Fast determination of some orbital elements of eclipsing binary stars on GPU

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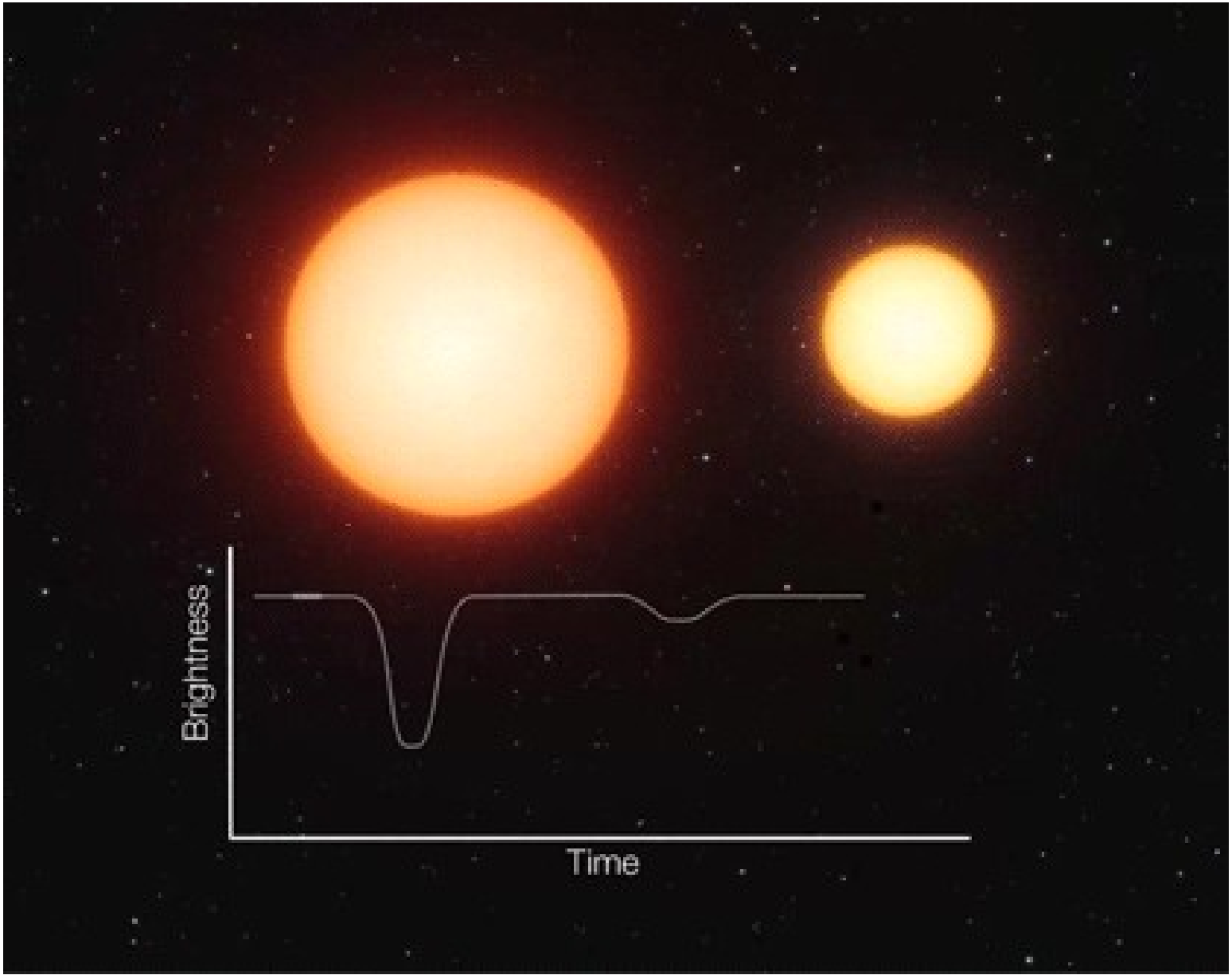
Classification of EBs

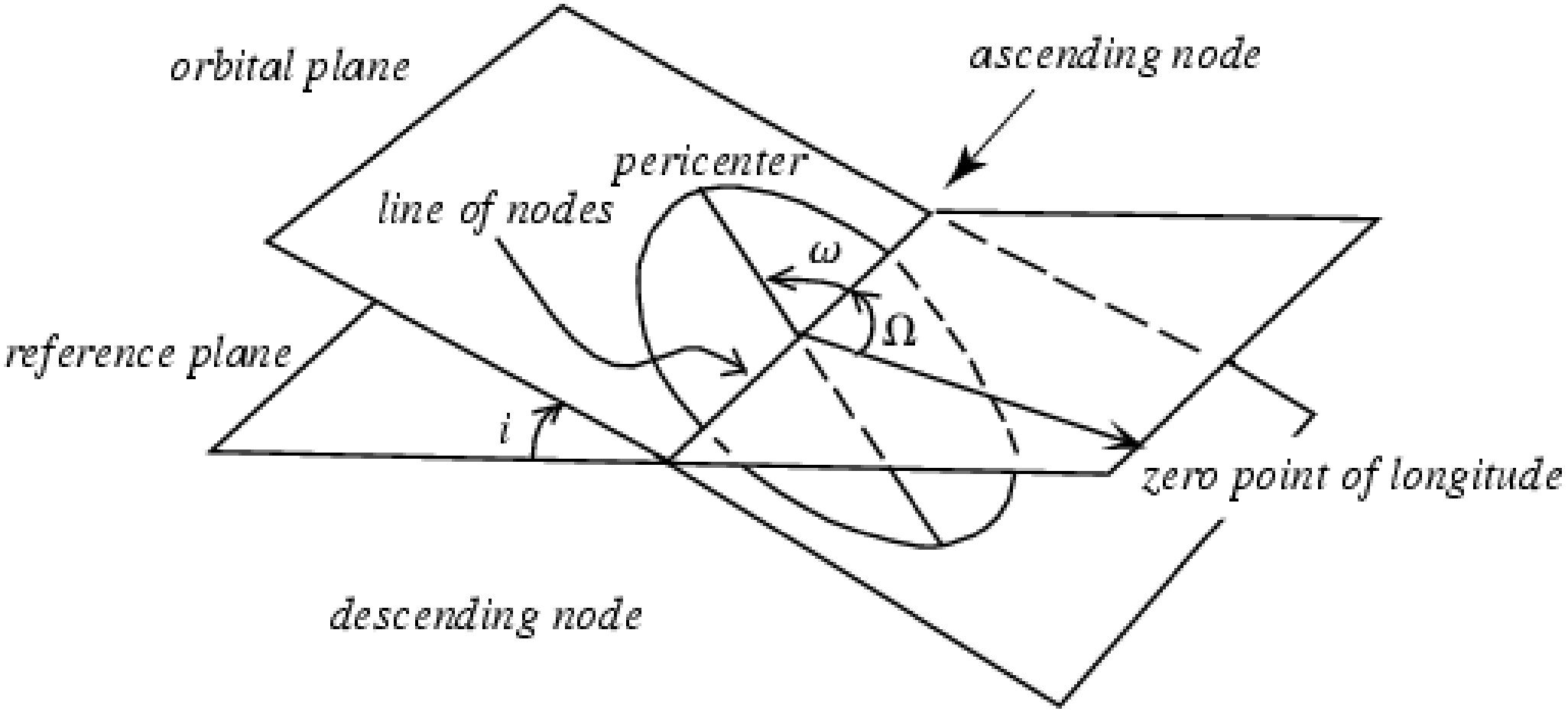
Eclipsing binaries (due to the shape of the light curve):

- Algol
- β Lyr
- W Uma

Algol-type eclipsing binaries

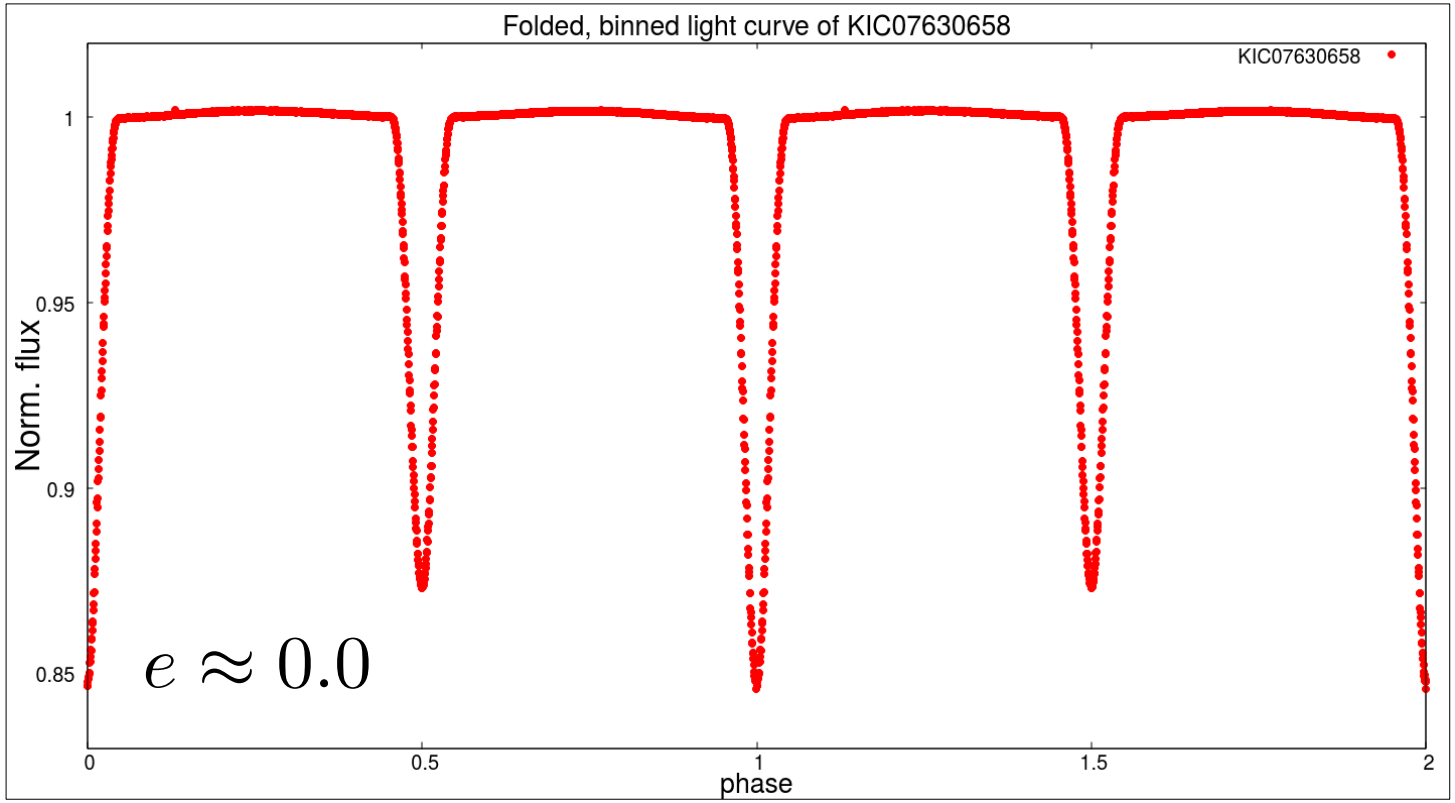


Orbital elements of eclipsing binaries



Algol-type eclipsing binaries

- Algol type binaries:
  - Deep, sharp minima
  - Well defined beginning and end of the eclipses



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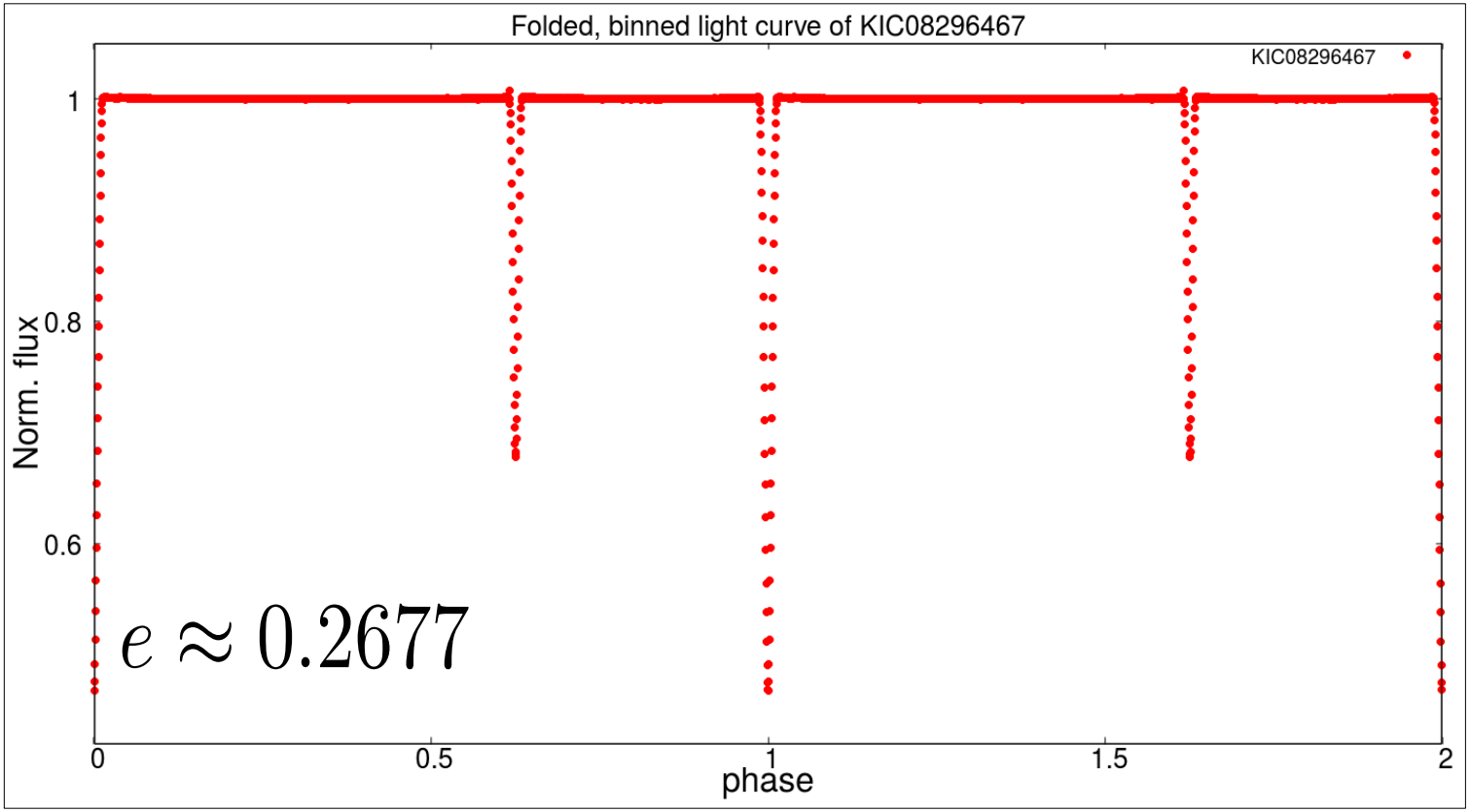
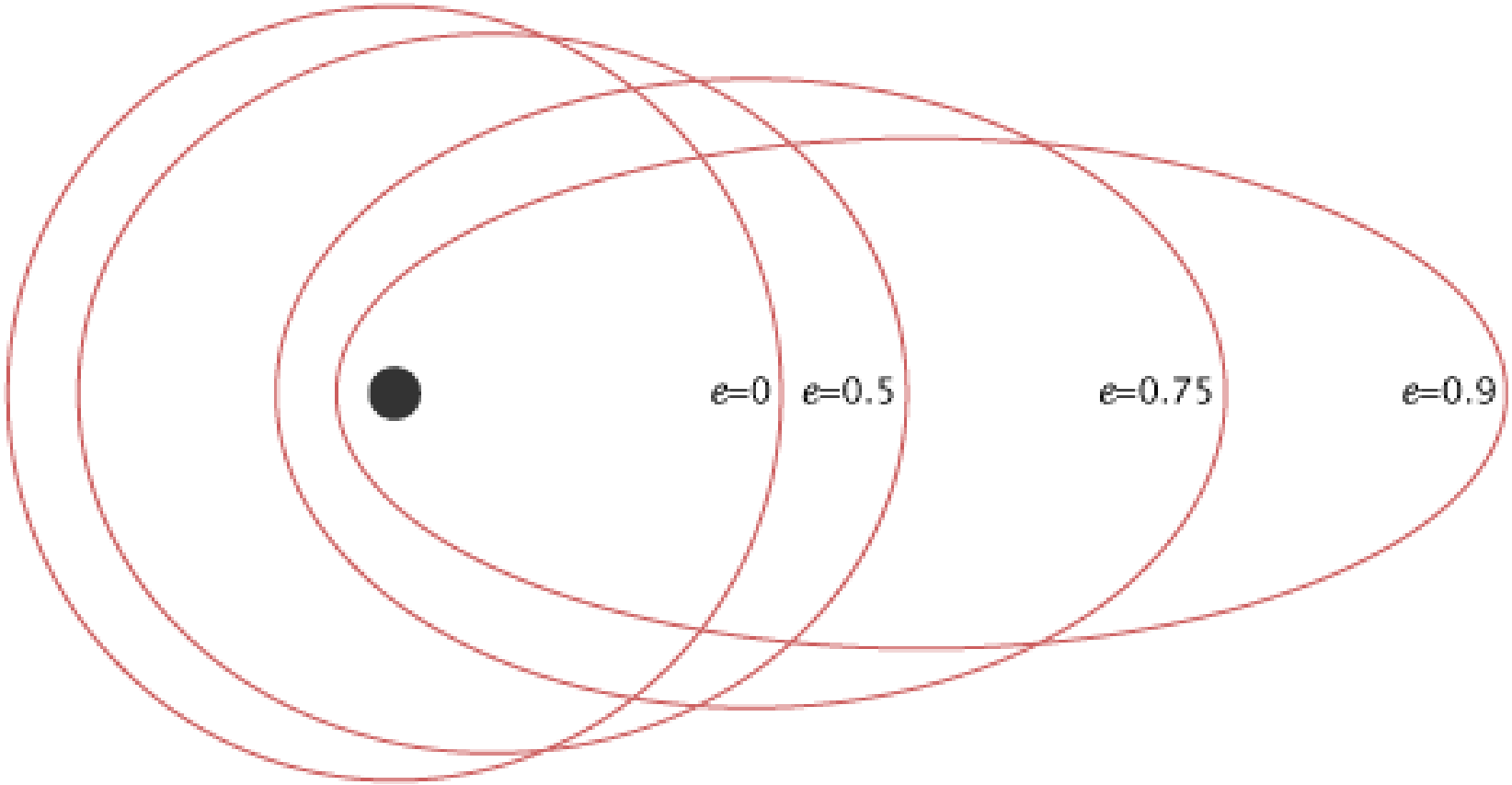


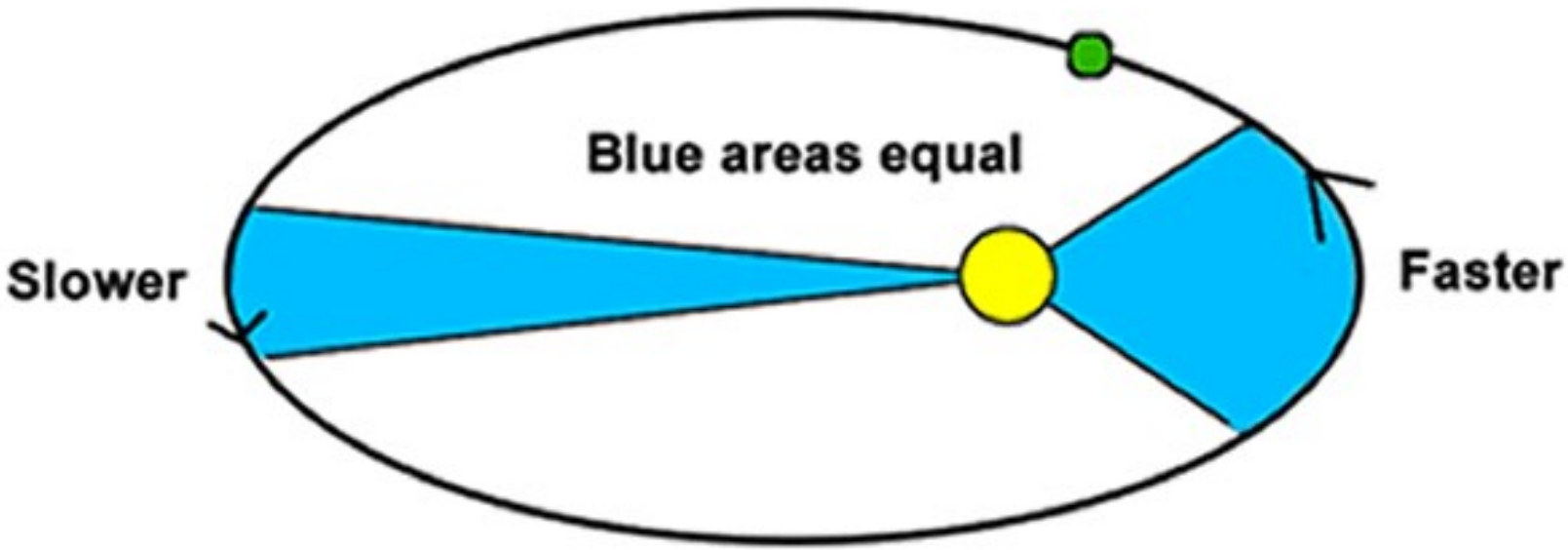
Eccentricity of eclipsing binaries

- Higher *e* -> stretched orbit



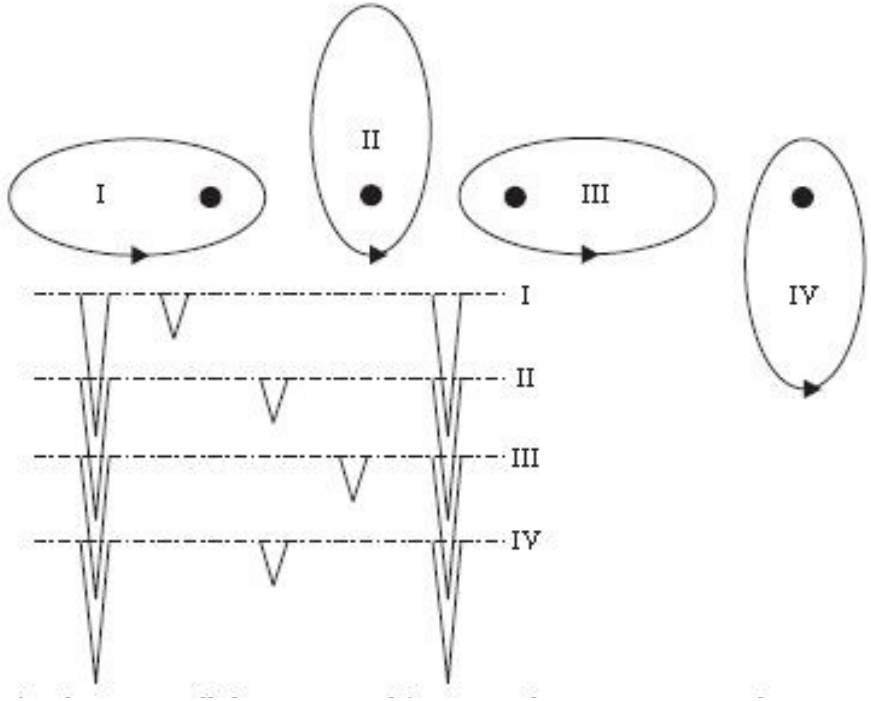
Eccentricity of eclipsing binaries

- Higher *e* -> stretched orbit
- Kepler's 2nd law:
  - Pericenter – faster, apocenter - slower



Eccentricity of eclipsing binaries

- Higher e → stretched orbit
- Kepler's 2nd law
- ω → argument of pericenter



http://fizikaiszemle.hu/archivum/fsz0902/borkovits09024.jpg

Orbital elements of eclipsing binaries

$$e \cos \omega \approx (0.5 - \delta\varphi) \frac{\pi}{2}$$

$$e \sin \omega \approx \frac{t_{p14} - t_{s14}}{t_{p14} + t_{s14}}$$

Orbital elements of eclipsing binaries

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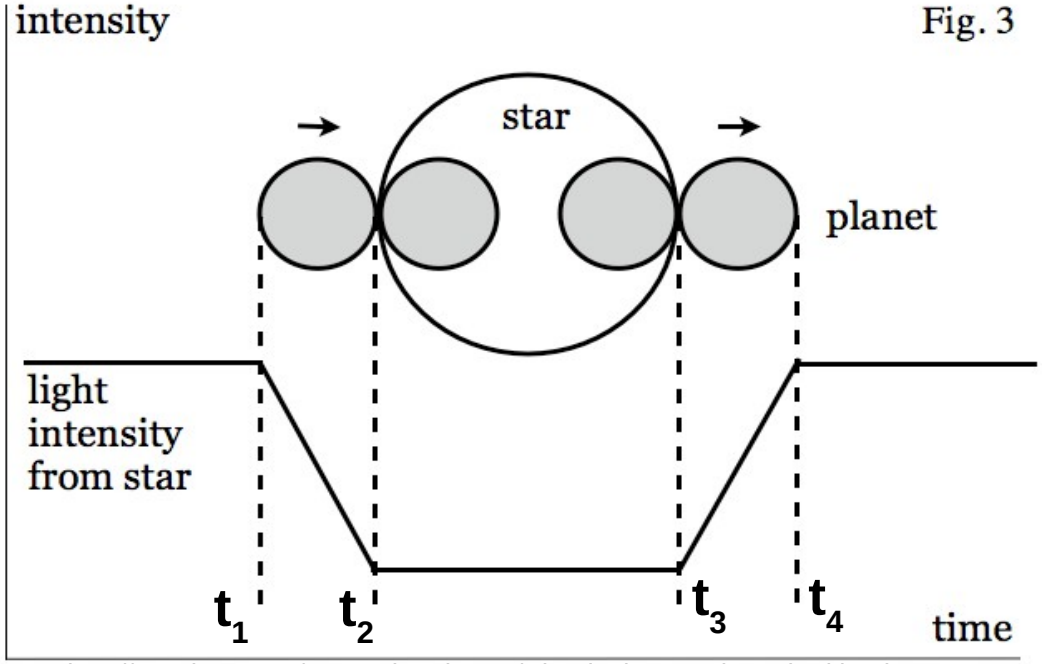

http://exoplanets.co/extrasolar-planets/what-is-the-transit-method.html

Orbital elements of eclipsing binaries

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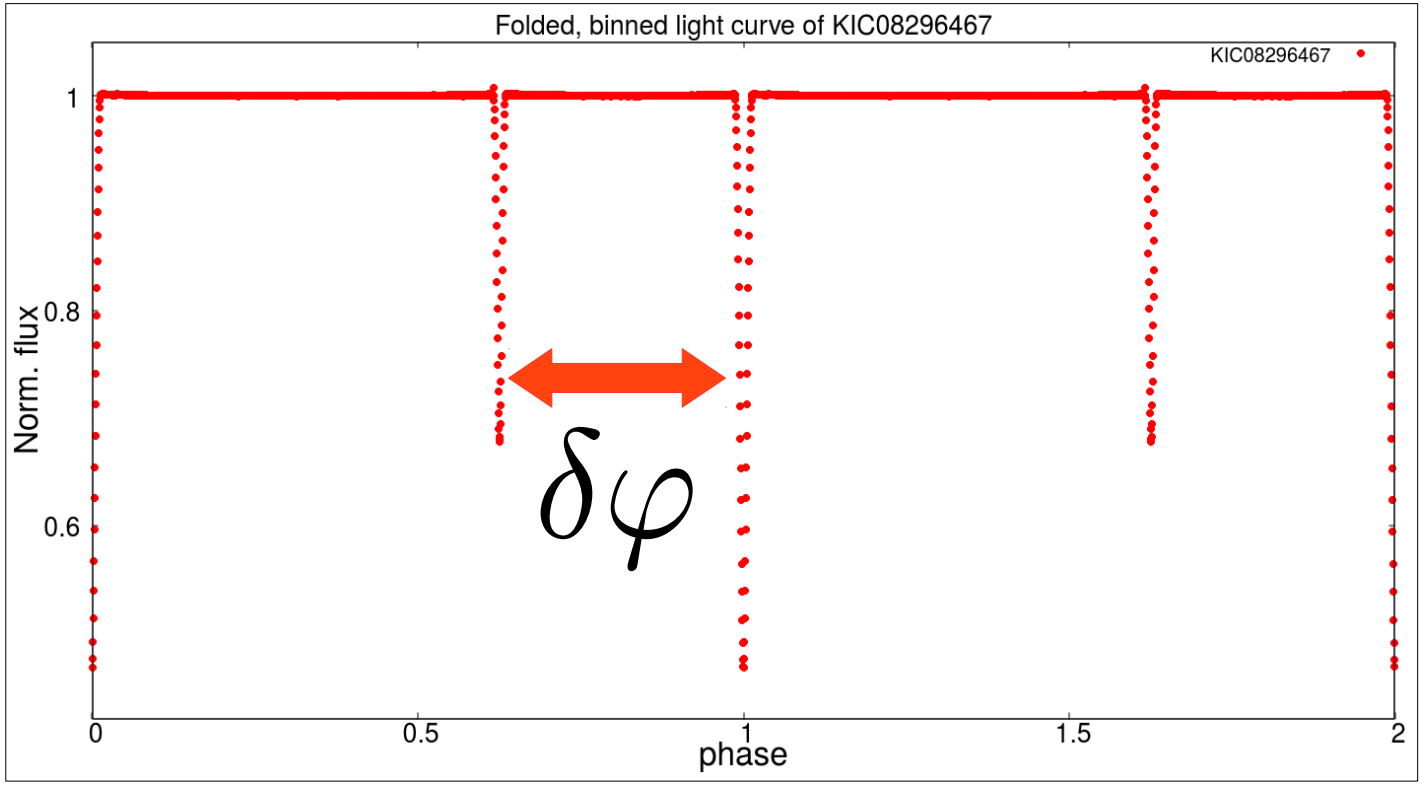
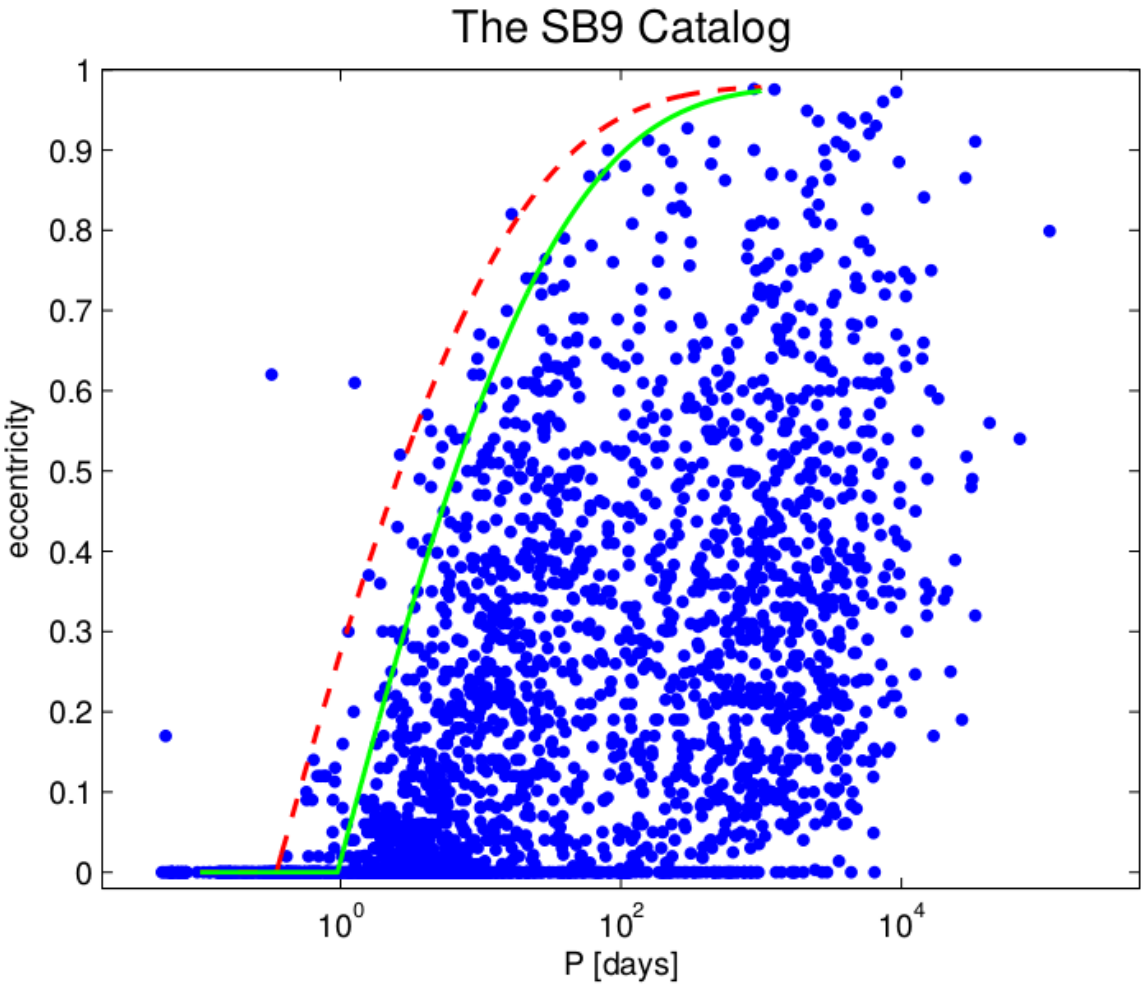


Why e, ω?

- Examine tidal forces in stars
- Understanding the circularization and evolution of binaries
- Period-eccentricity distribution

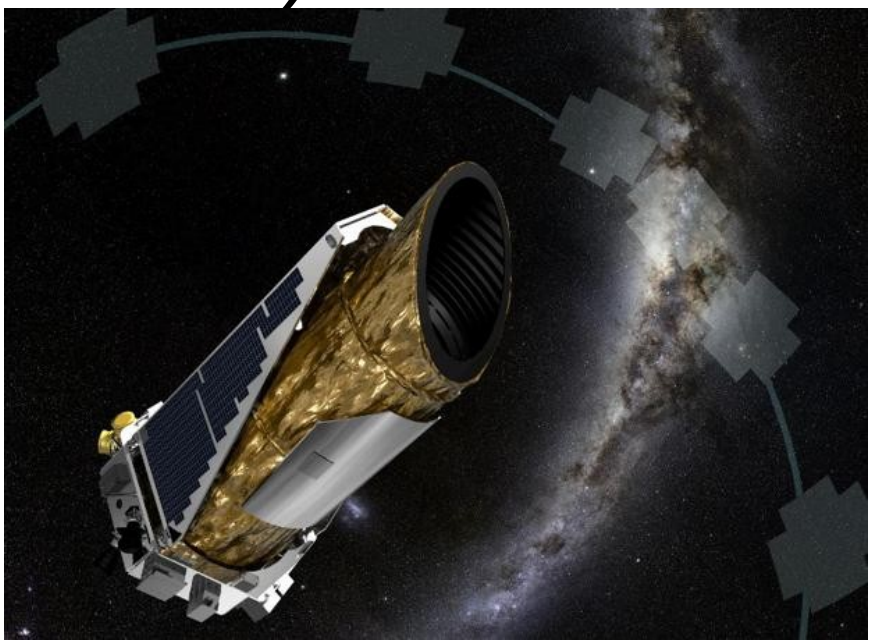
Period-eccentricity distribution

- Mazeh (2013): 2751 spectroscopic binaries
- Period and eccentricity from RV solutions



The data

- Kepler space telescope (original Kepler (2009-2013) & K2 (2013-))
- CoRoT (English: **CO**nvection **RO**tation and planetary **T**ransits) space telescope (2007-2012)



Kepler space telescope

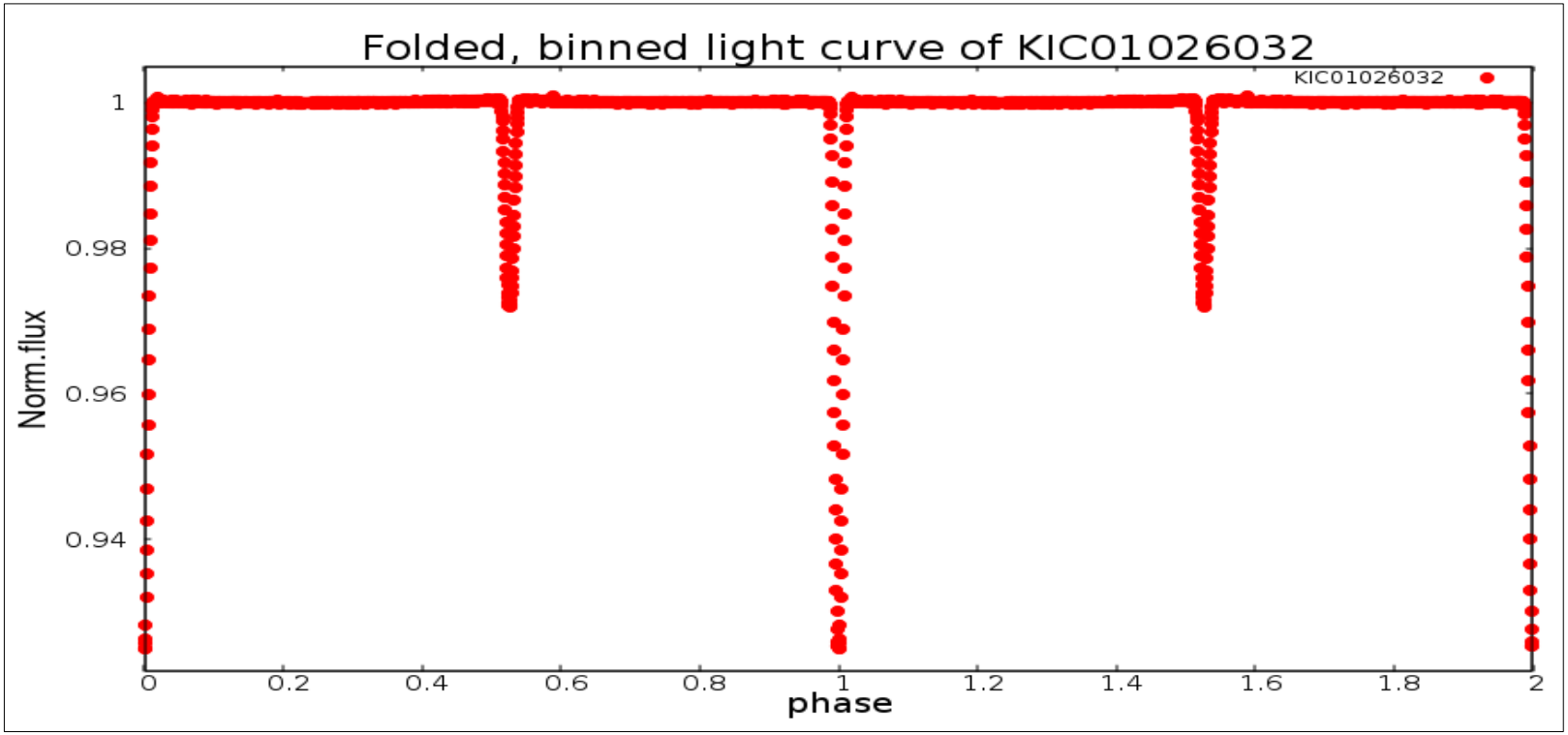
- Nearly 4 years of constant observation
- Constant FOV near the Cygnus
- Long cadence and short candence data
- Searching for exoplanets, but a huge amount of other variables, too
- Ultra-precise photometry

CoRoT space telescope

- Many FOV (each observed for a short time)
- Searching for exoplanets, but a huge amount of other variables,
- High-precision photometry

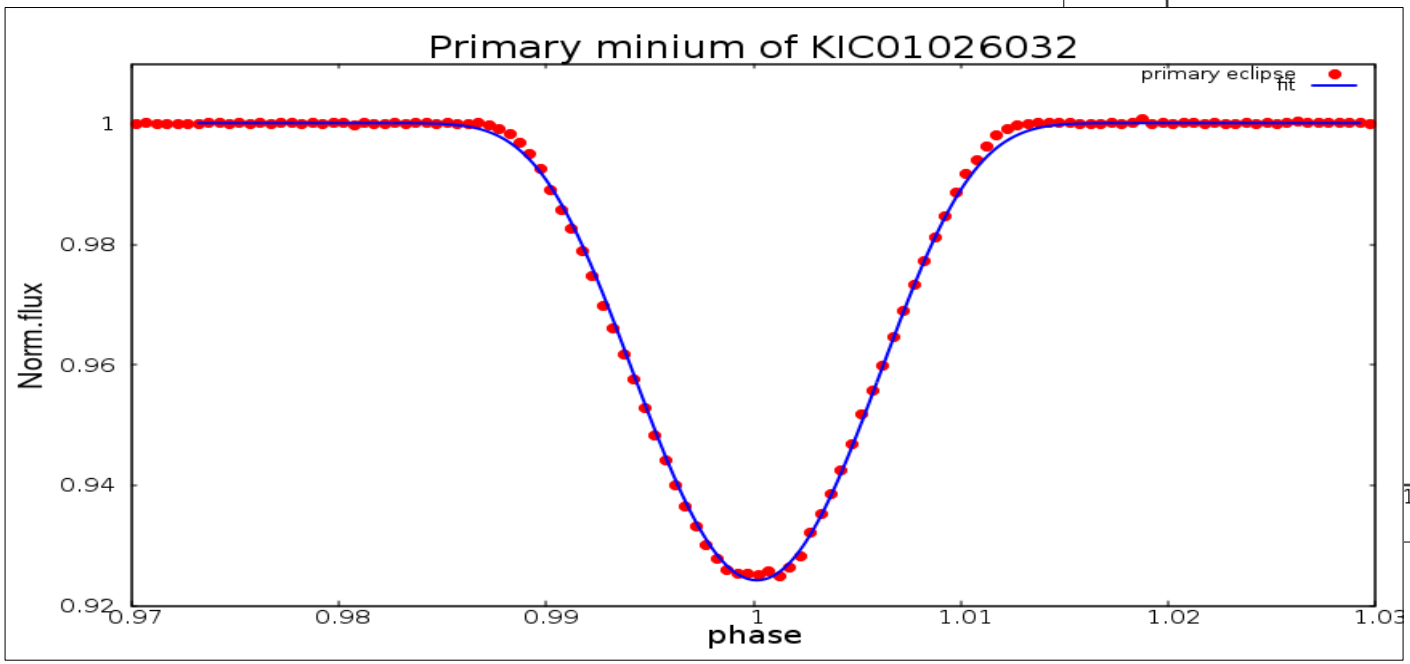
The algorithm - „preprocessing“

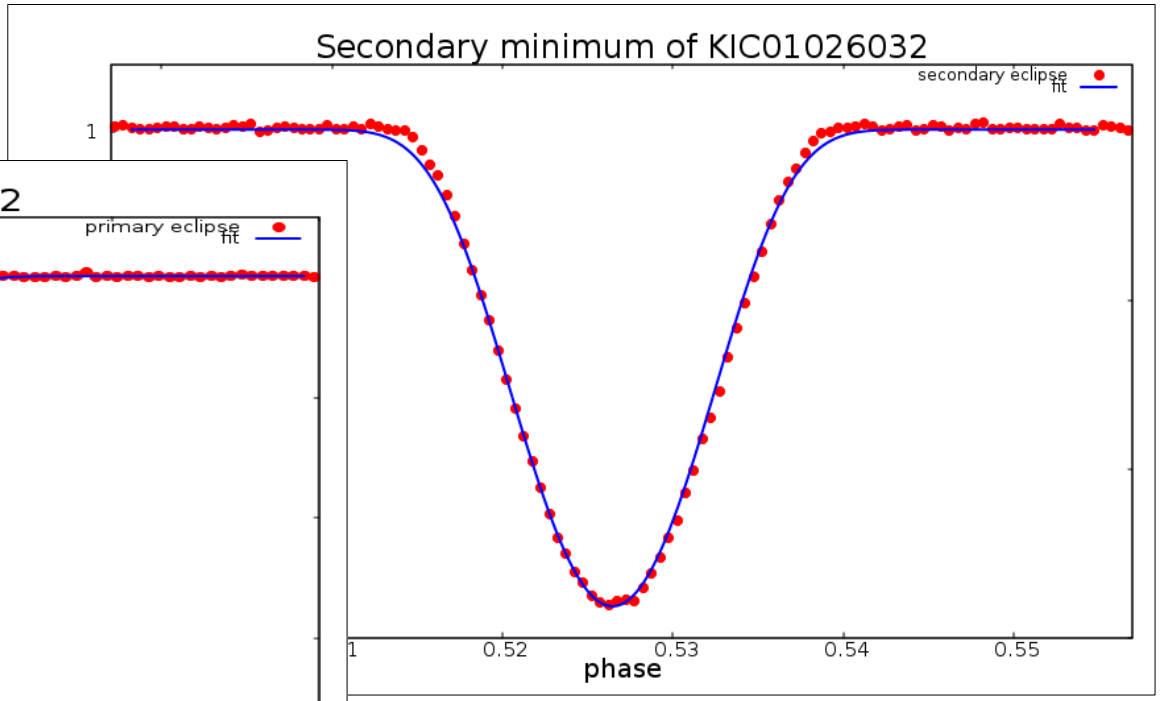
- Download the data (MAST, Villanova, Vizier)
- Determining periods
- Folding and binning light curves – coming soon



The algorithm

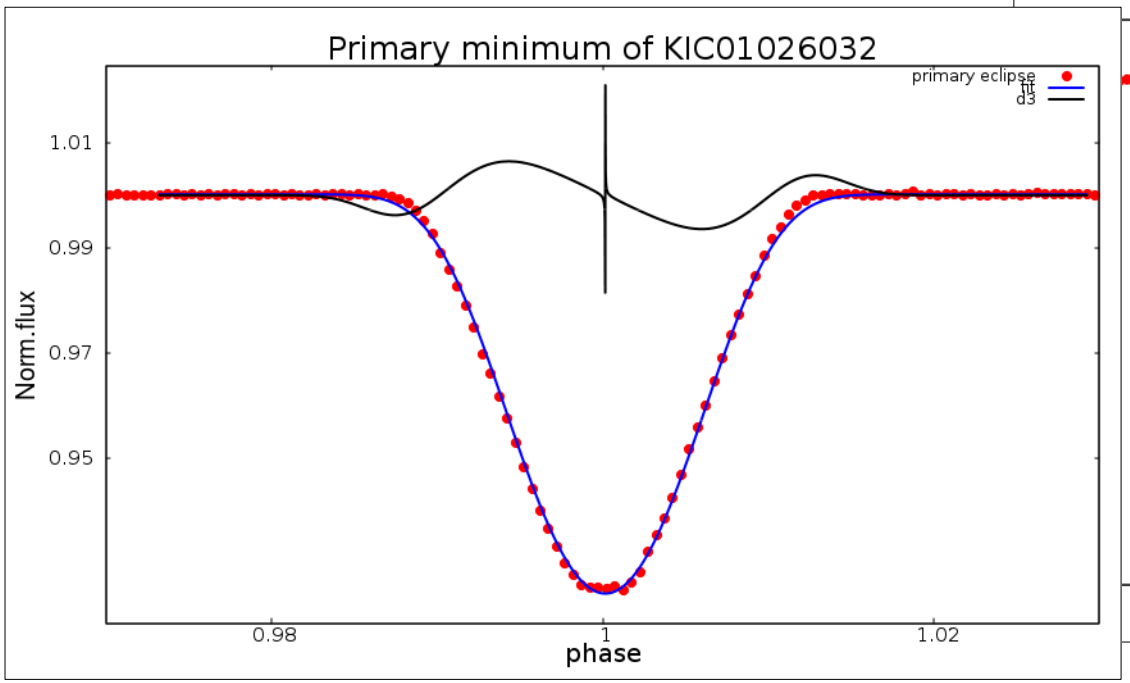
- CPU:
  - Find the primary and secondary minimum
  - Fit the shape of the minima with Levenberg-Marquardt method

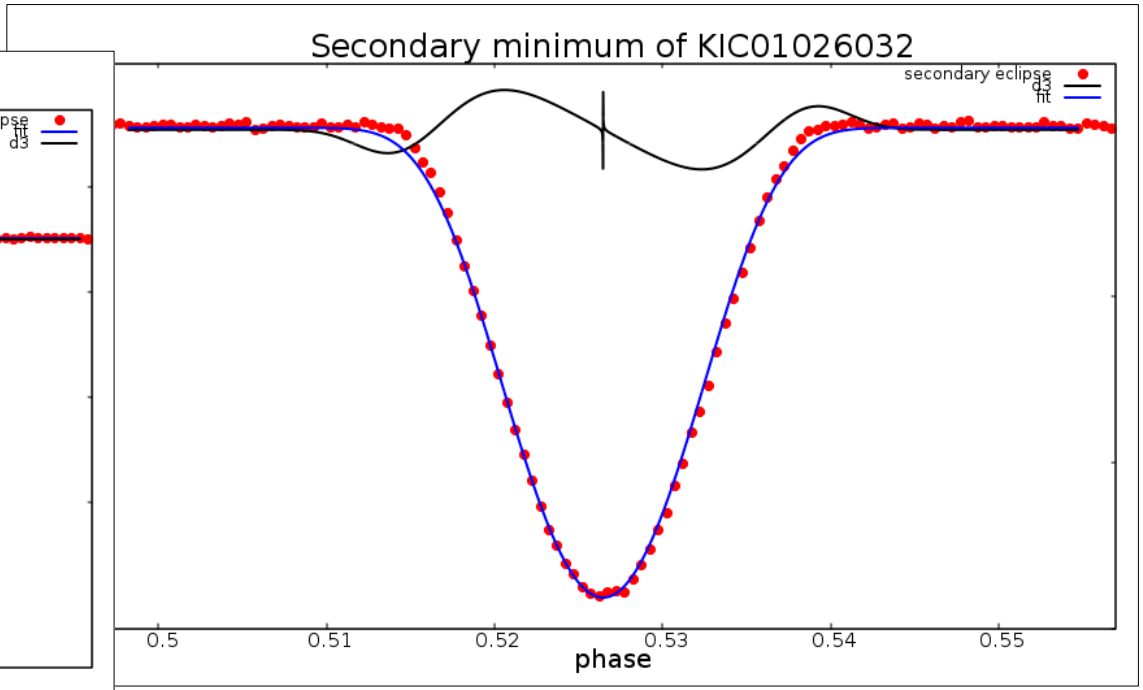




The algorithm

- GPU:
  - Refine the resolution of data in minima
  - Calculate the 3rd derivative with finite difference coefficients

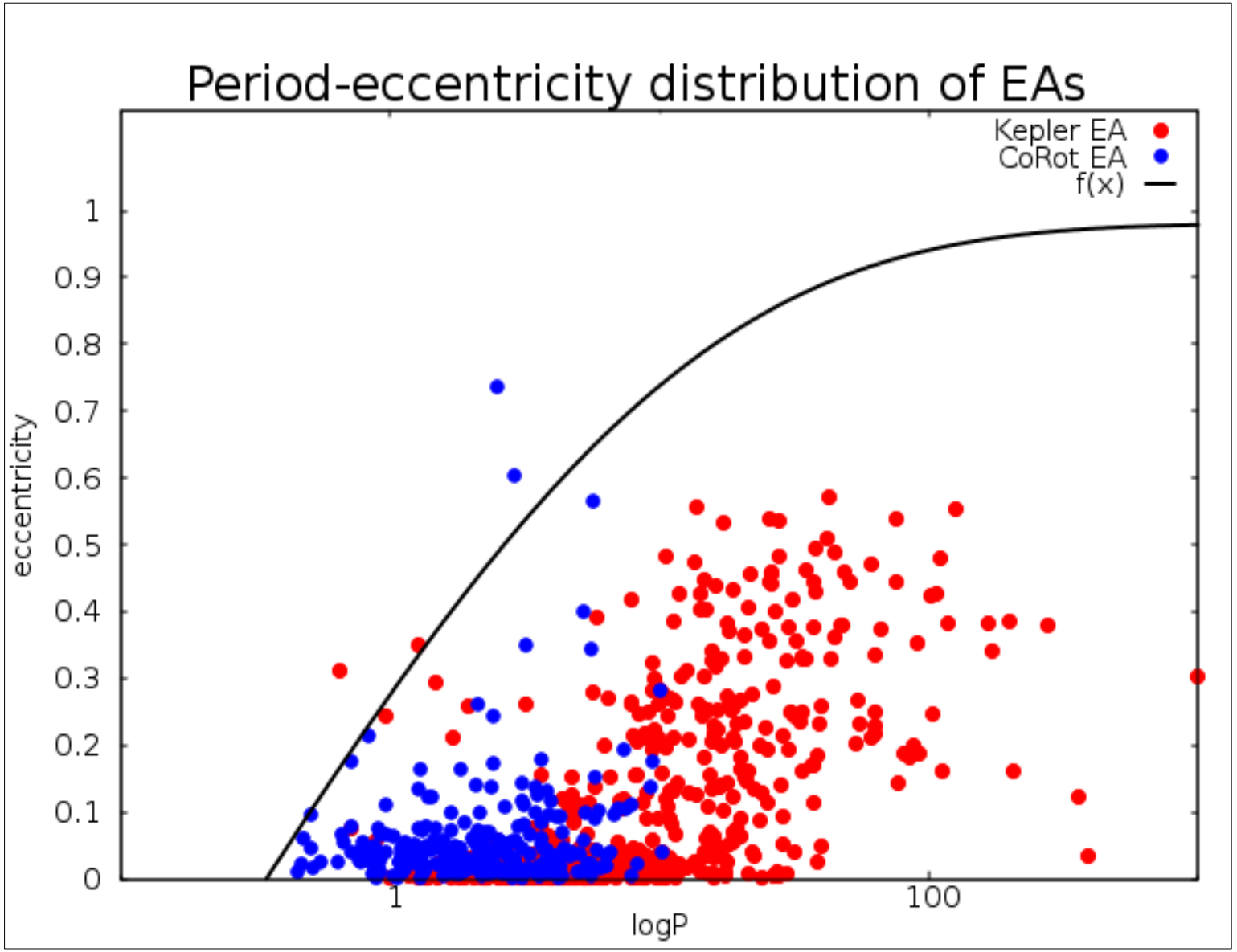




The algorithm

- GPU:
  - Determine t_1, t_4 with the 3rd derivative
  - thrust::minimum_value
  - thrust::maximum_value
- Calculate eclipse durations, ecosω,esinω
- Calculate e,ω
- Plot the results, create output file(s)

Results


Period-eccentricity distribution of EAs
Kepler EA
CoRot EA
f(x)
eccentricity
logP
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1
100

Results, further plans

- Determined e,ω for 754 systems from Kepler data
- < 20 min on GPU (about 20% faster)
- Further investigation for other (future) space missions
- Many more thousand systems to be investigated
  → statistics from period-eccentricity distribution

Thank you for your attention!

Special thanks to:

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