Electrodynamics of the inner acceleration region in pulsars and direction of plasma drift

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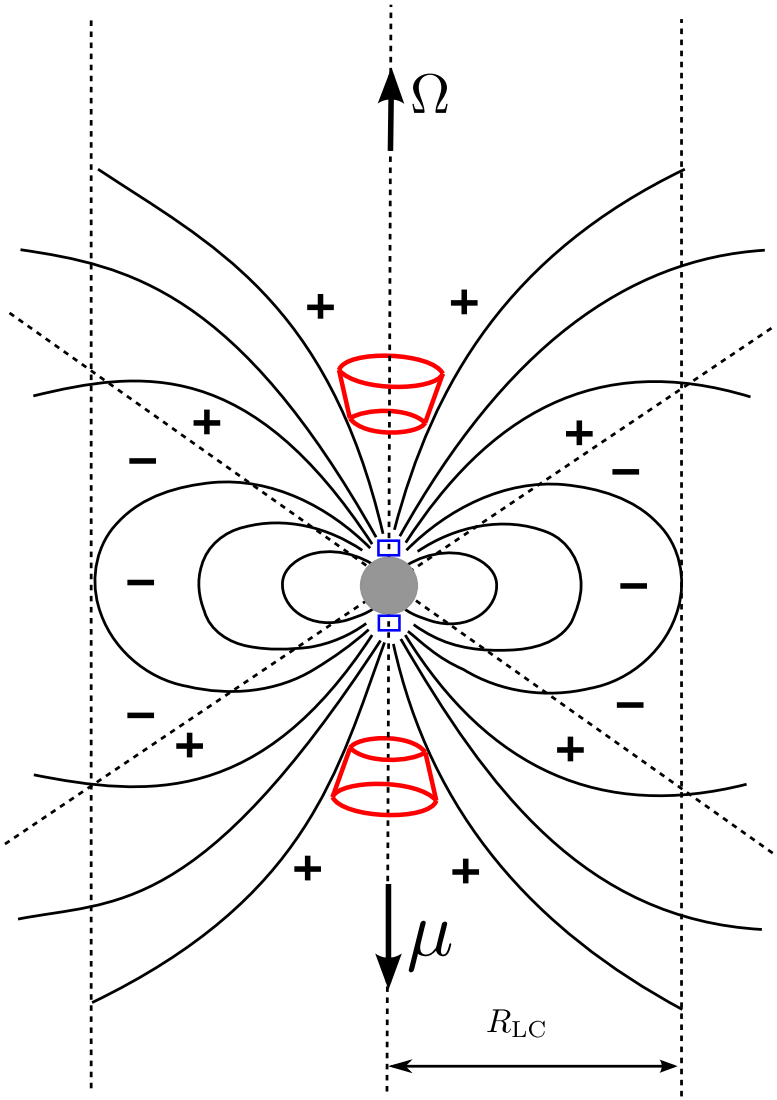
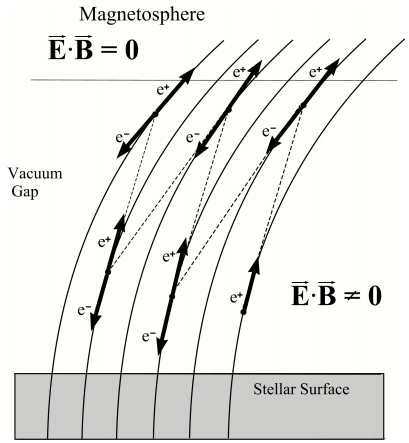
2023

Pulsars

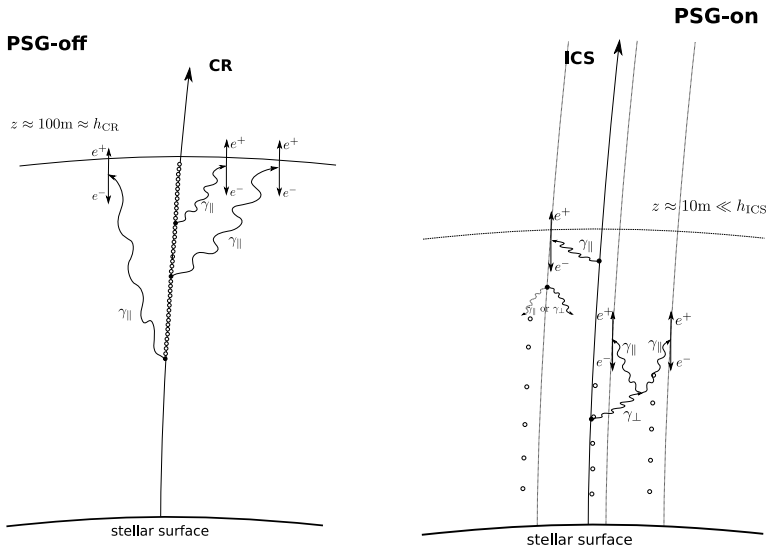
(Inner Acceleration Region)





Vacuum Gap

(Ruderman & Sutherland 1975)

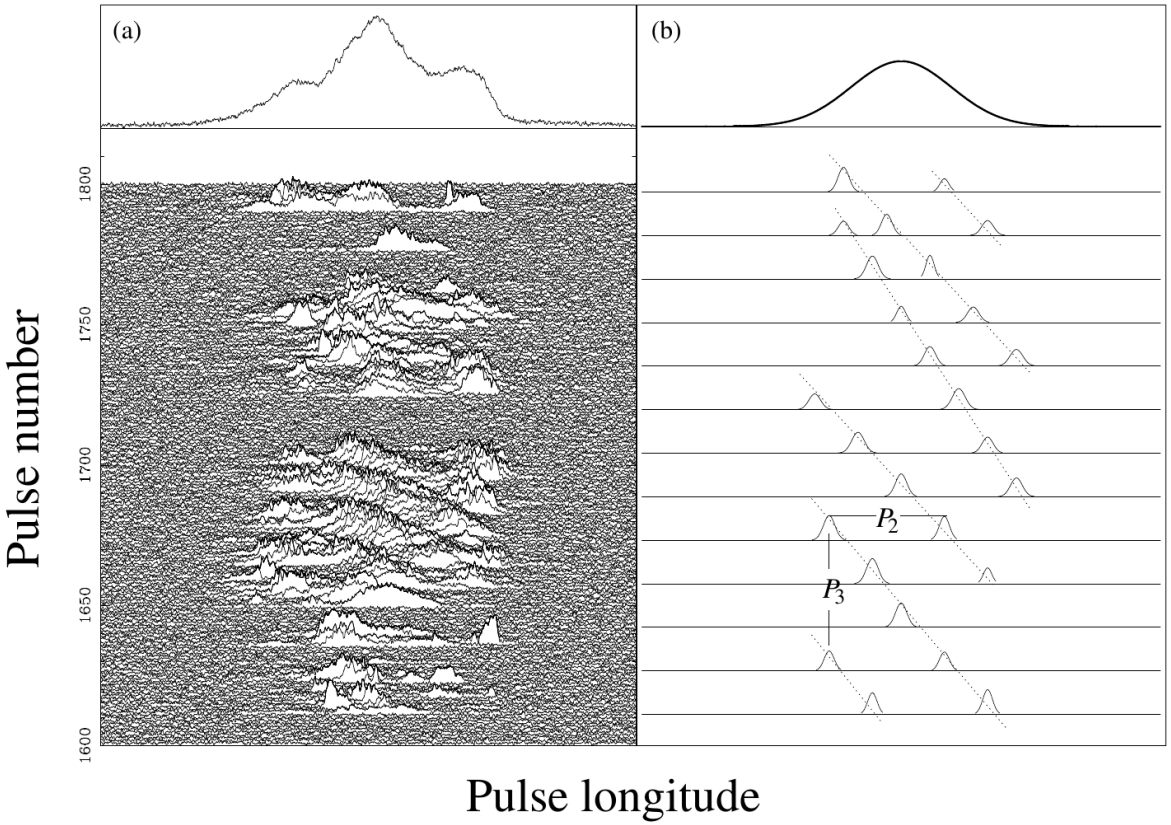


Partially Screened Gap

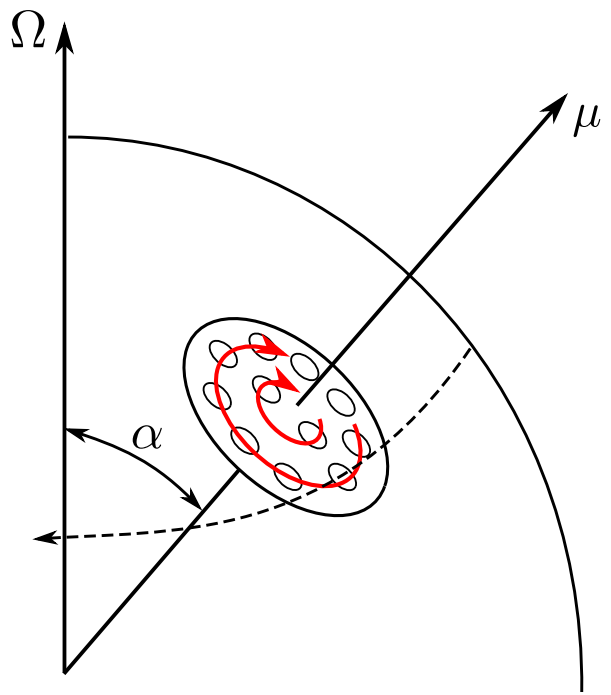
(Gil, Melikidze & Geppert 2003)

Drifting subpulses phenomenon

(The Carousel Model)



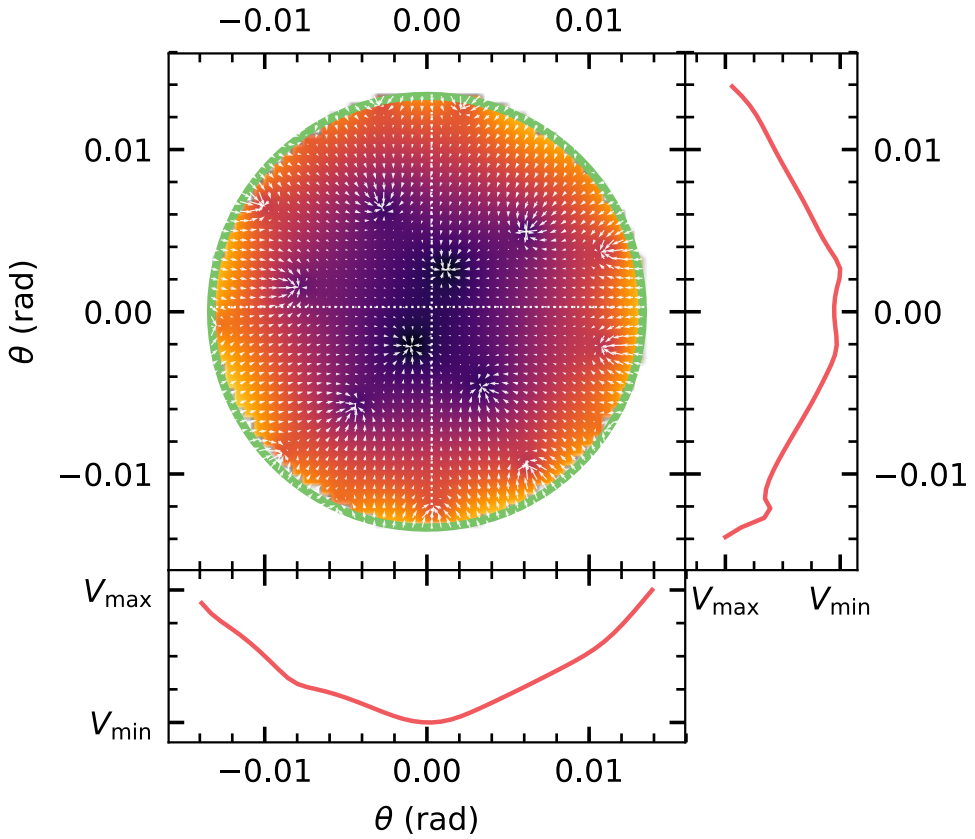
(a) Single pulses from PSR B1944+17 observed with the Arecibo telescope at 430 MHz showing drifting subpulses. (b) Schematic view of the drifting subpulse phenomenon showing periodicities P_2 and P_3. Taken from "Handbook of Pulsar Astronomy" by Lorimer & Kramer.

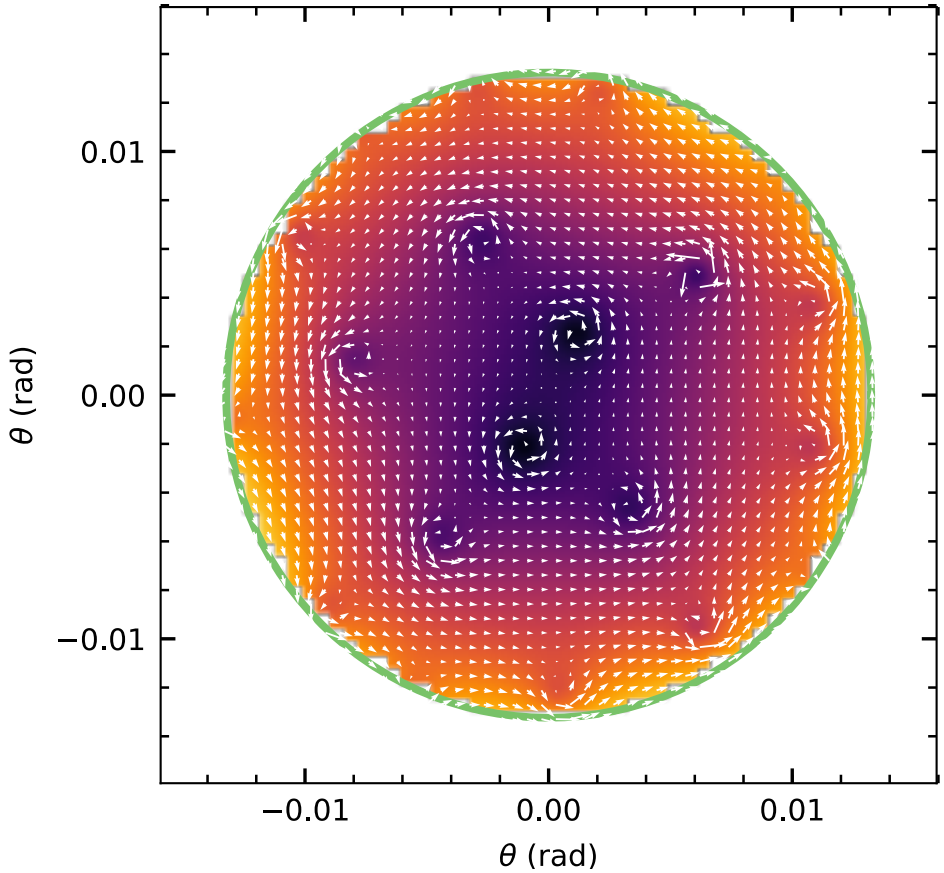


The Carousel Model of drifting subpulses

(Ruderman & Sutherland 1975)

Modified Carousel (MC) model





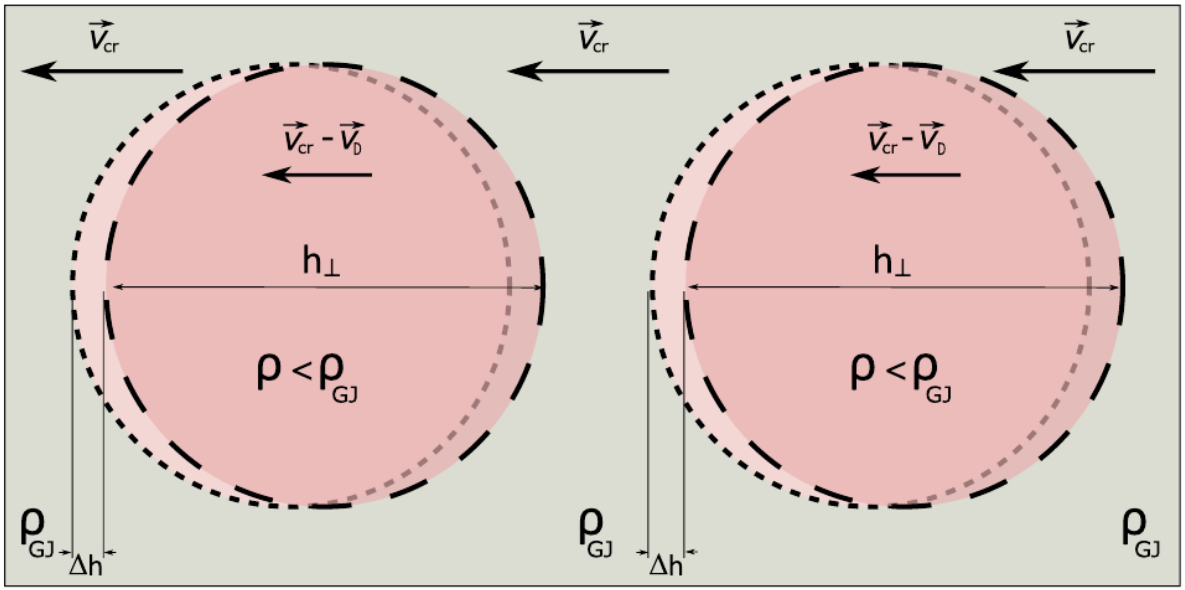
- electric field is not fully screened in regions between sparks

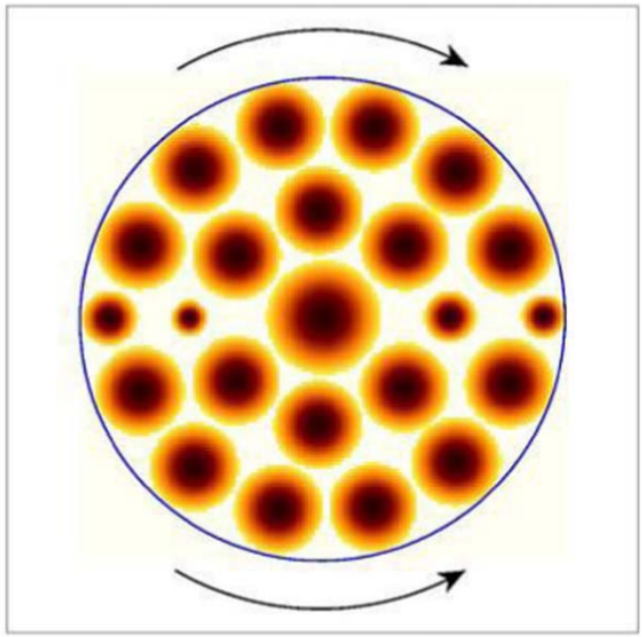
- drift of plasma around potential extremum at the polar cap

(Szary & van Leeuwen 2017)

Lagging Behind Corotation (LBC) model

$\vec{E}\cdot\vec{B}=0$ $\vec{\Omega}\cdot\vec{B}<0$





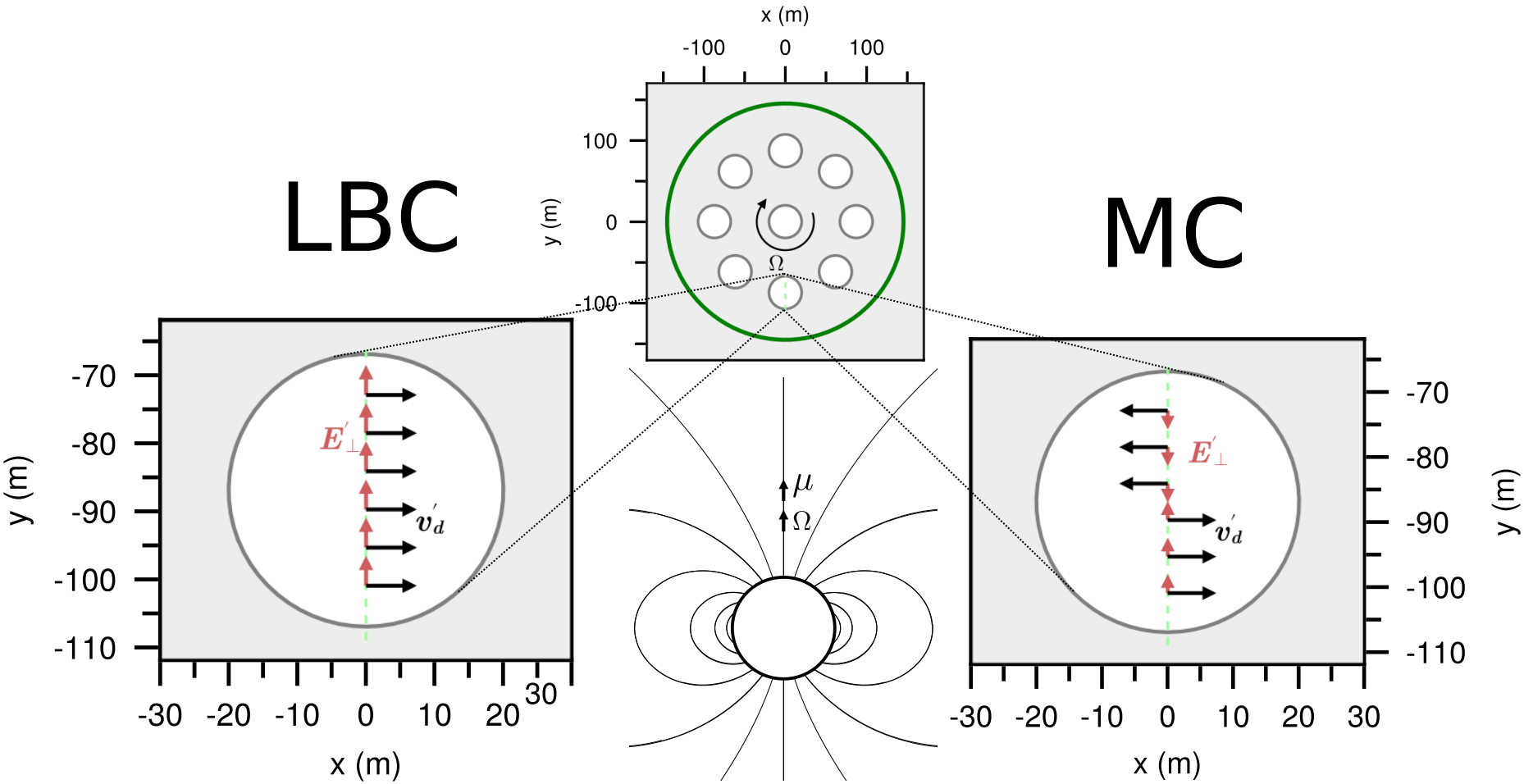
- in the plasma starved regions charged particles lag behing corotation

- plasma drifts around the rotation axis

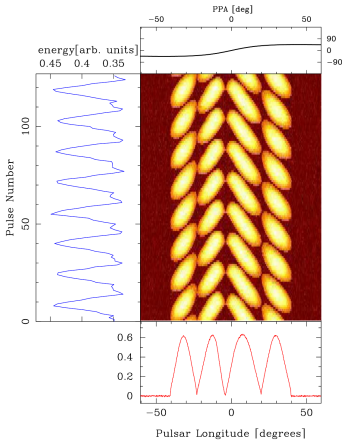
(in the direction opposite to the corotation in the c. f. r.)

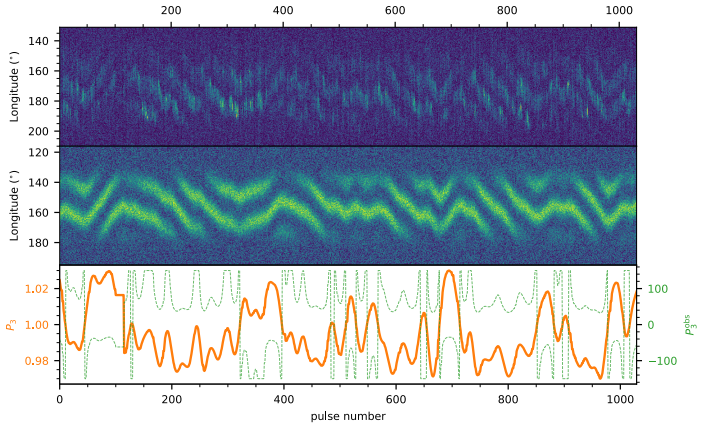
(Basu et al. 2020, 2022)

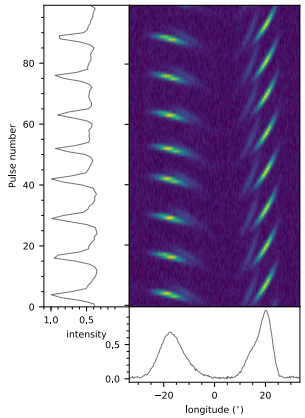
LBC vs MC


LBC
MC
x (m)
-100
0
100
y (m)
100
0
-100
Ω
μ
Ω
$E'_\perp$
v'_d
-70
-80
-90
-100
-110
y (m)
-30
-20
-10
0
10
20
30
x (m)

Research to date

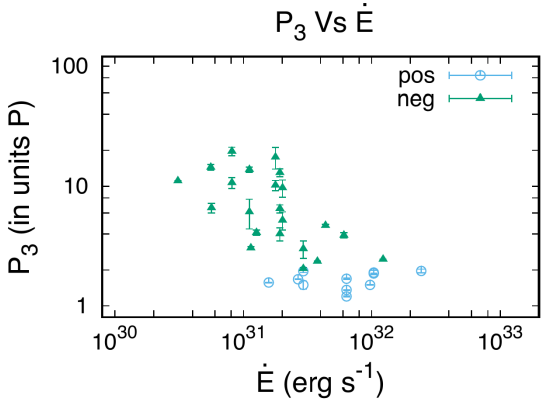


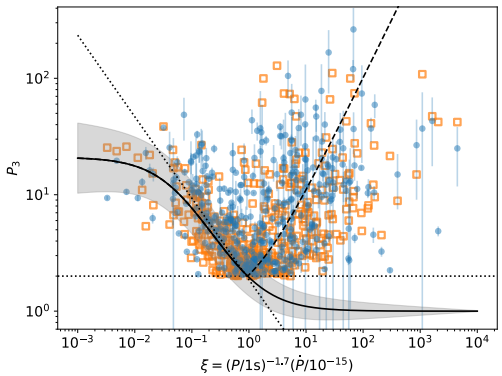




- both LBC and MC models can explain extraordinary drfting behaviours: e.g. bi-drifting, drifting reversals

(Basu et al. 2020, 2022, 2023, Szary & van Leeuwen 2017, Szary et al. 2020, 2022)



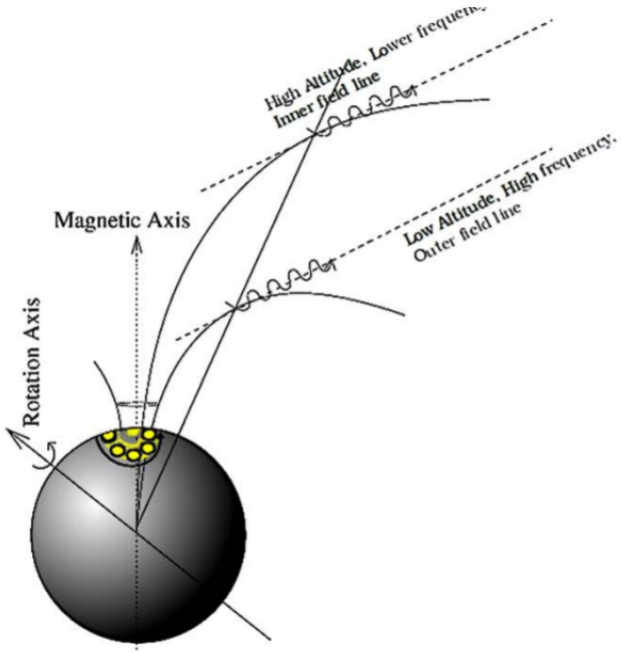


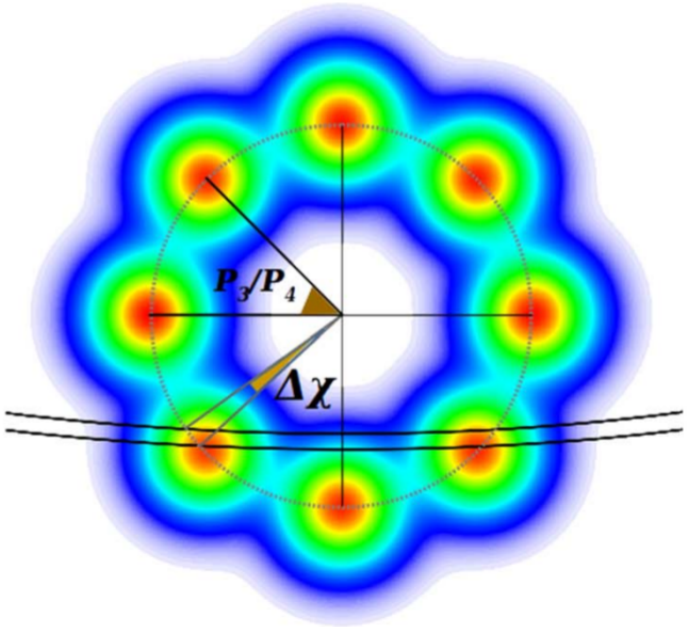
- the P3-Edot dependece confirmed, however the simple aliasing explanation disproved

(Basu et al. 2016, 2019, Song et al. 2023)

What's next? Multi-frequency subpulse drift analysis.

Expected Imprints of the Carousel in Multi-frequency Pulsar Observations ... (Maan 2019)





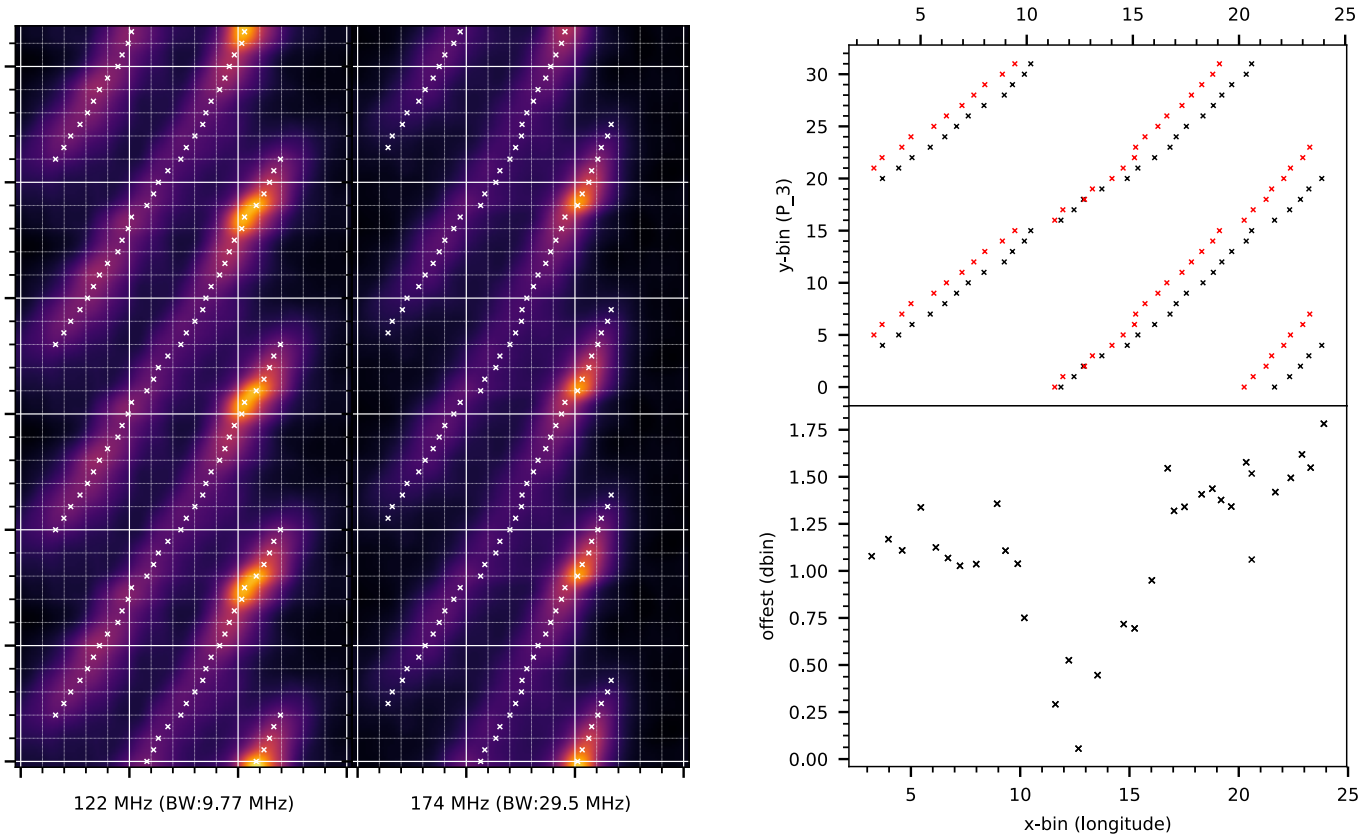
The geometry induced phase-offset in subpulse modulation can be expressed as

$$\Delta\theta = \left(n + \frac{P}{P_3^{\rm obs}}\right) \frac{2\pi(h_{\nu 1} - h_{\nu 2})}{cP},$$

where n is the aliasing order, $P_3^{\rm obs}$ is the observed modulation period, and $h_{\nu 1}$, $h_{\nu 2}$ correspond to the emission altitudes at two frequencies.

Can LOFAR help? Yes!

The offset analysis performed using LOFAR observations of PSR B0320+39



The P_3-folded profiles of PSR B0320+39 at two frequencies (the left panels). The white crosses in the left panels correspond to the component positions. The red crosses in the top right panel correspond to component positions at 122 MHz, while the black crosses correspond to positions at 174 MHz.

Data set summary

MeerKAT (L-band: 900-1700 MHz)

~1200 pulsars, 533 drifters

PRESS survey (UWL: 700-4000 MHz)

~176 pulsars, 106 drifters

LOFAR (HBA: 120-240 MHz)

Dec. > 0 deg.: 126 drifters

Dec. > 10 deg.: 75 drifters

Thank you!