Stellar Mass Compact Objects

Sandro Mereghetti

IASF-Milano

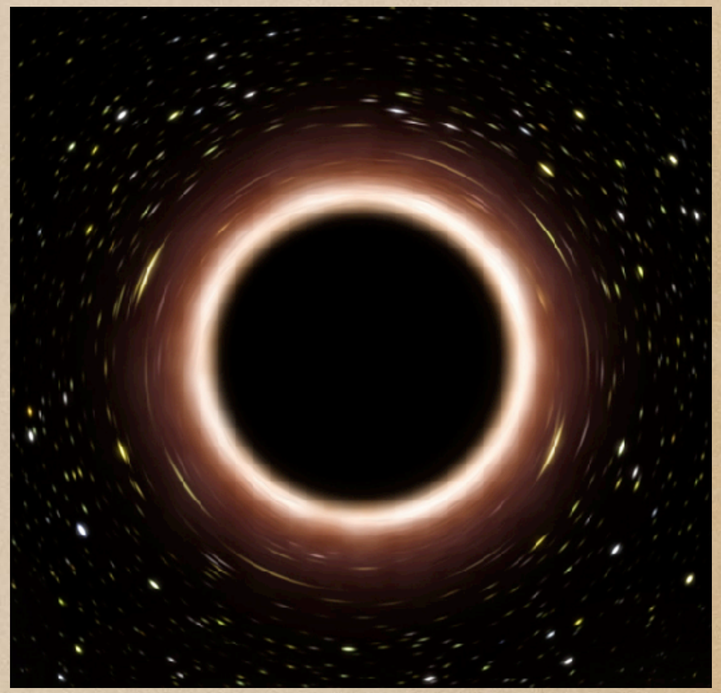
Giornate INAF RSN4 2026

Stellar Mass Compact Objects

White Dwarfs

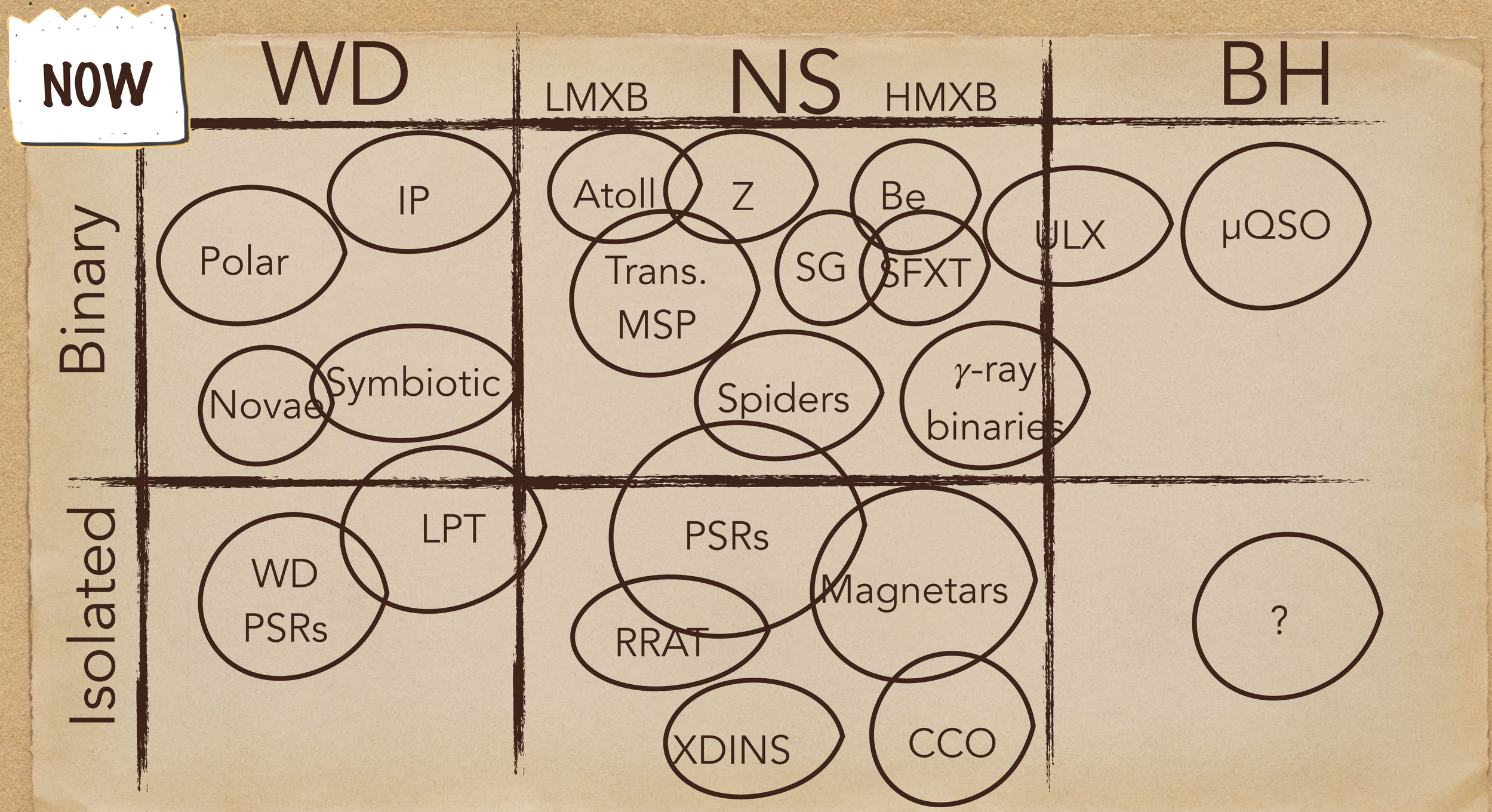
Neutron Stars

Black Holes

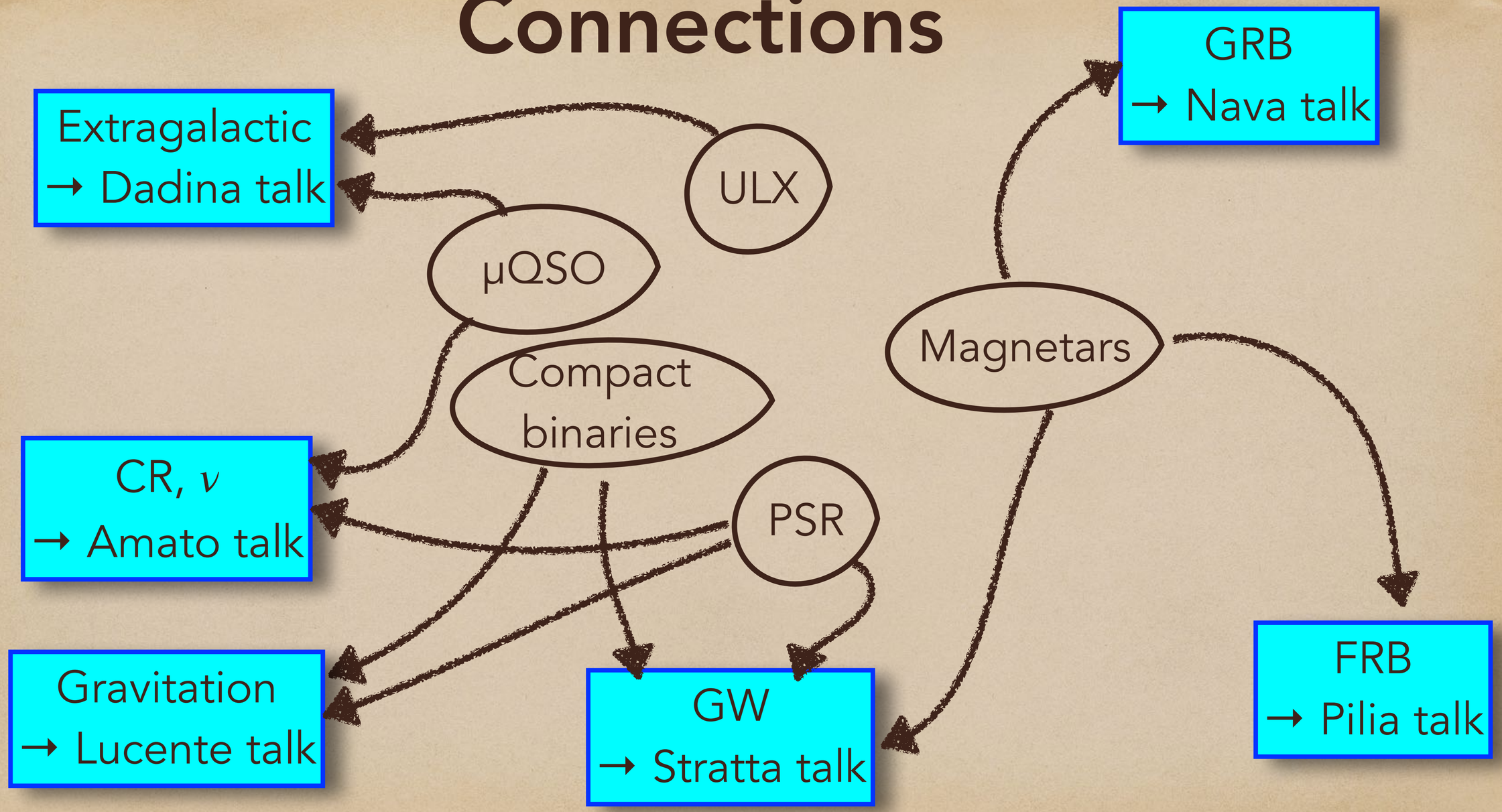


ONCE UPON A TIME

	WD	NS	BH
Binary	Cataclysmic variables	X-ray binaries	Cyg X-1 ?
Isolated	Many !	Radio pulsars	


NOW
WD
LMXB
NS
HMXB
BH
Binary
Isolated
IP
Polar
Atoll
Z
Be
SG
SFXT
Trans.
MSP
ULX
μQSO
Symbiotic
Novae
Spiders
γ-ray
binaries
LPT
WD
PSRs
PSRs
Magnetars
RRAT
?
XDINS
CCO

Connections



- ``laboratories" for extreme physical conditions
- end points of stellar evolution
- sources of gravitational waves
- production and acceleration of cosmic-rays

A few of the main open questions

Accretion/ejection in compact objects: What is the geometry ? super-Eddington ?
How is accretion coupled to outflows, such as winds and jets, at different accretion rates?

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What causes the different variability patterns in accreting HMXB and LMXB?
Magnetic gating? Companion's wind?

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Fundamental physics with timing of radio PSRs - Quest for exotic binaries

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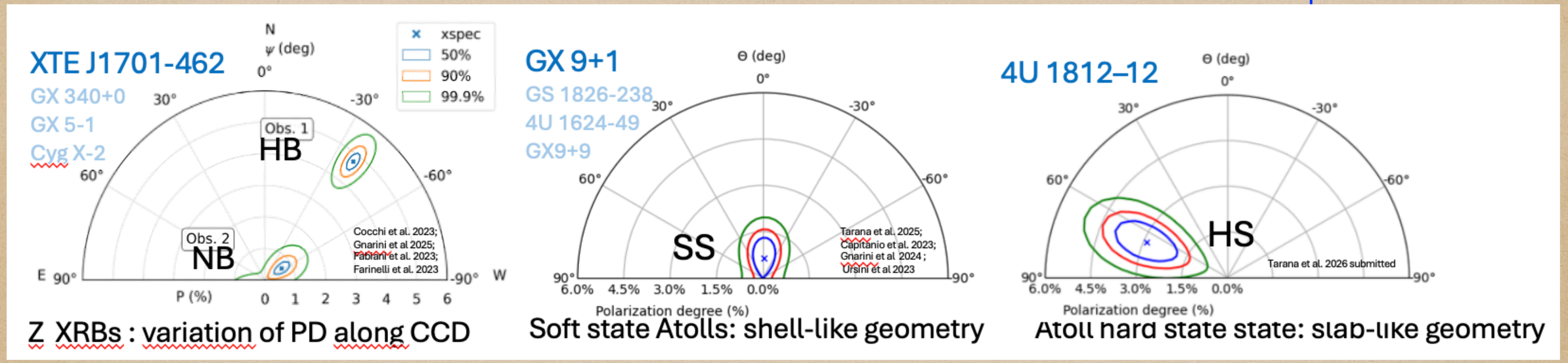
Census of **different classes of isolated NS and role of B field** - How common are magnetars ?
How are magnetars connected to cosmological Fast Radio Bursts ?
Do magnetars accreting at super-Eddington rates power pulsating ULX sources?
What are the long period radio transients?

Some highlights

… a difficult choice among
so many contributions!!

X-ray polarimetry of low magnetic field NS binaries

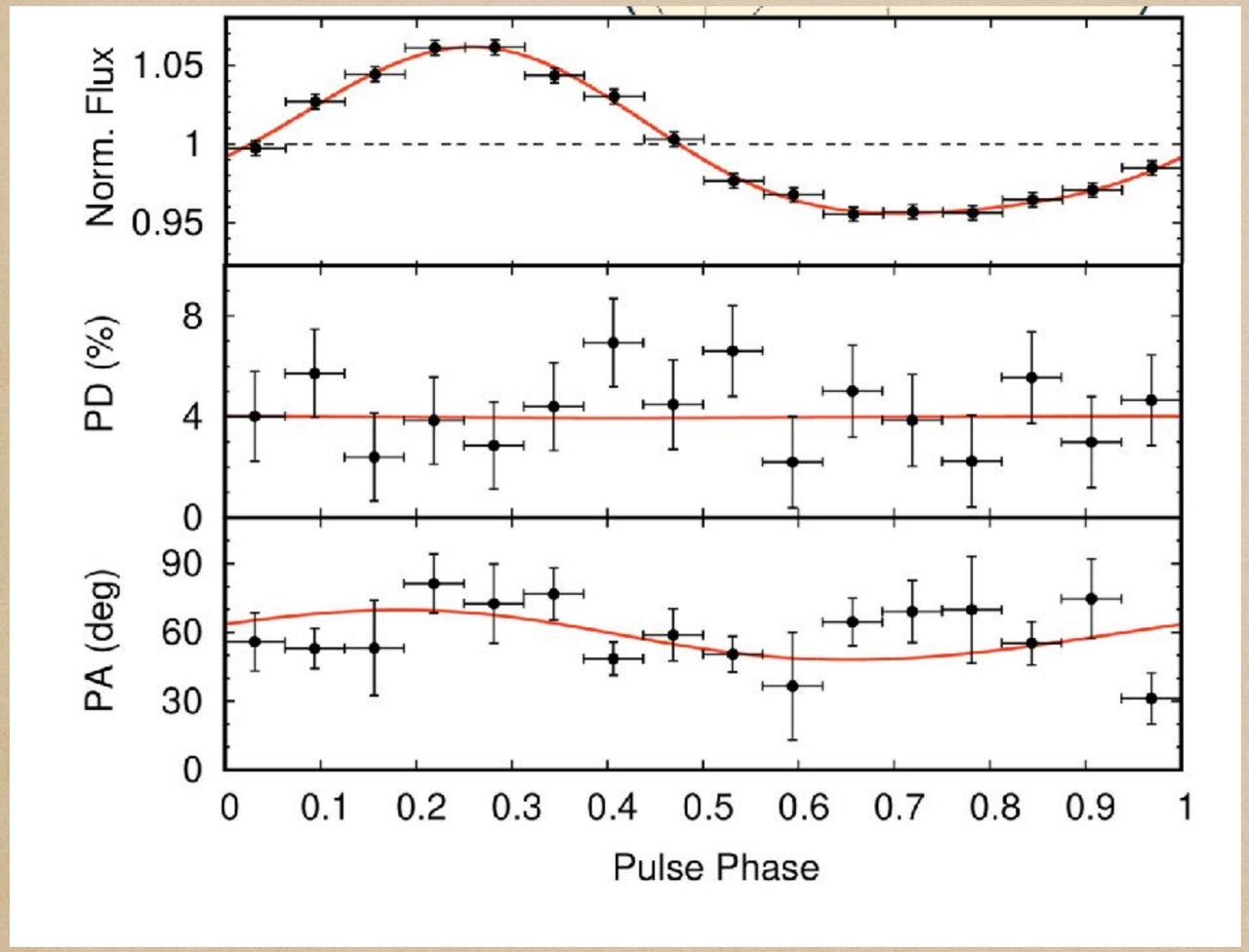
Tarana, Capitanio+ 2026

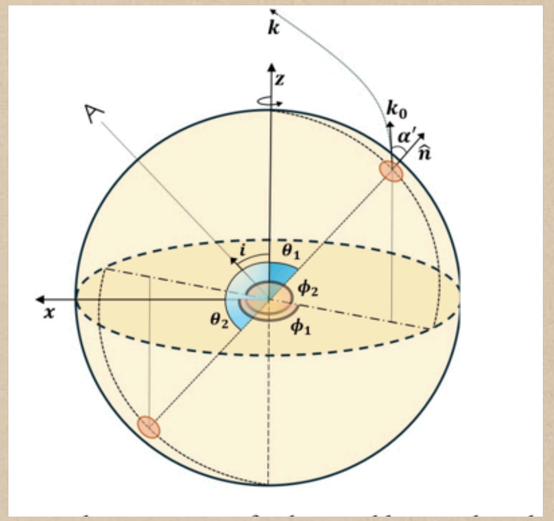


Geometry of accretion flow changes with source spectral state

Most of the results that have advanced the understanding of X-ray binaries through polarimetry come from an extensive campaign of simultaneous observations with IXPE and other facilities.

Discovery of polarised X-ray emission from an accreting ms-PSR



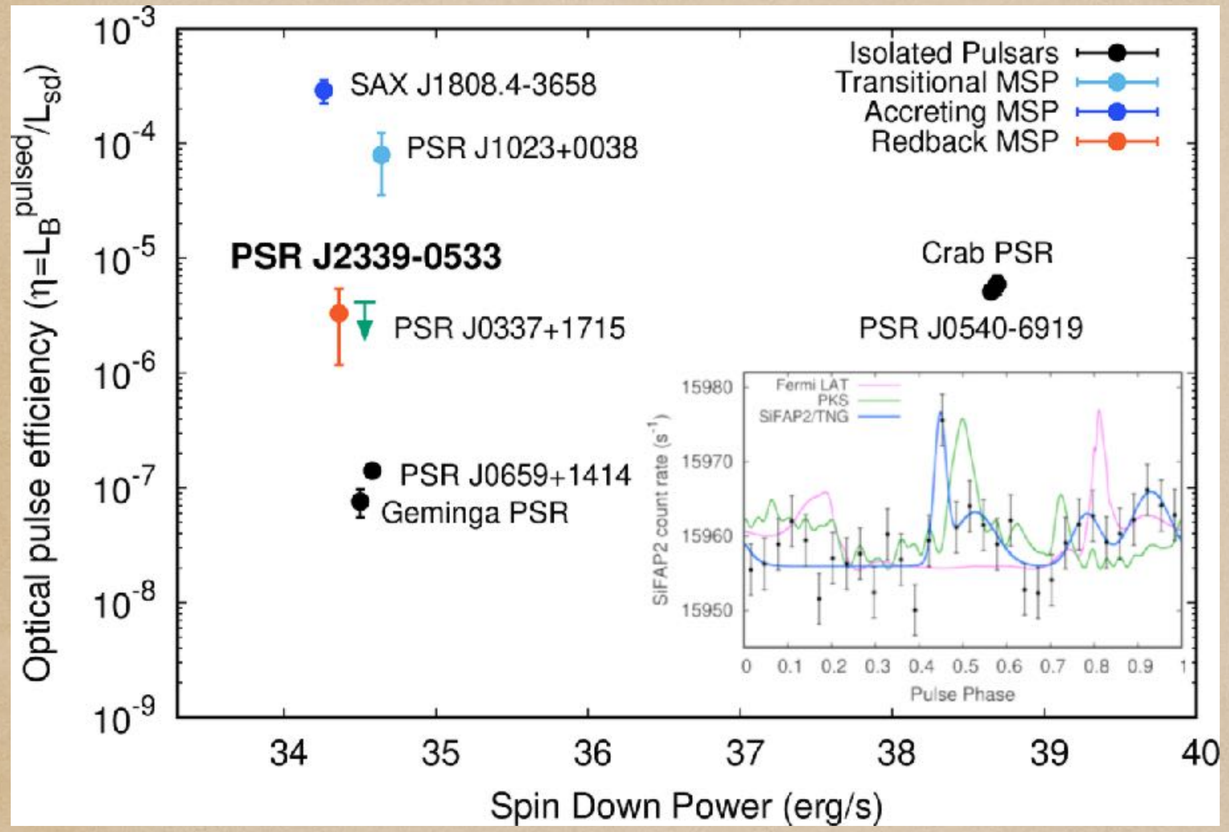


Geometry derived from polarisation properties of the X-ray emission of accreting ms pulsars helps to derive the NS equation of state from pulse profile modelling IXPE (+ eXTP in the future)

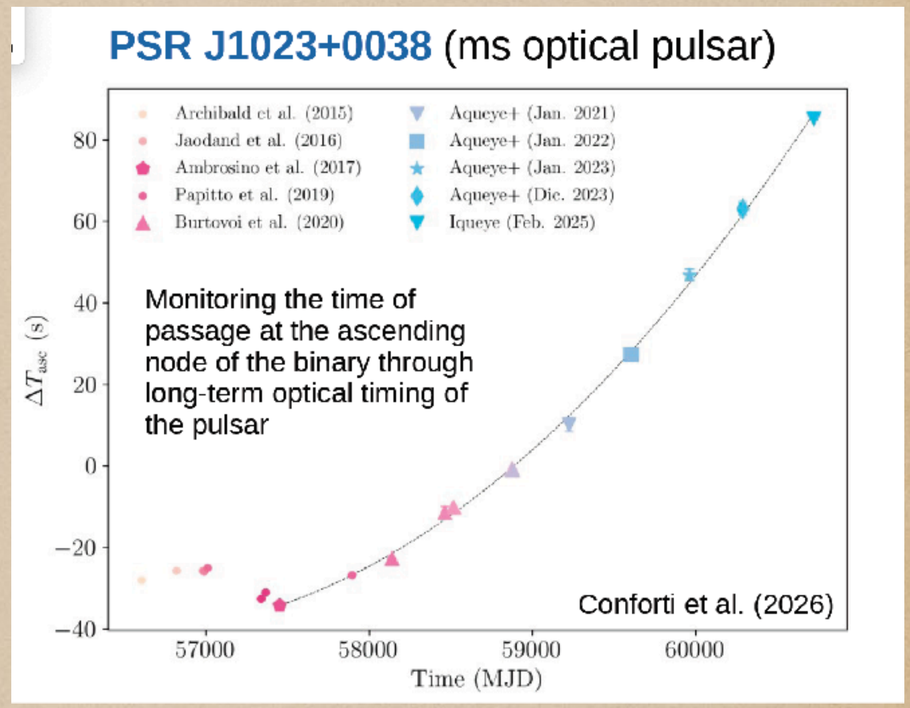
Papitto, Di Marco + 2025, A&A

Optical pulsations from ms PSRs in different emission regimes

Papitto, Ambrosino, Burgay + 2025, A&A



Conforti, Zampieri+ 2026

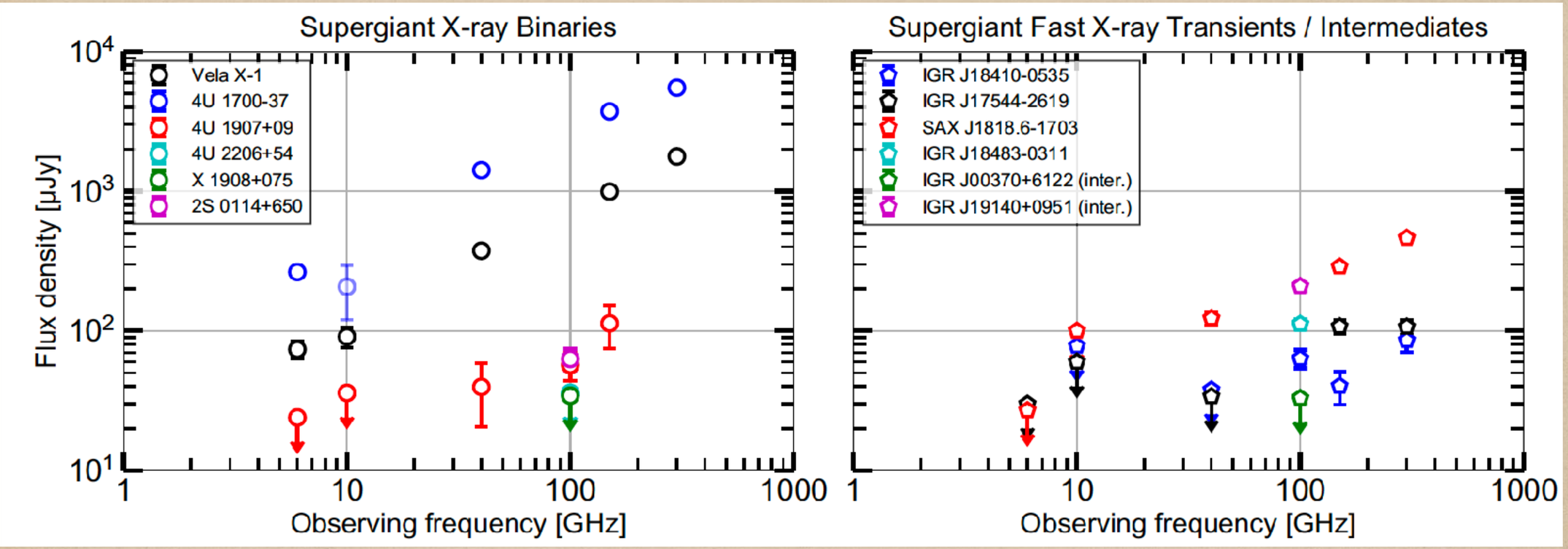


Fast optical photometry from TNG with SiFAP2 in coordination with radio and X-ray facilities to study different emission regimes (accreting, rotation-powered, transitional).

also Aqueye and Iqueye

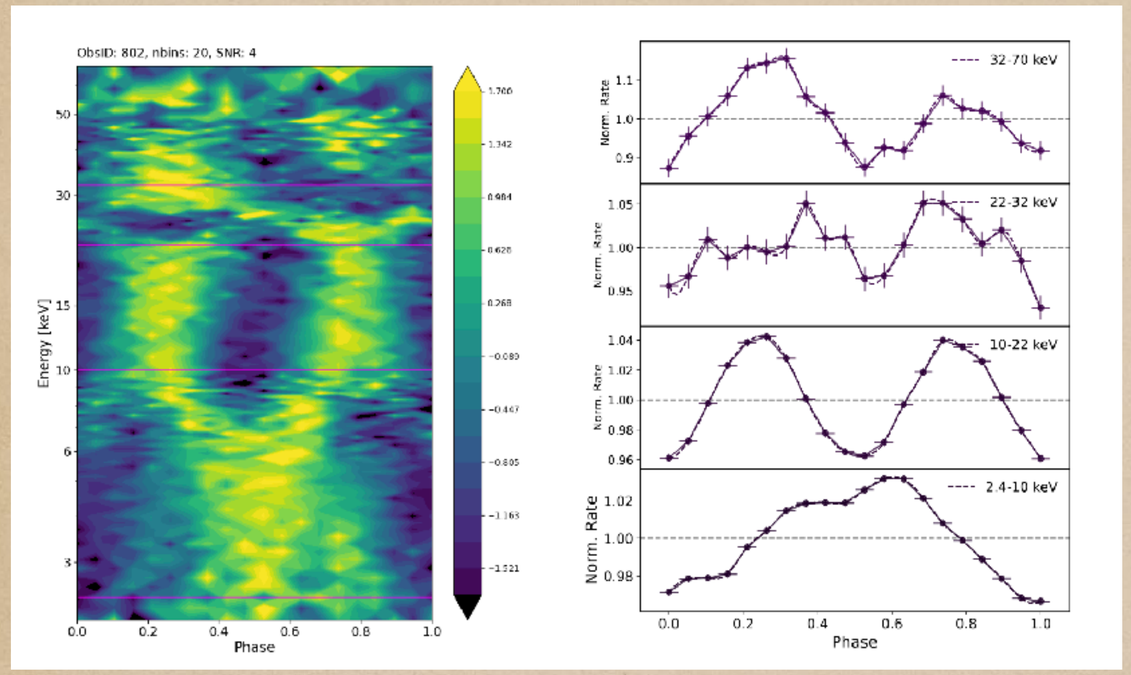
First deep ALMA+VLA survey of HMXB (persistent SgXB & SFXT)

van den Eijnden, Sidoli + 2025, MNRAS



Systematic investigation of the millimeter and radio emission from twelve HMXBs (both Supergiant X-ray Binaries and Supergiant Fast X-ray Transients). Low-frequency emission is dominated by thermal free–free emission from the stellar winds, with SFXTs being systematically fainter at 100 GHz compared to prototypical SgXBs, potentially due to differences in wind density and velocity.

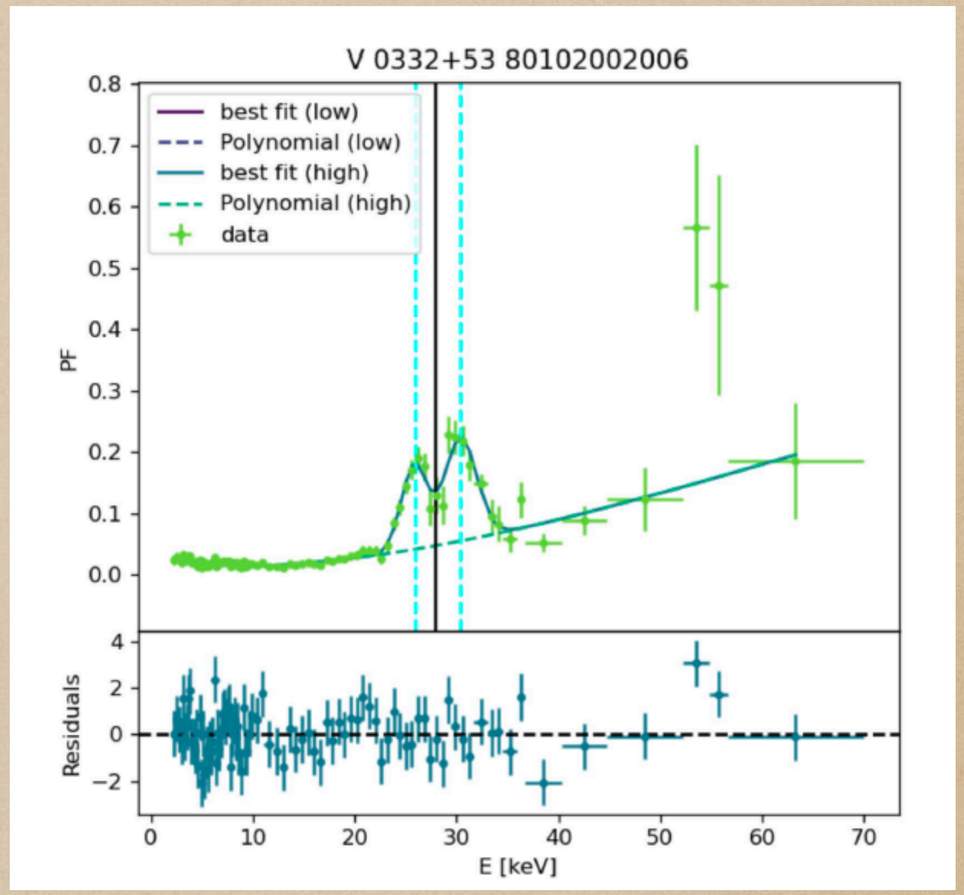
A new diagnostic technique fo studying accreting pulsars



Energy-resolved pulse profiles

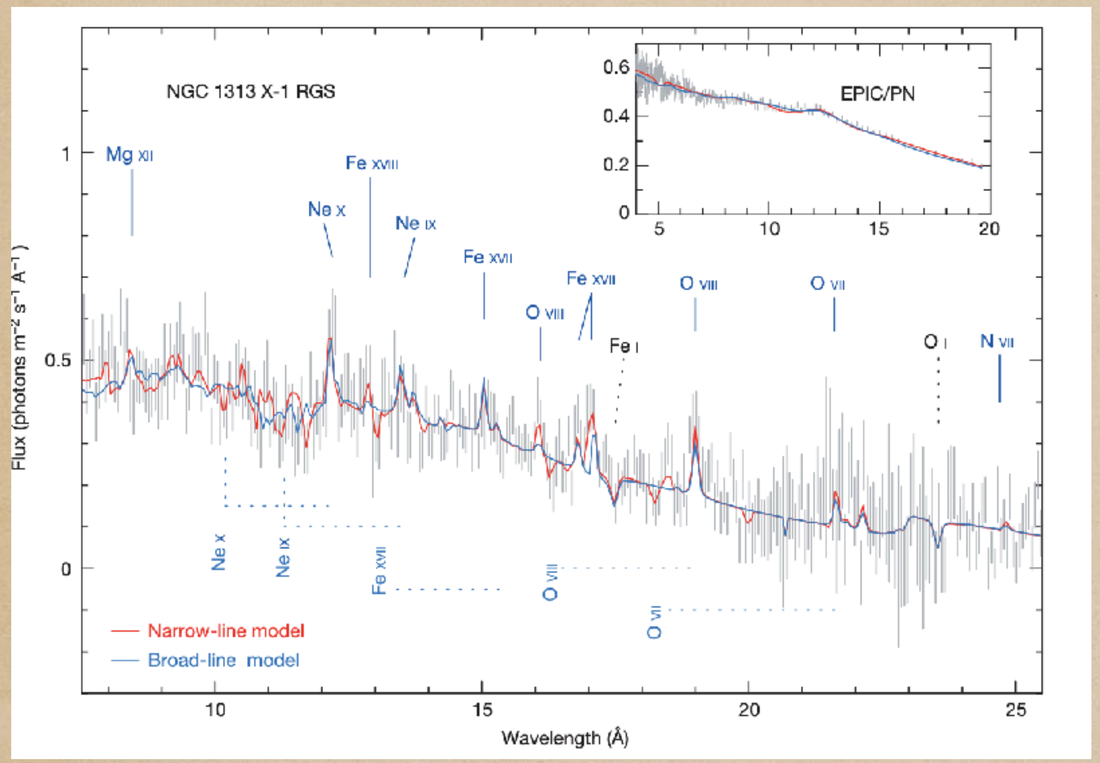
Modelling the broadband pulsed fraction spectra (PFS), provides a new method to investigate the local spectral features (e.g. cyclotron line shapes, iron lines) in X-ray pulsars

D'Aí+ 2025, A&A

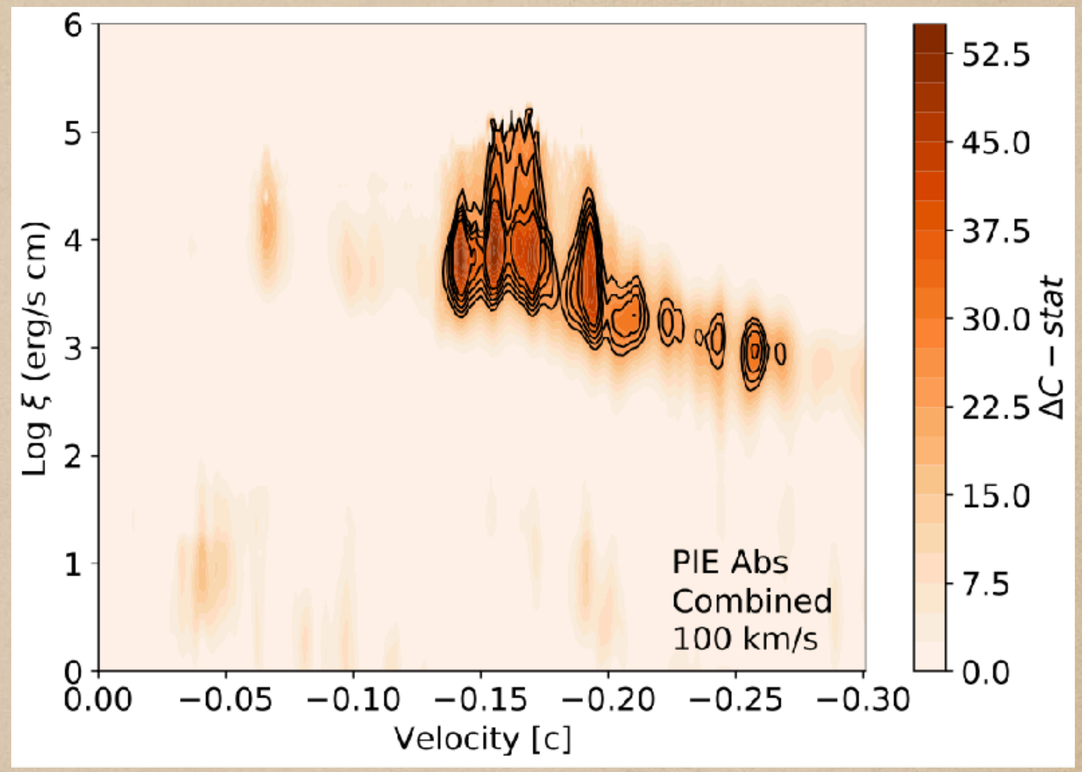


Cyclotron line wings in V0332+53

High resolution X-ray spectroscopy revealed fast (~0.2c) outflows in ULXs



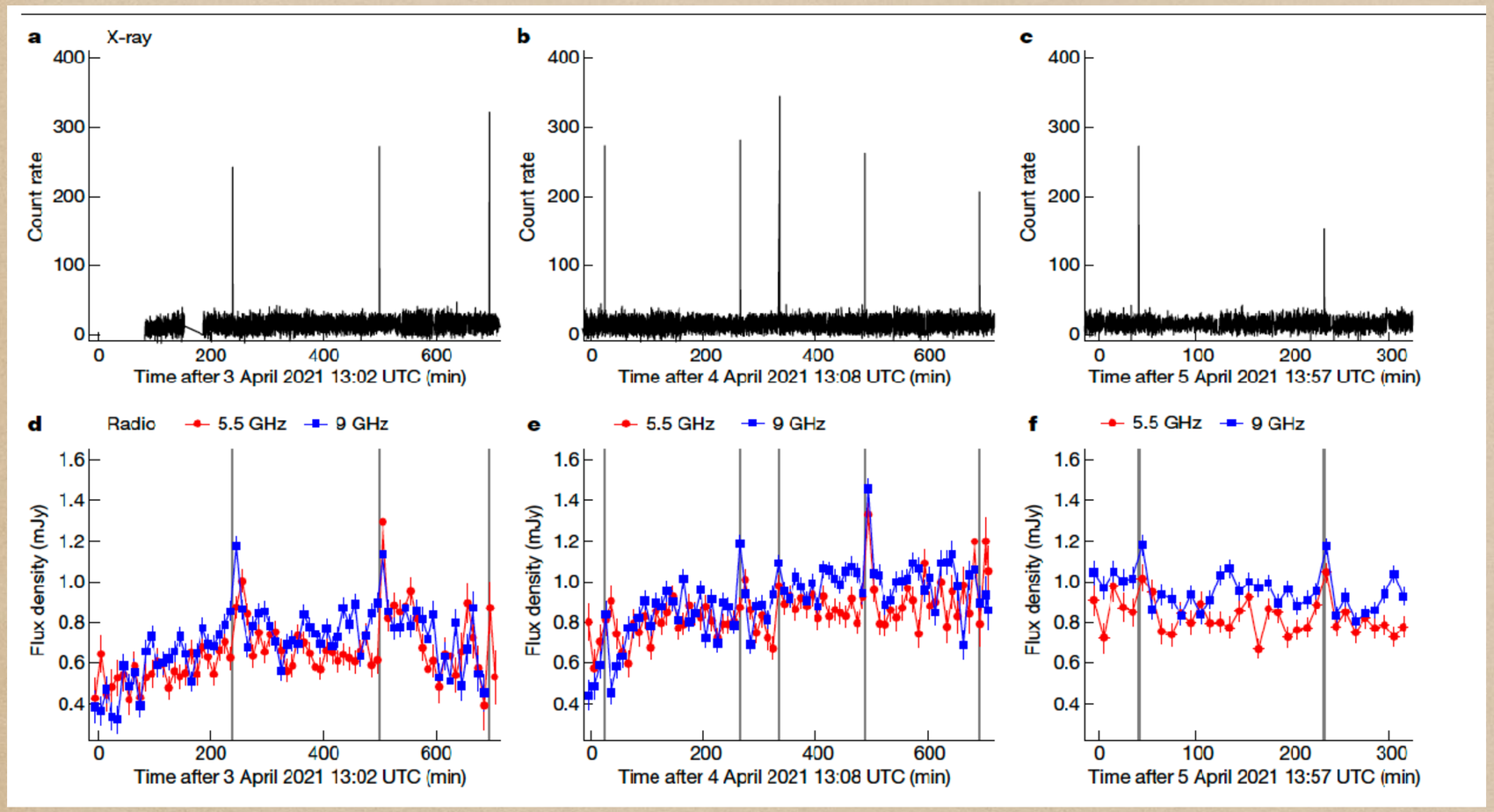
Pinto+ 2016, Nature



Pinto+ 2026, A&A

Deep exploration of the parameter space of an absorption photoionization model shows multiple high significance (>5σ) outflow components with v/c >0.15 in NGC 55 ULX-1. Unprecedented details on radiative winds in the super-Eddington accretion regime. Great prospects for XRISM, eXTP, newAthena.

First velocity measure of a jet launched by a NS after a thermonuclear burst



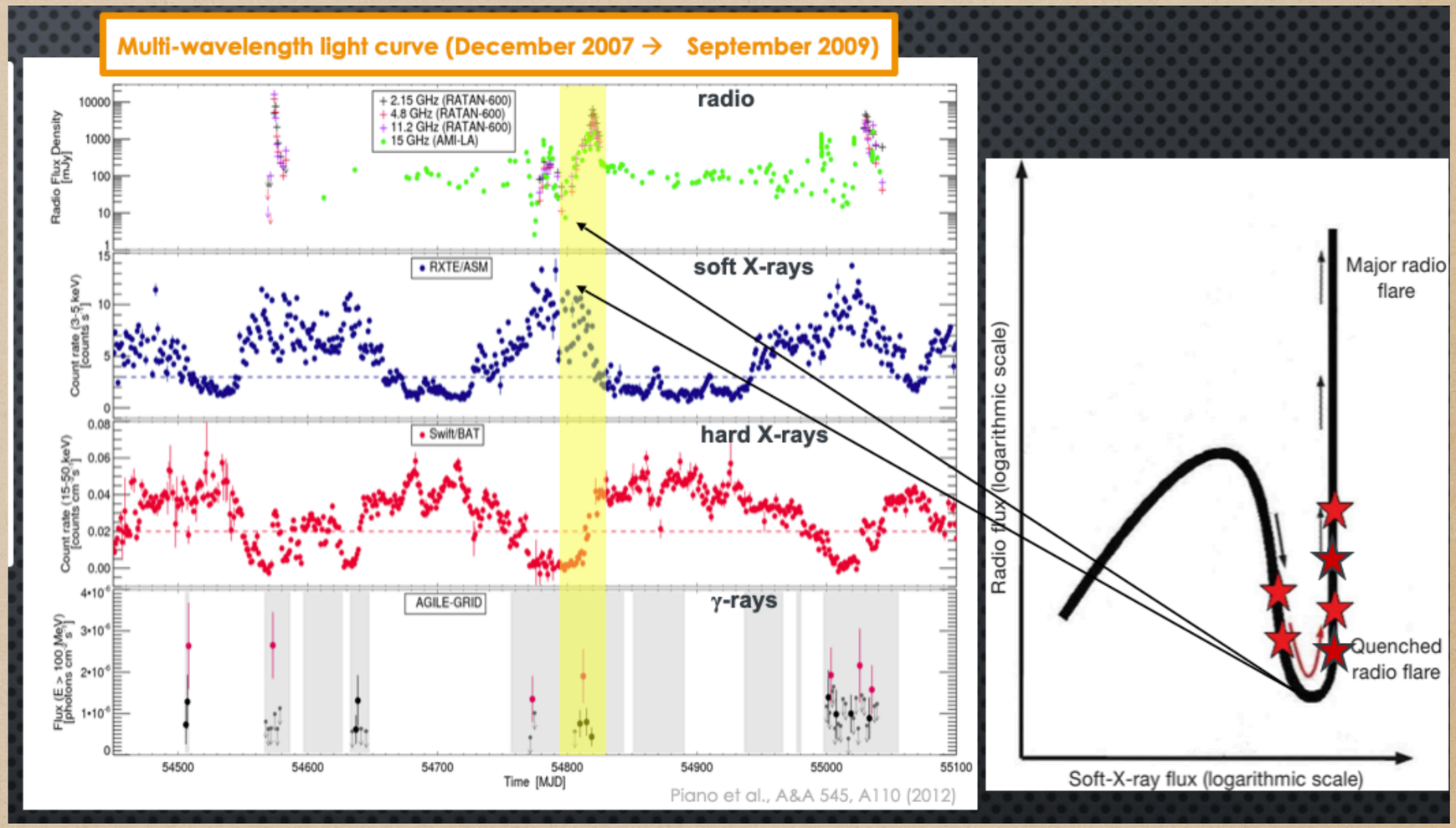
Speed of compact jet (0.4c) measured from X/radio time delays is significantly slower than those from jets of black holes at similar luminosities.

Russel, ..+.. Del Santo 2024, Nature

Pioneering studies of γ-ray emission from Cyg X-3 with AGILE

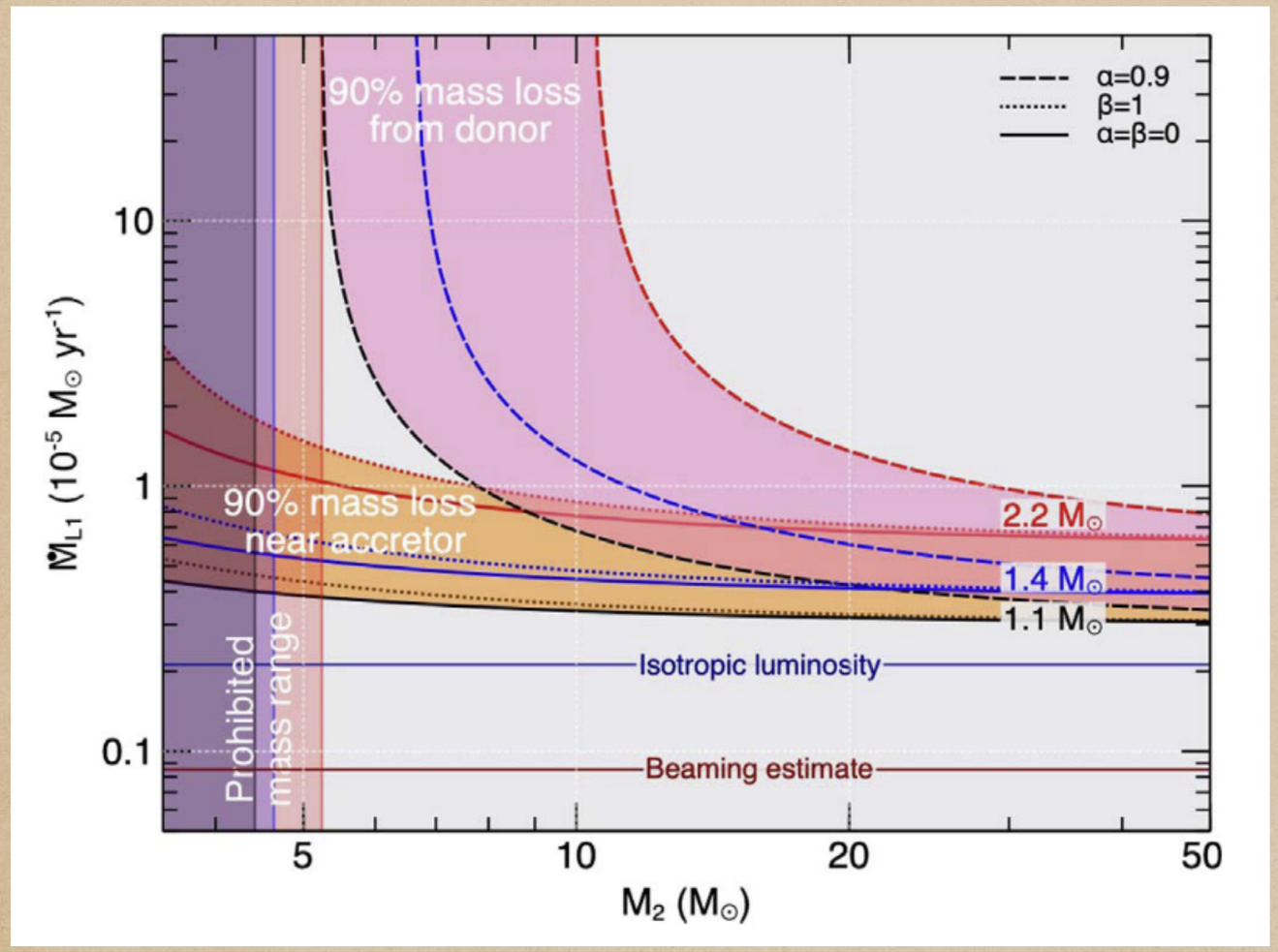
LHAASO recently confirmed that μQSOs are PeVatrons

Cygnus region optimal target for upcoming ASTRI mini-array observations



Piano, Tavani, Vittorini + 2012, A&A

Orbital decay in the ULX M82 X-2



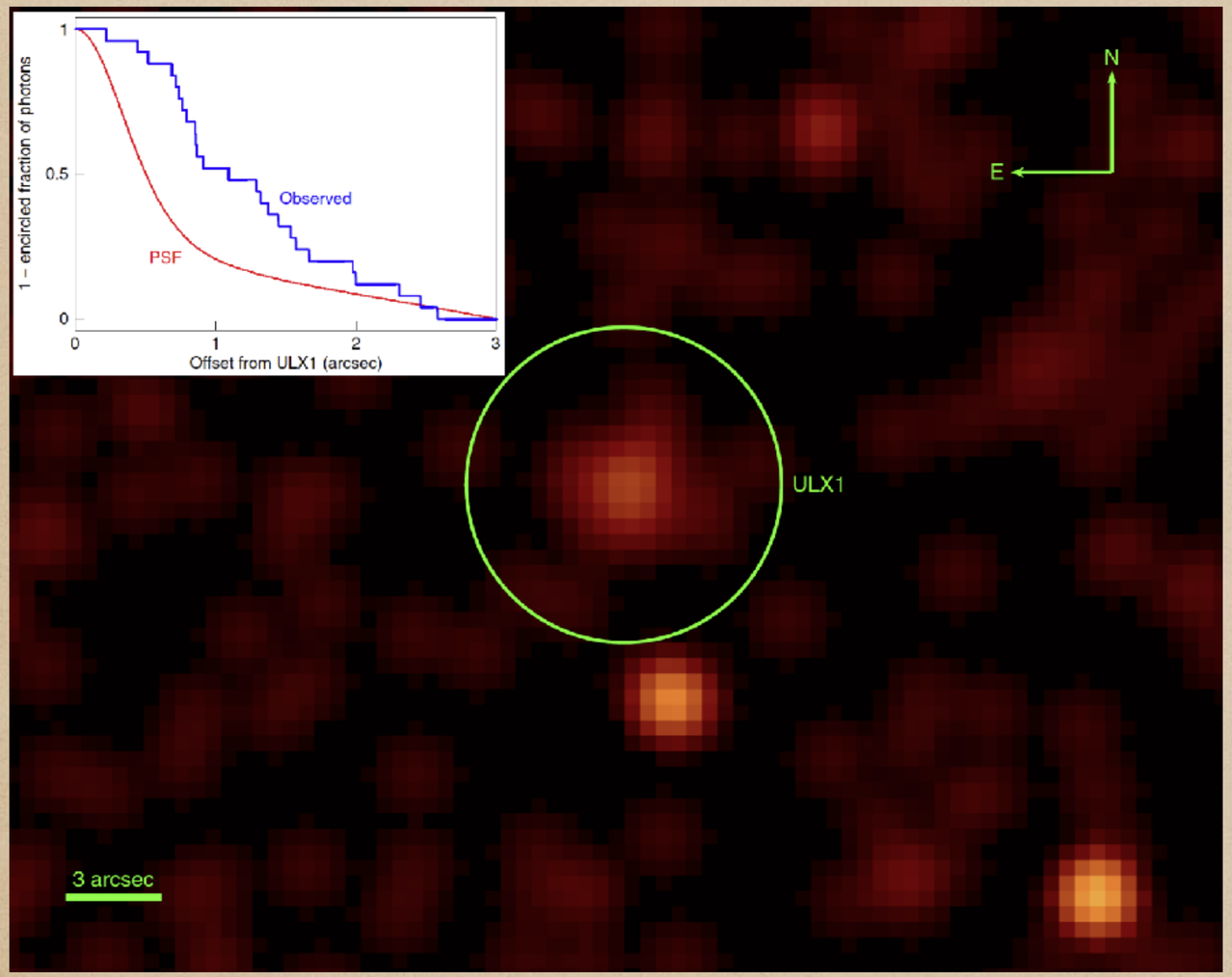
Bachetti,..,Israel+ 2022, ApJ

Orbital period decreases on ~100 kyr timescale

This implies mass transfer rate on the pulsar at ~150 x Eddington

→ No beaming required to explain the high observed luminosity

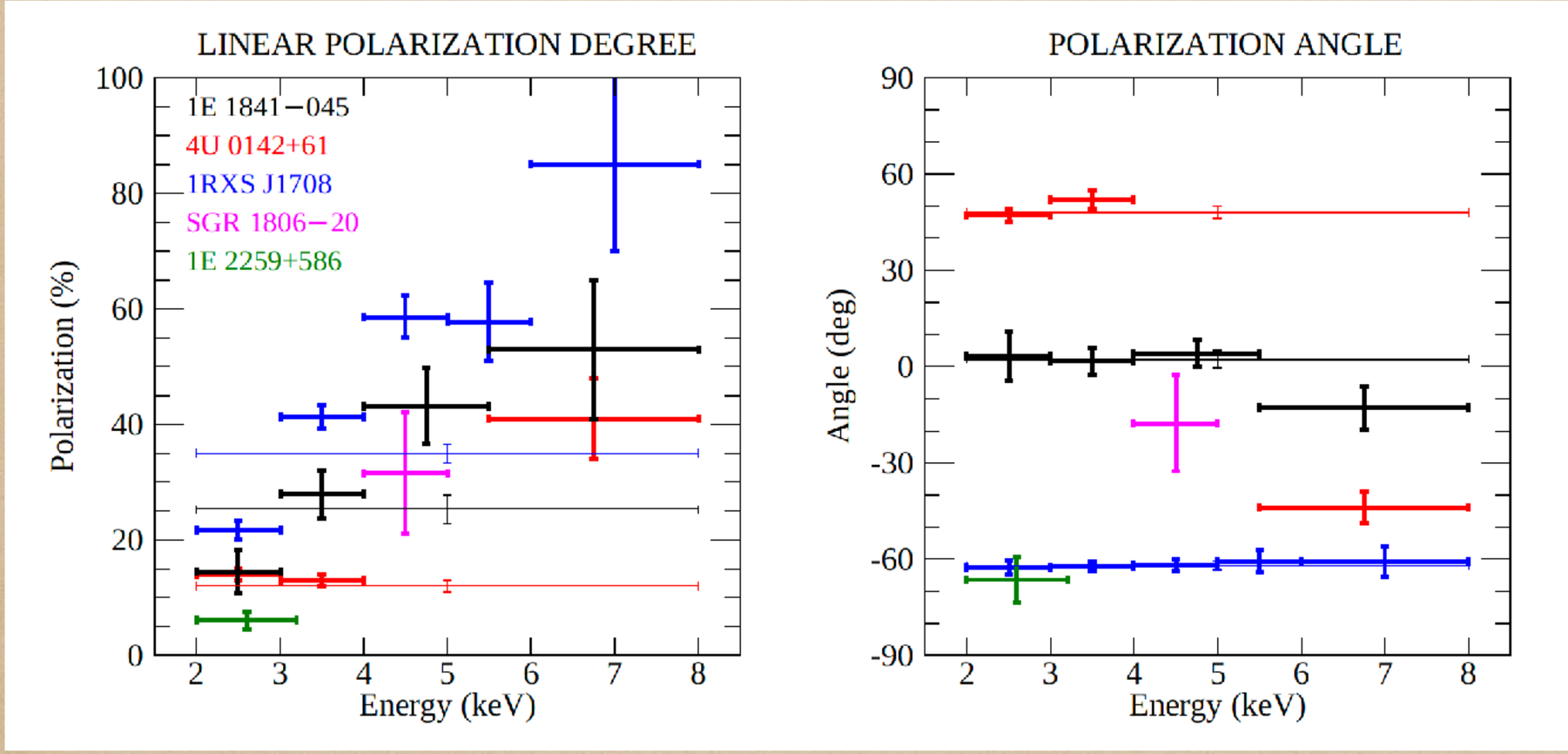
Discovery of diffuse X-ray emission around a Pulsed ULX source



The presence of a nebula around NGC 5907 X-1 implies that ULX phase lasts more than 100 kyrs

Belfiore, Esposito, Pintore+ 2019, Nature Astron.

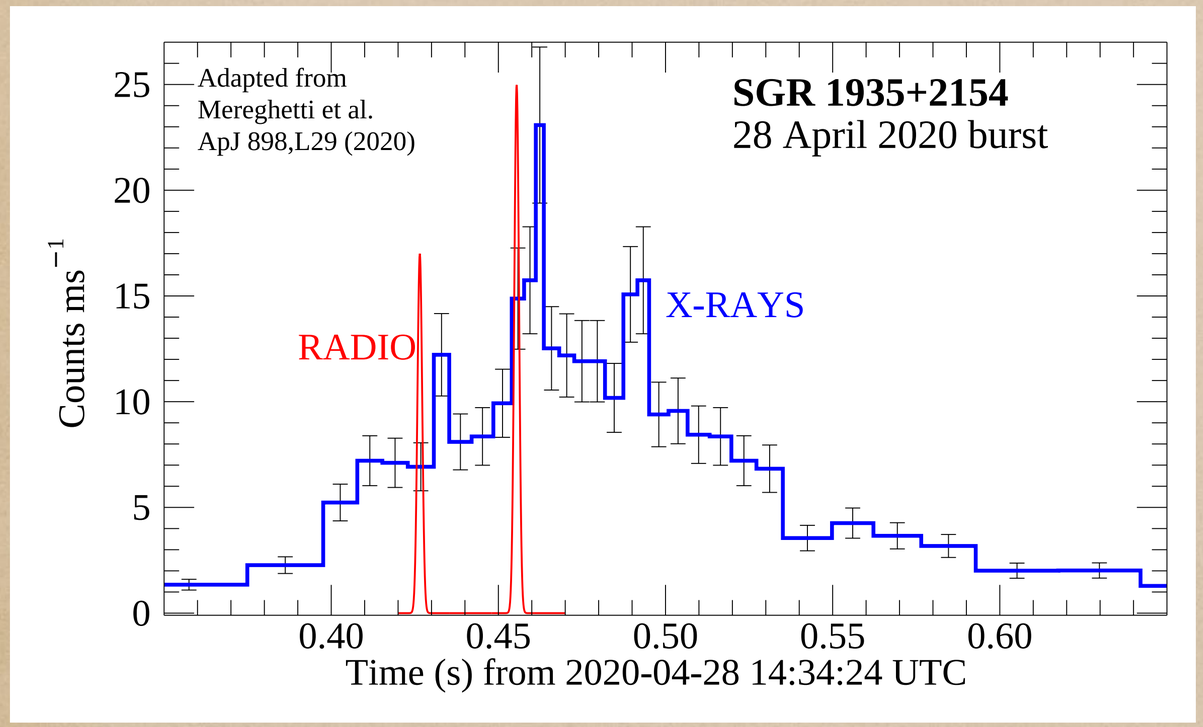
Variety of polarisations properties in 6 magnetars observed with IXPE



Rigoselli, Taverna, Mereghetti+ 2025 ApJ

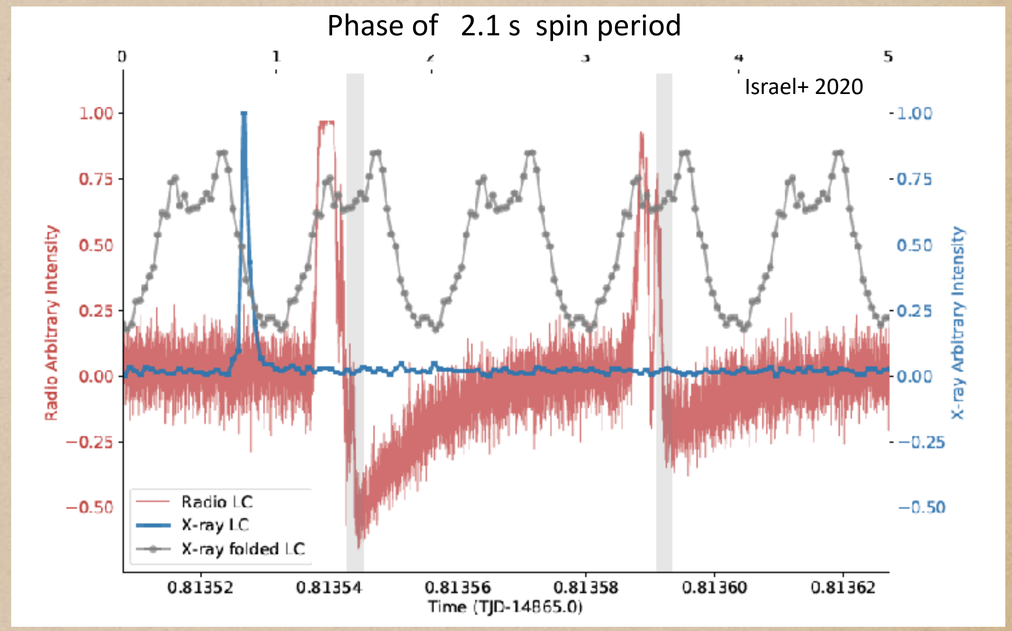
Observational proof of the Magnetar-Fast Radio Burst connection

FRB-like burst from Galactic Magnetar SGR 1935+2154



Mereghetti+ 2020, ApJ

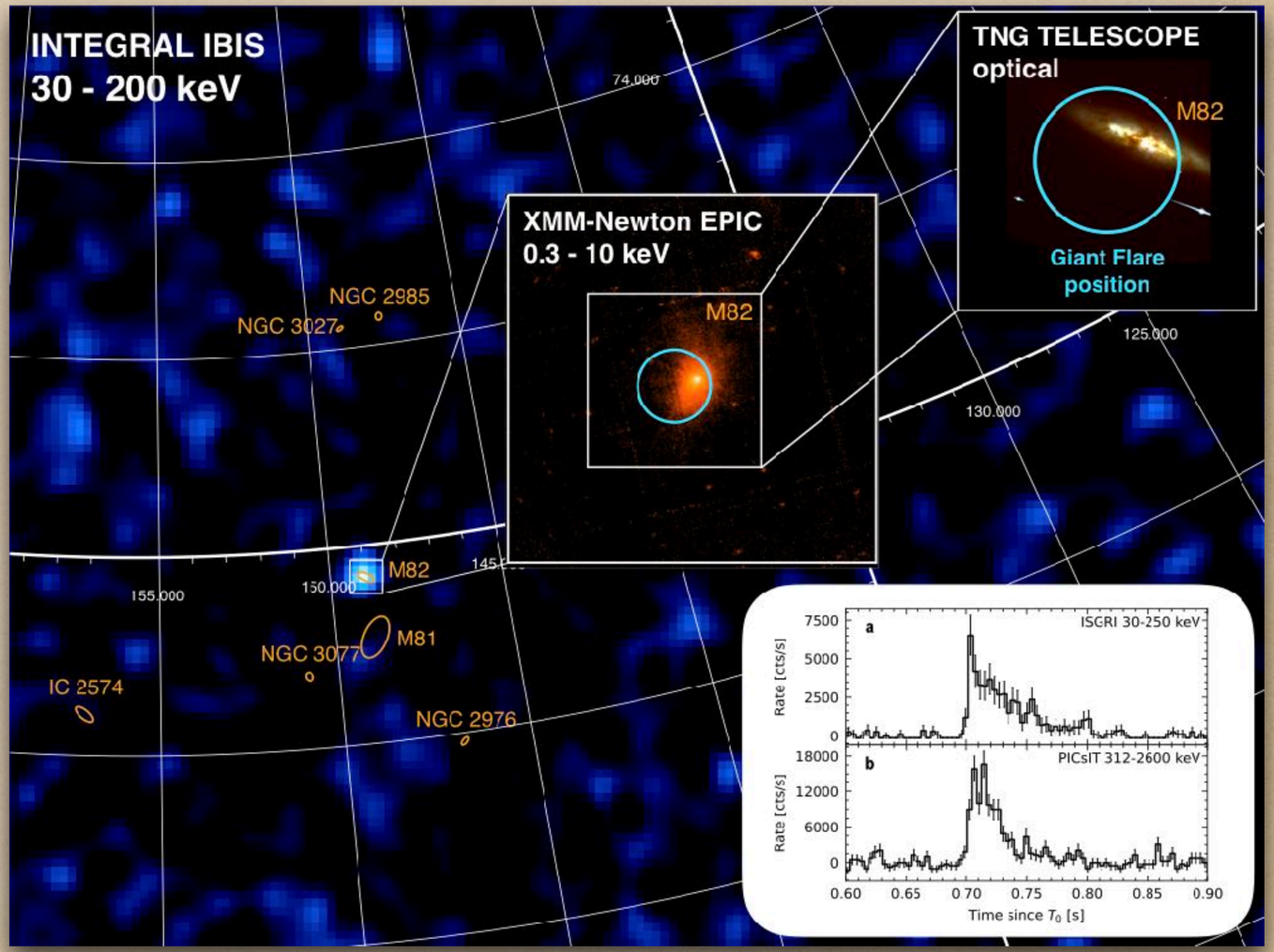
X-ray and radio bursts from 1E 1547-5408



Israel, Burgay + 2020, ApJ

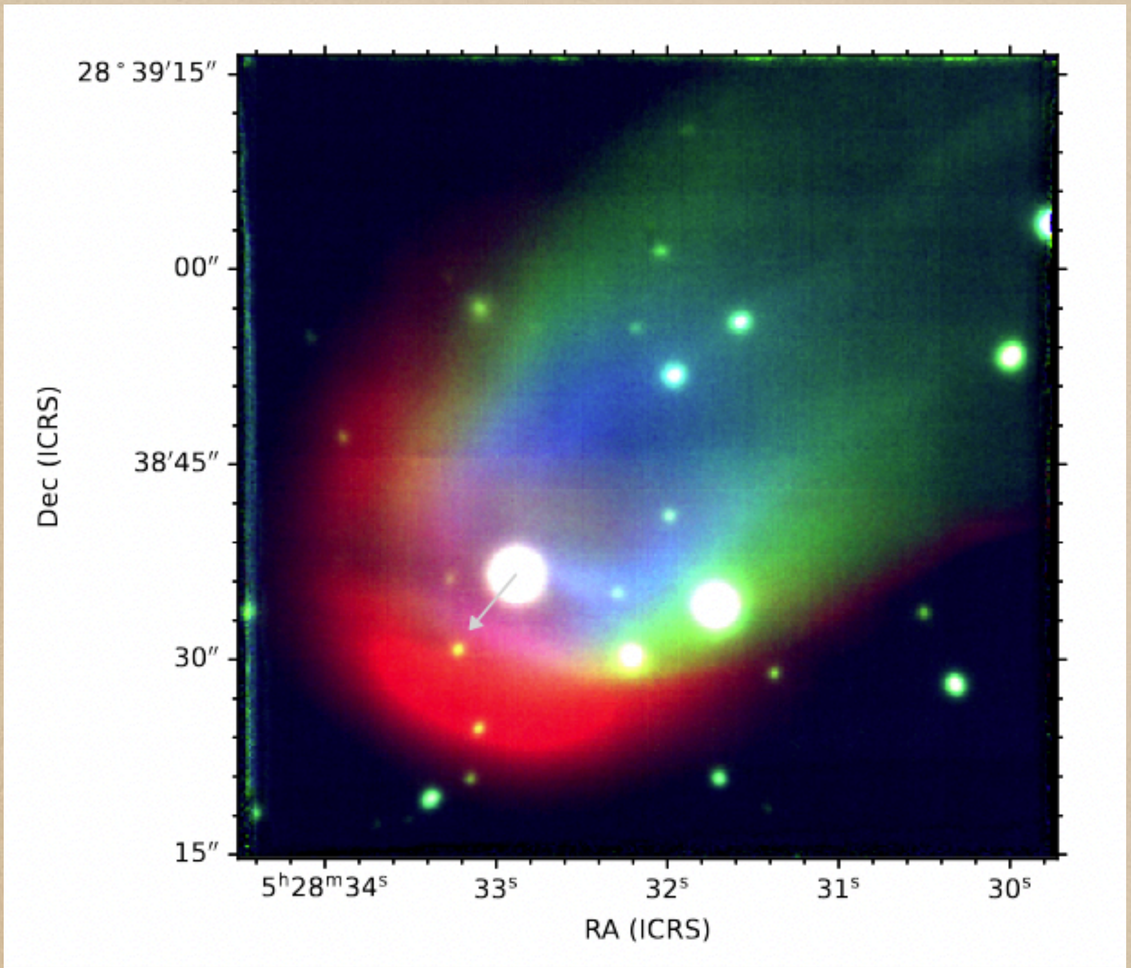
INTEGRAL discovery of MGF 231115A in starburst galaxy M82

The small error region (R~2 arcmin) automatically distributed after only 13 s thanks to the INTEGRAL Burst Alert System allowed a firm classification of 231115A as Giant Flare from a magnetar in the nearby starburst galaxy M82.



Mereghetti, Rigoselli, Salvaterra+ 2024, Nature

Bow shock in diskless magnetised (~40 MG) accreting WD



High luminosity (~10^{33} erg/s) cannot be explained by donor's wind or past thermonuclear explosions.

A different energy source (magnetic activity ?) active for last 1000 yrs required to explain the tail.

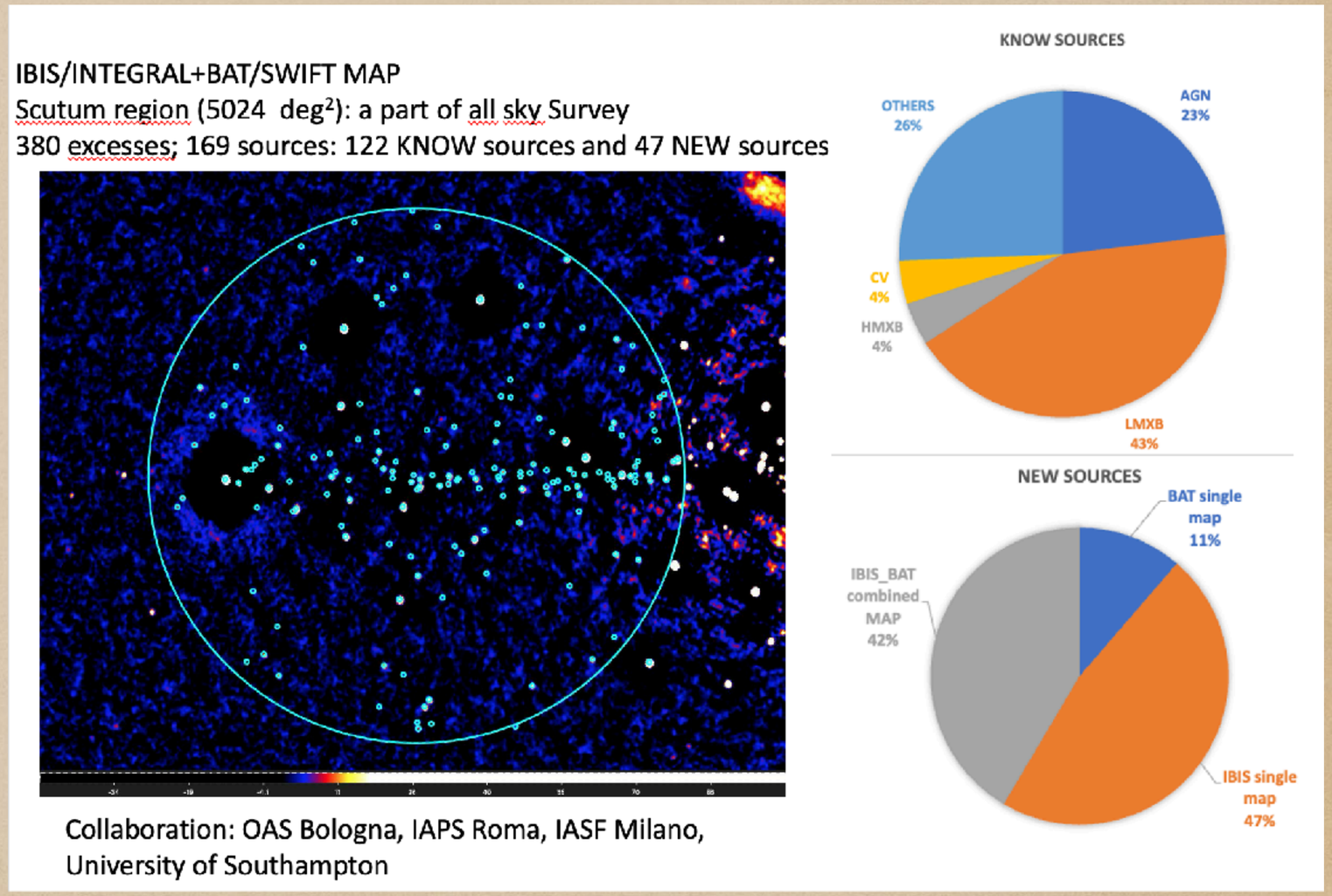
Ilkiewicz, Scaringi, De Martino + 2026, Nature Astron.

Important activities based on large datasets of archival data

e.g. :

- Joint INTEGRAL/IBIS + Swift/ BAT survey
- INTEGRAL SGR bursts Catalog
- EXTRAs project for variability with XMM-Newton/EPIC
- μQSOs in AGILE GRID data

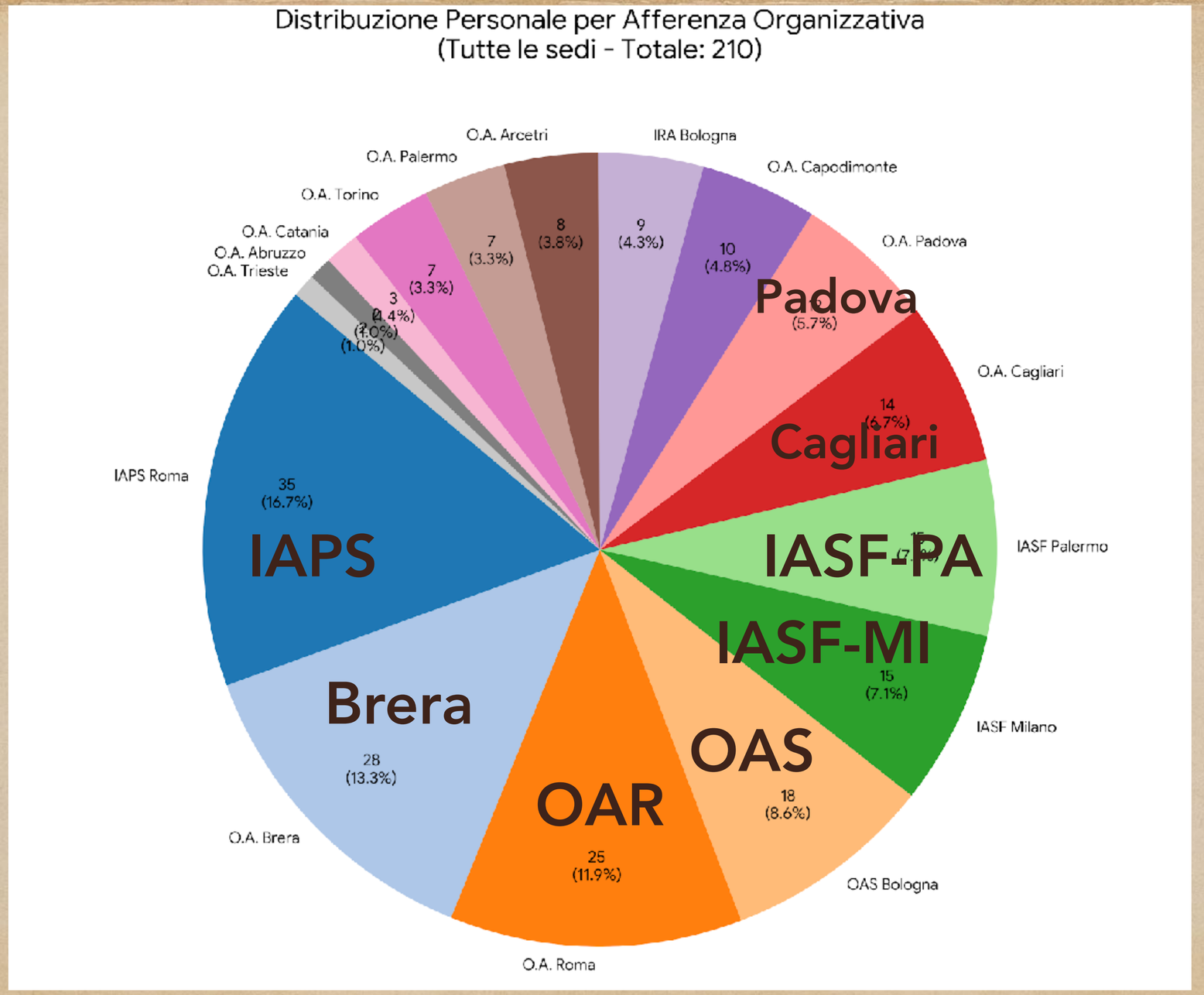
etc…



Courtesy M.Fiocchi

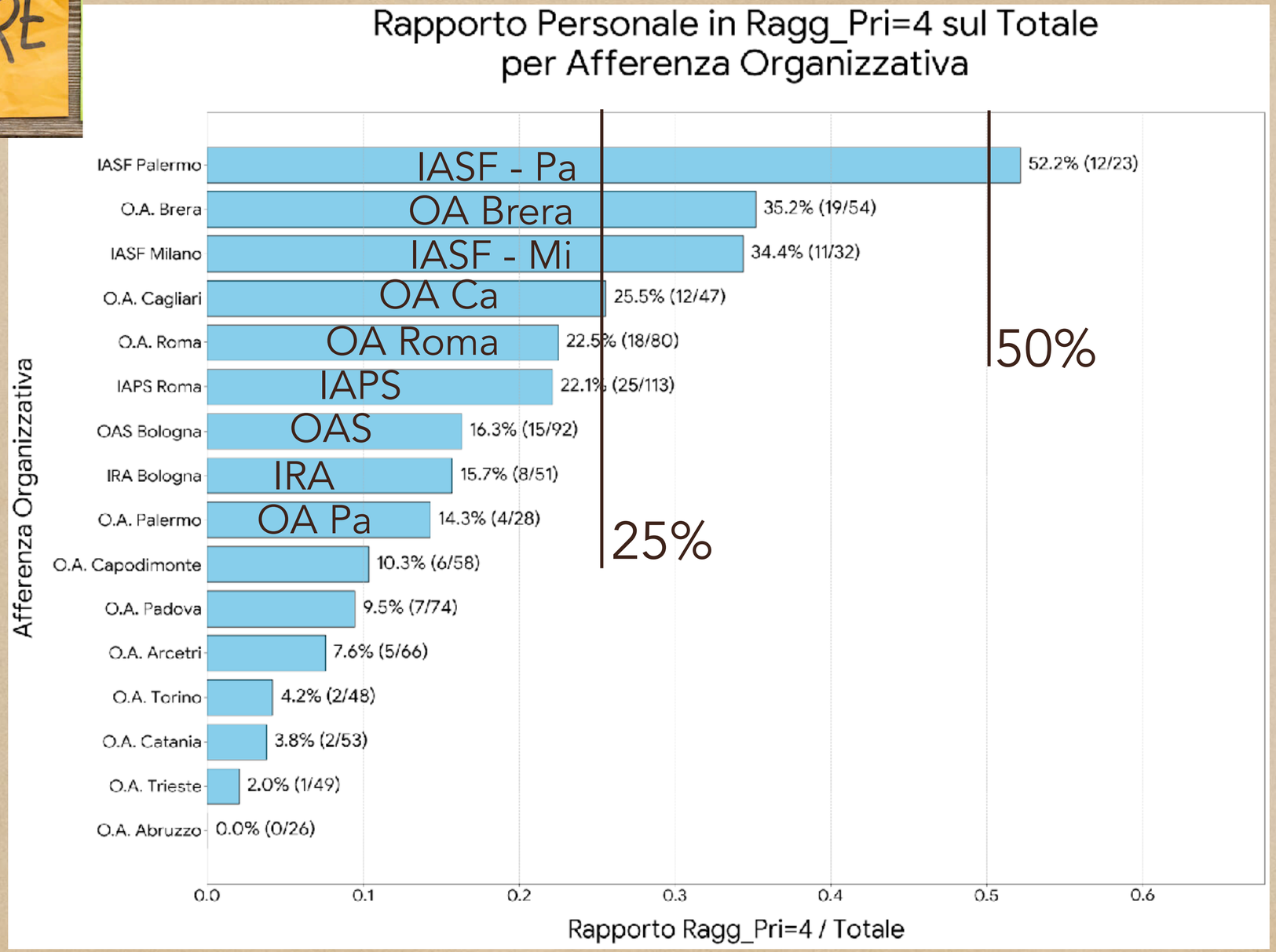

WHEN
WHERE
WHAT
WHO
HOW
WHY

WHERE



RSN4 presente in tutte le strutture

WHERE



In alcune strutture RSN4 rappresenta una grande frazione dell'attività di ricerca

Large **network** of **excellent** scientists and groups across ~all INAF structures, with **strong cohesion** deriving from long-established successful collaborations

World-wide recognised expertise - many collaborations with major international groups

Strict collaboration with Italian University groups

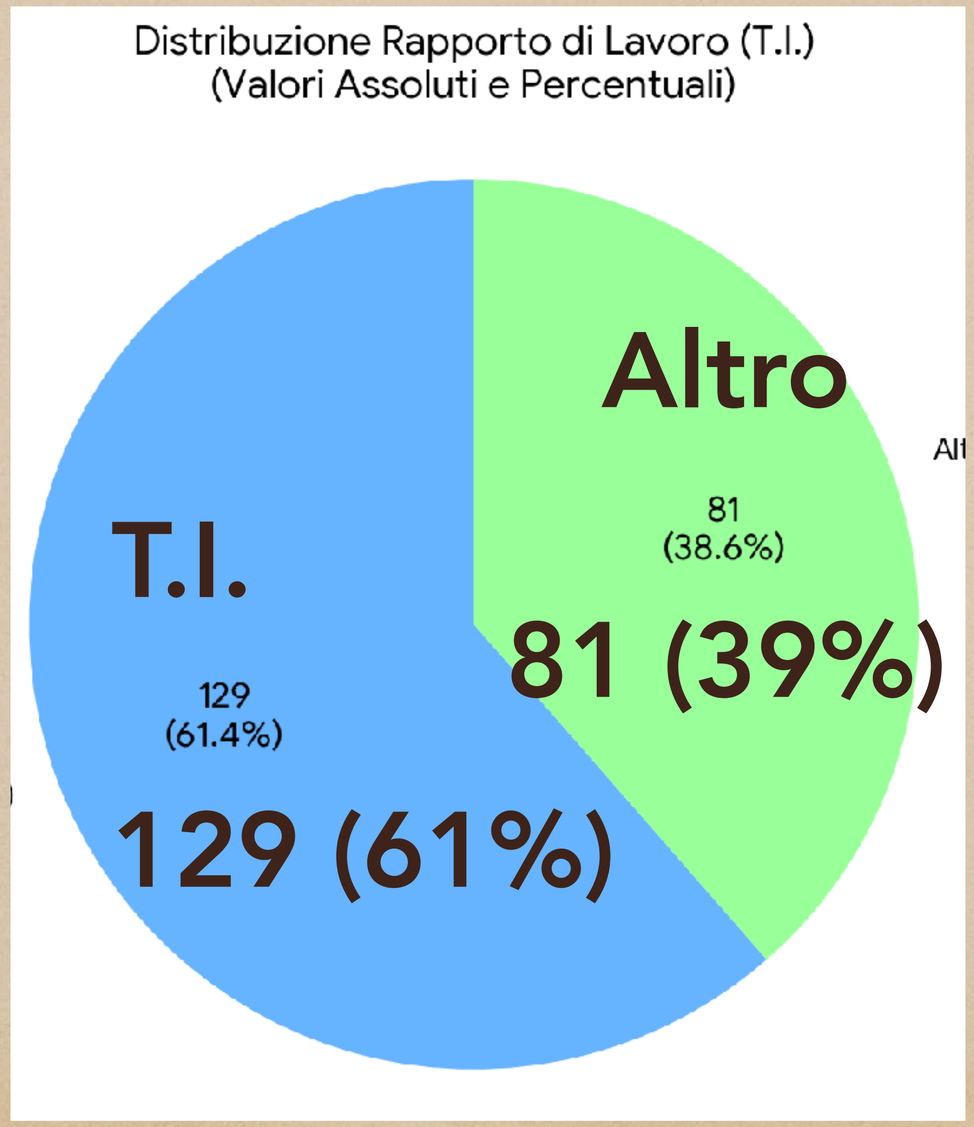
Deep involvement in space and ground facilities developed with significant INAF contributions

WHO

CNOC XIII

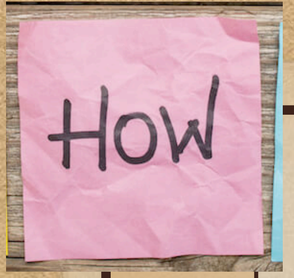
Congresso Nazionale Oggetti Compatti - Alghero - sett. 2025

Il contributo dei precari è essenziale per queste attività



210 ricerc. /tecnol.
in RSN4

< 60% Tempo
Indeterminato



2022	LG	**Magnetars** (Mereghetti)	126
		Pulsar/black-hole systems and other jewels in globular clusters (Possenti)	200
		FANS- Uncovering the optical beat of the **fastest magnetised neutron stars** (Papitto)	150
	GO + LGO + Theory + Mini		~130
2023	LG	Gravitational Wave Detection using **Pulsar Timing Arrays** (Perrodin)	199
		BLOSSOM - **Black holes** Swift fOrMation (Pinto)	200
	GO + LGO + Theory + Mini		~185
2024	LG	COMEFAR - COordinated Multiwavelength Exploration of **fast radio bursts** (Pilia)	200
		TULIP - Timing the **Ultra-Luminous X-ray Pulsars** (Israel)	166
	GO + LGO + Theory + Mini		~320

~ 600 k€ / anno da bando INAF Astrofisica Fondamentale

CONCLUSIONS

- The study of stellar mass compact objects is one of the fields of scientific excellence in INAF

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- It holds strategic importance for the scientific exploitation of several future facilities, where INAF plays a major role
- Adequate and stable funding is required to maintain and strengthen the existing **excellence network** of INAF scientists in this field, with particular attention to the youngest researchers

Il problema principale