
# A Highly Magnetized Environment in A Pulsar Binary System

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Reference: Li et al, 2023, *Nature*, 618, 484

2023/09, @ Journal Club, SWIFAR, Kunming

Article

# A highly magnetized environment in a pulsar binary system

https://doi.org/10.1038/s41586-023-05983-z

Received: 7 May 2022

Accepted: 20 March 2023

Published online: 17 May 2023

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Spider pulsars are millisecond pulsars in short-period (≲12-h) orbits with low-mass (~0.01–0.4 $M_{\odot}$) companion stars. The pulsars ablate plasma from the companion star, causing time delays and eclipses of the radio emission from the pulsar. The magnetic field of the companion has been proposed to strongly influence both the evolution of the binary system[1] and the eclipse properties of the pulsar emission[2]. Changes in the rotation measure (RM) have been seen in a spider system, implying that there is an increase in the magnetic field near the eclipse[3]. Here we report a diverse range of evidence for a highly magnetized environment in the spider system PSR B1744 − 24A[4], located in the globular cluster Terzan 5. We observe semi-regular profile changes to the circular polarization, *V*, when the pulsar emission passes close to the companion. This suggests that there is Faraday conversion where the radio wave tracks a reversal in the parallel magnetic field and constrains the companion magnetic field, *B* (>10 G). We also see irregular, fast changes in the RM at random orbital phases, implying that the magnetic strength of the stellar wind, *B*, is greater than 10 mG. There are similarities between the unusual polarization behaviour of PSR B1744 − 24A and some repeating fast radio bursts (FRBs)[5–7]. Together with the possible binary-produced long-term periodicity of two active repeating FRBs[8,9], and the discovery of a nearby FRB in a globular cluster[10], where pulsar binaries are common, these similarities suggest that a proportion of FRBs have binary companions.

Dr. Dongzi Li

Li et al, 2023, Nature, 618, 484

# PSR B1744–24A (Ter5A)

- **Pulsar name:** PSR B1744 – 24A (Ter5A)
- **Pulsar spin period:** 11.56 ms
- **Binary orbital period:** 1.82h
- **Companion mass:** 0.09 M⊙

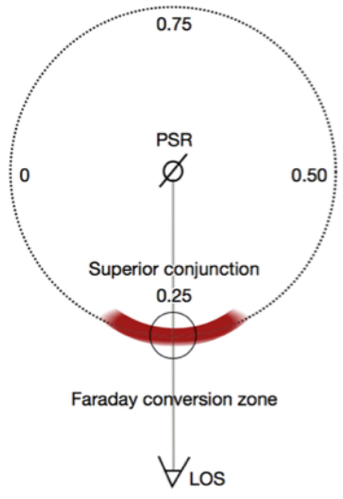
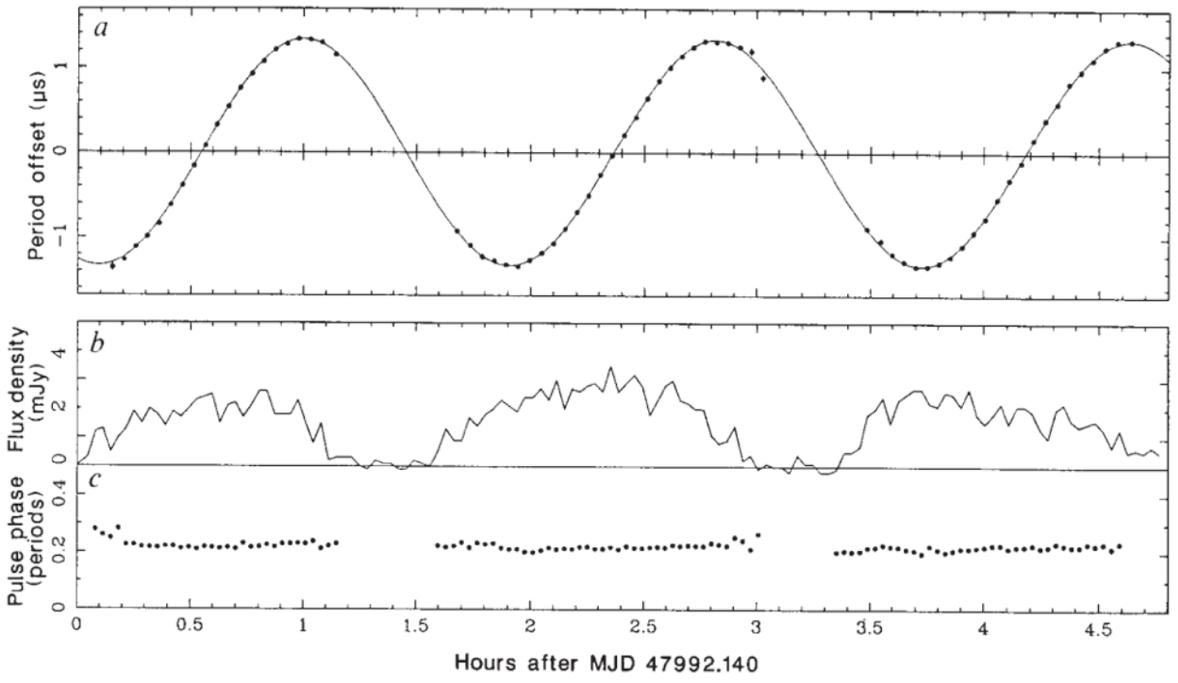
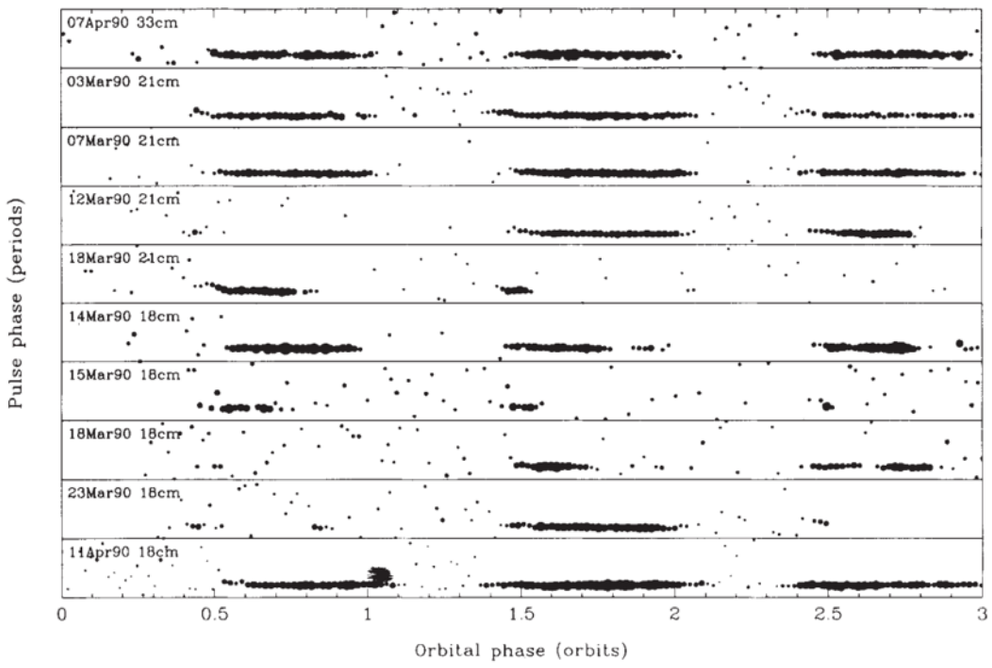



TABLE 1 Observed parameters of PSR 1744 – 24A

| | |
|---|---|
| Right ascension (B1950) | $17^h\,44^m\,57.70^s$ |
| Declination (B1950) | −24° 45′ 38.1″ |
| Galactic longitude | 3.84° |
| Galactic latitude | +1.70° |
| Barycentric period (ms) | 11.563 148 390 6 (12) |
| Period derivative | $(-5 \pm 9) \times 10^{-20}$ |
| MJD of period | 47837.0000 |
| Orbital period (d) | 0.075 646 114 (4) |
| Projected semi-major axis (s) | 0.119 67 (2) |
| Eccentricity | $<10^{-3}$ |
| MJD of ascending node | 47 953.299 686 (2) |
| Dispersion measure ($cm^{-3}$ pc) | 242.0 (2) |
| r.m.s. residual (μs) | 83 |
| Mass function (solar masses) | $3.215 \times 10^{-4}$ |
| Mean flux density at 50 cm (mJy) | 5 |
| Mean flux density at 20 cm (mJy) | 2.5 |
| Pulse width (ms) | 0.7 |

- **Observation:** 100-m Green Bank Telescope every few months for more than 15 years



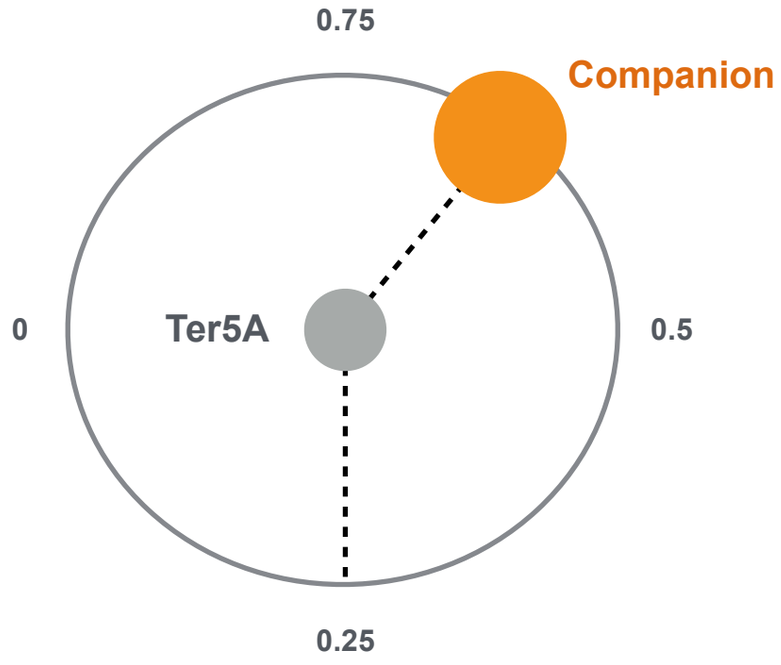

Lyne et al, 1990, Nature

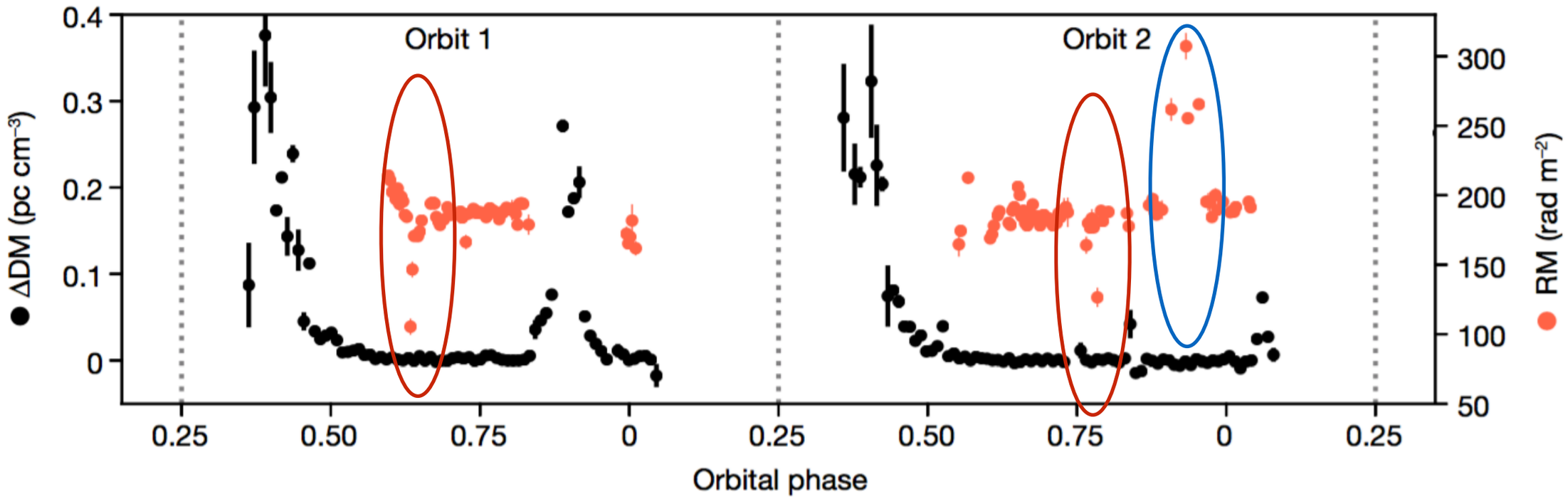
# DM & RM variation

The observation at a frequency of 1.5 GHz has **shown a sudden 50% decrease in RM at orbital phases of 0.65 in orbit 1 and 0.8 in orbit 2, 140° and 160° from the superior conjunction** respectively, when the companion is almost behind the pulsar.

**At orbital phase 0.9 of orbit 2, about 120° away from the superior conjunction, the RM has a sudden 50% increase.**

No notable variation in the DM up to 0.01 pc cm^−3 is detected during the RM jumps

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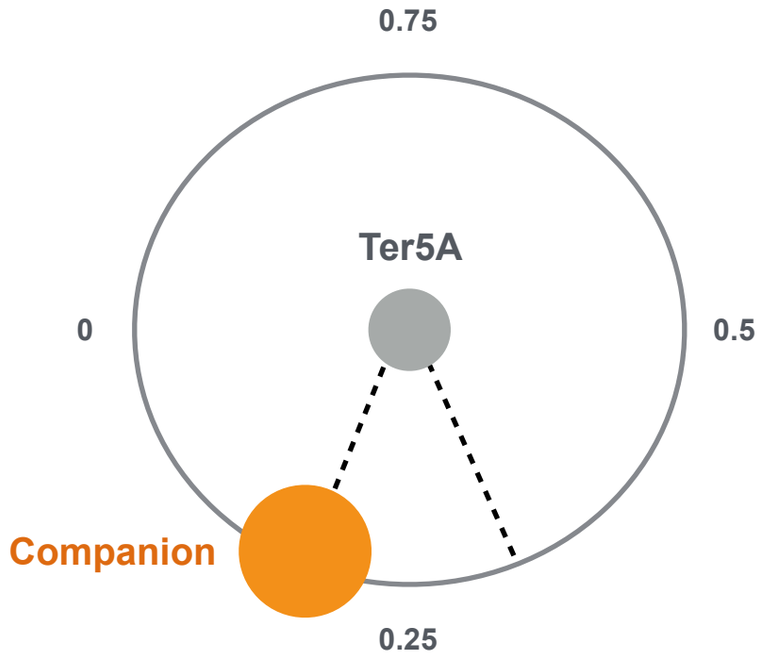
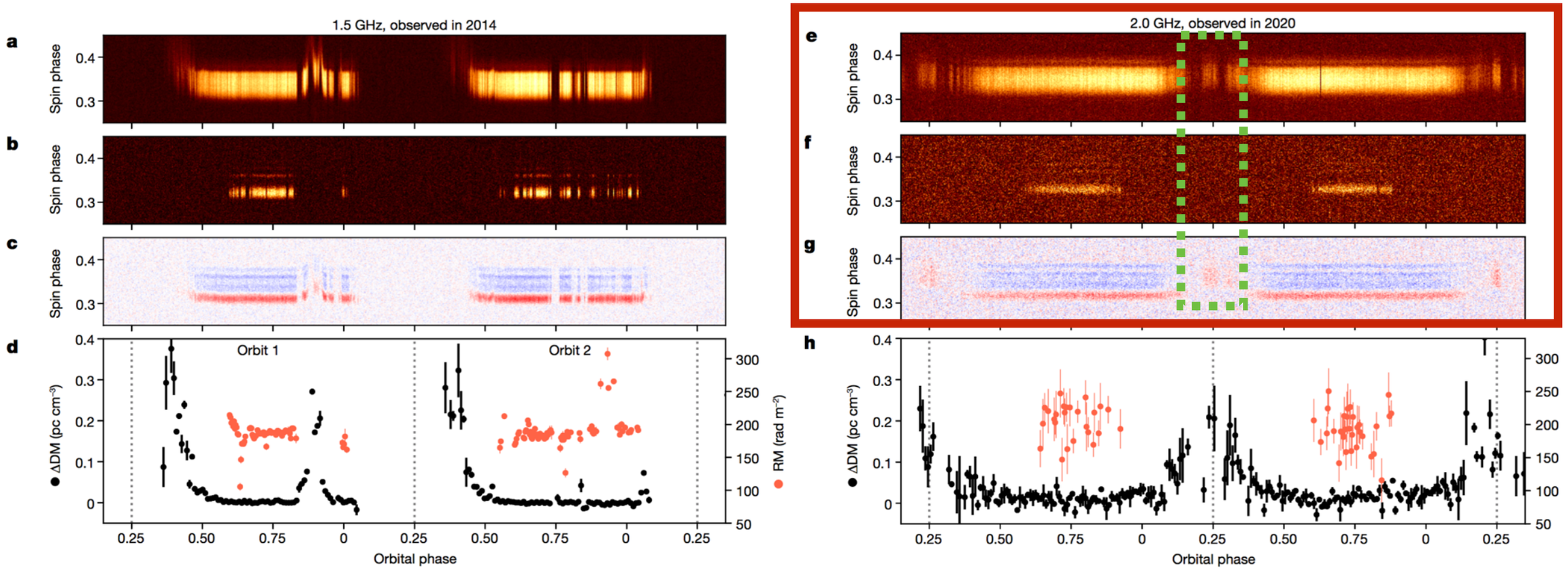
# Faraday Conversion

Near the superior conjunction, **the circular polarization has the opposite sign to the unperturbed V profile, slowly turning to zero and then flipping back to the unperturbed profile as the pulsar moves away from behind the companion.**

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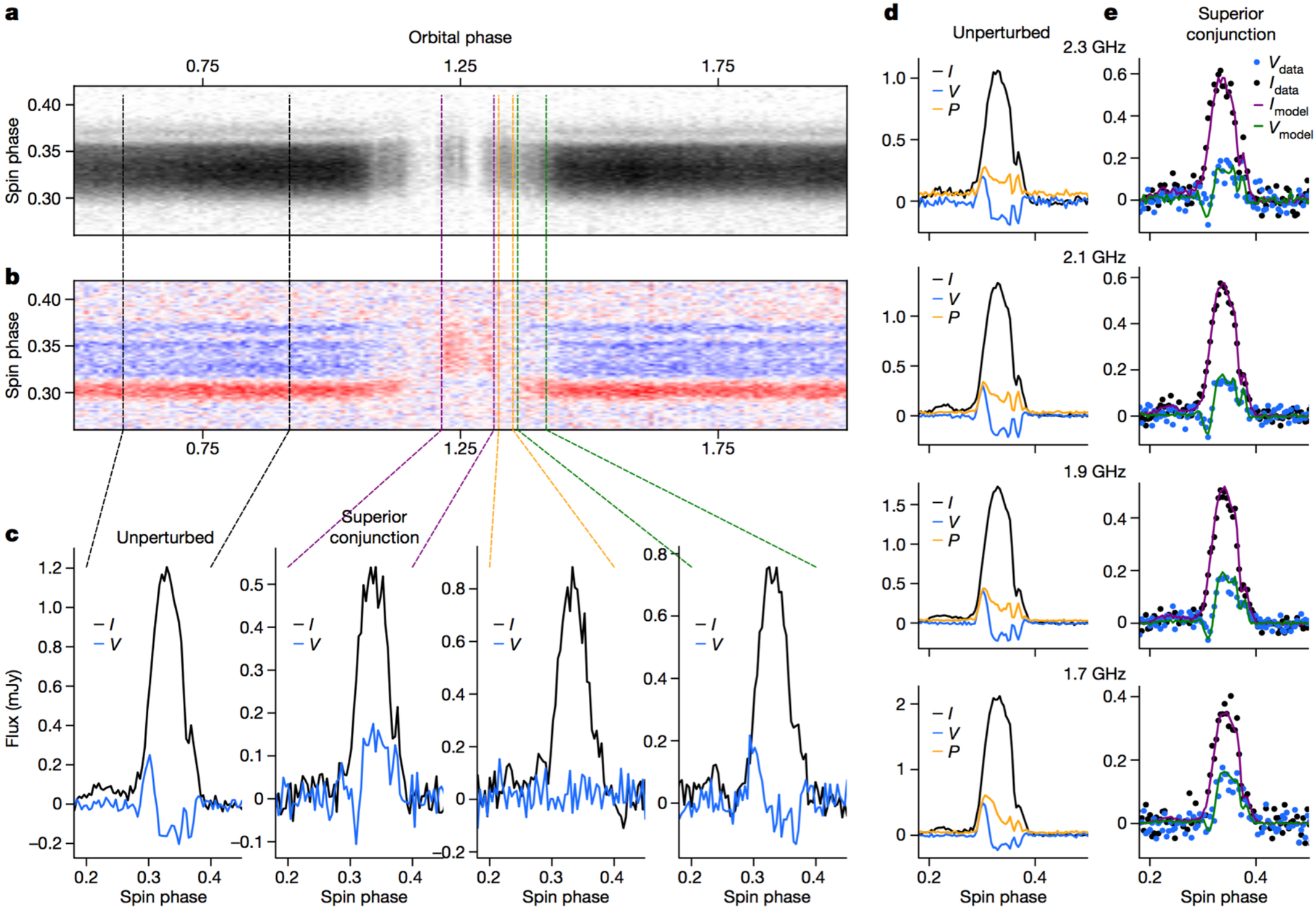
# Faraday Conversion

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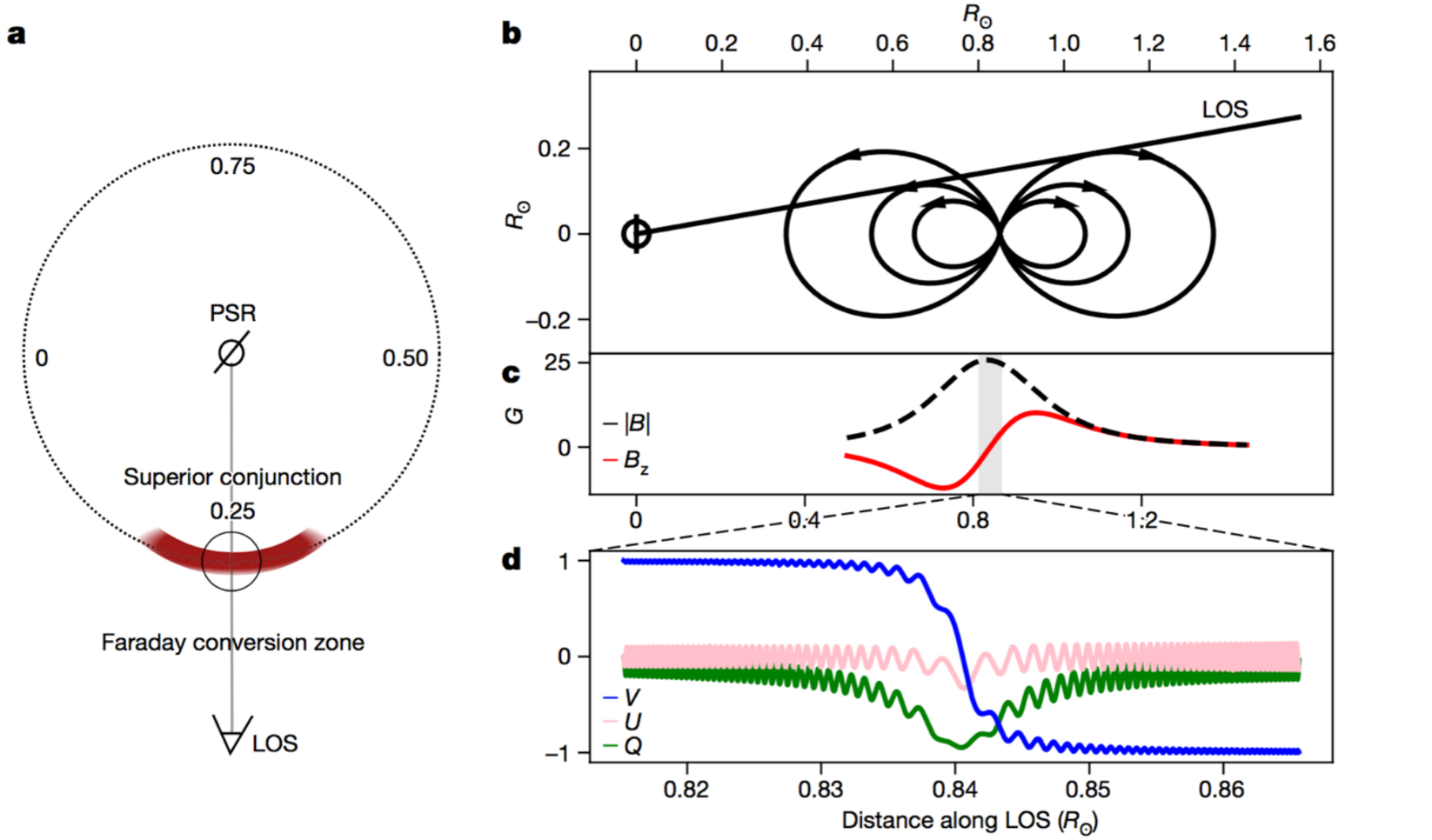
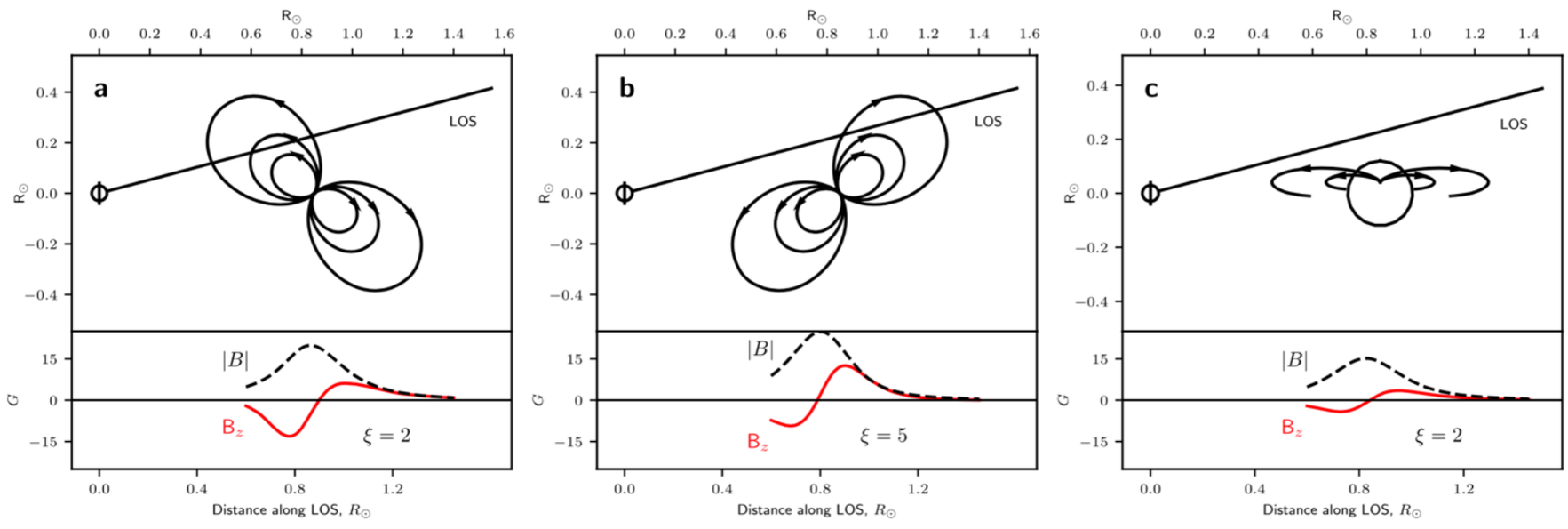
# Physical Picture

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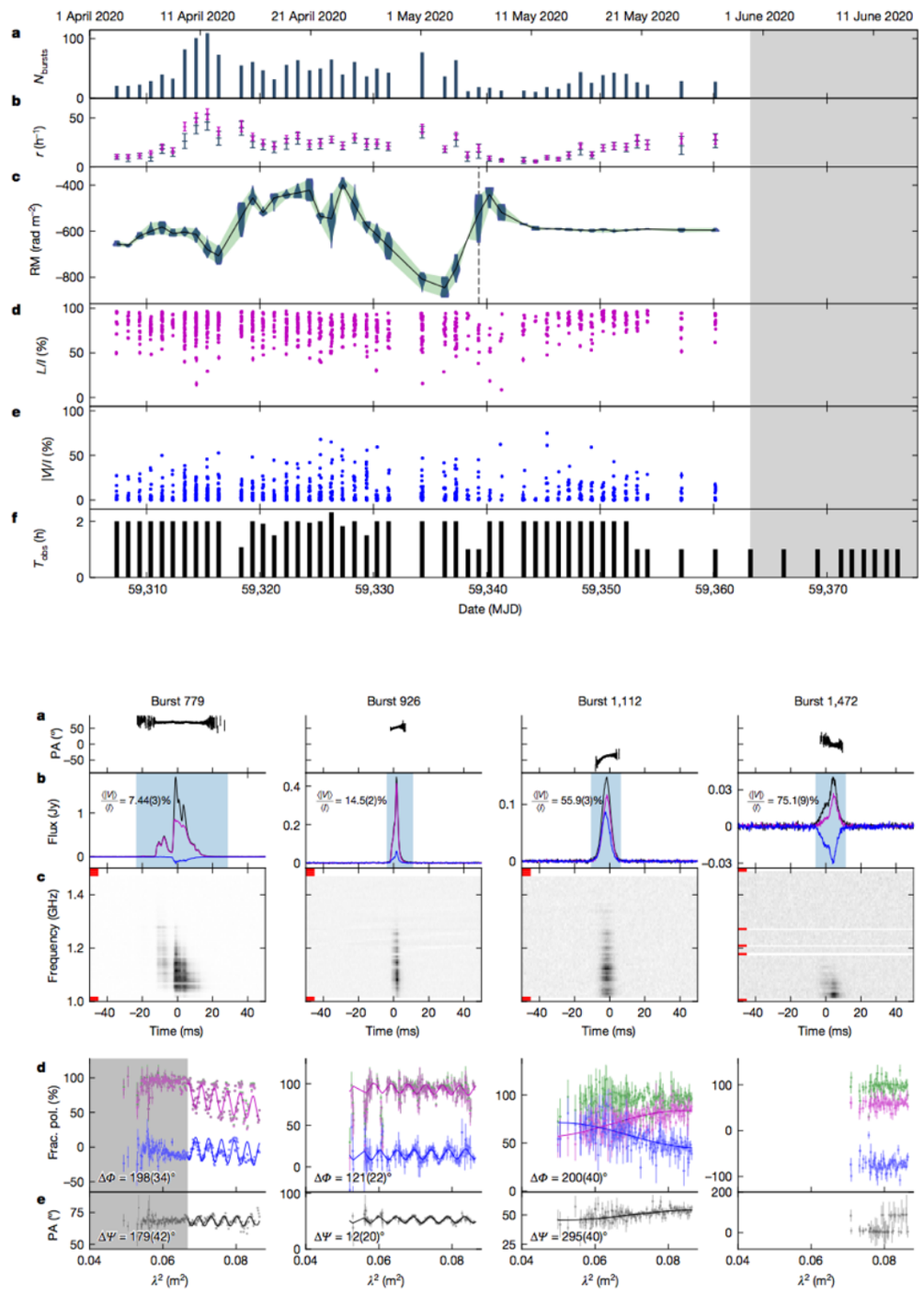
# Implication for FRBs

- The observation of Ter5A further show that the **magnetized wind of the companion can introduce order-one RM variation** even when the companion is almost behind the pulsar.

- **The large, irregular RM changes are similar to those observed in FRBs**, which are short, intense extragalactic radio bursts of unknown origin.

- FRB 20201124A and FRB 20181112 have shown changes in circular polarization that can be **attributed to either Faraday conversion or polarized absorption. We show that these effects can also be caused by the presence of a binary companion**.

- Together with the possible binary-produced long-term periodicity of two active repeating FRBs, and the discovery of a nearby FRB in a globular cluster, where pulsar binaries are common, these similarities suggest that **a proportion of FRBs probably have binary companions**.




Xu et al, 2022, Nature

# Thank You!