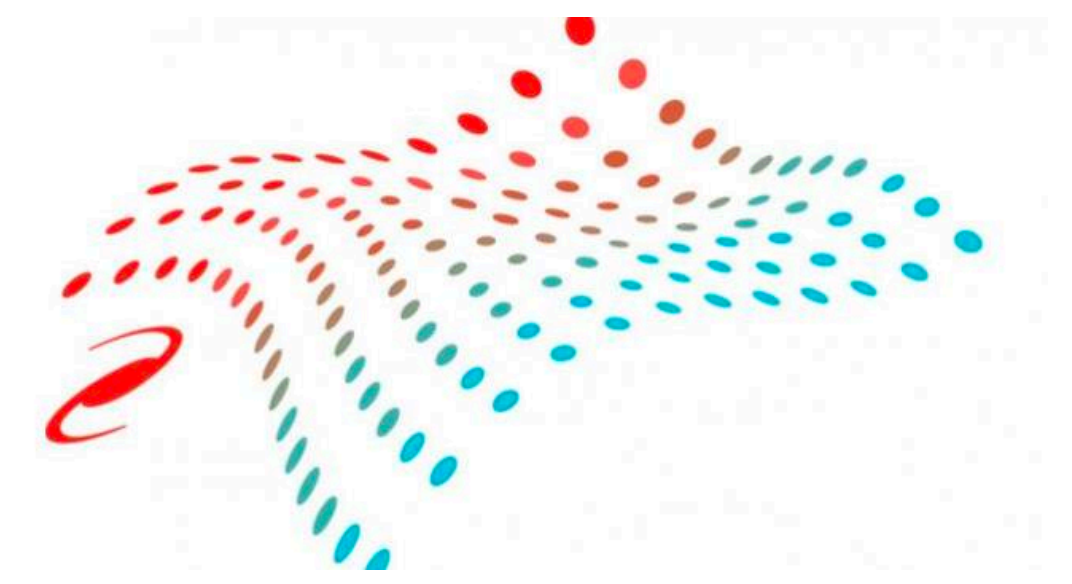




**Massachusetts  
Institute of  
Technology**



# **ORBITAL VARIATION OF GALACTIC PULSAR 4U1907+09**

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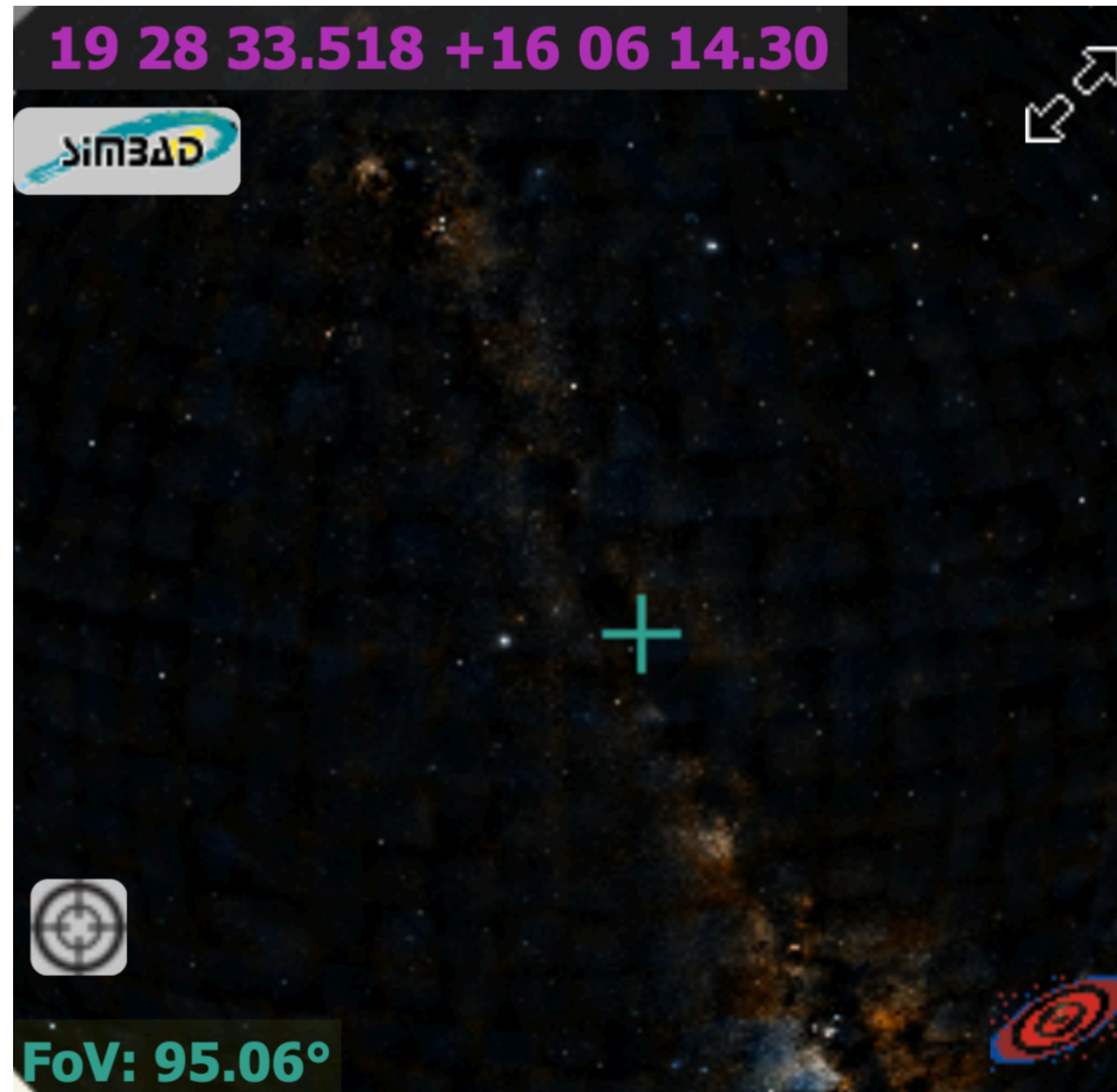
**Jun Yang**

**Paul Hemphill, Norbert S. Schulz, Claude R. Canizares, Jose M. Torrejon**

# GALACTIC PULSAR 4U1907+09 NEAR THE GALACTIC PLANE

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- One of  $\sim 35$  high-mass X-ray binaries with known high magnetic field strength





# X-Ray Telescopes & the Electromagnetic Spectrum

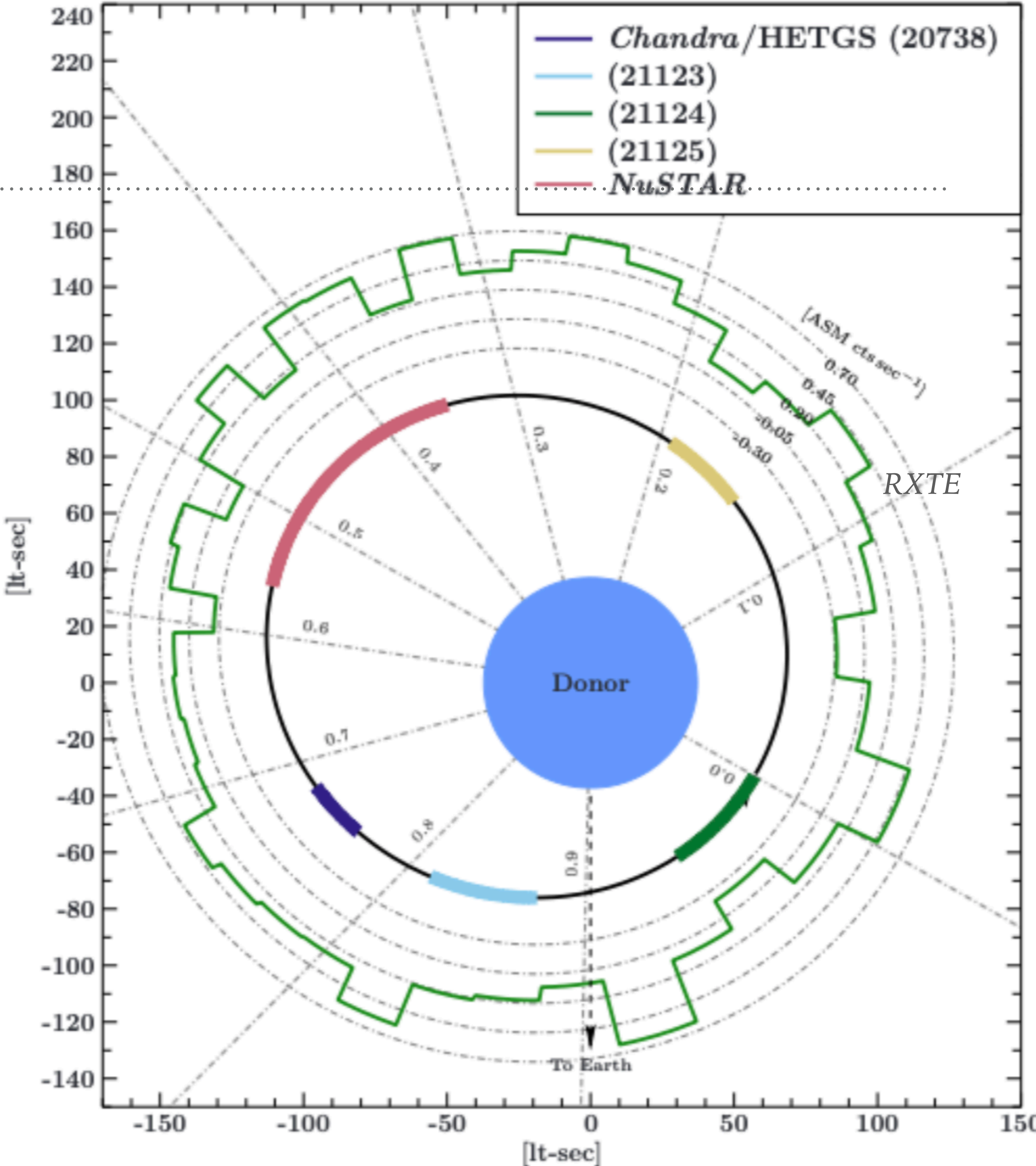
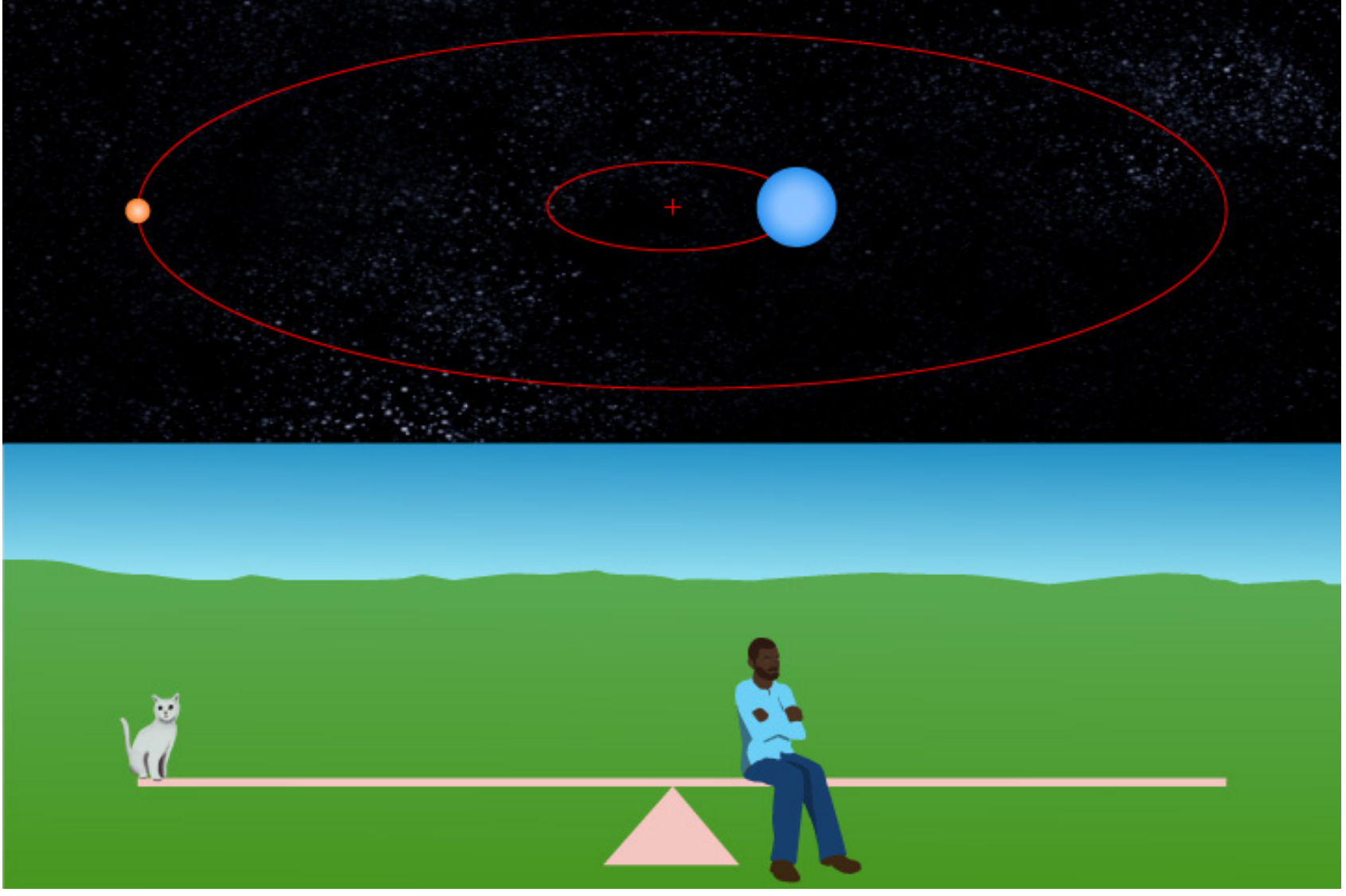




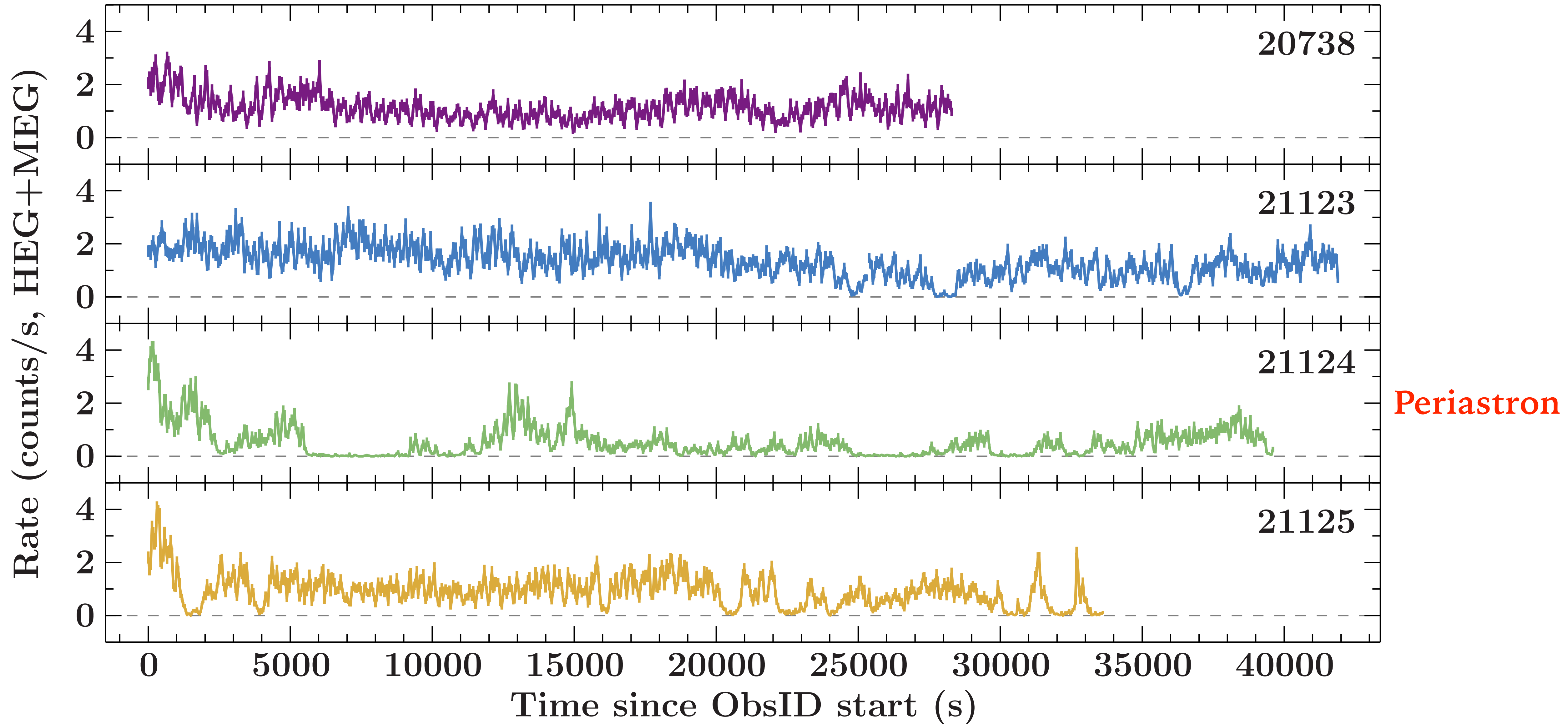
# CHANDRA (~140 KS) AND NUSTAR (78 KS)

4U1907+09

- (~440 s) X-ray pulsar
- accreting, stellar wind, an O8/9 supergiant.
- ~8.37 d orbit (e ~ 0.28) around its donor



# LIGHT CURVES OF 4U1907+09 WITH CHANDRA HETG



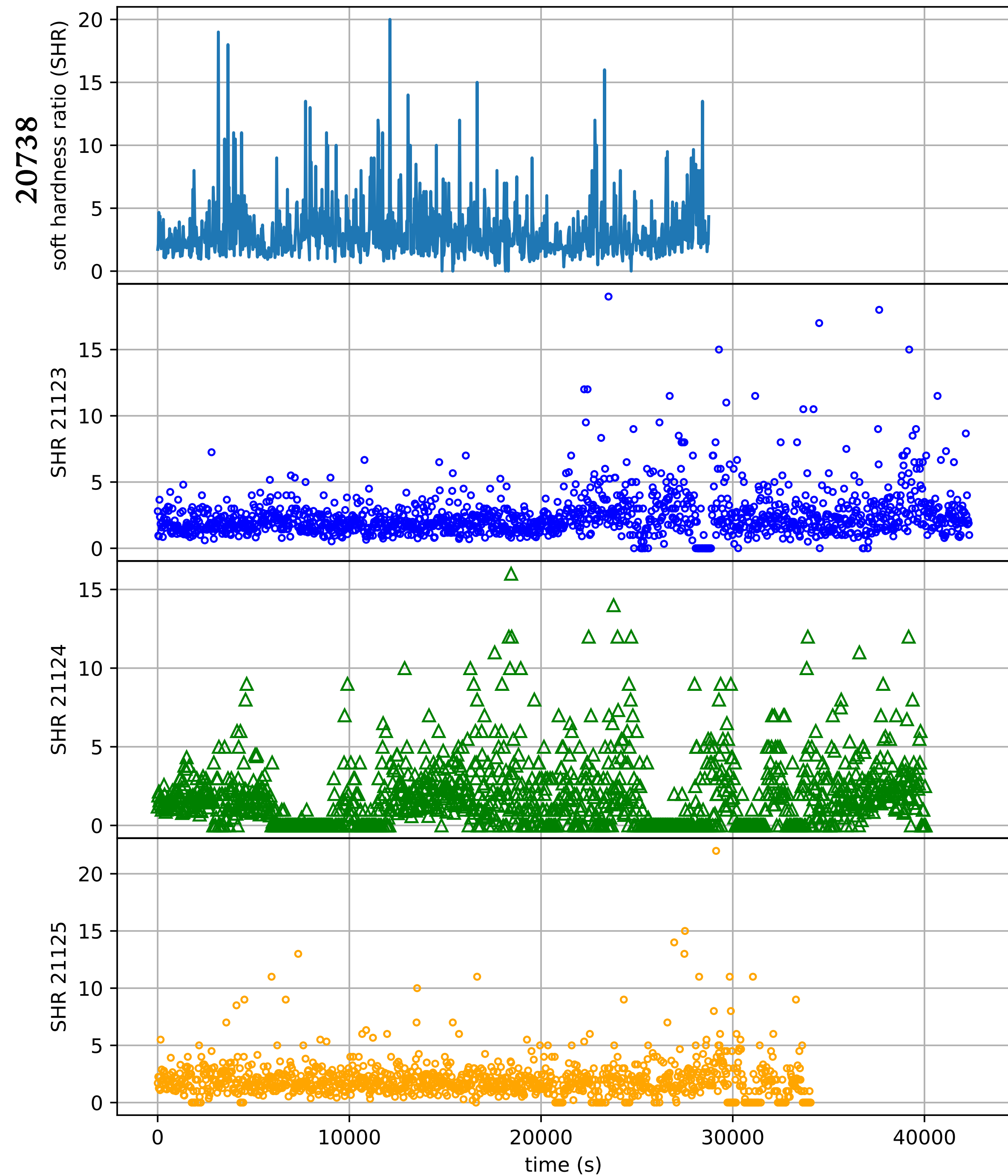


# HARDNESS RATIO IN SOFT BAND (SHR)

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Count rate (2.5~4.5 keV)

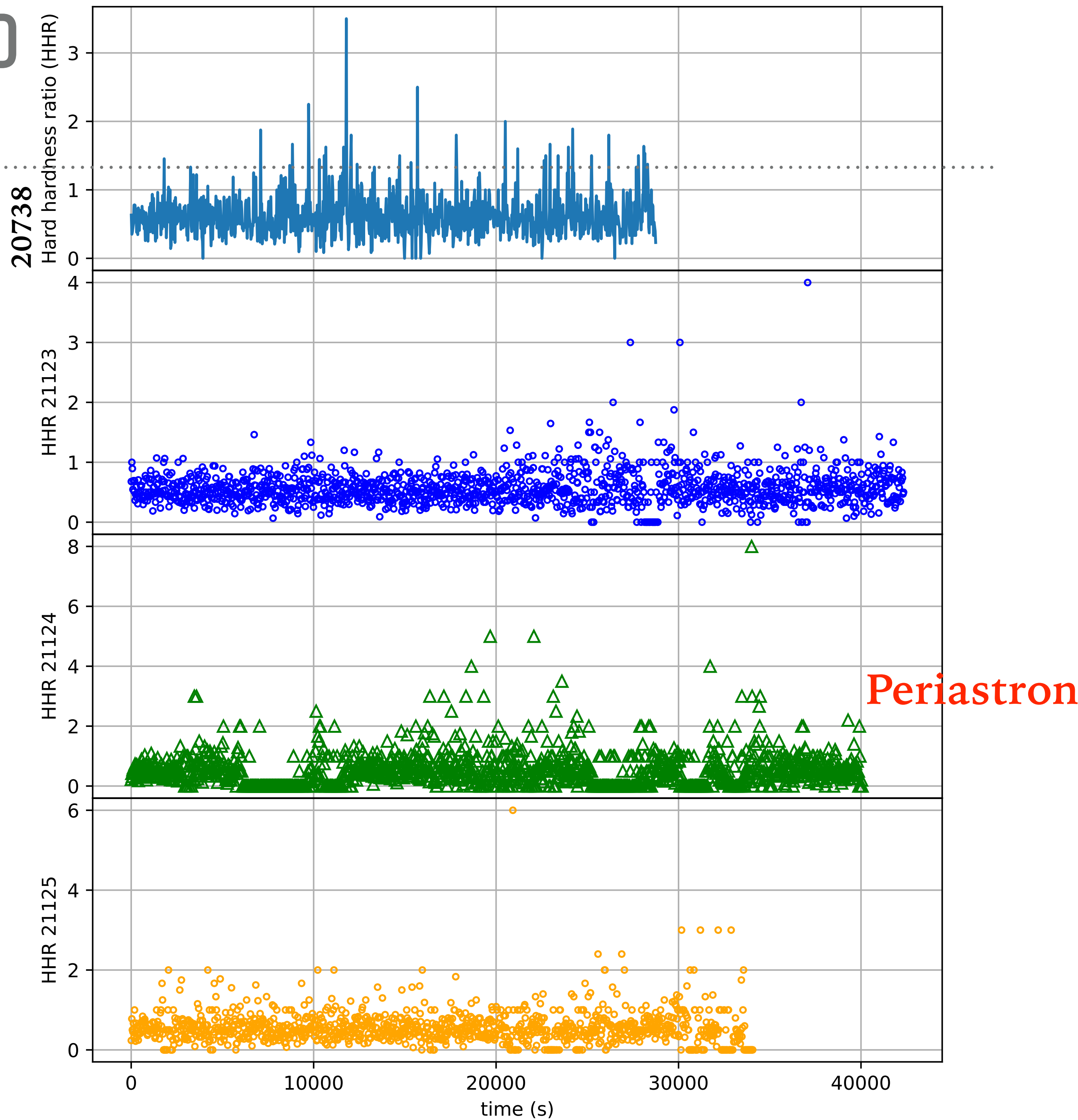
Count rate (0.5~2.5 keV)



# HARDNESS RATIO IN HARD ENERGY BAND (HHR)

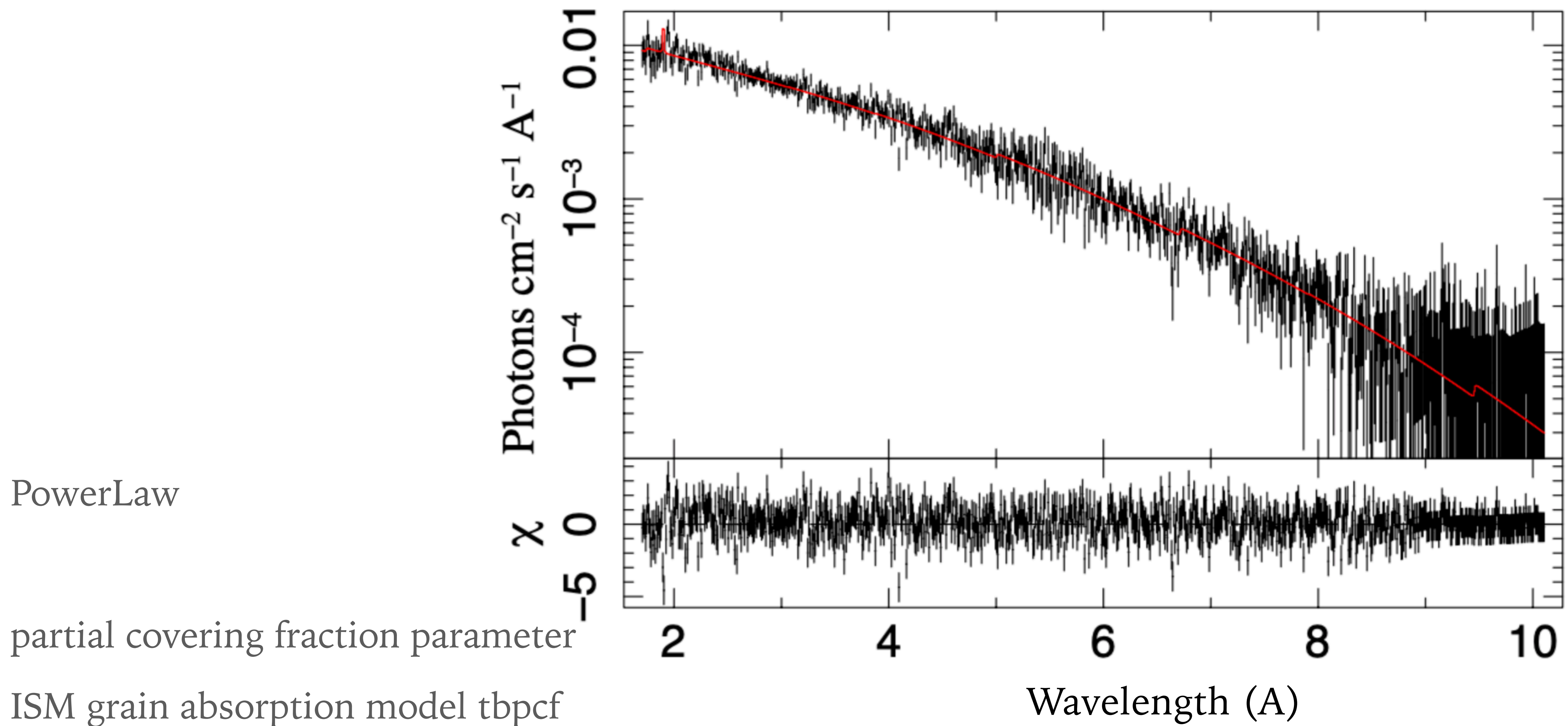
Count rate (4.5~8 keV)

Count rate (2.5~4.5 keV)



# CHANDRA HETG SPECTRUM OF 4U1907+09 FROM OBSERVATION ID 20738

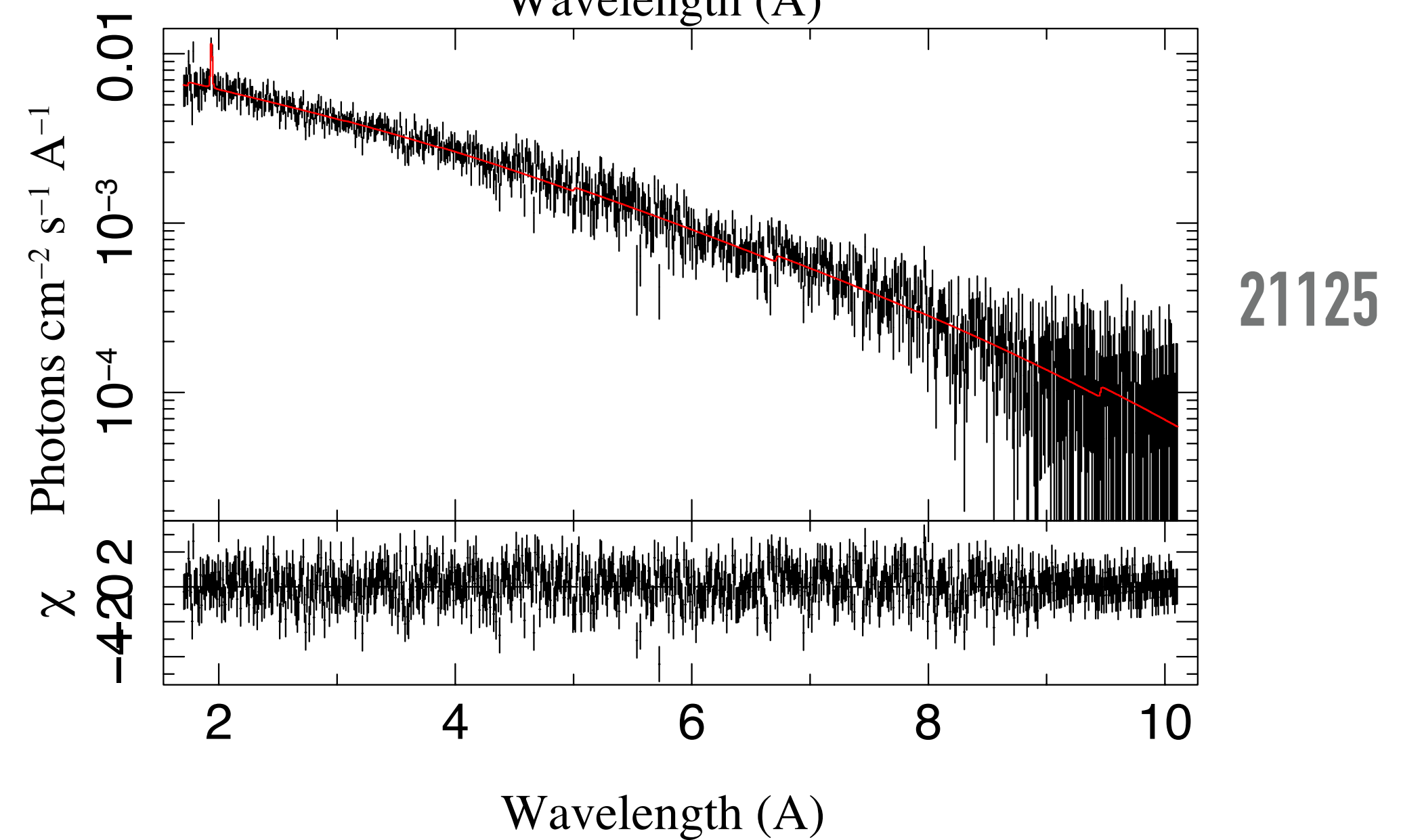
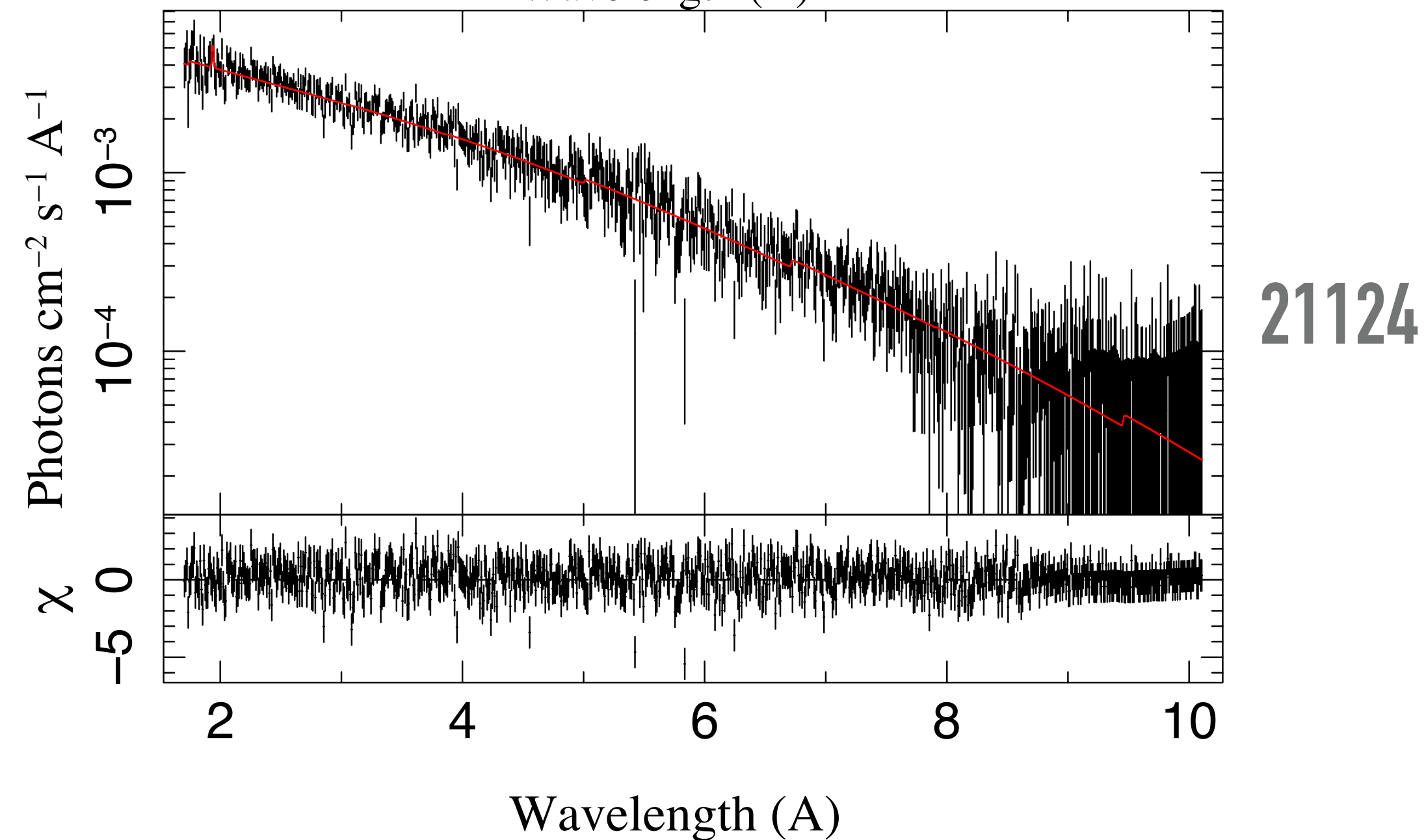
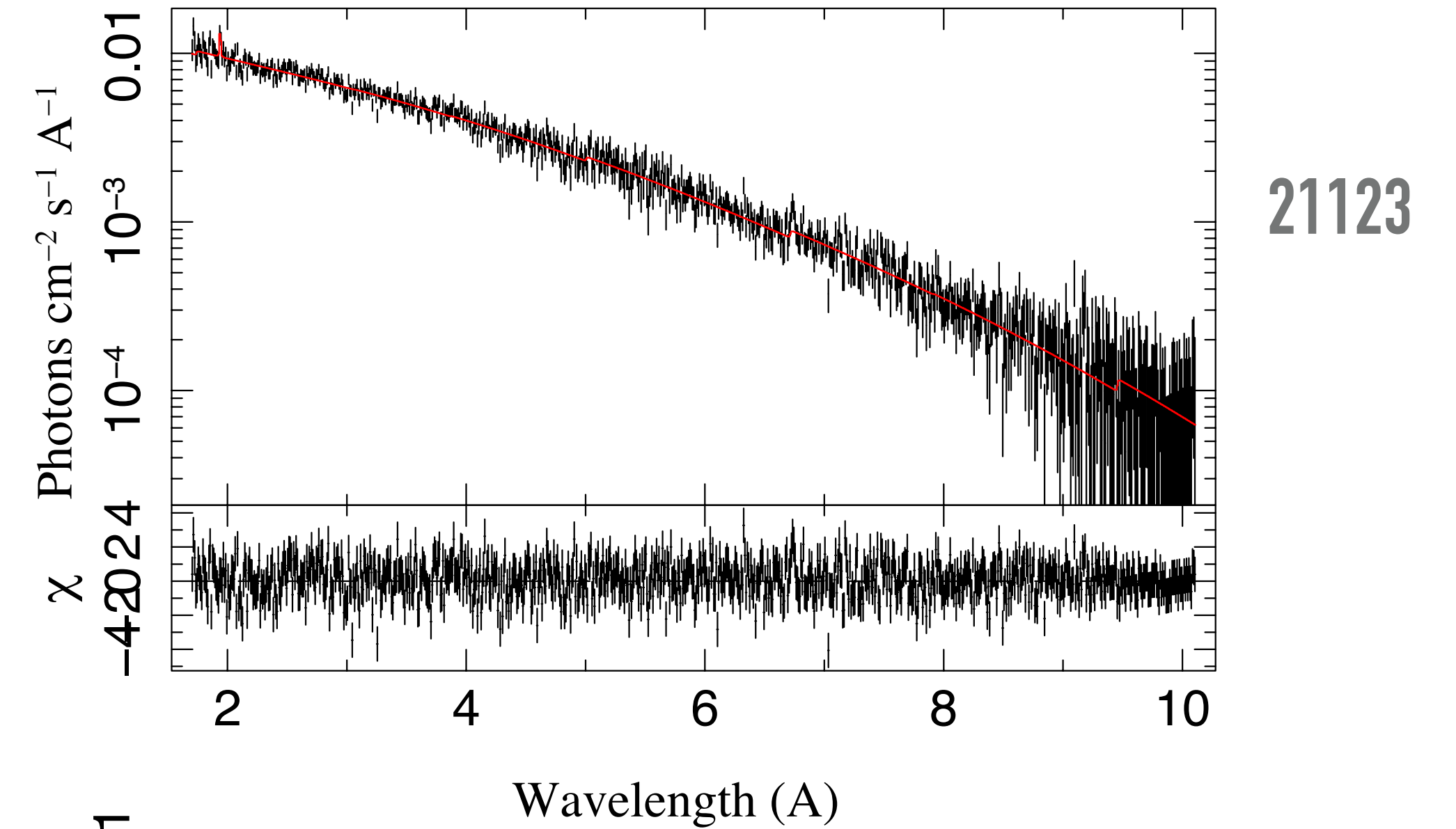
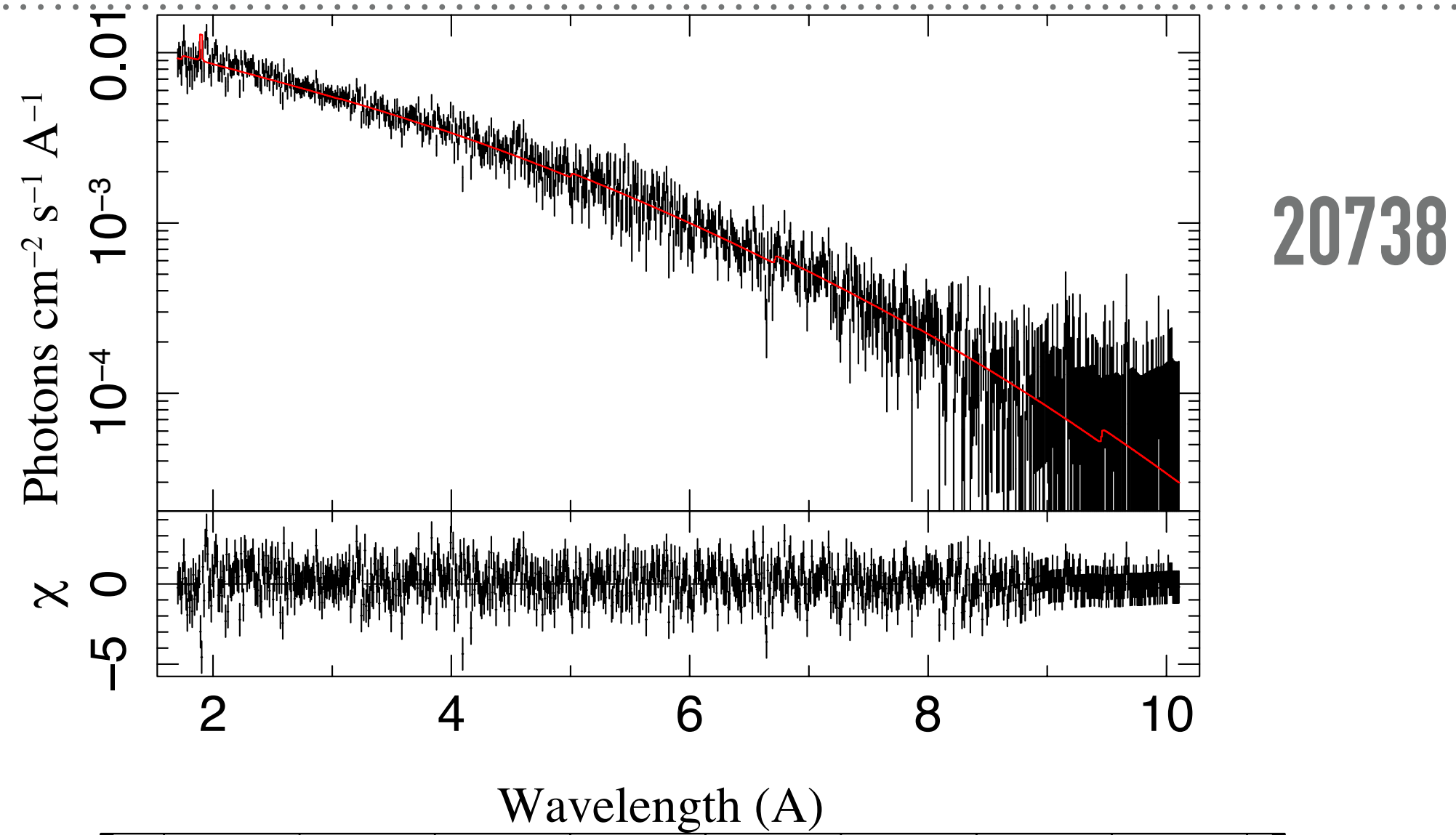
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# SHAPE OF SPECTRAL CONTINUUM WITH RESPECT TO ORBITAL PHASE

*powerlaw ( the core emission model) and the absorbing functions (TBfeo and TBpcf): TBfeo\*TBpcf\*powerlaw.*



# SHAPE OF SPECTRAL CONTINUUM WITH RESPECT TO ORBITAL PHASE

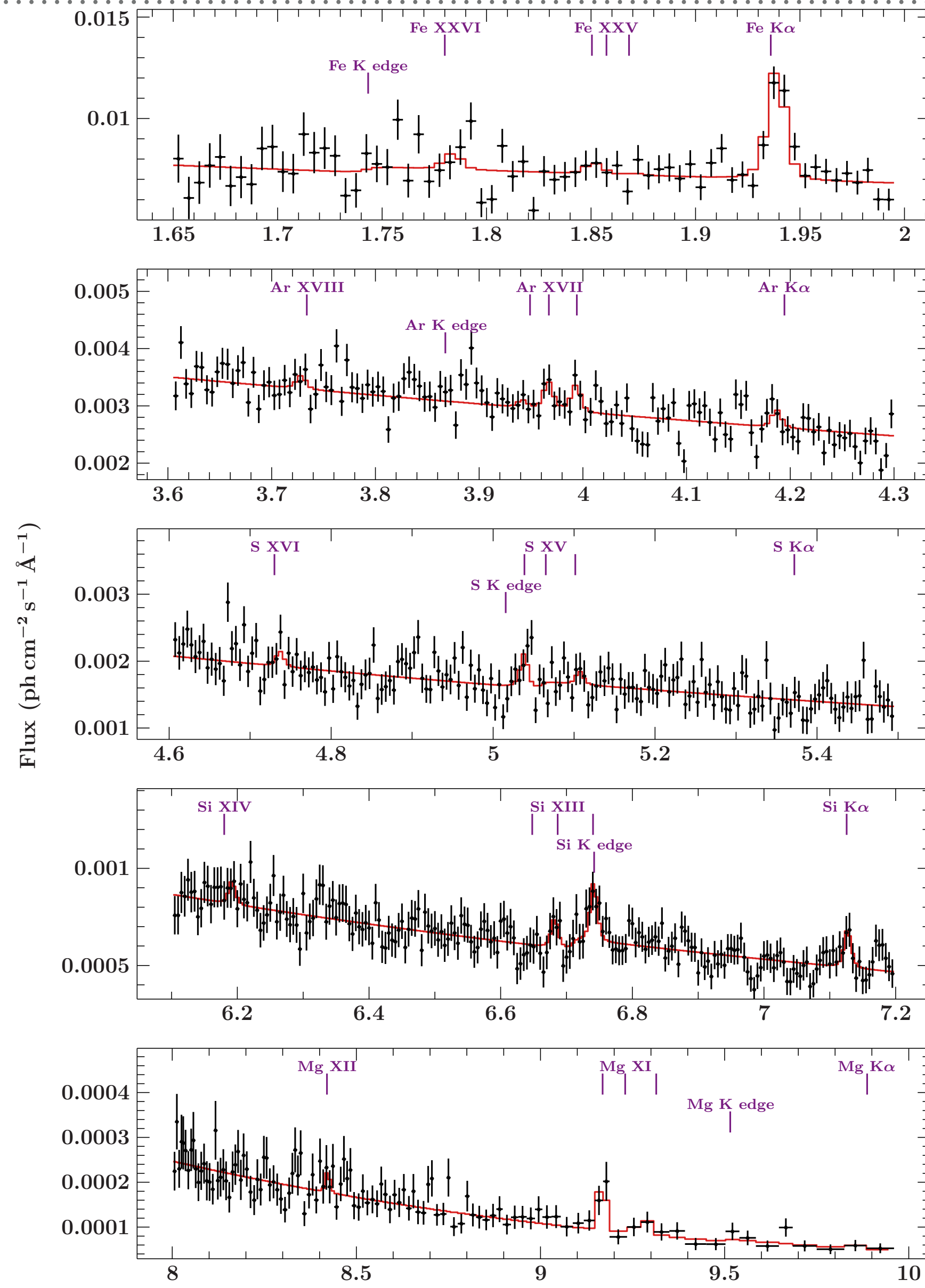
Continuum and iron  $K\alpha$  fits to *Chandra*-HETGS observations of 4U 1907+09

		20738	21123	21124	21125
$N_{\text{H,full}}$	$10^{22} \text{ cm}^{-2}$	$4.1^{+0.6}_{-1.9}$	$3.5^{+0.4}_{-0.5}$	$3.2^{+0.8}_{-2.2}$	$3.05^{+0.29}_{-0.38}$
$N_{\text{H,pcf}}$	$10^{22} \text{ cm}^{-2}$	$5.6^{+5.3}_{-2.8}$	$5.8^{+2.3}_{-1.8}$	$5.1^{+4.4}_{-2.0}$	$6.9^{+2.5}_{-2.3}$
$f_{\text{pcf}}$		$0.46^{+0.45}_{-0.16}$	$0.50^{+0.12}_{-0.09}$	$0.59^{+0.36}_{-0.19}$	0.526
$TBpcf(1).redshift$		(0.000)	(0.000)	(0.000)	(0.000)
PL norm	$10^{-2} \text{ ph cm}^{-2} \text{ s}^{-1}$	$3.6^{+1.6}_{-0.6}$	$4.6^{+1.2}_{-0.8}$	$1.6^{+0.8}_{-0.5}$	$3.1^{+1.0}_{-0.7}$
$\Gamma$		$1.36^{+0.19}_{-0.15}$	$1.45^{+0.12}_{-0.11}$	$1.37^{+0.22}_{-0.17}$	$1.46^{+0.16}_{-0.15}$
$A_{\text{FeK}\alpha}$	$10^{-5} \text{ ph cm}^{-2} \text{ s}^{-1}$	$9 \pm 4$	$7 \pm 4$	$2.8 \pm 2.0$	$11 \pm 5$
$\lambda_{\text{FeK}\alpha}$	$\text{\AA}$	$1.9428^{+0.0098}_{-0.0004}$	$1.939^{+0.004}_{-0.010}$	$1.939^{+0.004}_{-0.010}$	$1.938^{+0.005}_{-0.006}$
$\sigma_{\text{FeK}\alpha}$	$\text{\AA}$	0.001	0.001	0.003	0.004
reduced $\chi^2$		1.01	1.03	0.92	0.90

Periastron



# COMBINED CHANDRA HETG SPECTRA



Cool and dense material in the wind: clumps

Spectrum fitting with Fe K $\alpha$  line

K $\alpha$  lines of Si and Ar

Wavelength (Å)

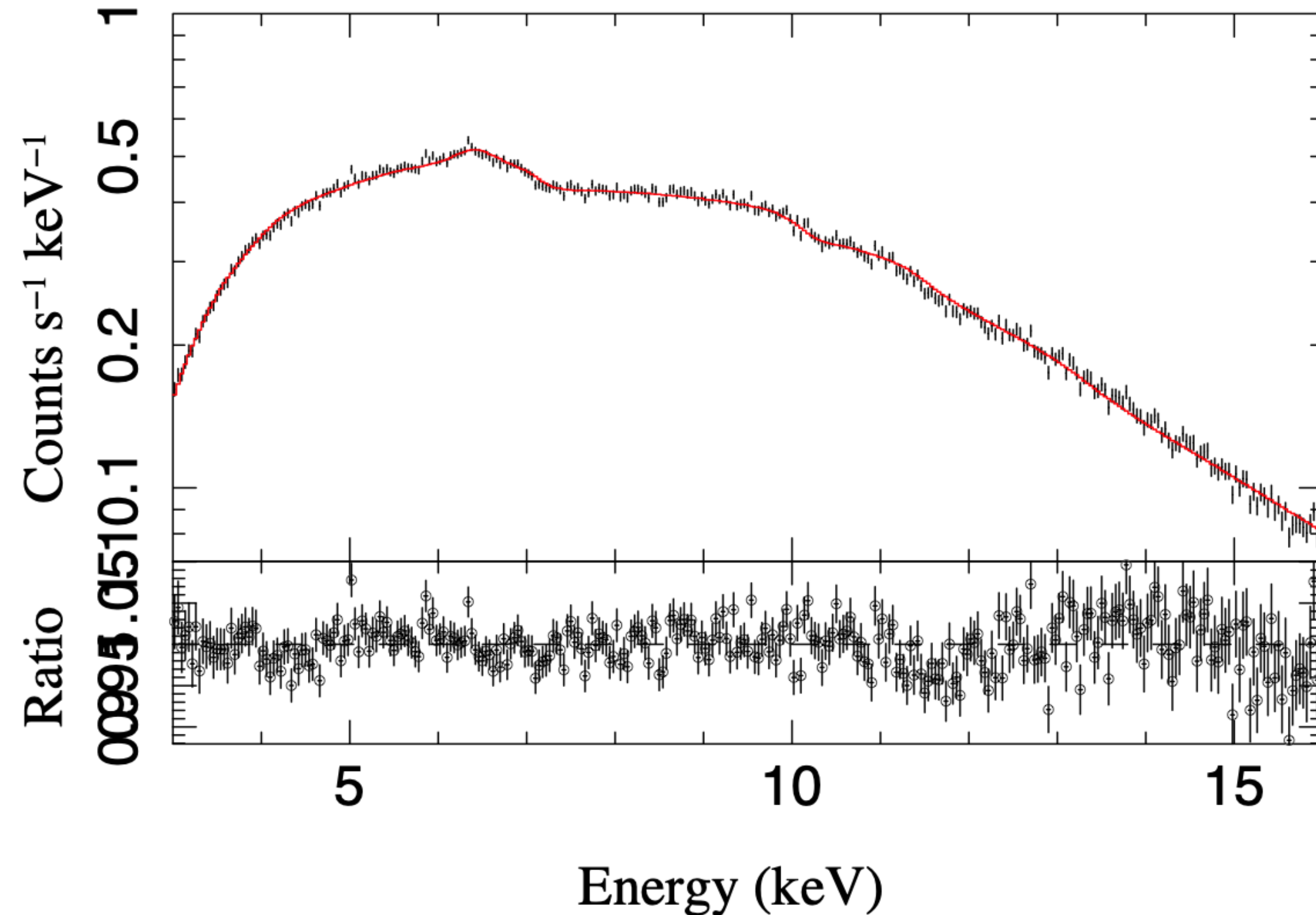
# NUSTAR SPECTRA

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➤ *powerlaw\*highcut*

fitted with a high energy cut-off continuum,

The extra absorption around 12.2 keV in the residuals is due to the *highcut* model's cutoff energy at 12.2 keV.





# SUMMARY: PULSAR 4U1907+09 IN DEPENDENCE OF BINARY ORBIT

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Chandra:  $\sim 140$  ks & NuSTAR: 78 ks, at different orbital phases, to probe the variation of **flux, brightness**, the absorbing column around the **orbit**.

1. Zero flux: **ultra-dense material** at periastron
2. Fe  $K\alpha$  fluorescence: various forms of **clumps** in the wind

**X-ray study** -> severe wind clumps in the innermost companion, variability in dependence of stellar radius

dense clumps **within** 1.5 R of **the massive companion star**