BINARY PULSAR B1259-63 SPECTRUM EVOLUTION

DETAILED STUDY AND CLASSIFICATION OF PULSAR SPECTRA

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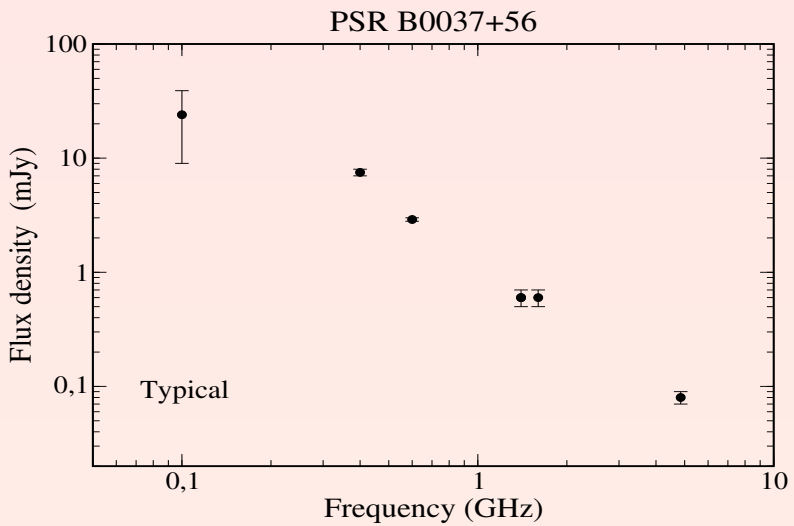
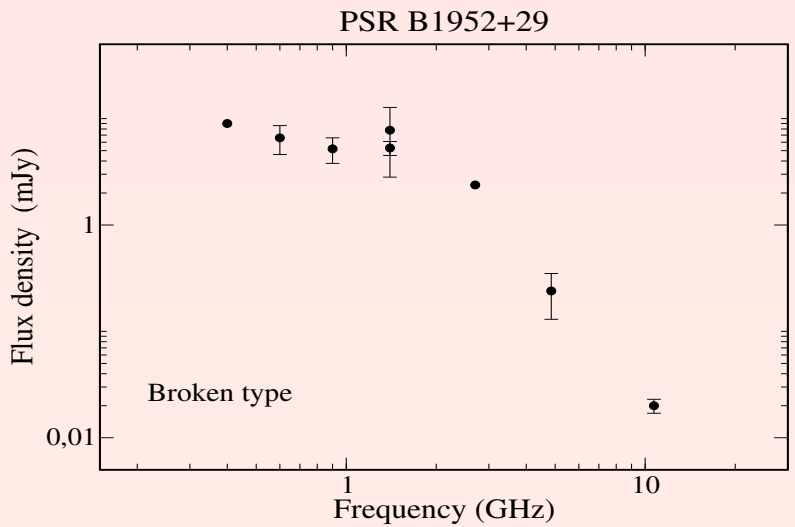

PSR B0037+56
Flux density (mJy)
100
10
1
0,1
Typical
0,1
1
10
Frequency (GHz)


PSR B1952+29
Flux density (mJy)
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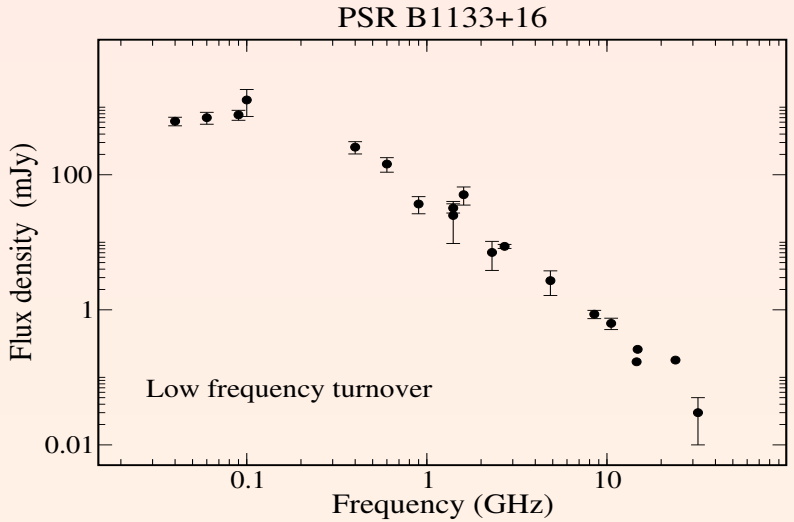
0,01
Broken type
1
10
Frequency (GHz)


PSR B1133+16
Flux density (mJy)
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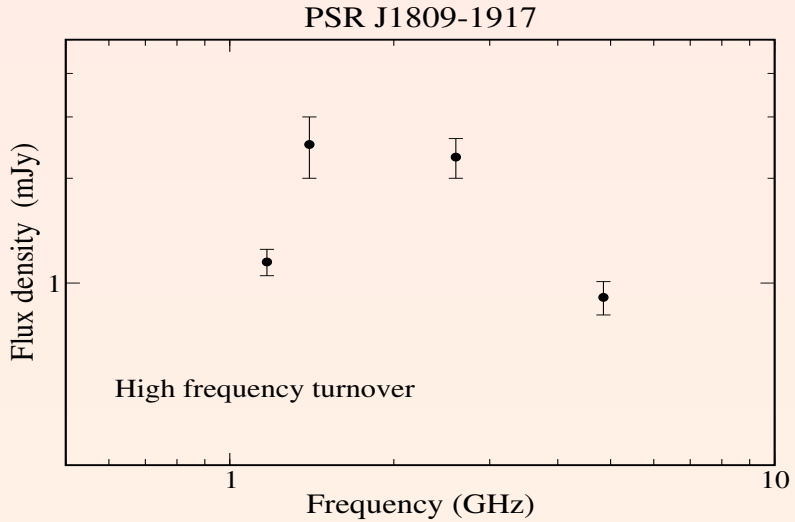
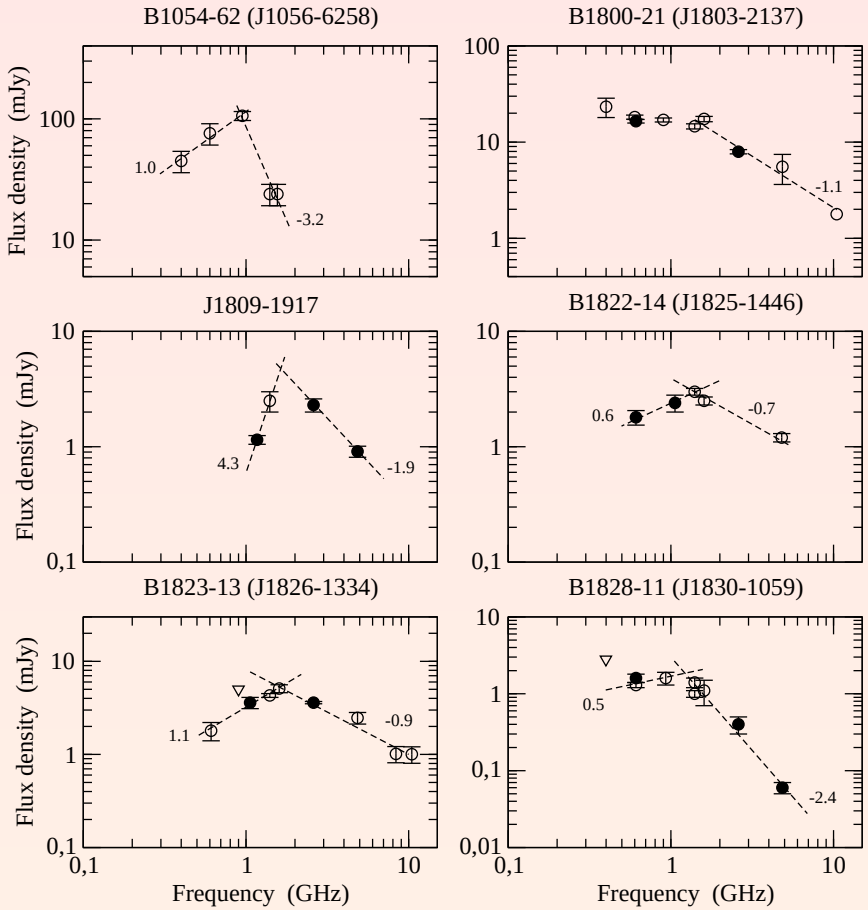
1
0.01
Low frequency turnover
0.1
1
10
Frequency (GHz)

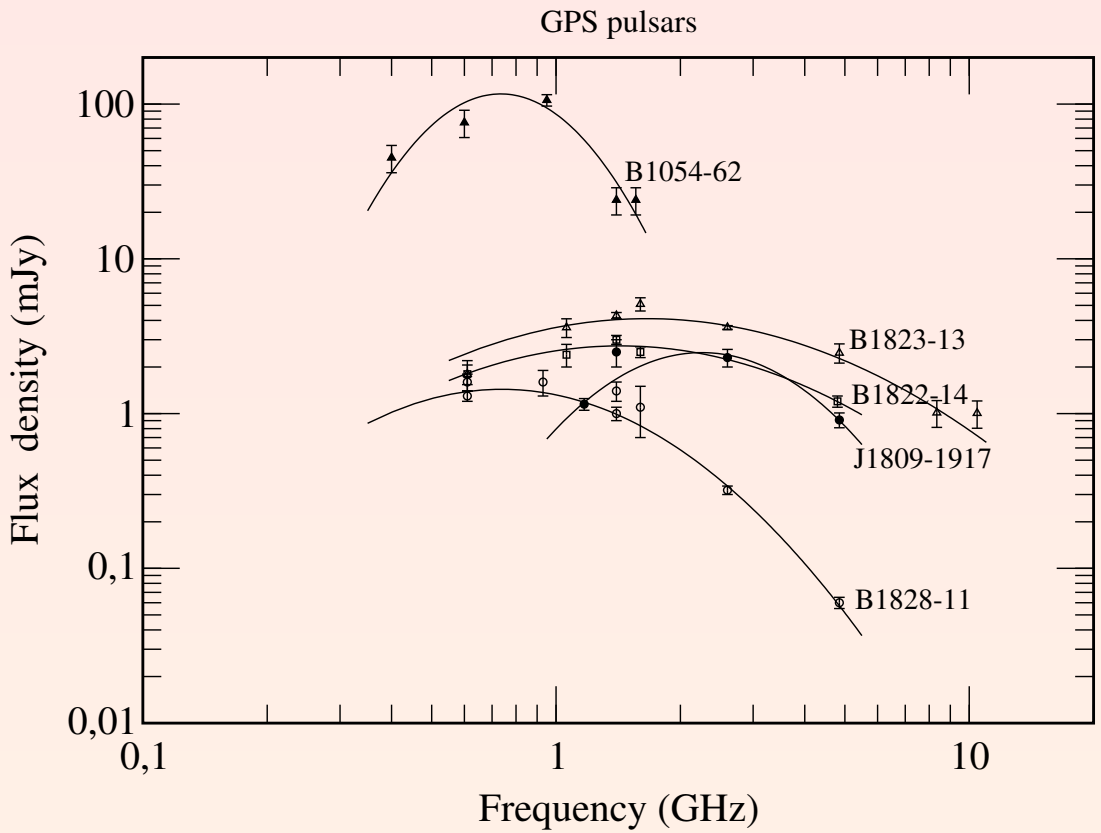

PSR J1809-1917
Flux density (mJy)
1
High frequency turnover
1
10
Frequency (GHz)



Kijak, Lewandowski, Bhattacharyya & Gupta 2011a, A&A

- Lorimer et al. 1995: radio spectra for some pulsars at low frequency (300 MHz – 1.6 GHz, Lowell), some pulsars have positive spectral index,
- Maron, Kijak, Kramer, Wielebinski 2000: radio spectra for about 280 pulsars at frequency from 300 MHz to 20 GHz,
- Kijak, Maron 2004: first analysis of turnover at high frequency,
-2005-2006: observation project (GMRT),
- Kijak et al. 2007: evidence of turnover at high frequency,
- Kijak et al. 2011a: results from observation 2006-2009 (GMRT, Effelsberg)
- Kijak et al. 2011b: B1259-63 spectrum evolution

The gigahertz-peaked spectra (GPS) pulsars



Kijak, Dembska, Lewandowski, Melikidze & Sendyk 2011b, MNRAS Letters

GPS pulsars

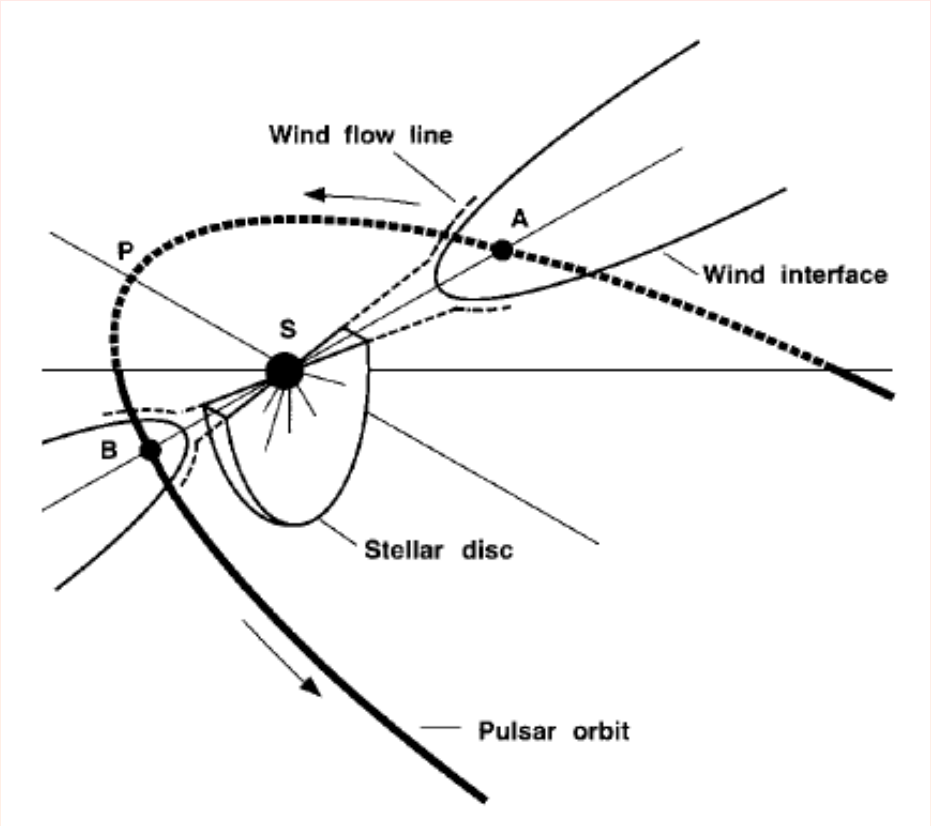
- relatively young
- high value of DM
- usually adjoin interesting environments

GPS pulsars and environment

Kijak et al. (2011a) indicated that the GPS pulsars are relatively young objects and they usually adjoin interesting environments.

- B1054-62 lies behind or within a dense HII region (Koribalski et al., 1995),
- B1823-13, B1800-21 – Vela-like pulsars, indication of Pulsar Wind Nebula in surroundings,
- J1809-1917 – new GPS pulsar with plerion as environment.

Additionally a few other candidates seem to be coincident with the known but sometimes unidentified X-ray sources from 3rd EGRET Catalogue or HESS observations. We can assume that the GPS appearance owes to the environmental conditions around the neutron stars rather than to the radio emission mechanism.



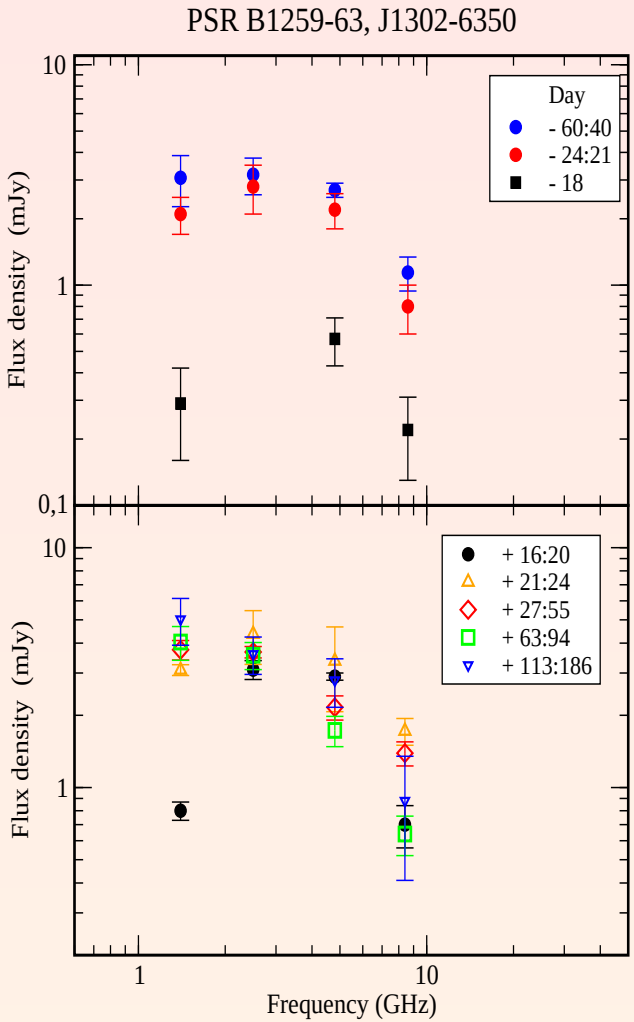
Johnston et al. 1999

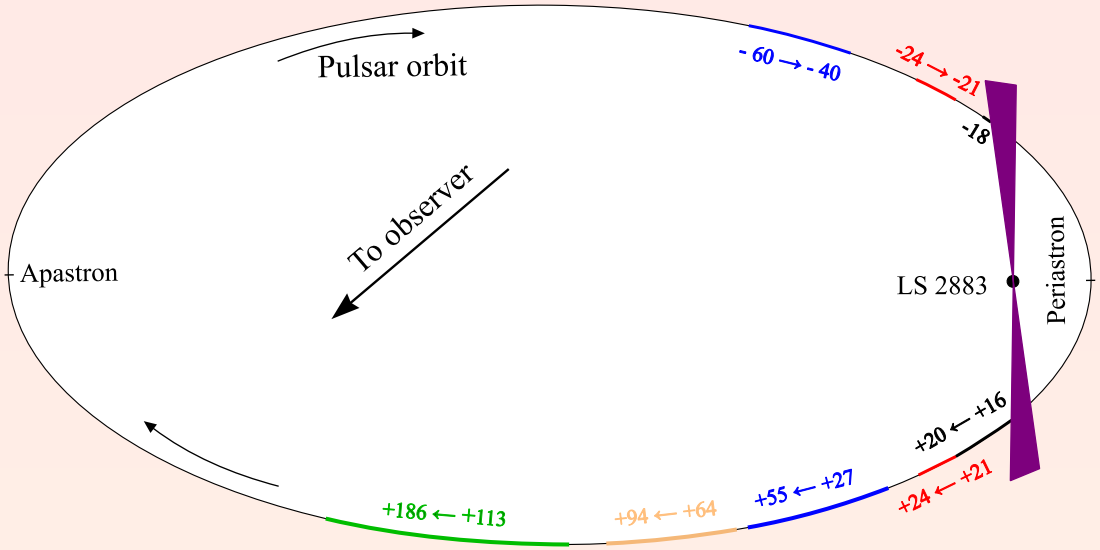
Why B1259-63?

- Lorimer et al. 1995: positive spectral index
- candidate for GPS pulsar (relatively young with high DM)
- extreme environment

B1259-63:
$P = 48$ ms, $\tau = 330$ kyr,
$DM = 147$ pc cm^3, $d = 2.75$ kpc,
$P_{orb} = 3.4$ yr, $e = 0.87$,
$a \sin i \approx 3.9 \times 10^{13}$ cm, $i \approx 39^o$.
LS 2883:
$M_* \approx 10 M_\odot$, $R_* \approx 6 R_\odot$.

B1259-63 spectrum evolution

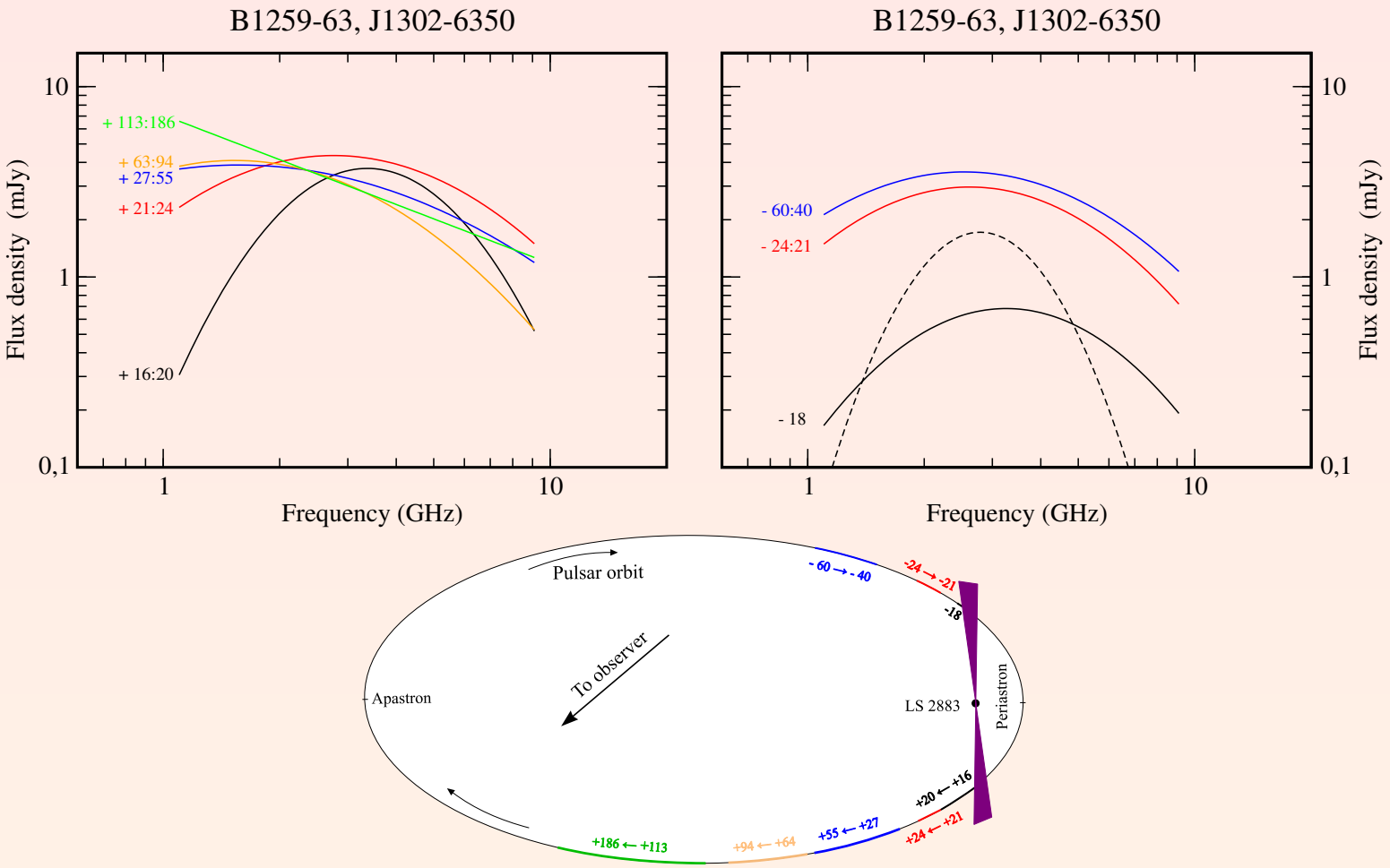




Kijak, Dembska, Lewandowski, Melikidze & Sendyk 2011b, MNRAS Letters

Data taken from published periastron passage observations in 1997, 2000 and 2004 (Johnston et al. 1999, Connors et al. 2002, Johnston et al. 2005).

B1259-63 spectrum evolution



Explanation model (Kijak et al. 2011b)

The observed variation of the spectra is caused by a combination of two effects: the **free-free absorption in the stellar wind** and the **cyclotron resonance in the magnetic field**.
According to the model we can estimate the peak frequency as follow

$$\nu_{\mathrm{GHz}} \approx 2.8 \times 10^{-3} \frac{B}{\gamma_p (1 - \cos\theta)},$$

where γ_p is a mean Lorentz factor of the plasma particles and θ is an angle between the wavevector and the magnetic field.
The frequency at which the optical depth of free-free absorption is unity is given by (Rohlfs & Wilson 1996)

$$\frac{\nu_0}{\mathrm{GHz}} = 0.3045 \left(\frac{T}{\mathrm{K}}\right)^{-0.643} \left(\frac{a(\nu, T) EM}{\mathrm{pc\,cm^{-3}}}\right)^{0.476},$$

where $a(\nu, T) \approx 1$ and EM is emission measure.

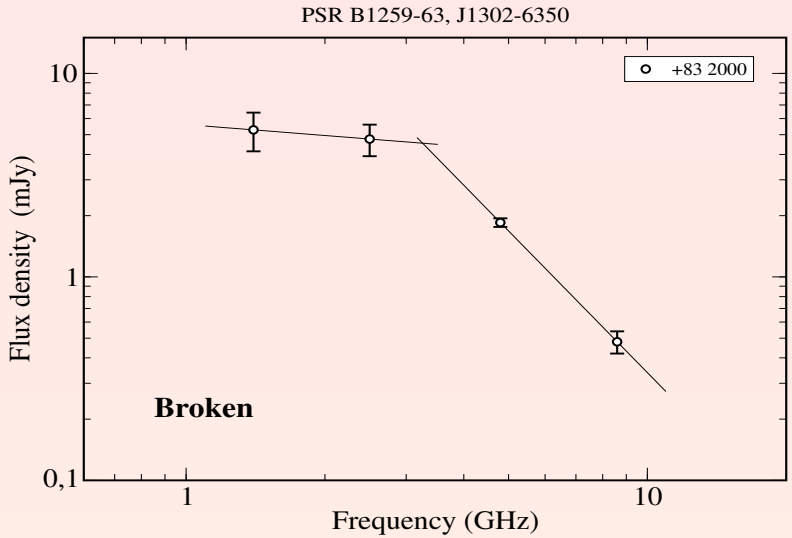
B1259-63 spectrum: detailed study and classification of pulsar spectra

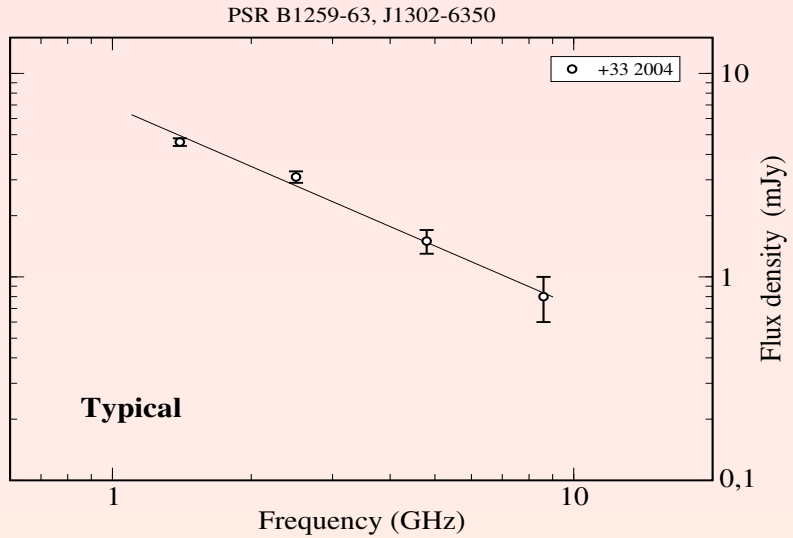
Detailed study

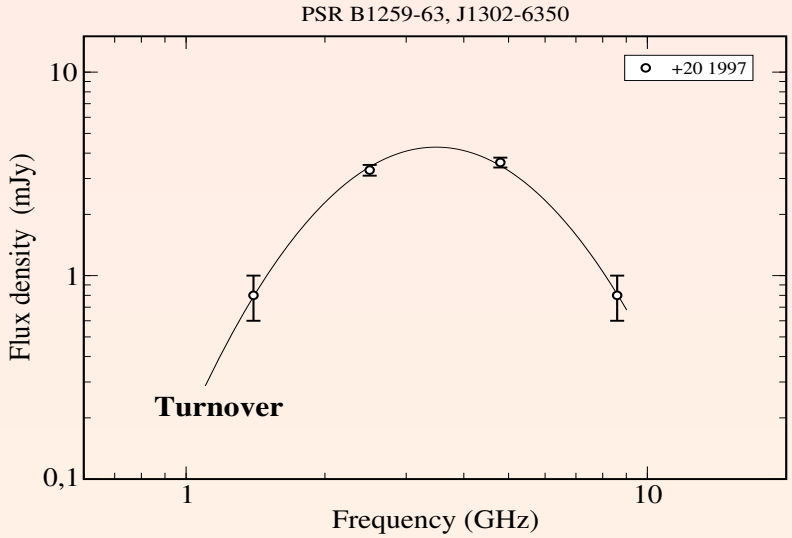
Using the same database we constructed spectra for chosen observing days. As previously (Kijak et al. 2011b) we analysed the shapes of the B1259-63 spectrum at various orbital phase ranges. We noticed all types of radio pulsar spectra.

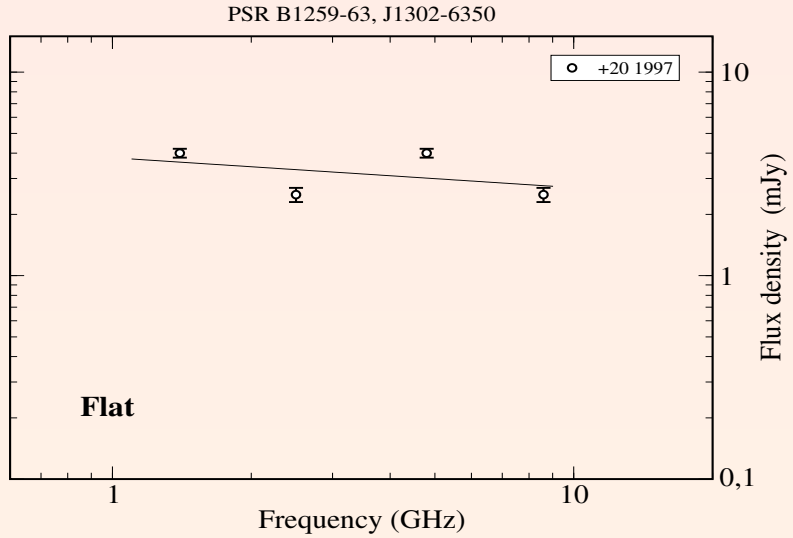
Classification of pulsar spectra?

The flux at the given frequency apparently changes with orbital phases. When the pulsar is close to periastron, the flux generally decreases at all observed frequencies and the most drastic decrease is observed at the lowest frequency.


PSR B1259-63, J1302-6350
+83 2000
Broken
Flux density (mJy)
Frequency (GHz)
10
1
0,1
1
10


PSR B1259-63, J1302-6350
+33 2004
Typical
Flux density (mJy)
Frequency (GHz)
10
1
0,1
1
10


PSR B1259-63, J1302-6350
+20 1997
Turnover
Flux density (mJy)
Frequency (GHz)
10
1
0,1
1
10


PSR B1259-63, J1302-6350
+20 1997
Flat
Flux density (mJy)
Frequency (GHz)
10
1
0,1
1
10

PSR B1259-63 Interstellar scintillations: McClure-Griffiths et al. 1998

Diffractive scintillations

Timescales from 40 s (1.4 GHz) to 360 s (8.4 GHz) suggests that diffractive scintillations should not affect the average flux measurements (observing sessions was usually 4 hours long).

Refractive scintillations

Roughly estimated refractive timescales varies from 12 hours (8.4 GHz) to more than 20 days (1.4 GHz). However, for lower frequencies the modulation index is relatively small which means lower uncertainty estimates when measuring flux. High frequency observations will be affected by refractive scintillations $\rightarrow$ flux values should be averaged over epochs and/or orbital phase intervals to be more reliable.

Conclusions
B1259-63 as key factor to explain the GPS phenomenon...

Having noticed the apparent resemblance between the B1259-63 spectrum and the GPS, we suggested that the same mechanisms should be responsible for both cases.

Thus, we believe that this binary system can hold the clue to the understanding of gigahertz-peaked spectra observed for the isolated pulsars with interesting environments. The only difference could be an invariable shape of the GPS.

. . . and other non-typical types of spectra

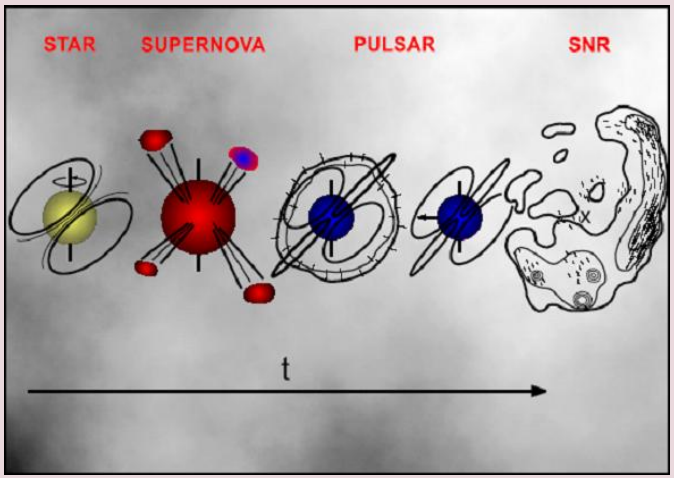
Close to the periastron point the spectra of B1259-63 resemble those of the GPS pulsars. The spectra for the orbital epochs further from the periastron point are more consistent with typical pulsar spectra (i.e. power-law). Moreover, detailed study revealed appearance of all types of spectra shapes.

We also believe that the case of B1259-63 can be treated as a key factor to our understanding of the appearance of other types spectra as well (e.g. different from power law). This in turn would suggest, that the appearance of various non-standard spectra shapes in the general population of pulsars can be caused by peculiar environmental conditions.

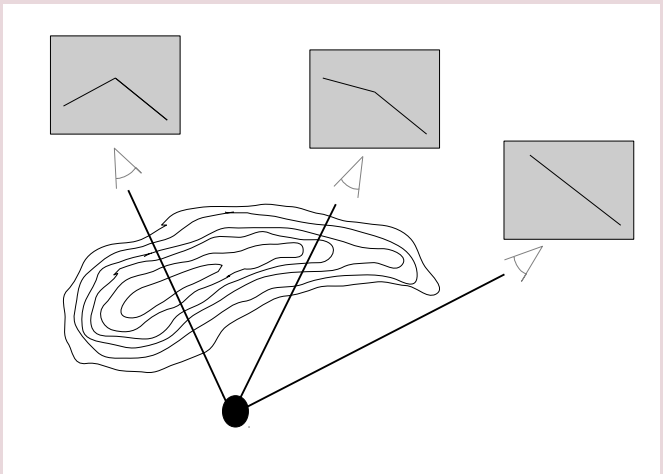
Future plans

MORE GENERAL MODEL FOR PSR B1259-63/LS 2883

MODEL FOR ISOLATED GPS PULSARS



Pavlov & Kargaltsev, 2008, ApJ



"asymmetry" of environment may play an important role

Future plans

Model for isolated GPS pulsars

- in most cases **free-free absorption** can be responsible for decrease of observed flux at low frequencies (Slee et al. 1986 – probably the first mention)
- **cyclotron resonance** can be considered in some cases (PWNe can play a similar role as LS 2883 stellar wind)
- other possible effects, i.e. **interstellar scintillations** and **flux dilution** need to be taken into account
- GPS appearance probably depends on an "asymmetry" of environment

MORE GENERAL MODEL BASED ON ENVIRONMENTAL INFLUENCE ON RADIO PULSAR SPECTRA