



Magnetic WD – MD Binaries in Pre-mCV Phase as Special Population of Long-Period Radio Transients

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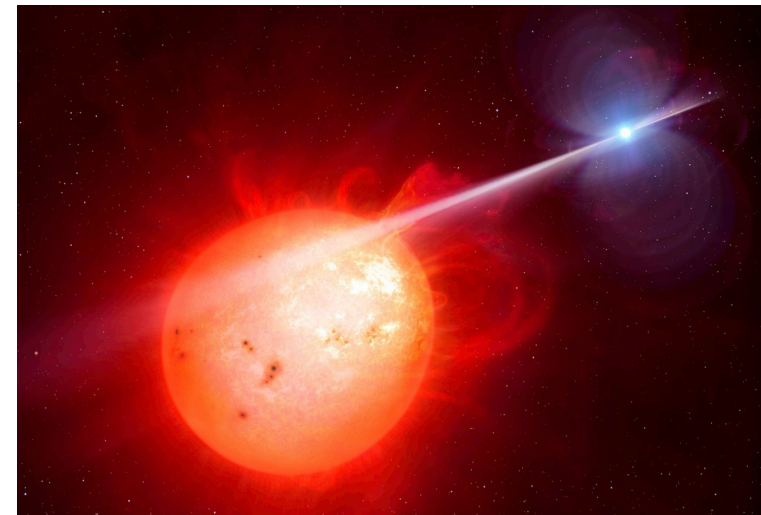
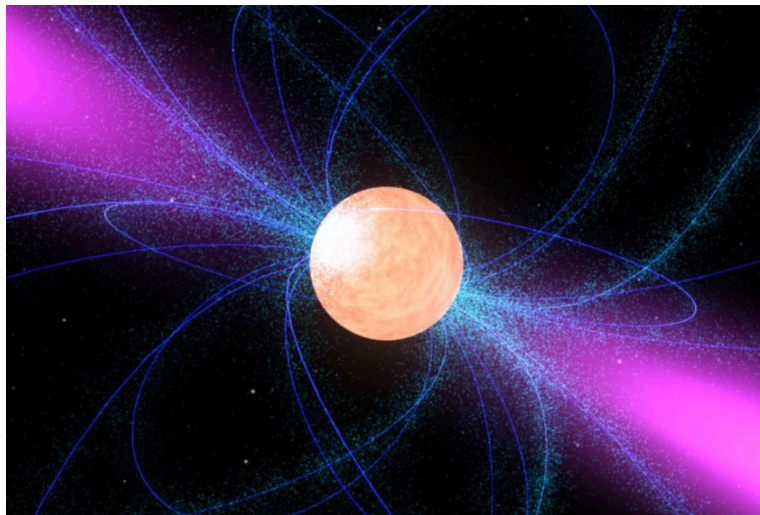
Reference: Yang, 2025, ApJ, arXiv: 2509.09224

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Long Period Radio Transients

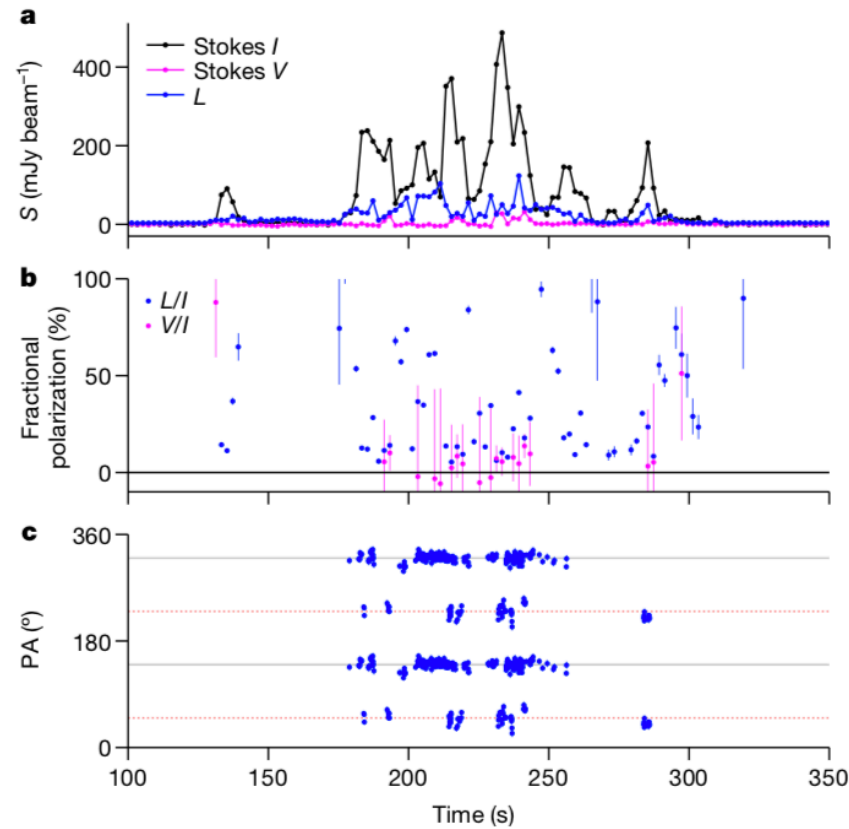
Published LPRTs with Distances, Periods, Flux Density, Luminosities, Linear Polarization Degrees (in the Radio Band), Possible Optical Counterparts and High-energy (HE) Counterparts

Source	D (kpc)	P (minutes)	S_ν (Jy)	Π_L (%)	Optical Counterparts	HE Counterparts	References
GCRT J1745–3009	<0.07	77	1	/	No detection	/	(1, 2)
GLEAM-X J1627-52	1.3 ± 0.5	18.18	5–40	88 ± 1	No detection	/	(3, 4)
GPM J1839-10	5.7 ± 2.9	21	0.1–10	10–100	KD or MD?	/	(5, 6)
ASKAPJ1935+2148	4.85	53.8	0.119	>90	near-IR source ?	/	(7)
ILT J1101+5521	0.504	125.5	0.041-0.256	51 ± 6	WD+RD	/	(8)
GLEAM-X J0704-37	1.5 ± 0.5	174	0.04	20–50	RD	/	(9)
DART/ASKAP J1832–0911	4.5	44	0.5-2	75–100	NS?	X-ray	(10, 11)
AR Scorpii	0.116 ± 0.016	213.6	0.003-0.012	~ 1	WD+RD	X-ray	(12, 13, 14)
J191213.72-441045.1	0.237 ± 0.005	241.8	~ 10	4–12	WD+RD	X-ray	(15)
ASKAP J1839-0756	4.0 ± 1.2	387	0.022-1.8	90	No detection	/	(16)

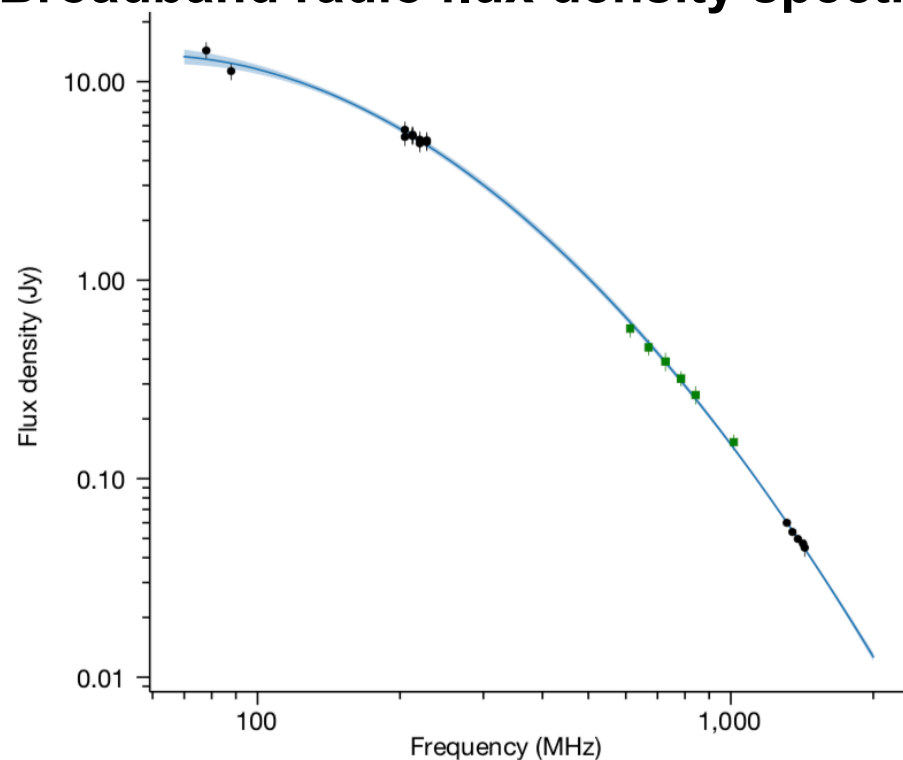


GPM J1839–10 with Complex Features

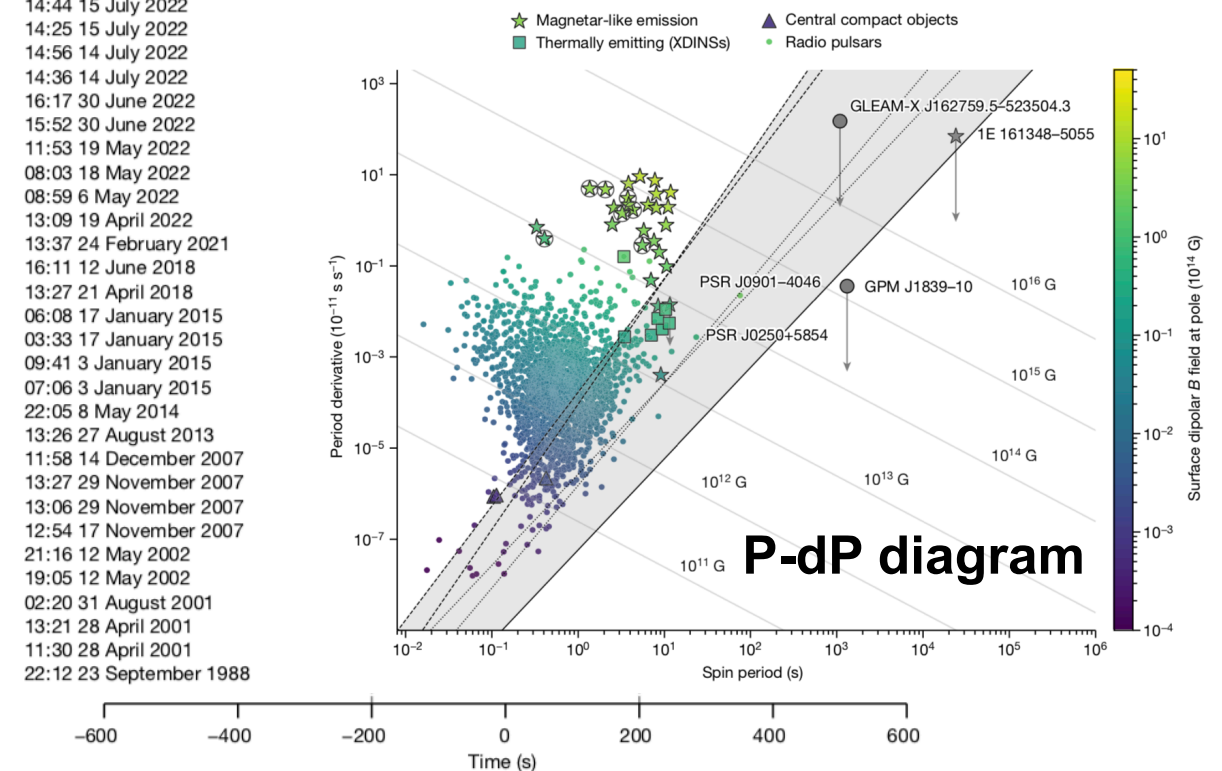
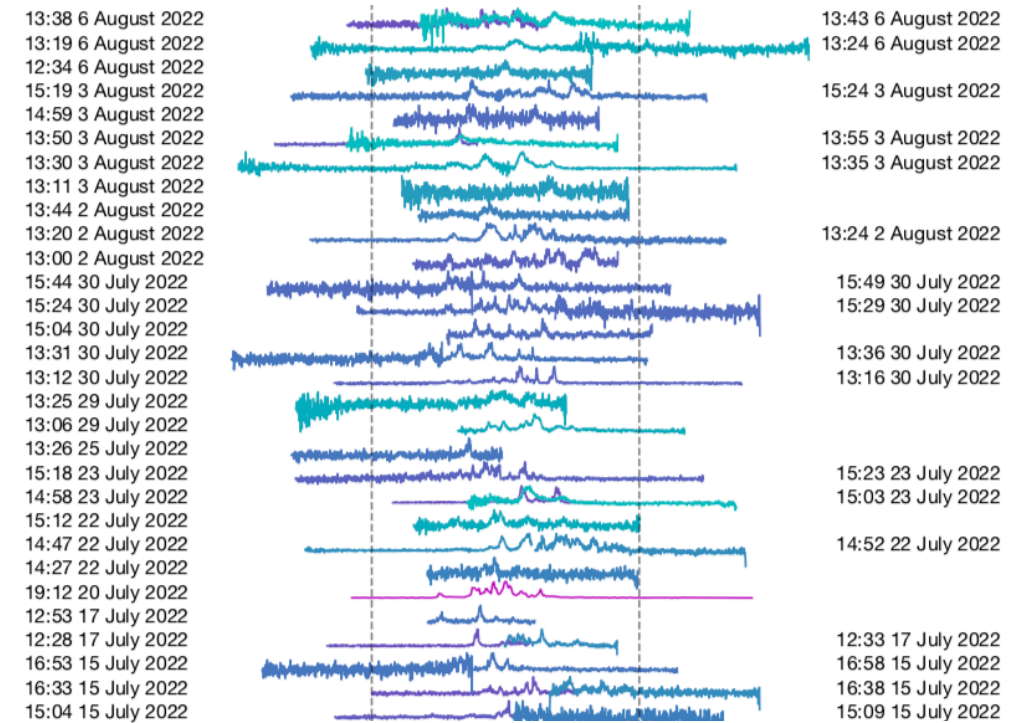
Polarization properties of brightest pulse



Broadband radio flux density spectrum



Pulse profile

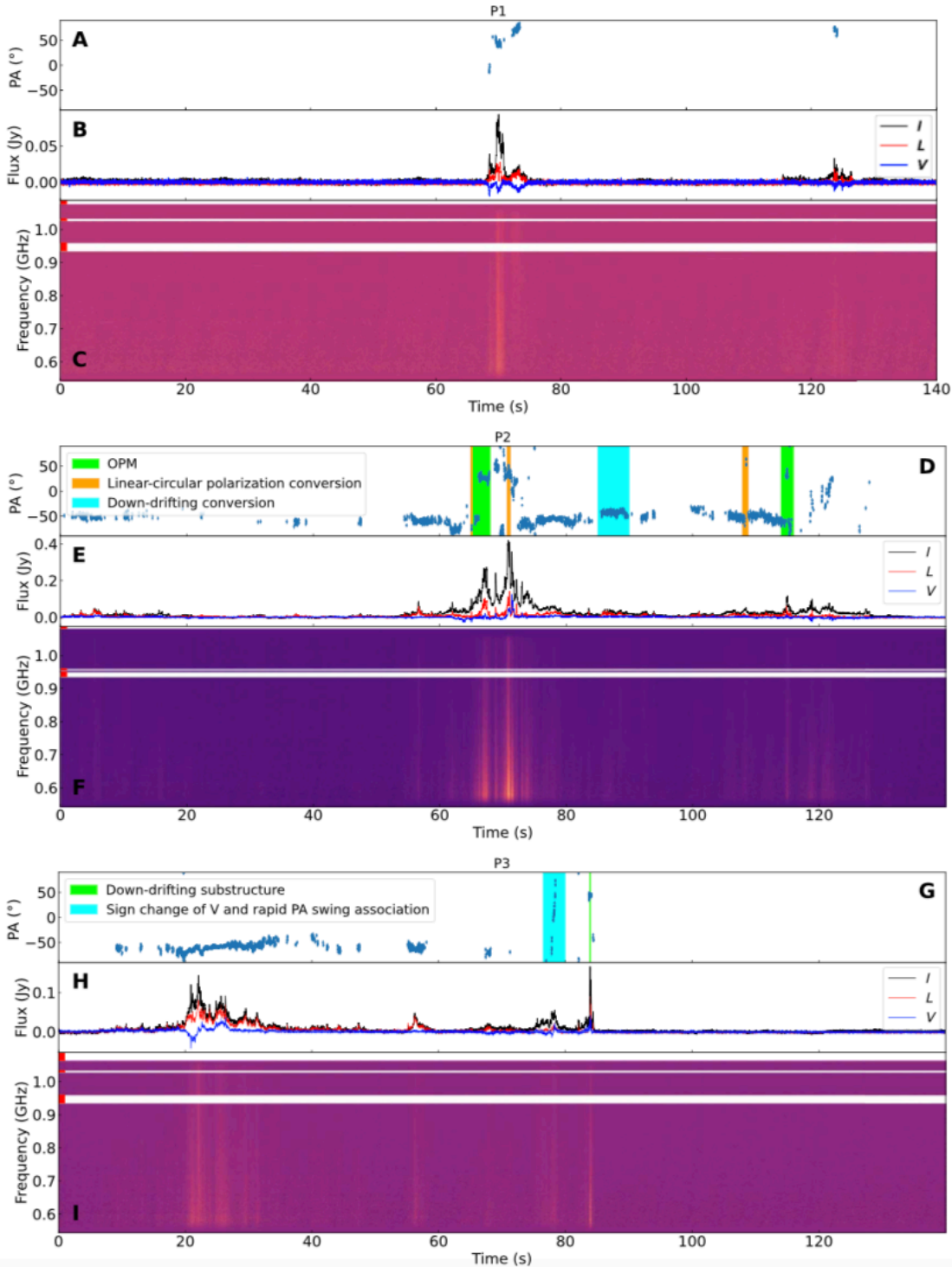


P=21 min

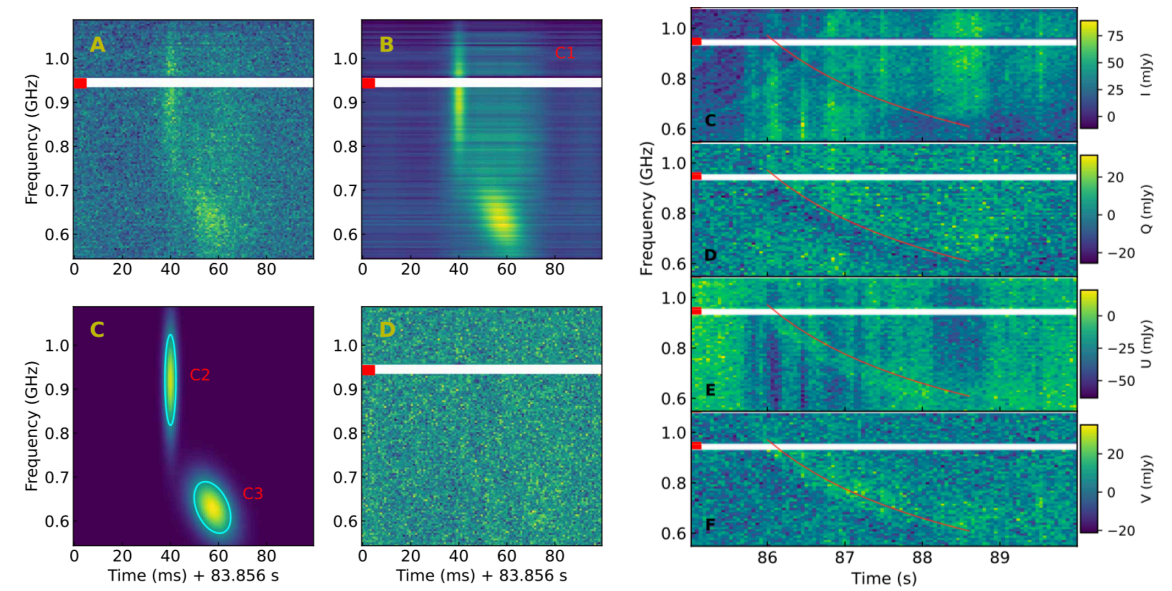
Hurley-Walker et al. 2023, Nature

GPM J1839–10 with Complex Features

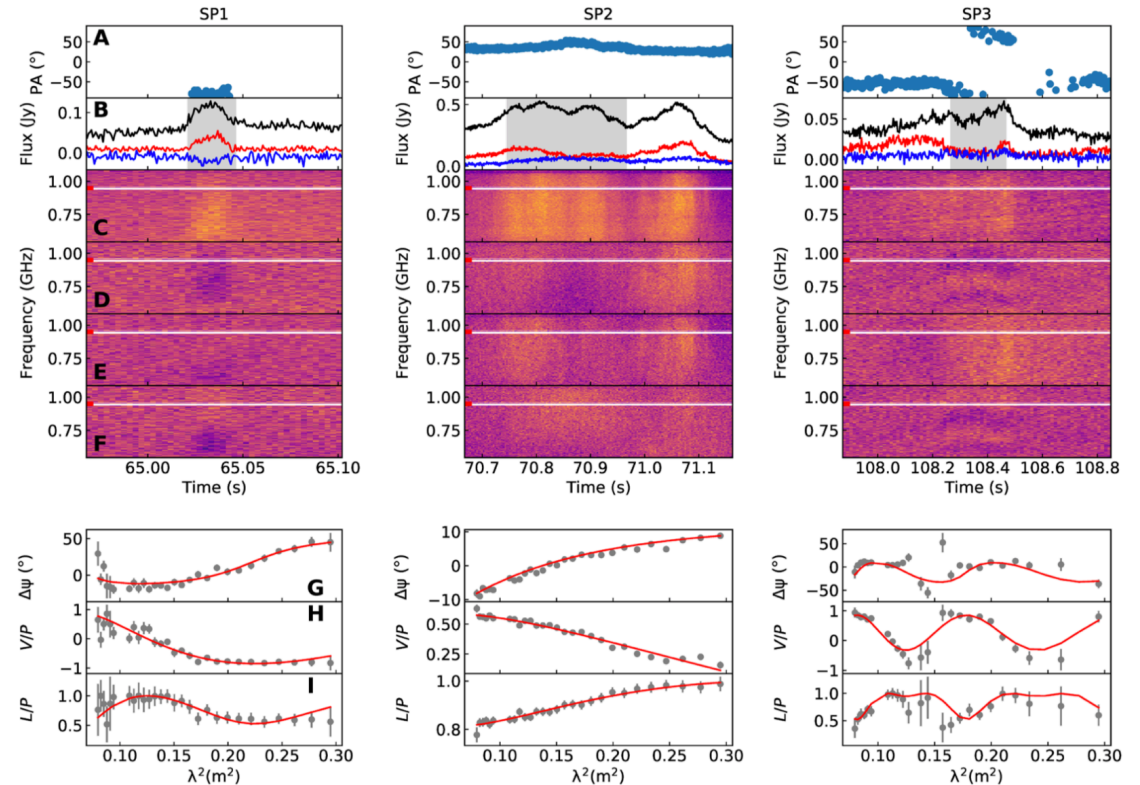
Dynamic spectra of three pulses



Down-drifting sub-structure and their Stokes spectra

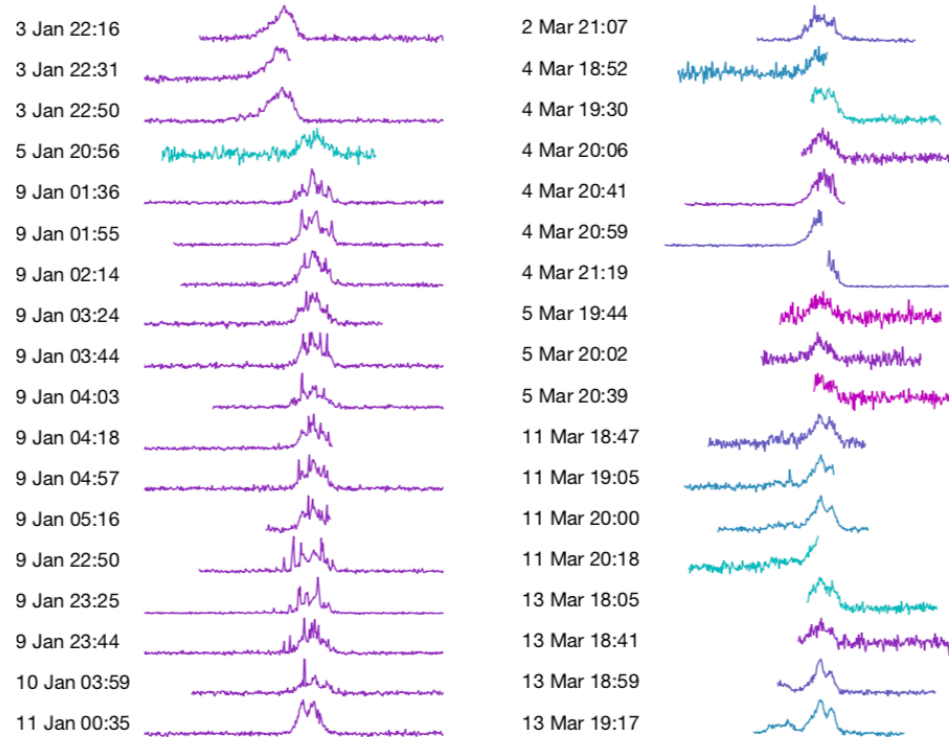


Stokes spectra of sub-pulses

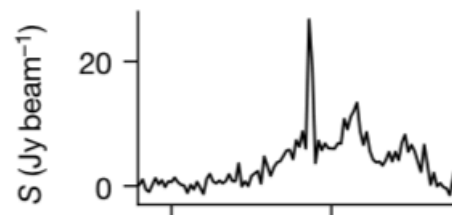
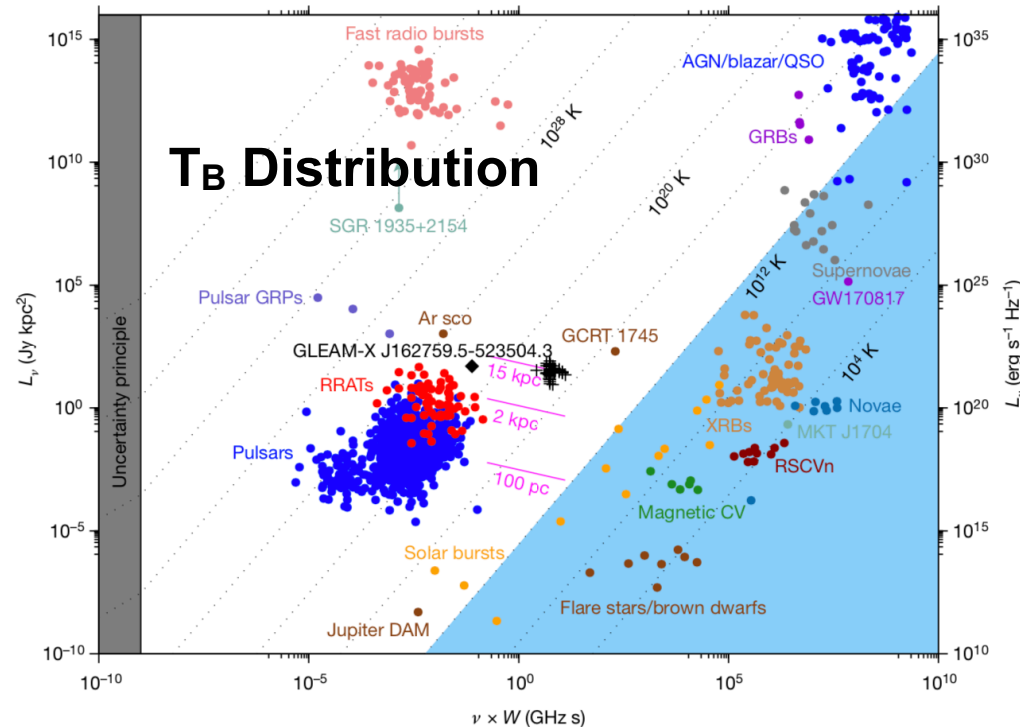
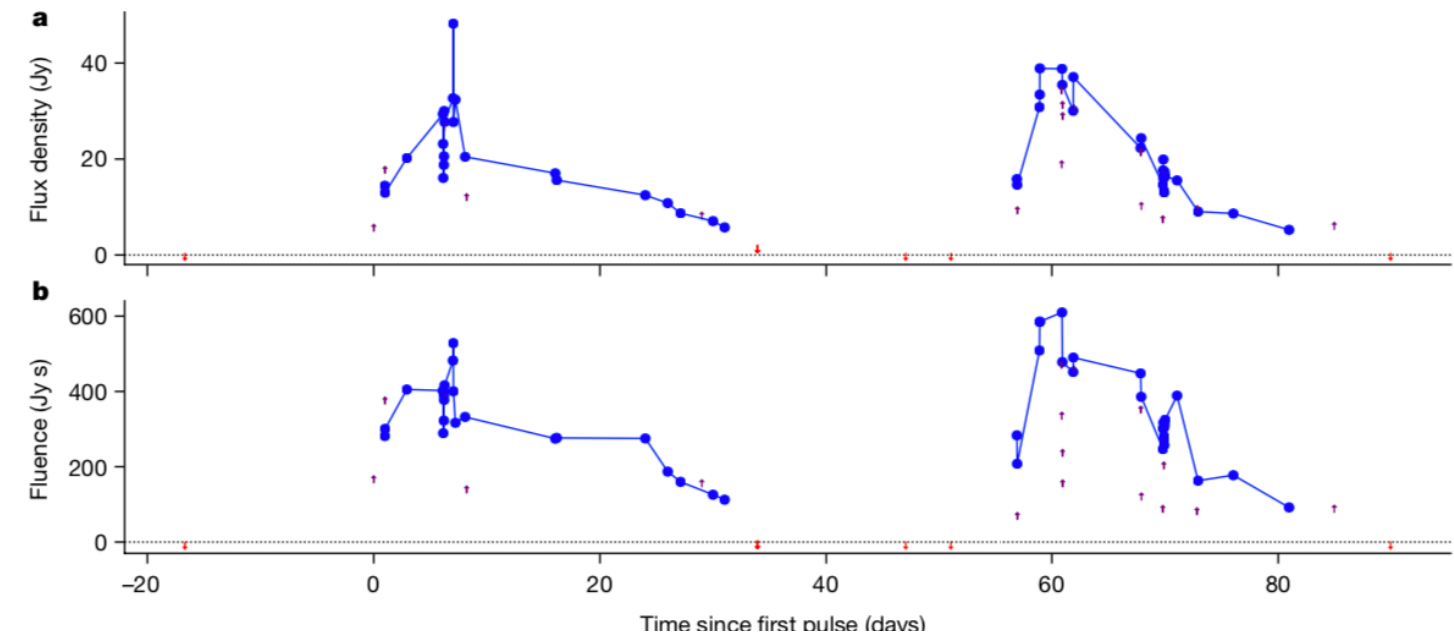


GLEAM-X J1627-52 as Slow Magnetar

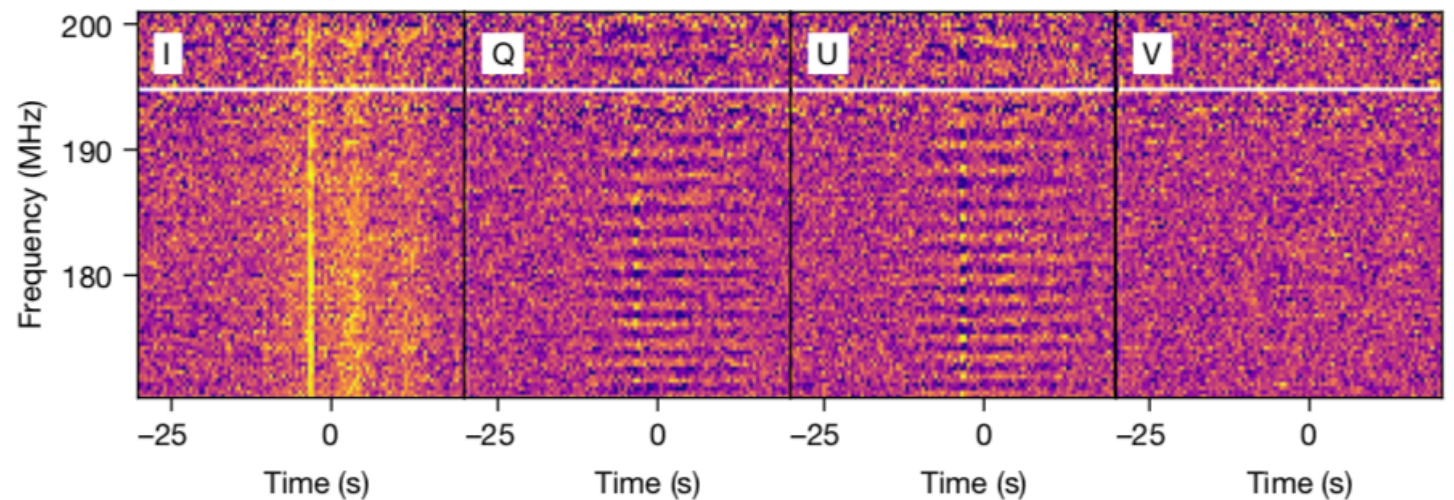
Pulse profile



Flux / Fluence long-term evolution



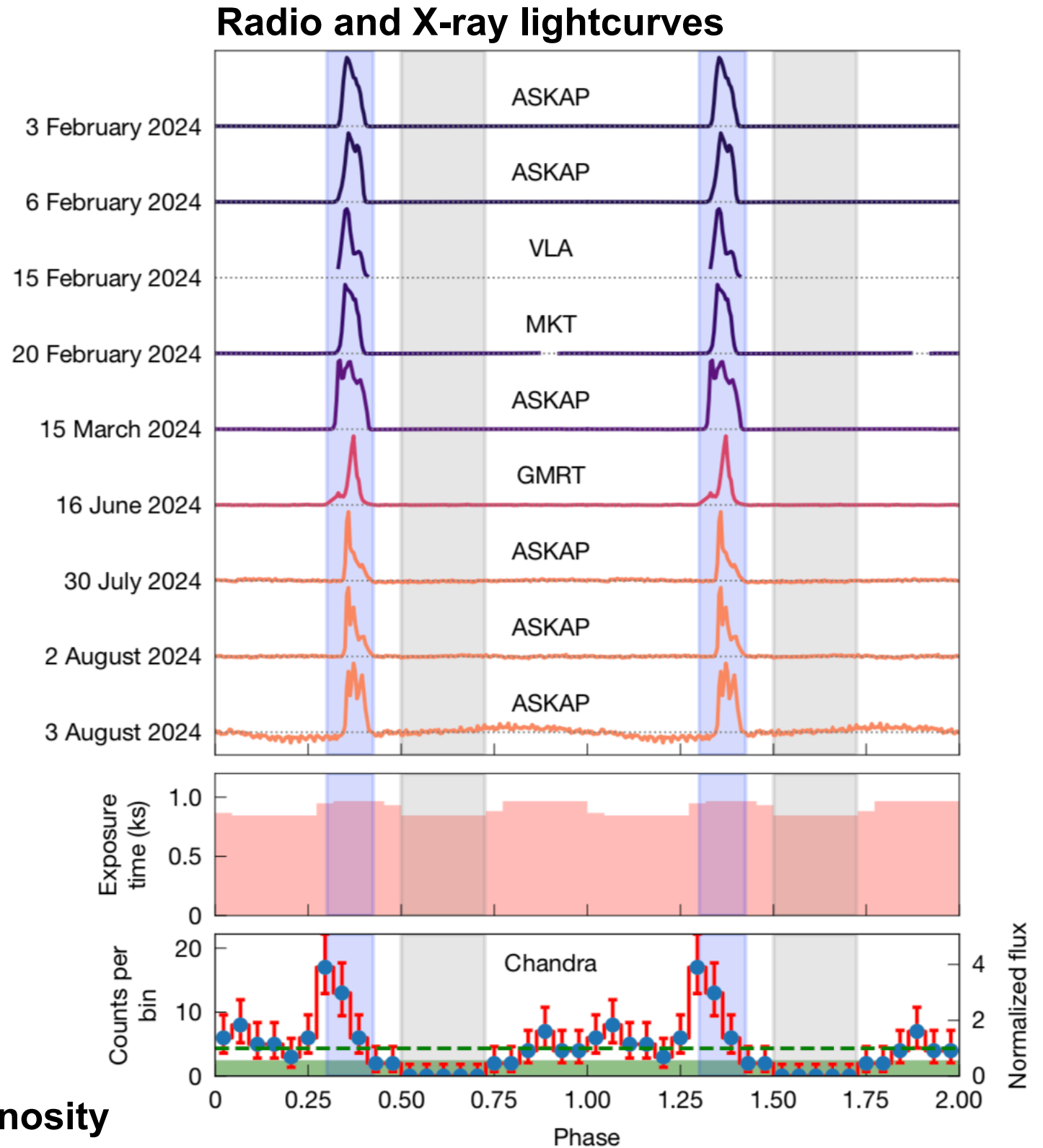
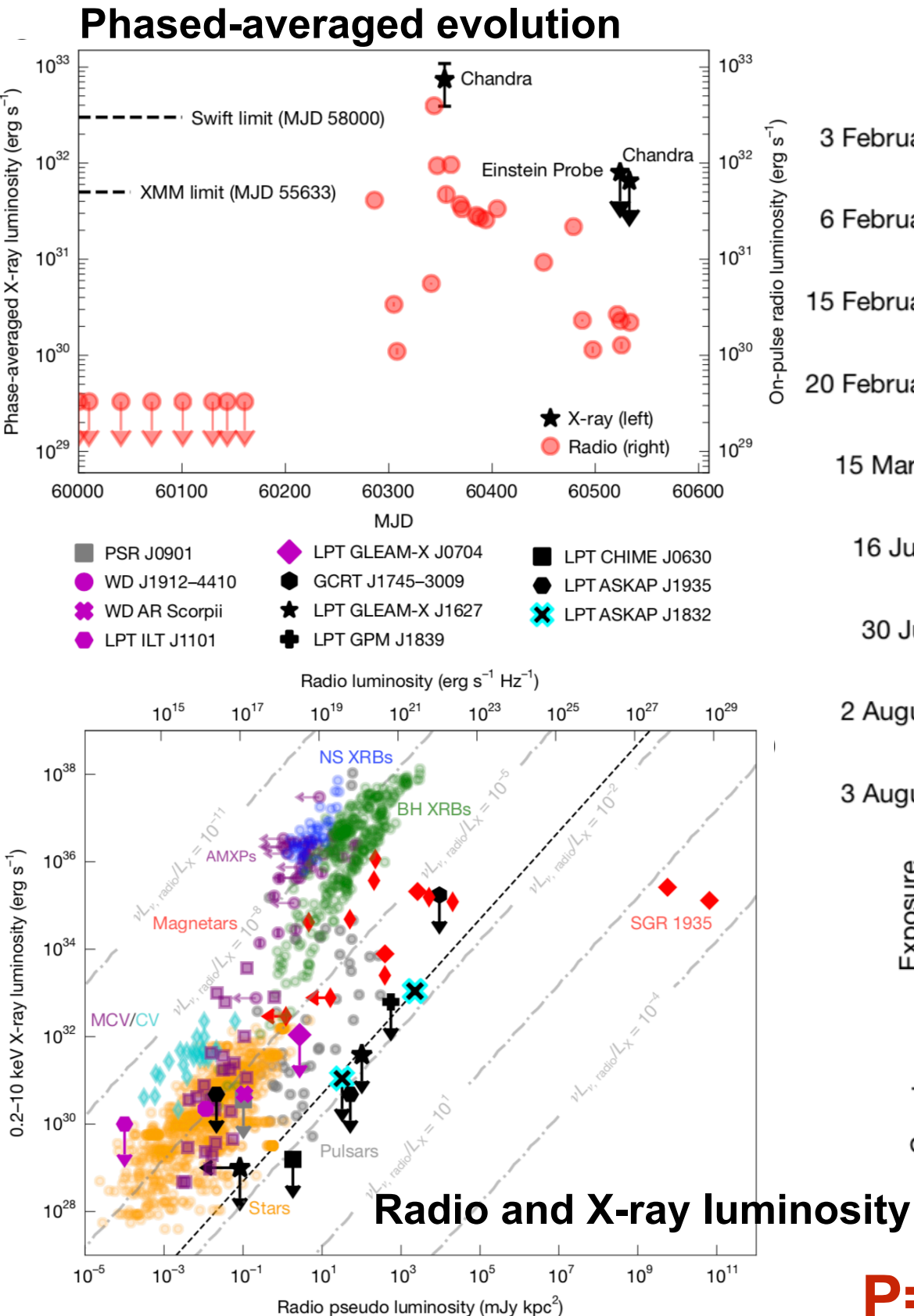
Dynamic Stokes spectra



P=18.18 min

Hurley-Walker et al. 2022, Nature

Phased-averaged evolution Radio and X-ray lightcurves

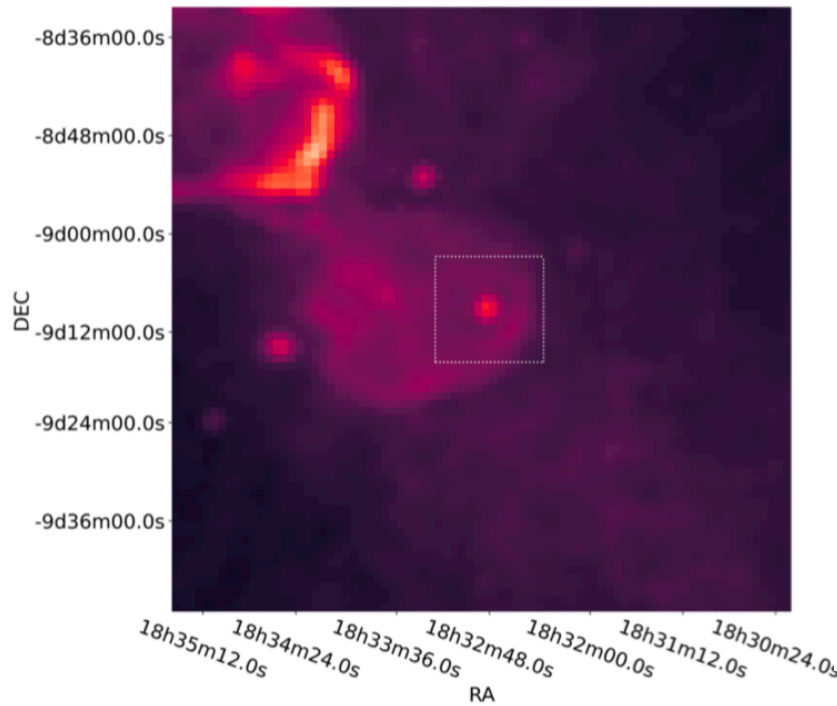


P=44.2 min

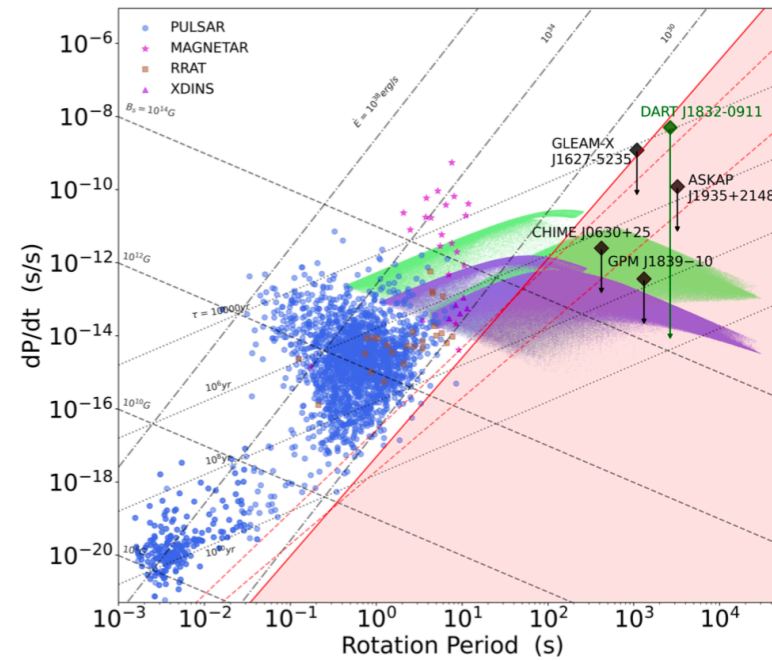
Wang et al. 2025, Nature

ASKAP J1832-0911 in SNR Candidate

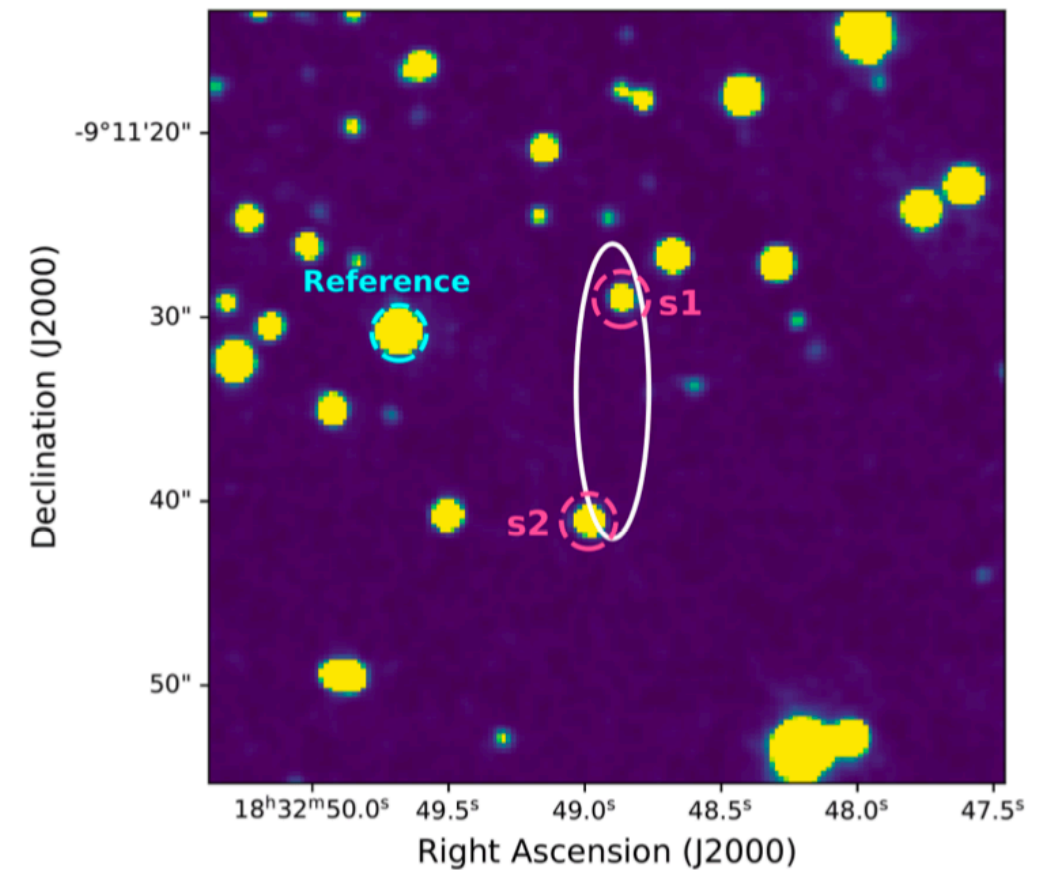
DART radio image



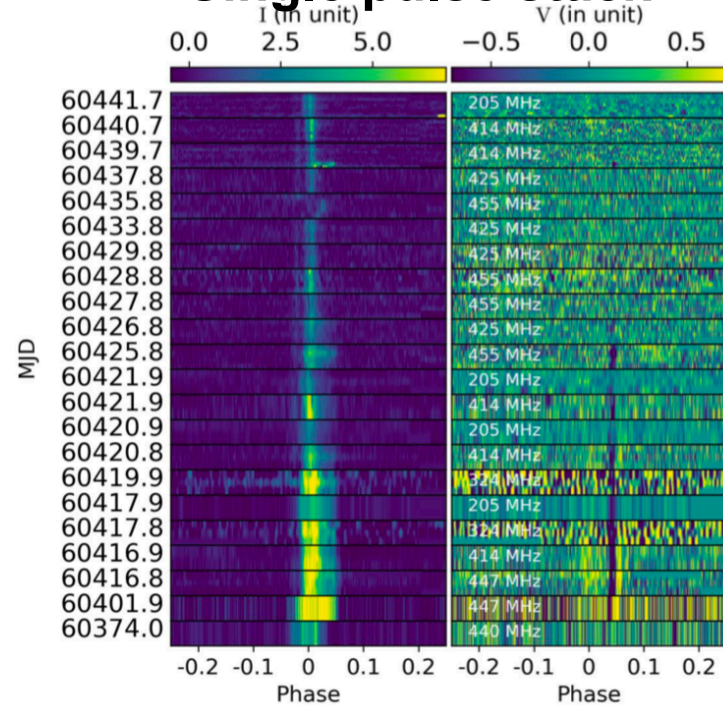
P-dP diagram



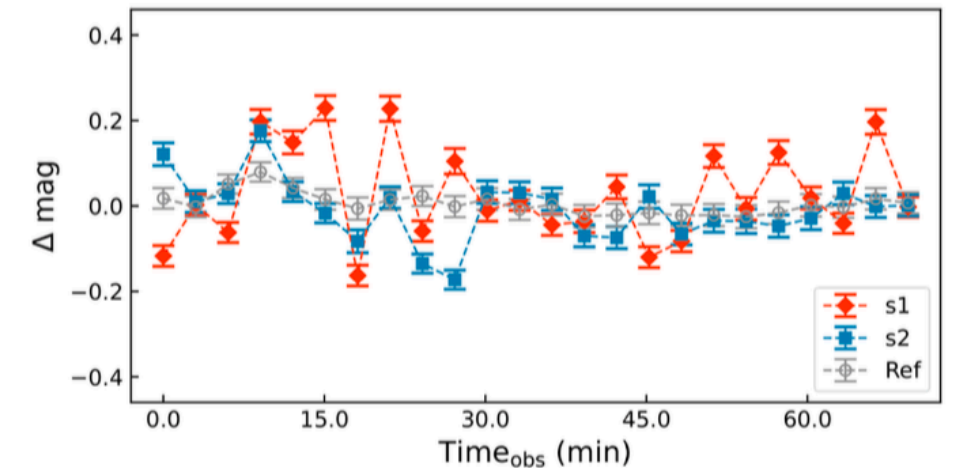
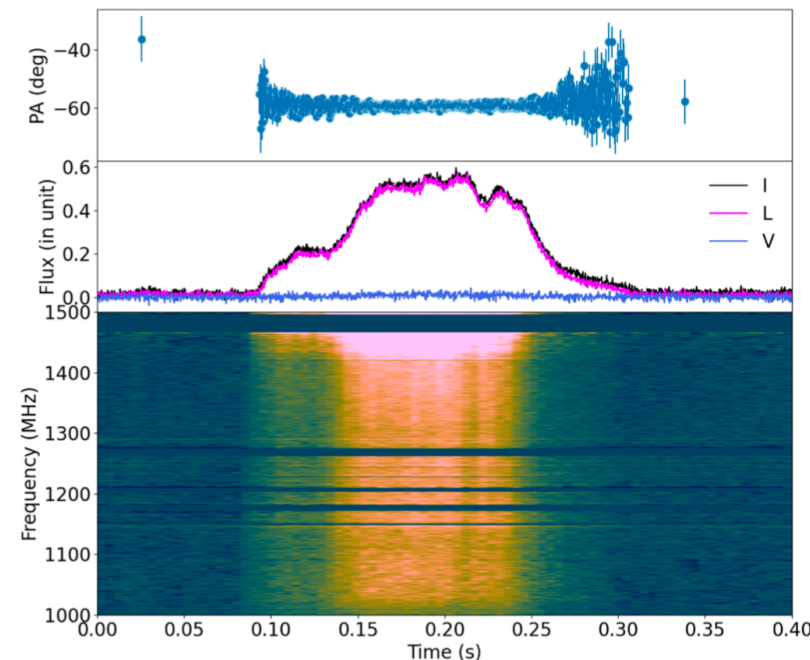
Optical search



Single pulse stack



FAST short pulse

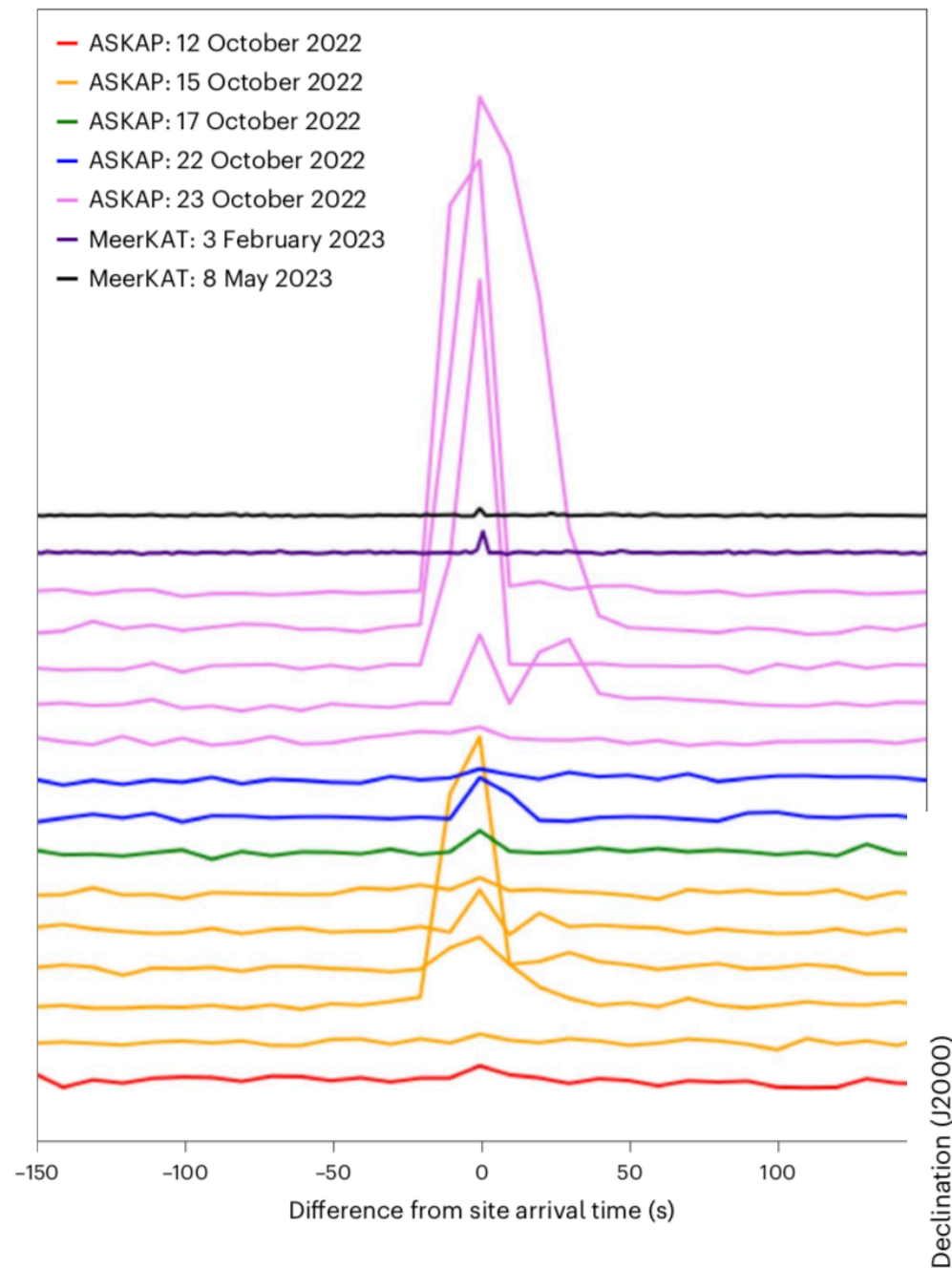


P=44.2 min

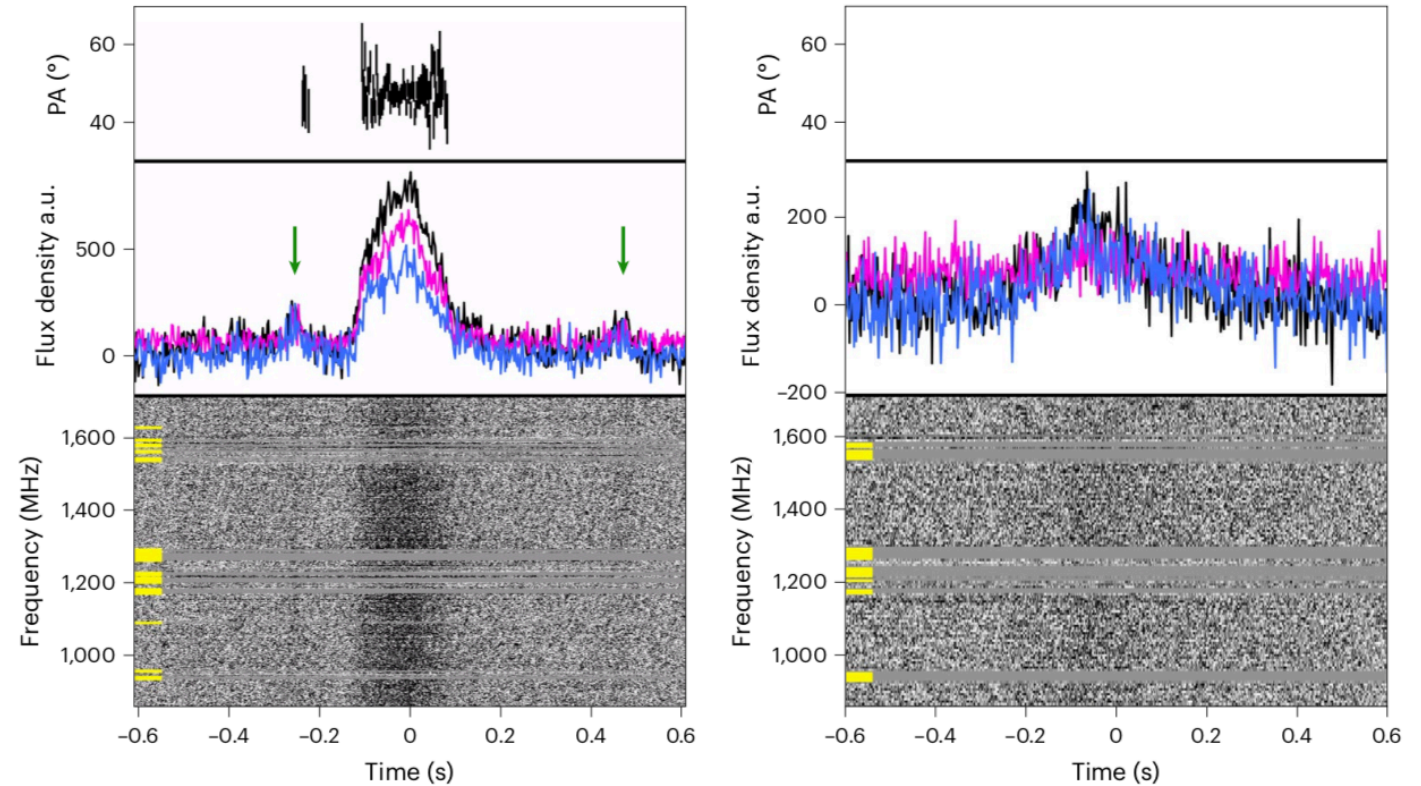
Li, 2025, arXiv: 2411.15739

ASKAP J1935+2148 with Distinct States

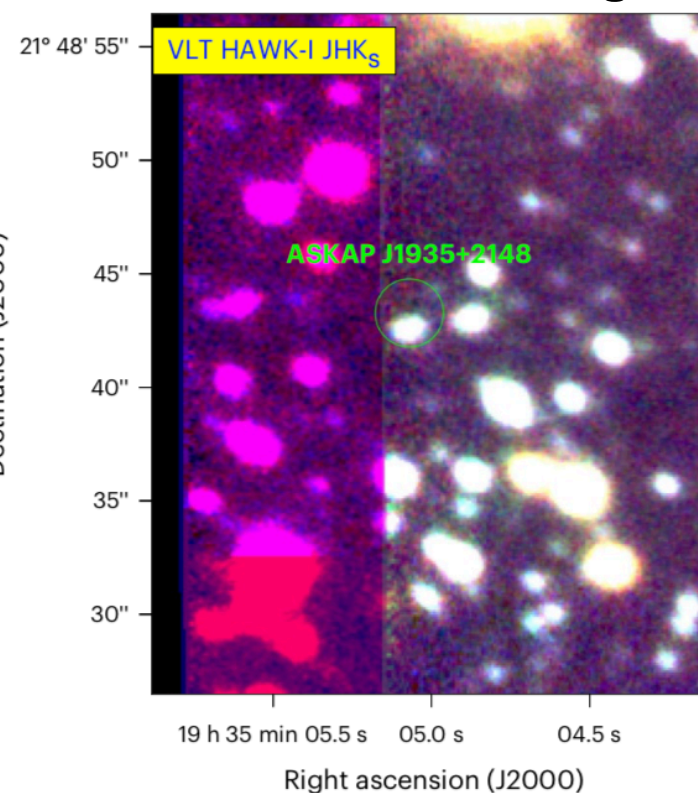
Light curves



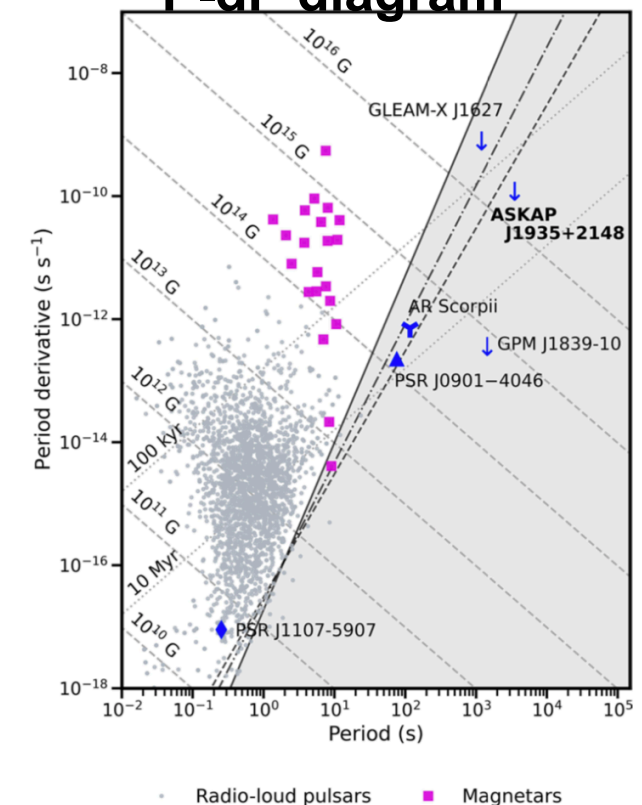
Pulse profiles and dynamic spectra



Near-infrared image



P-dP diagram

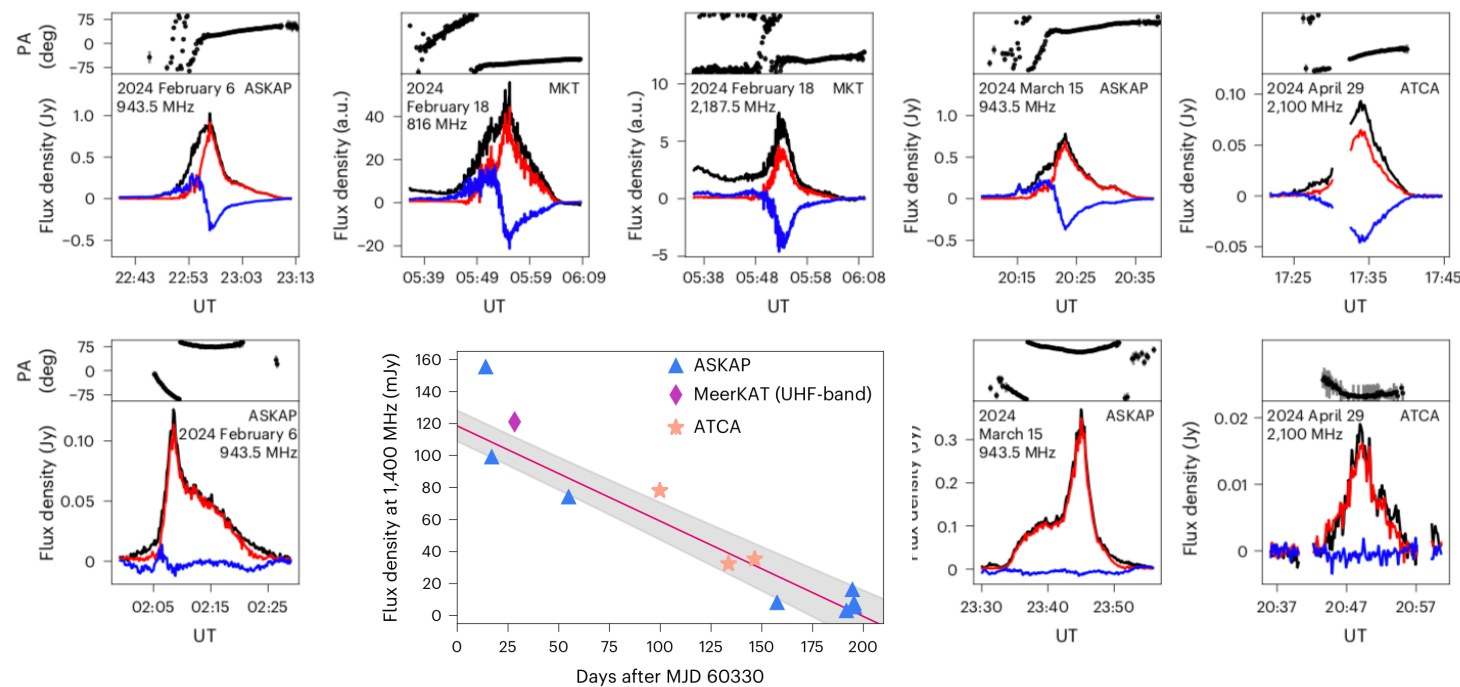


P=53.8 min

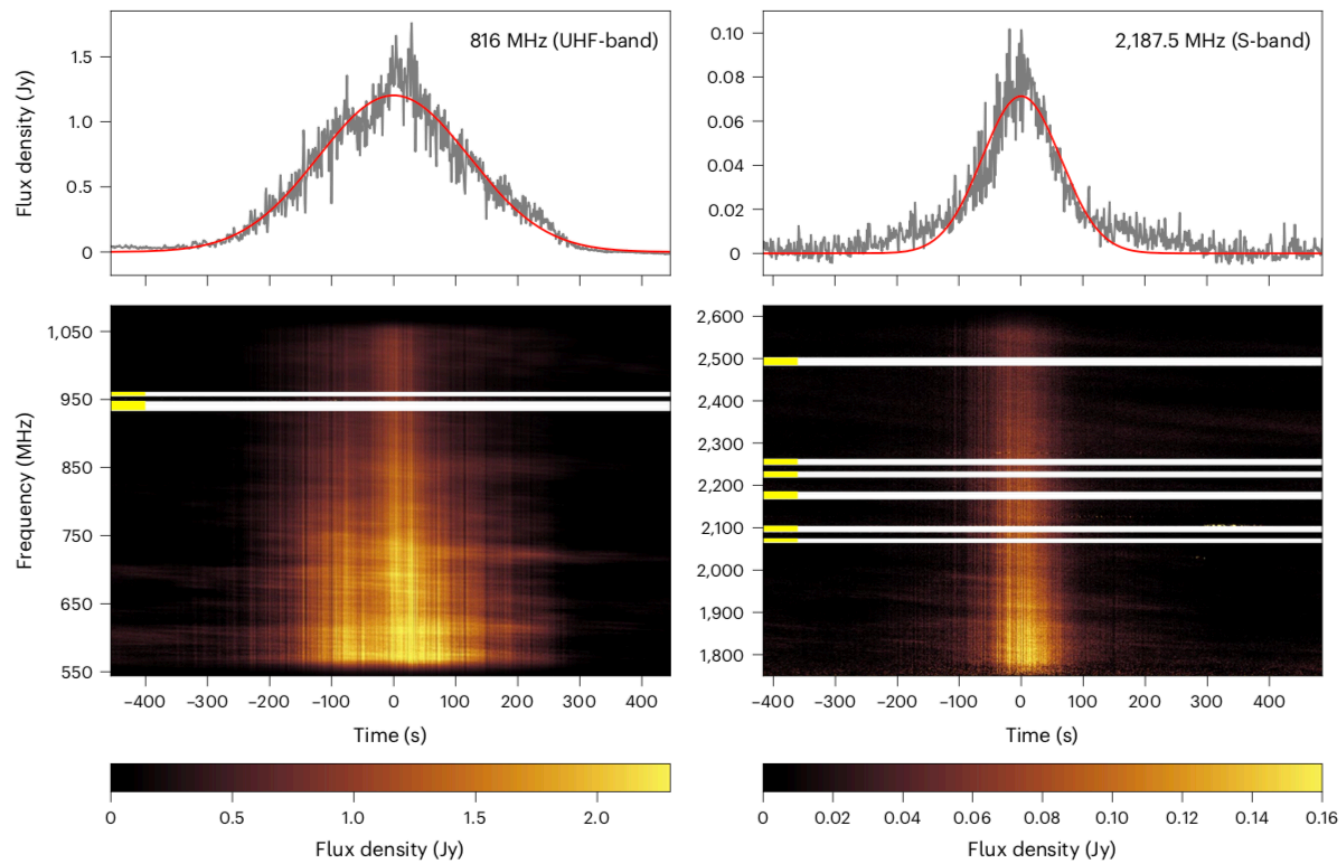
Caleb et al. 2024,
Nature Astronomy

ASKAP J1839–0756 with Longest Period

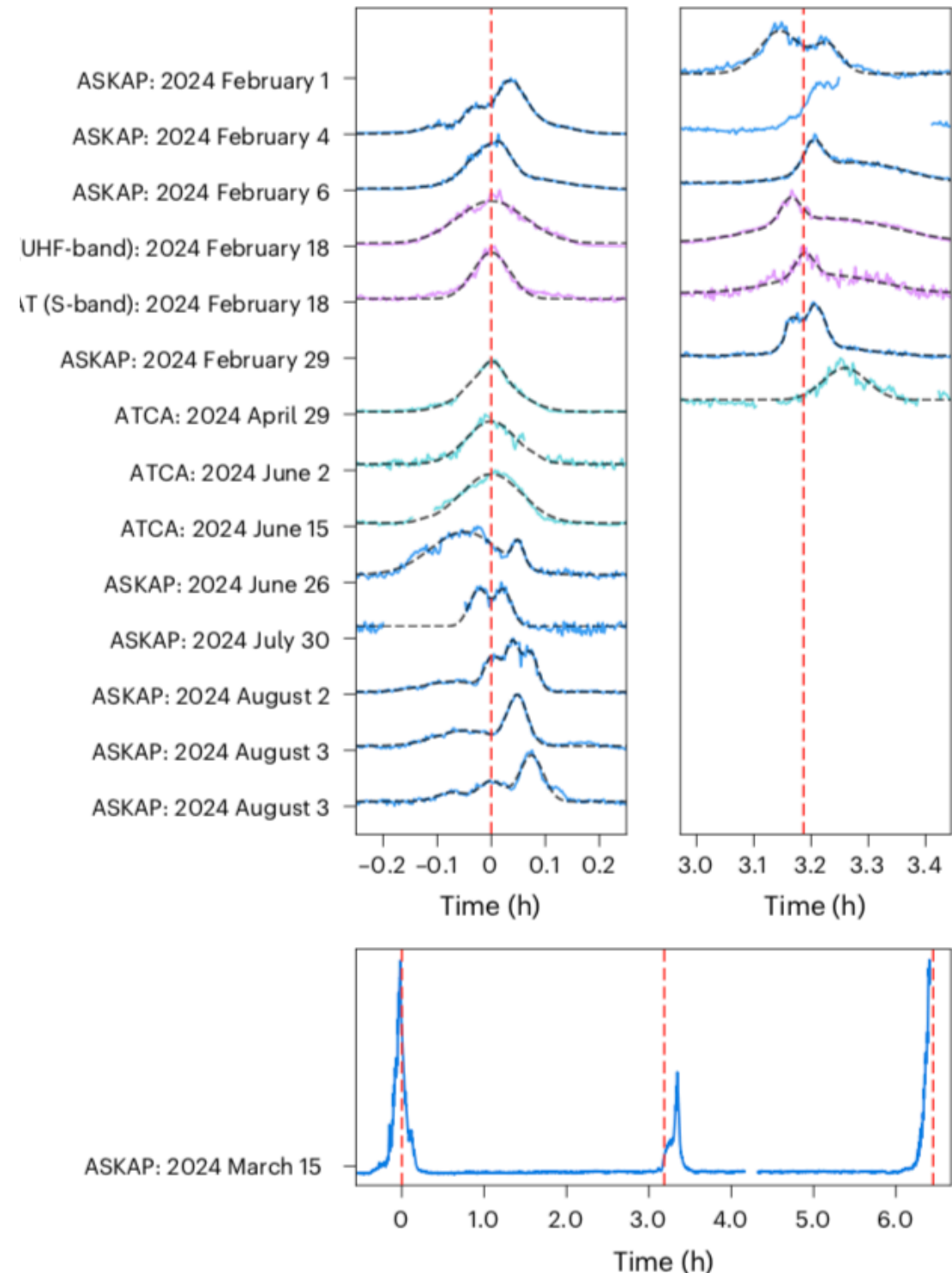
Pulse profiles



Light curves and dynamic spectra



Light curves

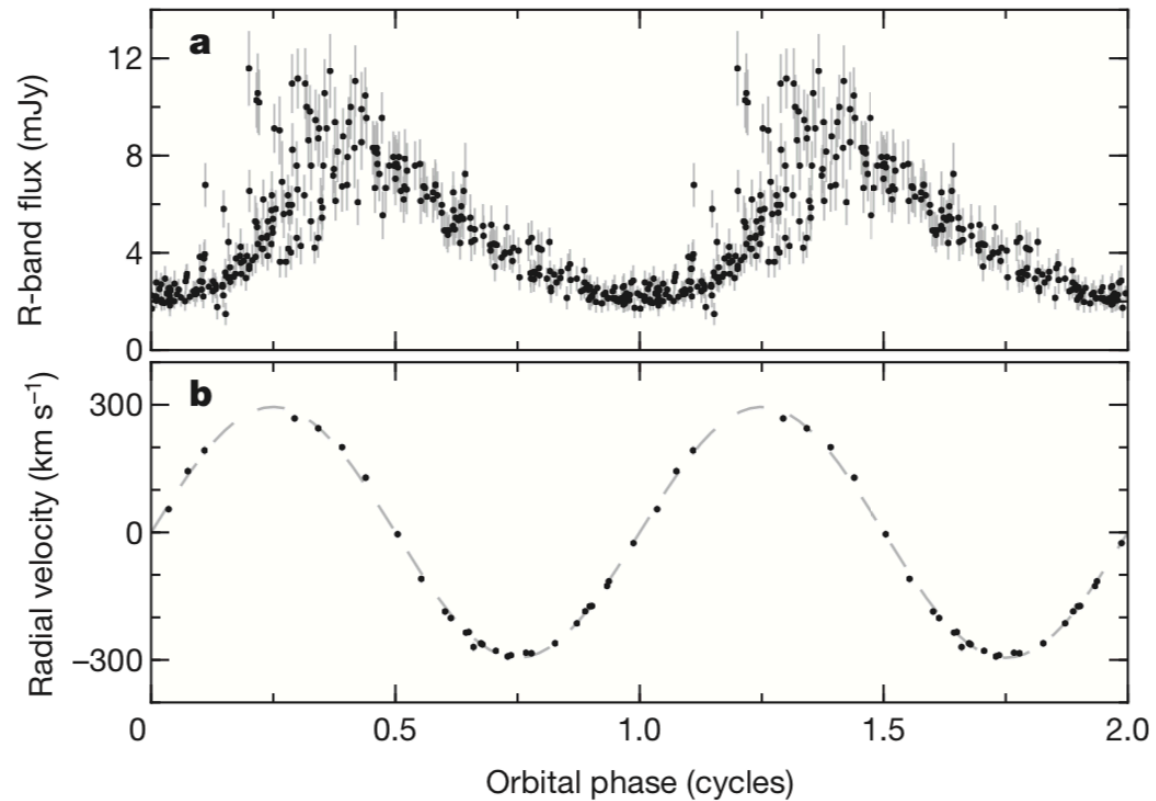


P=6.45 hr

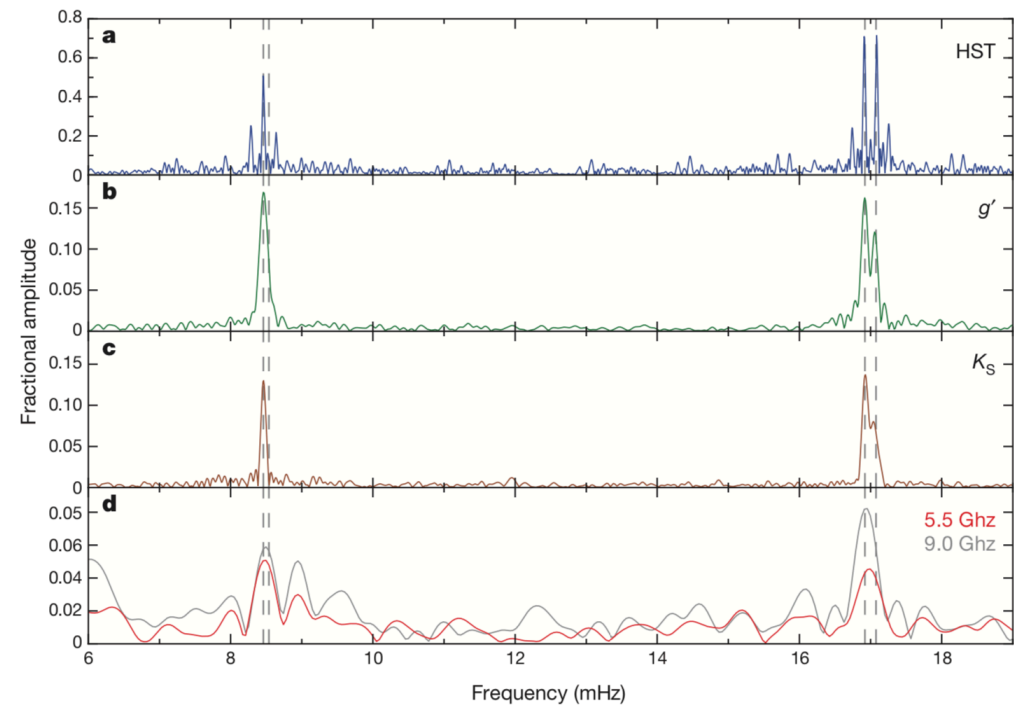
Lee et al. 2025,
Nature Astronomy

AR Scorpii as WD Pulsar

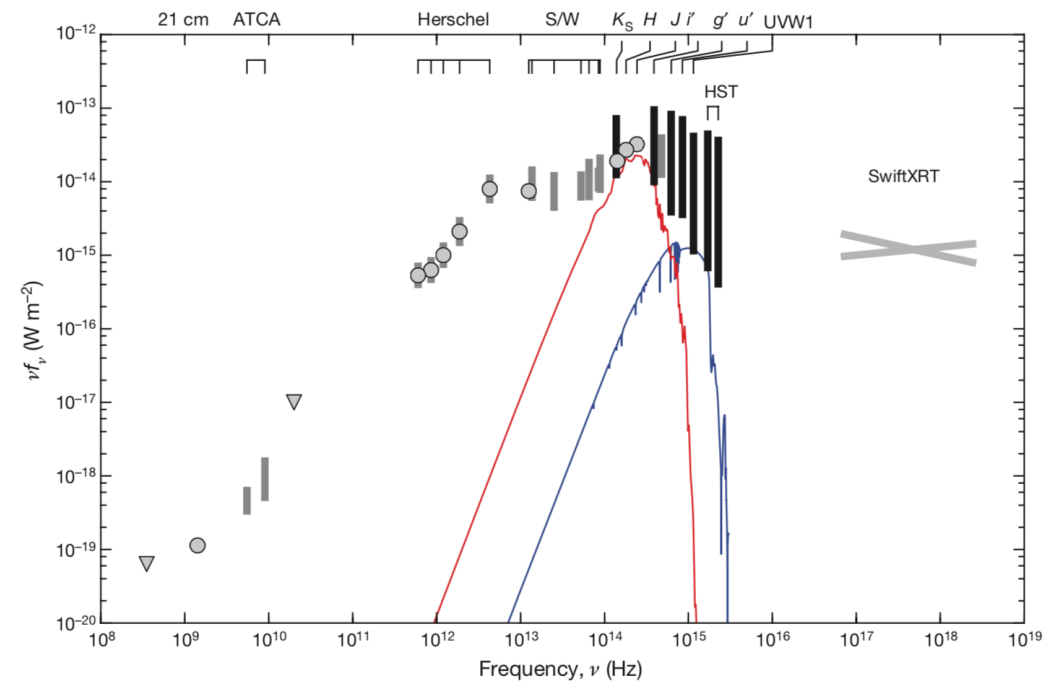
Optical light curve and radial velocity



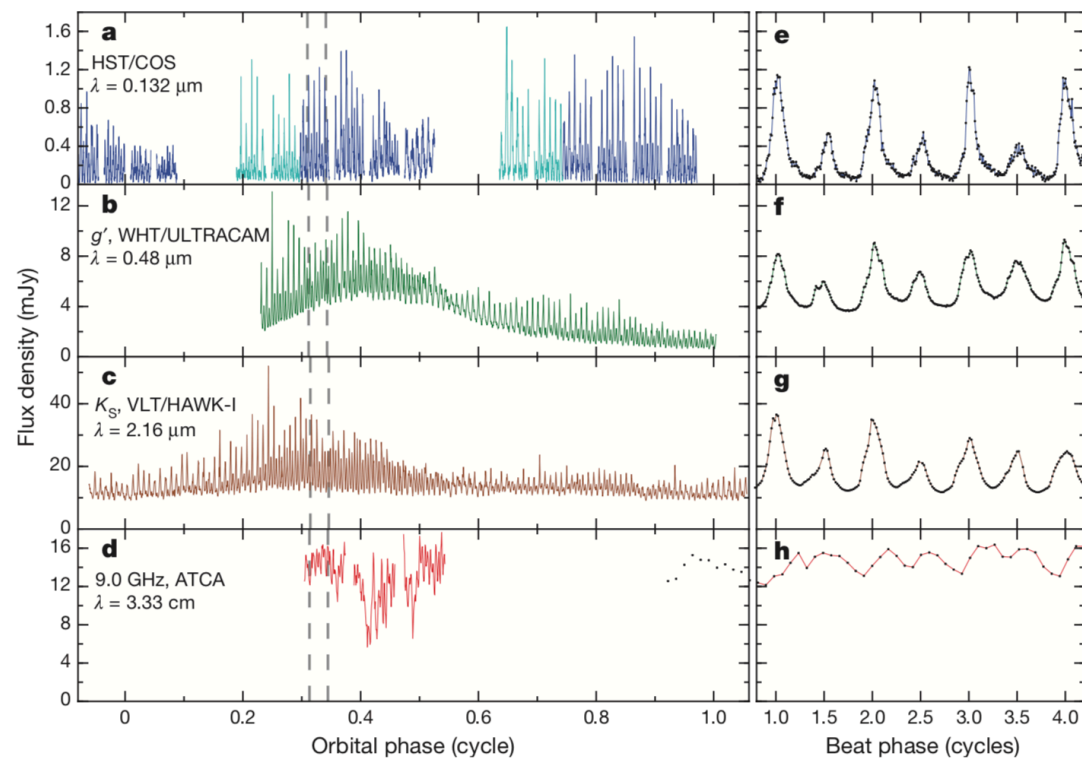
Fourier amplitudes



SED



Multiwavelength light curves



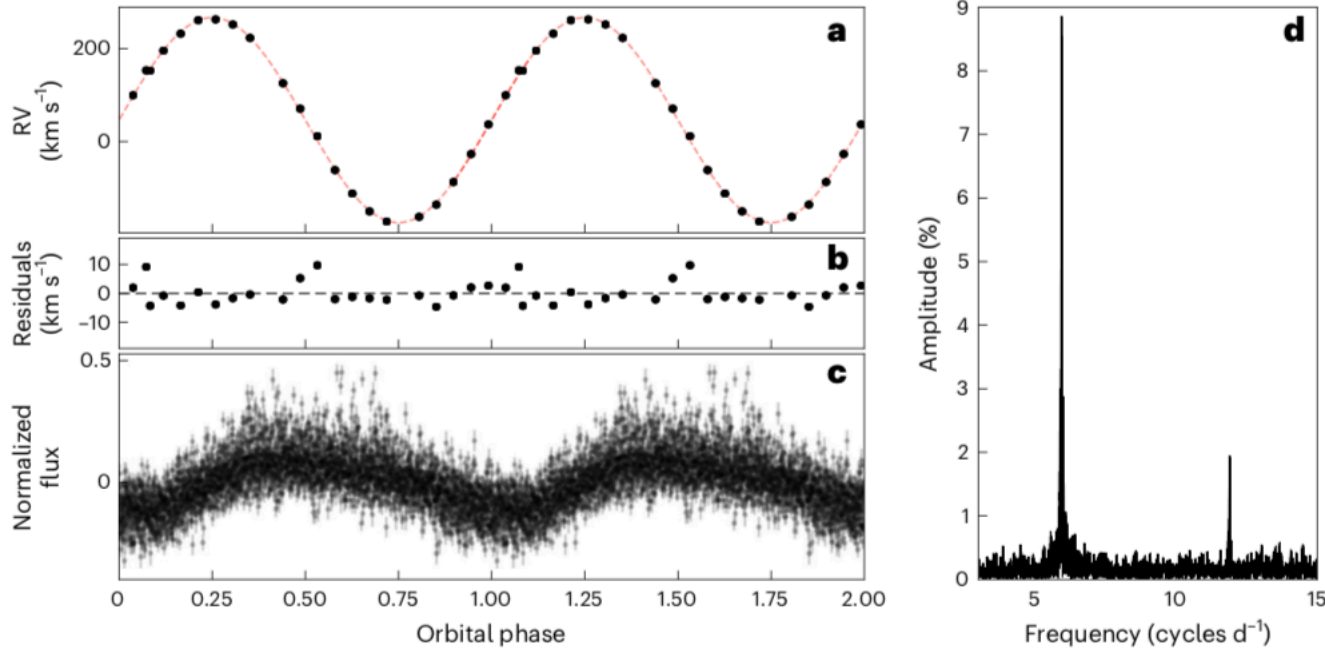
$P_{\text{spin}} = 1.97 \text{ min}$

$P_{\text{orb}} = 3.56 \text{ hr}$

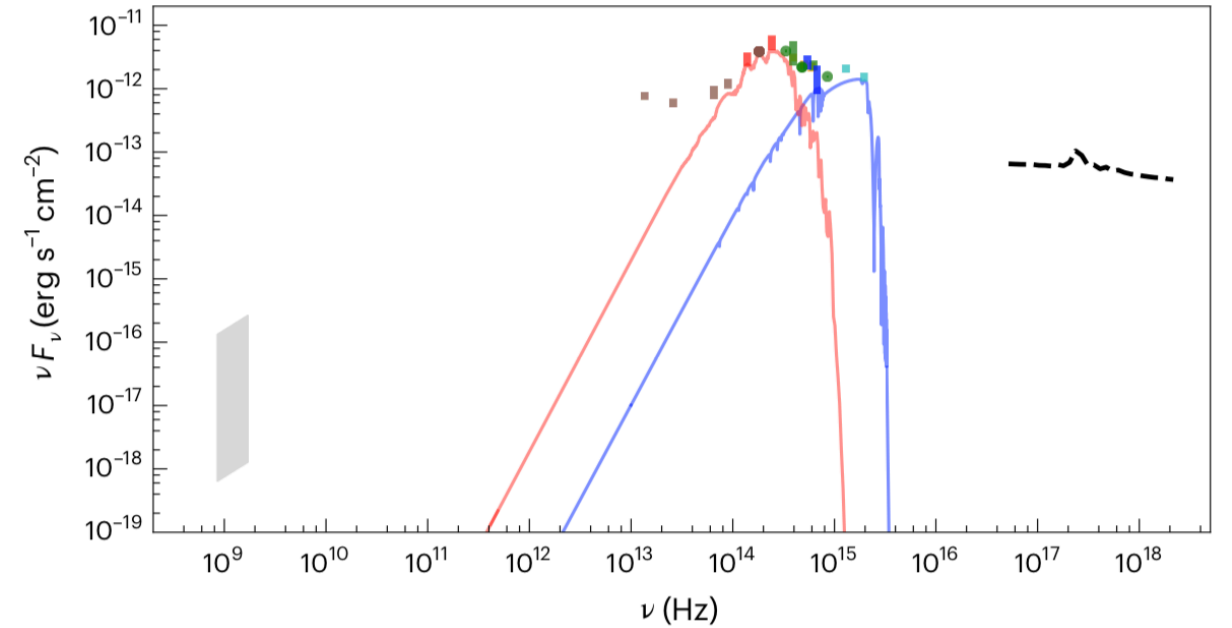
Marsh et al. 2016,
Nature

J191213.72-441045.1 as WD Pulsar

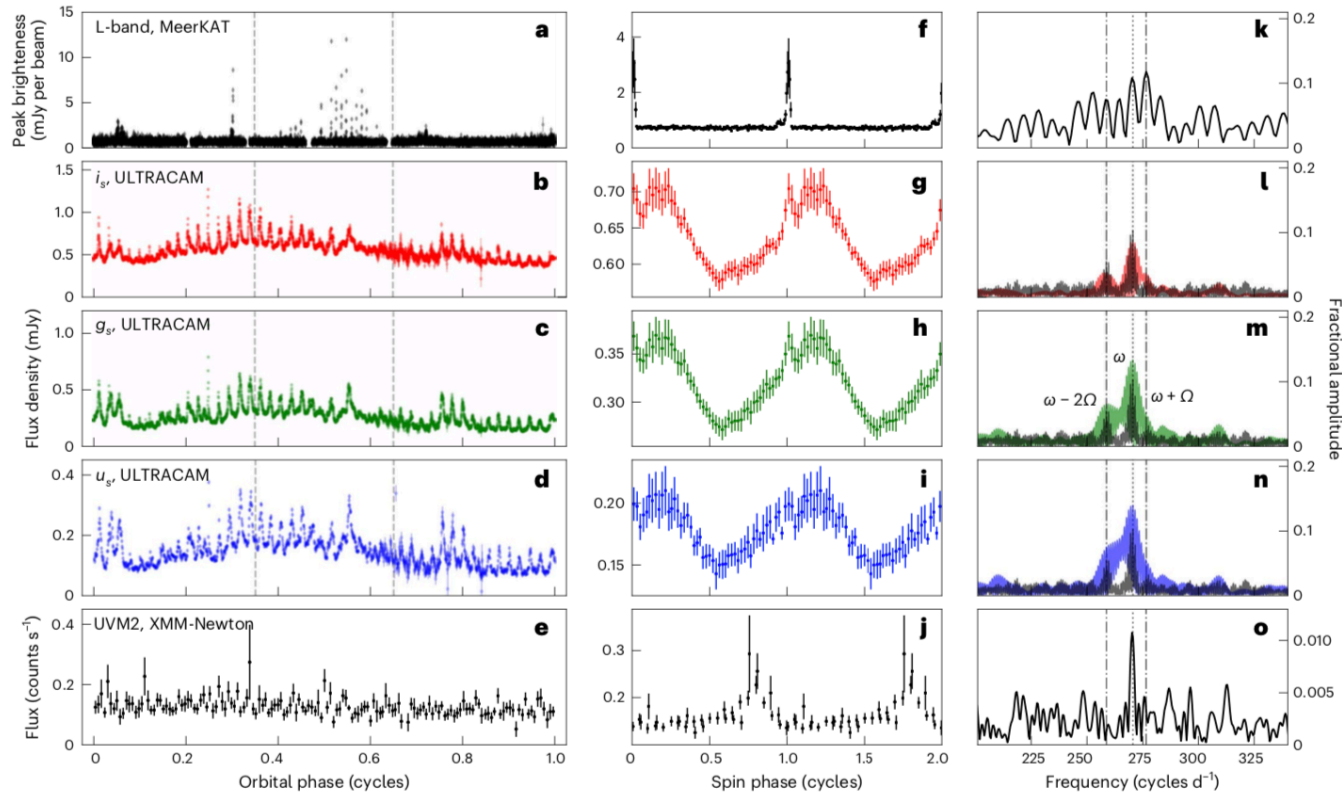
Photometry and radial velocities



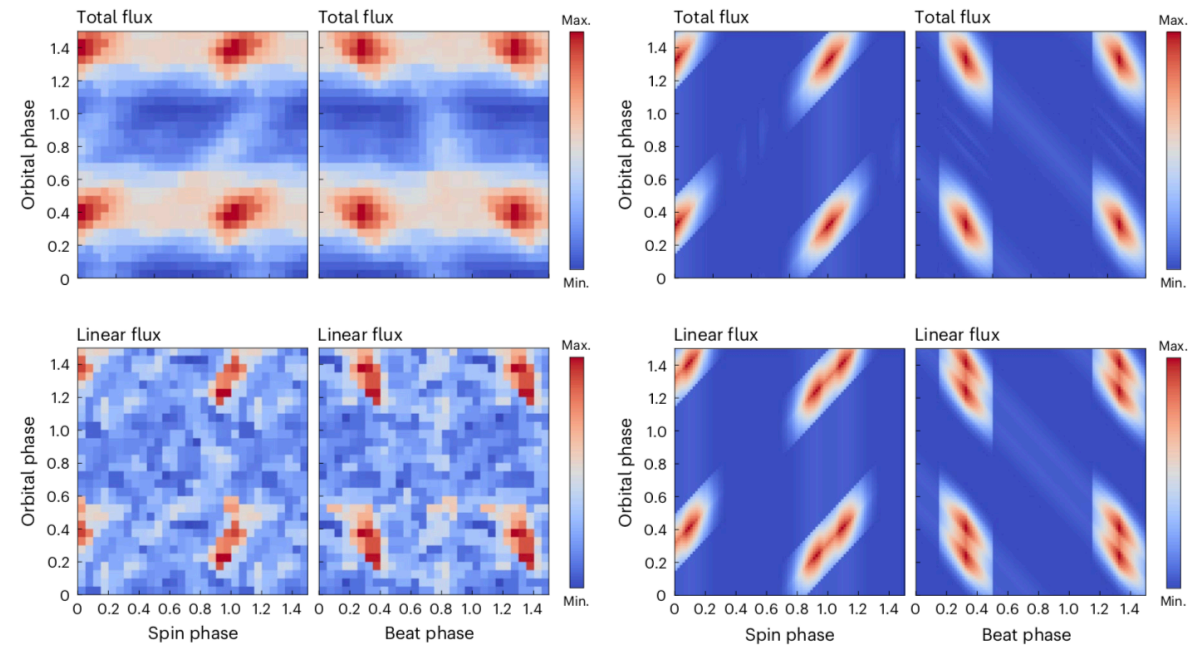
SED



Radio, optical and X-ray light curves



Photopolarimetry

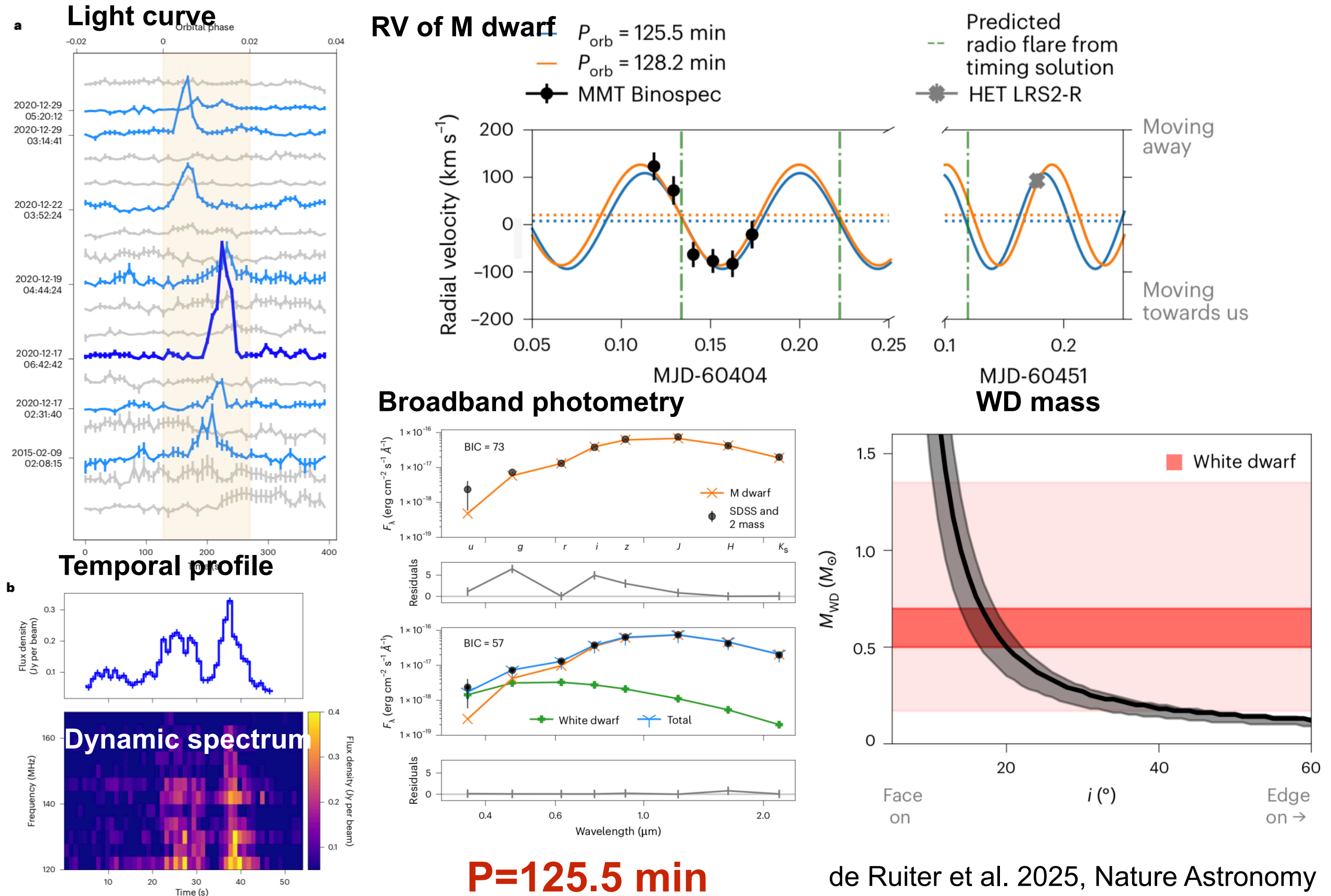


$P_{\text{spin}} = 5.30 \text{ min}$

$P_{\text{orb}} = 4.03 \text{ hr}$

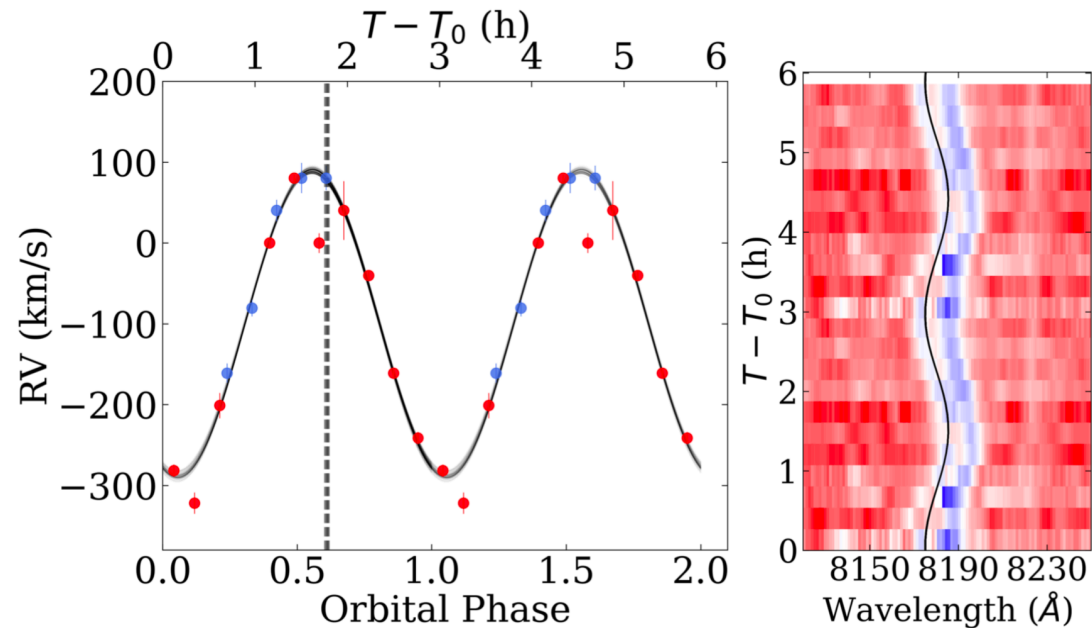
Pelisoli et al. 2023,
Nature Astronomy

ILT J1101+5521 in WD-MD Binary

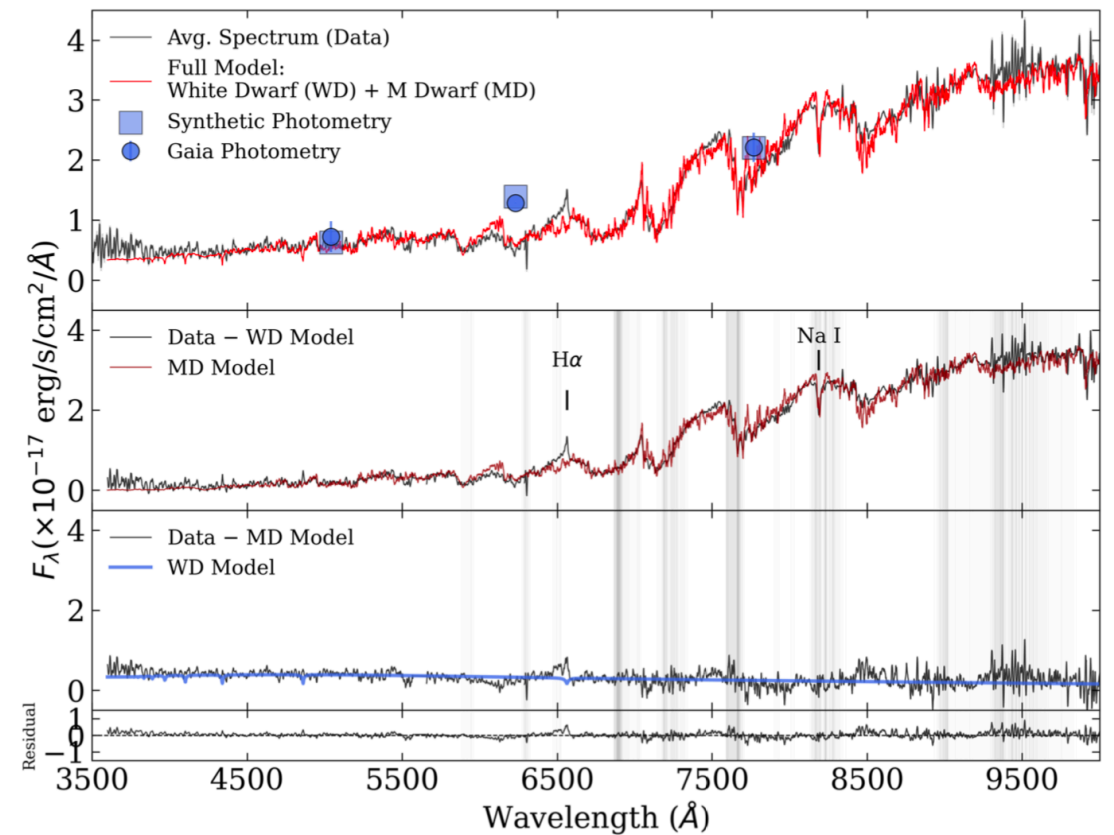


GLEAM-X J0704-37 in WD-MD Binary

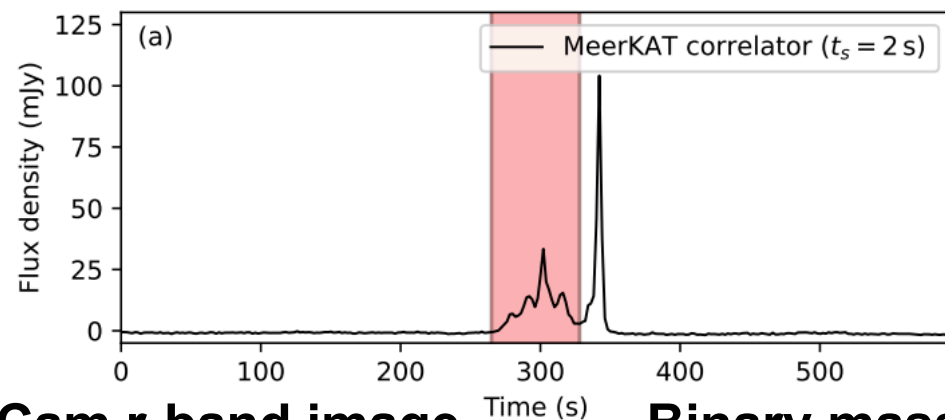
RV curve and trailed spectra



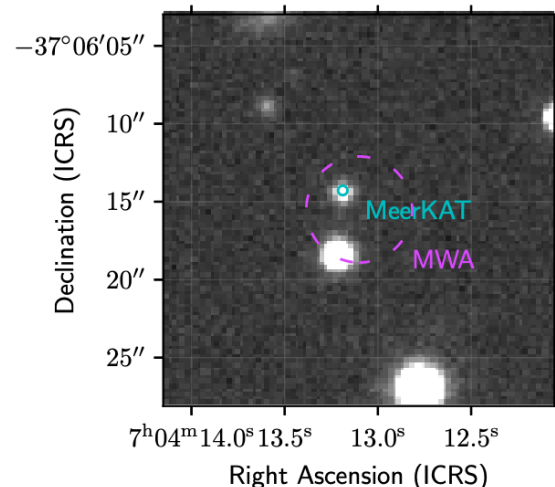
Optical spectrum



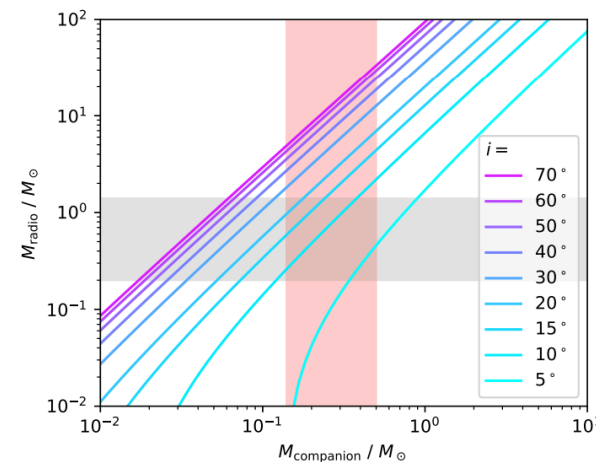
Light curve of one pulse



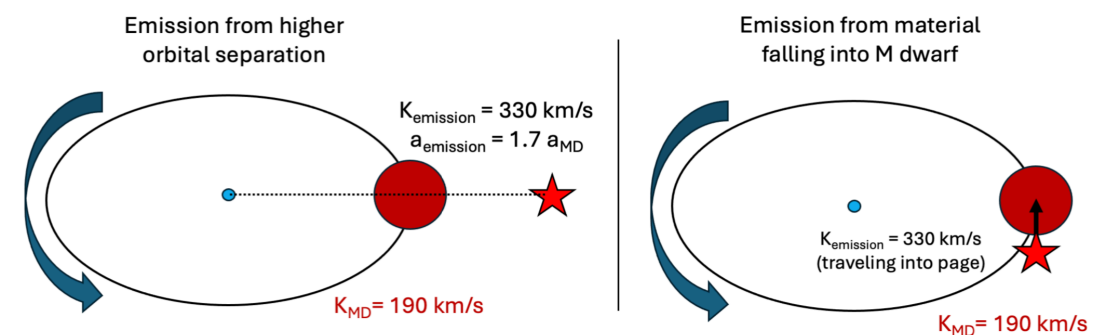
DECam r-band image



Binary mass



Possible scenarios of H α generation

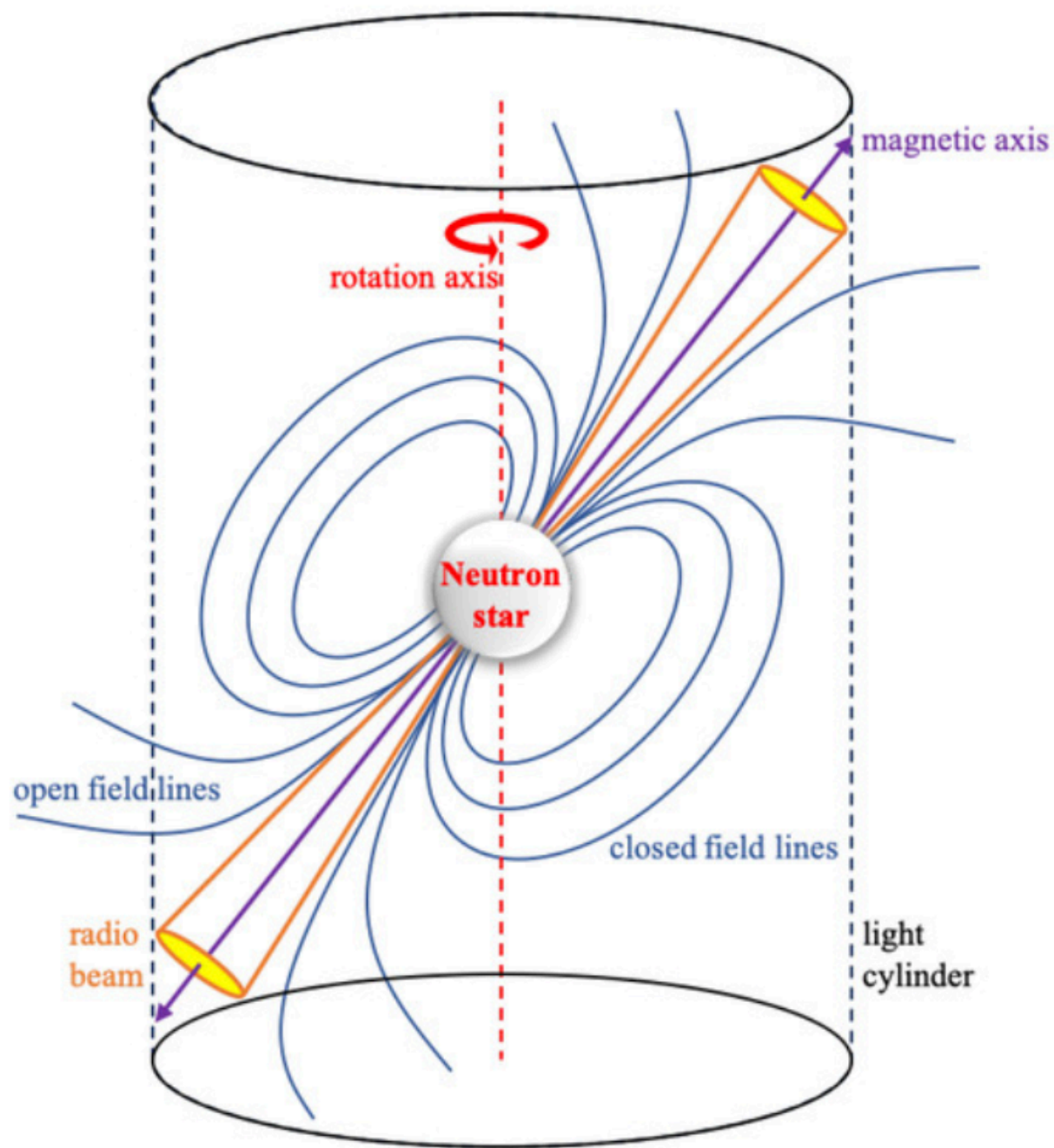


P=174 min

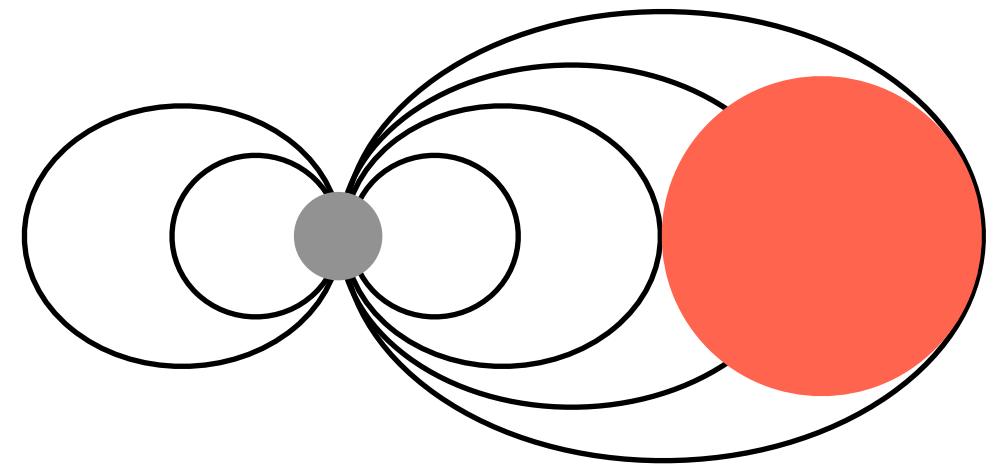
Hurley-Walker et al., 2024, ApJL
Rodriguez et al. 2025, A&A

Two Possible Physical Origins

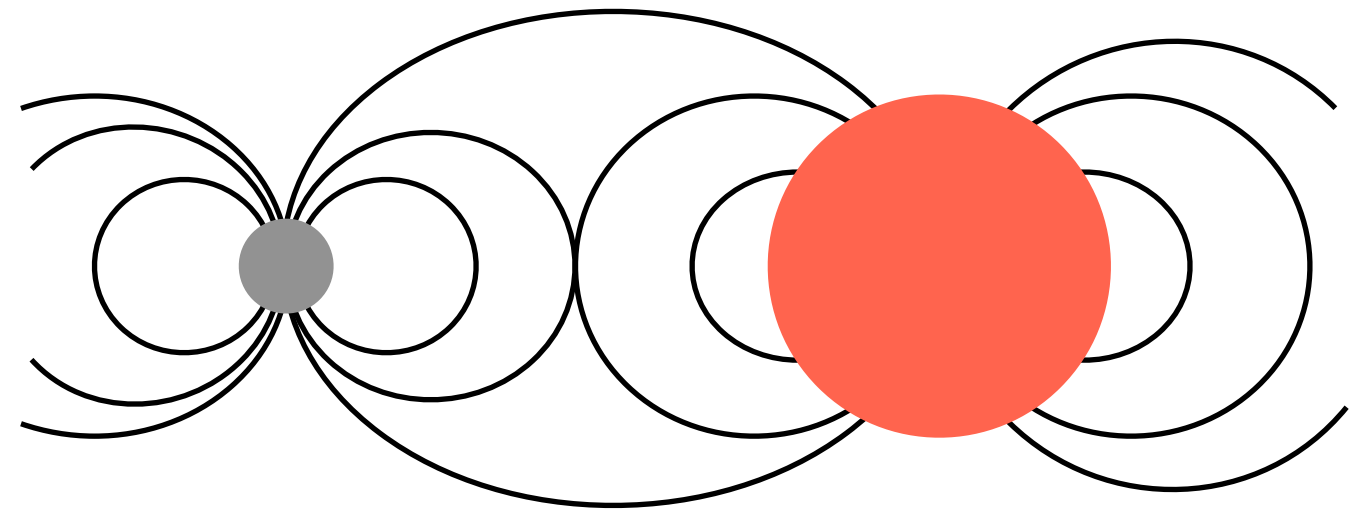
Rotating NS / WD



WD — MD Binary

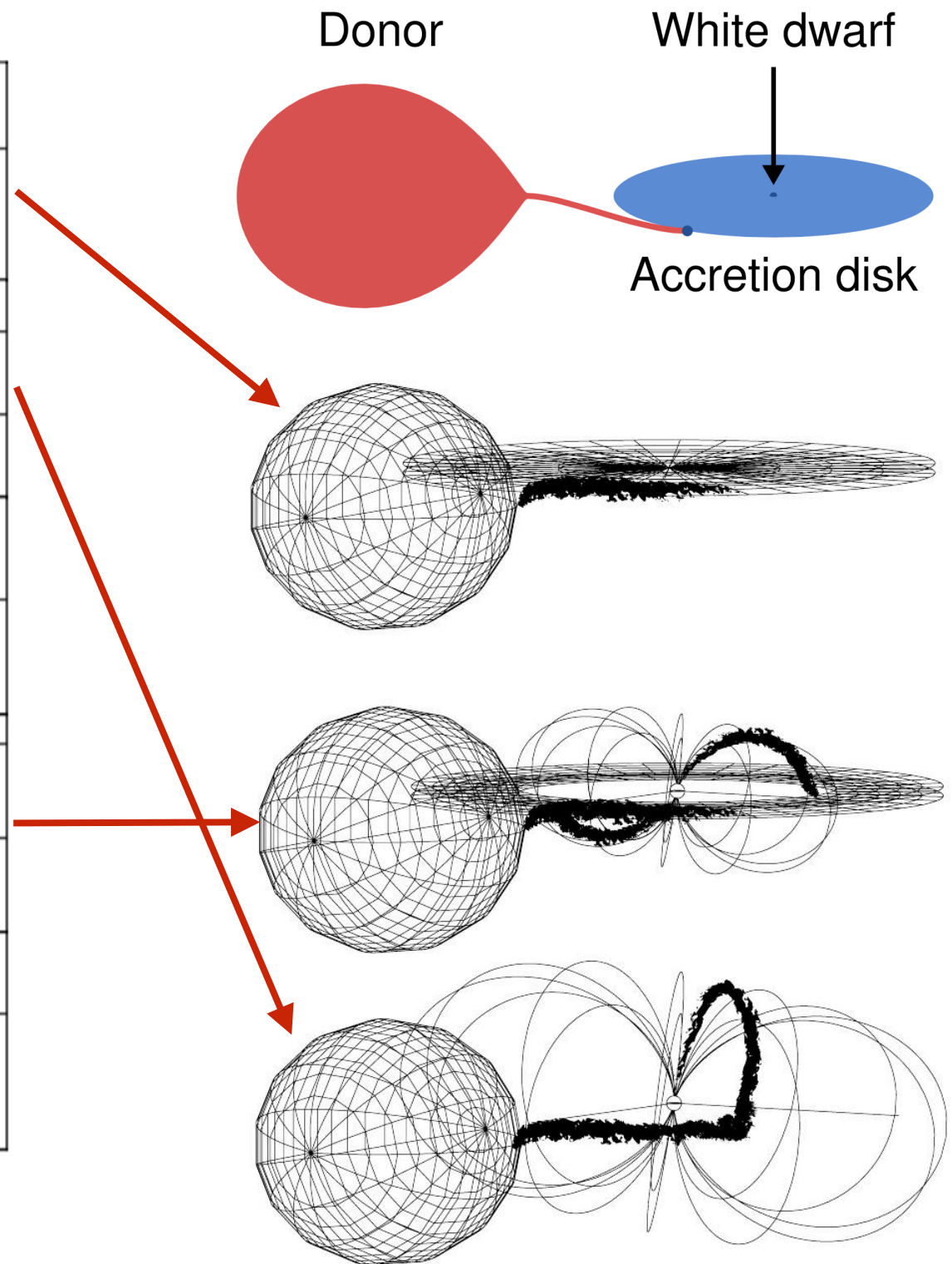
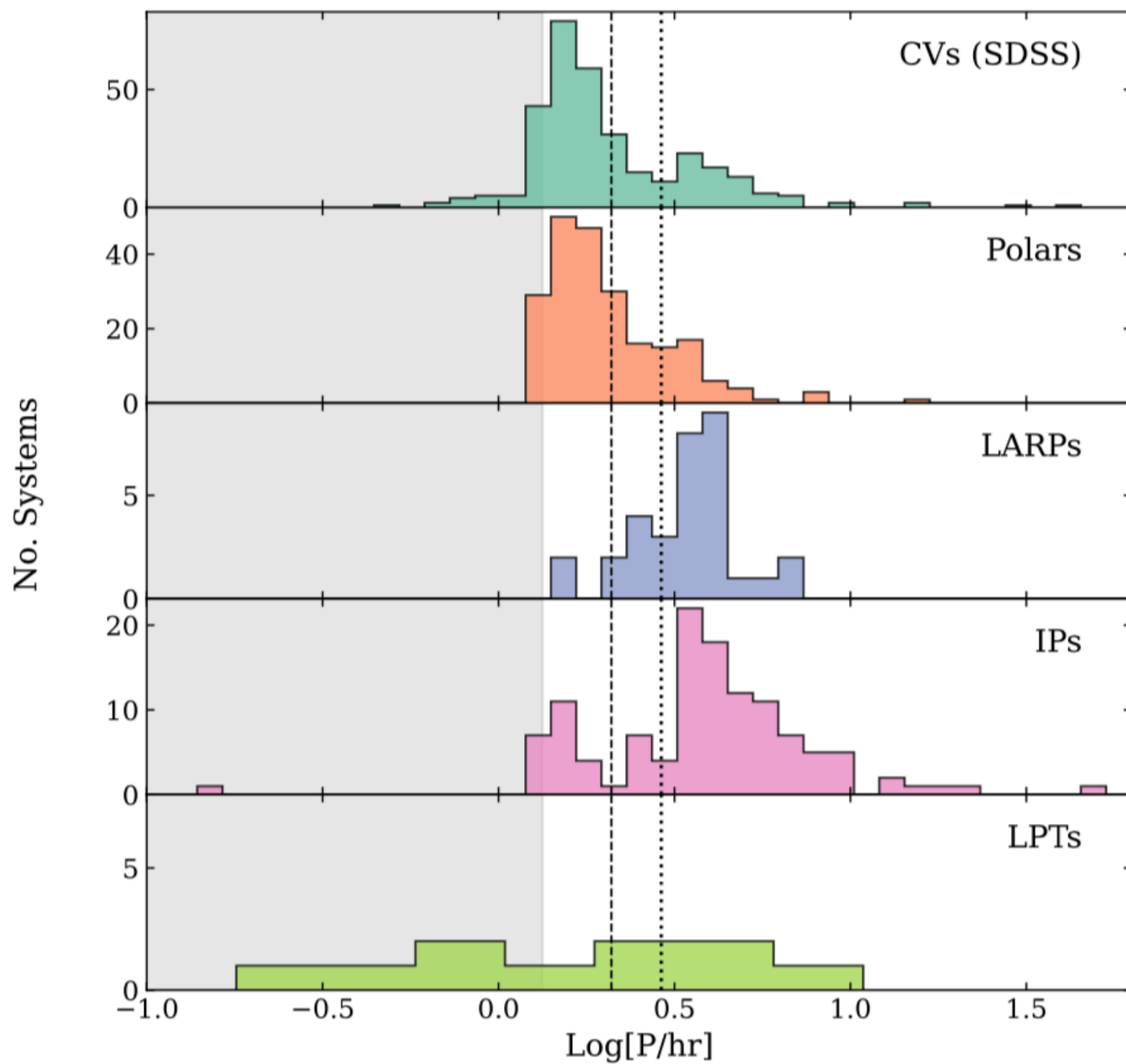


Unipolar Inductor



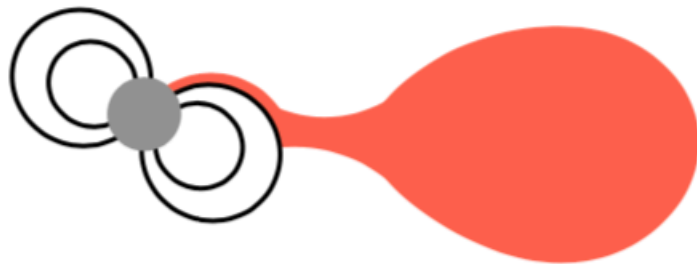
Magnetosphere Interaction

Period Distribution of LPTs

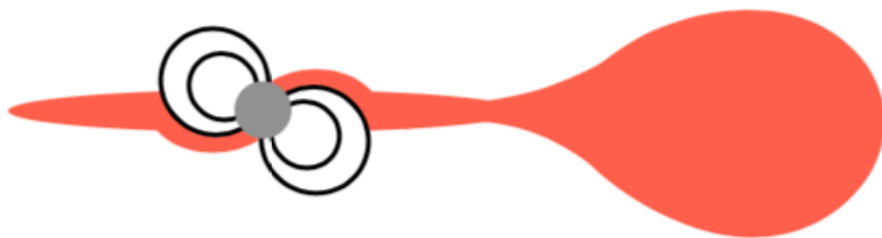


Evolutionary Stages

(a) Accretion Phase

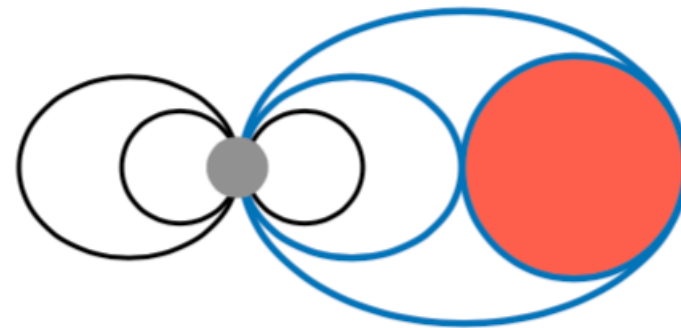


(1) Accretion Stream

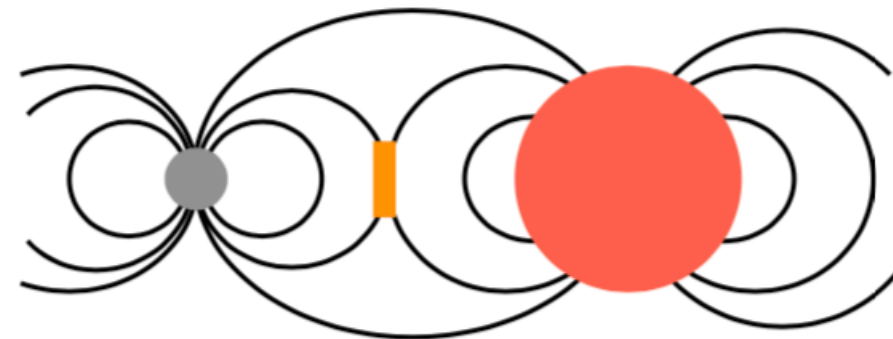


(2) Accretion Disk

(b) Unipolar—Inductor Phase

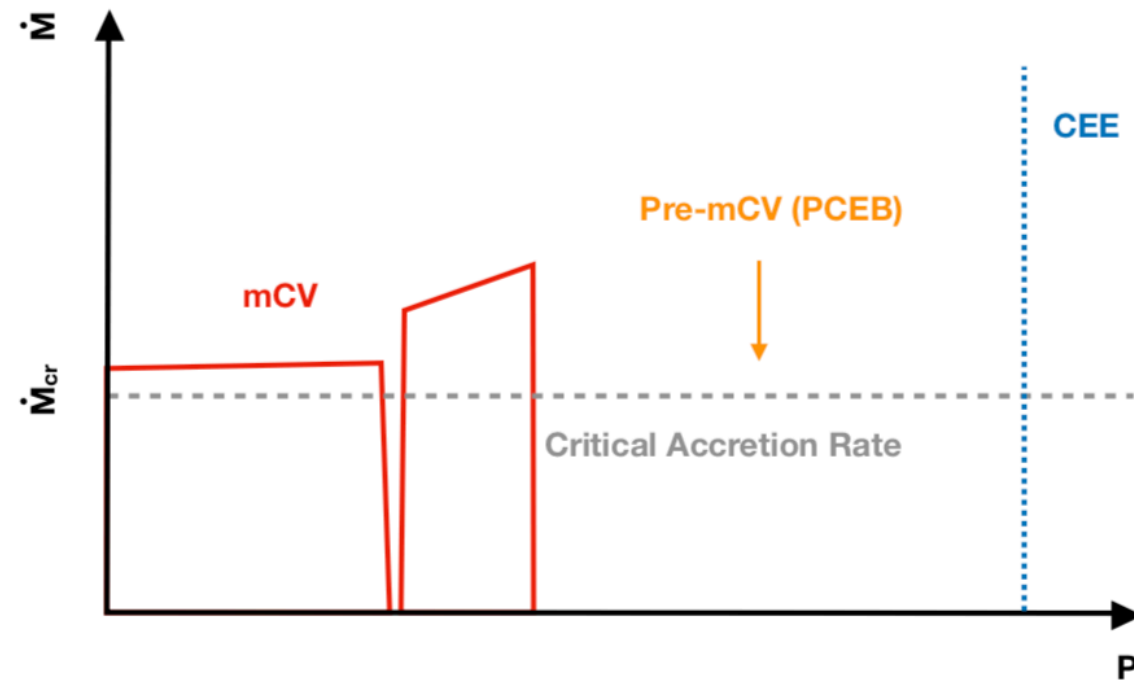


(c) Magnetosphere—Interaction Phase

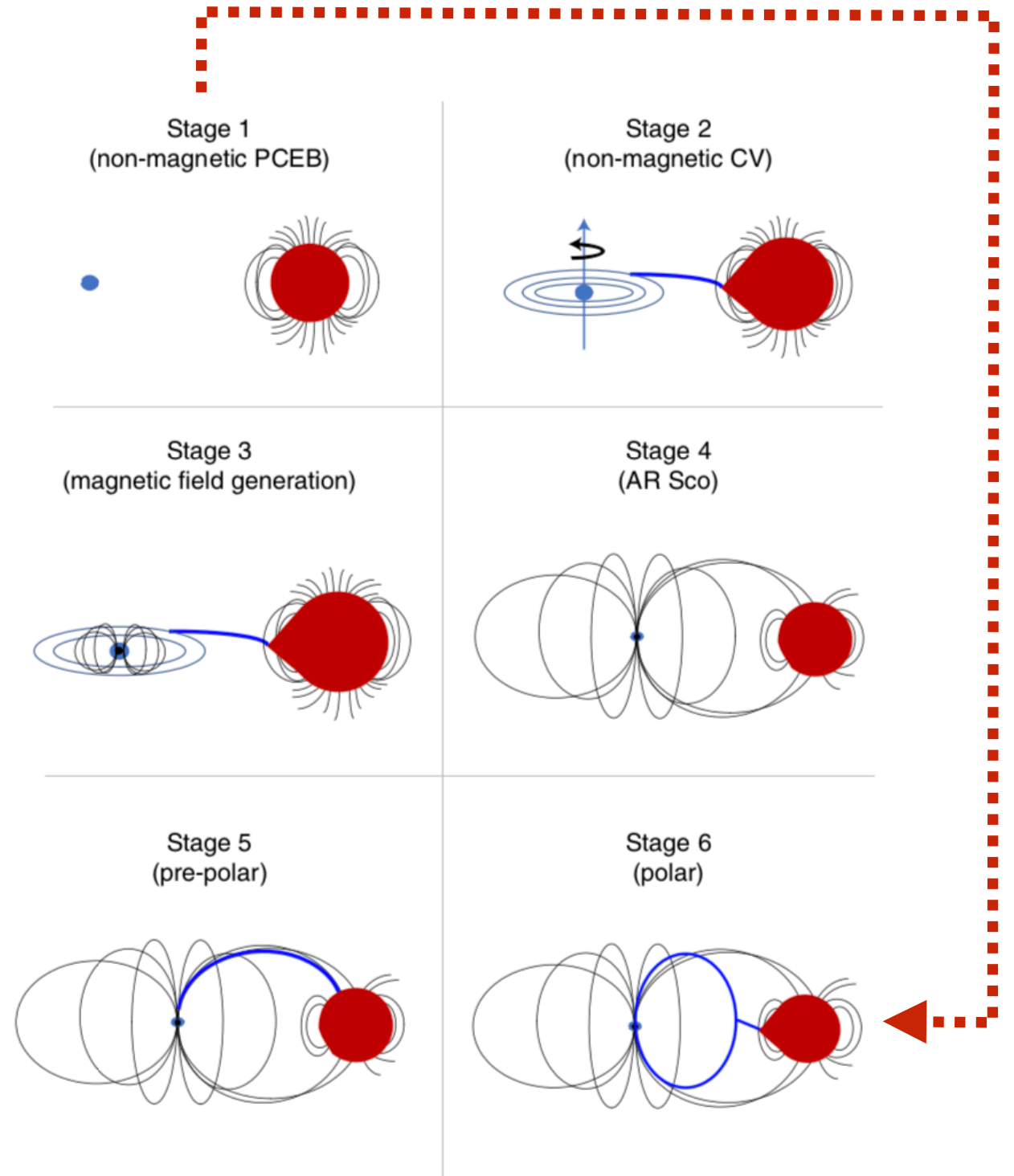
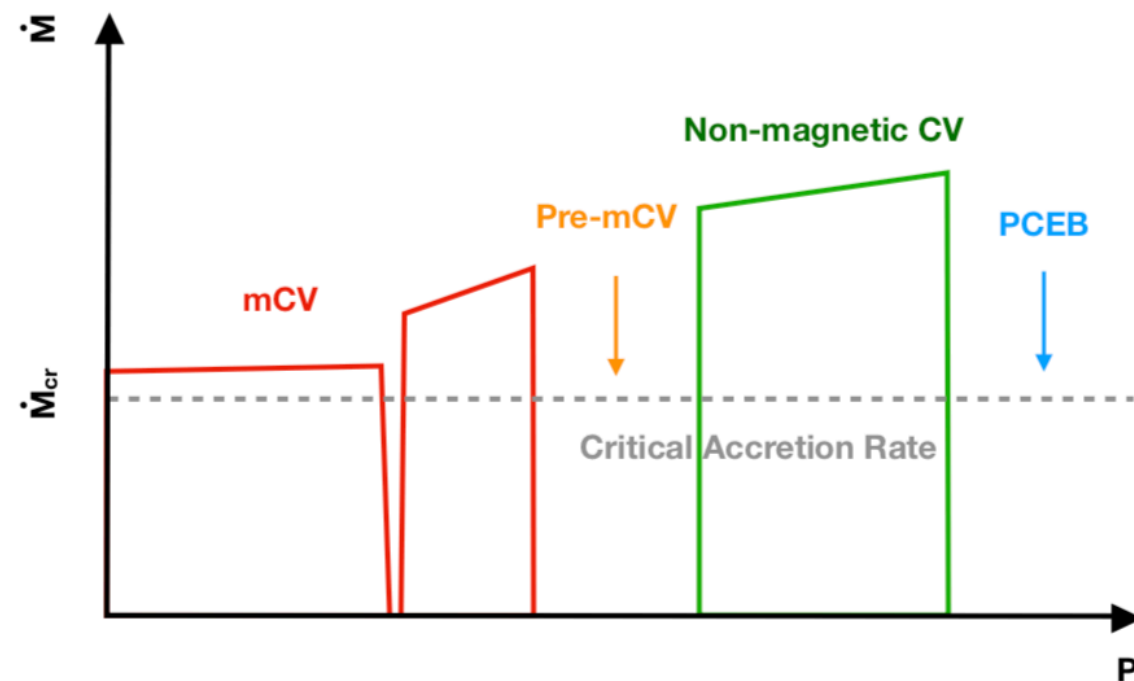


Accretion Evolution

(1) fossil field at birth or dynamo action during common-envelope evolution



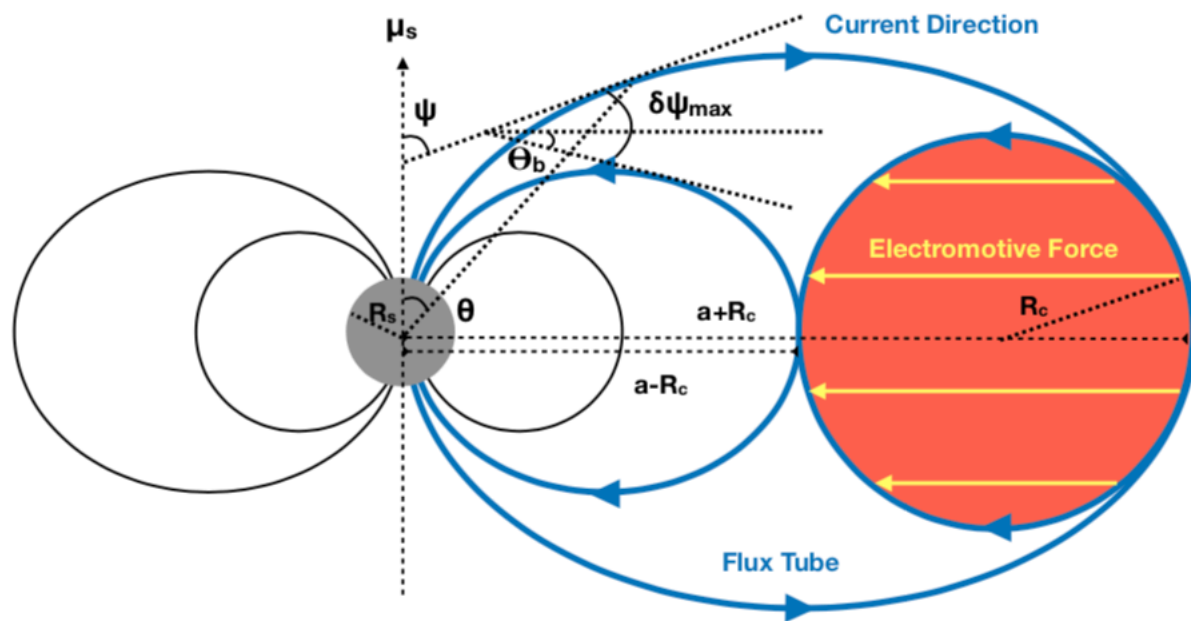
(2) crystallization- and rotation-driven dynamo during pre-mCV phase



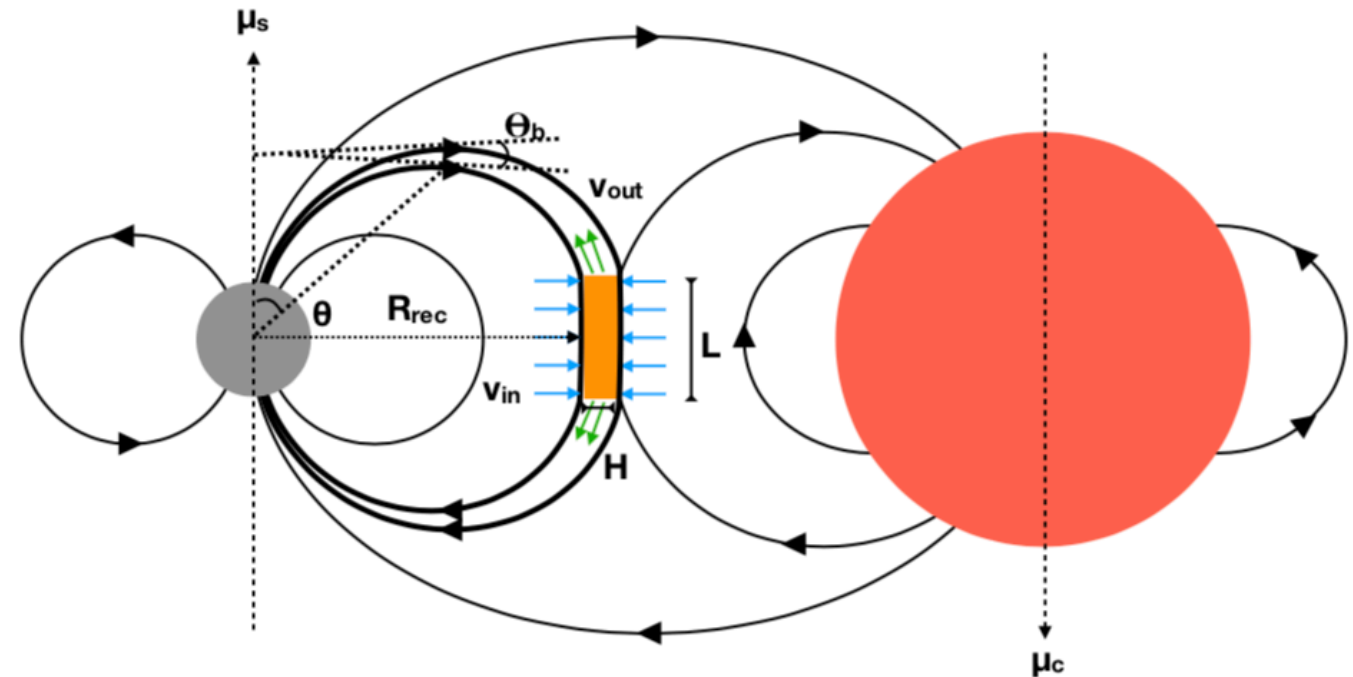
Schreiber et al. 2021, Nature Astronomy

Two Dissipation Mechanisms

Unipolar Inductor



Magnetosphere Interaction



Small separation:

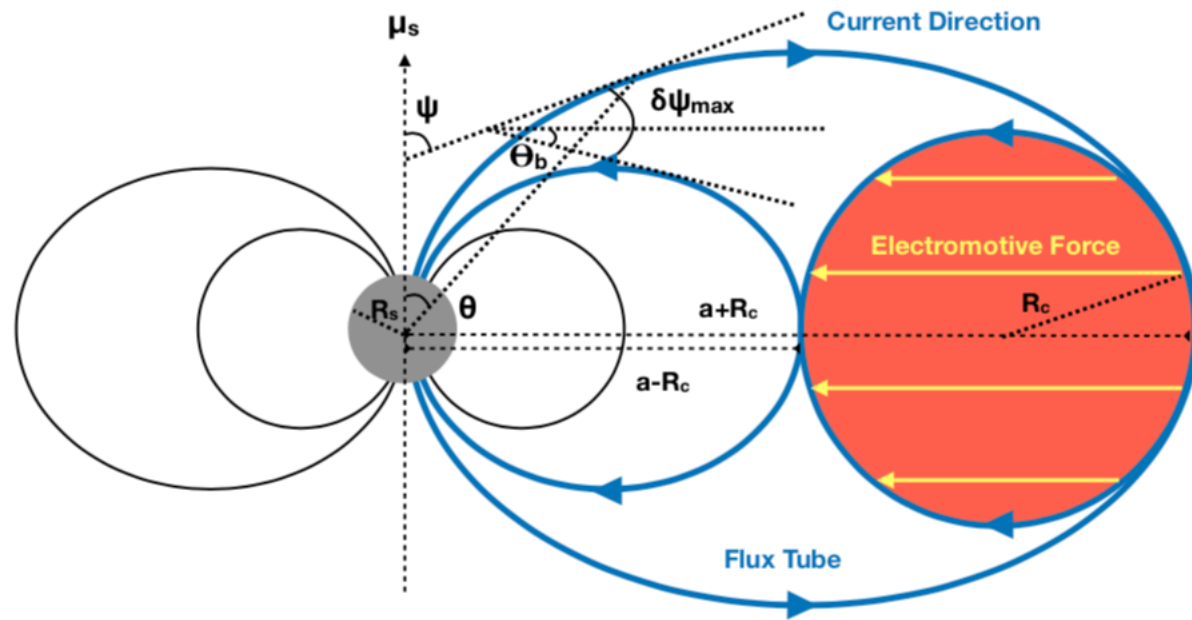
$$a \lesssim a_{\text{UI}} \equiv \left(\frac{\mu_s}{B_c} \right)^{1/3} \simeq 4.6 \times 10^{10} \text{ cm} \\ \times \left(\frac{\mu_s}{10^{34} \text{ G cm}^3} \right)^{1/3} \left(\frac{B_c}{10^2 \text{ G}} \right)^{-1/3}.$$

Large separation:

$$a \gtrsim a_{\text{UI}} \simeq 4.6 \times 10^{10} \text{ cm} \\ \times \left(\frac{\mu_s}{10^{34} \text{ G cm}^3} \right)^{1/3} \left(\frac{B_c}{10^2 \text{ G}} \right)^{-1/3}$$

Two Dissipation Mechanisms

Unipolar Inductor



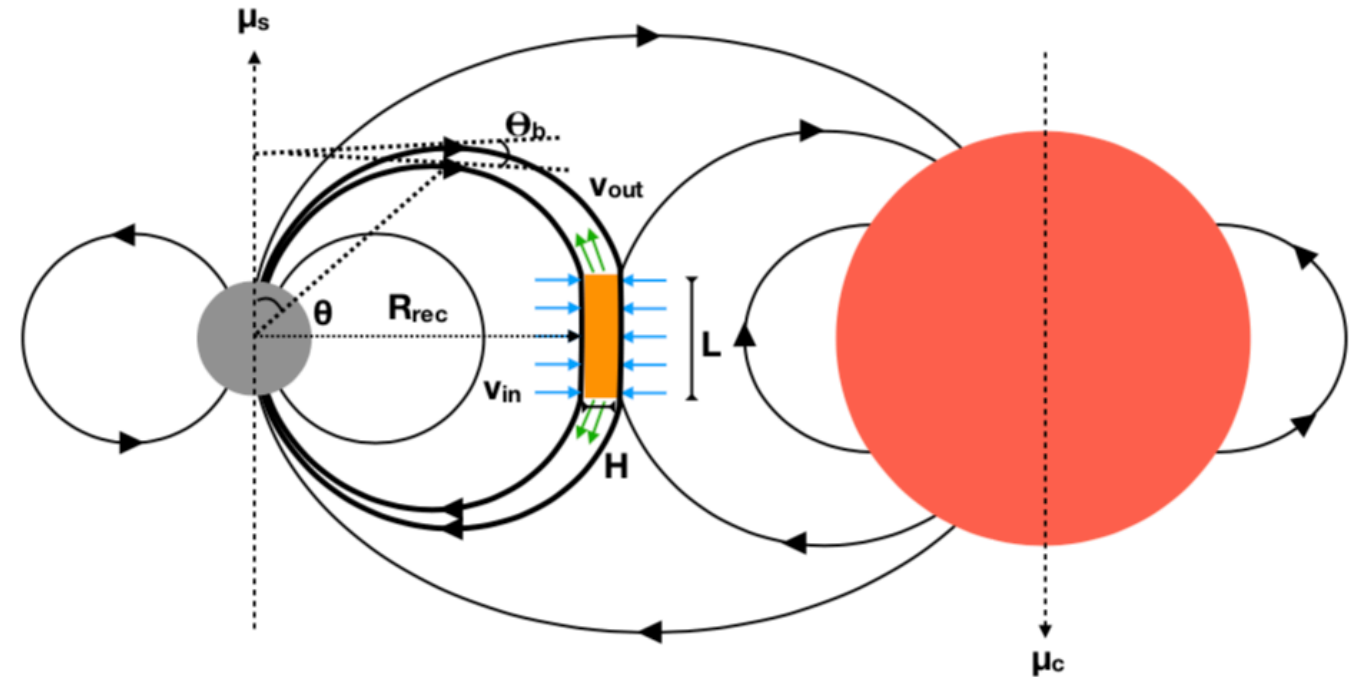
Energy dissipation rate:

$$\dot{E} \simeq 3.9 \times 10^{28} \text{ erg s}^{-1} \left(\frac{\mu_s}{10^{34} \text{ G cm}^3} \right)^2 \left(\frac{R_c}{10^{10} \text{ cm}} \right)^2$$

$$\times \left(\frac{P}{100 \text{ min}} \right)^{-14/3} \left(\frac{M_s + M_c}{M_\odot} \right)^{-4/3} \left(\frac{\Delta\Omega}{\Omega} \right)^2 \text{unsaturated}$$

$$\dot{E} \simeq 1.8 \times 10^{31} \text{ erg s}^{-1} \left(\frac{\mu_s}{10^{34} \text{ G cm}^3} \right)^2 \left(\frac{R_c}{10^{10} \text{ cm}} \right)^2 \times \left(\frac{P}{100 \text{ min}} \right)^{-13/3} \left(\frac{M_s + M_c}{M_\odot} \right)^{-5/3} \left(\frac{\Delta\Omega}{\Omega} \right) \text{ saturated}$$

Magnetosphere Interaction



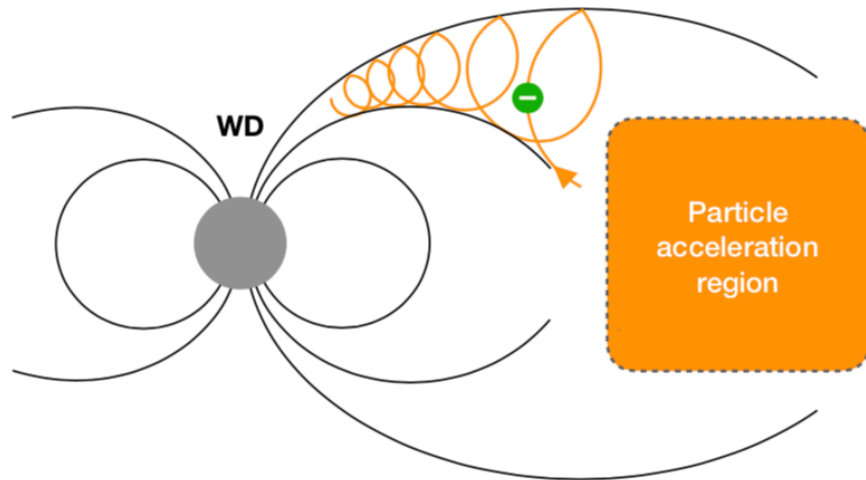
Energy dissipation rate:

$$\begin{aligned} \dot{E} &= N_B \Delta\Omega \sim \frac{\mu_s \mu_c \Omega^2 \Delta\Omega}{G(M_s + M_c)} \simeq 8.6 \times 10^{31} \text{ erg s}^{-1} \\ &\times \left(\frac{\mu_s}{10^{34} \text{ G cm}^3} \right) \left(\frac{\mu_c}{10^{33} \text{ G cm}^3} \right) \left(\frac{P}{100 \text{ min}} \right)^{-3} \\ &\times \left(\frac{M_s + M_c}{M_\odot} \right)^{-1} \left(\frac{\Delta\Omega}{\Omega} \right). \end{aligned}$$

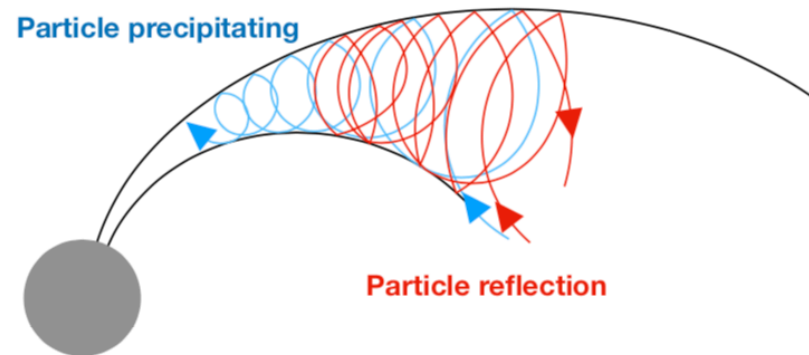
LPT luminosity strongly depend on P!

Radiation Mechanism: LCDM

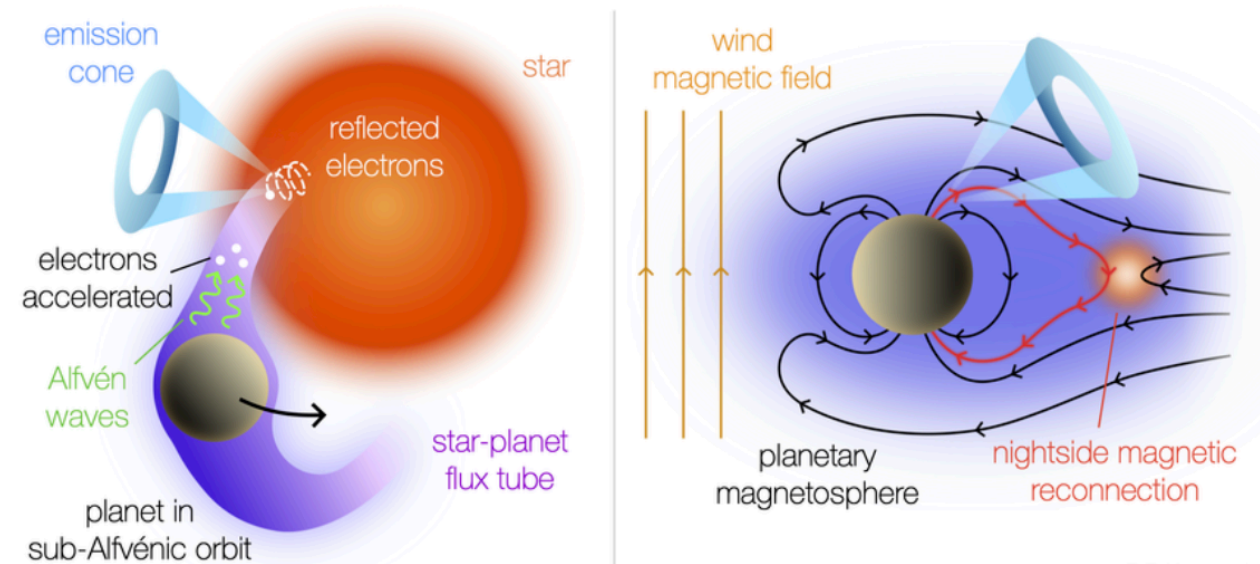
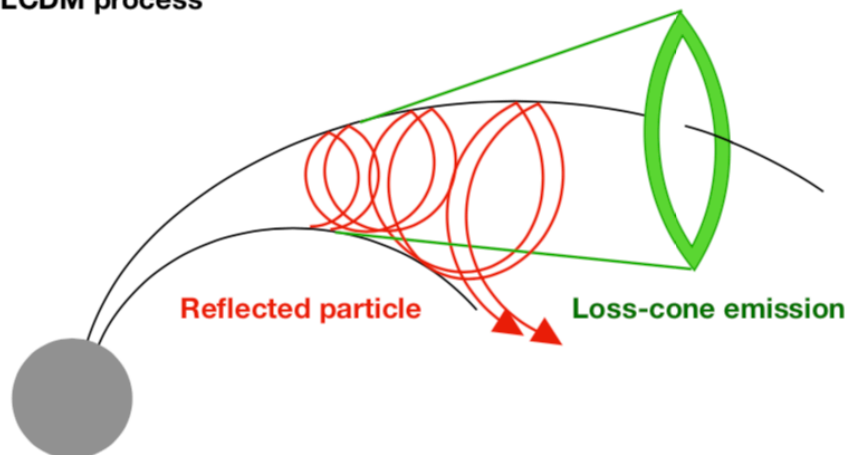
(a) Magnetic mirror in magnetosphere



(b) Formation of loss-cone particle distribution



(c) LCDM process



Typical frequency:

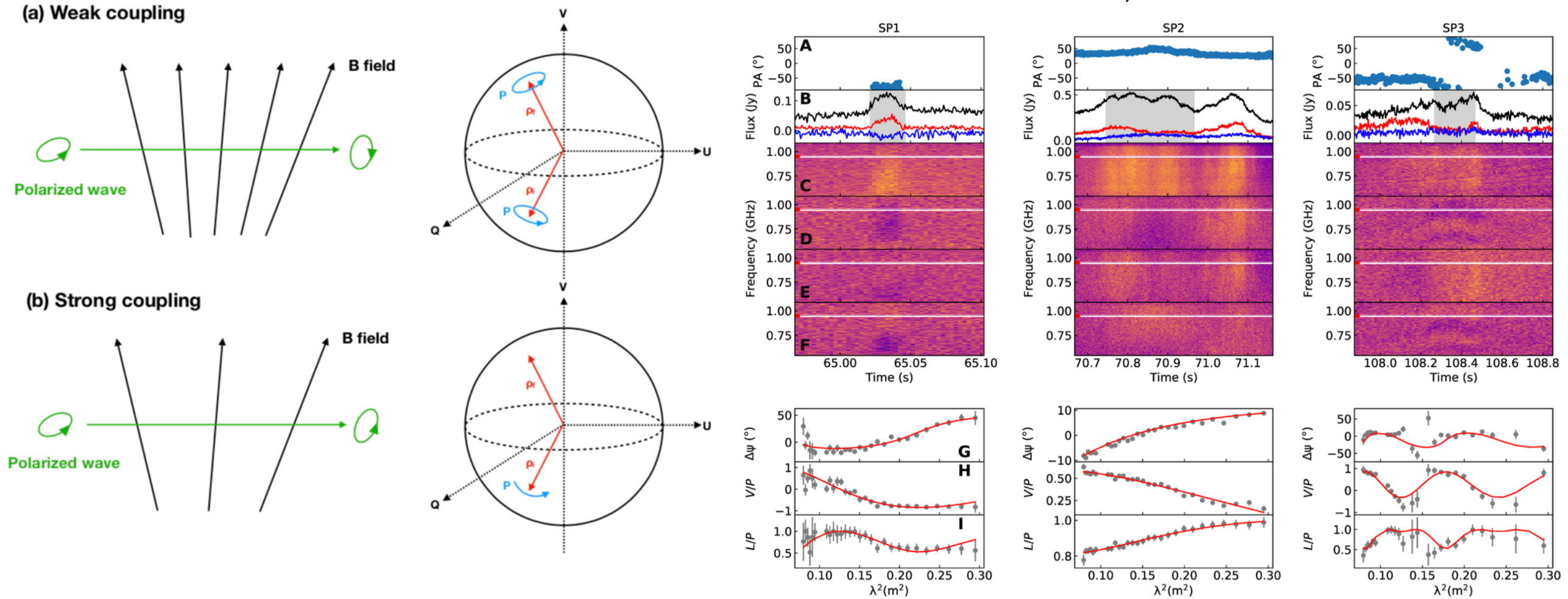
$$\nu \simeq \nu_B \sim \frac{e\mu_s}{2\pi m_e c r^3} \simeq 230 \text{ MHz} \left(\frac{\mu_s}{10^{34} \text{ G cm}^3} \right) \times \left(\frac{P}{100 \text{ min}} \right)^{-2} \left(\frac{M_s + M_c}{M_\odot} \right)^{-1} \left(\frac{r}{a} \right)^{-3}.$$

Predict brightness temperature:

$$T_B \simeq \frac{\pi m_e^2 c^4 v_0^2}{e^2 k_B L \omega^2} \simeq 3.1 \times 10^{13} \text{ K} \left(\frac{v_0}{0.1c} \right)^2 \left(\frac{\nu}{100 \text{ MHz}} \right)^{-2} \times \left(\frac{P}{100 \text{ min}} \right)^{-2/3} \left(\frac{M_s + M_c}{M_\odot} \right)^{-1/3} \left(\frac{L}{a} \right)^{-1},$$

Propagation Effect: Faraday Conversion

Men et al. 2025, Science Advances



Weak-field regime:

$$\Delta k \simeq \frac{\omega_p^2 \omega_B}{c \omega^2} \begin{cases} |\cos \theta|, & \text{QL} \\ \frac{\omega_B}{2\omega} \sin^2 \theta, & \text{QT} \end{cases}$$

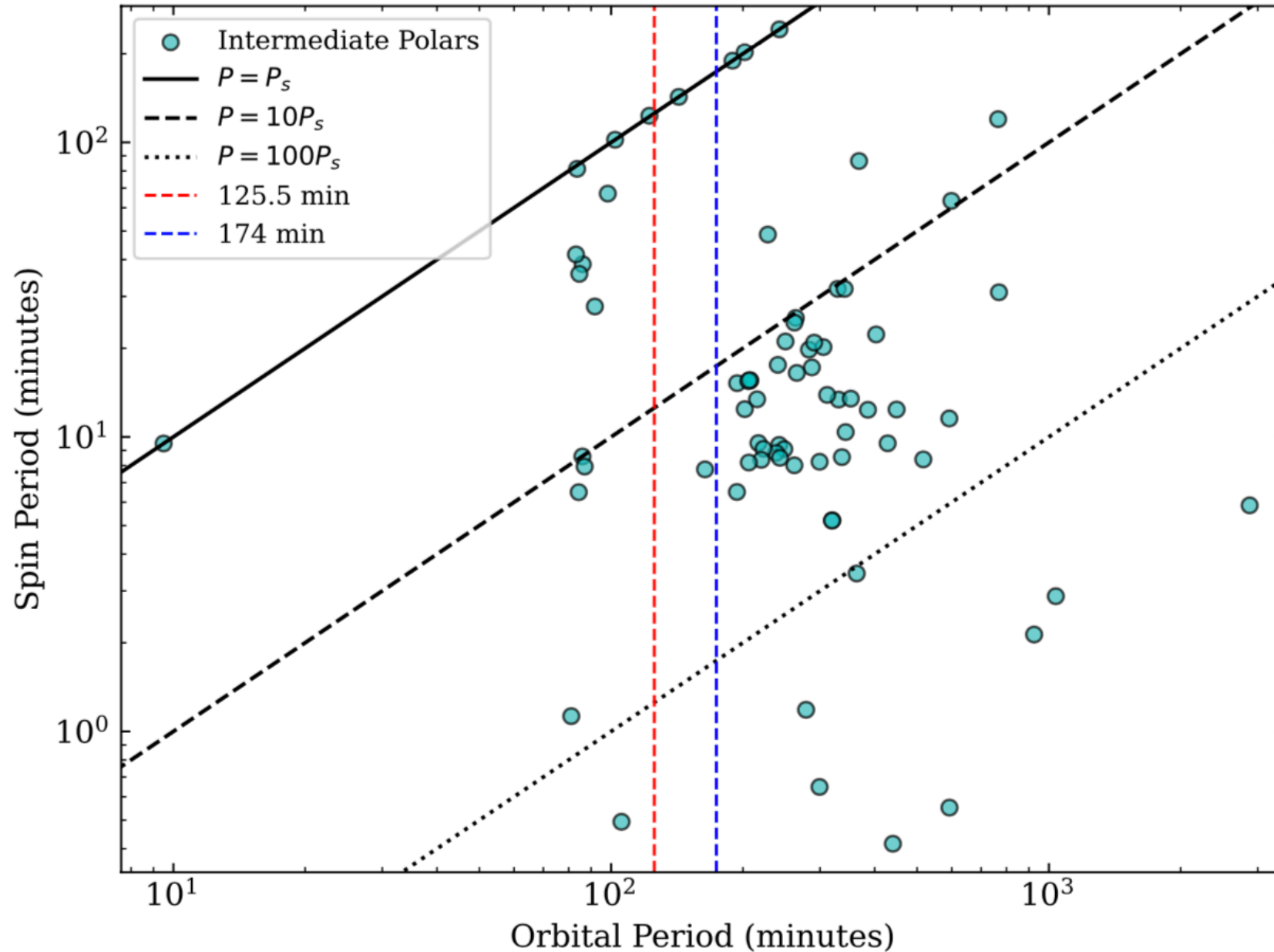
Strong-field regime:

$$\Delta k \simeq \frac{\omega_p^2}{c \omega} \begin{cases} \frac{\omega}{\omega_B} |\cos \theta|^{-1}, & \text{QL} \\ 1/2, & \text{QT} \end{cases}$$

Coupling effect:

$$C \simeq \frac{\delta \rho_V(L_\theta) / \rho_L}{\rho_L L_\theta} \sim \frac{\rho_V}{\rho_L^2 L_\theta} \simeq \left(\frac{\nu}{\nu_T} \right)^4,$$

Asynchronism of WD-MD Binary



Beat Period:

$$P_{\text{beat}} = \left| \frac{1}{1/P_s - 1/P} \right|.$$

Synchronizing torque:

$$N_B \sim \dot{E} / \Delta\Omega.$$

Synchronizing timescale:

$$\tau_{\text{syn}} \sim I_s \Delta\Omega / N_B.$$

Predicted Statistical Properties

Period evolution:

$$\dot{P} = 6\pi \left(\frac{J_{\text{orb}}}{GM} \right)^2 \left(\frac{M}{M_s M_c} \right)^3 \dot{J}_{\text{orb}} \propto \dot{J}_{\text{orb}} P^{2/3}. \quad \rightarrow$$

Period distribution:

$$f_P(P) \propto \frac{d\tau}{dP} \propto \frac{d|P/\dot{P}|}{dP} \propto P^\alpha,$$

Luminosity function:

$$f_L(L) = \frac{P}{L} \left(\frac{d \ln P}{d \ln L} \right) f_P(P) \propto L^{-\frac{\alpha+\beta+1}{\beta}}.$$

Note: LPT luminosity strongly depend on Period

		Magnetic Braking	Gravitational Radiation
Period Distribution		$P^{-2.33}$	$P^{-1.67}$
Luminosity Function	Unipolar-inductor (Unsaturated)	$L^{-2.25}$	$L^{-2.00}$
	Unipolar-inductor (Saturated)	$L^{-2.00}$	$L^{-1.80}$
	Magnetosphere-interaction	$L^{-2.67}$	$L^{-2.33}$

LPT source number density:

$$n_* \in \begin{cases} (0.15 - 1.6) \times 10^{-7} \text{ pc}^{-3} (\Theta_b/0.1)^{-1}, & \text{J0704-37} \\ (1.6 - 17) \times 10^{-7} \text{ pc}^{-3} (\Theta_b/0.1)^{-1}, & \text{J0630+25} \end{cases}$$

Cooling issue of Magnetic WDs

ILT J1101+5521: $T_{\text{eff}} = (4500\text{--}7500)$ K

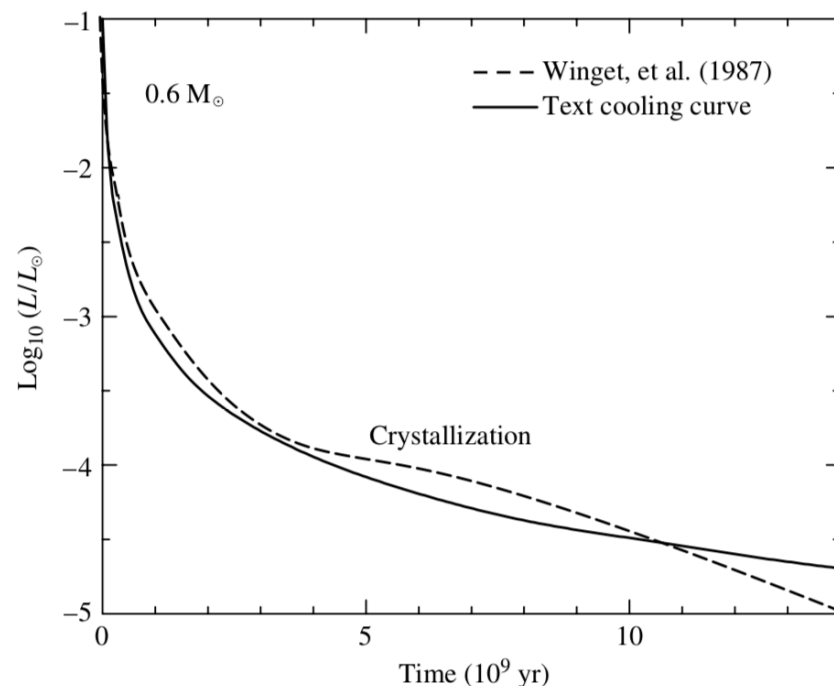
GLEAM-X J0704-37: $T_{\text{eff}} = 7300$ K

Isolated WD cooling:

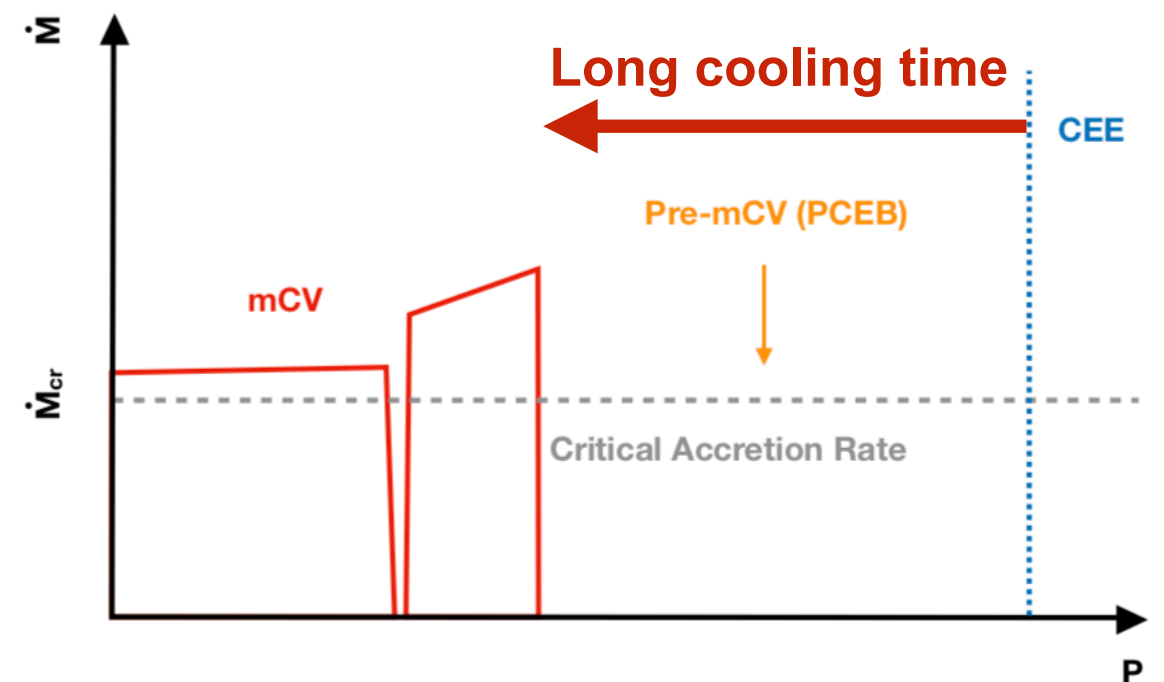
$$T_{\text{eff}}(t) = 7200 \text{ K} \left(\frac{M_s}{0.8M_{\odot}} \right)^{5/12} \left(\frac{t}{1 \text{ Gyr}} \right)^{-7/20}$$

WD cooling after compressional heating:

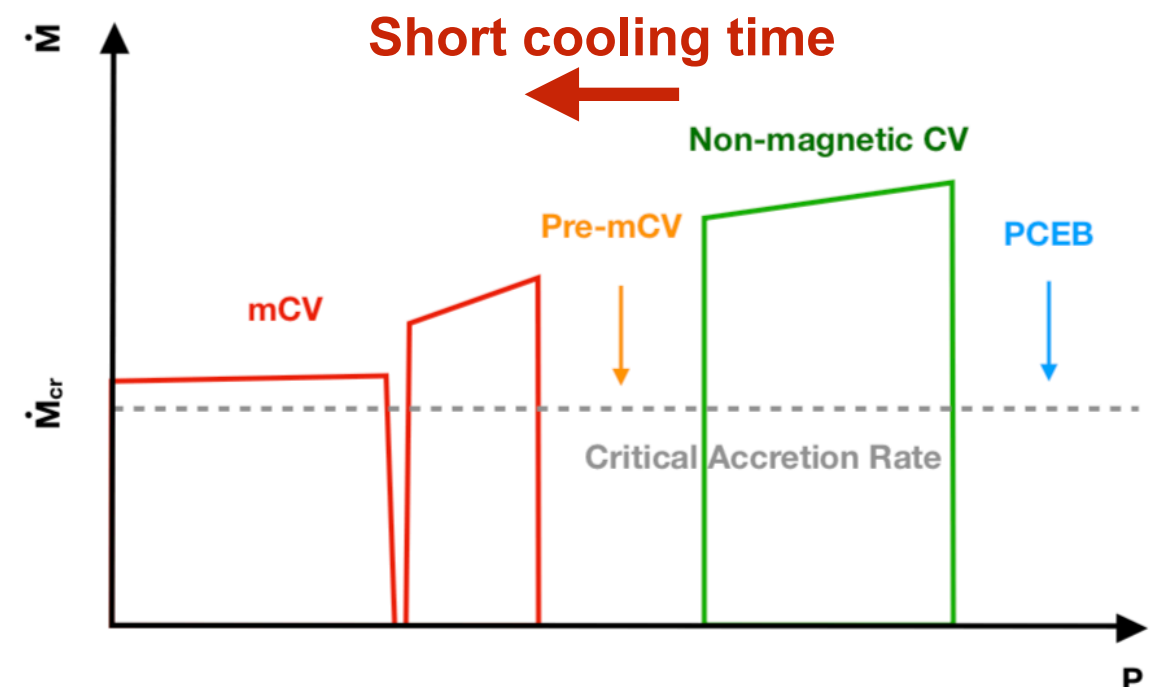
$$T_{\text{eff}}(t) \simeq T_{\text{eff},0} \min \left[1, \left(\frac{t}{t_0} \right)^{-7/20} \right],$$



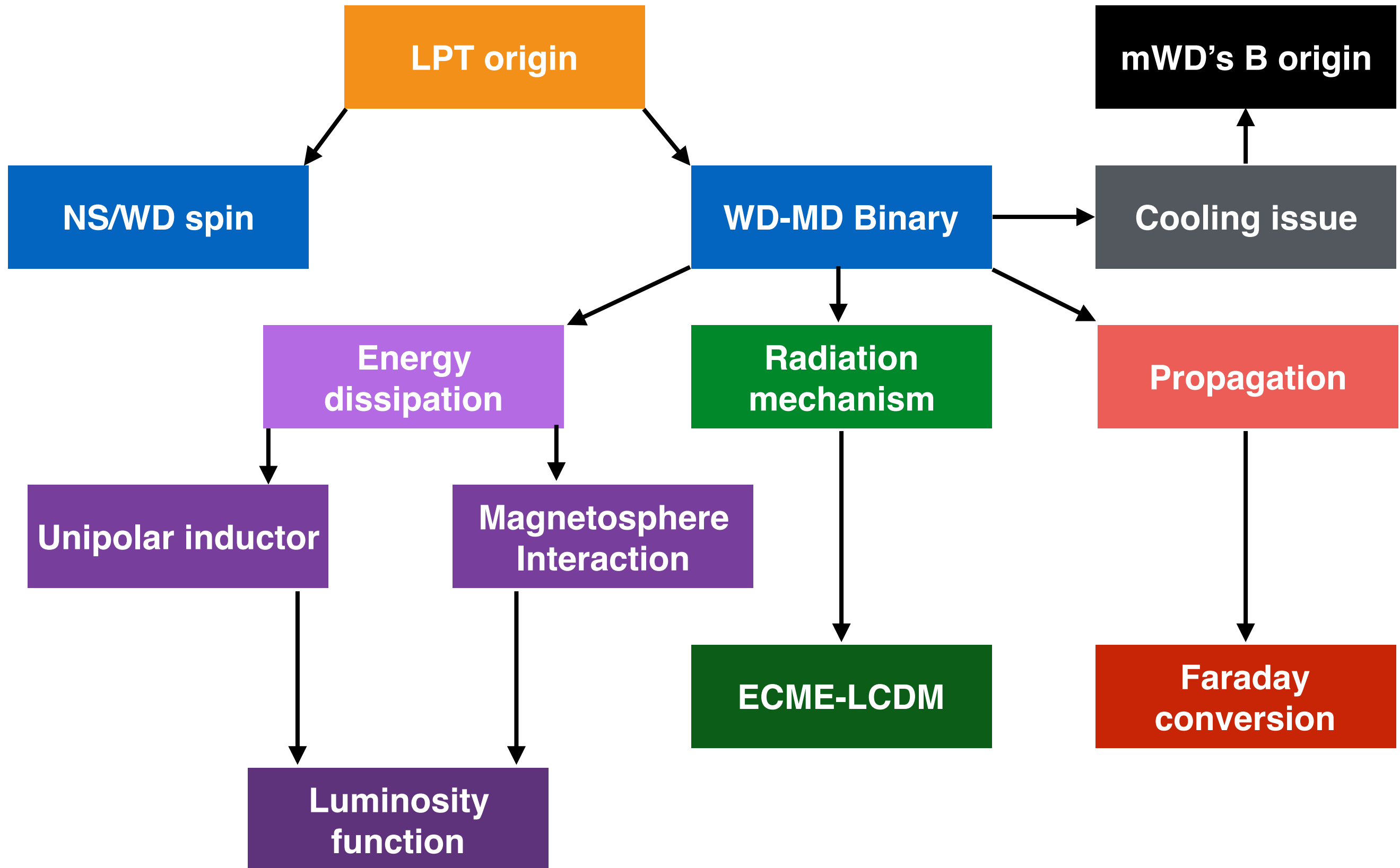
(1) fossil field at birth or dynamo action during common-envelope evolution



(2) crystallization- and rotation-driven dynamo during pre-mCV phase



Summary





Thank You!

