Prediction of photometric parameters of overcontact eclipsing binaries using deep-learning model

Š. Parimucha[1], M. Vaňko[2], P. Gajdoš[1,3], Y. Markus[1], V. Kudak[4]

[1] Institute of Physics, Faculty of Science, Pavol Jozef Šafárik University, Košice, Slovakia, stefan.parimucha@upjs.sk
[2] Astronomical Institute of Slovak Academy of Sciences, Taranská Lomnica, Slovakia
[3] Astronomical Institute of the Czech Academy of Sciences, Ondřejov, The Czech Republic
[4] Laboratory of Space Researches, Uzhhorod National University, Uzhhorod, Ukraine

INTRODUCTION

Eclipsing binary stars of the **W UMa type** (**overcontact binaries**) are among the most frequently found variable stars because of their short orbital period (up to ~1 d) and typical light curve shape. Space- and ground-based surveys (e.g., OGLE, SuperWasp, ZTF, Kepler, TESS, GAIA) have discovered several tens of thousands of such systems, but only small fraction of them have determined parameters.

For the analysis of light curves with no spots presented on the surface of the stars only 4 parameters are needed:

i – orbital inclination
q – photometric mass ratio
t_1/t_2 – temperature ratio
$\Omega_{1,2}$ – common potential

These parameters determine shapes of the stars, their relative dimensions and radiation properties. Solution with spot is more complicated, we need to add another 4 parameters for each spot.

For the determination of these parameters for a large set of overcontact binaries we can use methods based on deep-learning.

TRAINING AND EVALUATION DATASET

- training dataset was created with ELISa code (Čokina et. al, 2021)
- light-curves of overcontact binaries were simulated from parameters covering a wide range of physically correct values of stars using random uniform distribution in used intervals

Parameter	Interval of parameters for simulation
i	40-90˚
q	0.05-2.0
t_1/t_2	1.0 – 1.3
$\Omega_{1,2}$	2.0 – 4.0
Period	0.1 – 1.5

- 500 000 LCs were created in GAIA G passband
- for the evaluation of our model, we randomly selected 100 LCs of a set of overcontact eclipsing binaries from the GAIA catalogue of eclipsing binaries (classified by the model in Parimucha et. al, 2024). All these light cures were manually fitted using ELISa code to find the basic parameters of the systems
- for machine learning purposes, selected LCs from GAIA were iteratively fitted by a Fourier polynom to remove outliers and rebin curves to 100 points and were finally normalized to the maximum flux.

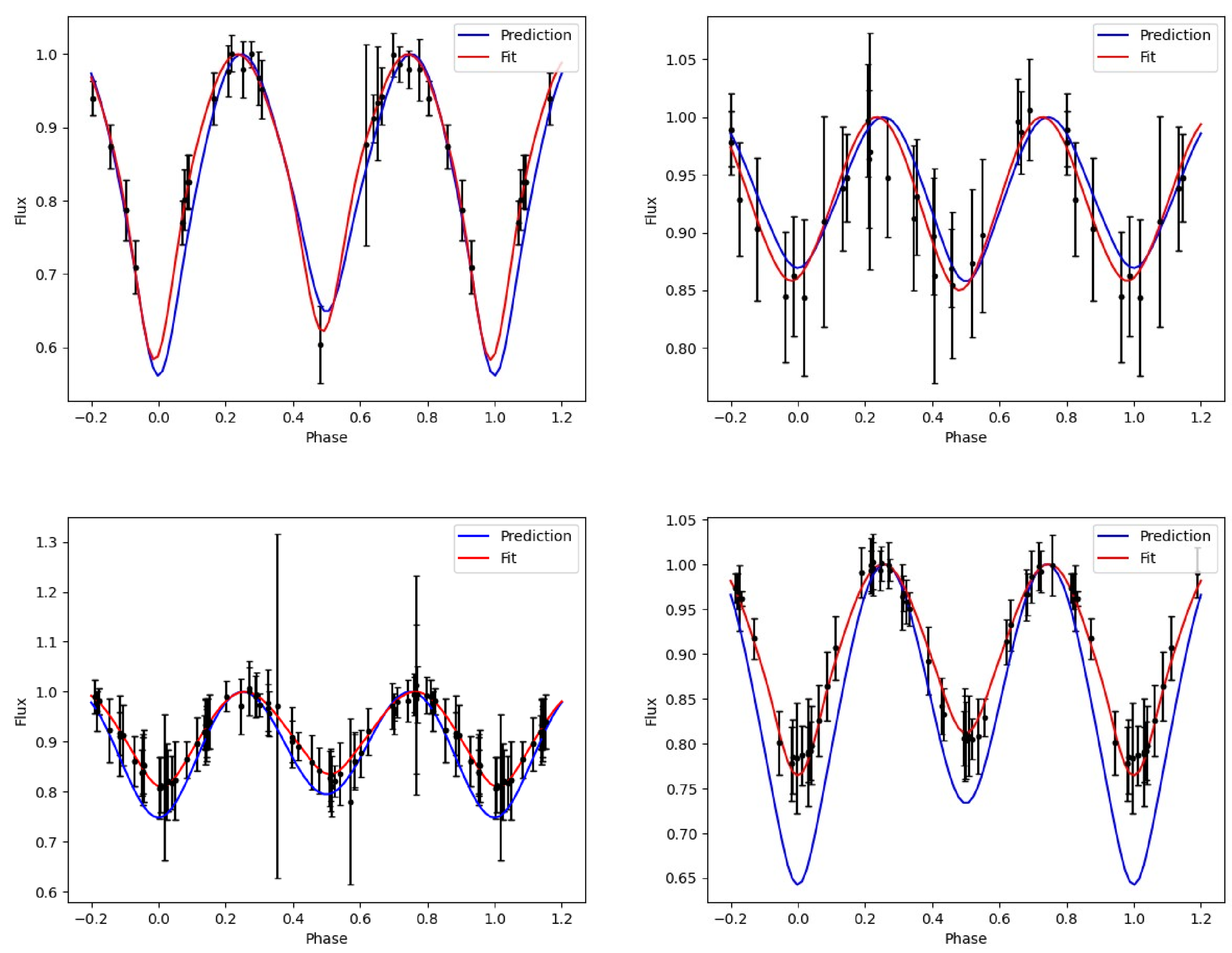
DEEP LEARNING MODEL AND ITS PERFORMANCE

- for the training of our model we used all simulated light curves and dataset was expanded by gaussian noise augmentation. 20% of them were randomly selected for the validation of the trained model.
- the best-tested deep learning model for the prediction of parameters consists of **two connected convolution networks (CNN) with two Long Short-Term Memory (LSTM) networks and three dense networks (DN)**
- mean Absolute Percentage Error (MAPE) of the model on validation data is **9.7%**

Examples of predicted and fitted values of parameters and corresponding light curves

GAIA	i		q		t_1/t_2		$\Omega_{1,2}$	
108221257325561472	72.9	74.9	0.58	0.59	1.07	1.03	2.88	2.98
4077421052072572288	50.1	49.7	1.19	1.22	0.92	0.94	4.05	4.06
4538018812390824704	54.6	55.9	0.53	0.48	1.11	1.09	2.73	2.80
5237931630761461248	62.9	58.5	1.32	1.19	1.17	1.12	3.96	4.00

predicted fitted



CONCLUSION

- our study leads to several conclusions:

  – quality of prediction of parameters strongly depends on the quality of the light curves, we need a good data coverage and remove outliers
  – observed light curve has to be well phase folded
  – space of simulated light curves have to be dense enough – random uniform distribution of parameters is necessary

- predicted parameters can be used as a good starting point for e.g. MCMC fitting to obtain precise results with parameters errors

This research was supported by the Slovak Research and Development Agency under contract No. APVV-20-0148. Y.M. was funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under project No. 09I03-03-V01-00011 and grant UPJŠ VVGS 2024-3096 V.K. was supported by Ukrainian national grant 0122U000937.

SLOVAK RESEARCH AND DEVELOPMENT AGENCY

PLÁN OBNOVY

Financované Európskou úniou NextGenerationEU