The treatment of Red dwarf Host stars

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Introduction

The next generation of spacecrafts dedicated to exoplanetary research will focus on detailed studies of planetary parameters with the goal to understand under what circumstances different types of planets and systems form and evolve.

CHEOPS, a small satellite with a unique instrument, is dedicated to measure light curves with unprecedented precision in order to extract a maximum of information from individual transits of exoplanets.

In order to perform such a task, detailed knowledge of the host star itself is required. The precision in measurements of exoplanetery parameters stems to a large extent from *uncertainties in the knowledge of the stellar host parameters.* As we progress to smaller and cooler host stars, the analysis becomes increasingly more complex. This is unfortunate because low-mass stars enable easier discovery and characterization of exoplanets, in particular small planets. With upcoming new missions the treatment of red dwarf host stars becomes very important.

M dwarfs and exoplanets

Planets orbiting the lowest mass stars, M dwarfs and Brown dwarfs, are both promising and challenging as targets where one could search for potentially habitable conditions [1].

The remote detection of the planetary parameters of such planets is challenging because of the apparent faintness of essentially all low-mass host stars. It is promising for essentially the same reasons where the intrinsic stellar faintness does not contaminate the planetary light to the same degree as with solar type stars.

Transiting planets of a fixed size provide a stronger and more detailed photometric signal from small stars, allowing several planetary parameters to be known accurately. These stellar types are also the most numerous in the solar neighborhood providing a large number of potential targets for studies [1].

As potential targets for the detailed study of geological and hydrological conditions they are promising also because of the better ratio of stellar to planetary light. While such studies are still mainly in the future, the recent launch of the JWST makes the search for and characterization of such potential targets important and are one of the key elements of current space missions like TESS and CHEOPS.

Two solutions for M dwarfs

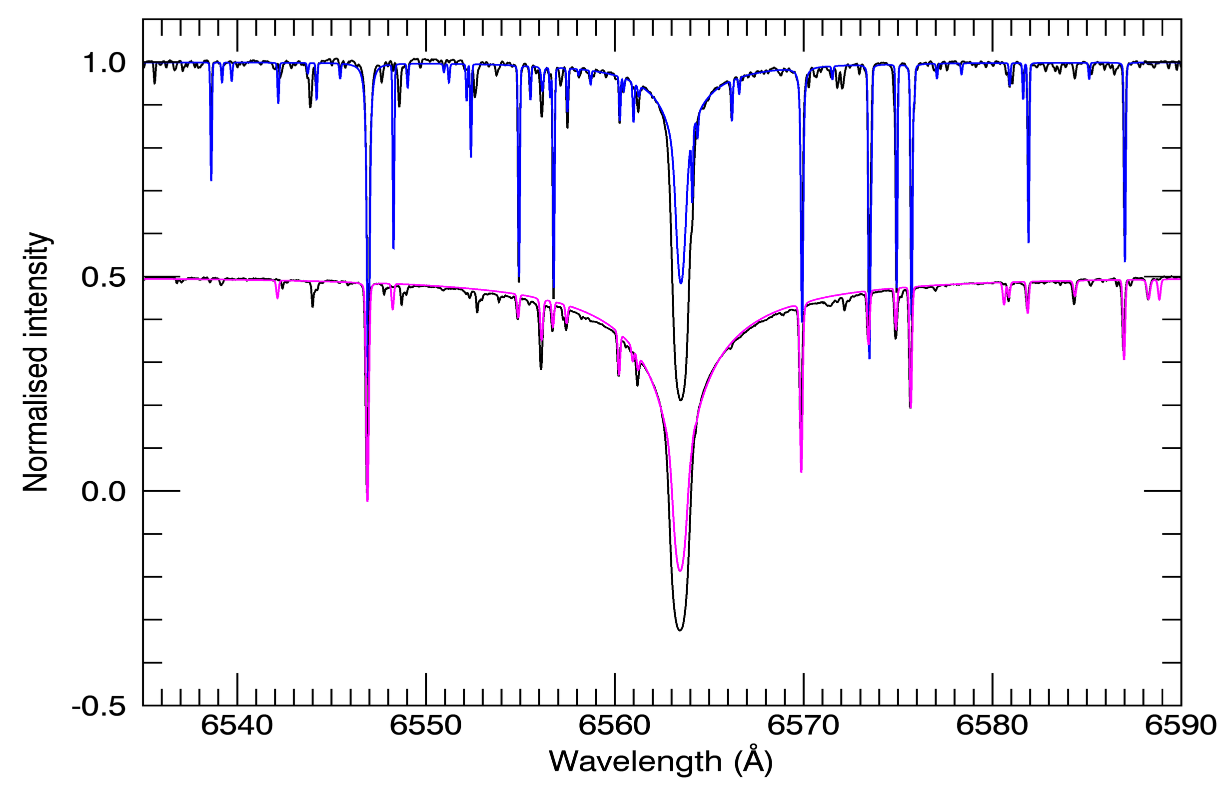
- TiO method: Fitting 500 TiO lines in high-resolution spectra simultaneously. Works if all other parameters are known. Time consuming.
- Photometry: Fitting the observed photometry with a blackbody and different stellar models.

This type of software use isochrones, (automatic) Gaia retrieval and statistical fitting of different stellar models.

No single method work for all cool stars:
A multi-method approach is necessary.

Effective temperature from the Balmer method for solar-type stars

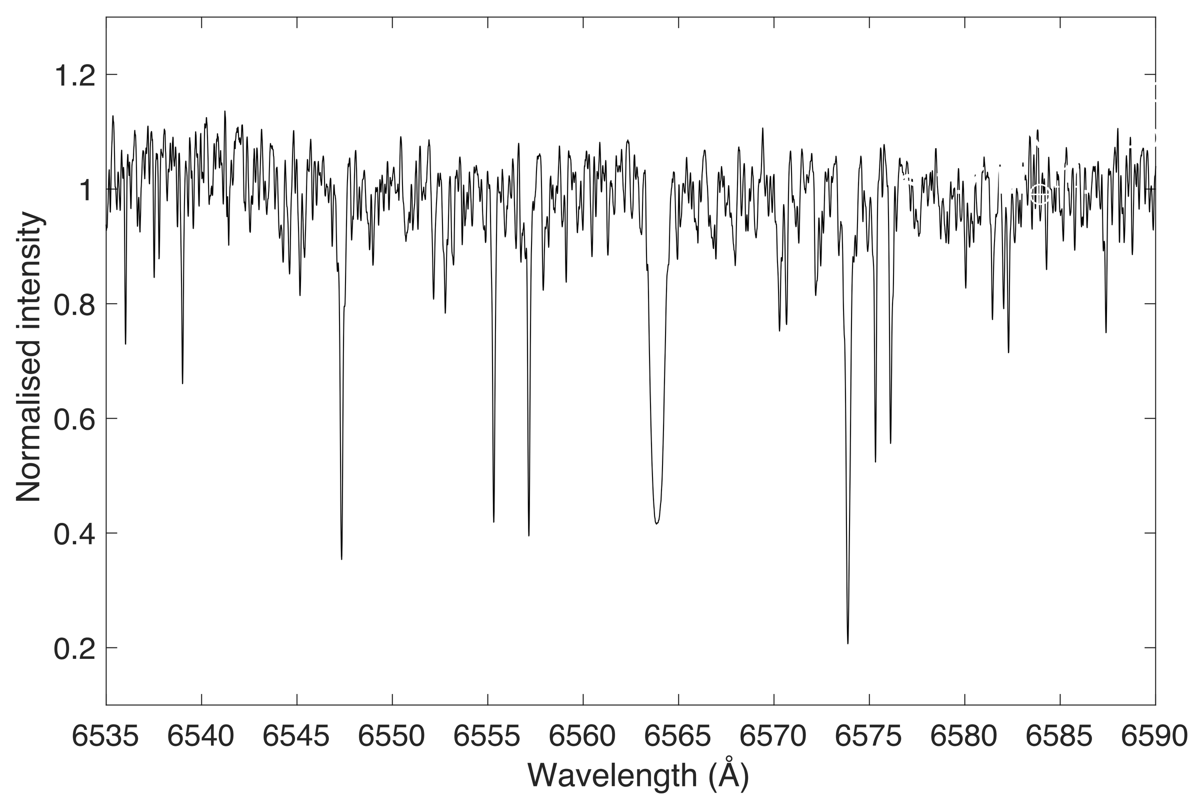
The stellar mass and radius can be modelled from the fundamental parameters effective temperature, T_{eff}, the surface gravity, and the metallicity. These parameters can be derived from high-resolution spectra methods based on the fact that different elements and spectral lines are sensitive to changes in various stellar parameters. The profile of the Balmer Hα λ6563 Å line shows broad line wings which are very sensitive to T_{eff} for stars in the ≈ 4800 – 6500 K interval. This property enables easy derivation of T_{eff} of solar-type host stars with e.g. the software Spectroscopy Made Easy [2] with a precison of ≈ 40-80 K.

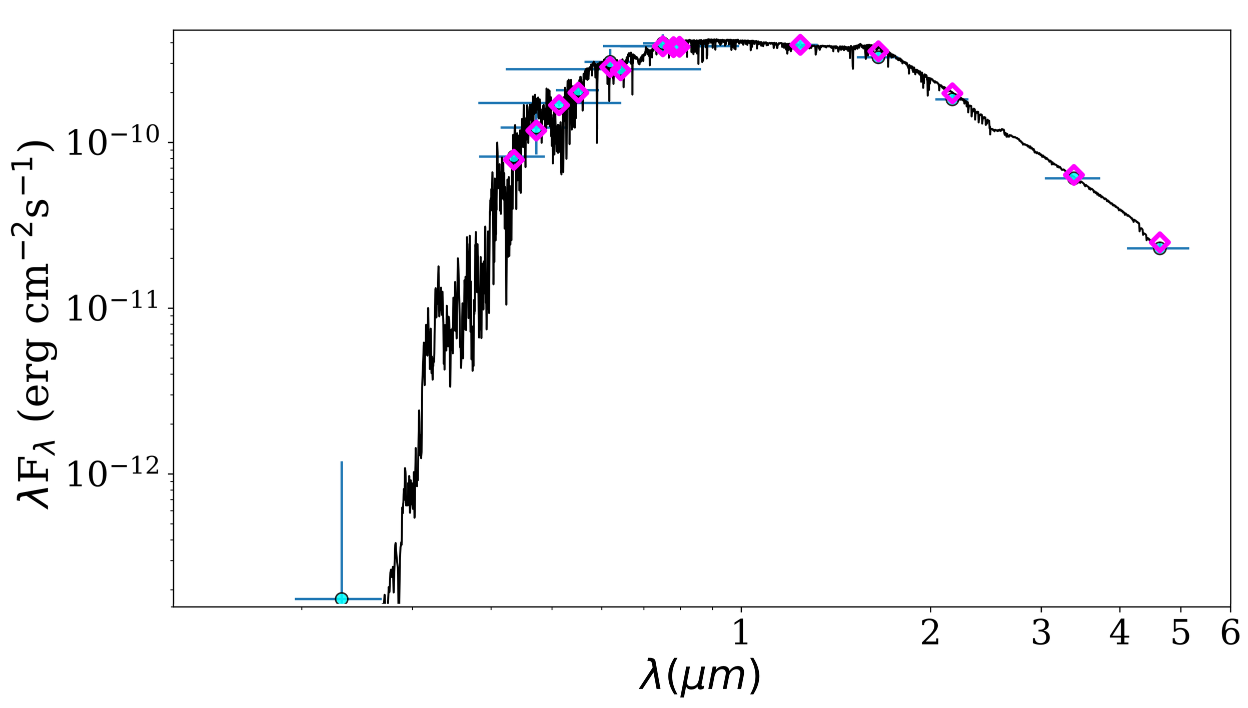


The observed Hα from HD40307 and HD1581 are shown with overplotted SME [2] models using ATLAS12. The resulting T_{eff} for HD1581 is 5866±47 K using ATLAS12, and 5728±50 K using ATLAS9. For HD40307 the resulting T_{eff} is 4670±70 K and 4602±102 K using ATLAS12 and 9, respectively.

The Balmer method can not be used for M dwarfs

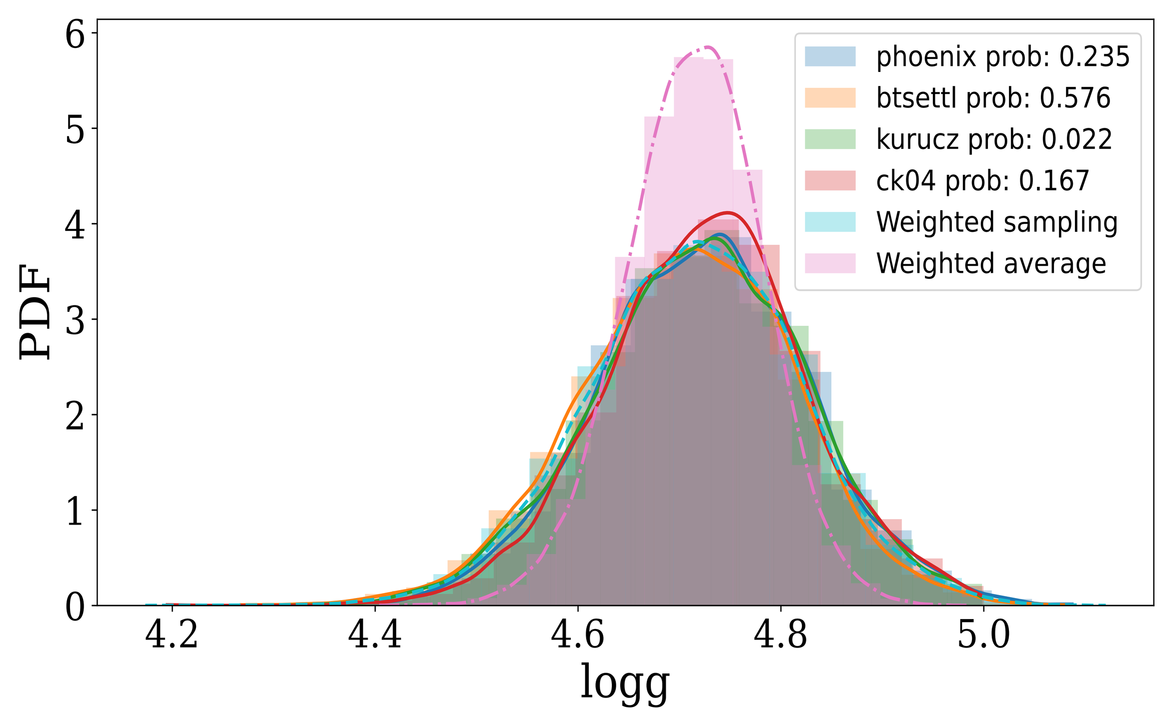
The width of the H-α line wings correlates with T_{eff}. Already below 4500 K the Balmer method will be less useful with increasing uncertainties. As evident from the below spectrum of an M1V star, the line wings of H-α has completely disappeared and hence this method is not useful for M dwarfs.





Left: Example of photometry fitting of the spectral energy distribution (software astroARIADNE [3]).

Right: weigthed avarage of four stellar models of the stellar surface gravity [3].



References:
[1] Scalo, J., Kaltenegger, L., Segurat, A., Fridlund, M., et al, 2007, AsBio, 7, 85.
[2] Piskunov & Valenti, 2017, A/A, 597, 16
[3] https://github.com/jvines/astroARIADNE.