Characterization of M dwarfs using SPIRou

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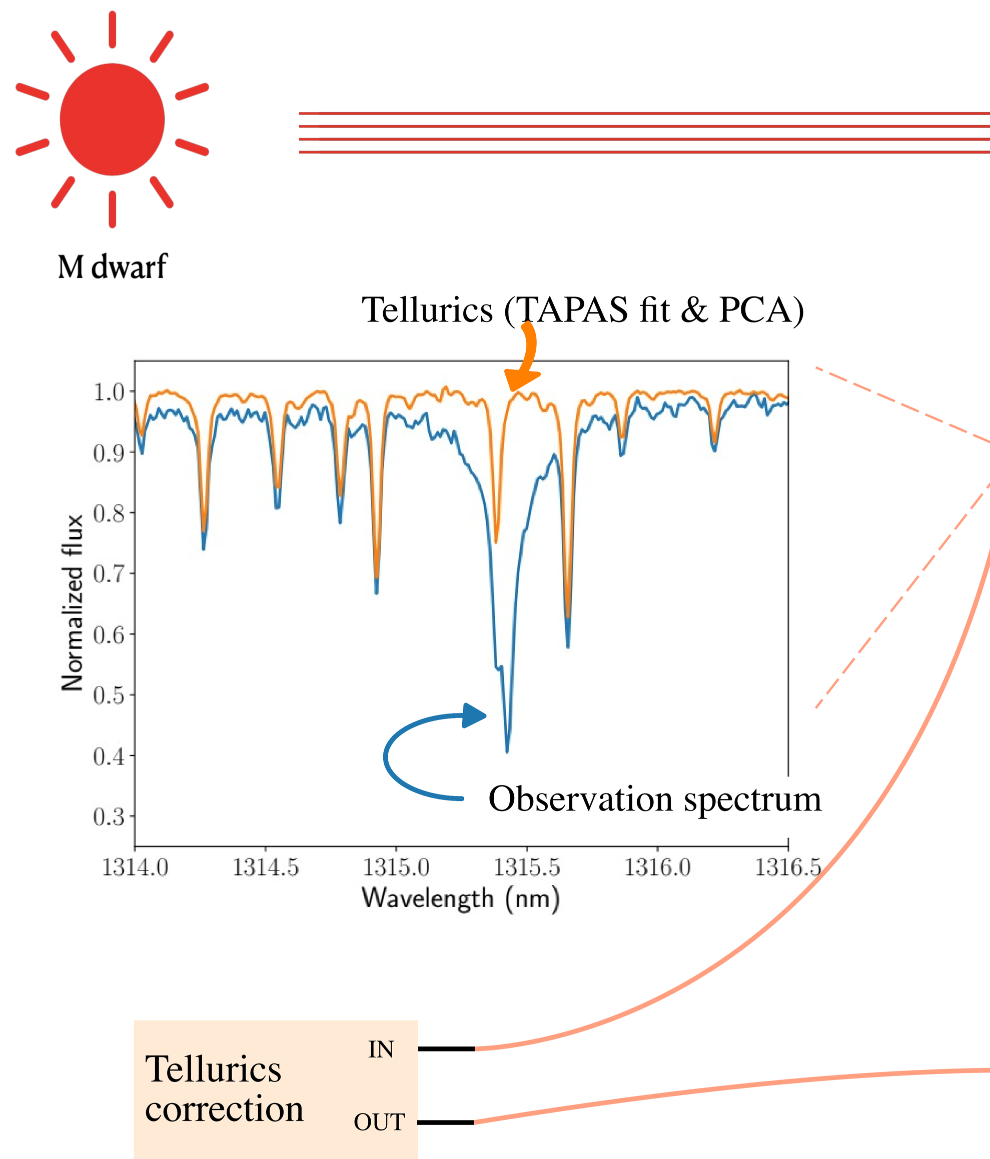
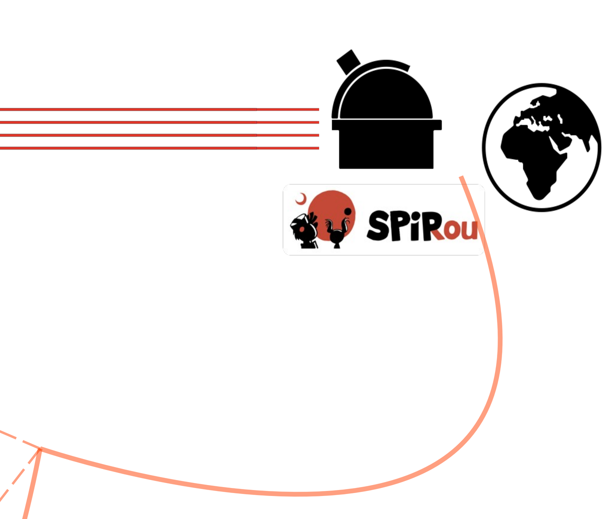
ABSTRACT

Context. M dwarfs are among the most numerous stars of the stellar vicinity, and are favored targets in the hunt for exoplanet. The near-infrared (nIR) spectropolarimeter SPIRou provides high-resolution spectra of M dwarfs. Characterization of the host stars are important to constrain the physical properties of planetary systems.
Goals. We propose to derive effective temperature ($T_{\rm eff}$), surface gravity (log(g)) and metallicity ([M/H]) for a dozen of non-active M dwarfs with a methodology relying on the analysis of their nIR spectra.
Method. Telluric lines are removed from observation spectra using a new two step procedure relying on atmosphere transmission modeling (TAPAS) and principal component analysis (PCA). The parameters determination procedure relies on the comparison of synthetic spectral grids – among which the widely used PHOENIX and MARCS models – to corrected observation spectra.
Results. The comparison allows to retrieve $T_{\rm eff}$, log(g) and [M/H] in good agreement with literature values, with observed discrepancies in some specific situations.

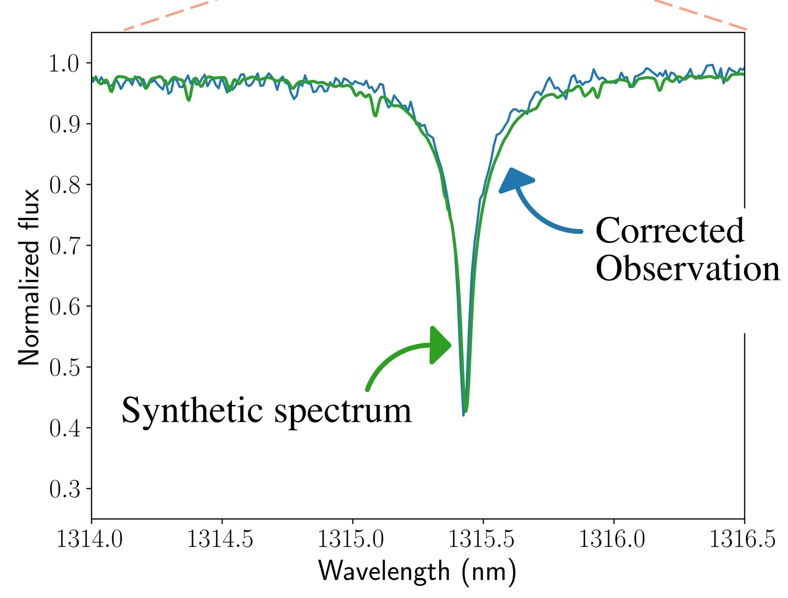
FROM OBSERVATION TO MODEL



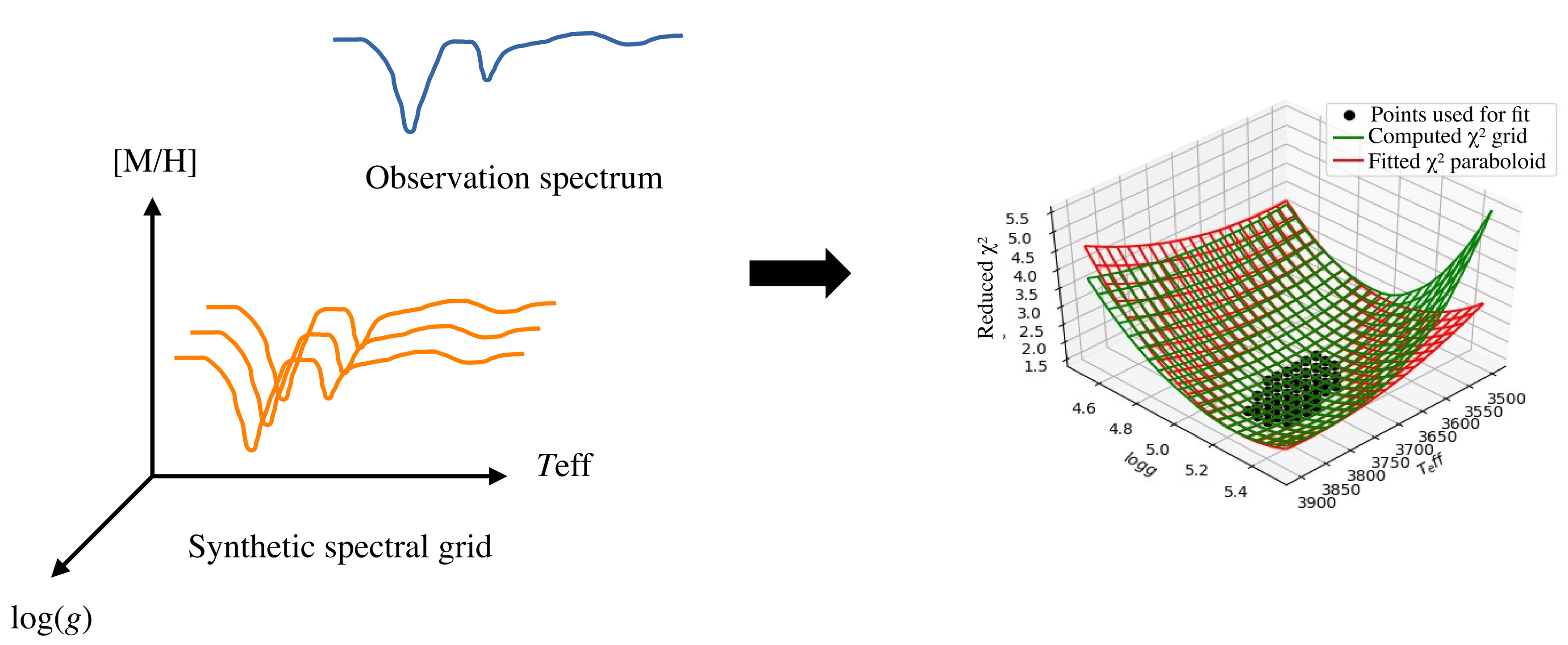


SPIRou spectra must be corrected to remove absorption features caused by our atmosphere. We use a two step process relying on TAPAS[1] synthetic spectra and PCA[2] to remove telluric features.

Corrected spectra are compared to synthetic models, either PHOENIX[3] of MARCS[4]. We identify lines of interest, i.e. lines that are:
– well reproduced by models
– sensitive to $T_{\rm eff}$, log(g) or [M/H]
– well corrected for tellurics



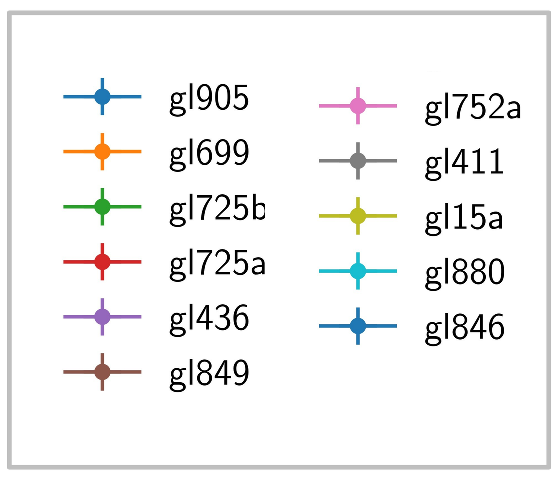
The determination of stellar properties relies on χ^2 minimization, used to compare synthetic spectra to observations. A χ^2 is computed for synthetic spectra of varying parameters. A parabolic fit is performed on the lowest points of the 3-dimensional χ^2 surface to retrieve optimal parameters and uncertainties on the parameters.

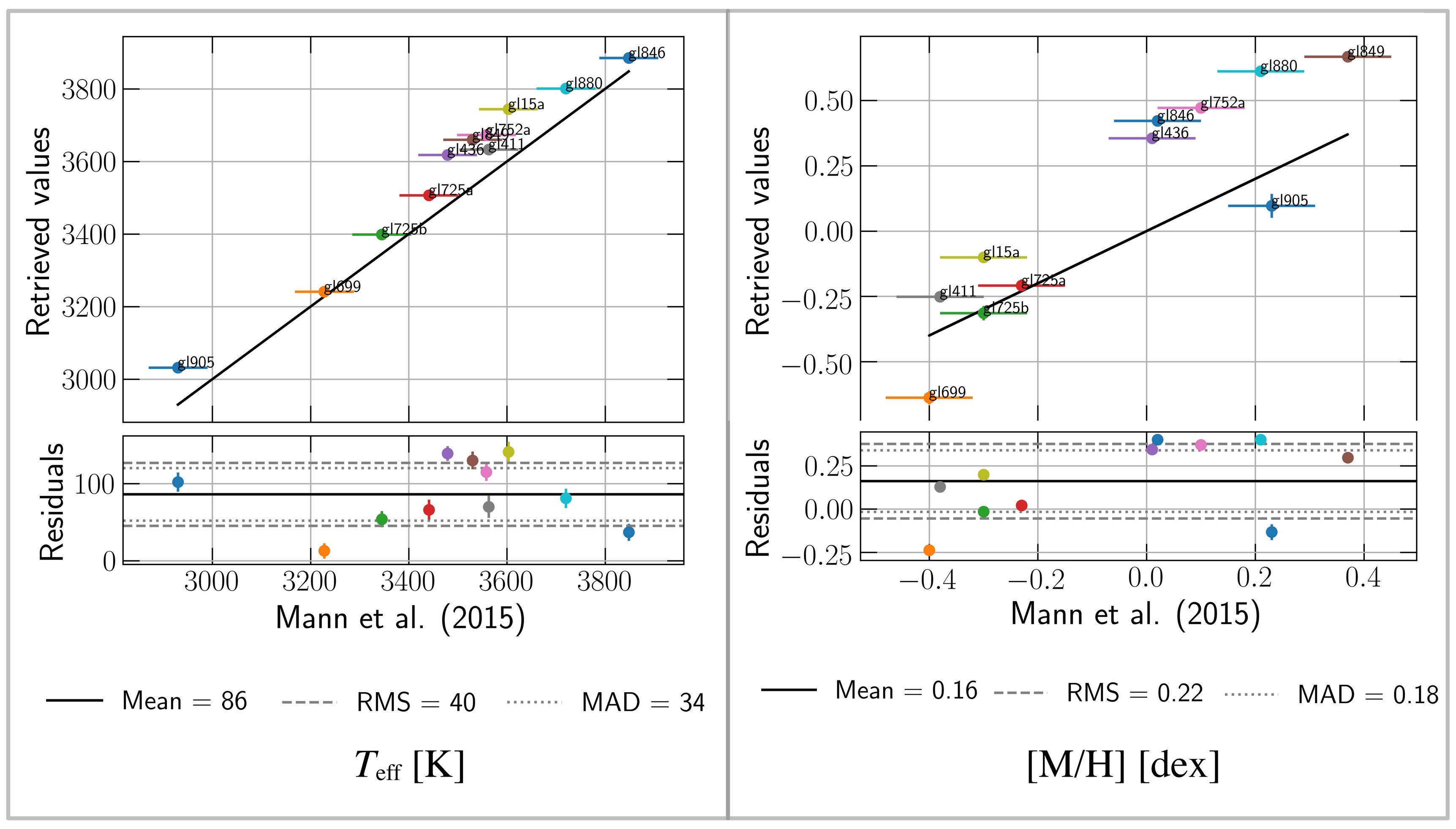


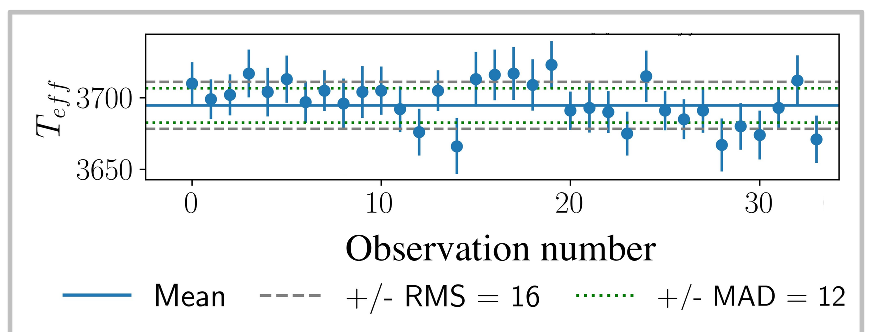
RESULTS

We select M dwarfs observed at high signal to noise ratio with SPIRou, covering a range of temperature from 3000 to 4000 K, for which stellar properties have been reported by previous studies.

For each parameter, we compute the root mean square (RMS), median absolute deviation (MAD) and mean of the residuals, i.e. retrieved values minus literature values[5]. Results presented here rely on the PHOENIX grid[3].

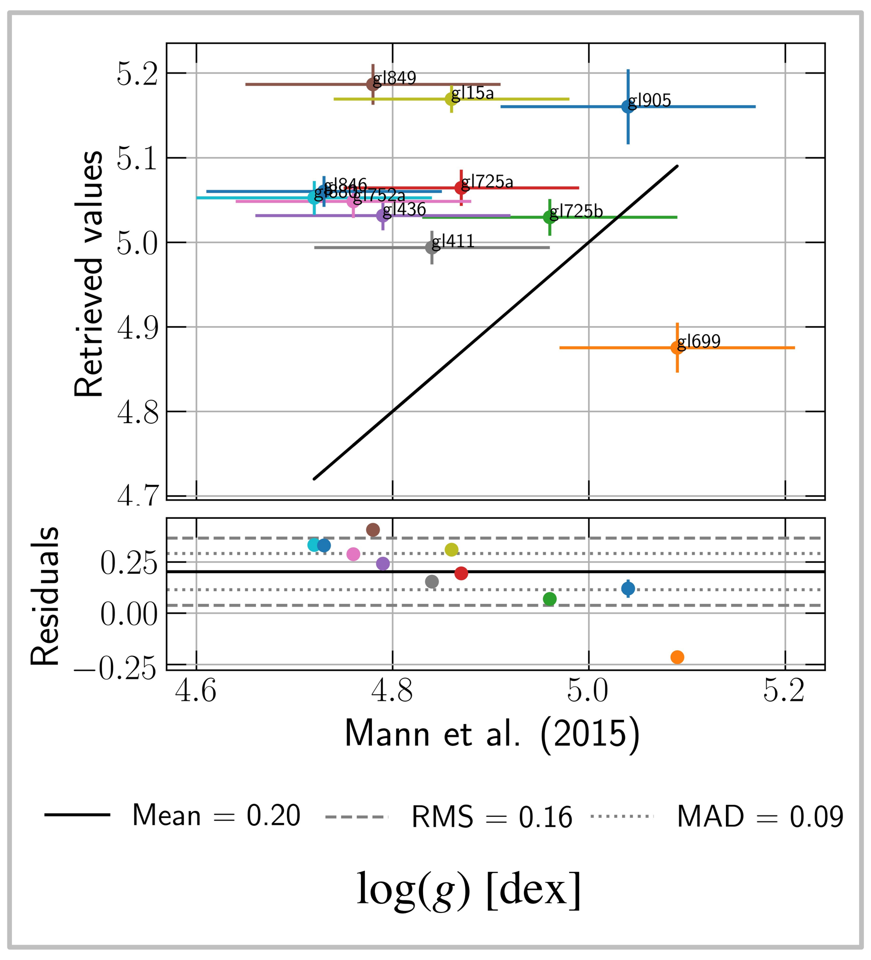






$T_{\rm eff}$ determination of Gl15A SPIRou spectra

An analysis of numerous individual spectra reveals the self-consistency of the described method. The deviation of the retrieved parameters is in agreement with computed uncertainties.



RMS and MAD of the residuals tells us about the deviation of the retrieved values to literature. RMS and MAD values are typically of the order of the uncertainties published in the literature, and mean offsets are also found when comparing literature references.

Surface gravity is strongly correlated to $T_{\rm eff}$, and yet our sample covers a small range of log(g), making the fit of this parameter especially challenging.

Similar conclusions can be drawn from the use of the MARCS spectral grid, although significant differences remain with PHOENIX. The latter leads to higher RMS on metallicity, while the former may lead to divergences on $T_{\rm eff}$ for the coolest stars.

CONCLUSIONS

What we have. We have a method to derive main stellar properties from high resolution SPIRou spectra of M dwarfs. The method provides fair estimations of $T_{\rm eff}$, log(g) and [M/H] for all stars in our sample. By including multiple models in the process, we are also capable of identifying main differences on modeling strategy and their impact on stellar properties derived when confronted to observation data.
What we want. The project aims at providing the community with a reliable self-consistent analysis procedure relying solely on nIR SPIRou spectra, destined to be systematically applied to SPIRou M dwarfs targets, in order to guide the characterization of observed systems.
Our next steps. The presented method is to be improved by adjustments of models and refined line selection. Most of the information contained in SPIRou spectra remains unused, while spectra correction methods and models are improving, opening exciting possibilities for the future.

REFERENCES

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