WP10–Automated analysis of GIRAFFE spectra of FGK stars for the Gaia–ESO survey

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Automated stellar parametrization

1. Gaia-ESO Large Public Survey

Co-P.Is G. Gilmore, S. Randich

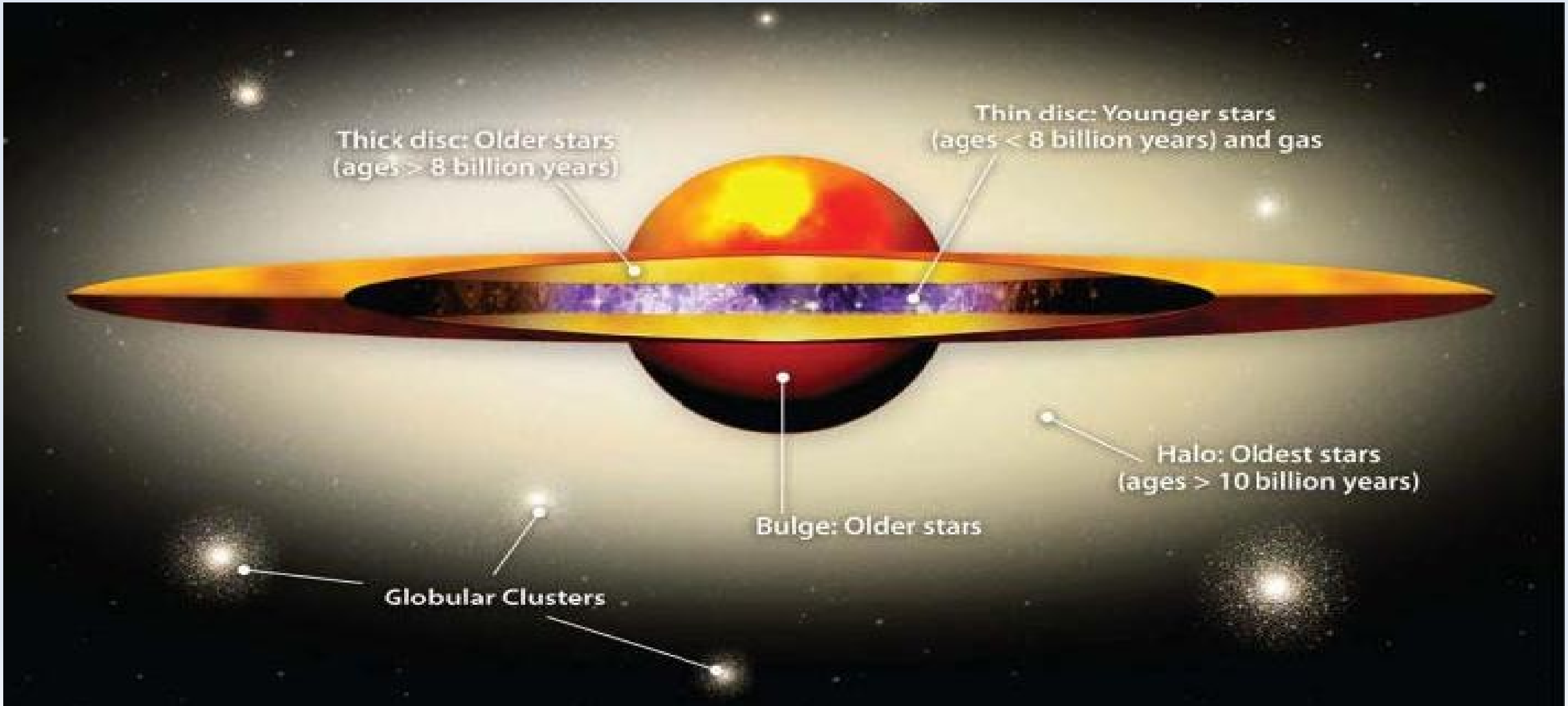
Consortium ~300 Co-Is

300 nights VLT FLAMES during 5 years

Start: January 2012

~10^5 stars of the Galaxy

100 open clusters



Automated stellar parametrization

1. Gaia-ESO Large Public Survey

setup	Resol	lmin	lmax
HR21	16200	848.413	900.087
HR10	19800	533.907	561.893

Solar Neighbourhood: UVES on FG turnoff stars

iron-peak, alpha, proton-capture and neutron-capture elements

Thin disc |b| < 5deg: HR21 on metal rich clump stars

Only [M/H] and Ca abundances.

Bulge and Inner Disc: HR21 and HR10 on metal rich GK giants.

Iron peak-elements (Fe, Cr, Mn, Co, Ni), several alpha-elements and proton capture elements (Sc and V)

Halo and outer Thick Disc: HR21 and HR10 (?) on F metal-poor dwarfs

Iron peak-elements (Fe, Cr, Mn, Co, Ni), several alpha-elements and proton capture elements (Sc and V)

Open Clusters: UVES + HR21 or HR15N, HR03, HR05, HR06, HR14

iron-peak, alpha, proton-capture and neutron-capture elements and Li

Automated stellar parametrization

1. Gaia-ESO Large Public Survey

Products

for stars observed with GIRAFFE:

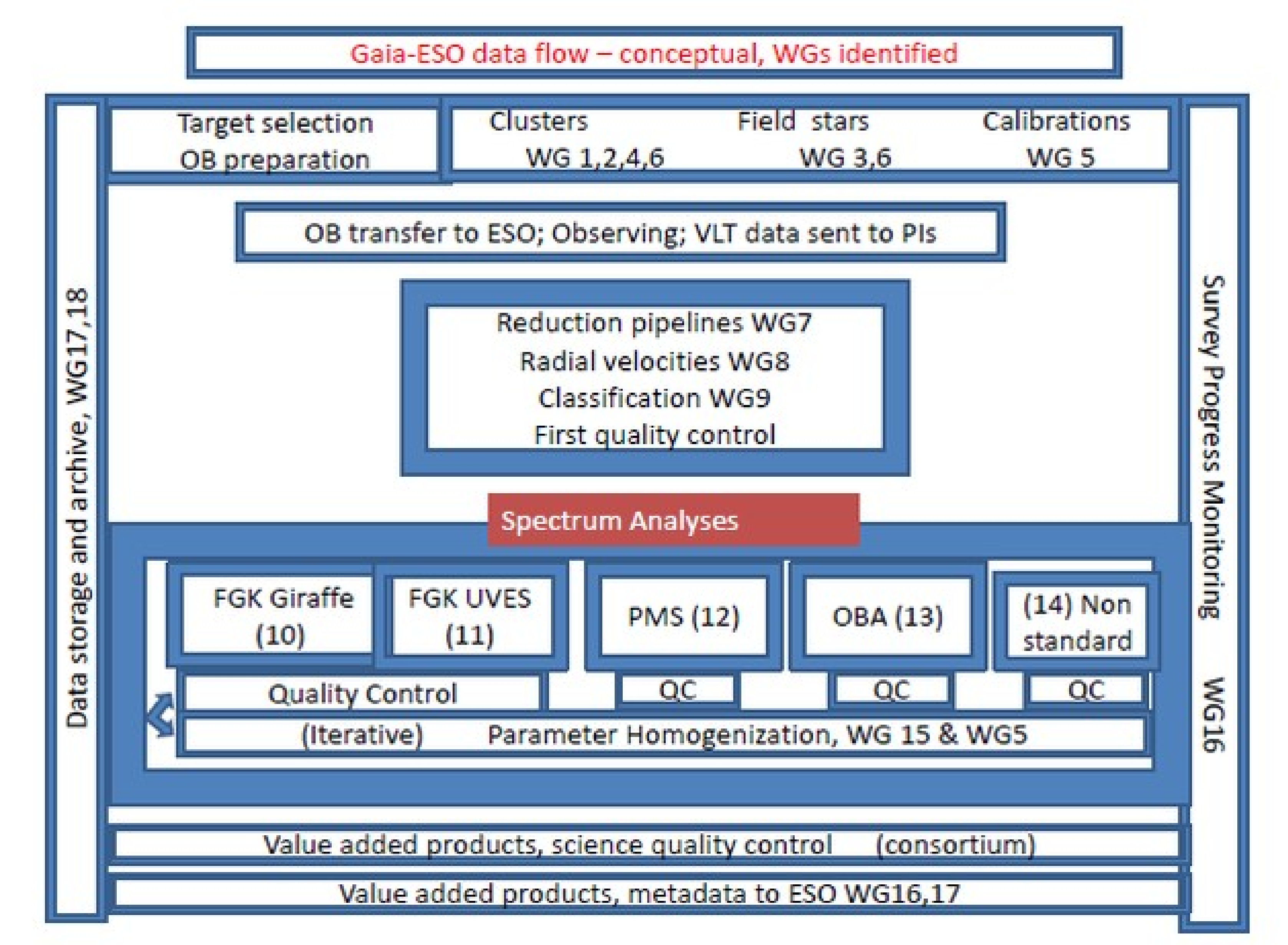
stellar astrophysical parameters: effective temperature, surface gravity
equivalent widths of absorption and emission lines (when present)
typically, stellar metallicity [Fe/H]
whenever possible [alpha/Fe]
lithium abundances for solar-type and cool stars in clusters
robustly determined errors on all parameters
measurements of chromosperic activity or accretion, for cluster members (where relevant)
quantitative mass loss estimates, for early-type stars
The GIRAFFE spectra should allow measurement of Mg, Ca, Ti and Fe for the majority of the F-G-K stars.
For Bulge K giants also Si, Cr, Mn, Co and Ni, and possibly other elements, should be measurable.

for stars observed with UVES:

stellar parameters derived from the spectra
robustly determined errors on all parameters
elemental abundance estimates for some or all of the following elements (where stellar abundance and astrophysical parameters permit):
C, O, Na, Mg, Si, Ca, Sc, Ti, Cr, Mn, Fe, Ni, Zn, Y, Zr, Ba, La, Ce, Eu

Automated stellar parametrization

1. Gaia-ESO Large Public Survey



Automated stellar parametrization

1. Gaia-ESO Large Public Survey

Spectrum analysis

Spectrum analyses			
FGK Stars: GIRAFFE incl QC	**WG10:** Paris, MPA, Lund, Uppsala, Nice, Bordeaux Arcetri, Bologna, Liège, Geneva, Alicante Nice, ESO, Porto, ZAH, Arcetri, Naples Catania, Padova, Kaypten, IAC, ANU	17	A. Recio-Blanco (Fr) & C. Allende Prieto (Sp)
FGK Stars: UVES incl QC	**WG11:** Paris, MPA, Lund, Uppsala, Nice, Vilnius Arcetri, ANU, Bologna, AIP, Indiana, UCM, Herts Groningen, ESO, Naples, Porto, Catania, Alicante Catania, Padova, Liege, Bordeaux, ZAH, IAC, Chile	14	A. Korn (Se) & R. Smiljanic (ESO)
WG10/11 Interface	Recio-Blanco, Allende Prieto, Pasquini, Smiljanic, Korn, Hill	0.5	
Pre-Main-Sequence stars incl QC	**WG12:** Arcetri, Catania, IAA Naples, Palermo, ETH, CAUP Keele, Exeter, Madrid (UCM, CAB)	8	A. Lanzafame (I)
OBA Stars incl QC	**WG13:** Liege, RO Belg, AIP, OMA, Madrid, Paris Alicante, Uppsala, MPIA, ZAH, Leuven, Herts Calar Alto, Nice, IAA, Armagh	2	R. Blomme (Be)
Unusual Objects incl QC	**WG14:** SRON, Nijmegen, Warwick, Leuven MPIA, Herts, ZAH	1	tbc

Automated stellar parametrization

1. Gaia-ESO Large Public Survey

Spectrum analysis

GIRAFFE FGK Spectrum analysis	Paris, MPA, Lund, Uppsala, Nice, IAC, Vilnius Liege, Arcetri, Bologna, AIP, Ind, Madrid, IAA, Vienna, ESO, Rome, Porto, ZAH, Arcetri, Naples Catania, Padova	A. Recio-Blanco (Fr) & C. Allende Prieto (Sp)
UVES FGK Spectrum analysis	Paris, MPA, Lund, Uppsala, Nice, IAC, Vilnius Liege, Arcetri, Bologna, AIP, Ind, Madrid, IAA, Vienna, ESO, Naples, Porto, ZAH, Arcetri, Naples Catania, Padova	A. Korn (Swe) & R. Smiljanic (ESO)
Pre-Main Sequence Star Spectrum analysis	Madrid, Catania, Granada, Arcetri, Naples, Palermo, Zurich, Armagh	A. Lanzafame (I)
OBA Star Spectrum Analysis	Liege, RO Belg, AIP, OMA, Madrid, Paris, Armagh Uppsala, MPIA, Leuven, Herts	R. Blomme (Be)

NODE	CONTACT	FTE	ANALYSIS	METHOD
ARCETRI	L. Magrini	2.0	GIRAFFE & UVES	EWs
BOLOGNA	E. Pancino	0.9	GIRAFFE & UVES	EWs
BOLOGNA-PADOVA	A. Bragaglia	1.2	UVES (maybe GIRAFFE) Red giants, red clump	TBD
CAUP (Porto)	S. Sousa	2.05	GIRAFFE & UVES	EWs
ESO	R. Smiljanic	0.35	GIRAFFE & UVES	EWs+Spec. Synth.
HEIDELBERG-PARIS	L. Sbordone	2.4 ?	GIRAFFE & UVES	MyGisFOS (Optimization+grid)
IAC	C. Allende Prieto	0.85	GIRAFFE & UVES	Optimization+grid Classification, Bayesian
GENEVA	N. Mowlavi	0.2	GIRAFFE and/or UVES	TBD
LIEGE	T. Morel	0.35	GIRAFFE & UVES	Optimization+grid
LUND-UPPSALA MPA-BORDEAUX	S. Feltzing	6.4	GIRAFFE & UVES	Optimization (on-the-fly)
GRONINGEN	B. Lemasle	0.2	GIRAFFE & UVES	EWs
NAPOLI-CATANIA	J. Alcala A. Frasca	1.4	GIRAFFE & UVES	Optimization+EW
NICE	A. Recio-Blanco	3.1	GIRAFFE & UVES	Optimi. Project.,Class.
VILNIUS	G. Tautvaisiene	?	?	?
BRUXELLES	S. van Eck	?	GIRAFFE (peculiar giants)	

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Automated stellar parametrization

1. WG 10 : GIRAFFE FGK spectra

1. Complex structure.
2. Real FTEs estimations
3. VARIETY OF METHODS

- Difficulties of comparison due to the different nature of the error sources!
  - use of a pre-computed synthetic spectra grid
  - on-the-fly synthetic spectra

  Or use of equivalent widths

- Imposed: same model atmospheres, atomic/molecular data
- Use of priors or not
- Different mathematical approaches
  - Optimization, projection, classification

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3. Types of methods

Different mathematical approaches:

- **Optimization : parameters derived through a distance minimization**

  Nelder-Mead (IAC), MyGisFos (Heildeberg), SME (Uppsala)

- **Projection : spectra are projected into a set of vectors derived during a learning phase**

  MATISSE (Nice)

- **Classification : pattern recognition problem**

  DEGAS (Nice), Bayesian

- **Equivalent Widths**

3. Types of methods

1. Optimization methods

- Minimum distance algorithm : **all the distances are computed : SME, MyGisfos, ...**
  - **No problems with secondary minima**
  - **The precision is limited by the grid parameter sampling**
  - **Very time consuming**

- Nelder-Mead algorithm : **transformation of a simplex in the distance space by reflexion, contraction...**
  - **Succesfully applied to SDSS/SEGUE: Allende-Prieto et al. (2008)**
  - **Problems in a non-convex space : secondary minima traps**

3. Types of methods

1. Optimization methods

- Stochastic methods :

  - Genetic algorithms: Allende-Prieto (2003)
    - **Improved convergence in a non-convex space**
    - **CPU time consuming**

2. Projection methods

- Penalized chi square : **local linear model interpolations with regularization.**
    - **Applied to RAVE (2nd release) : Zwitter et al. (2008)**
    - **Problems in a non-convex space**

2. Projection methods

- MATISSE : projection vectors are linear combinations of synthetic spectra. Two steps procedure to tackle non-linearity.

Recio-Blanco et al. (2006)

- Easy physical interpretability
- Very fast application
- Applied to FLAMES/GIRAFFE: Gazzano et al. (2010)
  Kordopatis et al. (2011a,b)
  Applied to ESO archive data: AMBRE project (P.I. P. de Laverny)
  Worley et al., submitted
  Integrated into the Gaia DPAC pipeline at CNES for RVS data
- Problems in a non-convex space

2. Projection methods

- Principal Component Analysis : **the spectra grid is considered as a set of statistical trials of Npix variables (fluxes).**

  - MOPED : **Fisher matrix projection vectors associated to a data compression. Heavens et al. (2003)**

  - MAχ : **Simplified version with gaussian noise. Jofre et al. (2010)**

Very fast application. Tested on SEGUE and UVES data

Possible problems with non-linearity

3. Classification methods

- Artificial Neural Networks and SVM : **back-propagation and multi-layer algorithms or classification with hyperplanes.**
  - 🙂 **Very fast application**
  - ☹ **Difficult interpretability: black-box effect**

- Oblique k-decision trees (Degas) : **space-partitioning structure in a k-dim space with projection vectors. Bijaoui et al. (2011) OCA-Nice**
  - 🙂 **Very fast and good results for non-convex, non-linear spaces**

  Applied to FLAMES/GIRAFFE data (Kordopatis et al. 2011a,b)

Automated stellar parametrization

4. WG10 : Analysis tests

Tests (before the proposal submission):

- Show that we were able to analyse a large number of spectra (> 300 000)

- Start working together to understand/detect the difficulties

- Test the performances in terms of atmospheric parameters of different GIRAFFE setups

Automated stellar parametrization

4. WG10 : Analysis tests

WHO was involved ?:

- 5 nodes of the Milky Way LoI :
  Uppsala-Lund, Heidelberg-Paris, Bologna, IAC, Nice

What setups of GIRAFFE where tested?:

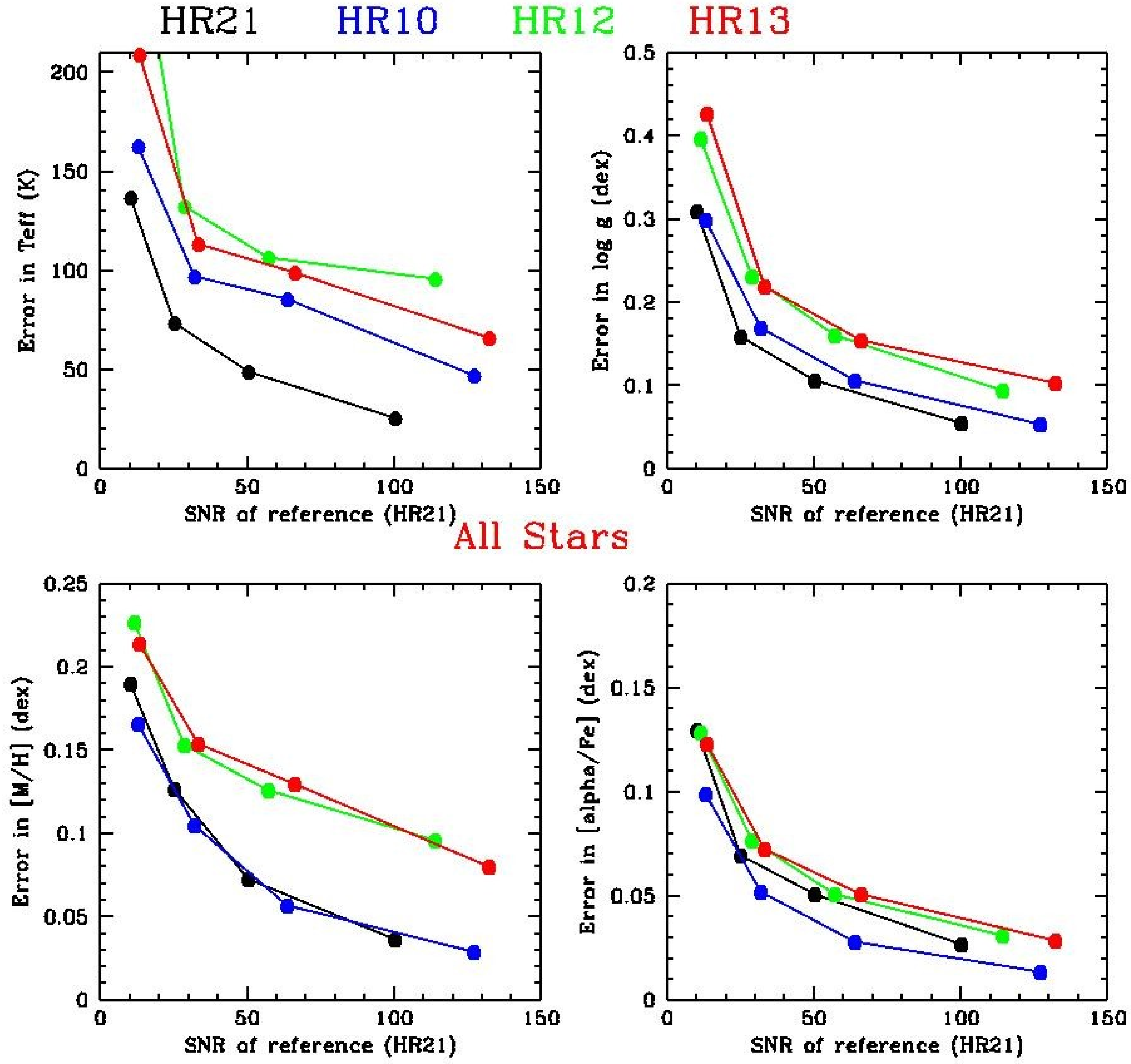
setup	Resol	lmin	lmax
HR21	16200	848.413	900.087
HR10	19800	533.907	561.893
HR12	18700	582.108	614.592
HR13	22500	612.007	640.593

2*10^4 spectra/setup

SNR=100,50,25,10

Computed in Nice

(P. de Laverny)



HR21
HR10
HR12
HR13
Error in Teff (K)
SNR of reference (HR21)
Error in log g (dex)
SNR of reference (HR21)
All Stars
Error in [M/H] (dex)
SNR of reference (HR21)
Error in [alpha/Fe] (dex)
SNR of reference (HR21)

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4. WG10 : Analysis tests

Conclusions of the first tests

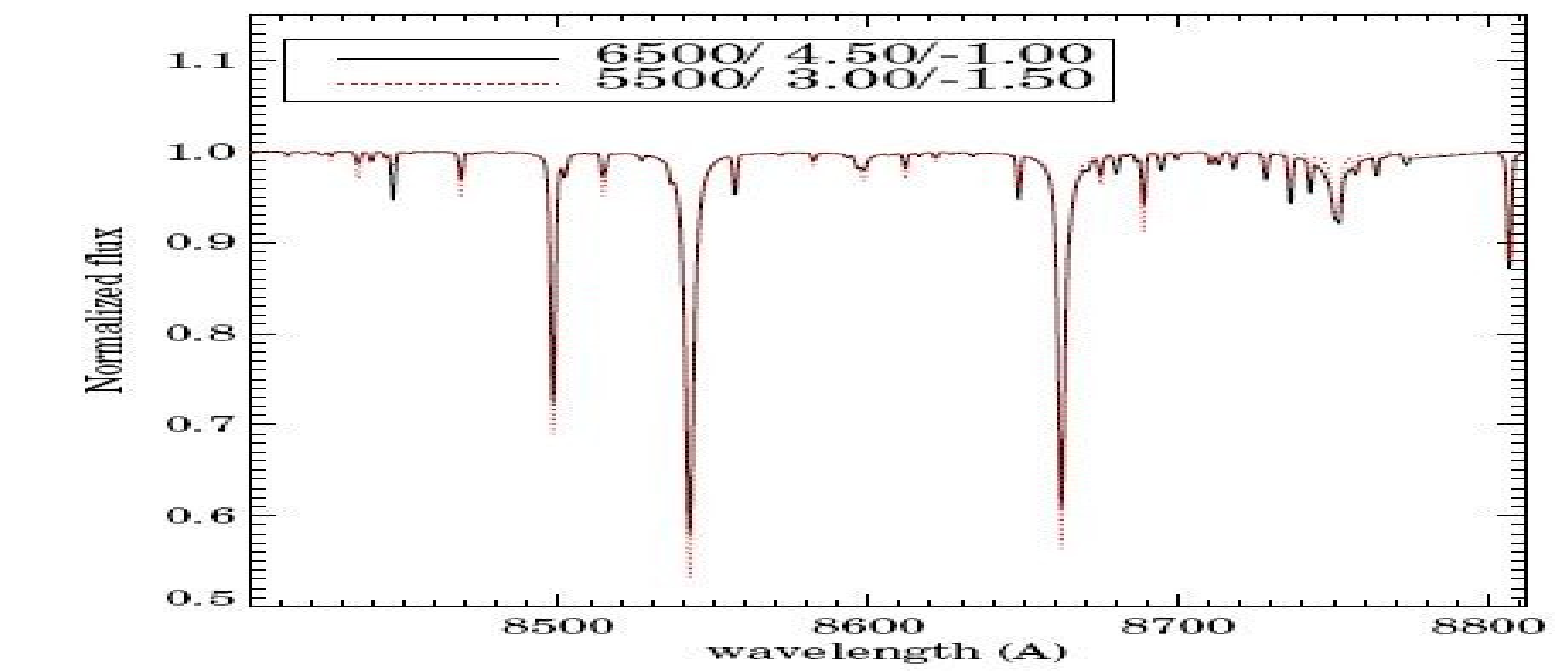
- **HR10** gives the best results for Teff, logg, [M/H] and [alpha/Fe]
- Errors for the different methods reflect various combinations of errors: purely internal (for those using only the reference grid), or a mix of internal and external (use of photometric information, different model atmospheres and transfer codes, line data,...).
- Consistent conclusions anyway!

New tests in course (IAC, Nice, Heidelberg)

- Final selection of the setup for Halo/Thick disc
- Refinement of performances in atmospheric parameters as a function of SNR (magnitude limit – number of objects).
- Errors on the individual abundances

Automated stellar parametrization
5. Parameter degeneracies

The IR CaII triplet



Kordopatis et al. (2011)

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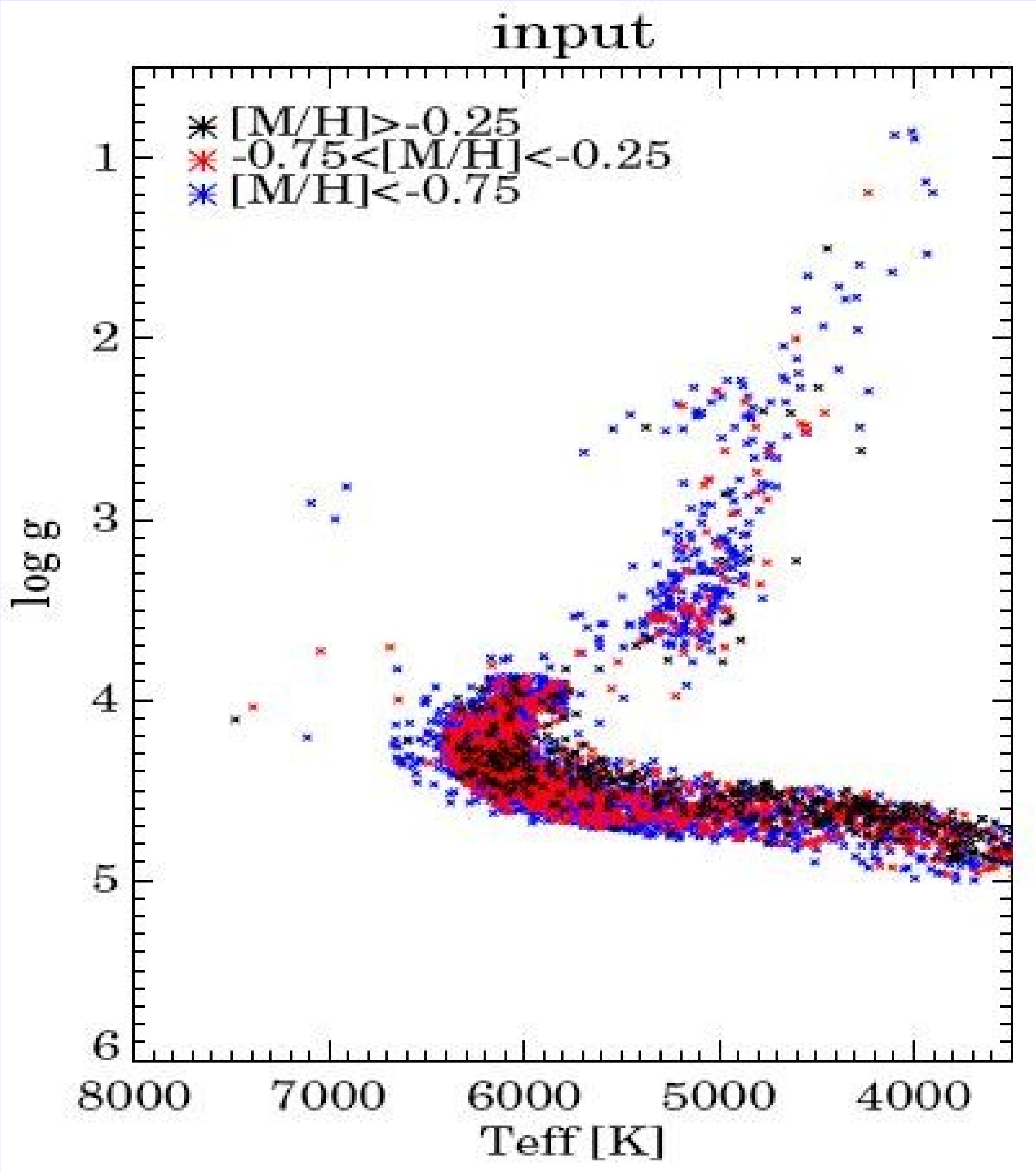
5. Parameter degeneracies



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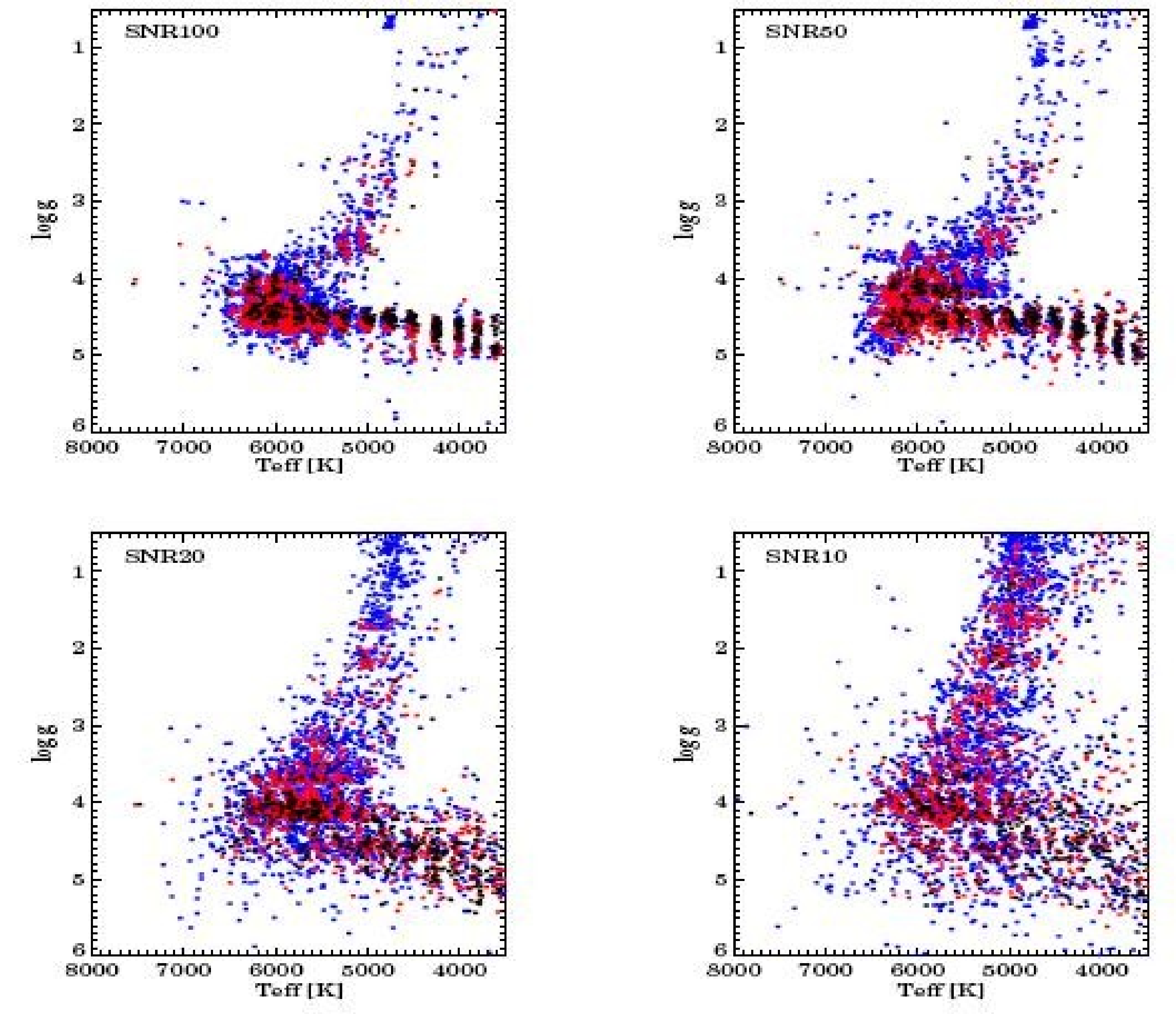
5. Parameter degeneracies



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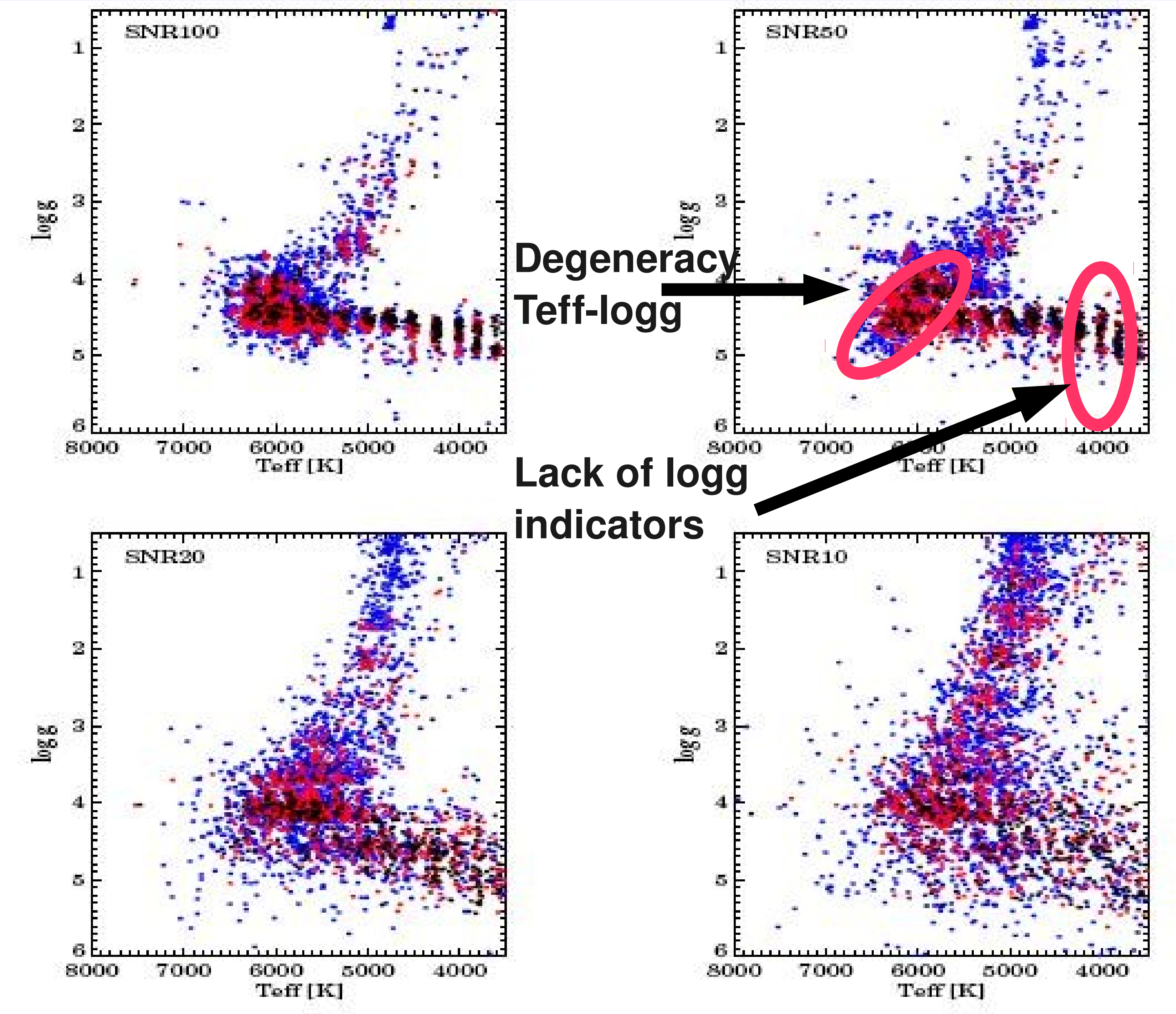

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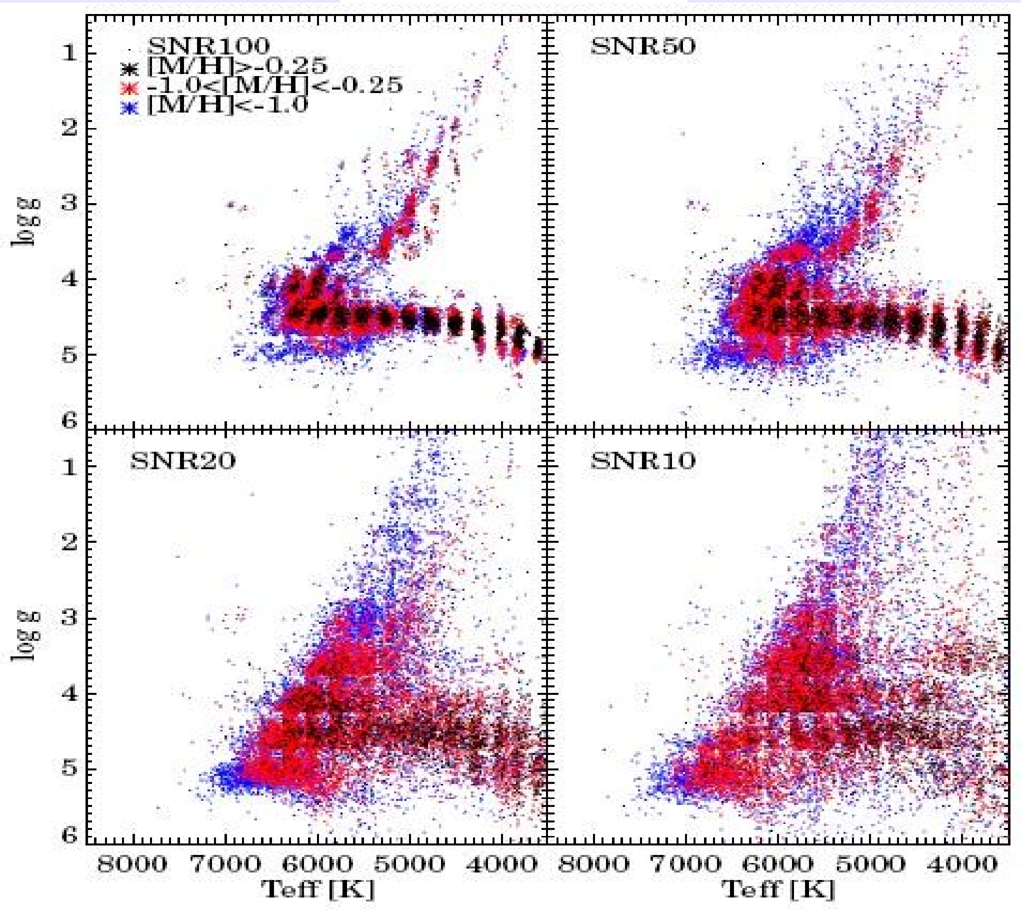
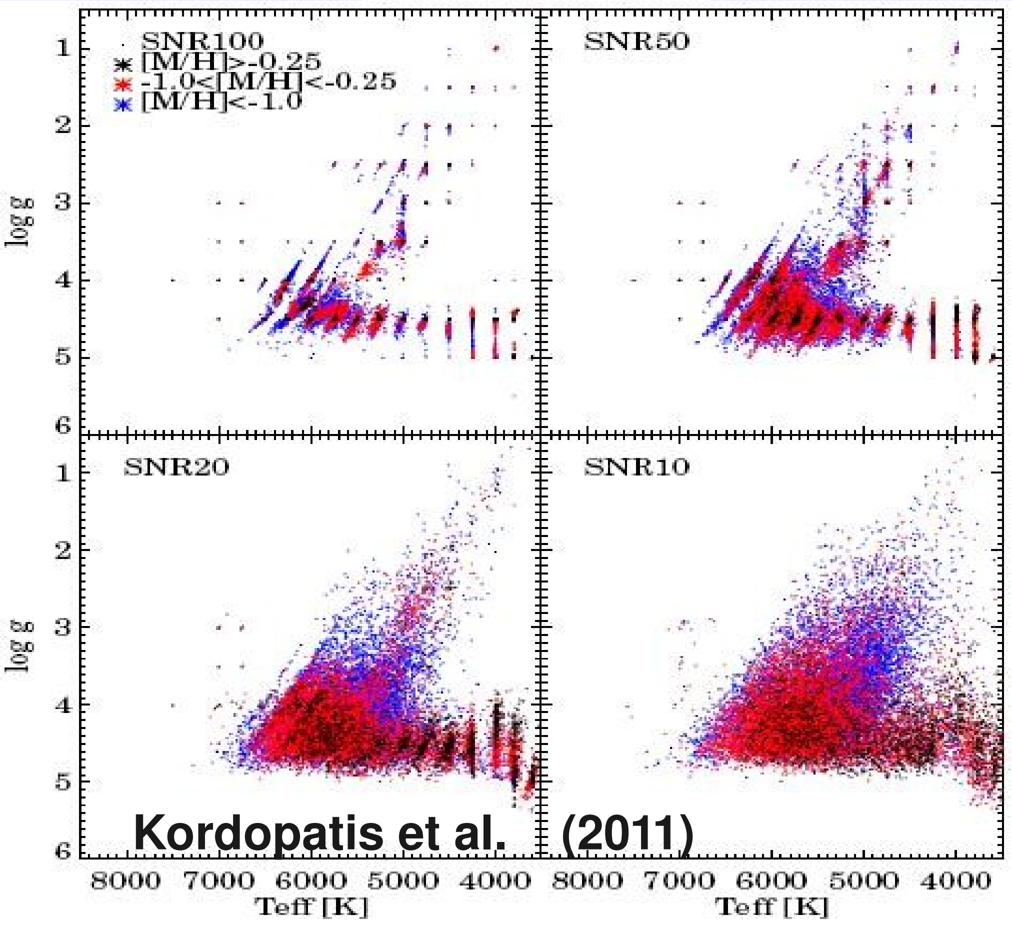
5. Parameter degeneracies

Different methods depending on the SNR can help.

MATISSE



DEGAS



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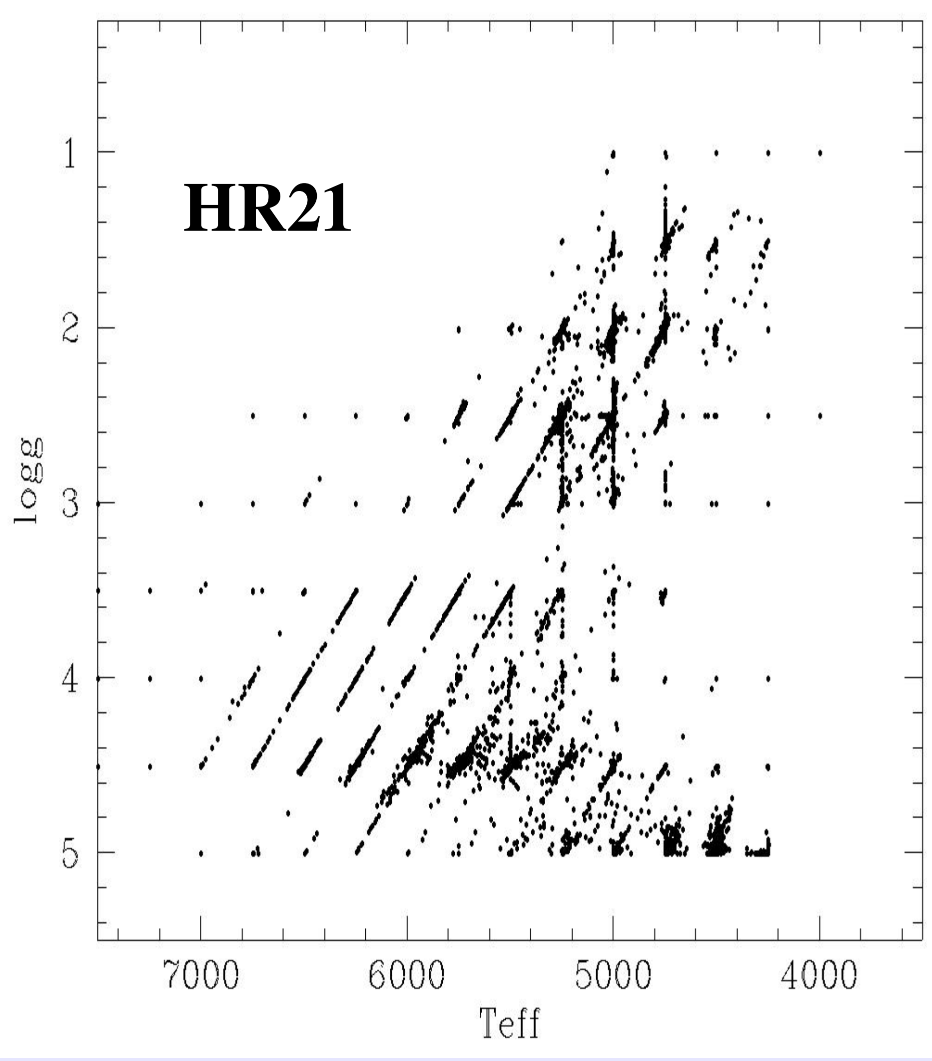
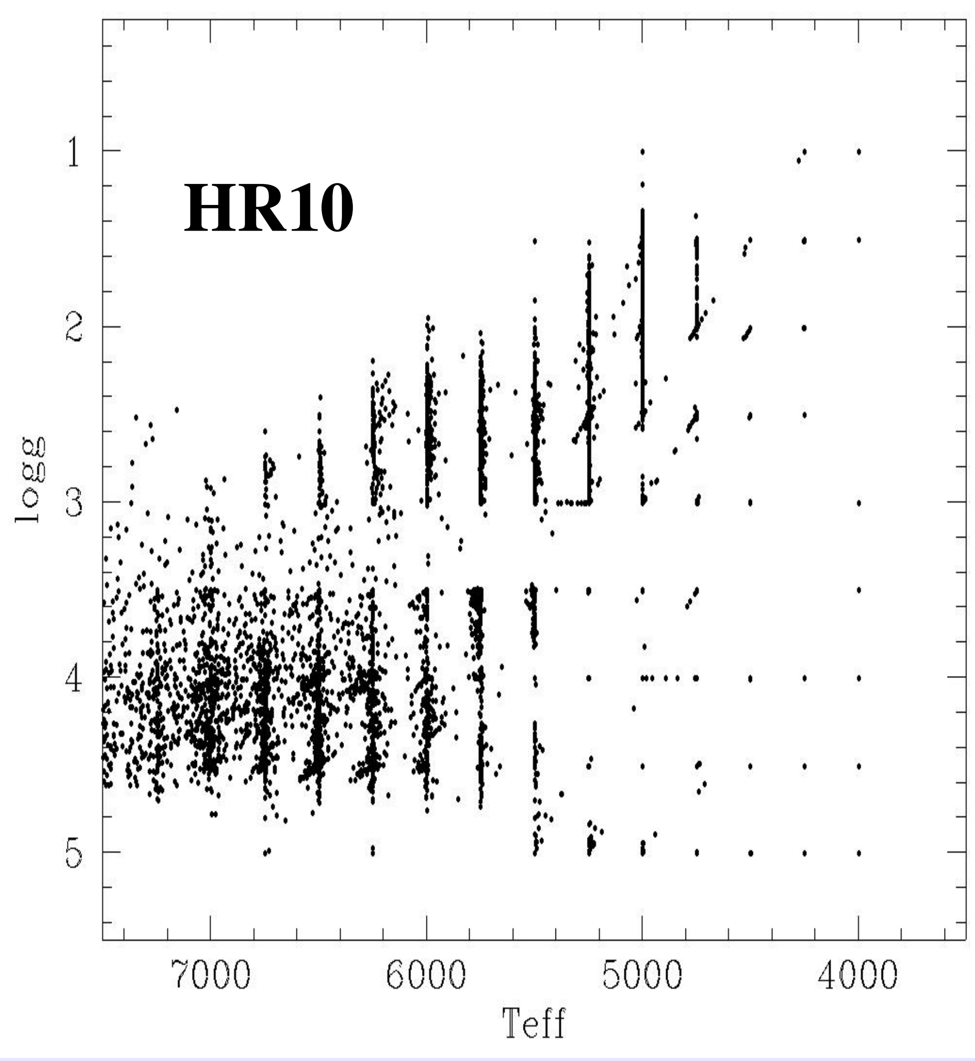
5. Parameter degeneracies





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6. Other applications

The AMBRE Project

Automated analysis of ESO archive stellar spectra : Teff, logg, [M/H] and [alpha/Fe]

P.I. : P. de Laverny
Post-docs : C. Worley, J.C. Gazzano

ESO-OCA agreement 2009-2012
Gaia secondary standards

ESO Spectrograph	Resolving Power	Spectral Domain	Approximate No. archived spectra
FEROS ✓	48,000	350nm - 920nm	23,000
HARPS	115,000	378nm - 691nm	40,000
UVES ✓	40,000 to 110,000	300nm - 1100nm	35,000
Flames/GIRAFFE	5,600 to 46,000	370nm - 900nm	100,000
		Total Sample	198,000

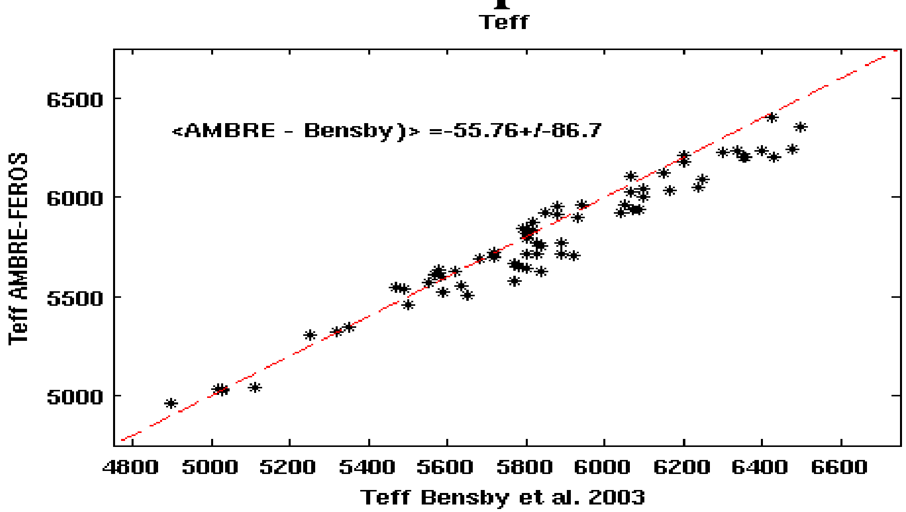
- Objectives 1) to classify the ESO archived spectra → Virtual Observatory
  2) to test MATISSE with large sets of real spectra
  3) to create a galactic chemical chart

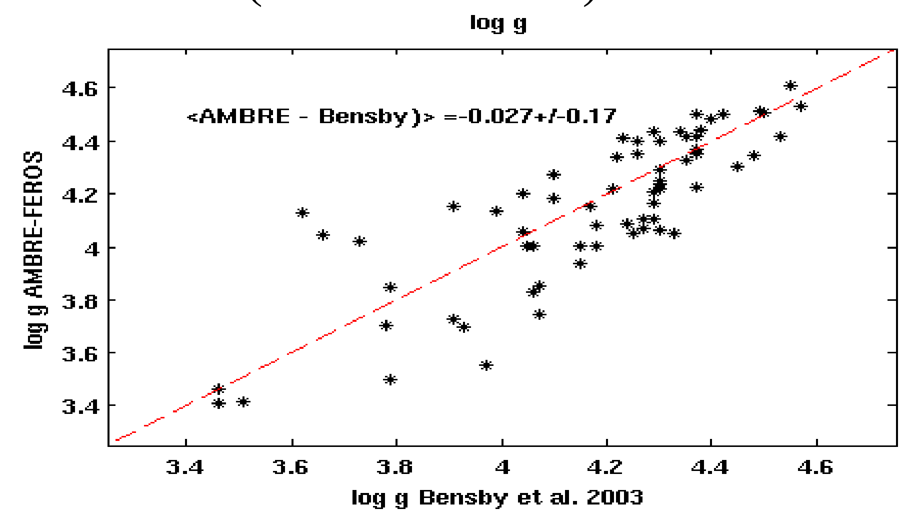
Automated stellar parametrization

6. The AMBRE project

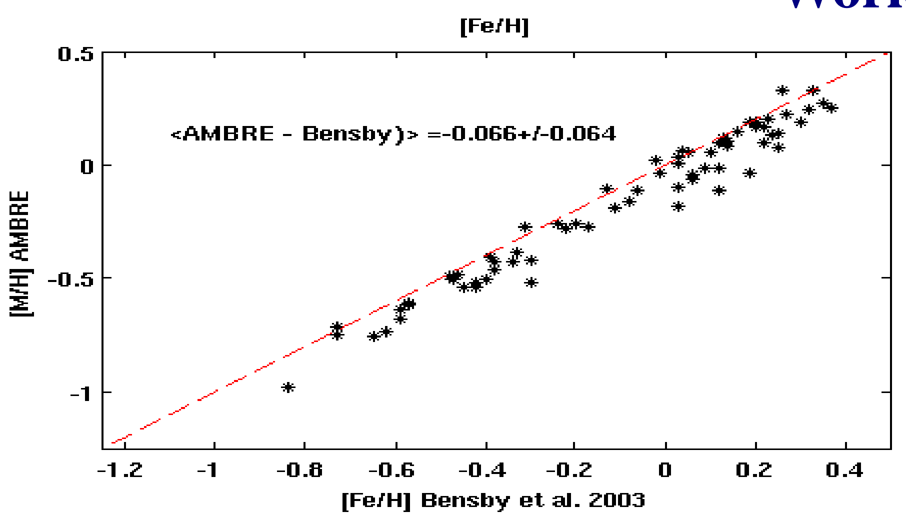
MATISSE application to ESO archive spectra

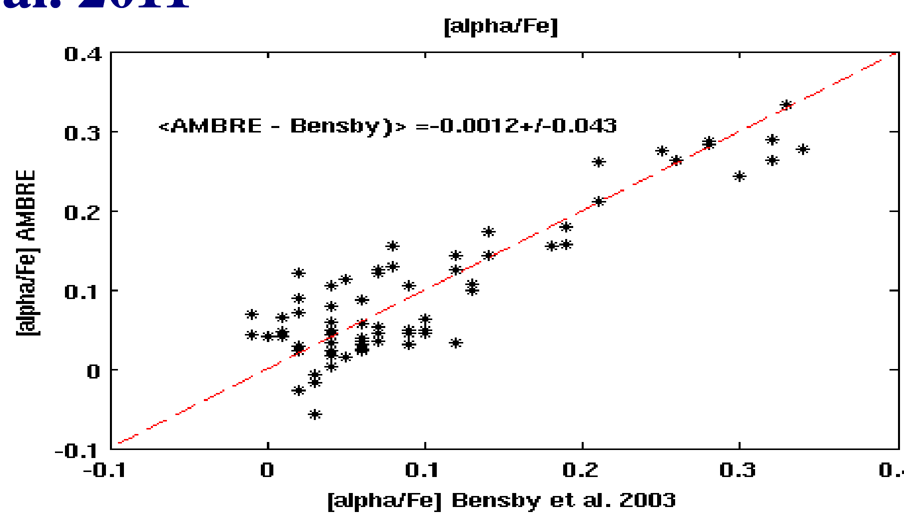
Comparison with Bensby et al. 2003 (FEROS data)





Worley et al. 2011





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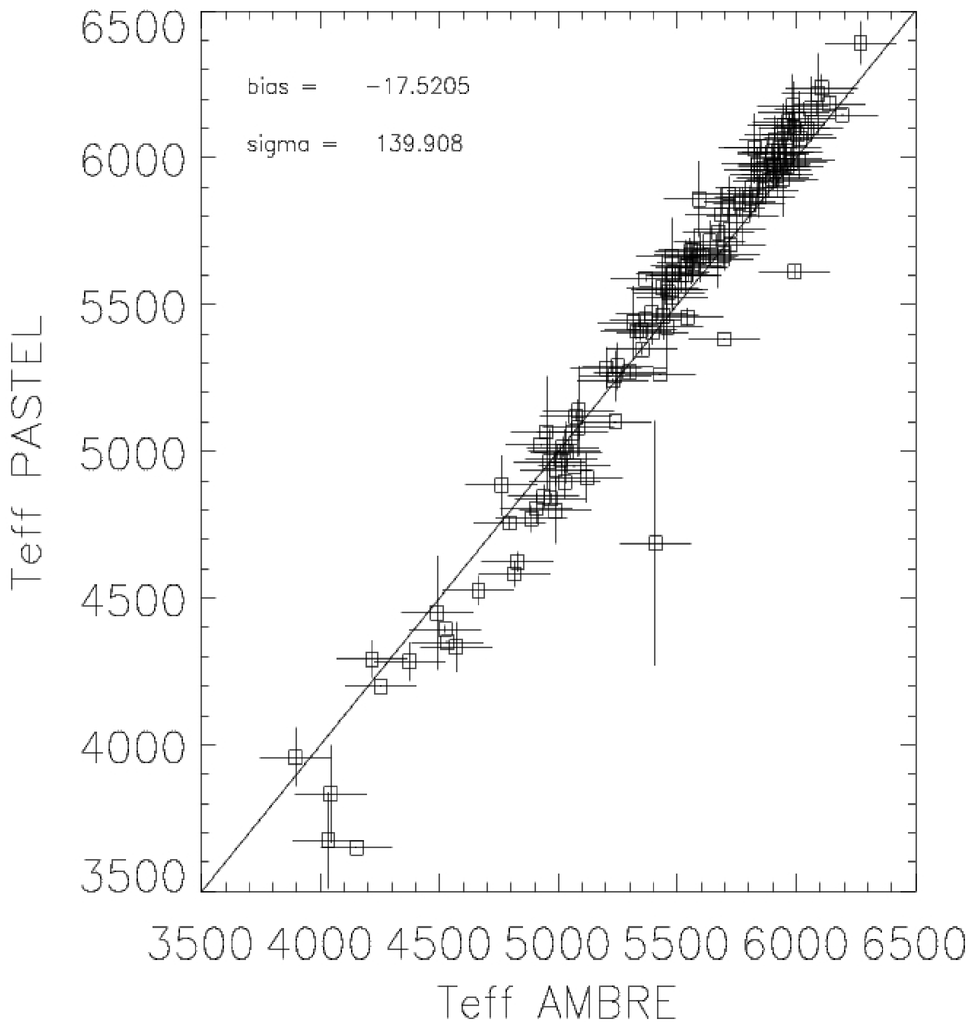
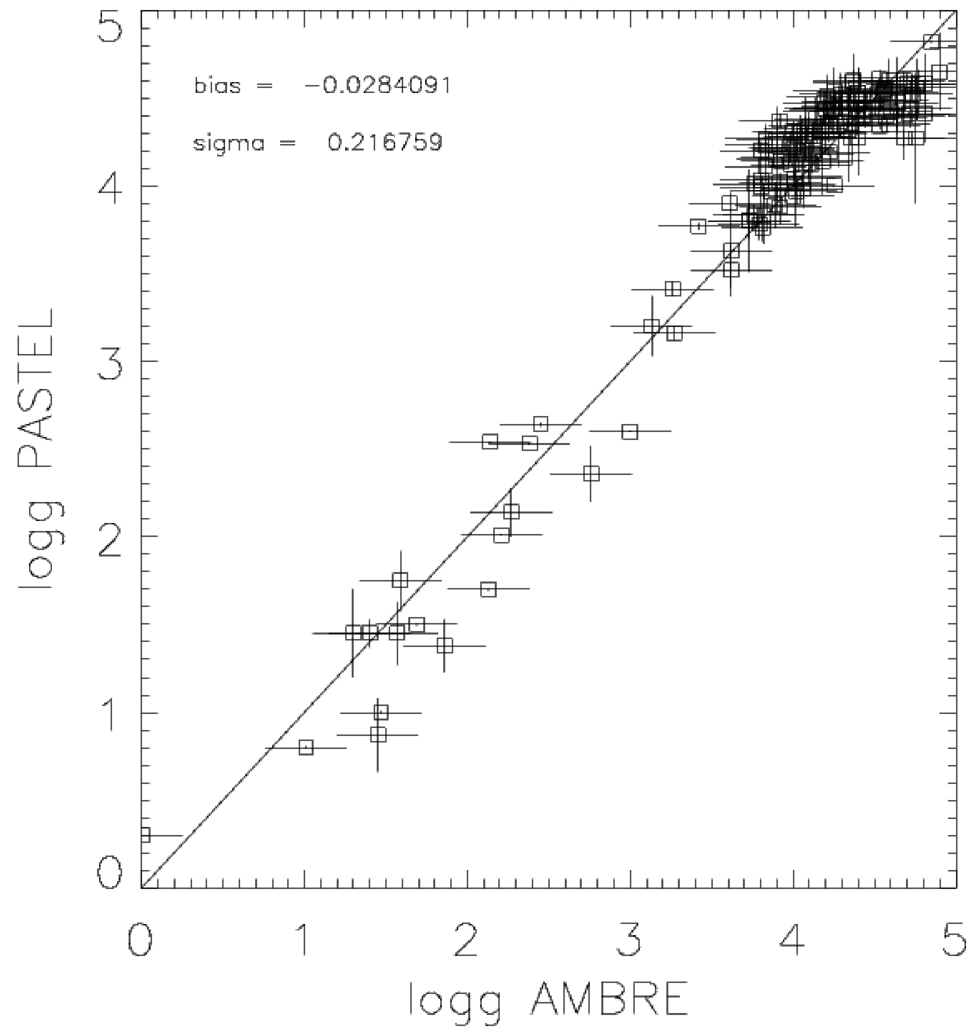
6. The AMBRE project

MATISSE application to ESO archive spectra

Test on real UVES data (PASTEL database)





Automated stellar parametrization

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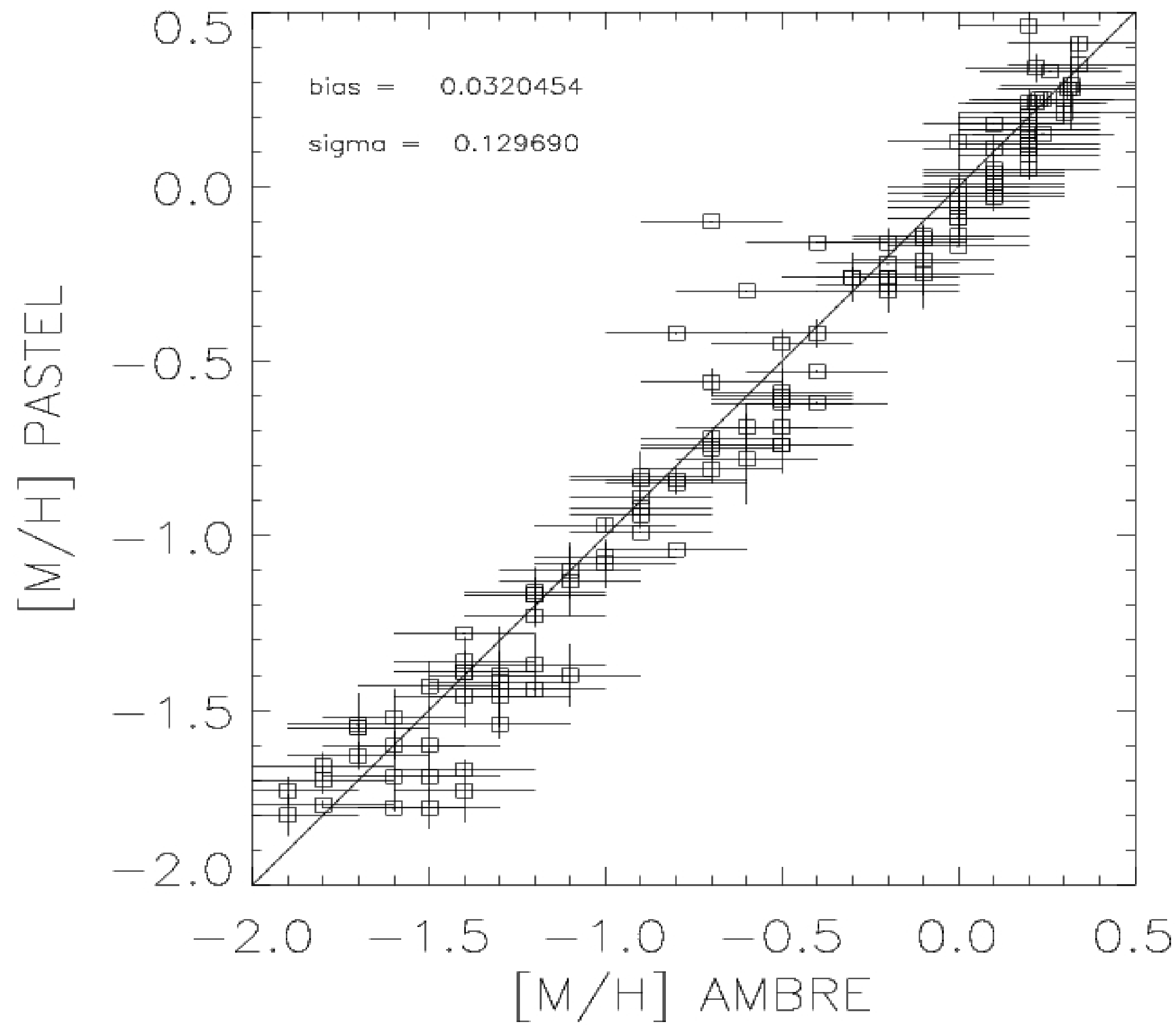


Automated stellar parametrization

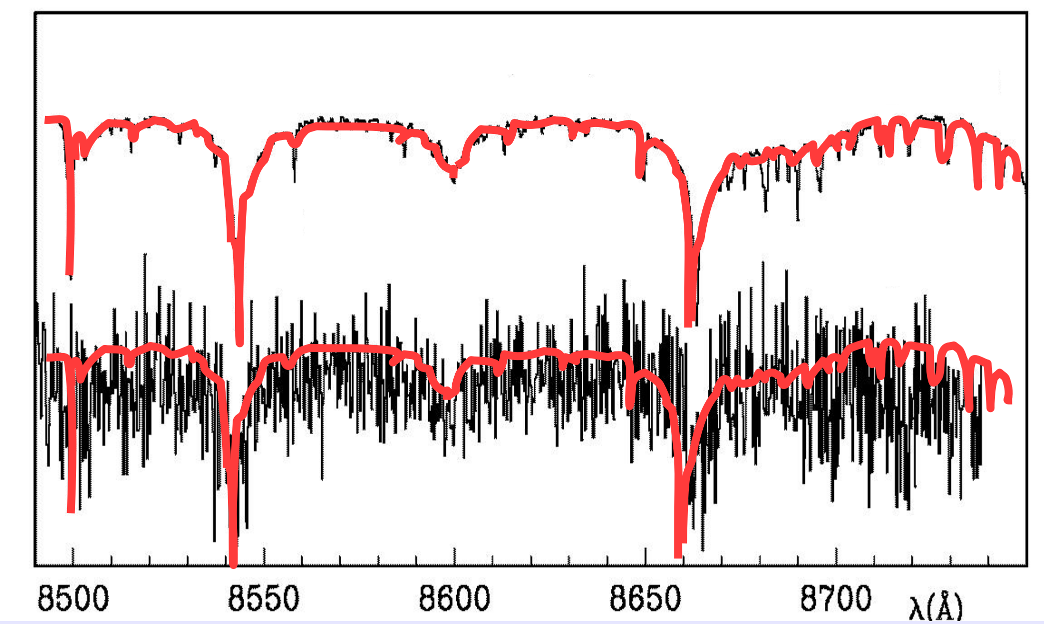
Conclusions

- **Important Spanish contribution to the GES WP10**
- **Several algorithms are ready to be applied for the spectrum analysis**
- **Each method has its application field, depending on the conditions of the parameter space for a given data set.**
  Several methods may be combined for an optimal result.
- **Parameter degeneracies : minimize impact with**
  - several setups, if possible
  - photometric information / target selection
- **The sources of errors can be very different for different methods.**
  Homogeneity is crucial for comparisons and relative error minimization.

Automated stellar parametrization

1. What is it?

To determine the stellar parameters (effective temperature, surface gravity, global metallicity, individual chemical abundances) **that best fit an observed spectrum with a synthetic one.**



Distance minimization:

$$D(\Theta) = \sum_{l=1,L} [O(l) - S(l,\Theta)]^2.$$

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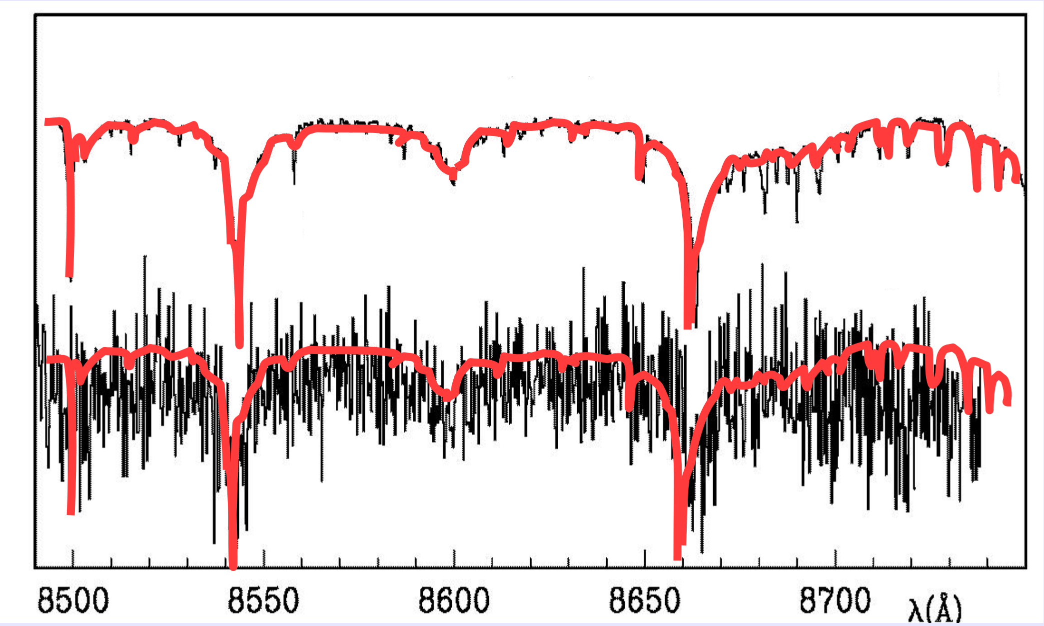

Complex physics :

Model atmospheres

Atomic/molecular line lists

***Atmospheric parameters:* Teff, log g, [M/H],...**

Impossible to work with analytical expressions !

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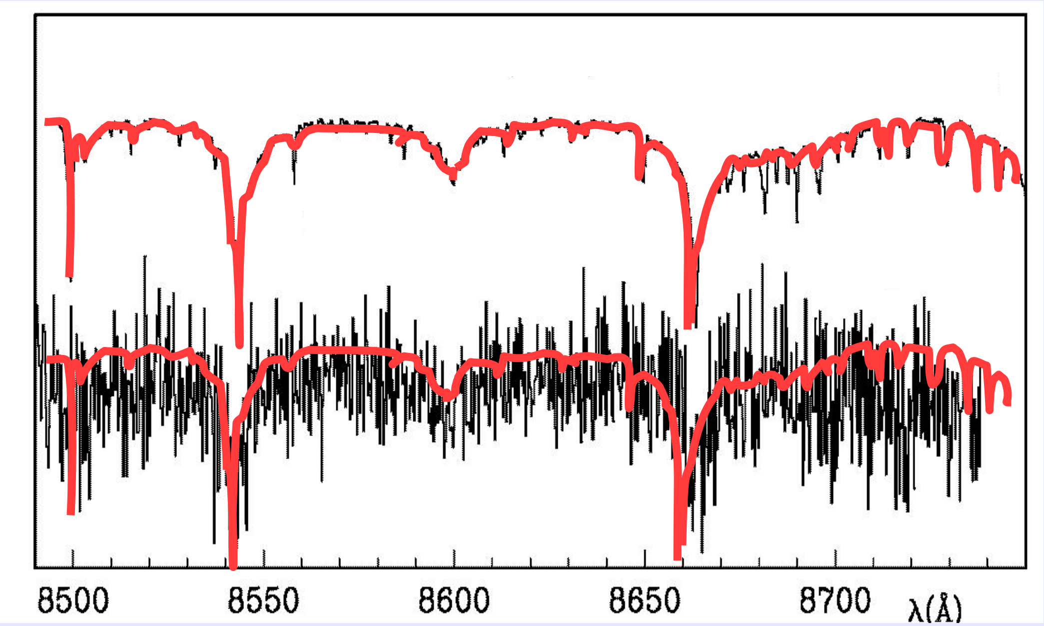

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Grid of synthetic spectra

Automated stellar parametrization

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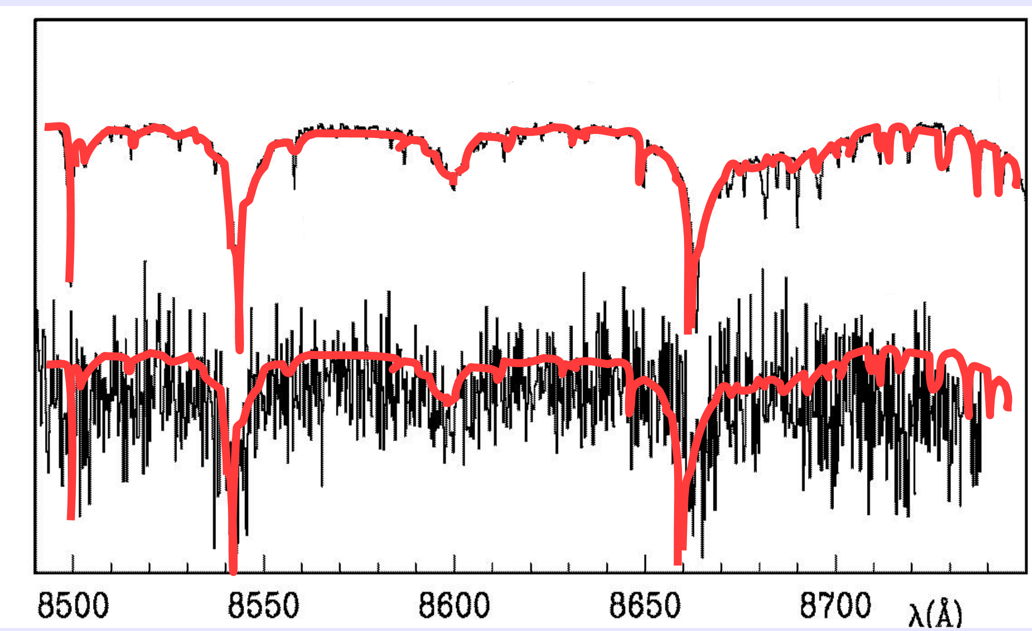


Warning!

Any method of parametrization RELIES on the physics of the synthetic spectra grid, that has to be verified.

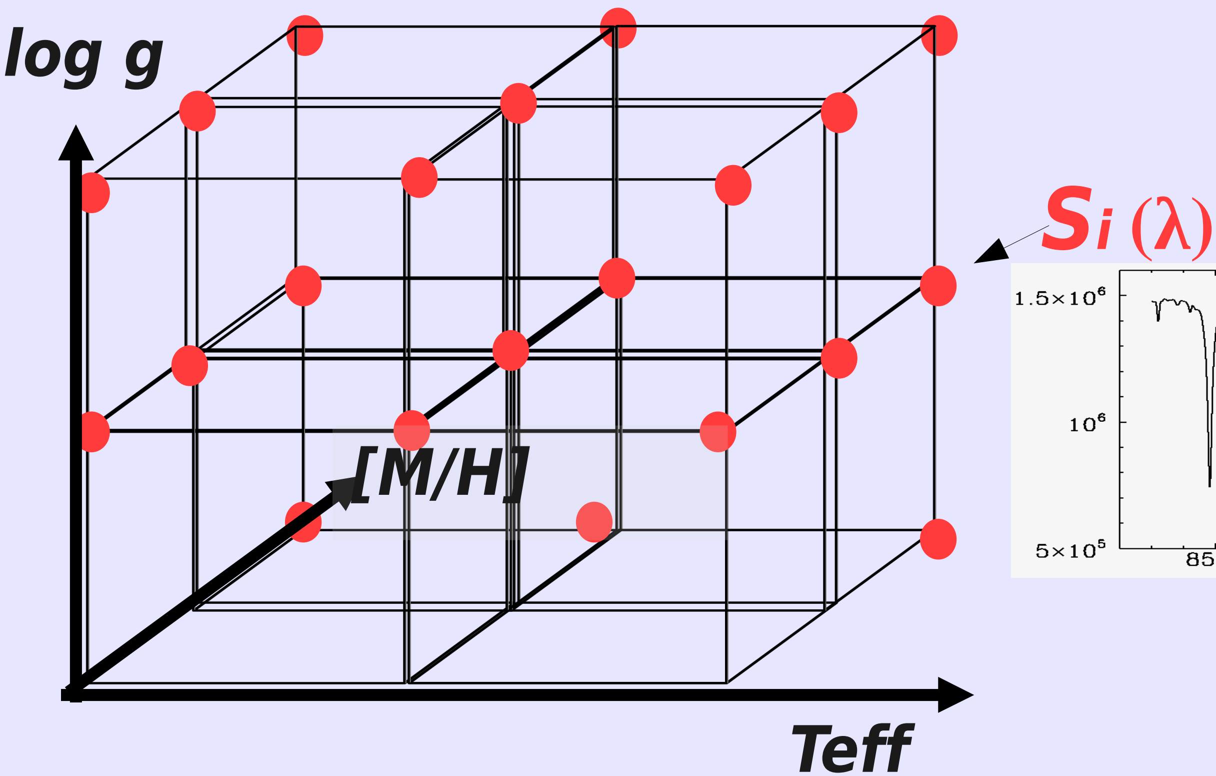
Impossible to work with analytical expressions ! =>

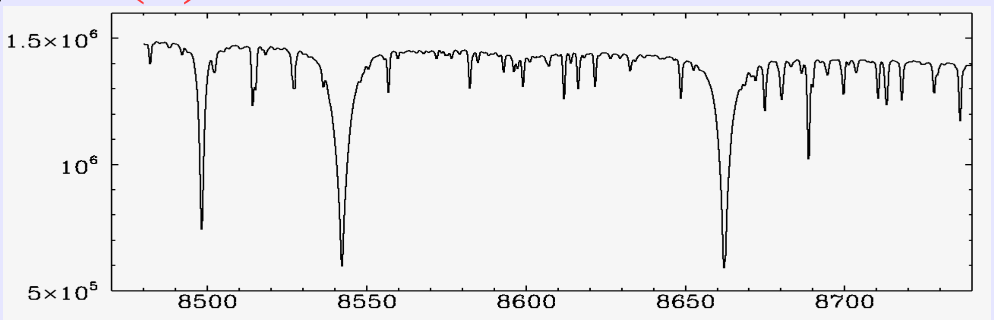
Grid of synthetic spectra

Automated stellar parametrization

2. Why is it difficult?

The parameter space (and the distance function) can suffer from :





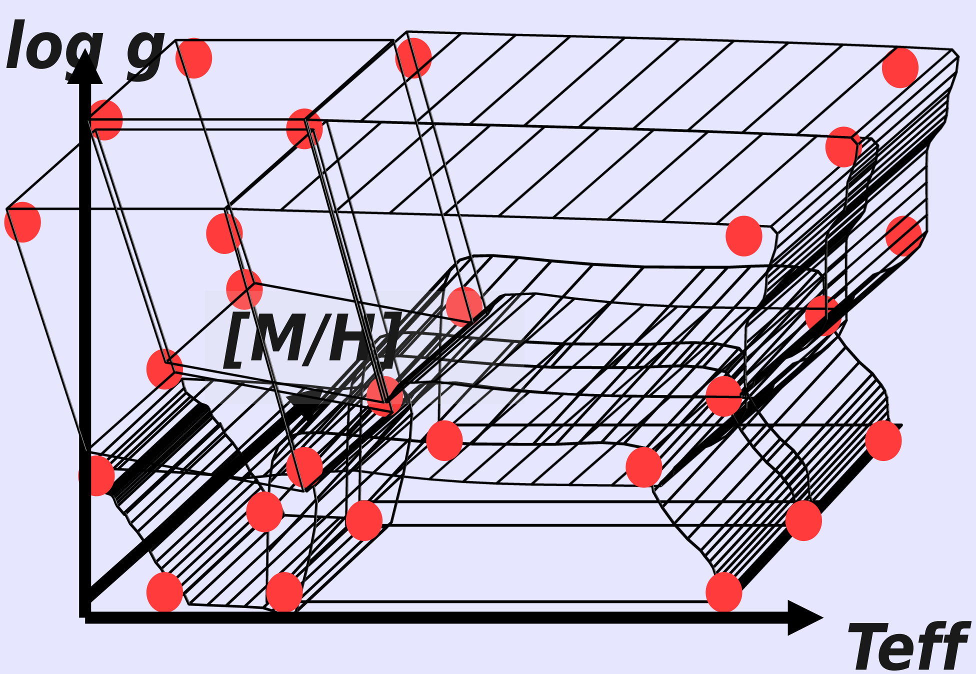
Automated stellar parametrization

2. Why is it difficult?

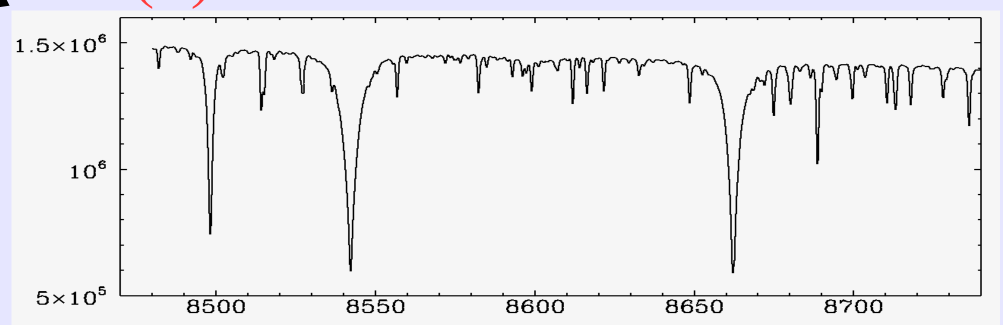
The parameter space (and the distance function) can suffer from :

- **<u>Non linearity</u> : non-linear variations of the spectral flux with atmospheric parameters variations.**

More important for large scales in the parameter space



$S_i\ (\lambda)$



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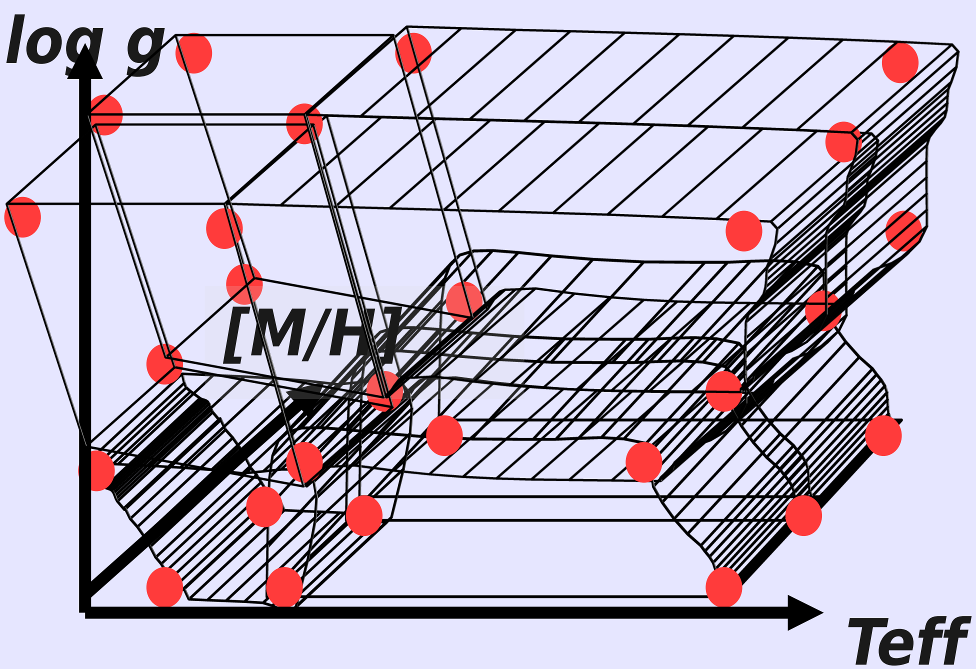
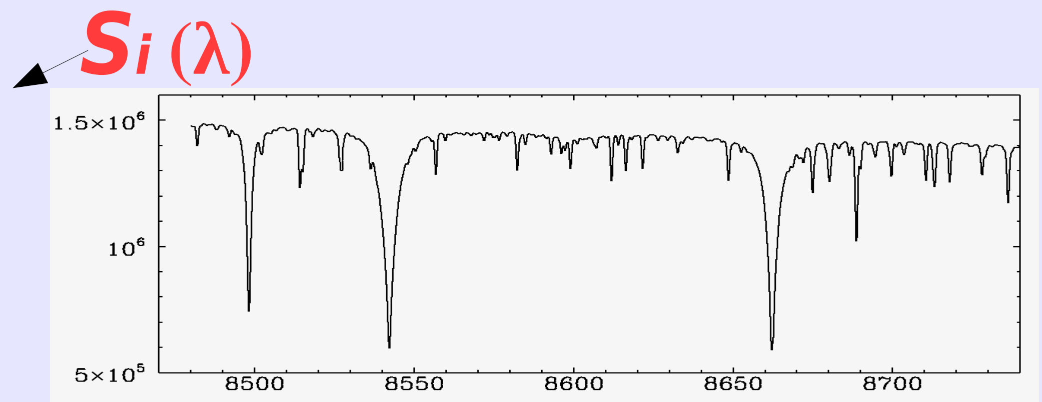
2. Why is it difficult?

The parameter space (and the distance function) can suffer from :

- **Non linearity**
- **Non convexity**

Degeneracy of the parameters :





Automated stellar parametrization

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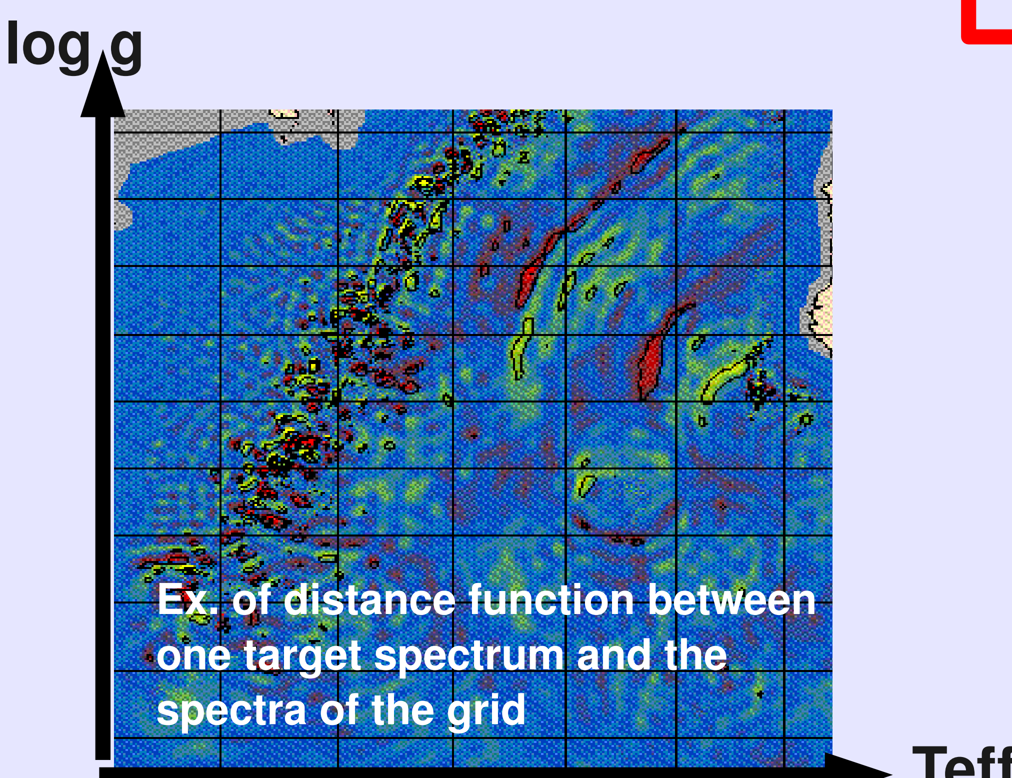
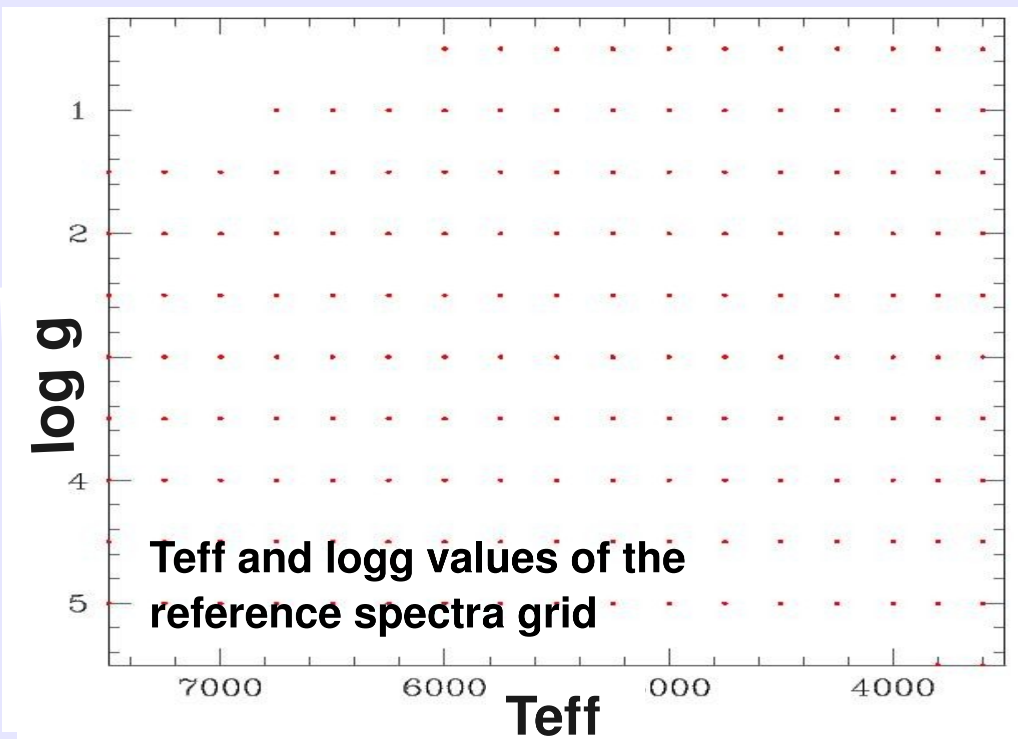
Degeneracy of the parameters :

Secondary minima



Ex. of distance function between one target spectrum and the spectra of the grid



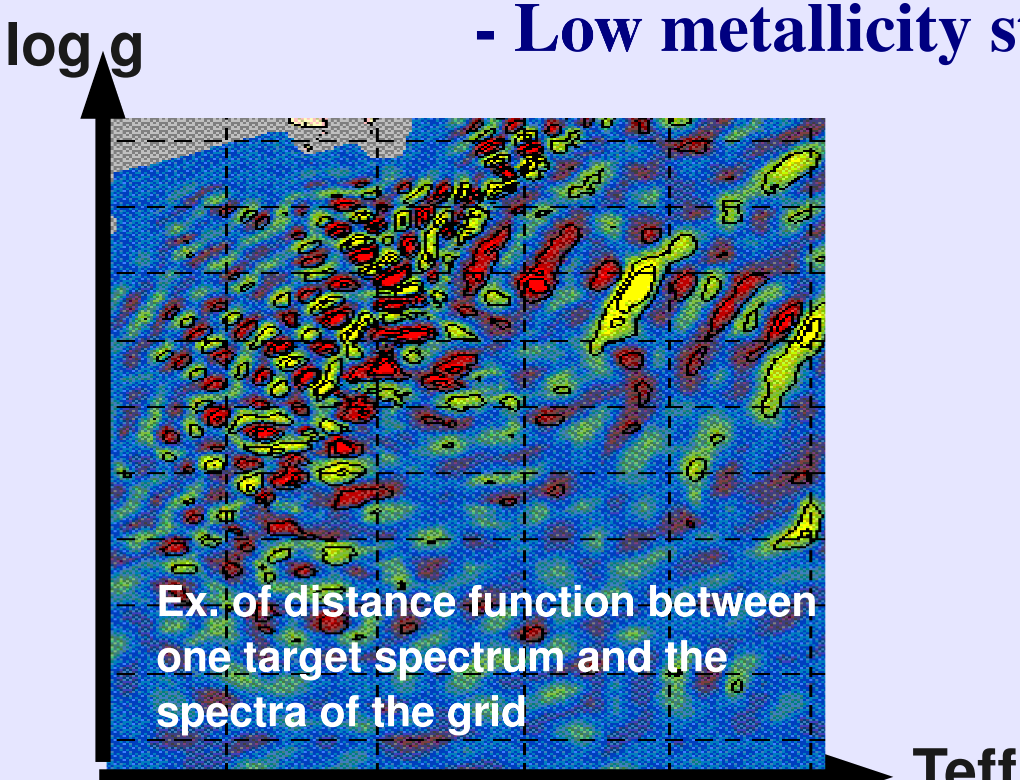
Teff and logg values of the reference spectra grid

Automated stellar parametrization

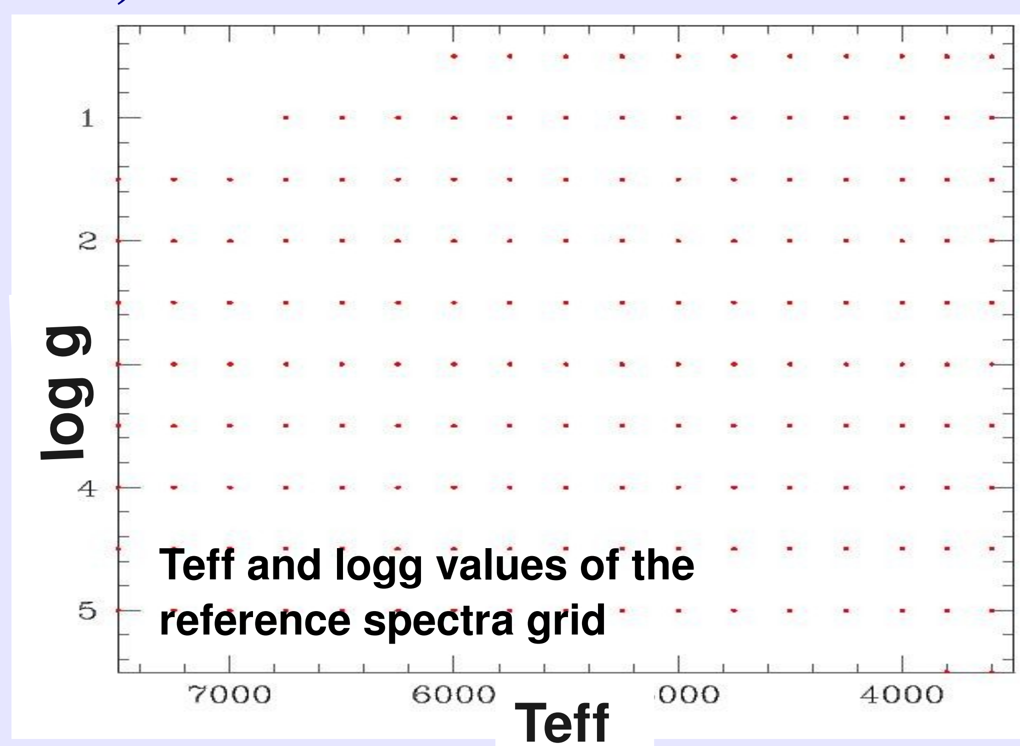
2. Why is it difficult?

The situation gets worse <u>when the spectra contain less information</u>:

- Low signal to noise ratio
- Low resolution
- Smaller spectral range
- Low metallicity stars, ...



Ex. of distance function between one target spectrum and the spectra of the grid



Teff and logg values of the reference spectra grid

4. The Gaia RVS context

Algorithm in charge of determining the stellar APs from RVS spectra of individual stars (CaII IR triplet, R = ~11 500/~6 000):
CU8/Generalized Stellar Parametrizer-spectroscopy **(Recio-Blanco et al.)**

Context (I) :

1. **Normalized and radial velocity corrected spectra**

2. **Preliminar selection of stellar spectra (Discrete Source Classifier)**

3. **Synthetic, simulated and standard spectra from DPAC**

Automated stellar parametrization

4. The Gaia RVS context

Gaia DPAC

GSP-spec

Algorithm in charge of determining the stellar APs from RVS spectra of individual stars (CaII IR triplet, R = ~11 500/~6 000):

CU8/Generalized Stellar Parametrizer-spectroscopy **(Recio-Blanco et al.)**

Context (II) :

4. **Four algorithms tested : 2 of them integrated**

5. **Integration at CNES for DPAC in 6-months cycles**
   Algorithms coded in Java with common tools implemented:
   Gaia data-model, dictionary tool, main database

6. **Possible inputs from GSP-phot (APs determined from BP/RP)**

Automated stellar parametrization

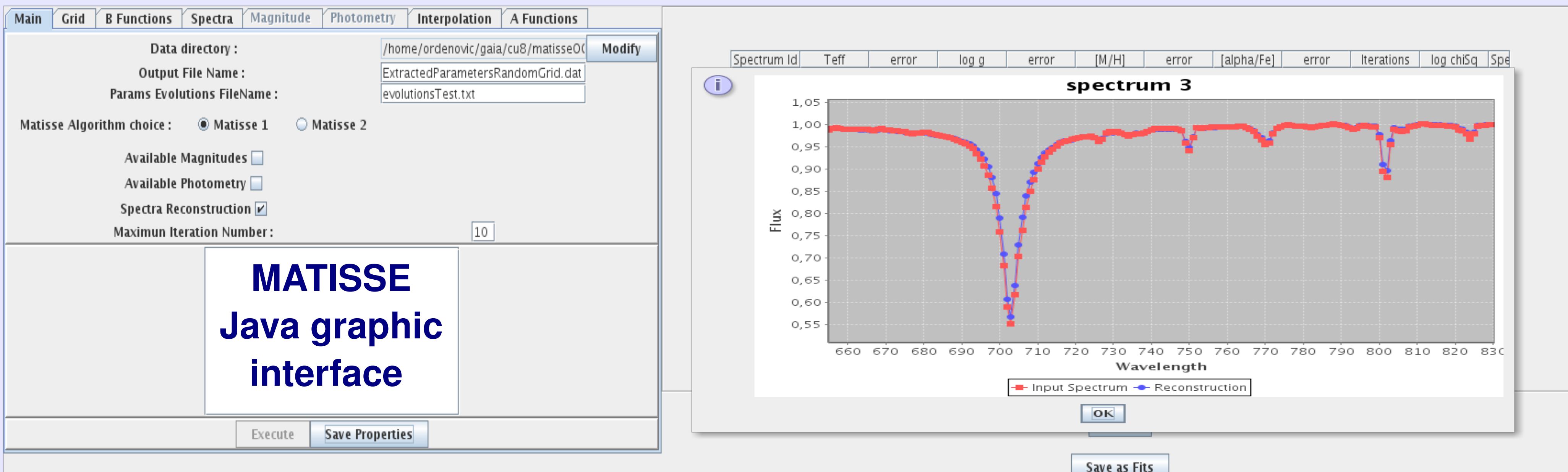
4. The Gaia RVS context

Generalized Stellar Parametrizer-spectroscopy tested methods :

- **MATISSE**
- **DEGAS**

} **Observatoire de la Côte d'Azur (Nice) : A. Bijaoui, P. de Laverny, G. Kordopatis, Ch. Ordenovic, A. Recio-Blanco, C. Worley**

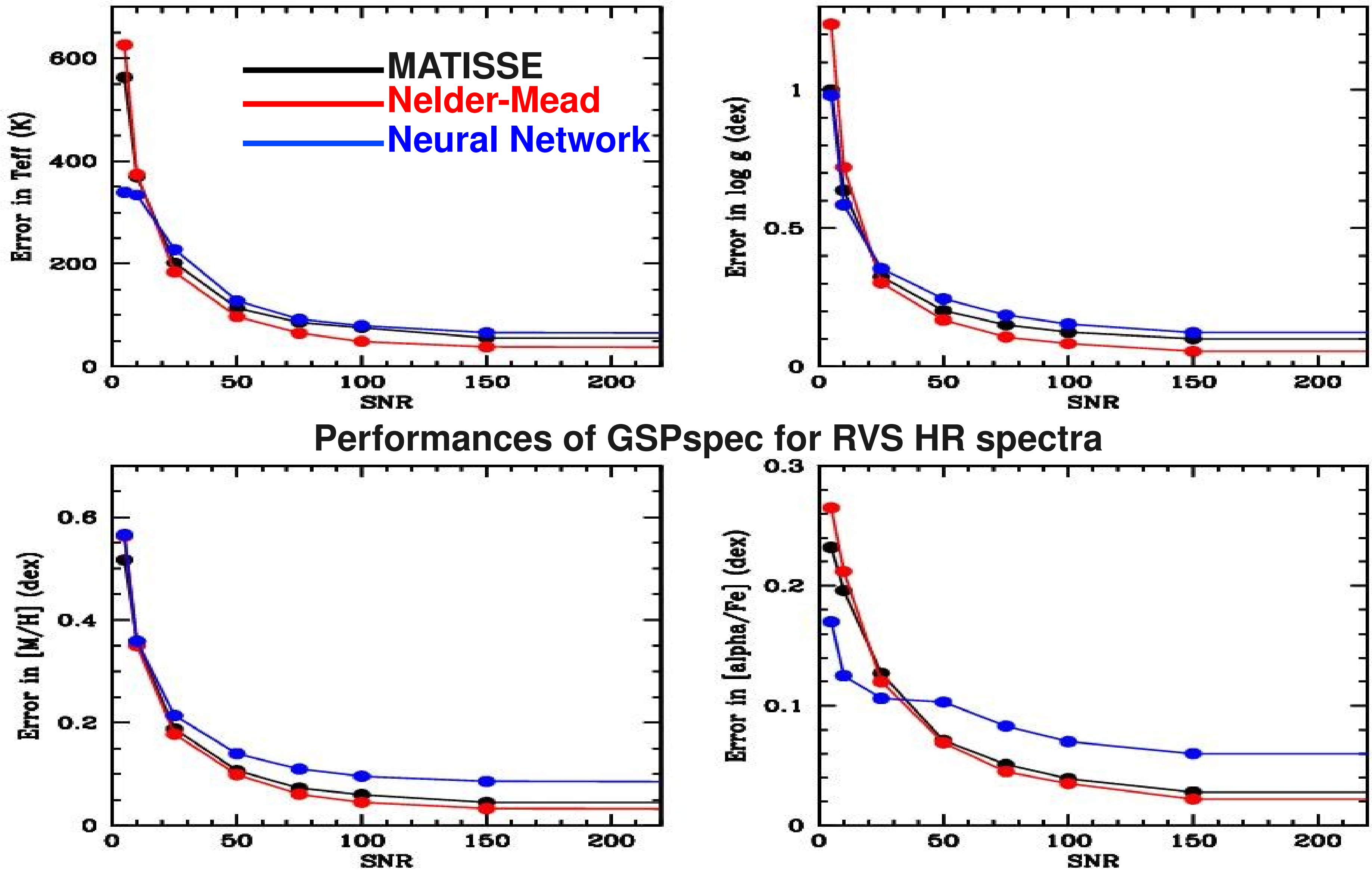
Integrated at CNES: D-track delivery



- **Nelder-Mead**: C. Allende-Prieto (Instituto de Astrofísica Canarias)
- **Artificial Neural Networks**: D. Ordóñez (Univ. de A. Coruña)

Automated stellar parametrization

4. The Gaia RVS context

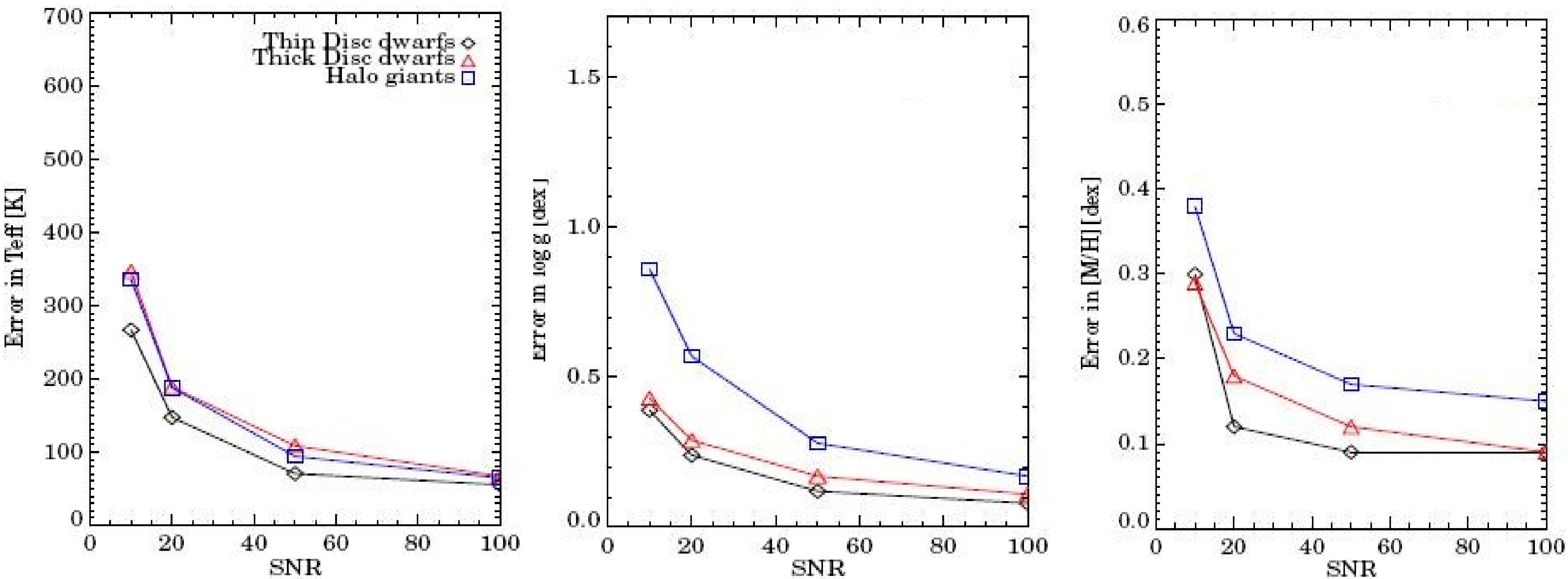


Automated stellar parametrization

4. The Gaia RVS context

Performances of GSPspec for RVS LR spectra

MATISSE+ DEGAS Combined

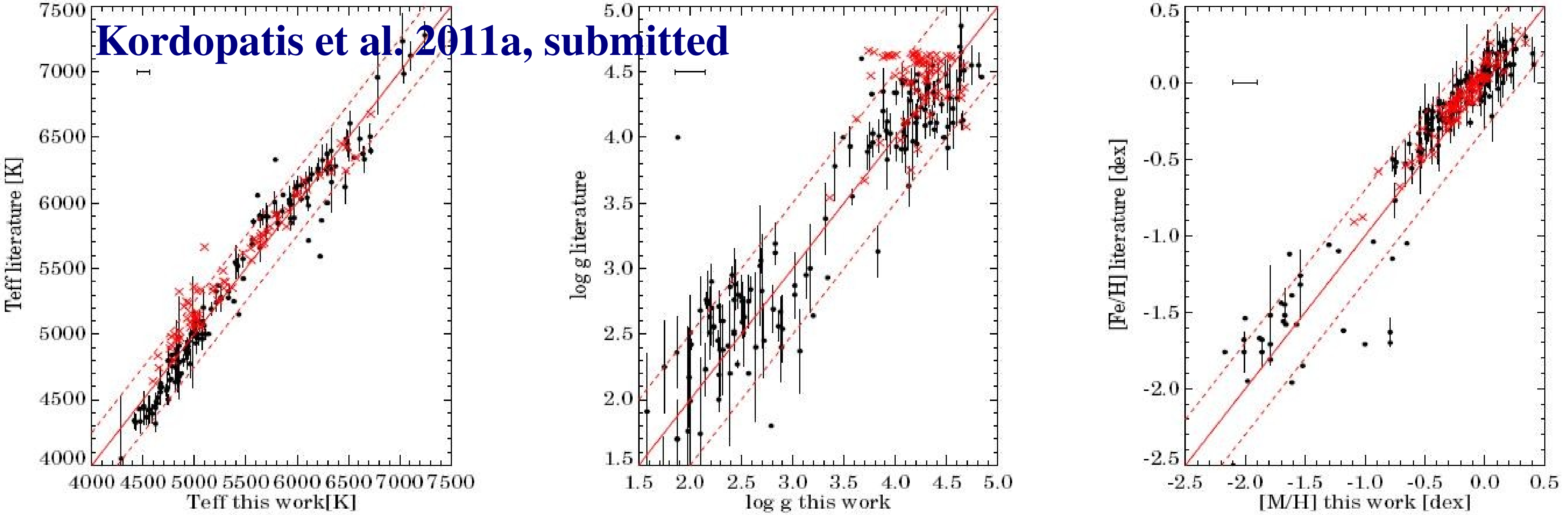


Kordopatis et al. 2011a, submitted

Automated stellar parametrization

4. The Gaia RVS context

Kordopatis et al. 2011a, submitted



	$T_{\rm eff}$ (K)	$\log g$ (dex)	[M/H] (dex)
S^4N (all)	-108 ± 145	-0.21 ± 0.32	-0.08 ± 0.09
CFLIB (all)	30 ± 171	-0.04 ± 0.42	-0.05 ± 0.21
CFLIB (dwarfs)	-27 ± 156	0.03 ± 0.26	-0.10 ± 0.10
CFLIB (giants)	91 ± 118	-0.05 ± 0.45	-0.04 ± 0.21

Automated stellar parametrization

5. Other applications

The AMBRE Project

Automated analysis of ESO archive stellar spectra : Teff, logg, [M/H] and [alpha/Fe]

P.I. : P. de Laverny
Post-docs : C. Worley, J.C. Gazzano

ESO-OCA agreement 2009-2012
Gaia secondary standards

ESO Spectrograph	Resolving Power	Spectral Domain	Approximate No. archived spectra
FEROS ✓	48,000	350nm - 920nm	23,000
HARPS	115,000	378nm - 691nm	40,000
UVES ✓	40,000 to 110,000	300nm - 1100nm	35,000
Flames/GIRAFFE	5,600 to 46,000	370nm - 900nm	100,000
		Total Sample	198,000

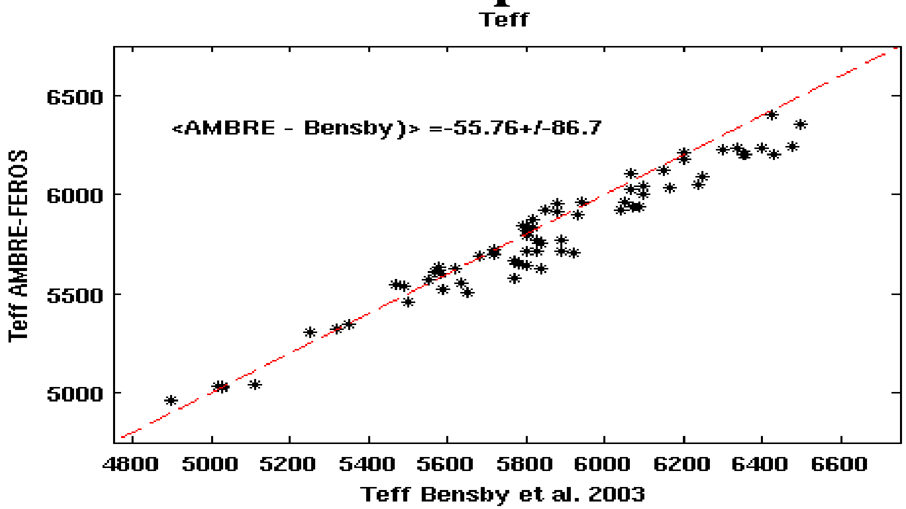
- Objectives 1) to classify the ESO archived spectra → Virtual Observatory
  2) to test MATISSE with large sets of real spectra
  3) to create a galactic chemical chart

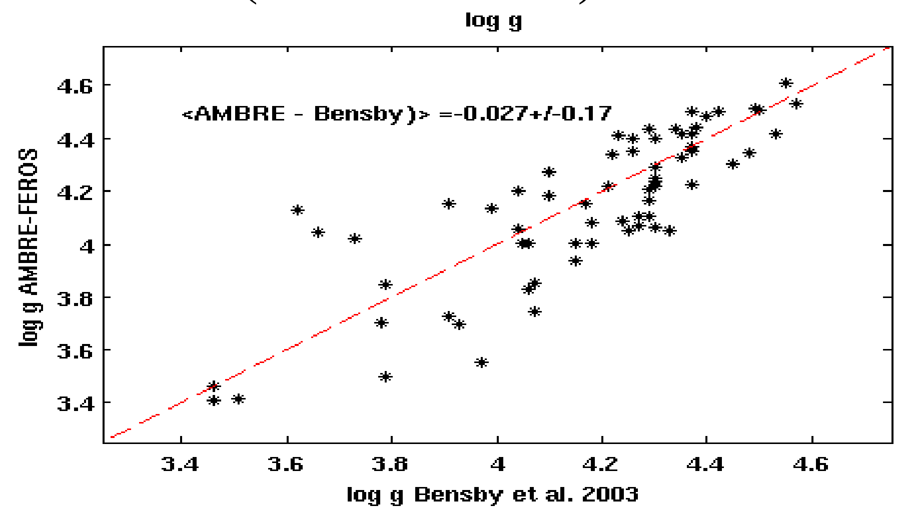
Automated stellar parametrization

5. The AMBRE project

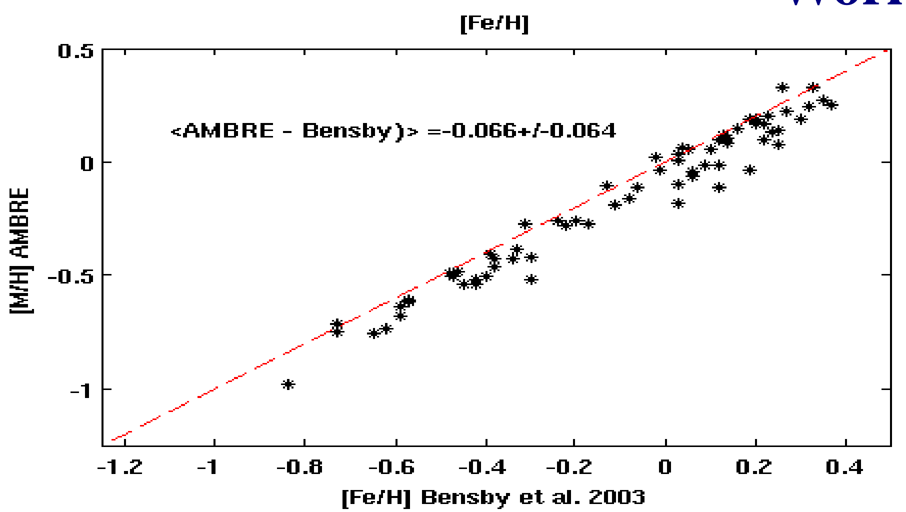
MATISSE application to ESO archive spectra

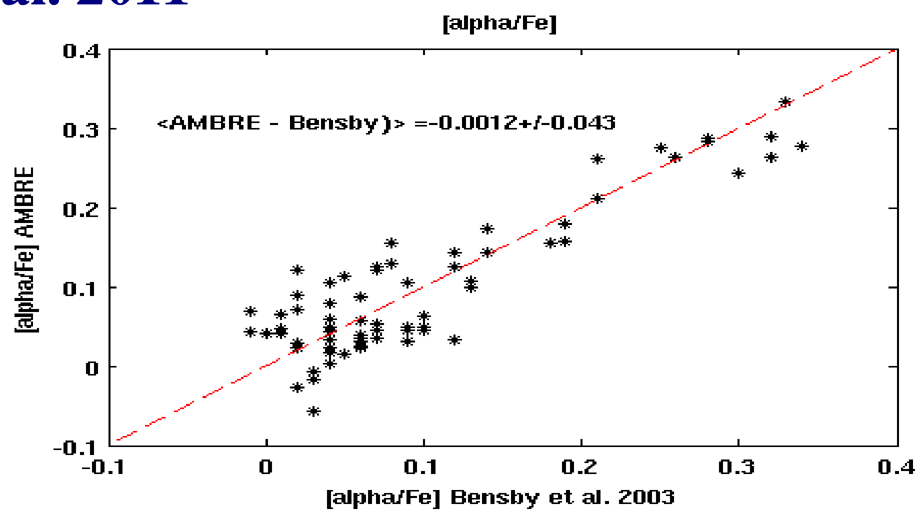
Comparison with Bensby et al. 2003 (FEROS data)





Worley et al. 2011





Automated stellar parametrization

5. Gaia-ESO Large Public Survey

P.I. G. Gilmore, Co-PI S. Randich

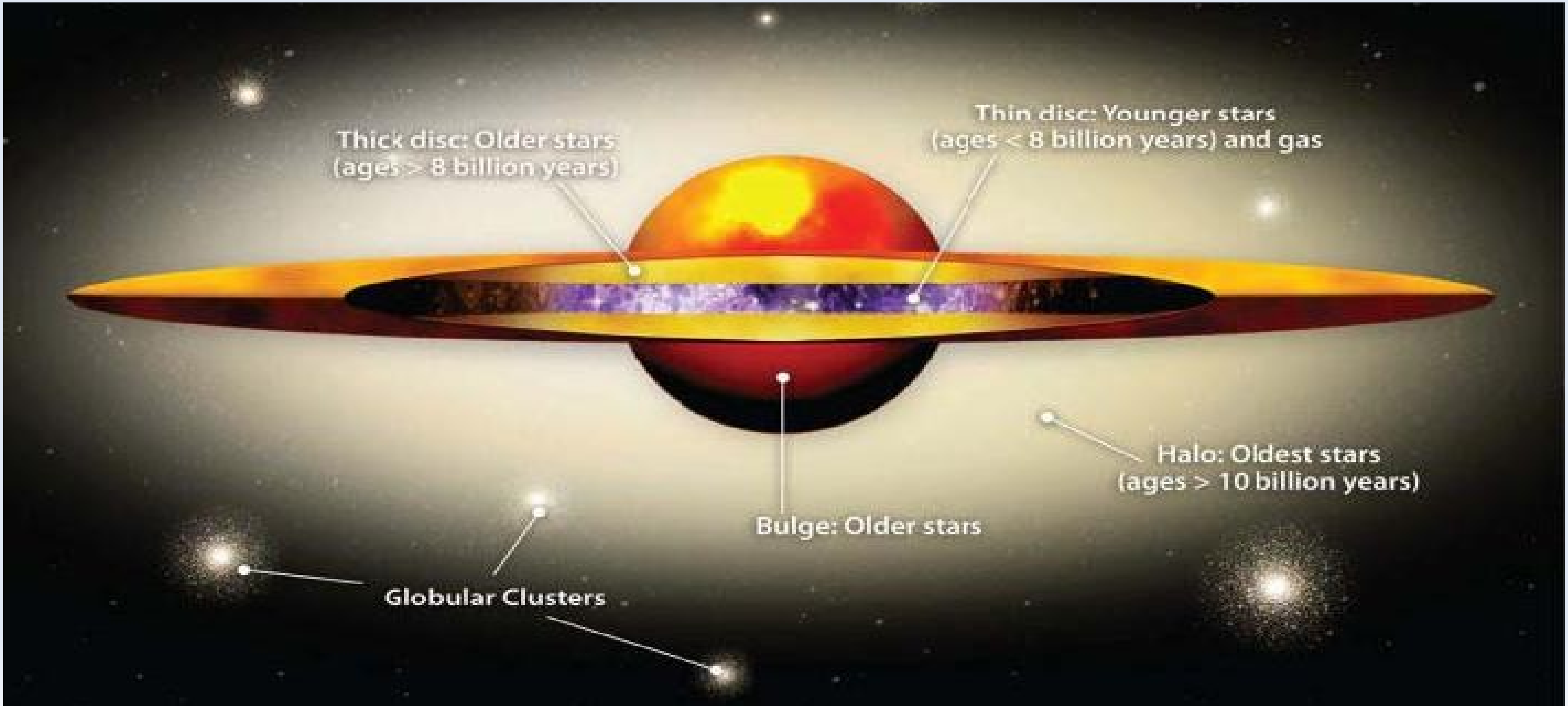
Consortium ~250 Co-Is

300 nights VLT FLAMES during 5 years

Start: January 2012

$2{\cdot}10^5$ stars of the Galaxy

100 open clusters



Automated stellar parametrization

5. Gaia-ESO Large Public Survey

Solar Neighbourhood: UVES on FG turnoff stars

iron-peak, alpha, proton-capture and neutron-capture elements

Thin disc |b| < 5deg: HR21 on metal rich clump stars

Only [M/H] and Ca abundances.

Bulge and Inner Disc: HR21 and HR10 on metal rich GK giants.

Iron peak-elements (Fe, Cr, Mn, Co, Ni), several alpha-elements and proton capture elements (Sc and V)

Halo and outer Thick Disc: HR21 and HR10 (?) on F metal-poor dwarfs

Iron peak-elements (Fe, Cr, Mn, Co, Ni), several alpha-elements and proton capture elements (Sc and V)

Open Clusters: UVES + HR21 or HR15N

iron-peak, alpha, proton-capture and neutron-capture elements and Li

Automated stellar parametrization

5. Gaia-ESO Large Public Survey

Spectra analysis

GIRAFFE FGK Spectrum analysis	Paris, MPA, Lund, Uppsala, Nice, IAC, Vilnius Liege, Arcetri, Bologna, AIP, Ind, Madrid, IAA, Vienna, ESO, Rome, Porto, ZAH, Arcetri, Naples Catania, Padova	A. Recio-Blanco (Fr) & C. Allende Prieto (Sp)
UVES FGK Spectrum analysis	Paris, MPA, Lund, Uppsala, Nice, IAC, Vilnius Liege, Arcetri, Bologna, AIP, Ind, Madrid, IAA, Vienna, ESO, Naples, Porto, ZAH, Arcetri, Naples Catania, Padova	A. Korn (Swe) & R. Smiljanic (ESO)
Pre-Main Sequence Star Spectrum analysis	Madrid, Catania, Granada, Arcetri, Naples, Palermo, Zurich, Armagh	A. Lanzafame (I)
OBA Star Spectrum Analysis	Liege, RO Belg, AIP, OMA, Madrid, Paris, Armagh Uppsala, MPIA, Leuven, Herts	R. Blomme (Be)

Automated stellar parametrization

5. Gaia-ESO Large Public Survey

Products

for stars observed with GIRAFFE:

stellar astrophysical parameters: effective temperature, surface gravity
equivalent widths of absorption and emission lines (when present)
typically, stellar metallicity [Fe/H]
whenever possible [alpha/Fe]
lithium abundances for solar-type and cool stars in clusters
robustly determined errors on all parameters
measurements of chromosperic activity or accretion, for cluster members (where relevant)
quantitative mass loss estimates, for early-type stars
The GIRAFFE spectra should allow measurement of Mg, Ca, Ti and Fe for the majority of the F-G-K stars.
For Bulge K giants also Si, Cr, Mn, Co and Ni, and possibly other elements, should be measurable.

for stars observed with UVES:

stellar parameters derived from the spectra
robustly determined errors on all parameters
elemental abundance estimates for some or all of the following elements (where stellar abundance and astrophysical parameters permit):
C, O, Na, Mg, Si, Ca, Sc, Ti, Cr, Mn, Fe, Ni, Zn, Y, Zr, Ba, La, Ce, Eu

NODE	CONTACT	FTE	ANALYSIS	METHOD
ARCETRI	L. Magrini	2.0	GIRAFFE & UVES	EWs
BOLOGNA	E. Pancino	0.9	GIRAFFE & UVES	EWs
BOLOGNA-PADOVA	A. Bragaglia	1.2	UVES (maybe GIRAFFE) Red giants, red clump	TBD
CAUP (Porto)	S. Sousa	2.05	GIRAFFE & UVES	EWs
ESO	R. Smiljanic	0.35	GIRAFFE & UVES	EWs+Spec. Synth.
HEIDELBERG-PARIS	L. Sbordone	2.4 ?	GIRAFFE & UVES	MyGisFOS (Optimization+grid)
IAC	C. Allende Prieto	0.7*	GIRAFFE & UVES	Optimization+grid Classification, Bayesian
GENEVA	N. Mowlavi	0.2	GIRAFFE and/or UVES	TBD
LIEGE	T. Morel	0.35	GIRAFFE & UVES	Optimization+grid
LUND-UPPSALA MPA-BORDEAUX	S. Feltzing	6.4	GIRAFFE & UVES	Optimization (on-the-fly)
GRONINGEN	B. Lemasle	0.2	GIRAFFE & UVES	EWs
NAPOLI-CATANIA	J. Alcala A. Frasca	1.4	GIRAFFE & UVES	Optimization+EW
NICE	A. Recio-Blanco	3.1	GIRAFFE & UVES	Optimi. Project.,Class.
VILNIUS	G. Tautvaisiene	?	?	?
BRUXELLES	S. van Eck	?	GIRAFFE (peculiar giants)	
RAVE	M. Steffen	?	?	?

Automated stellar parametrization

5. Gaia-ESO Large Public Survey

1. VARIETY OF METHODS

Difficulties of comparison due to the different nature of the error sources!

- Comparison with
  - a pre-computed synthetic spectra grid
  - on-the-fly synthetic spectra

  Or use of equivalent widths
- Different model atmospheres, atomic/molecular data
- Use of priors or not
- Different mathematical approaches
  - Optimization, projection, classification

Automated stellar parametrization

6. Conclusions

- **Several algorithms are ready to be applied to large surveys**
  New algorithms are under-development or at different levels of testing / application ***(my list of examples was not exhaustive!)***

- **Each method has its application field, depending on the conditions of the parameter space for a given data set.**
  Several methods may be combined for an optimal result.

- **The IR CaII triplet region has**
  - one degeneracy regime along the RGB (confusion giants-TO stars)
  - a lack of gravity information for cool dwarfs
  Important : good theoretical spectra for the cores of the CaII lines needed

- **The sources of errors can be very different for different methods.**
  Homogeneity is crutial for comparisons and relative error minimization.

Automated parametrization with MATISSE

The method

MATISSE performs a sort of automated spectral synthesis

Covariance MATrix Inversion for Spectral SynthEsis

- **Stellar parameters (θ=Teff, log g, [M/H], individual chemical abundances) derived by projection of an input observed spectrum on a basis $B_\theta(\lambda)$**

- **The $B_\theta(\lambda)$ basis is an optimal linear combination of theoretical spectra (calculated from a synthetic spectra grid : learning phase)**

Recio-Blanco, Bijaoui & de Laverny (2006)

Learning phase: derivation of B functions

$$B_\theta(\lambda) = \sum_i \alpha_i S_i(\lambda)$$

The parameter θ_i of an input spectrum S_i is estimated by its projection into the corresponding B_θ vector: $\hat{\theta}_i = \sum_j c_{ij}\alpha_j$ that is :

$$\hat{\theta}_i = \sum_\lambda B_\theta(\lambda) S_i(\lambda)$$

where c_{ij} is the covariance between the spectra S_i and S_j. The α_j coefficients are derived from the maximum correlation between θ_i and the recovered $\hat{\theta}_i$. That imposes:

Covariance matrix inversion to derive α_i

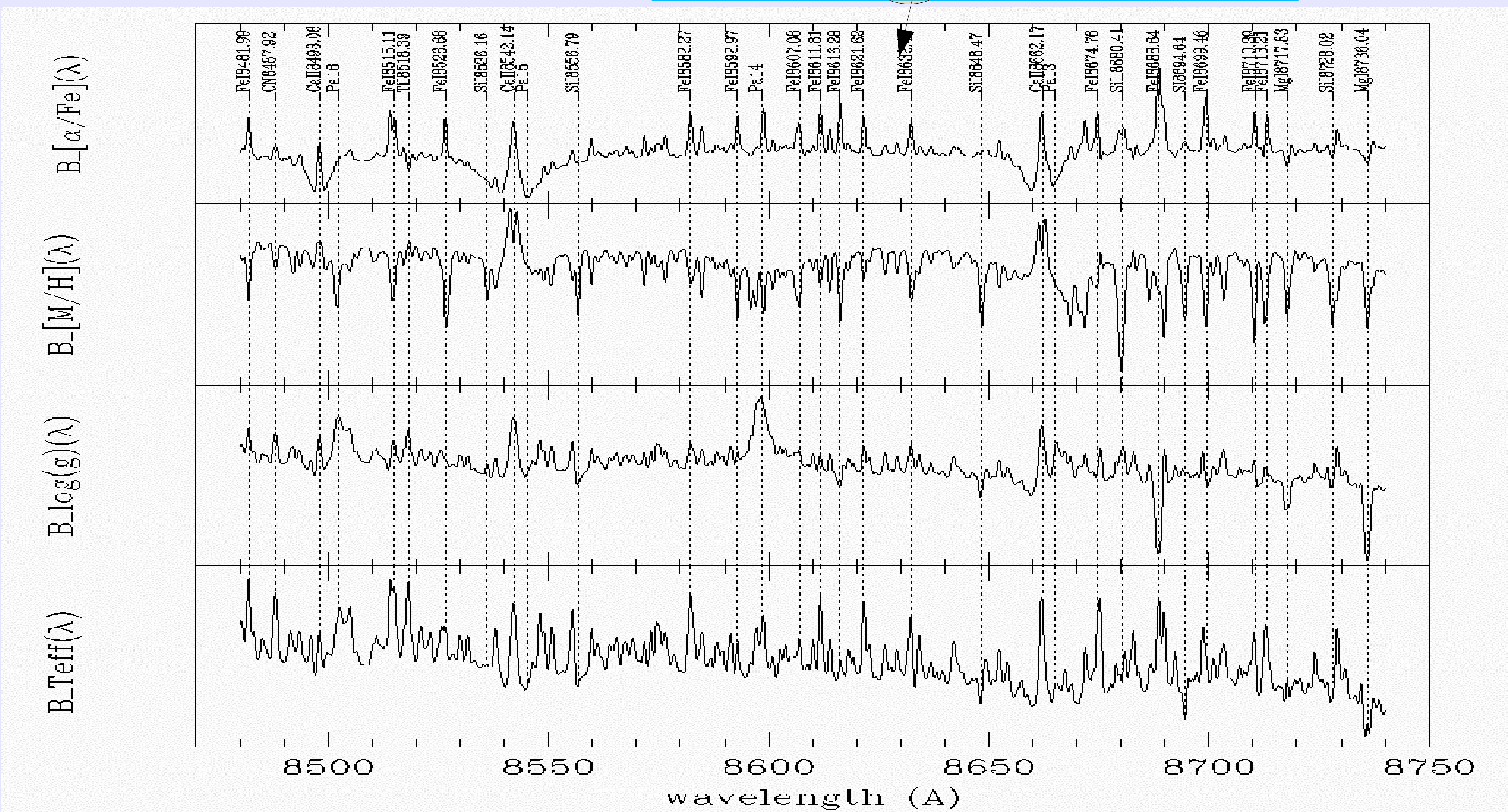
$$\sum_k \left(\sum_i c_{ij} c_{ik}\right) \alpha_k = a \left(\sum_i c_{ij}\theta_i\right)$$

Automated parametrization with MATISSE

Interpretability

Easy interpretation : variation of the spectrum when θ changes

$$\theta = a \, \Sigma \, B(\lambda) \, S(\lambda)$$



Performances at Low Resolution

NEW TESTS & DEVELOPMENTS

Development of a new algorithm: DEGAS

Oblique k-decission tree

At each node, a decission in taken in order to split the data into two sub-sets. The leaf level corresponds to identified classes

Bijaoui, Recio-Blanco, de Laverny & Ordenovic (2011)

Kordopatis et al. 2011a

1. The mean vector $\mathbf{M}$ of the flux values per pixel is computed.
2. For each spectrum $\mathbf{S_j}$ associated to the node, we calculate the scalar product $c_j = \mathbf{S_j} \cdot \mathbf{M}$. Let $\tilde{c}$ be the median value of c_j.
3. The data are bisected in two subsets, T_1 and T_2, according to the following criteria:
   S_j belongs to the subset T_1 if $c_j \leqslant \tilde{c}$
   S_j belongs to the subset T_2 if $c_j > \tilde{c}$
4. The mean vectors $\mathbf{M_1}$ and $\mathbf{M_2}$ of each subset are then computed, and the difference vector $\mathbf{D} = \mathbf{M_1} - \mathbf{M_2}$ is determined.

Recognition rules

Populations stellaires
Gaia-ESO Large Public Survey

- **Formation et dynamique des amas ouverts:** ***cinématique interne***
- **Evolution stellaire:** ***paramètres stellaires pour amas de plusieurs âges et métallicités, rotation, activité, binarité***
- **Halo, étoiles extrêmes:** ***sous-structures, recherche cinématique et chimique***
- **Nature du Bulbe:** ***Cinématique et chimie de bulbe ou pseudo-bulbe?***
- **Formation du Disque Epais:** ***évidences d'accrétions, évolution dynamique du disque mince?***
- **Disque mince et voisinage solaire:** ***5000 étoiles à haute résolution spectrale jusqu'à 1 kpc. Evolution chimique en fonction de l'âge. Combination avec données Gaia très précises.***