Measuring hydrogen-to-helium ratio from cool stars

Gajendra Pandey, IIA, Bangalore

Our inability to determine helium abundance in a cool star is very frustrating. But, I think, it is rarely expressed.

>Sun: from sampling the solar wind than from the solar absorption lines . However, impossible to obtain on other stars.

>Primordial He-abundance and that from local H II regions and

B-stars set the floor/ceiling for He-abundance.

>Measurements of He/H ratio in cool stars are essential to derive accurate elemental abundances including the He-abundance.

>For cool stars, elemental abundances are derived by adopting a "standard" He/H ratio assumed that from hot stars. How crucial is this assuption affecting the derived elemental abundances?

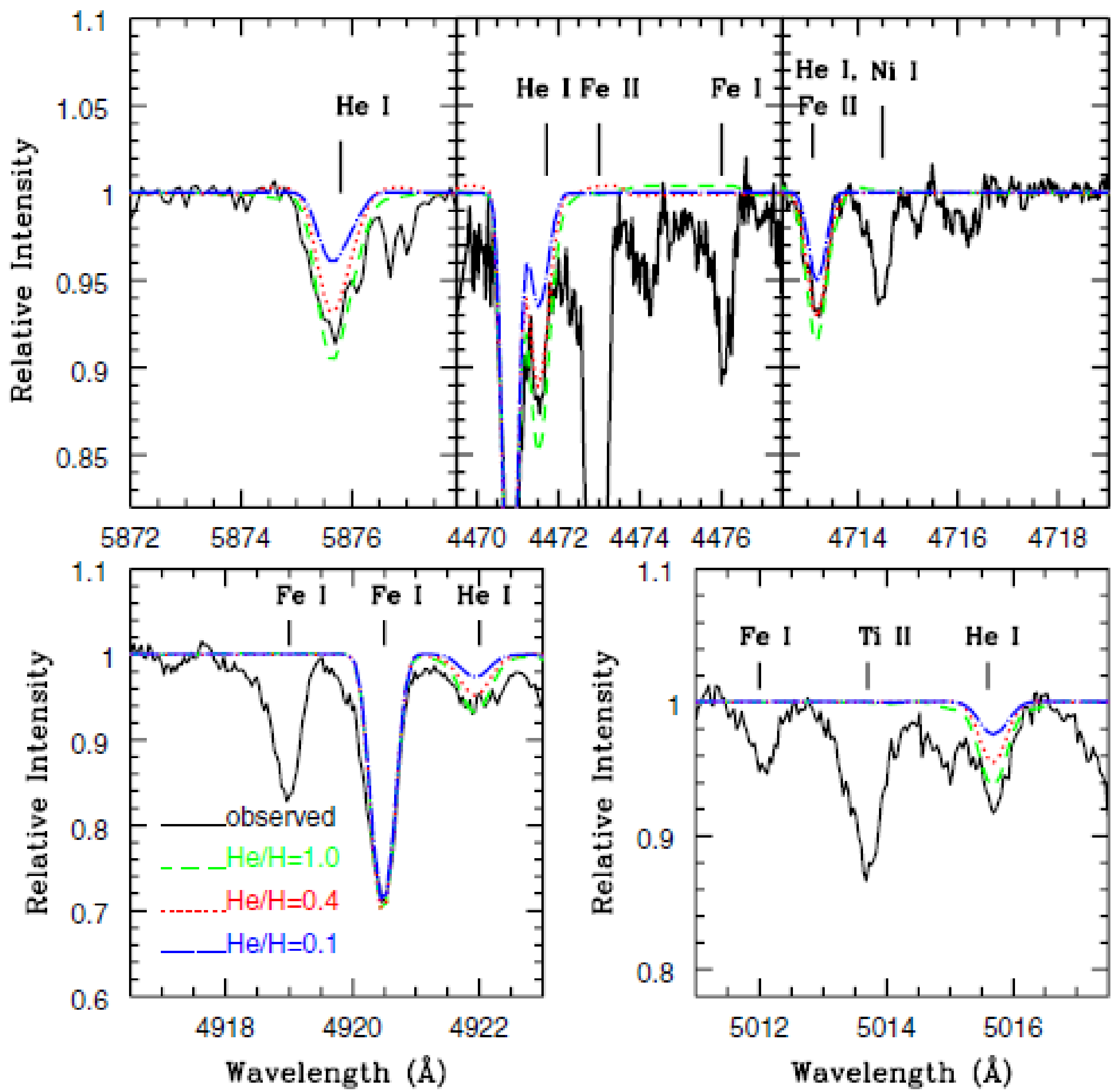
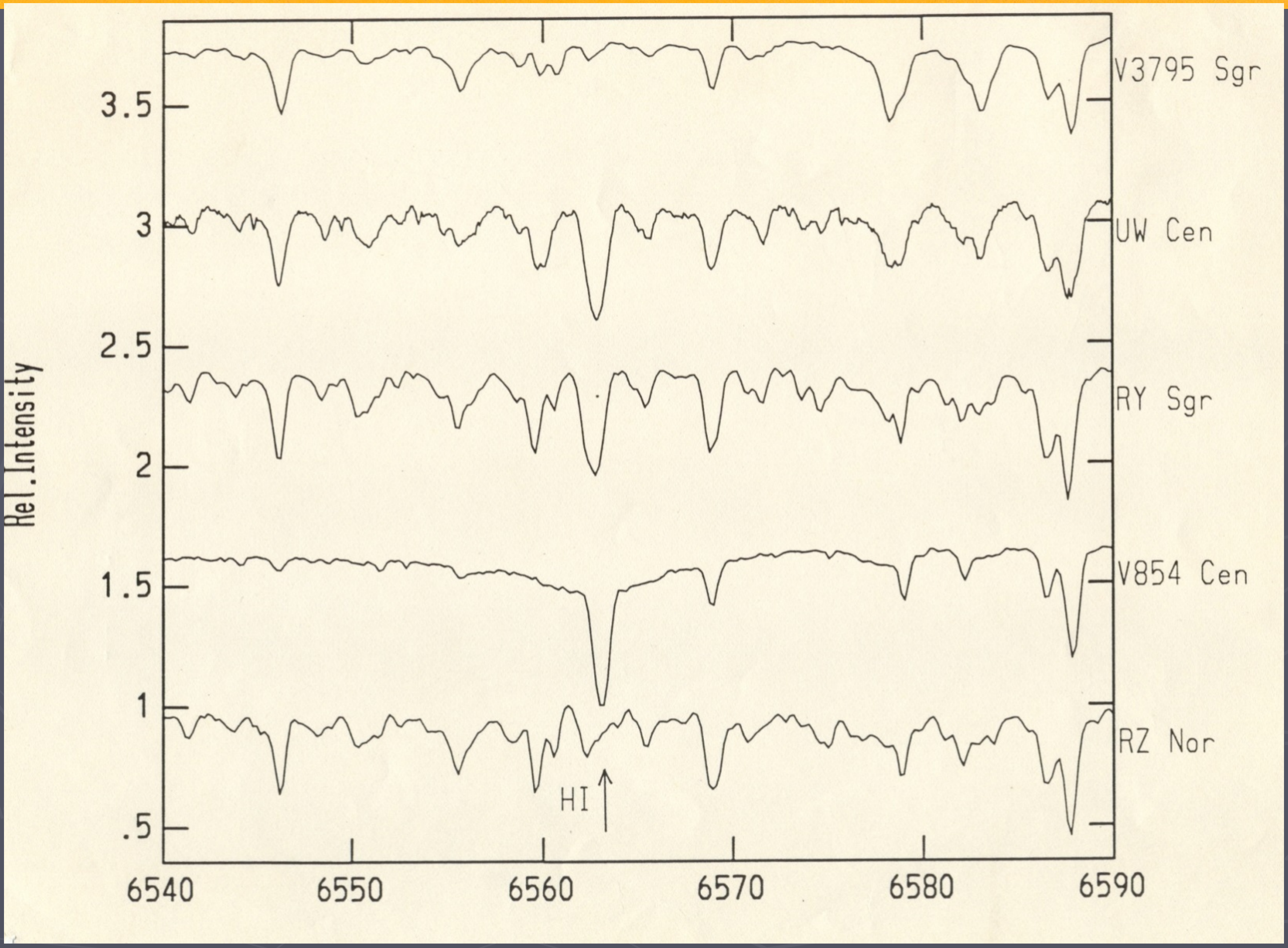


Figure 2. Observed and synthesized He I profiles for the triplet lines at 5876, 4471, and 4713 Å and for the singlet lines at 4922 and 5015 Å for SAO 40039 using models with $T_{\rm eff} = 8000$ K, log g = 0.75 for He/H = 1.0, 0.4, and 0.1—see keys on the figure.

Sumangala Rao, Pandey, Lambert & Giridhar 2011, ApJ Letters

HYDROGEN DEFICIENT STARS



VBT's low resolution spectra of Omega Cen giants

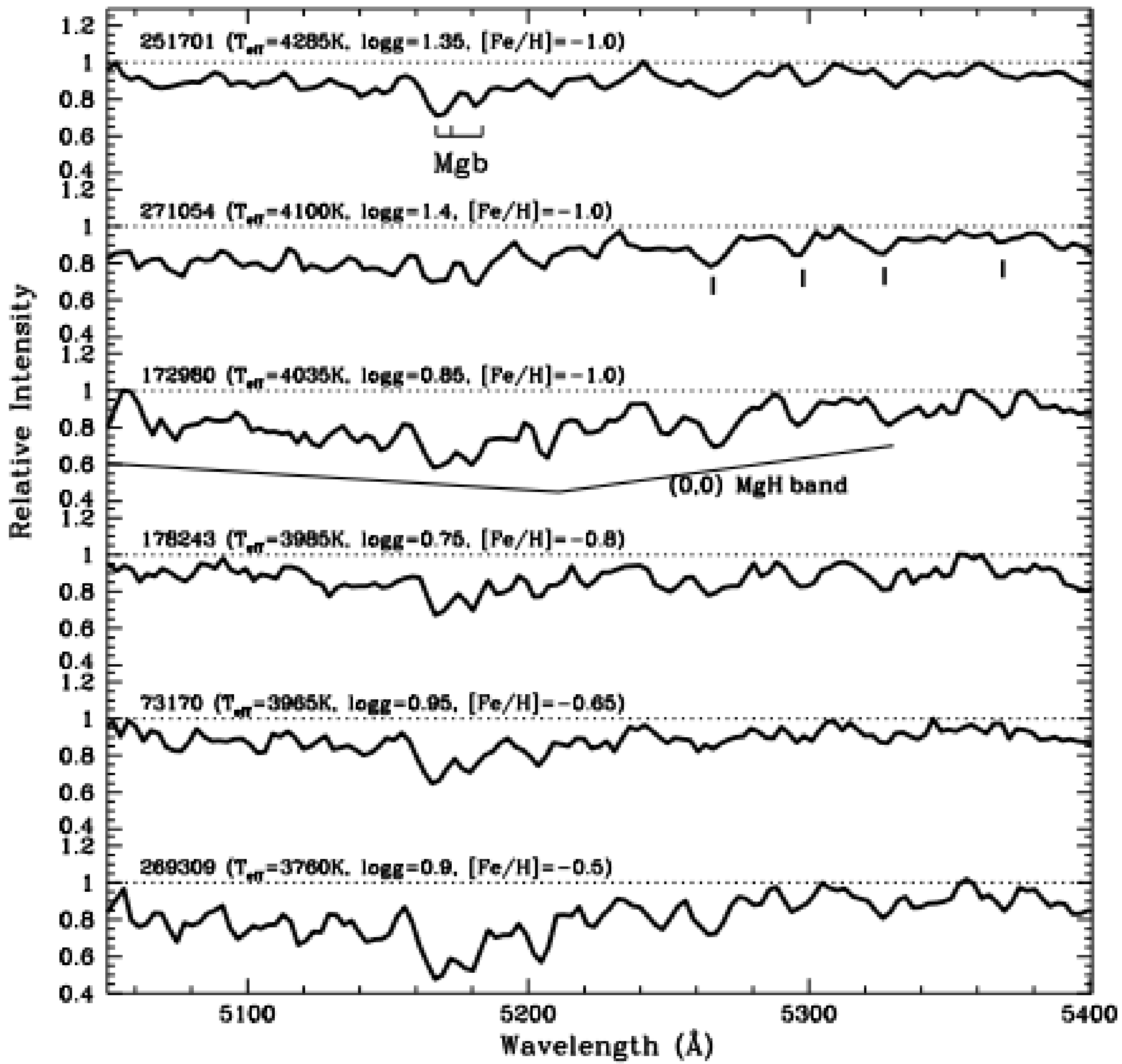


Figure 1. Spectra of the first group stars are shown in increasing order of $T_{\rm eff}$ from bottom to top. The strong Mg *b* lines and the (0, 0) MgH band are marked. The vertical lines marked to the red of the Mg *b* lines are the Fe I lines.

first group; Hema & Pandey 2014, ApJ Letters

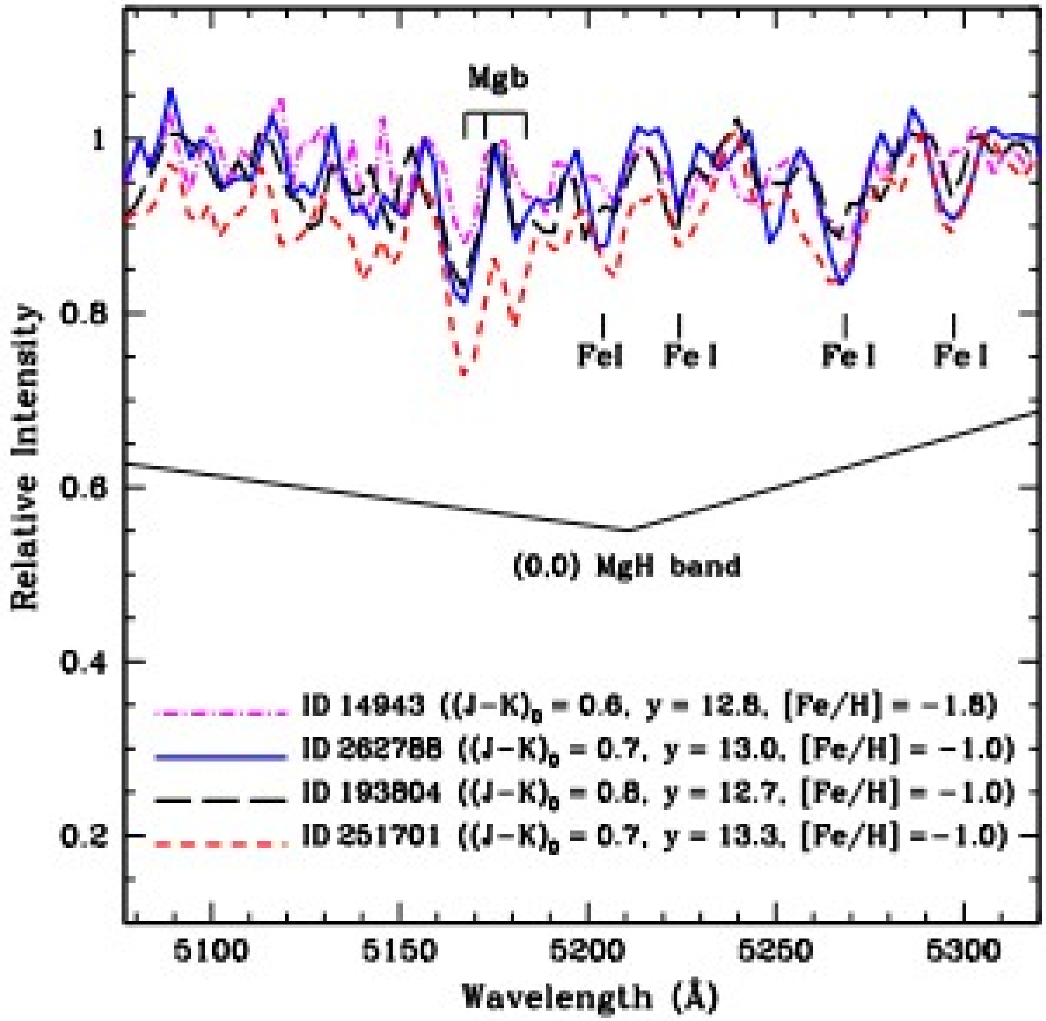


Figure 2. Observed spectrum of 262788 and 193804, the twins in the third group of stars, compared with the observed spectrum of 251701, the star in the first group. Also shown is the observed spectrum of 14943, the star in the second group. The key features such as Mg *b* lines, the MgH band, and the Fe I lines are marked.

ample spectra of first, second, and third group

Hema & Pandey 2014, ApJ Letters

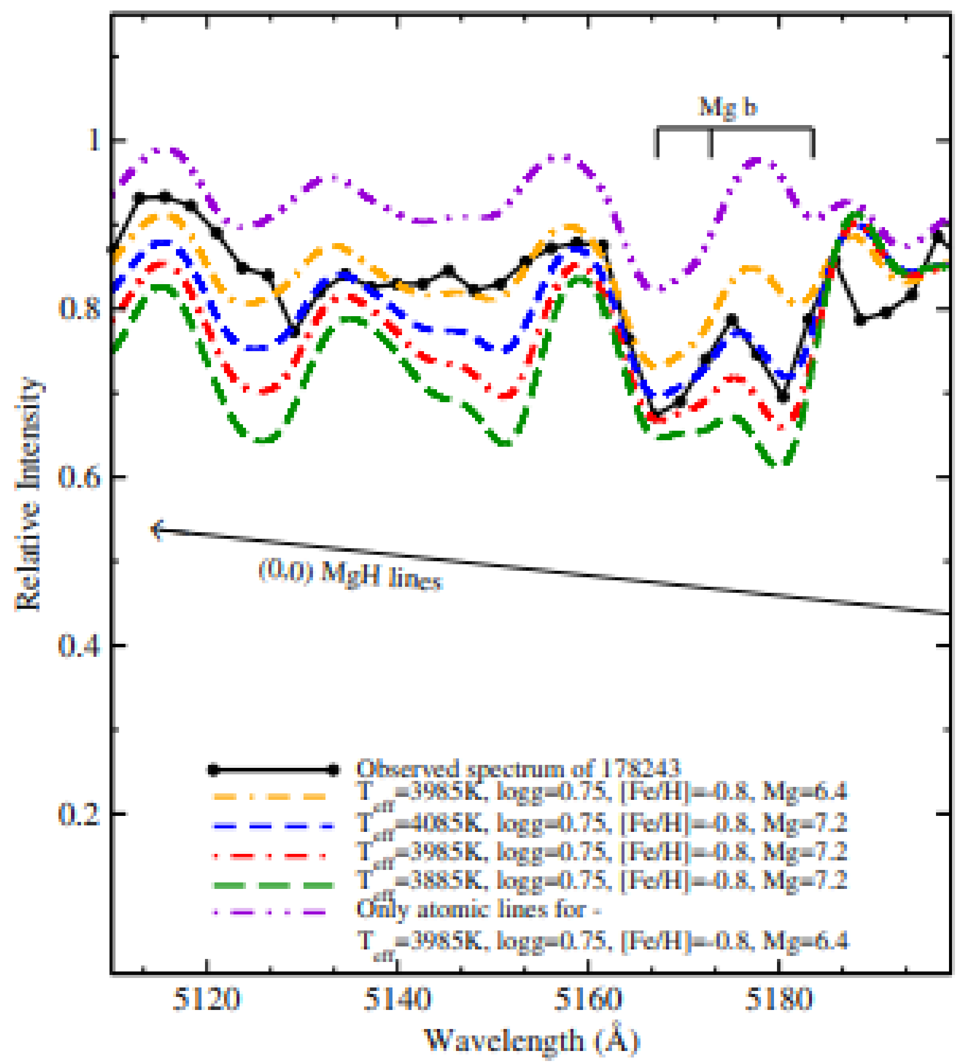


Figure 3. Observed spectrum and the synthesized spectra for the star 178243. The spectrum synthesized for the best-fit value of [Mg/Fe] and for different T_{eff} for the expected [Mg/Fe] of ω Cen red giants are shown in the figure—see the key on the figure.

Spectrum synthesis; Hema & Pandey 2014, ApJ Letters

Star	Star (LEID)[a]	S/N	T_{eff}	log g	[Fe/H]	Group	log ϵ(Mg)	[Mg/Fe]
269309	...	70	3760	0.90	−0.5	First	7.1 ± 0.2	0.0
73170	39048	100	3965	0.95	−0.65	First	6.75 ± 0.2	−0.2
178243	60073	100	3985	0.75	−0.8	First	6.4 ± 0.2	−0.4
172980[b]	61067	110	4035	0.85	−1.0	First	7.0 ± 0.2	+0.4
178691	50193	110	4075	0.65	−1.2	First	6.6 ± 0.2	+0.2
271054	...	100	4100	1.40	−1.0	First	6.7 ± 0.2	+0.1
40867	54022	110	4135	1.15	−0.5	First	7.2 ± 0.2	+0.1
250000	...	90	4175	1.40	−1.0	First	6.9 ± 0.2	+0.3
131105	51074	80	4180	1.05	−1.1	First	6.9 ± 0.2	+0.4
166240[b]	55101	60	4240	1.15	−1.0	First	6.8 ± 0.2	+0.2
262788	34225	110	4265	1.30	−1.0	Third	<6.0 ± 0.2	<−0.6
251701	32169	100	4285	1.35	−1.0	First	7.0 ± 0.2	+0.4
193804	35201	80	4335	1.10	−1.0	Third	<6.5 ± 0.2	<−0.1
5001638	...	150	4400	1.6	−0.5	First	7.3 ± 0.2	+0.2
270931	...	100	4420	1.25	−0.5	First	7.2 ± 0.2	+0.1
214247	37275	60	4430	1.45	−1.5	Third	6.5 ± 0.2	+0.4
216815	43475	80	4500	1.85	−0.6	First	7.3 ± 0.2	+0.3
14943	53012	100	4605	1.35	−1.8	Second	<6.7 ± 0.2	<+0.9

Notes.

[a] Stellar parameters are from Johnson & Pilachowski (2010) for the giants with LEID identification.

[b] Common stars with the sample of Norris & Da Costa (1995). Norris & Da Costa report [Mg/Fe] of 0.53 and 0.27 for 172980 and 166240, respectively.

Mg abundances derived from MgH band;

Hema & Pandey 2014, ApJ Letters

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CrossMark

High-resolution Spectroscopy of the Relatively Hydrogen-poor Metal-rich Giants in the Globular Cluster ω Centauri

B. P. Hema[1], Gajendra Pandey[1], and R. Srianand[2]
[1] Indian Institute of Astrophysics, Koramangala II Block, Bengaluru, Karnataka, 560034, India; hema@iiap.res.in
[2] Inter-University Centre for Astronomy and Astrophysics, Post Bag 4, Ganeshkhind, Pune 411007, India
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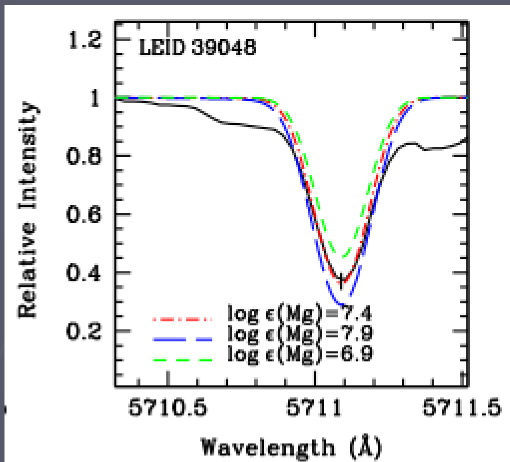
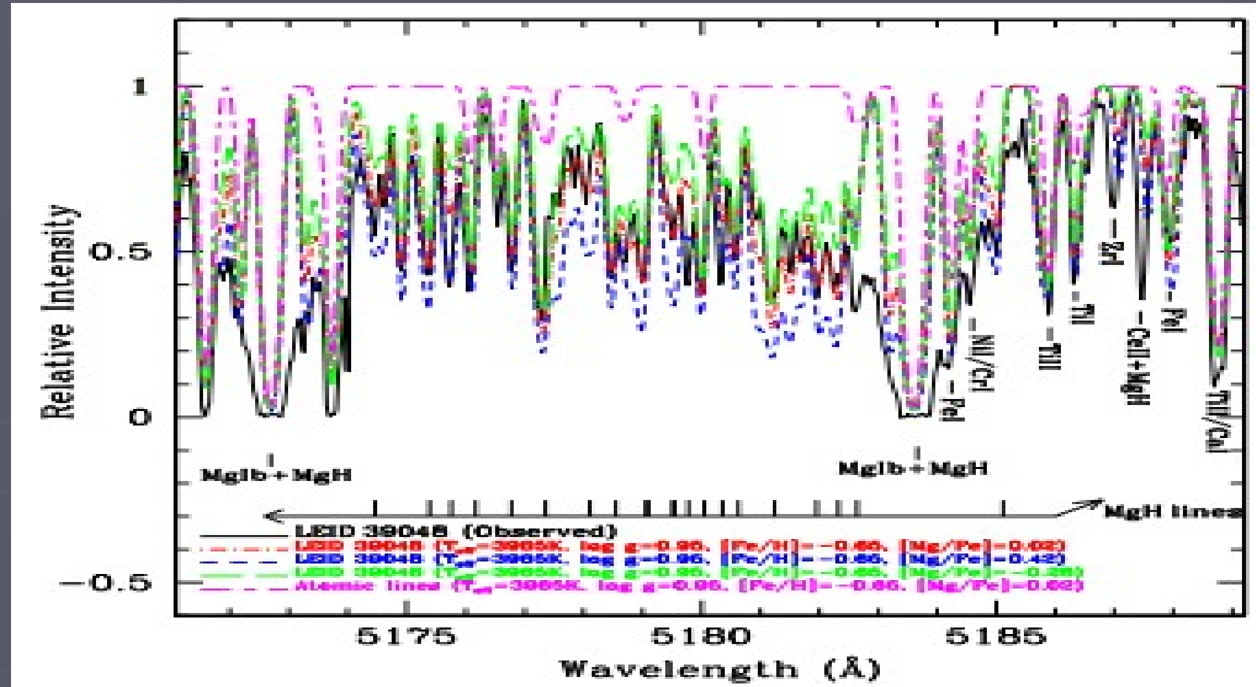
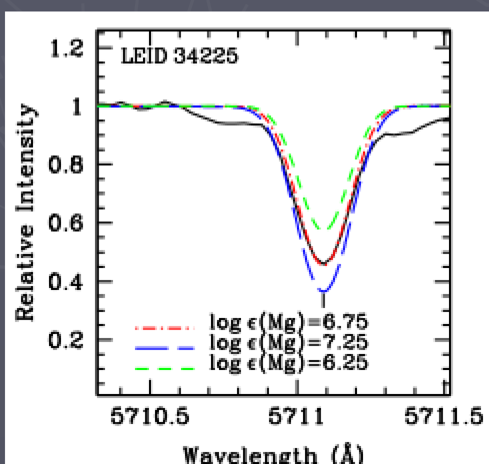
>High resolution spectra from SALT confirm our results derived from VBT's low resolution spectra

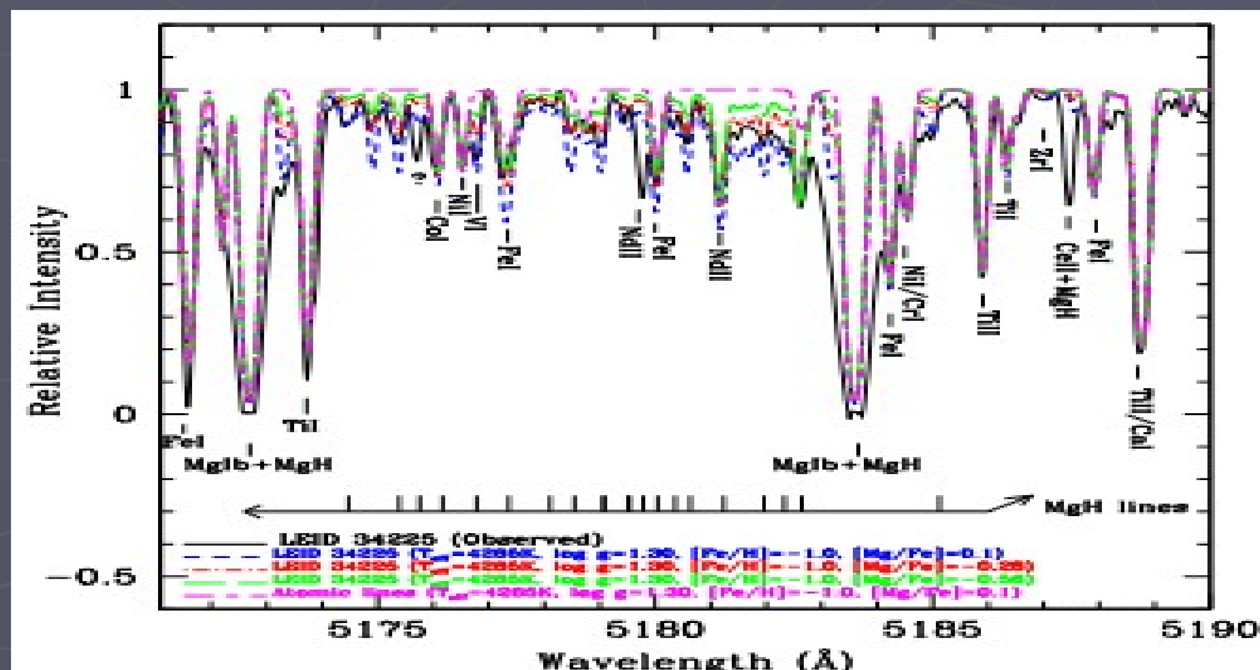
>Mg abundandance from Mg I lines is more than 0.3 dex than that from MgH band!

>Clearly suggesting He-rich or H-poor atmospheres than the "standard" He/H composition


LEID 39048
Relative Intensity
Wavelength (Å)
log ϵ(Mg)=7.4
log ϵ(Mg)=7.9
log ϵ(Mg)=6.9


Relative Intensity
Wavelength (Å)
MgIb+MgH
MgIb+MgH
MgH lines
LEID 39048 (Observed)
TiII/CaI
CeII+MgH
ZrI
TiI
TiII
NiI/CrI
FeI


LEID 34225
Relative Intensity
Wavelength (Å)
log ϵ(Mg)=6.75
log ϵ(Mg)=7.25
log ϵ(Mg)=6.25


Relative Intensity
Wavelength (Å)
FeI
MgIb+MgH
TiI
MgIb+MgH
MgH lines
LEID 34225 (Observed)
CoI
NiI
VI
FeI
NdII
FeI
NdII
FeI
NiI/CrI
TiII
TiI
ZrI
CeII+MgH
FeI
TiII/CaI

Derived Mg Abundances from Mg I Lines and the MgH Band for the Adopted Stellar Parameters and the Corresponding Uncertainties on Them

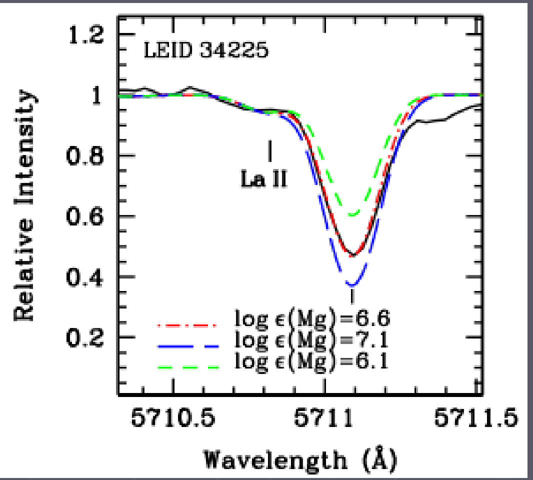
Stars	T_{eff}	log g	[Mg/Fe] from Mg I	[Mg/Fe] from MgH
LEID 39048	**3965**	**0.95**	**+0.42**	**+0.02**
	4015	0.95	+0.41	+0.11
	3915	0.95	+0.44	−0.06
	3965	1.05	+0.44	−0.08
	3965	0.85	+0.42	+0.02
LEID 34225	**4265**	**1.30**	**+0.10**	**−0.30**
	4315	1.30	+0.10	−0.25
	4215	1.30	+0.06	−0.44
	4265	1.40	+0.04	−0.26
	4265	1.20	+0.06	−0.26

Note. The adopted stellar parameters and their corresponding derived Mg abundances are given in boldface.

Hema, Pandey & Srianand 2018, ApJ

Measurements of He/H ratio in cool stars:

Adopting model atmospheres with differing He/H ratios including the "standard"



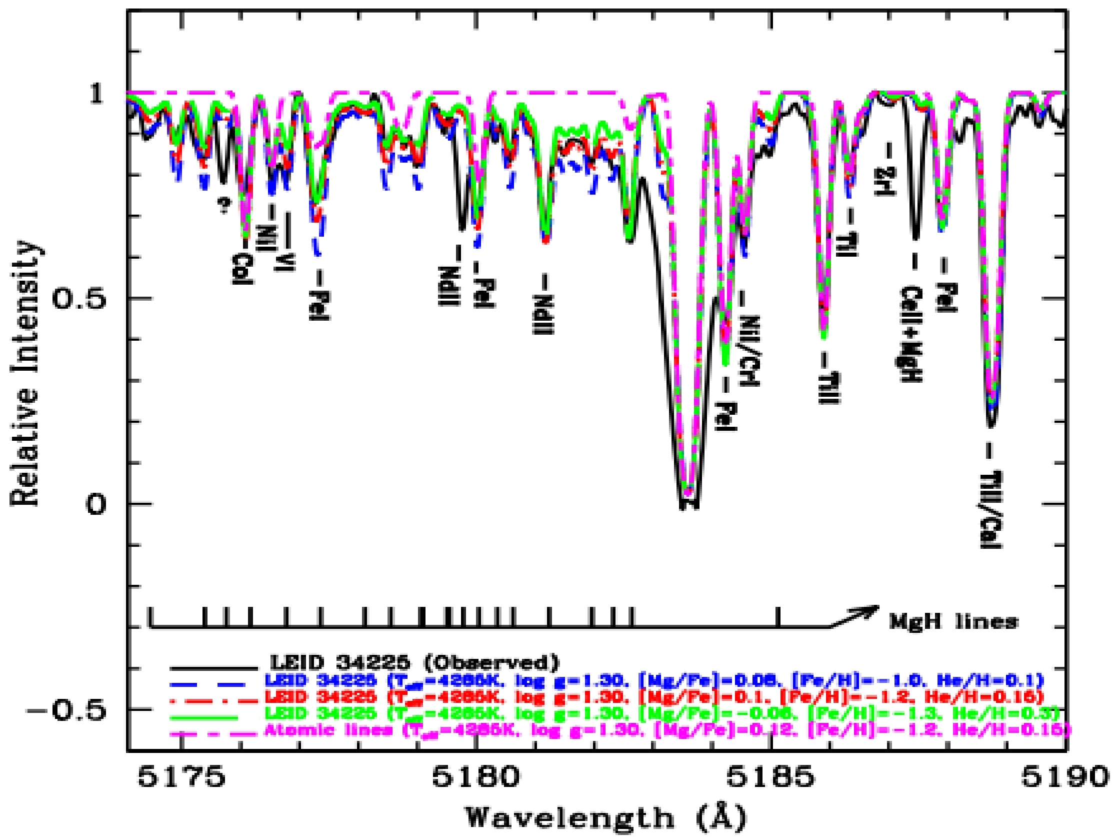


Figure 2. Observed and the synthesized MgH bands for LEID 34225 are shown. The spectra synthesized for the Mg abundance derived from the Mg I lines and the best-fit value of He/H ratio are shown by the red dashed–dotted line. The synthesis for the two value of the He/H are also shown.

Blue- 0.1 (He/H)

Red- 0.15

Green- 0.3

Abundances for Different He/H Ratios

		LEID 34225					LEID 39048				
Elements	log $\epsilon_{\odot}$	log ϵ(He/H = 0.1)	[X/Fe]	log ϵ(He/H = 0.15)	[X/Fe]	n	log ϵ(He/H = 0.1)	[X/Fe]	log ϵ(He/H = 0.2)	[X/Fe]	n
H	12.00	12.00	...	11.945	...	...	12.00	...	11.894	...	...
He	10.93	11.00	...	11.121	...	...	11.00	...	11.195	...	...
O	8.69	7.4	−0.25	7.36	−0.13	1	8.1 ± 0.06	0.03	7.99 ± 0.07	0.10	2
Na	6.24	5.72 ± 0.16	0.52	5.65 ± 0.16	0.61	4	6.50 ± 0.04	0.88	6.38 ± 0.04	0.94	2
Mg (Mg I)	7.60	6.65 ± 0.05	0.09	6.52 ± 0.02	0.12	4	7.41 ± 0.1	0.43	7.25 ± 0.06	0.45	5
Mg (MgH)	...	6.26	−0.29	6.50	0.10	...	7.0	0.02	7.20	0.40	...
Al	6.45	6.50 ± 0.12	1.09	6.32 ± 0.11	1.07	4	6.50 ± 0.13	0.67	6.33 ± 0.1	0.68	4
Si	7.51	7.00 ± 0.11	0.53	6.85 ± 0.11	0.54	5	7.36 ± 0.15	0.47	7.02 ± 0.16	0.31	7
Ca	6.34	5.40 ± 0.16	0.1	5.26 ± 0.16	0.12	9	5.9 ± 0.08	0.18	5.82 ± 0.08	0.28	8
Sc I	3.15	2.24 ± 0.16	0.13	2.20 ± 0.14	0.25	4	...	...	...	...	...
Sc II	3.15	2.25 ± 0.09	0.14	2.13 ± 0.09	0.18	5	2.60 ± 0.2	0.07	2.37 ± 0.20	0.02	5
Ti I	4.95	4.30 ± 0.14	0.39	4.24 ± 0.14	0.49	7	4.80 ± 0.17	0.47	4.80 ± 0.17	0.67	11
Ti II	4.95	4.29 ± 0.11	0.38	4.14 ± 0.11	0.39	4	...	...	...	...	...
V	3.93	2.66 ± 0.14	−0.23	2.64 ± 0.14	−0.09	6	3.20 ± 0.15	−0.11	3.20 ± 0.15	0.08	8
Cr	5.64	4.60 ± 0.13	0.0	4.53 ± 0.13	0.09	7	5.00 ± 0.1	−0.02	4.92 ± 0.11	0.08	...
Mn	5.43	4.39 ± 0.06	0.0	4.32 ± 0.07	0.09	3	4.85 ± 0.04	0.04	4.77 ± 0.04	0.14	3
Fe I	7.50	6.46 ± 0.16	−1.04	6.32 ± 0.12	−1.18	19	6.88 ± 0.14	−0.62	6.70 ± 0.13	−0.80	16
Fe II	...	6.46 ± 0.06	−1.04	6.25 ± 0.08	−1.25	2	...	...	...	...	...
Co	4.99	4.01 ± 0.14	0.06	3.92 ± 0.14	0.13	6	4.32 ± 0.13	−0.05	4.14 ± 0.11	−0.05	7
Ni	6.22	5.13 ± 0.09	−0.05	5.04 ± 0.09	0.02	3	5.74 ± 0.17	0.14	5.50 ± 0.18	0.09	7
La	1.10	1.10	1.04	0.95	1.05	1	1.32	0.84	1.19	0.89	1

Note. Abundances derived for the normal (He/H = 0.1) and the determined (He/H) for the program stars are given. The corresponding abundance ratios, the number of spectral lines used, and the solar abundances (Asplund et al. 2009) are also provided.

Hema, Pandey, Kurucz & Allende Prieto 2020, ApJ, 897, 32

Example for a lithium rich giant: He – Li connection?

T_{eff}	log g	[Mg/Fe] from Mg I	[Mg/Fe] from MgH
4270	**2.0**	**– 0.1**	**– 0.55**
4320	2.0	– 0.13	– 0.50
4220	2.0	– 0.11	– 0.70
4270	2.1	– 0.09	– 0.60
4270	1.9	– 0.12	– 0.50
4170	2.0	– 0.09	– 0.70
4370	2.0	– 0.13	– 0.30

Light Elements in the Universe
Proceedings IAU Symposium No. 268, 2009
C. Charbonnel, M. Tosi, F. Primas & C. Chiappini, eds.

doi:10.1017/S1743921310003790

Light elements - one observer's historical perspective

David L. Lambert

In light of the impossibility of direct detection of He lines in photospheric spectra of cool stars, one is led to wonder if mildly He-rich cool stars exist, how they might be detected, and how they might arise (diffusion, internal nucleosynthesis and mixing, binary interactions, etc.?).

THANK YOU