Machine learning and eclipsing binaries

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http://astronomy.science.upjs.sk

About...

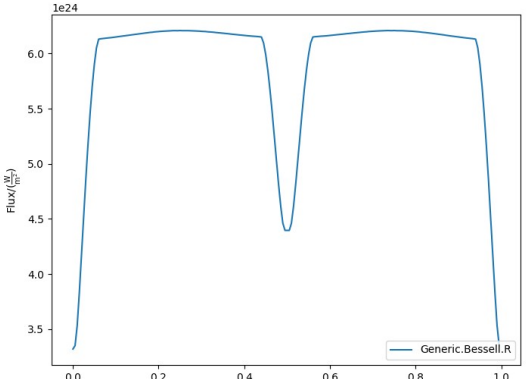
- something briefly about EB
- how we now solve light curves of EB
- main problems in light curves solving and what we can do with it…

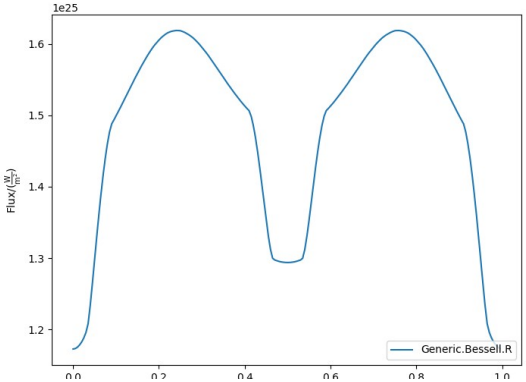
Eclipsing binaries

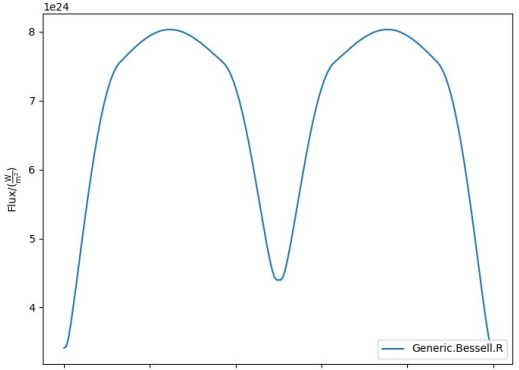
variable stars where change of their brightness is due to mutual eclipses of the components during movement around common mass centre.

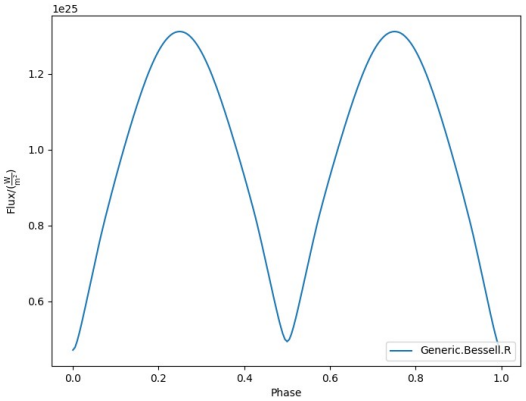
We can detect typical light curve, where almost all informations about components are hidden.

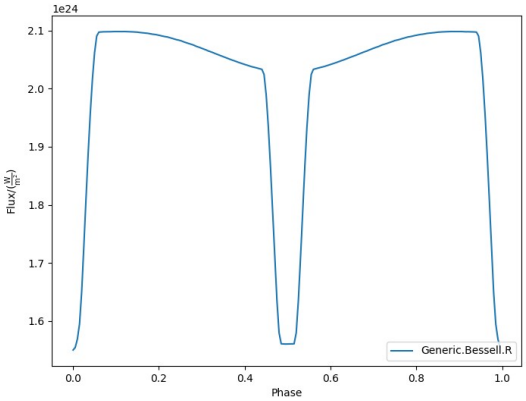
Eclipsing binaries

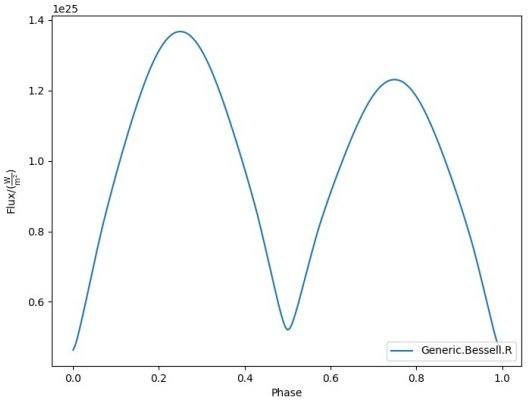












What we want to know about EB?

we need to solve a *light curve* - find **photometric parameters** from LC

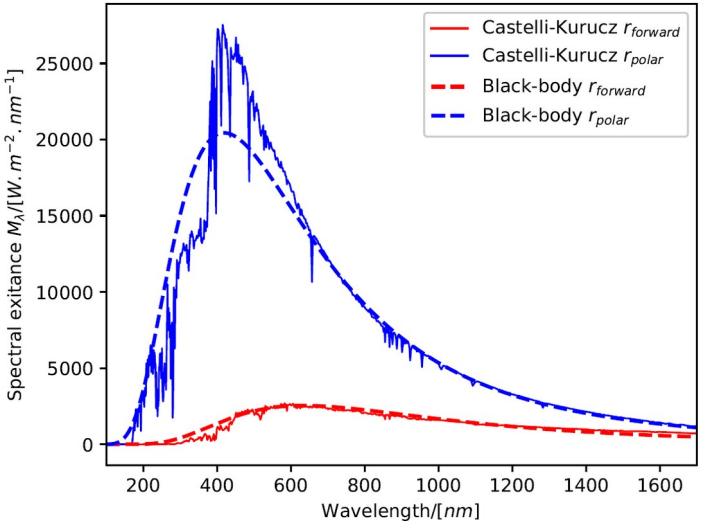
- **inclination of the orbit**
- temperatures of the components
- relative luminosities
- relative radii - system morphology
- photometric mass ratio
- potentials of the components
- detect inhomogeneities - spots, pulsations

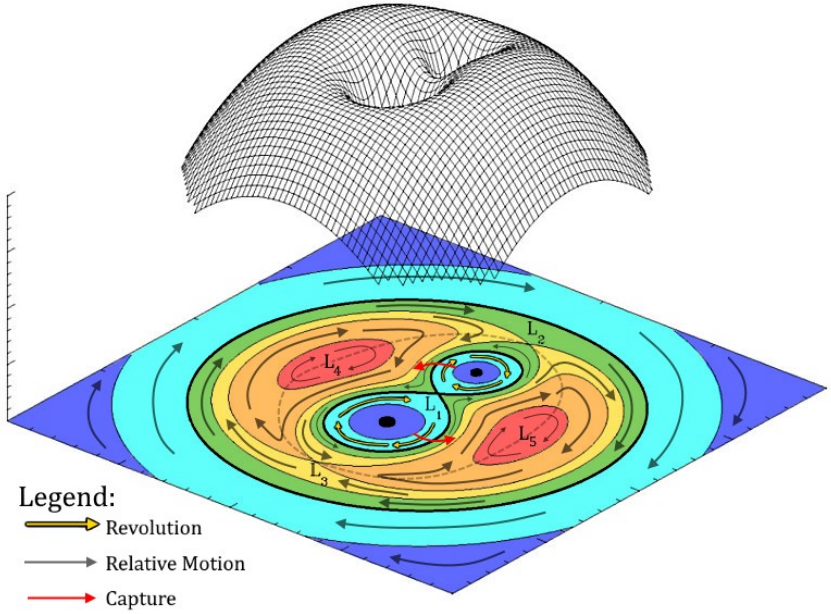
If we have radial velocities, we can find **absolute parameters**: masses, radii, distance of the components and luminosities

How we can solve light curve of EB?

Physical model based on:

- Roche geometry
- LTE models of the atmospheres





How we can solve light curve of EB?

Software packages:

- PHOEBE - http://phoebe-project.org
- JKTBOP - https://www.astro.keele.ac.uk/jkt/codes/jktebop.html
- ELLC - https://github.com/pmaxted/ellc
- ROCHE

All these packages require strong interaction of the user, do not have “the klates physics” and have a **bad ratio computing time / precision**

How we can solve light curve of EB?

These problems are partially solved by our new package **ELISA** (Čokina, Fedurco Parimucha, 2021 A&A 652, 163) https://github.com/mikecokina/elisa

- better triangulation of the stellar surfaces of the contact systems -better description of surface and radiation properties - better precision of the synthetic LC
- implementation of the complex structure of the spots
- symmetries on the calculation of LCs
- implementation to more CPU cores as well as GPU
- MCMC simulation for a realistic errors of the parameters

Main problems in the LC solution

- **initial values of parameters and morphology** - we need ***qualified estimate*** of initial parameters of the system and to know its morphology

- **correlations of parameters** - change of one parameter affects LC by the same value as change of some other , e.g. *q-i* correlation

- **underestimated errors of parameters** and underestimated errors of observations

Main problems in the LC solution

- we have parameters of cca ***2000 EB*** , most of them are “interesting” objects
- up to how we know ***several 100 000 EB***
- in near future we expect discovery of ***several tens millions of EB*** from surveys SuperWASP, Pan-STARRS, SDSS, Vera Rubin Observatory (LSST) as well as satellite missions Kepler, CoRoT, GAIA, TESS, BriTe and planned CHEOPS and PLATO.

What we can do about it?

We have to find a new methods and procedures, which will as much as possible automate LC’s fitting

We have to take into account quality of data, sampling ...

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Solution:

machine learning - ML

ML and eclipsing binaries

Main goal

determine as best as possible **limits of the parameters** of the light curve of EB, which can be then used by other methods (LS-fitting, MCMC) to find proper **solution**, and all this with **no human interaction**

ML and eclipsing binaries

How it should work

Suppose we have LCs from observation (maybe in more passbands)

1. test if orbit is circular or elliptic - we do need ML for it
2. test if LC is affected by spots or pulsation
3. set system morphology - contact or detached
4. find parameters limits by ML model
5. solve LC with conventional methods (LS and MCMC)

ML and eclipsing binaries

What we are doing now

creation of model LCs - LCs of EB with different parameters

- there must be enough of them to get statistically significant results
- LCs have to cover all parameters' space to avoid biases - preference of specific data

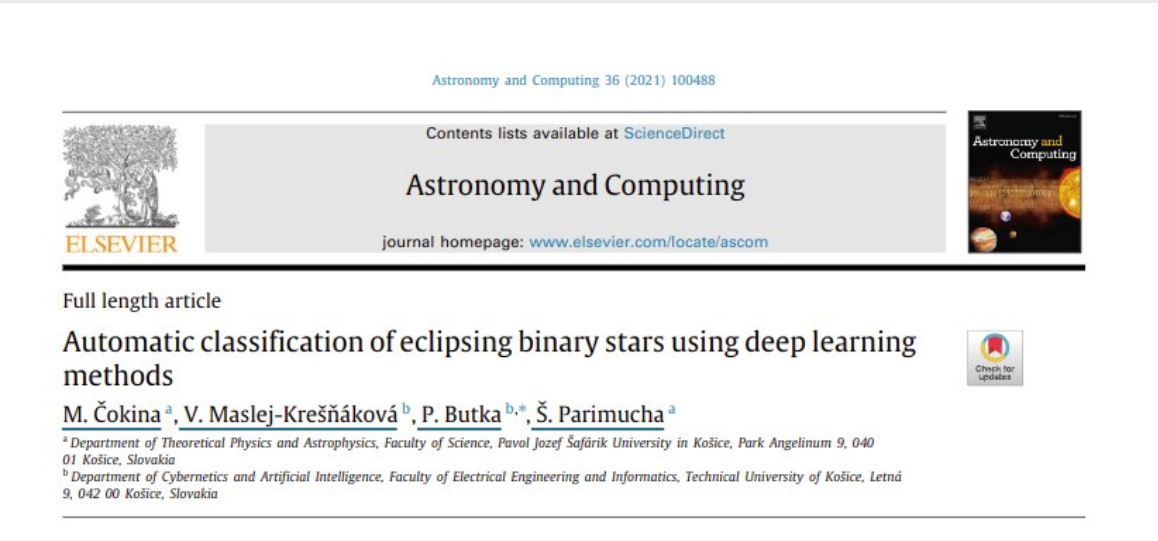
ACEB - Atlas of circular eclipsing binaries

(Fedurco & Parimucha, 2021 - submitted)

ML and eclipsing binaries

morphological classification of EB - contact and detached systems

Čokina et al., Automatic classification of eclipsing binary stars using deep learning methods, Astronomy & Computing 30, 3600488C (2021)



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Full length article

Automatic classification of eclipsing binary stars using deep learning methods

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ML and eclipsing binaries

morphological classification of EB - contact and detached systems

- now we work on improvement of classification using multicolour data (Parimucha et al. 2022, in preparation)

- we have to investigate influence of spots and pulsation to this classification

ML and eclipsing binaries

What we have to do:

train ML models for parameters determination

- it is the most complicated part and time consuming part
- we have to check many different methods and approaches

- first preliminary results give us limits of temperatures in the range of 500 K and it is very promising

Thank you for your attention !

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