EBERHARD KARLS UNIVERSITÄT TÜBINGEN

Faculty of Science
Institute for Astronomy and Astrophysics

Universität Tübingen · Faculty of Science
Institute for Astronomy and Astrophysics
Sand 1 · 72076/Tübingen · Germany
Email: sulei manov@astro.uni-tuebingen.de

Model atmospheres as a tool for high resolution soft X-ray spectra interpretation

V. F. Suleimanov, A. Tavleev, K. Werner

Institut für Astronomie und Astrophysik, Kepler Center for Astro and Particle Physics, Universität Tübingen, Sand 1, 72076 Tübingen, Germany

We present new sets of LTE model atmospheres of hot white dwarfs (WDs) computed for solar chemical composition, and for chemical compositions corresponding to the LMC and SMC. The model spectra were used for fitting Chandra and XMM-Newton grating spectra of the classical super-soft sources (SSSs) CAL 83 and RX J0513.9-6951 (RX J0513) in the Large Magellanic Cloud. The obtained parameters of CAL 83 ($T_{\rm eff} \approx$ 530-560 kK, $\log g \approx$ 8.5 - 8.7, $M_{\rm WD} \approx 1.1 - 1.4 M_\odot$) are very close to the parameters obtained using non-LTE model atmospheres. RX J0513 demonstrates an evolution in accordance with a model track in the $T_{\rm eff} - \log g$ plane, corresponding to thermonuclear burning on the surface of a WD with $M_{\rm WD} \approx 1.1\, M_\odot$. We find that RX J0513 becomes optically faint with increasing luminosity and WD photospheric radius and suggest a model for explaining this fact.

1 Model spectra

We present (see also Suleimanov et al., 2024) new sets of model spectra of hot white dwarfs (WDs). The models were computed for $T_{\rm eff}$ from 100 kK to 1 MK with a step 25 kK, eight values of $\log g$ and three chemical compositions, solar ($A = 1$) and metallicity reduced by factors of two ($A = 0.5$) and ten ($A = 0.1$). The models are freely available[1]. A model spectrum example is presented in Fig 1.

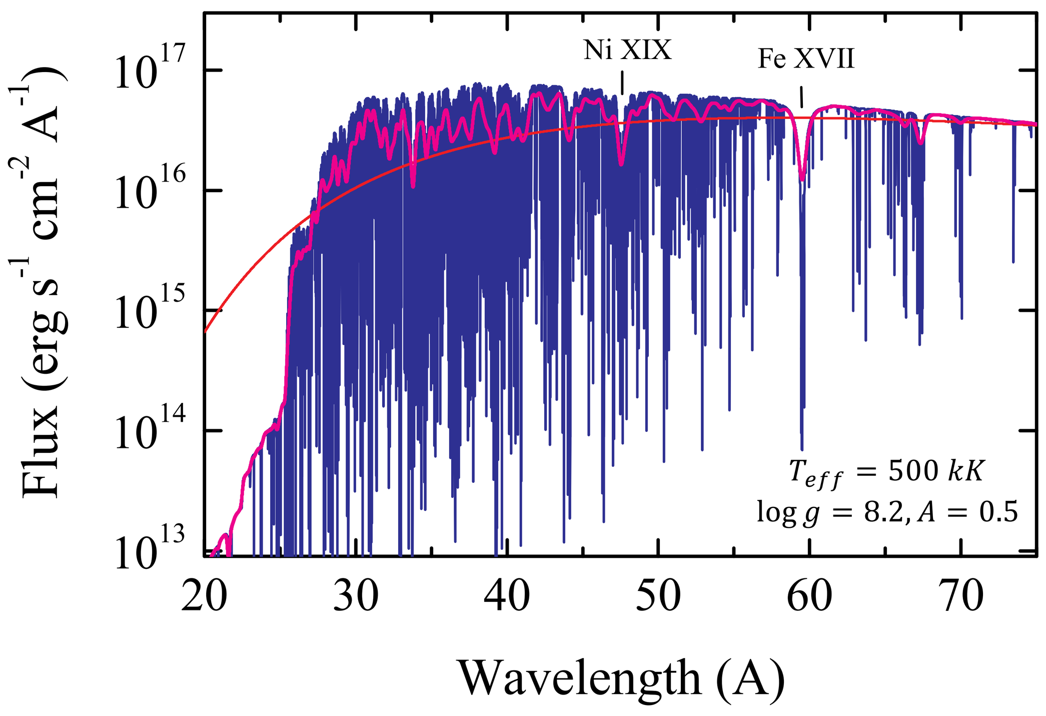

Figure 1: *Original model spectrum (blue) and model convolved with the Chandra resolution (magenta) together with blackbody (red).*

2 CAL 83

The model grid was tested using the grating *Chandra* and XMM observations of SSS CAL 83 in the LMC (see Fig. 2). The obtained WD parameters are close to values obtained before using non-LTE model atmospheres (Lanz et al., 2005, non-LTE values in brackets in Fig. 2).

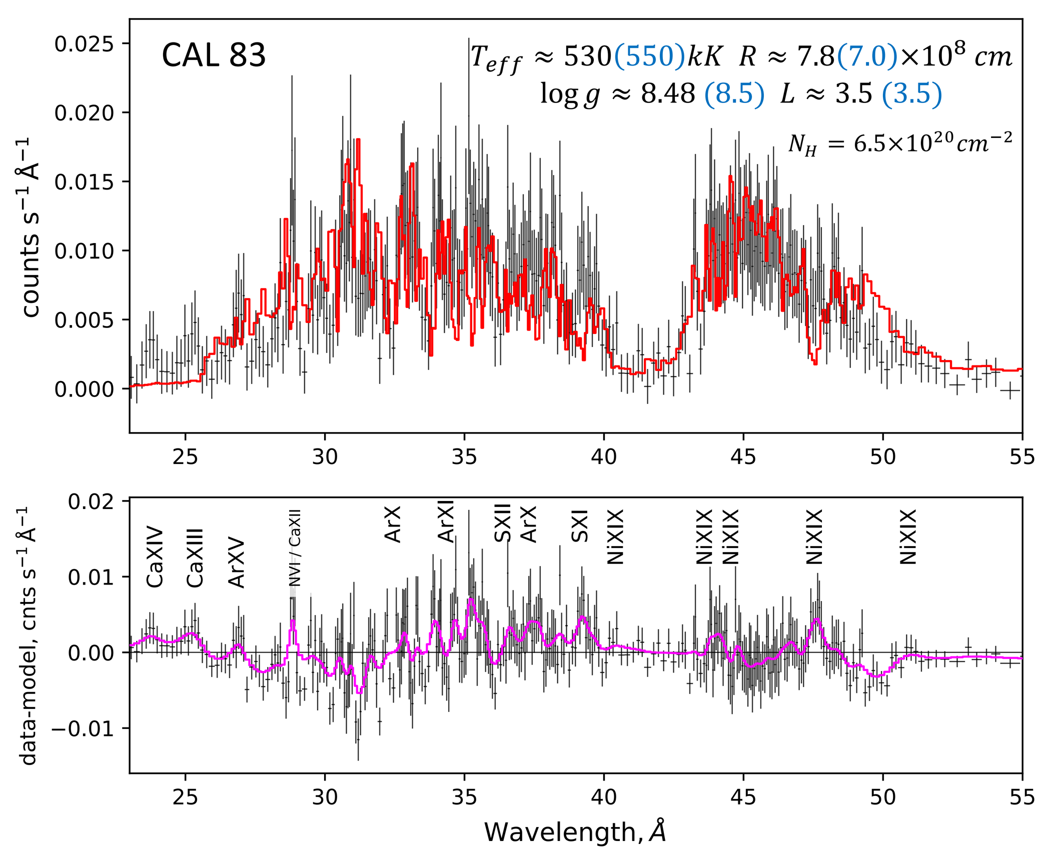

Figure 2: *Best fit (red) of CAL 83 spectrum (black). The possible emission lines are indicated in the residual spectrum (bottom). L in 10^{37} erg s^{-1} units. $N_{\rm H}$ is fixed.*

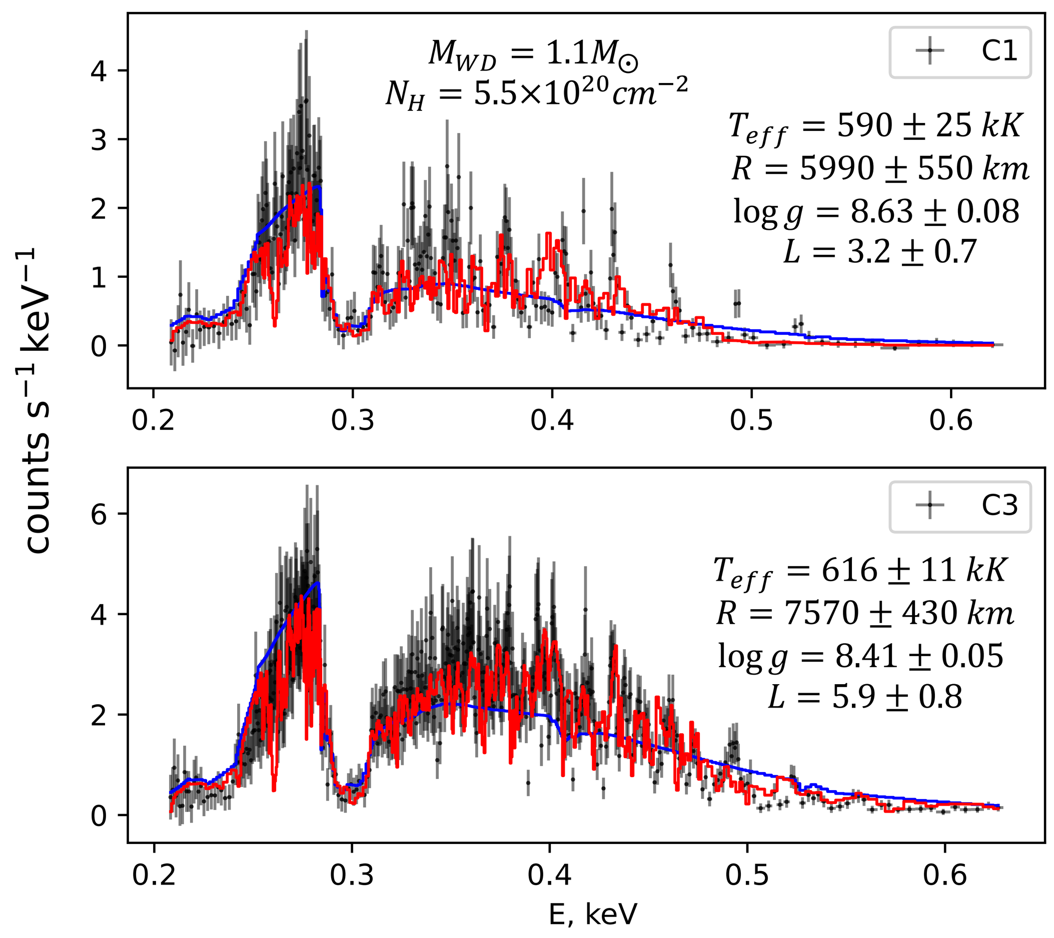

Figure 3: *Two Chandra spectra of RXJ0513 with the best-fit LTE models (in red) and best-fit blackbody models (in blue). L in 10^{37} erg s^{-1} units.*

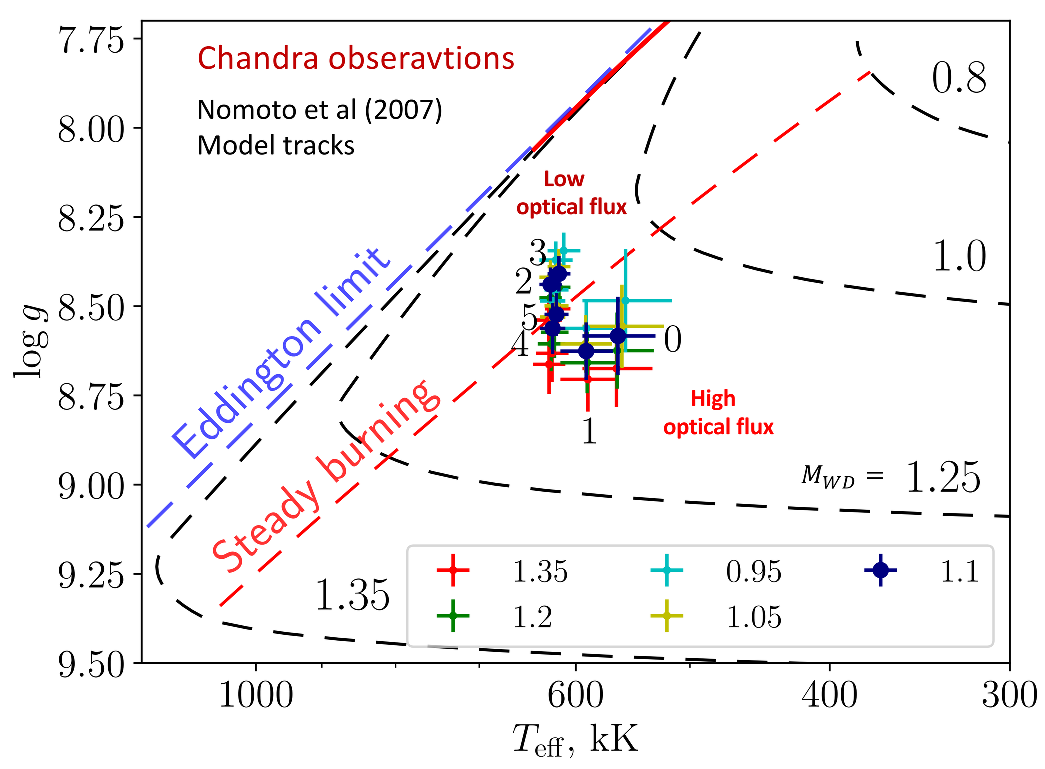

Figure 4: *Positions of the source (for different fixed $M_{\rm WD}$) in the $T_{\rm eff} - \log g$ plane at the different observations.*

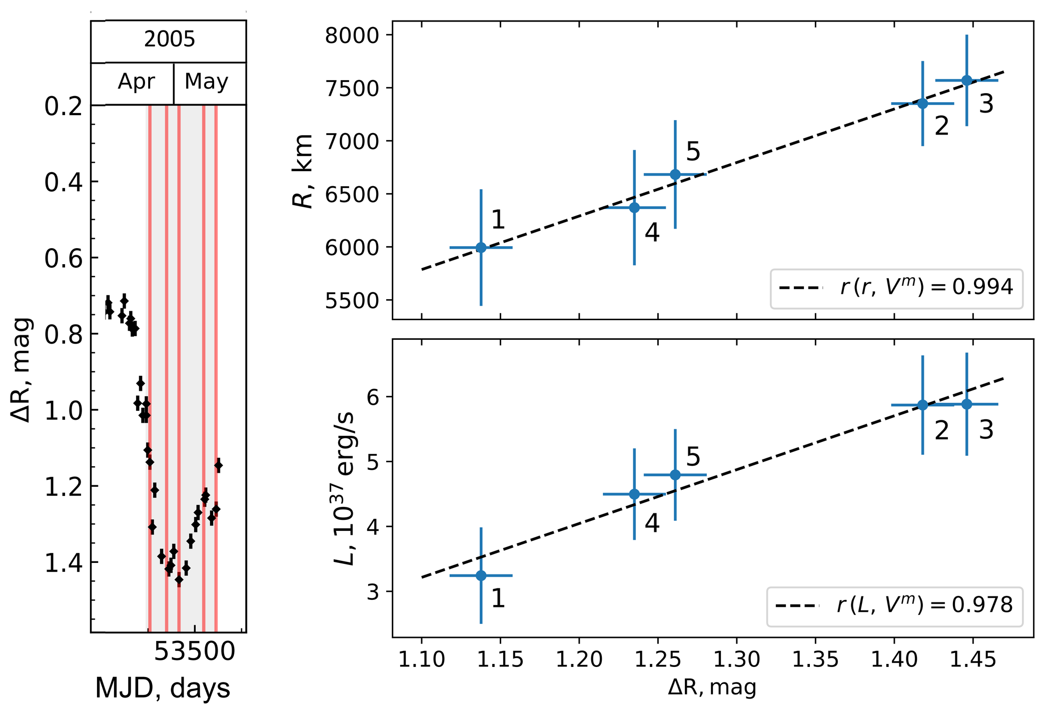

Figure 5: *Left: Dates of X-ray observation vs. optical brightness. Right: Radius of WD photosphere and its bolometric luminosity increase with decreasing optical brightness.*

3 RX J0513.9-6951

We present analyses of five archival grating *Chandra* spectra of this SSS. We fitted them by our model spectra (Fig. 3) and found that it evolves along a model track for a WD with $M \approx 1.1\, M_\odot$ (Fig. 4). The states with larger photospheric radii correspond to fainter optical brightness (Fig. 5). Therefore, increasing the accretion disk irradiation leads to optical luminosity decrease. Assuming that the optical emission arises due to reprocessing during multiple scattering between clouds above the accretion disk (Suleimanov et al., 2003) we conclude that the cloud number density decreases at the increase of irradiation, see Fig. 6 and details in Tavleev et al. 2024.

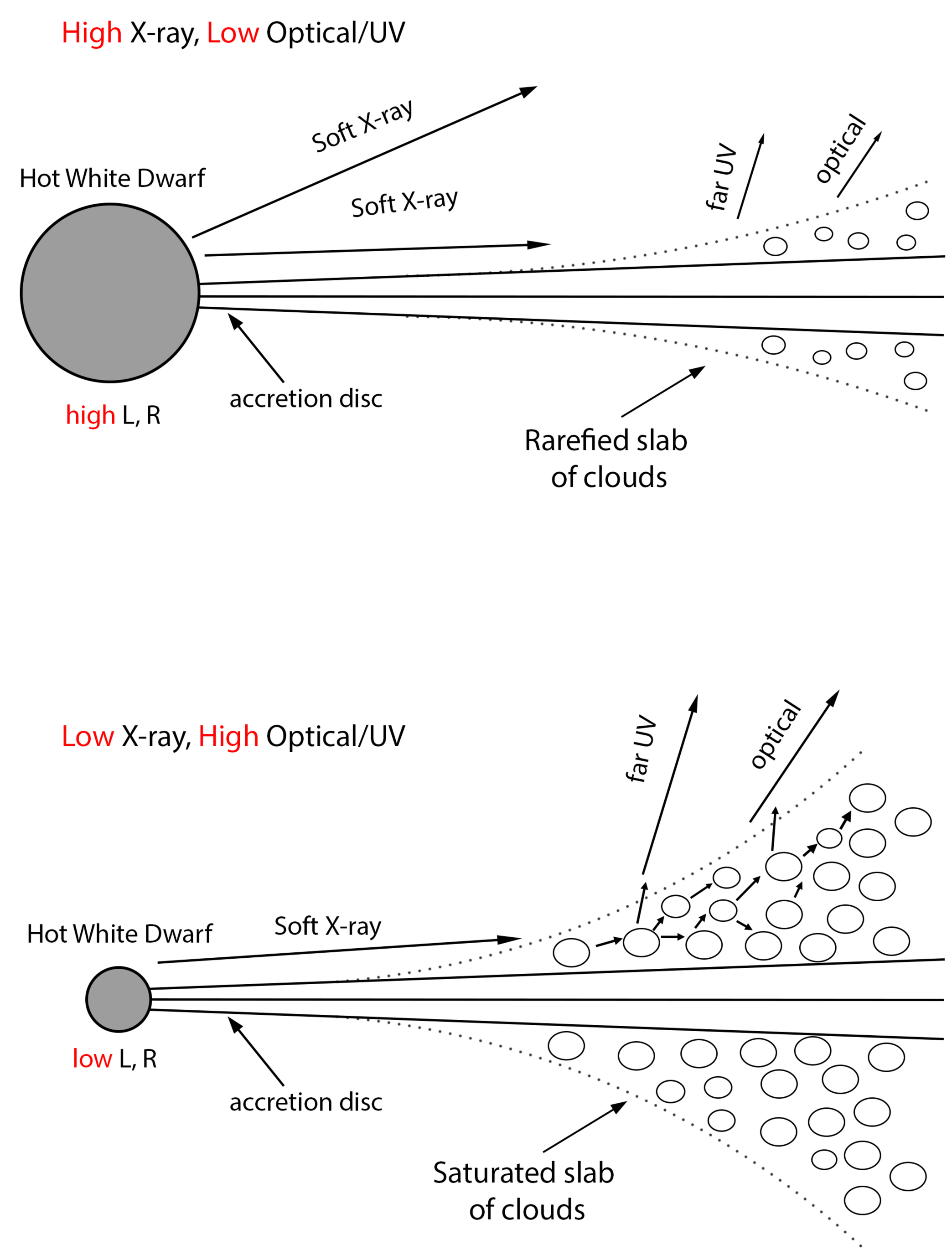

Figure 6: *Qualitative picture of the proposed high and low optical states. Shown are the WD, the accretion disc, and blobs or clouds above the disc.*

Acknowledgements:

VS and AT are supported by the German Research Foundation (DFG-GS, grants WE1312/59-1 and WE1312/56-1).

References

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[1] https://github.com/HEASARC/xspec_localmodels/tree/master/sss_atm