

# SPIDER - SYSTEMS

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Stellar arachnology at the highest energies

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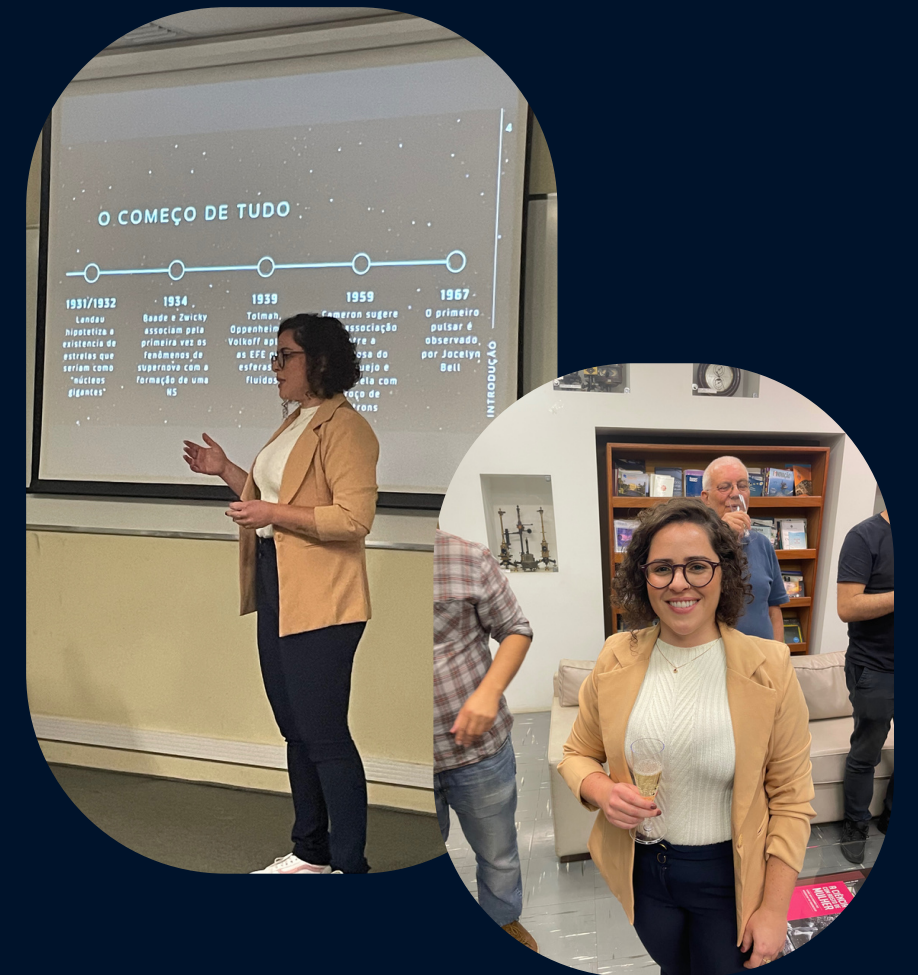
High-energy astrophysics in the multimessenger-era

08 to 12 of April - São Carlos



# Back in time...

- PhD at IAG - USP
  - Population statistics of neutron stars (NSs): imprints from formation channels, maximum mass
  - Equation of state
- Spider systems:
  - Most massive NSs
  - TeV emitters
- Postdoc at IFUSP
  - Spider systems as CTA targets



# Summary

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- Properties and location
- Formation channel
  - Link between RBs and BWs
- Geometry
  - Spectral energy distribution
- Transitional MSP
- Simulation of CTA observations

# PROPERTIES AND LOCATION

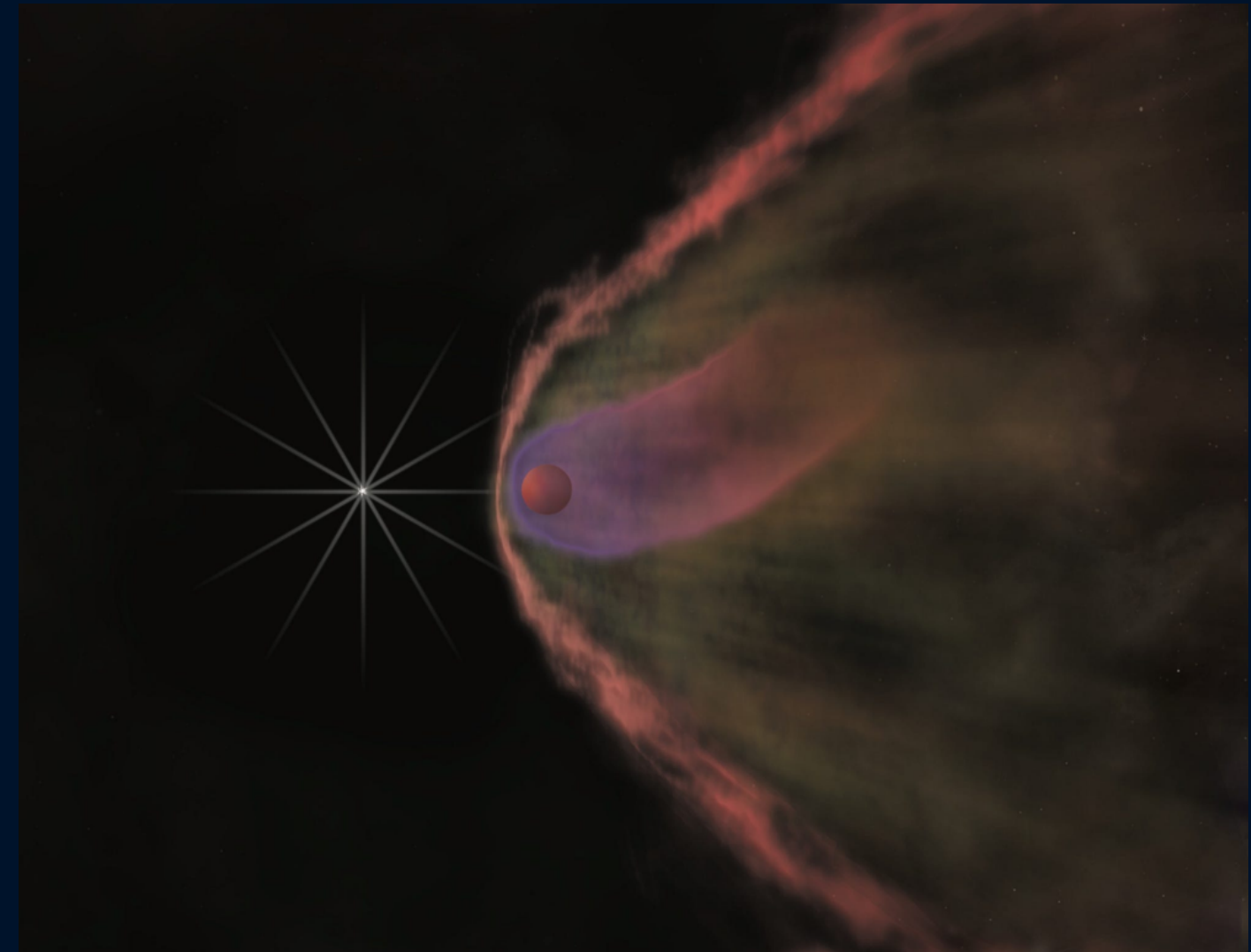
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# What are spider binaries?

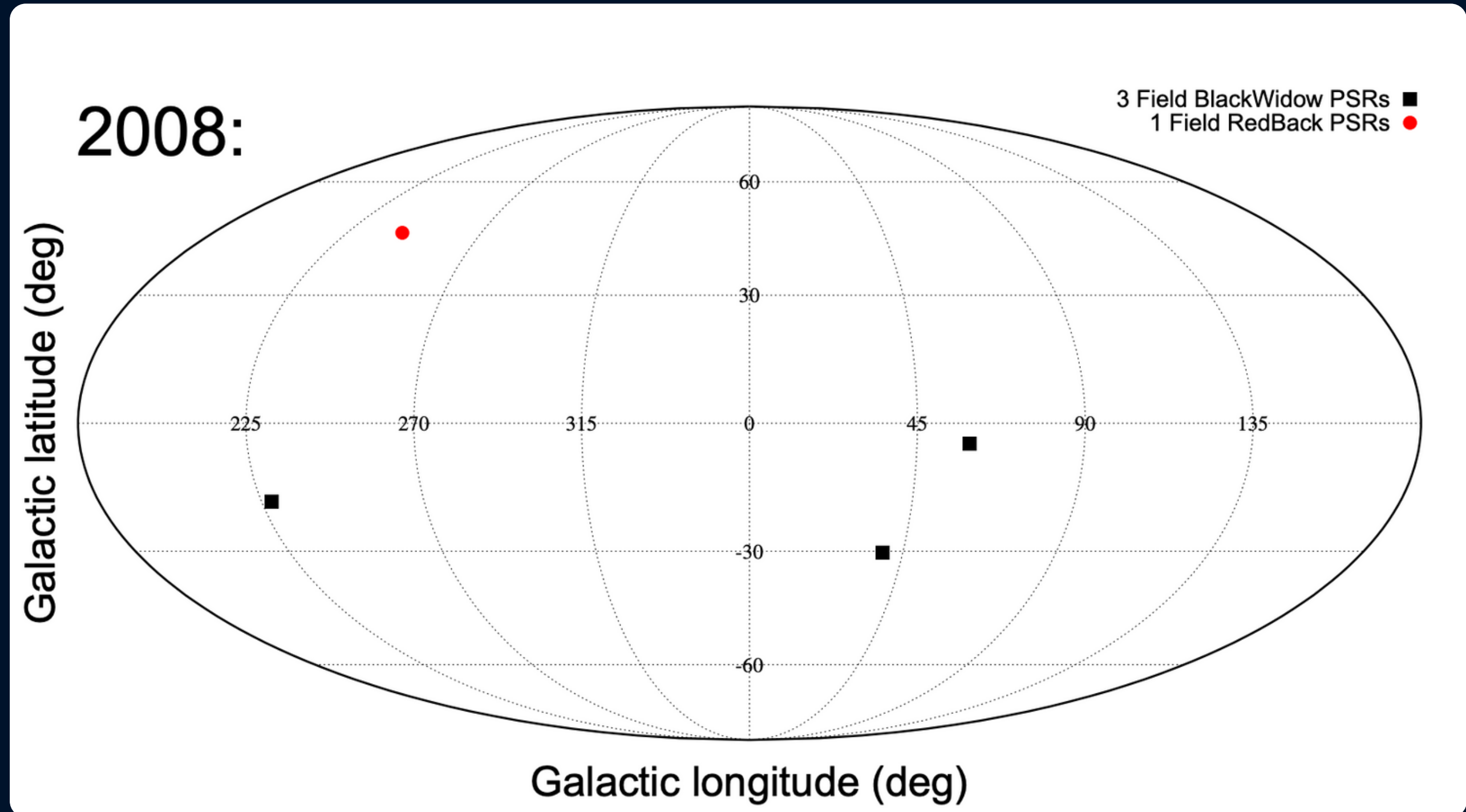
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- Binary pulsar systems
- Millisecond pulsars ( $< 15$  ms)
- Low-mass companion
  - Redbacks:  $0.1 - 0.5 M_{\odot}$
  - Black widows:  $\ll 0.1 M_{\odot}$
- Short-orbits ( $< 1$  day)
- Circular orbits (??)
- Radio (and gamma) eclipses
- Old systems



# Where are they?

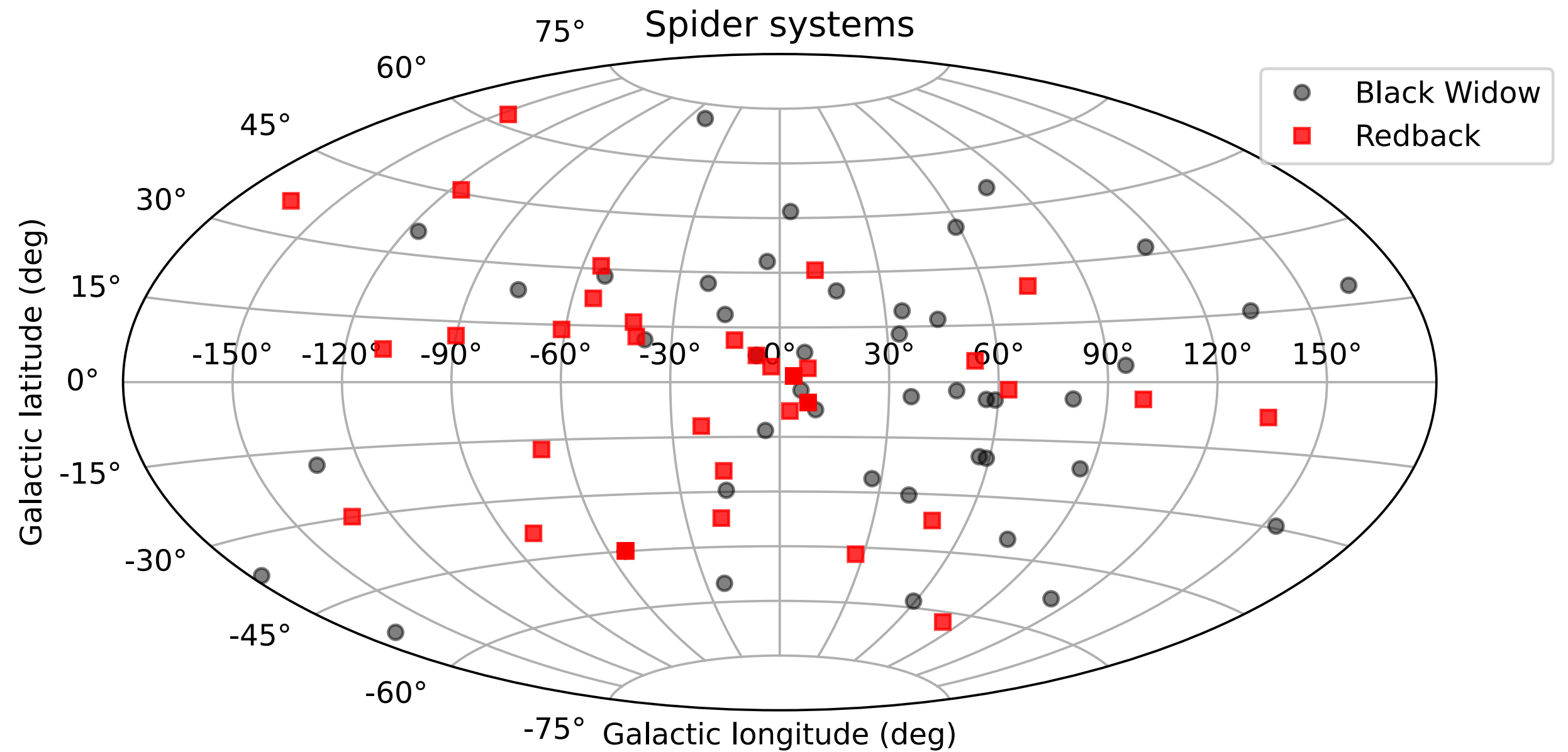
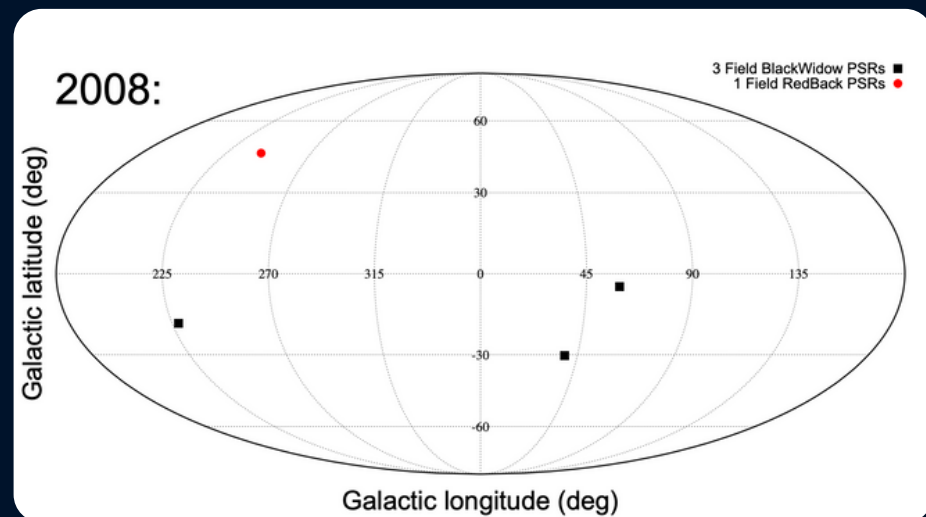
Before Fermi-LAT





# Where are they?

Nowadays



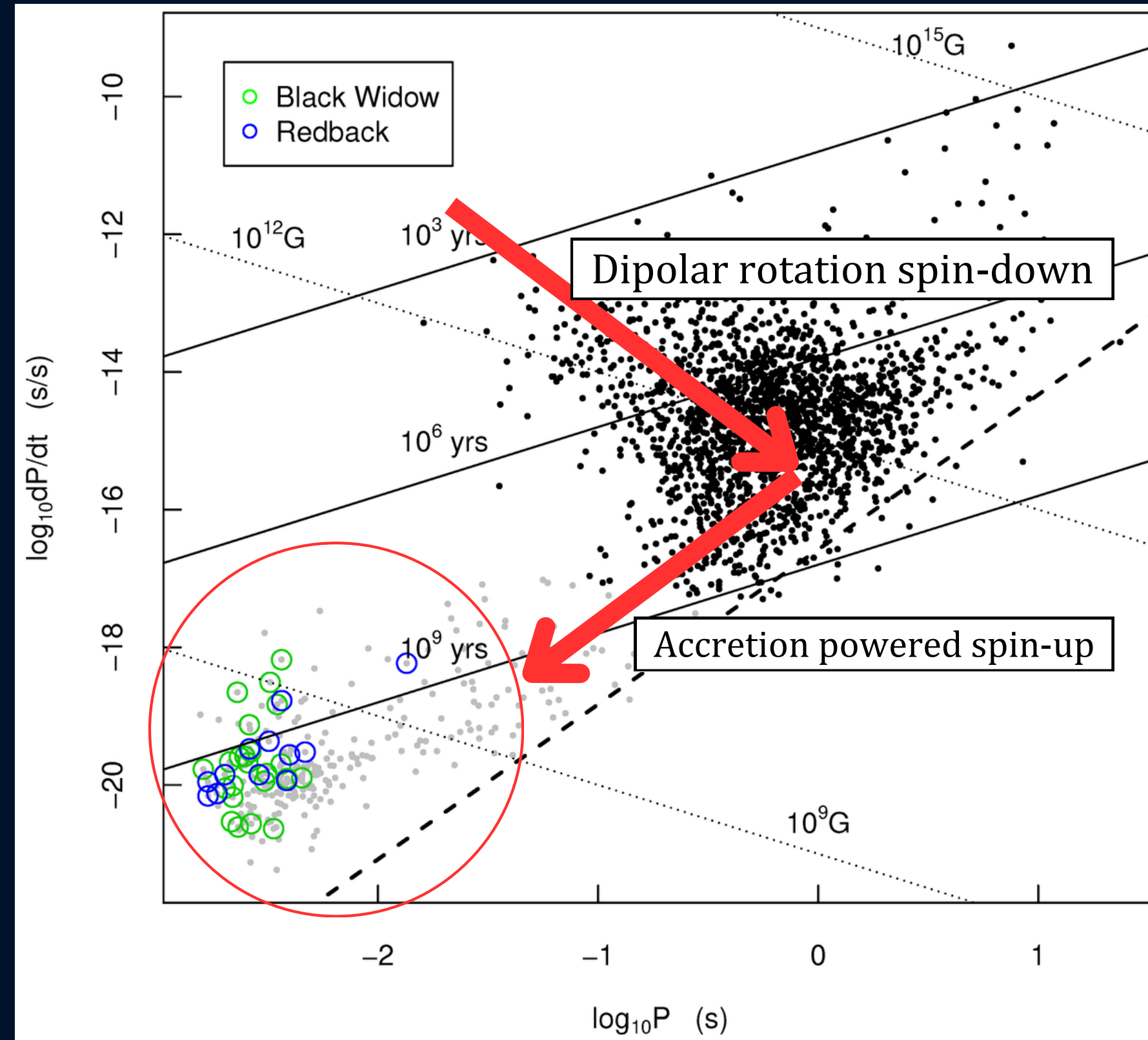
# FORMATION CHANNEL

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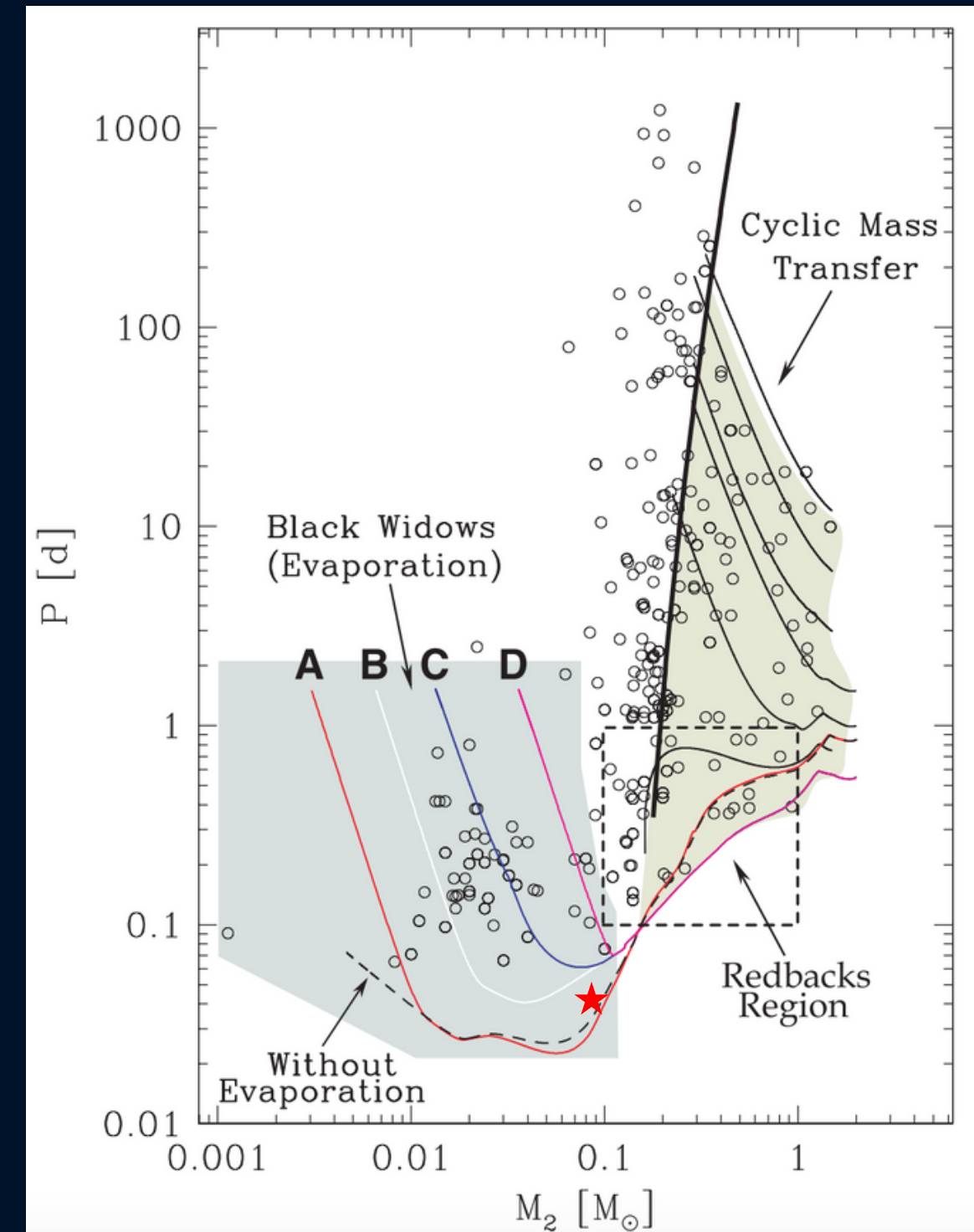
# Formation of millisecond pulsars



# A link between redbacks and black widows

- Distinction between RBs and BWs
  - Efficiency of irradiation process
- BWs can be descendants of RBs
  - Pan et al. (2023)
  - PSR J1953+1844 (M17E)

$$m \sim 0.07 M_{\odot}$$
$$P = 0.53 \text{ m}$$



Benvenuto, de Vito and Horvath (2014)

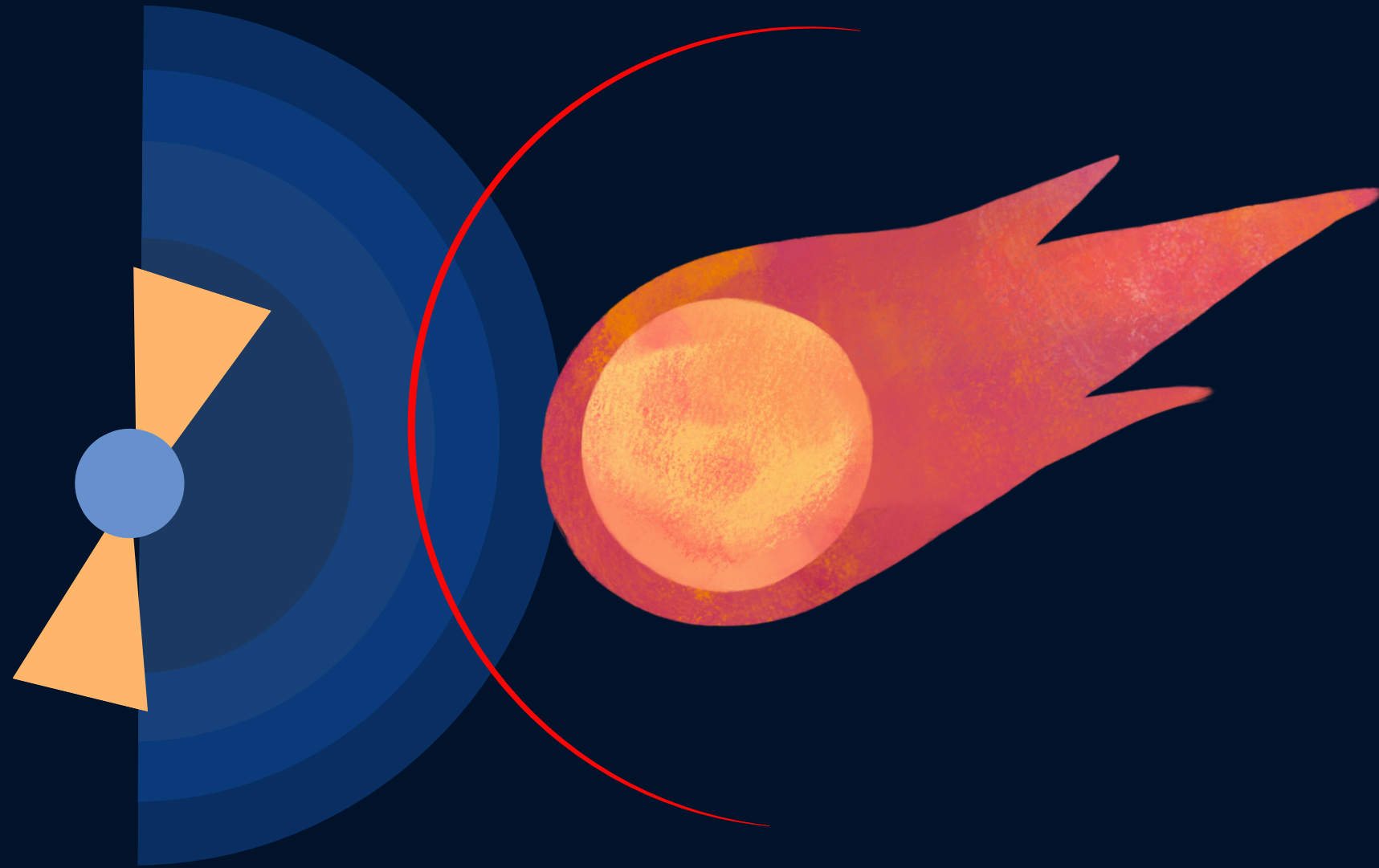
# GEOMETRY

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# Intrabinary shock

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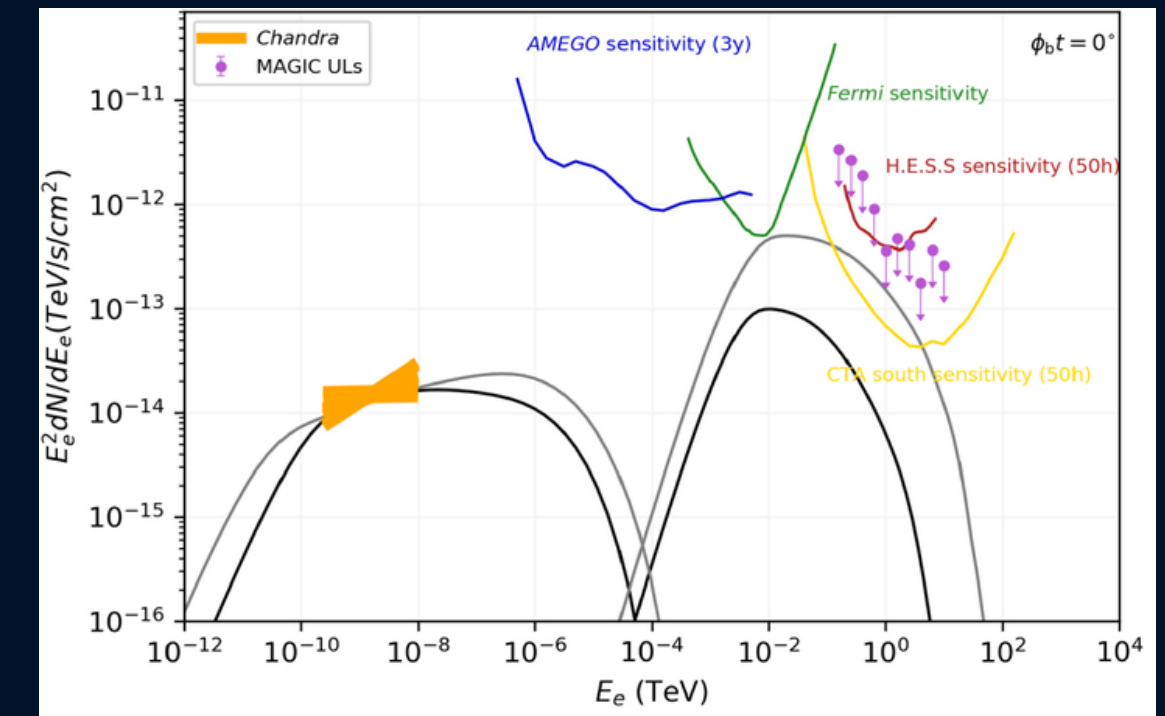
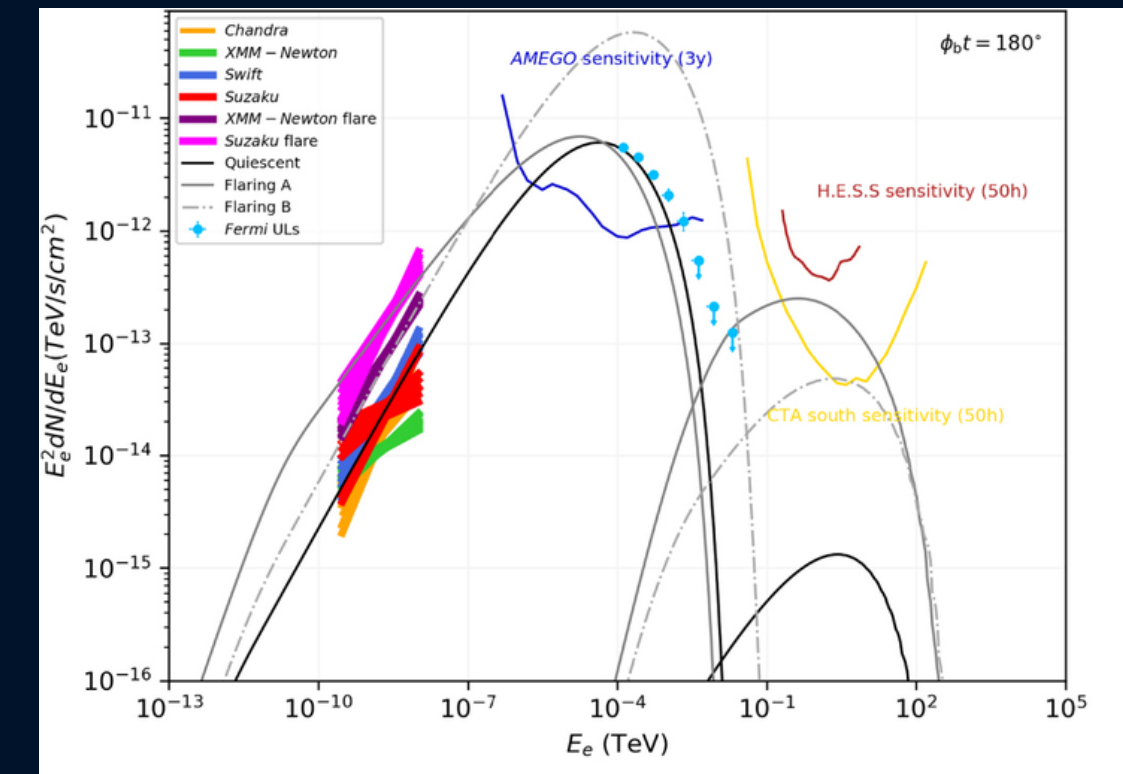
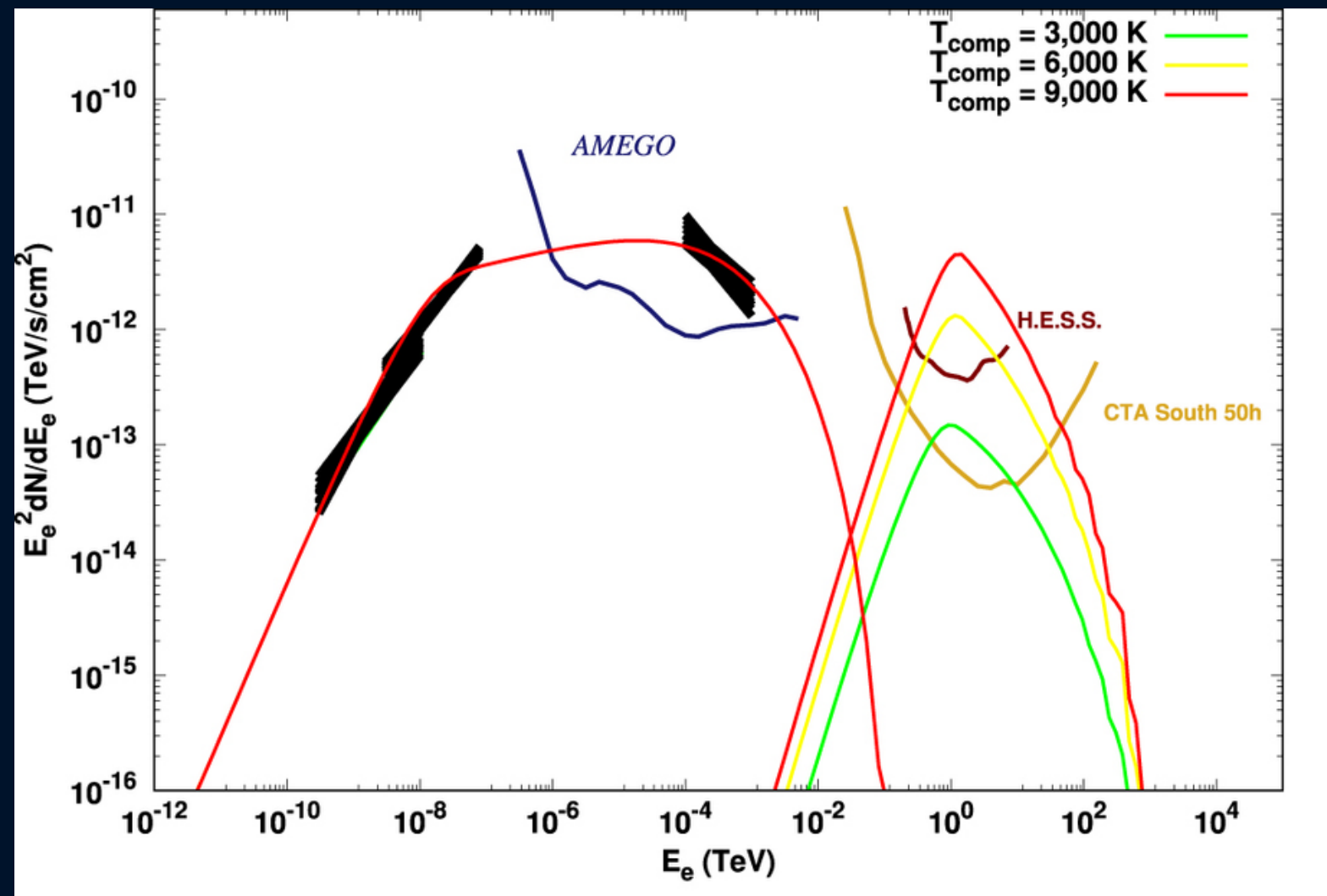


- Radio eclipses :
  - $\sim 10\%$  of orbital period (BW)
  - Pulsar wind ablates the companion
    - Dense ionized gas scatters and absorbs radio emission
- Shock orientation
  - Fraction of captured pulsar wind interacting with the shock

# Potential TeV emitters

van der Merwe et al. (2020):

- UMBRELA code: radiative model
- Impact of parameters
- Hot or flaring companions - detected by CTA



# TRANSITIONAL MILLISECOND PULSAR

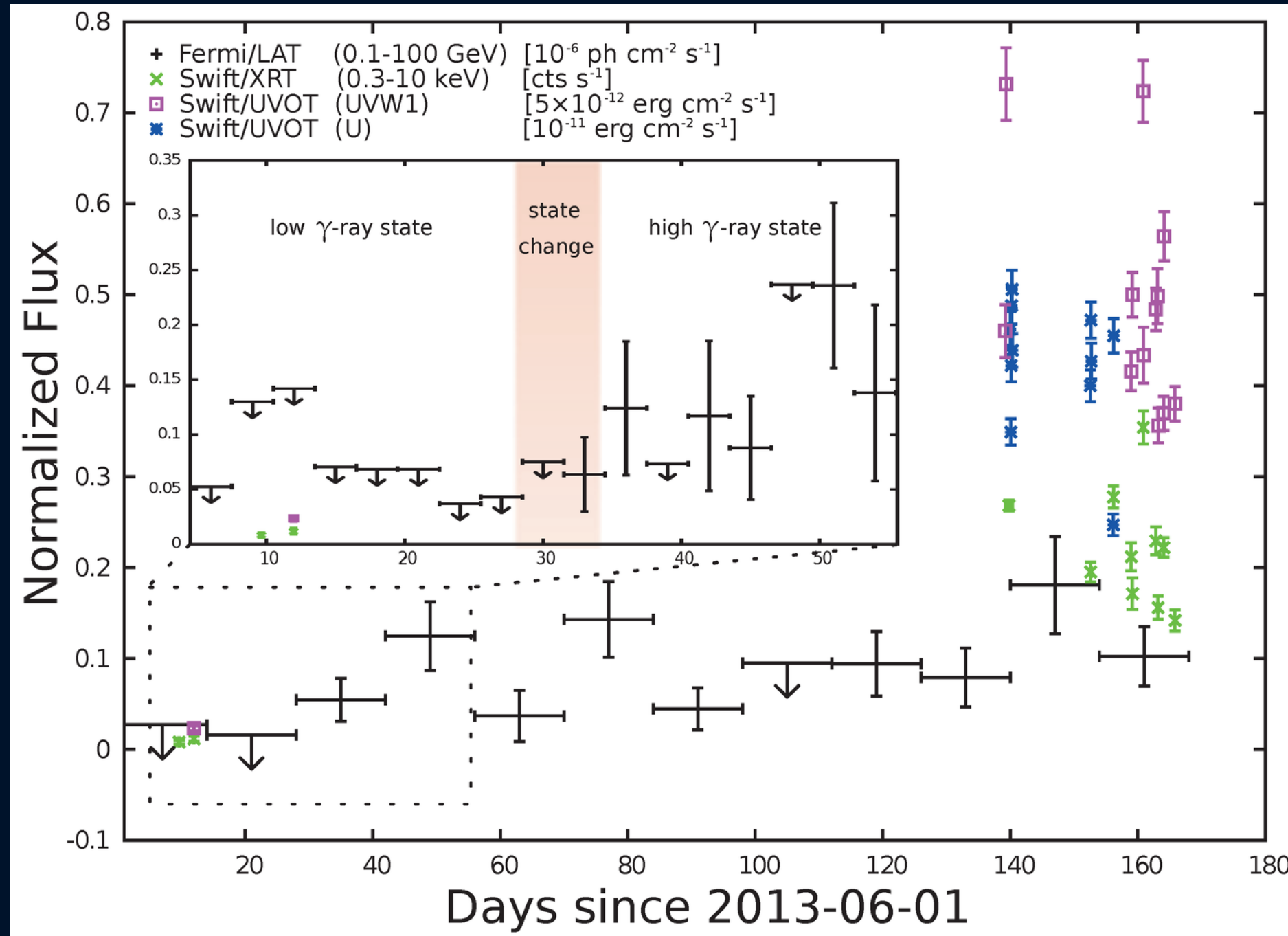
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# Transitional millisecond pulsars

## PSR J1023+0038



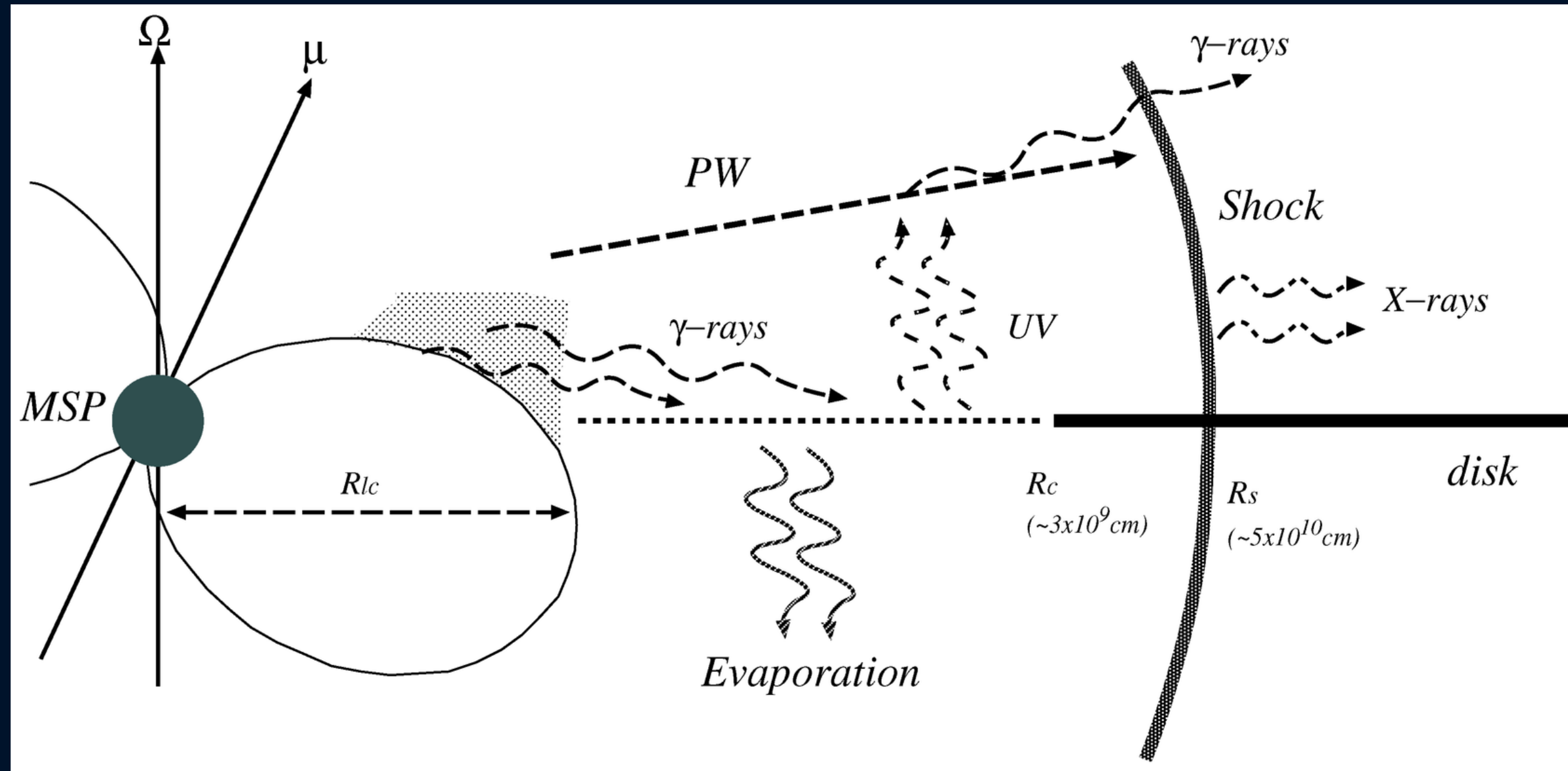
Three RBs are known to transit between a disk and a pulsar state

- PSR J1023+0038
- PSR J1227-4853
- PSR J1824-2452I

Takata et al. (2014)

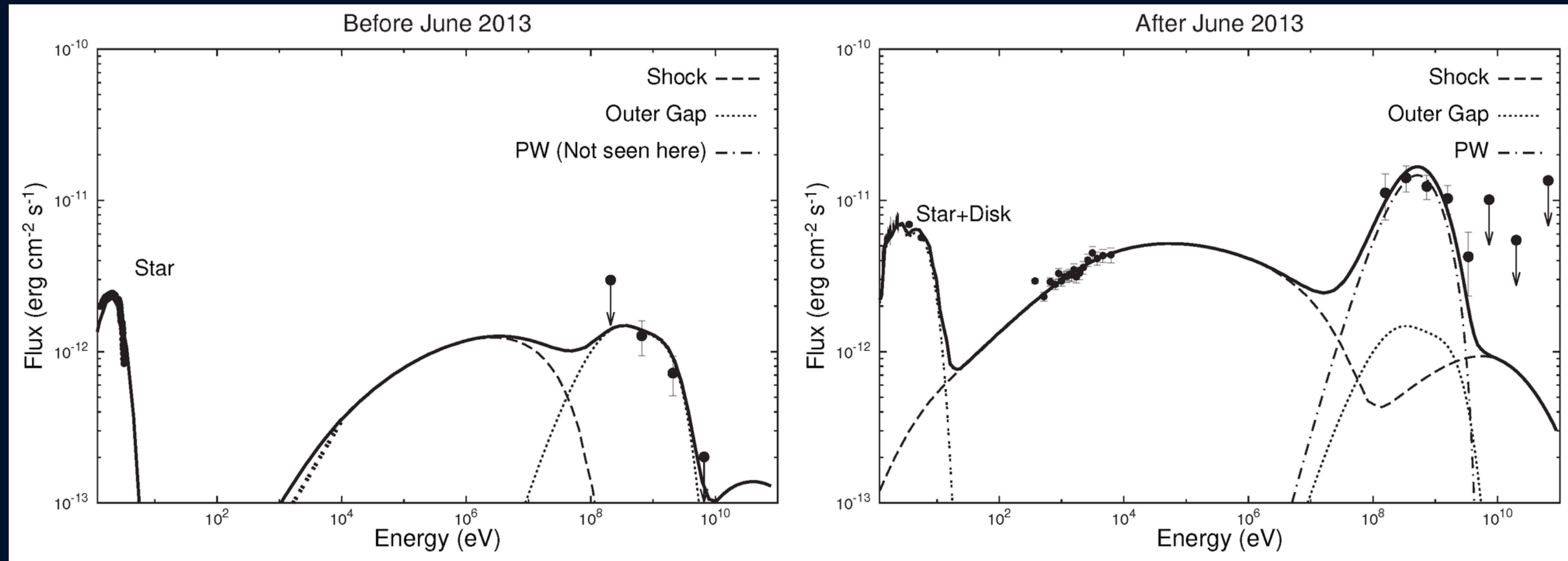


# Transitional millisecond pulsars



Takata et al. (2014)

# Transitional millisecond pulsars



Takata et al. (2014)

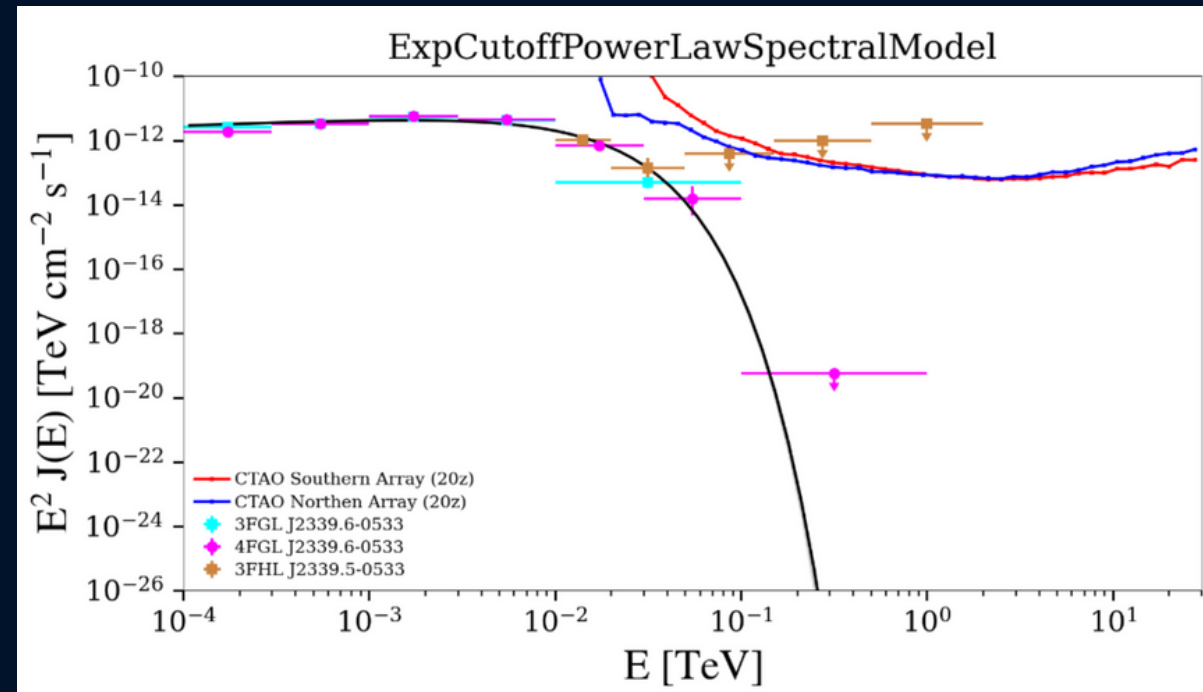
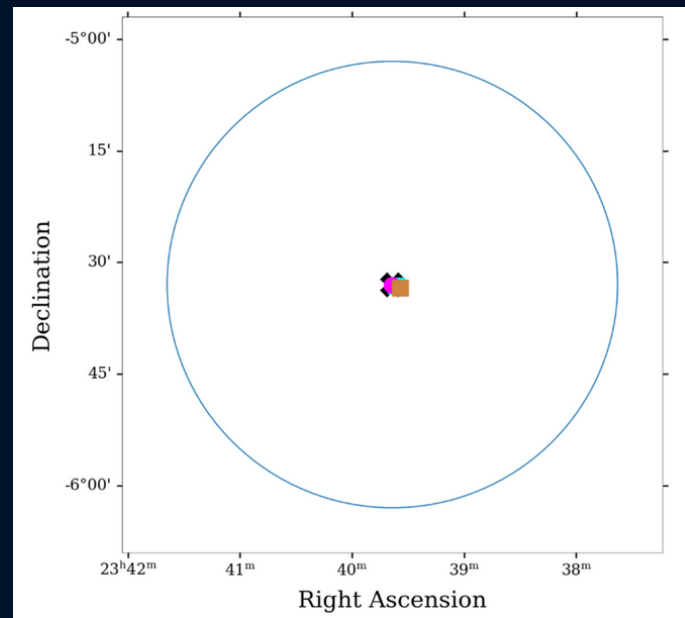
# SIMULATION OF CTA OBSERVATION

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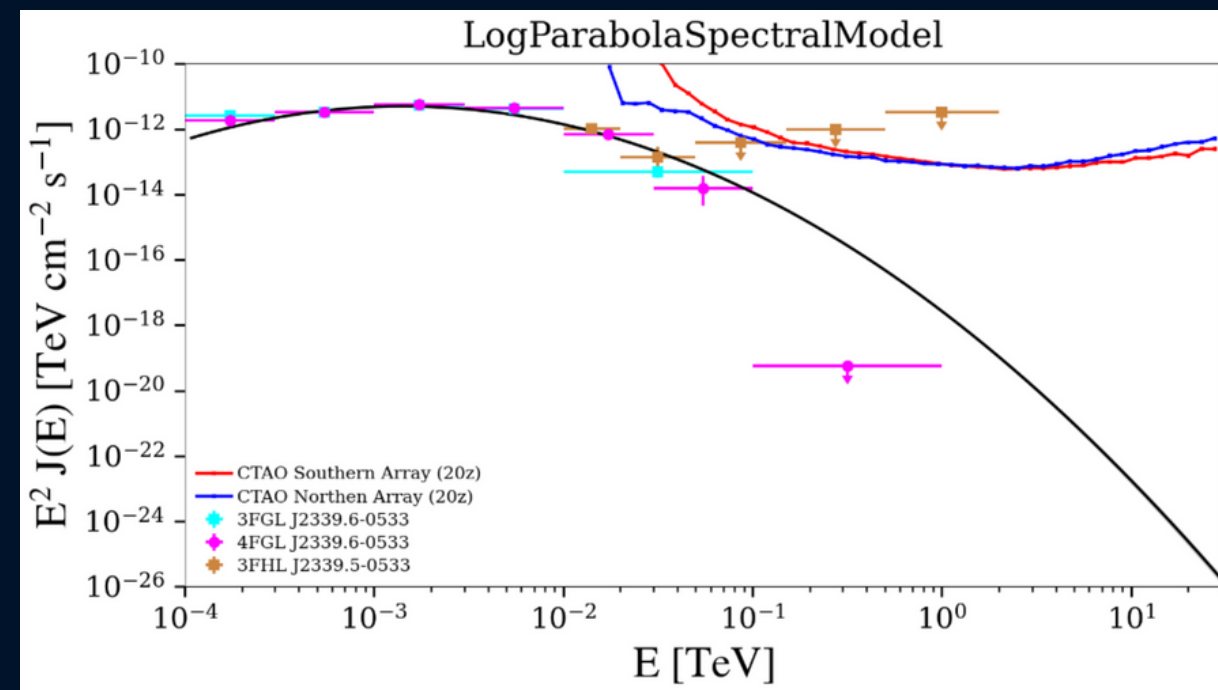
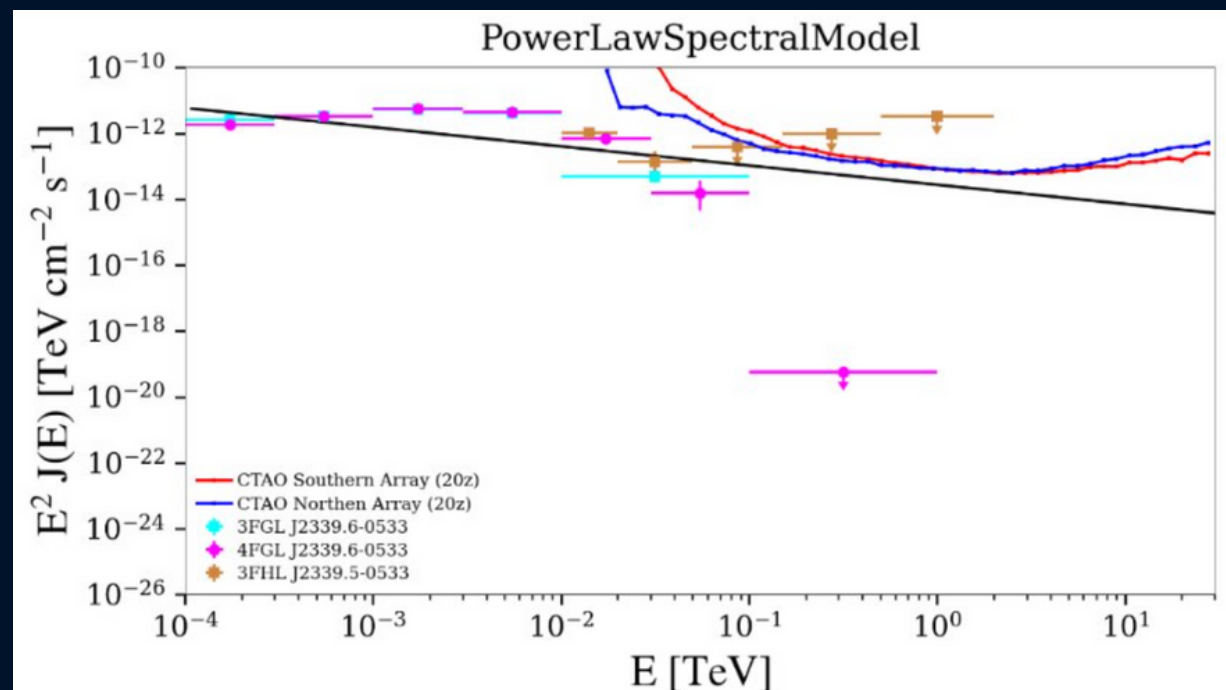


# Simulation of CTA observations

PSR J2339-0533



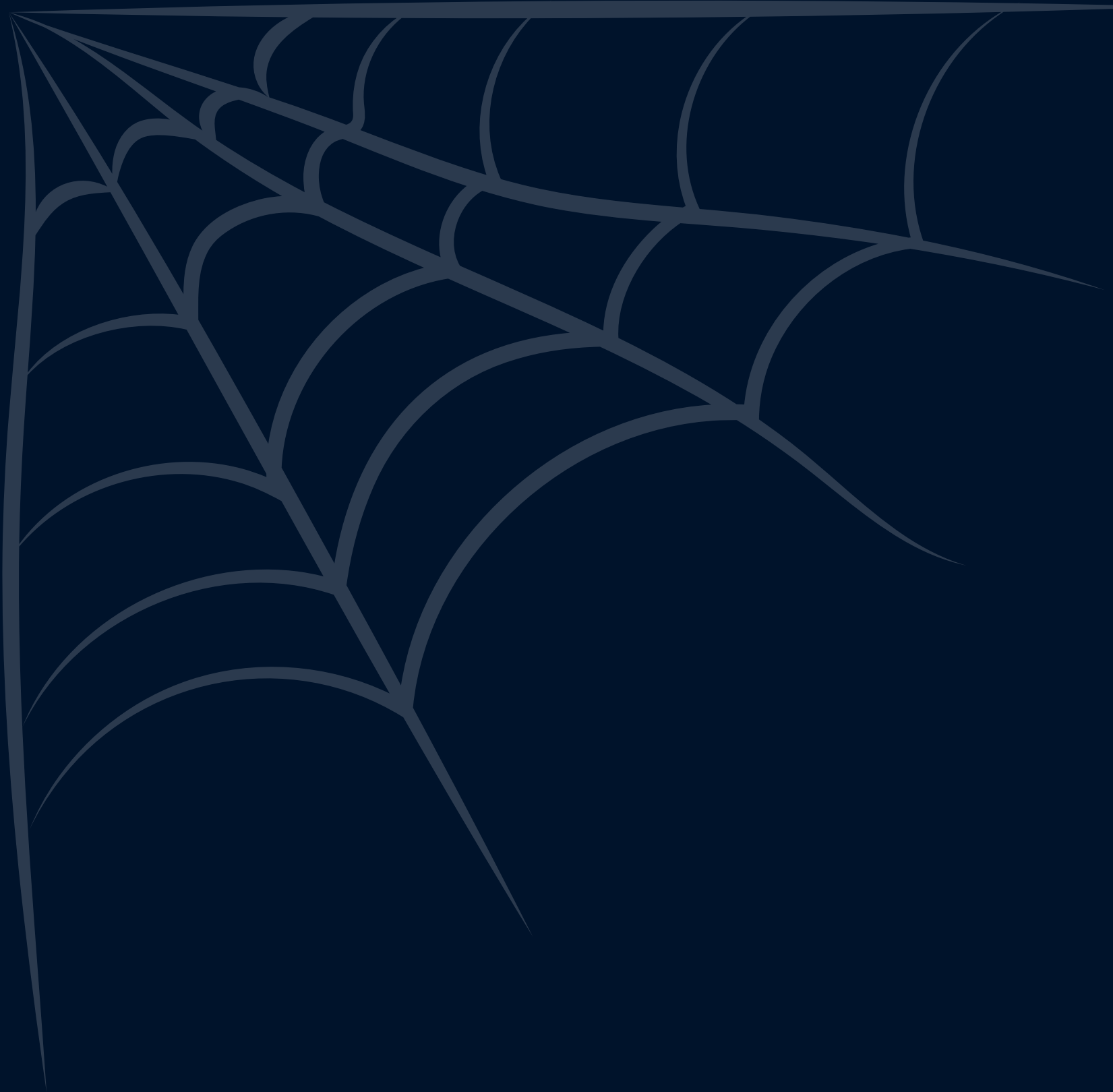
- Exclude GC systems
- Extract SED fit from available observations (Gammapy)
  - Sampling
  - Model comparison
- Inject spectral model in CTA simulations
- Pin-down best CTA targets



# Conclusion

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- **Very much an ongoing work:**
- **Select best sources to be observed with CTA**
- **Particle acceleration**
- **Spider prospects**
  - **Maximum mass of NSs**
  - **Equation of state at ultra high densities**
  - **Compact binary evolution**
  - **Pulsar winds**
  - **Positrons excess**

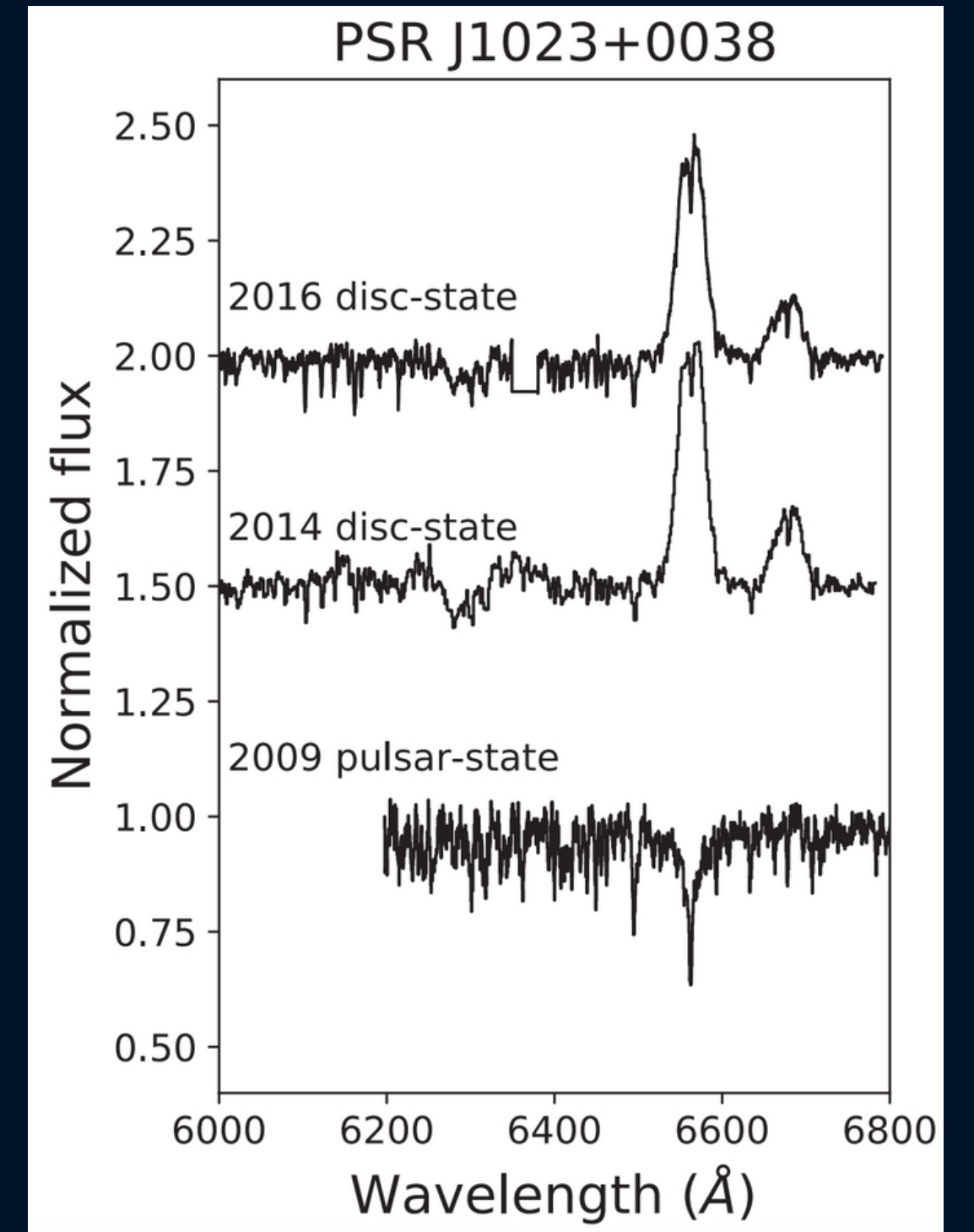
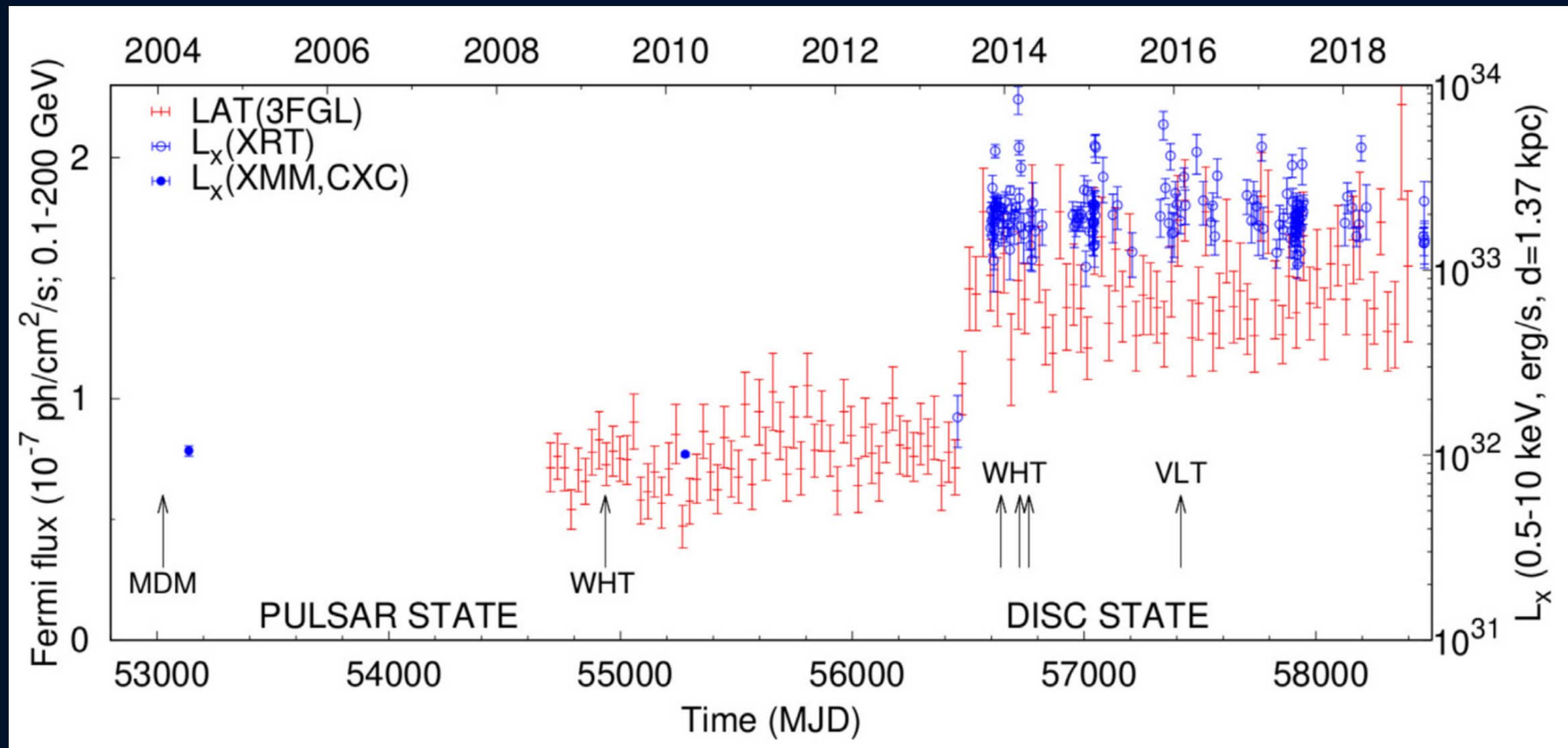


**Thank you for your attention.**



# Transitional millisecond pulsars

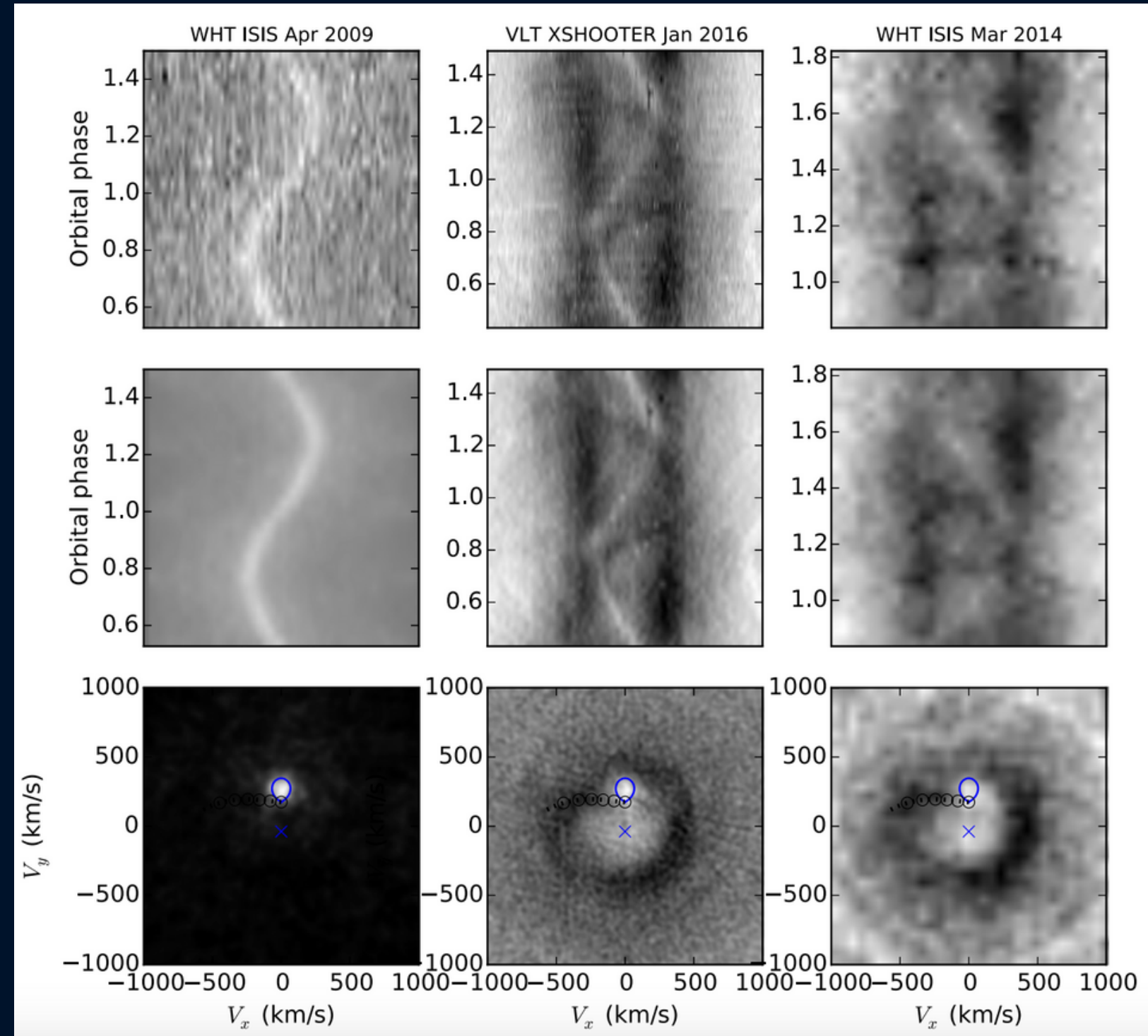
## Evidence of accretion disk





# Transitional millisecond pulsars

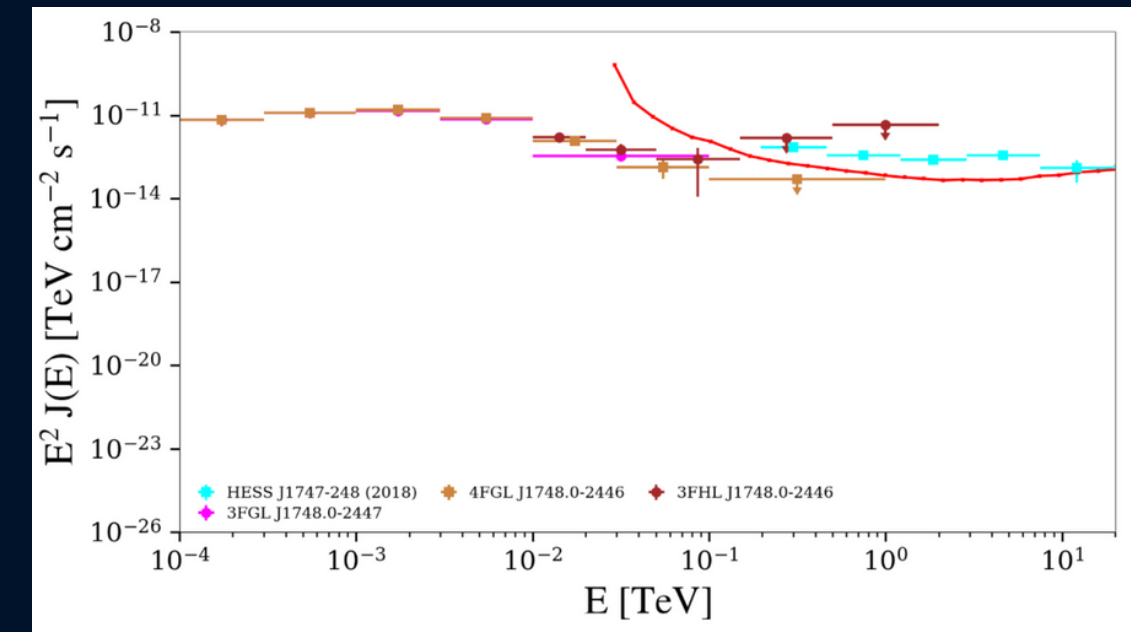
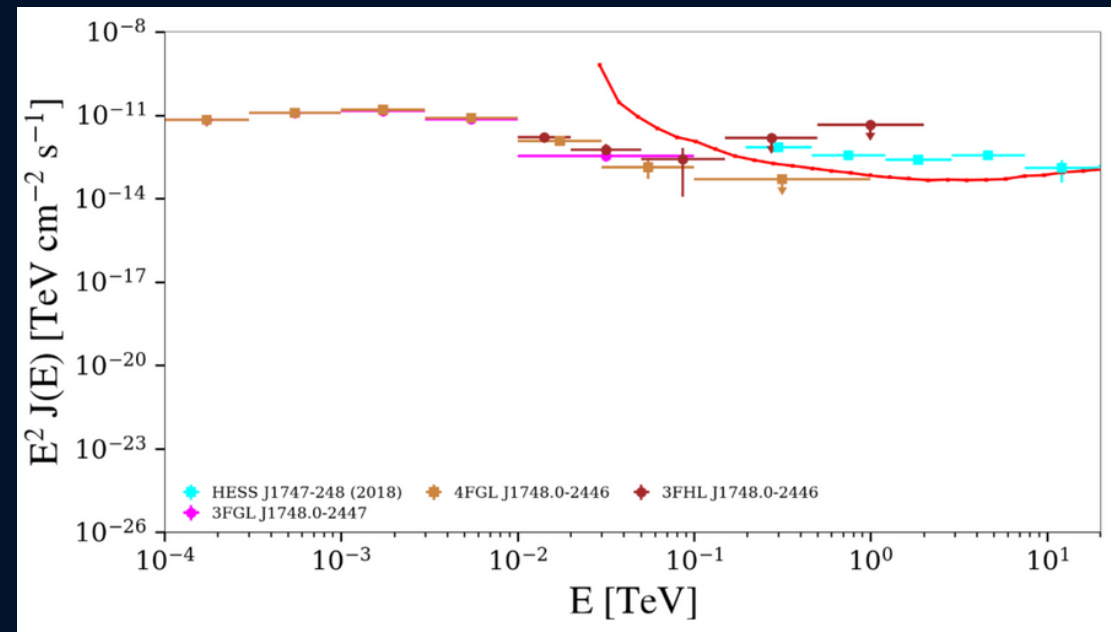
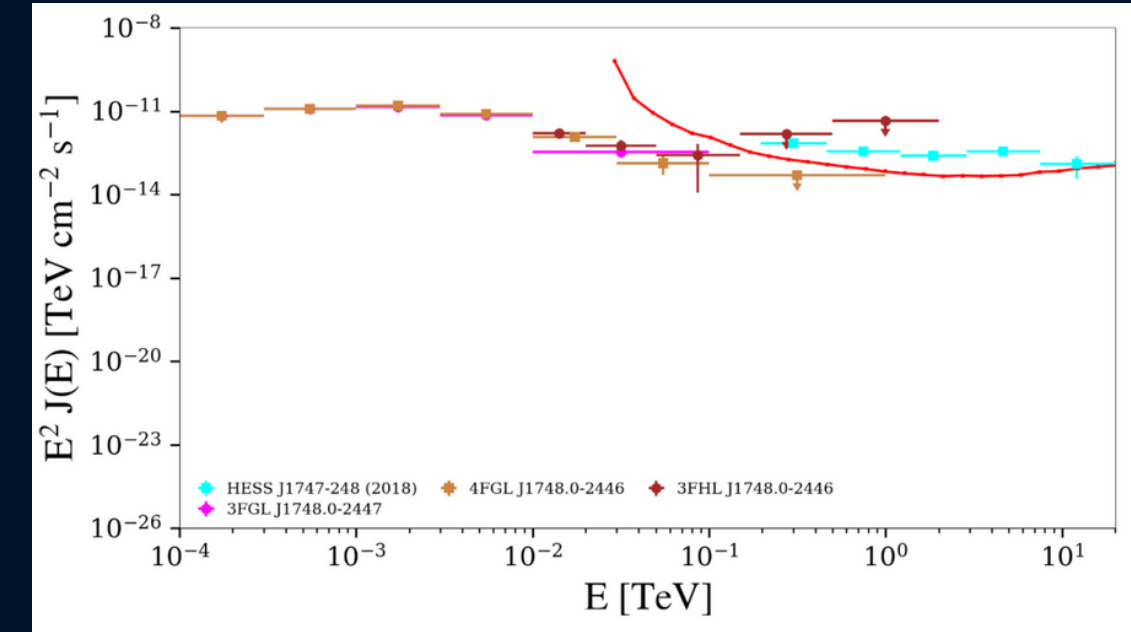
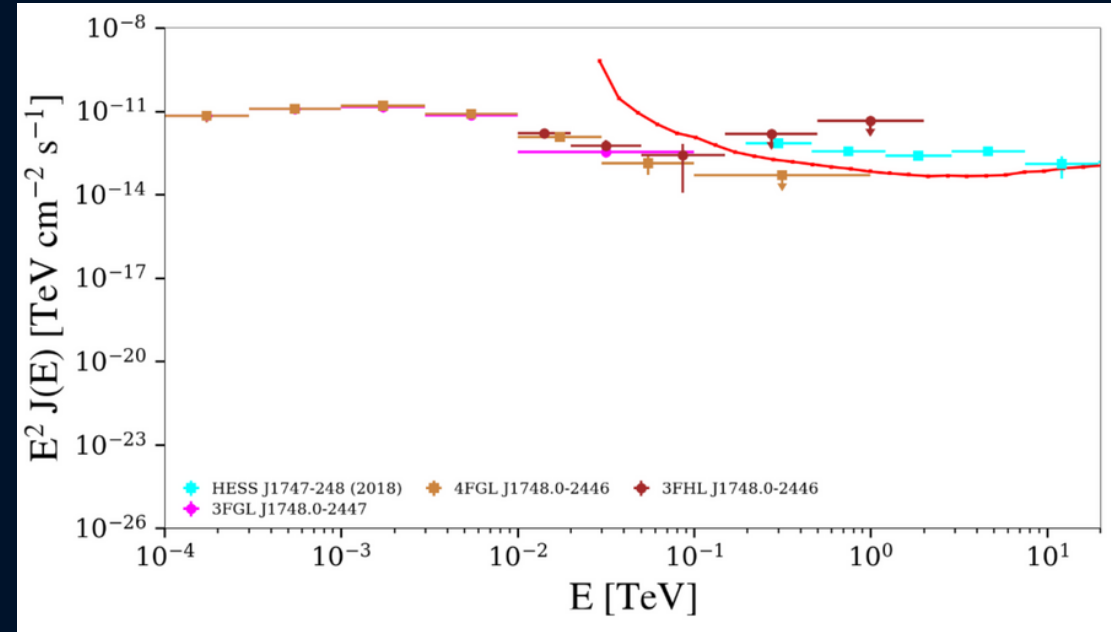
## Evidence of accretion disk



# Spiders in globular clusters

Terzan 5:

- J1748-2446A
- J1748-2446O
- J1748-2446P
- J1748-2446ad



It is difficult to resolve the gamma-ray emission...