Ground-based RV-Standard Stars for the Gaia RVS

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AS GAIA

What is meant by radial velocity ?

What is meant by RV standard star ?

For answers, see the list of excellent papers on these topics by the Lund team : L. Lindegren, D. Dravins, S. Madsen, …

The fundamental definition of "radial velocity "
Lindegren & Dravins, 2003, A&A401, 1185-1201

Astrometric radial velocities
1999, A&A 348, 1040-1051
2000, A&A 356, 1119-1135
2002, A&A 381, 446-463

Limitations of spectroscopic RV measurements :

- Gravitational redshift (sun: 0.6 km s-1)

- Convective shifts (F V: 1 km s^{-1} ; K V: 0.2 km s^{-1})

- Other astrophysical effects : stellar rotation, stellar activity (active regions + starspots), granulation …

- Small-mass companions : exoplanets…

- Instrumental effects

Conclusion by Lindegren & Dravins (2003) :

➔ **Precision on any standard > 0.3 km s^{-1} (~ 0.5 km s^{-1}), unless a detailed physical model of the observed star is developed.**

RVS performance

Radial velocity performance specifications
MP stands for metal-poor : [Fe/H] = −1.5 dex
Katz (SF2A 2009), and talk in this conference

Spectral type	V	Vr (km/s)
B1V	7	1
B1V	12	15
G2V	13	1
G2V	16.5	15
K1IIIMP	13.5	1
K1IIIMP	17	15

Why do we need RV standard stars for GAIA ?

The Gaia spectrometer (RVS) has no built-in calibration device and the RVS will rely on its own observations to carry out the wavelength calibration.

Radial Velocity Zero-Point for the Gaia RVS by G. Jasniewicz (GRAAL, Montpellier), F. Crifo (GEPI-MEUDON) - for DU640

Three categories of sources are envisioned for the wavelength calibration :

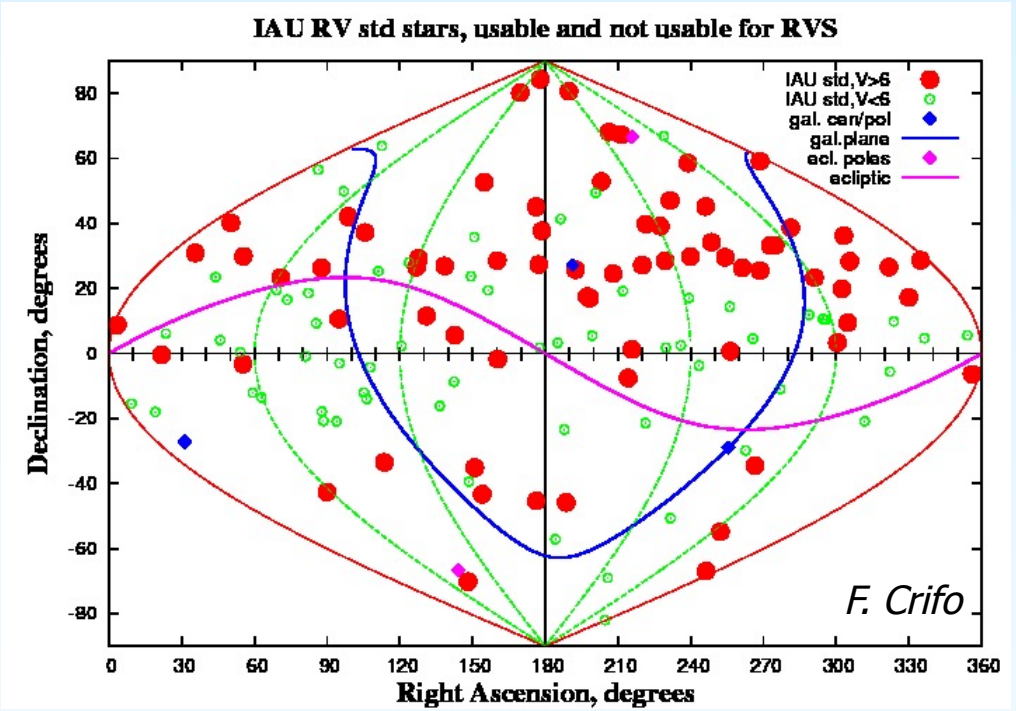
- A large sample (~10^4) of bright **RVS reference stars** :
with a stable Spectroscopic RV, deduced from SGIS (AGIS *alter ego*)
which will allow to iteratively derive the wavelength and the
RVs in a coherent manner, but without a well defined origine

- A small sample (~1400) of bright **RVS standard stars** :
with a 'stable' spectroscopic RV, determined and observed on the ground,
prior and during the mission

- A very small sample (~10) of bright **asteroids** :
with a very precise computed kinematic RV (from IMCCE),
but too few, and very unevenly distributed on the sky

Building a full-sky list of ground-based RV-standards

Existing IAU standards (IAU Commission 30): too bright, too few, particularly in the south.
Only the red stars are usable for RVS ; and according to our observations, some of them proved to be variable…



➔A full-sky list of ground-based bright (6<V<10) RV standard stars has been built, from well-known published RV catalogues : Nidever et al. 2002, Nordström et al. 2004, Famaey et al. 2005) for the determination of the Radial Velocity Zero Point (RVZP) of the RVS.

Building the list of ground-based standards

Constraints due to RVS:

- Initial RV accuracy :<=0.3km/s
- At least 1000 stars, for a full and uniform sky coverage
- No double or variable stars
- Magnitude range: 6<=V<=10
- Spectral type: >=F5; no M giants (variable)
- No disturbing neighbours (ΔV<4) within 80 arc sec
- HIP stars for homogeneous selection

Details of the selection criteria can be found in the DU640 (Gaia CU6) internal documents.

See also :
- Posters related to DU640 in the Proceedings of the SF2A (Société Française d'Astronomie & Astrophysique), 2007, 2008, 2009

- *Crifo, Jasniewicz, Soubiran et al., 2010*
Paper in progress, to be submitted

Strategy for observations

Ground-based observations of the sample of about 1400 stars which cover the sky :

- Sophie OHP ➔ $RVZP_{OHP}$
- Narval TBL➔ $RVZP_{TBL}$
- Coralie ESO-SET ➔ $RVZP_{SET}$

-Measurements of stars in common between the 3 observatories/spectrometers
-Measurements of Spectroscopic RV of several asteroids at each observing night

Homogenization of data ➔ final list of RV_standards ➔ RVZP of the RVS

Asteroids

Kinematic RV of asteroids are known with a high precision (some m s^{-1}) by celestial mechanics.

Effects on spectroscopic RV concerning : diameter & proper motion (rotation) have been investigated

Differences between kinematic and spectroscopic RV are expected to depend on each wavelength range. Thus Narval RV have been determined in the same range (masks) as for Sophie/Coralie, *and* in the RVS range.

But the number of bright (V<10) asteroids going across the RVS Field of View is rather small…

Asteroids

There are ~100 asteroids with V ≤ 10 at their maximum of brightness. All of them will not be observed by GAIA, because :

- they will be on average observed in quadrature

  Cf Hipparcos ;

- they will be too faint while crossing the FoV

Thus the number of bright (V<10) asteroids going across the RVS Field of View is rather small…

Asteroids
Simulation of the daily number of transits

Simulations by **F. Mignard** with the following parameters for the scanning law :

- solar aspect angle 45°
- constant spin rate of 60 arcsec s^{-1} corresponding to 6-hour great-circle scans
- precession of the spin axis in 63 days
- start of the simulations for a 5-year operational lifetime : January 1st 2012

Upper magnitude V for asteroids	Number of asteroids through the FoV	Average number of transits per day	Number of days without transits	Longest period without transits
10	13	0.1 ± 0.5	1685 days	176 days
11	46	0.3 ± 0.8	1507 days	38 days
12	124	0.8 ± 0.3	1053 days	21 days
13	299	2.3 ± 2.1	484 days	10 days

Table : *Simulations of the daily number of transits of asteroids carried out by F. Mignard.*

Asteroids are too few, and very unevenly distributed on the sky, and cannot be the only calibrators for the RVS RVZP. Our list of RVS-standard stars is thus mandatory…

Standard Stars
Simulation of the daily number of transits

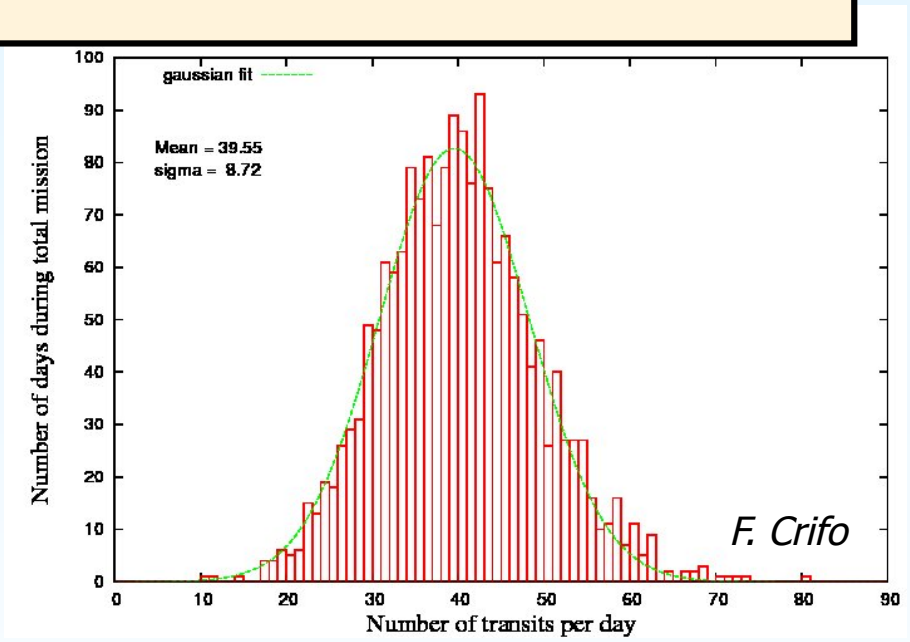
Simulations by **P. Sartoretti** with the same parameters used by F. Mignard for the asteroids

1420 stars V<10	Average number of transits per day 39 [10 , 80]	Longest time without transits 8.3 h

12 transits occur more than 6 hours (=1 full rotation) after the previous one.

17 days (~1%) with a number of daily transits < 20.

Total number of transits : 72398

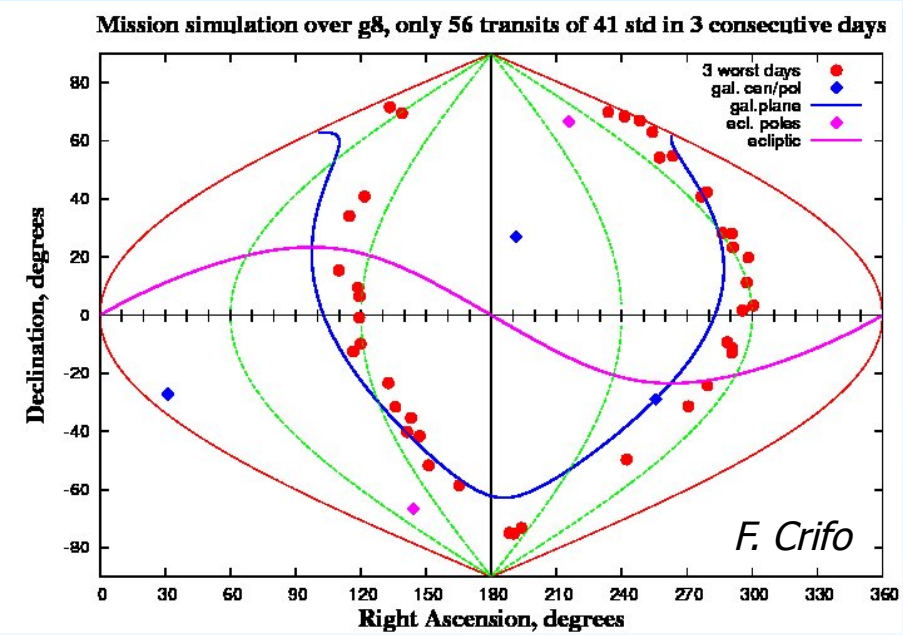


Standard Stars Simulations (ctd)

There is a period of time for which there are only 56 transits in 3 days

The 41 standard stars observed during this period are plotted in RED.

These stars are all close to the galactic equator, where the density of standards is lower (too many bad neighbours)



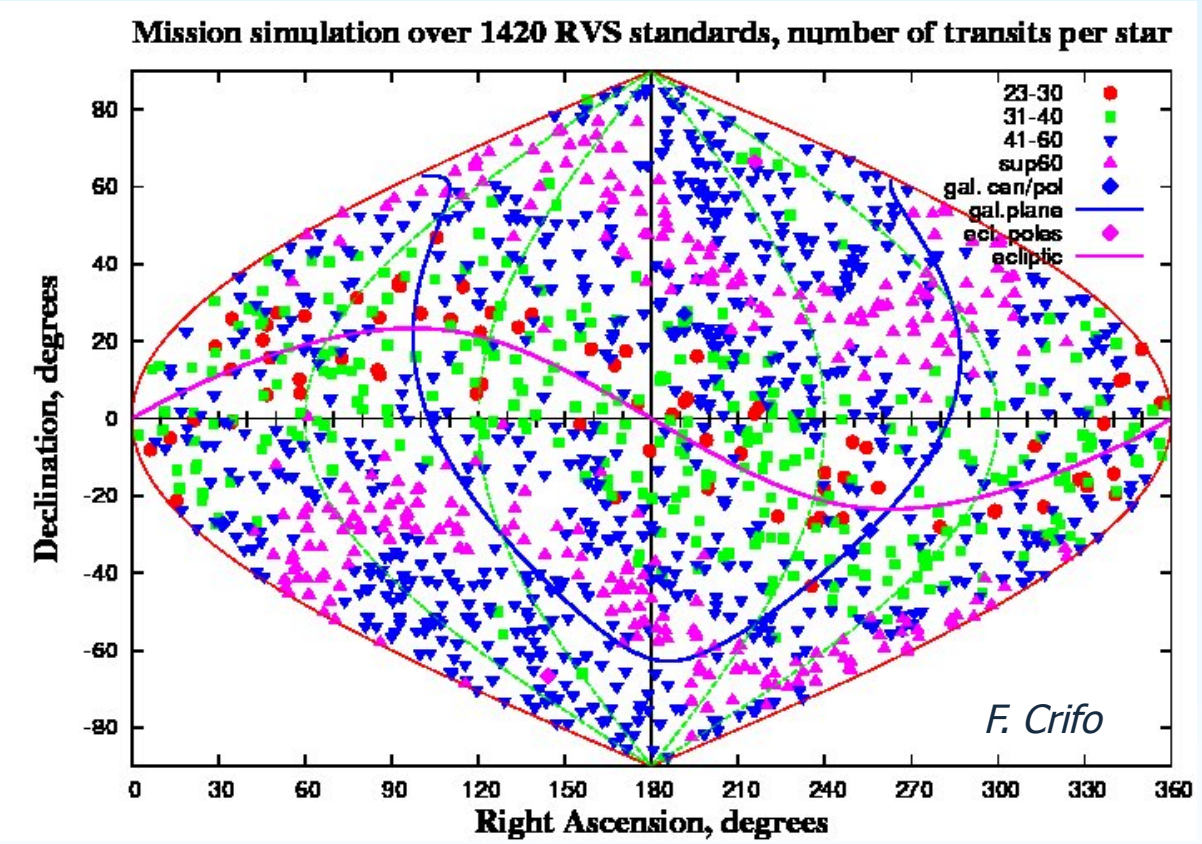
Standard Stars
Simulations : number of transits per star

Our list of ground-based RV standards covers the sky in an uniform way and will be useful for many other research projects.

(Collaboration with IAU commission 30)

Sky distribution of stars with a given number of transits: 4 colour groups.

Areas of same colour form "bands" parallel to ecliptic, due to scanning law.



Ground-based observations

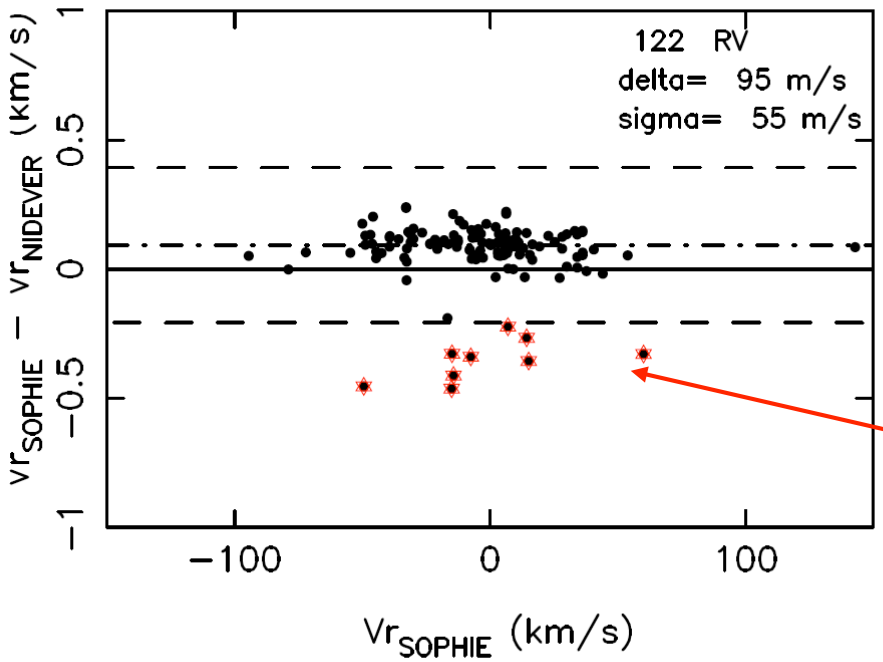
The 1420 candidates to be qualified as RV-STD : verify their stability at the 300 m/s level over several years

Long-term programme on échelle spectrographs on-going :

- SOPHIE@T193-OHP
- NARVAL@TBL-Pic du Midi
- CORALIE@Euler-LaSilla
- complemented by the ELODIE archive

IAU standards + asteroids systematically observed to homogenize the RV measurements from an instrument to another

pre-launch programme completed at 80% in the North, 50% in the South.

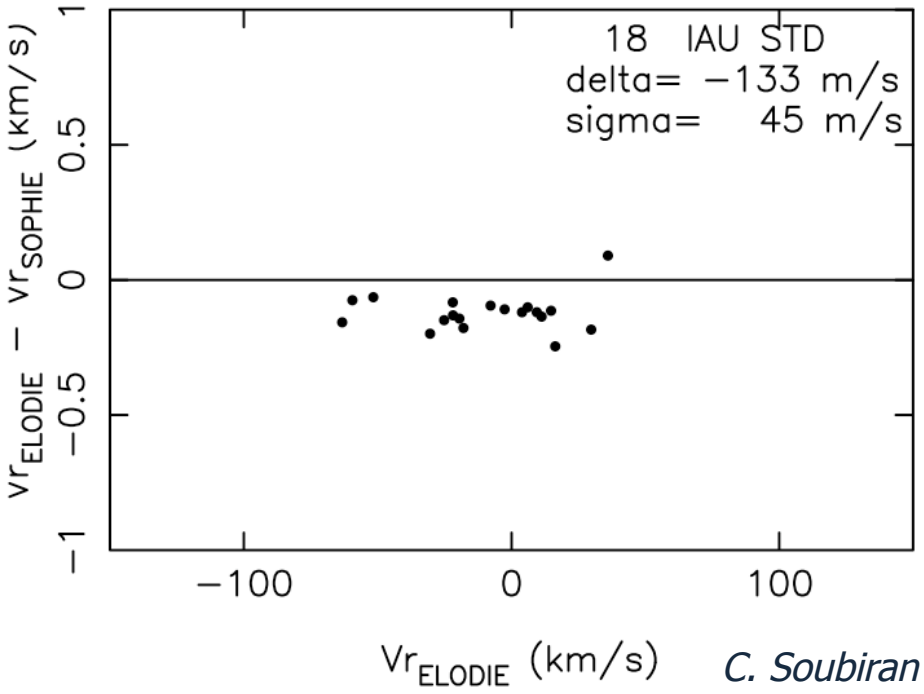


offset --> RVZP
sigma --> RV err ⊕ intrinsic variability

red stars --> variability > 300 m/s

C. Soubiran

even IAU STD show some variability



C. Soubiran

GAIA CU6/8 Database - Mozilla Firefox

Fichier Édition Affichage Historique Marque-pages Yahoo! Outils ?

http://gaia.aip.de/cu6a8/

GAIA CU6/8 Database

Database Description	How To	Database Content	Asteroid Ephemeris

DATABASE STATISTICS : Thu Jun 03 15:39:42 CEST 2010		
Table	**Total Number of Rows**	**Number of Unique Identifier**
Basic Data	43146	43146
Catalogue		
RV Stars	21544	9726
RV Asteroids	2607	135
Stellar Parameters	25071	5596
Measurements		
RV Stars	5020	2501
RV Asteroids	153	61
Stellar Parameters	0	0
Spectra	4804	2280
Number of rejected stars (variable at the 0.3 km/s level): 0		

Here you can find a page that describes the instruments used for the measurements

Additions:

may 2009:

- List of IAU RV standards
- Instruments description

Terminé

Kinematic Radial Velocities

Spectroscopic RV (SRV) determined within DU650 will be published in the final Gaia catalogue. CU6 also plans to publish Kinematic RV (KRV) for the brightest stars.

- **Gravitational redshift** will be computed by CU8 from Gaia-spectroscopy + Gaia-photometry.

- Spectroscopic RV will be determined from RVS thanks to Cross-Correlation (CC) technics with templates. If these templates were built from 3D-models including **convective shifts**, it should be perfect… BUT there will not be available before launch…

Thus 1D stellar atmosphere models will be used for the RVS templates, and SRV will be corrected LATER (i.e in the final Gaia catalogue) from convective shifts in using up-to-date 3D-atmospheric models.

Synthetic masks (selection of lines**)** should be useful for this purpose.

The AZP software
« Astrophysical Zero Point »

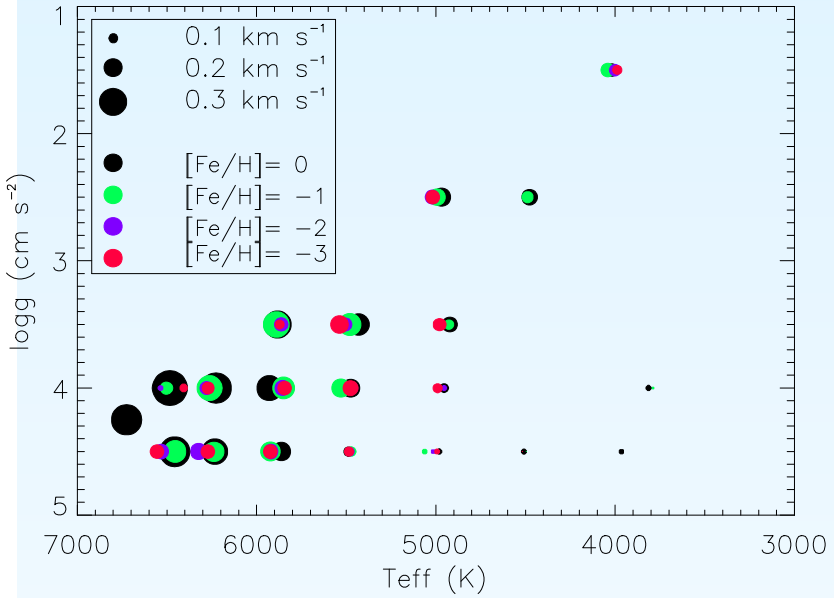
The goal of the AZP Work-Package within DU640 is :
to compute, for each star observed by the RVS
the ***Kinematic RV*** in using interpolation technics in a 4-D space
(T_{eff}, log*g*, [M/H], V_{rot}) for the calculation of the **convective shift**,
and to retrieve the **gravitationnal redshift** from CU8.

But many efforts are necessary (to build 3D models) & difficulties remain…

Note : At the end of the Gaia mission, AZP could be tested thanks to
astrometric RV of the nearbiest stars (from parallaxes & p.m.)

Theoretical convective shifts in the Gaia range

RV-shifts calculated as the difference between 3D models (including convective shifts) and corresponding 1D models (hydrostatic, no shifts), according to:
Allende Prieto, Lars Koesterke, and H. Ludwig

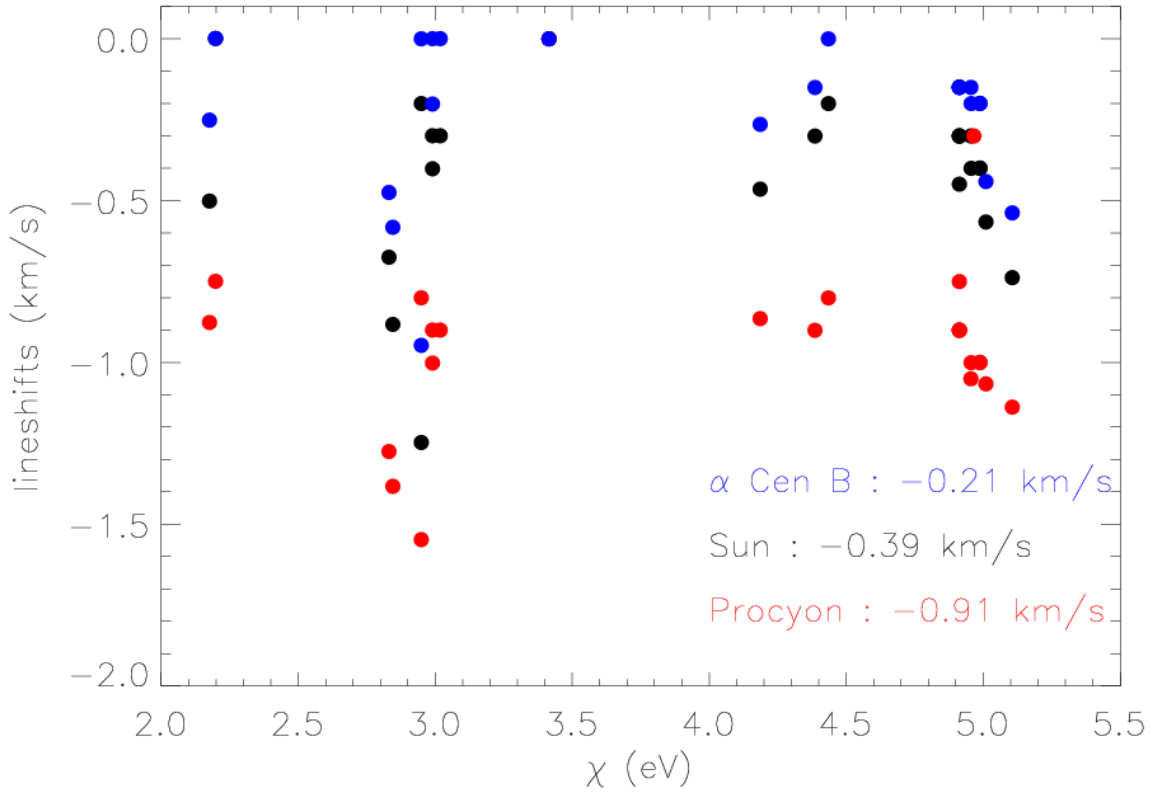


The 3D hydrodynamical model atmospheres come from the **CIFIST 3D grid** by

Ludwig H.G., Caffau E., Steffen M., Freytag B., Bonifacio P., Kucinskas A. 2009, MmSAI, 80, 711

Theoretical convective shifts (ctd)

Blueshifts of FeI lines in the RVS range for three dwarfs (K, G and F). According to Bigot & Thévenin (2008)



The 3D hydrodynamical model atmospheres come from Nordlund & Galsgaard (1995), Stein & Nordlund (1998)

Lines selected by Bigot & Thévenin (2006)

THAT'S ALL