Review of the four years of IXPE operation

Frédéric Marin

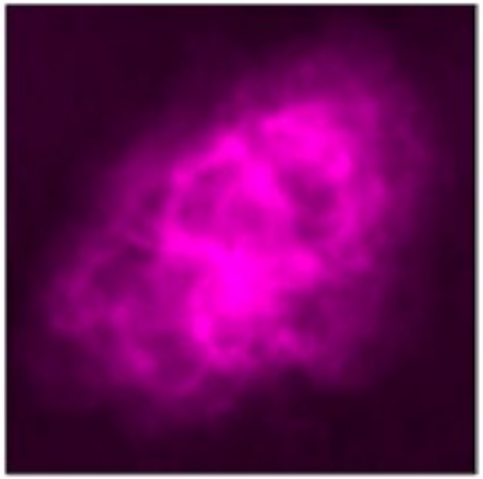
Observatoire astronomique de Strasbourg | ObAS

Université de Strasbourg

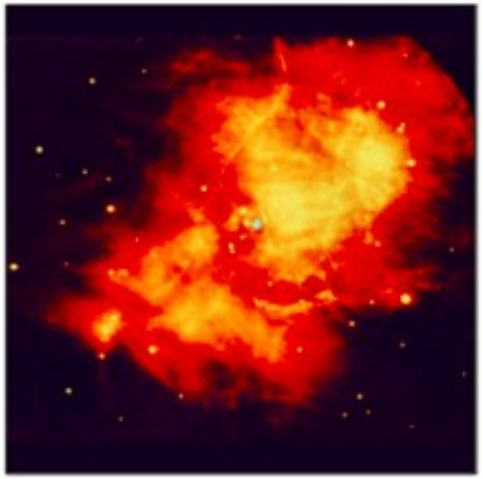
cnrs dépasser les frontières

Journées de l'ATPEM 2025 – 3 octobre 2025 – Paris, France

The polarized sky



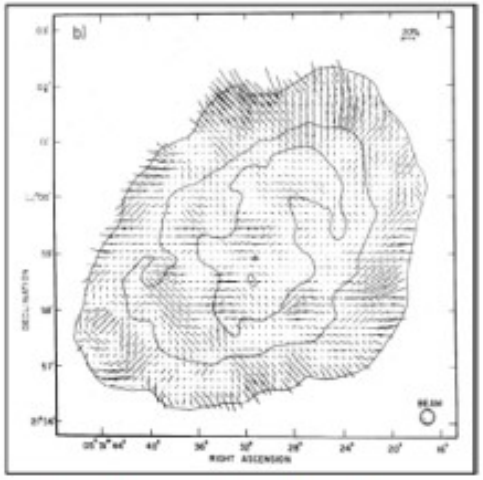
Radio (VLA)



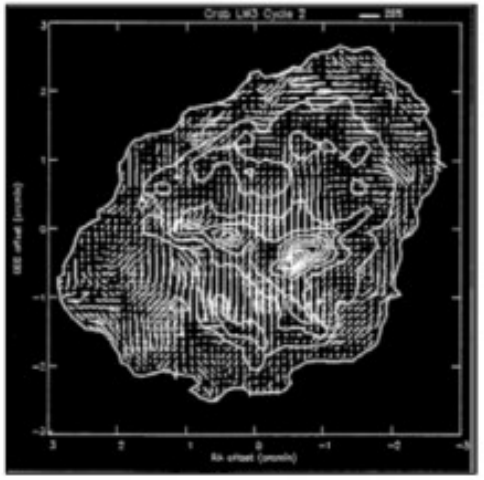
Infrared (Keck)

Optical (Palomar)

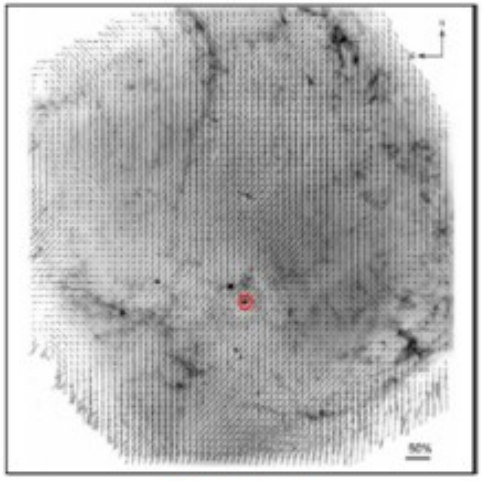
X-rays (Chandra)



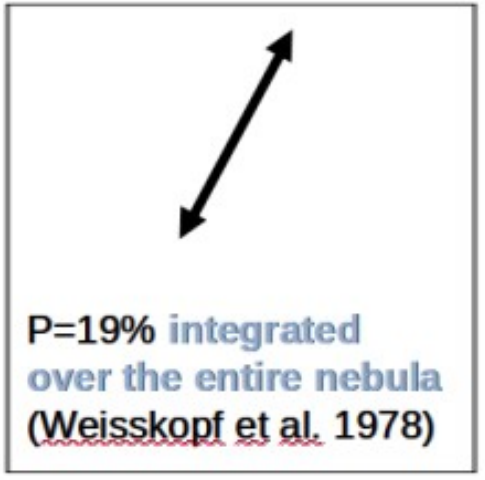
Radio polarization



IR polarization



Optical polarization



X-ray polarization

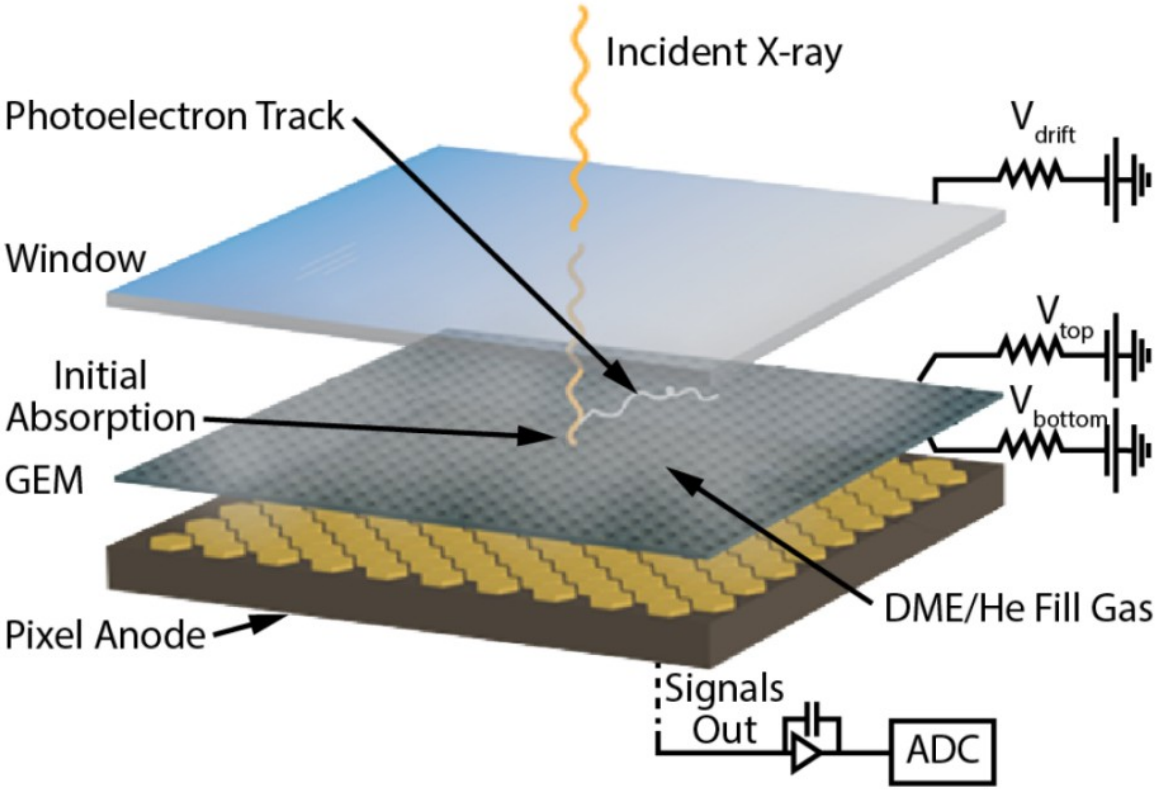
Ferrazzoli (2020)

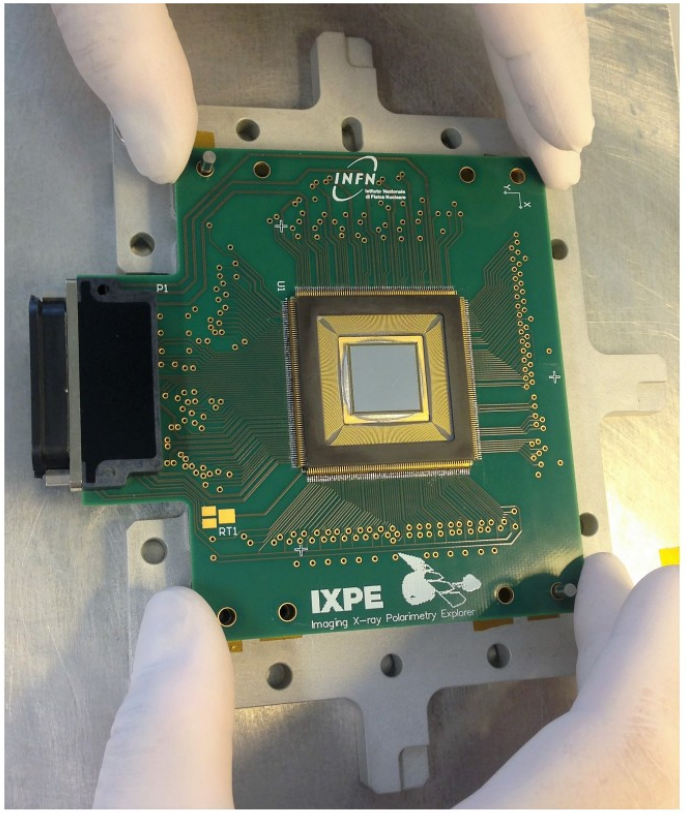
How to open this window?

The lack of X-ray satellites dedicated to X-ray polarimetry comes from multiples arguments:

- X-ray polarimetry needs rotation (movable parts);
- Technologically less advanced than spectroscopy, timing or imaging;
- Polarized fluxes are often much lower than total fluxes (long integration time).

Early 2000's, the game changed (Costa et al. 2001, Bellazzini et al. 2006,2007):





Sgrò et al. (2017)

The Gas Pixel Detector

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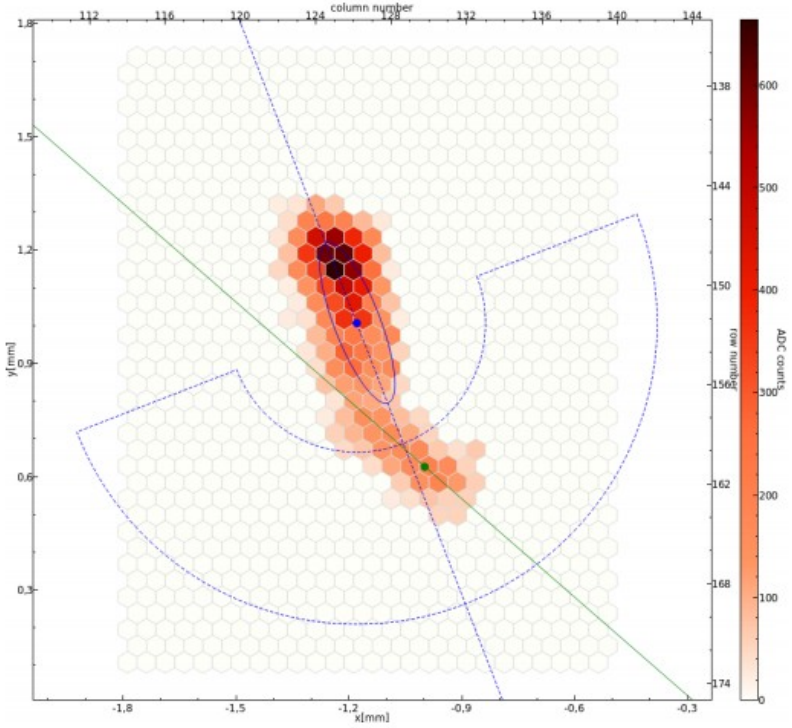
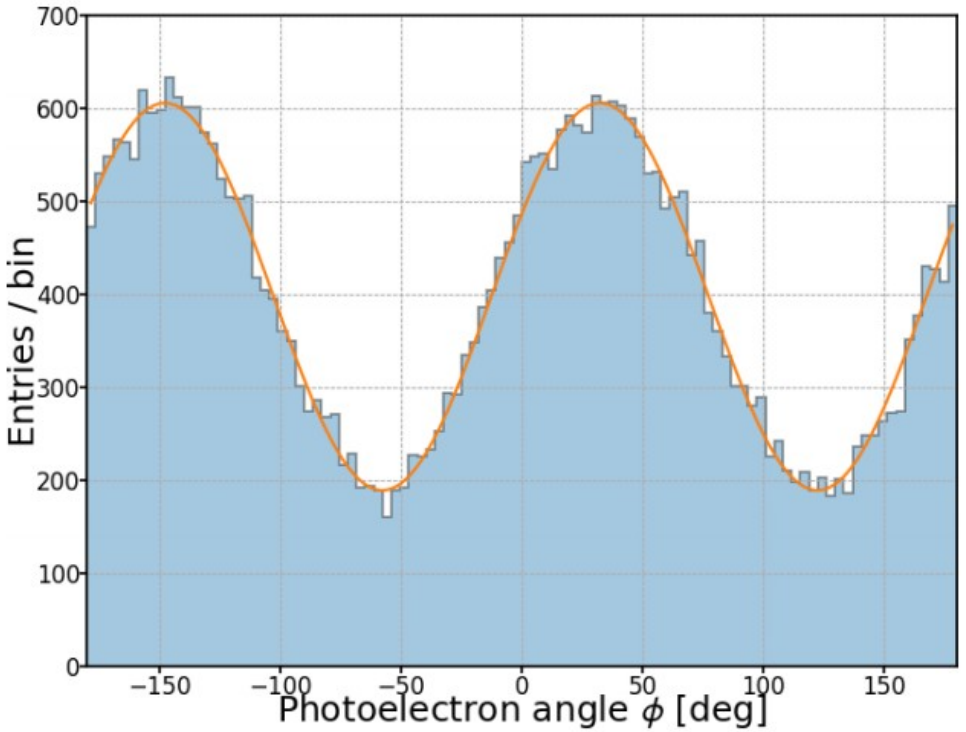


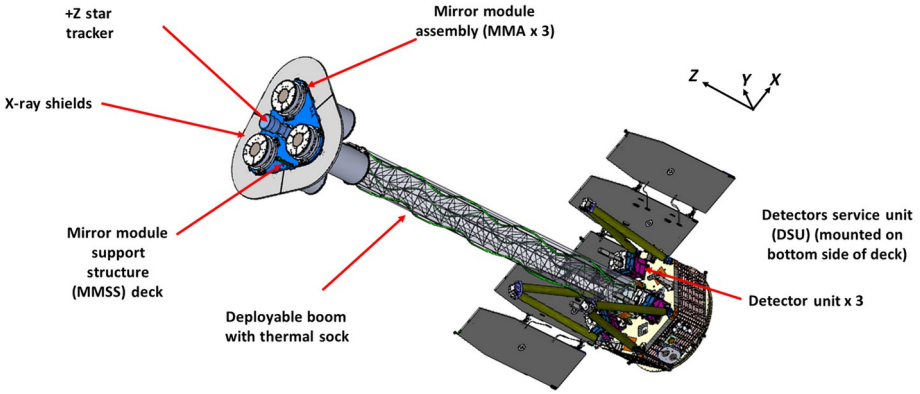
Trace onto the pixelized anode



Signal modulation

IXPE

This is why we launched the Imaging X-ray Polarimetry Explorer (IXPE) in 2021
(a Small Explorer mission undertaken by NASA in partnership with the Italian Space Agency)

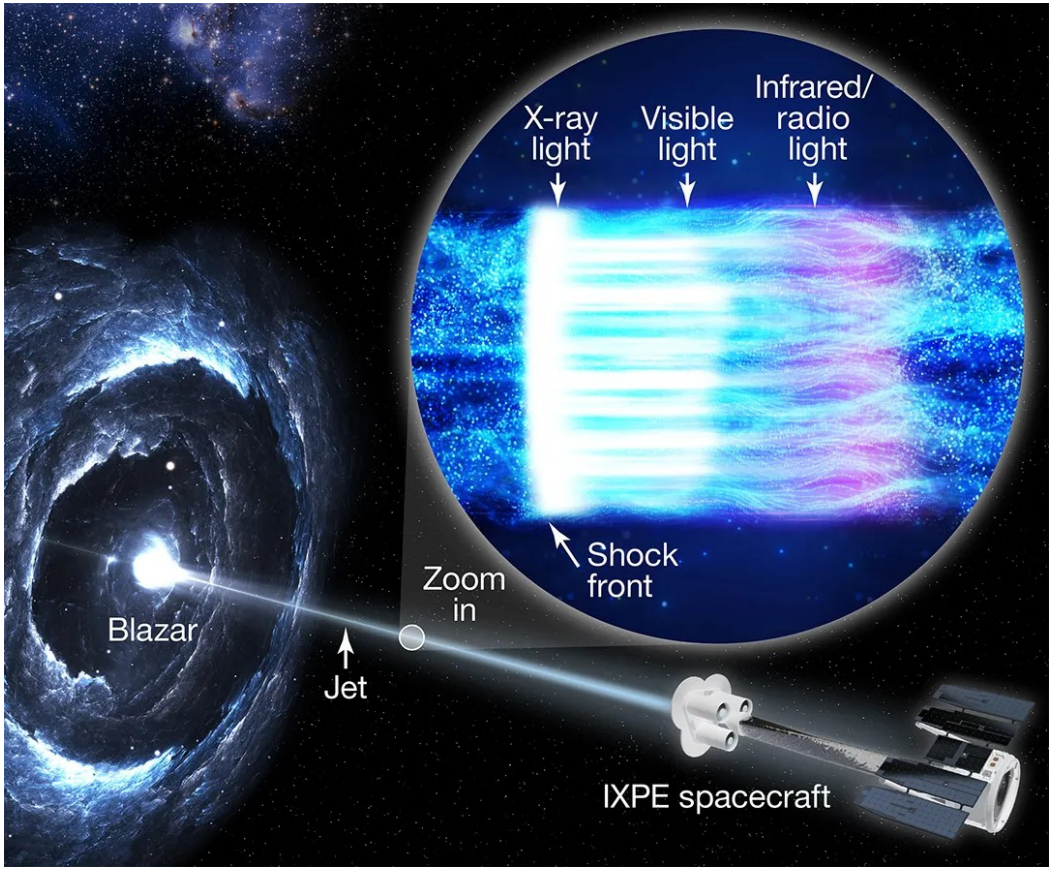


Parameter	Performance
Launch mass	330 kg
Length	5.2 m (deployed)
Nominal lifetime	2 years (no life-limiting consumables)
Energy band	2 to 8 keV
FOV (detector limited)	12.9 arcmin square
half-power diameter	28 arcsec @ 4.5 keV
Effective area per mirror module (x3)	166 cm^2 @ 2.3 keV
Energy resolution (FWHM)	0.52 keV @ 2 keV ($\propto \sqrt{E}$)
Timing	1 μs

Four years of operation

As of August the 22nd, 2025, IXPE has made 199 pointings, looking at 108 different targets

- → about 15 Ms of observing time per year
- → all kinds of sources (including a GRB), except for stars and planets
- → **637** NASA/ADS entries, **234** refereed publications (since the begining of the mission)
- → opened to everyone (Year 3 General Observing program, starting in February 2026)
- → joint programs with XRISM and NRAO
- → all observation publicly available (no proprietary time)



NASA Press release
Mrk 501

Four years of operation

From the IXPE Senior Review proposal:

Table 1a: IXPE science highlights

Topic	Result	Target(s)
Stellar Black Holes (BHs)	Comptonizing medium in hard state is extended along the disk plane for accreting stellar BHs.	Cyg X-1, Swift J1727
Supermassive BHs	Comptonizing medium is extended along the disk plane also for accreting supermassive BHs.	NGC 4151
Supermassive BH jets	Electrons are accelerated at shock fronts and lose energy as they propagate into turbulent regions.	Mrk 501, Mrk 421, 1ES 1959+750, …
Supermassive BHs	X-ray-obscuring tori around supermassive BHs are geometrically thick, thicker than revealed in radio/ infrared.	Circinus galaxy, NGC 1068
Supernova Remnants	Magnetic fields near forward shocks in young SNR are radial, thus are stretched along the flow.	Cas A, Tycho, SN 1006
Supernova Remnants	Conversely, older SNR have tangential magnetic fields indicating compression in forward shocks.	RX J1713, Vela Jr
Pulsar Wind Nebulae (PWNe)	PWNe radiation zones are well organized by the pulsar spin and exhibit unexpectedly low turbu- lence, at odds with diffusive shock acceleration.	Crab, Vela, MSH 15-52, SNR 0540-69
Accreting Neutron Stars	Measurement of the magnetic geometry, leading to detection of neutron star (NS) free precession.	Her X-1
NS-LMXBs	Comptonized emission is strongly polarized in weakly-magnetized neutron star low-mass X-ray binaries (NS-LMXBs).	Sco X-1, Cyg X-2, GX 13+1, 4U 1624-49, GX 9+9, …
Galactic Cen- ter	The supermassive BH at the center of our Galaxy was active a few hundred years ago.	Sgr A*/Sgr A
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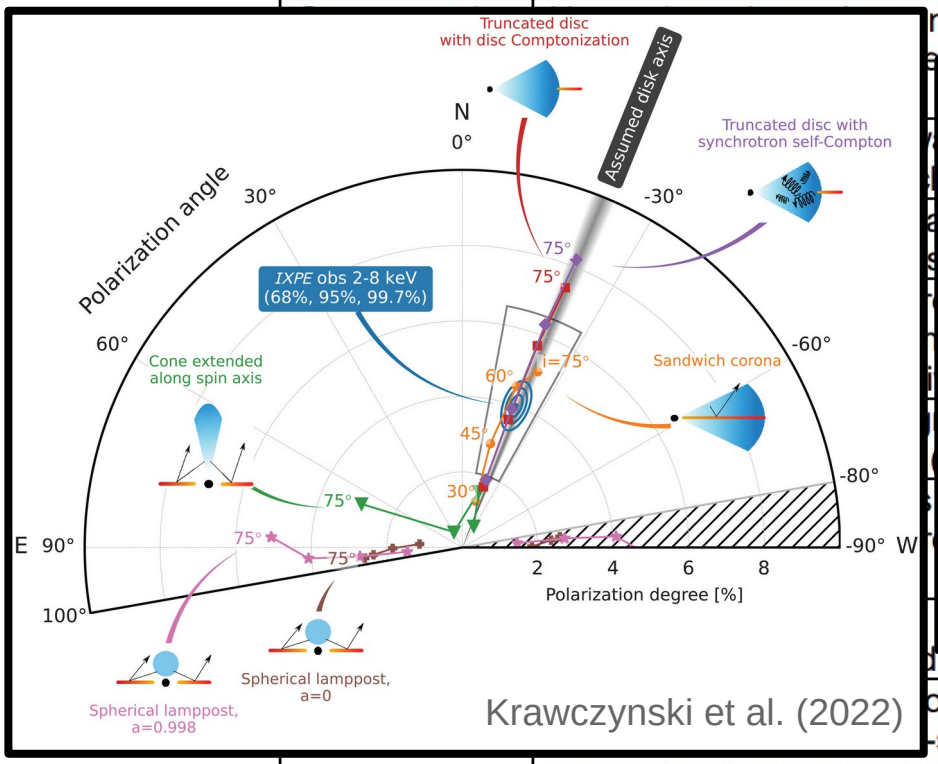
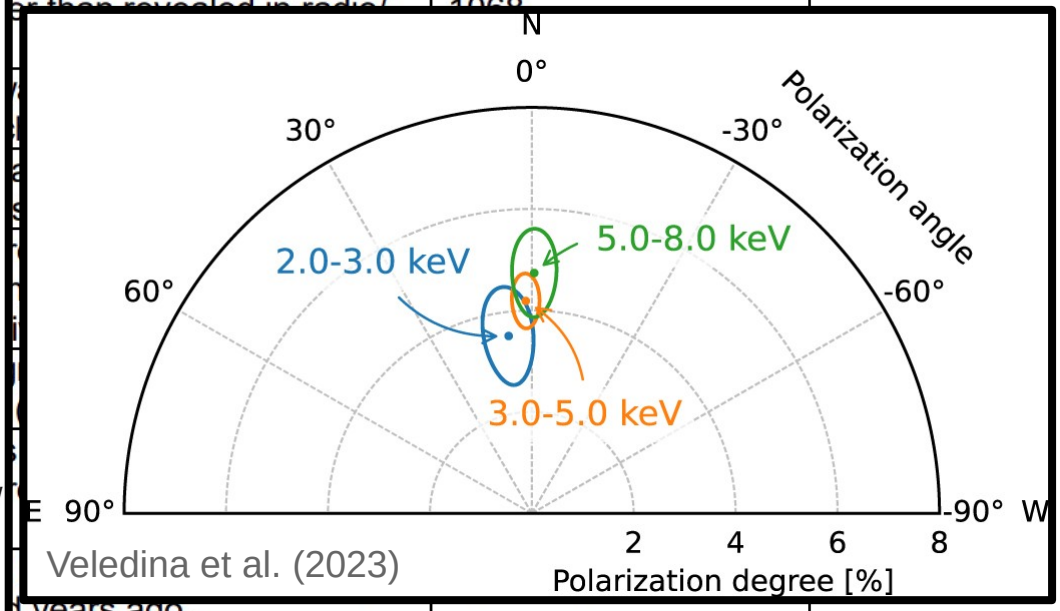


Krawczynski et al. (2022)



Veledina et al. (2023)

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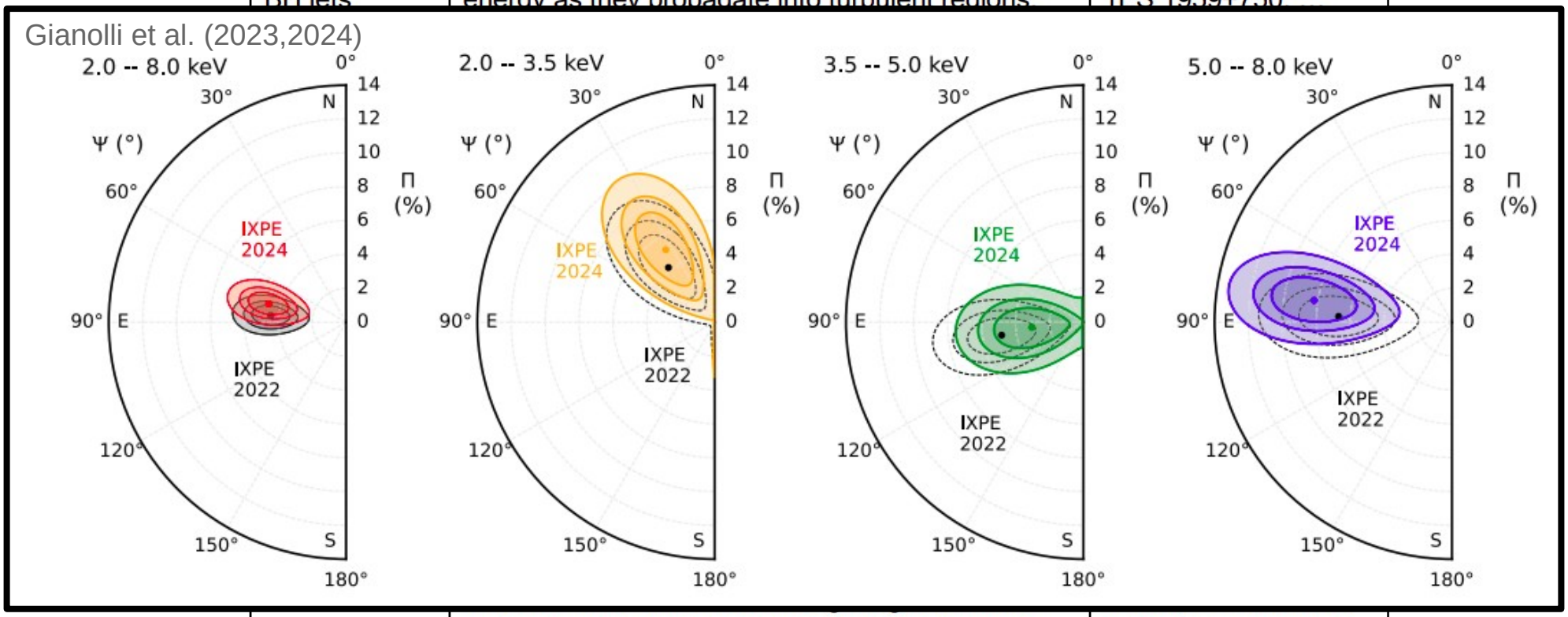
Gianolli et al. (2023,2024)



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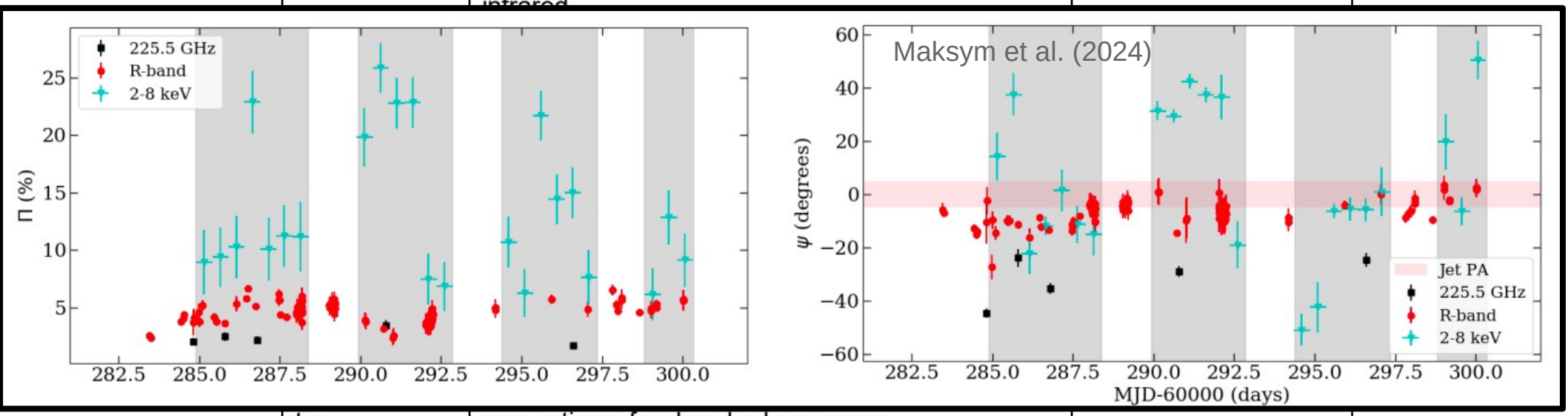

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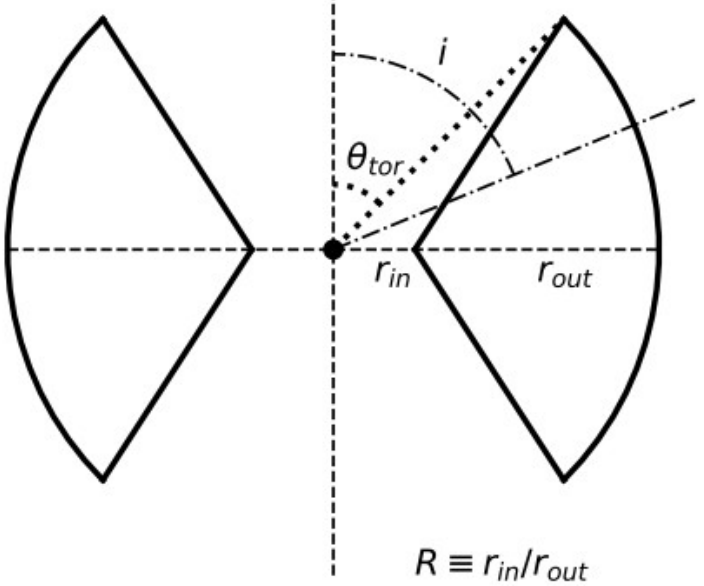
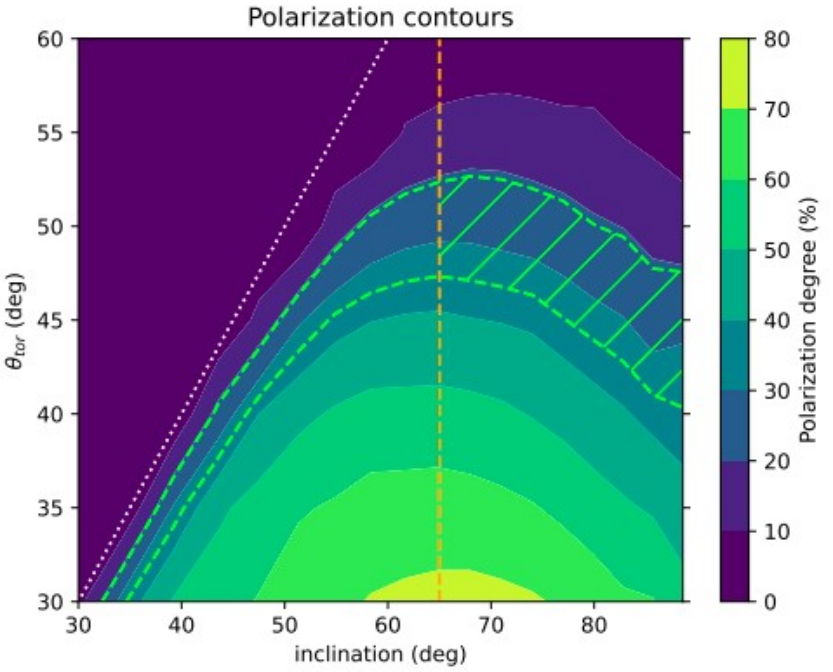
Ursini et al. (2023), Marin et al. (2024)





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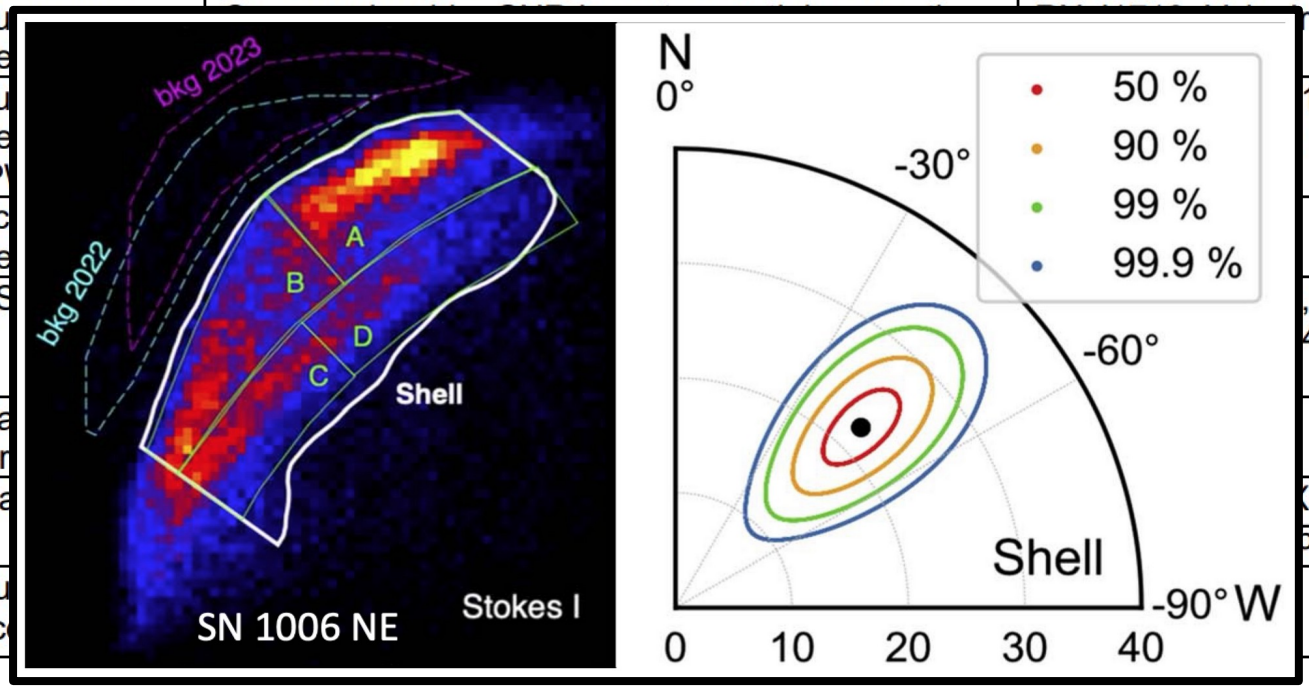
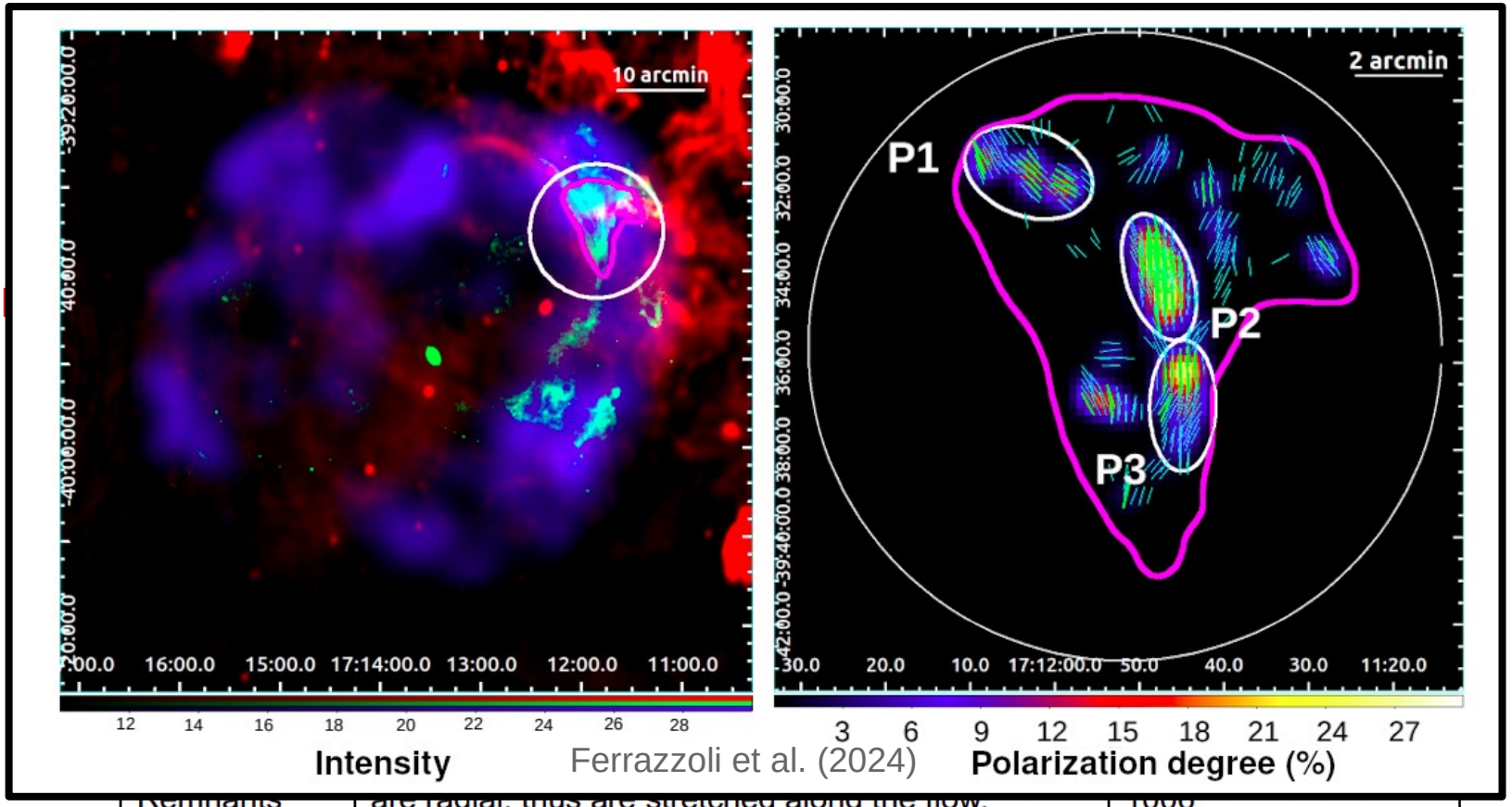


Slane et al. (2024)

From the



Ferrazzoli et al. (2024)

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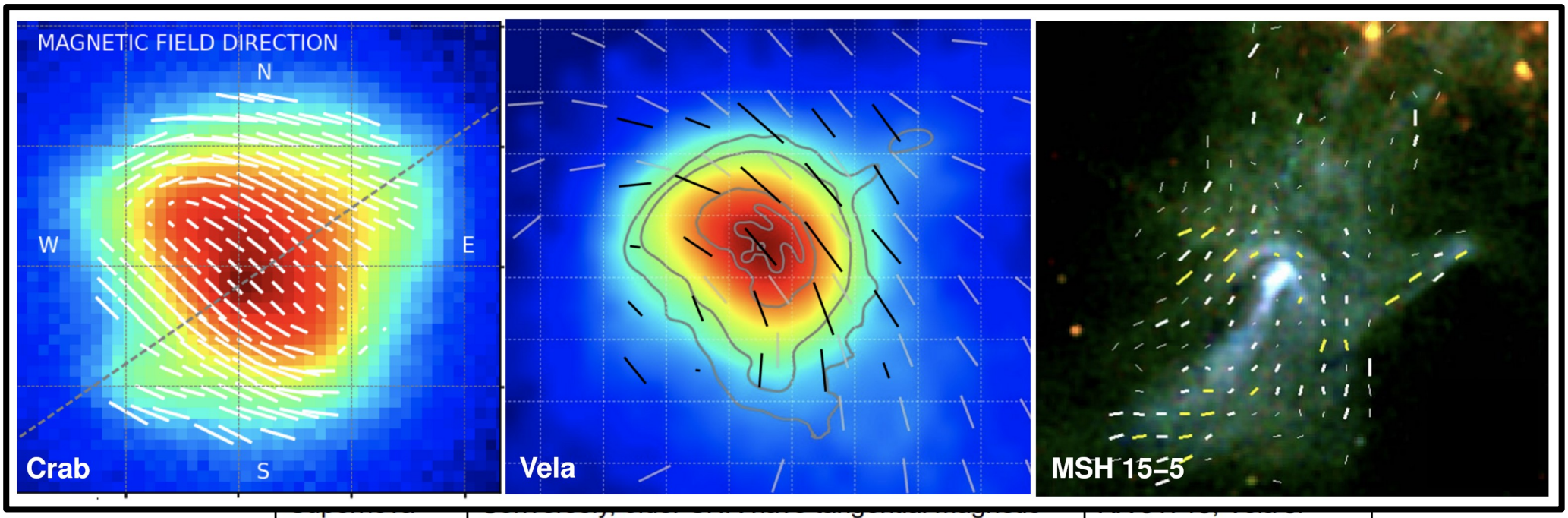
Bucciantini et al. (2024)



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Doroshenko et al. (2023)

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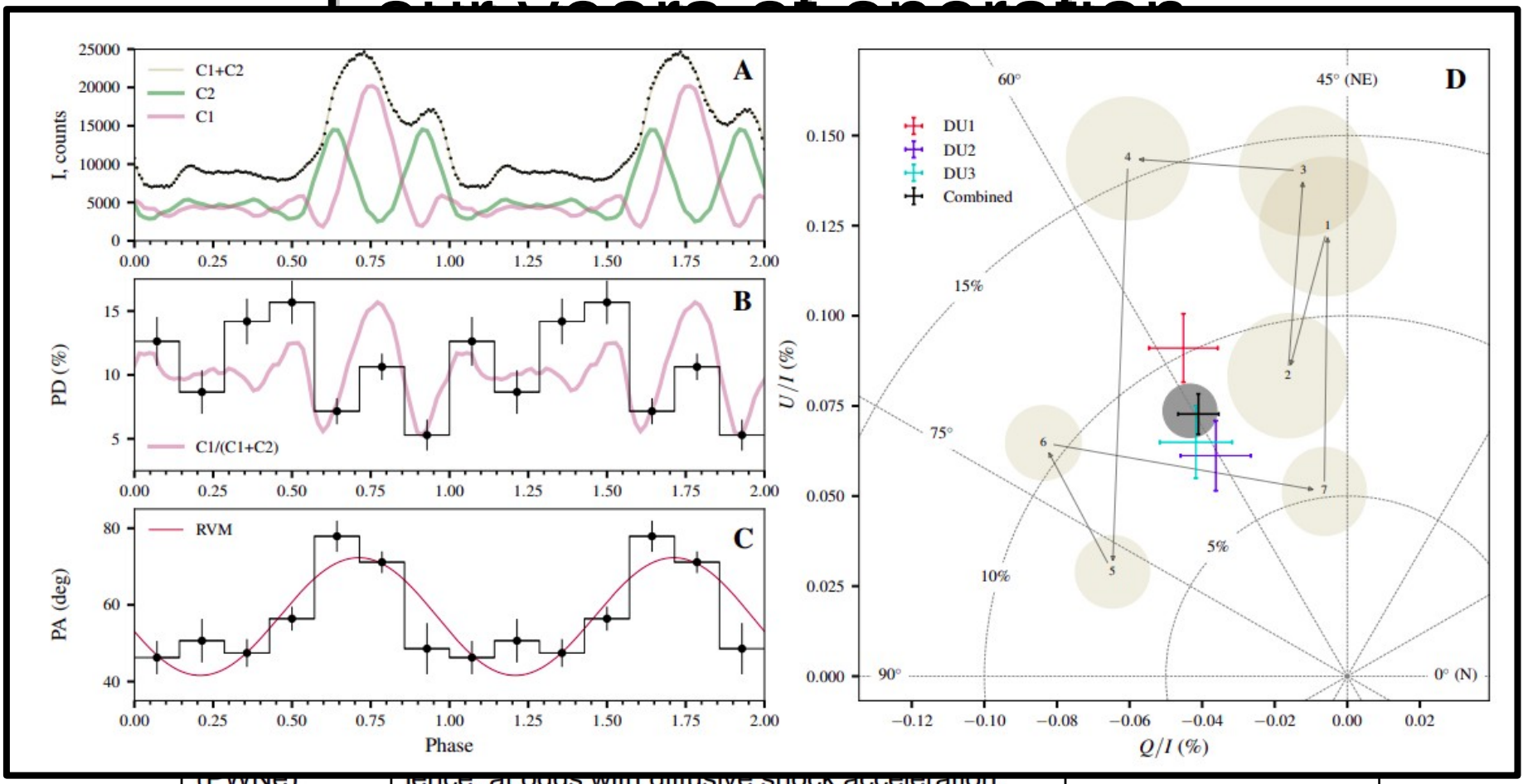
From



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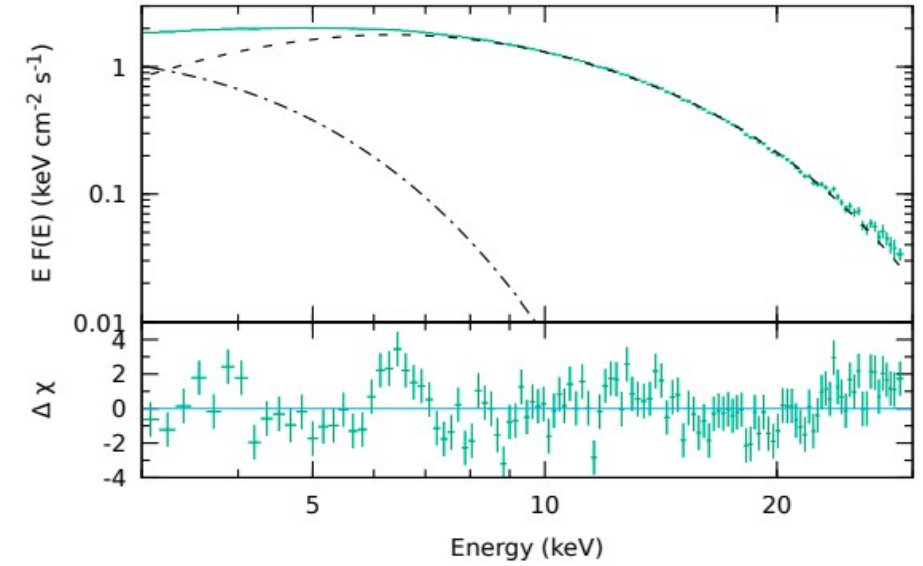

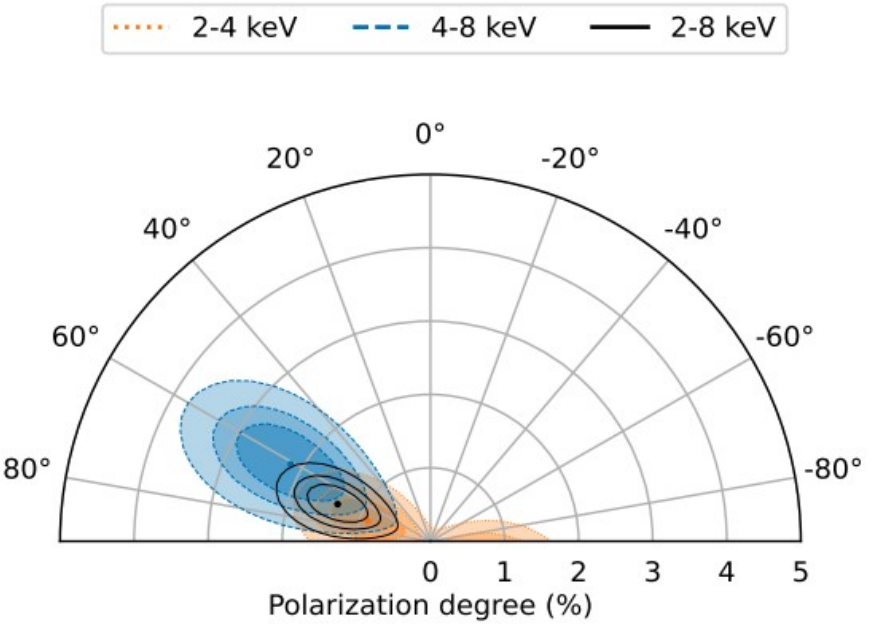

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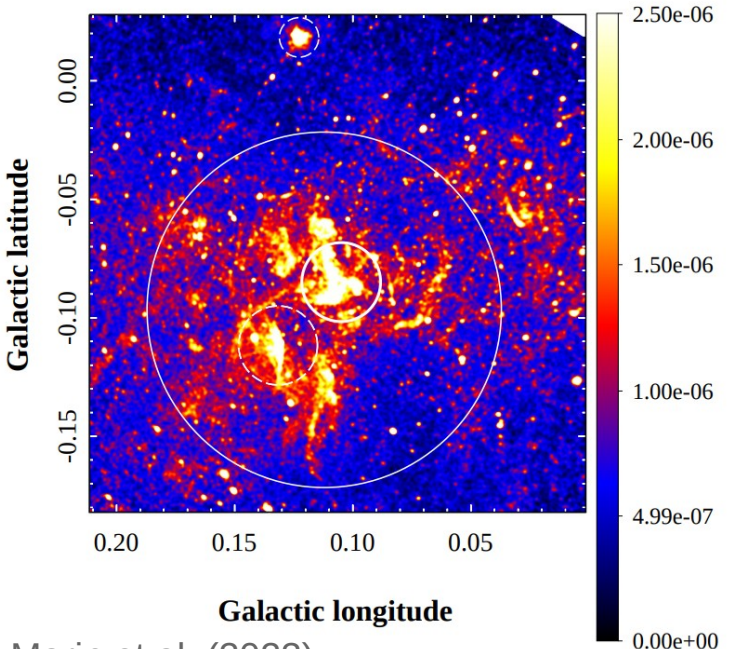
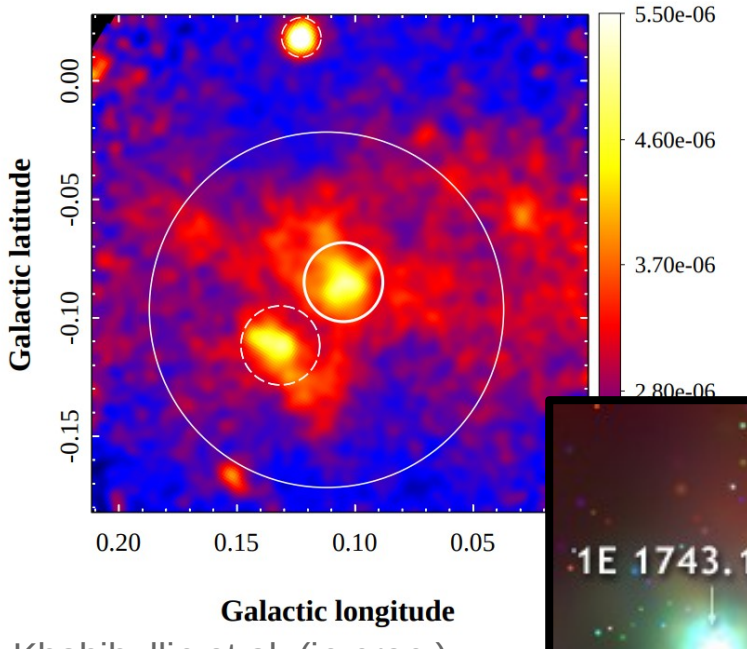
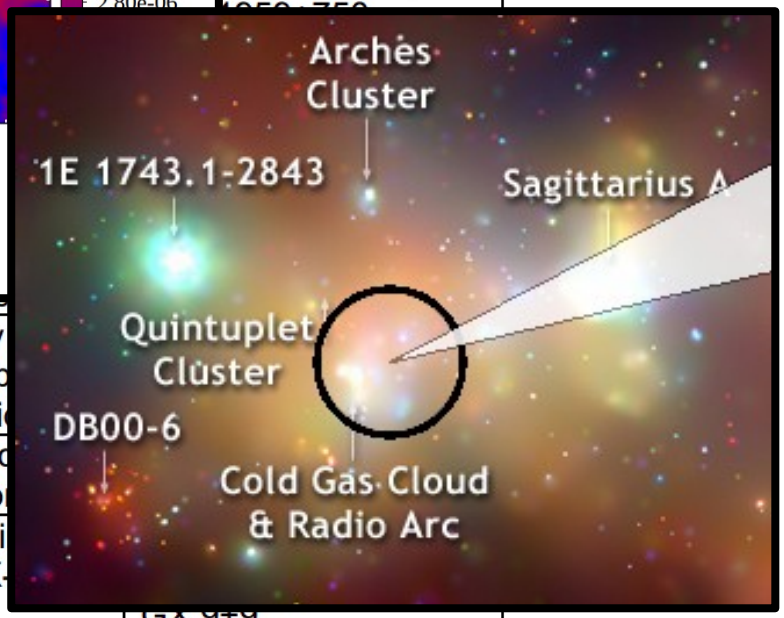


Marin et al. (2023)



Khabibullin et al. (in prep.)



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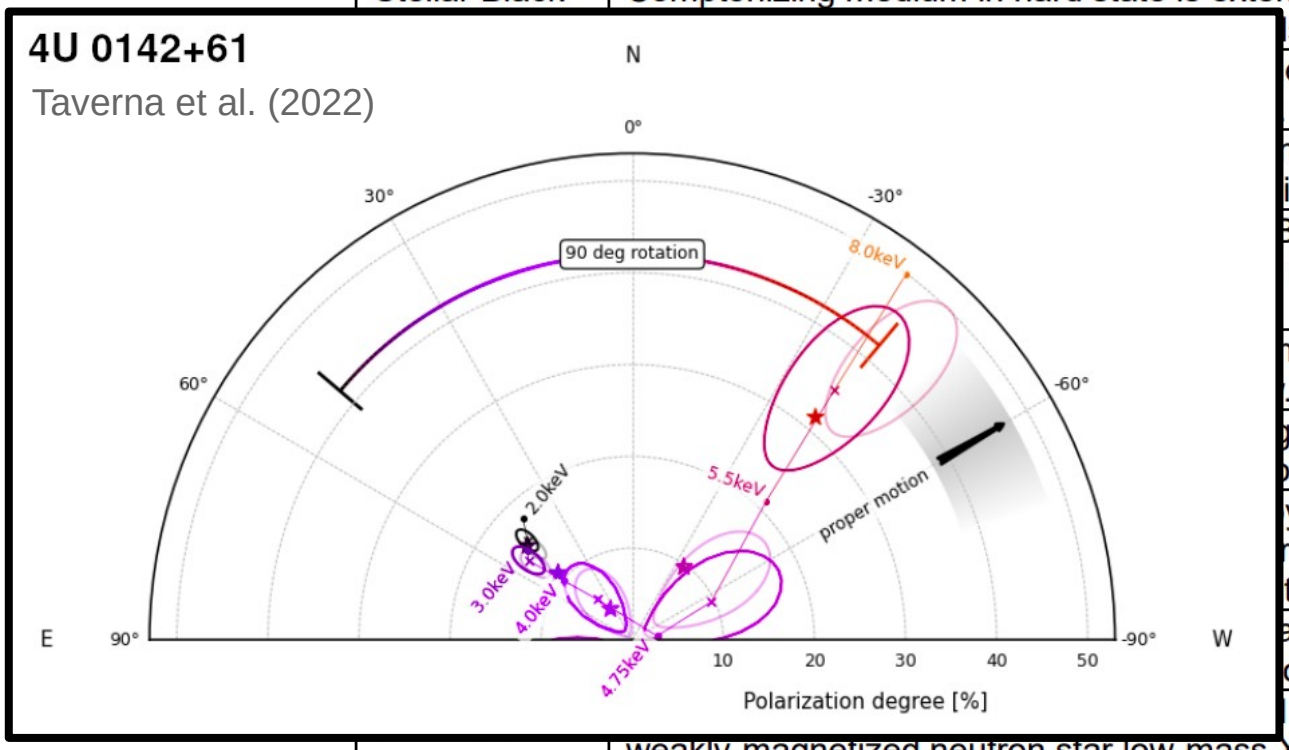

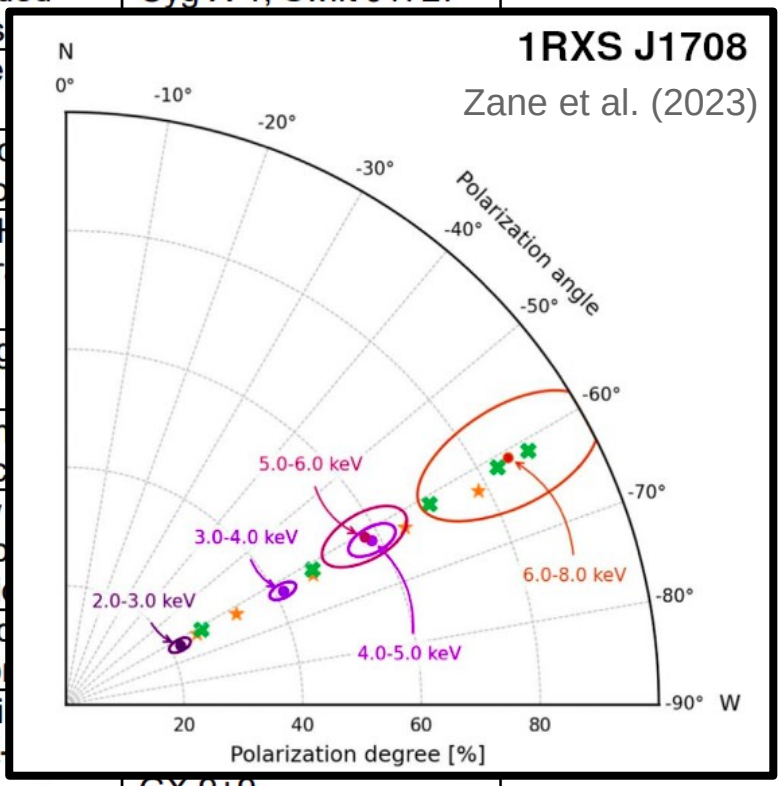

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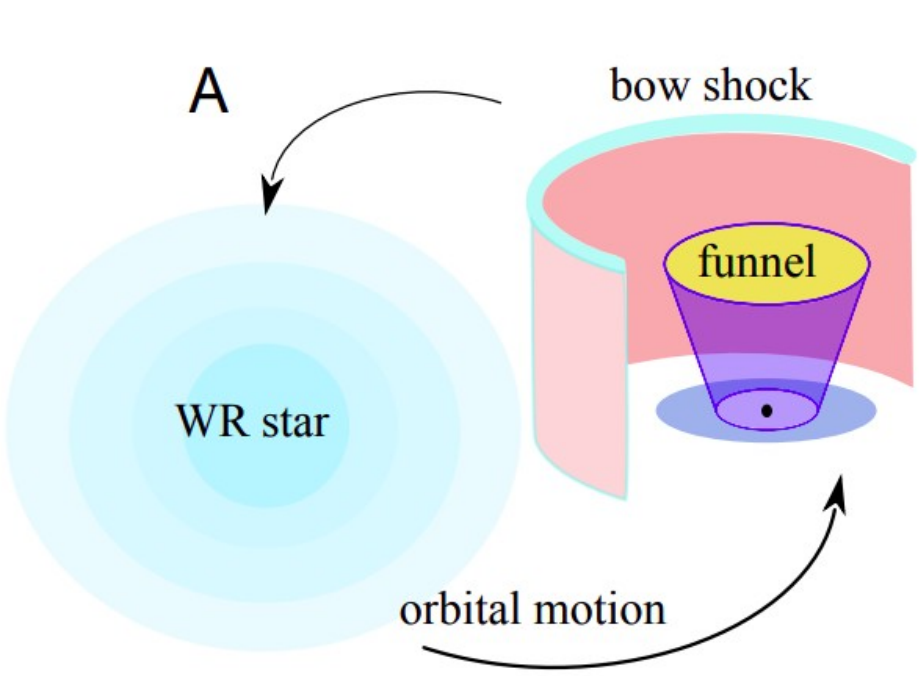
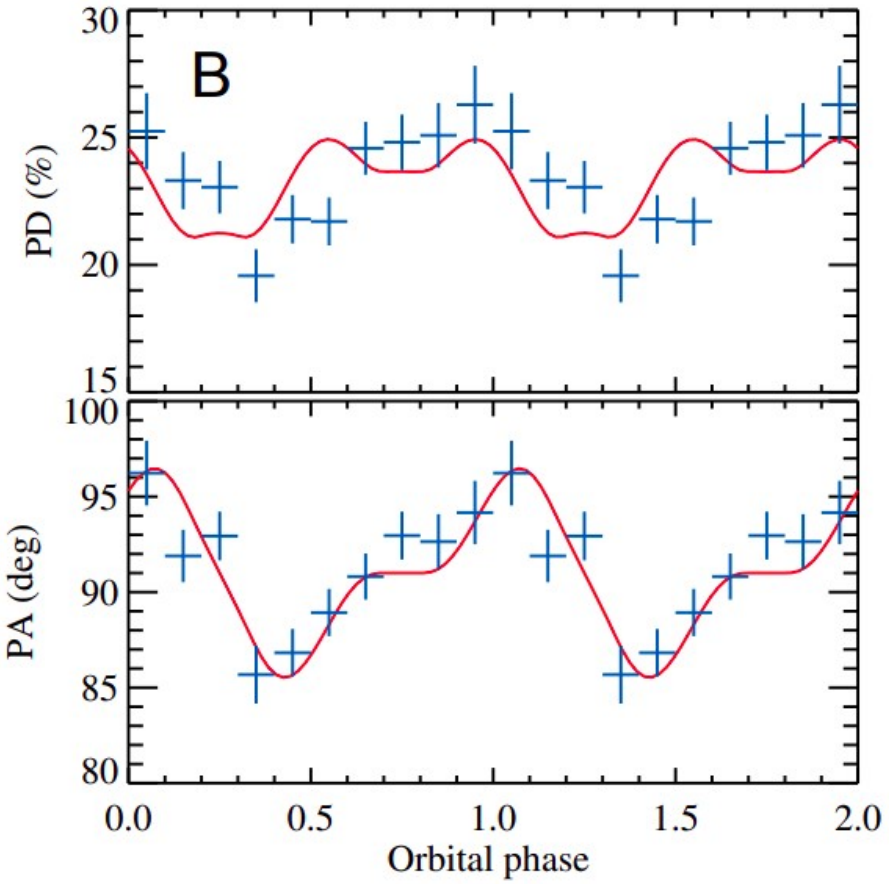
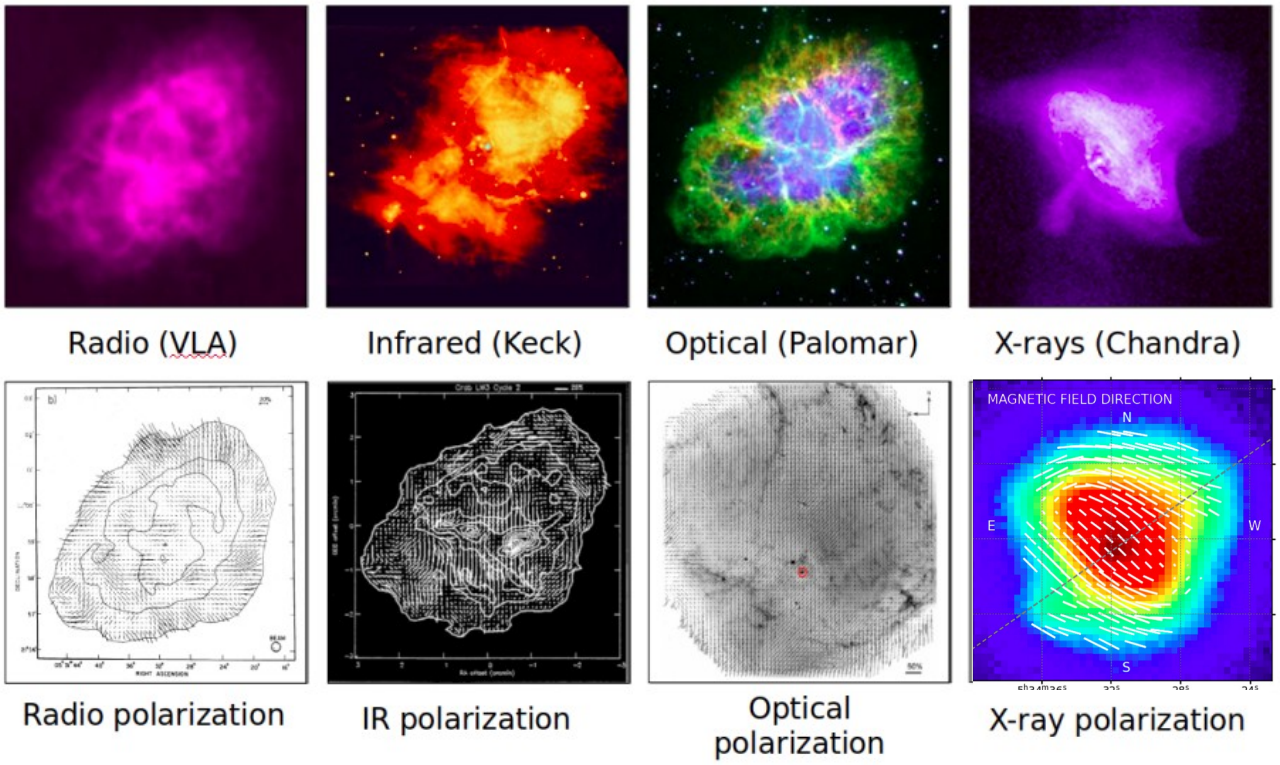




	evidence in favor of ultra-strong magnetic fields.	J1708, 1E 2259+586
Super-critical accretion	High polarization in Cyg X-3 indicates it is accreting at super-Eddington rates.	Cyg X-3

Conclusions

IXPE has opened a new observational window and the strong positive feedback from the NASA executives and the scientific community pushes for exploiting this small satellite to its end (~2030)



What's next?

- → eXTP mission (China-lead)
- → ESA M8 call (EXPO, Phemto)
- → don't forget γ-ray polarimetry!

Conclusions

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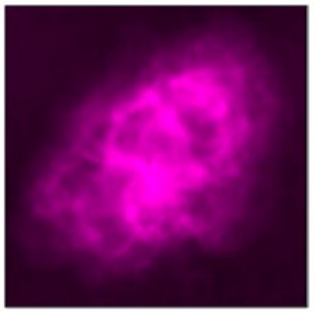
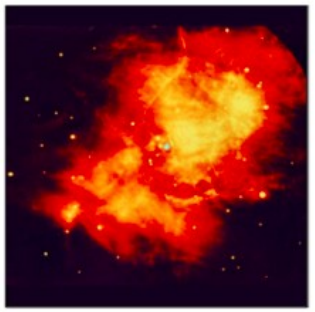
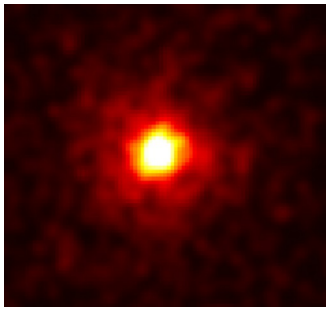
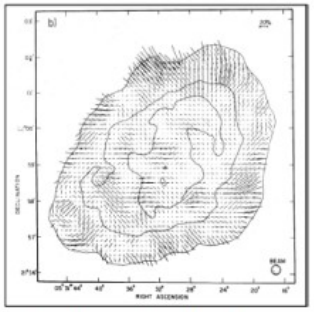

Radio (VLA)

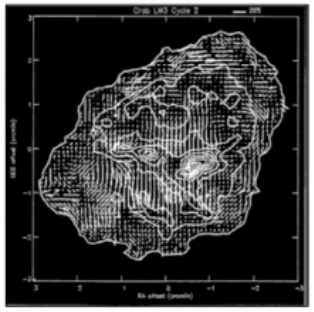

Infrared (Keck)

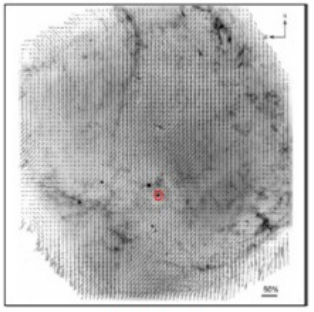

Optical (Palomar)

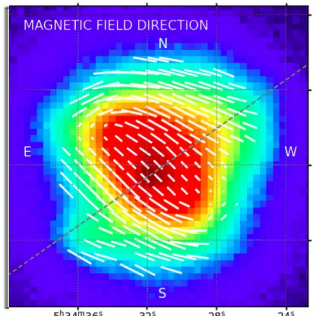

X-rays (Chandra)


γ-rays (Fermi)


Radio polarization


IR polarization


Optical polarization



X-ray polarization

?

γ-ray polarization

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