Early Pulsar Science with LOFAR

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

LOFAR

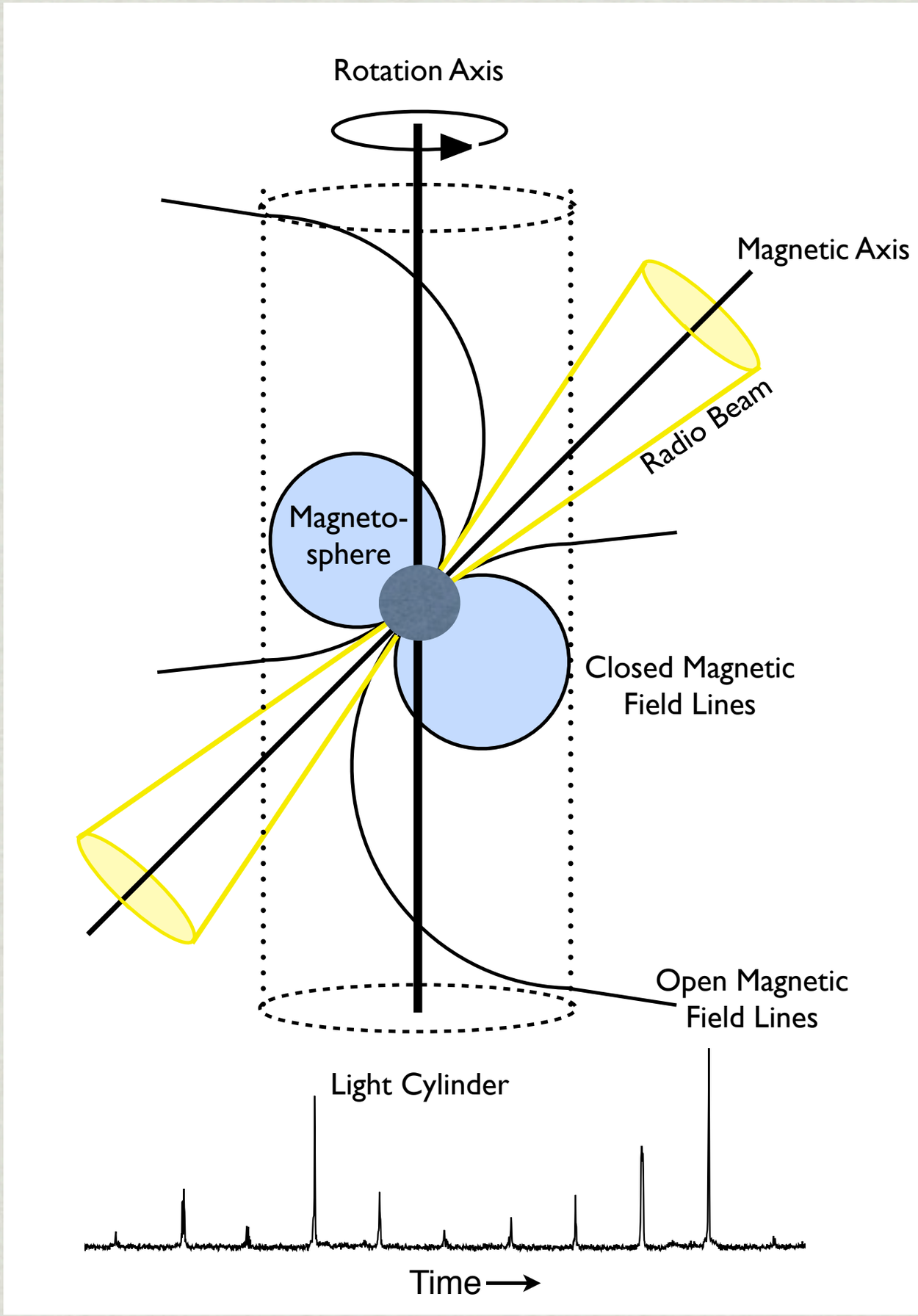
UNIVERSITY OF Southampton

ROYAL ASTRONOMICAL SOCIETY · QUICQUID NITET NOTANDUM · 1820

NAM
UKSP · MIST
2012 Manchester

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



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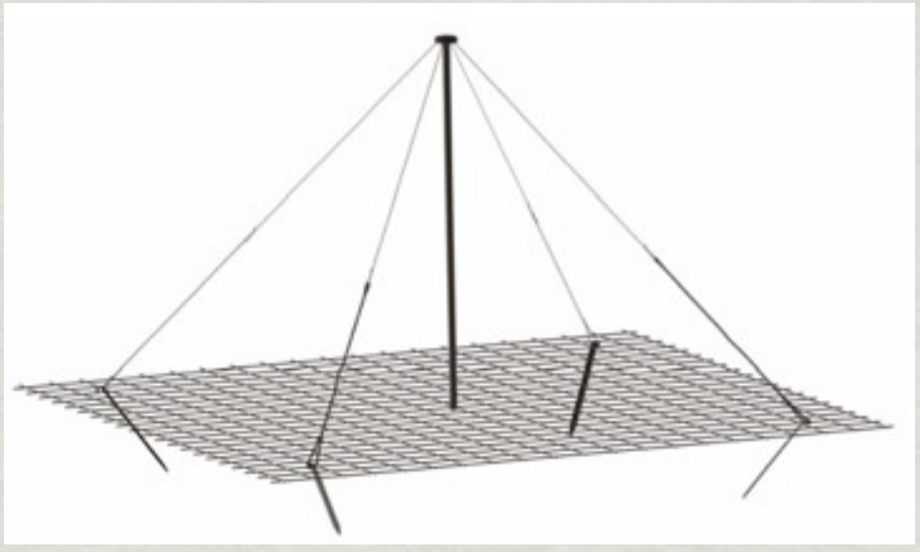
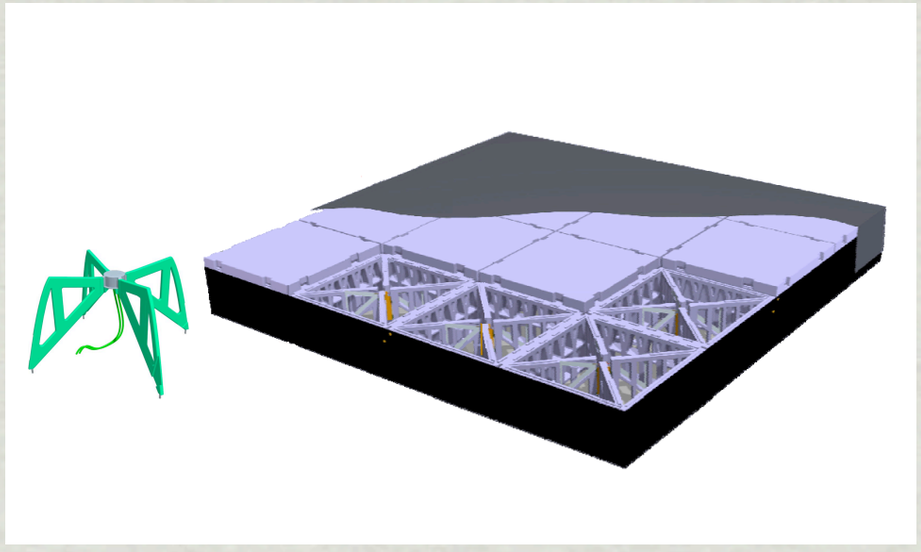


Low Band Antennas (LBAs)
15-90 MHz
48 MHz band



High Band Antennas (HBAs)
110-240 MHz
48 MHz band

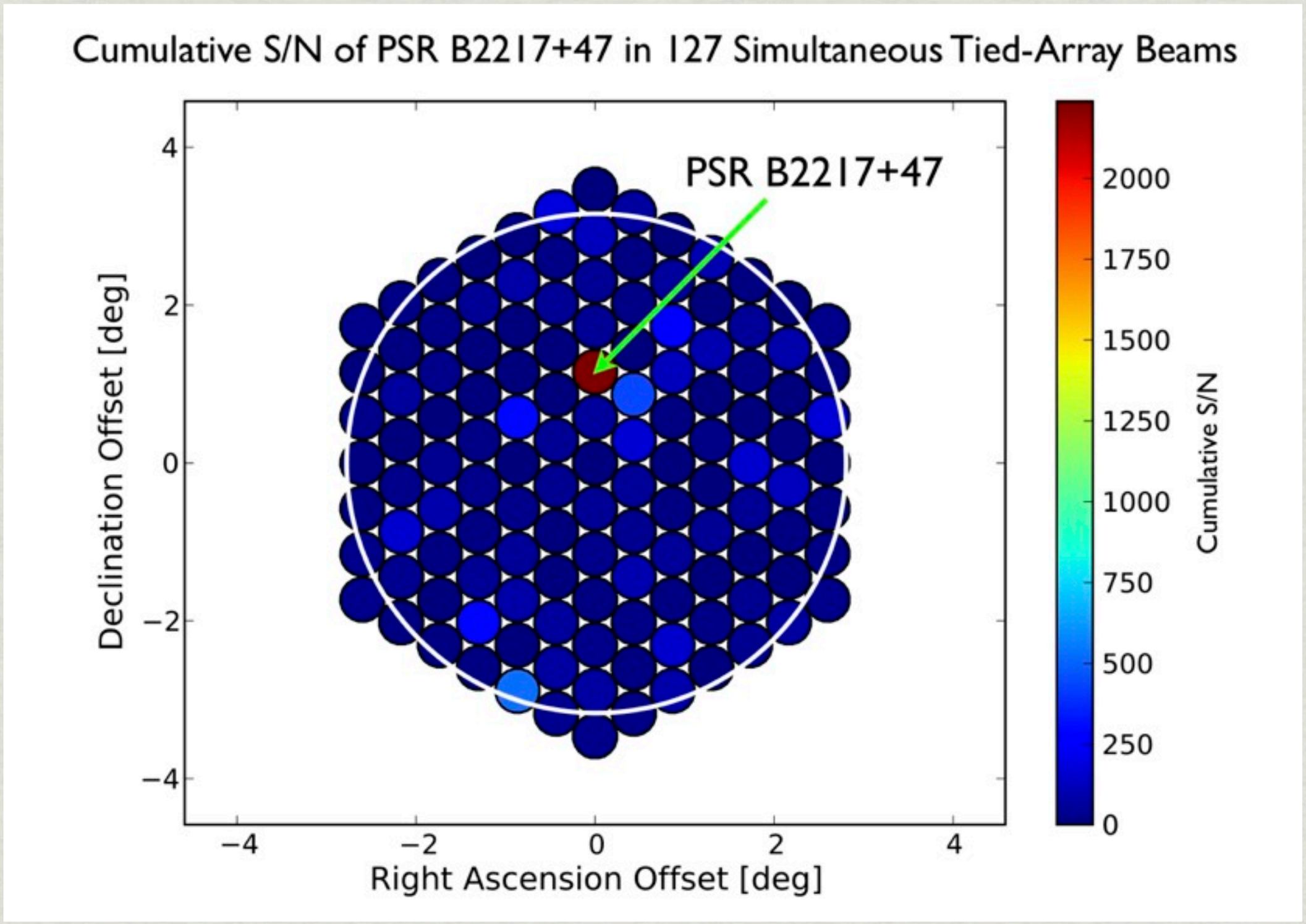
- Instead of a big dish, many antennas
- Combining their signals improves sensitivity and resolution
- “Pointed” by using a supercomputer to introduce different time delays to each element

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

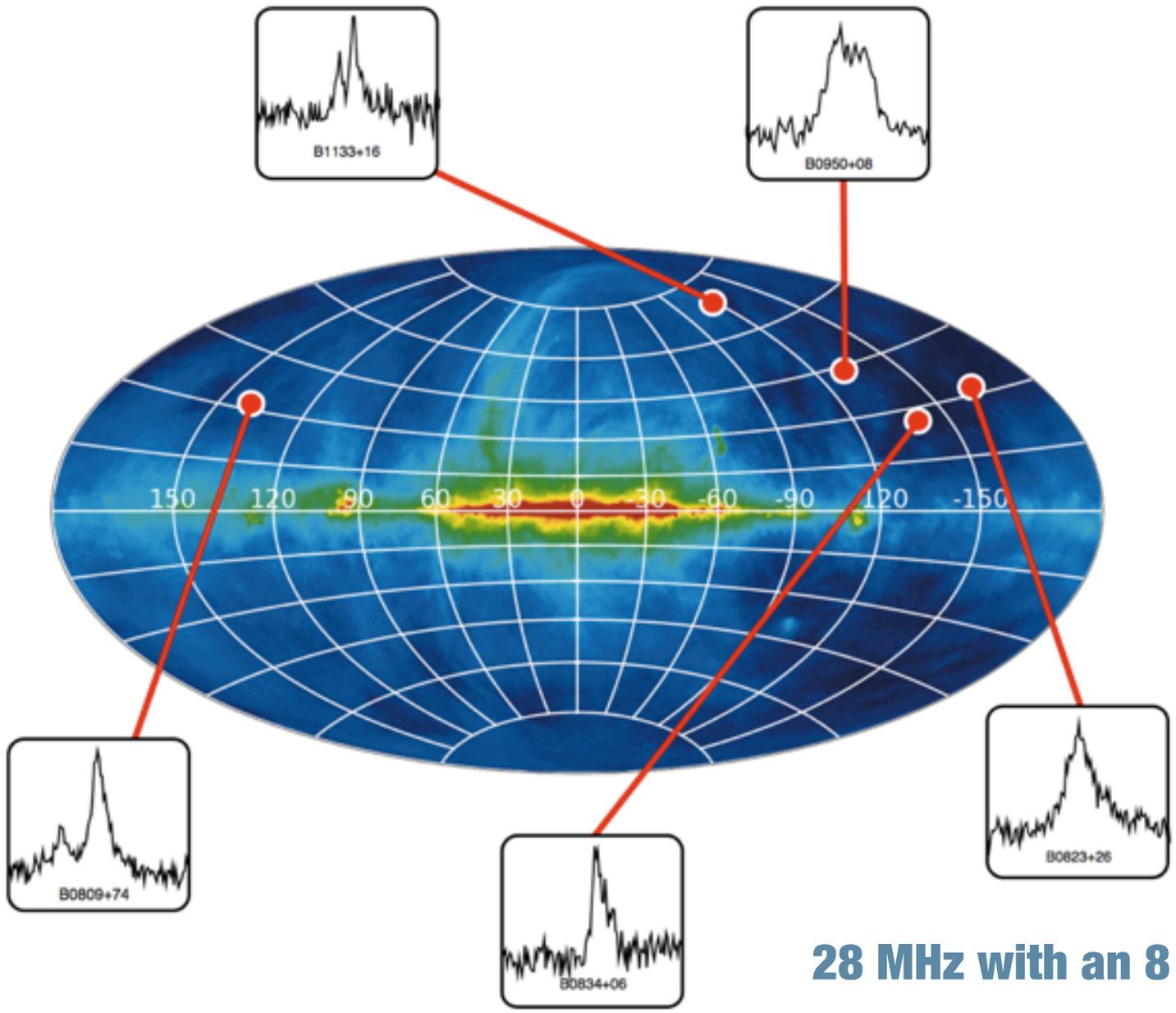
CREDIT: HESSELS



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

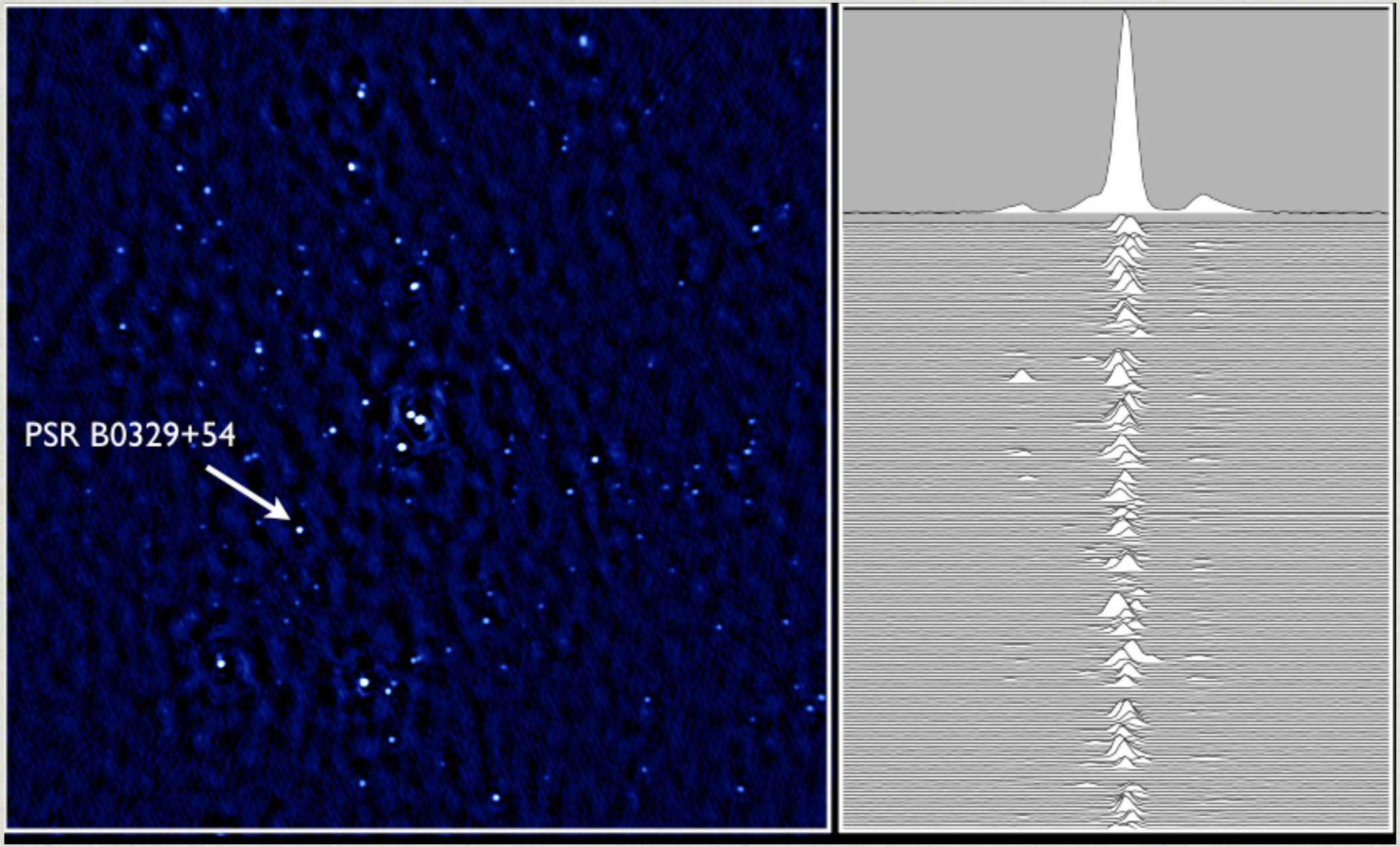
BeamFormed



28 MHz with an 8 MHz band

Imaging and BeamFormed

CREDIT: ALEXOV & HEALD

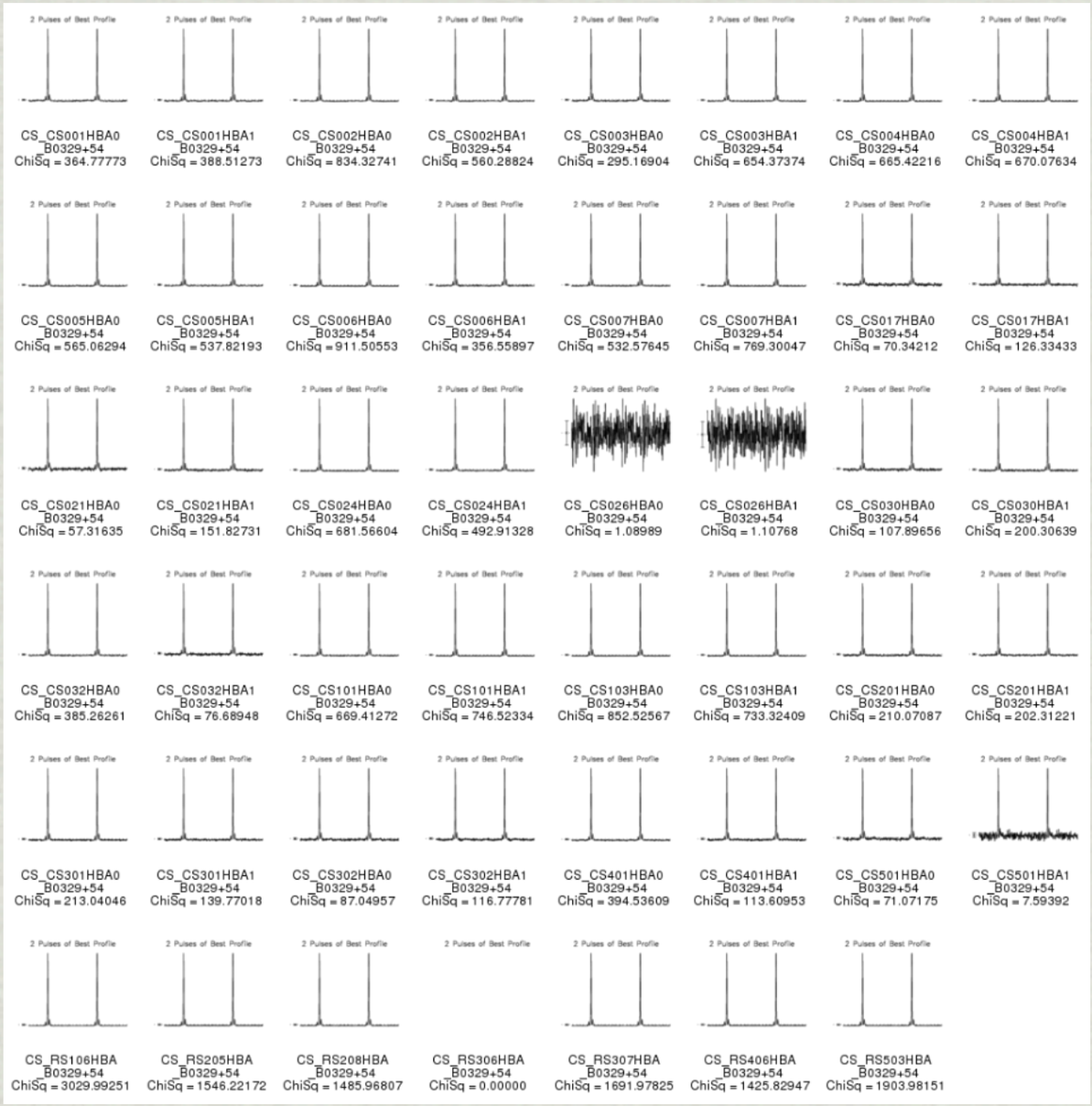


B0329+54 -130-178MHz, 10 Stations, 12 hours

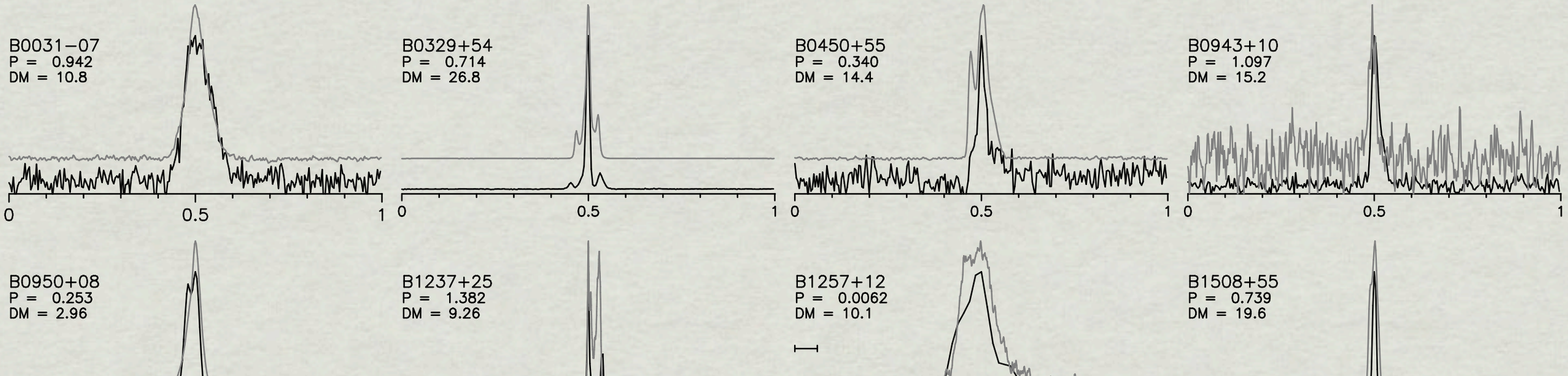
Fly's Eye Mode

- 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...

CREDIT: ALEXOV & HESSELS



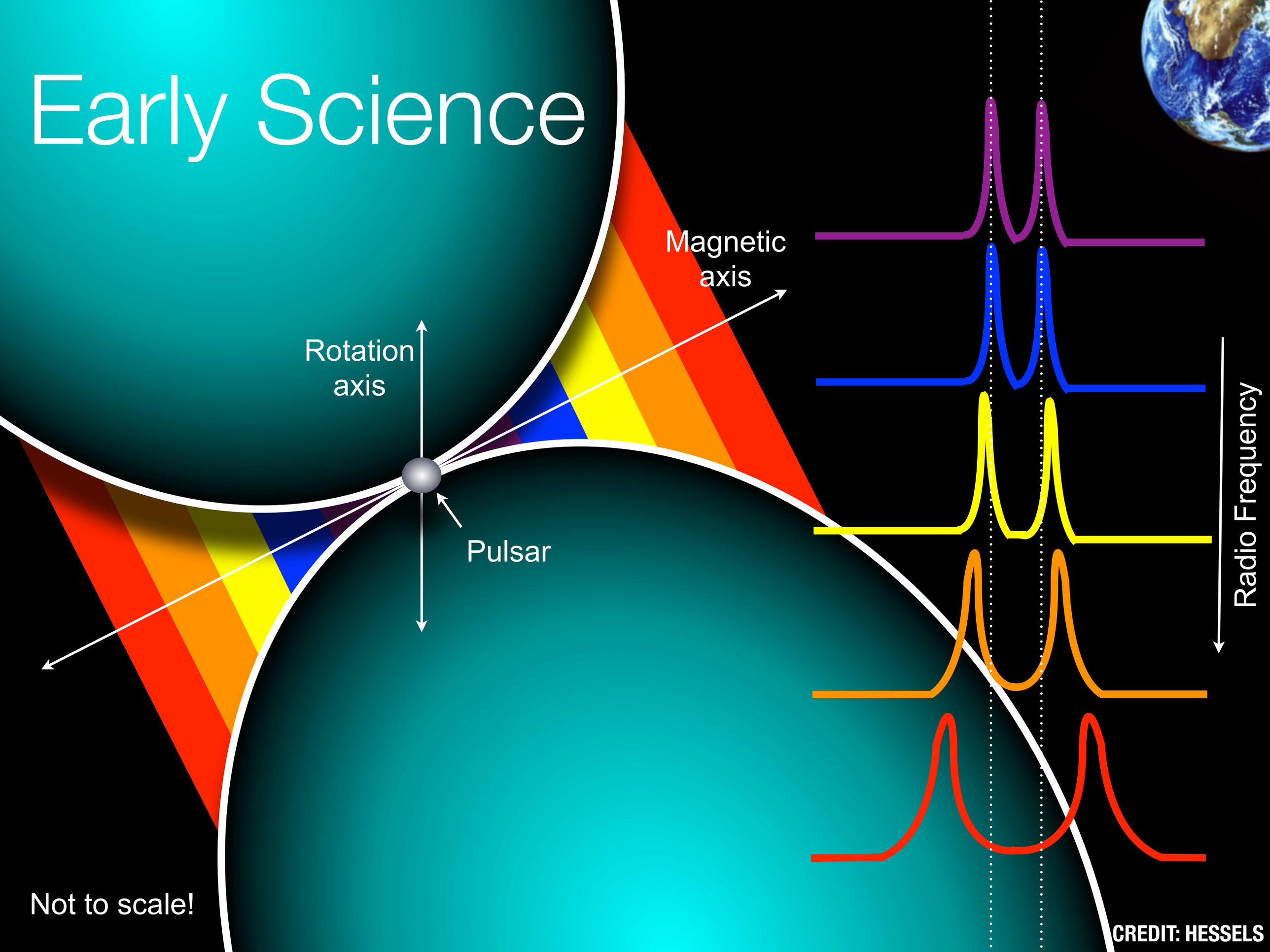
CREDIT: STAPPERS



48 MHZ BW / 150 MHZ / MS TIME RESOLUTION

EXAMPLE PROFILES OBTAINED WITH THE HBAS CF. WITH EPN 21CM PROFILES

Early Science



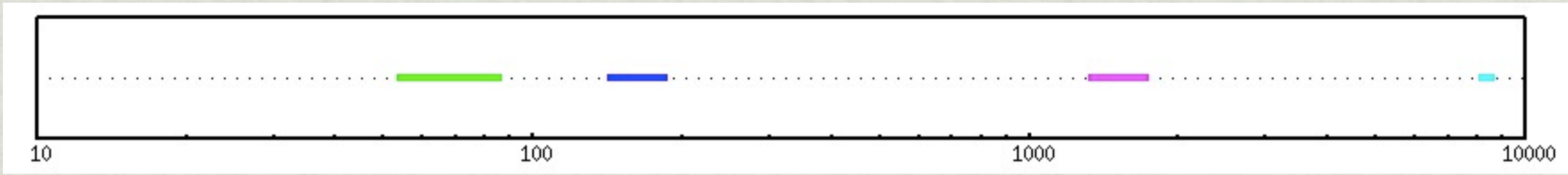
Early Science

LOFAR LBA
(DE601)
60 MHz
36 MHz band

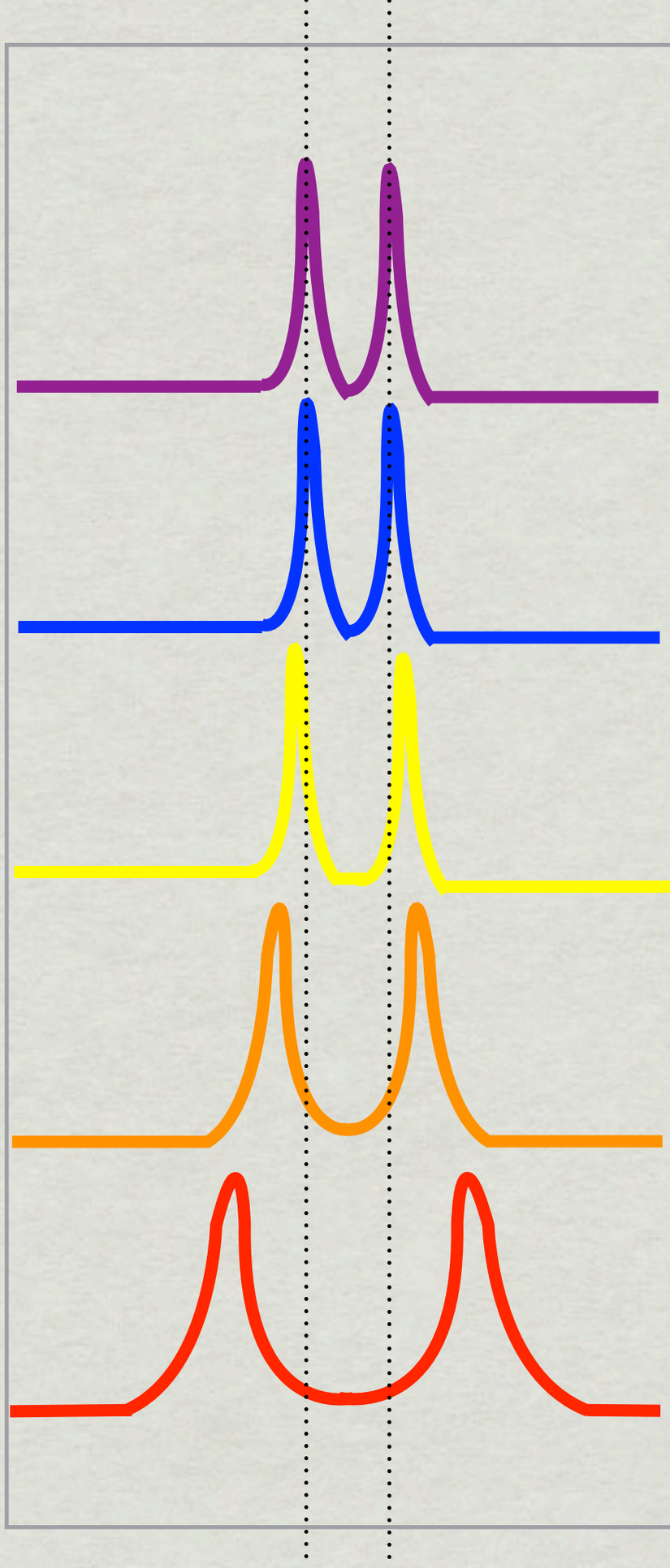
LOFAR HBA
(CS302)
163 MHz
48 MHz band

The Lovell
Telescope
1524 MHz
512 MHz band

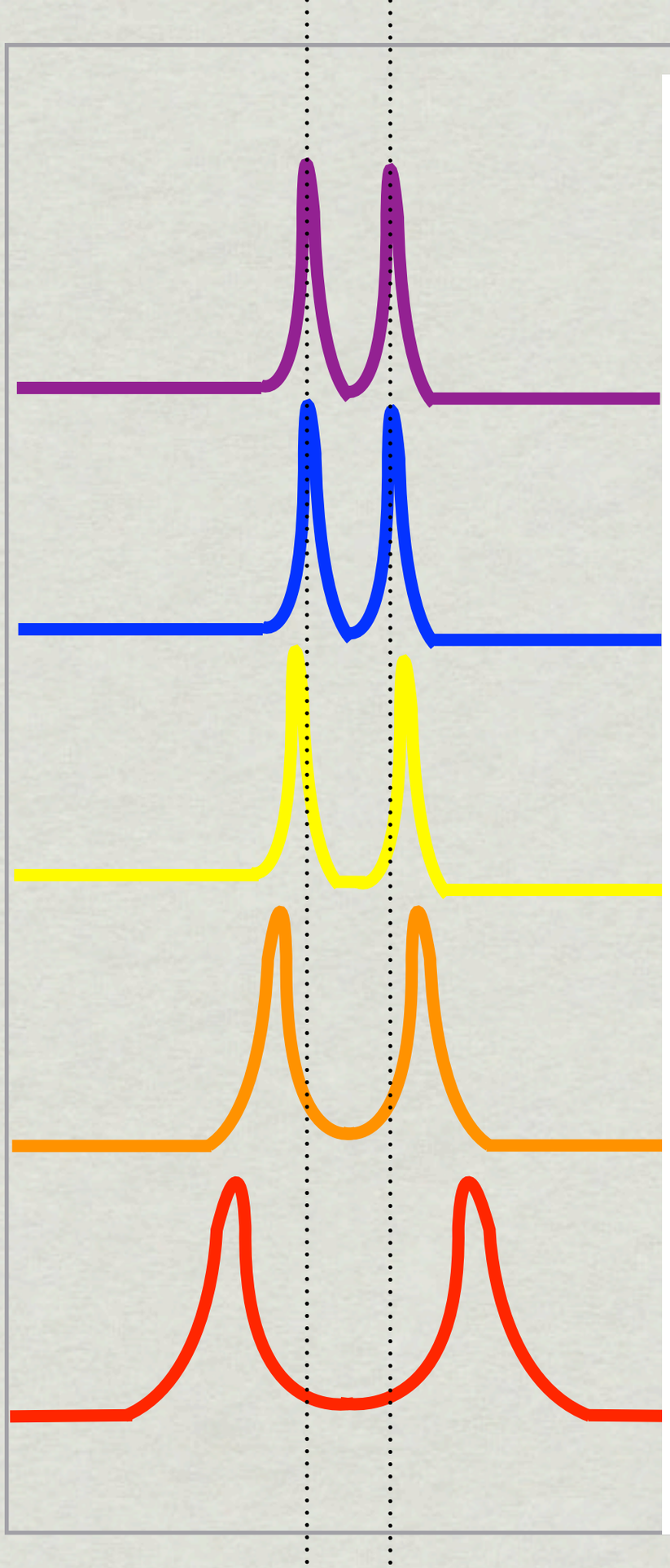
The Effelsberg
100-m Telescope
8.350GHz
1GHz band

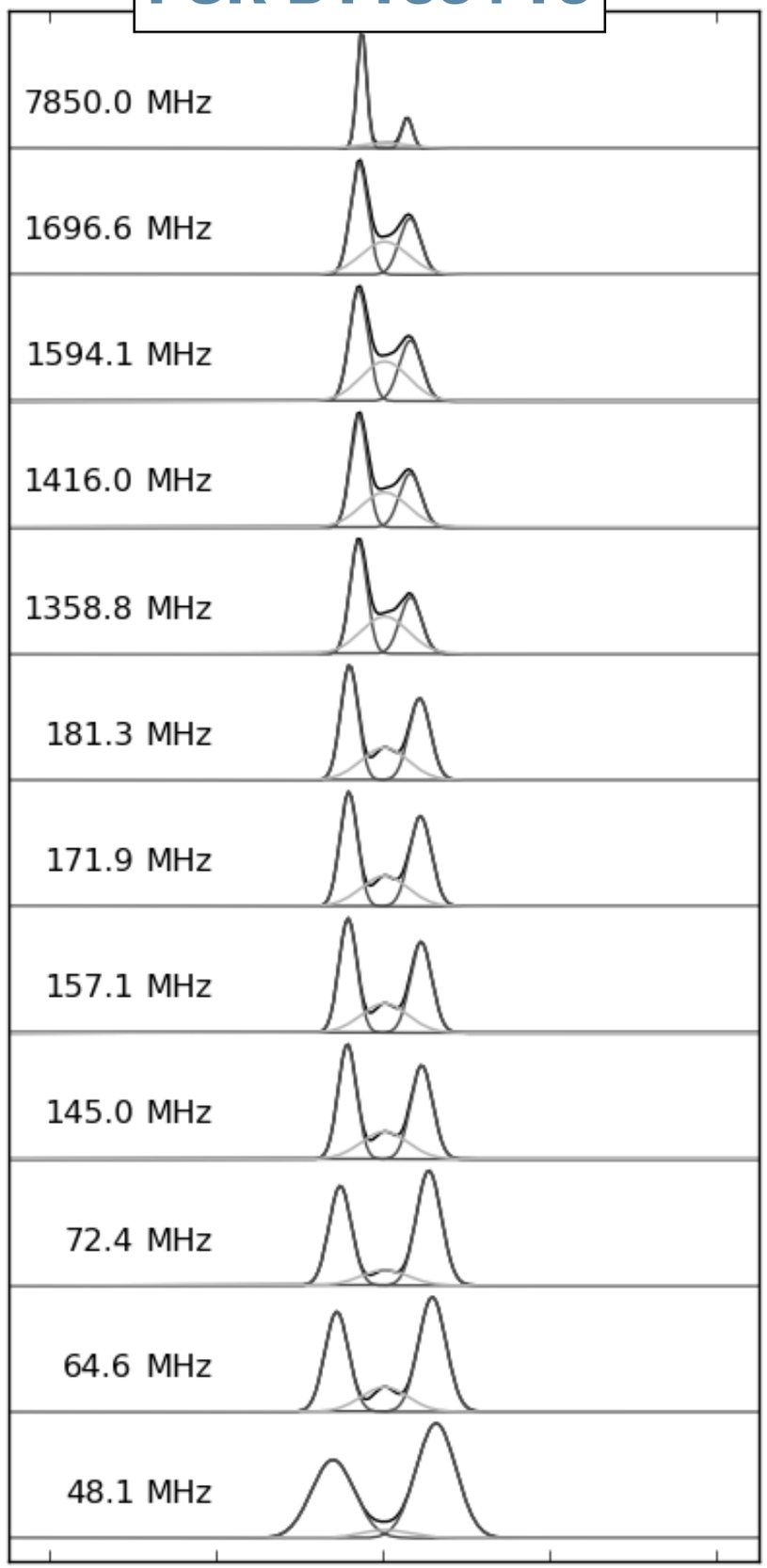


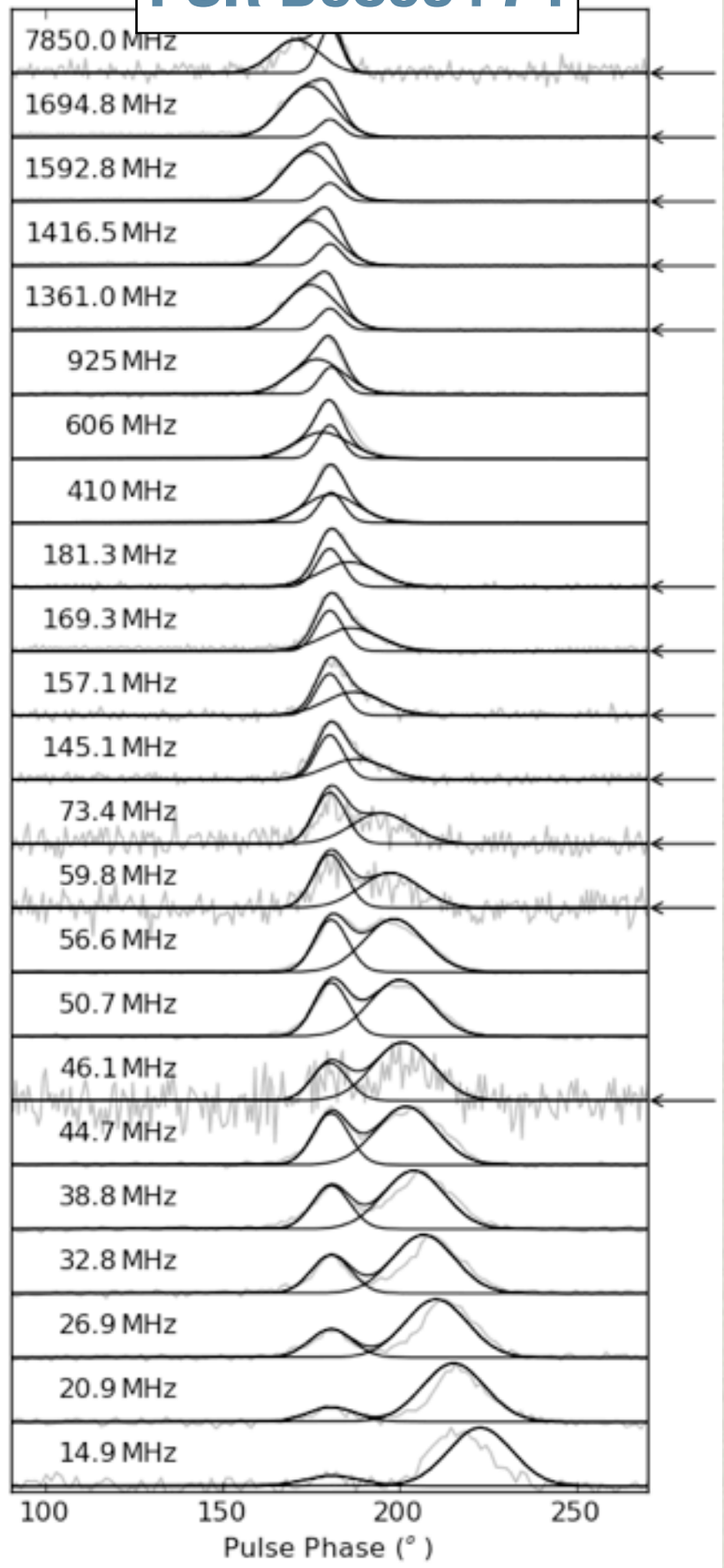
Frequency (MHz)



Aligning the pulses at different frequencies




PSR B1133+16
7850.0 MHz
1696.6 MHz
1594.1 MHz
1416.0 MHz
1358.8 MHz
181.3 MHz
171.9 MHz
157.1 MHz
145.0 MHz
72.4 MHz
64.6 MHz
48.1 MHz
140
160
180
200
220
Pulse Phase (°)


PSR B0809+74
7850.0 MHz
1694.8 MHz
1592.8 MHz
1416.5 MHz
1361.0 MHz
925 MHz
606 MHz
410 MHz
181.3 MHz
169.3 MHz
157.1 MHz
145.1 MHz
73.4 MHz
59.8 MHz
56.6 MHz
50.7 MHz
46.1 MHz
44.7 MHz
38.8 MHz
32.8 MHz
26.9 MHz
20.9 MHz
14.9 MHz
100
150
200
250
Pulse Phase (°)

133+16

PSR B0809+74

7850.0 MHz
1694.8 MHz
1592.8 MHz
1416.5 MHz
1361.0 MHz
925 MHz
606 MHz
410 MHz
181.3 MHz
169.3 MHz
157.1 MHz
145.1 MHz
73.4 MHz
59.8 MHz

250

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!)

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- Shape of the pulse is not what we expect
- How do pulsars shine? (LOFAR should find out!)

IN CHINA, 2010 THERE WAS A TRAFFIC JAM THIS LONG

The End.