Understanding the nature of ULX with SIMBOL-X

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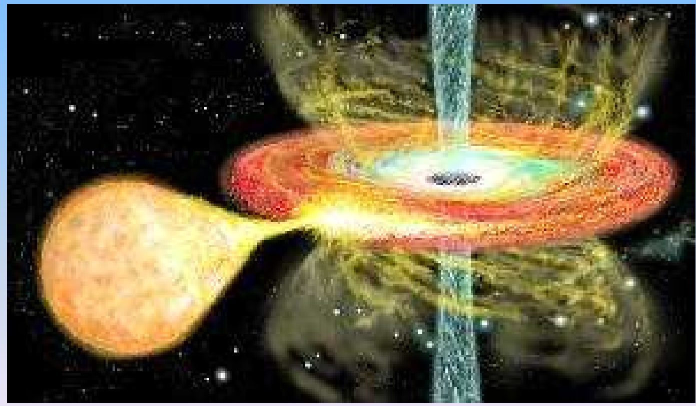
Summary:
- Introduction, general concepts;
- What is possible to observe now;
- What is possible to observe with SIMBOL-X.

Definition of ULX

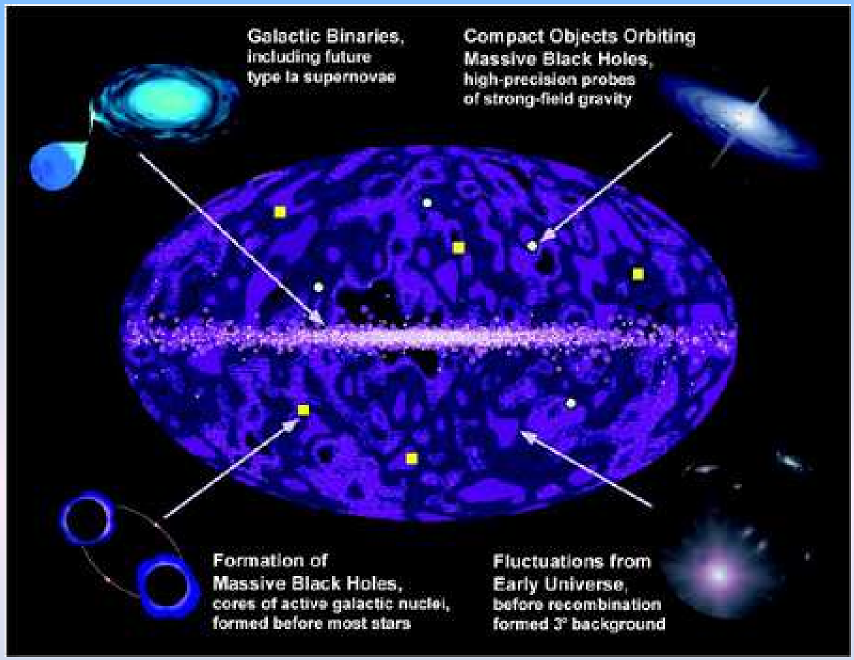
- The ***Ultraluminous X-ray sources*** (ULX) are point sources with luminosity greater than 10^{39} erg/s in the 0.5-10 keV energy band (cf with the Eddington luminosity for 1 solar mass object: $1.3 \cdot 10^{38}$ erg/s; please note that this value refers to the bolometric luminosity!);
- The ULX must be located inside the D_{25} ellipse (optical borders) of the host galaxy, i.e. should potentially belong to the host galaxy (unless the redshift measurement will tell us the contrary).
- The object must be sufficiently far from the optical or dynamical centre to avoid confusion with the galaxy's active nucleus.

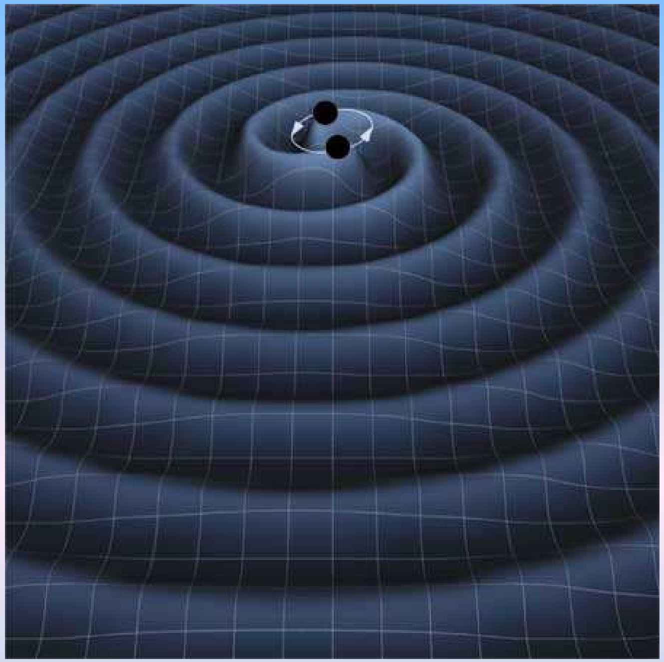
Why search and study ULX?


- ULX can potentially be **Intermediate Mass Black Holes** (10^2-10^4 $M_\odot$). Cf the cases of NGC 1313 X-1 and X-2 (Miller et al. 2003) or M81 X-9 (Miller et al. 2003). This is the most intriguing case with several follow up in other research fields.
- ULX are often identified as **stellar mass BH** with genuine super-Eddington rate or with sub-Eddington rate plus some kind of anisotropic emission (relativistic jets, inhomogeneities, anisotropies in optical depth, and so on...) or spinning BH. E.g., M33 X-8.
- ULX could also be **young supernovae remnants** (e.g. NGC 6946 Schlegel et al. 1994, Dunne et al. 2000) or even **background AGN** (NGC 4698 X-1, Foschini et al. 2002; NGC 4168 X-1, Masetti et al. 2003).

Implications of Intermediate Mass BH





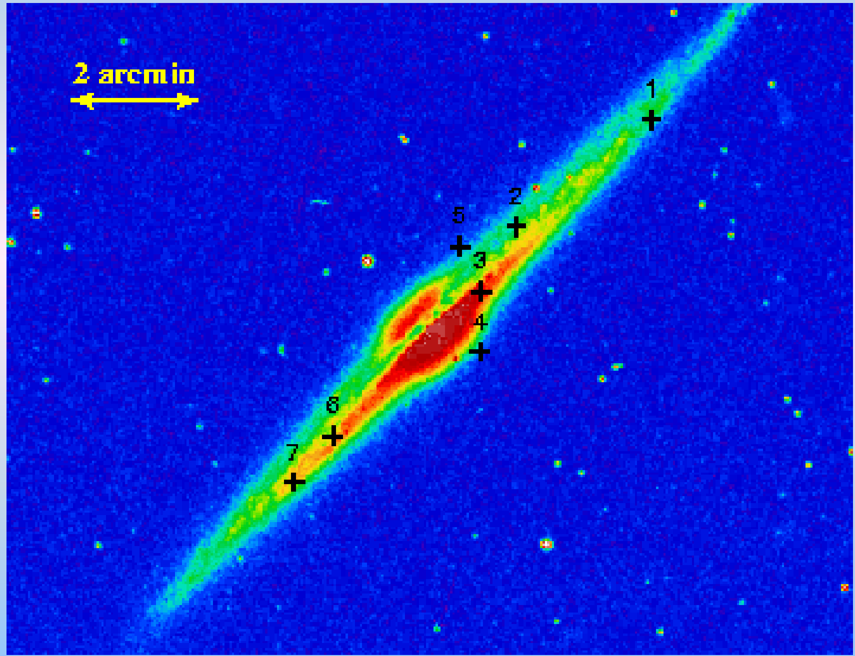
⇨ Formation and evolution of supermassive BH (AGN);

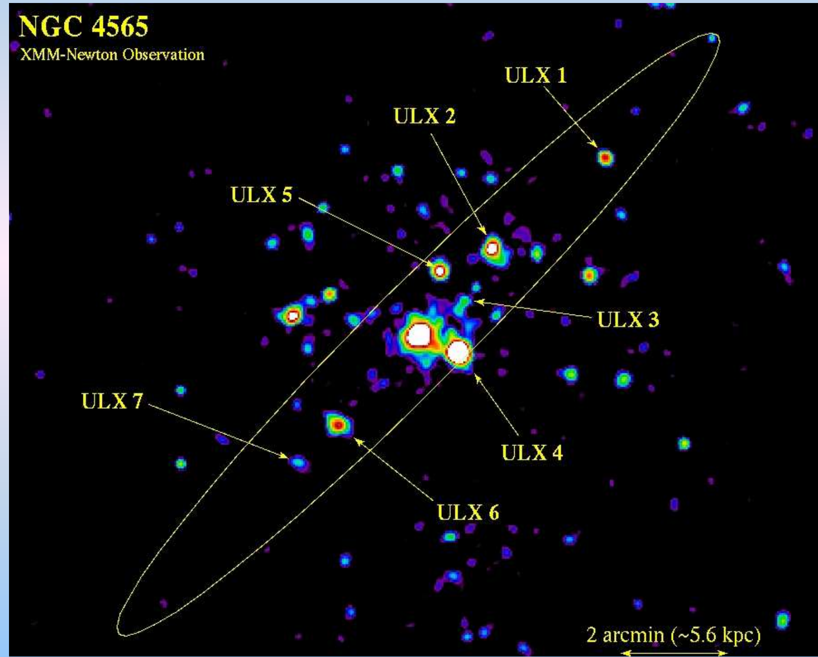
⇨ Gravitational radiation sources: binary systems: IMBH+AGN, IMBH+IMBH, coalescence phenomena, and so on…

⇨ Targets for LISA, ESA & NASA mission to be launched in 2012 (+1 year to have first data).

Observables - I

⇨ ULX are generally inside the galaxy's bulge or behind dust lanes: therefore it is difficult to find optical/IR counterparts;



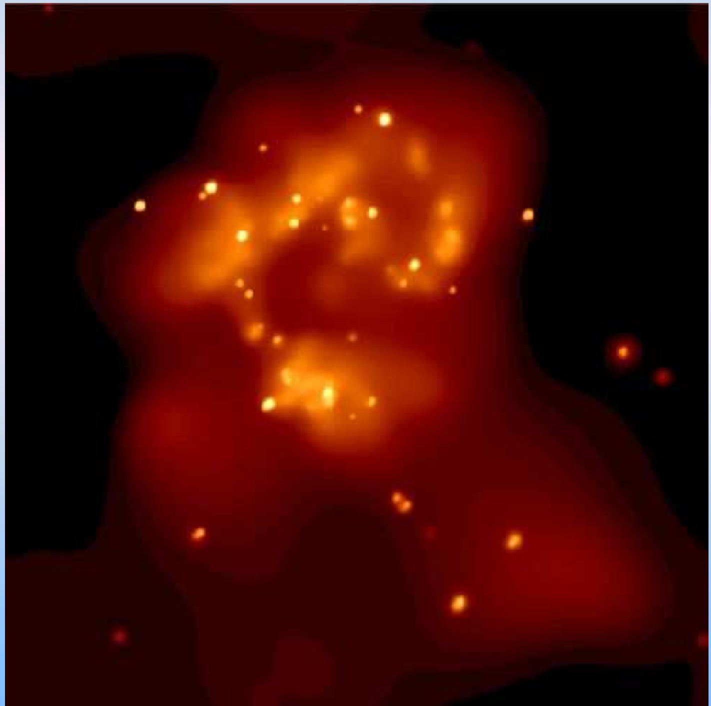


⇨ Radio counterparts found in only a very few cases;

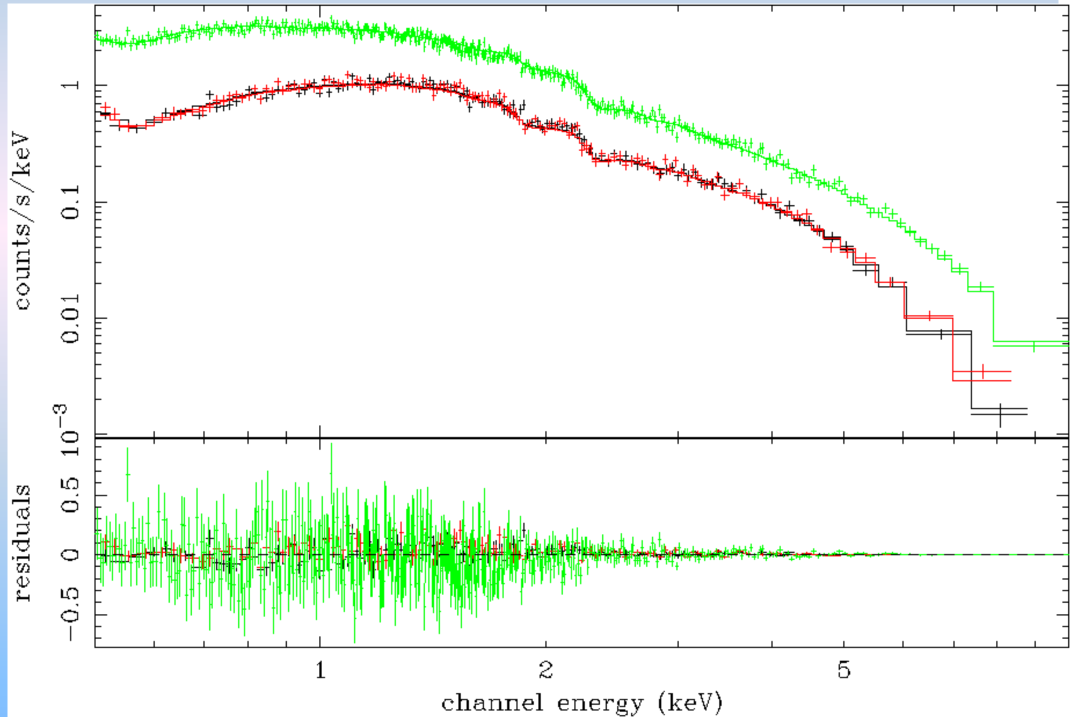
⇨ X- and γ-ray observations appear to be the only available source of informations in most of the cases, but…

Observables - II

⇨ X-ray (≈0.2-10 keV): good sensitivity with Chandra and XMM-Newton; very good images (Chandra) and spectra (XMM-Newton).



Chandra: Antennae Galaxies (Fabbiano et al. 2001).



XMM-Newton: M33 X-8 (Foschini et al. 2004).

Observables - III

⇨ Hard X-ray (>10 keV): sensitivity generally not sufficient for the ULX search with the present satellites (INTEGRAL, RXTE).

⇨ Angular resolution not sufficient:

⇨ RXTE has non-imaging instruments (≈1° FOV);

⇨ INTEGRAL/IBIS has a good resolution (12′ sampled in 5′/pixel in ISGRI), but still not good enough for ULX research;

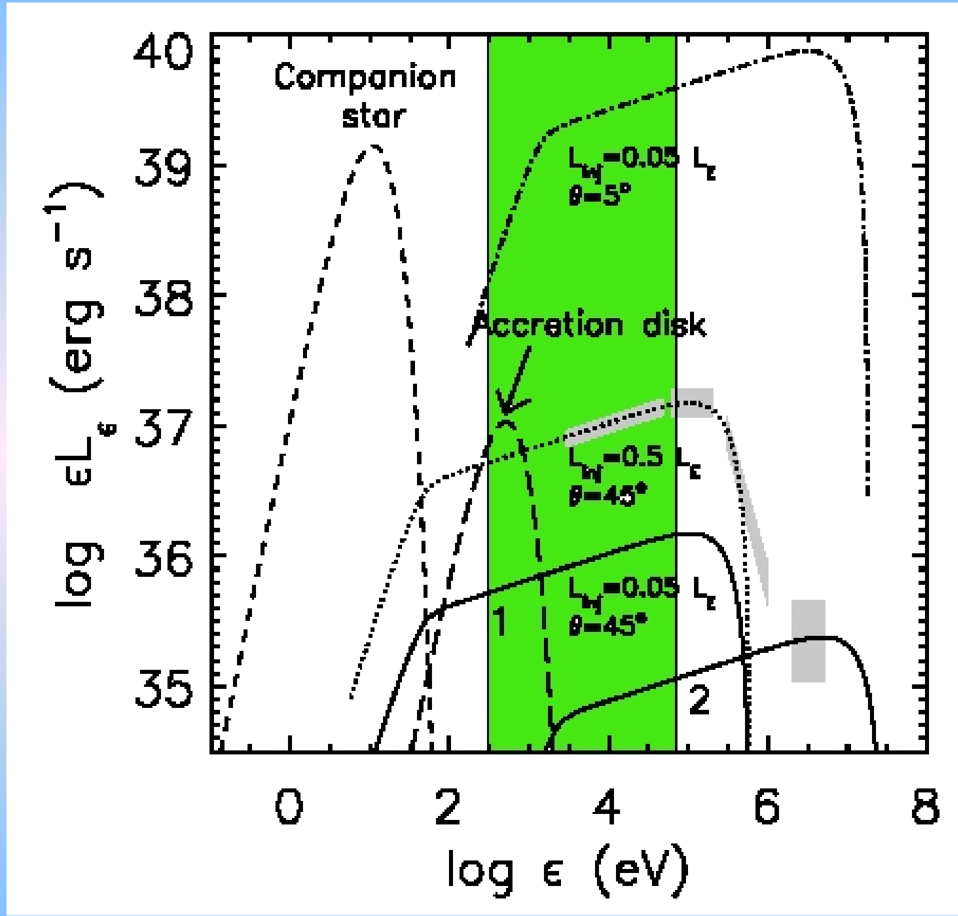
⇨ SIMBOL-X can fill this gap!

Observables – IV

The importance of a broad-band spectrum (SX = 0.5-70 keV)

⇨ Soft X-rays: thermal emission from the accretion disk;

⇨ Hard X-rays: non-thermal emission (corona, inverse Compton, reflection?, etc…).



Simulation of the broad-band spectrum of a ULX of type HMXRB (like Cyg X-1) by Georganopoulos et al. (2002). Colored area is the energy band of Simbol-X.

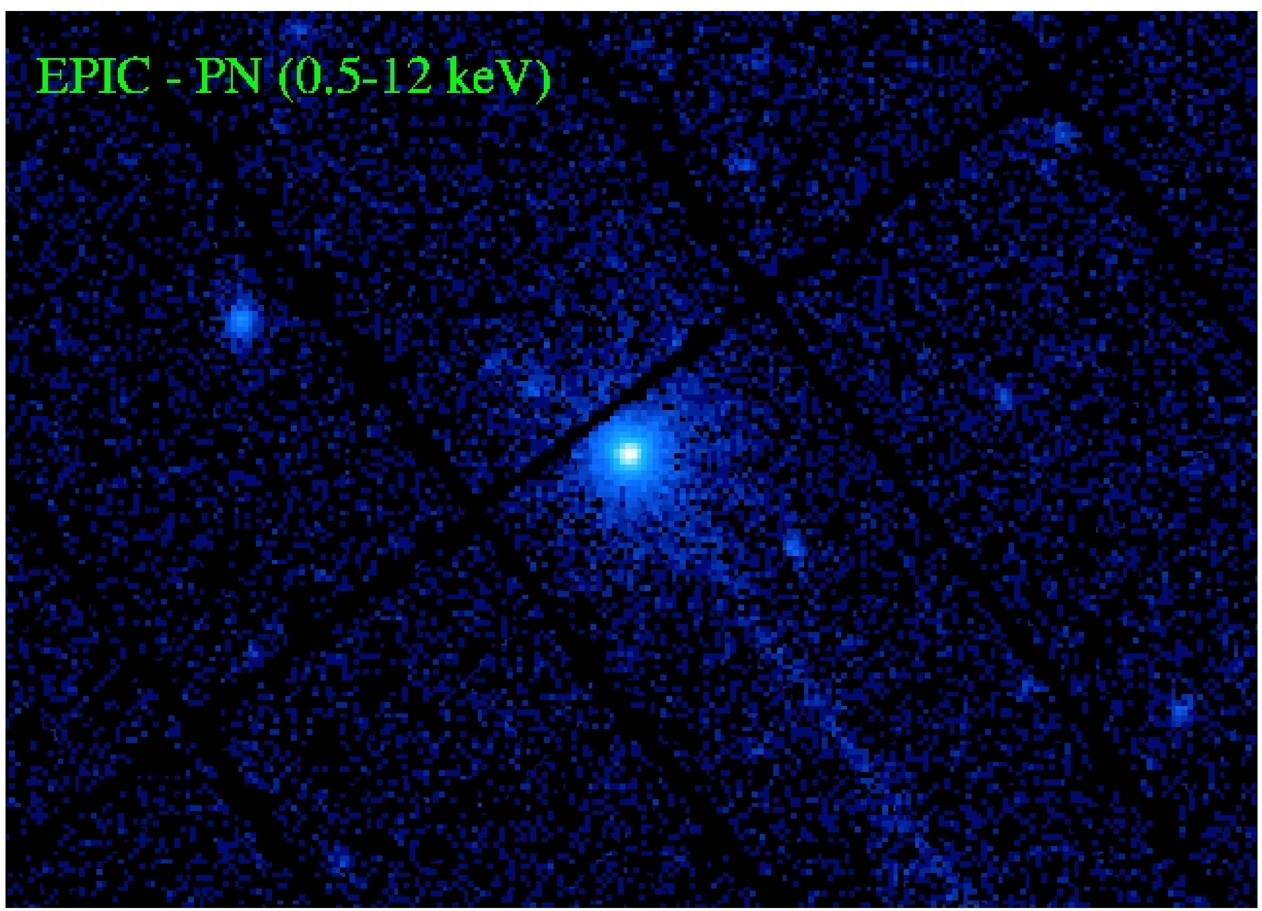
Example: M81 X-9 (Ho IX X-1)

Host galaxy: Holmberg IX, d=3.4 Mpc; Hubble type: Im, Dwarf galaxy.

Originally, it was thought that the ULX belonged to M81.

M81 X-9 could harbor an intermediate mass BH of some hundreds of solar masses.

(Miller et al. 2003)



Spectral model of M81 X-9 (Ho IX X-1) obtained from XMM-Newton data

Xspec model: wabs(diskbb+po)

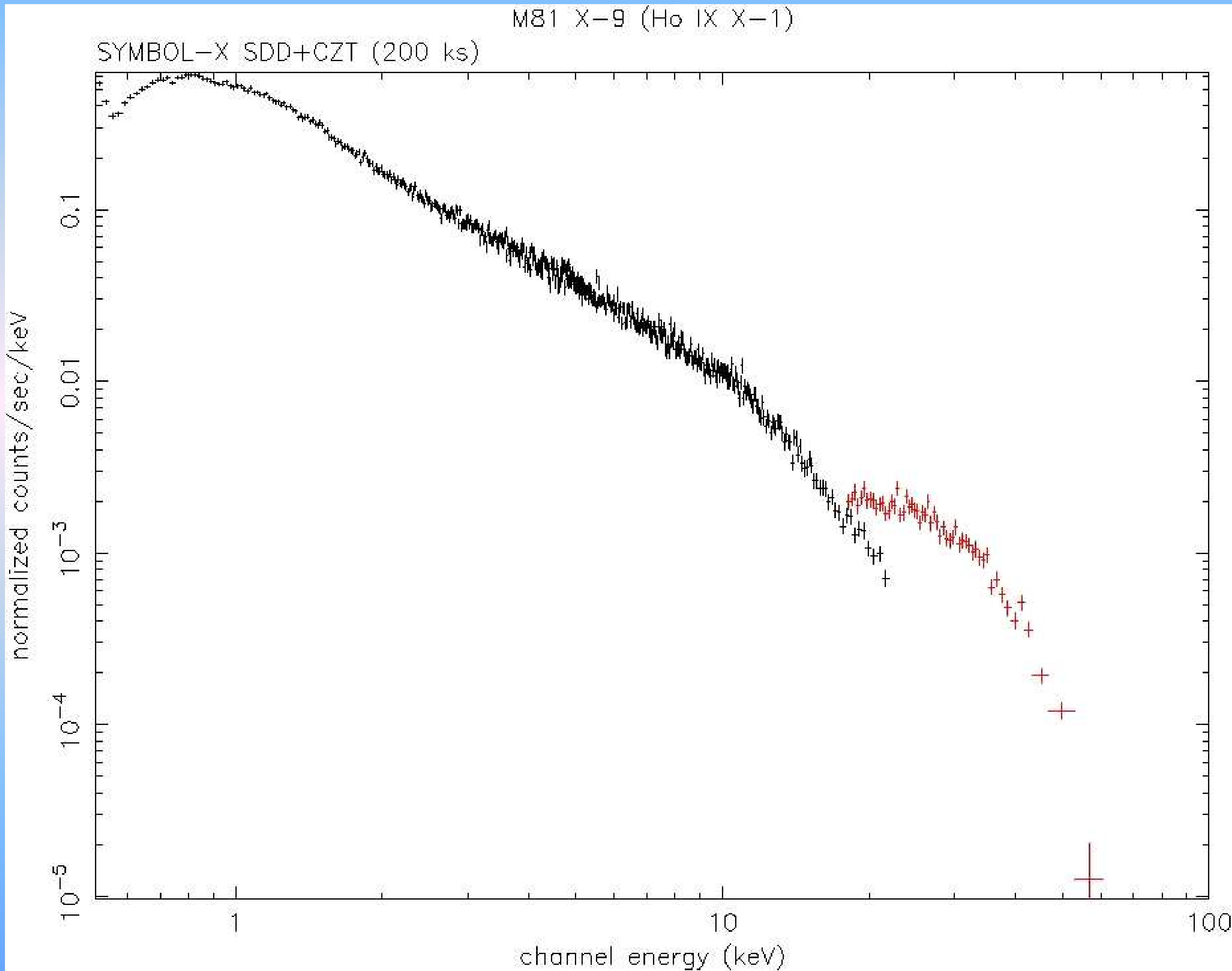
wabs ⇨ $N_H=(2.3\pm0.3)\times10^{21}$ cm^{-2}
diskbb ⇨ $T_{in}=0.26\pm0.05$ keV
power law ⇨ $\Gamma=1.73\pm0.08$

From diskbb ⇨ $M\approx330M_\odot$

Flux[0.3-10 keV]= 8×10^{-12} erg cm^{-2} s^{-1}

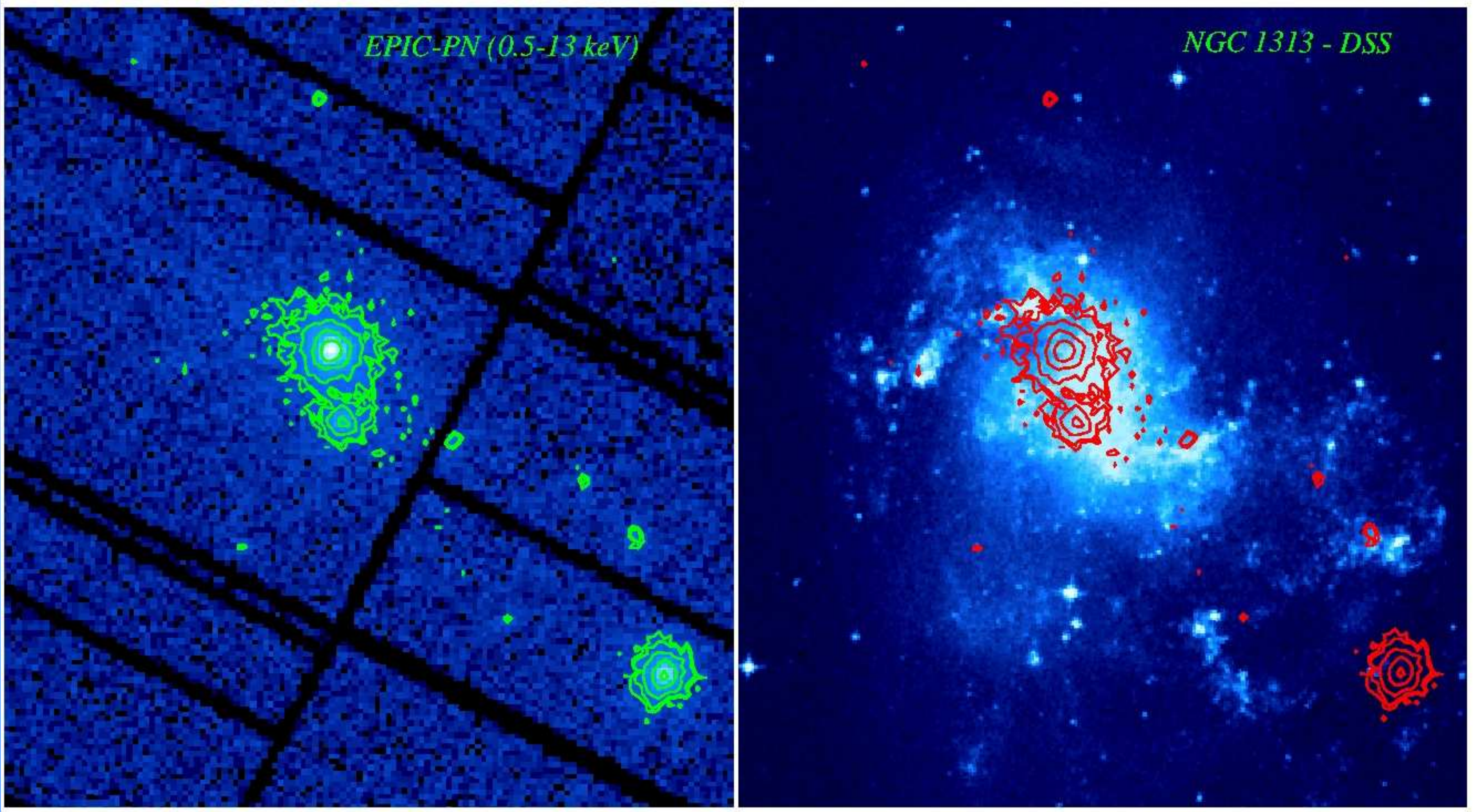
(from Miller et al. 2003)

Simulation of the count spectrum of M81 X-9 (Ho IX X-1) with Simbol-X



Example: NGC1313 X-1

Host galaxy: NGC1313, d=3.7 Mpc; Hubble type: SB(s)d. It hosts 2 ULX (X-1, X-2) that could harbor IMBH. NGC 1313 X-1 could be around some hundreds of solar masses (Miller et al. 2003).



Spectral model of NGC1313 X-1 obtained from XMM-Newton data

Xspec model: wabs(diskbb+po)

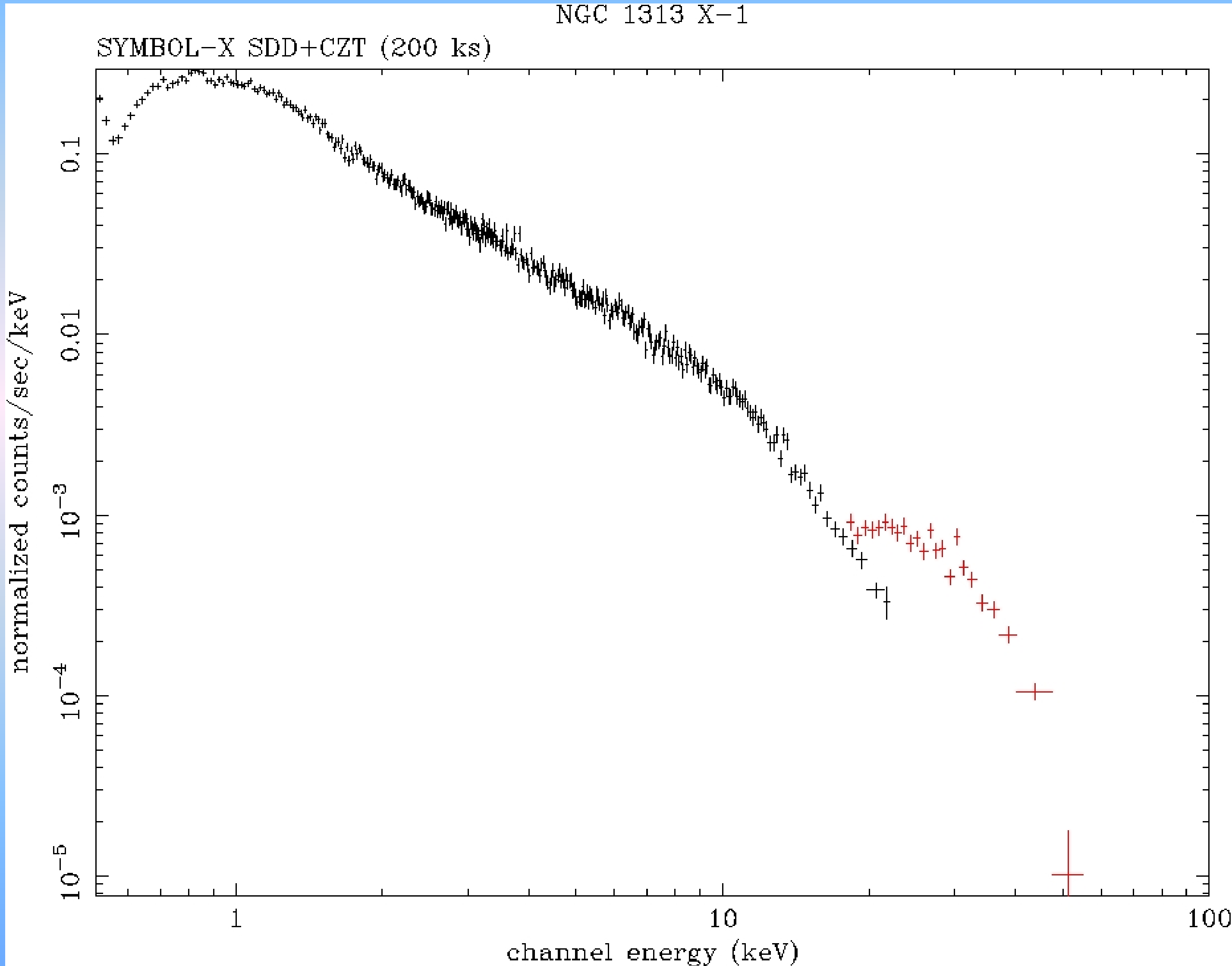
wabs ⇨ $N_H=(3.1\pm0.3)\times10^{21}$ cm^{-2}
diskbb ⇨ $T_{in}=0.23\pm0.02$ keV
power law ⇨ $\Gamma=1.76\pm0.07$

From diskbb ⇨ $M\approx400M_\odot$

Flux[0.3-10 keV]= 4.3×10^{-12} erg cm^{-2} s^{-1}

(from Miller et al. 2003)

Simulation of the count spectrum of NGC1313 X-1 with Simbol-X



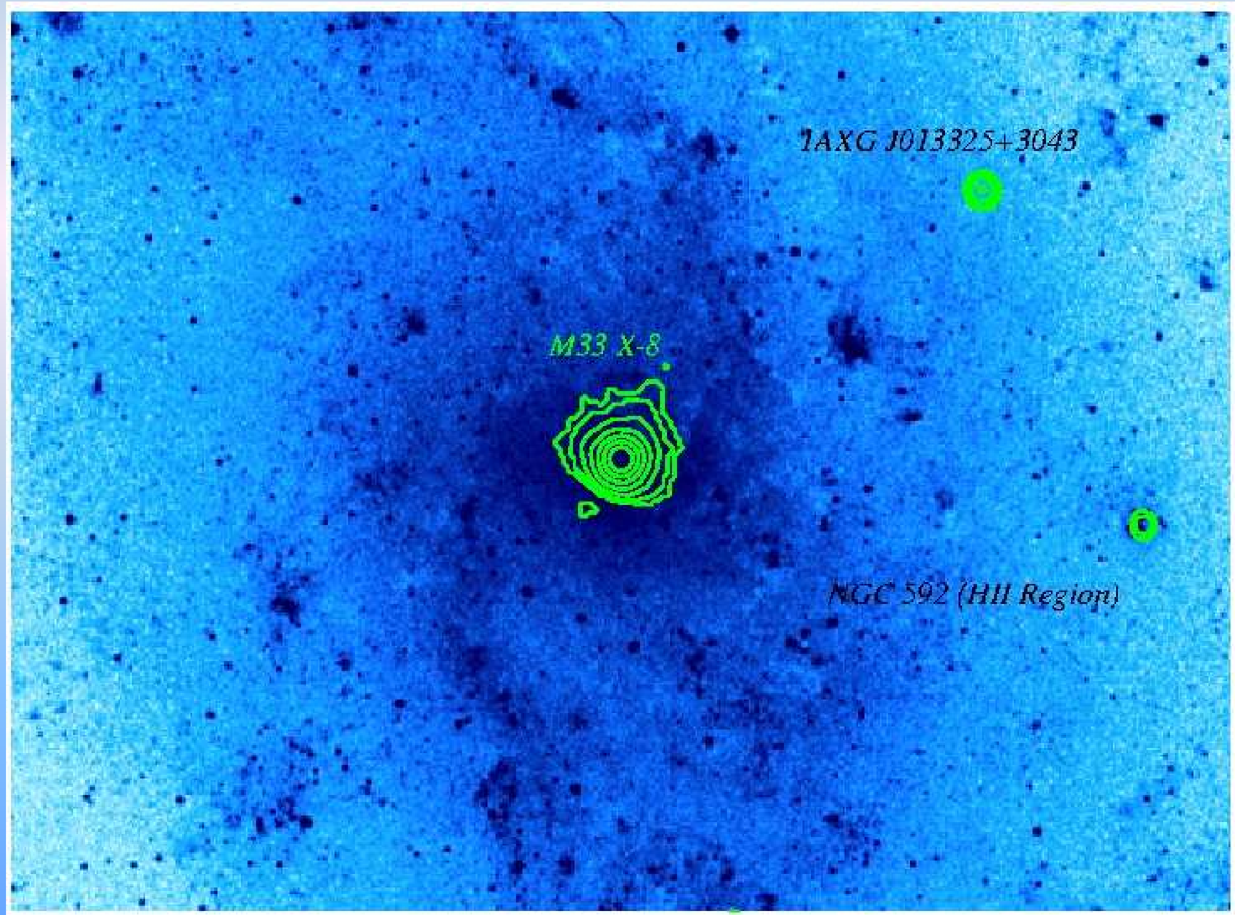
Example: M33 X-8

Host galaxy: M33 (NGC 598, *Triangulum Galaxy*), d=795 kpc; Hubble type: SA(s)cd; inclination 55°. It has no bulge, but the central region is very crowded.

Also the HST is not able to resolve the nuclear region.

M33 X-8 is a ULX with a distance from the centre of M33 of less than 2.3 pc and harbor a stellar mass BH ($\approx 12 M_{\odot}$).

(Foschini et al. 2004)



Spectral model of M33 X-8 obtained from XMM-Newton data

Xspec model: wabs(diskbb+po)

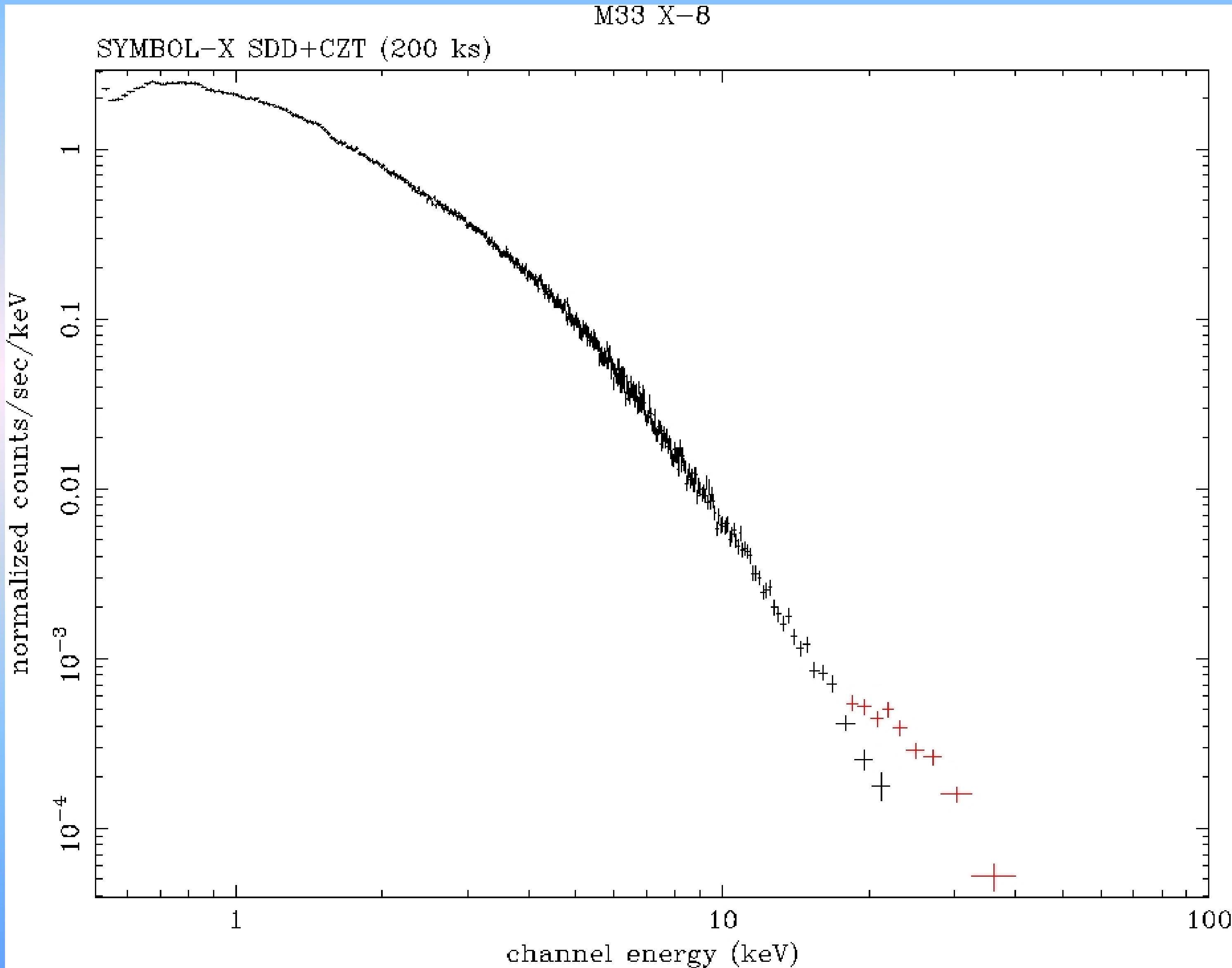
wabs ⇨ $N_H=(1.8\pm0.2)\times10^{21}$ cm^{-2}
diskbb ⇨ $T_{in}=1.16\pm0.04$ keV
power law ⇨ $\Gamma=2.5\pm0.2$

From diskbb ⇨ $M\approx12M_\odot$

Flux[0.5-10 keV]= 1.7×10^{-11} erg cm^{-2} s^{-1}

(from Foschini et al. 2004)

Simulation of the count spectrum of M33 X-8 with Simbol-X



Conclusions

Summary of the characteristics of SIMBOL-X useful to investigate ULX:

- ⇨ Good sensitivity, particularly at E>10 keV;
- ⇨ Good angular resolution (baseline HEW=30”), although it would be extremely better with multilayer coating (HEW=10”);
- ⇨ Broad energy band (0.5-70 keV).