Luminosity Functions and Point Source Properties from Multiple Chandra Observations of M81

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Summary

We use 16 *Chandra* observations of a nearby galaxy, M81, to study a range of aspects of its X-ray point source population. One of these observations (~ 50 ksec) was taken in 2000 (Swartz et al. 2003, ApJS, 144, 213), and the other 15 observations (each ~ 11 ksec), were taken in 2005. Using CIAO's wavdetect, we find hundreds of sources in these images and, after making significance cuts, we form a list of 265 sources in our master list. Then, using ACIS Extract and CIAO's Sherpa, we extract and fit the spectra of each point source in each observation, integrating the best-fit models to derive the luminosities. Using these luminosities, we conduct variability studies on both the individual point sources as well as luminosity functions. In particular, we address the question: does the individual variability of each of the X-ray point sources contribute significant variability to the X-ray luminosity function of the galaxy or its bulge and disk separately? Despite significant source variability seen on timescales of weeks and years (Figures 4-12), the corrected X-ray luminosity functions seem fairly robust (Figures 13 and 14). We also consider information from the merged exposures in computing luminosities and X-ray colors. With the X-ray colors, we are able to distinguish the bulge and disk populations of sources in certain restricted regions of this galaxy (Figure 1).

X-ray Colors — Hardness Ratios

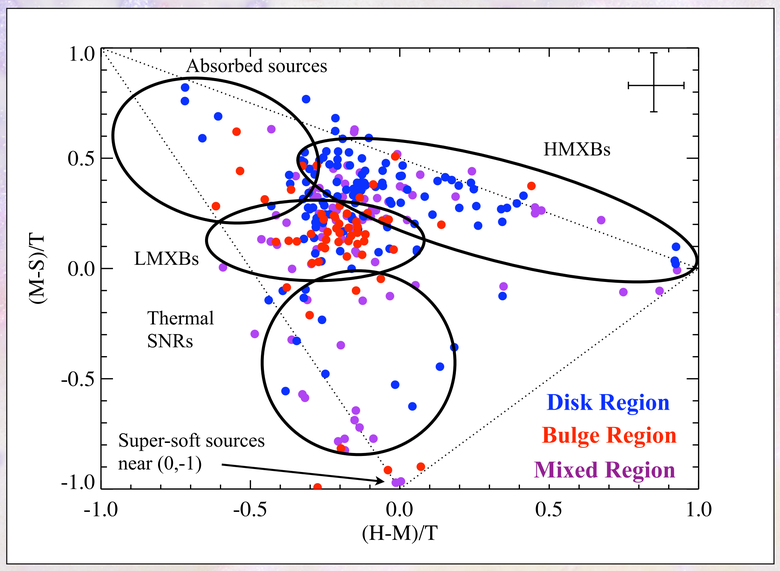
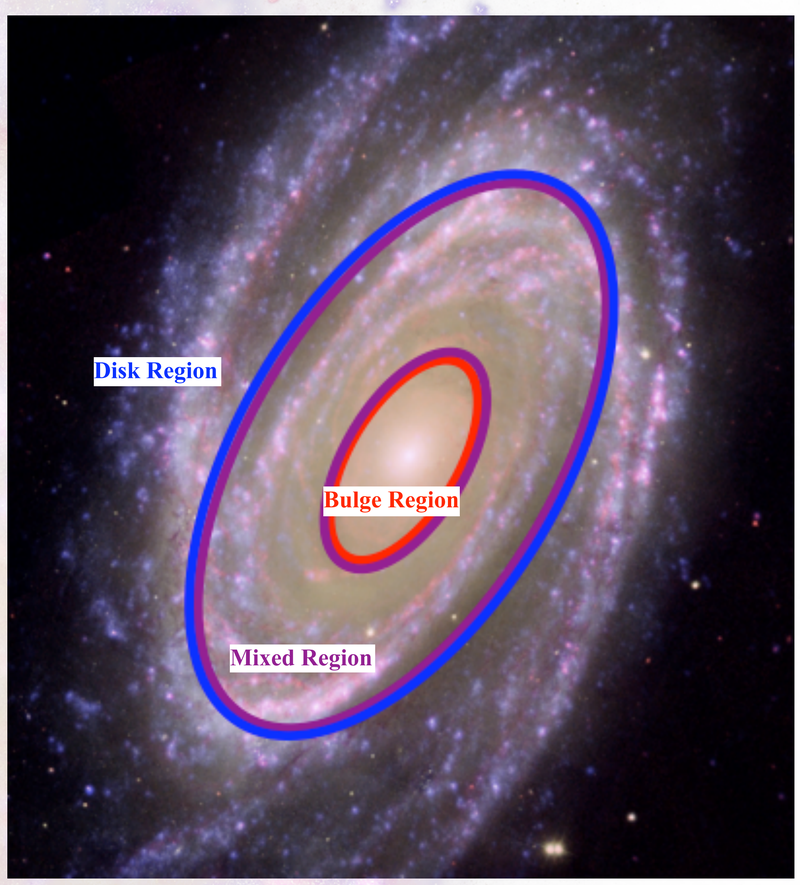
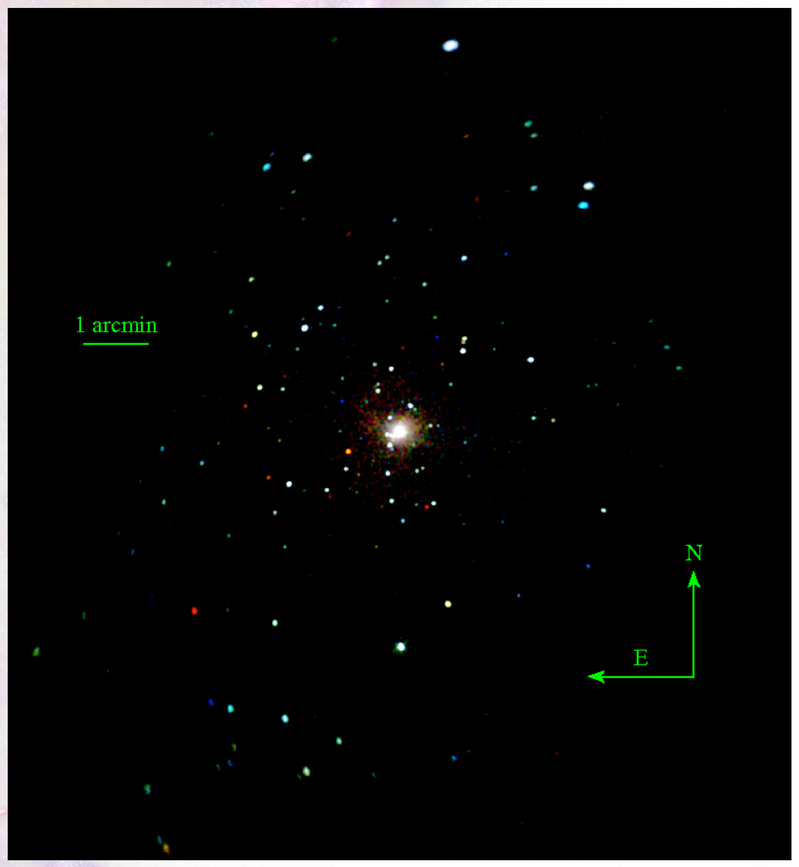


Figure 1. Using the merged source information, we analyze the X-ray colors of the total point source population following the method suggested by Prestwich et al. (2003, ApJ, 595, 719) to separate populations of sources. The colors are calculated from the net counts in four bands: hard (2-8 keV "H"), medium (1-2 keV "M"), soft (0.5-1 keV "S"), and total (0.5-8 keV "T"). The median 1σ error bars are provided in the upper right corner. The sources are color-coded by their position in the galaxy according to their inclination-corrected radius (see the figure to the right) — red=bulge, blue=disk, and purple=intermediate region where there appears to be considerable mixing between the bulge and disk. The dotted lines represent the region where the net counts are non-negative. Due to background subtraction, faint sources can fall outside this region.

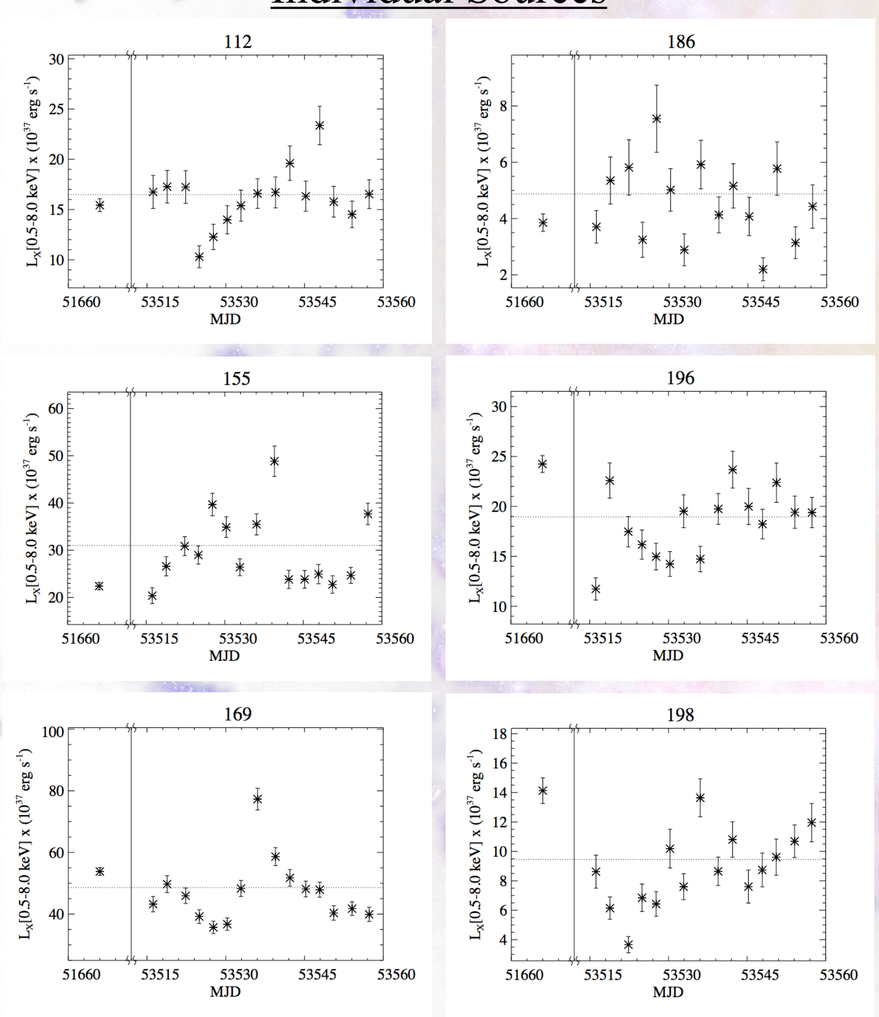




Figures 2 and 3. We illustrate our regional separations between the bulge and disk of the galaxy with a combined UV/optical/IR image of M81 (top). The bottom figure is a *Chandra* color-coded image of the same field showing the wide range of point source colors in M81 (red=0.5-1 keV, green=1-2 keV, and blue=2-8 keV). Both images are approximately 12 x 13 arcminutes.

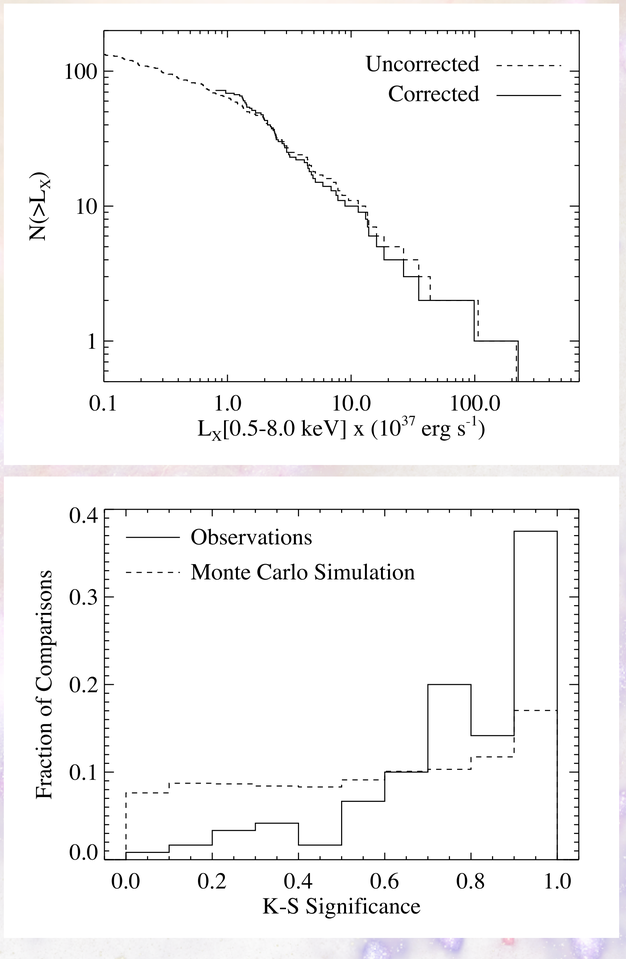
X-ray Point Source Variability

Individual Sources



Figures 4-9. Above are some examples of approximately 20% of the sources in our catalog that show significant variability on both the ~3-day and ~5-year time-scales that we probe. The solid vertical line marks the 5-year time-scale division and the dotted horizontal line marks the weighted average luminosity.

Luminosity Functions



Figures 10 and 11. We first correct our luminosity functions for incompleteness (top). We then use the two-sided K-S test, which compares the normalized cumulative distribution functions and returns a statistic indicating how likely that they were drawn from the same parent distribution, which is a measure of the variability of the luminosity function of the galaxy. A K-S significance statistic near 0 indicates variability, and a K-S significance statistic near 1 indicates no variability. Upon inspecting the distribution of these K-S significance statistics (bottom), we find that, although most of the comparisons return a K-S significance near 1, some are near 0. However, we still conclude that there is no significant variability in the X-ray luminosity function of M81 because Monte Carlo simulations show that this is not unexpected for the number of trials we performed.