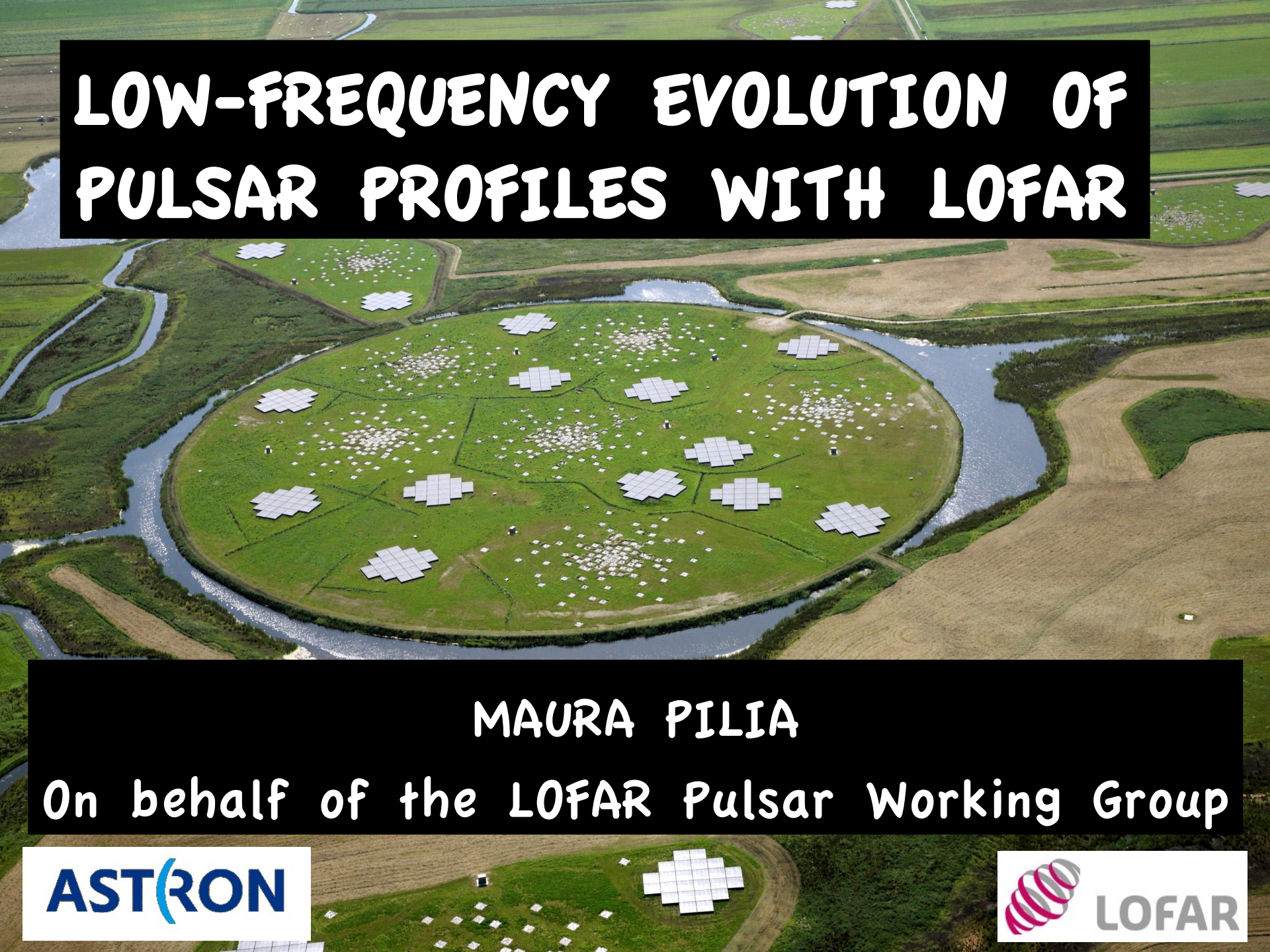

LOW-FREQUENCY EVOLUTION OF PULSAR PROFILES WITH LOFAR

MAURA PILIA

On behalf of the LOFAR Pulsar Working Group

ASTRON

LOFAR

PWG

LOFAR Pulsar Working Group

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Ben Stappers (co-lead)	University of Manchester
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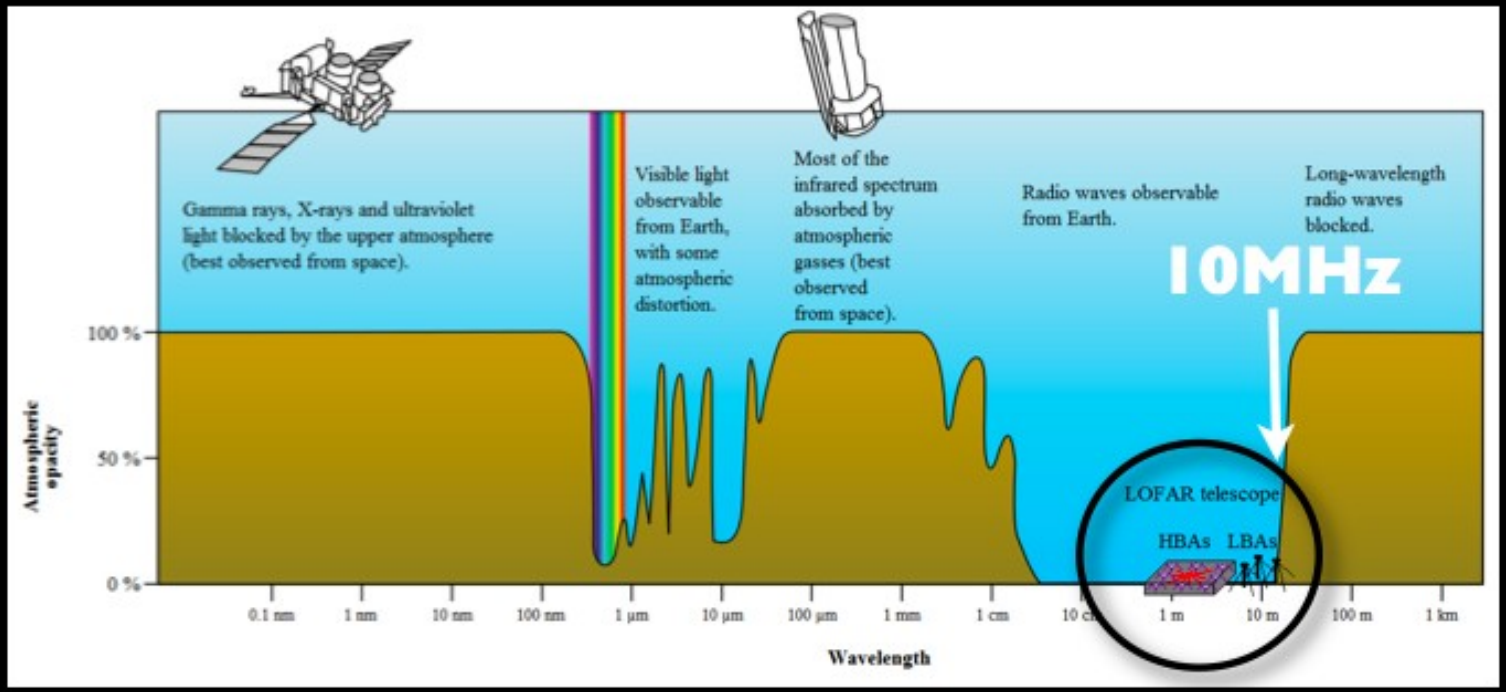
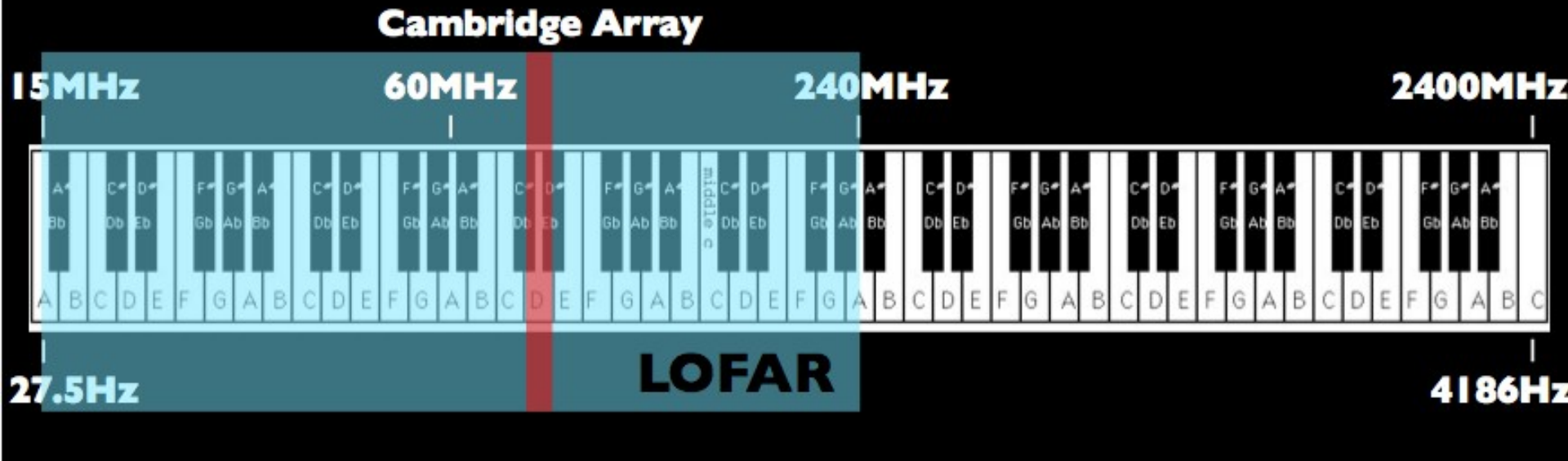
Aris Karastergiou	University of Oxford
Evan Keane	MPI für Radioastronomie
Vlad Kondratiev	ASTRON
Michael Kramer	MPI für Radioastronomie
Masaya Kuniyoshi	MPI für Radioastronomie
Joeri van Leeuwen	ASTRON / Universiteit van Amsterdam
Aris Noutsos	MPI für Radioastronomie
Maura Pilia	ASTRON / Universiteit van Amsterdam
Maciej Serylak	LPC2E/CNRS
Charlotte Sobey	MPI für Radioastronomie
Sander ter Veen	Radboud Universiteit Nijmegen
Joris Verbiest	MPI für Radioastronomie
Patrick Weltevrede	University of Manchester
Kimon Zagkouris	University of Oxford

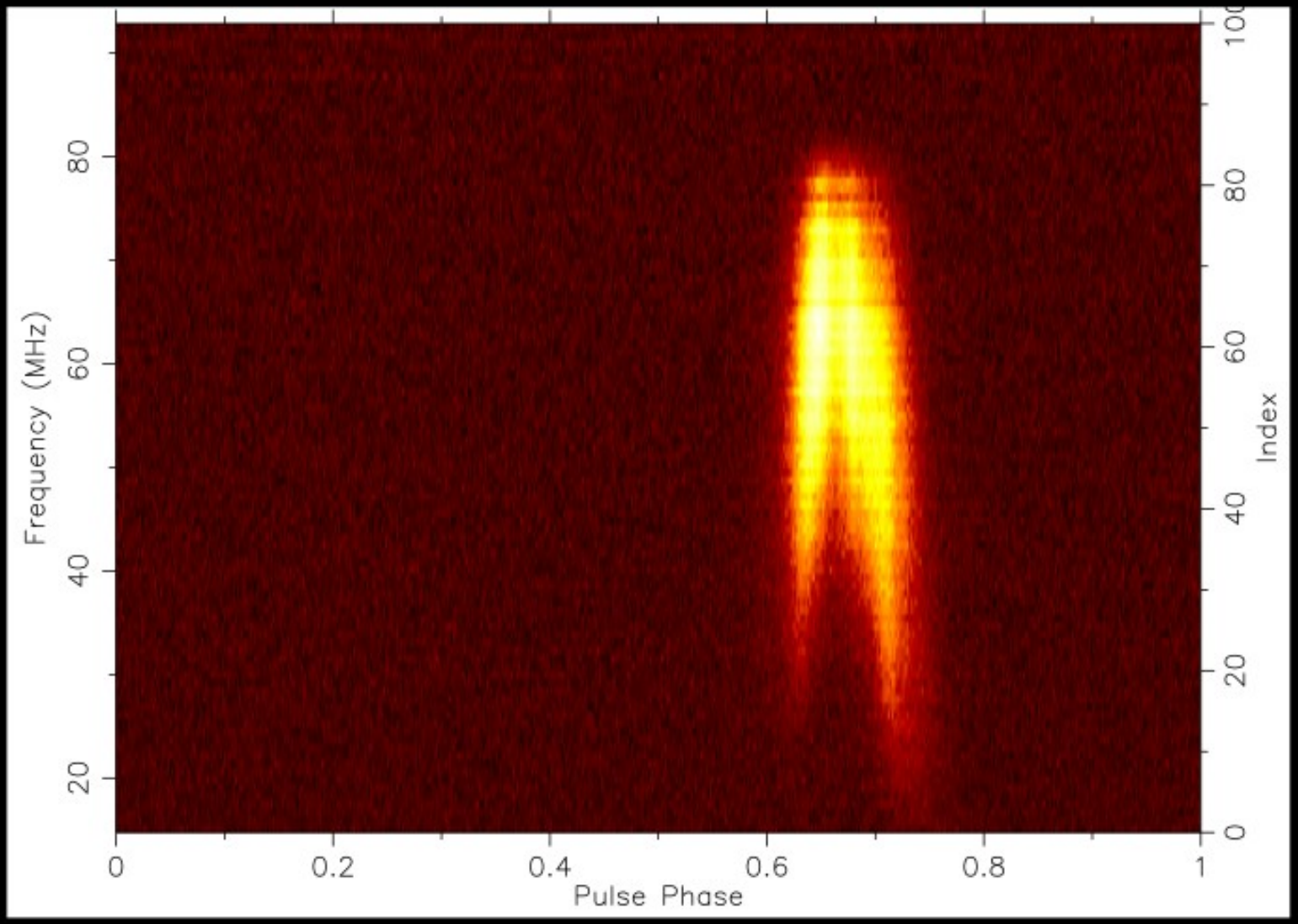
LOFAR's Enormous Frequency Range





LOFAR's Enormous Frequency Range

93MHz



15MHz

PSR B0809+74 detected down to 15MHz

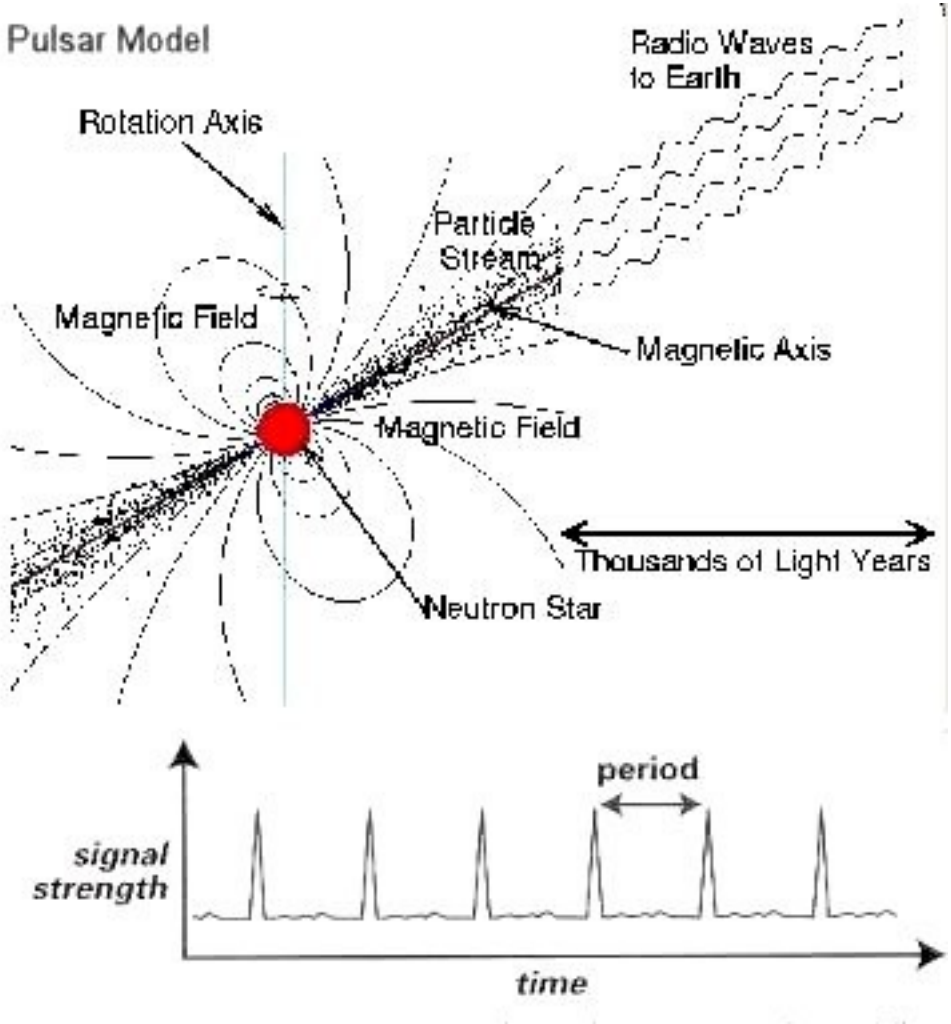
Observations with LOFAR - Advantages

Large fractional bandwidth (up to ~80 MHz)
can be recorded at any time allows for continuous studies of the evolution, as opposed to studies via a number of widely separated narrow bands:
CONTINUOUS FREQUENCY COVERAGE

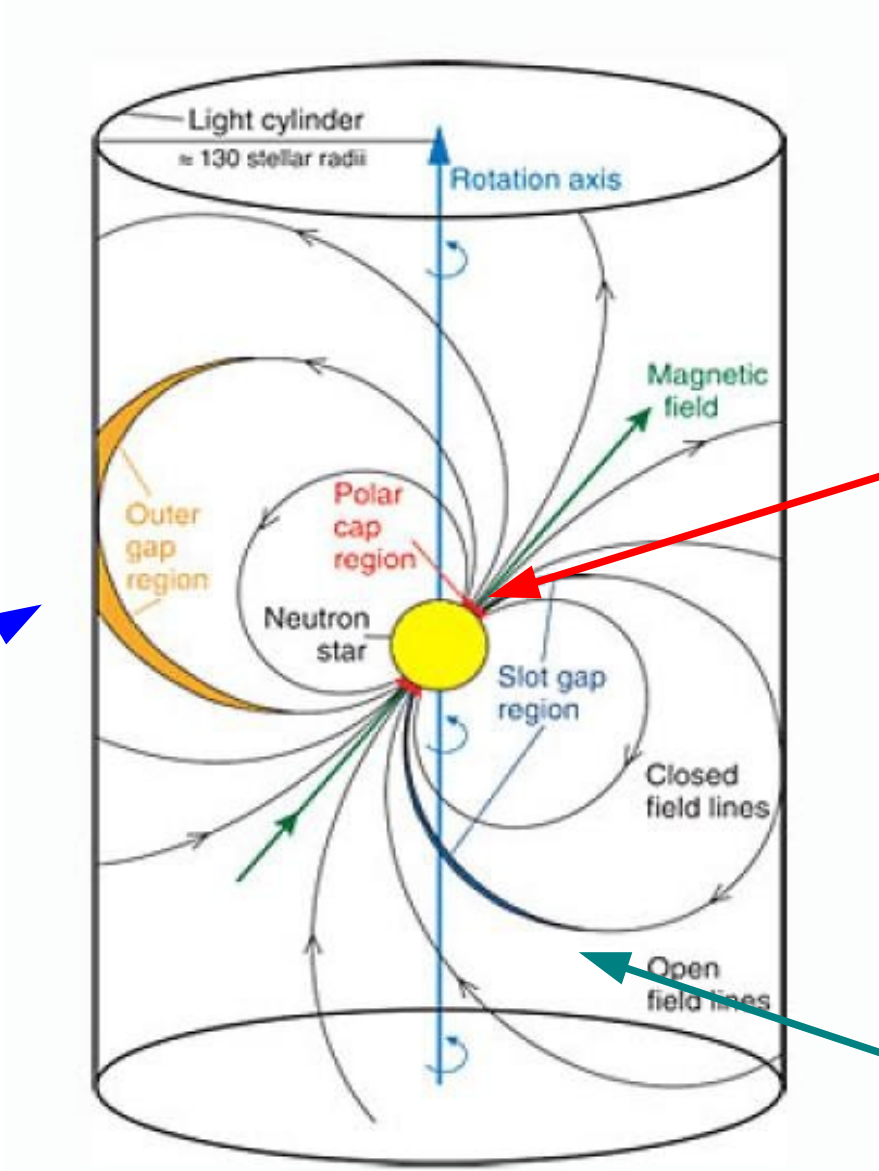
Ability to track sources:
an adequate number of pulses can be collected in a single observing session rather than having to combine several short observations

Excellent frequency and time resolution necessary for properly dedispersing the pulses as well as resolving narrow features in the profile.
LOFAR is also capable of coherently dedispersing the data.

Pulsar Model



Pulsar Magnetosphere



POLAR CAP

OUTER GAP

SLOT GAP

Building the Model

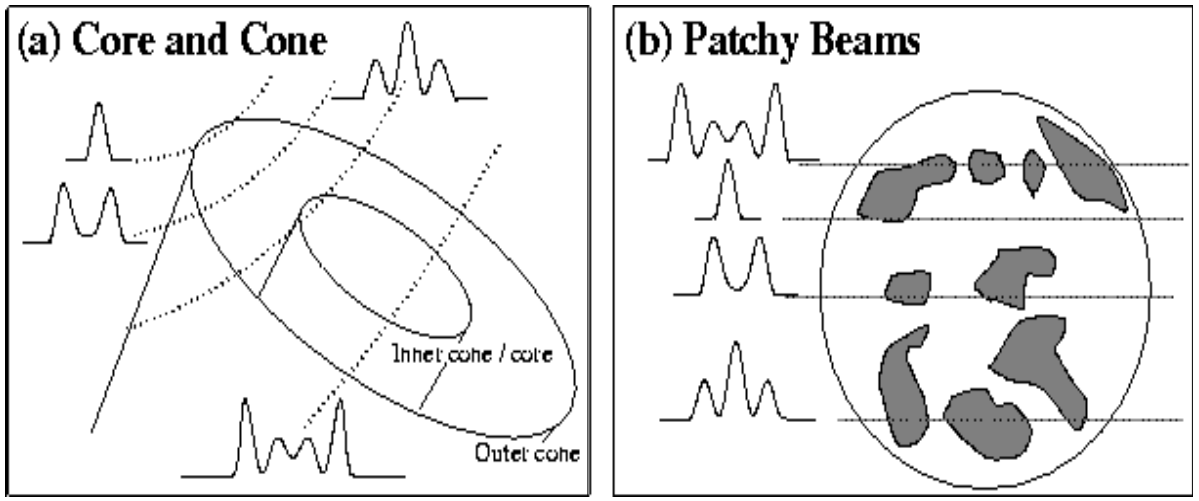
Conal components

Height vs Longitude

CORE - CONE vs PATCHY

Single profiles

Patches



Rankin 1983+ Lyne & Manchester 1988

Period-width dependance

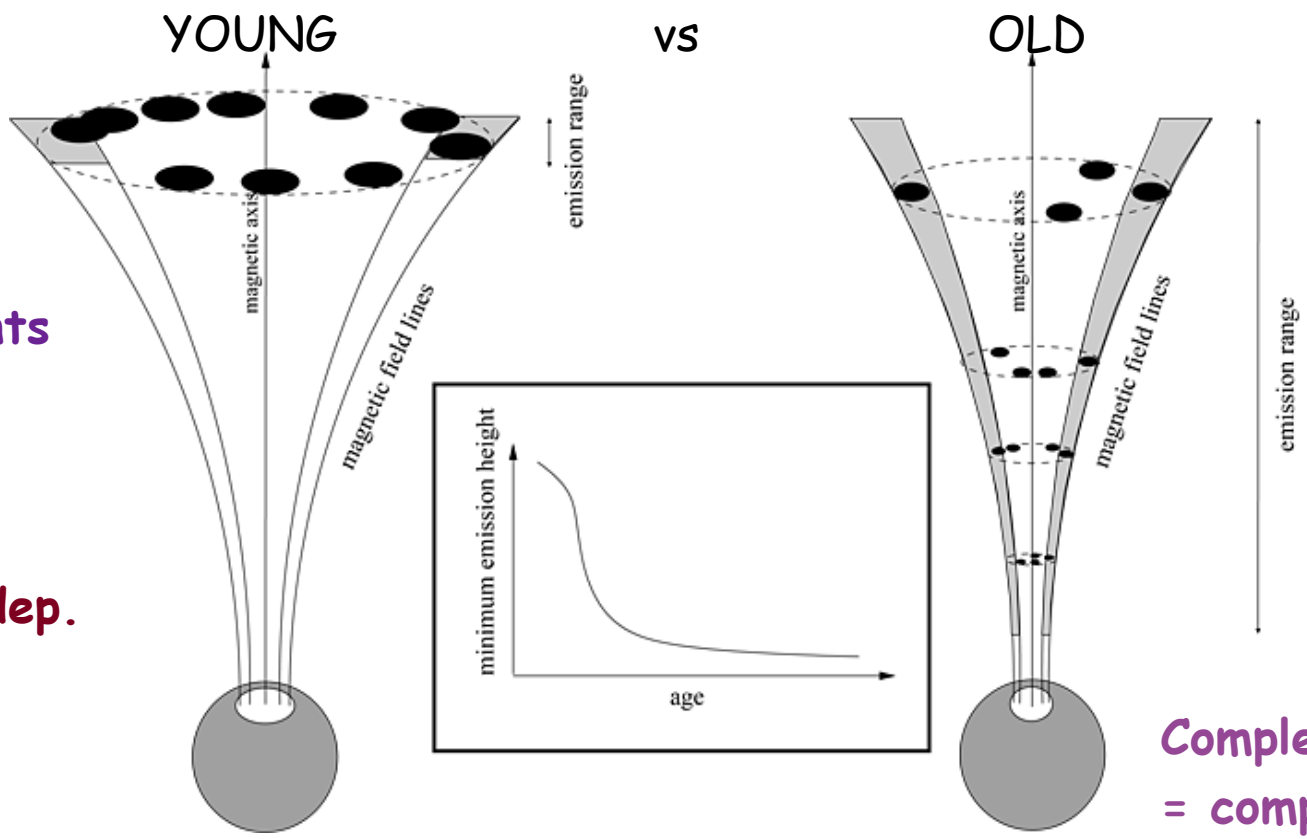
Complex profs = complex PA

RFM

Building the Model

Single profiles

Simple young



Patches

Conal components

RFM

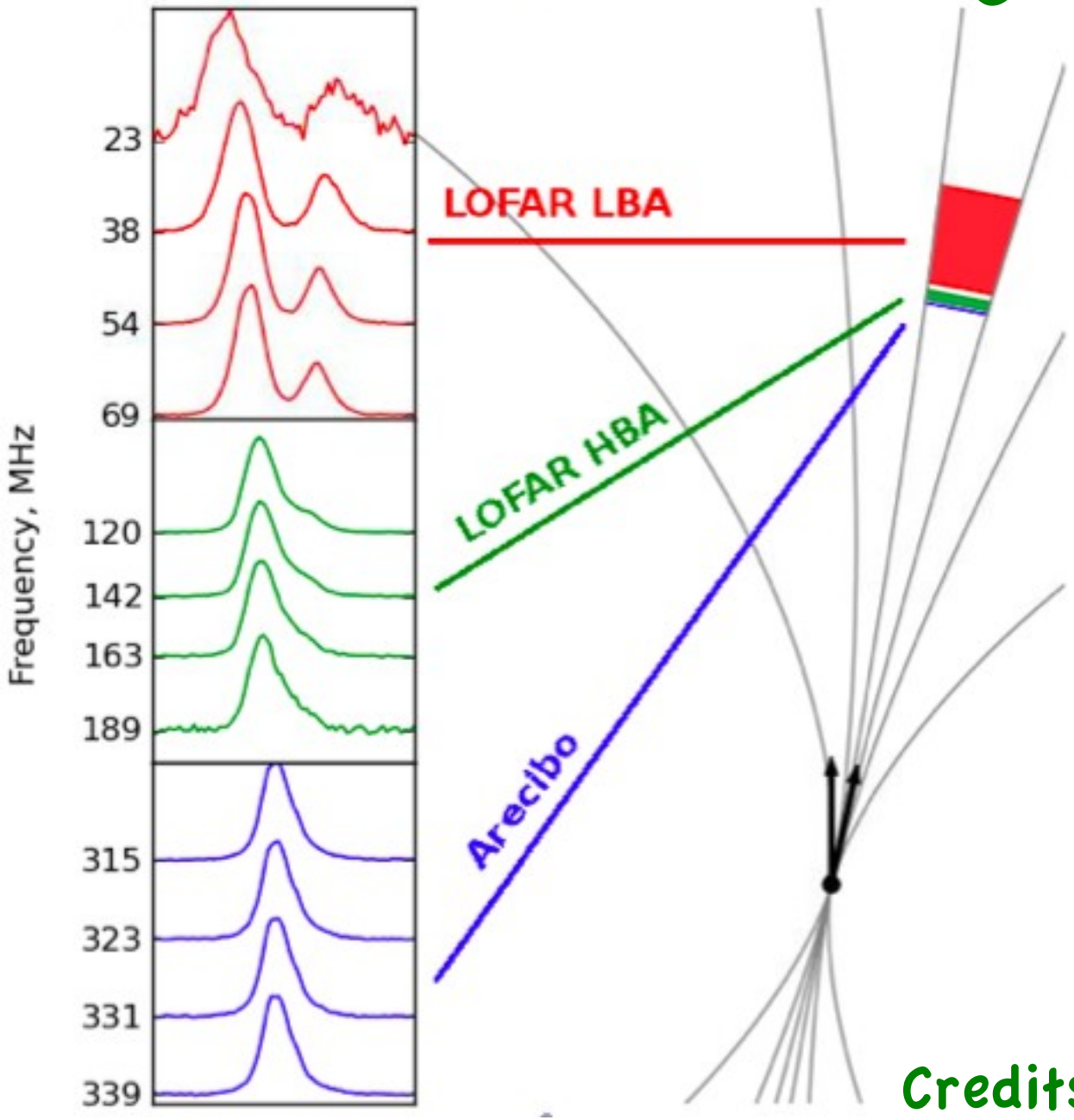
Period-width dep.

Complex profs
= complex PA

Height vs Longitude

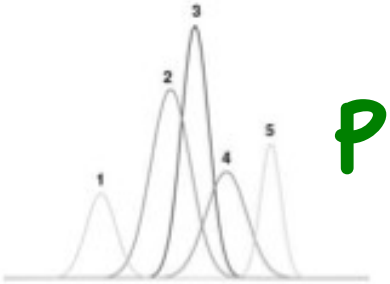
Karastergiou & Johnston 2007

Pulsar Emission Regions



Credits: Anna Bilous

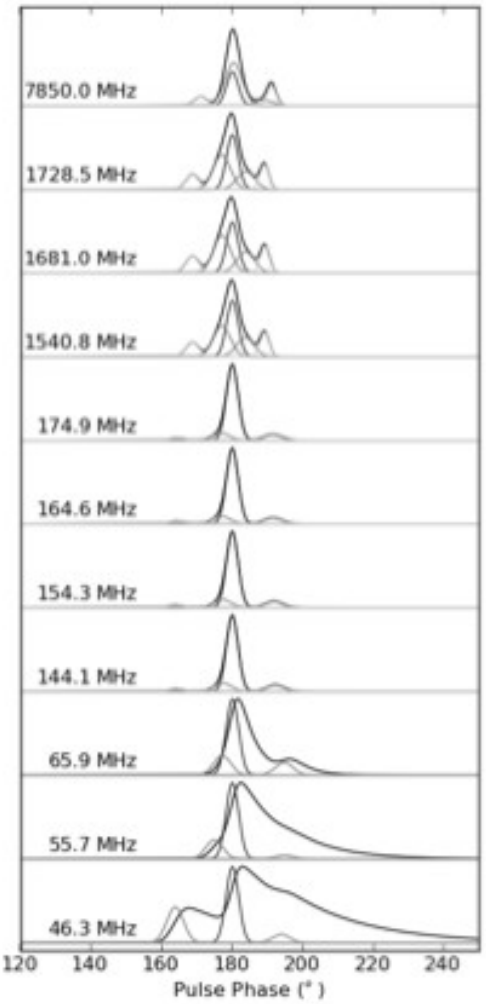
Profile evolution



extrinsic effects

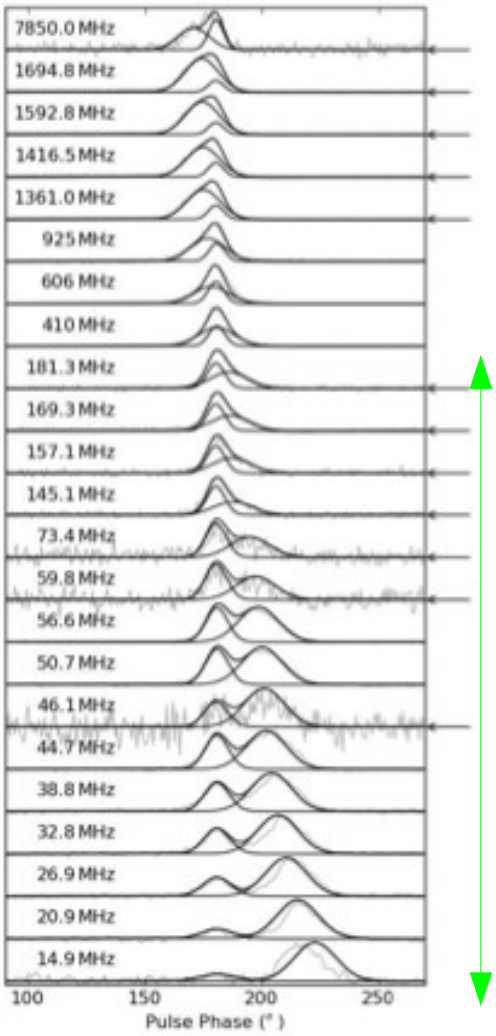
Hassall et al. 2012

intrinsic effects



LOFAR bands

B0329+54



LOFAR bands

B0809+74

LOFAR Observations:

HBA observations

SUPERTERP

120 – 167 MHz

240 subbands

17 minutes

LBA observations

FULL CORE

25 pulsars

15 – 61 MHz

57 minutes

Using the full core has allowed to go a factor 4x deeper!

see Cooper's talk

LOFAR Observations:

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Using the full core has allowed to go a factor 4x deeper!

+ WSRT @ 300MHz - 1.4GHz

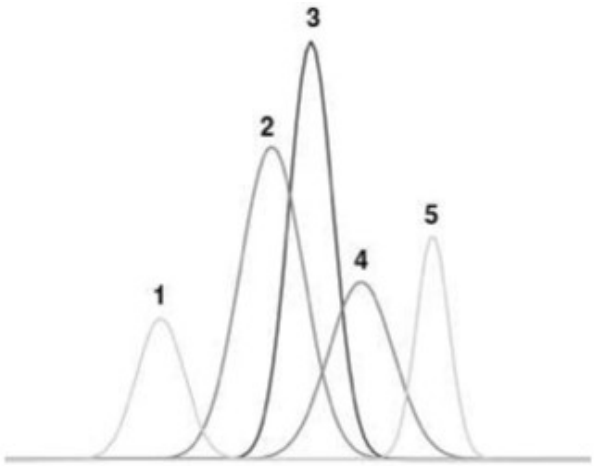
+ Jodrell Bank @ 1.5 GHz

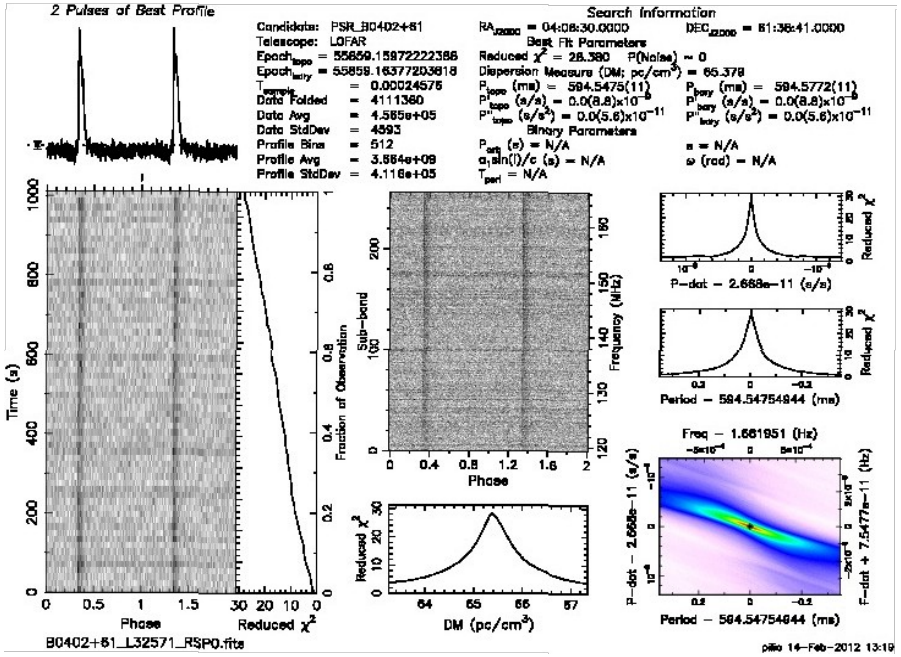
Observations with LOFAR - Analysis

psrfits format data obtained from the initial HDF5 format

Dedispersion and folding

using the **prepfold** tool from presto and an accurate rotational **ephemeris**

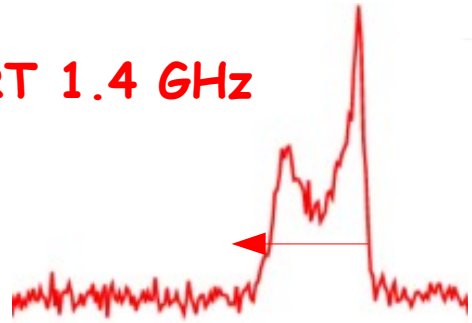




Multi-gaussian fit to the profiles in a number of frequency bands

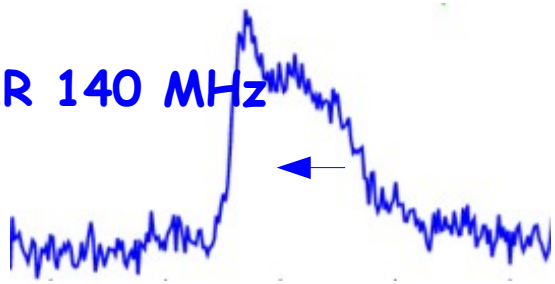
Observations with LOFAR - Alignment

WSRT 1.4 GHz

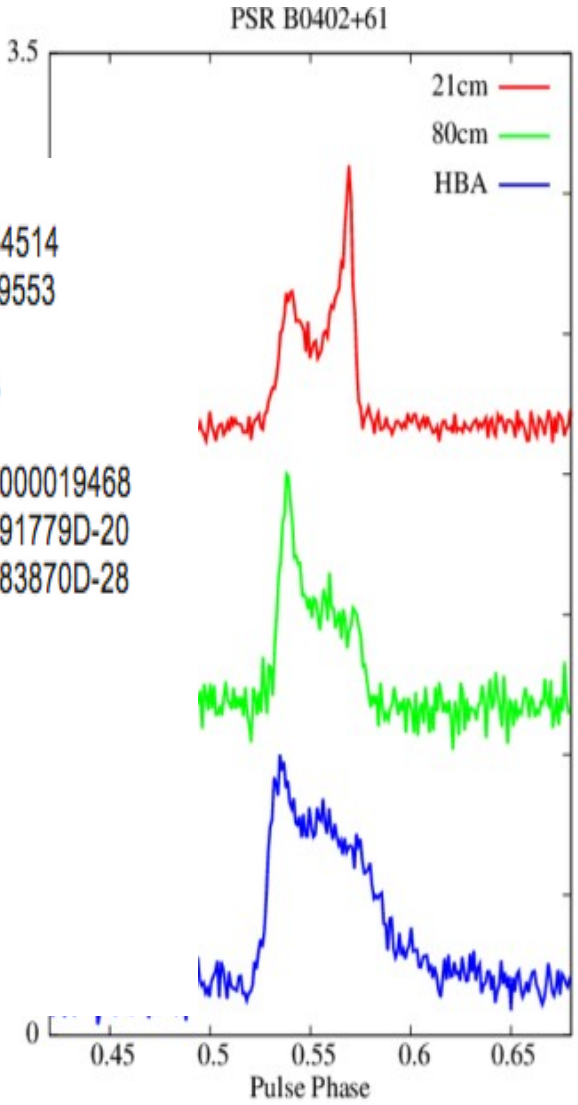


WSRT 300 MHz

LOFAR 140 MHz

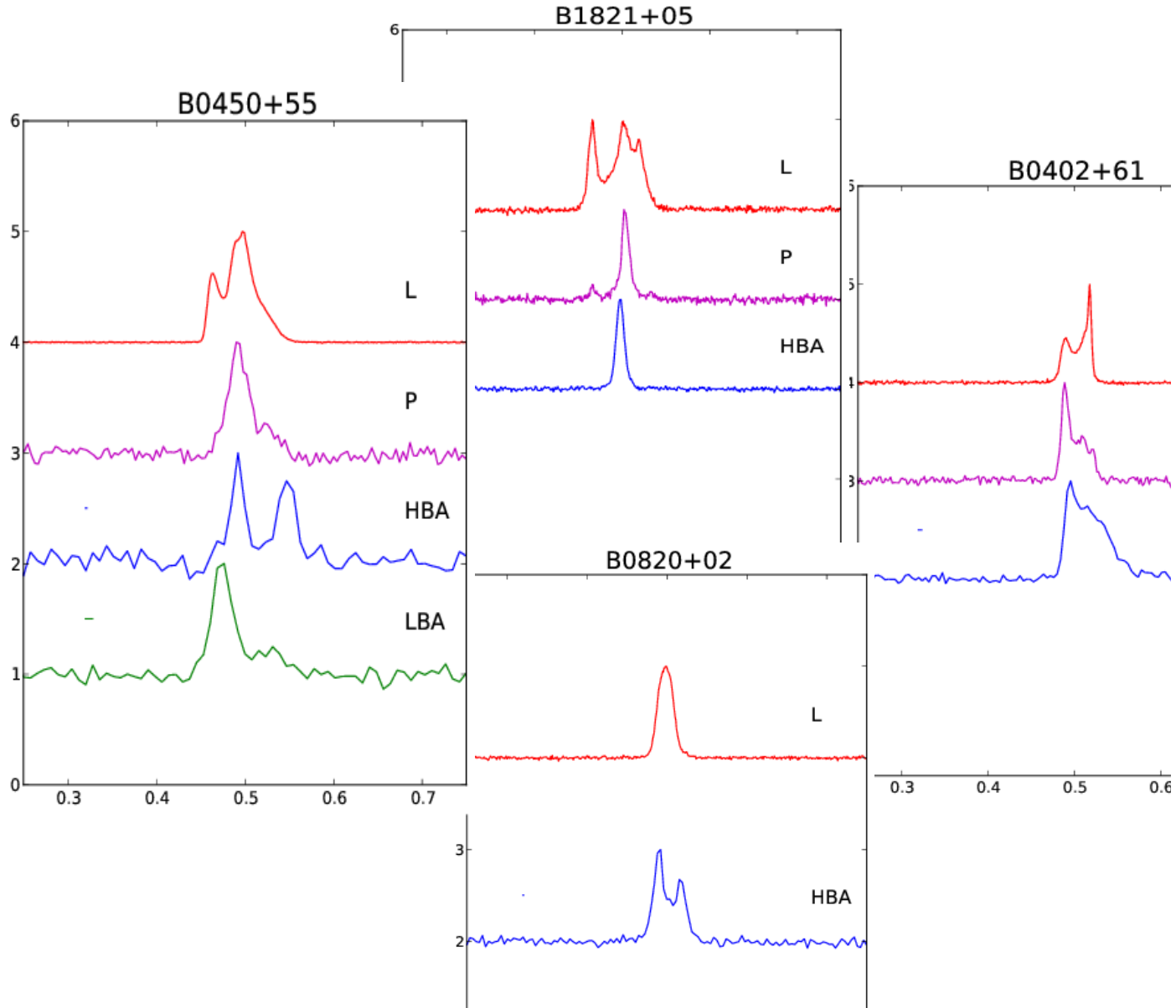


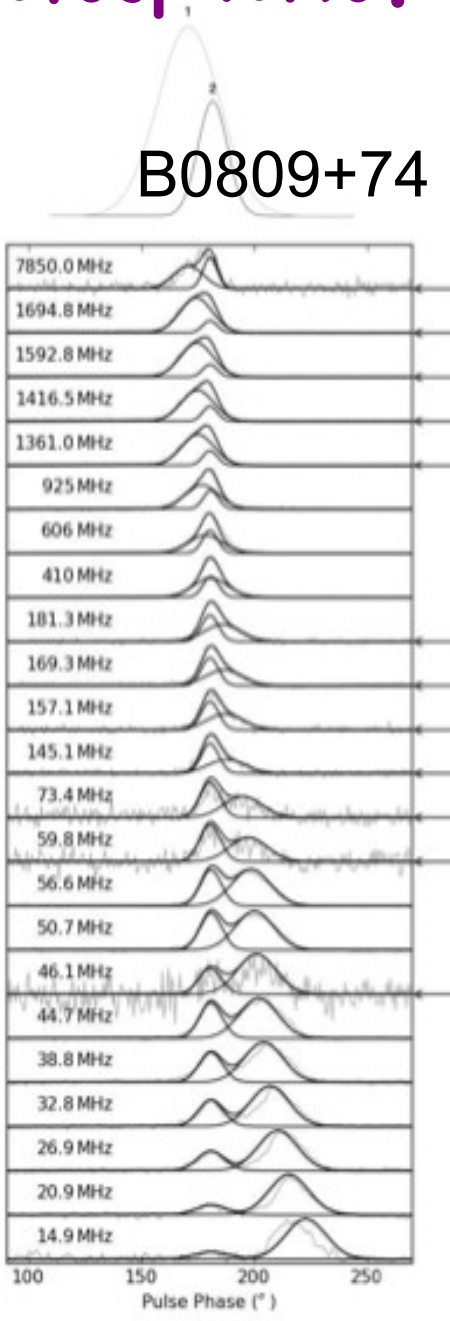
PSR	0402+61		
RAJ	04:06:29.86781532	0	0.00154514
DECJ	61:38:40.2807886	0	0.0159553
PMRA	113.9046	0	2.7164
PMDEC	52.2482	0	4.2388
POSEPOCH	49876.0000		
F0	1.6818673177083718	0	0.0000000000019468
F1	-1.576508166061D-14	0	3.794388991779D-20
F2	-1.557870025896D-28	0	2.995224983870D-28
PEPOCH	55981.999999		
START	52874.476		
FINISH	55974.070		
DM	65.303000		
EPHEM	DE200		
CLK	UNCORR		
NTOA	263		
TRES	1795.98		



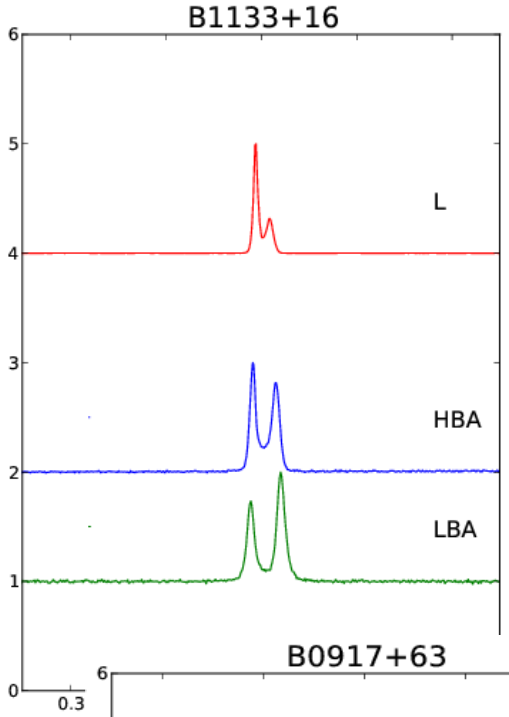
Pulsar Profile Variation-Magnetospheric?

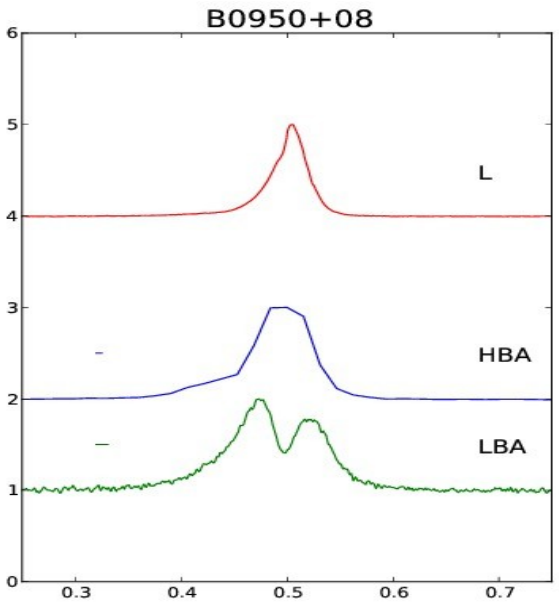
Pilia et al., in prep

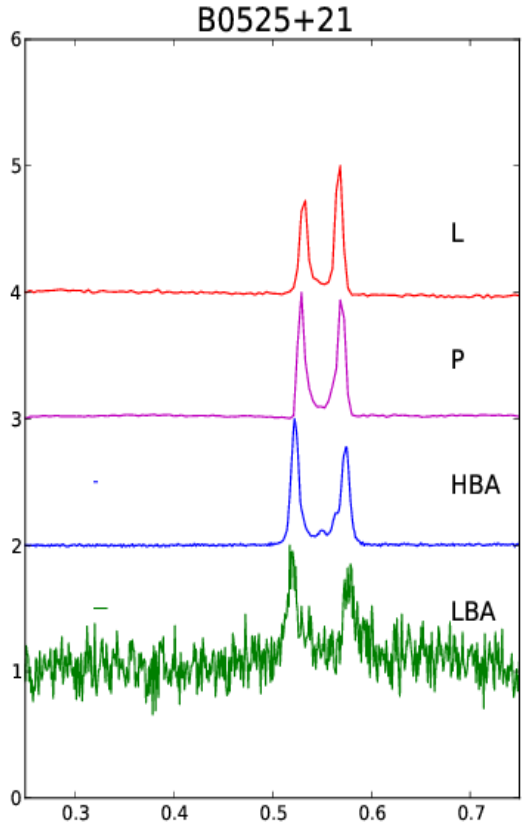


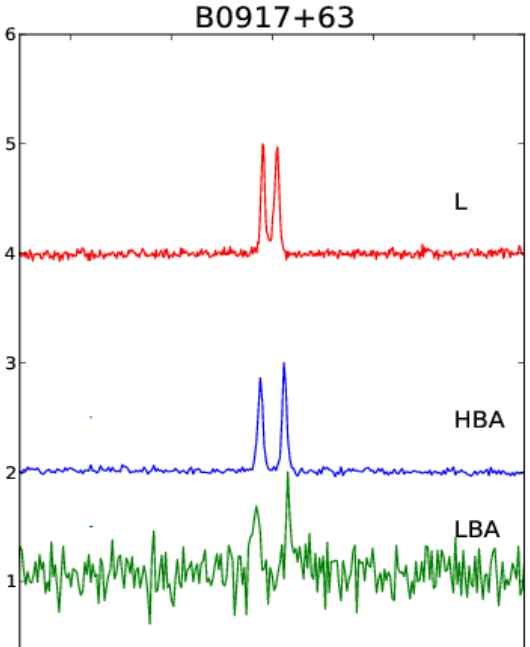


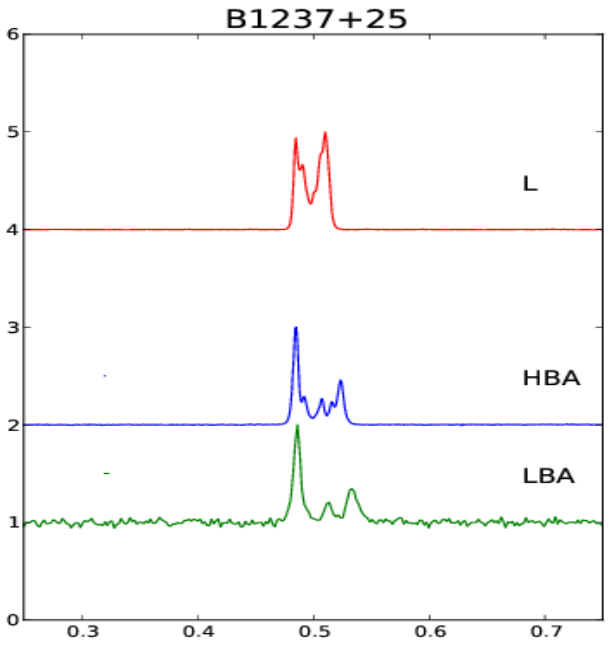
Pulsar Profile Variation - Widening







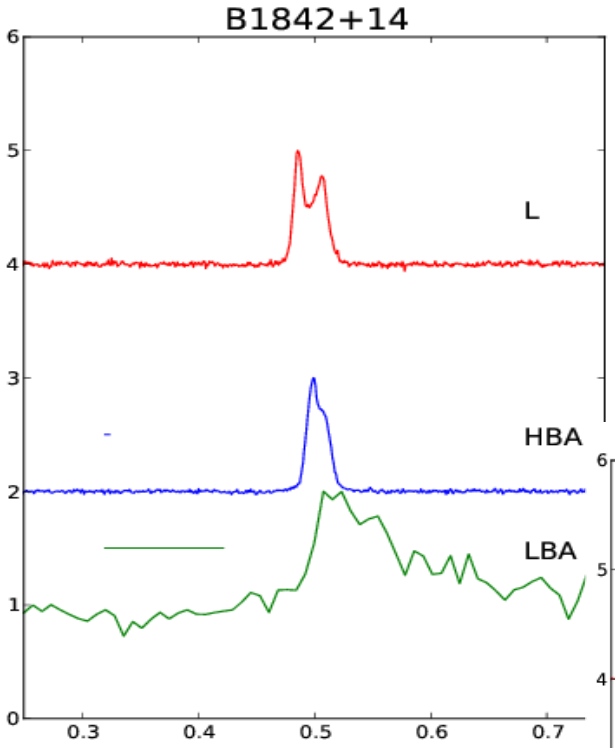


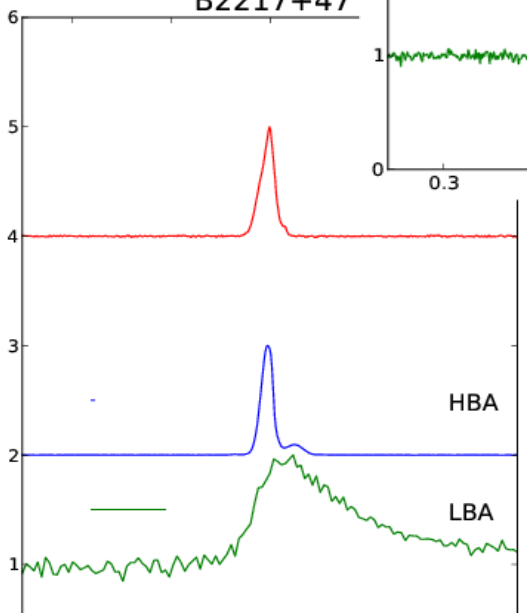


Pilia et al., in prep

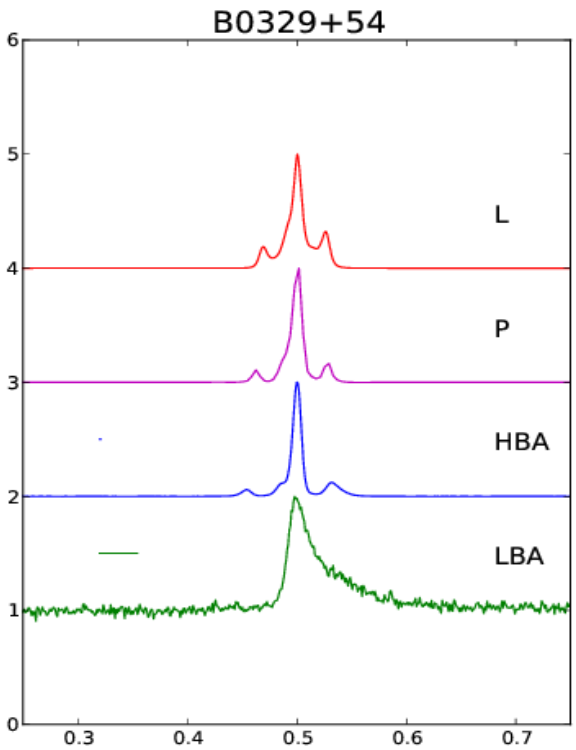
Pulsar Profile Variation - External Effects

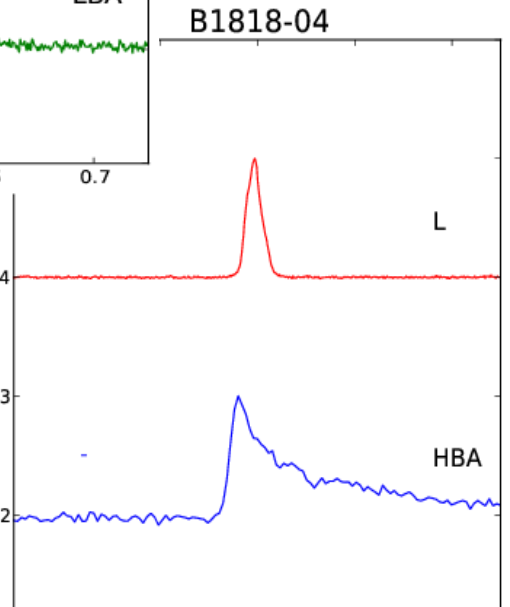
DM smearing





Scattering

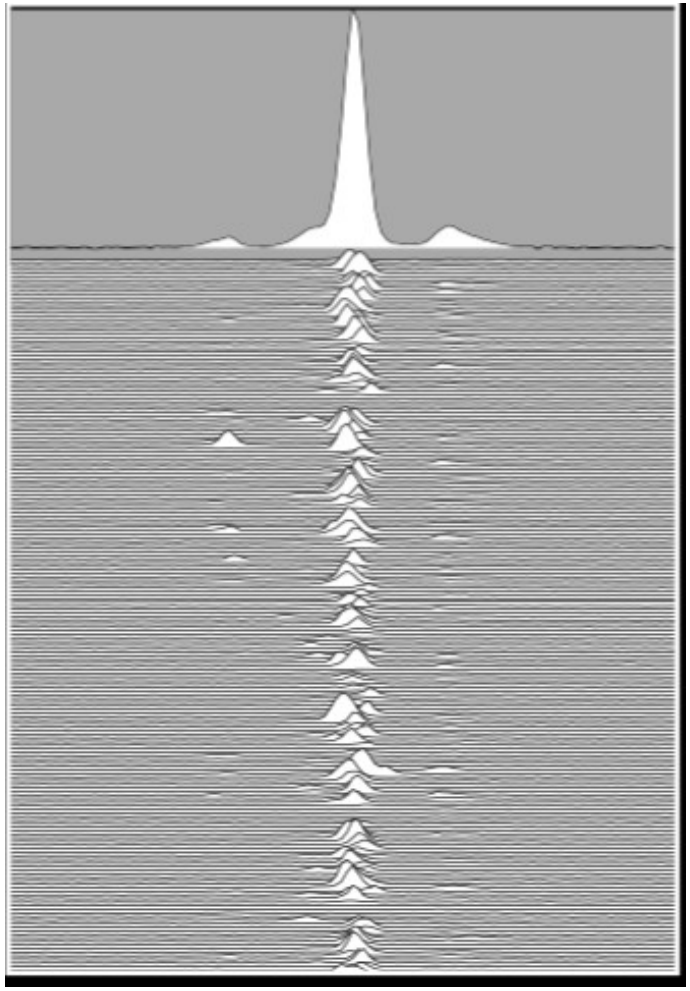




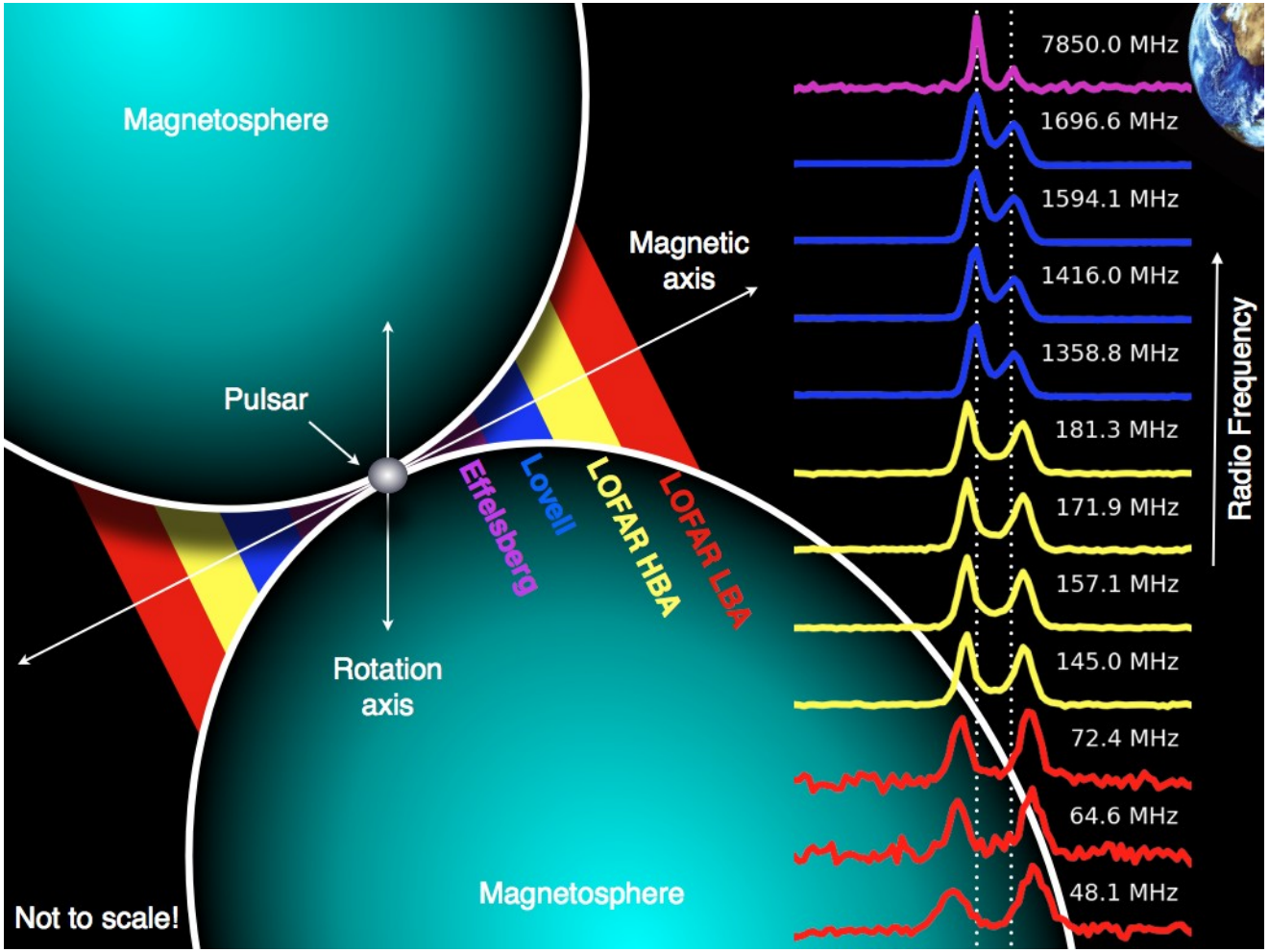
Pilia et al., in prep

Pulsar Profile Variation - Single pulses

B0329+54

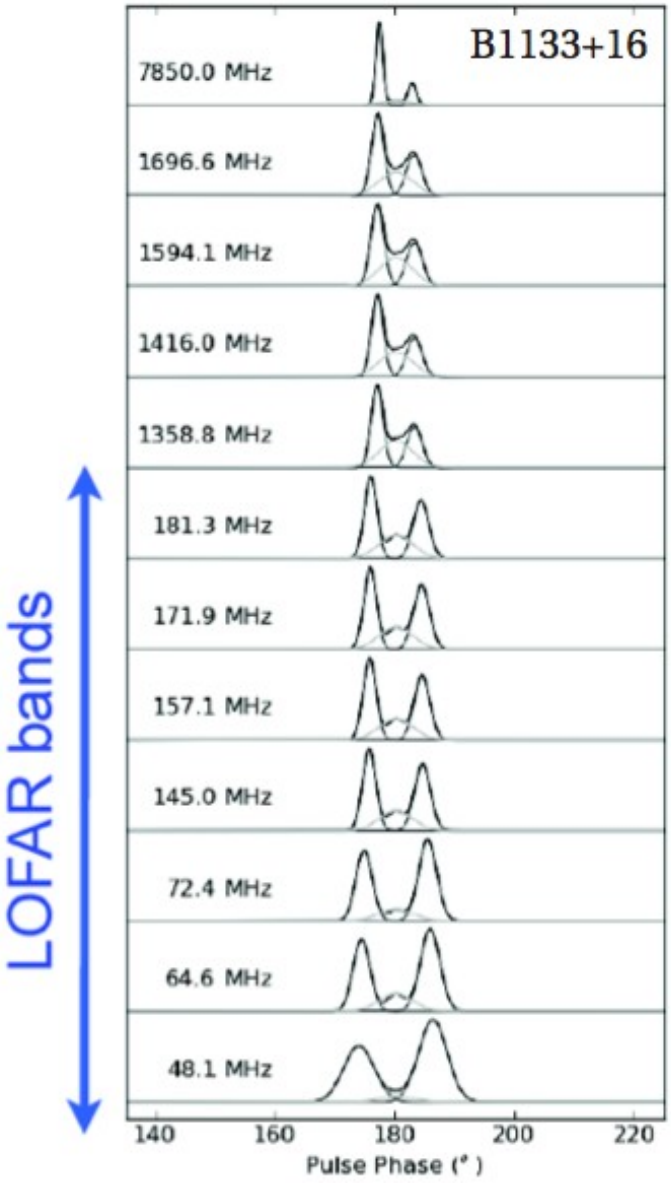


Radius to Frequency Mapping (RFM)



Hassall et al. 2012, A&A

DM vs Profile variations



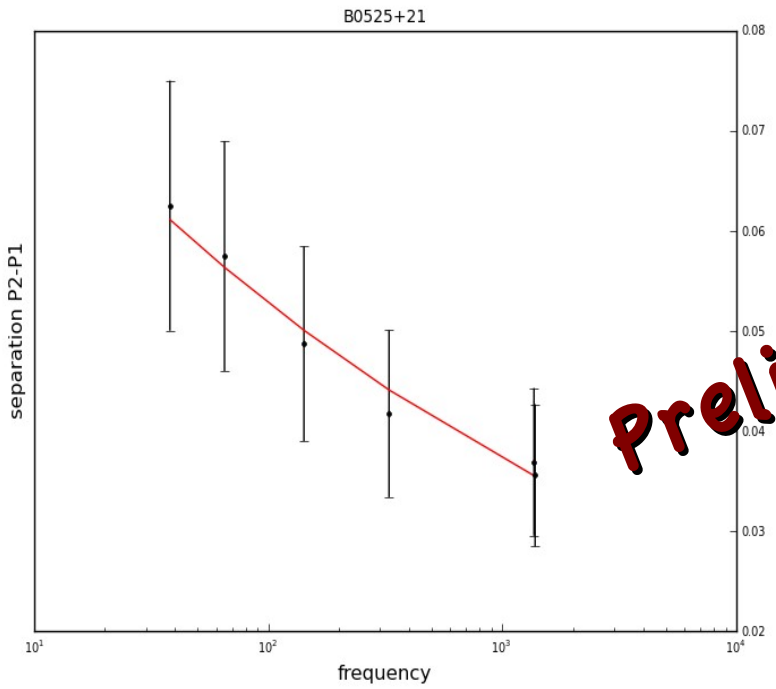
- Cold-dispersion law good to 1/100,000

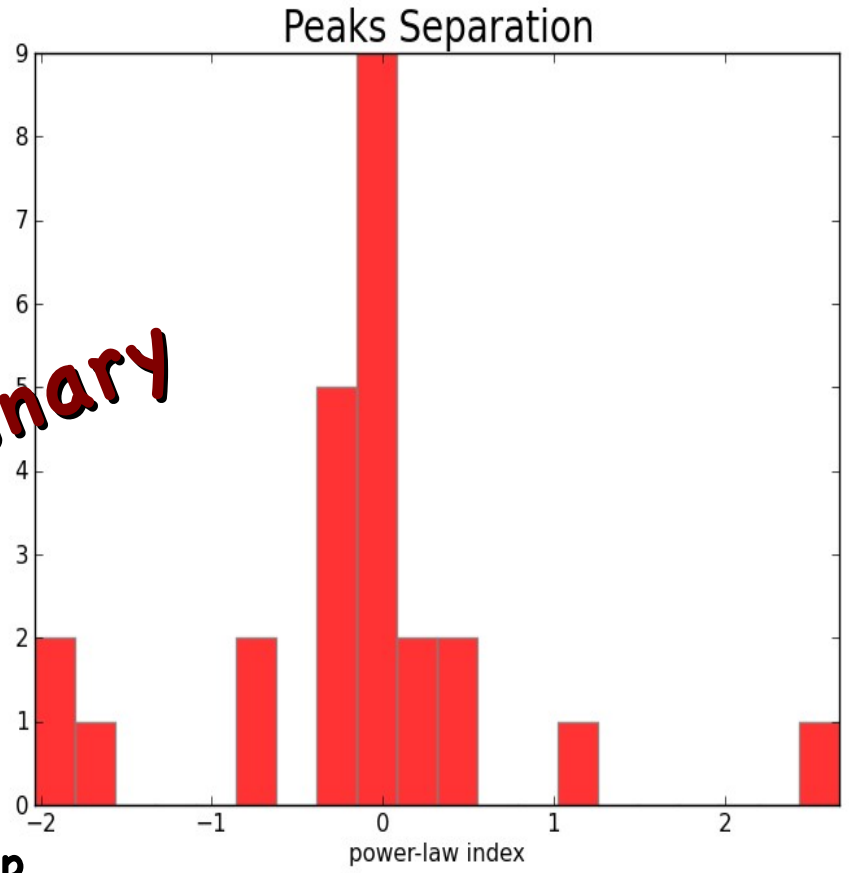
- For PSR B1133+16 all radio frequencies come from a region $\Delta R < 59$ km in altitude below 110 km from NS surface (0.2% of the light cylinder)

Hassall et al. 2012

RFM - Peaks Separation

We calculated, in the case of multiple peaks pulsars, the separation of the two most prominent peaks as it evolves with frequency.





Preliminary

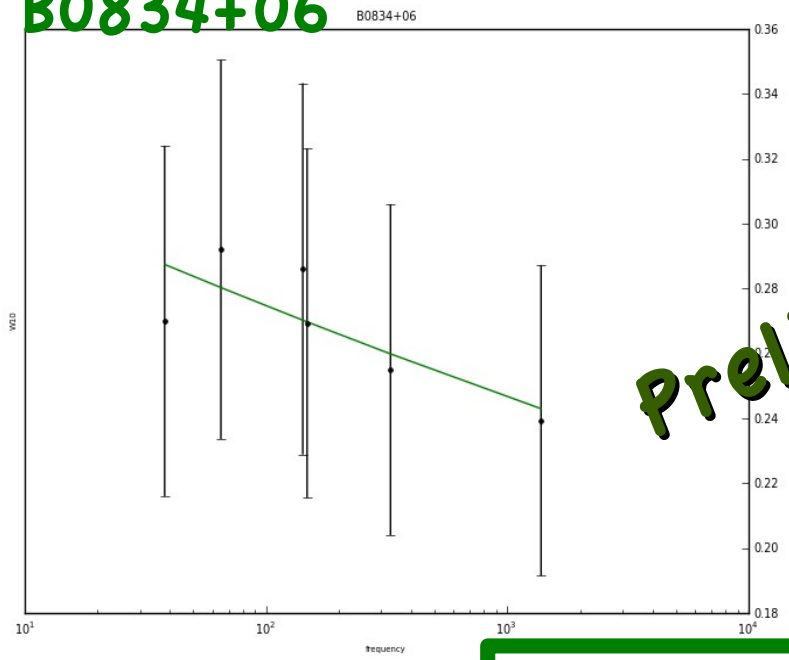
B0525+21

Pilia et al., in prep

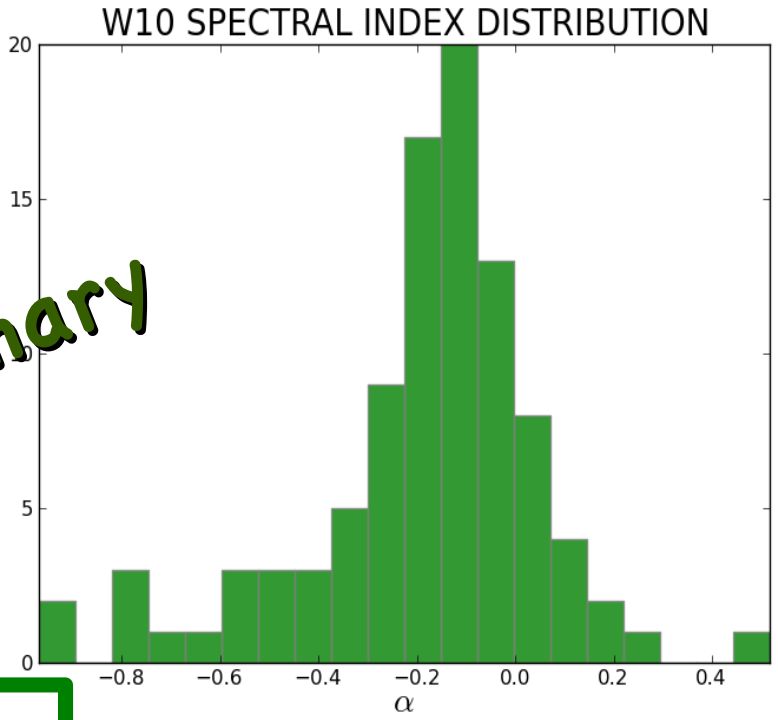
RFM - Width of the Pulse Profile

For all pulsars, were possible, we calculated the width of the profile at the 10% level of the full width of the outer components of the profile. This gives an indication on the opening of the cone of the emission.

B0834+06



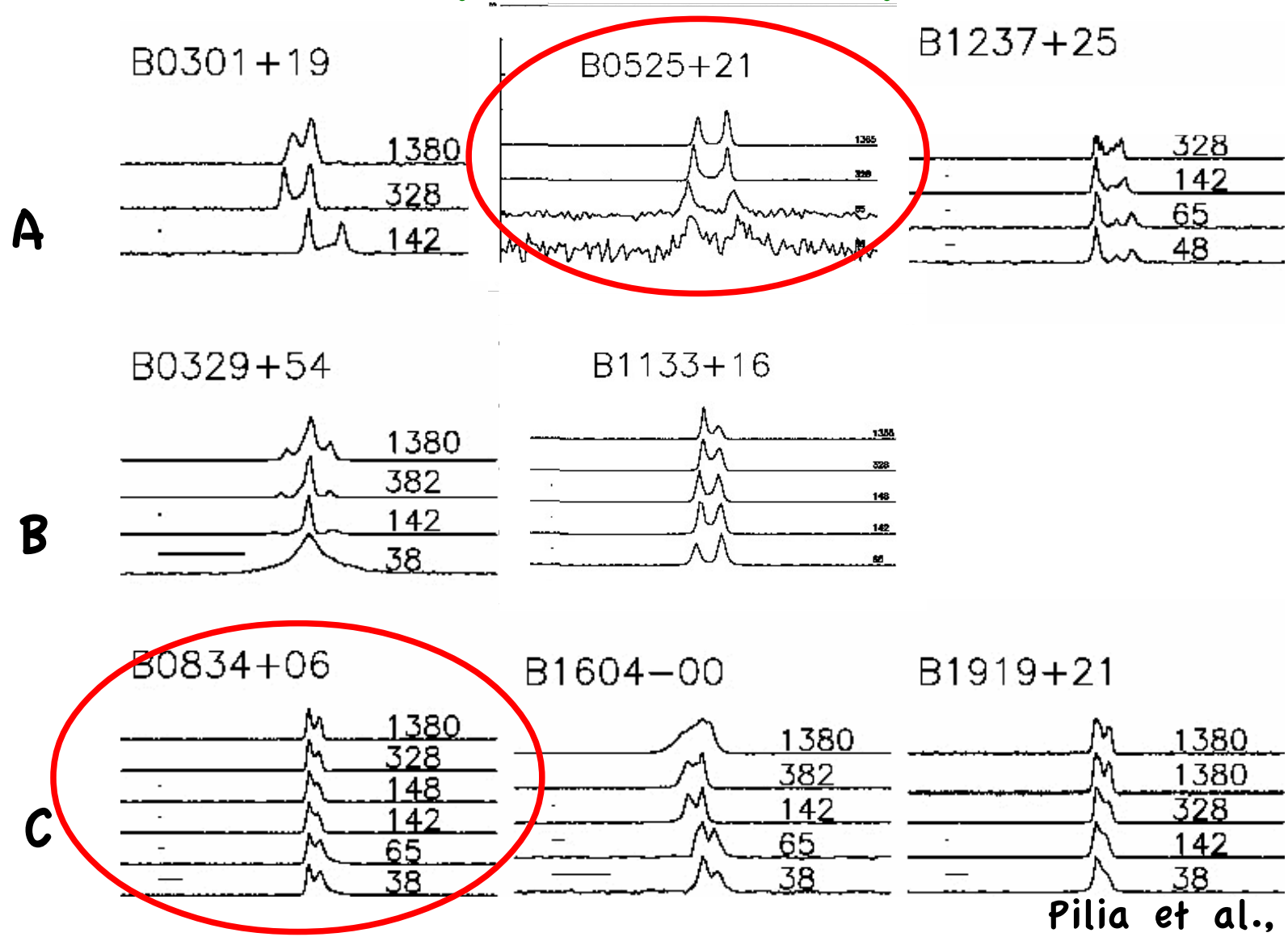
Preliminary



Index = -0.2

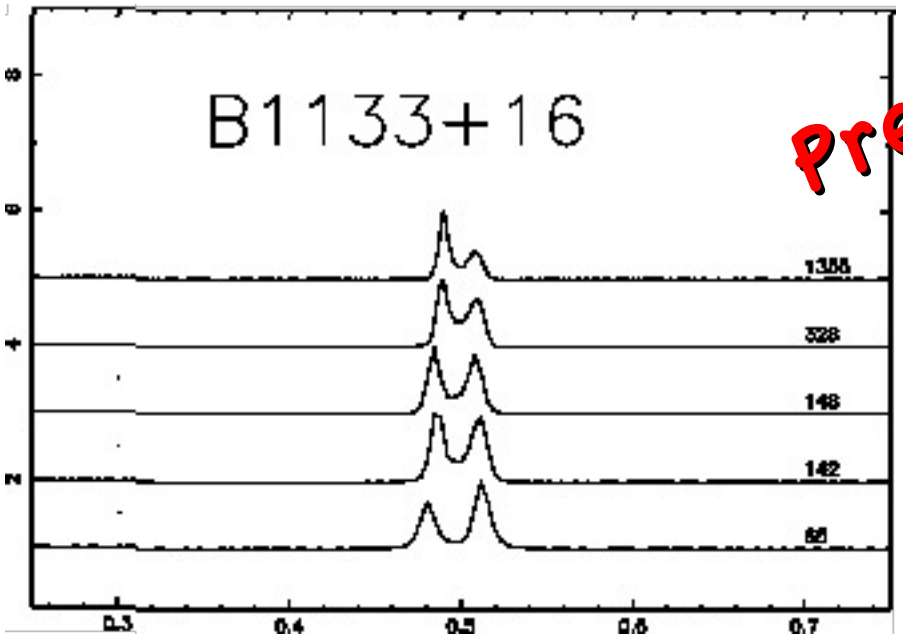
Pilia et al., in prep

RFM - Comparison with the models - Rankin's Groups for Multiple Peaks

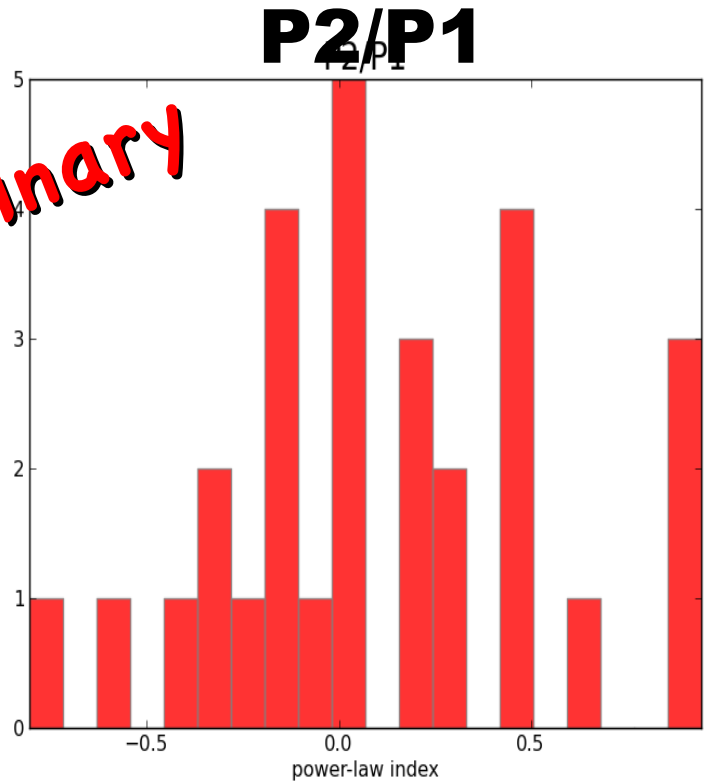


Pilia et al., in prep

Profile Evolution - Peaks Ratio

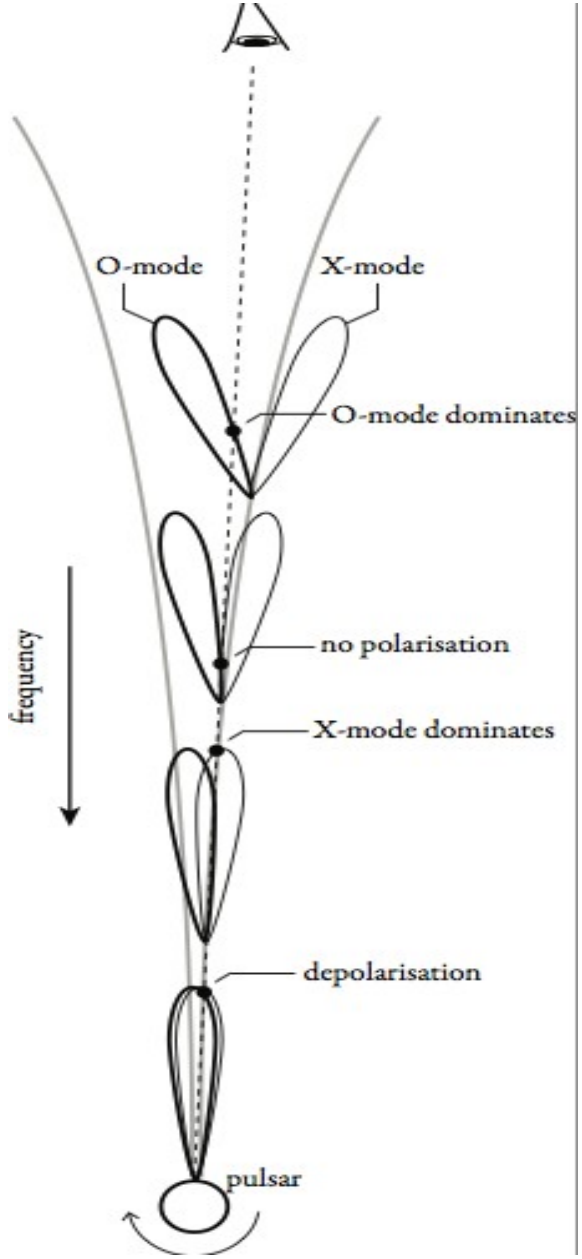


Preliminary



Pilia et al., in prep

Birefringence

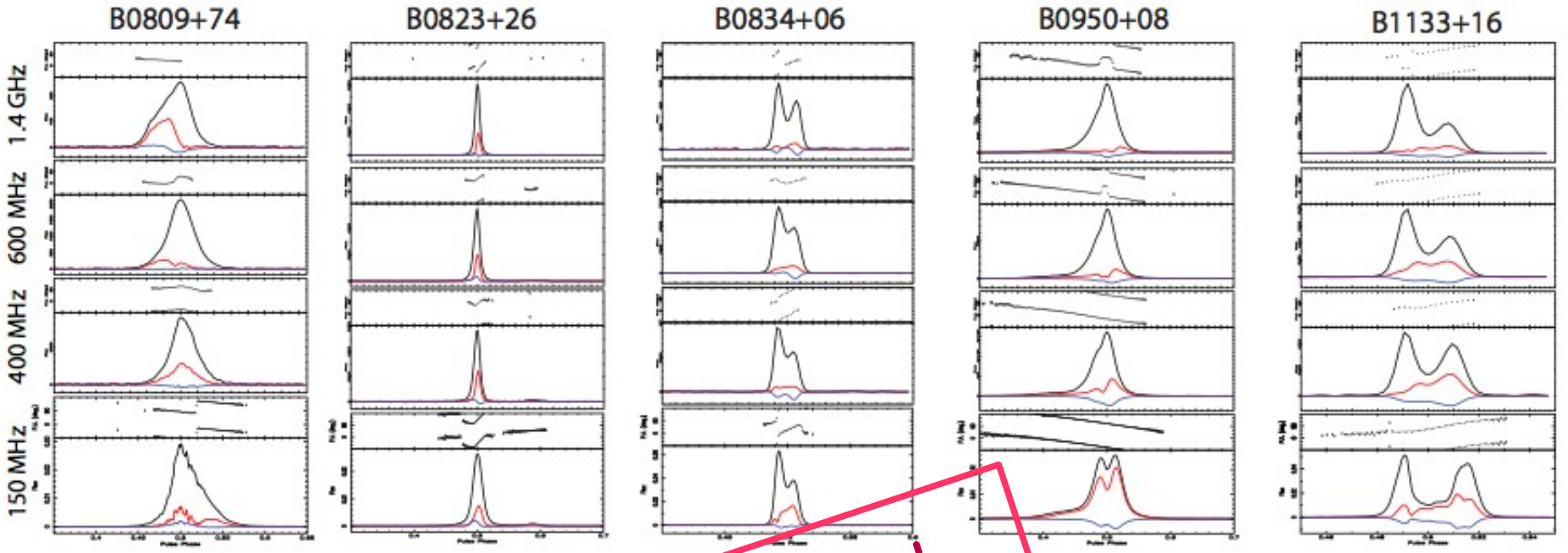


The broadening at low radio frequency is caused by the separation of the individual beams of the two propagation modes, and the depolarization at high frequency results from the merger of their orthogonal polarizations.

Credits: Aris Noutsos

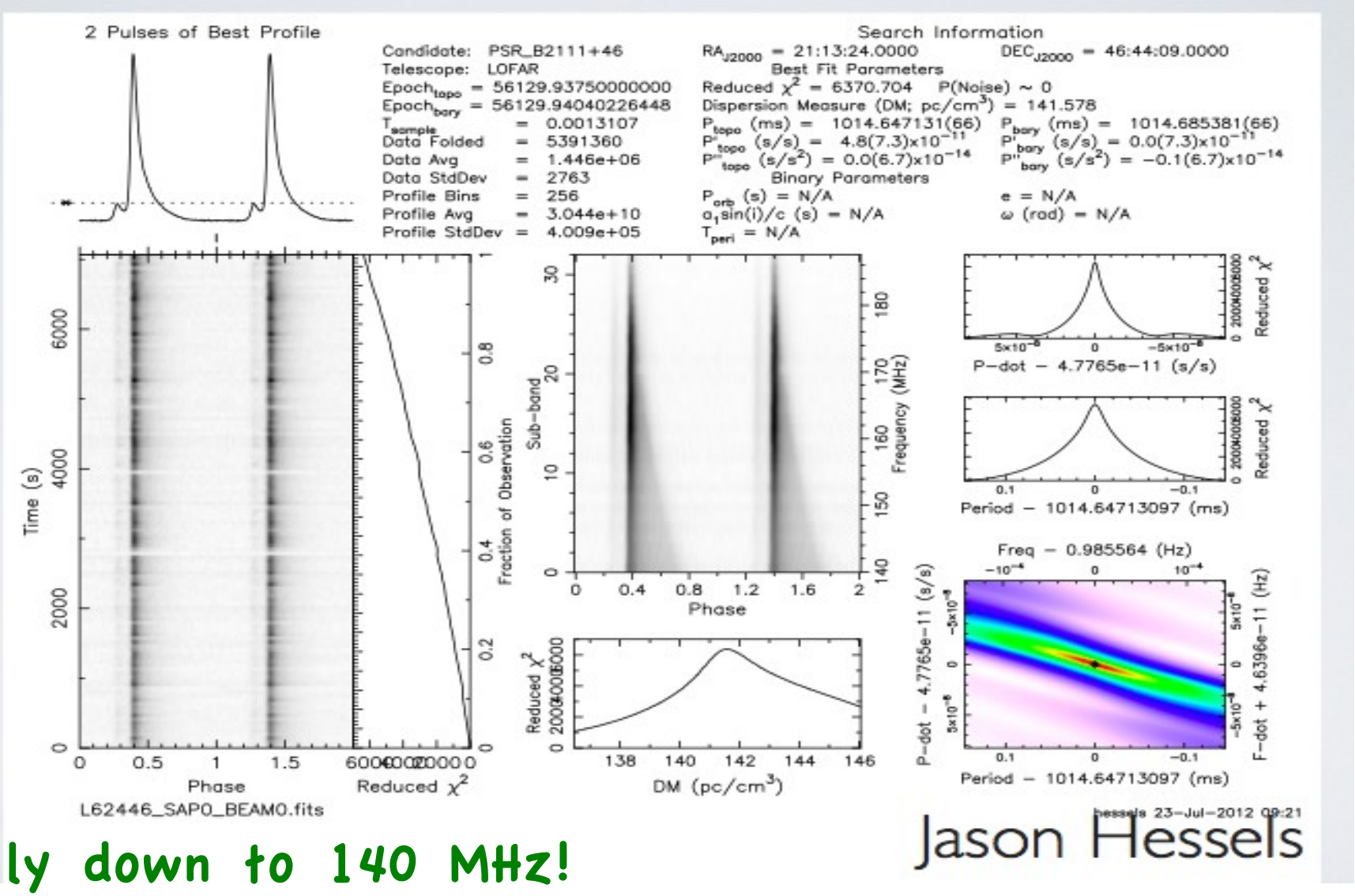
Polarization Profiles

In total, we have obtained high-quality polarisation profiles at 150 MHz, for **20 pulsars**.



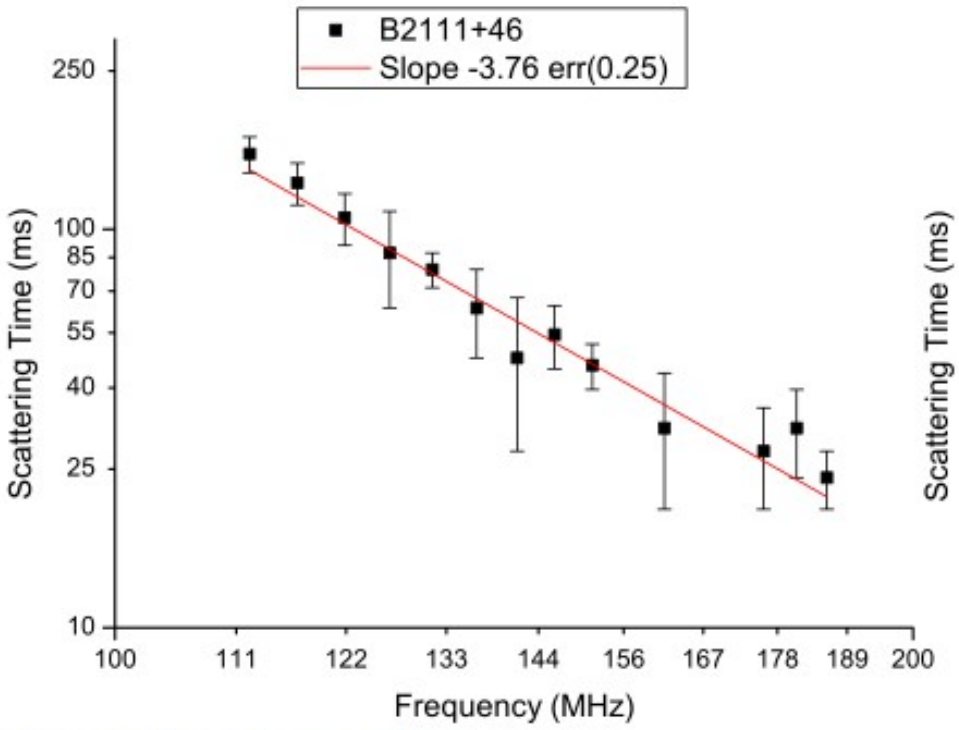
see Noutsos' talk

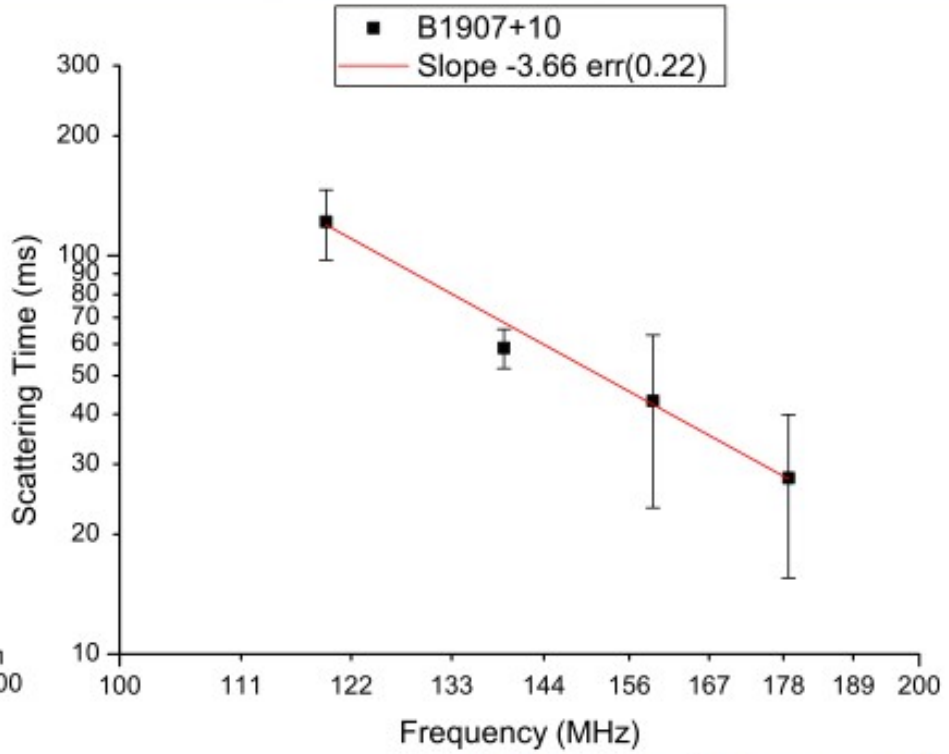
Interstellar Scattering



Only down to 140 MHz!

Frequency Scaling of Scattering

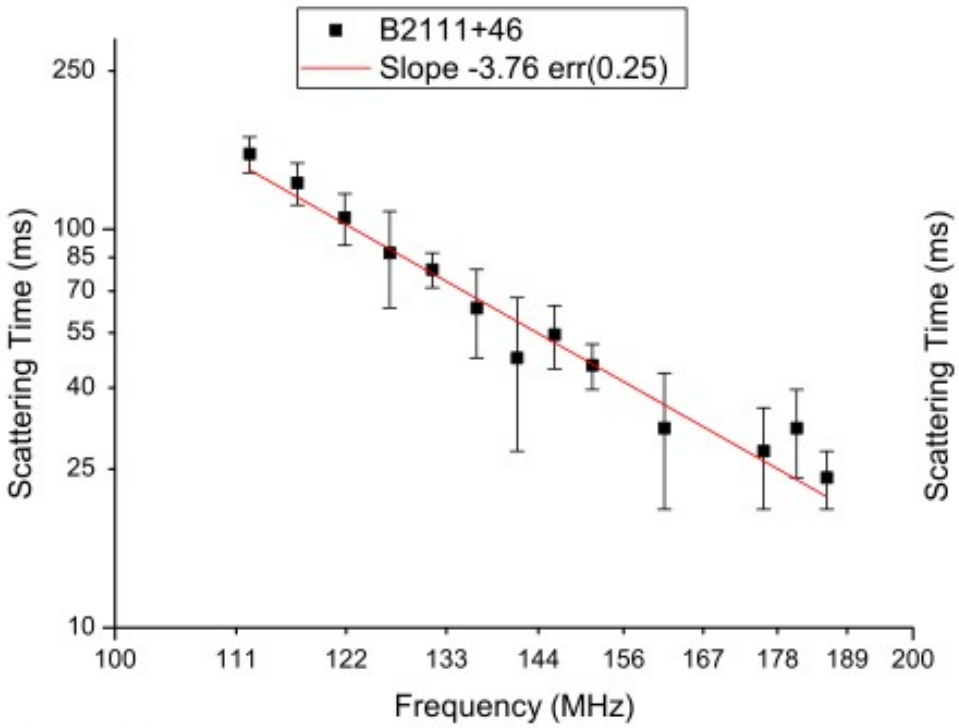


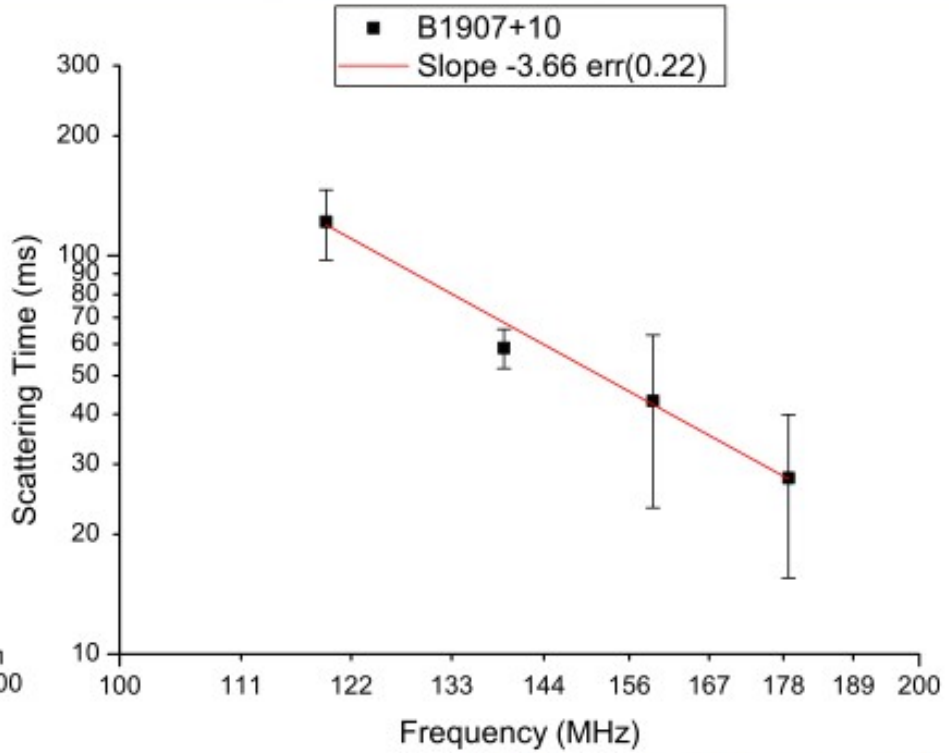


Preliminary

Kimon Zagouris

Frequency Scaling of Scattering





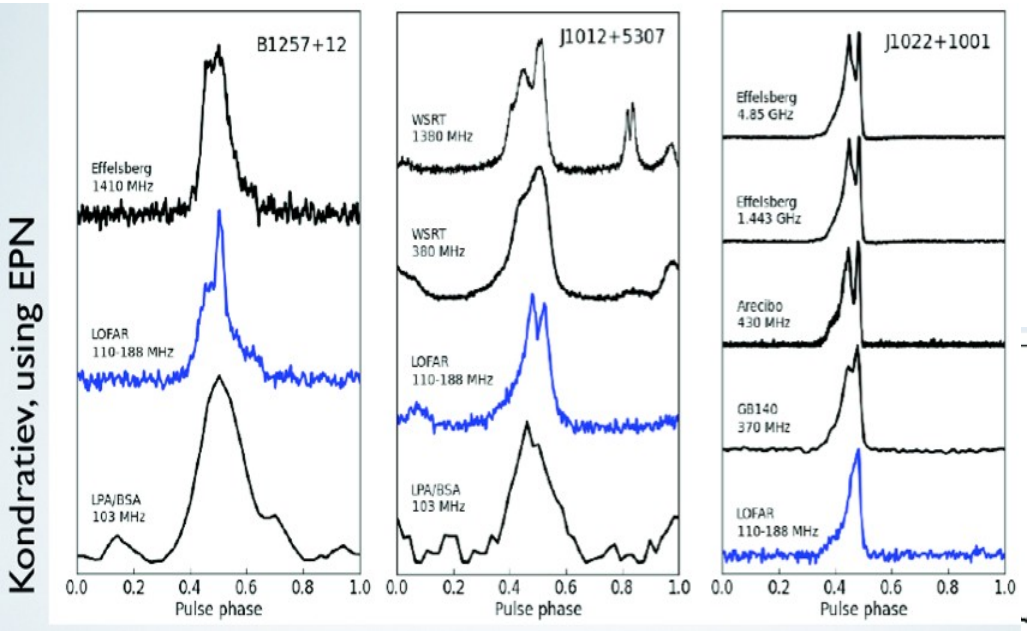
Preliminary

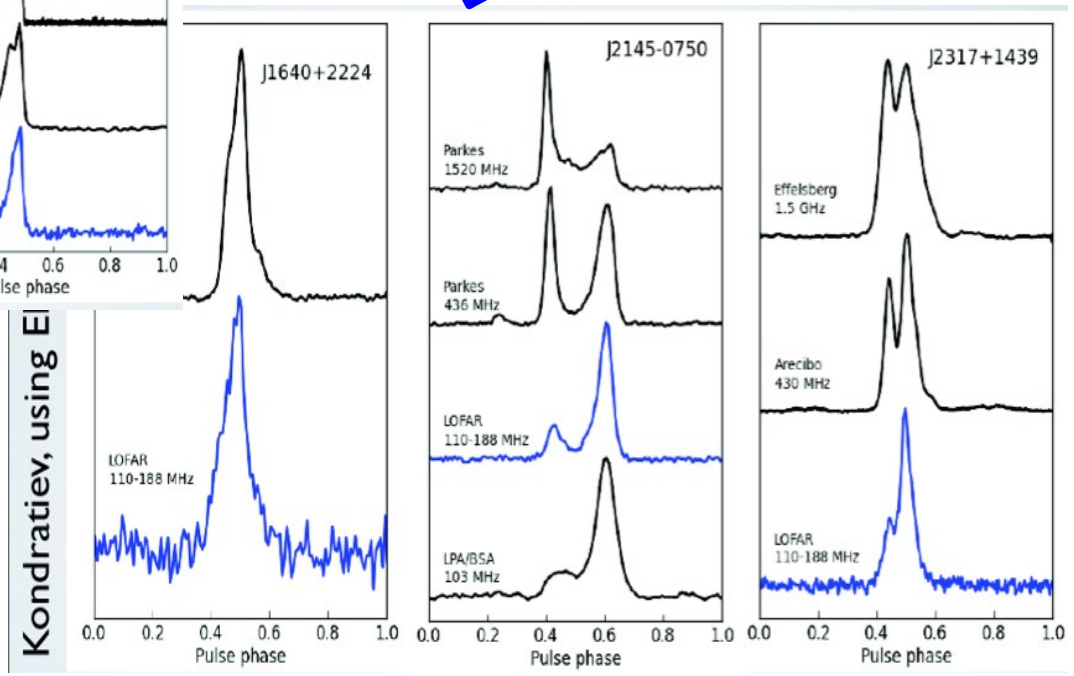
Kimon Zagouris

Not all pulsars that were expected to be scattered in LOFAR data actually are

Evolution for MSPs?

from Kondratiev's talk





Careful modelling of the evolution will aid in precision timing: creation of 2D (frequency and phase) analytic templates.

Summary and Conclusions

We are completing the analysis of 100 PSRs

- Intrinsic variations in the profiles (variation of the height of emission, sites of the emission)
- Extrinsic variations in the profiles (ISM)

Opportunity to go much deeper

- Full core
- Coherent dedispersion
- 80 MHz band

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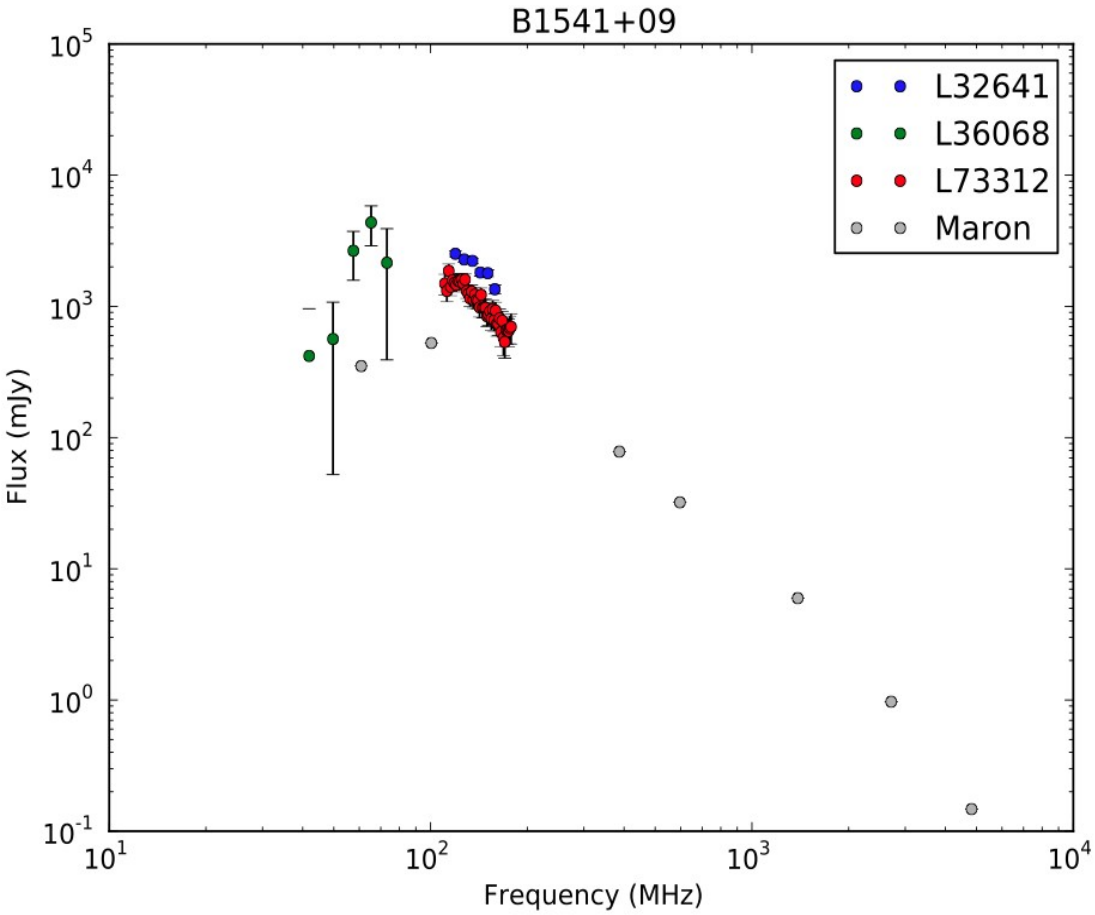
- 80 MHz band

Pulsar Spectra



Credits: Tom Hassall