CPTA 56 颗毫秒脉冲星的偏振研究

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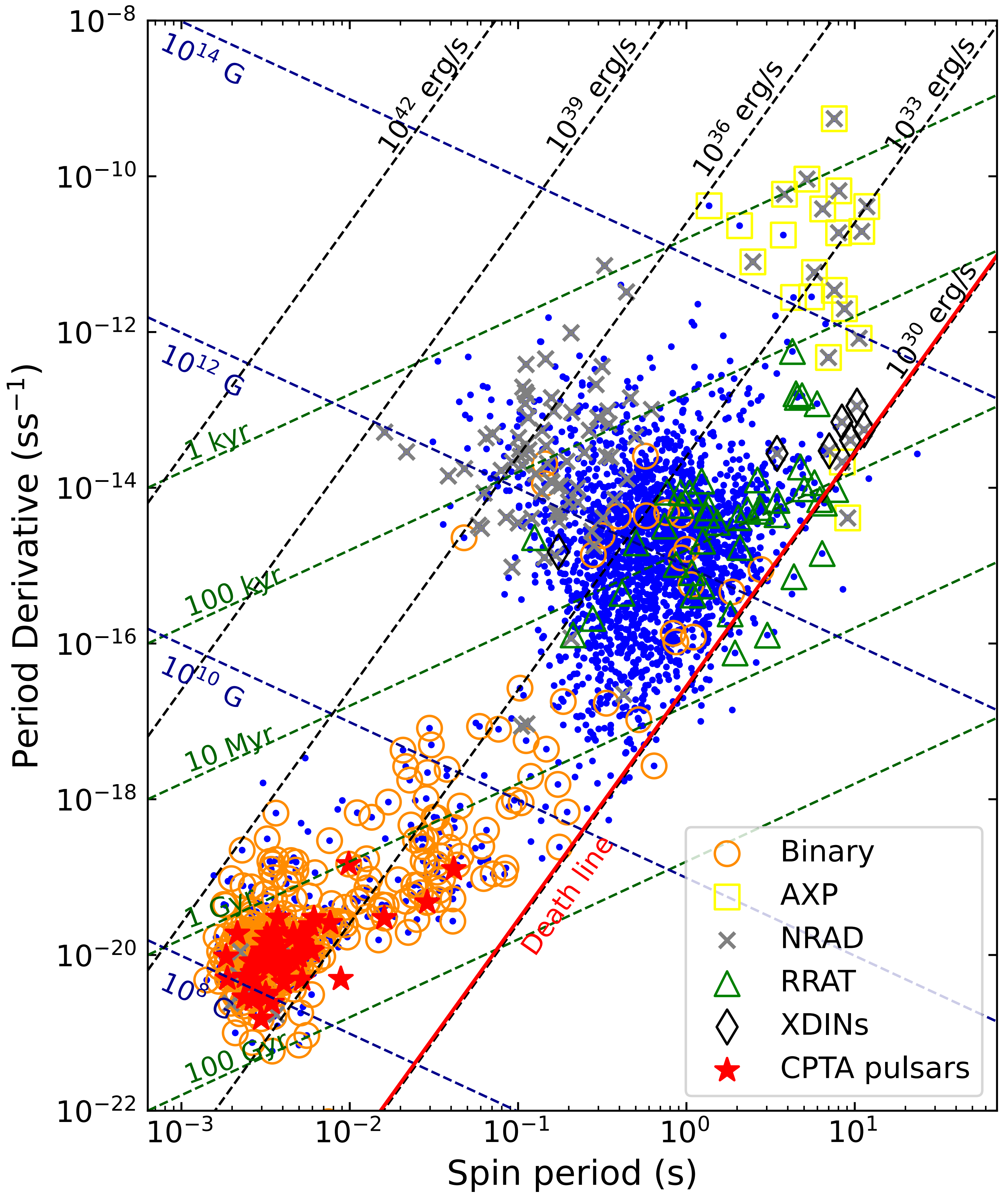
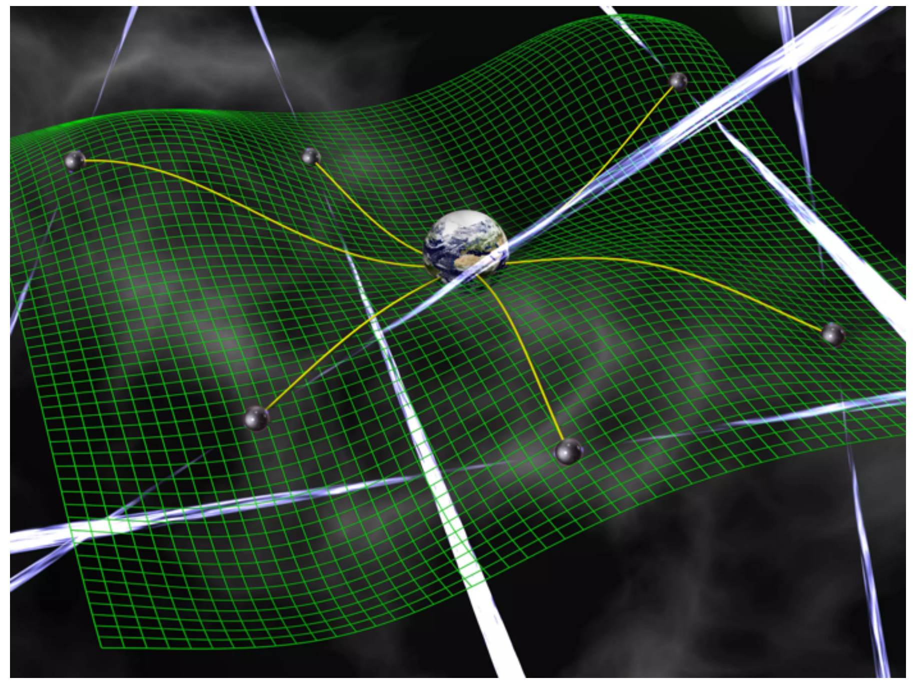
Introduction



Data from psrcat website

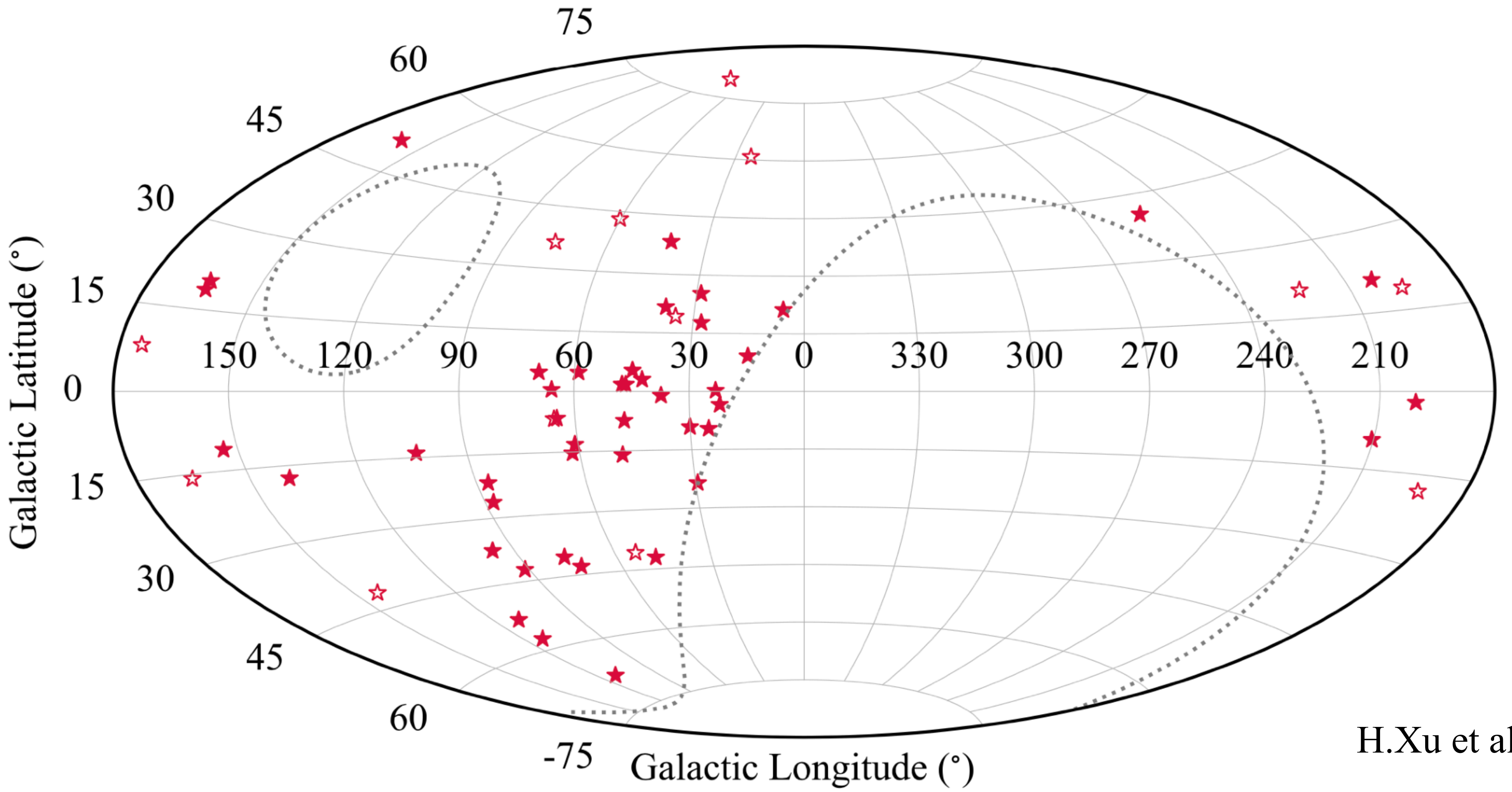


Edit from David Champion

- Millisecond pulsar(MSP): $P < 100\,\text{ms}, \dot{P} < 10^{-17}\text{ss}^{-1}$
- Large PTA datasets, more clear fine structures
- Polarization calibration affects timing results
- Recycling process, polarization properties differences

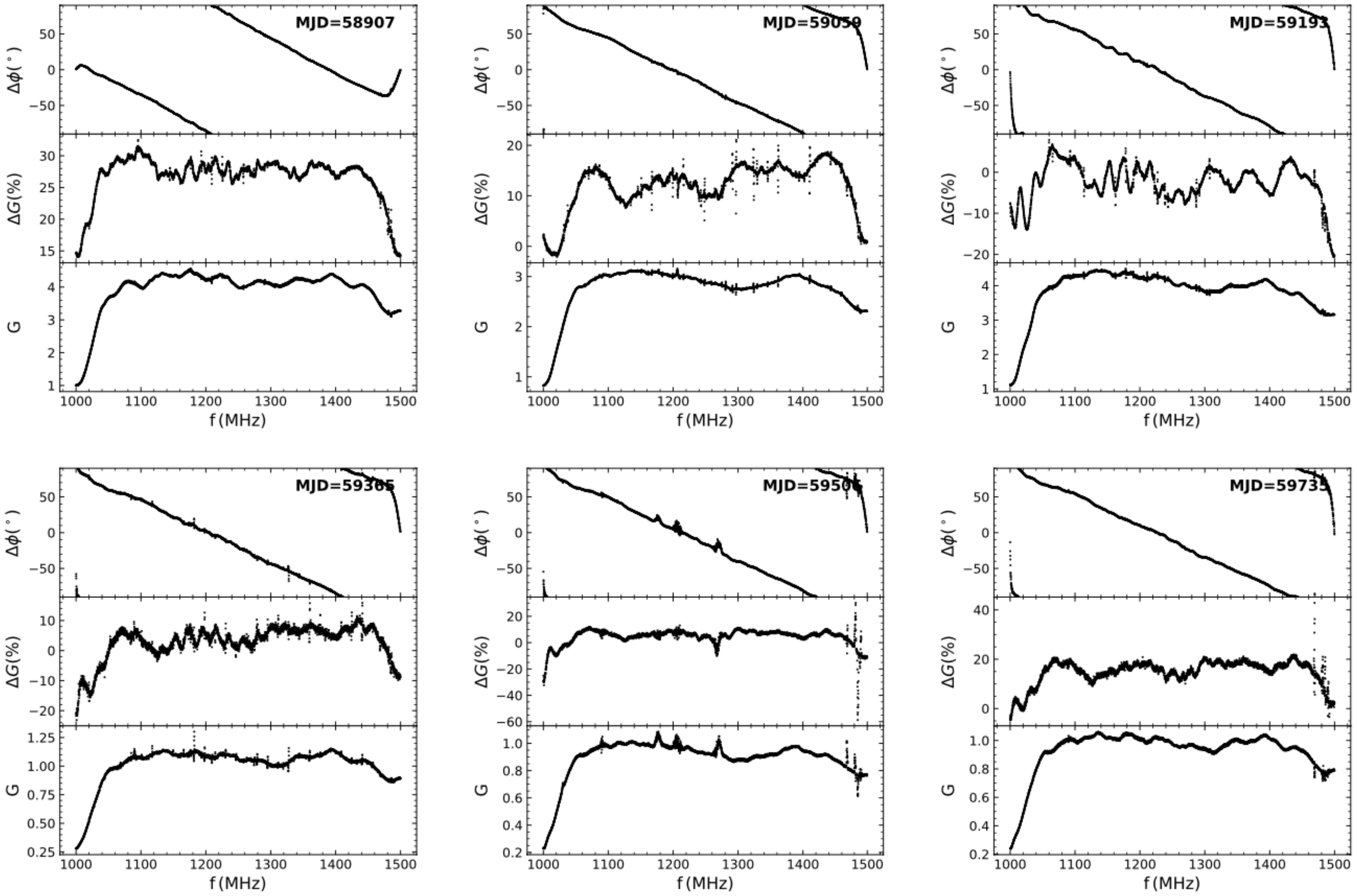
Introduction

- 56 pulsars for polarimetry measurement
- From April, from 2019 to September, 2022
- 1.05-1.45 GHz, 4096 channels, 49.152 us
- Observation time used for polarimetry ~20h (J1713+0747: ~50h)



H.Xu et al. 2024(in prep)

Polarization calibration



A noise diode signal is injected into dual feeds

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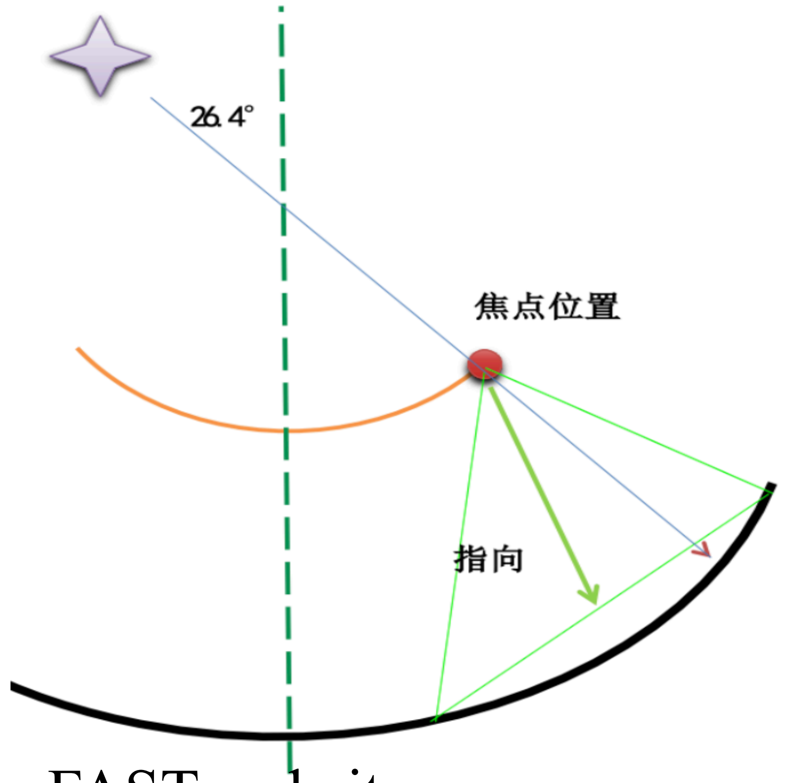
Polarization properties of FAST



From FAST website

$$\chi_\nu^2 = \left(\mathscr{P}_\nu - \alpha_\nu \mathscr{T}_\nu - \beta_\nu\right)^2$$

$$(\frac{|\delta I|}{I})_{tot} < 0.02\,\%\,,$$

$$(\frac{|\delta L|}{L})_{tot}, (|\frac{\delta V}{V}|)_{tot} < 0.5\,\%$$

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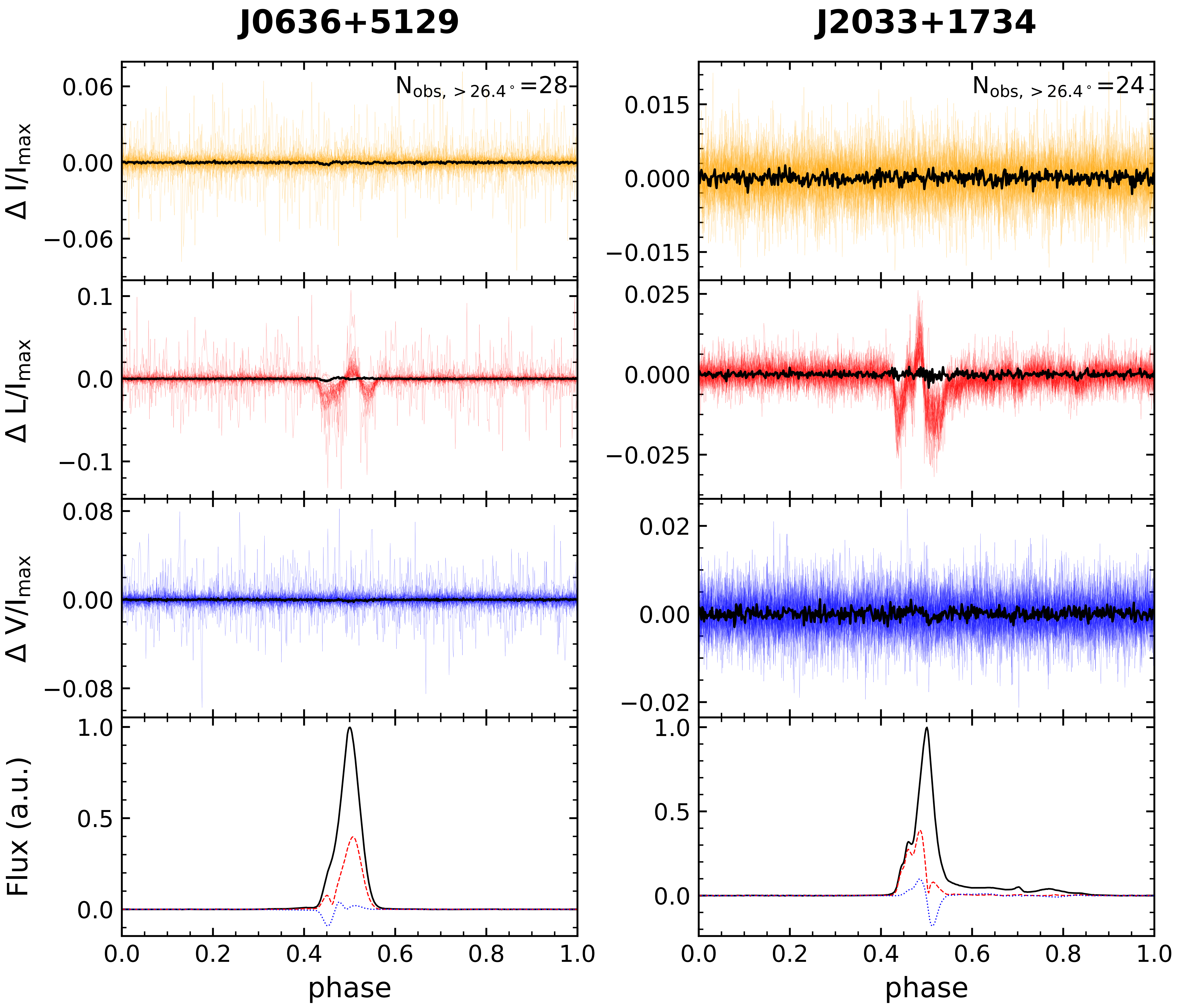
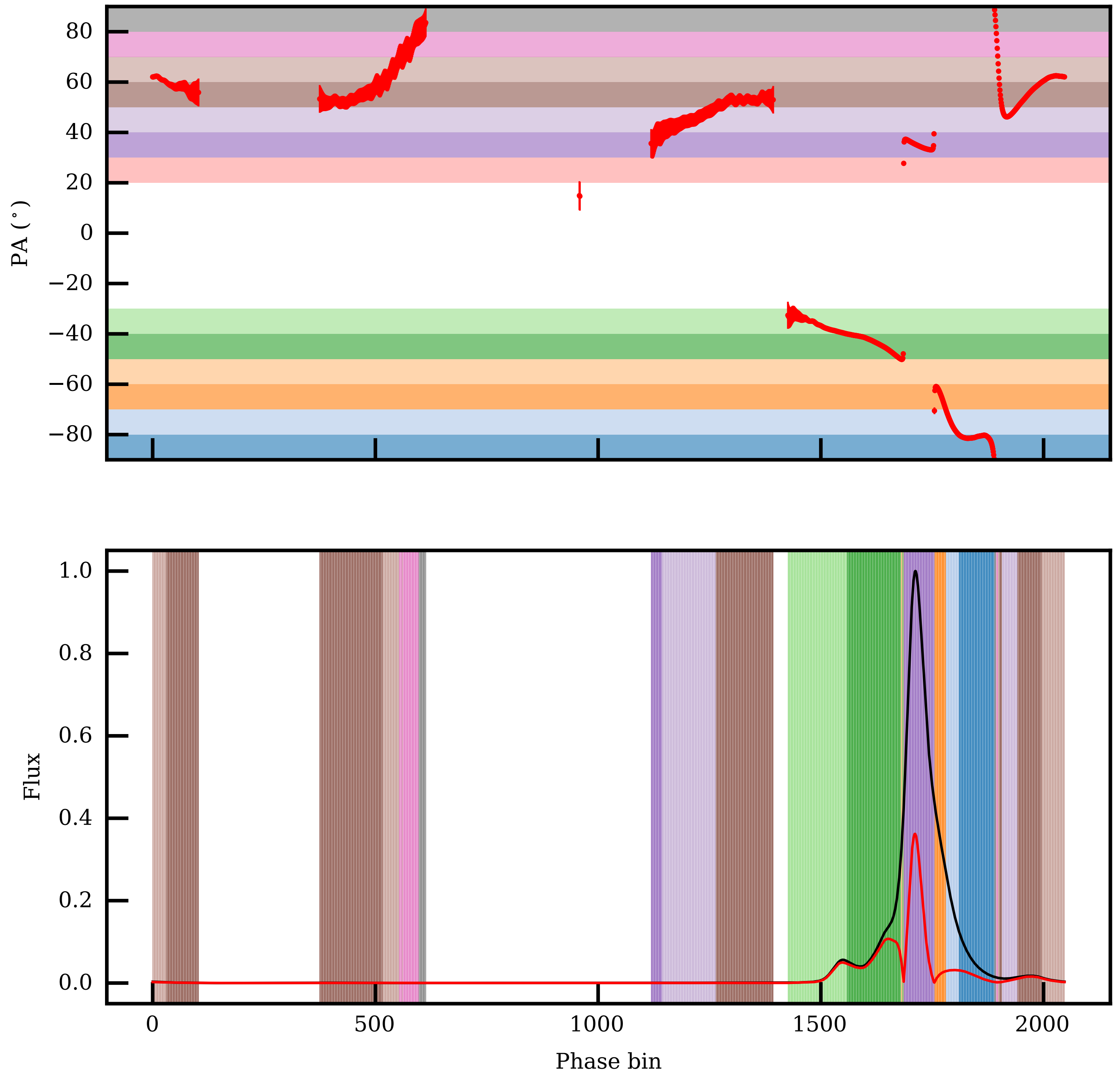
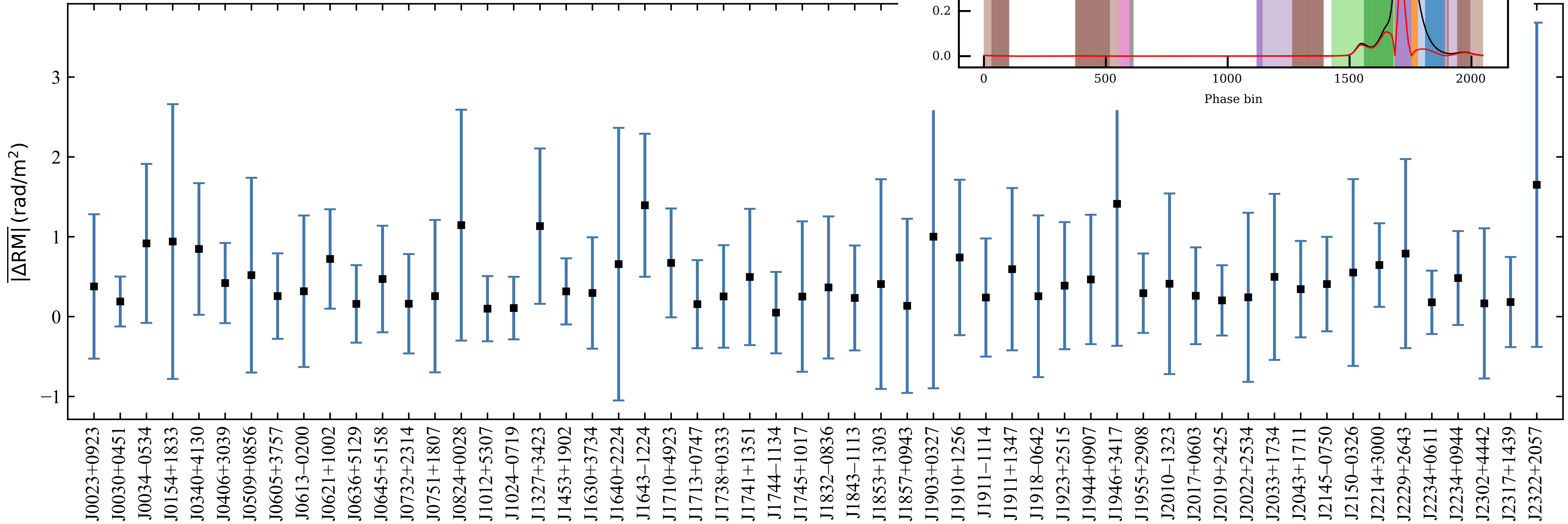


Data processing pipeline

- Position angle(PA) intervals of 10°
- RM synthesis and Q,U curve fitting





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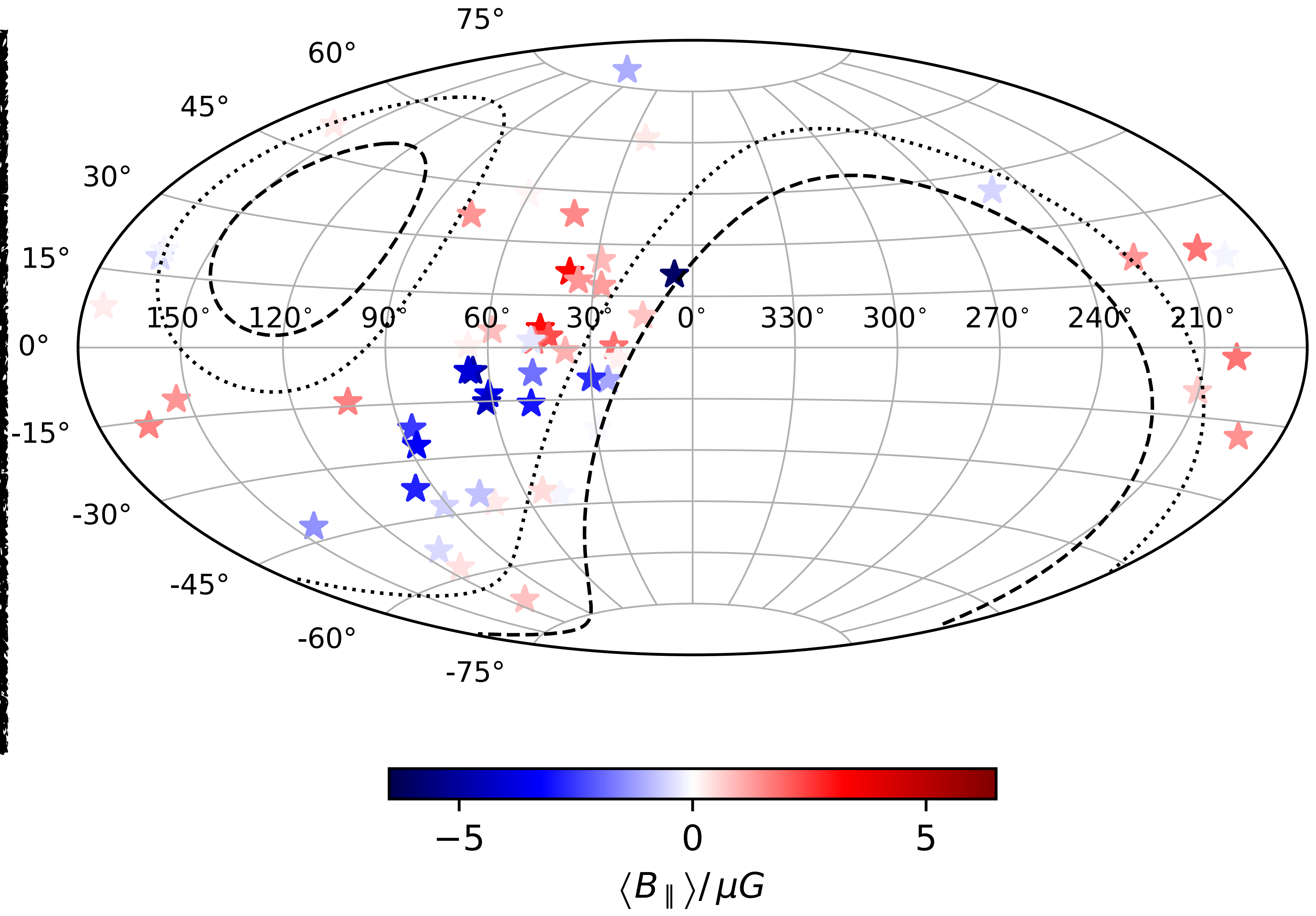
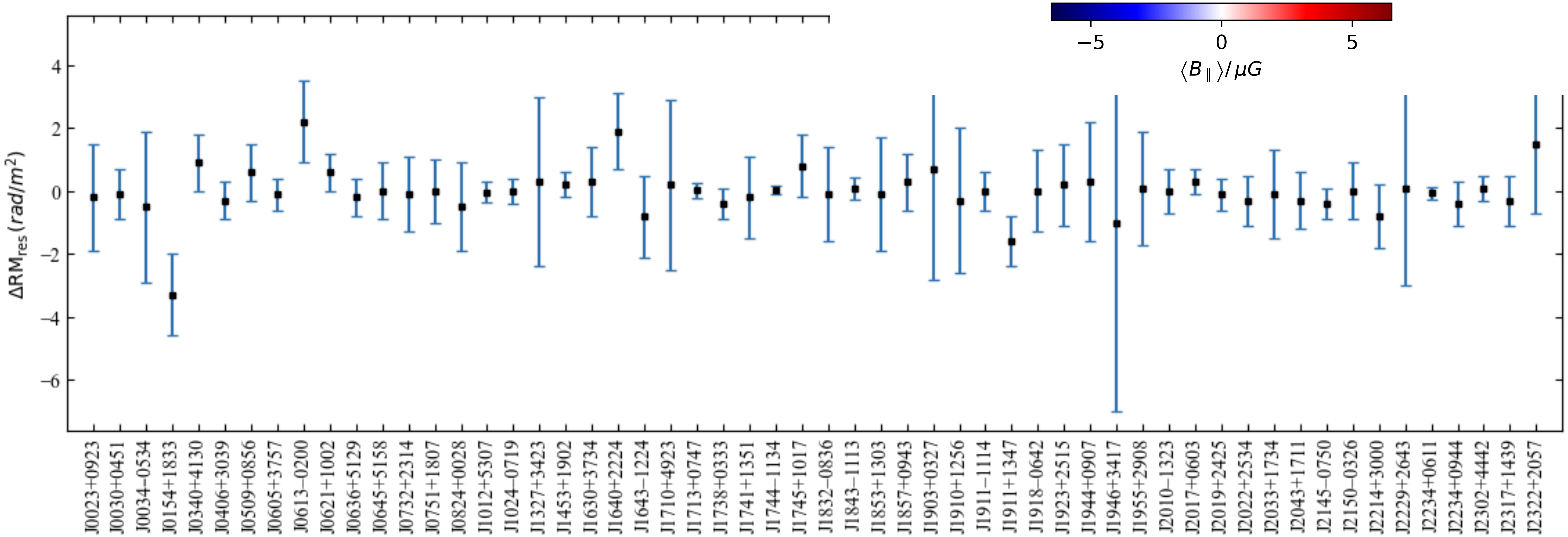
Data processing pipeline

- Combing all observations

$$D[:,f,:]=\frac{\sum_i^{N_{obs}} d_i[:,f,:]\omega_{i,f}}{\sum_i^{N_{obs}}\omega_{i,f}},\quad \omega_{i,f}=\frac{1}{\sigma_{i,I_f}^2}$$

- The phase is divided into 64 bins(SNR>10)
- The residual RM nears zero for most pulsars





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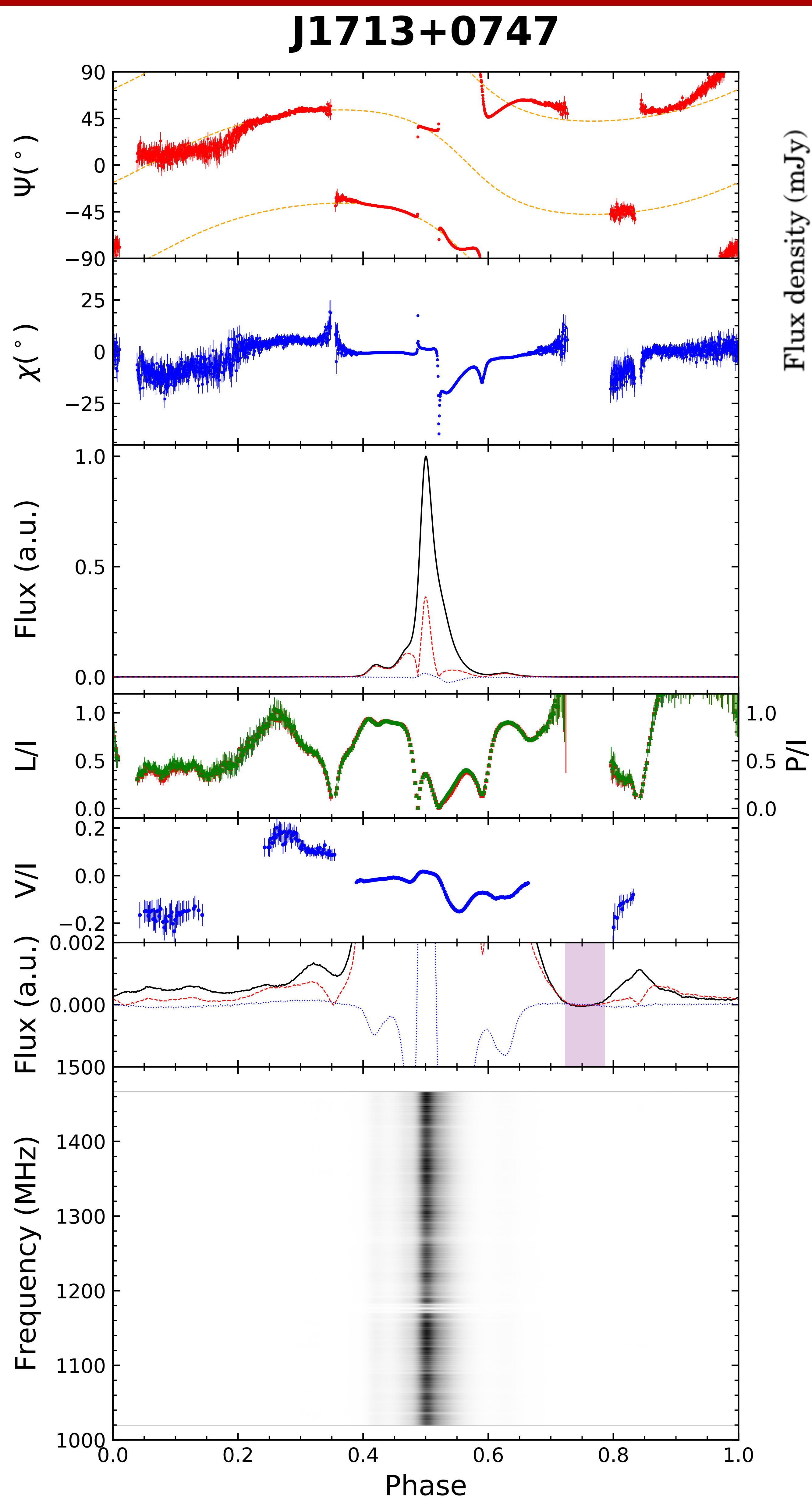
Polarization profiles



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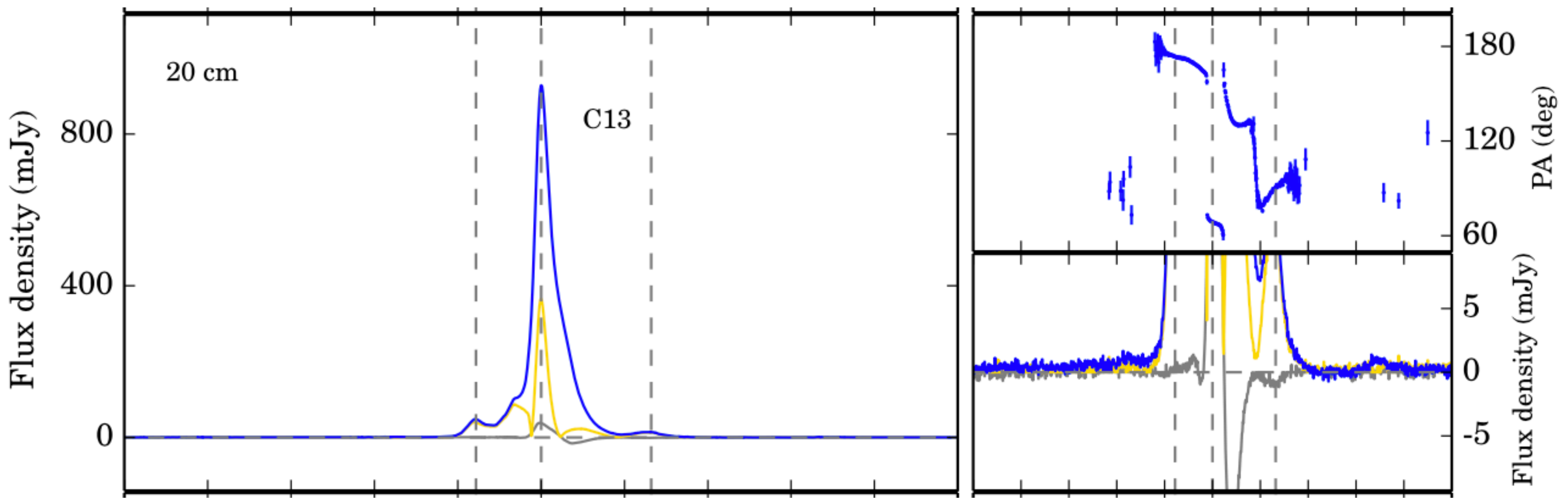
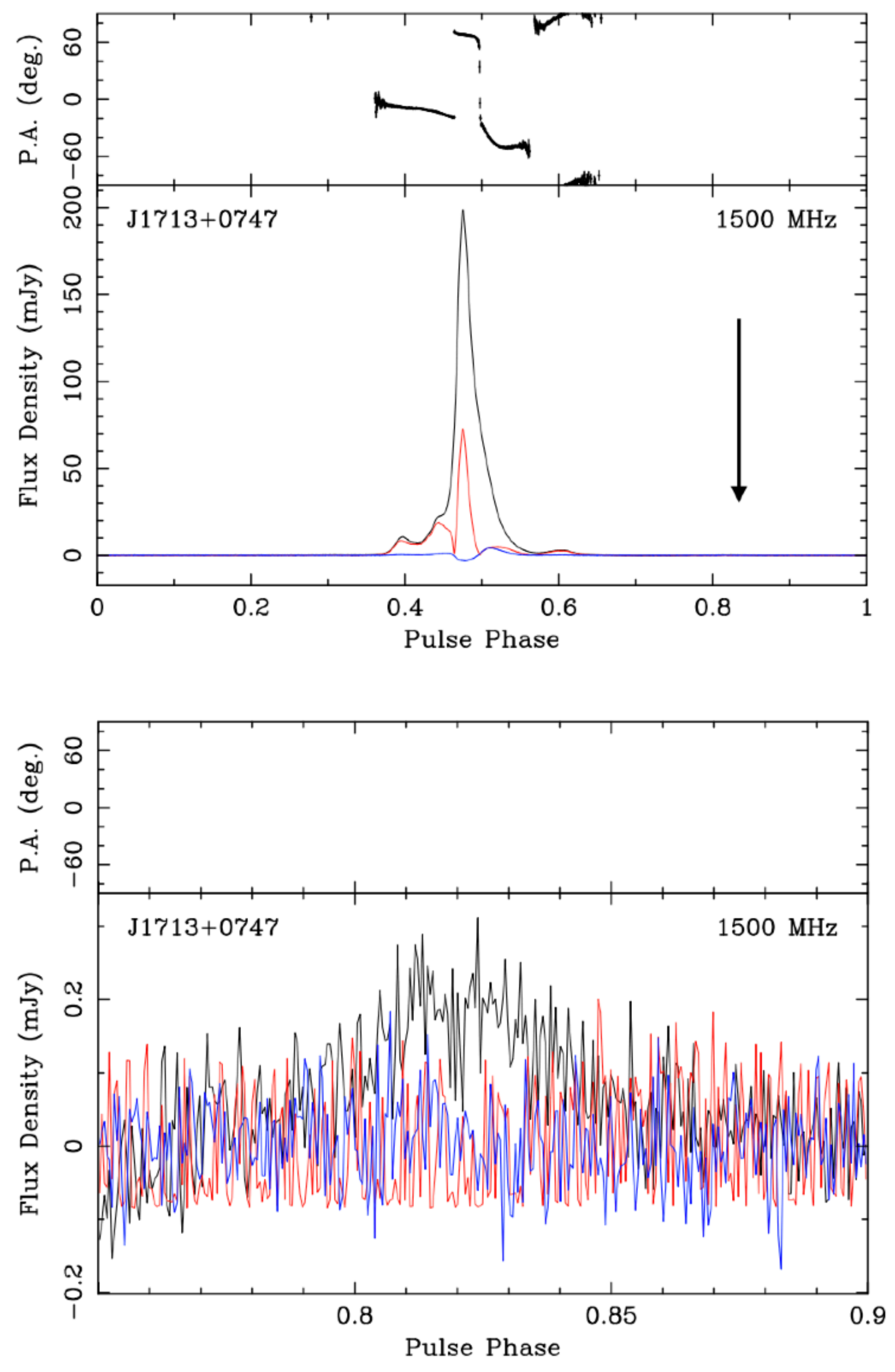


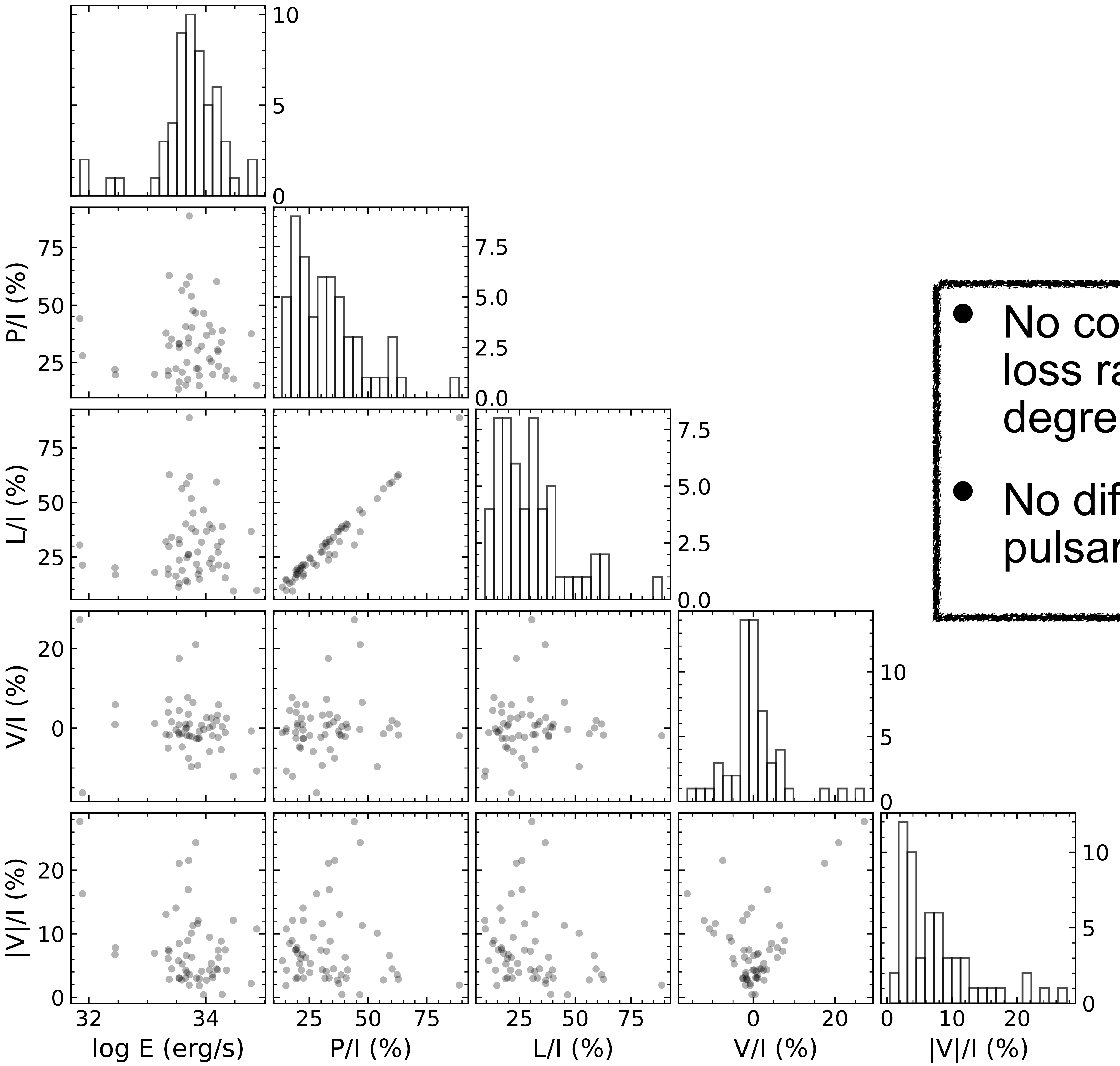
Dai et al. 2015



Wahl et al. 2022

consistent and much more extended

Polarization properties



- No correlation between energy loss rate and polarization degree is found
- No difference with normal pulsars

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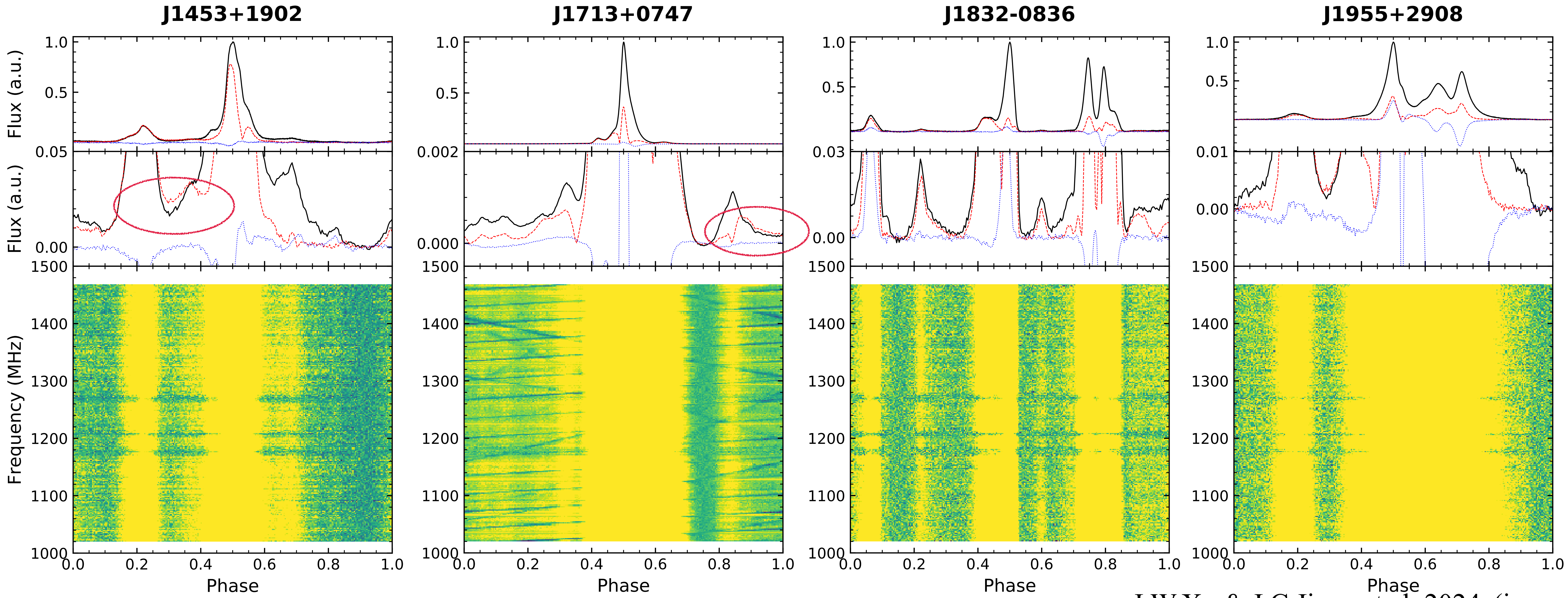
Large duty cycles



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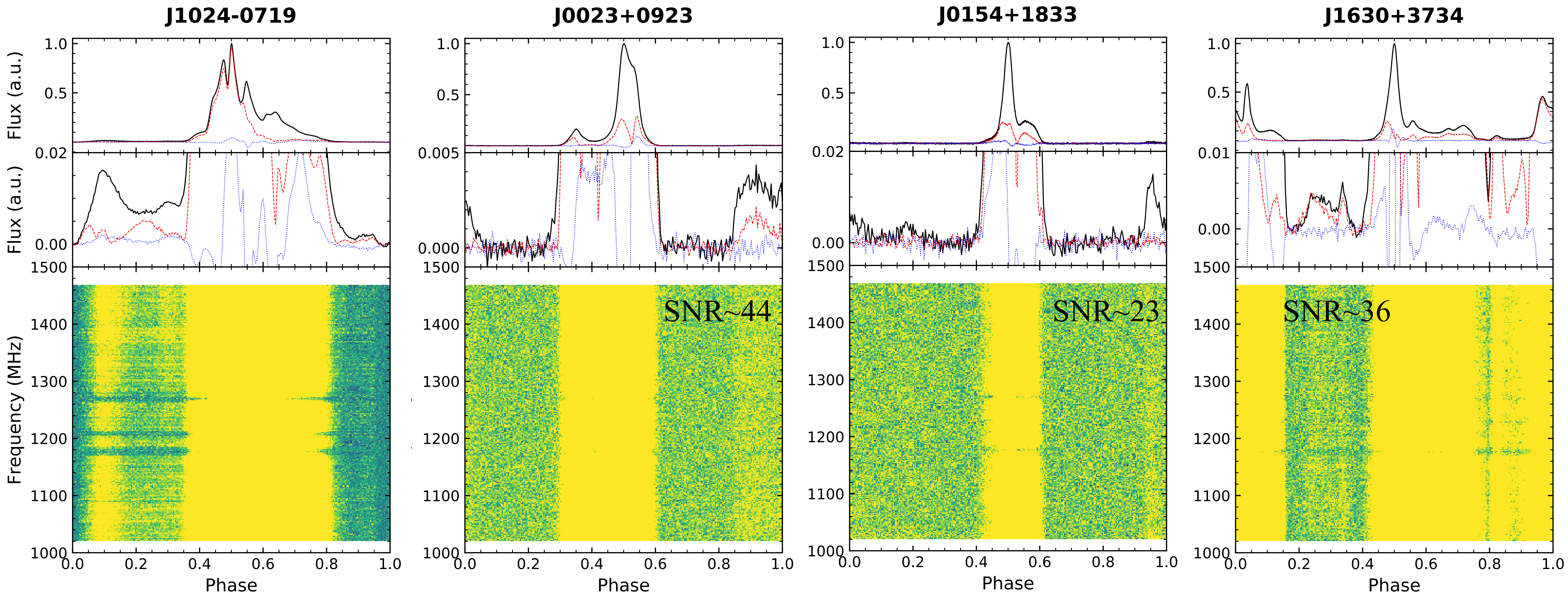
- 3/4 CPTA pulsars > 50%, six pulsars larger than 90% ($> 3\sigma_n$)
- May be close to light cylinder
- 14 pulsars are potential whole phase radiators, 10 pulsars present polarization excess
- The polarization profiles are less affected

Weak components

- Not instrumental effects
- For PSR J1713+0747, the bridge emission covers ~40% spin period
- Most have low polarization degree and nearly zero circular polarization



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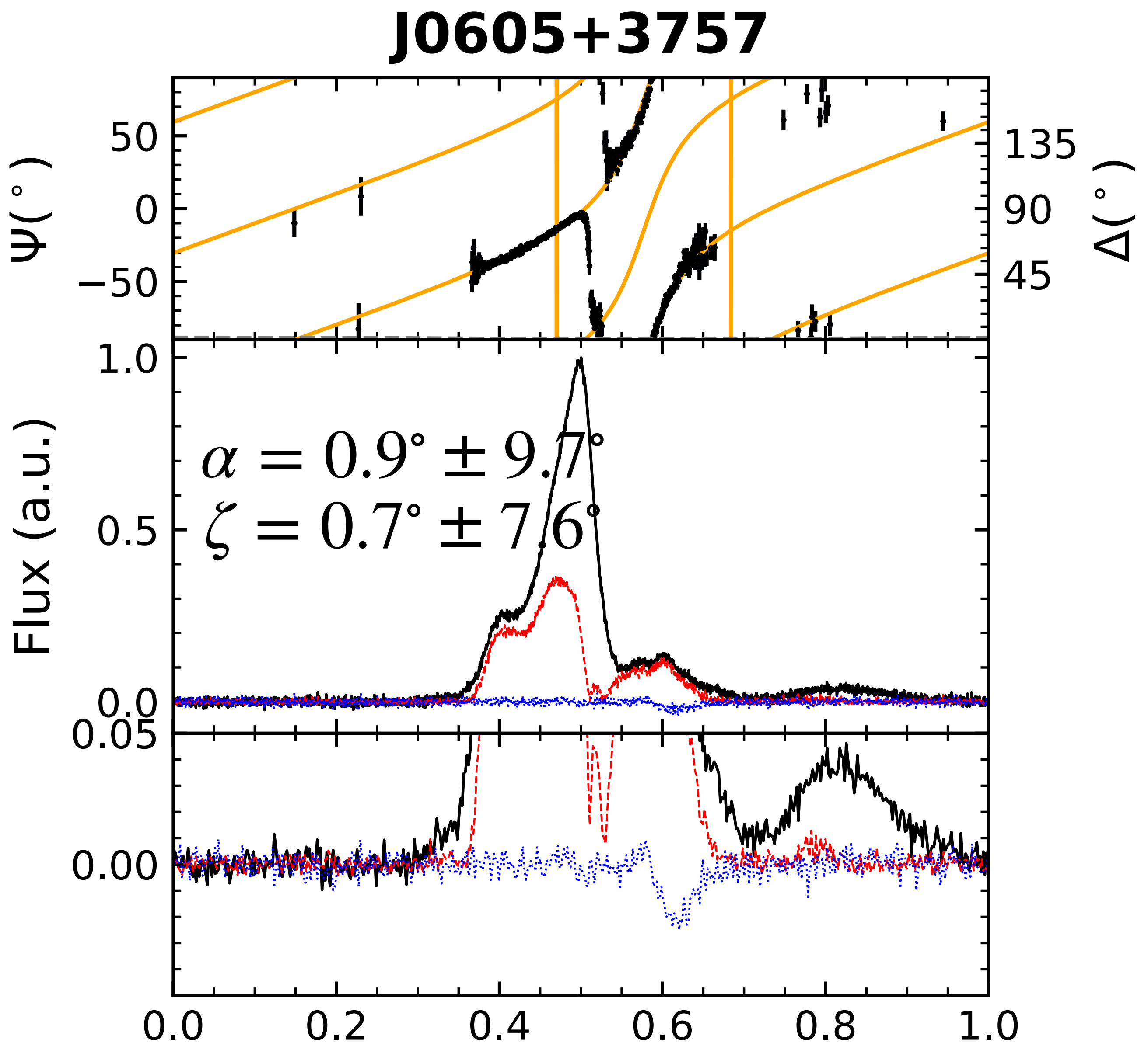
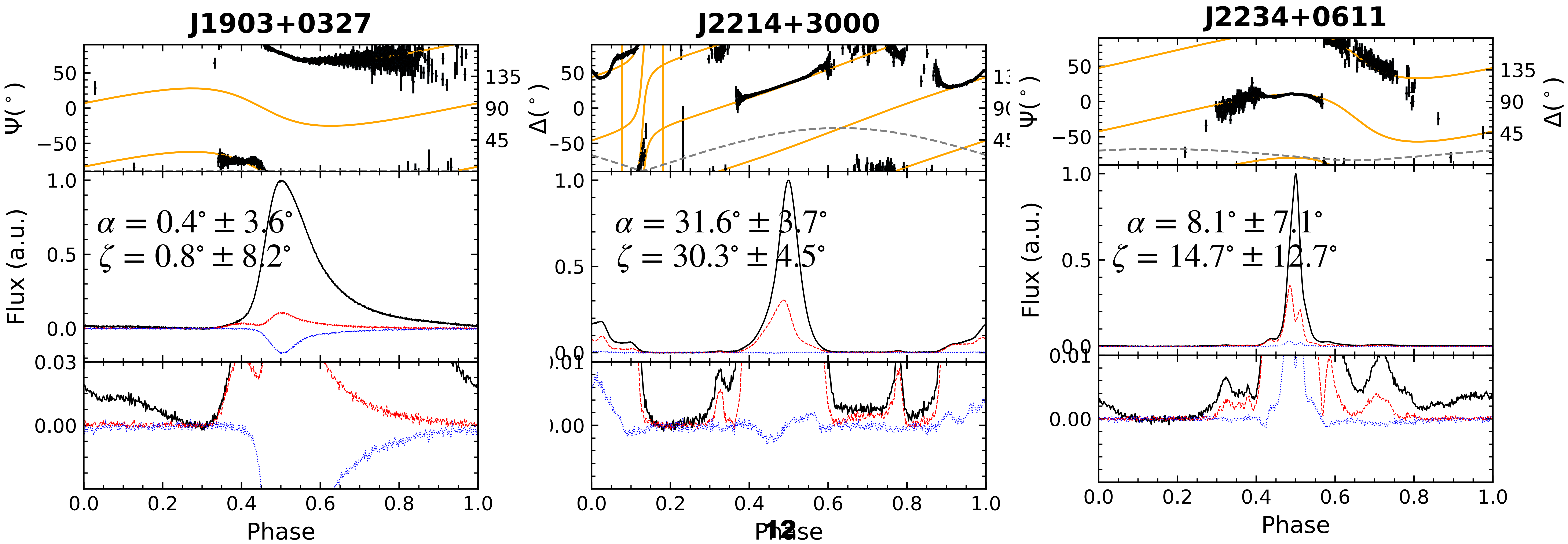
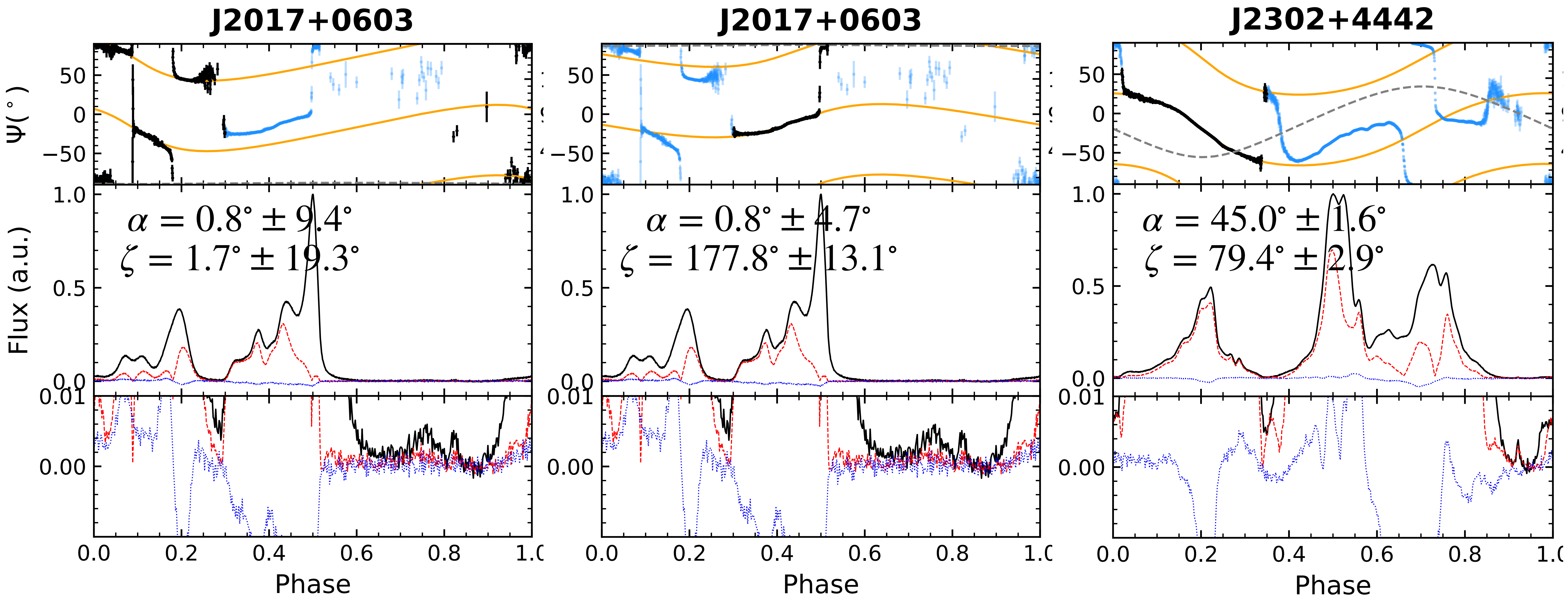
RVM fitting

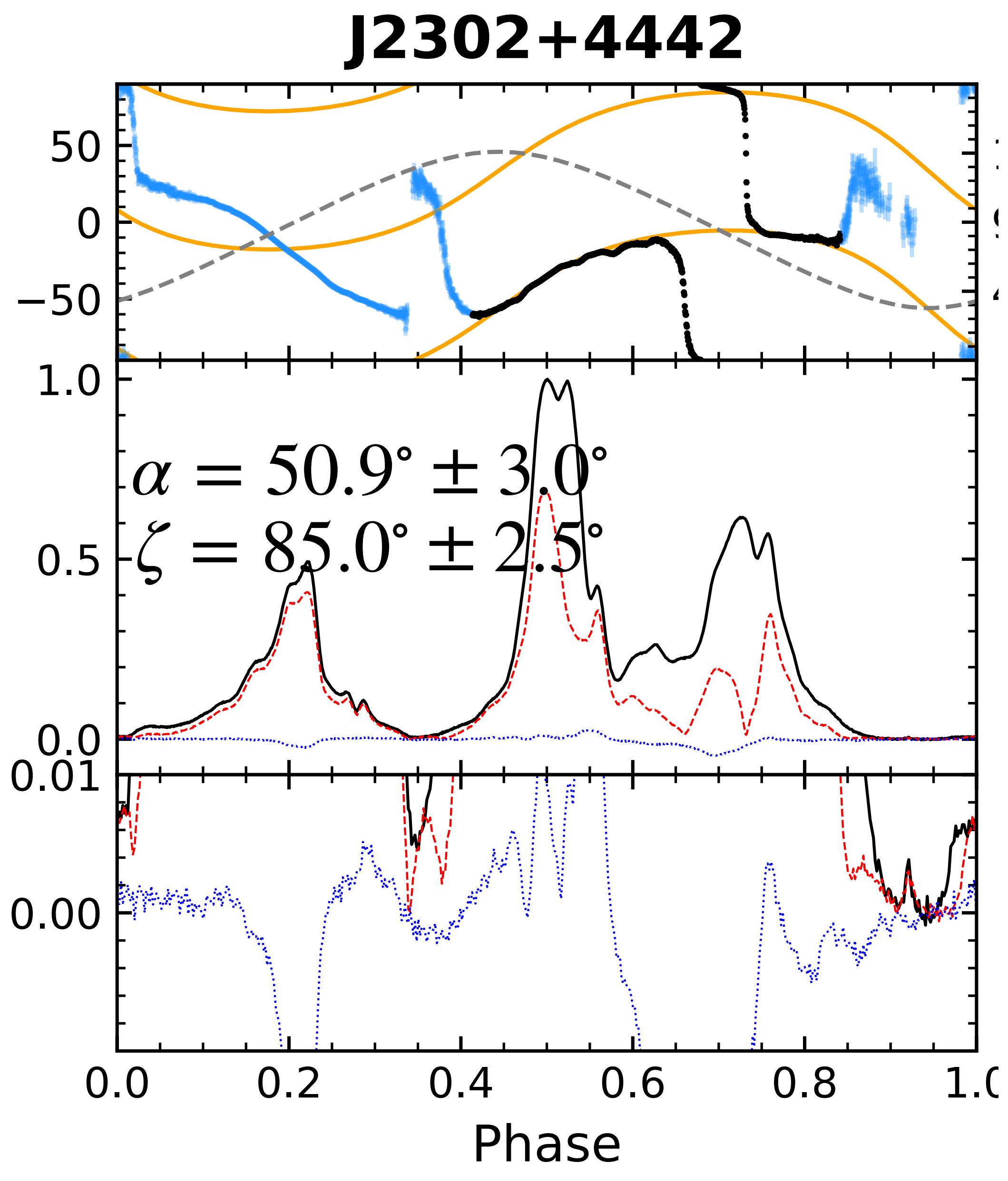


- PSR J0605+3757, J1903+0327, J2214+3000 and J2234+0611 generally fulfill the RVM model
- Distorted magnetic field, high emission height, aberration effect and sweepback effect
- The phase separation is constant



RVM fitting





- 15 pulsars present S shape PA for part of pulse phases
- Local magnetic field is dipolar

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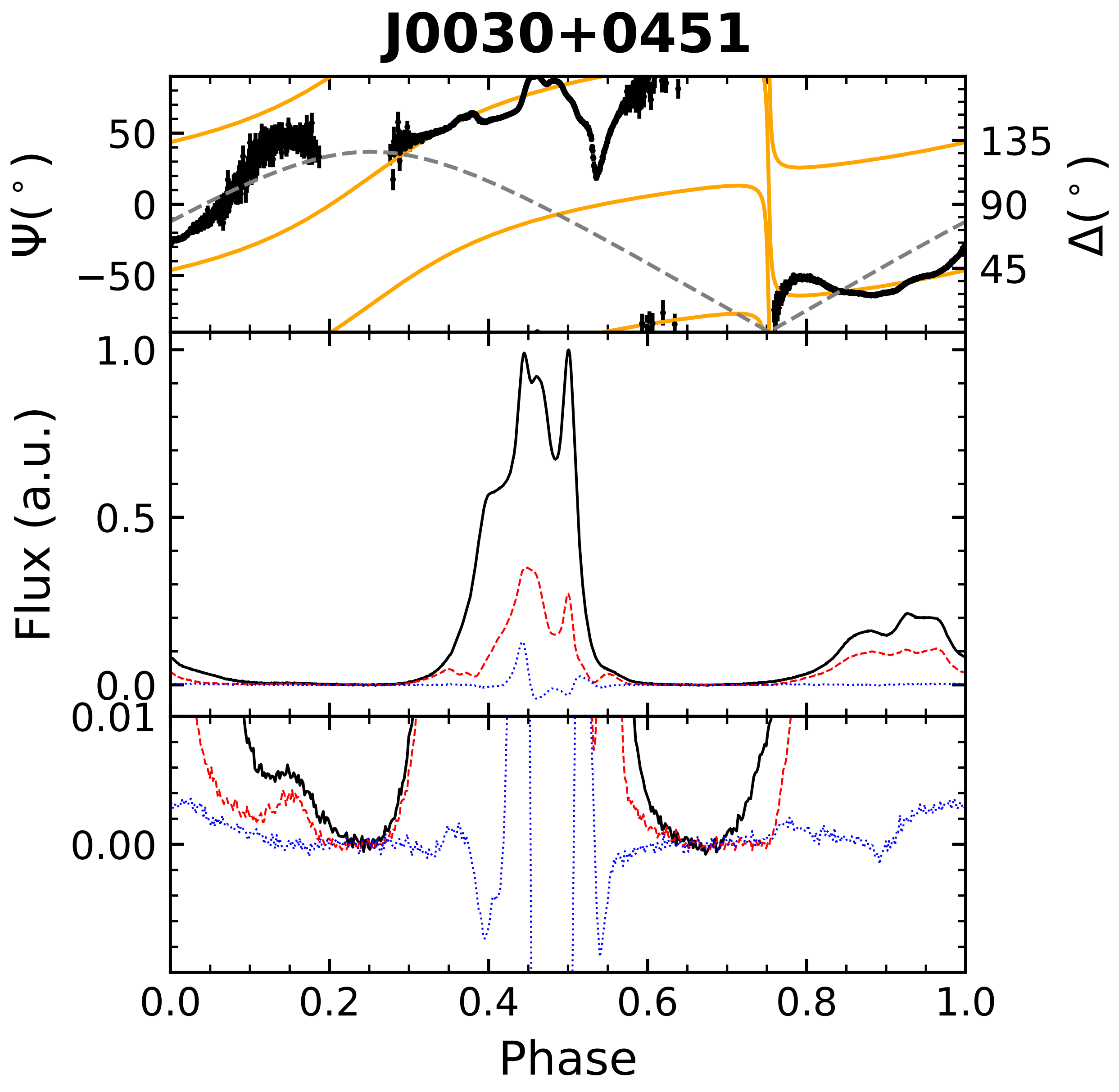
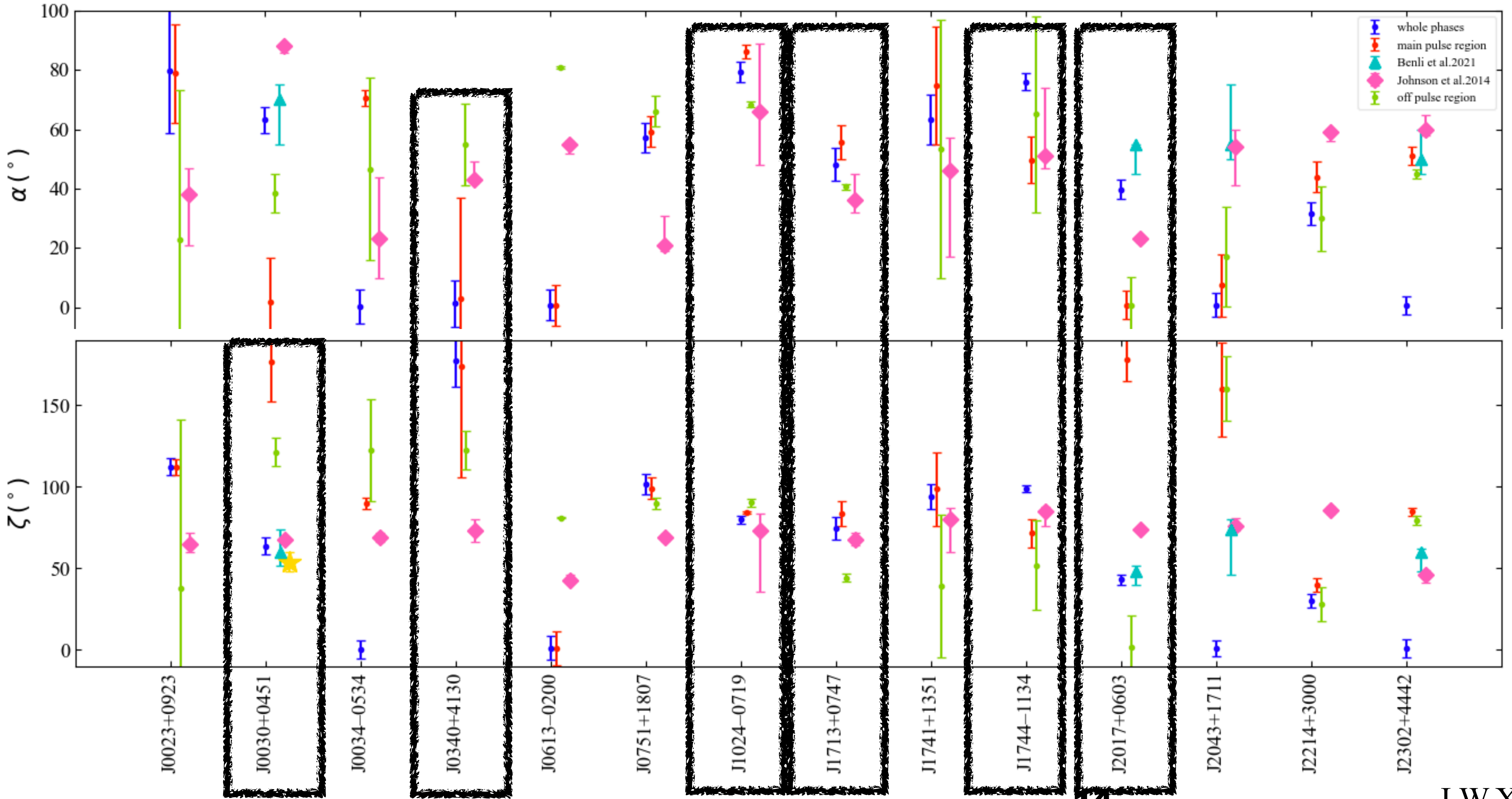
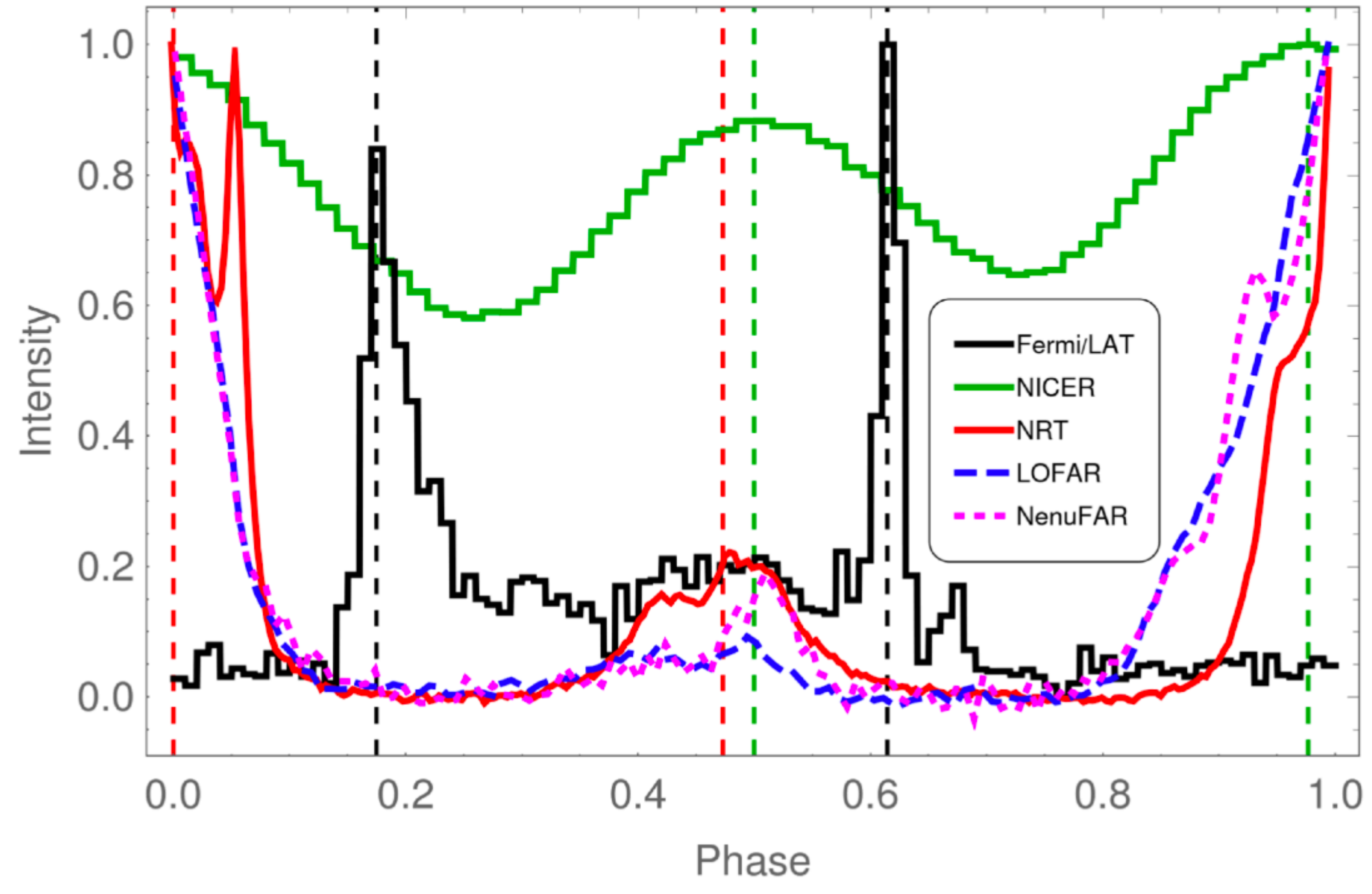
Compared with high energy observations

- The sight angle of J0030+0451
- PSR J0030+0451, J1024-0719, J1713+0747, J1744-1134 and J2017+0603 present close radiation geometry for radio and gamma ray observations
- Radiation geometry is hard to describe on both bands







Petri et al. (2023)

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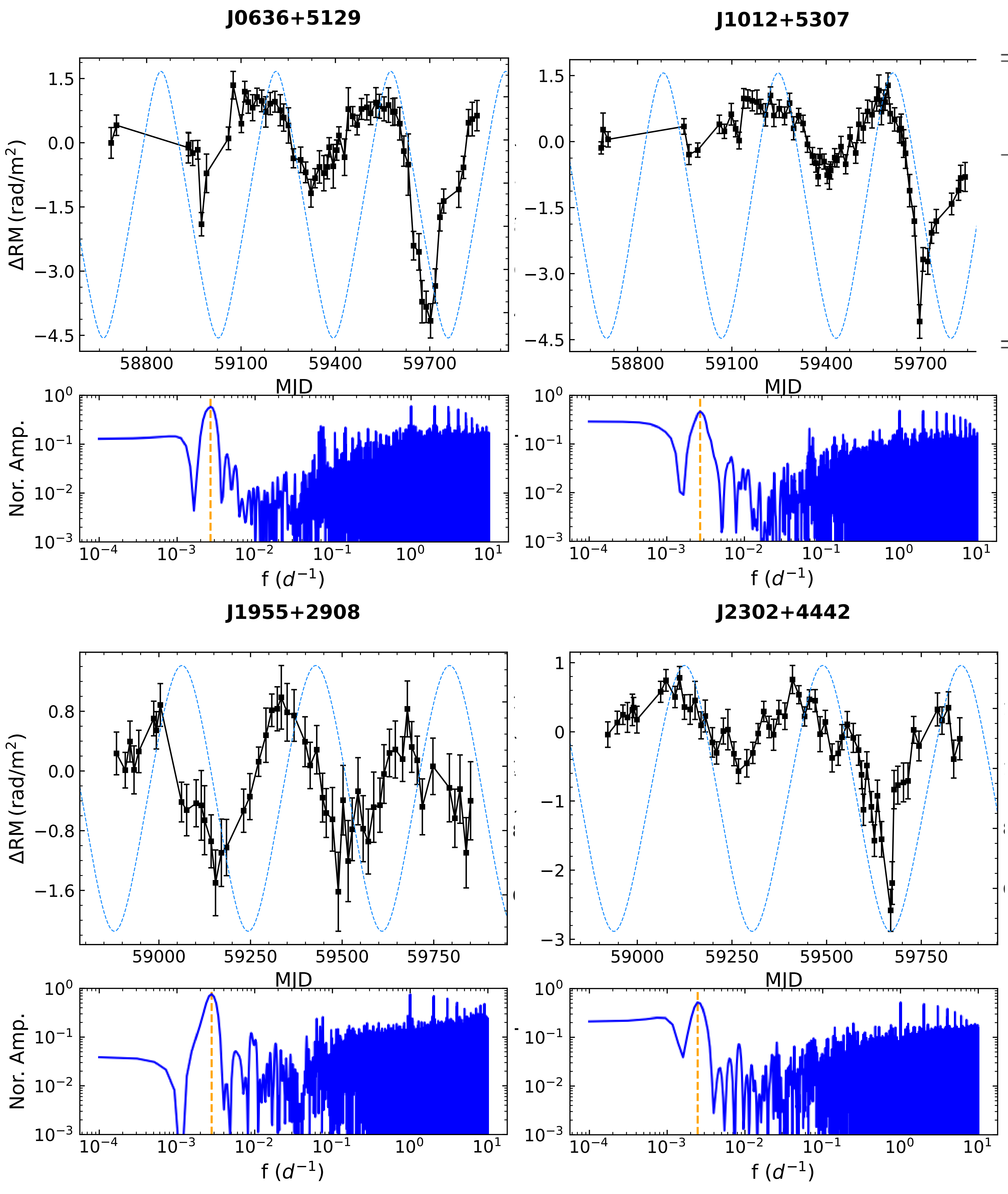
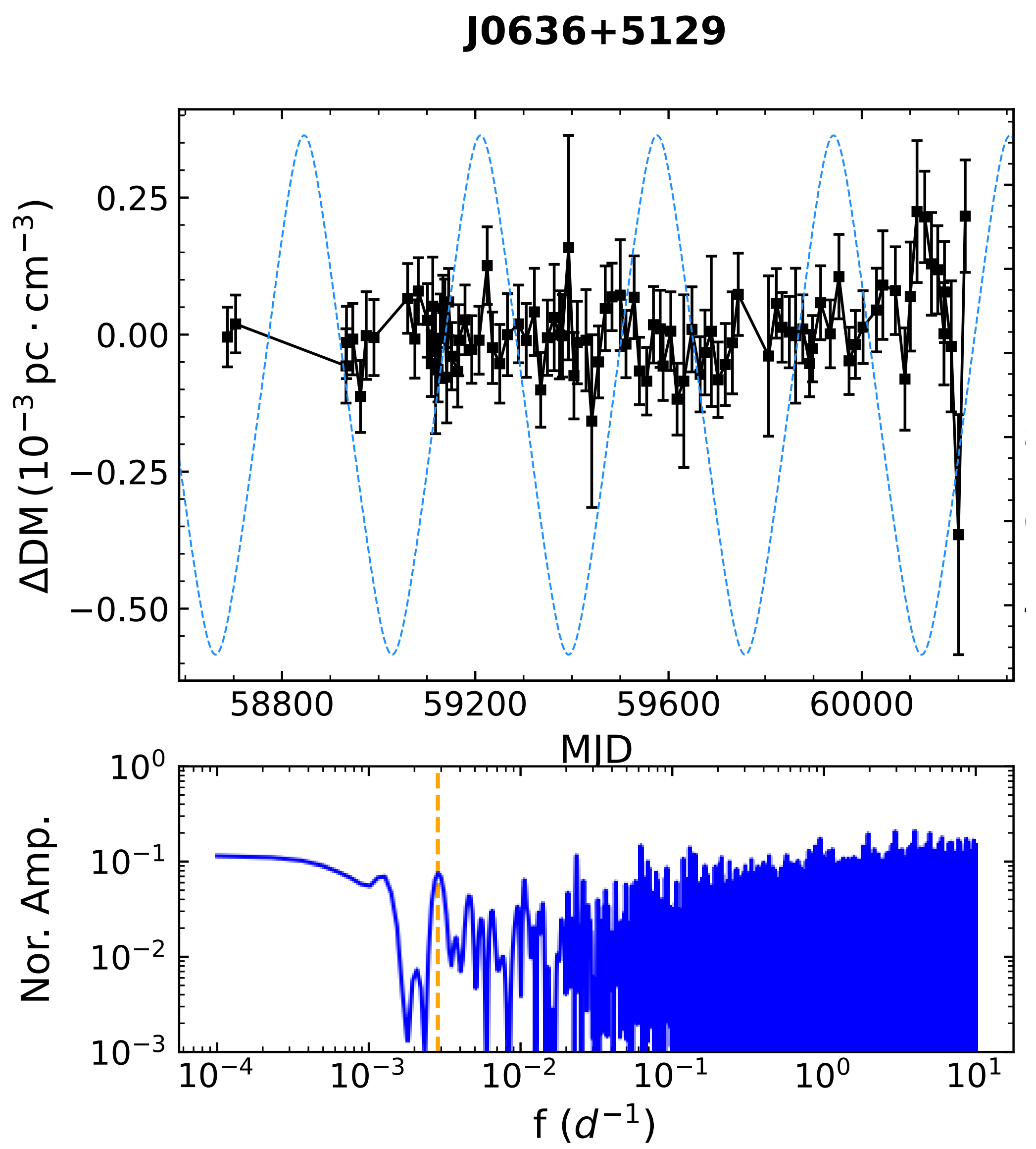
Annual variations of RM



Pulsar	A_{RM}	Period	FAP	r	τ
	rad · m^{-2}	d			d
J0636+5129	0.93 ± 0.11	373.1	5.07×10^{-9}	−0.75	63.7
J1012+5307	0.70 ± 0.09	371.6	1.83×10^{-6}	−0.67	24.4
J1955+2908	0.81 ± 0.07	358.3	1.04×10^{-13}	0.86	61.2
J2302+4442	0.52 ± 0.08	405.4	2.49×10^{-7}	0.64	−49.2

- Correlated with variation of angles between pulsars and sun
- No similar annual behavior in DM variation



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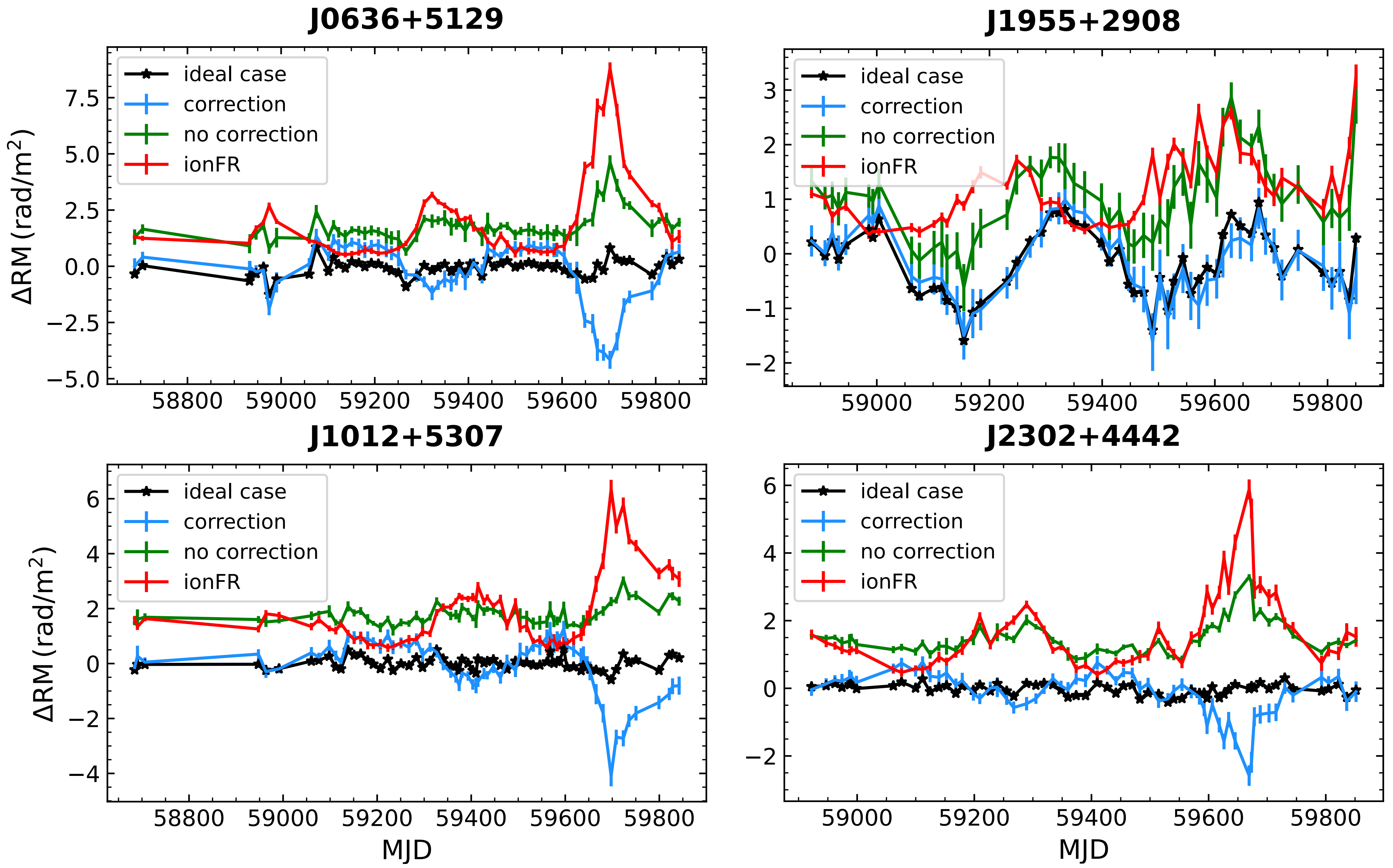
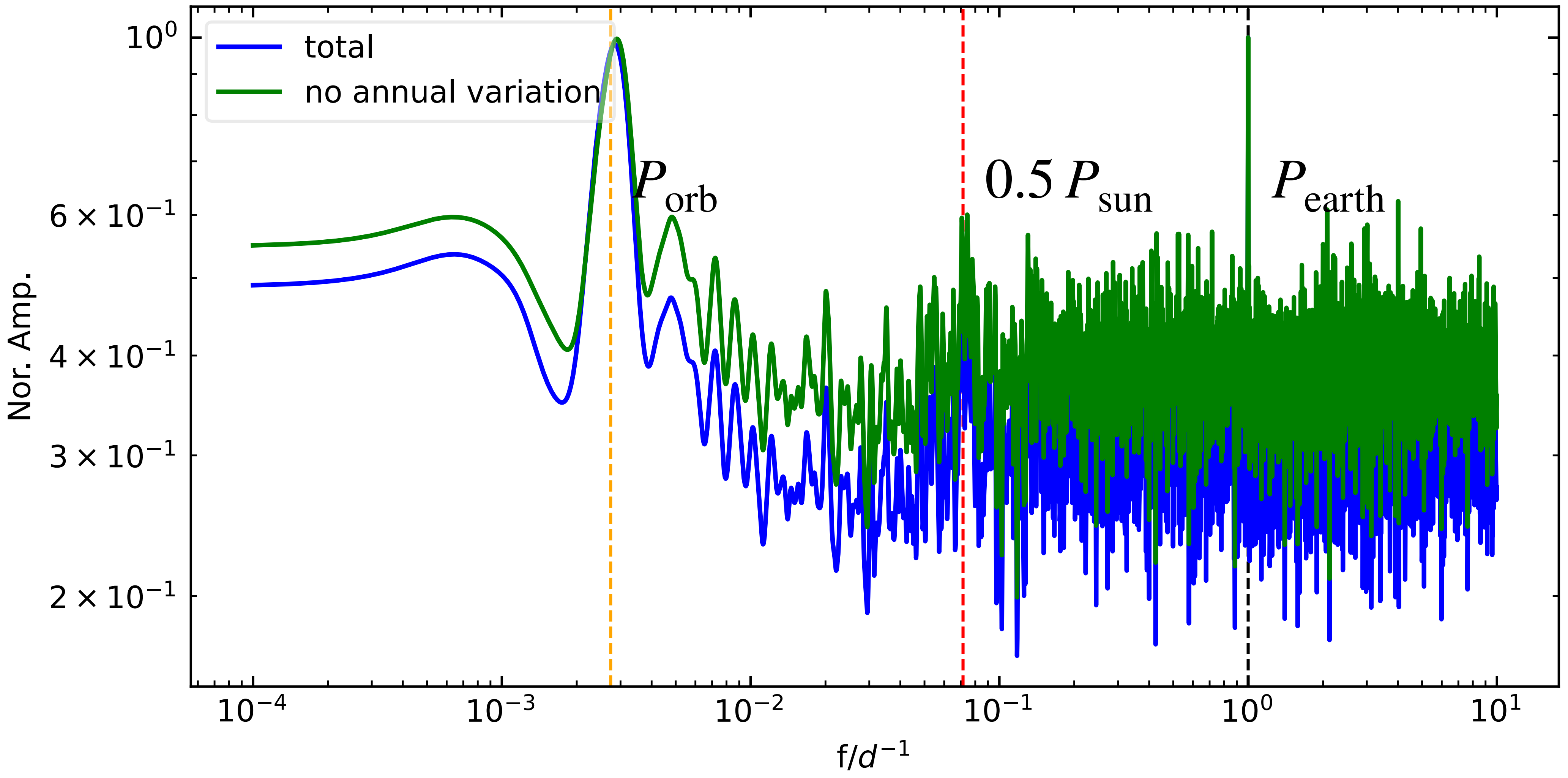
Potential origins

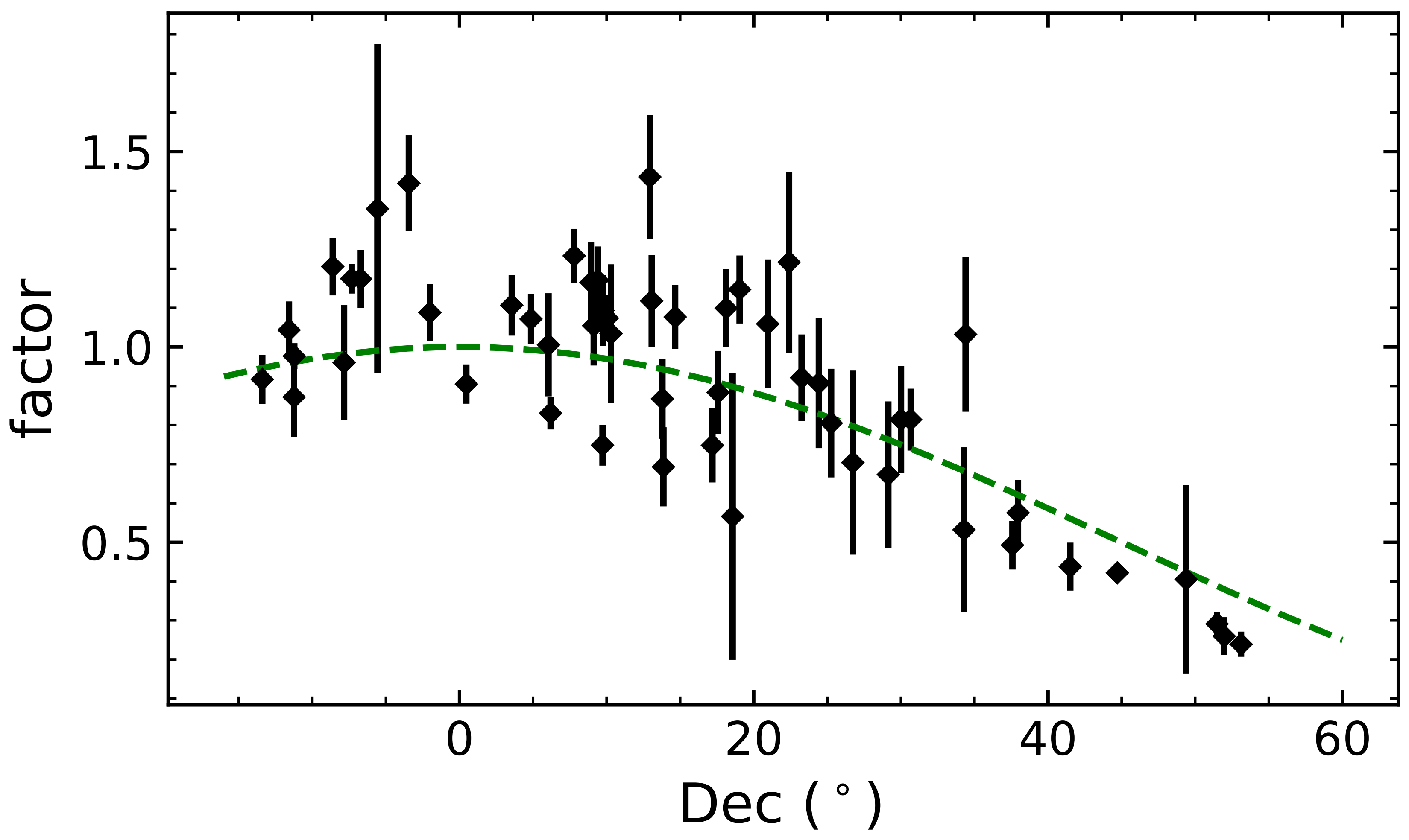
- Three peaks also present for power spectrum of RM variations

$$\left\langle B_{\parallel}\right\rangle = \frac{2\pi m_e^2 c^4}{e^3}\cdot\frac{\Delta \mathrm{RM}}{\Delta \mathrm{DM}} = 12.3\left(\frac{\Delta \mathrm{RM}}{1\mathrm{rad/m^2}}\right)\cdot\left(\frac{\Delta \mathrm{DM}}{10^{-4}\mathrm{pc}\cdot\mathrm{cm}^{-3}}\right)^{-1}\mathrm{mG}$$

- A more precise Total electron content global map is needed







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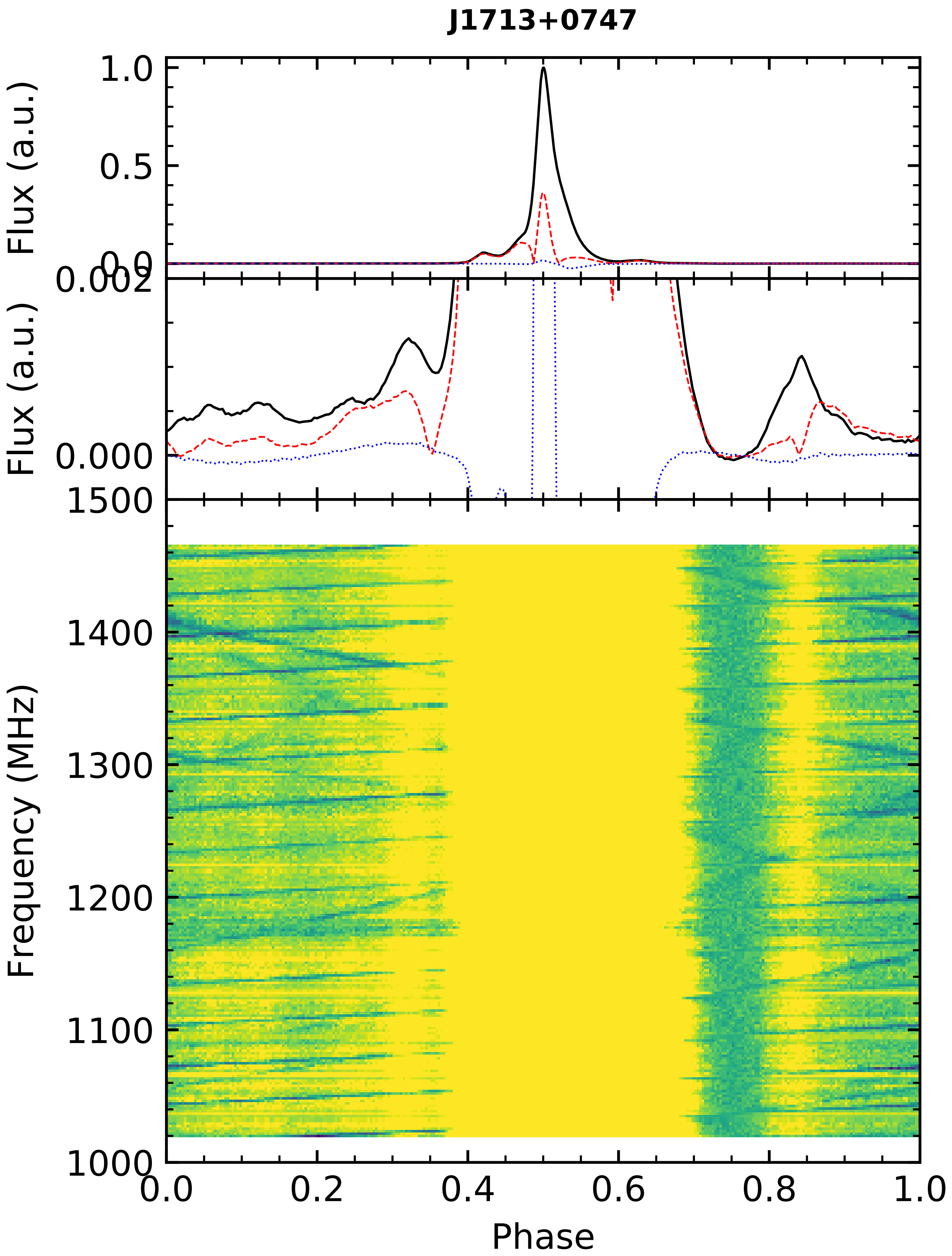
Weak artifacts

- of high stability
- weak artifacts appear for several CPTA pulsars
- PSR J1713+0747, J1744-1134, J2145-0750 have frequent appearances
- Seems to be related to signal strength(However PSR J0636+5129,J0645+5158…)
- weaker than surrounding noise level



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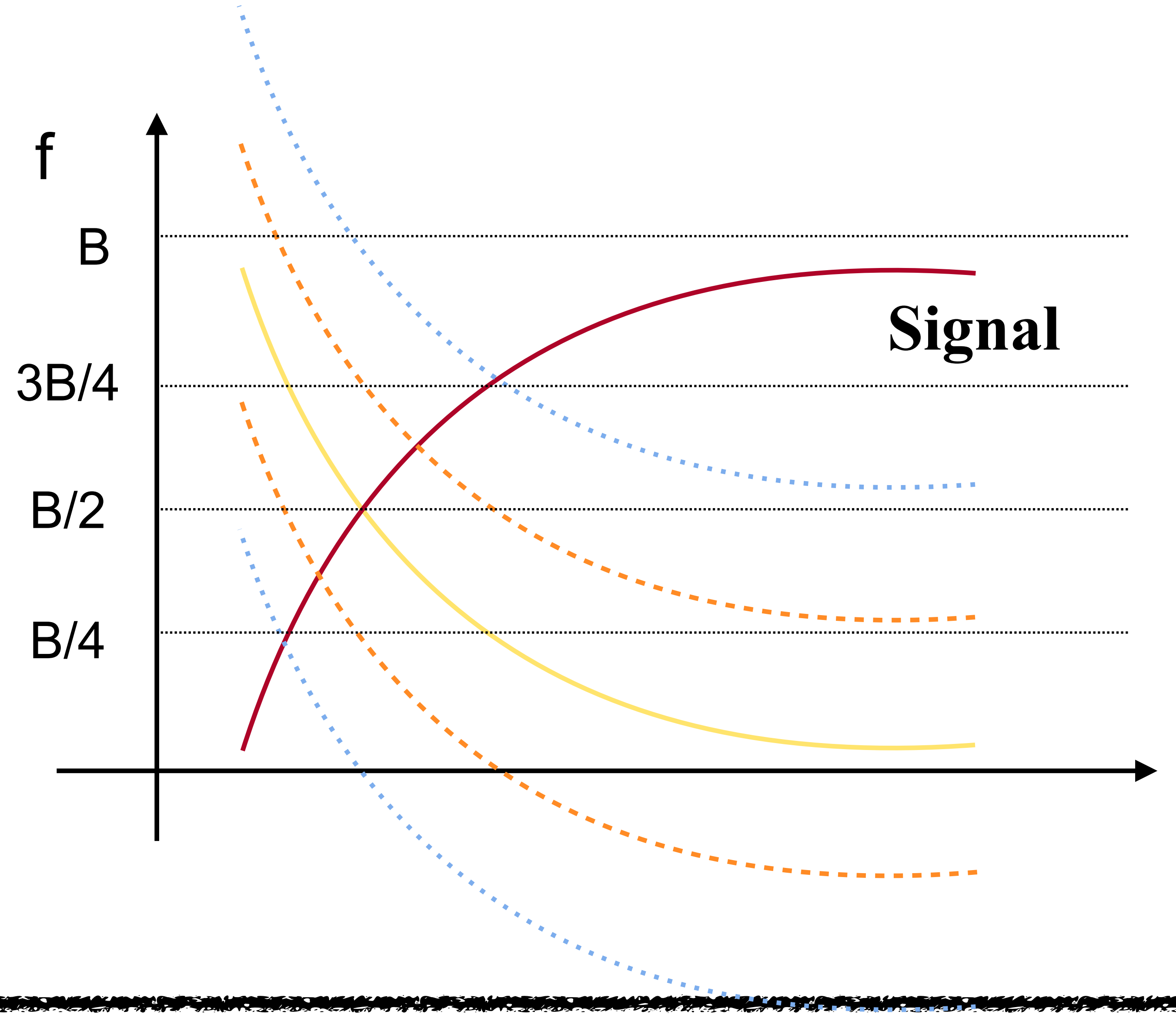
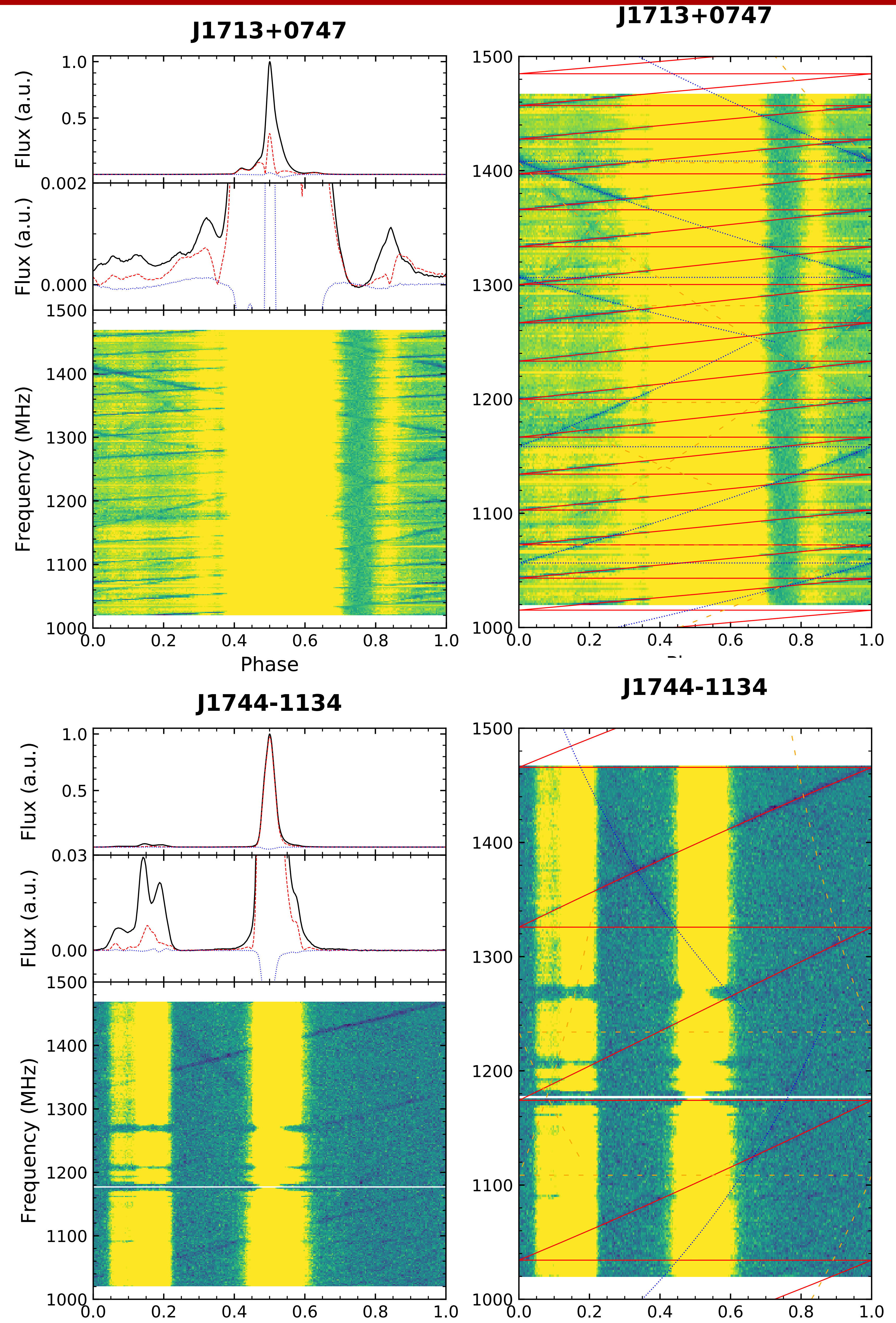
Weak artifacts





- The main artifact is reflection of dispersed signal about band center
- dispersed signal with a shift of half or quarter bandwidth
- NANOGrav datasets also present such main artifacts but are much stronger than noise level..

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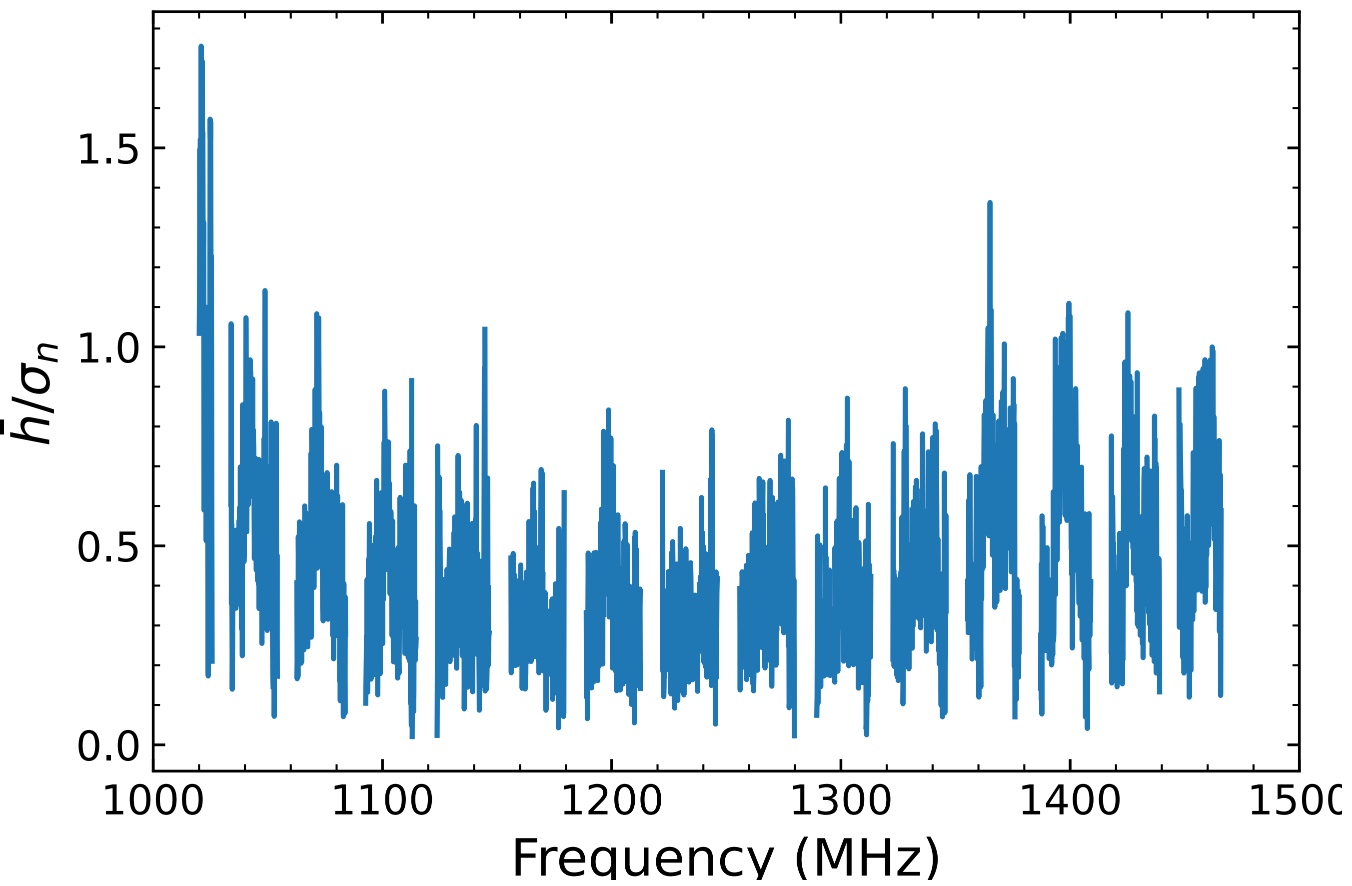
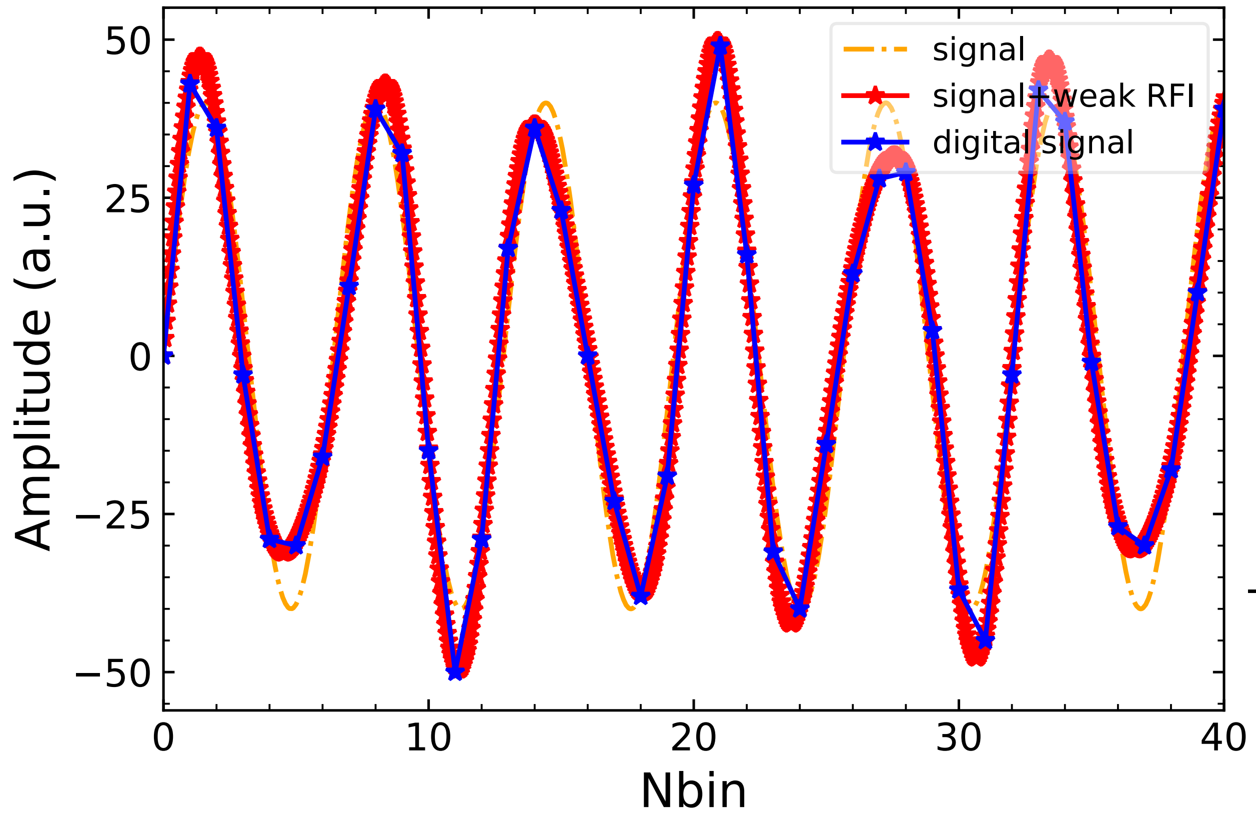
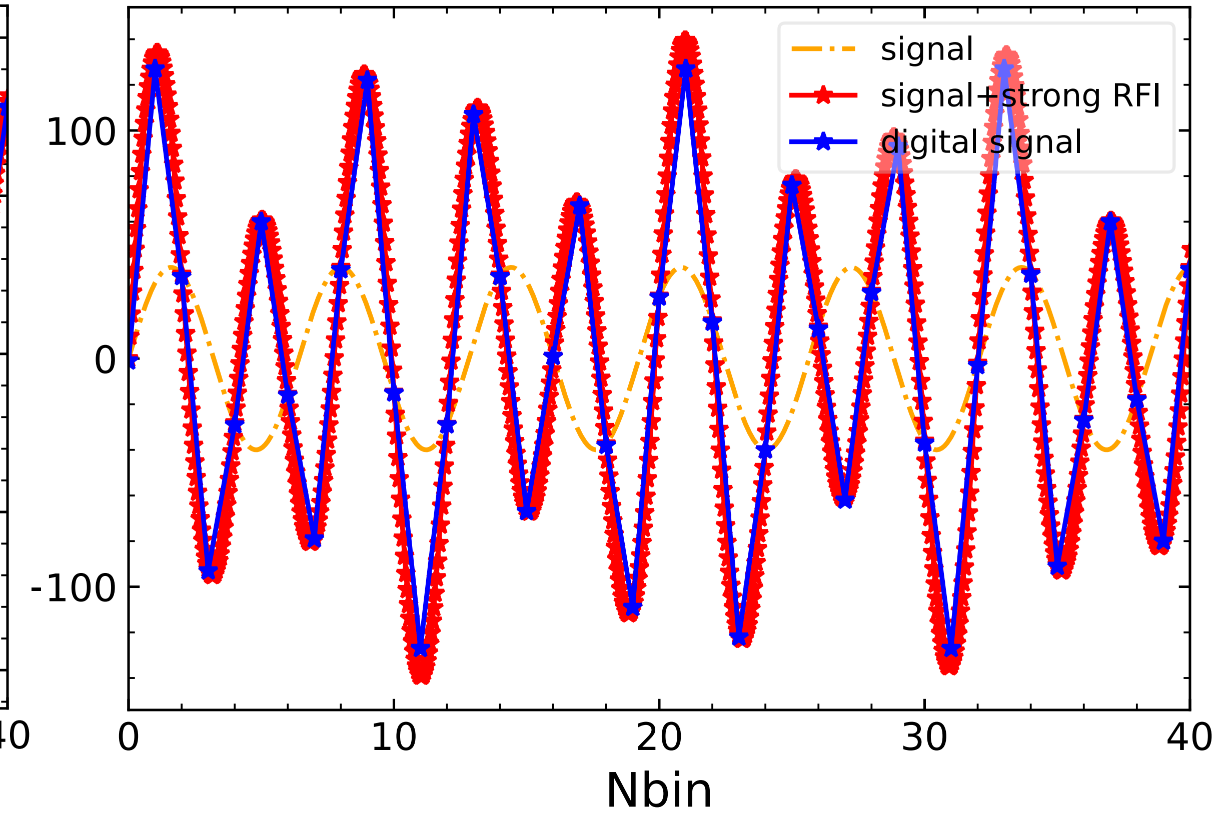
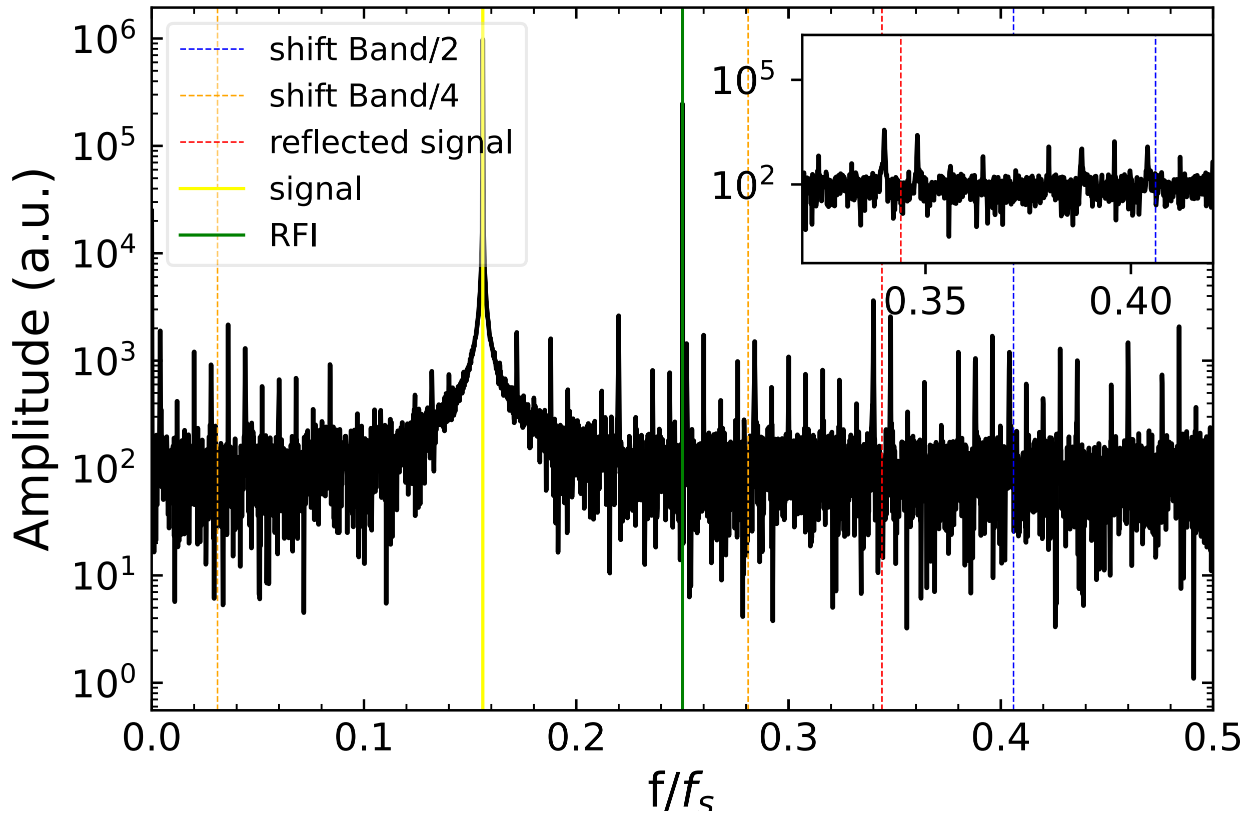
Possible Explanation

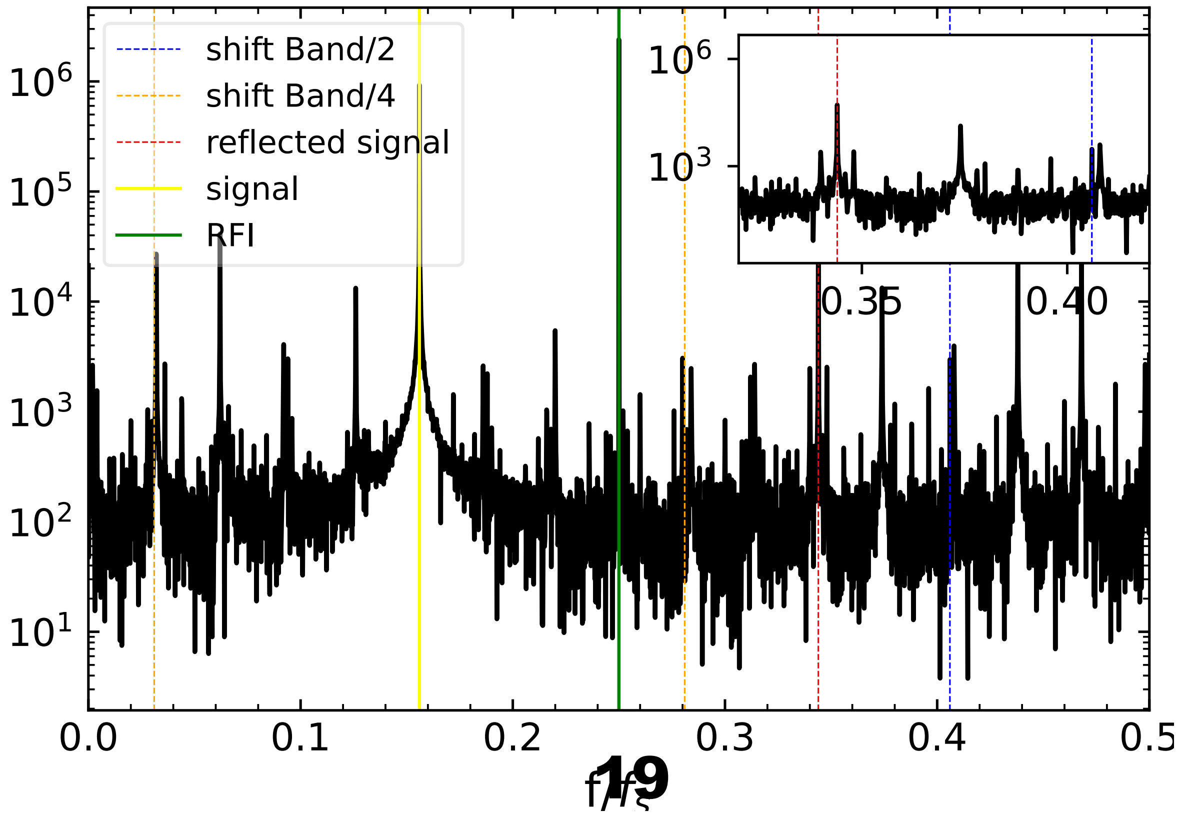
- The ADC is saturated due to strong signal(scintillation) or strong RFI
- The ADC sampling range: [-127,127], number of samplings: 8192
- Signal frequency: 0.156 f_s, RFI frequency: 0.25 f_s











- Such saturation can also be caused by fronted amplifier
- Cover small fractions of pulse phases and bandwidth
- Their amplitude is smaller than noise level

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Conclusion

- Large duty cycles, may be at high emission height
- Some weak components detected
- Magnetic field deviates from dipole structure
- Quasi-annual RM variations, the resolution of global electron density map

Thanks!