A deep TRANSFER learning approach to photospheric parameters of CARMENES target stars

Antonio Bello-García
J. Ordieres-Mere, V.M. Passegger, J.A. Caballero,
A. Schweitzer, and A. Gonzalez-Marcos

A&A 642, A22 (2020)
https://doi.org/10.1051/0004-6361/202038787

Astronomy & Astrophysics

The CARMENES search for exoplanets around M dwarfs

A deep learning approach to determine fundamental parameters of target stars

V. M. Passegger[1,2], A. Bello-García[3], J. Ordieres-Meré[4], J. A. Caballero[5], A. Schweitzer[1], A. González-Marcos[6], I. Ribas[7,8], A. Reiners[9], A. Quirrenbach[10], P. J. Amado[11], M. Azzaro[12], F. F. Bauer[11], V. J. S. Béjar[13,14], M. Cortés-Contreras[5], S. Dreizler[9], A. P. Hatzes[15], Th. Henning[16], S. V. Jeffers[9], A. Kaminski[10], M. Kürster[16], M. Lafarga[7,8], E. Marfil[17], D. Montes[17], J. C. Morales[7,8], E. Nagel[15,1], L. M. Sarro[18], E. Solano[5], H. M. Tabernero[19], and M. Zechmeister[9]

1. Different architectures and spectral ranges
2. Influence of training with synthetic spectra

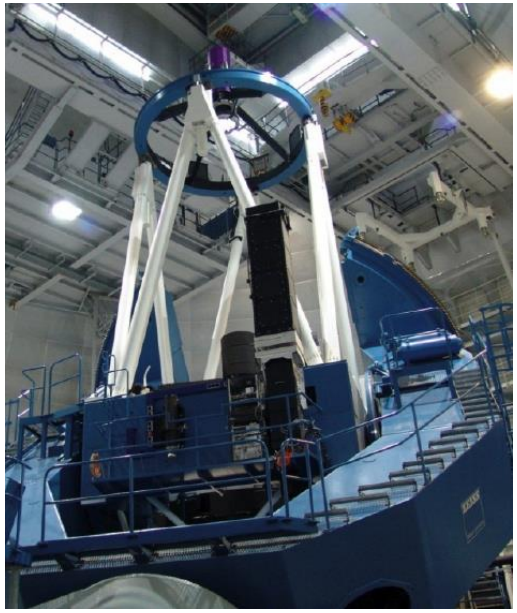
Synthetic spectra

- PHOENIX-ACES grid (Husser et al. 2013)
- Linear interpolation → 449,806 synthetic models
- Constrain grid to physically realistic parameter space for M dwarfs → PARSEC library (Bressan et al. 2012)

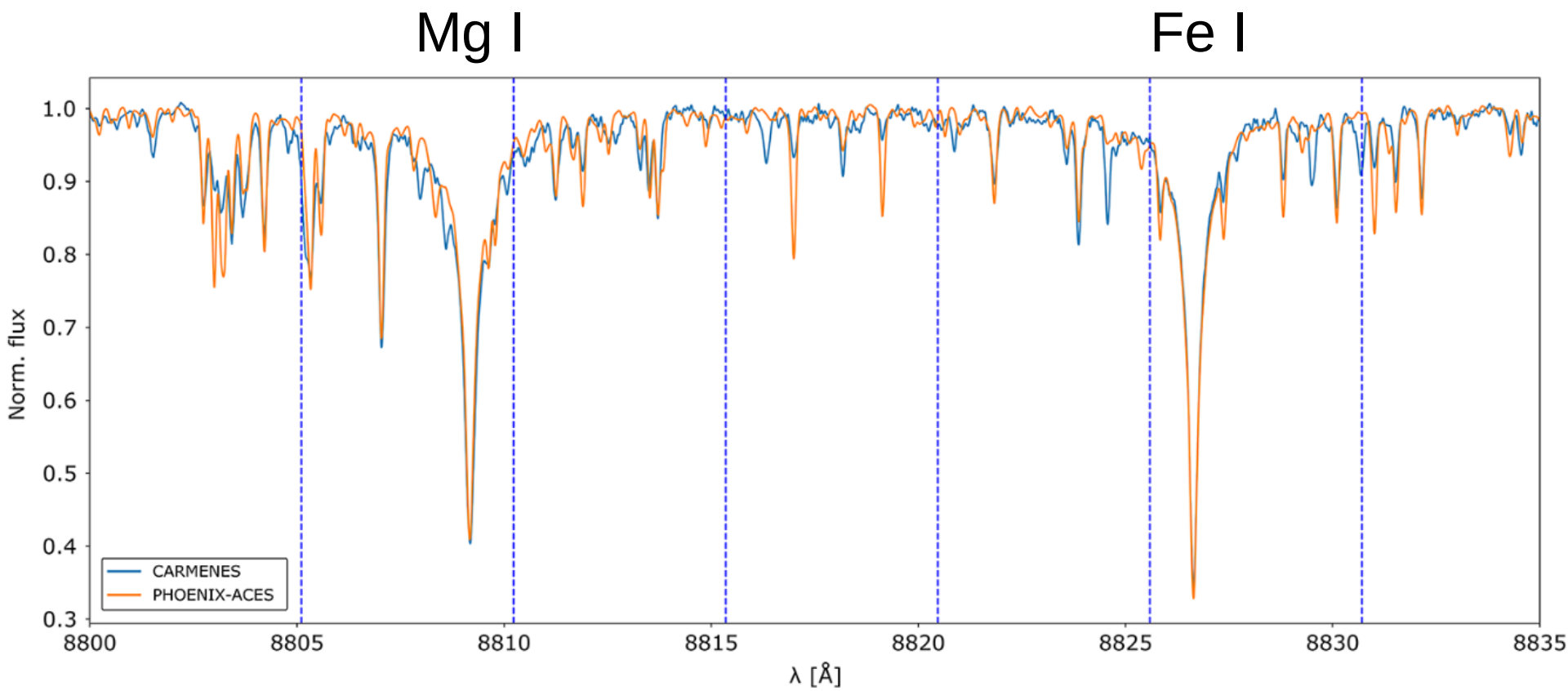
Parameter	Minimum	Maximum	Step size
$T_{\rm eff}$ [K]	2300	4500	25
$\log g$ [dex]	4.2	5.5	0.1
[M/H] [dex]	−1.0	+0.8	0.1
$v \sin i$ [km s^{-1}]	1.5	3.0	0.5
	3.0	6.0	1.0
	6.0	10.0	2.0
	10.0	60.0	5.0

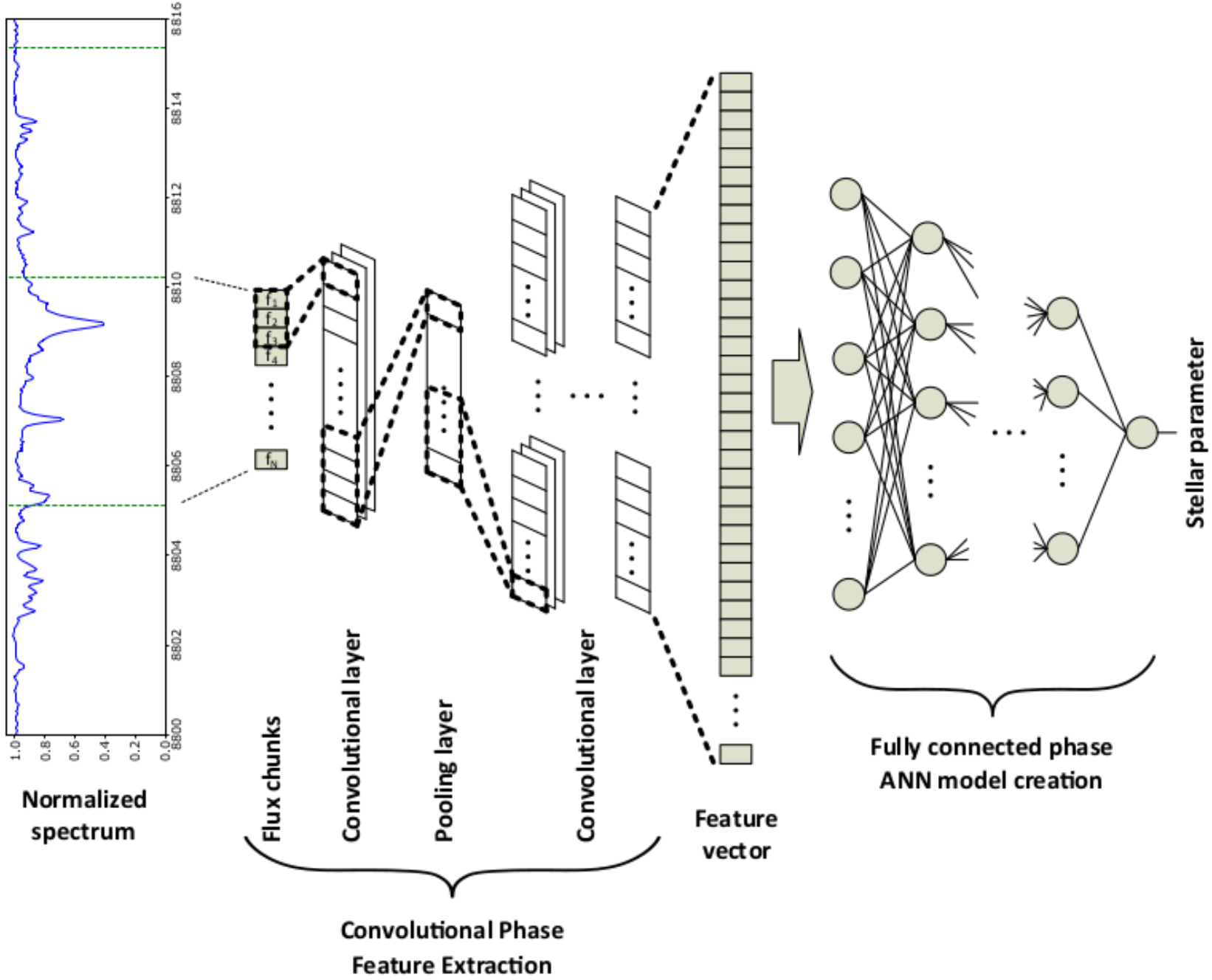
Observed spectra

- CARMENES instrument
- 3.5m telescope at Calar Alto Observatory (Spain)
- VIS: 5200–9600 Å, R ~ 94,600
  NIR: 9600–17100 Å, R ~ 80,400
- High-S/N "template" spectra of bright, nearby M-dwarfs



Spectral windows





Approaches (outcome)

- **A**: Different DL architectures → number of convolutional, pooling and hidden layers

  No influence from different architectures

- **B**: Combining parameters → individual, T_{eff} + log g, [M/H] + v sin i, all together

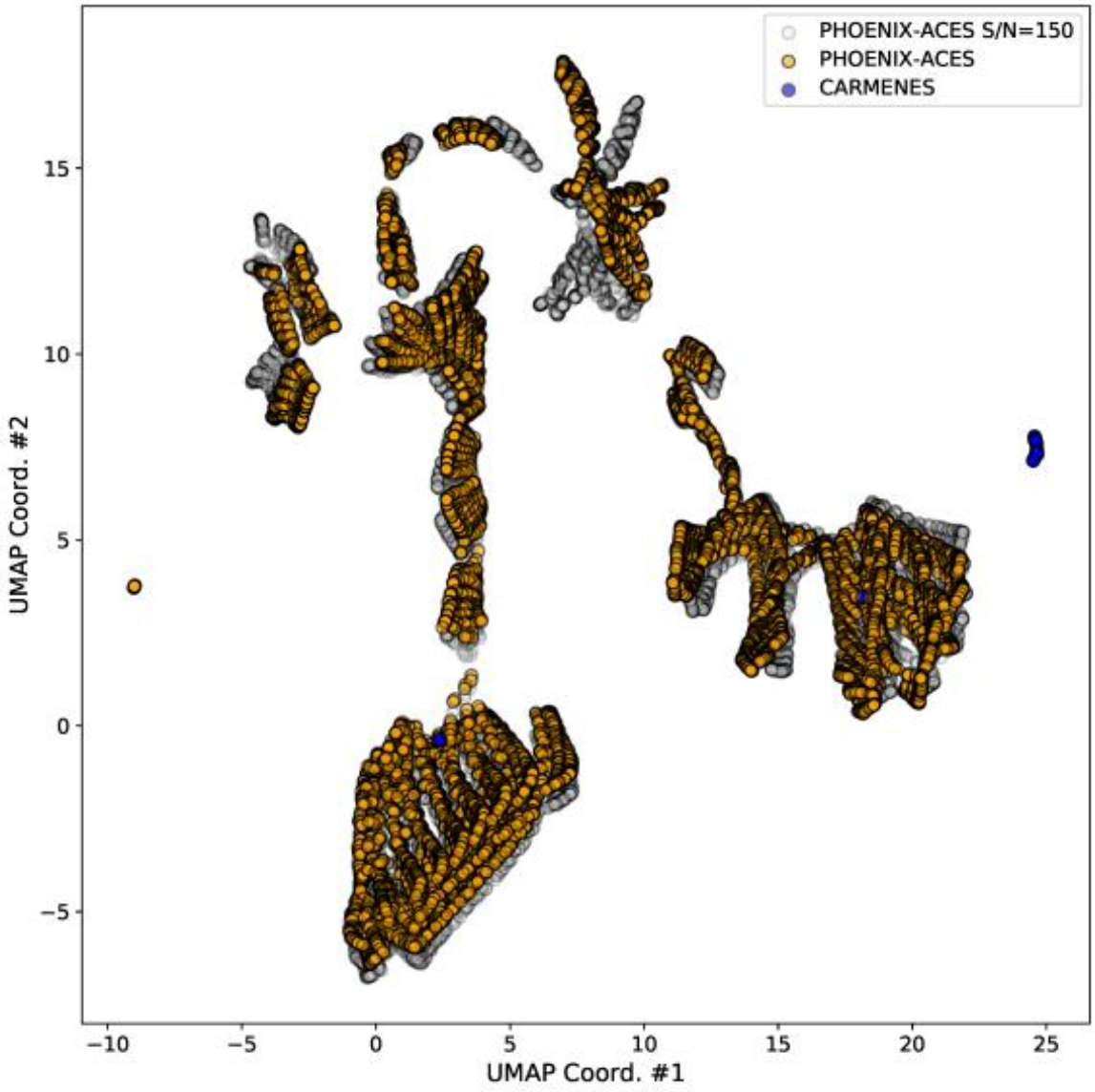
  Predictions for all four stellar parameters are worse → estimate them individually

- **C**: Combining spectral windows

  No influence from different spectral windows→ each window contains enough spectral information (theoretically)

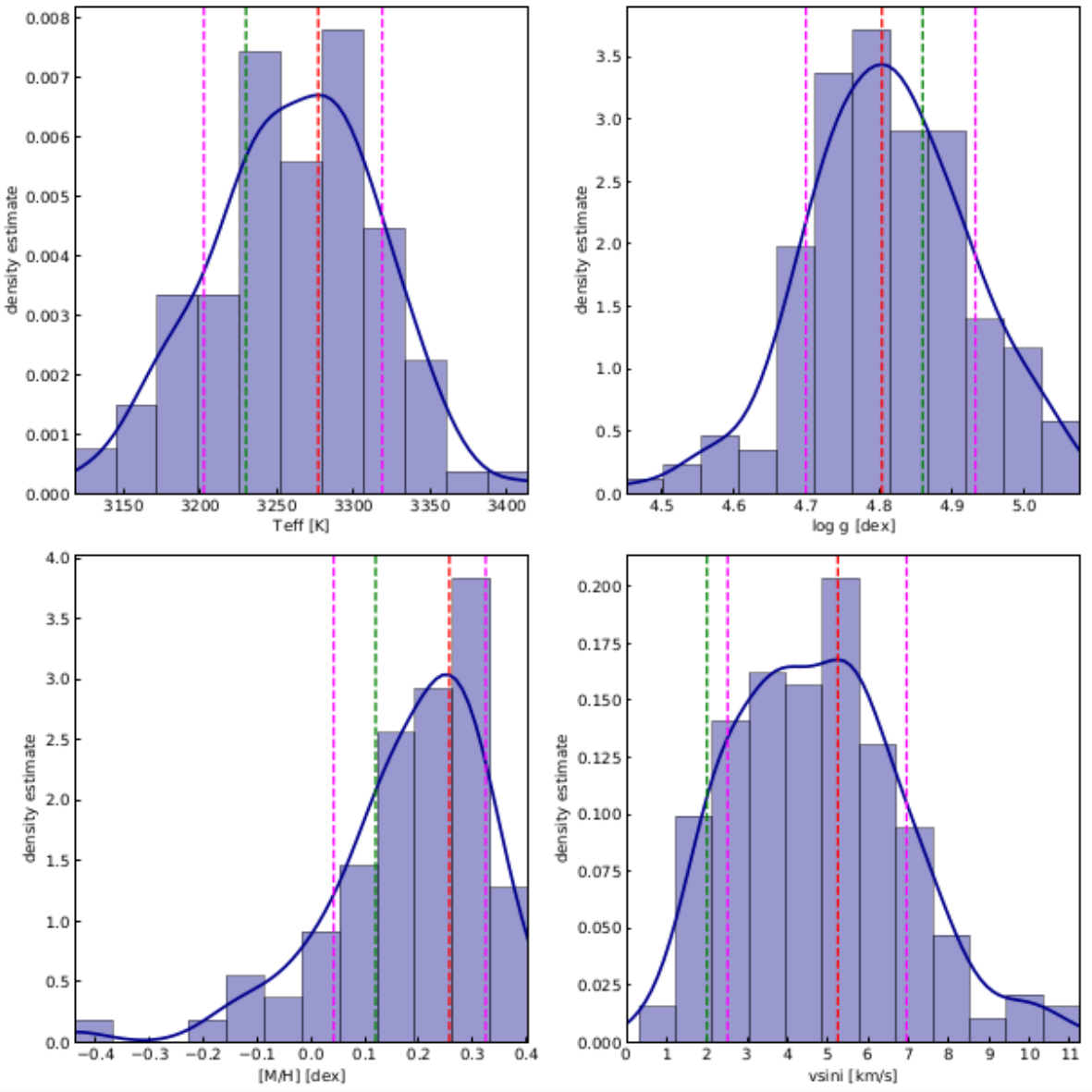
The Synthetic Gap

- Difference of feature distribution between observed and synthetic spectra
- Synthetic models are not perfect
- Dimensional reduction for visualisation → UMAP
- Use synthetic models with care !!!

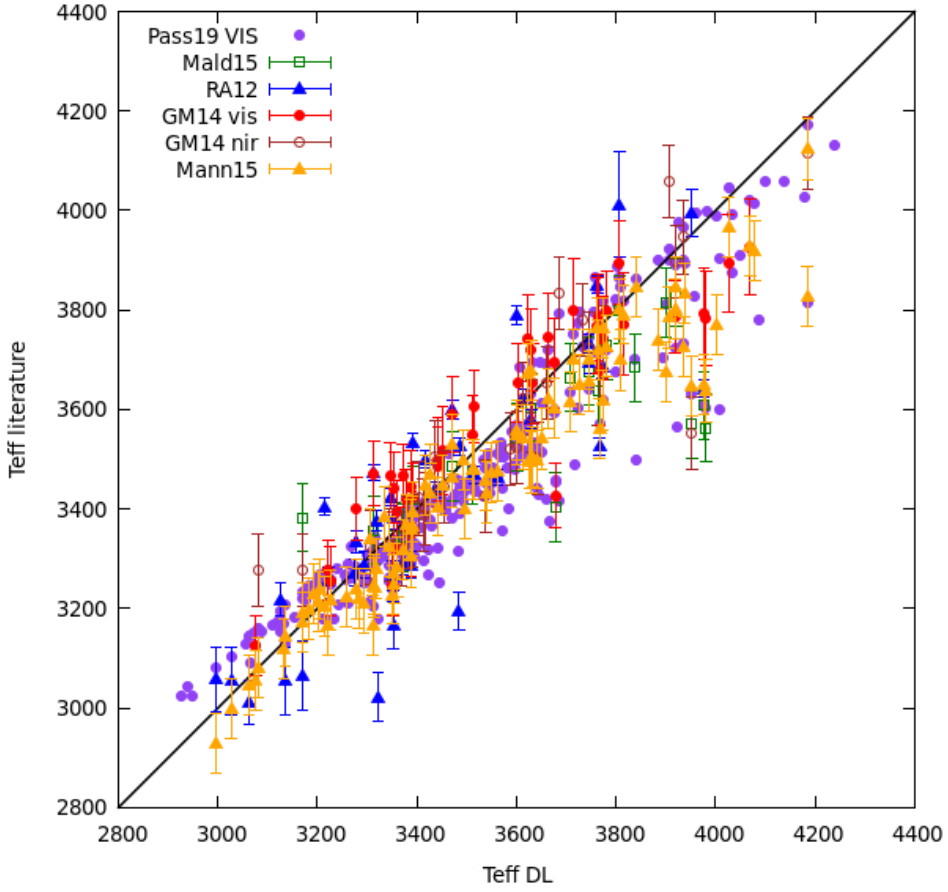


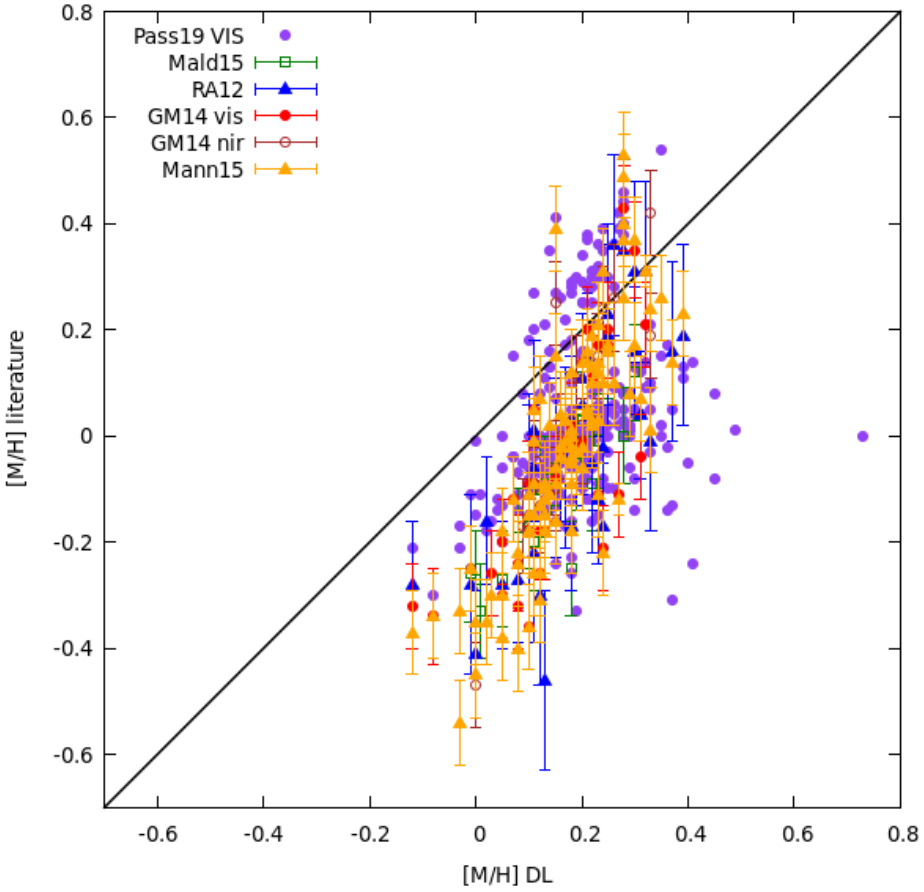
Final stellar parameters

- Selected all good DL models for window 8800–8835Å
- Collecting all estimations and drawing probability density function → maximum = final parameter
- Uncertainties from 1-σ threshold



Literature comparison





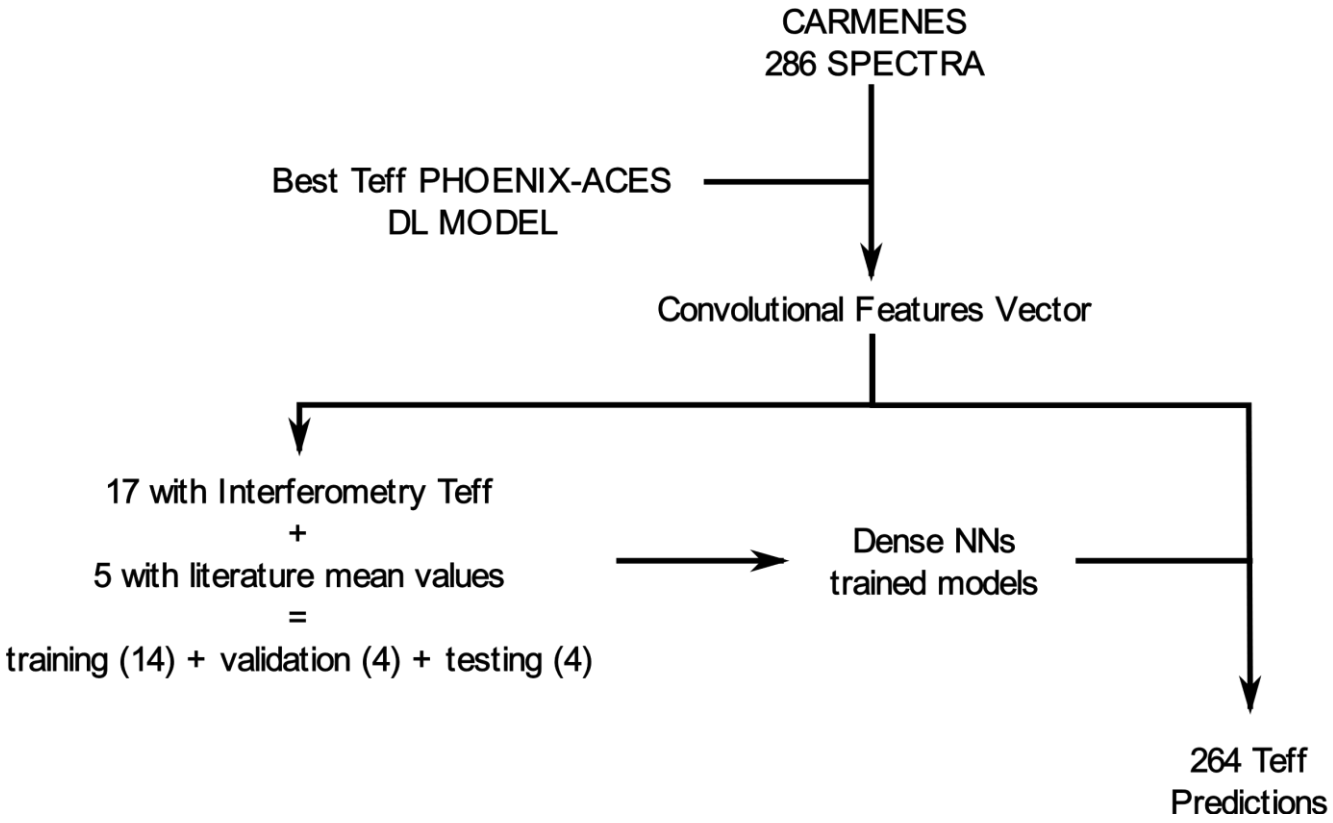
DL results for Teff and [M/H]. Literature values are color-coded.
The approach from Passegger et al. (2020) was applied to the last release of 286 CARMENES spectra

A Deep TRANSFER Learning

T*eff* predictions

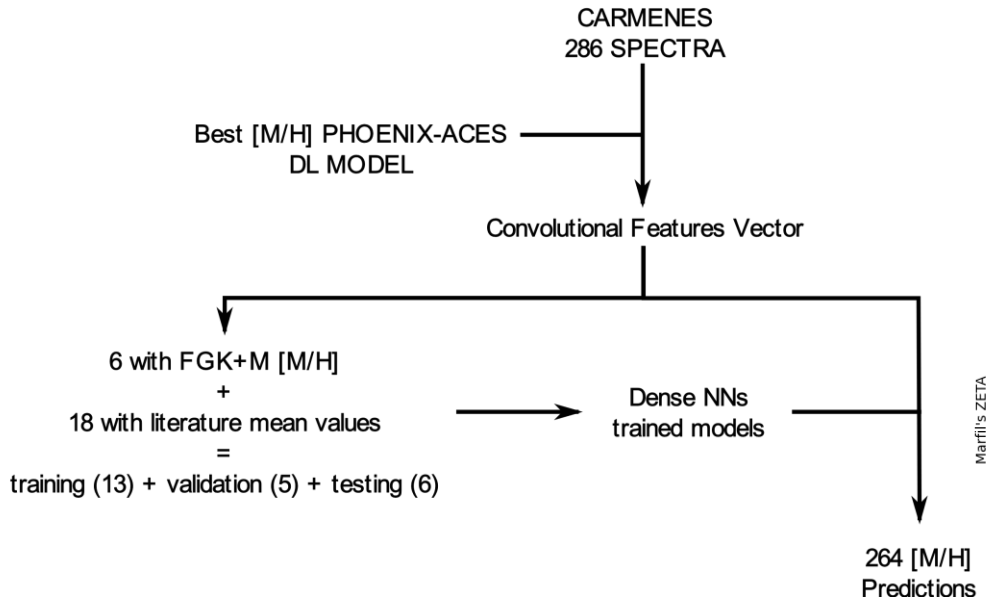
Boyajian et al. (2008, 2012), and von Braun et al. (2014)

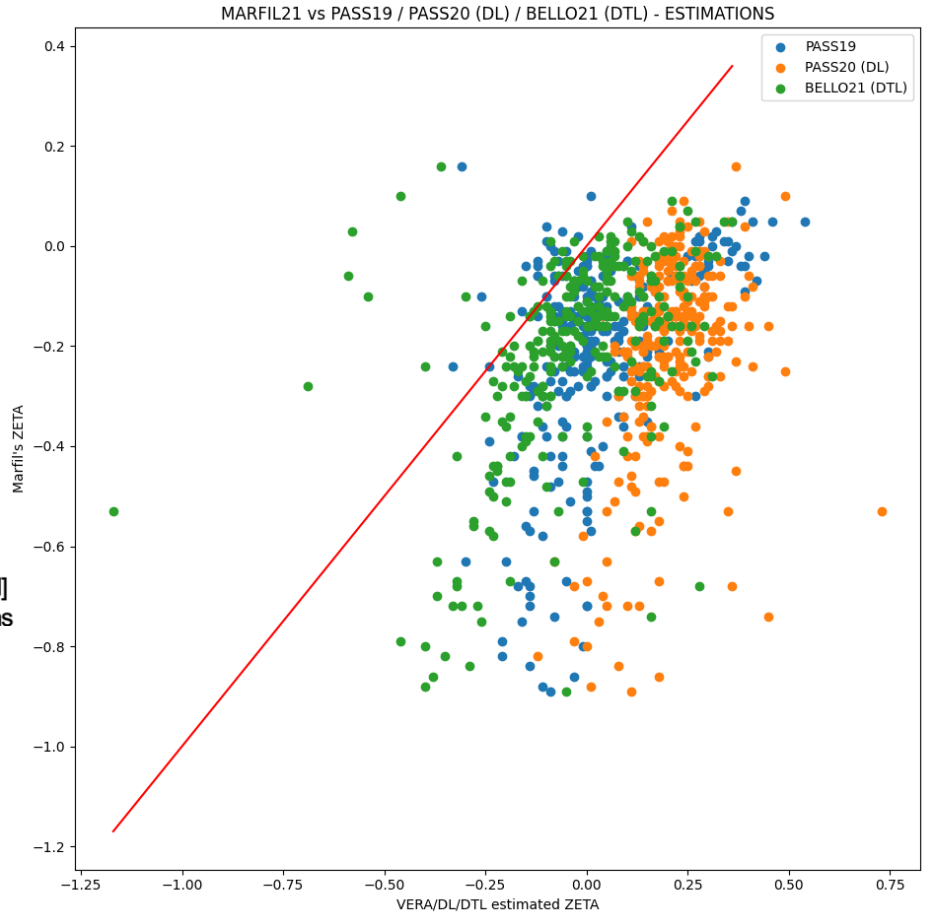
- Not enough observed (interferometry+binaries) data
- Complemented with literature values for getting a TRAINING+VALIDATION+TESTS datasets



A Deep TRANSFER Learning

[M/H] predictions from Montes et al. (2018)





The CARMENES search for exoplanets around M dwarfs. Stellar atmospheric parameters of target stars with StePar Syn. Marfil et al. (2021)

Forthcoming Publications

- *Metallicities in M dwarfs: Investigating different determination techniques*. Passegger et al. (2021, in press)

- *The CARMENES search for exoplanets around M dwarfs: A deep transfer learning approach to determine Teff and [Fe/H] of target stars*. Bello-García et al (2021, in preparation)

© https://xkcd.com/303/