Chemical abundances and kinematics of symbiotic giants in S-type systems

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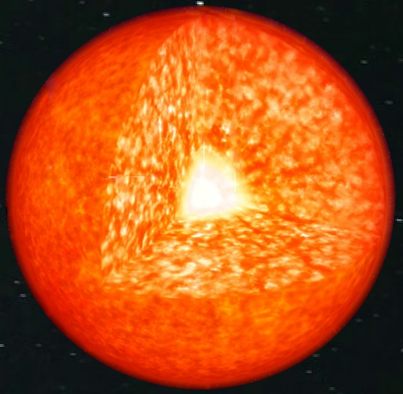
What can we know from measured abundances?

Galactic populations

Metallicity ([Fe/H] is its proxy):

- impact on the mass outflow rate;
- effect on the s-process efficiency in AGB stars;
- is linked with the age of parent population.

Processes in stars interiors



Binary systems

Origin from stellar populations:

- **α-elements** (**O**, Ne, Mg, Si, S, Ar, Ca, **Ti**): produced by massive stars and SNe II, over short time-scales;
- **iron (Fe):** produced by SNe Ia over much longer time-scales.

C, N, O abundances – evolutionary status:

- $^{12}C/^{13}C$ and $^{12}C/^{14}N$ – the 1-st dredge-up indicator;
- $^{12}C/^{13}C$ – informations on the interior mixing;
- $^{16}O/^{17}O$ – the initial masses of giants;
- $^{16}O/^{18}O$ – the initial oxygen abundances.

Chemical abundances of symbiotic giants from high-resolution spectra for >50 SySt

Gemini-South (8m)

southern objects

SPECTROGPAPHS

PHOENIX: ~1.56, 2.23, 2.36 μm; R ~50k, 70k
IGRINS: ~1.5 - 1.7, 20.8 - 24.0 μm; R ~45k
S/N > 100

KPNO Mayall (4m)

northern objects

Analyses are now completed for 52 objects:

24 southern SySt (PHOENIX, *H*- and *K*-band) Gałan, C., et al.., 2016, MNRAS, 455, 1282
13 southern SySt (PHOENIX, *H*-band) Gałan, C., et al., 2017, MNRAS, 466, 2194
14 northern SySt (PHOENIX, *H*- and *K*-band) Gałan, C., et al., 2023, MNRAS, 526, 918
V934 Her (IGRINS) Hinkle K. H., et al., 2019, ApJ, 782, 43

Methods and analysis

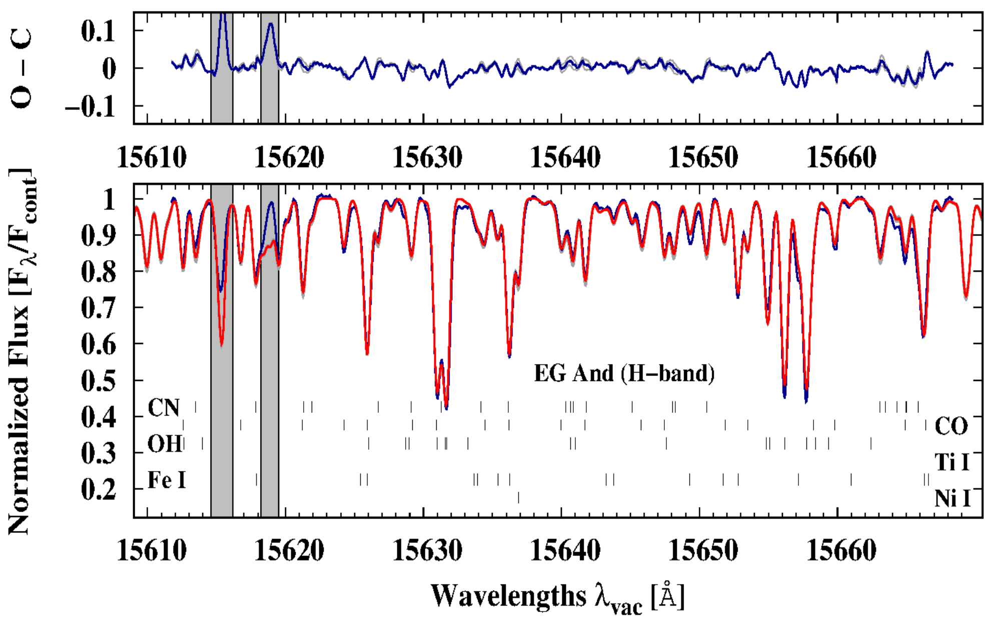
SPECTRUM SYNTHESIS:

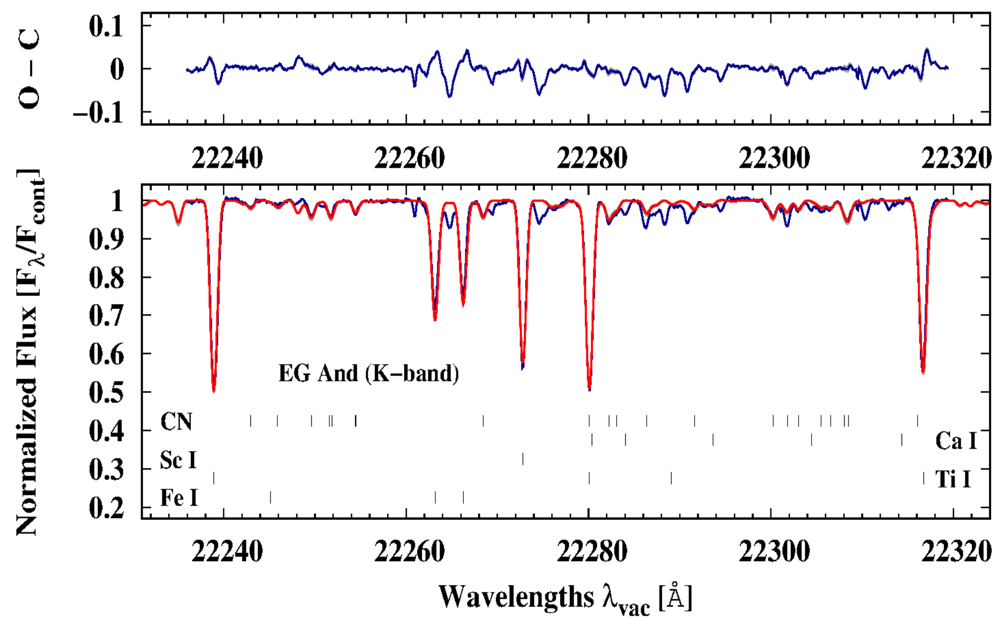
Standard LTE analysis,
hydrostatic *MARCS* models atmospheres (Gustafsson et al. 2008).

Spectral synthesis codes: *WIDMO* (Schmidt et al. 2006),
Turbospectrum (Plez 2012).

Semi–automatic X^2 minimization: *Simplex* algorithm (Brandt 1998).

Measured abundances: C, N, O, Sc, Ti, Fe, Ni & $^{12}C/^{13}C$.





Derived abundances

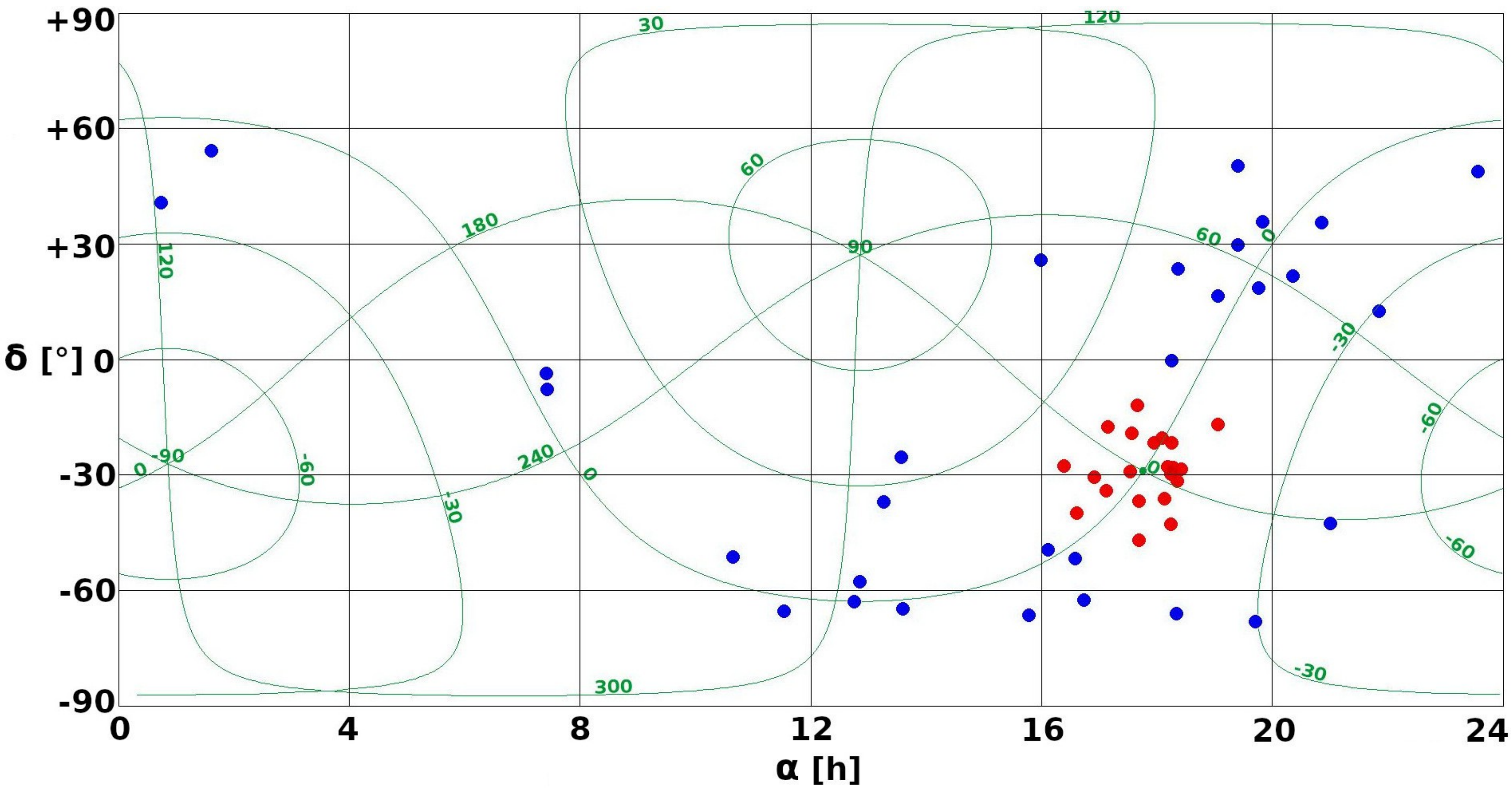
Abundances derived on the scale of log (X) = log (N(X)N(H)−1) + 12.0, relative to the Solar abundances, and ^{12}C/^{13}C.

Northern sample.

	C log ϵ(X) [X][c]	N	O	Sc[b]	Ti	Fe	Ni	^{12}C/^{13}C
EG And	7.70 ± 0.03	7.81 ± 0.04	8.37 ± 0.01	3.34 ± 0.05	4.80 ± 0.04	6.93 ± 0.01	5.90 ± 0.07	7.0 ± 0.3
	−0.73 ± 0.08	−0.02 ± 0.09	−0.32 ± 0.06	+0.18 ± 0.09	−0.13 ± 0.08	−0.54 ± 0.05	−0.30 ± 0.11	
AX Per	7.84 ± 0.01	8.05 ± 0.03	8.41 ± 0.02	3.87 ± 0.07	5.04 ± 0.06	7.21 ± 0.06	6.26 ± 0.06	9.5 ± 0.3
	−0.59 ± 0.06	+0.22 ± 0.08	−0.28 ± 0.07	+0.71 ± 0.11	+0.11 ± 0.10	−0.26 ± 0.10	+0.06 ± 0.10	
T CrB	8.40 ± 0.02	8.65 ± 0.04	8.79 ± 0.01	...	5.12 ± 0.09	7.82 ± 0.04	6.57 ± 0.06	...
	−0.03 ± 0.07	+0.82 ± 0.09	+0.10 ± 0.06	...	+0.19 ± 0.13	+0.35 ± 0.08	+0.37 ± 0.10	
FG Ser	8.08 ± 0.01	7.83 ± 0.03	8.52 ± 0.01	...	4.79 ± 0.06	7.39 ± 0.02	6.23 ± 0.05	...
	−0.35 ± 0.06	0.00 ± 0.08	−0.17 ± 0.06	...	−0.14 ± 0.10	−0.08 ± 0.06	+0.03 ± 0.09	
V443 Her	8.18 ± 0.02	8.07 ± 0.03	8.62 ± 0.01	...	4.97 ± 0.10	7.45 ± 0.04	6.29 ± 0.05	...
	−0.25 ± 0.07	+0.24 ± 0.08	−0.07 ± 0.06	...	+0.04 ± 0.14	−0.02 ± 0.08	+0.09 ± 0.09	
V1413 Aql	8.10 ± 0.05	7.74 ± 0.10	8.31 ± 0.03	...	4.45 ± 0.14	7.35 ± 0.07	6.35 ± 0.12	...
	−0.33 ± 0.10	−0.09 ± 0.15	−0.38 ± 0.08	...	−0.48 ± 0.18	−0.12 ± 0.11	+0.15 ± 0.16	
BF Cyg	7.87 ± 0.03	8.23 ± 0.08	8.52 ± 0.01	3.89 ± 0.15	4.89 ± 0.10	7.22 ± 0.03	6.02 ± 0.06	6.1 ± 0.5
	−0.56 ± 0.08	+0.40 ± 0.13	−0.17 ± 0.06	+0.73 ± 0.19	−0.04 ± 0.14	−0.25 ± 0.07	−0.18 ± 0.10	
CH Cyg	8.26 ± 0.01	8.20 ± 0.02	8.66 ± 0.01	...	5.06 ± 0.08	7.60 ± 0.05	6.39 ± 0.07	...
	−0.17 ± 0.06	+0.37 ± 0.07	−0.03 ± 0.06	...	+0.13 ± 0.12	+0.13 ± 0.09	+0.19 ± 0.11	
QW Sge	8.30 ± 0.03	8.20 ± 0.07	8.67 ± 0.02	4.25 ± 0.12	5.28 ± 0.09	7.57 ± 0.10	6.54 ± 0.10	13.9 ± 0.8
	−0.13 ± 0.08	+0.37 ± 0.12	−0.02 ± 0.07	+1.09 ± 0.16	+0.35 ± 0.13	+0.10 ± 0.14	+0.34 ± 0.14	
CI Cyg	7.97 ± 0.04	8.17 ± 0.07	8.50 ± 0.02	4.52 ± 0.14	5.25 ± 0.06	7.37 ± 0.03	6.17 ± 0.10	12.6 ± 1.1
	−0.46 ± 0.09	+0.34 ± 0.12	−0.19 ± 0.07	+1.36 ± 0.18	+0.32 ± 0.10	−0.10 ± 0.07	−0.03 ± 0.14	
PU Vul	8.00 ± 0.02	7.97 ± 0.03	8.34 ± 0.01	3.37 ± 0.09	4.35 ± 0.06	7.10 ± 0.02	5.90 ± 0.09	16.2 ± 0.8
	−0.43 ± 0.07	+0.14 ± 0.08	−0.35 ± 0.06	+0.21 ± 0.13	−0.58 ± 0.10	−0.37 ± 0.06	−0.30 ± 0.13	
V1329 Cyg	8.45 ± 0.03	8.27 ± 0.07	8.66 ± 0.02	4.36 ± 0.08	5.09 ± 0.06	7.59 ± 0.05	6.35 ± 0.06	24.0 ± 1.5
	+0.02 ± 0.08	+0.44 ± 0.12	−0.03 ± 0.07	+1.20 ± 0.12	+0.16 ± 0.10	+0.12 ± 0.09	+0.15 ± 0.10	
AG Peg	7.62 ± 0.03	7.82 ± 0.06	8.18 ± 0.02	3.60 ± 0.04	4.61 ± 0.05	6.96 ± 0.02	5.81 ± 0.03	5.2 ± 0.1
	−0.81 ± 0.08	−0.01 ± 0.11	−0.51 ± 0.07	+0.44 ± 0.08	−0.32 ± 0.09	−0.51 ± 0.06	−0.39 ± 0.07	
Z And	8.11 ± 0.03	8.17 ± 0.06	8.56 ± 0.02	4.13 ± 0.12	5.01 ± 0.11	7.41 ± 0.04	6.33 ± 0.11	10.5 ± 0.9
	−0.32 ± 0.08	+0.34 ± 0.11	−0.13 ± 0.07	+0.97 ± 0.16	+0.08 ± 0.15	−0.06 ± 0.08	+0.13 ± 0.15	
Sun	8.43 ± 0.05	7.83 ± 0.05	8.69 ± 0.05	3.16 ± 0.04	4.93 ± 0.04	7.47 ± 0.04	6.20 ± 0.04	

Position in the equatorial and the Galactic coordinate systems

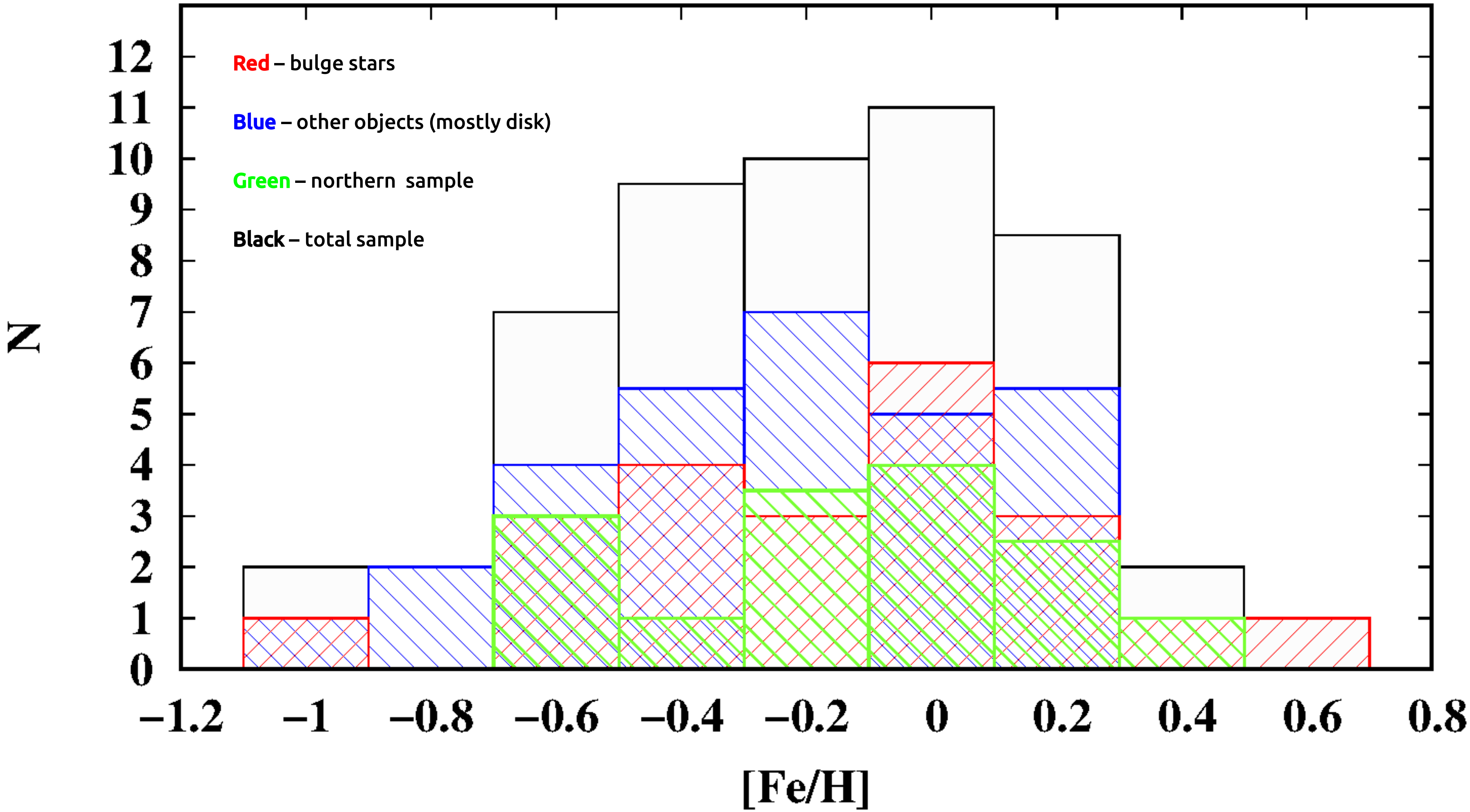
Black-grid – the Equatorial coordinate system.
Green-lines – the Galactic coordinate systems.



Southern sample dominated by objects concentrated around the Galactic center.
Northern sample dominated by the Galactic disc.

Metallicity

Median of [Fe/H] distribution at ~-0.2 dex (consistent with a disk populations)

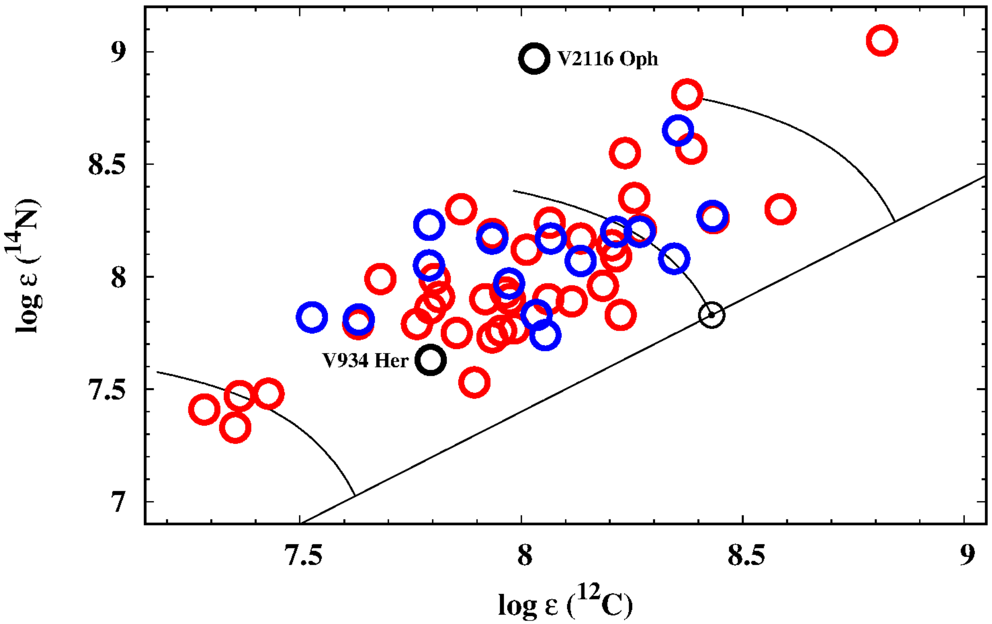


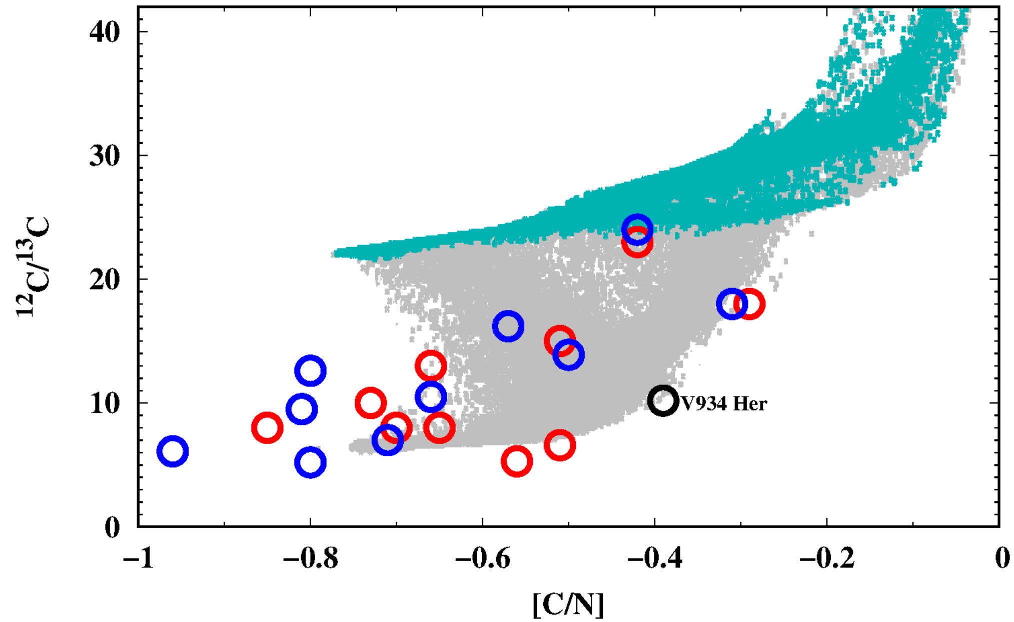
Carbon and Nitrogen abundances.

Evolutionary status, mixing and interactions

Evidences of the 1-st dredge-up in the SySt red giants.

Increase in ^{14}N, depletion of ^{12}C, and decreased $^{12}C/^{13}C$.



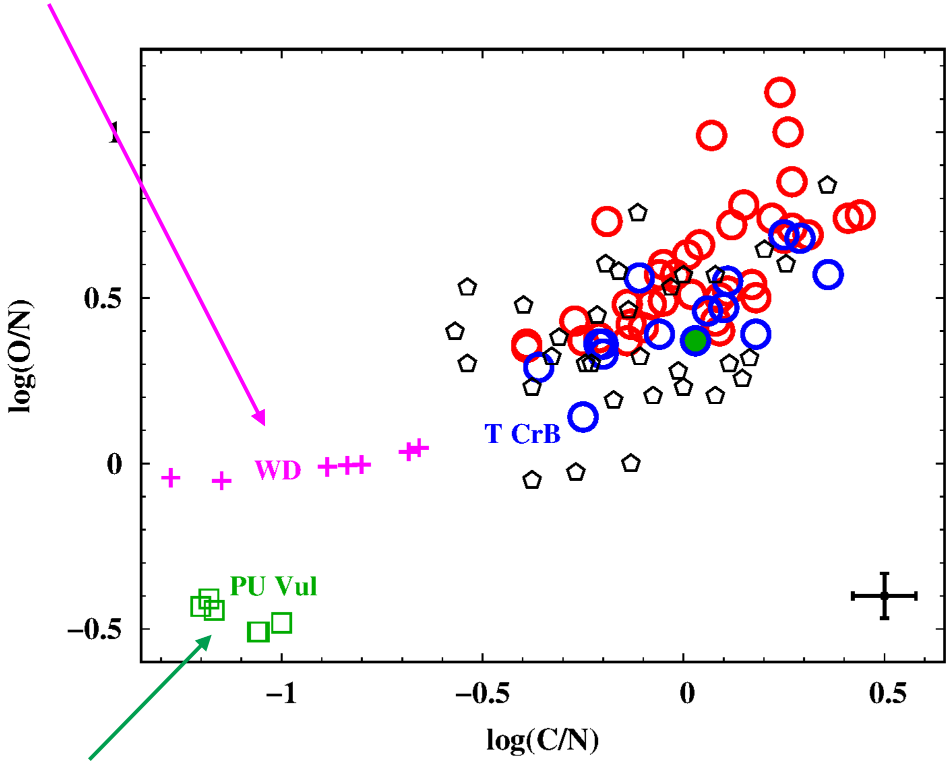


- $^{12}C/^{13}C$ too low (Lü et al. 2008) – mixing from the 1-st dredge-up is insufficient,
- thermohaline mixing (eg. Charbonnel & Zahn 2007) is a likely possibility,
- it seems that binary interaction has not significantly affected the evolution of symbiotic giants.

O/N, C/N, and C/O
in symbiotic giants and symbiotic nebulae

'Photospheric' O/N and C/N ratios in symbiotic gaints (*coloured circles*) compared with those in symbiotic nebulae (*pentagons*: Nussbaumer et al. 1988, Schmid & Schild 1990, Pereira 1995, Schmidt et al. 2006).

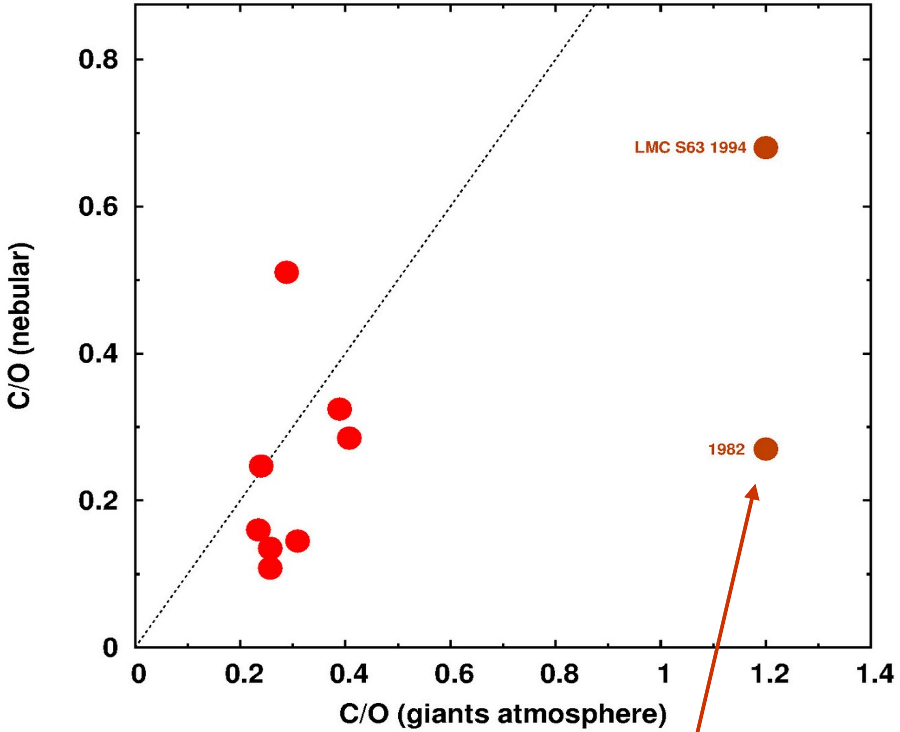
Theoretical values for ejecta from 0.65 $M_\odot$ white dwarf during nova ouburst (*magenta croses*) Kovetz & Prialnik (1997)



PU Vul in outburst (Vogel & Nussbaumer 1992)

C/O ratios in symbiotic gaints versus those observed in nebulae around of these SySt.

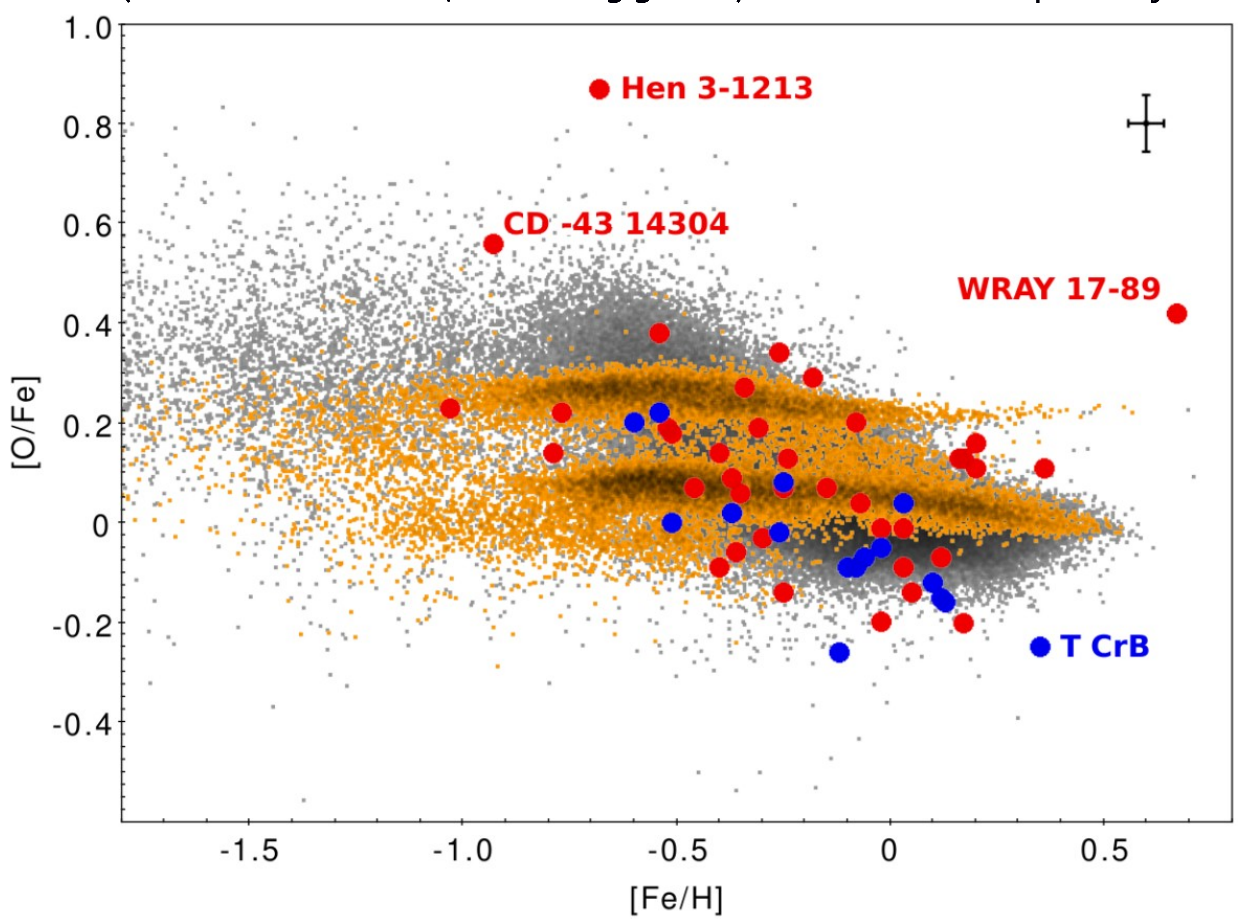
C/O ratio grows continuously after active phase in symbiotic LMC S63.



Iłkiewicz et al. (2015)

α elements
[O/Fe] versus [Fe/H]

APOGEE DR16 release (**grey points**) and the extracted sample of giant stars (**orange points**) corresponding to the atmospheric parameters (3100 ≤Teff ≤ 4100 K, and 0 ≤log g ≤ 1.5) similar to our sample of SySt.



- most giants in Galactic disk,
- a few in the extended thick-disk/halo.

Too high T_{eff} adopted in literature at least for some yellow giants: eg. CD-43°14304

Long-term program on HRS/SALT to monitor the yellow SySt is underway!

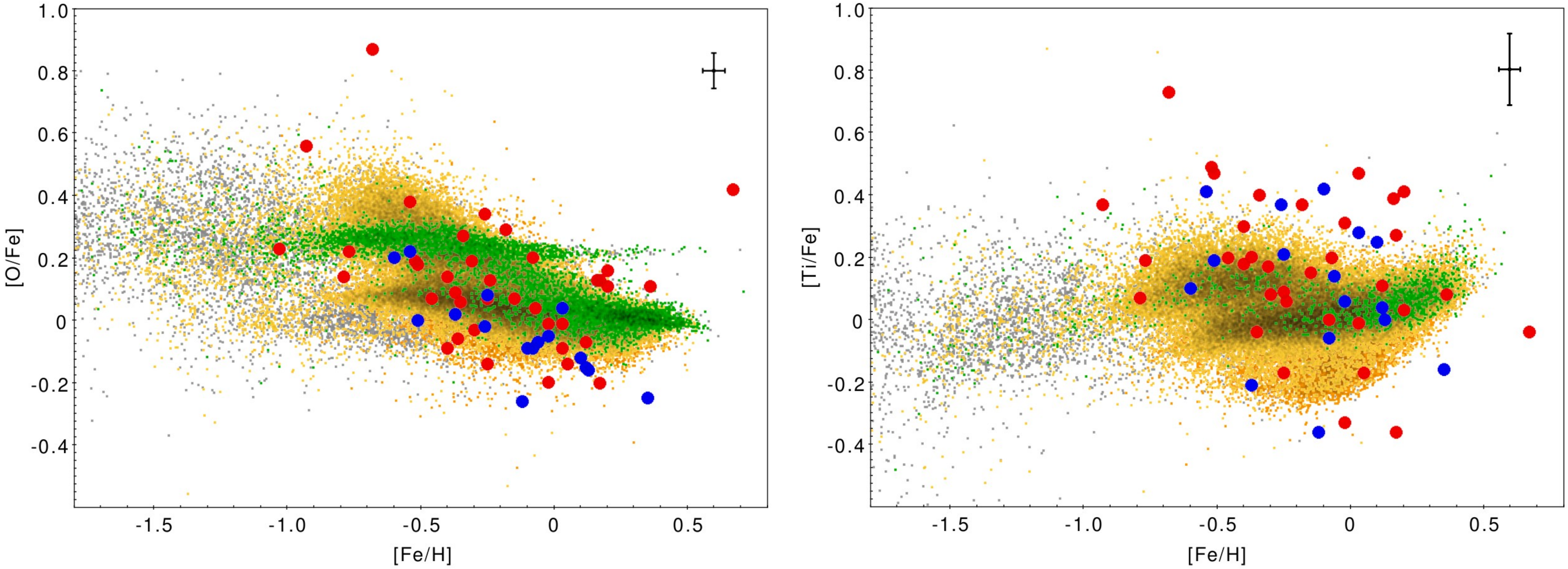
Poster 05

α elements
[O/Fe] & [Ti/Fe] versus [Fe/H]

Relative abundances of [O/Fe] and [Ti/Fe] versus [Fe/H] of our SySts (**northern** and **southern** samples)

compared to stars from various Galactic populations extracted from APOGEE data set for:
thin-disc, **thick-disc**, **halo**, and **bulge** stars

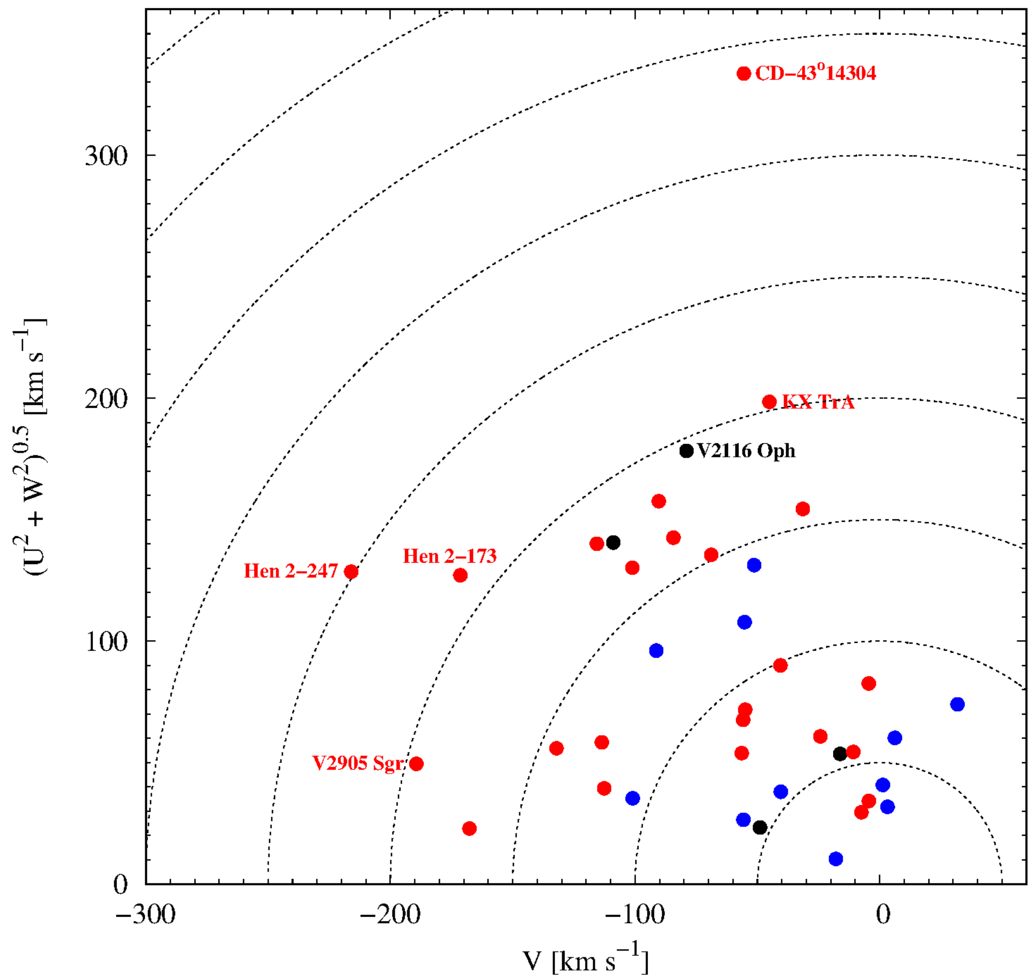
Most of SySt belong to the disc or bulge populations with a few halo candidates.



Kinematics.
Toomre diagram

Northern sample – mainly thin- and rarely thick-disc populations

Southern sample – more concentrated on the Galactic bulge – looks to have representatives in all populations including the Galactic halo



Thin-disc: $V_{tot} \leq 50$ km/s

Thick-disc: $70 \leq V_{tot} \leq 180$ km/s

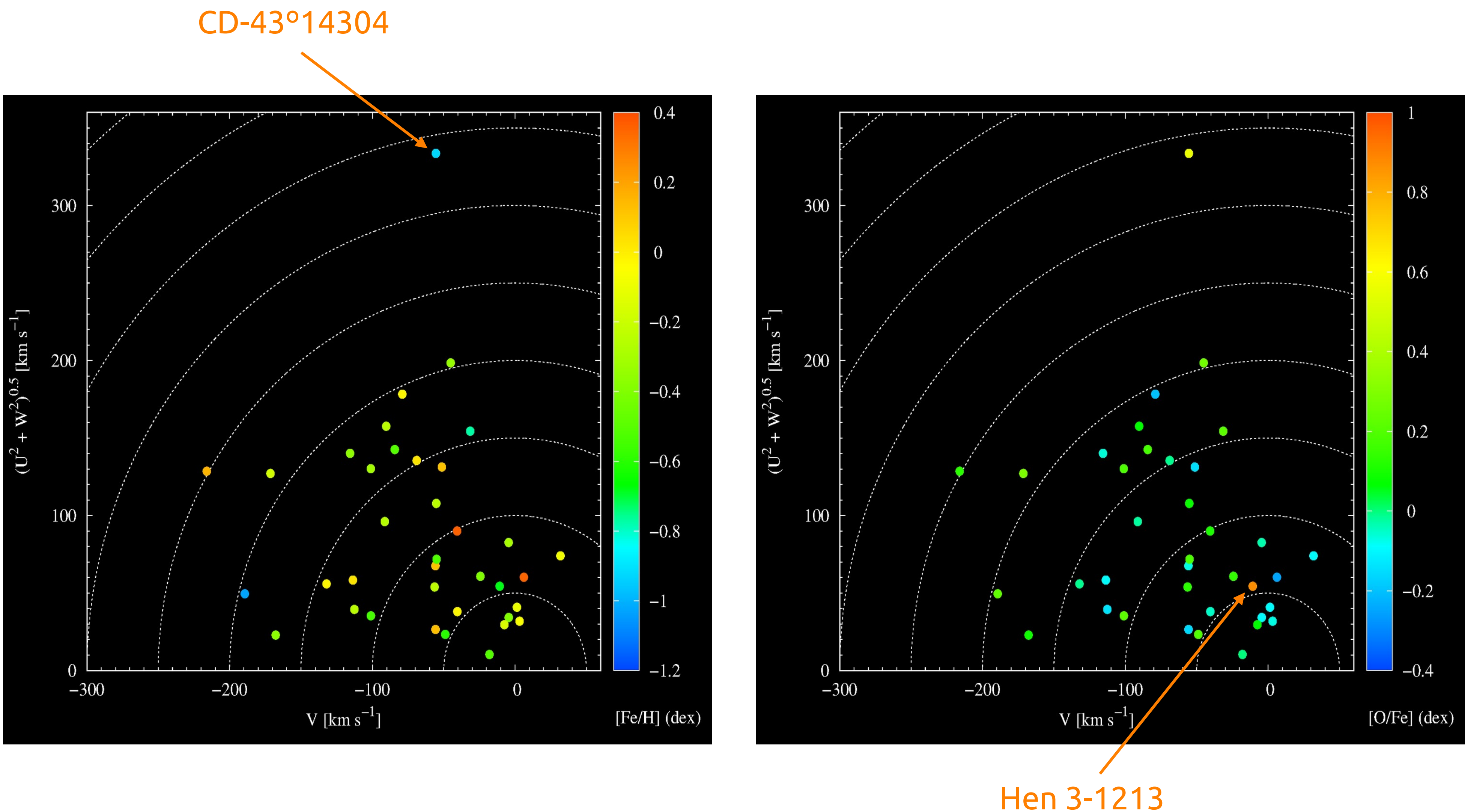
Halo: $V_{tot} > 200$ km/s

$V_{tot} = (U^2 + V^2 + W^2)^{0.5}$

Rough criteria for populations in Toomre diagram after Bensby, Feltzing & Oey (2014)

Kinematics.
Toomre diagram

Color-coded are added information on chemical properties: [Fe/H] (left) and [O/Fe] (right)



Summary

- Generally slightly sub-solar metallicity, with a median at [Fe/H] ~ −0.2 dex.
- Enhanced ^{14}N, depleted ^{12}C, and decreased $^{12}C/^{13}C$ – all these giants have experienced the 1-st dredge-up.
- Comparison with theoretical predictions indicates that additional mixing processes had to occur.
- Relative O and Fe abundances agree with those represented by Galactic disc and bulge giant populations, with a few cases thay can be attributed to membership in the extended thick-disc/halo.


Thank you