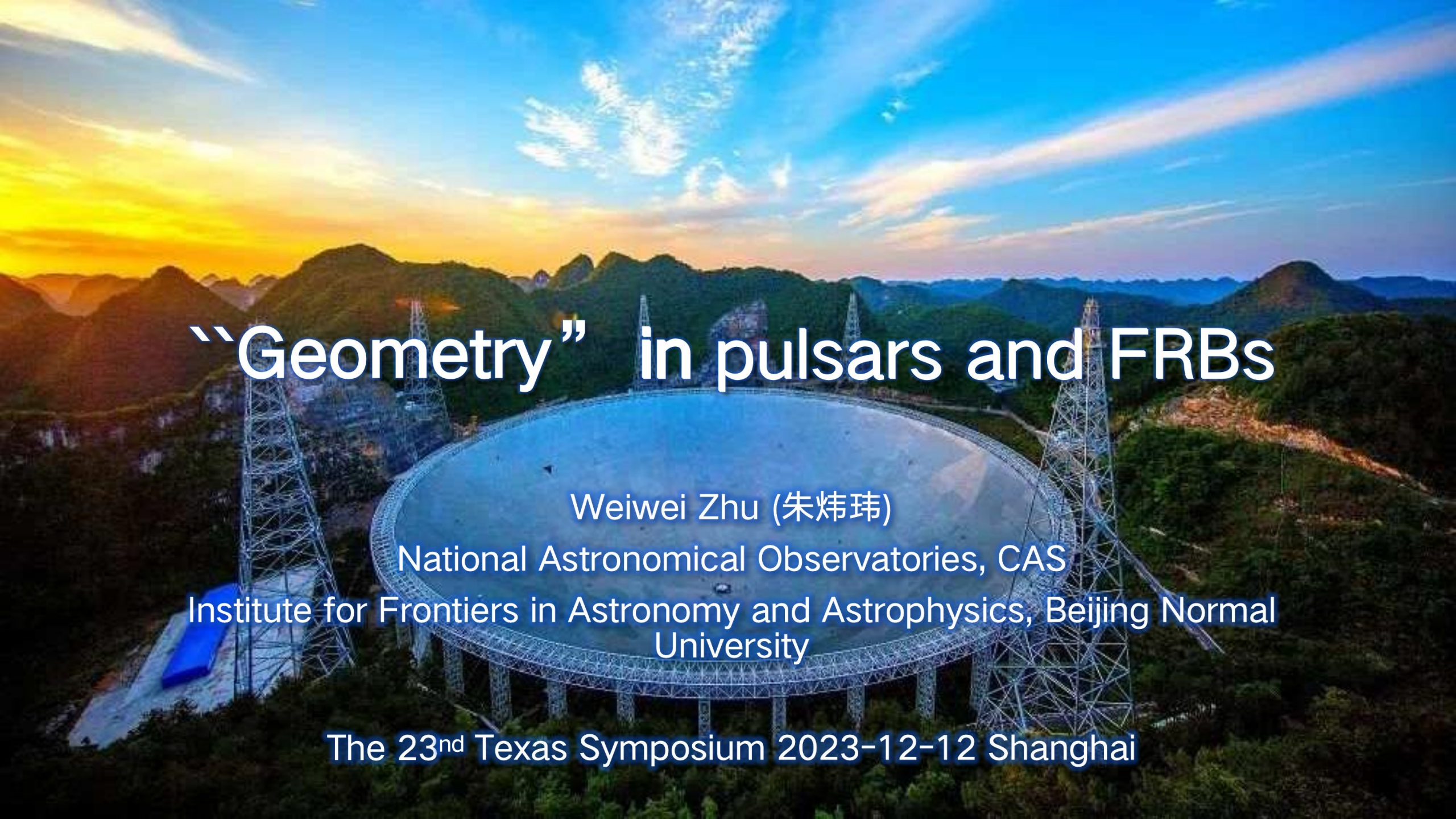


``Geometry" in pulsars and FRBs

Weiwei Zhu (朱炜玮)

National Astronomical Observatories, CAS

Institute for Frontiers in Astronomy and Astrophysics, Beijing Normal University

The 23nd Texas Symposium 2023-12-12 Shanghai

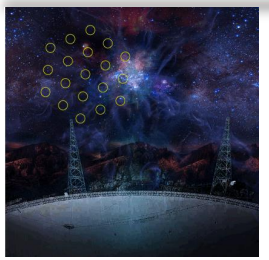
The FAST key science projects

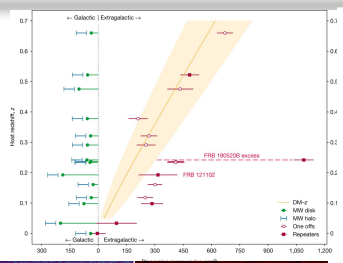
- The Commencial Radio Astronomy FAST Survey (**CRAFTS**; PI: Di Li)
- Fast Radio Burst Search and Multi-wavelength Observations (**FRB KSP**; PI: Bing Zhang, Weiwei Zhu)
- The Galactic Plane Pulsar Search (**GPPS**; PI: JinLin Han)
- M31 HI imaging and pulsar search (PI: Jie Wang)
- The Chinese Pulsar Timing Array (**CPTA**; PI: Kejia Lee)
- Pulsar Physics and Evolution (PI: Nina Wang)

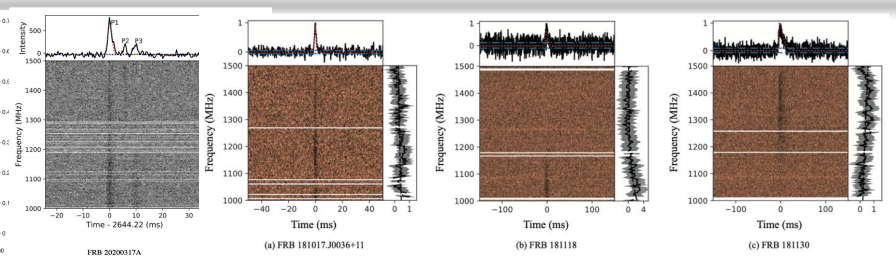
CRAFTS
The Commensal Radio Astronomy FAST Survey
FAST多科学目标同时扫描巡天

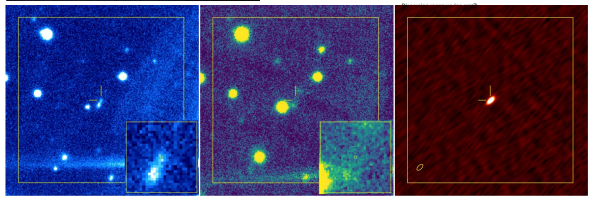
FAST 快速射电暴优先及重大项目
FAST Fast Radio Burst (FRB) Key Science Project

CRAFTS pulsar discoveries

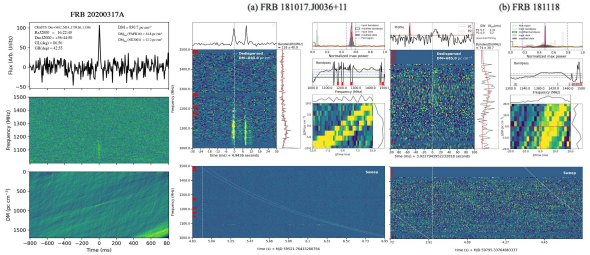




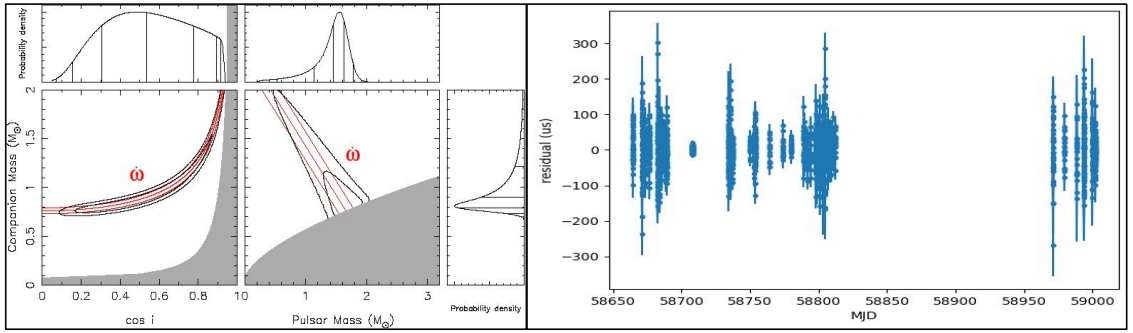




FRB 20190520B

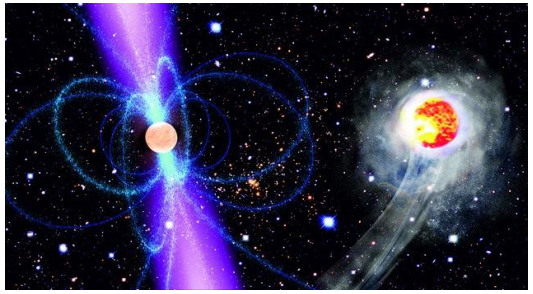


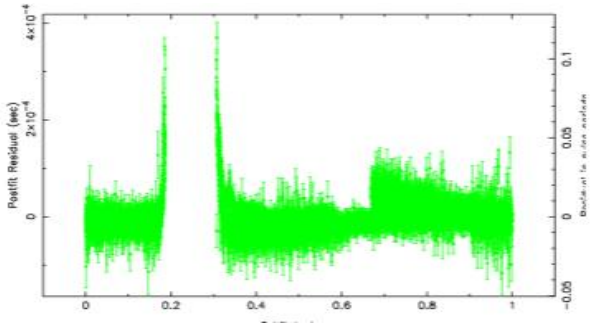
The CRAFTS survey have discovered:
180 pulsars
incl. 40 MSPs
20 binaries (3 DNS)
30 RRATs
8 FRBs (*Zhu et al. 2020; Niu et al. 2021; Niu et al. 2022 Nature; more in prep.*)



3 double neutron star systems

Wu et al. 2023
Zhao et al. 2023 in prep.
Miao et al. 2023 in prep.





MSP-black widow system with interesting eclipes

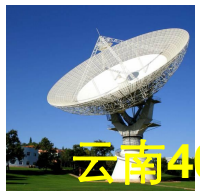
Wang et al.MNRAS 2022
Miao et al. RAA 2023

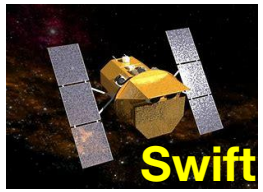
The FAST FRB Key Science Project

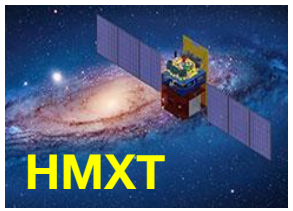
FAST 快速射电暴优先及重大项目

FAST Fast Radio Burst (FRB) Key Science Project

- ~100 participants from 10s institu
- Observers and theoreticians
- Multi wavelength & observatorie







NAOC 中国科学院国家天文台 NATIONAL ASTRONOMICAL OBSERVATORIES, CAS

Shanghai Astronomical Observatory, Chinese Academy of Sciences

XAO 中国科学院新疆天文台 XINJIANG ASTRONOMICAL OBSERVATORY, CAS

南京大学 NANJING UNIVERSITY

中国科学院云南天文台 YUNNAN OBSERVATORIES, CHINESE ACADEMY OF SCIENCES

云南大学

中国科学院紫金山天文台

中国科学院高能物理研究所 Institute of High Energy Physics Chinese Academy of Sciences

NTS 中国科学院国家授时中心 National Time Service Center, Chinese Academy of Sciences

Caltech

CSIRO

The FAST FRB Highlights

FAST 快速射电暴优先及重大项目

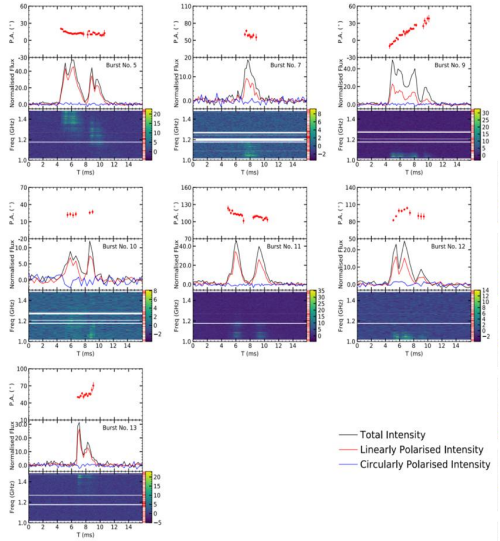
FAST Fast Radio Burst (FRB) Key Science Project

CRAFTS

The Commensal Radio Astronomy FAST Survey

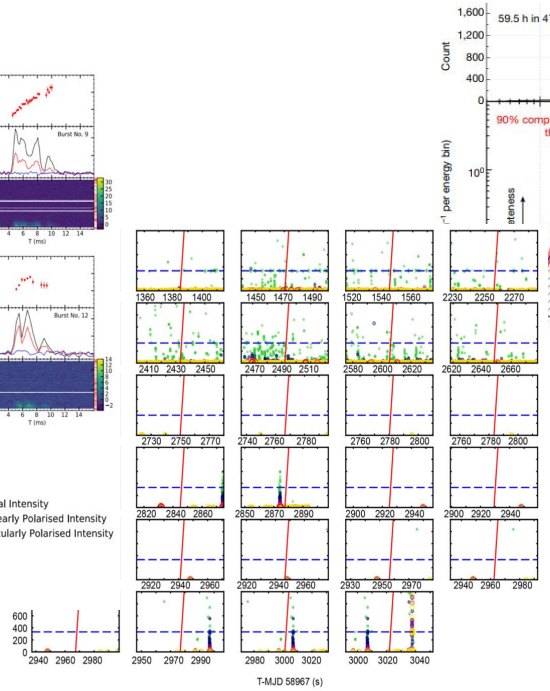
FAST多科学目标同时扫描巡天

- 5 Nature，1 Science since 2020



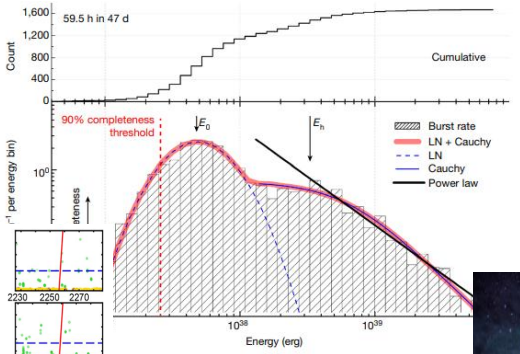
First FRB polarization swings

Luo et al. 2020 Nature



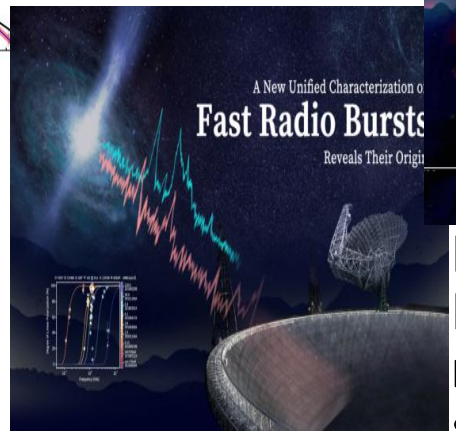
Stringent radio limit On the FRB-magnetar

Lin et al. 2020 Nature



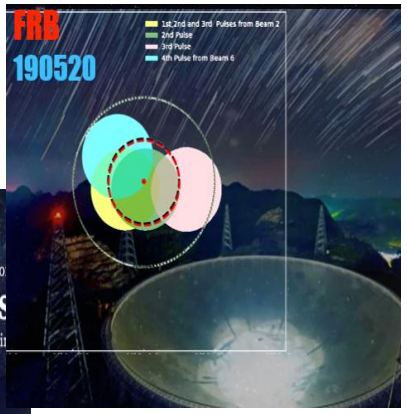
Largest sample of a repeating FRB

Li et al. Nature 2021



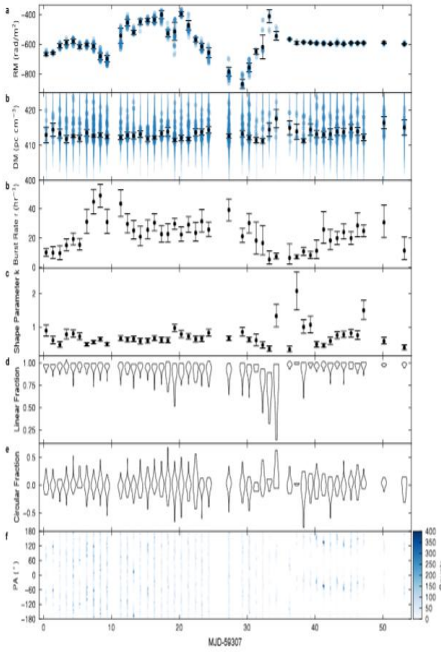
Key signature of FRB polarization

Feng et al. Science 2022



FRB190520, FAST 1st repeating FRB, special birth place and persistent radio source （PRS）

Niu et al. Nature 2022



Probing the complex magnetic environment of an repeating FRB

Xu Heng et al. Nature 2022

``Geometry'' in Pulsars and FRBs

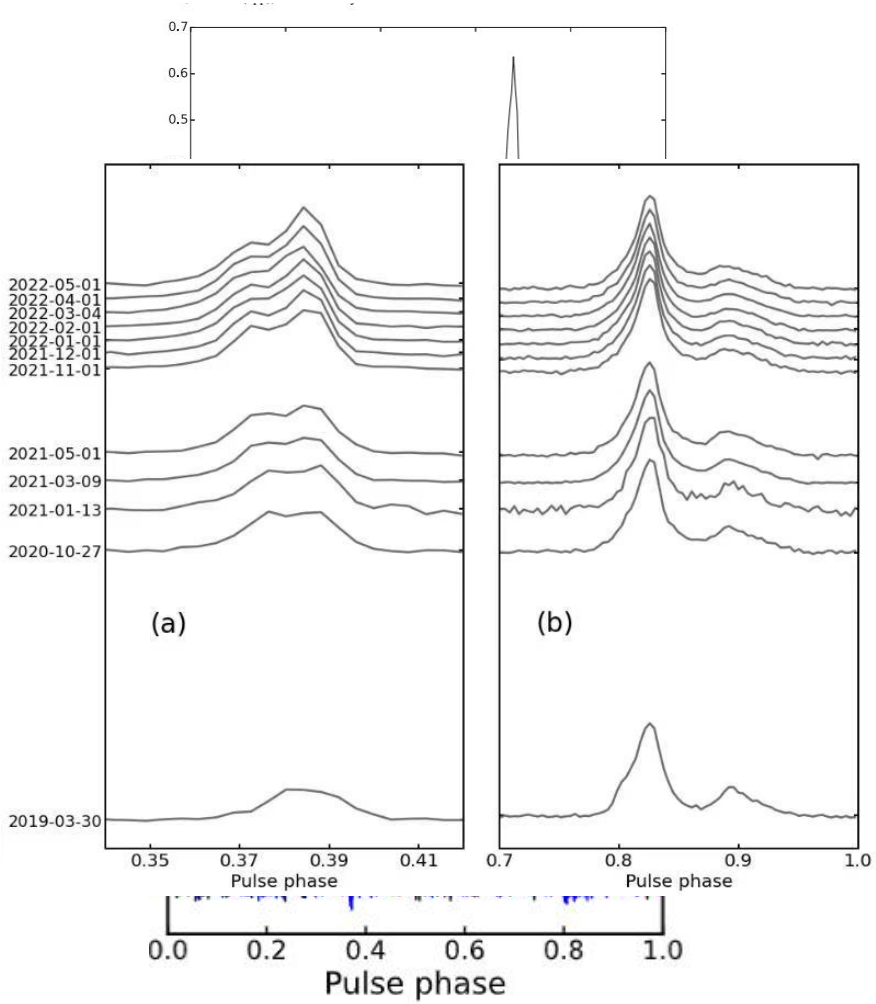
- How do we get to the ``Geometry''?

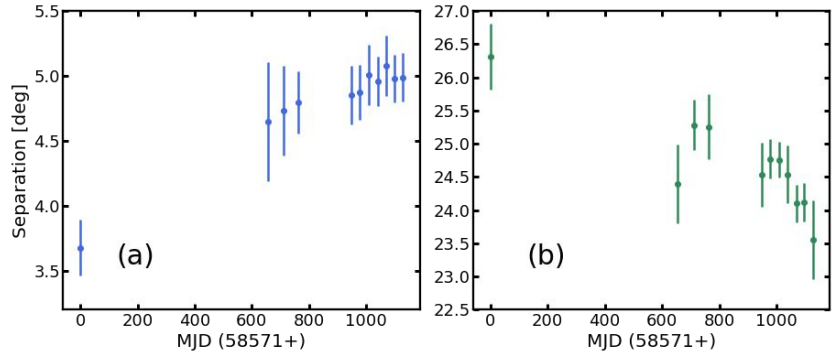
1. Profiles (Polarizations)
2. Scintillation (arcs)
3. Spin (phases)

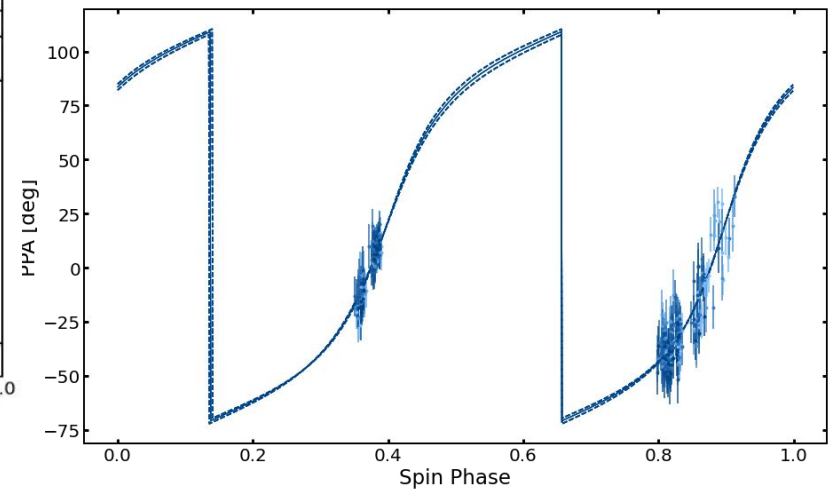
Relativistic spin precession in DNS

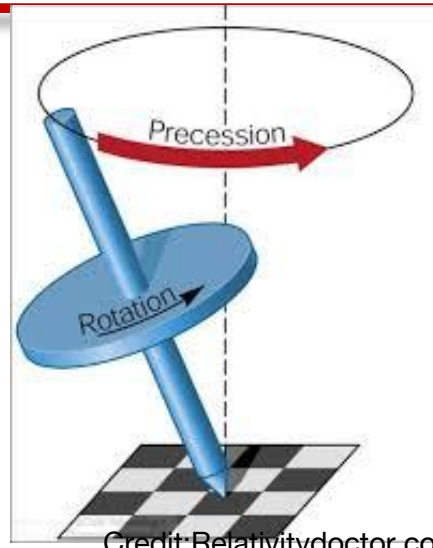
- Profiles (Polarizations)

PSR J1946+2052
Closest DNS Pb=1.8 hr

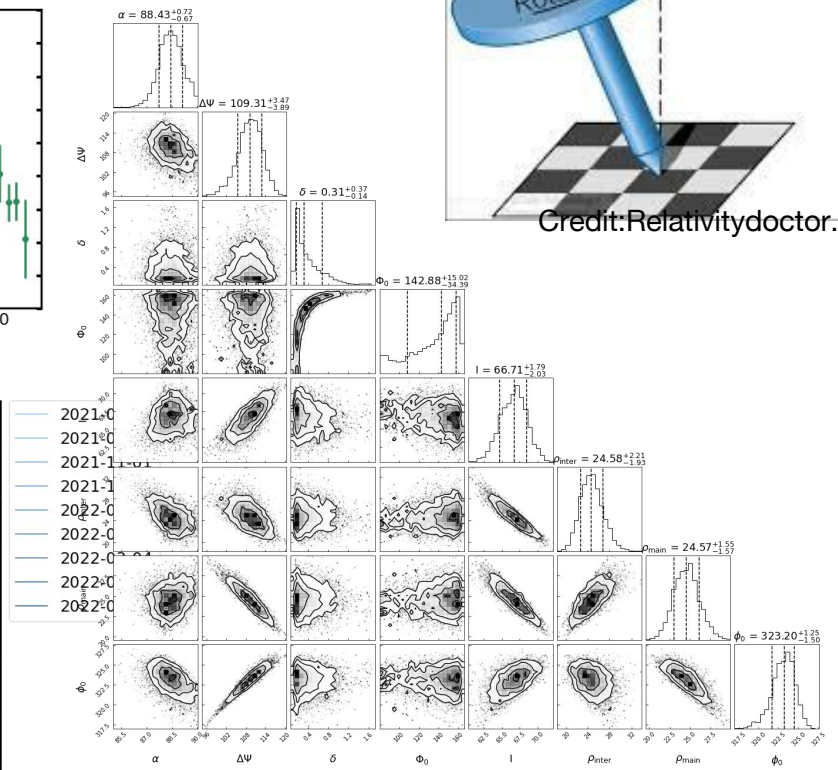








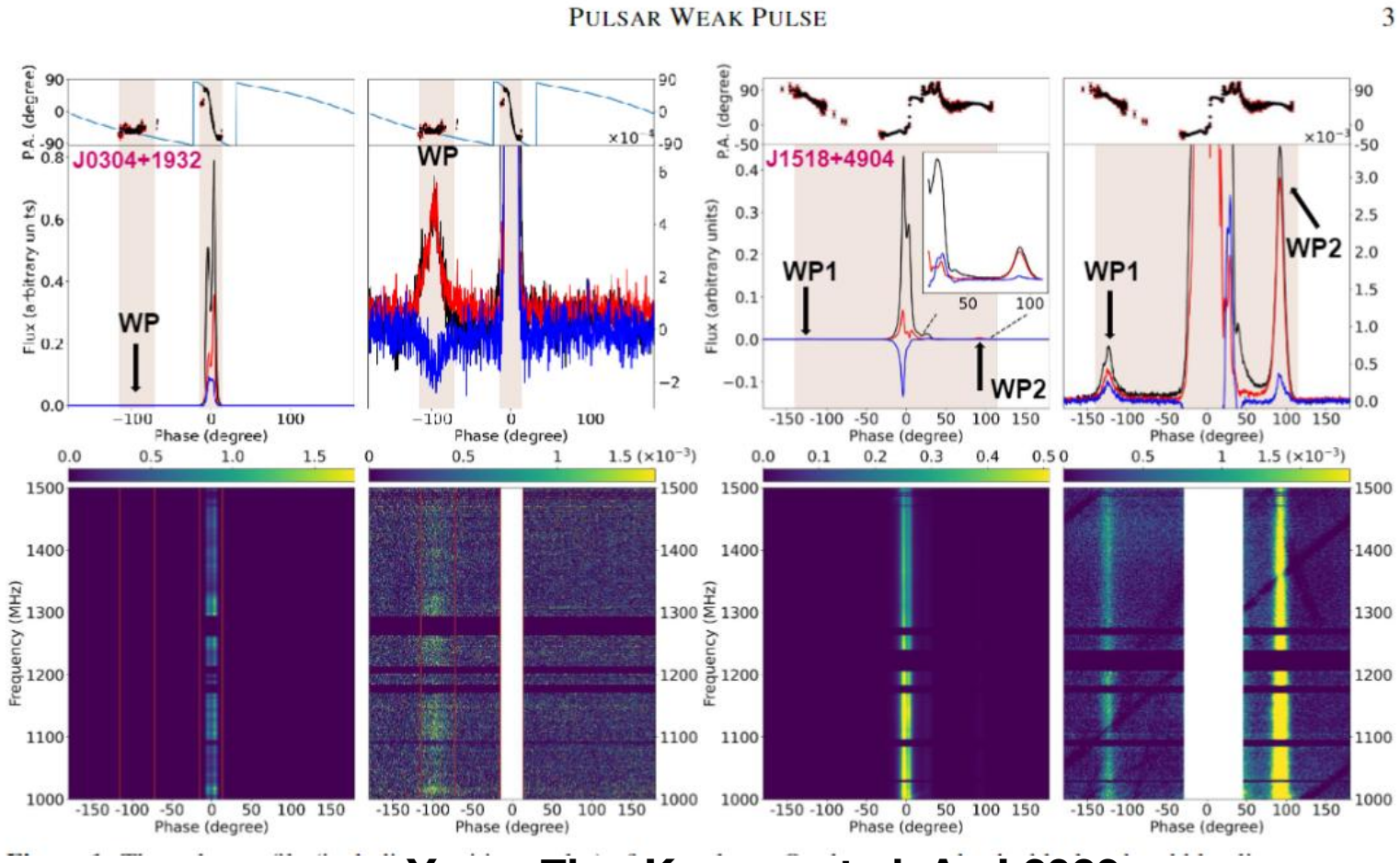
Credit:Relativitydoctor.co



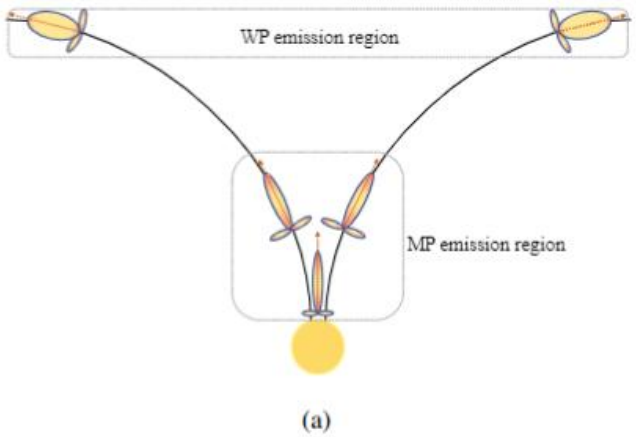
Meng Zhu Kramer et al. 2022 submitte

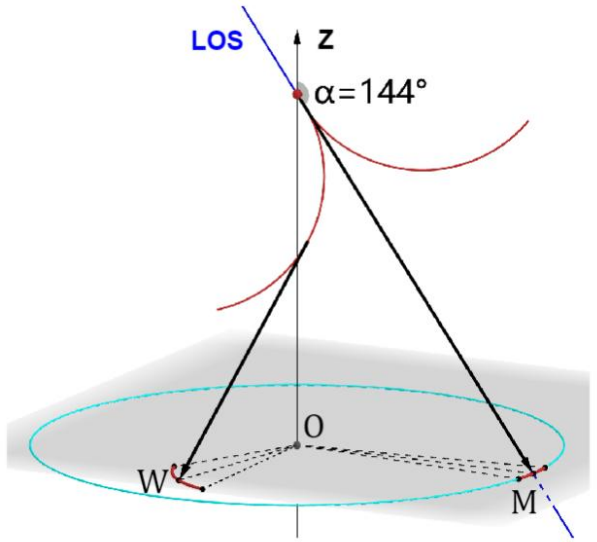
New weak pulsar emission components

- Profiles (Polarizations)
  - Emissions from high magnetosphere altitudes



Yuan, Zhu, Kramer et al. ApJ 2023

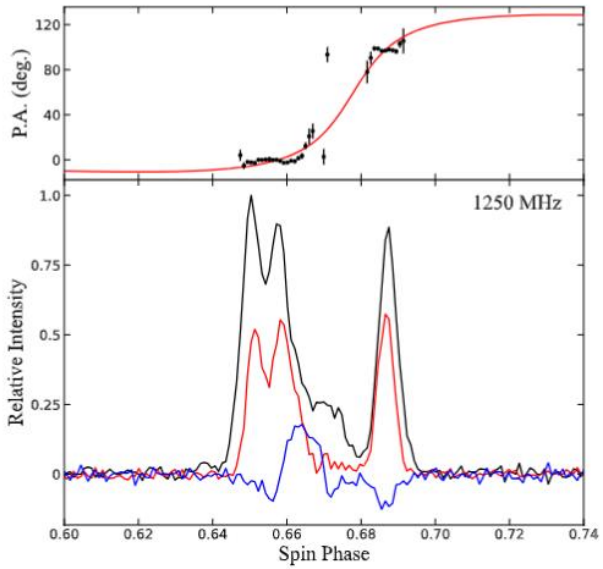


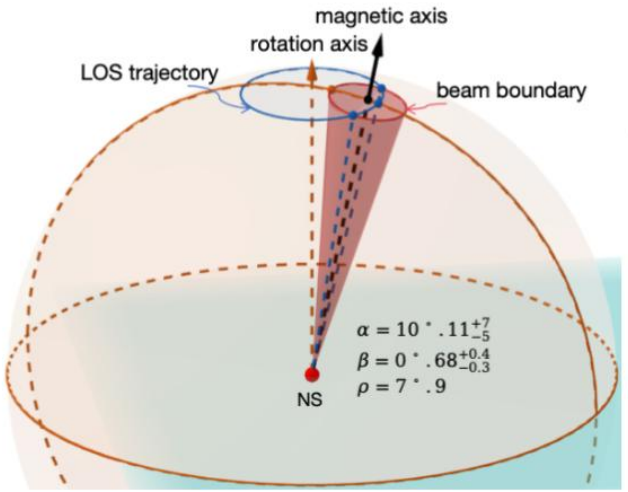


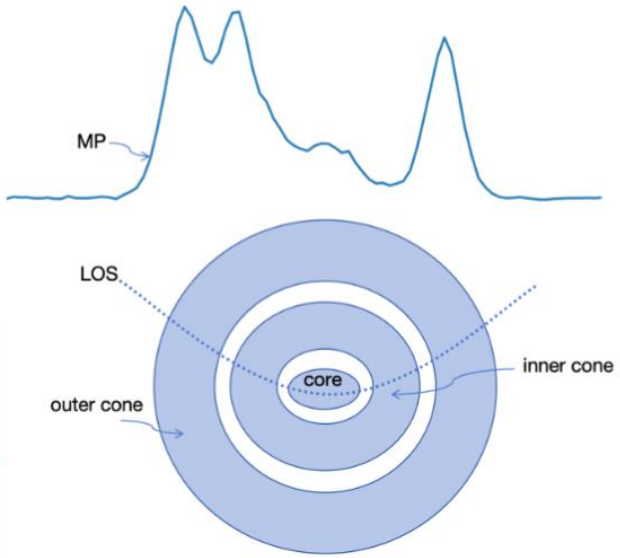
A four components Pulsar

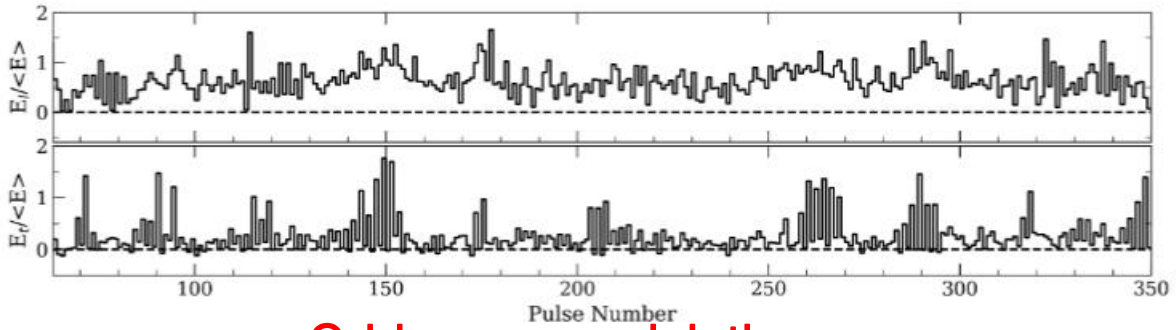
Profiles (Polarizations)

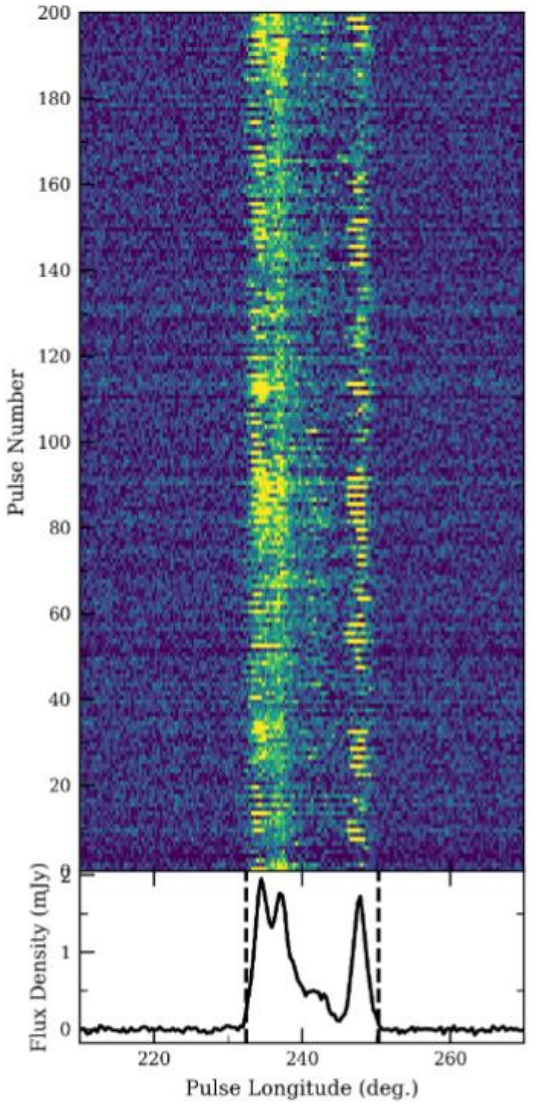
PSR J1239+0326
Double cone beam pattern









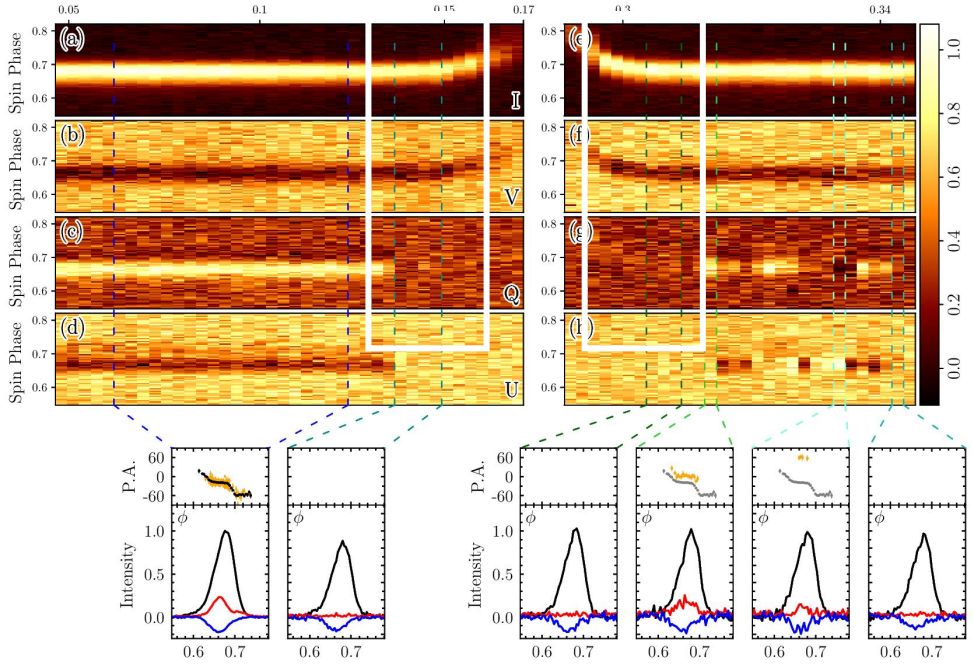


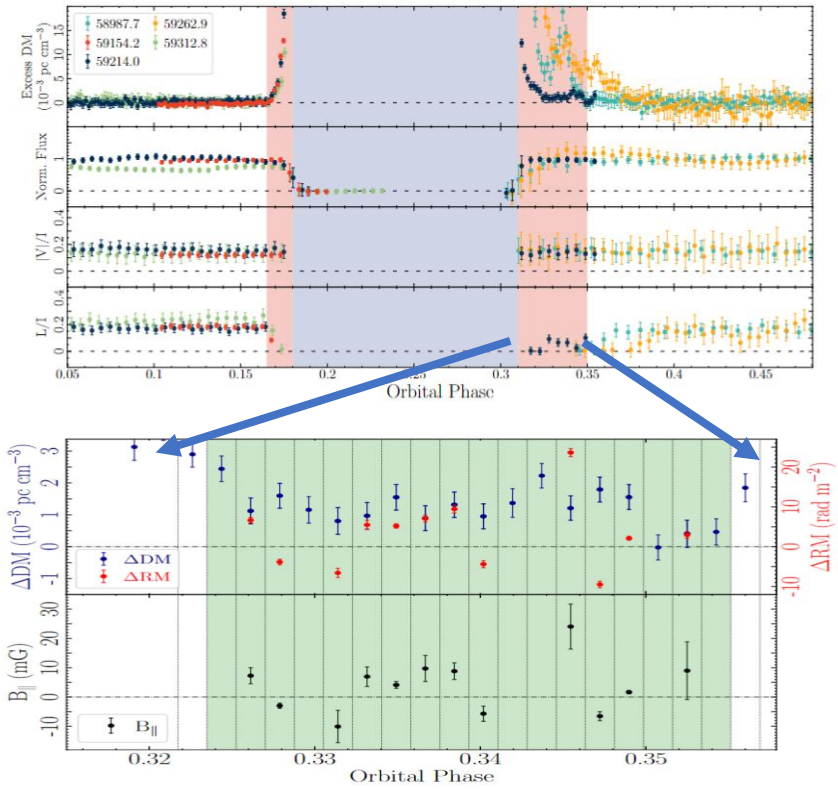
Rejep et al. in prep.

Odd-even modulation

Black Widow Pulsar Wind

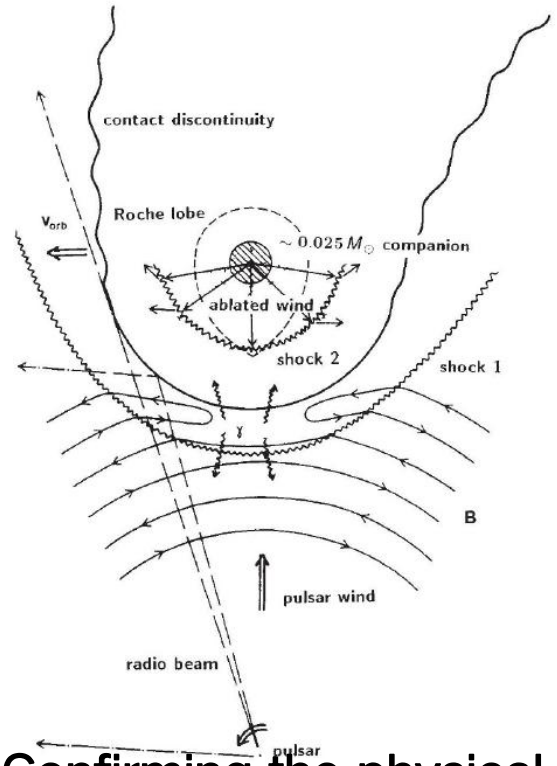
- Profiles (Polarizations)
- First evidence for Reciprocating Magnetic Fields in the Pulsar Wind from black-widow binary





Miao, Blackmon, Zhu* et al. RAA 2023

In collaboration with authors from MPIfR, WVU, CSIRO etc.

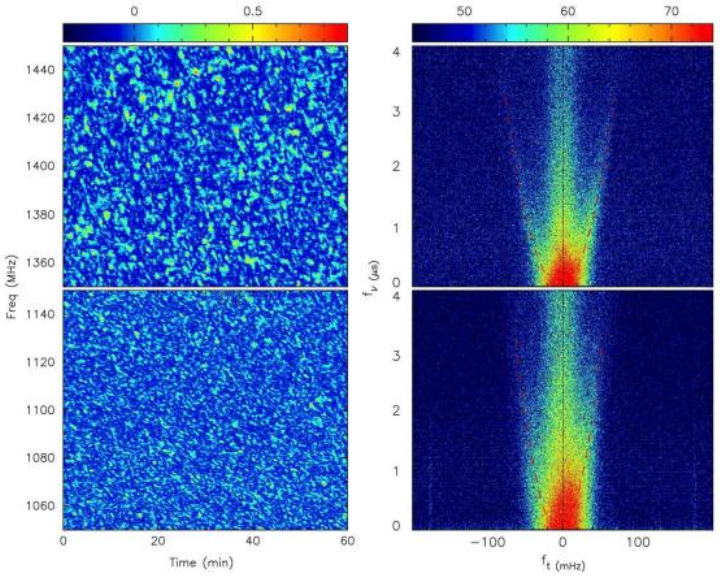


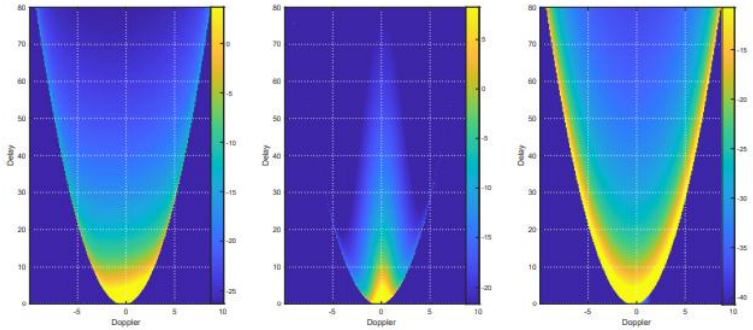
Confirming the physical picture proposed 35 years ago

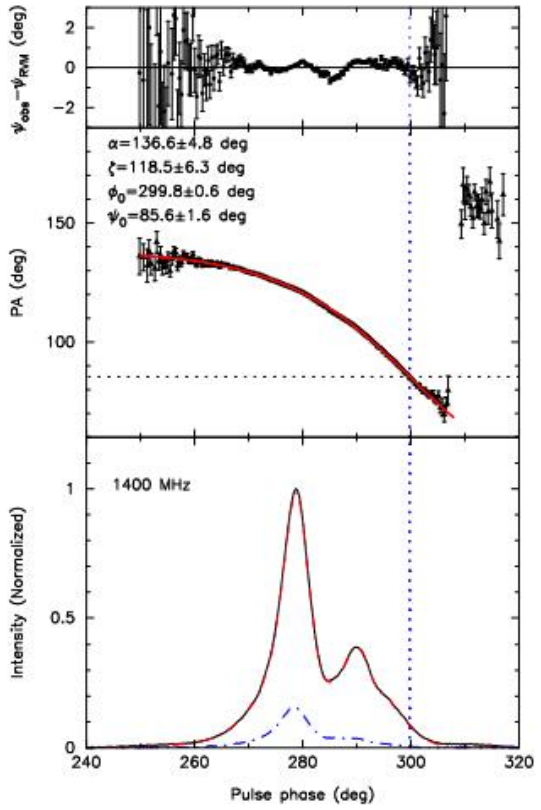
Phinney Evans Blandford &Kulkarni 1988 Nature

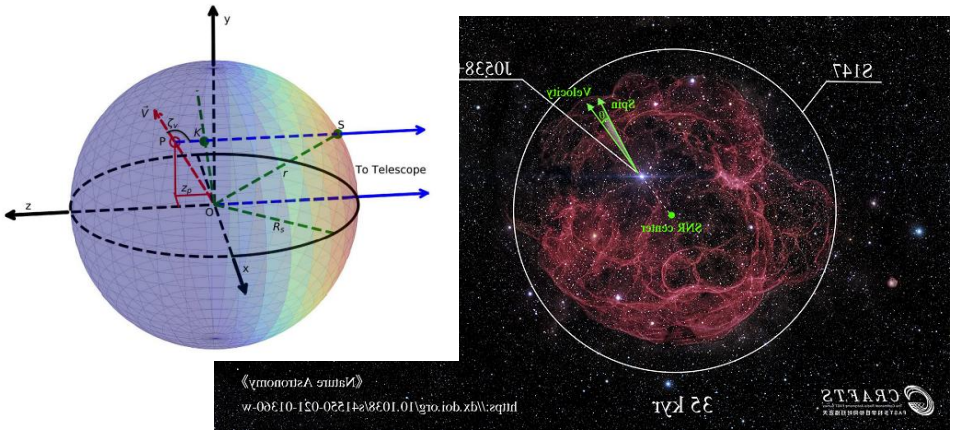
The Pulsar spin-kick 3D alignment

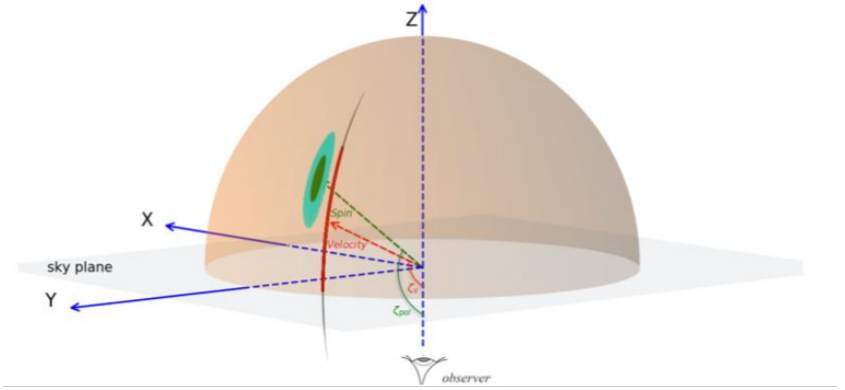
Scintillation (arcs)











Yao J. M.*, Zhu W. W.*, Manchester R. N. ⋯ Li D.* et al. 2021 **Nature Astronomy**

High altitude ISM structures

- Scintillation (arcs)

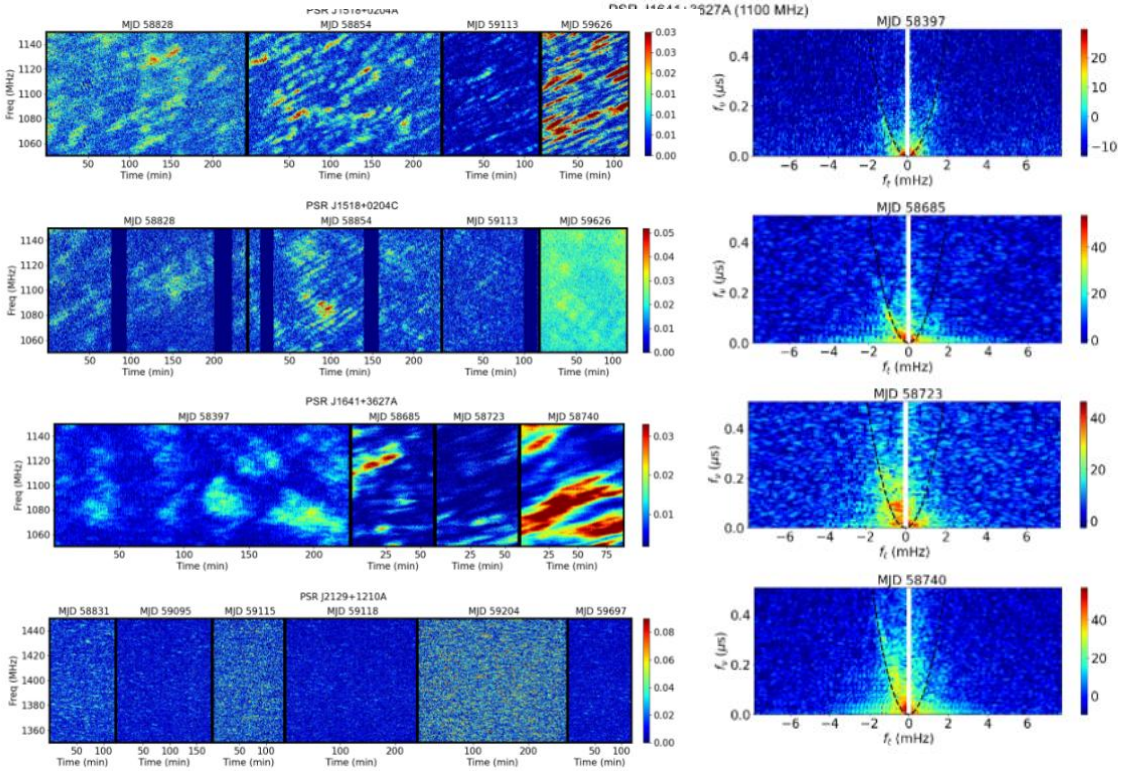
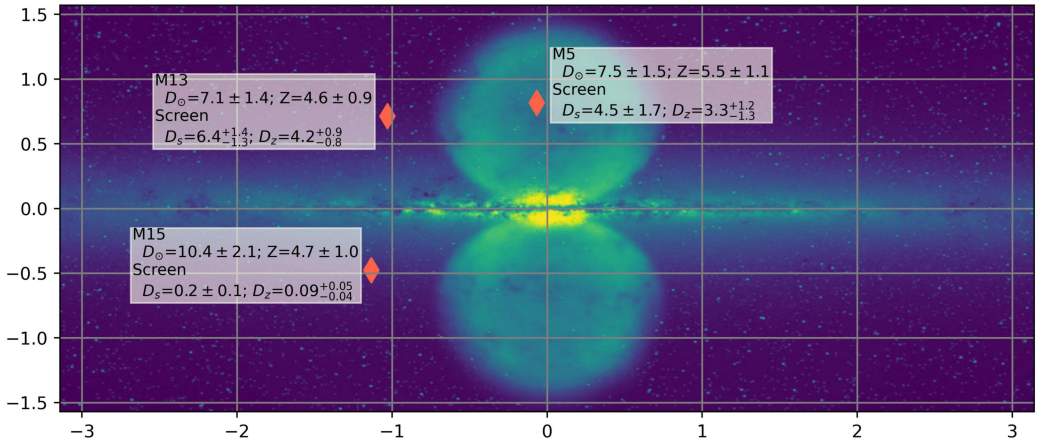
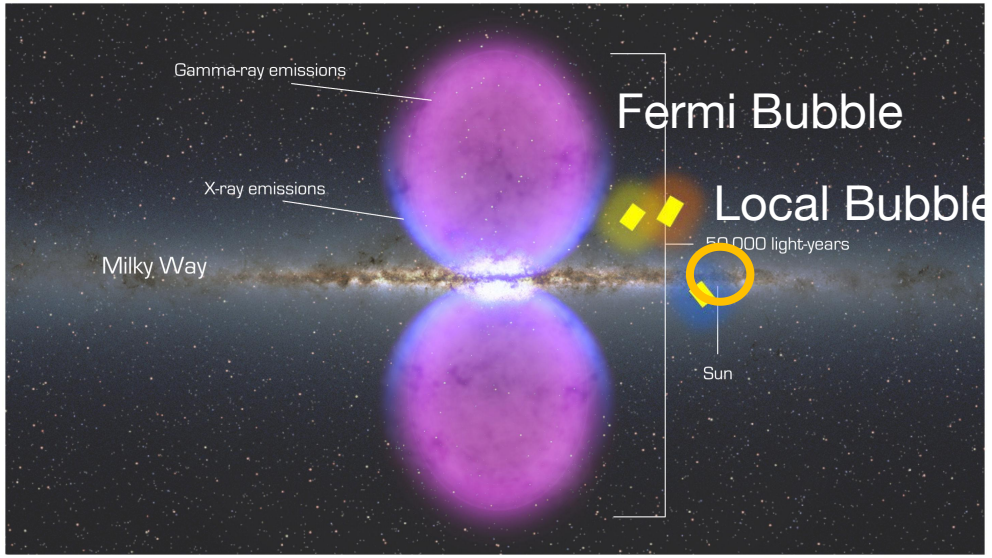


Figure A11 As in FigureA6, results of arc curvature fittings and secondary spectra for PSR J1641+3627A at 1100 MHz.

Zhang D. D. et al. SCPMA 2023





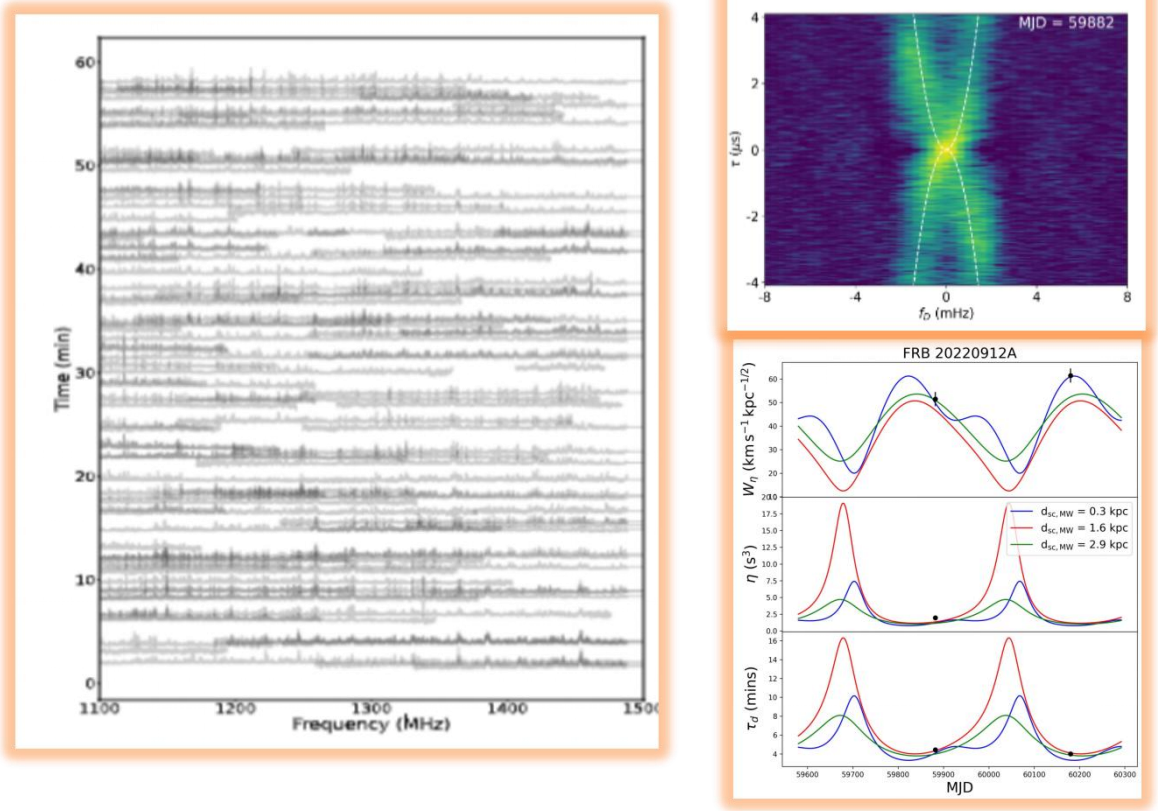
FRB scintillation study

FAST 快速射电暴优先及重大项目

FAST Fast Radio Burst (FRB) Key Science Project

Scintillation (arcs)

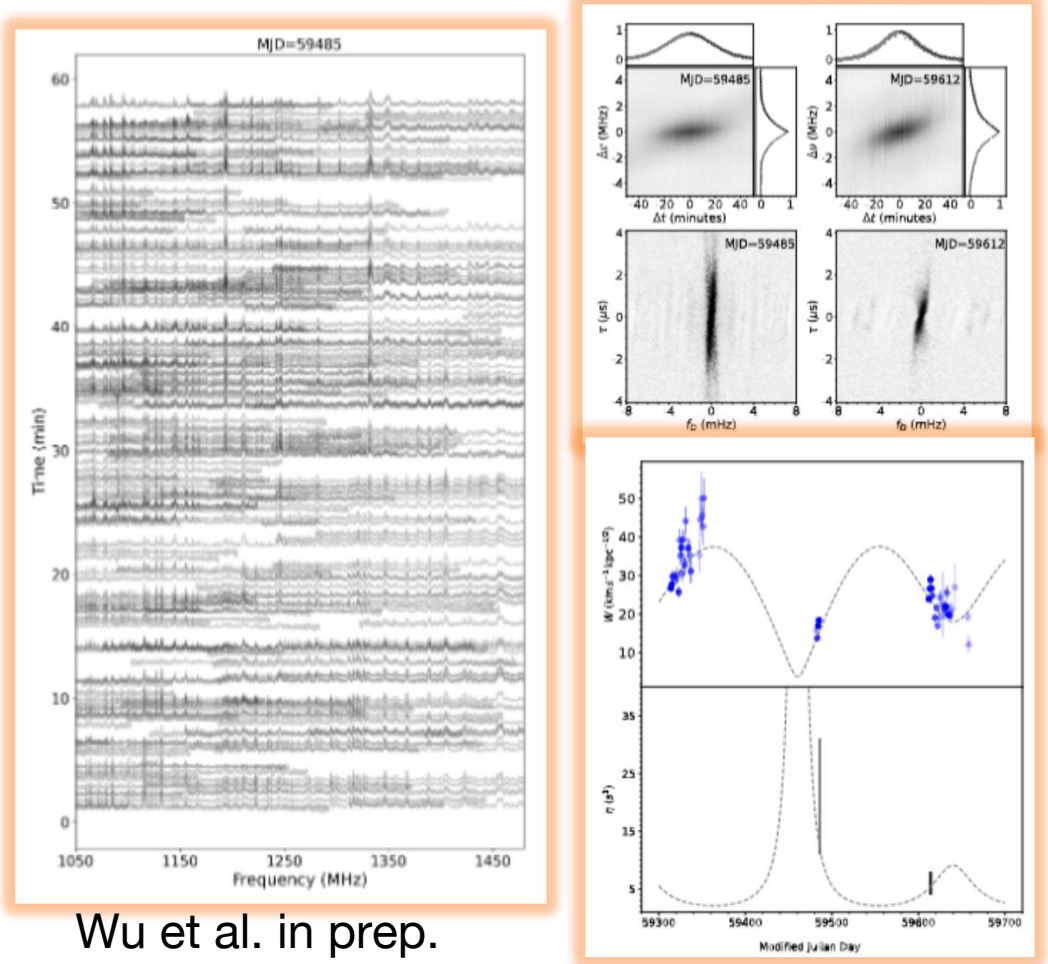
Scintillation arc and time scales of FRB20220912A



First detection of scintillation arc from FRBs

Wu, Main, Zhu et al. SCPMA in

Scintillation arc and time scales of FRB20221124A



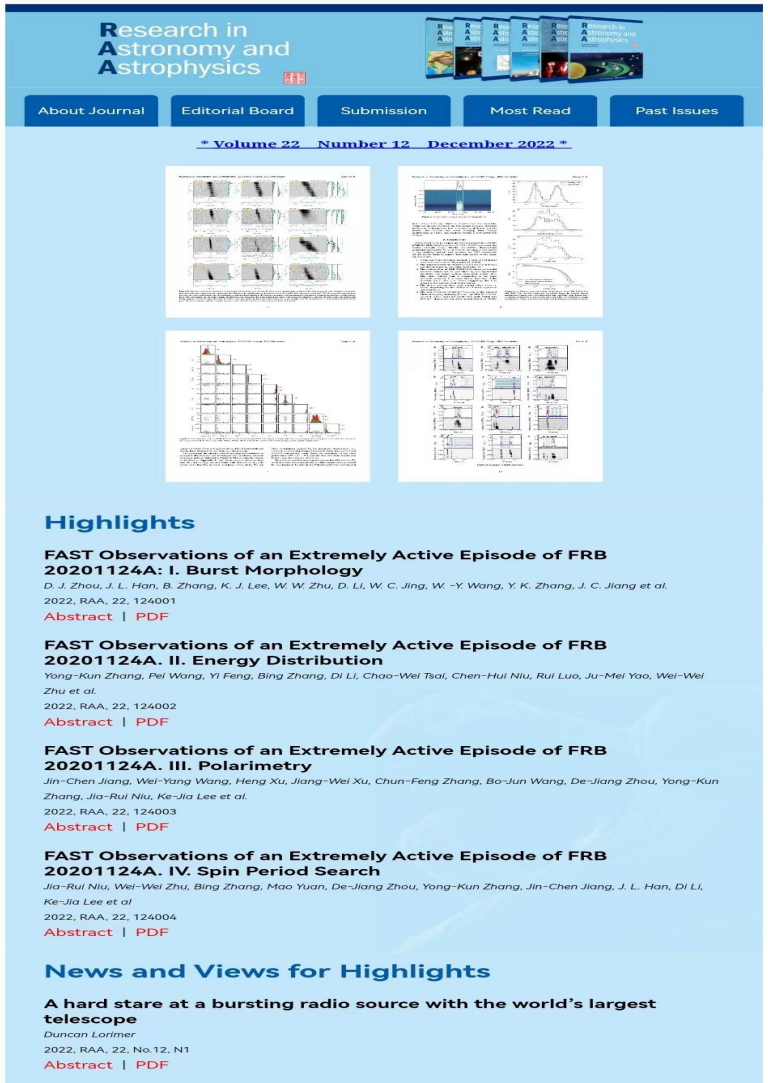
Wu et al. in prep.

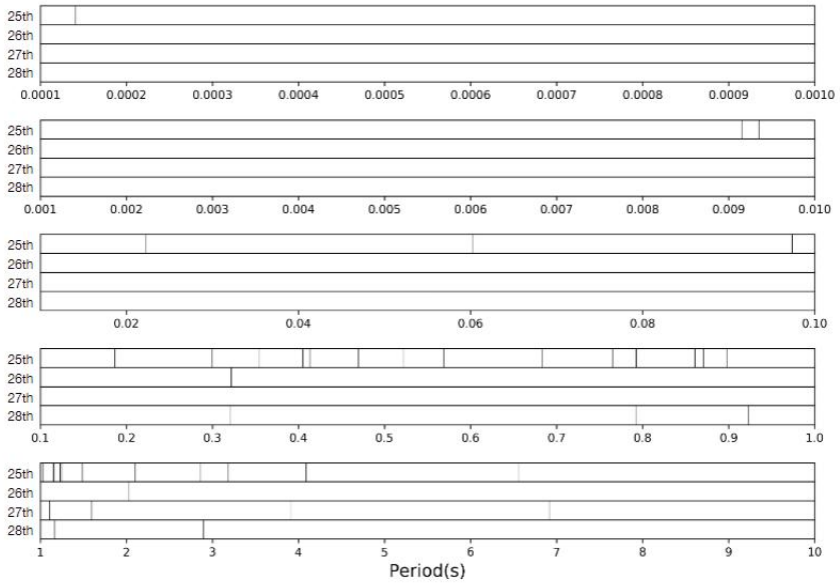
FRB spin period search

FAST 快速射电暴优先及重大项目

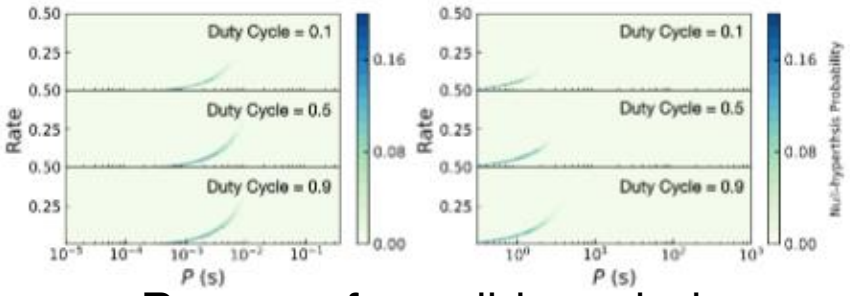
FAST Fast Radio Burst (FRB) Key Science Project

☐ Spin (phases)

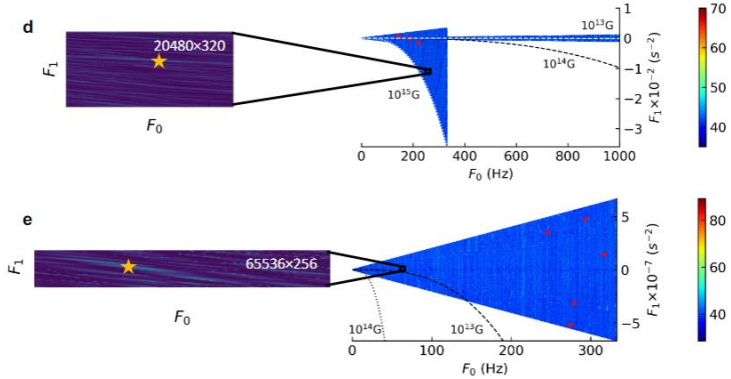




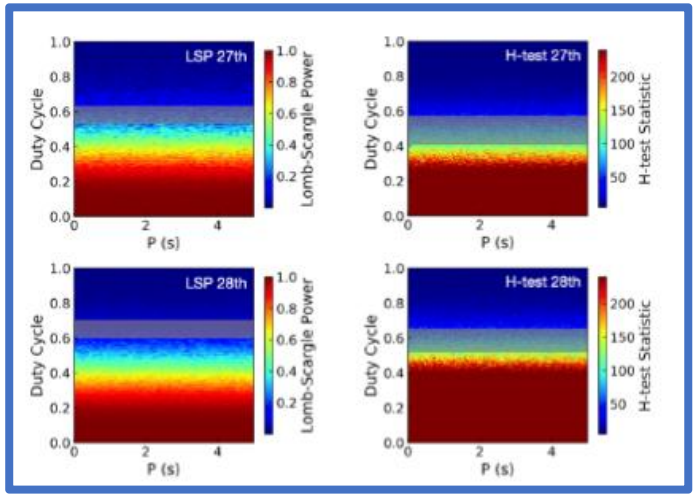
Compare Lomb-Scargle Periodogram from 4 days



Ranges of possible period



P-Pdot search for a large range
Cover B up to 10^{15} G
And a large range of binaries



Niu J. R. et al. 2022 RAA

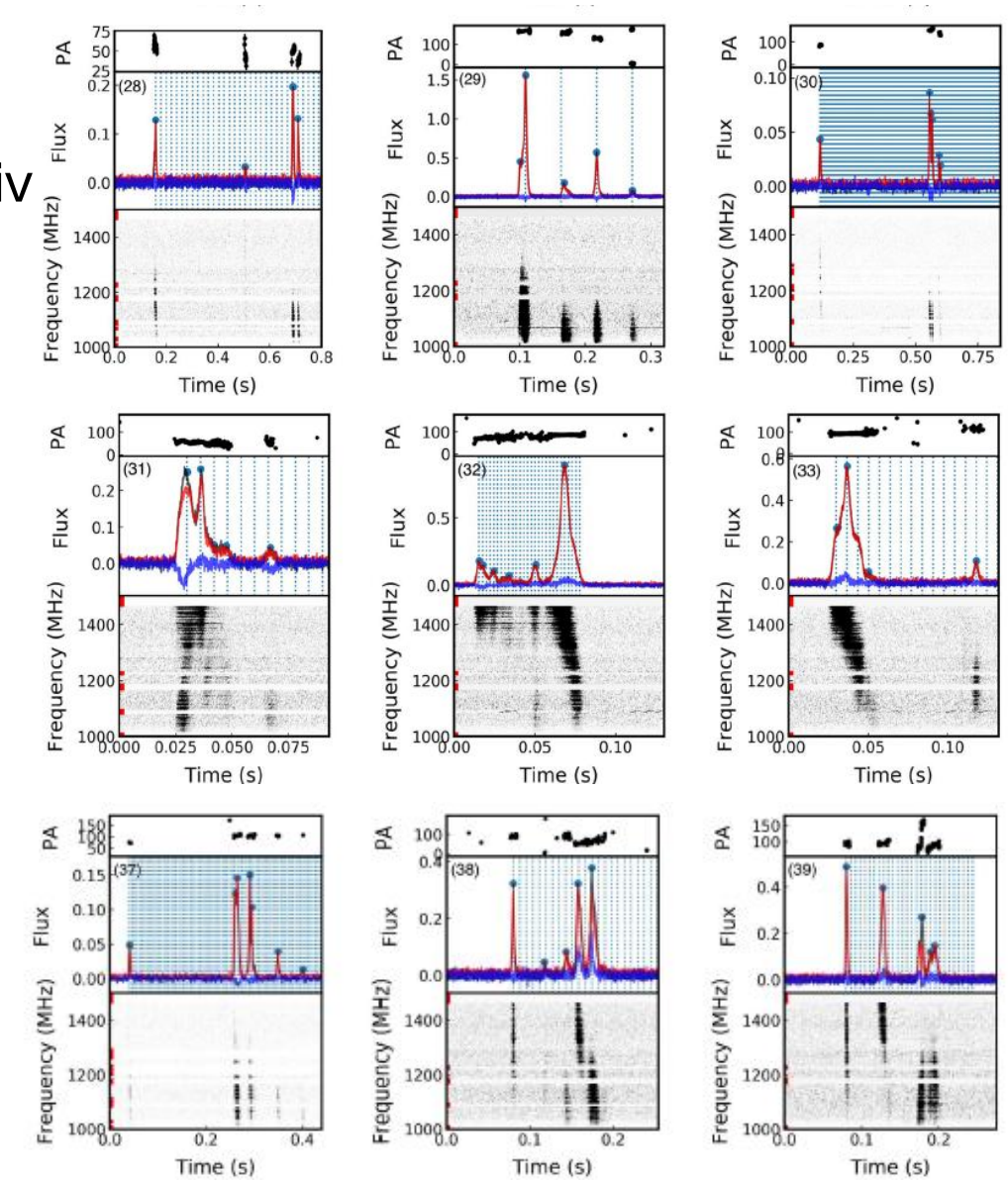
FRB fine structures

FAST 快速射电暴优先及重大项目

FAST Fast Radio Burst (FRB) Key Science Project

◻ Spin (phases)

- FRB20201124A most activ episode
- Highest burst rate ~400 bursts/hr
- Burst fine structure study
- Many period-like fine structures < 4σ



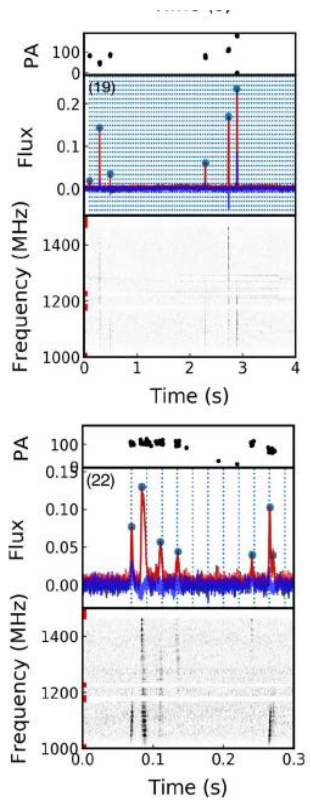


Table 6
Multi-components of FRB 20201124A

Index	N^a	P (ms)	$\bar{R}$	MJD
1	5	7.164	0.0240	59 484.8 16 06
2	7	2.638	0.0411	59 484.8 16 50
3	5	2.471	0.0685	59 484.8 21 73
4	4	11.996	0.0368	59 484.8 22 57
5	6	5.587	0.0415	59 484.8 23 57
6	5	3.801	0.0347	59 484.8 26 33
7	6	3.504	0.0716	59 484.8 30 85
8	4	5.637	0.0077	59 484.8 34 19
9	5	5.182	0.0337	59 484.8 40 94
10	8	13.521	0.0272	59 484.8 43 49
11	5	6.409	0.0308	59 484.8 47 19
12	4	8.077	0.0609	59 484.8 49 38
13	4	12.532	0.0532	59 484.8 51 48
14	4	9.736	0.0748	59 485.7 83 25
15	5	2.766	0.0198	59 485.7 83 38
16	5	4.013	0.0761	59 485.7 84 88
17	8	14.655	0.0238	59 485.7 85 61
18	4	9.308	0.0381	59 485.7 86 53
19	6	48.734	0.0058	59 485.7 89 12
20	5	4.869	0.0436	59 485.7 89 33
21	4	6.446	0.0931	59 485.7 90 68
22	7	21.804	0.0355	59 485.7 93 74
23	5	9.623	0.0456	59 485.7 94 32
24	5	9.678	0.0552	59 485.7 95 15
25	10	1.465	0.0471	59 485.7 96 12
26	5	4.255	0.0748	59 485.7 99 22
27	5	5.115	0.0209	59 485.7 99 49
28	4	20.35	0.0087	59 485.7 99 96
29	4	54.227	0.0292	59 485.8 00 02
30	6	4.915	0.0120	59 485.8 00 20
31	4	5.999	0.0629	59 485.8 01 31
32	6	2.311	0.0463	59 485.8 01 33
33	4	6.764	0.0444	59 485.8 01 61
34	4	21.211	0.0045	59 485.8 01 71
35	4	39.408	0.0172	59 485.8 03 09
36	5	12.762	0.0208	59 485.8 03 23
37	7	5.069	0.0078	59 485.8 03 79
38	5	7.867	0.0674	59 485.8 05 21
39	5	6.075	0.0679	59 485.8 07 17
40	6	21.629	0.0080	59 485.8 07 29
41	5	3.457	0.0429	59 485.8 07 64
42	4	4.967	0.0888	59 485.8 08 08
43	5	6.835	0.0148	59 485.8 09 27
44	4	8.007	0.0439	59 485.8 11 31
45	4	6.675	0.0213	59 485.8 11 93
46	4	4.045	0.0574	59 485.8 12 67
47	6	7.354	0.0171	59 485.8 12 70
48	4	3.547	0.0763	59 485.8 12 70
49	6	5.155	0.0141	59 485.8 17 02
50	5	33.551	0.005	59 485.8 17 85
51	4	4.956	0.0169	59 485.8 18 90
52	7	5.918	0.0061	59 485.8 20 70
53	4	4.677	0.0258	59 485.8 21 38

Note.
[a] Number of pulses.

and More …

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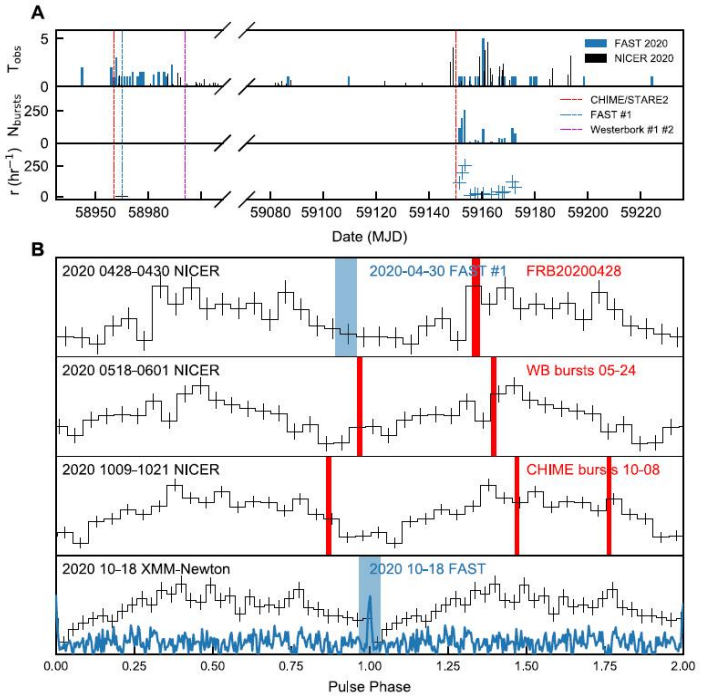
FAST detects pulsar emission from SGR J1935+2154, the FRB-magnetar

FAST 快速射电暴优先及重大项目

FAST Fast Radio Burst (FRB) Key Science Project

☐ Spin (phases)



Radio—Xray Phase

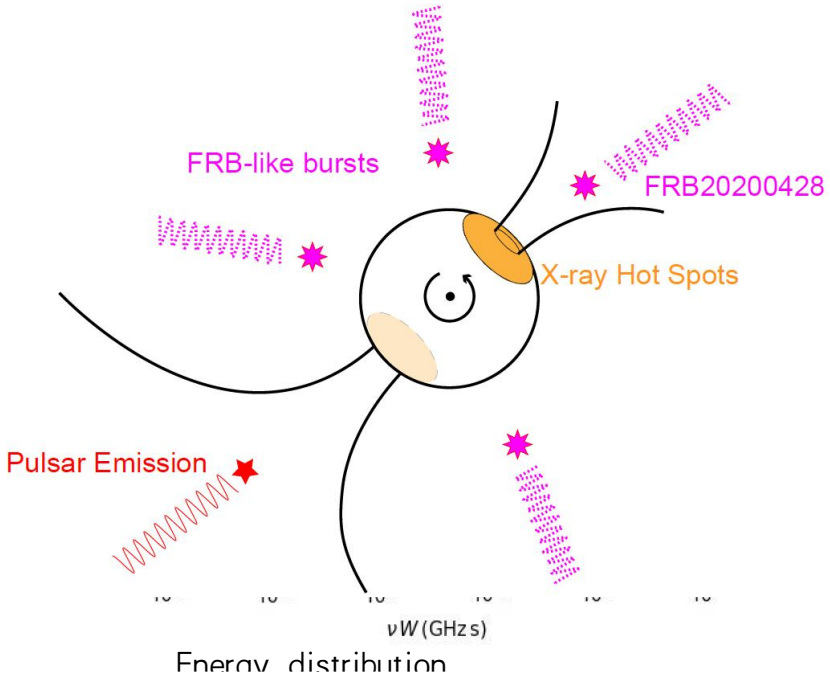
Table 1. Timing model parameters.

Parameter	Value
Measured Parameters	
Spin Frequency ν (s^{-1})	0.307899190(3)
Spin down rate $\dot{\nu}$ (s^{-2})	$-3.524(3) \times 10^{-12}$
Fixed Parameters	
Dispersion Measure (pc cm^{-3})	332.703 [a]
Reference epoch (MJD)	59131.377113
Right Ascension, α (J2000)	19:34:55.5978 [b]
Declination, δ (J2000)	21:53:47.7864 [b]
Solar System Ephemeris	DE436
Derived Parameters	
Dipole magnetic field, B (G)	3.52×10^{14}
Characteristic age, τ_c (yr)	1.38×10^{3}

[a]fixed to the weighted average DM value of single pulses; see method session for details.

[b]position taken from X-ray imaging[25] with an uncertainty of 0.4".

Timing results



FRB bursts and pulsar emission

~800 pulses detected by FAST in Oct 2020

Zhu W.W.* Xu H. Zhou D. J. Zhang B.* Lee K. J.* et al. Science Advances 2023

Photo credit: Zhang C. F