High quality broad-band X-ray spectra of ULXs: testing and comparing phenomenological models of accreting compact objects

Fabio Pintore

Inaf-Iasf Milano

In collaboration with: 1) Luca Zampieri, Tim Roberts, Andy Sutton, Matt Middleton;

2) Luca Zampieri, Luigi Stella, Anna Wolter;
Most ULXs are believed to be BHs of stellar origin accreting at super-Eddington rates. However, the ULX population may in fact hide accreting compact objects with significantly smaller or larger masses, as intermediate mass BHs (HLX-1, NGC 2276, ...) or neutron star (M82 X-2). Poor quality data can be highly misleading.
IMBHs

IMBHs can be looked for between the brightest ULXs

A sub-sample of bright ULXs is in Sutton et al. (2013) but others can be found

Here we present the source NGC 5643 ULX1
NGC 5643 ULX-1

Distance:
- Probably less (13.9 Mpc, Sanders et al. 2003).

Discovered by Rosat (Guainazzi et al. 2004)
0.8 arcmin from the AGN
Observed once with Chandra and 3 times with XMM-Newton

Pintore et al. (2016)
Luminosity variability up to a factor of 3
From low quality data, spectral and timing properties consistent with a hard state of Galactic BHs.

Best-fit with a hard powerlaw ($\Gamma \sim 1.7-1.8$), high luminosity ($> 1e40$ erg s$^{-1}$), and short-term variability $> 10\%$ (although consistent with $3\%$ at $3\sigma$).
AN
IMBH??
Power spectrum averaged over 3 intervals between $6\times10^{-3} - 1\text{Hz}$

High quality XMM-Newton data (~100 ks)

No variability (less than 5%)
High energy residuals with simple models.

No short-term variability and spectral shapes different from both hard or soft states of Galactic BH binaries
AN IMBH??

NO!

Low quality data are misleading most of the time
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Low quality data are misleading most of the time

... SO WHAT?
Best-fit:
- a hot advection dominated disc ($kT \sim 2.6$ keV, $p \sim 0.6$)
- or with an optically thick corona ($kT_{\text{seed}} \sim 0.1$ keV, $kT_e \sim 1.7$ keV, $\tau \sim 10$).

Similar fits to the low-quality data gave the same spectral results.

Clear high energy roll-off (confirmed also by Annuar et al. 2015 with NuSTAR data).
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Clear high energy roll-off (confirmed also by Annuar et al. 2015 with NuSTAR data).
- No IMBH accreting sub-Eddington;
- A standard ULX, possibly with a stellar mass BH accreting super-Eddington;
- Flux variability not accompanied by spectral variability;
- Marginally evidence of short-term variability;
- Hardly to explain it only with an advection dominated disc;
- Possibly classified as hard/ultraluminous source (see Sutton et al. 2014);
- Powerful winds;
- View face-on?
- Strong beaming?
- Variability produced by clumps of the wind?
- From the luminosity, more likely a 30 solar masses BH (If the distance was 13.9 Mpc, the luminosity would be 30% less);
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A challenging question:

We already know of the NS in M82 X-2.

Is it possible that there are other NSs amongst presently known ULXs?
We could apply to ULX spectra phenomenological models which were widely adopted for accreting NS.

absorbed highecut*powerlaw

Test on one source: **NGC 1313 X-1**

\[ M(E) = \begin{cases} 
\exp\left(\frac{E_c - E}{E_f}\right) & E \geq E_c \\
1.0 & E \leq E_c 
\end{cases} \]
Clearly evidence for strong residuals
Instead of adding a blackbody, we add three broad, gaussian absorption lines.

\[
\chi_v \sim 1
\]
\[
\Gamma \sim 2.2
\]
Energy cut-off \sim 8 \text{ keV}
Folding energy \sim 16 \text{ keV}

<table>
<thead>
<tr>
<th>Line1</th>
<th>Line2</th>
<th>Line3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (KeV)</td>
<td>0.75 +/− 0.02</td>
<td>1.56 +/− 0.05</td>
</tr>
<tr>
<td>(\sigma) (keV)</td>
<td>0.06 +/− 0.02</td>
<td>0.35 +/− 0.08</td>
</tr>
<tr>
<td>Strenght</td>
<td>0.016 +/− 0.007</td>
<td>0.14 +/− 0.07</td>
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Three absorption lines
Blending of absorption lines from the most abundant elements (Ne, Mg, S, O, Si, Fe); see Middleton et al. (2015), Pinto et al. (2016)
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Cyclotron lines (fundamental and two armonics). Electrons, protons?
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Cyclotron lines (fundamental and two harmonics). Electrons, protons?

\[ B_e \sim 8 \times 10^9 \text{ G} \]

Blending of absorption features for the two low-energy lines, and one cyclotron lines at 2.5 keV (electrons, protons)?

\[ B_e \sim 3 \times 10^{11} \text{ G} \]
\[ B_p \sim 5 \times 10^{14} \text{ G} \]
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Three absorption lines

MAGNETAR??
- This is only a phenomenological model;

- It described NS spectra of very low quality;

- The variability would still be in the hard component;

- Possibility to have the wind;
Thanks for your attention