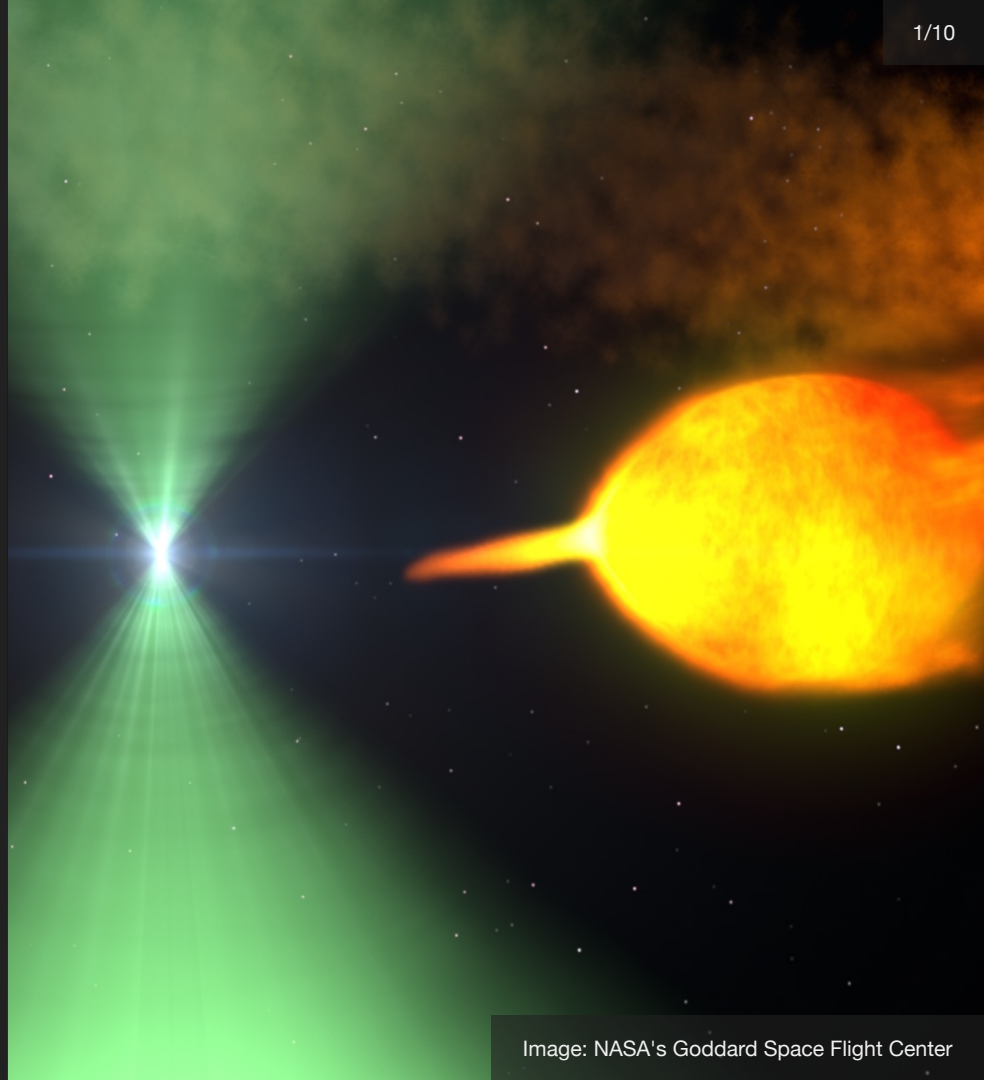# The power of the dark side: Hunting spiders to find the most massive neutron stars

Jordan Simpson, Manuel Linares
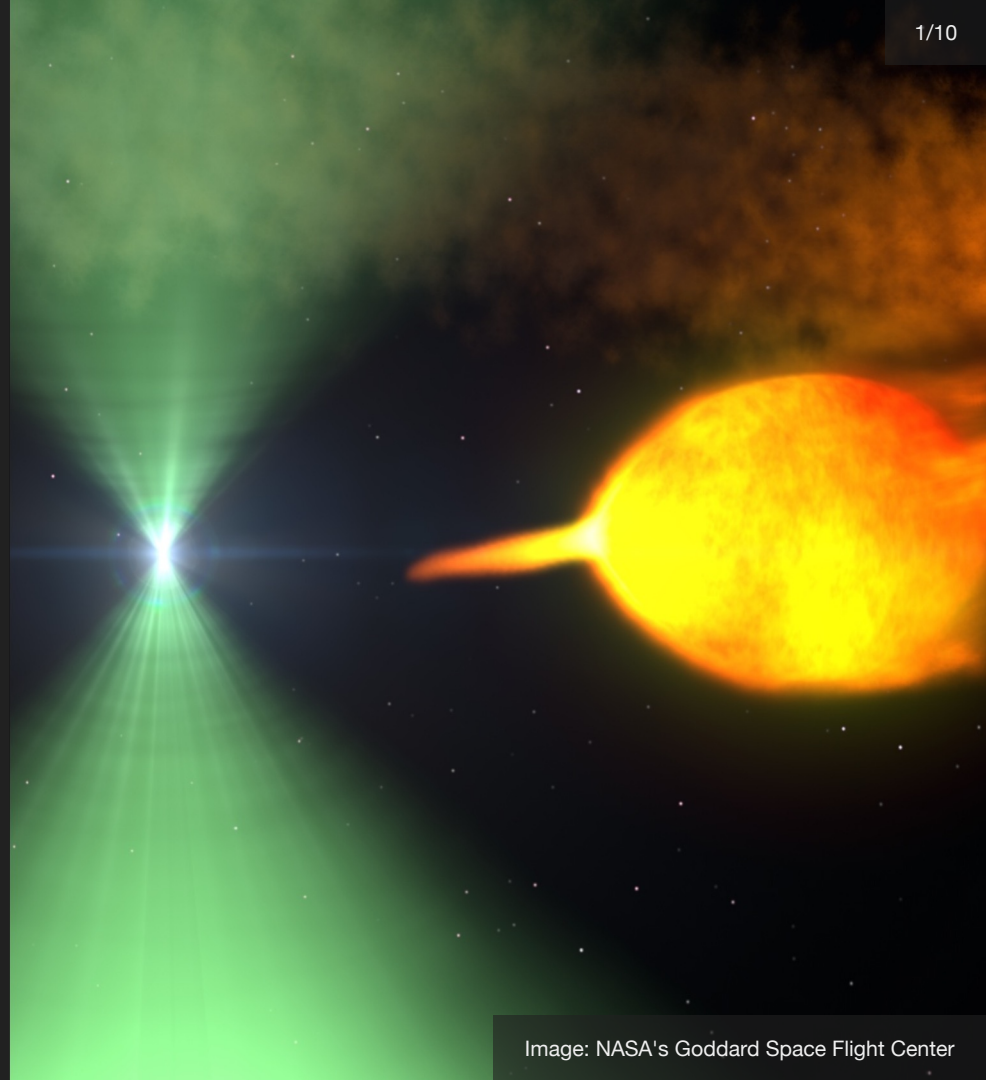
XMM-Newton workshop, 6 June 2024, Madrid, Spain

LOVE NEST

NTNU
Department of Physics

erc

Spiders

- Compact binary millisecond pulsars

Image: NASA's Goddard Space Flight Center

Spiders

- Compact binary millisecond pulsars

- Most massive neutron stars

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  - Astrophysics: SNe, mass gap

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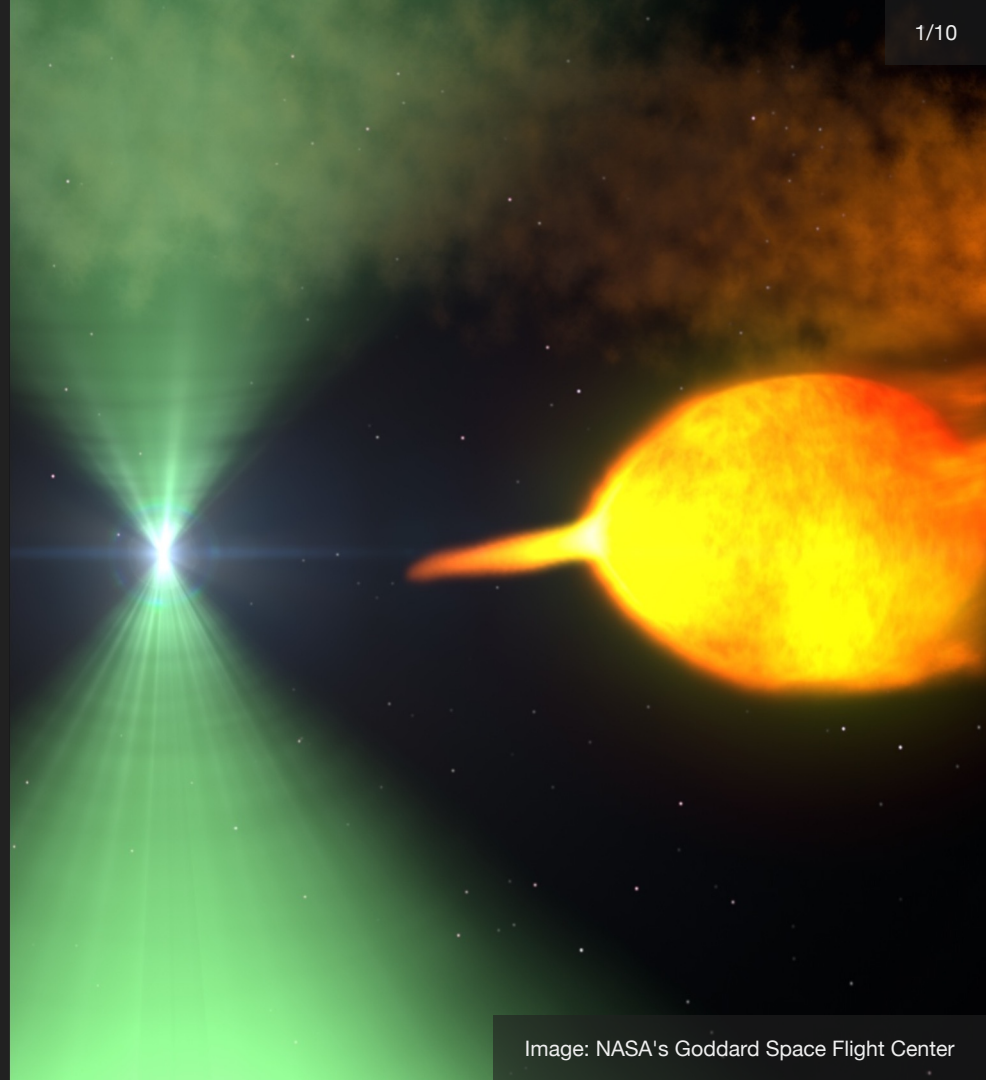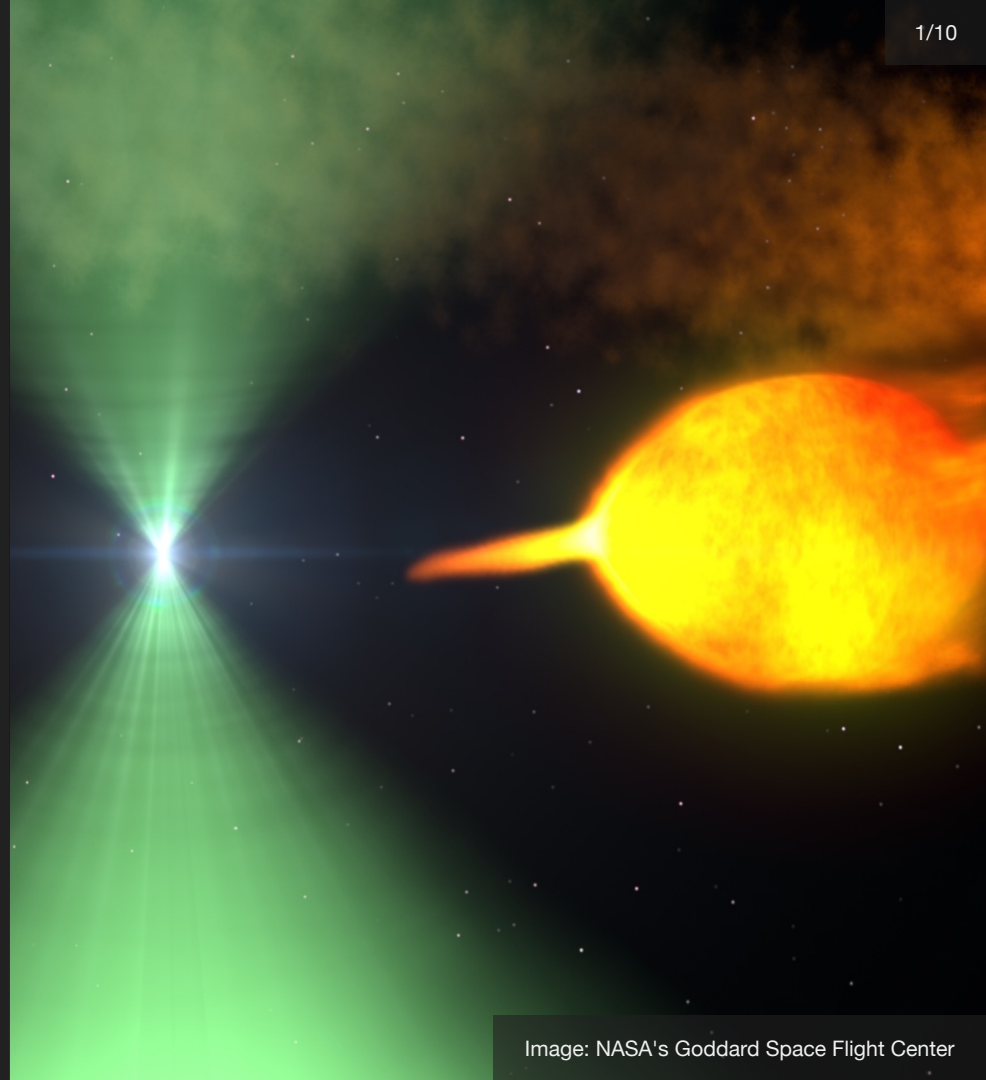
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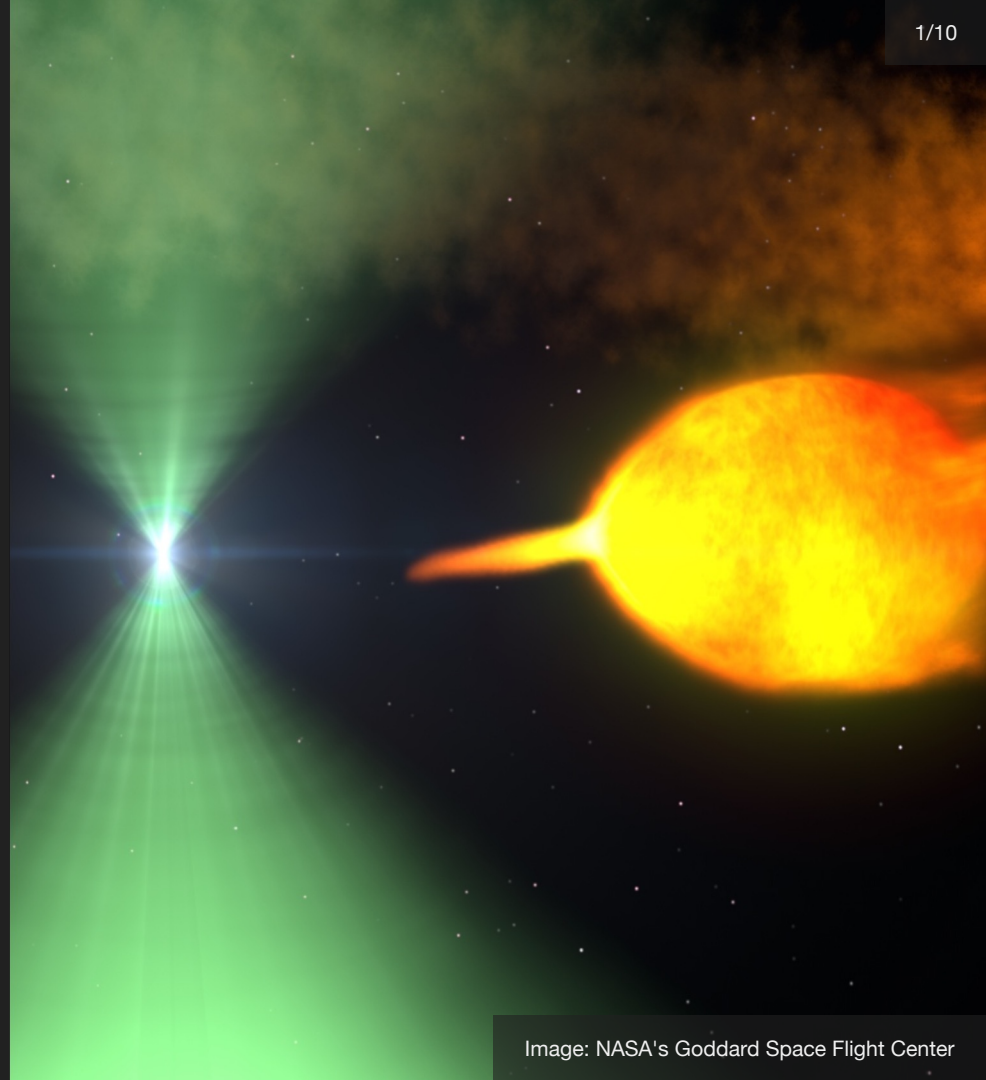Image: NASA's Goddard Space Flight Center

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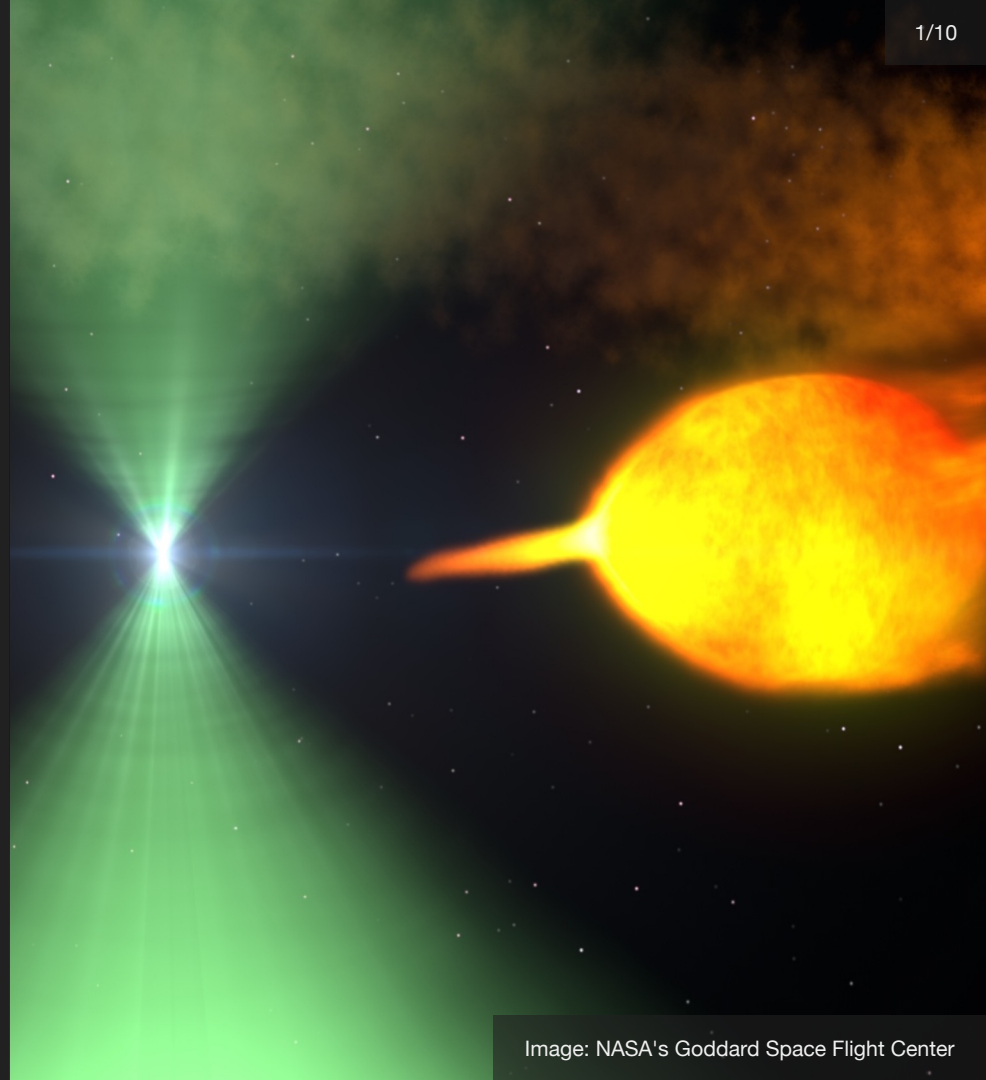Image: NASA's Goddard Space Flight Center

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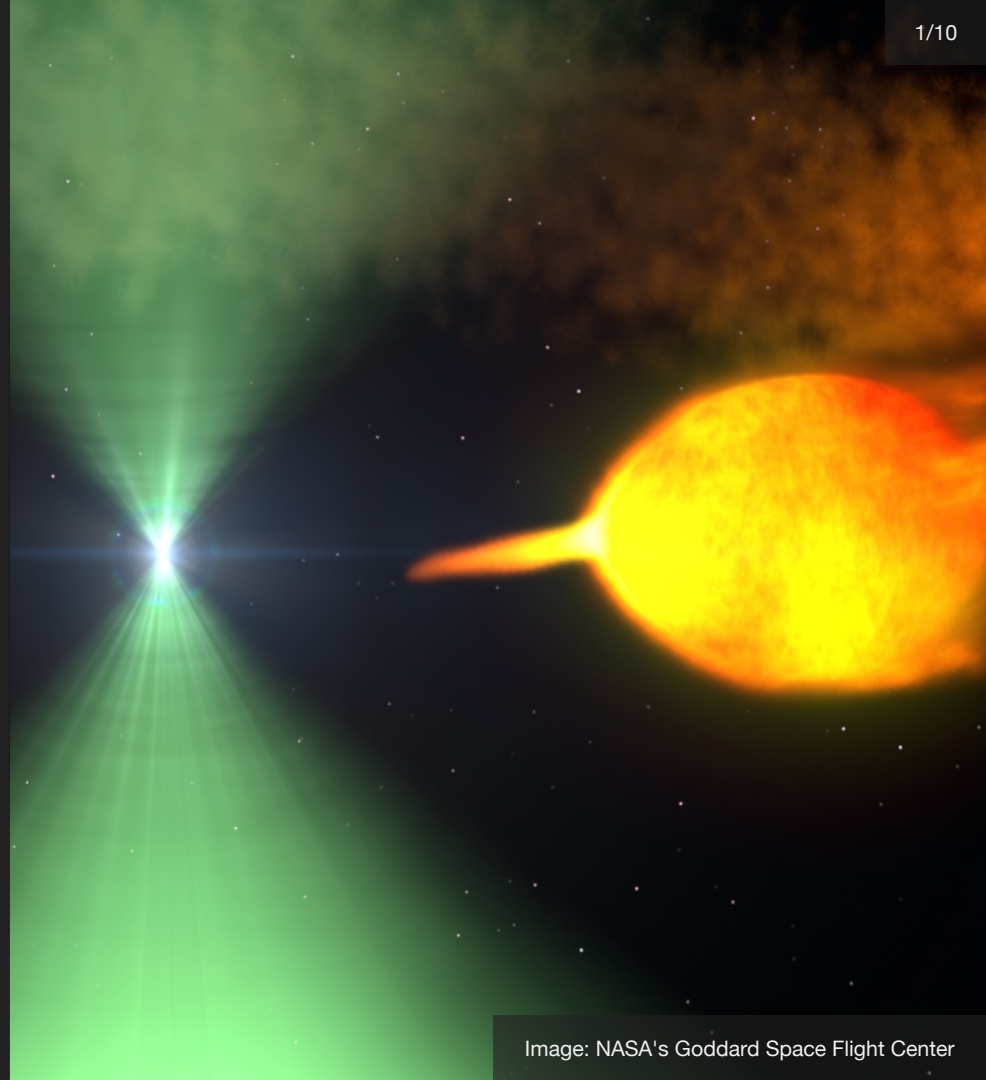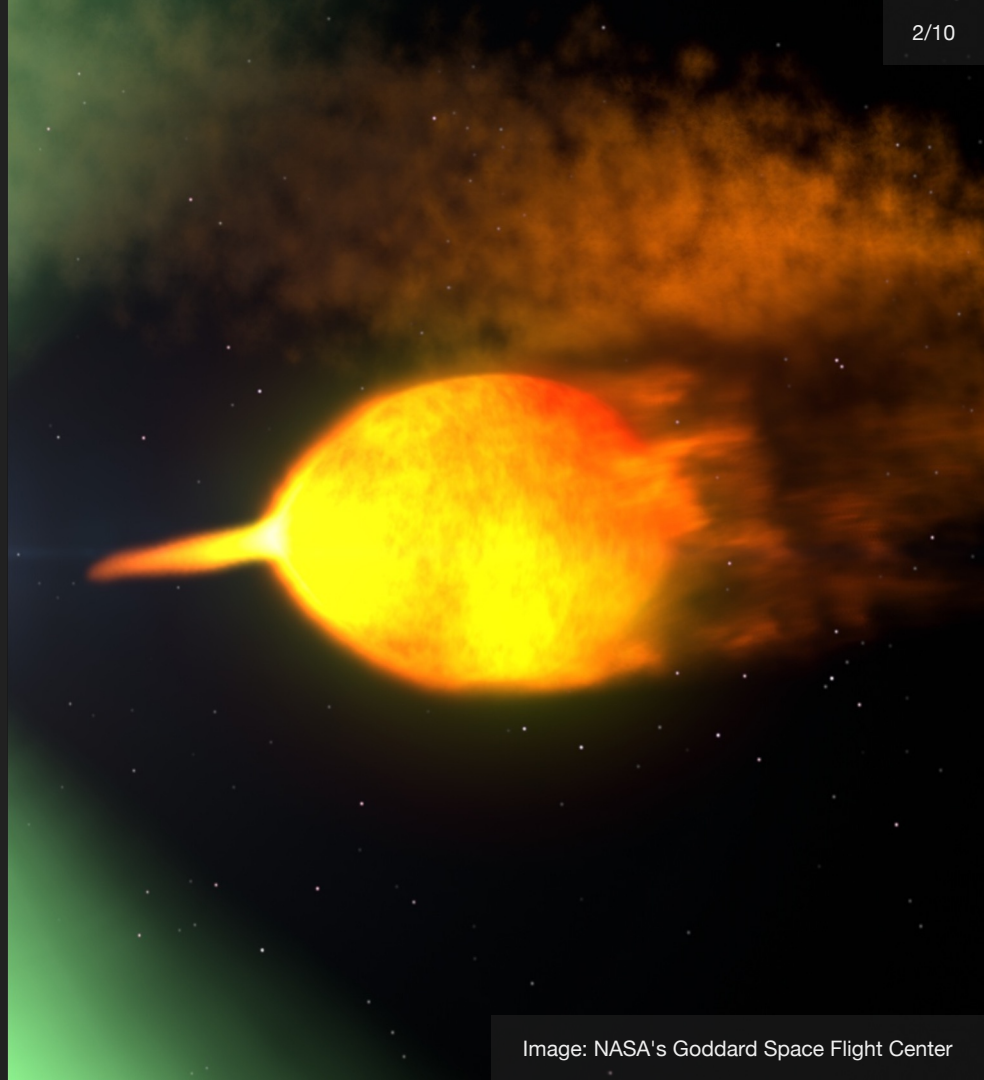
Spiders

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- Redbacks: $M_2 \sim 0.1 \ M_\odot$

- Black widows: $M_2 \sim 0.01 \ M_\odot$
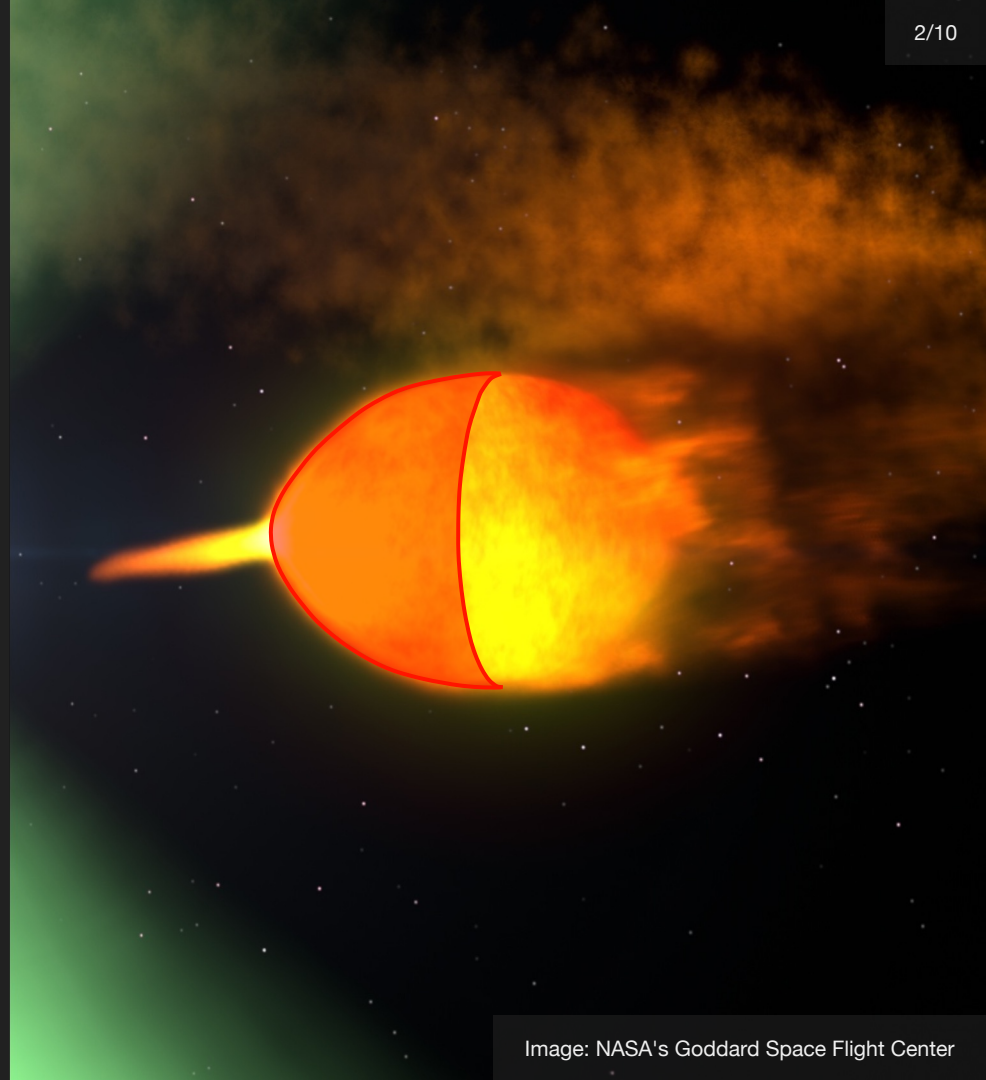
Image: NASA's Goddard Space Flight Center

1/n

The dark side

- Companion often heavily irradiated

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- Centre of light ≠ centre of mass

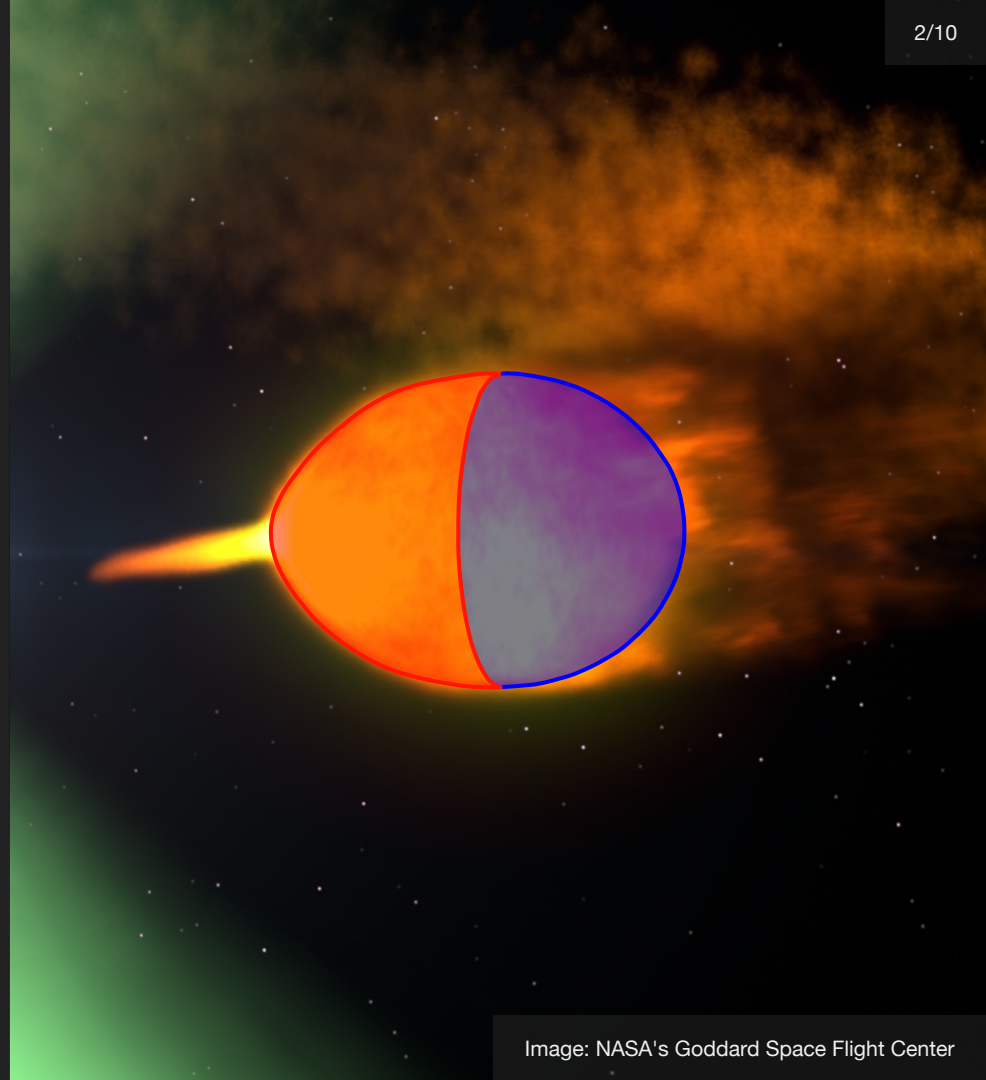Image: NASA's Goddard Space Flight Center

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  $M_{\mathrm{NS}} \propto (K_2)^3$

Image: NASA's Goddard Space Flight Center

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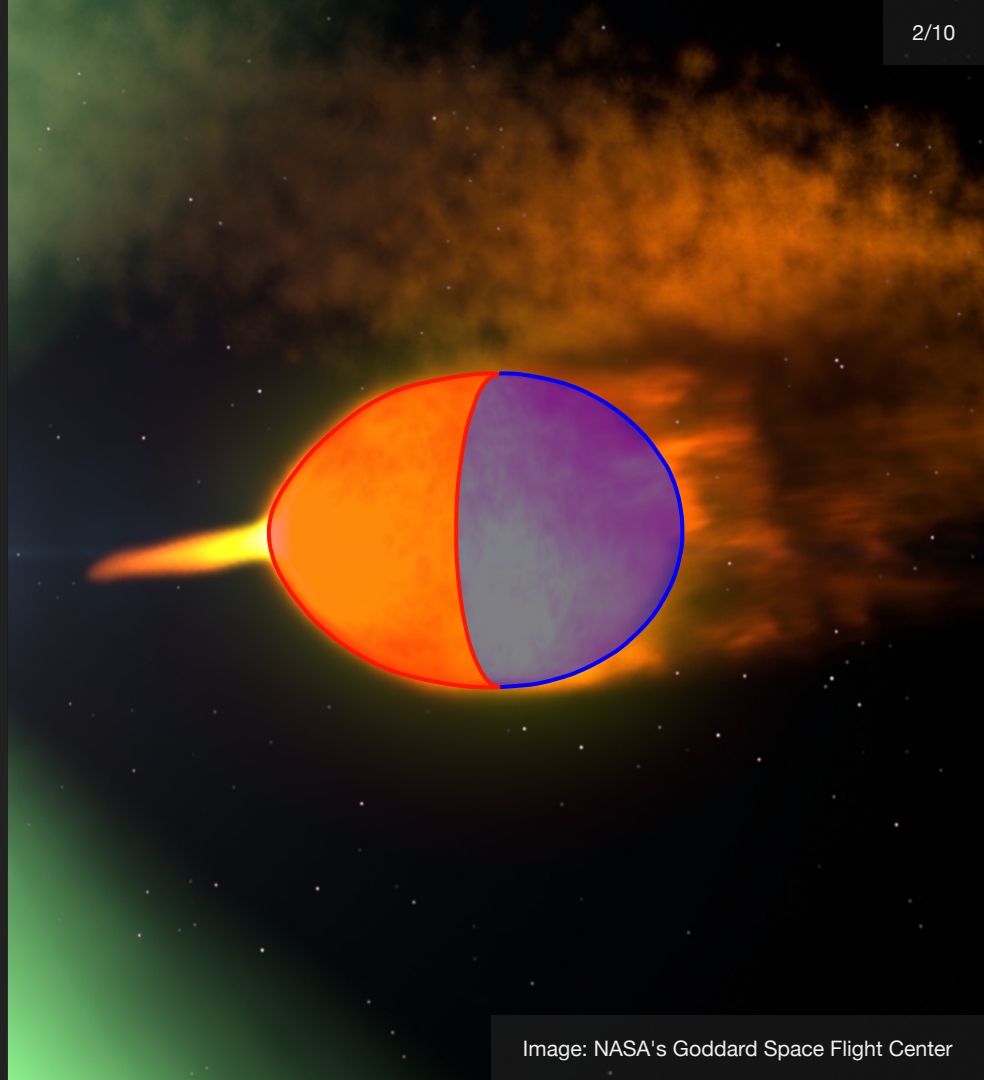 sides of companion

Image: NASA's Goddard Space Flight Center

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- Temperatures inform models

Image: NASA's Goddard Space Flight Center

Observations

- Gran Telescopio Canarias (GTC)

- 10.4 m primary mirror - world's largest single aperture optical telescope

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- Observed 3 systems:
  - PSR J1048+2339 / J1048
  - PSR J1810+1744 / J1810
  - PSR J1908+2105 / J1908

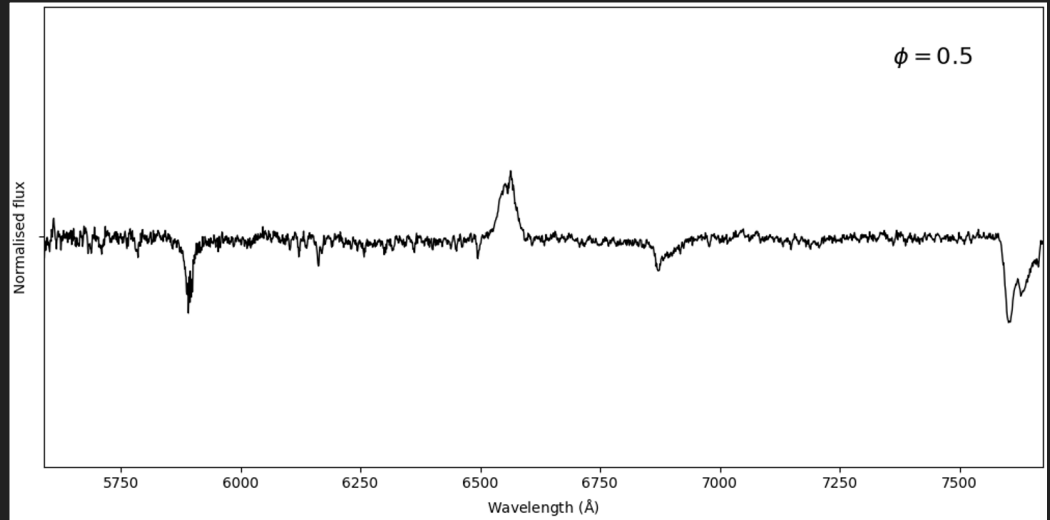- Full orbit coverage over one night each

A highly variable redback

PSR J1048+2339

- Orbital period = 6 hours
- 4.66 ms pulsar
- Minimum M_2 = 0.30 M$_\odot$
- Transient irradiation

Simpson et al. (in prep)

References: Timing solution - Deneva J. S. et al., 2016, ApJ 823 105
Photometry - Tidemann A., 2023, Master's thesis, NTNU
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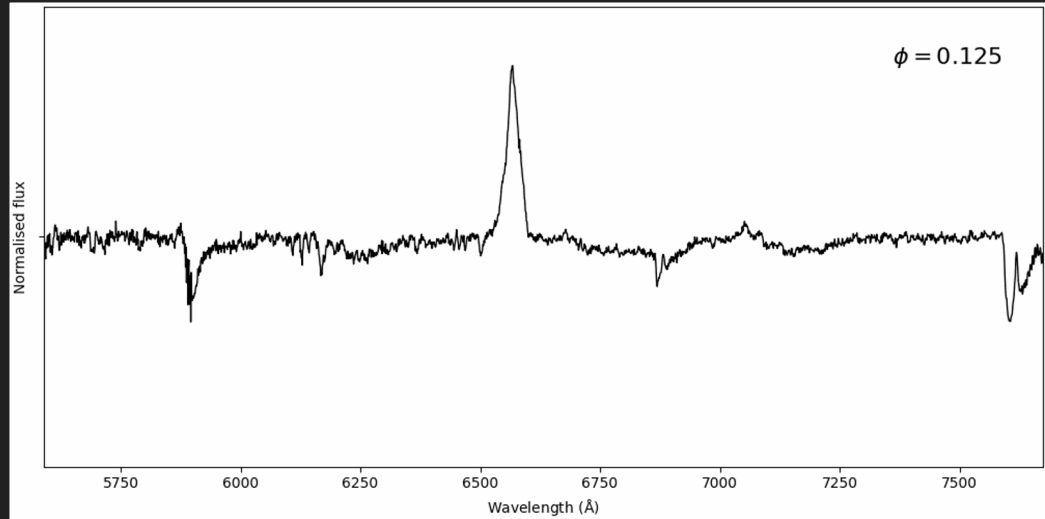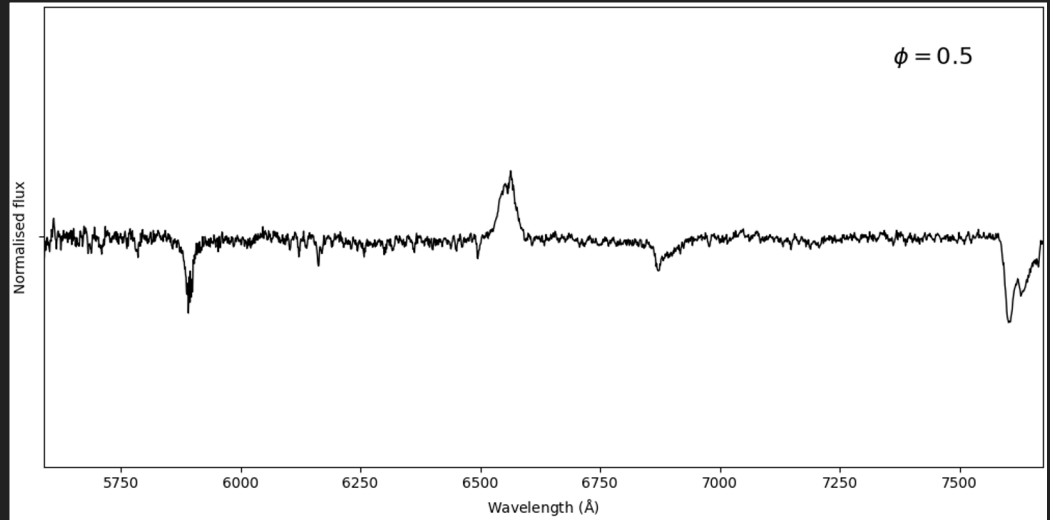- Minimum M_2 = 0.30 M$_\odot$
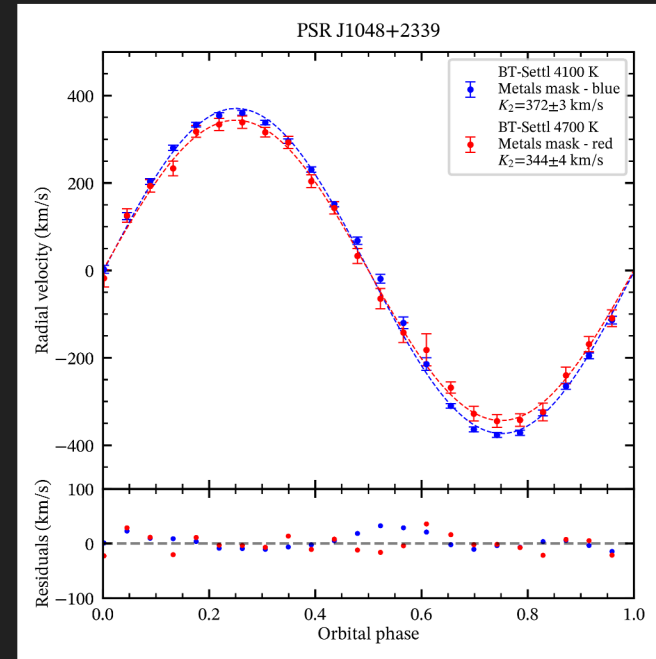- Transient irradiation

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- T_{day} = 4690 ± 51 K
  T_{night} = 4072 ± 32 K

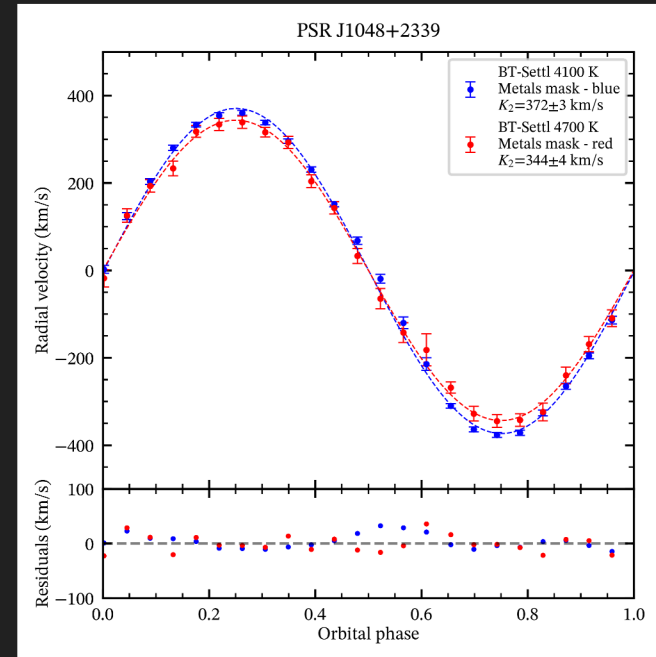- K_{day} = 344 ± 4 km s^{-1}
  K_{night} = 372 ± 3 km s^{-1}

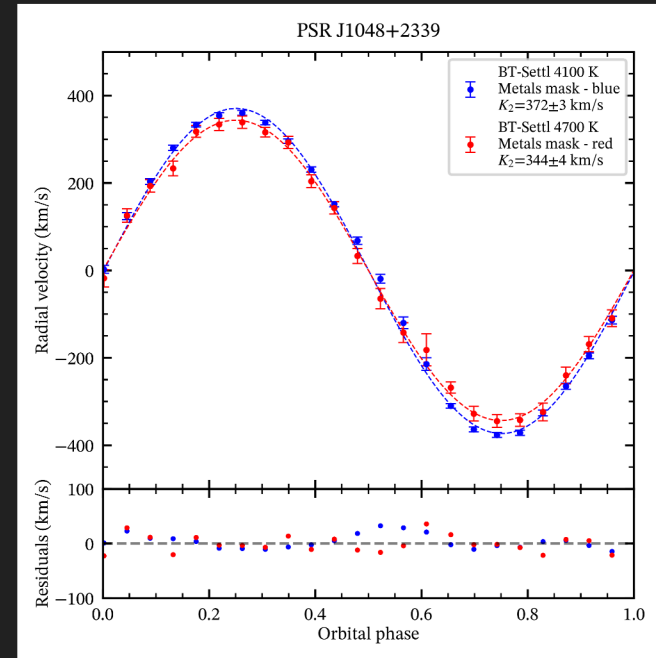Simpson et al. (in prep)

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A strongly irradiated black widow

PSR J1810+1744

- Orbital period = 3.6 hours
- 1.66 ms pulsar
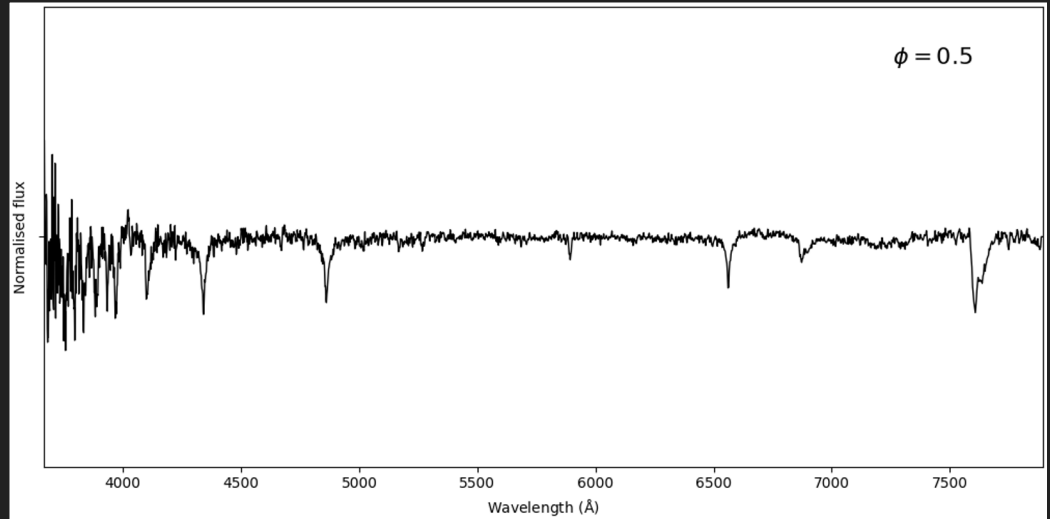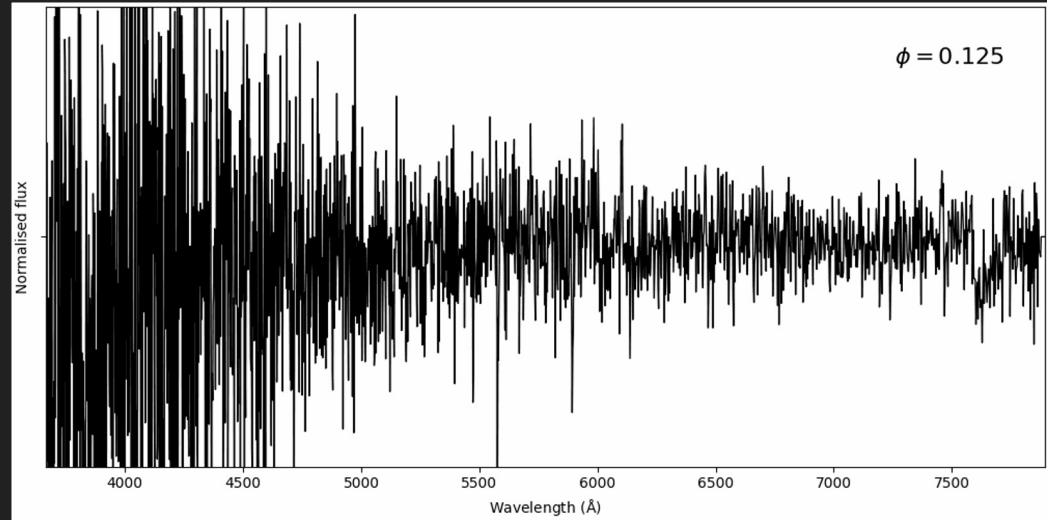- Minimum M_2 = 0.045 M$_\odot$
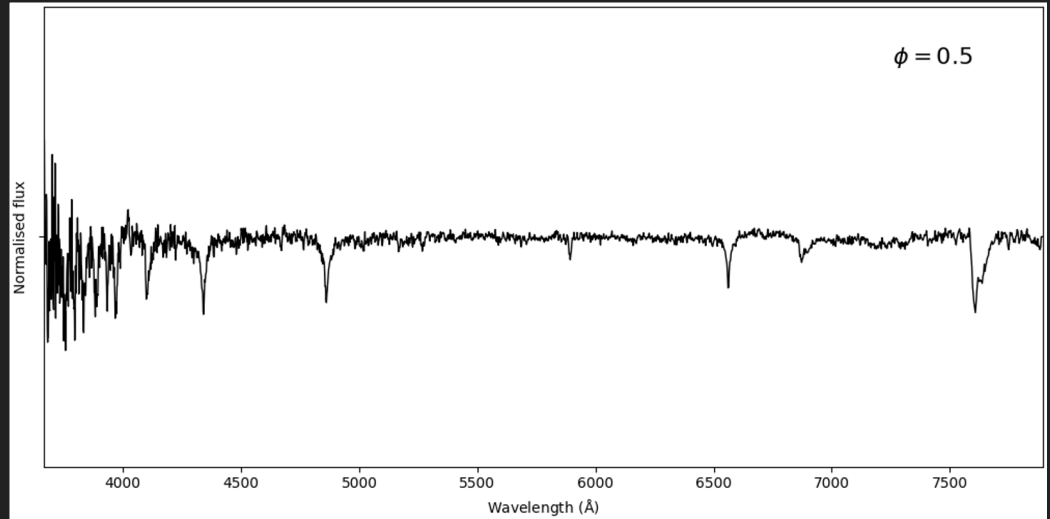- Strong day/night contrast

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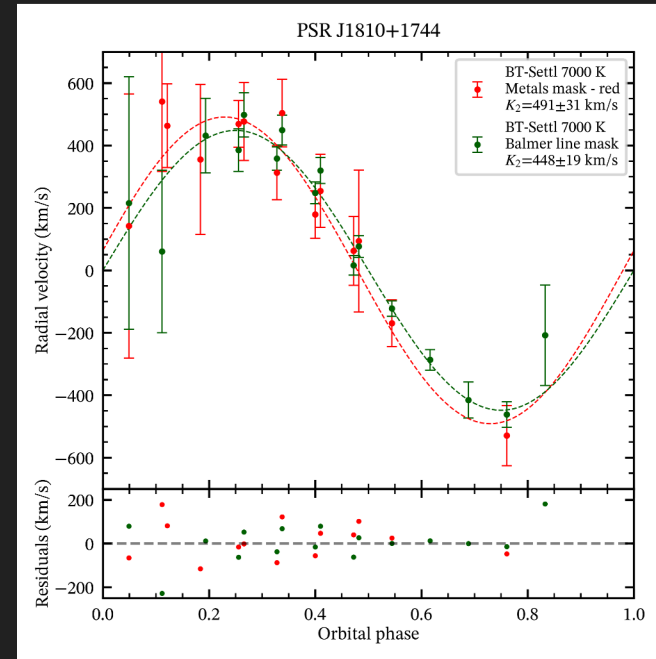- Minimum M_2 = 0.045 M$_\odot$

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- T_{day} = 7827 ± 90 K
  T_{quad} = 7093 ± 138 K

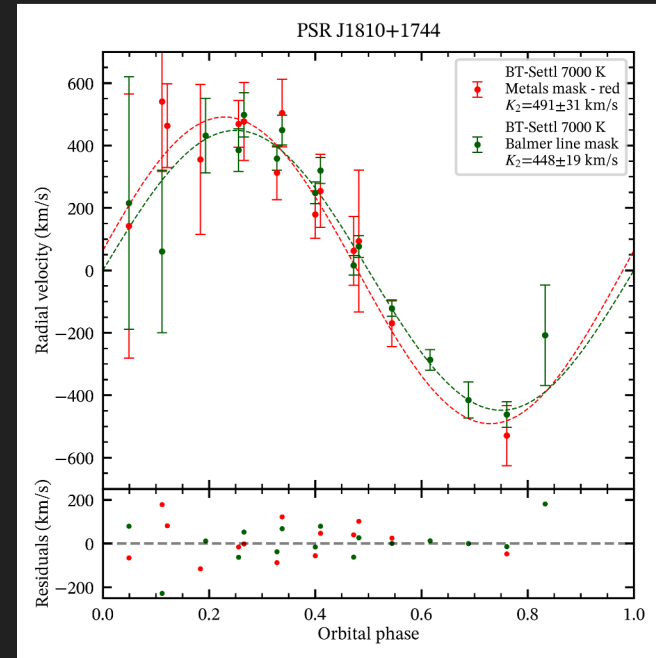- K_{day} = 448 ± 19 km s^{-1}
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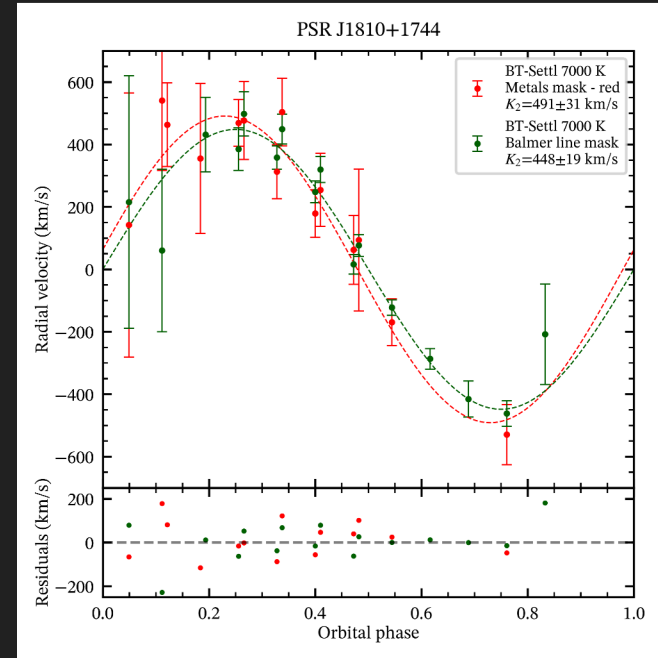

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- Using i < 84.7° (Clark et al. 2023):
  M_NS > 1.3 M$_\odot$
  M_2 : 0.04 - 0.07 M$_\odot$

Simpson et al. (in prep)

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- or i = 66.3 ± 0.5° (Romani et al. 2021):
  M_{NS} > 1.7 M$_{\odot}$
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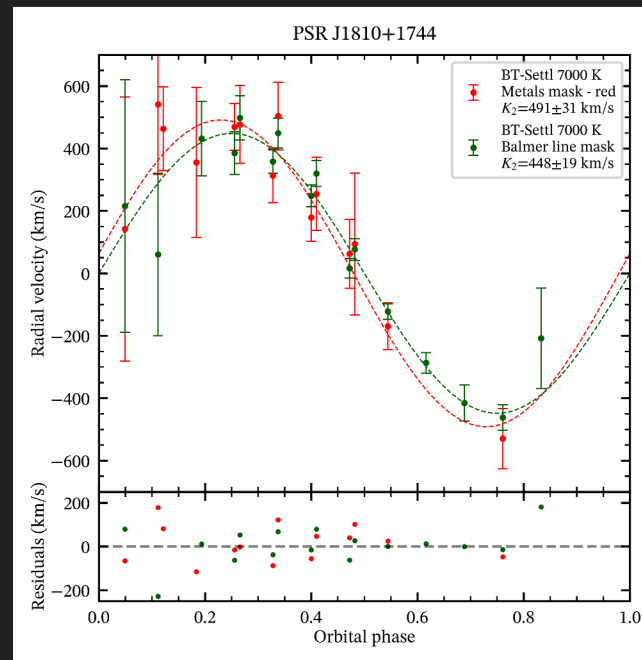Simpson et al. (in prep)

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A mysterious intermediate system?

PSR J1908+2105

- Orbital period = 3.5 hours
- 2.56 ms pulsar
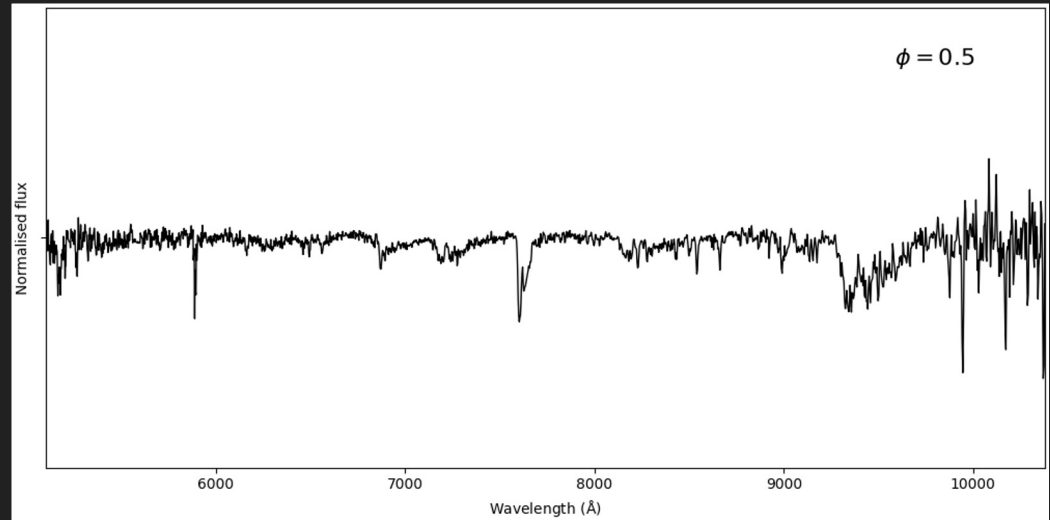- Minimum M_2 = 0.055 M$_\odot$
- An intermediate case?

Simpson et al. (in prep)

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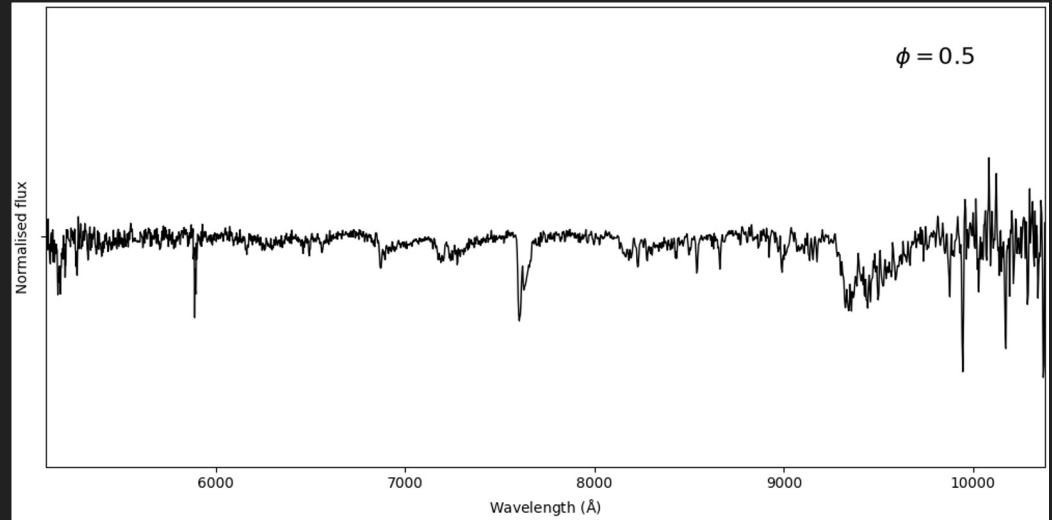- An intermediate case?
- No previous optical observations

Simpson et al. (in prep)

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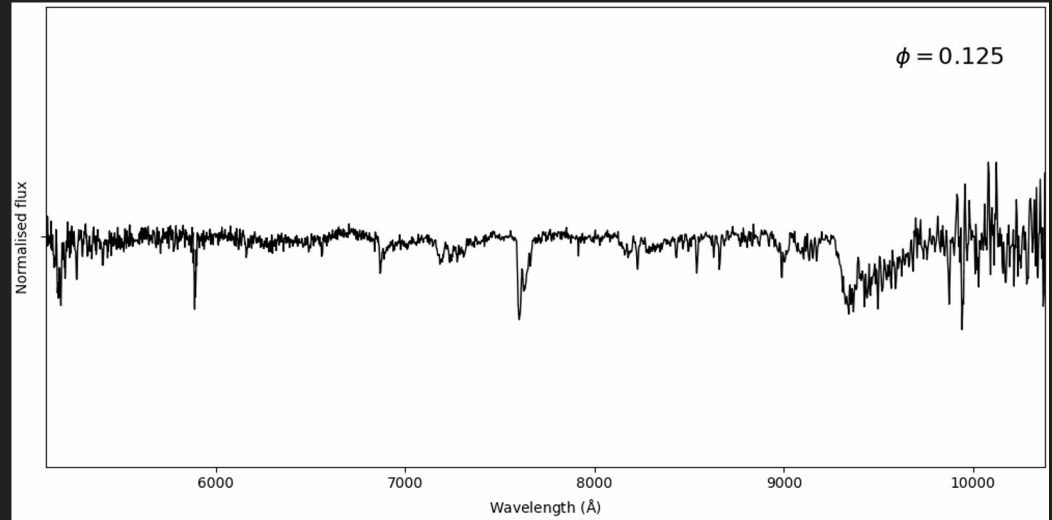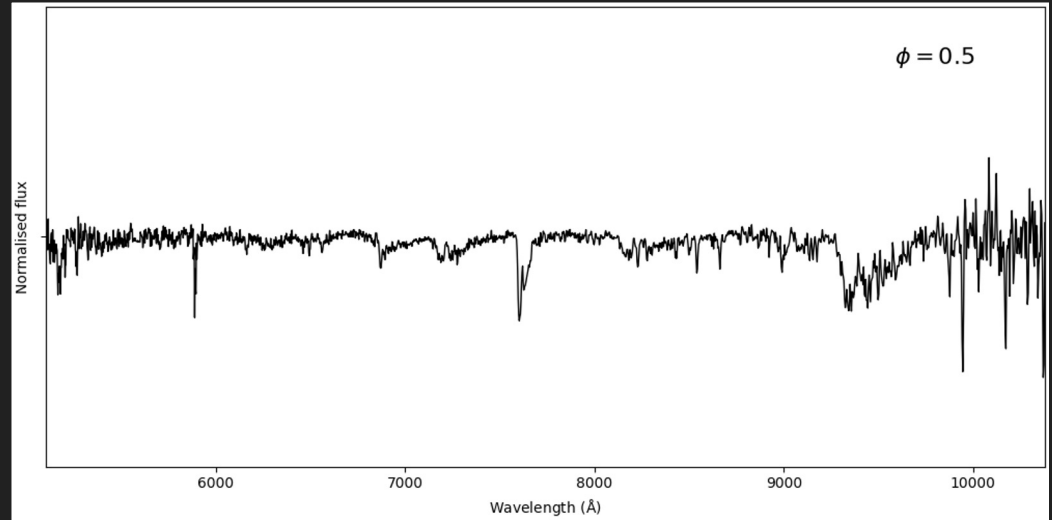- An intermediate case?
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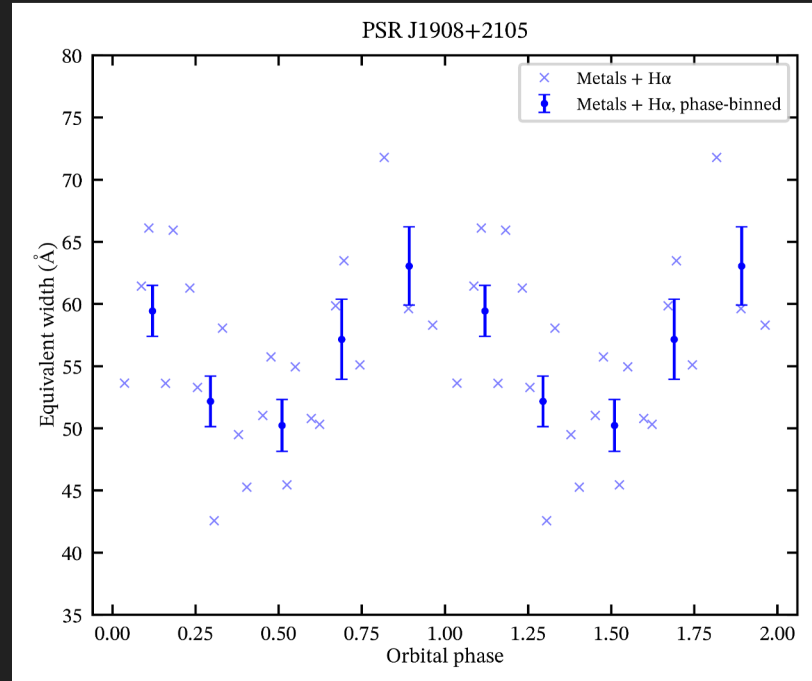

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Simpson et al. (in prep)

A mysterious intermediate system?

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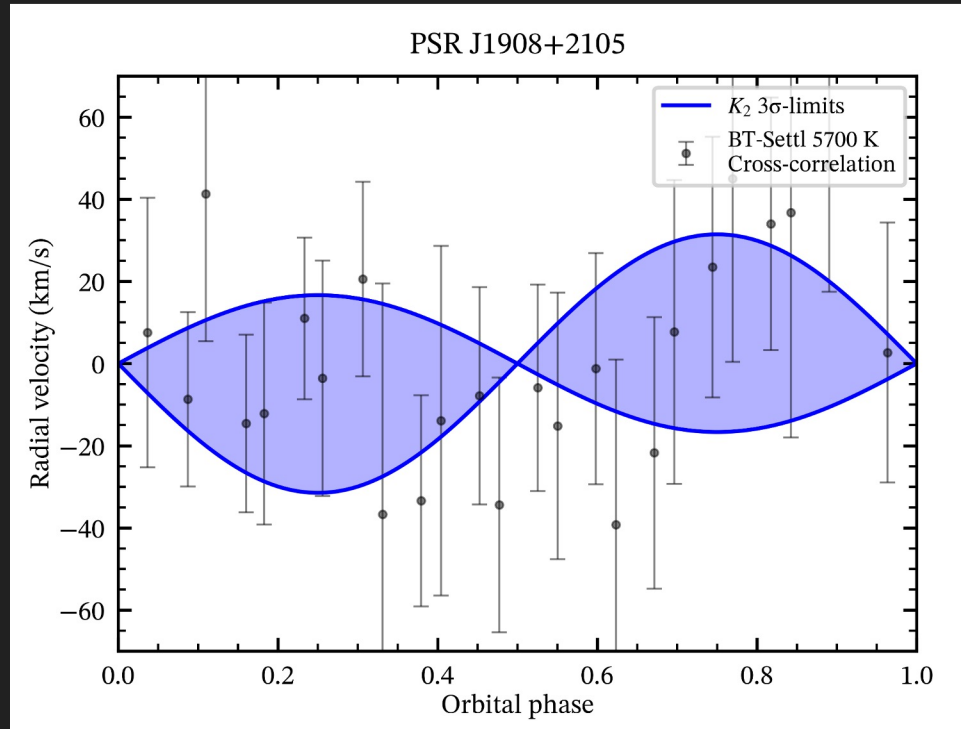

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A mysterious **redback** system!

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- **J1908 is a redback**
  q > 0.55 i < 6.0° M_2 > 0.5 M$_\odot$

Simpson et al. (in prep)

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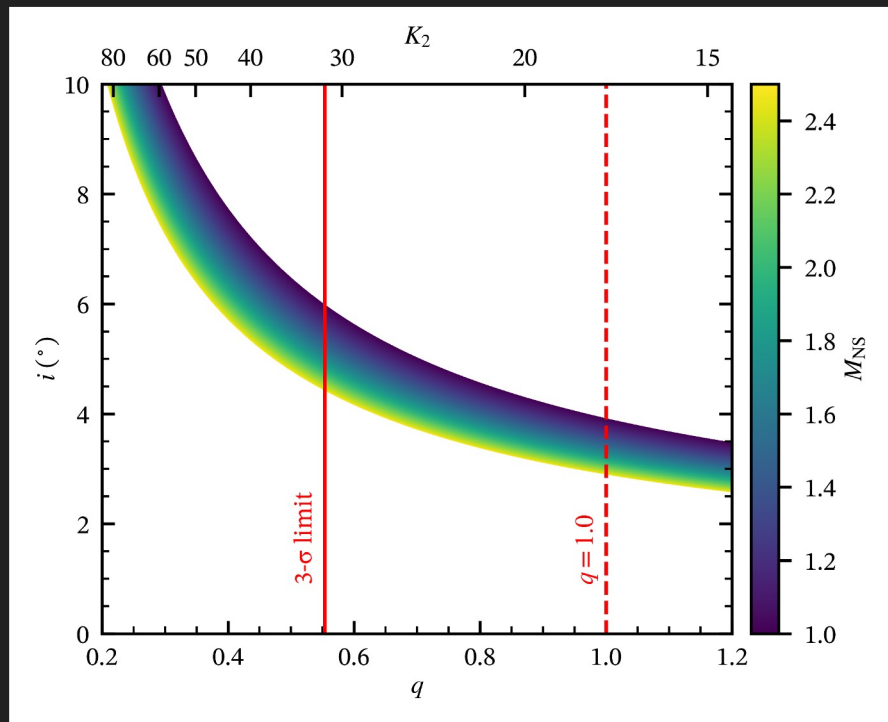
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- **Highest mass ratio, lowest inclination redback yet**

Simpson et al. (in prep)

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Conclusions

- 3 systems across full range of inclinations:

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Simpson et al. (in prep)

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Simpson et al. (in prep)

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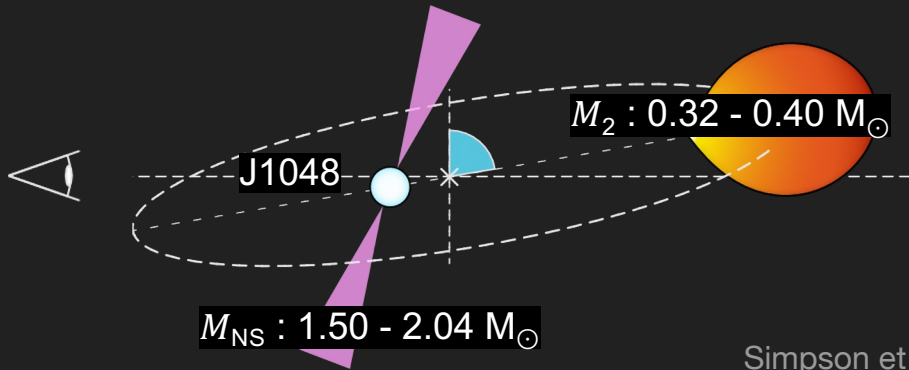
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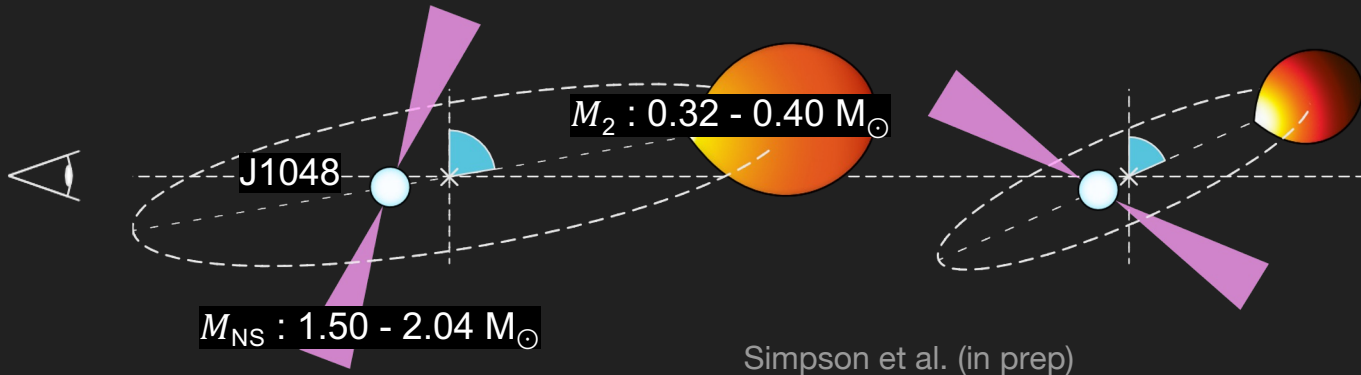M_{NS} : 1.50 - 2.04 M$_\odot$

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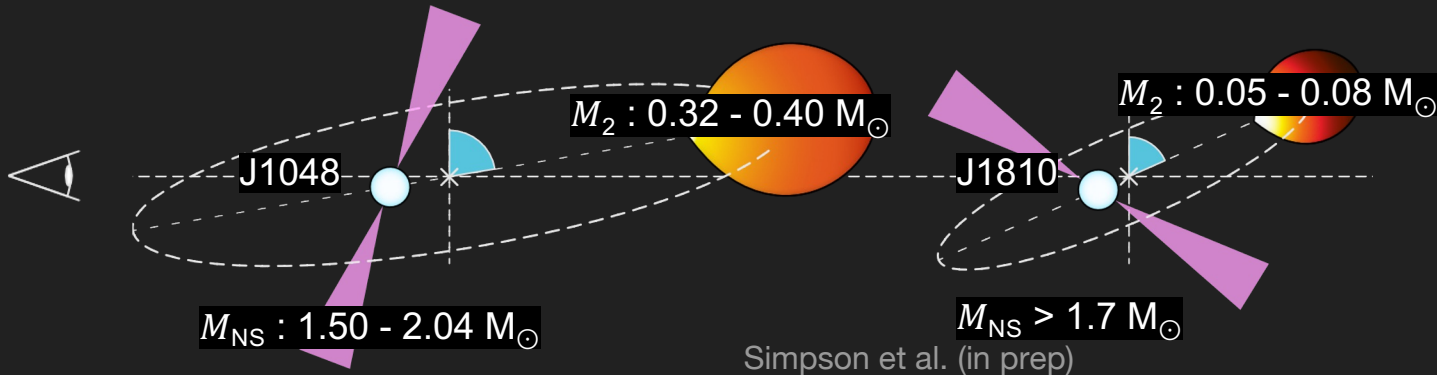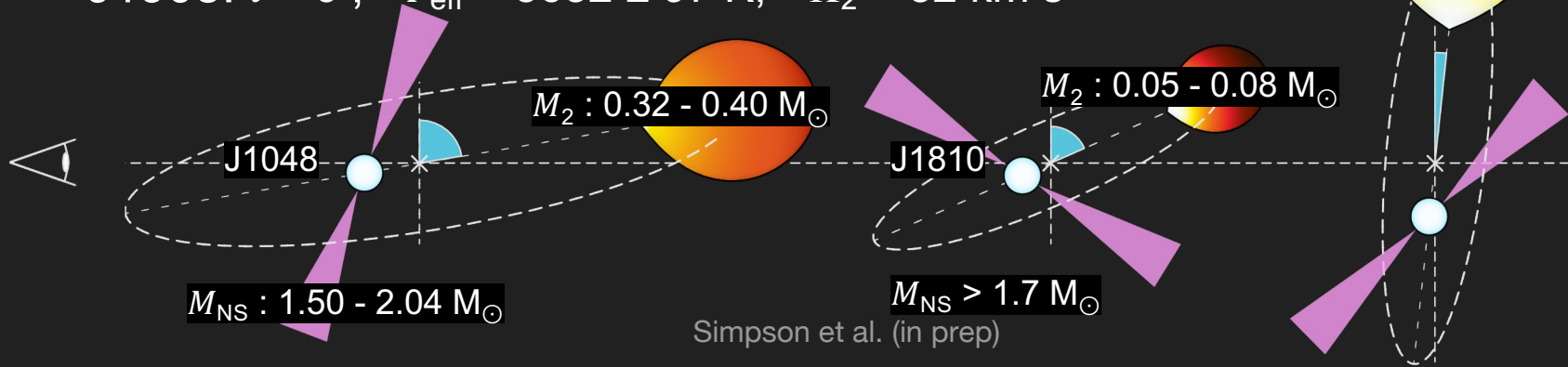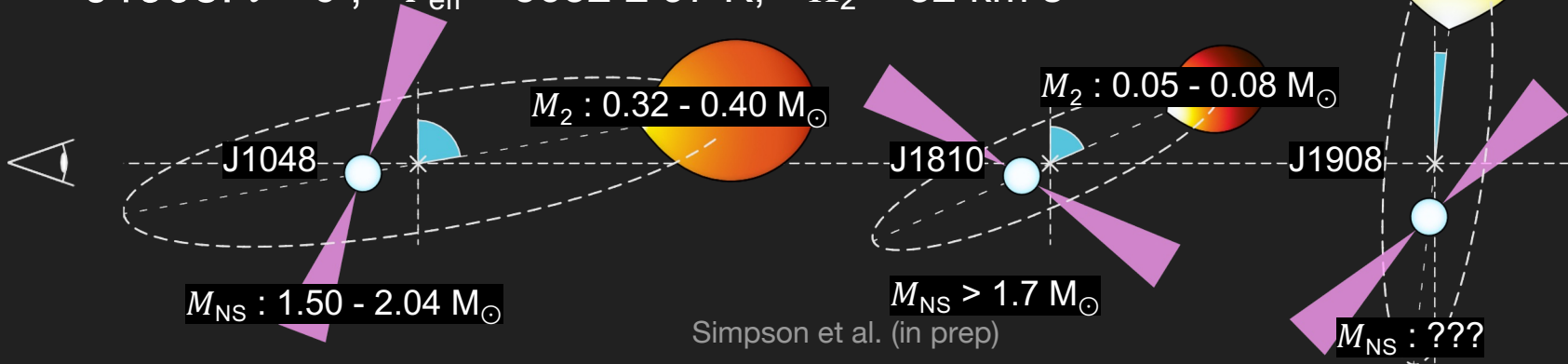
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Simpson et al. (in prep)

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- **J1908 confirmed as a redback**

$M_2 > 0.5$ M$_\odot$

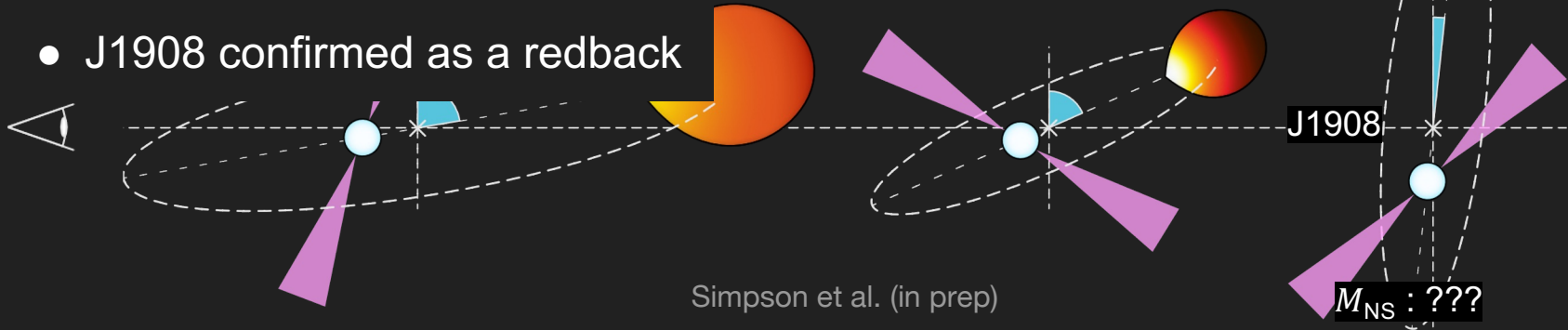J1908

Simpson et al. (in prep)

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- Future work:
  - Modelling of spectra
  - Other systems
  - High resolution/IR

Simpson et al. (in prep)

Thank you for listening!

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- 3 systems across full range of inclinations:

  J1048: $i > 80°$, T_{eff} : 4072 - 4690 K, K_2 : 344 - 372 km s^{-1}

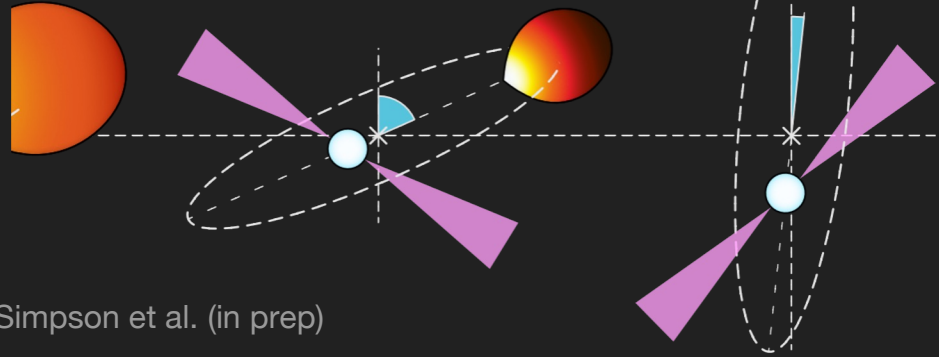 J1810: $i = 66°$, T_{day} = 7827 ± 90 K, K_2 : 448 - 491 km s^{-1}

  J1908: $i < 6°$, T_{eff} = 5632 ± 97 K, K_2 < 32 km s^{-1}

- J1908 confirmed as a redback

$M_2 > 0.5\ M_\odot$

M_2 : 0.05 - 0.08 $M_\odot$

M_2 : 0.32 - 0.40 $M_\odot$

J1810

J1908

J1048

M_{NS} : 1.50 - 2.04 $M_\odot$

$M_{\mathrm{NS}} > 1.7\ M_\odot$

M_{NS} : ???

Simpson et al. (in prep)