Investigations of High Energy Astrophysics Data To Understand Magnetars

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ABSTRACT

The purpose of this project was to investigate timing data of the magnetar Swift J1822.3-1606, following its 2011 outburst, in order to determine the evolution of the upper bound of photon energy in the pulsed emission during and after the outburst. We analyzed RXTE observations and used a Fourier transform based method for signal detection. Our result is that following the outburst the energy upper bound of the pulsed emission decays from 9.0 keV to 3.3 keV in about 84 days, after which we did not detect pulsations. Possible future work includes using different methods for signal detection, modeling the pulsed emission mechanism based on its decay and comparing the behaviour of Swift J1822.3-1606 with other similar sources.

Figure 1: RXTE Spacecraft Animation [1]

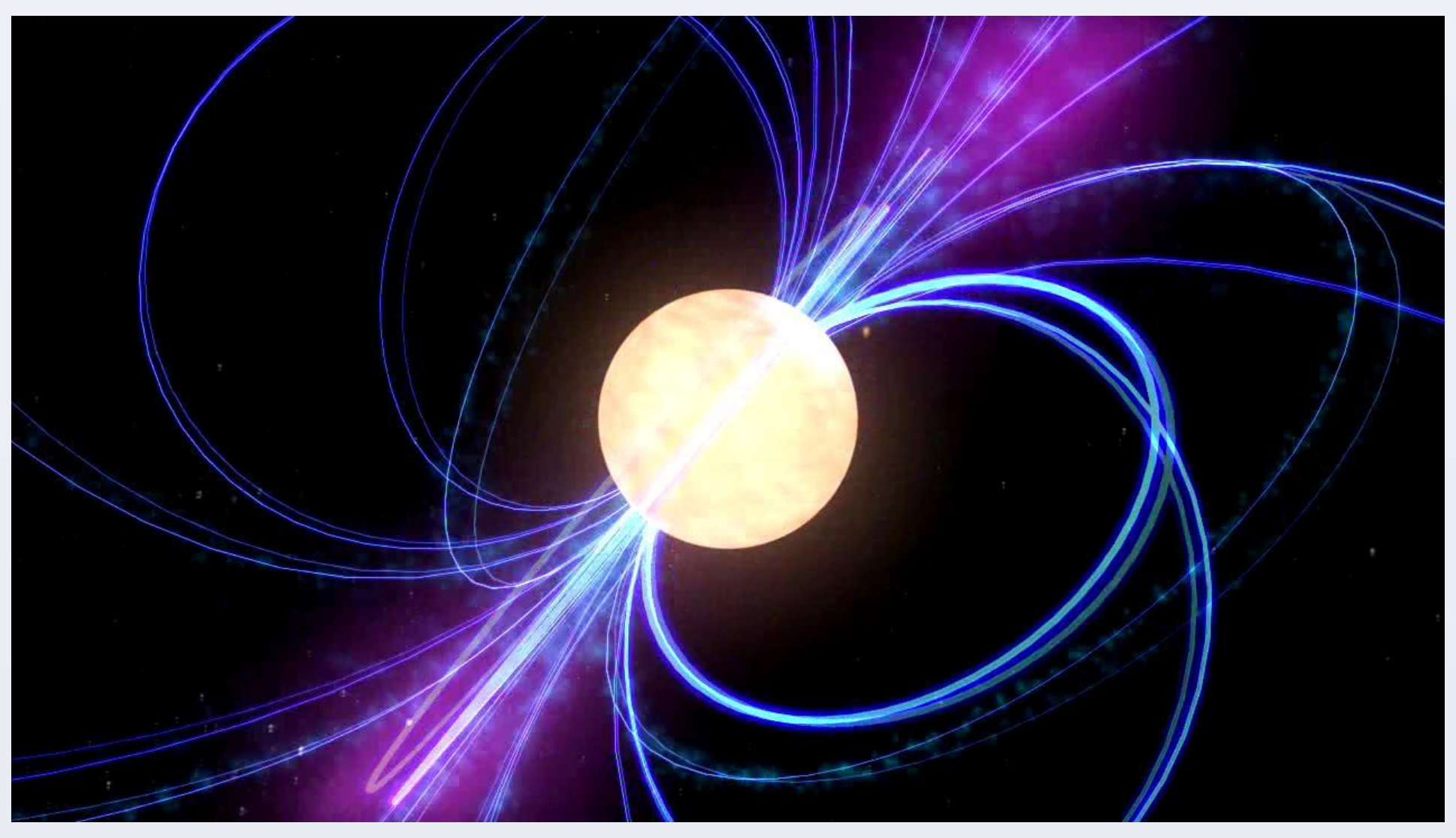

Figure 2: Illustration of a neutron star [2]

Motivation

Magnetars are neutron stars whose emission are powered by their very high magnetic fields of about 10^{14} G. The extreme conditions on magnetars make their study interesting. Swift J1822.3-1606 is a magnetar (Livingstone et al., 2011) that was detected in 2011 (Cummings et al., 2011) during an outburst. This project was aimed to analyze how the pulsed emission energy levels of Swift J1822.3-1606 change after the 2011 outburst.

Observations

We used 33 observations from the Rossi X-Ray Timing Explorer (RXTE) mission's Proportional Counter Array (PCA) instrument (see Figure 1). The observations are from a 135 day period. The observation data consists of photon arrival times and energy levels.

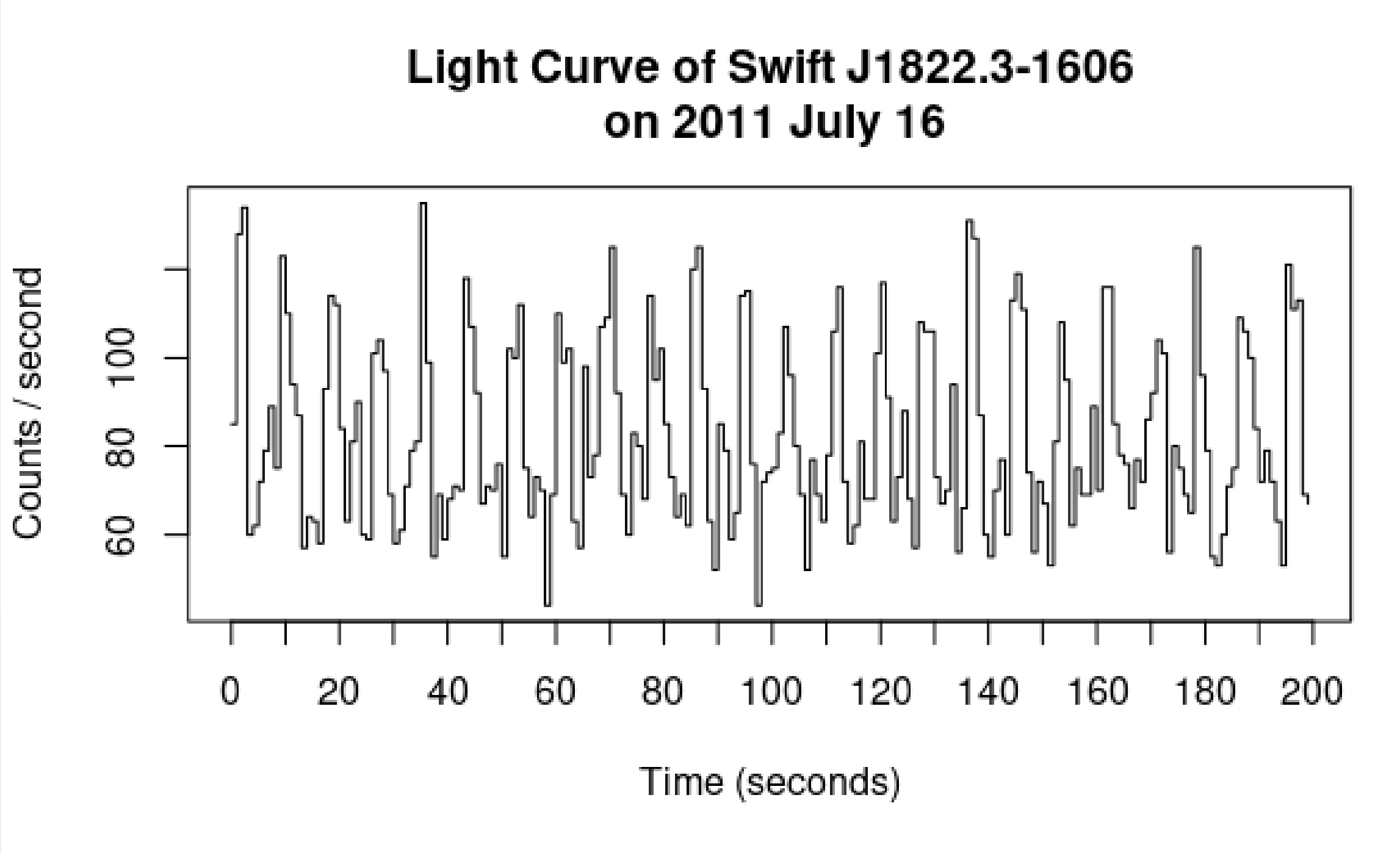

Figure 3: Light curve with 1 second bins.

Data Analysis

We used R platform (version 3.4.1) to perform data analysis and visualization of our results. Times of arrival within the energy range of 2.5 keV to 12.7 keV were grouped into 1s bins, producing the light curve data. The light curve can be considered to be a sampling of the emission intensity (see Figure 2).

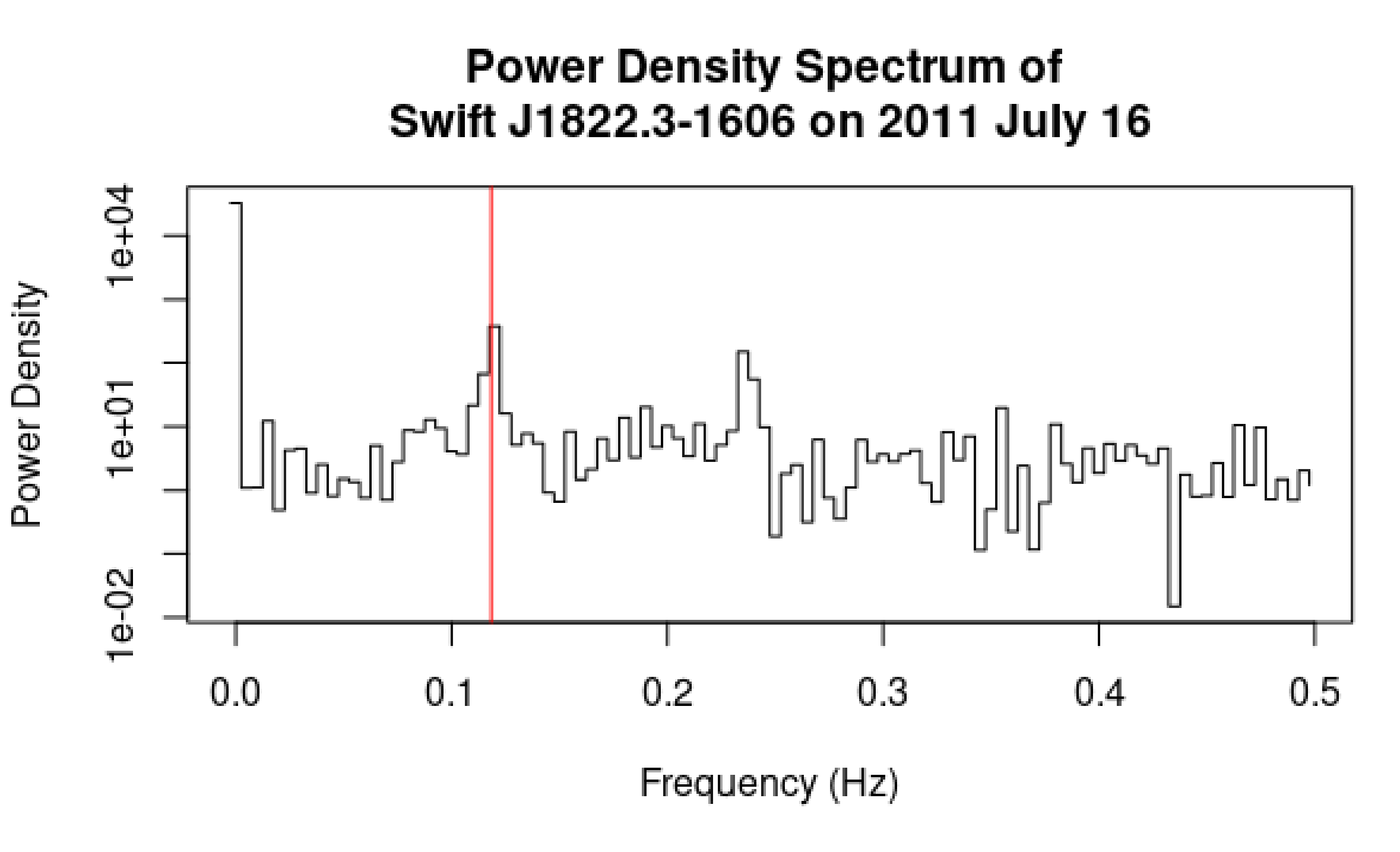

Figure 4:Power density spectrum of the light curve in Figure 3. The red line shows the spin frequency of the source. Note the logarithmic scale on the vertical axis.

We used the Fast Fourier Transform (FFT) to calculate the discrete Fourier transform of the light curves. From the Fourier coefficients we calculate the power density (see Figure 4) using the Leahy normalization (Leahy et al., 1983). By averaging the power density spectra from 100s segments of the observation (see Figure 5), we introduce the uncertainty of the power density, with which we determine the significance of the signal with respect to a noise sample and find the energy level where the signal drops below the 3-sigma significance.

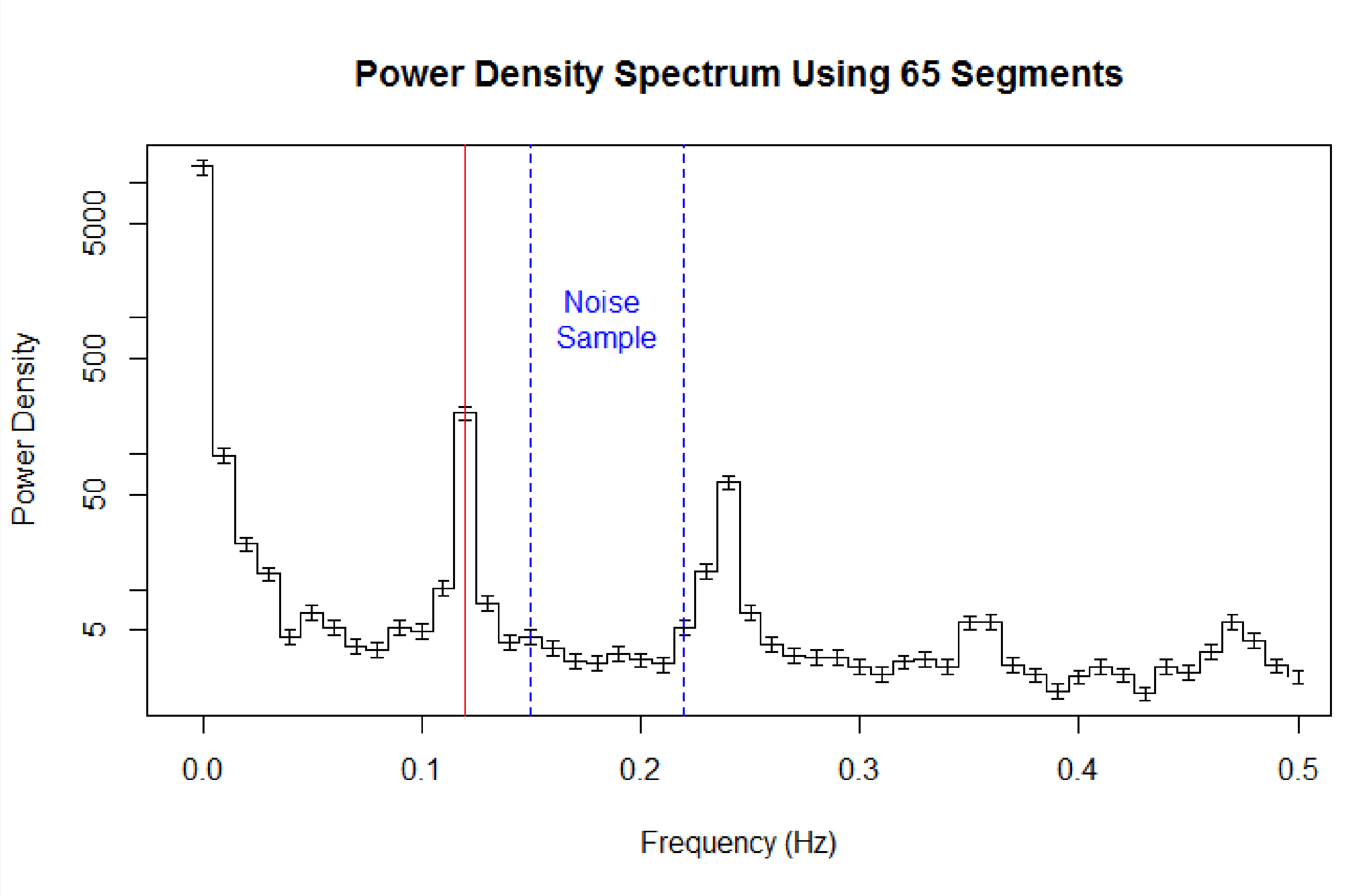

Figure 5: Power Density Spectrum of Swift J1822.3-1606. The red line shows the signal frequncy, the blue dashed lines show the interval used as the noise sample. The bars on the plot points show the error of the power density.

Results

33 observations between 2011 July 16 and 2011 November 28 were analysed. For the last five observations no pulsations with 3-sigma significance were detected by our method. For the remaining 28 observations, we find that the energy upper bound of the pulsed emission decays from 9.0 keV down to 3.3 keV in about 84 days (see Figure 6).

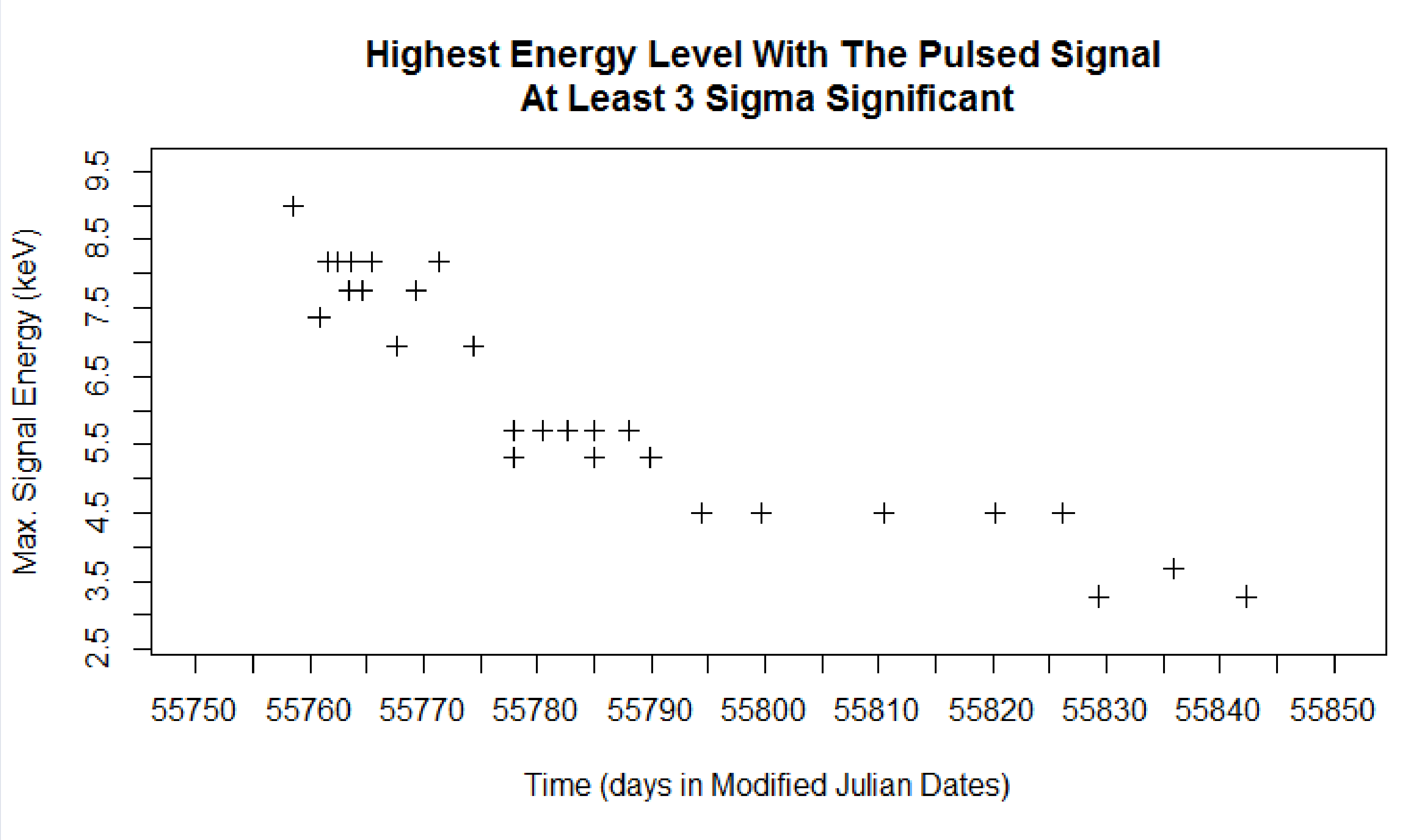

Figure 6: Plot of the maximum energy level with the pulsed signal at least 3 sigma significant vs. the observation times.

Conclusions

In this project, we aimed to determine the maximum photon energy that took place in the process of pulsed signal emission. This way, we would be able to constrain the physical mechanism responsible for the pulsed high-energy X-ray emission. We found that the maximum photon energy of the pulsations evolved from 9.0 keV at the onset of magnetar outburst to 3.3 keV in approximately 84 days (see Figure 6). We do not detect pulsations in the remaining RXTE observations, which indicate that the underlying mechanism was possibly ceased.

Future Work

- Fitting the observed decay with models.
- Employing a wavelet transform based signal search to identify the signal when the pulsed amplitude is small.
- Investigating other magnetars to check whether the these results are common among magnetars, or unique to Swift J1822.3-1606
- Employing observations from other space based X-ray telescopes to determine the characteristics of the observed time evolution with an independent data sample.

References

Cummings, J. R., Burrows, D., Campana, S., et al. (2011). Swift J1822.3-1606: A Probable New SGR in Ground Analysis of BAT Data. The Astronomer's Telegram. ATel #3488

Leahy, D. A., Darbro, W., Elsner, R. F., Weisskopf, M. C., Sutherland, P. G., Kahn, S., Grindlay, J. E. (1983). On searches for pulsed emission with application to four globular cluster X-ray sources - NGC 1851, 6441, 6624, and 6712. The Astrophysical Journal, 266 (1), 160-170. doi:10.1086/160766

Livingstone, M. A., Scholz, P., Kaspi, V. M., Ng C.-Y., Gavriil, F. P. (2011). The Spin-down of Swift J1822.3−1606: A New Galactic Magnetar. The Astrophysical Journal Letters, 743 (2), L38. doi:10.1088/2041-8205/743/2/L38

[1] Image credit: NASA. [2] Image credit: NASA.