Youth assessment in near infrared spectra of brown dwarfs and very low mass stars: a case study in NGC2244

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Yo-BD
YOUNG BROWN DWARFS

Introduction

The study of youth features in cool dwarfs is important for:

- Populations of Star Forming Regions (SFRs) and Nearby Young Moving Groups (NYMGs)
- Application to planetary mass objects youth determination, including exoplanets
- Future facilities: hundreds of spectra at the same time, need for efficient analysis

Our goal is to **perform the best age/gravity classification** from low resolution spectra

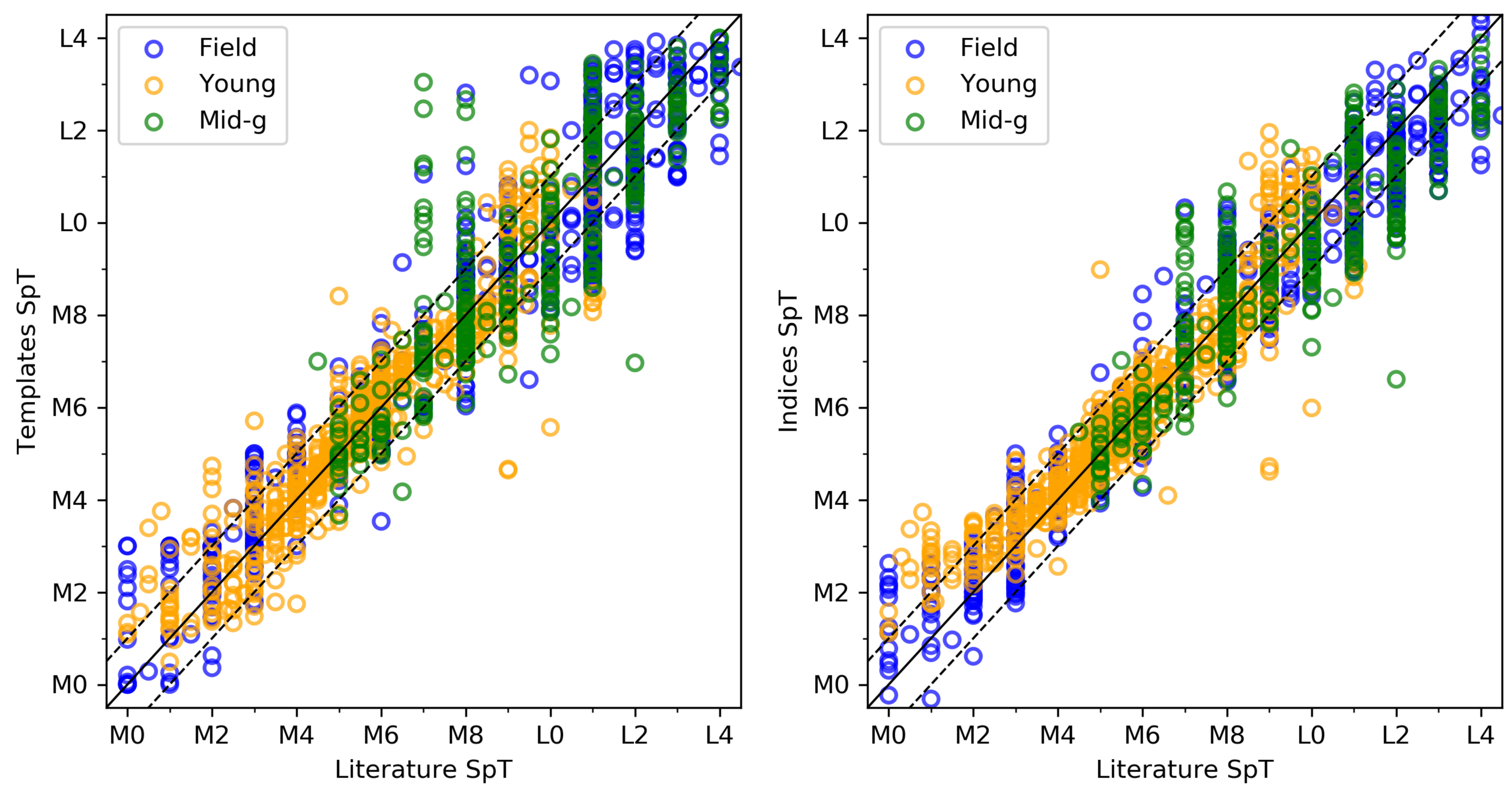

Fig. 1: Derivation of dataset's SpT using comparison with templates (left) and spectral indices (right)

Data

Spectral library with all available NIR spectra of cool dwarfs (spectral type in M0-L5). Age classes: **Young** (SFRs, <15 Myr), **mid-gravity** (NYMGs, >15 Myr and VL-G or INT-G from Allers & Liu 2013) and **field** (765, 261 and 577 spectra respectively)

Homogenization

- **Re-derivation of Spectral Type** (SpT) in [M0-L3] and **extinction** from comparison with templates and spectral indices (including two newly defined ones) (Fig. 1)
- Use same wavelength grid: JHK bands, wavelength step: 0.043 microns
- Normalize spectra to an integrated flux of one

Youth determination methods

Spectral indices

- **TLI-g:** Definition of a **new gravity-sensitive spectral index** based on the H-band water absorption band: better age classes separation than any other index defined (Fig. 2)

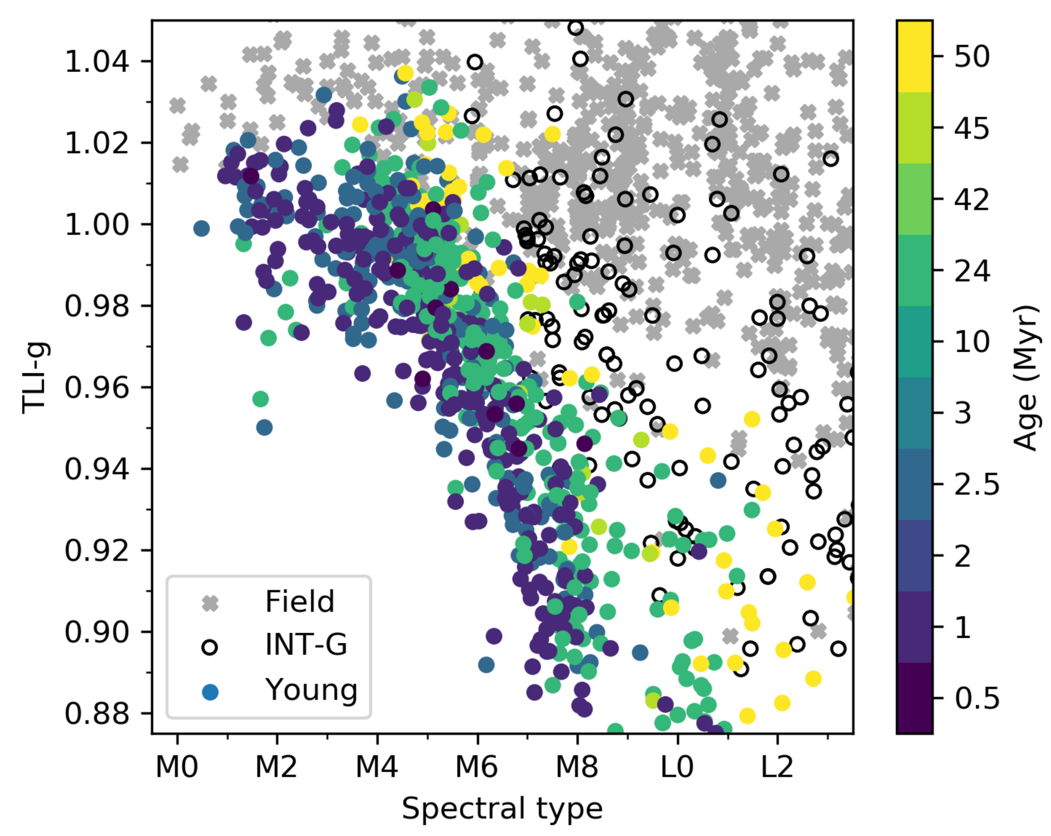

Fig 3: The gravity-sensitive TLI-g index. The objects are color-coded by their age, with the black circles showing the objects classified as INT-G by Allers & Liu 2013.

Machine learning

We apply three different machine learning models:

1. SVM: Non-linear classifier (**Support Vector Machine**) with *rbf* kernel applied to **TLI-g+SpT**

2. PCA+SVM: Extract most important features of the entire spectrum with **Principal Component Analysis** (PCA), then feed the output to the SVM

3. RF: Apply **Random Forests** (RF) to the whole spectrum (Fig.3)

Models validation process:

- Optimization of hyper-parameters
- Run models with 80/20 training test division until convergence of the evaluation metrics
- Evaluate performance with the mean confusion matrix, precision and recall

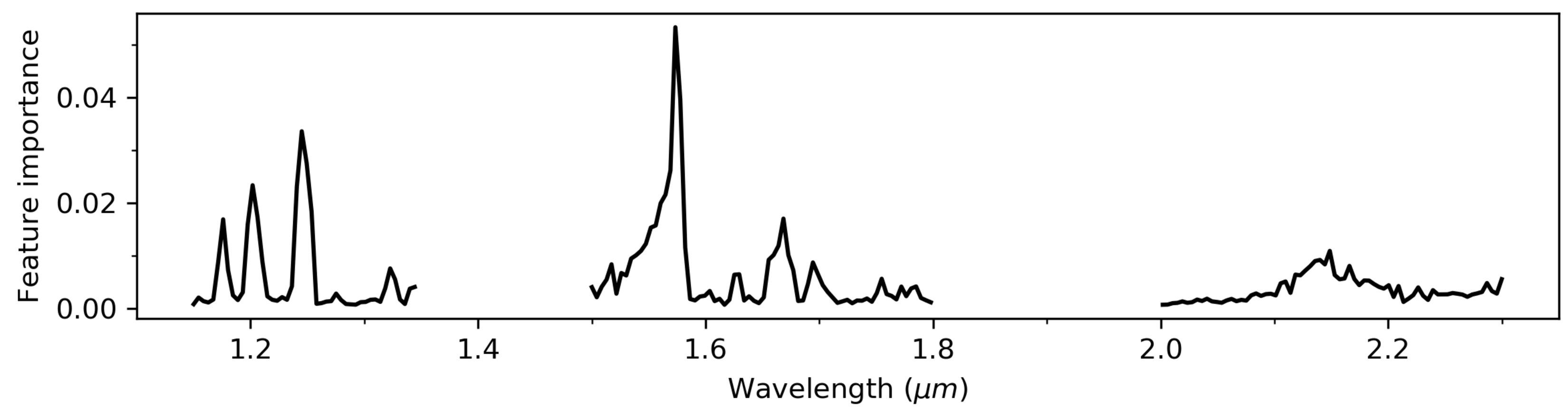

Fig 3: Feature importance map from RF, the highest peaks are well-known gravity-sensitive features

Validation of machine learning models

Two age classes (young and field): The three models have similar performance. PCA+SVM and RF give **similar results using only HK bands** and have the advantage of not relying on the spectral type

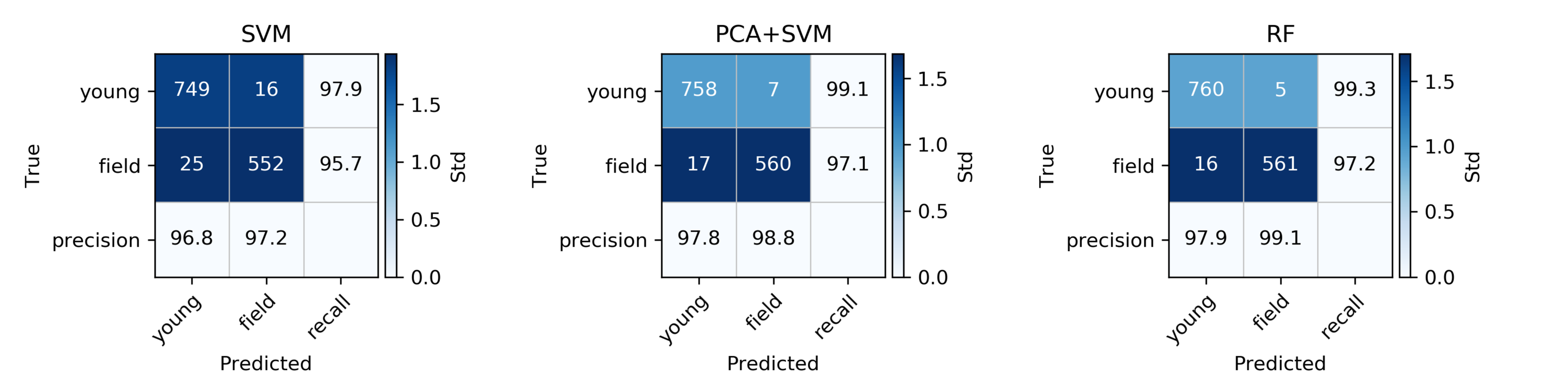

Fig. 4: Confusion matrix for two age classes predicton for SVM, PCA+SVM and RF methods

Using the TLI-g index and the SpT alone, the young and field classes are almost completely separable in the whole SpT range (M0-L3)

Three age classes (young, mid-age and field): The TLI-g index cannot effectively disentangle all three classes, but the methods using the entire spectra (PCA+SVM, RF) show a better performance.

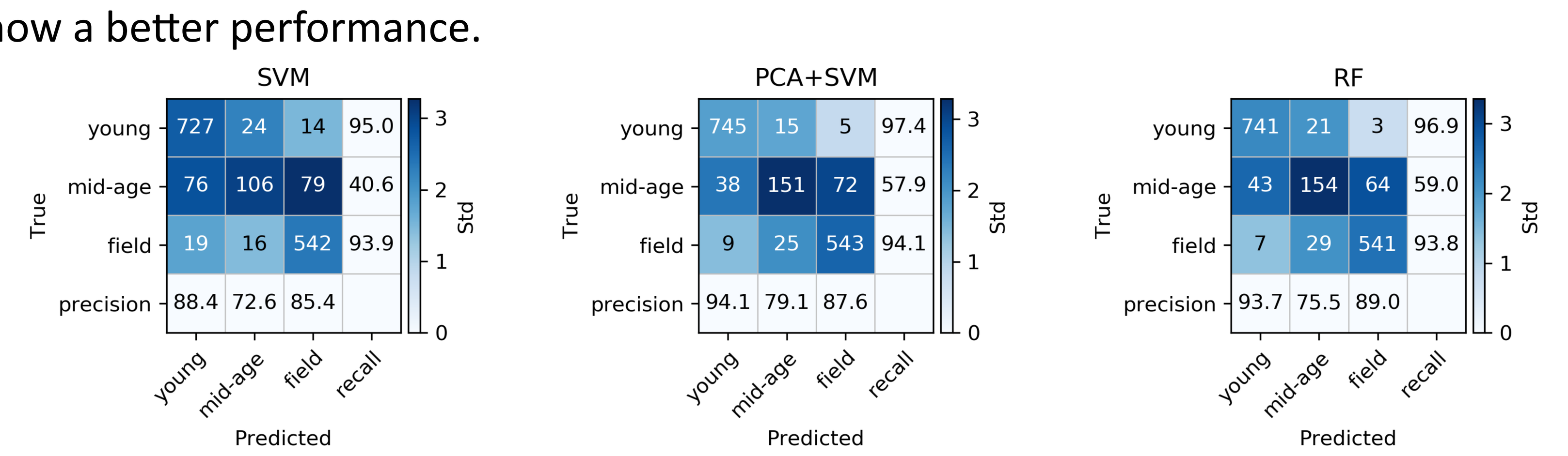

Fig. 5: Confusion matrix for three age classes prediction for SVM, PCA+SVM and RF methods

Open questions

- Can we use PCA+SVM or RF for a complete (extinction, Teff, SpT) analysis of cool dwarfs?
- Can we use machine learning models to perform regression and obtain ages?
- **Does the sequence extend to >L3 objects?** The trend seems to maintain towards later spectral types, but there are very few young planetary-mass objects to do this analysis

NGC2244

We applied these method to 140 KMOS/VLT HK bands spectra (Fig. 6) of NGC2244 low-mass candidates from Muzic et al. (2019):

- We confirm the **first bone-fide brown dwarfs identified beyond 1 kpc**
- We confirm at least **22 new** low-mass **members** of NGC2244 (SpT in **M2-L0**)
- Obtain a low-mass **IMF** slope similar to the purely photometric (Muzic et al. 2019), **steep but still universal**

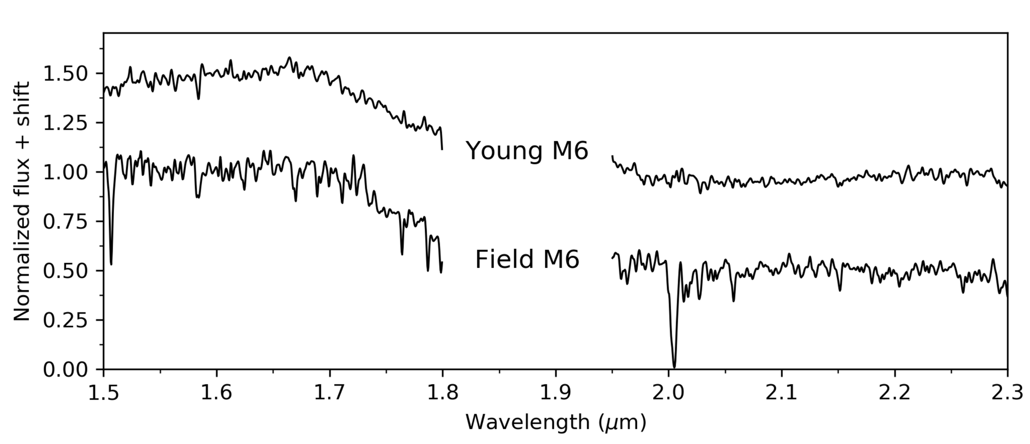

Fig. 6: Comparison of a young M6 spectrum (top) and a field contaminant (bottom; identified through the shape of the H-band), both from the NGC2244 spectroscopic sample.

Acknowledgements:
This work has been supported by the FCT, references: PTDC/FIS-AST/28731/2017 and SFRH/BD/143433/2019.
Spectral library built from IRTF/SPEX, Spex/prism, BDSS and Montreal online spectral libraries, Acala et al. (2014, A&A, 561, A2), Allers and Liu (2013, ApJ, 772, 79), Bonnefoy et al. (2014, A&A, 562, A27), Covey et al. (2010, ApJ, 722, 971), Dawson et al. (2014, MNRAS, 442, 1586), Esplin et al. (2018, AJ, 156, 75), Esplin et al. (2019, AJ, 158, 54), Lodieu et al. (2007, MNRAS, 383, 1385), Luhman et al. (2016, ApJ, 827. 52), Luhman et al. (2017, AJ, 153, 46), Luhman et al. (2020, AJ, 160, 44), Manara et al. (2013, A&A, 551, A107), Manjavacas et al. (2014, A&A, 564, A55), Muench et al. (2007, AJ, 134, 411), Muirhead et al. (2014, ApJS, 213, 5), Rojas-Ayala et al. (2012, ApJ, 748, 93) and Venuti et al. (2019, A&A, 632, A46).

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Allers and Liu 2013, ApJ, 772, 79
Muzic et al. 2019, ApJ, 881, 79

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