A self-consistent approach to the reflection component in NS LMXBs

Antonino D'Aí
T. Di Salvo, R. Iaria, N.R. Robba, A.Papitto, D. Ballantyne

Dipartimento di Scienze Fisiche ed Astronomiche
Università di Palermo

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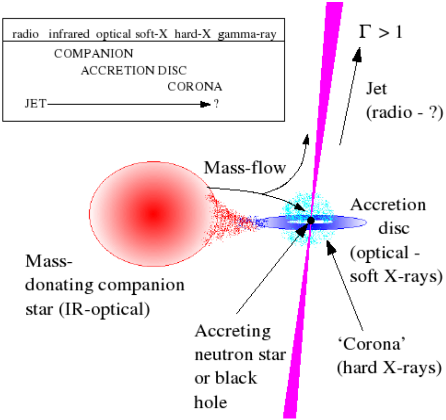
Summary

Spectral decomposition in LMXBs

Emission processes and geometry

- Z-sources: always very soft spectra
- Atoll sources: banana and island states
- Soft component (below 3 keV) → SS disk
- Hard component (3-10 keV) → Comptonization in corona (boundary layer)
- Hard tails (above 20 keV) → emission from outflows or jets (open)
- Broad lines → Reflection component



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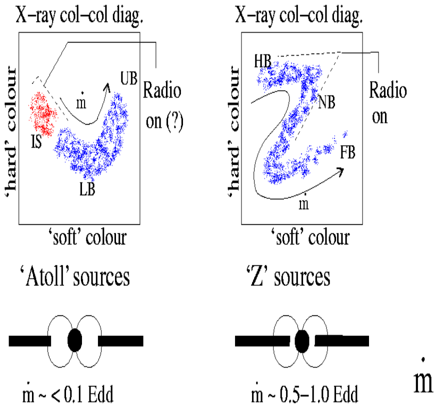
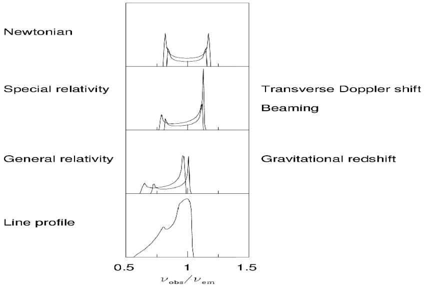
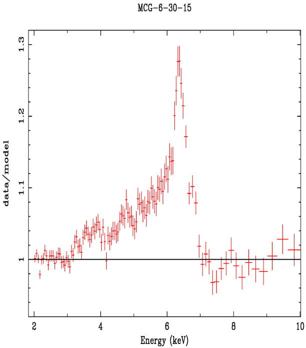


Relativistic lines in LMXBs I





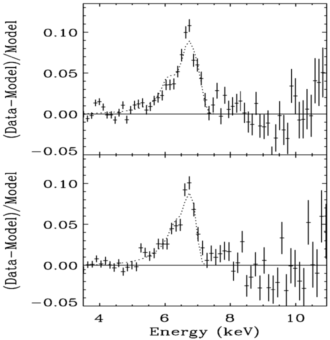
Line Shape

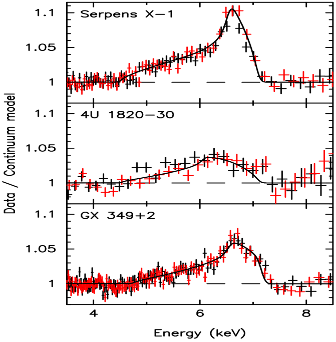
- Inclination angle
- Disk inner radius
- Disk outer radius
- Emissivity law ($\epsilon(r) = r^{-q}$)

Reference

Fabian et al., 2002, MNRAS
XMM data

Relativistic line in LMXBs II





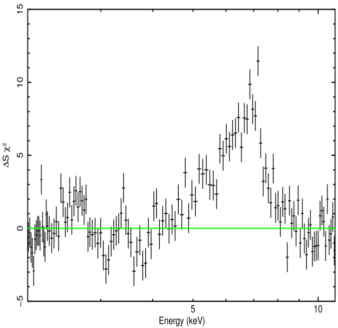
Reference

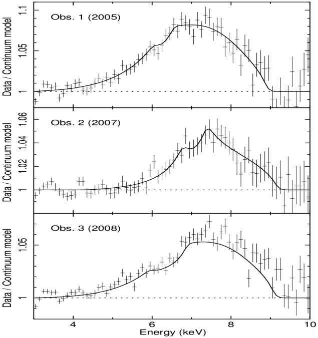
NS LMXB: Ser X-1
Bhattacharyya et al., 2007, ApJ
XMM data

Reference

NS LMXBs systems
Cackett et al., 2008, ApJ
Suzaku data

Relativistic line in LMXBs III





Reference

NS LMXB: SAX J1808.6-3658
Papitto et al., 2009, A&A
XMM data

Reference

NS LMXB: 4U 1636-56
Pandel et al., 2008, ApJ
XMM data

The case GX 340+0: results

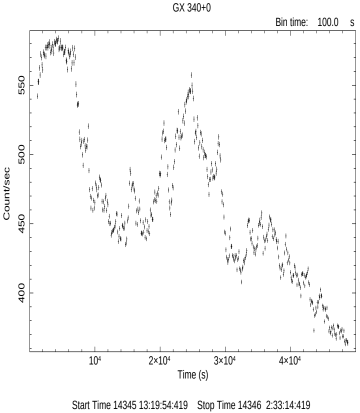
Spectral decomposition

Simple model phabs(diskbb+bb)
Observed spectral variability:

- Disk temperatures: 1.5 - 2.3 keV
- BB temperature: 2.4 - 3.5 keV
- Broad irone line at 6.7 keV
- Other reflection signatures: Ca XIX line at 3.90 keV and absorption edge at 8.7 keV.

Reference

D'Aí A. et al., 2009, ApJL
arXiv:0906.3716



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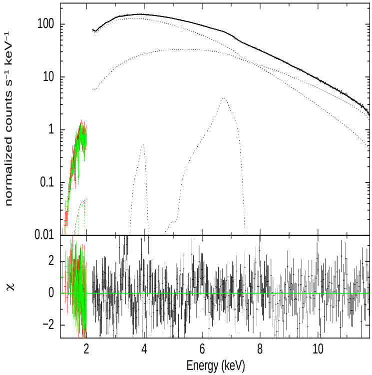


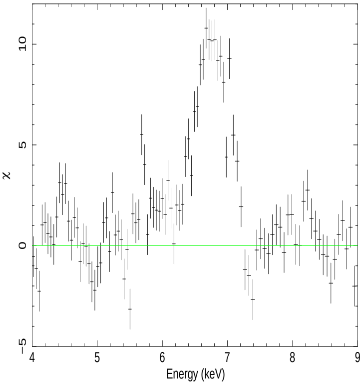
The case GX 340+0: results

Diskline parameters

Line energy at 6.69 $\pm$ 0.02 keV
Inclination 34.6 $\pm$ 1.3
Emissivity index 2.50 $\pm$ 0.10
Inner disk radius 13 $\pm$ 3 R_g
Outer radius $>$ 3000 R_g

Reference

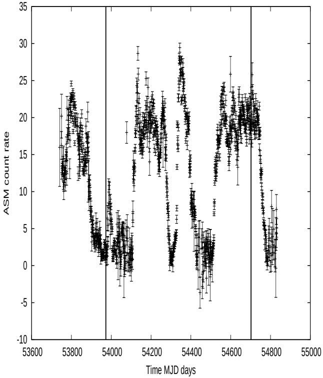
D'Aí A. et al., 2009, ApJL
arXiv:0906.3716



The atoll source 4U 1705-44

Times of the observation

- XMM-Newton observed the atoll source 4U 1705-44 on two occasions:
- Low luminosity hard state (island state)
- High luminosity soft state (banana state)



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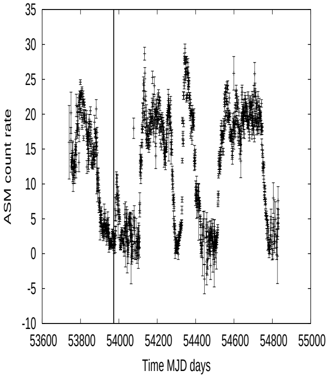

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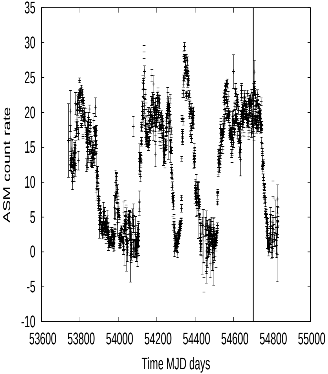


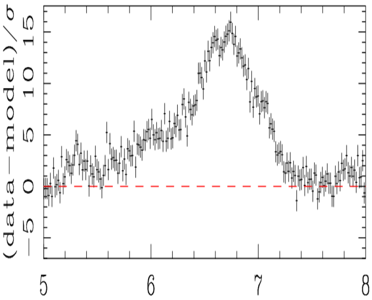
4U 1705-44: the soft state

Times of the observation

- Model phabs*(bb+ctt)
- Double-peaked structure of the iron line
- Multiple reflection signatures
- Fitting through disklines

Disklines parameters

Inclination 39 ± 1 degrees
Emissivity index 2.3 ± 0.1
Inner disk radius 14 ± 2 R_g
Outer radius 3500 ± 1000 R_g



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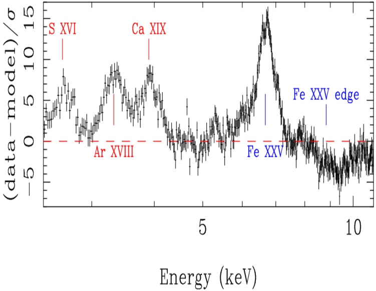

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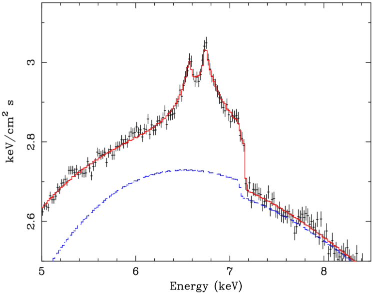

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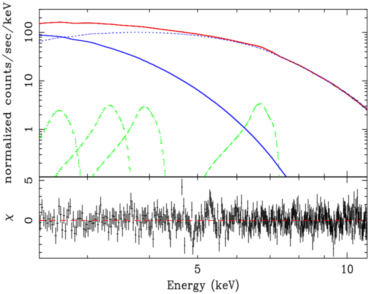

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Need for a self-consistent reflection model

Why a reflection model?

- The high quality of the XMM-Newton spectra allow broad-band (0.5-12 keV) self-consistent reflection models to be tested
- This allows to better constrain:
  1. the ionization structure of the disk reflecting skin
  2. the spectral shape of the ionizing incident flux
  3. to weight the chemical abundance of iron/other metal
  4. to self-consistenly evaluate the total energetic contribution in extrapolated bands

The **refbb** component

- Table model of reflection from an optically thick slab of costant density
- Model developed from the **reflion** code (Ross & Fabian, 1993; Ballantyne et al. 2004 on 4U 1820-30)
- *Incident radiation a **black-body** spectrum*
- Lines and edges from Fe, O, Si, Mg, N and C
- Variable iron abundance

The soft state of 4U 1705-44

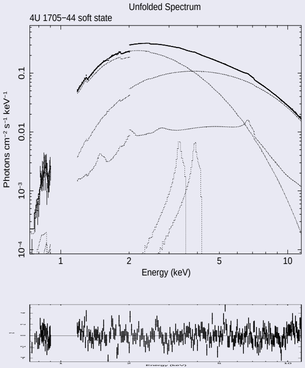
1705 - Spectral parameters

- Disk temperature : 1.15 $\pm$ 0.03 keV
- BB temperature: 1.91 $\pm$ 0.01 keV
- log ξ : 2.36 $\pm$ 0.07
- Luminosity $\sim$ 1 $\times$ 10^{38} erg s^{-1}
- Fractional BB flux 60%
- Fractional diskbb flux 30%
- Fractional refbb flux 10%

How reflection reprocesses the incident radiation

0.1-1.0 keV	1-10 keV	10-100 keV
63 %	32 %	5 %

1705 - refbb model



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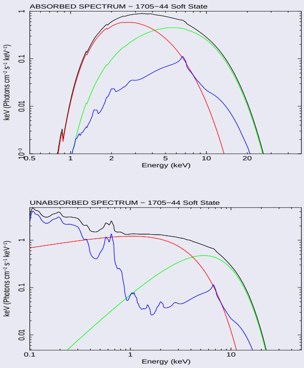
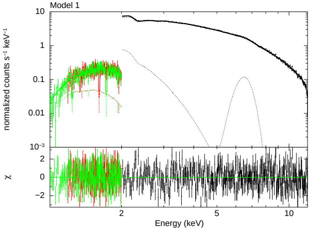
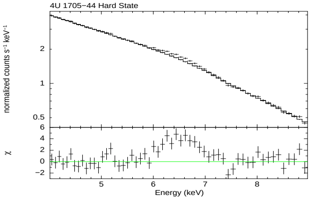


From Soft to Hard State

- Model phabs*(BB+Comptt)
- BB kT : 0.30 $\pm$ 0.04 keV
- kT_0 temperature: 0.55 $\pm$ 0.02 keV
- kT_e temperature: 14.4 $\pm$ 0.2 keV
- τ: 5.5 (fixed)
- Luminosity: $\sim$ 1% L_{Edd}
- BB frac. flux: 10%
- Comptt frac. flux 90%
- Gaussian line: 6.50 $\pm$ 0.07 keV
- Gaussian σ 0.41 $\pm$ 0.08 keV
- Gaussina EQW: 60 $\pm$ 25 eV





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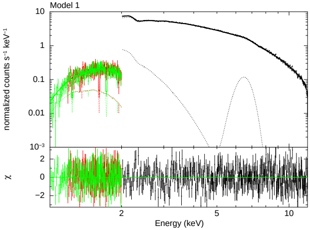
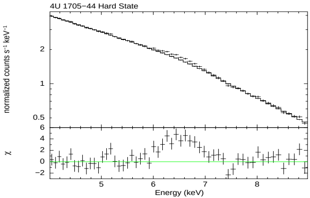




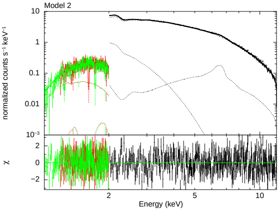
Buried thermal disk emission?

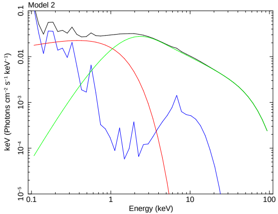
The soft state model

- Model phabs*(diskBB+Comptt+rdblur*refbb)
- Disk inner radius at $\sim 10\ R_g$
- Blurred reflection (using constraints from the soft state)
- Thermal Comptonization

Results

- R_{in} Reflection $< 90\ R_g$ (90 % c.l.)
- $kT_{IONIZING}$ 1.8 ± 0.2 keV
- But flux ratio *inconsistent*...





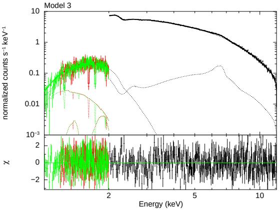
How far can be the disk truncated?

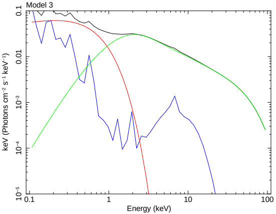
The soft state model

- Disk inner radius constrained at 30 R_g
- Blurred Reflection (using constraints from the soft state)
- log ξ : $<$ 1.6

Results

- R_{in} Reflection fixed at 30 R_g.
- $kT_{IONIZING}$ 1.6±0.3 keV
- Diskbb flux can be very low.





Conclusions & Future Prospects

Talk Highlights

- Broad reflection features are an unvaluable tool to have direct insight on the accretion mechanism and inner geometry of NS LMXBs.
- Our self-consistent approach shows that the thermal boundary layer emission *is* the direct source of the photo-ionizing flux on the accretion disk.
- This approach allows for a correct broadband interpretation of the overall X-ray emission in Z-sources and in the soft state of atolls.
- In atoll hard states, broad iron lines are not unambigously resolved and require additional insight. Reflection can be still at work with a disk truncated at some R_{NS}.