Revealing the X-ray Binary Population of the Starburst Galaxy NGC 253 with *Chandra*

Neven Vulic

N. Vulic (NASA GSFC/UMCP/CRESST), A. E. Hornschemeier (NASA GSFC/JHU), M. Yukita (JHU/NASA GSFC), A. F. Ptak (NASA GSFC/JHU), A. Zezas (Crete/CfA), T. J. Maccarone (Texas Tech), B. D. Lehmer (Arkansas)

Motivation

X-ray binaries (XRBs) are signposts for the remnants of massive stars, revealing accreting neutron star (NS) and black hole (BH) systems. The formation of XRBs (demographics) correlates with the characteristics of their formation sites, and thus, correspondingly, with the properties of their surrounding stellar populations.

Many intriguing XRB discoveries have been associated with extreme starburst environments, where violent star formation processes result in the production of rare objects and events. These include the massive stellar-mass BHs that serve as progenitors to the gravitational wave events detected by LIGO/VIRGO as well as the specific sub-class of the most massive Wolf-Rayet (WR) XRBs, ultraluminous X-ray sources (ULXs, ULX pulsars), magnetars, and gamma-ray bursts. Recent evidence also suggests that XRBs in starburst cores (primordial galaxies) at redshift 10<z<20 contributed to the heating of the early intergalactic medium.

Key Questions

What are the most important conditions and processes governing the growth of stellar-origin compact objects?
What are the progenitor paths for gravitational wave sources?

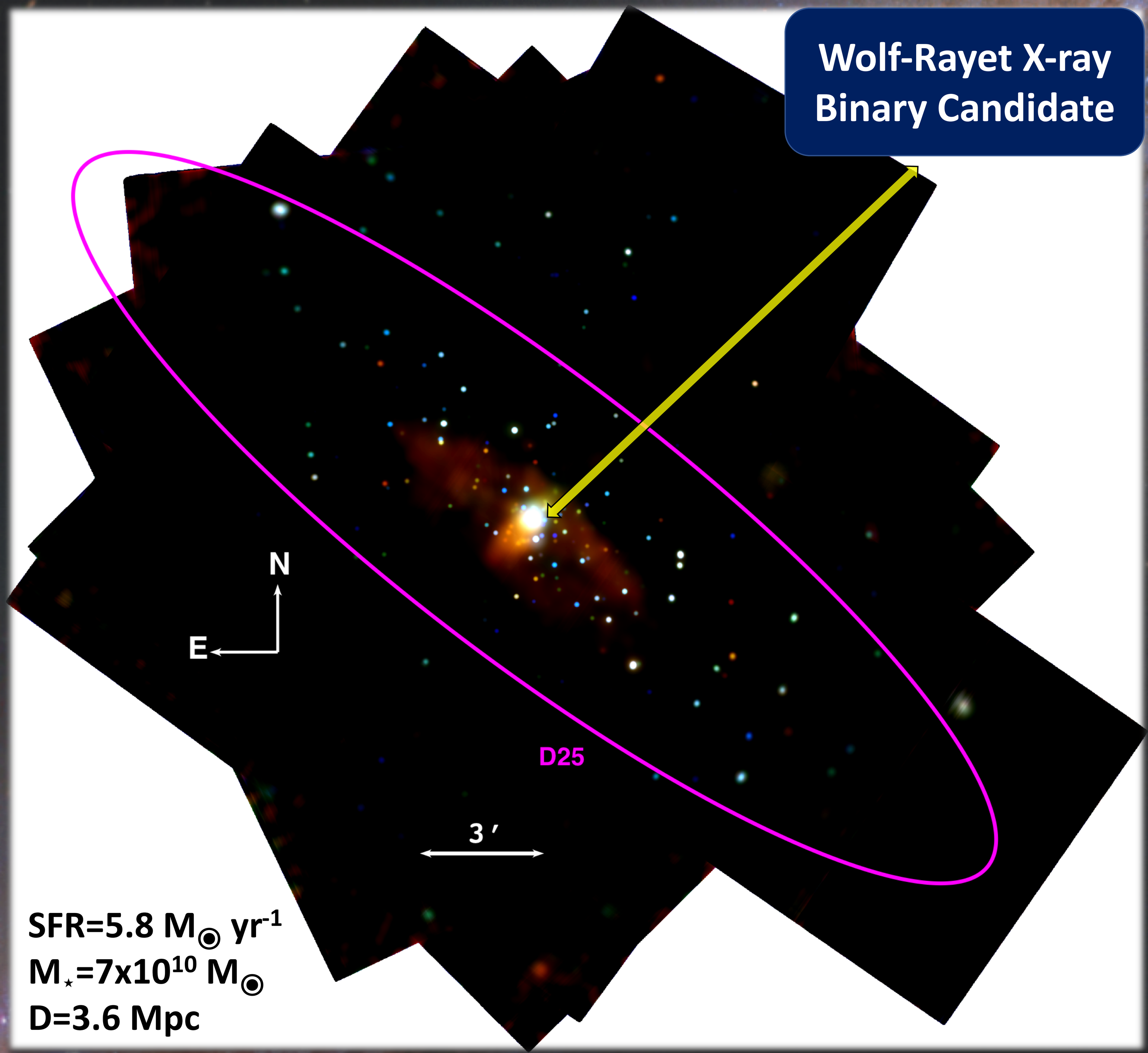

Figure 1. False-color adaptively-smoothed image of merged *Chandra* ACIS observations of NGC 253 totaling 330 ks.

Chandra Campaign

-A continuous 150 ks *Chandra* ACIS-I observation (PI Hornschemeier) completed in 2018 to obtain the orbital period of the candidate WR XRB, estimated to be $\mathbf{P_{orb}}$**=15 hr**.
-Candidate WR XRB source was reported by Maccarone et al. (2014) based on archival Chandra and XMM-Newton observations.
-Persistent but highly variable source, located in the nuclear starburst.
-Only 4 known WR XRBs in the Universe (3 candidates).

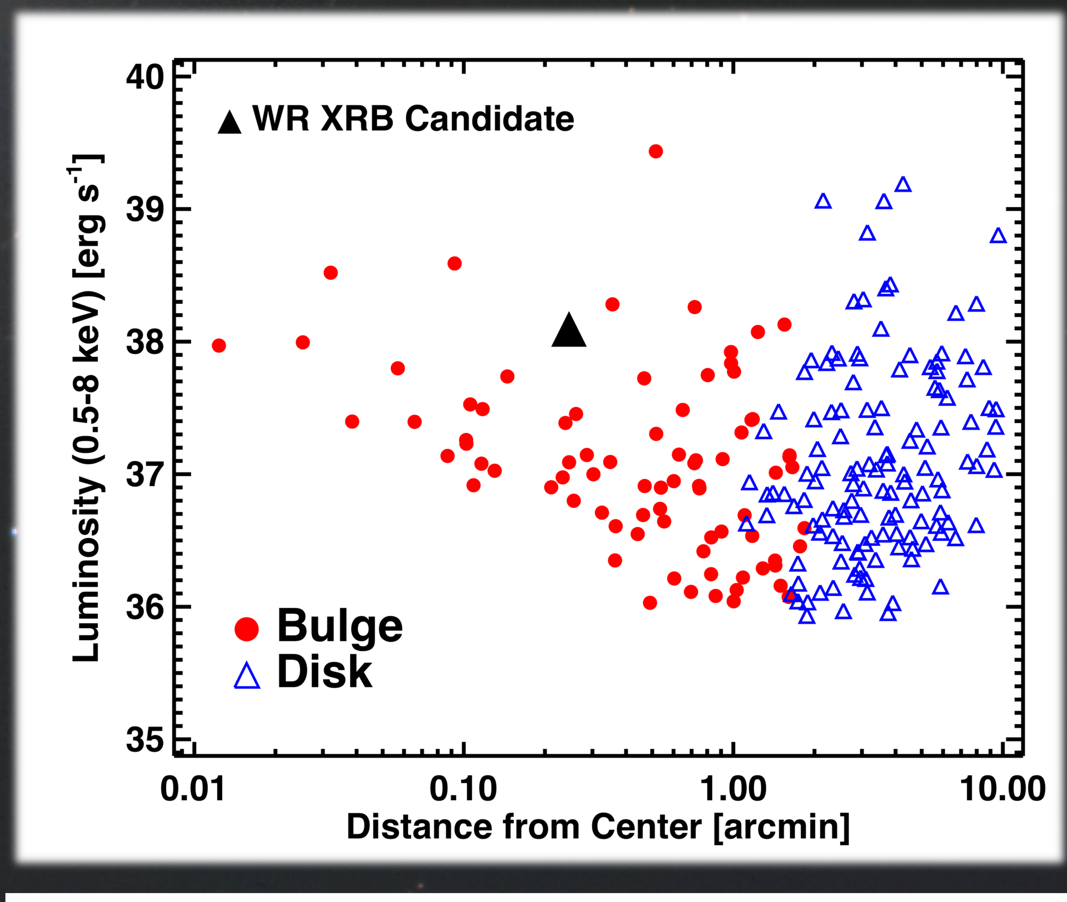

Figure 2. X-ray point source luminosity vs. distance from the center of NGC 253. The 81 bulge and 132 disk sources are indicated along with the WR XRB candidate.

Wolf-Rayet XRB Variability

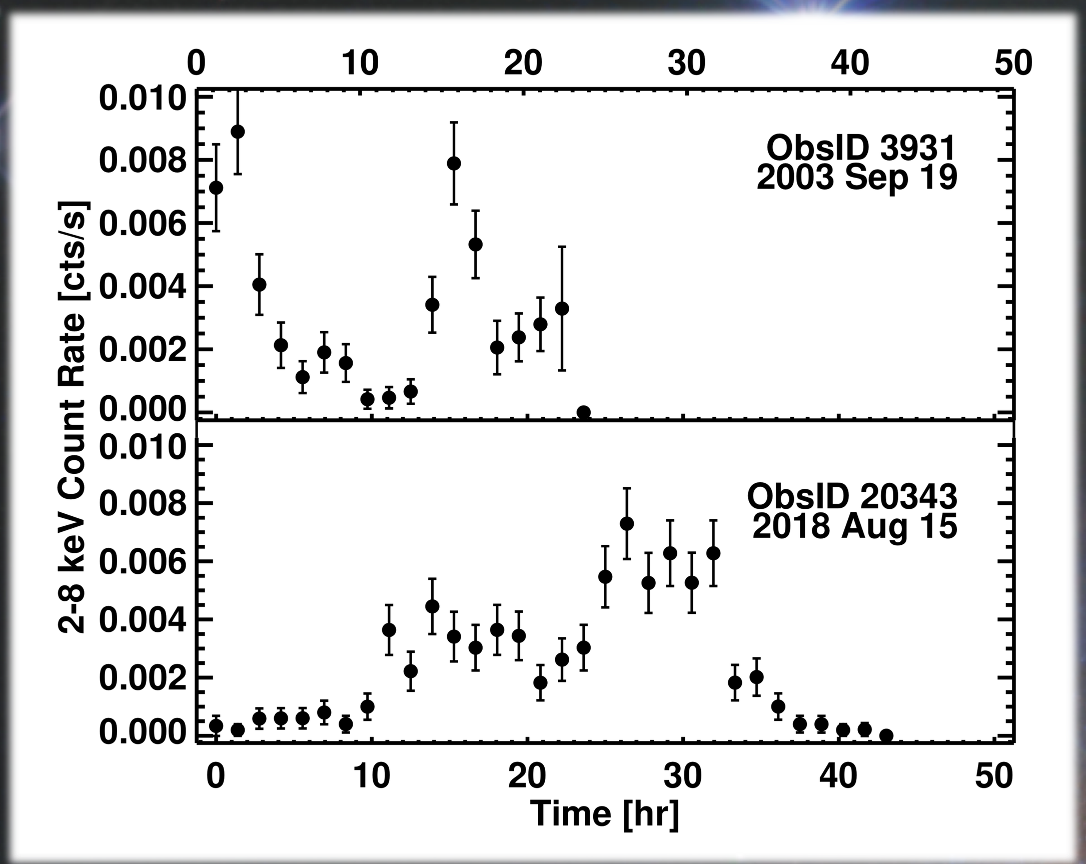

Figure 3. *Chandra* background-subtracted light curve for the candidate WR XRB in NGC 253, showing bins of 5000 s for the ObsIDs with the longest continuous exposures. The time-sampling in the 2003 observation was insufficient to confirm the candidate orbital period of 15 hr, whereas the 2018 observation shows no periodic signal in the 2018 data. Timing analysis using a Lomb-Scargle Periodogram indicated no strong signal in the 2018 data.

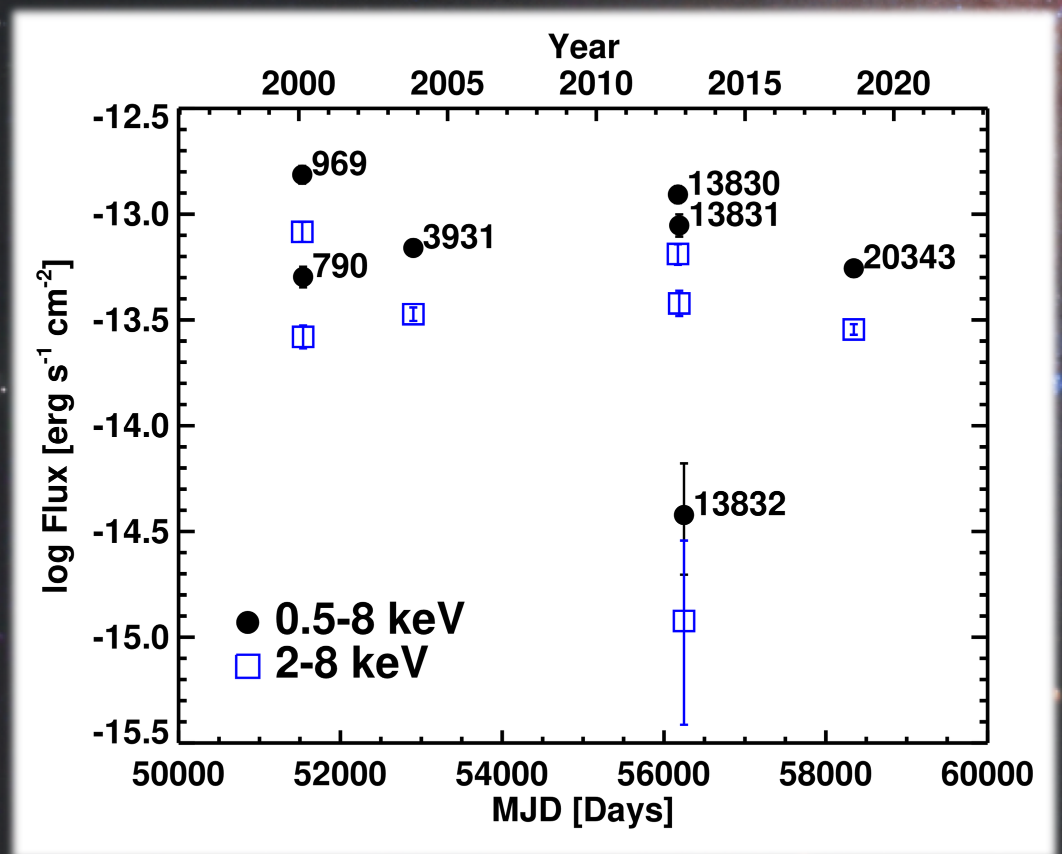

Figure 4. Flux of the candidate WR XRB in each *Chandra* observation, with the corresponding ObsID indicated beside the 0.5-8 keV flux value. The order of magnitude decrease in flux for ObsID 13832 was accompanied by a drop in the 2-8 keV flux contribution from 86% to 57% of the total flux.

Wolf-Rayet XRB Spectral Fits

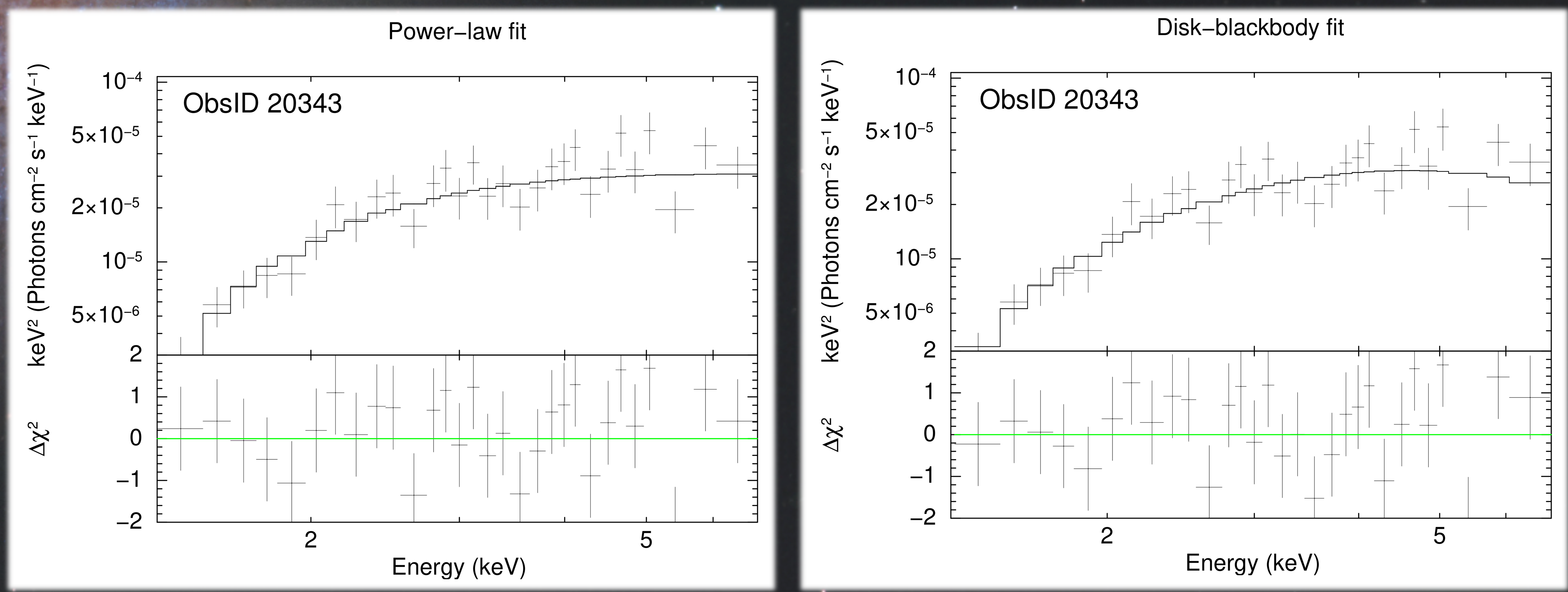

Figure 5. Unfolded *Chandra* spectra and residuals for the candidate WR XRB from the 150 ks observation. The disk blackbody (left) and power law (right) models both fit the data well. The best-fit parameters for the power law were Γ=2.1 and N_H=2.4x10^{22} cm^{-2} and for the diskbb were $k_B T_{in}$=1.8 keV and N_H=1.5x10^{22} cm^{-2}. We attempted to fit the peak of the light curve from 90 to 115 ks to investigate whether the spectrum changed in this state. The paucity of counts prevented a satisfactory fit, but the results were broadly consistent with the fits above.

References
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Background Image: NGC 253 *Subaru*/*HST*/*VLT* R. Gendler