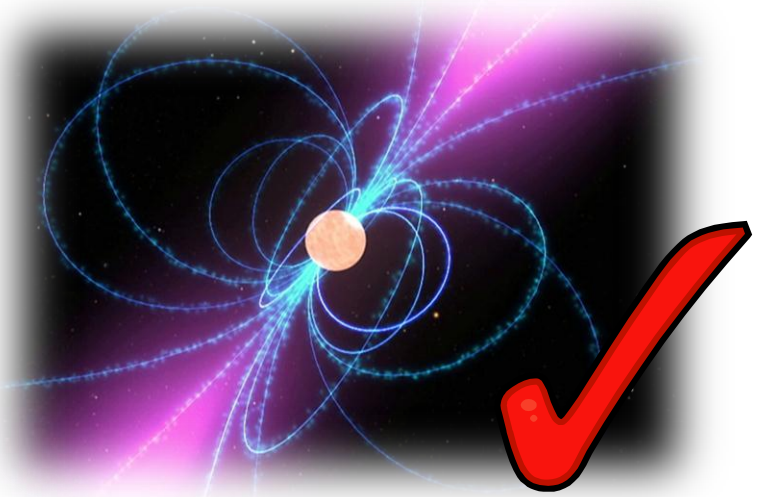
First pulsars in polarisation with LOFAR



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Max-Planck-Institut für Radioastronomie

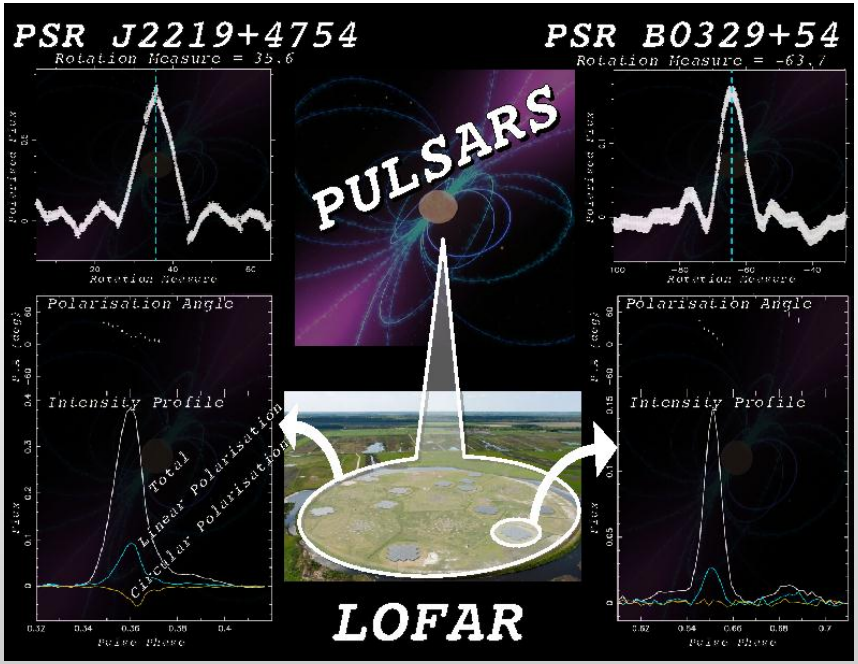
DFG Research Unit 1254

Magnetisation of Interstellar and Intergalactic Media: The Prospects of Low-Frequency Radio Observations

Kick-Off Meeting, Irsee, October 2010

Outline

- First polarisation profiles of pulsars with LOFAR HBA
  - MKSP & PWG (TKSP)
- Why? Pulsars and polarisation
- Observation details
- Resulting profiles
- Application of RM Synthesis
- Investigation of current data
  - including Ionosphere



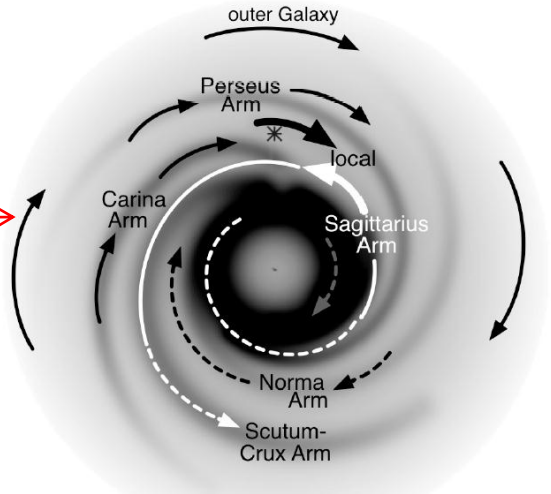
ASTRON Daily Image 16th February 2011

Pulsars and polarisation…

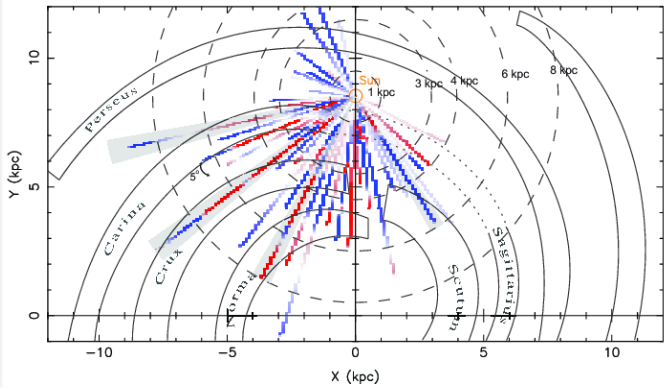
- Many areas of research:
  - Determining Faraday Rotation, RM

$$RM = 0.810 \int_{receiver}^{source} n_e(s)\bar{B}(s).d\bar{s}$$

  - Magnetic field structure of M.W
  - Deflection of HECRs, heat transport
  - Highly polarised, ISM only, many l.o.s
- Emission mechanism, Pulsar orientation
- ISM: Scattering, Scintillation…



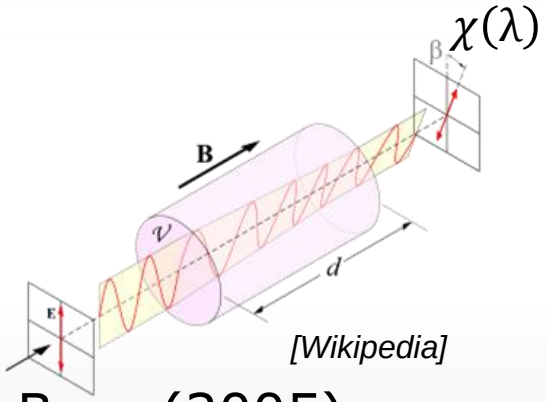
[Van Eck et al. 2010]



[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: Burn (1966), Brentjens & De Bryn (2005)

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

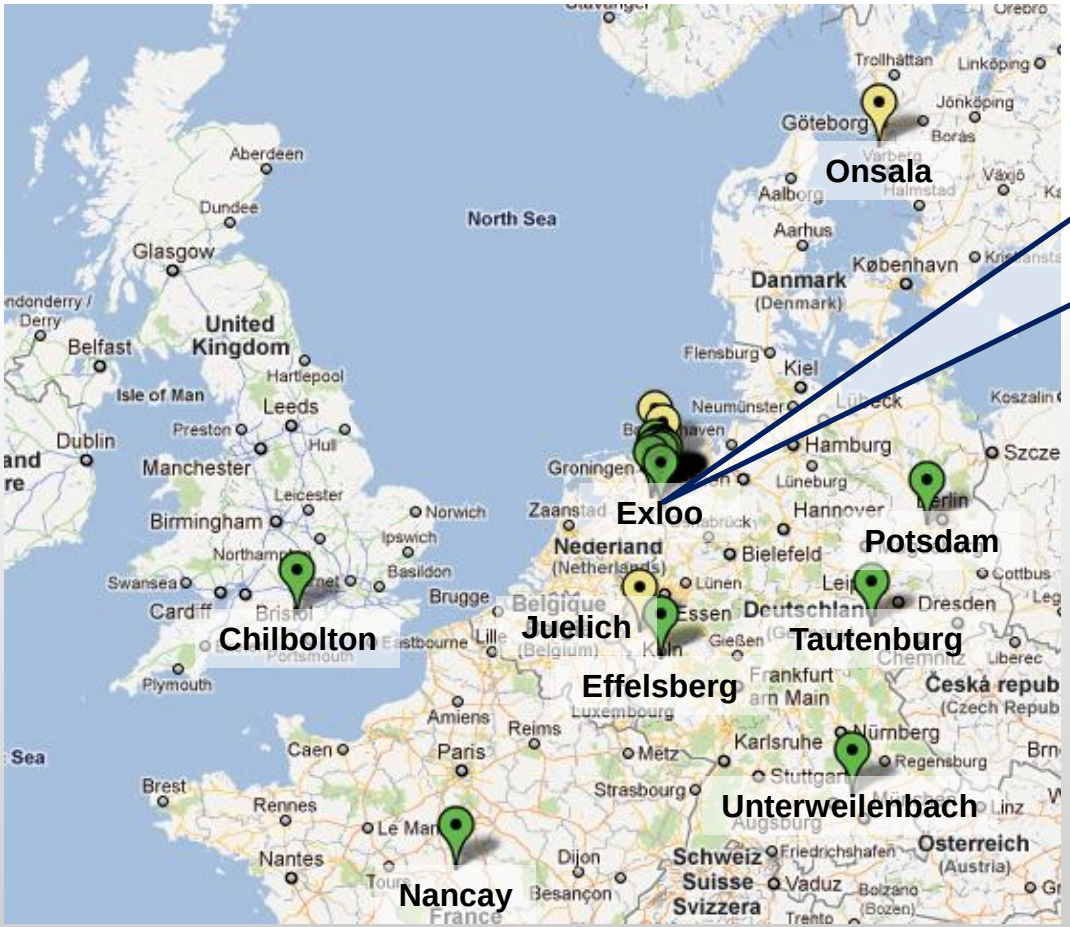
  Substitute RM for Faraday depth (ϕ): $P(\lambda^2) = \int_{-\infty}^{+\infty} F(\phi) e^{2i\phi\lambda^2} d\phi$

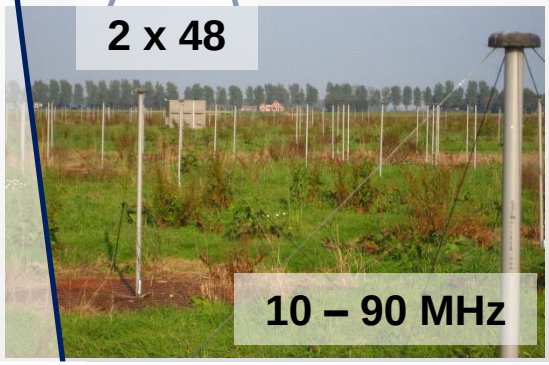
  Fourier transform inverted: $F(\phi) = \int_{-\infty}^{+\infty} P(\lambda^2) e^{-2i\phi\lambda^2} d\lambda^2$

  Practically, $FWHM = {}^{3.8}/_{\Delta\lambda^2}$ hence BW determines accuracy…

  LOFAR: Low frequency and large bandwidth (~48 MHz)!

LOFAR

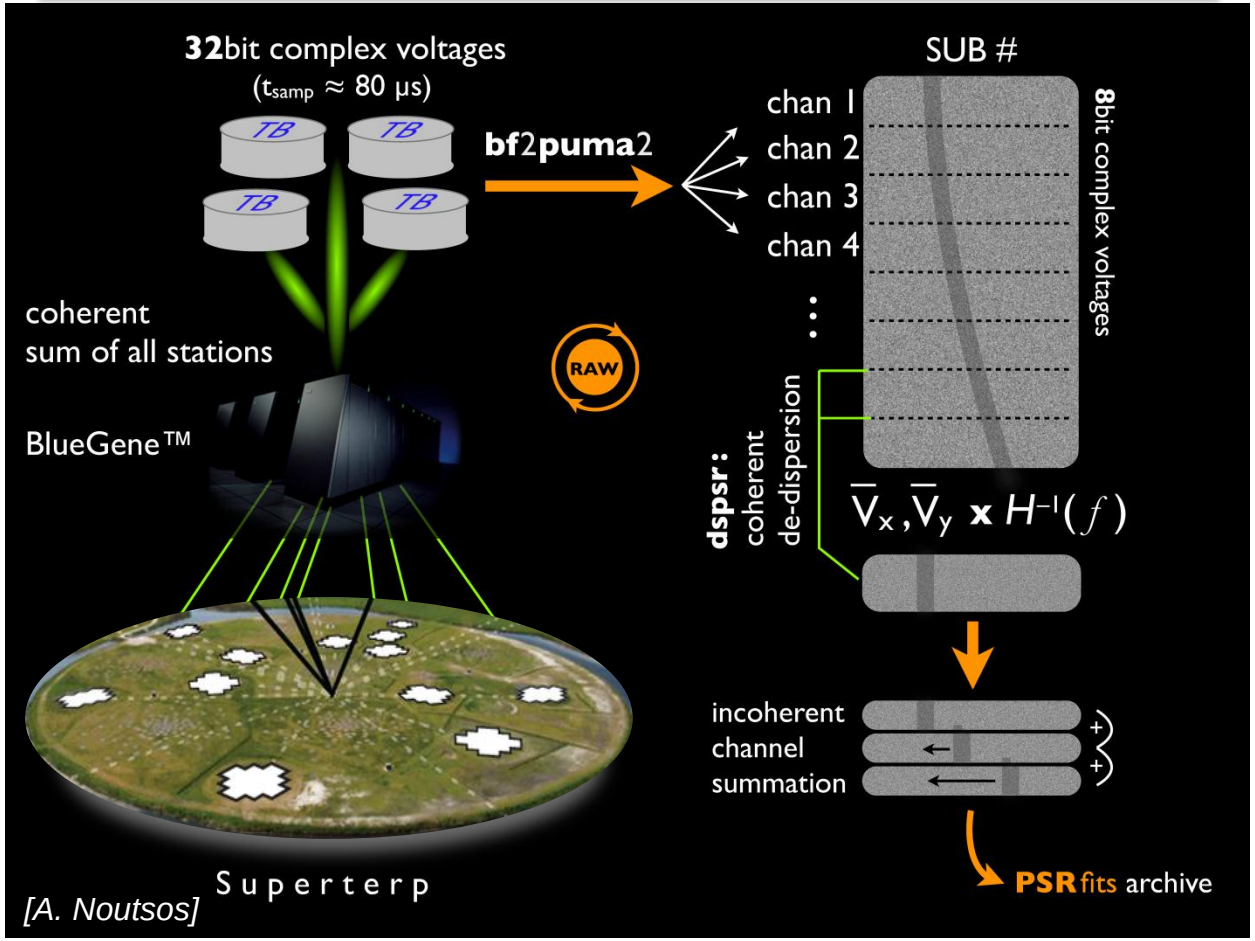




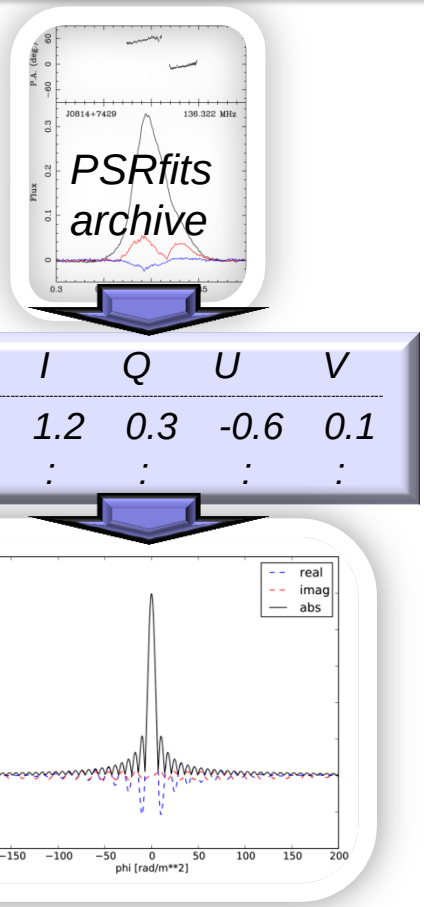
http://www.astron.nl/~heald/lofarStatusMap.html

RAW Voltages to RMs...

Coherent dedispersion with Stokes

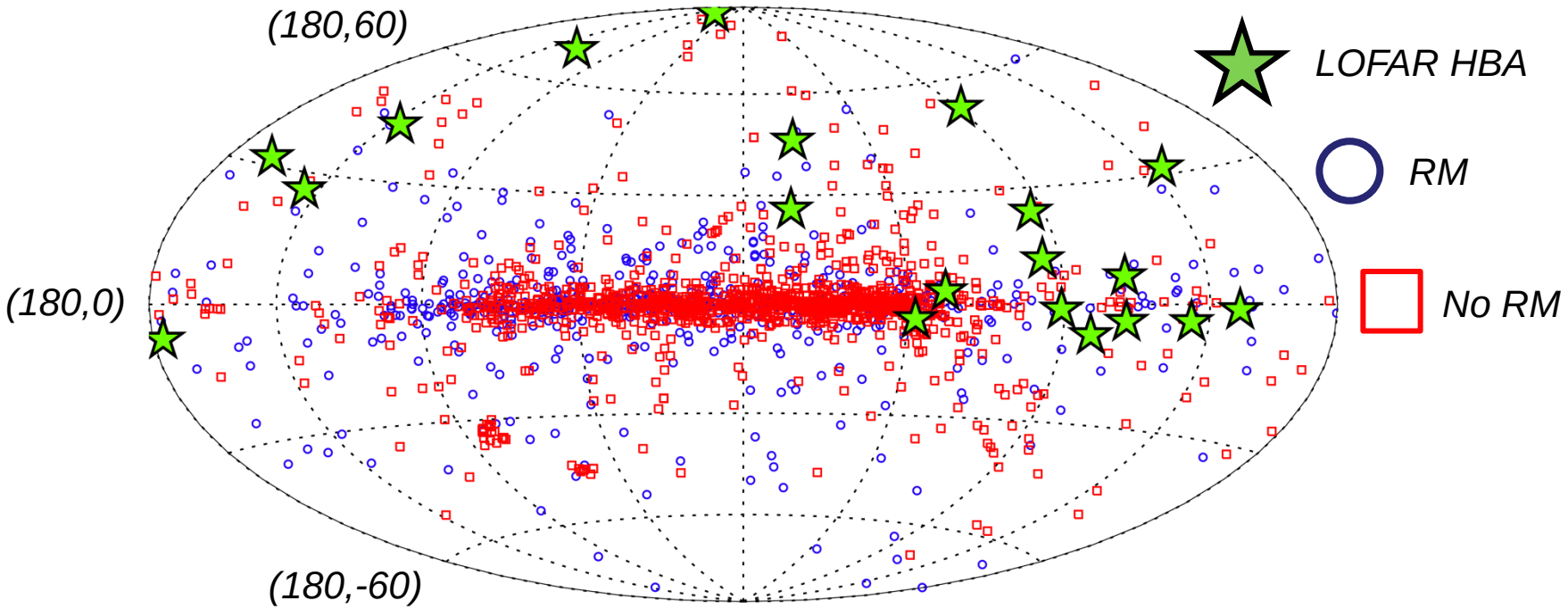


RM synthesis

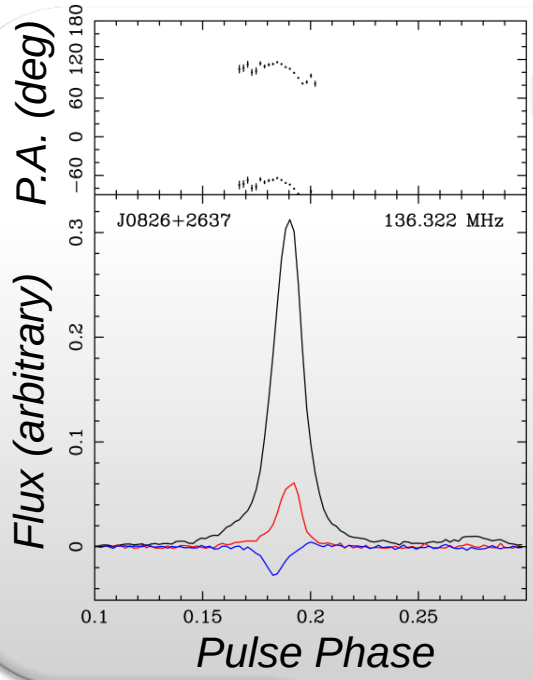


Polarisation observations – 'survey'

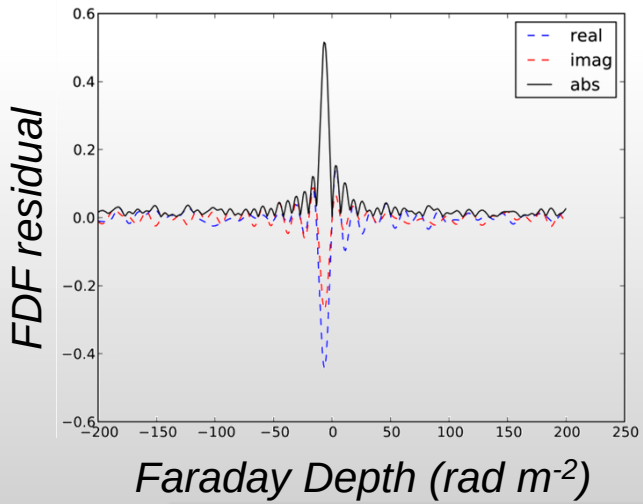
- 'Survey' of bright pulsars in raw voltage mode (after I 'survey')…
  - Coherent addition of Superterp stations (12 sub-stations)
  - Frequency = 136.322 MHz
  - Bandwidth = 6.250 MHz

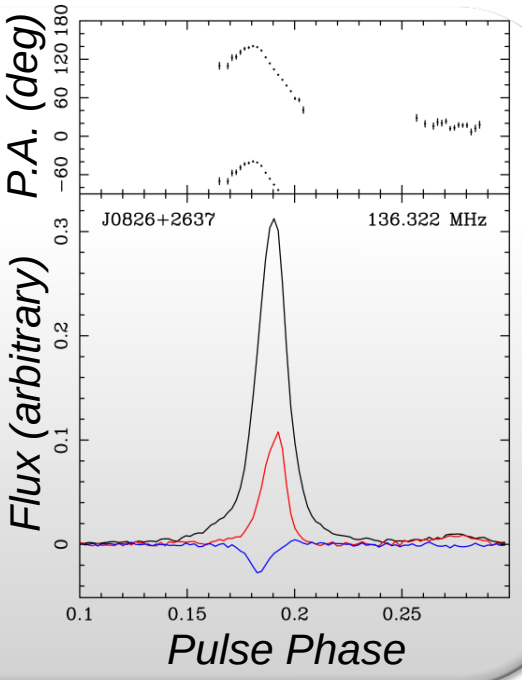


Example Profile.... B0823+26

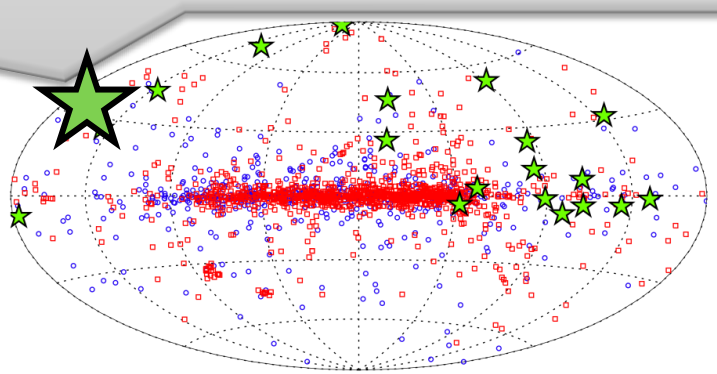


RM Synthesis



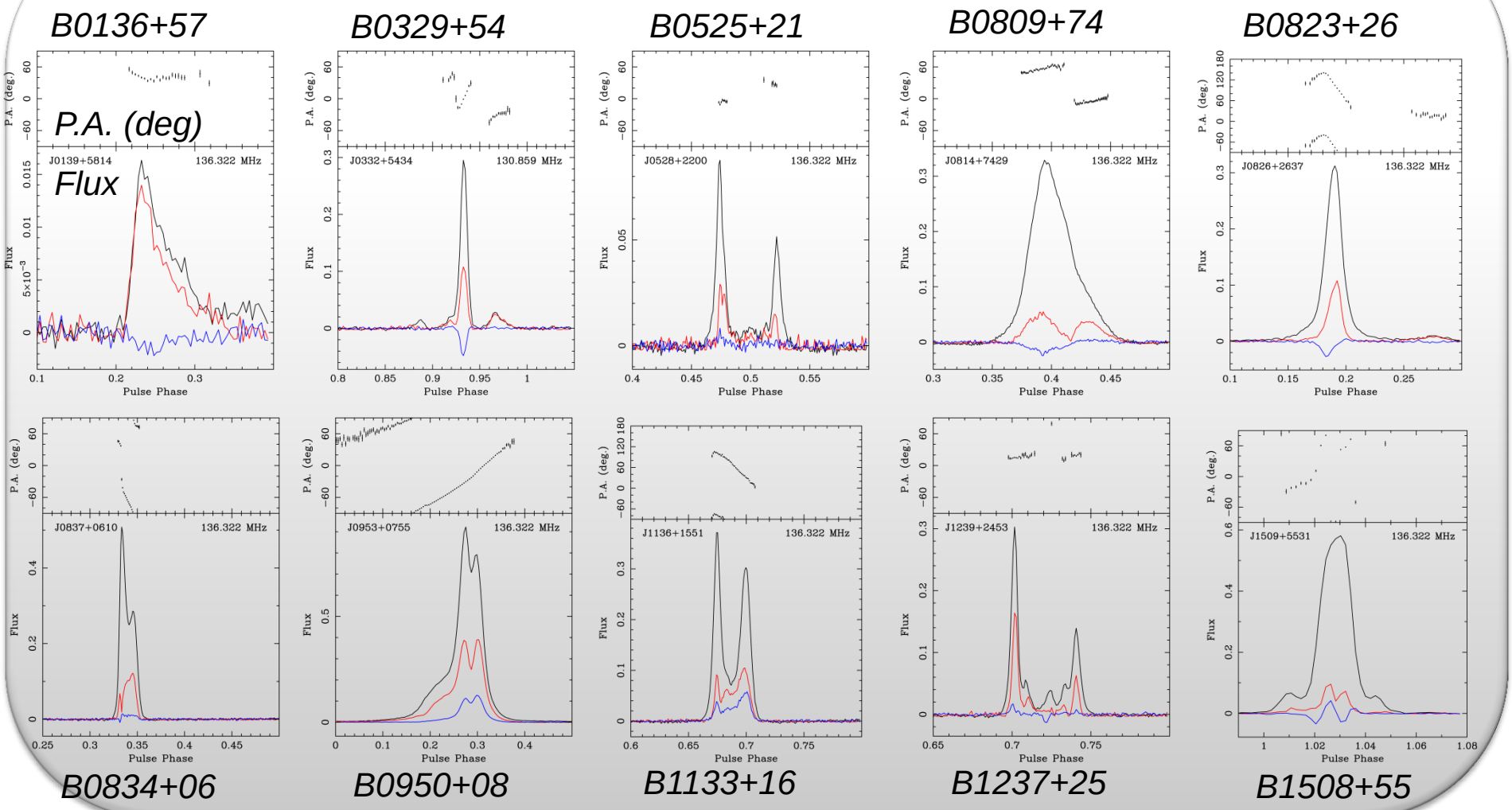


Before RM

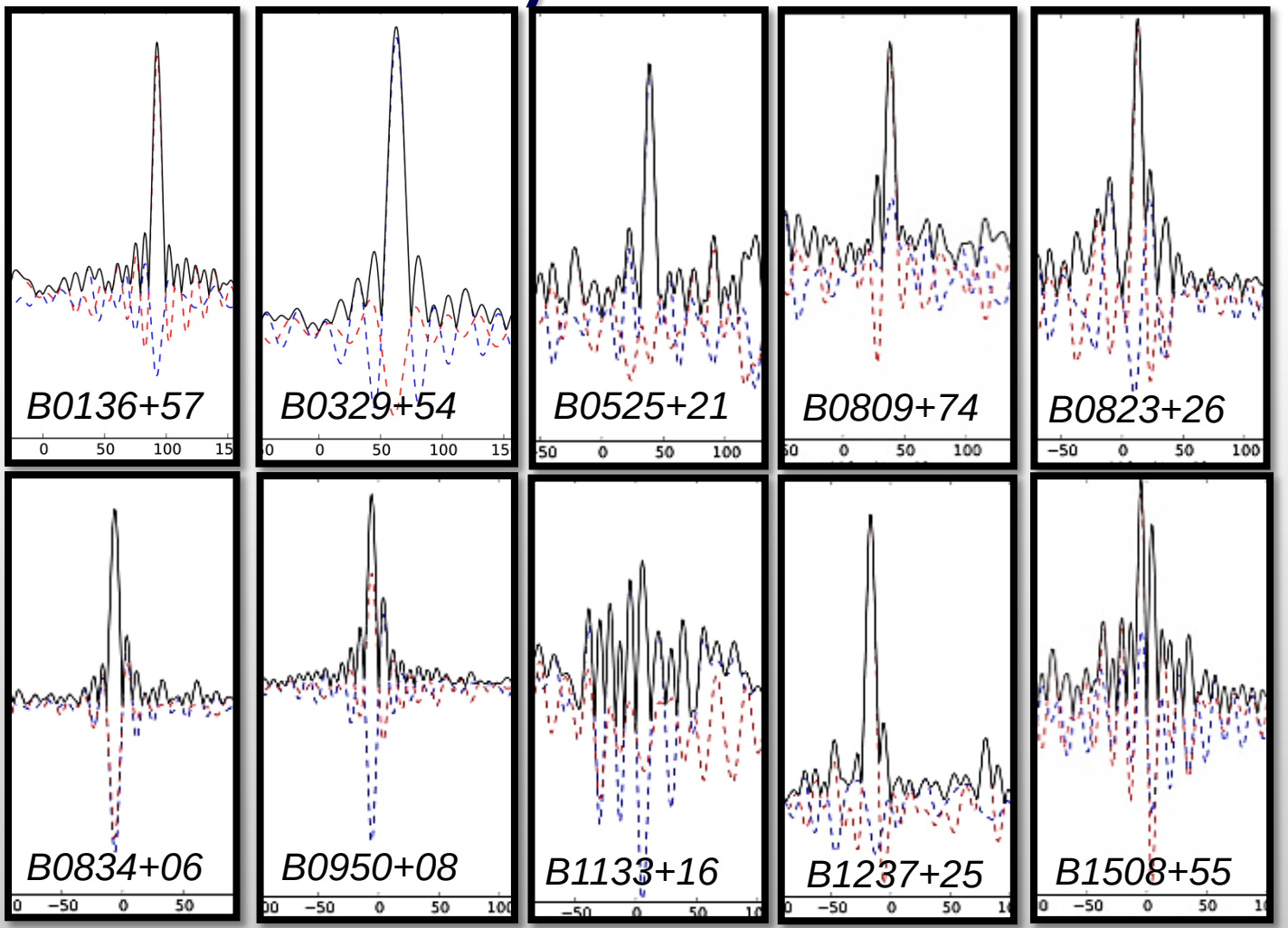


After RM

LOFAR Observations I

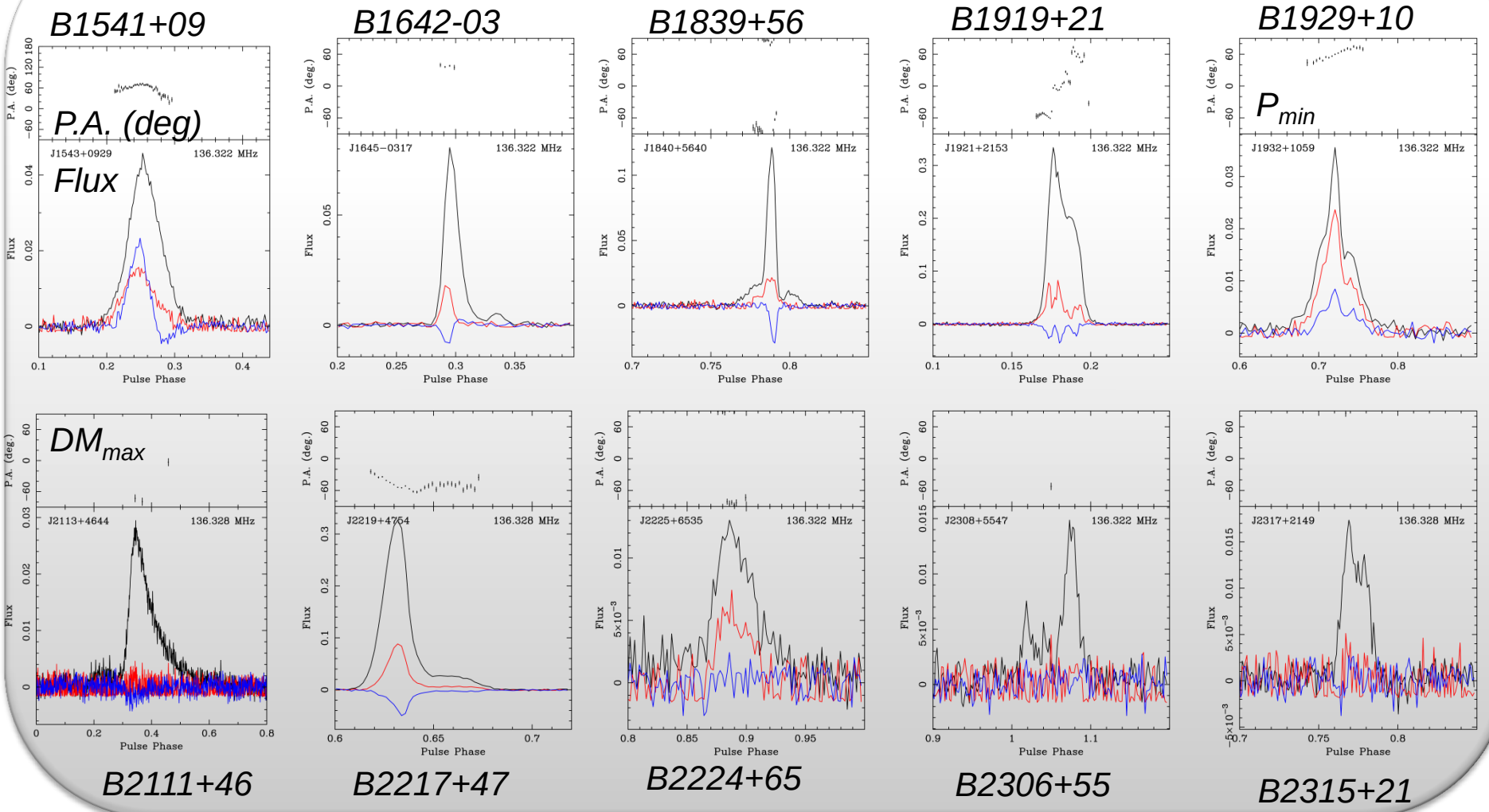


RM synthesis I

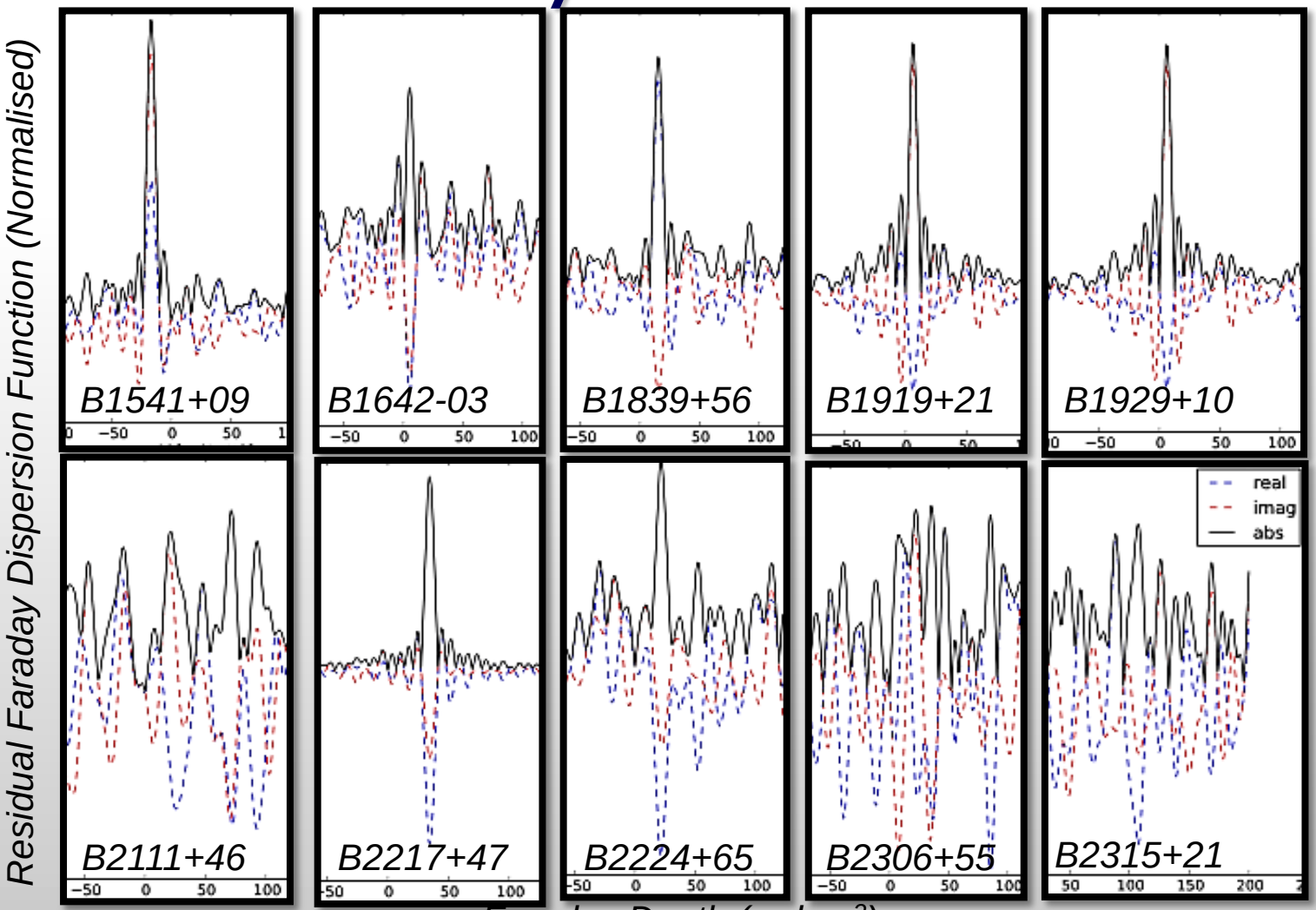


FWHM = 6.9 rad m^{-2}

LOFAR Observations II



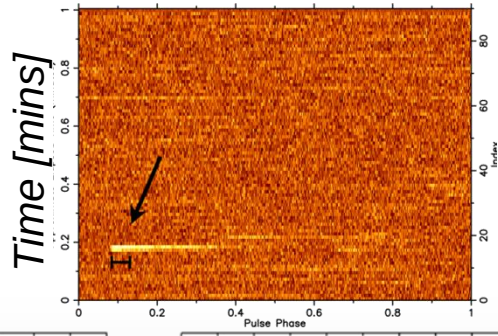
RM synthesis II

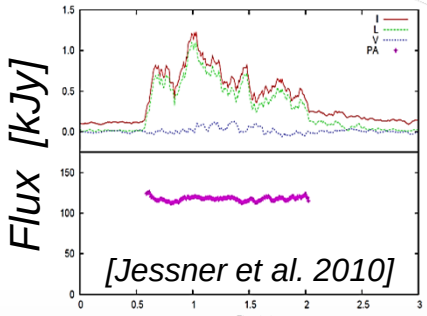


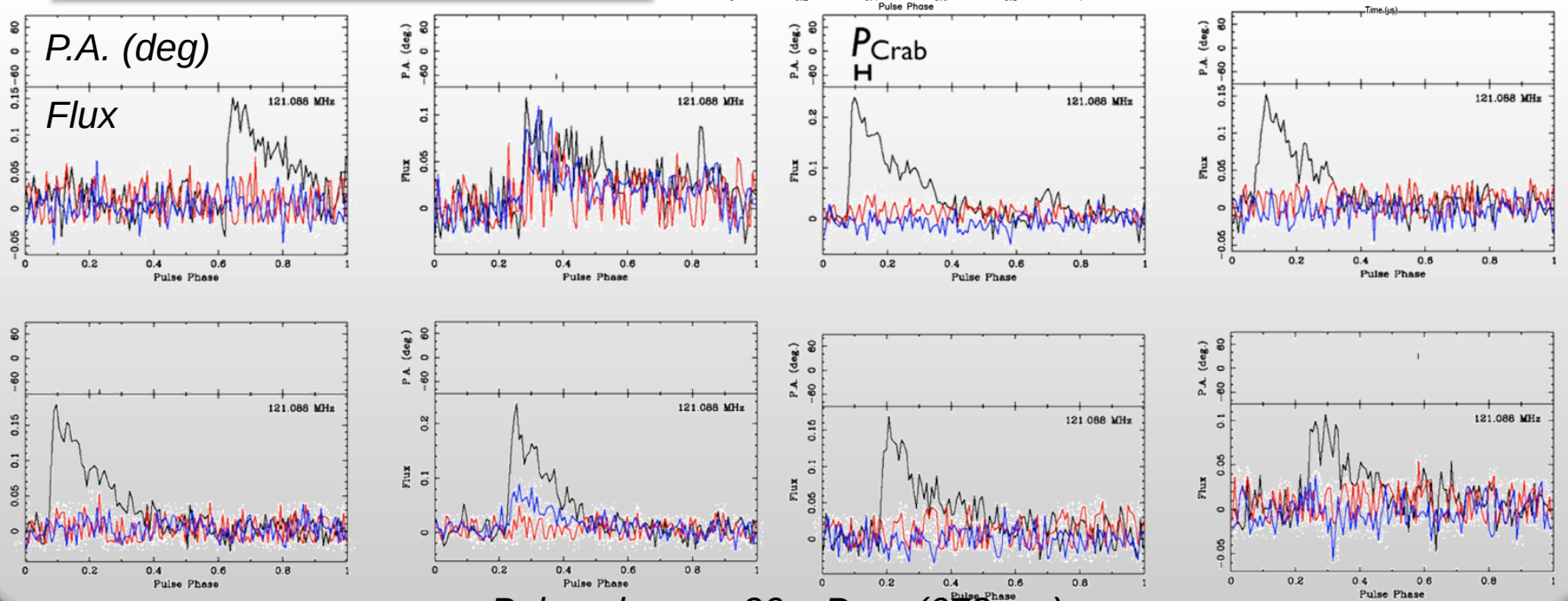
FWHM = 6.9 rad m^{-2}

Crab Pulsar Giant Pulses

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





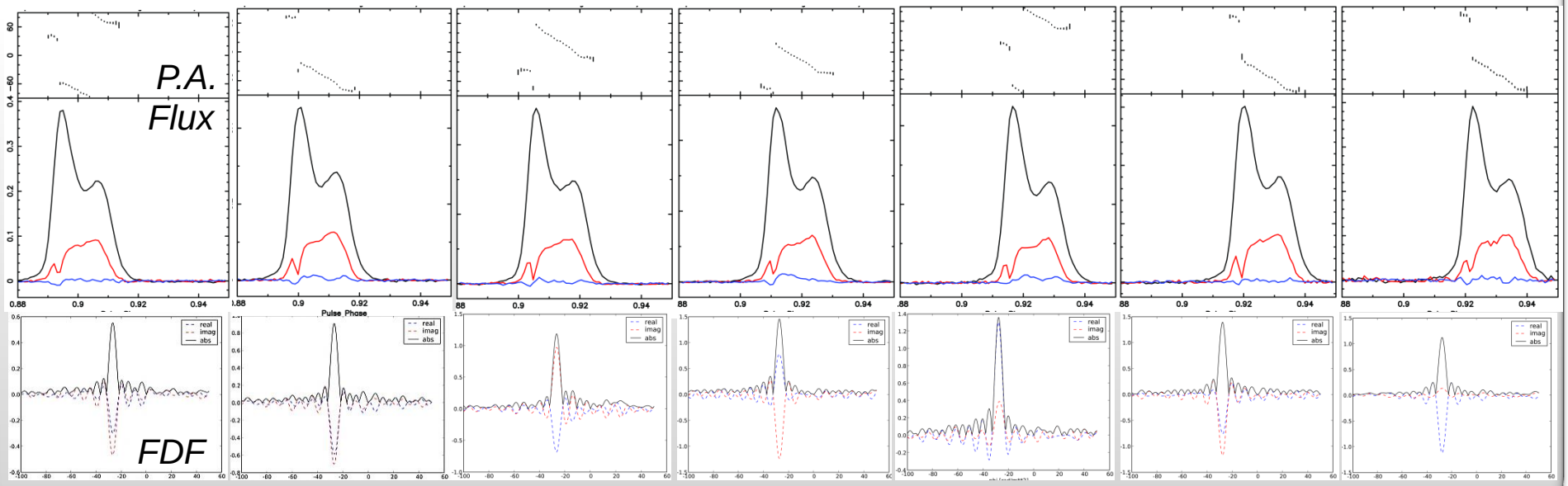


Pulse phase = 20 x P_{Crab} (673 ms)

[A. Noutsos]

RM stability... B0834+06

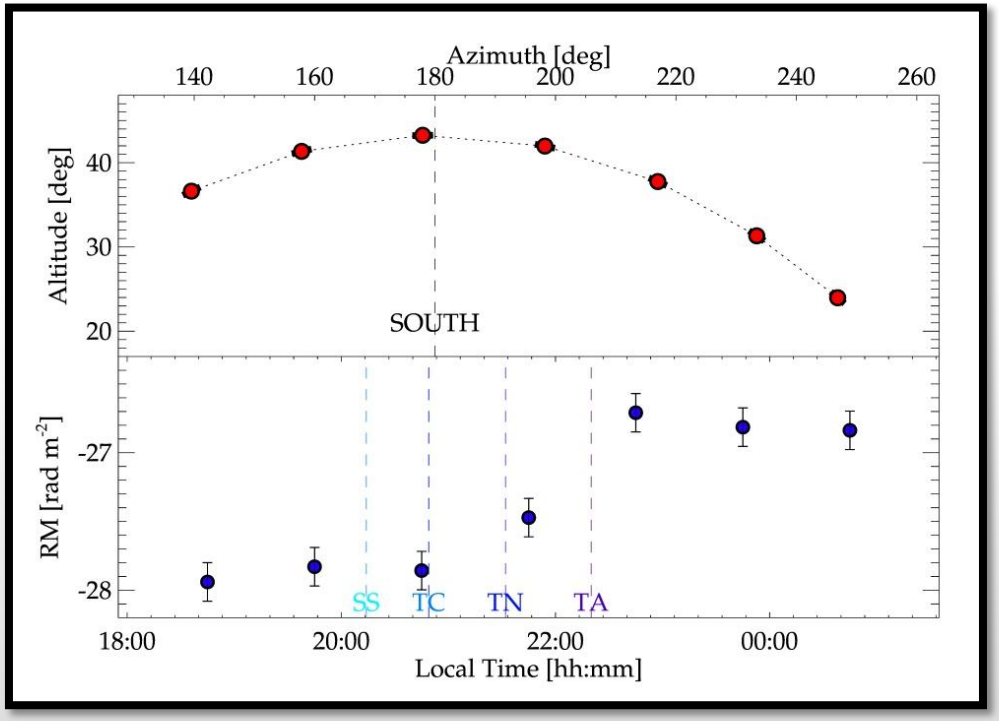
- 12 CS, 10 min
- BW = 6.250 MHz
- Freq = 122.650 MHz
- FWHM = 6.9 rad m^{-2}



18:40 19:40 20:40 21:40 22:40 23:40 00:40

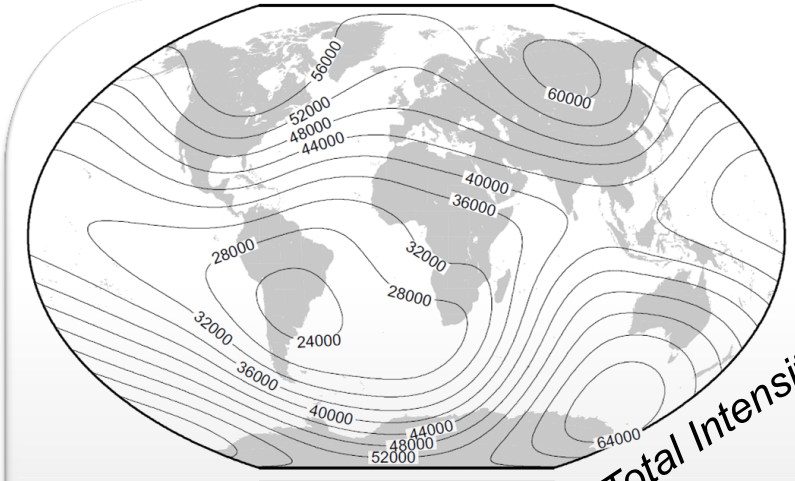
Local Time

RM stability... B0834+06 (II)

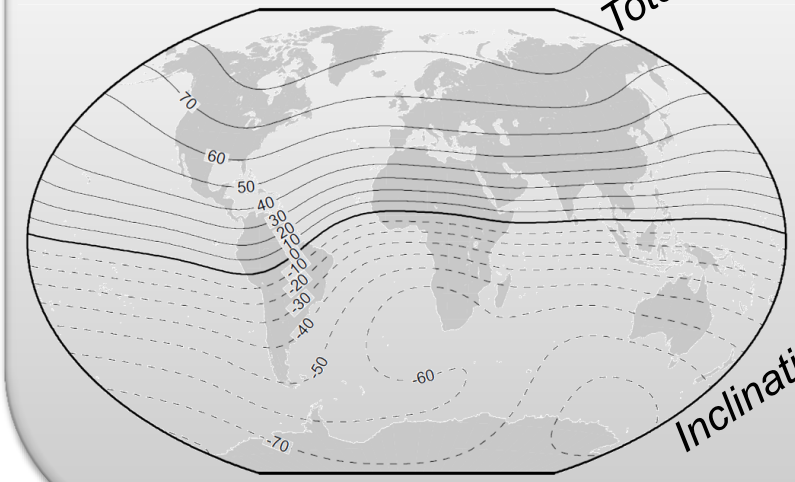


- SS = Sunset
- T[C,N,A] = Twilight [Civil, Nautical, Astronomical]

Ionospheric effects



Total Intensity (|B|)



Inclination (Θ_B)

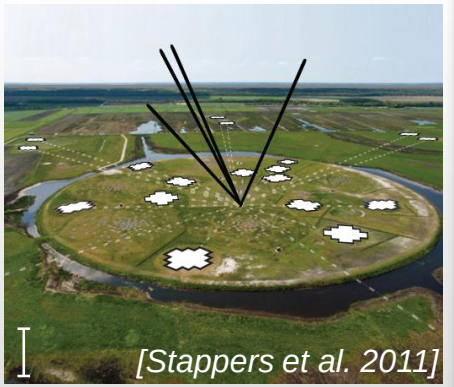
[British Geological Survey 2010]

$$RM = 0.810 \int_{receiver}^{source} n_e(s)\bar{B}(s).d\bar{s}$$

TECU = 10^{16} e^- m^{-2}

|B| ≈ 50,000 nT

Θ_B ≈ +65 deg



RM variation of ~1 rad m^{-2} ≈ 10 TEC

More sensitive than GPS data

Future calibration essential…

Conclusions

- Pulsar polarisation observations with LOFAR HBAs!
- Observations, analysis and investigation...
- Ionospheric variation – calibration…
- LOFAR future: discoveries of ~250 by 12.12.12!
- SKA
  - Pulsar discoveries (1000s)
  - RM precision improved (BW 250 MHz & SNR)

Thank you for listening!!