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ASTR 499 Winter 2022 Report

1. Background

Active Galactic Nuclei (AGN) are supermassive blackholes at the center of galaxies. Material falling into the blackholes emits large amounts of light at all wavelengths. The apparent magnitude of this light is often much greater than the host galaxy and varies greatly on a day-to-day basis. The latter suggests that the variability of the light curves must be a stochastic process.

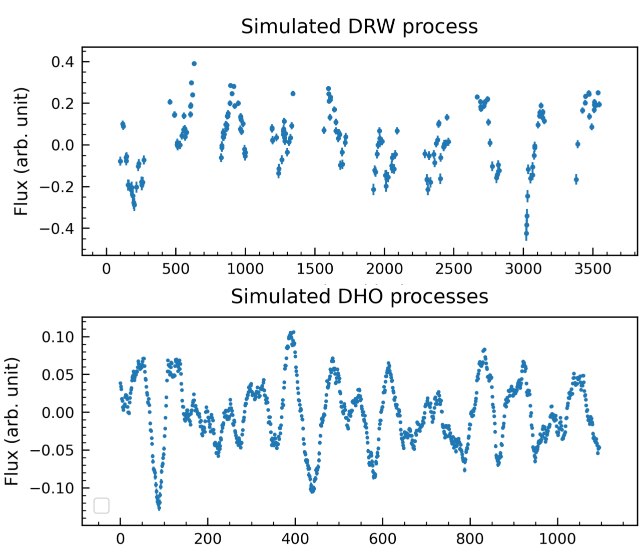
2. Main Goals

The main objective of this project is to fit a model to AGN light curves. Doing so might provide insight as to which properties influence the perceived randomness of their luminosity.

Additional topics explored are Time Series, Markov chain Monte Carlo (MCMC), and a deeper understanding of the properties of AGN.

3. Methodology

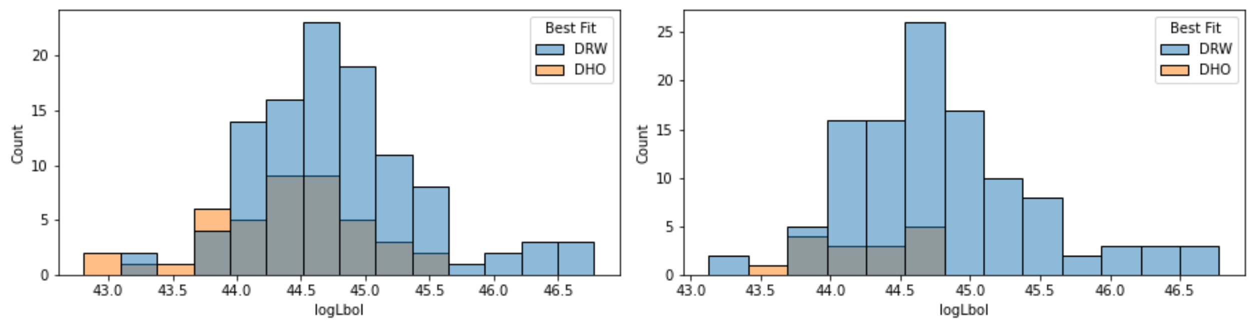
We used 384 AGN that were identified by the Swift Burst Alert Telescope (BAT) and analyzed by the BAT AGN Spectroscopic Survey group. The light curves were observed from the Zwicky Transient Facility.



The models used to fit the AGN light curves were Continuous-time Autoregressive Moving Average (CARMA) processes made available in the Python package, EzTao. More specifically, we compared the fits of a Damped Random Walk (DRW) and a Damped Harmonic Oscillator (DHO). To better ensure our fits were accurate, an MCMC process was used in conjunction with the DHO process to find the best possible fit. Determining the best process–either DRW or DHO–was accomplished by comparing the results of the chi-sqared test on the simulated light curves generated by the processes.

4. Data and Results

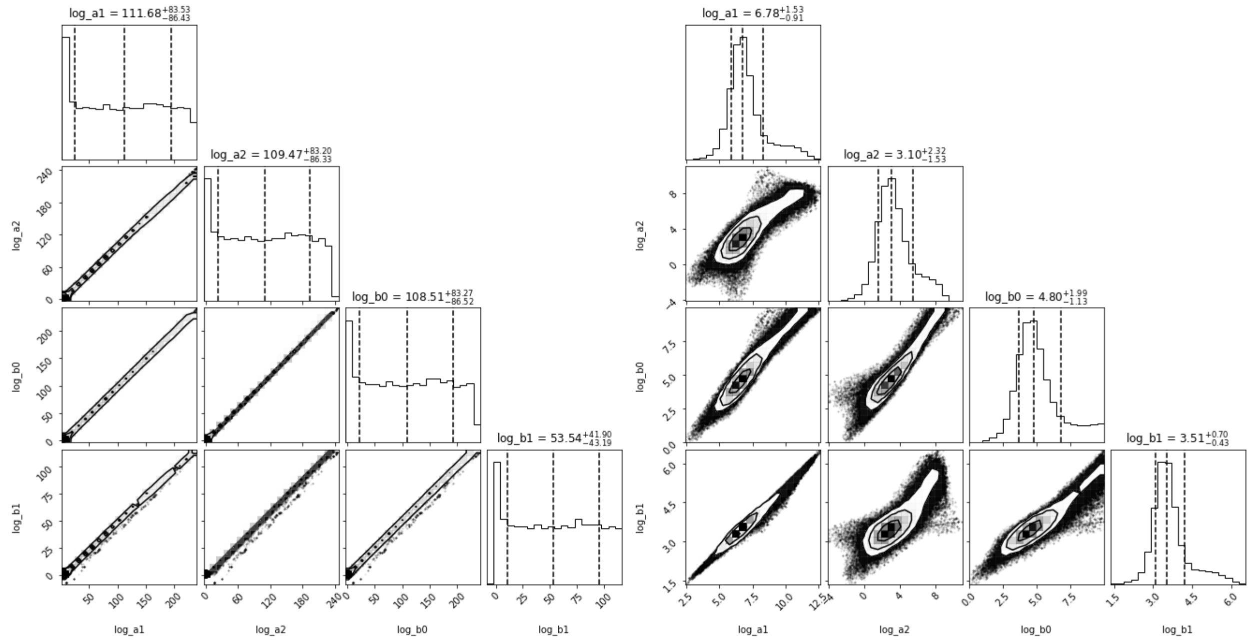
Running the DRW and DHO processes on the AGN light curves showed that the DHO processes work best when applied to light curves of relatively lower bolometric luminosity. However, early on we identified an issue with the DHO processes where many of the simulated light curves included NaN values. Further analysis showed that these values were all positive infinity. Removing the AGN from the dataset that included values of infinity in their simulated DHO light curves presented the same results.



The histogram on the left is of the DRW and DHO processes plotted against the bolometric luminosity–including the AGN that presented values of infinity in their simulated DHO light curves. The histogram on the right excludes those AGN from the dataset.

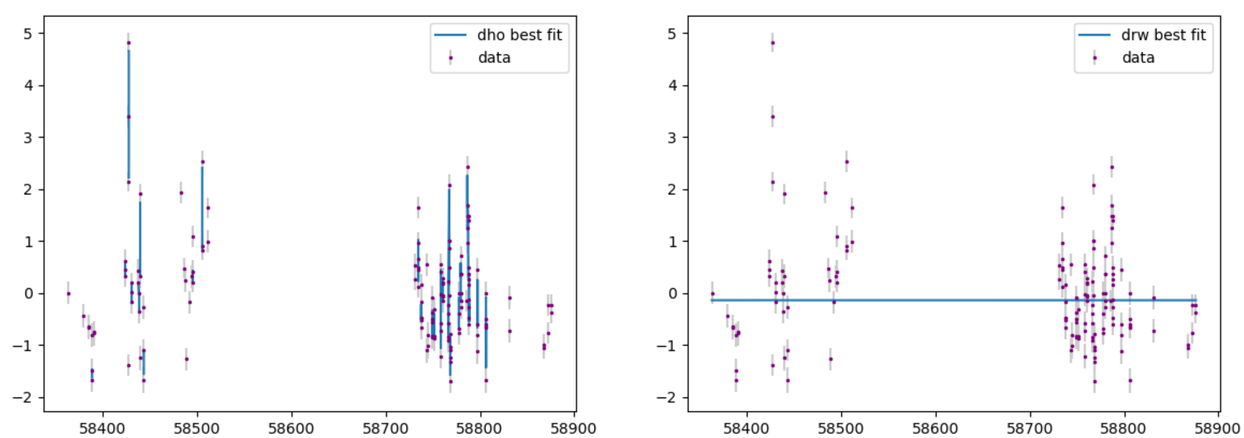
So far no, no source has been identified as to why some simulated DHO light curves include infinity.

To attempt at combating this dilemma, an MCMC was applied when finding the DHO fit. In addition, bounds were applied which would prevent the absolute value of the DRW and DHO terms from getting too large. After applying the MCMC and bounds, no change in the simulated light curves was noticed, however, there was a major improvement in the quality of the DHO fits.



Corner plot of the DHO terms before and after using MCMC for the AGN 2.2982 -0.6152 ZTFG.

This is not all to say that the DRW fits are perfect. Many of the simulated DRW light curves produced a line with slope of zero.



Simulated light curves for the DHO and DRW processes on the AGN 78.8324 18.9143 ZTFG. The plot on the left is for DHO, and the right is DRW. The purple points are the real values from our data.

5. Conclusion

MCMC has proven to be an excellent tool for finding the best DHO terms. In the future, it would be worth applying to the DRW processes as well.

A cause for the appearance of positive infinity in the simulated DHO light curves is still unknown. Finding the cause might be useful in producing more accurate fits.