

High Mass X-ray Binaries

Lara Sidoli

(INAF-IASF Milano)

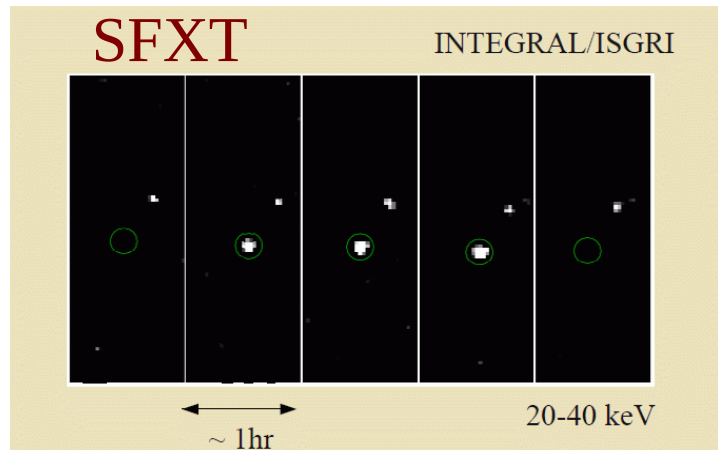
Bazzano A., Esposito P., Fiocchi M., **Israel GL., La Palombara N.,**
Mereghetti S., Natalucci L., **Paizis A.,** Pintore F., Rodriguez Castillo G.A.,
Sguera V., Tiengo A.

*(in **grassetto** hanno contribuito alle slides)*

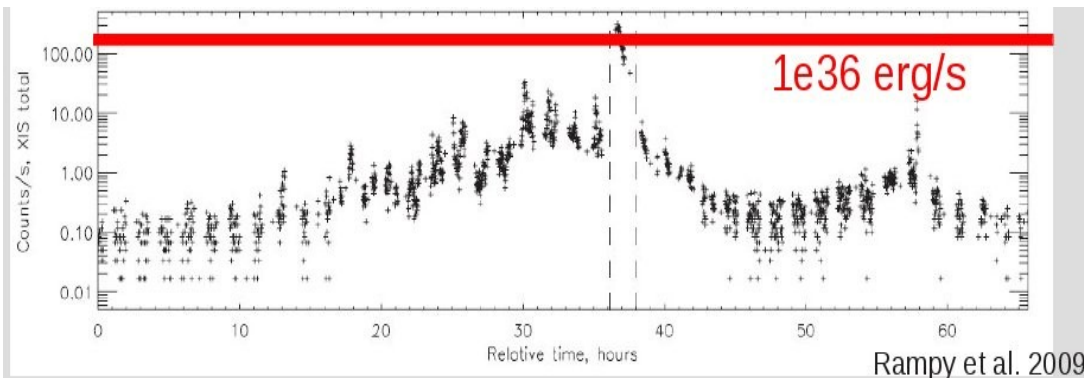
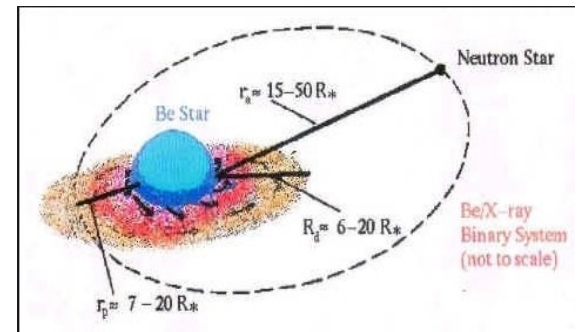
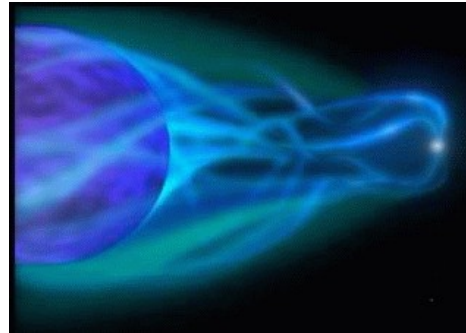
WS MA4 (IASF-Bologna, 7/6/2016)

CASO SCIENTIFICO

Quale tipo di accrescimento nelle Supergiant Fast X-ray Transients?
E' possibile l'unificazione dei 3 tipi di HMXBs?

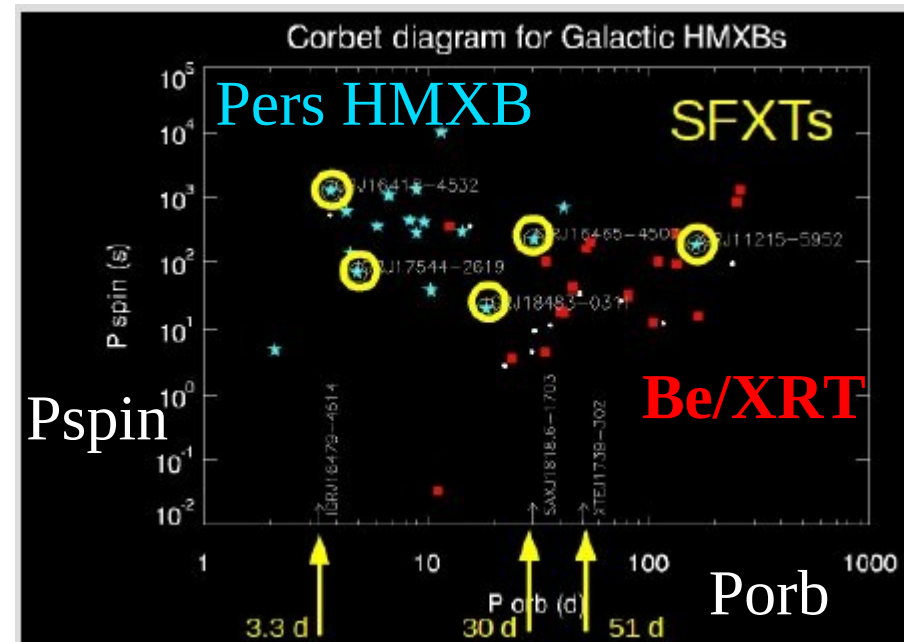


Sguera et al. 2005



SFXT light curve

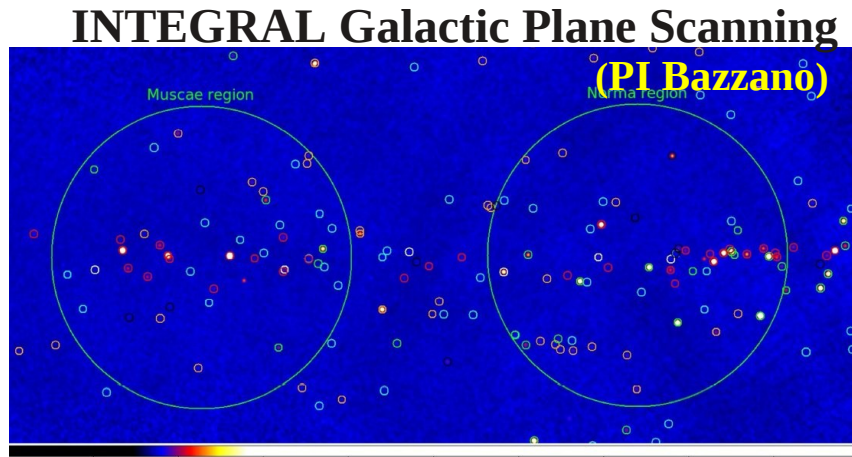
Rampy et al. 2009



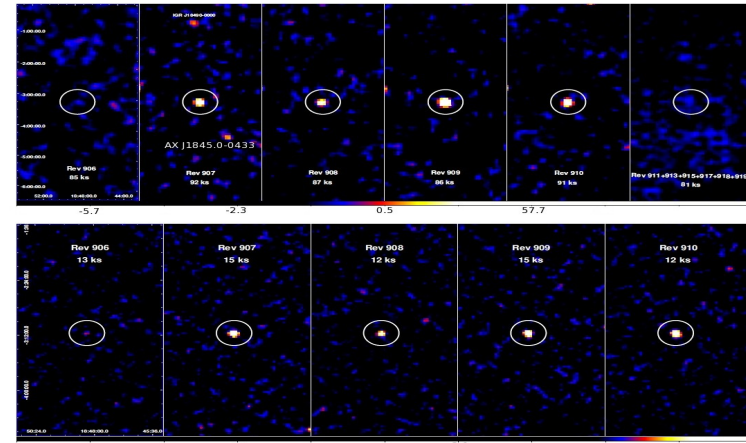
Finanziamenti attivi

- PRIN INAF 2014 (PI Sidoli)
- ASI Nustar 2015 (PI Sidoli; grazie a osservazione accettata XMM+**NuSTAR** della SFXT IGRJ11215-5952)
- Fondi ASI INTEGRAL (PI Ubertini) per archivio e hardware

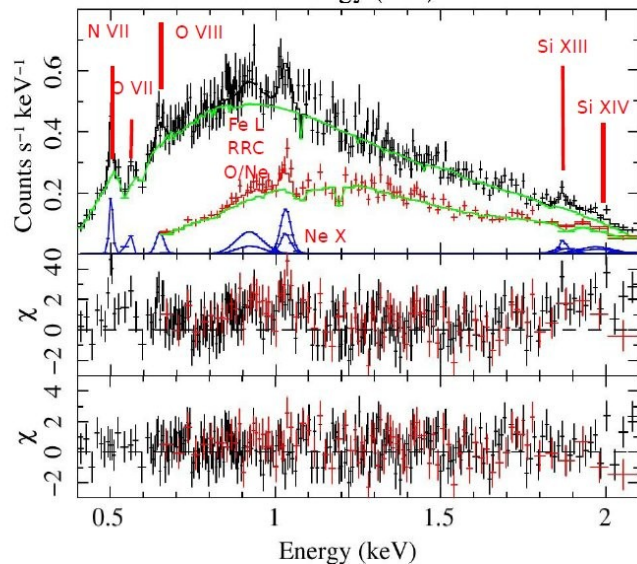
Osservazioni: programmi di monitoring + proposal su singole sorgenti



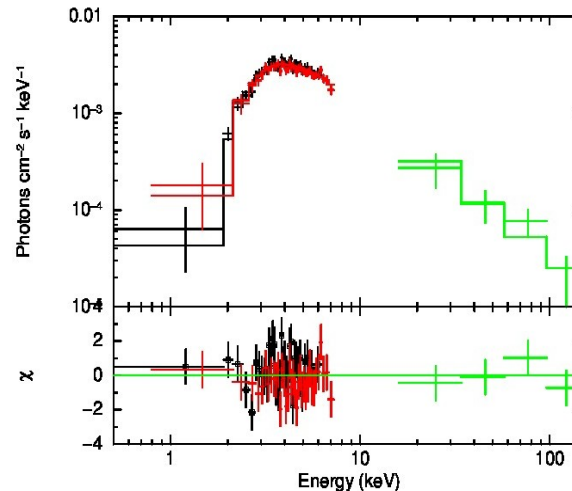
<http://gpsiasf.iasf-roma.inaf.it/>



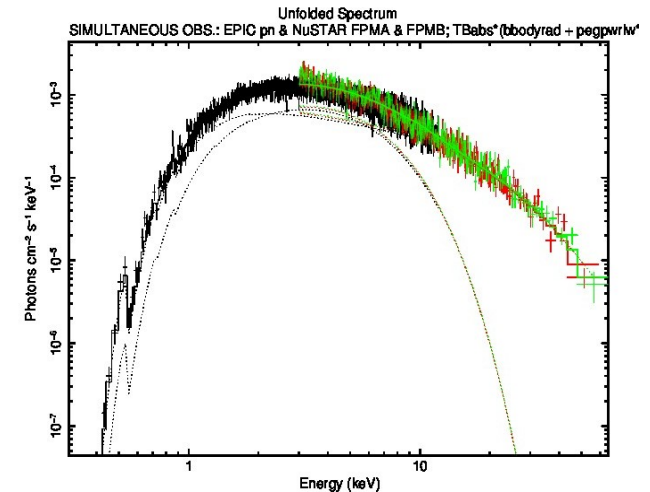
INTEGRAL PoM (Sguera et al. 2015)



XMM-RGS (La Palombara et al. 2016)



Chandra+Swift/BAT (Paizis et al. 2015)



XMM+NuSTAR
(Sidoli et al. 2016, XMM conf)

Principali collaborazioni internazionali

Tony Bird et al.



Shakura & Postnov



Universita' di Mosca

Sinergie con esperti di venti stellari da stelle massive:



Team **ISSI** (PI Martinez-Nunez)

Towards a unified view of inhomogeneous stellar winds in isolated supergiant stars and supergiant high mass X-ray binaries

Silvia Martínez Núñez · Peter Kretschmar ·
Enrico Bozzo · Lidia M. Oskina · Joachim
Puls · Lara Sidoli · Jon Olof Sundqvist ·
Pere Blay · Maurizio Falanga · Felix Fürst ·
Angel G3mez-Garc3a · Ingo Kreykenbohm ·
Matthias K3hnel · Andreas Sander · Jos3
Miguel Torrej3n · J3rn Wilms



Berna

Evento E 1.10 on HMXBs and stellar winds

(MSO: Sidoli, DO: Sguera)

“HMXBs are multidisciplinary objects bridging together different communities, the experts of **stellar winds** and the experts of **accretion onto compact objects**”

INTEGRAL archive(s) @IASF-Mi

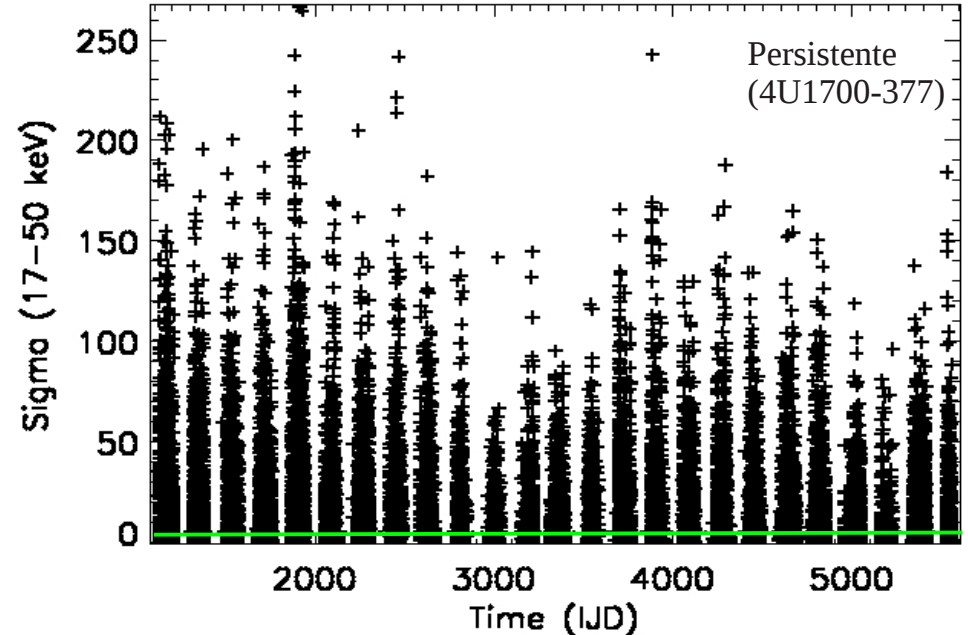
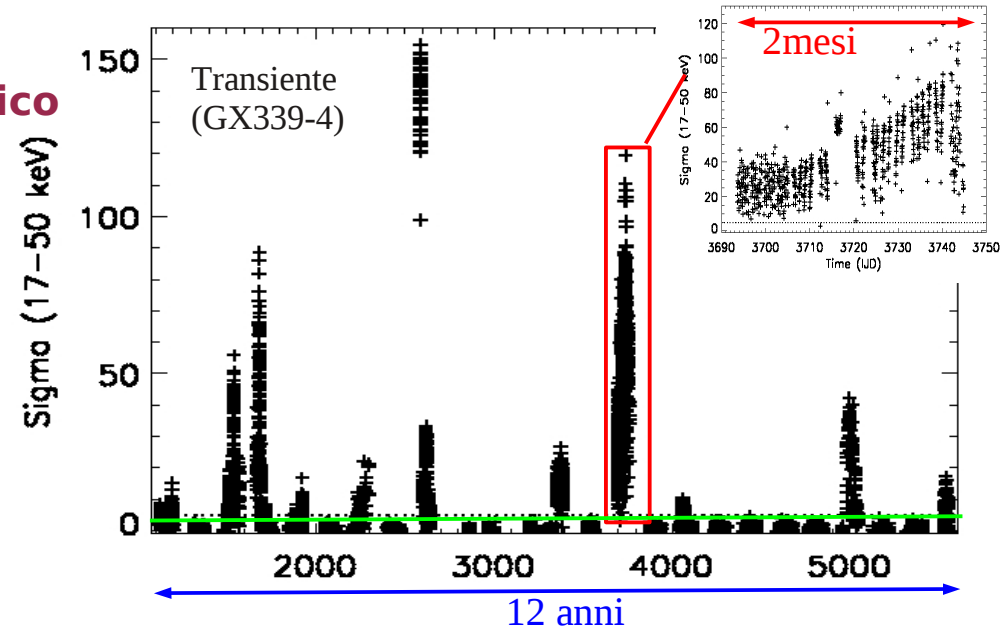
(creature di Ada Paizis, con supporto tecnico di M.Fiorini e R.Regni Ponzeveroni)

GOLIA

- 12 Tb di dati pubblici INTEGRAL 2002-2014
- Analisi di IBIS
- Tools per estrarre/visualizzare i risultati dell'analisi
- Descrizione archivio e lavori HMXB:
 - Paizis, Mereghetti et al 2013
 - Paizis & Sidoli 2014
 - Shakura, Postnov, Sidoli, Paizis 2014
 - Sidoli, Paizis et al., 2015
 - Shakura, Postnov et al., 2015
 - Sidoli, Paizis, Postnov 2016

ANITA (on-going)

- 24 Tb disponibili
- Dati pubblici: 2002-fine missione
- Analisi di IBIS & JEMX
- ... e poi si vedrà!



The Chandra Timing Survey (2TI + 2TD; initial funds from ASI 2007-10)

A systematic and automatized search for signals in 10.700 public Chandra fields.

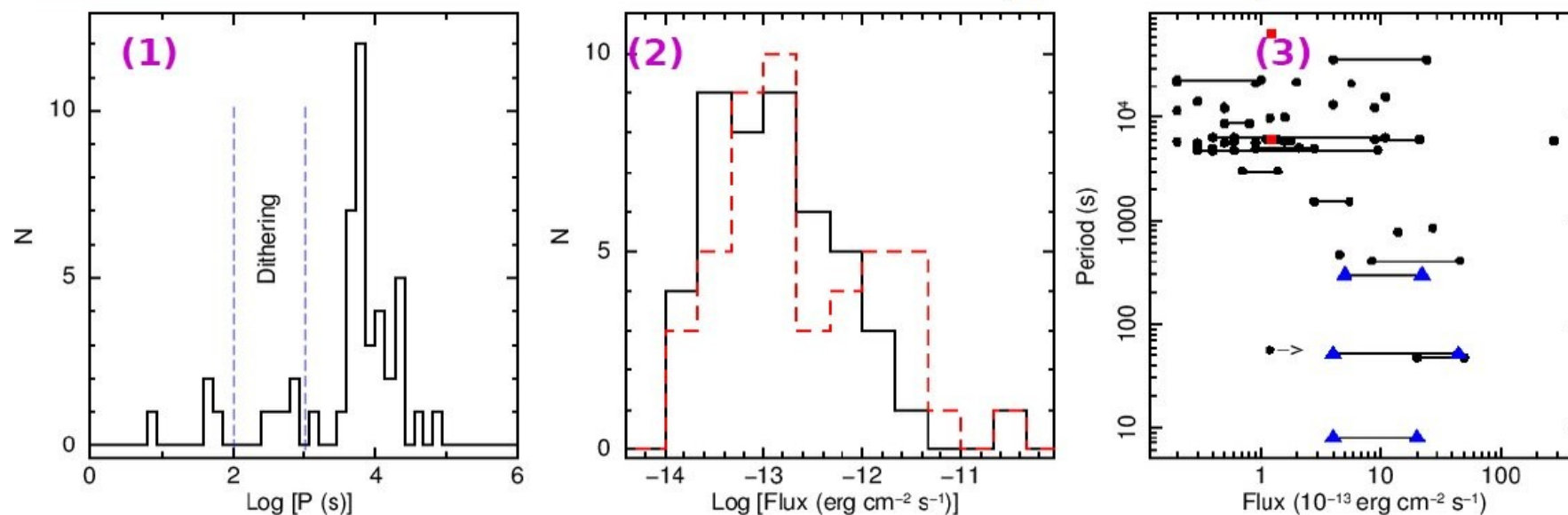
190.000 time series searched with a FFT and an ad hoc algorithm.

42 new X-ray pulsators identified so far: living project. (Israel et al. 2016, MNRAS submitted)

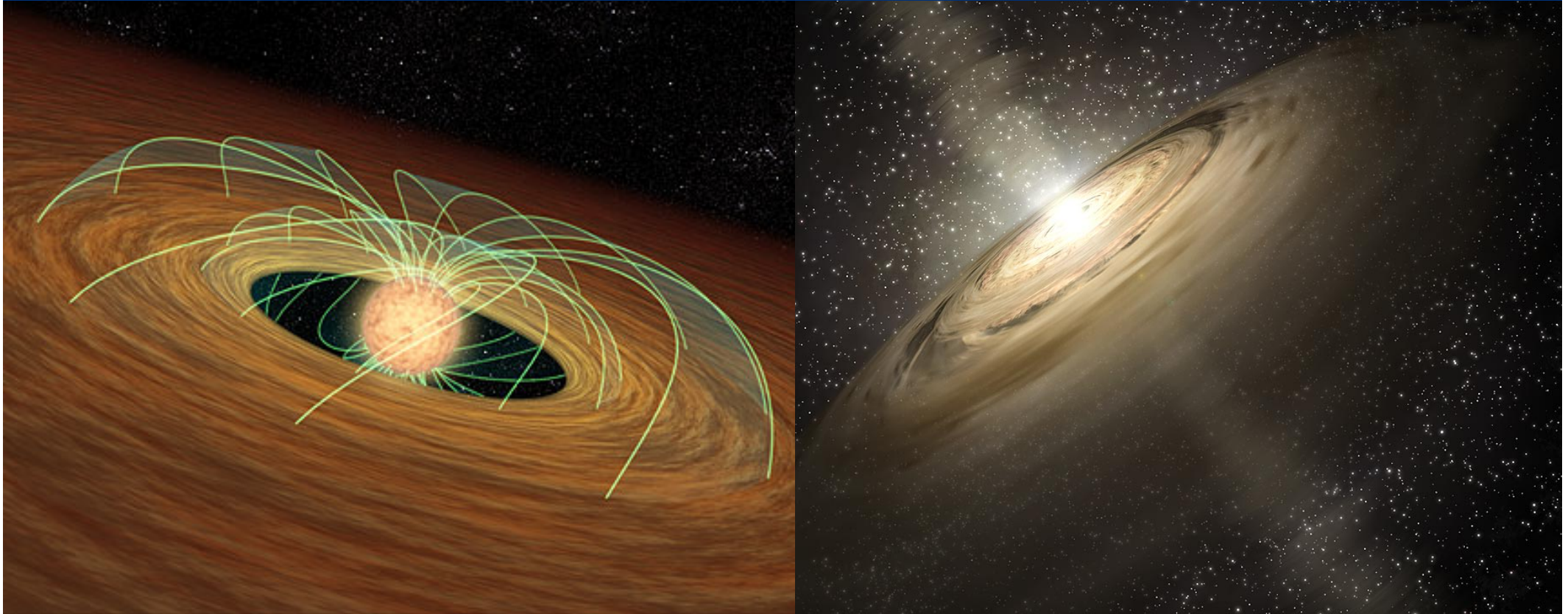
Main properties: (1) long period distribution similar to that of Cvs, (2) more than 3 order of magnitudes in flux sampled (peaking around 10^{-13} ergs/cm²/s), (3) short period distribution likely in agreement with the magnetic gating scenario.

Main results: 2 pulsars in HMXB, one BHC in a WR binary, the CV population in the Circinus Galaxy, a new supergiant HMXB or a SFXT. (Esposito et al. 2013a, 2013b, 2013c, Esposito et al. 2015; Sidoli et al. 2016)

Future: XMM EPICs → EXTraS (FP7), 50-100 new X-ray pulsators expected



Stelle di Neutroni in Low Mass X-ray Binaries



Tiziana Di Salvo
Dipartimento di Fisica e Chimica
dell' Università di Palermo

Workshop INAF M4
Bologna, 7 Giugno 2016

Gli Oggetti della ricerca

Objects:

- Classical LMXB: Transient and Persistent sources, High-inclination (dipping and eclipsing) sources, Very Faint and burst-only LMXBs
- Accreting Millisecond Pulsars and Transitional Pulsars

Studies:

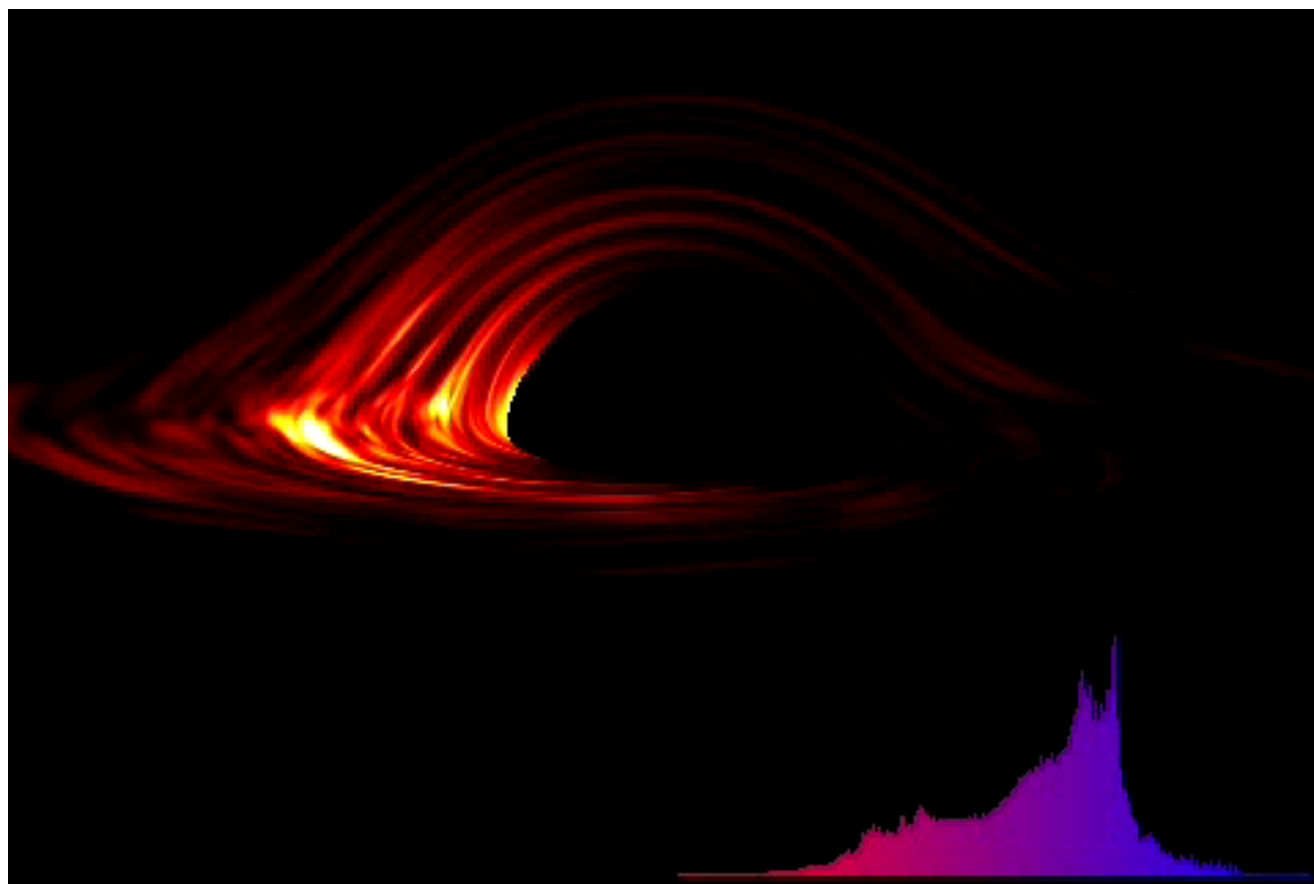
- Broad-band Spectral analysis and Spectroscopy: diagnostic and modeling of the emitting region
- Spin and Orbital Timing: Properties and long-term evolution
- Theoretical Studies: Modeling and Secular evolution (Recycling Scenario)
- Multi-Wavelength Studies: X-ray, radio, IR/Optical/UV, Gamma

Highlights della Ricerca: Spettroscopia

studio dei profili relativistici della riga del Fe

Dallo studio del profilo di riga (ed altre features di riflessione) ricaviamo informazioni dettagliate sulla regione di emissione a pochi km dalla superficie della NS.

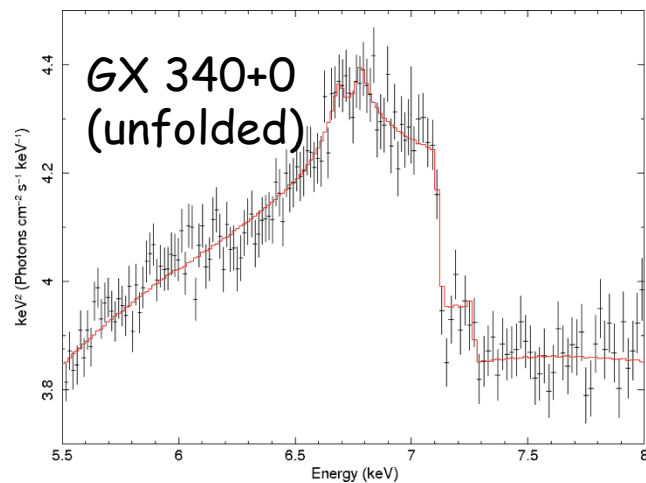
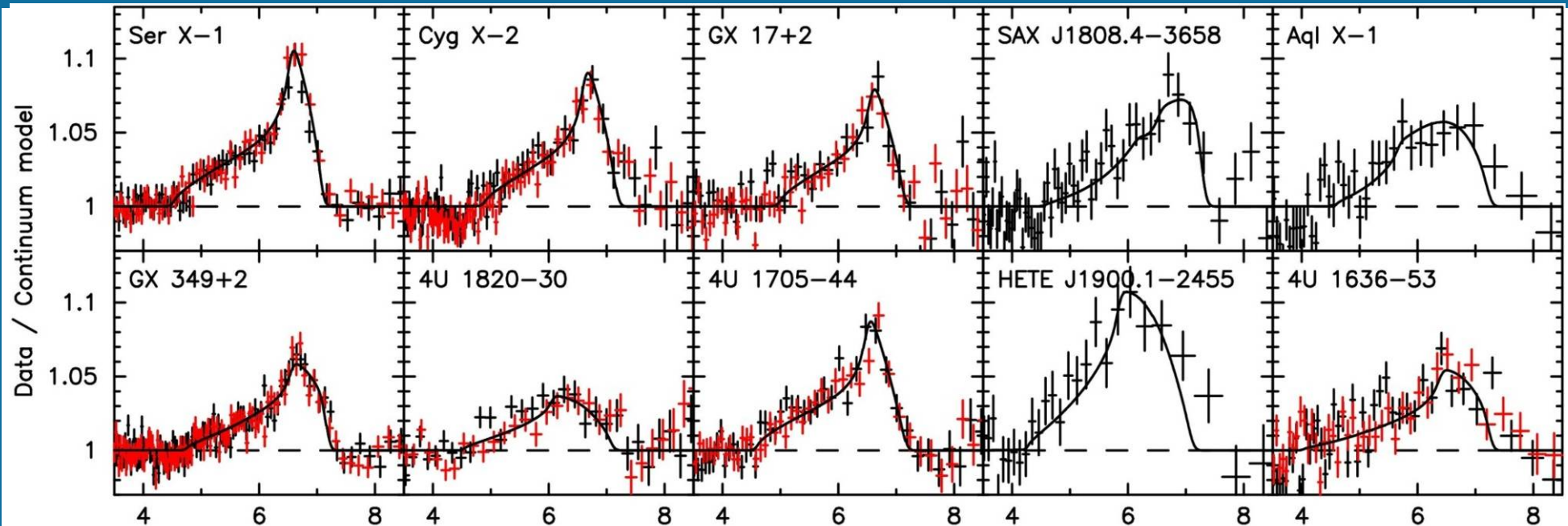
In prospettiva tale studio potrebbe portare alla determinazione della massa e raggio della NS (e quindi alla EoS della Materia Ultra-densa)



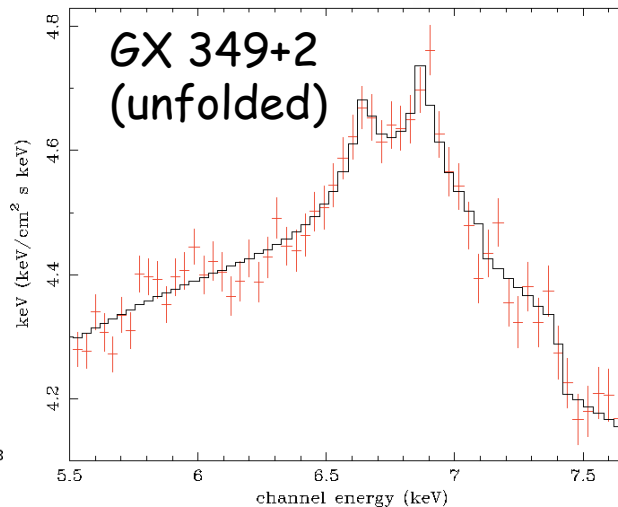
La luce emessa dal retro del disco viene distorta e risulta visibile all' osservatore

Line profiles in Neutron Star Binaries

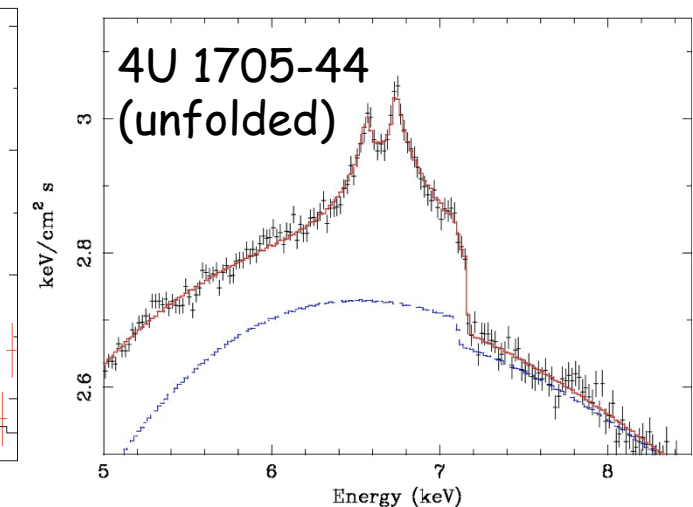
Cackett et al. 2009



D'Ai et al. (2009)



Iaria et al. (2009)



Di Salvo et al. (2009)

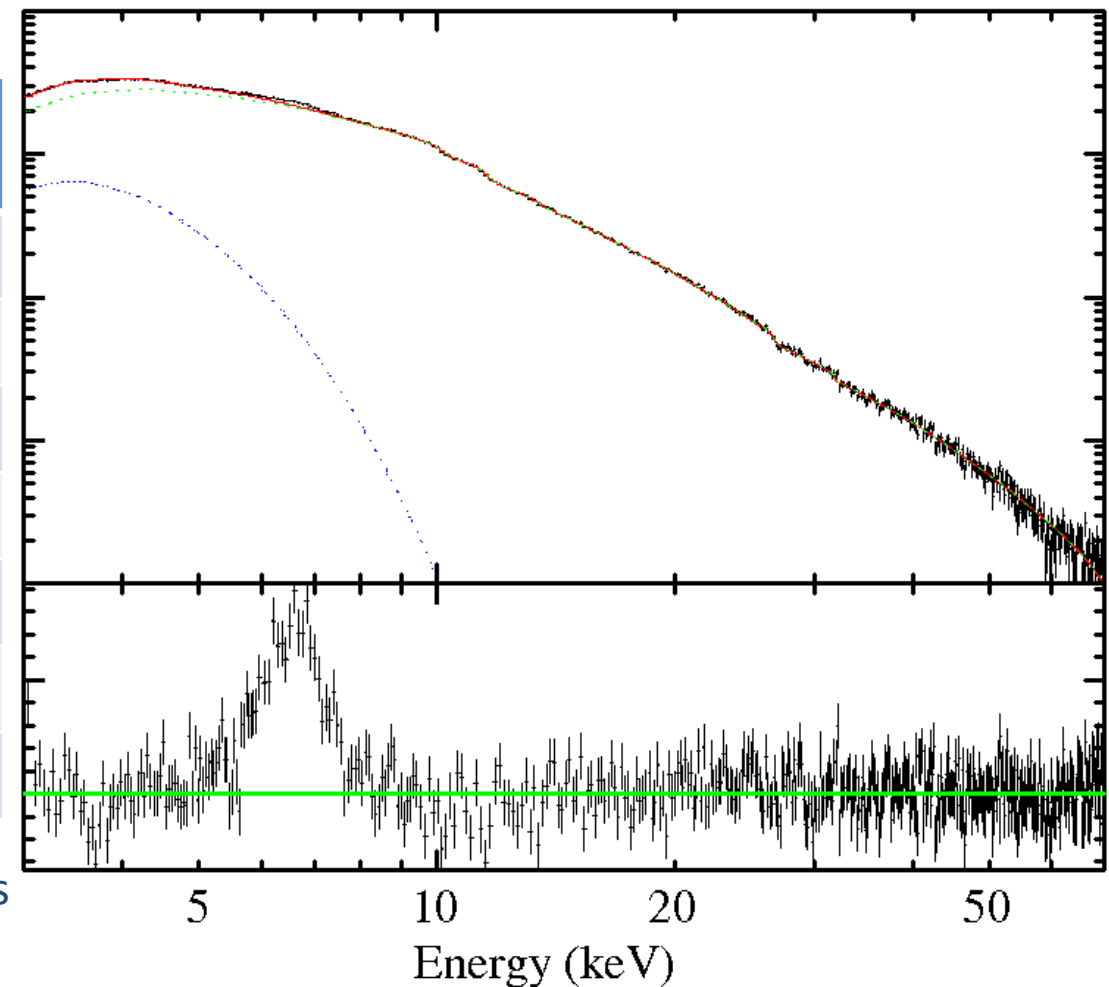
NuSTAR broad-band spectrum of SAX J1808

Continuum fitted by photoelectric absorption, a soft blackbody ($kT \approx 0.68$) and a thermal Comptonization spectrum ($kT_{\text{seed}} \approx 0.05$ keV, $\Gamma \approx 1.8$, $kT_e \approx 30$ keV)

NuSTAR spectrum of SAX J1808.4–3658

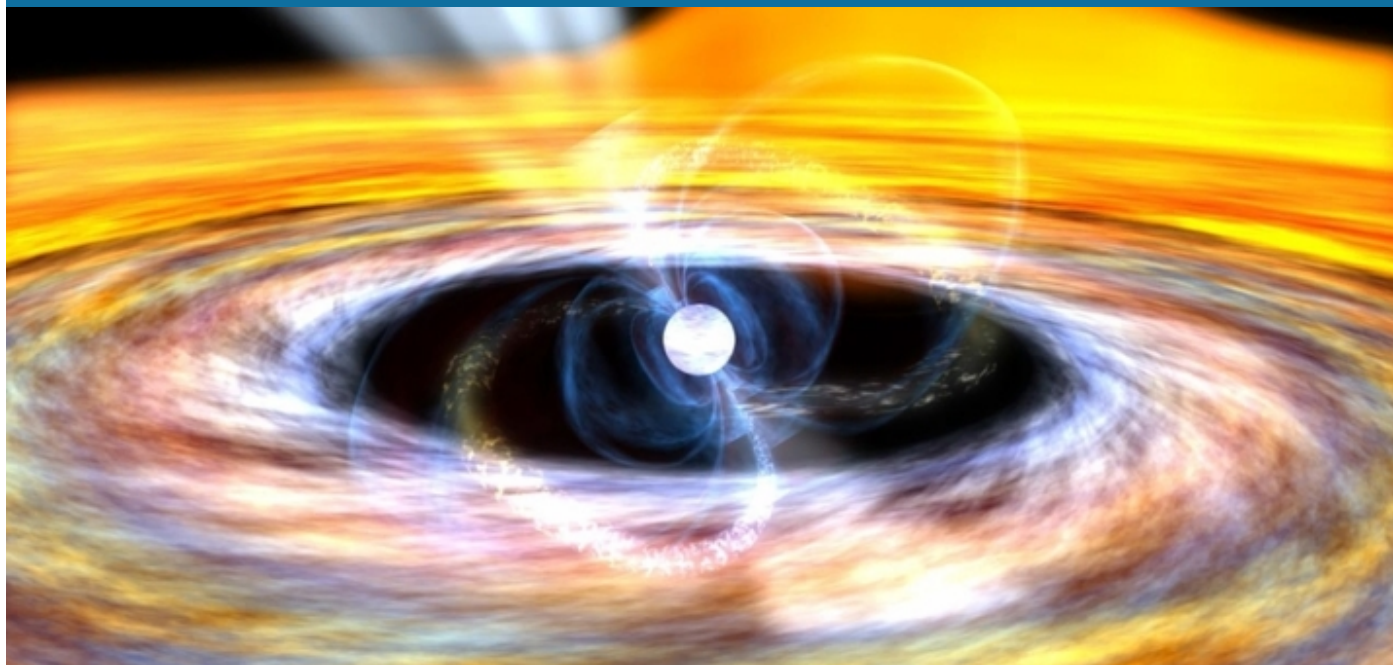
Results of the fitting with a diskline 10

Parameter	Value (NuSTAR)	2008 (XMM)
E (keV)	6.47 ± 0.06	6.43 ± 0.08
Betor	-2.2 ± 0.3	-2.3 ± 0.3
Rin (Rg)	< 10	8.7 ± 0.4
Rout (Rg)	$240 \div 1800$	$127 \div 318$
Incl (deg)	50 (fixed)	> 58
Eqw (eV)	100 ± 10	120 ± 20
χ^2	1676/1663	810/639



The broad Fe line is visible in the residuals
Gaussian sigma would be ≈ 0.7 keV

Highlights della Ricerca: Timing



Il **timing di alta precisione dello spin delle millisecond pulsar** in accrescimento permette di studiare lo scambio di momento angolare tra la materia in accrescimento e la NS. L'evoluzione a lungo periodo dello spin ci dà info sullo spin-down secolare.

Effettuiamo anche il **timing del periodo orbitale** al fine di studiare l'evoluzione secolare di questi sistemi e verificare lo scenario del “**recycling**”, ed il link evolutivo tra le LMXBs e le Millisecond Radio Pulsars (e.g. Black Widow, Red-Back, etc.).

Highlights della ricerca

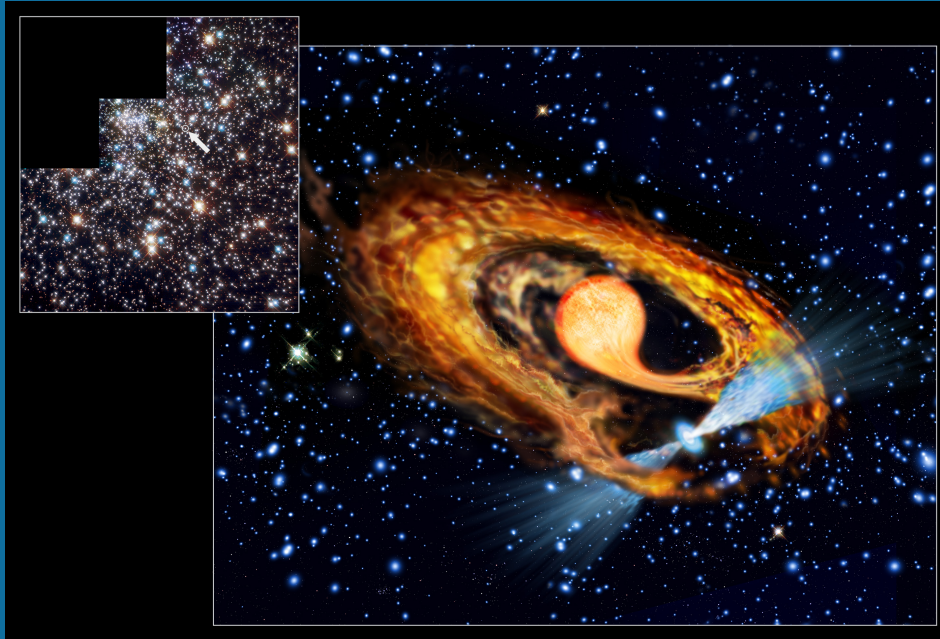


Illustrazione di una sorgente durante la fase di Radio ejection (Burderi et al. 2001, 2003).

Il modello del “radio-ejection” ha avuto importanti conferme (e.g. PSR J1740-5340 qui raffigurata, Courtesy of NASA). La più recente conferma del recycling scenario nell’articolo qui sotto.

Swinging between rotation and accretion power in a millisecond binary pulsar

A. Papitto¹, C. Ferrigno², E. Bozzo², N. Rea¹, L. Pavan², S. Campana³, P. Romano⁴, L. Burderi⁵,

T. Di Salvo⁶, A. Riggio⁵, D. F. Torres^{1,7}, M. Falanga⁸, J. W. T. Hessels^{9,10}, M. Burgay¹¹, J. M. Sarkissian¹²,

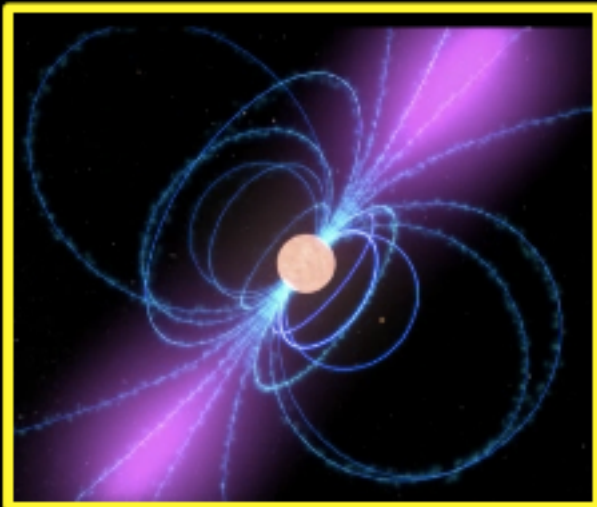
M. H. Wieringa¹³, M. D. Filipović¹⁴, G. F. Wong¹⁴

Papitto et al. 2013, published on Nature

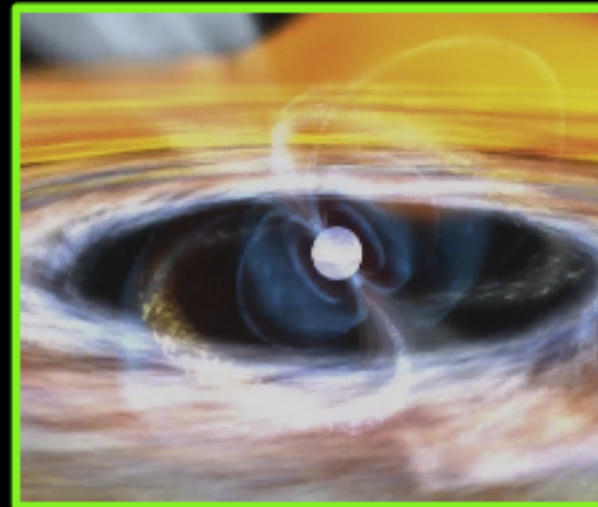
Important discoveries in latest years

- So-called Transitional Millisecond Pulsars (**PSR J1023+0038** – Archibald et al. 2009, Science; **XSS J12270-4859** – De Martino et al. 2010, 2013; Bassa et al. 2014) and the unique object, the missing-link binary X-ray and Radio Millisecond Pulsar, M28, **IGR J18245-2452** (Papitto et al. 2013, Nature).
- The three/four transitional pulsars discovered so far are red-backs.
Why are these ones the only one to switch from X-ray to radio and viceversa?

Radio PSR (rotation power)



X-ray pulsar (accretion power)



Discovery of a millisecond pulsar swinging between:

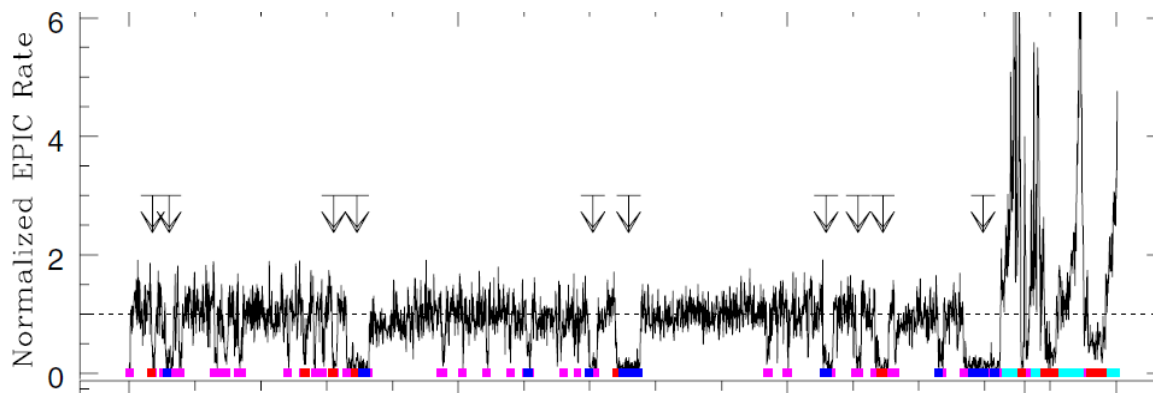
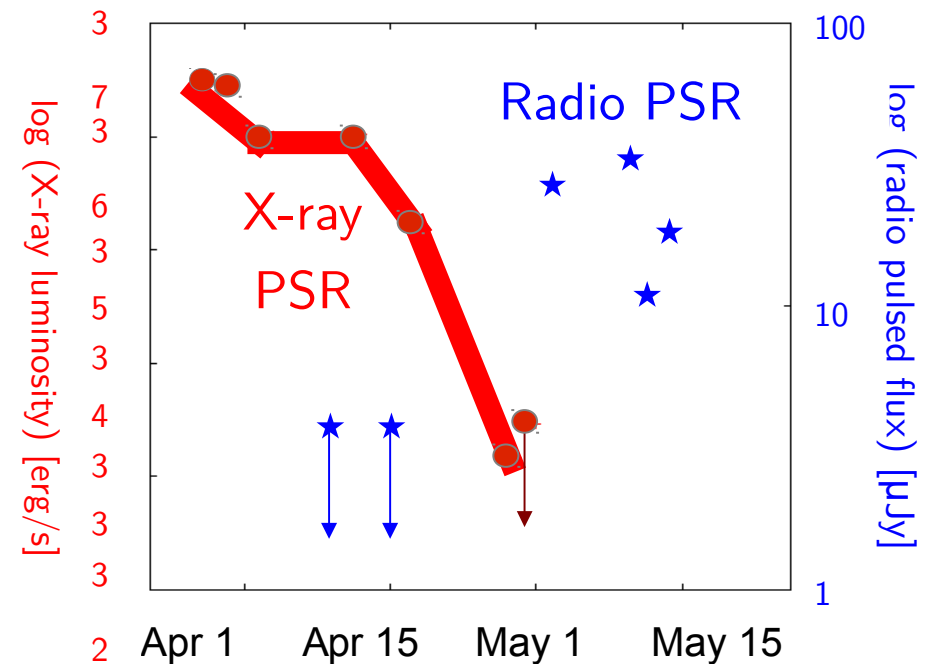
- a rotation-powered radio pulsar state
 - an accretion-powered X-ray pulsar state
- in less than a couple of weeks, as driven by variations of the mass accretion rate

[Papitto, A. et al. 2013, Nature, 501, 517]

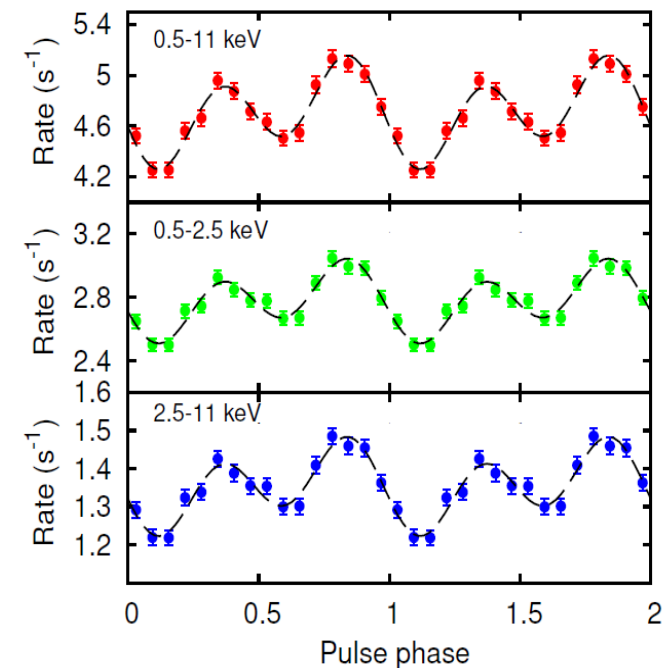
More transitional ms pulsars are being discovered

A sub-luminous accretion disk state with:

- X-ray pulsations at very low luminosity
- Typical variability in X-rays, UV and optical
- Enhanced Gamma-ray emission and radio jets



de Martino et al. 2013



Papitto et al. 2015

Discovery of state transitions of ms pulsars:

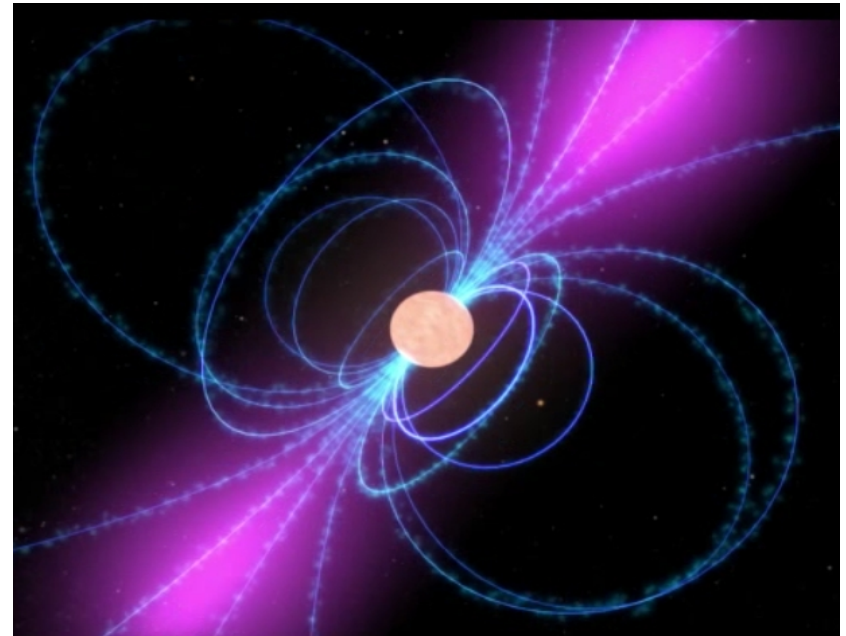
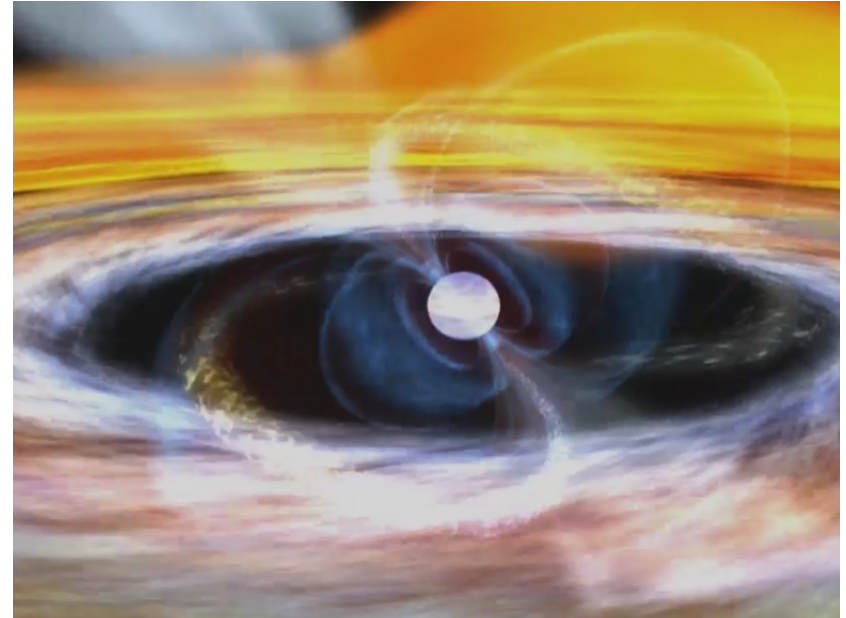
- study of the interaction between the pulsar field/radiation and mass lost from the companion
- coupling between accretion and outflows
- study of the evolution of ms pulsar binaries

A multiwavelength approach:

XMM, Chandra, NuSTAR, INTEGRAL, Swift (X-rays), Fermi (gamma-rays), GTC, REM, TNG, Loiano, OadM (optical), SRT, ATCA (radio)
ongoing observational programs.

A broad collaboration:

A. Papitto, L. Stella (INAF OAR),
L. Burderi (U.Cagliari), T. Di Salvo (U. Palermo),
D. De Martino (INAF OANa), T.M. Belloni, S.
Campana, P. D'Avanzo (INAF OA-Brera),
M. Burgay, A. Possenti, A. Pellizzoni (INAF OACa),
P. Romano (IASF Pa),
N. Rea, D. Torres, E. de Oña (ICE Barcelona),
E. Bozzo, C. Ferrigno (ISDC),
T. Tauris (U.Bonn), J. Hessels (U.Amsterdam),
S. Ransom (NRAO), M. Falanga (ISSI),
I. Stairs (ATNF)



Gruppi Italiani coinvolti nella ricerca

- Gruppo di Astrofisica delle Alte Energie dell' **Università di Palermo**
(Prof. T. Di Salvo, Prof. R. Iaria)
- In collaborazione con **INAF – IASF Palermo** (Dr. M. Del Santo, Dr. P. Romano, Dr. A. D'Ai)
- Gruppo di Astrofisica delle Alte Energie dell' **Università di Cagliari**
(Prof. L. Burderi, Dr. A. Riggio, Dr. A. Sanna)
- In collaborazione con **INAF – Osservatorio Astronomico di Cagliari**
(Prof. N. D'Amico – Direttore SRT, Dr. A. Possenti – Direttore OAC, Dr. M. Burgay)
- **INAF – Roma** (A. Papitto, L. Stella, M.T. Menna, V. Testa, G. Israel)
- **INAF – Brera** (T. Belloni, S. Campana, P. D'Avanzo, M.C. Baglio)
- **INAF – Capodimonte** (D. De Martino)
- **INAF – IASF Roma** (A. Bazzano, P. Ubertini, A. Tarana, M. Focchi, L. Natalucci)

Italiani all'estero coinvolti nella ricerca

- **Spain/Netherlands** (N. Rea, D. Torres)
- **Switzerland** (E. Bozzo, C. Ferrigno, M. Falanga)
- **Germany** (A. Santangelo, S. Piraino, J. Wilms)

Altre collaborazioni internazionali:

- **USA** (J. Miller, E. Cackett, J. Garcia, D. Ballantyne, P. Kaaret, etc.)

Progetti in atto

Prin 2015 (in fase di valutazione):

Coordinatore Nazionale: T. Di Salvo (UNIPA)

Coordinatore Locale: L. Burderi (UNICA)

Coordinatore Locale: G.L. Israel (INAF-OAR, Roma)

A. Papitto ha ottenuto una **Marie Curie Individual Fellowship** per un totale di 168k€ (660657-TMSP-H2020-MSCA-IF-2014). Inoltre, la ricerca sulle Transitional Millisecond Pulsars è stata parzialmente finanziata tramite finanziamenti ottenuti per il **piano nazionale di ricerca spagnolo** (200k€, PI: Torres AYA2015-71042-P).

Abbiamo ricevuto fondi (nel 2015 e 2016) per lo sfruttamento scientifico dei dati di **NuSTAR** (osservatorio in banda X della NASA).

Progetto finanziato dall'ASI (Coordinatore: L. Burderi) per la realizzazione di un detector Gamma di grandissima area (**HERMES**, posizionato sulla Stazione Spaziale Internazionale).

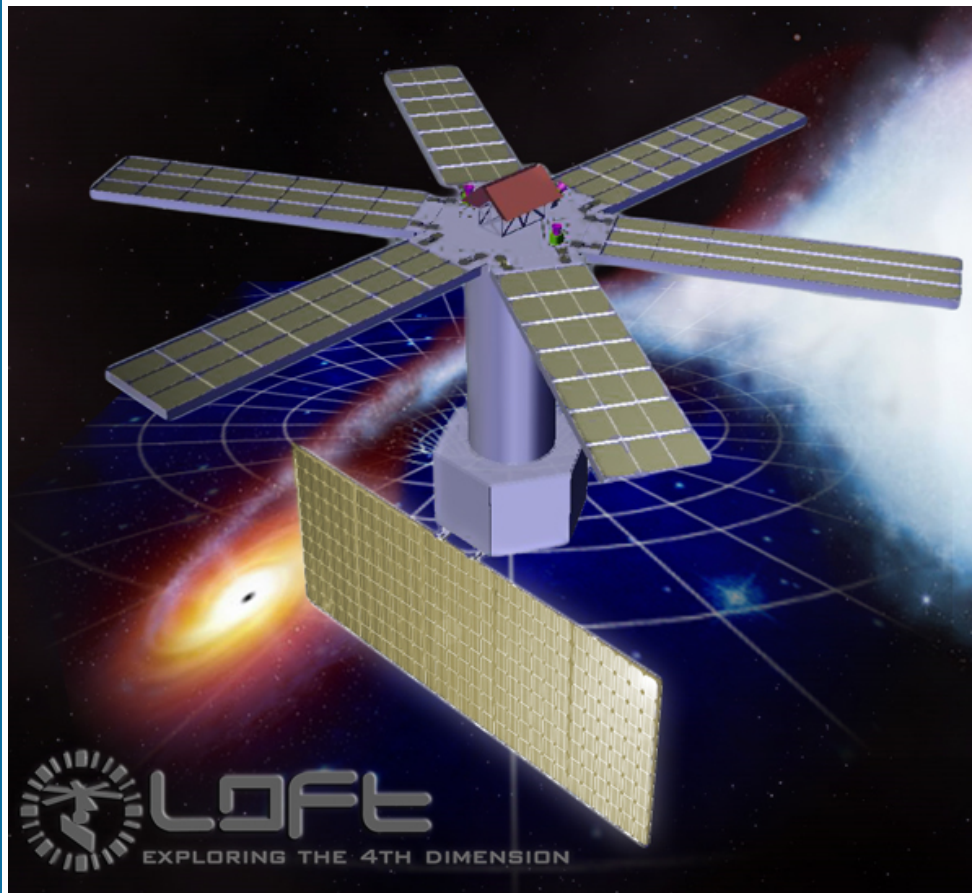
Nuove Facilities

SRT (San Basilio, Cagliari): Radio Telescopio della Sardegna

Lo specchio primario dello strumento è costituito da 1008 pannelli d'alluminio comandati da 1116 elettroattuatori e uniti a formare una superficie attiva, una parabola del diametro complessivo di 64 m



Nuove facilities

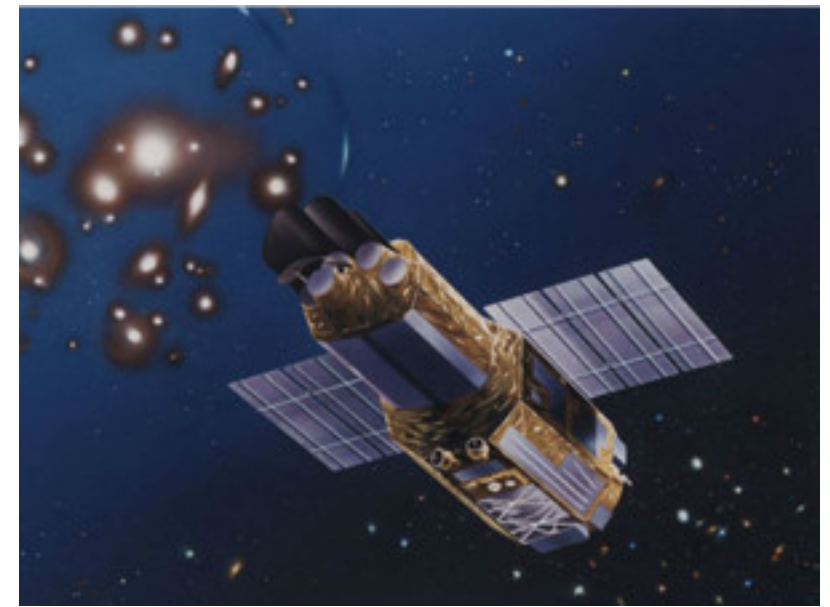


The Large Observatory For X-ray Timing (LOFT): ??

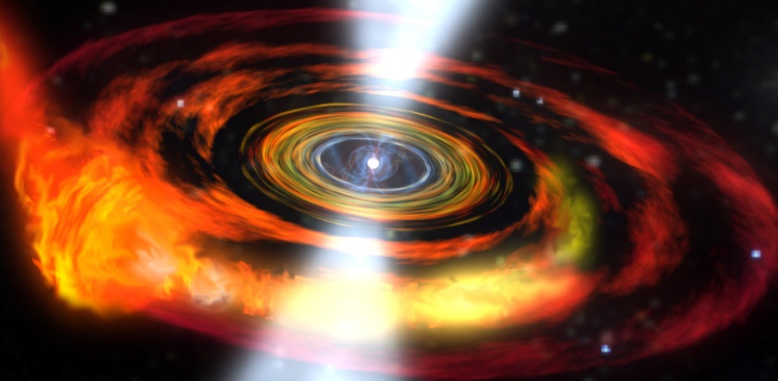
Abbiamo fatto parte dei gruppi di lavoro internazionali per i seguenti argomenti:

- Strong Gravity
- Observatory Science

ASTROSAT, Indian satellite successfully launched into its orbit on September 28, 2015.



Grazie per la vostra
attenzione!



Black Hole Candidates

Speaker: Melania Del Santo (IASF-Palermo)

Personale INAF (staff) e Associati

Angela Bazzano, Tomaso Belloni, Fiamma Capitanio, Piergiorgio Casella, Massimo Cocchi, Giovanni De Cesare, Melania Del Santo, Mariateresa Fiocchi, Enrico Massaro, Teresa Mineo, Lorenzo Natalucci, Gabriele Ponti, Alberto Segreto, Luigi Stella, Vincenzo Testa, Pietro Ubertini

Istituti INAF coinvolti

IASF-Palermo, OA Brera, OA Roma, IAPS, IASF-Bologna

Contrattisti INAF e studenti

1. Federico Vincentelli (PhD Insubria/OAR/OAB)
2. Antonino D'Ai (assegnista IASF-Pa, Swift)

Dottorato in Fisica UniPa/IASF-Pa XXXII ciclo (Tutor: MDS). Per massima diffusione.

Maithili Kalamkar (postdoc OAR – terminato da pochi mesi)

Collaborazioni con istituti e Università straniere

Center for Theoretical Physics, Polish Academy of Sciences (A. Janiuk)
Copernicus Astronomical Center, Varsavia (A. A. Zdziarski)
IRAP Toulouse (J. Malzac, R. Belmont, E. Jourdain, J.-P. Roques)
ISDC Geneve (C. Ferrigno)
IUCAA, Pune, India (D. Bhattacharya, G. Dewangan, R. Misra)
TIFR Mumbai, India (A.R. Rao, Y. Yadav)
TTU – Texas (T. Maccarone)
UCC – IE (A. Pe'er)
Università di NY, Abu Dhabi, UAE (D. Russell)
Università di Groningen, NL (M. Méndez)
Università di Oxford, UK (S.E. Motta, R.P. Fender, K. O'Brien)
Università di Southampton, UK (D. Altamirano, P. Gandhi)
Università di Creta, Iraklio, Grecia (N. Kylafis)
UvA – NL (P. Uttley)

Disc Truncated Model

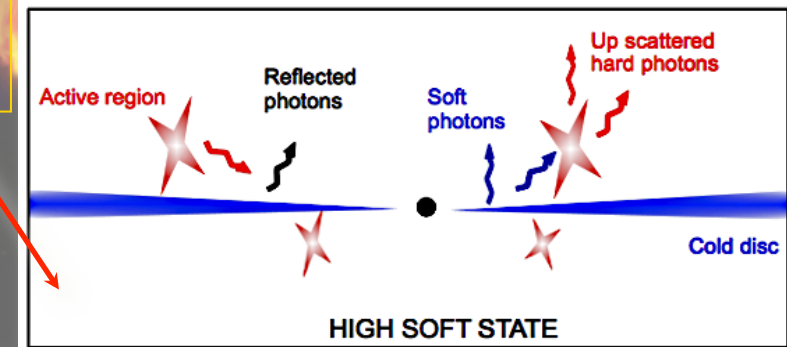
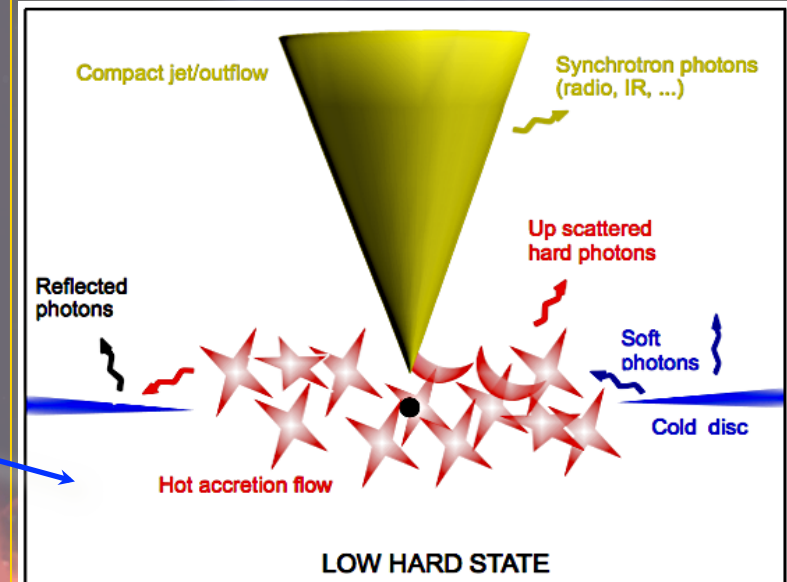
(Done, Gierlinski, Kubota 2007)

Hard state

- ✓ Truncated disc at 100-1000 R_g $\Rightarrow$ Faint black-body disc emission, weak reflection component
- ✓ Hot accretion flow $\Rightarrow$ thermal Comptonisation in the hot plasma
- ✓ Radio jets $\Rightarrow$ Synchrotron photons (radio, IR)

Soft State

- ✓ Cold disc extended up to the last stable orbit $\Rightarrow$ Dominant disc emission, strong reflection
- ✓ Magnetic flares on the top of the cold disc $\Rightarrow$ Non-thermal Comptonisation in the active regions



Scientific Projects and methods

- Measuring GR effects in X-ray binaries → fast X-ray variability study
- Understanding the hot accretion flow (corona) → X-ray and soft γ -ray spectral modelling
- Corona-jet connection → hard-X/radio correlation and time lags
- Disc-jet connection → fast OIR photometry coordinated with X-rays
- Understanding the disk instability in LMXB with black hole → X-ray spectra and modelling
- Searching for annihilation line (511 keV) and high-energy emission (up to MeV) in BH binaries → INTEGRAL spectral analysis
- Understanding the outbursts trigger mechanism and recurrence times → Swift/BAT and INTEGRAL long term monitoring

Facilities

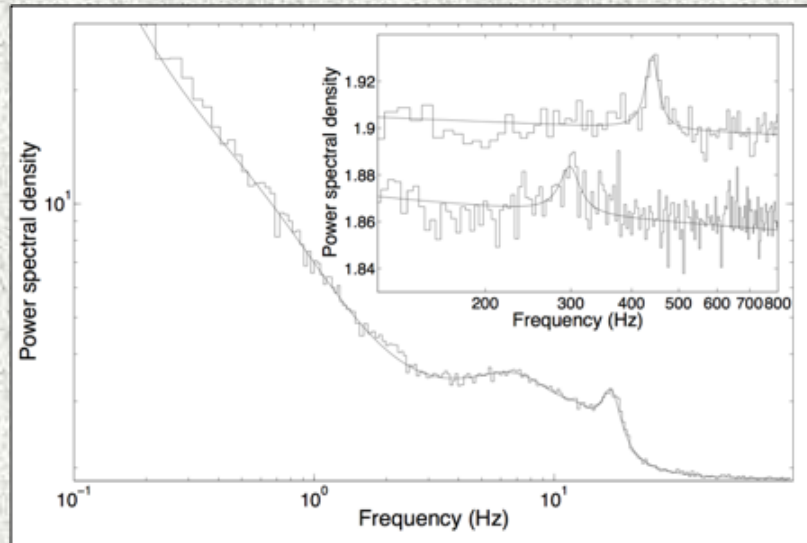
- X-ray data Archive: Rossi-XTE, XMM-Newton, INTEGRAL, Swift, NuSTAR, BeppoSAX
- ToO: INTEGRAL, Swift/XRT
- Astrosat (T. Belloni Collaboration)
- Optical: ULTRACAM, OM@XMM, UVOT@Swift
- Near-IR: ISAAC@VLT, HAWK-I@VLT, CIRCE@GTC
- OIR long term context (low time resolution): REM, SMART

SCIENCE OBJECTIVES

Understanding/constraining/tracking/measuring:

- jet internal energy
- launching regions/mechanism
- systems geometry (jet, corona)
- confirmation of detection of GR effects
- emission model for variability (connection to accretion)
- physical processes and components causing the hard X-ray emission (thermal/non-thermal Comptonisation from hot plasma, synchrotron from jets...)
- spectral transitions mechanism in BHC
- strong winds emitted from the disc (when systems in soft state)
- quasi periodic outbursts in BHC
- peculiar failed outbursts
- the peculiar BHC V404 Cyg
- annihilation line in BHC

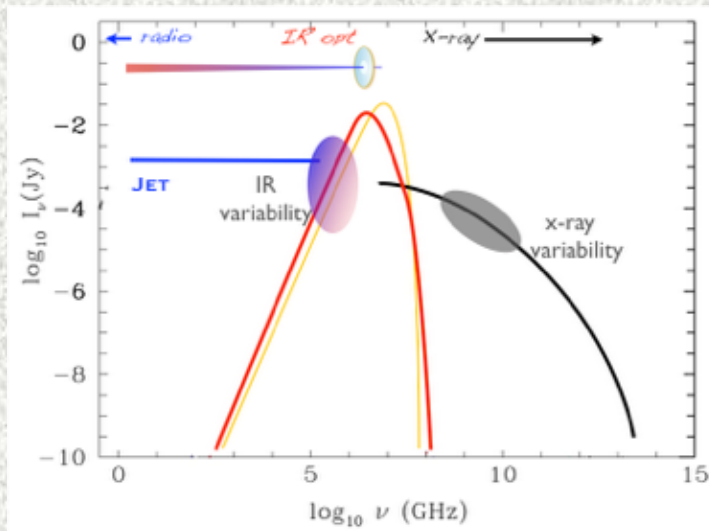
A few results



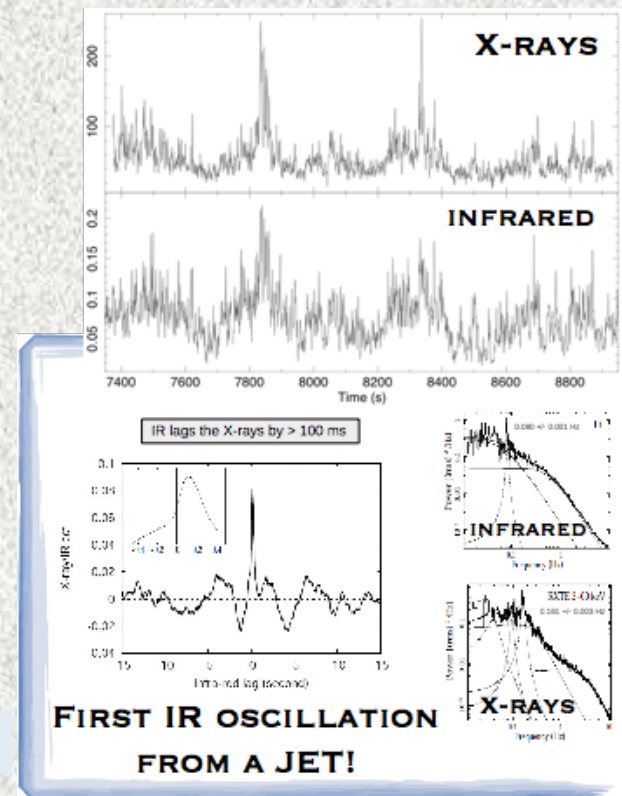
Motta, Belloni, Stella et al. (2014)

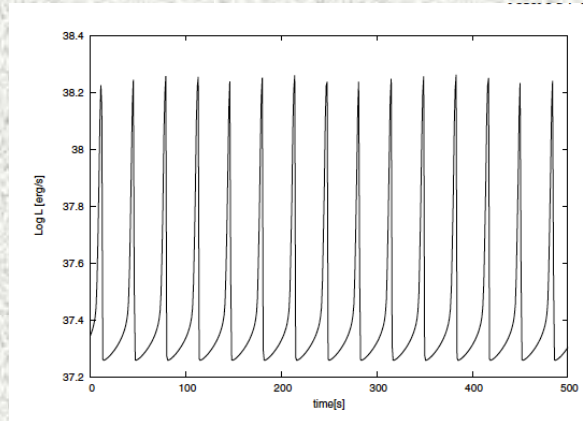
From Quasi-Periodic Oscillations in a bright system (GRO J1655-40), using the relativistic precession model we obtained:

- First direct evidence of a BH
 - First measurement of ISCO
 - Precise spin measurement
 - Test GR prediction in strong field
- We need more data (Astrosat)



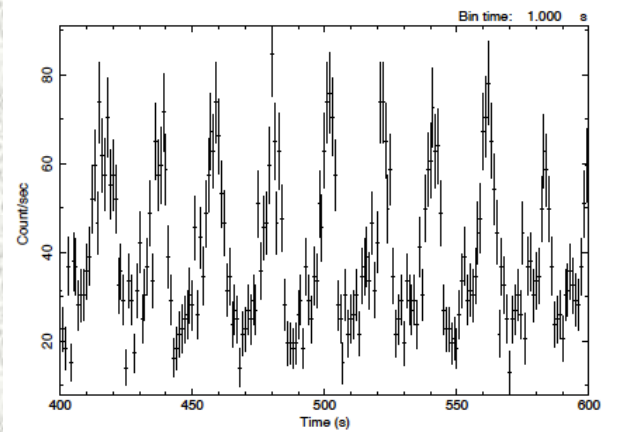
Kalamkar, Casella, et al. (2016)



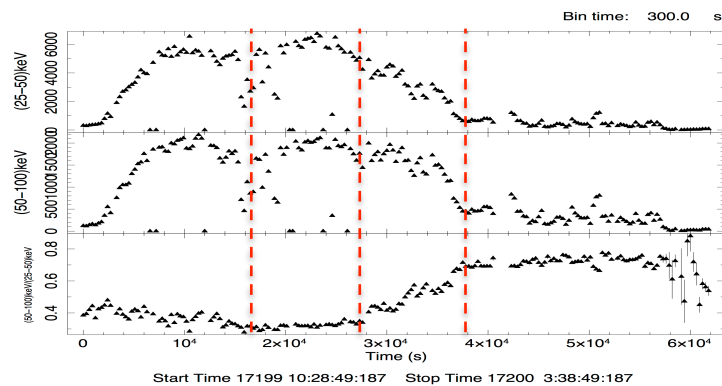


Simulations indicate that a strong wind launched from the disk is a plausible mechanism to regulate the amplitude of oscillations and at some point may suppress the heartbeat completely. These results are fully in agreement with the IGR J17091-3624 behaviour during the 2011 outburst.

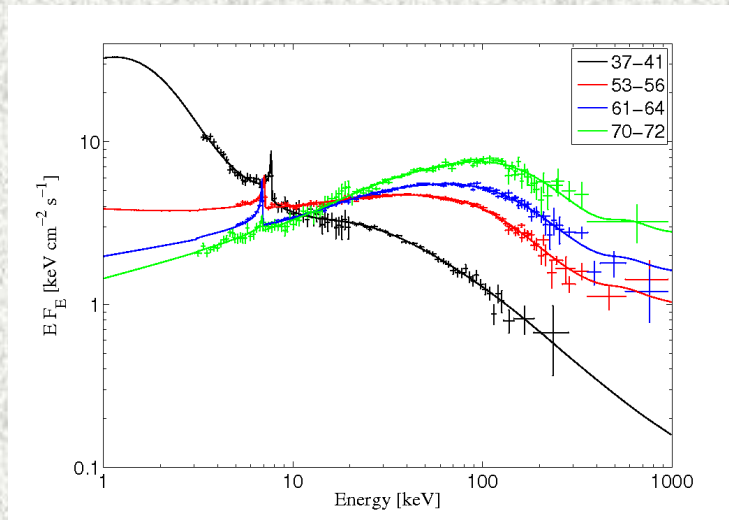
Janiuk, Grzedzielski, Capitanio, Bianchi (2015)



INTEGRAL data analysis outburst of V404 Cyg outburst. Comptonisation vs jet: the estimated seed photons are not compatible with disc photons. Spectral analysis based on the flux variability is on going.



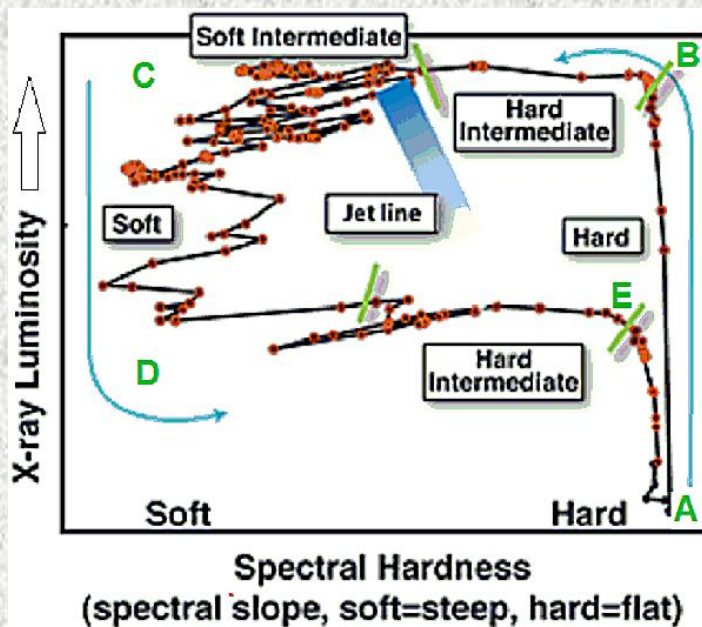
Natalucci, Fiocchi, Bazzano, Ubertini, et al. (2015)
Roques, Jourdain, Bazzano, Fiocchi, Natalucci, Ubertini (2015)



First measurement of the magnetic field in the X-ray corona of Cygnus X-1 (with the new model BELM):

- B is at most of the order of 3×10^6 G in the soft state
- a few 10^5 G in the hard state.

Del Santo, Malzac, Belmont, Bouchet, De Cesare (2013)



A number of outbursts deviate from the standard pattern. Why?

Del Santo, Belloni, Tomsick, Sbarufatti, Cadolle Bel, Casella et al. (2016)
 Capitanio, Campana, De Cesare, Ferrigno et al. (2015)
 Ferrigno, Bozzo, Del Santo, Capitanio (2012)
 Capitanio, Belloni, Del Santo, Ubertini (2009)

The Future

XIPE

WG 3.1: X-ray binaries and QPOs, WG4.2: strong gravity, WG 1.4: microquasars

- Measure of black hole spin in disc dominated spectral states
- spectro-polarimetry could help constrain the geometry of the corona in hard state
- the dynamics of the corona i.e. outflowing/base-of-jet vs static/accreting
- highly polarised contribution from synchrotron X-ray jet can be tested
- source of seed photons for comptonisations i.e. disc emission vs synchrotron (as in ADAF)

LOFT/eXTP

WP: The physics of accretion-ejection with LOFT (Casella,..., Belloni,...Del Santo et al. 2015)

Athena

WG 2.5: accretion physics

- Determine geometry of the disc-corona system to understand how winds and jets are launched
- Measure black hole spins through reverberation, timing, time-resolved spectroscopy and average spectral methods.

SKA → radio counterpart from jets

CTA → VHE counterpart from jets

FOUNDING

- PRIN-INAF 2012 (PI T. Belloni, 20k€ for BH studies)
- ASI-NuSTAR (PI T. Belloni, 23.6k€ for BH studies)
- FP7 - Career Integration Grant (PI: Casella): 100.000€ (end Sept 2016)

Applied: PRIN MIUR (minimal participation, P.I. Tiziana Di Salvo)

Politica della ricerca (MDS)

Fondi: mancanza di fondi per analisi dati.

- Ultimo bando ASI/INAF nel 2010.
- Bando ASI/INAF Nustar (2014/2015). Totale fondi 200 keuro annui (irrisori).
- PRIN INAF: a che punto siamo? L'ultima volta i fondi sul PRIN erano 1 Meuro per tutti. E' possibile aumentare questo budget?
- PRIN MIUR: fondi totali irrisori. Pochissime possibilità.
- ERC advanced grant appena uscito. Interessi da parte di senior? Richiesta di maggiore supporto da INAF.
- Fondi ricerca di base inesistenti. Possibilità di richiedere una quota per ricercatore? Non a pioggia, ma almeno in base alla produttività scientifica.

Personale precario: quale futuro?

Riforma Madia (ultima bozza):

- eliminazione III livello
 - Assegni di ricerca max per 3 anni
 - Contratti a tempo determinato (tipo A e B) come nelle Università SOLO sul bilancio dell'ente
- N.B. Al momento sembra che per bilancio dell'ente si intenda solo gli FFO e non i fondi eterni**

Qualche punto sulla riforma Madia per il personale staff

- Garantire la Carta Europea dei Ricercatori attraverso gli statuti: libertà di ricerca e valorizzazione professionale. Ma nell'Art. 1 comma 3 Statuto INAF si dice già: L'INAF ispira la sua azione a quanto previsto dalla Carta Europea dei Ricercatori allegata alla raccomandazione n. 2005/251/CE).
- Autonomia degli enti su autorizzazioni di spesa, statuti, regolamenti...
- de-contrattualizzazione di ricercatori e tecnologi, II e I livello (I ric. e dirigente)
- eliminazione III livello → ruolo ad esaurimento
- 30% dei posti da II livello riservati per il personale III livello (il resto aperto a tutti e ai TD di tipo B)
- concorsi I e II fascia normati da regolamento unico
- ai contratti TD di tipo B va destinato almeno il 50% del bilancio dell'ente
- il numero dei dirigenti (I fascia) non può superare del 30% quelli di II
- per il trattamento economico di ricercatori e tecnologi si rimanda ad un DPCM apposito
- Eliminazione delle fasce stipendiali: premialità (si rimanda all'apposito DPCM)
- Norme di semplificazione per missioni, acquisti, appalti, manutenzione...

MAGNETARS: OGGETTI COMPATTI ALL'ESTREMO

GianLuca Israel
(INAF - Rome Astronomical Observatory)

INAF: S. Mereghetti, M. Burgay, A. Possenti, L. Stella, V. Testa, F. Pintore*,
G. Rodriguez*
ALTRI ENTI: R. Turolla#, A. Tiengo#, F. Coti Zelati*#,
C. INTERNAZIONALE: N. Rea#, D. Gotz#, J. Pons, S. Zane, K. Kouveliotou,
A. Watts, R. Perna, R. Mignani, F. Bernardini*, S. Dall'Osso*#, P. Esposito*, ecc.
* TD , # Associato INAF

Fondi

In passato: PRIN MIUR/INAF, ASI

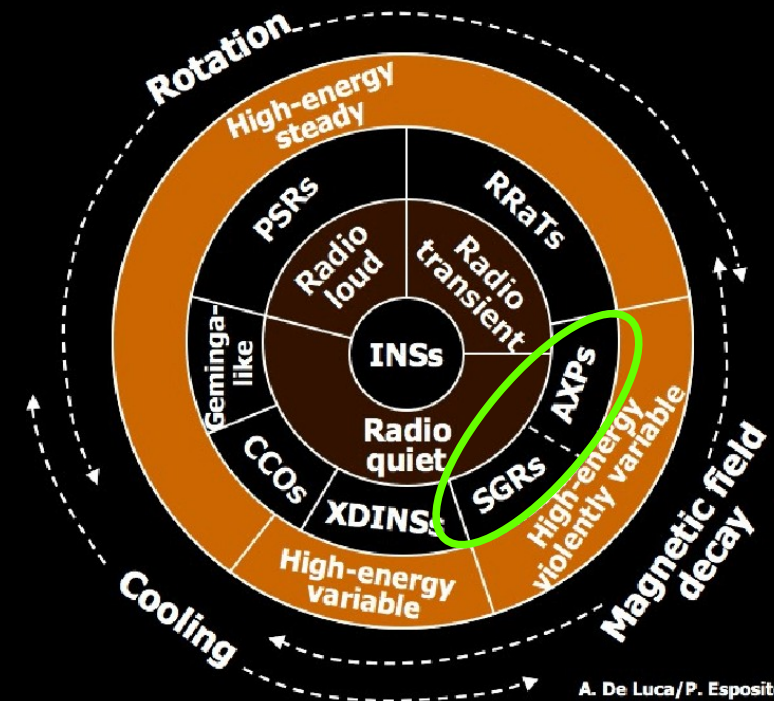
Ultimi fondi: PRIN INAF (PI Mereghetti) 2014-16

PERCHE' ?

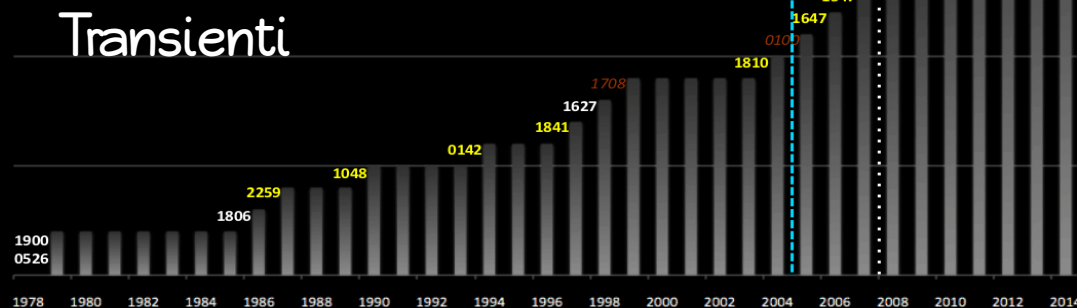
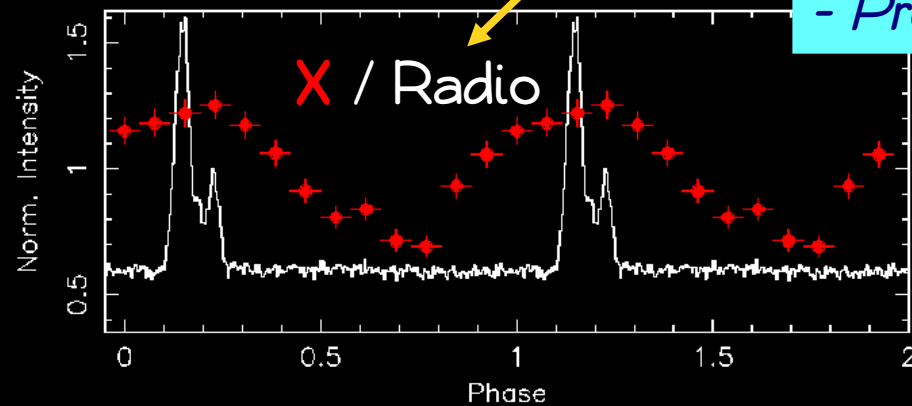
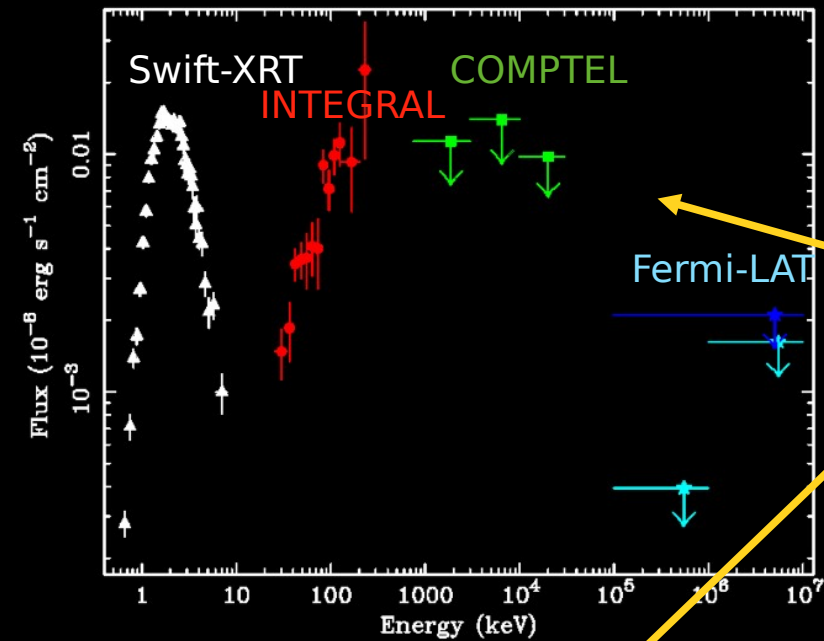
Interesse che nasce da una tradizione di lunga data in INAF a seguito, negli anni 90, della scoperta di pulsazioni nei dati EXOSAT di 4U0142+614 (Israel, Mereghetti & Stella 1994), e l'identificazione di un gruppo di pulsatori X soffici con proprietà "anomale", le AXP (Mereghetti & Stella 1995).

- Nuovo processo di emissione in astrofisica (decadimento di un intenso campo magnetico). NS isolate.
- Parametri astrofisici (campo gravitazionale e magnetico, densità), non riproducibili in laboratorio. Proprietà estreme tra le varie classi di NS anche in termini di variazione di flusso (fino a 10 ordini di grandezza). Emissione dal radio al Gamma.

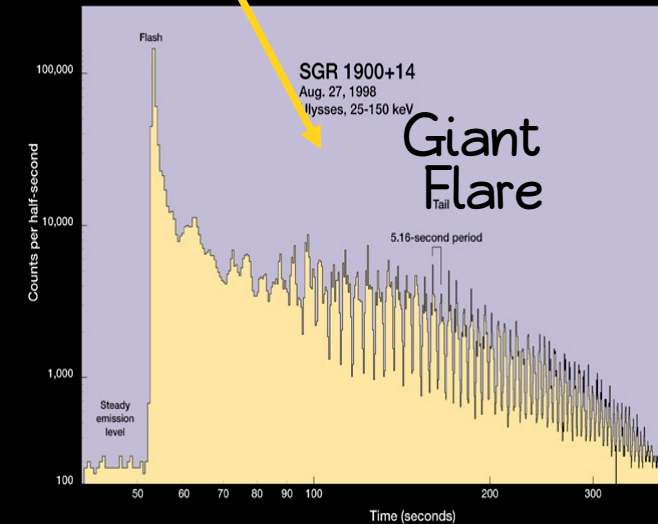
Implicazioni nello studio dell'interazione radiazione materia ad alti B, nella ricerca della EOS delle NS, dell'evoluzione stellare e dei progenitori, connessioni con altri campi di indagine astrofisica, ecc.



I MAGNETAR IN BREVISSIMO



- Circa 25 oggetti
- *Molti oggetti Transienti*
- Emissione fino a $\sim 300 \text{ keV}$
- *Alcune sono Pulsar radio transienti*
- L_{Gflare} fino a 10^{47} erg/s
- *QPO tra 20 e 2000 Hz durante flares*
- Indirect evidences of $B > 10^{14} \text{ G}$
- *Progenitori $M > 30 M_{\text{sun}}$*
- P tra 2s e 12s
- $\dot{P}$ 10^{-12} - 10^{-10} s/s
- $B_{\text{dip}} > 10^{14} \text{ G}$
- Bursts e flares
- 3 flare giganti
- emissione IR variabile
- *modello magnetar largamente adottato*



CASO SCIENTIFICO

Progetti con 3 finalita':

- o osservativa
- o teorica ed interpretativa
- o supporto a future missioni/strumentazione

- Magnetar transienti → implicazioni sulla demografia, emissione
- Emissione Hard X → implicazioni sui processi di emissione
- QPO durante flares → EOS*
- Magnetar con $B \sim 10^{12}$ G → demografia/connessione con radio pulsar*
- Magnetar in orbita intorno a Sgr A* → studio effetti relativistici*
- Spettroscopia dei flares → interazione γ -materia, distanza*
- Misura diretta B_{surf} (assorbimento di ciclotrone)*
- Variabilita' X correlata a quella IR/ottica → processi di emissione
- Emissione ottica pulsata e in fase con l'X
- Correlazione burst X e radio → processi emissione*
- Evoluzione del dust halo → composizione ISM, distanza*
- Sviluppo modello twist magnetosferico*
- Sviluppo modello magneto termico*

* Forte coinvolgimento ricercatori INAF/Associati

APPROCCIO OSSERVATIVO MULTIBANDA

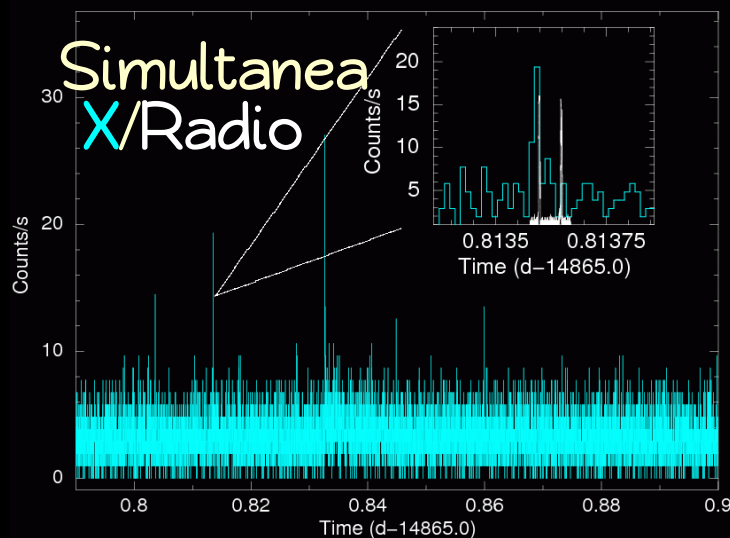
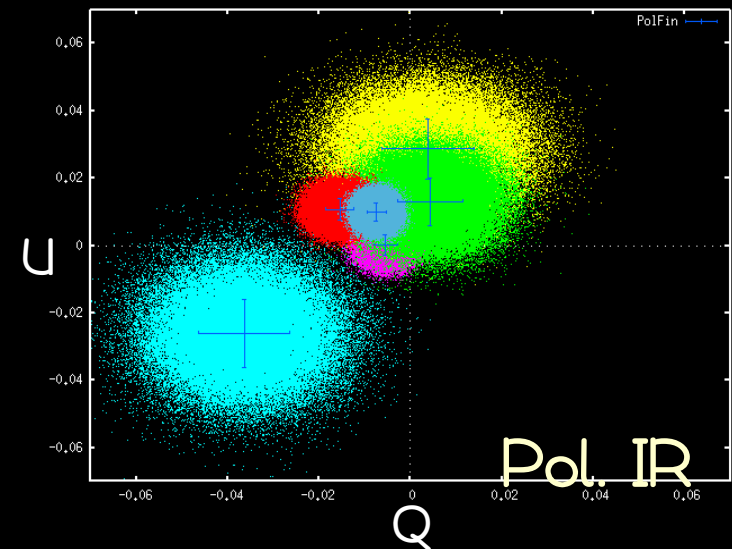
Circa 10 anni fa costituzione del TRIGGERATOR GROUP (TRIGRO) con responsabilita' di monitorare gli alert Swift/INTEGRAL/Fermi e attivare tempestivamente le varie ToO o chiederne DDT (XMM, Chandra, Swift, INTEGRAL, Parkes, GBT, SRT, VLT, GTC, ecc.)

Attualmente: **Esposito***, **Coti Zelati**, **Israel**, **Rea**, **Tiengo** (INAF, Associato, *ora ad Amsterdam)

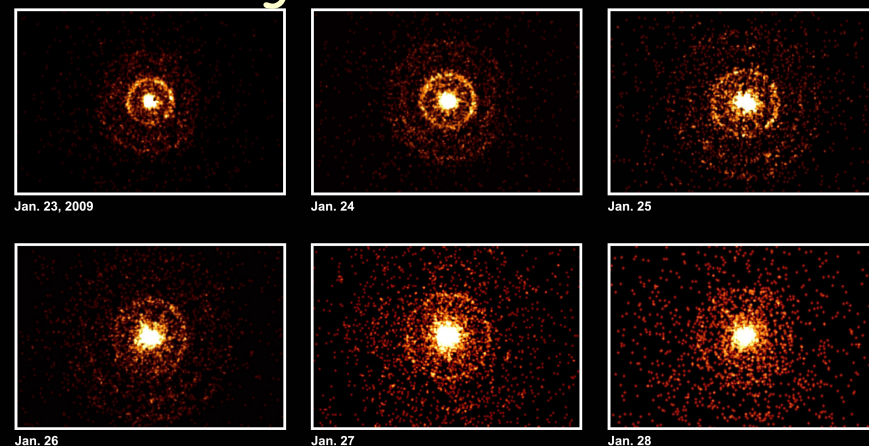
~1-2 trigger ogni anno per un totale di
~15 trigger totali sino ad oggi

Approx. 6 articoli l' anno referati come primi autori

3 esempi X/IR/Radio per 1E1547

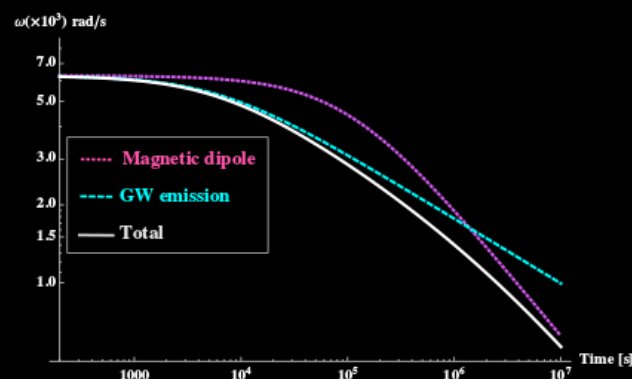


Dust Rings X

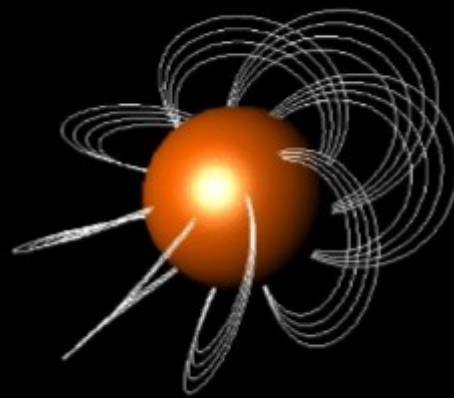


APPROCCIO TEORICO (SOTTORAPPRESENTATO IN INAF)

Qualita'/quantita' dei dati ha reso necessario lo sviluppo ulteriore del modello generale di magnetar

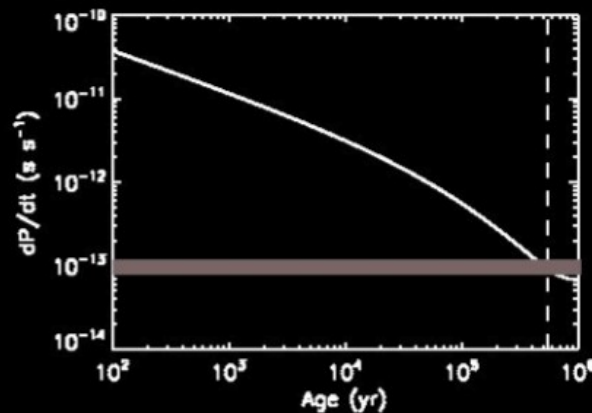
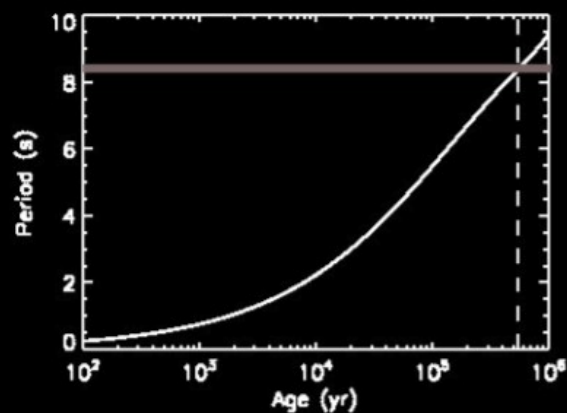
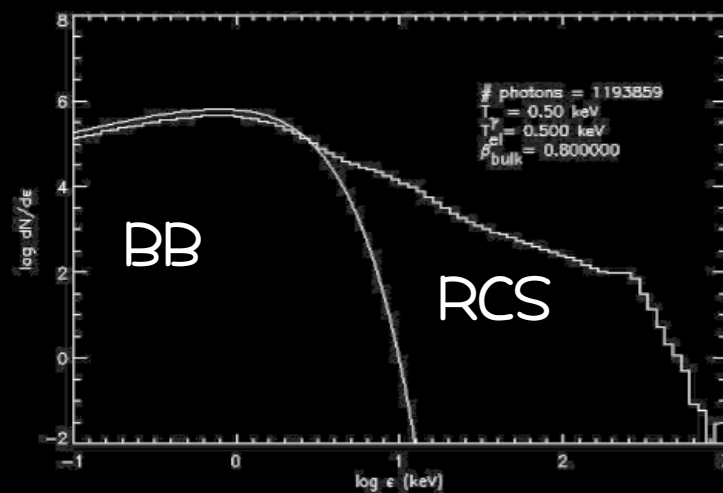


GW/magnetars/short GRBs



Modifica dello spettro uscente indotto dal twist

Resonant scattering per promuovere i fotoni termici alle alte energie

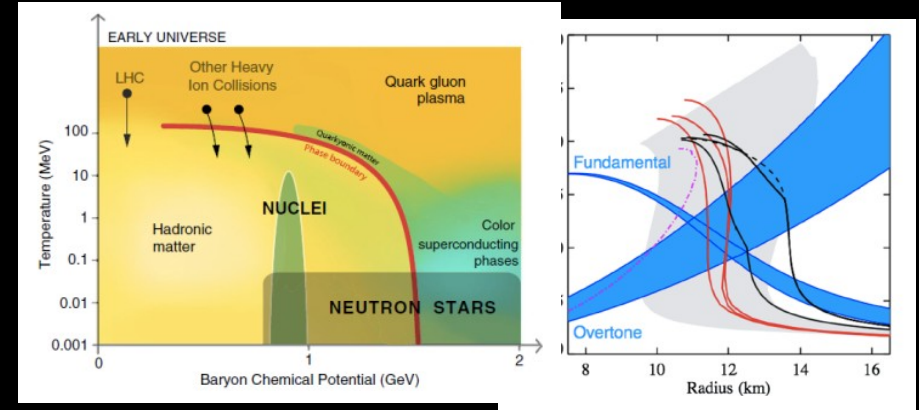


Sviluppo modello magneto termico e previsioni sulla evoluzione dei parametri osservativi

SVILUPPO MISSIONI (LOFT/EXTP/LOFT-P/XIPE)

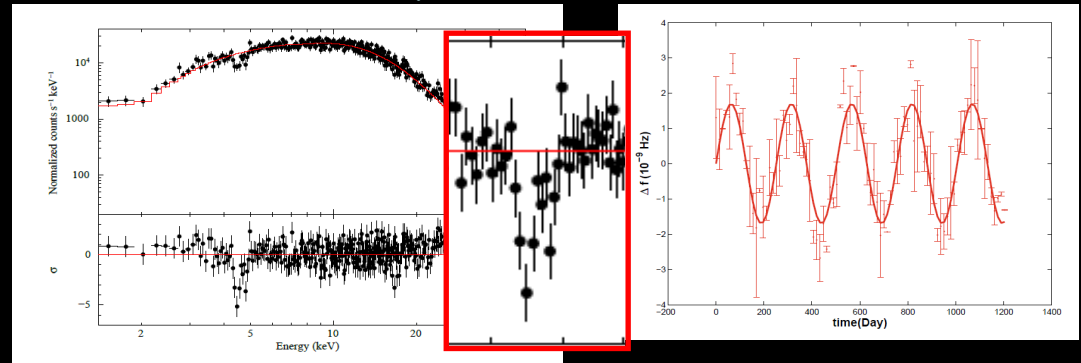
Fundamental physics parameters:

Asteroseismology allows interpretation as seismic vibrations and connect them to EoS, providing constraints in the M-R diagram → flares



Astrophysics of magnetars:

Large throughput ($\sim 4\text{-}10\text{ m}^2$) uniquely combined with spectral resolution allows for unprecedentedly fine studies. High-significance detection of absorption features and detection of precession features, predicted by the magnetar model.



XIPE: vedere i 5' di R. Turolla

SINERGIA FACILITIES FUTURE

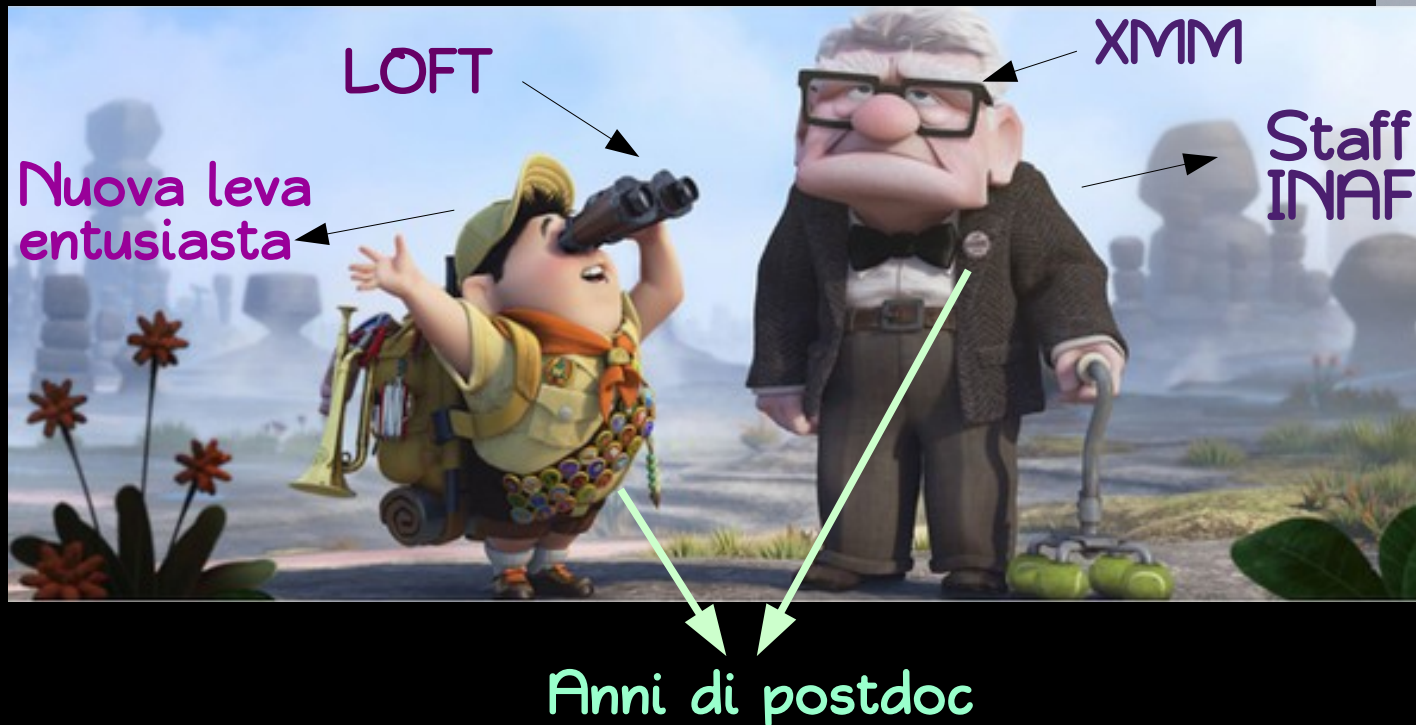
Da SRT a SKA: SRT ha osservato 4 magnetar (1 rivelata) partendo da trigger X SKA permettera' di identificare le magnetar direttamente nel radio !!

Lo scopo finale, dal punto di vista osservativo, e' quello di riuscire a effettuare osservazioni multibanda simultanee e monitorare le variazioni nelle diverse bande

NECESSITA' IMPELLENTI

Nuove leve entusiaste (posti !!)
.... soprattutto in vista dell' arrivo
della nuova generazione di strumenti e
facilities

Magnetar attivo



Le entusiaste leve dovranno rispondere ad alcune domande come:

- Qual'è un numero realistico della popolazione dei magnetar?
- Quale connessione esiste con le radio pulsar ?
- E' possibile ottenere verifiche non ambigue sui meccanismi/modelli Proposti ?

White Dwarf binaries and Novae in MA4

1. Identification programme of accreting WD binaries in hard X-ray surveys (INTEGRAL/Swift) by means of multi-wavelength observations
D. de Martino (INAF-OANA), *F. Bernardini* (NYU-UAE), *K. Mukai* (Univ, Baltimore-Maryland and NASA/GSFC), *N. Masetti* (INAF- IASFBO), *M. Falanga* (ISSI-Bern) , *L. Israel* (INAF-OAR)
2. Fundamental parameters of WD in binaries
D. de Martino (INAF-OANA), *B.T. Gaensicke*, *T.Marsh* (Univ.Southampton), *P.Szkody* (Univ.Washington), *R.Silvotti* (INAF-OATO)
3. The secular evolution of WD binaries accreting at high rate, through their cycles
M. Orio (INAF-OAPD and University of Wisconsin-Madison), *P. Zemko* (Padova University), *D. de Martino* (INAF-OANA), *K. Mukai*, *G.J.M. Luna* (UBA-Conicet)
4. Symbiotics and Be+WD binaries in the Local Group and beyond: statistics of pre-SNe Ia progenitors (X-rays + UV, optical with Gemini, SALT, WIYN)
M. Orio (INAF-OAPD and University of Wisconsin-Madison), *P. Zemko* (Padova University), *G.J.M. Luna* (UBA-Conicet), *J. Gallagher* and *R. Kotulla* (U Wisconsin) and other collaborators...
5. High resolution X-ray spectra of Galactic and Local Group novae in outburst
M. Orio, *INAF-OAPD*, *J. Gallagher* (U Wisconsin), *E. Behar* & *U. Peretz* (Technion Dept. of Physics)

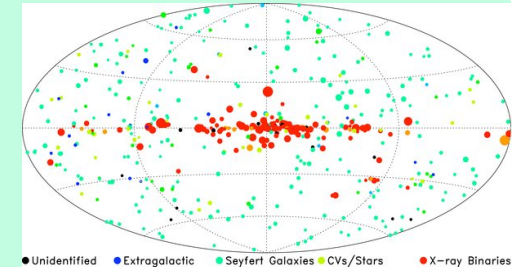
**PROJECTS 1 and 3 FUNDED BY ASI-INAF NuSTAR PROGRAMME: I/037/12/0
NARO14 (18ke) & NARO15 (5ke)**

WD Binaries in Hard X-ray Surveys

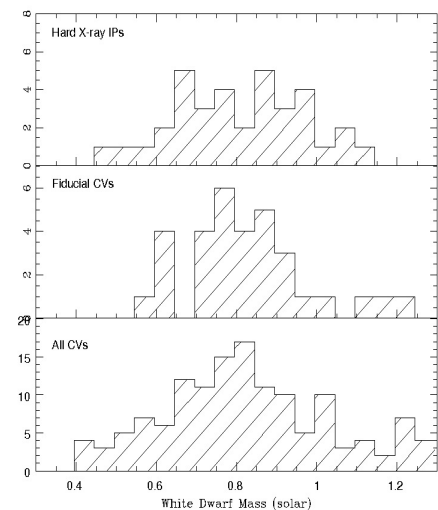
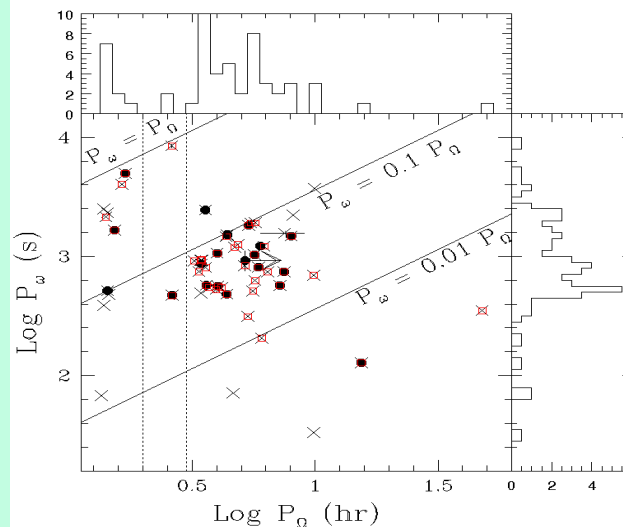
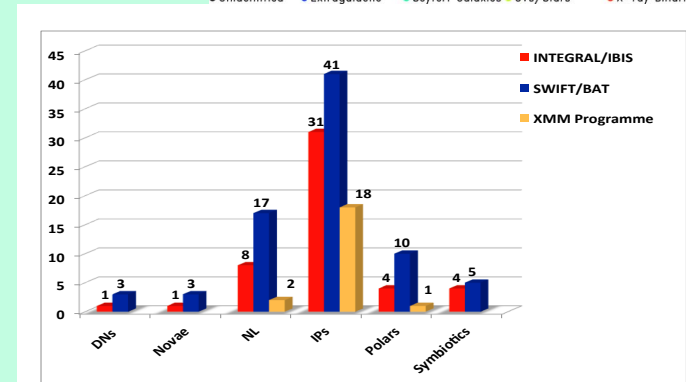
1. Identification programme of WD accreting binaries from INTEGRAL/SWIFT surveys with:

- XMM-Newton, Swift, INTEGRAL, NuSTAR, Chandra
- REM, Loiano, ESO/NTT, SAAO, CASLEO

(Bernardini et al. 2011,12,13,14,15; Mukai et al. 2015; Ferrario, deMartino, Gaensicke 2015)



- WD binaries 6-7% of galactic hard X-ray sources
- Magnetic CVs dominate the WD X-ray population
- Characterization (P_{spin} , P_{orb} , WD Mass)
- Role of B, WD mass, $\dot{M}$
- Donor star parameters (Mass, T_{eff})
- Evolutionary state of mCVs



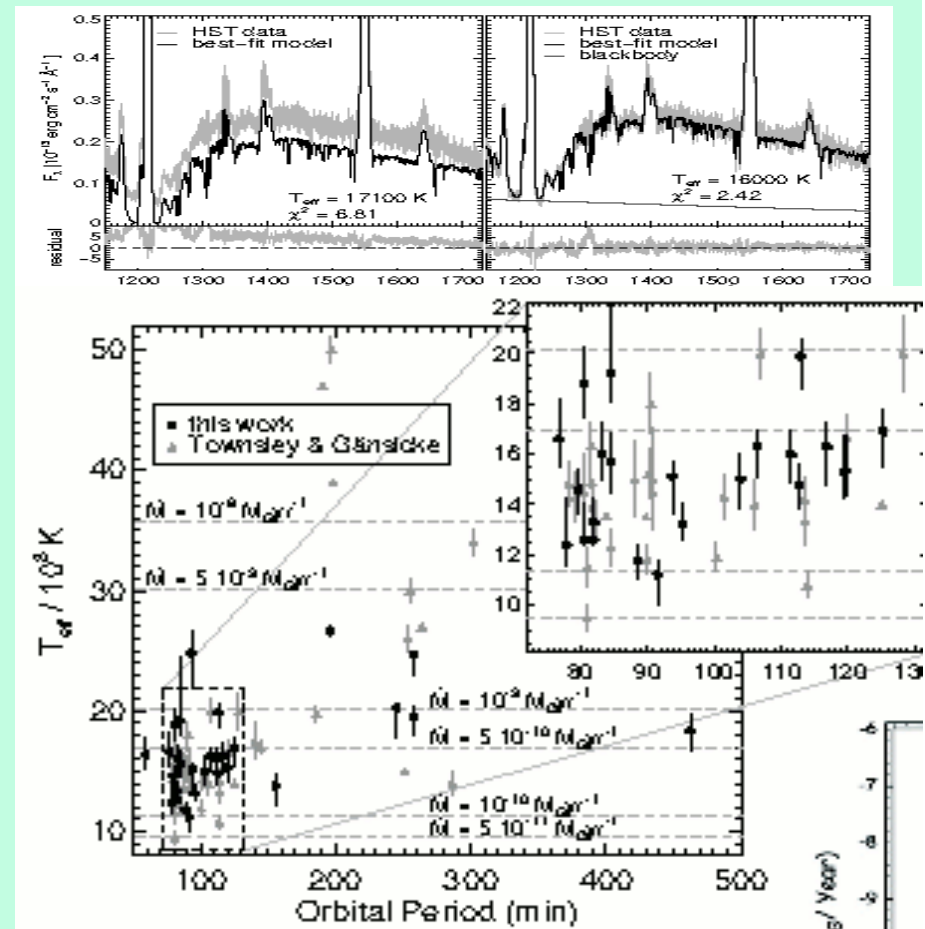
WD fundamental parameters in CVs

3. HST/COS Cycle 20 Large Programme - 122 orbits (PI:Gaensicke): to determine WD parameters (Teff, Log g) and Mdot → evolutionary status

- 31 CVs with WD signatures identified totalling 74 WD/CVs so far
- Accretion disc masks WD photosphere: Multicomponent UV spectra (WD+Disc)
- Teff as proxy of secular Mdot - Angular Momentum Loss evolution

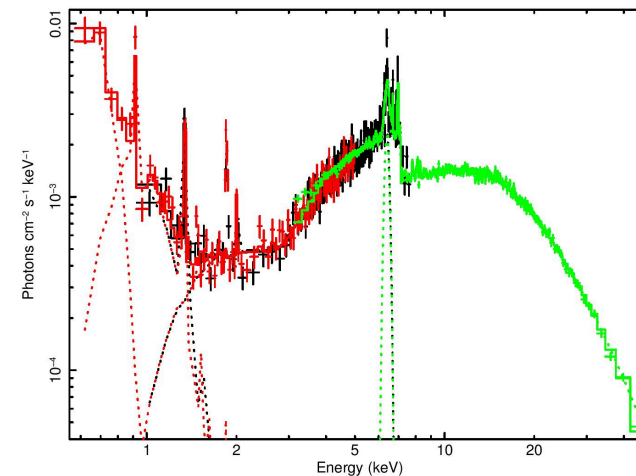
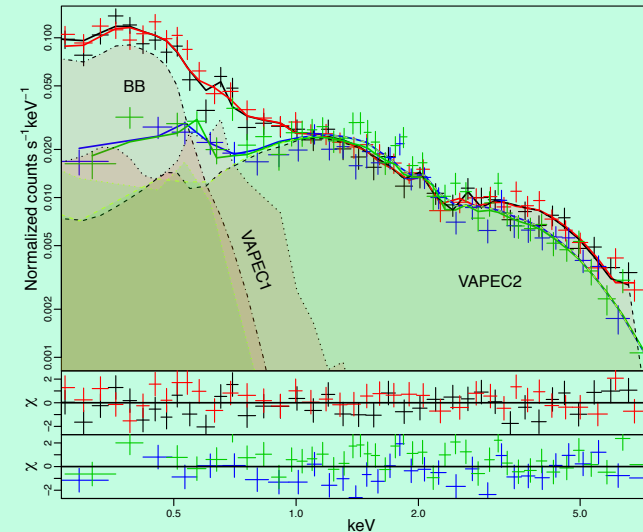
- Higher Teff @ long Porb
but magnetics at lower Teff
→ reduced MB efficiency
- Lower Teff @ short Porb
but higher than predicted
→ GR not only responsible for evolution
- Need accurate distances (GAIA) to break degeneracy Teff-log(g)
- Need wider range (X-shooter being acquired)

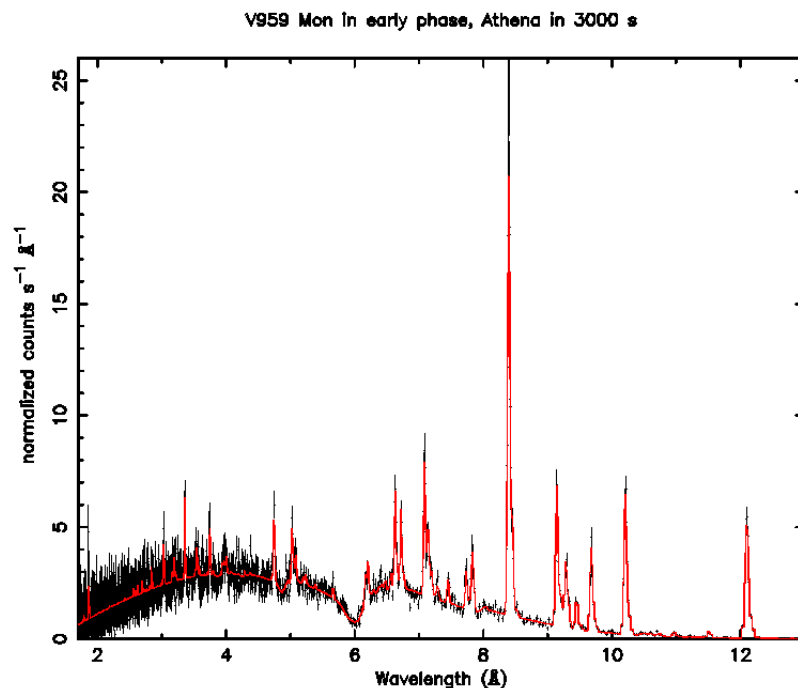
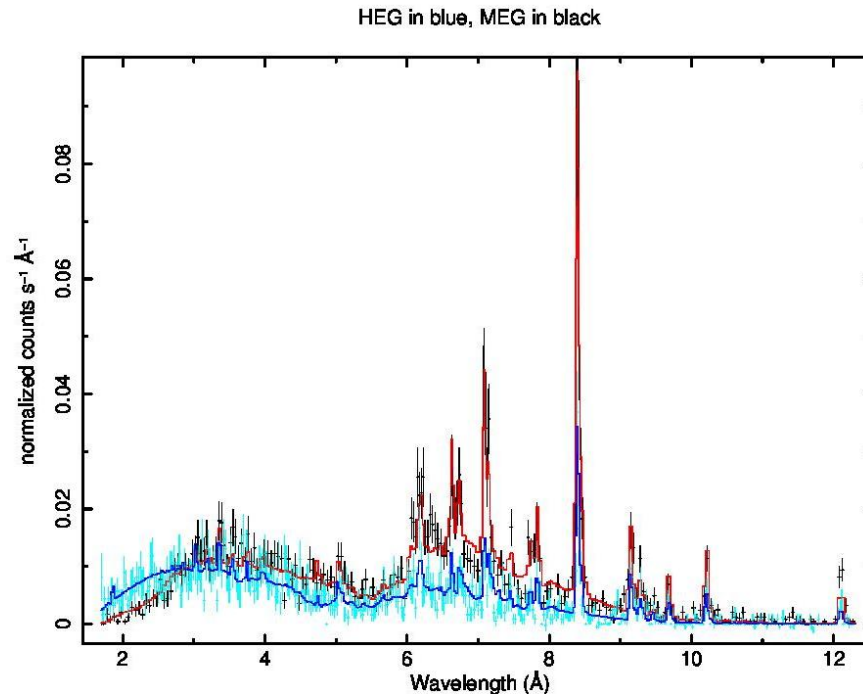
(Pala et al. 2015; Toloza et al. 2016,..in progress)



Following fast-accreting systems over tens of years, and hunting for possible SN progenitors

- Observations of the X-ray brightest novae as they return to quiescence and accrete again (X-rays, optical, PI Orio)
- Nova-like and SuperSoft X-ray sources, accrete (and sometimes burn) at high rate expected for SNe Ia – if burning, detected up to 10 Mpc away
- Looking for massive WDs in the regime of high accretion rate in which burning is ignited, but does not eject mass => SNe Ia? (PIs Orio, Luna)
- WDs in high mass binaries: 2 B stars of which one turns into a WD long before the other, the companion forms an excretion disk as a Be star.
- TOP: Complex multi-component XMM-Newton broad band spectrum of post-nova V4743 Sgr (Nova in 2002) 2, 3.5yrs after (Zemko et al. 2016).
- BOTTOM: NuSTAR+Chandra HETG spectrum of post-nova GK Per in ‘dwarf-nova-like’ eruption (PI’s Zemko, Orio)





An example of what X-ray gratings can obtain in a nova eruption:

TOP: Chandra spectrum of V959 Mon, known as gamma-ray transient before it could be observed optically
Not the most intrinsically luminous nova in X-rays, but at a distance of only 1.4 kpc. ~2.5 months after maximum, strong shocks in a portion of the ejecta, with many atomic transitions (Peretz et al. 2016)

NeO novae like this one are not rare and contribute greatly to the chemical evolution of the Galaxy with intermediate atomic weight elements. Aluminum, for instance, is critical!

BOTTOM: Athena will obtain higher S/N in 3ks instead of the 25ks Chandra HETG. We will reach many more of these objects and calculate their chemical yields from the X-rays.

Future Perspectives for WD research

X-RAY FACILITIES:

- **ATHENA+ : High resolution X-ray spectra: (SWG3.3)**
 - a) Gravitational redshifts → WD mass in all-types provided system parameters known
 - b) Accretion flow diagnostics → densities, temperature, chemical abundances, velocities
 - c) Constraints of space parameters for ~50 classical and recurrent novae in ~5 years
 - d) Whether RNe occur on CO or on ONe WDs, with implication for SNe Ia models
 - e) Compare Galactic and extra-Galactic novae populations
- **XIPE:** Polarization measures in mCVs to probe physics/geometry of accretion flows
- **LOFT/eXTP:** Fast timing and broad spectral range to :
 - a) identify periodic/non-periodic variability in many magnetics, non-magnetic CVs & Novae
 - b) spectral hard component in several types → Tshock, reflection

UV/OPTICAL/nIR FACILITIES:

- **WIDE FIELD SURVEYS from SPACE: KEPLER, GAIA, PLATO**
GROUND-BASED: VST, WYNN, WEAVE, LSST
→ faint WD binary populations & transients
- **UV:** none beyond HST
- **VLT/EELT:** spectroscopic follow-ups

RADIO:

- **SKA:** synergies with X-rays and optical to investigate Outflows & Jet launching



A comprehensive approach to the investigation of Ultraluminous X-ray Sources

Multi-wavelength variability, broadband spectra, and theoretical modelling

Luca Zampieri
INAF-Astronomical Observatory of Padova

Contributors:

E. Ambrosi, M. Bachetti, T. Belloni, P. Esposito, G. Israel, M. Mapelli, F. Pintore, I. Prandoni, E. Ripamonti, L. Sidoli, M. Spera, L. Stella, G. Trinchieri, A. Wolter

Ultraluminous X-ray sources (ULXs)

What do we know?

- *Point-like off-nuclear X-ray sources in nearby (< 100 Mpc) galaxies*
- *Intrinsically powerful but faint*
- *L exceeds (although not necessarily all the time) the Eddington limit for spherical accretion onto a $\sim 10 M$ black hole ($L > 1.0e39$ erg/s)*

Hundreds of sources in various surveys/catalogues:

ROSAT: Roberts & Warwick 2000, Colbert & Ptak 2002

Liu & Bregman 2005, Liu & Mirabel 2005

Chandra: Swartz et al. 2011

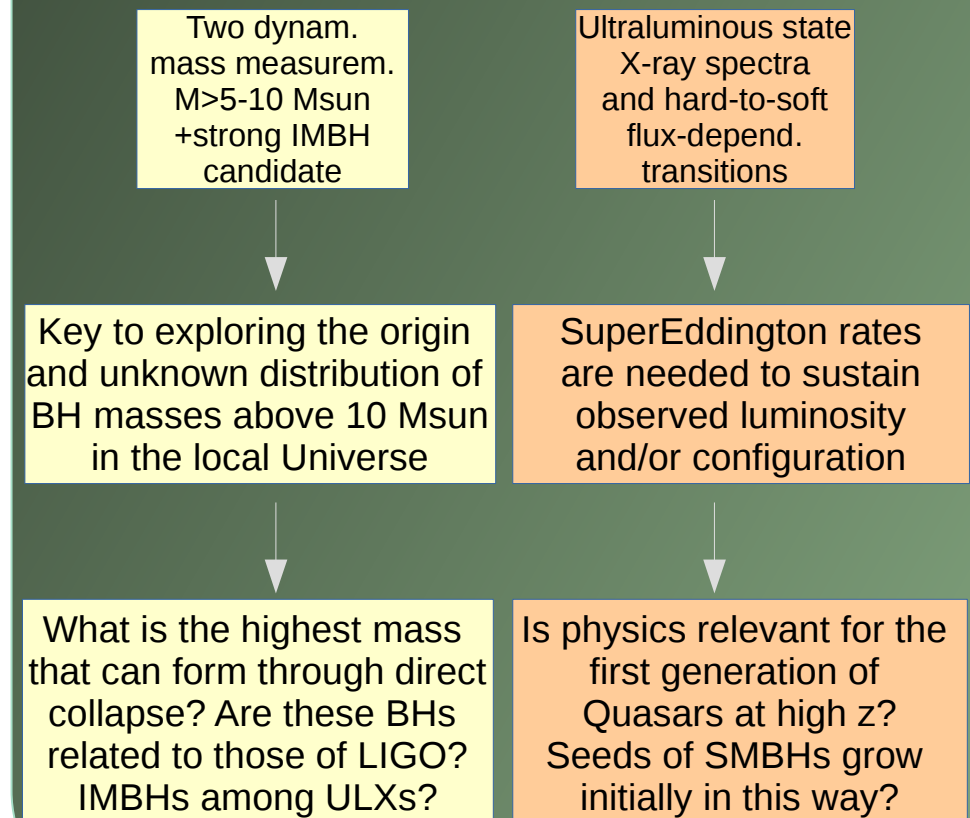
XMM-Newton: Walton et al. 2011

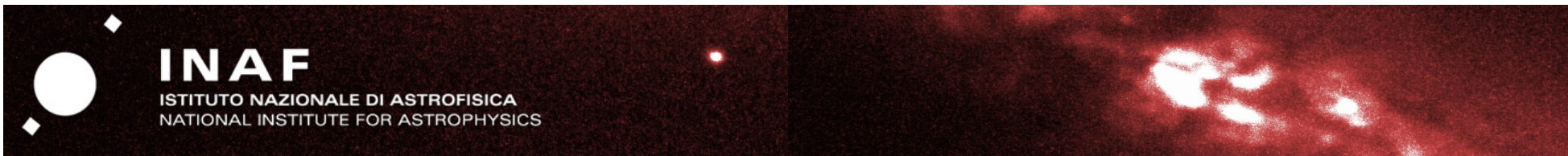
~ 20% Background AGNs

~ 5% Supernovae interacting with circumstellar medium

60-70% Accreting binaries

What is their importance?





ULXs: People, Collaborations, Funds in INAF

People (INAF)

M. Bachetti, T. Belloni, P. Esposito (AdR), G. Israel, M. Mapelli, F. Pintore (AdR), I. Prandoni, L. Sidoli, M. Spera (AdR), L. Stella, G. Trinchieri, A. Wolter, L. Zampieri

People (Associati INAF)

E. Ambrosi, E. Ripamonti

International collaborations

D. Barret (IRAP, France)	
<u>E. Bertone</u> (INAOE, Mexico)	<i>from INAF</i>
<u>P. Esposito</u> (from June 1 st at University of Amsterdam, The Netherlands)	<i>from INAF</i>
A. Fruscione (SAO, U.S.A.)	
F. Grise' (Observatoire astronomique de Strasbourg, France)	
F. Harrison (Caltech, U.S.A.)	
M. Middleton (Cambridge, UK)	
<u>S. Motta</u> (Oxford, UK)	<i>from INAF</i>
T. Roberts (Durham University, UK)	
R. Soria (Curtin University, Australia)	
A. Sutton (NASA Marshall Space Flight Center, USA)	
D. Walton (JPL/Caltech, U.S.A.)	
N. Webb (IRAP, France)	

Funds available at present

[2 dedicated PRIN INAF awarded in 2007 and 2011]

- Project "Accretion onto stellar and intermediate-mass compact objects with NuSTAR" (PI: T. Belloni), ASI - INAF I/037/12/0
 UdR OABrera-Merate: Resp. T. Belloni UdR OARoma: Resp. P. Casella UdR OAPadova: Resp. L. Zampieri

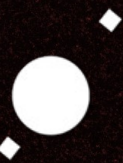
2014-2015: 6200 Euro per UdR

2015-2016: 5600 Euro per UdR

- PhD fellowship, University of Padova

E. Ambrosi (Resp. L. Zampieri)

2015-2018: 49000 Euro



INAF

ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

ULXs: What do we know and are we doing?

Optical/IR monitoring campaigns of counterparts (Liu et al. 09, [Zampieri et al. 12](#); Heida et al. 14)

First measurements of a mass function in ULXs

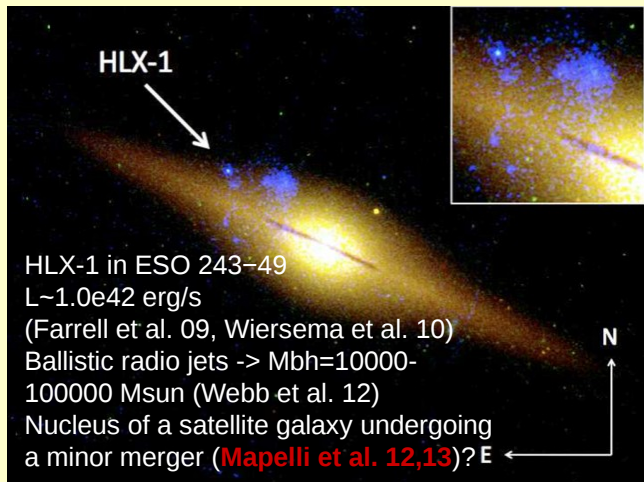
M 101 ULX-1 (Liu et al. 2013):

Mbh > 5 Msun

ULX P13 in NGC 7793 (Motch et al. 2014):

Mbh < 15 Msun

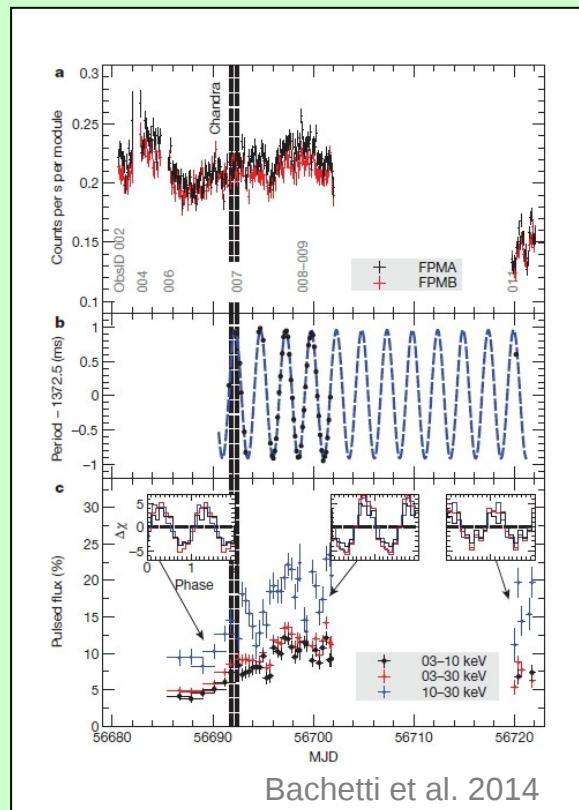
Intermediate mass Black Holes?



An ultraluminous accreting pulsar!

Background-subtracted 3–30 keV **NuSTAR** light curve from the region of **M 82 X-2** shows a modulated periodicity ([Bachetti et al. 2014](#))

Mean period: 1.37252266(12) s
Orbital modulation: 2.51784(6) d



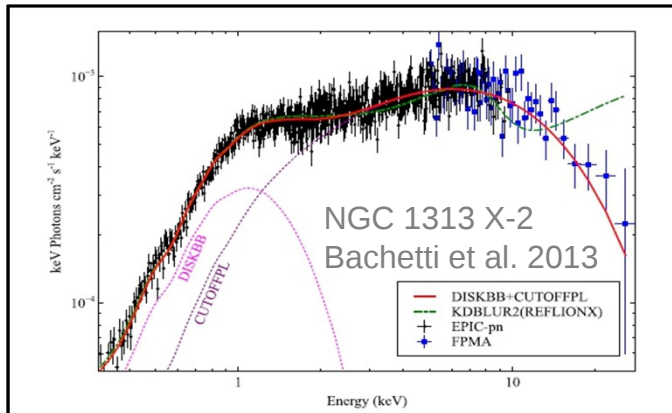
Present activities

Follow-up of M 82 X-2 with NuSTAR and Chandra ([Bachetti](#))

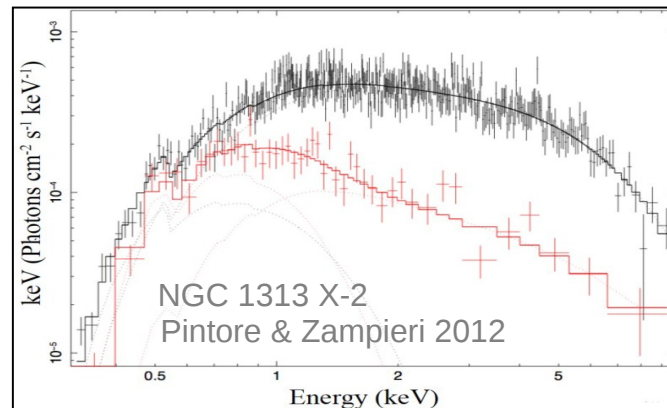
Grantecan/Swift monitoring campaign of Holmberg IX X-1 ([Fiori, Zampieri, Bertone, Ripamonti, Esposito, Pintore](#)) – Michele Fiori is a grad. student working on this project

ULXs: What do we know and are we doing?

Ultraluminous state (Gladstone et al. 2009)



No significant change of cutoff energy observed with NuSTAR (Bachetti et al. 2013; Walton et al. 2014, 2015)



Hard/high to soft/low transitions (Kajava & Poutanen 09; Pintore & Zampieri 12; Sutton et al. 13; Pintore et al. 14)

Short term variability (QPOs+noise) in 4 ULXs

M82 X-1 (Strohmayer & Mushotzky 2003, Mucciarelli et al. 2006, Pasham et al. 2014); NGC 5408 X-1 (Strohmayer et al. 2007); IC 342 X-1 (Agrawal & Nandi 2014); M82 X-2 (Feng et al. 2010)

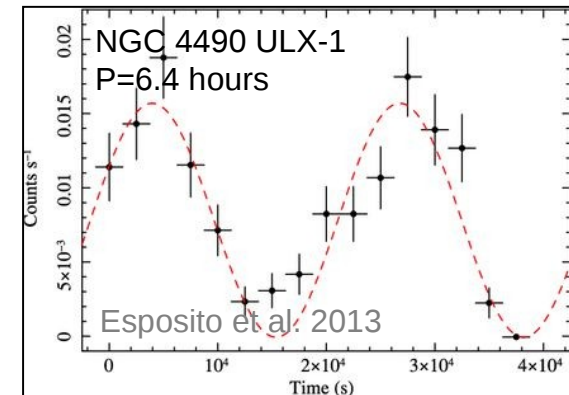
Absence of variability in a significant fraction of ULXs (Heil et al. 2009)

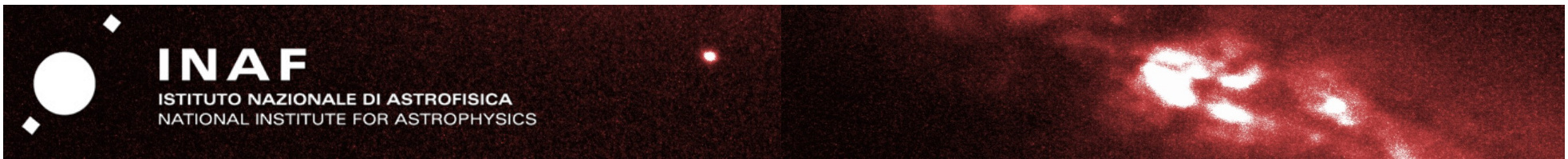
Present activities

Testing and comparing phenomenological models of accreting compact objects to broad-band XMM-Newton +NuSTAR spectra of ULXs (Pintore, Bachetti, Zampieri, Stella, Wolter)

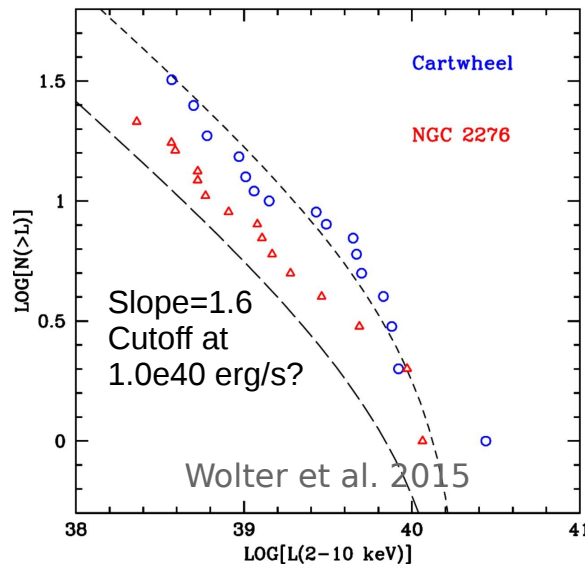
Structured long-term variability by a factor up to 5-10, with flux-dependent flaring activity (Kong et al. 2010, Grise' et al. 2016; Pintore et al. 2015)

X-ray modulations detected in RXTE, Swift, Chandra data: super-orbital periods or true periodicities (Kaaret et al. 2006, Lin et al. 2015; Esposito et al. 2013, 2015)?





ULXs: What do we know and are we doing?



X-ray luminosity function (normalized to the SFR) of Cartwheel and NGC 2276 (Wolter et al. 2015)

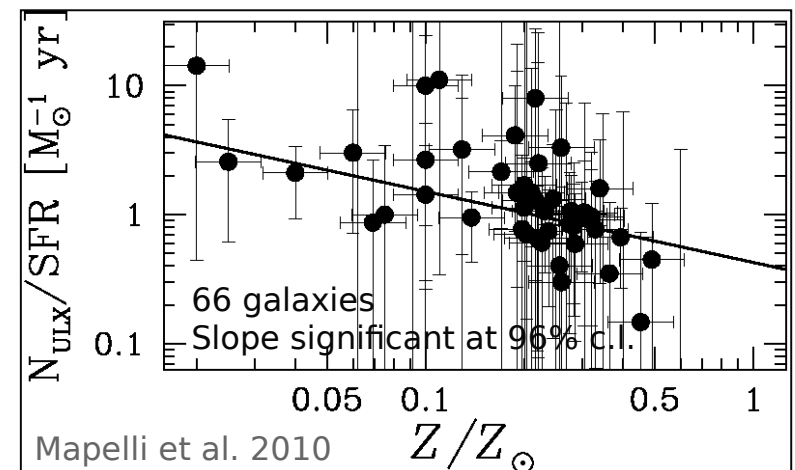
Strong correlation between number of ULXs per galaxy (Nulx) and star formation rate (SFR), as for Galactic high mass X-ray binaries (Grimm et al. 2003; Mineo et al. 2012)

Evidence of association of ULXs with low metallicity environments (Swartz et al. 08; Walton et al. 2011; Prestwich et al. 2013)

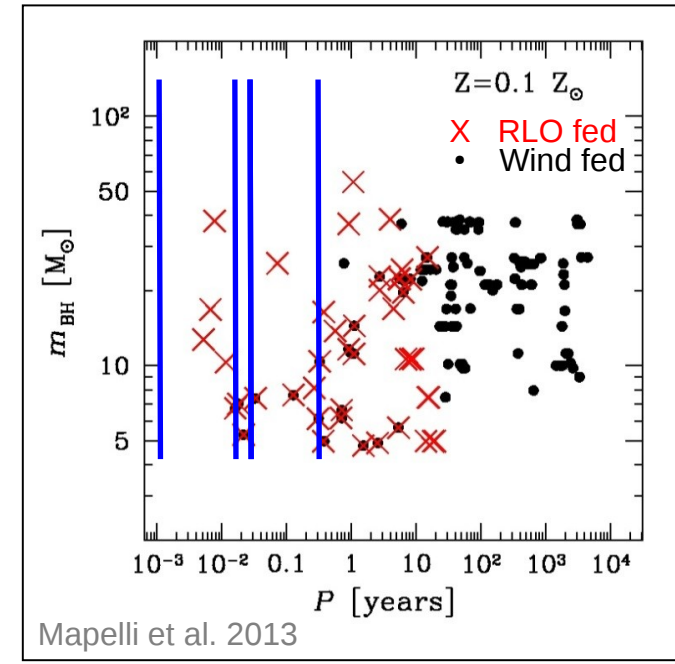
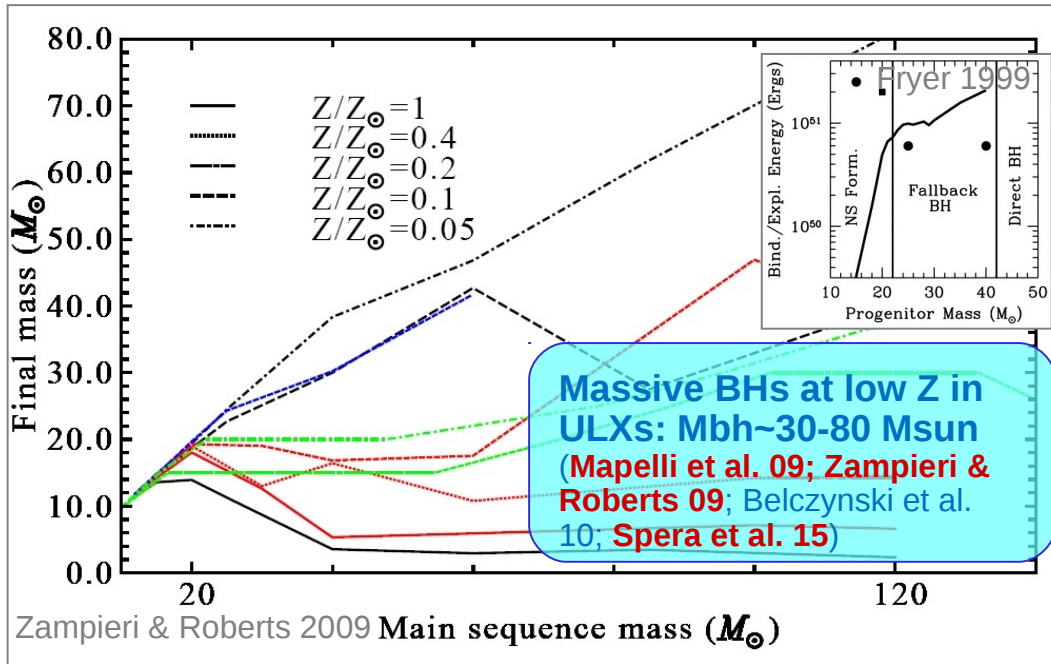
Line intensities of HII region give $Z=0.1-0.5 Z_{\odot}$ and **marginal anticorrelation of Nulxs/SFR vs Z** (Mapelli et al. 2010)

Present activities

Statistics of ULXs in a selected sample of ring galaxies (Wolter, Mapelli, Ripamonti, Trinchieri, Zampieri)



ULXs: What do we understand and would like to understand?



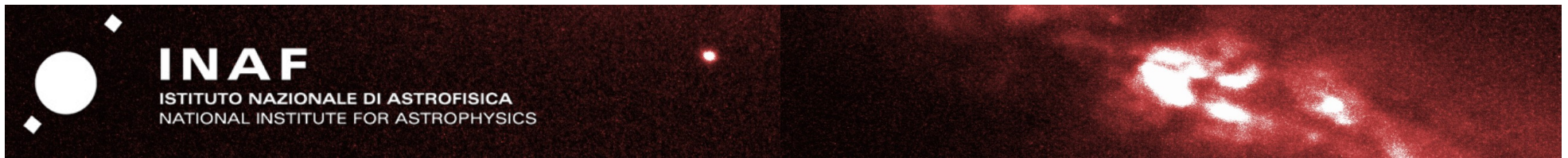
Binary evolution in a cluster with Z-dependent stellar evolution (Mapelli et al. 13; Mapelli & Zampieri 14)

Blue counterparts are mostly short period primordial binaries with younger MS/post-MS donors and low mass BHs

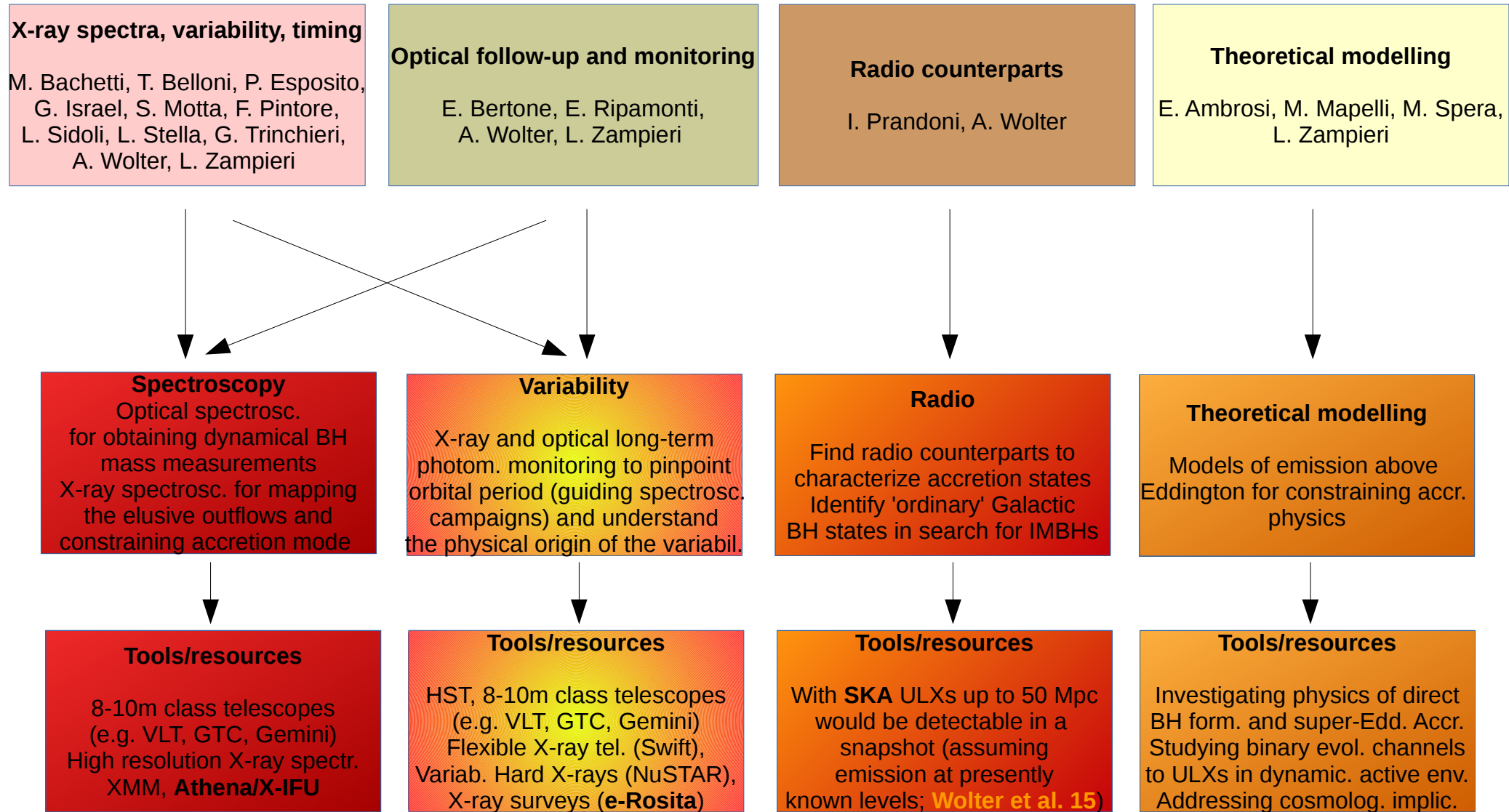
Red counterparts are mostly long-period exchange binaries with older and more evolved donors, more extended discs, and both low mass and massive BHs

Present activities

Modelling multiwavelength emission of ULX binaries above the Eddington limit (Ambrosi, Zampieri, Mapelli)



ULXs: Areas of activity and future projects – A comprehensive multi-wavelength approach



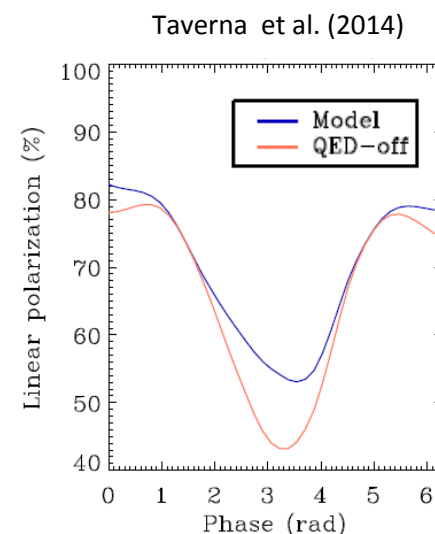
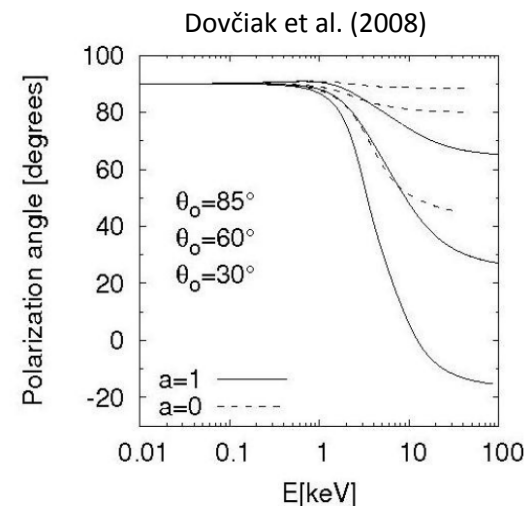
X-ray Polarimetry

Paolo Soffitta, Enrico Costa, Giorgio Matt, Domitilla de
Martino, Fabio Muleri, Luca Baldini, Niccolò Bucciantini,
Riccardo Campana, Giampietro Tagliaferri, Imma
Donnarumma, Roberto Turolla, Roberto Taverna, Enrico
Massaro, Luigi Foschini, Marco Roncadelli
and many others

INAF, Associati INAF, INFN

What Polarimetry Could Do - I

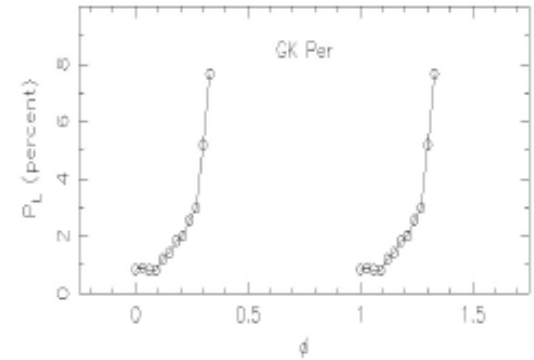
- Black hole sources
 - Thermal disc photons scatter in crossing the corona and get polarized
 - GR induces a rotation of the polarization plane
 - Sensitive to spacetime structure: measure a/M
- Magnetars
 - QED predicts ‘vacuum birefringence’ in strong magnetic fields (Heisenberg & Euler 1936)
 - Direct impact on polarization
 - Test QED in the strong field limit



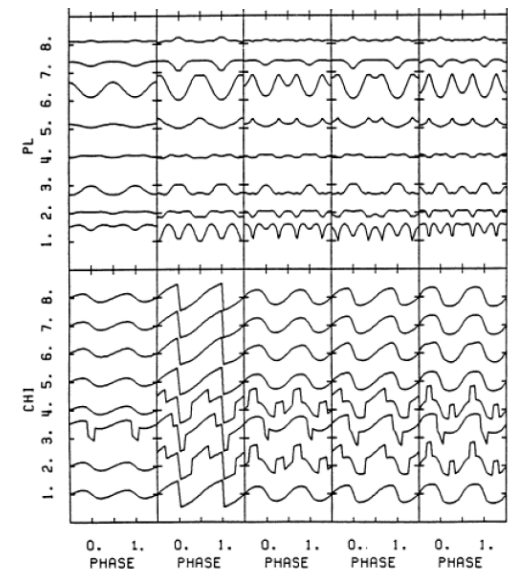
What Polarimetry Could Do - II

- Accreting Magnetized Objects (CVs, X-ray pulsars)
 - Polarization from Compton scattering in a stratified accretion column
 - Expected polarization degree up to 10% in CVs and 70% in AXPs
 - Probe the physics/geometry of the accretion flow
 - Test directly the fan/pencil radiation pattern

McNamara et al. (2008)

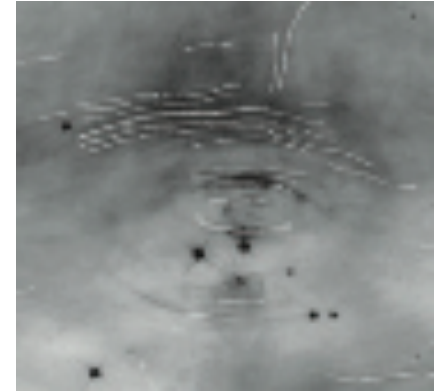


Meszáros (1988)

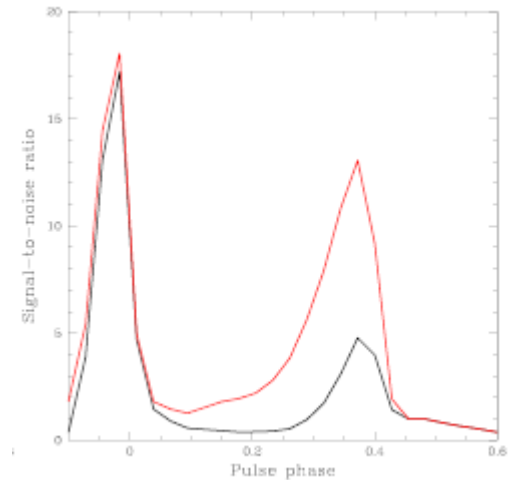


What Polarimetry Could Do - III

- PSRs and PWNe
 - Constrain the level of magnetic turbulence in PWNe and in the Jet, and the role of re-acceleration inside these nebulae
 - Investigate the dynamics of the shock and possible relation between polarization and flaring activity
 - Discriminate between different polarization scenarios in Crab-like PSRs



Hester (2008)



Massaro et al. (2016)

Upcoming Missions

- XIPE (X-ray Imaging Polarimetry Explorer), PI P. Soffitta, ESA M4
- IXPE (Imaging X-ray Polarimetry Explorer), PI M. Weisskopf, NASA Smex
- PRAXys (Polarimeter for Relativistic Astrophysical X-ray Sources), PI K. Jahoda, NASA Smex
- eXTP (enhanced X-ray Timing and Polarization satellite), CAS

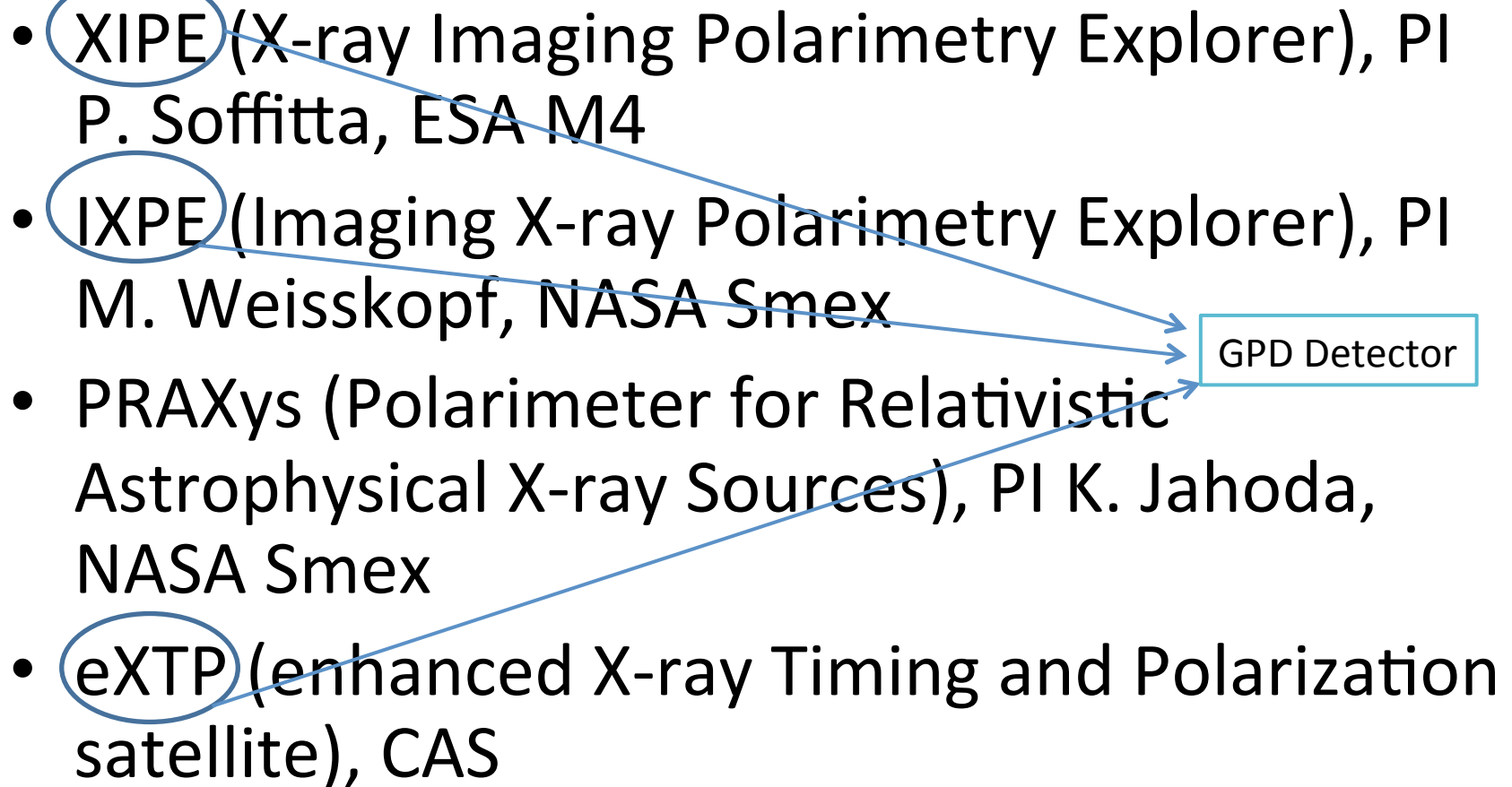


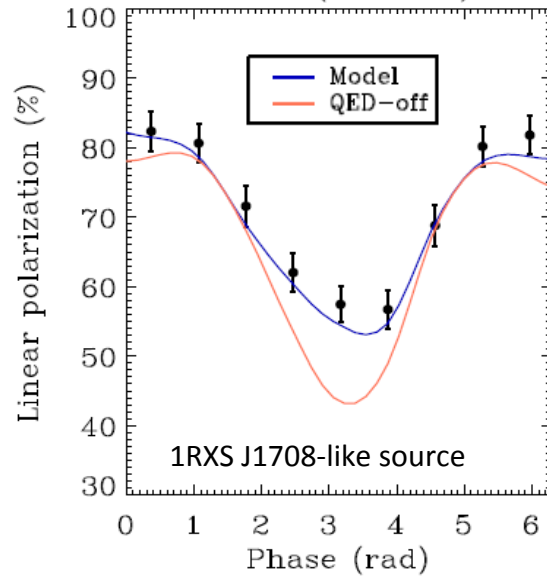
Diagram illustrating the connection between the missions and the GPD Detector:

- Arrows point from the circled mission names (XIPE, IXPE, and eXTP) to the GPD Detector box.
- There is also a direct arrow from the PRAXys mission name to the GPD Detector box.

GPD Detector

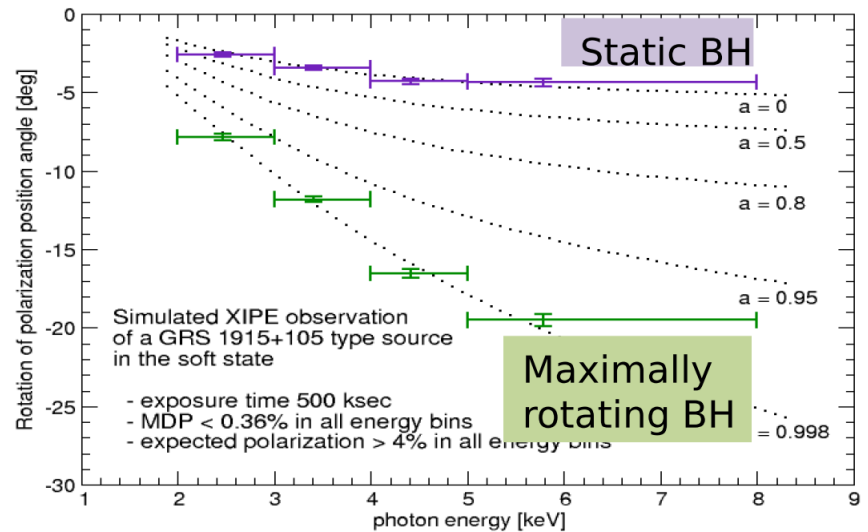
What Polarimetry Can Do - I

XIPE simulation (250 ks) – Average



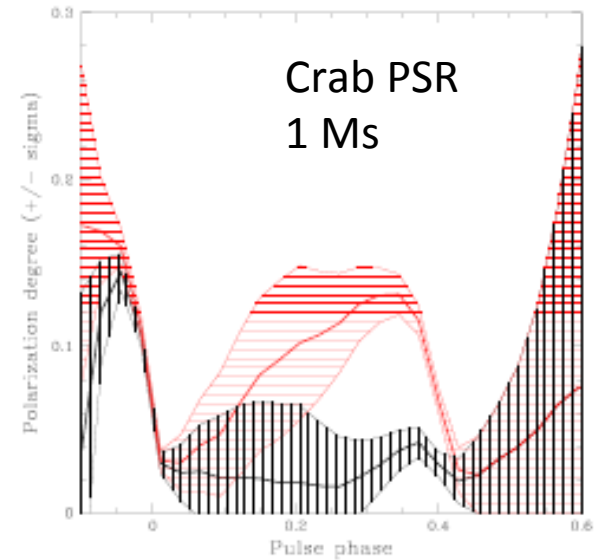
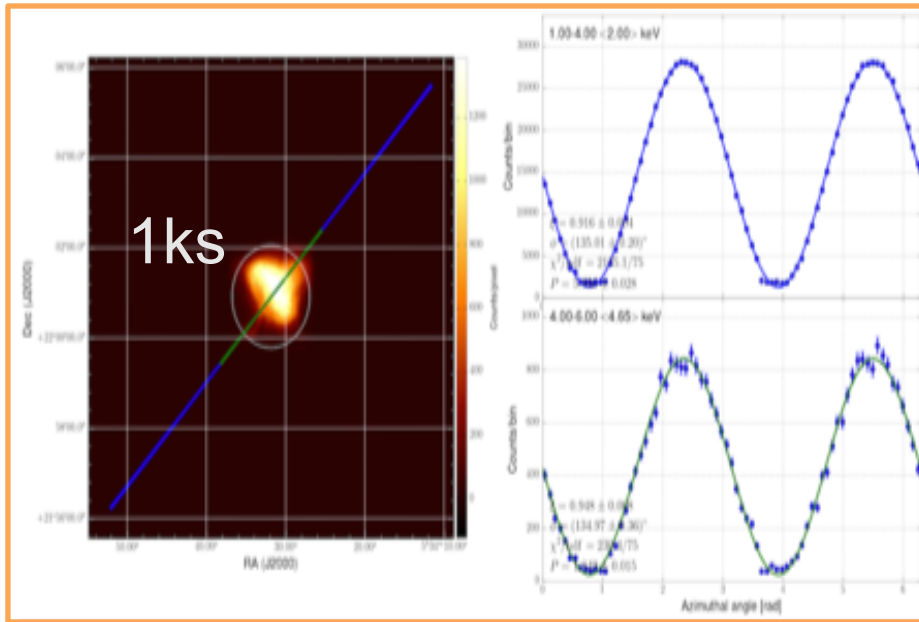
XIPE can pick up the polarization signature of the vacuum in a bright persistent magnetar

XIPE



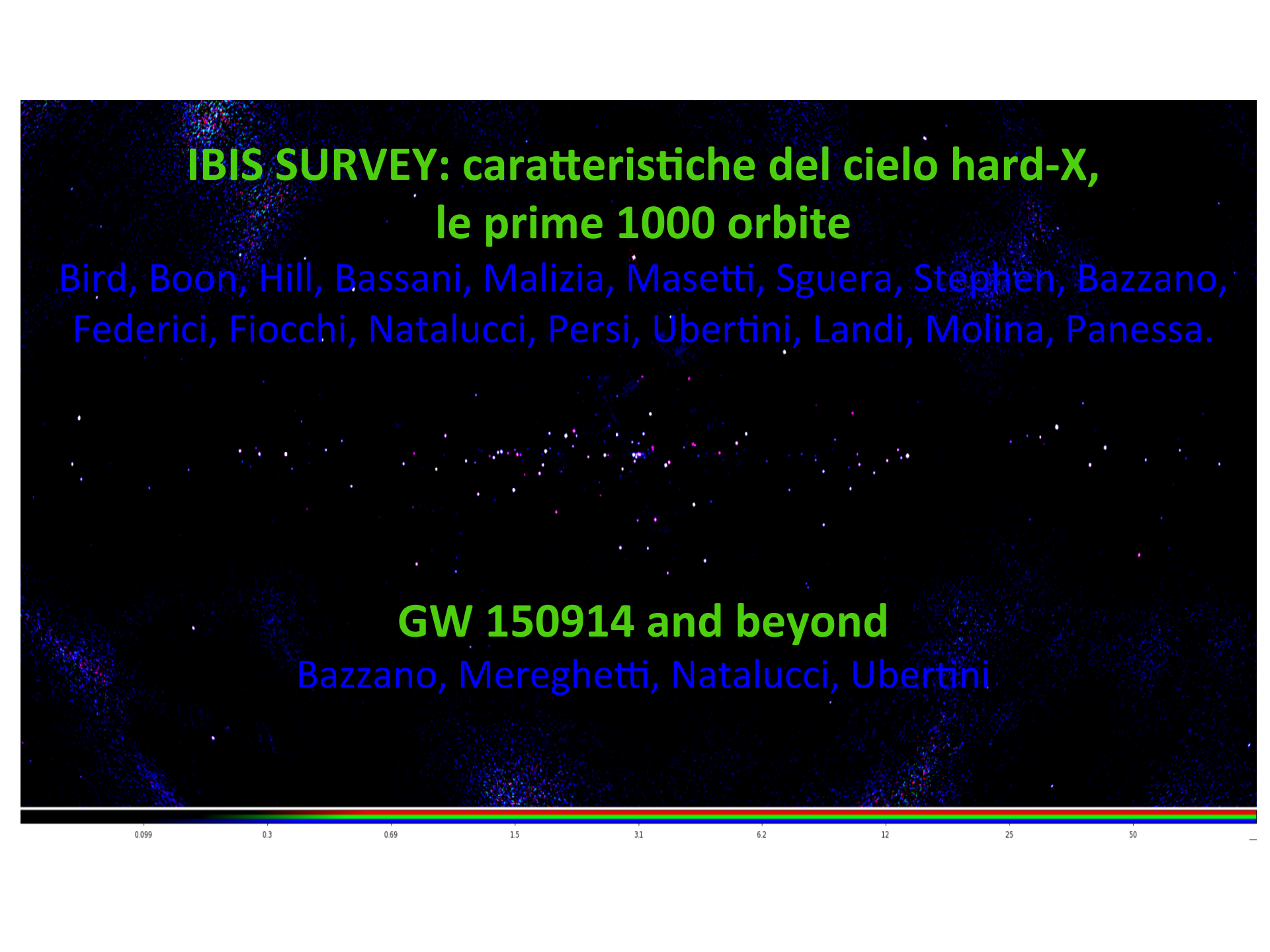
XIPE can achieve a measure of the BH spin in a bright Galactic BH source

What Polarimetry Can Do - II



A 1 ks exposure with XIPE can measure the PA and the PF of the Crab with 1% accuracy. Space-resolved polarimetry in 3 PWNe (Crab, Vela , MSH15-52)

XIPE can successfully discriminate between different polarizations of the X-ray components

The background of the slide is a deep space image showing a dense field of stars. The stars are represented as small white and blue dots against a black background. At the bottom of the image, there is a horizontal color calibration bar with a series of colored squares (black, grey, white, red, green, blue, yellow, cyan, magenta, brown, pink, light blue, dark blue, light green, dark green, light red, dark red, black) and numerical values below them: 0.099, 0.3, 0.69, 1.5, 3.1, 6.2, 12, 25, 50. The text is overlaid on this image.

IBIS SURVEY: caratteristiche del cielo hard-X, le prime 1000 orbite

Bird, Boon, Hill, Bassani, Malizia, Masetti, Sguera, Stephen, Bazzano,
Federici, Fiocchi, Natalucci, Persi, Ubertini, Landi, Molina, Panessa.

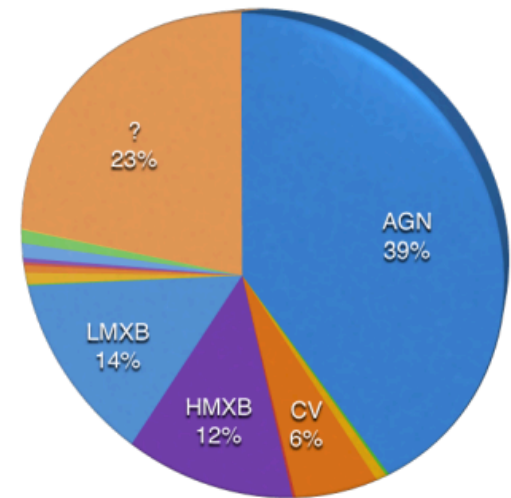
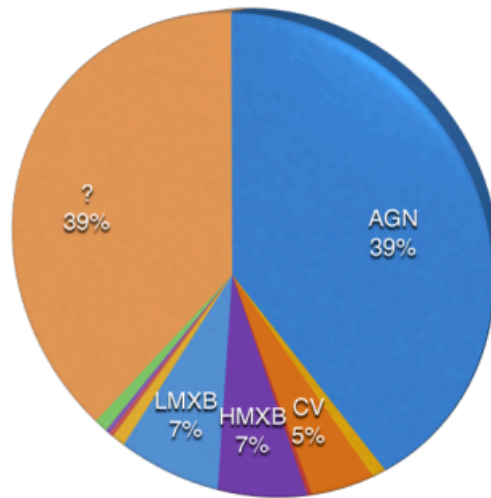
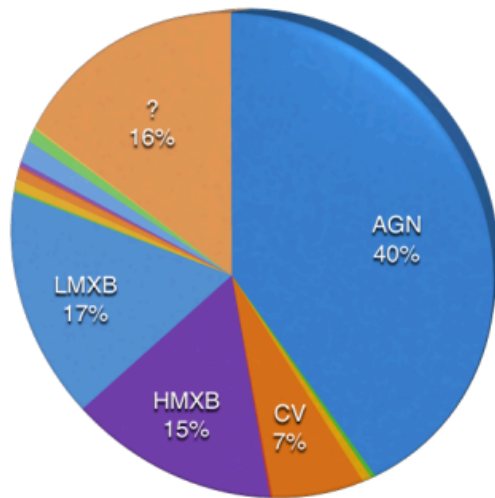
GW 150914 and beyond

Bazzano, Mereghetti, Natalucci, Ubertini

IBIS SURVEY: caratteristiche del cielo hard-X (1000 orbite)

- 120 Ms data, 75000 pointings (dic 2010): 939 sorgenti , ~ 307 nuove rivelazioni di cui, **120 sono sorgenti rivelate per la prima volta**
- Infos disponibili: posizione, flussi in due bande e tempi di esposizione e tempi e durata di outbursts e livelli di variabilita' per le transienti
- Sinergia con SWIFT/BAT

● AGN ● AXP ● Cluster ● CV ● GRB ● HMXB ● LMXB ● Mol cloud ● PSR ● PWN ● RSCVn ● SGR ● SNR ● XB ● XP ● ?



Collaborazione: IASF-Bologna, IAPS e Universita' di Southampton

Bird, Boon, Hill, Bassani, Malizia, Masetti, Sguera, Stephen, Bazzano, Federici, Fiocchi, Natalucci, Persi, Ubertini. **No stuff: Landi, Molina, Panessa.**

Fondi ASI: solo per mantenimento Archivio dati e aggiornamento hardware di analisi

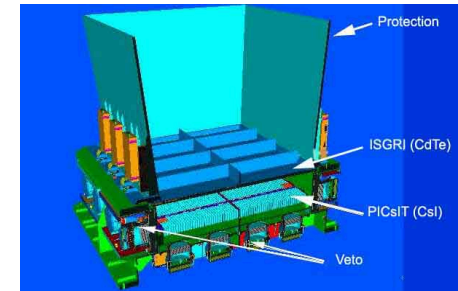
IBIS SURVEY: attività' in corso e futura:

- Produzione Curve di Luce e Spettri per le 939 sorgenti **aggiornate** con un totale di 116000 puntamenti (genn. 2015), ~200 Ms di dati
- Follow-up in banda X, Swift (approvate) e nell' Ottico e NIR per le sorgenti persistenti
- Caratterizzazione delle sorgenti transienti su tempi scala brevi (0.5-100 giorni) e identificazione della natura basata su durata outburst, proprietà spettrali e temporali, emissione quiescente, SED ottico/IR.
- Creazione di spettri su larga banda tramite dati in banda X e al MeV/GeV
- Richiesta di ToO (SWIFT/XRT, XMM, CHANDRA, NuSTAR) per eventuali transienti in outburst
- Proposte osservative INTEGRAL: Monitoring Galactic Bulge, Galactic Centre, Galactic Plane Scanning e singoli oggetti.

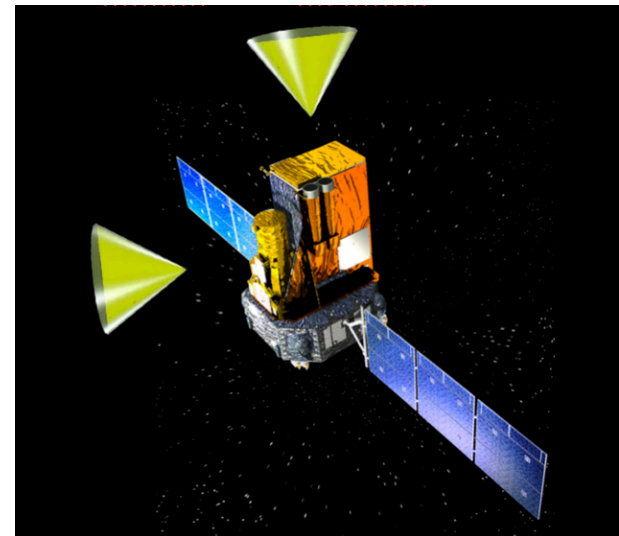
Questo data set e le future surveys saranno un "database" per future missioni

GW 150914 and beyond

- The SPI/ACS sensitivity in FOV vary up by a factor 5, but its optimal value applies to 75% of the sky
- GW150914: U.L. range is $0.2\text{--}4.5 \times 10^{-7}$ erg cm⁻² for event durations of 0.05 to 10s, respectively (applies to 95% of the Adv. LIGO error region)
- The ratio of e.m. to grav. energy is $R_{\gamma/g} = 0.2\text{--}5 \times 10^{-6}$
- In case of events in the ~ 300 sq.deg FOV of INTEGRAL, the search flux limits would decrease by a factor ~ 5 at least
- Starting from the next O2 campaign, aLIGO + Virgo will start to approach their design performance. The error region will size < 100 sq.degrees
- INTEGRAL can characterize the prompt and also the delayed emission using dedicated TOO programs.
- The INTEGRAL data archive will be searched for transient events using new tools, not only for candidate GW but also in coincidence with e.g. ICECUBE neutrino detections



The IBIS detectors ISGRI and PICsIT have max sensitivity to directions normal to SPI/ACS factor of 5 at least



GW 150914 and beyond

- Collaborazione Internazionale con membri dell'INTEGRAL User Group
- Staff INAF: Bazzano, Mereghetti, Natalucci, Ubertini
 - +possibile INAF phd fellowship (ottobre 2016)
 - +ESA fellowship, co-tutela con E. Kuulkers (fine2016)
- Al momento non ci sono fondi dedicati.
- MOU interno con gruppi GRAWITA e Swift
- MOU con consorzio aLigo-Virgo, O2