Finding X-ray Cycles in Low Mass Stars

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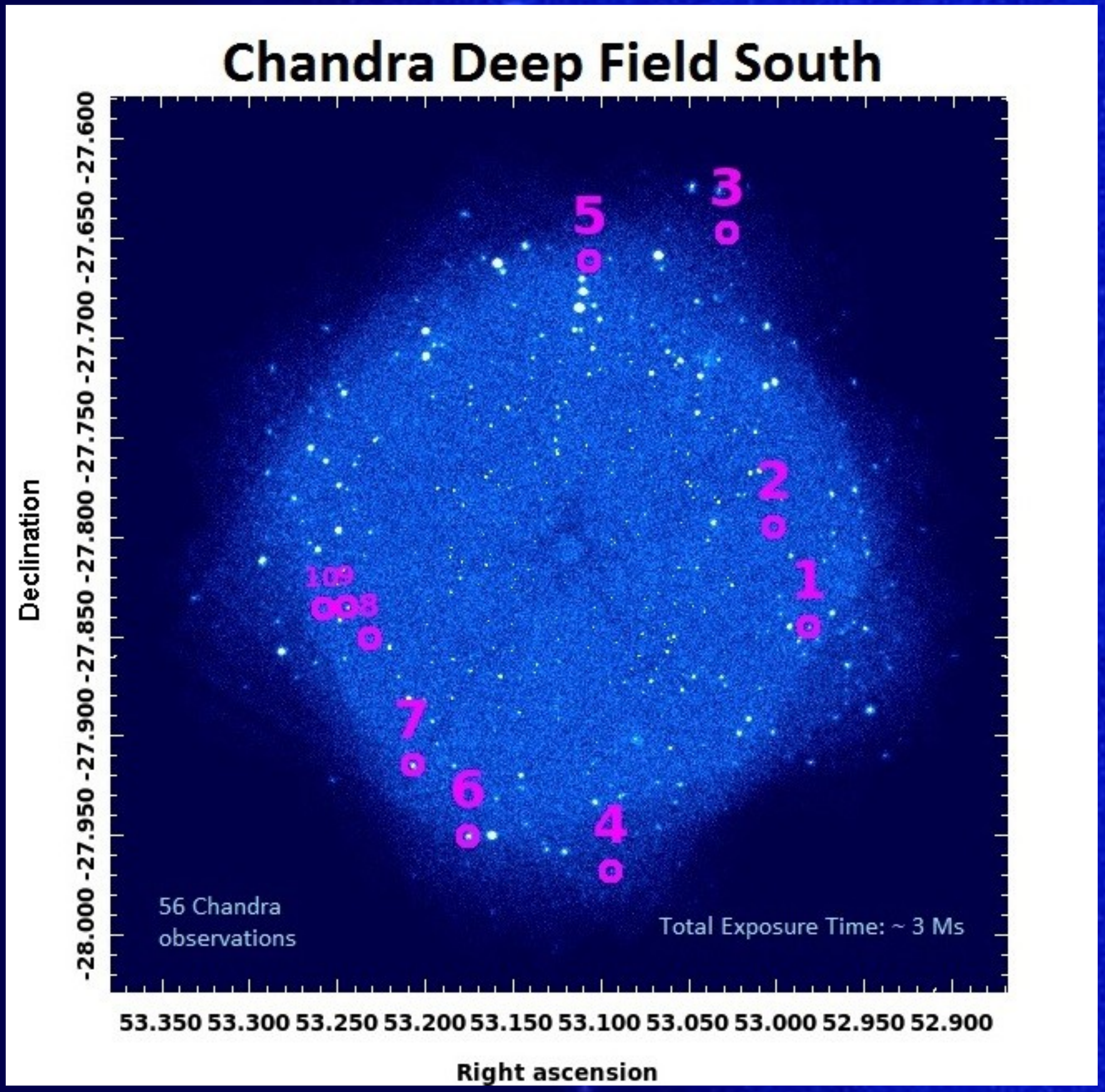
The full report of this research can be found at http://hea-www.cfa.harvard.edu/~guenther/pdfs/M_Wilson.pdf

We seek to increase the number of stars known to have an X-ray coronal cycle. Four stars (including the Sun) are known to experience periodic long-term coronal flux variability but the statistics are not superb. In this analysis, we analyze four stellar sources that have been observed frequently by Chandra and XMM-Newton over the last ~11 years. These four sources were the brightest among numerous stellar point sources within the Chandra Deep Field South. Solar flares can dramatically increase the flux measured for our stars on short time intervals and, in observations with insufficient time coverage, can be confused for the maximum of the stars' magnetic cycles (if they have one). We have discarded times where solar proton flares are detected in the data. We utilize an APEC model, which represents the coronal plasma, to fit our stellar spectra. As our sources are very faint, we do not subtract the background, but instead we fit the background and source spectra simultaneously. We use the chi-squared statistic to evaluate the confidence of our fits. We present four light curves which suggest that a long-term X-ray flux variability similar to our Sun (the solar X-ray flux can vary by a factor of 10 over ~11 years) is not present in these stellar sources. None of our stars experienced a flux variability exceeding a factor of 3 over an 11 year time scale but one of the four stars in our sample exhibits short term variability over a one year period. However, our stellar sources are too faint to conclusively state that the flux remains constant throughout all epochs.

X-ray Observations

In this analysis, **nine stars**, that have been observed repeatedly by *Chandra* and *XMM-Newton*, are analyzed as potential **candidates for detecting cyclic variability** in their magnetic activity. These nine were chosen because they all are in the Chandra Deep Field South (CDFS). *Chandra* and *XMM-Newton* have **observed them frequently for over a decade** and will continue to do so in the future. This field is primarily observed for studying galaxies. However, there are stellar point sources seen near the edge of this field. Although these point sources are faint, both X-ray observatories have gathered much data over the years since their missions commenced. Because of the long length of time these stars were observed, it is likely that we may discern flux variability over a long time period similar to our Sun's magnetic cycle.



Exposure corrected mosaic image of 56 Chandra deep field south observations. This image covers an energy range of 0.5 – 6.0 keV and only the ACIS-I (ccd id = 0 – 3) detector of Chandra. The total exposure time of this image is 3.8 Ms.

Circles' size is exaggerated to allow observer to see how faint the point sources are. ACIS-I detectors are rotating over time, and thus point sources on edge of CCD chip are not visible in all observations. (e.g. sources 6, 7, and 9). The tenth star was discarded due to its excessively faint signal.

References

Lomb, N. R. 1976, Ap&SS, 39, 447
Scargle, J. D. 1982, ApJ, 263, 835

Acknowledgements

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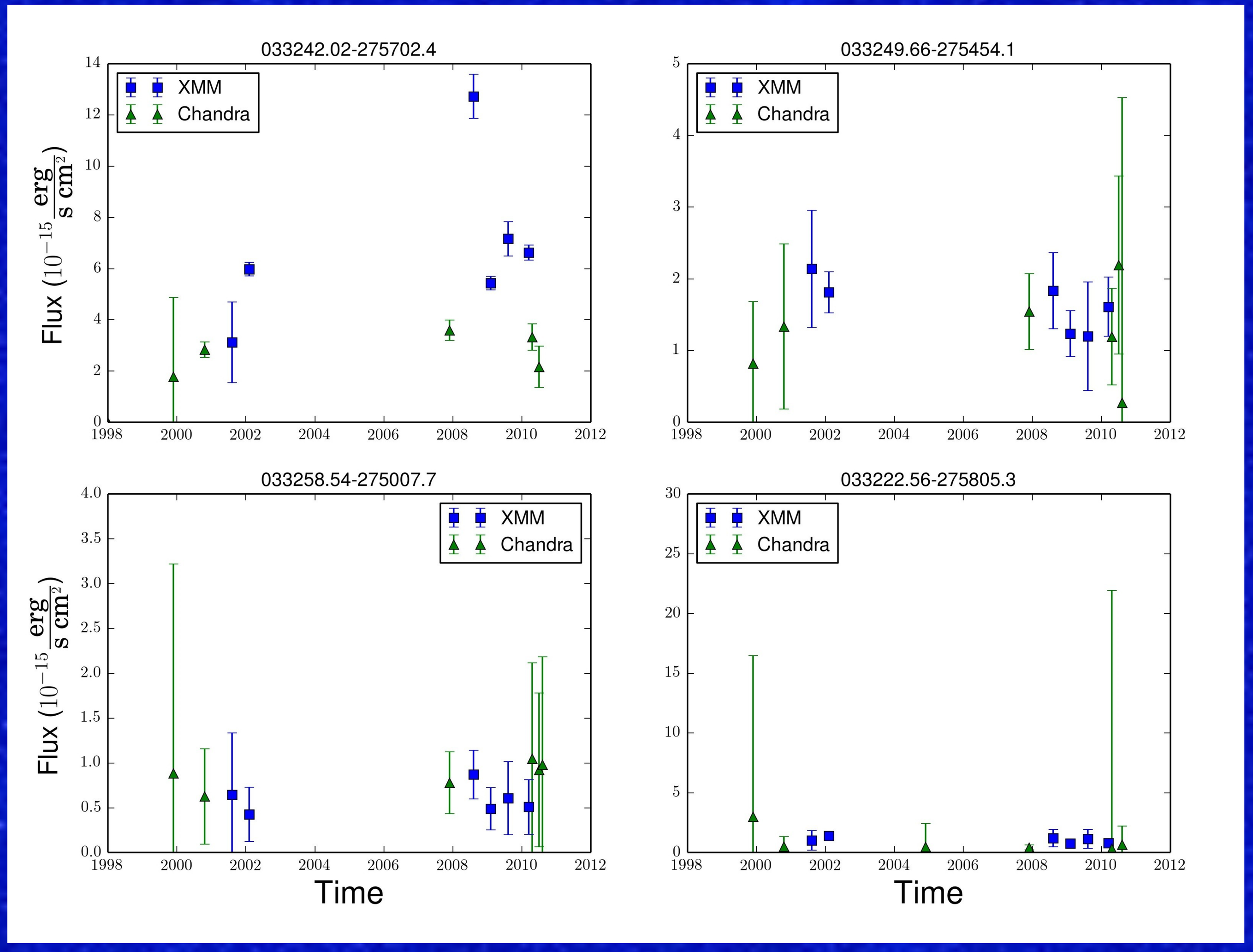
Four Resultant Light Curves

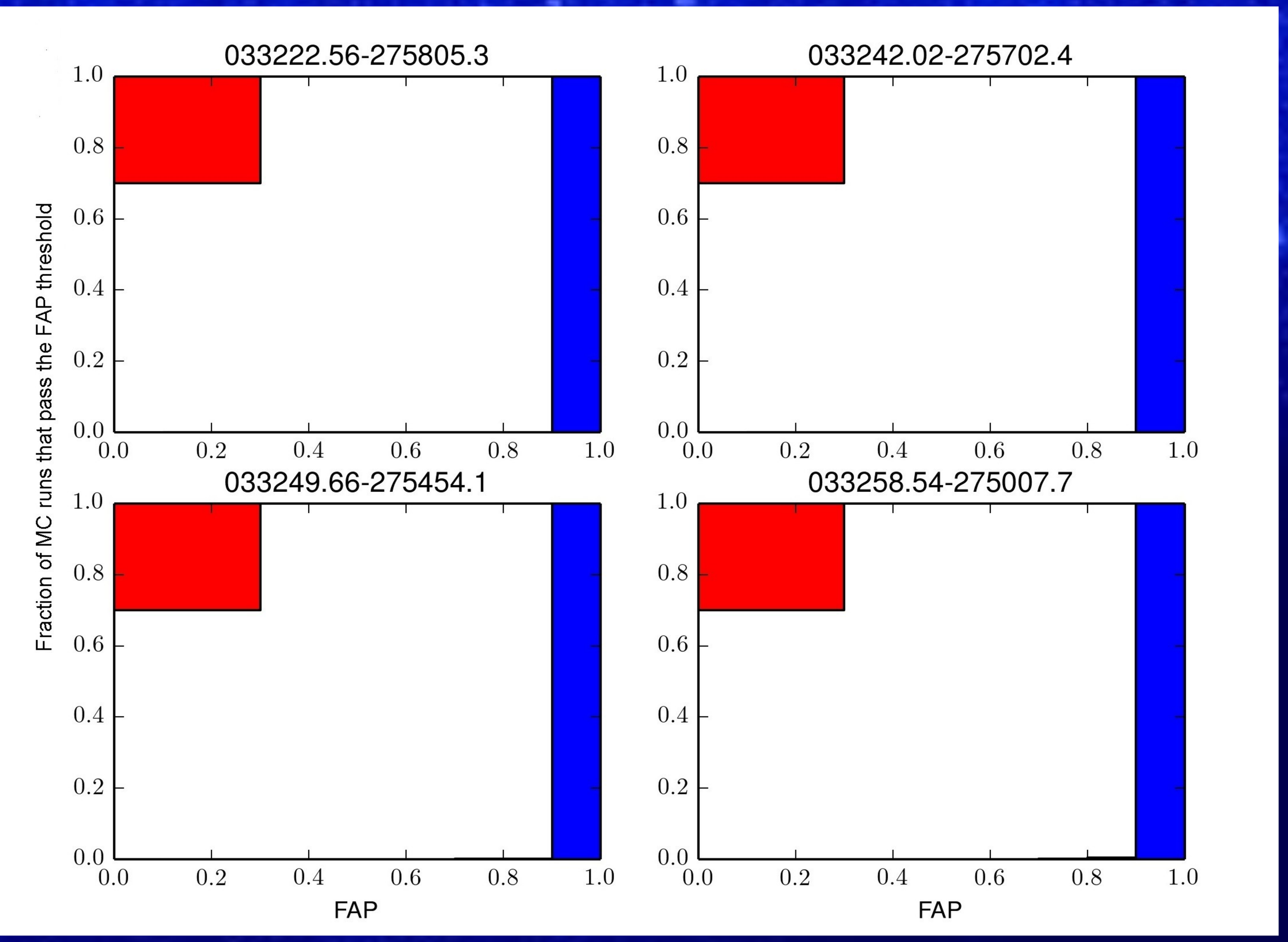
Four light curves are presented for the four brightest sources. Some of the large errors are due to short observations (with exposure times of ~10 ks) within certain epochs. In all four light curves, the *XMM-Newton* fluxes have smaller error bars than the *Chandra* fluxes. The *XMM-Newton* data provided stricter constraints than for the *Chandra* data. Nonetheless, valuable information can be extracted from the light curves in regards to the sources' long term variability, only if we use the days from both observatories to obtain the maximal time coverage.



We have concluded that none of our sources exhibit flux variability of a factor of ~10 like the Sun. Source #6 (033242.02-274702.4) seems to be the best candidate within our nine star sample for possibly having a long-term coronal cycle. However, **none of the four light curves** suggest that any of the sources express a long-term variability **above a factor of 3.** Despite the lack of variability illustrated by the plots, we cannot confidently conclude that any of the sources do not have a coronal activity cycle. This is primarily due to the lack of data within the large gap of ~6 years between 2002 and 2008.

Conclusions and Ongoing Work

To determine if any of the light curves exhibit periodic behavior, we use the Lomb-Scargle periodogram (LSP; Lomb 1976; Scargle 1982). This LSP yields the frequency of the sinusoidal function that best fits the data. It also provides the "false alarm probability" (FAP) of the strongest periodicity found, which is the probability that periodic behavior of a selected strength could be seen in Gaussian noise, as opposed to the source's signal. We run Monte Carlo (MC) simulations to account for the uncertainties that vary from observation to observation.



We consider a light curve to be periodic if 68% of all MC trials indicate it to have an FAP < 0.30.

These plots show a cumulative, normalized histogram in blue (i.e. the last bin always is always 1) of the FAP for the MC run. The first bin shows the fraction of runs with FAP < 0.1, the second bin shows the fraction of runs with FAP < 0.2, and so on. If the histogram hits the red area, then we have detected a significant cycle according to the definition above (at least 68% of all runs have FAP < 0.3). We **do not detect any periodicity** within our detection limits.

This lack of periodicity detected is not surprising when considering that our sources (including the four brightest) are very faint compared to their background noise. Our results do not convey the possibility of a solar cycle because the data is currently not good enough.

This analysis attests to the difficulty of conclusively discovering long-term X-ray coronal cycles **without the initial aid of the Ca II H and K emission** information from the stellar chromospheres.

These stars will receive further scrutiny once Chandra completes its new observations of the CDFS (for a total of 3 Ms), which will certainly give us plenty of data **that will substantially decrease the flux uncertainties** in the light curves to be produced later. Only then will we be able to confidently conclude whether or not our stellar sources have magnetic activity cycles in their coronae.