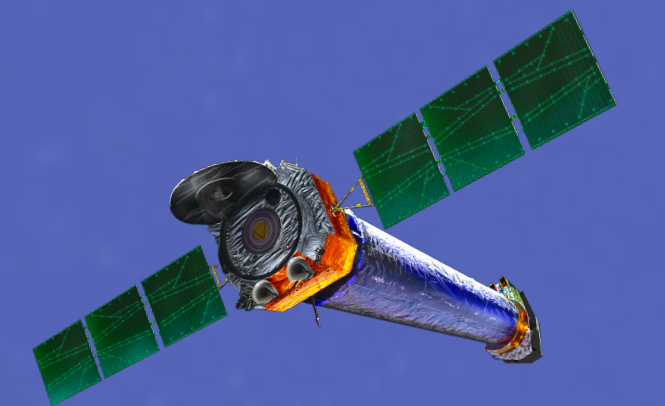




# CSC 2.0 Spectral Properties and a ULX Case Study



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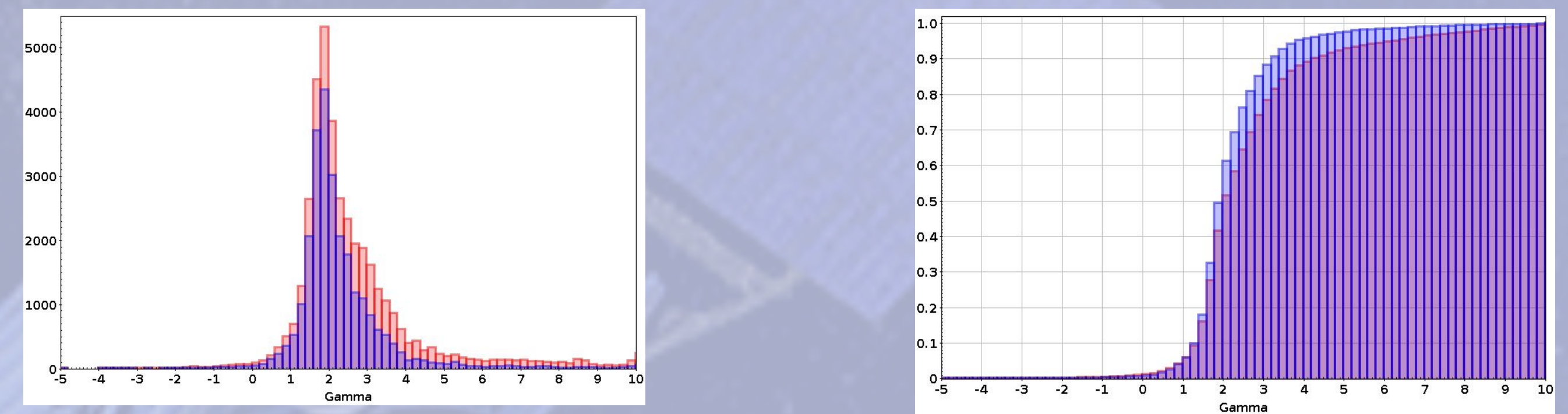
## 1. Introduction

The second release of the Chandra Source Catalog (CSC) contains all sources identified from ~ fifteen years' worth of publicly accessible observations. The vast majority of these sources have been observed with the ACIS detector and have spectral information in 0.5-7 keV energy range. Here we present a discussion of the available spectral properties that can be found in the catalog. Sources with high signal to noise ratio (exceeding 150 net counts) were fit with three models: an absorbed power-law, blackbody, and Bremsstrahlung emission. The fitted parameter values for the power-law, blackbody, and Bremsstrahlung models were included in the catalog with the calculated flux for each model. The CSC also provides for all of the sources energy fluxes computed from the normalization of predefined absorbed power-law, black-body, Bremsstrahlung, and APEC models needed to match the observed net X-ray counts. For sources that have been observed multiple times we performed a Bayesian Blocks analysis. For each of blocks a joint fit is performed for the mentioned spectral models and the fit parameters are stored in a user data product. The most significant block parameters will be stored in the CSC databases at the master level. In addition, we provide access to data products for each source: a file with source spectrum, the background spectrum, and the spectral response of the detector. Hardness ratios were calculated for each source between pairs of energy bands (soft, medium and hard).

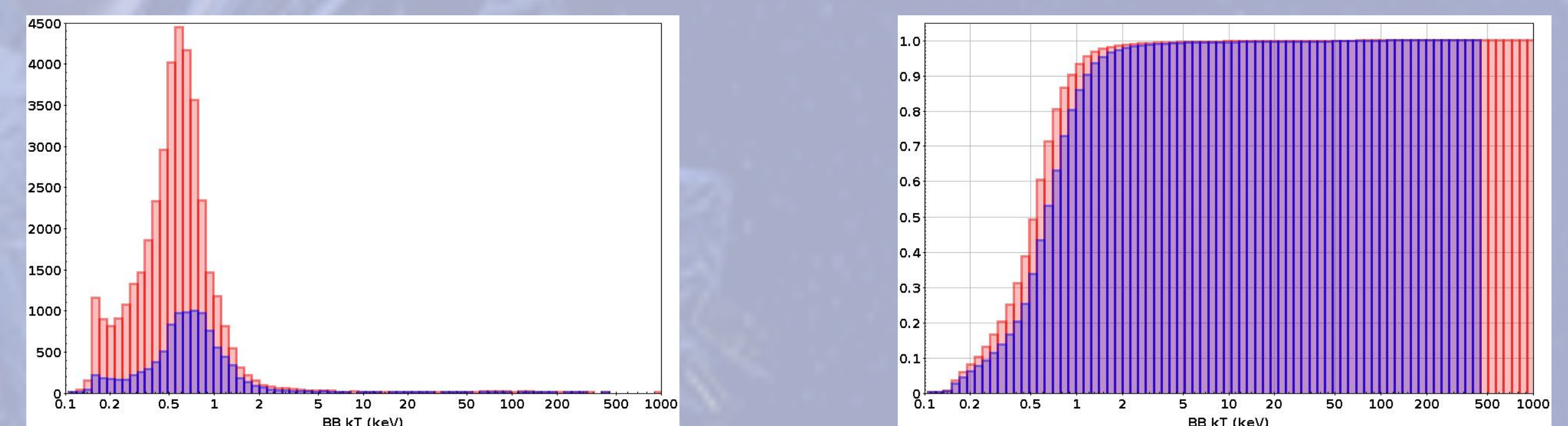
As a case study of how these spectral properties can be used we will examine a group of ULX sources found from Chandra datasets (Swartz,D.et al.,2011, ApJ,741,49S) and compare results from the catalog with published results.

## 2. Spectral Model Fit Results

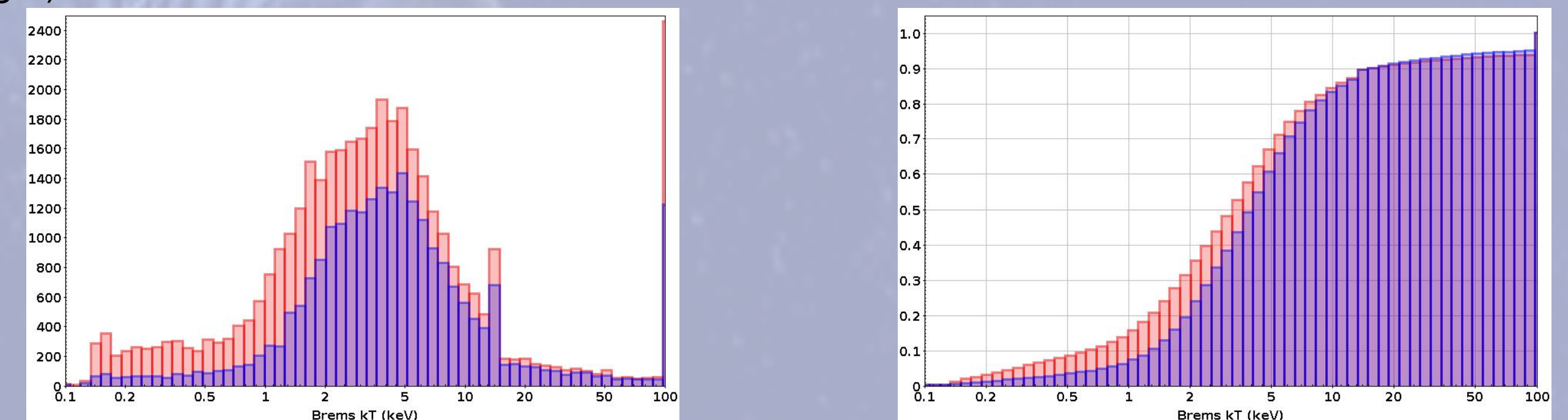
As part of the Chandra Source Catalog 2.0 (CSC2) spectral fits we made for all the sources which have more than >150 net counts in the 0.5-7.0 keV energy band. For the CSC2 there was a total of 38656 sources that met this criteria. For each of these sources there were done for three models: (1) an absorbed power law; (2) an absorbed black body; and (3) an absorbed bremsstrahlung. The spectra were grouped into 16 count bins and a chi-squared statistic was used in the fitting.



**Power-Law:** The histograms of the power law photon index (gamma) for all the model fits to the CSC 2 data. The red marks all the fits and the blue marks the results with a good reduced  $\chi^2$ . (25529) A histogram of gamma. (left) A normalized cumulative histogram of gamma (right).



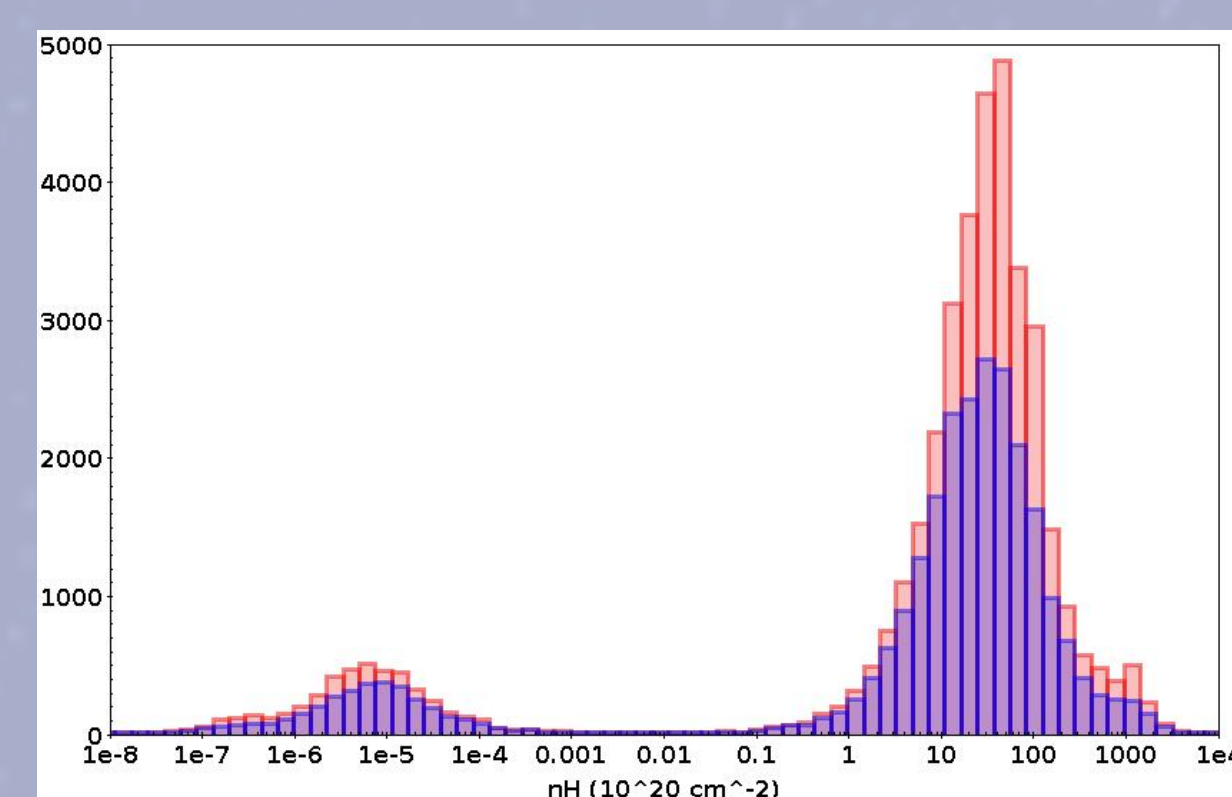
**Blackbody:** The histograms of the kT values for the black body model fits to the CSC2 data. The red histogram marks all the fits and the blue one the fits with a good reduced  $\chi^2$ . (9936). A histogram of the values of kT. (left) A normalized cumulative histogram of the best-fit kT values (right).



**Bremsstrahlung:** The histograms of Bremsstrahlung kT values for the CSC2 data. The red marks all the fits, and the blue the fits with a good reduced  $\chi^2$ . (23738). A histogram of the best-fit values of kT. (left) A normalized cumulative histogram of the best-fit kT values (right).

## 3.0 Absorption Model for the Spectral Fits

For all the above model fits we included an absorption model component (phabs). We found the distributions of the absorption column density, NH, to cluster around two peaks. As an example, we show the results for the power-law model. One peak is located at around  $\sim 7 \times 10^{21} \text{ cm}^{-2}$ , and another peak at around  $\sim 10^{19} \text{ cm}^{-2}$ . This latter peak is unrealistic given that the expected lower bound to the column density is around  $\sim 10^{19} \text{ cm}^{-2}$ , as determined by the density of the ISM inside the local bubble (Cox & Reynolds, 1987, ARA&A, 25, 303; Egger & Aschenbach, 1995, A&A, 294, L25). A study (Brassington, et al. 2010, ApJ, 725, 1805) has shown that these low nH values are likely a result of fitting spectra with a simple model, while the true spectra are more complex and likely require multiple spectral components to describe the X-ray data. This leads to the nH values being artificially low.

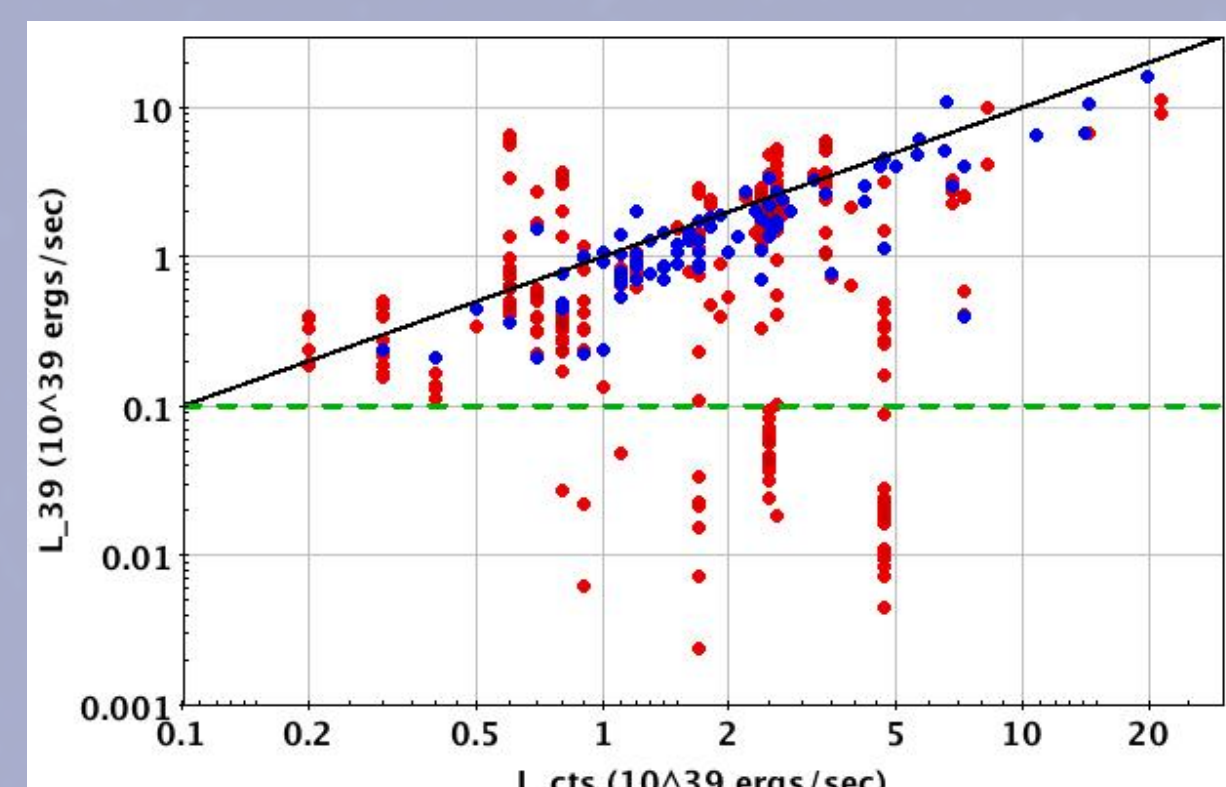


## 4. Spectral Fits (Bayesian Blocks)

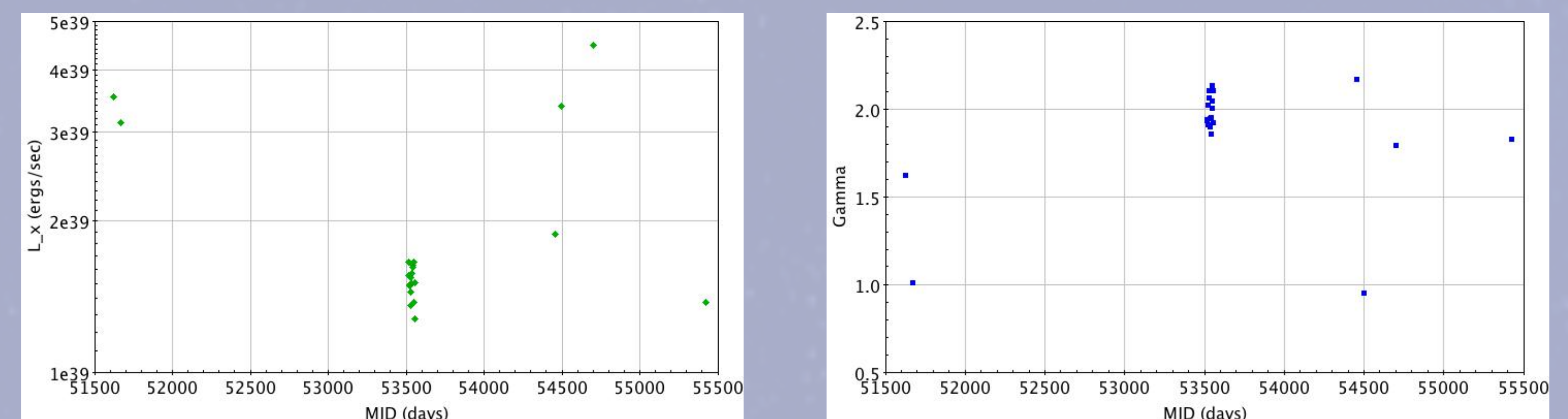
- Sources which are observed multiple times are grouped into 'blocks' of observations. In each block, a constant source flux is consistent with the fluxes of all observations in the block, in the s, m, h, and b bands.
- All spectra in the block are simultaneously fit with the assumed models if the sum counts in these spectra are  $\geq 150$  counts in the 0.5-7 keV band.
- Spectral properties for all blocks are contained in the Master Source Bayesian Blocks Source Properties (blocks3.fits) data product.

## 5. ULXs (Swartz, et al. 2011)

In Swartz, et al.,2011, ApJ,741,49S a review of 107 ULXs was presented. To compare to what one can obtain from the CSC2 we performed a quick study. For the 107 sources we found 98 sources in the catalog for which there was 360 unique observations. We took the b band flux (0.5-7.0 keV) flux and converted it into a luminosity ( $L_{39}$ ) and compared it to the luminosity from Swartz et al. 2011 ( $L_{\text{cts}}$ ). In the figure the red points are all of the data and the blue are the ones which came from the same obsids in Swartz et al. 2011. The black line is the one to one line. Because the Swartz et al 2011 values are from a larger band pass (0.3-10.0 keV) we expect that the values we calculate to be slightly lower. From the figure we can see the correlation and that overall our values are slightly less. What we also see where we have multiple observations is that the ULXs can be very variable. Dropping at times below the upper limit for most X-ray binaries ( $\sim 10^{38}$  ergs/sec) as shown by the dashed green line.



## 6. ULX Temporal and Spectral Variation (2CXOJ0955329p690033)



For one of the ULXs we looked at the data contained in the block 3 files. From the time ordered blocks we have plotted the luminosity, calculated from the power-law b band flux versus time (mjd). We also plotted the gamma from the power-law fits as a function of time (mjd). For all the fits the reduced  $\chi^2$  values were all less than or equal to 1.3. We see evidence that as ULX brightens the spectra become harder.

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