alpha Cen A&B: Fundamental Parameters the return from the atmosphere studies

The atmosphere gives

Teff
logg
Z/X : Fe/H, O/H, Li, …
L/Lo : depend on Teff, logg, M/H via BC
Vsini
VR

Other Fundamental param using diagnostics of the atmosphere:
R (interferometry data + LD)
Mass : astrometric orbit, VR, parallaxe
Age

alpha Cen A&B: Fundamental Parameters the return from the atmosphere studies

Teff, Mass, Linear Radius, (logg), Z/X, age (HR studies + asteroseismology)

Excellent data exist from:
photometry, astrometry, kinematics, spectrometry, interferometry, asteroseismology

→ Alpha Cen A&B are the best **Gaia benchmark stars** as defined in Heiter+15 (see talk by Heiter)

but **Gaia** cannot observe it: too bright !
Proxima for an help for the astrometry

Note :
The proximity of the 2 stars is a problem with the overlapping of their light: stars are very bright (self pollution)

alpha Cen A&B: Fundamental Parameters the return from the atmosphere studies

Recent studies :

Akenson+21: parallaxe, masses (radio astrometry)
Kervella+17 : angular diameter (IR interferometry VLTI/PIONIER)
(under hypothesis of Z/X for LD and BC)
→ **Teff, logg**

From these 2 studies one get strong constraints on Teff & logg

Masses, Linear Radius, Teff, logg: all with incertainties ≤ of 1 % !

A : **Teff=5800K +-13K logg=4.30+-0.01** L/Lo=1.5059+-0.0019 R/Ro=1.2175+-0.0055
B : **Teff=5236K +-13K logg=4.53+-0.01** L/Lo=0.4981+-0.0007 R/Ro=0.8591+-0.0036

alpha Cen A&B: Fundamental Parameters the return from the atmosphere studies

Teff_A=5800+-13K
Teff_B=5236+-13K

How does this compare with litterature?

A : 5720 K < Teff < 5850 K see Morel Th.2018
B : 5200 K < Teff < 5350 K ‘’

I based my paper Thévenin+02 on Chmiliewski+94 : 5800K (A) & 5325K (B)
BUT
I corrected these values to **5790**+-30K (A) and **5260**+-50K (B) in particular B based on H_alpha that I found too high.

→ very close to suggested values using Akeson+21 & Kervella+17

alpha Cen A&B: Fundamental Parameters the return from the atmosphere studies

Teff_A=5800+-13K
Teff_B=5236+-13K

Let see what Morel, 2018 write

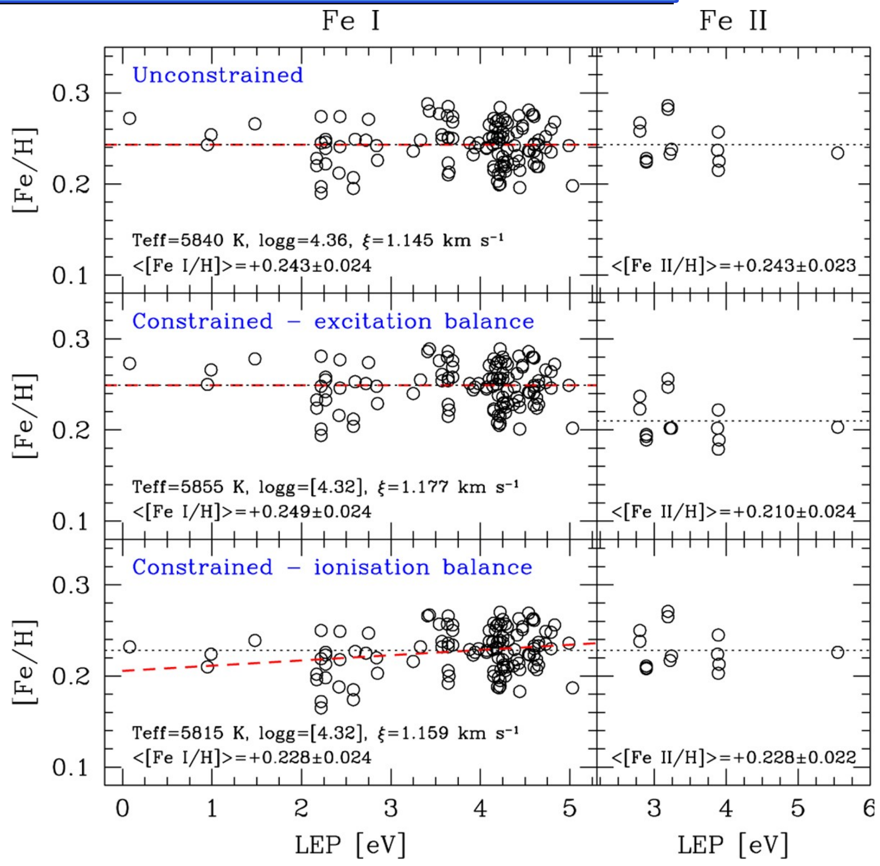
As summarised by Heiter et al. (2015), the parameters of both stars are accurately known thanks to nearly model-independent techniques: Teff from interferometry and logg from asteroseismology. The former offers an opportunity to assess the accuracy of our Teff estimates (Sect. 5.1). We adopt as reference the values recently determined by Kervella et al. (2017a) from combining their VLTI/PIONIER measurements of the limb-darkened linear radii with the bolometric fluxes of Boyajian et al. (2013): 5795 ± 19 and 5231 ± 21 K for α Cen A and B, respectively. These values are fully consistent with those reported by Heiter et al. (2015) based on different interferometric measurements (Kervella et al. 2003; Bigot et al. 2006). On the other hand, it is becoming increasingly popular to use the asteroseismic gravity as prior for the spectroscopic analysis (e.g. Huber et al. 2013). We therefore also conducted a constrained analysis whereby log g is frozen to the asteroseimic value. We assume the recommended values quoted by Heiter et al. (2015): log g = 4.32 ± 0.02 and 4.53 ± 0.02 dex for α Cen A and B, respectively. They are computed from scaling relations (see their Eq. (3)) making use of the frequency of maximum oscillation power, νmax, determined from RV time series by Kjeldsen et al. (2008). The logg values are compatible within the errors with those derived by grid-based seismic studies (e.g. Creevey et al. 2013) or through a combinationof interferometric, astrometric, and spectroscopic measurements yielding the stellar radii and masses (e.g. Kervella et al. 2017a)5.

alpha Cen A&B: Fundamental Parameters the return from the atmosphere studies

Teff_A=5829+-6K
Teff_B=5189+-18K
(Morel, Th 2018)

These values are not compatible with a logg asteroseismic or a logg computed with M and R !
The fig shown is not convincing me

I desagree!



alpha Cen A&B: Fundamental Parameters the return from the atmosphere studies

Adopt Teff as:

Teff_A=5800+-13K
Teff_B=5236+-13K

Now what about logg?

alpha Cen A&B: Fundamental Parameters the return from the atmosphere studies

logg_A= 4.30+-0.01
logg_B= 4.53+-0.01

from:
Astrometric masses and parallaxe: Akeson+21
Angular diameters: Kervella+17

Adopted Thévenin+02 similar values
Heiter+15 similar values...

alpha Cen A&B: Fundamental Parameters the return from the atmosphere studies

logg_A= 4.30+-0.01
logg_B= 4.53+-0.01

And Morel 2018 wrote

On the other hand, it is becoming increasingly popular to use the asteroseismic gravity as prior for the spectroscopic analysis (e.g. Huber et al. 2013). We therefore also conducted a constrained analysis whereby log g is frozen to the asteroseimic value. We assume the recommended values quoted by Heiter et al. (2015): log g = 4.32 ± 0.02 and 4.53 ± 0.02 dex for α Cen A and B, respectively. They are computed from scaling relations (see their Eq. (3)) making use of the frequency of maximum oscillation power, νmax, determined from RV time series by Kjeldsen et al. (2008). The logg values are compatible within the errors with those derived by grid-based seismic studies (e.g. Creevey et al. 2013) or through a combination of interferometric, astrometric, and spectroscopic measurements yielding the stellar radii and masses (e.g. Kervella et al. 2017a)5.

Morel adopted for B logg=4.3 same as for A forcing the ionization balance. It compensates the lower Teff adopted.

Definitively unacceptable because of the difference in mass and evolution compared to A

alpha Cen A&B: Fundamental Parameters the return from the atmosphere studies

From
Astrometric masses and parallaxe: Akeson+21
Angular diameters: Kervella+17
logg_A= 4.30+-0.01
logg_B= 4.53+-0.01

From
Asteroseismology Creevey+13
logg_A= 4.312+-0.01
logg_B= 4.527+-0.01

alpha Cen A&B: Fundamental Parameters the return from the atmosphere studies

Suggestion : adopt

logg_A= 4.30+-0.01
logg_B= 4.53+-0.01

With a mass of 1.079 for A
and 0.909 for B

Now what are the chemical element abundances of A & B ?

alpha Cen A&B: Fundamental Parameters the return from the atmosphere studies

Let see what the good paper by Morel (2018) discussing the litterature and what his own analysis suggests as points of discussion/desagreement

alpha Cen A&B: Fundamental Parameters the return from the atmosphere studies

T. Morel: The chemical composition of α Centauri AB revisited

Table 2. Stellar parameters adopted by previous abundance studies in the literature.

Study	α Cen A T_{eff} [K]	α Cen A log g [cgs]	α Cen A ξ [km s^{-1}]	α Cen A [Fe/H]	α Cen B T_{eff} [K]	α Cen B log g [cgs]	α Cen B ξ [km s^{-1}]	α Cen B [Fe/H]
Reference values	5795 ± 19	4.32 ± 0.02	...	...	5231 ± 21	4.53 ± 0.02	...	...
Edvardsson (1988)[a]	5750	4.42 ± 0.11	1.5	0.20	5250	4.65 ± 0.11	1.3	0.26
Neuforge-Verheecke & Magain (1997)	5830 ± 30	4.34 ± 0.05	1.09 ± 0.11	0.25 ± 0.02	5255 ± 50	4.51 ± 0.08	1.00 ± 0.08	0.24 ± 0.03
Allende Prieto et al. (2004)[b]	5519 ± 123	4.26 ± 0.10	1.04	0.12 ± 0.05	4970 ± 180	4.59 ± 0.04	0.81	0.27 ± 0.07
Gilli et al. (2006)[c]	5844 ± 42	4.30 ± 0.19	1.18 ± 0.05	0.28 ± 0.06	5199 ± 80	4.37 ± 0.27	1.05 ± 0.10	0.19 ± 0.09
Porto de Mello et al. (2008)	5847 ± 27	4.34 ± 0.12	1.46 ± 0.03	0.24 ± 0.03	5316 ± 28	4.44 ± 0.15	1.28 ± 0.12	0.25 ± 0.04
Bruntt et al. (2010)	5745 ± 80	4.31 ± 0.06	1.00 ± 0.07	0.22 ± 0.07	5145 ± 80	4.52 ± 0.04	0.83 ± 0.07	0.30 ± 0.07
Jofré et al. (2015)[d]	5792 ± 16	4.30 ± 0.01	1.20 ± 0.07	0.24 ± 0.08	5231 ± 20	4.53 ± 0.03	0.99 ± 0.31	0.22 ± 0.10
Luck (2018)[e]	5753	4.26	1.07	0.20 ± 0.04	5242	4.57	0.25	0.29 ± 0.05
This study[f]	5829 ± 6	4.35 ± 0.02	1.26 ± 0.02	0.24 ± 0.01	5189 ± 18	4.30 ± 0.05	0.95 ± 0.04	0.22 ± 0.02

alpha Cen A&B: Fundamental Parameters

See Morel 2018

using Asplund+09 for the Solar refer

Alpha Cen A&B

are

Oxygen deficient !

To be re-done

	α Cen A			α Cen B			A – B
	N	Before GCE	After GCE	*N*	Before GCE	After GCE	
T_{eff} [K]	9	5829 ± 6		9	5189 ± 18		...
log *g* [cgs]	9	4.35 ± 0.02		9	4.30 ± 0.05		...
ξ [km s^{-1}]	9	1.265 ± 0.012		9	0.950 ± 0.039		...
[Fe/H][a]	9	0.237 ± 0.007	...	9	0.221 ± 0.016	...	0.012 ± 0.018
[C/Fe]	2	0.025 ± 0.018	–0.018 ± 0.036	2	–0.001 ± 0.045	–0.044 ± 0.054	0.037 ± 0.049
[O/Fe]	6	–0.046 ± 0.014	–0.062 ± 0.019	6	–0.074 ± 0.040	–0.090 ± 0.042	0.030 ± 0.043
[Na/Fe]	7	0.094 ± 0.010	0.058 ± 0.027	7	0.128 ± 0.036	0.092 ± 0.044	–0.029 ± 0.038
[Mg/Fe]	6	0.013 ± 0.023	–0.004 ± 0.026	6	0.044 ± 0.041	0.027 ± 0.043	–0.028 ± 0.048
[Al/Fe]	7	0.044 ± 0.013	0.013 ± 0.025	7	0.077 ± 0.031	0.046 ± 0.038	–0.030 ± 0.034
[Si/Fe][b]	8	0.024 ± 0.009	0.009 ± 0.014	8	0.034 ± 0.018	0.019 ± 0.021	–0.007 ± 0.021
[Ca/Fe][b]	8	–0.020 ± 0.010	–0.017 ± 0.011	8	0.001 ± 0.030	0.004 ± 0.030	–0.024 ± 0.032
[Sc/Fe][b]	4	0.029 ± 0.014	–0.002 ± 0.026	5	0.036 ± 0.018	0.005 ± 0.028	–0.011 ± 0.024
[Ti/Fe][b]	8	0.016 ± 0.011	0.005 ± 0.014	8	0.063 ± 0.033	0.052 ± 0.034	–0.044 ± 0.035
[V/Fe]	5	0.019 ± 0.017	0.017 ± 0.017	5	0.073 ± 0.050	0.071 ± 0.050	–0.049 ± 0.053
[Cr/Fe][b]	8	0.011 ± 0.011	0.017 ± 0.012	7	0.043 ± 0.033	0.049 ± 0.033	–0.038 ± 0.036
[Mn/Fe]	2	0.034 ± 0.019	0.024 ± 0.021	0	...	...	...
[Co/Fe]	4	0.051 ± 0.019	0.040 ± 0.020	4	–0.019 ± 0.044	–0.030 ± 0.045	0.065 ± 0.048
[Ni/Fe]	8	0.049 ± 0.009	0.028 ± 0.018	8	0.057 ± 0.019	0.036 ± 0.024	–0.009 ± 0.022
[Cu/Fe]	2	0.058 ± 0.020	0.016 ± 0.035	2	0.070 ± 0.034	0.028 ± 0.045	–0.012 ± 0.040
[Zn/Fe]	4	0.029 ± 0.027	0.001 ± 0.033	4	0.075 ± 0.031	0.047 ± 0.037	–0.044 ± 0.042
[Y/Fe]	3	–0.034 ± 0.013	0.008 ± 0.032	3	0.047 ± 0.029	0.089 ± 0.041	–0.080 ± 0.032
[Zr/Fe]	1	0.033 ± 0.053	0.064 ± 0.057	1	0.122 ± 0.060	0.153 ± 0.064	–0.090 ± 0.081
[Ba/Fe]	5	–0.052 ± 0.025	0.017 ± 0.055	5	–0.042 ± 0.025	0.027 ± 0.055	–0.017 ± 0.036
[Ce/Fe]	1	–0.065 ± 0.055	–0.034 ± 0.059	0	...	...	...

alpha Cen A&B: Fundamental Parameters

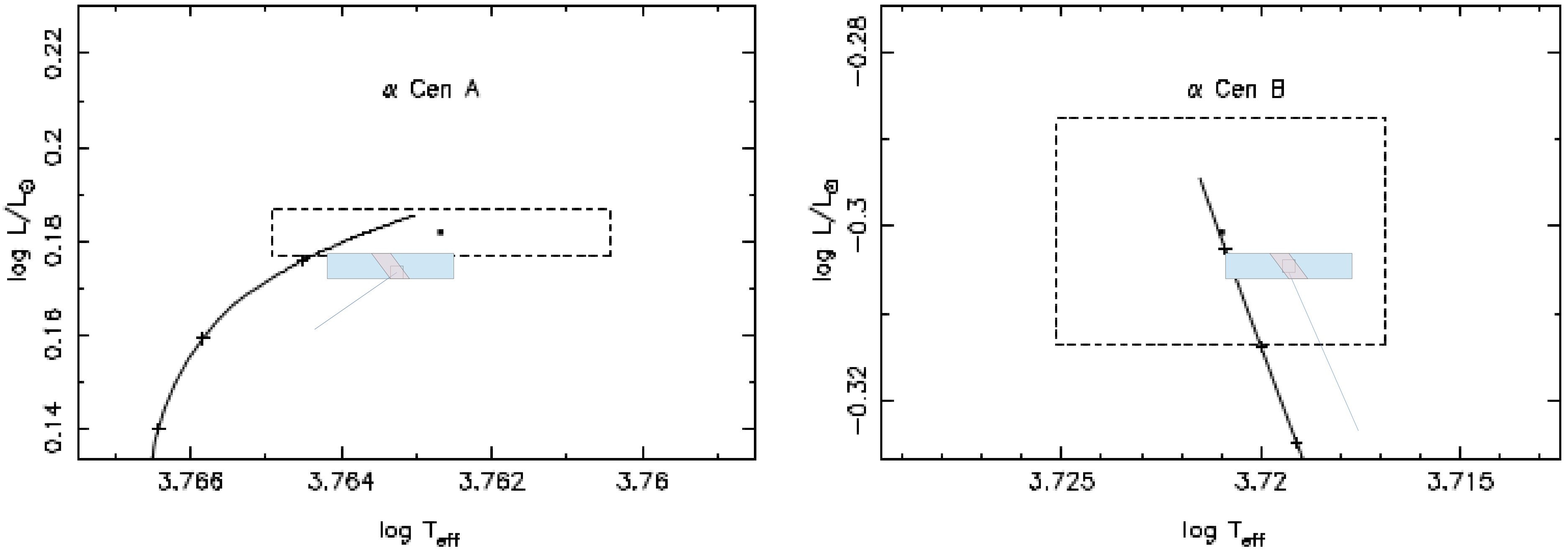
1) the binary looks very well constrained with 1D LTE atmospheres
A : +0.24 dex B : +0.22 dex +-0.05 dex

2) **surface chemical element abundances need to be revisited & improved with 3D atmospheres & 3D synthetic spectra**
same as done for the Sun (Asplund+09, Cafau+08, Magg+22)
The main difference between 1D & 3D for the Sun is Oxygen O/H
AND
controvertial but O/H_3D < O/H_1D
Recently Magg+22 suggest O/H=8.77 only -0.1dex lower than old values and Fe/H a bit more abundant 7.52

3) What about alpha Cen A&B : IMPORTANT for Z/X used in computations
This O/H deficiency is already suggested by the 1D spectro analysis !

alpha Cen A&B: Fundamental Parameters
Evolutionary Tracks

Thévenin et al.: Asteroseismology of α Cen (2002)



New blue error boxes: solution age = 5.910 Ga
with masses, Lum, (Akeson+21), CESAM2k (Morel & Pichon)

alpha Cen A&B: Fundamental Parameters One solution not based on asteroseismology

		alpha cenA		alpha cen B
			Age = 5.905 Ga +- ?	
Mass		1.079		0.909
Y		0.300		0.300
Teff	K	5802		5240
log g	dex	4.529		4.301
[Z/X]	dex	0.237		0.220
Luminosity		1.504		0.858
Mixing length		1.587		1.705

alpha Cen A&B: Fundamental Parameters

Modelisation to be improved.

See talk by Michael & others

Overshooting ?

alpha Cen A&B: Fundamental Parameters

→ Produce synthetic 3D spectra for A & B (see **Bigot+08 [Fe/H] = 0.16**)

↓

Get 3D chemical element abundances

and conclude the comparaison with Sun

Is it a common property of stars with exoplanets to have O deficiency ?

alpha Cen A&B: Fundamental Parameters
Signature of exoplanets ?

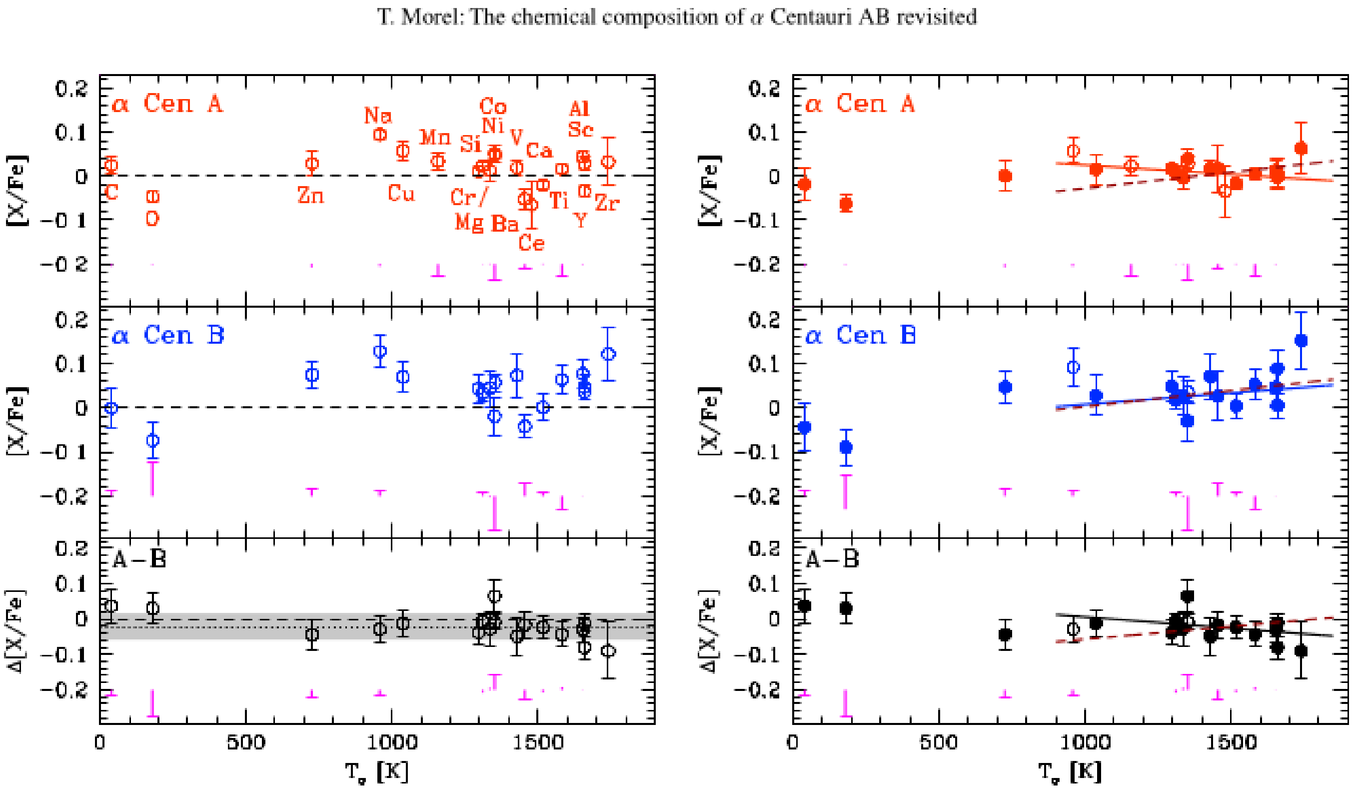
Morel,Th 2018

6.3.2. **Trends with condensation temperature**

Meléndez et al. (2009) and Ramírez et al. (2009) convincingly demonstrated that the Sun is depleted at the 20% level in species that can easily condensate in dust grains (refractory elements) relative to volatiles when compared to most solar analogues. They showed that only ∼15% of all the stars in their samples have an abundance pattern closely resembling that of the Sun or are poorer in refractories. Moreover, the level of depletion is an increasing function of Tc. They proposed that a similar behaviour in other stars might provide indirect evidence for the existence of rocky material trapped in terrestrial planets (see also, e.g. Ramírez et al. 2010). Chambers (2010) and Meléndez et al. (2012) went a step further by claiming that an extremely precise abundance analysis can help to constrain the total mass and relative amount of Earth-like and meteoritic material around the star. How gas giant planets fit into this scenario is not completely clear, but it has been postulated that their formation could lead to a global metal deficiency in the parent star and not necessarily a discernable trend in the [X/Fe]–Tc relation (Ramírez et al. 2014).

alpha Cen A&B:

Morel,Th 2018



There is no clear conclusions on that dependency of the elements with the temperature of condensation

I agree with the Morel's conclusion : one need 3D to progress non-LTE ?

alpha Cen A&B: Fundamental Parameters

Suggestion for RVs

1) to produce synthetic 3D spectra for A & B

↓

2) Reprocess all HARPS spectra with these two 3D spectra, used as masks for the cross correlation and get the Vrs.

The advantage : the convective shift is present in individual lines (blueshift and redshift): no need of global conv_shift corrections for A&B

M&R are very well known: Grav Shift perfectly known to be corrected
reprocess the astrometry : get new masses ?

alpha Cen A&B: Fundamental Parameters

With these 3D spectra +HARPS … :

One can expect with so **accurate RVs to detect exoplanets**
(Lionel's talk, S. Sullis & others)

New asteroseismic frequencies

alpha Cen A&B: Fundamental Parameters

Abundances of **alpha Cen A&B and Proxima** suggest some questions.
Same origin?

[Fe/H]=0.24/0.22 for A&B
[Fe/H]=0.05 for Proxima (Maldonado+20) [M/H]-0.04

Is Proxima co-evolved ? Need to redo the abundance analysis of Proxima

Explore polluted models of A&B compared to Proxima (fully convective).

We did some models of the Sun polluted (lMorel & Thévenin, 2000 unpublished)

Should we redo such exercice for the Sun and alpha Cen A&B ?
To explain depleted Li ?

alpha Cen A&B: Fundamental Parameters

Li & Be are depleted in alpha Cen A&B (and also 16 Cyg!)

Oreshina+17, Thévenin+17
Study of the Sun and solar twins demonstrate that in the early phase of the stars an increase of the convective zone is able to explain the low Li abundance

In contrast, at the pMS stage, an overshooting region with a value of approximately 0.18H P is enough to produce the observed lithium depletion.

*If we conclude that the dominant **lithium burning takes place during the pMS stage**, the dispersion of the lithium abundance in solar twins is explained by different physical conditions, primarily during the early stage of evolution before the MS.*

Producing polluted models helping ?

alpha Cen A&B: Fundamental Parameters

Li & Be are depleted in alpha Cen A&B (and also 16 Cyg!)

Producing polluted models helping to understand this overshooting?

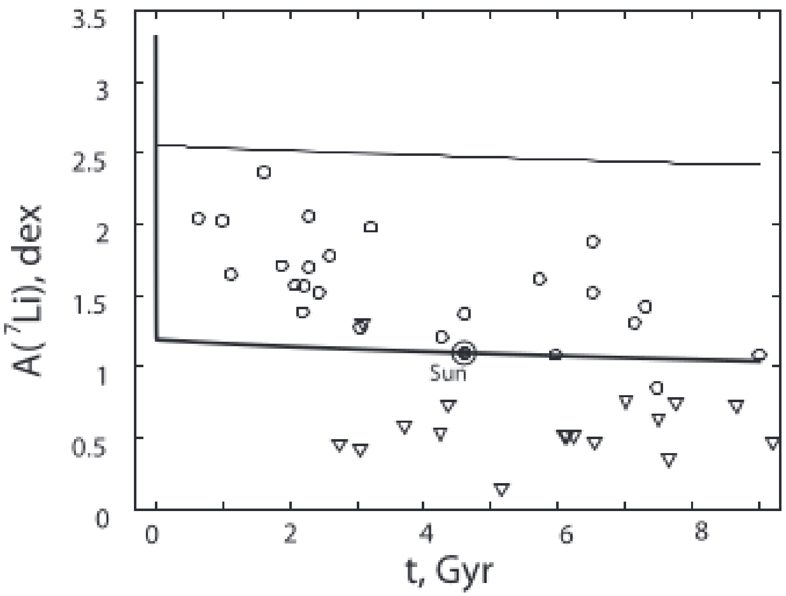


Fig. 6. Evolution of lithium abundance in solar twins. Solid lines show two examples of our computations in framework of early depletion scenario: thin line shows standard solar model without overshooting, thick line shows solar model with overshooting $0.18H_p$. Circles and triangles indicate solar twins considered by (Delgado Mena et al. 2014), and selected over the ranges of parameters proposed by (Carlos et al. 2016); triangles are upper limits on lithium abundance.

alpha Cen A&B: Fundamental Parameters

Conclusions :

1) Teff and logg looks well fixed for A&B.

2) Compute 3D atmospheres and **3D spectra**
Derive 3D abundances to improve [Z/X], discuss **O** and **Li**

3) Used 3D spectra as template for new **VR**s, redo **astrometry (masses)**

4) Detection of exoplanets ?

5) Re-process the evolutionary tracks for the 2 stars : derive an **age**
Explore **Z/X_interior < Z/Xsurface**

6) role of activity ? on **LD on BC (SED) in particular for B**

alpha Cen A&B: Fundamental Parameters

From where alpha Cen is coming from?

Can we trace the past of that star among the neighborhood and compare to the Sun?

THANK YOU!