Catching super-giant pulses from nearby galaxies at low frequencies – rates and implication for faint radio bursts

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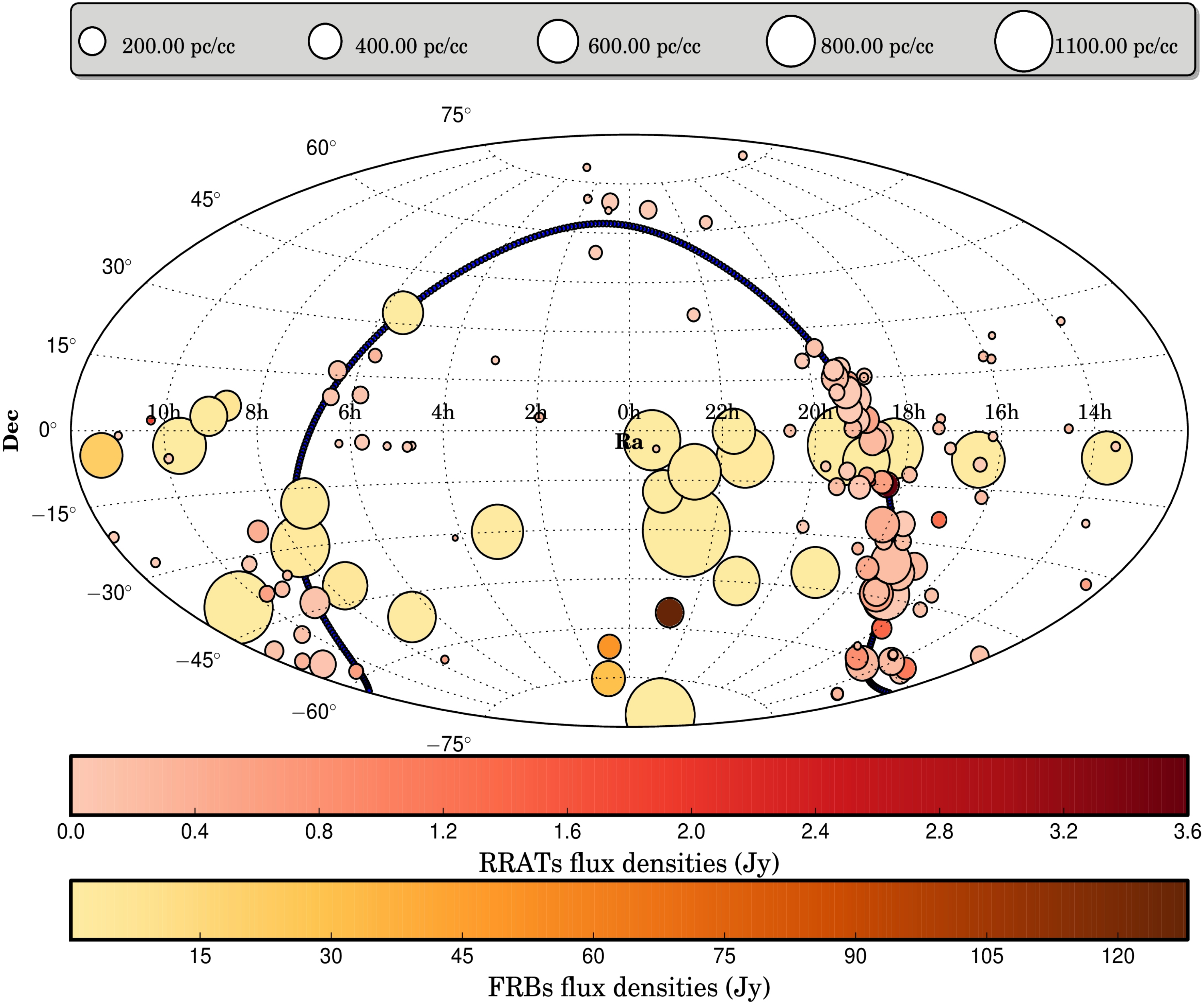
Outline

- Why search in nearby galaxies?
- Why low frequency observations?
- Observations of the Crab Pulsar with LOFAR
- Rates and implication for faint radio bursts

The Radio Pulse Zoo

- Radio pulsars
  - stable rotators, highly periodic
  - more than 2500 known in our Galaxy
- RRATs
  - emit sporadic, single-DM pulses
  - more than 100 known in our Galaxy
- FRBs
  - mostly isolated bursts, 30 published so far
  - one (FRB121102) is known to repeat and has milliarcsec-resolved host galaxy ⇒ extragalactic searches in nearby galaxies?
  - one (FRB131104) appeared in the direction of a galaxy ⇒ extragalactic searches in nearby galaxies?



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Past surveys in Local Group

- Observed nearby galaxies
  - NGCs, ICs, DWs, Leos, Ands, M31, M33, M81, M82
- Covered distances
  - from tens of kpcs up to tens of Mpcs
- Telescopes
  - Arecibo, Parkes, GBT, WSRT & LOFAR
- Explored frequency range
  - 150 – 1440 MHz

Detections only in the Small and Large Magellanic Clouds (Crawford et al. 2001; Ridley et al. 2013)

Why LOFAR?

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- Frequency range (110-190 MHz) ⇒ the expected flux density peak, before turnover

- Large bandwidth (30-80 MHz), high core gain (2-4 K/Jy) ⇒ higher sensitivity

- Multi-beaming option ⇒ covers entire galaxy, gets improved localization, reduces RFI contamination

Why LOFAR?

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- The high system temperature (600-800 K)

- Dispersion (δDM_{max} ~ 0.03 s) and scattering ($\tau_{sc,NE2001}$ ~ 1.37 ms) degrade the inherently sharp pulsar peaks

Andromeda galaxy / M31

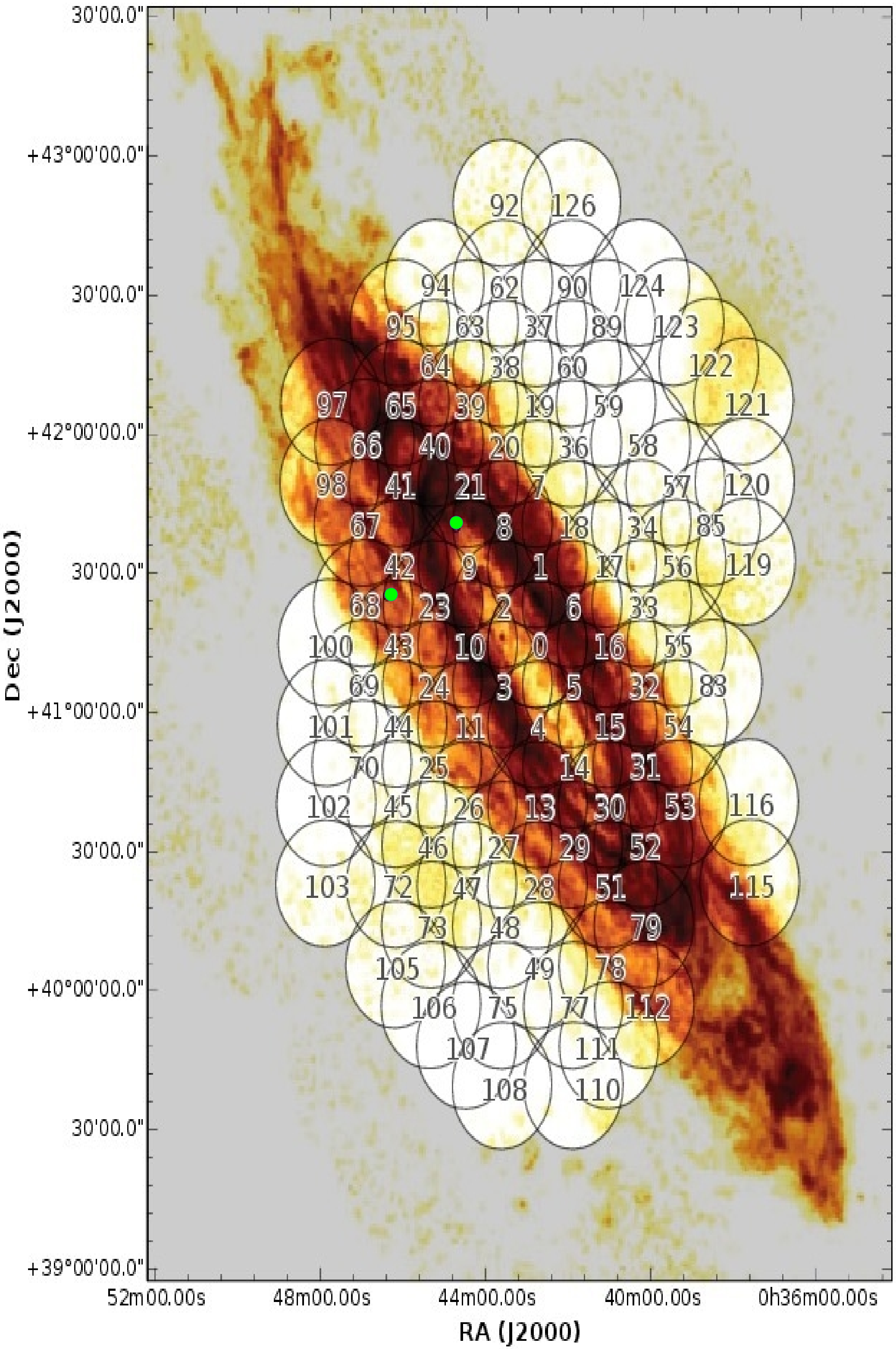
- Distance to the galaxy: 785 ± 25 kpc
- Angular diameter: 178′ × 63′
- Galactic DM contribution towards M31: 60-70 pc/cc
- Star formation rate ~3 times lower than for MW
- $M_{M31} / M_{MW} = 1.55$
- similar (poor) metallicity and H II star-forming regions
- $SNR_{M31} / SNR_{MW} = 0.5$

(Sasaki et al., 2012, Lee & Lee 2014a)

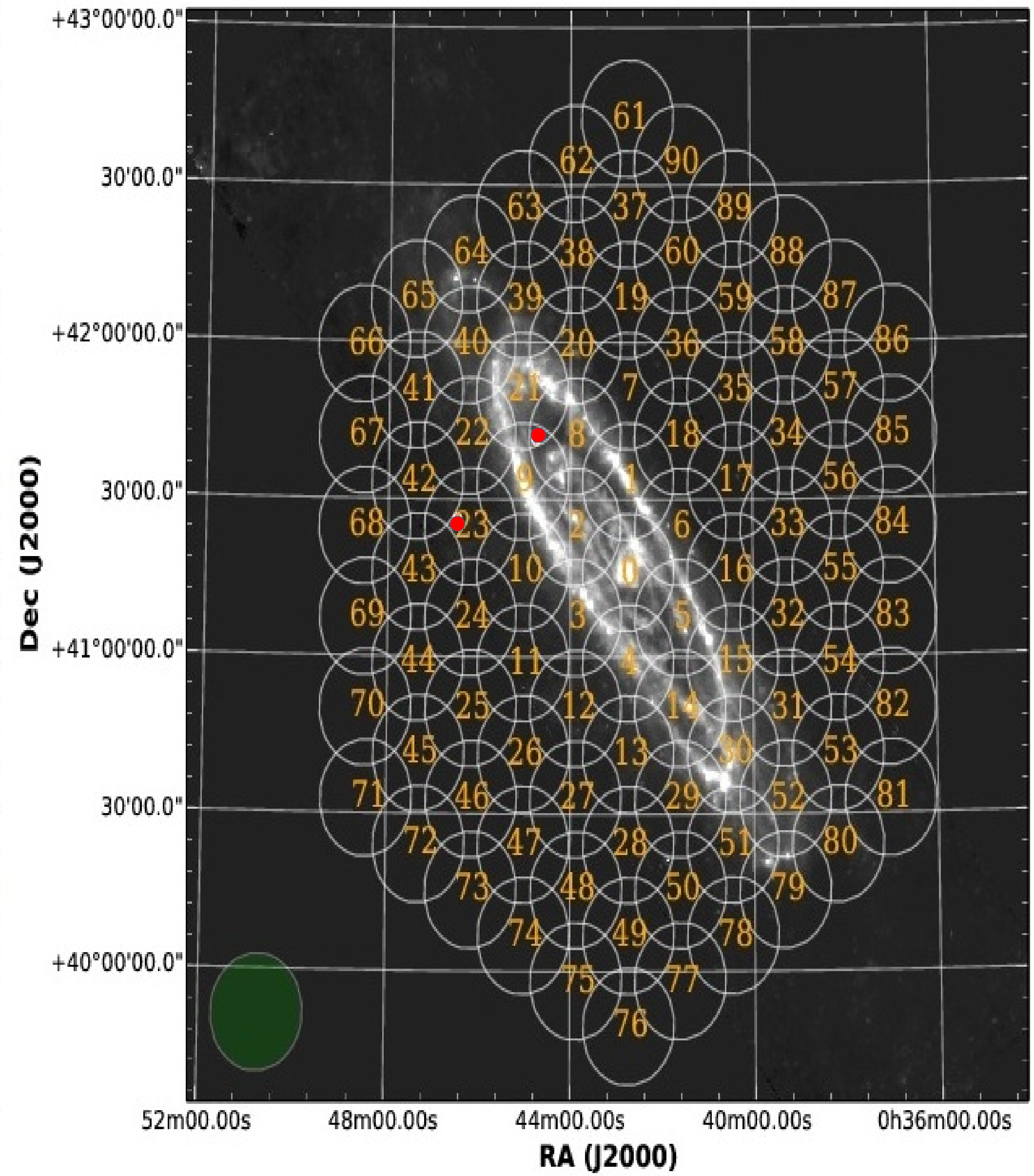
Observations and data analysis

Parameter	Value	
Obs. date	Sept 18, 2011	Oct 1, 2014
Number of TABs	102	91
Central frequency	150 MHz	
Bandwidth	30 MHz	80 MHz
No frequency channels	2400	6400
Sampling time	2600 μs	650 μs
Integration	3600 s	14400 s
TAB resolution	0.25 deg	

DM_{max} = 1000 – 2500 pc/cc ⇒ huge DM_{IGM} uncertainties + extragalactic FRBs



Tied-array beam setups



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PS / SPS results

- No definitive pulsar / RRAT candidates found
  - $T_{sys} = (8.3 \pm 1.6) \times 10^2$ K
  - G = 1.4 ± 0.7 K/Jy
- For W/P = 10% and S/N = 10σ
  - $S_{min,ps} = 1.3 \pm 0.7$ mJy
  - $S_{min,sps} = 15 \pm 8$ Jy

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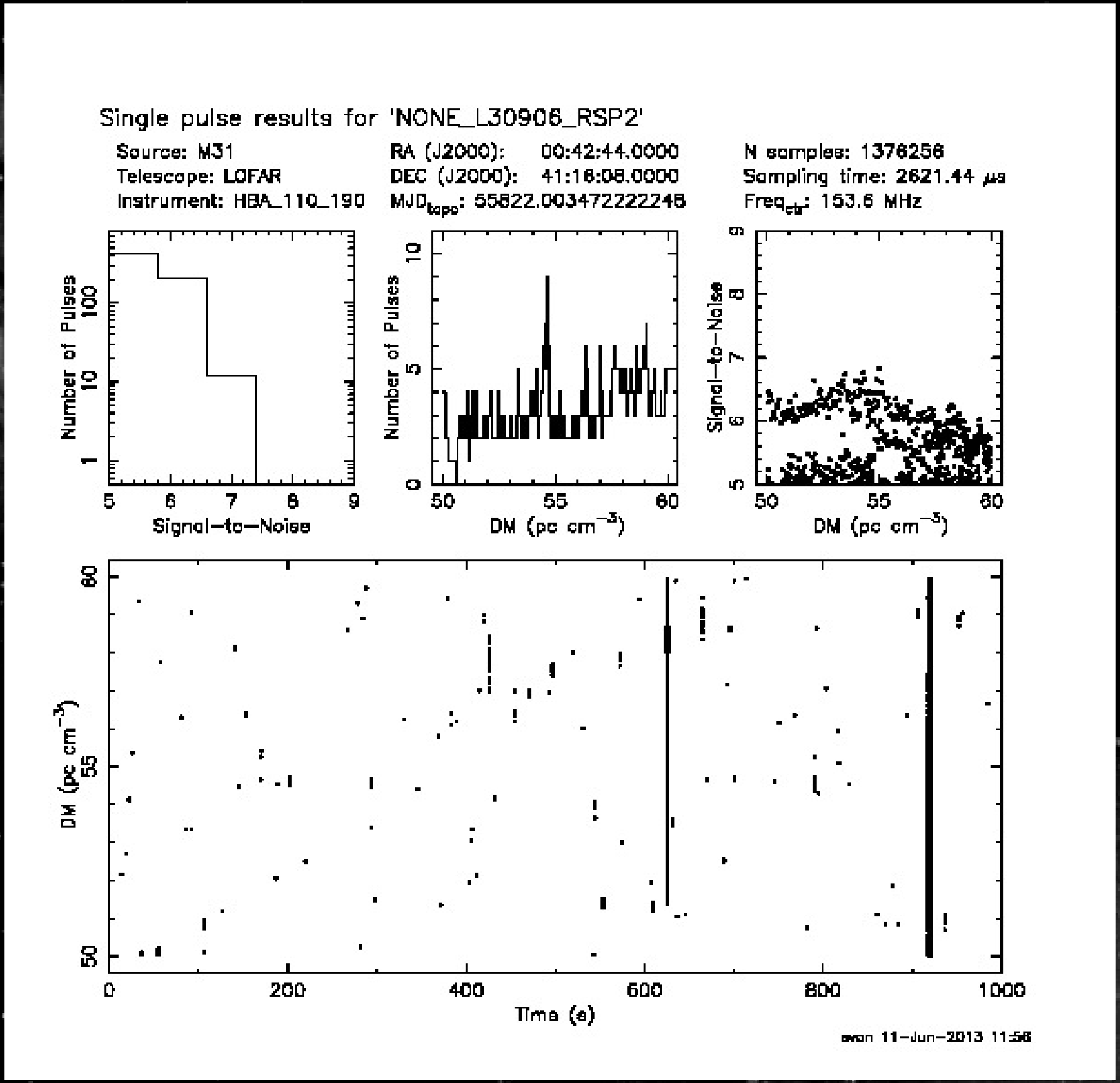
For J1644–4559
(S_{1400} = 296.4 mJy; d = 4.5 kpc)
$S_{150,Galaxy} \sim 6.7$ Jy ($\alpha = -1.4$);
$S_{150,M31} \sim 0.2$ mJy



8 single pulses at DM=54.7 pc/cc during first 1000 seconds of 2011 observation

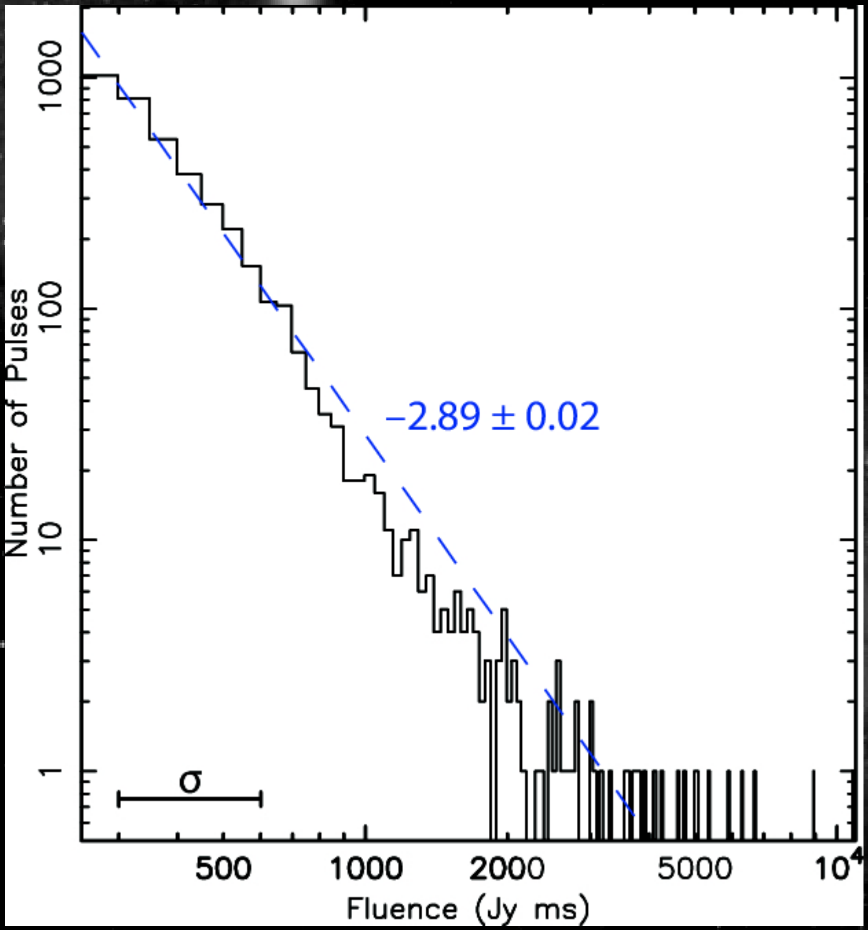
The Crab pulsar at LOFAR frequencies

- Main goals
  - Build the pulse flux density distribution N(S)
  - Fit GP distribution with a power law and get its index
  - Estimate how long we should observe to get extremely bright / super-giant Crab pulses
  - Extrapolate this rate to M31

The Crab pulsar at LOFAR frequencies

- Frequency range
  - 20 MHz – 8.8 GHz
- Telescopes
  - LWA, Algonquin, WSRT, MWA, GBT, Arecibo, Kalyazin, Parkes, ATCA, LOFAR?
- Total integration
  - from 15 min up to 160 hrs
- S/N threshold
  - from 12σ down to 3σ
- PL index (α): $N_{GP} \propto S^{-\alpha}$
  - 1.65 ± 0.14 – 4.71 ± 0.17

Crab single pulse logN – logS @ LOFAR



1 hr of 150 MHz observation, 50% error indicated
(J. van Leeuwen, K. Mikhailov et al., in prep.)

Giant pulses in M31

- $S_{min,sps}$ = 15 Jy ⇒ $S_{Crab,M31} \sim S_{min,sps} \times (D_{M31} / D_{Crab})^2 \sim 2.3 \times 10^6$ Jy

- We have α = 2.89 and $F_{max} = 1.1 \times 10^4$ Jy ms. Assuming pulse as boxcar envelope (W_{GP} = 0.025 ms), we need $\Delta t = (S_{max} / S_{Crab,M31})^{1-\alpha} \sim 20$ hrs to catch a Crab GP from M31

- Given N Crabs in M31, we need Δt / N. No supergiant pulses have been detected so far ⇒ M31 does not have multiple Crab-like pulsars with pulse widths $W \leq W_{GP}$

- Higher S_{max} and smaller α also result in less observational time needed

Discussion

- No FRBs in the field of M31 and behind

FRB 121102: $S_{121102,Crab} = 10^5 \times S_{max}(W_{GP})$

- LOFAR is yet not sensitive enough to catch bright enough bursts from M31

$S_{max}(W_{GP})$: $S_{min,sps} \sim 3$ Jy needed

- Improved single pulse search for extragalactic bursts

ML based real-time search and RFI excision

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$S_{max} (W_{GP})$: $S_{min,sps}$ ~ 3 Jy needed

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Thank you for attention