The Thousand-Pulsar-Array programme on MeerKAT XIV: On the high linearly polarized pulsar signals

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(Shunshun Cao)

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15 pages in total

Contents

I. Introduction

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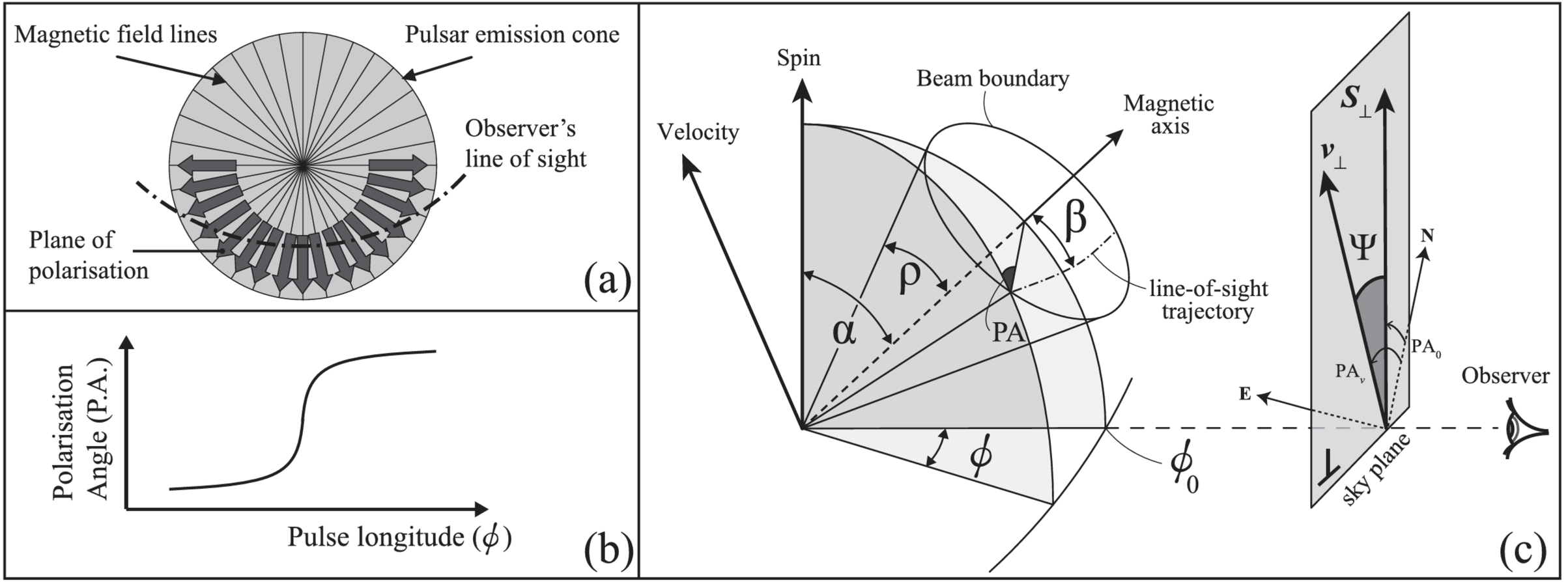
Rotating Vector Model

(RVM, Radhakrishnan & Cooke 1969): Linearly polarized emission follows dipole magnetic fields.

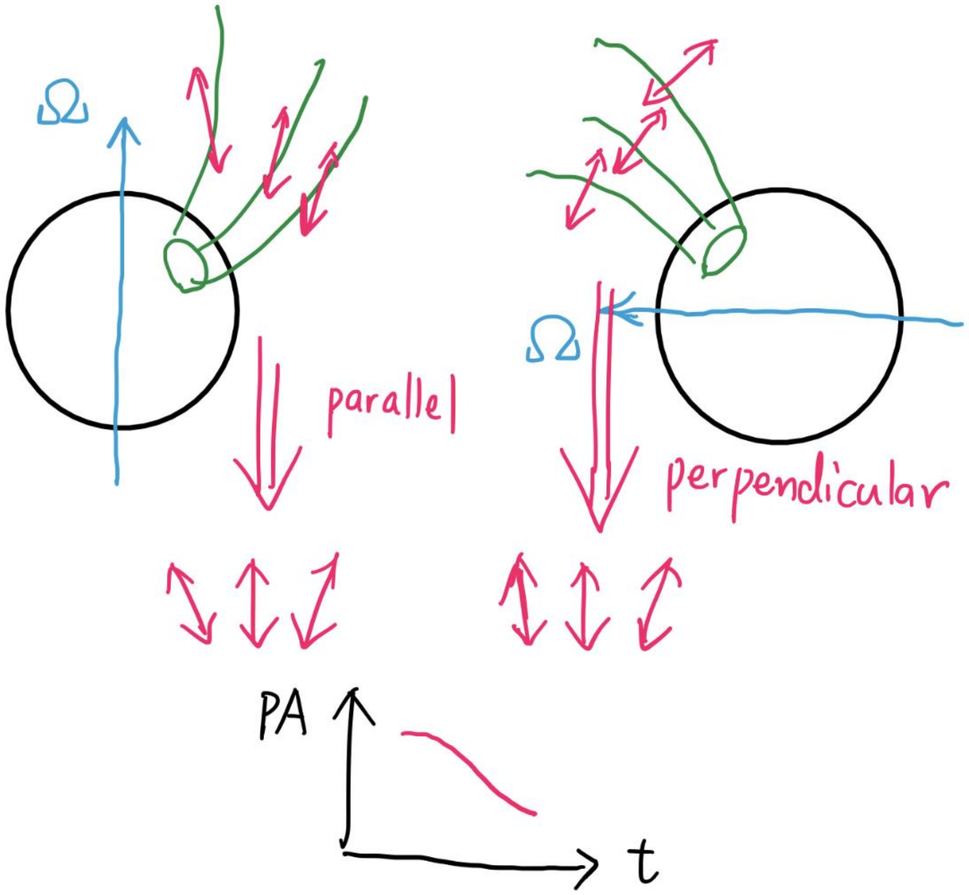


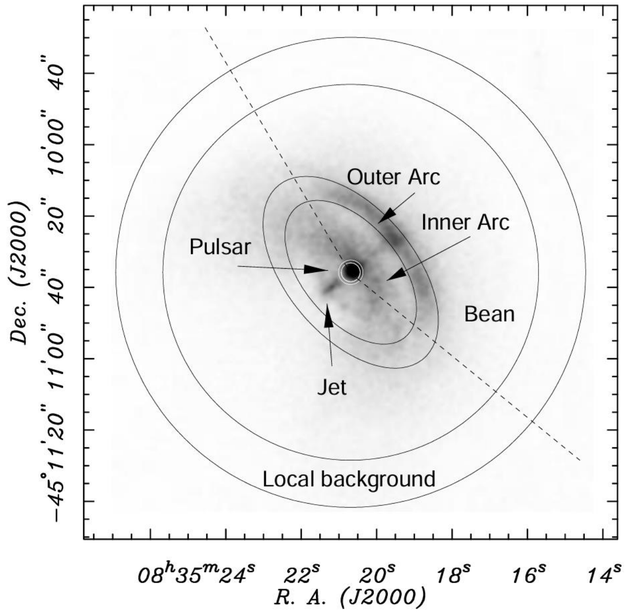
Noutsos et al. 2012

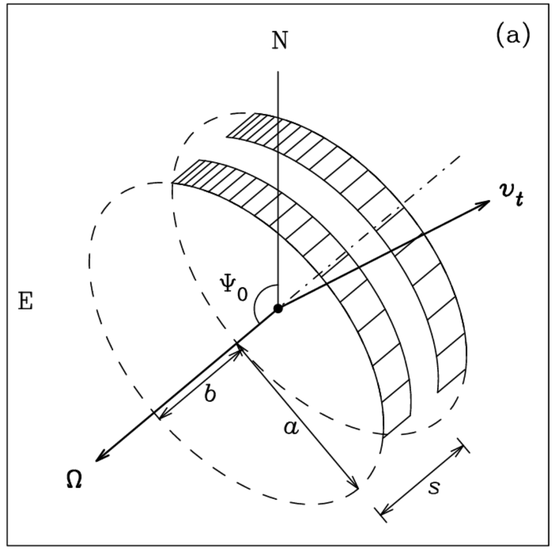
The physics behind RVM: on radiation mechanisms

Radhakrishnan 1969: ultra-relativistic electrons' curvature radiation ➔ $\tilde{E}//B_0$

Tell $\tilde{E}//B_0$ from $\tilde{E} \perp B_0$ ➔➔ determine the directions of spin-axis/magnetic-axis.





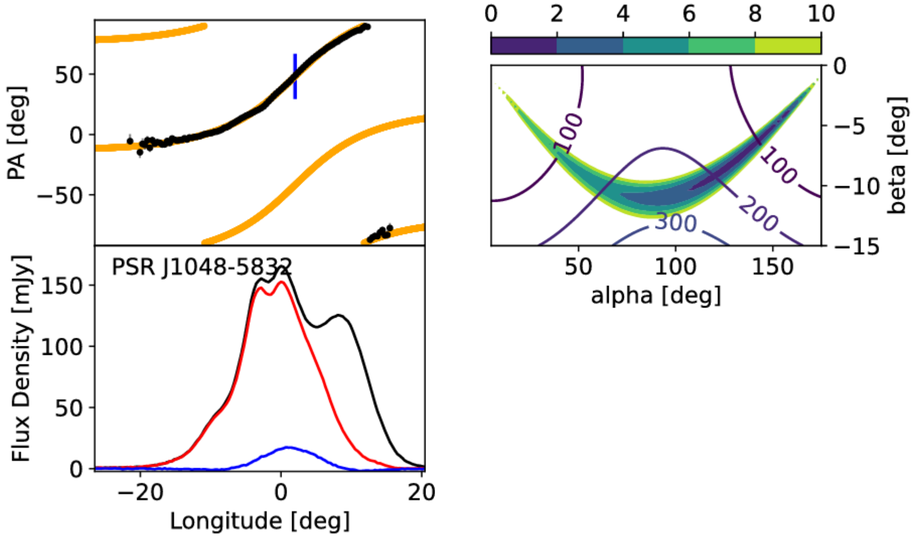


Chandra X-ray observation of Vela pulsar

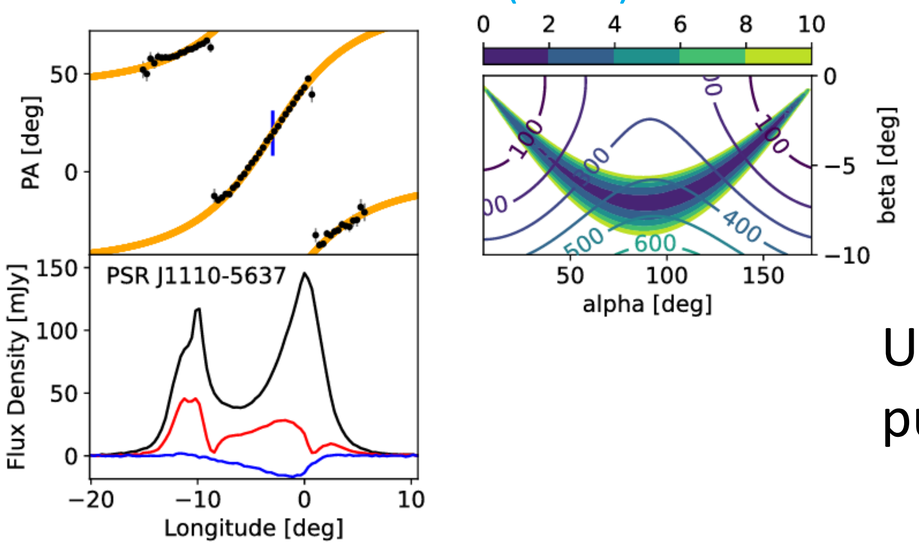
➔➔➔ $\tilde{E} \perp B_0$ more likely for Vela pulsar's case.

(Helfand, Gotthelf, Halpern 2001)

Some successful examples:

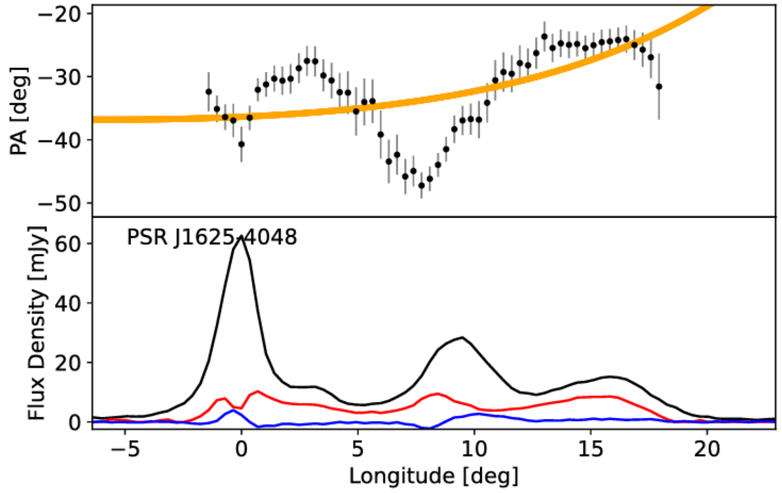


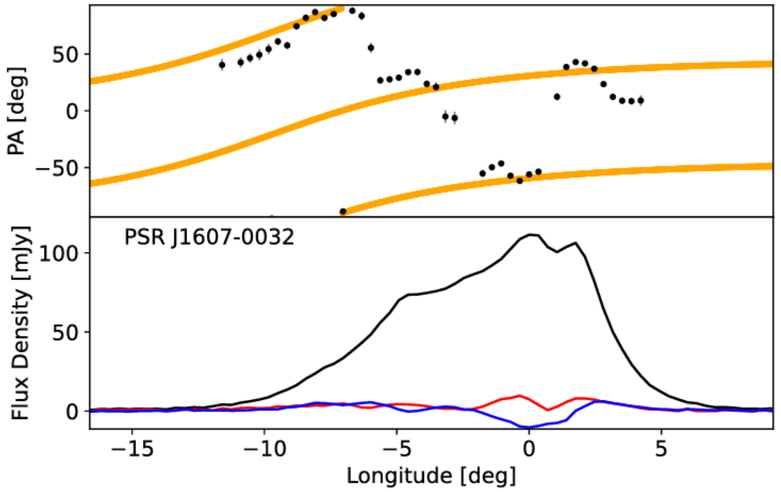
Orthogonal
Polarization Modes (OPM)



Usually on **integrated** pulse profiles.

Some unsuccessful examples:

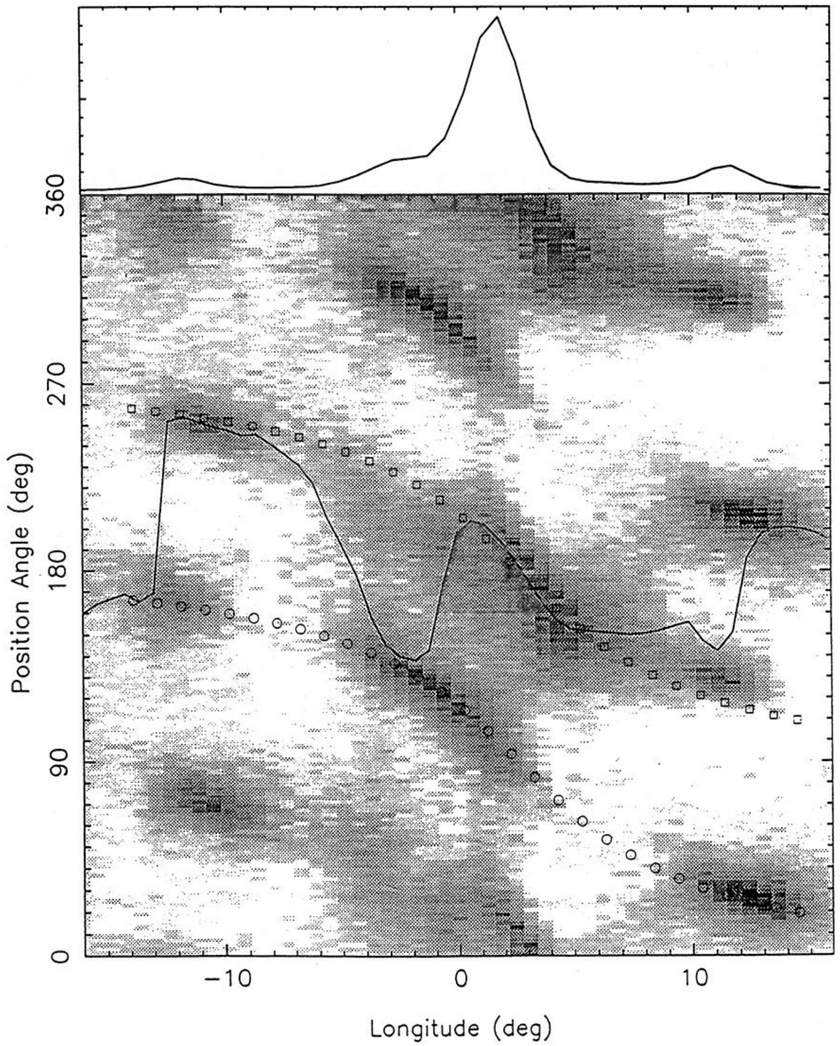




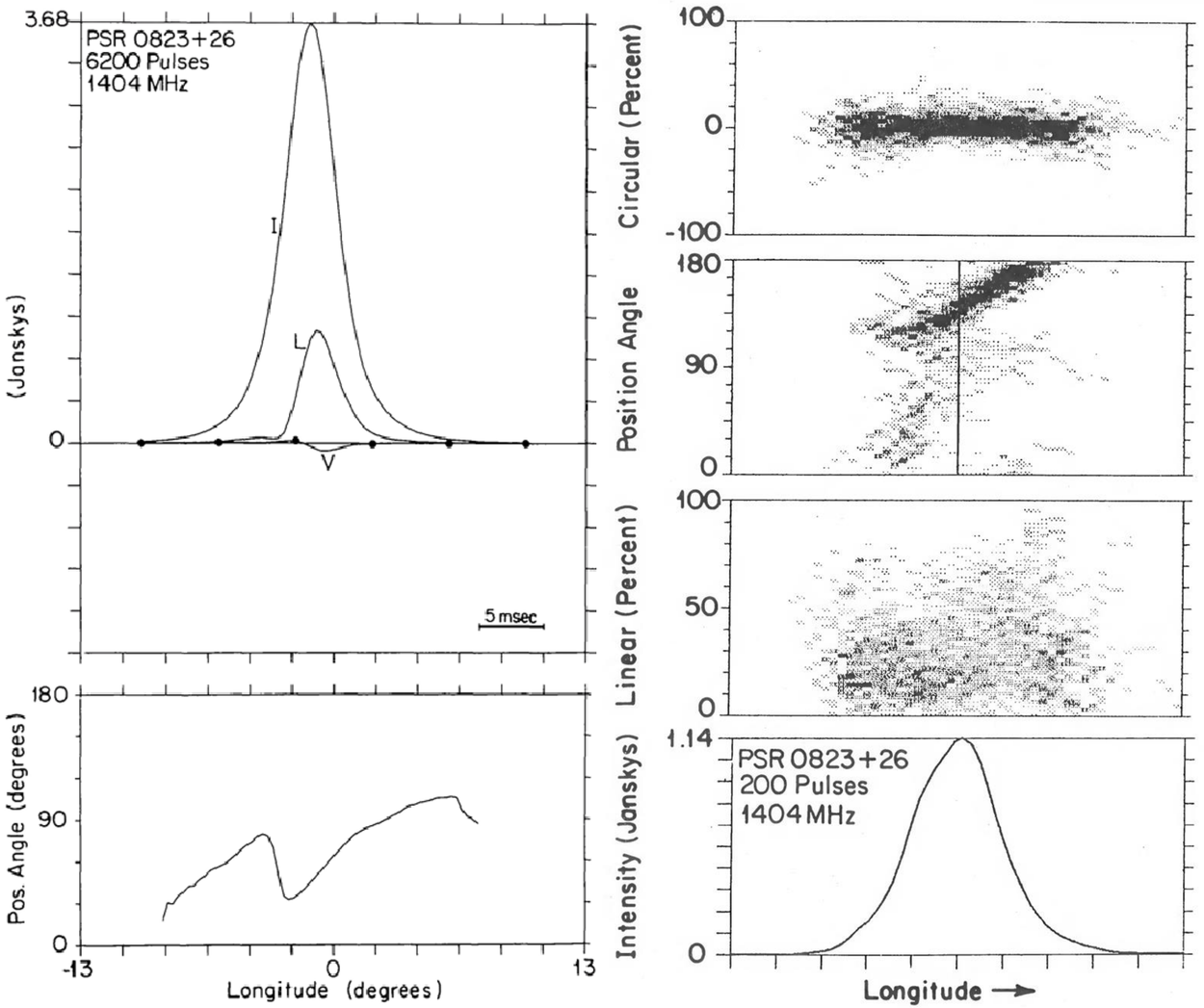
All **normal** pulsars from Johnston et al. 2023

Class	Number
RVM	431
Flat	71
Non-RVM	352
Total	854

Polarization on a continuous train of time-samples (bins): more RVM-like.

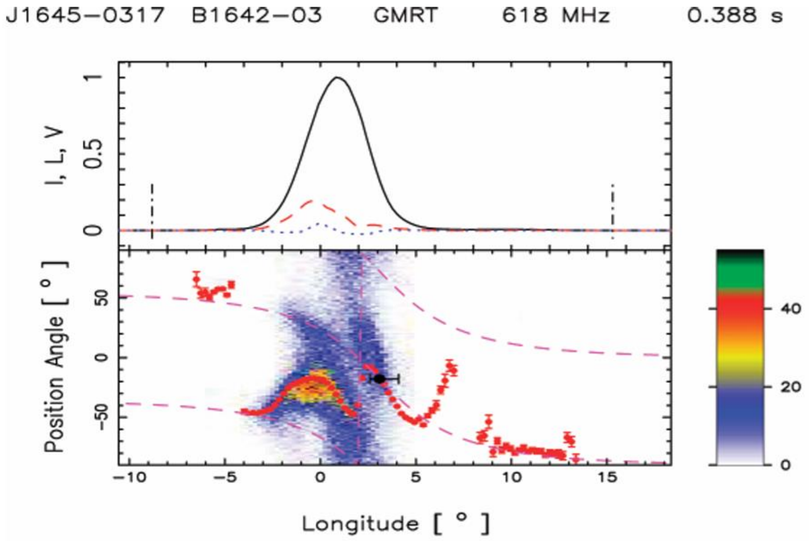


Gil & Lyne 1995, on PSR B0329+54.

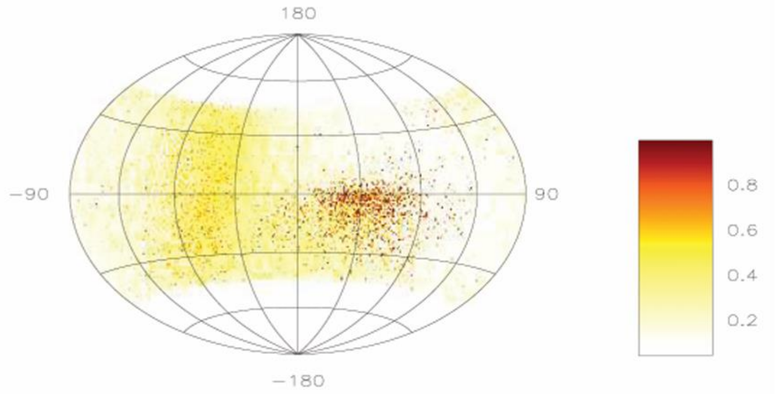


Stinebring et al. 1984, on PSR B0823+26.

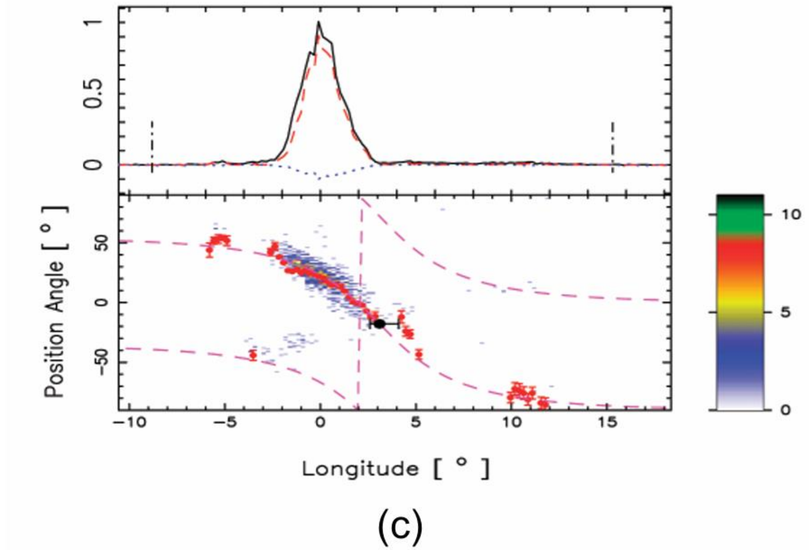
Mitra, Melikidze, Basu 2023a: highly polarized time samples are RVM like.



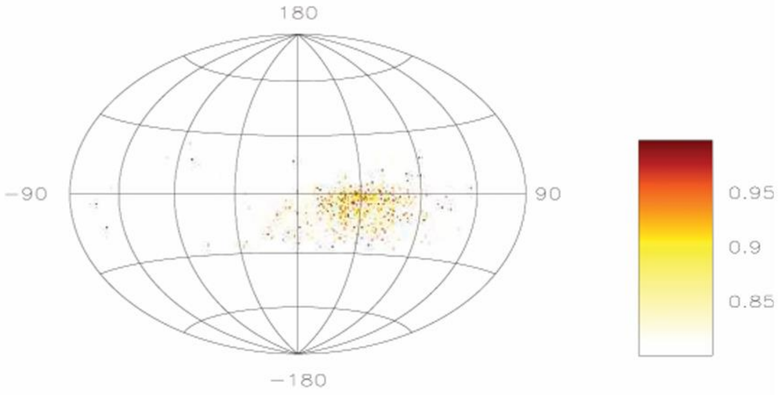
(a)



(b)



(c)



(d)

Johnston et al. 2024:
Try this on more pulsars

II. Observation & Pulsar Selection

MeerKAT observation: 896MHz – 1671MHz 1202 pulsars

1024 bins per rotation period.

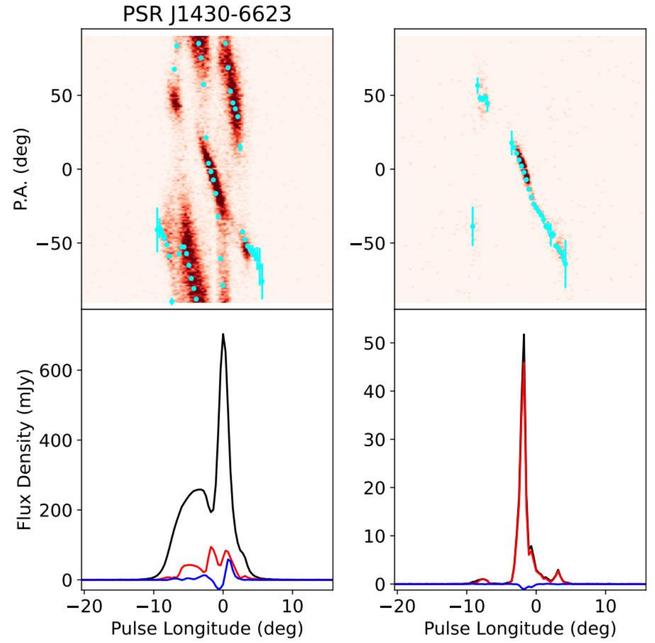
Pulsar data selection:
(a) > 500 pulses recorded
(b) > 60% pulses having S/N > 5σ in Stokes *I*

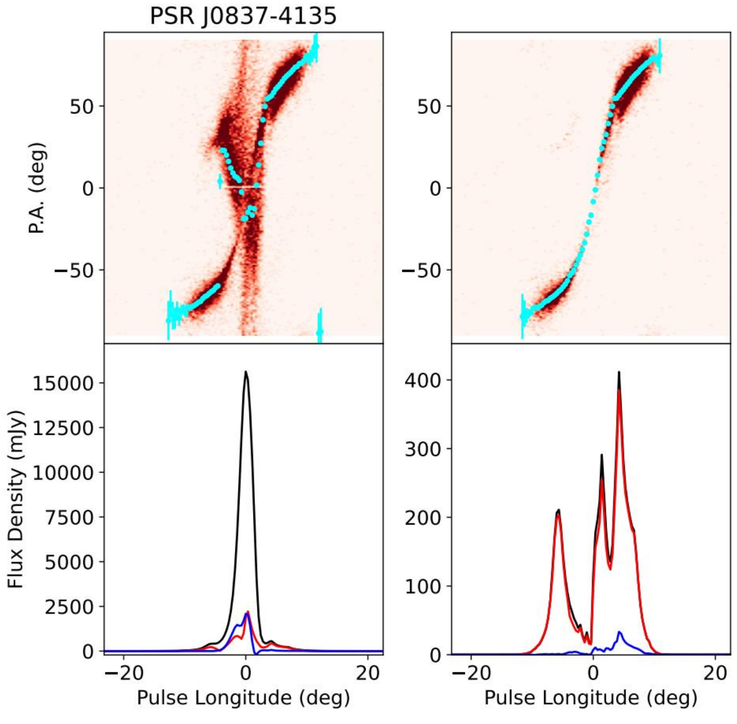
➔➔ 249 pulsars selected.

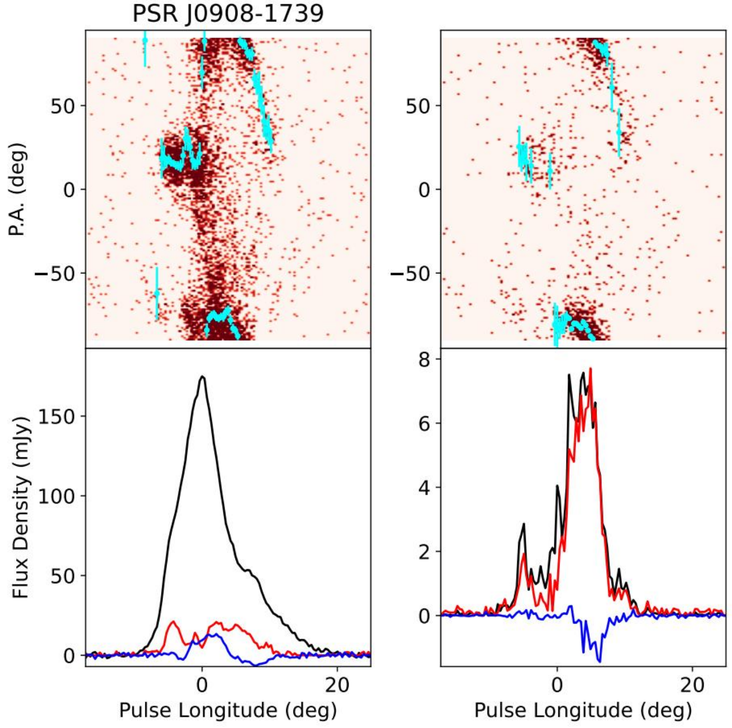
III. Results & Analysis

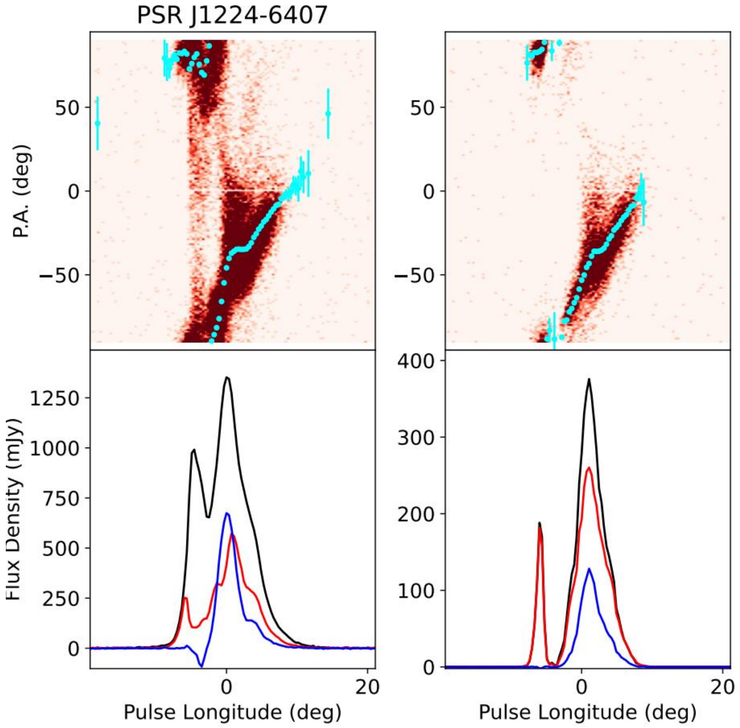
(3.1) Highly polarized profiles' formation

Individual pulses ➔ Integrated profiles ➔ set on-pulse window
➔select time samples with L/σ_L > 3.5 and L/I > 80%
➔➔ calculate PA, integrated profiles and their PA

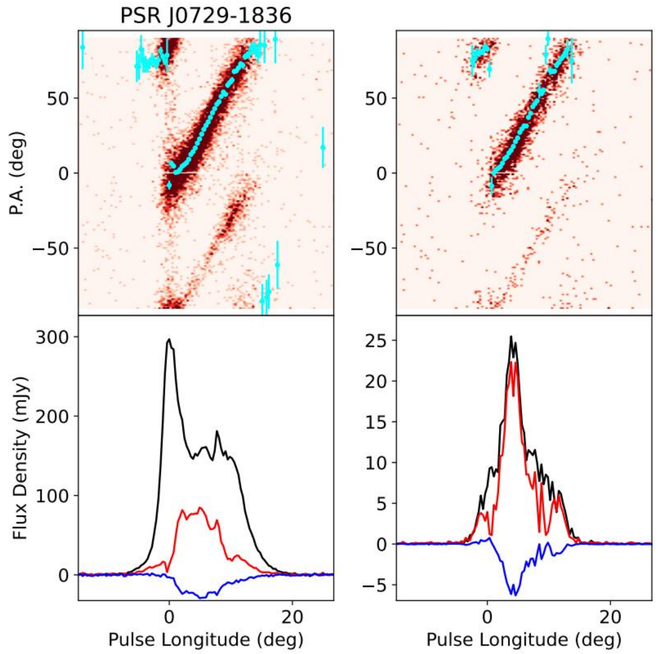


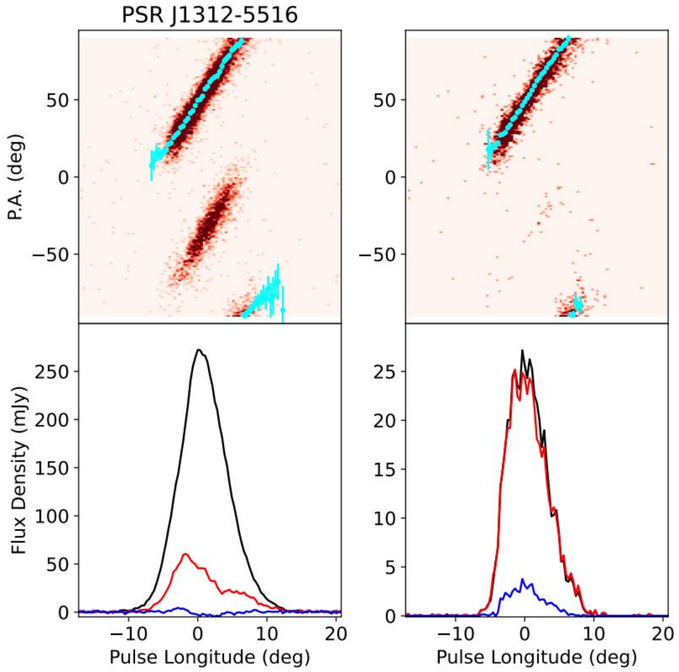




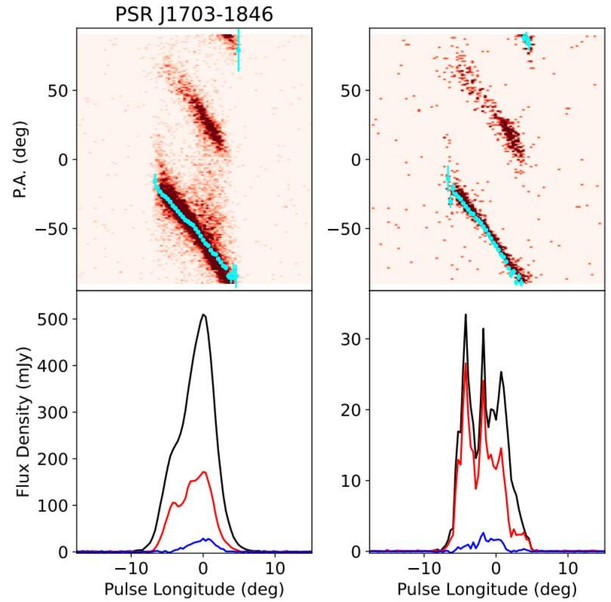


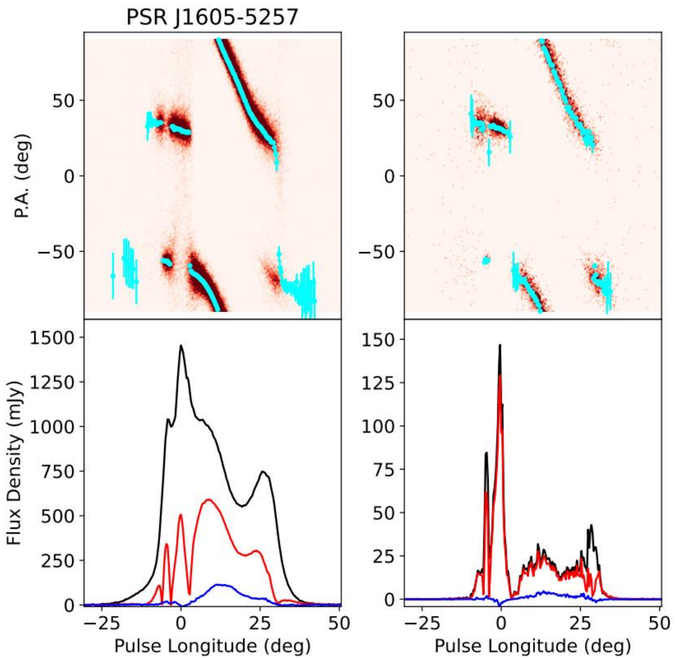
For some pulsars showing RVM-like PA with OPM in **original** integrated profiles:





OPM ceases





(3.2) RVM fitting

$$\mathrm{PA} = \mathrm{PA}_0 + \arctan\left(\frac{\sin\alpha \sin(\phi - \phi_0)}{\sin\zeta \cos\alpha - \cos\zeta \sin\alpha \cos(\phi - \phi_0)}\right) \qquad \zeta = \alpha + \beta$$

· OPMs taken into account

· Judgement: chi^2 < 3 ➔ fitted
Otherwise ➔ non-RVM

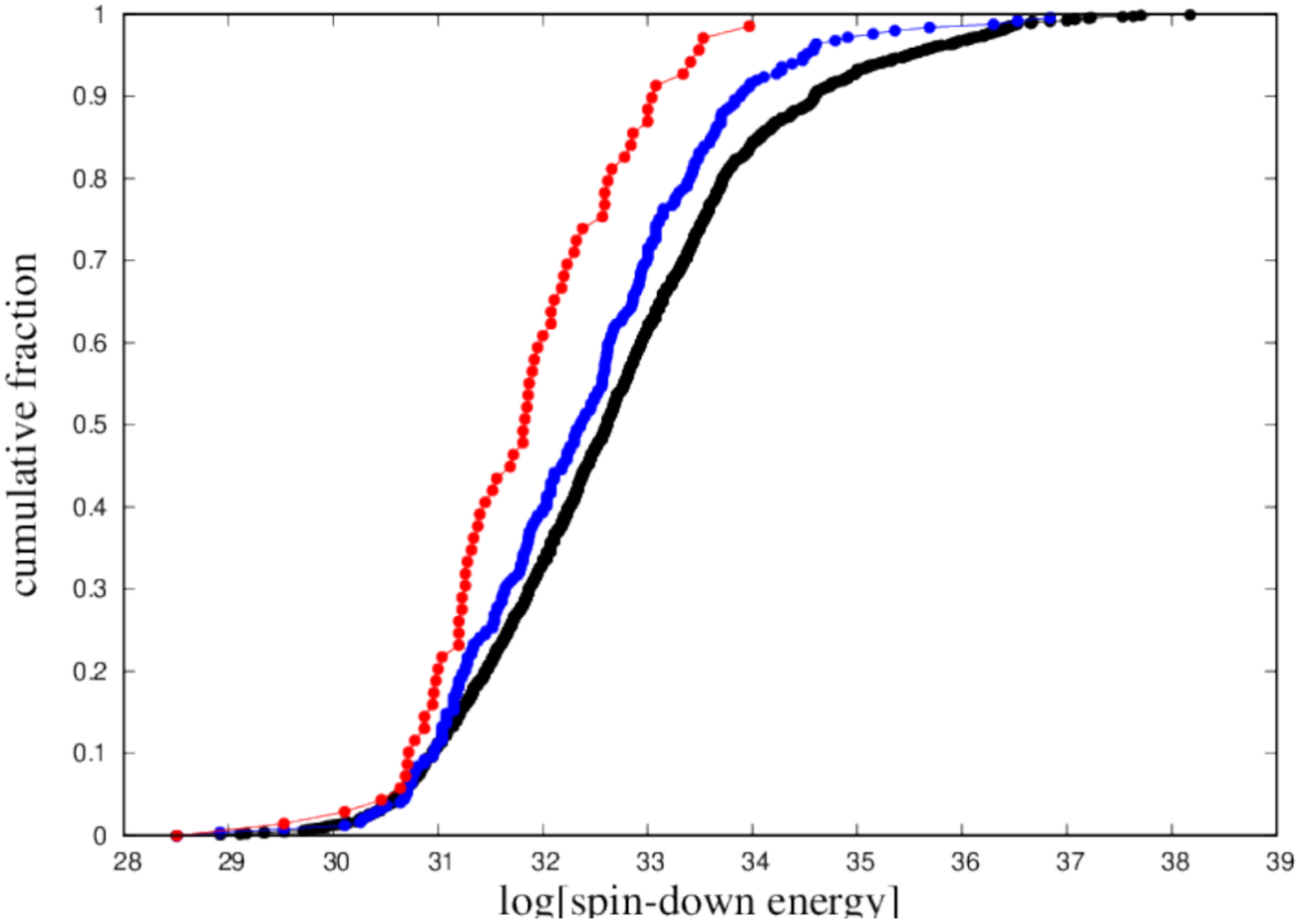
· 72 pulsars out of 249 have no enough high L/I samples.

Class	J23	current work
RVM	90	146
Flat	11	9
non-RVM	146	22
No Pol	2	72

J23: Johnston et al. 2023

p.s. If set criterion L/I > 80% to L/I > 90%
➔➔ non-RVM number drop from 22 to 9.

Whole 1202 pulsars (black) v.s. Selected 249 pulsars (blue) v.s. No high L/I pulsars (red)



(1) Low E-dot pulsars have brighter single pulses.
[because of smaller distances?]

(2) Low L/I ➔ Low E-dot

↑Maybe pulses are still not enough…

J1534-5334: no L/I > 50%, though very bright (s1400 = 6.8mJy, ATNF)

(3.3) Circular polarization and OPM jumps

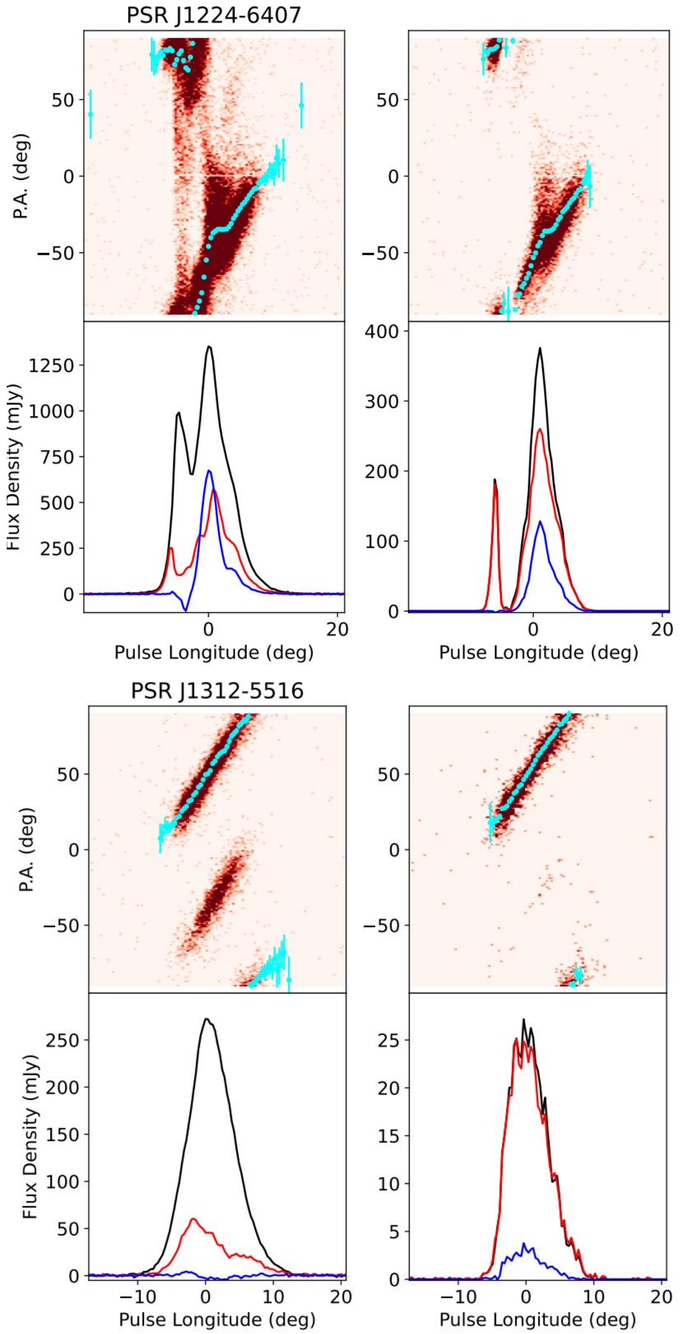
· some highly linearly polarized samples'(HLPS) profile:
still significant circular polarized.
➔➔possible elliptically polarized normal modes.

· 35% HLPS profiles show OPM tracks.
(J23: 28% in RVM/flat original profiles.)

· 50% original profiles with OPM
show OPM in their HLPS profile.

· Integrated profiles' PA follow one of OPMs
in certain phase regions.

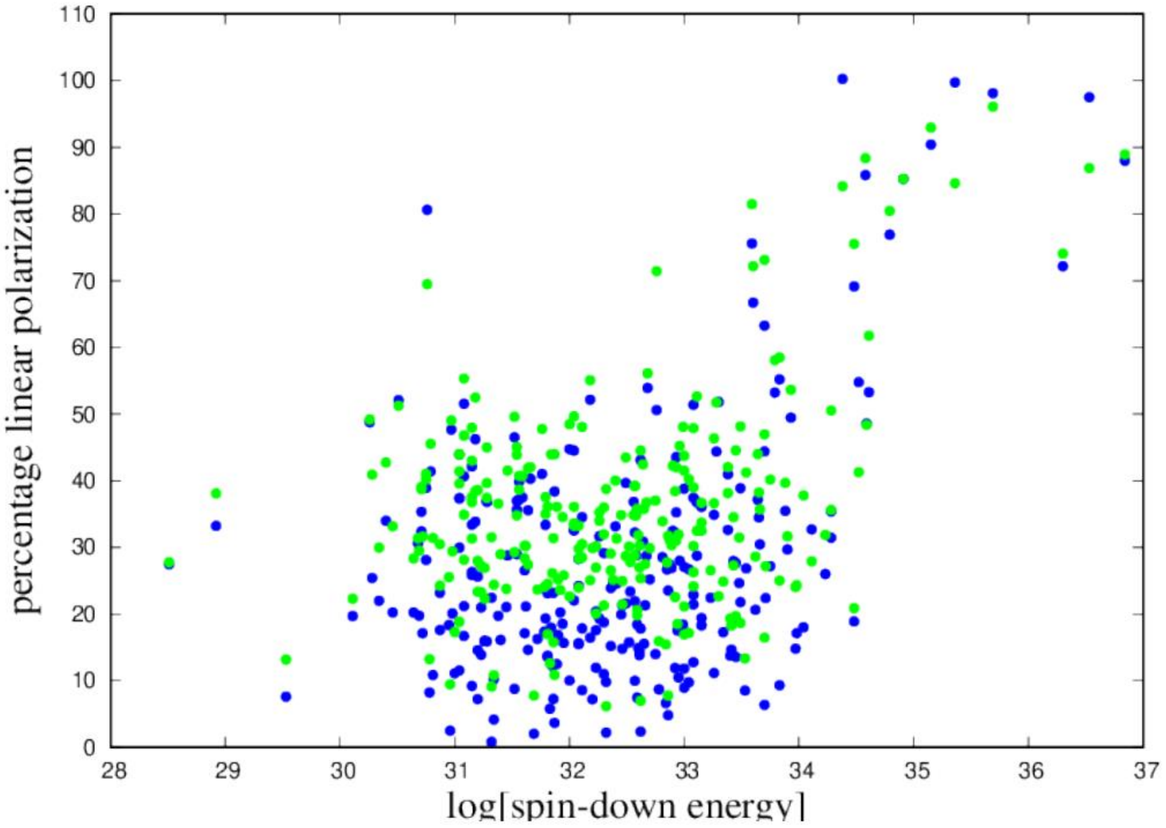
· No immediate way to tell O/X modes.



(3.4) Tabular description of results

Table A1. Results for 249 pulsars. The first two columns report the pulsar's Jname and the log of the spin–down energy ($\dot{E}$). Columns 3 and 4 given the number of single pulses recorded (N_p) and the percentage of those above 5–σ (N_f). Columns 5 and 6 give the percentage of linear ($\%L_t$) and circular ($\%V_t$) polarization in the integrated profile. Columns 7 and 8 give the mean percentage of all the samples in linear ($\%L_s$) and circular ($\%V_s$) polarization. The last two columns give the Class from the RVM fitting according to Johnston et al. (2023) and after formation of the high linear profile. The dagger symbol denotes pulsars which remain non–RVM even after application of a higher linear threshold.

JNAME	log($\dot{E}$)	N_p	N_f	$\%L_t$	$\%V_t$	$\%L_s$	$\%V_s$	Old Class	New Class
J0034–0721	31.3	1042	54.5	15.9	4.4	37.4	4.0	non–RVM	RVM
J0108–1431	30.8	1042	55.6	80.6	12.1	69.5	7.4	flat	flat
J0134–2937	33.1	1110	88.1	51.4	–20.3	47.9	–13.7	RVM	RVM
J0151–0635	30.7	1039	97.6	38.9	0.2	41.0	–1.0	RVM	RVM
J0152–1637	31.9	1047	86.4	15.7	–1.4	25.8	–1.6	non–RVM	No poln
J0255–5304	31.1	1226	81.9	9.2	–5.0	31.3	–4.5	non–RVM	non–RVM
J0302+2252	30.3	1030	57.2	25.4	–0.2	40.9	–0.1	non–RVM	non–RVM
J0304+1932	31.3	1032	89.2	36.8	12.5	45.0	12.6	RVM	RVM
J0401–7608	32.6	1078	98.1	28.8	–2.3	34.8	–2.4	non–RVM	RVM
J0448–2749	31.8	1048	58.1	23.1	–15.3	36.1	–17.3	flat	flat
J0452–1759	33.1	1042	100.0	18.3	–0.0	33.7	0.5	RVM	RVM
J0517+2212	31.6	1036	83.0	21.1	6.1	30.2	6.7	non–RVM	RVM
J0525+1115	31.8	1048	95.1	13.8	9.1	24.5	9.2	non–RVM	No poln
J0536–7543	31.1	1041	92.6	51.5	–11.6	55.3	–10.9	RVM	RVM
J0543+2329	34.6	1033	97.8	53.3	–11.1	61.7	–12.2	RVM	RVM
J0601–0527	32.9	1063	96.9	32.1	1.5	38.4	–0.5	non–RVM	RVM
J0614+2229	34.8	1032	100.0	76.9	16.2	80.5	15.9	RVM	RVM



High L/I ← High E-dot

(Though no many selected high E-dot pulsars ---- no strong single pulses)

Conclusion: Highly linearly polarized samples' profiles have more RVM-like PA curves, still with circular polarization and orthogonal modes.

Related to:

(i) Escape of O/X modes

(ii) Circular polarization mechanisms

(iii) Bunching mechanisms (charge solitons…), coherent curvature radiation

Thank you for your attention ☺