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# Reflection and Absorption in NGC 3783

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**Introduction:** NGC 3783 is one of the brightest Sy 1 AGN observed by *Chandra*, offering one of the richest troves of HETG data in the archive. These spectra depict a forest of absorption lines from a multi-phase outflowing wind, as well as underlying emission signatures from reflection off of distant and inner disk gas. The >1 Ms of available HETG archival spectra has informed the modeling of many subsequent datasets, including those from *XMM-Newton, Suzaku* and *NuSTAR*. Combining the results of these observing campaigns has yielded new insights into the primary continuum, absorption and reprocessed emission components in NGC 3783. Here we report on the results of these spectral modeling studies and also discuss their implications on our understanding of the corona, the spin of the supermassive black hole, and the structure of the absorbing gas in this bright, nearby AGN.

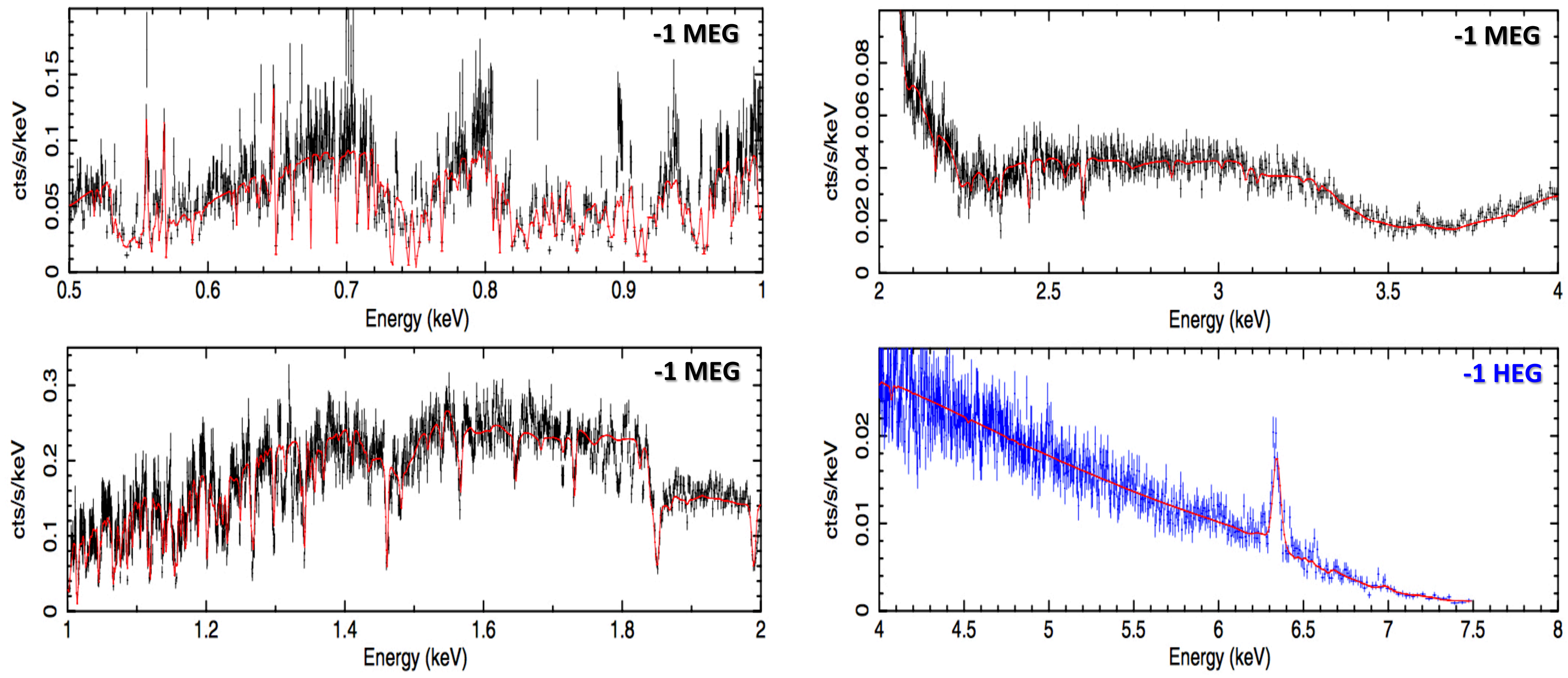


***Figure 1:*** Folded *Chandra*/HETG spectrum and best-fitting model as a function of observed energy. The model is fitted simultaneously to the ±1 MEG (0.5–7 keV) and HEG (1–7.5 keV) data. However, for clarity, we only show here the -first-order MEG data (black; first three panels) and the -first-order HEG data (blue; bottom panel). The >1 Ms of *Chandra*/HETG data in the archive is a critical template for fitting the warm absorber in subsequent epochs. When fit with a three-zone warm absorber, the total column is $N_H \sim 4.4\times10^{22}$ cm$^{-2}$, log $\xi \sim 1.15$–$2.83$, a blackbody soft excess component is present with kT ~ 107 eV, and cold reflection from the torus has a reflection fraction of R ~ 0.5. A contribution from inner disk reflection has been notoriously difficult to assess with *Chandra*, as its effective area decreases rapidly in the Fe K band.

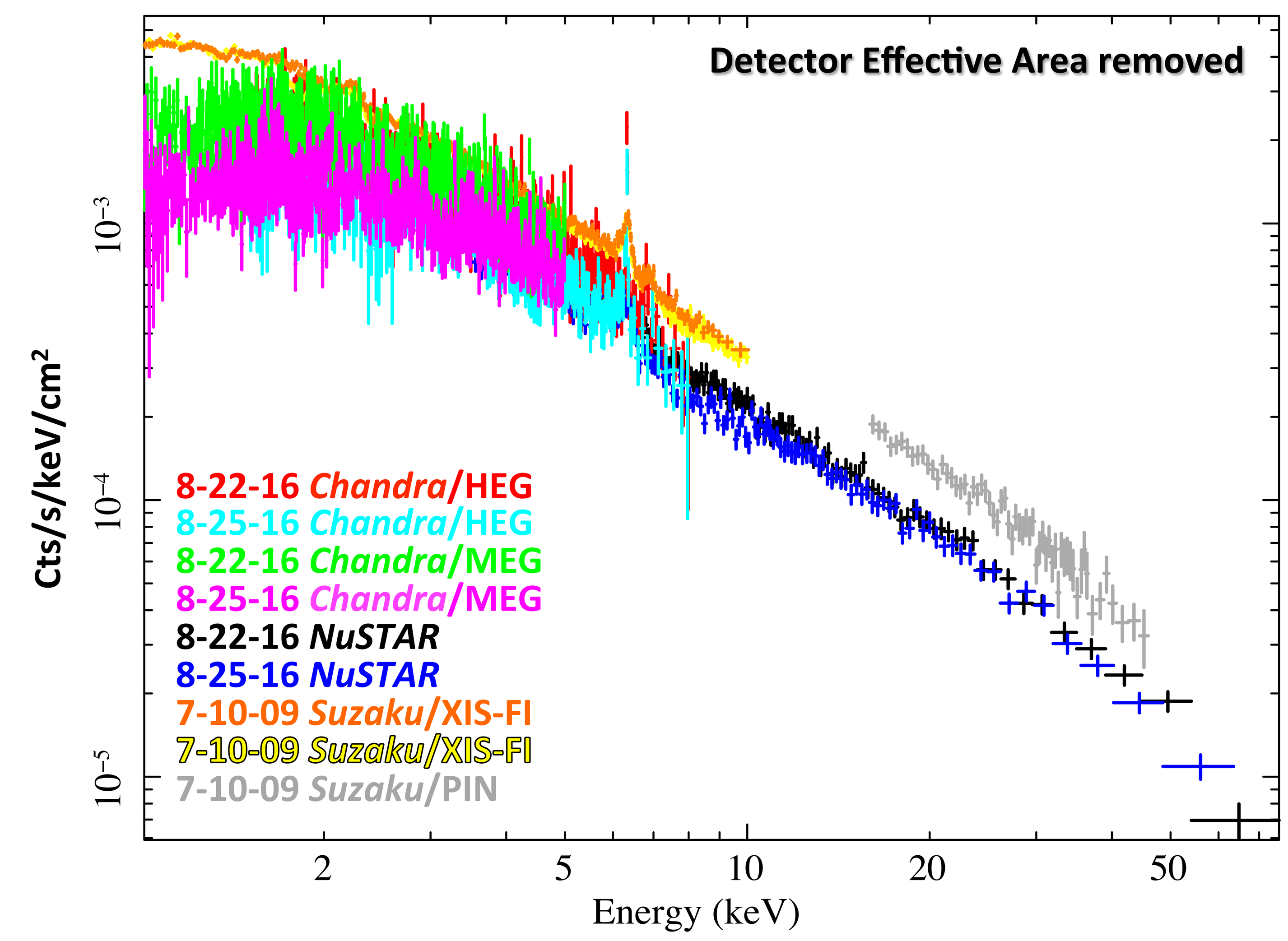


***Figure 2:*** 2009 *Suzaku* and 2016 *Chandra*/HETG + *NuSTAR* time-averaged spectra. There is a clear change in the intrinsic flux of the continuum between the two epochs, as well as an evident change in the intrinsic absorbing column: the spectral shape change is more pronounced below ~3 keV, both between 2009 and 2016 and between the two observations in August 2016.

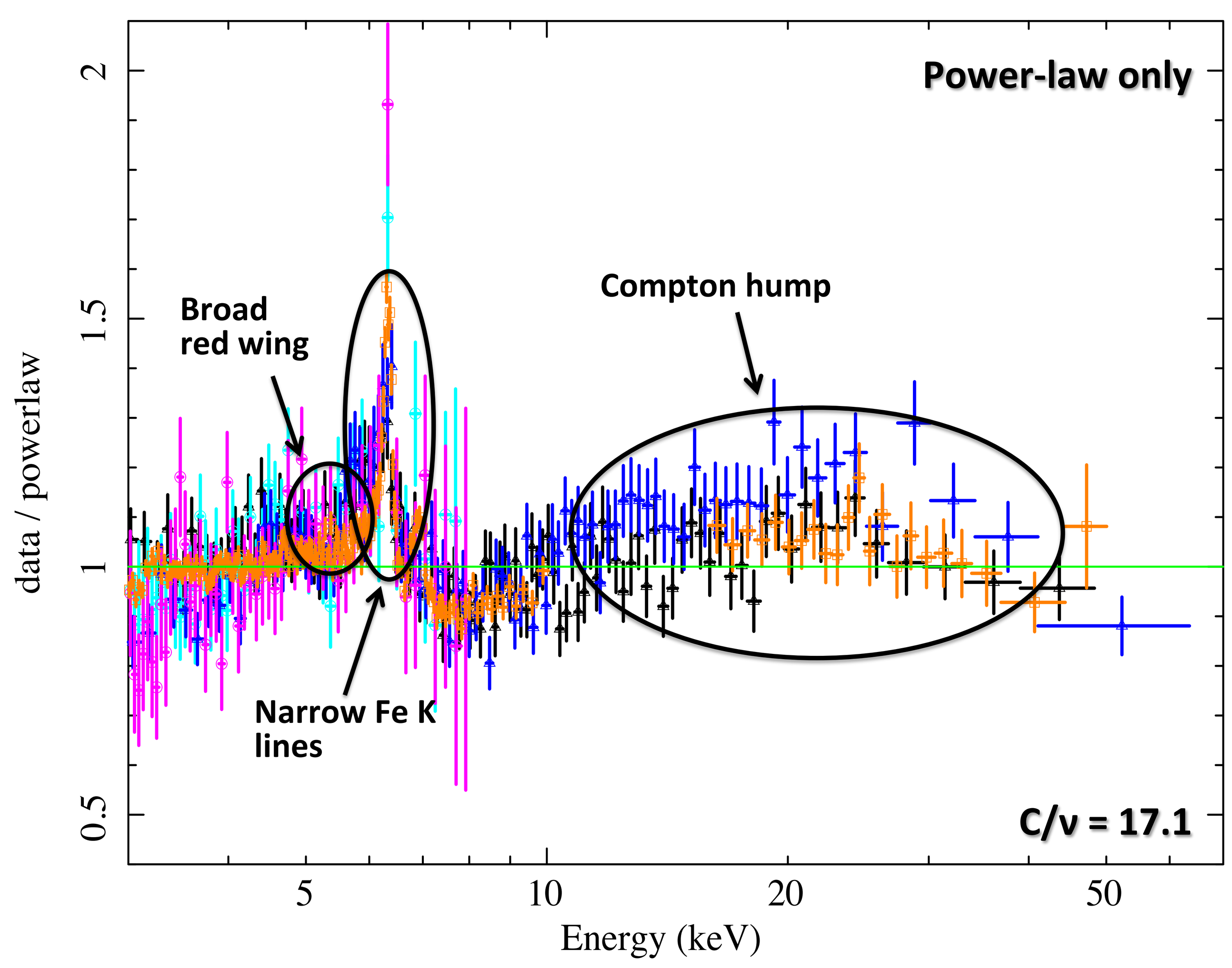


***Figure 3:*** Spectra ratioed against a fiducial continuum power-law model between 3-4.5 and 7.5-10 keV. Note the presence of strong residual features in emission in the Fe K band as well as the putative Compton hump; absorption features are also evident in the Fe K band.

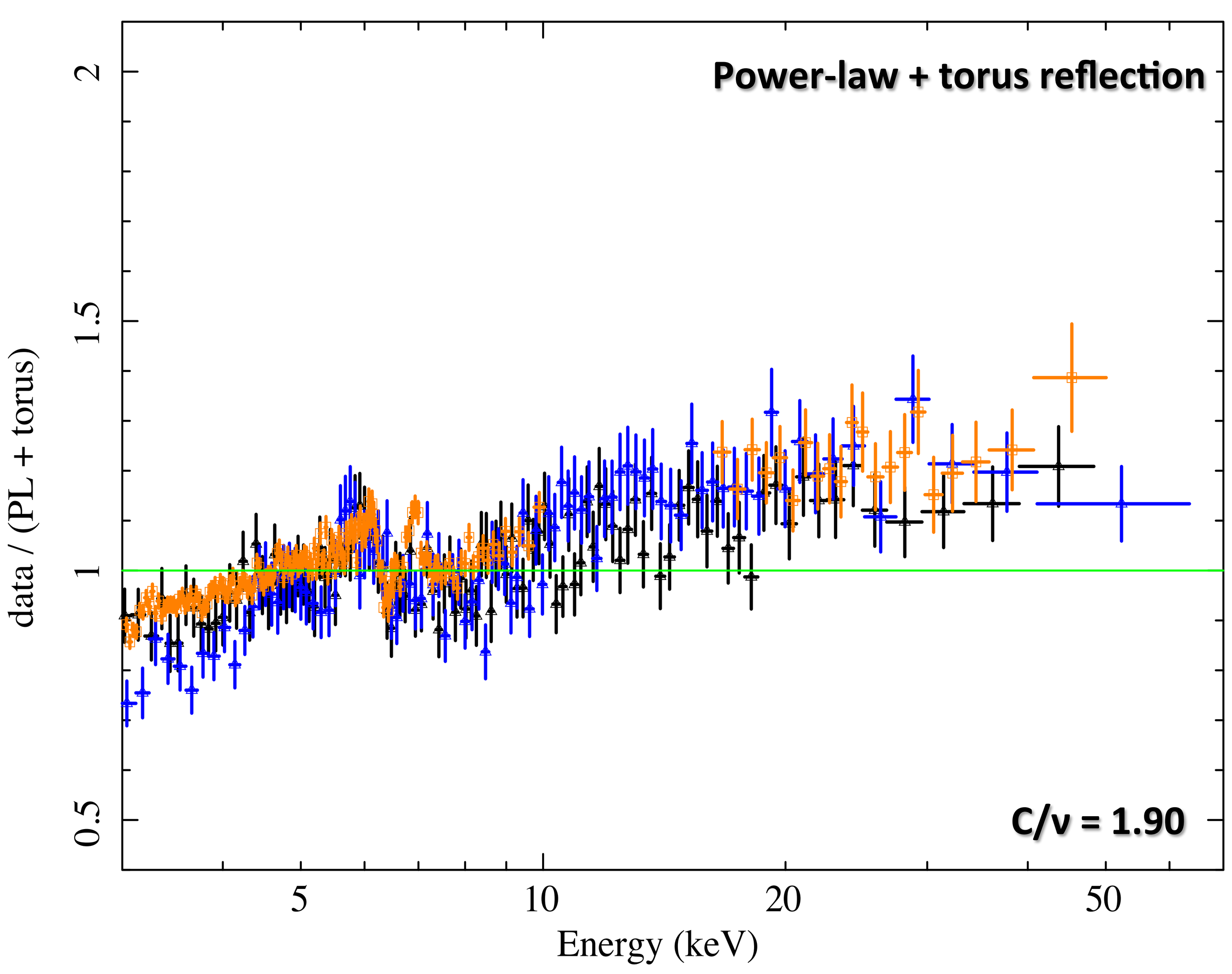


***Figure 4:*** Reflection from the molecular torus is now included in the model using the XILLVER model (Garcia+ 2013). Note the remaining residuals in the Fe K band and above 10 keV, indicating that a cold, distant reflector alone cannot adequately fit the data.

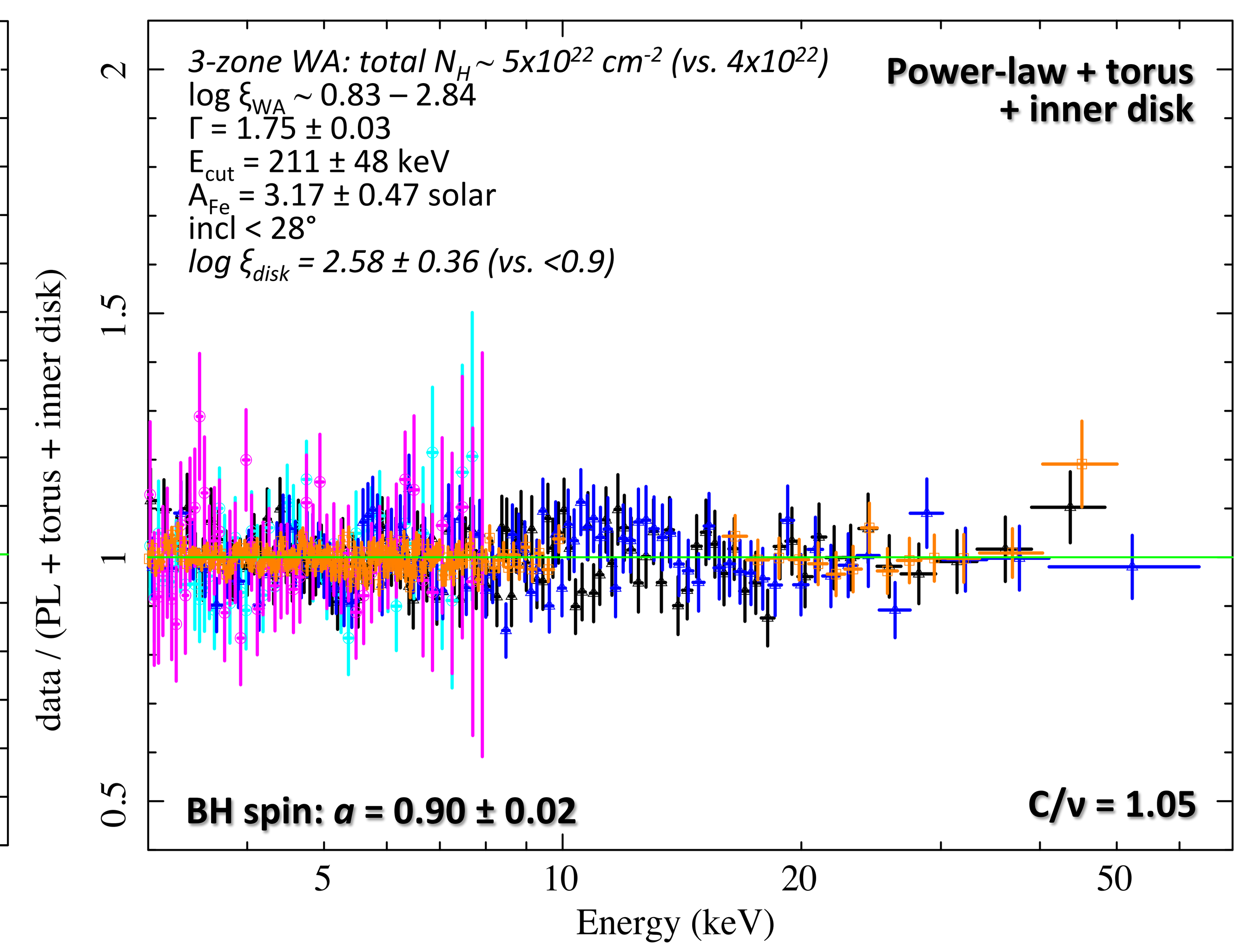


***Figure 5:*** Once relativistic reflection from the inner disk is included with the RELXILL model (Garcia, Dauser+ 2014), the residuals are greatly reduced and a good fit is obtained. We have also included a three-zone warm absorber in the fit consistent with historical data. Parentheses show the comparison best-fit parameter values for the 2009 *Suzaku* observation.

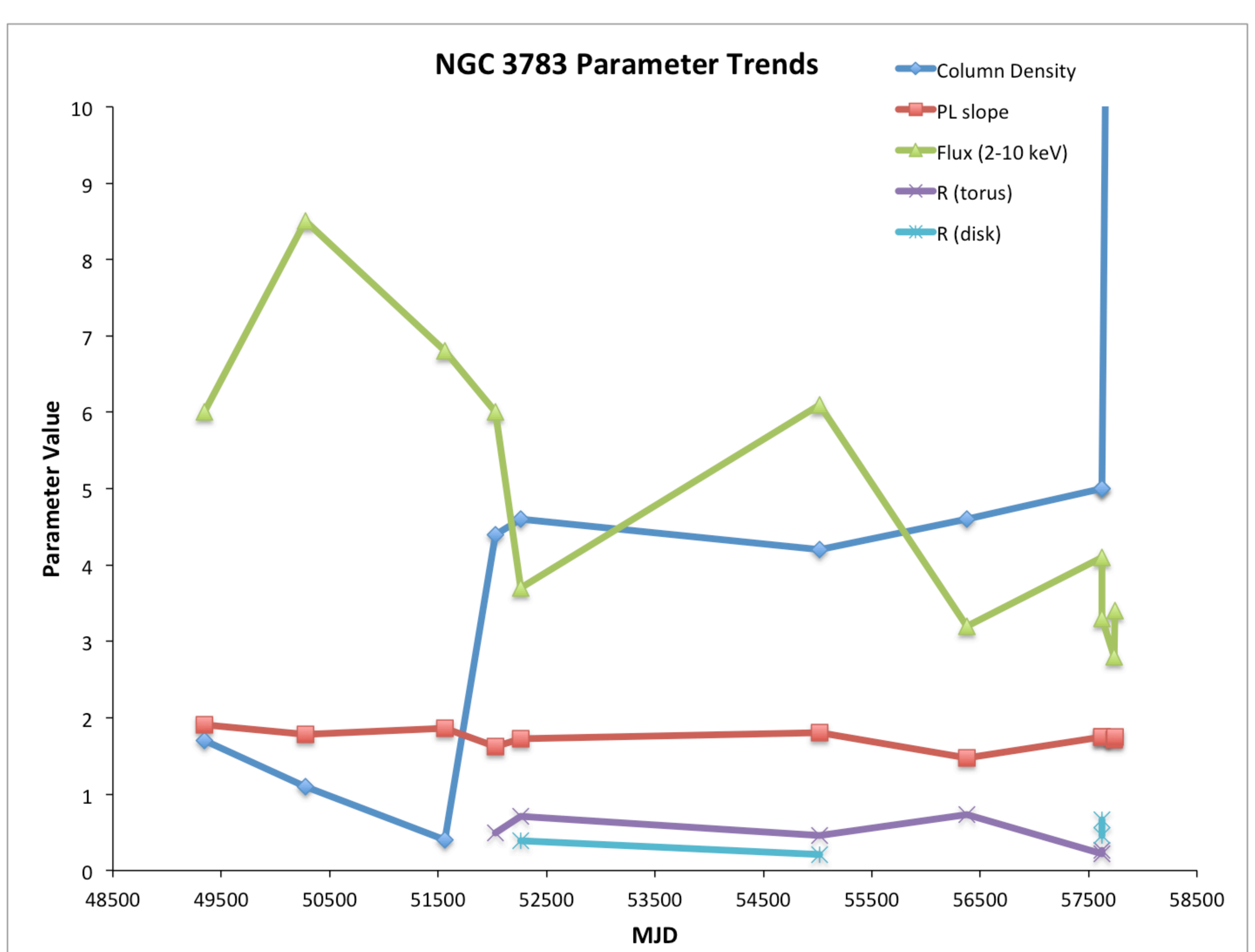


***Figure 6:*** Selected best-fit parameters for the spectrum of NGC 3783 since 1993. Note that not all published datasets quote values of the reflection parameters ("R") for the disk and torus. Nonetheless, it appears that, while the power-law slope is roughly constant, the 2-10 keV flux (in units of $10^{-11}$ ergs/cm²/s) and the column density (in units of $10^{22}$ cm$^{-2}$) are anti-correlated. The dramatic spike in column in the latest epoch of observations is indicative of a new "obscurer" crossing our line of sight to the hard X-ray source (Kaastra+ 2018), resulting in the lowest recorded flux for this AGN.

## Preliminary Conclusions:

- We have performed a preliminary spectral analysis of the 2016 *Chandra*/HETG + *NuSTAR* data from NGC 3783 in conjunction with the 2009 *Suzaku* data.
- In spite of continuum flux and absorption column changes between observations, results indicate that the SMBH is rapidly spinning, with $a = 0.90 \pm 0.02$. This is consistent with Brenneman+ (2011): $a \geq 0.88$ (99% confidence, *Suzaku* alone).
- The broad bandpass of our observations and the high spectral resolution of the HETG enable us to accurately distinguish and constrain the signatures of the continuum, torus and warm absorber, thereby isolating the reflection from the inner disk.
- Future work remains to be done, including more detailed modeling of the absorber (e.g., direct comparison with the recent results of Mehdipour+ 2017 and Kaastra+ 2018 on *XMM-Newton + NuSTAR* observations of NGC 3783 from Dec. 2016), as well as more detailed Comptonization modeling of the continuum to yield coronal temperature, optical depth and geometry.