



Nature of 4FGL J1838.2+3223: A flaring `spider` pulsar candidate

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Outline

- **Introduction**
- **Observation**
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1.1 Spider Binaries

PSR 1959+2048

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Letter | [Published: 19 May 1988](#)

A millisecond pulsar in an eclipsing binary

[A. S. Fruchter](#), [D. R. Stinebring](#) & [J. H. Taylor](#)



Spiders: Spider consist of a millisecond pulsar and a low-mass companion in tight <1 day orbits, with the companion heated and evaporated by the pulsar spin-down power, appearing as **eclipsing MSP system**. Based on mass differences, they are categorized into two types.

Black widow: Companion with mass of $\sim 0.01-0.05 M_{\text{sun}}$.

Redback: Companion with mass of $\sim 0.1-0.3 M_{\text{sun}}$.

Due to the close distance between the binary stars and the strong pulsar wind, a bow-shaped shock forms near the companion, and directed towards it.

Black widow (North American)



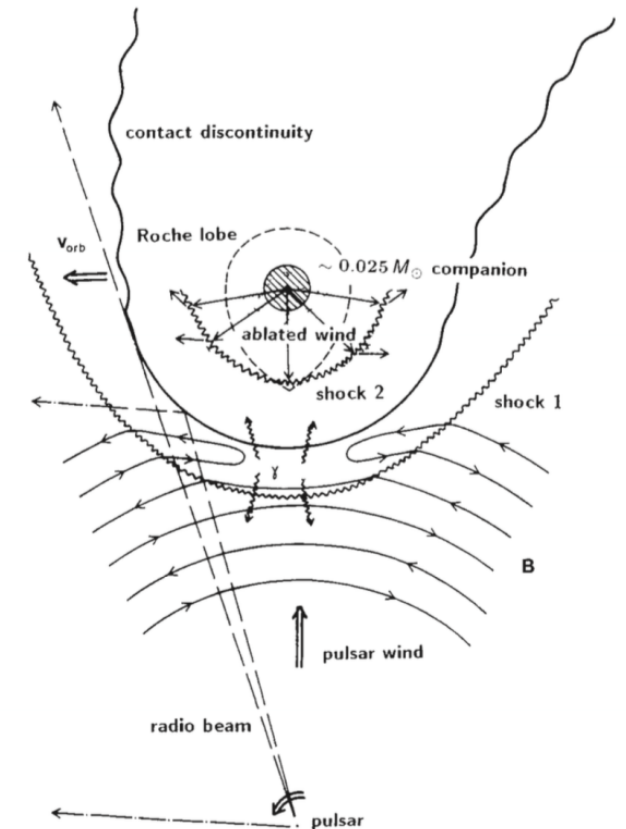
Redback (Australian cousin)



Spider eating mate

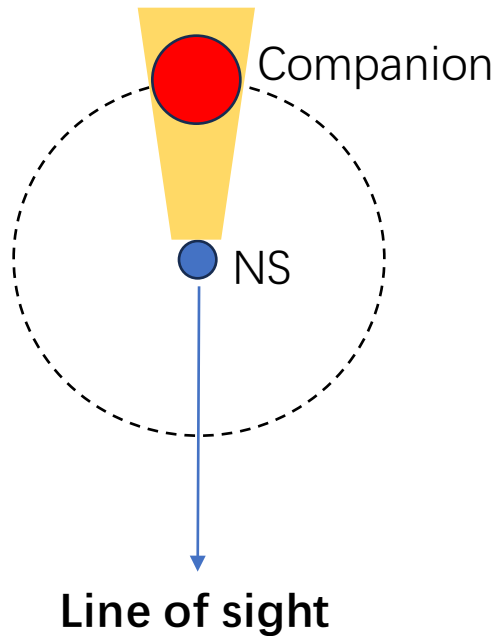


Near a hundred of spider have been observed

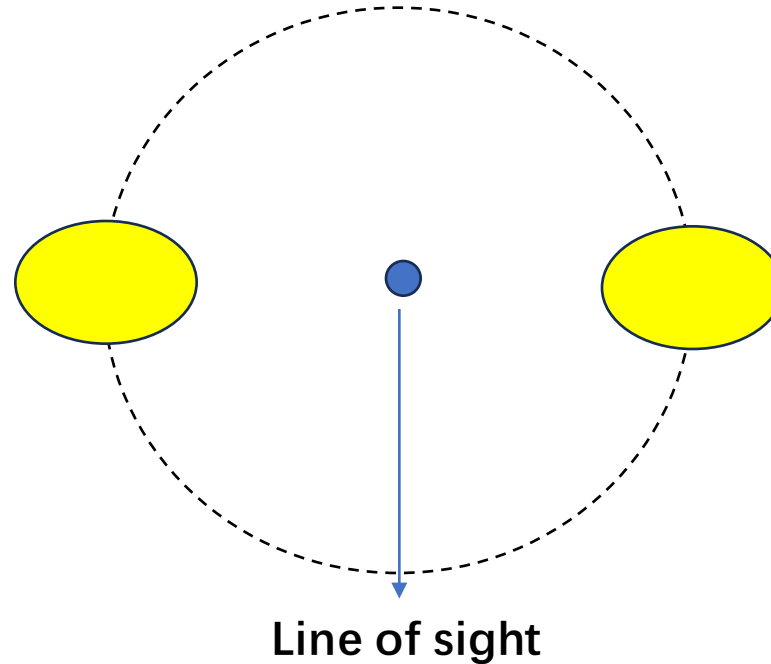


1.1 Spider Binaries

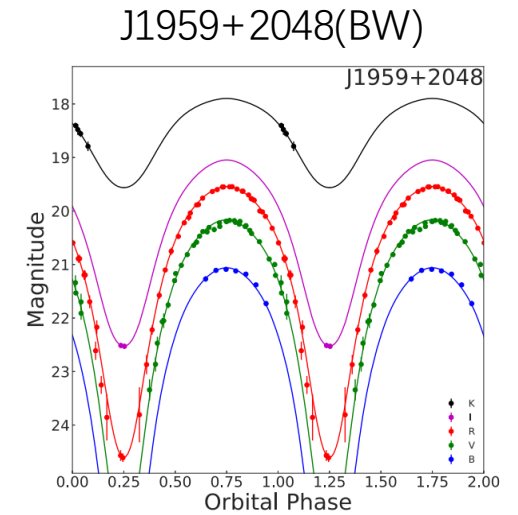
Black Widow(BW)



Red Back(RB)



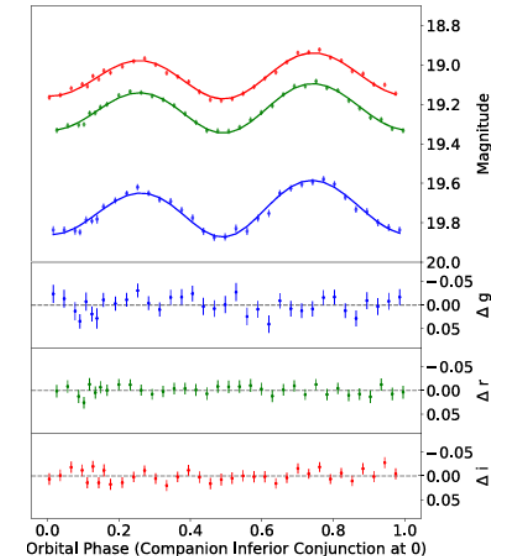
Black Widow generally have single peak(heating by the pulsar) in light curve of one orbital period, and have more obvious brightness variation. because they have smaller orbit which may corresponding to the more efficient heating.



Paul Draghis, 2019, ApJ

2 orbital phase in total

J1622+0315(RB)



Bidisha Sen, 2024, ApJ

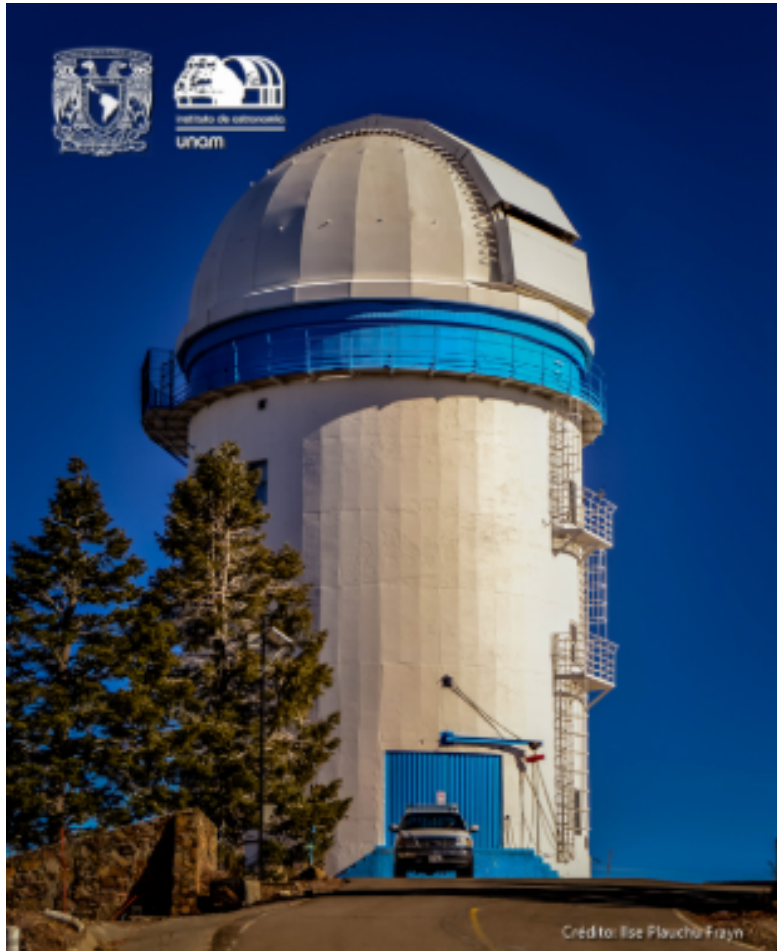
1 orbital phase in total



The OAN-SPM 2.1m telescope

The field of view of the detector is 6×6 arcmin² with an image scale of 0.34 arcsec in the 2×2 CCD pixel binning mode. Individual exposures varied from 350 to 700 s.

Date YYYY/MM/DD	Filter	Number of exposures	Airmass	Seeing, arcsec
2022 July 21	<i>B</i>	3	1.0 – 1.5	1.2–1.4
	<i>V</i>	18	1.0 – 1.3	
	<i>R</i>	8	1.0 – 1.5	
	<i>I</i>	4	1.0 – 1.4	
2022 July 22	<i>B</i>	5	1.0 – 1.5	1.5–1.7
	<i>V</i>	6	1.0 – 1.3	
	<i>R</i>	30	1.0 – 1.5	
	<i>I</i>	6	1.0 – 1.3	
2022 July 24	<i>B</i>	5	1.0 – 1.1	1.3–1.8
	<i>V</i>	5	1.0 – 1.2	
	<i>R</i>	30	1.0 – 1.2	
	<i>I</i>	5	1.1 – 1.2	



Credito: Ise Plaucha-Frayn

Observation from OAN-SPM 2.1m telescope

Image of J1838

maximum (left) and the minimum (right) brightness phases of the source(R band)

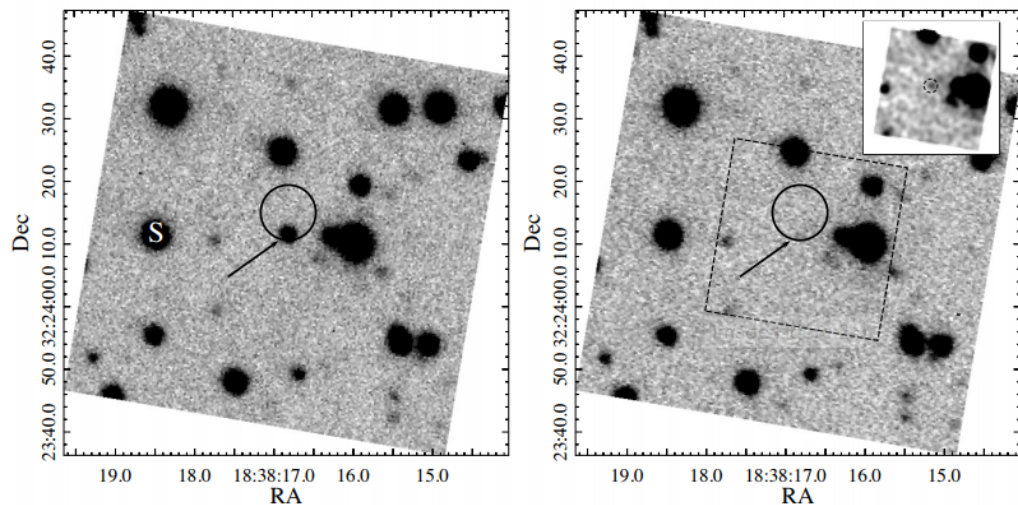
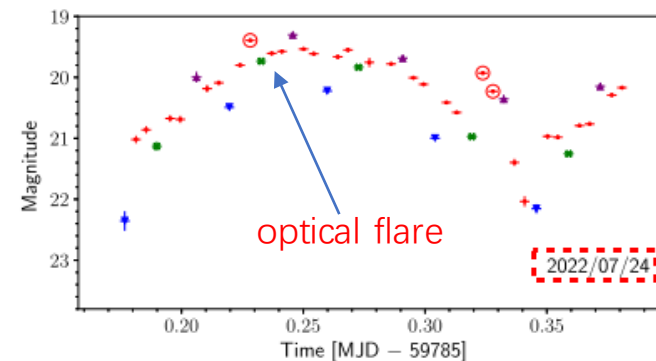
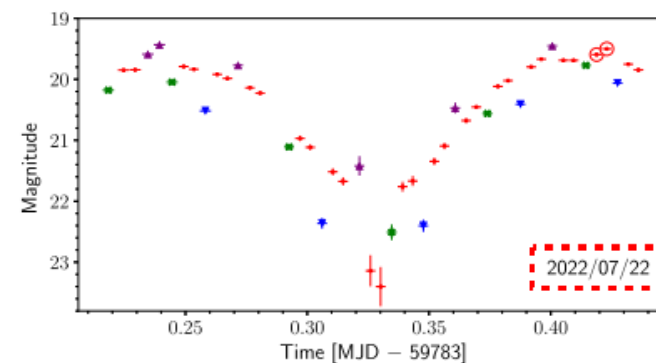
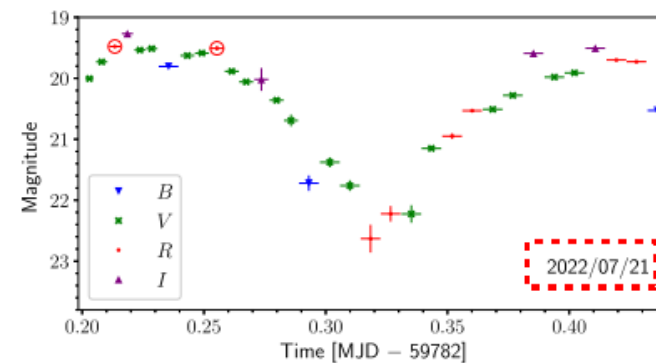


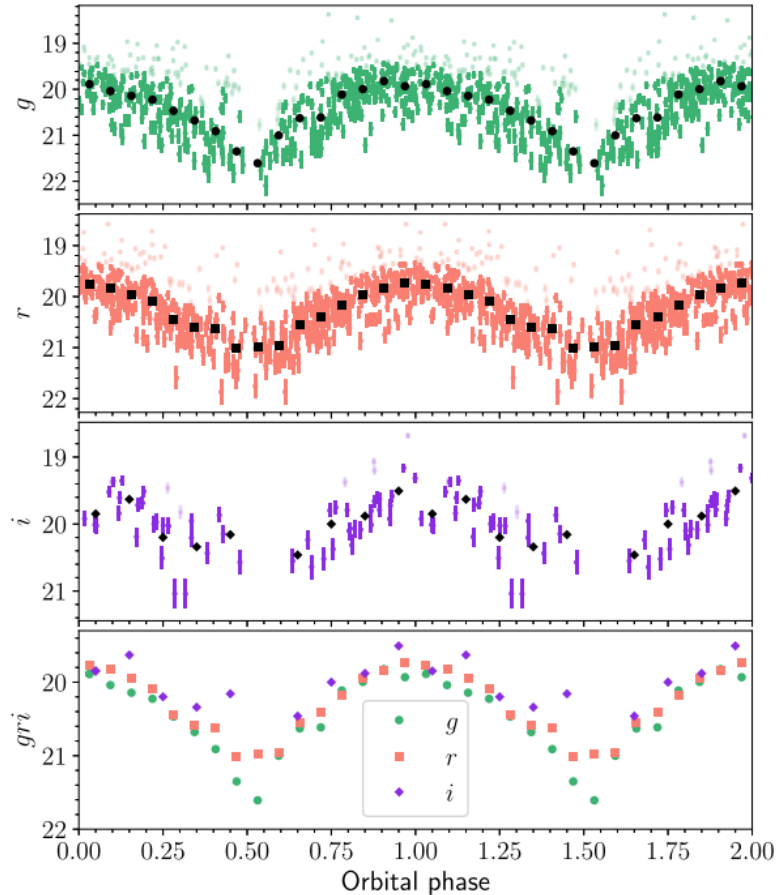
Table 1. Parameters of the J1838 and its counterpart candidate.

Parameters from the literature	
RA in the optical α_{opt}	$18^{\text{h}}38^{\text{m}}16^{\text{s}}.81807(12)$
Dec. in the optical δ_{opt}	$+32^{\circ}24'11.''4148(11)$
Galactic longitude l , deg	61.283
Galactic latitude b , deg	16.706
PM in RA direction $\mu_{\alpha}\cos\delta$, mas yr $^{-1}$	-4.9(2.0)
PM in Dec. direction μ_{δ} , mas yr $^{-1}$	-9.9(1.2)
Distance D_{geom} , kpc	1.0–3.5



Optical flare, Observation from from ZTF

Multiband light curve of J1838 based on the data from ZTF



The data from the ZTF DR16 catalogue which covers about 4.7 yr (MJD 58204–59905), also shows obvious flare activity as marked in the light curve with faint color.

Other optical flare spider:

BW

PSR J1311-3430 (Romani 2012)

4FGL J0935.3+0901 (Halpern 2022)

4FGL J1408.6-2917 (Swihart et al. 2022)

RB

PSR J1048+2339 (Cho, Halpern & Bogdanov 2018)

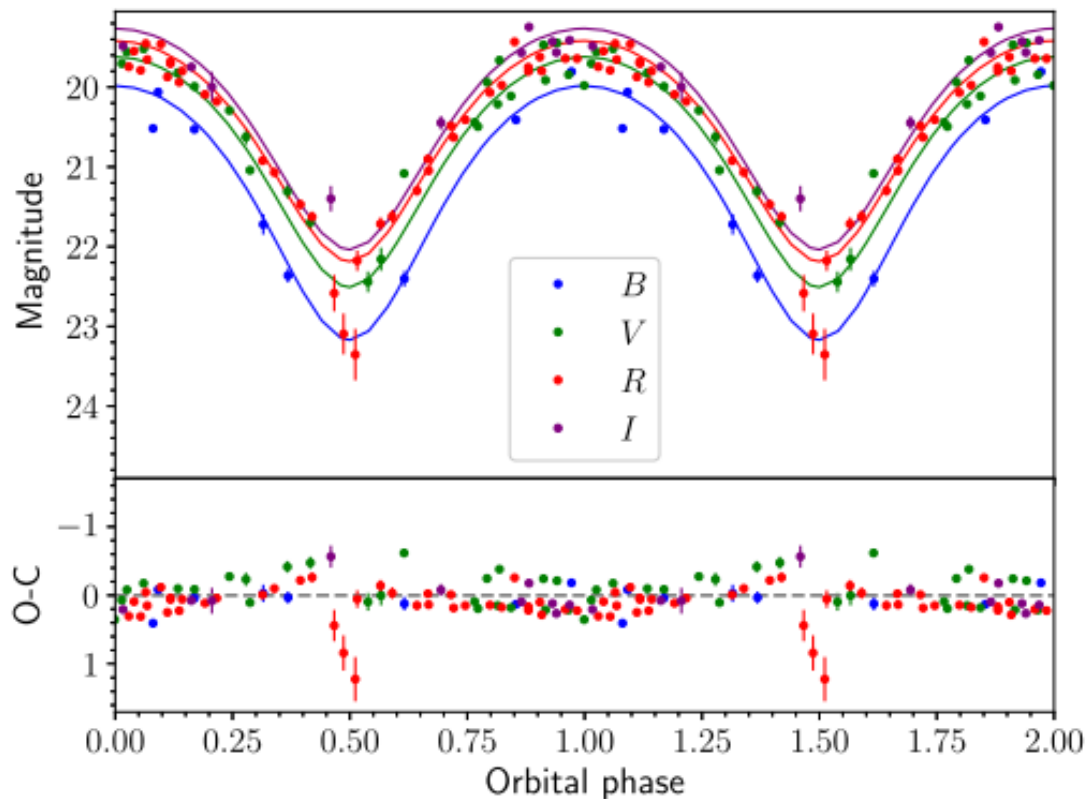
XMMU J083850.38-282756.8

1FGL J0523.5-2529 (Halpern, Perez & Bogdanov 2022)

- Intro-binary shocks?
- Intrinsic companion magnetic activity?

Observation from OAN-SPM 2.1m telescope

Light Curve Fitting Analysis

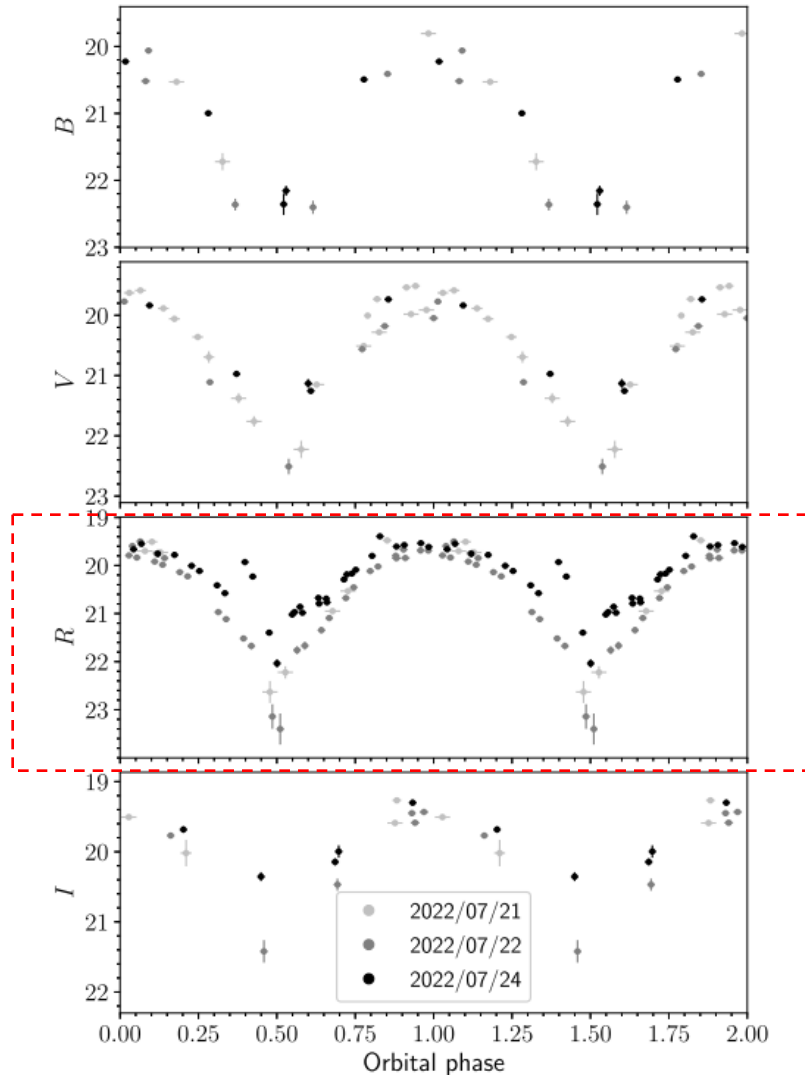


Fitting Parameters

Fitted parameters	Values
Pulsar mass $M_{\text{NS}}, M_{\odot}(\text{fixed})$	1.4
Mass ratio $q = M_{\text{c}}/M_{\text{NS}}$	0.065(15)
Distance D , kpc	3.1(2)
'Night-side' temperature $T_{\text{n}}, 10^3 \text{ K}$	2.3(7)
Inclination i , deg	36(10)
Roche lobe filling factor f	$0.60^{+0.10}_{-0.06}$
Irradiation factor $K_{\text{irr}}, 10^{20} \text{ erg cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$	0.16(3)
Extinction $E(B - V)$, mag	0.092(45)
Derived parameters	
Companion mass $M_{\text{c}}, M_{\odot}$	0.10(5)
Companion radius $R_{\text{c}}, R_{\odot}$	0.16(3)
'Day-side' temperature:	
Minimum $T_{\text{d}}^{\text{min}}, 10^3 \text{ K}$	6.0(2)
Maximum $T_{\text{d}}^{\text{max}}, 10^3 \text{ K}$	11.3(4)

Fitting Period: 4.0246 h.

Observation from OAN-SPM 2.1m telescope

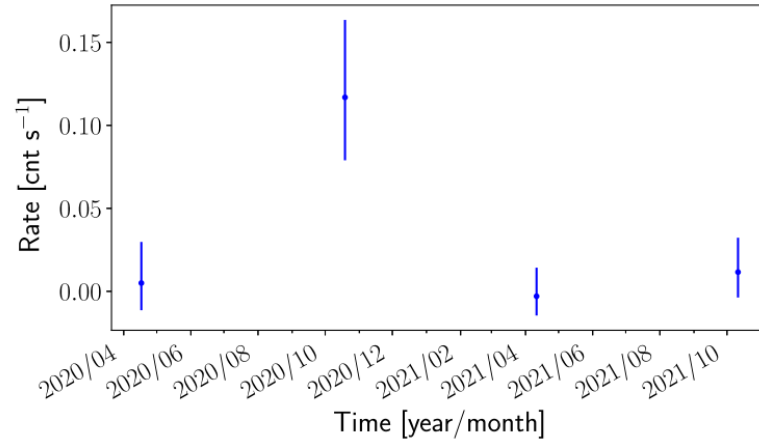
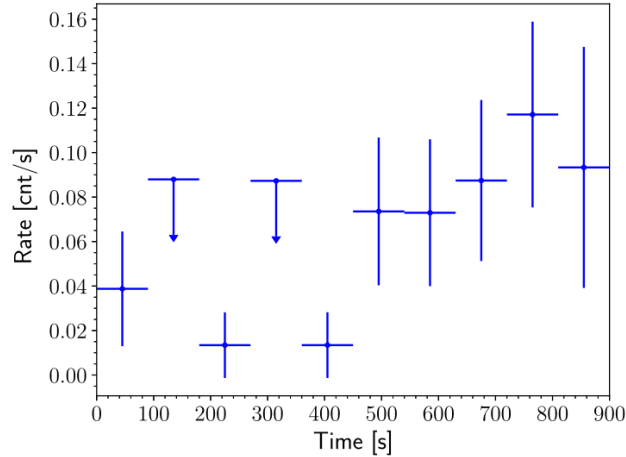


On 2022 July 24 the source was apparently brighter as compared to the two previous nights. This is clearly seen in the R band light curve at the phase ranges between about 0.2 and 0.8.

“It may reflect a global change of the presumed pulsar companion and/or the binary system stage.”

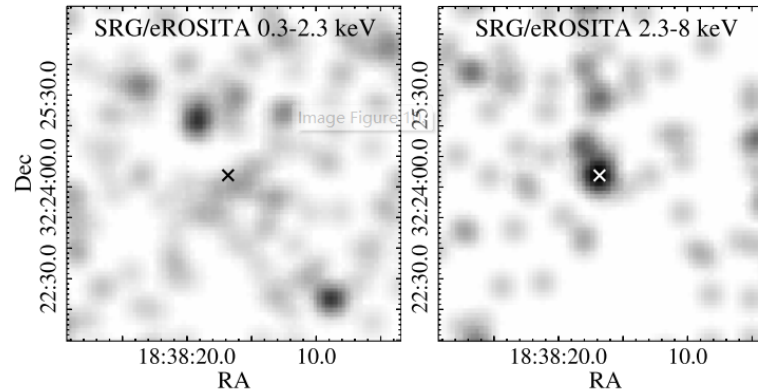
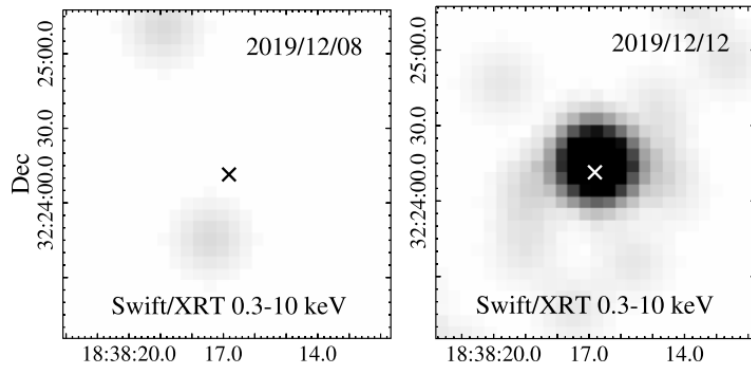
Have not yet do the research on that problem?

1.2 X-ray flare from J1838



Parameters derived in this paper

RA in X-rays α_X	18 ^h 38 ^m 16 ^s .71
Dec. in X-rays δ_X	+32°24'1."8
Orbital period P_b , h	4.02488(15)
X-ray flux (flare) F_X^{flare} , erg s ⁻¹ cm ⁻²	$\sim 10^{-11}$
X-ray flux (quiescence) F_X , erg s ⁻¹ cm ⁻²	$< 9 \times 10^{-14}$
X-ray luminosity (flare) L_X^{flare} , ($D/3.1$ kpc) ² erg s ⁻¹	$\sim 10^{34}$
X-ray luminosity (quiescence) L_X , ($D/3.1$ kpc) ² erg s ⁻¹	$< 10^{32}$



Other X-ray flare spider:

PSR J1311–3430
 PSR J1048+2339
 XMMU J083850.38–282756.8
 1FGL J0523.5 –
 2529($L_f \sim 10^{34}$ erg s⁻¹)

The bright flare occurred on 2019 December 12
 Swift XRT(top)

The bright flare occurred in October 2020.
 ROentgen Survey(ROS) with an Imaging Telescope Array
eROSITA

All of these X-ray flare spiders have optical flare activities. That maybe indicate that there are some potential relationships between the two phenomenon.

Summary

- An unidentified source J1838.2+3223 has been proposed as a spider candidate
- They present the optical time-series multiband photometry of its likely optical companion obtained with the 2.1-m telescope of Observatorio Astronomico ´ Nacional San Pedro Martir, ´ Mexico
- The source brightness variability with a period of ≈ 4.02 h likely associated with the orbital motion of the binary system. The folded light curves have a single sine-like peak per period with an amplitude of about three magnitudes accompanied by fast sporadic flares up to one magnitude level.
- The observation result implies that J1838.2+3223 likely belongs to the ‘spider’ pulsar family. The estimated distance of ≈ 3.1 kpc is compatible with *Gaia* results.
- They detect a flare from the source in X-rays and ultraviolet using *Swift* archival data and another one in X-rays in the *eROSITA* all-sky survey.

That`s all, and thanks for your attention!