Variability of Hundreds of X–ray Binary Systems

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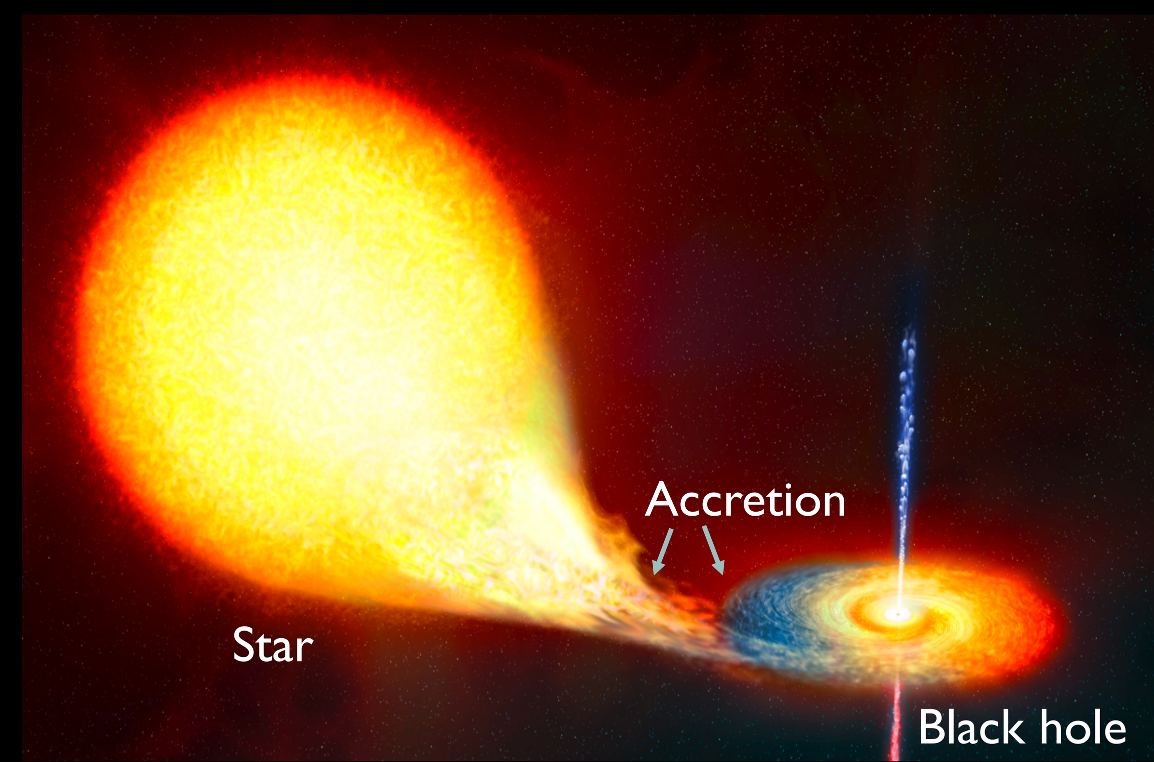
Abstract

X-ray binaries are a fascinating class of astrophysical objects. They tend to be highly variable over both short and long time scales, and can experience sudden flares and long intervals of quiescence. Several physical phenomena, including eclipses, can produce periodic behavior. It has even been hypothesized that some X-ray binaries are orbited by planets. If this is the case, dips in the observed X-ray emission may occur. Here we report on our study of archived *Chandra* data from several hundred X-ray sources in the galaxies M51, M101, and M104. We analyzed the data by searching for interesting time signatures in the light curves of the X-ray sources, most of which are X-ray binaries, and have found flares and dips. We present the results and consider their implications, including the prospects for planet detection and for the search for X-ray triples. This research was made possible by the SAO REU program and is funded in part by the National Science Foundation REU and Department of Defense ASSURE programs.

What is an X-ray Binary?



X-ray binaries are systems consisting of a donor star and a compact object, where the compact object accretes matter from the donor star. The compact objects in these systems can be black holes, neutron stars, or white dwarfs. The gas in the inner most region of the accretion disk is the hottest and contains the most energy, and will therefore give off X-rays.

Methodology

Using approximately 19 years of archived *Chandra* data, we investigated the light curves of hundreds of X-ray sources located in the M51, M101, and M104 galaxies, all containing some sources with luminosity $\geq 10^{38}\ erg\ s^{-1}$. To investigate these X-ray light curves, we used the same methodology used in Irwin et al. 2016 by creating cumulative photon count and count rate plots, and we examined these by eye in order to identify dips and flares in the light curves. Out of the 239 X-ray sources, we found 31 containing at least 2000 photon counts. Most of the X-ray light curves we examined contained significant variability, and as expected, the count rates from the X-ray sources vary significantly from one another. In M51, for example, the average count rate ranges from 0.0001 counts per second to 0.2309 counts per second. Within the subset containing the 31 brightest sources, we found a total of 3 flares, 1 dip, and 1 signature that may be evidence of a dip.

Flares

These three figures display possible X-ray flares. At the top of each figure is the cumulative photon count, and at the bottom of each figure is the quantity that is derived from the count rate, where we subtracted the average count rate from the instantaneous.

- Figure 1: Source J140229.904+542118.79 located in the M101 galaxy. At approximately 40 kiloseconds into the observation, the cumulative photon count and count rate increases significantly. This flare was published in Swartz et al. 2004 and was characterized as an ultraluminous X-ray source (ULX), though Guo et al. 2018 later confirmed that it is actually an M star appoximately 133 parsecs away.
- Figure 2: Source J123945.204-113849.99 located in galaxy M104. The cumulative photons and count rate increases at approximately 70 ks. This flare has not yet been characterized or published.
- Figure 3: Source J133007.553+471106.00 in galaxy M51. The cumulative photon count and count rate start to increase at the beginning of the observation, then decrease at approximately 20 ks. This source has been characterized as a ULX by Terashima et al. 2006. We have yet to find a characterization of the flare itself.

Figure 1

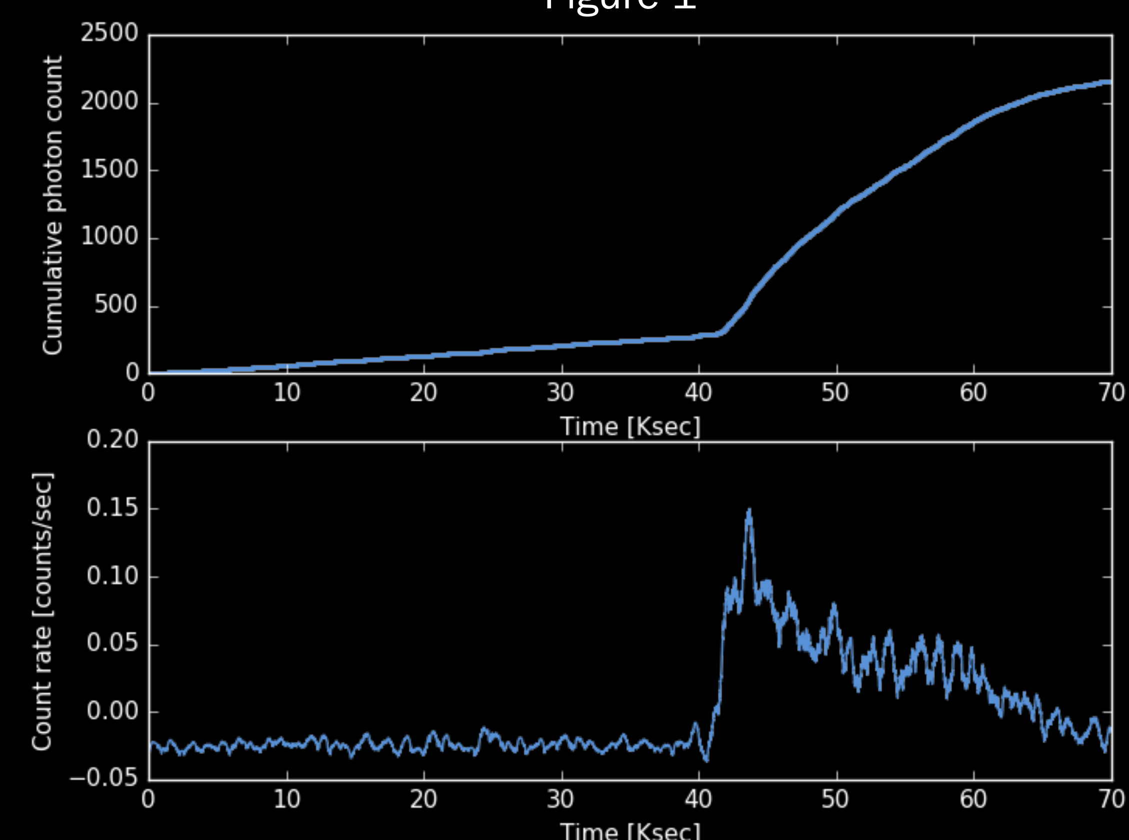


Figure 2

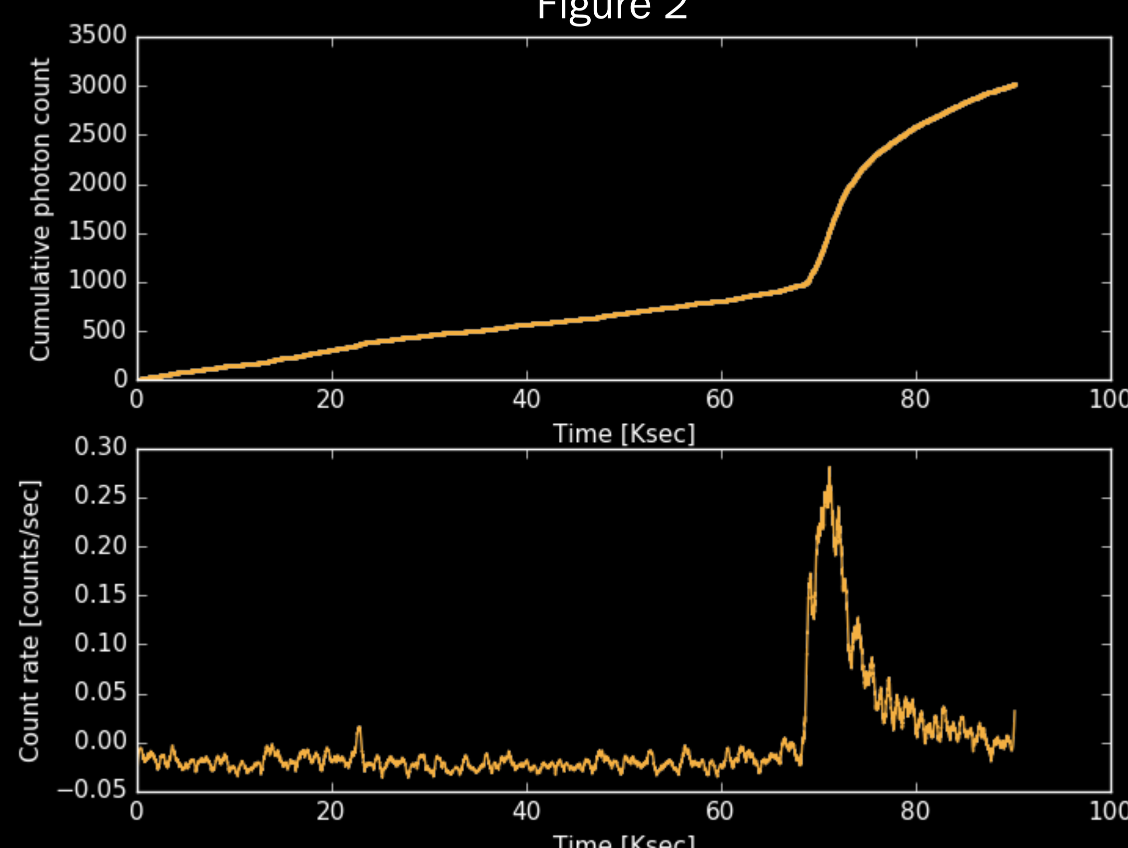
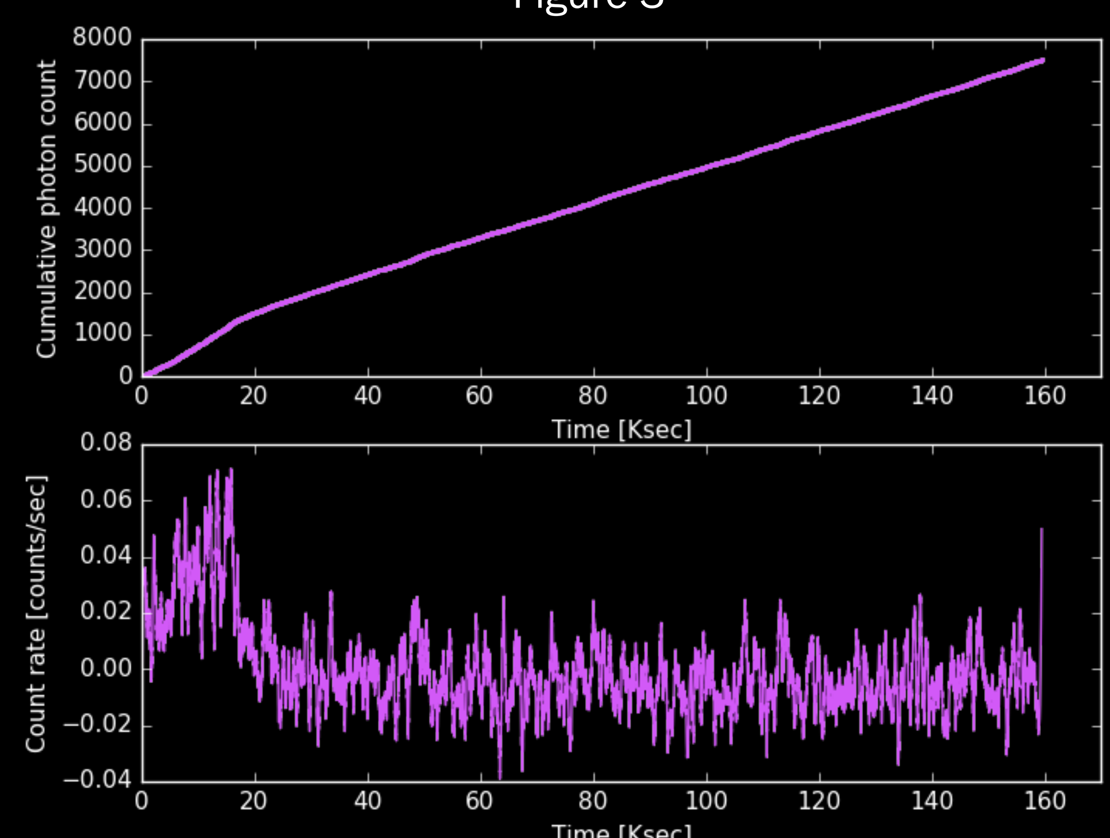


Figure 3



Dips

Figure 4

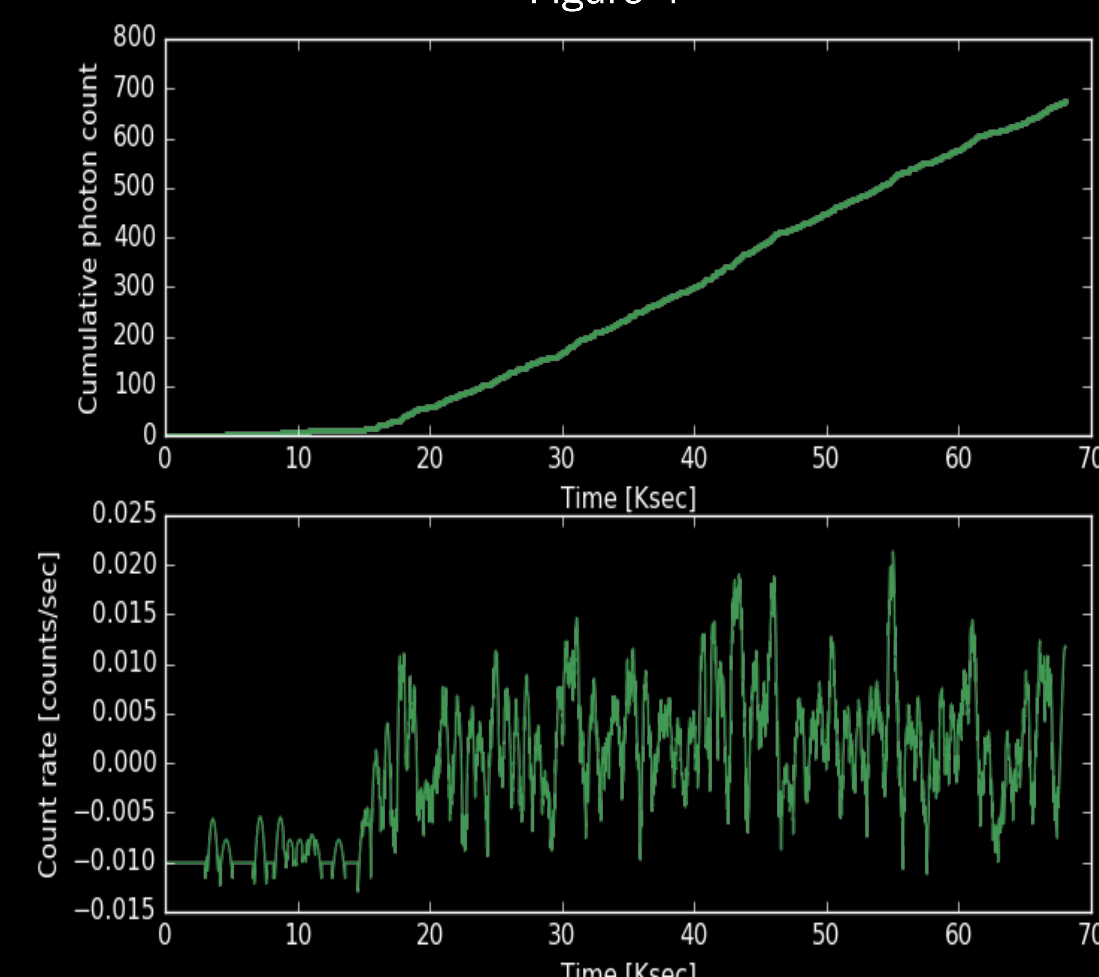


Figure 5

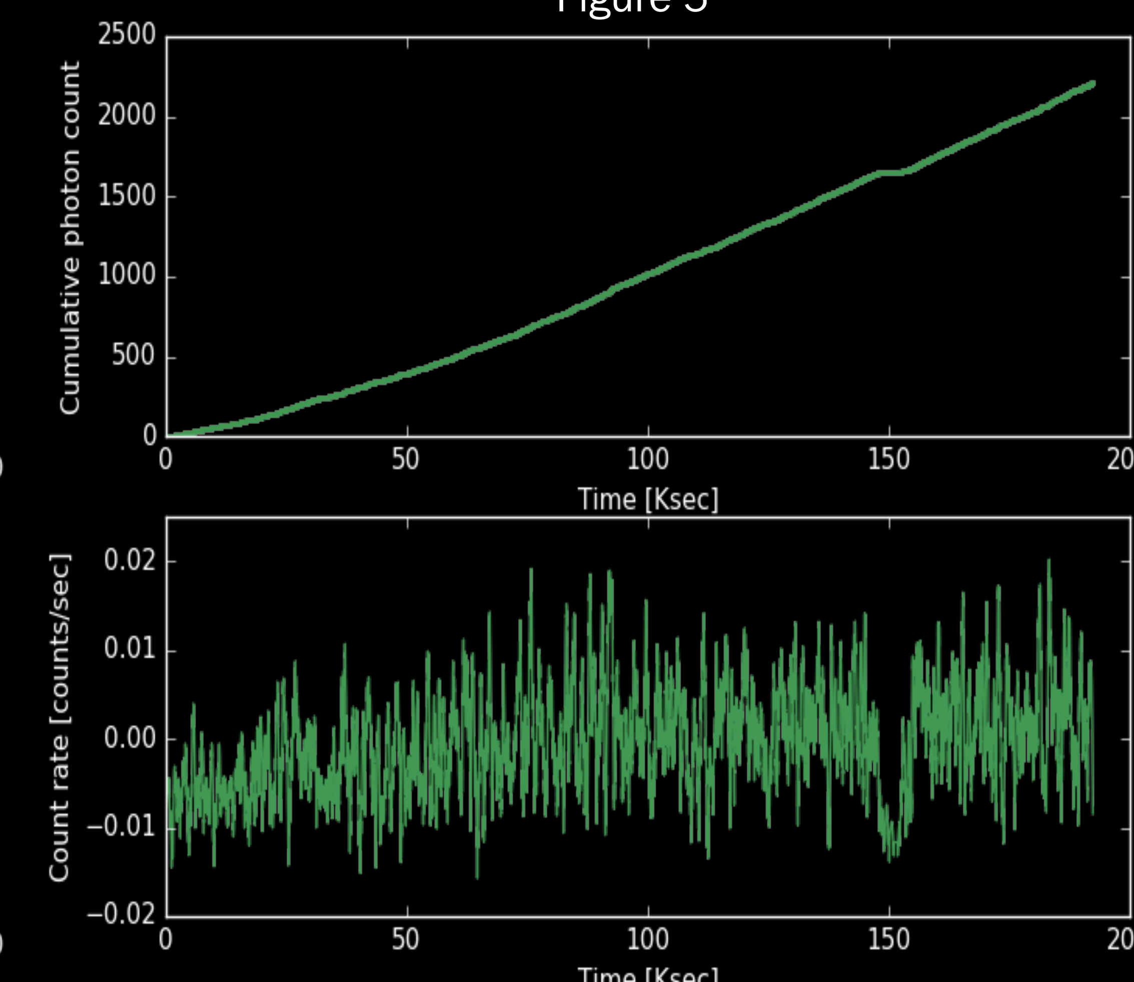


Figure 4 and Figure 5 both correspond to source J132943.306+471134.80 in M51, each corresponding to a different observation. This is a ULX, which reaches luminosities $\geq 10^{39}\ erg\ s^{-1}$.

- Figure 4: The cumulative photon count and count rate remain relatively low for approximately 15 ks into the observation, where the source then turns on.
- Figure 5: In the cumulative photon count plot, the slope remains relatively constant up until approximately 150 ks, where it goes to 0, then starts to increase again. This signature becomes much more noticeable in the count rate plot below, where we see a sharp dip at 150 ks. This dip lasts for a total of 5 ks. This signature has been published by Wang et al. 2018, Terashima et al. 2006, Armitage et al. 1996 and Frank et al. 1987. Wang et al. 2018 theorizes that it may have been caused by a clump of matter in the outer region of the accretion disc passing in front of the X-ray region, causing an eclipse. We are working on an alternative model where it may have been caused by a transiting planet.

Conclusions and Future Work

Using archived *Chandra* data, we have presented the light curves of X-ray binaries containing significant variability in M51, M101, and M104. We have focused on the variability that corresponds to dips and flares, and have found 3 flares corresponding to a source in all 3 galaxies and possibly 2 dips corresponding to the same X-ray source in M51. We are continuing these investigations, which will include sources in other galaxies, and we are also searching for periodicities. Additionally, we may incorporate machine learning to help identify flares, dips, and periodic behavior.

References

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