

Searching for pulsars in globular clusters

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ASTRON

Why do we study pulsars?

Precise clocks + Point masses

Study orbital parameters in binary and triple systems (test GR)

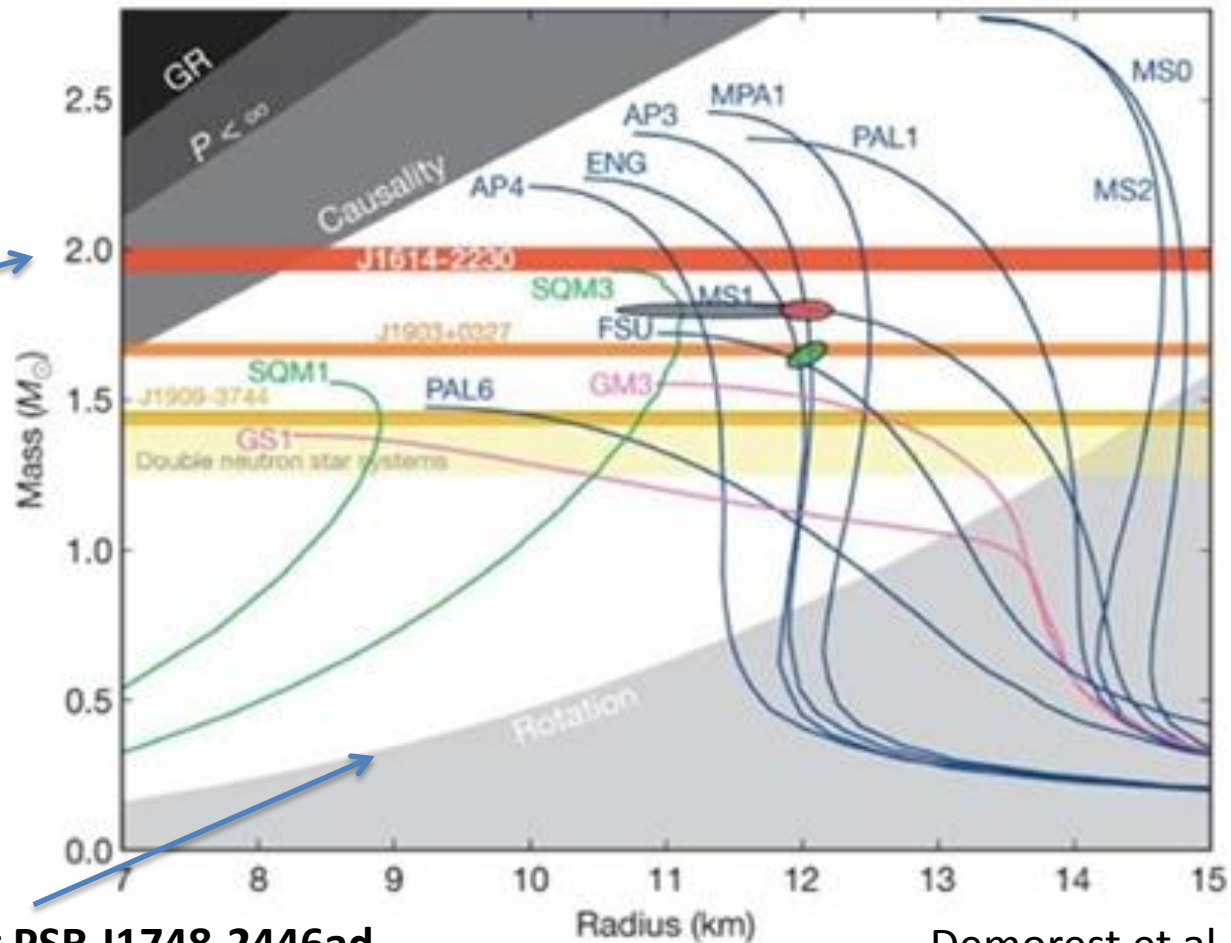
Study interstellar matter (dispersion, scattering)

Equation of State of dense matter (quarkstars?)

Holy grail: NS – BH binary

Gravitational waves

Equation of State



High Mass

Fastest pulsar **PSR J1748-2446ad**
716 Hz, Hessels et al. Science 2006

Demorest et al.
Nature 2010

Globular clusters

- Dense group of stars ($10^3 - 10^6 / \text{pc}^3$)
- Old, most stars evolved
- Many binary interactions /systems
- Many millisecond pulsars (124/144)

Highlights GC pulsars

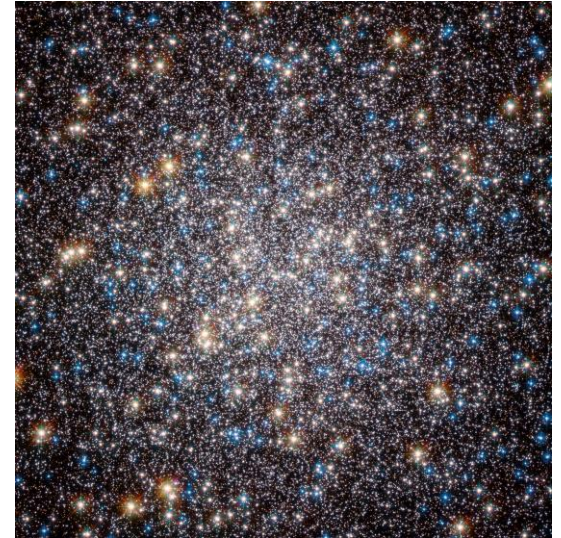
- Fastest pulsar known (716 Hz, PSR J1748-2446ad, Hessels et al. 2006)
- Triple system (WD+ Planet, Lyne et al. 1988)
- Eclipsing binaries with low mass companion
- Intra-cluster ionized gas (from DM, Freire et al. 2001)
 - Similar with LOFAR: Measure Magnetic field?

Pulsar searches

- Search for dispersed, repeated pulses with unknown:
 - Dispersion Measure (DM)
 - Period
 - Period derivative
 - Orbital parameters (binary systems)

M13 known pulsars

Name	Period (ms)	DM (pc /cc)	S400 (mJy)	S1400 (mJy)
B1639+36A	10.377	30.36(4)	3	0.14
B1639+36B	3.528	29.5(1.5)		0.022
J1641+3627C	3.722	30.1		0.030
J1641+3627D	3.118	30.6		0.024
J1641+3627E	2.487	30.3		0.010

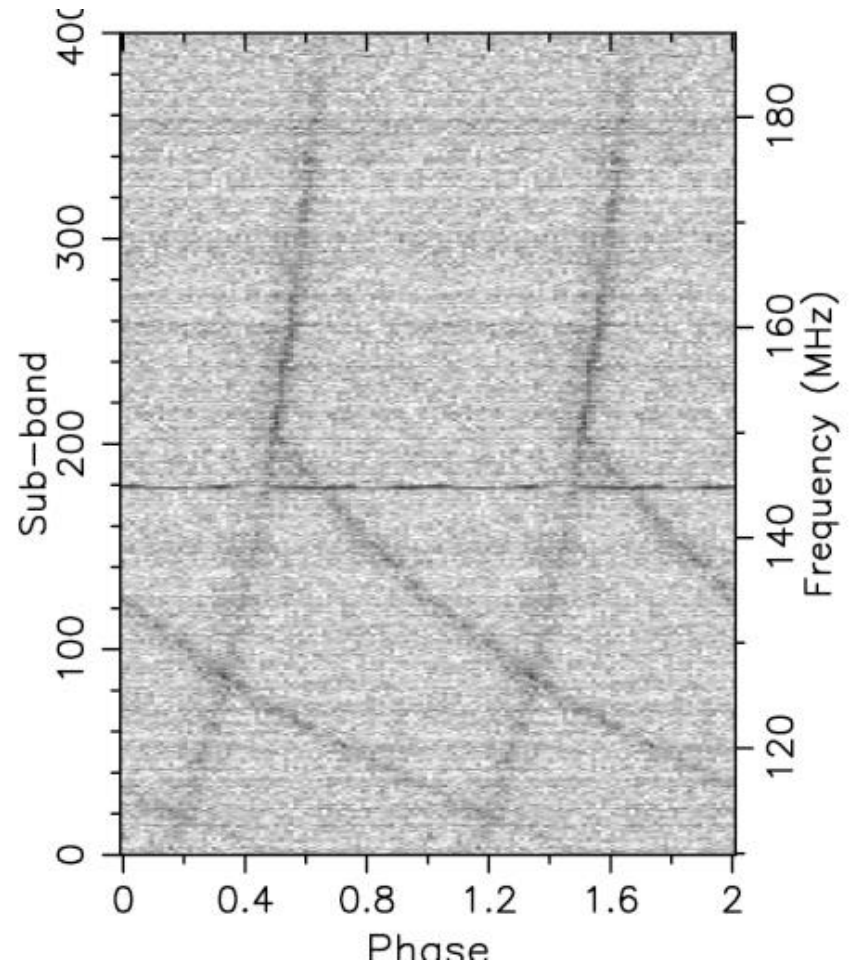


ESA/Hubble and NASA

Name	Binary period	Semi-major axis (lt sec)	Minimum Mass (Solar Mass)	Companion type
B1639+36B	1.259	1.389	0.160590	He WD
J1641+3627D	0.592	0.924	0.178036	
J1641+3627E	0.117	0.037	0.019532	Planet?

Search method

- Coherently dedispersed dynamic spectra on multiple DM trials (new approach!)
- Fine incoherent dedispersion
- (DMstep=0.0005 pc/cc, Resolution 0.1 ms, Dmrange 29.0-31.0 pc/cc)
- Searching for periodicities
- Searching for binary pulsars
- Debug along the way

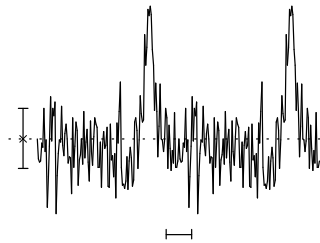


M13A found!

DM = 30.4305 ± 0.0005 , Literature 30.36

Detected in Search Pipeline!

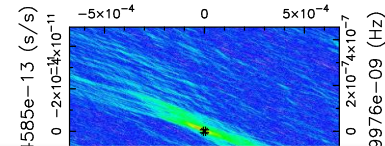
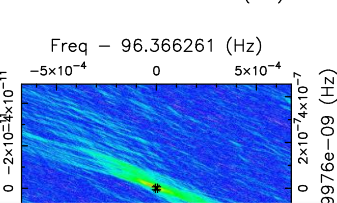
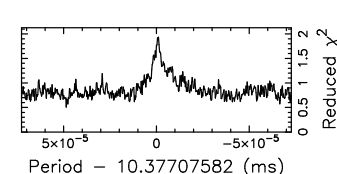
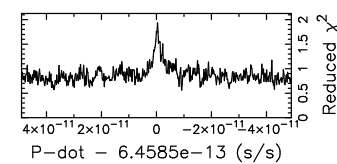
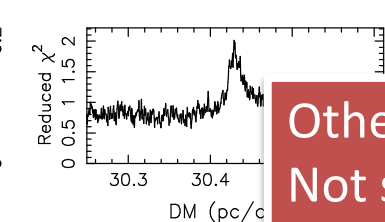
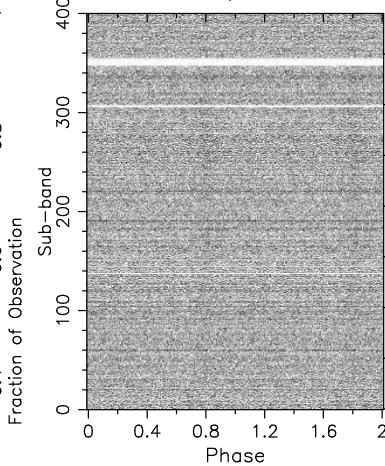
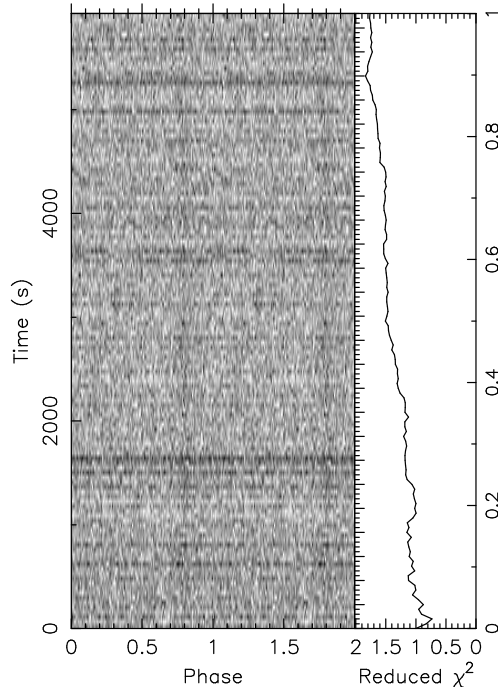
2 Pulses of Best Profile



Candidate: 10_38ms_Cand
 Telescope: LOFAR
 Epoch_{topo} = 56745.17769447431
 Epoch_{bary} = 56745.18034936816
 T_{sample} = 4.096e-05
 Data Folded = 144703488
 Data Avg = 4.08e+05
 Data StdDev = 1161
 Profile Bins = 128
 Profile Avg = 4.613e+11
 Profile StdDev = 1.235e+06

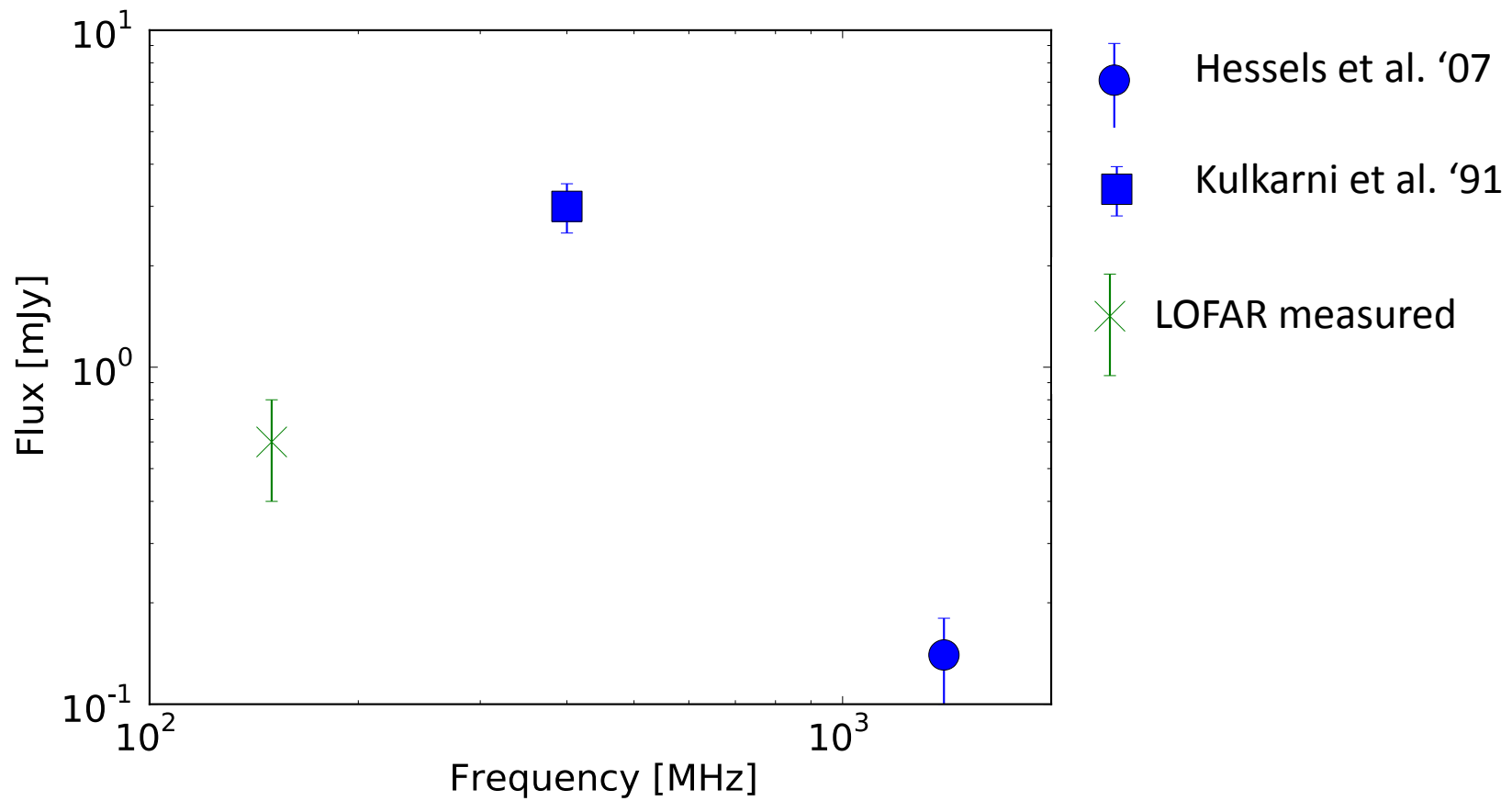
Search Information

RA_{J2000} = 16:41:40.8800 DEC_{J2000} = 36:27:15.4000
 Folding Parameters
 Reduced χ^2 = 1.765 P(Noise) < 2.36e-07 ($\approx 5.0\sigma$)
 Dispersion Measure (DM; pc/cm³) = 30.430
 P_{topo} (ms) = 10.37707582(54) P_{bary} (ms) = 10.37751000(54)
 P_{topo} (s/s) = $6.5(7.1) \times 10^{-15}$ P_{bary} (s/s) = $0.0(7.1) \times 10^{-13}$
 P_{topo} (s/s²) = $0.0(7.7) \times 10^{-16}$ P_{bary} (s/s²) = $0.1(7.7) \times 10^{-16}$
 Binary Parameters
 P_{orb} (s) = N/A e = N/A
 a₁ sin(i)/c (s) = N/A ω (rad) = N/A
 T_{peri} = N/A



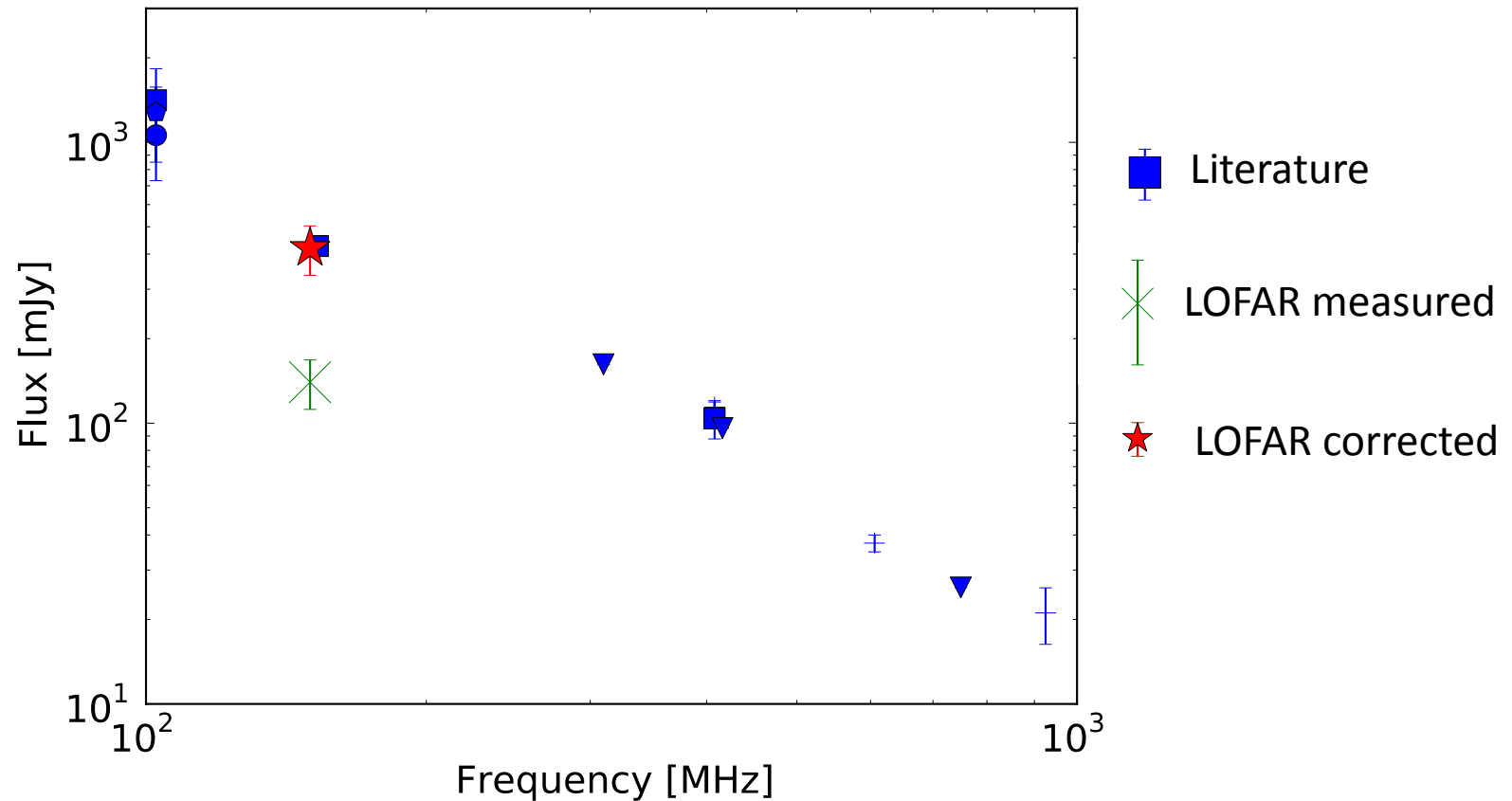
Other M13 pulsars not detected.
 Not surprising (RFI, scattering, etc.)

M13A flux



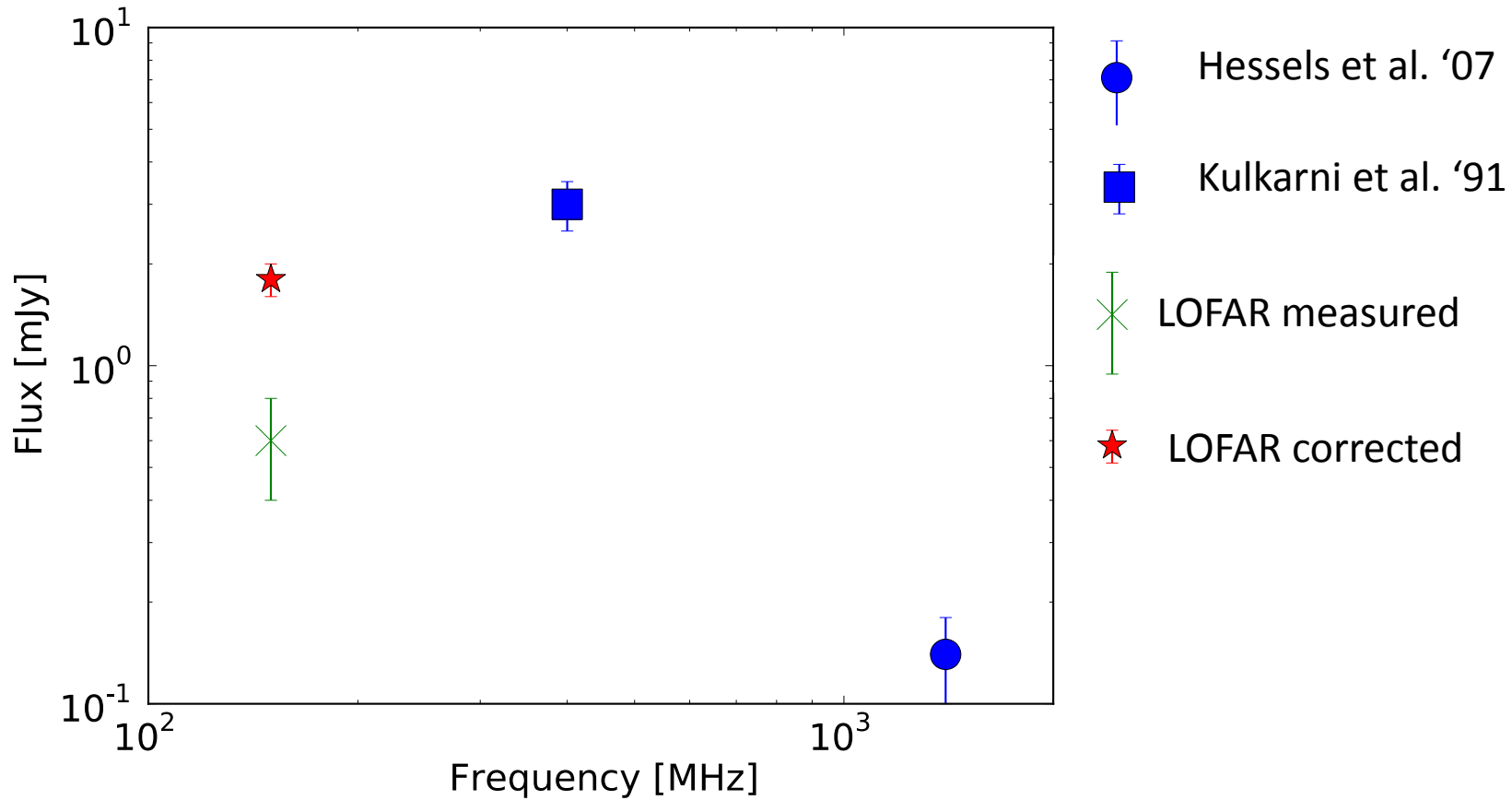
Flux correction on B1508+55

Correction factor: 3x



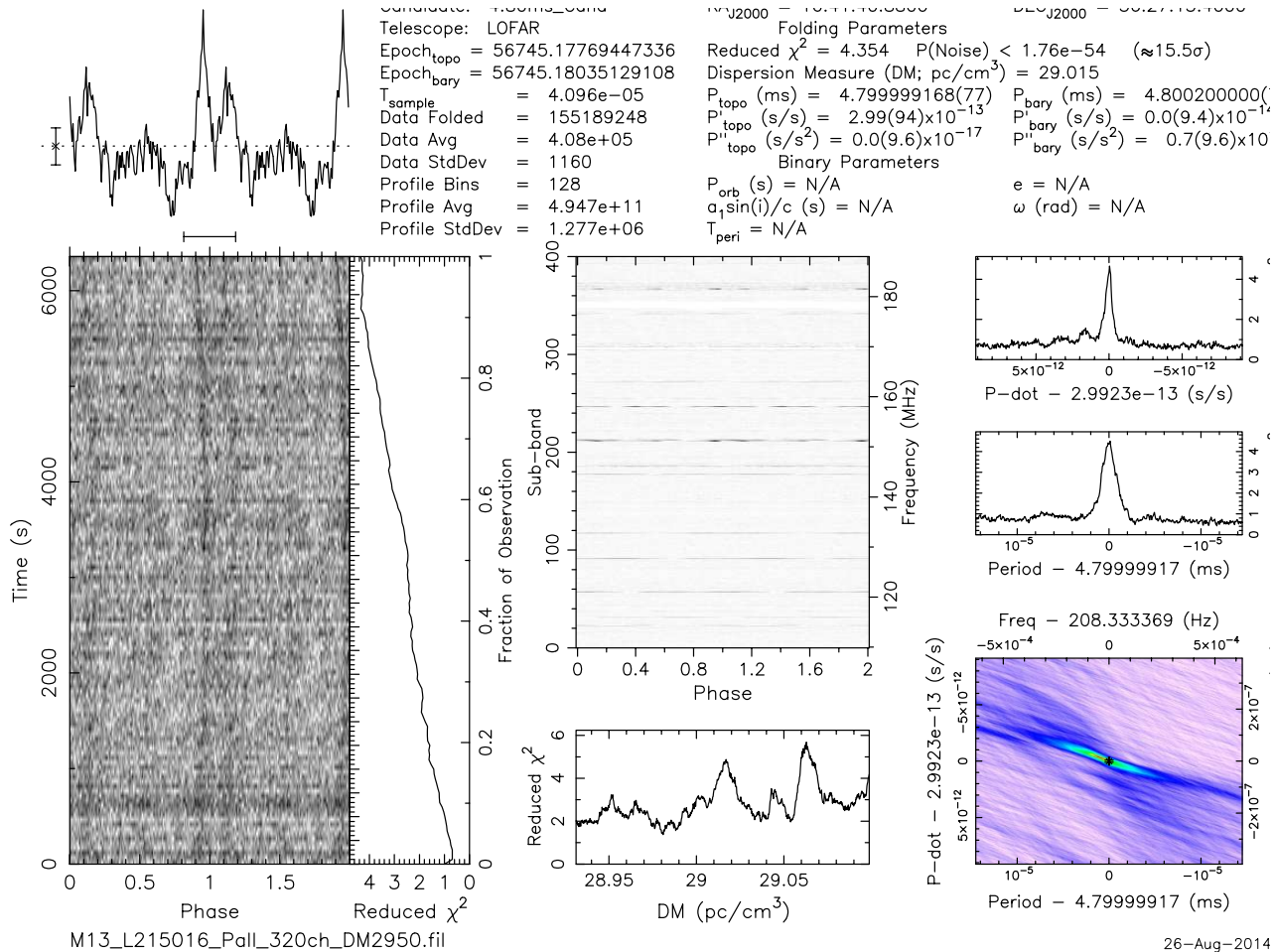
M13A flux

1.8 mJy (expected 12-18 mJy)

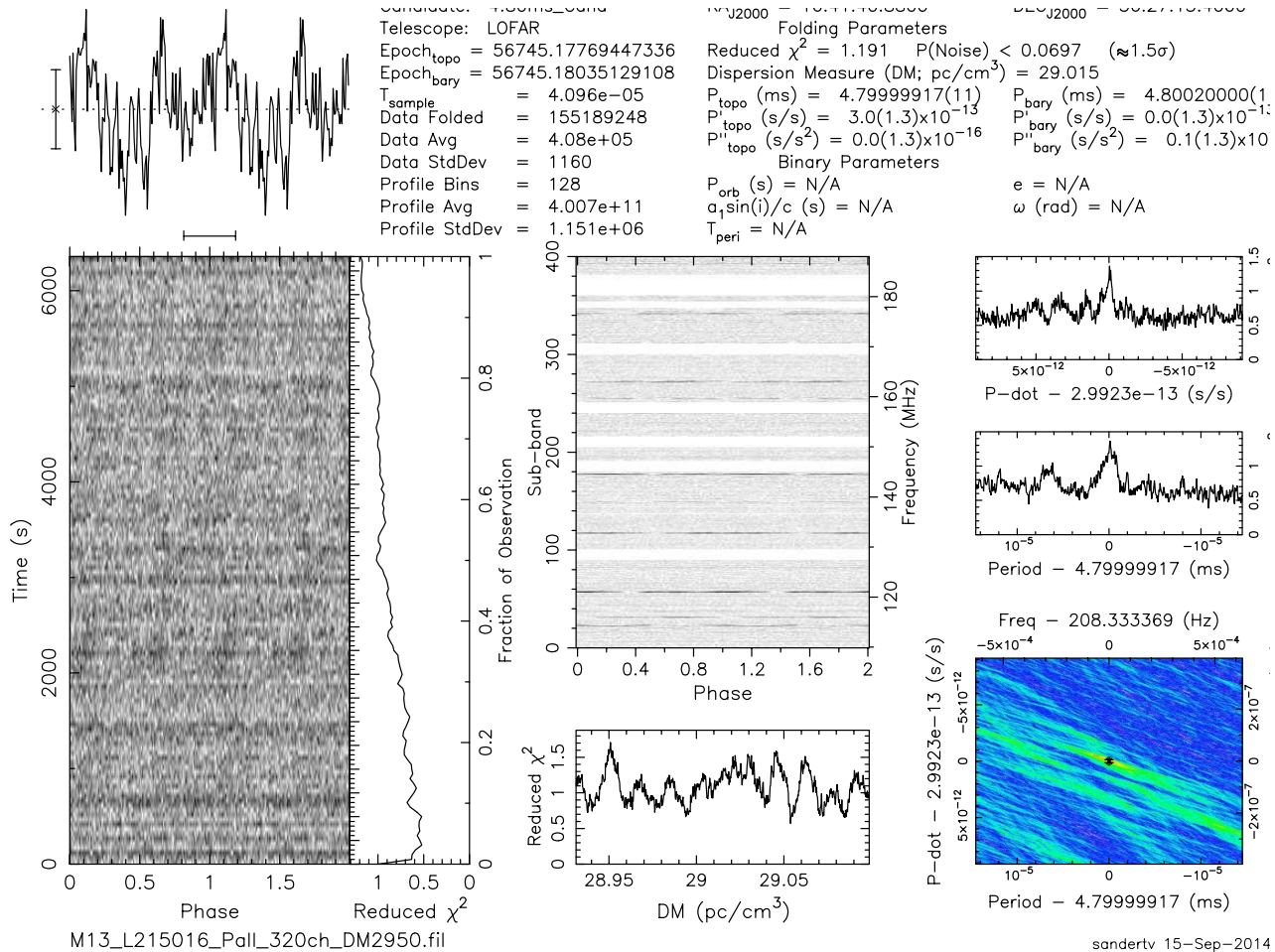


Spectral turnover

Pulsar candidate?

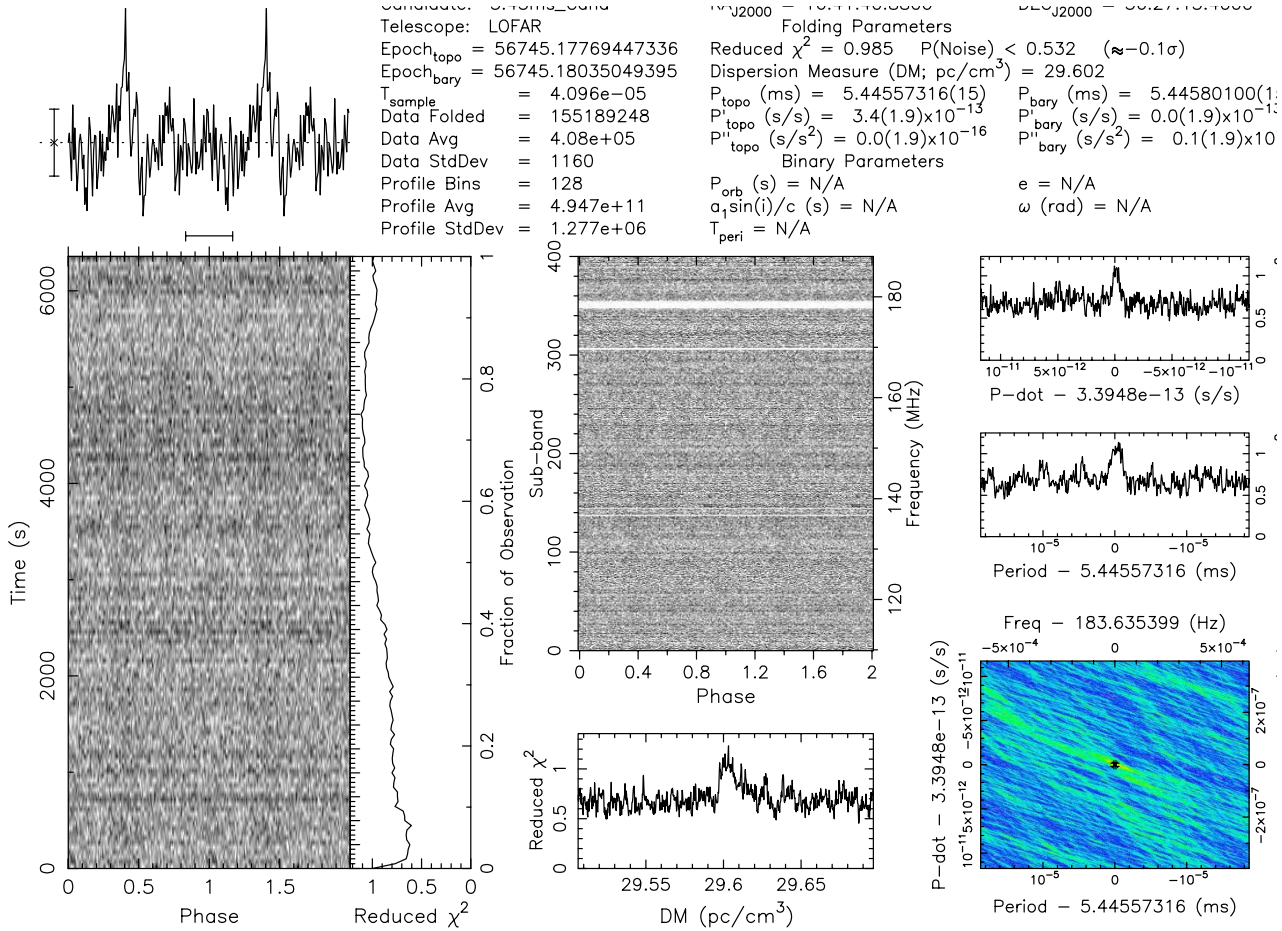


Pulsar candidate?



Best candidate

DM=29.602, P=5.4458 ms



M13_L215016_Pall_320ch_DM2950.fil

26-Aug-2014

Detect other GC pulsars

Peak S/N for a 4h observation with the LOFAR core. Assuming a spectral index of -1.4

Name	Globular Cluster	Period (ms)	DM (pc/cm)	Expected S/N
B2127+11A	M15	110.665	67.31	337.5
B2127+11B	M15	56.1330	67.69	118.5
B2127+11C	M15	30.5293	67.13	85.5
B1516+02A	M5	5.55359	30.08	75.8
B1516+02B	M5	7.94694	29.54	30.0
J1518+0204C	M5	2.48393	29.31	26.6
B1310+18	M53	33.1632	24.0	92
J1953+1846A	M71	4.888	117	30.3

Summary

- Globular clusters are an interesting place to find complex pulsar systems
- LOFAR has redetected pulsar M13A at $DM=30.4305$, Flux=1.8 mJy in the search pipeline
- M13A has turned over or weakened over time
- No other M13 pulsars detected
- More clusters need to be observed to see if this is a general trend