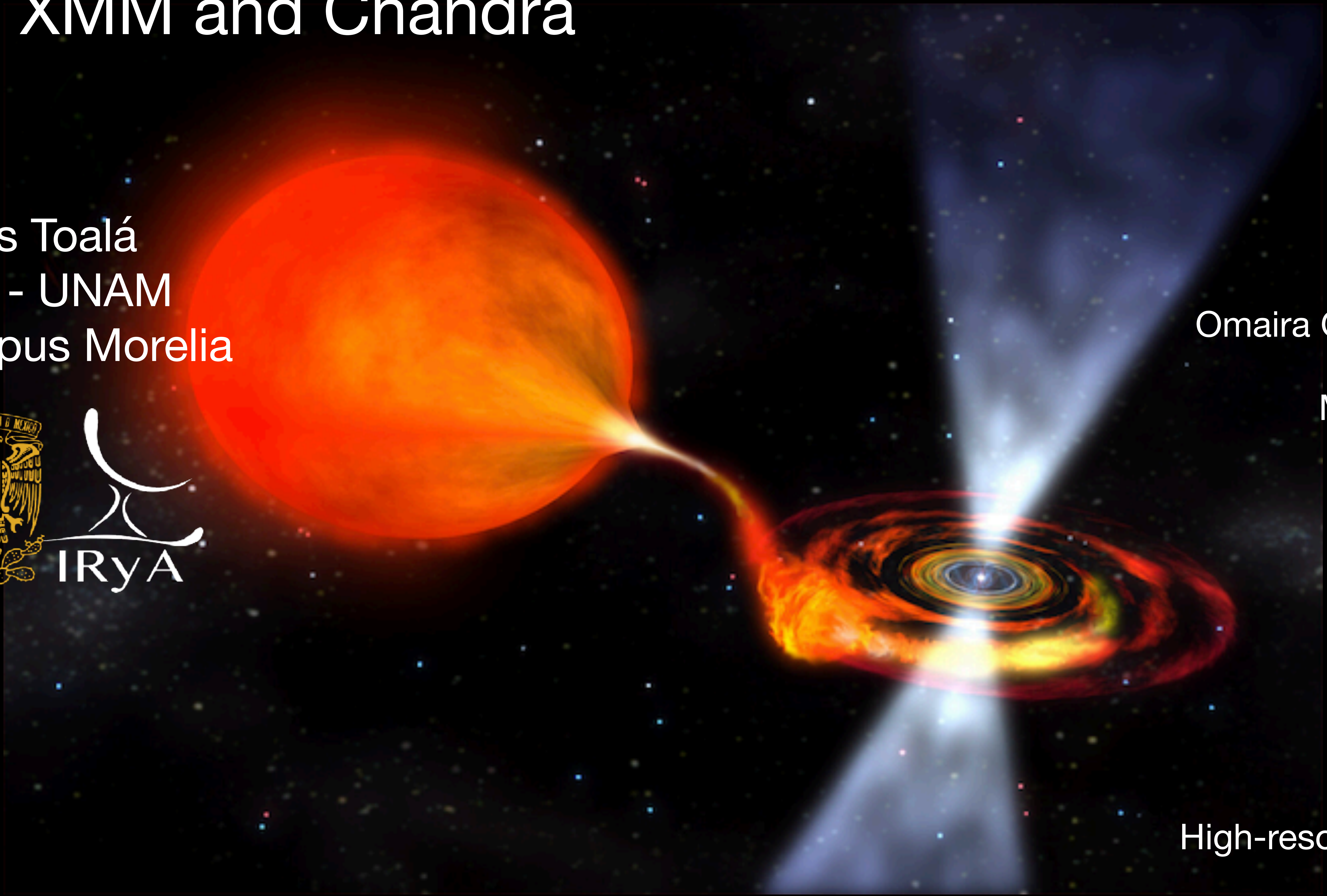
Studying the symbiotic star CH Cyg With XMM and Chandra



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High-resolution X-ray spectroscopy
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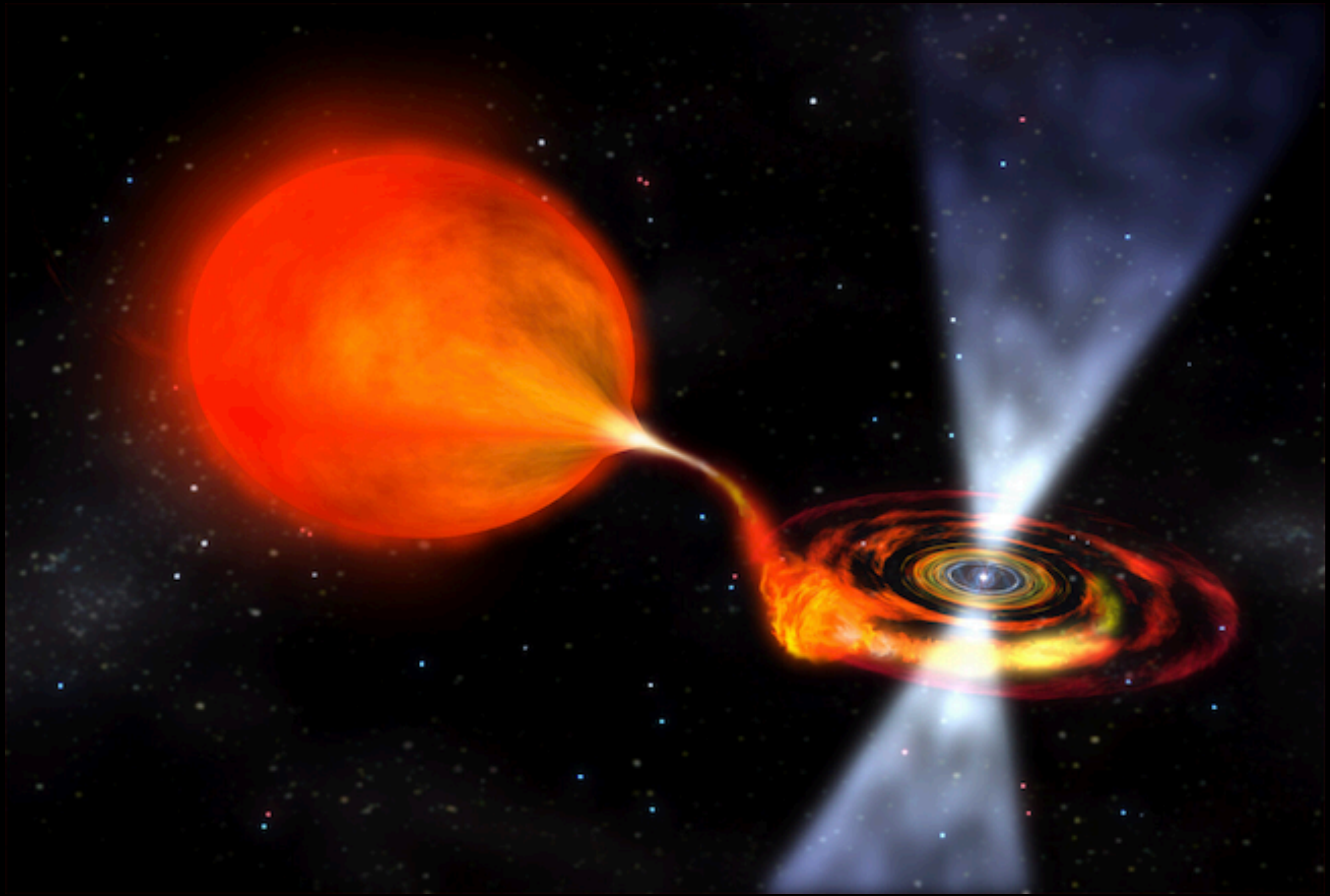
What are **symbiotic stars** (**SySts**)?

Binary systems consisting of a **compact object** accreting enough material from a **red giant** to produce emission at any wavelength (Luna et al. 2013)



Compact Object

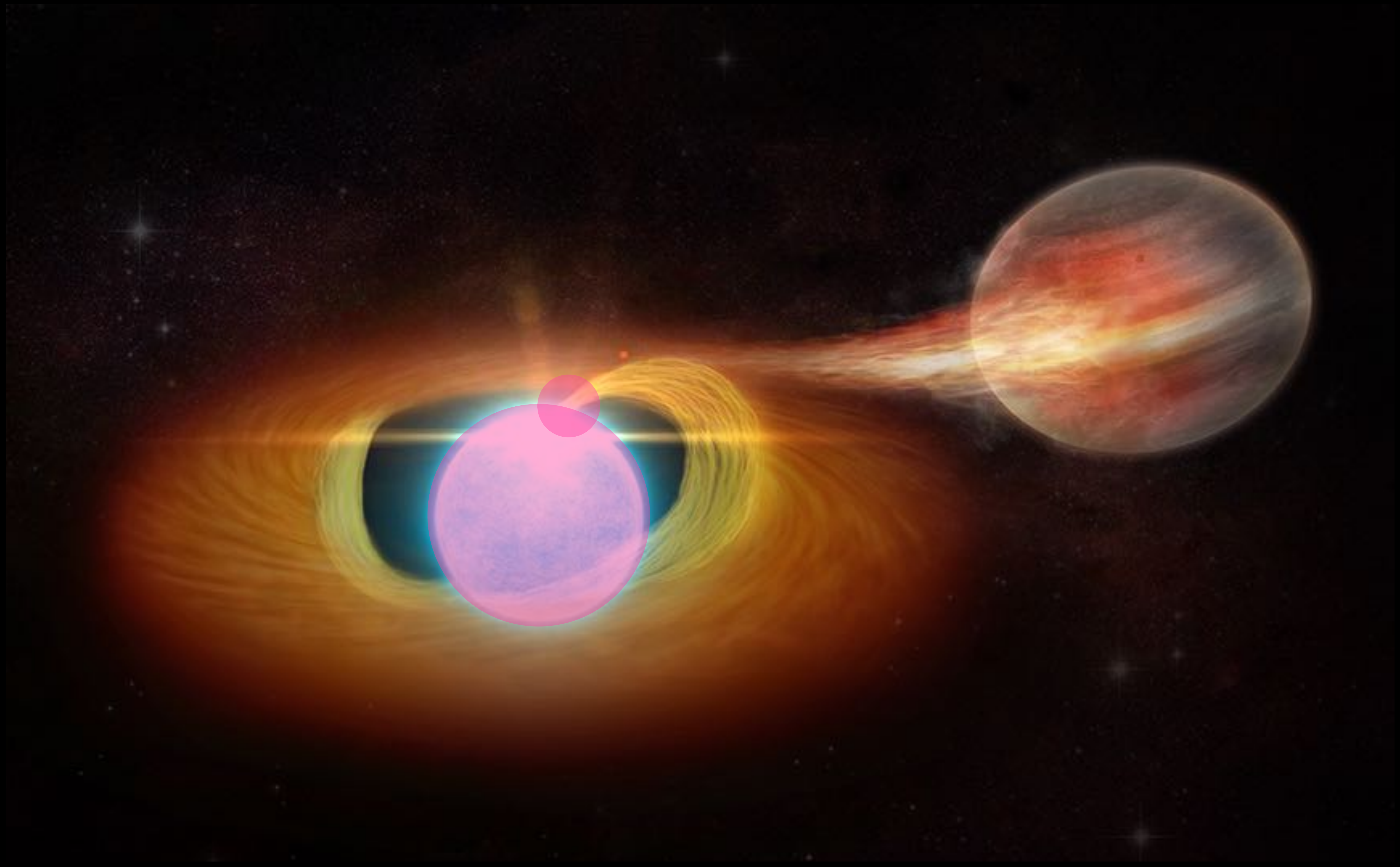
- White Dwarf (**WD**)
- Black Hole
- Neutron Star

(Masetti et al. 2006)

The origin of X-rays in SySts

(See Mukai 2017, PASP, 129, 2001)

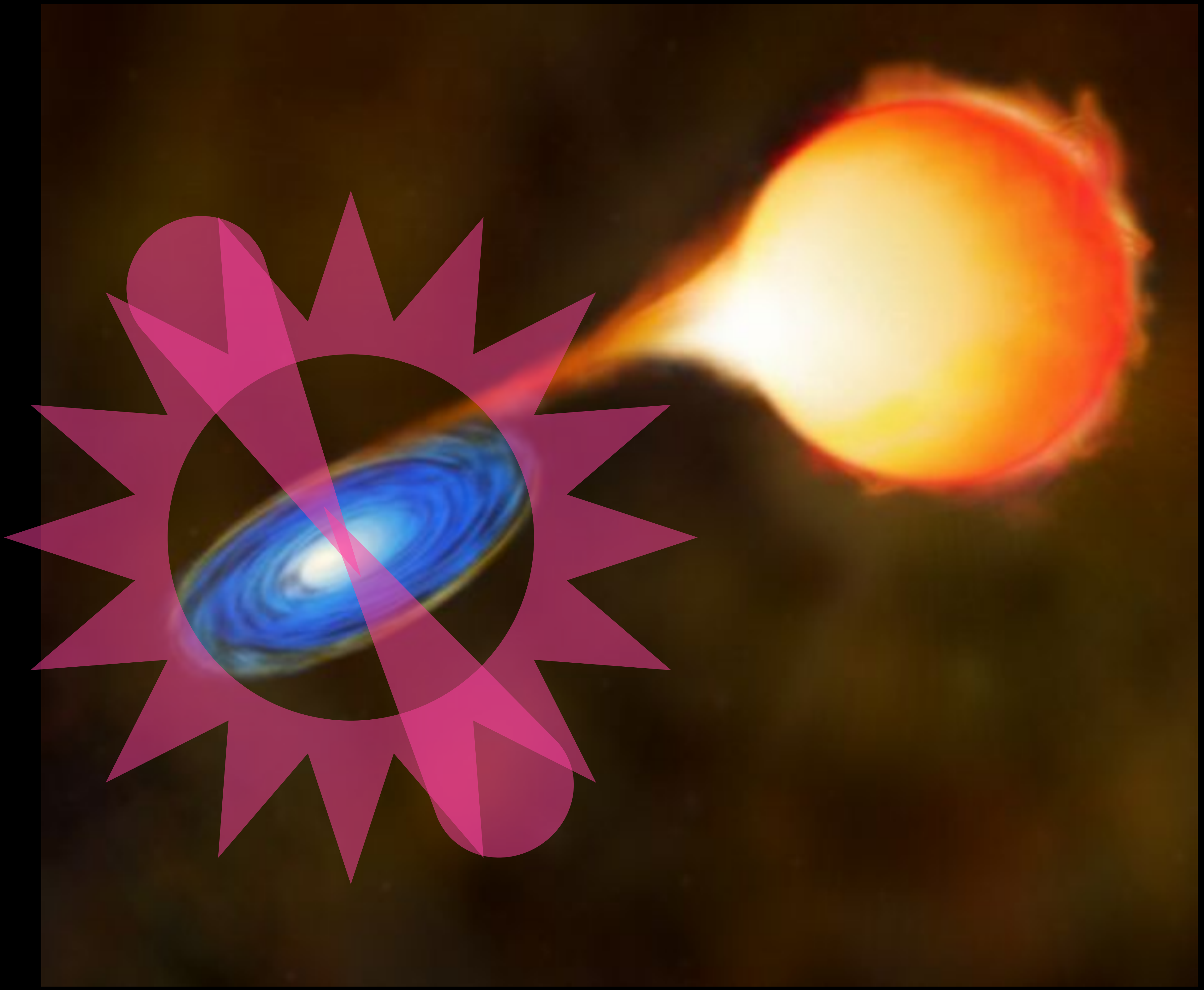
1. Extreme soft sources (α-type) are produced by nuclear burning at the surface of the WD or shocks at the surface of the WD



The origin of X-rays in SySts

(See Mukai 2017, PASP, 129, 2001)

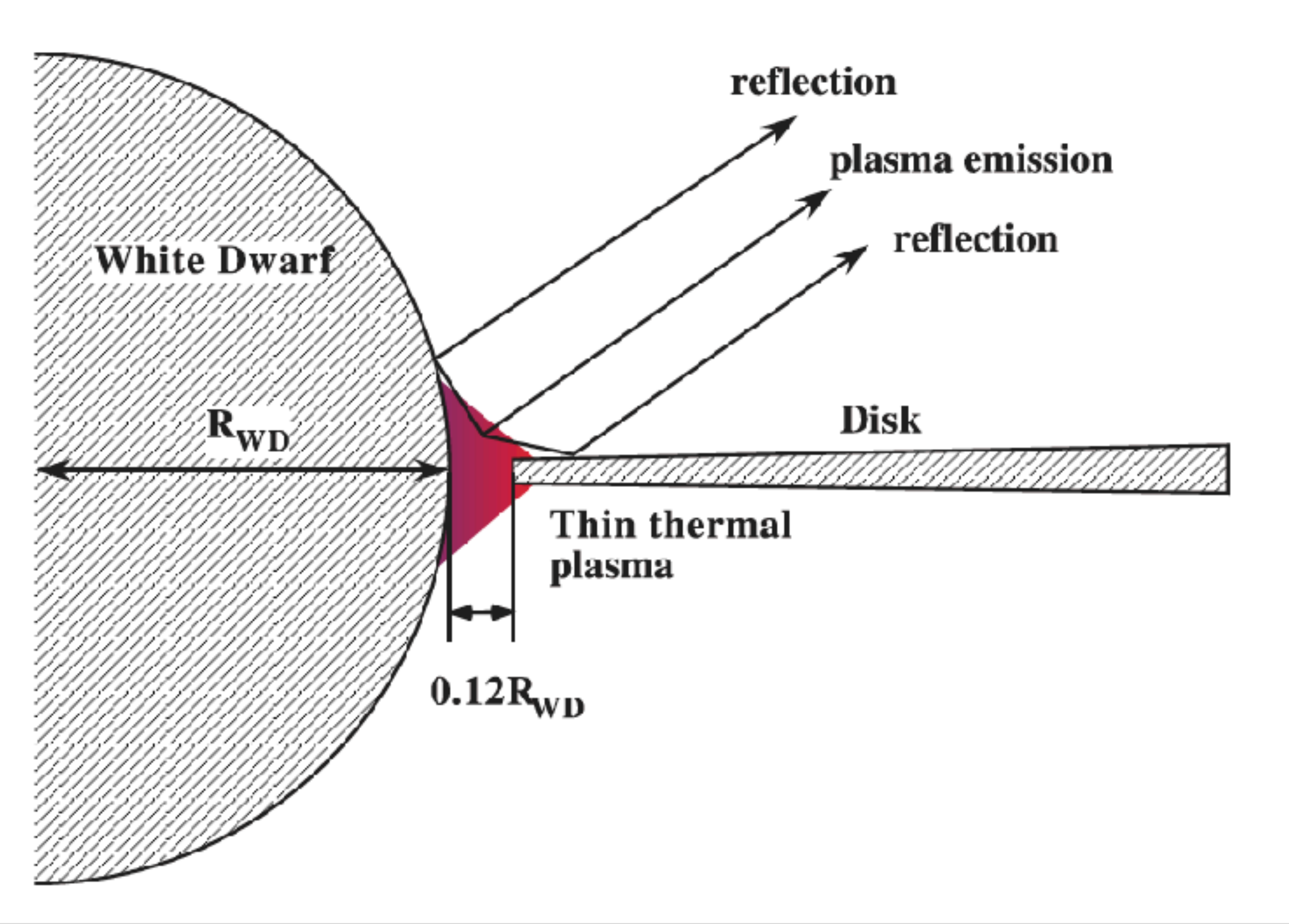
2. Shocks (winds/jets) interacting with the companion (could produce β and γ-type)

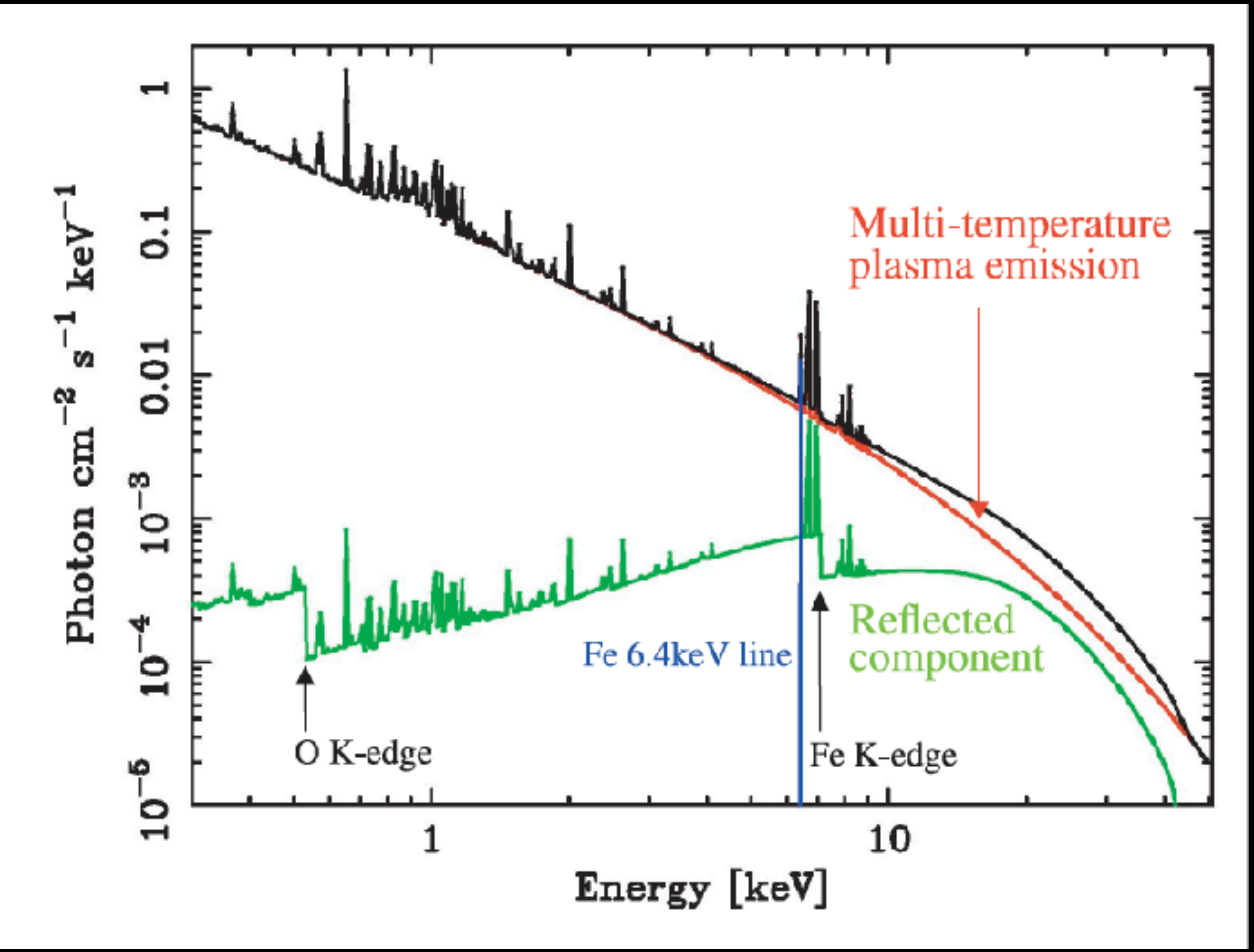


The origin of X-rays in SySts

(See Mukai 2017, PASP, 129, 2001)

3. Highly-absorbed, hard X-ray sources (producing δ-type)



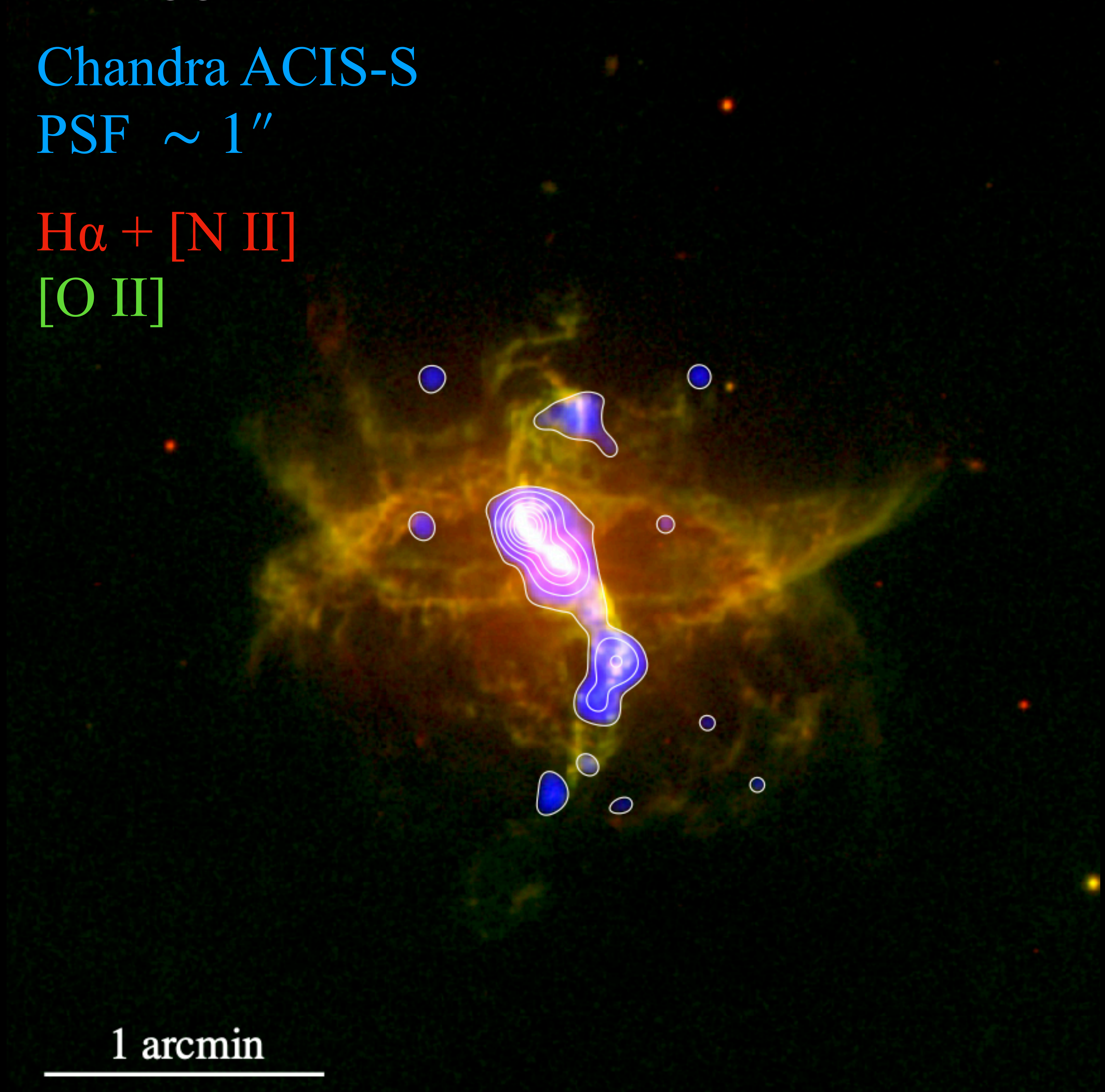


Ishida et al. (2009, PASJ, 61, 77)

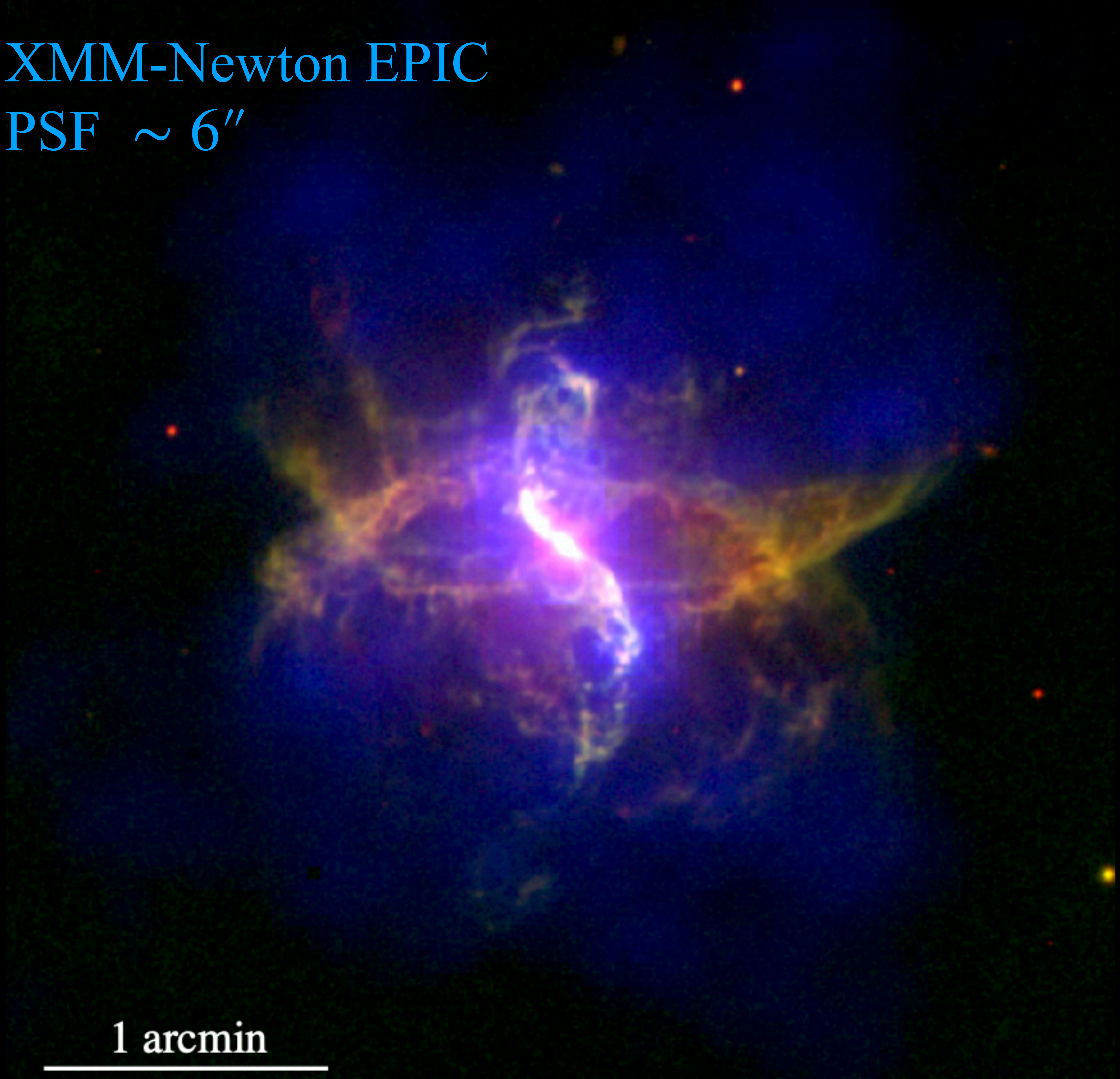
4. β/δ-types are a combination of the previous ones

R Aqr

Kellogg et al. (2001, 2007)



Toalá et al., (2022)



Optical data from Limits et al. (2018)

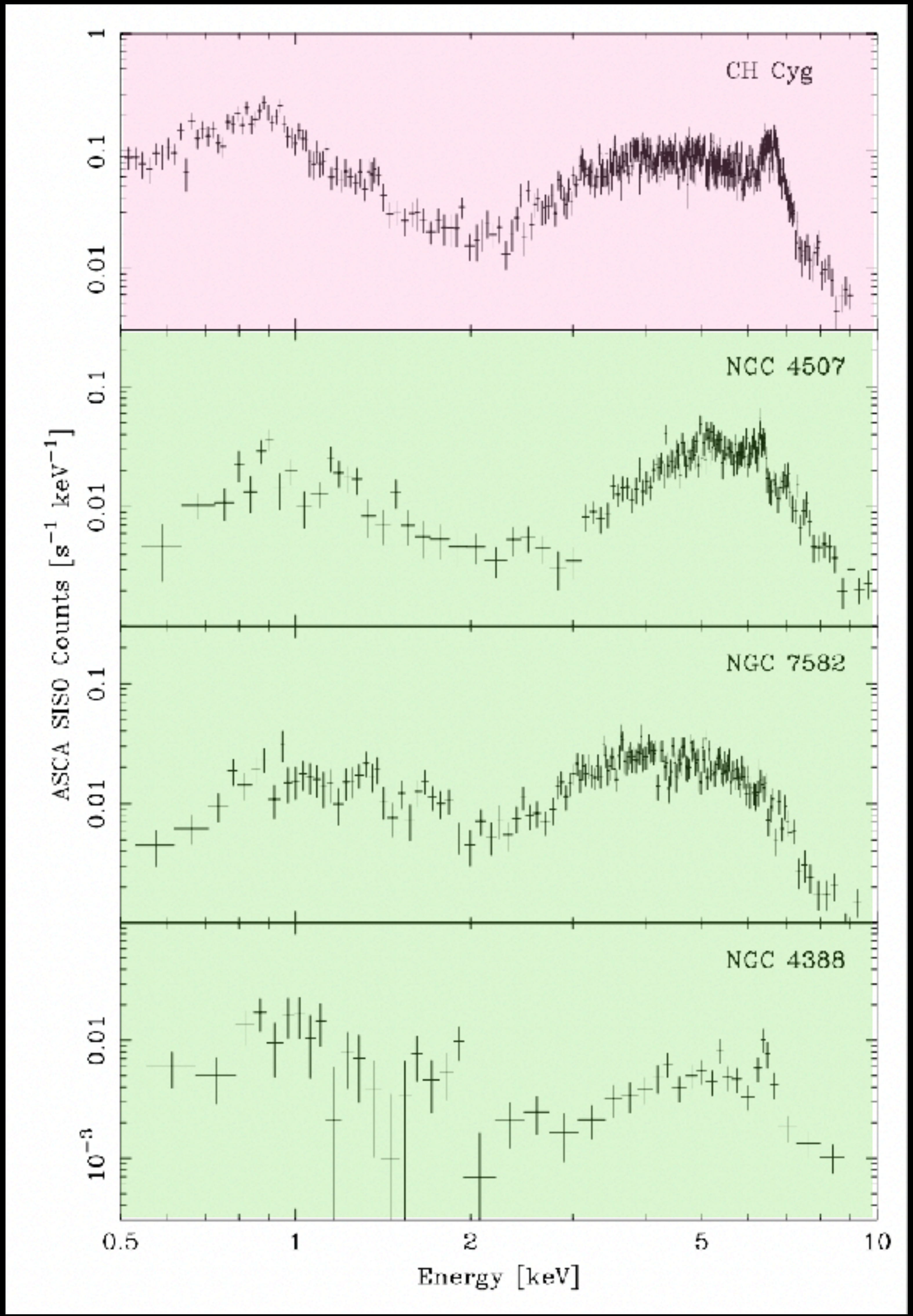
In general, SySts are not resolve and we only have spectral information

Some of them (β/δ-type; Muerset et al. 1997) have spectra that resemble AGNs (Wheatley & Kallman 2006)

Our target
CH Cyg

It has been observed by most X-ray missions EXOSAT, ROSAT, ASCA, Chandra, Suzaku and XMM

(Leahy & Taylor 1987; Leahy & Volk 1995; Muerset et al. 1997; Ezuka et al. 1998; Galloway & Sokoloski 2004; Karovska et al. 2007; Mukai et al. 2007)

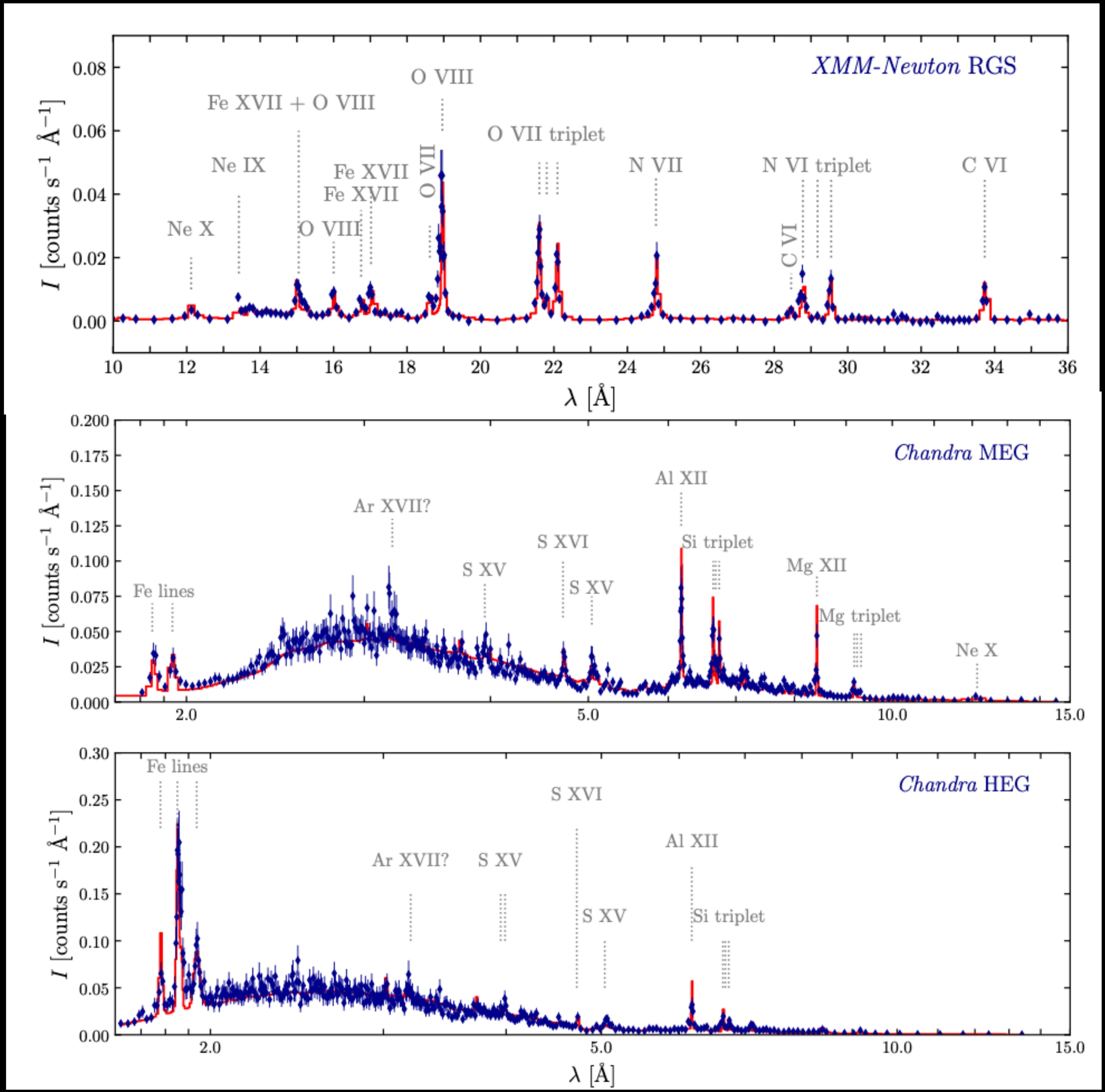


Seyfer 2 galaxies

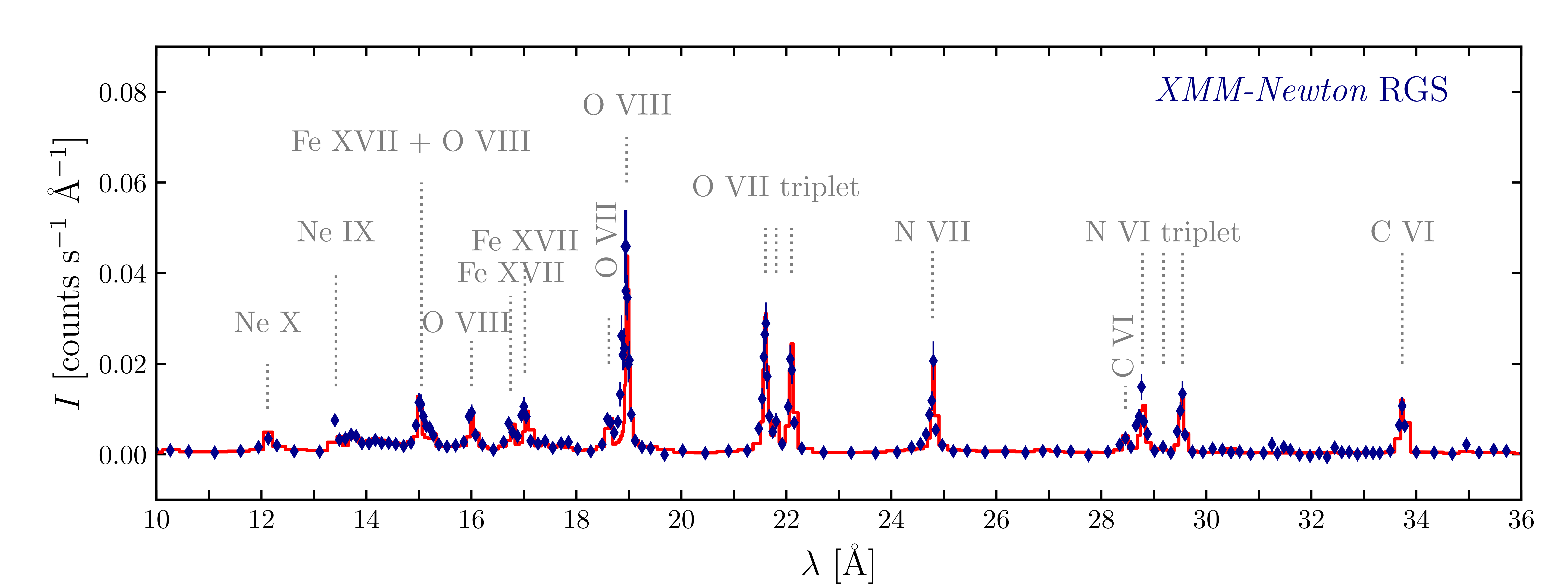
1) High-resolution X-ray spectra of CH Cyg

The first study of the
high-res X-ray spectra

(Toalá et al., 2023, MNRAS, 522, 6102)



1) High-resolution X-ray spectra of CH Cyg



A fit (XSPEC) to the RGS spectrum resulted in

$N_H = (0.04 \pm 0.02) \times 10^{22}$ cm^{-2}

$kT_1 = 0.12 \pm 0.01$ keV (= 1.4×10^6 K)

$kT_2 = 0.47 \pm 0.03$ keV (= 5.4×10^6 K)

$kT_3 = 42 \pm 200$ keV

Element	Schmidt et al. (2006) 12+log$X$	Schmidt et al. (2006) $X/X_\odot$	RGS (Model D) $X/X_\odot$
C	8.37 ± 0.22	$0.95^{+0.63}_{-0.38}$	1.2 ± 0.3
N	8.08 ± 0.13	$1.65^{+0.58}_{-0.43}$	2.8 ± 0.4
O	8.76 ± 0.24	$1.07^{+0.79}_{-0.45}$	1.4 ± 0.2
Mg	8.68 ± 0.21	$13.08^{+8.58}_{-5.29}$	1.0
Si	7.40 ± 0.18	$0.74^{+0.38}_{-0.25}$	1.0
Fe	7.50 ± 0.19	$1.09^{+0.60}_{-0.38}$	0.3 ± 0.1

2) He-like triplets in the high-res X-ray spectra of CH Cyg

r - resonance

i - intercombination

f - forbidden

$$G = \frac{f+i}{r}$$

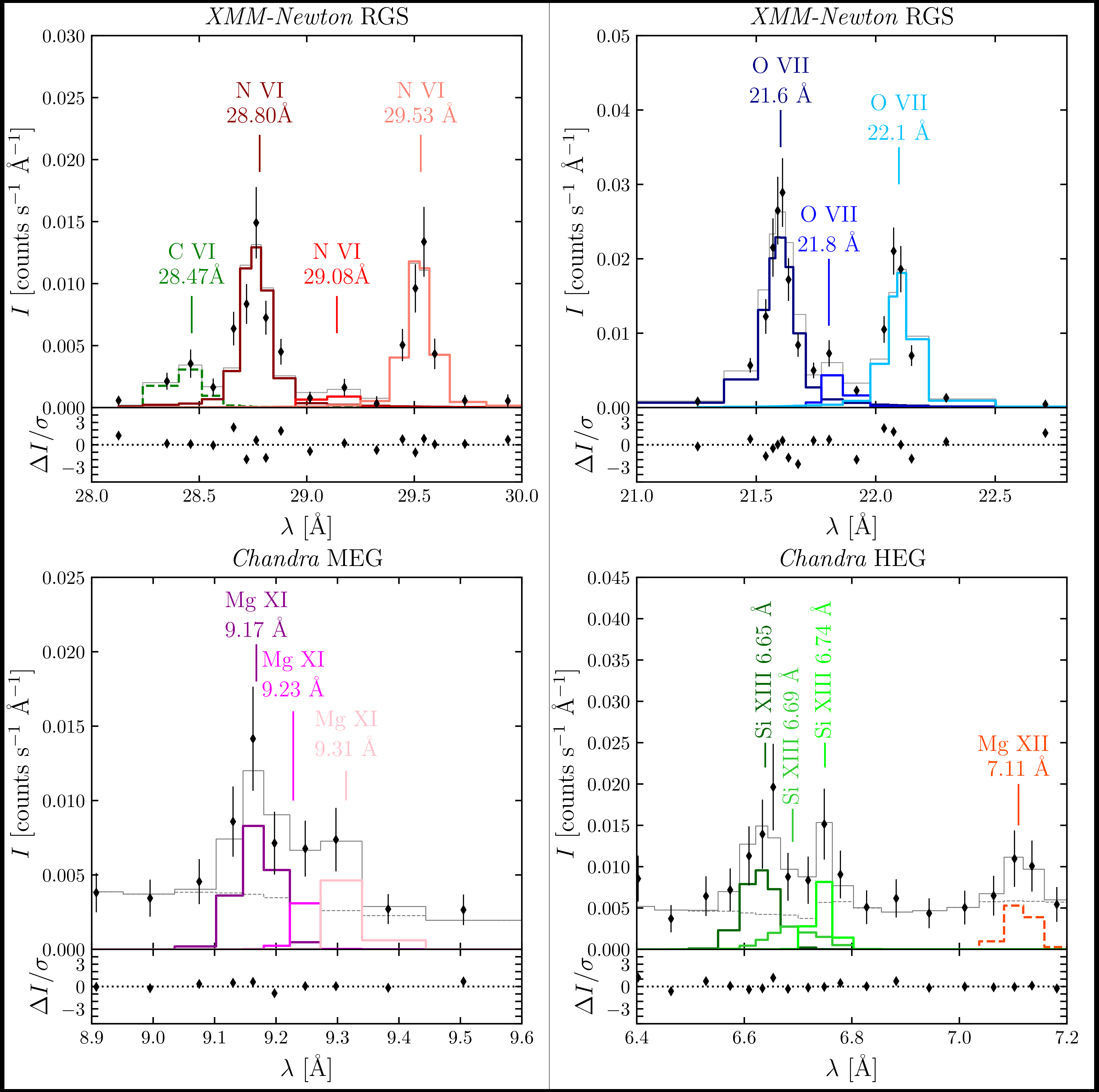
T_e can be estimated following Parquet & Dubai (2000)

$$T_e(\mathrm{N\ VI}) = (2.3 \pm 0.7) \times 10^6\ \mathrm{K}$$

$$T_e(\mathrm{O\ VII}) = (2.4 \pm 0.6) \times 10^6\ \mathrm{K}$$

$$T_e(\mathrm{Mg\ XI}) = 4.6 \times 10^6\ \mathrm{K}$$

$$T_e(\mathrm{S\ XIII}) = 7.5 \times 10^6\ \mathrm{K}$$



3) The Fe emission lines

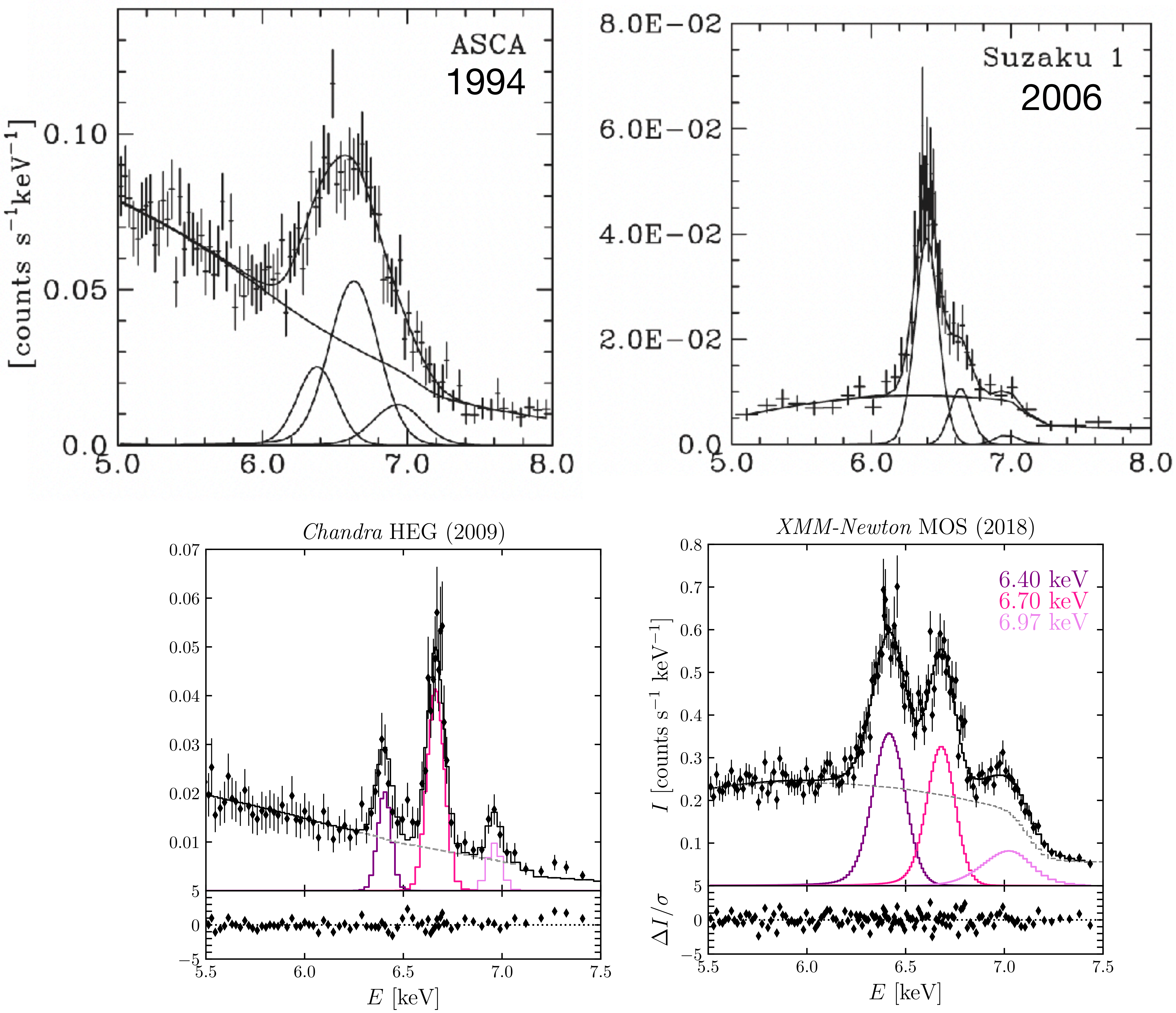
Fluorescent line @6.40 keV
He-like Fe emission @6.70 keV
H-like Fe emission @6.97 keV

The EW of the fluorescent line (Inoue 1985)

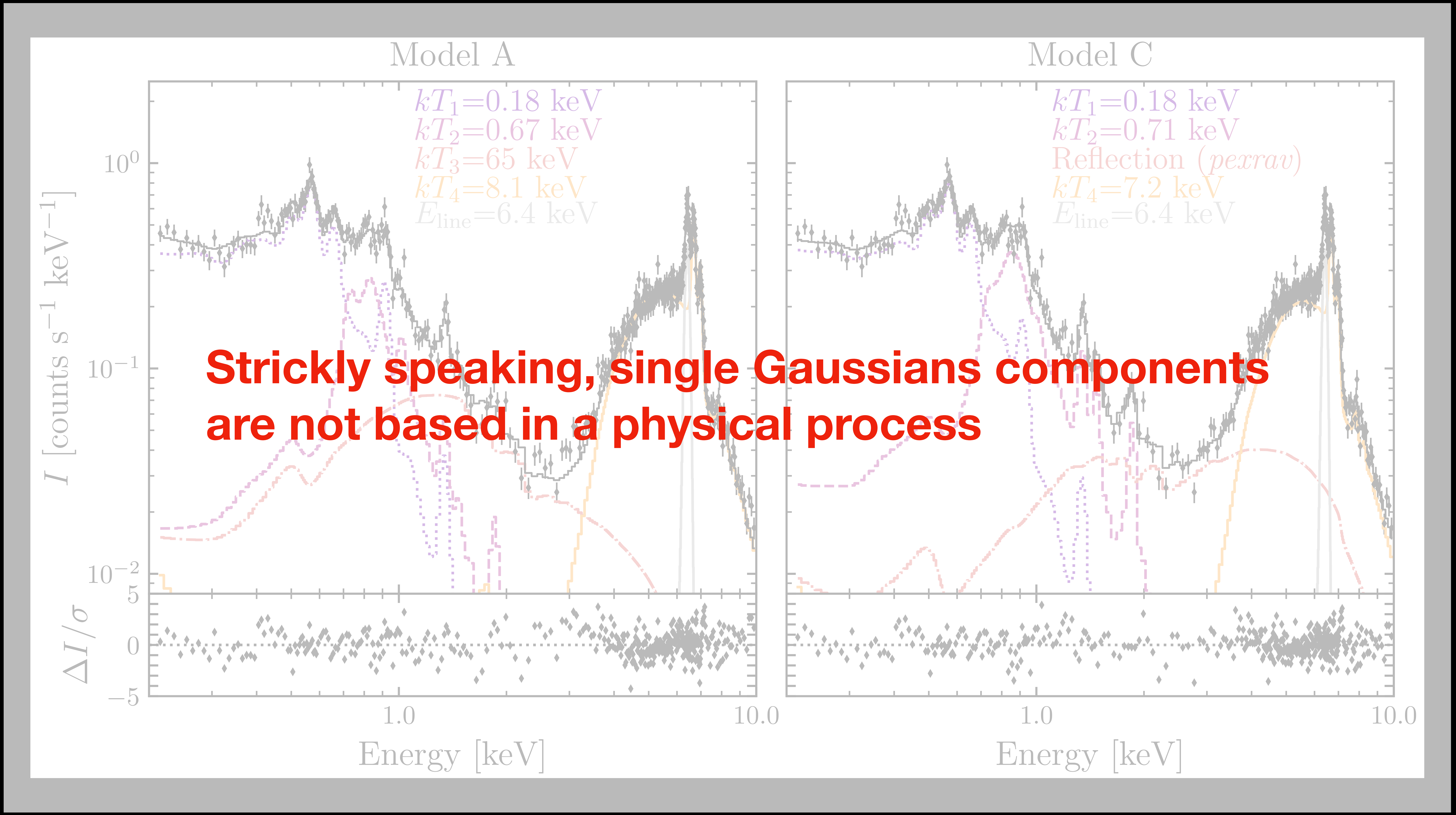
$$EW = \frac{\Omega}{4\pi}\left(\frac{N_H}{10^{21}\ \mathrm{cm}^{-2}}\right)\ \mathrm{eV}$$

Fe emission line variability related to column density variations!

Taken from Mukai (2007)



4) The need of a more general model of the X-ray emission from SySts



Previous authors found (see Mukai 2007):

Two-marginally absorbed components (kT_1, kT_2)

+

One heavily-absorbed component (kT_4)

CH Cyg
MOS (1+2) spectra

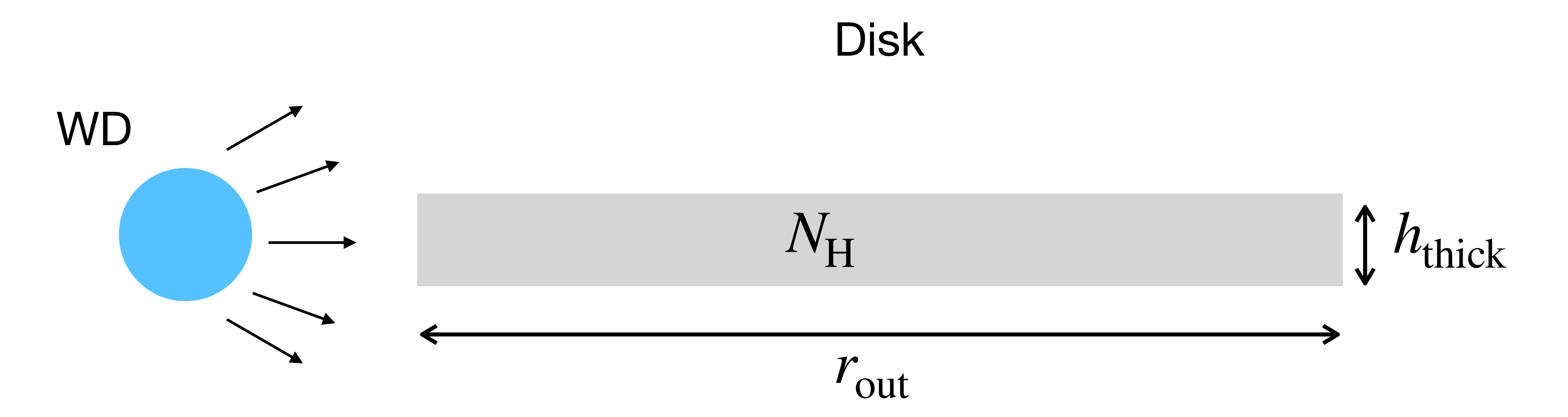
Statistically-accepted models
$\chi^2_{\rm DoF} \approx 1.5$

5) A tailored reflection model

We ran radiative-transfer simulations using REFLEX (Paltani & Ricci, 2017, A&A, 607, 31)

Simulates the physical processes of propagation of X-ray through a medium around a central source using Monte Carlo simulations to track individual photons

$$L_X \approx 2 \times 10^{33} \text{ erg s}^{-1}$$



**Abundances obtained from our spectral analysis

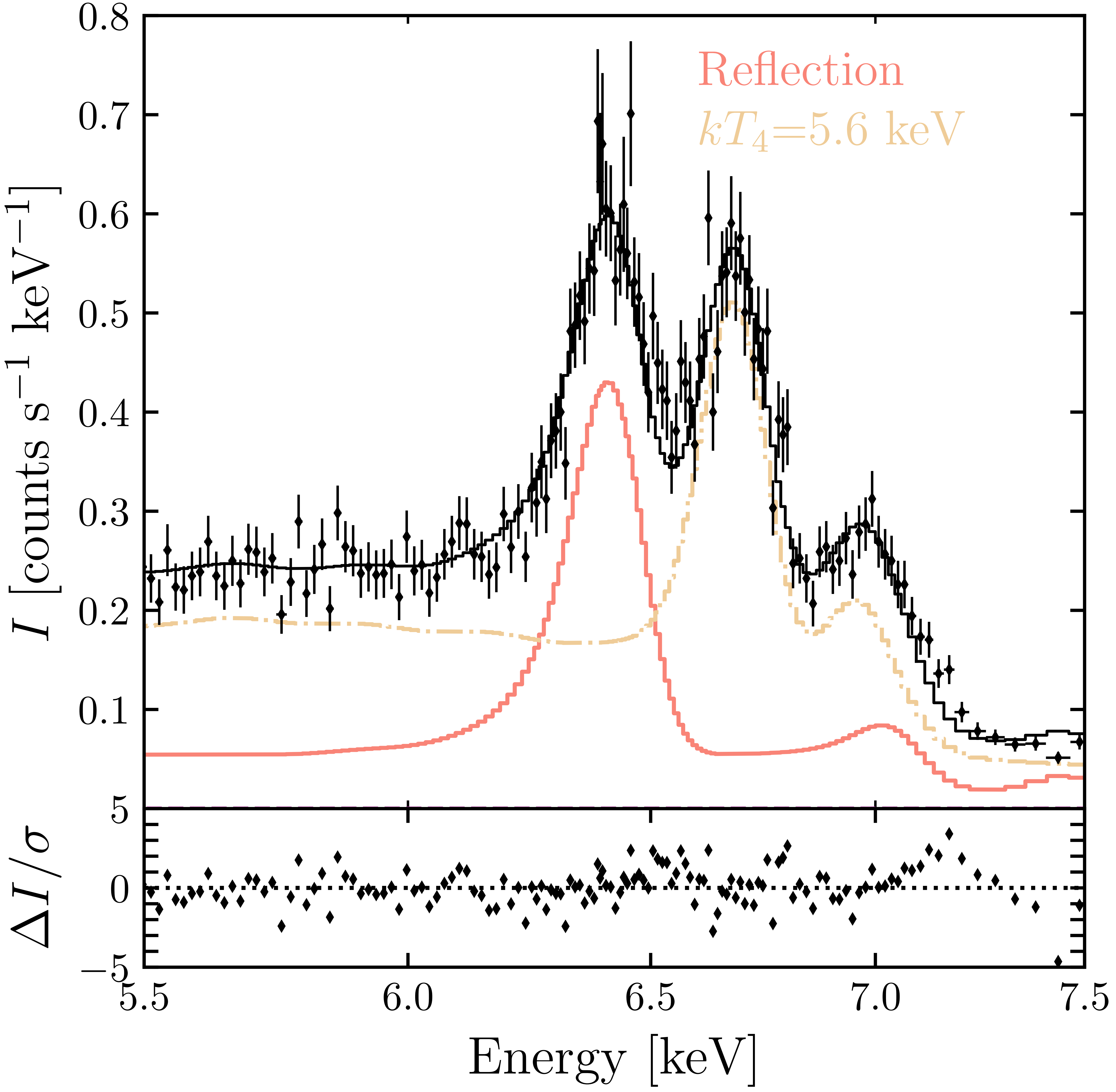
5) A tailored reflection model : RESULTS

The disk

$N_{\rm H} = 5 \times 10^{23}\ {\rm cm}^{-2}$
$h_{\rm thick} = 0.1\ r_{\rm out}$

Effective

$N_{\rm H} = (7.5 \pm 0.2) \times 10^{23}\ {\rm cm}^{-2}$
$kT_4 = 5.6 \pm 0.1\ {\rm keV}$

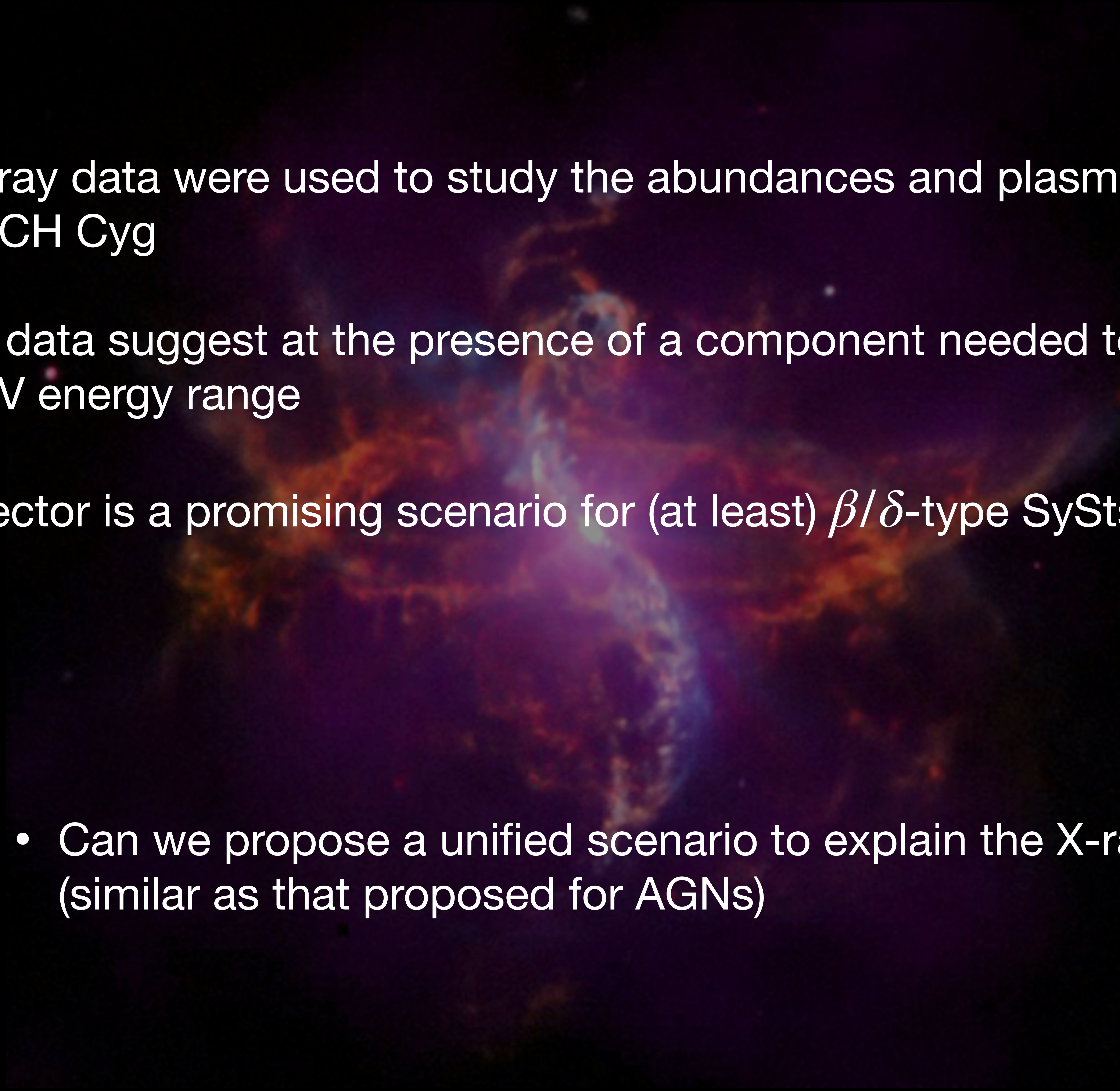


Take aways

- High-res X-ray data were used to study the abundances and plasma temperatures in the SySt CH Cyg

- Deep X-ray data suggest at the presence of a component needed to fit the 2.0—4.0 keV energy range

- Ionized reflector is a promising scenario for (at least) β/δ-type SySts



• Can we propose a unified scenario to explain the X-ray emission from SySt? (similar as that proposed for AGNs)