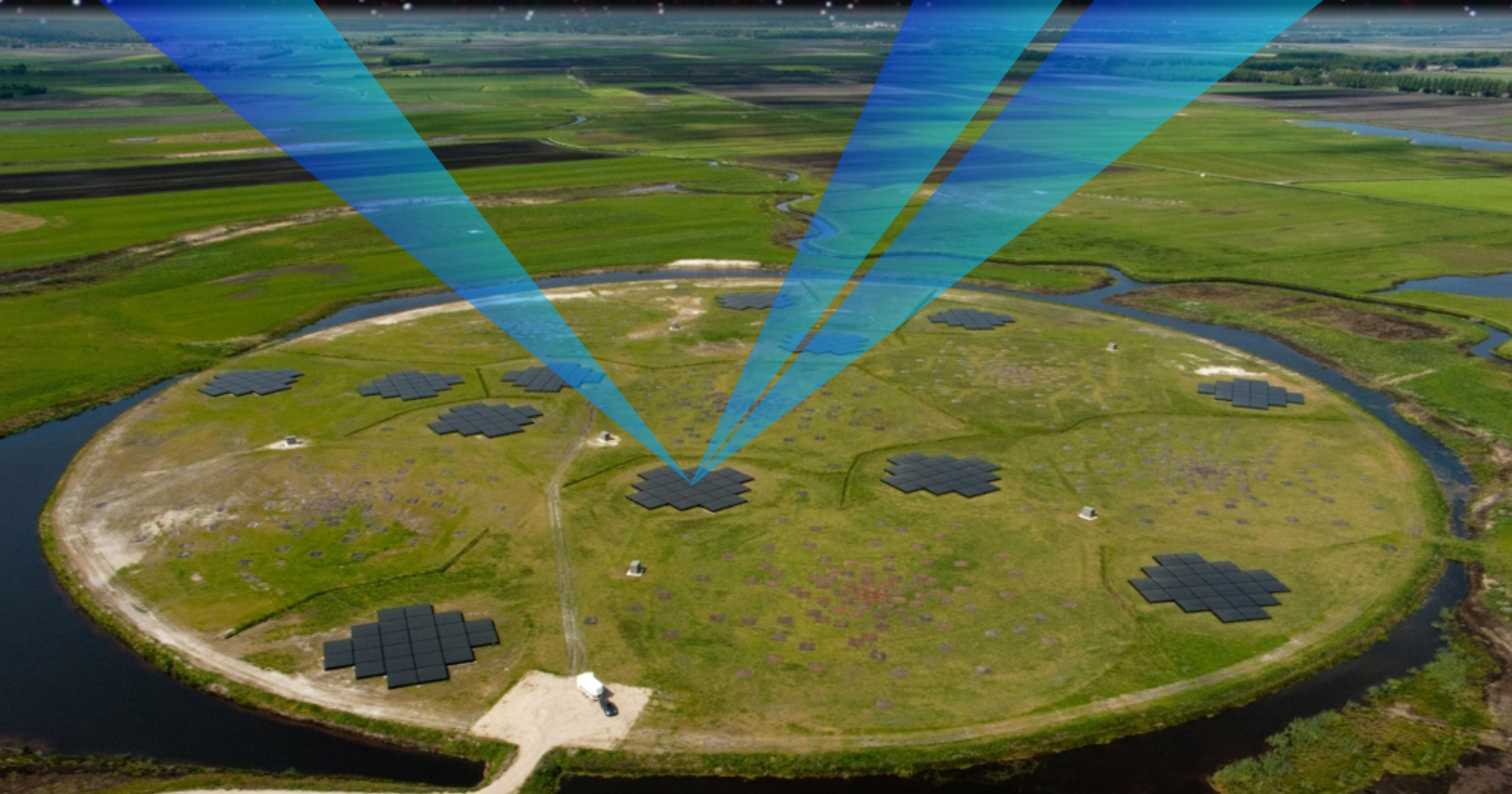


LOFAR MSP Observations (LC0_011)

Jason Hessels (ASTRON / UvA)

Joris Verbiest, Vlad Kondratiev
& Ben Stappers



Why Low-Frequency MSPs?

- **Almost unexplored regime for MSPs.**
- Some (most?) MSPs don't turn over.
- Profile and polarization evolution with frequency.
- Time-variable dispersion, rotation measure, and scattering from ISM.
- Improve high-frequency timing?
- Eclipses in black widows and redbacks.
- Study ionosphere?
- Something completely unexpected?

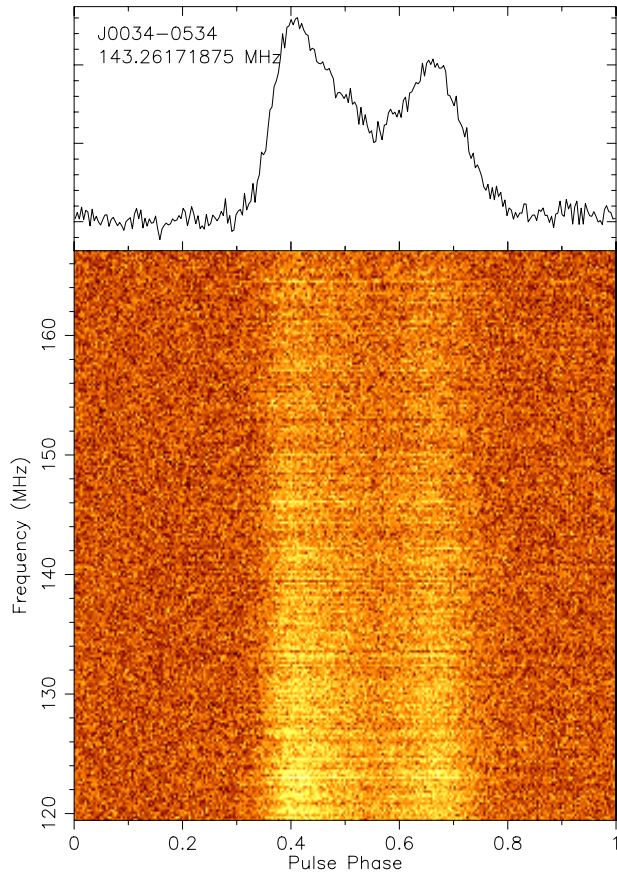
Past Observations

- B1855+09 at 102MHz: Kuz'min 1990
- J2145-0705 prof evolution: Kuz'min & Losovskii 1996
- Spectra: Kuz'min & Losovskii 1999, 2001
- WSRT 150MHz: Stappers, Karuppusamy & Hessels 2009
- GMRT 240MHz: Joshi & Kramer 2009

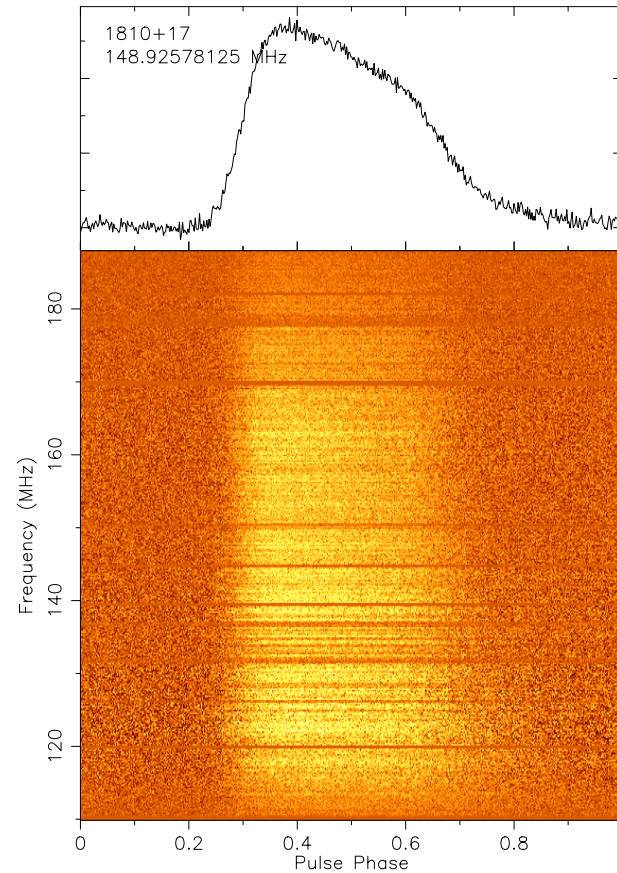
LOFAR MSP Detections

All data taken in the last few weeks!

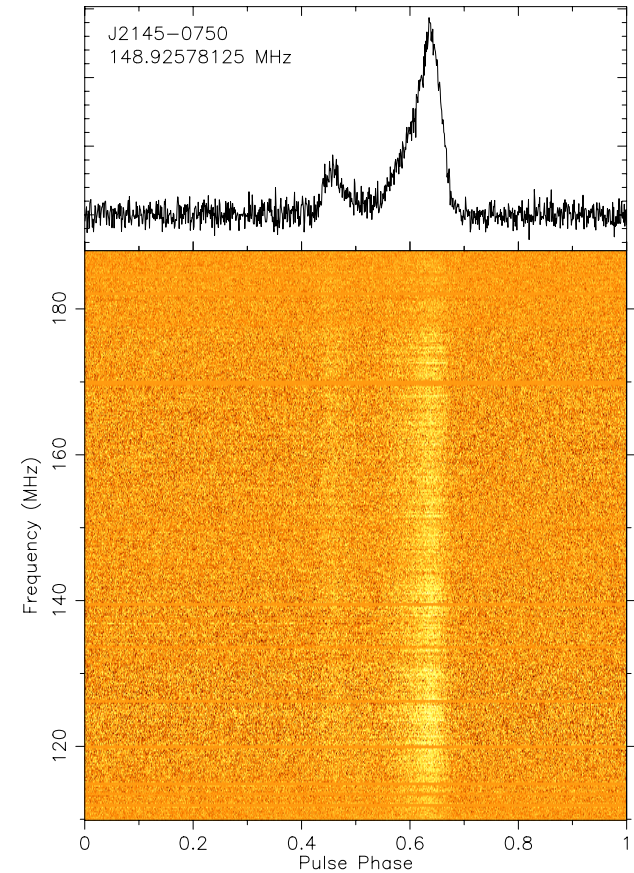
(110-190MHz)



J0034-0534



J1810+1744



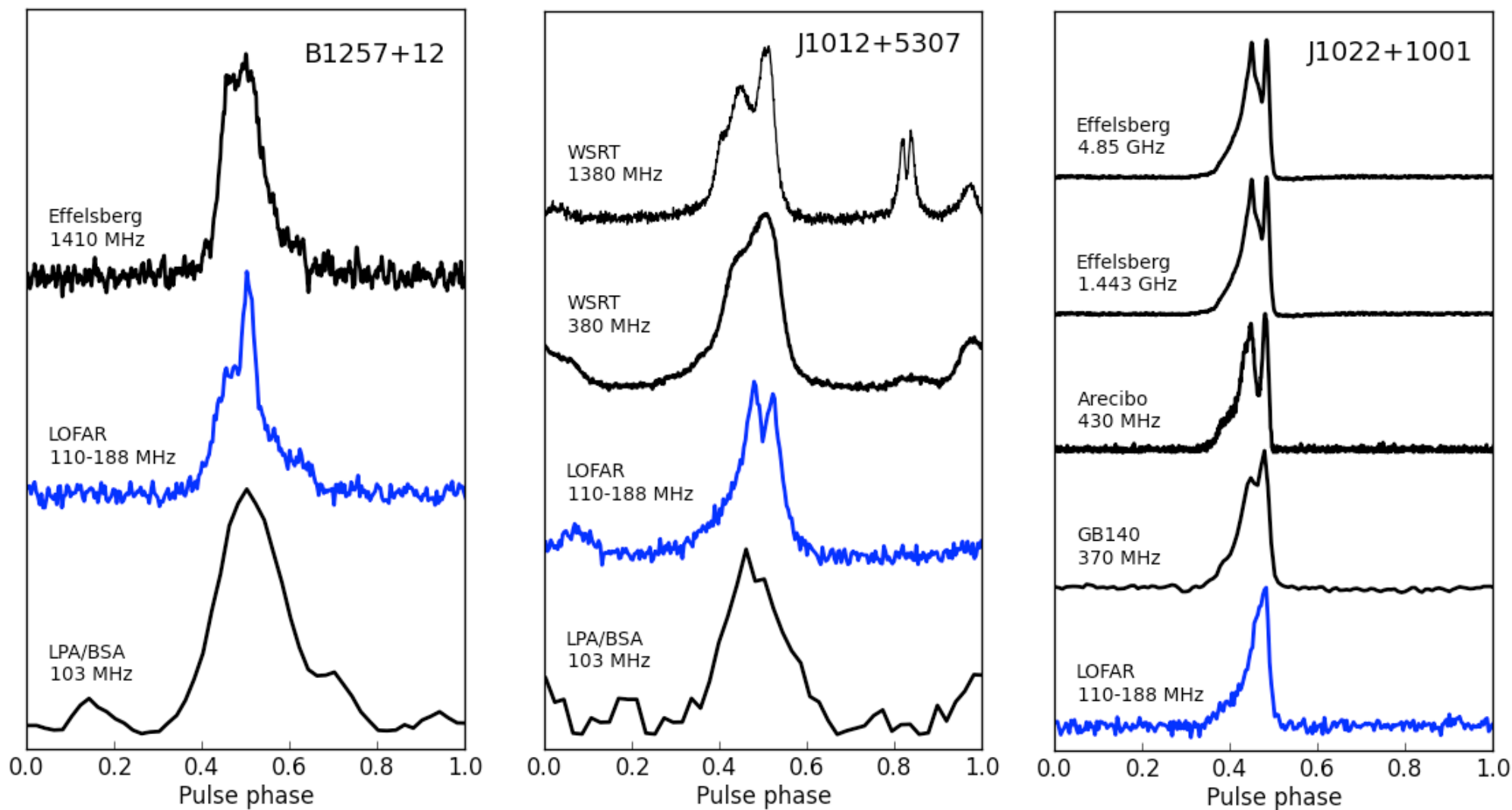
J2145-0750

Verbiest

Multi-Frequency Profiles

Blue is LOFAR 110-190MHz

Kondratiev, using EPN

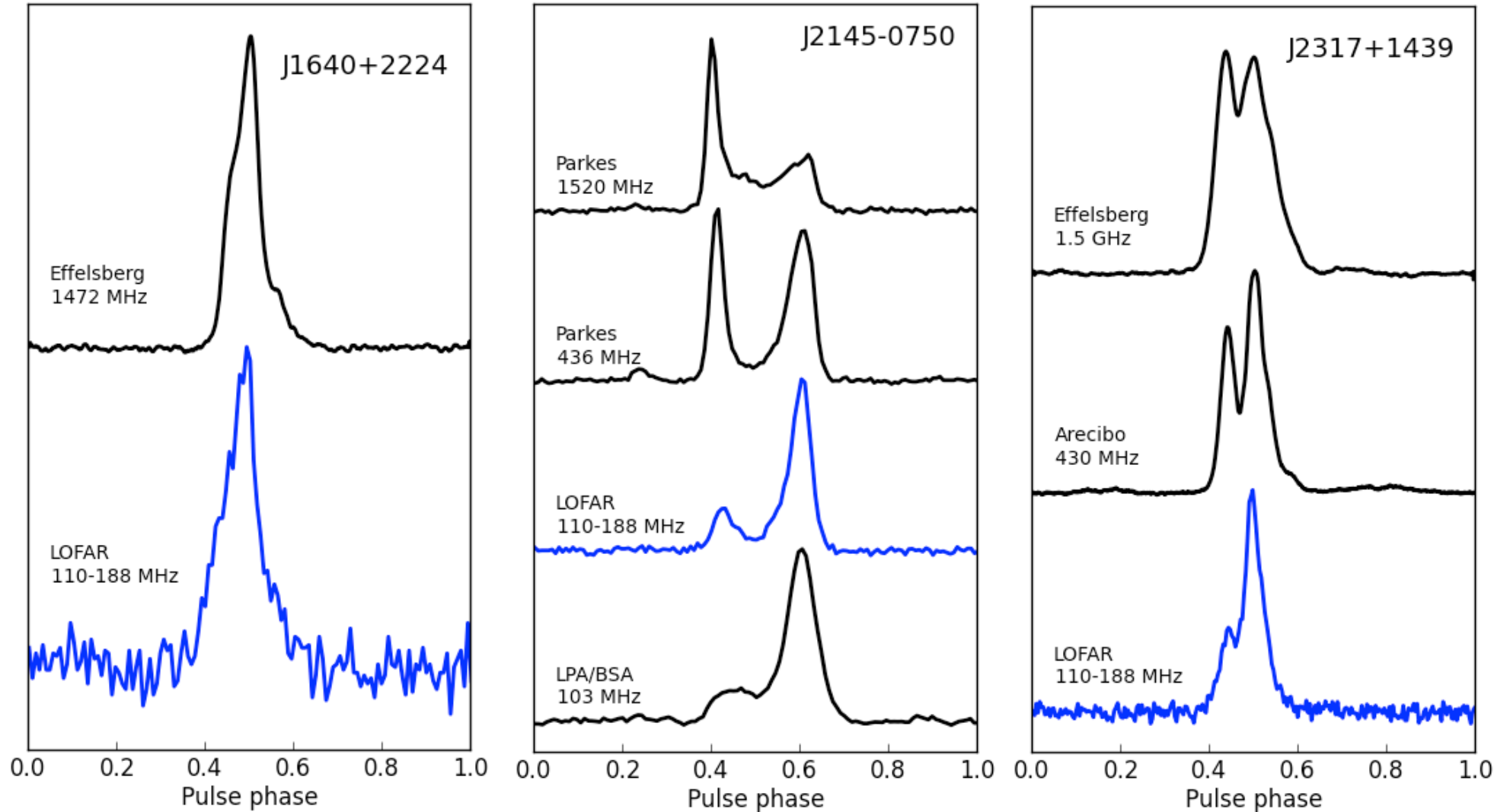


Some profiles getting narrower?

Multi-Frequency Profiles

Blue is LOFAR | 110-190MHz

Kondratiev, using EPN



Start of the Timing Campaign

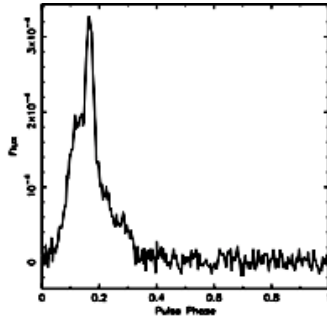
Pulsar	Comment	Single Epoch DM prec.	VLSS (mJy @ 74MHz)	KL01 (mJy @ 103MHz)	LOFAR SNR (in 20m)
J0030+0451	EPTA2, NGAO			380	137
J0034-0534	EPTA3			250	395
J0613-0200	NGGB, PPTA			240	
J0621+1002	EPTA2			50	40
J0751+1807	EPTA2			70	
J1012+5307	EPTA1, NGGB	0.0003		30	51
J1022+1001	EPTA1, PPTA			90	76
J1023+0038	Redback				
J1024-0719	EPTA1, NGGB, PPTA			200	24
B1257+12	Planets			150	132
J1640+2224	EPTA1, NGAO			450	41
J1643-1224	EPTA1, NGGB, PPTA				
J1713+0747	EPTA1, NGGB, NGAO, PPTA	0.0003		250	9
J1738+0333	EPTA2, NGAO	0.001			12
J1741+1351	EPTA2, NGAO				
J1744-1134	EPTA1, NGGB, PPTA	0.0001		220	12
J1810+1744	Black Widow	0.00001	1290		673
B1855+09	EPTA1, NGAO, PPTA	0.001		450	8
J1911-1114	EPTA3			260	22
J1918-0642	EPTA1, NGGB				
B1937+21	EPTA, NG, PPTA				
B1957+20	Black Widow		1360		58
J2145-0750	EPTA1, NGGB, PPTA	0.00005		480	~150
J2317+1439	EPTA1, NGAO			90	86

Start of the Timing Campaign

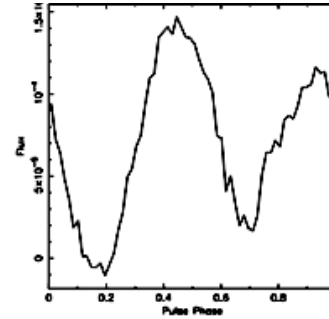
Pulsar	Comment	Single Epoch DM prec.	VLSS (mJy @ 74MHz)	KL01 (mJy @ 103MHz)	LOFAR SNR (in 20m)
J0030+0451	EPTA2, NGAO			380	137
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J0613-0200	NGGB, PPTA			240	
J0621+1002	EPTA2			50	40
J0751+1807	EPTA2			70	
J1012+5307	EPTA1, NGGB	0.0003		30	51
J1022+1001	EPTA1, PPTA			90	76
J1023+0038	Redback				
J1024-0719	EPTA1, NGGB, PPTA			200	24
B1257+12	Planets			150	132
J1640+2224	EPTA1, NGAO			450	41
J1643-1224	EPTA1, NGGB, PPTA				
J1713+0747	EPTA1, NGGB, NGAO, PPTA	0.0003		250	9
J1738+0333	EPTA2, NGAO	0.001			12
J1741+1351	EPTA2, NGAO				
J1744-1134	EPTA1, NGGB, PPTA	0.0001		220	12
J1810+1744	Black Widow	0.00001	1290		673
B1855+09	EPTA1, NGAO, PPTA	0.001		450	8
J1911-1114	EPTA3			260	22
J1918-0642	EPTA1, NGGB				
B1937+21	EPTA, NG, PPTA				
B1957+20	Black Widow		1360		58
J2145-0750	EPTA1, NGGB, PPTA	0.00005		480	~150
J2317+1439	EPTA1, NGAO			90	86

Bright (almost) un-scattered

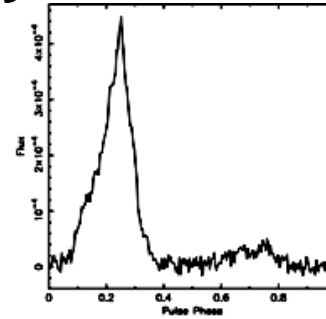
B1257+12



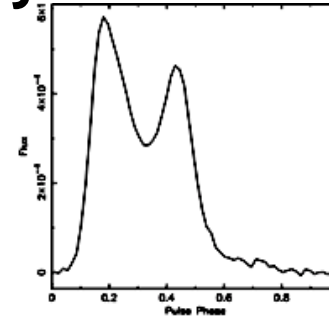
B1957+20



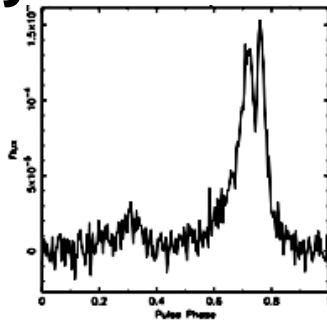
J0030+0451



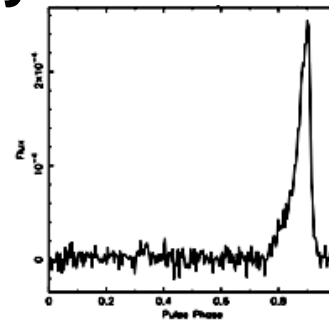
J0034-0534



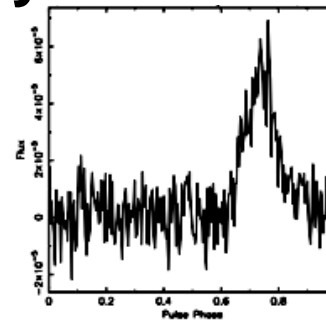
J1012+5307



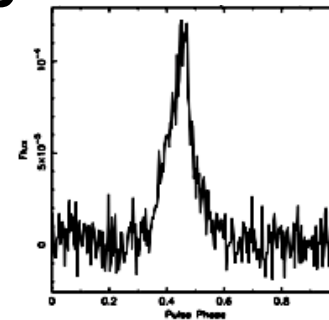
J1022+1001



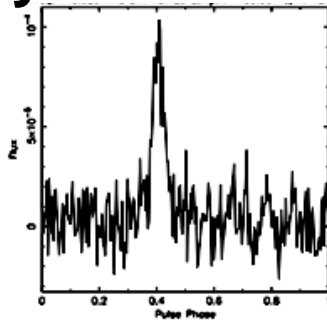
J1024-0719



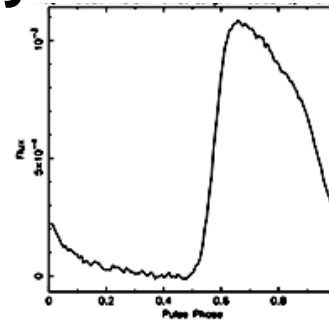
J1640+2224



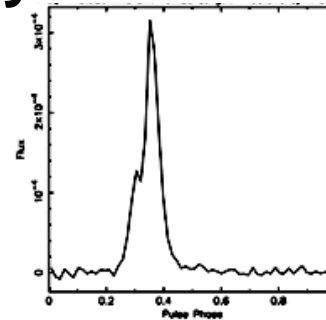
J1744-1134



J1810+1744



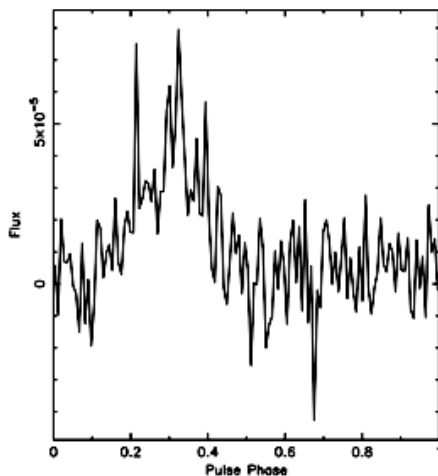
J2317+1439



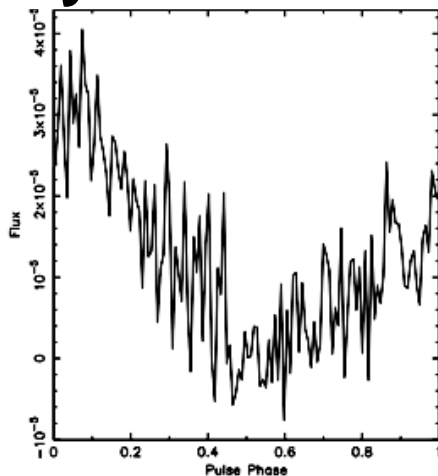
Kondratiev & Hessels

Weak, *possibly* somewhat scattered

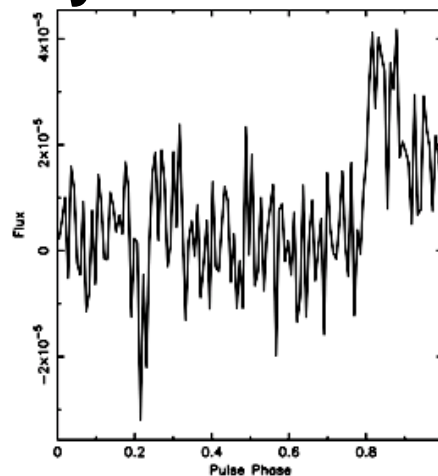
B1855+09



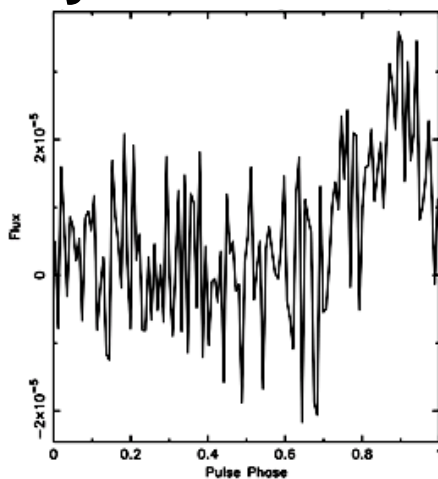
J0621+1002



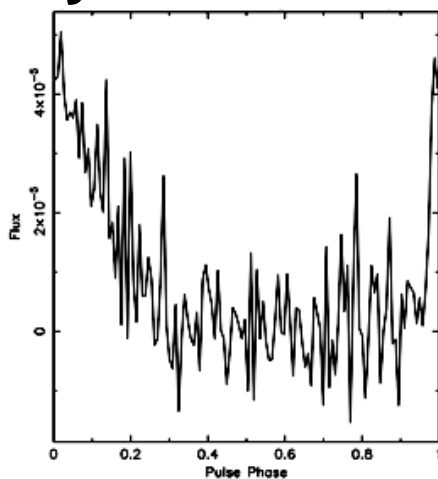
J1713+0747



J1738+0333



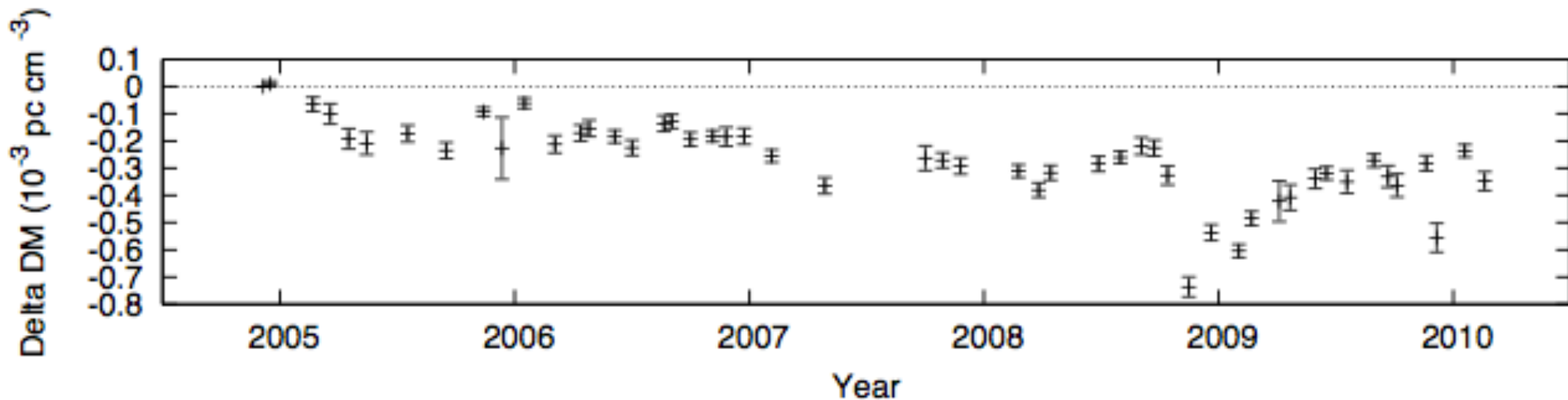
J1911-1114



Kondratiev & Hessels



The LOFAR Weather Report

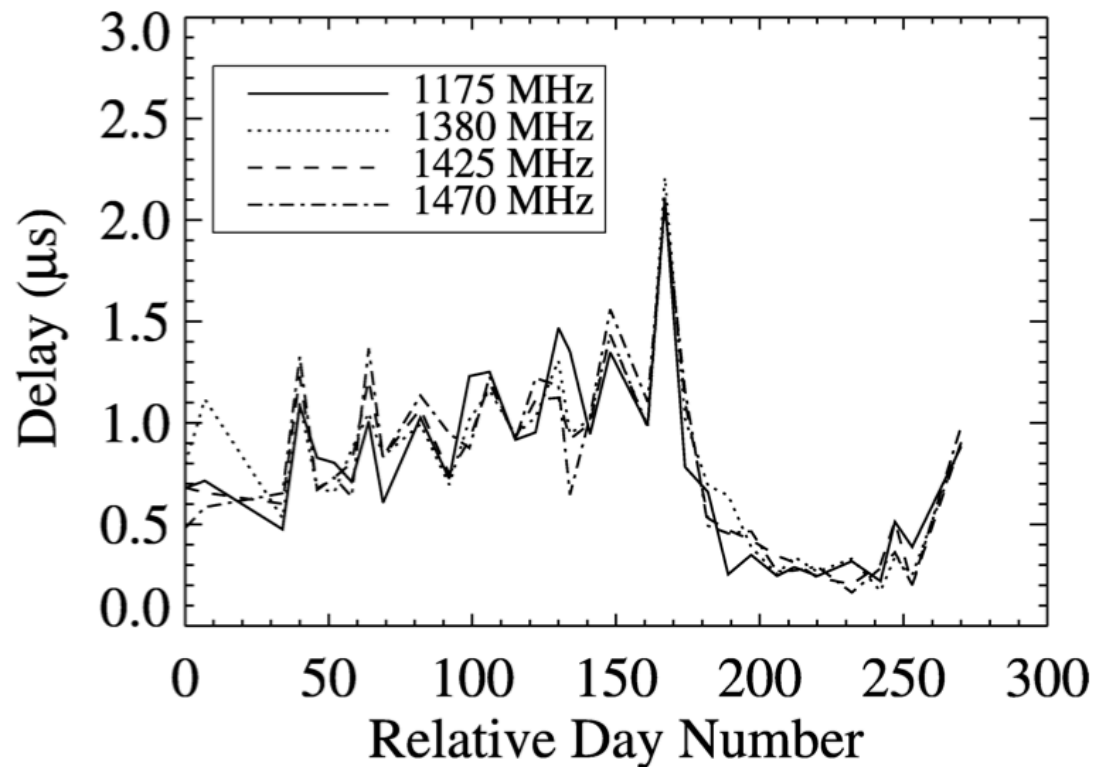
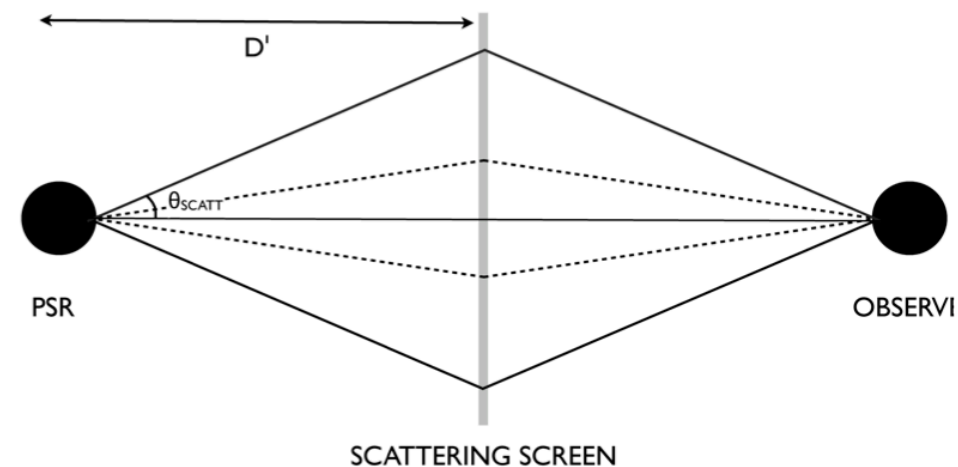


Demorest et al. 2013

Provide 1/10000
DMs at least
once a month

Provided through the IPTA website???

The LOFAR Weather Report



Hemberger & Stinebring 2008

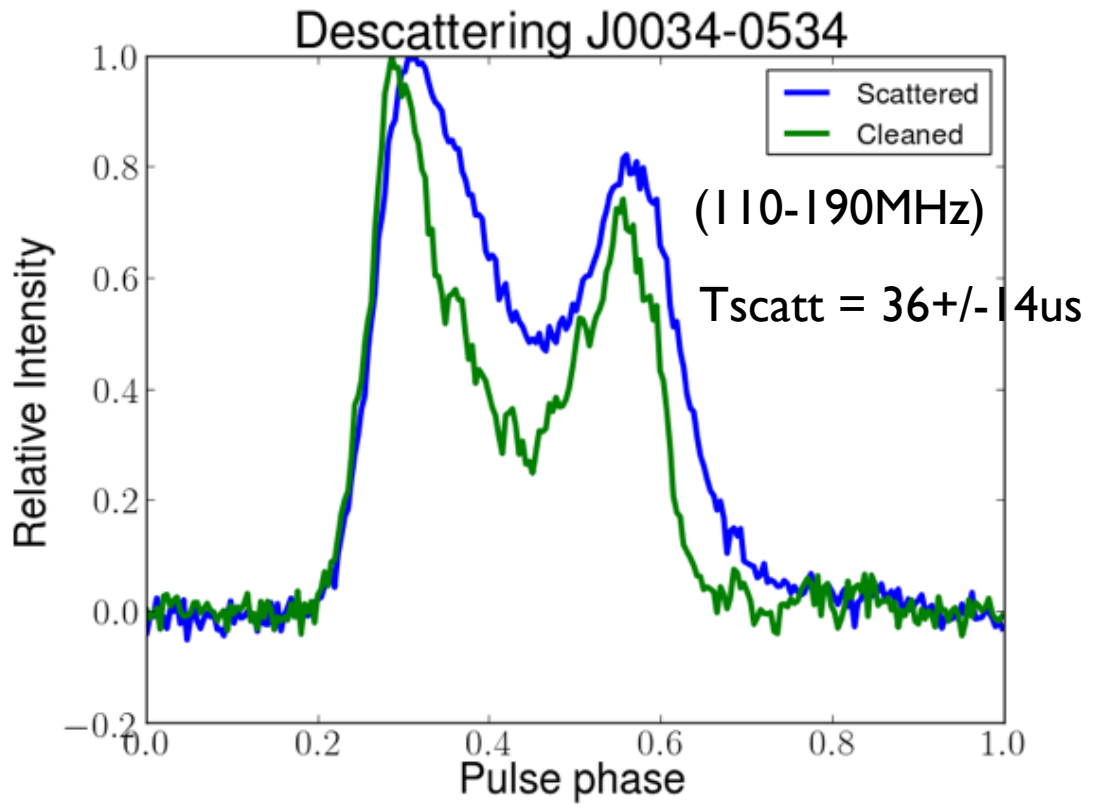
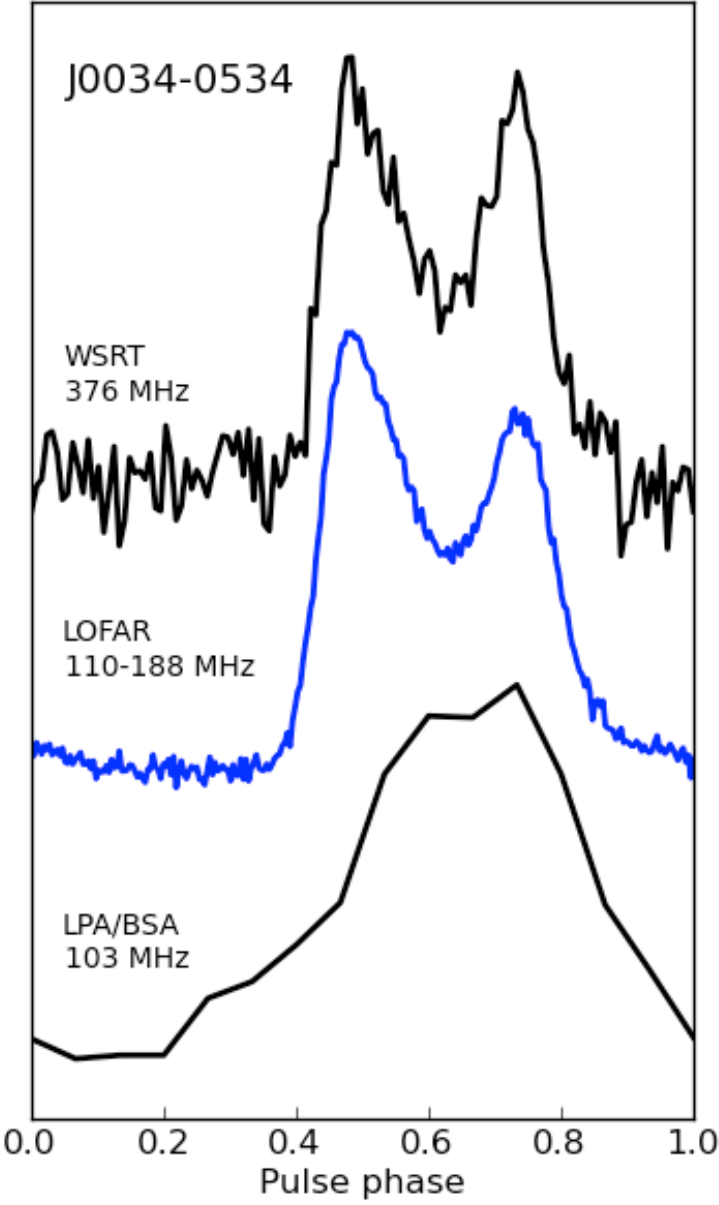
1 μs scatt. at 1400MHz is 10 ms scatt. at 140MHz

1 ms scatt. at 140MHz is 100 ns scatt. at 1400MHz

Do LOFAR DMs/Scatt. agree with those at high-freq.?

Scattering

Kondratiev, using EPN

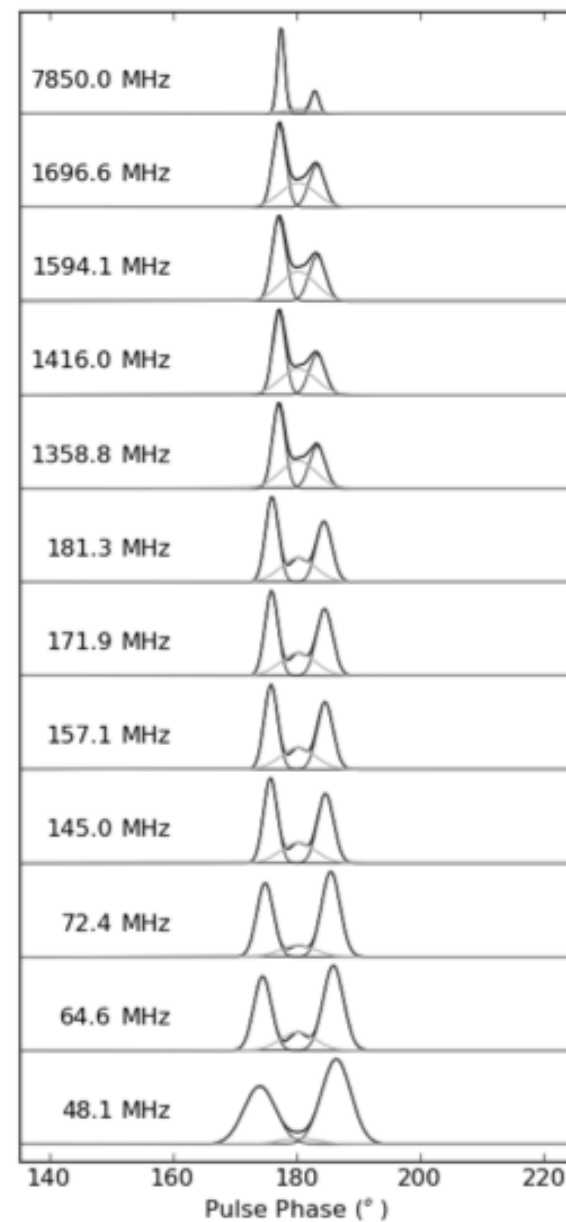
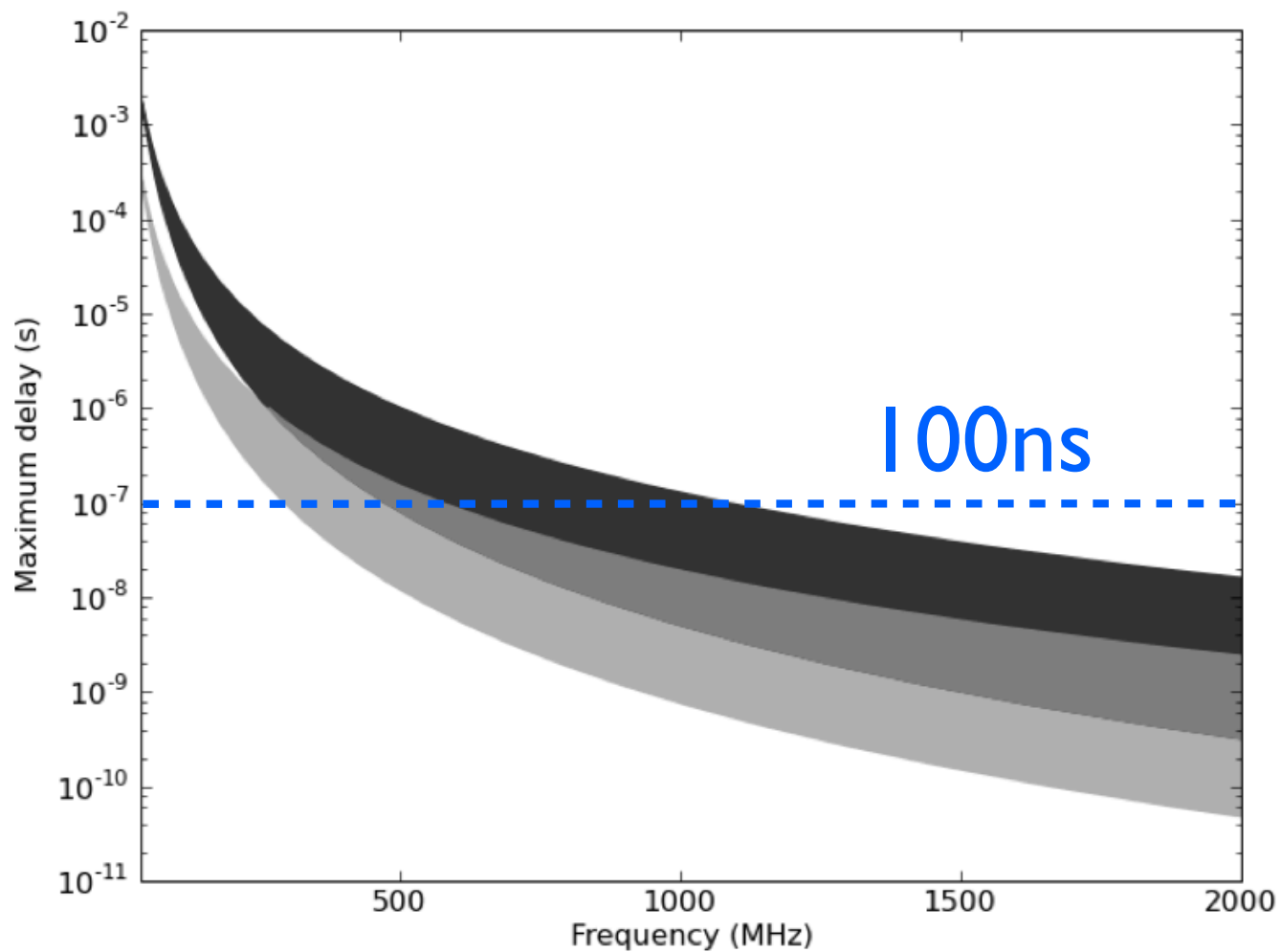


Zagkouris & Karastergiou

Constraining the ISM

Simultaneous LOFAR, Jodrell and Effelsberg Observations (40-8000MHz)

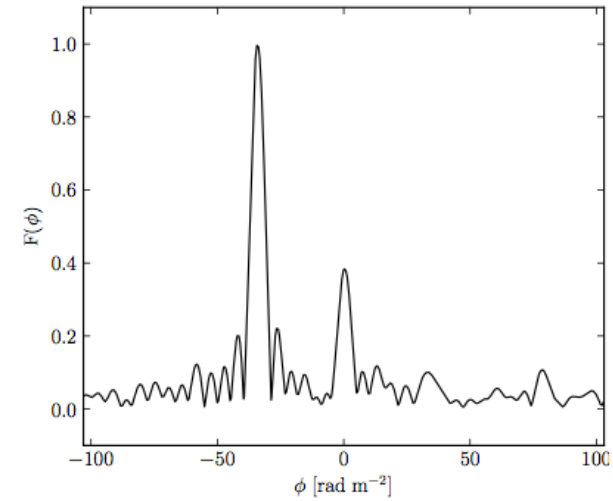
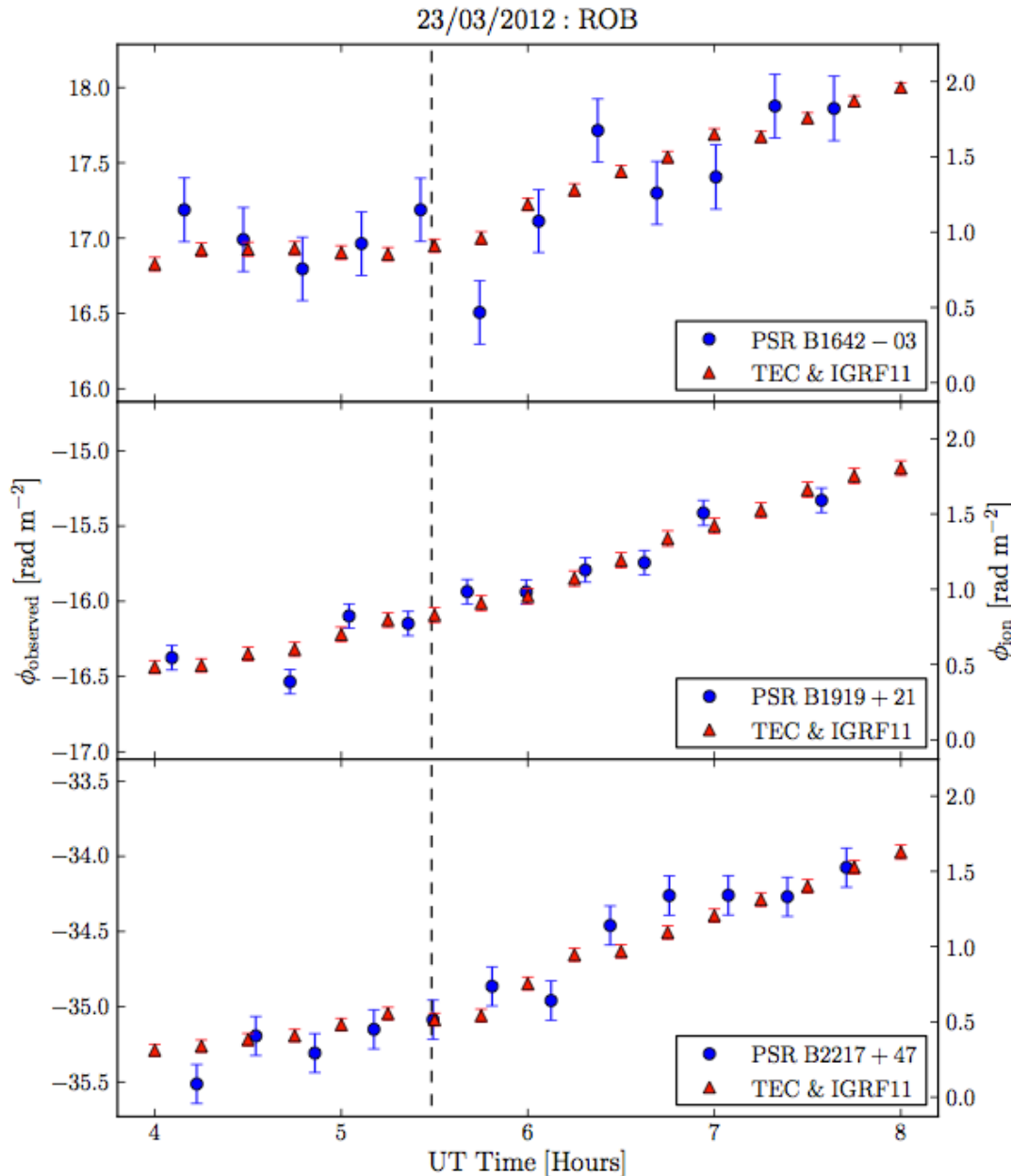
Dispersion law good to 1/100,000 (4 lines of sight)



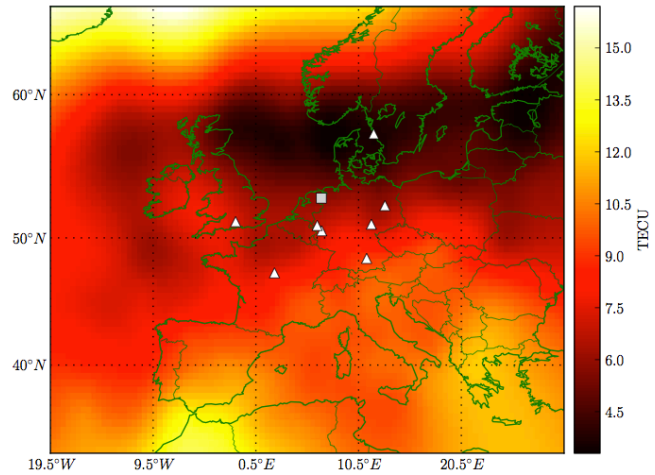
Hassall, Stappers, Hessels, Kramer et al. 2012

Calibrating RM and DM

Sotomayor-Beltran, Sobey, Hessels, de Bruyn et al. 2013



Sobey



ROB

1 TECU = 10^{16} electrons/m² = 3.2×10^{-7} pc/cc

Maximum expected $\text{DM}_{\text{ion}} = \sim 7 \times 10^{-6}$ pc/cc

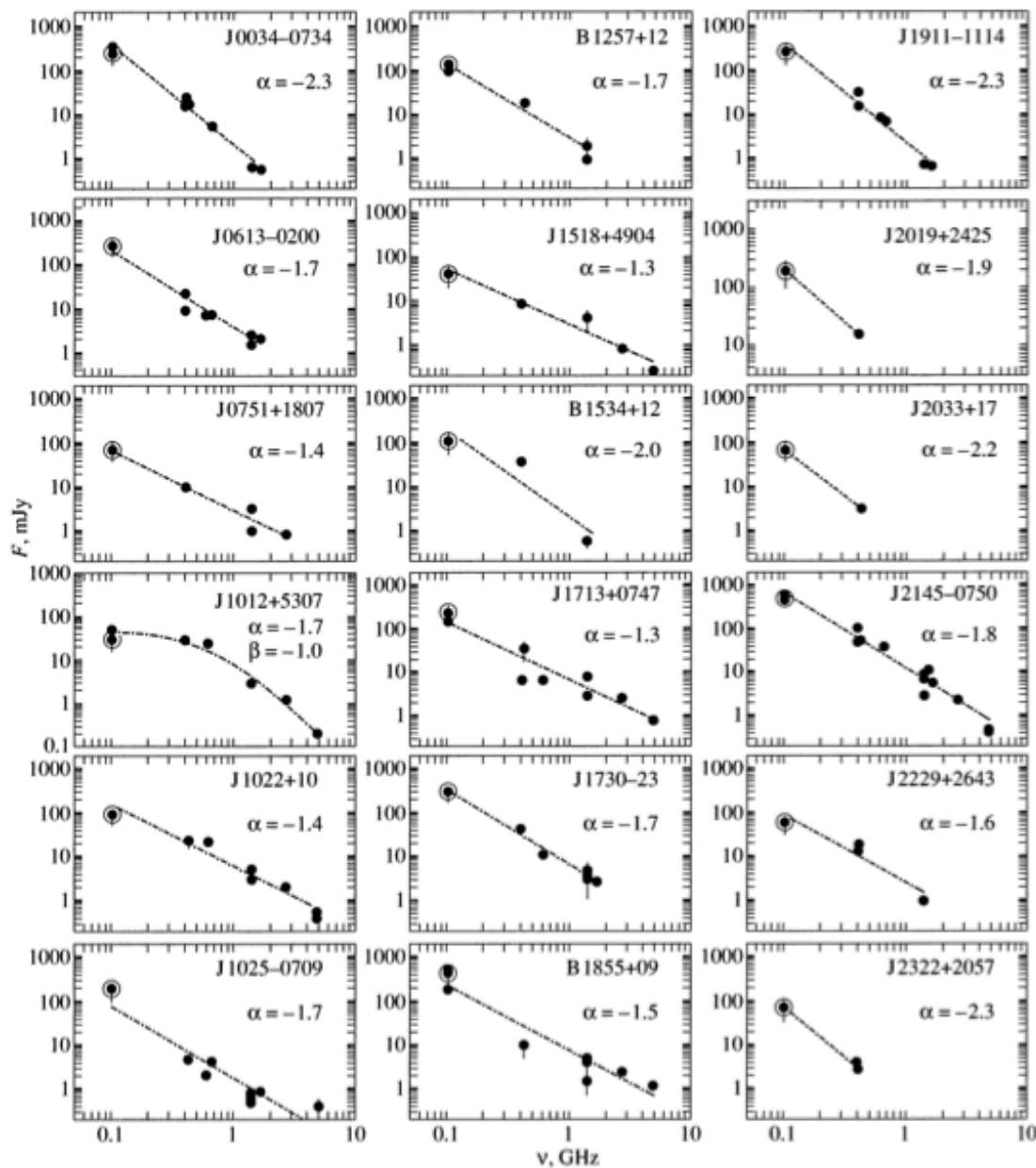
Summary & Future Work

- First high-quality sample of MSP profiles below 200MHz.
- Continued timing will measure high-precision DMs, RMs, and scattering.
- DM, RM, scattering measurements will be publicly available.
- Try some of these pulsars in the 10-90MHz range.

Extra Slides

MSPs (mostly) don't turn over

Kuz'min & Losovskii 2001

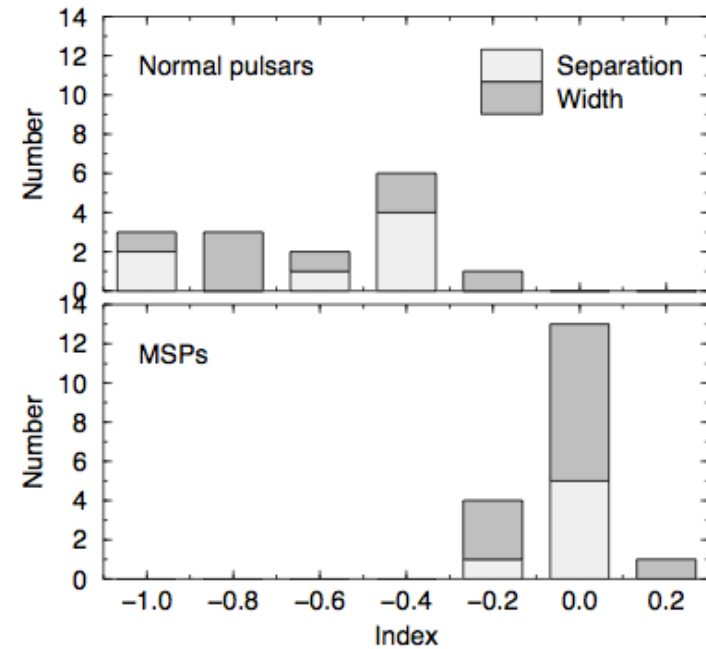
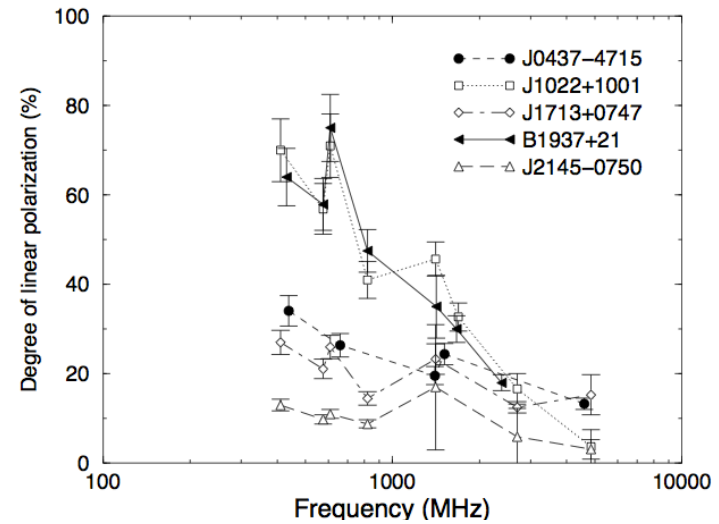
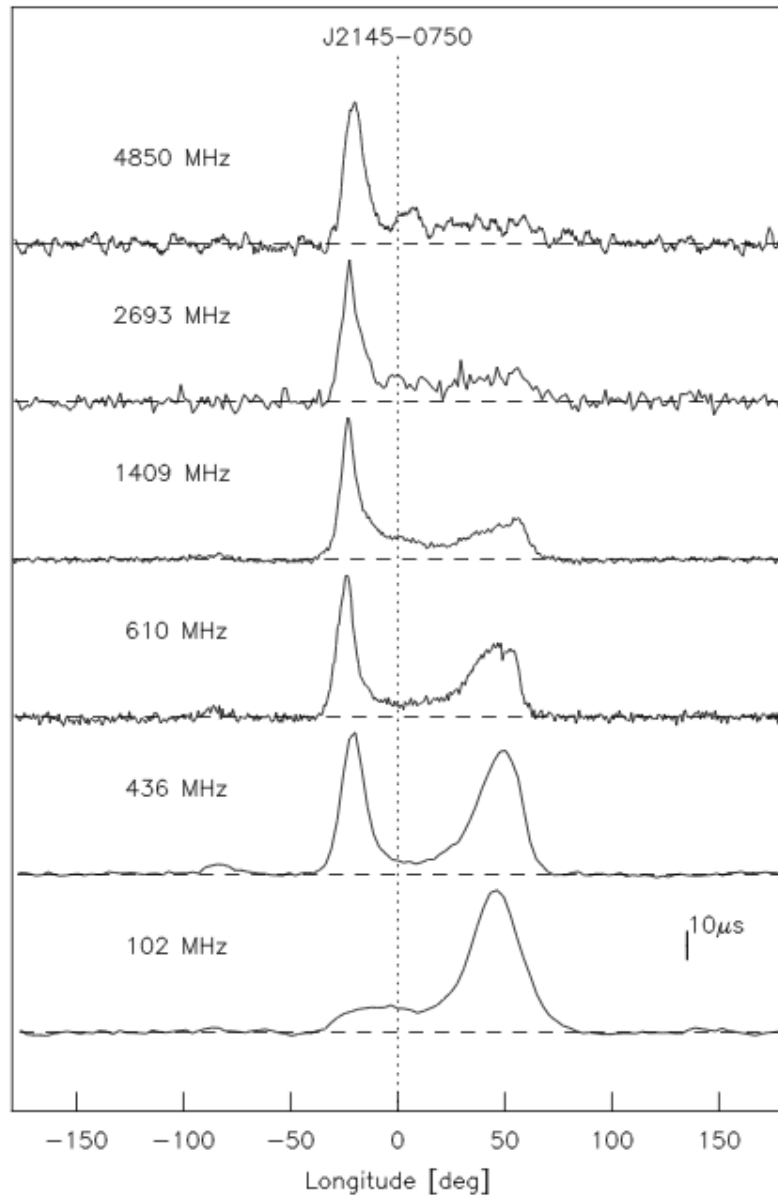


Using “Large Phased Array” (BSA) at Puschino (110km south of Moscow)



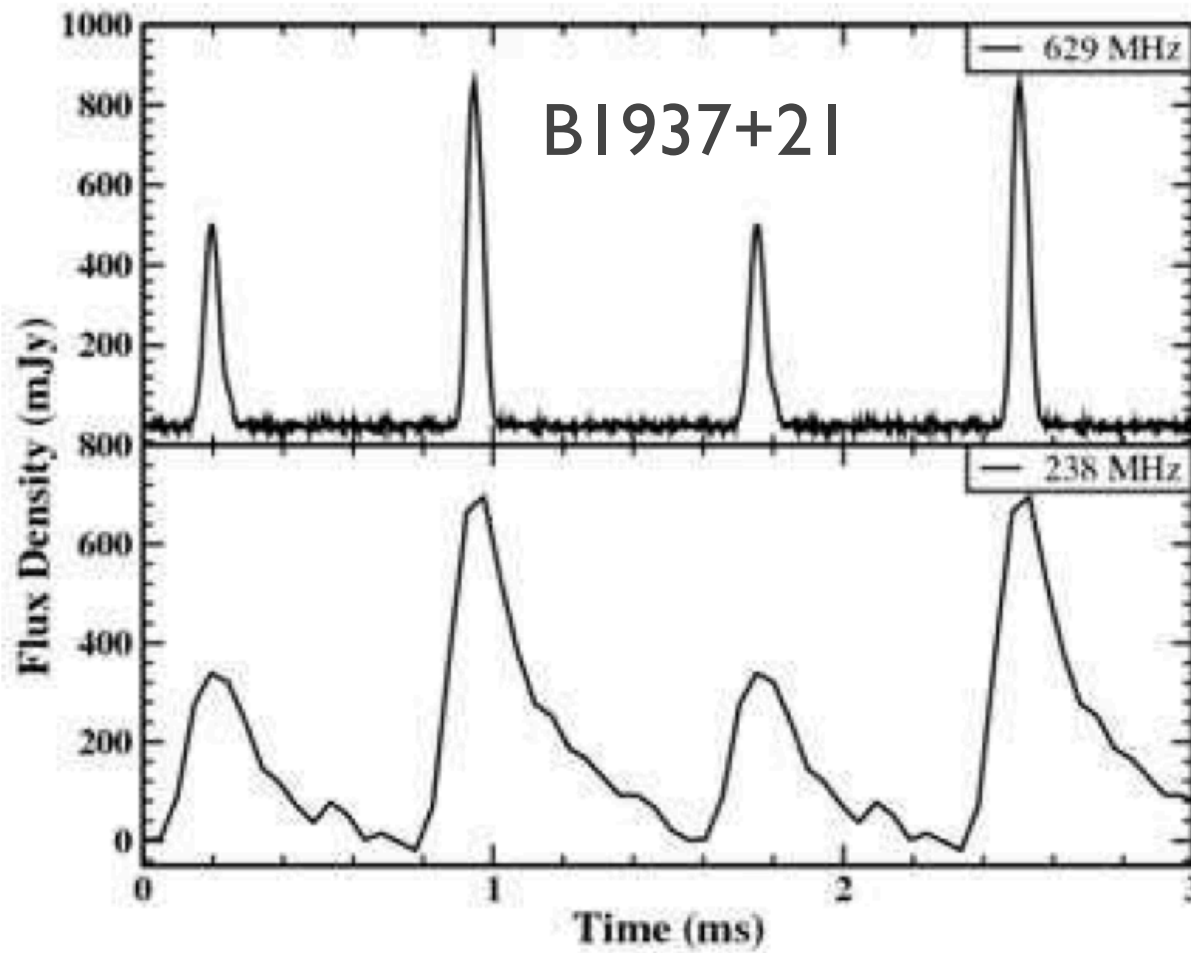
Frequency Evolution

Kramer et al. 1999

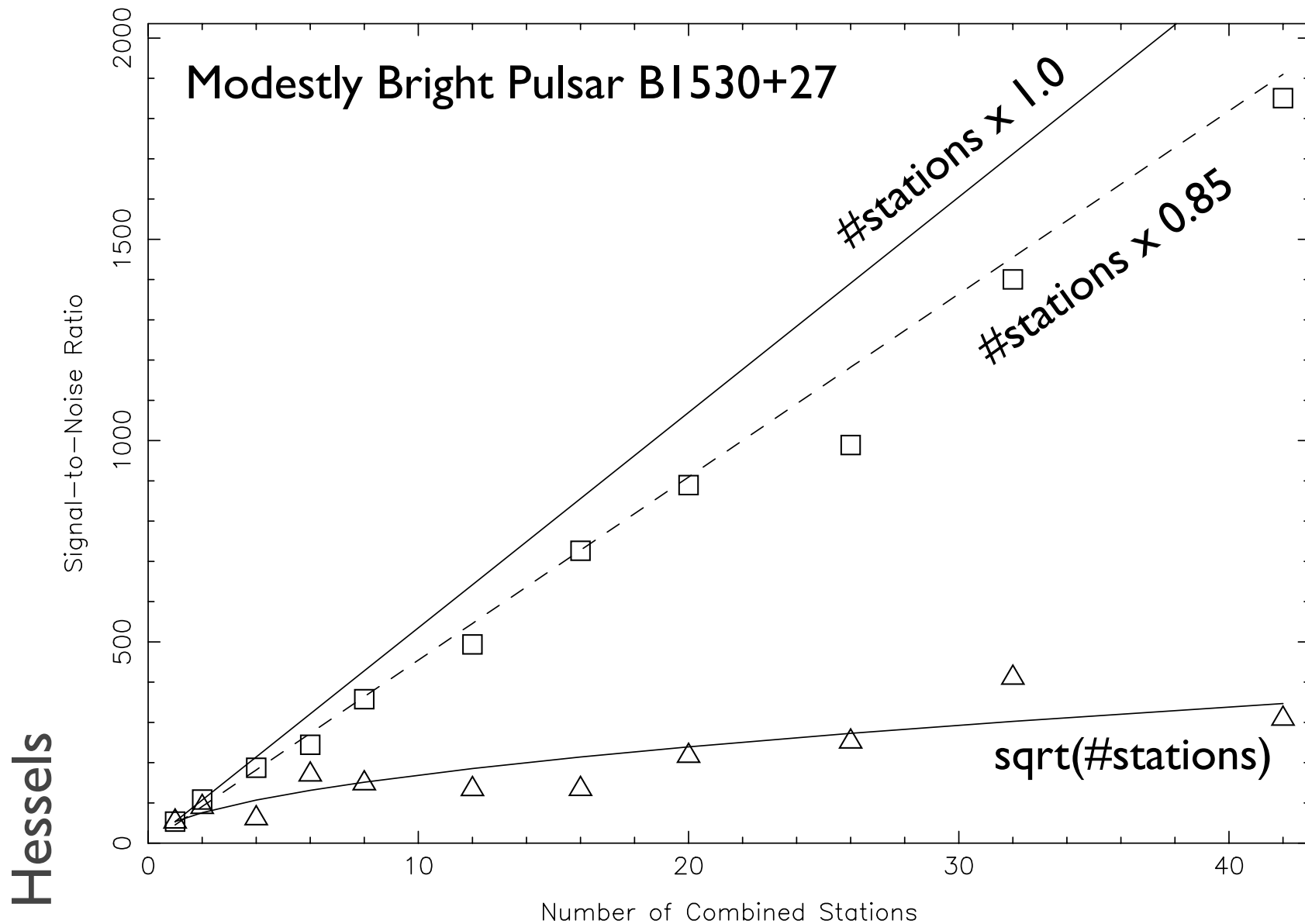


Scattering

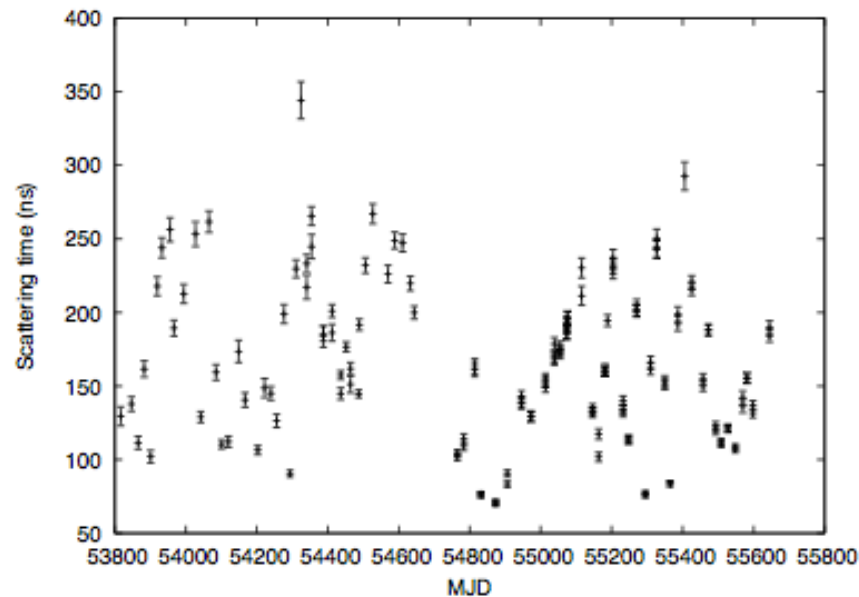
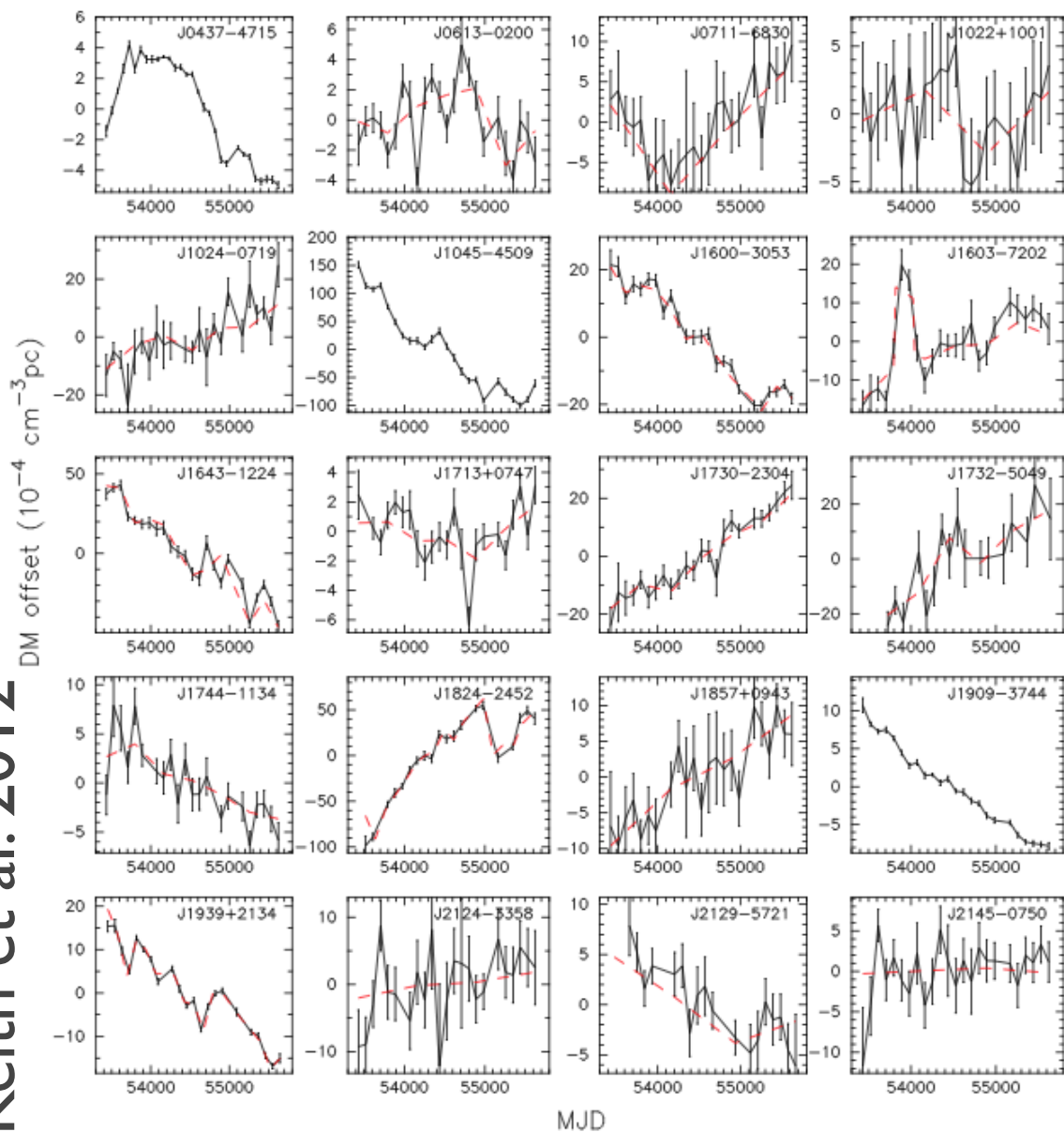
Joshi & Kramer 2009



Sensitivity Scaling of Core Tied-Array Beams



Scattering Variations and DM



Keith et al. 2012

