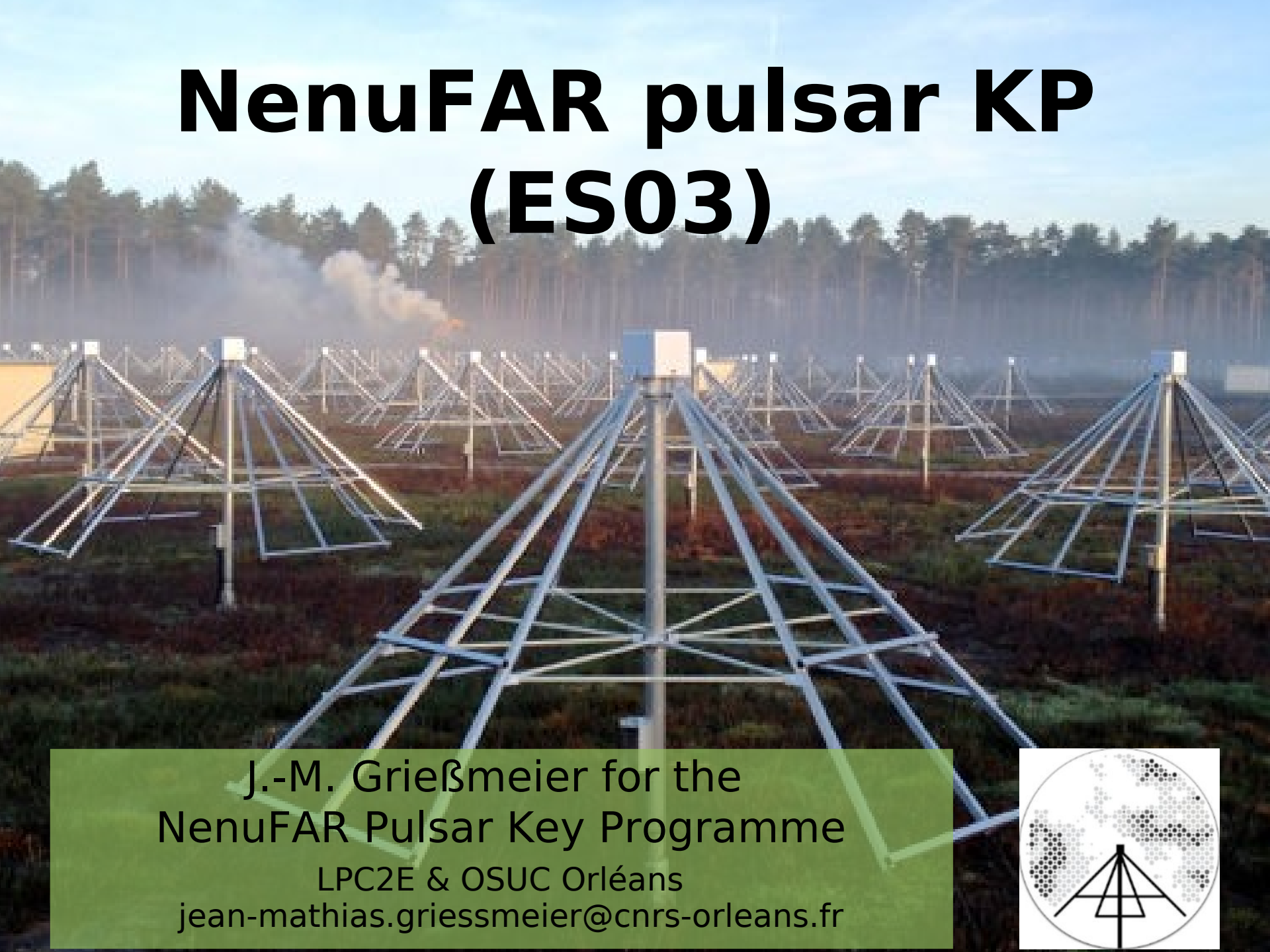
NenuFAR pulsar KP (ES03)



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NenuFAR Pulsar Key Programme
LPC2E & OSUC Orléans
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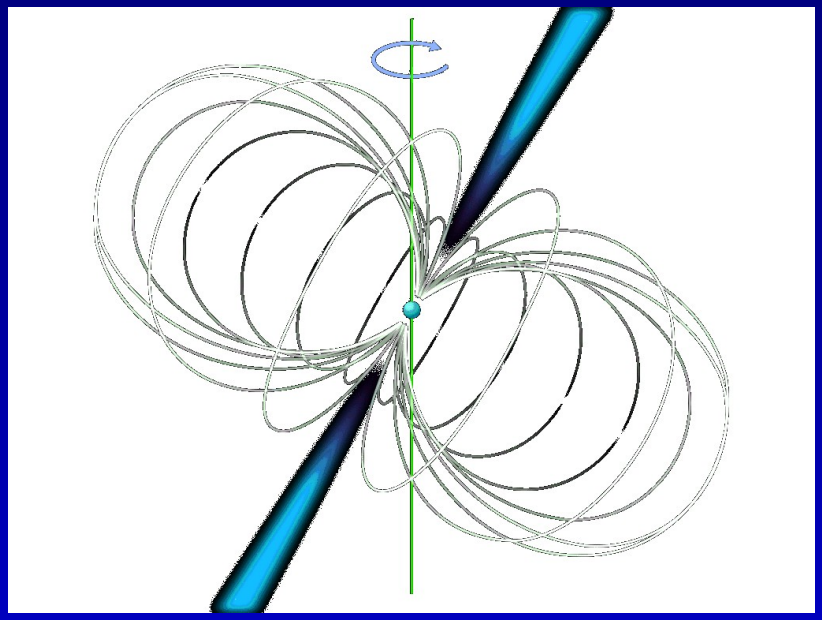
Outline

- KP team
- NenuFAR pulsar hardware + software
- Scientific context
- Observations & first results

KP Team

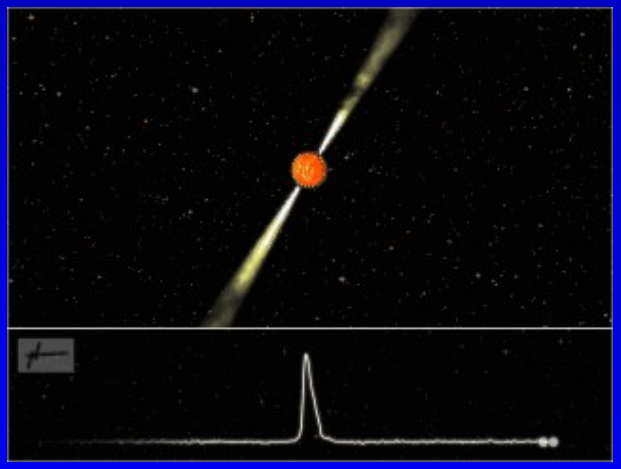
- Jean-Mathias Grießmeier, Gilles Theureau (PIs)
- Anna Bilous, Louis Bondonneau, Mark Brionne, Ismaël Cognard, Gemma Janssen, Julian Donner, Lucas Guillemot, Krishnakumar M.A., James McKee, David McKenna, Michael Kramer, Vlad Kondratiev, Robert Main, Aris Noutsos, Jérôme Petri, Maura Pilia, Andrea Possenti, Macej Serylak, Golam Shaifullah, Caterina Tiburzi, Oleg Ulyanov, Joris Verbiest, Ziwei Wu, Olaf Wucknitz, Serge Yerin, Vyacheslav Zakharenko
- open for new team members!

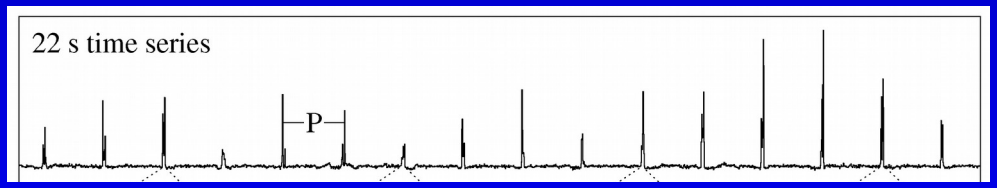
Pulsars



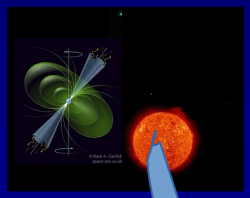
rotating neutron star

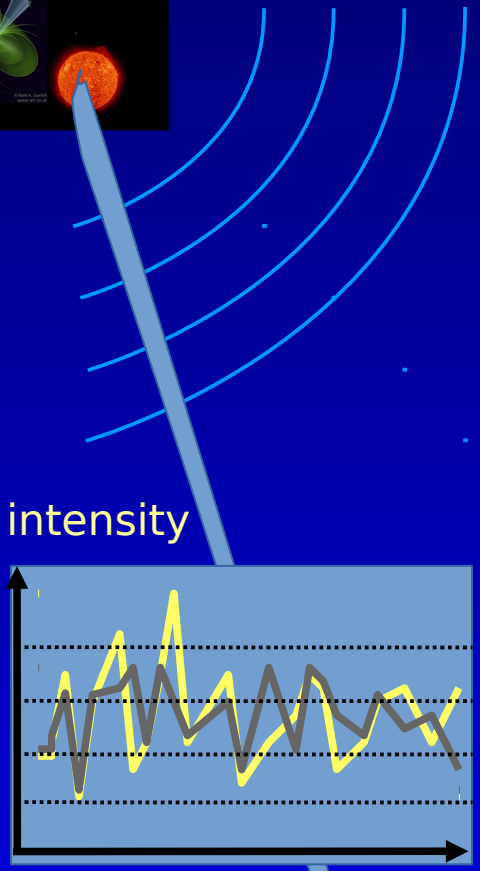
- Mass of ~1.4 M⊙
- Diameter of ~14 km
- Period of rotation ~1 s
- Curvature radiation from magnetic poles → radio beam
- emission is always « on » ; visible 1/rotation « lighthouse effect »
- average pulse ≠ individual pulse

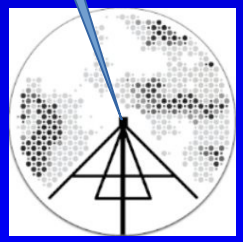




NenuFAR as stand-alone phased array







targets: compact sources
data products: → light-curves
→ dynamic spectra
→ pulsar data

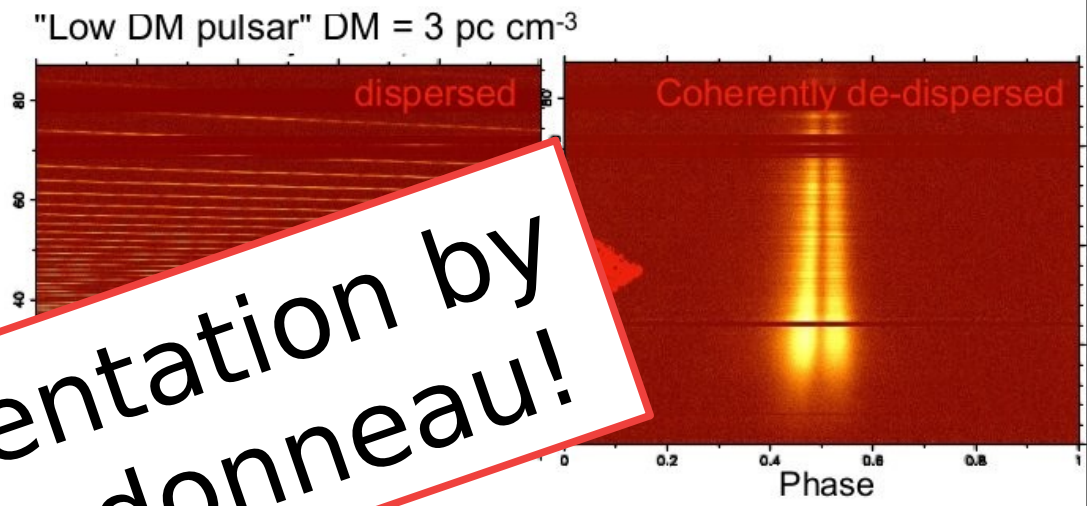
NenuFAR ES1: Cosmic Dawn
NenuFAR ES2: Exoplanets & Stars
NenuFAR ES3: Pulsars
NenuFAR ES4: Transients
NenuFAR ES5: Fast Radio Bursts
NenuFAR ES6: Planetary Lightning
NenuFAR ES7: Jupiter joint studies
NenuFAR ES8: Cluster of galaxies & AGNs
NenuFAR ES9: Cluster Filament & Cosmic Magnetism
NenuFAR ES10: Radio recombination lines
NenuFAR ES11: Sun
NenuFAR ES12: Radio Gamma
NenuFAR ES13: SETI
NenuFAR ES14: Cas A
NenuFAR ES15: Large Scale Background Survey
NenuFAR ES16: Formation of students
NenuFAR ES17: Radio-Amateurs

NenuFAR pulsar hardware

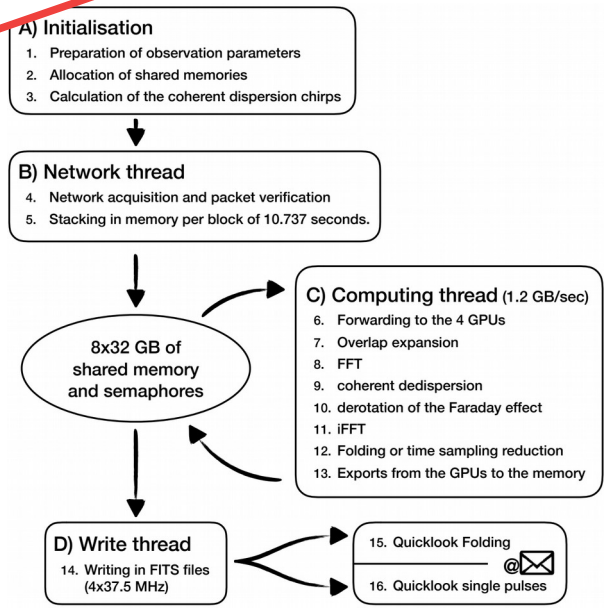
real-time pulsar backend
“LUPPI” (10-85 MHz)

- folding
- coherent de-dispersion
- coherent correction of Faraday rotation (unique to NenuFAR!)

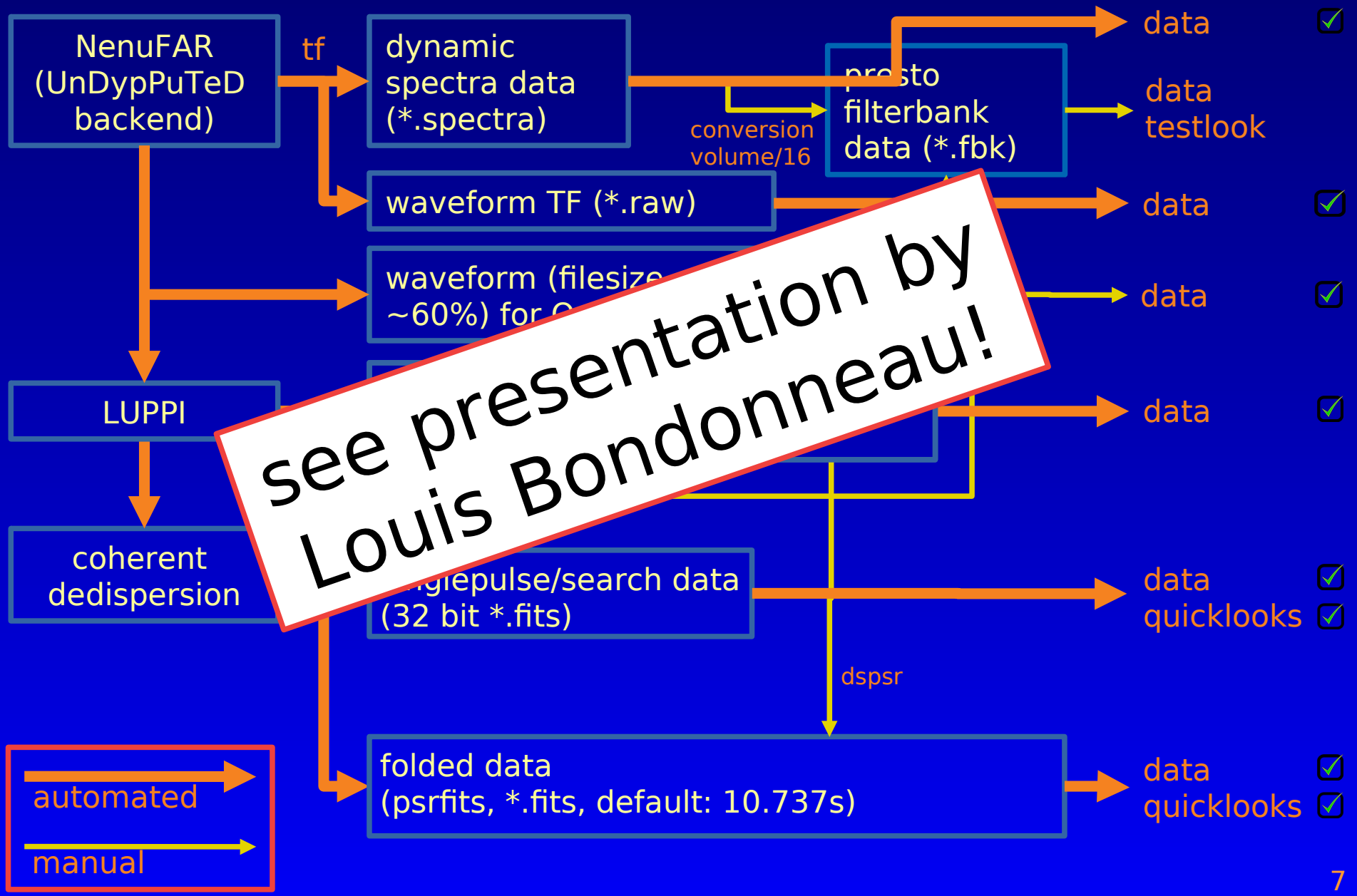
[Bondonnea
Bondonneau



see presentation by Louis Bondonneau!

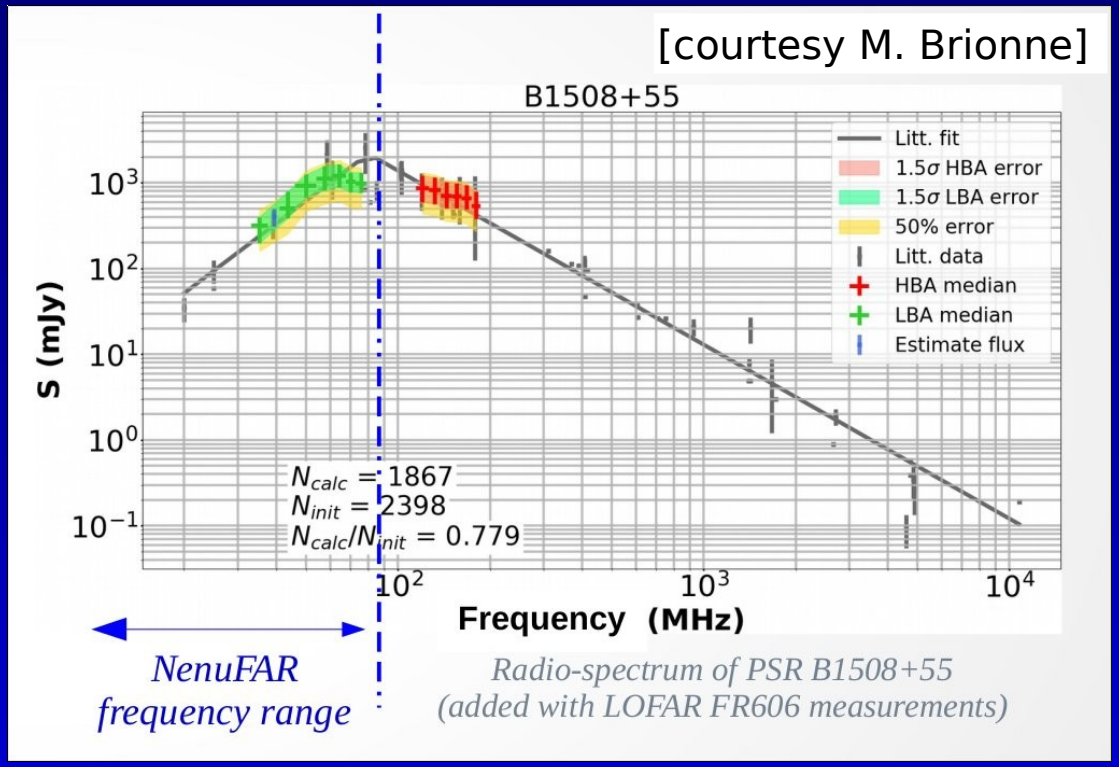


NenuFAR pulsar software



Pulsars at low frequencies

- turnover at 100-140 MHz for many pulsars
- high sky temperature (galactic background)
- strong dispersion, scattering, scintillation, ...



→ difficult to observe
→ high precision on DM, scattering, ...
→ RFM model: study high altitudes & large volume in magnetosphere
→ test emission models, ...

NenuFAR pulsars projects

project	targets	progress
Blind survey	DEC > 39°	observations : ongoing (1st pass observed) analysis: ongoing
Census (including LOTAAS + low DEC)	DEC > -20°, DM < 100	observations : done analysis: ongoing (187 pulsars detected) Bondonneau et al. in prep.
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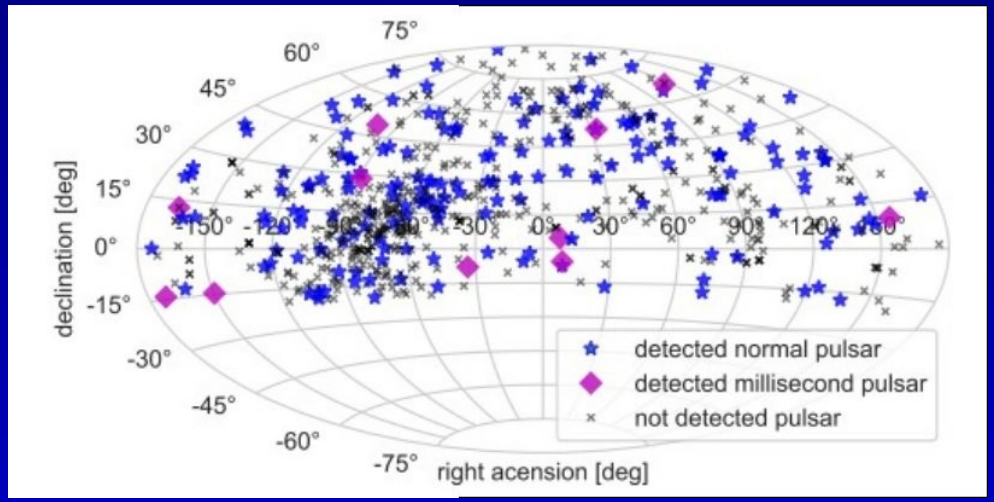
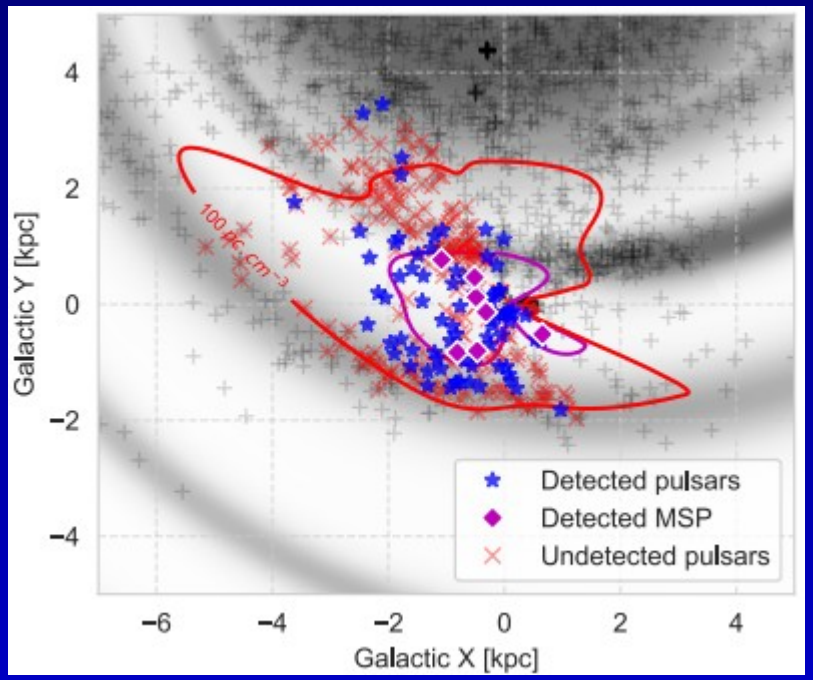
Slow pulsar	J0250+5854; simult. obs. with UTR planned	observations : done/pending analysis: done/pending Agar et al. 2021
Solar Wind	16 pulsars observed close to solar conjunction since 07/2019; two dense campaigns for J1022+1001	observations : ongoing analysis: ongoing for J1022+1001 Tiburzi et al. submitted
RRATs	phase 1: 28 sources (CHIME, GBT and Pushchino sources), 60-90 minutes each. Aim: detection. Can be extended to the study of spectral energy distribution of single pulses	observations : ongoing analysis: ongoing
VLBI	observations of B1508+55 every 6-7 weeks, simultaneously with LOFAR	observations : ongoing until 2021-12 analysis: pending

- regular NenuFAR observations since 07/2019
- some observations during commissioning)
- >3000 observations (~1000h)
- 15 projects
- NenuFAR alone
- with other radio-telescopes

Pulsar census

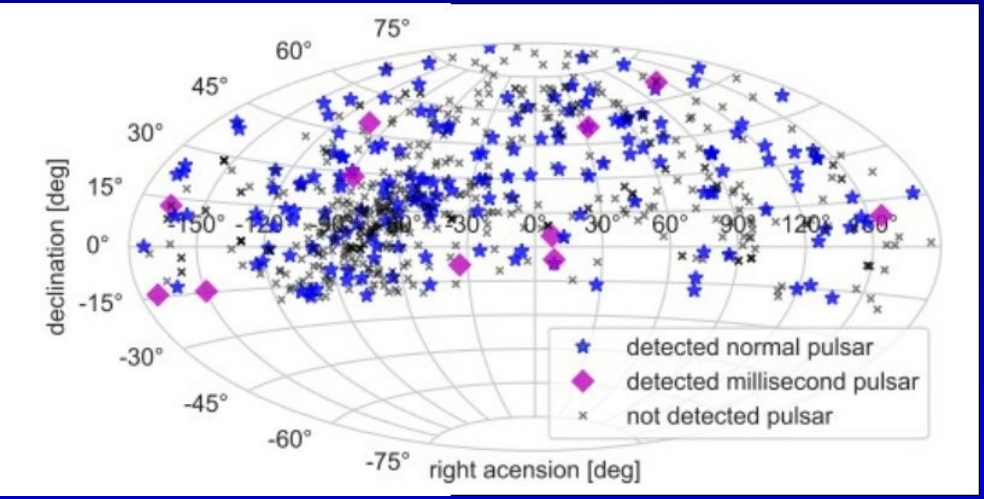


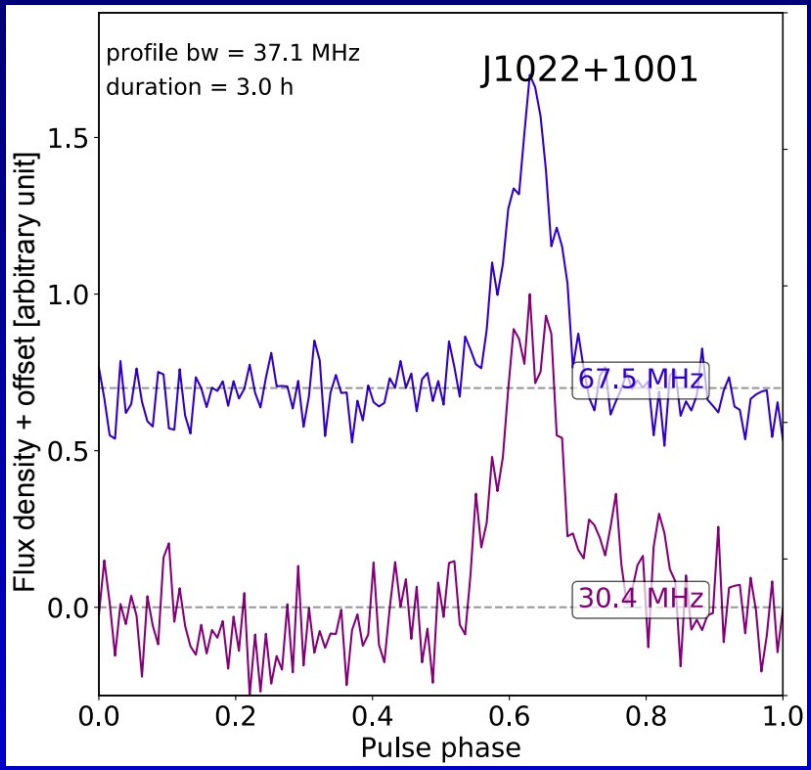


- observation of 711 pulsars known at higher radio frequencies
- DEC > -20°, DM < 100 pc/cm^3
- 184 pulsar detected (~100 for the first time <100 MHz)

- [Bondonneau et al. in prep.]

Pulsar census & MSPs





- observation of 711 pulsars known at higher radio frequencies
- DEC > -20°, DM < 100 pc/cm^3
- 184 pulsar detected (~100 for the first time <100 MHz)
- 11 MSPs detected (7 for the first time <100 MHz)
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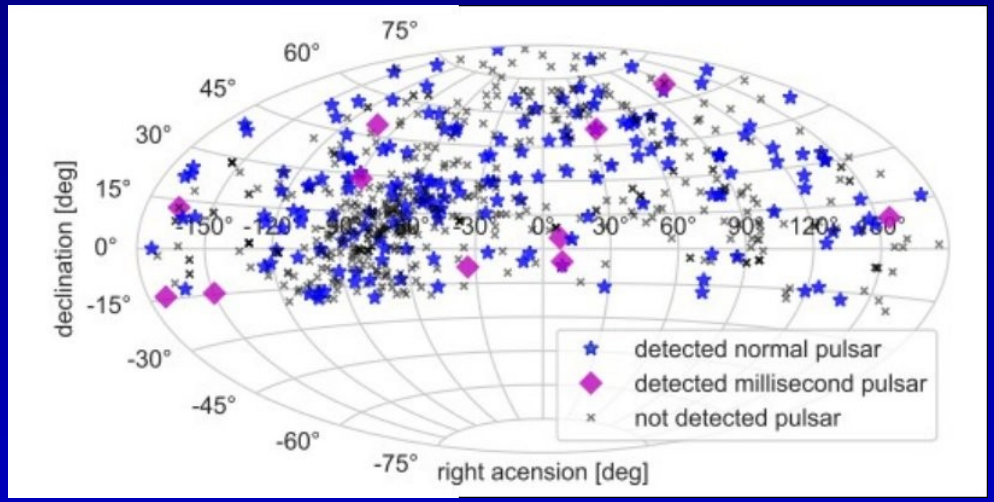
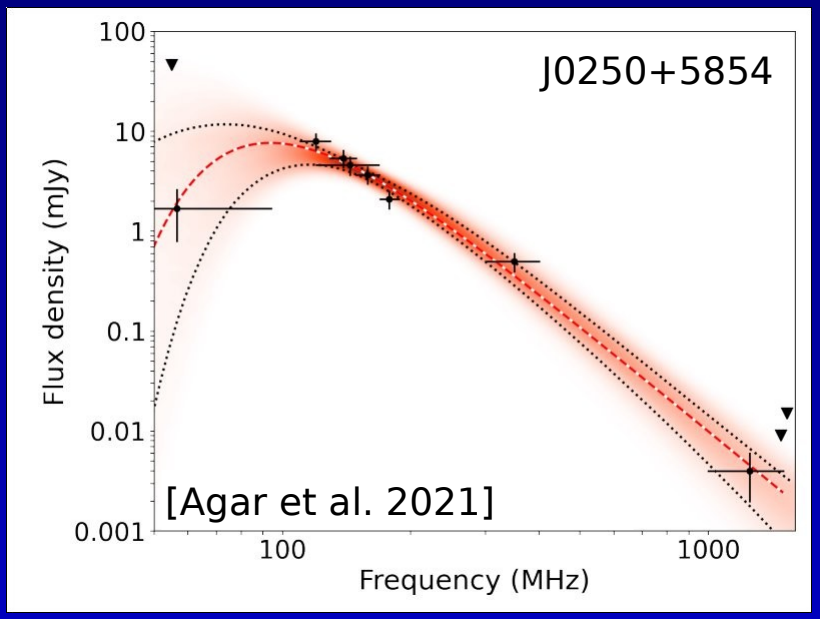
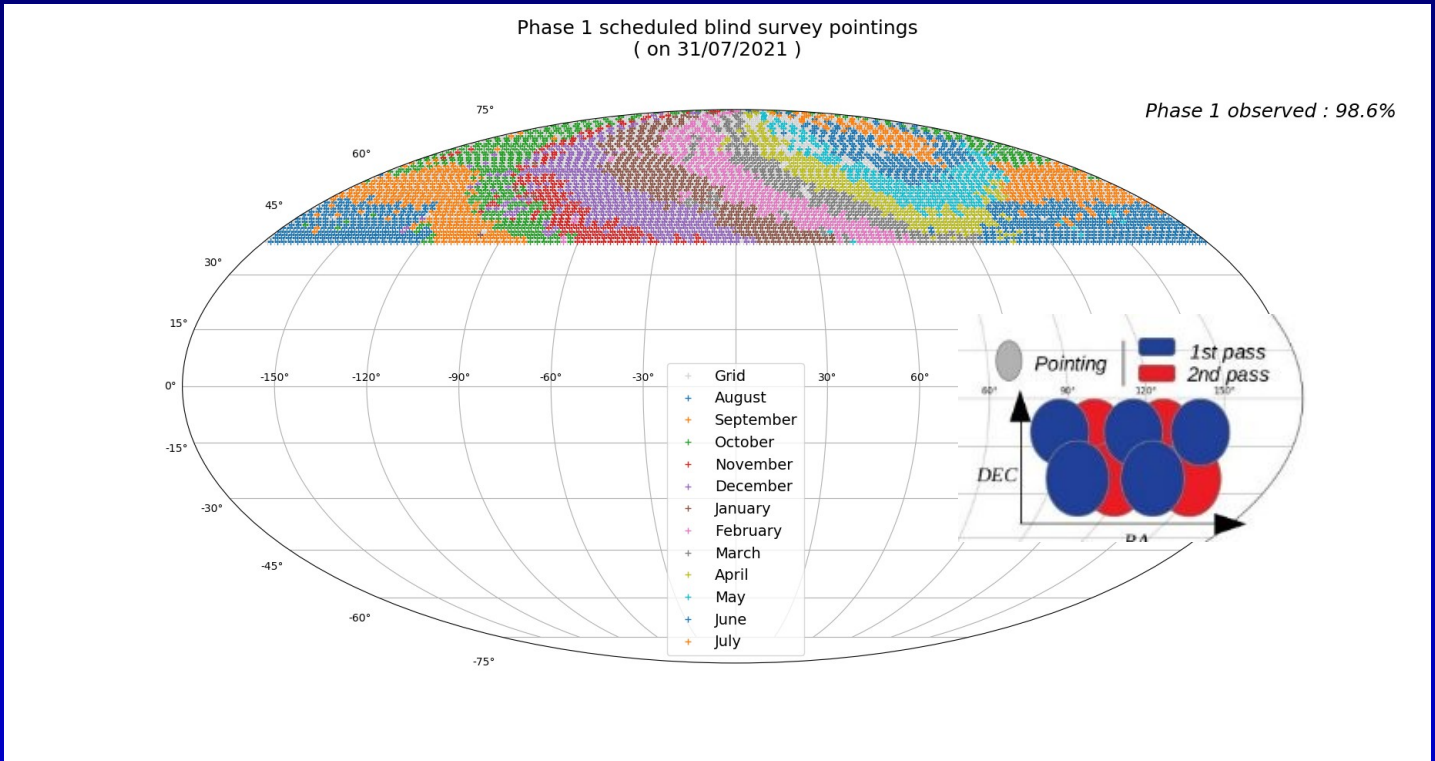
Pulsar census & MSPs





- observation of 711 pulsars known at higher radio frequencies
- DEC > -20°, DM < 100 pc/cm^3
- 184 pulsar detected (~100 for the first time <100 MHz)
- 11 MSPs detected (7 for the first time <100 MHz)
- [Bondonneau et al. in prep.]
- study of pulsar spectra, turnover, … (e.g. [Agar et al. 2021])

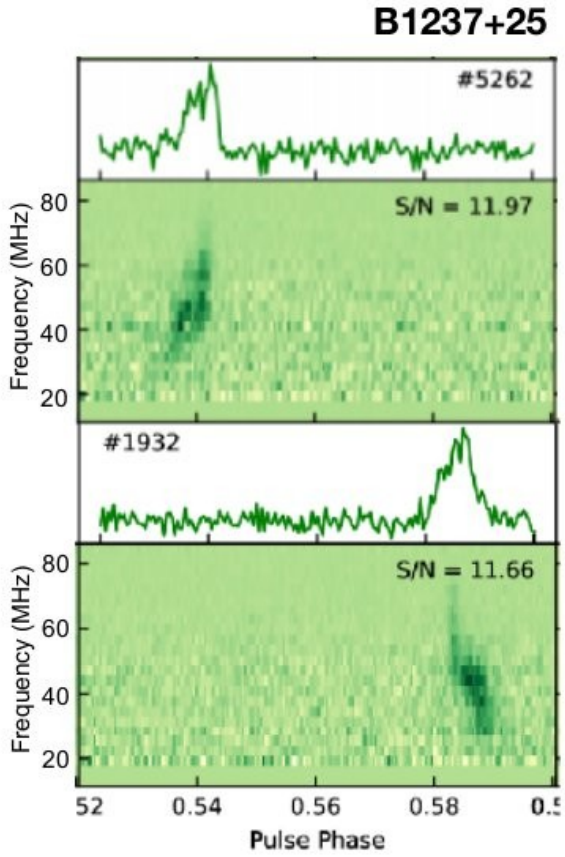
Pulsar blind survey



- survey of north polar cap (DEC > 39°)
- 7691 pointings
- observations since August 2020 (1st pass complete)
- search space: DM < 100 pc/cm^3 & P > 80 ms
- expect slow pulsars [Tan et al. 2018]
- [Brionne et al. in prep.]

Single pulses & giant pulses

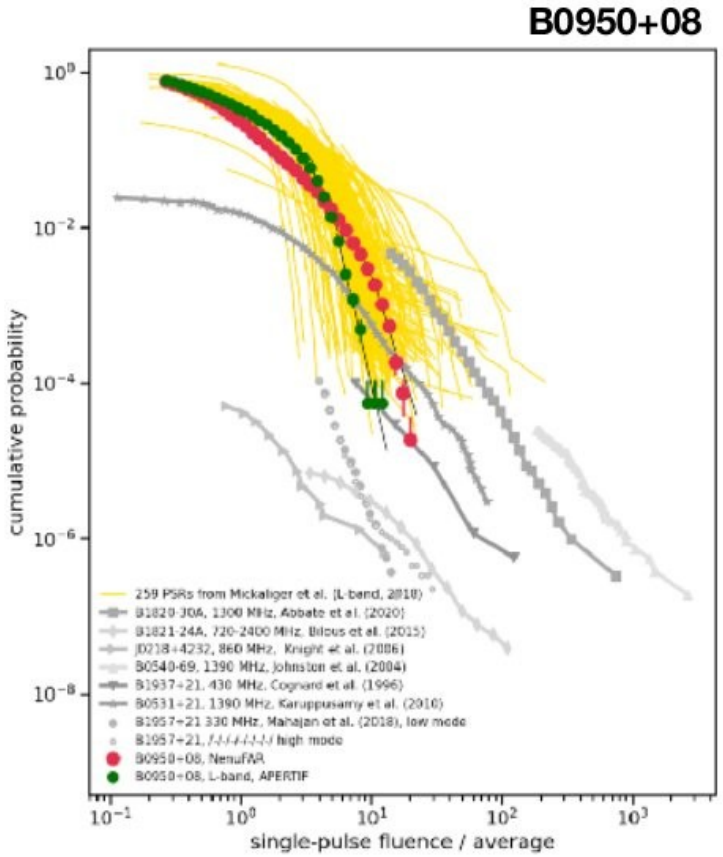
Single pulses



[Kondratiev et al. in prep.]

Frequency evolution of single pulses at low frequency: Radius-to-frequency mapping

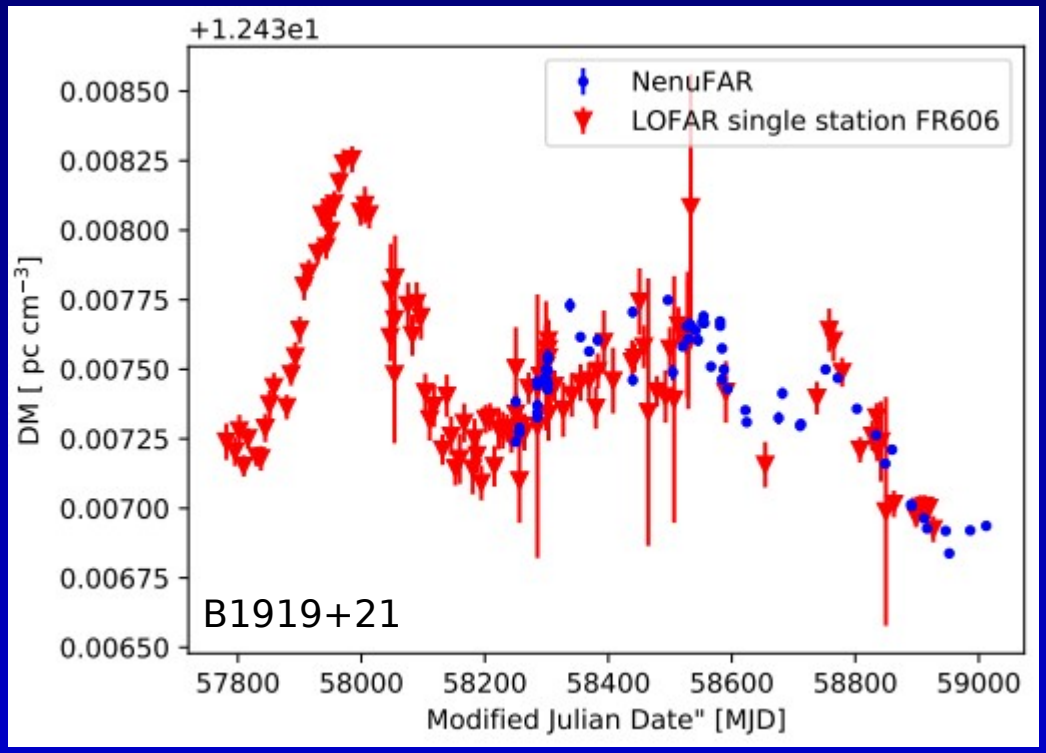
Study of giant pulses



[Bilous et al. in press]

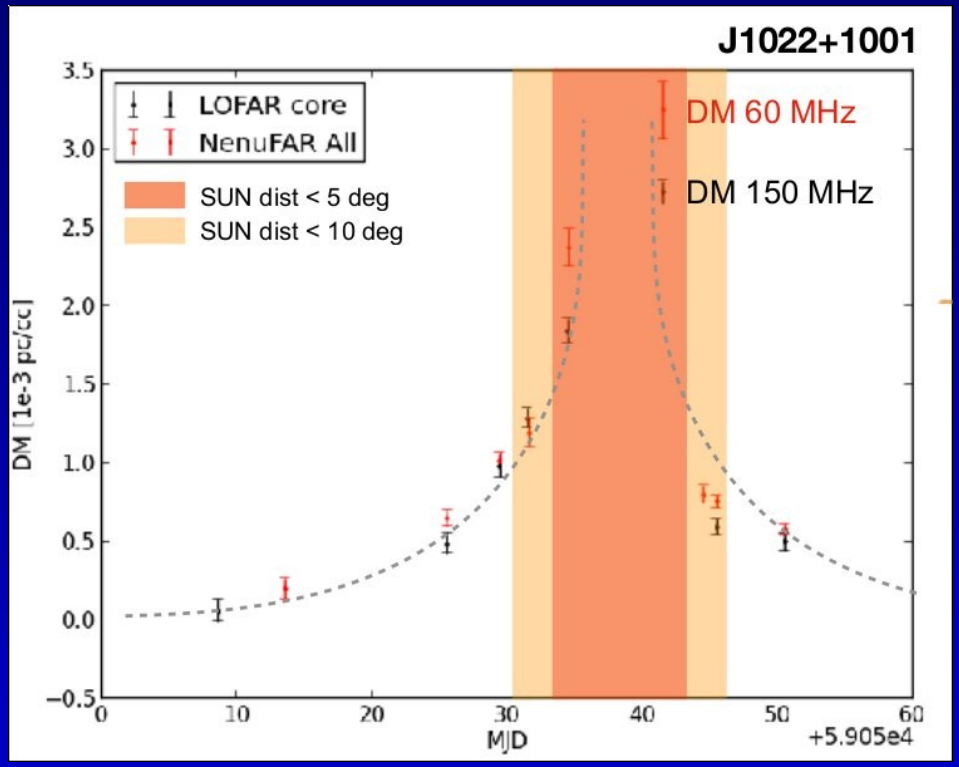
Characterisation of single pulses from B0950+08.

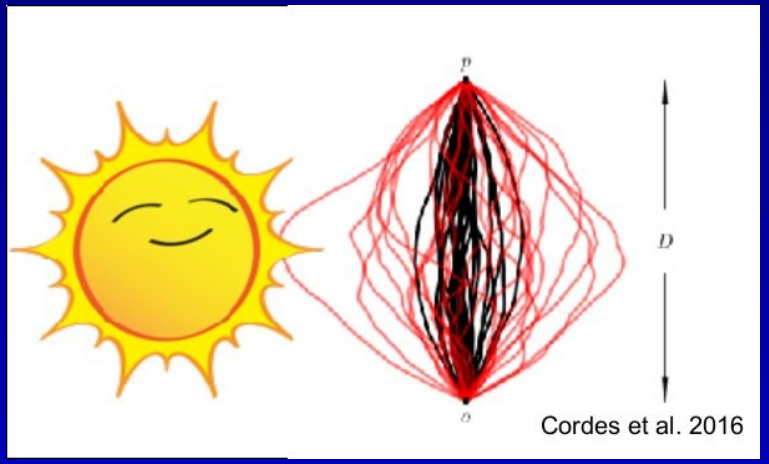
Ionized interstellar medium



- high sensitivity & low frequencies
- → precision of 10^{-4} or even 10^{-5} pc/cm^3 on DM
- [Bondonneau et al. 2021]
- → DM monitoring, statistics of DM events
- → improve timing (e.g. for pulsar timing arrays)
- long-term project!

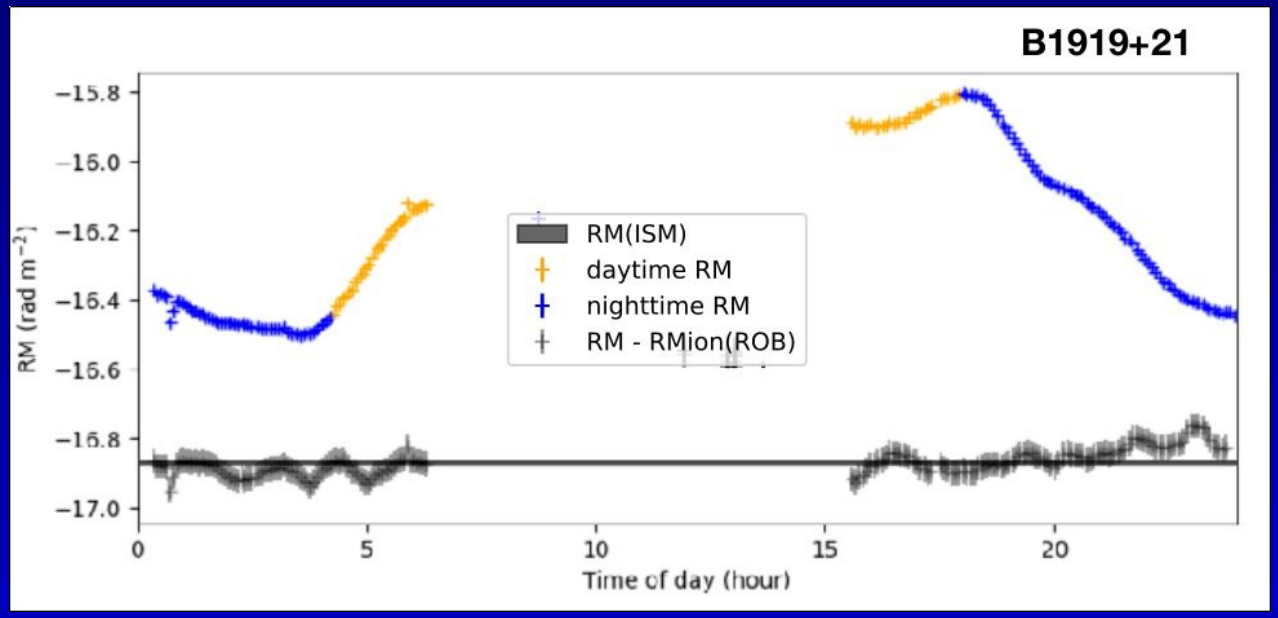
Heliosphere





- DM contribution of solar wind
- observation near solar conjunction
- wider signal path at low frequencies [Cordes et al. 2016]
- → expect frequency-dependent DM
- different DM observed LOFAR-HBA ↔ NenuFAR
  → more observations taken 2021/08-2021/09, under analysis
- [Tiburzi et al. submitted; Shaifullah et al. in prep.]

Terrestrial ionosphere



- high sensitivity, coherent Faraday correction, low frequencies
- → precision of 10^{-5} to 10^{-4} rad/m^2 on RM
- 100 times more accurate than existing ionospheric models
- → can be used to compare ionospheric models
- [Bondonneau et al. in prep.]

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[Brionne et al. in prep.]

[Bondonneau et al. in prep.]

[Bondonneau et al. 2021; Bondonneau et al. in prep.]

[Bilous et al. in press; Kondratiev et al. in prep.]

[Agar et al. 2021]

[Tiburzi et al. submitted; Shaifullah et al. in prep.]

… and more in preparation!

monitoring campaign
- spectra
- DM monitoring

scintillation studies
- monitoring
- test of scintillation laws

globular clusters
- population

single pulses
- nulling
- mode switching
- drifting subpulses

VLBI
- scintillation/pulse echoes

polarisation
- polarisation fraction
- profiles