SpiderCat

A CATALOGUE OF COMPACT BINARY MILLISECOND PULSARS

Karri Koljonen (NTNU/Trondheim)

In collaboration with:
Manuel Linares (NTNU)
(Thanks to Iacob Nedreaas & Bogdan Voiadas)

Catalogue paper: Koljonen & Linares (2025), ApJ, 994, 8

Web interface: https://astro.phys.ntnu.no/SpiderCAT

Vizier: J/ApJ/994/8

NTNU
Norwegian University of Science and Technology

LOVE NEST

European Research Council
Established by the European Commission

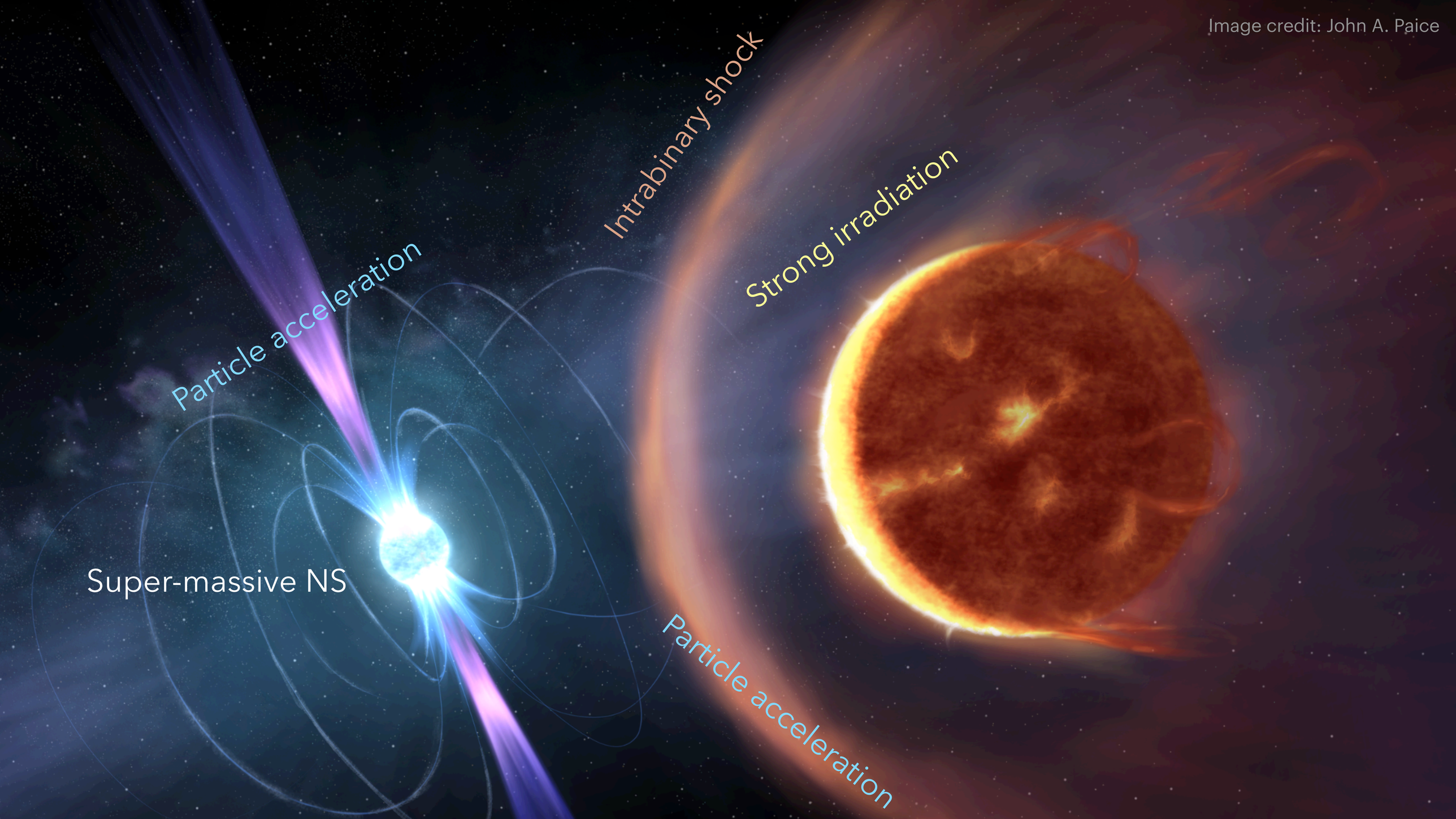


Image credit: John A. Paice
Intrabinary shock
Strong irradiation
Particle acceleration
Super-massive NS
Particle acceleration

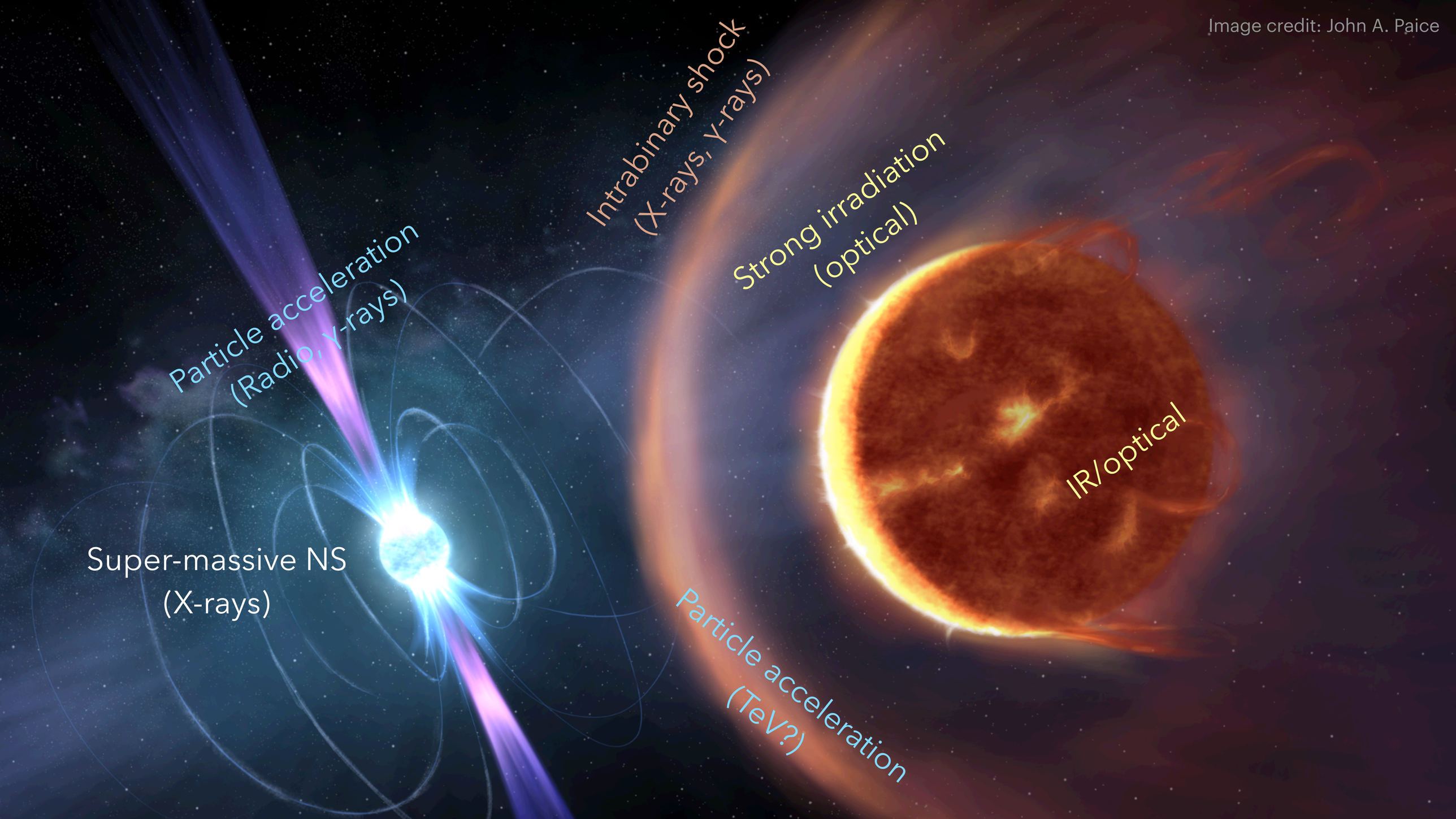
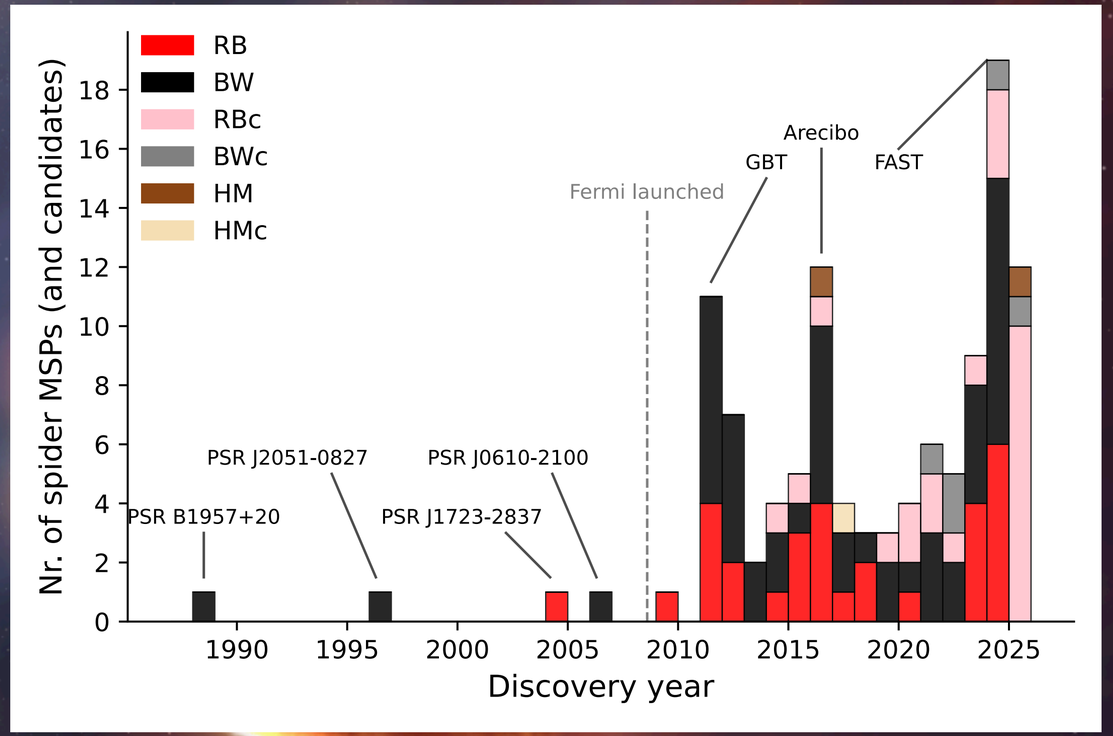


Image credit: John A. Paice
Particle acceleration
(Radio, γ-rays)
Intrabinary shock
(X-rays, γ-rays)
Strong irradiation
(optical)
IR/optical
Super-massive NS
(X-rays)
Particle acceleration
(TeV?)

SPIDER BOOM

- Only a handful pre-2008; dramatic rise after Fermi launch
- Multiple discovery channels: γ-ray-guided radio/optical, blind γ-ray searches, X-ray selection
- Spider population now >100 Galactic-field systems → population studies feasible
- Existing pulsar catalogs emphasize radio timing (e.g. ATNF); spider information is multiwavelength and scattered

Koljonen & Linares 2025



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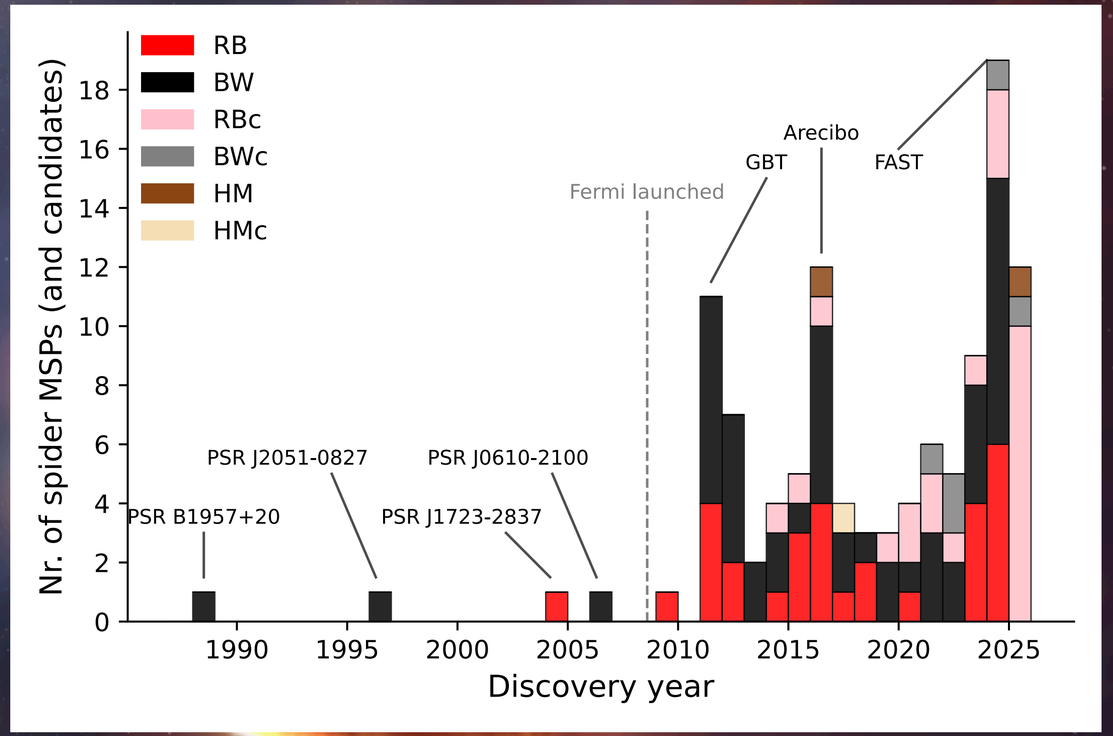
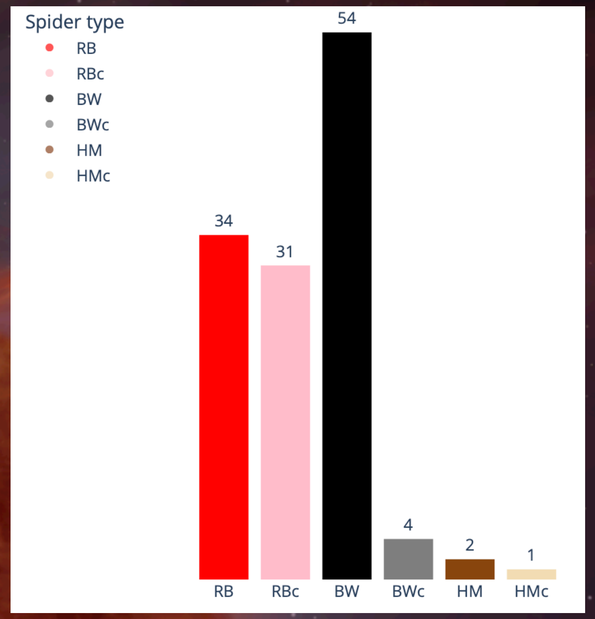
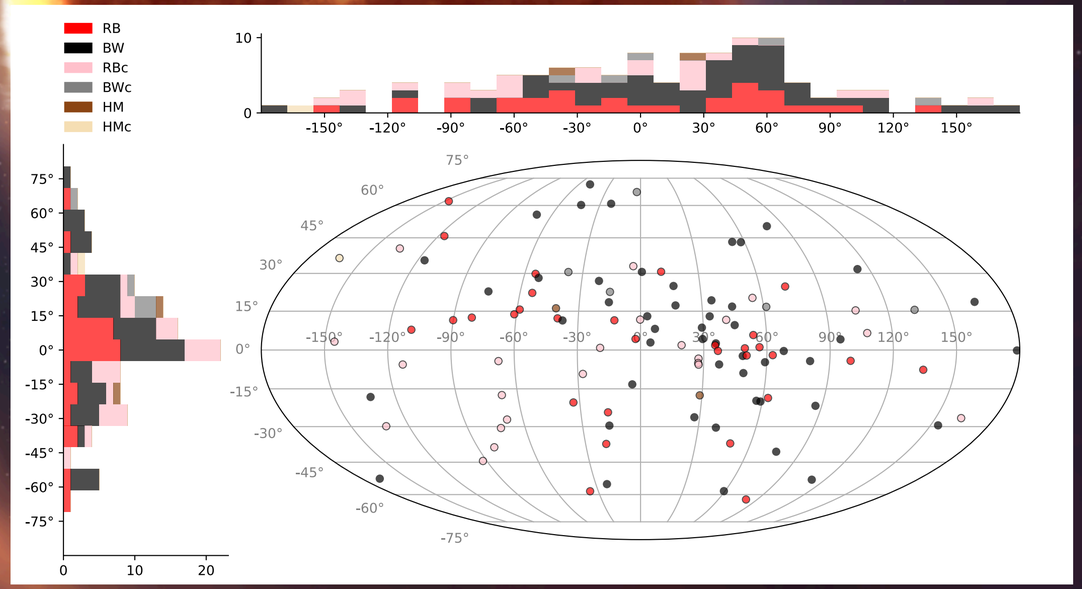


Unified, public, queryable resource

SPIDERCAT

- 109 (first release) → 126+5 (today)
  - >20 increase in 1 year!
  - 90 confirmed systems (54 BW, 34 RB, 2 HM)
    - 41 candidates (no pulses detected so far)
- Key per-source parameters:
  - Coordinates, spin (P, $\dot{E}$), binary (P_b, $M_{c,min}$), discovery metadata, distance (DM + Gaia)
  - Data compiled from literature + public catalogs (e.g., ATNF)



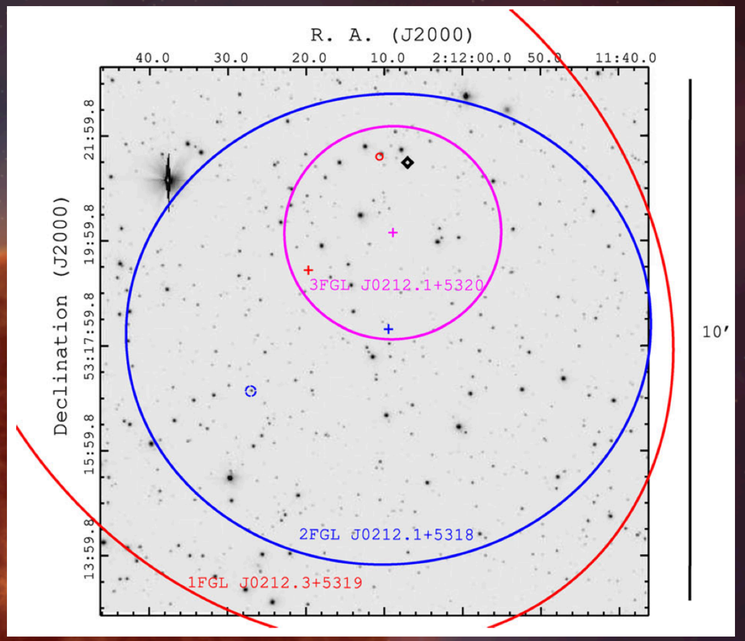


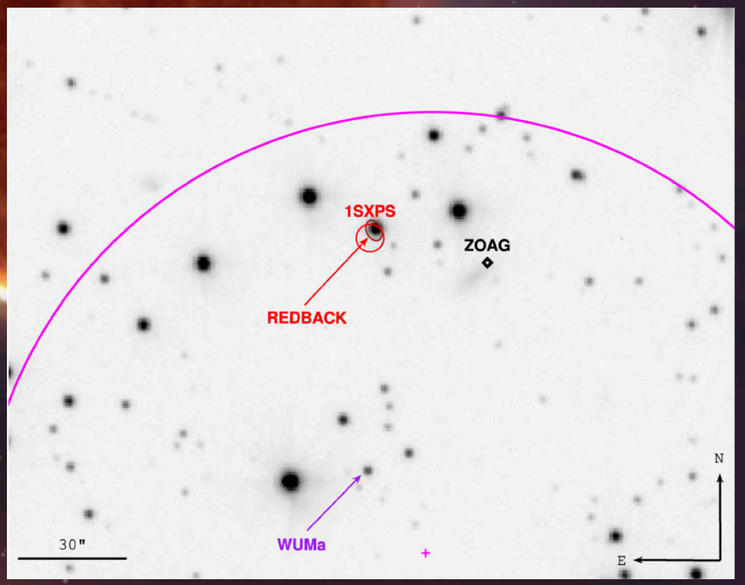
Koljonen & Linares 2025

MULTIWAVELENGTH CROSSMATCH

- Crossmatches through various data archives (e.g. Vizier)
- **γ-ray:** Fermi 4FGL (search radius 10′)
- **X-ray:** XMM/Swift/Chandra/eROSITA (2–9″ radii)
- **Optical/IR:** Gaia, Pan-STARRS, SkyMapper, 2MASS (2″ radius)
- Planned: **Radio** (LOFAR)
- Outputs: fluxes, estimated luminosities with Gaia/DM distances, mags/colors

Linares+17

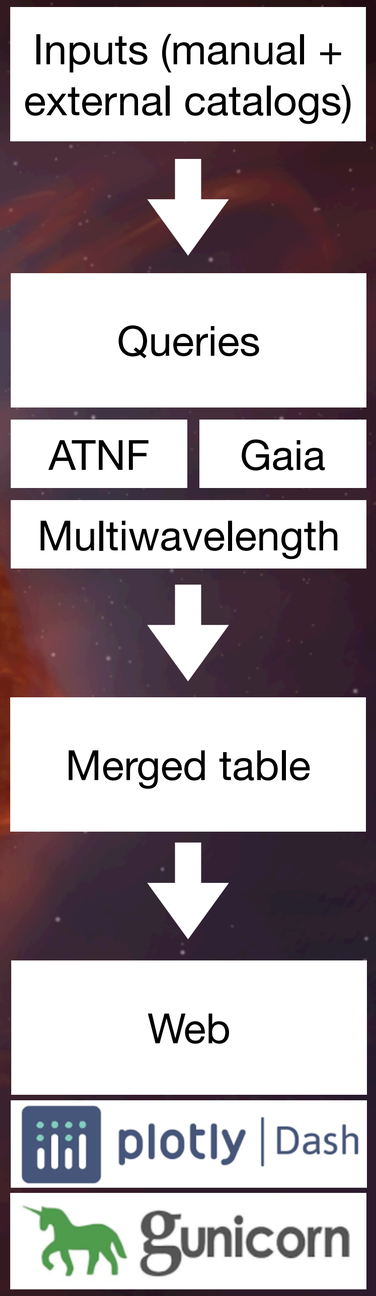




SPIDERCAT UNDER THE HOOD

- Reproducible pipeline plus a web front end.

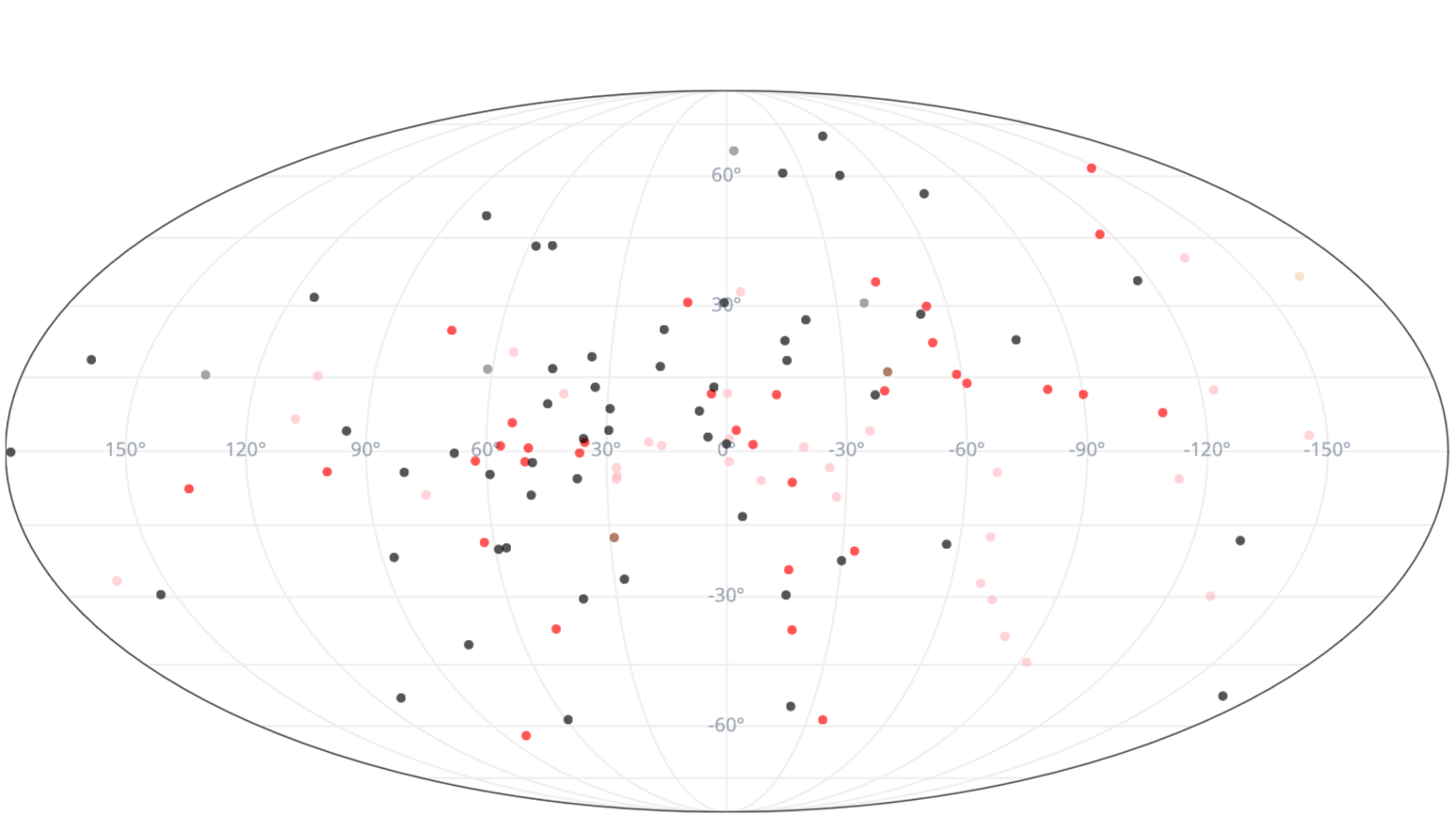
1. Pipeline builds intermediate products to a master table
   - ATNF queries for timing/DM and DM distances
   - Gaia queries for parallax-based distances with explicit priors and other parameters
   - Automated multiwavelength counterpart searches via VizieR with configurable radii
   - Manual curation: new systems not found in ATNF or with insufficient/incorrect information
2. Web app (Dash + Gunicorn): loads the master table and provides interactive table and plotting tools with exports, and dynamic per-source pages

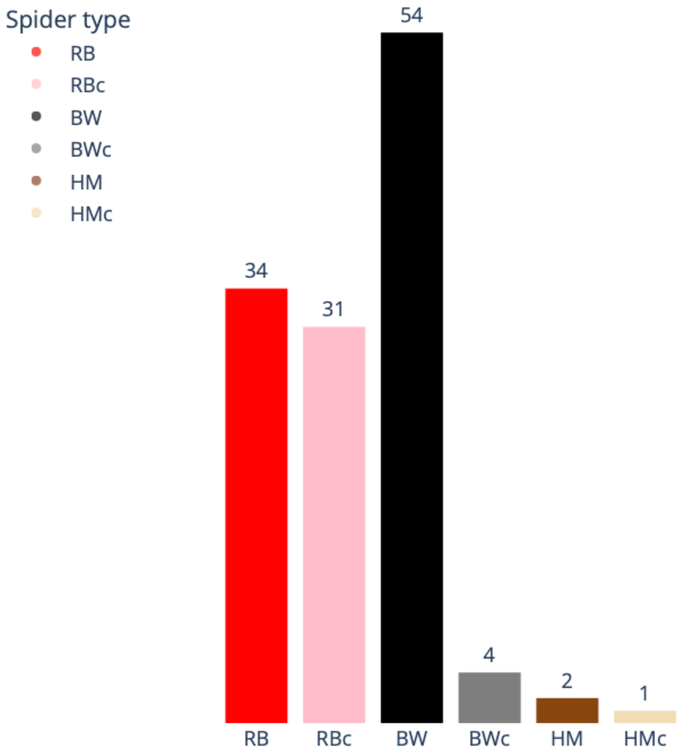


Description

Usage instructions

Current spider population (N=126)





Page navigation

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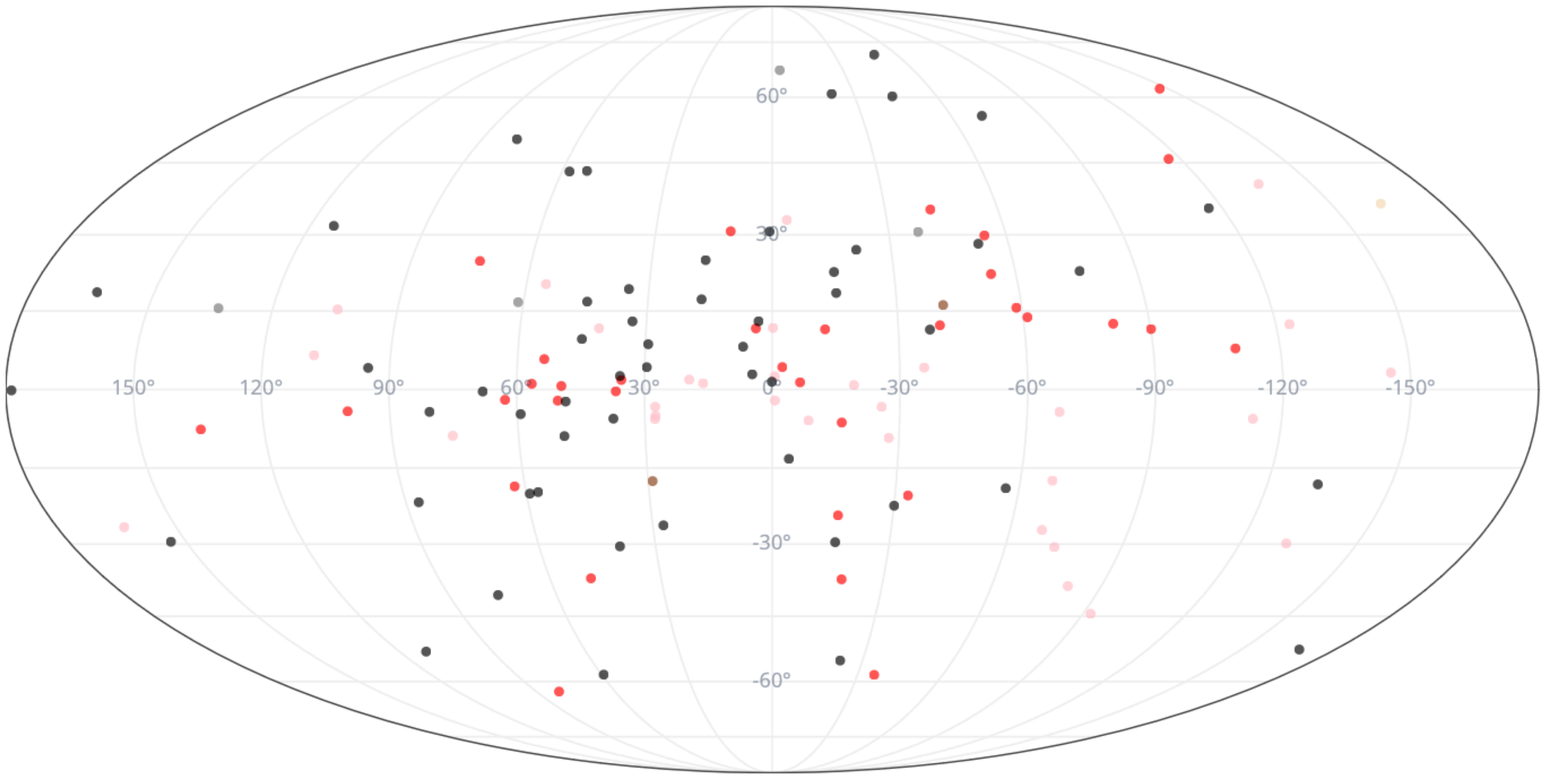

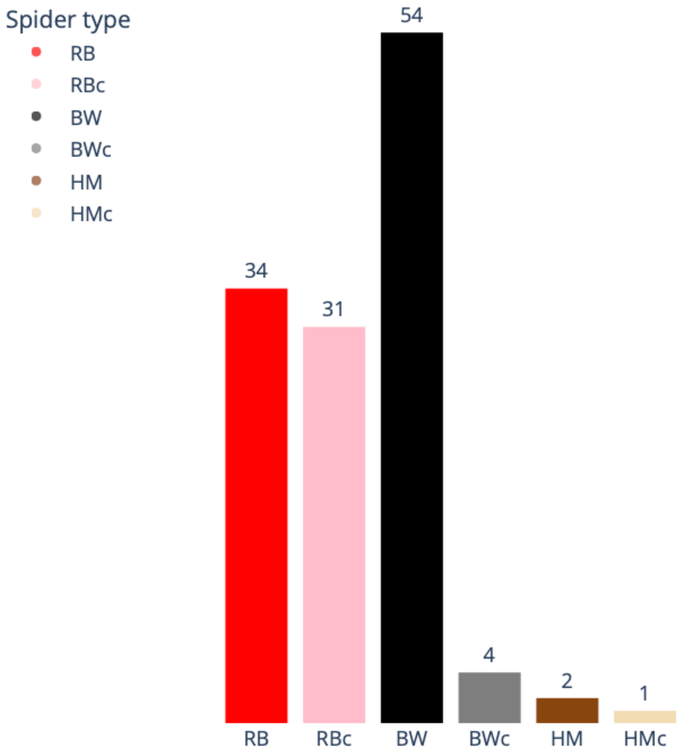

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Page navigation

Clickable info boxes

▼ Description

▼ Usage instructions

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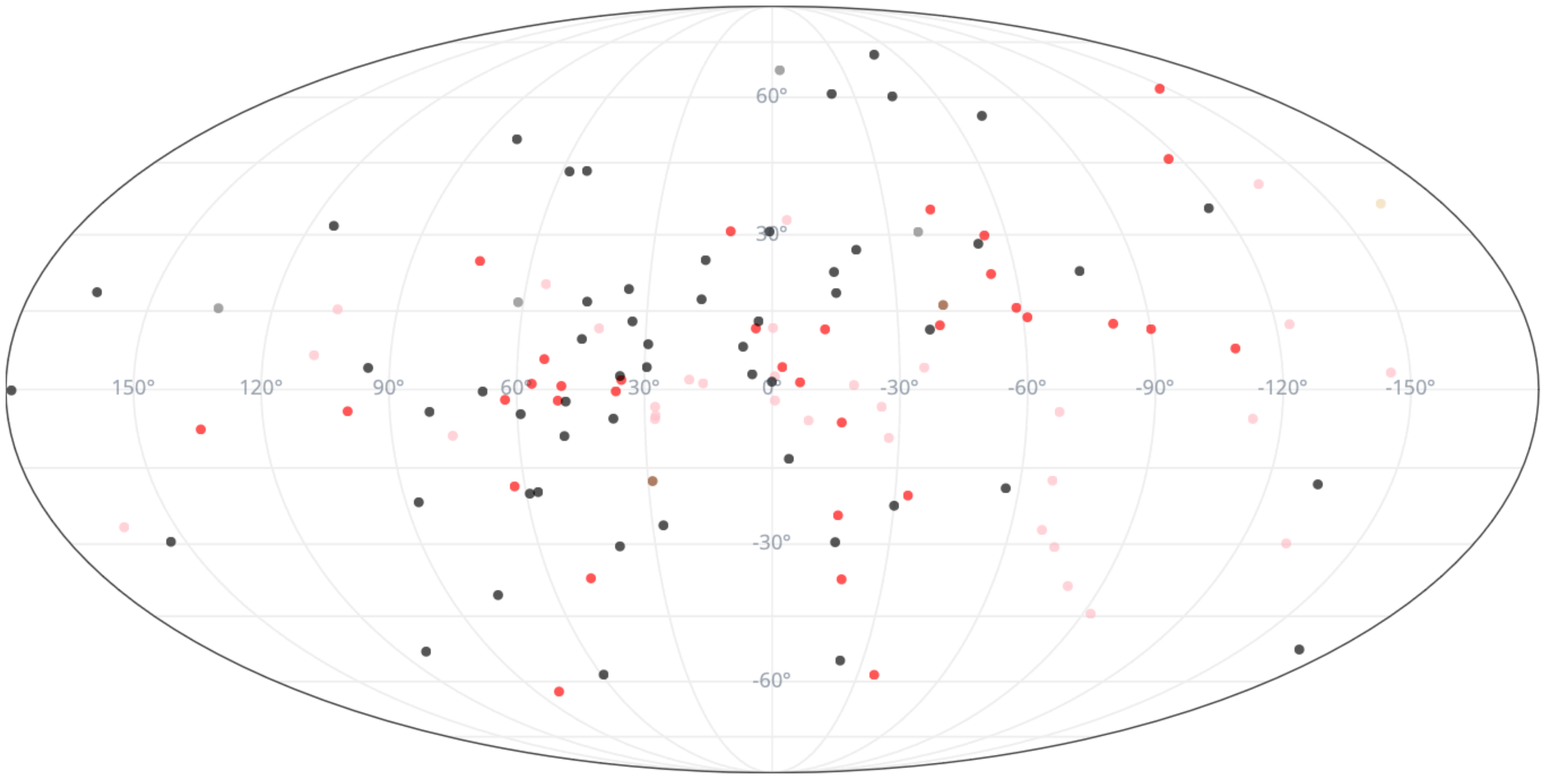

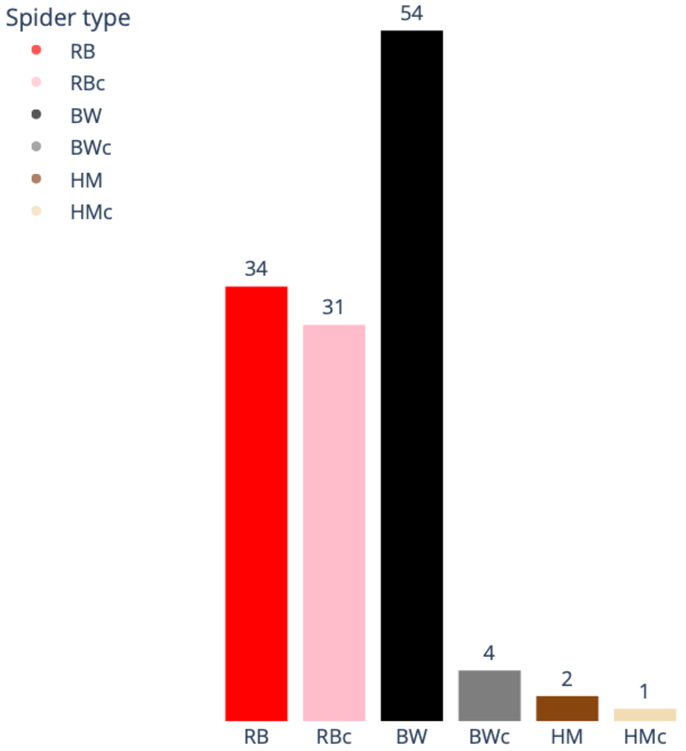

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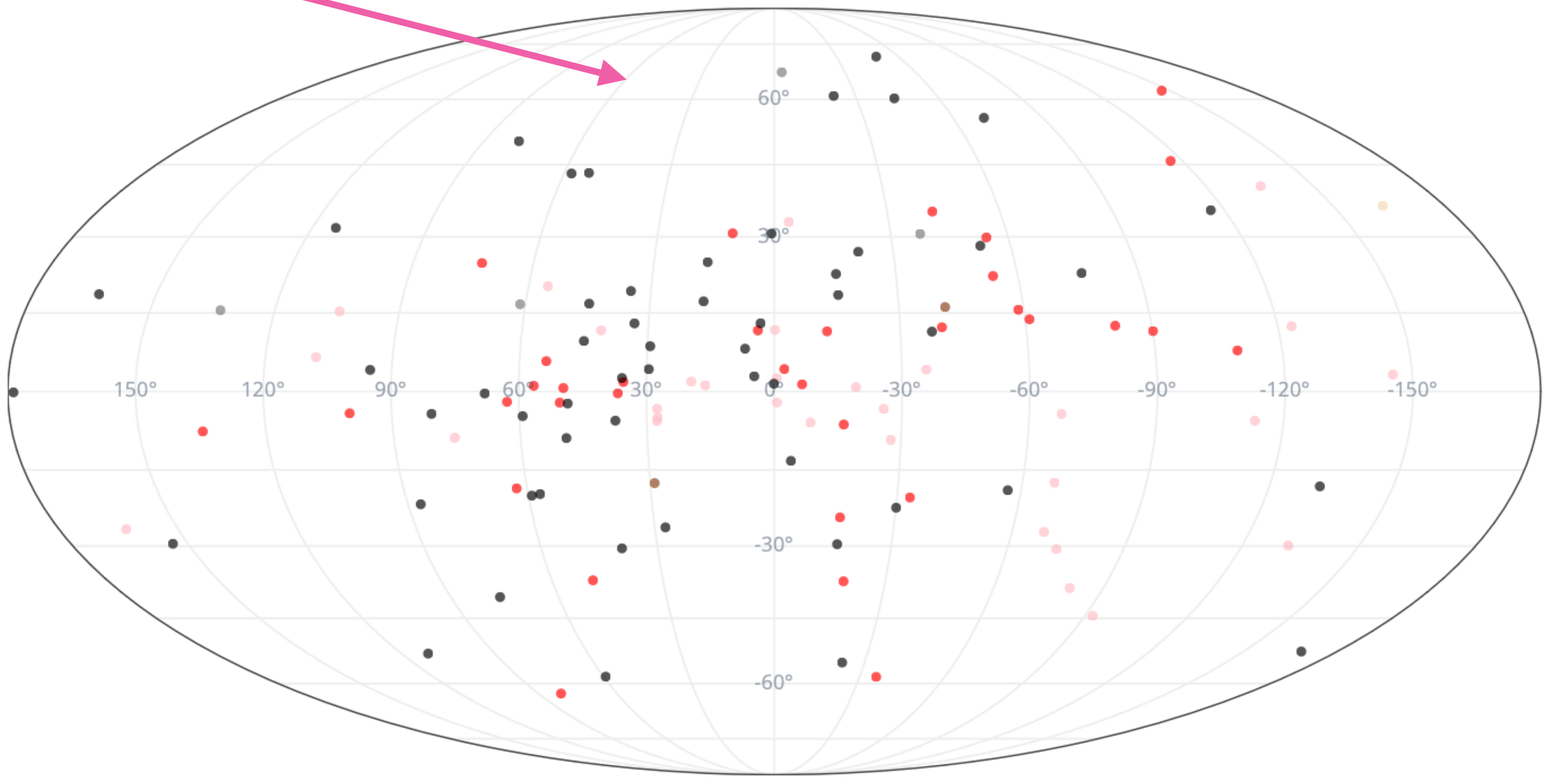
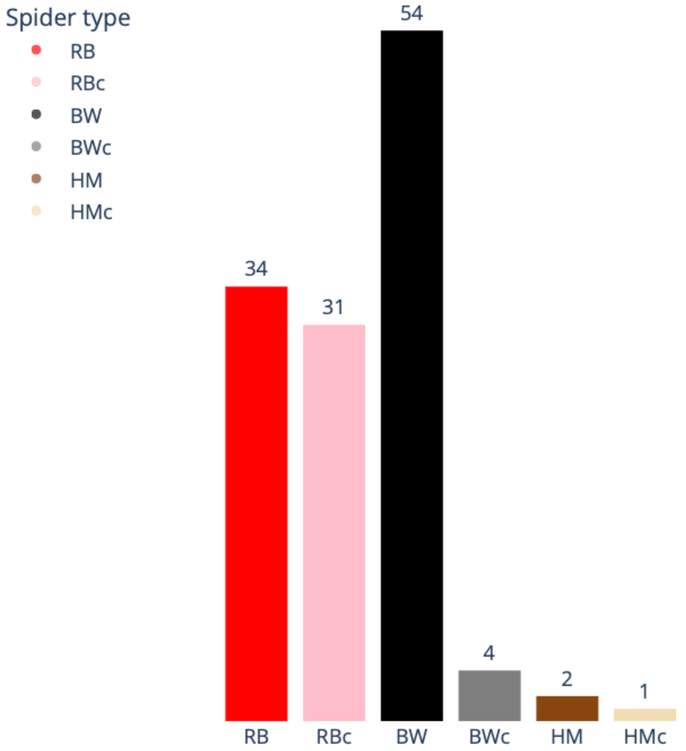
Interactive galactic map (hovername + link to per-source pages)





PSR B1957+20

BLACK WIDOW

RA	DEC	l	b
19:59:36.76988	+20:48:15.1222	59.19695472698977	-4.697475795869231

Discovery year: 1988; Fruchter, A. S., et al. (1988)
Dynamical reference: Arzoumanian, Z., et al. (1994)
External links: Fermi 3PC ATNF PSRCAT XCatDB SIMBAD QUERY VISIBILITY
ADS searches: FULL TEXT ABSTRACT TITLE KEYWORD

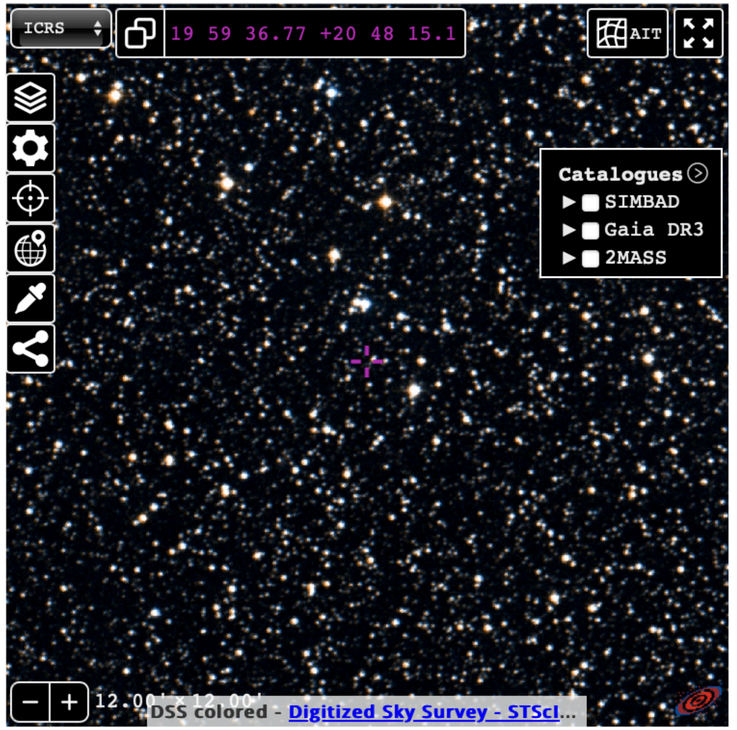
Basic Data

Orbital period [hr]	9.17
Spin [ms]	1.61
Dispersion measure [pc.cm**-3]	29.11
Distance (YMW16) [kpc]	1.73
Distance (NE2001) [kpc]	2.49
Galactic height [kpc]	-0.14
X-ray luminosity [erg.s**-1]	2.44e+31 (0.2-12 keV; XMM)
Gamma-ray luminosity [erg.s**-1]	5.61e+33 (0.1-100 GeV; Fermi)

Optical properties

Gaia counterpart	
Angular separation [arcsec]	0.75
G-band [mag]	20.30 (A_G = nan)
Pan-STARRS counterpart	
Angular separation [arcsec]	0.52
g-band [mag]	20.97 (A_g = 1.44)
r-band [mag]	20.27 (A_r = 1.03)
i-band [mag]	19.85 (A_i = 0.76)
z-band [mag]	19.60 (A_z = 0.60)

Aladin Sky View



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Useful links

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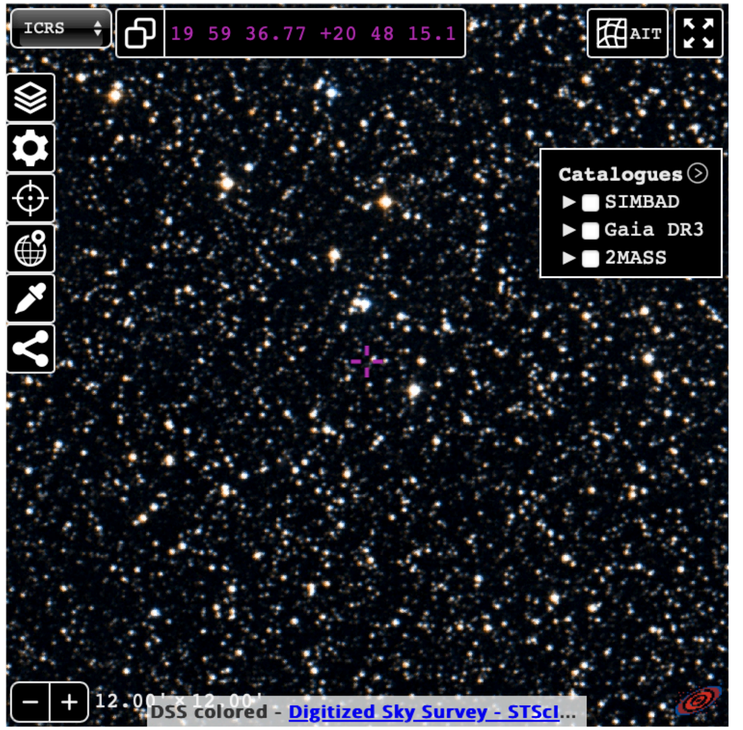

Usage instructions

Parameters

NAME | JNAME | Type | RA | DEC | P0 | PB | MSP | DISCyr | DISCnote | REFdisc | STATE | Edot | MCOMP_i90 | g_mag | LX | LG

Show full precision | Select format | Download

NAME	Type	P0	PB	MSP	DISCyr	REFdisc	Edot	MCOMP_i9
filter data...								
PSR_B1957+20	BW	1.61	9.17	1	1988	fst88	1.6e+35	0.0214
PSR_J0023+0923	BW	3.05	3.33	1	2011	hrm+11	1.59e+34	0.0164
PSR_J0251+2606	BW	2.54	4.86	1	2016	cck+16	1.82e+34	0.0241
PSR_J0312-0921	BW	3.7	2.34	1	2021	trr+21	1.53e+34	0.00896
PSR_J0541+2959g	BW	3.21	9.01	1	2024	why+24		0.0565
PSR_J0610-2100	BW	3.86	6.86	1	2006	bjd+06	8.45e+33	0.0214
PSR_J0636+5128	BW	2.87	1.6	1	2014	slr+14	5.77e+33	0.00687
PSR_J0952-0607	BW	1.41	6.42	1	2017	bph+17	6.67e+34	0.0191
PSR_J1124-3653	BW	2.41	5.45	1	2011	hrm+11	1.7e+34	0.0271
PSR_J1221-0633	BW	1.93	9.27	1	2023	spp+23	2.87e+34	0.0131

Usage instructions

Parameters

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Clickable buttons to show/hide parameters from the table

Show full precision | Select format | Download

NAME	Type	P0	PB	MSP	DISCyr	REFdisc	Edot	MCOMP_i9
filter data...								
PSR_B1957+20	BW	1.61	9.17	1	1988	fst88	1.6e+35	0.0214
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Download csv or txt file

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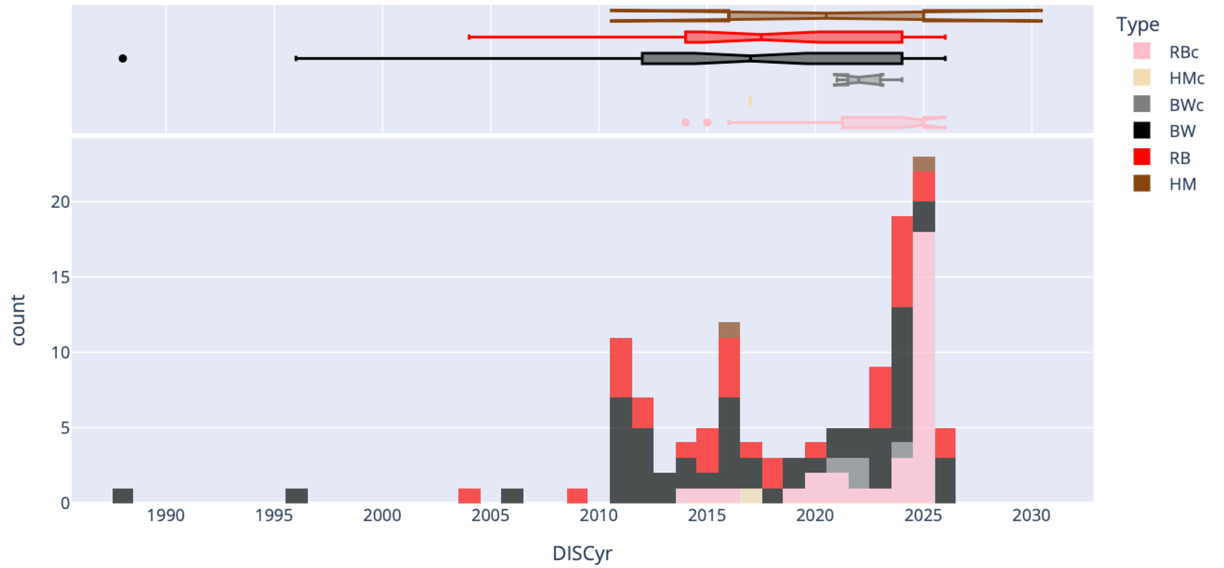
Histogram

Select parameter:

DISCyr



Select number of bins:

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Select Axis Scaling:

Lin Log

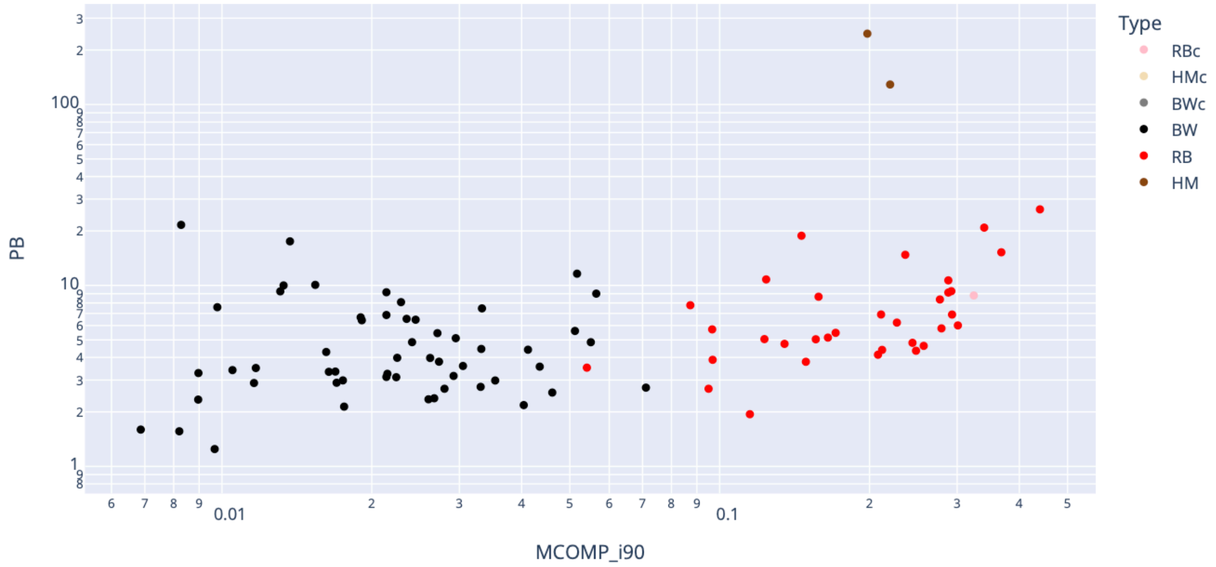
Scatter plot

Select X-axis parameter:

MCOMP_i90

Select Y-axis parameter:

PB



Select Axis Scaling:

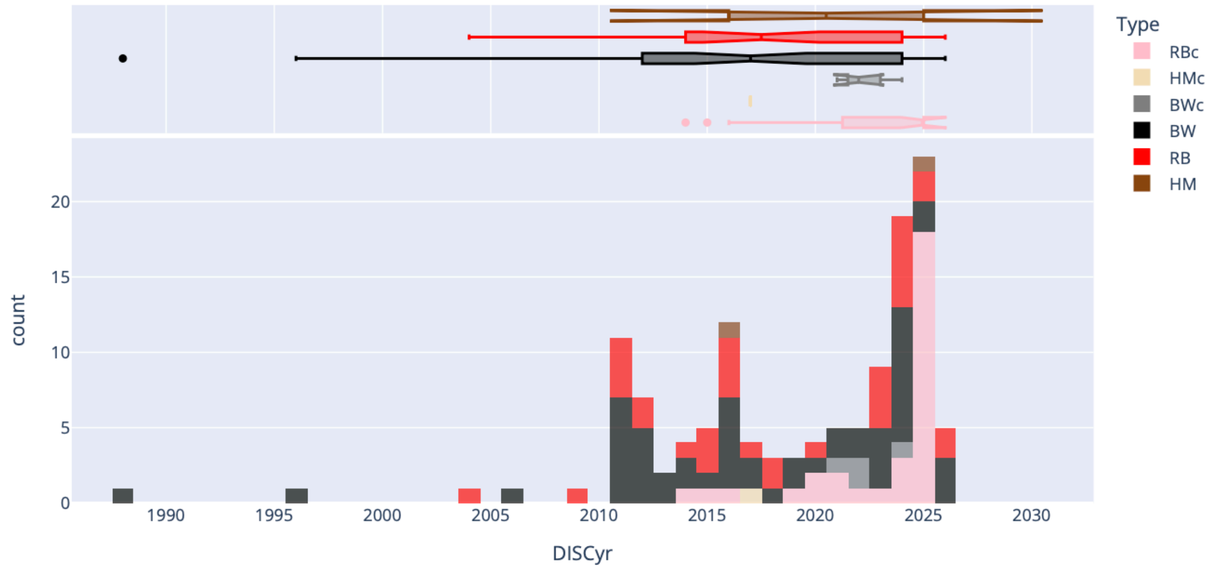
Lin-Lin Log-Lin Lin-Log Log-Log

Histogram

Select parameter:

DISCyr

Parameter selector



Select number of bins:

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Lin Log

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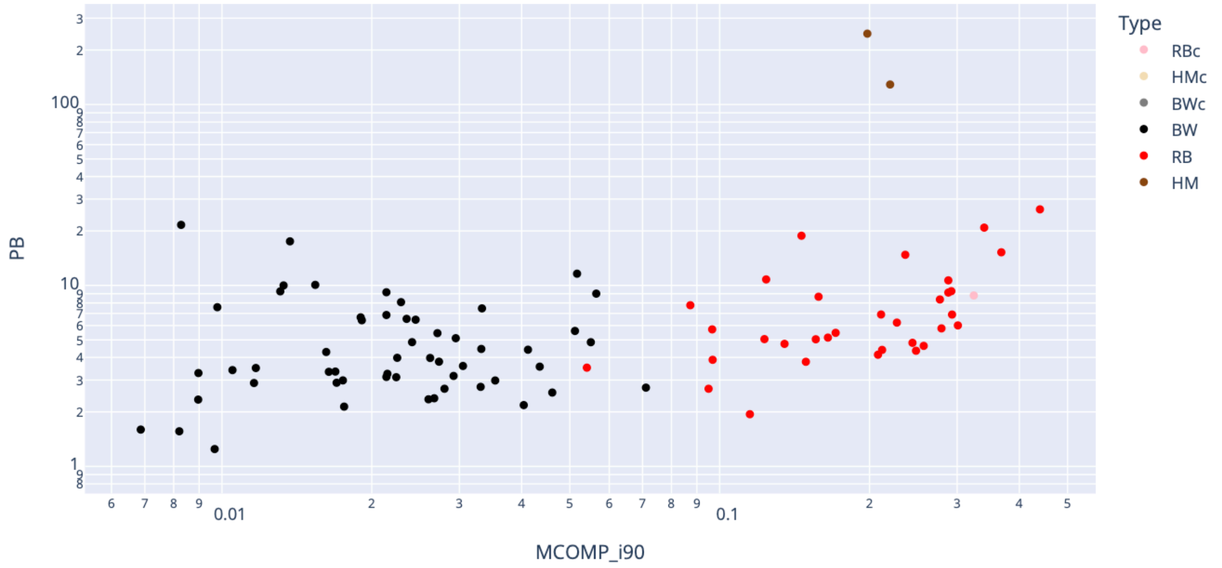
Select X-axis parameter:

MCOMP_i90

Select Y-axis parameter:

PB



Select Axis Scaling:

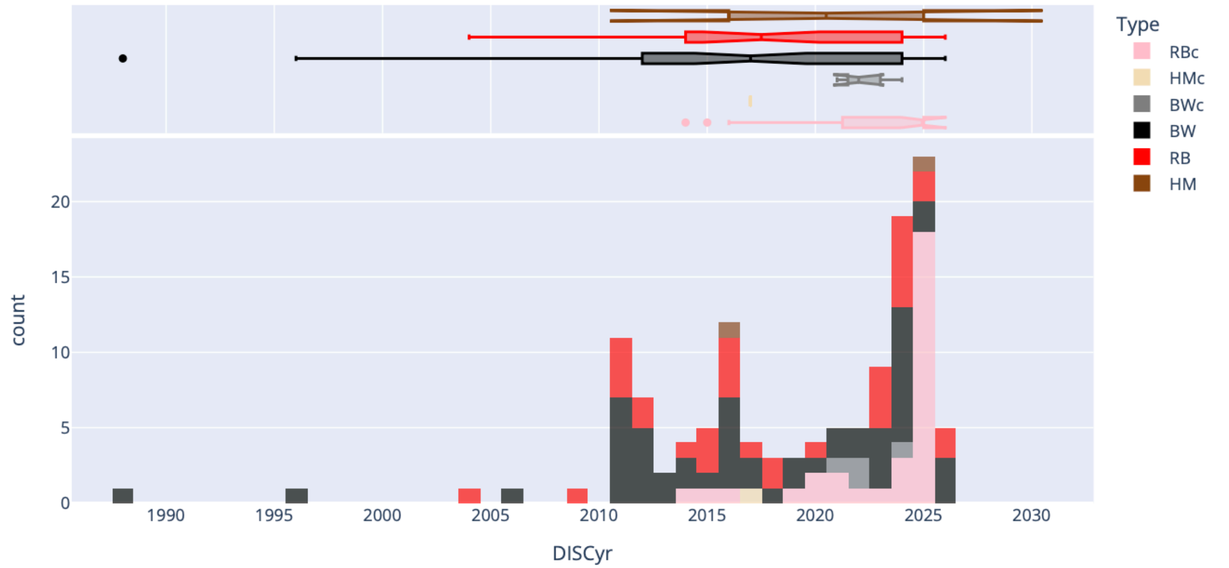
Lin-Lin Log-Lin Lin-Log Log-Log

Histogram

Select parameter:

DISCyr

Parameter selector



Select number of bins:

50

Binning slider

Select Axis Scaling:

Lin Log

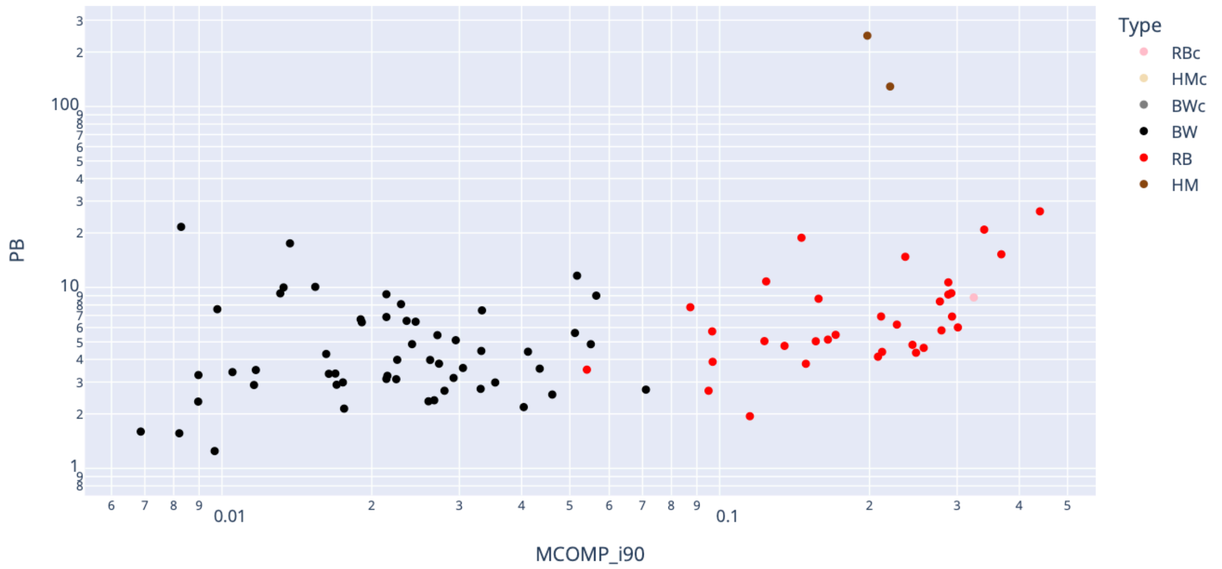
Scatter plot

Select X-axis parameter:

MCOMP_i90

Select Y-axis parameter:

PB



Select Axis Scaling:

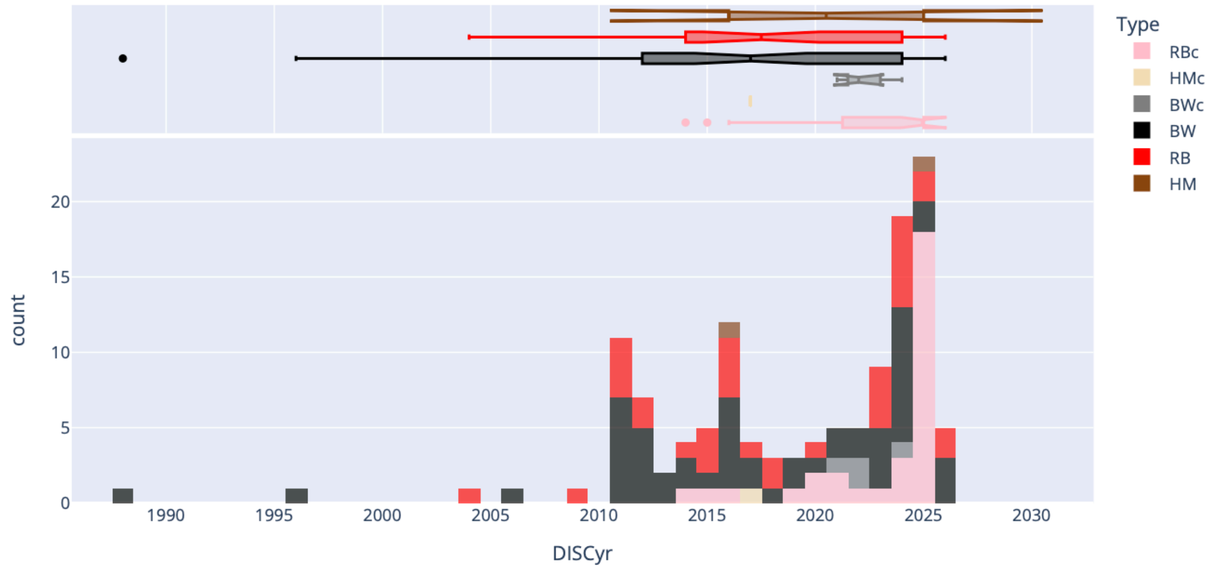
Lin-Lin Log-Lin Lin-Log Log-Log

Histogram

Select parameter:

DISCyr

Parameter selector



Select number of bins:

50

Binning slider

Select Axis Scaling:

Lin Log

Axis scaling

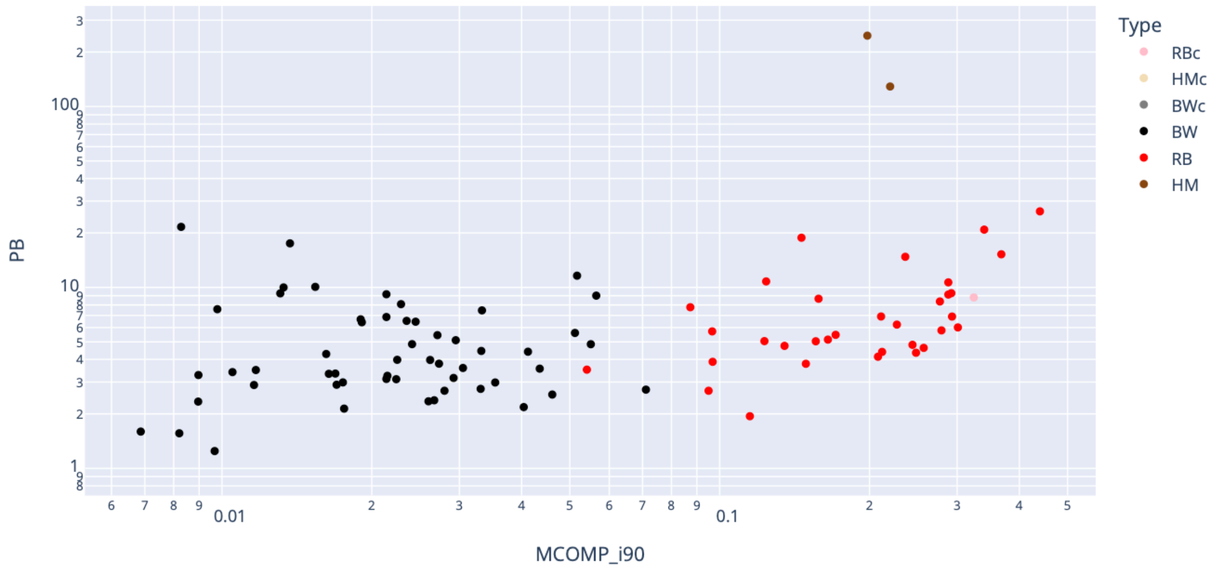
Scatter plot

Select X-axis parameter:

MCOMP_i90

Select Y-axis parameter:

PB



Select Axis Scaling:

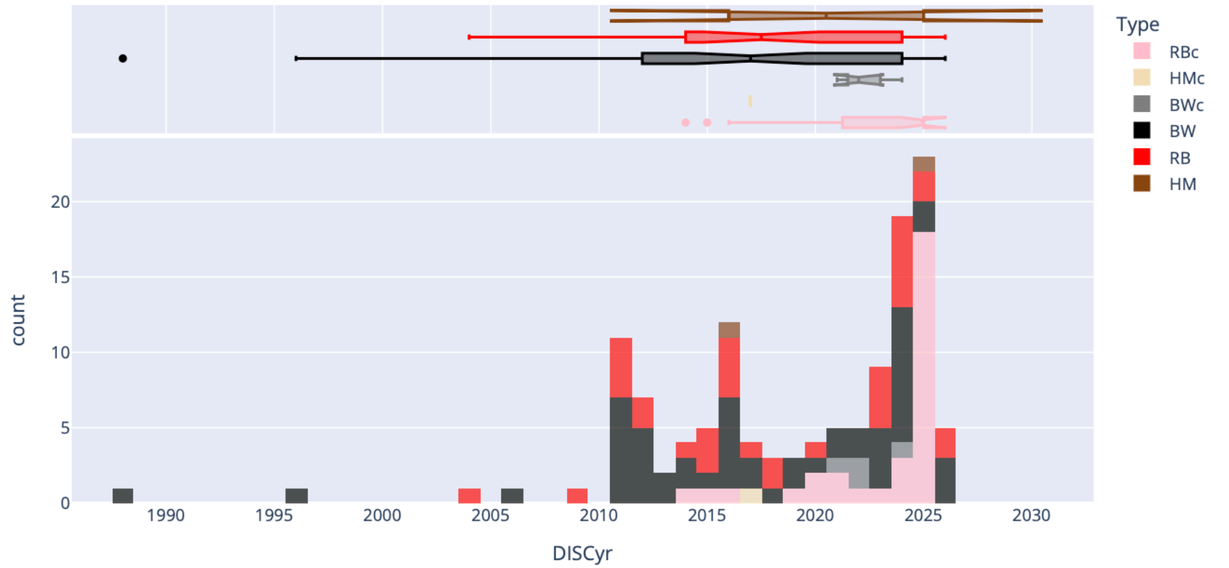
Lin-Lin Log-Lin Lin-Log Log-Log

Histogram

Select parameter:

DISCyr

Parameter selector



Select number of bins:

50

Binning slider

Select Axis Scaling:

Lin Log

Axis scaling

Scatter plot

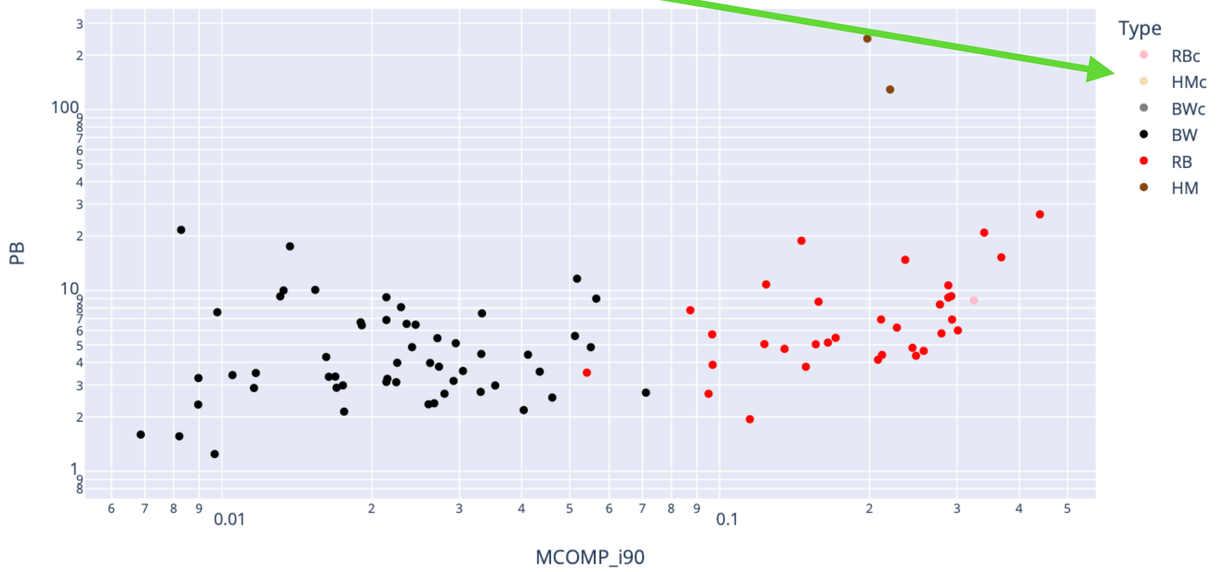
Select X-axis parameter:

MCOMP_i90

Select Y-axis parameter:

PB

Spider type selector

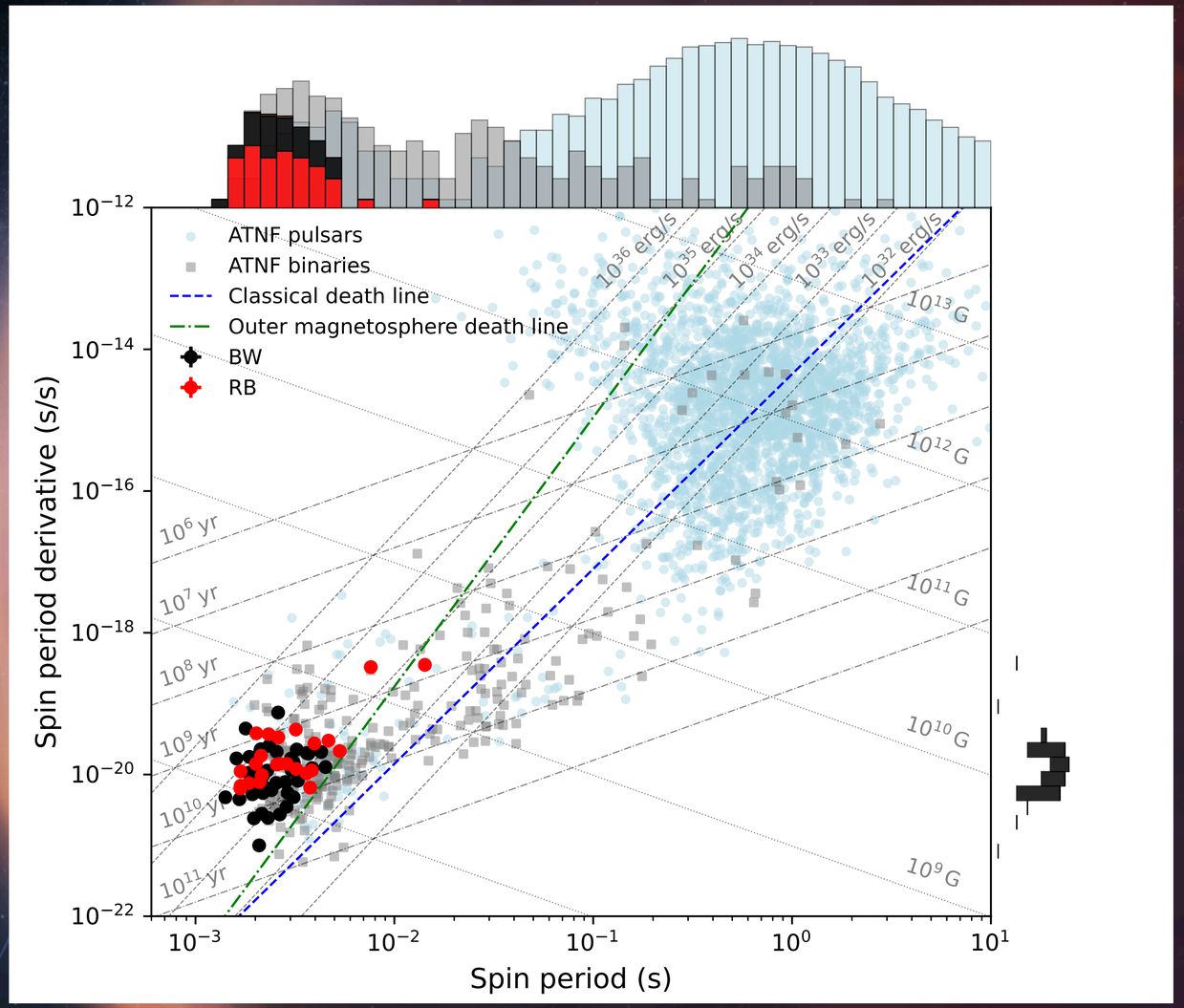


Select Axis Scaling:

Lin-Lin Log-Lin Lin-Log Log-Log

SPIDER DEMOGRAPHICS

- Contain the fastest spinning pulsars (1.5–5 ms)



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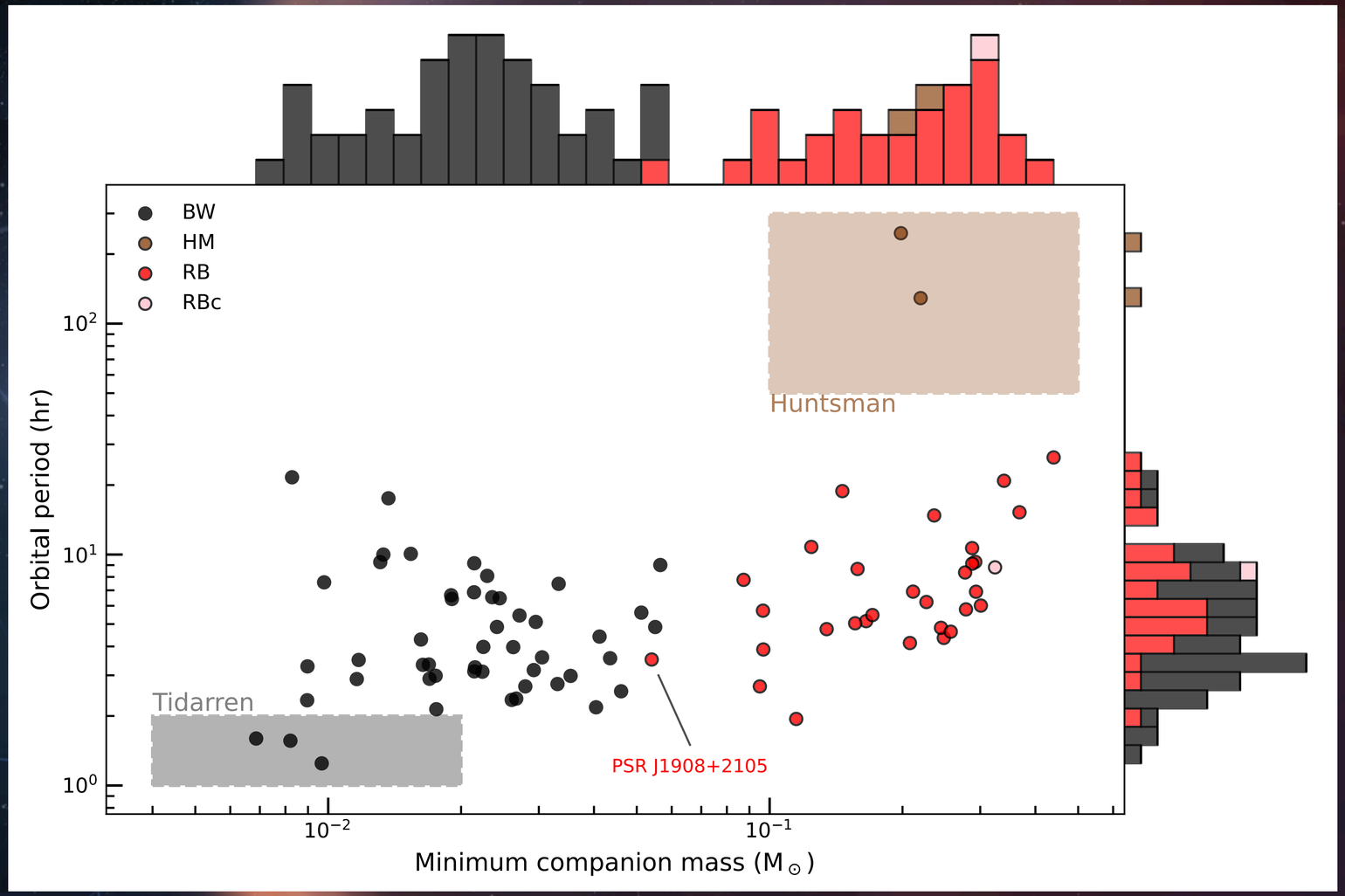
SPIDER DEMOGRAPHICS

- Contain the fastest spinning pulsars (1.5–5 ms)
- **Companion masses are bimodal** → clean RB vs BW separation via $M_{c,min}$
- Orbital periods mostly 2–30 hr (excluding tidarrens/HM)
  - RB median P_b~6.2 hr; BW median P_b ~3.6 hr



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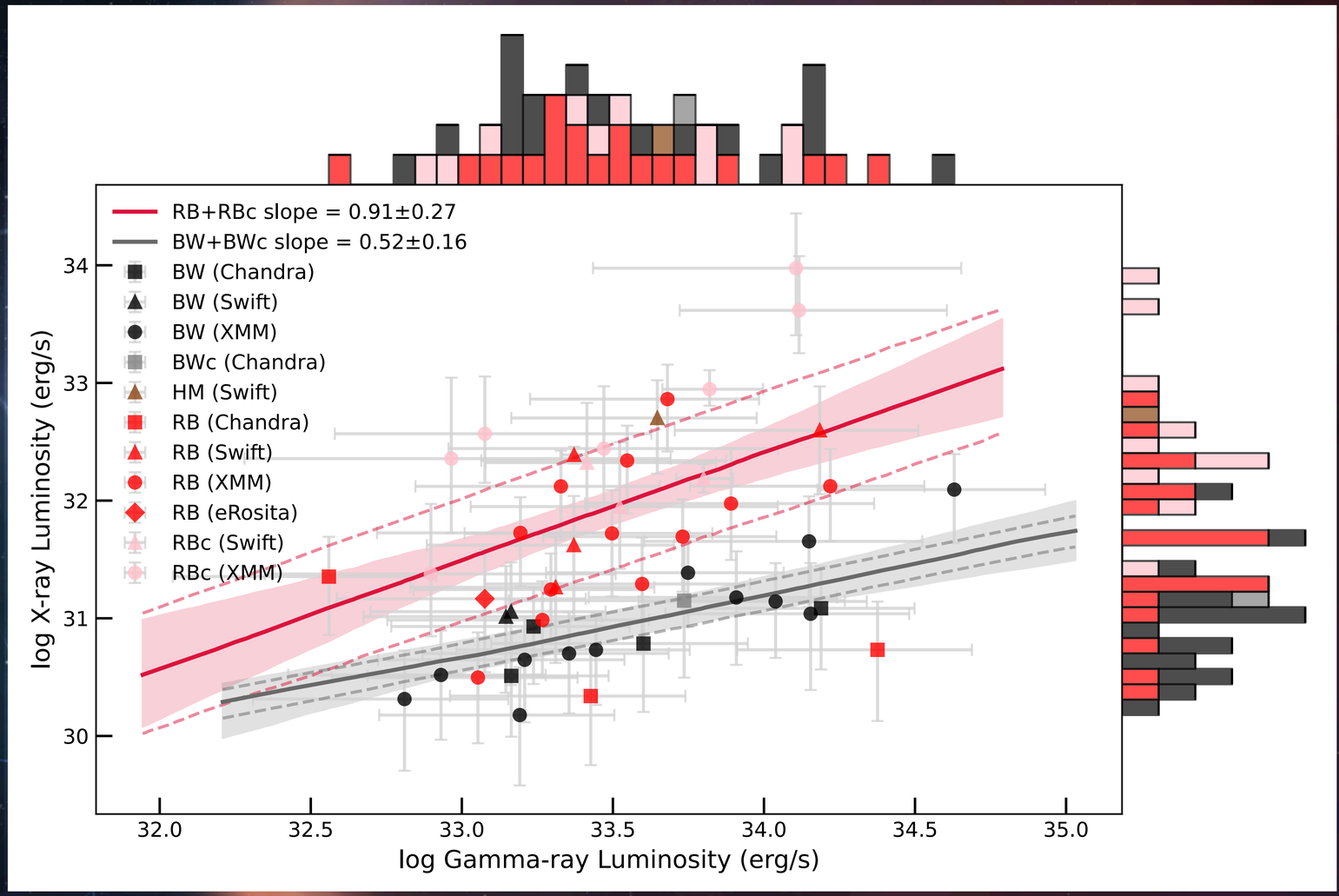
HIGH ENERGY PROPERTIES

- L_γ : ~10^{32}–10^{35} erg/s; no strong subtype split
- L_X : ~10^{30}–10^{34} erg/s; RBs systematically higher
  - $L_X \gtrsim 10^{32}$ erg/s appears **only in RBs**
- Both show **correlation** between L_X and L_γ (linked to $\dot{E}$)



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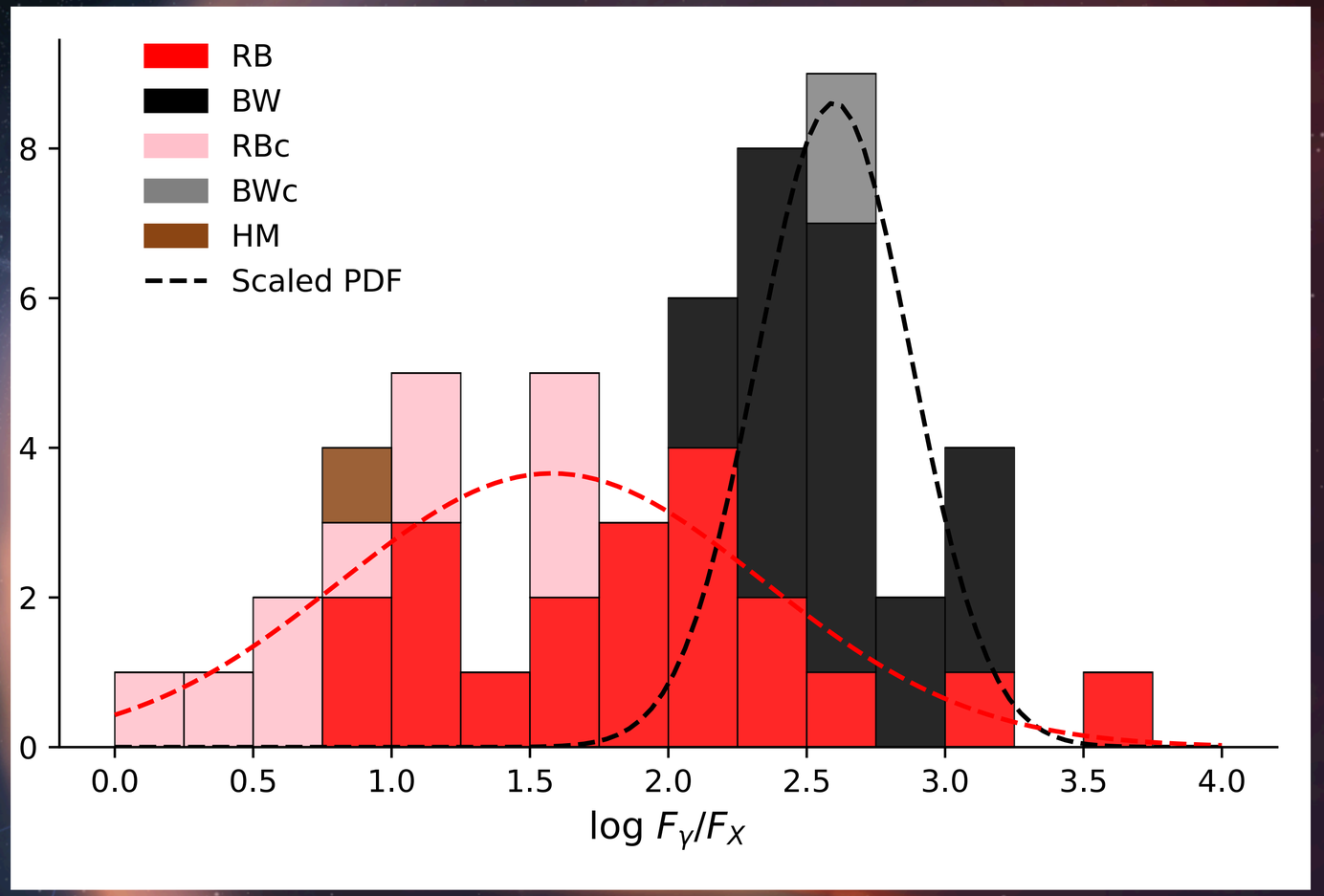
HIGH ENERGY PROPERTIES

- $\log(F_\gamma/F_X)$ distributions differ:
  - BW mean ~2.6 ± 0.3 (narrow)
  - RB mean ~1.6 ± 0.8 (broad)
- Practical rule for RBs: $\log(F_\gamma/F_X) < 2$



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SPIDERS IN COLOR–MAGNITUDE DIAGRAM

- Spiders sit mostly between main sequence and WD branch
- Empirical “spider region”:
  - upper: $M_g = 4.5(g-r) + 4.5$
  - lower: $M_g = 2.7(g-r) + 10.3$
- RBs are ~2 mag brighter than BWs at similar colors

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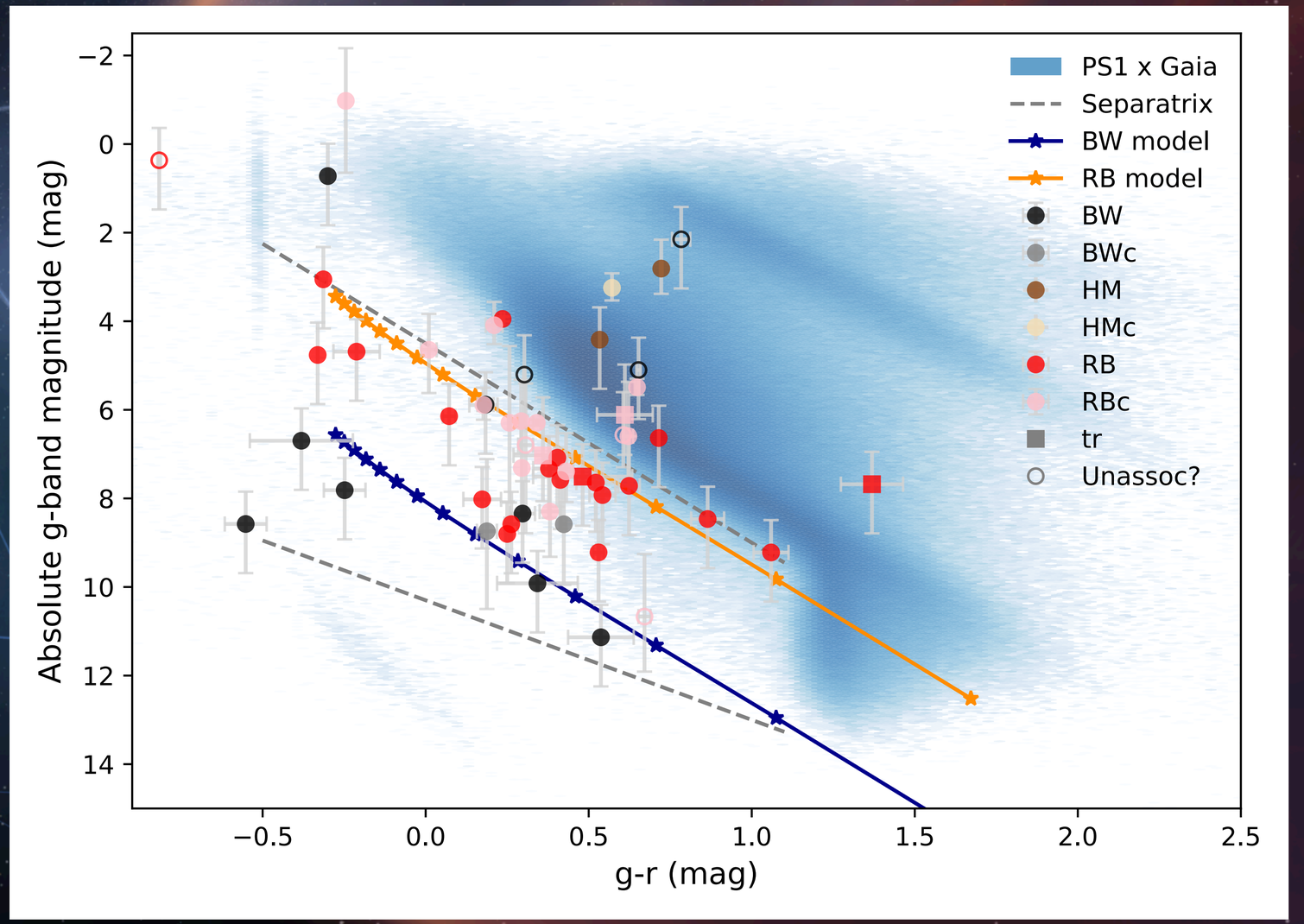

SPIN–ORBIT CLUSTERING

- K-means clustering suggests two groups in P vs P_b:
  - **Cluster 1:** very fast spins + wide range of P_b
  - **Cluster 2:** short P_b + broader spin range
- Clusters differ in $\dot{E}$ and B_{LC} , not strongly in age
  - Efficient accretion during recycling phase leading to faster spins and stronger companion irradiation?

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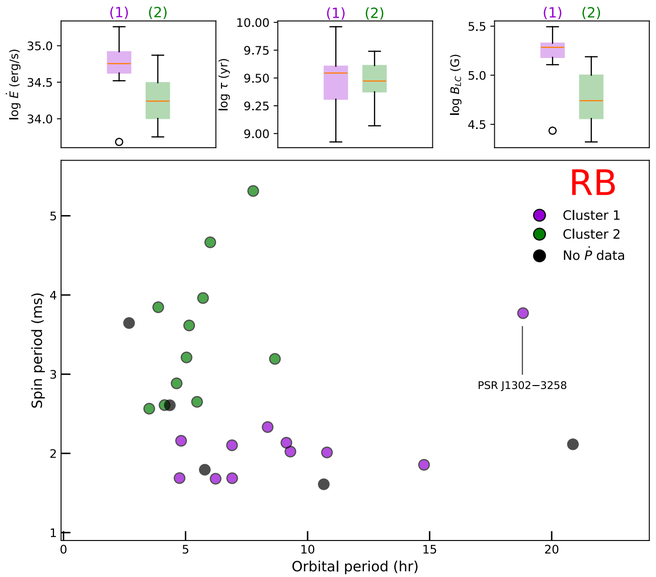

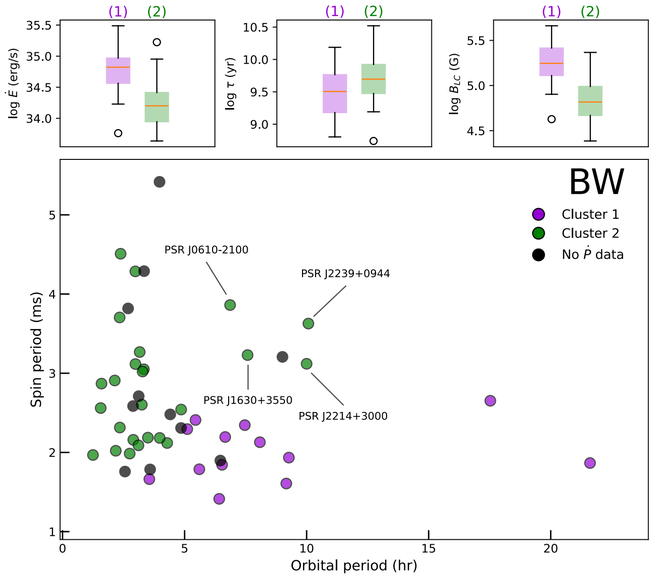

CONCLUSIONS

- SpiderCat provides standardized, multiwavelength reference set of the known population of spiders + useful web interface.
- SpiderCat is both infrastructure and science: it's immediately useful for identifying and classifying candidates, and it supports broader questions about evolution and emission mechanisms in compact MSP binaries.
- Web catalog will be **updated continuously**. Future updates include per-source SEDs, lightcurves, more multiwavelength catalogs.
- Try it yourself: https://astro.phys.ntnu.no/SpiderCAT
  - Grab me if you want to see a super-secret, enhanced developer version :)