

# X-ray polarimetry of weakly magnetized neutron stars

**Anna Bobrikova**

**Imaging X-Ray Polarimetry Explorer (IXPE) Science Team**

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**What are weakly magnetized  
neutron stars?**

The background features a series of overlapping, wavy, layered shapes that create a sense of depth and movement. The colors transition from a deep purple at the top to a bright yellow at the bottom, with intermediate shades of red and orange. The shapes are smooth and fluid, resembling a stylized landscape or a series of ripples.





Roche lobe  
overflow

$B \sim 10^8 G$

$M < M_{\odot}$

no  
pulsations!

# What are weakly magnetized neutron stars?

	Top	J-name	Flux in 4–10 keV (mCrab)	$1\sigma$ error	MJD	Name
→	001	<a href="#">J1619-156</a>	24626	420	61186.5	Sco X-1
→	002	<a href="#">J1801-250</a>	1254	35	61184.5	GX 5-1, 1RXS J180108.7-250444
↗	003	<a href="#">J0534+220</a>	924	23	61184.5	Crab, M 1
↗	004	<a href="#">J1816-140</a>	791	27	61184.5	GX 17+2, NP Ser
↗	005	<a href="#">J1801-205</a>	762	27	61184.5	GX 9+1, 1RXS J180132.3-203132
↘	006	<a href="#">J1705-364</a>	745	23	61184.5	GX 349+2, V1101 Sco
↗	007	<a href="#">J1645-456</a>	661	20	61184.5	GX 340+0, 1RXS J164547.8-453642
↘	008	<a href="#">J2144+383</a>	565	24	61169.5	Cyg X-2
↘	009	<a href="#">J2032+409</a>	556	80	61174.5	Cyg X-3, V1521 Cyg
↗	010	<a href="#">J1814-171</a>	455	58	61185.5	GX 13+1, Sgr XR-2
↘	011	<a href="#">J1958+352</a>	369	26	61176.5	Cyg X-1, V1357 Cyg
↗	012	<a href="#">J1520-571</a>	356	41	61186.5	Cir X-1, BR Cir
↘	013	<a href="#">J1747-265</a>	301	24	61184.5	GX 3+1, 1RXS J174755.8-263352
→	014	<a href="#">J1839+050</a>	260	27	61184.5	Ser X-1, MM Ser
↗	015	<a href="#">J1738-444</a>	212	11	61184.5	H 1735-444, V926 Sco
↘	016	<a href="#">J1731-169</a>	192	18	61184.5	GX 9+9, V2216 Oph
→	017	<a href="#">J1823-303</a>	167	16	61184.5	NGC 6624, H 1820-303
↗	018	<a href="#">J1745-290</a>	158	28	61185.5	Galactic Center Region
↗	019	<a href="#">J1731-338</a>	146	11	61184.5	GX 354-0_Slow-Burster with Rapid-Burster, 4U 1728-34, 1RXS J173157.7-335007
↘	020	<a href="#">J1708-441</a>	126	8	61184.5	4U 1705-440, SAXWFC J1708.9-4406.9

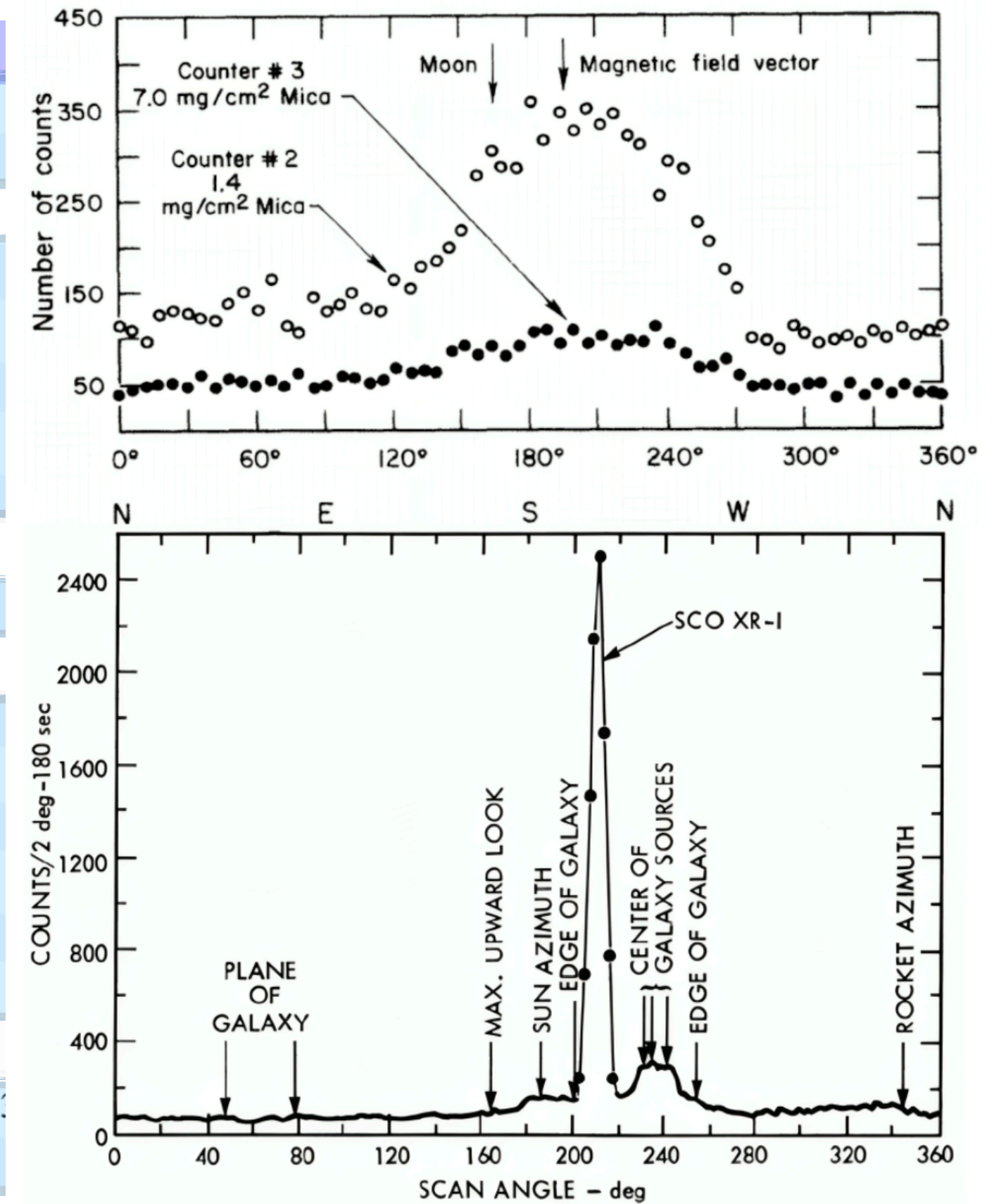
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*Monitor of All-sky X-ray Image (MAXI) Top Flux of the Day*

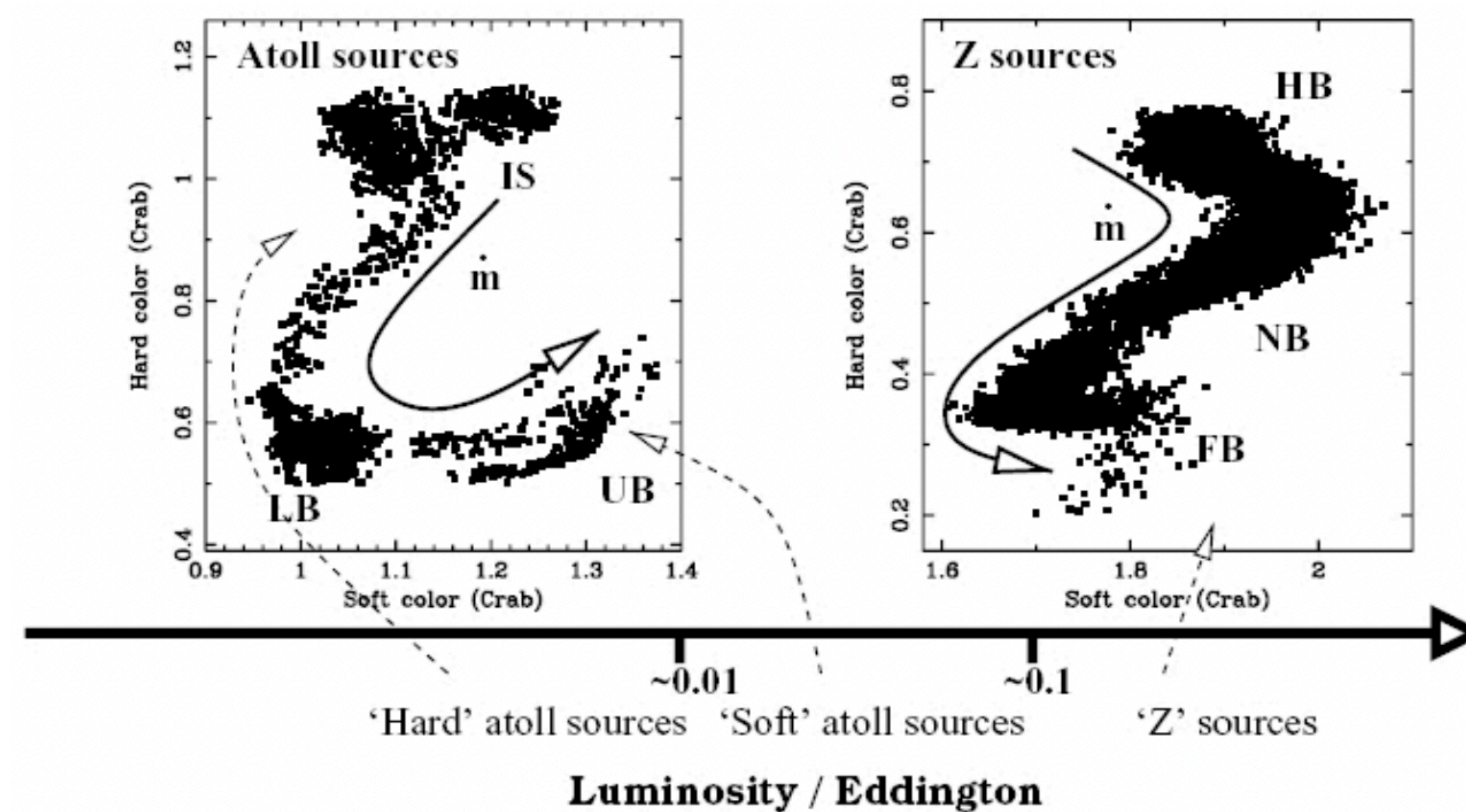
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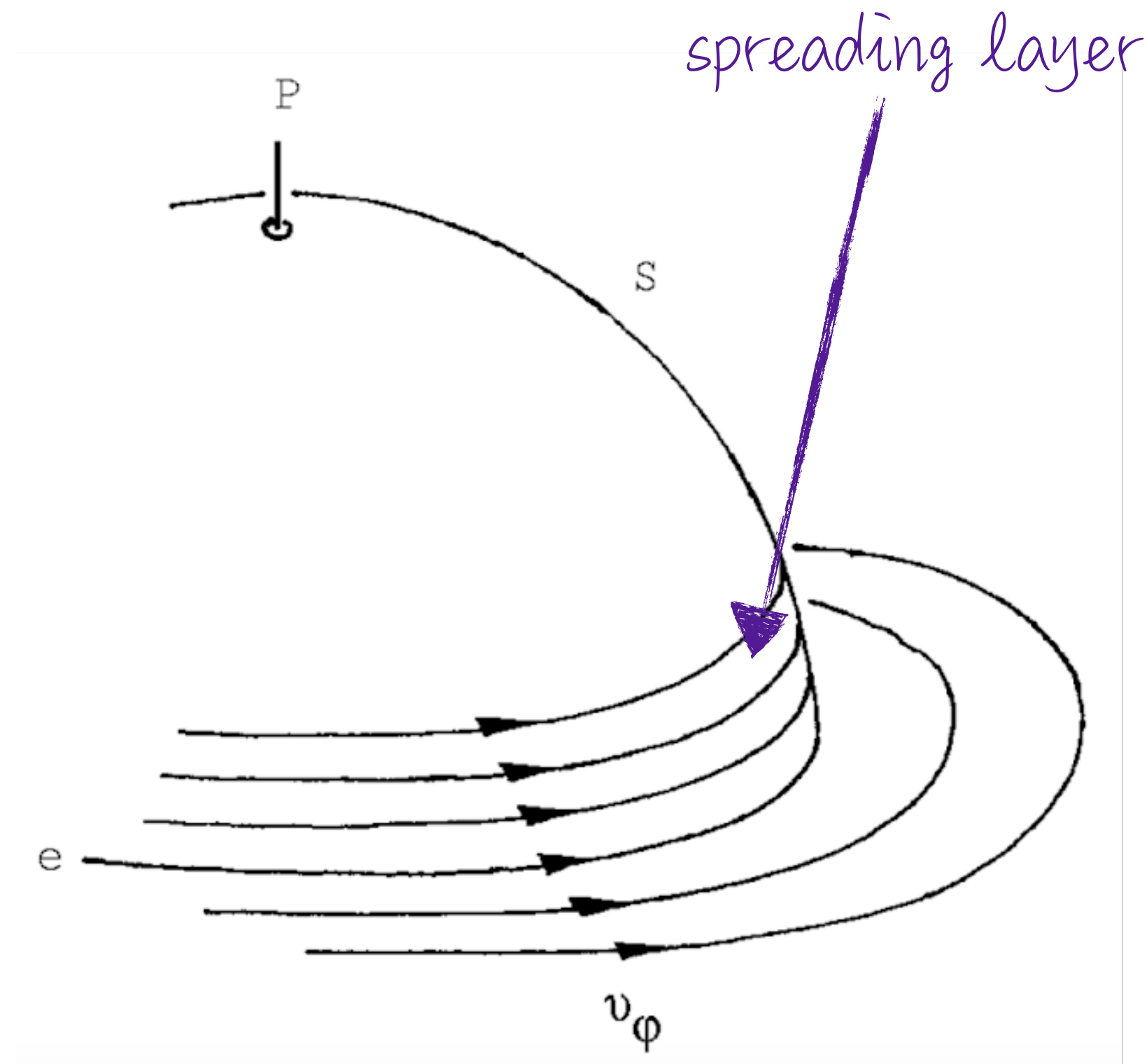
## Classification



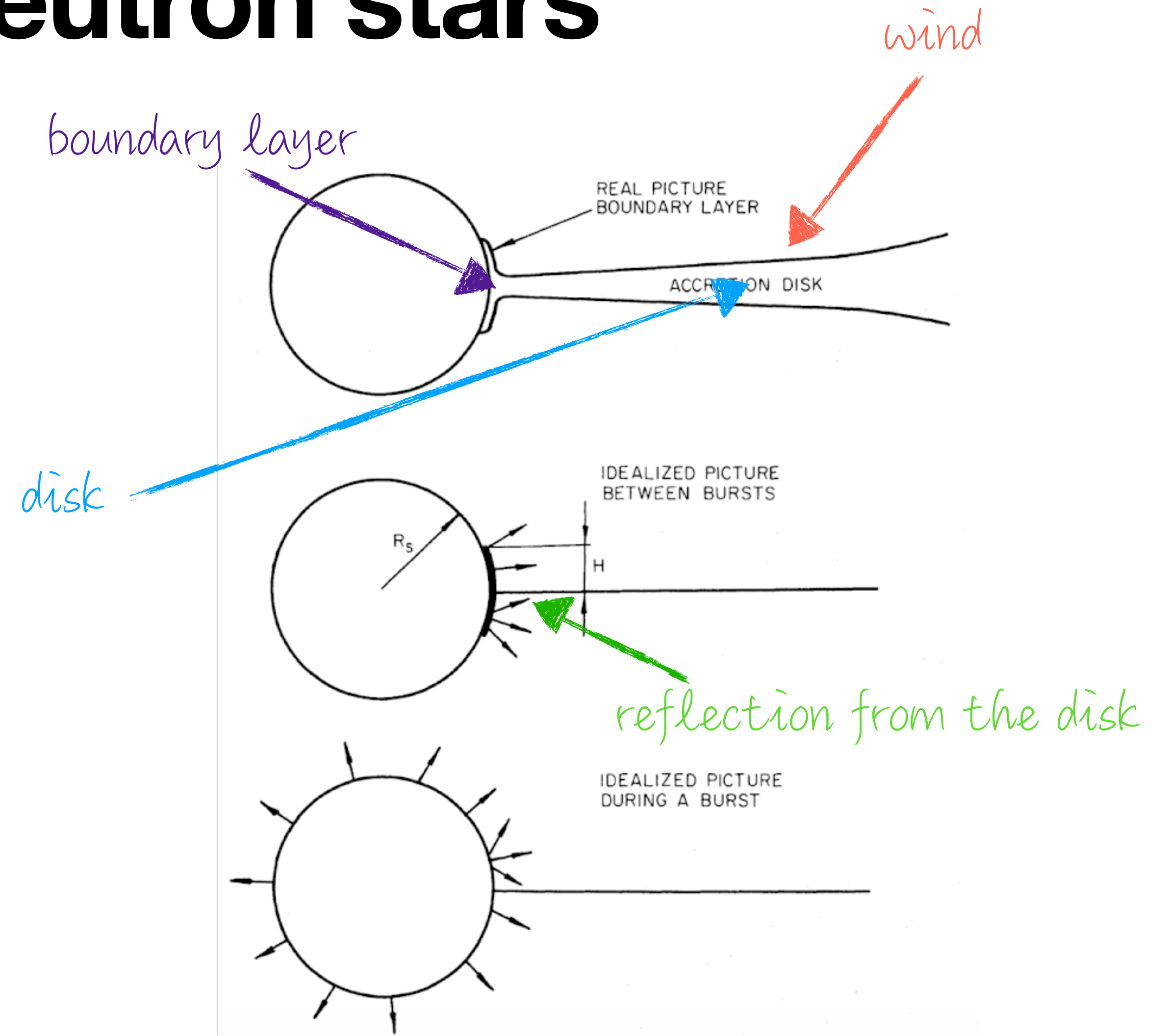
# Theoretical expectations for the WMNS polarized emission

# Weakly magnetized neutron stars

## Components of the emission



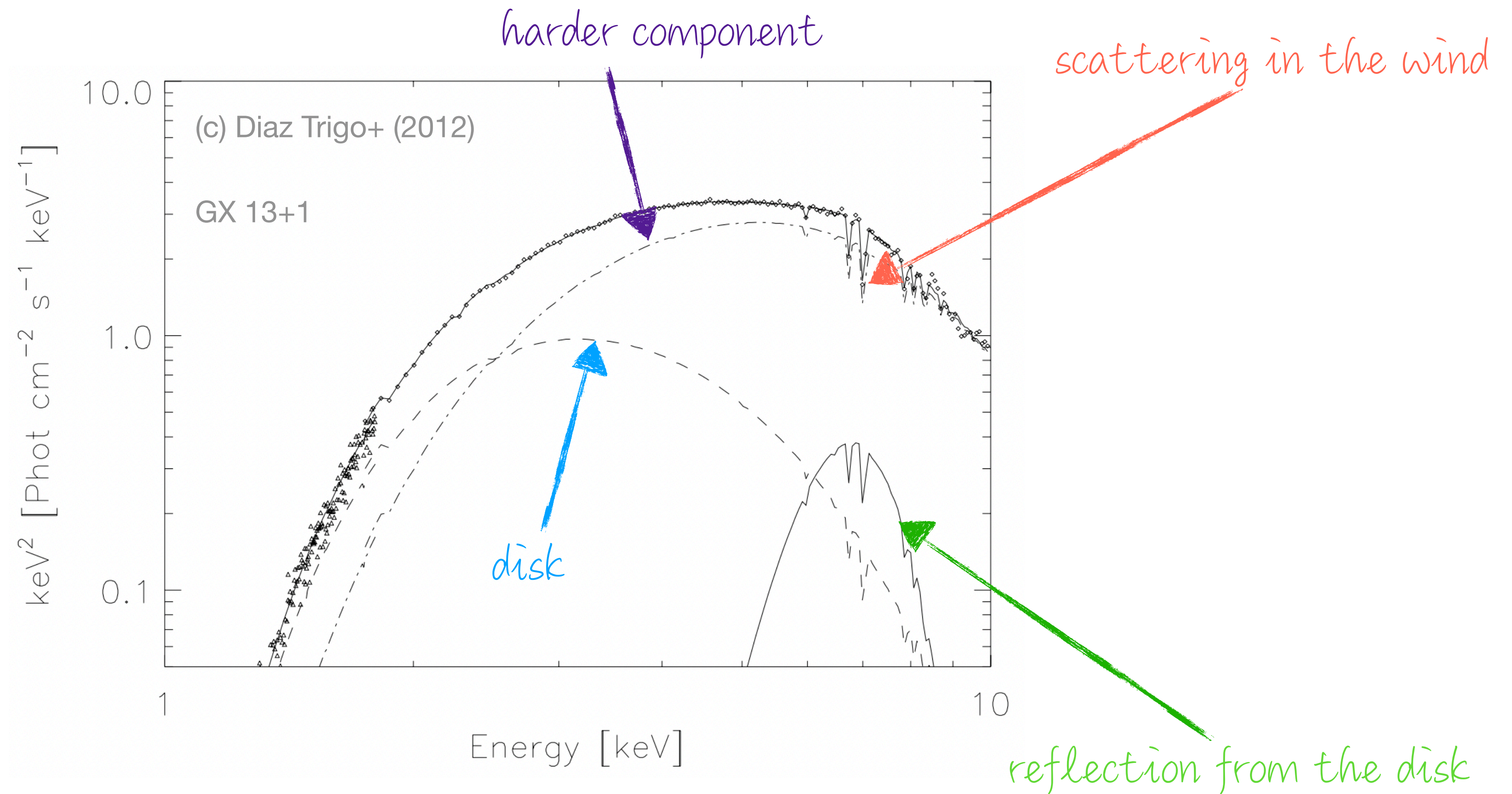
Inogamov & Sunyaev 1999



Lapidis & Sunyaev 1985

# Weakly magnetized neutron stars

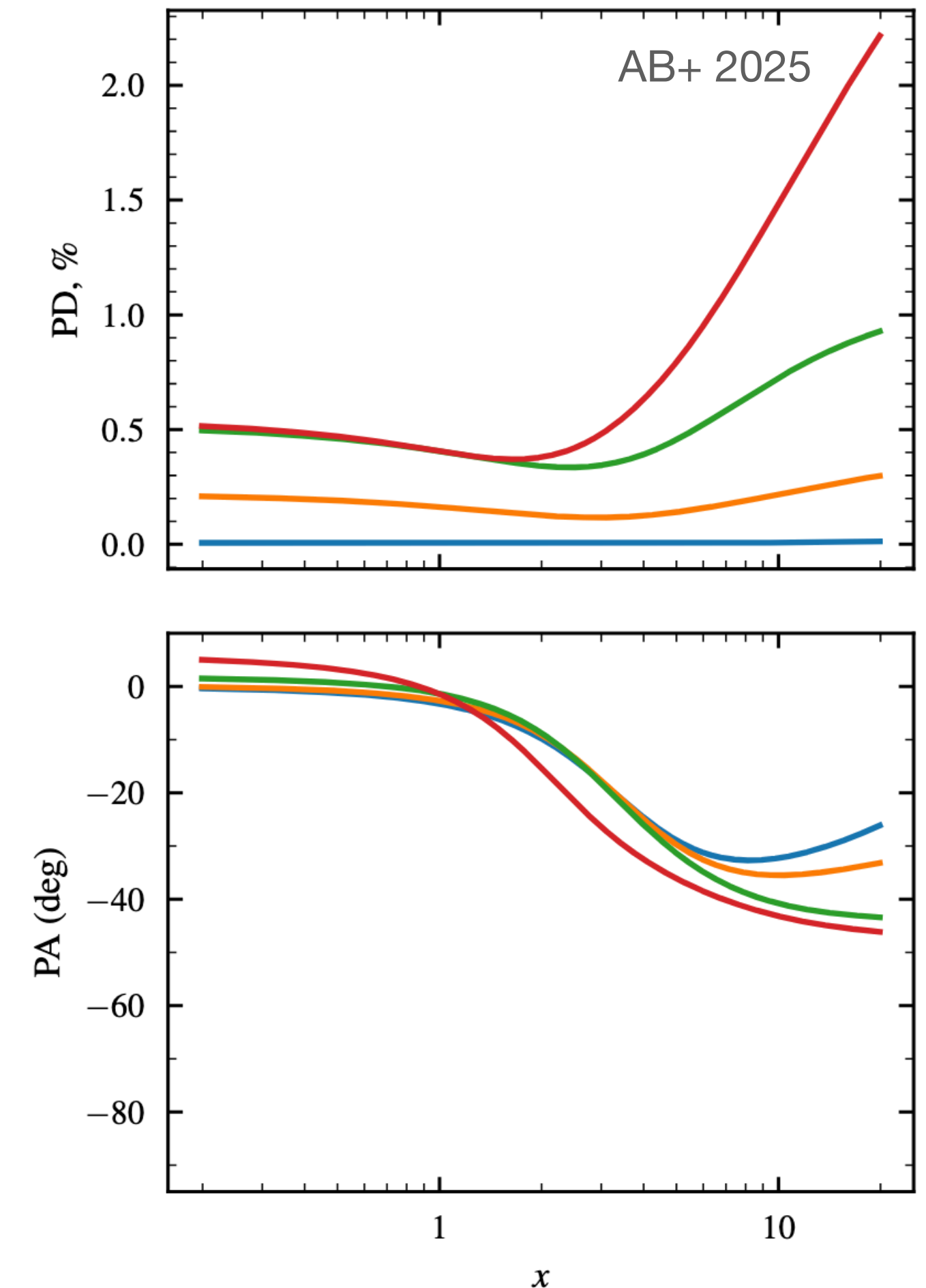
## Components of the emission



# Weakly magnetized neutron stars

## Expected polarimetric properties of the emission components

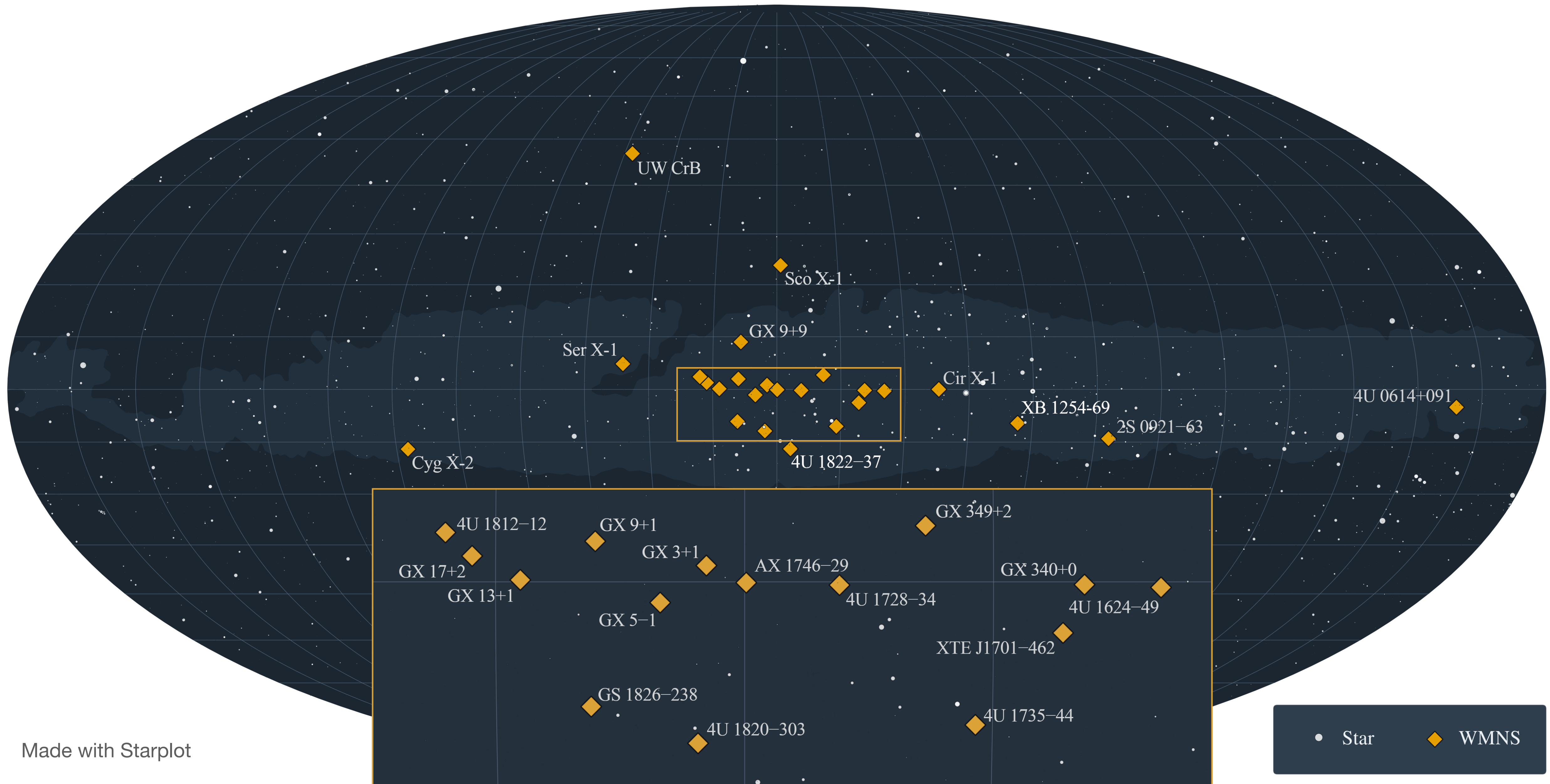
	PD	PA	Ref (incomplete!)
<b>Disk</b>	~2%	∥ disk plane	Loktev+ 2022
<b>BL</b>	~6%	∥ disk plane	Sunyaev & Titarchuk 1985
<b>SL</b>	<1.5%	⊥ disk plane	AB+ 2025
<b>Wind</b>	~10% ~3%	depends	Nitindala+ 2025 Tomaru+ 2024
<b>Reflection (disk)</b>	~10%	⊥ disk plane	Matt 1993 Poutanen 1996
<b>Reflection (comp)</b>	~1%	⊥ disk plane	Ahlberg+ 2024



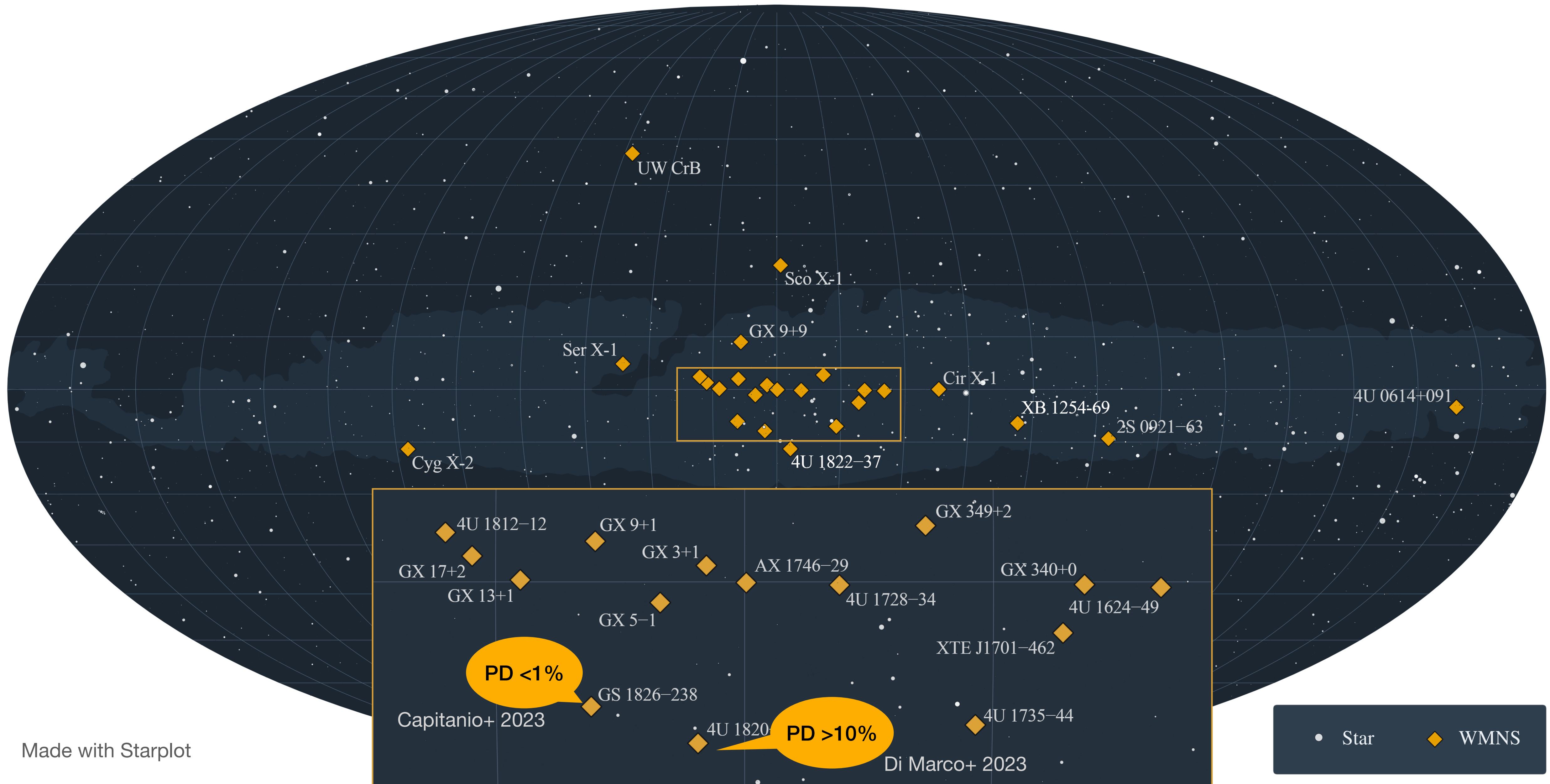
# Observational results

The background features a series of overlapping, wavy, horizontal bands of color. From top to bottom, the colors transition from a dark purple at the top, through various shades of red and maroon, to a bright orange and yellow at the bottom. The shapes are fluid and organic, creating a sense of depth and movement.

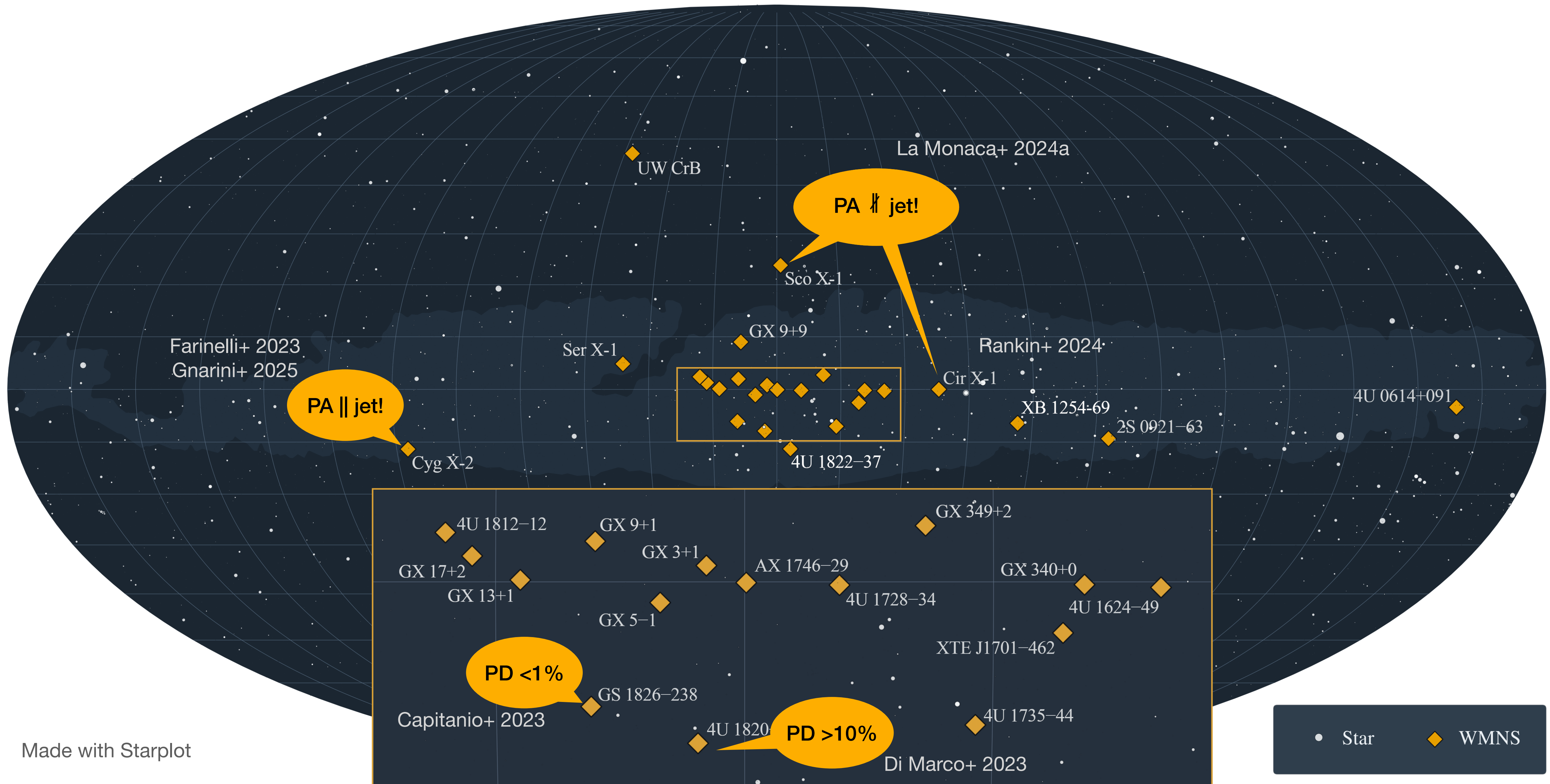
# Weakly magnetized neutron stars observed with IXPE



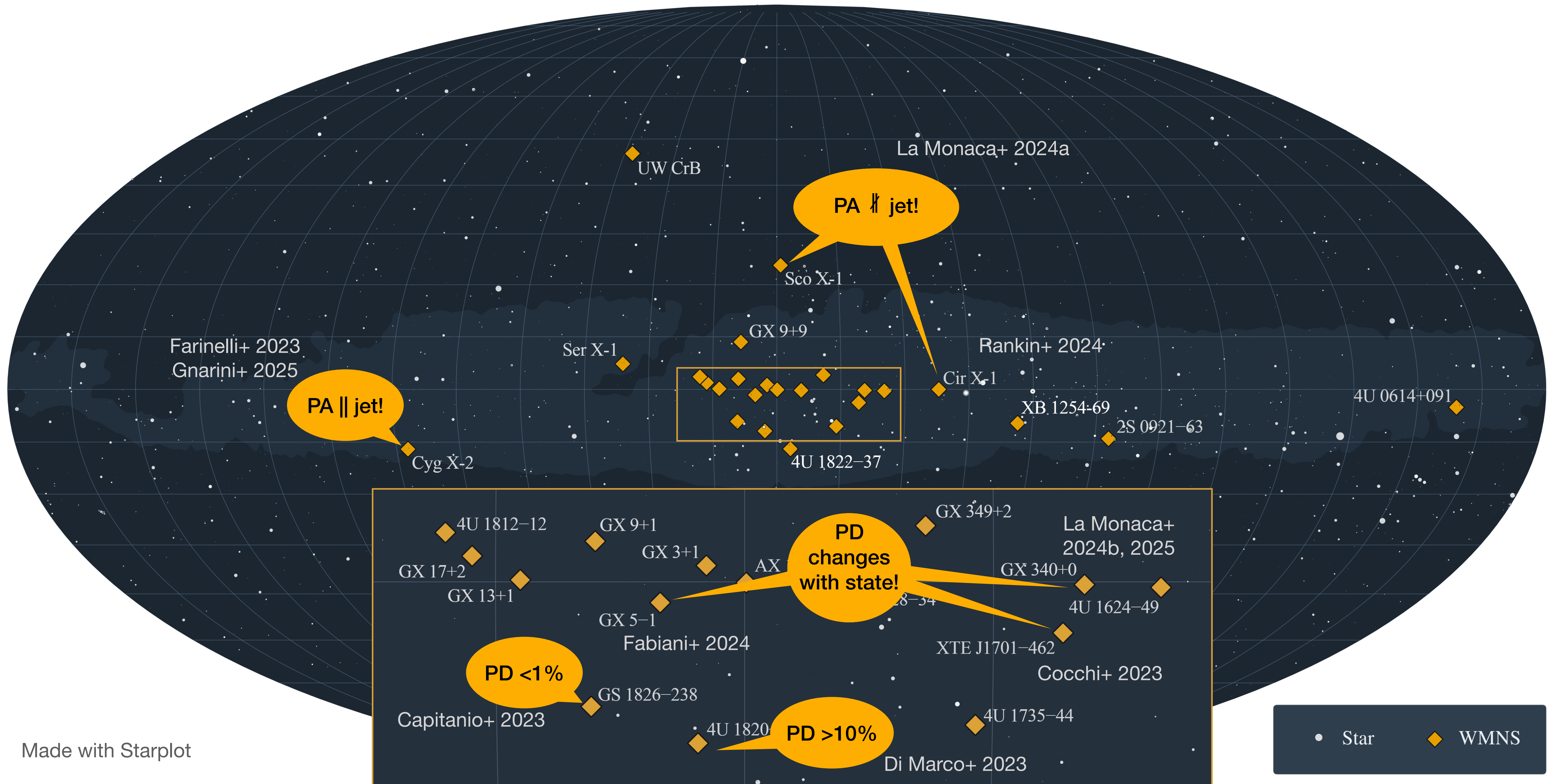
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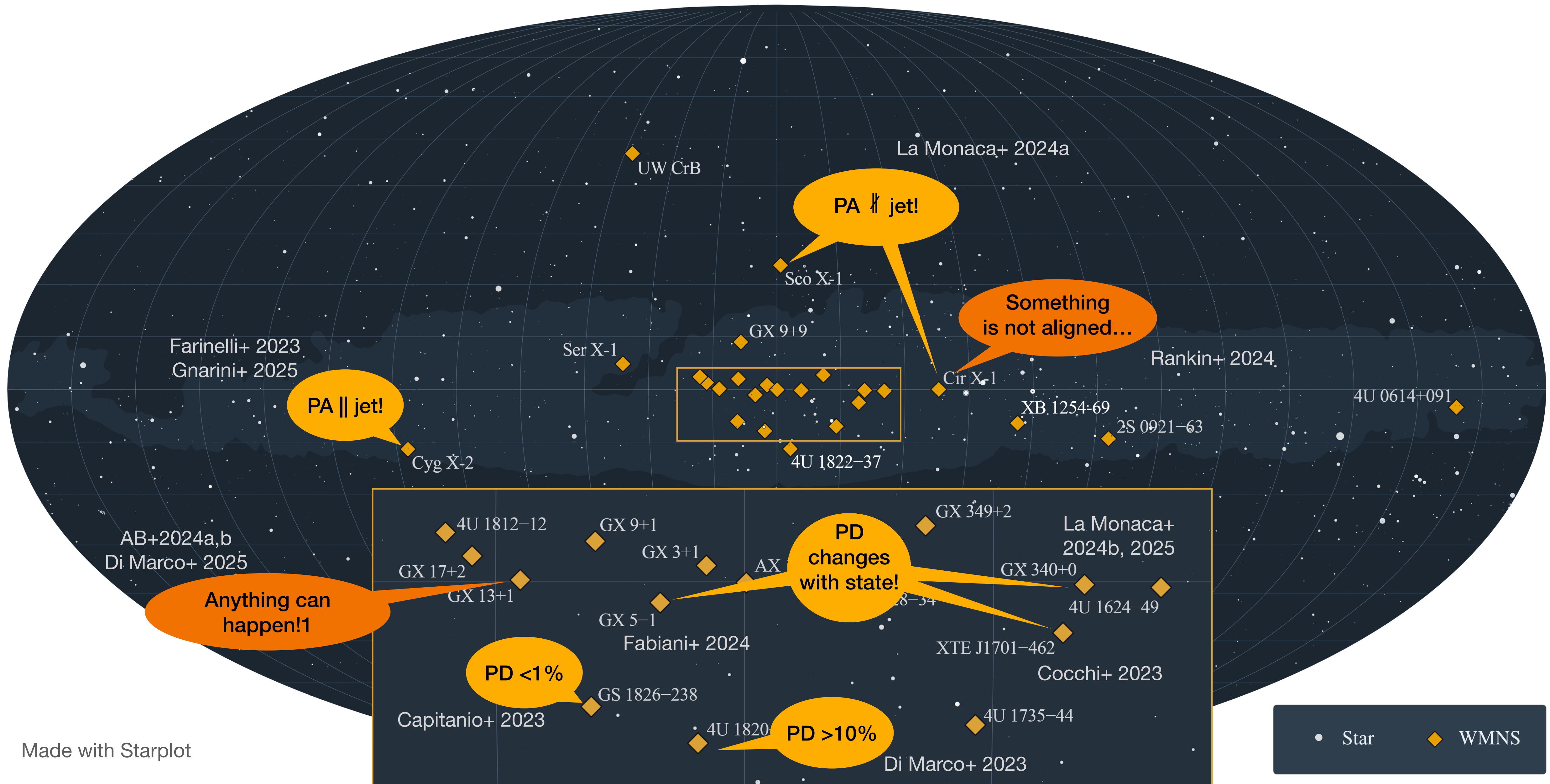
# Weakly magnetized neutron stars observed with IXPE



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# Observational results

## Trends and peculiarities

- BL/SL emission dominates in IXPE energy range -> crucial to understand in more detail!
- In many sources, PD increases with energy and significantly exceeds the theoretical predictions at higher energies
- In Z-sources, PD is higher in the hard state than in the soft state
- On average, Z-sources have higher PD than atolls
- In several sources, variability or rotation of PA with time were observed
- In at least two sources, Cir X-1 and GX 13+1, obliquity was suggested as a possible explanation

# Conclusions

- Weakly magnetized neutron stars are a broad and important class of objects
- The most peculiar processes happen near the neutron star surface
- IXPE has observed 25 weakly magnetized neutron stars
- Several major trends in polarimetric behaviour have been discovered
- There are crucially important discrepancies between theory and observations
- We're working on making some sense out of it all. Stay tuned~

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