The consequences of the existence of Gigahertz Peaked Spectra pulsars in low frequency observations.

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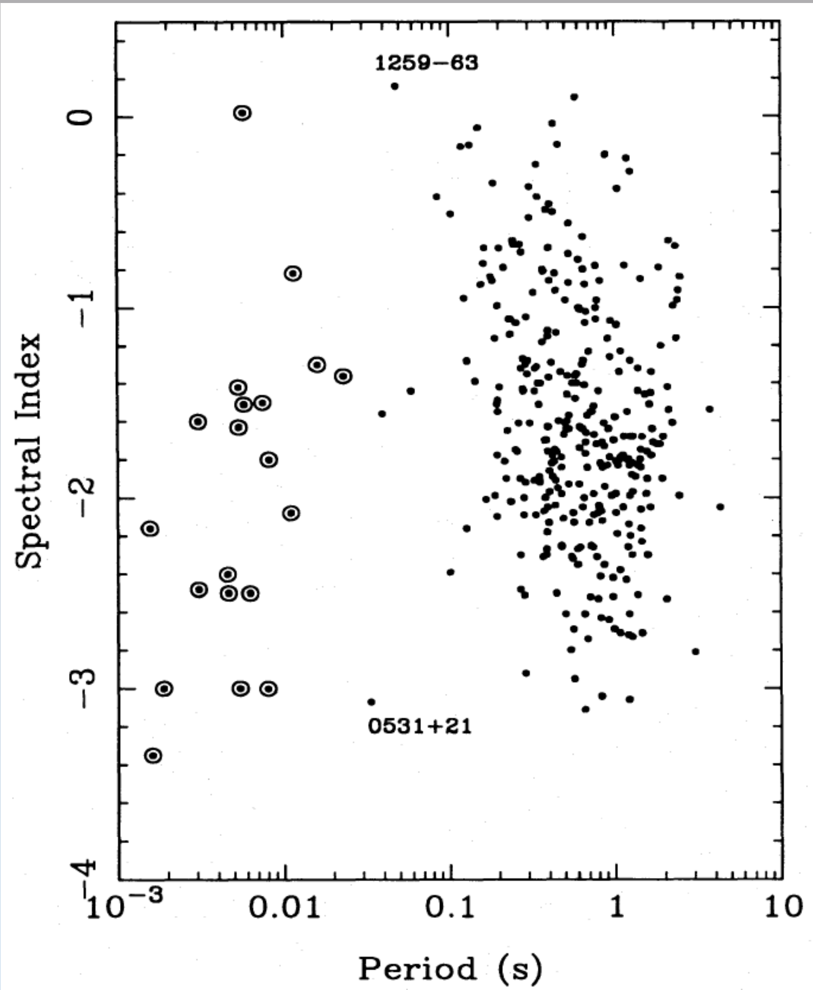
What are the Gigahertz-Peaked Spectra pulsars?

Timeline:

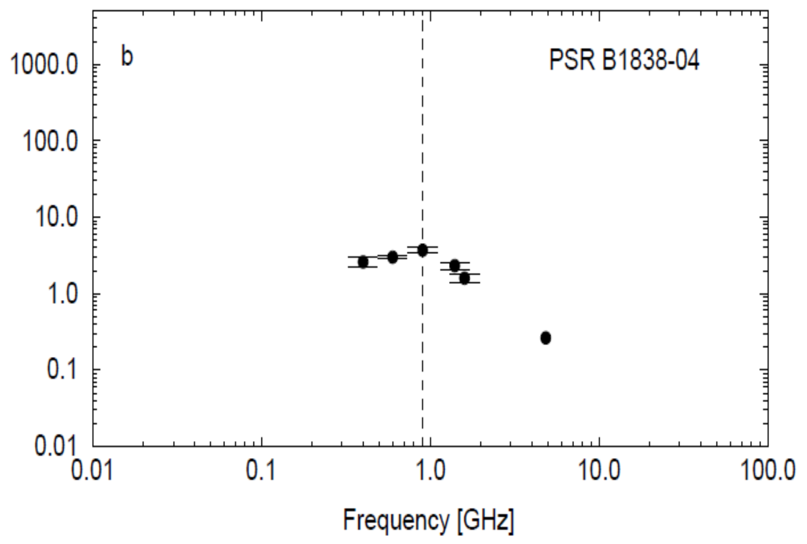
1995 – Lorimer et al., spectra of 280 pulsars, some of them nearly flat

2000 – Maron et al. - an extension of the above with new observations. Pulsars with broken spectra, a hint of a high frequency beaks

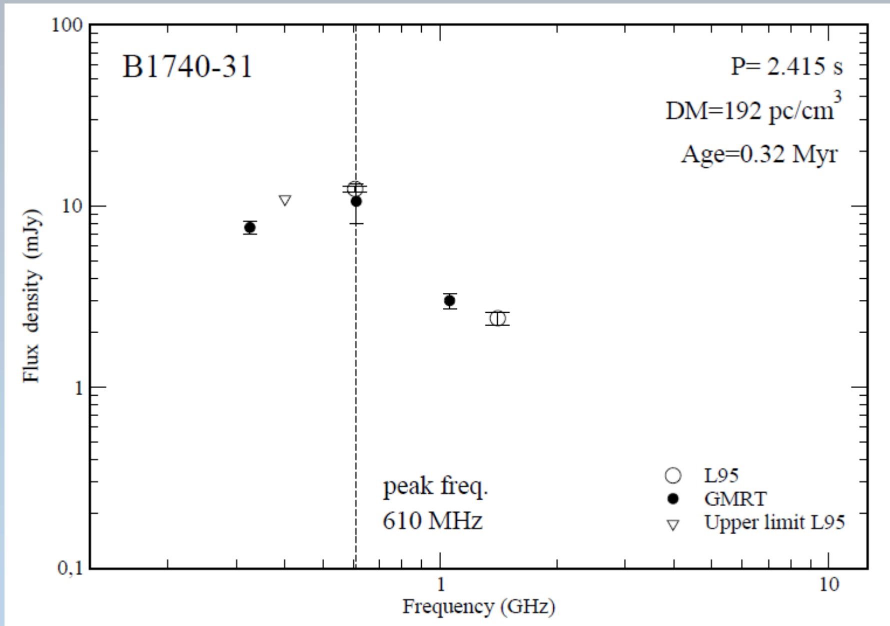
2007 – Kijak et al. – two pulsars with a high frequency turn-overs



Lorimer, Yates, Lyne, Gould, 1995, MNRAS, 273, 411



Maron, Kijak, Kramer, Wielebinski, 2000, A&AS, 147, 195

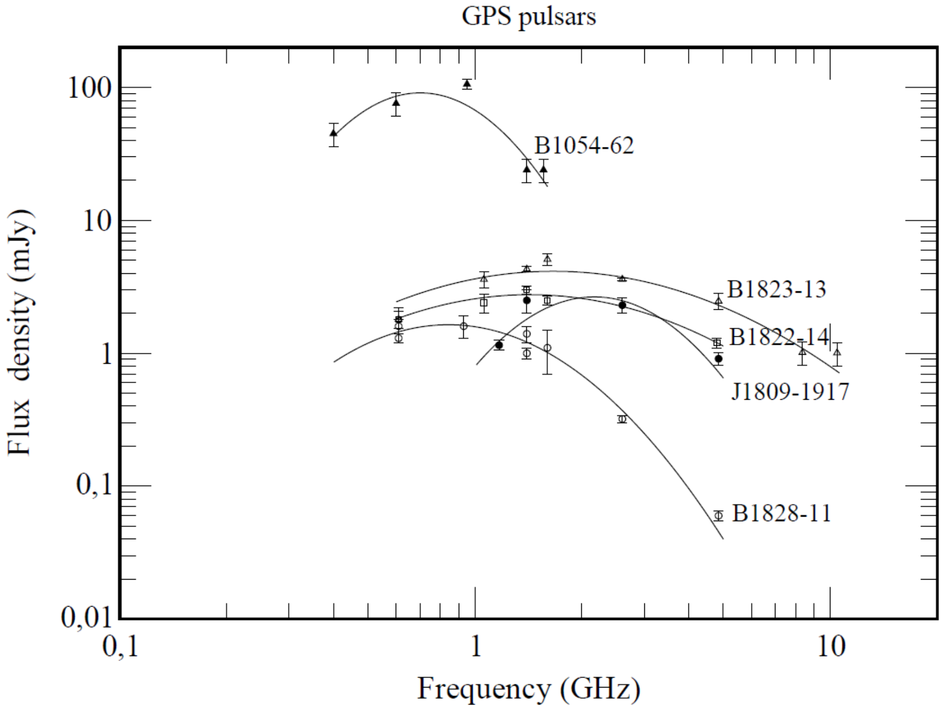


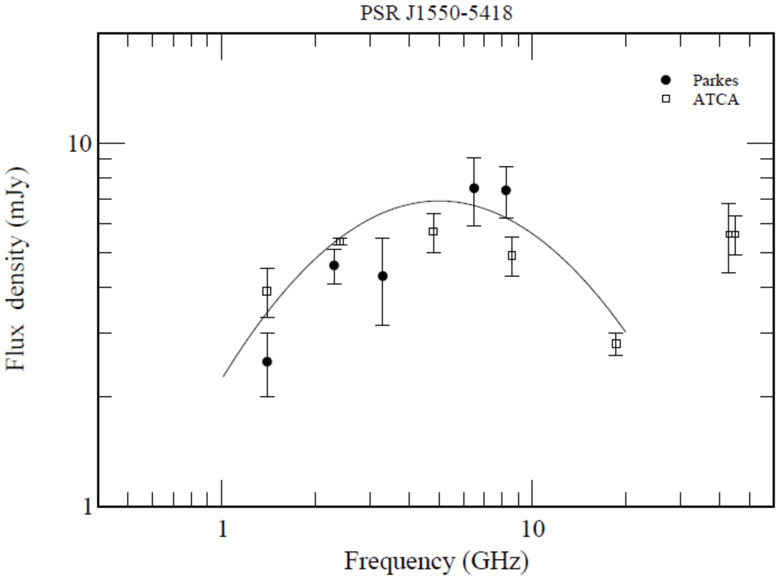
Kijak, Gupta, Krzeszowski, 2007, A&A, 462, 699

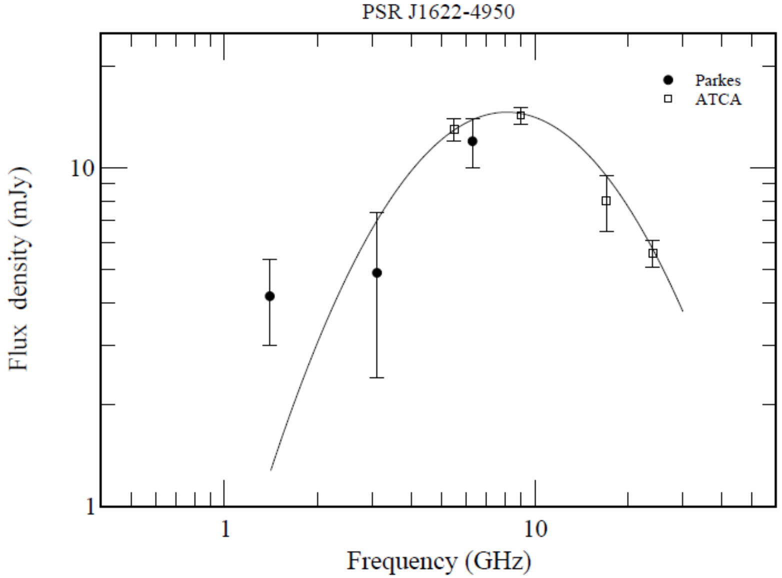
2011 – Kijak et al. - another three objects with a turn-over above 1 GHz. The name **Gigahertz-Peaked Spectra** pulsars (**GPS**) introduced. These objects:

- tend to adjoin various peculiar surroundings, i.e. PWNe and dense HII regions
- preffer large DMs
- are usually relatively young

2013 – Kijak et al. – based on literature data: two radio magnetars with GPS!







Kijak, Tarczewski, Lewandowski, Melikidze, 2013, ApJ, 722, 4

Kijak, Lewandowski, Maron, Gupta, Jessner, 2011, A&A, 521 A16
Kijak, Dembska, Lewandowski, Melikidze, Sendyk, 2011, MNRAS, 418, L114

What causes the GPS?

PSR B1259-63 may hold a key to the puzzle.

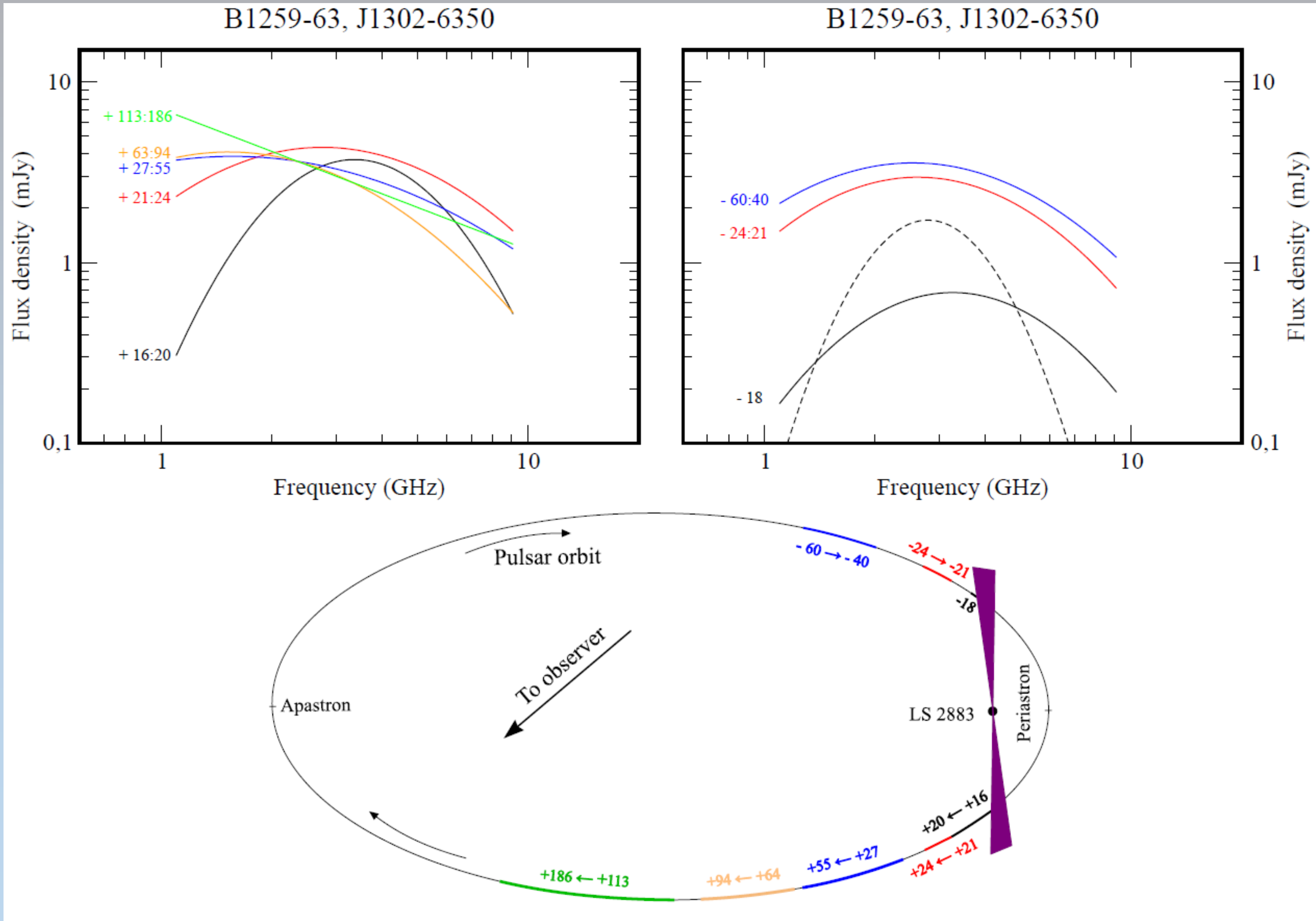
A pulsar-*Be* star binary with a long-period (1237 day), eccentric orbit (e=0.87).

Be stars are known to have strong stellar wind, both equatorial and polar.

The disk formed from the equatorial wind causes the pulsar eclipses.

Thermal absorption in the polar wind may be enough to cause B1259-63 spectra to bend.

The spectrum evolves with the orbital phase.



Kijak, Dembska, Lewandowski, Melikidze, Sendyk, 2011, MNRAS, 418, L114

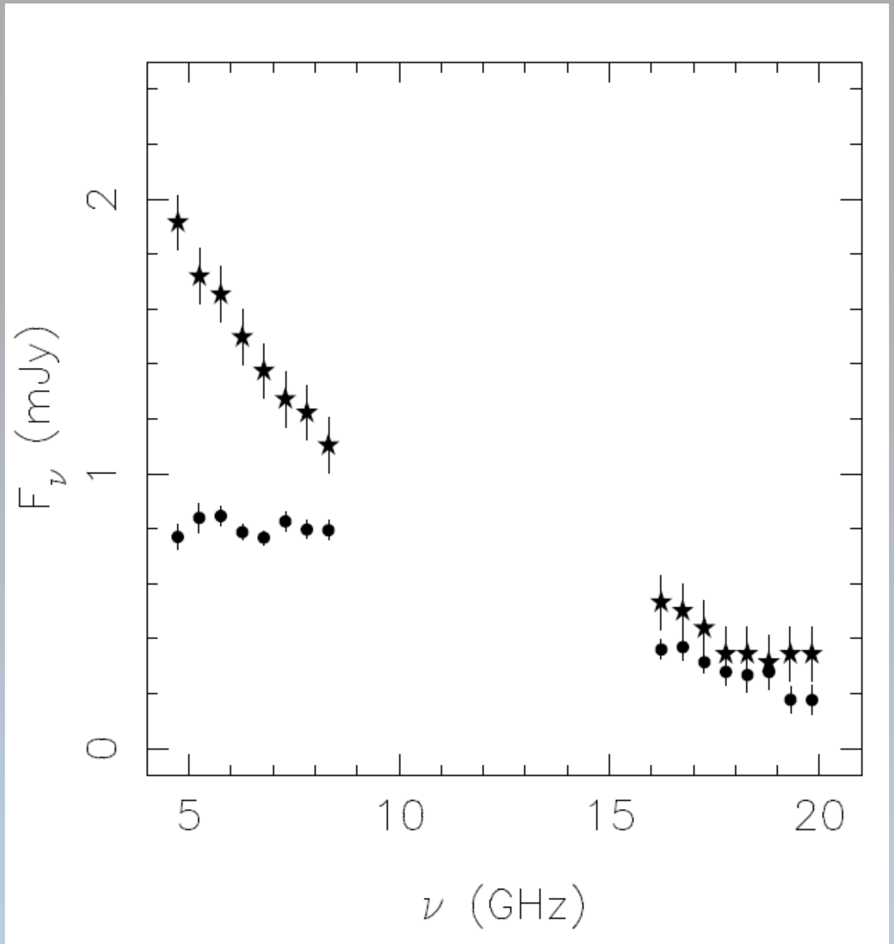
2013 – Shannon & Johnston – ATCA observations of Sgr-A magnetar (PSR J1745–2900)

- May 1, 2013 – GPS like spectrum? (circles)
- May 31, 2013 – regular pulsar spectrum (star)

Possible explanation: absorption in the surrounding medium (like matter thrown away during outburst)?

Emission mechanism cause: if radio emission from magntars is pulsar-like, why would be there no change in high frequency part of the spectrum?

High frequency emission originating closer to the NS surface would be the first to show any change in the emission mechanism.



Shannon & Johnston (2013)

How does B1259-63 relate to isolated GPS pulsars?

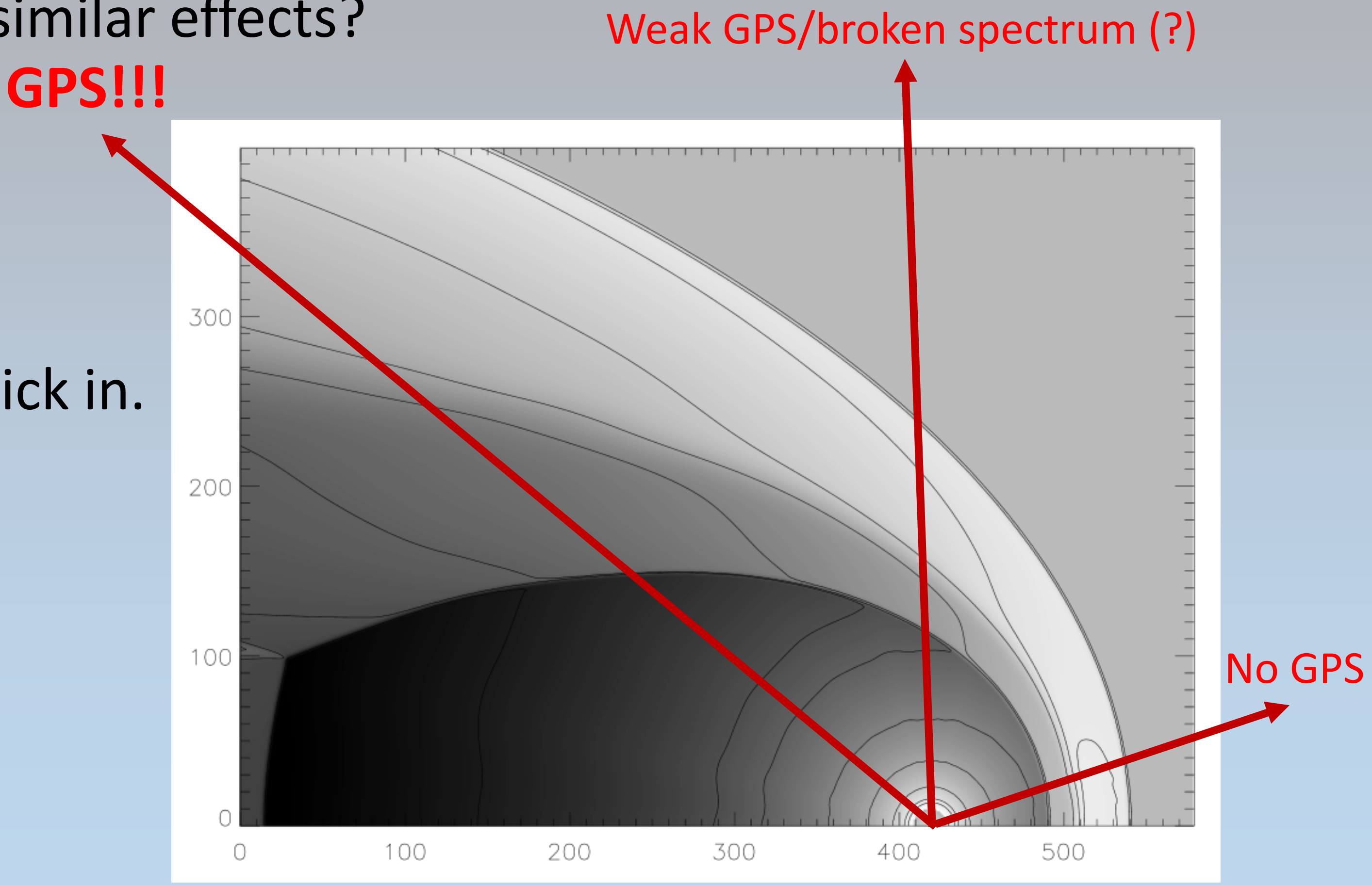
Pulsars in or behind *HII* regions: same case as B1259-63, only the matter is lower density, but the several-parsec sizes make up for it.

Pulsar Wind Nebulae – may they cause similar effects?

Seems that some PWNs may have large enough densities (up to n_e=2000 cm^{-3}) and sizes (up to 1 parsec) for the thermal free-free absorption to kick in.

SNR filaments which may by another candidate (densities up to 8000 cm^{-3}) and sizes up to a fraction of a parsec.

K. Rożko masters thesis, publication in prep.



PWN simulation (Bucciantini, 2002, A&A, 387, 1066)

Are there only seven GPS neutron stars, or do we have problem with pulsar spectra?

- At the moment we know the spectra of about 400 pulsars.
- Most of the spectra are known well at high frequencies (above 1 GHz), as low frequency observations tend to be more difficult to obtain
- GPS pulsars would be weaker and harder to detect and/or discover at low frequencies
- The phenomenon is rather uncommon, which means that most of the objects will be rather distant (and show large DM values)
- large DM values mean lots of ISM on the way and strong scaterring effects

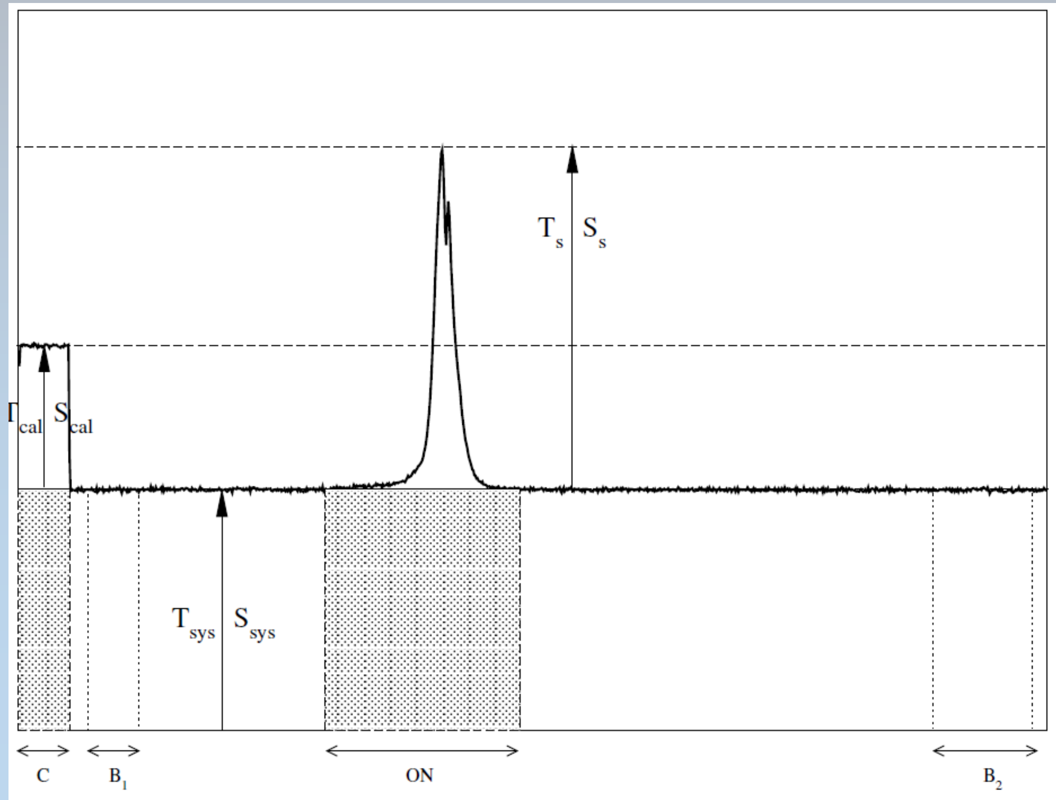
Interstellar scattering: a nuissance or a cause?

For large DMs scattering may be a serious issue at low frequencies.

In extreme cases pulsars cease to be pulsating sources due to scattering

What is more dangerous are the not-so extreme cases, when pulsing emission is still visible, but the scattering is large.

A standard method of flux density measurement requires that you have to be able to measure the background flux level.

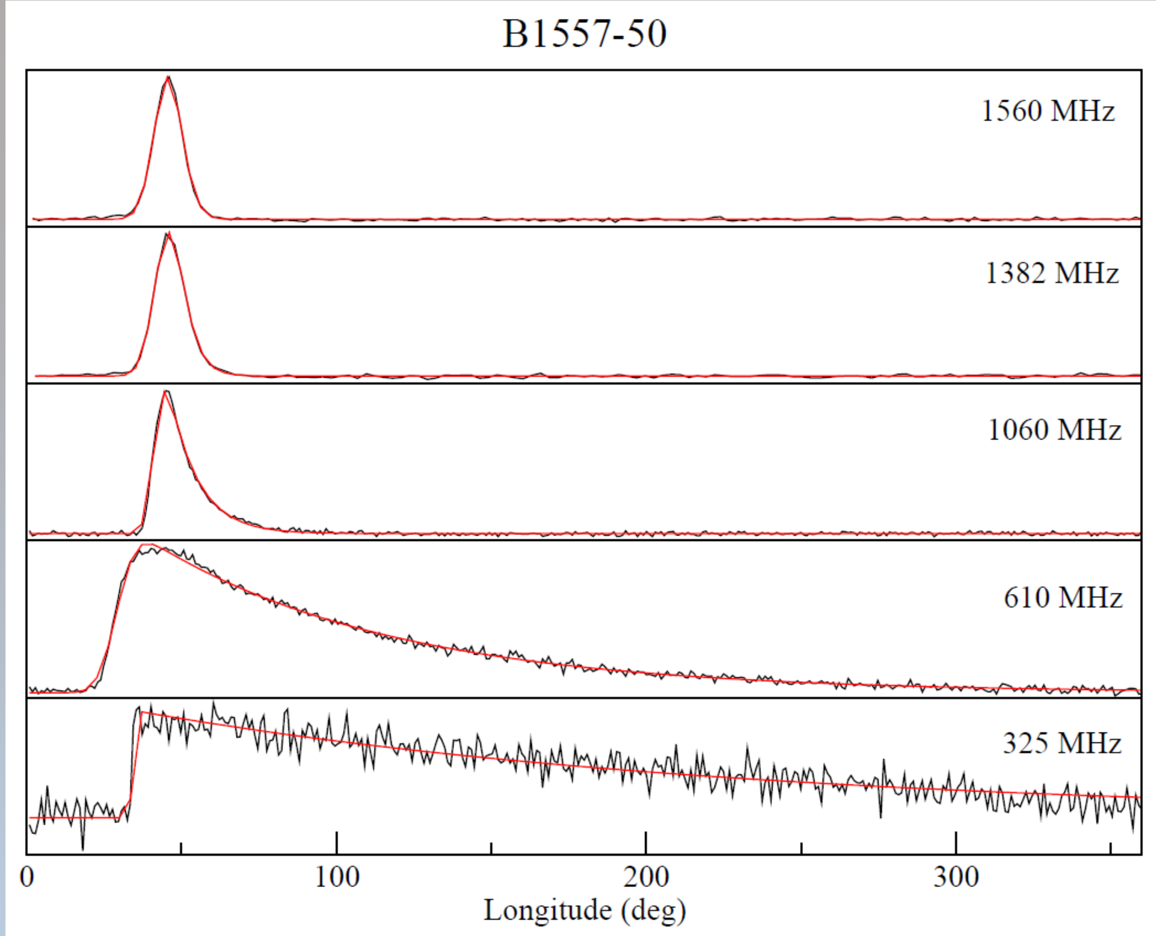


How can one go wrong?

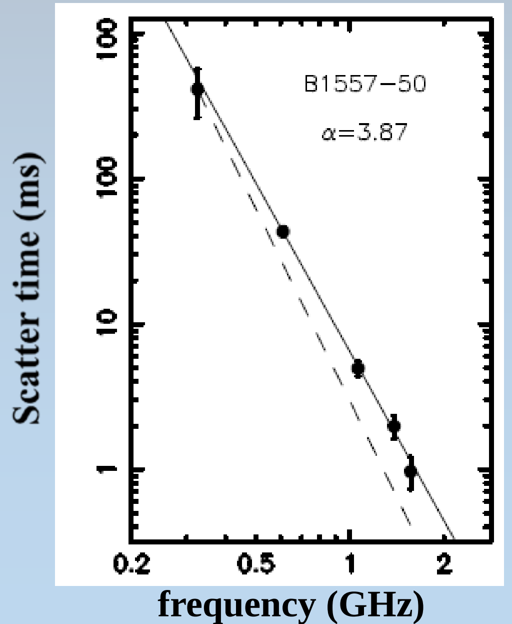
B1557-50 – scatter time at 610 MHz is of order of 80 degrees.

At 325 MHz it should be by a factor of about 13 greater ($\tau_d \approx f^{-4.4}$), i.e. 1000 degrees (2.7 pulse periods). Yet the pulses are still visible.

Not taking that into account may lead to severe flux underestimation!



Lewandowski, Dembska, Kijak, Kowalinska, 2013, MNRAS, 434, 69



Looking at higher frequency profiles and scatter time measurements is required.

For this pulsar the actual scatter time is 700 degrees (the scattering spectral index is much less than theoretical 4.4).

What to do to find more GPS pulsars? Are there any?

To understand the GPS phenomenon we need more than **eight** cases

Bates, Lorimer & Verbiest (2013) using statistical analysis of past search surveys (low-frequency and Pmof PS) estimated that GPS and broken spectra pulsars (which would be harder to detect in those surveys) may consitute up to 10% of the entite pulsar population.

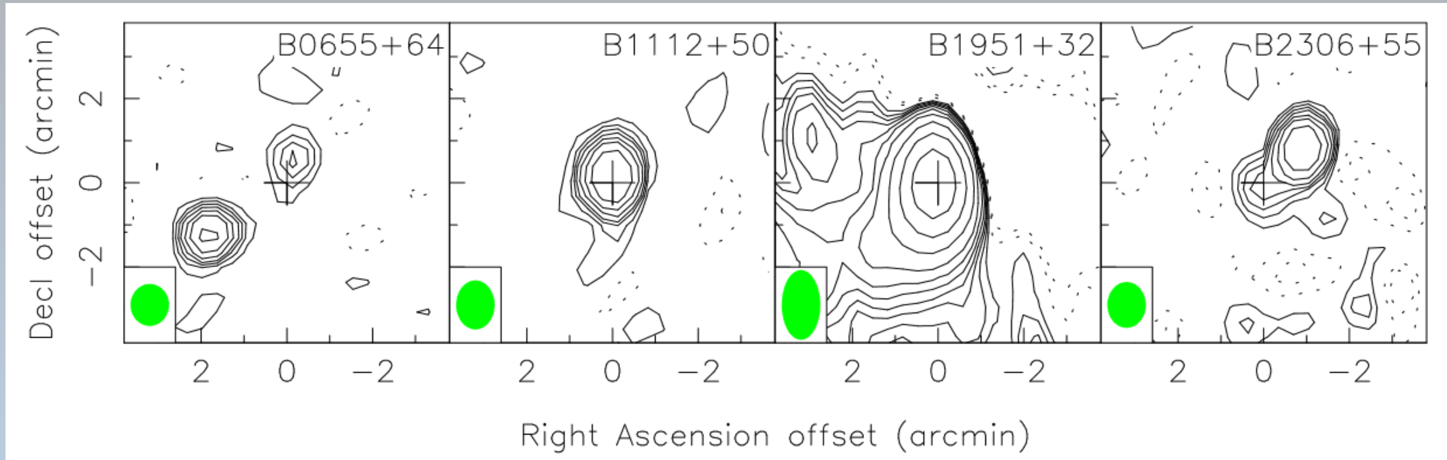
That would mean that we may know up to 200 GPS pulsars already, we just don't know their spectra!

This is likely the case, since GPS pulsars deviate from the standard spectra at lower frequencies, where measurements by the means of the standard method are problematic due to interstellar scattering and inherent weakness of these sources.

What do we do about it?

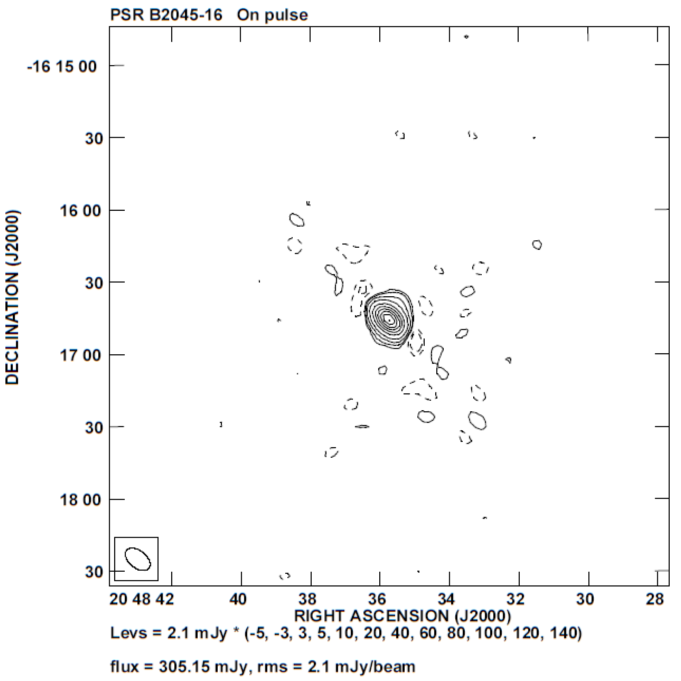
Answer: Interferometric Flux Measurements

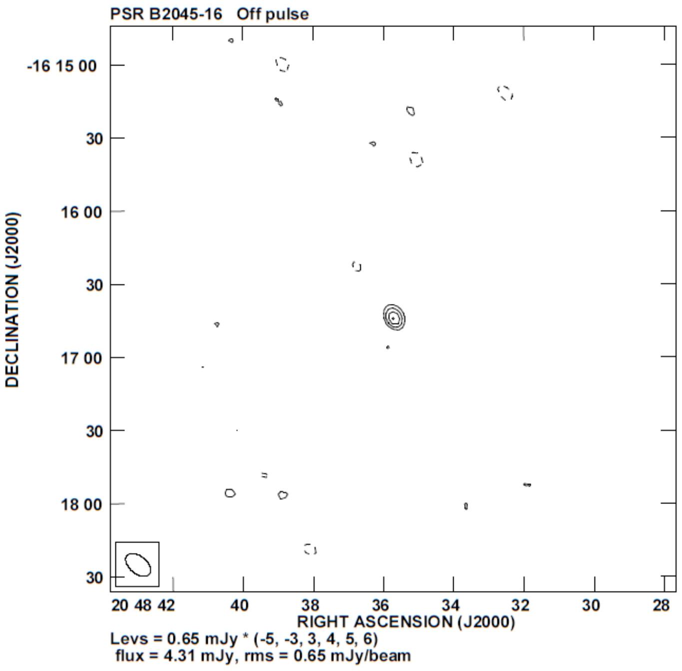
To alleviate issues connected to interstellar scattering the ***interferometric imaging*** method seems to be the perfect answer.



Westerbork maps used for flux measurements at 325 MHz
(Kouwenhoven, 2000, A&AS, 145, 243)

On-pulse and off-pulse maps of PSR B0245-16 from GMRT at 325 MHz
(Basu, Athreya, Mitra, 2011, Apj 728, 10)





Advantages of using the imaging method:

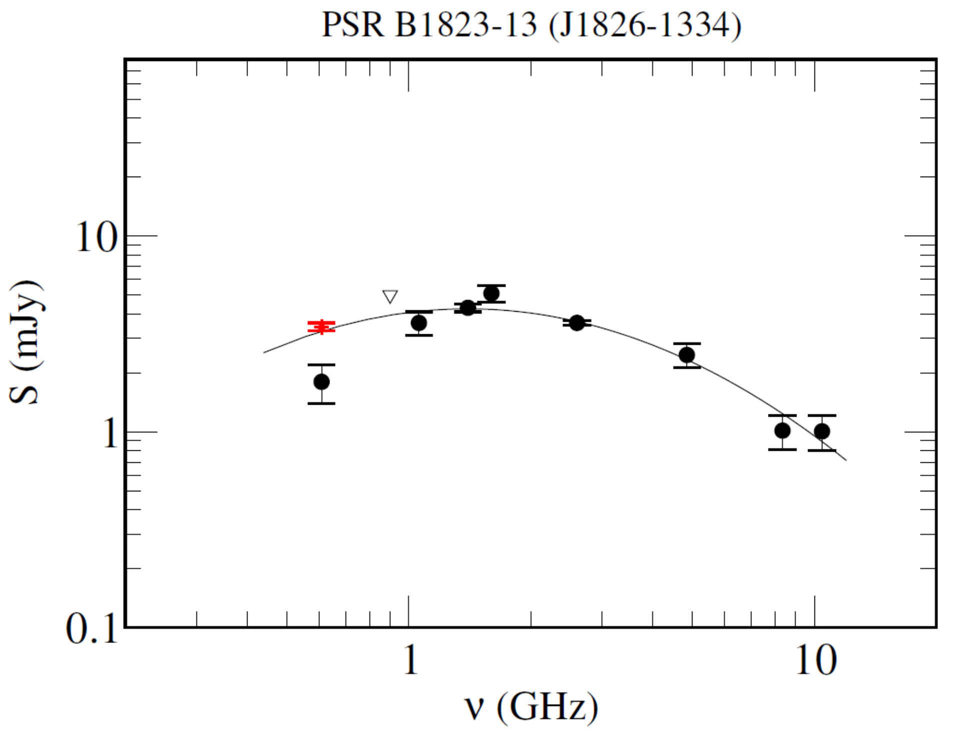
The sources selected for our studies are high DM pulsars which as mentioned earlier leads to a scattering tail especially at low frequencies. **Imaging techniques provide the only secure means to estimate the flux in these pulsars.**

Self-calibration of interferometric data can correct instrumental and atmospheric gain fluctuations on very short timescales. The corrections are determined by the flux densities of the constant and bright background sources in the field and hence would not be affected by the pulse variation of the relatively weak pulsar.

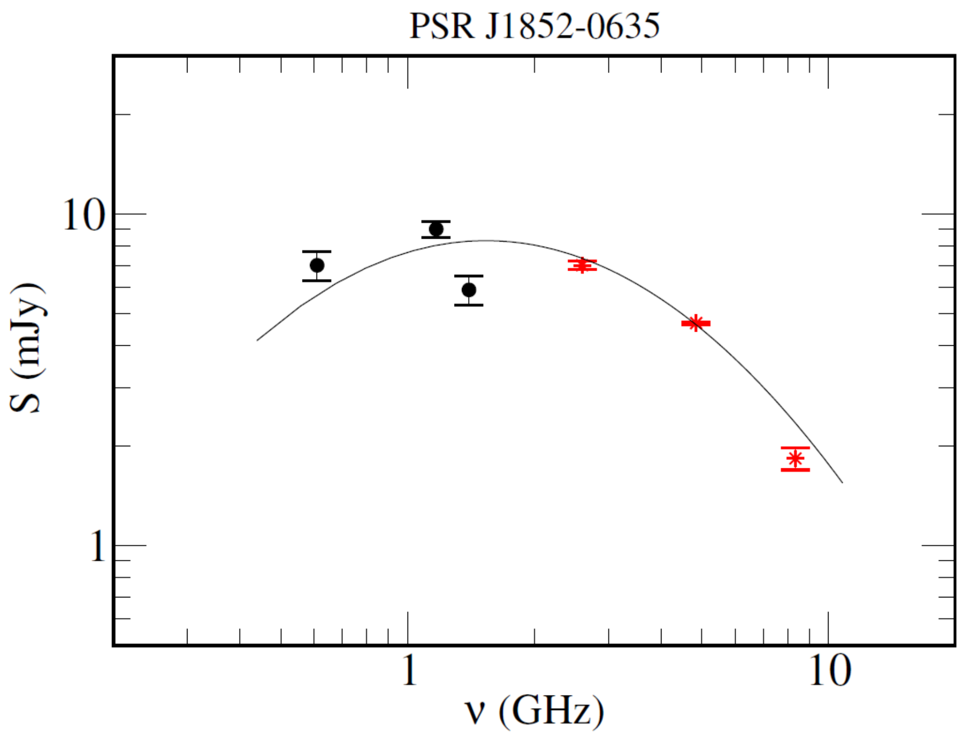
The pulsars studied reside in some very interesting environments with the possibility of continuum emission in the surroundings. We intend to look for these emissions which will provide a clue the origin of the GPS sources.

Preliminary results from GMRT (+Effelsberg)

Interferometric data: solving the scattering issue.



Supplementary observations: Effelsberg at high frequencies



We have reached 100 μJy noise rms at 610 MHz after one hour of integration 'On source (5-σ detection limit of 0.5 mJy).

In the case of 325 MHz we expect to reach noise rms between 200–300 μ Jy (with one hour integration 'On-source' with a 5-σ detection limit of 1.0–1.5 mJy).

Publication in preparation (Dembska, Basu, Kijak, Lewandowski), and **next observations** comming (GMRT, Dec 2013/Jan 2014).

Summary:

GPS pulsars are there - what are the consequences?

Future pulsar search surveys, especially those performed at low frequencies, need to take GPS pulsars into account (***LOFAR, MWA, SKA*** *and prototypes*).

High-frequency search surveys may be a good source of GPS pulsar candidates (like J1834−0821 found in Parkes Methanol Multibeam survey at 6.5 GHz, *Bates et al. 2011*).

Other GPS candidates: radiomagnetars (!!!), flat- and broken-spectra pulsars, high-DM pulsars with high scattering below 1 GHz *(and we are open for any other ideas and suggestions).*

High-energy observations: if the GPS phenomenon arises from pulsar surroundings, these objects would be good targets for high-energy observations. And vice-versa, pulsars with PWNs/SNRs found in high-energy may be excelent GPS candidates.

Southern Hemisphere GPS pulsars: the main instrument we're using (GMRT) can not really make any flux measurements below -40° declination (and realistically even less than that, especially at 325 MHz). (**MWA, SKA, Molonglo**)