X-RAY SPECTRA & BLACK HOLE MASSES IN ULXs

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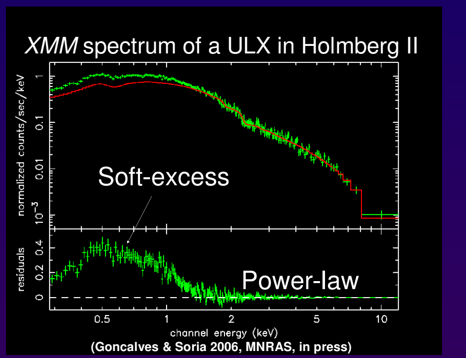
WHAT ARE ULXs? : Ultraluminous X-ray sources (ULXs) are interpreted as accreting black holes (BHs) with X-ray luminosities up to ~ 3E40 erg/s. They appear ~ 10 times brighter than Galactic BHs, ~ 100 times brighter than neutron star X-ray binaries.

X-RAY SPECTRA OF THE BRIGHTEST ULXs : they are mostly dominated by a power-law component. When the slope of the power-law is chosen by fitting it to the 2-5 keV range, there is an additional soft component, or *"soft excess".* If the soft excess is modelled as thermal emission (blackbody or disk-blackbody), it has a *characteristic temperature kT ~ 0.15-0.20 keV*



(Goncalves & Soria 2006, MNRAS, in press)

INTERMEDIATE-MASS BH MODEL : from the fitted luminosity and temperature of the soft excess, taken at face value, standard accretion disk models (with a disk extended to the innermost stable circular orbit) suggest a ***BH mass ~ 1000 M_{sun}*** (JM Miller et al 2003, 2004).
If so, ULXs would be powered by IMBHs: intermediate between stellar-mass and supermassive BHs.

MAIN PROBLEMS OF THE IMBH MODEL

- Difficult to form IMBHs, especially in the local universe. They might be primordial remnants of Population-III stars; however, today's bright ULXs are mostly found in young stellar environments. Or, they could form today via runaway core collapse in the core of young super star-clusters; however, most ULXs are not inside or near a super star-cluster.
- If they had a mass ~ 1000 M_{sun}, we would expect to see some of them at X-ray luminosities ~ a few E41 (by analogy with stellar-mass BHs, which often reach or exceed their Eddington limit). Instead, the ULX luminosity distribution cuts off at ~ 3E40 erg/s.

THREE POSSIBLE ALTERNATIVES TO THE IMBH MODEL

1) The cool thermal component is emitted by a downscattering corona or outflow, not by the disk (King & Pounds, Titarchuk et al).

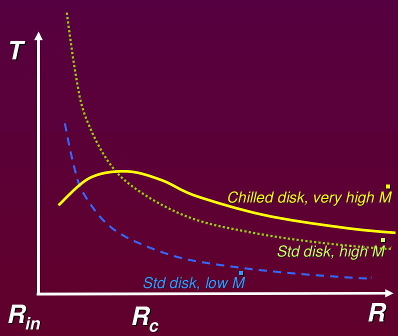
2) The BH mass is only ~ 10-100 M_{sun} but the disk is much cooler than expected for a standard Shakura-Sunyaev model, for a given accretion rate and total power (Soria & Kuncic 2006).

3) The soft excess is in fact a soft deficit: it is *absorption* from the power-law, when its slope is fitted to the 5-10 keV range. It is a combination of smeared absorption lines, re-emission and reflection by a *highly ionized, fast outflow* (Done & Gierlinsky, Crummy & Fabian, Chevallier et al, Goncalves & Soria).

We argue that models 2) and 3) are the best options. Here, we summarize their main features.

CHILLED DISK

For a given accretion rate and total power, the inner disk is cooler than a standard disk, because ~ 90% of the power is drained from it, and channelled into mechanical power and Poynting flux (fast jets, magnetized outflows).



For R <~ R_c, *most of the power is not radiated but is instead transferred to a jet or a corona*, via disk coupling of a large-scale magnetic field (Kuncic & Bicknell 2004). Part of this power is then converted to radiation via inverse-Compton scattering, thus producing the *dominant power-law spectrum* observed in ULXs; the outer disk produces the soft excess.

There are *three observational parameters* in our chilled-disk model: the colour temperature of the thermal component (corresponding to the maximum *T* of the disk, at $R \sim R_c$); the flux in the thermal component; the ratio between the flux in the power-law and in the thermal component. From them, we can *solve for the BH mass, accretion rate and R_c*.

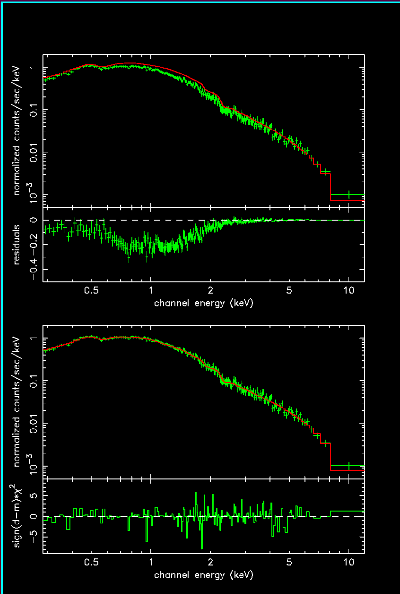
For typical ULX spectra, our chilled-disk model predicts:
$M \sim 20\text{-}80\ M_{sun}$, $R_c \sim 100\ R_g$, $\dot{M} \sim 10\text{-}20\ \dot{M}_{Edd}$

If so, ULXs would be a new X-ray spectral state for the most massive stellar-mass BHs, when they accrete at >~ 10 times above Eddington (via RL overflow from an OB donor star).

SMEARED ABSORPTION

We have shown (Goncalves & Soria 2006) that the deviation from a power-law spectrum can be modelled as a broad absorption feature around 1 keV. This is well fitted with a combination of smeared emission and absorption lines, in a fast (~ 0.1 c), highly ionized outflow surrounding the primary X-ray source. If so:

- it may be the same physical mechanism that produces the "soft-excess" in many AGN (especially Narrow-Line Seyfert 1).
- we may not even see the disk directly. Its emission may be entirely comptonized into a power-law-like spectrum.
- it gives us *no indication on the mass of the accreting BH:* the position and depth of the broad feature depend only on atomic physics and on the conditions inside the ionized absorber.
- it may be indicative a *new X-ray spectral state* of accreting BHs, with super-Eddington accretion inducing strong outflows and shrouding the inner disk from our direct view.



Top panel: the same XMM spectrum of the ULX in Ho II can be interpreted as broad, smeared absorption by an ionized medium on an underlying power-law spectrum, depending on where we fit the power-law slope. The soft excess has become a soft deficit. **Bottom panel**: the spectrum is well fitted by Chevallier et al's ionized outflow model (based on the photoionization TITAN code implemented in XSPEC), plus neutral absorption.

We are currently starting to test between those two proposed models (Soria, Kuncic & Goncalves, in prep.)