

A Study of PSR J0034-0721 with the ultra-wide-band receiver on the Parkes Radio Telescope

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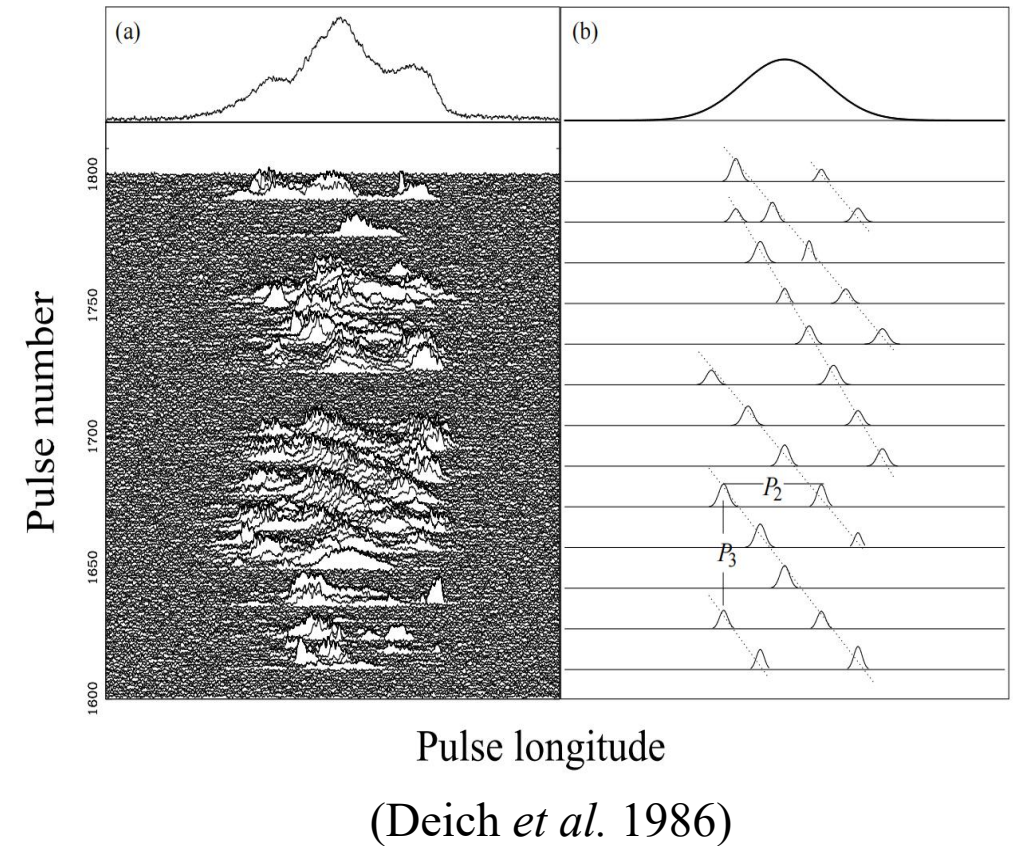
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Summary

01. Background-Single Pulse

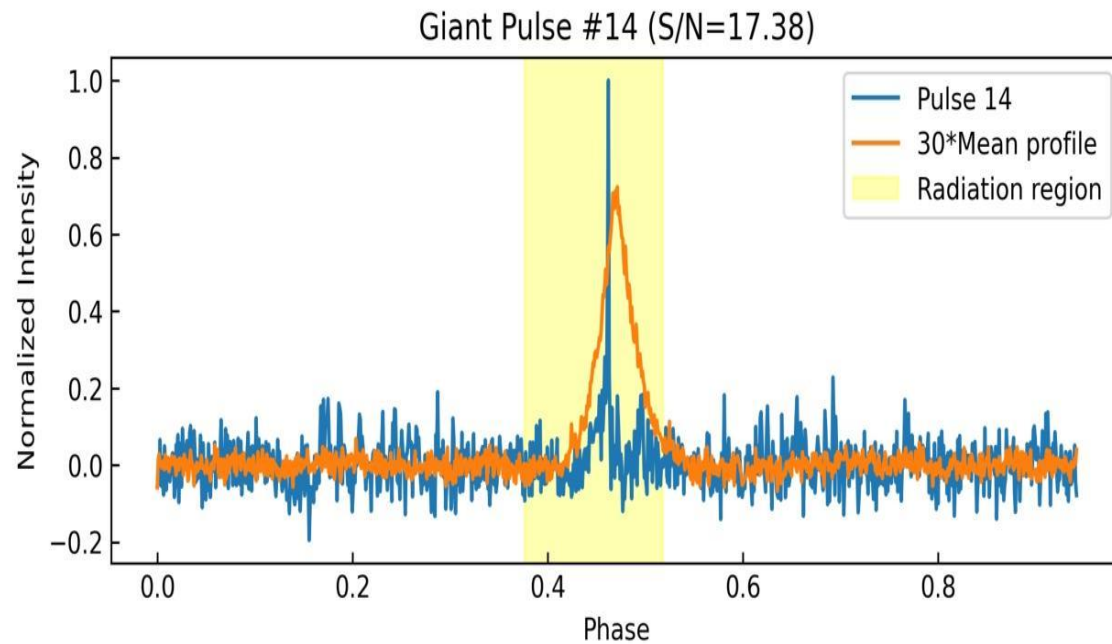
Single pulse: a pulse signal recorded by the radio telescope backend

- * Highly variable in shape
- * Composed of multiple subpulses – narrow, with random positions
- * The averaged profile formed by folding subpulses shows diversity



01. Background-Giant Pulses (GPs)

GPs: A very short-duration radio burst, typically tens to hundreds of times brighter than the average pulse



- * Extremely high peak flux density, far exceeding the average

- * Very short duration – microseconds to nanoseconds

- * Only 18 pulsars are known to exhibit giant pulses to date

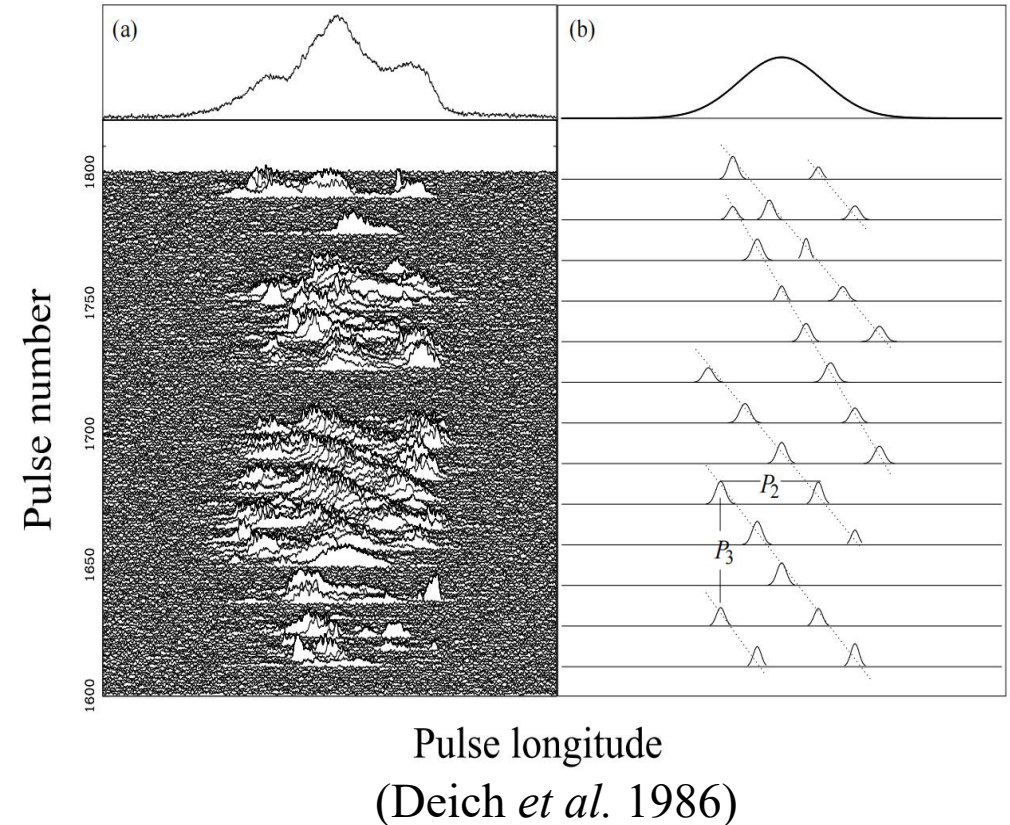
01. Background-Nulling and Subpulse Drifting

Nulling: in some periods, the intensity of individual pulses drops below 1% of the normal pulse level – i.e., the pulse disappears

- * Radiation suddenly ceases and reappears after several periods
- * About 8% of pulsars show nulling

Subpulse Drifting: subpulses move forward or backward across the pulse window at a certain rate

- * Drifting patterns can be complex, with possibly multiple drift rates
- * About 60% of pulsars exhibit subpulse drifting



01.Observations and Data Processing

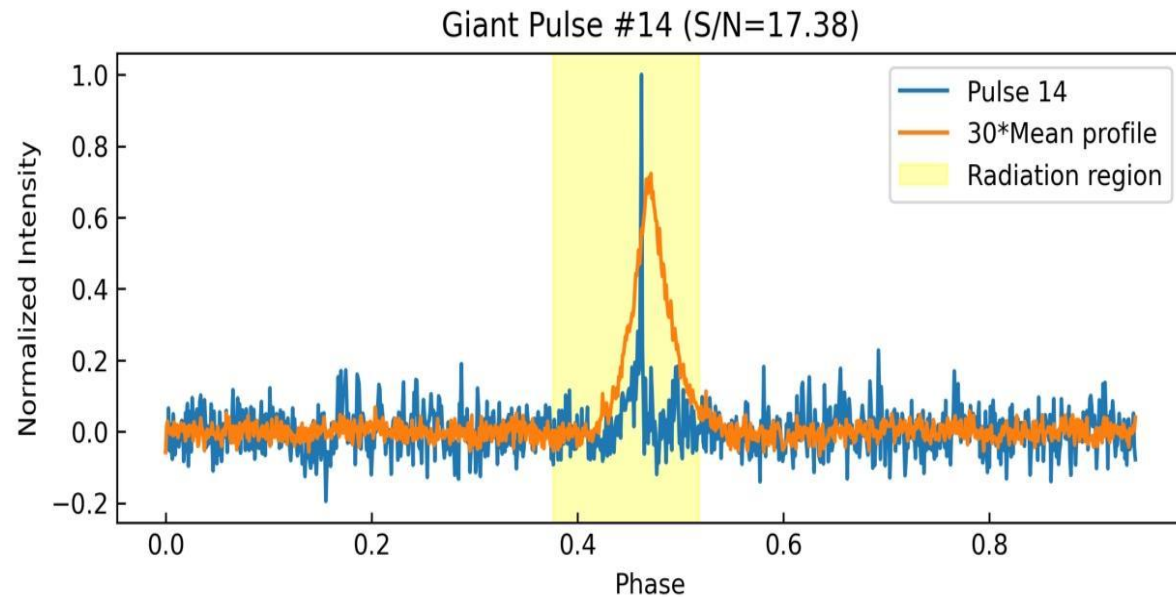
Observation period: four sessions between May 2021 and June 2022, each about 1 hour

Instrument: Parkes 64-m radio telescope in Australia, using the ultra-wide-band low-frequency (UWL) receiver (704–4032 MHz) at a central frequency of 2368 MHz, with a sampling time of 128 μ s

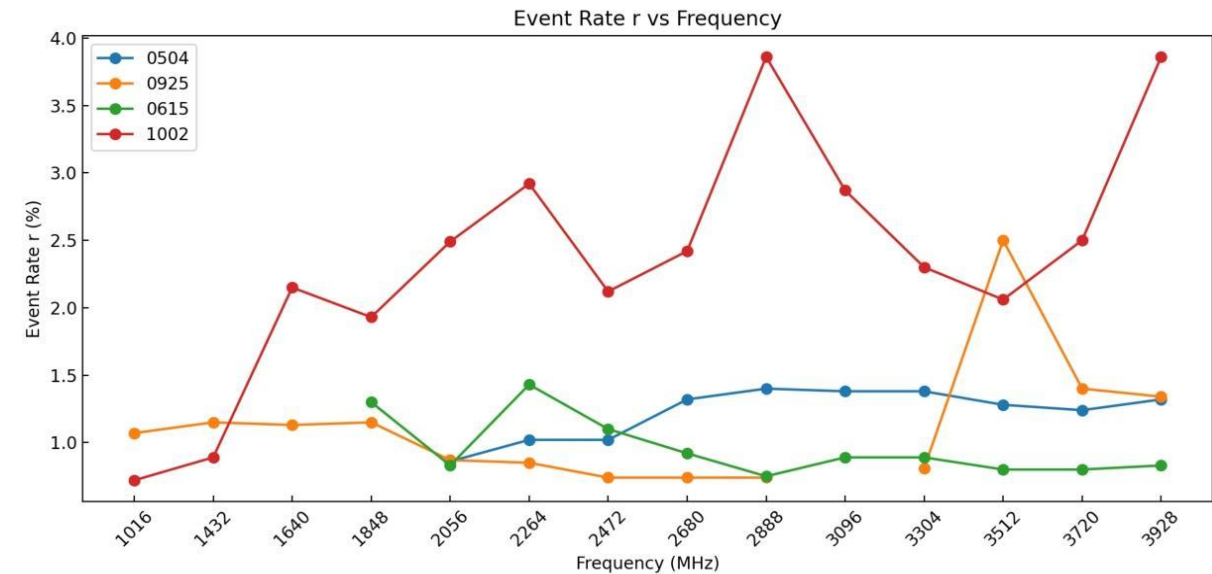
Bandwidth and channels: total bandwidth 704–4032 MHz, divided into 16 channels, each 208 MHz wide

2. Results and Discussion

2.1 Giant Pulses (GPs) – Statistics and Broadband Properties

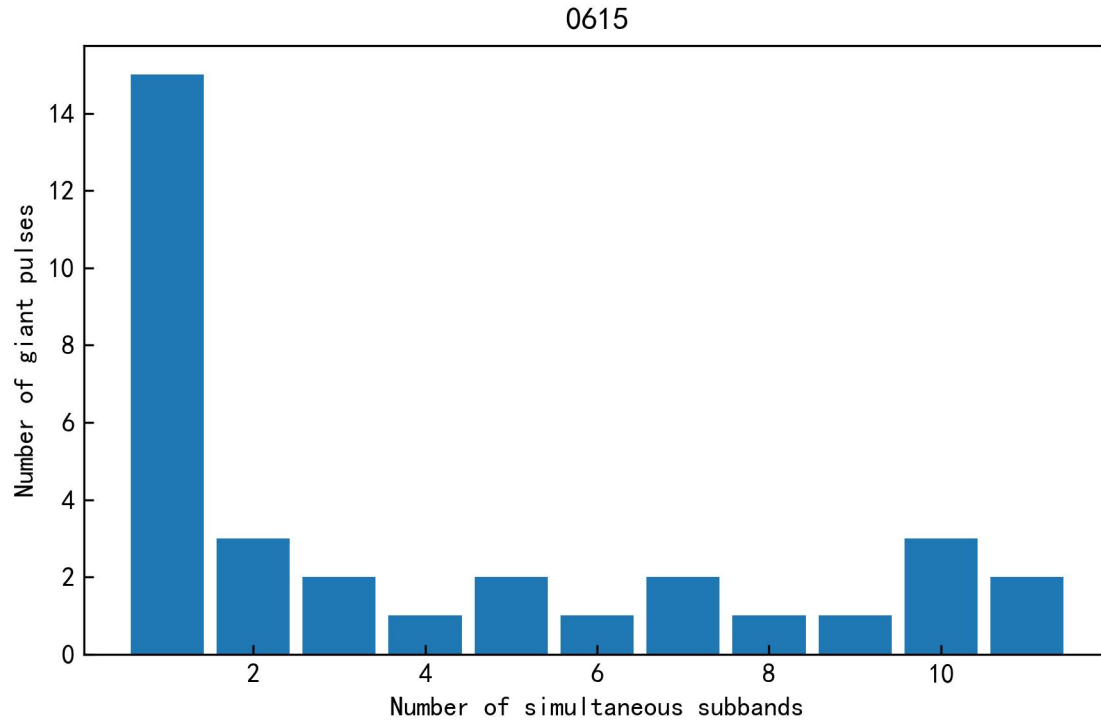


On-pulse and off-pulse regions defined from the average profile; single pulses with $S/N > 5$ selected; those with peak flux > 30 times the average profile peak are classified as giant pulses, followed by visual inspection



Occurrence rate per rotation period: $\sim 0.72\% - 3.86\%$;
intervals generally follow a Poisson distribution, but with short clustering episodes

Broadband Properties



Histogram of simultaneous sub-band occupancy

Table 1. Cumulative broadband fraction of GPs across epochs.

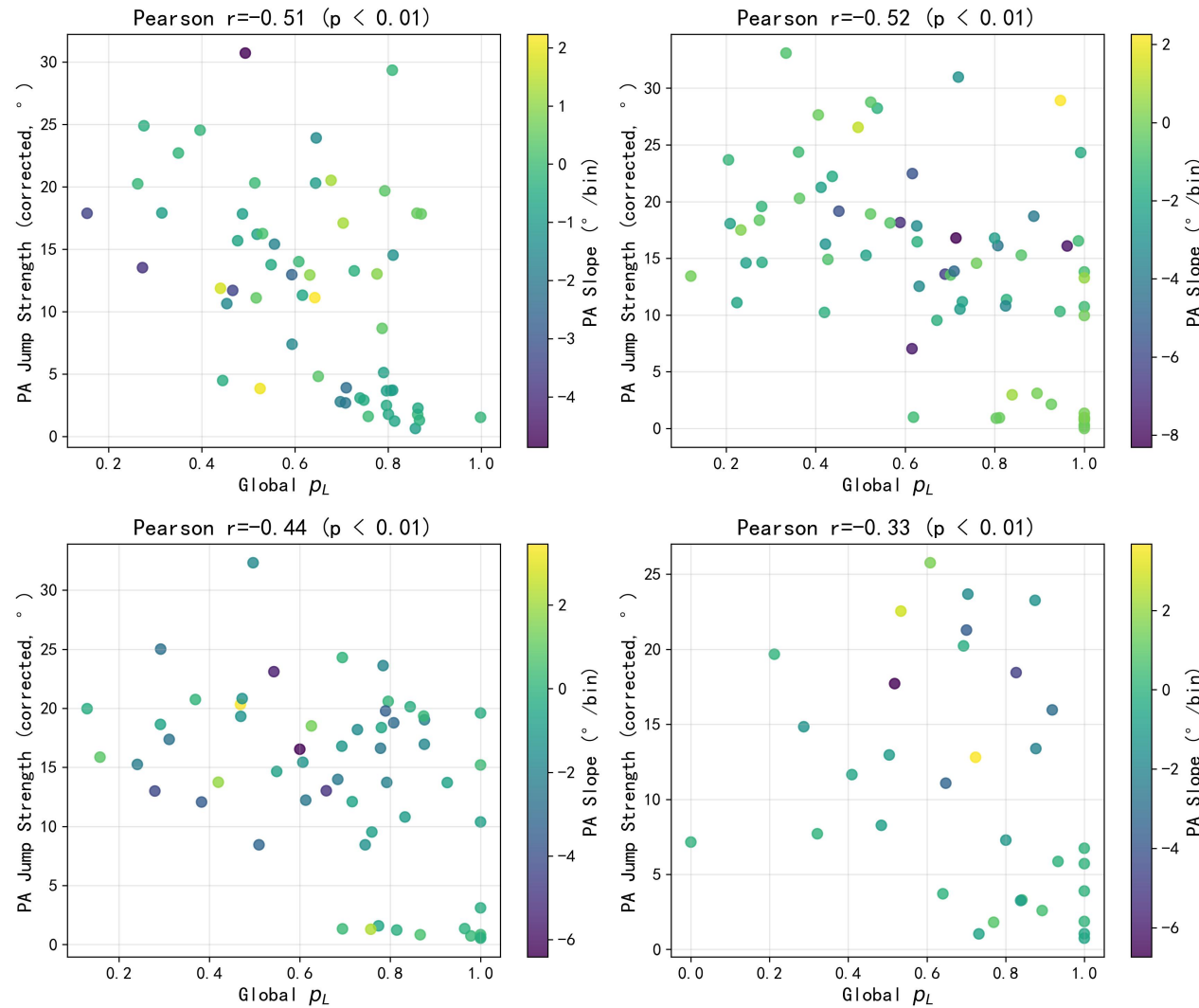
Minimum subbands	1002	0504	0615	0925
1	1.00	1.00	1.00	1.00
2	0.87	0.86	0.55	0.86
5	0.57	0.62	0.36	0.43
10	0.26	0.28	0.15	0.14
11+	0.09	0.00	0.06	0.00



GPs are not intrinsically wideband; band coverage and simultaneity vary strongly across epochs

Full-band (>10 sub-bands) GPs are rare: only 14%–28% GPs

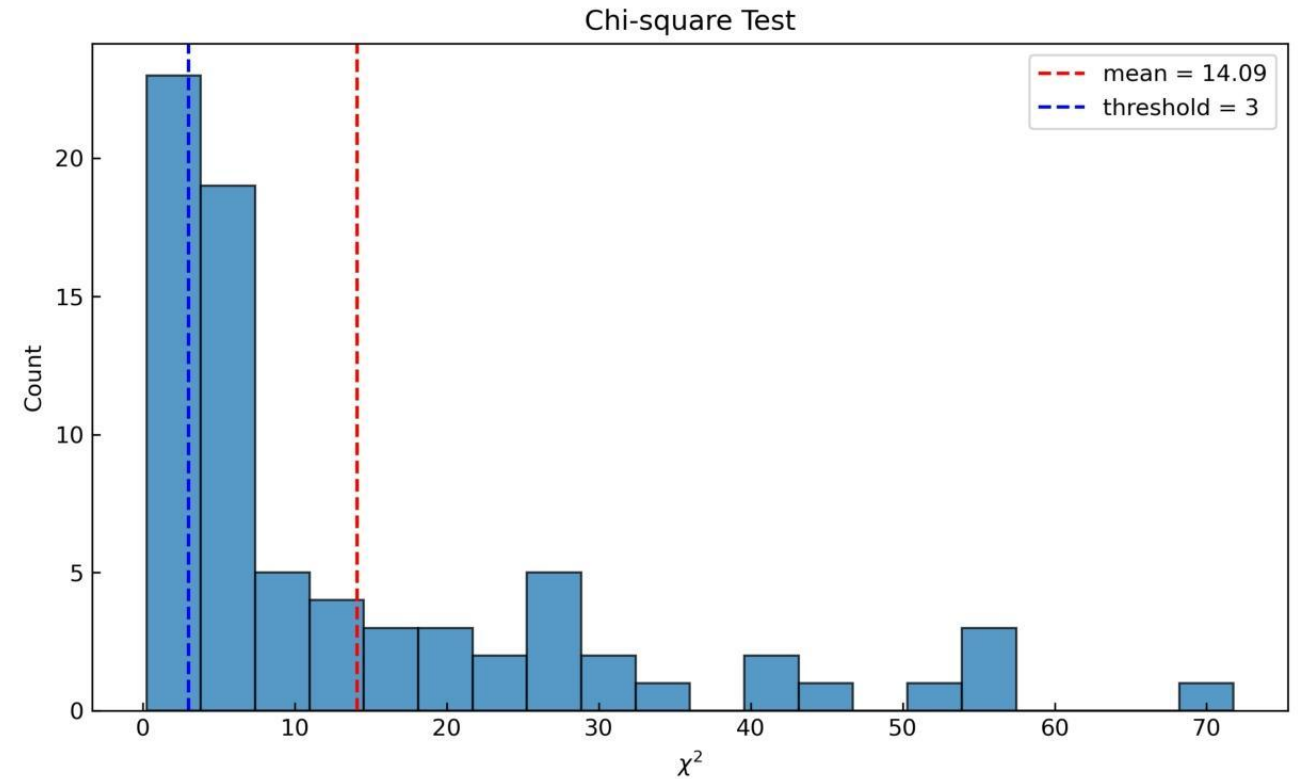
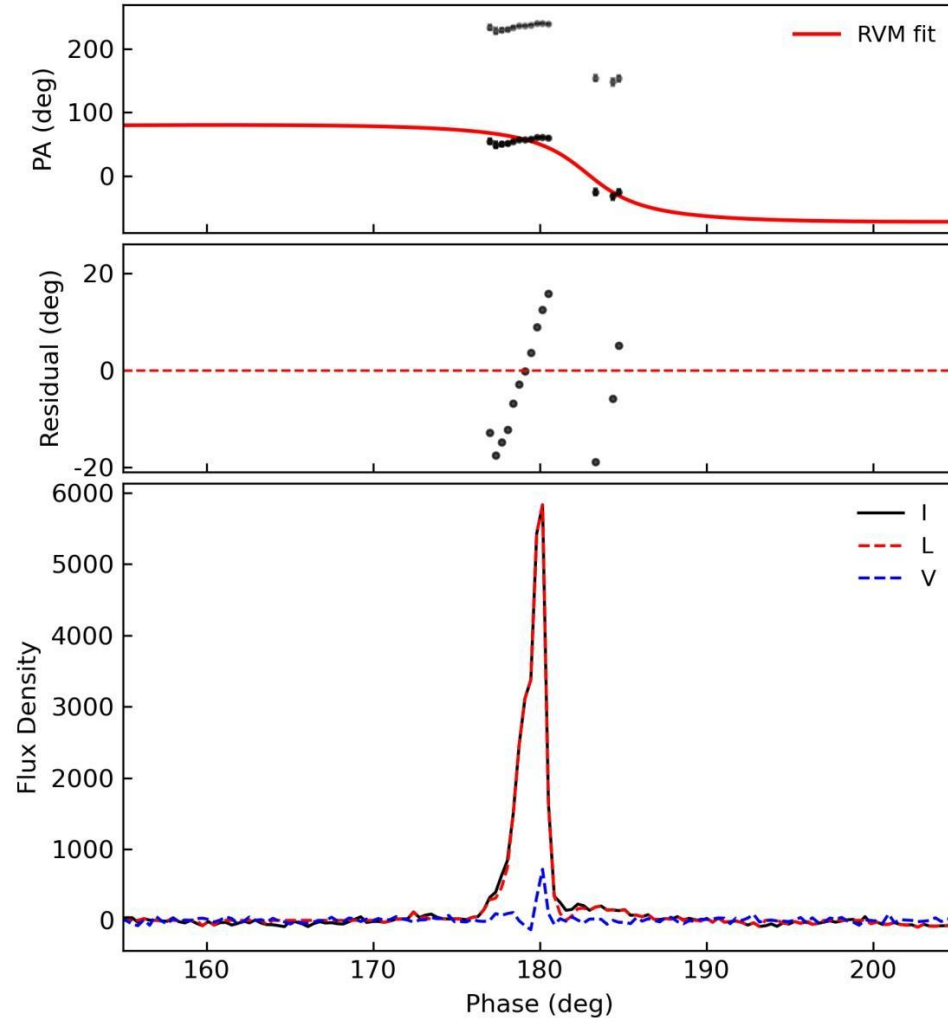
Polarisation Properties of GPs



High linear polarisation: average linear polarisation fraction 0.64–0.71

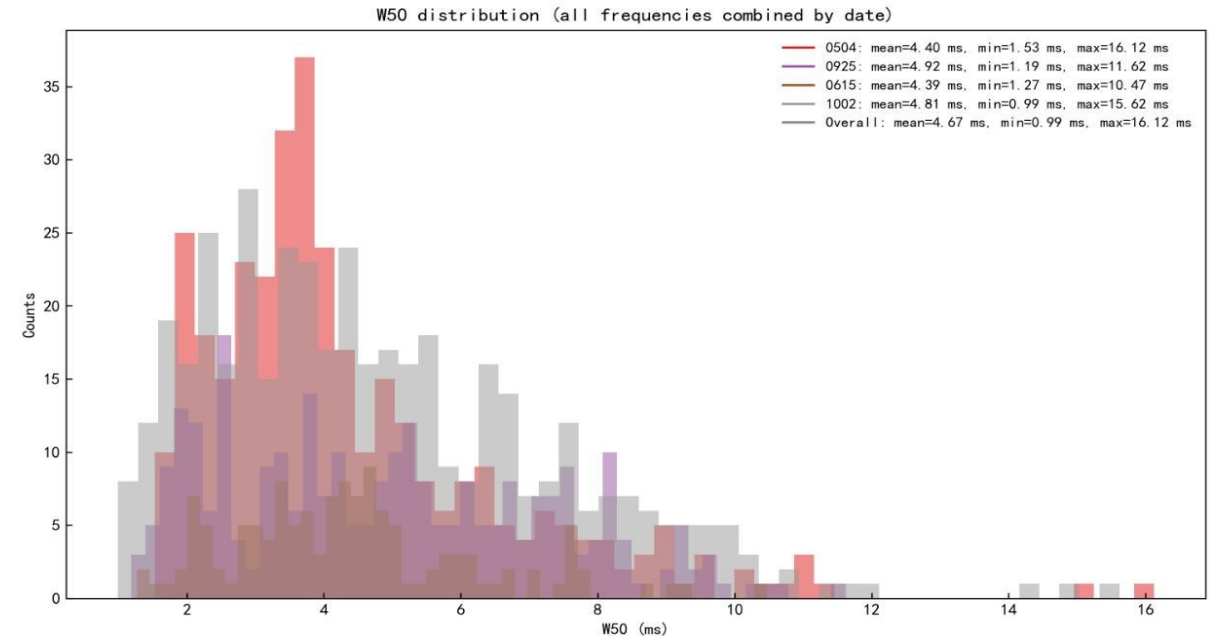
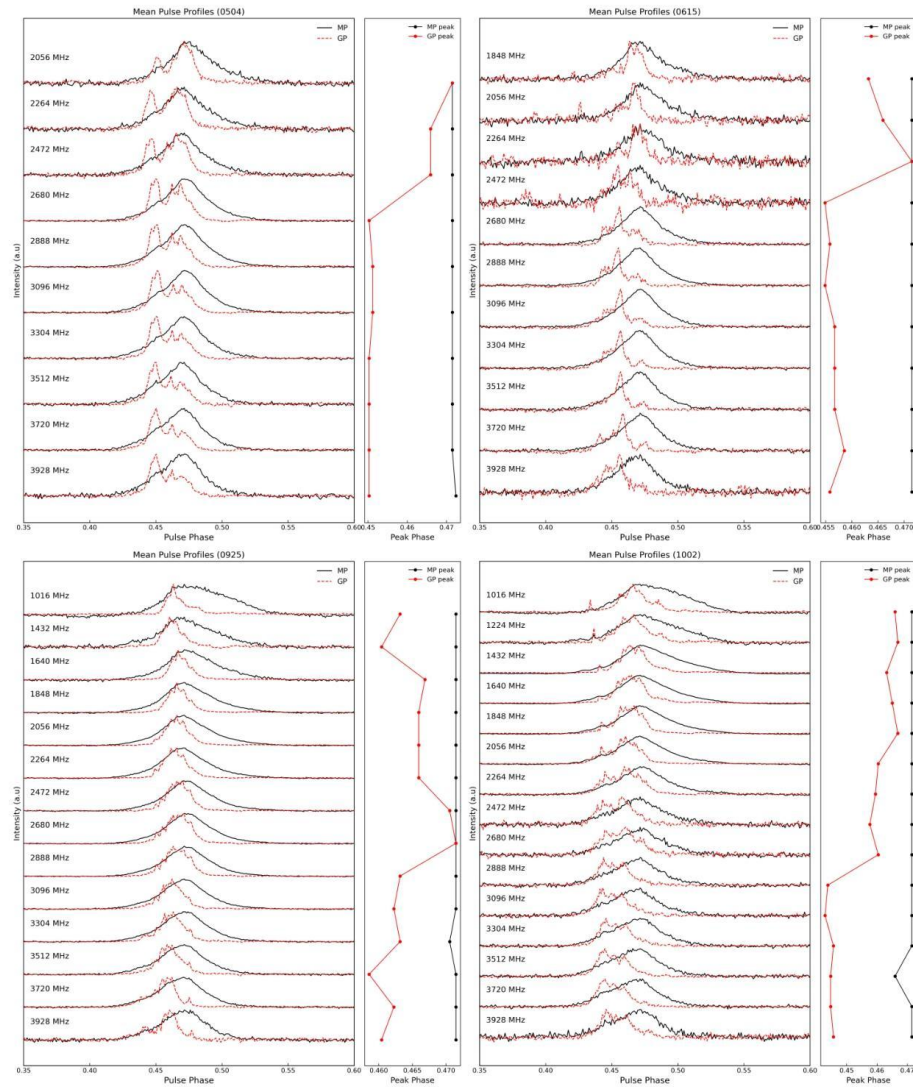
PA stability: the jump intensity of polarisation position angle (PA) is anti-correlated with linear polarisation fraction; highly polarised GPs show more stable PA evolution

Rotating Vector Model (RVM) fitting generally fails for the GP sample



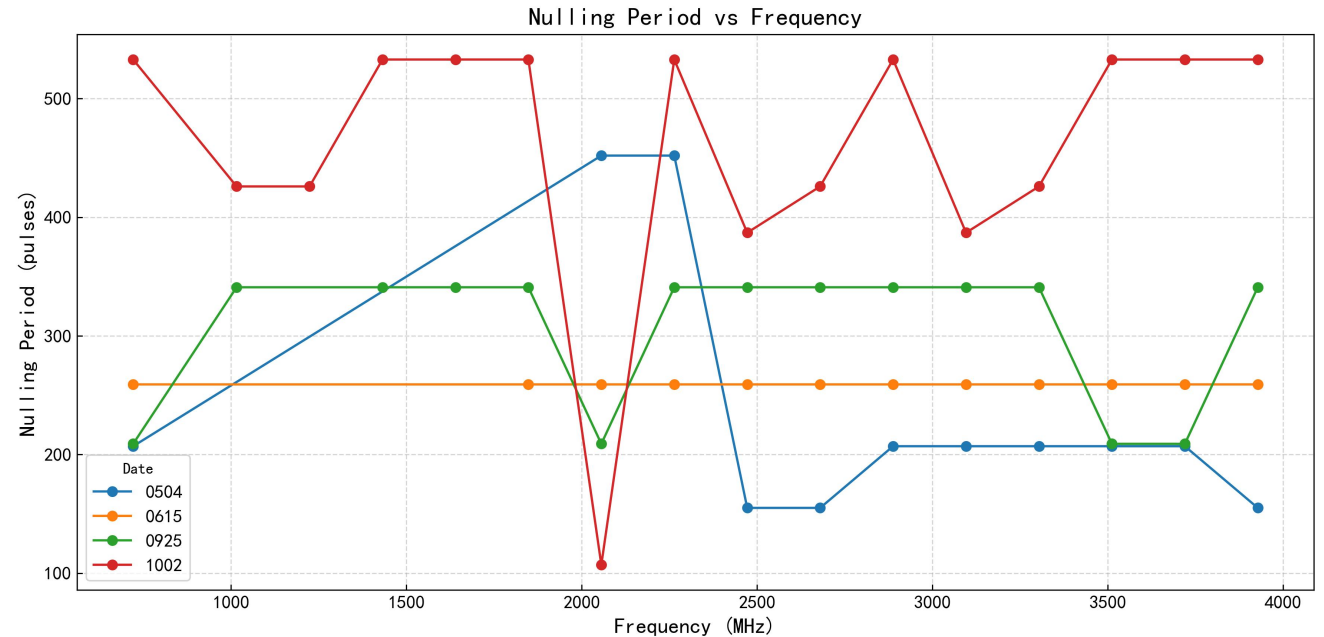
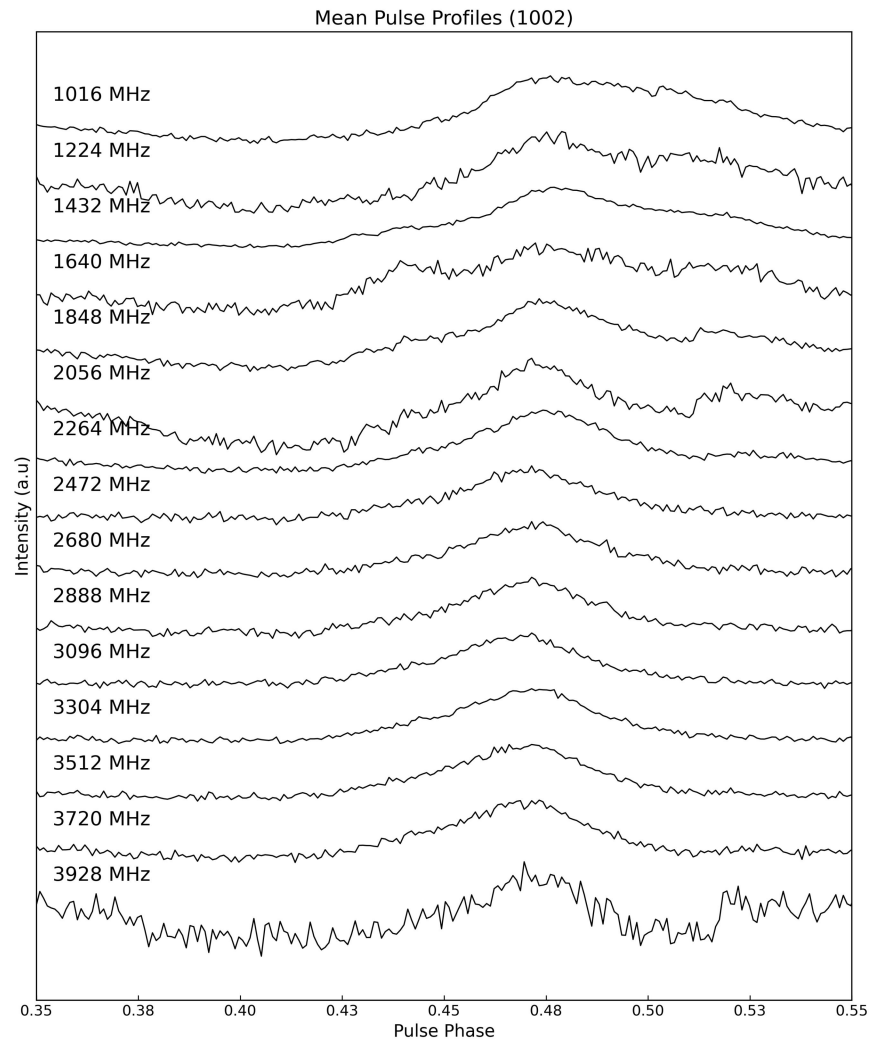
For all GPs with linear polarisation fraction >0.8 , RVM fitting yields reduced χ^2 far greater than 1 for most pulses, indicating that RVM cannot reasonably explain the PA variations of most giant pulses

Phase Offset and Morphological Evolution of GPs



- Phase characteristics: GP peak phase always occurs earlier than the average profile peak
- Width: mean full width at half-maximum (W_{50}) is only 4.67 ms, much narrower than normal pulses (by a factor of ~ 10)
- Spatial implication: GPs likely originate from higher, more dynamic emission regions in the magnetosphere

2.2 Nulling



Basic features: observable across the entire band; nulling fraction ranges from 30% to 90%, with large inter-epoch variations; null durations last from tens to hundreds of periods, showing quasi-periodicity

Nulling states: two types – complete nulling and incomplete nulling

2.3 Multi-modality of Subpulse Drifting

Table 3. Measured drifting properties of PSR J0034–0721 at different observing frequencies. The quoted P_2 values correspond to the dominant horizontal modulation scale derived from the full 2DFS bottom projection within each burst segment, rather than mode-separated measurements.

Frequency (MHz)	P_3 (P_1)	P_2 ($^\circ$)	Drift Mode
2056	12.73 ± 1.45	-9.61 ± 1.08	A
	6.36 ± 0.43	-9.61 ± 1.08	B
2264	12.83 ± 1.34	-9.61 ± 1.08	A
	6.29 ± 0.38	-9.61 ± 1.08	B
2472	12.90 ± 1.25	-9.61 ± 1.08	A
2680	12.65 ± 1.02	-9.60 ± 1.08	A
2888	12.67 ± 1.06	-9.61 ± 1.08	A
3096	12.62 ± 0.99	-9.61 ± 1.08	A
3304	12.90 ± 1.25	-9.61 ± 1.08	A
3512	12.65 ± 1.02	-9.61 ± 1.08	A
3720	12.52 ± 1.01	-9.61 ± 1.08	A
3928	12.83 ± 1.11	-9.61 ± 1.08	A
	6.31 ± 0.59	-9.61 ± 1.08	B
	4.71 ± 0.21	-9.61 ± 1.08	C

Three distinct drift modes identified ($A \approx 12.73P_1$, $B \approx 6.36P_1$, $C \approx 4.71P_1$)

Dominant mode (A): $P_3 \approx 12.73P_1$

Frequency independence: mode evolution and subpulse separation P_2 ($\approx -9.61^\circ$) remain nearly constant across the entire observed bandwidth

Core Conclusions:

1. Heterogeneity of GPs – GPs are strongly epoch-dependent and not intrinsically broadband. They maintain very high linear polarisation in a highly magnetised environment, likely originating from higher altitudes with locally ordered magnetic fields; broadband radiation appears only during magnetospheric active episodes.
2. Nulling characteristics – Nulling exhibits both complete and incomplete states, with large temporal variations.
3. Multi-mode subpulse drifting with weak frequency dependence – collectively demonstrates that the emission is governed by a dynamic magnetosphere.

Future Prospects and Limitations:

Low-frequency bands suffer from severe RFI; lack of complementary observations at lower frequencies.

Future work: combine with FAST/SKA low-frequency observations, and compare polarisation properties of giant pulses across multiple sources.

Thanks