Classification of system variability using a CNN

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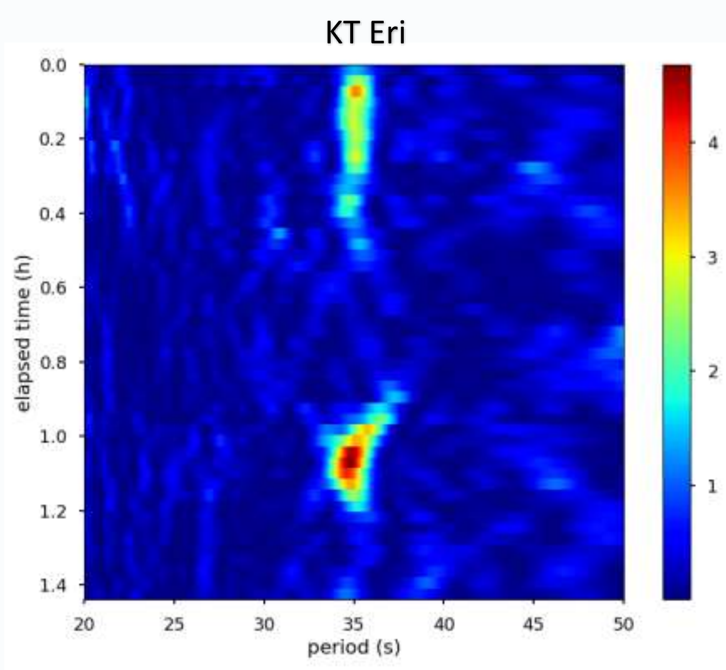
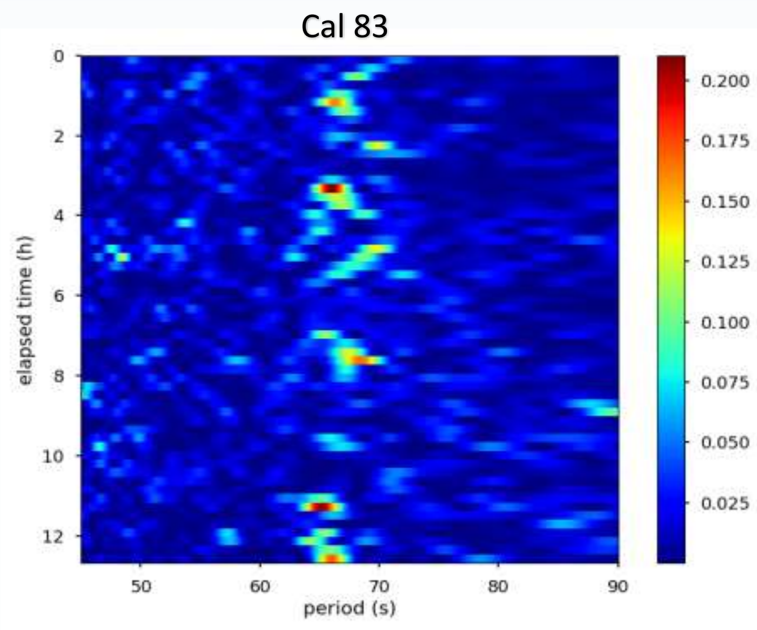
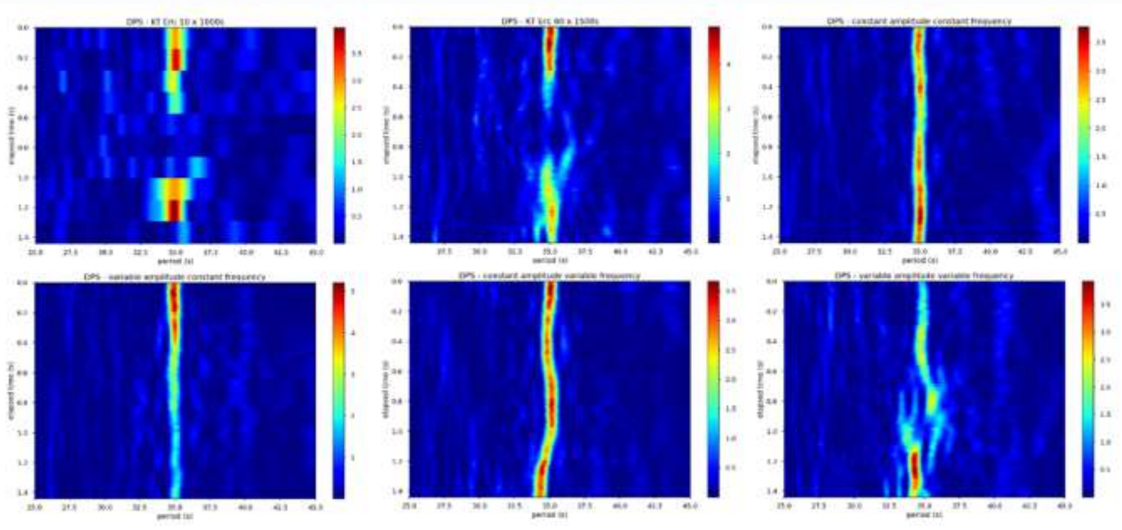
Abstract

The nature of detected variability (whether the frequency is variable or stable) is decisive in binary systems. By creating a light curve and then a periodogram from the detected signal, it is possible to determine the significance of certain frequencies as well as their character. Dobrotka & Ness (2017) [1] demonstrated, that a typical double-peak pattern in periodogram can be the result not only of two close frequencies, but also of one frequency with a variable amplitude. This suggests, that a misinterpretation of a white dwarf (WD) rotation as a pulsation on the WD surface is possible. Therefore we implemented a CNN algorithm in order to find some hidden features in the DPSs and subsequently identify the type of variability correctly. We performed multiple simulations of light curves with different types of variability based on XMM-Newton observations of binaries Cal 83 and KT Eri. Both systems were discussed as probably variable in frequency (Ness et al. 2017) [2]. By creating their dynamic power spectra (DPS) and using convolutional neural network (CNN) AlexNet algorithm we tried to find out, whether it is possible to distinguish between variability in amplitude and variability in frequency.

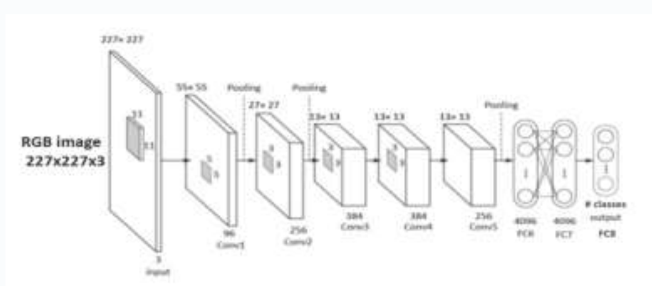




Data Simulation & CNN



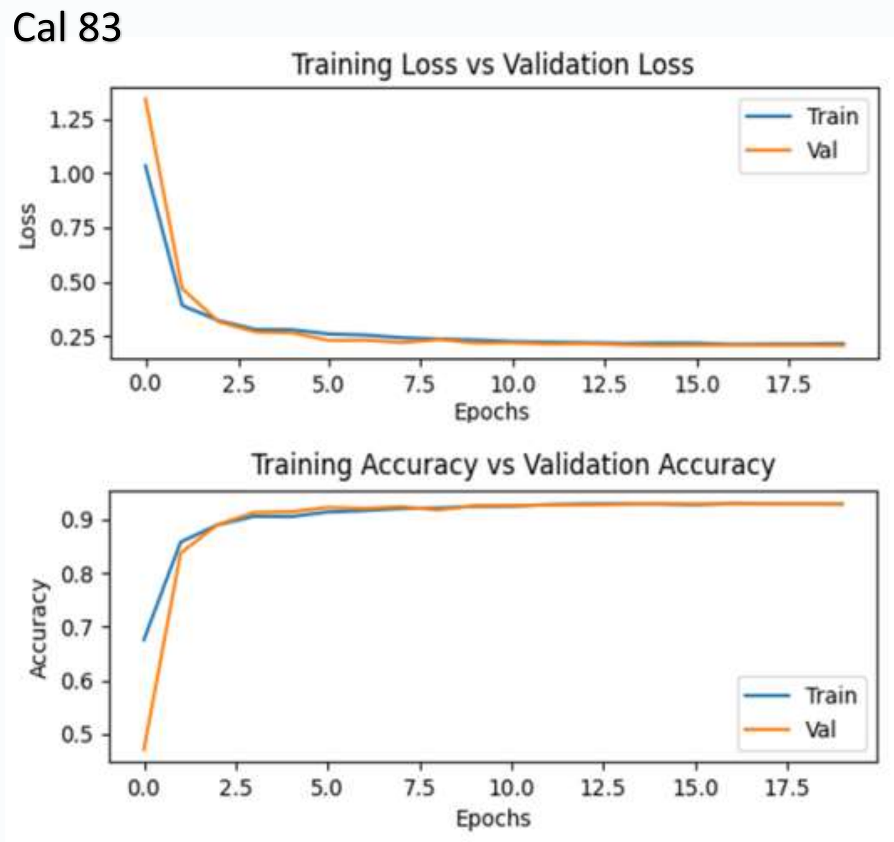
- 20 000 DPSs for every type of variability
- created DPSs as in Ness et al. 2017
  - each row of 1500s snapshot and 62s overlap
  - higher resolution to better detect the variability



- AlexNet arch.
- TensorFlow

Results

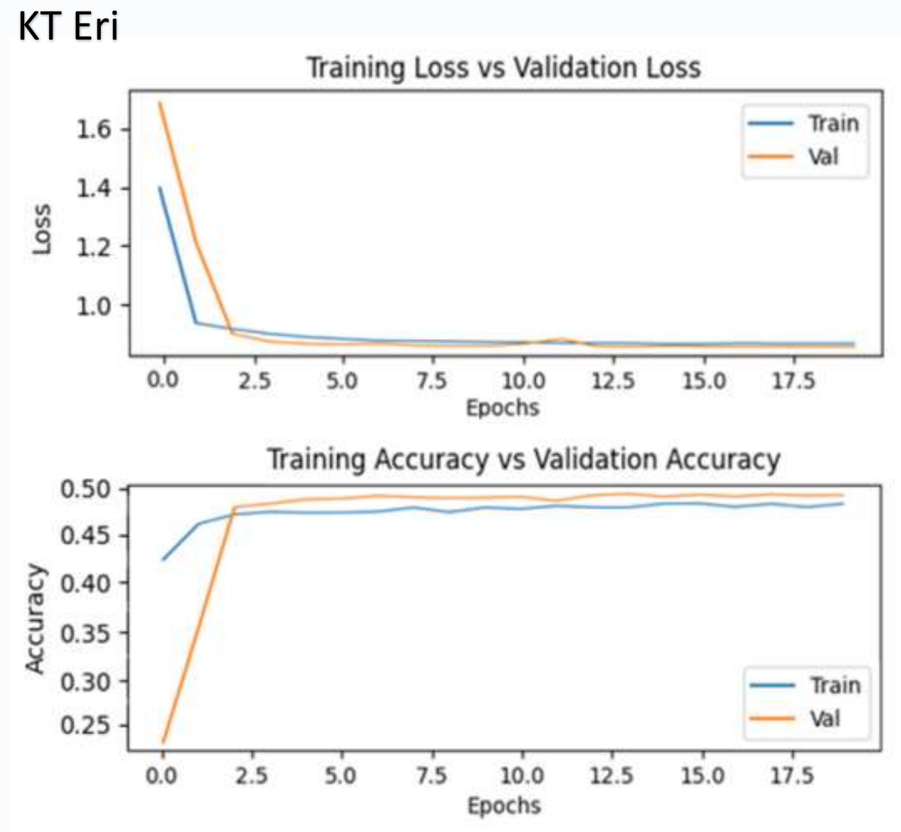
Cal 83



The Cal 83 was classified as:

- constant amplitude & constant frequency - 0.00%
- variable amplitude & constant frequency - 0.03%
- constant amplitude & variable frequency - 0.00%
- variable amplitude & variable frequency - 99.97%

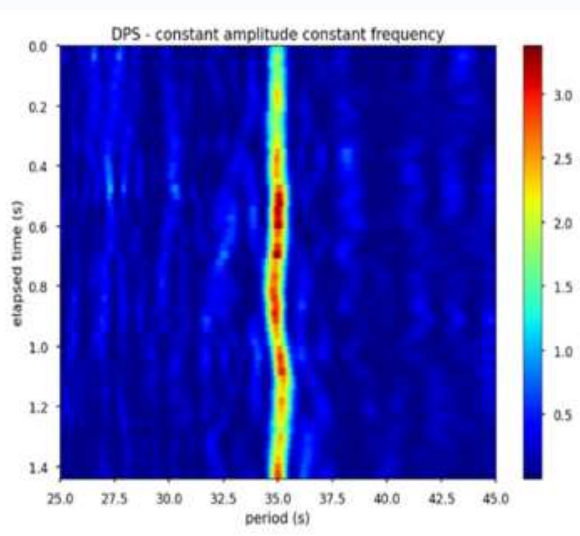
KT Eri

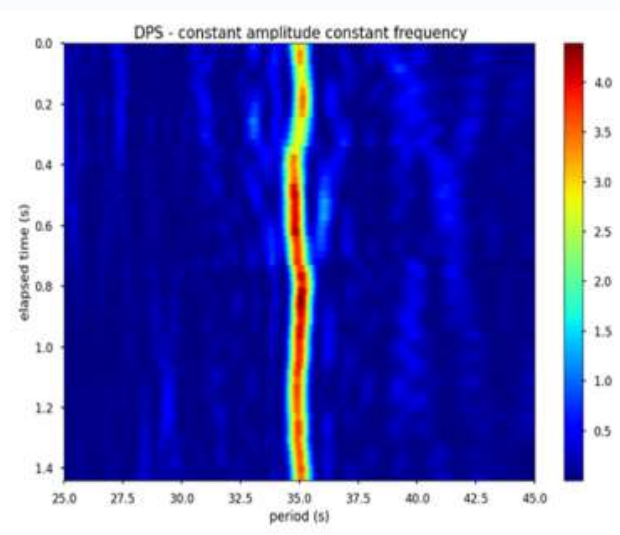


The KT Eri was classified as:

- constant amplitude & constant frequency - 0.01%
- variable amplitude & constant frequency - 0.01%
- constant amplitude & variable frequency - 51.07%
- variable amplitude & variable frequency - 48.91%

Discussion





We used the AlexNet CNN architecture to determine if it is able to detect some hidden features and classify the type of variability by which the observed systems are modulated. The CNN trained on simulated Cal 83 data reports 92% accuracy and the system itself was classified as variable in amplitude and frequency, unlike in the paper, where it was classified as variable in frequency only. On the other hand, the CNN trained on simulated KT Eri data did not perform well. The accuracy around 50% is too low to reliably classify any system and data verification will be required. We also found some DPSs similar to those simulated with variable frequency, but constant frequency and constant amplitude was used here. Therefore we will need to look deeper into data and also determine the statistical significance of such results. If the constant frequency with noise alone can mimic the variability in frequency, that will give us new insight on the variability in systems.

Future work

To create a DPS requires extensive data processing. Next we want to repeat the learning process, but this time with periodograms and then only with light curves. We want to avoid unnecessary data intervention and reduce the risk of unwanted inputs to the CNN algorithm.

References

[1] A. Dobrotka, J.-U. Ness. Counter evidence against multiple frequency nature of 0.75 mHz oscillation in V4743 Sgr. Royal Astronomical Society, 2017

[2] J.-U. Ness at all. Short-period X-ray oscillations in super-soft novae and persistent super-soft sources. Astronomy & Astrophysics, 2018

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