Inversion of stellar fundamental parameters from Espadons-Narval high-resolution spectra

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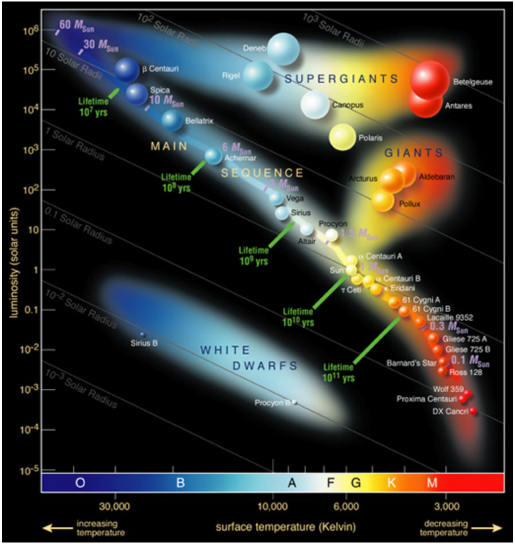
- **Sources and characteristics of the data**
- **A PCA–based inversion method**
- **First results and discussion**

Stellar classification

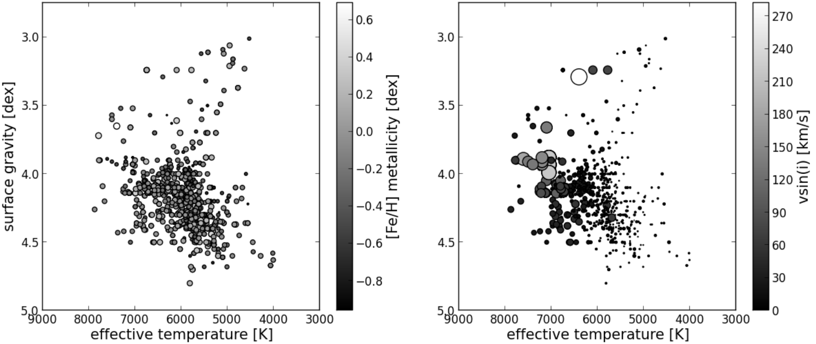


→ The Hertzsprung–Russell diagram.

Sources of data

- **Espadons-Narval database** (polarbase.irap.omp.eu)
  - $\mathcal{R} \sim 65\,000$; spectral coverage $\sim$ 380-1000 nm
  - 180 000 independent spectra, for 2 000 distinct targets
  - Covers quite well the H–R diagram
  - see *Petit et al. (2014)* for a more complete description
- **Elodie Spectral Library** *(Prugniel et al. 2007)*
  - Observed spectra for the training database
  - $\mathcal{R} \sim 48\,000$; spectral coverage $\sim$ 390-680 nm
  - 905 spectra selected for FGK stars
- **Projected rotational velocities** ($v\sin i$)
  - Taken from Vizier@CDS III/244 *(Głebocki & Gnaciński 2005)*
- **Harvesting data:** see e.g., *Paletou & Zolotukhin (2014)* [arXiv:1408.7026]

The training database



→ Graphical summary of the coverage in stellar parameters corresponding to the content of our Elodie spectra training database (for FGK stars).

PCA reduction of dimensionality

- **Variance-covariance matrix** ($\{S_i\}$: training database)

$$\mathbf{C}_{(N_\lambda;N_\lambda)} = (\mathbf{S} - \bar{S})^T \cdot (\mathbf{S} - \bar{S}) \; ; \; N_\lambda = 8000 \quad (1)$$

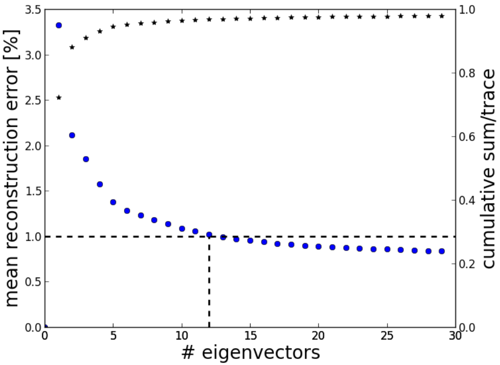
- Knowing its **eigenvectors** $\vec{e}_k$ ($k \leq k_{max}$) allows for the computation of **projection coefficients**:

$$p_{jk} = (\vec{S}_j - \bar{S}) \cdot \vec{e}_k \quad (2)$$

- **Reduction of dimensionality**
  - Each spectra of N_λ (8000) points will be described by "just" k_{max} **(**$\ll N_\lambda$**)** projection coefficients

- **How many orders k_{max} to keep?**

Reduction of dimensionality



→ Reconstruction error $E(k_{\max}) = \left\langle \left(\frac{|\bar{S} + \sum_{k=1}^{k_{\max}} p_{jk} \vec{e}_k - S_j|}{S_j} \right) \right\rangle$ as a function of the number of eigenvectors used for the computation of the projection coefficients p.

Inversion of stellar parameters

- **Nearest neighbour(s) search**
- **Observed spectra:** $\vec{O}(\lambda)$
- **Projected on k_{max} eigenvectors:** $\varrho_k = (\vec{O} - \bar{S}) \cdot \vec{e}_k$
- **Compute squared (euclidian) distances:**

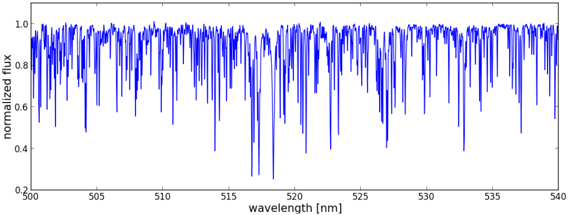
$$d_j^{(O)} = \sum_{k=1}^{k_{\max}} (\varrho_k - p_{jk})^2 \quad (3)$$

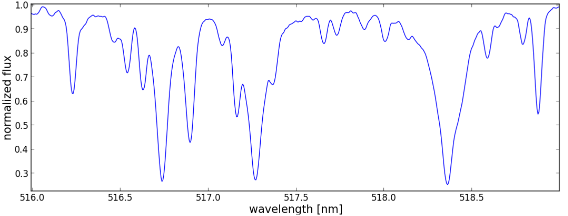
- **Consider neighbours in domain:**

$$\min\left(d_j^{(O)}\right) \leq d_j^{(O)} \leq 1.2 \times \min\left(d_j^{(O)}\right) \quad (4)$$

- **Simple mean of every stellar parameters of the identified neighbours** $\rightarrow$ ($T_{\rm eff}$; $\log g$; [Fe/H] ; $v\sin i$)

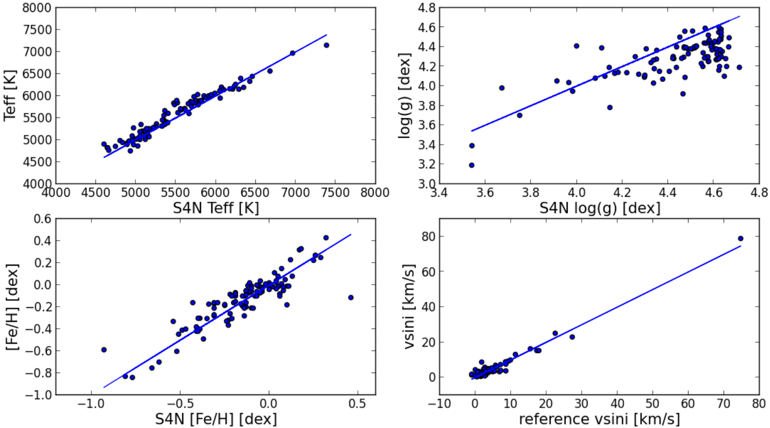
Which spectral domain(s)?





→ We chose to test our approach at the vicinity of the Mg I b triplet (known to be log$g$ sensitive).

Inverting S^4N data



→ First tests by inverting data from the S^4N survey *(Allende Prieto et al. 2004).*

Inverting PolarBase data

- A selection of **140 spectra (of FGK stars)** in common with the "Spectroscopic Properties of Cool Stars" data collection *(Valenti & Fischer 2005)*

Parameter	$T_{\rm eff}$	$\log g$	[Fe/H]	$v\sin i$
bias	23	0.10	0.02	-0.04
σ	115	0.19	0.10	1.68

- **Advantages of working with observed spectra**
  - **Object to objects relation!**
  - Independent from whatever method of determination of stellar parameters have been used for the reference spectra
  - One may **also** invert any other parameter contributing to the spectral signature of the star

Conclusion

- **PCA is simple to implement**
- **It leads to a fast and robust inversion method**
- **Very encouraging results with Espadons and Narval spectra:** further details in *Paletou et al. 2014 (A&A, in press)*
- **Future work is...**
  - Use (also) synthetic spectra, for spectral domains not covered by Elodie like e.g., the RVS@GAIA Ca II Infra-Red Triplet domain
  - Combine inversion results from several spectral domains
  - Extend the range of application to **A**–FGK–**M** spectral types
  - Implement at `polarbase.irap.omp.eu`
  - ...