The Alpha Centauri System

Prospects to new worlds

A tribute to Frédéric Thévenin's Career

26-30 June 2023

Hôtel Saint Paul, Nice

Frédéric Thévenin

More than 40 years dedicated to stellar physics and beyond (to be continued)

XXth century 😉

« Spectroscopic » time

XXIth century

Most fields of stellar physics

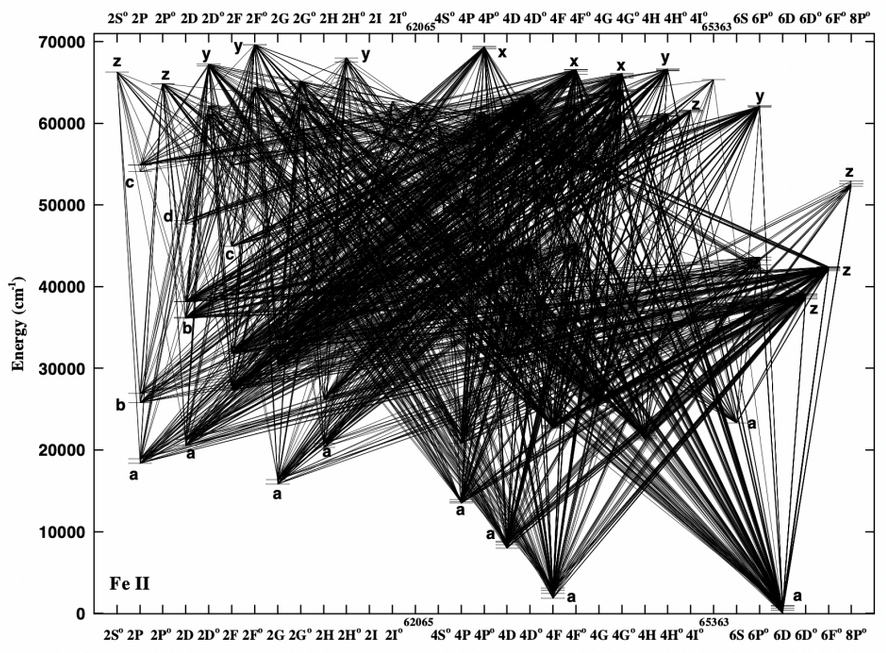
- **Galactic archaeology** (Jasniewicz)
- **Lithium & Beryllium** (Jasniewicz, Vauclair)
- **LMC and SMC** (Jasniewicz)
- **Stellar parameter determination** (R. Foy, Cayrel de Strobel)
- **Primordial nucleosynthesis** (Pacheco Phys Rev)
- **The role of Calcium Triplet** (« Tiens tiens … » Idiart)

… « spectroscopic» epoch concluded with NLTE !!

Thévenin & Idiart (1999)

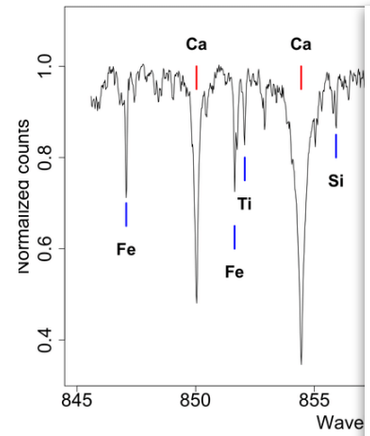
Idiart & Thévenin (2000)

More than 350 citations !



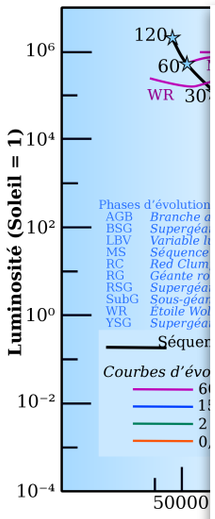
A career with a leitmotiv = Curiosity

Stellar Spectroscopy



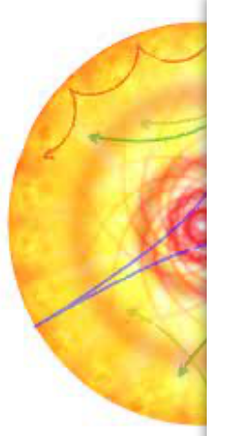
Stellar evolution

(From 2000)



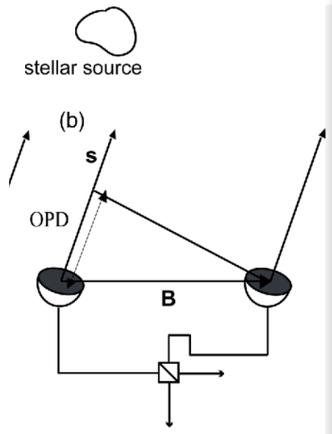
Asteroseismology

(From 2002)



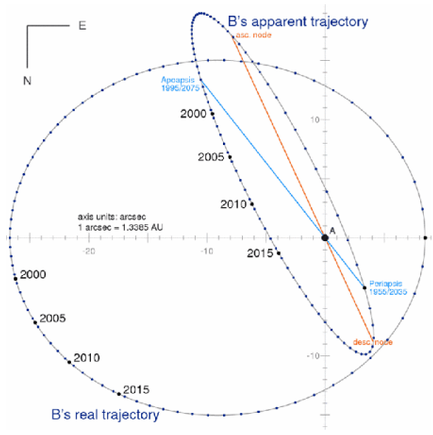
Stellar Interferometry

(From 2003)



Astrometry

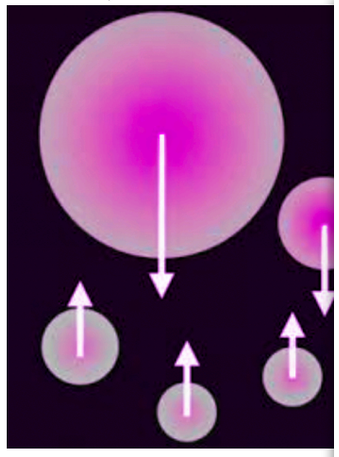
(From 2015)



A career with a leitmotiv = Curiosity

Radiative levitation in stellar evolution

(P. Morel, *in CESAM code*)

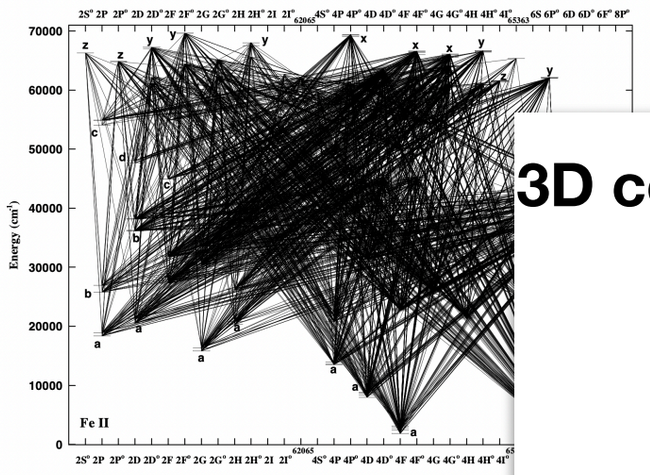


« Dirty » stellar models

(Morel, Pichon … *in CESAM code*)

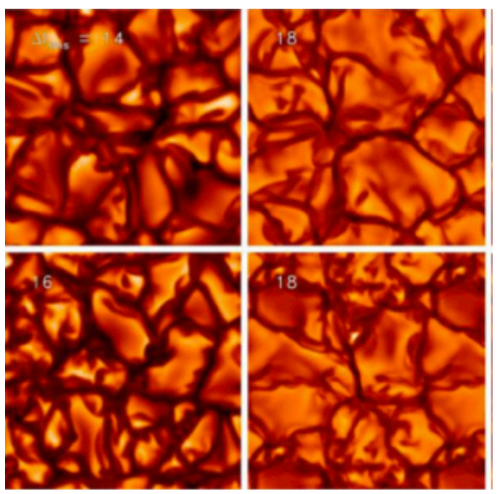
NLTE effects in stellar atmospheres

(Idiart, Merle)



3D convection simulations

(Bigot, Chiavassa …)



Why Alpha Centauri Sytem and this workshop ?

XXth century 😉

« Spectroscopic » time

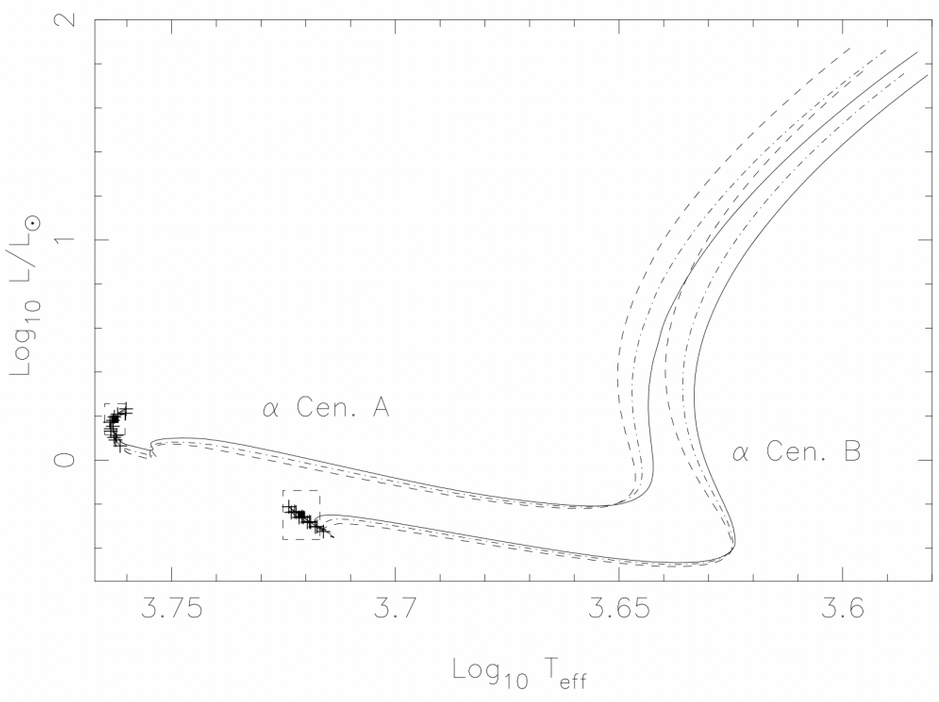
XXIth century

Most fields of stellar physics

2000

Calibrations of α Cen A & B

P. Morel[1], J. Provost[1], Y. Lebreton[2], F. Thévenin[1] and G. Berthomieu[1]



Using **combined** stellar evolutions to calibrated the system

—> Reduced number of « tunable » parameters
(Age, initial composition, …)

Using astrometric masses
(Thanks to the work of **Dimitri Pourbaix** 1969-2021)
Pourbaix+1999, 2002, 2016

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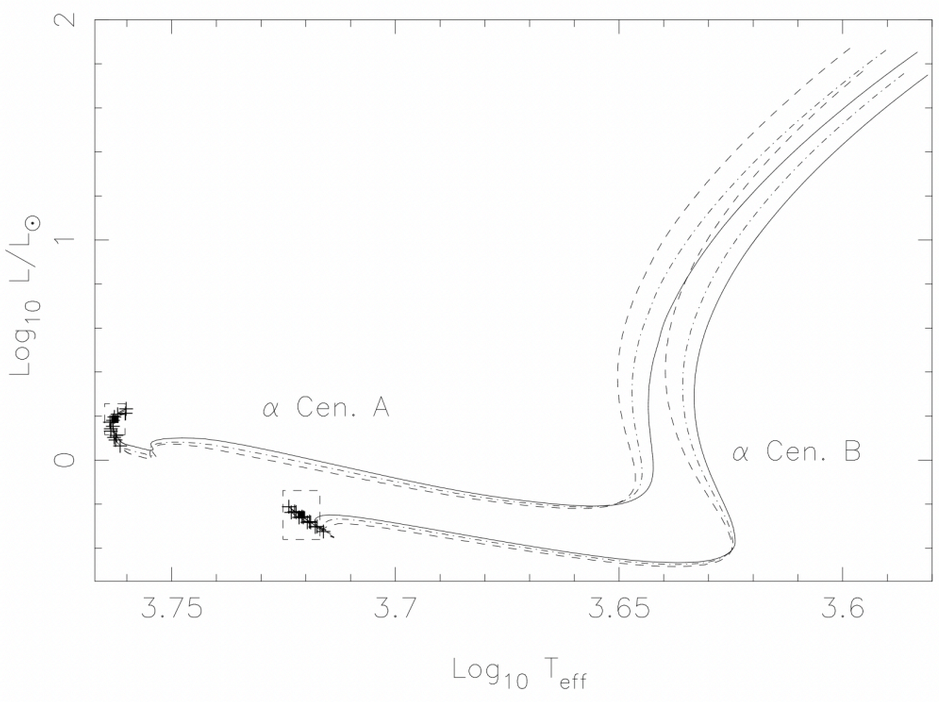
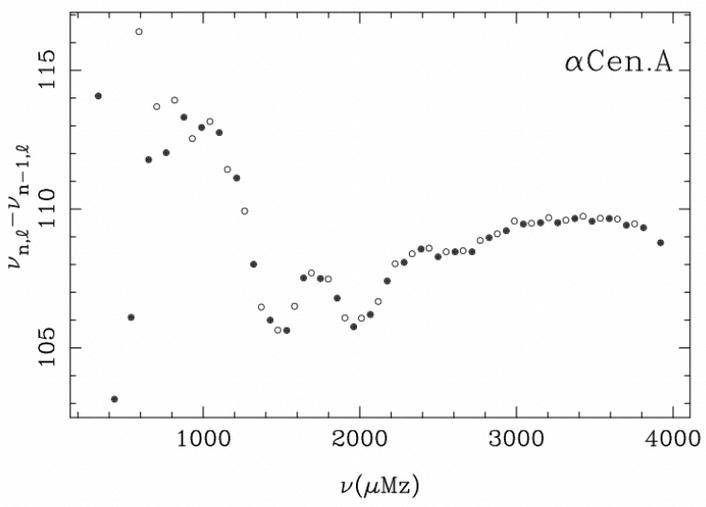
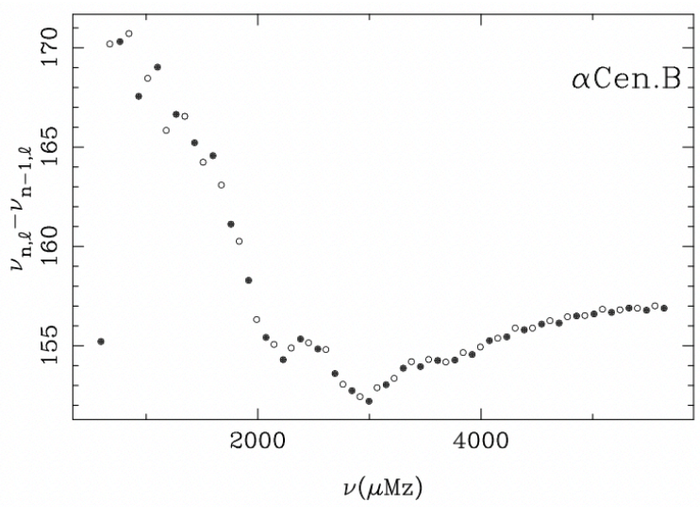


Predicted small and large frequency separations





XXth century 😉

« Spectroscopic » time

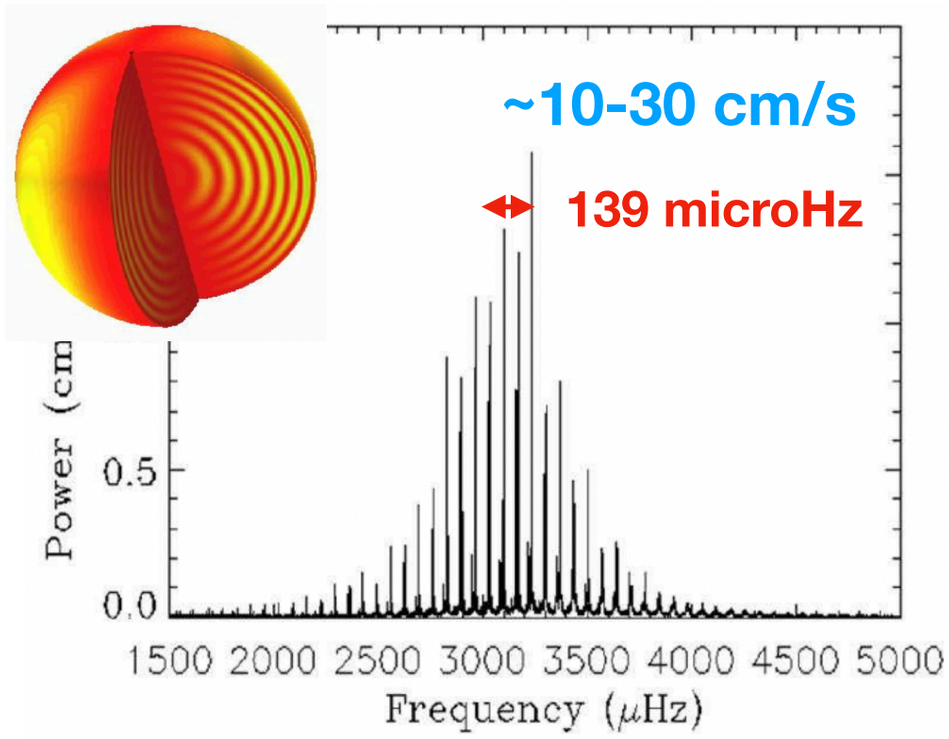
XXIth century

Most fields of stellar physics

2000 **2002**

Late 90s

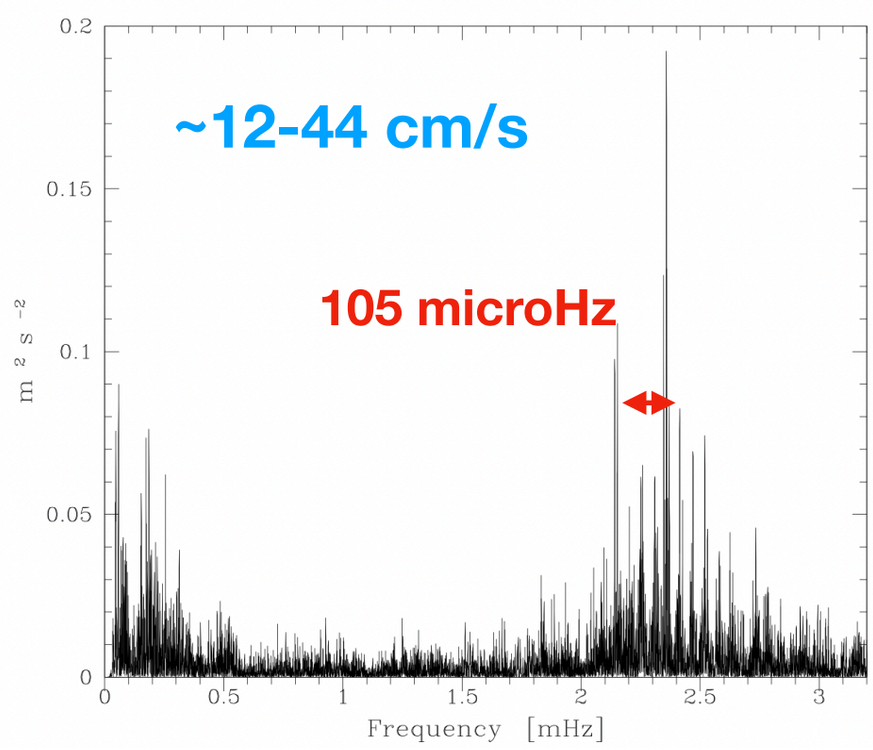
Only the Sun shows oscillations among MS stars



Bouchy & Carrier 2002

First detection of stochastic oscillations in MS stars

In ACenA



XXth century 😉

« Spectroscopic » time

XXIth century

Most fields of stellar physics

2000 **2002**

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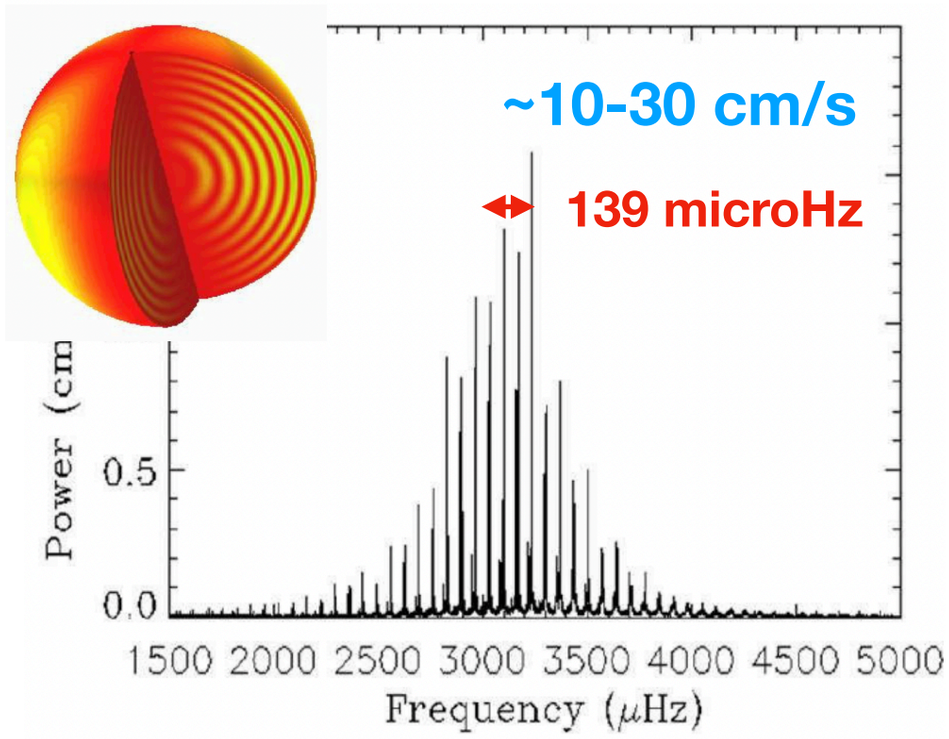
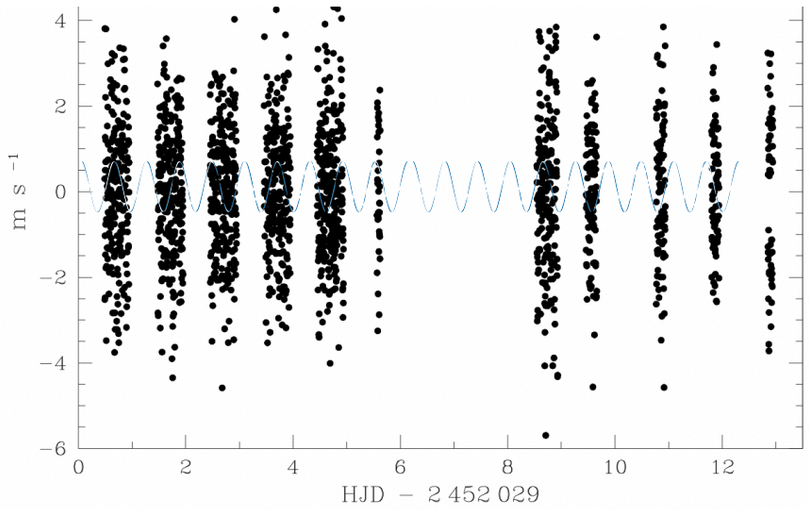


Bouchy & Carrier 2002

First detection of stochastic oscillations in MS stars

In ACenA

Needed stability for « weak » RV signal (ELODIE, OHP)



XXth century 😉

« Spectroscopic » time

XXIth century

Most fields of stellar physics

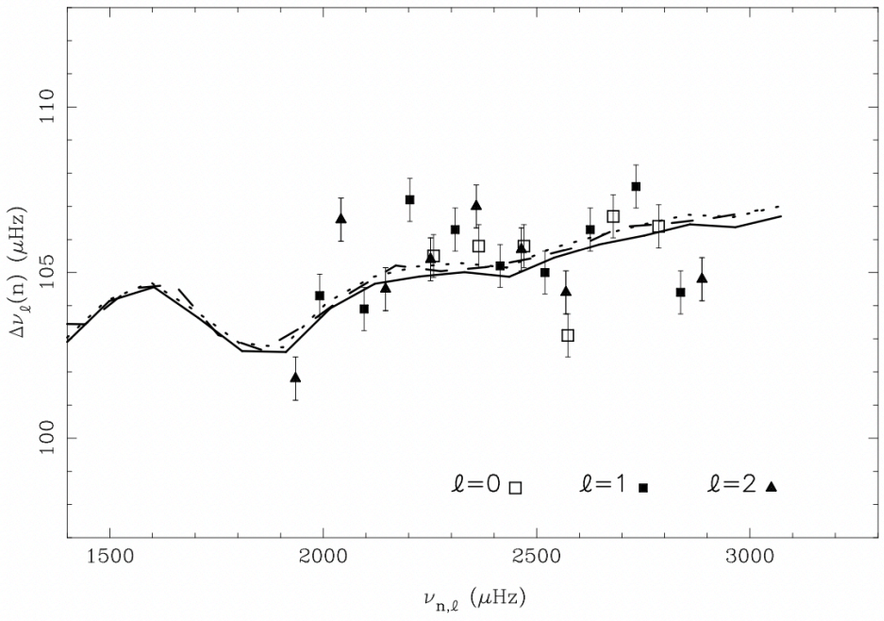
2000 2002

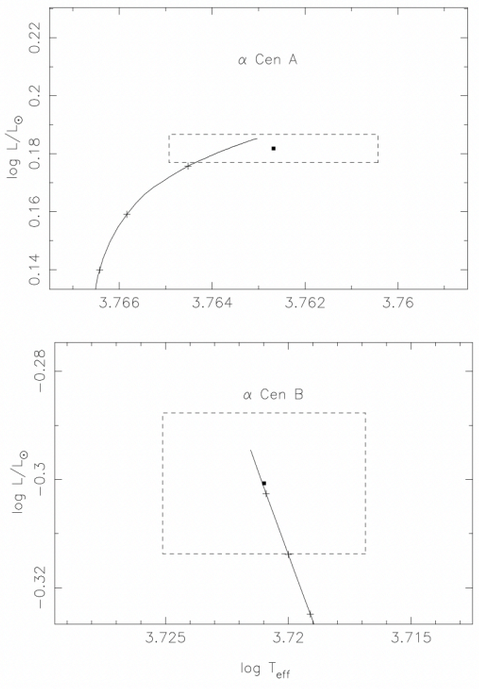
2002

Asteroseismology and calibration of α Cen binary system

F. Thévenin[1], J. Provost[1], P. Morel[1], G. Berthomieu[1], F. Bouchy[2], and F. Carrier[2]

[1] Département Cassini, UMR CNRS 6529, Observatoire de la Côte d'Azur, BP 4229, 06304 Nice CEDEX 4, France.
[2] Observatoire de Genève, 51, chemin des Maillettes, 1290 Sauverny, Switzerland





Inputs →

Outputs →

Others →

New evolutionary models

	α Cen A	α Cen B
$T_{\rm eff}$	5790 ± 30 K	5260 ± 50 K
[Fe/H]	0.20 ± 0.02	0.23 ± 0.03
$L/L_\odot$	1.519 ± 0.018	0.5002 ± 0.016
Δ_0	105.5 ± 0.5	
$t_{\alpha\,\rm Cen}$ (Myr)	$4\,850 \pm 500$	
$Y_{\rm i}$	0.300 ± 0.008	
$(Z/X)_{\rm i}$	0.0459 ± 0.0019	
λ	0.98 ± 0.04	
$M/M_\odot$	1.100 ± 0.006	0.907 ± 0.006
$R/R_\odot$	1.230	0.857
$X_{\rm s}$	0.715	0.694
$Y_{\rm s}$	0.258	0.277
$(Z/X)_{\rm s}$	0.0384	0.0417
$[{\rm Fe/H}]_{\rm s}$	0.195	0.231
$R_{\rm cz}/R_\star$	0.725	0.679
$T_{\rm cz}$	1.893	2.802
$R_{\rm co}/R_\star$	0.052	
$T_{\rm c}$	19.00	13.89
$\rho_{\rm c}$	177.1	117.1
$X_{\rm c}$	0.182	0.428
$Y_{\rm c}$	0.785	0.539

First study of combining calibration and asteroseismology for MS dwarf star

XXth century 😉

« Spectroscopic » time

XXIth century

Most fields of stellar physics

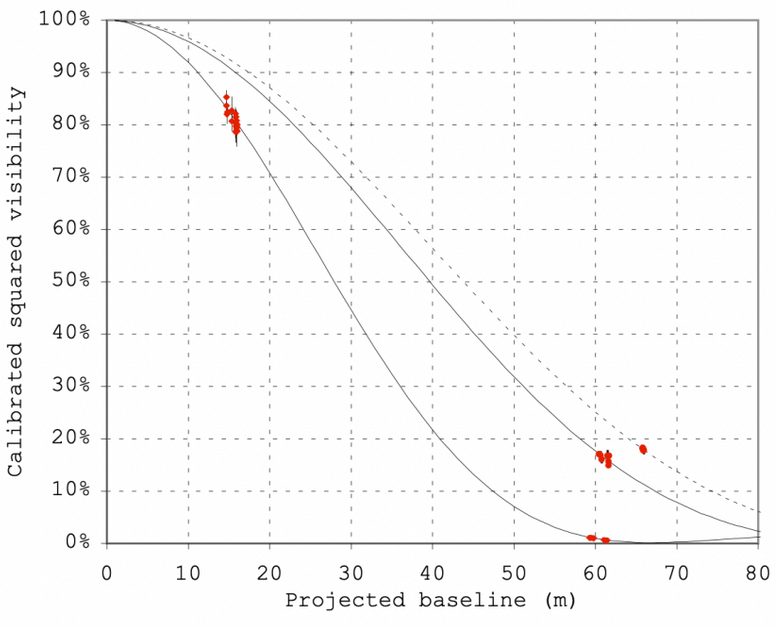
2000 2002 **2003**

2002

The diameters of α Centauri A and B

A comparison of the asteroseismic and VINCI/VLTI views

P. Kervella[1], F. Thévenin[2], D. Ségransan[3], G. Berthomieu[2], B. Lopez[4], P. Morel[2] and J. Provost[2]



First combined study of interferometry and asteroseismology for dwarf MS stars

First determinations of angular diameters of dwarf MS stars

XXth century 😉

« Spectroscopic » time

XXIth century

Most fields of stellar physics

2000 2002 2003 **2004** **2005**

2002 **2003** **2004**

VLTI/VINCI diameter constraints on the evolutionary status of δ Eri, ξ Hya, η Boo

F. Thévenin[1], P. Kervella[2], B. Pichon[1], P. Morel[1], E. Di Folco[3], and Y. Lebreton[4]

The interferometric diameter and internal structure of Sirius A

P. Kervella[1], F. Thévenin[2], P. Morel[2], P. Bordé[3] and E. Di Folco[4]

The diameter and evolutionary state of Procyon A

Multi-technique modeling using asteroseismic and interferometric constraints

P. Kervella[1], F. Thévenin[2], P. Morel[2], G. Berthomieu[2], P. Bordé[3] and J. Provost[2]

VLTI near-IR interferometric observations of Vega-like stars

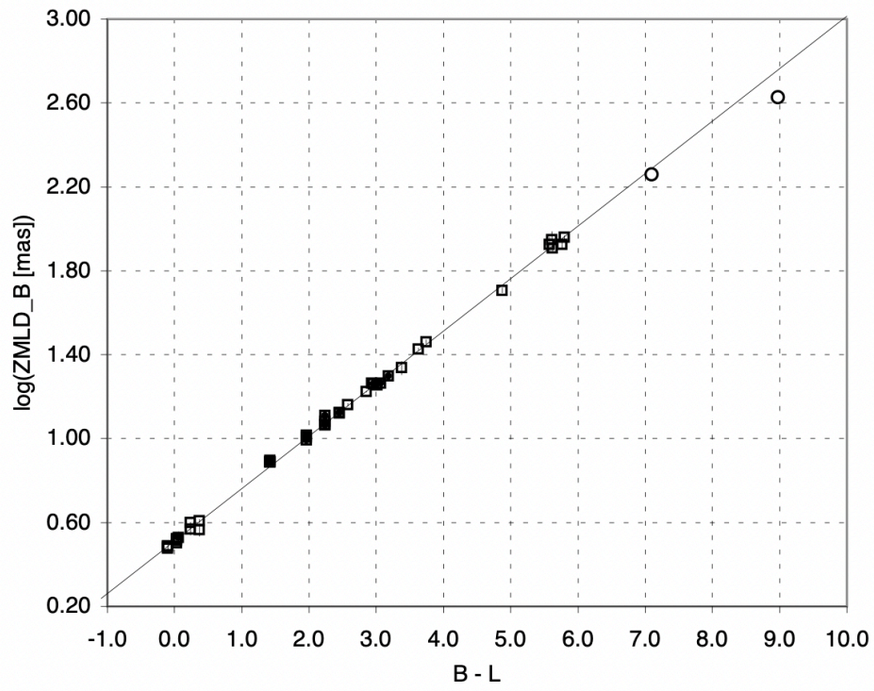
Radius and age of α PsA, β Leo, β Pic, ϵ Eri and τ Cet

E. Di Folco[1], F. Thévenin[2], P. Kervella[3,4], A. Domiciano de Souza[5,6], V. Coudé du Foresto[4], D. Ségransan[7], and P. Morel[2]

The angular sizes of dwarf stars and subgiants

Surface brightness relations calibrated by interferometry

P. Kervella[1,2], F. Thévenin[3], E. Di Folco[4] and D. Ségransan[5]



More than 350 citations!

XXth century 😉

« Spectroscopic » time

XXIth century

Most fields of stellar physics

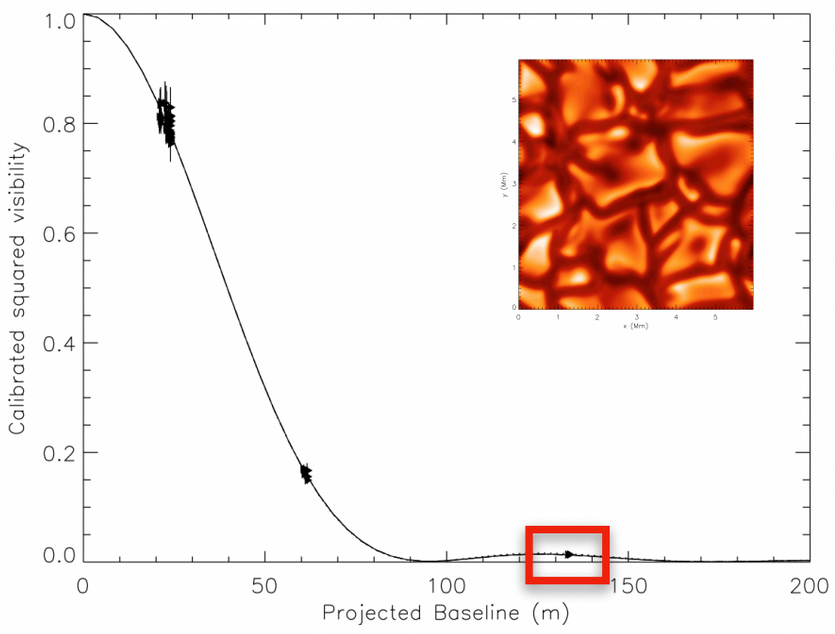
2000 2002 2003 2004 2005 **2006**

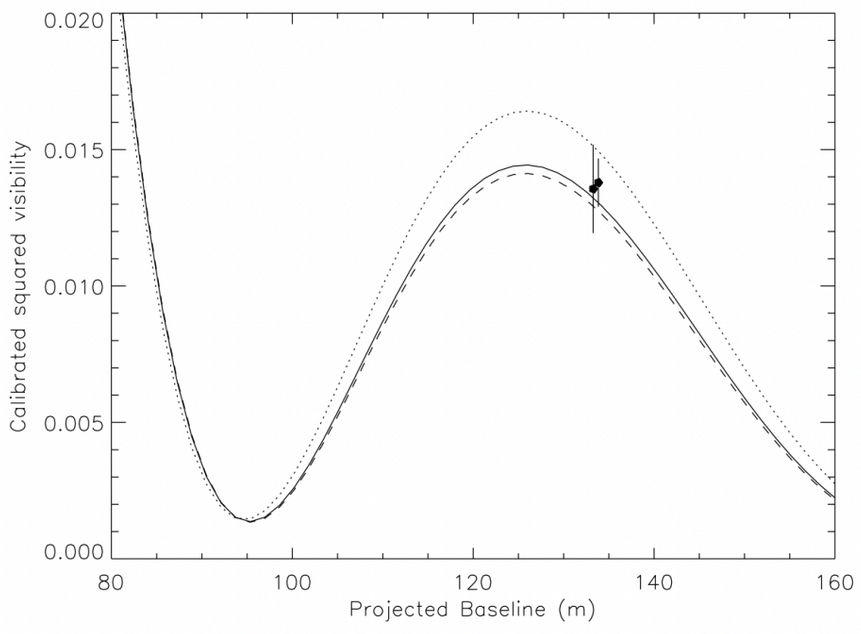
2002 2003 2004

The limb darkening of α Centauri B

Matching 3D hydrodynamical models with interferometric measurements

L. Bigot[1], P. Kervella[2], F. Thévenin[1], and D. Ségransan[3]





$$\theta_{1D} = 6.017 \pm 0.021\,\text{mas}$$

$$\theta_{3D} = 6.000 \pm 0.021\,\text{mas}.$$

$$\theta_{UD} = 5.881 \pm 0.021\,\text{mas}$$

First use of 3D LD for angular diameters of dwarf MS star

XXth century 😉

« Spectroscopic » time

XXIth century

Most fields of stellar physics

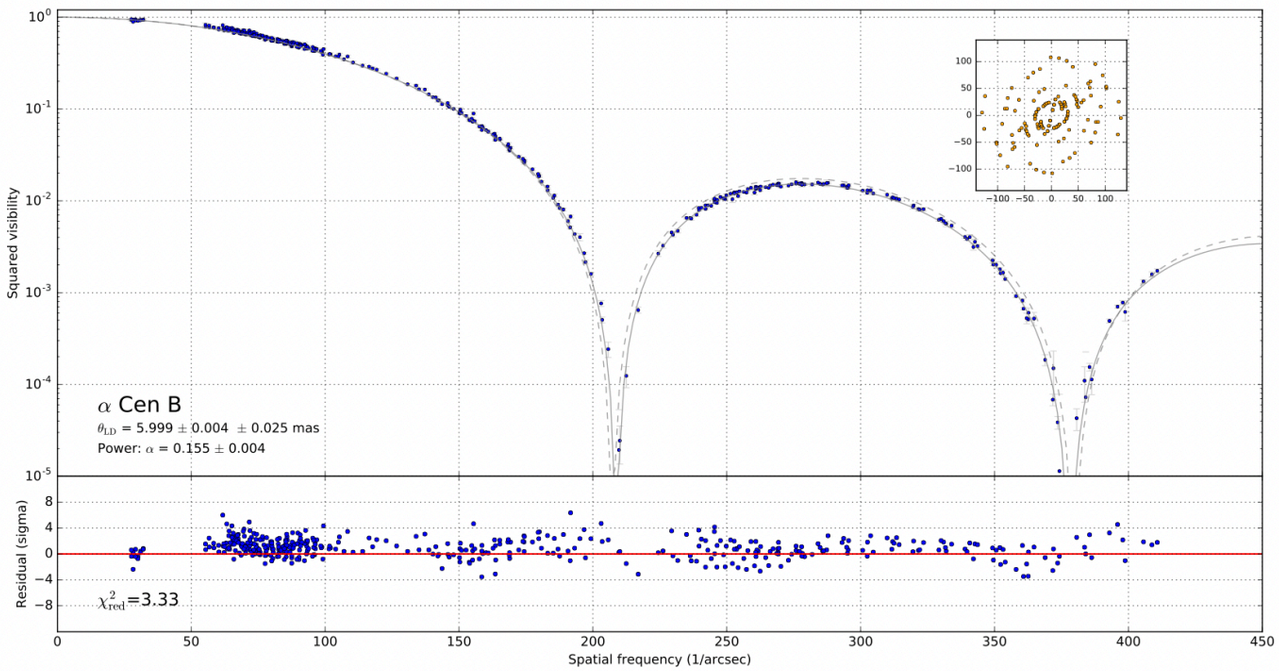
2000 2002 2003 2004 2005 2006 … **2017**

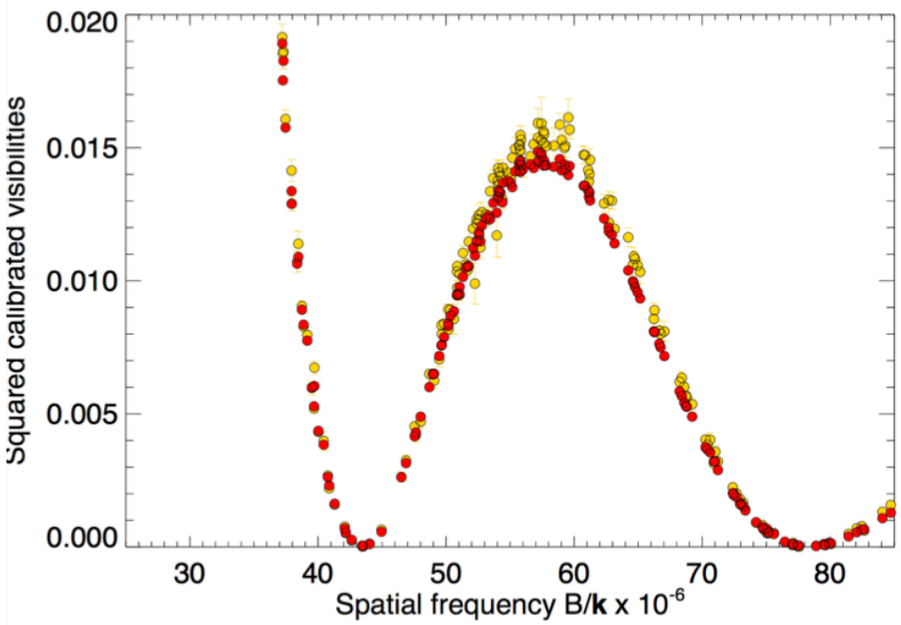
2002 2003 2004

The radii and limb darkenings of α Centauri A and B

Interferometric measurements with VLTI/PIONIER★

P. Kervella[1,2], L. Bigot[3], A. Gallenne[4], and F. Thévenin[3]





(adapted from Kervella et al. 2017)

XXth century 😉

« Spectroscopic » time

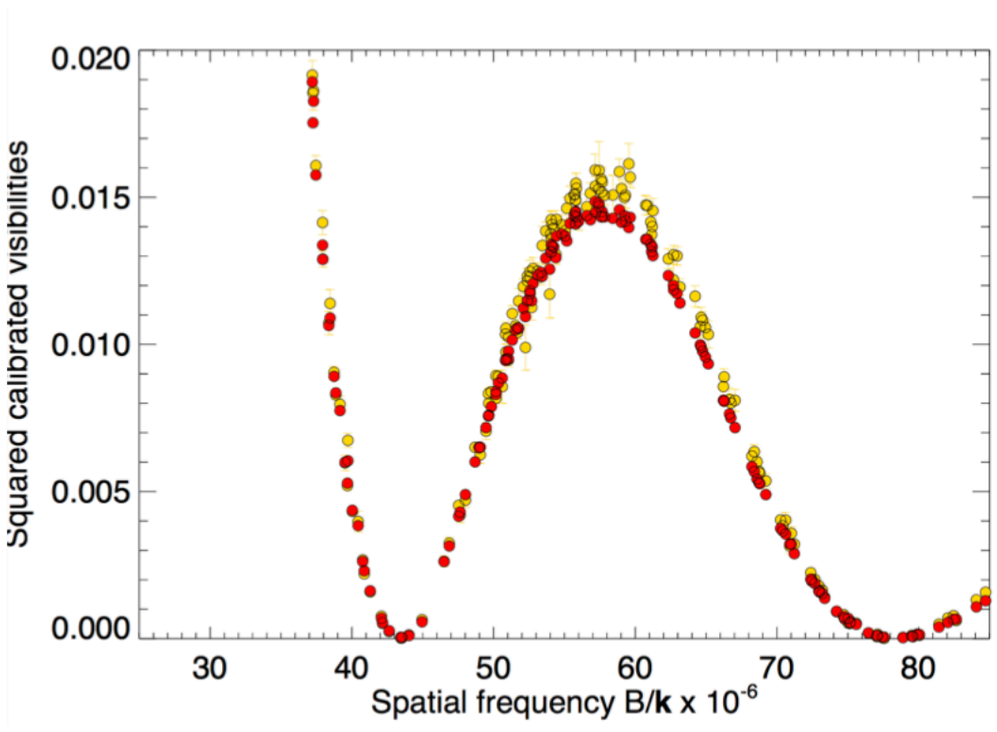
XXIth century

Most fields of stellar physics

2000 2002 2003 2004 2005 2006 … **2017**

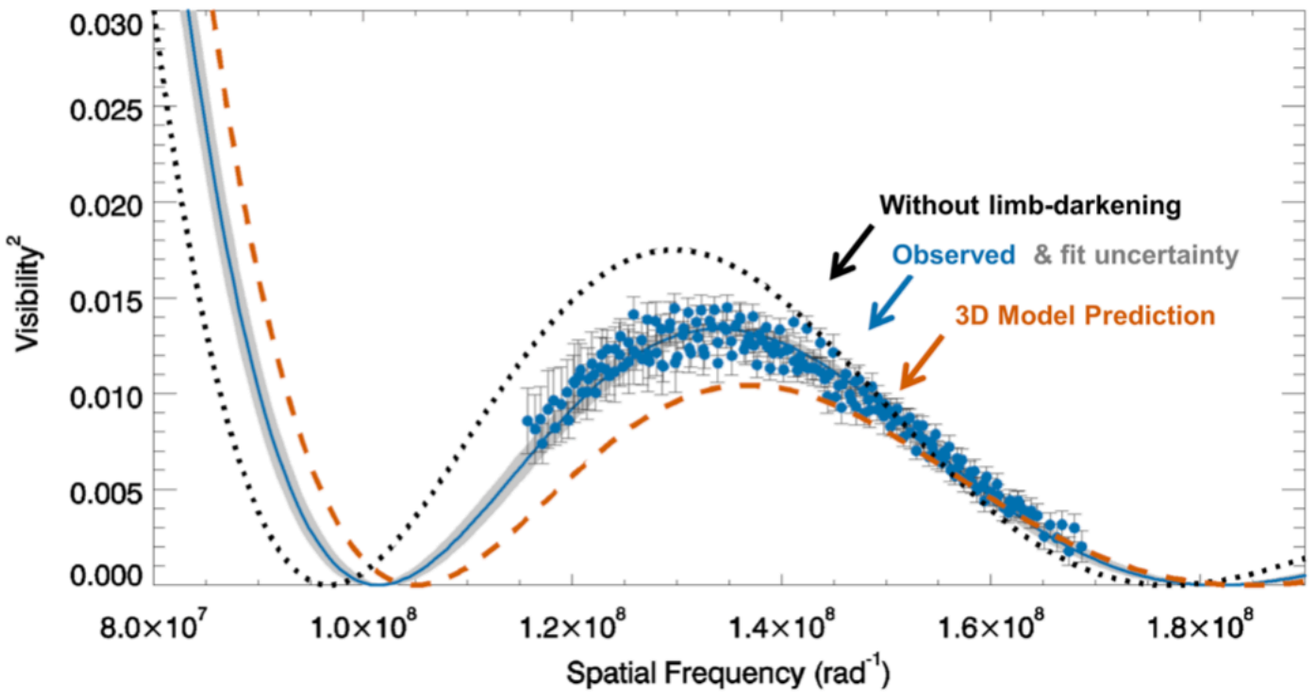
2002 2003 2004

dwarf K0 αCenB



(adapted from Kervella et al. 2017)

subgiant K0 η Cep



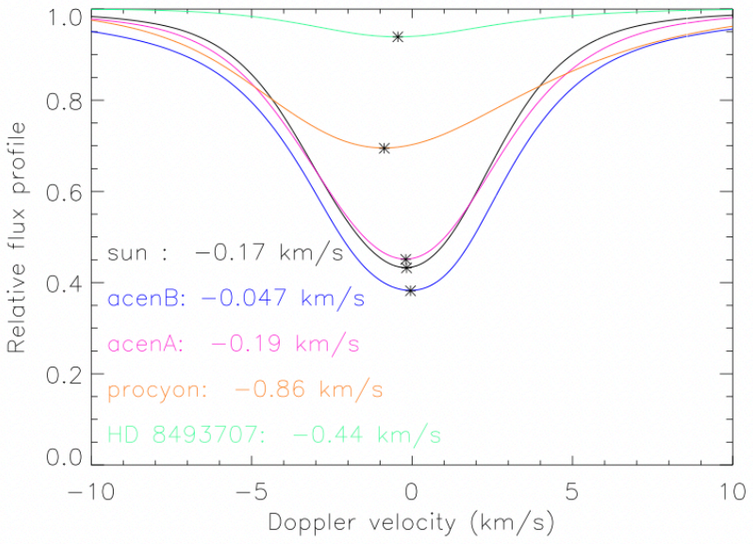
(White et al. in prep)

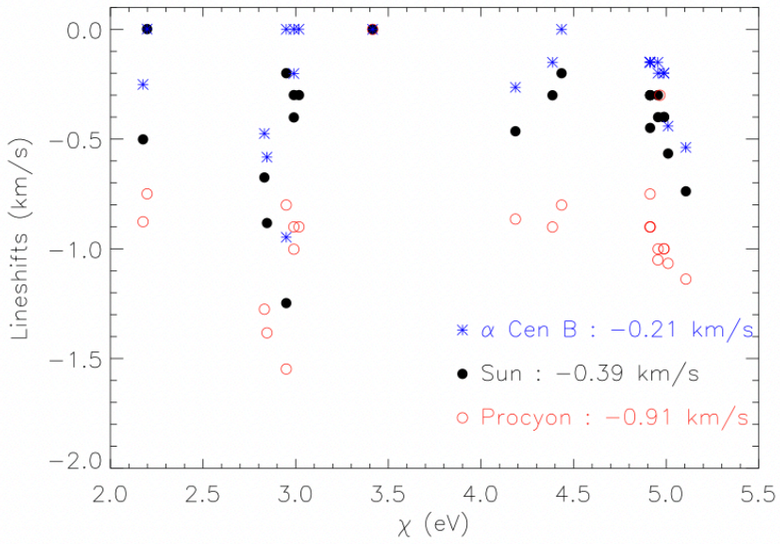
3D models produce too strong limb darkened intensities

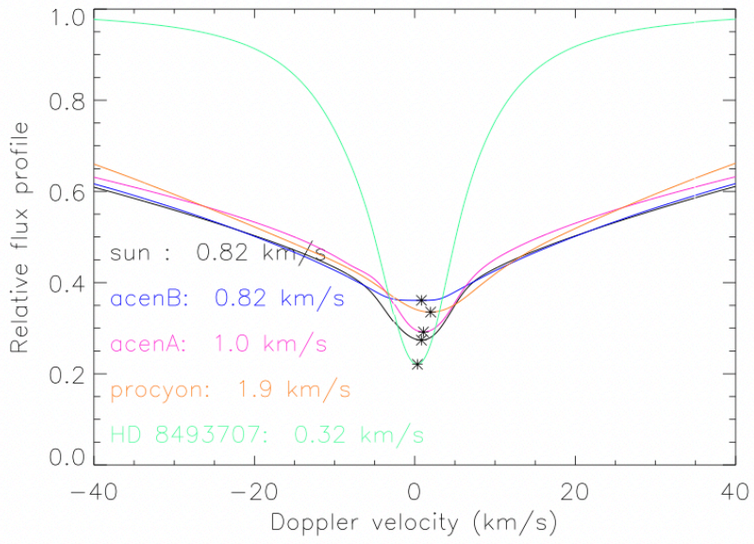
Slides of Pierre
Astrometry, Interferometry, imaging,
2003-2023

slide on 3D for Gaia

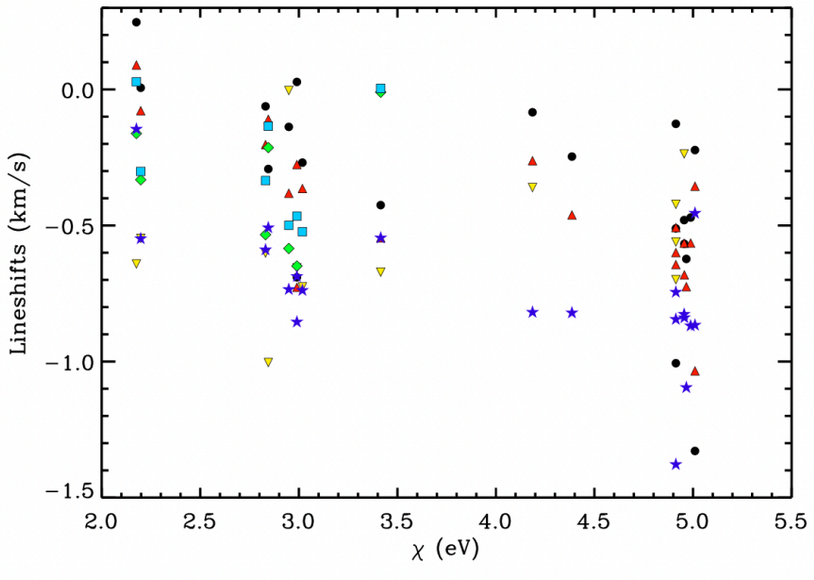
correction on convective shifts for RVS (Bigot & Thévenin 2008)



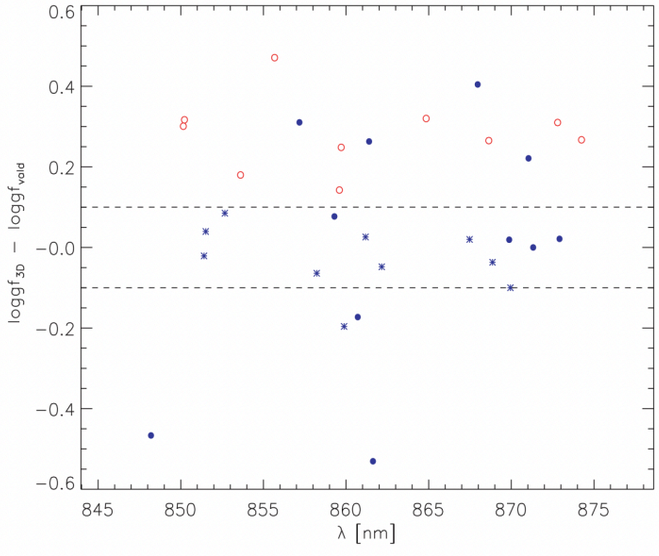




Chiavassa, Bigot, Thévenin+ (2011)



Bigot & Thévenin (2006)



Loggf correction
Thanks to 3D
Refinement of
Thévenin (1990) with 1D

NLTE corrections for Gaia (Merle, Thévenin, Pichon Bigot, 2011)

Improved model atoms for MgI, CaI, CaII

- New energy levels
- New radiative/collision transitions (e-, H)
- Hyperfine structure

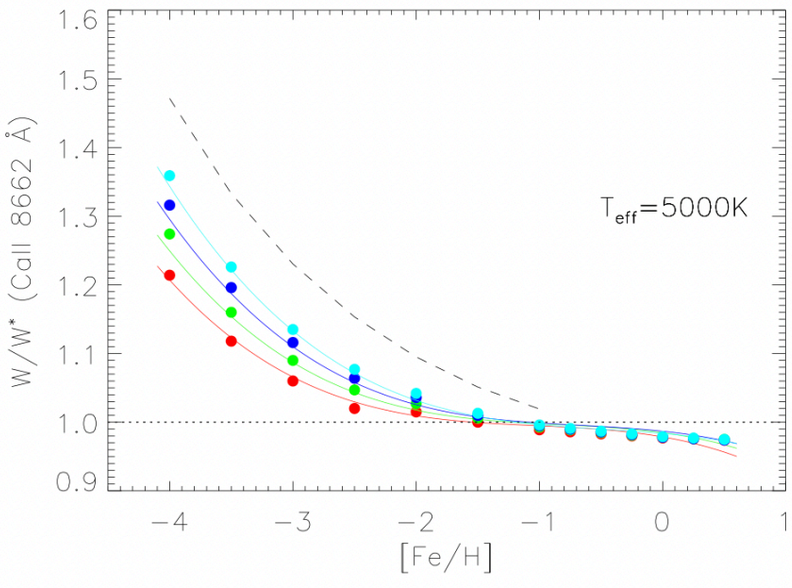
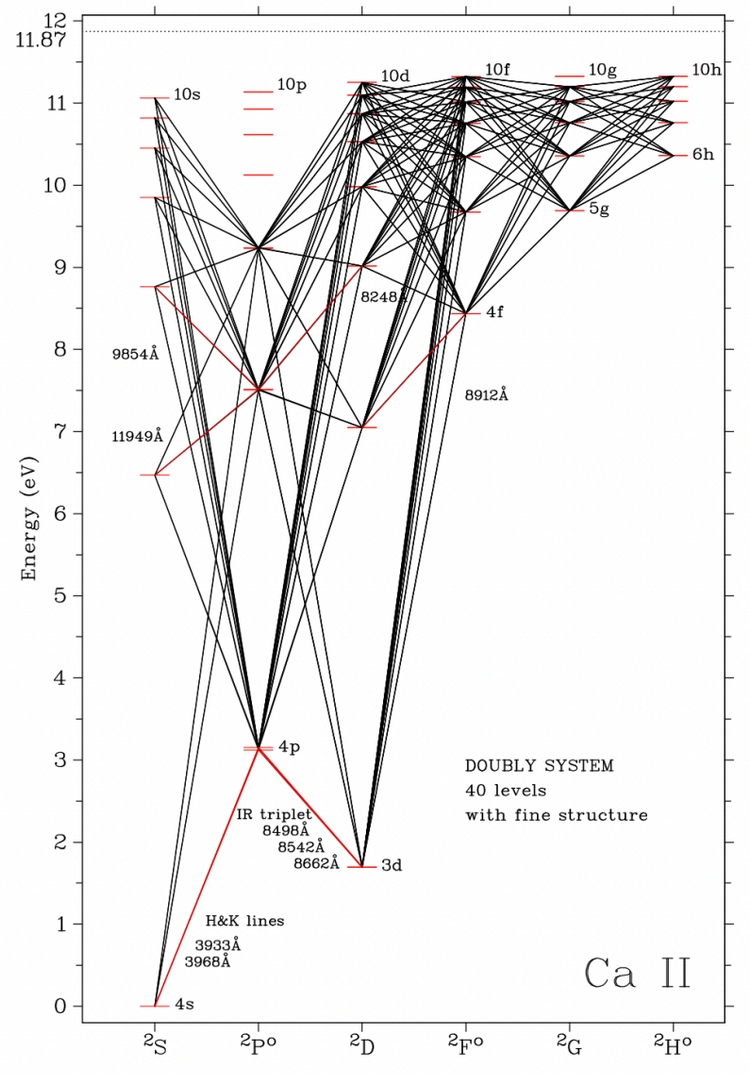


Figure 13. NLTE/LTE EW ratio of Ca II IR 8662 Å line as



A career with a leitmotiv = Curiosity + Altruism

Bigot, Kervella, Thévenin + (2006)
Brought the idea of 3D hydro for LD

Merle, Thévenin, Thévenin + (2011)
Brought the idea of NLTE correction for Gaia

Kervella, Thévenin + (2003)
Brought the idea of interfero+astero

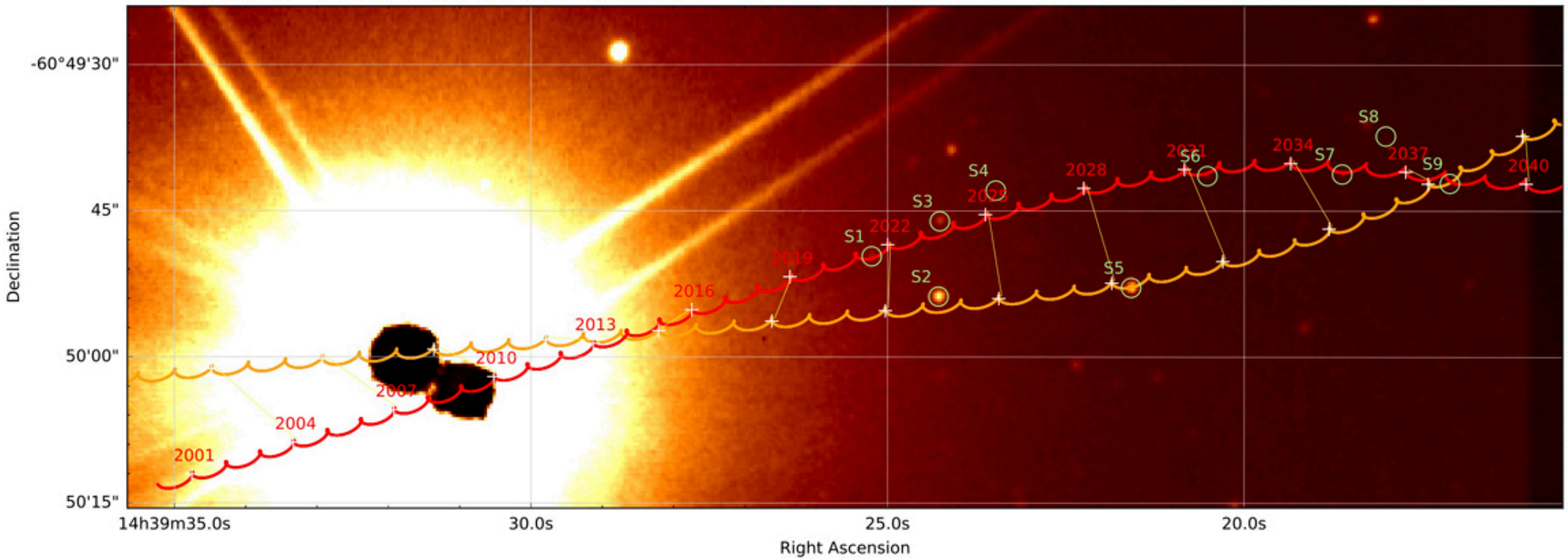
Bigot, Thévenin (2008),
Chiavassa, Bigot, Thévenin (2011)
Brought the idea of 3D hydro correction for Gaia/RVS

Creevey, Thévenin, + (2012)
Creevey, Thévenin, + (2013)
Creevey, Thévenin, + (2015)
Brought the idea of …

Always good/innovative ideas … but always preferred to be co-author (not first author) to help his (not so) young colleagues.
All of us now with permanent positions and tenure tracks

Thank you Frédéric

🙏


-60°49'30"
45"
50'00"
50'15"
Declination
14h39m35.0s
30.0s
25.0s
20.0s
Right Ascension
2001
2004
2007
2010
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