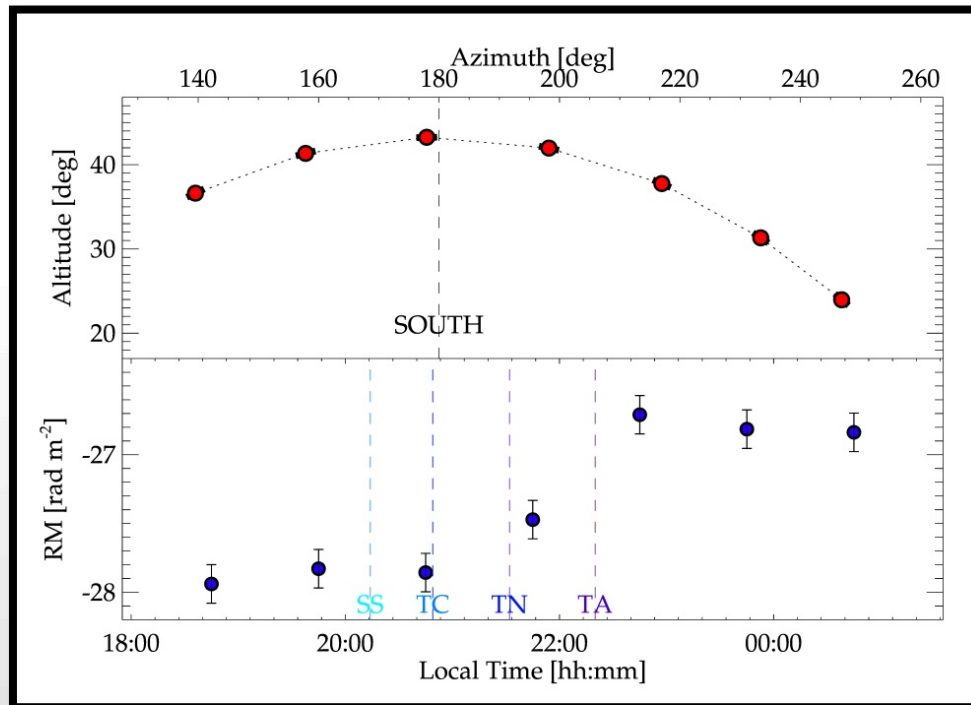
BW = 6.250 MHz

Freq = 122.650 MHz

FWHM = 6.9 rad m⁻²



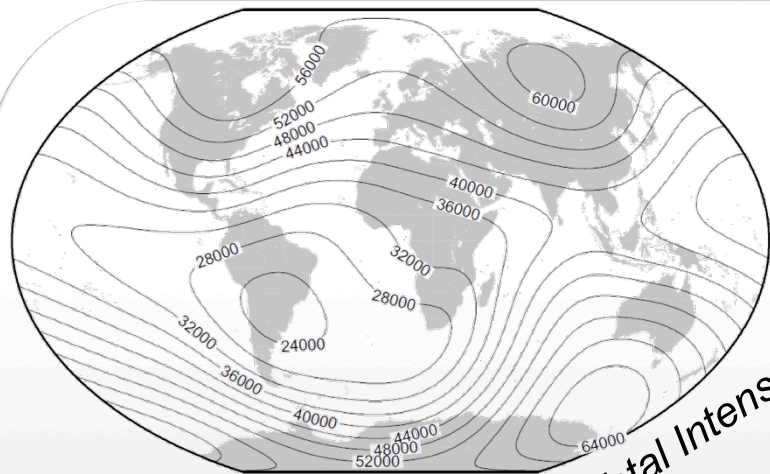
RM stability... B0834+06 (II)



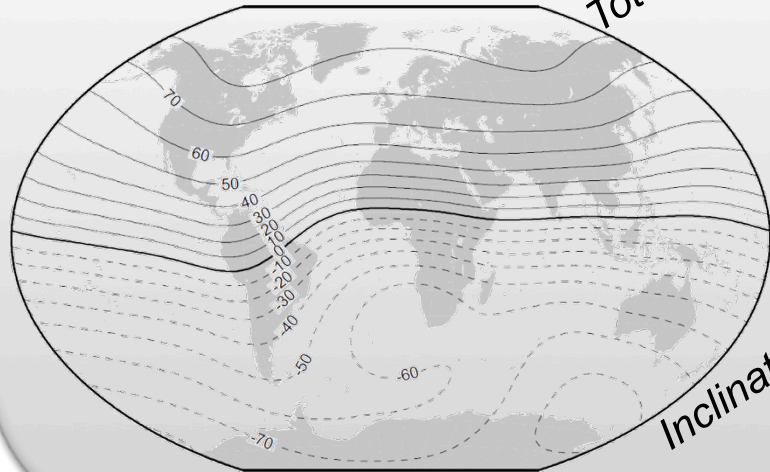
Ⓢ SS = Sunset

Ⓢ T[C,N,A] = Twilight [Civil, Nautical, Astronomical]

Ionospheric effects



Total Intensity ($|B|$)



Inclination (Θ_B)

[British Geological Survey 2010]

Using

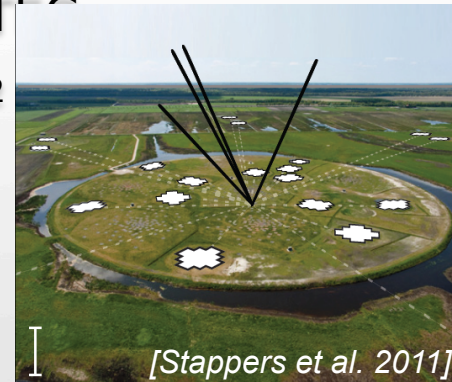
$$RM = 0.810 \int_{\text{receiver}}^{\text{source}} n^2 - 1 \, ds \quad (s)$$

$$RM \approx 2.63 \times 10^{-6} B T \text{ TECU}$$

$$\text{TECU} = 10^{16} \text{ e}^- \text{ m}^{-2}$$

$$|B| \approx 50,000 \text{ nT}$$

$$\Theta_B \approx +65 \text{ deg}$$



[Stappers et al. 2011]

RM variation of $\sim 1 \text{ rad m}^{-2} \approx 10 \text{ TECU}$

More sensitive than GPS data

Future calibration essential...

Conclusions

- ⊙ Pulsar polarisation observations with LOFAR HBAs!
- ⊙ Observations, analysis and investigation...
- ⊙ RM synthesis accuracy dependant on bandwidth & SNR
- ⊙ Ionospheric variation – calibration...
- ⊙ Future discoveries of pulsars with LOFAR!

Thank you for listening!!

