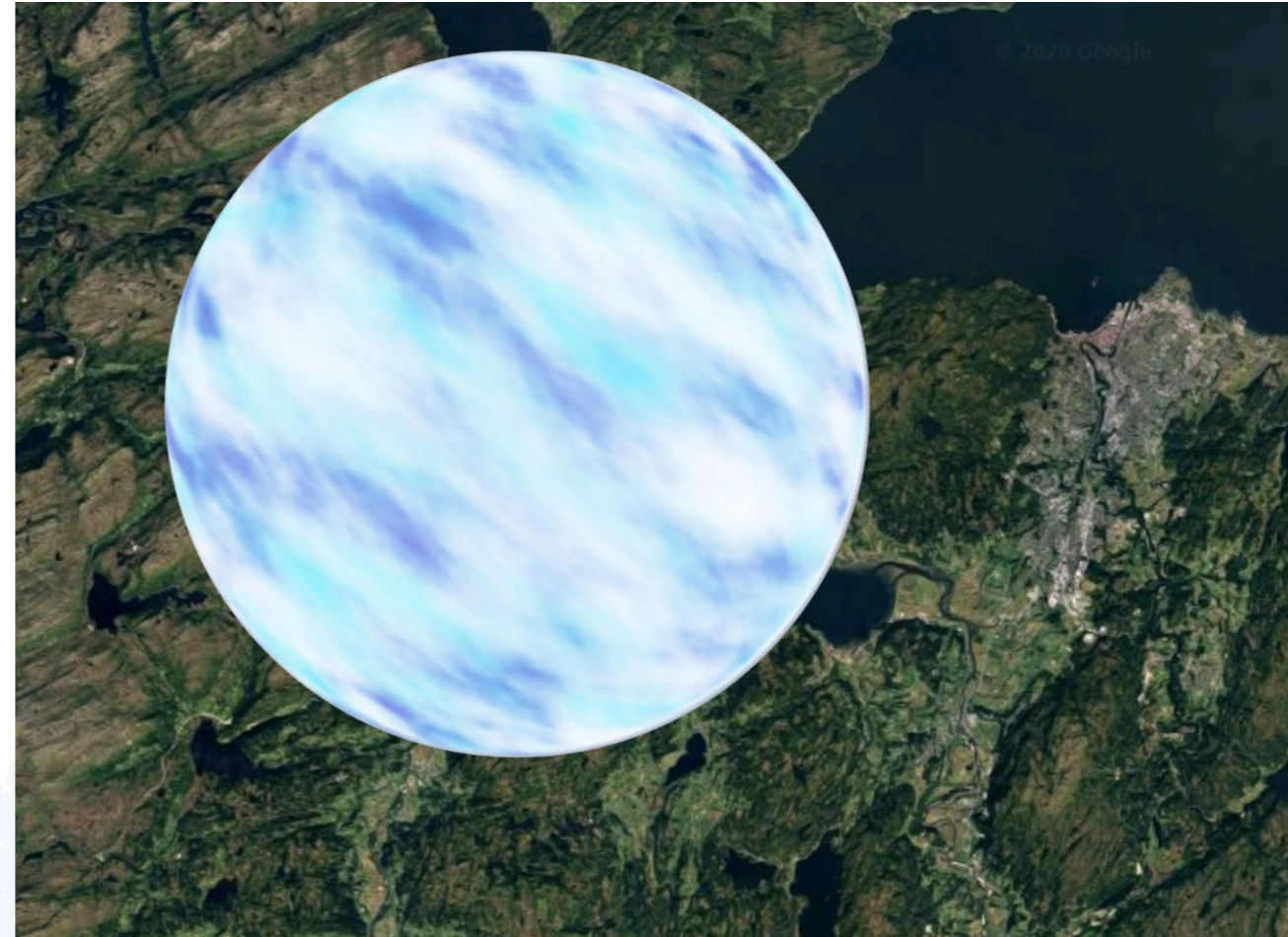


# Spider Pulsars and Neutron Star Astrophysics in Norway

## *Super-Massive Neutron Stars and Pulsar Winds*



# Spider Pulsars and Neutron Star Astrophysics in Norway



# Compact Binary Millisecond Pulsars

*A growing, nearby population of millisecond pulsars*

“Spider Pulsars” (redbacks RBs / blackwidows BWs):

- Millisecond pulsar (neutron star, NS)  
(wind,  $\gamma$ -rays, spin-down luminosity:  $L_{sd} \sim 10^{34} - 10^{35}$  erg/s)

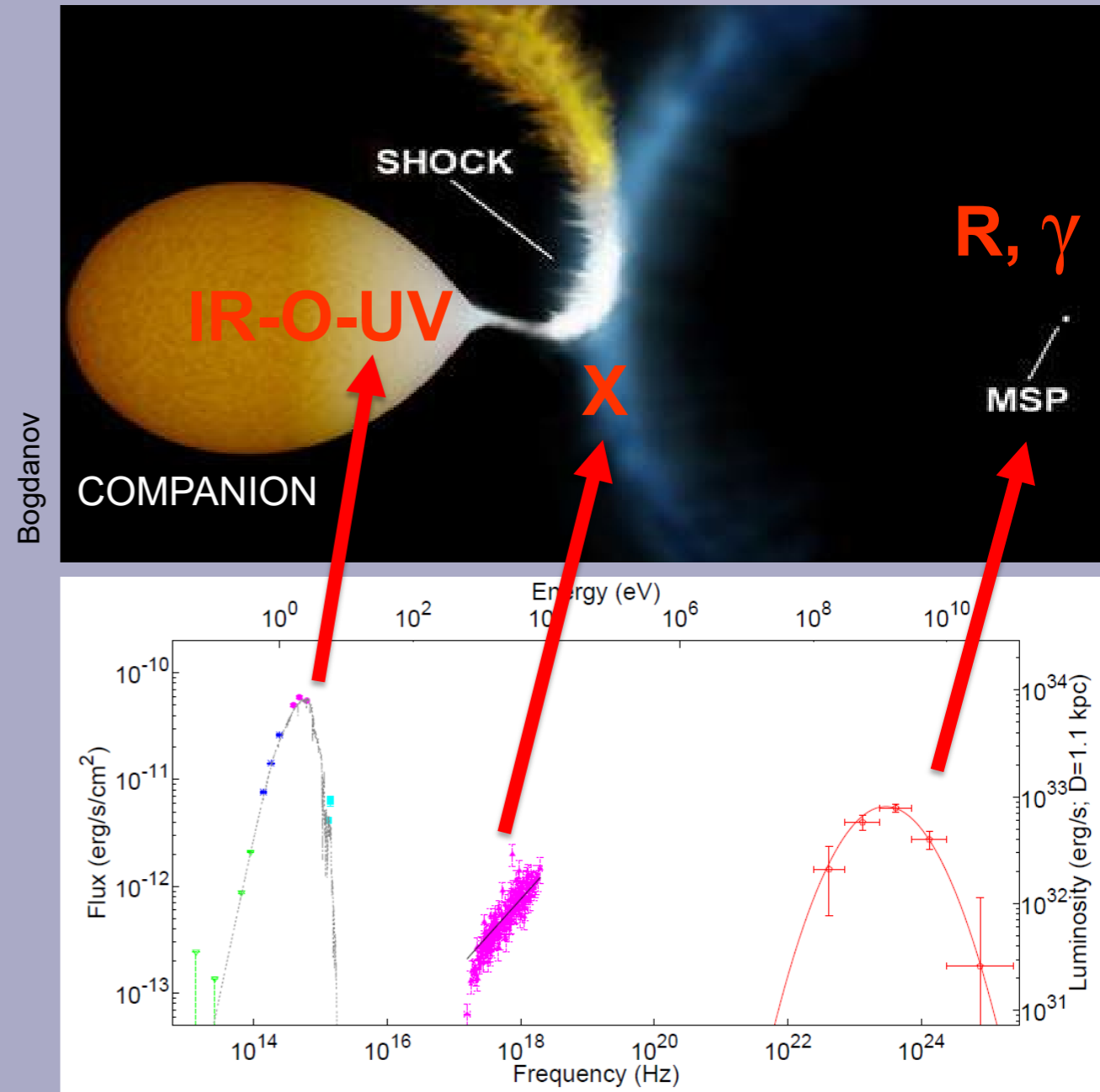
**RADIO AND GAMMA-RAYS: NS MAGNETOSPHERE!**

- Companion star (ablated  $\rightarrow$  “cannibalism”)  
(low/very-low mass, RBs / BWs:  $\sim 0.1$  /  $\sim 0.01 M_{Sun}$ )

**IR-OPTICAL-UV: MEASURE NS MASS! (e.g. NOT)**

- Binary, compact orbit  $\rightarrow$  intra-binary shock  
( $P_{orb} \leq 1$  day;  $a \sim R_{Sun}$ )

**X-RAYS: PROBE INNER PULSAR WIND!**



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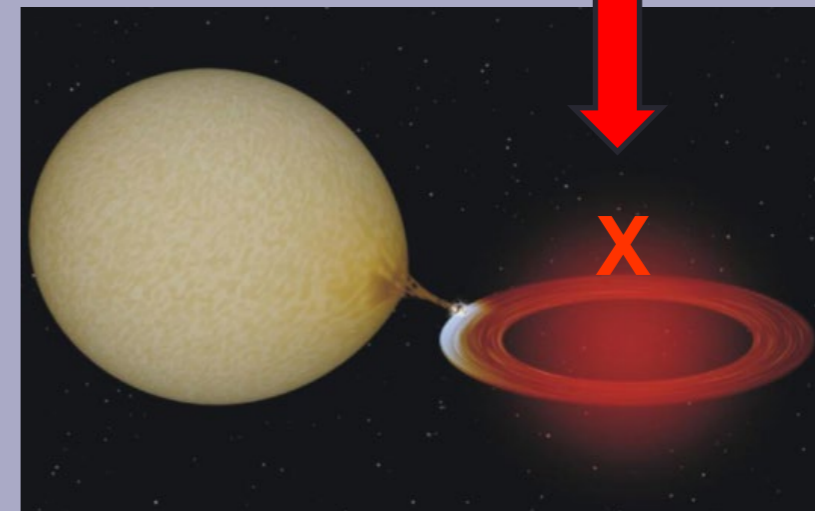
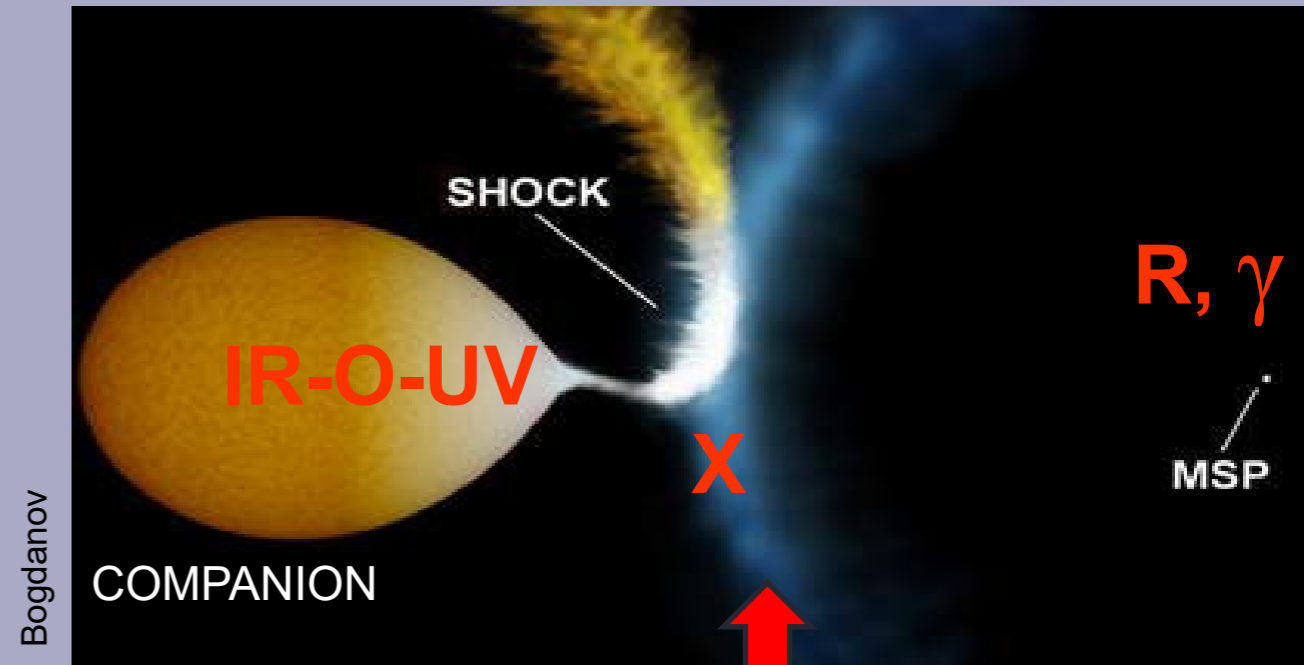
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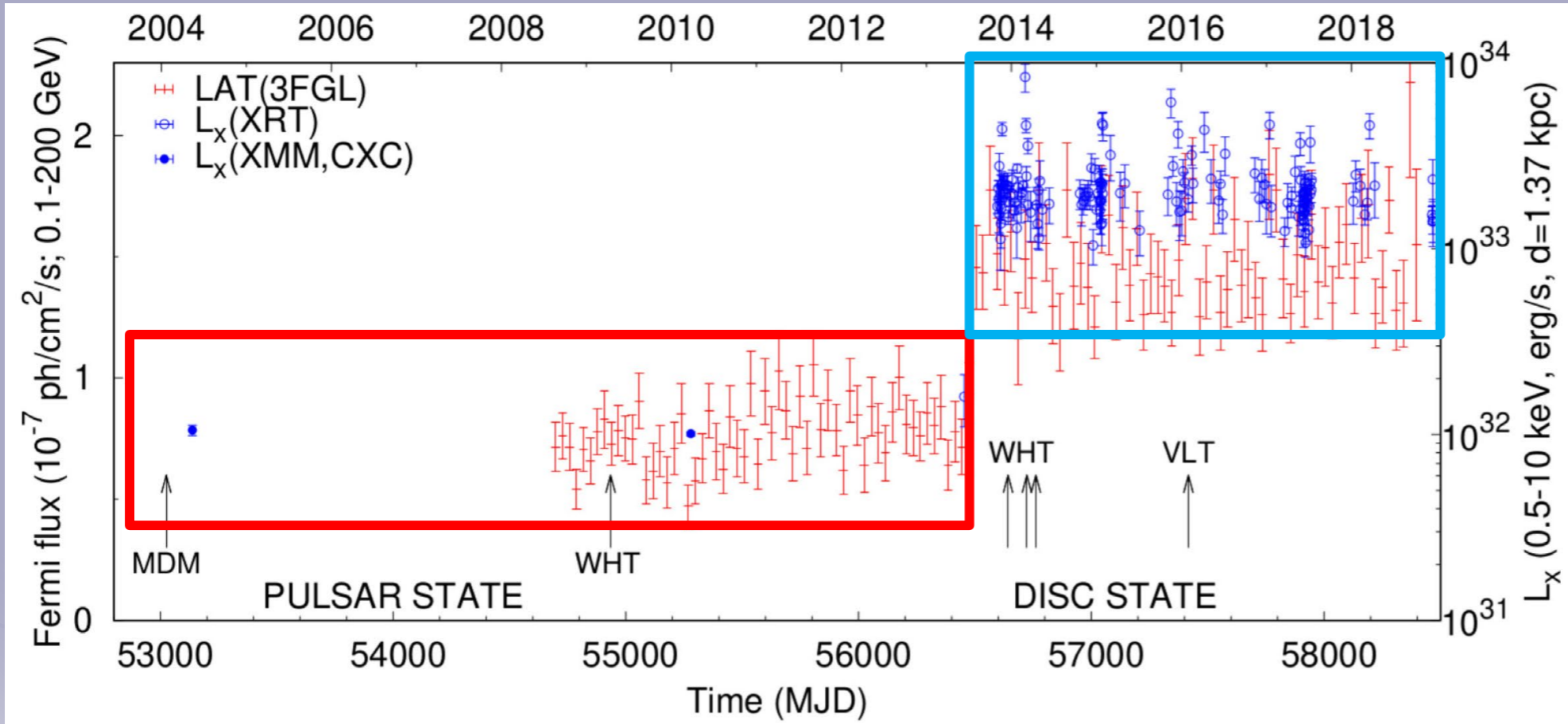
$\rightarrow$  “Elite”: Transitional MSPs (2-9 out of 88-133)

**X-RAYS: PROBE INNER ACCRETION FLOW!**

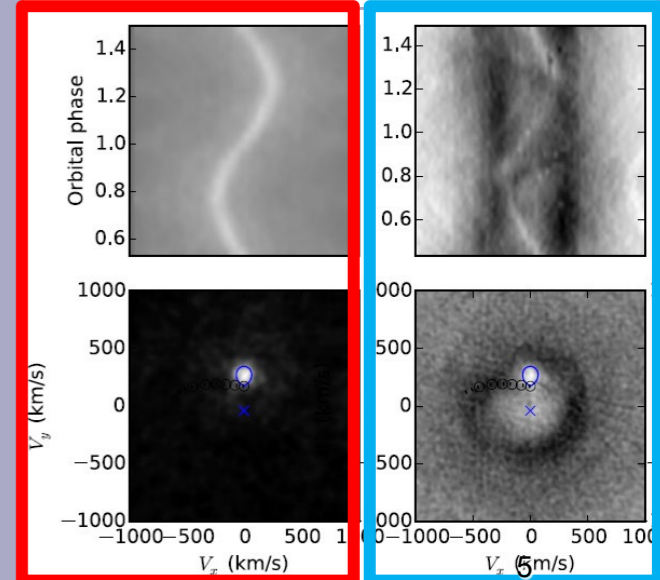
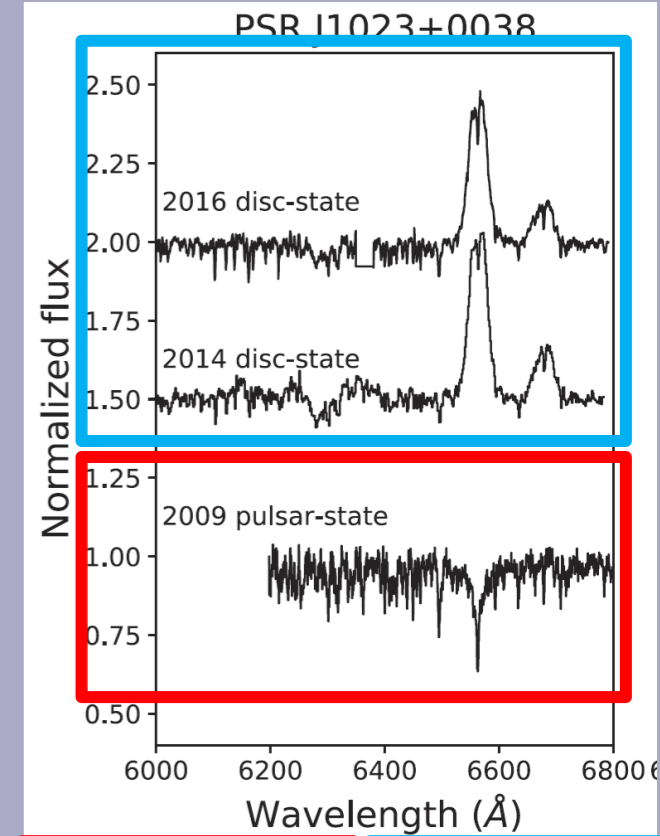


# State transitions: weeks-years

*At the boundary between accretion and rotation power*



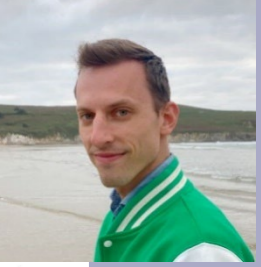
PSR J1023+0038: Shahbaz, ML+ (2019), Archibald+ (2009), Patruno+ (2014), Stappers+ (2014)



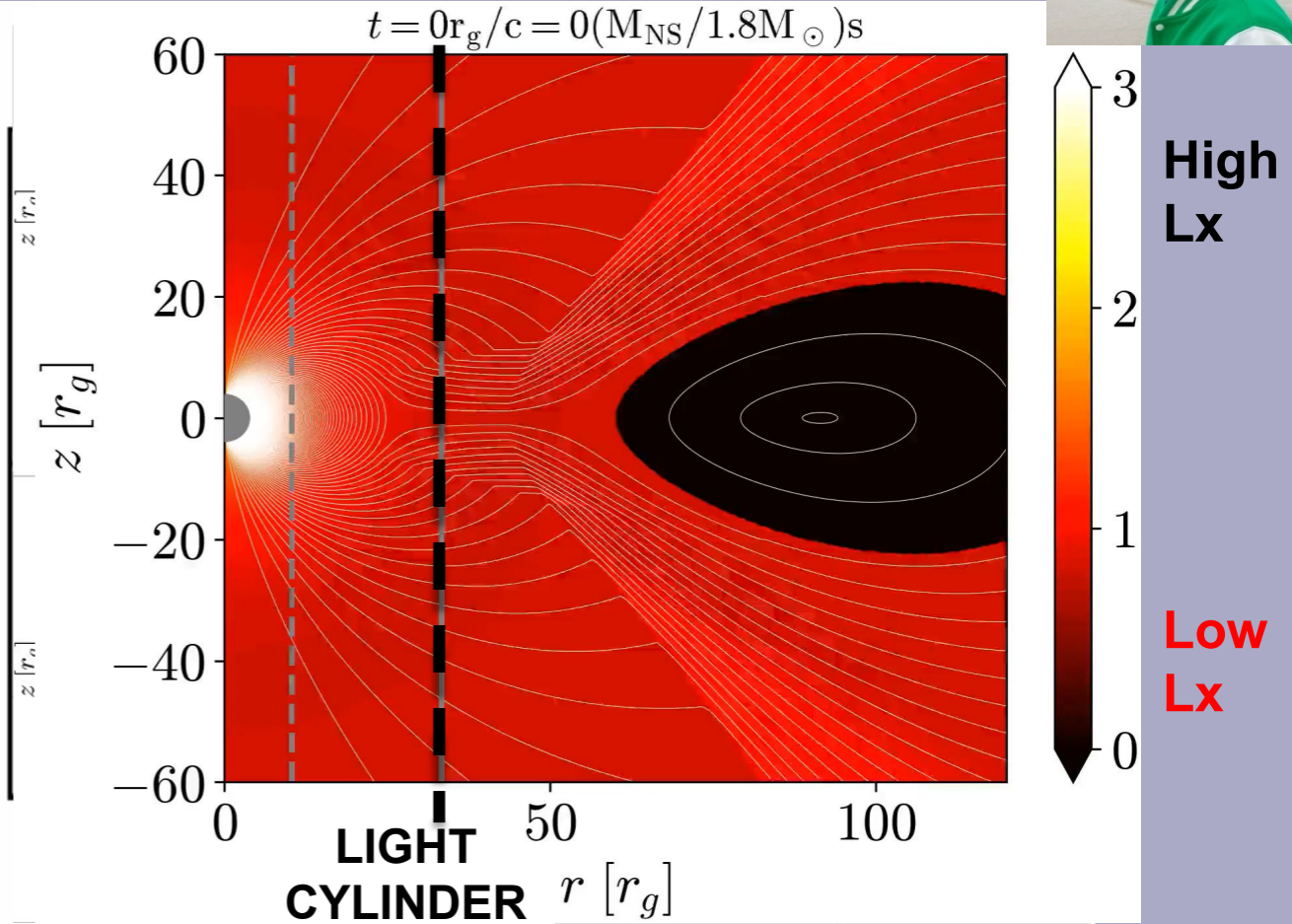
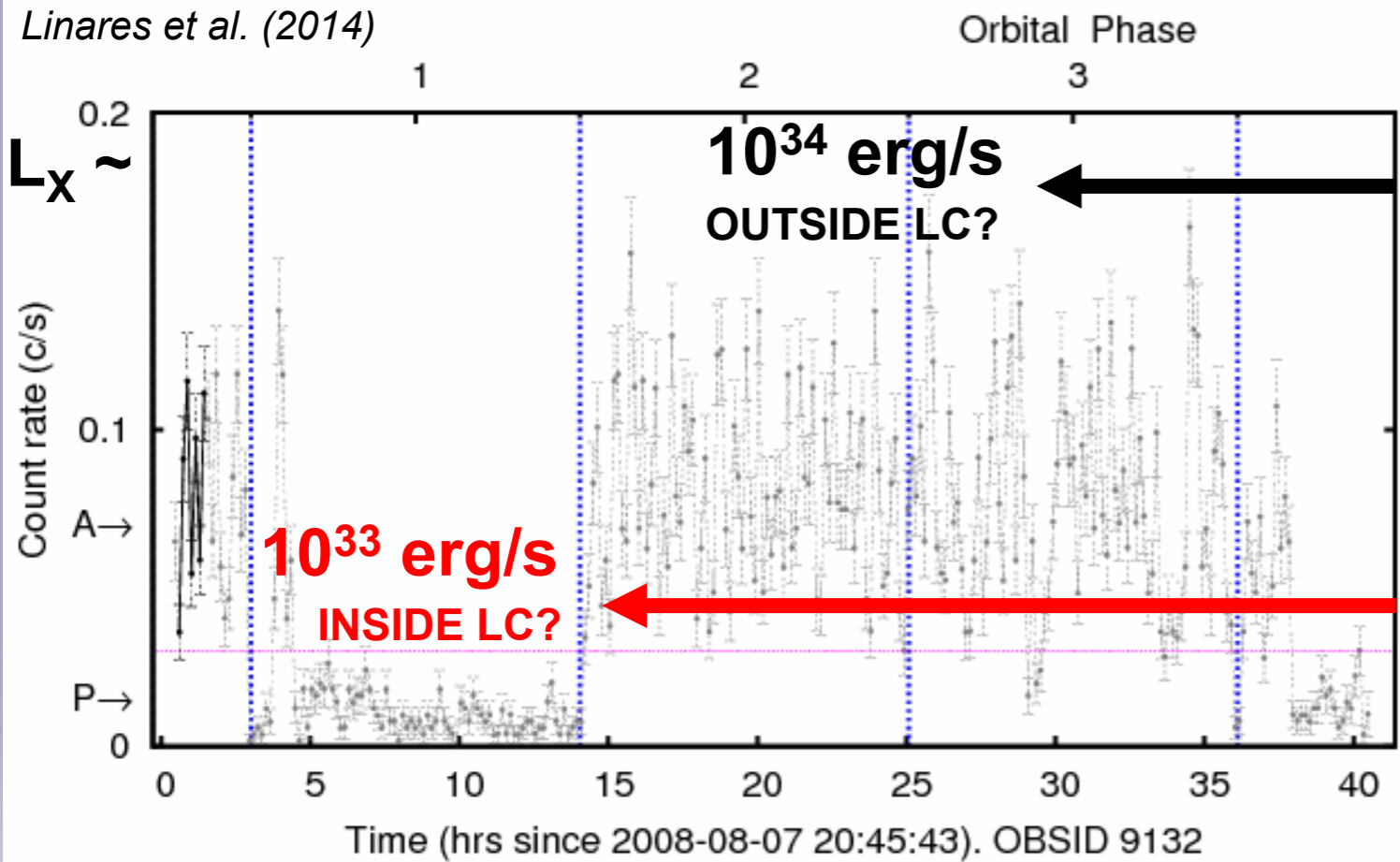
**2 STATES** in tMSPs: **PULSAR** & **DISK**  
 (radio MSP,  $L_X$ ,  $L_G$ , optical lines)

# Mode Switching: seconds-hours

Mignon-Risse+,  
in prep.

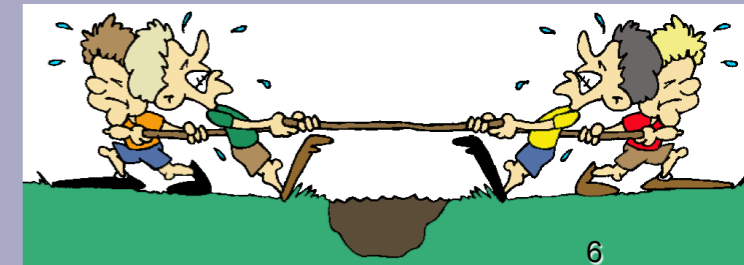


GR-MHD simulations with radiative transfer



**INNER DISK OUTSIDE LIGHT CYLINDER:  
HEATED AND MORE LUMINOUS!**

(Veledina et al. 2019; Papitto et al. 2019; Mignon-Risse, ML, Parfrey & al. in prep.)

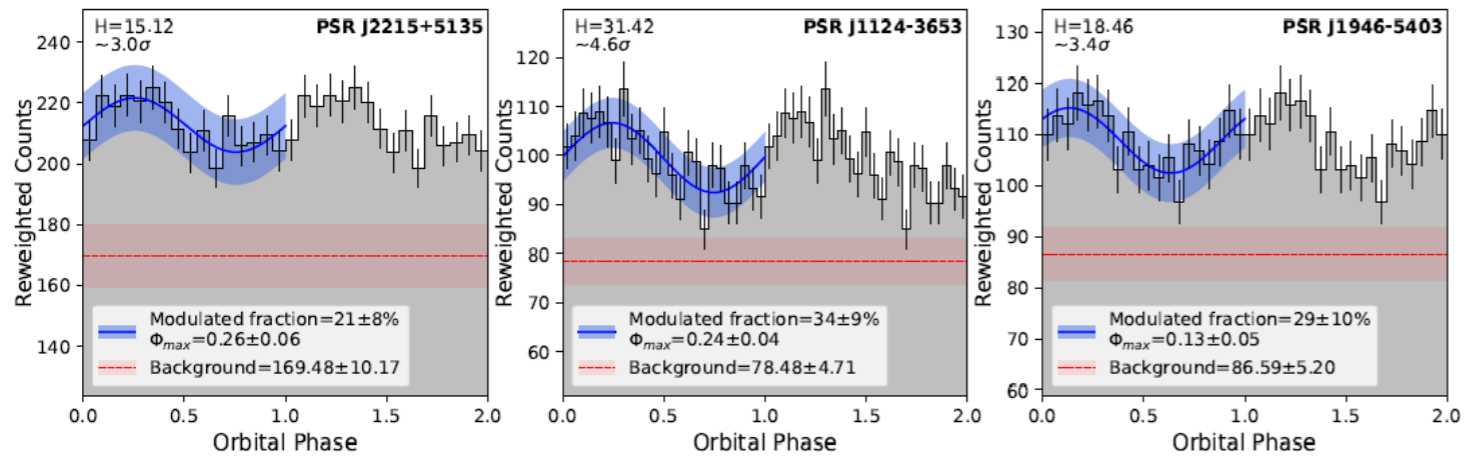
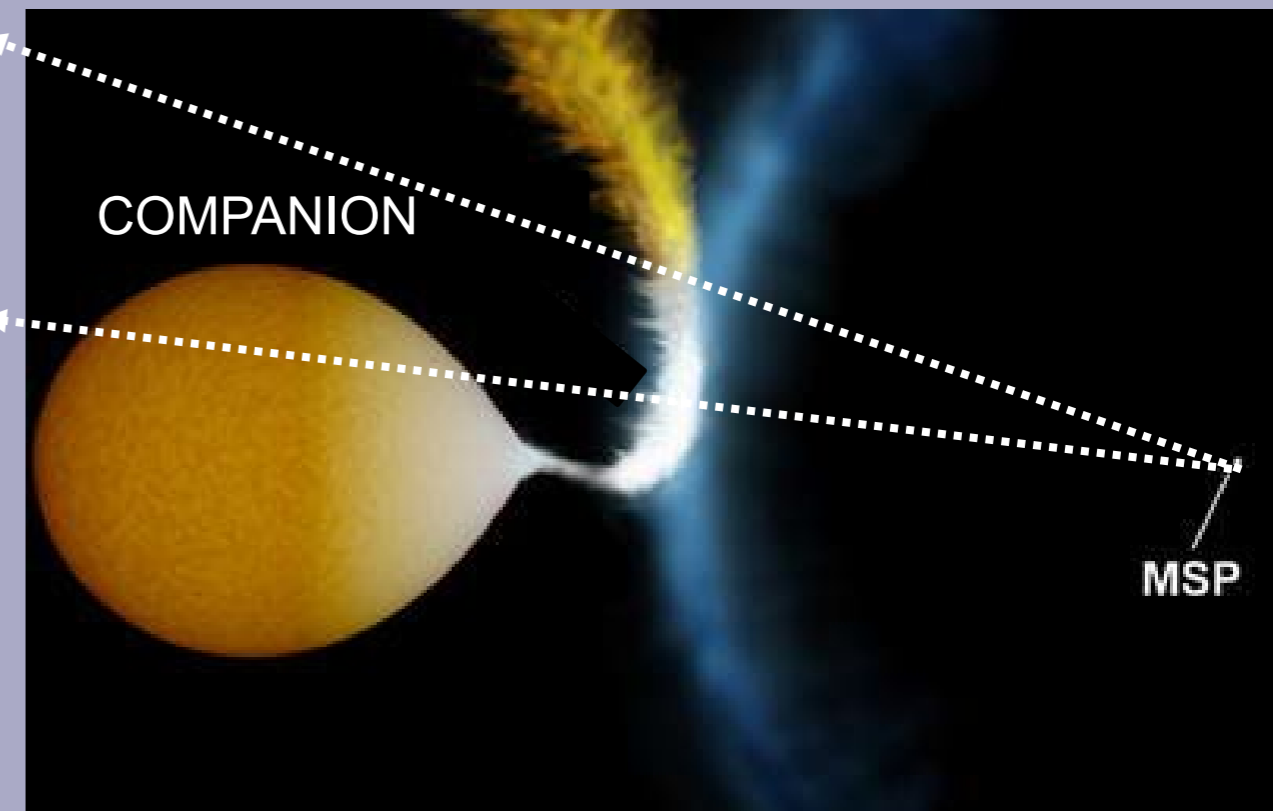
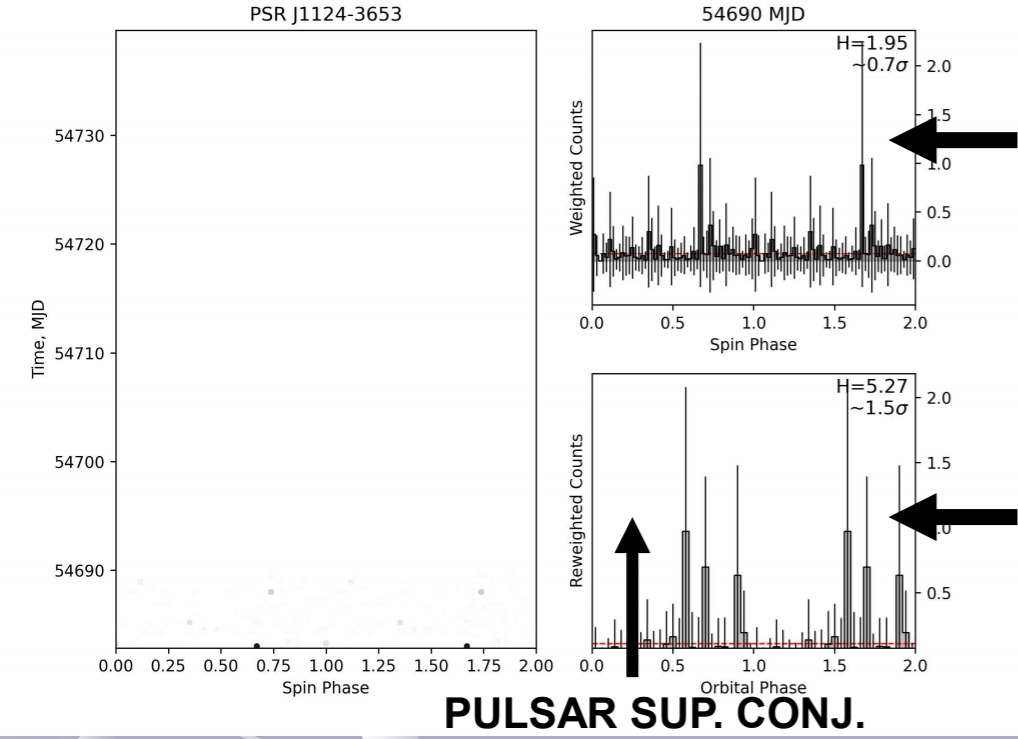


# Compact Binary Millisecond Pulsars

Gamma-Ray Orbital Modulation



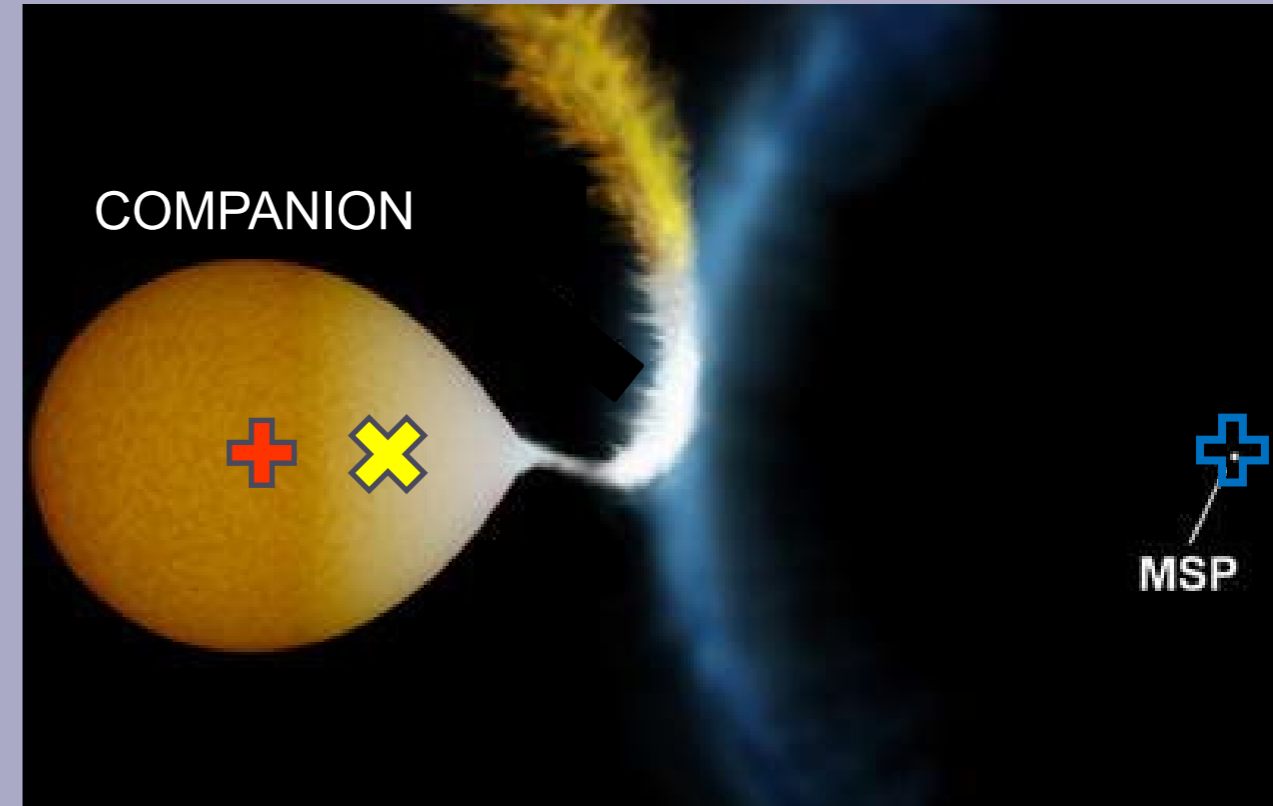
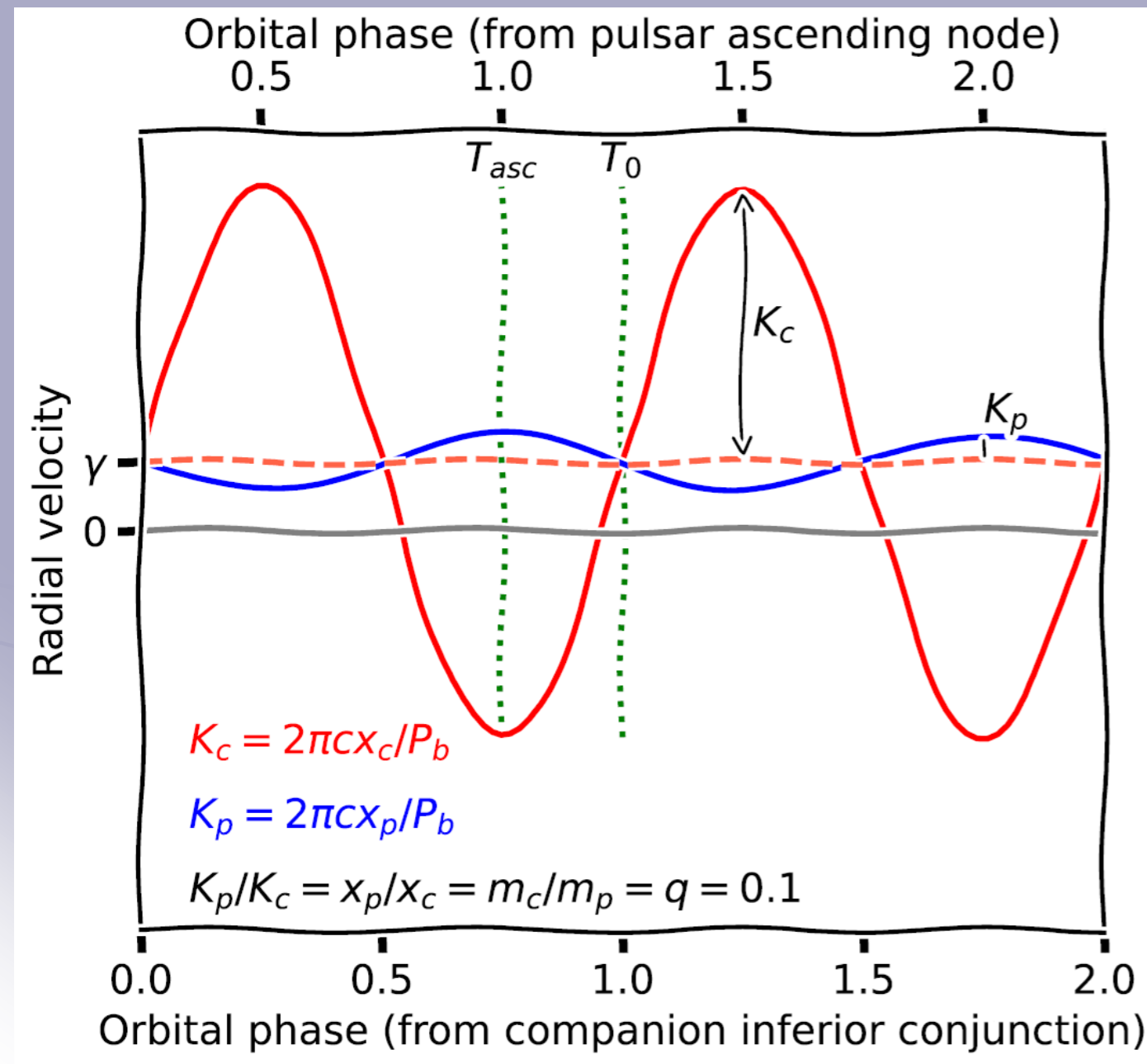
Satyrbaldiev et al. (2026)



- **Discovered orbital modulation in 3 new spiders!** (and confirmed 4 existing reports)
- Modulated fraction of 22.0+/-2.6 %, **independent of orbital inclination**
- Modulated by the innermost pulsar wind?

# Compact Binary Millisecond Pulsars

Optical + Radio Mass Measurements



$$q = m_p / m_c = K_2 / K_1$$

$$m_p = m_c \frac{K_2 P_{orb}}{2\pi x_1} \quad (\text{e.g. Antoniadis+13})$$

$$m_p = \frac{P_{orb} \left(1 + \frac{1}{q}\right)^2}{2\pi G} \left(\frac{K_2}{\sin i}\right)^3 \quad (\text{e.g. LSC18})$$

# Neutron Star Mass

Spider Mass Distribution: 23 (and counting)

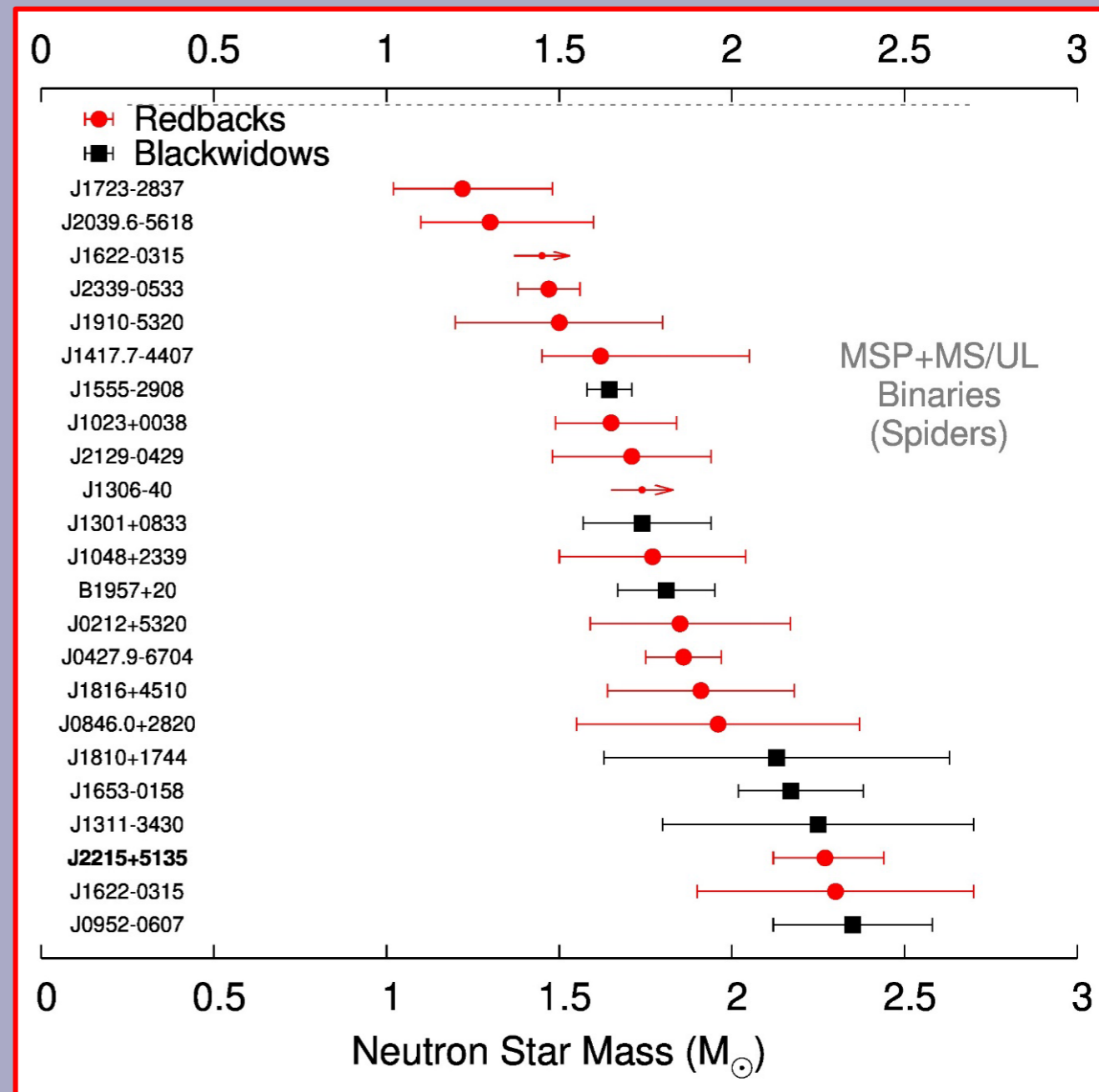
Adapted from Linares (2020, PoS)

23 spider mass measurements  
in the 1.2-2.4  $M_{\text{sun}}$  range:

Compact Binary MSPs (Spiders):  
**Key to finding the most massive  
neutron stars!**

$M_{\text{max}} > 2.3 M_{\text{Sun}}?$

REFs (update Sep'2024):  
Romani15b, Romani16b, Shahbaz17, Linares18b,  
Strader19, Nieder20, Clark20, Kandel20, Romani21,  
Romani22, Clark23, Sen24, Dodge24, Simpson24



# Summary

*Kiitos!*

**1. SUB-LUMINOUS DISK: HEATED BY THE PULSAR WIND**

(Mignon-Risse et al. in prep.)

**2. GAMMA-RAY ORBITAL MODULATION: AT ALL ORBITAL INCLINATIONS**

(Satybaldiev et al. 2026)

**3. SUPER-MASSIVE NEUTRON STARS: UP TO 2.3  $M_{\text{sun}}$**

(Linares 2020)

...STAY TUNED FOR KK:



<https://home.phys.ntnu.no/LOVE-NEST/>