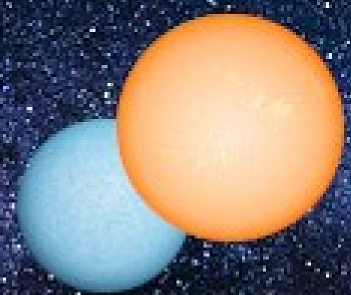
Parameters and chemical composition of binary systems components from spectroscopic analysis



Cezary Gałan

Annual Report 2023,
January 31, 2024

Aims

Possibly accurate the values of parameters:
T_{eff}, [M/H], ξ, V_{rot}, abundances

- External information to set the effective temperature scale (calibration of SBCR);
- Issues concerning synchronization of rotation in binary systems;
- Studies of convective core overshooting;
- Tests of the evolutionary status and the mass loss or signs of mass transfer.

GSSP code (Tkachenko 2015, A&A 581, 129; version: Aug 2020), high-resolution spectra (*HARPS*, *MIKE*, *UVES*)

Spectrum synthesis: SynthV LTE-based radiative transfer code (Tsymbal, 1996, ASPC 108, 198)

LLMODELS (Shulyak et al., 2004, A&A 428, 993)

MARCS (Gustafsson et al., 2008, A&A 486, 951)

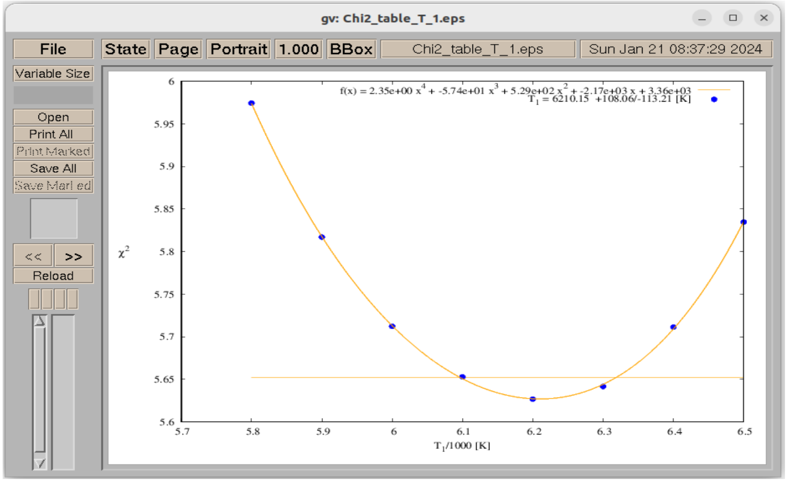
Parameter, step width					
[M/H] (dex)	Δ[M/H] (dex)	$T_{\rm eff}$ (K)	$\Delta T_{\rm eff}$ (K)	$\log g$ (dex)	$\Delta \log g$ (dex)
		MARCS			
[-1.0, 1.0]	0.1	[2 500, 5 500]	100	[1.0, 5.0]	0.1
		LLMODELS			
[-0.8, 0.8]	0.1	[5 600, 10 000]	100	[2.5, 5.0]	0.1
		[10 000, 25 750]	250	[3.0, 5.0]	
		[25 750, 30 000]		[3.3, 5.0]	
		[30 000, 33 000]	500	[3.5, 5.0]	
		[33 000, 34 000]		[4.0, 5.0]	

- Authomatic calculations of abundances,

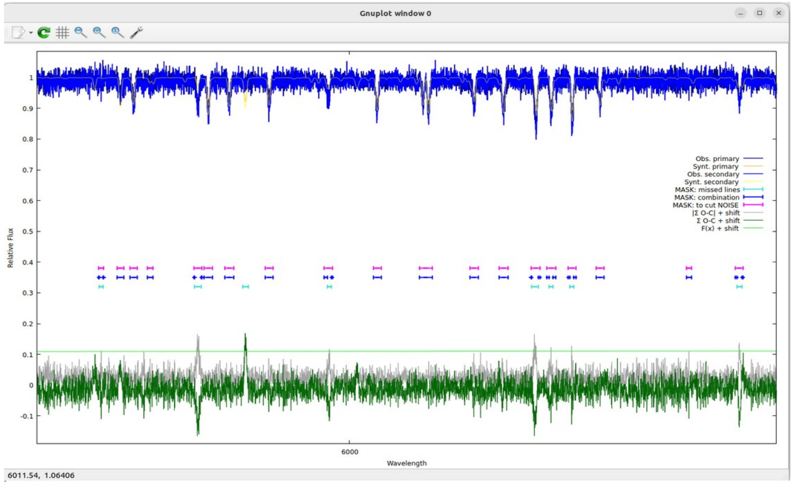
```
$ ./AbElAut_4_GSSP_single_v20231227.out

26 Fe  0.2  6100.0 2.5 4.2  3.0  -4.52  13.0    111177.56852  1.00000 4.11910  4.15080
22 Ti  0.2  6100.0 2.5 4.2  3.0  -6.89  13.0    109988.02782  1.00000 4.07500  4.10640
28 Ni  0.2  6100.0 2.5 4.2  3.0  -5.94  13.0    109716.35678  1.00000 4.06490  4.09630
24 Cr  0.2  6100.0 2.5 4.2  3.0  -6.24  13.0    109124.02348  1.00000 4.04300  4.07420
14 Si  0.2  6100.0 2.5 4.2  3.0  -4.52  13.0    109068.91982  1.00000 4.04090  4.07210
20 Ca  0.2  6100.0 2.5 4.2  3.0  -5.62  13.0    109031.84354  1.00000 4.03960  4.07070
25 Mn  0.2  6100.0 2.5 4.2  3.0  -6.90  13.0    108863.77043  1.00000 4.03330  4.06440
60 Nd  0.2  6100.0 2.5 4.2  3.0  -9.68  13.0    108802.09473  1.00000 4.03110  4.06210
58 Ce  0.2  6100.0 2.5 4.2  3.0  -9.61  13.0    108771.10115  1.00000 4.02990  4.06100
23 V   0.2  6100.0 2.5 4.2  3.0  -7.89  13.0    108769.64917  1.00000 4.02980  4.06090
27 Co  0.2  6100.0 2.5 4.2  3.0  -7.19  13.0    108727.66995  1.00000 4.02830  4.05940
39 Y   0.2  6100.0 2.5 4.2  3.0  -9.42  13.0    108727.01958  1.00000 4.02830  4.05930
```

- Authomatic calculations of the errors,

```
$ ./mk_Chi2_tables_and_FIT_4errors_GSSP-bin_v20230812.out
```



- Masks to eliminate wrong/noisy ranges.



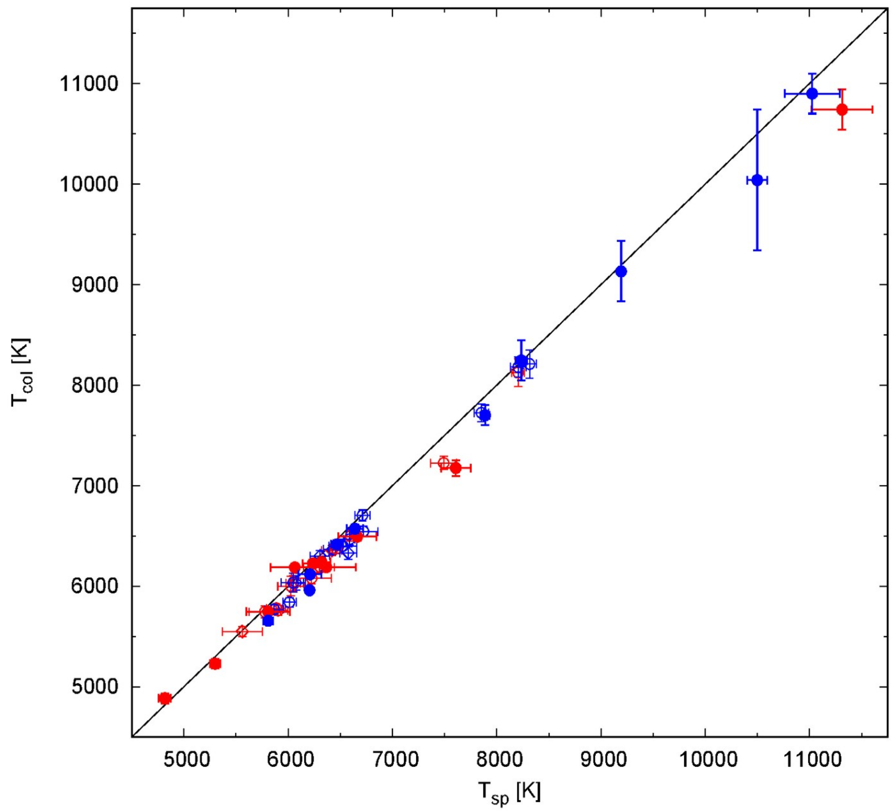
Results for the new sample of 12 binary systems

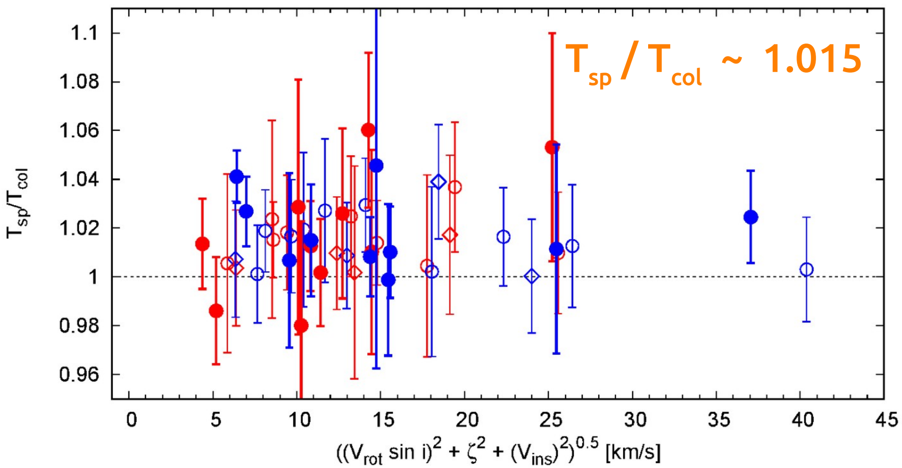
metallicity: from -0.4 dex up to super-solar in AM-type stars ([M/H] ~ +0.6 dex).

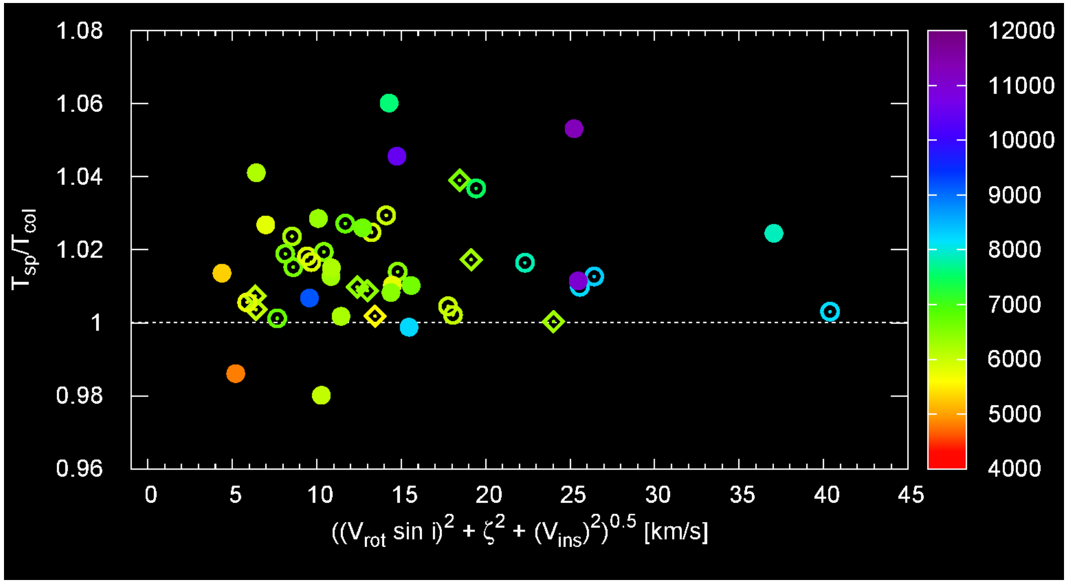
		Primary							Secondary							high abundances of	
Name	R1/R2	[M/H]	[α/Fe]	T_{eff}	log g	ξ	ζ	V_{rot} sin i	[M/H]	[α/Fe]	T_{eff}	log g	ξ	ζ	V_{rot} sin i	lithium	s-process
TYC 1243-402-1	1,299	-0,41 ± 0,07	0,07	6564 ± 64	4,30	0,95 ± 0,19	3,5	3,63 ± 0,55	-0,36 ± 0,09	0,06	6039 ± 104	4,46	1,0	2,5	2,80 ± 0,80	Y , Y	-
TYC 1257-132-1	0,852	-0,39 ± 0,08	0,08	6116 ± 80	3,96	1,11 ± 0,19	5,0	9,5 ± 0,74	-0,41 ± 0,08	0,08	5666 ± 74	3,85	1,12 ± 0,17	3,5	12,63 ± 0,64	Y , Y	-
CG Scl	1,707	-0,04 ± 0,09	0,04	5809 ± 45	4,21	1,08 ± 0,12	2	5,54 ± 0,54	0,09 ± 0,12	0,08	4817 ± 58	4,57	1,24 ± 0,27	1	3,46 ± 1,03	-	-
BD+17 1832	1,328	0,04 ± 0,08	-0,20	8235 ± 56	4,13	3,75 ± 0,24	8	12,96 ± 0,54	-0,14 ± 0,14	0,12	7607 ± 143	4,29	2,26 ± 0,31	7	12,16 ± 1,24	-	Y
HD 149946	1,764	-0,40 ± 0,06	0,06	6639 ± 80	3,92	1,58 ± 0,17	6,5	13,65 ± 0,61	-0,04 ± 0,10	0,12	6662 ± 183	4,31	0,91 ± 0,28	6,5	10,27 ± 1,10	-	-
HD 159246	1,022	0,51 ± 0,09	-0,17	11025 ± 265	4,16	0,11 ± 0,36	10	23,28 ± 2,20	0,60 ± 0,09	-0,26	11311 ± 292	4,17	0,17 ± 0,44	10	23,01 ± 2,03	-	Y , Y
TYC 6511-1799-1	0,909	-0,08 ± 0,09	0,04	6210 ± 111	3,91	1,22 ± 0,22	4	9,75 ± 0,66	-0,07 ± 0,08	0,07	6320 ± 84	3,83	1,58 ± 0,22	4,5	9,50 ± 0,70	y , y	-
HD 27476	1,704	0,37 ± 0,05	-0,12	10498 ± 105	4,28	0,72 ± 0,47	10	10,51 ± 0,83	0,19 ± 0,18	0,17	6064 ± 235	4,43	0,9	4	9,09 ± 2,01	Y	Y (?)
AW Col	1,546	0,09 ± 0,08	-0,19	7889 ± 43	4,29	3,21 ± 0,17	8	36,09 ± 0,71	-0,04 ± 0,19	0,04	5807 ± 210	4,49	1,40 ± 0,53	4	13,66 ± 1,71	Y	Y
TYC 266-718-1	1,471	-0,01 ± 0,08	-0,04	6205 ± 32	4,34	1,12 ± 0,09	5	1,47 ± 0,90	0,04 ± 0,09	0,02	5301 ± 51	4,57	0,87 ± 0,15	2	1,09 ± 0,95	Y	-
VZ PsA	2,778	0,39 ± 0,05	-0,18	9193 ± 25	3,84	2,54 ± 0,10	9	1,89 ± 0,89	0,27 ± 0,36	-0,05	6366 ± 282	4,41	0,8	5,5	8,05 ± 2,20	Y	Y
HD 219869	1,333	-0,40 ± 0,04	0,14	6468 ± 59	4,07	1,64 ± 0,12	7	11,99 ± 0,35	-0,41 ± 0,06	0,10	6237 ± 97	4,32	1,20 ± 0,17	6	8,97 ± 0,59	Y , Y	-

T_{spect} vs T_{color}

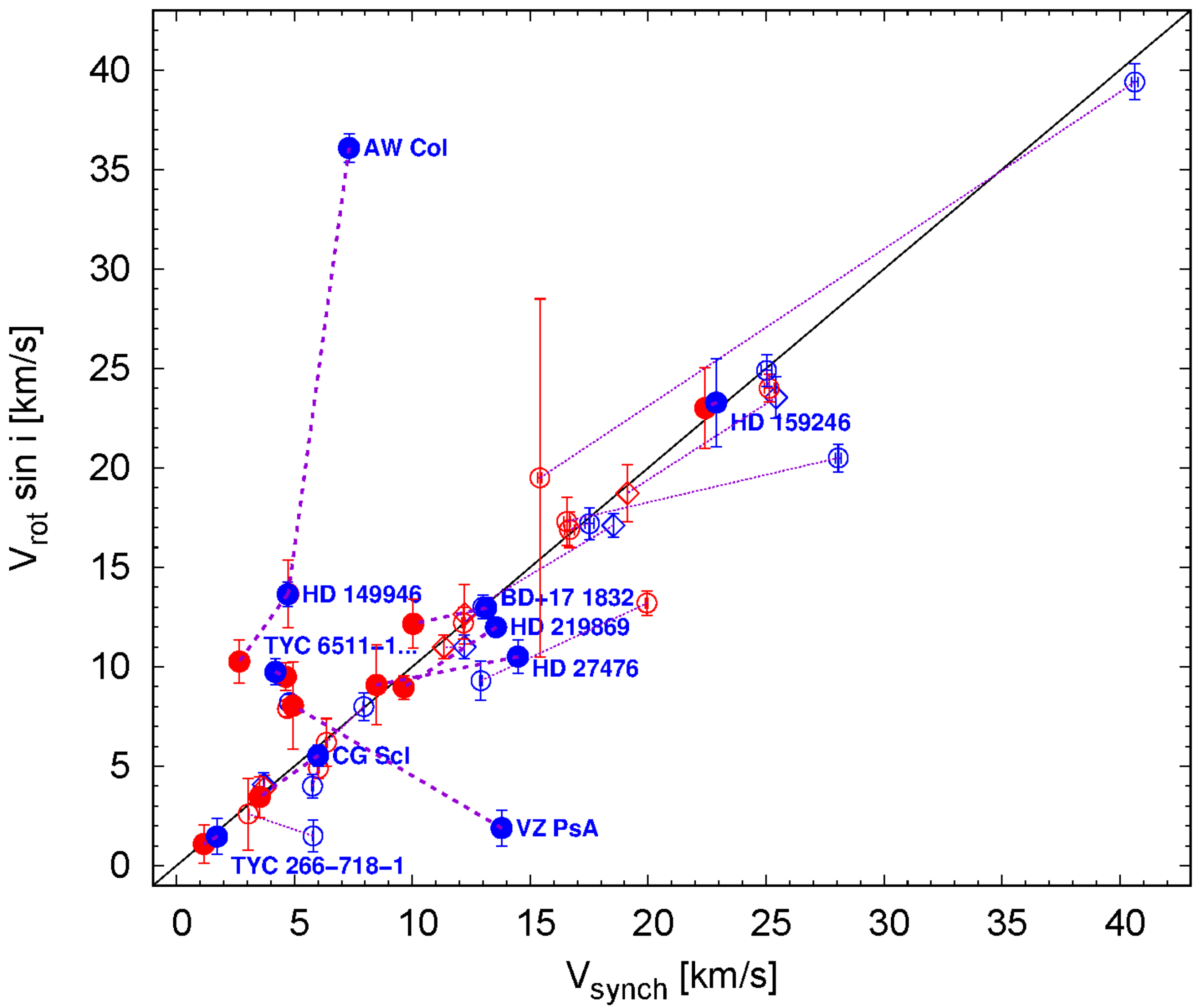
T_{eff} with a few exceptions agrees with those from photometric colors to ~1 σ







Mostly synchronous rotation



Abundances

Chemical composition of up to ~30 elements is measured for 18 systems.

		Primary							Secondary							high abundances of	
Name	R1/R2	[M/H]	[α/Fe]	T_{eff}	log g	ξ	ζ	V_{rot} sin i	[M/H]	[α/Fe]	T_{eff}	log g	ξ	ζ	V_{rot} sin i	lithium	s-process
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CG Scl	1,707	-0,04 ± 0,09	0,04	5809 ± 45	4,21	1,08 ± 0,12	2	5,54 ± 0,54	0,09 ± 0,12	0,08	4817 ± 58	4,57	1,24 ± 0,27	1	3,46 ± 1,03	-	-
BD+17 1832	1,328	0,04 ± 0,08	-0,20	8235 ± 56	4,13	3,75 ± 0,24	8	12,96 ± 0,54	-0,14 ± 0,14	0,12	7607 ± 143	4,29	2,26 ± 0,31	7	12,16 ± 1,24	-	Y
HD 149946	1,764	-0,40 ± 0,06	0,06	6639 ± 80	3,92	1,58 ± 0,17	6,5	13,65 ± 0,61	-0,04 ± 0,10	0,12	6662 ± 183	4,31	0,91 ± 0,28	6,5	10,27 ± 1,10	-	-
HD 159246	1,022	0,51 ± 0,09	-0,17	11025 ± 265	4,16	0,11 ± 0,36	10	23,28 ± 2,20	0,60 ± 0,09	-0,26	11311 ± 292	4,17	0,17 ± 0,44	10	23,01 ± 2,03	-	Y , Y
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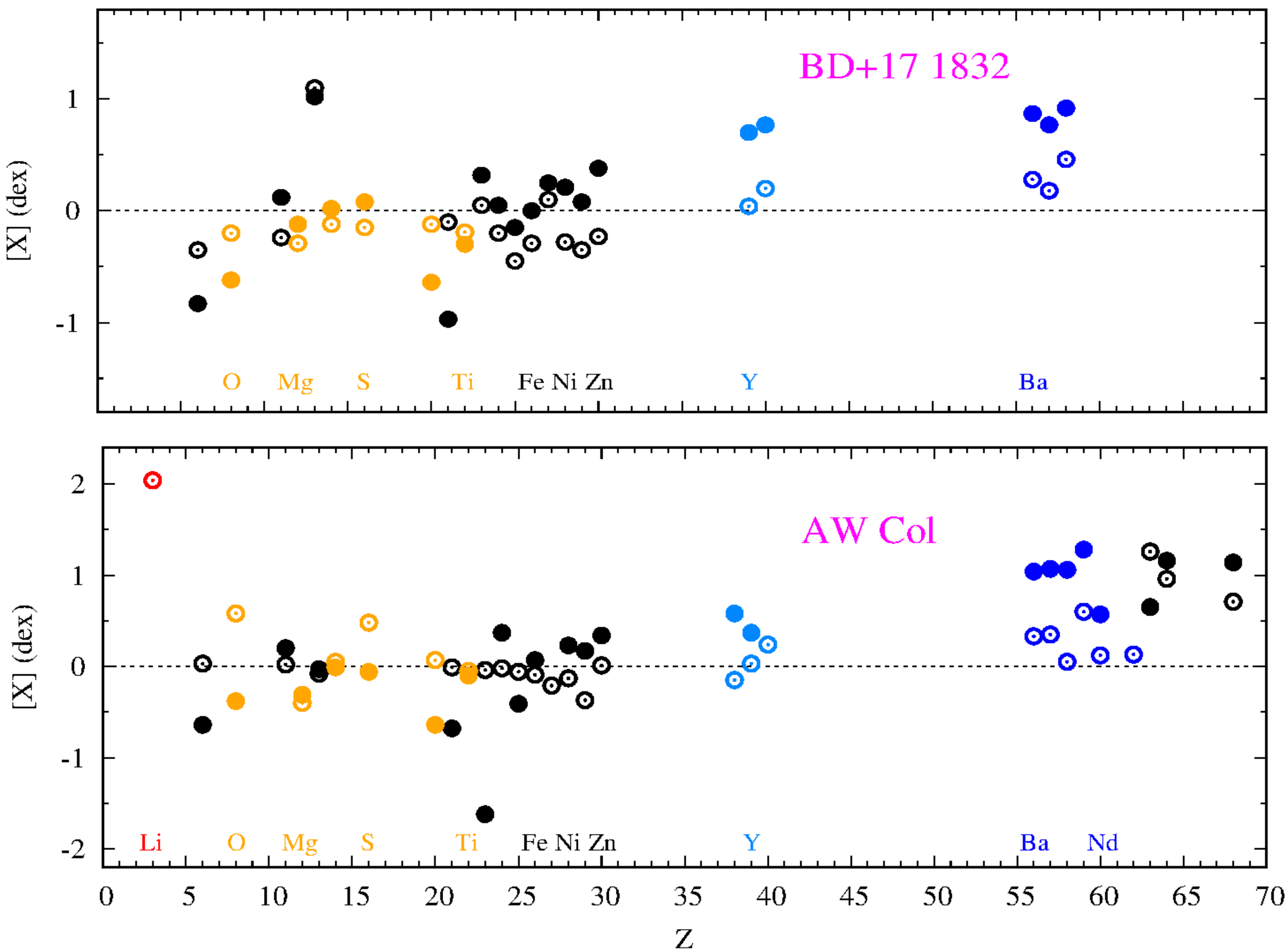
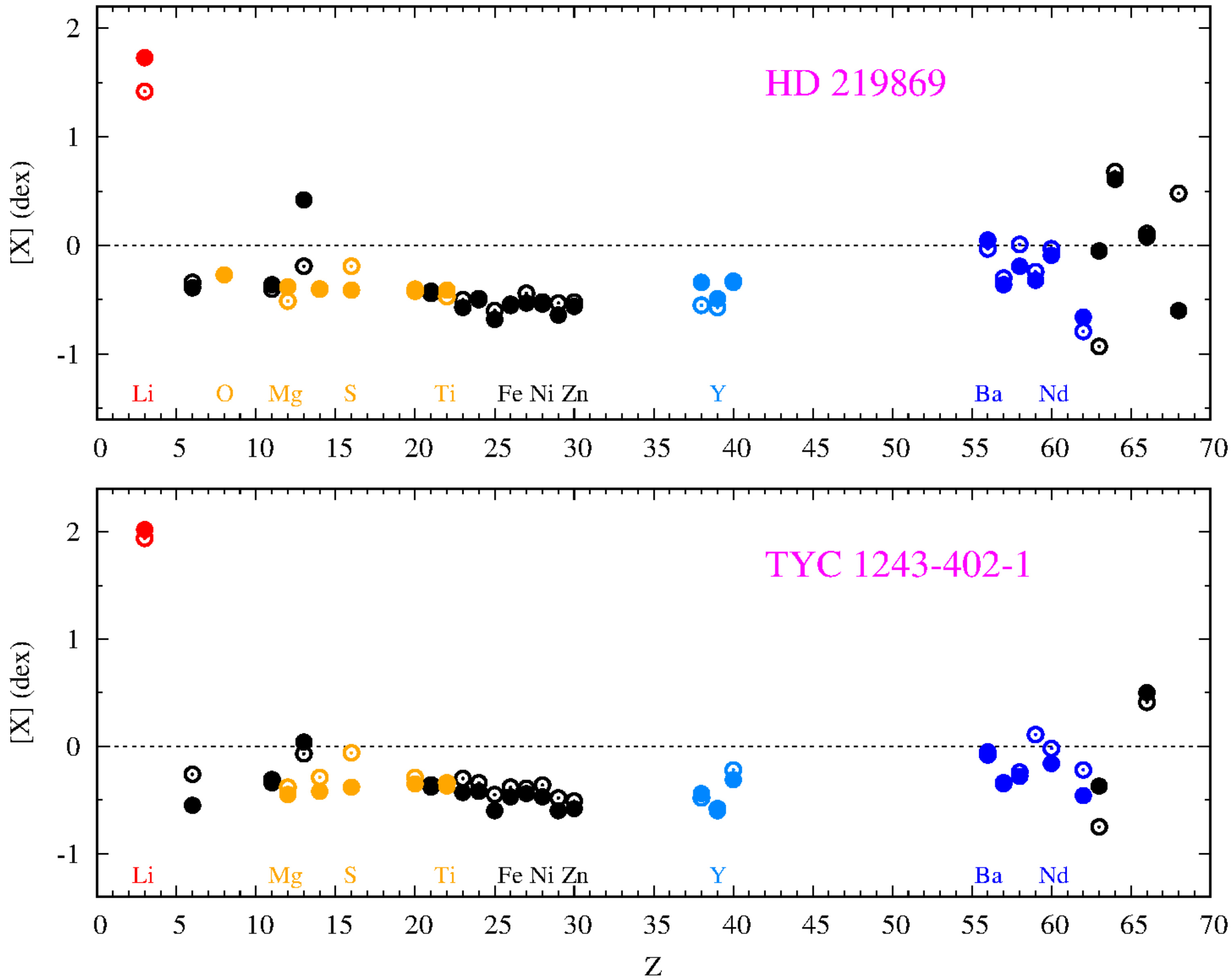
AW Col	1,546	0,09 ± 0,08	-0,19	7889 ± 43	4,29	3,21 ± 0,17	8	36,09 ± 0,71	-0,04 ± 0,19	0,04	5807 ± 210	4,49	1,40 ± 0,53	4	13,66 ± 1,71	Y	Y
TYC 266-718-1	1,471	-0,01 ± 0,08	-0,04	6205 ± 32	4,34	1,12 ± 0,09	5	1,47 ± 0,90	0,04 ± 0,09	0,02	5301 ± 51	4,57	0,87 ± 0,15	2	1,09 ± 0,95	Y	-
VZ PsA	2,778	0,39 ± 0,05	-0,18	9193 ± 25	3,84	2,54 ± 0,10	9	1,89 ± 0,89	0,27 ± 0,36	-0,05	6366 ± 282	4,41	0,8	5,5	8,05 ± 2,20	Y	Y
HD 219869	1,333	-0,40 ± 0,04	0,14	6468 ± 59	4,07	1,64 ± 0,12	7	11,99 ± 0,35	-0,41 ± 0,06	0,10	6237 ± 97	4,32	1,20 ± 0,17	6	8,97 ± 0,59	Y , Y	-

Am-type stars

Enhanced: Ba, Y, Zr, Sr, Zn. Deficiences: Ca, Sc.



High lithium abundance



Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

MNRAS **526,** 918–930 (2023) https://doi.org/10.1093/mnras/stad2153
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Chemical abundance analysis of symbiotic giants. Metallicity and CNO abundance patterns in 14 northern S-type systems

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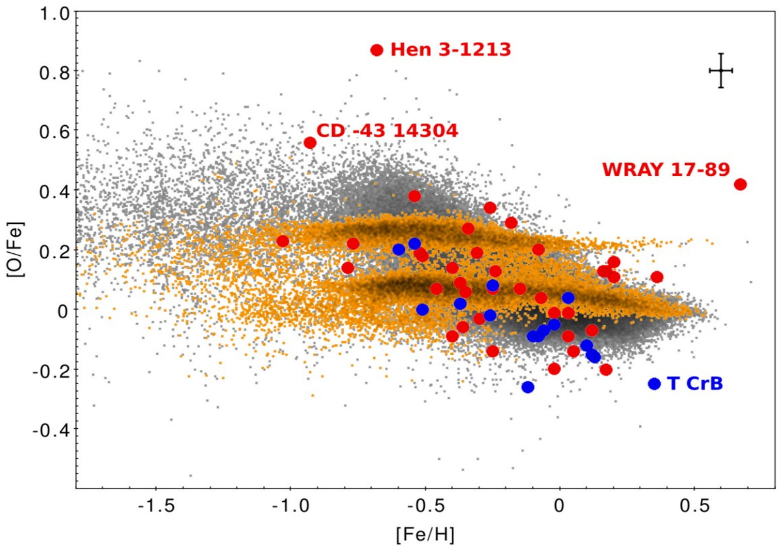
ABSTRACT

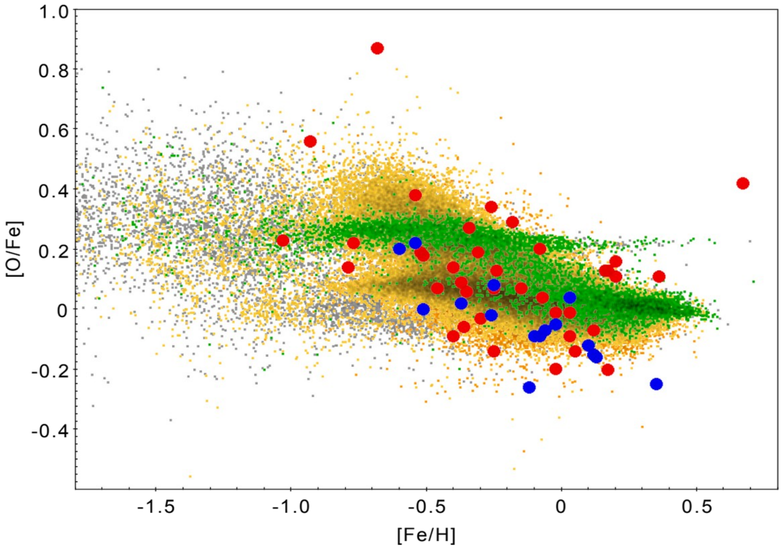
In previous works, we computed abundances for the red giant in nearly four dozen S-type symbiotic systems (SySt). The abundances provide information about metallicity, evolutionary status, and possible memberships in Galactic stellar populations. Here, we extend our studies with a northern hemisphere sample of SySt. This northern sample is dominated by Galactic disc/halo objects, whereas our previous southern sample is heavily biased toward the bulge population. Spectrum synthesis of high-resolution (R ∼ 50 000), near-*IR* spectra using standard LTE analysis and atmospheric models have been used to measure abundances of CNO and elements around the iron peak (Fe, Ti, Ni, and Sc) in the atmospheres of the red giant component. The SySt sample shows generally slightly sub-solar metallicity, as expected for an older disc population, with a median at [Fe/H] ~ -0.2 dex. Enhanced ^{14}N, depleted ^{12}C, and decreased ^{12}C/^{13}C, indicate that all these giants have experienced the first dredge-up. Comparison with theoretical predictions indicates that additional mixing processes had to occur to explain the observed C and N abundances. Relative O and Fe abundances agree with those represented by Galactic disc and bulge giant populations in the *APOGEE* data, with a few cases that can be attributed to membership in the extended thick-disc/halo. As an interesting byproduct of this study, we observed a blue-shifted additional component on the wings of absorption lines in the spectra of AG Peg, which could be connected with accretion on to the hot component.

Key words: stars: abundances – stars: atmospheres – binaries: symbiotic – stars: evolution – stars: late-type.

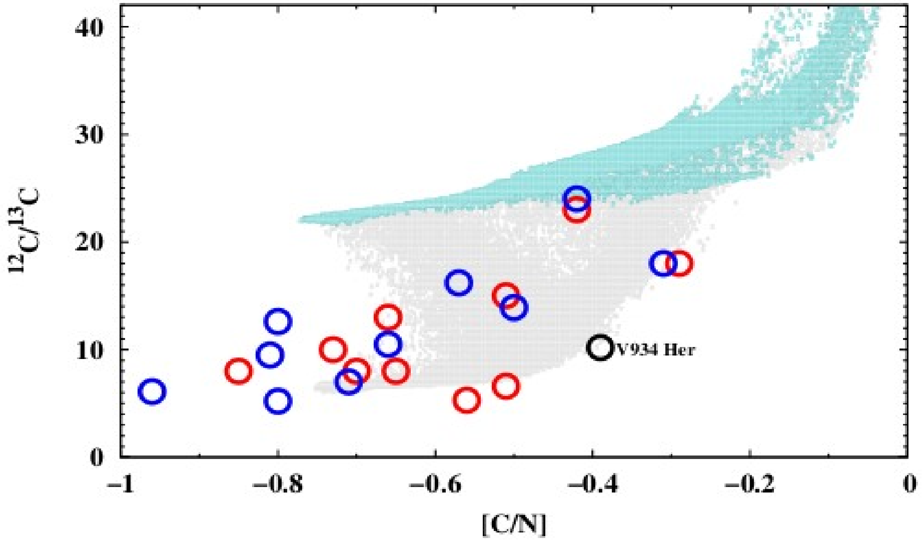
Chemical abundances of 14 northern symbiotic giants

Oxygen and Iron abundances (comparison with the *APOGEE* data).





Additional mixing processes - thermohaline instability (Charbonnel & Zahn, 2007, A&A, 467, 15).



HRS monitoring of symbiotic stars with yellow giants and active systems during outbursts

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[1] *Nicolaus Copernicus Astronomical Center, Polish Academy of Sciences, Bartycka 18, 00-716 Warsaw, Poland;*
[2] *Kleinkaroo Observatory, Calitzdorp, Western Cape, South Africa.*

PROGRAM: The long-term program **2019-1-MLT-008** – the continuation of **2018-2-SCI-021** – was launched in 2019 to monitor the yellow symbiotic systems (SySt). The sample consists of 21 objects (**Table 1**). For the majority of them, there don't exist spectroscopic orbits with two only exceptions: **BD-21°3873** (Smith et al. 1977[1]) and **CD-43°14304** (Schmid et al. 1998[2]). The parameters of these systems may need to be revised as we found in our study of chemical composition in the S-type SySt (Gałan et al. 2017[3]). Reported previously relatively high abundances of titanium as well as enhanced s-process elements and low [M/H] could result from the adoption of too high T_{eff} of giant components. The use of high-resolution spectra is essential to address these issues.

AIMS: Our project has twofold, main objectives. (***I***) First is an analysis of chemical composition preferably from the spectra obtained when the contribution from the hot component is not very significant (phases of low activity/occultations). We would like to derive system parameters and investigate the evolutionary status and mass transfer. We are particularly interested in the region above 5700 Å up to ~8000 Å where are placed spectral features from red giants.
(***II***) The long-term monitoring to measure the radial velocities (RV) preferably through complete orbital cycles would enable us to derive and analyze spectroscopic orbits.
(***III***) We incorporated also into our sample several SySt in, and around active phases and outbursts. Particularly two objects – **St 2-22**, and **V618 Sgr** – that are experiencing currently long-lasting outbursts are observed at the highest possible frequency.

OBSERVATIONS: We use the HRS spectrograph in the Medium–Resolution mode (R~40000). Spectroscopic monitoring has been continued for ~4.5 years so far. The known orbital periods for these systems are typically in the range of ~2/3 up to ~4 years and above 6 years in one case of Hen 3-1591. Thus continuing this project we should be able to cover with observation most of the orbital cycles for most of our targets.
Simultaneous *V* and *I*C-band light curves which we explore to study photometric changes come from the long-term systematic monitoring carried out in *V* and *I*C band filters by Berto Monard at Kleinkaroo Observatory in South Africa (35 cm Meade RCX400 telescope) for almost three decades.

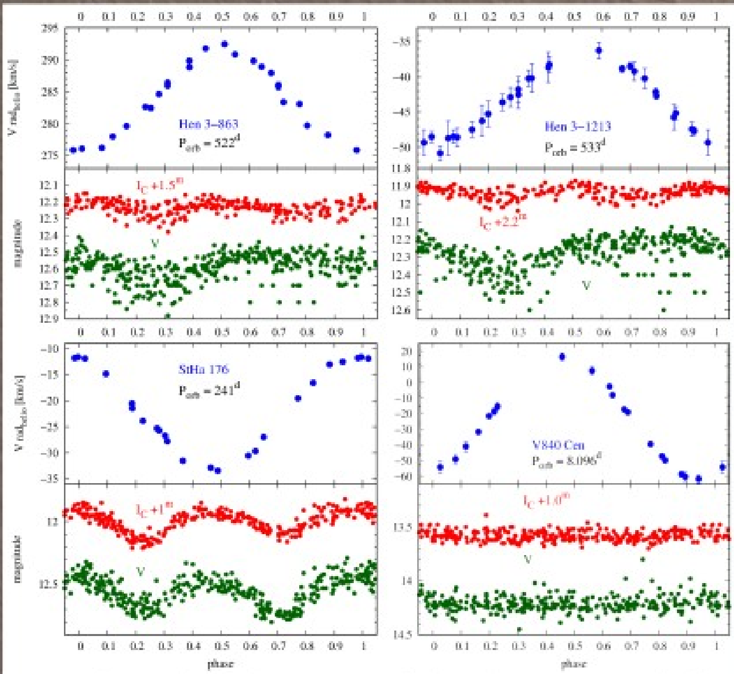


Fig. 1. The sample of the RV curves of giants in SySt compared with photometry (taken at Kleinkaroo Observatory), folded with orbital periods.

Table 1. The list of monitored yellow SySt with addition of two systems in active state (St 2-22 and symbiotic nova V618 Sco).

Id No[a]	Name	JD_{1st}	$JD_{last-1st}$	$N_{obs.}$	P_{orb} [d]	$(JD_{last-1st})/P_{orb}$
-	StHa 63	2458446	1618	13	-	-
25	WRAY 15-157	2458446	1643	13	-	-
28	AS 201	2458439	1602	16	-	-
32	SS73 29	2458473	1607	16	-	-
40	Hen 3-863	2458487	1605	24	522[b]	3.07
41	St 2-22	2458530	1544	20	918	1.68
43	V840 Cen	2458494	1597	18	8.096[b]	2.02
50	V417 Cen	2458497	1591	23	1652	0.95
51	BD-21 3873	2458505	1560	27	281.6	5.54
55	HD 330036	2458517	1522	22	1678	0.91
65	Hen 3-1213	2458559	1525	29	533[b]	2.97
112	AS 255	2459009	1082	8	-	-
116	AS 269	2458664	1352	9	-	-
-	PN G001.7-03.6	2458617	1408	5	-	-
122	Hen 3-1591	2458602	1420	9	2350	0.60
s22	V618 Sgr	2458544	1546	20	-	-
126	PN Ap 1-9	2458574	1506	7	-	-
s25	Hen 2-379	2458559	1454	10	-	-
-	SS383	2458576	1498	17	385[b]	3.89
153	MWC 960	2458577	1514	14	-	-
-	StHa 176	2458581	1458	24	241[b]	6.02
182	CD-43 14304	2458442	1604	21	1448	1.11
184	StHa 190	2458617	1255	15	-	-

[a] Id. Number (Belczyński et al. 2000[4]); [b] Provisional values of P_{orb}.

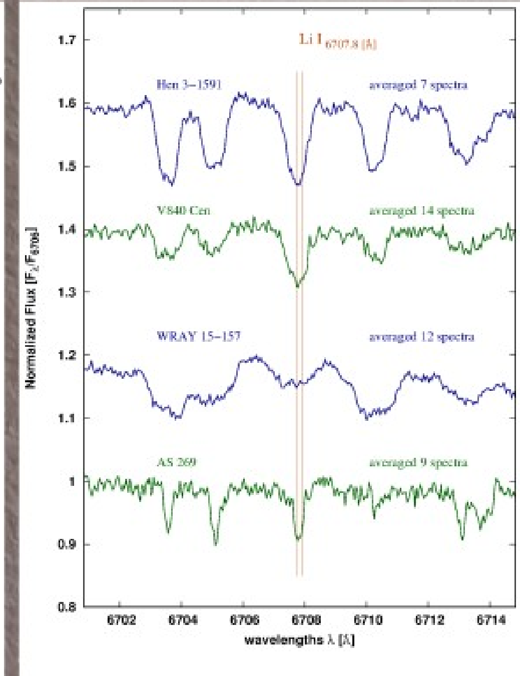
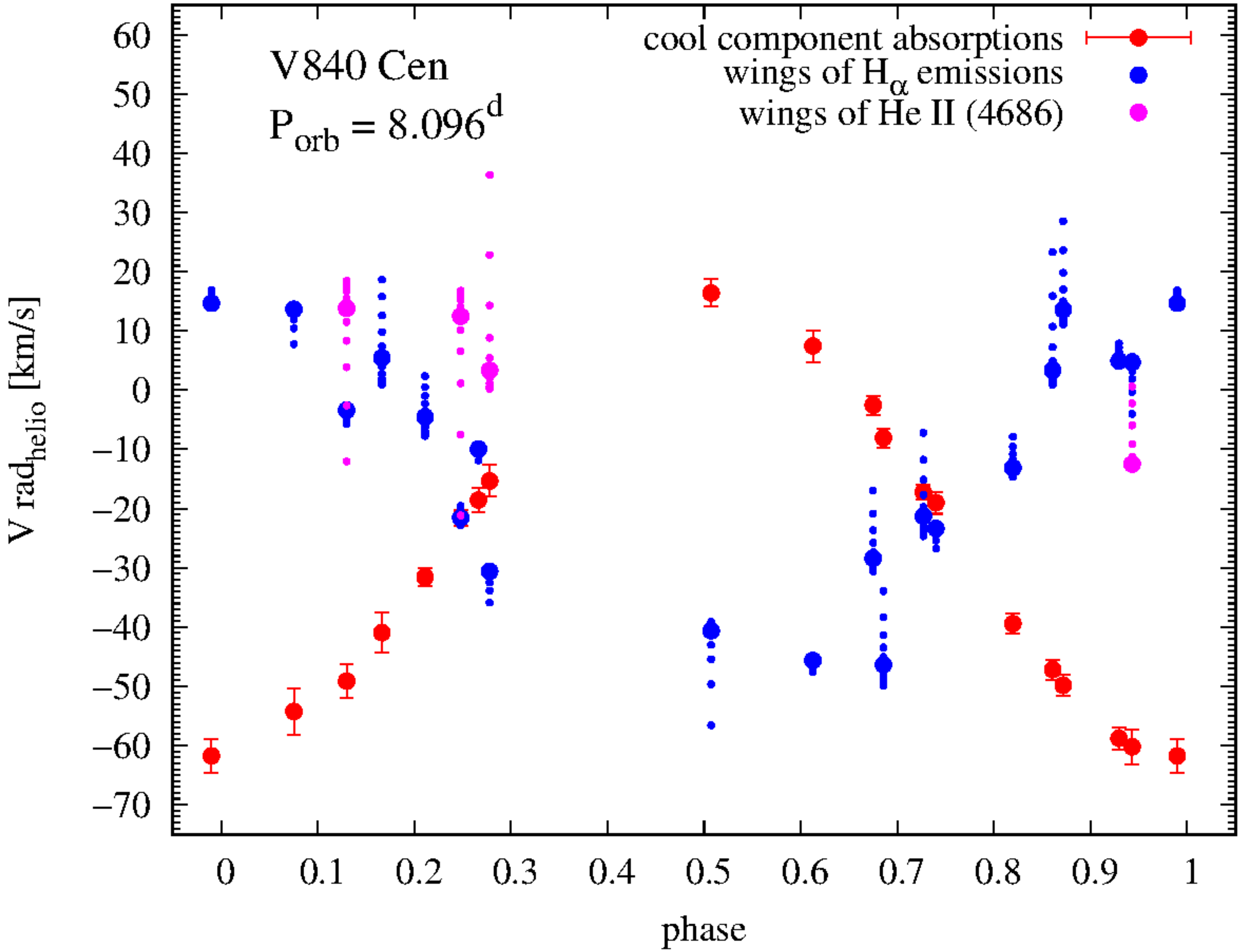
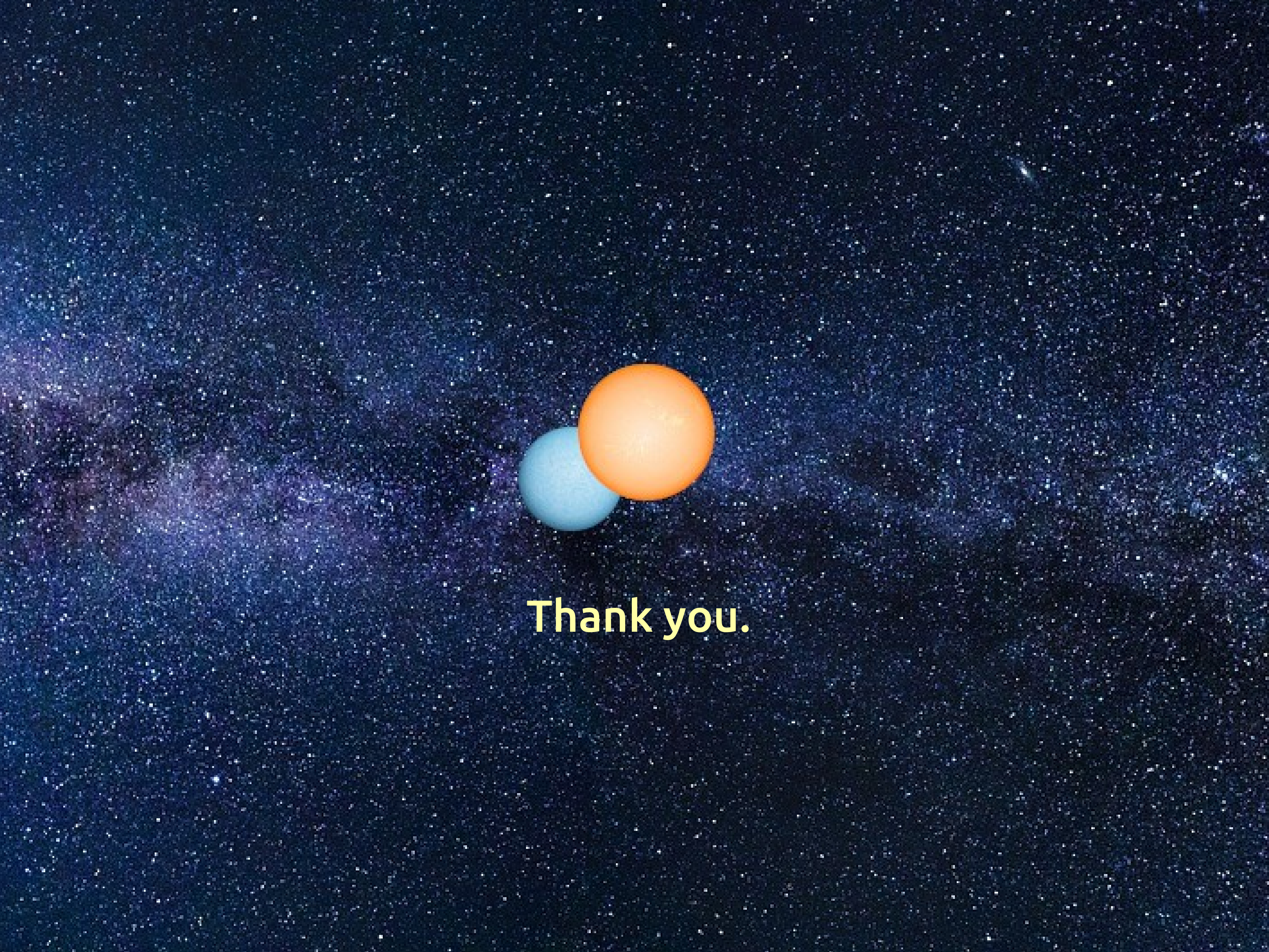


Fig. 2. Lithium line 6707.8 Å detected in the spectra of **Hen 3-1591**, **V840 Cen**, **WRAY 15-157**, and **AS 269**.

RESULTS: So far we have covered with roughly evenly spaced spectra significant parts of orbital phases. For the majority of the sample, we have most of the orbit observed – for 8

V840 Cen (P_{orb} ~ 8.1 days)




Thank you.

Chemical properties of the stripped giants in XRB systems

„Chemical properties of the stripped giants in XRB systems. GX 339-4 and GRS 1915+105”,
Gałan, C.; Zdziarski, A.; Mikołajewska, J., in preparation

X-shooter/VLT, near-IR spectra (R ~ 5000 – 8000) from the ESO archives.

Telluric features removed with MOLECFIT package (Smette et al., 2015; Kauch et al., 2015).

In the GX 339-4 spectrum detected >60 absorption lines from Fe I, K I, Mg I, Si I, Ti I, Mn I, and Al I.

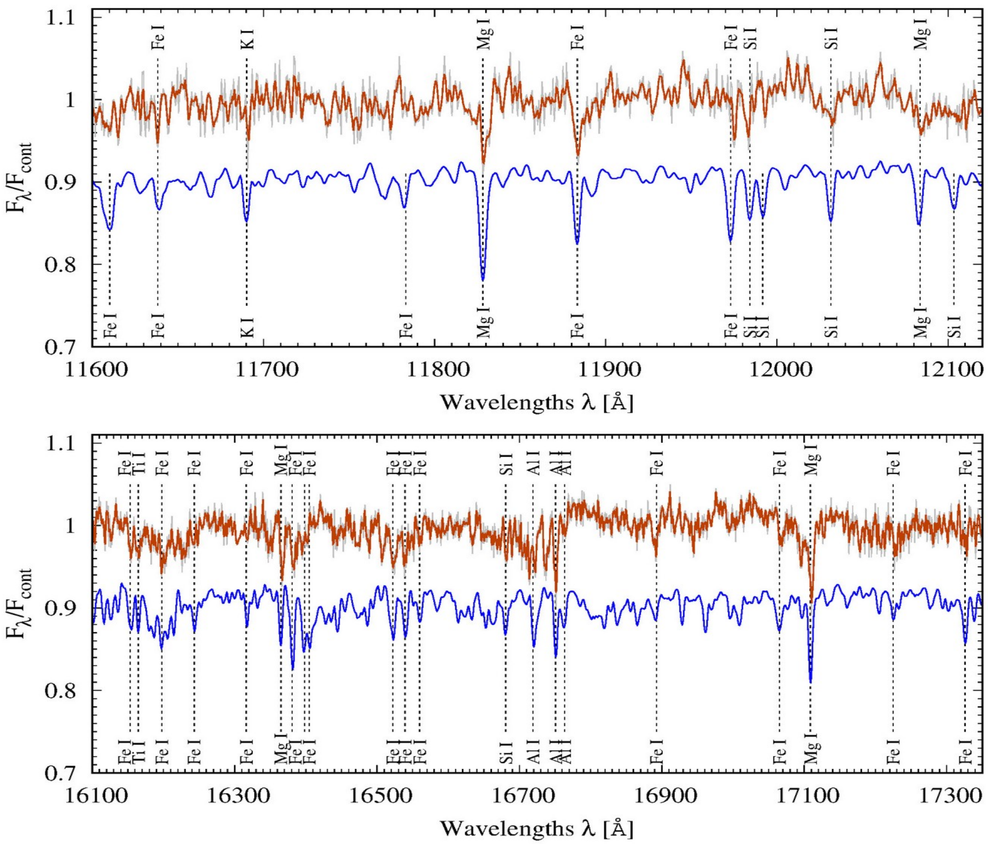


Table 1: Lines identified in the spectrum of K2III star (HD 175545) which can be simultaneously identified in the spectrum of GX 339-4. With bold are highlighted those ones that were yet reported by Heida et al. (2016).

Line	Wavelength [Å]	Line	Wavelength [Å]	Line	Wavelength [Å]
Fe I	11638.25	Fe I	15294.56	Fe I	16197.62
K I	11690.24	Ti I	15334.84	Fe I	16243.07
Mg I	**11828.17**	Fe I	15376.93	Fe I	16316.33
Fe I	**11883.39**	Fe I	15395.72	Ti I	16364.28
Fe I	11973.05	Fe I	15423.42	Mg I	16364.75
Si I	11984.24	Fe I	15499.40	Mg I	16364.85
Si I	12031.55	Fe I	15591.50	Fe I	16380.86
Mg I	12083.61	Fe I	15692.75	Fe I	16398.17
K I	12432.23	Mg I	15740.69	Fe I	16404.60
K I	12522.09	Mg I	15748.97	Fe I	16522.08
Fe I	12638.76	Mg I	15765.81	Fe I	16539.20
Paβ	12818.07	Fe I	15818.14	Fe I	16559.68
Mn I	12899.69	Fe I	15835.16	Si I	16680.76
Mn I	12975.87	Si I	15888.39	Al I	16718.95
Al I	**13123.40**	Fe I	15911.30	Al I	16750.57
Al I	**13150.75**	Si I	15960.07	Al I	16763.35
Si I	13176.83	Cu I (?)	16006.60	Fe I	16892.37
Mg I	14877.53	Fe I	16006.76	Fe I	17065.26
Mg I	15025.00	Fe I	16040.66	**Mg I**	**17108.63**
Mg I	15040.25	Fe I	16153.25	Fe I	17224.89
Mg I	15047.71	Ti I	16164.60	Fe I	17325.91