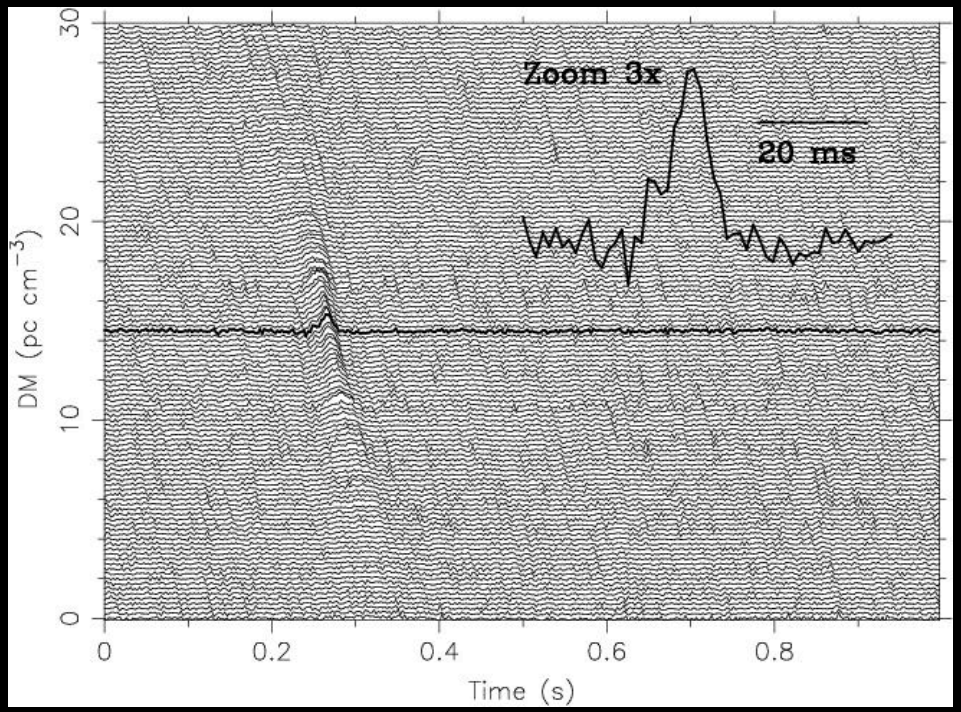
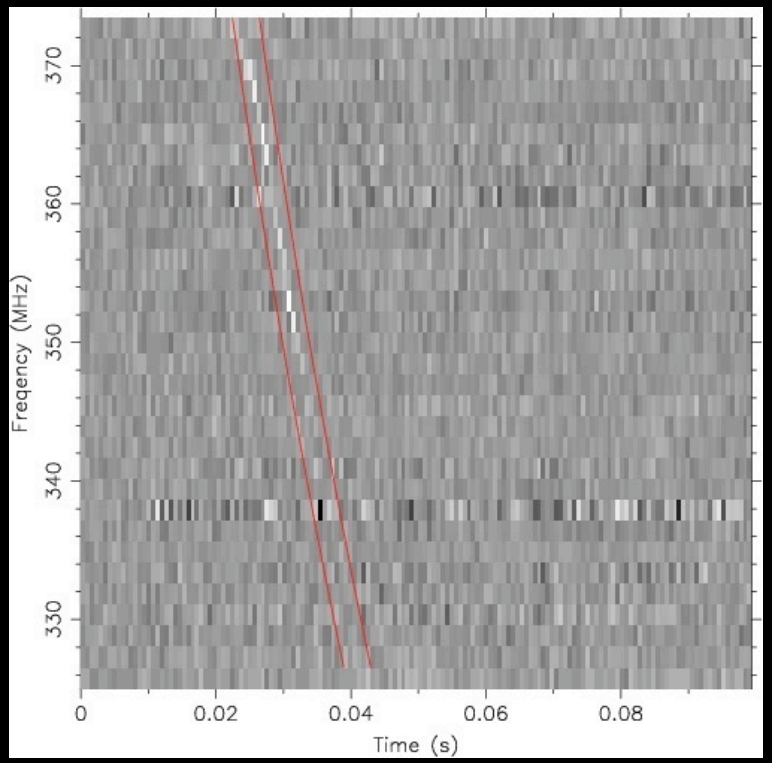
Pulsars with LOFAR

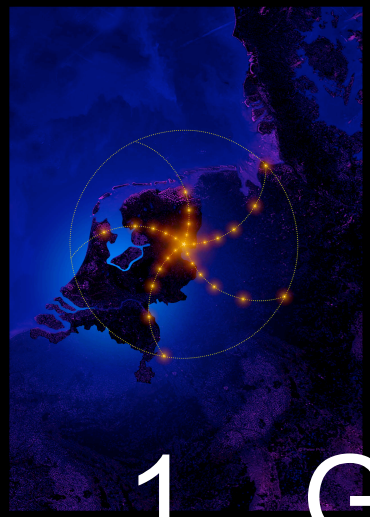




Jason Hessels (API, UvA)

with Ben Stappers and Joeri van Leeuwen

Young LOFAR - November 26th, 2007

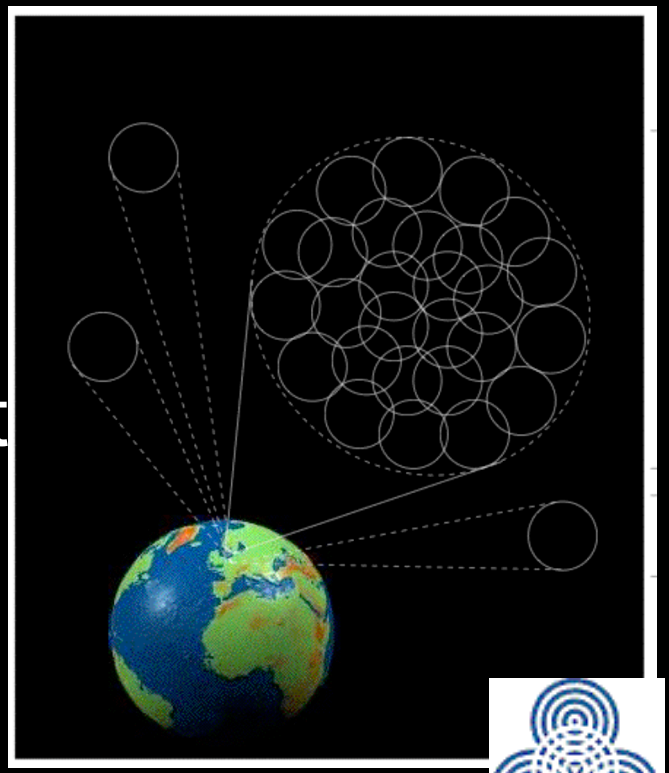


Outline

1. General observing strategy
Pulsar Surveys
Millisecond Radio Pulses
Other Pulsar Science

Observing: Beam Forming

- Pulsar observations will use beam-formed data
  Survey figure of merit is A^2xFoV
  Forming multiple beams makes for much more efficient observing.



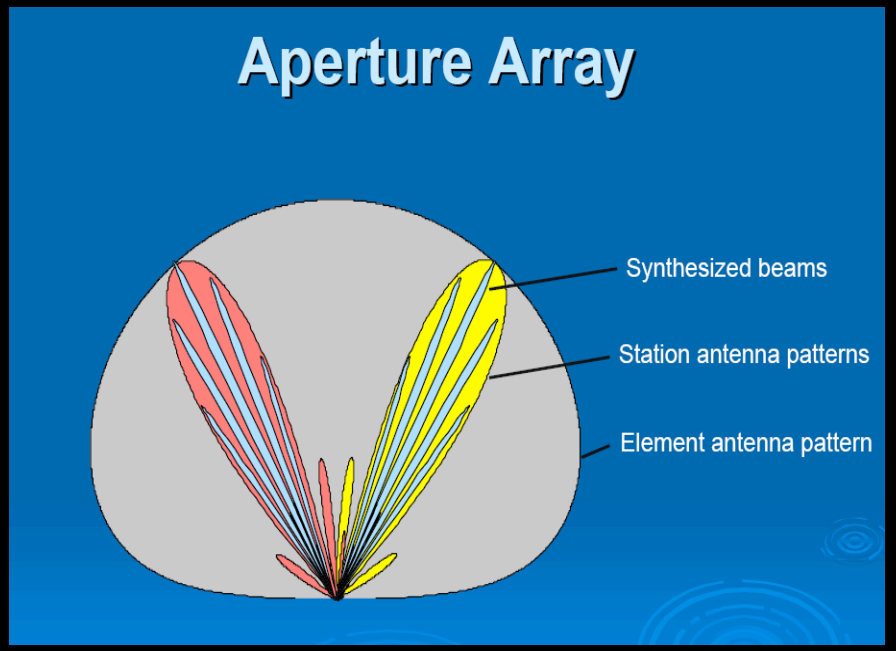
Observing: Beam Forming

Wide Pulsar Surveys:

- e.g. Galactic Plane
- Incoherent sum of core stations
- Use "super station"?

Narrow Pulsar Surveys and known sources:

- e.g. Other galaxies and GCs
- As many stations as possible
- Multiple TA beams possible



Observing: Dedispersion

- Data must be “dedispersed” to correct for dispersive delay of the signal by the ISM
  Several 10,000s of trial DMs will be needed for a full survey out to DMs of a few 100 pc cm^{-3}

Observing: Dedispersion

$$\Delta t = 4150s \times (\nu^{-2}_{low} - \nu^{-2}_{high}) \times DM$$

For 50MHz band at 350MHz

$\Delta t = 10$ ms x DM

For 50MHz band at 150MHz

$\Delta t = 130$ ms x DM

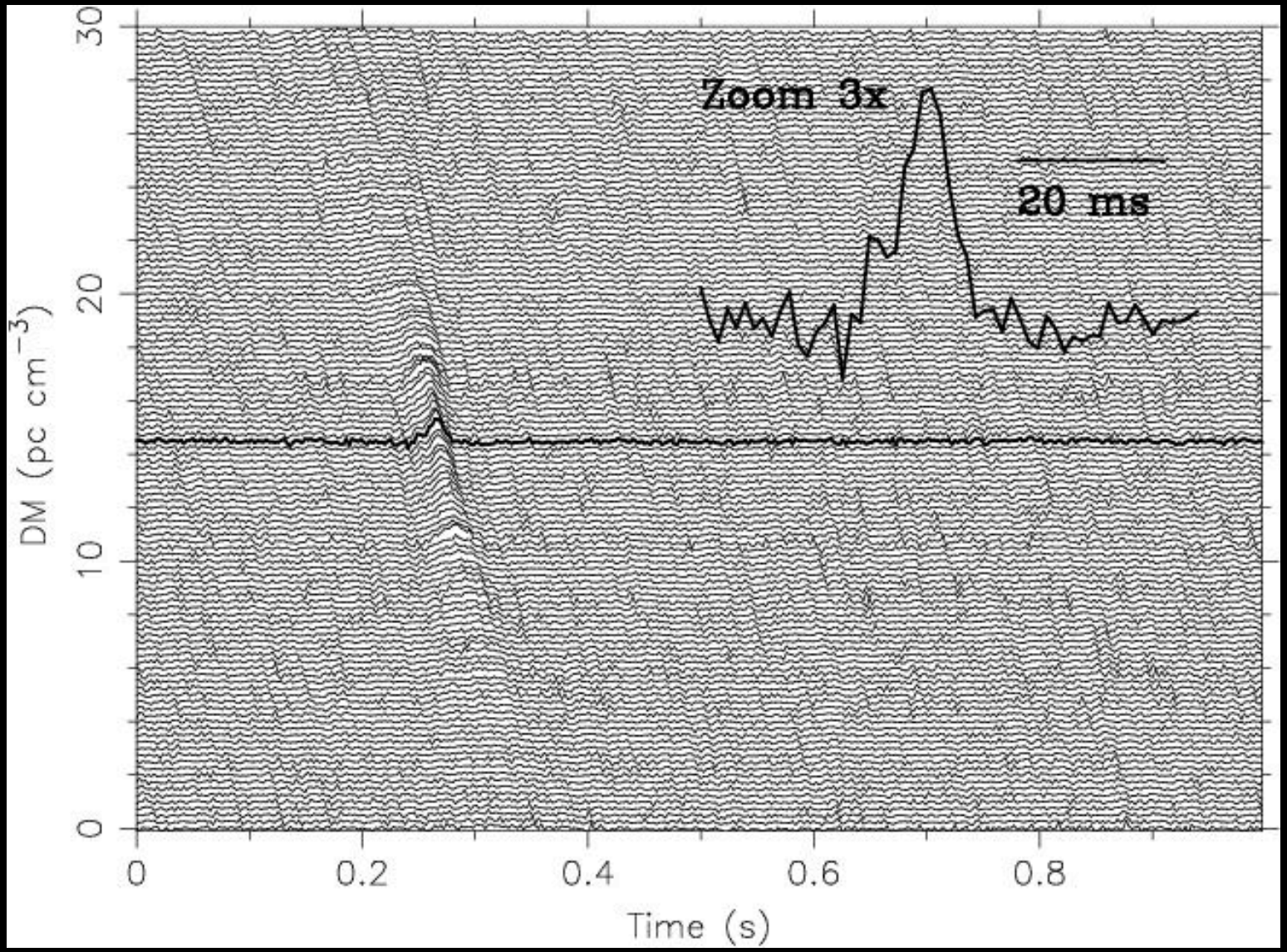
For 200kHz band at 120MHz

$\Delta t = 1$ ms x DM

For pulsar work we want $\Delta t <= 1$ms,

so we must form channels.

Observing: Dedispersion



Observing: Super Station

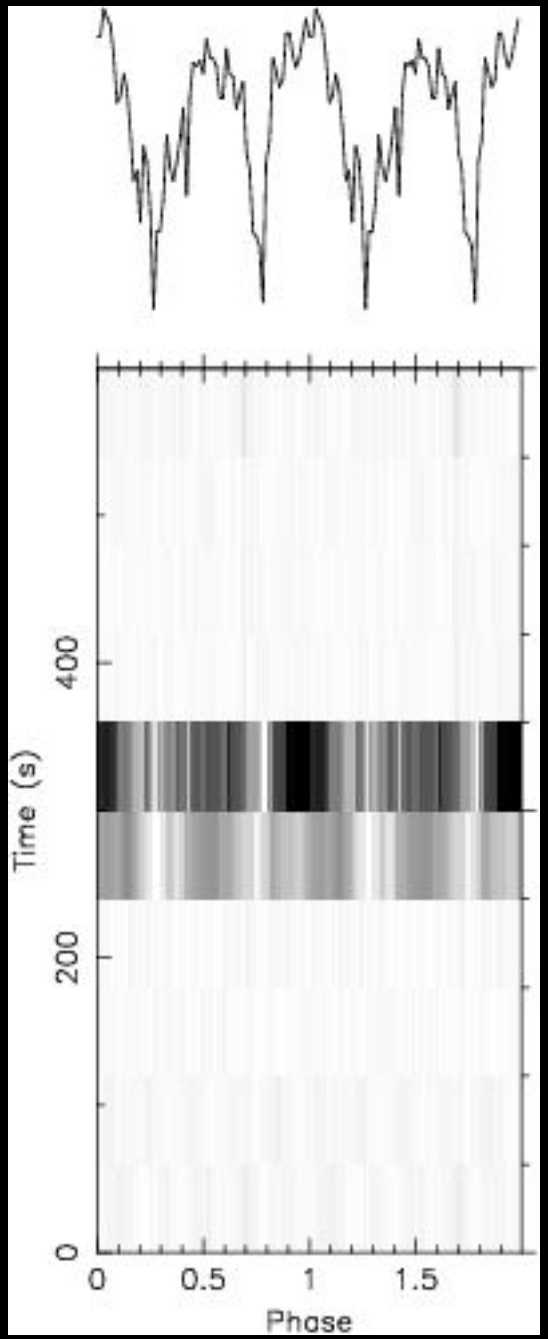
- 12 “half” HBA stations in 350m
  50 “half” HBA stations in whole core with diameters of 35m
  SS has higher “filling factor”
  Field of view of coherently added SS is 100 times smaller than incoherent sum of core stations.

Observing: Super Station

- ...but, comparing figure of merit (A^2 x FoV):

  $M_{SS}/M_{Core}=(144/50)(1/100)=1/34$
  Thus, with 34+ beams, we can do better with the SS!
  Advantages to survey with smaller beam size and shorter pointings.

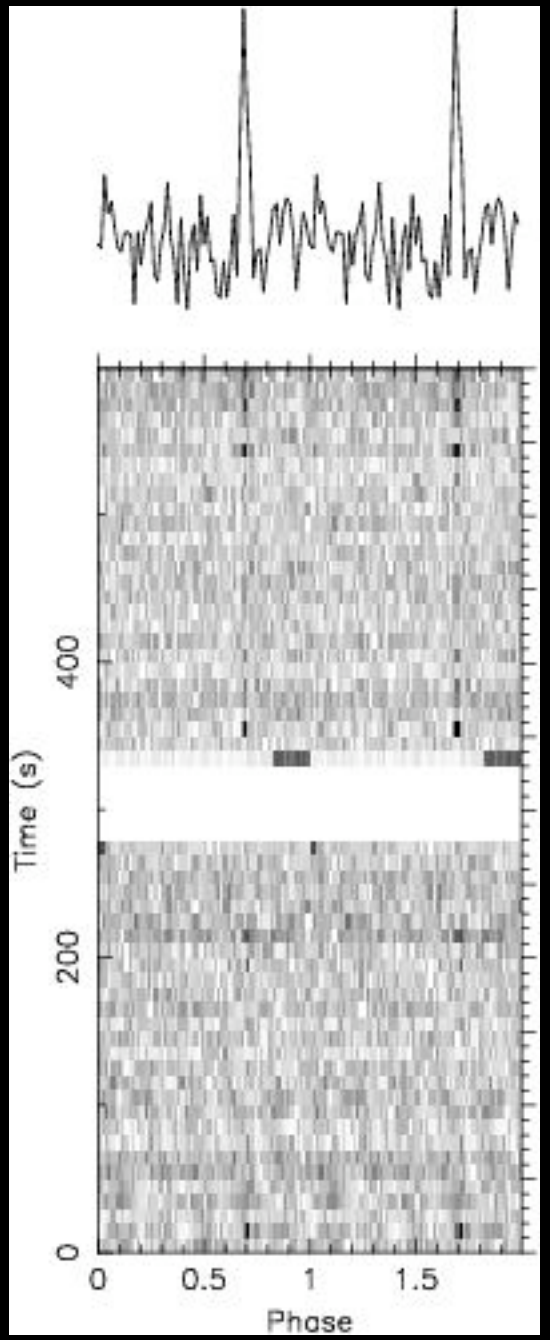
RFI Excision is crucial



P = 1.39s ?
DM = 14.5 pc cm^{-3}

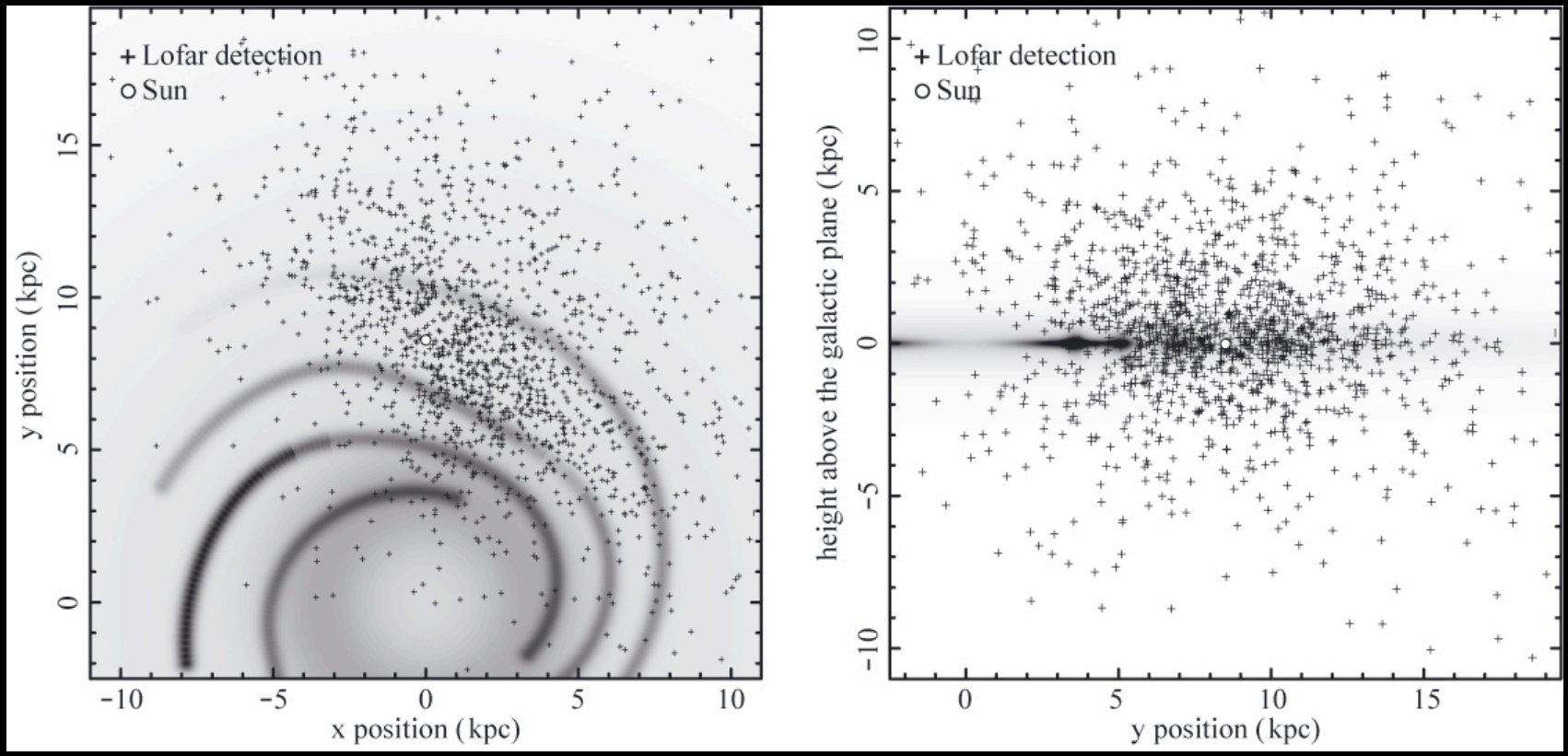
With RFI Excision! --->

<--- No RFI Excision!



LOFAR Pulsar Survey Sims

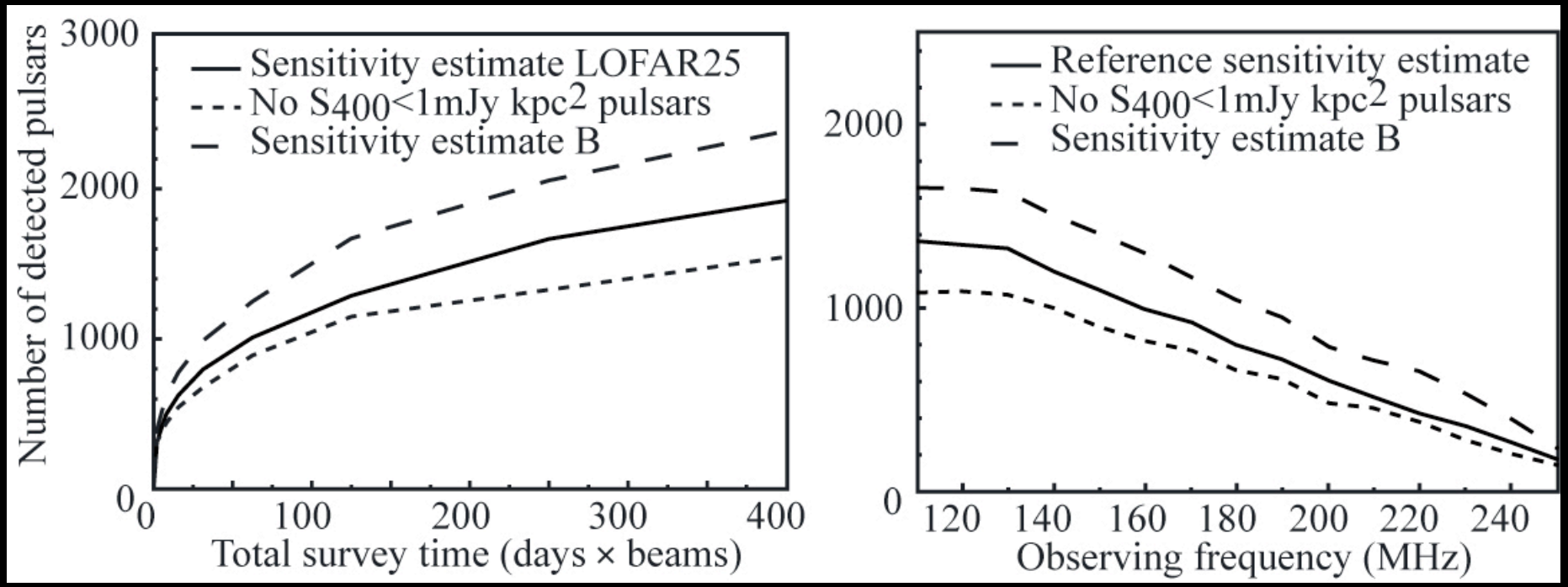
(from Joeri van Leeuwen and Ben Stappers)



Pulsars peak in brightness around 150MHz, but we're limited by scattering. Luminosity law below L_{400} = 1 mJy kpc^2 is uncertain.

LOFAR Pulsar Survey Sims

(from Joeri van Leeuwen and Ben Stappers)

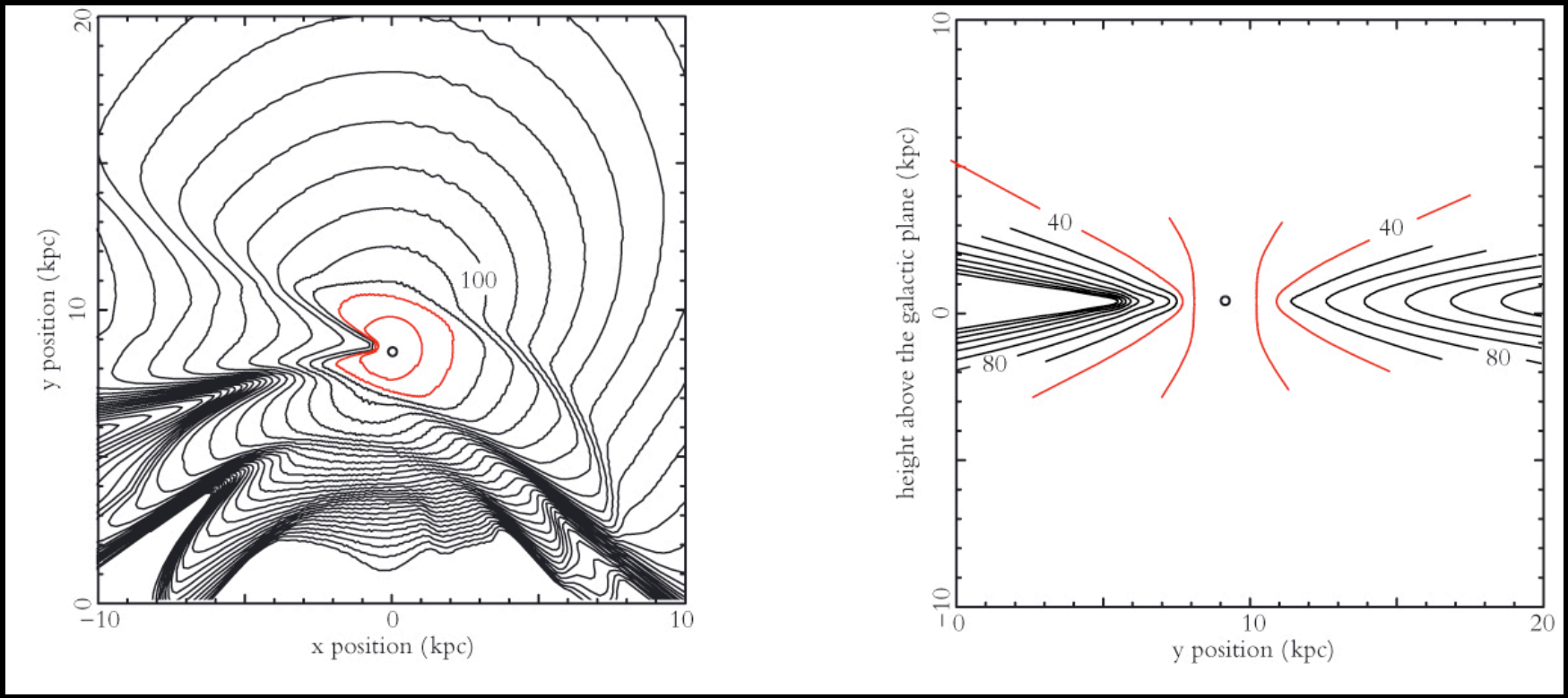


Potential for a 1,000+ new pulsars!

Either map low-luminosity distribution or find all pulsars beamed towards us and within ~1.4 kpc.

LOFAR Survey for ms Bursts

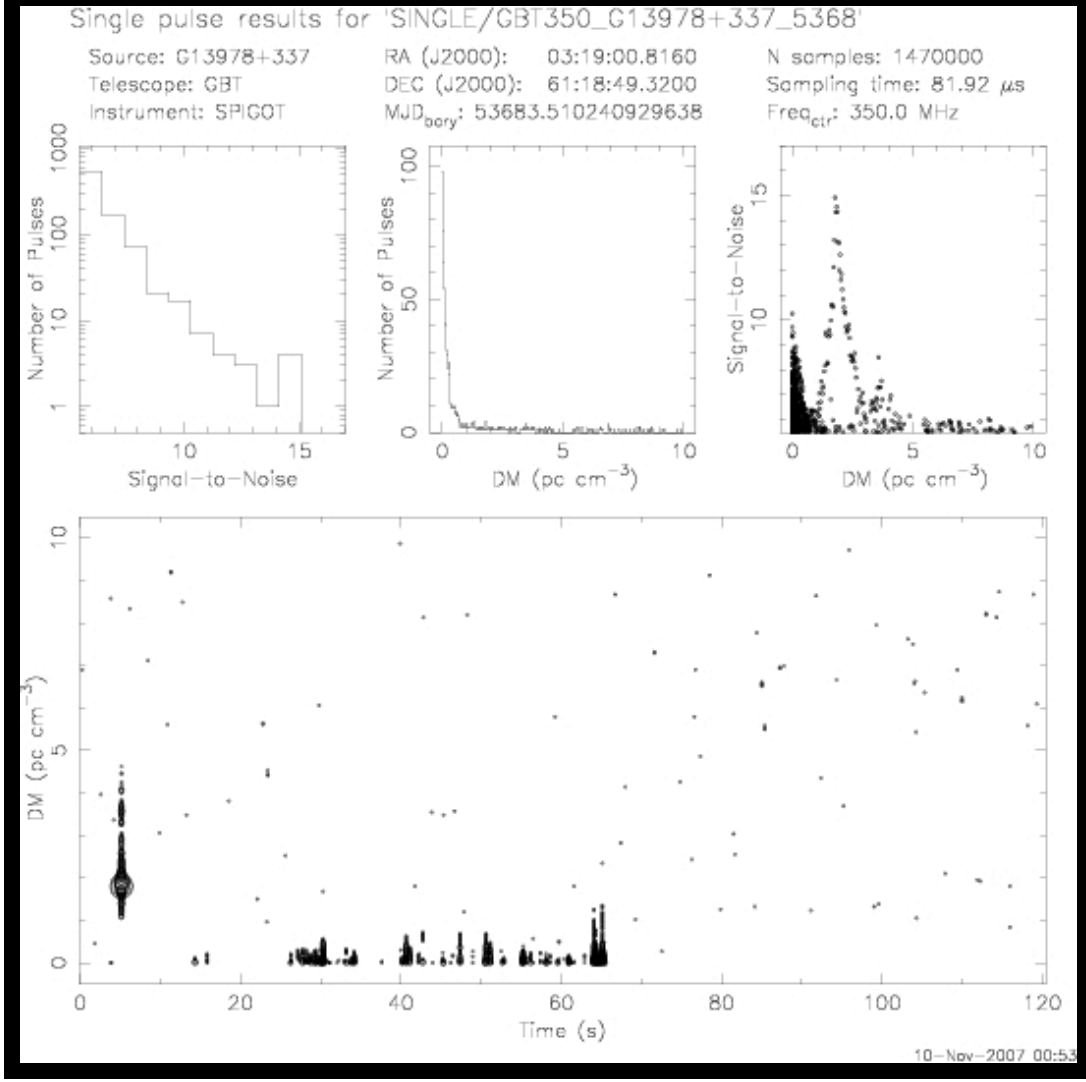
(120-240 MHz)

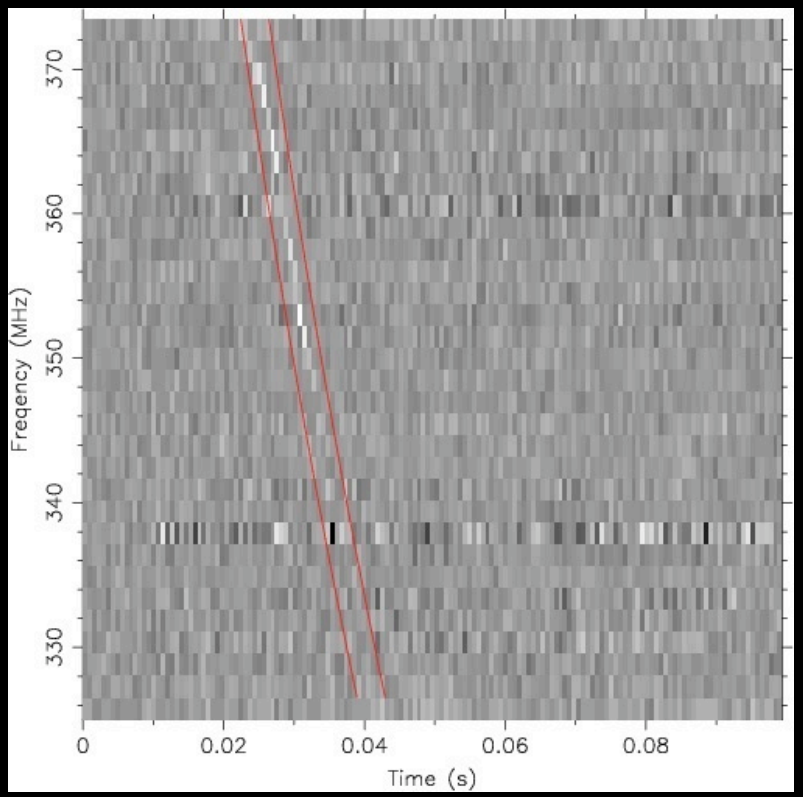


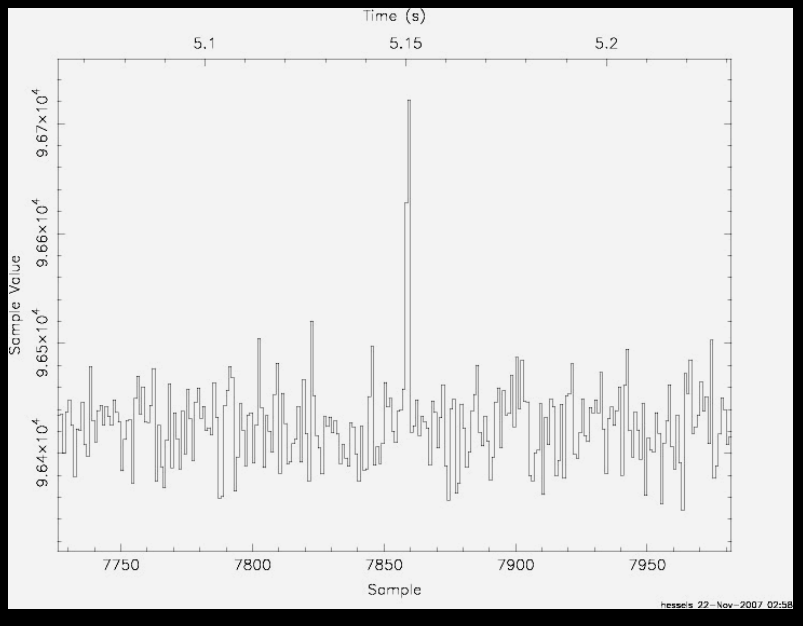
At ~150 MHz, one is limited to d < 2kpc for millisecond bursts in Galaxy.

10,000+ DM trials required!!! *Can't do realtime*.

Very low DM sources:
new DM = 1.8 pc cm^{-3} src







Summary

- LOFAR can find a 1,000+ new pulsars.
  Map out the low-luminosity pulsar distribution.
  Excellent for low-DM sources.
  Census of nearby pulsars (follow-up at other wavelengths).
  Lots of other pulsar science I haven't touched on!!!

RRATs: Rotating Radio Transients

(McLaughlin et al. 2006, Nature, 439, 817)

- Associated with rotating neutron stars.
- Bright pulses from distant pulsars (Weltevrede et al. 2006)?
- 11 found in Parkes Multibean Survey.
- Burst durations: 2 - 30 ms
- Repeat times: 4 min. - 3 hours
- Periodicities: 0.4 - 7 s

PSR J0240+62

- Identified in single pulse search.
- DM ~ 4 pc cm^{-3}
- D ~ 400pc!
- L_{400} ~ 0.2 mJy kpc^2
- *Discovery depends on low observing frequency.*
- Type of source LOFAR will find.