Stellar parameters, Chemical composition of stars and Models of chemical evolution

Tamara Mishenina (1),

Marco Pignatari ++++….

1-Astronomical Observatory of Odessa National University

Basel Workshop, September 30, 2016, Swithzerland

photo credit: Jenny Mottar

Aim:

– the abundance differences resulting from consideration of the different sources of enrichment are not significant (up to 0.1 dex, for example), and here the accuracy of observational data comes to the fore and has become an important key factor in the choice of element's origin;

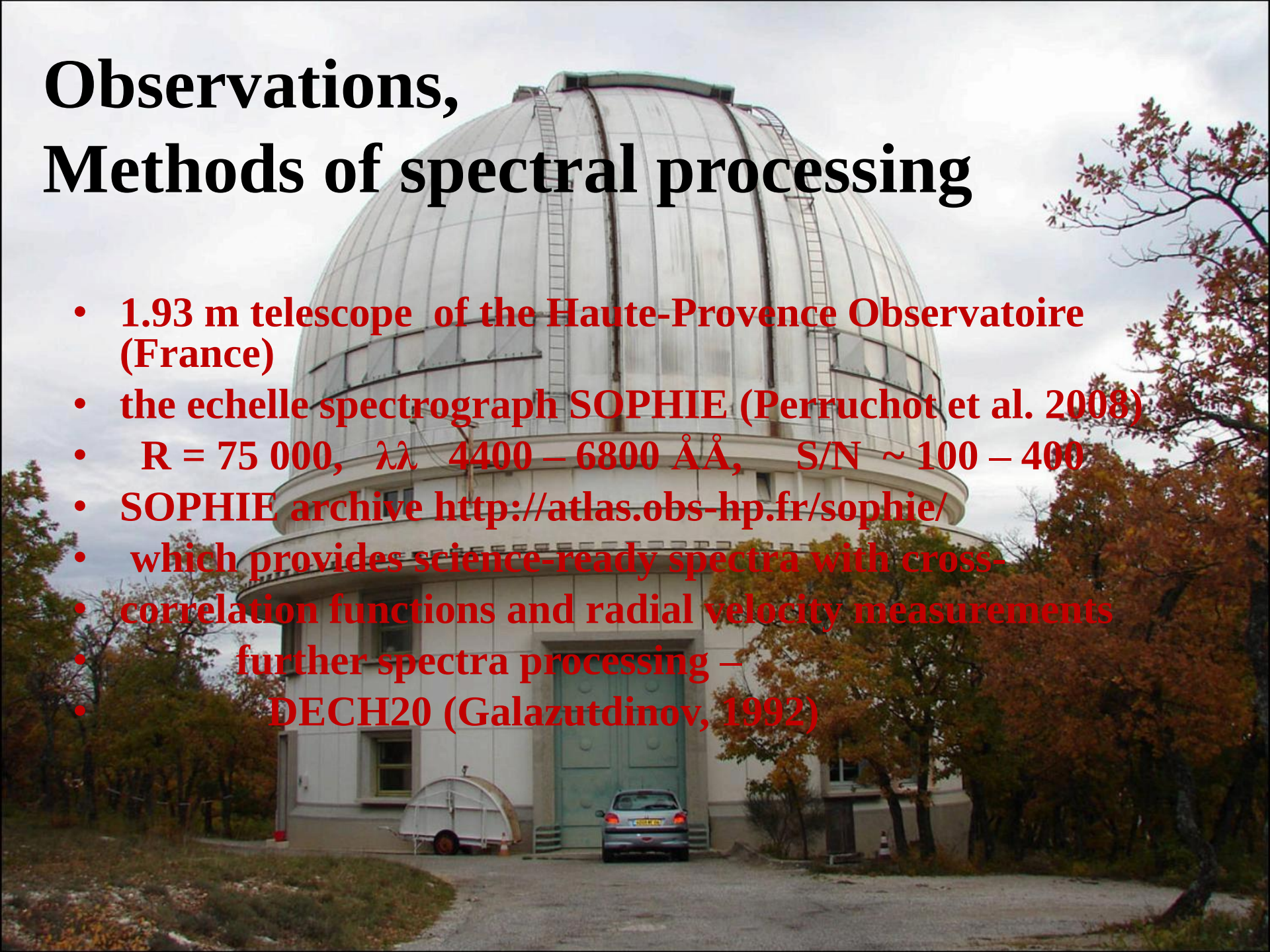
– to provide new observational data to study in the metallicity region from -2.2 to -0.6 dex:

1) that reveal crucial insights about the chemical evolution of the Galaxy:

- [Fe/H] < - 1 : massive stars and super Asymptotic Giant Branch (AGB) stars;
- [Fe/H] > -1: lower mass AGB stars and supernovae type Ia (SNe Ia) affects the chemical enrichment history;

2) with special attention to observational uncertainties because to study the stars with low metal abundances is more complicated.

Observations, Methods of spectral processing



- 1.93 m telescope of the Haute-Provence Observatoire (France)
- the echelle spectrograph SOPHIE (Perruchot et al. 2008)
- R = 75 000, λλ 4400 – 6800 ÅÅ, S/N ~ 100 – 400
- SOPHIE archive http://atlas.obs-hp.fr/sophie/
- which provides science-ready spectra with cross-
- correlation functions and radial velocity measurements
- further spectra processing –
- DECH20 (Galazutdinov, 1992)

Observation data for our target stars

HD	date	S/N	RV, km/s
6582	05.12.2013	418	-96.305
6833	19.09.2006	234	-243.410
19445	17.01.2010	102	-139.936
22879	06.12.2013	207	120.397
84937	09.12.2013	167	-15.015
103095	06.12.2013	259	-97.922
170153	30.08.2011	317	37.781
216143	19.09.2006	153	-116.462
221170	19.09.2006	201	-121.717
224930	16.01.2011	326	-41.105

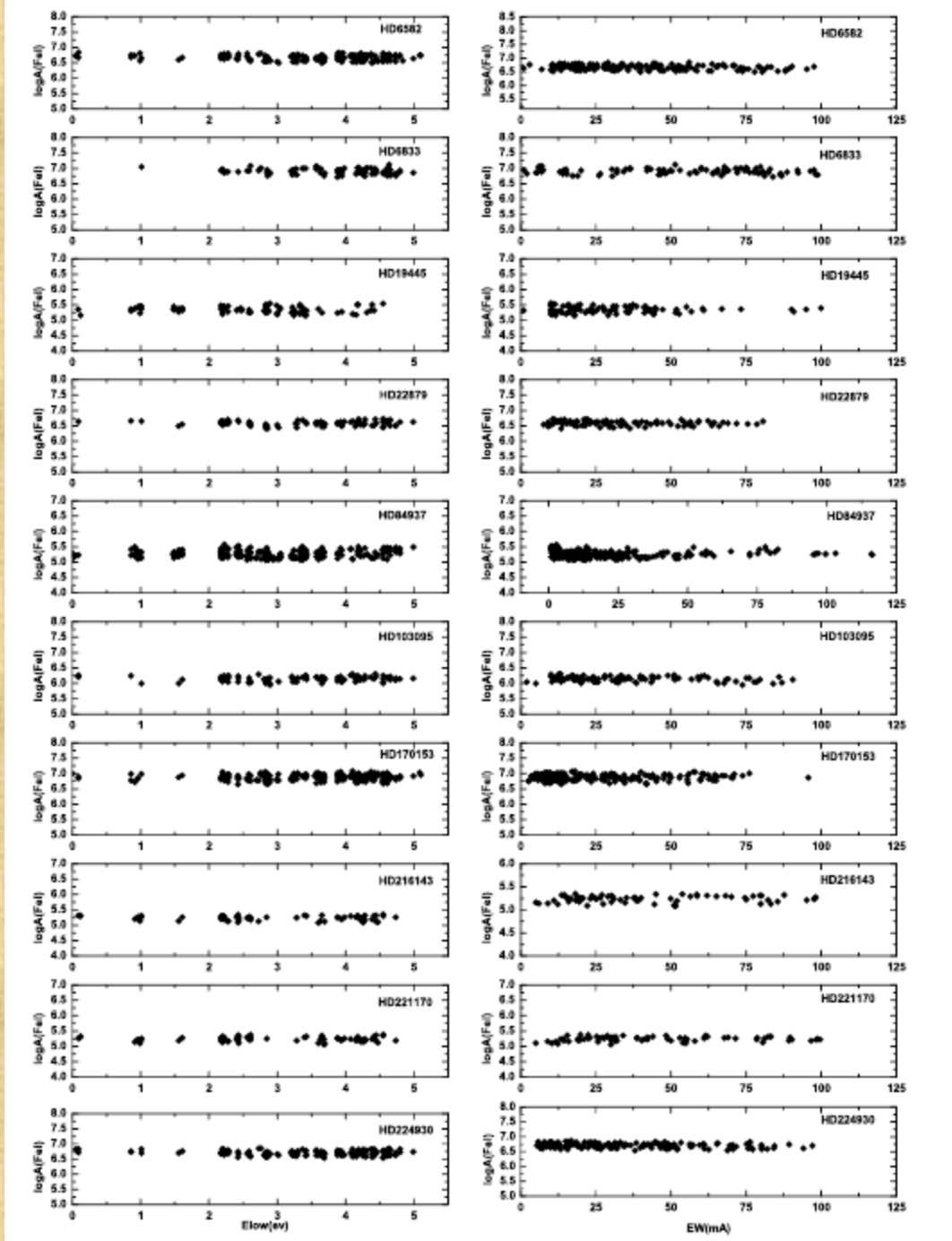
Parameter determination

- $\mathbf{T_{eff}}$: on photometric calibrations and spectroscopic approach;
- the color-Teff calibrations of the B-V and b-y colour indices for dwarfs (Alonso, Arribas & Martinez-Roger 1996) and giants (Alonso, Arribas & Martınez-Roger 1999);
- assuming the absence of any relationship between the elemental abundance estimated by a certain spectral line and the lower excitation potential Elow of the line
- **[Fe/H]** – iron abundance determined from Fe I lines NLTE corrections are from 0.05 to 0.15 dex (Mashonkina et al. 2011, Bergemann et al. 2012, Sitnova et al.2015);
- **log g**: two methods (iron ionisation balance and using parallaxes);
- $\mathbf{V_t}$ **–** independence of log A(Fe) from EW for Fe I lines

Parameter determination

Teff vs. Elow (ev)

Vt vs. EW (mA)



Parameters of studied stars

HIP	HD	V	B-V	b-y	c1	[Fe/H]	Teff spec	Teff (B-V)	Teff (b-y)	log{P}	log{IE}	Vt
5336	6582	5.17	0.7	0.437	0.213	-0.83	5350	5241	5336	4.56	4.50	0.4
				0.441	0.208				5311			
5458	6833	6.74	1.17	0.753	0.487	-0.77	4415	4382	4309	1.79	1.50	1.3
14594	19445	8.06	0.45	0.352	0.208	-2.16	5830	5923	5892	4.45	4.00	1.1
17147	22879	6.69	0.54	0.365	0.272	-0.91	5825	5793	5804	4.29	4.42	0.9
				0.369	0.302				5867			
48152	84937	8.32	0.41	0.293	0.39	-2.24	6325	6084	6429	4.18	3.95	1.4
			0.37	0.302	0.369		6259	6349				
57939	103095	6.45	0.74	0.484	0.155	-1.35	5100	5023	5035	4.88	4.65	0.4
		0.76	0.487	0.151				4966	5017			
			0.475	0.196					5103			

HIP	HD	V	B-V	b-y	c1	[Fe/H]	Teff spec	Teff (B-V)	Teff (b-y)	log{P}	log{IE}	Vt
89937	170153	3.58	0.5			-0.61	6170	6000		4.17	4.25	0.7
			0.479					6083				
112796	216143	7.81		0.69	0.572	-2.26	4455		4471	0.92	1.05	2.0
				0.681	0.558				4491			
			0.97					4357				
115949	221170	7.66	1.08	0.747	0.564	-2.26	4415	4403	4354	1.89	1.05	1.9
			0.985	0.756	0.556			4354	4337			
171	224930	5.75	0.66	0.432	0.218	-0.79	5500	5382	5371	4.44	4.40	0.3
			0.67	0.435	0.225							

- the using of (B-V) , (b-y) colour indexes depends on the reddening!!
- the spectroscopic method for Teff determination depends on the atomic parameters of lines (the oscillator strengths) and applying of assumption of deviations from LTE.

Parameters of our target stars and comparison with Heiter et al. (2015) for 4 common Gaia Benchmark Stars

	Teff, K	σ,±	logg	σ, ±	Teff, K	logg	Δ_Teff, K	Δ logg
	Heiter et al. 2015				*our*			
6582 μ Cas	5308	29	[4.41]	[0.06]	5350	4.50	42	0.09
22879	5868	89	4.27	0.04	5825	4.42	-43	0.15
84937	6356	97	4.06	0.04	6325	3.95	-31	-0.11
103095 (Gmb 1830)	[4827]	[55]	4.60	0.03	5100	4.65	273	0.05

Heiter et al. (2015) preferred the value Teff obtained by the method, based on measuring the diameter of star (it is need ”the further interferometric observations at longer baselines ….”) ; 5168 K (Casagrande et al. 2011) and 5129 K (Gonzarlez Hernarndez & Bonifacio 2009)

Comparison of our parameter determinations with those of other authors:

<Δ Teff>, K	<Δ logg>	<Δ[Fe/H]>	n	references
60 ± 166	0.04 ± 0.11		4	Heiter et al., 2015
-11 ± 46	0.04 ± 0.14		3	Heiter et al., 2015
22 ± 96	-0.05 ± 0.20	-0.09 ±0.08	6	Gratton et al., 2003
29 ±107	0.07 ± 0.15	0.05 ±0.14	9	Fulbright , 2000
-16 ±66	0.00 ±0.14	-0.04 ±0.10	10	(mean values)

ΔT_{eff} = ±100 K; $\Delta \log g$ = ±0.20 dex;
ΔV_t = ±0.1 km/s; Δ [Fe/H]= ±0.10 and
an uncertainty of ±2 mA in the EW
an uncertainty of 0.02 dex in fitting of profiles

Abundance determination

- Kurucz's models (LTE)
- WIDTH9, LTE (Kurucz R.) – Si, Ca, Ni, Fe, Zn, Y, Zr, La, Ce, Pr, Nd, Sm
- STARSP, LTE (new version) (Tsymbal V. , 1996) – Li, S (HFS), Eu (HFS)
- Modified MULTI, NLTE (Carlsson M., Korotin S.) – O, Na, Al, Mg, and Ba
- Differential approach: the spectra of Moon and asteroids obtained with SOPHIE as solar spectrum
- The total uncertainty due to parameter and EW errors for Fe I, Fe II is 0.06, 0.08, respectively
- The determination accuracy of element's abundance varies from 0.05 – 0.11 dex for the hot and more metallicity stars and to 0.06 – 0.18 dex for the cold metal-poor stars,
- for [Fe/H] it is from 0.08 to 0.12 dex, respectively

Abundance determination fitting

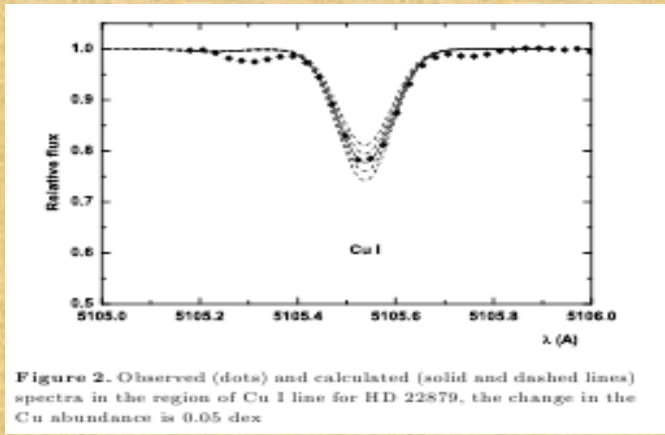


Figure 2. Observed (dots) and calculated (solid and dashed lines) spectra in the region of Cu I line for HD 22879, the change in the Cu abundance is 0.05 dex

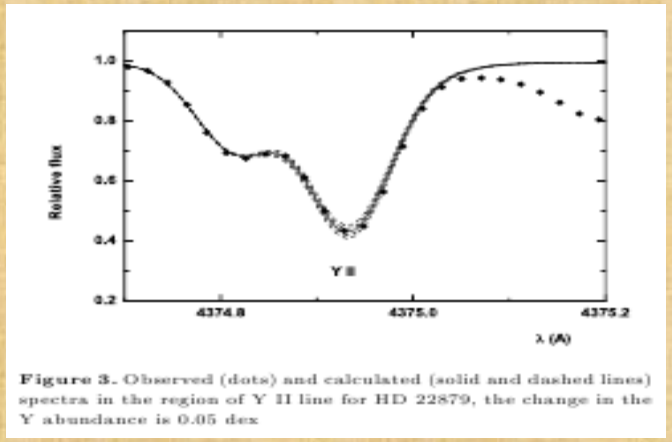


Figure 3. Observed (dots) and calculated (solid and dashed lines) spectra in the region of Y II line for HD 22879, the change in the Y abundance is 0.05 dex

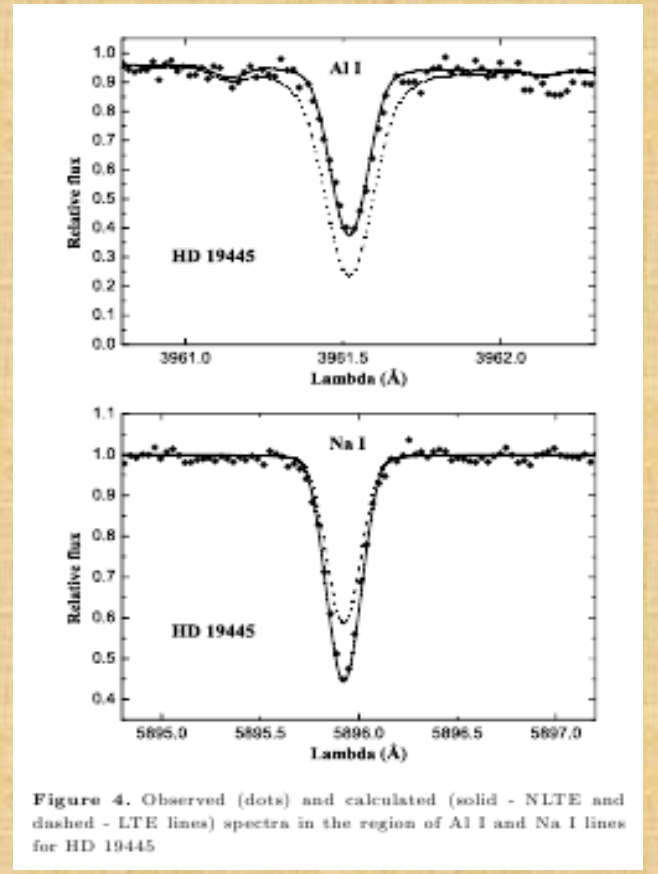


Figure 4. Observed (dots) and calculated (solid - NLTE and dashed - LTE lines) spectra in the region of Al I and Na I lines for HD 19445

Abundance errors due to atmospheric parameter uncertainties as examples of stars different values of stellar parameters:

HD170153 (Teff = 6170 K, logg = 4.25, Vt = 0.7 km/s, [Fe/H] = --0.61) and
HD221170 (Teff = 4415 K, logg = 1.05, Vt = 1.9 km/s, [Fe/H] = --2.26)

	HD170153				HD221170			
El	**ΔTeff+**	**Δlogg+**	**ΔVt+**	**tot**	**ΔTeff+**	**Δlogg+**	**ΔVt+**	**tot**
NaI	0.04	-0.02	-0.01	**0.05**	0.08	-0.02	-0.03	**0.09**
MgI	0.04	-0.03	-0.01	**0.05**	0.07	-0.03	-0.05	**0.09**
AlI	0.04	0.05	0.00	**0.06**	0.07	-0.02	-0.02	**0.08**
SiI	0.05	0.04	-0.01	**0.06**	0.04	0.00	-0.04	**0.06**
CaI	0.07	-0.04	-0.03	**0.09**	0.11	-0.04	-0.07	**0.14**
ScII	0.03	0.08	-0.01	**0.09**	0.02	0.07	-0.01	**0.07**
TiI	0.08	-0.01	-0.02	**0.08**	0.18	-0.02	-0.01	**0.18**
TiII	0.03	0.07	-0.03	**0.08**	0.02	0.06	-0.01	**0.06**
VI	0.09	0.00	-0.02	**0.09**	0.18	-0.03	-0.01	**0.18**
CrI	0.09	-0.02	-0.04	**0.10**	0.17	-0.03	-0.04	**0.18**
CrII	0.00	0.07	-0.03	**0.08**	-0.03	0.07	-0.02	**0.08**
MnI	0.06	0.00	-0.01	**0.06**	0.12	-0.02	0.00	**0.12**

	HD170153				HD221170			
El	**ΔTeff+**	**Δlogg+**	**ΔVt+**	**tot**	**ΔTeff+**	**Δlogg+**	**ΔVt+**	**tot**
• FeI	0.07	-0.02	-0.03	**0.08**	0.12	-0.02	-0.02	**0.12**
• FeII	0.00	0.06	-0.04	**0.07**	-0.03	0.07	-0.02	**0.08**
• CoI	0.09	-0.03	-0.05	**0.11**	0.17	-0.03	-0.04	**0.18**
• NiI	0.06	0.00	-0.01	**0.06**	0.10	-0.01	-0.01	**0.10**
• CuI	0.08	0.00	-0.01	**0.08**	0.14	-0.02	-0.01	**0.14**
• ZnI	0.05	0.02	-0.04	**0.07**	0.01	0.04	-0.02	**0.05**
• SrII	0.05	0.02	-0.02	**0.06**	0.04	0.05	-0.08	**0.10**
• YII	0.04	0.06	-0.03	**0.08**	0.03	0.07	-0.01	**0.08**
• ZrII	0.04	-0.02	0.08	**0.09**	0.03	0.07	-0.02	**0.08**
• BaII	0.07	0.01	-0.09	**0.11**	0.06	0.07	-0.06	**0.11**
• LaII	0.05	0.09	-0.02	**0.10**	0.06	0.07	0.00	**0.09**
• PrII	0.04	0.07	0.00	**0.08**	0.06	0.07	0.00	**0.09**
• NdII	0.04	0.07	0.00	**0.08**	0.06	0.07	0.00	**0.09**
• SmII	0.04	0.07	0.00	**0.08**	0.06	0.07	0.00	**0.09**
• EuII	0.04	0.08	0.00	**0.09**	0.07	0.08	0.04	**0.11**
• GdII					0.03	0.07	0.00	0.09

Comparison of our abundance determinations with those of other authors:

HD	<Δ[El/Fe]>	references
6582	-0.01 ±0.10	Fulbright (2000)
	0.04 ±0.07	Gratton et al.(2003)
6833	-0.15 ±0.20	Fulbright (2000)
19445	0.04 ± 0.08	Fulbright (2000)
	0.12 ±0.22	Roederer et al. (2014)
	0.07 ±0.17	Gratton et al. (2003)
22879	-0.02 ±0.06	Fulbright (2000)
22880	0.07 ±0.09	Klochkova et. al.(2011)
	0.06 ±0.12	Gratton et al. (2003)

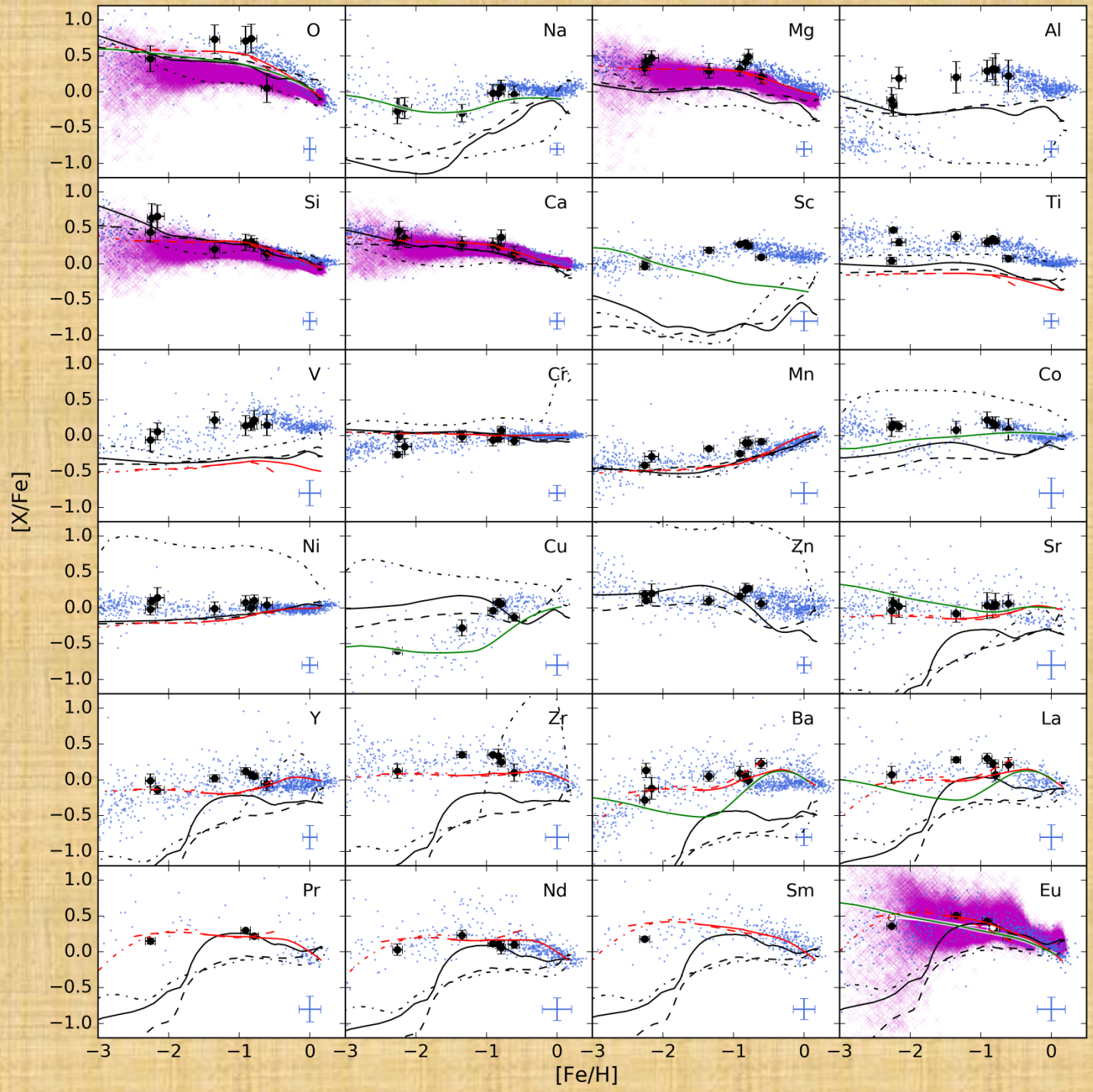
HD	<Δ[El/Fe]>	references
84937	0.01 ±0.10	Fulbright (2000)
	0.05 ±0.11	Gratton et al. (2003)
103095	0.01 ±0.11	Fulbright (2000)
	0.09 ±0.10	Gratton et al. (2003)
216143	-0.03 ±0.16	Fulbright (2000)
221170	0.04 ±0.13	Fulbright (2000)
	0.00 ±0.13	Ivans et al. (2006)
224930	0.00 ±0.14	Fulbright (2000)
	0.06 ±0.09	Stonkute et al. (2012)
	0.04 ±0.08	Gratton et al. (2003)

HD6833: Fulbright (2000) -- used only three lines of Fe I for this stars, while from 30 to 60 lines for other stars;

HD19445: the Al abundance obtained by us (NLTE[Al/Fe] = 0.19) and that one by Roederer et al. (2014a) (LTE[Al/Fe] = -0.56), without Al, $< \Delta[El/Fe] > = 0.08 \pm 0.13$.

How to improve the accuracy?

- Defining the parameters and abundances for stars with close parameters to each other
- For example, for the dwarfs, with parameters close to the sun, solar analogue stars, Teff = 60 K, logg = 0.14, [Fe/H] = 0.06 (Mishenina et al. 2016)
- Note! to determine the temperature in this case the method of the line intensity ratios that gives the internal accuracy from 10 to 30 K were used
- A differential elemental abundance analysis of unprecedented accuracy (~0.01 dex) of 11 solar twins and 10 solar analogs from planet searches that was obtained by Melendez et al. (2009)
- Now, Marco present the comparison of the observation results with different chemical evolution predictions:


O
Na
Mg
Al
Si
Ca
Sc
Ti
V
Cr
Mn
Co
Ni
Cu
Zn
Sr
Y
Zr
Ba
La
Pr
Nd
Sm
Eu
[X/Fe]
[Fe/H]
1.0
0.5
0.0
−0.5
−1.0
−3
−2
−1
0

Conclusions

•Using homogeneous spectral data (SOPHIE echelle spectrograph at the OHP, France) and techniques for determination of parameters and abundances of a series of elements, we have compared the results obtained for the stars with models of chemical evolution.

•We have examined 10 stars with precise parameter determination.

Co-authors:

Thielemann F., Côté, B., Soubiran C., Basak N., Gorbaneva N., Korotin S., Kovtyukh V., Wehmeyer B., Jordan C., Gibson B., Bisterzo S., Travaglio C., Paul A., Ritter C., Herwig F.


Thank you for your attention!