Title: Modelling the Pause Phenomenon in X-ray Bursts from Low-Mass X-ray Binaries
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Introduction

This project investigated nuclear explosions on the surface of neutron stars. High energy photons (X-rays) emitted during explosions are used to study these 'bursts', by plotting the X-ray counts against time we can see how a neutron star behaves before, during, and after an explosion. By examining the shape of the burst we can learn details about the explosion - how quickly it began, how long it lasted, and if anything unusual happened.

My work focused on an unusual feature found in 2019, a pause in counts during the initial rise of an explosion. For context on why a pause in a rise phase is so intriguing, imagine you let a ball role down a hill and halfway down it just stops for a second, before carrying on. Much like a ball gaining momentum, nuclear explosions don't tend to just, pause.

The Physics behind bursts

When a neutron star orbits very tightly around a star similar to our sun, they form what is known as a binary system. In these systems, under special conditions, neutron stars can pull matter from its companion star due to their insense gravity. This matter is often Hydrogen, a stars nuclear fuel, and as it begins to pile up on the neutrons stars surface the bottom layers are crushed under the weight of the layers above it. This raises the temperature at the bottom until a critical point is reached, and ignition occurs. Within seconds the explosion spreads to cover the stars surface giving off extremely high-energy photons, X-rays, that we can detect through use of specialised telescopes mounted on the Internation Space Station.

Method of investigation

Alongside the initial discovery, only one other pause is well known. My method of investigation was to attempt to find as many pauses as possible so that future studies might be able to workout key details as to why pauses occur. To achieve this I assess 124 bursts for pauses by first applying quality control filters to remove 'bad' bursts from the data set. I then fitted the bursts.

Fitting refers to the practise of trialling different curves and lines on the data to see which one best fits the overall shape. luckily, programs exist that trail a bunch of different shapes for you and present you with best lines and curves that represent your data, as can be seen in the burst fitted on the next page. The green dots are the data (X-ray counts), the three pink lines are the fit, an initial rise, a pause, and a continuation.

Results

Three bursts were found to have significant pauses:

4U_0513-40 with a pause of **10.07 s ± 0.38** (Shown burst)

4U_1636-536 with a pause of **0.47 s ± 0.053**

4U_1728-34 with a pause of **0.53 s ± 0.014**

Discussion

The first pause found is the strongest by far, more than one method of fitting it resulted in significant values and more importantly, different fittings found the pause to be in the same location and the same length. A very good argument that the pause is real.

The second and third pauses are a little more interesting, while there is definitely something happening at the locations pauses are found, the fitting method used to find them might not have been as accurate as I'd hoped. However, it has left a path for future work to explore.

Conclusions

This work primarily aimed to investigate the pause feature seen in previous plots of bursts. 124 bursts were assessed, and following quality controls alongside other checks not mentioned here. Three significant pauses were found in three different bursts, the first being the most robust and pictured below.

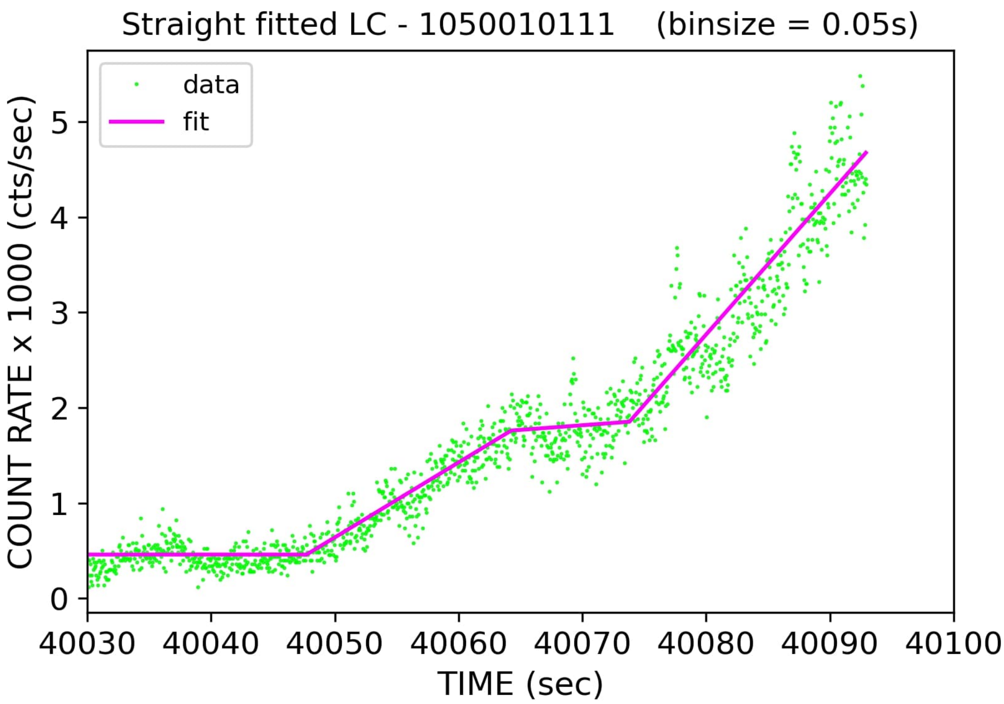

Figure 1: Fitting Light Curve for 4U_0513-40. Showing a clear pause in the second fitted segment.