A deep view into the black holes high energy emission

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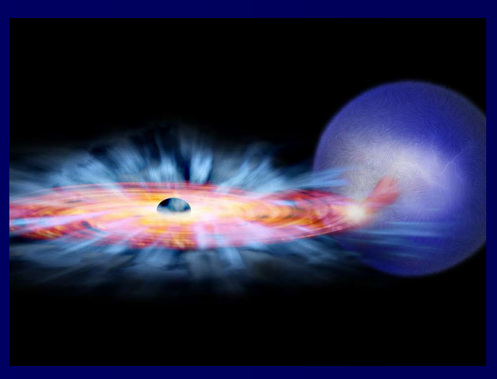
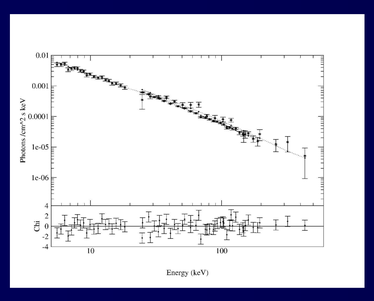
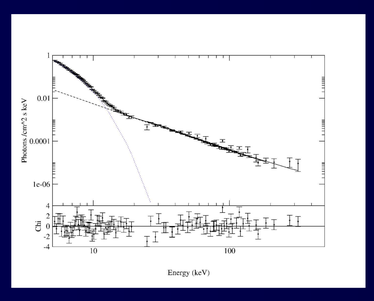
Deep ToO observations with INTEGRAL (3-1000 keV) and XMM (0.5-10 keV) of the black hole candidates in our galaxy are the key ingredients in the understanding of the physical processes responsible for the X-ray and Γ-ray emission in these sources. Thanks to our approved AO-3 and AO-4 INTEGRAL programs we observed GRO J1655-40 and GX 339-4 during the outbursts occurring in 2005 and 2007 with exposures of 4x100 ks and 5x150 ks, respectively. These results will appear in Caballero-García, Miller, Kuulkers et al. (2007) in two separate ApJ papers.

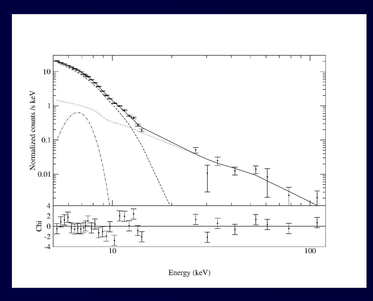
The case of GRO J1655-40

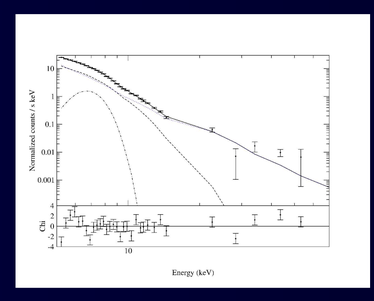


The X-ray transient GRO J1655-40 (also called X-ray Nova Scorpii 1994) is a black hole candidate whose parameters are best understood. Optical studies determined that the system is a LMXB composed by a blue subgiant (spectral type F4 IV) as the secondary and a black hole as the primary (m_{BH}= 7.02±0.22M) (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 observation of skewed Fe Kα (a ≥ 0.9 as per r < 1.4 R_g) by Miller et al. (2005) indicated that this system harbors a spinning black hole. This system also shows exteremely relativistic radio jets (Hjellming & Rupen, 1995).



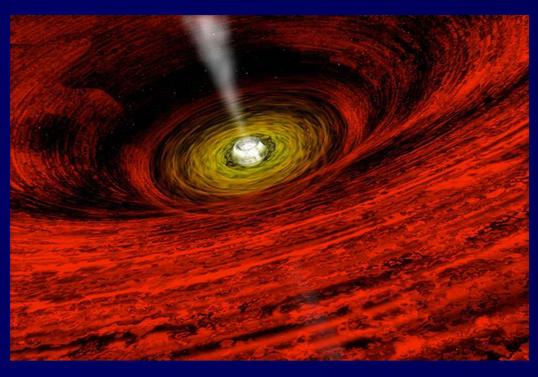






Unfolded INTEGRAL spectra obtained during a) 27-28 February, b) 16-18 March, c) 26-28 March and d) 10-11 April of 2005 (power-law component in dotted line in epochs a, c and d and a slashed-line in epoch b), multicolor black body component (dotted-line in epoch b and slashed-line in epochs c and d) and a gaussian line at 6-8 keV mymicking the effects of the strong residuals observed in this region (possibly related to absorption effects) (dotted-slashed line). An spectral evolution from the low-hard state to the high-soft (with properties related to non-thermal processes as pointed out by Saito et al. 2007) was observed.

The low-hard state

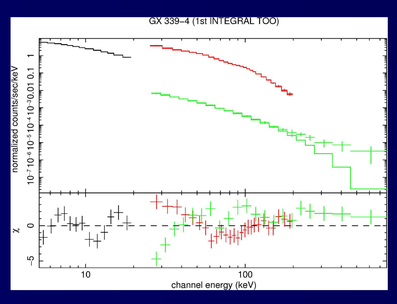


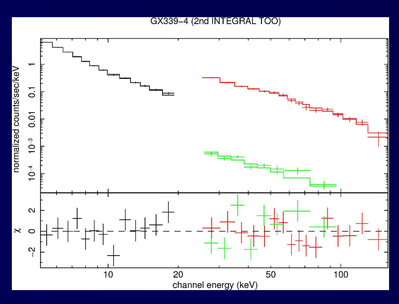
This is the state expected to show the fluorescence emission Fe Kα lines and reflection components, both being part of the same physical process (George and Fabian, 1991). In GRO J1655 we did not observe neither reflection and residuals compatible with any fluorescent iron emission line, possibly due to the high inclination of the accretion disk. Instead, we observed an un-broken high-energy emission up to 500 keV. This issue is not compatible with the classical picture of a simple spherical and extended corona of thermal electrons extending the above and below regions of the accretion disk, as pointed out by Titarchuk (1994), Frontera et al. (2003). This picture was extensively reported in order to describe the high energy emission of several black hole candidates, as GX 339-4 and Cyg X-1 (Joinet at al. (2006) and Cadolle Bell et al. (2006) as recent studies), but both systems are characterized by low accretion disk inclinations, so the physical scenario could be very different. As noticed by Coppi (1999), if high energy emission is noticeable up to 500 keV, then non-thermal processes have to be taken into account to describe the high energy emission of black holes (although there are other anternative and more sophysticated pictures involving only thermal processes). We used the model EQPAIR to model the spectrum in epoch a), confirming the last proposed picture by the better description of the data. However, the sensitivity was not high enough in order to constrain the value of the compactness parameter, which would allow to disentangle between the different geometries proposed in the literature in order to explain the origin of this non-thermal population of electrons (centrally-concentrated corona, consistent with the base of a jet or flares above the disk).

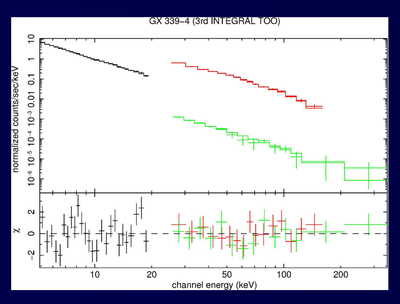
The high-soft state

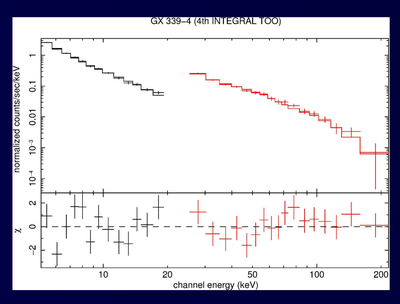
In this state Fe Kα lines and reflection are expected to appear if light bending effects are important (Miniutti & Fabian, 2004). In our INTEGRAL and XMM observations of GRO J1655-40 taken during the high-soft state, we noticed the presence of important residuals in the form of Fe absorption edges at 8-10 keV and emission around 8.4-6.97 keV. The last feature (observed also in simultaneous XMM observations, Díaz Trigo et al. 2006), if confirmed as being due to fluorescent line from Fe Kα, would strongly support the light bending picture. However, absorption effects would produce a similar shape in the residuals and this picture is more consistent with the changing of the outflow properties already seen in observations c) and d) with respect to previous observations. However, the picture of light bending processes should not be ruled out but and more and deeper observations (and may be next generation of X-ray observatories) are needed in order to get plausible conclusions.

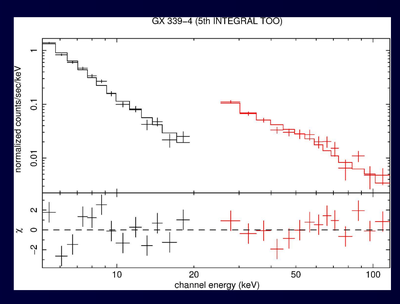
The case of GX 339-4











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). Spectra obtained with INTEGRAL/JEM-X, IBIS/ISGRI and SPI (black, red and green, respectively) are shown. The former INTEGRAL observation corresponds to the low-hard state (while the remainder correspond to the high-soft state), with a photon index of Γ=1.66±0.05 and a clear cut-off observed at around 20 keV and a e-folding energy at around 60 keV. A similar break is very likely also observed in the third INTEGRAL observation. In the last two observations, this break disappears, as in the second one; however the presence of emission residuals at 6-8 keV (confirmed with XMM simultaneous observations) is compatible with either the presence of a fluorescent iron model (although reflection is missing) or the presence of strong absorption effects. The latest picture being the most trustable if changes in the accretion flow properties with respecto to the previous observations are taken into account. The presentation of preliminary results is given in Atels #1000, #1012, #1029, #1032 and #1050.