

Early Pulsar Science with LOFAR Tom Hassall (University of Southampton) and the LOFAR Pulsar Working Group



Pulsars

- * Neutron star
- * ...with a very strong magnetic field
- * ...which rips particles from the surface of the star and accelerates them
- * The accelerated charges produce a beam of radio emission
- * As the star rotates the beam sweeps around the sky like a lighthouse







Low Band Antennas (LBAs) 15-90 MHz 48 MHz band High Band Antennas (HBAs) 110-240 MHz 48 MHz band

- * Instead of a big dish, many antennas
- * Combining their signals improves sensitivity and resolution
- * "Pointed" by using a supercomputer to introduce different time delays to each element

BeamFormed Observations

- Instead of cross-correlating each dipole pair, combine them
- * Still use time delays to "point" the telescope
- * Possible to form many beams at once
- In HBAs -> Useful for searches for pulsars

BeamFormed

CREDIT: HESSELS

Cumulative S/N of PSR B2217+47 in 127 Simultaneous Tied-Array Beams



BeamFormed Observations

- Instead of cross-correlating each dipole pair, combine them
- * Still use time delays to "point" the telescope
- * Possible to form many beams at once
- * In HBAs -> Useful for searches for pulsars
- * In LBAs, these can be pointed in any direction on the sky

BeamFormed



Imaging and BeamFormed

CREDIT: ALEXOV & HEALD



B0329+54 -130-178MHz, 10 Stations, 12 hours

5.5°

Fly's Eye Mode

- * Data from each station is recorded separately
- # HUGE field of view (up to 8400 sq. deg)
- * Or, point all the beams in the same direction to test everything is working properly...

2 Puises of Best Profile	2 Pulses of Best Profile	2 Pulses of Best Profile	2 Putes of Best Profile	2 Putes of Best Profile	2 Pulses of Best Profile	2 Pulses of Best Profile	2 Puises of Best Profile
CS_CS001HBA0 B0329+54 ChiSq = 364.77773	CS_CS001HBA1 B0329+54 ChiSq = 388.51273	CS_CS002HBA0 B0329+54 ChiSq = 834.32741	CS_CS002HBA1 B0329+54 ChiSq = 560.28824	CS_CS003HBA0 _B0329+54 ChiSq = 295.16904	CS_CS003HBA1 B0329+54 ChiSq = 654.37374	CS_CS004HBA0 B0329+54 ChiSq = 665.42216	CS_CS004HBA1 B0329+54 ChiSq = 670.07634
2 Pulses of Best Profile	2 Puises of Best Profile	2 Pulses of Best Profile	2 Pulses of Best Profile	2 Pulses of Best Profile			
CS_CS005HBA0 _B0329+54 ChiSq = 565.06294	CS_CS005HBA1 _B0329+54 ChiSq = 537.82193	CS_CS006HBA0 _B0329+54 ChiSq =911.50553	CS_CS006HBA1 _B0329+54 ChiSq = 356.55897	CS_CS007HBA0 _B0329+54 ChiSq = 532.57645	CS_CS007HBA1 _B0329+54 ChiSq = 769.30047	CS_CS017HBA0 _B0329+54 ChiSq = 70.34212	CS_CS017HBA1 _B0329+54 ChiSq = 126.33433
2 Pulses of Best Profile	2 Puters of Best Profile	2 Puises of Best Profile	2 Pulses of Best Profile	2 Pulses of Best Profile			
CS_CS021HBA0 	CS_CS021HBA1 B0329+54 ChiSq = 151.82731	CS_CS024HBA0 B0329+54 ChiSq = 681.56604	CS_CS024HBA1 B0329+54 ChiSq = 492.91328	CS_CS026HBA0 B0329+54 ChiSq = 1.08989	CS_CS026HBA1 B0329+54 ChiSq = 1.10768	CS_CS030HBA0 B0329+54 ChiSq = 107.89656	CS_CS030HBA1 B0329+54 ChiSq = 200.30639
2 Pulses of Best Profile	2 Puises of Best Profile	2 Puises of Best Profile					
CS_CS032HBA0 _B0329+54 ChiSq = 385.26261	CS_CS032HBA1 	CS_CS101HBA0 B0329+54 ChiSq = 669.41272	CS_CS101HBA1 B0329+54 ChiSq = 746.52334	CS_CS103HBA0 	CS_CS103HBA1 54 ChiSq = 733.32409	CS_CS201HBA0 	CS_CS201HBA1 B0329+54 ChiSq = 202.31221
2 Pulses of Best Profile	2 Putes of Best Profile	2 Putses of Best Profile	2 Putses of Best Profile	2 Putaes of Best Profile	2 Putses of Best Profile	2 Puises of Best Profile	2 Puises of Best Profile
CS_CS301HBA0 _B0329+54 ChiSq = 213.04046	CS_CS301HBA1 _B0329+54 ChiSq = 139.77018	CS_CS302HBA0 B0329+54 ChiSq = 87.04957	CS_CS302HBA1 _B0329+54 ChiSq = 116.77781	CS_CS401HBA0 B0329+54 ChiSq = 394.53609	CS_CS401HBA1 _B0329+54 ChiSq = 113.60953	CS_CS501HBA0 _B0329+54 ChiSq = 71.07175	CS_CS501HBA1 _B0329+54 ChiSq = 7.59392
2 Pulses of Best Profile							
CS_RS106HBA _B0329+54 ChiSg = 3029.99251	CS_RS205HBA _B0329+54 ChiSg = 1546.22172	CS_RS208HBA _B0329+54 ChiSg = 1485.96807	CS_RS306HBA _B0329+54 ChiSg = 0.00000	CS_RS307HBA _B0329+54 ChiSg = 1691.97825	CS_RS406HBA _B0329+54 ChiSg = 1425.82947	CS_RS503HBA _B0329+54 ChiSg = 1903.98151	

CREDIT: ALEXOV & HESSELS





Early Science

LOFAR LBA (DE601) 60 MHz 36 MHz band

LOFAR HBA (CS302) 163 MHz 48 MHz band

The Lovell Telescope 1524 MHz 512 MHz band

The Effelsberg 100-m Telescope 8.350GHz 1GHz band



10	100	1000	10
T A			







Results

* The "well-behaved" pulsar (PSR B1133+16)

- Pulses all arrived at the same time (within ~0.3 ms)
- * All emission must be within 110 km(!) of stars surface
- * But the profile broadens more than expected in that height range
- * The other one (PSR B0809+74)
 - * Pulses also all arrived at the same time
 - * Shape of the pulses is very unexpected
- * Two other pulsars were observed and none of them agree well with the standard model
- ★ Is the model right? → We are working on it...

Summary

* LOFAR's beamformed modes are working well

- * ...already taking science-quality data
- * ...in an array of unique and very useful modes
- * ...more results coming soon!
- * Pulsar emission is confined to a very narrow region in the pulsar magnetosphere
 - Pulses which can be seen from ~10,000,000,000,000,000 km away are produced in a region no bigger than 110 km!
- * Shape of the pulse is not what we expect

* How do pulsars shine? (LOFAR should find out!)

Summary

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THERE WAS A

* Shape of the pulse is not what we expect TRAFFIC JAM THIS LONG

How do pulsars shine? (LOFAR should find out!)

The End.