The EREBOS project – Studying the influence of low mass objects on late stellar evolution

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EREBOS collaboration

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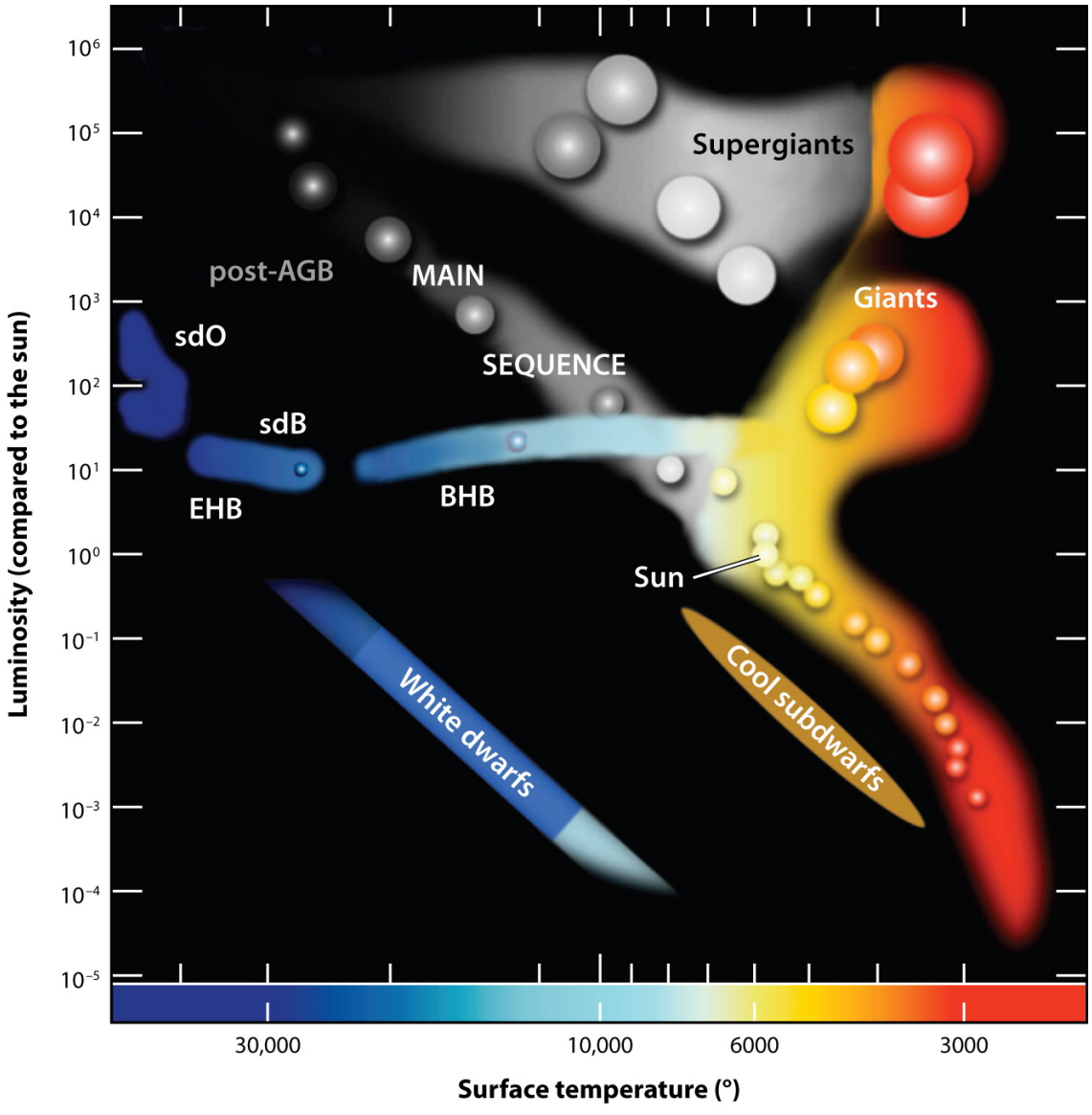
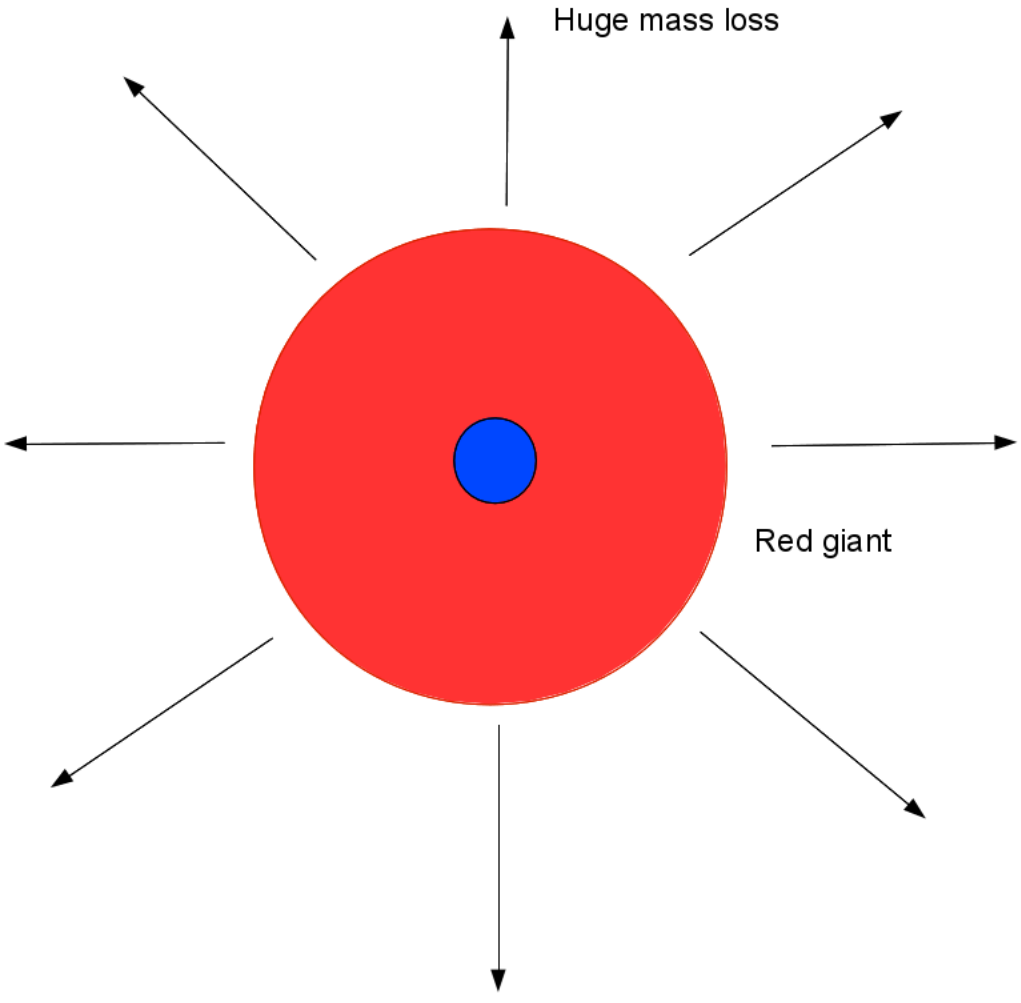
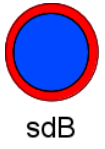
Hot subdwarf stars of spectral type B (sdB)



Heber U. 2009.
Annu. Rev. Astron. Astrophys. 47:211–51

Stripped red giant at the tip of the RGB





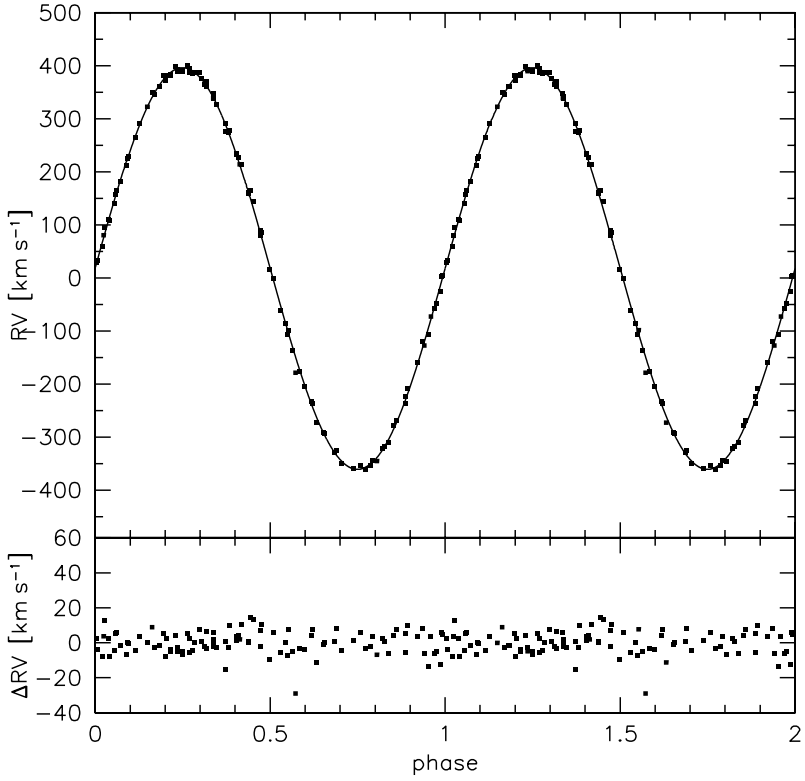
in He-core burning phase

direct observation, e.g., Maxted, .., Schaffenroth 2013, Nature

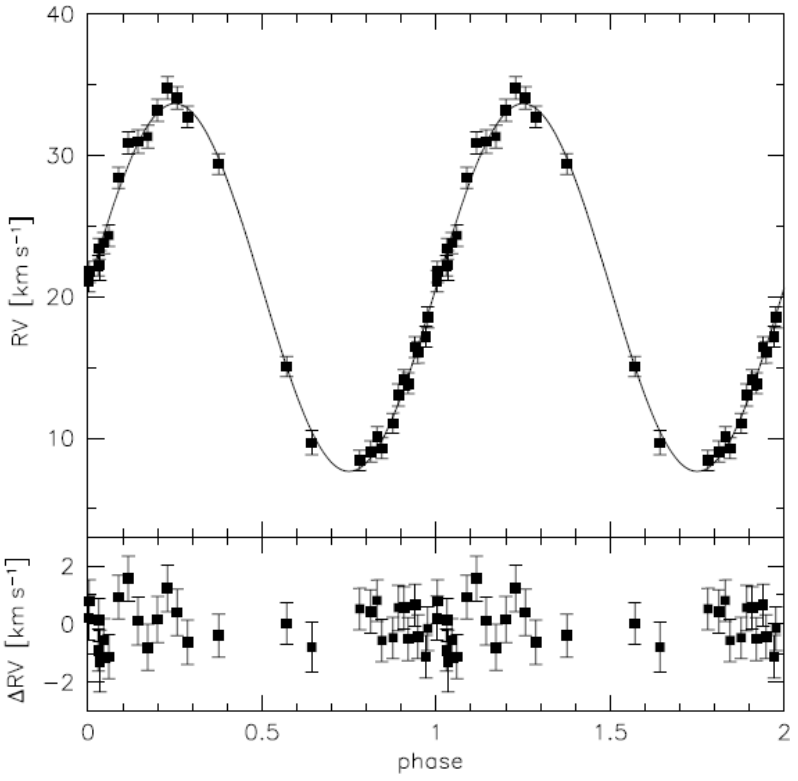
drawing is not in scale

Hot subdwarfs in binaries

unseen companion discovered by radial velocity method



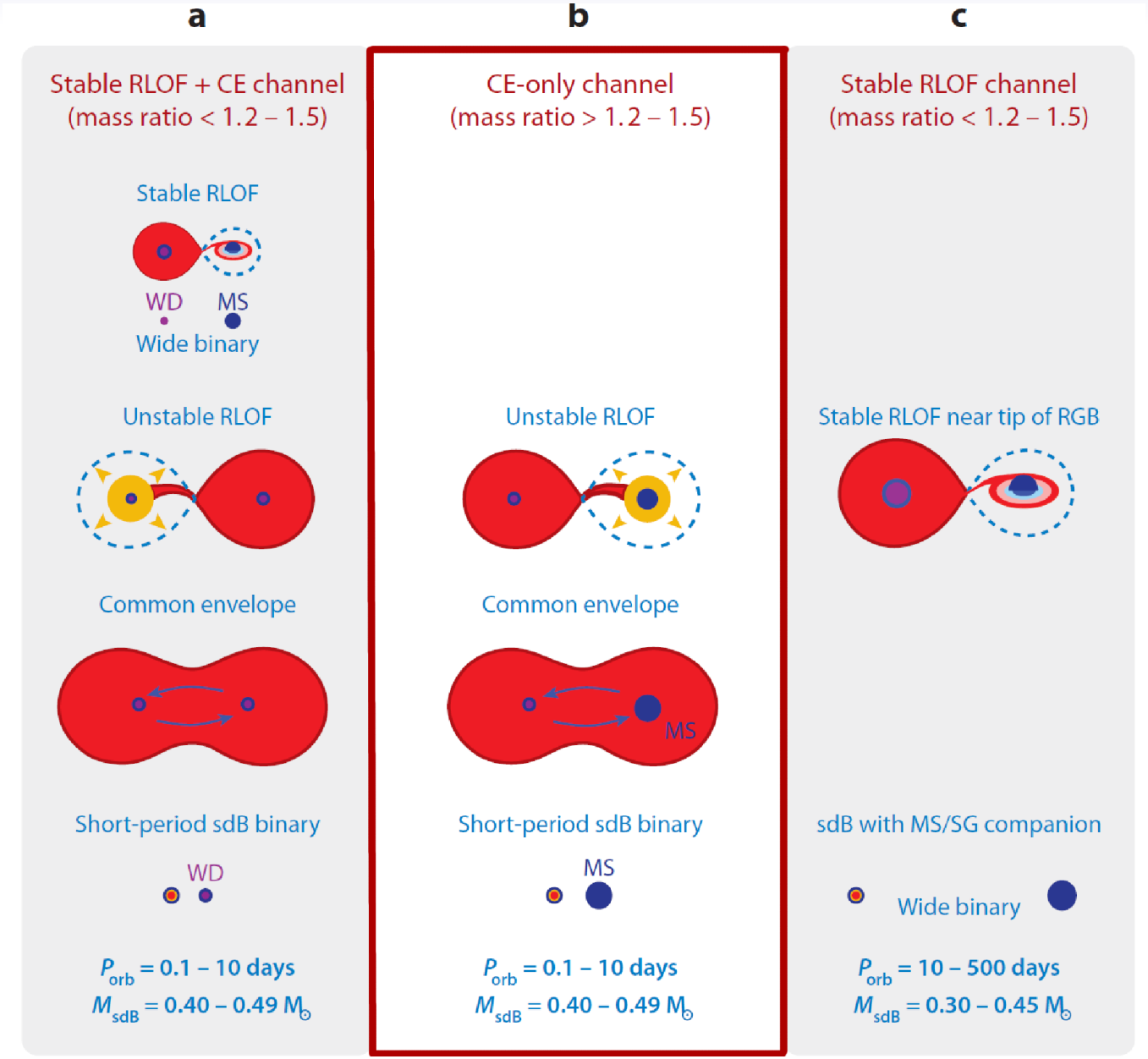
CD-30°1122, $P = 0.0498$ d
(Geier,.., Schaffenroth et al. 2013)



PHL 457, $P = 0.3131$ d
(Schaffenroth et al. 2014)

more than 50% of sdBs in close binaries ($P < 30$ d)

Formation of sdB binary

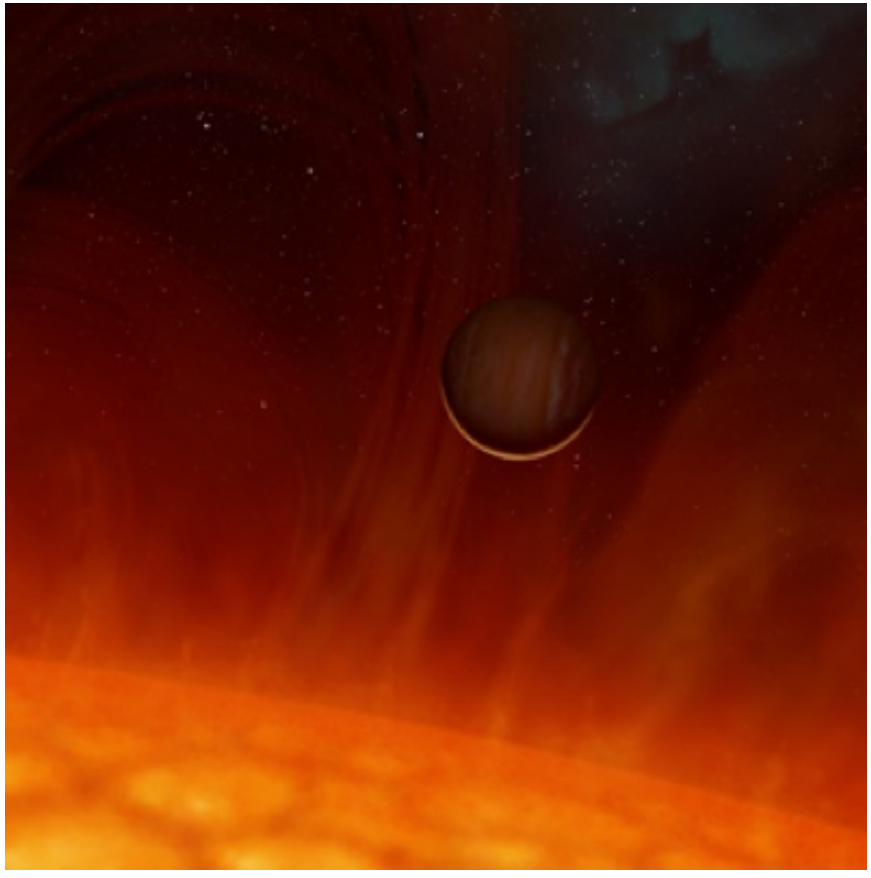


Han et al. (2002,2003)

Formation of sdBs by substellar objects

Soker 1998 AJ

- Orbit of planet in envelope of evolved star
- fate of planet:
  - evaporation
  - merger with the core
  - survival for $\geqslant 10 M_{\mathrm{Jupiter}}$ depending on separation
    $\rightarrow$ ejection of envelope



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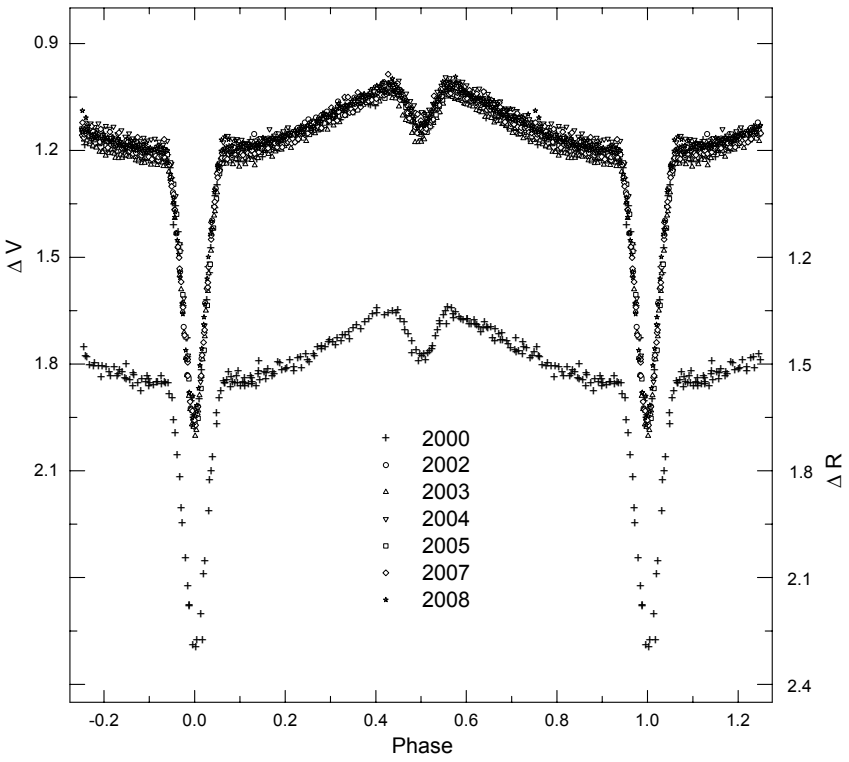
$\rightarrow$ **studying the influence of low-mass stellar or substellar companions on stellar evolution**

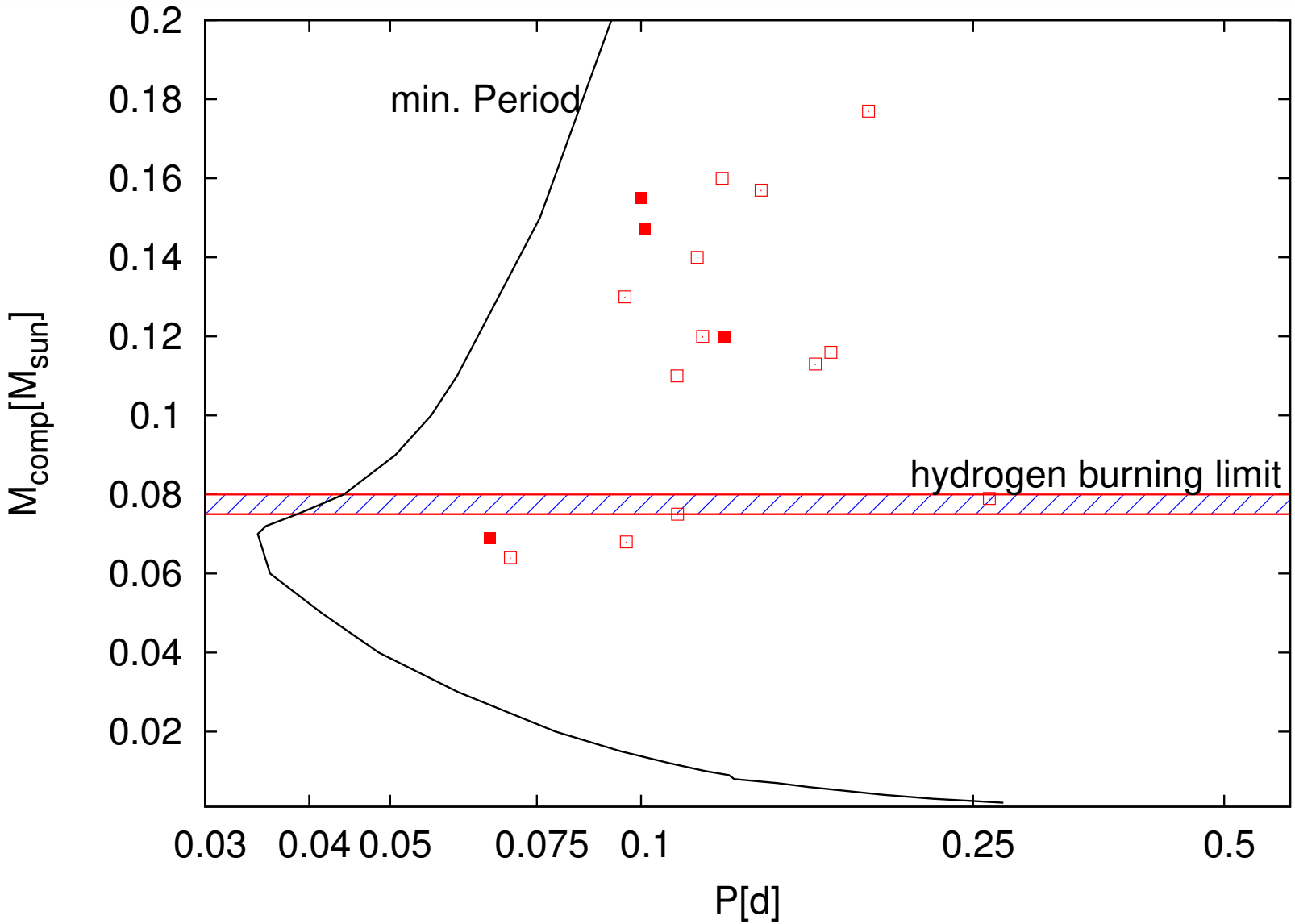
HW Virginis systems

- eclipsing post-common envelope binaries consisting of sdB and cool, low mass stellar or substellar companion
- determination of absolute masses, radii and separation of both components
- 17 HW Vir systems published
- very short period $\sim$ 1.5-6 h (separation $\sim 0.5 - 1\,R_{\odot}$)
- unique lightcurve
  - $\Rightarrow$ prominent reflection effect
- only sdB visible in spectrum



Lightcurve of HW Virginis (Lee et al. 2009)

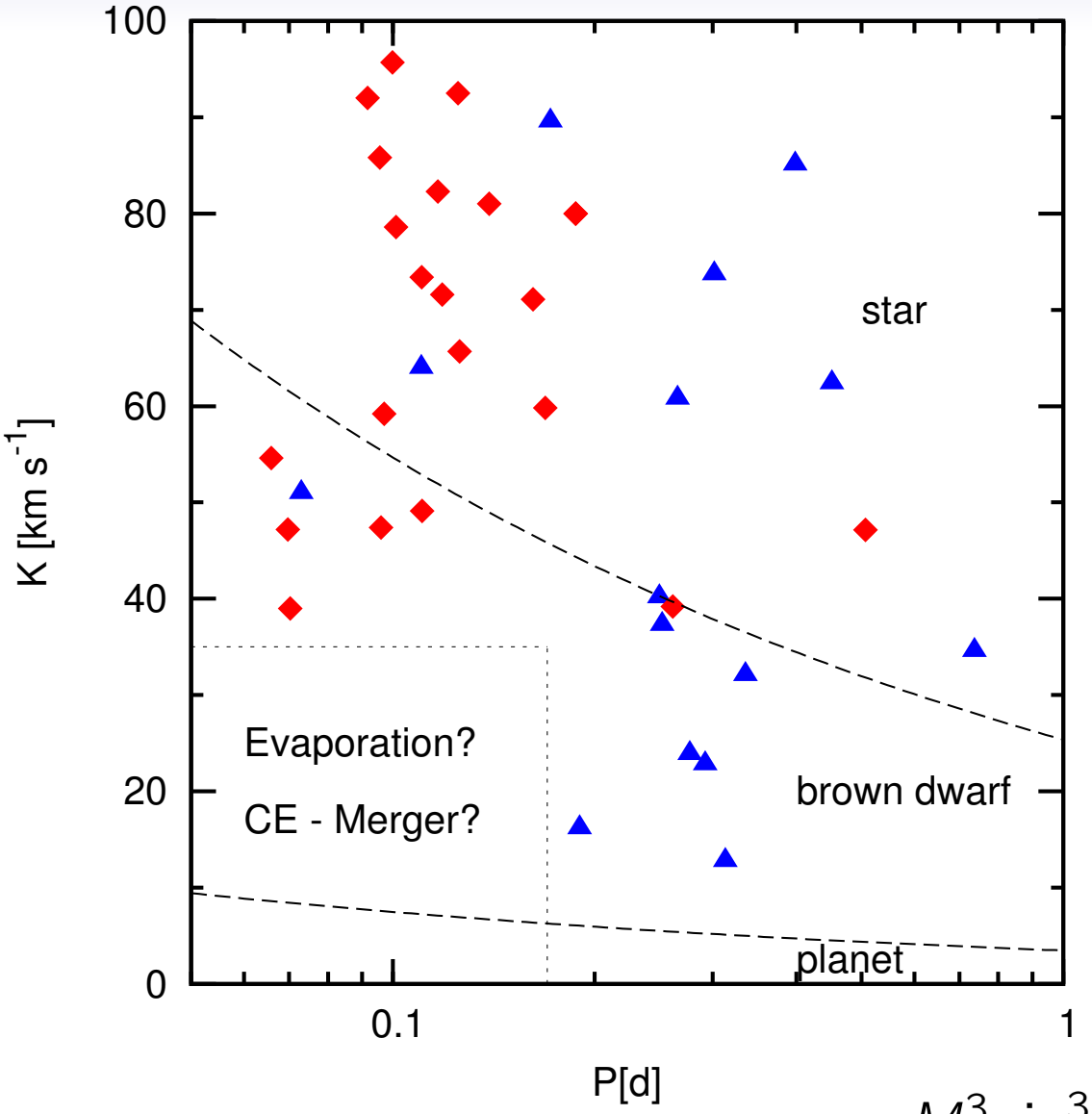
Period vs. companion mass of the HW Vir systems



Schaffenroth 2015

→ substellar companions preferably at the shortest periods

Minimum companion masses of reflection effect binaries

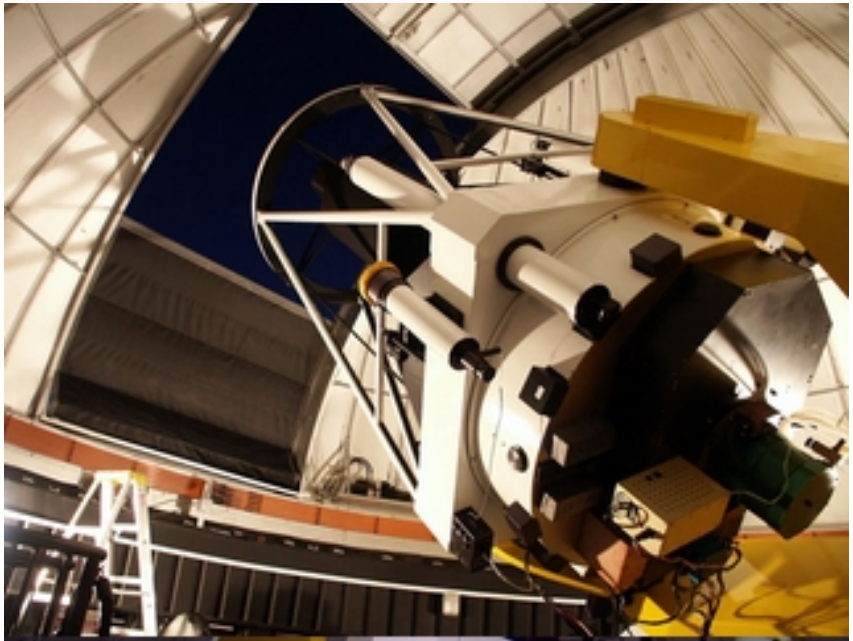


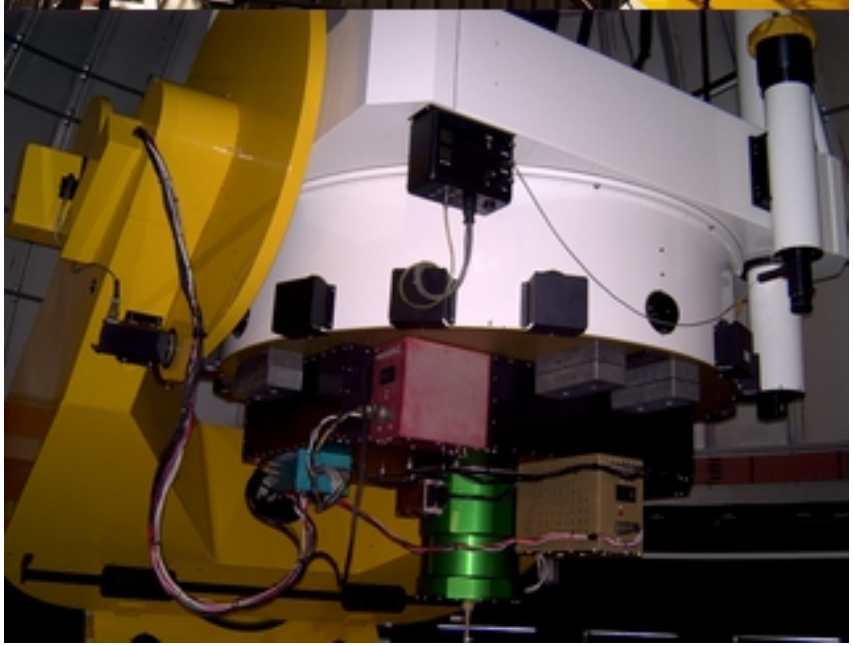
Schaffenroth 2015

$$f(m) = \frac{M_2^3 \sin^3 i}{(M_1 + M_2)^2} = \frac{K_1^3 P}{2\pi G}$$

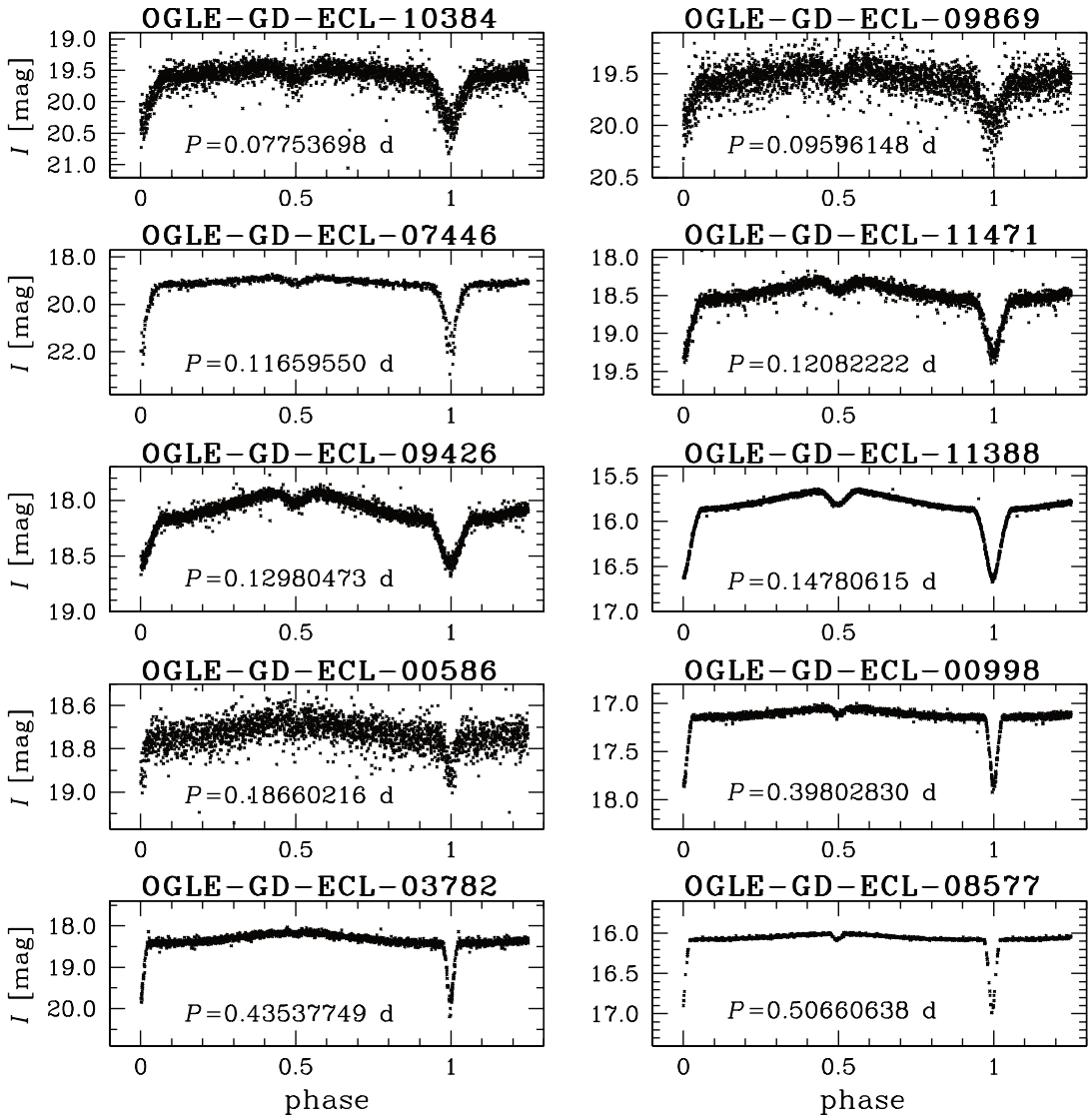
The Optical Gravitational Lensing Experiment (OGLE)

- Polish astronomical project based at the University of Warsaw
- photometric survey $\rightarrow$ discovery of microlensing events, planetary transits, pulsators, eclipsing binaries
- different fields in SMC, LMC, Buldge and Galactic Disc observed



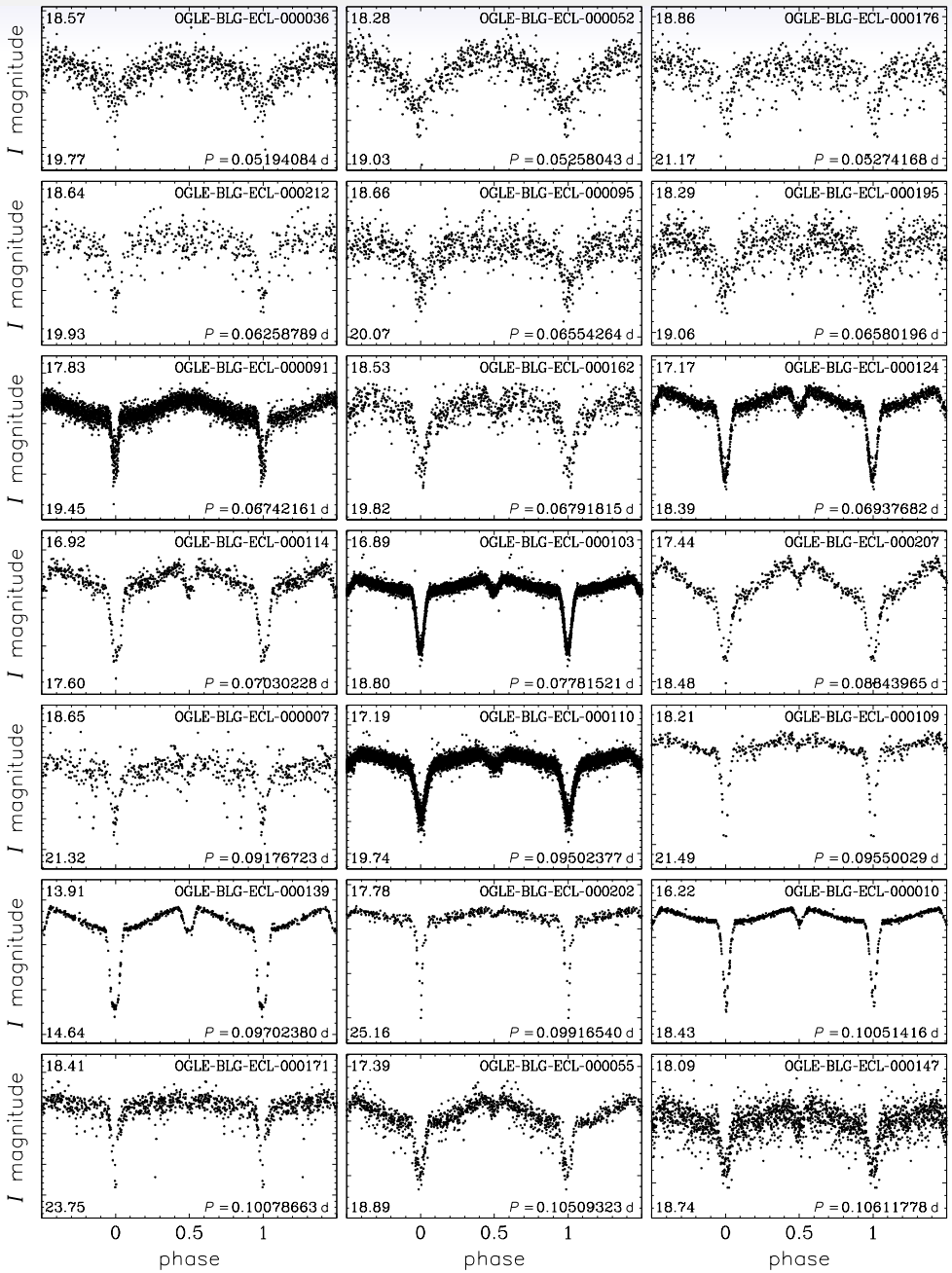


OGLE-III Galactic disc field



Pietrukowicz et al. 2013

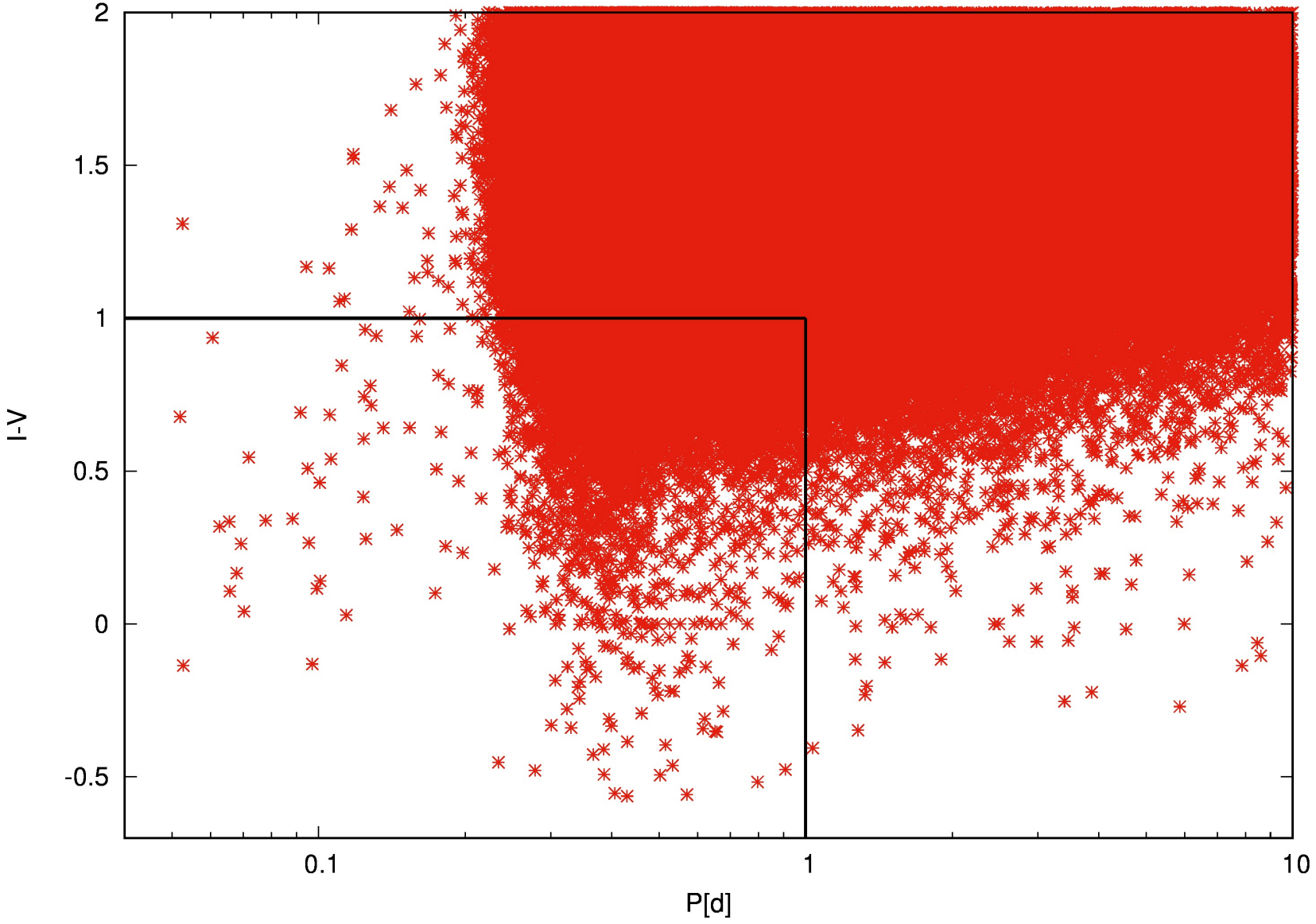
OGLE-IV Bulge field



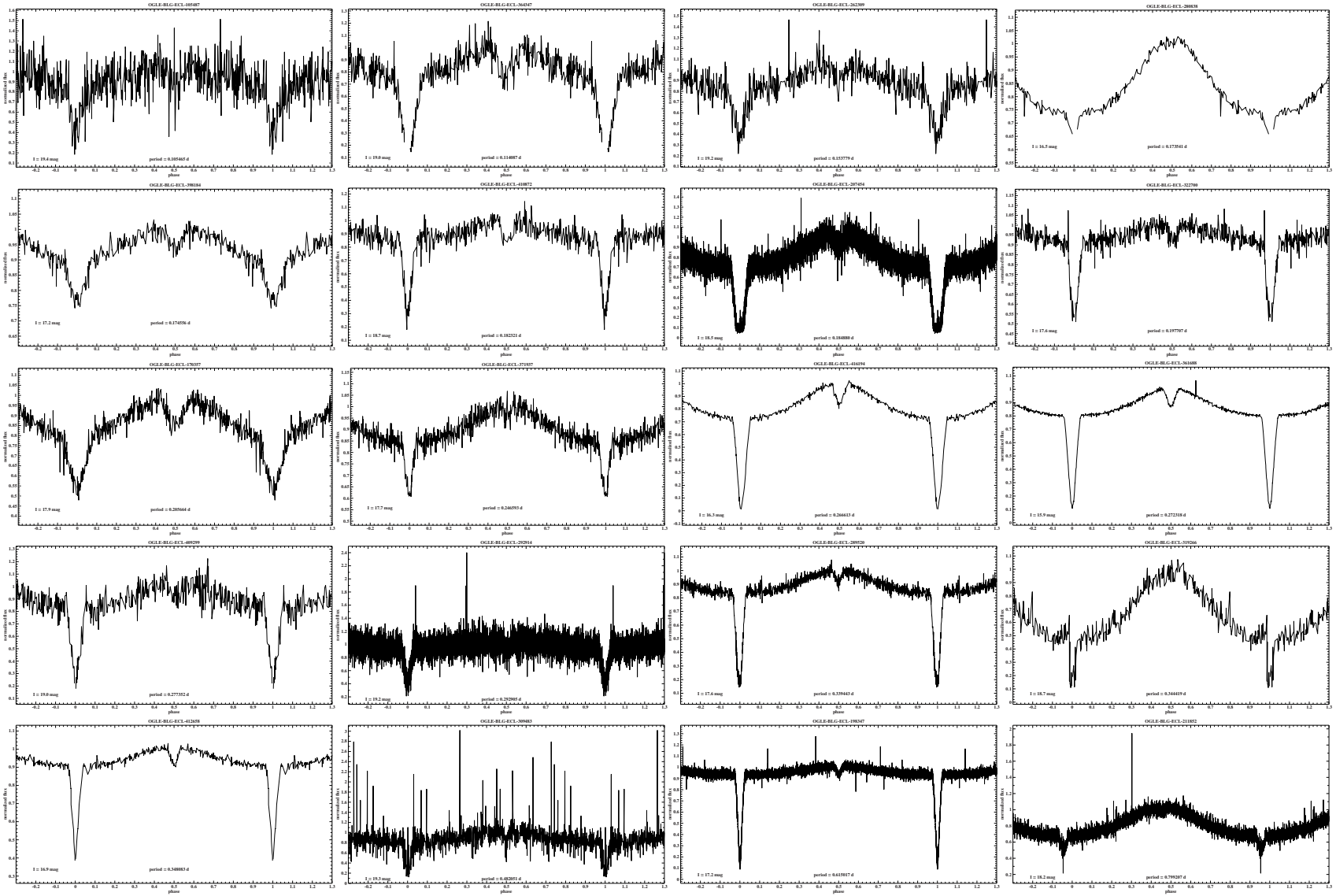
Soszyński et al. 2015

450 000 eclipsing binaries in the BULGE field

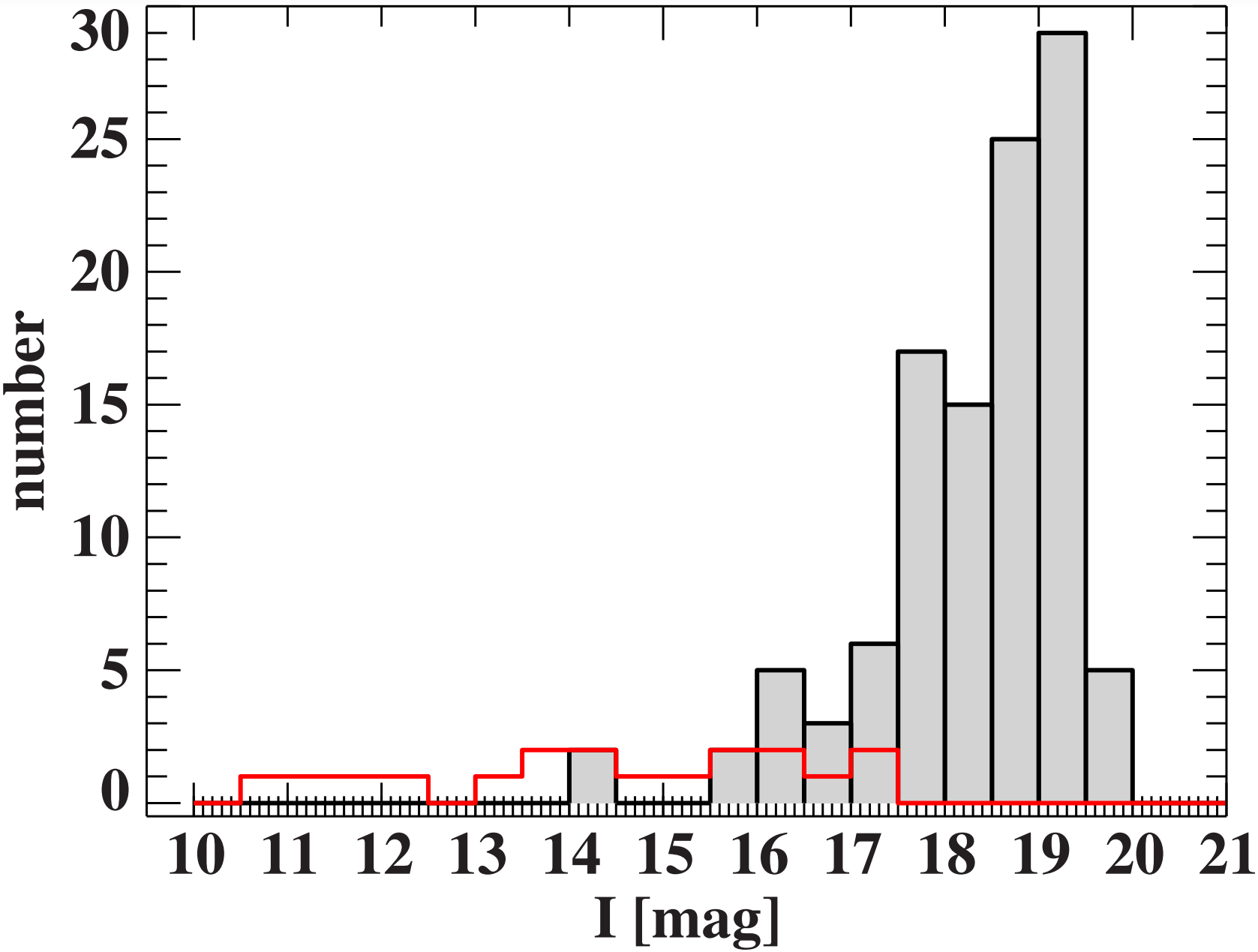
Soszyński et al. 2017



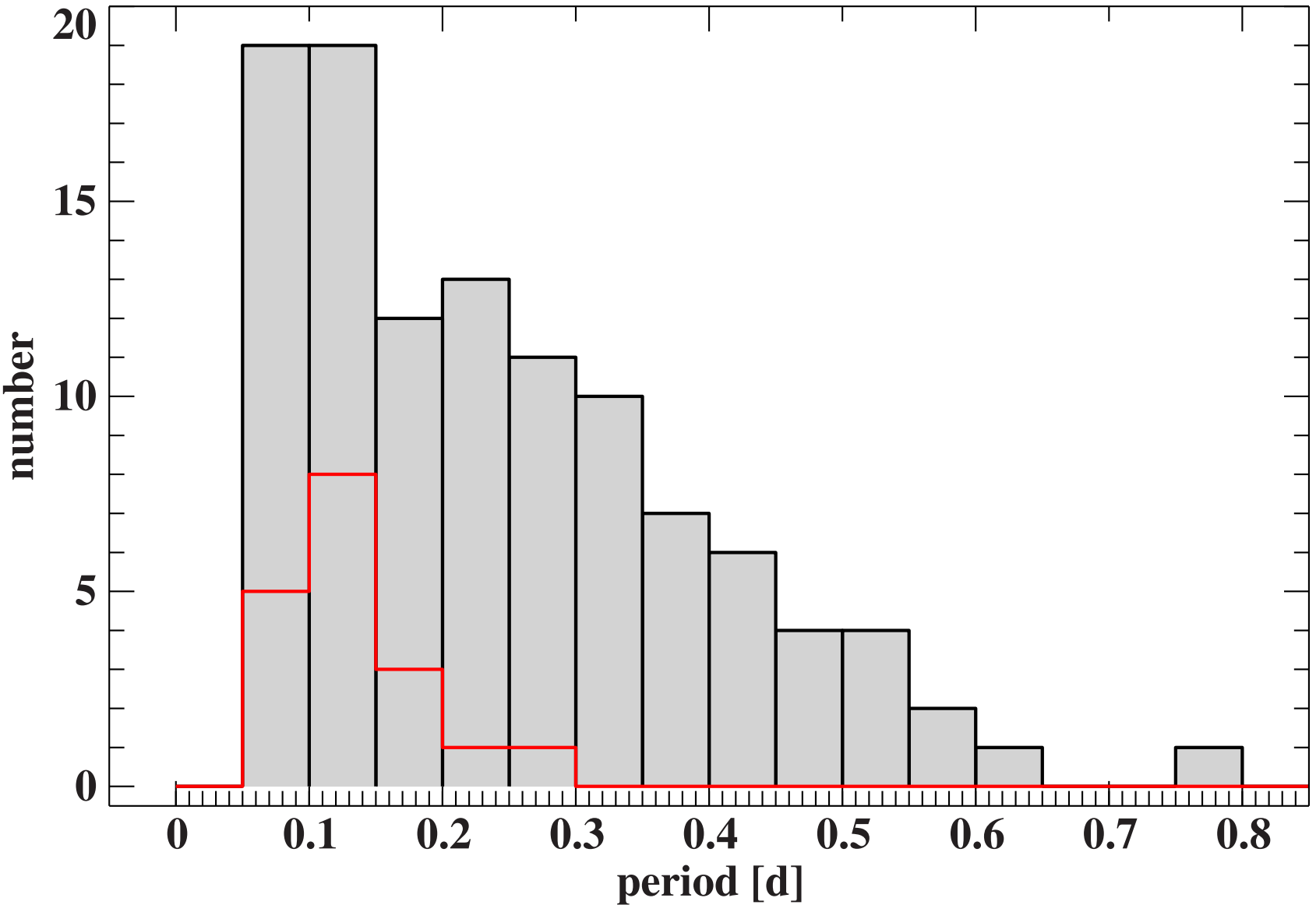
75 additional HW Vir systems: periods from 0.1 to 0.8 d



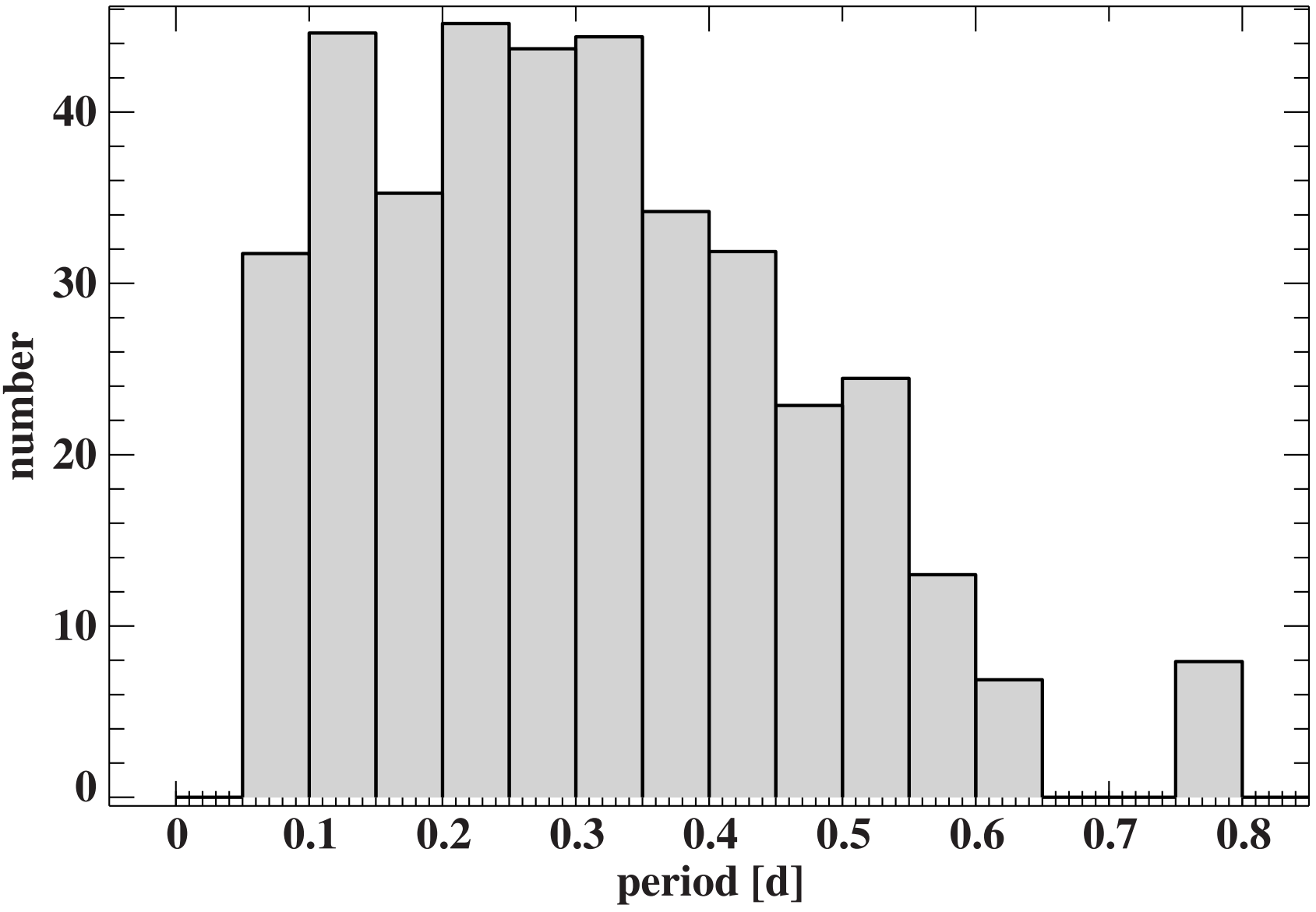
Magnitude distribution



Period distribution



Corrected period distribution



The EREBOS project

EREBOS (Eclipsing Reflection Effect Binaries from the OGLE Survey)

- 36 (+75) new HW Vir systems found in the OGLE
  → homogeneous target selection
- photometric and spectroscopic follow-up of all targets to determine fundamental (M, R), atmospheric ($T_{\rm eff}$, $\log g$) and system parameters (a, P)
- ESO Large Program for time-resolved spectroscopic follow-up with ESO-VLT/FORS approved for the 23 targets with the shortest periods
- additional spectroscopic and photometric follow-up with all southern telescopes we have access to

EREBOS
God of darkness

Goals of the EREBOS project

investigation of systems of the short-period end of the period distribution to answer our key questions:

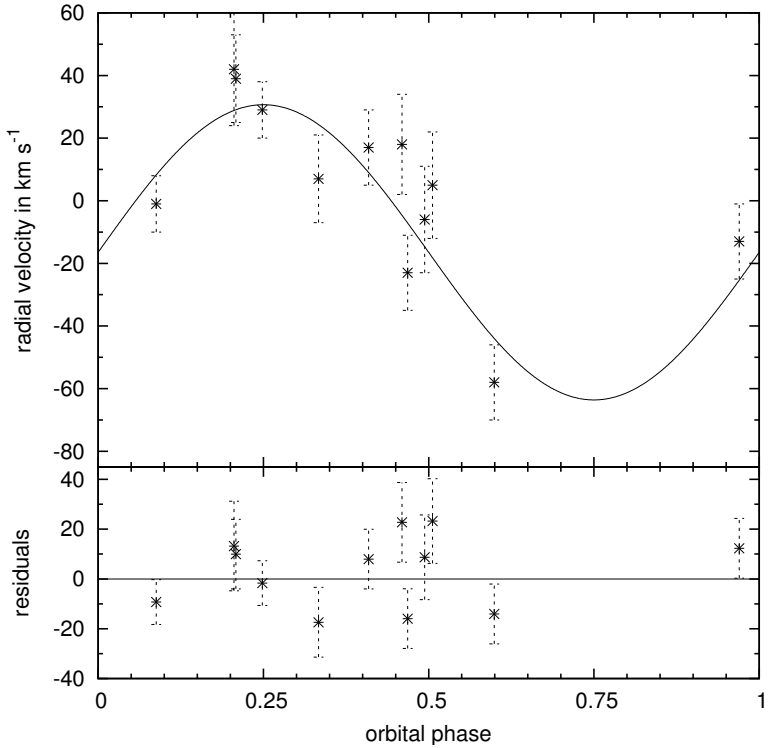
- minimum mass of the companion necessary to eject the common envelope?
- well defined minimum mass or a continuum ranging from the most massive brown dwarfs down to hot Jupiter planets?
- fraction of close substellar companions to sdB stars and how does it compare with the possible progenitor systems like main sequence stars with brown dwarf or hot Jupiter companions?

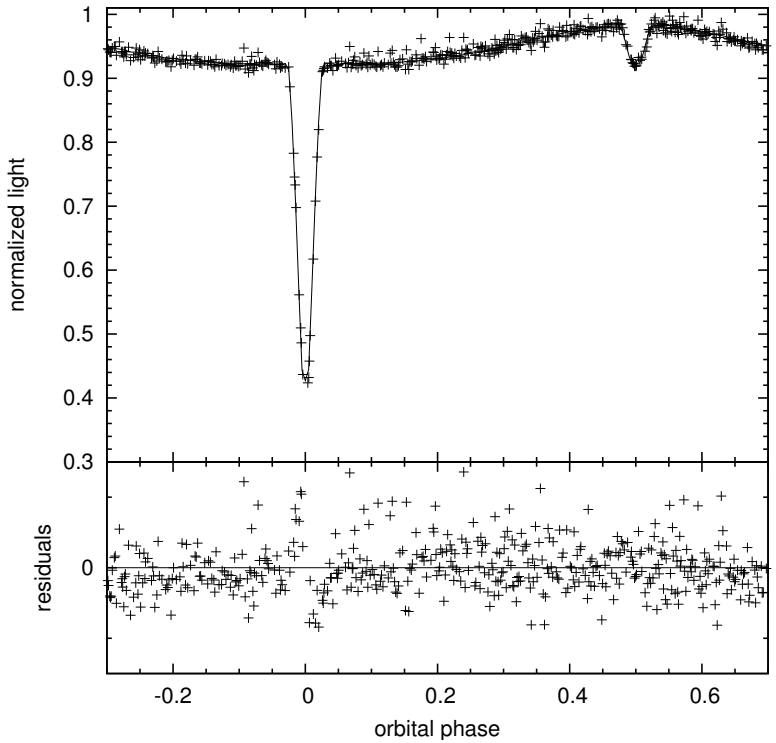
investigation of a homogeneous sample over a large period distribution for a better understanding of the

- common-envelope phase (short-lived phase not directly observed $\Rightarrow$ only observation of post-commmon envelope systems)
- physical model of the reflection effect

Preliminary results of the EREBOS project

OGLE-GD-ECL-08577: longest period HW Vir system





→ spectroscopic follow-up with ESO-NTT/EFOSC

reflection effect too strong, very high albedo necessary!

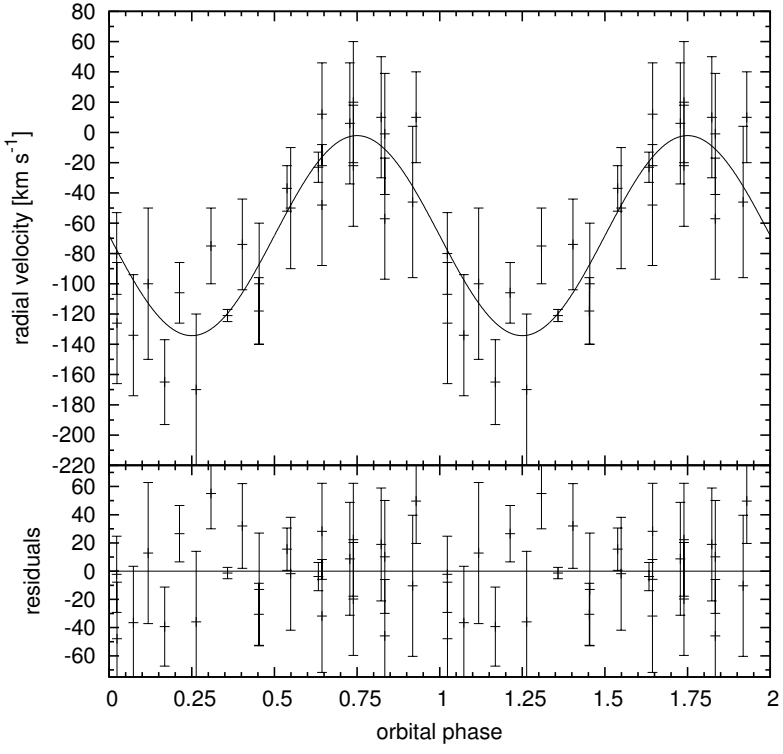
K=47 $\pm$ 7.5 km/s, P = 0.5066 d,

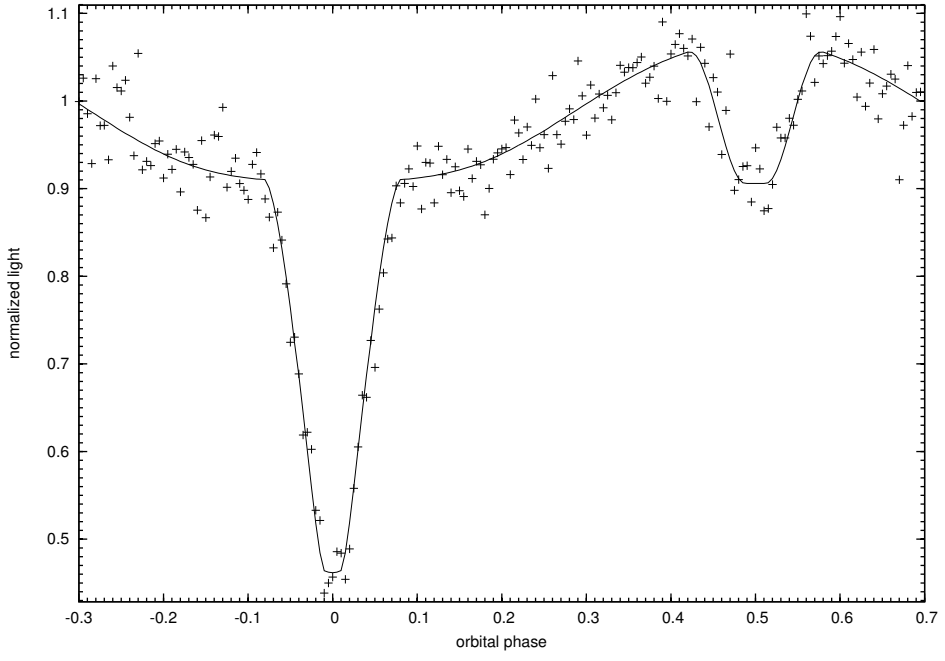
$M_1 = 0.46\,M_\odot$, $M_2 = 0.12 \pm 0.03\,M_\odot$

$T_{\rm eff} = 28400 \pm 1000$ K, $\log g = 5.5 \pm 0.15$, $\log y = -2.01$

Preliminary results of the EREBOS project

OGLE-GD-ECL-10834: an 19.5th mag HW Vir with a low-mass M dwarf companion





→ spectroscopic follow-up with FORS

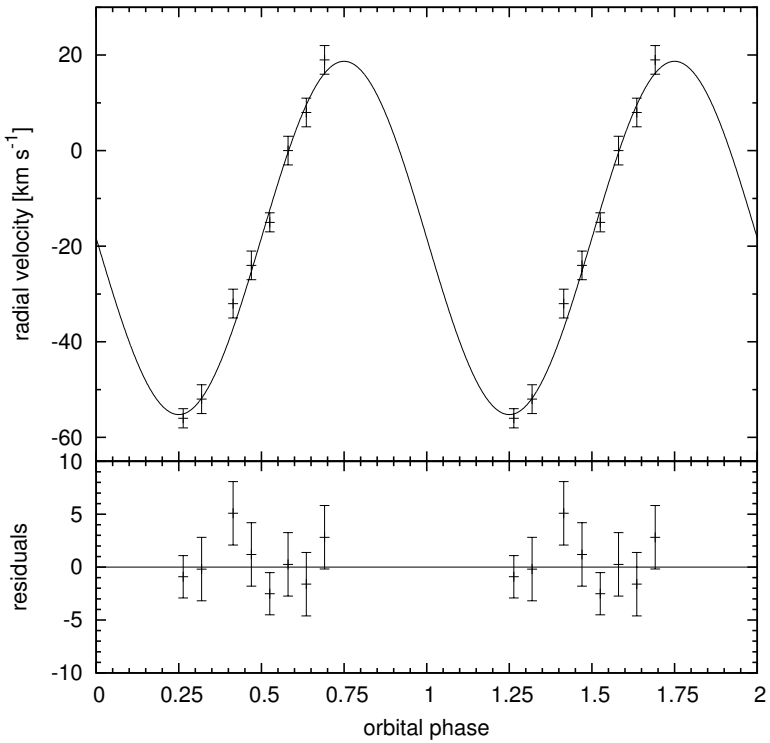
K=66 $\pm$ 5 km/s, P = 0.07753698 d,

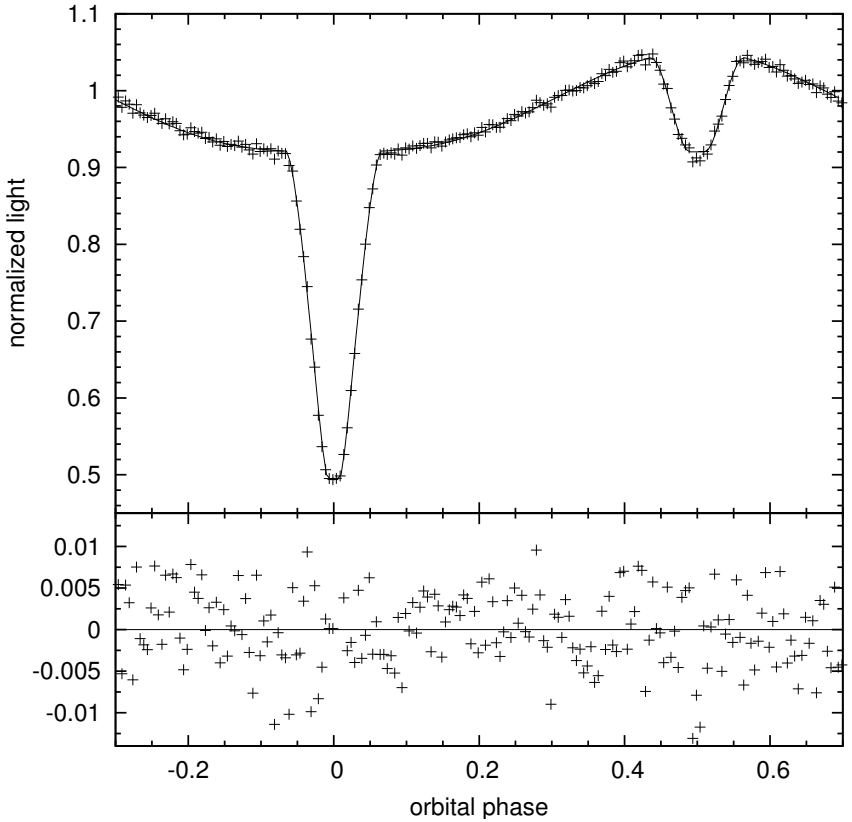
$M_1 = 0.47\,M_\odot$, $M_2 = 0.091 \pm 0.01\,M_\odot$

$T_{\rm eff} = 27600 \pm 770$ K, $\log g = 5.64 \pm 0.16$, $\log y = -2.54$

Preliminary results of the EREBOS project

OGLE-BLG-ECL-000103: an HW Vir with a low-mass substellar companion





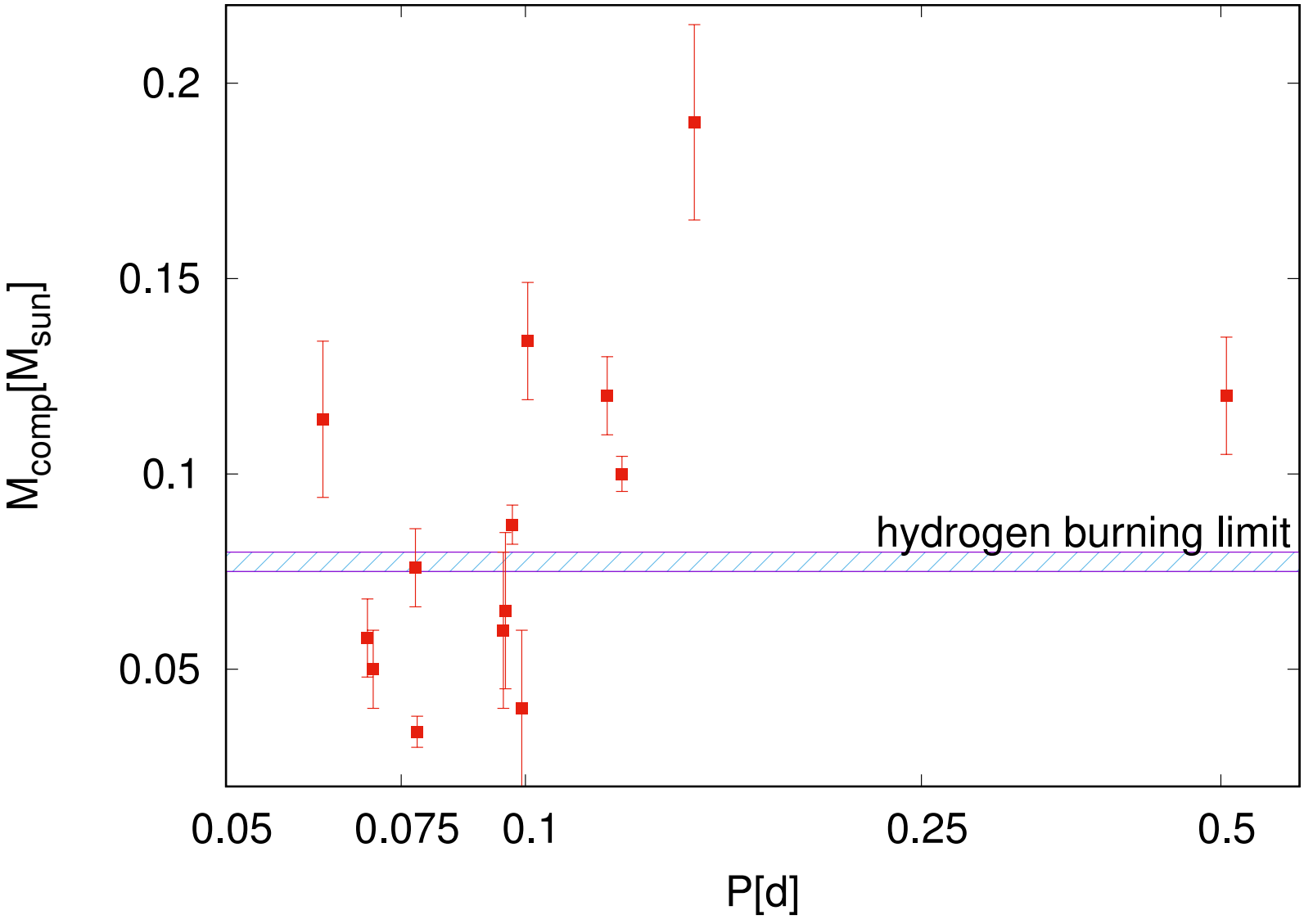
→ spectroscopic follow-up with FORS2

K=37.0 ± 1.5 km/s, P = 1.867563(42) h,

$M_1 = 0.28\,M_\odot$, $M_2 = 0.032 \pm 0.02\,M_\odot$

$T_{\rm eff} = 29500 \pm 500$ K, $\log g = 5.70 \pm 0.05$, $\log y = -2.27$

Preliminary period-companion mass diagram



Outlook

- 14 systems with RV curve, 6 more targets just observed with FORS
- photometric follow-up in other bands for some targets available
  $\longrightarrow$ essential for accurate analysis of the reflection effect
- quantitative analysis of the sdB+dM/BD population in the OGLE fields
  $\longrightarrow$ fraction of HW Vir systems, fraction of substellar companions, period distribution...
- investigation of the progenitor population with the help of Gaia (about solar-mass MS+dM/BD with 1 AU separation)

Questions?