BeppoSAX Studies of a Sample of Accreting Pulsars

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BeppoSAX

BeppoSAX - **S**atellite italiano per **A**stronomia **X** (1996 - 2002):

- NFI (Narrow Field Instruments):
  1. LECS (0.1 - 10 keV);
  2. MECS (1.3 - 10 keV);
  3. HPGSPC (4 - 120 keV);
  4. PDS (15 - 300 keV)

- WFC (Wide Field Cameras) - 2 coded mask telescopes (2 - 30 keV, $20^0 \times 20^0$)

GOAL OF THIS WORK

- Analyze the data received from the satellite to study properties of the sample of the accreting pulsars with a CRSF in a uniform way.
- Attempt to describe the spectra with various continuum models and find out which one works better.
- Compare with the work of Coburn et al. (2002) (RXTE data) and look for the correlations among the spectral parametrs.
- Understand how the choice of the continuum model affects the measured CRSF parameters.
- Attempt to describe the continuum not only with phenomenological, but also with reasonably physical models.

CONTINUUM MODELS

1.Power law with a high energy cutoff («POWERLAW», «HIGHECUT» in XSPEC).	$\mathrm{PLCUT}(E) = AE^{-\Gamma}\begin{cases} 1 & (E \le E_{\mathrm{cut}}) \\ e^{-(E-E_{\mathrm{cut}})/E_{\mathrm{fold}}} & (E > E_{\mathrm{cut}}) \end{cases}$
2.Power law with a Fermi-Dirac form of the cutoff («POWERLAW», «FDCUT» in XSPEC).	$\mathrm{FDCO}(E) = AE^{-\Gamma}\dfrac{1}{1+e^{(E-E_{\mathrm{cut}})/E_{\mathrm{fold}}}}$
3.NPEX (Negative-Positive power law EXponential) model (Mihara, 1995).	$\mathrm{NPEX}(E) = A\left(E^{-\Gamma_1} + BE^{+\Gamma_2}\right)e^{-E/E_{\mathrm{fold}}}$
4.Power law with a high energy exponential cutoff («CUTOFFPL» in XSPEC).	$A(E) = KE^{-\alpha}\exp\left(-E/\beta\right)$
5. CompTT - analytic model describing Comptonization of soft photons in a hot plasma (Titarchuk, 1994).	4 free parameters: input soft photon (Wine) temperature; the plasma temperature; the plasma optical depth; the geometry switch.
6.«BW» - theoretical model for the emission from the magnetized accretion columns based on the bulk and thermal comptonization (Becker & Wolff, 2007).	6 free parameters: the column radius r_0; the accretion rate M_{dot}; the electorn temperature T_e; the magnetic field strength B; the photon diffusion parameter ξ; the comptonization parameter δ.

BEPPOSAX SOURSES WITH CYCLOTRON LINE

Source	Type	P_{orb} (days)	P_{spin} (s)
$XTEJ1946+274$	Transient	~ 80	15.8228(2)
$4U1626-67$	LMXB	0.0289	6.6679(1)
$4U1907+097$	HMXB	8.38	440.59(3)
$4U1538-52$	HMXB	3.73	528.218(1)
Her X-1	LMXB	1.7	1.237(1)
Cen X-3	HMXB	2.09	4.814315(2)
$4U0115+63$	Transient	24.3	3.7
Vela X-1	HMXB	8.96	283

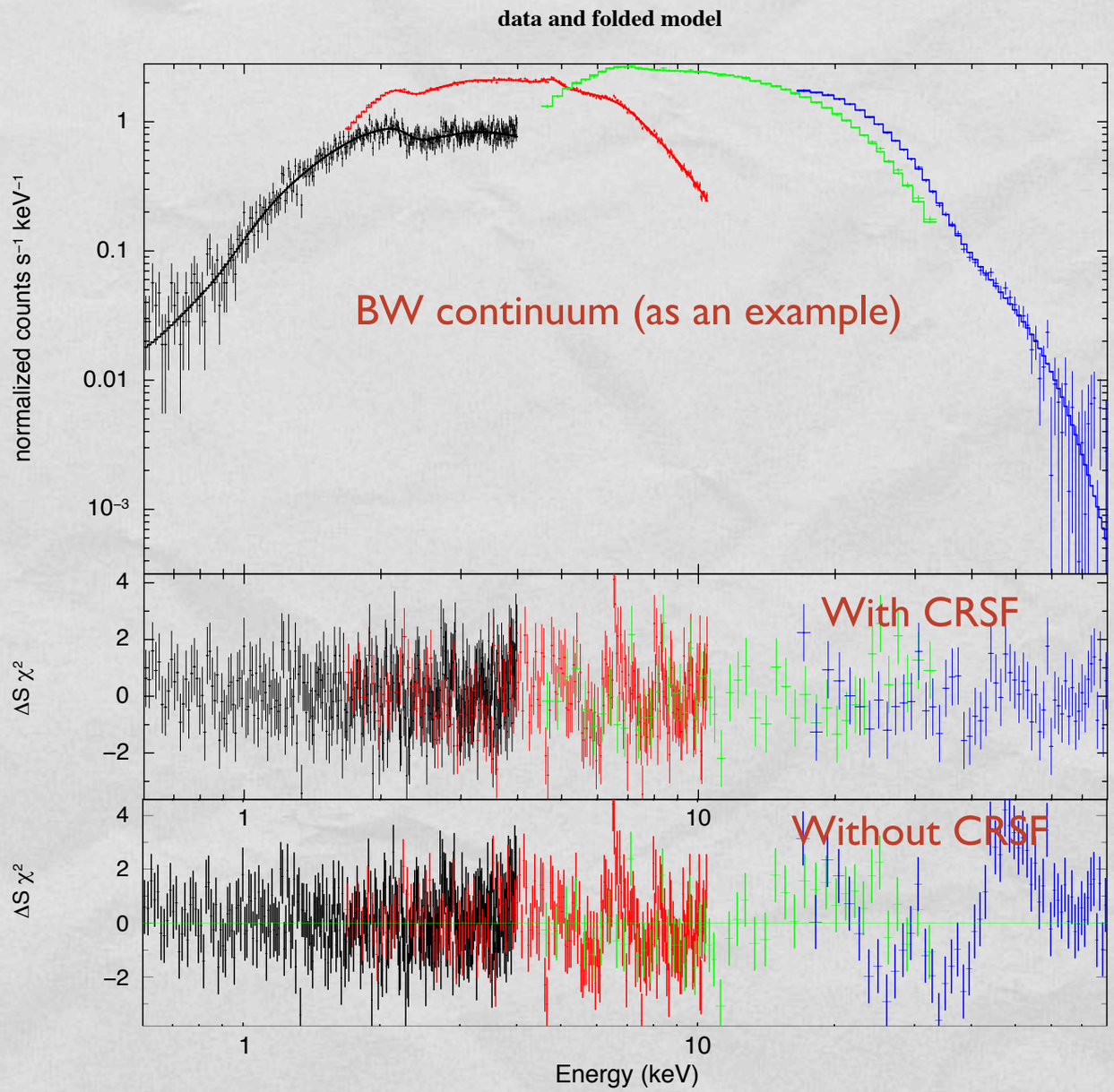
MODEL OF ACCRETION COLUMN BY BECKER AND WOLFF (2007)

* For BW model additional assumptions must be made. As an initial approximation we assumed:

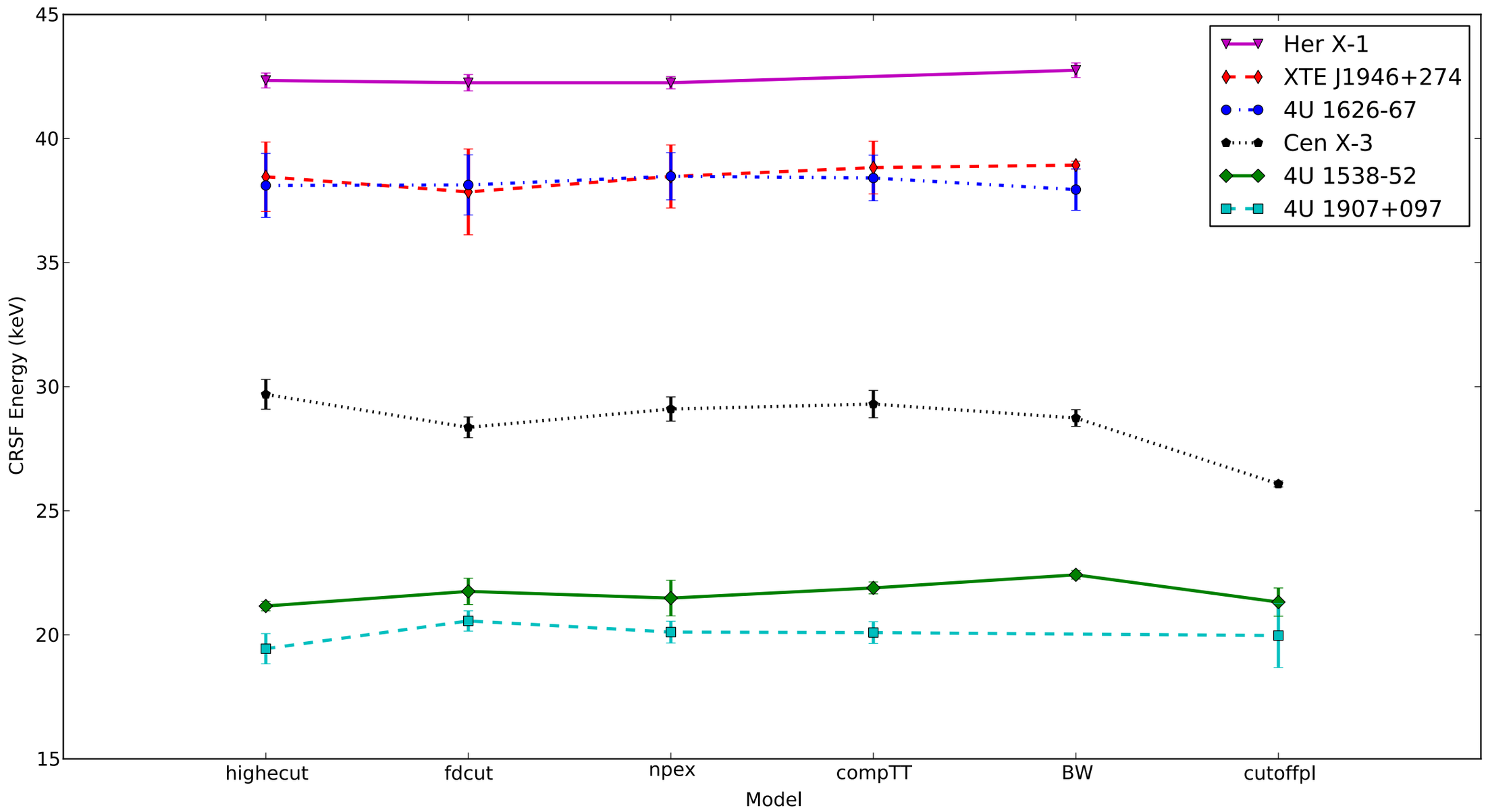
- the magnetic field strenght **B** from cyclotron line energy in «highecut» model in XSPEC;
- the accretion rate $\mathbf{M_{dot}}$ (using flux obtained from «highecut» model and assuming conversion factor of $Lx \sim 0.1 * Mdot * c^2$);
- the column radius $\mathbf{r_0}(B, M_{dot})$ as $r_0 \leq R_* (R_*/r_A)^{1/2}$;

* The model works well for 2 and quite well for 3 sources.

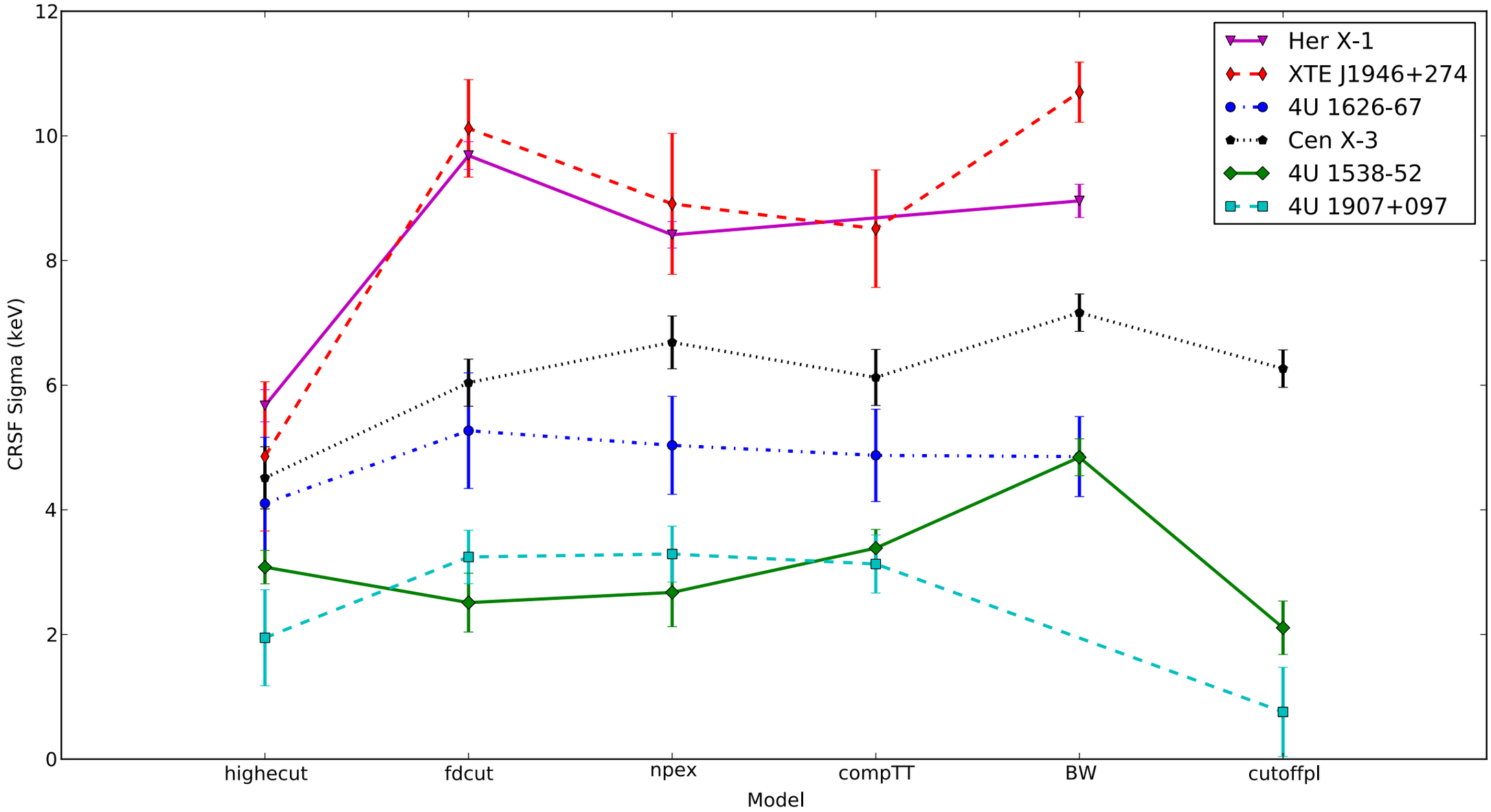
XTE J1946+274



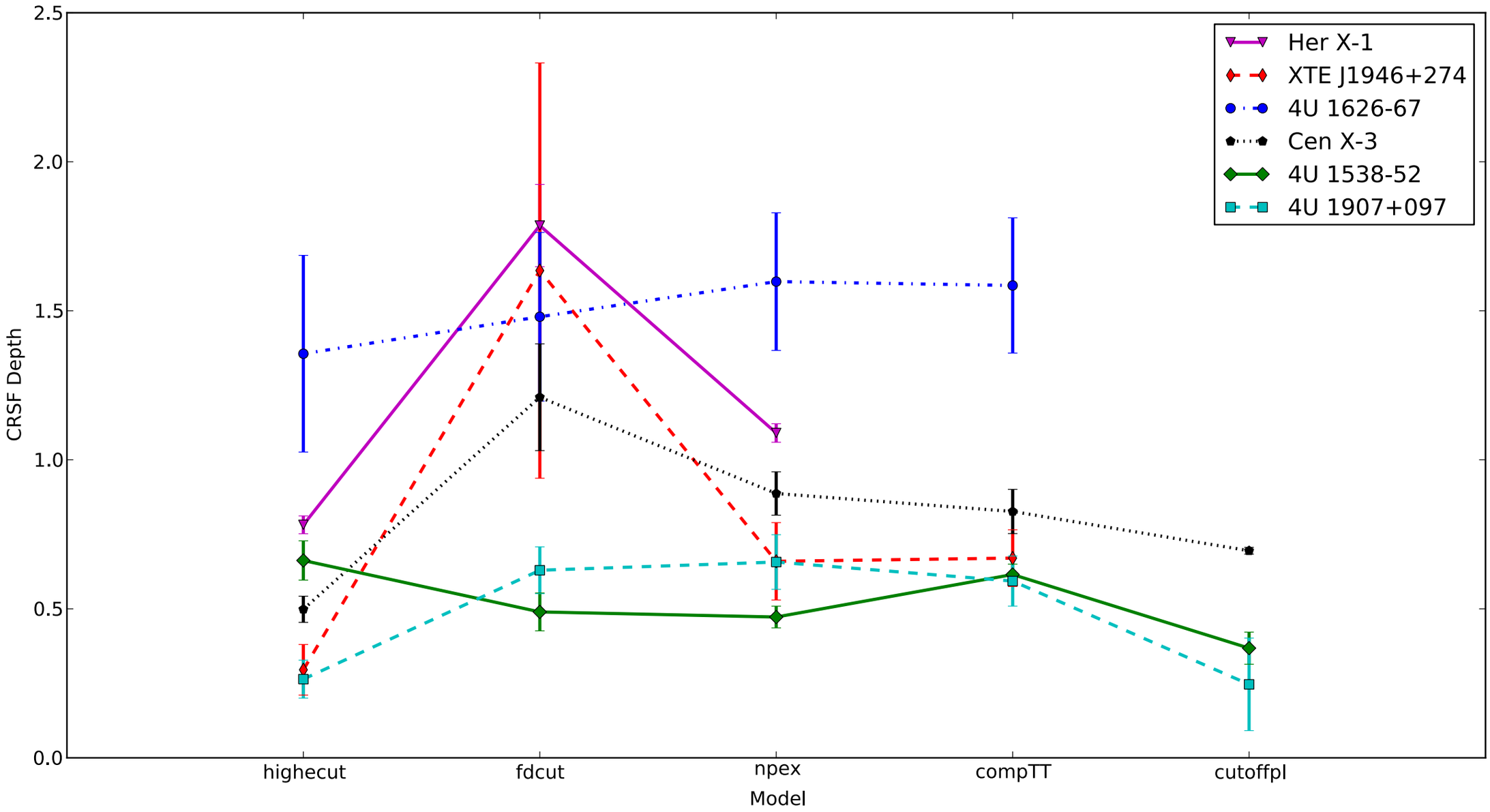
MODEL-ECYC


45
40
35
30
25
20
15
CRSF Energy (keV)
highecut
fdcut
npex
compTT
BW
cutoffpl
Model
Her X-1
XTE J1946+274
4U 1626-67
Cen X-3
4U 1538-52
4U 1907+097

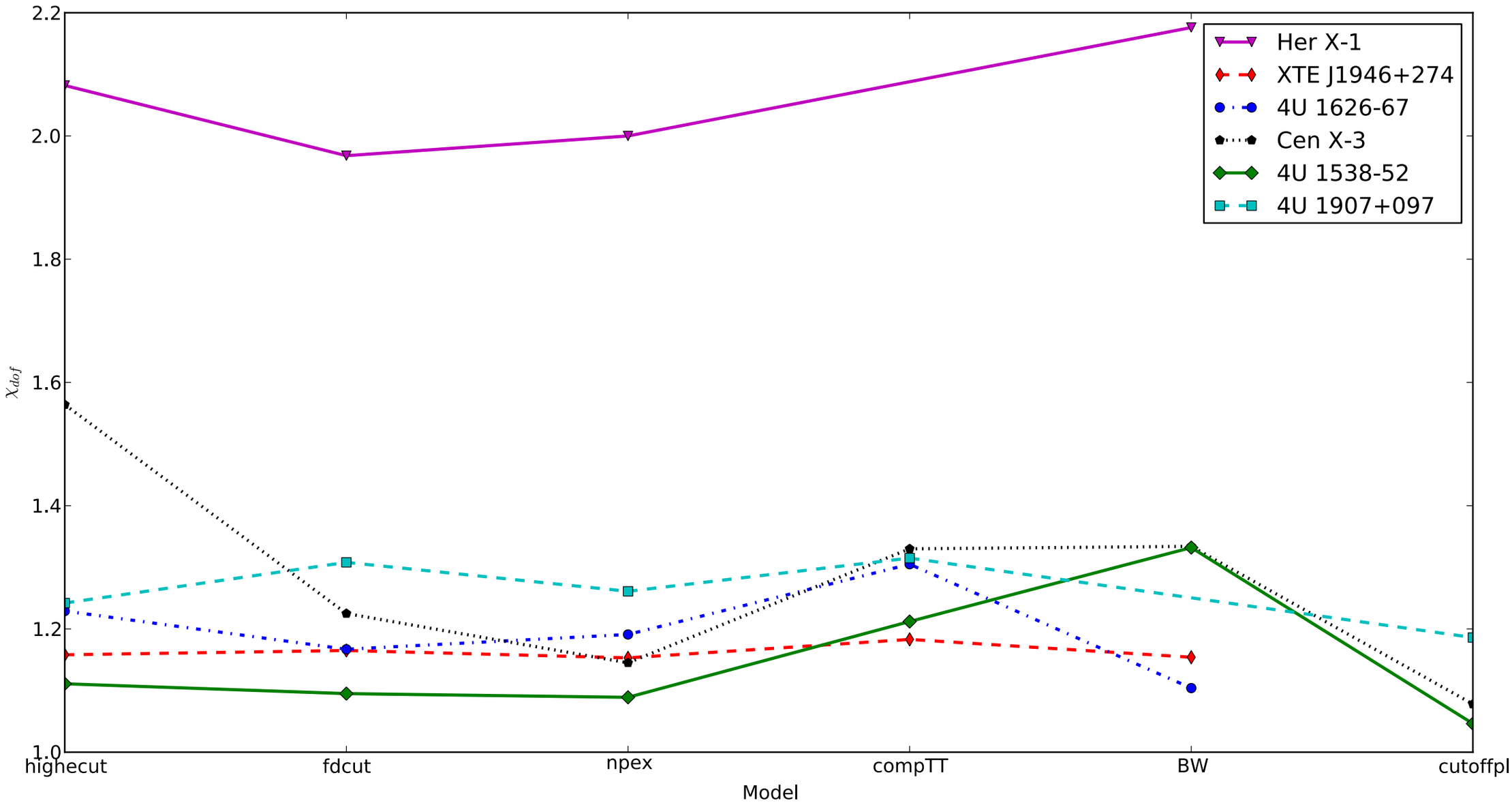
MODEL-σ_{CYC}



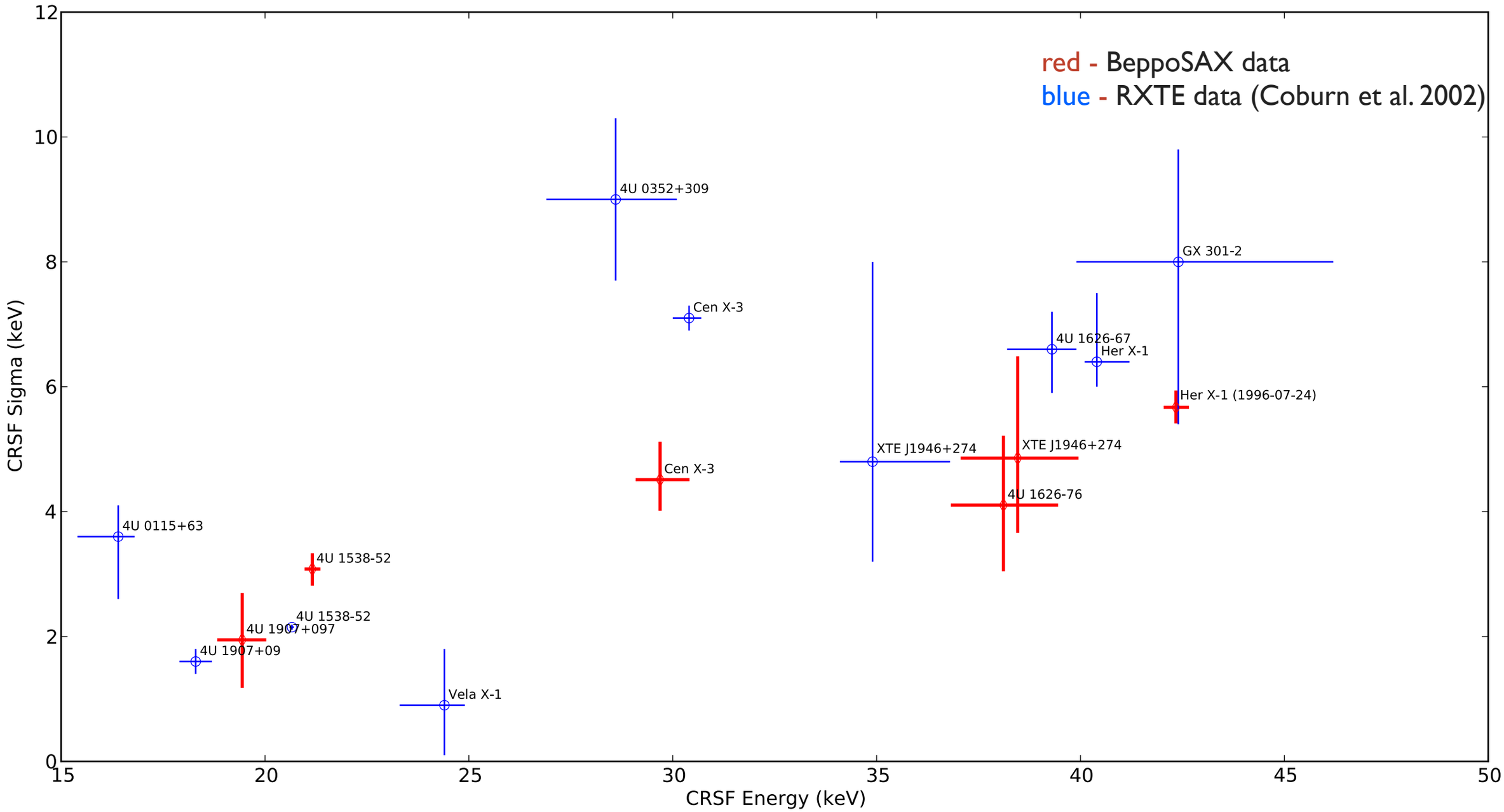
MODEL-DEPTH$_{CYC}$



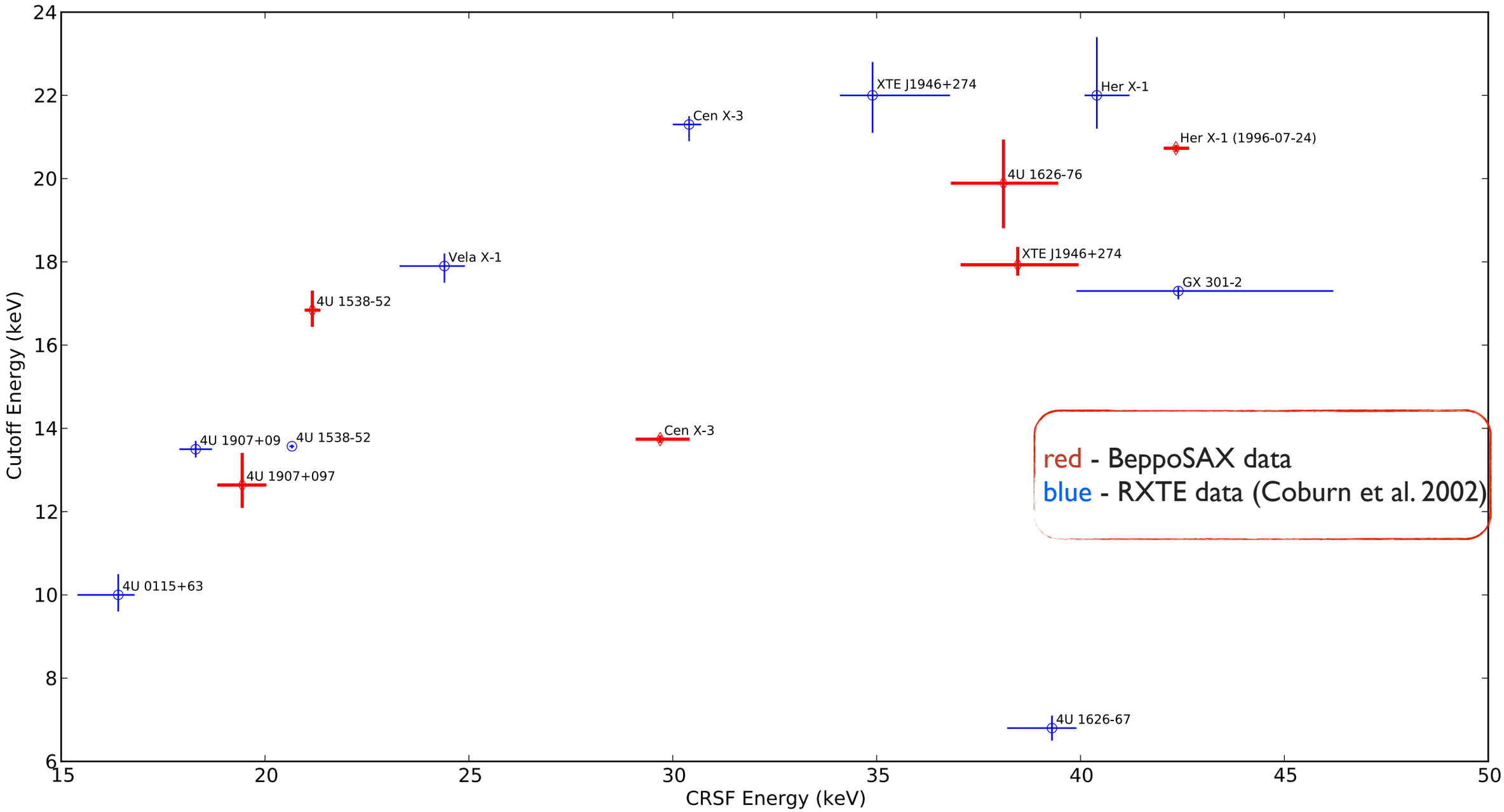
MODEL-χ_{dof}



$E_{cyc} - \sigma_{cyc}$



E_{cyc}-E_{cut}


Cutoff Energy (keV)
CRSF Energy (keV)
Cen X-3
XTE J1946+274
Her X-1
Her X-1 (1996-07-24)
4U 1626-76
Vela X-1
4U 1538-52
XTE J1946+274
GX 301-2
4U 1907+09
4U 1538-52
Cen X-3
4U 1907+097
4U 0115+63
4U 1626-67
red - BeppoSAX data
blue - RXTE data (Coburn et al. 2002)

CONCLUSION

- Presented the results of the spectral analysis of 6 pulsars observed by BeppoSAX.
- Our results show that currently the most universal continuum model is the power law with exponential cutoff.
- In most cases the spectrum can also be approximated by a comptonisation model.
- It is not always possible to describe the spectrum with the physical model of accretion column (Becker & Wolff, 2007) and meaningful model parameters.