Detection of X-ray emission from a bright long-period radio transient(LPT)

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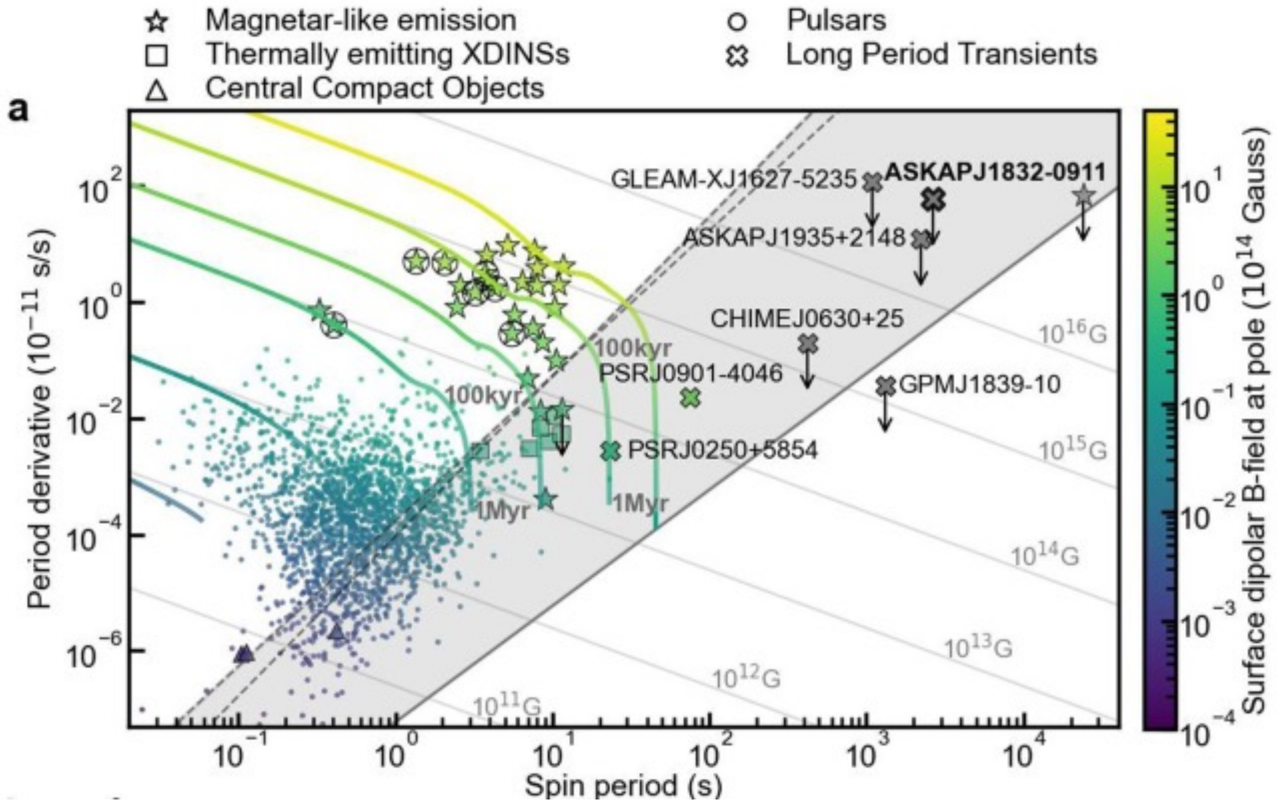
Outline

- Introduction
- Observation
- Summary & Discussion

Long-Period Radio Transients(LPTs)

Recently, a class of long-period radio transients (LPTs) has been discovered. They were only detected in radio band and their pulse duration is thousands of times(tens of minute to hours) longer than radio pulsars(milliseconds to seconds).



These findings, challenge existing models of rotationally powered pulsars. (Long P and low value of $\dot{P}$ result in a weak electric field($\Delta V \propto \sqrt{\frac{\dot{P}}{P^3}}$) above the pulsar's polar caps. This field is insufficient to accelerate particles to the high energies needed to trigger the electron-positron pair cascade. Without the cascade, There is not enough plasma for creating coherent radio emission,) Proposed models include highly magnetized neutron stars, white-dwarf pulsars and white-dwarf binary systems with low-mass companions. Although some models predict X-ray emission, no LPTs have been detected in X-rays.

Historical Observation

区分长期稳定和短期活跃

LPT Name	Key Features (Period)	Active Timescale (Observation-Based)	First Discovery/Publication	Radio Flux Density	
GCRT J1745-3009	Period: ~77 min	**Transient**, active for ~6 months (2002)	2002	Up to ~1 Jy	
GLEAM-X J1627-5235	Period: ~18.2 min	**Transient**, active for ~3 months (2018)	2022	Several Jy	
ASKAP J1935+2148	Period: ~54 min	**Transient**, shows complex state switching (2022-2024)	2024	Varies, up to ~160 mJy	
ASKAP J1832-0911	Period: ~44.2 min	**Transient**, active for several months (2023-2024)	2023 (Observed) 2025 (Published)	Highly variable, up to ~20 Jy	
GPM J1839-10	Period: ~21 min	**Persistent**, active for over 30 years (1988-2018)	2023 (Published from archive)	Highly variable, up to several Jy	
LPT GLEAM-X J0704*	Period: ~2.9 hr (Orbital)	**Persistent**, observed active across epochs spanning nearly a decade (e.g., in 2014 & 2023)	2024	up to ~30 mJy	WD+M5V
LPT ILT J1101+5521*	Period: ~2.9 hr (Orbital)	**Persistent**, observed active in all observations over ~5 years (approx. 2019-2024)	2025	up to ~10 mJy	WD+M4.5V
CHIME J0630+25	Period: ~7 min (421 s)	**TBD** (Too Soon to Determine), discovered recently	2024	~140 mJy	

paz

Historical Observation

LPT ILT J1101+5521(WD binary contain a M4.5V dwarf)

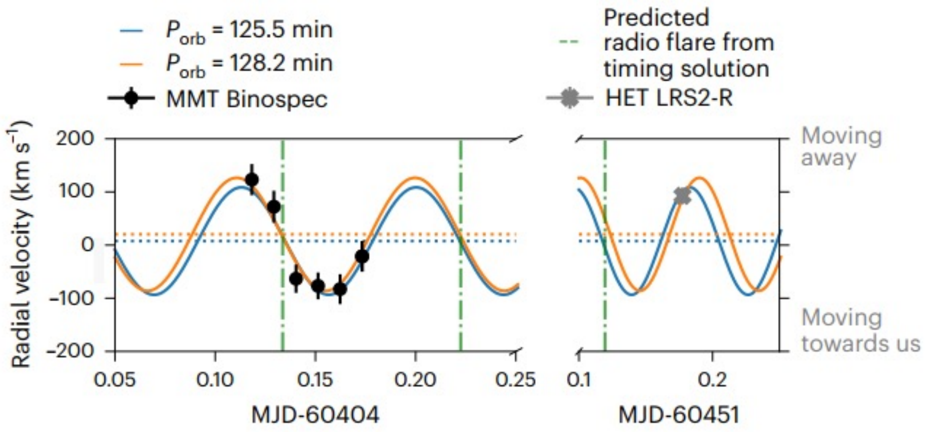
nature astronomy

Article https://doi.org/10.1038/s41550-025-02491-0

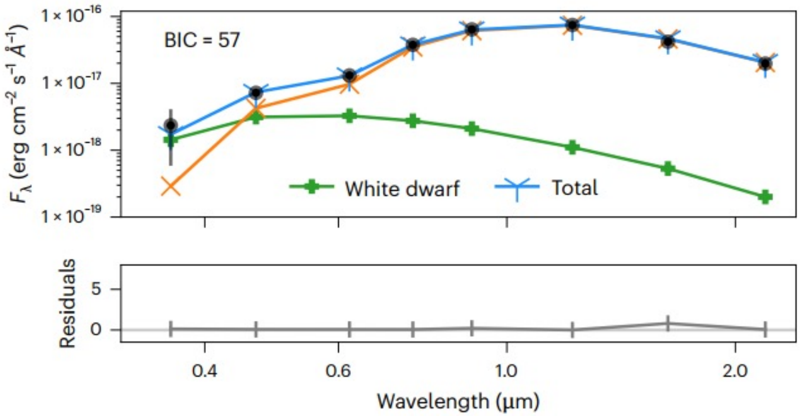
Sporadic radio pulses from a white dwarf binary at the orbital period

The group found a radio signal repeating every 125.5 minutes and traced it to a red dwarf. By studying the star 's light, they discovered it was orbiting a hidden companion at high speed. The crucial link was the timing: the star' s orbital period was also 125.5 minutes, a perfect match to the signal. The radio pulses only appeared when the star moved behind its companion from our viewpoint. The companion was identified as a white dwarf because the system's light was unusually blue for a red star, and the data perfectly fit a red dwarf–white dwarf binary model.

Radial velocity of the M dwarf associated with ILT J1101



Broadband photometry fits for ILT J1101(WD+M dwarf)

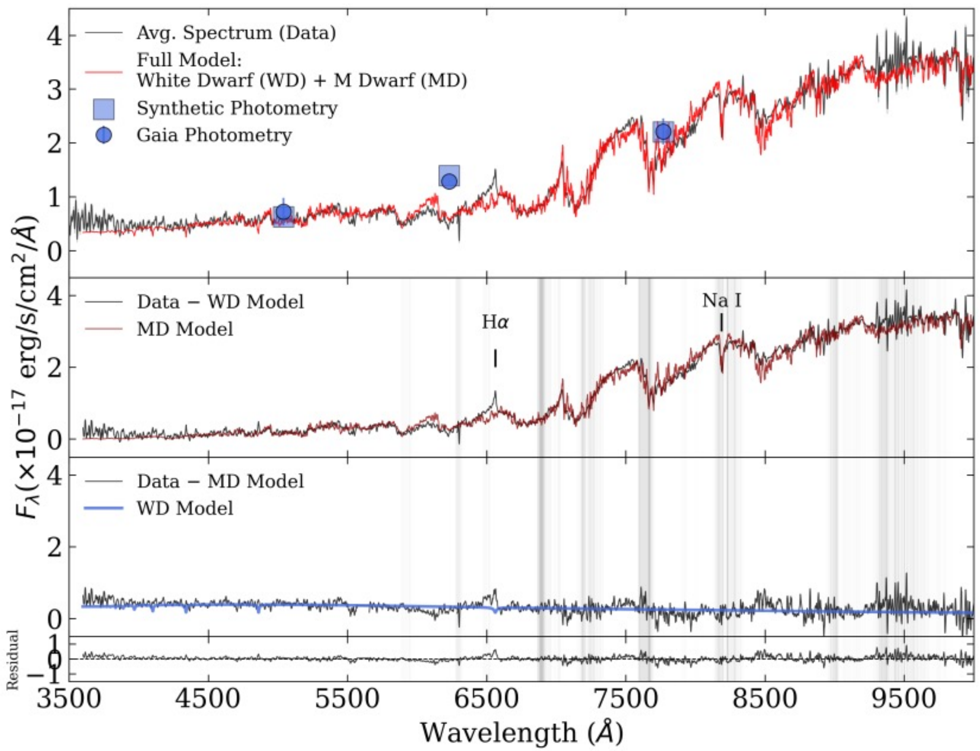


I. de Ruiter et.al, 2005, NatAs

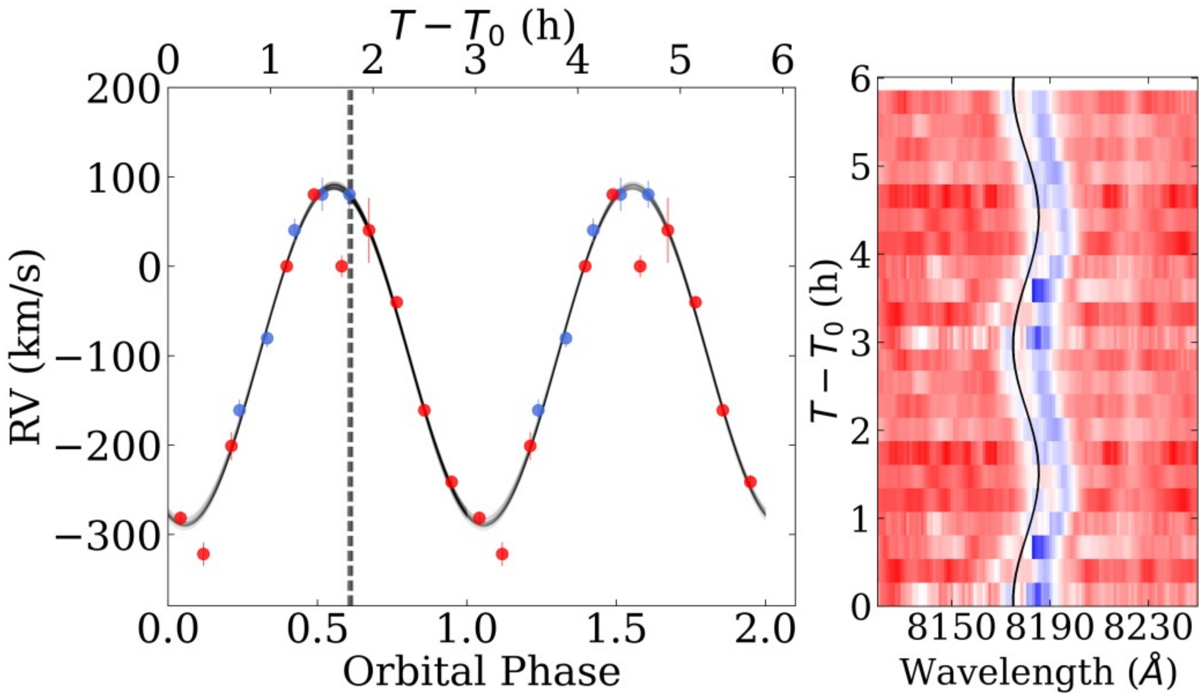
Historical Observation

LPT GLEAM-X J0704(WD binary contain a M5V dwarf)

Spectrum fitting by a WD + MD binary model



RVs measured using the Na I absorption line with J0704



I. de Ruiter et.al, 2005, NatAs

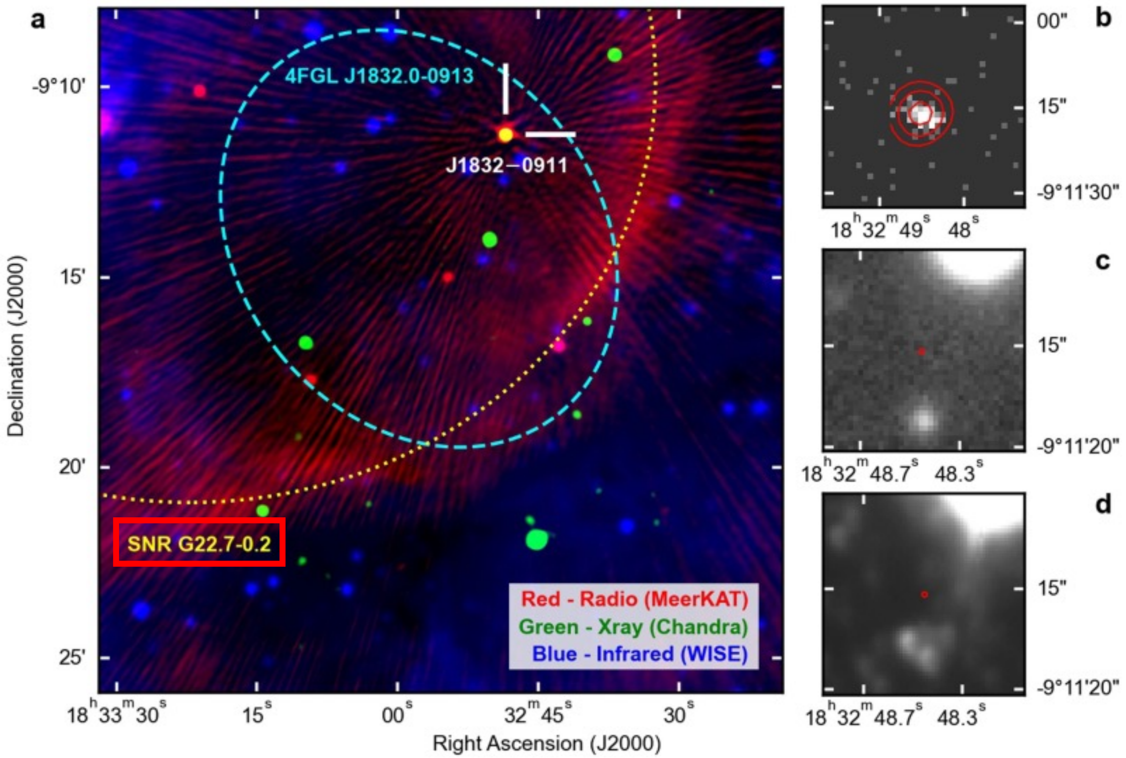
LPT ASKAP J1832

No infrared counterpart was detected with 3σ magnitude limits of 19.86 and 19.98 at *K* and *J*-band, using the FourStar infrared camera on the Magellan telescope and the Wide-field Infrared Camera on the Palomar 200-inch Telescope, respectively. The derived limits allow us to rule out the presence of a main-sequence star with a spectral type earlier than M0 or a white-dwarf star with a temperature greater than 10^5 K.

Notably, (Di Li, 2024, arxiv) the follow-up observations with FAST yielded a precise dispersion measure (DM) of **464.5 ± 0.7 pc·cm^{-3}**. The inferred distance(about 4.5 kpc) is highly consistent with that of the SNR G22.7-0.2 which confirming their association. This is the first LPT found within an SNR.

SNR具体信息

Field of ASKAP J1832



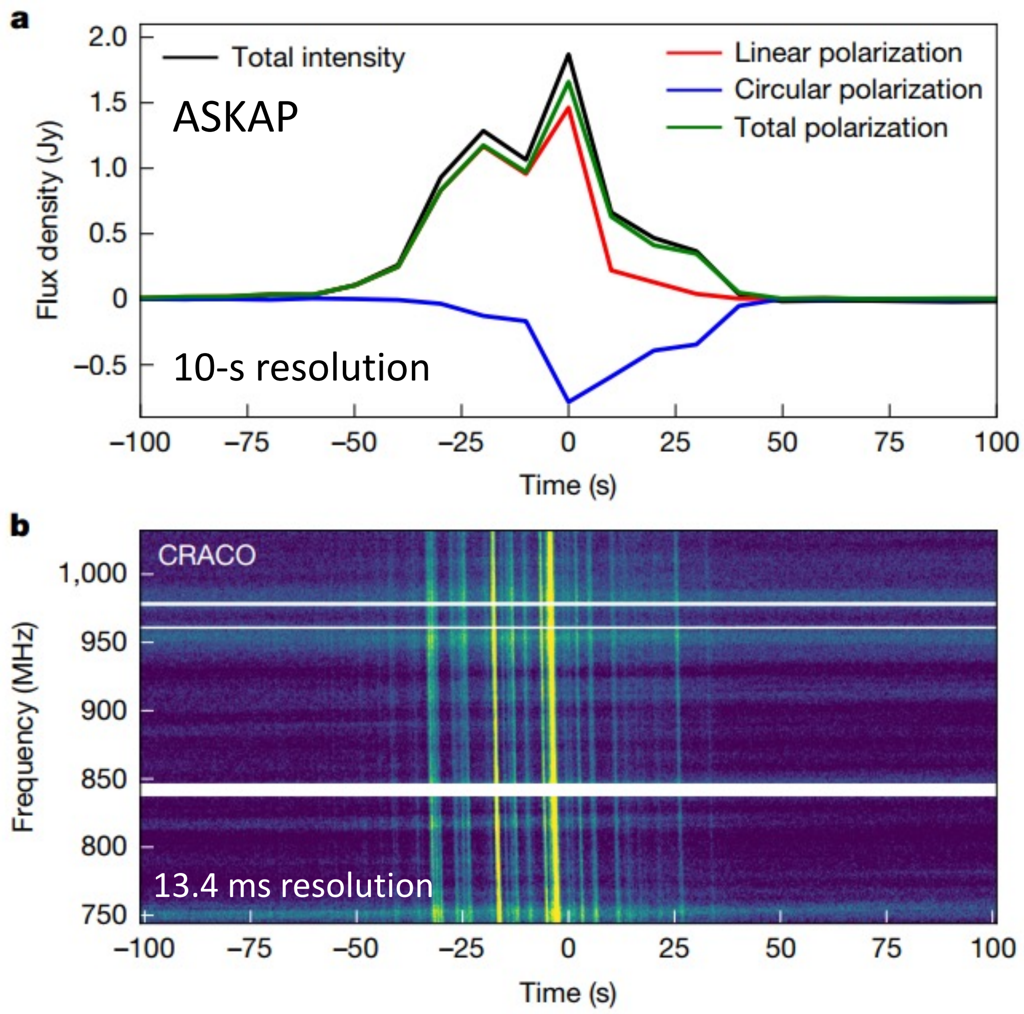
Panel (a) shows a composite emission of radio (MeerKAT 816 MHz, red), X-ray (*Chandra* 1–10 keV, green), and infrared(*WISE* 12 μm, blue). (b)MeerKAT intensity contours at 30,40,50 mJy on 2024 February 14. . Panel (c) and (d) show the deepest near-infrared images at *J*- and *K* *s*-band, respectively.

LPT ASKAP J1832

ASKAP J1832-0911 was identified as a compact circularly polarized transient radio source using the Australian Square Kilometre Array Pathfinder (ASKAP). The lightcurve shows a signal duration of approximately 2 min, with a maximum peak flux density of 1,870 ± 6 mJy per beam. The pulse showed substantial linear and circular polarization, with a total fractional polarization of 92 ± 3%.

The shortest 0.5-s flux-density variations constrain the emission region to be smaller than 150,000 km, indicating the presence of a compact object: a white dwarf star, a neutron star or a black hole

Radio band dynamic spectra and light curve for ASKAP J1832

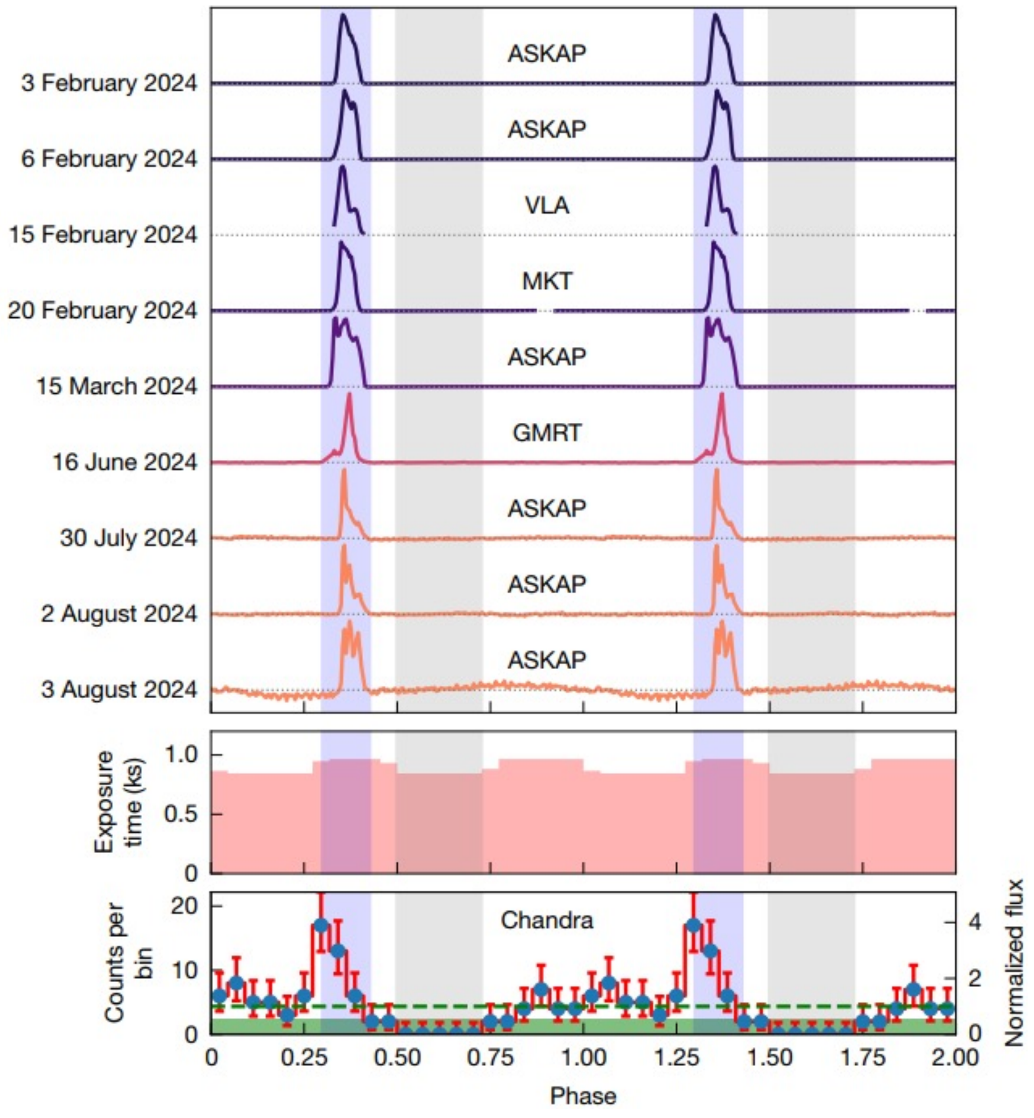


LPT ASKAP J1832

ASKAP J1832-0911 was observed in a serendipitous X-ray observation with Chandra for 20 ks on 14 February 2024, targeting the supernova remnant SNR G22.7–0.2. An uncatalogued X-ray source was detected that is positionally coincident with ASKAP J1832. A blind Lomb–Scargle periodicity search identified a period of 2,634 s at 3σ significance, consistent with the radio periodicity.

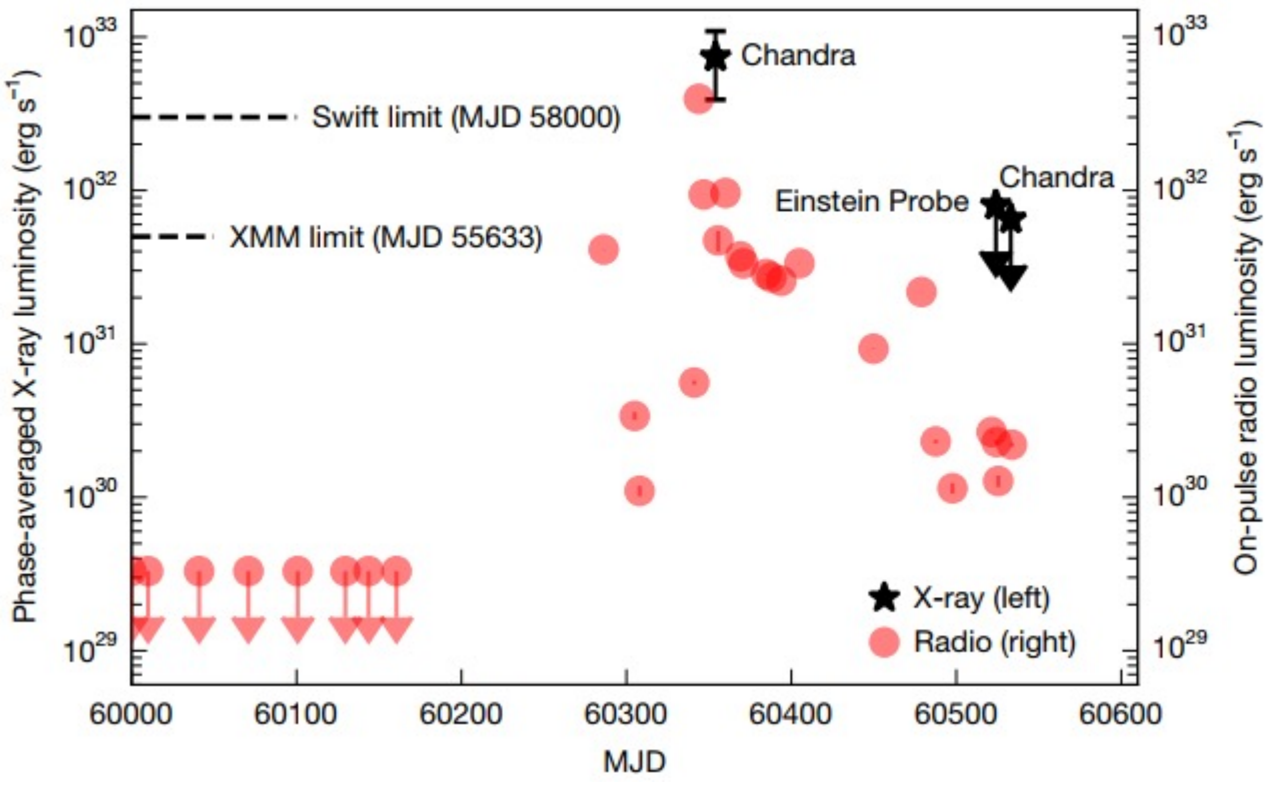
Crucially, the X-ray and radio pulses are nearly synchronized in phase, providing strong evidence that both emissions originate from the same region. This marks the first confirmation of LTP as a radio/X-ray pulsar.

Radio and X-ray light curves of ASKAP J1832



LPT ASKAP J1832

Phased-averaged X-ray and on-pulse radio luminosity evolution for ASKAP J1832



This LPT is also a transient one with an activity window of about half a year

The search of 40 hours of both radio and X-ray data taken between 2013 and 2023 did not detect any emission, suggesting that the source(start it activity) may have activated only after November 2023. The Radio luminosity peak above 10^{32} erg s^{-1} around MJD 60350 (mid-February 2024), followed by extreme variability with fluctuations of over two orders of magnitude.

Coinciding with this radio peak, Chandra made the X-ray detection, measuring a X-ray luminosity of approximately 7.4×10^{32} erg s^{-1}. Approximately 170 days after this detection, a high-energy follow-up observation(by Chandra and EP) placed an upper limit on X-ray luminosity at 6×10^{31} erg s^{-1}, showing a drop of more than an order of magnitude.

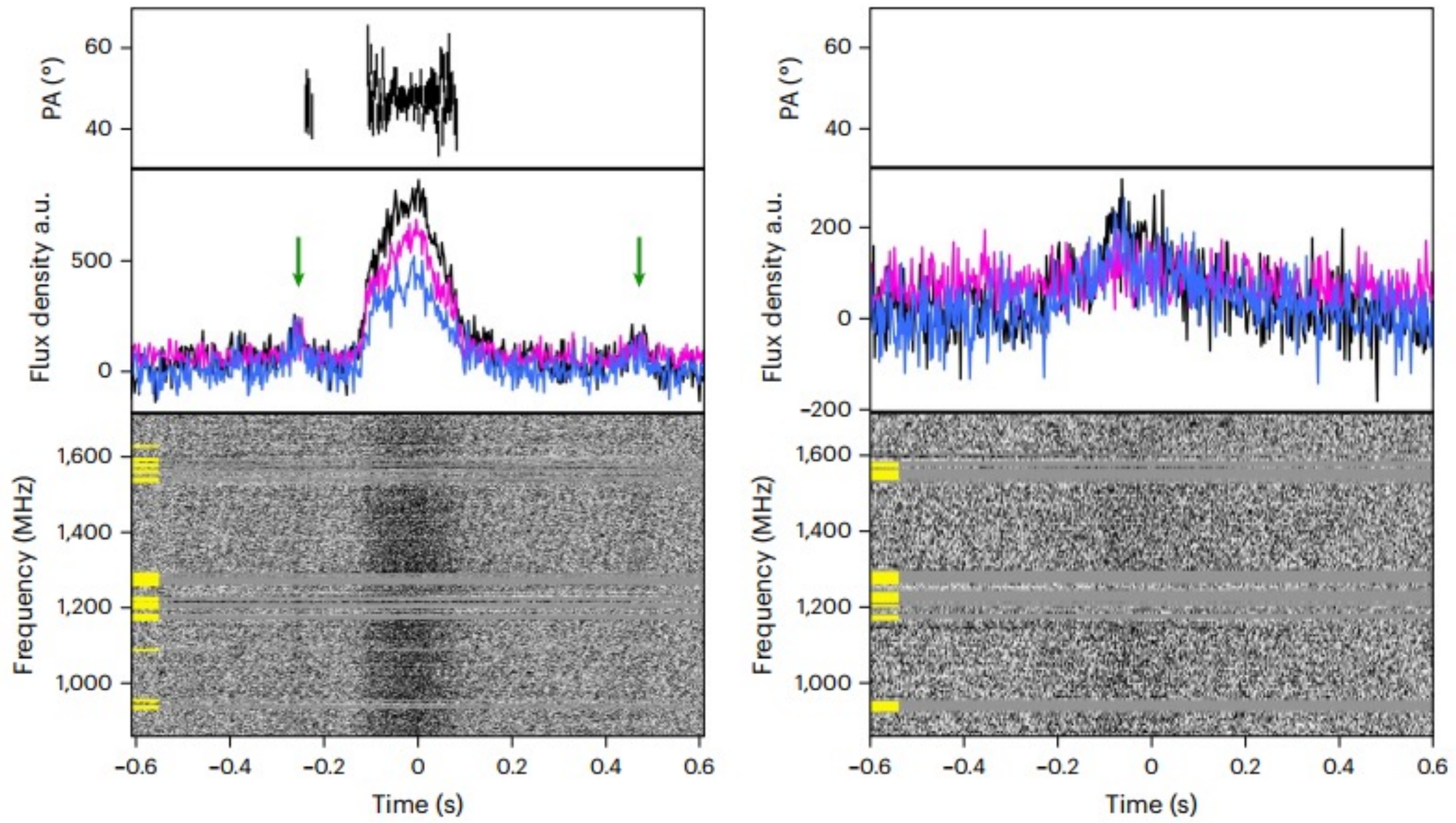
Summary & Discussion

- **Only LPT source with an X-ray counterpart:** The source exhibits highly correlated radio and X-ray emission, both pulsed with a 44.2-minute period.
- **LPT source with no detected companion:** Deep infrared observations have ruled out the presence of any bright companion star (specifically, main-sequence stars earlier than M0 or hot white dwarfs).
- **Only LPT source spatially associated with a supernova remnant (SNR):** Its position on the sky is coincident with SNR G22.7-0.2.

- **Support for an Old Magnetar Origin**: The source's lack of a companion, high X-ray luminosity, and SNR association rule out white dwarf models, strongly supporting an old magnetar origin.
- **The Activation Puzzle**: Its extremely low spin-down rate indicates an old magnetar. Triggering such a powerful outburst from an ancient object presents a major theoretical challenge for current models.
- **Implications of Transient Emission**: The X-ray emission was only detected during a brief active phase. This suggests previous non-detections for other LPTs were likely due to missed observational windows.
- **Challenging the LPT Paradigm**: The diversity of LPTs supports a multi-origin model. The extreme properties of this source challenge existing theories for both magnetars and white dwarfs.

That`s all, and thanks for listening.

ASKAP J1935+2148



ASKAP J1935+2148

Epoch	SBID	Start Time UT, J2000	Duration UT, J2000	Frequency MHZ	Observation	Peak flux density mJy	Note
0	20200507-0039	2020-05-08 05:16:47	01:16:49	1284	MeerKAT	–	no detection.
0	20200510-0034	2020-05-11 03:01:01	03:17:30	1284	MeerKAT	–	no detection.
0	20200514-0008	2020-05-15 00:40:59	03:19:20	1284	MeerKAT	–	no detection.
1	44780	2022-10-12 07:00:00	06:02:35	887.5	AS113_66	6.9	one 7σ.
2	44857	2022-10-15 07:15:02	06:02:36	887.5	AS113_67	118.8, 93.7, 18.4, 17.9, 13.8	Discovery - four $> 6\sigma$; one $> 4\sigma$.
3	44918	2022-10-17 06:31:08	03:01:27	887.5	AS113_68	10.8	one $> 10\sigma$.
4	45060	2022-10-22 06:31:34	06:02:05	887.5	AS113_69	17.7, 10.2	one $> 10\sigma$ sigma; one $> 4\sigma$.
5	45086	2022-10-23 06:13:17	06:02:19	887.5	AS113_70	234.7, 209.3, 170.7, 146.6, 112.5	five $> 6\sigma$.
6	45416	2022-11-05 05:01:15	06:02:00	887.5	AS113_71	4.0	one $> 4\sigma$.
7	46350	2022-12-13 02:27:01	05:23:05	887.5	CRACOTest_A	–	no detection.
8	46419	2022-12-14 02:16:02	06:02:08	887.5	CRACOTest_A	–	no detection.
9	46492	2022-12-15 04:15:00	05:01:49	887.5	CRACOTest_B	–	no detection.
10	46554	2022-12-16 02:07:02	05:02:10	887.5	CRACOTest_B	–	no detection.
11	20230203-0012	2023-02-03 09:55:15	01:00:12	1284	MeerKAT	9.0, 2.3	DDT - one pulse and weak sub-pulse.
12	47635	2023-02-04 04:20:38	01:02:24	887.5	ULP2	–	no detection.
13	48611	2023-02-25 21:33:58	06:03:32	887.5	CRACO_ULP2	–	no detection.
14	20230302-0029	2023-03-04 06:48:46	00:59:56	1284	MeerKAT	–	DDT - no detection.
15	20230409-0012	2023-04-10 03:06:57	00:59:49	1284	MeerKAT	–	DDT - no detection.
16	20230508-0002	2023-05-08 01:41:45	01:00:10	1284	MeerKAT	2.9, 1.1	DDT - one pulse and weak sub-pulse.
17	20230821-0011	2023-08-21 16:46:25	01:00:12	1284	MeerKAT	–	DDT - no detection.

补充：

产生辐射的过程

这个过程可以分为四个关键步骤，像一个宇宙级的发电机：

1. **建立磁场交互舞台 (The Magnetic Stage)**
   - 系统中有一个拥有极强磁场（像一个巨大的磁力网）的**白矮星**。
   - 它的伴星，一颗**M矮星**，自身也有磁场，并且像太阳一样，会不断向外喷射带电粒子（等离子体），形成恒星风。这两颗星的磁场会相互连接和纠缠。
2. **注入能量——轨道运动是引擎 (Energy Injection from Orbital Motion)**
   - M矮星在其轨道上高速运行，实质上是在**切割白矮星巨大的磁场磁力线**。
   - 这个过程就像在发电机里转动线圈一样，会在两颗恒星之间的等离子体中激发出强大的电场，将电子加速到接近光速，赋予它们巨大的能量。**因此，产生辐射的能量直接来源于双星的轨道运动。**
3. **产生辐射——电子回旋脉泽 (Radiation via ECMI)**
   - 这些被轨道运动加速的高能电子，在强大的磁场中会以螺旋路径运动。
   - 在这种条件下，电子会通过一种名为**"电子回旋脉泽不稳定性 (ECMI)"**的物理过程，极高效地将自身的能量转化为一束非常明亮、非常集中的射电波。ECMI机制能完美解释观测到的极高亮度和陡峭的频谱。
4. **形成固定的辐射束 (A Fixed Beam)**
   - 由于辐射的产生区域是由两星磁场相互作用最强的特定位置决定的（例如，在M矮星前进方向的激波前沿），所以这束射电波的**方向是固定的**，它相对于两颗恒星的连线方向是基本不变的。它**不会**随着白矮星的自转而摆动。