Binary stars with an RR Lyrae component - new candidates

Marek Skarka
marek.skarka@gmail.com
Department of Theoretical Physics and Astrophysics, Masaryk University, Brno, Czech Republic

In cooperation with Z. Prudil
(Heidelberg) & J. Liška (CEITEC Brno)

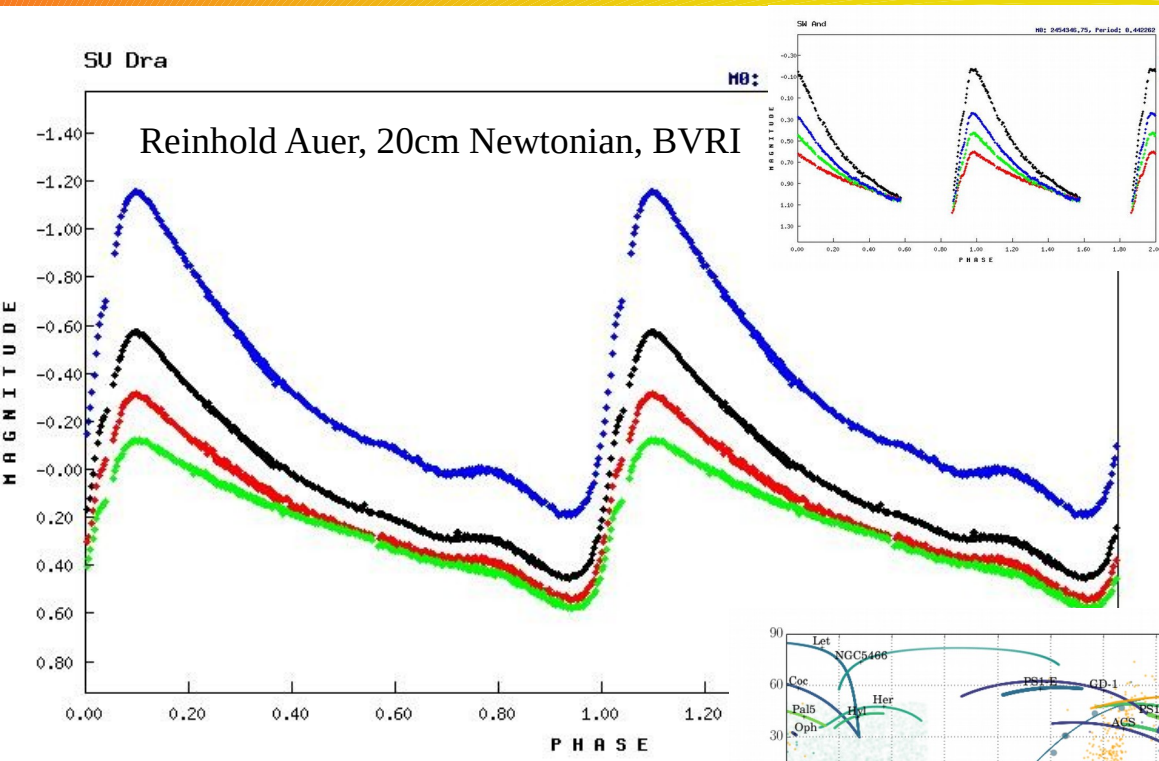
EVROPSKÁ UNIE
Evropské strukturální a investiční fondy
OP Výzkum, vývoj a vzdělávání

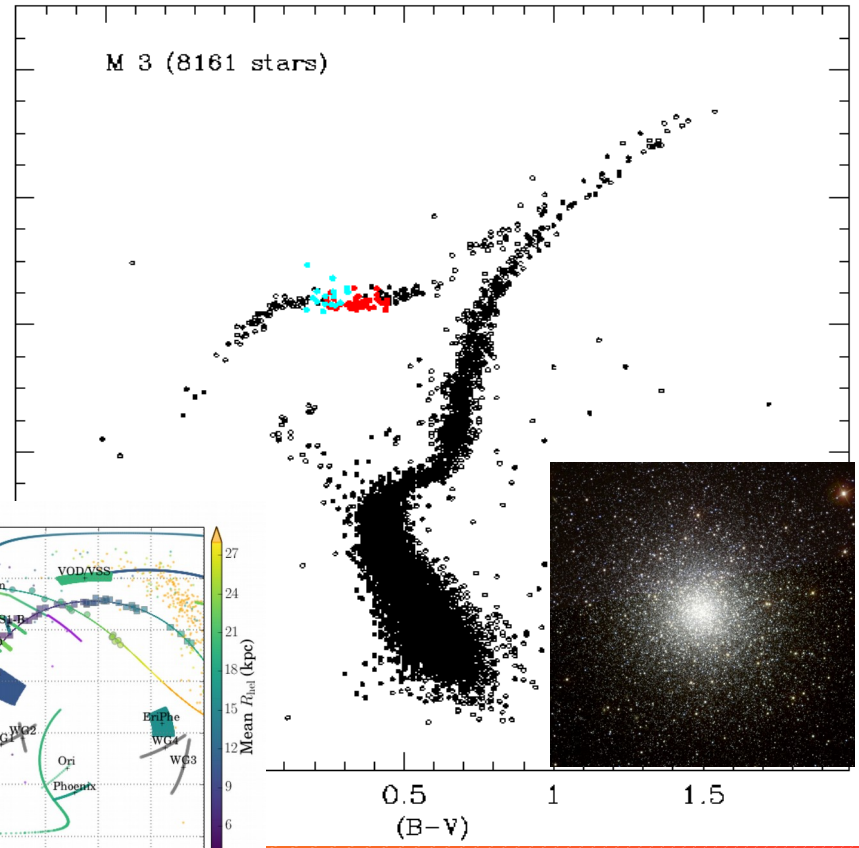
Postdoc@MUNI

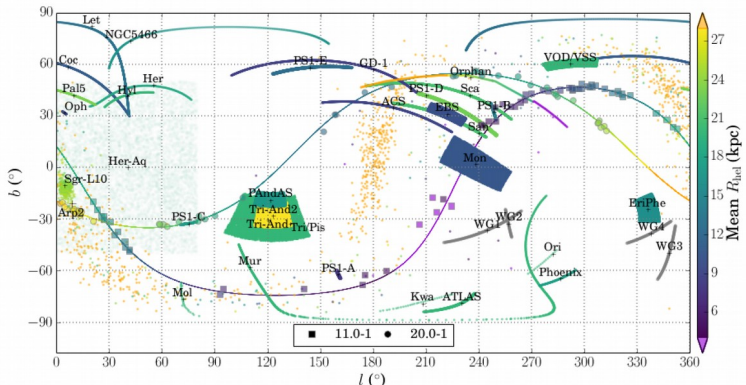
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

What are RR Lyrae stars

- (non)Radially pulsating, He core-burning, population II stars (age>9 bil. years)
- Pulsation periods 0.2-1.0 days, amplitudes V<1.5 mag
- Distance indicators, stellar evolution and metallicity tracers, Galactic archaeology
- Luminosity ~40-80 Lsun, R~4-6 Rsun



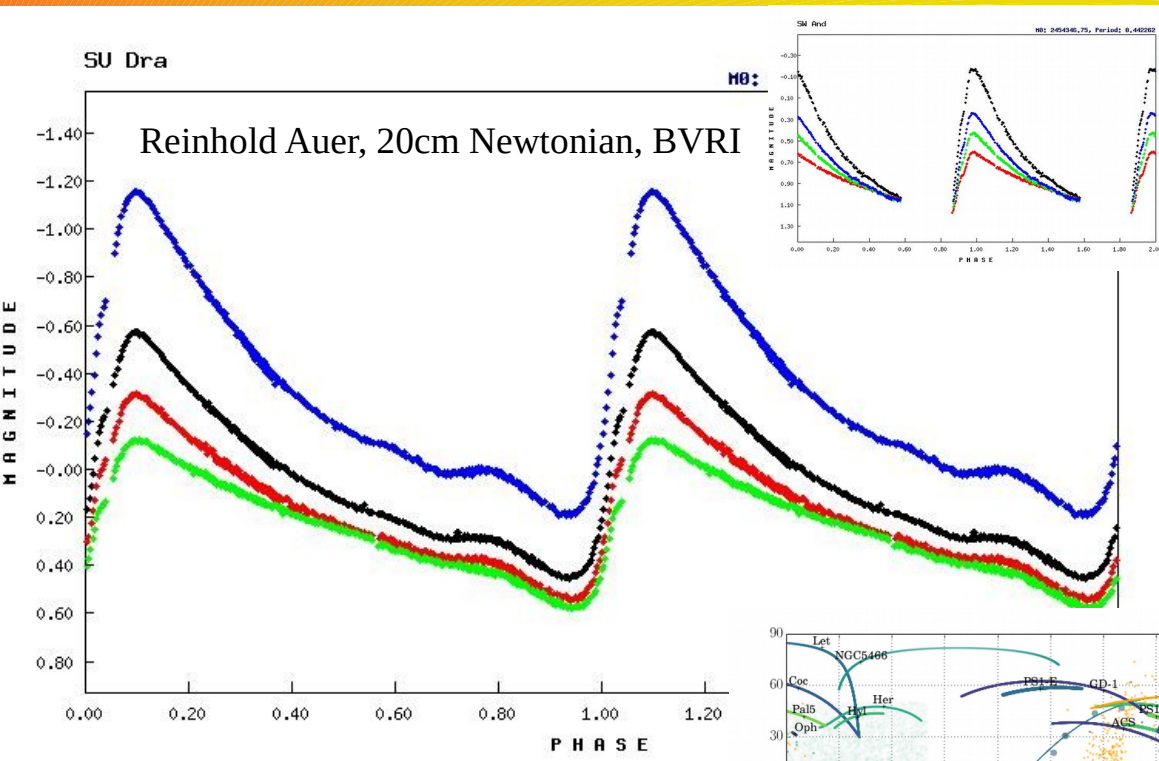


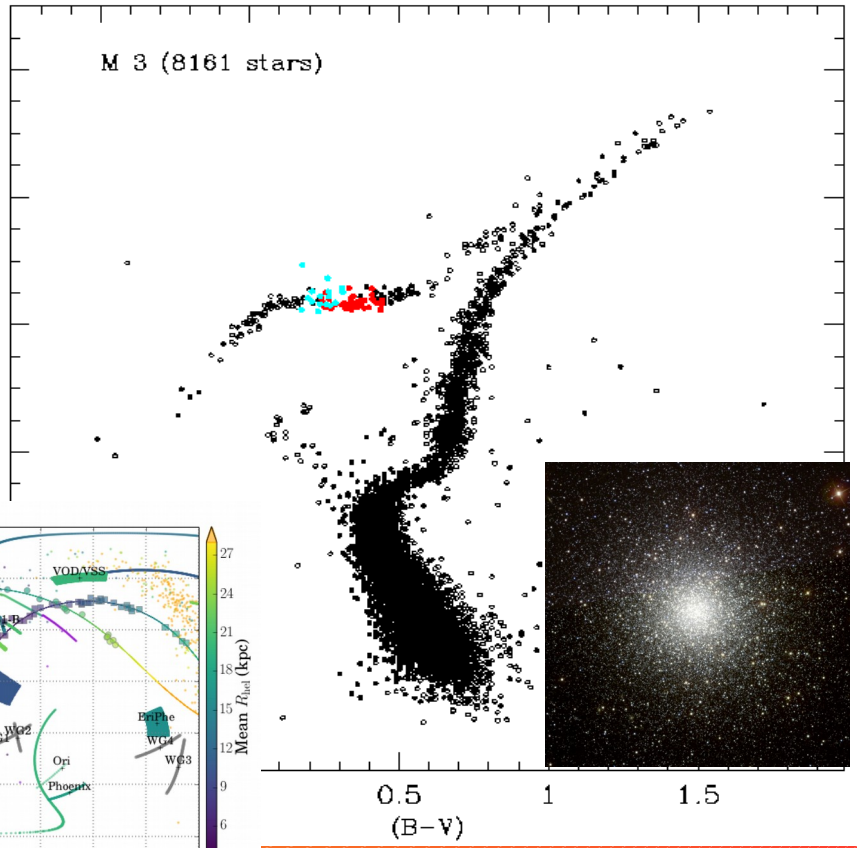


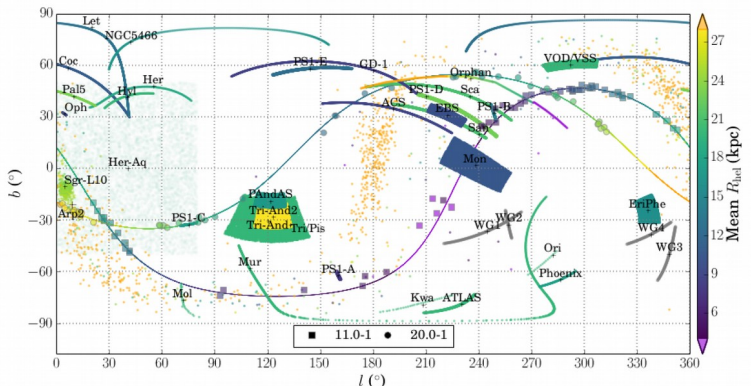
What are RR Lyrae stars

- (non)Radially pulsating, He core-burning, population II stars (age>9 bil. years)
- Pulsation periods 0.2-1.0 days, amplitudes V<1.5 mag
- Distance indicators, stellar evolution and metallicity tracers, Galactic archaeology
- Luminosity ~40-80 Lsun, R~4-6 Rsun

M<0.9 Msun – **only from pulsation and evolutionary models**

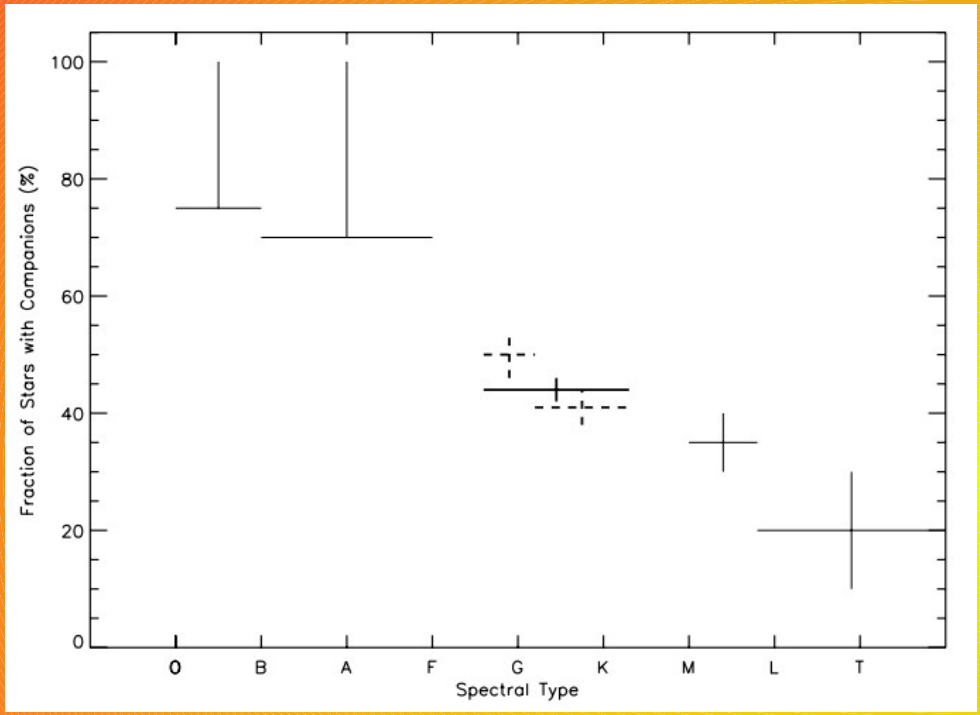


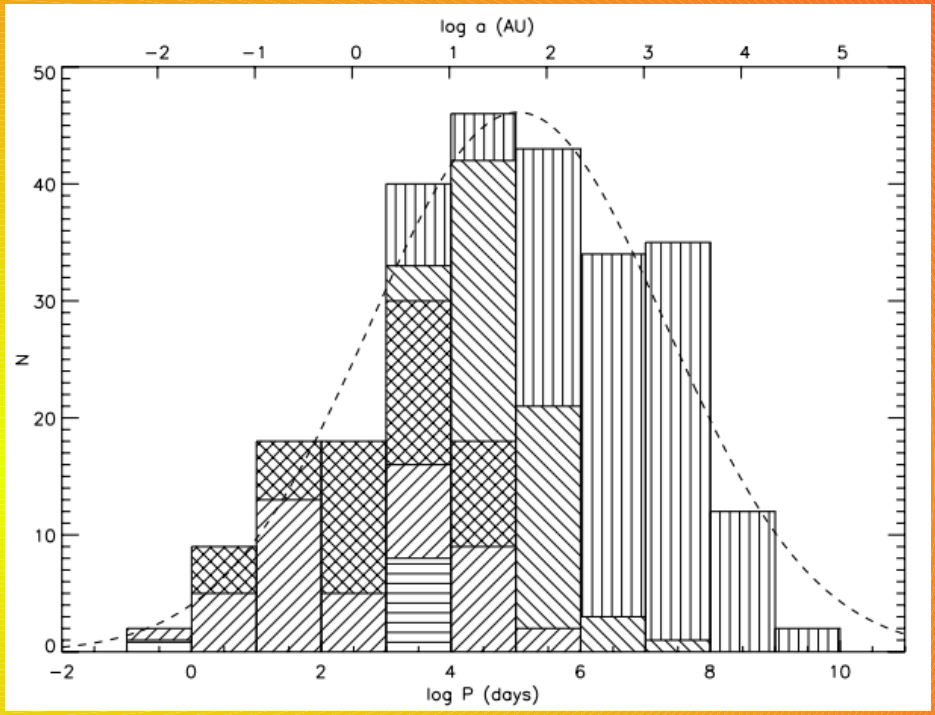




RR Lyrae in binaries (?)

- Stars bound in pairs are very common …





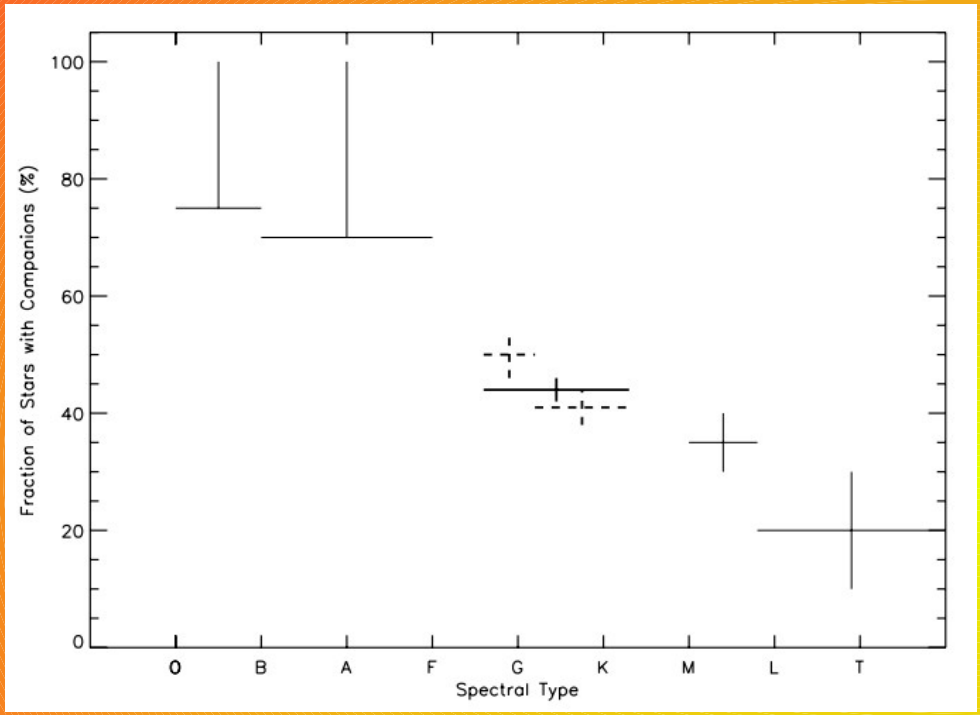
Raghavan et al. 2010, ApJSS, 190, 1

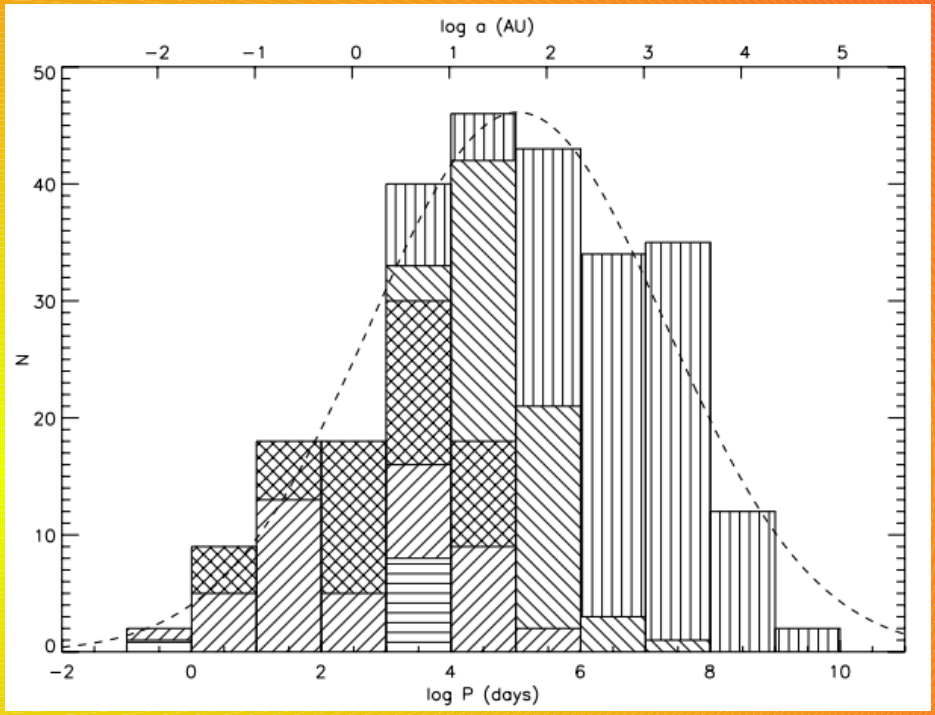
Total multiplicity frequency of population II binaries is similar as for population I stars or higher

Latham et al. 2002, AJ, 124, 1144, Rastegaev 2010, AJ, 140, 2013, Moe et al. 2019, ApJ, 875, 61

RR Lyrae in binaries (?)

- Stars bound in pairs are very common …





Raghavan et al. 2010, ApJSS, 190, 1

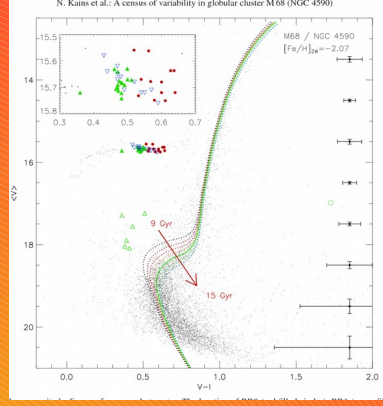
Total multiplicity frequency of population II binaries is similar as for population I stars or higher

Latham et al. 2002, AJ, 124, 1144, Rastegaev 2010, AJ, 140, 2013, Moe et al. 2019, ApJ, 875, 61

- ~400 000 catalogized RR Lyrae stars – **ONE** confirmed to be in a binary system

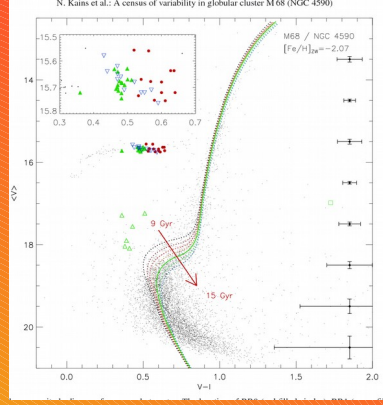
WHY?

RR Lyrae in binaries (?)



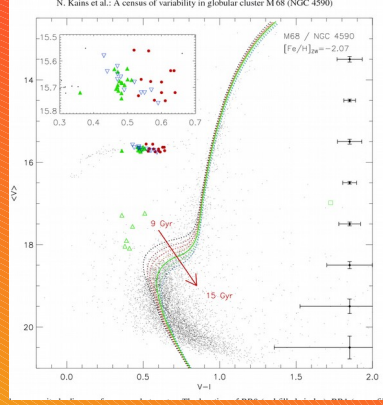
- Wide systems with long orbital periods
  - ➔ Very low probability of eclipses
  - ➔ Small radial velocity amplitudes (1-10 km/s vs. 40-80 km/s from pulsations)
  - ➔ Extremely time-demanding

RR Lyrae in binaries (?)

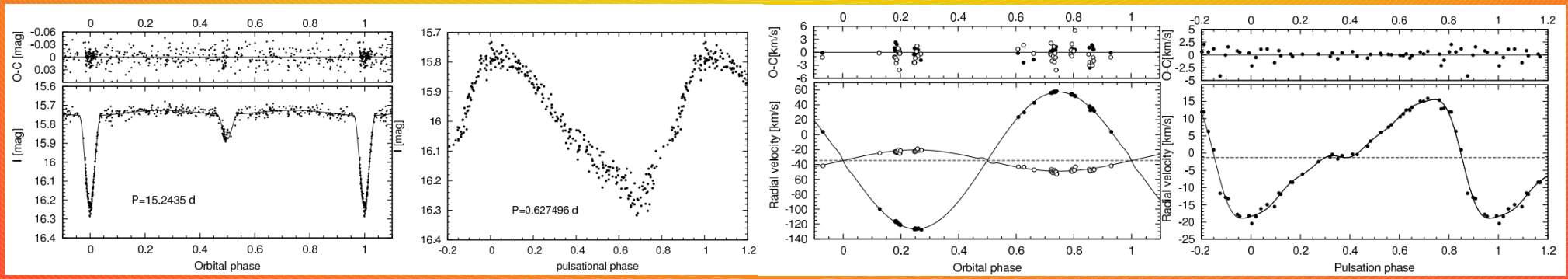


- Wide systems with long orbital periods
  - ➔ Very low probability of eclipses
  - ➔ Small radial velocity amplitudes (1-10 km/s vs. 40-80 km/s from pulsations)
  - ➔ Extremely time-demanding
- Old, large, luminous objects that are faint
  - ➔ WD, NS, BH → no eclipses, possible CEMP, RVs, LTTE, PM, X-rays
  - ➔ MS star → very small eclipses, LTTE, RVs, PM
  - ➔ HB, AGB, RGB → eclipses, LTTE, RVs, PM, colour discrepancy, lower amplitude

RR Lyrae in binaries (?)



- Wide systems with long orbital periods
  - ➔ Very low probability of eclipses
  - ➔ Small radial velocity amplitudes (1-10 km/s vs. 40-80 km/s from pulsations)
  - ➔ Extremely time-demanding
- Old, large, luminous objects that are faint
  - ➔ WD, NS, BH → no eclipses, possible CEMP, RVs, LTTE, PM, X-rays
  - ➔ MS star → very small eclipses, LTTE, RVs, PM
  - ➔ HB, AGB, RGB → eclipses, LTTE, RVs, PM, colour discrepancy, lower amplitude



Pietrzynski et al. 2012, Natur, 484, 75; The first Binary Evolution Pulsator, M=0.26 Msun

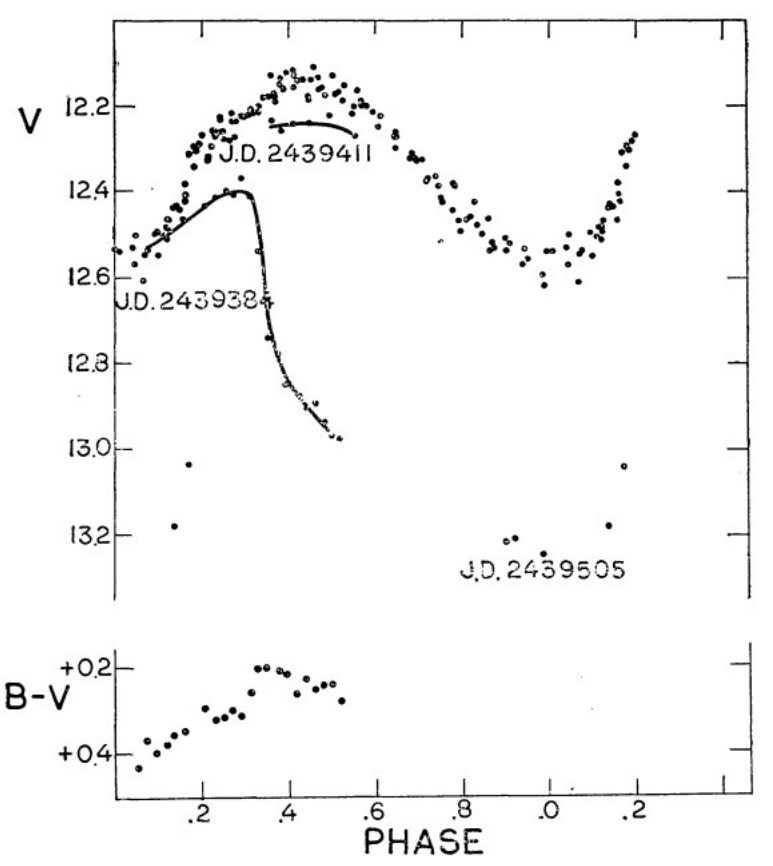
Karczmarek et al. 2017, MNRAS, 466, 2842; BEPs can constitute 0.8 % of RR Lyr population

Current status

- RRLyrBinCan database (106 candidates; https://rrlyrbincan.physics.muni.cz/)

  Liška&Skarka 2016, CoKon, 105, 209

  - Eclipses (12 candidates)
    - Blends in LMC, GB (Soszynski et al. 2003, 2016, 2017; Prsa et al. 2009)
    - RW Ari, RZ Cet, VX Her – never confirmed



RW Ari; Wisniewski 1971, AcA, 21, 307

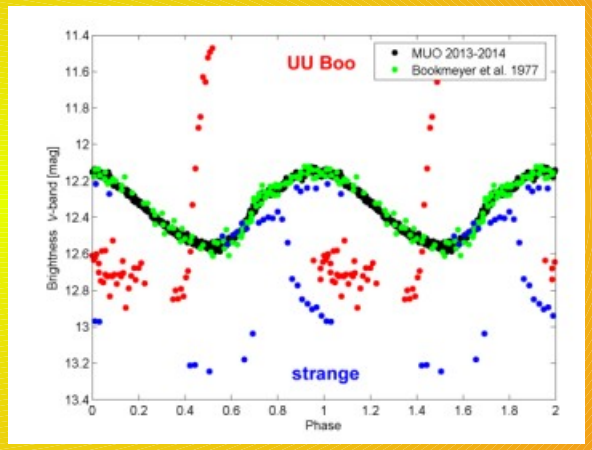
Woodward 1972, JAAVSO, 1, 68

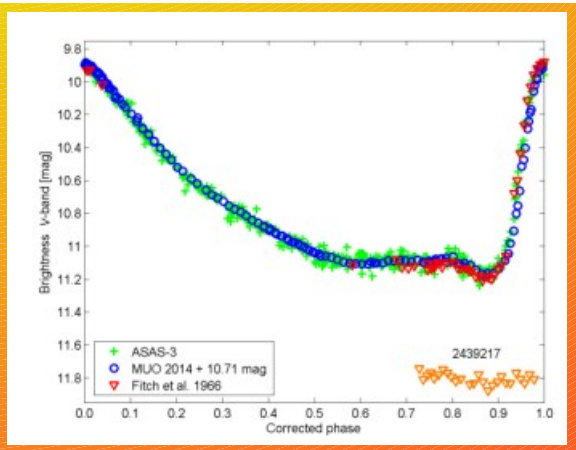
Abt&Wisniewski, IBVS, 697, 1

Sidorov 1978, PZ, 20, 557

Dahm, 1992, BAV, 41, 62

Odel&Sreedhar, IBVS, 6180, 1





Liška, Skarka, Hájková, Auer 2016, OEJV, 176, 4

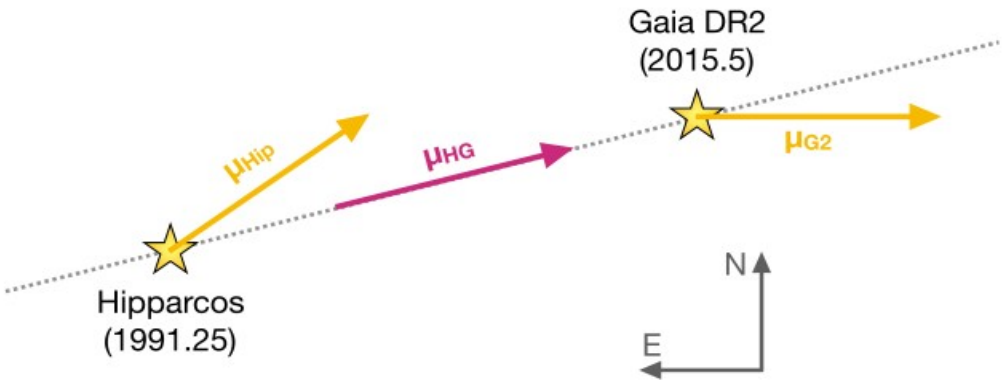
Current status

- RRLyrBinCan database (106 candidates; https://rrlyrbincan.physics.muni.cz/)

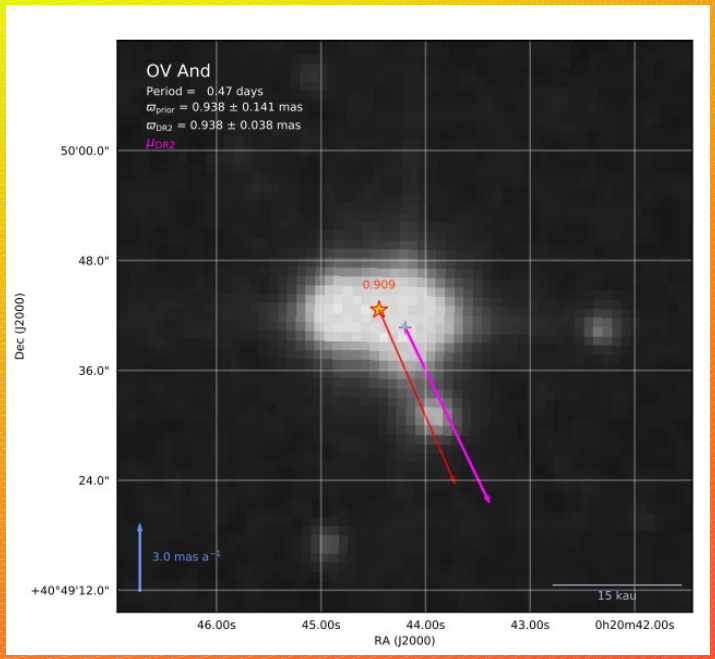
  Liška&Skarka 2016, CoKon, 105, 209

  - Eclipses (12 candidates)
  - Colour discrepancy (3 stars, e.g. Kinman&Carretta, PASP, 104, 111)
  - Carbon-enhanced stars (9 stars, e.g.Kennedy et al. 2014, ApJ, 787, 6)
  - Radial velocity discrepancy (9 stars, e.g. Solano et al. 1997, A&AS, 125, 327)
  - Proper-motion anomaly (13+61(!) candidates, Kervella et al. 2019a, 623, 116)
  - Common proper motion (3+14 candidates; Kervella et al. 2019b, 623, 117)

Name	Period	ϖ	μ_{HG} (mas a^{-1})		$\mu_{Hip} - \mu_{HG}$ (mas a^{-1})	
	(d)	(mas)	μ_α	μ_δ	μ_α	μ_δ
SW And	0.44	1.81	$-6.56_{0.04}$	$-18.83_{0.03}$	$-0.30_{1.33}$	$+1.25_{0.88}$
XX And	0.72	0.72	$+58.31_{0.04}$	$-32.84_{0.05}$	$+1.36_{1.50}$	$-1.34_{1.31}$



Kervella et al. 2019A, 623, 116

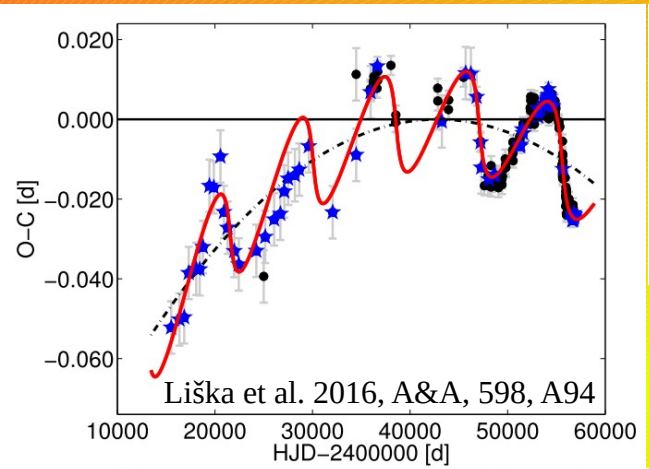


Kervella et al. 2019b, 623, 117

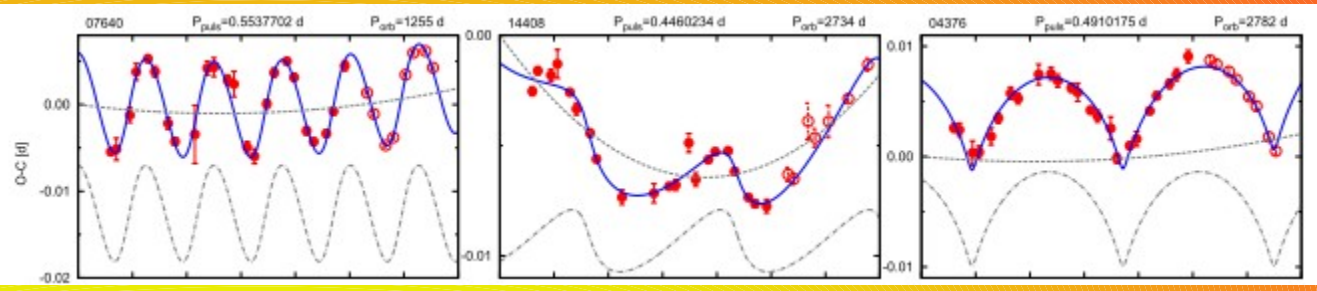
Current status

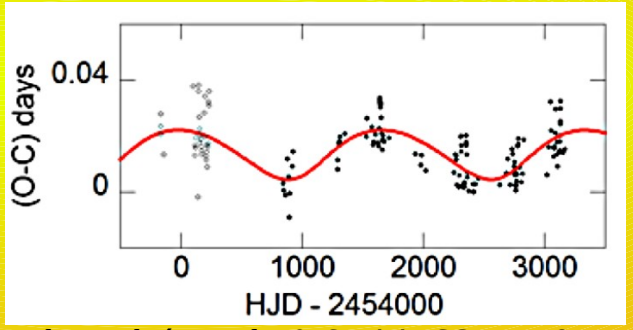
- RRLyrBinCan database (106 candidates; https://rrlyrbincan.physics.muni.cz/)
  - Light Travel Time Effect (1 binary + 55 candidates)

Hajdu et al. 2015, MNRAS, 449, L113

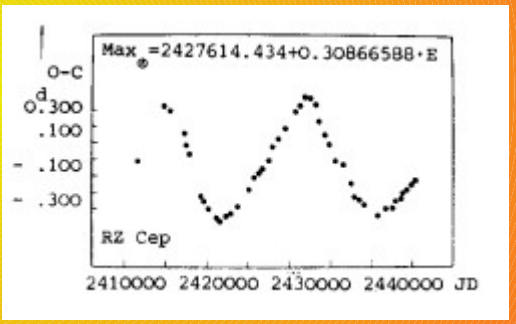


Liška et al. 2016, A&A, 598, A94

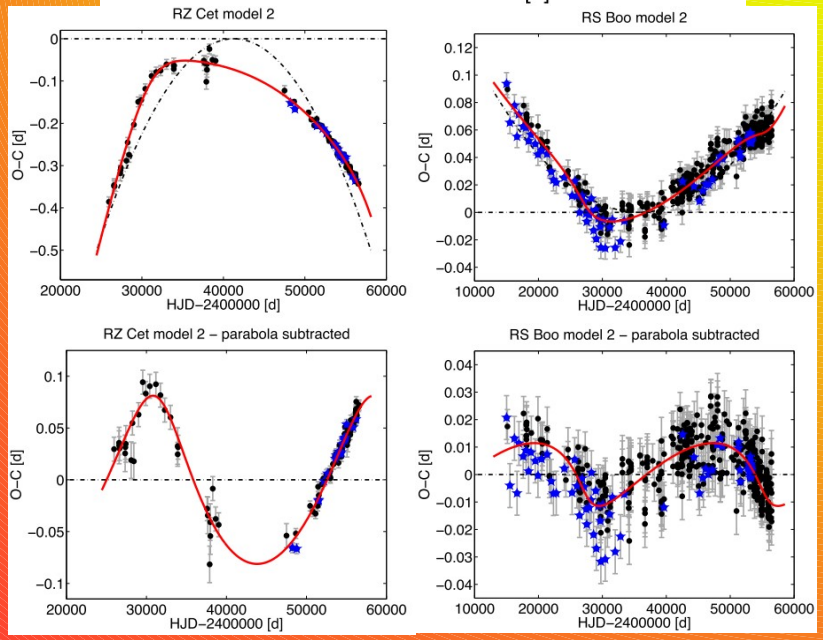




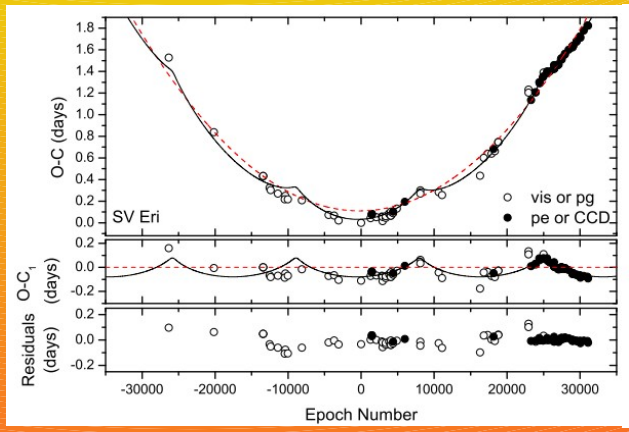
de Ponthiére et al. 2016, JAAVSO, 44, 18

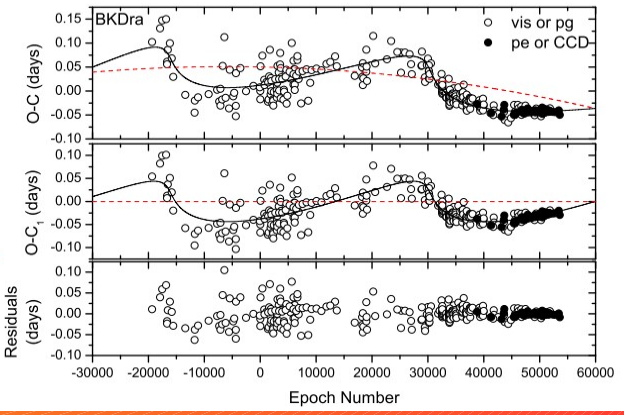


Firmanyuk 1982, IBVS, 2247



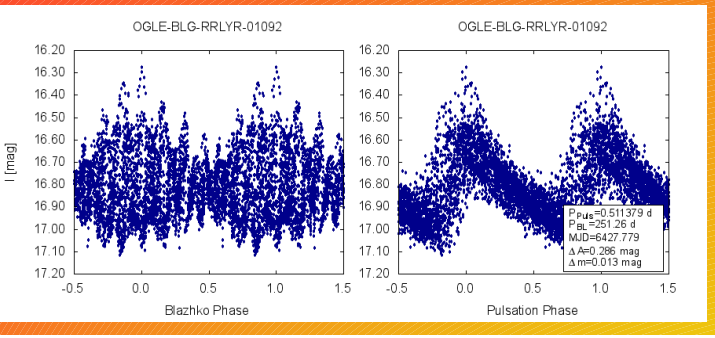
Liška et al. 2016, MNRAS, 459, 4360

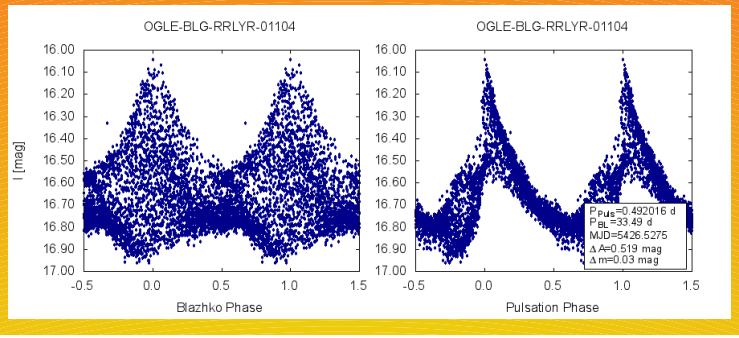


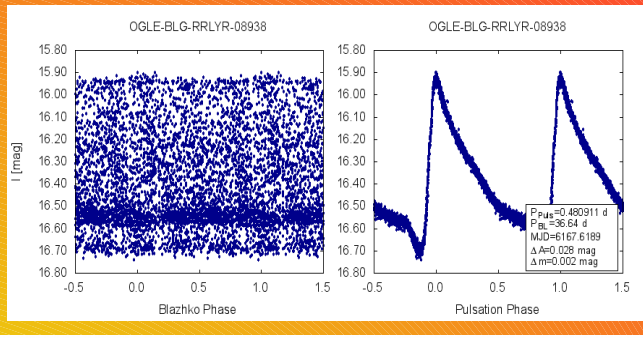


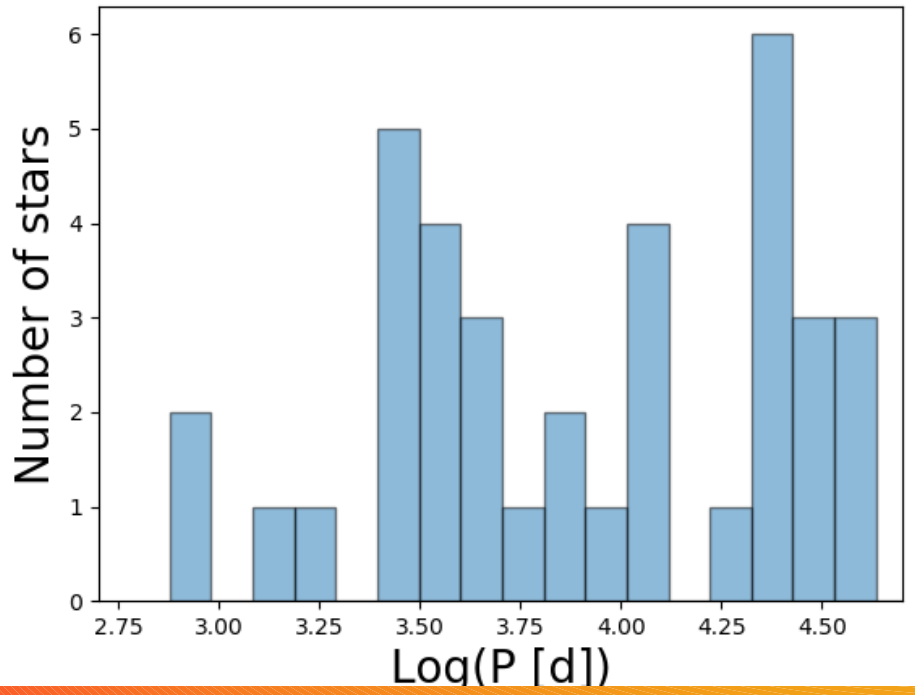
Li et al. 2018, ApJ, 863, 151

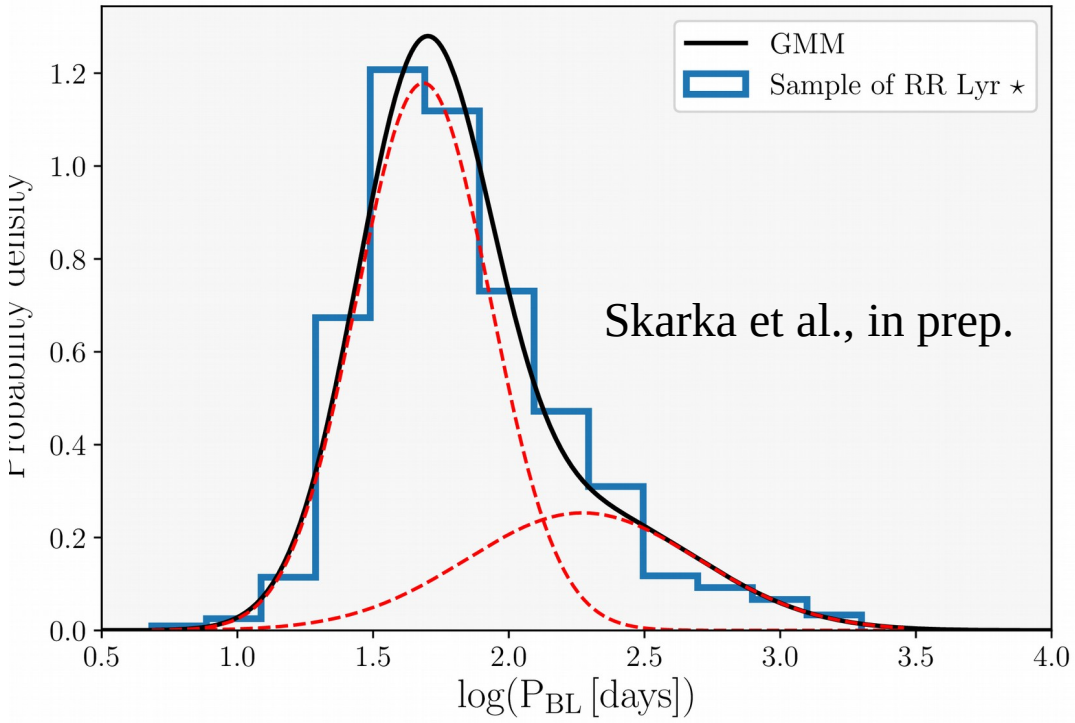
Current status







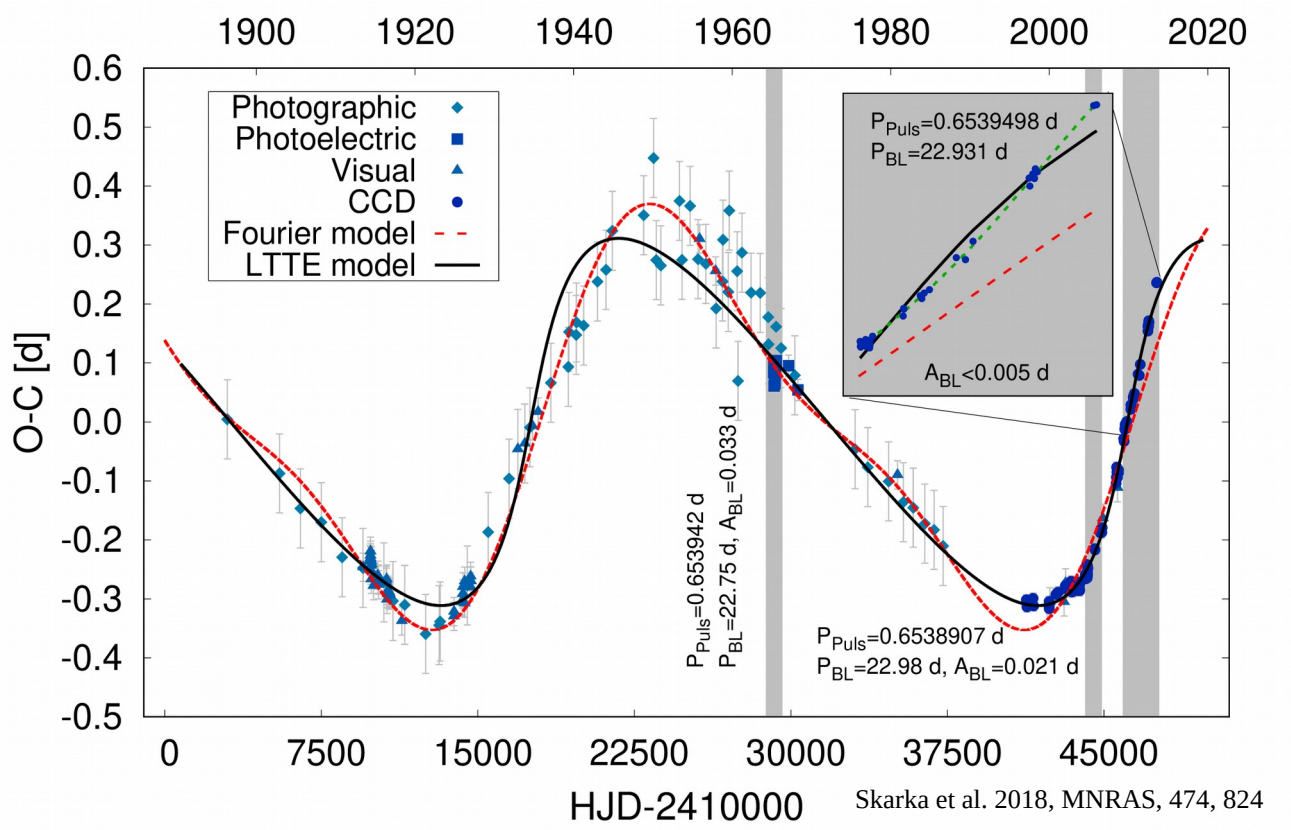




Period variations can be mixed with the variation caused by the long-period Blazhko effect

Current status

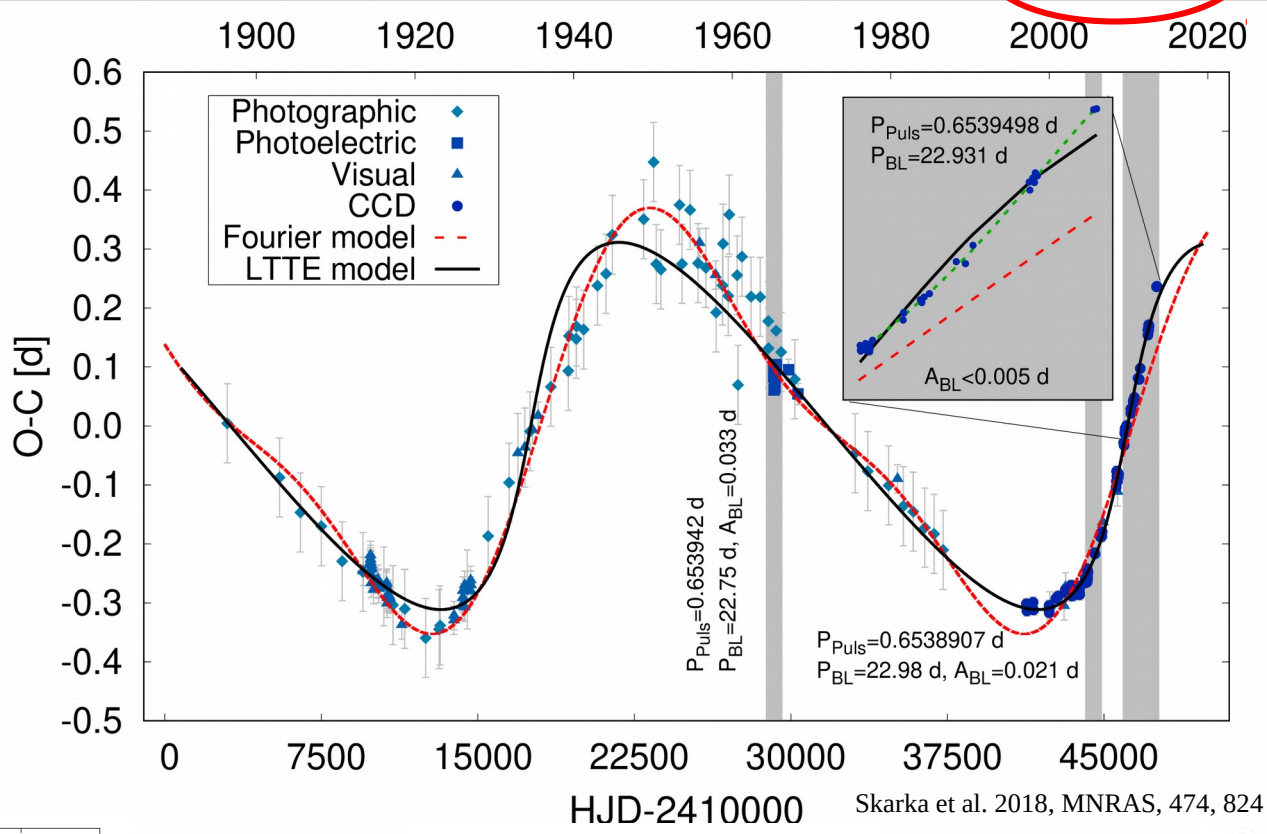
P_{puls}	M_0	P_{orbit}	T_0	e	ω	A	$a_1 \sin i$	$f(\mathfrak{M})$	$\mathfrak{M}_{2,min}$	K_1	χ^2_R	N_{max}
$[d]$	[HJD]	[d]	[HJD]		$[^\circ]$	[light day]	[au]	$[\mathfrak{M}_\odot]$	$[\mathfrak{M}_\odot]$	$[km\,s^{-1}]$		
0.65384853^{+11}_{-10}	2453531.6768^{+44}_{-52}	28590^{+130}_{-110}	2456149^{+74}_{-88}	0.6344^{+98}_{-85}	$0.7^{+1.6}_{-1.8}$	0.4027^{+55}_{-61}	$69.7^{+1.0}_{-1.1}$	$55.3^{+2.3}_{-2.6}$	$56.5^{+2.3}_{-2.6}$	34.33^{+52}_{-54}	1.074(95)	227



Skarka et al. 2018, MNRAS, 474, 824

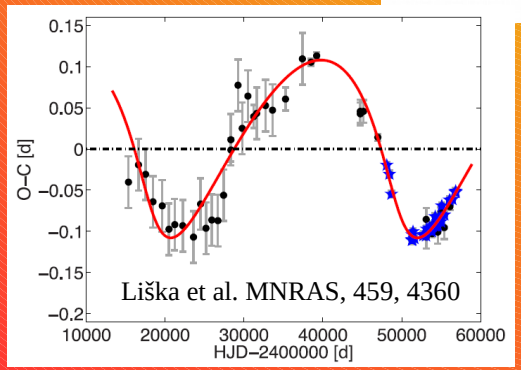
Current status

P_{puls} [d]	M_0 [HJD]	P_{orbit} [d]	T_0 [HJD]	e	ω [°]	A [light day]	$a_1 \sin i$ [au]	$f(\mathfrak{M})$ [$\mathfrak{M}_\odot$]	$\mathfrak{M}_{2,min}$ [$\mathfrak{M}_\odot$]	K_1 [km s^{-1}]	χ^2_R	N_{max}
0.65384853^{+11}_{-10}	2453531.6768^{+44}_{-52}	28590^{+130}_{-110}	2456149^{+74}_{-88}	0.6344^{+98}_{-85}	$0.7^{+1.6}_{-1.8}$	0.4027^{+55}_{-61}	$69.7^{+1.0}_{-1.1}$	$55.3^{+2.3}_{-2.6}$	$56.5^{+2.3}_{-2.6}$	34.33^{+52}_{-54}	1.074(95)	227

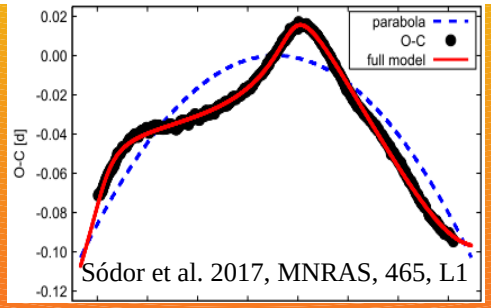


Skarka et al. 2018, MNRAS, 474, 824

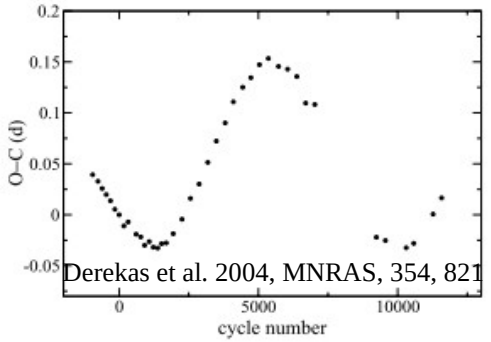
BLACK HOLE!?



Liška et al. MNRAS, 459, 4360



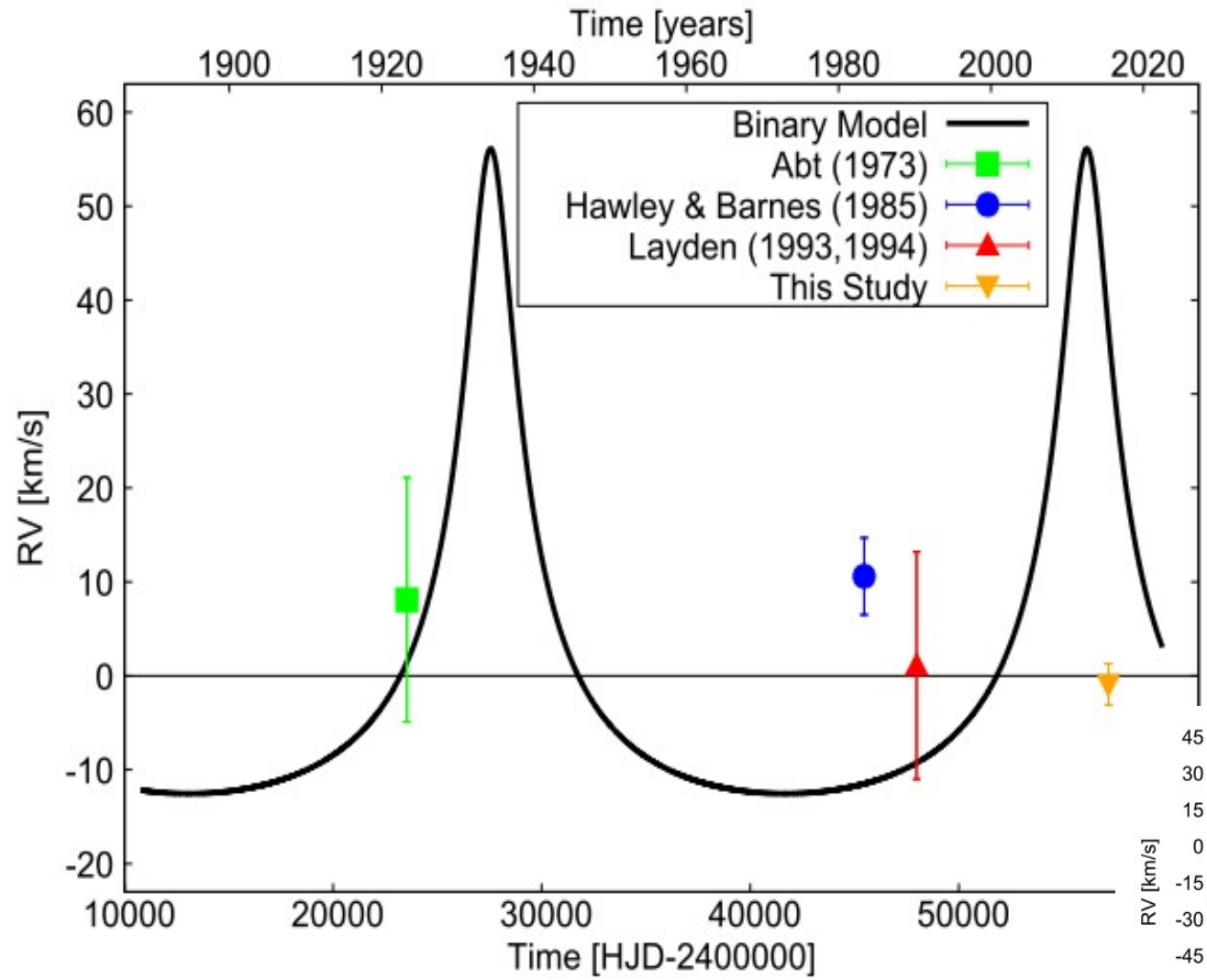
Sódor et al. 2017, MNRAS, 465, L1



Derekas et al. 2004, MNRAS, 354, 821

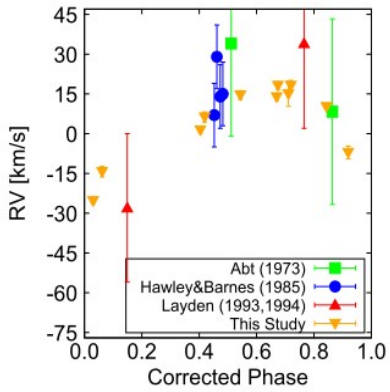
Current status

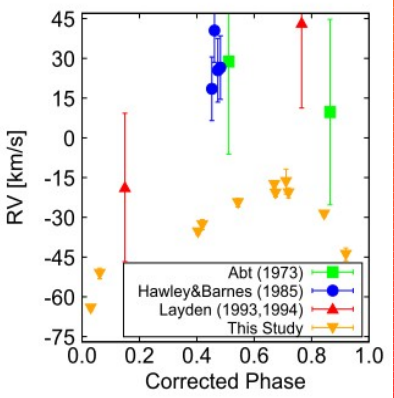
P_{puls}	M_0	P_{orbit}	T_0	e	ω	A	$a_1 \sin i$	$f(\mathfrak{M})$	$\mathfrak{M}_{2,min}$	K_1	χ^2_R	N_{max}
$[d]$	[HJD]	[d]	[HJD]		[°]	[light day]	[au]	$[\mathfrak{M}_\odot]$	$[\mathfrak{M}_\odot]$	$[km\,s^{-1}]$		
0.65384853^{+11}_{-10}	2453531.6768^{+44}_{-52}	28590^{+130}_{-110}	2456149^{+74}_{-88}	0.6344^{+98}_{-85}	$0.7^{+1.6}_{-1.8}$	0.4027^{+55}_{-61}	$69.7^{+1.0}_{-1.1}$	$55.3^{+2.3}_{-2.6}$	$56.5^{+2.3}_{-2.6}$	34.33^{+52}_{-54}	1.074(95)	227



BLACK HOLE!?

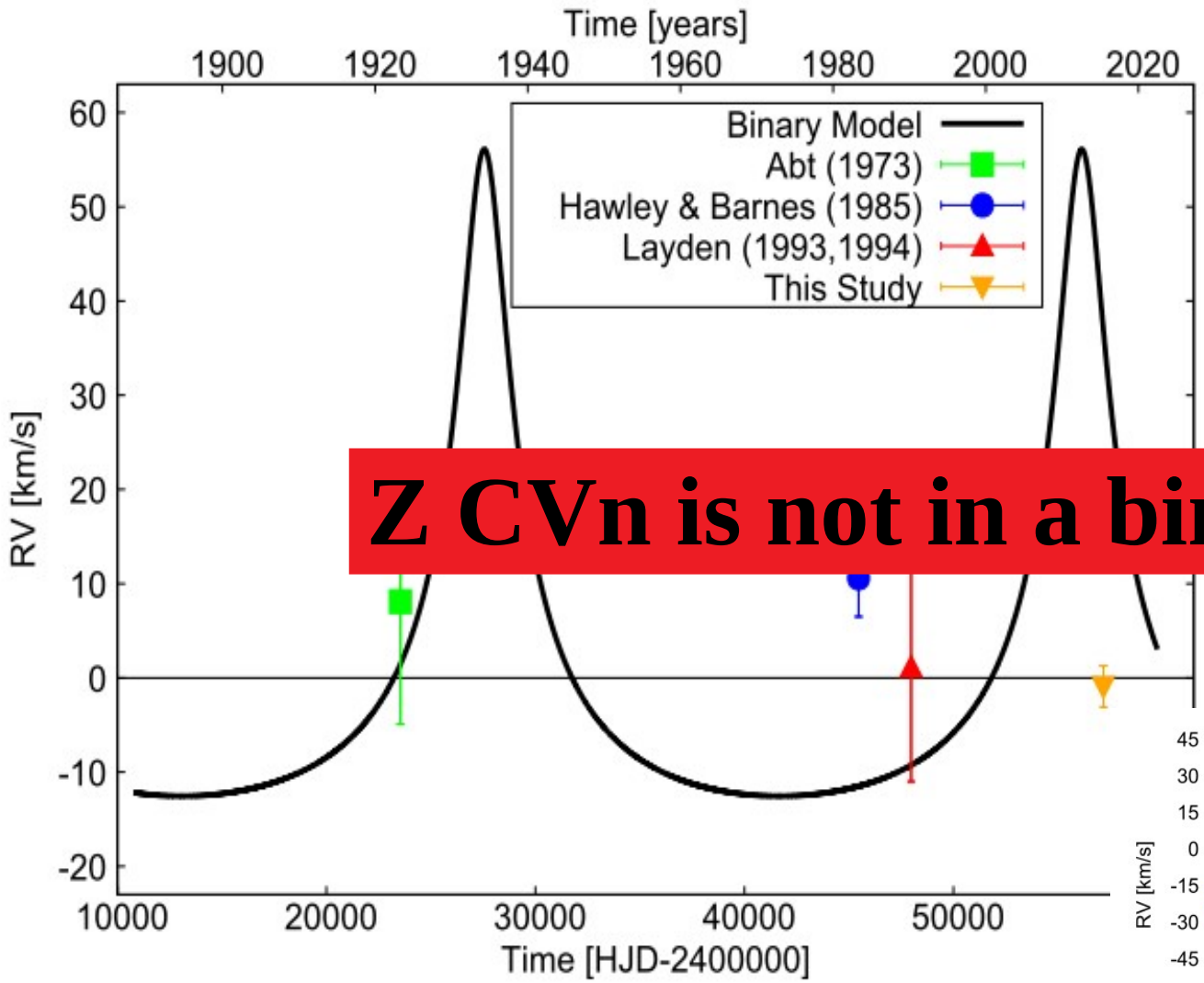
Skarka et al. 2018, MNRAS, 474, 824





Current status

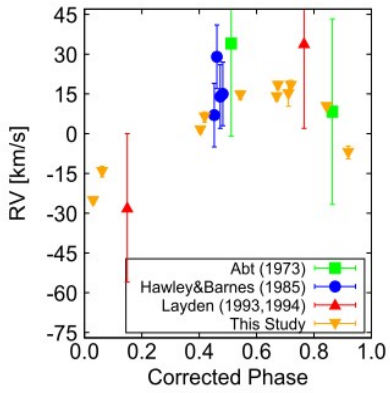
P_{puls}	M_0	P_{orbit}	T_0	e	ω	A	$a_1 \sin i$	$f(\mathfrak{M})$	$\mathfrak{M}_{2,min}$	K_1	χ^2_R	N_{max}
$[d]$	[HJD]	[d]	[HJD]		[°]	[light day]	[au]	$[\mathfrak{M}_\odot]$	$[\mathfrak{M}_\odot]$	[km s^{-1}]		
0.65384853^{+11}_{-10}	2453531.6768^{+44}_{-52}	28590^{+130}_{-110}	2456149^{+74}_{-88}	0.6344^{+98}_{-85}	$0.7^{+1.6}_{-1.8}$	0.4027^{+55}_{-61}	$69.7^{+1.0}_{-1.1}$	$55.3^{+2.3}_{-2.6}$	$56.5^{+2.3}_{-2.6}$	34.33^{+52}_{-54}	1.074(95)	227

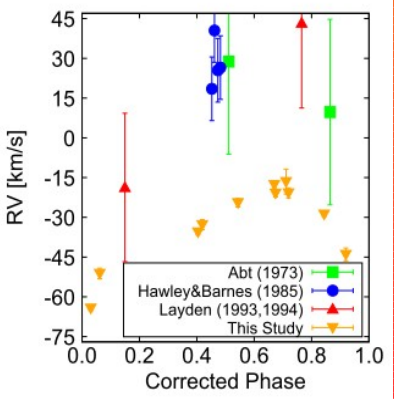


Z CVn is not in a binary

BLACK HOLE!?

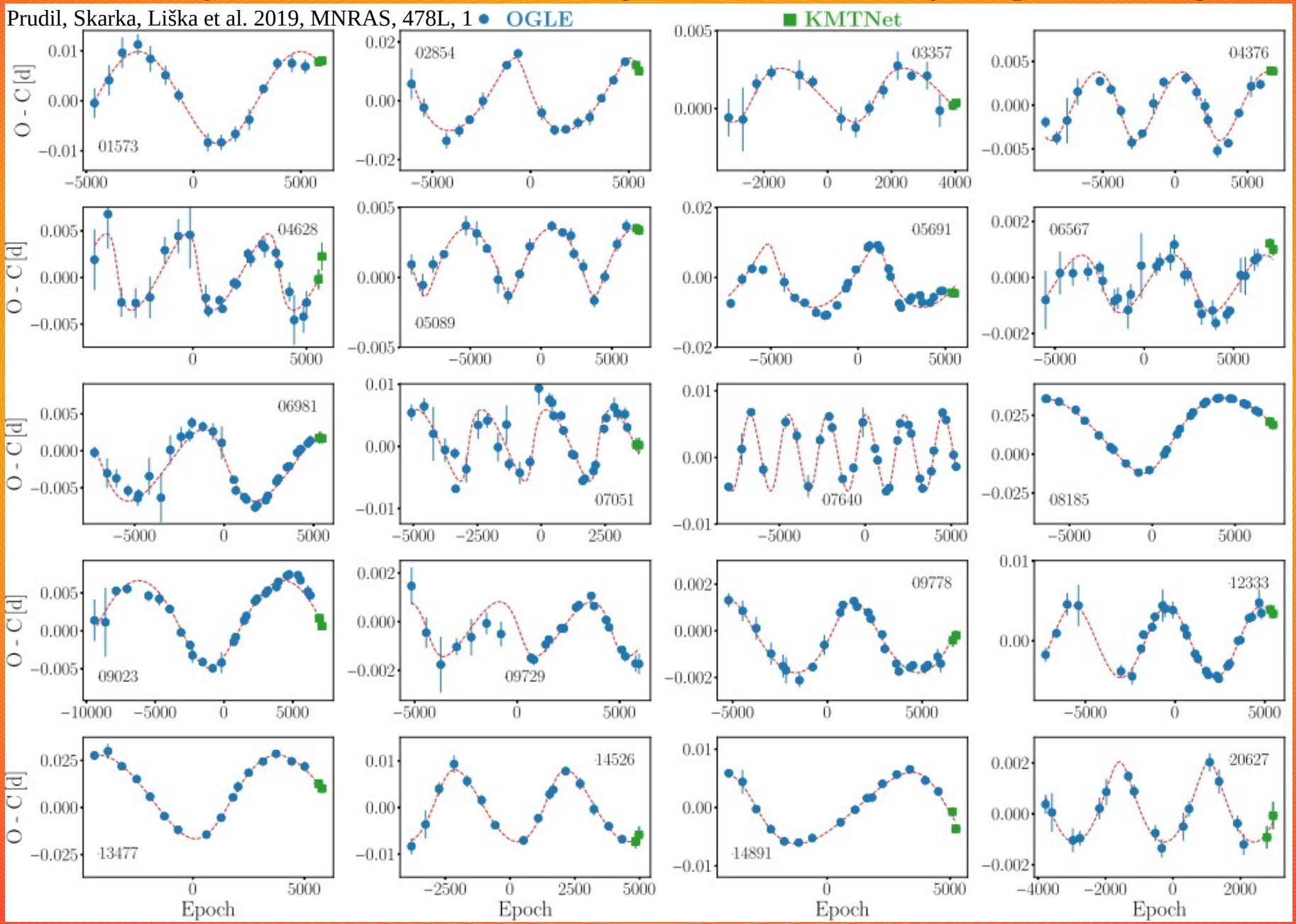
Skarka et al. 2018, MNRAS, 474, 824





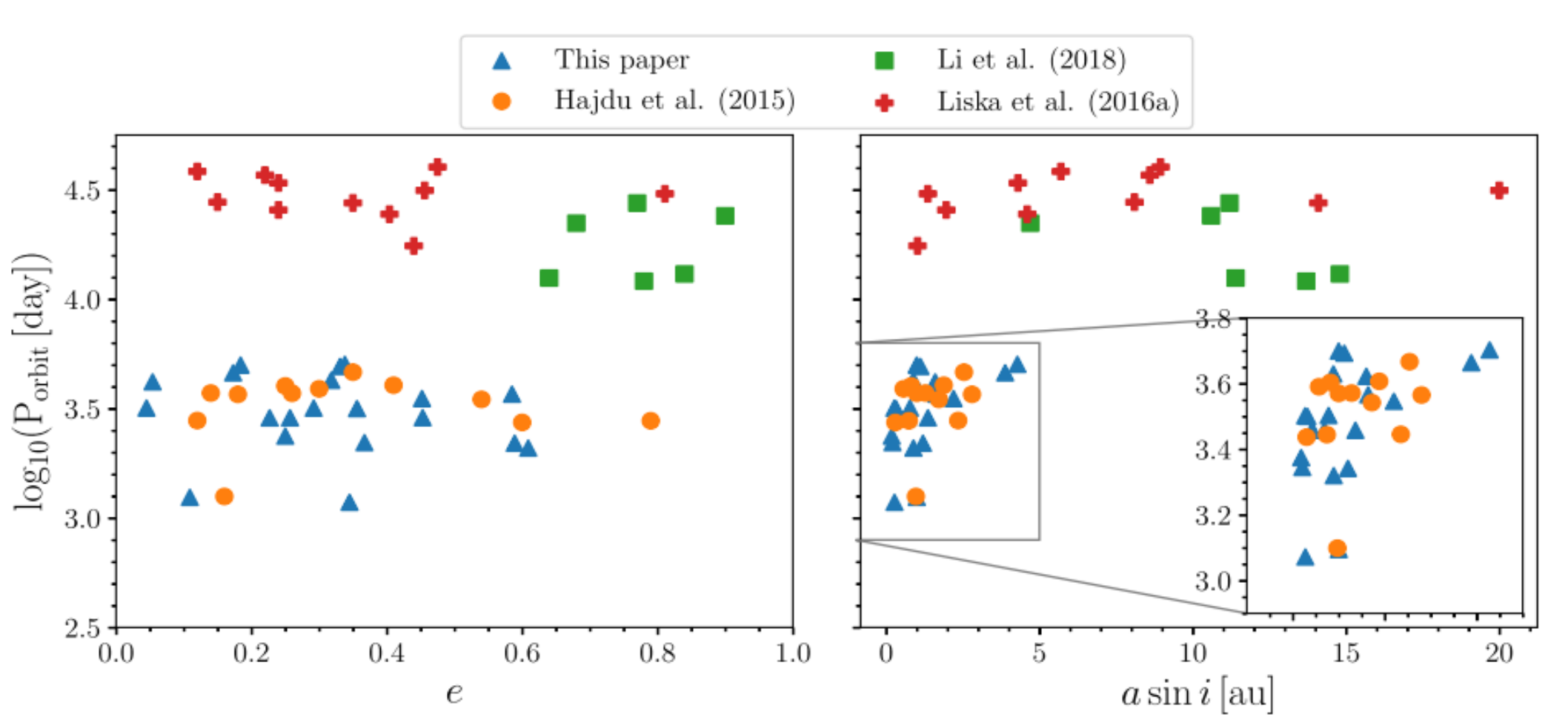
New candidates

- 9000 RR Lyraes from the Galactic bulge → 20 stars with cyclic period change



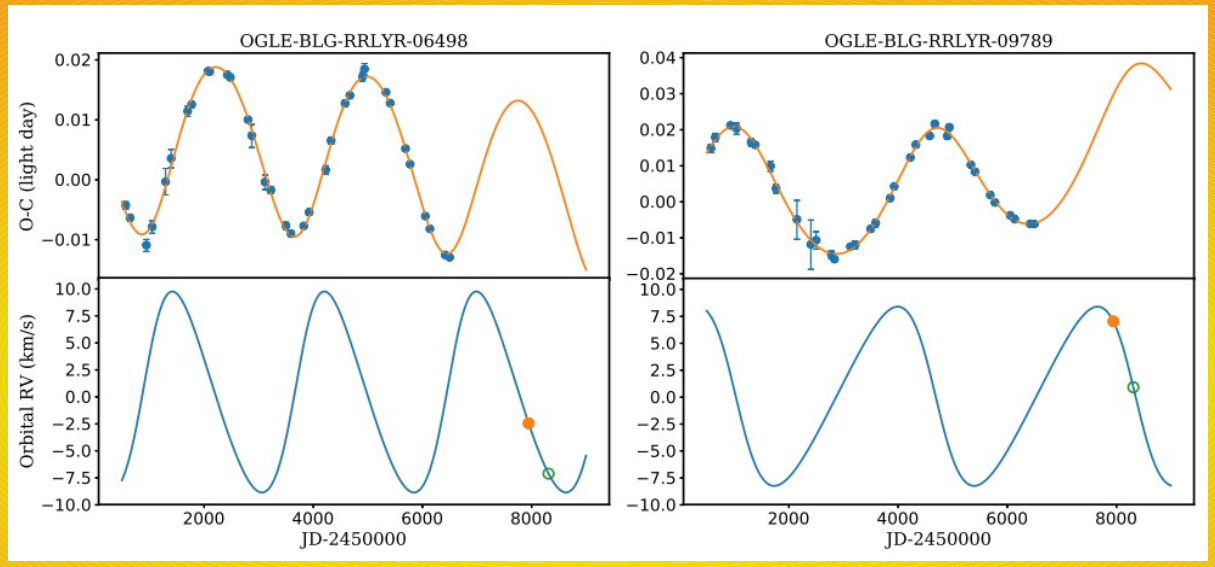
New candidates

- 9000 RR Lyraes from the Galactic bulge → 20 stars with cyclic period change



Current work and future plans

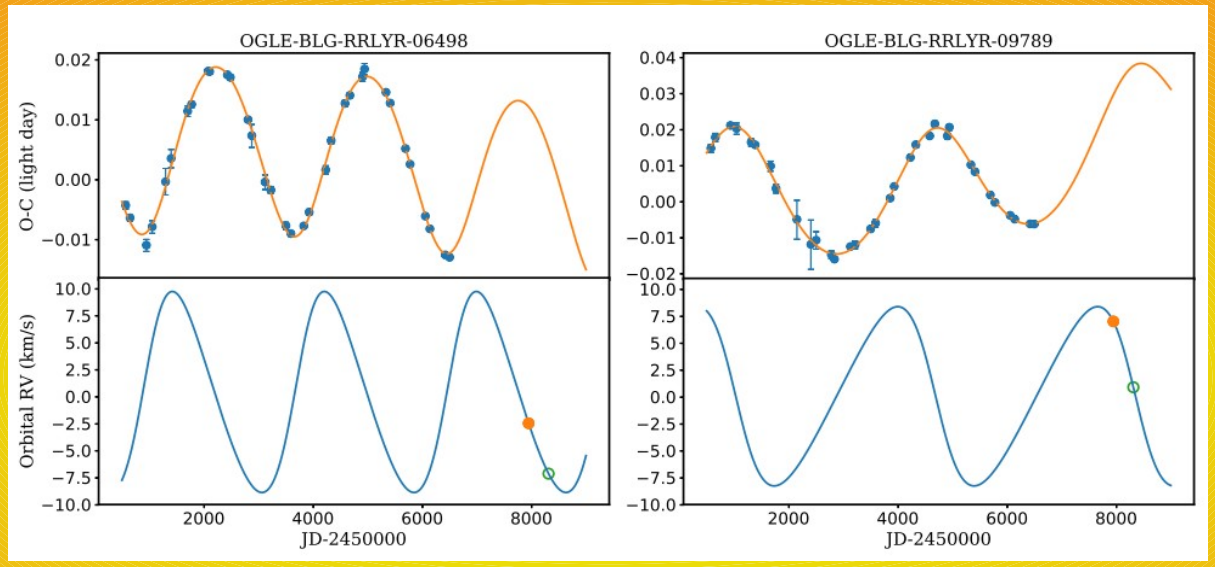
- Guggenberger et al. 2016, CoKon, 105, 145 – radial velocity templates
- Hajdu et al. 2018, pas6conf, 248 – spectroscopic follow-up of GB candidates



- Skarka et al. 2020(?) - searching for CEMP candidates, 4 nights at INT La Palma
- Skarka et al. 2020(?) - searching for new candidates using GAIA paralaxes and expected luminosity

Current work and future plans

- Guggenberger et al. 2016, CoKon, 105, 145 – radial velocity templates
- Hajdu et al. 2018, pas6conf, 248 – spectroscopic follow-up of GB candidates



- Skarka et al. 2020(?) - searching for CEMP candidates, 4 nights at INT La Palma
- Skarka et al. 2020(?) - searching for new candidates using GAIA paralaxes and expected luminosity

Thank you for your attention