Further work on cross-calibration results obtained from observations of the INS RX J1856, and the WDs HZ 43 and Sirius B

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Overview

- Paper on this topic published in 2006 A&A 458, 541

- Absolute Calibration Soft X-rays

  → dependant on model spectra of WDs

  what models to use?, uncertainties?

- Analyse LETG + HRC-S data HZ 43A, Sirius B and RX J1856.5-3754

  → determine spectral parameters

  → improve effective area.

- Compare obtained photon spectra with EUVE and ROSAT

  and XMM (work together with Frank Haberl)

The Paper published: 2006 A&A 458, 541

Establishing HZ43 A, Sirius B, and RX J185635-3754 as soft X-ray standards: a cross-calibration between the Chandra LETG+HRC-S, the EUVE spectrometer, and the ROSAT PSPC

K. Beuermann, V. Burwitz and T. Rauch

Context. The absolute calibration of space-borne instruments in the soft X-ray regime rests strongly on model spectra of hot white dwarfs.

Aims. We analyze the *Chandra* LETG+HRC observations of the white dwarfs HZ43 A and Sirius B and of the neutron star RX J185635−3754 with the aim of resolving current uncertainties in the soft X-ray spectral fluxes and photospheric parameters of the three stars. We apply the derived photon spectra to a cross-calibration of the LETG+HRC-S with the short-wavelength *EUVE* spectrometer and the *ROSAT* PSPC.

Methods. We tie HZ43 A to the flux of RX J1856 in the 44–48Å range and perform a simultaneous least squares fit to the LETG+HRC spectra of the three stars. This allows us to determine an internally consistent set of spectral energy distributions and an empirically derived wavelength-dependent correction to the LETG+HRC-S effective area. We employ NLTE model atmospheres calculated with *TMAP* for the white dwarfs and a two-blackbody model for RX J1856, tied to the respective optical fluxes.

NLTE pure H model spectrum of HZ43

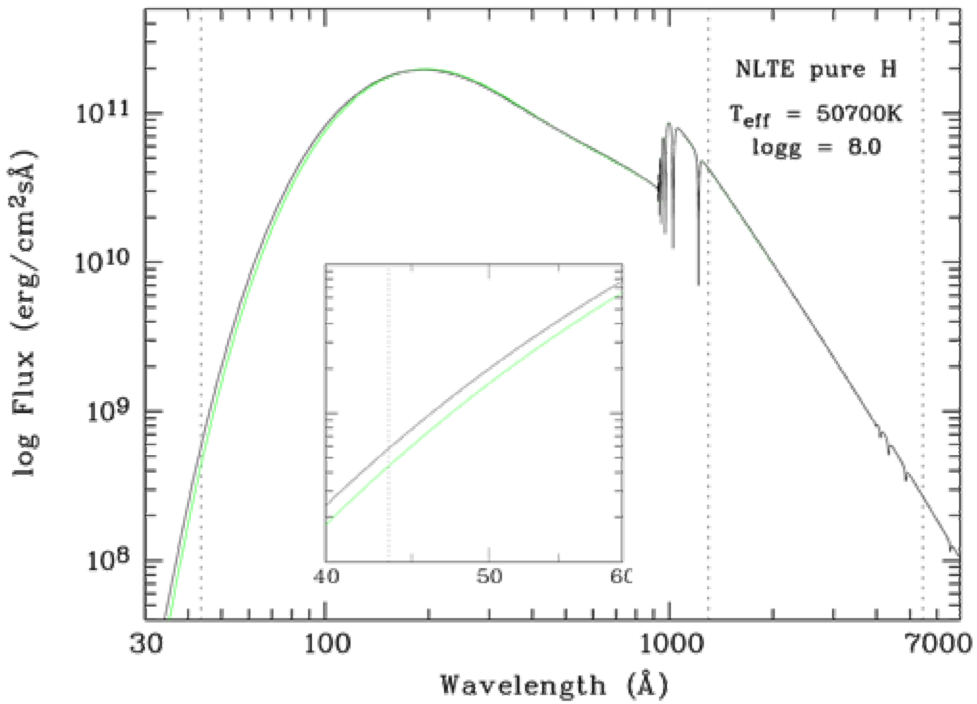


Fig. 2. NLTE pure hydrogen spectra for T_{eff}=50700 K and log g=8.0, calculated with TMAP using two versions of the bound-free and free-free absorption coefficients, Seaton's approximation (dashed curve) and the full Karszas & Latter (1961) description (solid curve). Both models yield practically identical results at optical/ultraviolet wavelengths, but differ by a factor of 1.33 at 44Å (vertical dotted line). The insert shows an expanded view. Two further dotted lines mark λ = 1300Å and λ = 5450Å

HZ43 temperature vs. gravity

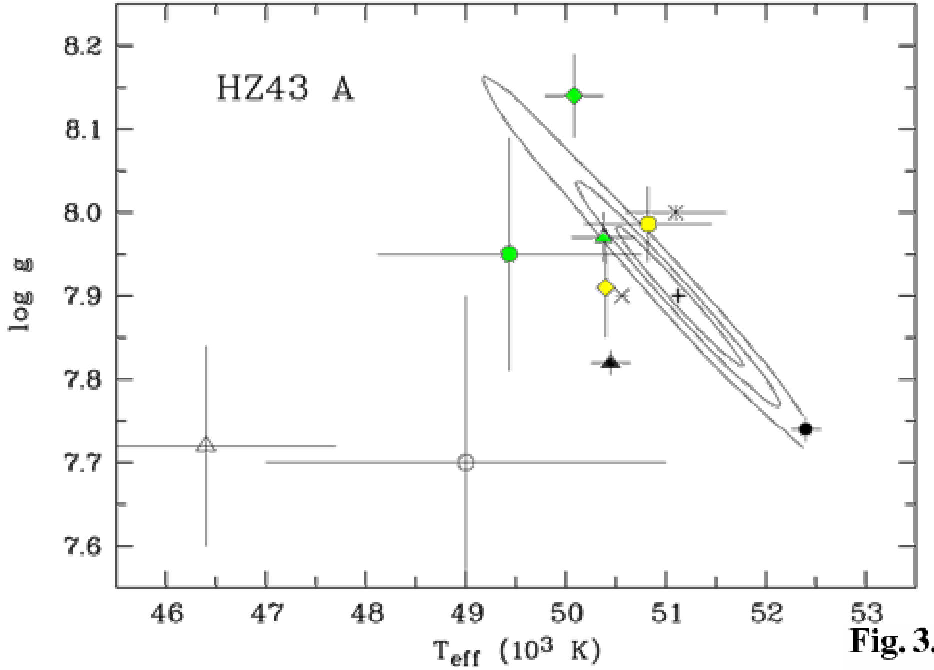
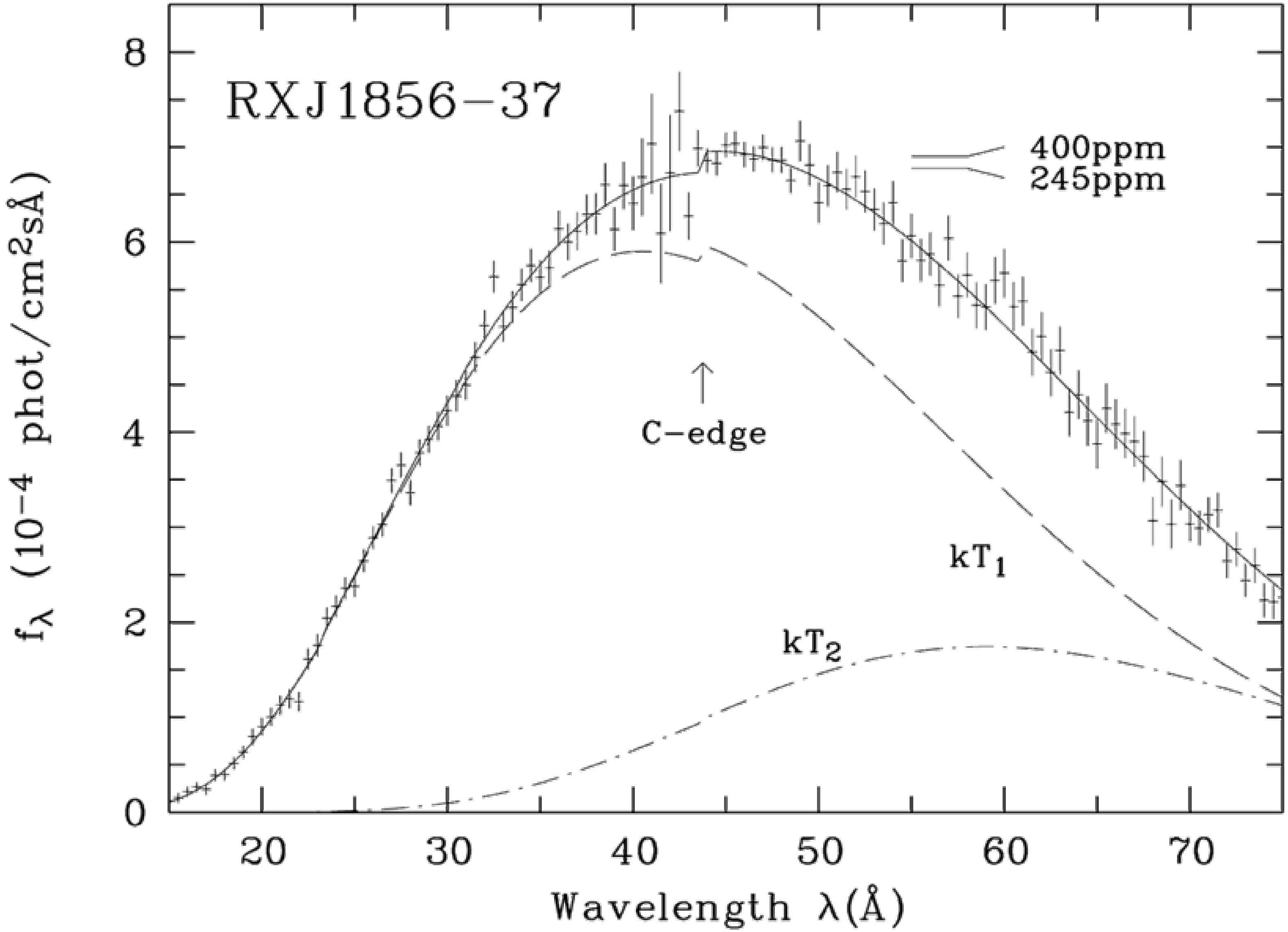


Fig. 3. Summary of $T_{\rm eff}$–$\log g$ determinations for HZ43 A from fits to the Balmer lines (circles) and the Lyman lines (triangles and rhombs): Napiwotzki et al. (1993) (Balmer, open circle); Finley et al. (1997) (Balmer, light gray filled circle); Barstow et al. (2003) (Balmer, gray filled circle); this work (STIS Balmer lines, black solid circle); Barstow et al. (2001) (*ORFEUS*, gray lozenge; HUT, open circle); Dupuis et al. (1998) (*ORFEUS*, light gray rhomb); Barstow et al. (2003) (*FUSE* Lyman, gray filled circle); this work (*FUSE* Lyman, black solid triangle); Barstow et al. (1995) (*EUVE* continuum, ×); and Vennes & Dupuis (2002) (*EUVE* continuum, asterisk). The error ellipses indicate the results of the present fits to the *Chandra* soft X-ray continuum and refer to the 68%, 90% and 95% confidence levels.

RX J1856-37 two temperature bb fit



RX J1856-37 two temperature bb fit

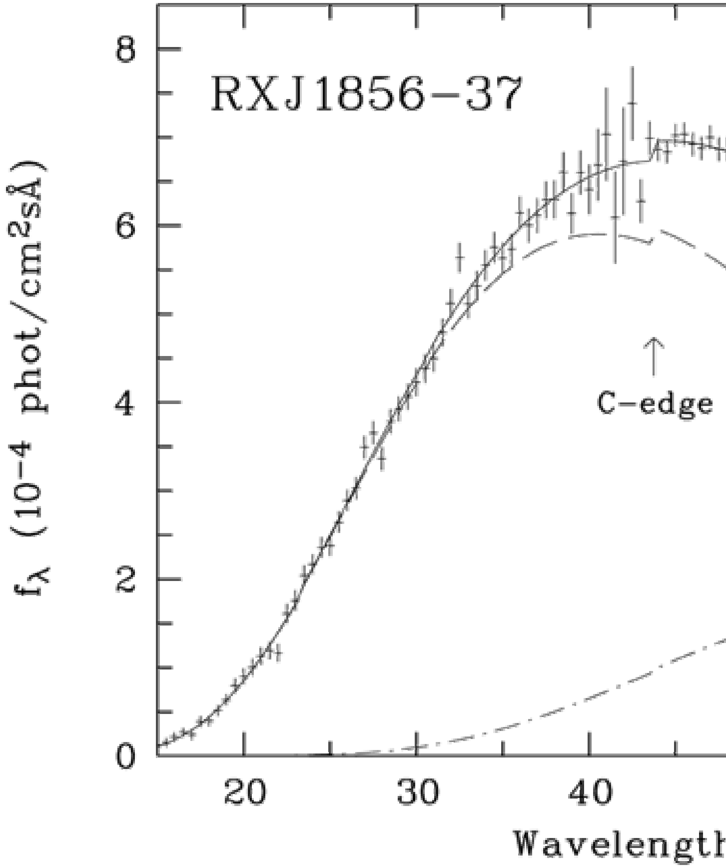
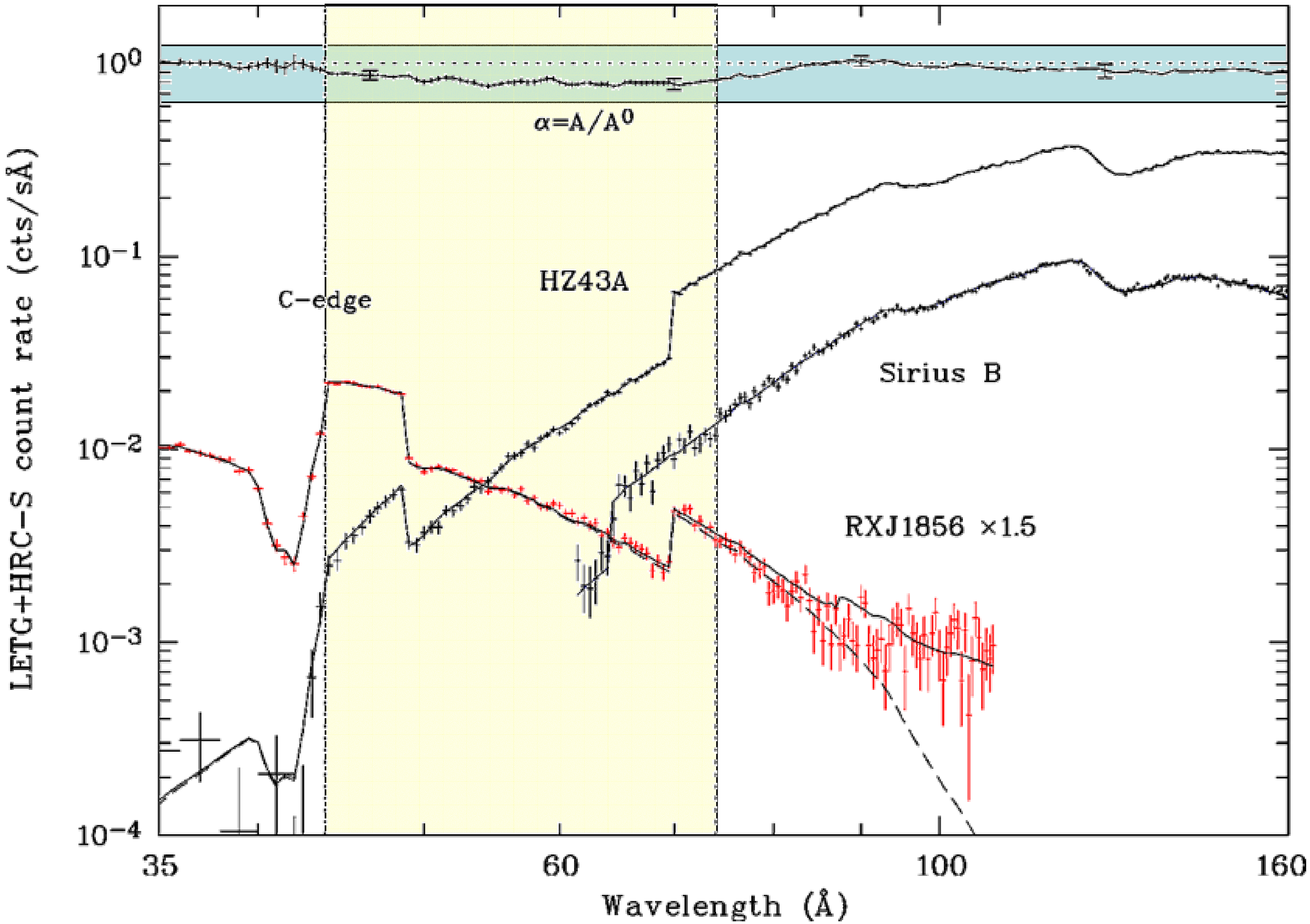


Fig. 4. *Chandra* LETG+HRC spectrum of RX J1856 binned to 0.5Å, derived with the effective area at wavelengths longwards of the carbon edge corrected to fit an abundance of carbon in the interstellar medium of $a(C) = 245 - 400$ ppm with 60% in dust grains. The two-temperature fit shown is for 320 ppm, with the upper level of the step indicated for 245 and 400 ppm, too. The fit has a $\chi^2 = 97.7$ for 115 dof (see Sect. 4.5). The model parameters are quoted in Table 2.

Simultaneous fit to RXJ1856 and the WDs



Parameters obtained from fit

Parameter	Value±Error
(a) *HZ43 A* ($\lambda = 45 - 160\,\AA$)	
$T_{\rm eff}$ (K)	51126 ± 660
$\log g$	7.90 ± 0.08
R^2/d^2 (10^{-23})	3.011 ± 0.010
$N_{\rm HI}$ $(10^{17}\ {\rm cm}^{-2})$	8.91 ± 0.37
(b) *Sirius B* ($\lambda = 74 - 160\,\AA$)	
$T_{\rm eff}$ (K)	24923 ± 115
$\log g$	8.6 *f* [1]
R^2/d^2 (10^{-21})	4.877 ± 0.010
$N_{\rm HI}$ $(10^{17}\ {\rm cm}^{-2})$	6.5 ± 2.0 [2]
(c) *RX J1856* ($\lambda = 15 - 74\,\AA$)	
$kT_{\rm spot}$ (eV)	62.83 ± 0.41
$kT_{\rm star}$ (eV)	32.26 ± 0.72
R_1/d (km/pc)	0.0378 ± 0.0003
R_2/d (km/pc)	0.1371 ± 0.0010
$N_{\rm HI}$ $(10^{20}\ {\rm cm}^{-2})$	1.10 ± 0.03

[1] Based on Barstow et al. (2005); Holberg et al. (1998)
[2] Hébrard et al. (1999). Our fit is required to stay within the 1-σ error.

Table 2. Parameters of HZ43 A, Sirius B, and RX J1856 based on the simultaneous fit of our model spectra to the LETG+HRC count rate spectra in the wavelength intervals given. The quoted 1-σ ($\Delta\chi^2 = +1$) errors are correlated and derived from fits with the other parameters for each object kept free. The letter *f* indicates: fixed.

Comparison of photon spectra

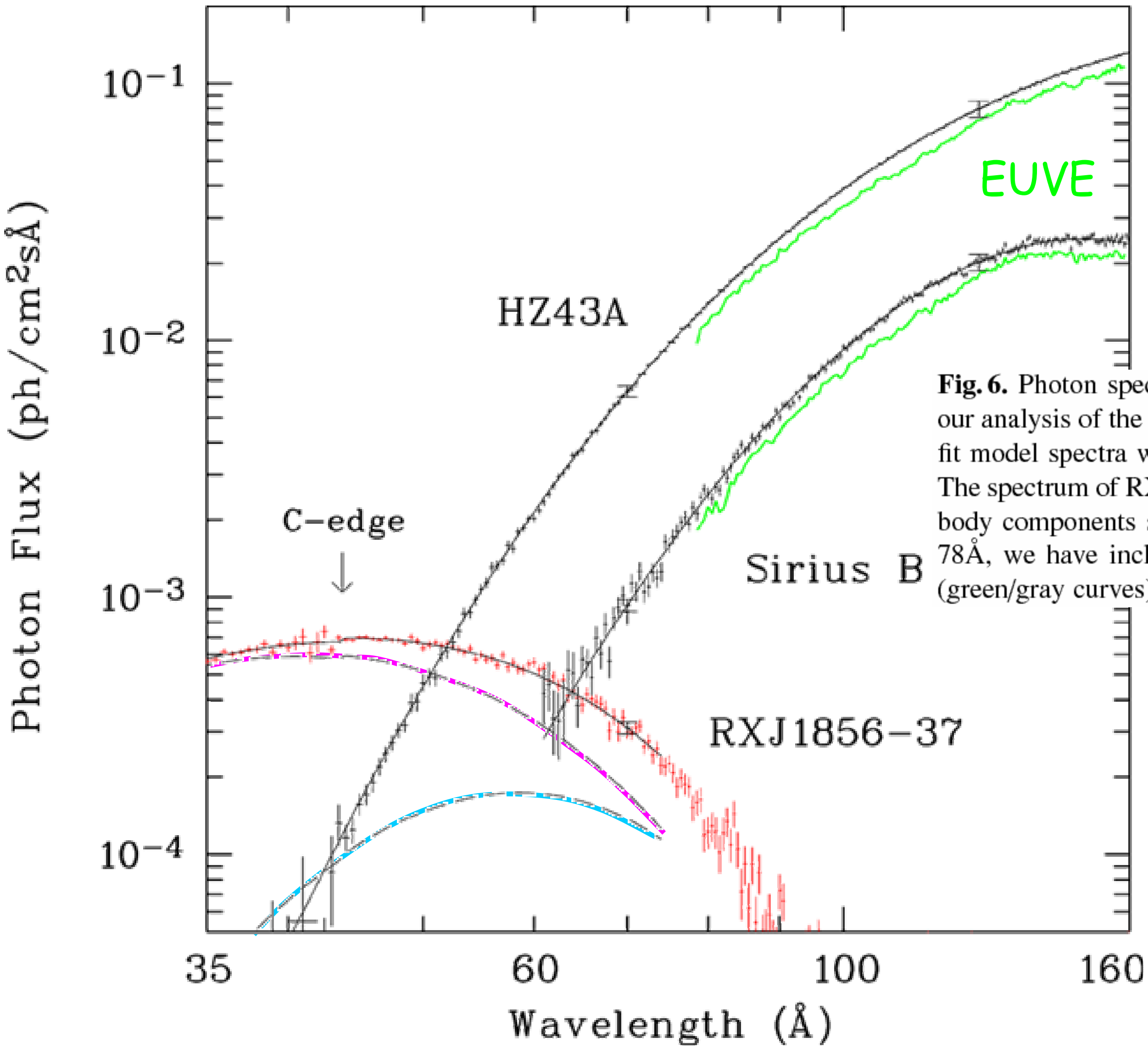
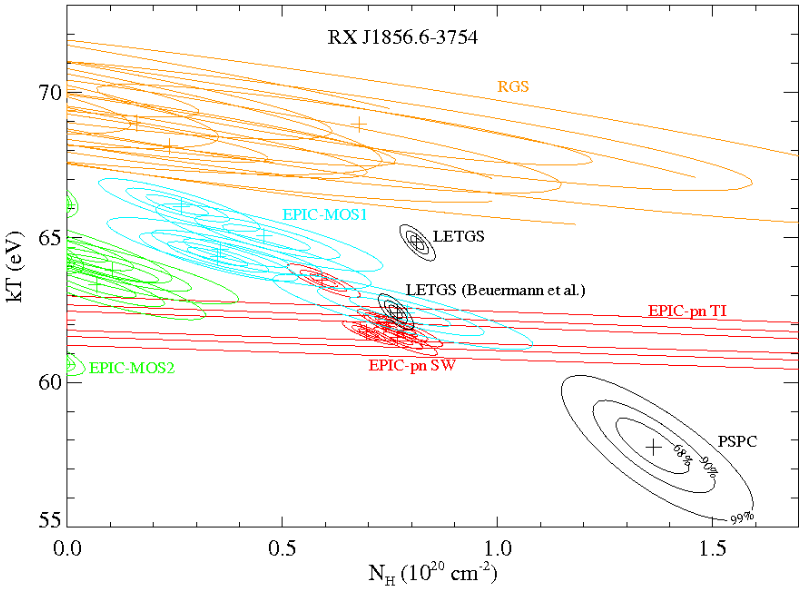
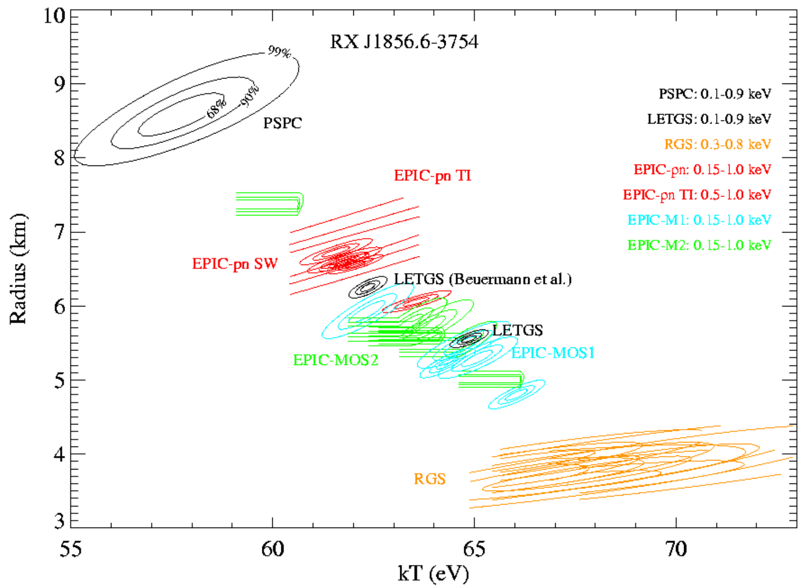


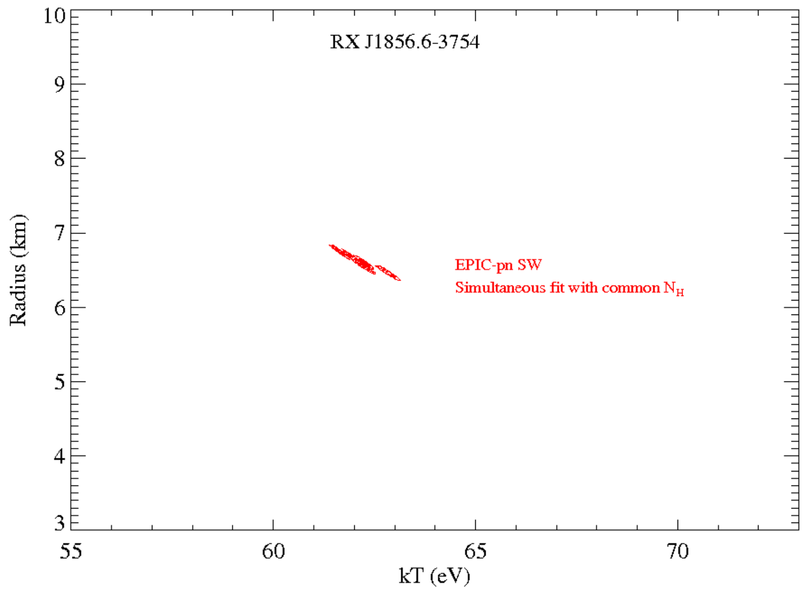
Fig. 6. Photon spectra of RX J1856, HZ43 A, and Sirius B based on our analysis of the LETG+HRC-S observations (data points) and best fit model spectra with parameters as given in Table 2 (solid curves). The spectrum of RX J1856 is the same as in Fig. 4 with the two black-body components shown separately as dashed curves. Longwards of 78Å, we have included the *EUVE* spectra of the two white dwarfs (green/gray curves).

RX J1856.5-3754: A `stable' neutron star





Individual fits with all parameters free:



Simultaneous fits with N_H linked:

Model:
tbabs*bbody

from Frank Haberl

Summary

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Results. The two-blackbody model for RX J1856 features a hot spot on a cooler star and yields $kT_{spot} = 62.8 \pm 0.4$ eV and $kT_{star} = 32.3 \pm 0.7$ eV with a stellar radius as seen from infinity of 16.0 ± 0.1 km for a distance of 117 pc. For HZ43 A, our fit yields T_{eff}=51126±660 K and log g=7.90±0.080 (cgs) with anti-correlated errors (1-σ) which include not only the statistical but also the systematic uncertainties of the fit. HZ43AB displays a previously detected bremsstrahlung component with a temperature $kT \simeq 0.6$ keV. For Sirius B, we find T_{eff}=24923±115 K for fixed log g=8.6. The calibration of the short-wavelength *EUVE* spectrometer differs from that of the LETG+HRC-S by 15 ± 7%. The *ROSAT* PSPC is found to be correctly calibrated within a few percent and reports of a major miscalibration are unfounded.

Conclusions. We have obtained improved parameters for RX J185635−3754, HZ43 A, and Sirius B which fit the observations from the optical to the soft X-ray regime. Our approach allows us to quote their absolute spectral fluxes at selected wavelengths which may aid the calibration of other space-borne instruments.