A Survey of Spider binary

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2023.1.5

Outline

- Introduction
- My Survey
- Result
- Summary

1.1 Spider Binaries

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 **~0.01-0.05 M_sun**.

Redback: Companion with mass of **~0.1-0.3 M_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

PSR 1959+2048

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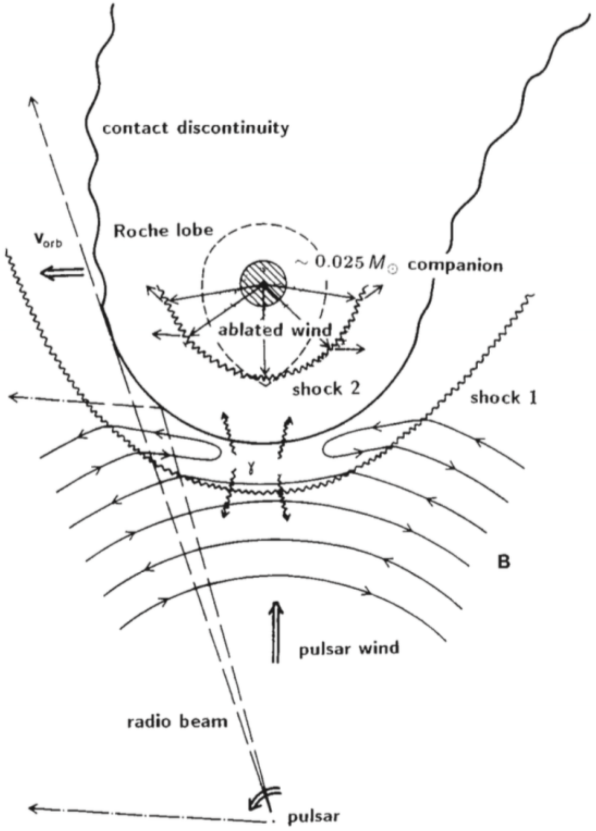
Letter | Published: 19 May 1988

A millisecond pulsar in an eclipsing binary

A. S. Fruchter, D. R. Stinebring & J. H. Taylor

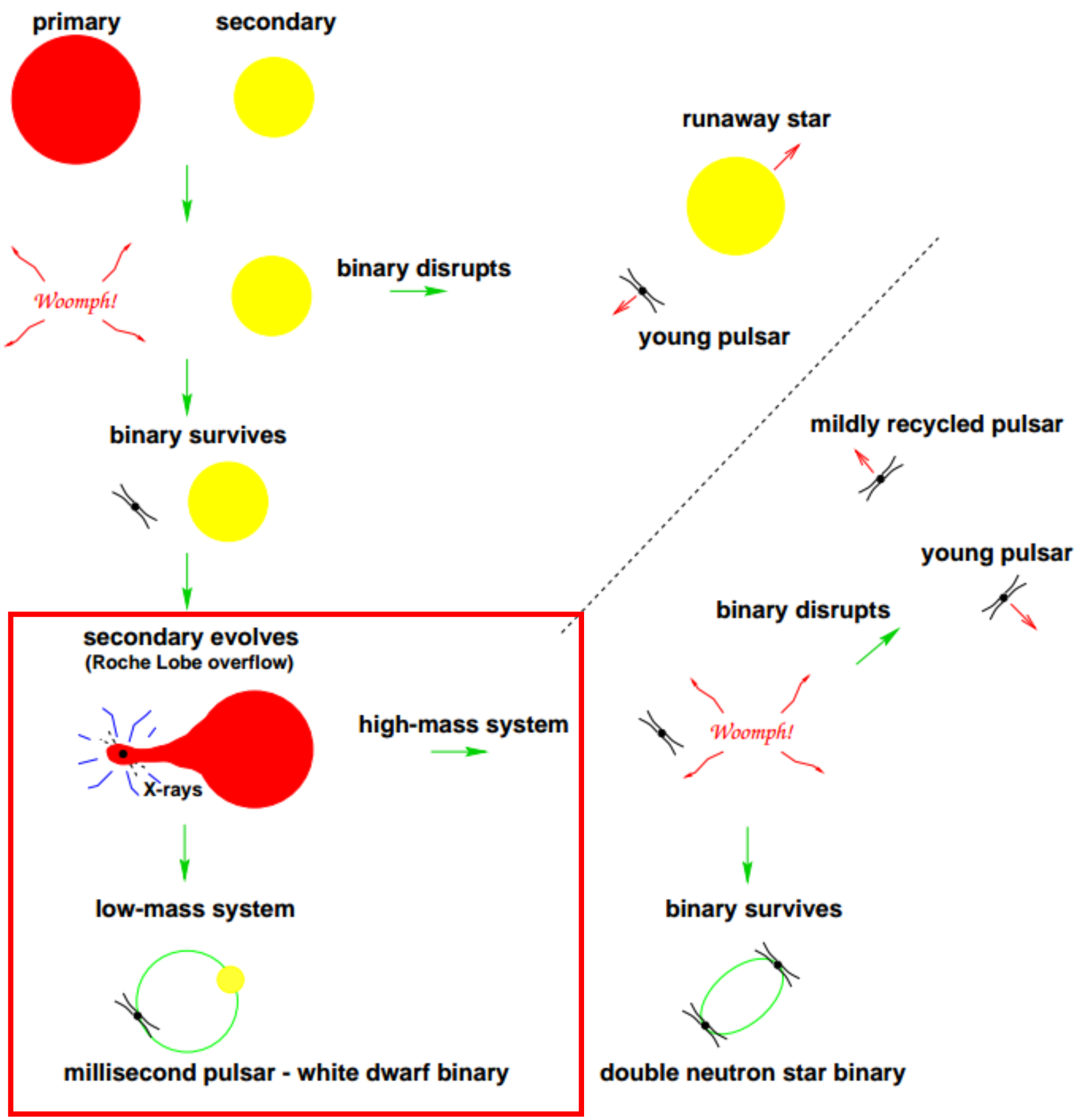


1.2 Finding Maximum mass of neutron stars

Mass Transfer

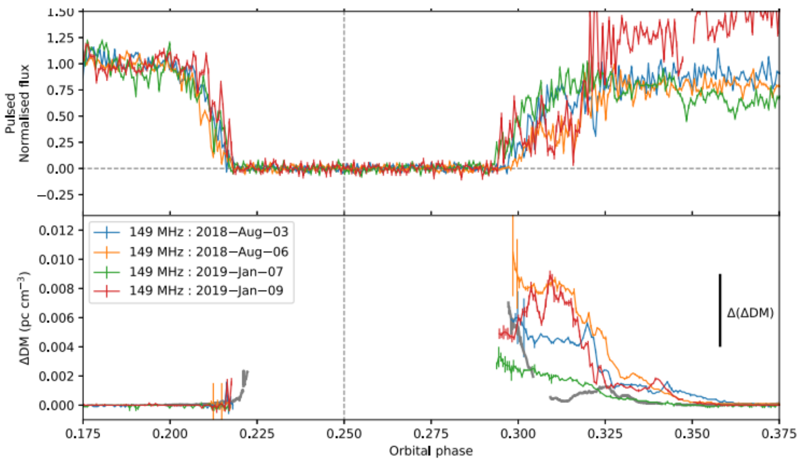
- Consider the process of stellar collapse, the star mass has to be large enough without exceeding the upper limit(~50 solar masses) that would collapse into a black hole. So that we get a massive neutron star. But such cases are extremely rare.

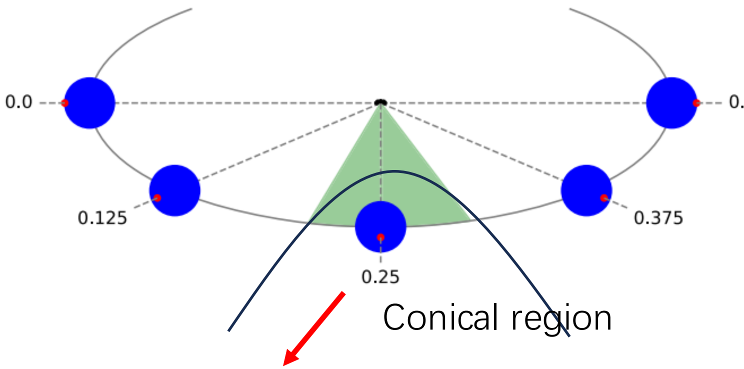
- Slow mass transfer during the X-ray binary phase allows substantial neutron star (NS) mass growth, reaching black hole collapse. So the heaviest Black Widow that avoiding this fate can probe the upper limit on the mass of a neutron star.



1.3 Multiband Emission (J1959+2048)

Pulsed flux densities of PSR J1959+2048 for 4 separate eclipse

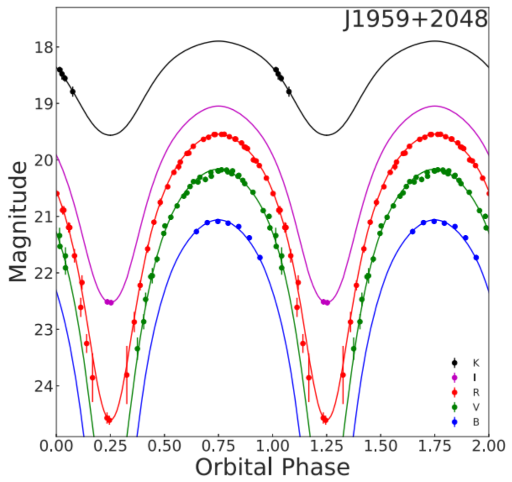




dispersion, scattering and absorption(free-free)

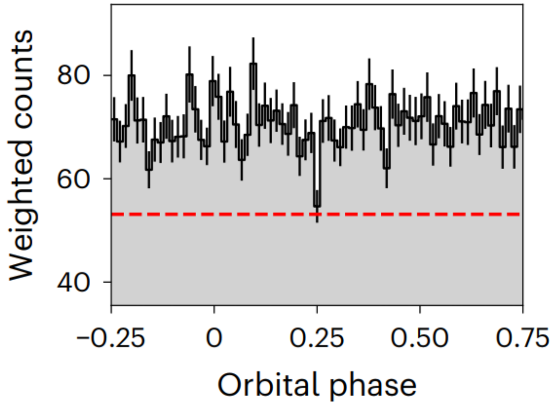
E. J. Polzin et.al, 2020, MNRAS

Multiband optical light curve



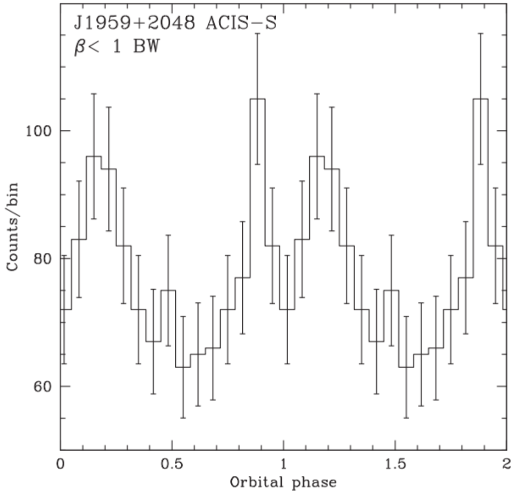
Paul Draghis, 2019, ApJ

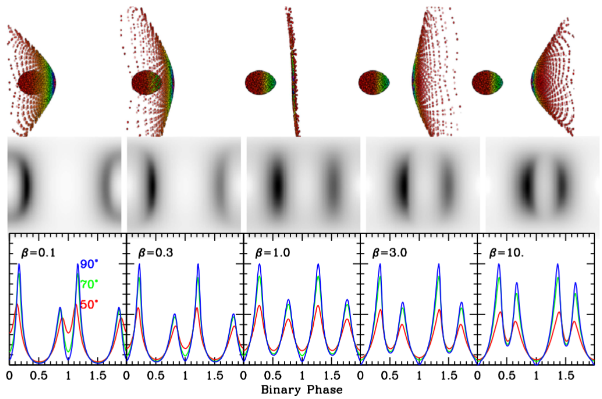
Gamma-ray eclipse



C. J. Clark, 2023, Natur Astro

X-ray light curve





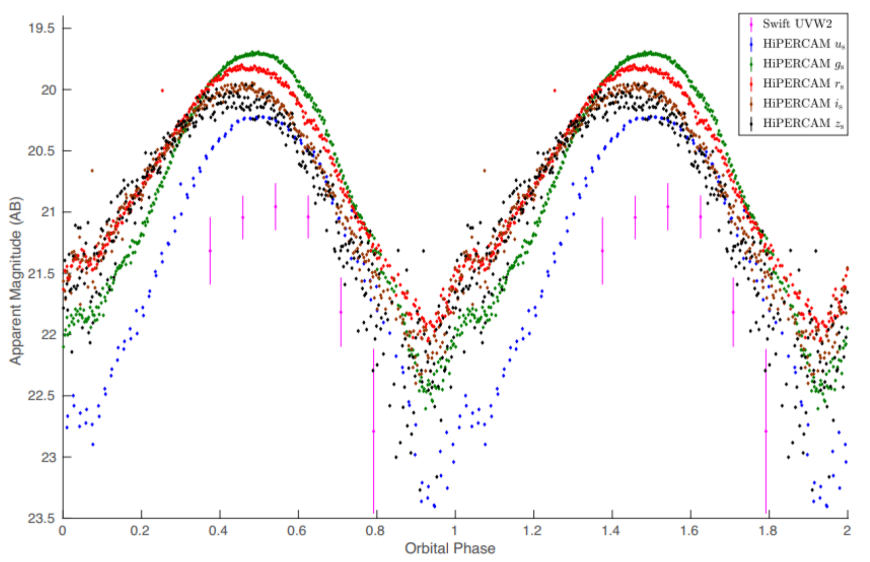
synchrotron emission pattern

Roger W. Romani, 2016, ApJ

1.4 Unique Characteristics in Optical Band

Light curve of ZTF J1406+1222

Article



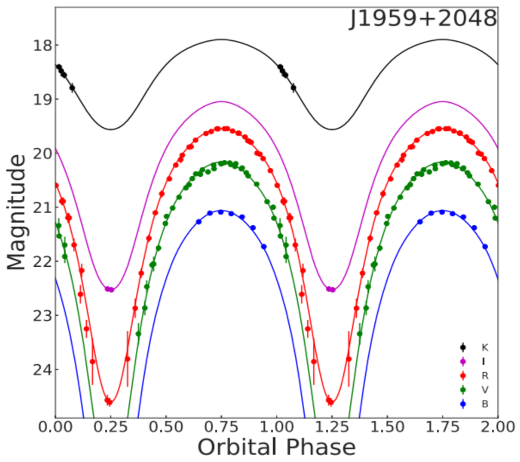
ZTFJ1406+1222 exhibits misalignment in the peak of light curves at different frequencies, suggestive of an asymmetric temperature distribution on the surface of the irradiated object.

Kevin B. Burdge, 2022, Nature

Disagreement between optical and gamma analysis for PSR J1959+2048

Optical light curve analysis

Multiband light curve



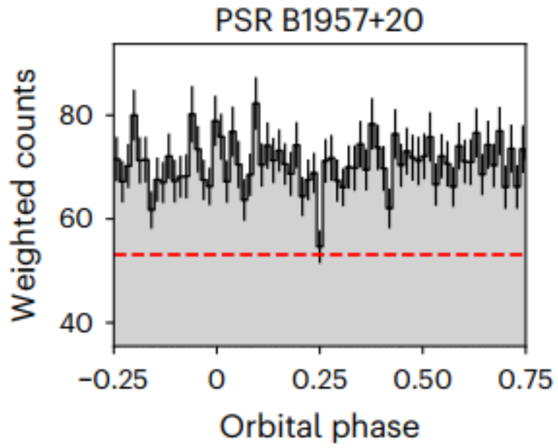
Paul Draghis et. Al, 2019, ApJ

Predict inclination: $62.5°^{+1.3}_{-1.1}$

Prediction NS mass: ~2.4 M_{sun}

Gamma-ray eclipse analysis

Light curve of gamma-ray



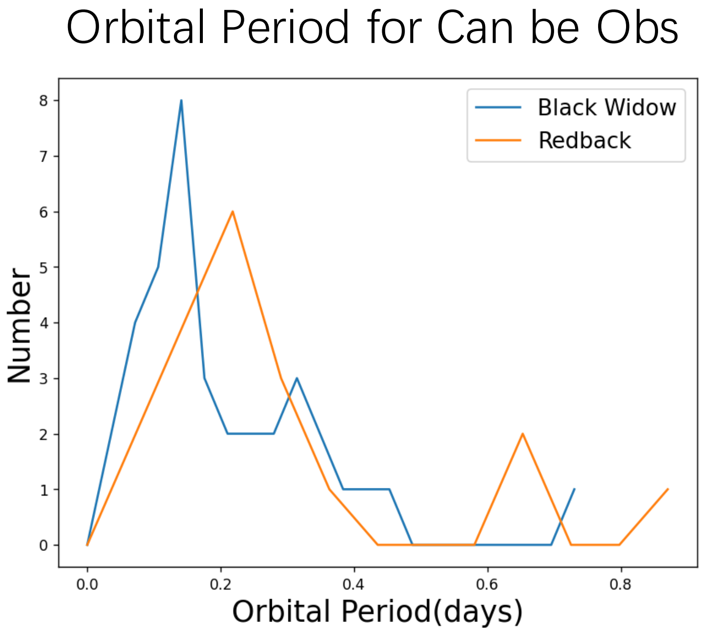
C. J. Clark et. al, 2023, NaA

Predict inclination: ⩾ 84.1°

Prediction NS mass: 1.67-1.94 M_{sun}

2.1 Investigation Process

Type	Number
Black Widow	51
Redback	42
Transform millisecond pulsar(tMSP)	4
Huntsman	2
Can be Observed(DEC∈[-30, 90])	60



Published data(2022)

OPEN ACCESS

A New Flaring Black Widow Candidate and Demographics of Black Widow Millisecond Pulsars in the Galactic Field

Samuel J. Swihart[1], Jay Strader[2], Laura Chomiuk[2], Elias Aydi[2], Kirill V. Sokolovsky[2,3], Paul S. Ray[4], and Matthew Kerr[4]

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Published data(2019)

Optical Spectroscopy and Demographics of Redback Millisecond Pulsar Binaries

Jay Strader[1], Samuel Swihart[1], Laura Chomiuk[1], Arash Bahramian[2], Chris Britt[3], C. C. Cheung[4], Kristen Dage[1], Jules Halpern[5], Kwan-Lok Li[6], Roberto P. Mignani[7,8]
+ Show full author list

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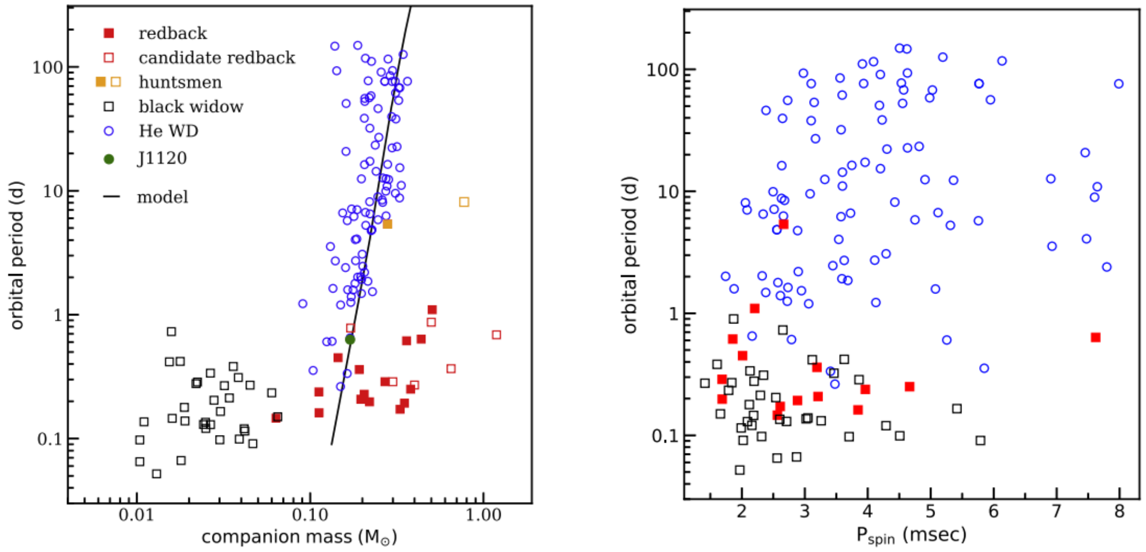
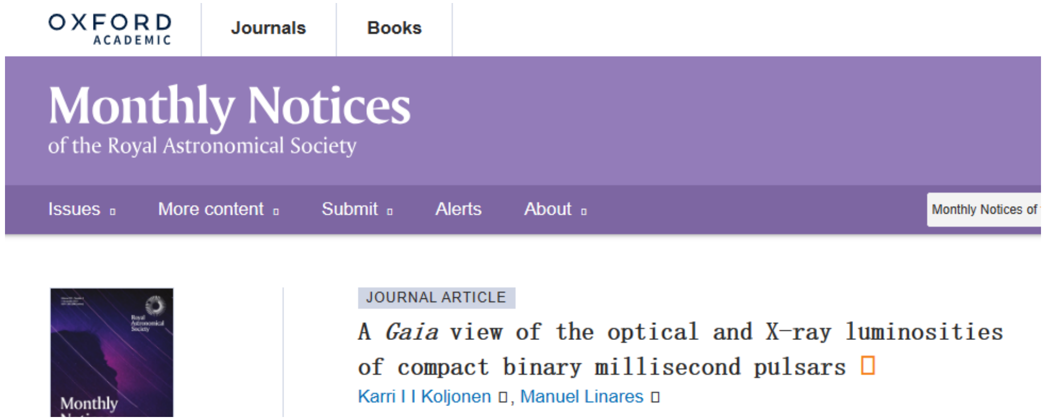


2.2 Optical Information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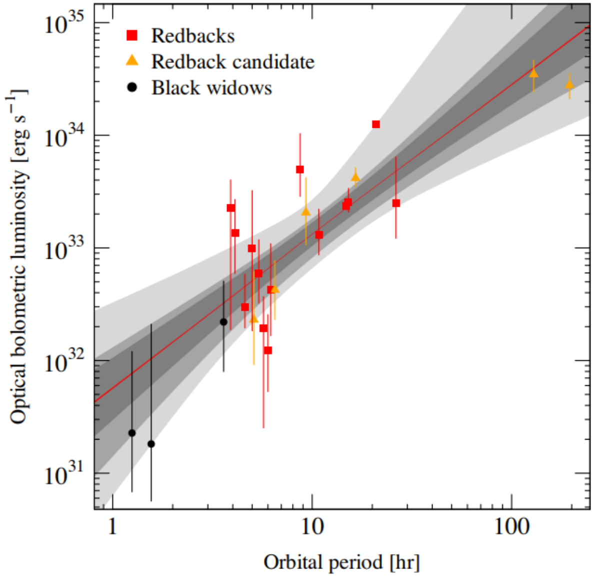
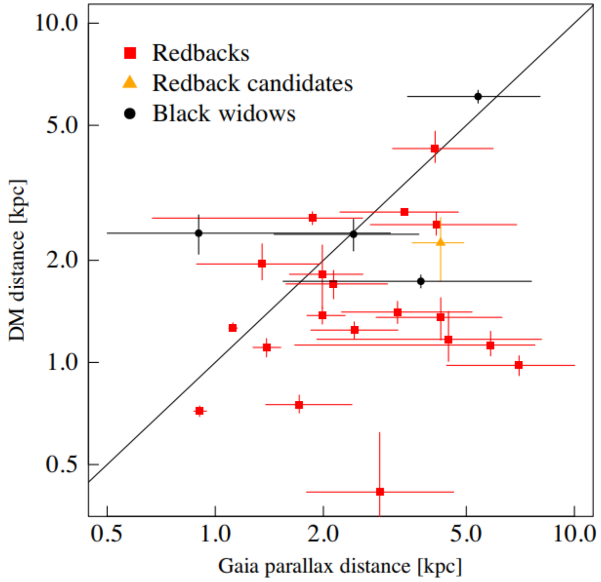
JOURNAL ARTICLE

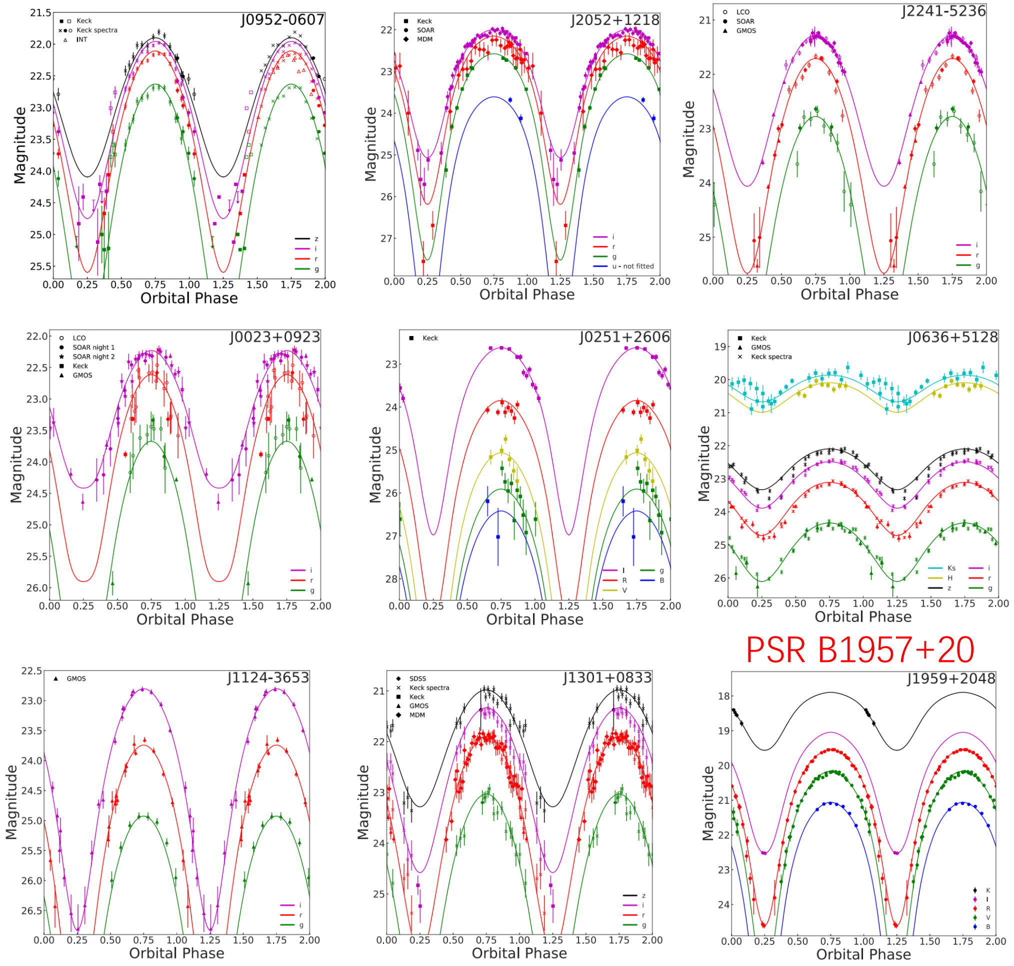
A *Gaia* view of the optical and X-ray luminosities of compact binary millisecond pulsars

Karri I I Koljonen, Manuel Linares





Light curve of Spider binaries



Paul Draghis et. Al, 2019, ApJ

3.1 Sources with short period and high Mag

Black Widow

	Name	RA	DEC	P_{orb} (days)	MagU	MagB	MagV	MagR	MagI	MagG (Gaia)
1	1FGL J0334.2+7501	03 36 06.0	+75 03 00	0.1549						20.6
2	3FGL J0935.2+0903	09 35 19.8	+09 01 50	0.1015						20.6
3	ZTF J1406+1222	14 06 56.17	+12 22 43.39	0.0430						20.1
4	PSR J1555-2908	15 55 40.65	-29 08 28.42	0.2335						20.4
5	PSR J1653-0158	16 53 38.07	-01 58 36.84	0.0519		20.4		19.4		20.4
6	PSR J1810+17	18 10 37.28	+17 44 37.42	0.1481						20
7	PSR J1908+2105	19 09 32.0	+21 02 56	0.146						20.8
8	PSR J1928+1245	19 28 45.38	+12 45 53.39	0.1366						18.2
9	PSR J2055+3829	20 55 10.30	+38 29 30.90	0.1295						21

Screening Condition: P_{orb} < 0.3d or 7.2h & Mag<21

3.1 Sources with short period and high Mag

Redback

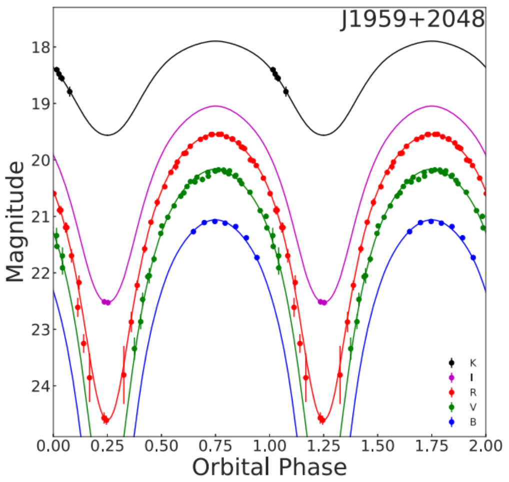
	Name	RA	DEC	P_{orb}(days)	MagU	MagB	MagV	MagR	MagI	magG (Gaia)
1	PSR J0838-2827	08 38 30.15	-28 25 55.5	0.2145						19.4-20.5
2	PSR J1048+2339	10 48 43.43	+23 39 53.57	0.2505			19.47			19.6
3	1FGL J1544.5-1127	15 44 14.33	-11 24 42.0	0.2415						18.6
4	PSR J1622-0315	16 22 59.64	-03 15 37.30	0.1617						19.2
5	PSR J1908+2105	19 09 32.0	+21 02 56	0.146						20.8
6	PSR J1957+2516	19 57 34.61	+25 16 02.24	0.2381						20.3
7	PSR J2215+51	22 15 32.68	+51 35 36.40	0.1725						18.7-20.0
8	PSR J2339-0533	23 39 38.74	-05 33 05.10	0.1930			18.48			17.8-20.6

Screening Condition: P_{orb} < 0.3d or 7.2h & Mag<21

3.2 First Spider PSR J1959+2048

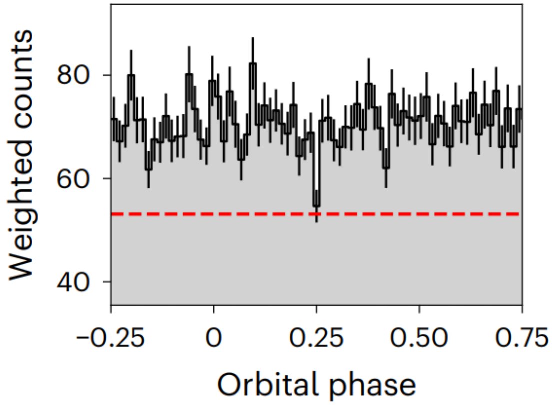
Name	PSR 1959+2048
RA	19 59 36.76
DEC	+20 48 14.89
P_{orb}(days)	0.3819
Mag B	21.08
Mag V	20.16
Mag R	19.53
Mag I	18.79
Mag G(Gaia)	20.2
Special Mag	k~18 I~20 R,V~21 B~22 (Paul Draghis, 2019 ,ApJ)
Type	Redback

Multiband optical light curve



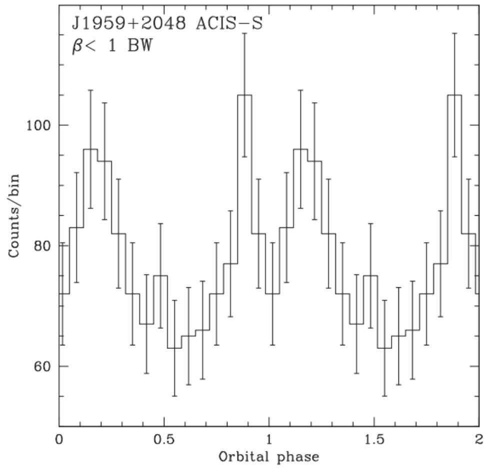
Paul Draghis, 2019, ApJ

Gamma-ray eclipse



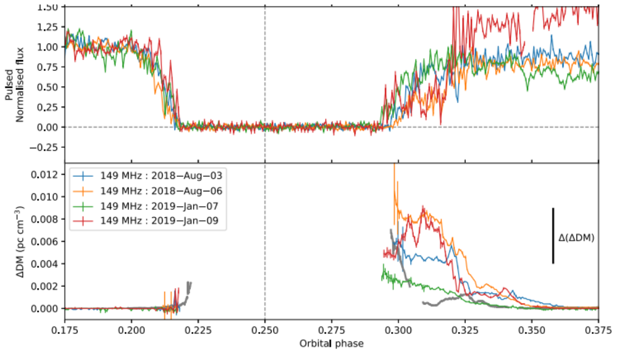
C. J. Clark, 2022, Natur Astro

X-ray light curve



Roger W. Romani, 2016, ApJ

Pulsed flux densities of PSR

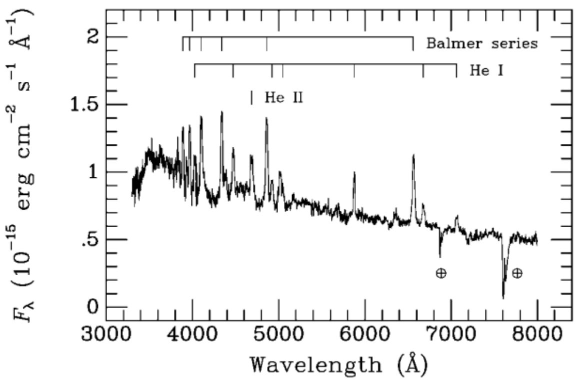


E. J. Polzin, 2020, MNRAS

3.3 tMSP PSR J1023+0038

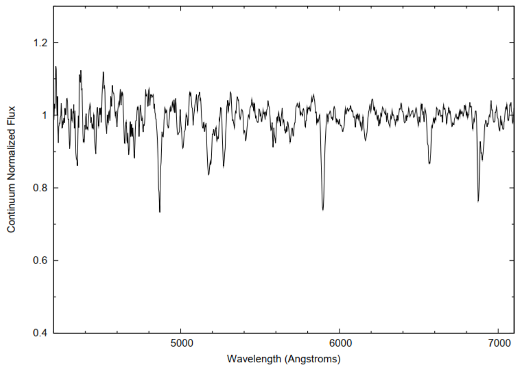
Name	PSR 1023+0038
RA	10 23 47.68
DEC	+00 38 41.00
P_{orb}(days)	0.1980
Mag V	17.31
Mag G(Gaia)	15.8-16.7
Type	Redback/tMSP

First time identified in 2002
(Accretion State)



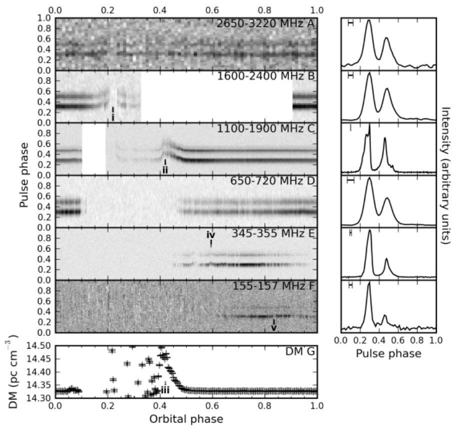
Howard E. Bond, 2002, PASP

Model Changing in 2005
(Radio Pulsar State)



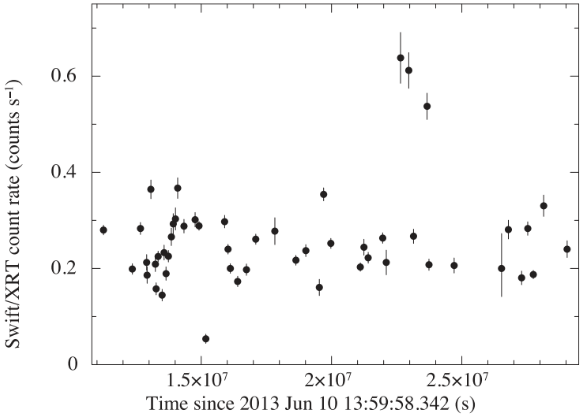
John R. Thorstensen, 2005, ApJ

Radio pulse detected in 2009



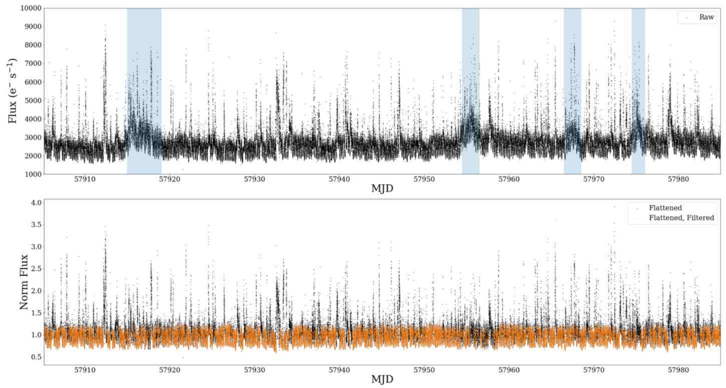
Anne M. Archibald, 2009, Sci

Model Changing in 2014
(LMXB State)



F. Coti Zelati, 2014, MNRAS

Long term Optical flaring activity in the NS accretion disc

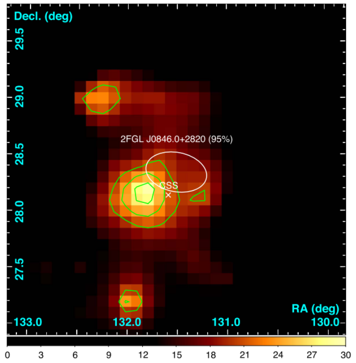


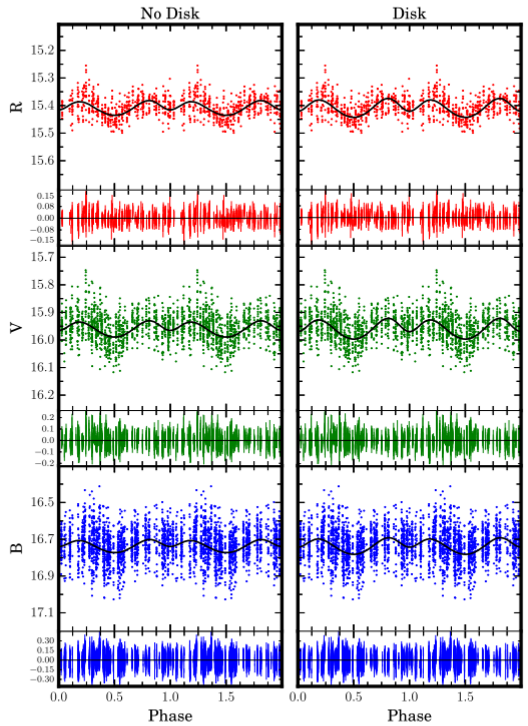
M. R. Kennedy, 2018, MNRAS

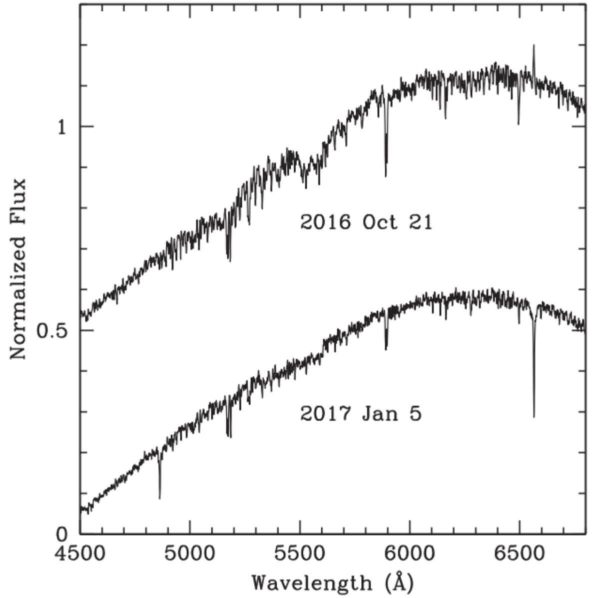
3.4 Huntsman 2FGL J0846.0+2820

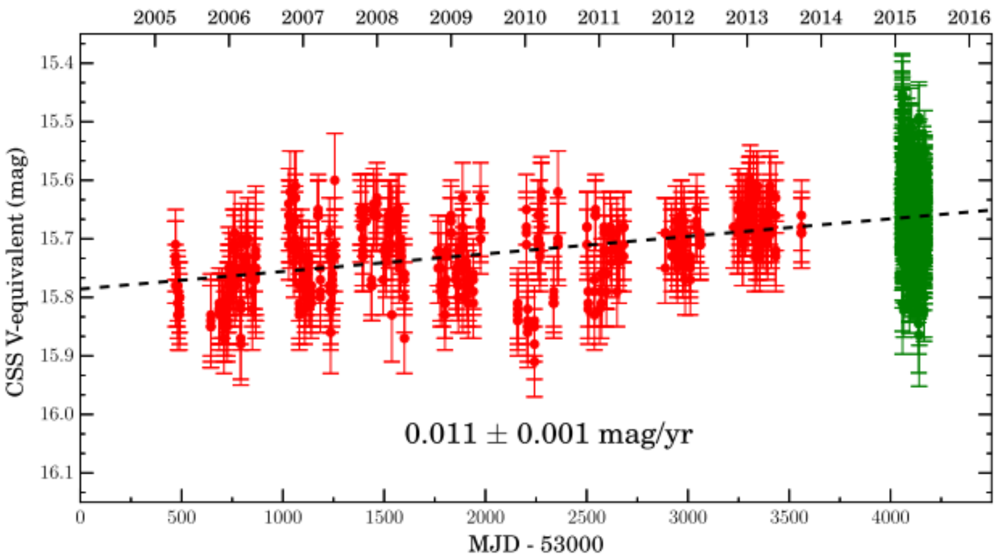
Name	2FGL J0846.0+2820
RA	08 46 21.87
DEC	+28 08 40.83
P_{orb}(days)	8.1328
Mag G(Gaia)	15.6-15.7
Type	Redback/Huntsman

Long-term optical light curve showing a monotonic increase in the system brightness over the past decade. This trend may be due to the slowly increasing in companion`s radius, the increasing of mean effective temperature (either globally or due to a change in the properties of starspots), or the accretion disk getting brighter.









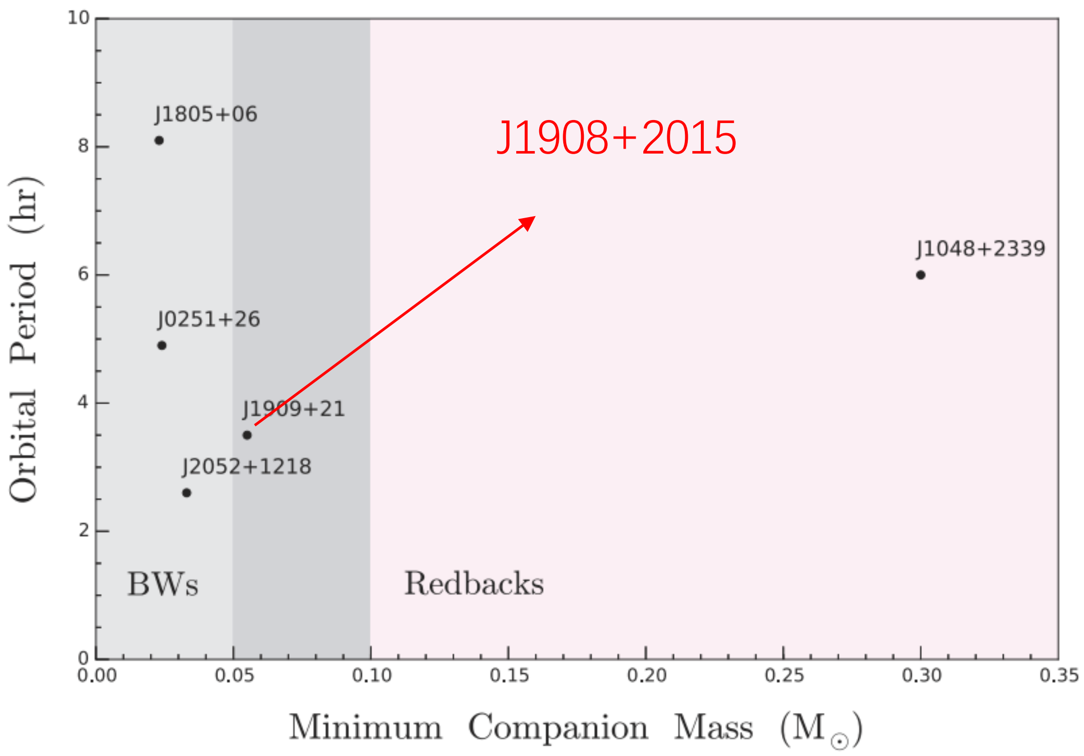
Samuel J. Swihart, 2017, ApJ

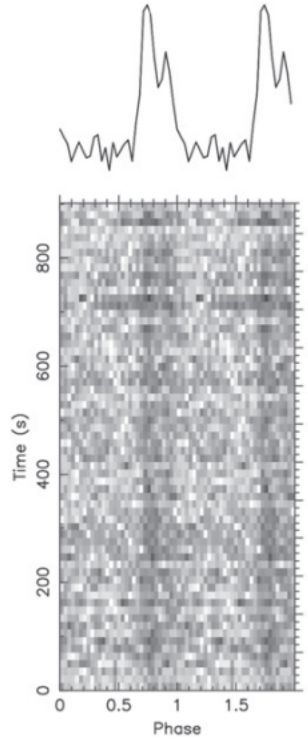
3.5 PSR J1908+2105 (Type uncertainty)

Name	PSR J1908+2105
RA	19 08 57.29
DEC	+21 05 02.22
P_{orb}(days)	0.146
Mag G(Gaia)	20.8
Type	Redback/Huntsman

The mass of J1908+2105`s companion seems to be on the boundary between the Redback and black widow. The radio eclipse of this source is about 40% of the orbit(no relevant paper was found), while the typical for the redback and black widow are respectively 50% and 20%. There are also few of optical information of this source unless the Gaia's observations in the G-Band. But considering the uniqueness of this source, perhaps observing it could yield some very interesting results.

First Gamma Pulse Detection in 2016

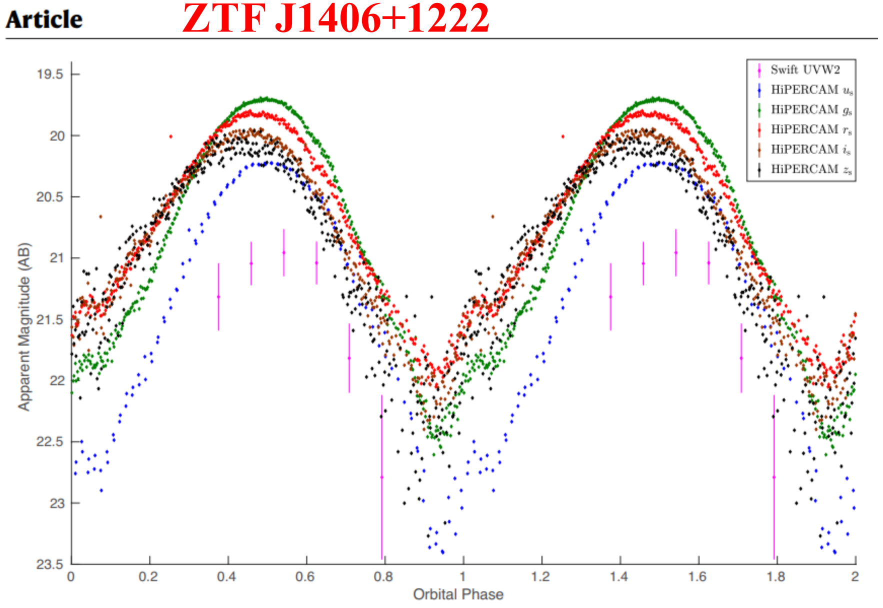




H. T. Cromartie, 2016, ApJ

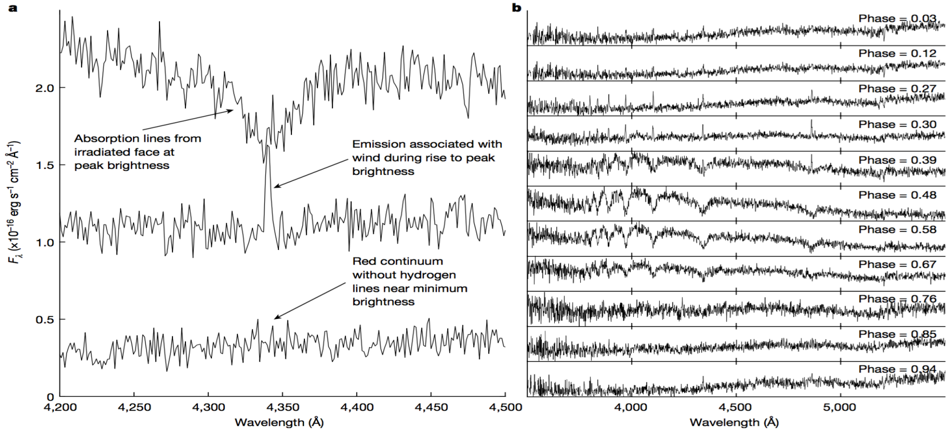
3.6 ZTF J1406+1222

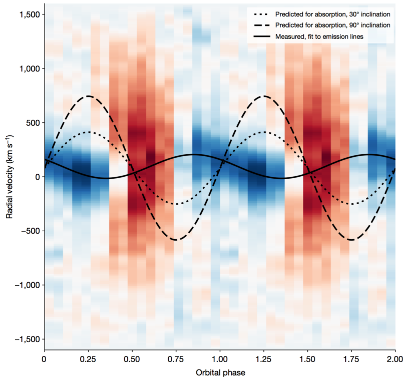
Light curve of ZTF J1406+1222

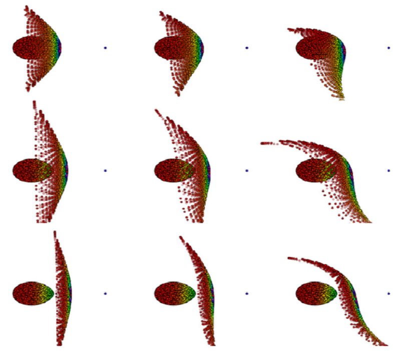


The light curves exhibits prominent phase shifts in the peak flux for different frequency, suggestive of an asymmetric temperature distribution on the surface of the irradiated object.

Spectroscopy of ZTF J1406+1222







Romani & Sanchez, 2016, ApJ

Kevin B. Burdge, 2022, Nature

Summary

- We give a simple introduction of Spider system. They have multiband emission and some unique optical characteristics, which is different from other classical binary. Its value lies in the ability to search for massive pulsars by looking for massive spiders.

- We conducted a systematic search for spider based on two articles (Jay Strader, 2019, ApJ; Samuel J. Swihart, 2022, ApJ), ultimately identifying about 90 sources, of which 60 meet the coordinate selection criteria.

- We selected some sources with low magnitude and short period and some special sources, hoping to get some interesting results in the observation of these sources in the future.

That`s all, and thanks for your attention!