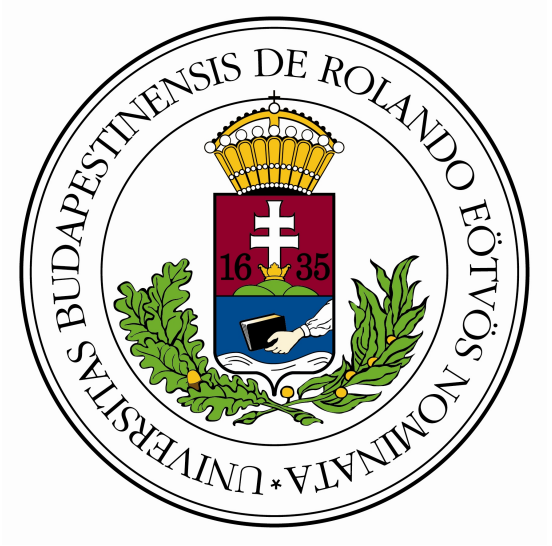
ETV analysis of eclipsing binaries with CUDA

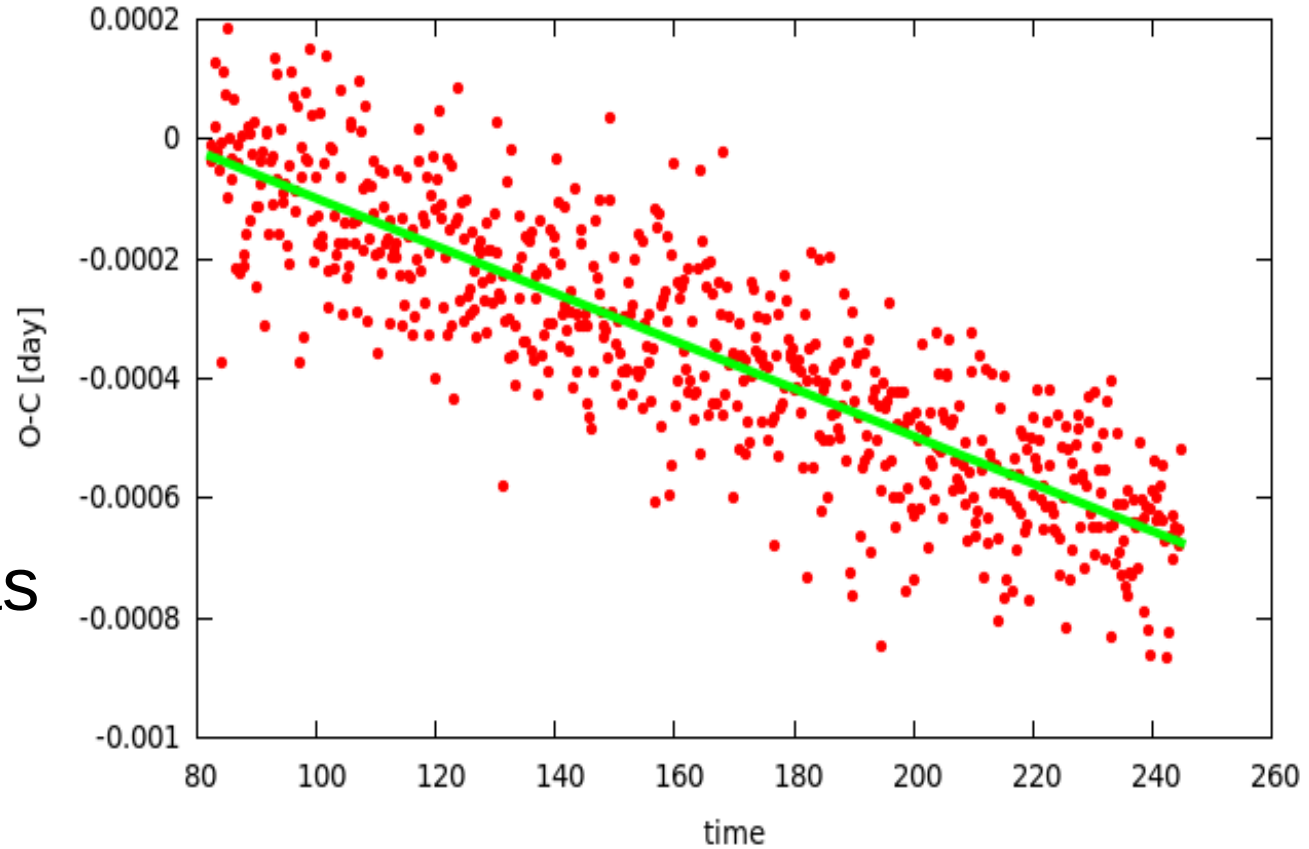
Tamás Hajdu



ELTE TTK

O-C (Observed-Calculated) diagrams

- From some observed eclipse → period → eclipse time can be predicted
- Observed eclipse time – predicted eclipse time = O-C diagram
- In case of circular orbits without any perturbation → constant line in zero
- If predicted period has error → accurate it



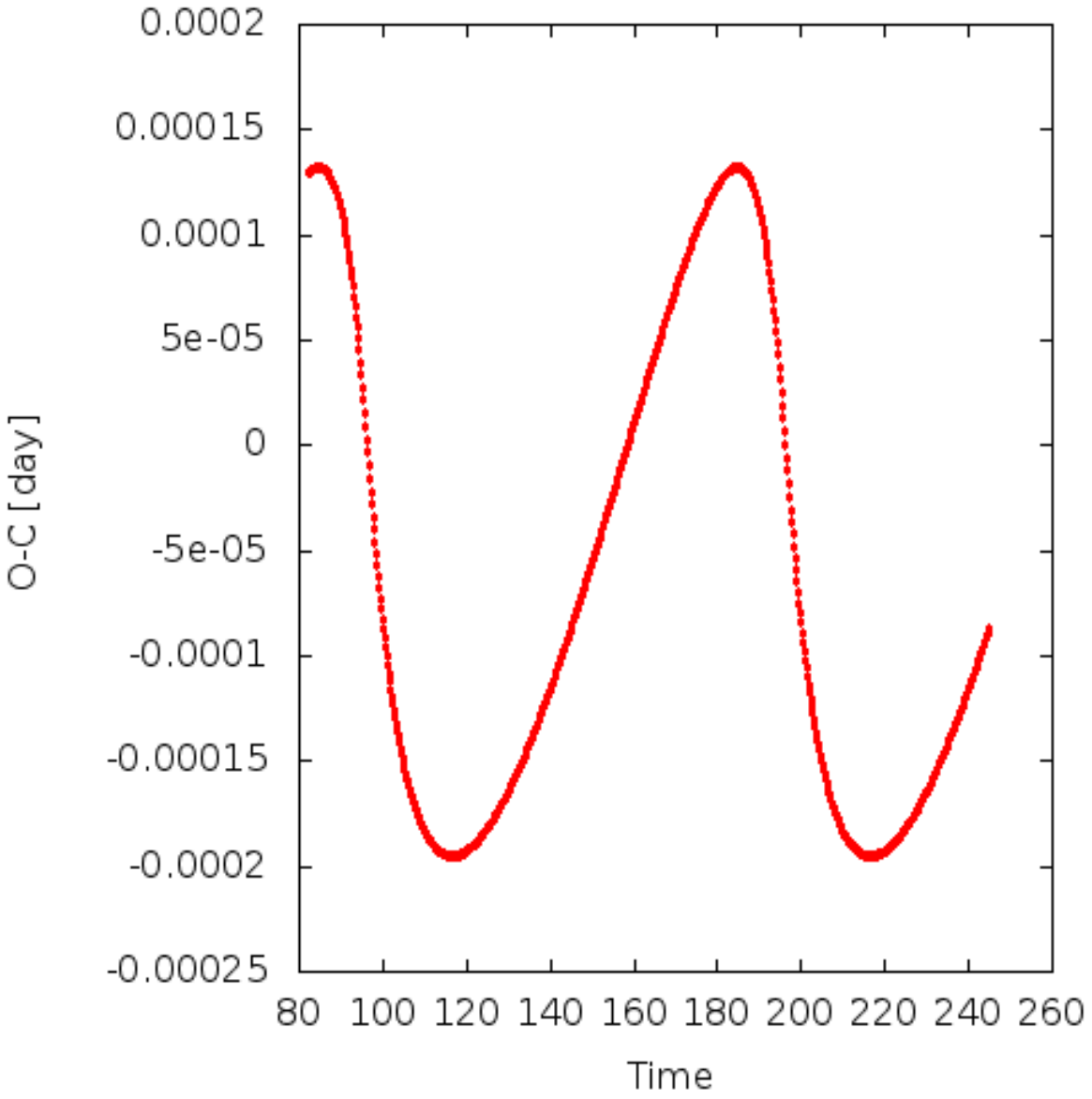
Perturbations

- Third body (LTTE, Dinamical perturbation)
- Apsidal motion
- Mass transfer
- Star activity

Third body (in hierarchical system)

- Just apparent change
- Because of the finite speed of light
- O-C diagram:

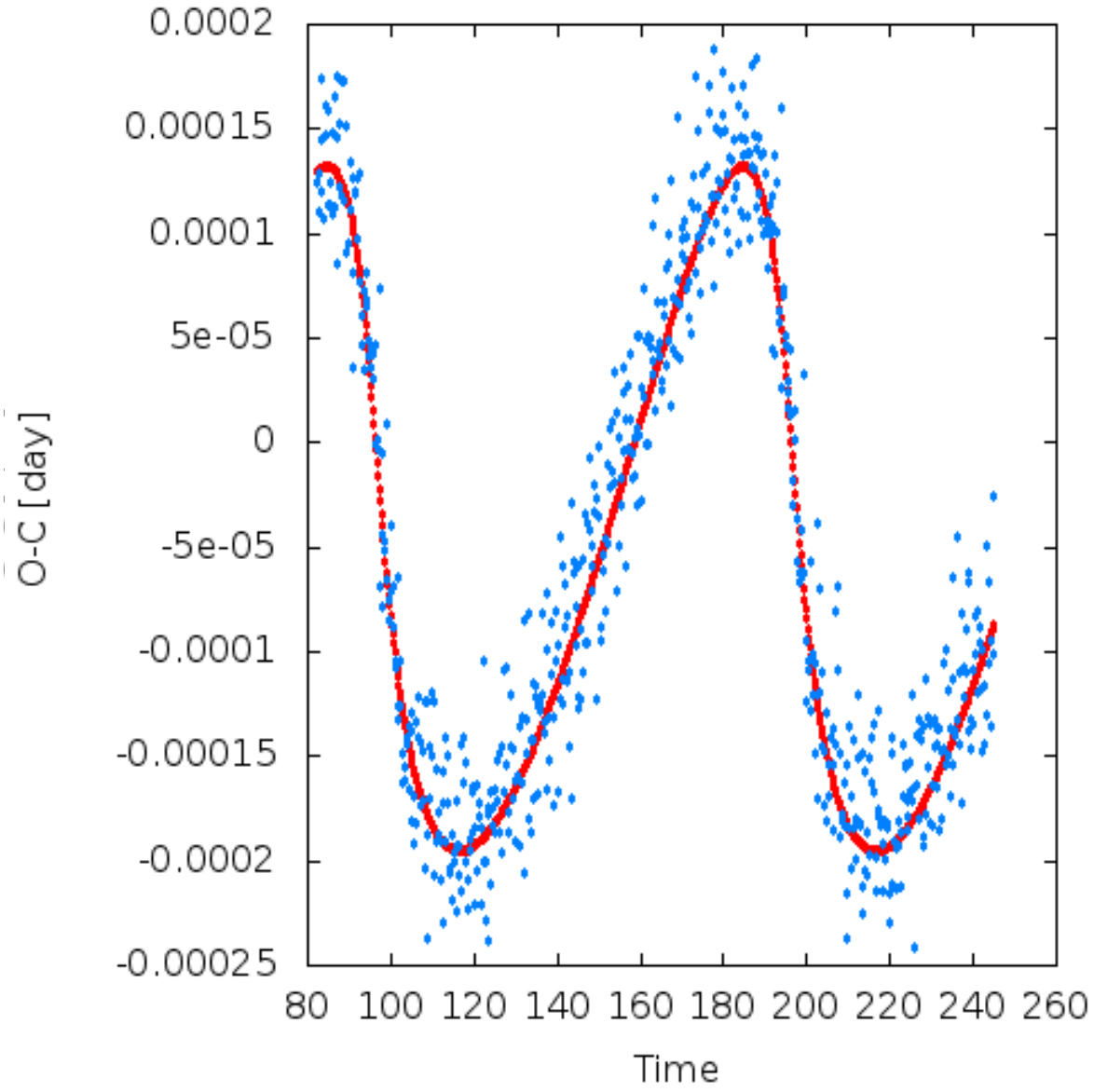
  (ideal)



Third body (in hierarchical system)

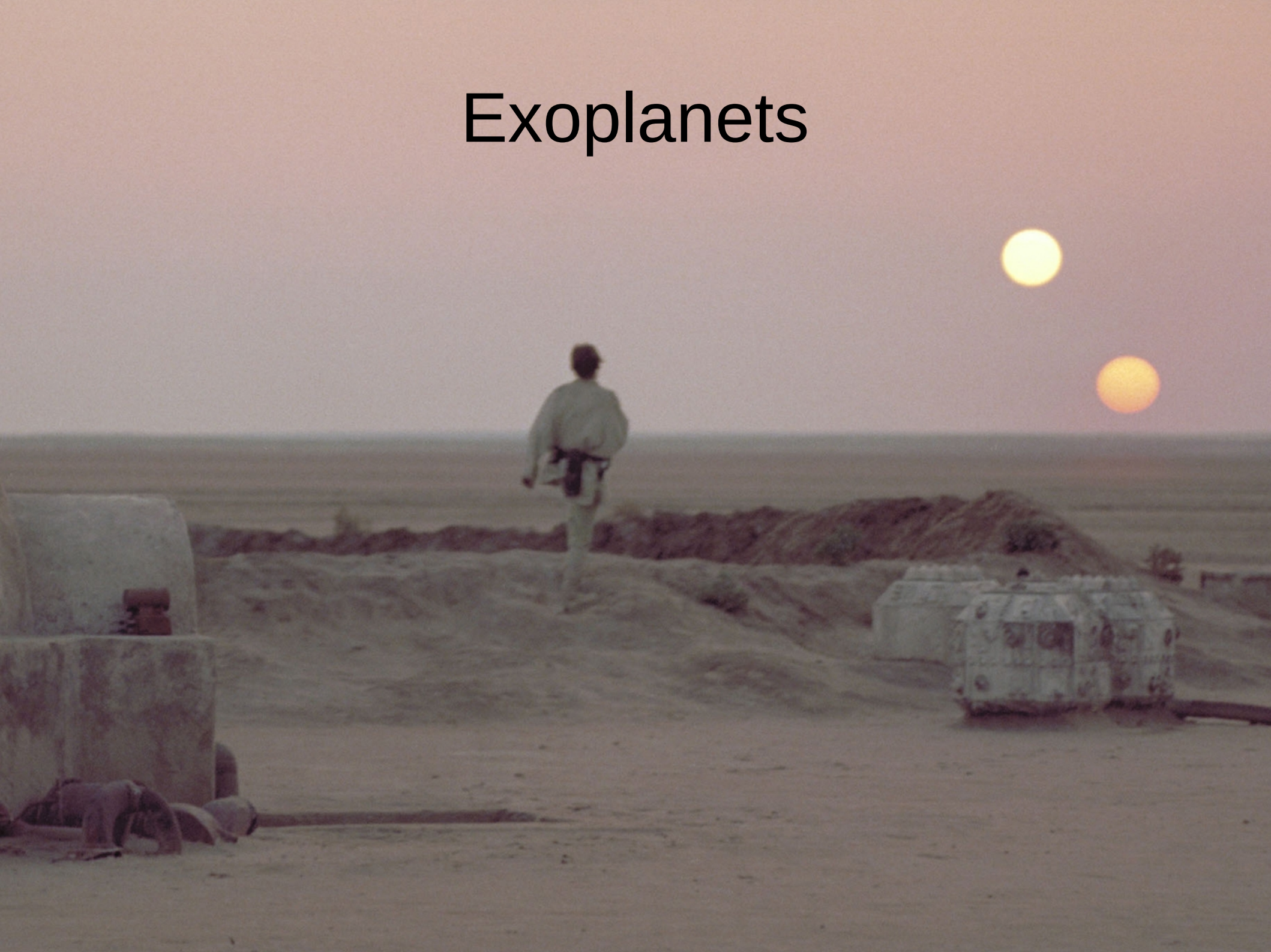
- Just apparent change
- Because of the finite speed of light
- O-C diagram:

  (reality)



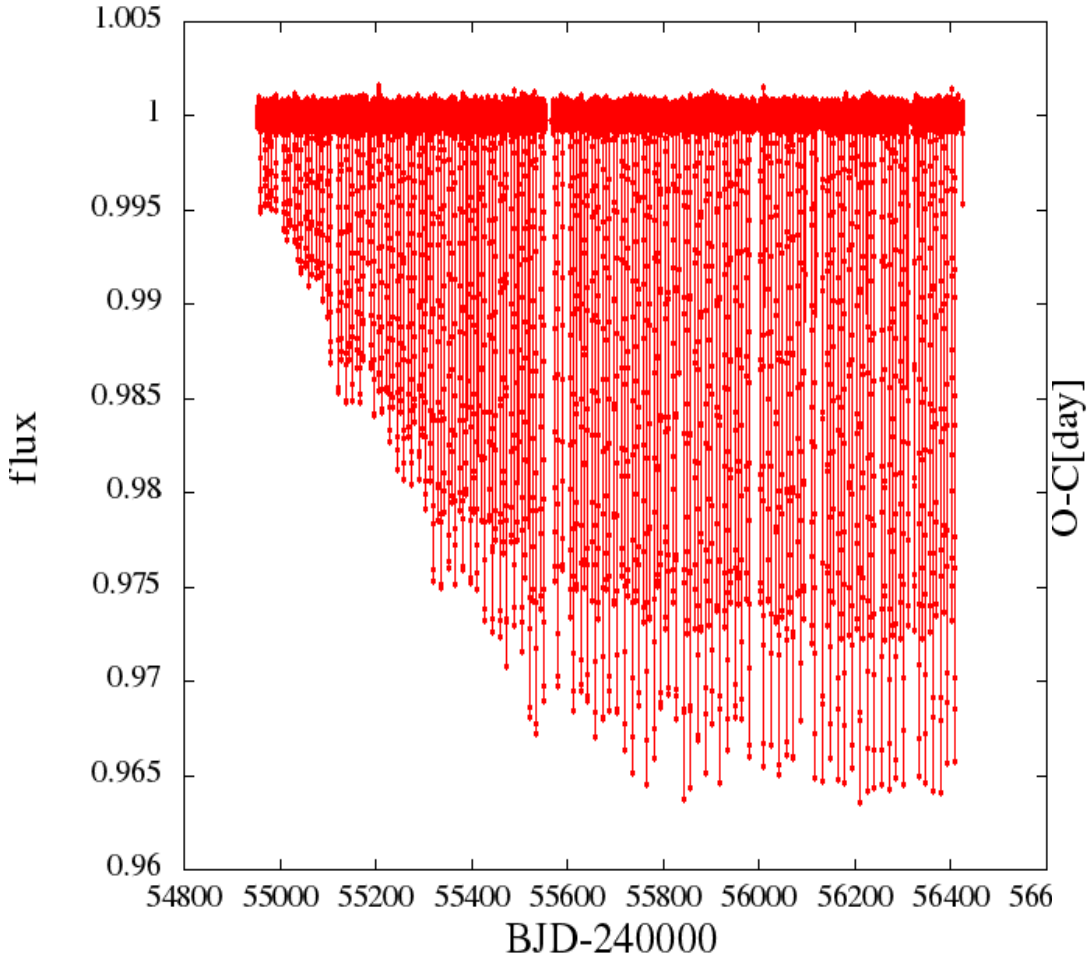
Third body

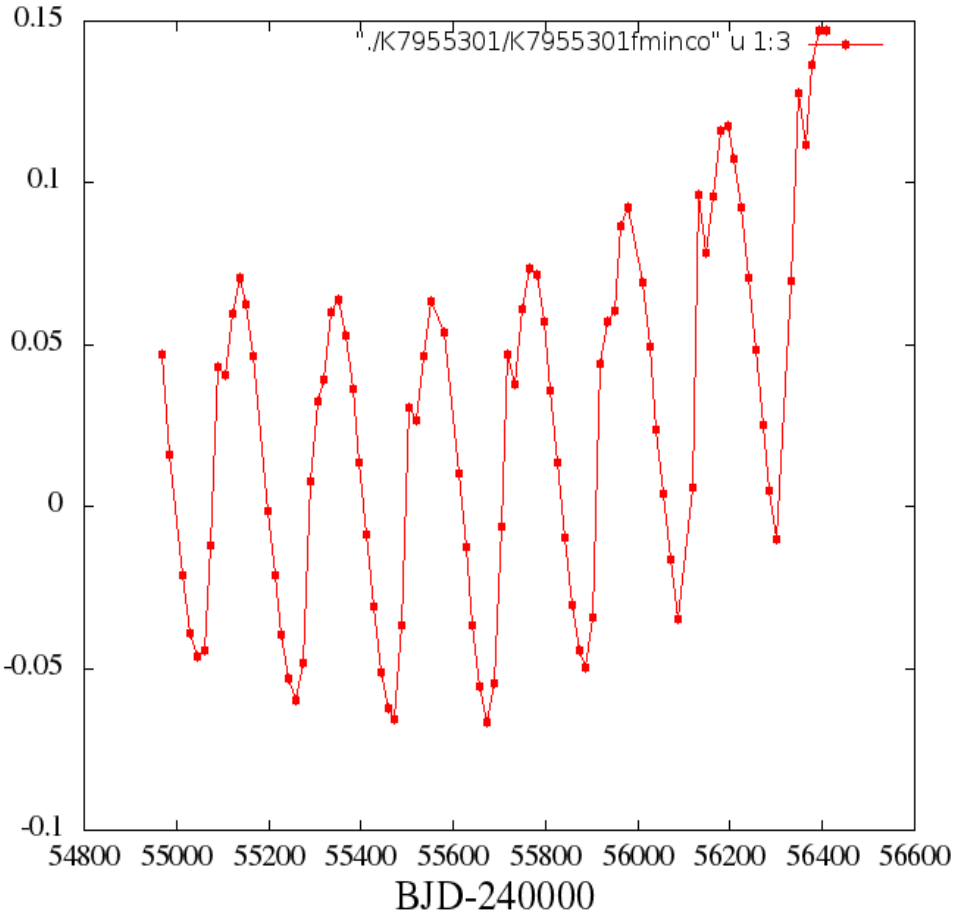
Exoplanets



Close approach

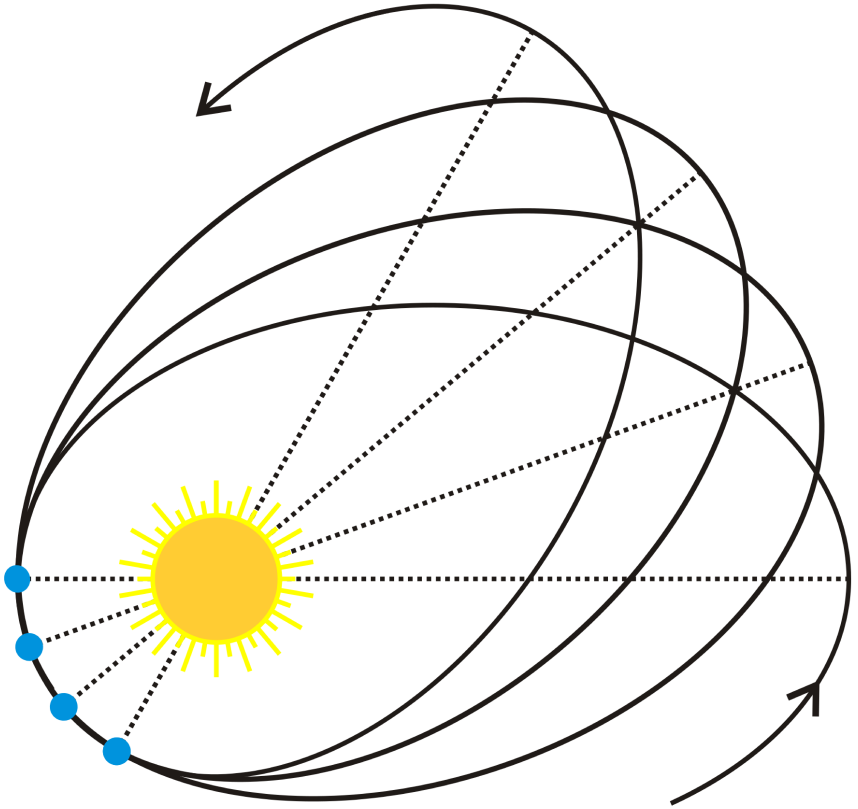
- Orbit of the close binary changes

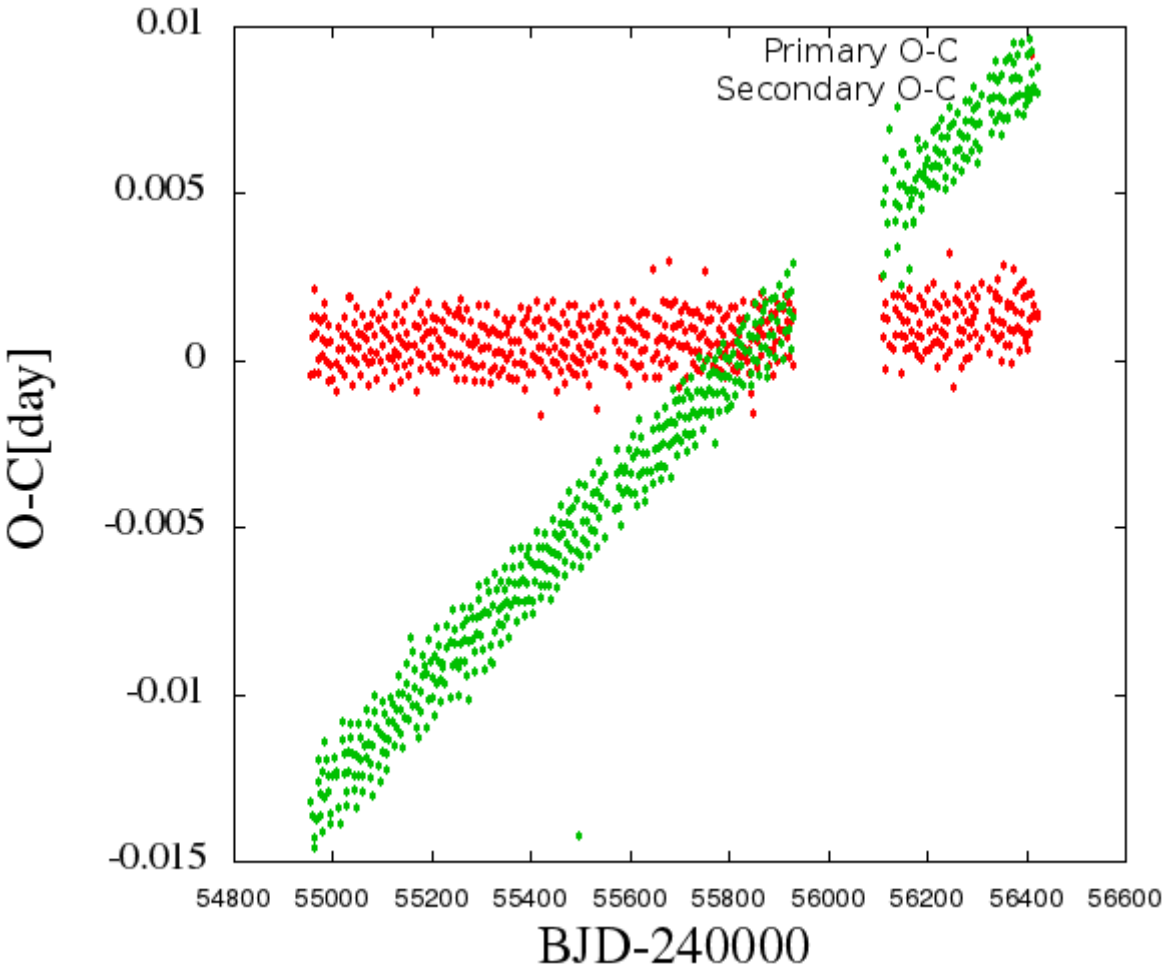




Apsidal motion

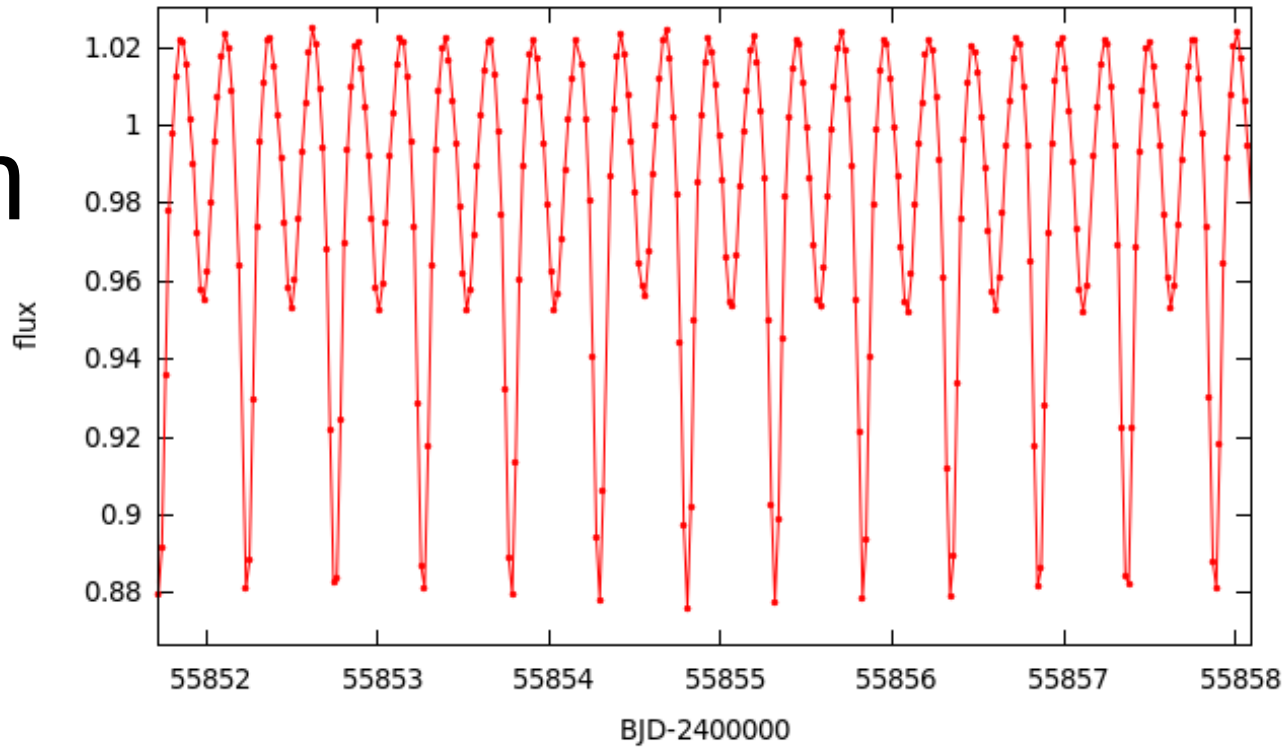
- Apparent
- Tidal effect
- Timescale

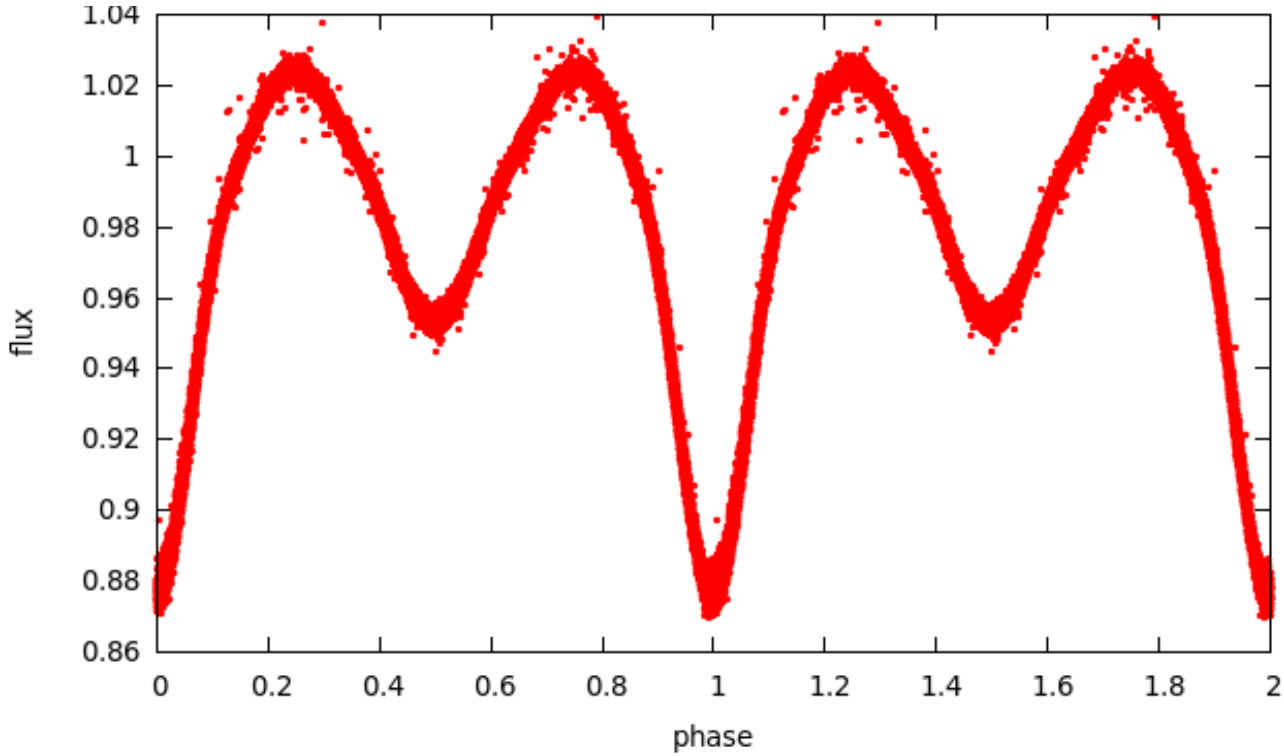




The program

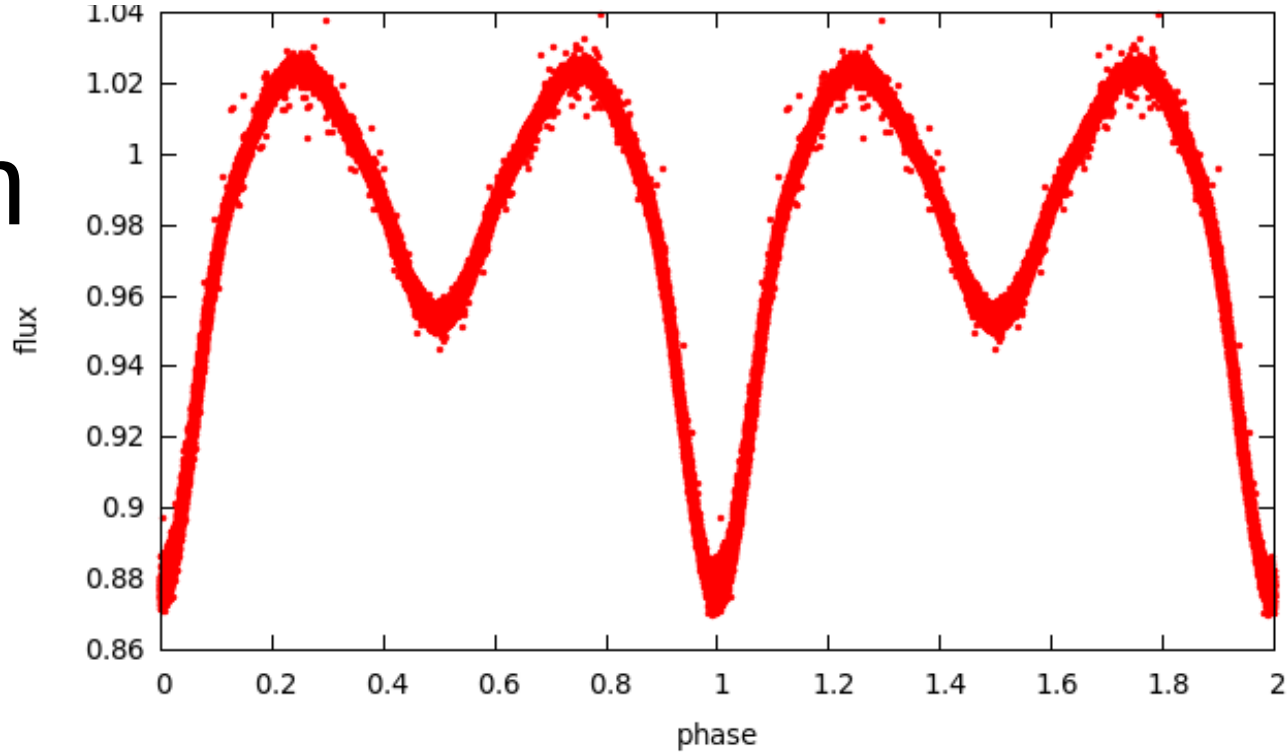
- Time to phase folding

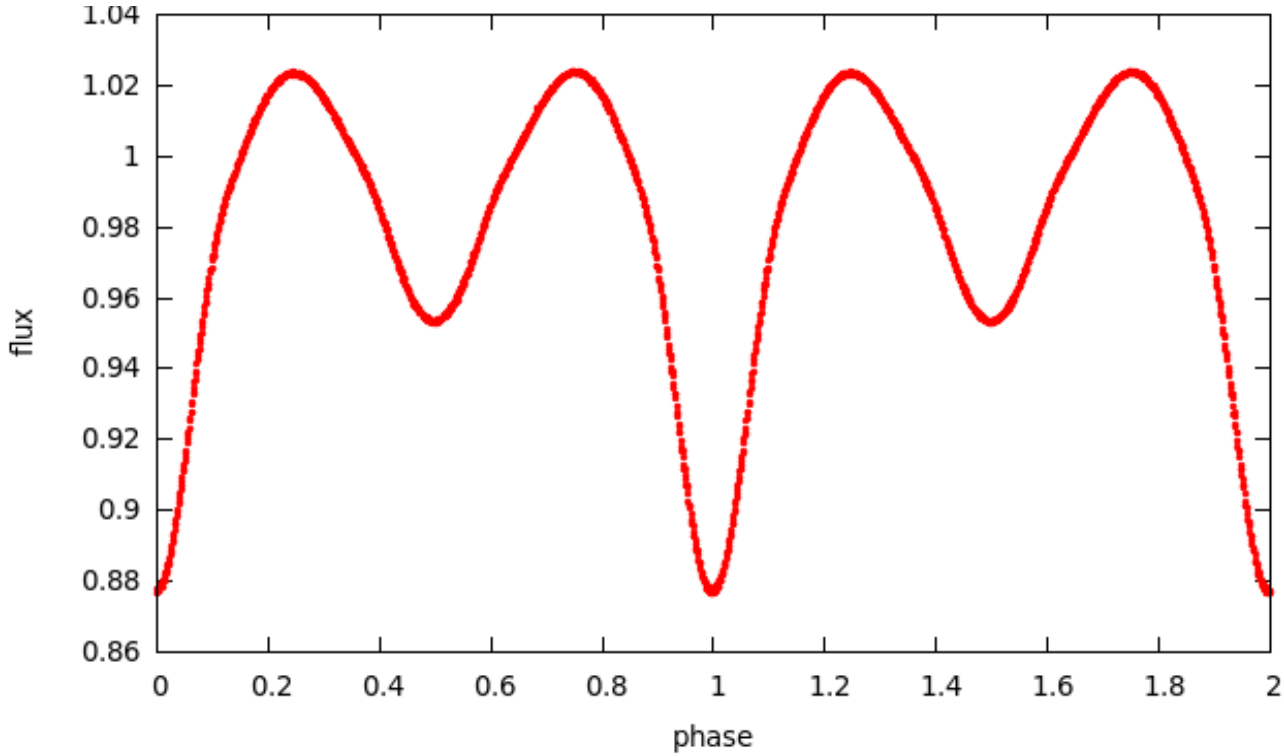




The program

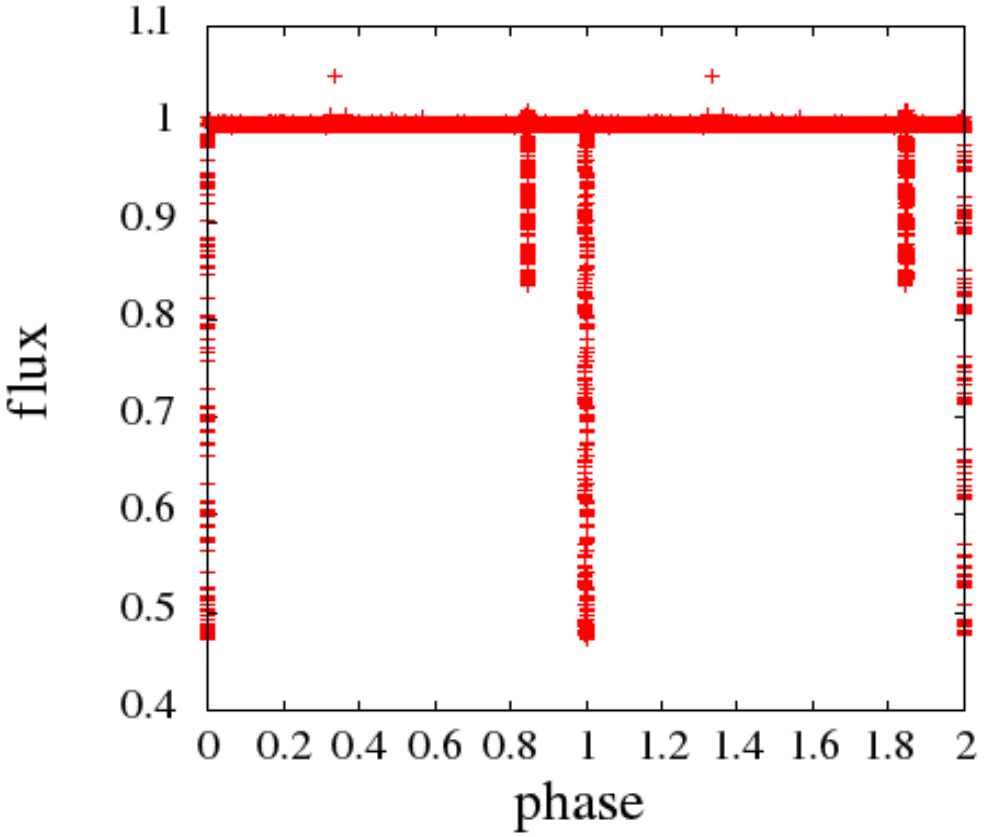
- Time to phase folding
- Binning

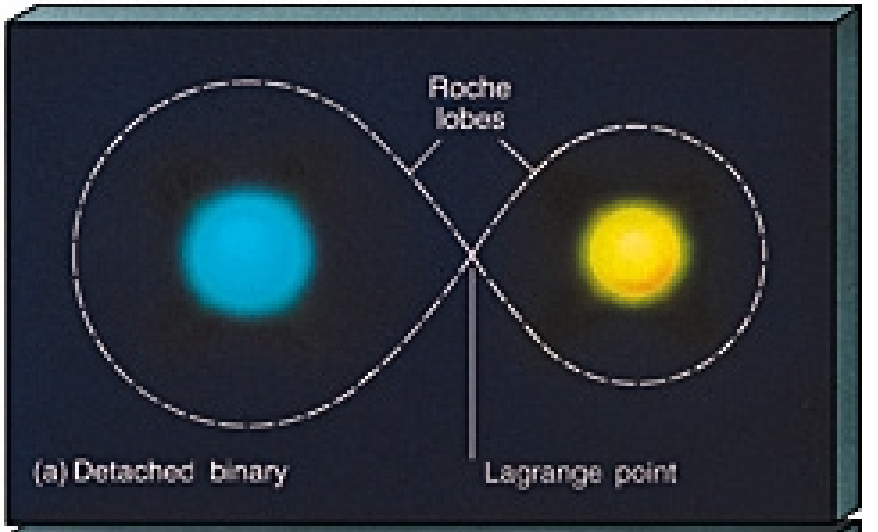


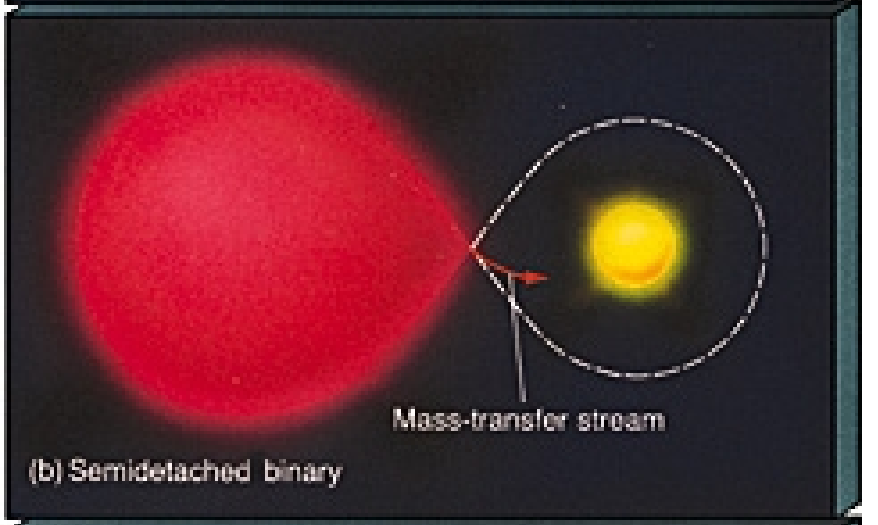


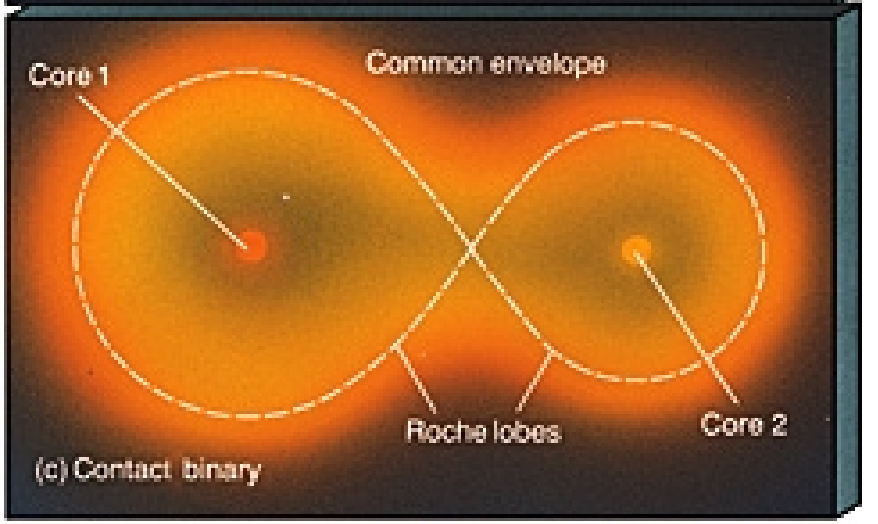
Search for eclipses automatically

- Different depth
- Different shape
- Different length









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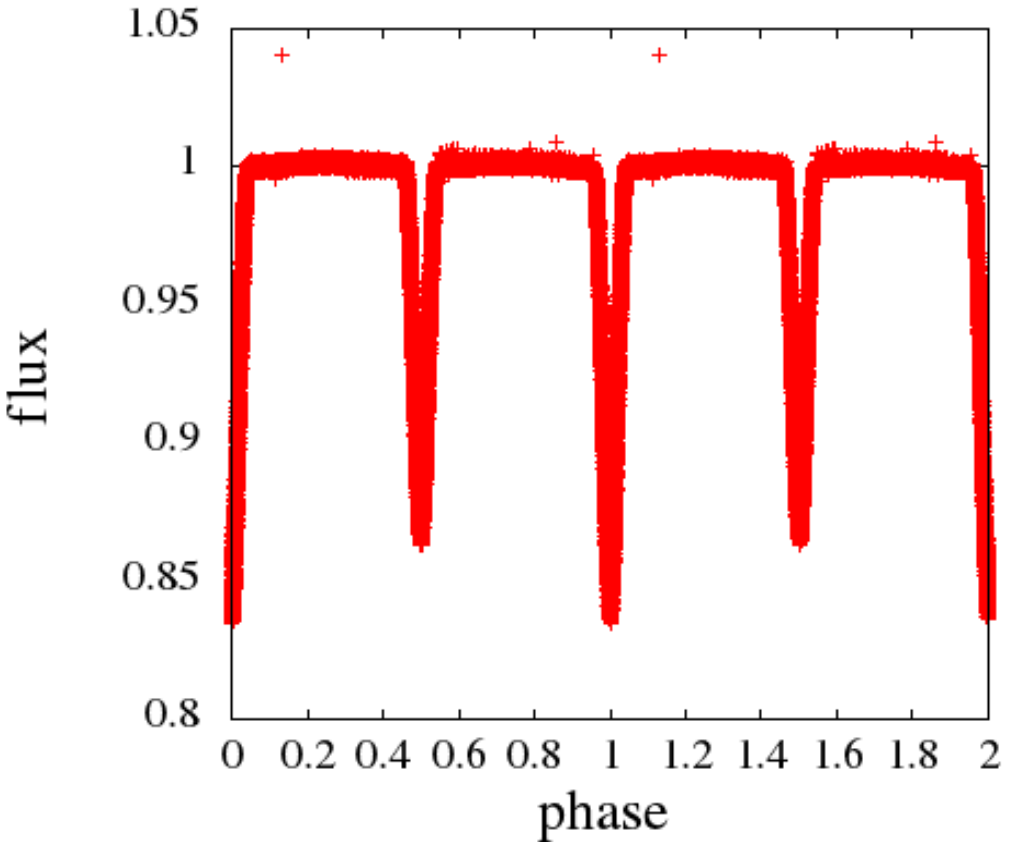

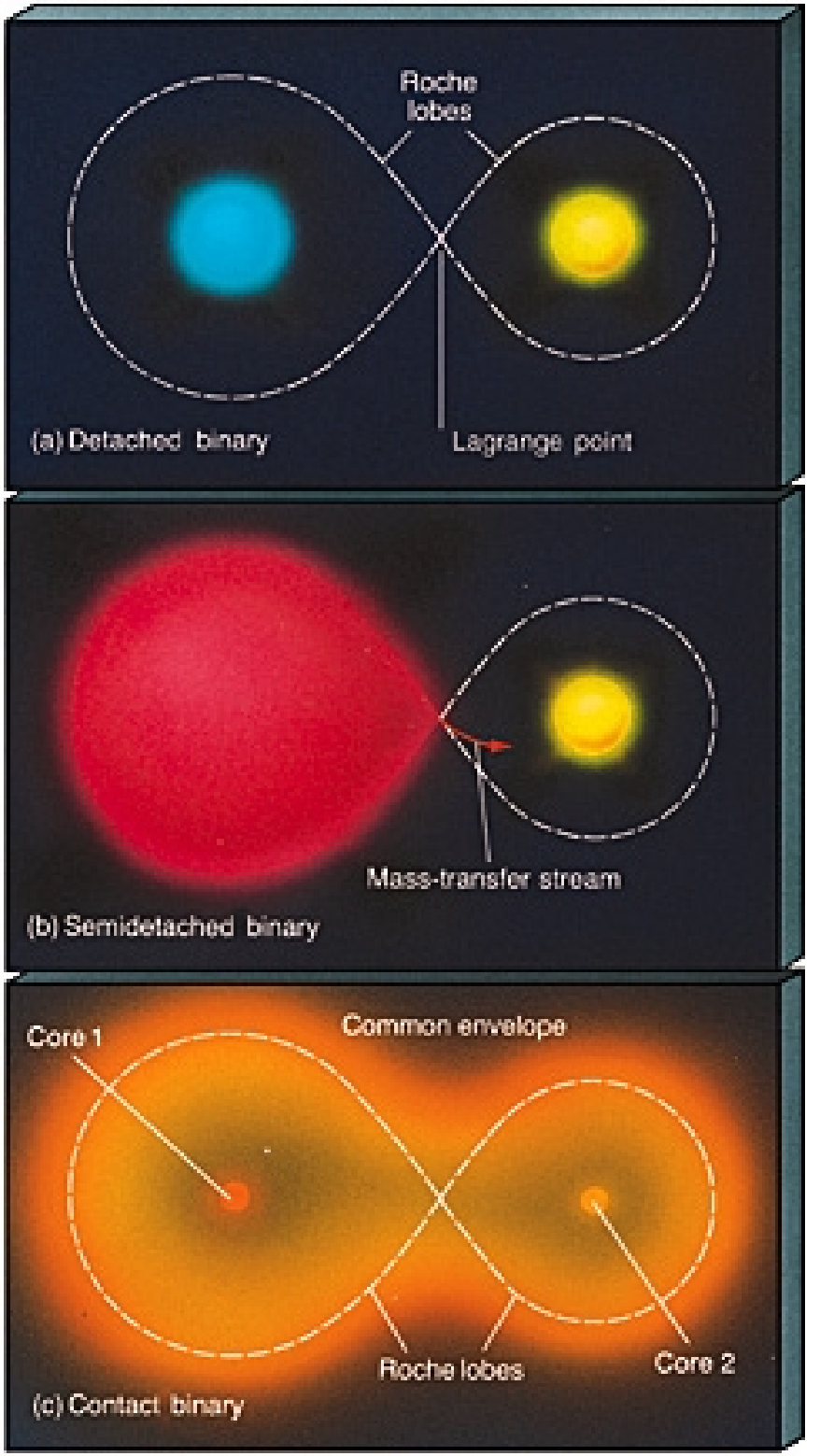

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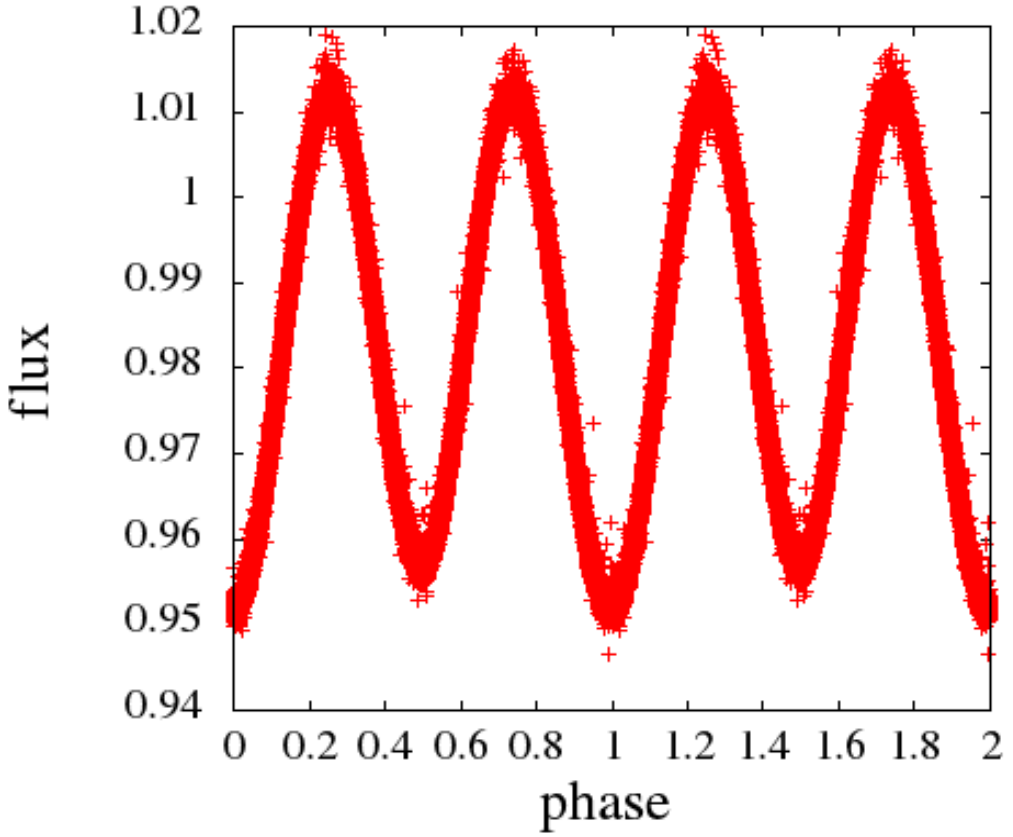
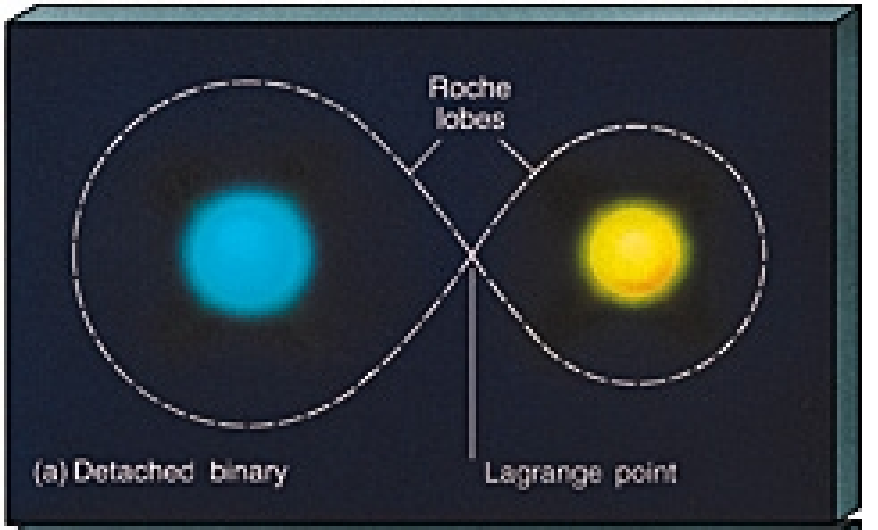
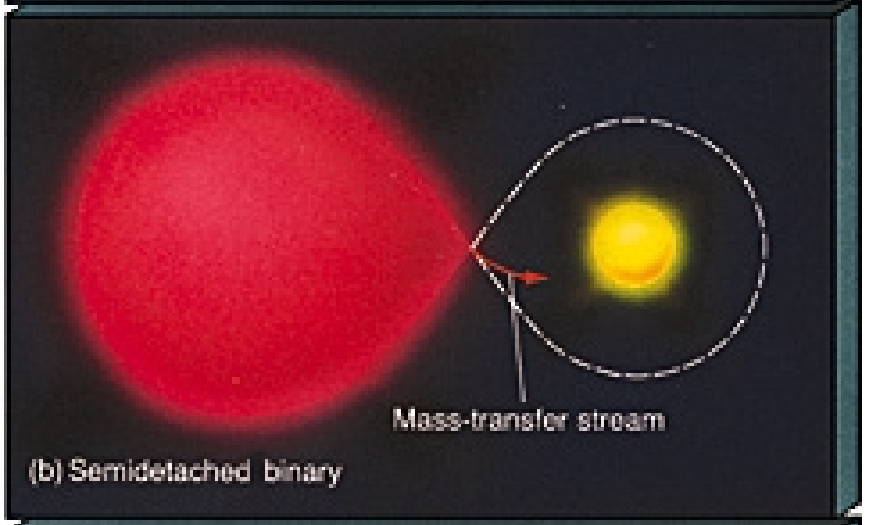
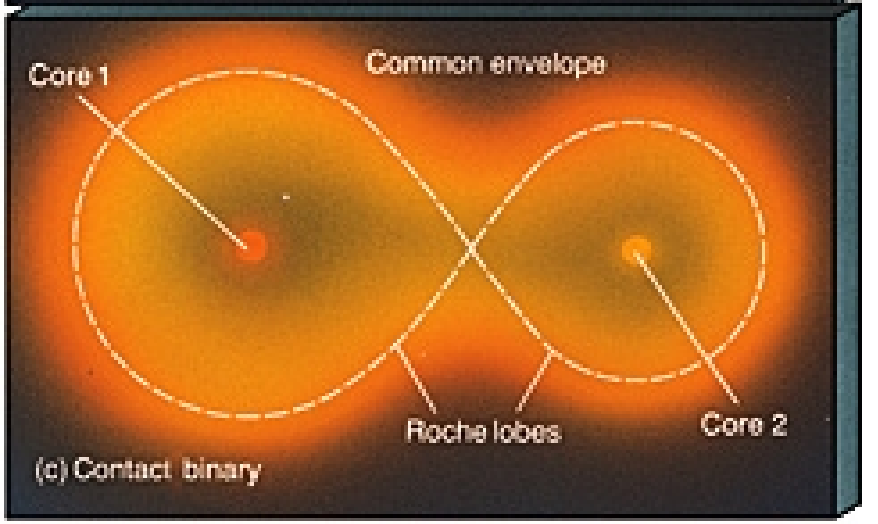








Search for eclipses automatically

- Different depth
- Different shape
- Different length

→ average value of the flux and standard deviation

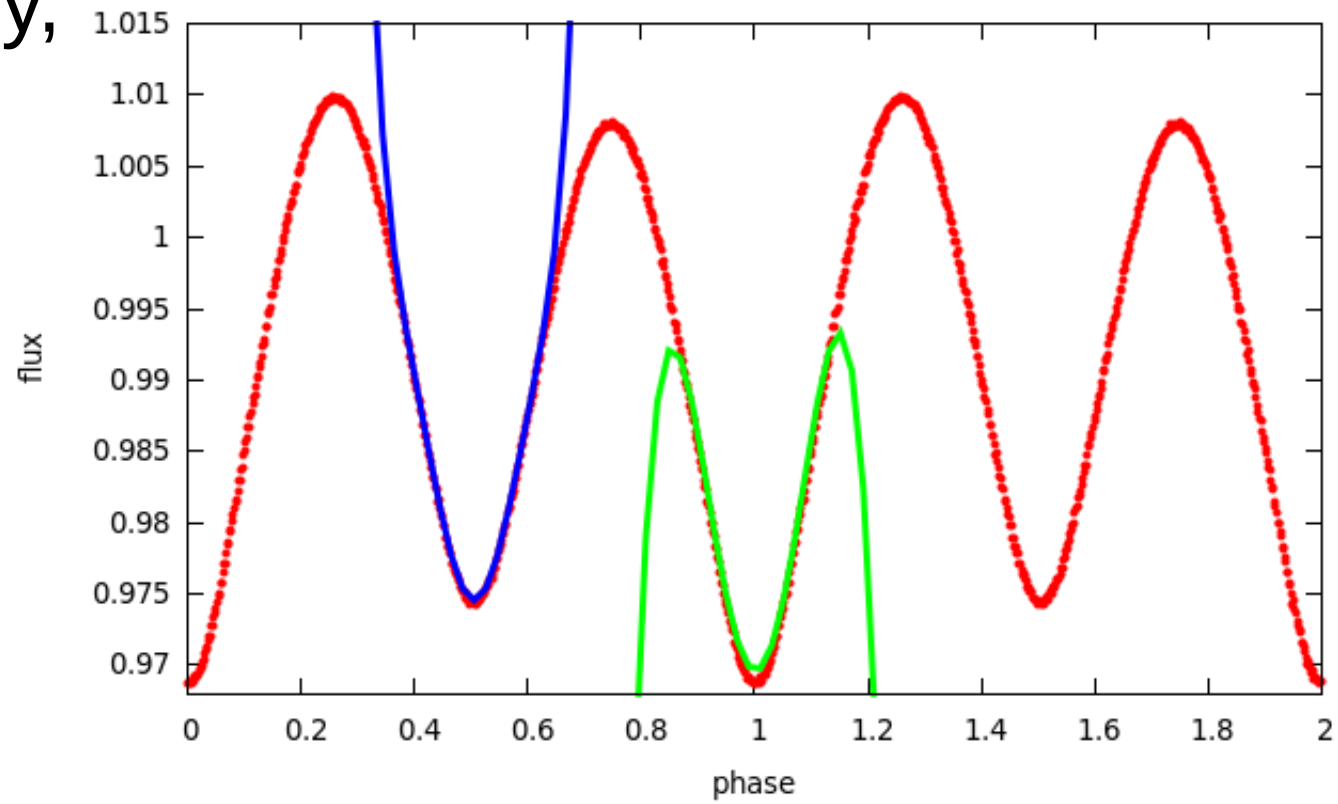
→ Two big area under this line → primary minimum and secondary minimum

→ borders in phase

Polynomial fit

- Polynomial of degree 6

  Shape of the eclipse doesn't change
- Newton–Raphson method → minima of the eclipses (primary, secondary)



Levenberg-Marquardt fit

- Keep the shape of the main eclipse
- Variable parameters
  - base line (b0)
  - amplitude (b1)
  - phase (b2)
- Fitted equation:

$$g(x) = b_0 + b_1 \cdot f(x + b_2)$$

More cases

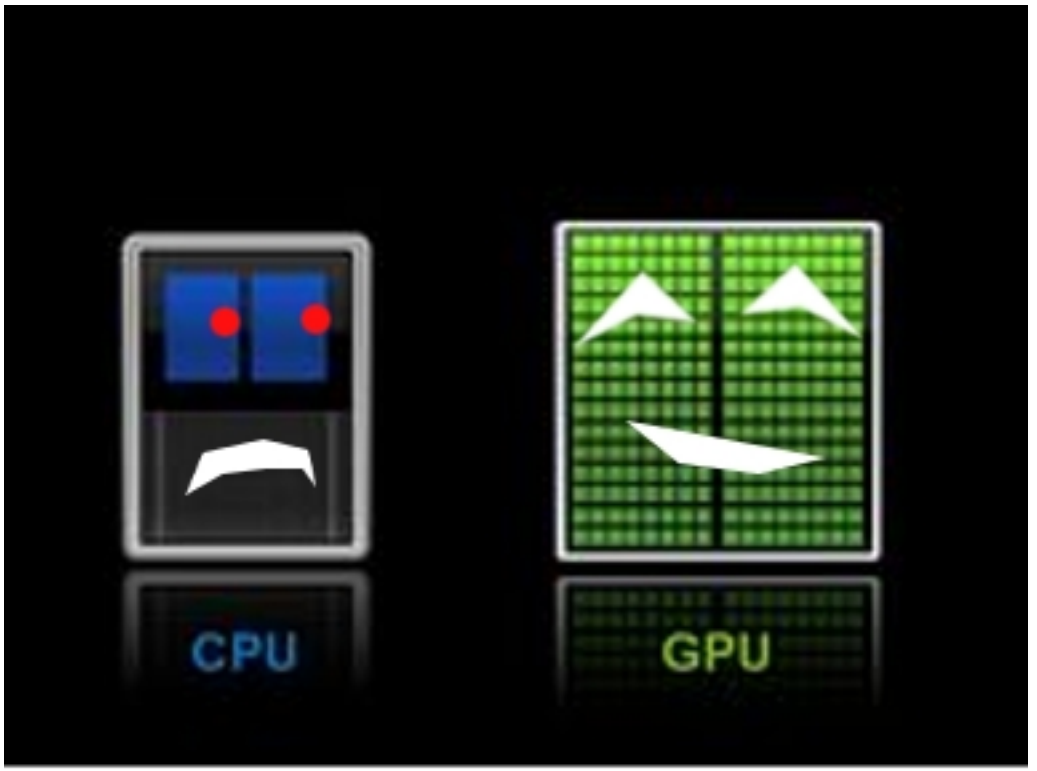
- Period changes, but phase borders can't follow it

  → shift left and right → 2 more case
- Star activity (flers, short term spots,...) → annoying points → series with less points

  Finally we got huge amount of series to fit.

GPU vs CPU

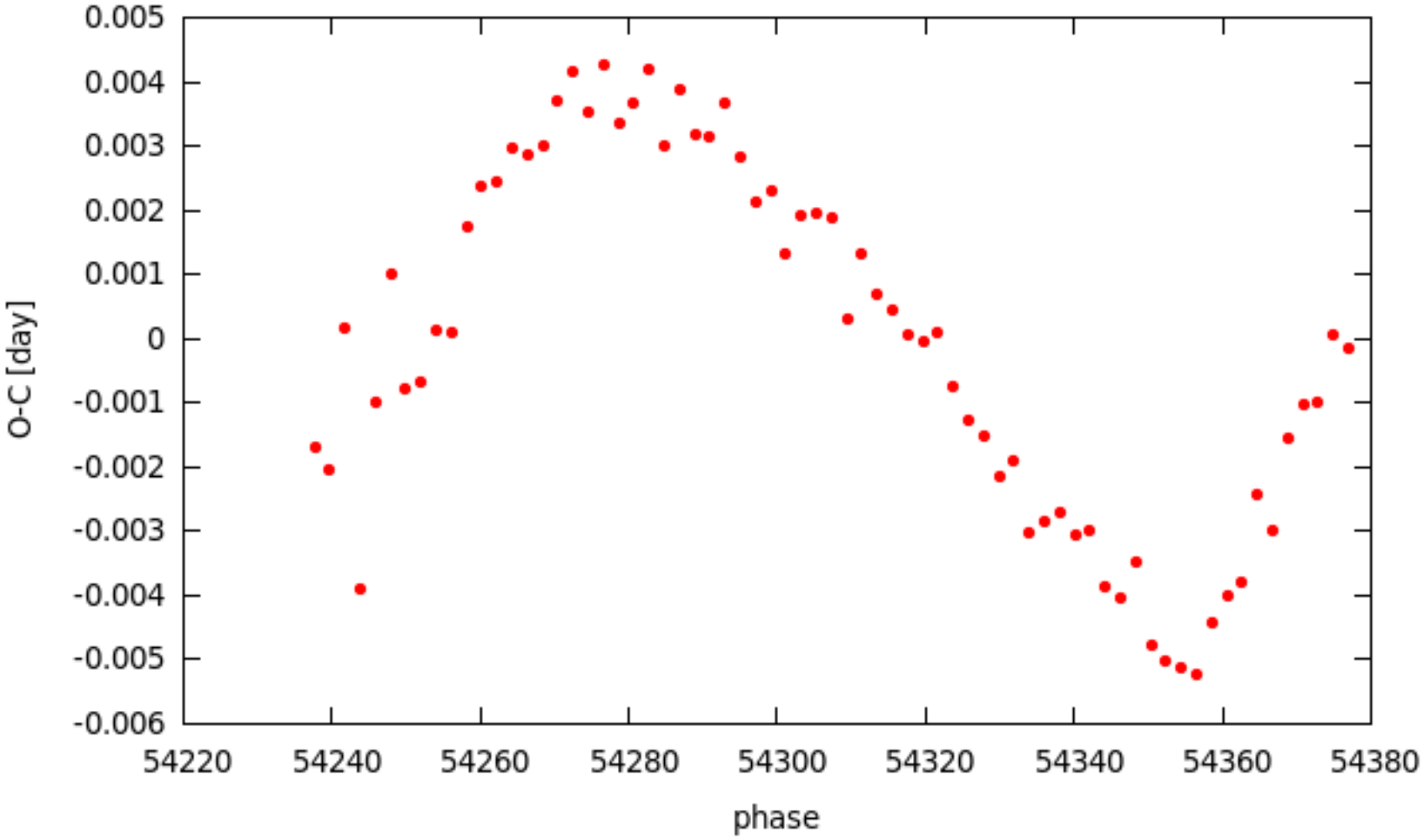
Benefits of parallel programing:



- Binning is faster
- All series at once
- Primary and secondary at once
- For Kepler series 5-6 times faster
- For binaries from K2 mission with short period 2 times slower

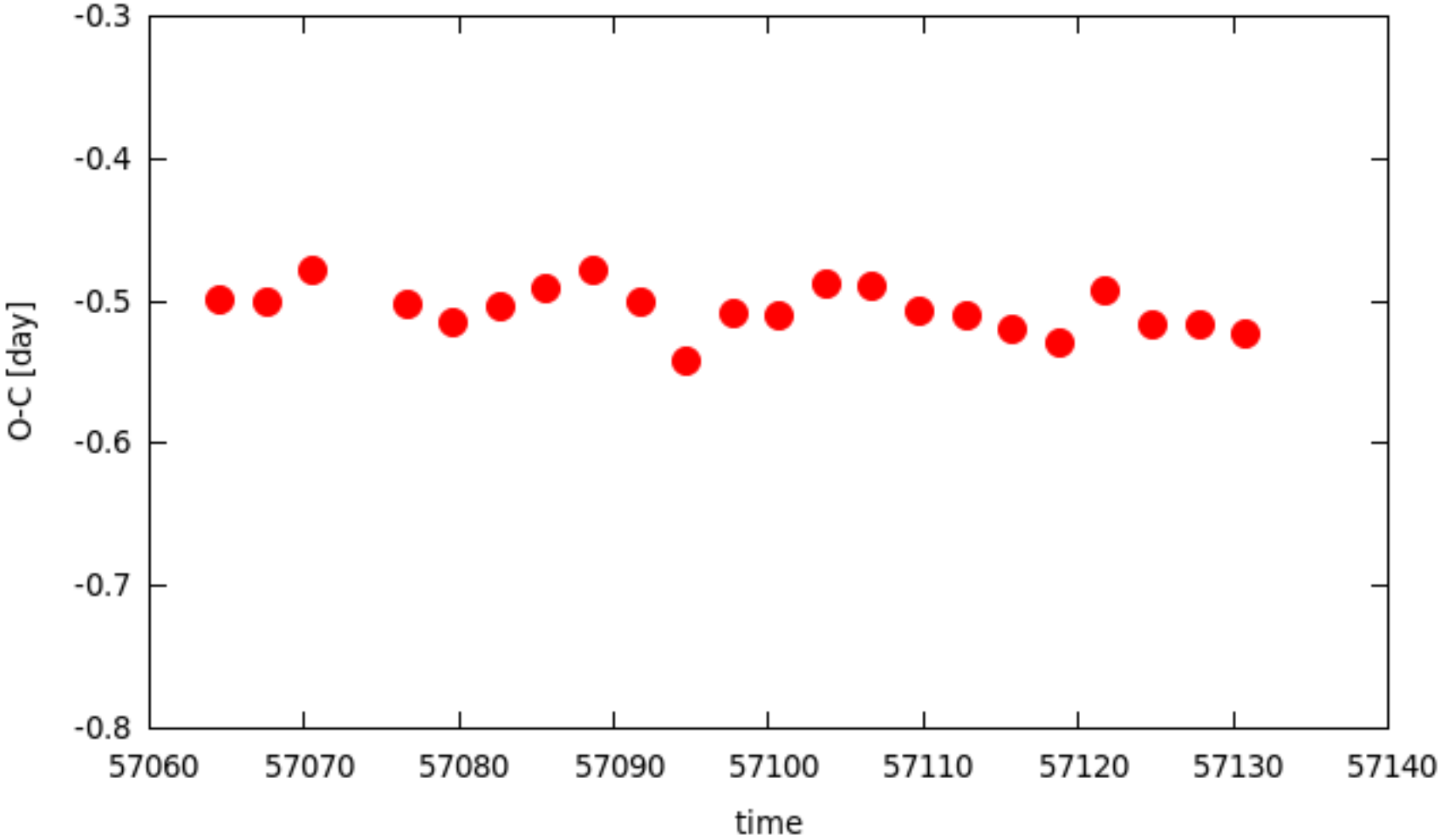
Results

- We have already found some exciting systems in CoRoT



Results

- We have already found some exciting systems in CoRoT and K2 series



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