The high energy emission from black holes

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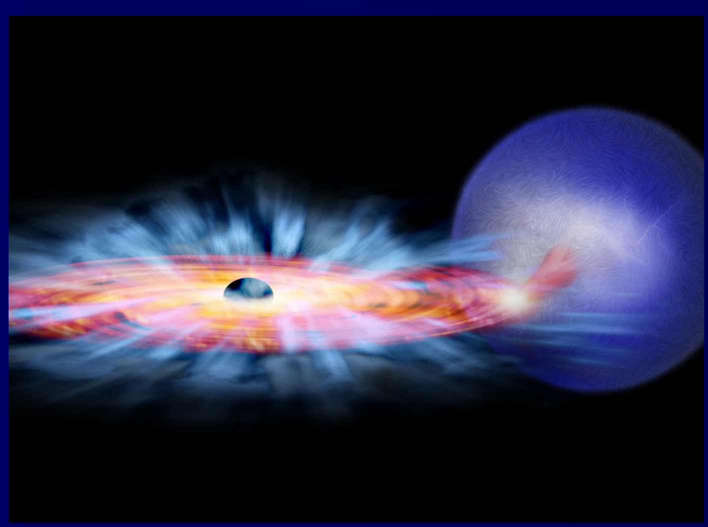
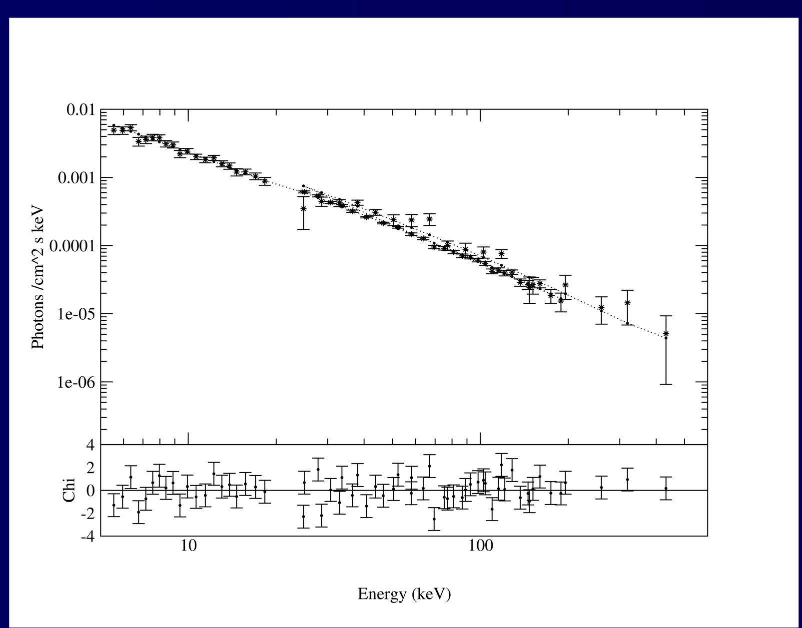
Deep ToO observations with INTEGRAL (3-1000 keV) and XMM (0.5-10 keV) of the black hole candidates in our galaxy are the key ingredients in the understanding of the physical processes responsible for the X-ray and γ-ray emission in these sources. We observed GRO J1655-40 and GX 339-4 during the outbursts occurring in 2005 and 2007 during 4 and 5 observations with exposures of 4x100 ks and 5x150 ks, respectively. These results appear in Caballero-García et al. (2007, 2008).



The case of GRO J1655-40

The X-ray transient GRO J1655-40 (also called X-ray Nova Scorpii 1994) is a black hole candidate whose parameters are best understood. Optical studies determined that the system is a LMXB composed by a blue subgiant (spectral type F4 IV) as the secondary and a black hole as the primary (m_{BH}= 7.02±0.22M) (Orosz & Bailyn, 1997), located at a distance of 3.2 kpc (Tingay et al. 1995). The orbital inclination of this system is very high (60°-75°, Kuulkers et al. 1998), while some independent studies stablished it to be as high as 85° (Hjellming & Rupen, 1995).

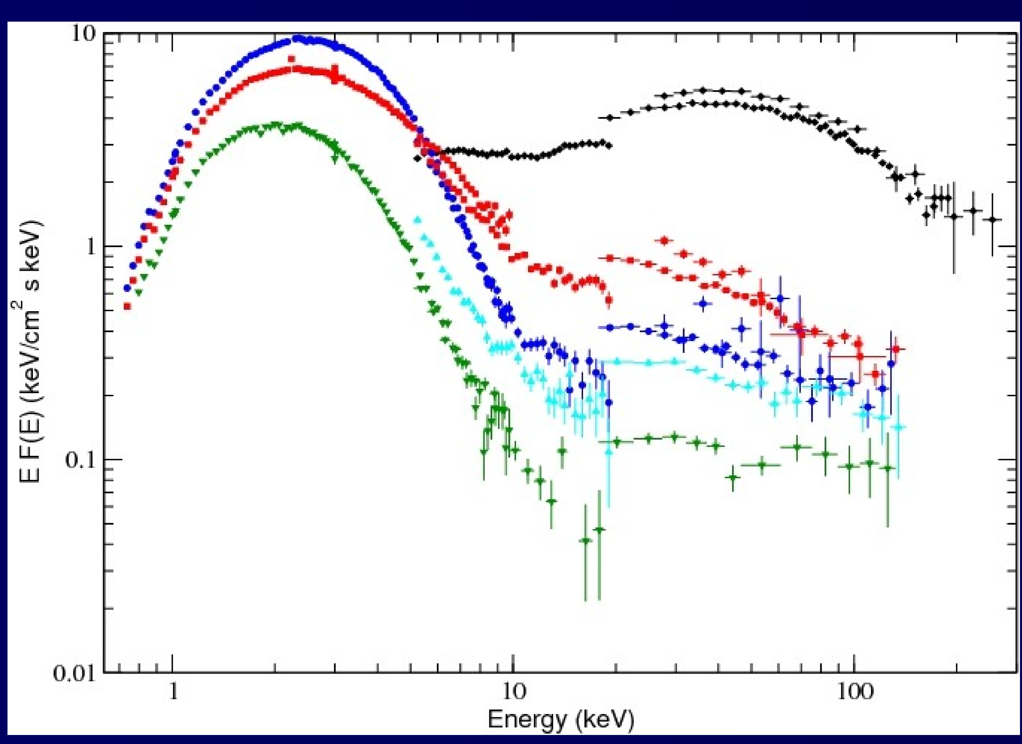
The low-hard state



This is the state expected to show the fluorescence emission Fe Kα lines and reflection components, both being part of the same physical process (George and Fabian, 1991). In GRO J1655 we did not observe neither reflection and residuals compatible with any fluorescent iron emission line, possibly due to the high inclination of the accretion disk. The results obtained can be summarized as follows:

- GRO J1655-40 is detected out to 500 keV ,
- The emission extending out to 500 keV is a power-law; with no breaks,
- Spectral breaks are common in the low-hard state The absence of a break rules-out the possibility that thermal Comptonization is the dominant mechanism in the low-hard state we observed,
- Instead, non-thermal Comptonization (e.g. magnetic flare reconnection lines) and/or processes in the base of the jet (e.g. synchrotron emission) are required.

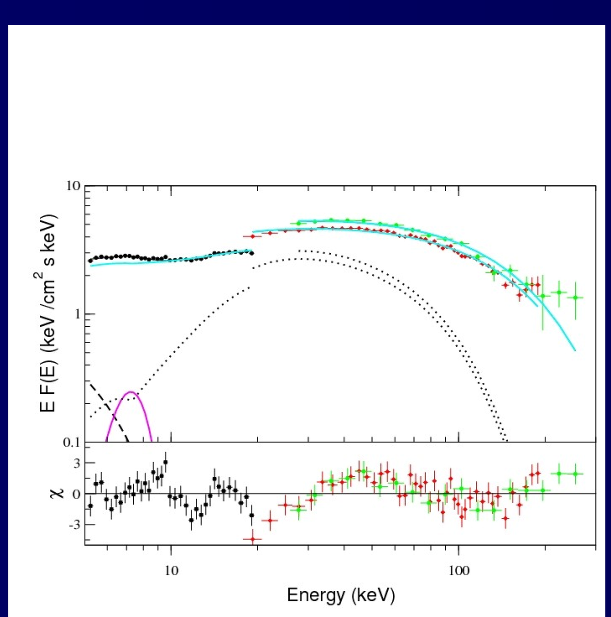
The case of GX 339-4



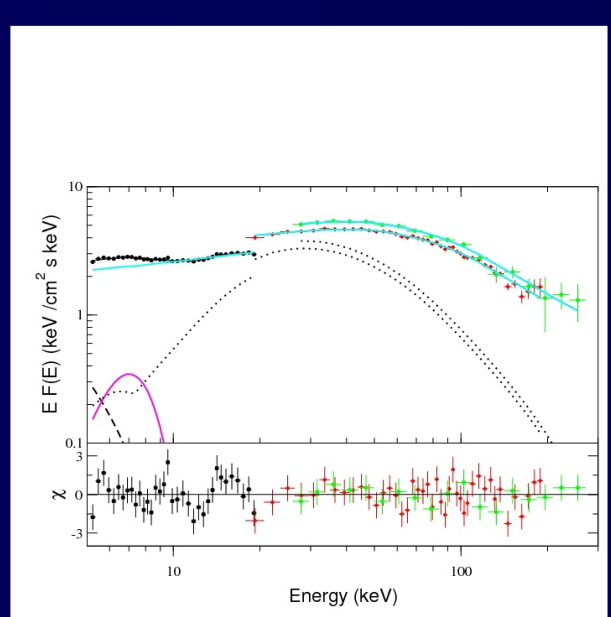
GX 339-4 is a black hole candidate with a low inclination of the accretion disk (i=45°, Zdziarski et al. 1998) and an estimated distance of 8 kpc (Hynes et al. 2004). This issue likely makes this system to have more similar spectral properties (in the form of breaks and/or cut-offs in the spectrum) closer to Cyg X-1 system (i ∊ 25° - 67°, Gierlinski et al. 1999). During the outburst of 2007, we obtained 5 INTEGRAL observations (being symultaneous to 3 XMM observations). These observations cover spectral transitions between the HIMS (black), SIMS (dark blue), VH (red) and HS state (light blue and green).

The HardInterMediateState (HIMS)

This state can be considered an extension of the low/hard state to brighter luminosities. An exponential cut-off at 66±1 keV is observed, which correponds to the thermal signature of the electrons with a kinetic temperature of kT_e = 15.3 keV. The high energy emission extends up to 300 keV, showing an excess of emission expected from purely thermal processes.



Unfolded model fitted with the thermal Comptonization model of Poutanen & Svensson (1996) (left)



Spectrum fitted with the EQPAIR model (Coppi, 1999). An excellent fit is obtained with the following parameters (figure to bottom-left):

- l_{nth}/l_h= 1 (f)
- l_h/l_s= 21 ± 5 (compactness)
- kT_e= 15.3
- Γ_p= 4.2 ± 0.4
- Γ_{min}= 1.3 (f)
- Γ_{max}= 100 (f)
- $\Omega/2\pi$ = 0.16 ± 0.05

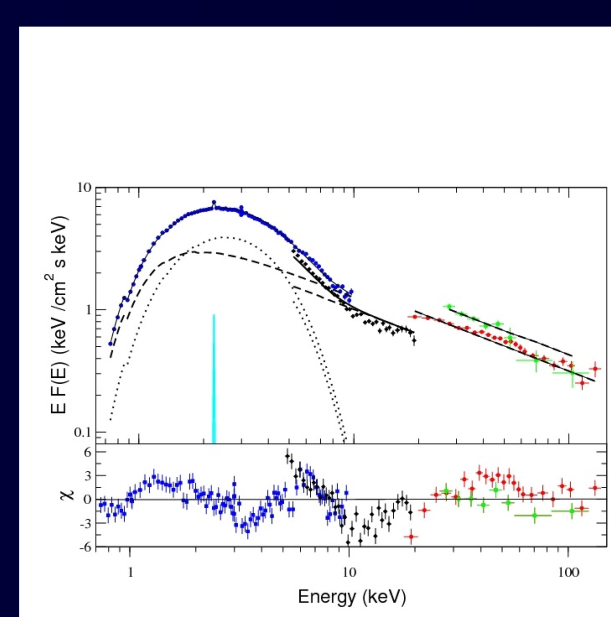
→ Very compact corona driven by non-thermal processes at high energies.

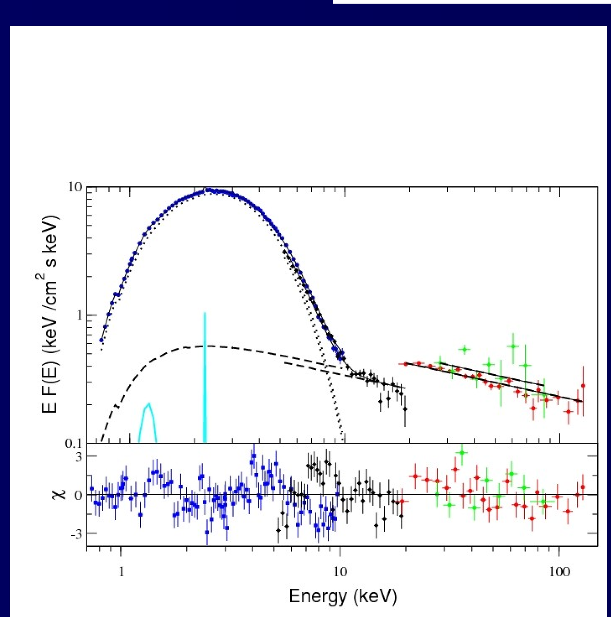
The Very/High (VH) state

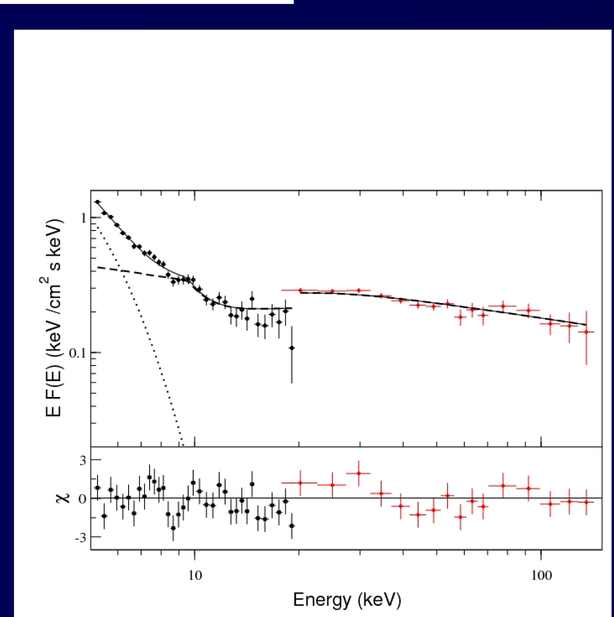
Spectral hardening (with respect SIMS) observed with the appearance of a relativistic Fe Kα line and smeared edge, mimicking the effecs of reflection. Parameters obtained from fits with laor model:

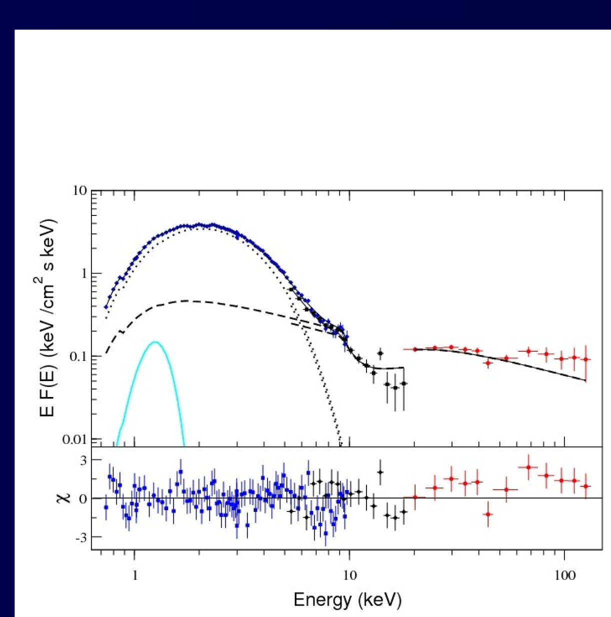
- E = 6.89±0.08 keV
- q = 4.7±0.4
- r_{in}= 2.04(+0.3-0.04) R_g
- r_{out} = 100 R_g (f)
- i = 27.5±2.6°

→ High-energy source compact and close to the black hole.









The SoftInterMediateState (SIMS) and HighSoft (HS) state

Spectral softening observed with no Fe Kα line. During the HS states smearing effects are important, may be due to reflection effects being important in this state.