Atmospheric Parameters and Ages of M Dwarfs in the Solar Neighborhood

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Context. M dwarfs are the most numerous stars in the Galaxy, accounting for more than 70% of nearby stars, making them the most likely hosts hosts to diverse systems of low-mass planets. They are prime candidates to shelter habitable earthlike planets, as stressed by the recent discoveries of terrestrial exoplanets inside the habitable zones of the nearby M dwarfs Proxima Centauri and Ross 128. Both the transit and radial velocity techniques for detecting exoplanets are much more sensitive to the presence of earth-size planets around M dwarfs than in solar-type dwarfs. Thus the first habitable exoplanet will probably be detected and characterized in a M dwarf environment, making these stars extremely relevant to both astrobiology and planetary science. Even though they are hotspots for the detection of habitable earthlike planets, our knowledge of their properties and even their accurate census still lags behind with respect to more massive stars.

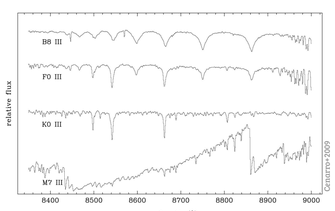
Aims. The main goal of this project is to improve our knowledge of the Teff/[Fe/H] and ages of nearby, still poorly studied M dwarfs, by means of moderate resolution, high S/N NIR spectra, obtained at the coudé spectrograph of the Brazilian 1.6m telescope.

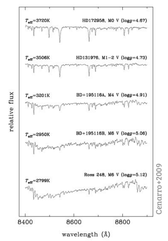
Methods. We introduce a technique which exploits the flux in different bands called spectral indices as a proxy of the atmospheric parameters using a statistical procedure called Principal Component Analysis (PCA). We derived a competitive calibration able to derive Teff/[Fe/H] with internal errors <100K and <0.1 dex respectively, calibrated against stars with interferometric Teff and [Fe/H] from solar-type binary companions. We also plan to estimate stellar ages by measuring chromospheric fluxes of the Ca II triplet lines, plus an activity-age calibration specifically tailored to M dwarfs derived by our own group. We determine effective temperatures, metallicities and ages for a large sample of nearby M dwarfs, for which median resolution spectra were taken using the Coudé spectrograph. We introduce a technique which exploits the flux in different bands called spectral indices as a proxy of the atmospheric parameters.

M DWARFS: CURRENT SCENARIO

- Inherently faint and many lurk unrecognized in the solar neighborhood due to their low luminosity (Henry+1997)
- The most numerous stars in our Galaxy, amounting to about two thirds in number and about 40% in stellar mass (Kirkpatrick+2012)
- Despite the intrinsic difficulties in their characterization, low-mass stars are today at the centre of the search for small, rocky planets with the potential capability of hosting life (e.g. Dressing & Charbonneau+2013; Sozzetti+2013)
- Have on average 3 planets per star (Tuomi+2019)
- The small mass and radius of M dwarfs are favourable to reveal their planetary companions, and with the additional benefit that their habitable zones lie close enough to the star to allow discoveries of habitable planets

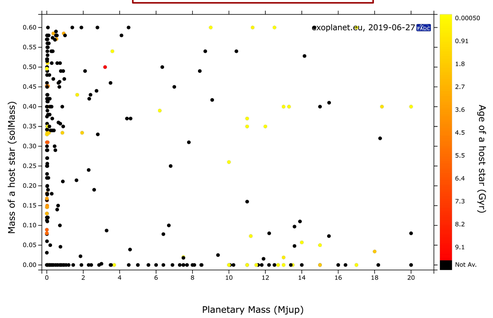
Spectral synthesis techniques do not reach yet a high precision comparable to FGK dwarf methods, due to the fundamental lack of knowledge of billions of molecular line strengths and transitions





Spectral features changing drastically from M0V to M6V

Lack of knowledge about properties of the host M dwarf stars



SAMPLE AND OBSERVATIONS

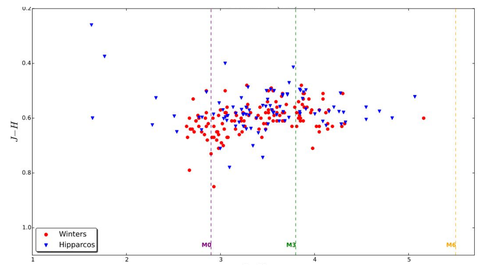
Hipparcos Catalogue
(calibration sample)

83 stars within 10pc (V <= 11.5)
80 with known parameters

3000 K < Teff < 3900 K
-0.5 < [Fe/H] < +0.2

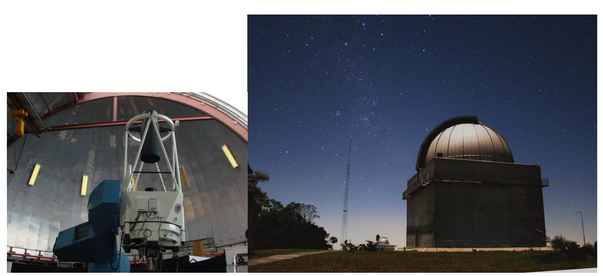
Winters+2015

347 stars within 20pc (V <= 13.0)



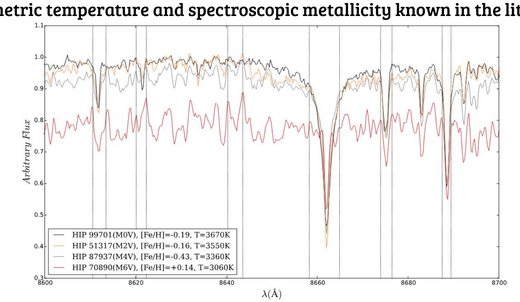
Color-color diagram showing all stars that were observed. The outliers located on the left side are K stars that will connect our method with traditional analyses of atmospheric parameters applied to solar-type stars that provide fundamental abundances.

- We obtained 1139 spectra of 300 stars with spectral types between K5.0 V and M6.0 V
- The observations were performed at the coudé spectrograph of the 1.60m telescope of the Observatório do Pico dos Dias (OPD), operated by the Laboratório Nacional de Astrofísica (Brazil), in a series of observing runs between 2007-2011 and 2017-2018.
- Spectra were mostly exposed to S/N > 100 at a spectral resolution of 0.85 Å (R ~ 10,000), the median of the S/N values being ~150 and reaching out to ~250 in the best exposed spectra.
- Coverage is λλ ~ 8400-8900 Å.
- For most of the stars no published Teff or [Fe/H] was found in the literature, our results being thus the first ever atmospheric parameters provided for these objects.



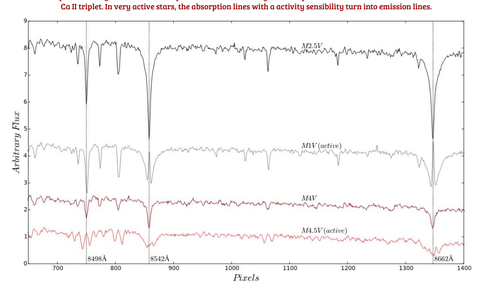
WORK IN PROGRESS

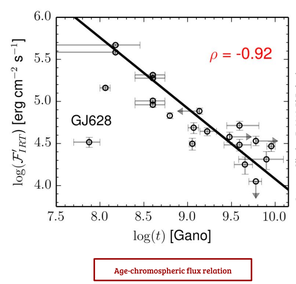
- In this work we develop a technique which exploits the flux in different bands called spectral indices as a proxy of the atmospheric parameters using PCA to obtain high precision determinations of both metallicity and effective temperature of M dwarfs.
- We split the entire spectral range into spectral indices for every single visually group of transition in common for 4 stars taken as templates for spectral types with interferometric temperature and spectroscopic metallicity known in the literature.



- Ages will be obtained by calibrating the observed chromospheric fluxes of the spectra in the Ca II triplet lines λ8498, λ8542 and λ8662 Å for stars with known ages (Lorenzo-Oliveira, D. 2016, PhD thesis; Husser+2013).
- Ages for the calibrating M dwarfs were attributed from membership either in moving groups and clusters, binary systems for which the primary star is a solar-type star with known isochronal age, or binary systems in which the primary is a white dwarf with known cooling age.

Example of activity effects on stellar spectra. There is a activity-chromospheric flux relation that can be seen in the Ca II triplet. In very active stars, the absorption lines with a activity sensibility turn into emission lines.





Age-chromospheric flux relation