X-ray Binaries

Lara Sidoli
&
Ada Paizis
Sandro Mereghetti
Nicola La Palombara
Andrea Tiengo

Students:

Lorenzo Ducci (PhD student from Univ. Insubria-Como)
Renzo Capelli (undergraduate student from Univ. Milano-Bicocca)
The *main* activities of the “XRBs group”

**High Mass X-ray Binaries:**
- *new INTEGRAL sources*
- *Supergiant Fast X-ray Transients*
- *Be/XRB*

**Low Mass X-ray Binaries:**
- *new INTEGRAL sources*
- *hard tails in LMXBs*
High Mass X-ray Binaries:

new INTEGRAL sources
Supergiant Fast X-ray Transients

“SHORT” outbursts lasting few hours
typically < 1 day
as observed with IBIS/ISGRI

About 20 SFXTs to date
By definition, a SFXT is a source with:

**Transient & “SHORT” X-ray OUTBURSTS** (biased def)

&

**OB supergiant companions**

**Other properties:**

**Luminosity:**

\[
\begin{align*}
L_{x\, \text{outburst}} & \sim 1E36 \text{ erg/s} \\
L_{x\, \text{quiescence}} & \sim 1E32 \text{ erg/s}
\end{align*}
\]

-> high dynamic range \( \sim 1000-10000 \)

**Spectrum similar to typical accreting pulsars**

0.1-10 keV – hard powerlaw

cut-off around 10-30 keV
A key system to understand SFXTs: **IGR J11215-5952**

discovery of a **periodicity** in the outburst recurrence with INTEGRAL data (Sidoli et al. 2006)

outbursts every ~ 330 days

likely orbital period?

outbursts near periastron passage?
The predictable outbursts led us to propose a monitoring campaign with Swift / XRT of IGR J11215-5952 during the February 2007 outburst

The accretion phase lasts longer than what previously known!!!(Romano, Sidoli, Mangano et al. 2007)

9th February 2007
Swift / XRT observations of IGR J11215-5952 allowed us to trigger our XMM-Newton and INTEGRAL observations (PI: Sidoli)

9th February 2007
An important result of the Swift/XRT monitoring

The lightcurve is **too narrow and steep** to be explained within a model of Bondi accretion from a spherical and homogeneous wind in an eccentric binary (even with extreme eccentricities!)

We proposed a new model to explain the SFXTs outbursts.
Persistent BeXRBs of low luminosity ($L_X \sim 10^{34-35}$ erg s$^{-1}$) and long pulse period ($P \sim 1000$ s)

XMM observation of 4U 0352+309 and RX J0146.9+6121

- data excess over the main PL component of BB type (~ 30 % of the total flux)
- high BB temperature ($kT > 1$ keV)
- small emission area ($R < 0.5$ km)
- no evidence of an Iron line between 6 and 7 keV (EQW < 0.1 keV)
the pulse profile is energy dependent and not simply sinusoidal

- pulsed emission also below 2 keV
- spectral variability with the pulse phase

**thermal emission from the neutron star polar caps?**
<table>
<thead>
<tr>
<th>X-ray source</th>
<th>4U 0352+309</th>
<th>RX J0146.9+6121</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luminosity (2-10 keV)</td>
<td>$\sim 10^{35} \text{ erg s}^{-1}$</td>
<td>$\sim 10^{34} \text{ erg s}^{-1}$</td>
</tr>
<tr>
<td>Accretion rate</td>
<td>$\sim 5 \times 10^{14} \text{ g s}^{-1}$</td>
<td>$\sim 5 \times 10^{13} \text{ g s}^{-1}$</td>
</tr>
<tr>
<td>Magnetospheric radius</td>
<td>$\sim 9.5 \times 10^{8} \text{ cm}$</td>
<td>$\sim 1.8 \times 10^{9} \text{ cm}$</td>
</tr>
<tr>
<td>Accretion column radius</td>
<td>$\sim 330 \text{ m}$</td>
<td>$\sim 230 \text{ m}$</td>
</tr>
<tr>
<td>Black-body radius</td>
<td>$\sim 360 \text{ m}$</td>
<td>$\sim 150 \text{ m}$</td>
</tr>
</tbody>
</table>

the BB size is in agreement with the polar-cap origin of the thermal excess

La Palombara & Mereghetti 2006, 2007
Low Mass X-ray Binaries: *hard tails in LMXBs*

NS LMXBs: spectral states dominated by IC by different plasma temperatures

High/soft state:
- disc: \(~1\) keV
- NS: \(~2\) keV
- plasma: \(kT \sim 3\) keV
- \(\tau \sim 5-15\)

Low/hard state:
- plasma: \(kT \sim 30\) keV
- \(\tau \sim 2-3\)

Efficient cooling \((\sim 3\text{keV})\) -> Mdot

Non-efficient cooling \((\sim 30\text{keV})\)
Low Mass X-ray Binaries: hard tails in LMXBs

No physical scenario has been proposed up to now in order to explain in a coherent way all the spectral states that are observed (i.e. the spectral evolution).

Hard Tails *Mostly* fit with power-laws

Current physical interpretations:

- Hybrid corona (Coppi 1999) - local injection of non-thermal electrons *ad hoc*;
- Emission from the jet (Markoff et al., 2005)
- Bulk motion Comptonization – bulk expected in the vicinity of compact object caused by the intense gravitational potential. It produces an extended PL (Titarchuk et al., 1996, 1997)
Paizis et al., (2006, P06) proposed for the first time a unified physical scenario to both explain the hard tail and the evolution between the spectral states. P06 identified four different spectral states that they studied with the Bulk Motion Comptonisation model (BMC, Titarchuk et al., 1996, 1997).

- The BMC model can explain the spectral evolution and the Radio – X-ray tail correlation;
- In this scenario, bulk motion is at the origin of the hard X-ray tails;
- The final spectral state is the result of interplay of thermal and bulk Comptonization and it is driven by the accretion rate;

A clear correlation between our average hard X-ray tail and Radio emission is found.
Given the success of the model to describe the hard X-ray data of NS LMXBs, we developed a new model (XSPEC format) to optimize and complete the existing BMC model: CompFT (Farinelli, Titarchuk, Paizis & Frontera submitted)

- CompFT includes simple thermal as well as thermal plus bulk Comptonization;
- SAX, RXTE and INTEGRAL spectra of NS LMXBs can be fitted with two CompFT
  1) thermal component from outer corona
     (seed photons mainly from disc)
  2) thermal+bulk component from inner region
     (seed photons mainly from NS)

On-going work: QPO vs spectral evolution (simultaneous RXTE-INTEGRAL, PI Paizis); theoretical support to the model
Multi-λ follow-up observations of new INTEGRAL sources
(Paizis et al., 2007, Paizis et al., 2005, Rodriguez et al., 2007, Beckmann et al., 2005)

Sept. 19, 2006: INTEGRAL discovers a new source in the Galactic Centre (Soldi et al., 2006). Paizis et al. 07 performed X-ray (Chandra/HETGS) and NIR (NTT/SofI) follow-up observations.

The 0.6 arcsec (90%) Chandra error box (versus 5.3 Swift/XRT) allowed us to find a possible NIR counterpart (m Ks ~16)

The synergy of NIR and X-ray properties seem to suggest that IGRJ17497-2821 is a LMXB with red giant K-type companion, most likely hosting a black hole.

Chandra AO 9 still active (PI: Paizis)
Future perspectives of our group in the study of XRBs

We are *PIs* of several approved on-going observing programs:

Programs to monitor Galactic sources AND test/optimize our new physical models on SFXTs and LMXBs:

**INTEGRAL:** L.Sidoli & A.Paizis are PIs of 3 on-going *Key Programs* on XRB

-> this implies ~ 1 Ms/source of observing time (for 12 sources!)

**Swift:** L.Sidoli is PI of several on-going monitoring programs to observe 4 SFXTs and 1 very faint X-ray transient

-> this implies ~ 1-2ks/week/source during 2008

Observations to study the Be/XRBs thermal component and the nature of the pulsating RXJ0648.0-4418:

**XMM-Newton:** N.LaPalombara & A.Tiengo are PIs of 3 accepted *AO7* proposal -> for a total obs time = 210 ks

Identification of new INTEGRAL sources:

**Chandra:** A.Paizis is PI of a ToO (AO9) on 2 IGR sources

-> 40 ks in total
A few words about the non-permanent staff

- A significant part of the scientific output of our institute (not only of the XRBs group) comes from NON-PERMANENT staff

- Non permanent staff in IASF Milano (updated to 2008/01/01):
  14 scientists (excluding PhD students!) who have on average 7.5 years of experience in the research field (including 3 years of PhD) and PhD students

- A clear long-term human resource plan is lacking (both in our institute and in INAF in general)