Stellar parameters from CARMENES spectra

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StePar code (python 3.X powered)

Equivalent Width method (Tabernero et al. 2012)

Fe lines

Nelder-Mead

Fast method – Not for general use

Spectral Synthesis (Tabernero et al. 2018)

MCMC + Gaussian Processes

Slow – It “always” works

Fe lines +Ti lines

Tools

Automated EWs

TAME (**Kang and Lee 2012**)

ARES 2 (**Sousa et al. 2015**)

Stellar atmospheric models

MARCS models (**Gustaffson et al. 2008**)

PHOENIX models (**Allard et al. 2012**)

Radiative transfer codes

MOOG 2017 (**Sneden 1973**)

Turbospecturm (**Álvarez and Plez 1998**)

Atomic data

Synthesis:

Atoms: VALD3, **Molecules**: B. Plez, ExoMol, and Kurucz

TiO SiH MgH CaH CrH FeH C_2 ZrO H_2O OH CN CO VO

Equivalent Widths:

Atoms: VALD3 **(again)**

Atmospheric Models

Model	Effective temperature	Surface gravity	Metallicity
PHOENIX	2600 K < T_{eff} < 8000 K	-0.5 < log g < 6	-4 < [M/H] < 0.5
MARCS	2500 K < T_{eff} < 8000 K	-0.5 < log g < 5.5	-4 < [M/H]< 1

These are stellar atmospheric models
They are NOT synthetic spectra

We can generate *almost* anything at any wavelength and model (just ask)

Robust interpolation scheme ⟶ scipy.interpolate (python)

Both grids are appropriate for Milky Way stars
[α/Fe] enhanced models

StePar Equivalent widths

Four line lists (TAME/ARES 2)

Better suited for FGK stars

Classical method (Fe I-II)

EP vs A(FeI), RW vs A(Fe I), A(Fe I) – A(Fe II)

Nelder-mead Optmization (Press et al. 2002)

MARCS models+ *MOOG*

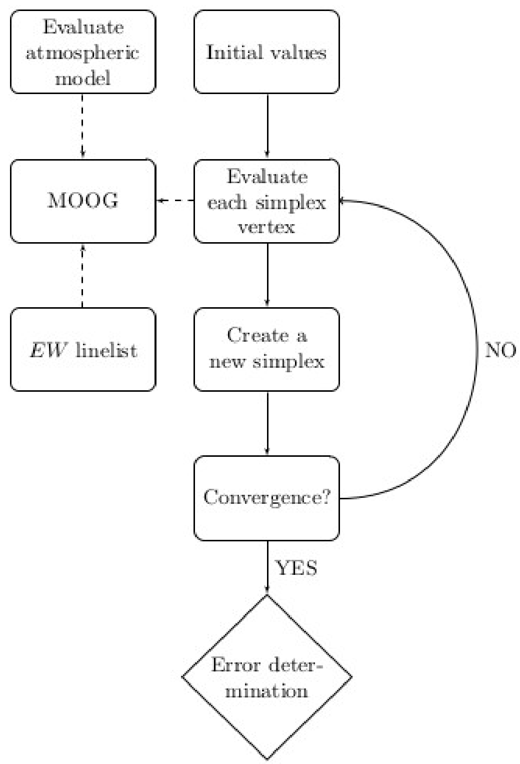
Tested on CARMENES stellar library (OBA*FGKM*)

See Tabernero et al. (2012)

StePar Equivalent widths (workflow)

StePar: an automatic code to infer stellar atmospheric parameters

H. M. Tabernero[1], E. Marfil[2], D. Montes[2], and J. I. González Hernández[3,4]



Tabernero et al. (2019, to be submitted)

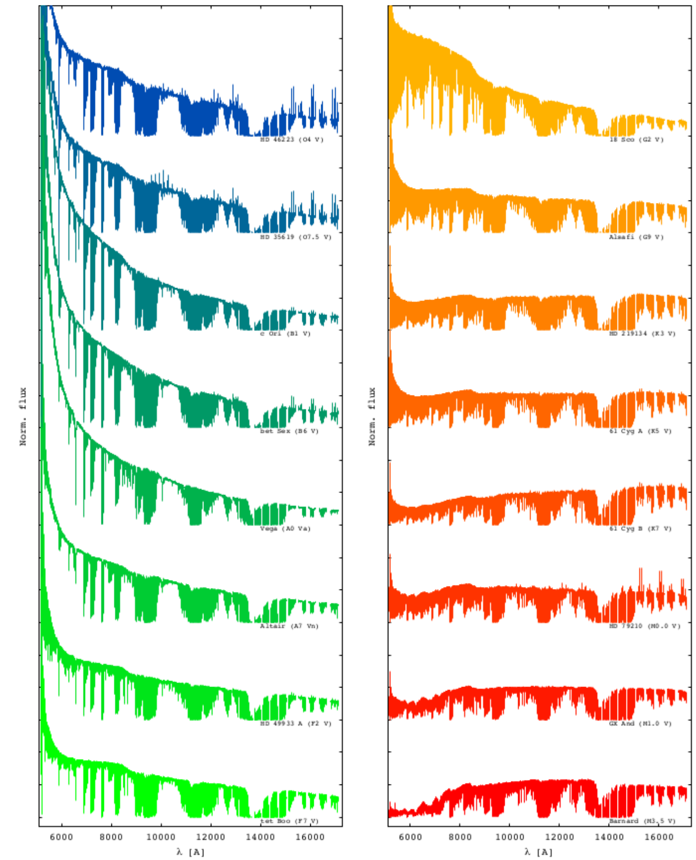
StePar Equivalent widths (library)

Spectroscopic stellar parameters of FGK-type stars from visible and near-infrared CARMENES spectra

E. Marfil[1], D. Montes[1], H. M. Tabernero[1,2] J. A. Caballero[3], and J. I. González Hernández[4,5] et al.

Star	SpT[a]	T[K][b]	log g[b]	[Fe/H][c]
18 Sco	G2 V	5747	4.43	+0.03
μ Cas	K1 V	5308	4.41	−0.81
ϵ Vir	G8 III	4983	2.77	+0.15
Arcturus	K1.5 III	4247	1.59	−0.52
HD 49933 A	F2 V	6635	4.21	−0.41
Procyon	F5 IV–V	6545	3.99	+0.01
Pollux	K0 IIIb	4858	2.88	+0.13
HD 84937	F8 V	6275	4.11	−2.03
μ Leo	K2 III	4433	2.50	+0.25
β Vir	F9 V	6083	4.08	+0.24
CF UMa	G8 Vp	4827	4.60	−1.46
c Vir	K0 IIIb	4590	2.20	−0.33
η Boo	G0 IV	6056	3.86	+0.23
HD 122563	F8 IV	4608	1.61	−2.64
61 Cyg A	K5 V	4339	4.43	−0.33
61 Cyg B	K7 V	4045	4.53	−0.38
7 Psc	K1 IV	4266	1.43	−0.74

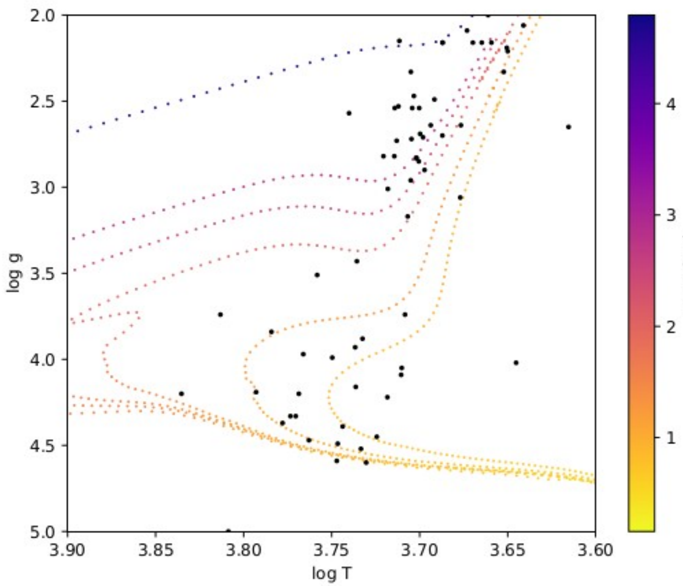
Gaia Benchmark stars (Heiter et al. 2015) observed with CARMENES



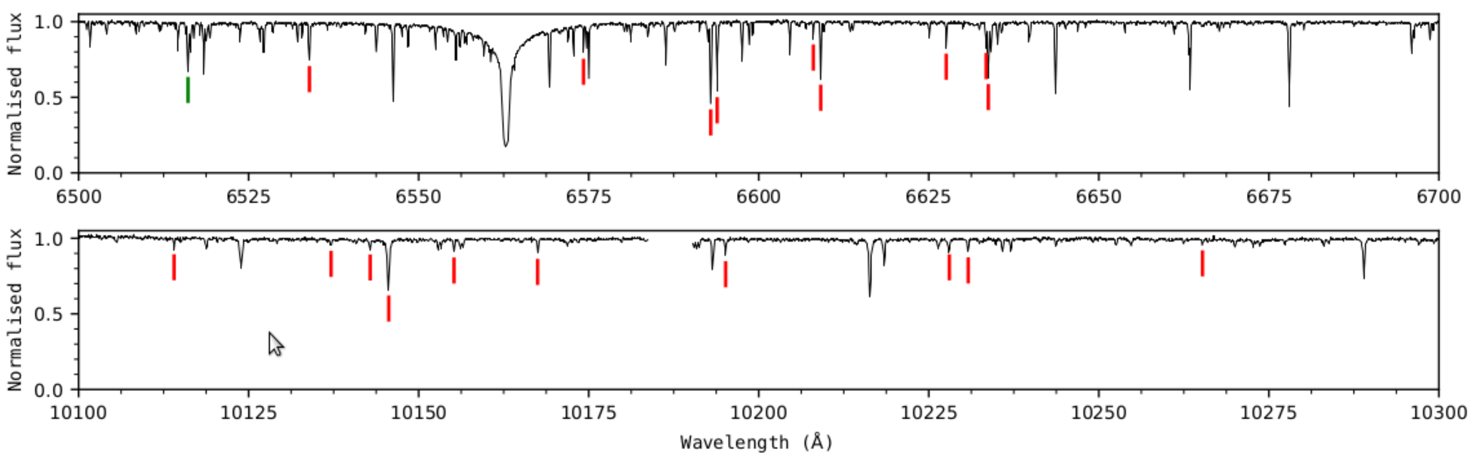
Only FGKs → Marfil et al. (2019, in prep)

StePar Equivalent widths (results)

Star	Type	SpT	log g	[Fe/H]
18 Sco	Metal-Rich Dwarf	G2 V	4.43	+0.03
μ Cas	Metal-Poor Dwarf	K1 V	4.41	−0.81
ϵ Vir	Metal-Rich Giant	G8 III	2.77	+0.15
Arcturus	Metal-Poor Giant	K1.5 III	1.59	−0.52



18 Sco Fe I-II lines



StePar Synthesis

Three linelist templates:

GX And (M1 V)
Luyten (M3.5 V)
Teegarden (M7 V)

70 Fe + Ti lines ⟶ Ranks + Line masks

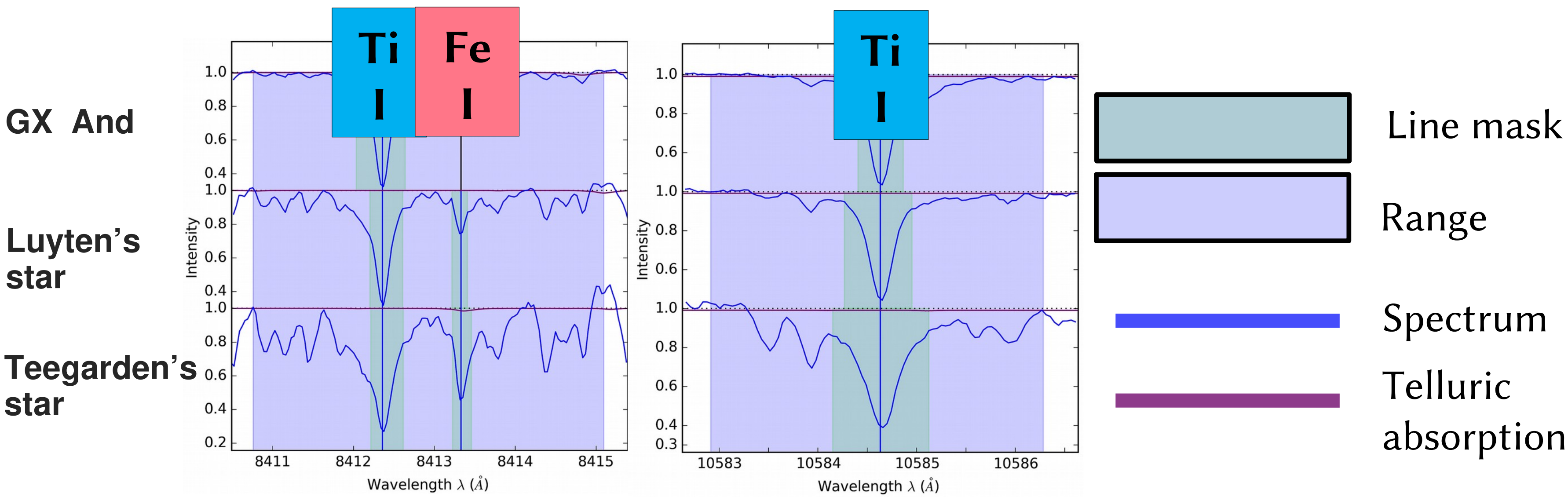
TiO bands (work in progress)

PHOENIX models + Turbospectrum

MCMC + Gaussian processes + PCA grid

See Tabernero et al. (2018)

StePar Synthesis (Fe+Ti)

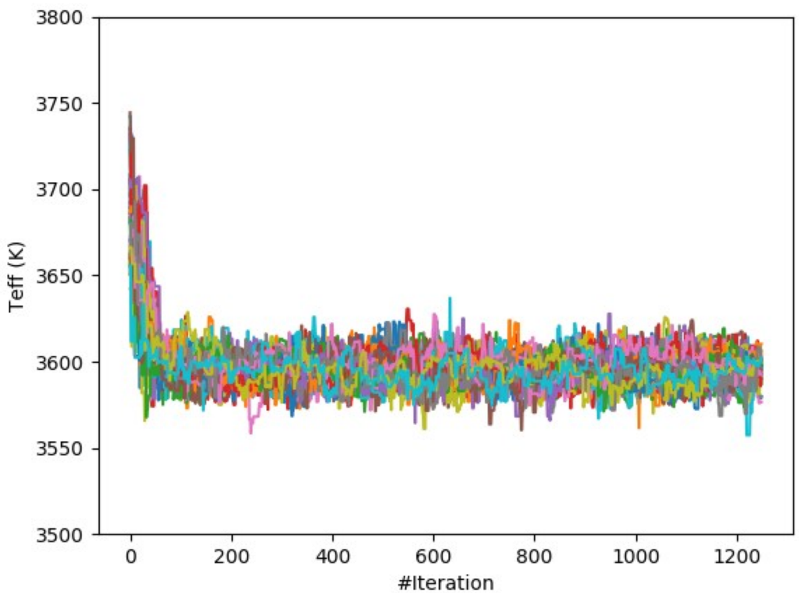


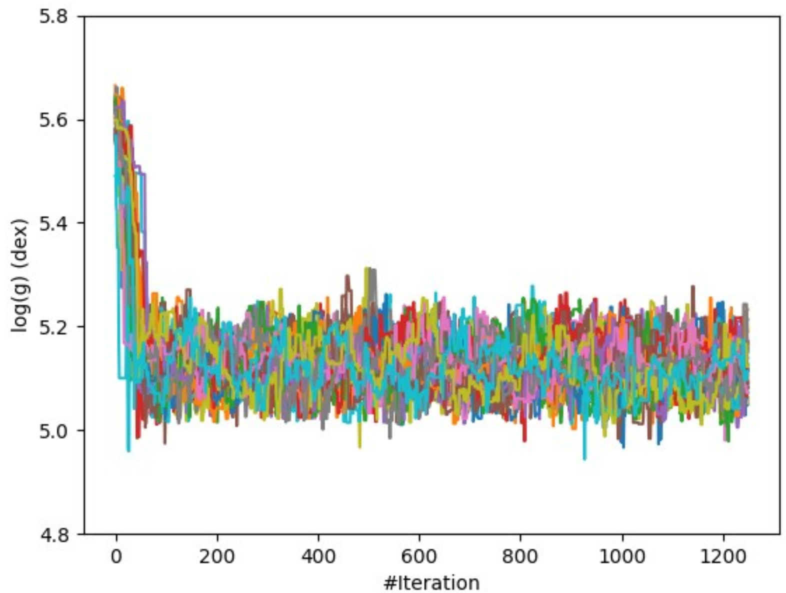
@ ~ 8400 Å   @ ~ 10580 Å

Linelist selection: F. J. Lázaro (MSc thesis)

StePar Synthesis (MCMC)

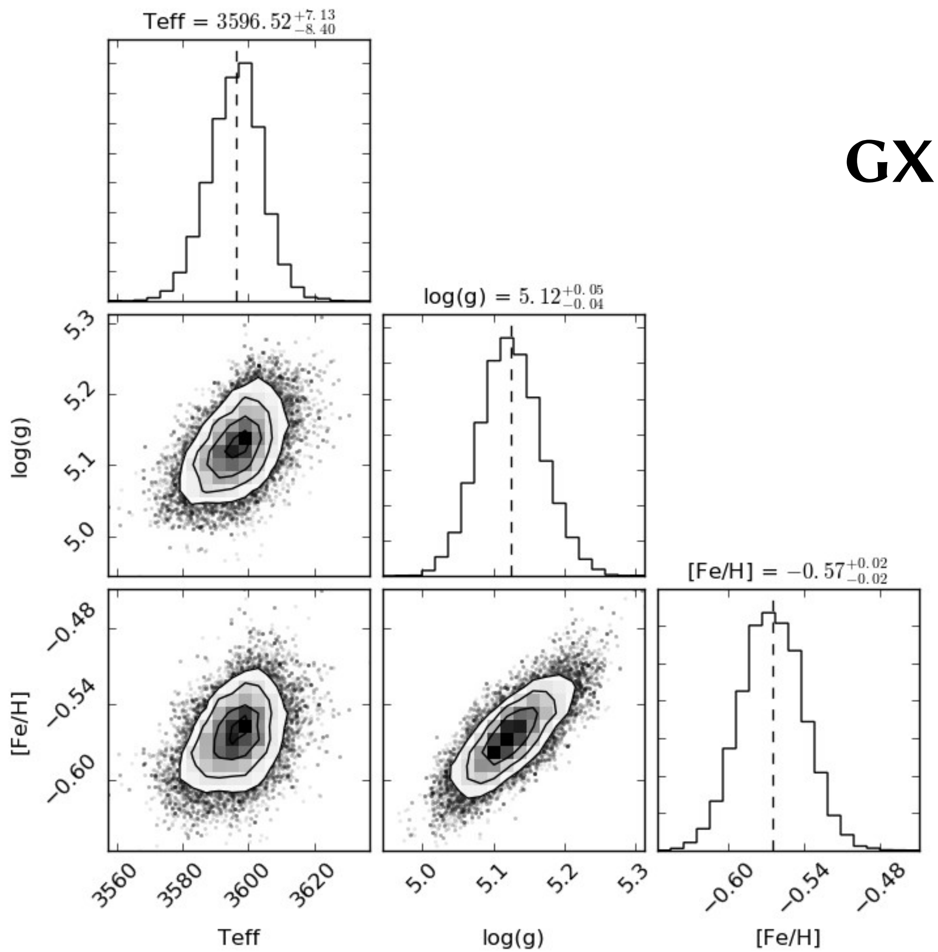
1250 iterations, 40 walkers , burn-in 250 iterations





Python packages: scipy.interpolate, emcee (MCMC)

StePar Synthesis (Results)



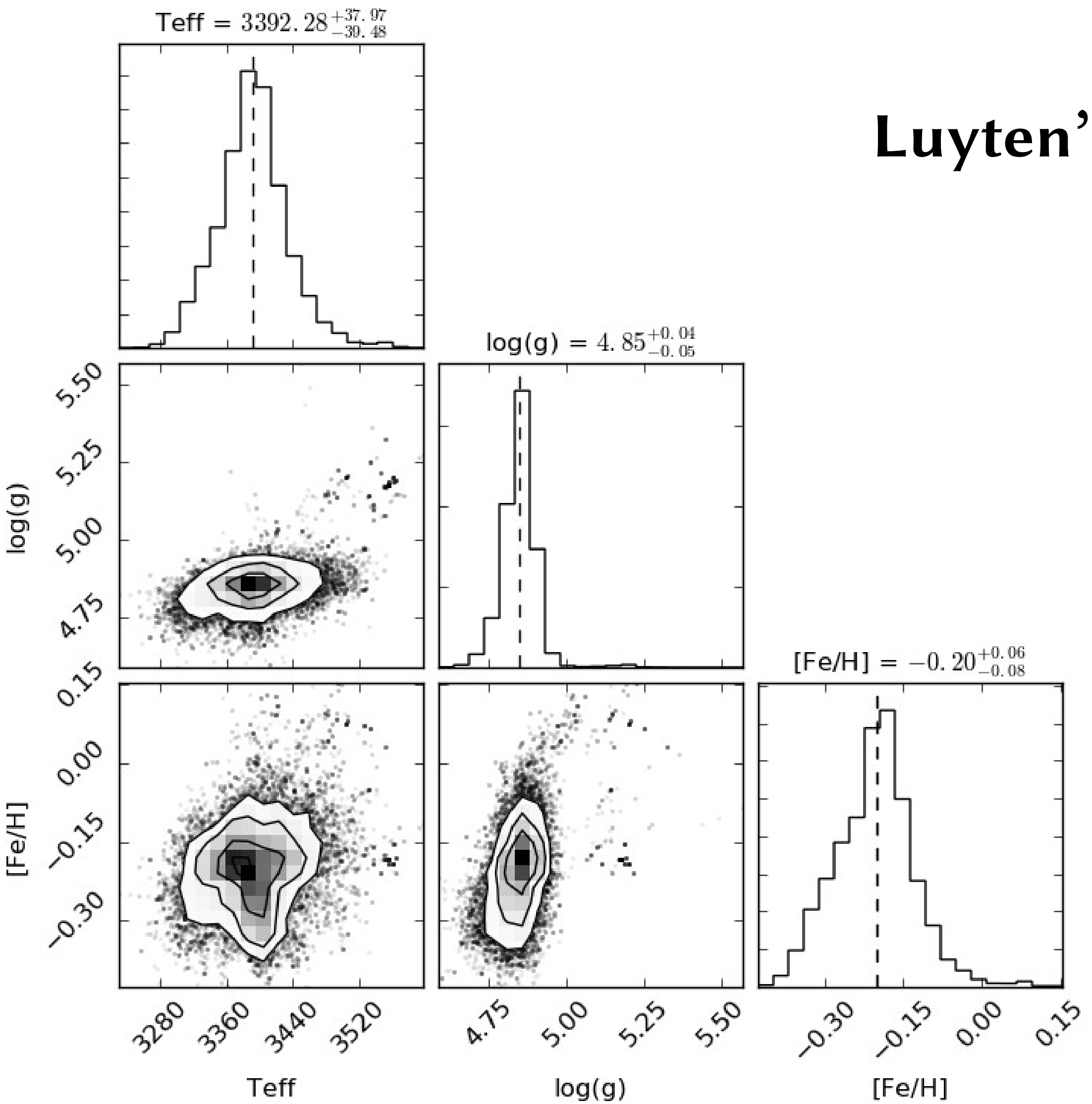
GX And (J00183+440) **M1.0 V**

T_{eff} = 3596 ± 8 K

log g = 5.12 ± 0.05 dex

[M/H] = -0.57 ±0.02 dex

StePar Synthesis (Results)



Luyten's star(J07274+052)
M3.5 V

T_{eff} = 3392 ± 38 K
log *g* = 4.85 ± 0.05 dex
[M/H] = -0.20 ±0.07 dex

Teegarden's star:
⚠ Work still in progress

StePar Synthesis (Results)

Other CARMENES **M1.0 V** stars (StePar in Action)

Karmn	Name	$T_{eff} \pm \Delta T_{eff}$	$\log g \pm \Delta(\log g)$	$[M/H] \pm \Delta[M/H]$
J00051+457	GJ 2	3665 ± 5	4.66 ± 0.02	-0.17 ± 0.01
J00183+440	GX And	3596 ± 8	5.12 ± 0.05	-0.57 ± 0.02
J05415+534	HD233153	3762 ± 13	4.60 ± 0.04	-0.07 ± 0.03
J10023+480	BD+481829	3651 ± 12	4.51 ± 0.22	-0.21 ± 0.03
J10251-102	BD-093070	3668 ± 5	4.63 ± 0.02	-0.14 ± 0.02
J11054+435	BD+442051	3604 ± 11	4.96 ± 0.06	-0.70 ± 0.03
J13209+342	BD+352429	3658 ± 6	4.70 ± 0.02	-0.20 ± 0.01
J14010-026	HD 122303	3646 ± 11	4.75 ± 0.03	-0.21 ± 0.01
J14082+805	BD+81465	3685 ± 6	4.04 ± 0.03	-0.06 ± 0.02
J15598-082	BD-074156	3651 ± 7	4.72 ± 0.02	-0.20 ± 0.01
J16581+257	BD+253173	3665 ± 6	4.66 ± 0.02	-0.17 ± 0.01
J17378+185	BD+183421	3592 ± 12	4.10 ± 0.15	-0.65 ± 0.03
J18051-030	HD 165222	3602 ± 6	4.56 ± 0.30	-0.42 ± 0.07
J18409-133	BD-135069	3679 ± 13	4.13 ± 0.19	-0.10 ± 0.02
J21221+229	GSC 02187-00512	3645 ± 28	4.96 ± 0.18	-0.20 ± 0.07
J22330+093	BD+084887	3601 ± 4	4.57 ± 0.29	-0.37 ± 0.06
J22559+178	StkM 1-2065	3677 ± 5	4.04 ± 0.03	-0.11 ± 0.01
J23245+578	BD+572735	3706 ± 11	4.06 ± 0.05	0.00 ± 0.02
J23492+024	BR Psc	3533 ± 16	4.81 ± 0.09	-0.86 ± 0.03

The end