Accurate Teff and [M/H] determinations for the CARMENES M dwarfs from deep transfer learning

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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)

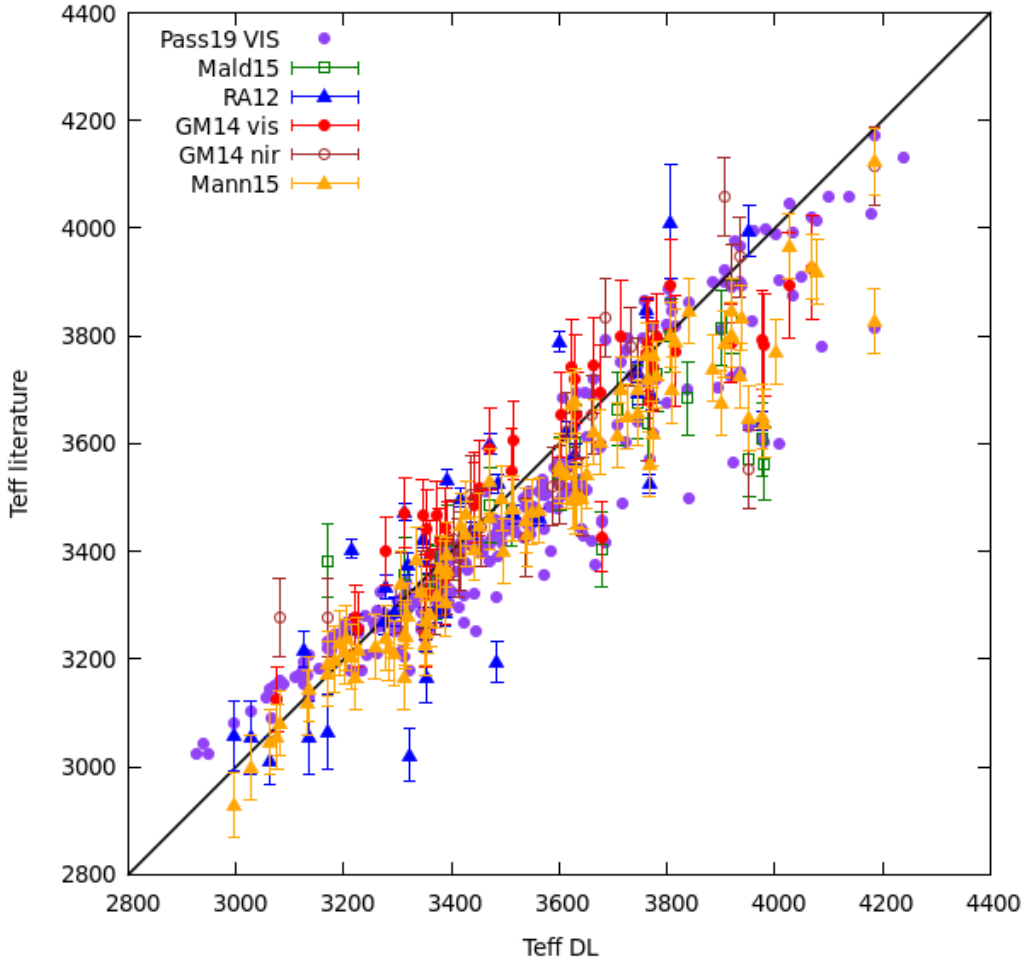
Parameter	Minimum	Maximum	Step size
$T_{\rm eff}$ [K]	2300	4500	25
$\log g$ [dex]	4.2	5.5	0.1
[M/H] [dex]	−1.0	+0.8	0.1
$v \sin i$ [km s^{-1}]	1.5	3.0	0.5
	3.0	6.0	1.0
	6.0	10.0	2.0
	10.0	60.0	5.0

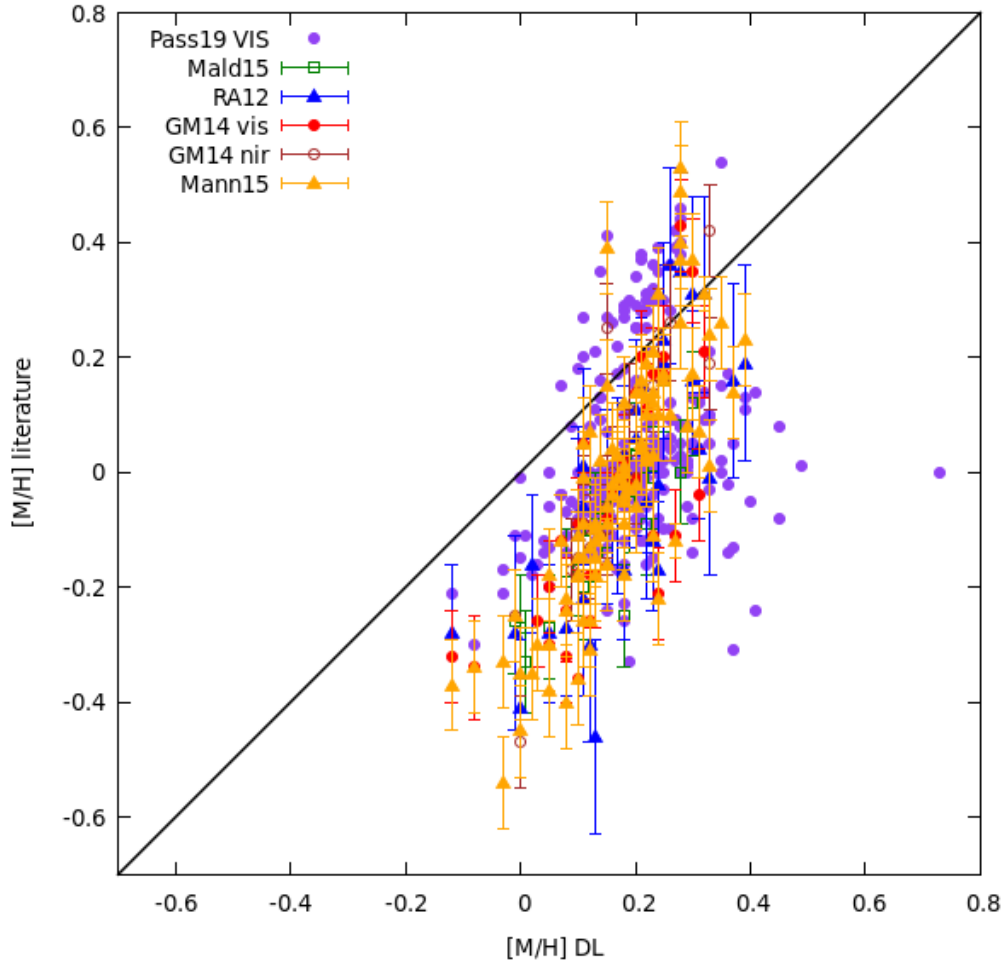
Observed spectra

- 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

The CARMENES search for exoplanets around M dwarfs: A DL approach to determine fundamental parameters of target stars. A&A 642, A22 (2020)

Literature comparison

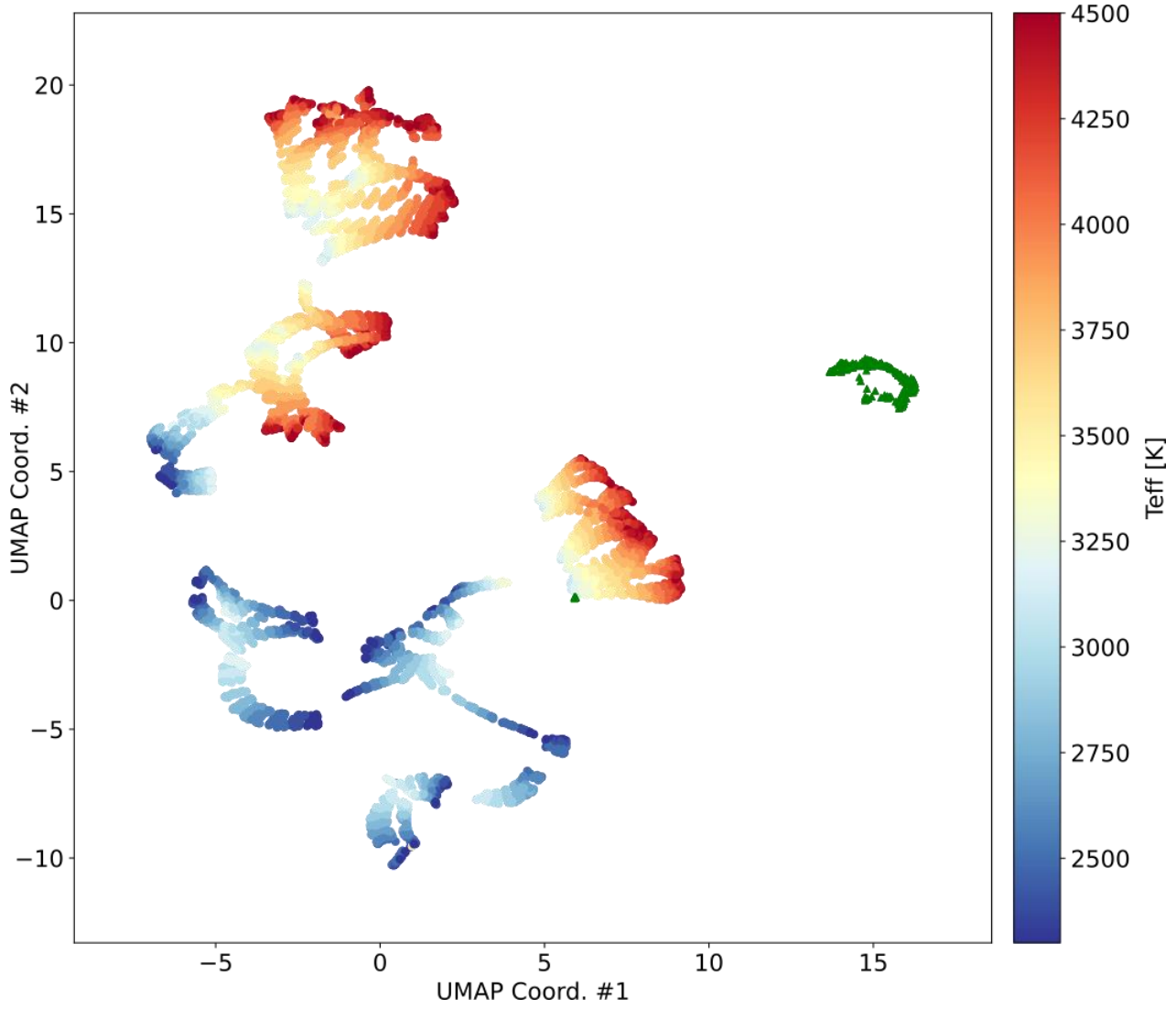




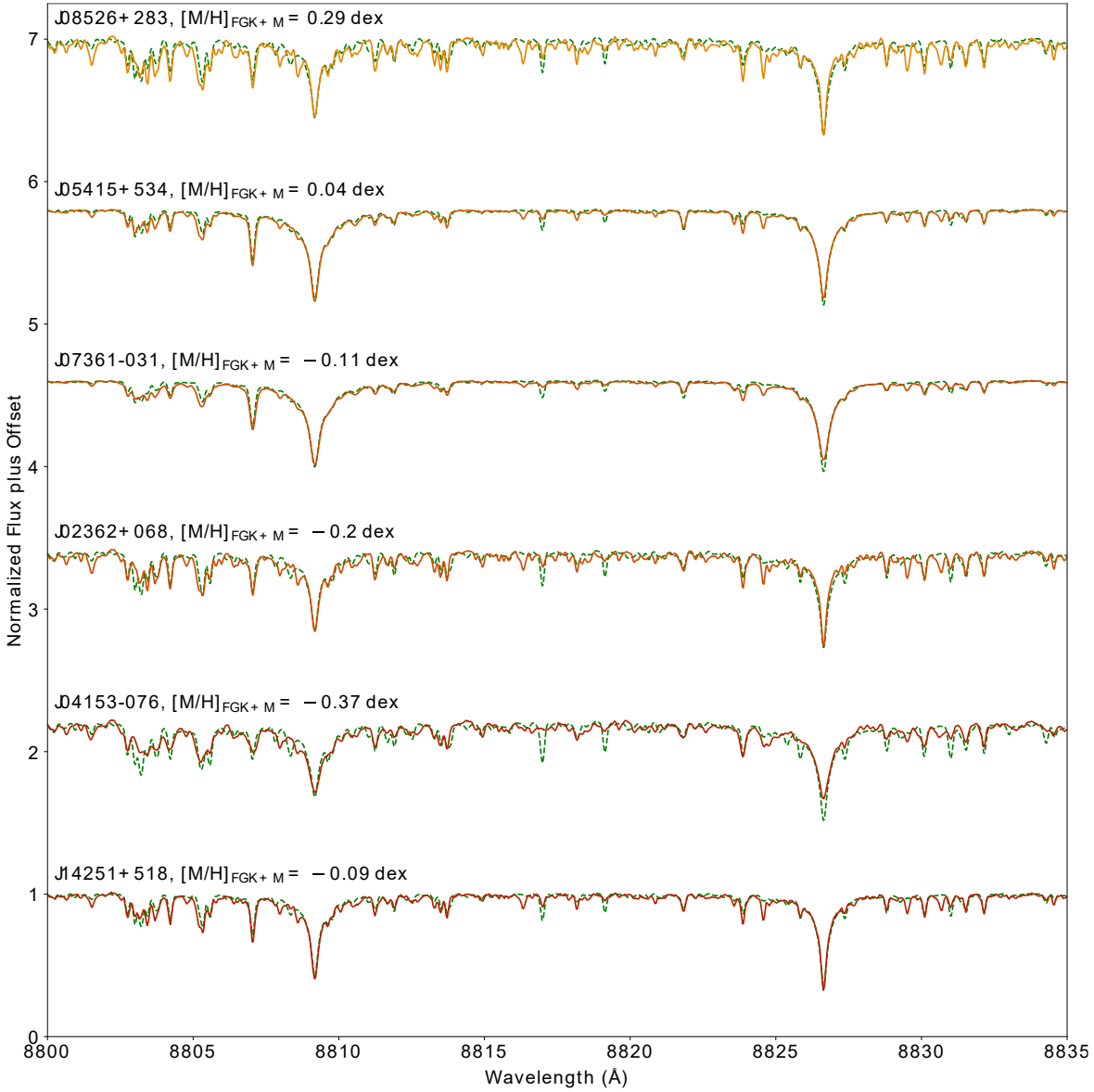
DL results for Teff and [M/H]. Literature values are color-coded.
The approach from Passegger et al. (2020) was applied to the last release of 286 CARMENES spectra

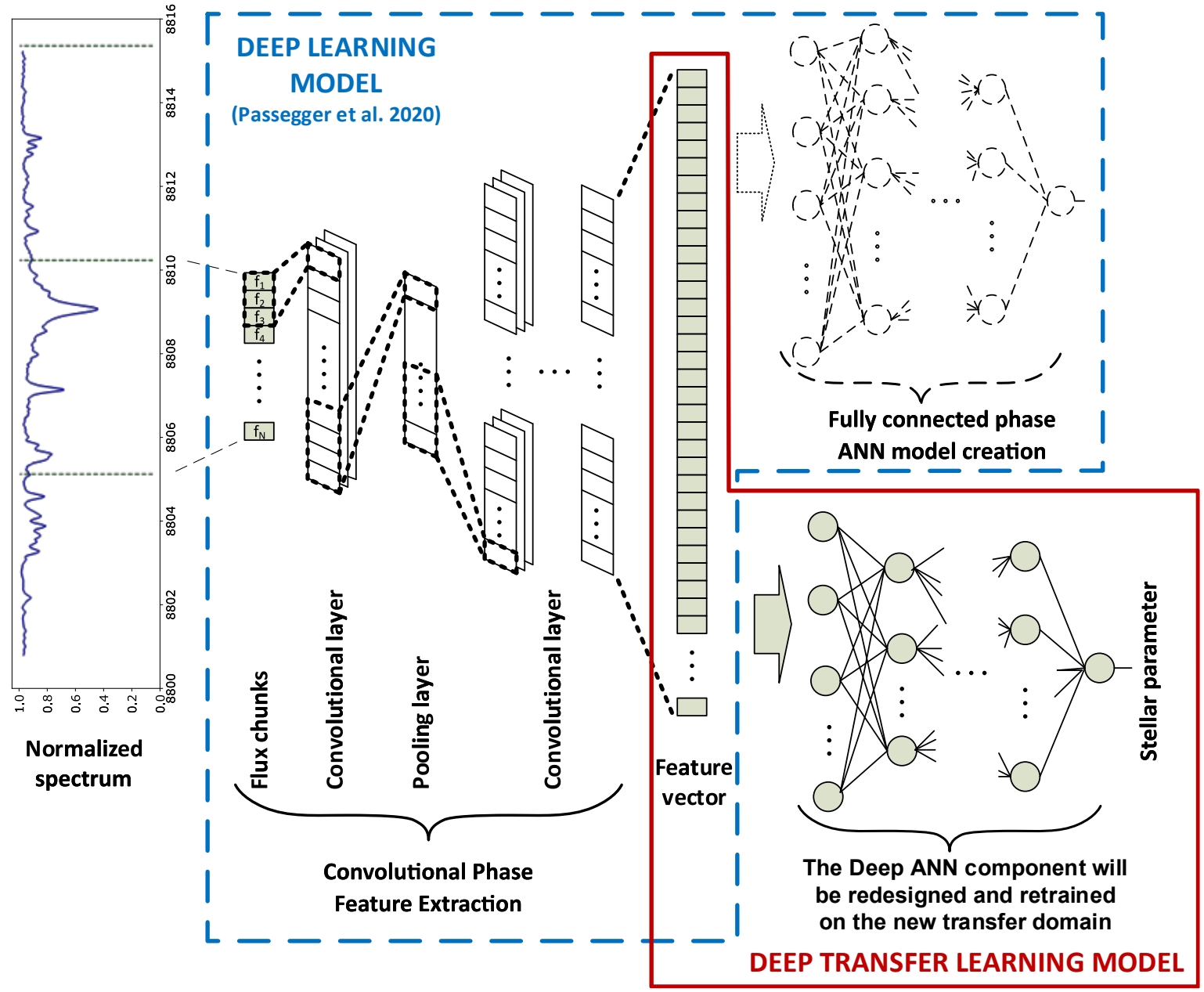
The Synthetic Gap

- Dimensional reduction for visualization → UMAP
- Difference of feature distribution between observed and synthetic spectra
- Observed spectra (green triangles) should be distributed all over the colored pattern on the left
- Synthetic models are not perfect
- Use synthetic models with care !!!



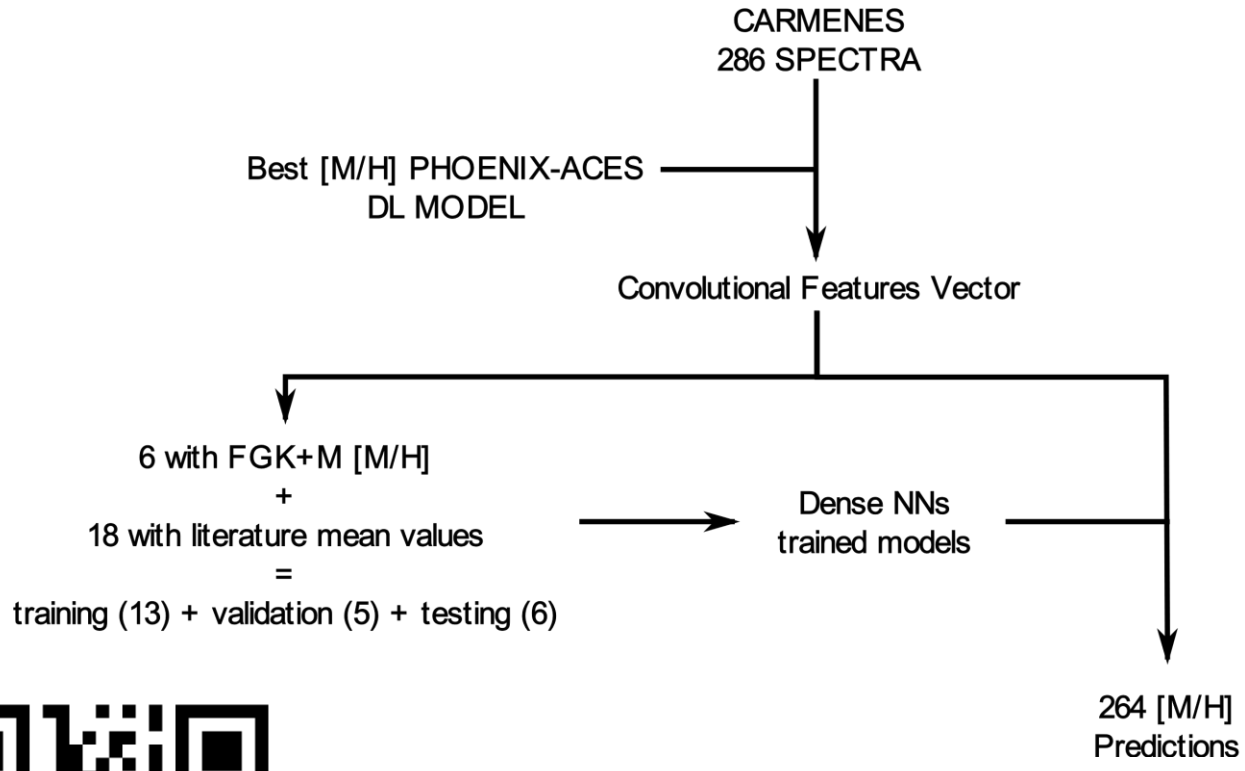
Transferred Knowledge

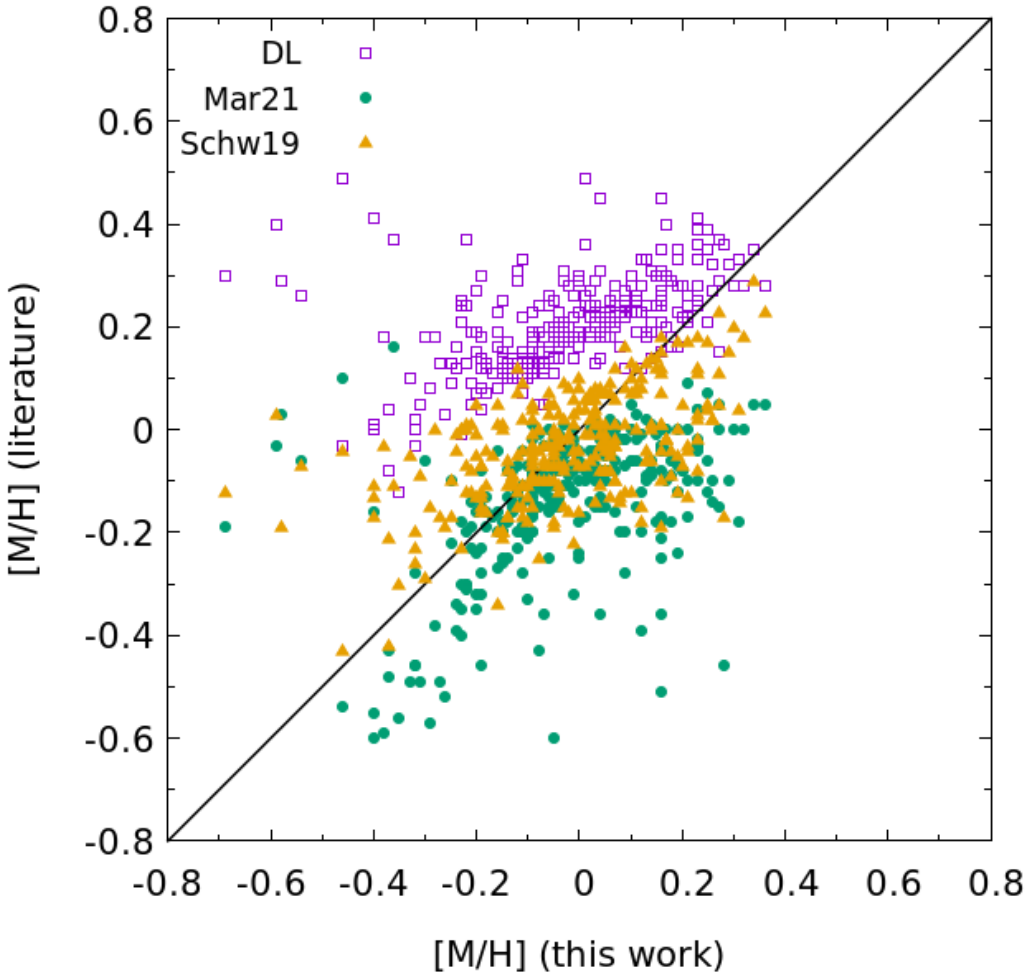



DEEP LEARNING MODEL
(Passegger et al. 2020)
Normalized spectrum
Flux chunks
Convolutional layer
Pooling layer
Convolutional layer
Feature vector
Convolutional Phase Feature Extraction
Fully connected phase ANN model creation
Stellar parameter
The Deep ANN component will be redesigned and retrained on the new transfer domain
DEEP TRANSFER LEARNING MODEL

A Deep TRANSFER Learning

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





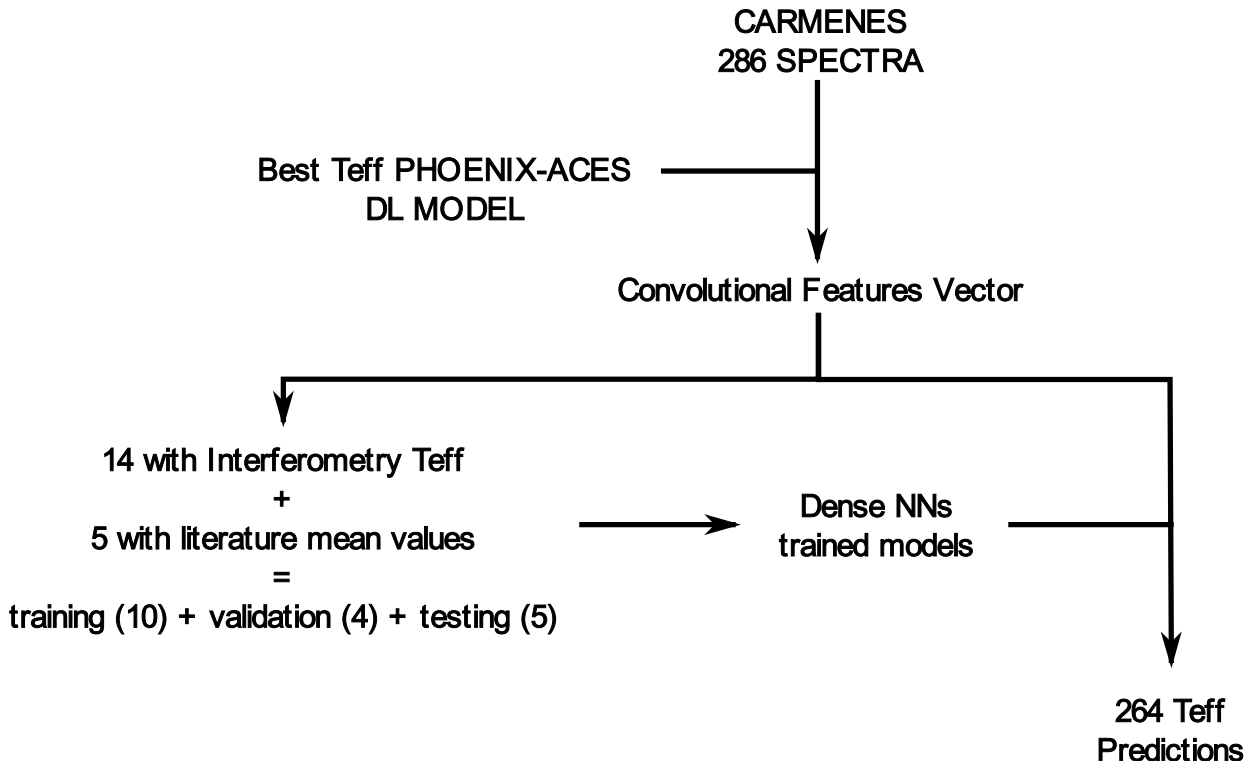
The CARMENES search for exoplanets around M dwarfs. Stellar atmospheric parameters of target stars with SteParSyn. Marfil et al. (2021)

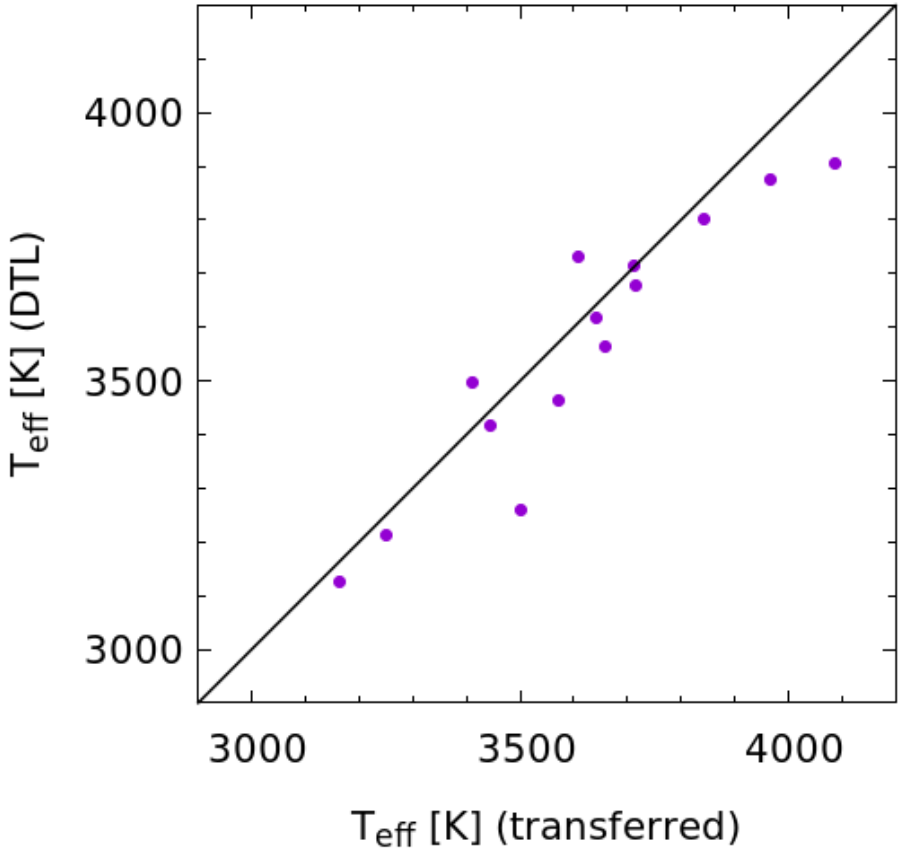
A Deep TRANSFER Learning

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





Conclusions

- DTL estimations are closer to the “real” values than DL’s
- A larger transferred sample would be much appreciated
  (Please, more FGK+M binaries and Interferometry)

- *Metallicities in M dwarfs: Investigating different determination techniques*. Passegger et al. (A&A 658, A194 – 2022)
- *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 (2022, submitted)