

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

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Planets beyond the main sequence II
Haifa 9.3.17



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TÜBINGEN

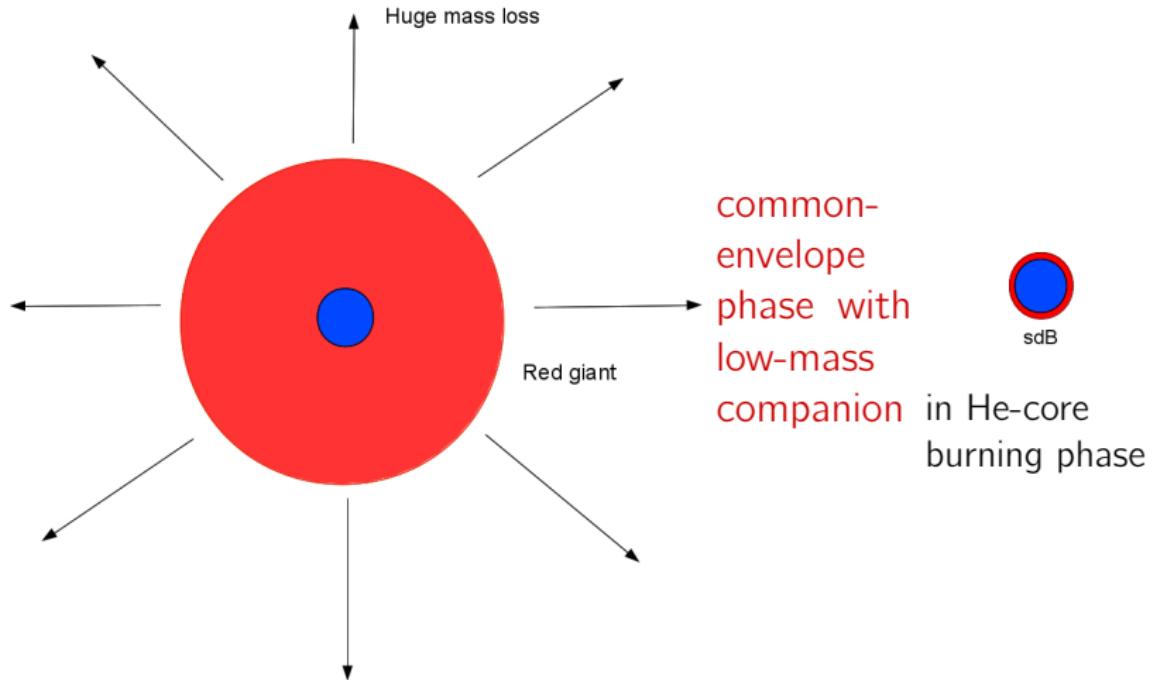


EREBOS collaboration

Veronika Schaffenroth (PI);

[Alphabetical hereafter] **Brad Barlow (HPU)**, Thomas Boudreaux (HPU), Horst Drechsel (Erlangen Universitaet), **Stefan Dreizler** (Göttingen), Bart Dunlap (UNC), **Stephan Geier** (Tübingen), **Uli Heber** (Erlangen Universitaet), Ryan Hegedus (HPU), **Dave Kilkenny** (UWC), **Stefan Kimeswenger** (Innsbruck, Antofagasta), Thomas Kupfer (Caltech), Tom Marsh (Warwick), Peter Nemeth (Erlangen Universitaet), Tugca Sener-Satir (KASSI), Matt Sky (HPU), **Maja Vuckovic** (Valparaiso)

Stripped red giant → hot subdwarf stars

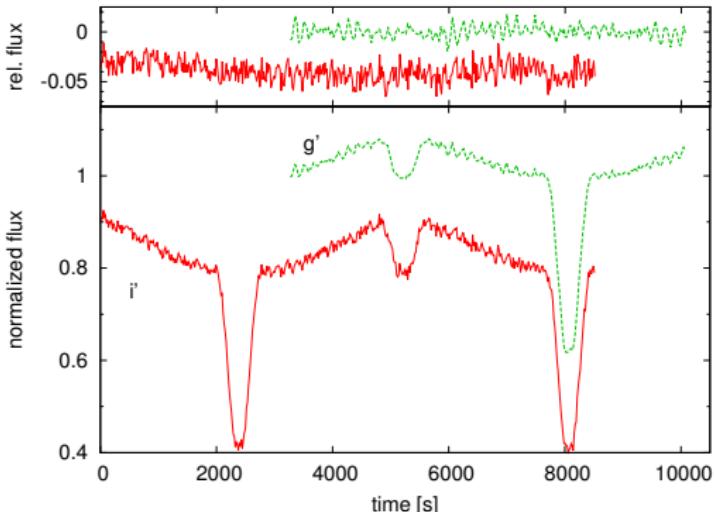


direct observation, e.g., Maxted et al. Nature

drawing is not in scale

HW Virginis systems

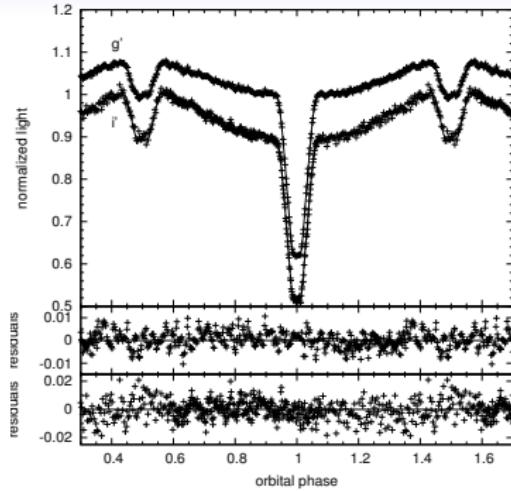
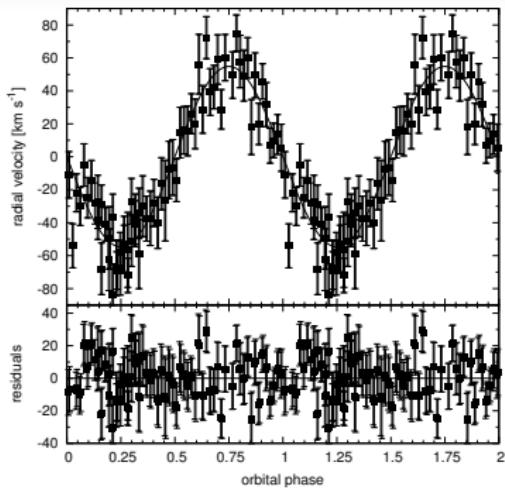
eclipsing post-common envelope sdO/B+dM/BD binaries



lightcurve of V2008-1753

- only 18 published systems
- unique lightcurve with strong reflection effect
- constraint of mass, radius and separation by combined spectroscopic and lightcurve analysis

Close substellar companions around sdBs



V2008(Schaffenroth et al. 2015):

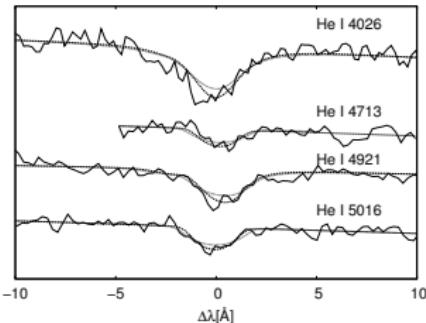
$$K = 54.6 \text{ km/s},$$

$$P = 0.065817 \text{ d},$$

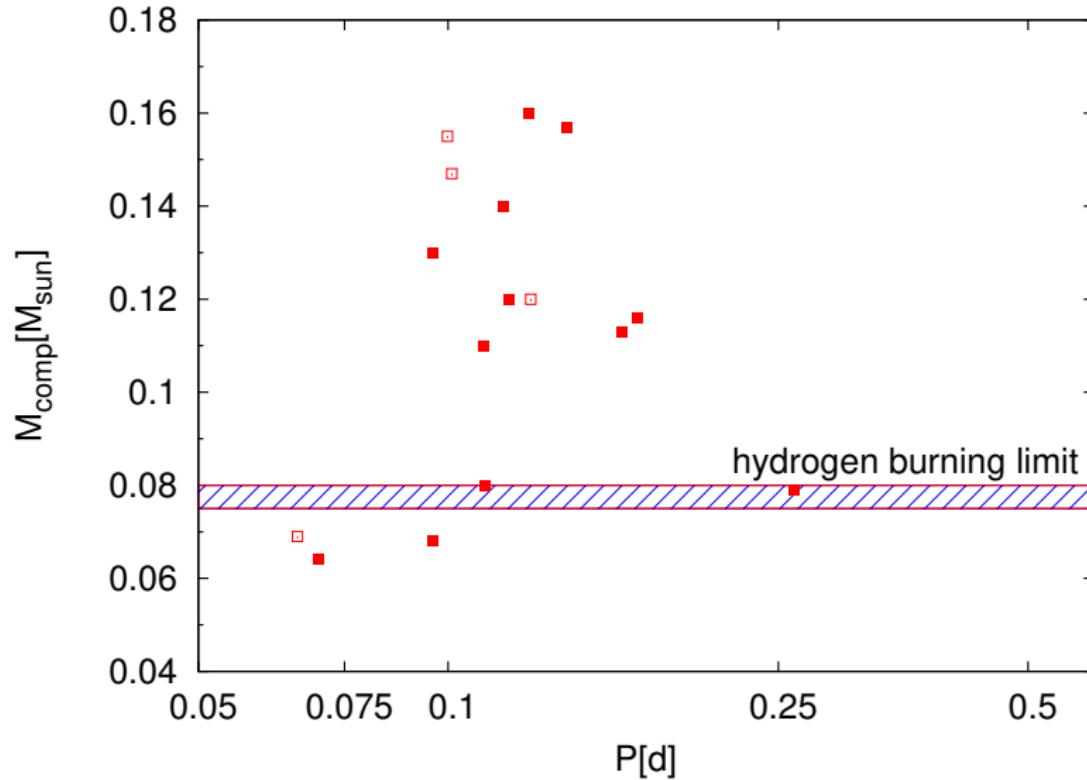
$$M_2 = 0.069 M_{\odot}$$

not synchronized:

$$\frac{v_{\text{rot,obs}}}{v_{\text{rot,synchro}}} = 0.76 \pm 0.06$$

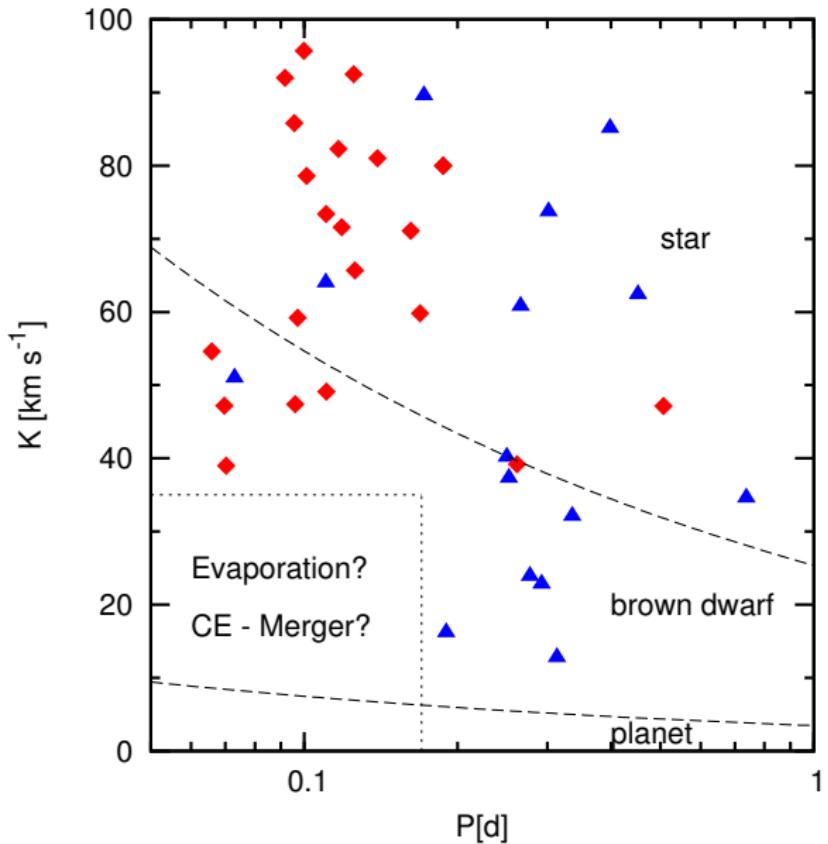


Period vs. companion mass



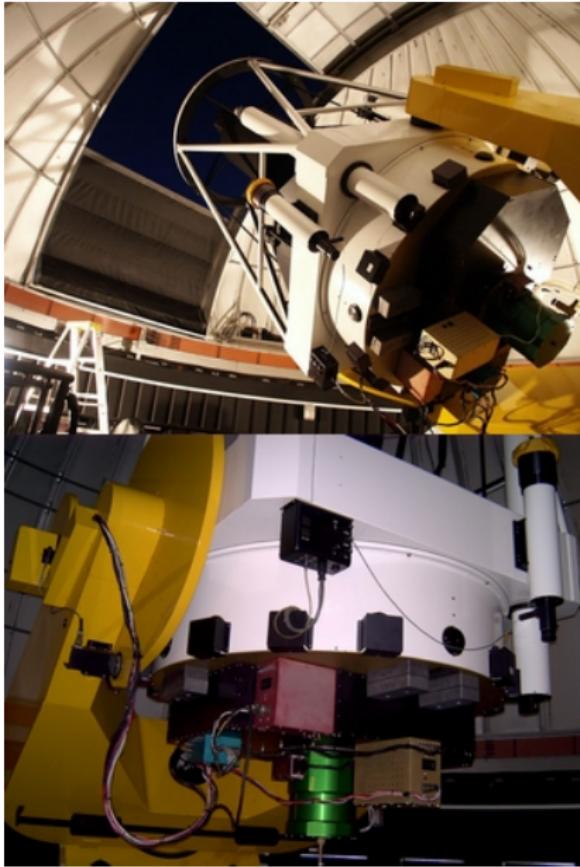
3% of all sdB stars and 50% of sdB binaries with low companions might be brown dwarfs

Minimum companion masses of reflection effect binaries

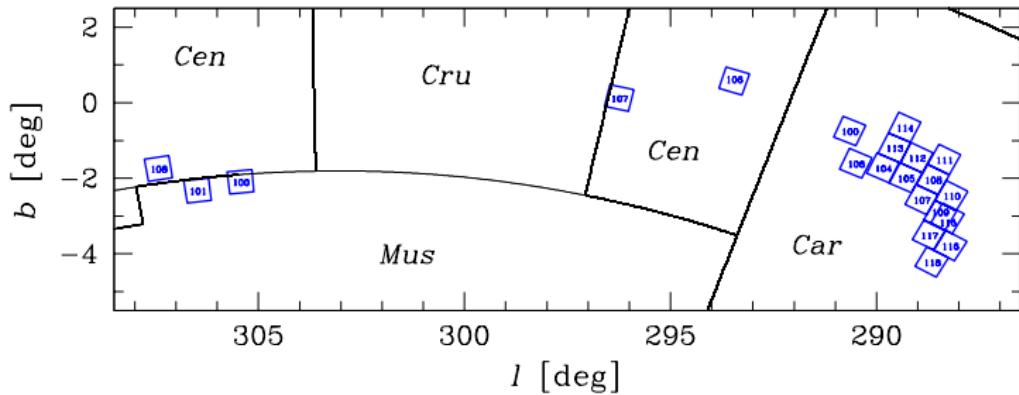


The Optical Gravitational Lensing Experiment (OGLE)

- Polish astronomical project based at the University of Warsaw
- discovering dark matter using the microlensing technique
- very rare event
 - observation of the lightcurve of many stars in different fields
 - discovery of planetary transits, pulsators, eclipsing binaries
- different fields in SMC, LMC, Buldge and Galactic Disc observed

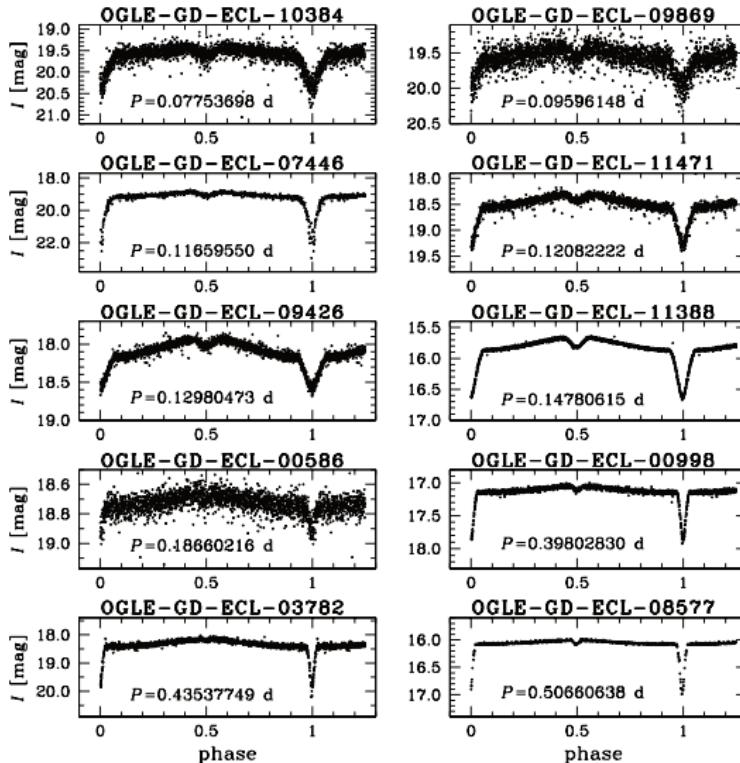


OGLE-III Galactic disk field

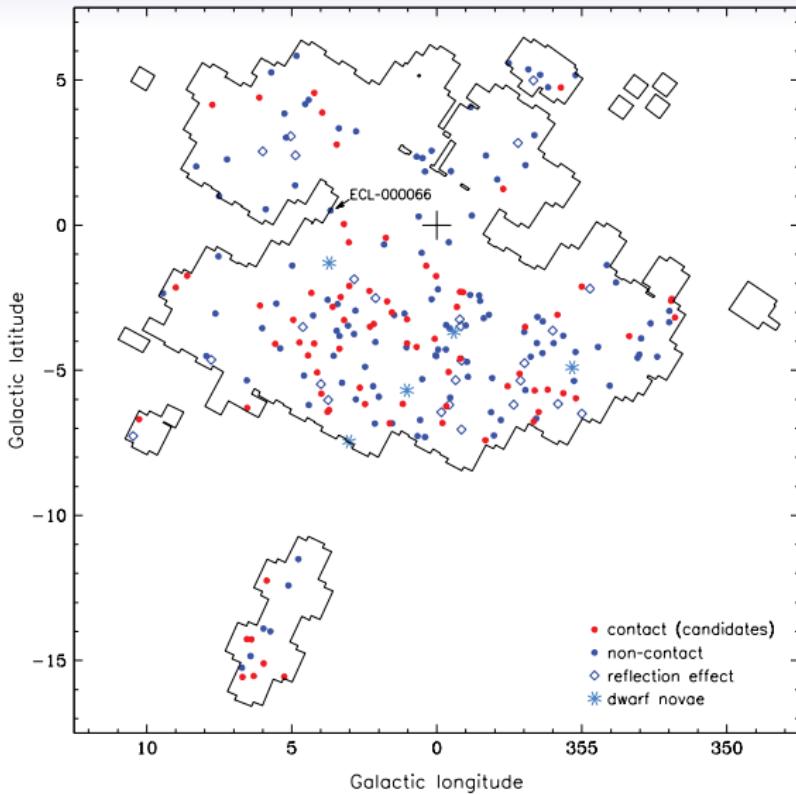


RA $\sim 10\text{ h} - 13\text{ h}$, DEC $\sim -60^\circ - -65^\circ$

OGLE-III Galactic disk field

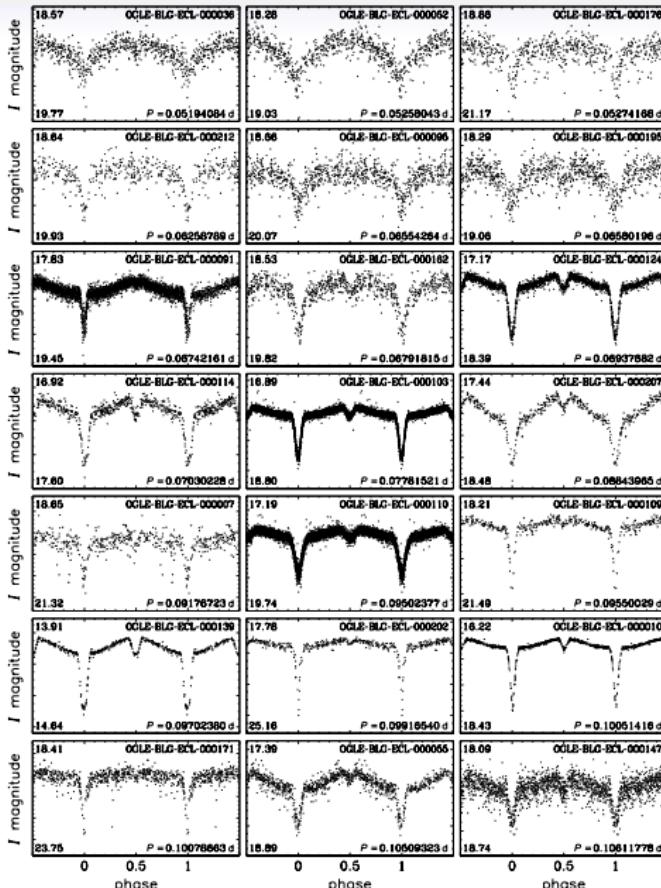


OGLE-IV Bulge field

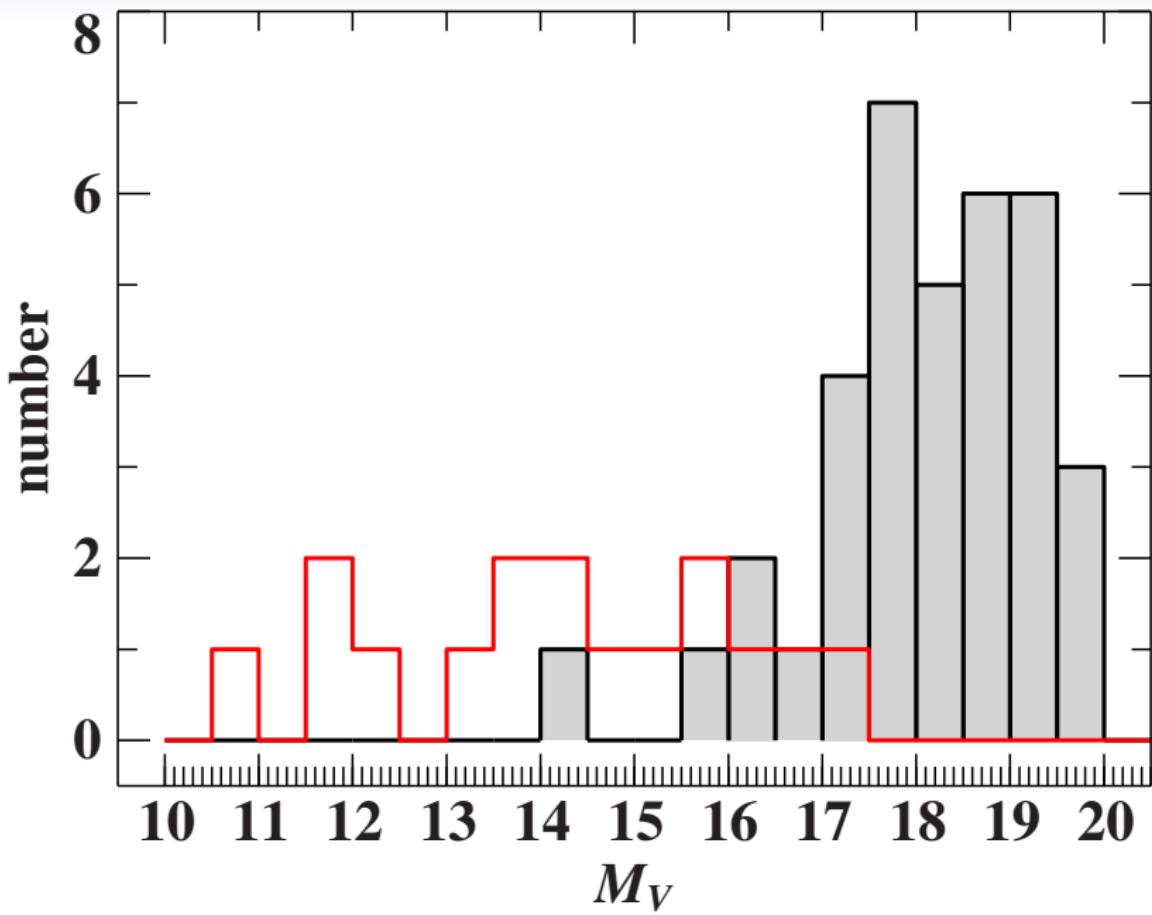


RA $\sim 17\text{h} - 18\text{h}$, DEC $\sim -25^\circ - -35^\circ$

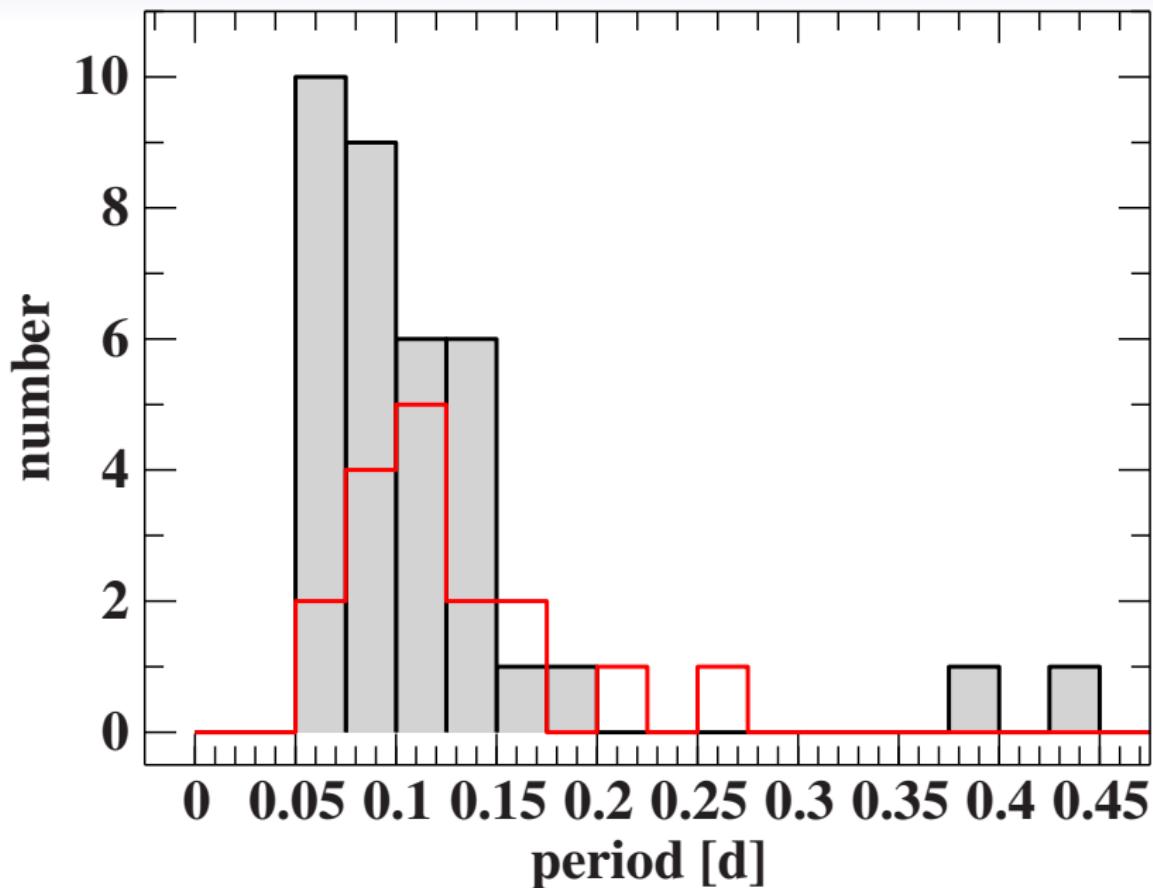
OGLE-IV Bulge field



Magnitude distribution



Period distribution



The EREBOS project

EREBOS (Eclipsing Reflection Effect Binaries from the OGLE Survey)

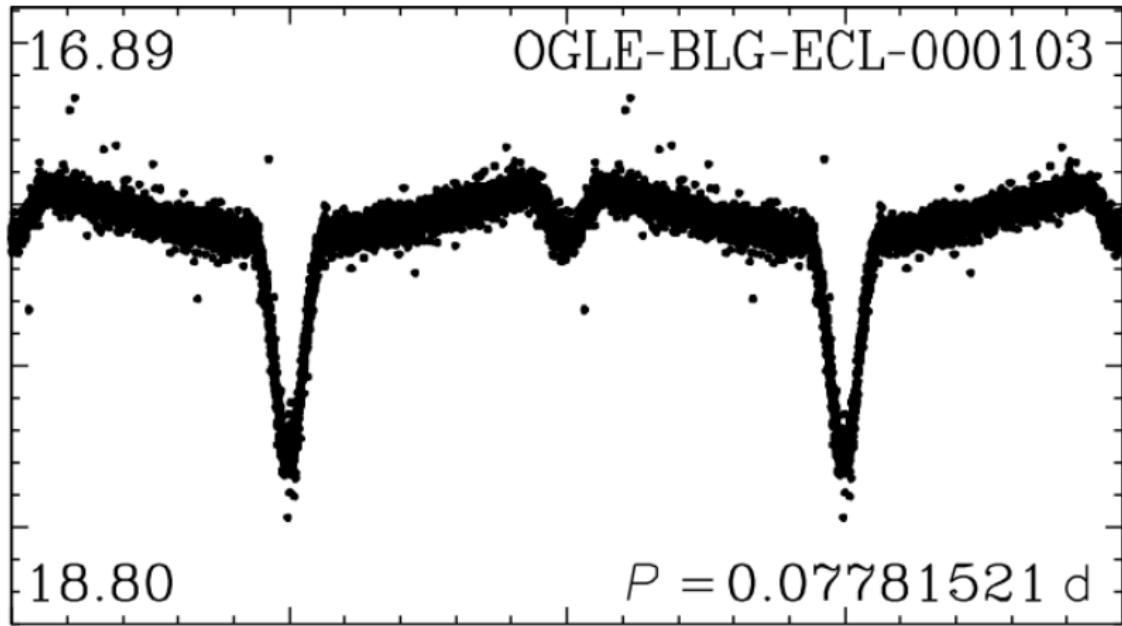
- 38 new HW Vir systems found in the OGLE (Optical Gravitational Lensing Experiment)
- photometric and spectroscopic follow-up of all targets to determine mass, radius and separation of both components
- **ESO Large Program for ESO-VLT/FORS approved** for the 23 targets with the shortest periods
 - Studying the influence of substellar objects on late stellar evolution
 - Better understanding of the common-envelope phase
 - Better understanding of the reflection effect



EREBOS
God of darkness

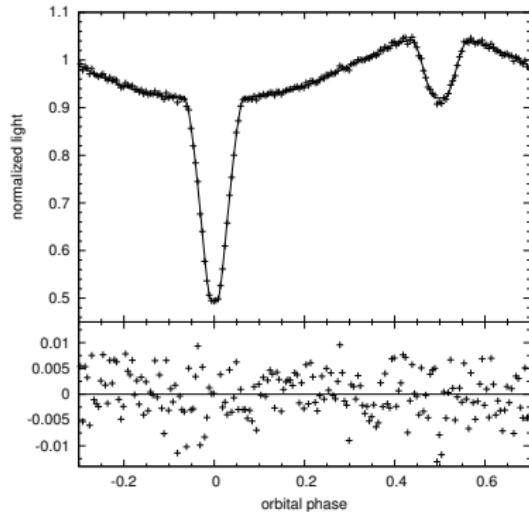
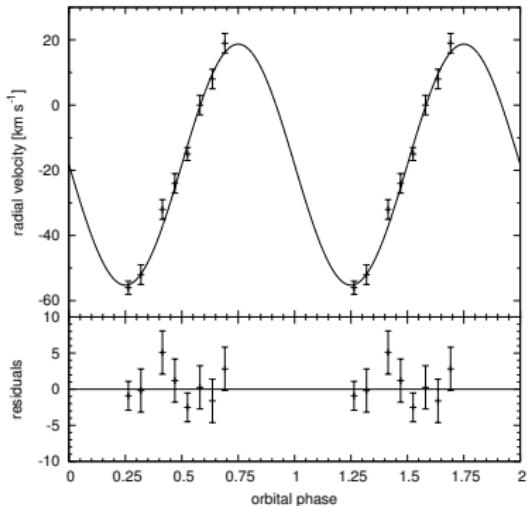
An exemplary EREBOS target

OGLE-BLG-ECL-103



- 17.5 mag in I
- 8 FORS spectra
- I band OGLE lightcurve

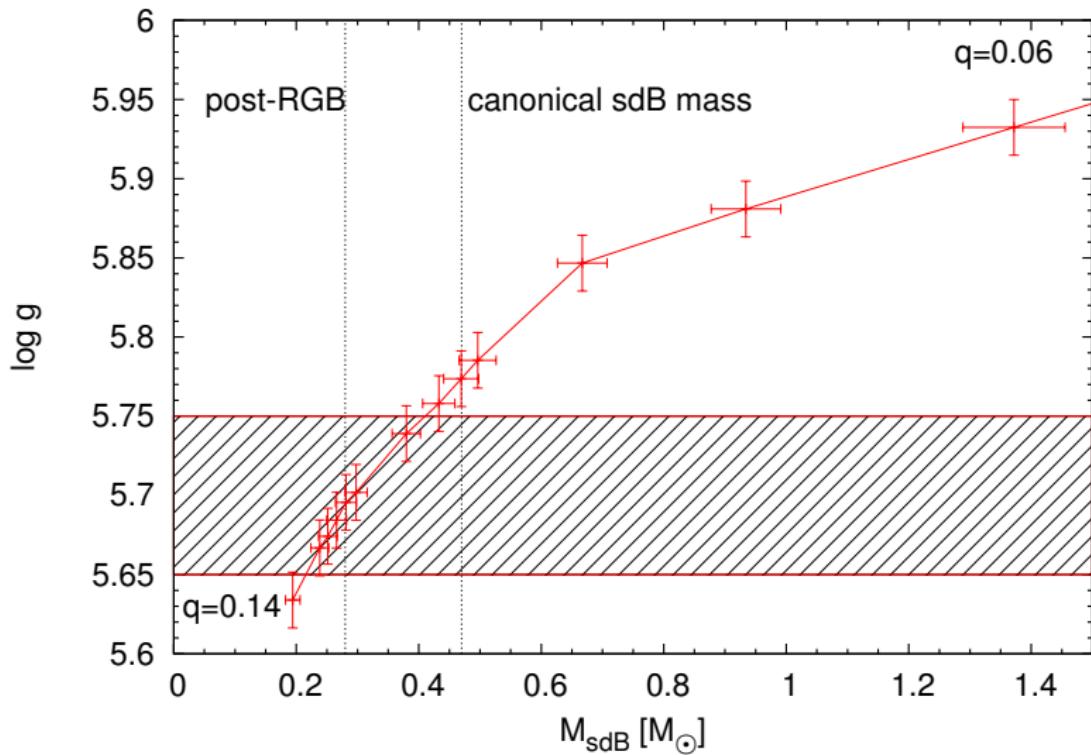
Analysis of OGLE-BLG-ECL-00103



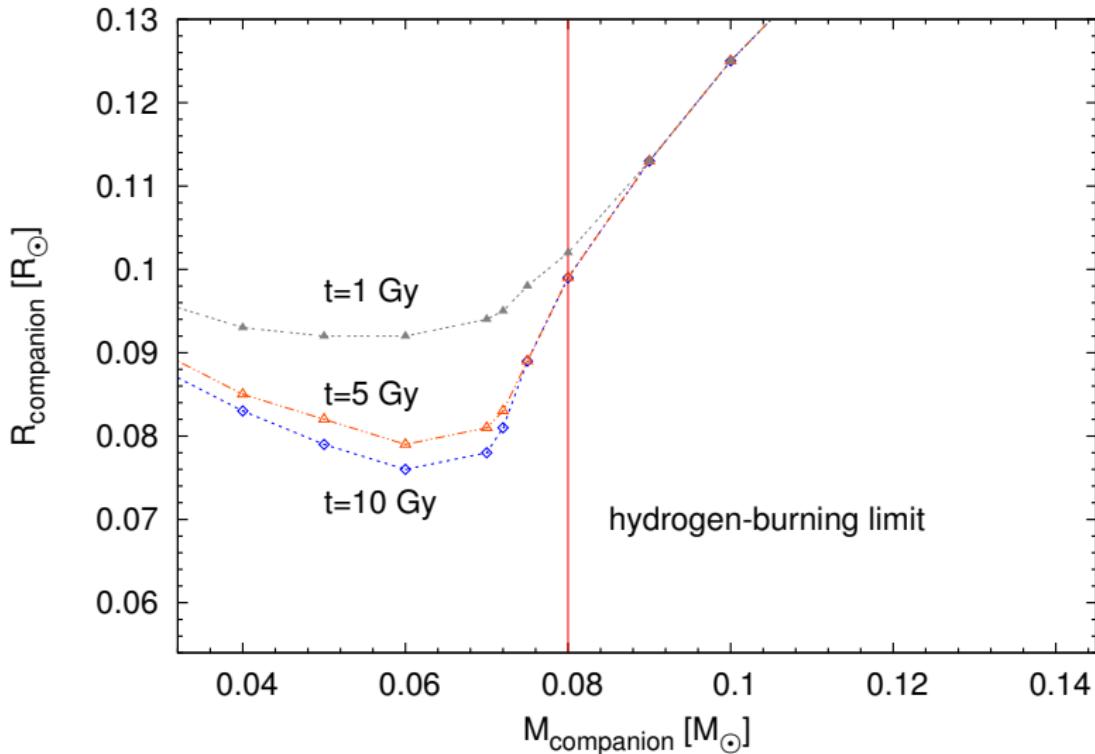
$$K = 37 \pm 1.5 \text{ km/s}, P = 0.07781521 \text{ d},$$

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

sdB radius

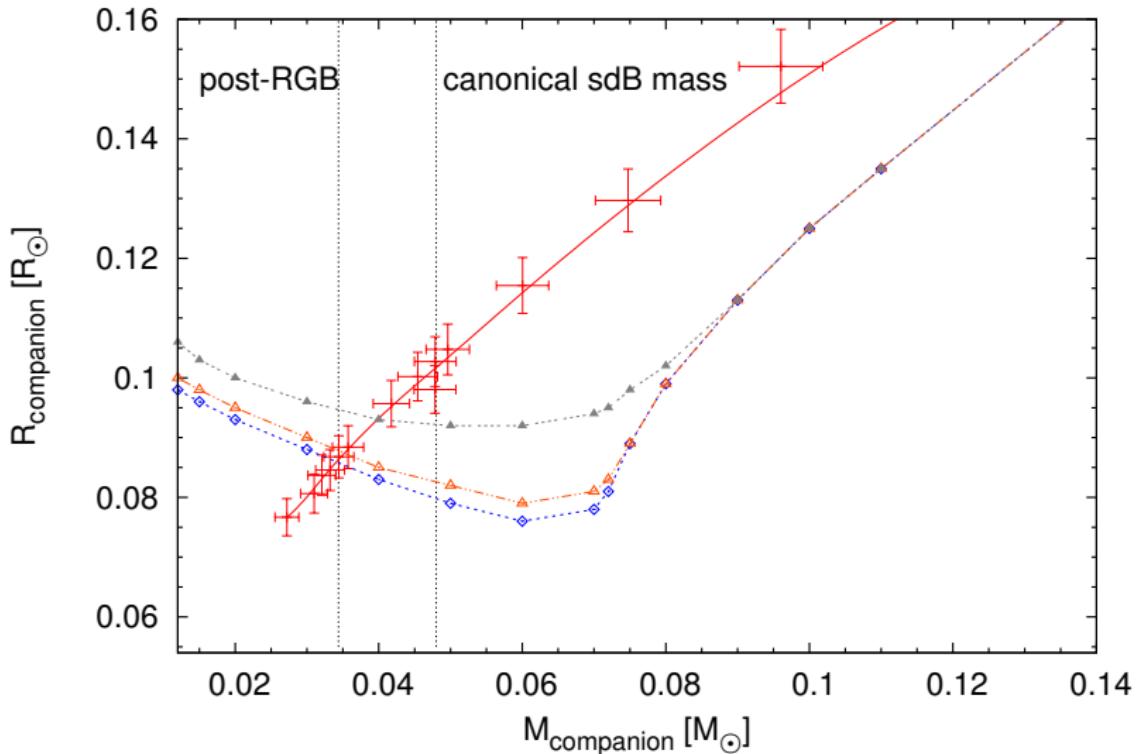


Mass-radius-relation for the companion



mass-radius relation taken from Baraffe et al. 2003

Mass-radius-relation for the companion



Results

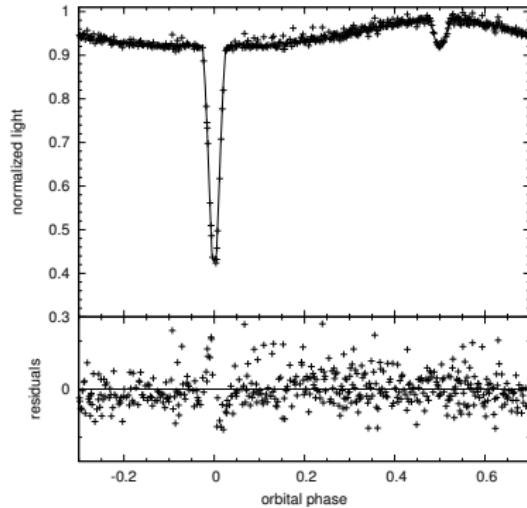
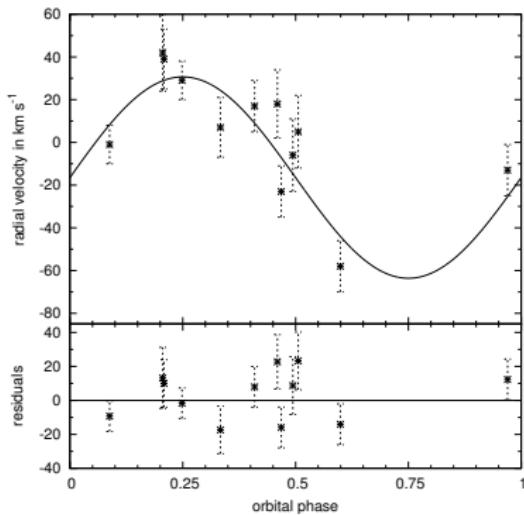
| | | EHB | | post RGB | |
|-------------------|-----------|-------|---------|----------|---------|
| i | ° | 86.9 | ± 0.3 | 86.9 | ± 0.3 |
| M_{sdB} | M_\odot | 0.47 | ± 0.03 | 0.28 | ± 0.02 |
| M_{comp} | M_\odot | 0.048 | ± 0.003 | 0.032 | ± 0.002 |
| a | R_\odot | 0.62 | ± 0.02 | 0.52 | ± 0.02 |
| r_{sdB} | R_\odot | 0.147 | ± 0.006 | 0.125 | ± 0.005 |
| r_{comp} | R_\odot | 0.103 | ± 0.004 | 0.087 | ± 0.003 |

Schaffenroth et al. in prep.

- ⇒ companion is a the **lowest** mass **Brown Dwarf** discovered
- more FORS data and lightcurves in other bands already observed

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!

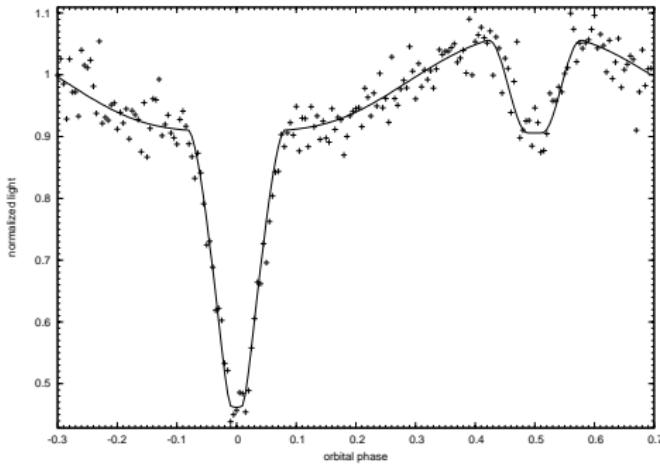
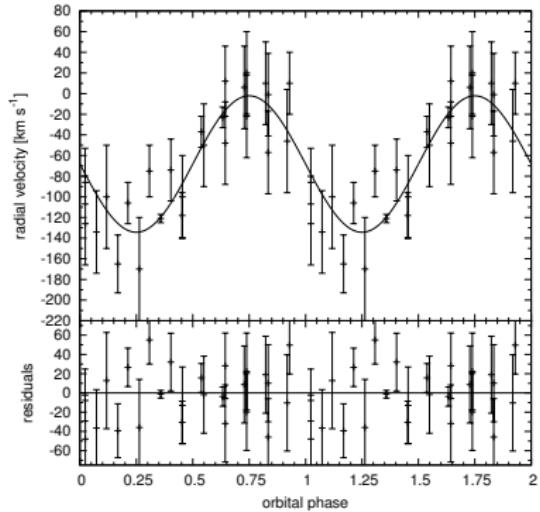
$K = 47 \pm 7.5$ km/s, $P = 0.5066$ d,

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

$T_{\text{eff}} = 28400 \pm 1000$ 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 BD or low-mass dM companion



→ spectroscopic follow-up with FORS

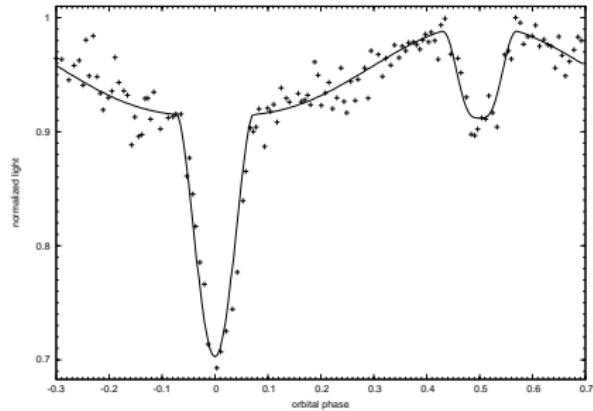
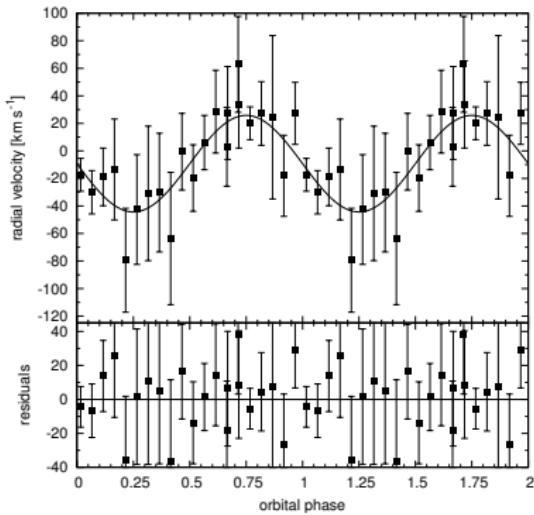
$$K = 56 \pm 5 \text{ km/s}, P = 0.07753698 \text{ d},$$

$$M_1 = 0.47 M_{\odot}, M_2 = 0.076 \pm 0.01 M_{\odot}$$

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

Preliminary results of the EREBOS project

OGLE-BLG-ECL-000114: an HW Vir with a substellar companion



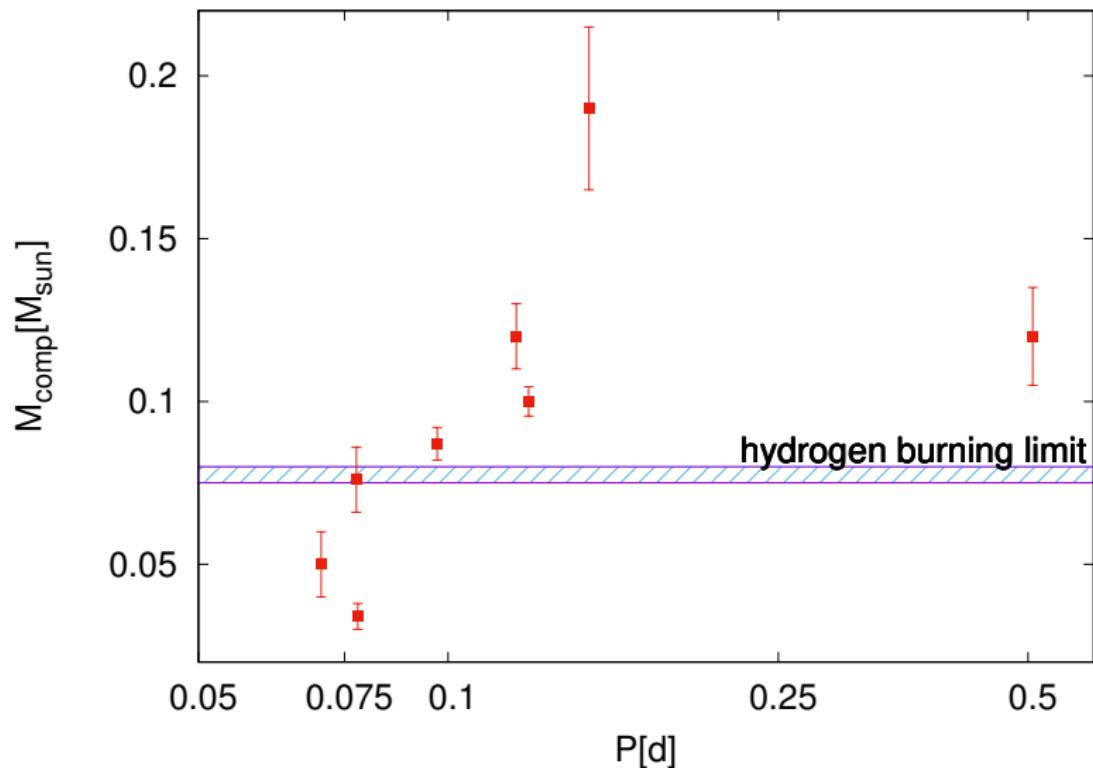
→ spectroscopic follow-up with SOAR/Goodman and VLT/FORS2

$$K = 39 \pm 6 \text{ km/s}, P = 0.070302 \text{ d},$$

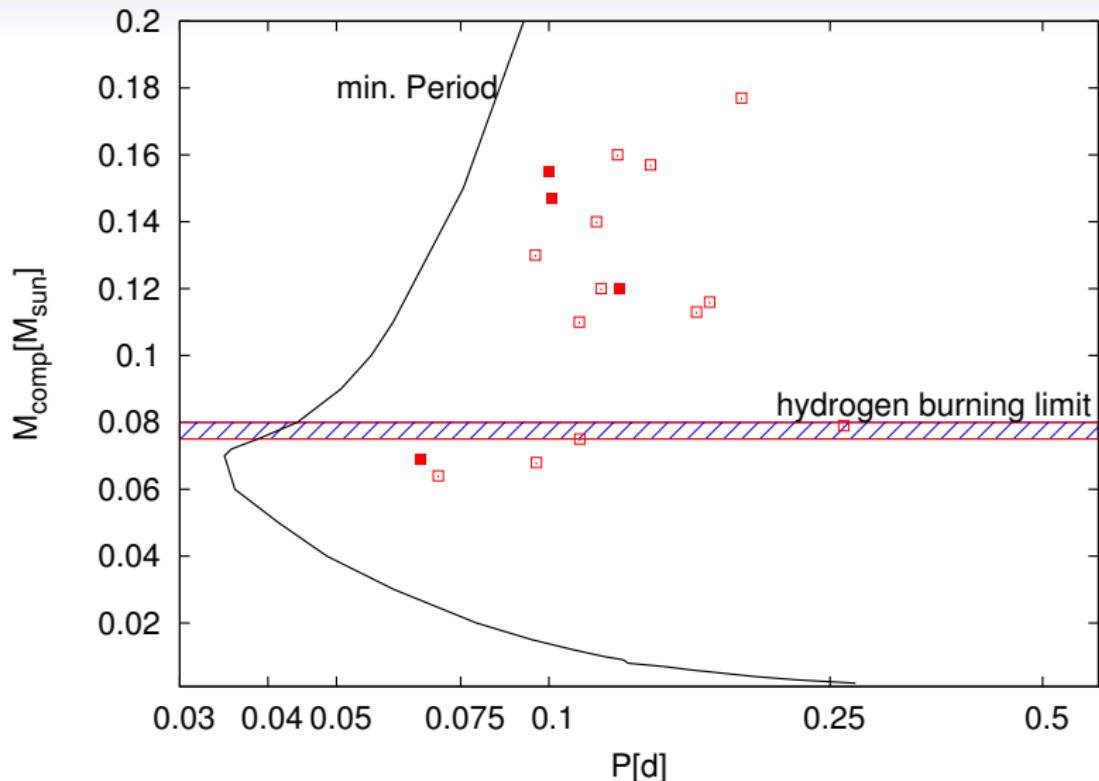
$$M_1 = 0.47 M_{\odot}, M_2 = 0.05 \pm 0.01 M_{\odot}$$

$$T_{\text{eff}} = 29000 \pm 500 \text{ K}, \log g = 5.55 \pm 0.07, \log y = -2.28$$

Preliminary period-companion mass relation for the Erebus targets



Where to expect close planets around sdB stars?



- ⇒ lightcurve of sdB with a hot Jupiter looks the same
- ⇒ FORS spectra not accurate enough to detect such small RV variations → look for non-detections in low resolution data

Outlook

- FORS observations of 8 more targets already available
- photometric follow-up in other bands for some targets available, more time for photometric follow-up to come
→ essential for accurate analysis of the reflection effect
- FORS data of 7 more targets to be taken



Questions?

Interested in the project, talk to me or Stephan!