Joeri van Leeuwen
Pulsar mode changes and subpulse drift
Pulsars: cosmic lighthouses

Join the 21st century already!

http://www.astron.nl/pulsars/animations/
Moding and drifting -- B0943+10 data

Backer (1977)
Mode changes and/or subpulse drift in four pulsars

PSR B0809+74
Very bright (B) and stable. But with nulls, then Quiet (Q)?

PSR B0826-34
Drift-reversals in B mode; RRAT-like and bursty in Q mode

PSR B0815+0393
Bi-drifting (?) in B mode; existence of Q mode yet unknown

PSR B0943+10
Stable drifting in B mode; chaotic in Q mode; x-ray source
The problem: subbeams move very slowly (cf. B0809+74)
The basic ExB model (Ruderman & Sutherland 1975)
A solution: a partially screened gap

Van Leeuwen

Pulsar mode changes and subpulse drift

Goddard Magnetospheres 2016
A solution: a partially screened gap

Average Flux
Block averaged pulses

Pulse Number
1000 1500
6000
4000
2000
0

Longitude (deg.)
-20 -10 0 10

10^4 2×10^4

Rankin et al. (2004)
A solution: a partially screened gap – PSR 0815+0393
Other solution: use the actual $dV/dr$

Potential drop $V$ (RS75)
Other solution: use the actual $dV/dr$
PSR B0826-34: fortuitous geometry

![Graph showing relative power vs phase and longitude.](Image)
PSR B0826-34: fortuitous geometry

van Leeuwen & Timokhin (2012)
PSR B0826-34: both steady and varying drifting

van Leeuwen & Timokhin (2012)
PSR B0826-34: A very clean machine

\( \frac{\partial V}{\partial \xi} \) vs Magnetic colatitude \( \xi \)

- Curve e
- Curve c
- Curve a
- Curve b
- Curve d

Magnetic colatitude \( \xi \)

van Leeuwen & Timokhin (2012)
Moding and drifting -- B0943+10 data
B0943+10 with LOFAR

LOFAR pulsar work steadily ramping up towards 200 beam survey

APERTIF exploiting PAFs + regular array layout for surveying

First multi-beam pulsar observations with test system already started

Preparing for 600-beam transient/pulsar survey

EMBRACE Aperture Array

Proven to be excellent for multi-beam pulsar observations

Allows for wide angles for timing, large FoVs for surveys

SKA most compact core scenario

10,000 beams

~10-100 P-OPS

Hermsen et al. (2013)
Large sample of radio B <-> Q mode transitions

Including high-S/N single pulse / single x-ray photon studies.

van Leeuwen et al. 2016 (in prep.); also Bilous et al. 2016 (in prep.)
Interest in mode changes

PSR B1931+24 was the first pulsar shown to cease emitting for tens of days, then spin down ~50% less rapidly (Kramer et al. 2006).

Several other pulsars display smaller changes in spin-down rate that correlate with changes in pulse shapes (Lyne et al. 2010).
Conclusions

LOFAR data will dive more in to the 1s – 8hr behavior of B0943+10.

Time variable drifting (including reversals) in B0826-34 can be explained with little variation (~1E-4) of the potential drop over 20% of polar cap.

What causes these variations? And, what determines the drifting 2\textsuperscript{nd} modulation (20 Hz in a 1 Hz pulsar)? Or the nulling / moding time scales 1 s – 100 days ..