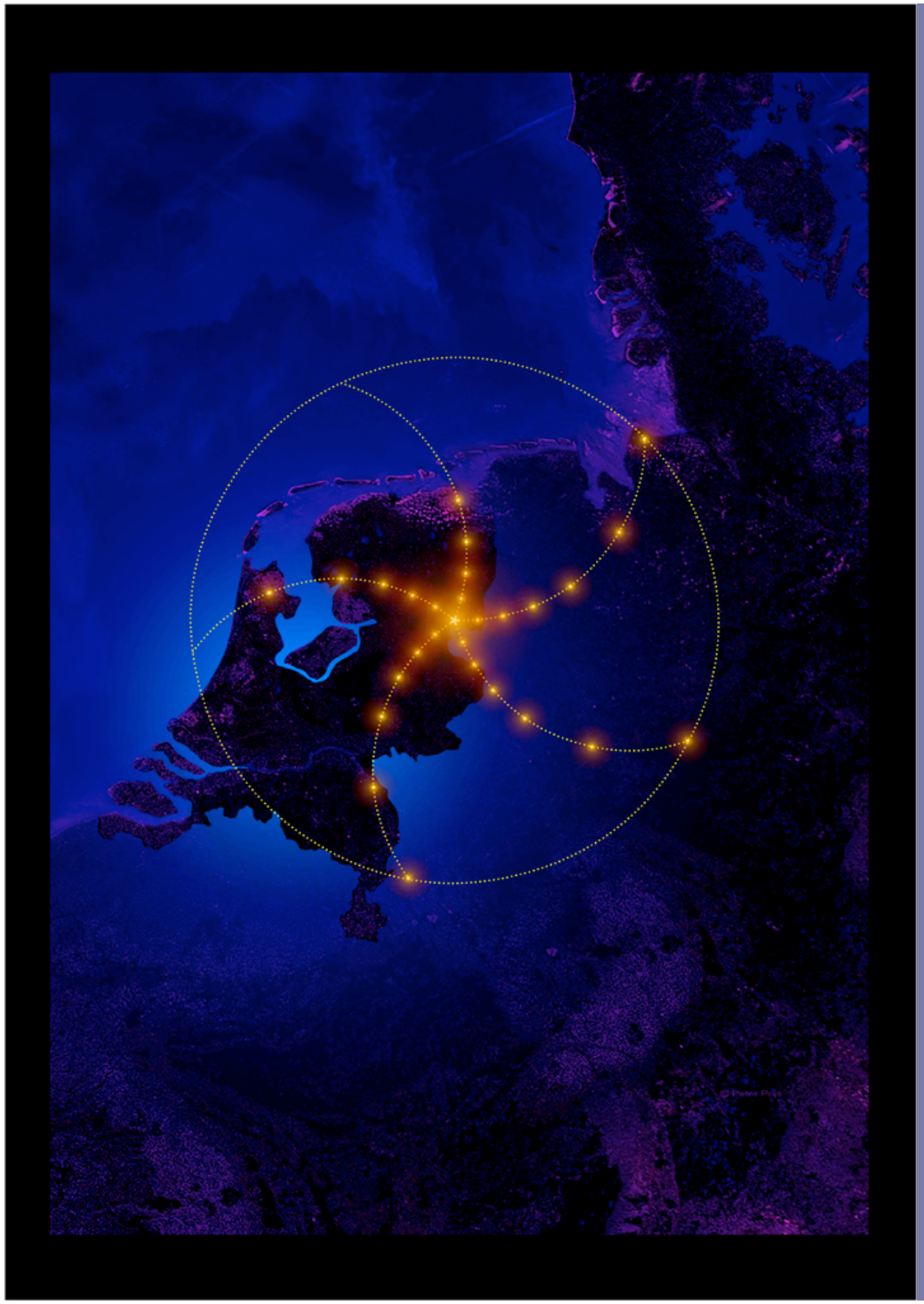

LOFAR and Superstation for Pulsars

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Outline:

- LOFAR: briefly what we need from LOFAR
- Pros and cons of low-frequency observations
- How to find new pulsars with LOFAR
- How many pulsars will we find?
- Some definitions
- What about a superstation?
- Is survey figure of merit all?
- Is the LBA a good place to search for pulsars?
- Conclusions

Pulsar Survey with LOFAR: The Challenge

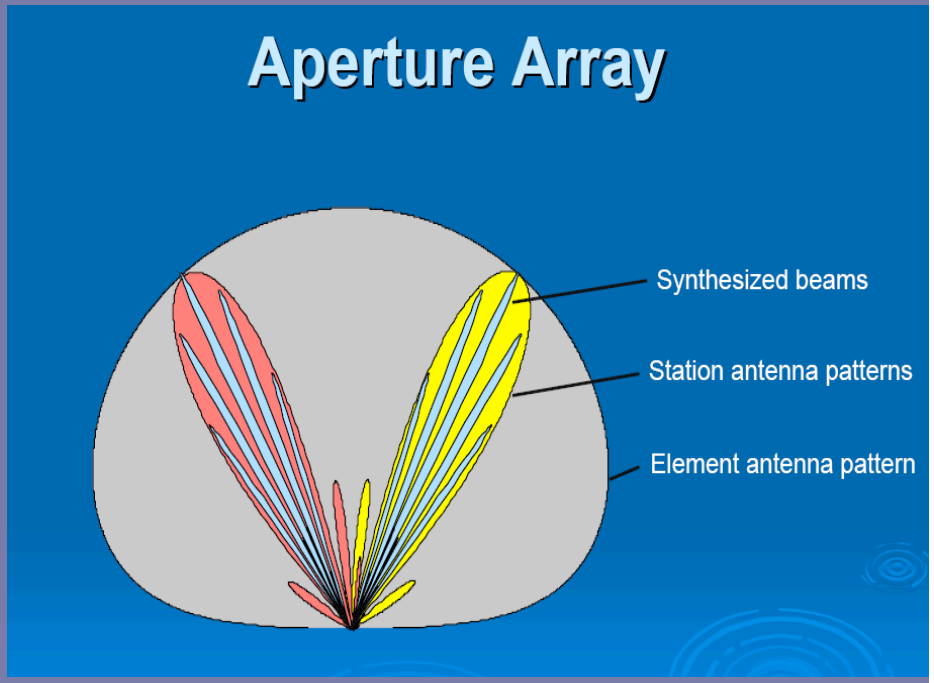
Sensitivity scales as:

$M = N * FoV * (A/T)^2 * BW * (\nu^{-1.8})^2$

Need to maximise FoV
but LOFAR is a sparse array!

D_{core} = 2 km, $D_{station}$ = 30 m
< 25 stations in the core

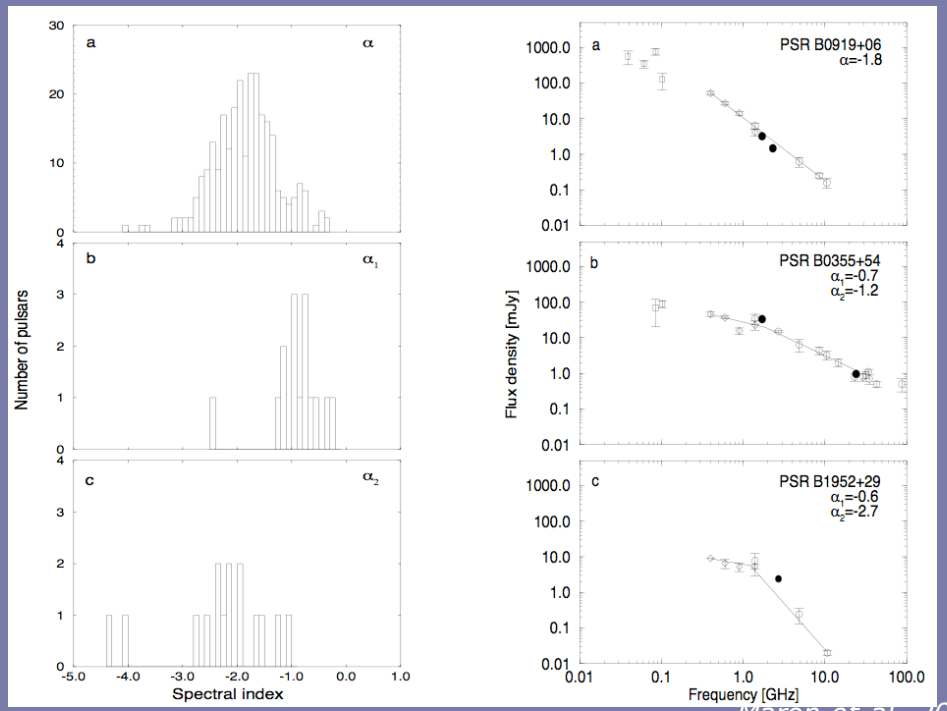
Can a superstation help?



SOLUTION:
Either add telescopes incoherently or have many TABs
BUT:
at least 35 times more data throughput and signal processing.
On the other hand: It does give significantly better positions.
Due to shorter integrations required also possibly less total resources

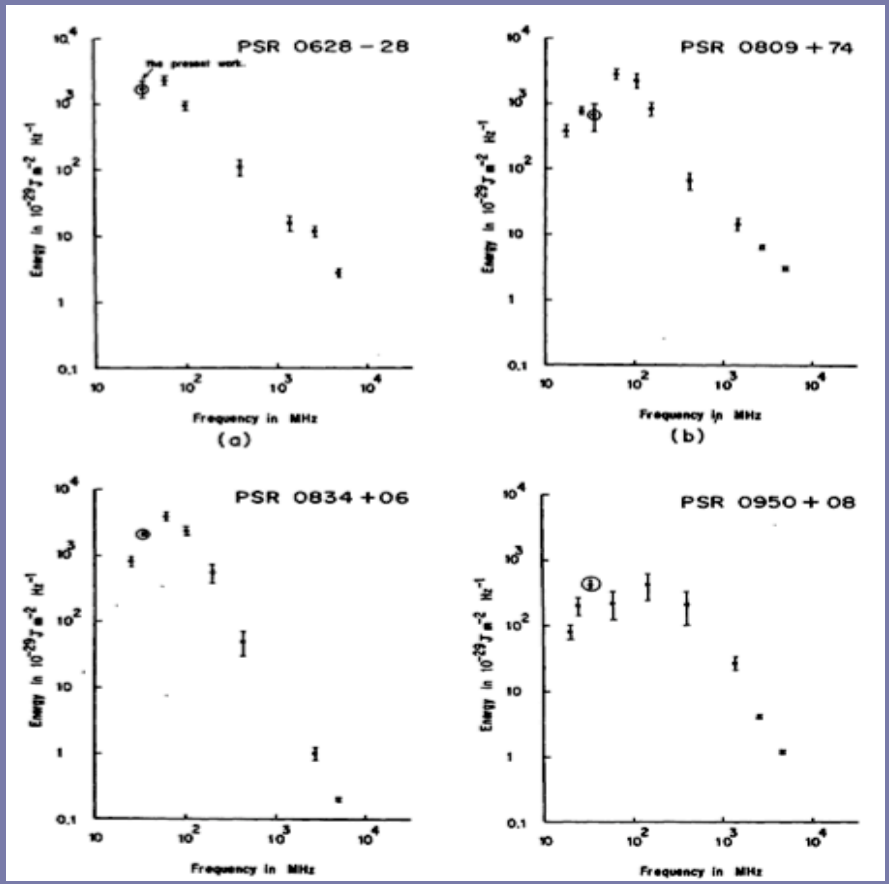
The Spectra

Typical pulsar spectra



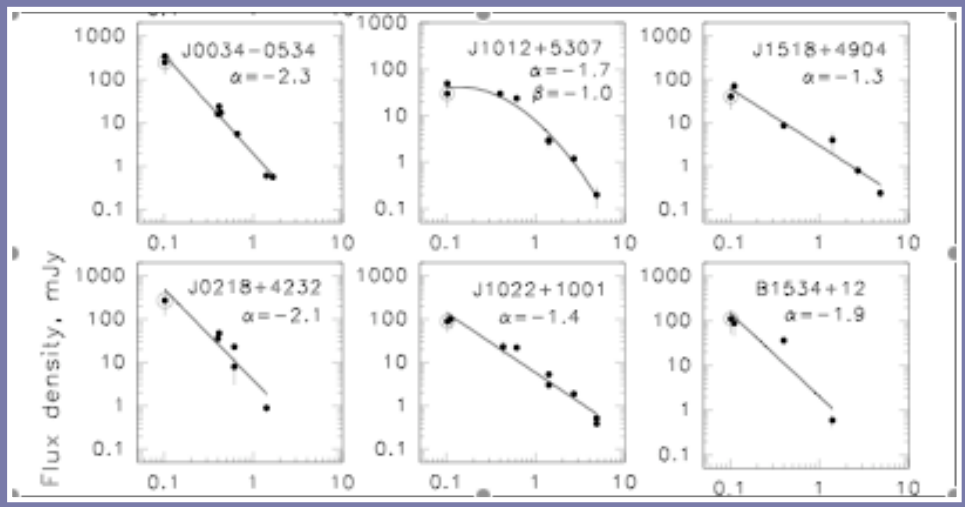
Maron et al 2000

When 34 MHz data incl.



Deshpande & Radhakrishnan 1992 (34.5 MHz data)

MSP spectra, no turnover?



Kuzmin & Losovsky 2001

Pulsar Survey with LOFAR: Optimal Freq.

$$\text{Max}(M = N * FoV * (A/T)^2 * BW * (\nu^{-\alpha})^2)$$

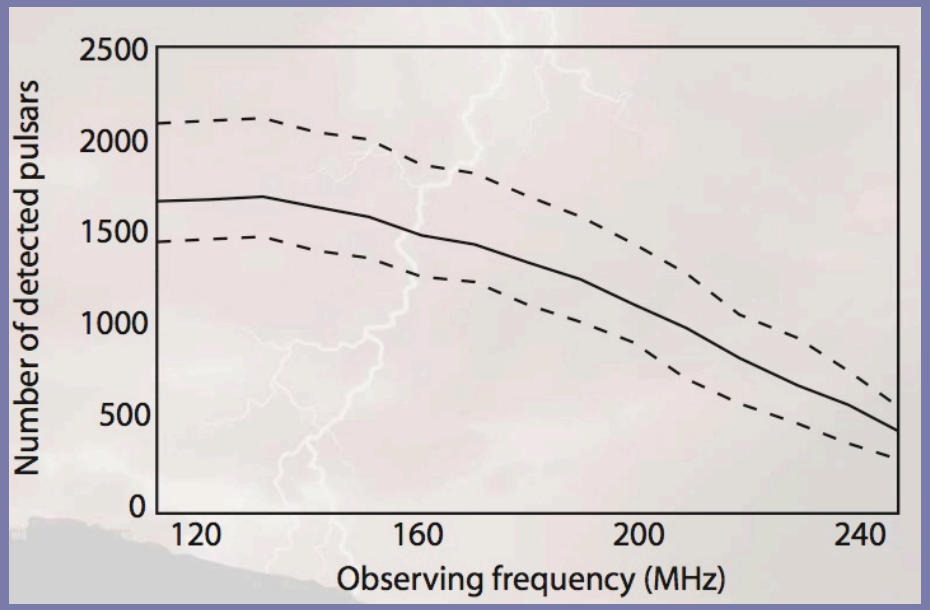
- FoV scales as ν^2
- A_{eff} scales as ν^{-2} above 140 MHz and ν^2 below
- Pulsar flux scales (on avg) as $\nu^{-1.5}$ (i.e. $\alpha = -1.5$)
- T should be dominated by T_{sky} and it scales as $\nu^{-2.6}$

Extra considerations for:

- Dispersion increases as we go to lower ν but we can correct for it.
- Scattering is the biggest problem $\nu^{-4.4}$ limits distance to which detect pulsars

$T_{scatt} = 5.2 \times 10^{-7} DM^{3.8}$ s at 140 MHz

van leeuwen & Stappers 2007

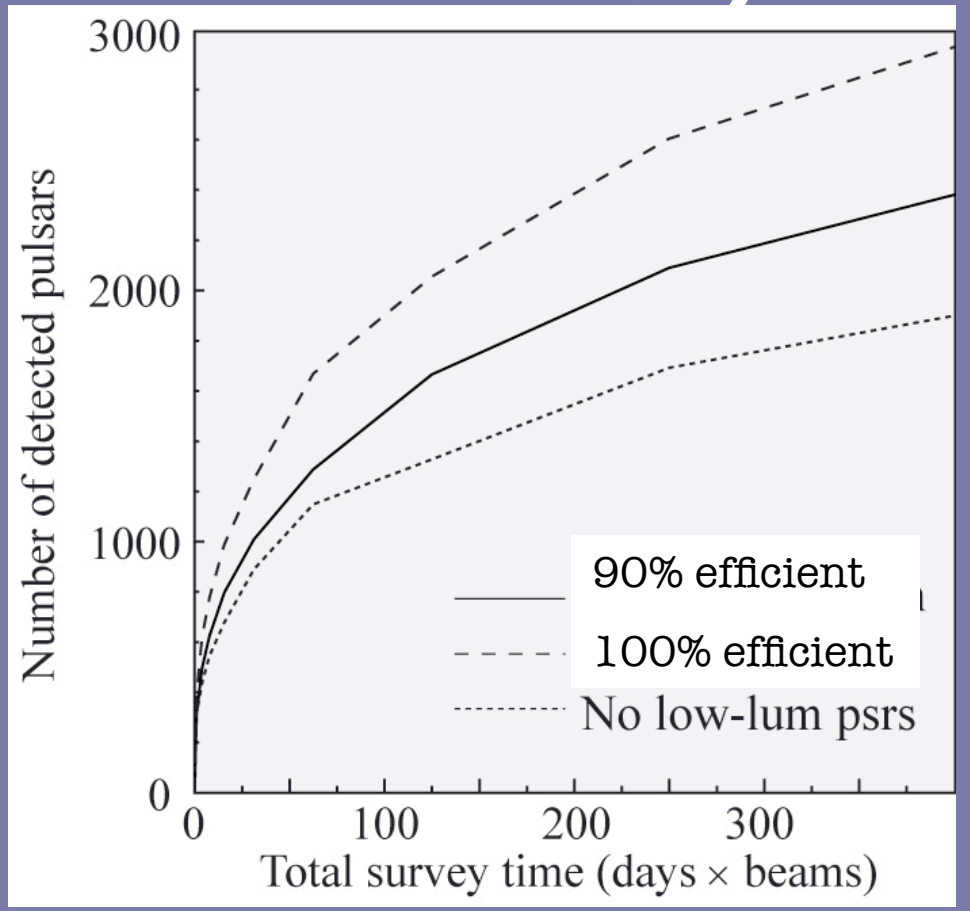


Pulsar Survey with LOFAR:How Many?

Model Parameters

- all from previous page
- model of pulsar luminosity (v. impt)
- model of birth periods & sky distribution
- sky seen from LOFAR in NL
- location dependent sensitivity of LOFAR

With 60 minute pointings LOFAR could detect at least 1000 new pulsars in the Northern sky in just 60 days of observing.



12 sigma, 50*24 tile stations, 80% of 32 MHz

Survey time reduced if more Beams are available In the core.

Depend. on lum fn. longer pointings not necc. more PSRs found.
If use TABs pointings shorter. More than 22 TABs = survey faster or can get back some of lost sensitivity.

Some Definitions

With LOFAR becoming a heterogeneous array we need to define what we will be using on the coming slides.

1. I define an LBA station as one containing 96 actively used dipoles which are compactly arranged.
2. The LOFAR core stations are therefore 1/2 the collecting area and twice the field of view of these.
3. I assume that the superstation has 8 times the collecting area of an LBA station and is close packed so has 1/8th the field of view.
4. An incoherent sum is formed by simply summing station signals “after” detection, so no phase info used and area scales as sqrt(Number of stations)
5. A tied array is formed by correcting for all phase and clock delays and results in a narrower beam but area scales as (Number of stations)

What about a superstation?

$$M = N * FoV * (A/T)^2 * BW * (\nu^{-\alpha})^2$$

Ignoring BW, N and ν for now as they are constant we can compare a single station, incoherent sum of LOFAR core, Tied-Array formed from LOFAR core, and a superstation

Defining $M = M_{single}$ for a single LBA station we have:

- $M_{inc} = (2*FoV) * (sqrt(18/2)*A/T)^2 = 18\ M_{single}$
- $M_{coherent} = (1/625 * FoV) * (18/2*A/T)^2 = 0.13\ M_{single}$
- $M_{super} = (1/8 * FoV) * (8 * A/T)^2 = 8\ M_{single}$

On the face of it the incoherent sum is the best. However it is planned that multiple tied array beams will be formed in the core and if there are > 60 of them then the coherent sum is the best.

If multiple beams were possible in the superstation then it could be fastest.

Is Survey Figure of Merit all?

So the ability to make a few beams with a SS will make it excellent for performing pulsar surveys.

Moreover the SS will give better positions than the incoherent sum.

This is very good for follow up observations.

If multiple beams were possible then the SS would be a great instrument for finding the rarely bursting sources like RRATs or even with one beam if lots of time were available then the chances of finding these rare bursts would also be enhanced.

The very good sensitivity of the SS would also make it excellent for regular monitoring work of known pulsars that could not be done with the higher demand core.

Is the LBA good for PSR surveys?

Detailed simulations like those done by van Leeuwen & Stappers are needed to assess how many pulsars can be found with an LBA survey

Unfortunately there are some negatives:

- Scattering in the ISM will limit the distance to which pulsars can be seen
- Most “known” pulsar spectra turn over at about 100 MHz
- The overall sensitivity might not be as good as the HBA survey

There are also some positives though:

- There are a number of pulsars with steep spectra that do not turnover and this includes some millisecond pulsars
- The low frequency means that dispersion due to the interstellar medium will enable us to distinguish low-dm and thus very nearby pulsars from interfering sources, something which is impossible at higher frequencies.
- Similarly this will make it much easier to identify nearby burst sources
- There may be a population of sources which have very steep spectra which we just haven’t been able to see before.

Conclusions

- A superstation with 8 times the number of dipoles would be a very good tool for pulsar work at low frequencies.

- It is competitive with other parts of LOFAR in terms of survey speed and with the right hardware/software it could be fastest.

- While the LBA will not find the most pulsars it will be the best for finding the nearby population.

- Using the SS in piggyback mode to search for single bursts from sources like RRATs will be a fantastic tool for finding these sources

- The SS would also be a very valuable tool for studying known pulsars at LBA frequencies.