Using autoencoders and deep transfer learning to determine the stellar parameters of CARMENES M dwarfs

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Deep Transfer Learning

- Deep learning (DL): subset of machine learning in which deep neural networks automatically extract features and create a hierarchical representation of the data.
- DL has two major constraints:
  - → **Expensive training processes.**
  - → **Massive training data:** synthetic data is often used to train the models.
- In deep transfer learning (DTL), the knowledge of a source domain is transferred to a related but not identical target domain.

A DL model is pre-trained in a data-rich domain

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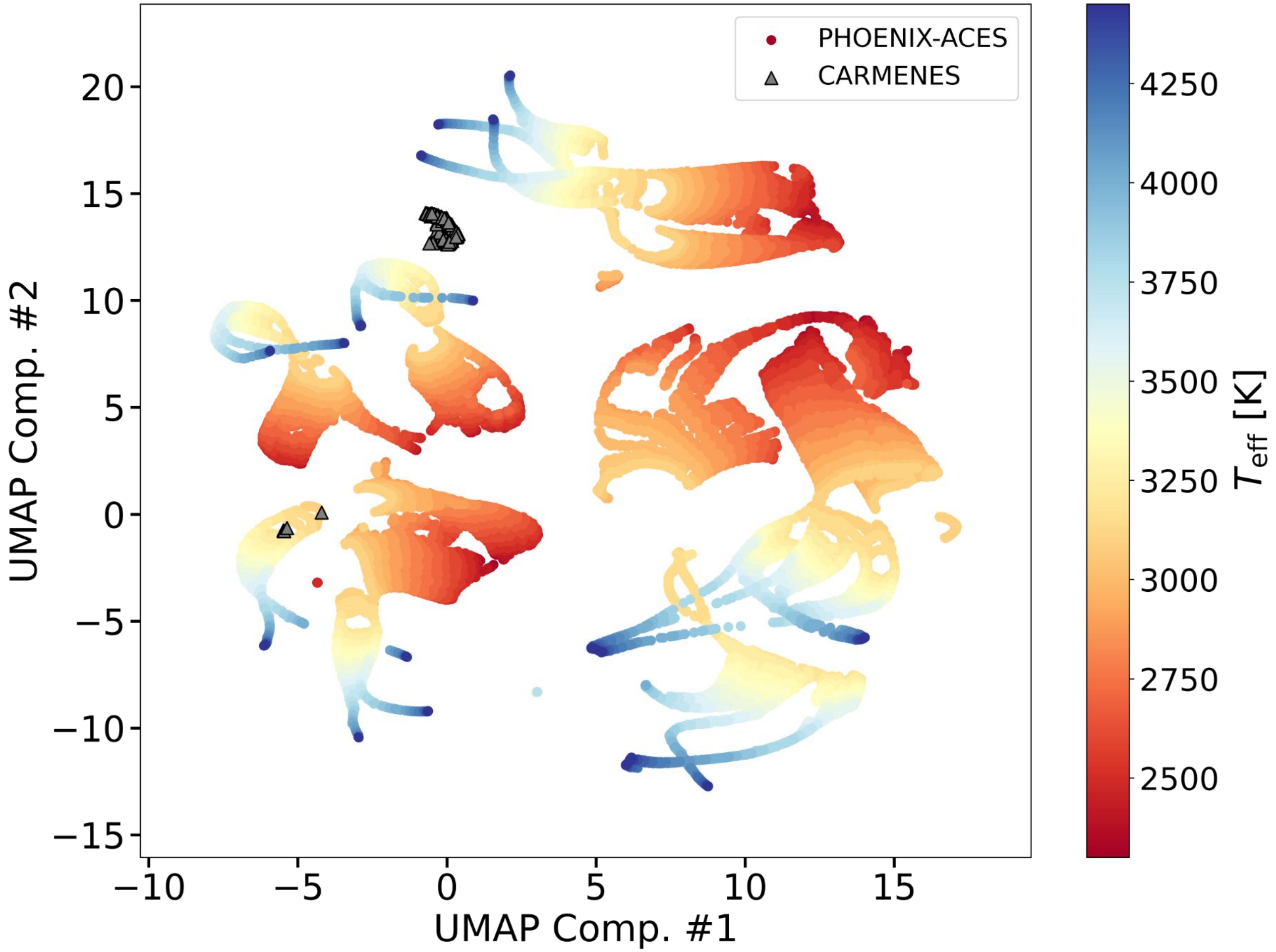
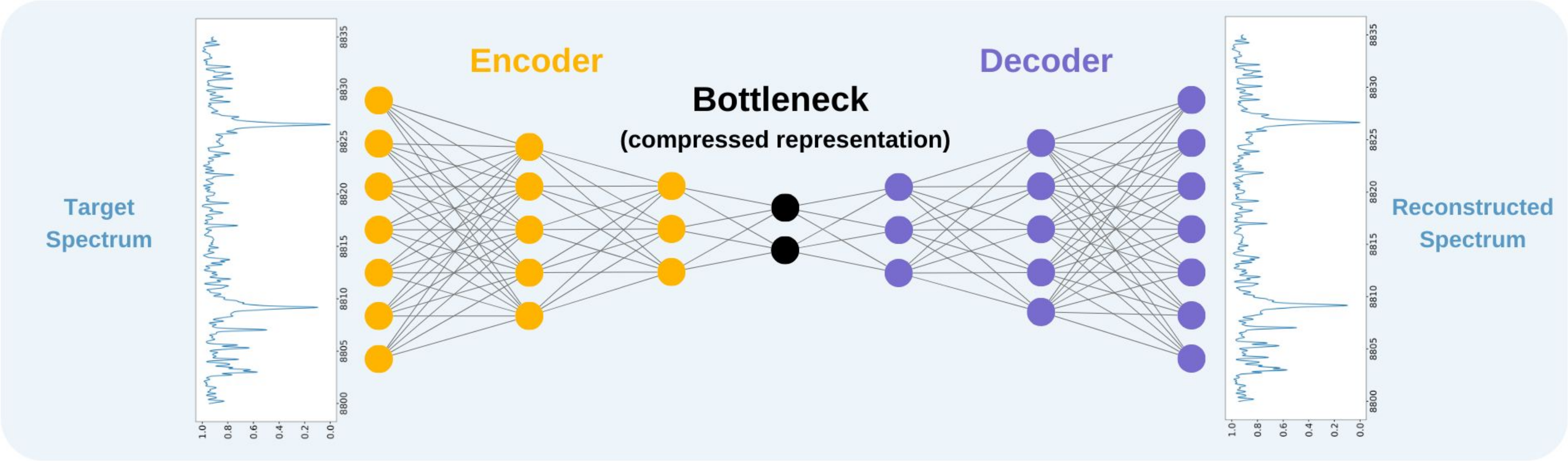
The knowledge acquired is exploited to improve generalization in another setting

Big Picture

- To develop a **deep transfer learning approach based on autoencoders,** to determine stellar parameters from high-resolution spectra:
  - → **Target sample:** 286 M dwarfs high-resolution spectra observed with CARMENES.
  - → **Synthetic data:** Grid of synthetic spectra based on the PHOENIX-ACES models.
- **Expectation:** To bridge the **synthetic gap:**
  - → Differences in feature distributions between synthetic and observed data.



Autoencoder Step



Narrow the flow of information

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Minimize loss function between reconstructed and input spectra

We force the autoencoder to automatically learn a meaningful low-dimensional representation of the synthetic spectra

Deep Transfer Learning step

- **Goal:** Transfer knowledge from a **data-rich source domain** (synthetic spectra) to our **data-poor target domain** (observed CARMENES spectra).
    - → The autoencoder network is **re-trained with the CARMENES spectra.**
    - → All the **encoder layers until the last one are kept frozen** (not updated in re-training).

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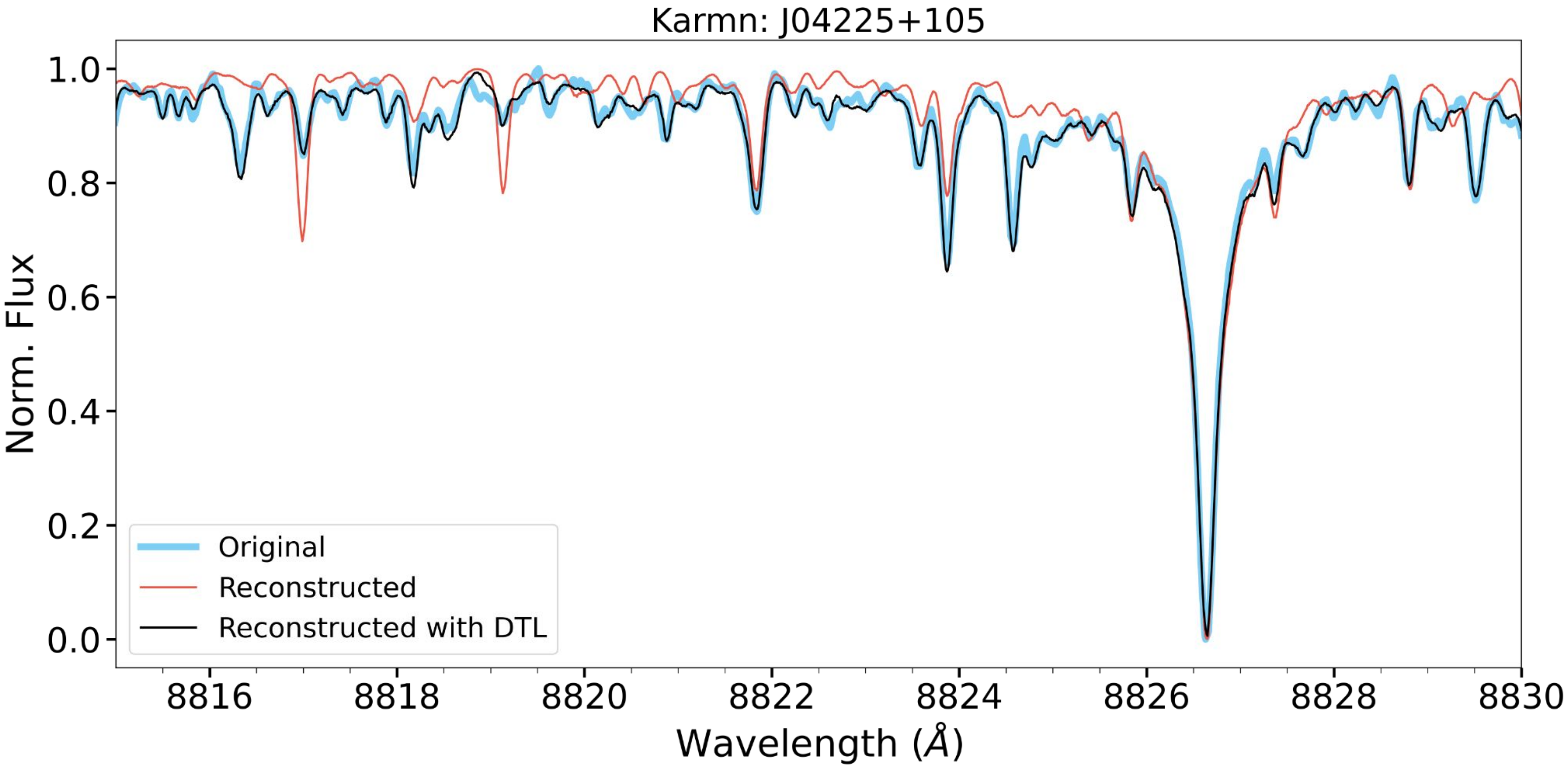
Why?

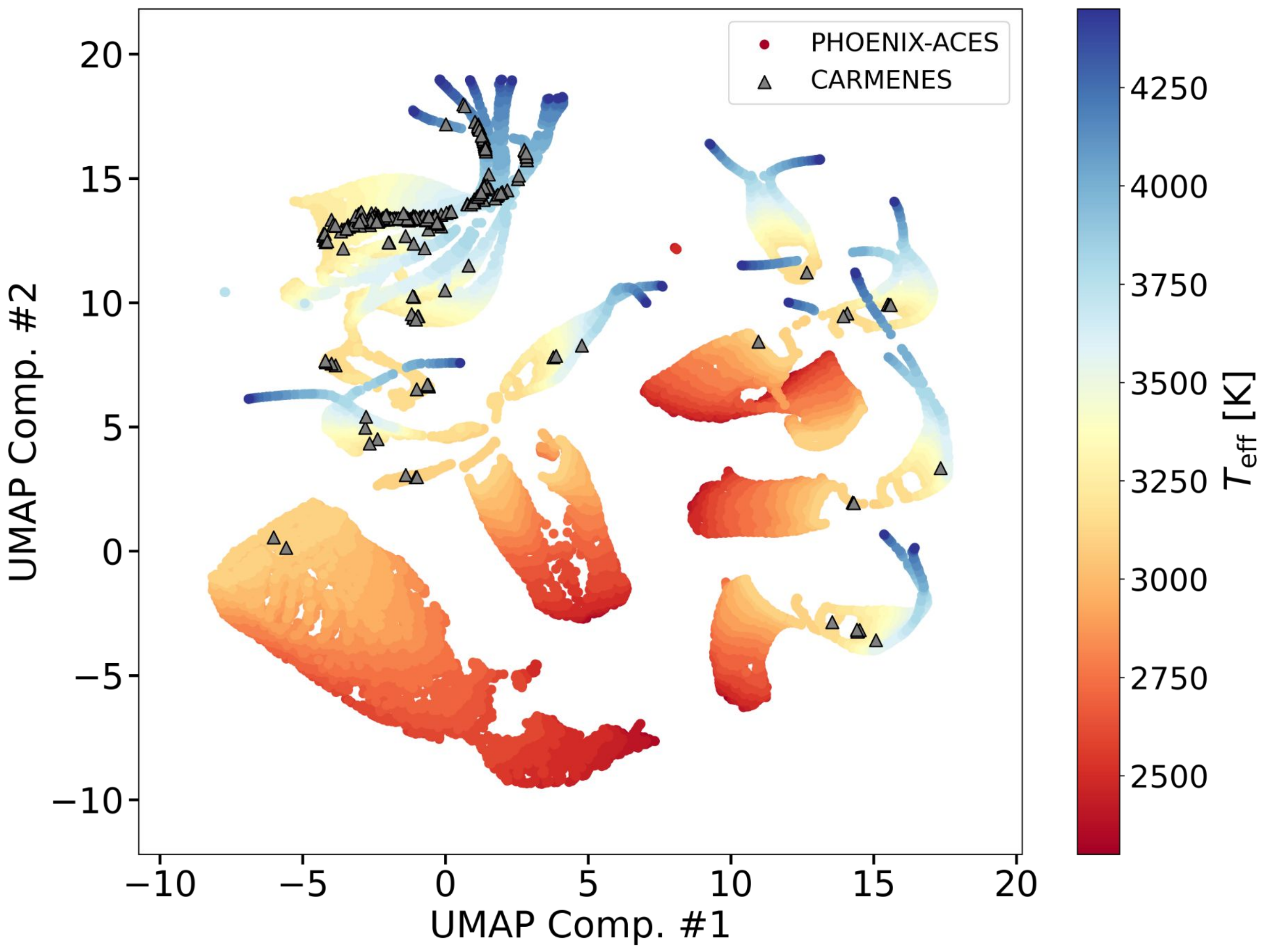
Neural networks are hierarchical: we want to **preserve generic learning** (lower layers, closer to the input) from the source domain and **tailor specific features** (higher layers) to the target spectra.

Deep Transfer Learning step



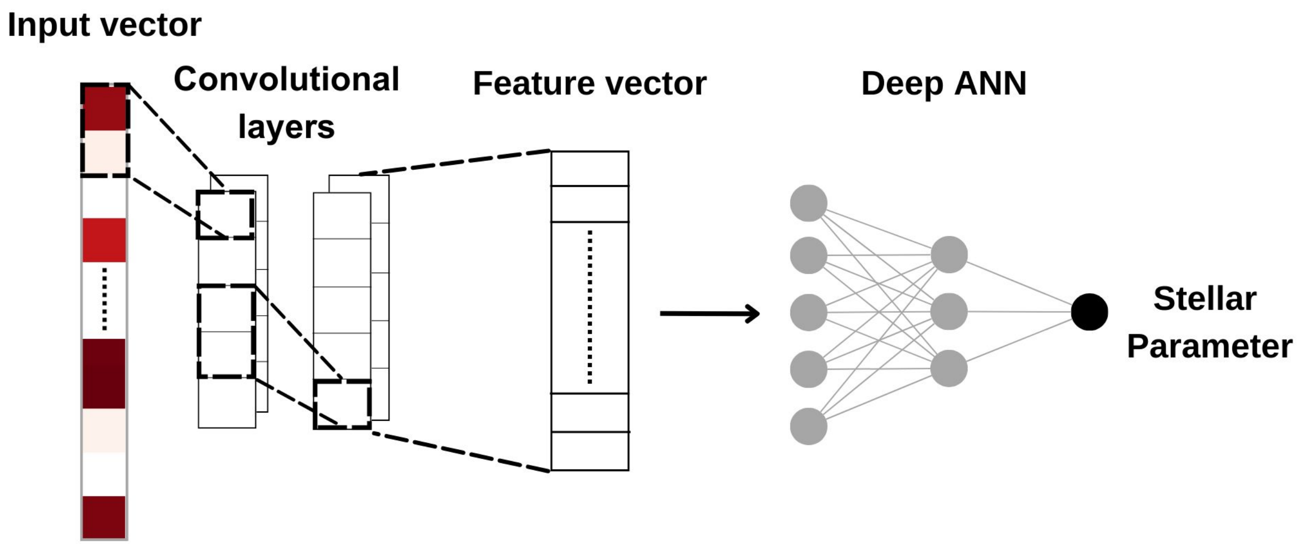
Autoencoder + DTL: New Feature Space

- Initial training of the autoencoder: Low-dim representations of the synthetic spectra.
- Fine-tuning process: Low-dim representations of the CARMENES spectra.
- We end up with a new feature space with **no significant differences in the feature distributions between the synthetic and observed spectra.**



Stellar Parameter Determination

- Using the **new low-dim feature space as input**, we train a 1-D convolutional neural network (CNN) to estimate the stellar parameters.
  - → The CNN is trained with the synthetic low-dim representations.
  - → Once trained, we use the model on the low-dim CARMENES representations to determine the stellar parameters.
- For an in-depth discussion of the results see **Mas-Buitrago et al. 2024, in prep.**



Key Takeaways

- Using a DTL approach based on autoencoders, we obtain a new feature space where the **synthetic and observed data are much closer**.
- The DTL process **does not involve high-quality measurements**, a main limitation of previous works.
- **Future work:** we will explore this approach to classify late-type stars from low-resolution **EUCLID** spectra.

Let's Connect!

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