Eclipsing Binaries in the Era of Large Surveys and Big Data

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SLOVAK RESEARCH AND DEVELOPMENT AGENCY

Eclipsing binaries

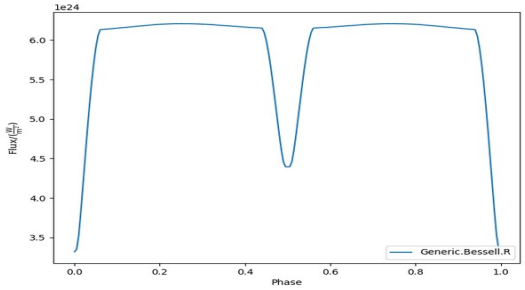
binary stars, where changes in brightness are due to mutual eclipses of the components during movement around the common mass center

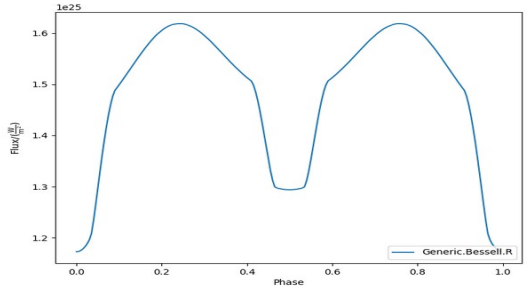
- **“classical” eclipsing binaries** - components are on main sequence (MS), orbital periods in range of few hours (~5h) up to years (~27y, ϵ Aur), temperatures from ~3000 - 15000K
- **“special” eclipsing binaries** - components are e.g. *giant* and *WD* (symbiotics, P~several years, AX Per, CI Cyg), *low mass MS* and *WD* (cataclysmic, P~minutes to few hours IP Peg), or accretion disc, and/or circumbinary shell is presented

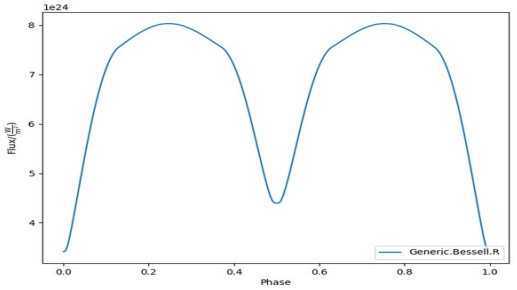
Eclipsing binaries

- produce typical light curves where almost all informations about the components are hidden
- based on the shapes of their light curve we often classify them into 3 classes

➔ EA - Algol
➔ EB - β Lyrae
➔ EW - W UMa



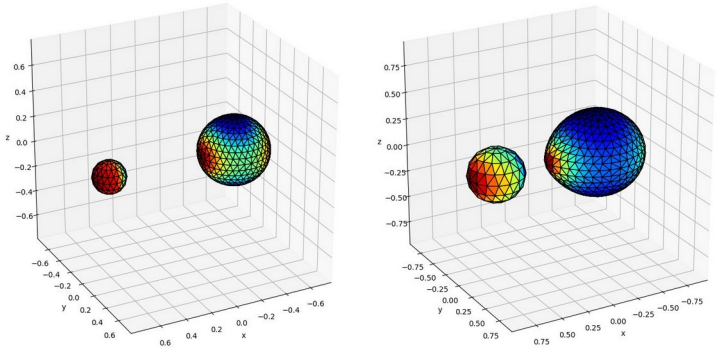




Eclipsing binaries

- if we want to know physical parameters of EB - we need to describe them by ***Roche geometry***

detached



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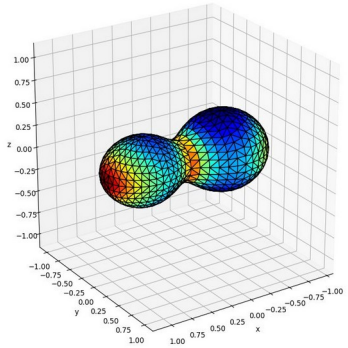


Eclipsing binaries

What we want to know from EB?

from the LC **- photometric parameters**

- inclination of the orbit i
- photometric mass ratio q_{ph}
- potentials of the components - Ω_1, Ω_2
- ratio of components temperatures T_1/T_2
- relative luminosities L_1/L, L_2/L
- relative radii - system morphology r_1 , r_2
- detect inhomogeneities - spots, pulsations and their parameters

Eclipsing binaries

What we want to know from EB?

combination of **LC** and **radial velocities** or **LC** and independent **distance** to star (e.g. from GAIA) + some theoretical and/or semi-empirical models (e.g. bolometric correction) - **absolute parameters**

- masses M_1, M_2
- radii R_1, R_2
- separation between the components a
- luminosities L_1, L_2

Eclipsing binaries

What we want to know from EB?

from the analysis of period changes - (O-C) diagram - **multiplicity of system**

- presence of the another bodies in the system and determination of their orbital parameters and their minimal mass
- we can detect also exoplanets

Eclipsing binaries

Why we need to study EB?

- *determine stellar parameters* - masses, luminosities, radii
- *understand stellar evolution* - in EBs are often stars on different evolutionary stage
- *study of stellar Interactions* - mass transfer, tidal forces, and gravitational influences strongly affect evolution
- *study of stellar multiplicity* - EBs have often more components and also exoplanets
- *distance measurement* - as standard candles for calibrating the cosmic distance ladder - distances to galaxies and the scale of the universe.
- *testing physical laws* - test the laws of physics under extreme conditions, such as strong gravitational fields and high velocities.

Eclipsing binaries and large sky surveys

Due to typical shape of light curves and relatively short period of the most of the EB (several hour up to tens of days) eclipsing binaries are often by-product of **large photometric sky surveys**

surveys are focused to other field of astrophysics - exoplanets, dark matter, transients - produce light curves of many objects by different time sampling

EB can be easy detected in the huge amount of produces light curves.

Eclipsing binaries and large sky surveys

Surveys with the largest influence to EB research

- **OGLE** - >500000 EB was detected and classified mainly in Galactic Bulge but also in LMC and SMC
- **ASAS-SN** - monitor whole sky, with ~ nightly cadence, no special catalog for EB are available, but LC can be simply downloaded for specific object
- **ZTF** - monitor northern hemisphere every 3 days and Milky Way plane twice per day, > 300000 EB was detected
- **Kepler** - ~2600 EB detected in small field of sky - high cadence and precision
- **TESS** - observe entire sky in sectors (~30 days per one) high cadence data
- **GAIA** - detected ~2.1 million EBs additional informations are given (temperature, metallicity distance)

Eclipsing binaries and large sky surveys

Planned surveys

- **Vera Rubin Telescope** - 8.4m telescope which will scan ~60% of the entire sky with 3 days cadence with limiting magnitude ~25 in r. Discovery of more than 10 000 000 new EB is expected
- **Plato** - will follows Kepler and TESS with primary goal to detect Earth-size planets. Limiting magnitude is V<11 so high quality LC of bright EB systems are expected

Eclipsing binaries and Big data

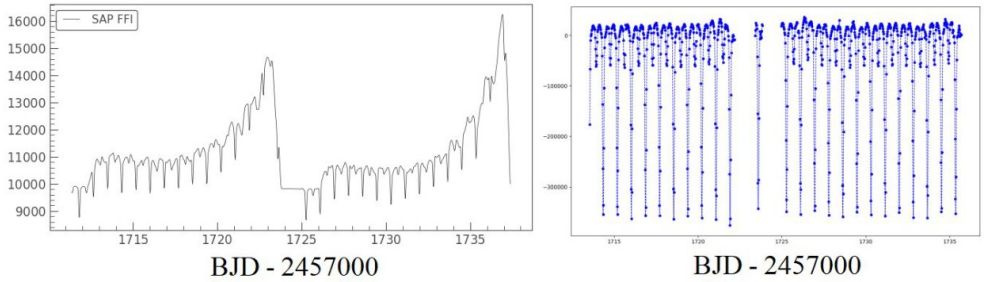
Pros:

- LC of lot of eclipsing binaries
- large statistical sample
- interesting and rare objects can be found

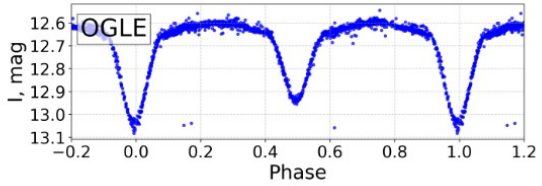
Eclipsing binaries and Big data

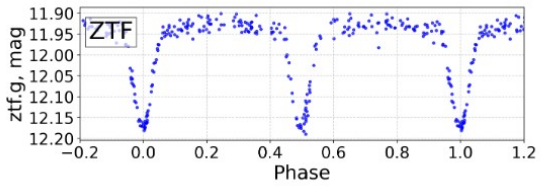
Cons :

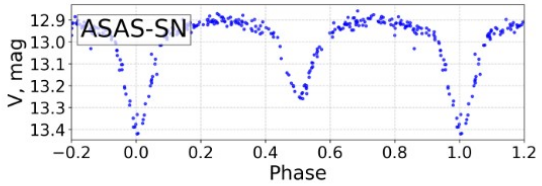
- LC of lot of eclipsing binaries
- different quality LC with strong trends mainly in space data
- different time span of observation - one point in few days or large cadence in short time interval
- different passbands (often only one) - no colour information - no temperature

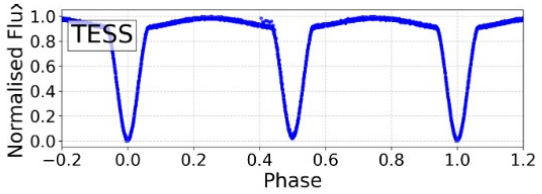


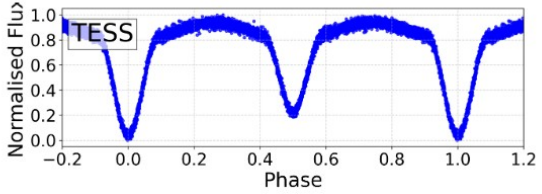
Eclipsing binaries and Big data

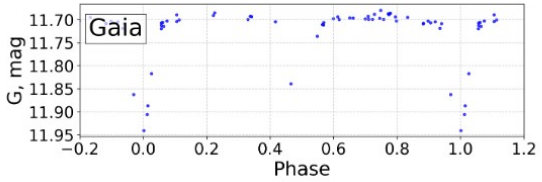


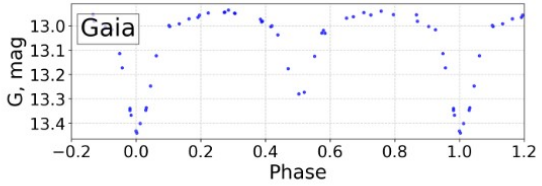




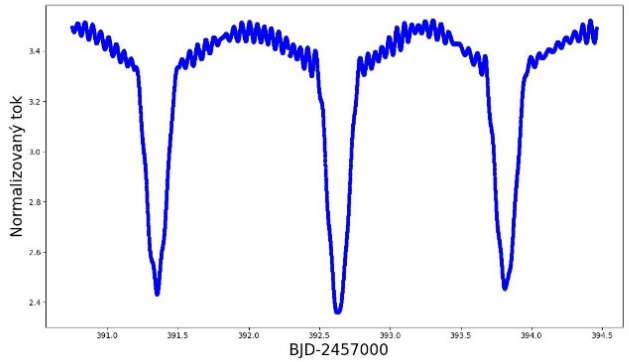




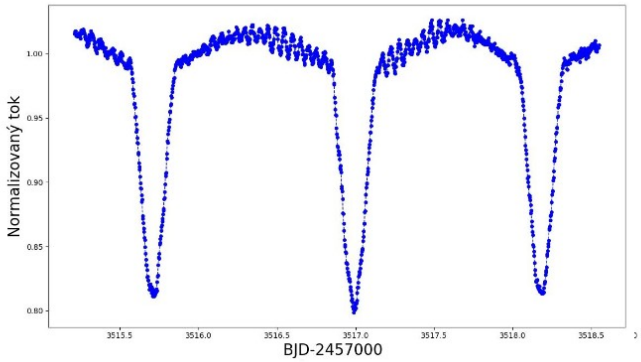




Eclipsing binaries and Big data



Kepler



TESS

Eclipsing binaries and Big data

Cons :

- most of the EB cannot be observed with 1m class (“cheap”) telescopes - too faint and too many stars - we cannot study e.g. period variations and/or spots
- for the vast majority of EB we cannot in near future obtain RV measurements - simply too faint
- standard method for the analysis LC are not feasible - too slow, user interaction is needed

Eclipsing binaries and Big data

Challenges:

- improve classification of variable stars - to be sure that star in catalogue is really EB
- change access to data - everybody use their own format no standardization, cross identification between catalogues
- improve data de-trending mainly from space data
- from all up to now known EB ***(2.3 millions)*** we have photometric parameters of about ***2500 EB*** , absolute parameters are known for **~600 EB** - robust methods are needed for LC fitting (based on ML), strong statistical methods for absolute parameters and detection of rare and anomaly objects
- new survey dedicated to EB?

Thank you for your attention

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https://astronomy.science.upjs.sk