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Magnetic Fields in the Pulsar Wind Observed from the Spider Pulsars

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Organization: Zhijiang Lab (之江实验室)
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Outline

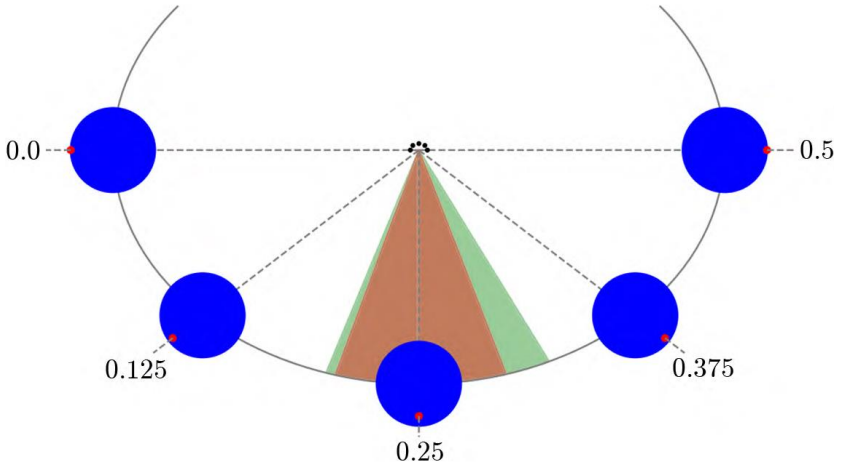
1. Background
2. Black widow pulsar J1720-0534
3. Timing results of PSR J1720-0534
4. Magnetic field measurement of PSR J1720-0534
5. 计算天文研究室

1. Background

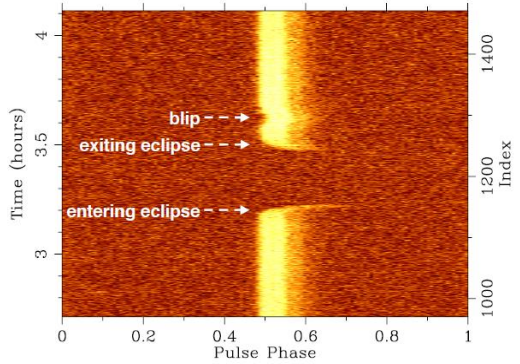
Observation features of Spider pulsar

- Pulsar signal diminished or fully eclipsed for some orbital phases
- Eclipse frequency dependence
- Centered near companion inferior conjunction
- Eclipse medium larger than companion's Roche lobe

Polzin et al. MNRAS 2017

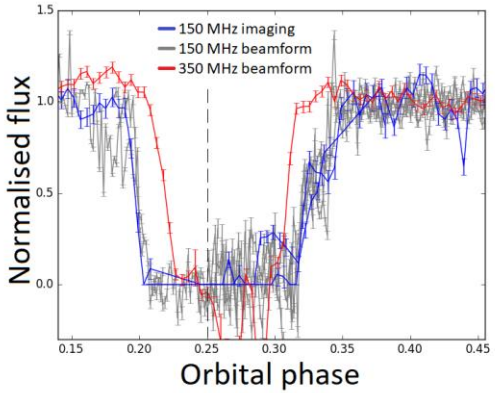


Crowter et al. MNRAS 2020

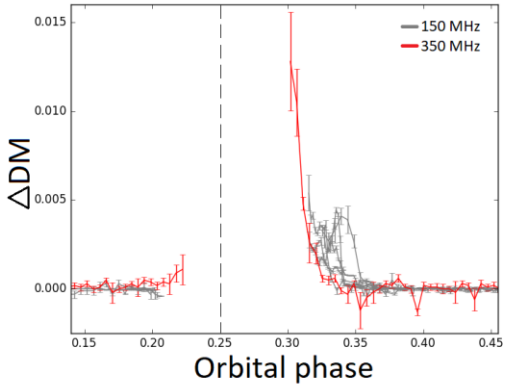


(a) Eclipse at 820 MHz on MJD 55 181 - GUPPI

Polzin et al. MNRAS 2017



Polzin et al. MNRAS 2017



1. Background

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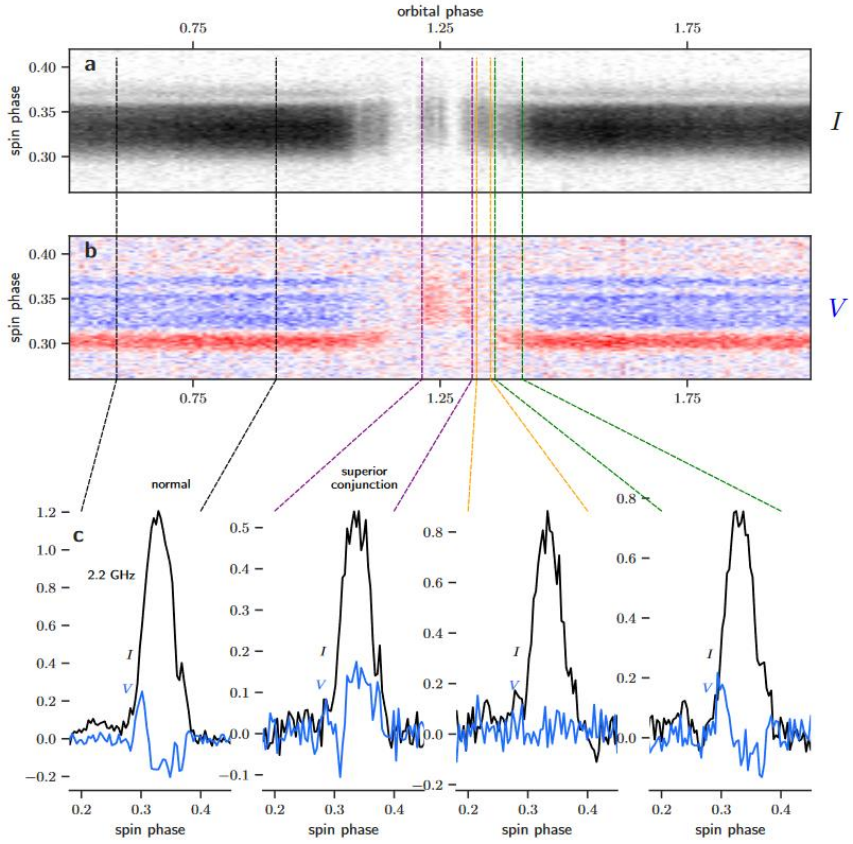
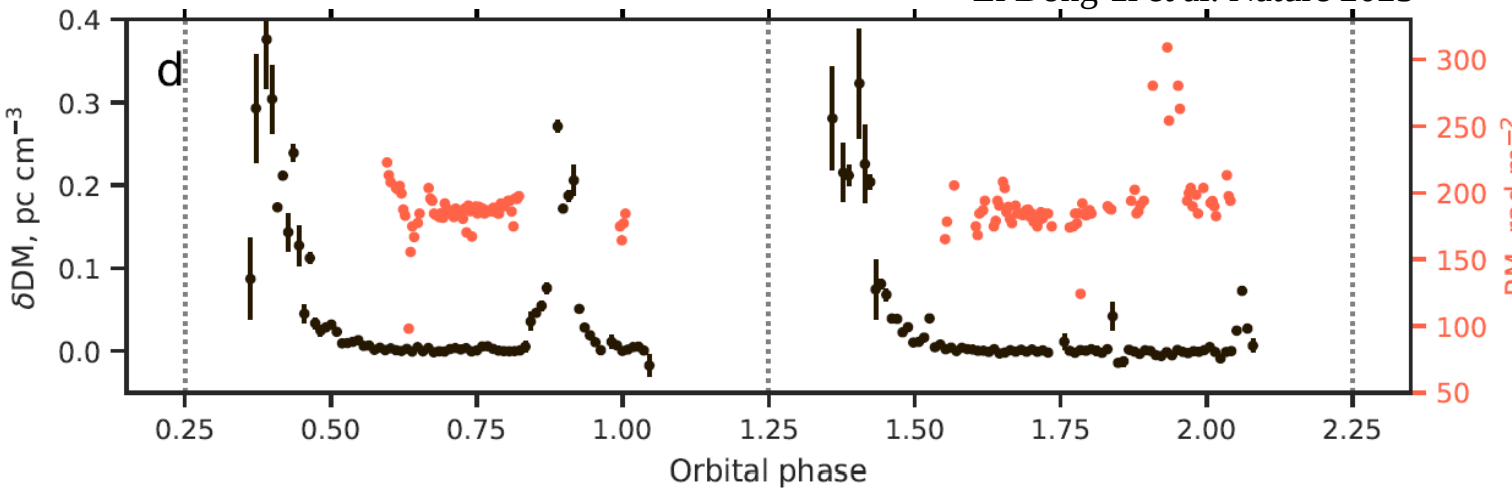
New Observation features

- linear depolarization
- sign reversal of V

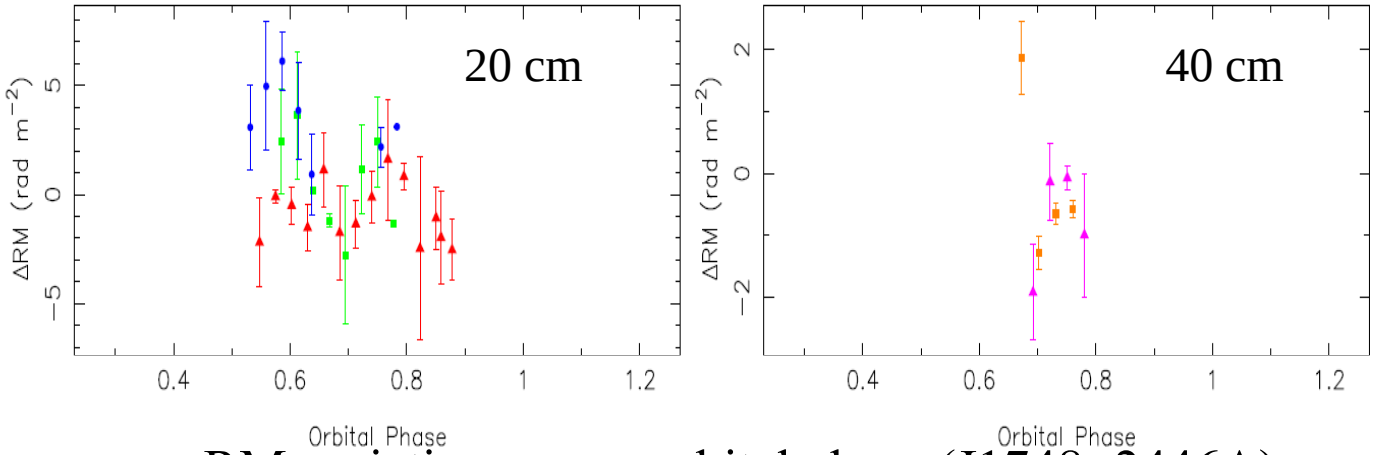


Li Dong-zi et al. Nature 2023



DM&RM variation versus orbital phase (Ter5A)

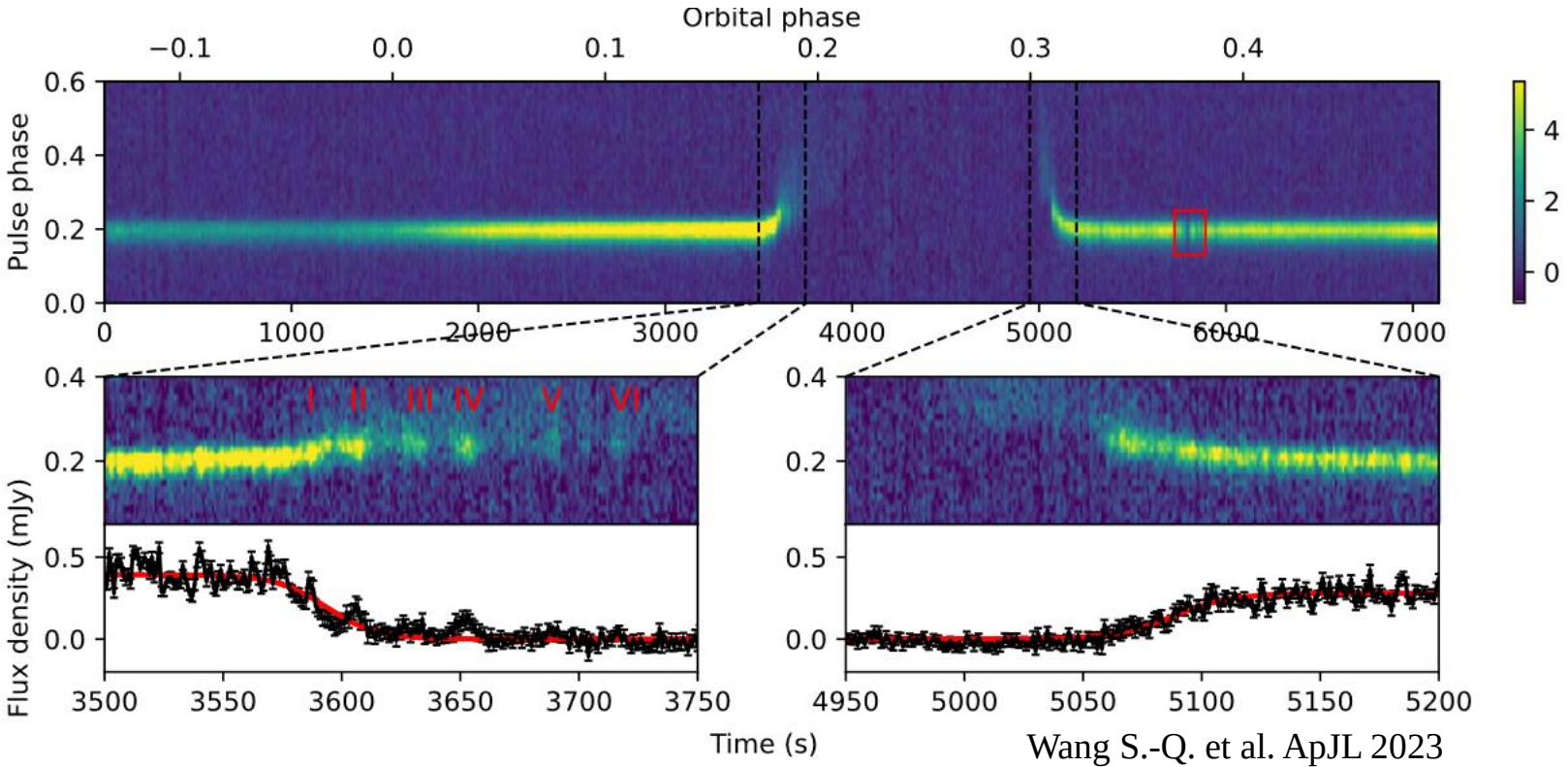
You Xiao-peng et al. ApJ 2018



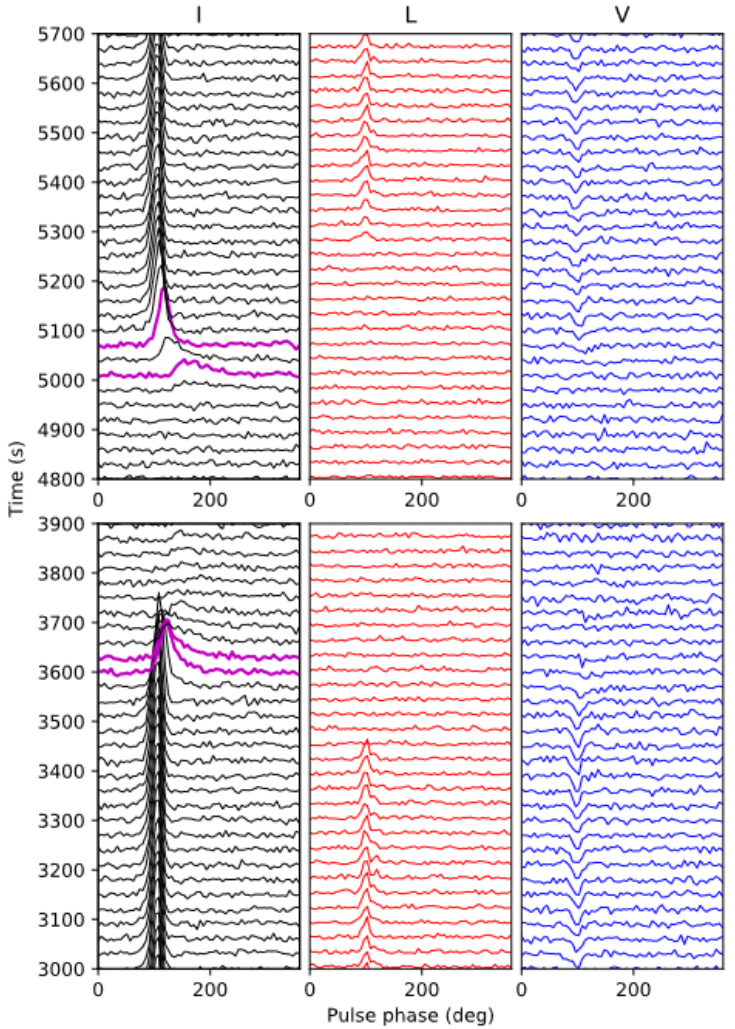
RM variation versus orbital phase (J1748−2446A)

2. Black widow pulsar J1720-0534

- The first black widow pulsar in CRAFTS
- First reported in Wang et al. 2021
- Pulse emission variations ~22 s during the ingress
- Linear depolarization near the eclipse



Wang S.-Q. et al. ApJL 2023



Wang S.-Q. et al. ApJL 2023

3. Timing results of PSR J1720-0534

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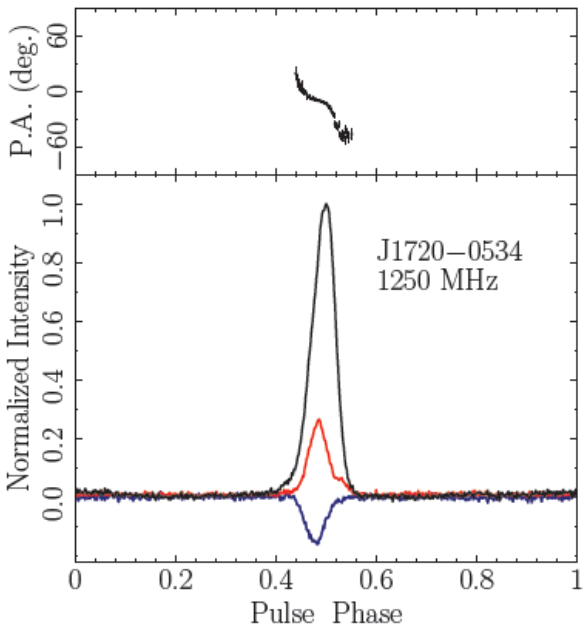
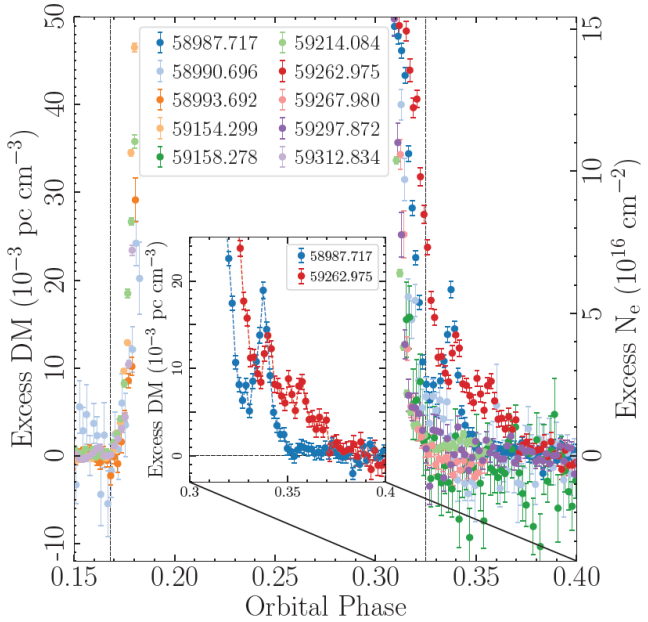
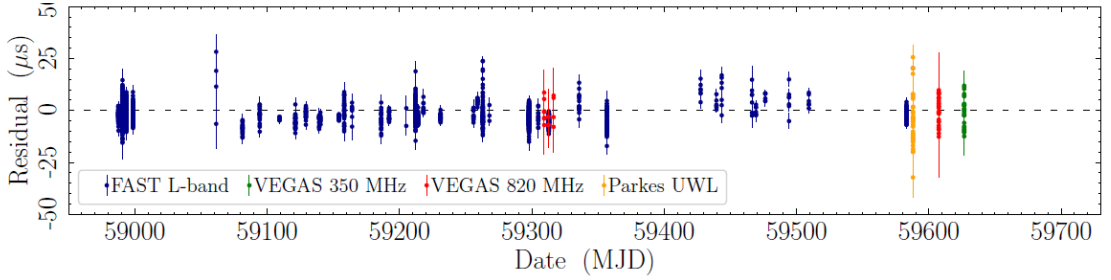
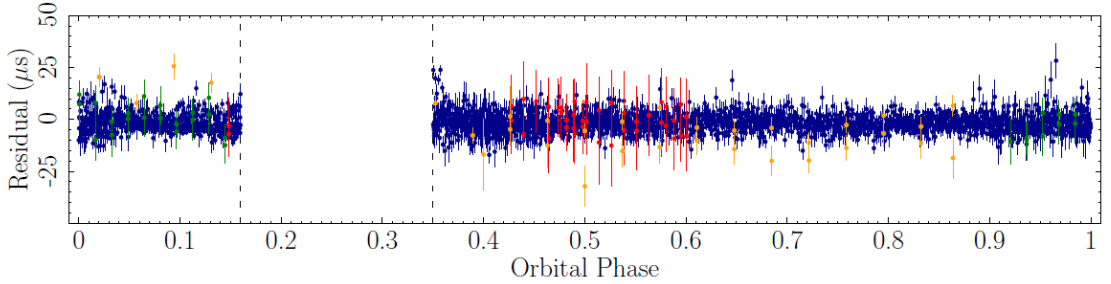
- Spin period: 3.26 ms
- Dispersion Measure: 36.82 $cm^{-3}pc$
- Orbital period: 3.16 hr
- Pulsar-companion separation: 1.2 $R_\odot$
- Minimum companion mass: 0.029 $M_\odot$
- Eclipse length: ~24 min

https://arxiv.org/abs/2307.00731









4. Magnetic field measurement

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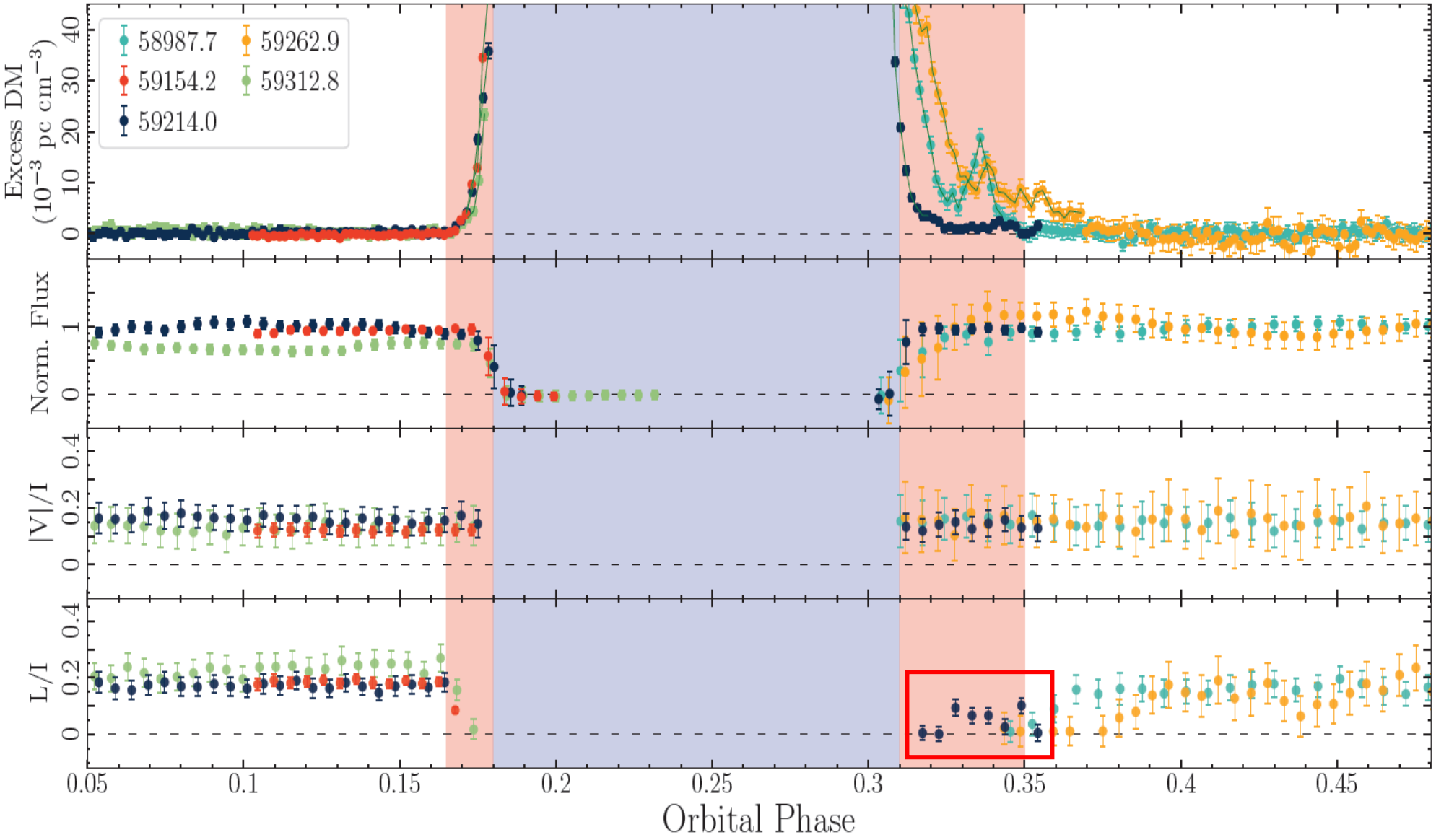

DM variation

Intensity variation

Polarization fraction variation

Polarization fraction variation

4. Magnetic field measurement

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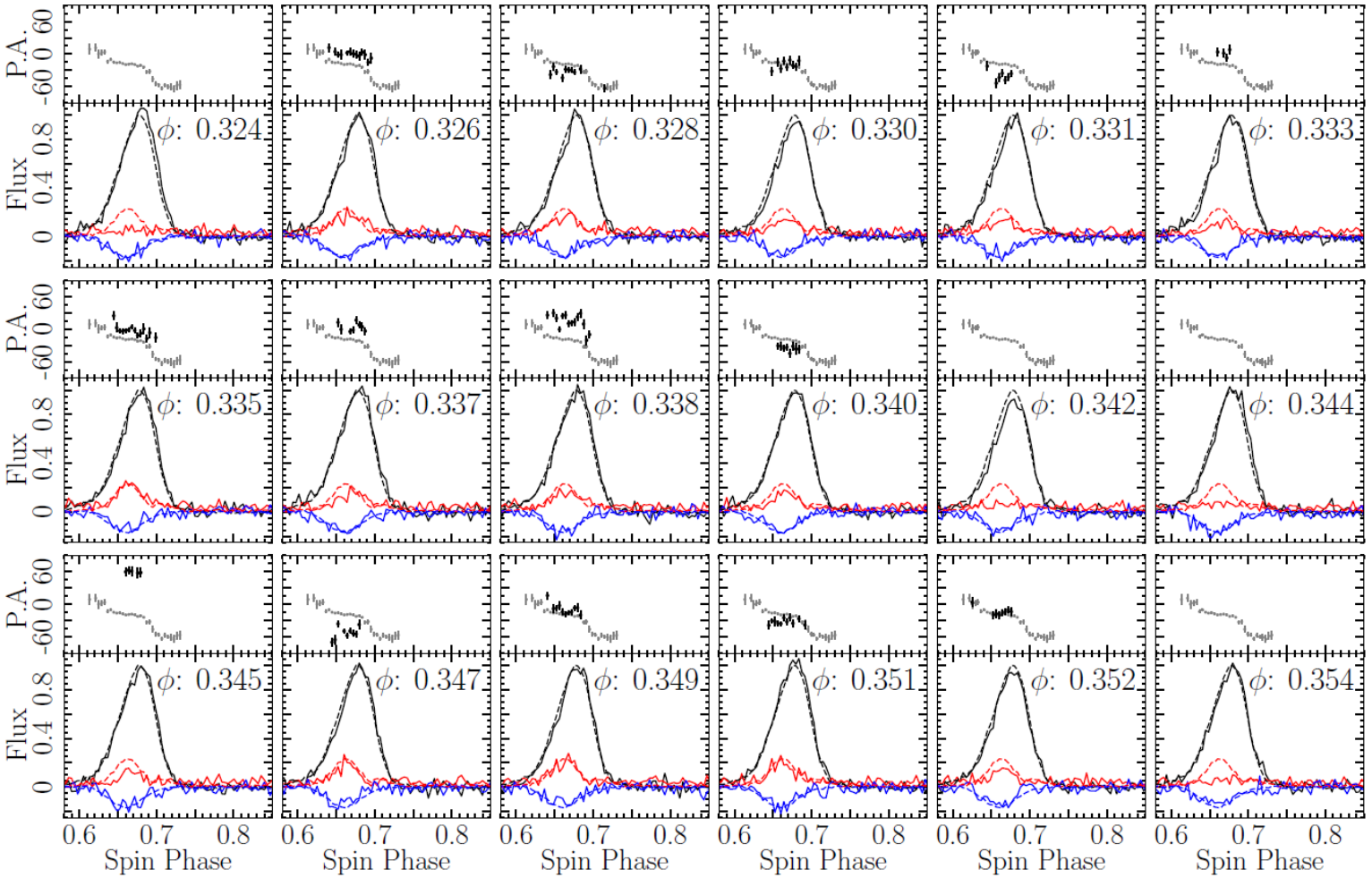
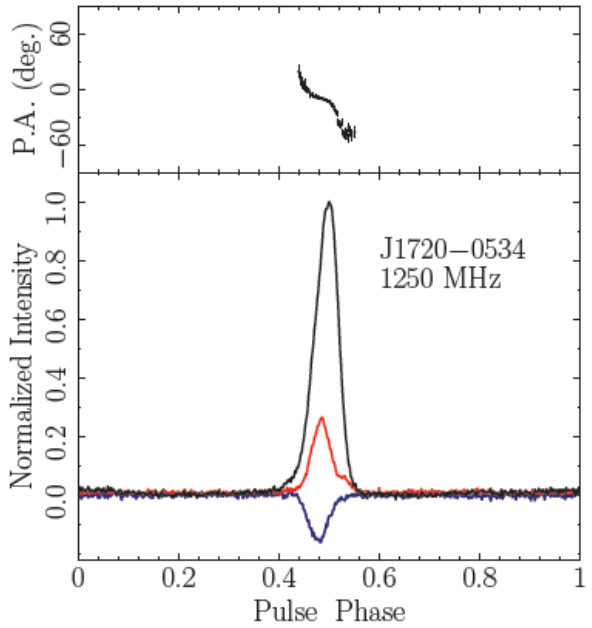
Linear polarization and PA variation between orbital phase 0.3 and 0.35





Pulse profile at 1250 MHz from non-eclipse phase

Magnetic field measurement

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- $\mathrm{PA_{obs}} = \mathrm{RM}\lambda^2 + \mathrm{PA}_\infty$
- The cause of the PA shift:

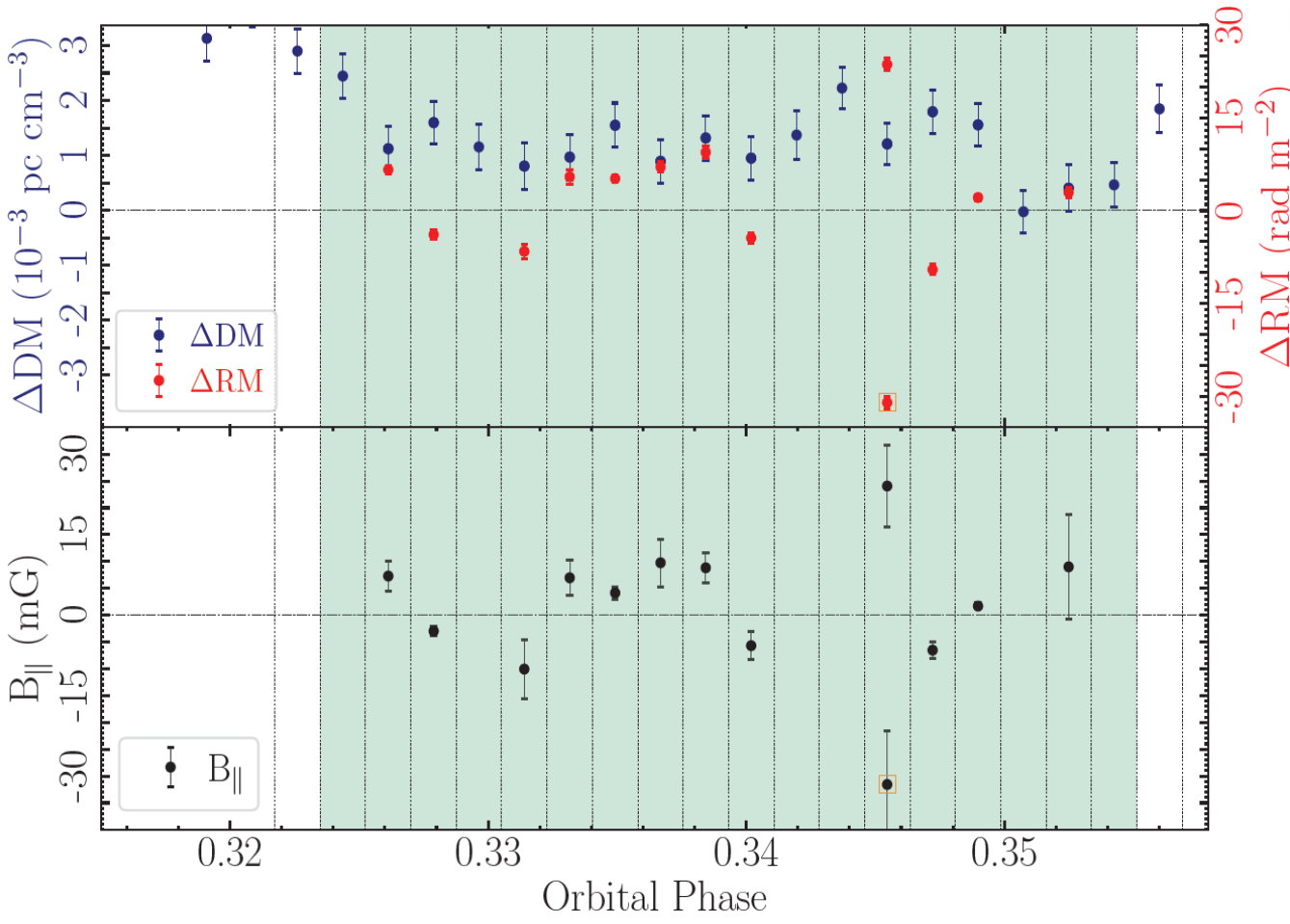
  RM variation ($\Delta\mathrm{RM} = \Delta\mathrm{PA}\lambda^2$)

- RM and DM gives the average B strength

$$\langle B_\parallel \rangle = 1.232\ \mu\mathrm{G} \left(\frac{\mathrm{RM}}{\mathrm{rad\ m^{-2}}}\right) \left(\frac{\mathrm{DM}}{\mathrm{pc\ cm^{-3}}}\right)^{-1}$$

$$\mathrm{RM} = \Delta\mathrm{PA}\lambda^2$$

$$t_{\mathrm{ex}} = 4.15 \times 10^3 \times \Delta\mathrm{DM} \times \nu_{\mathrm{MHz}}^{-2}$$



Magnetic field measurement

- Results:

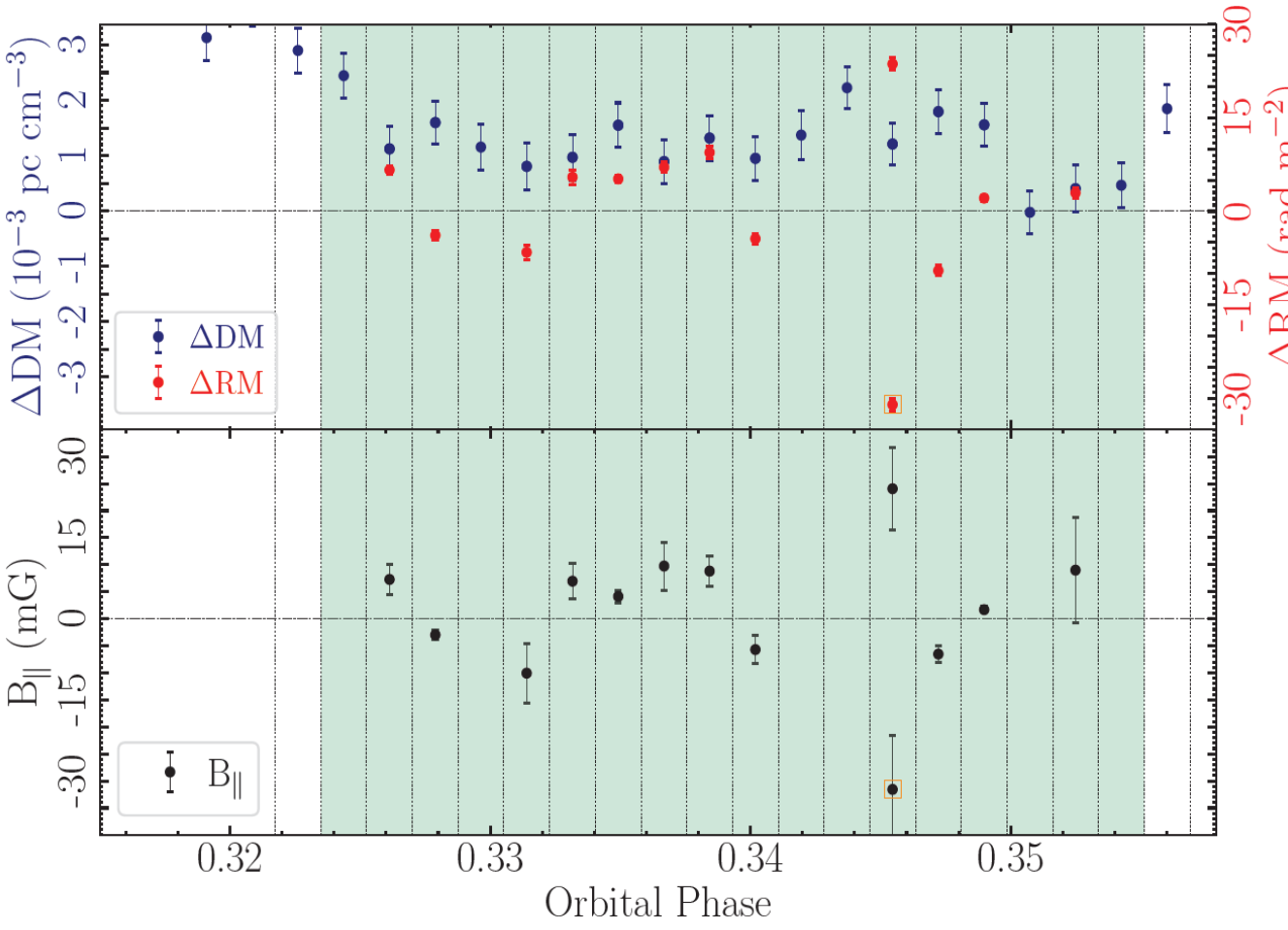
B_{Max} towards the LOS : -24 ± 8 mG

B_{Max} at opposite direction : -10 ± 5 mG

$$\langle B_{\parallel} \rangle = 1.232\ \mu\mathrm{G} \left(\frac{\mathrm{RM}}{\mathrm{rad\ m^{-2}}} \right) \left(\frac{\mathrm{DM}}{\mathrm{pc\ cm^{-3}}} \right)^{-1}$$

$$\mathrm{RM} = \Delta \mathrm{PA} \lambda^2$$

$$t_{\mathrm{ex}} = 4.15 \times 10^3 \times \Delta \mathrm{DM} \times \nu_{\mathrm{MHz}}^{-2}$$



Magnetic field measurement

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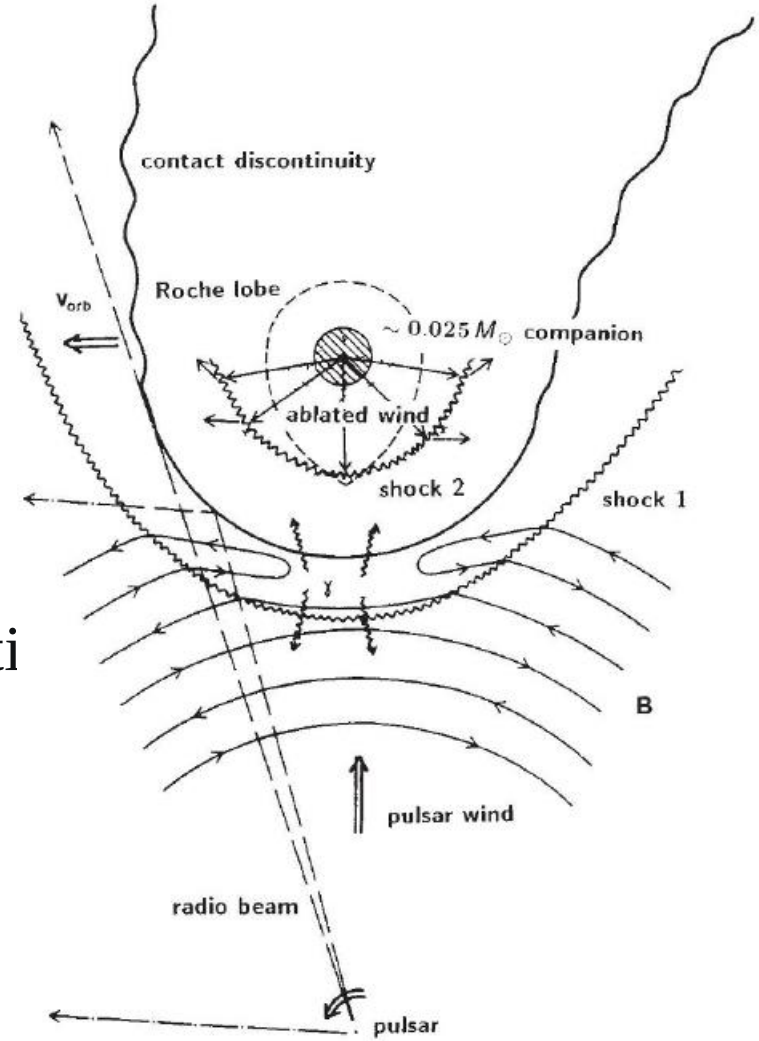
A simple explanation

- Magnetic fields provided by pulsar winds
- Ionized materials from companion's magnetosphere
- Oscillating pulsar wind around the shock boundary

magnetic + ionized materials = Faraday rotation

- Varying RMs/DMs cause the depolarization
- An appropriate electron density allows us to detect this magneti

Phinney Evans Blandford Kulkarni 1988 Nature



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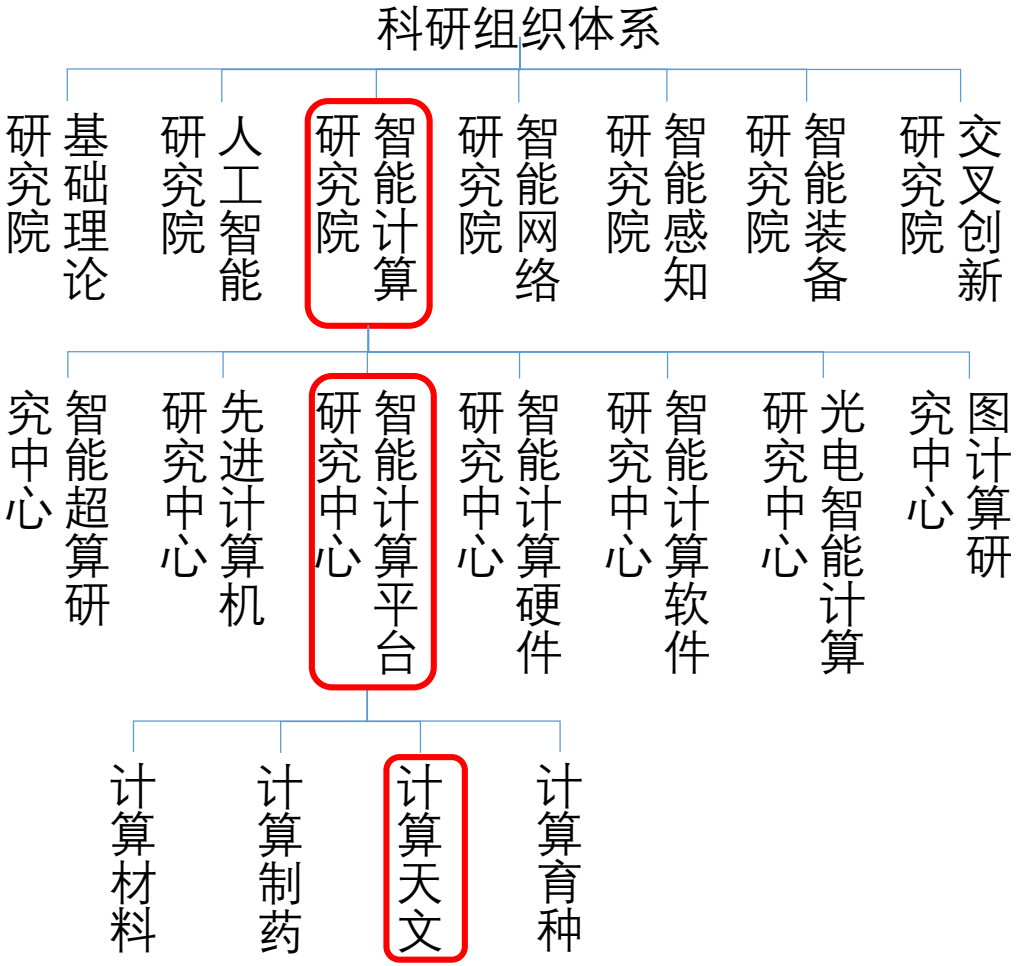

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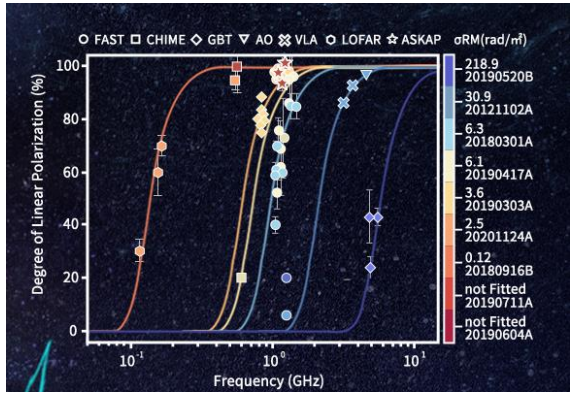
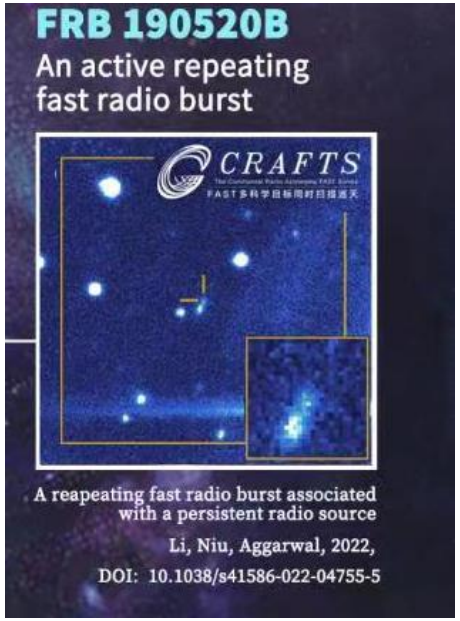
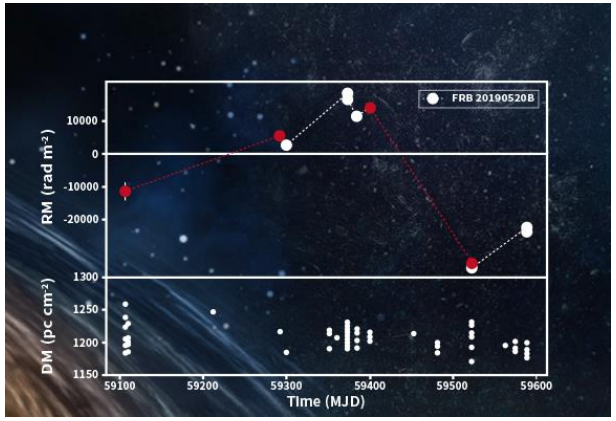


Feng & Li* et al. 2022, **Science**, 375, 1266



Niu, Aggarwal & Li* et al. 2022, **Nature**, 606, 873



Anna-Thomas*, Dai, Feng & Li* et al. 2023, **Science**, 380,599

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冯毅

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陈华曦

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- **博士后10人**
- **实习、项目聘6人**

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