Analysis of M dwarfs spectra and search for small planets at the Galileo Telescope

J. Maldonado[1], L. Affer[1], G. Micela[1], and the GAPS team

[1]**INAF - Osservatorio Astronomico di Palermo**, Piazza Parlamento 1, 90134 Palermo, Italy
jmaldonado@astropa.inaf.it

Interested? Ask me!

Within the framework of GAPS: Global Architecture of Planetary Systems, a long-term project at the Telescopio Nazionale Galileo, our team has started an observational monitoring of nearby, early-type, M dwarfs, using HARPS-N to search for small planets around low-mass stars. In this contribution we present a brief summary of the project status, as well as the efforts of our team to determine accurate stellar parameters for these stars taking advantage of the high-quality HARPS-N spectra.

GAPS in a nutshell

The GAPS project aims to improve our understanding of the architectural properties of planetary systems in connection with the characteristics of their host stars. Specific objectives are: i) To study the frequency of low-mass planets as a function of stellar mass, stellar metallicity, density of the stellar environment; ii) To characterize known planetary systems; iii) To analyze the activity of the host stars and its effect on the derivation of the planet parameters; iv) To derive accurate measurements of planet mass by means of astereosismology.

The promise of M dwarfs

Low-mass stars have been recognized as promising targets in the search for rocky, small planets with the potential of supporting life. Within GAPS, our team has started an observational monitoring of a sample of nearby, bright (V < 12), early-type M0-M2 stars. The sample amounts up to around 90 stars selected from the Palomar-Michigan State University (PMSU) catalogue, Lèpine & Gaidos (2011), and targets observed by the APACHE transit survey (Sozzetti et al. 2013).

Our methodology aims to obtain an uniform sensitivity to Super Earths in their Habitable Zone by performing about 40 observations for each star in four semesters. Up to now, around 1150 useful observations have been performed, with an obtained radial velocity (RV) precision of the order of 1 m/s at V ~ 10 (see Figure 1), and some tentative candidates with planetary masses in the Neputne Super-Earth range are emerging (Figure 2).

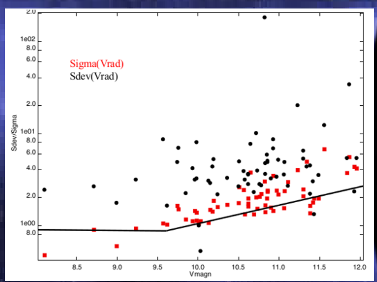

Fig. 1. RV precision (red points) and RV standard deviation (black points) vs V magnitude for series of 15 min HARPS-N spectra of M dwarfs. The black line represents the HARPS-S sensitivity.

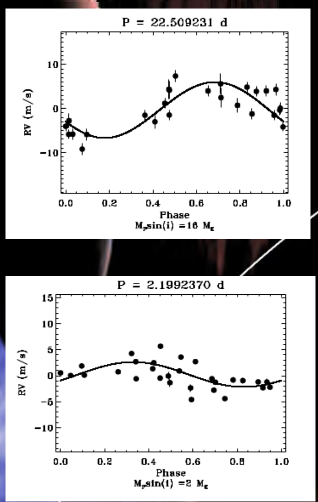

Fig 2. Two examples of planet candidates (RV measurements and planet orbital fit).

Our capability to detected Super Earth planets in their Habitable Zone is shown in Figure 3, where the detection limits on msini are presented for one of our tentative candidates.

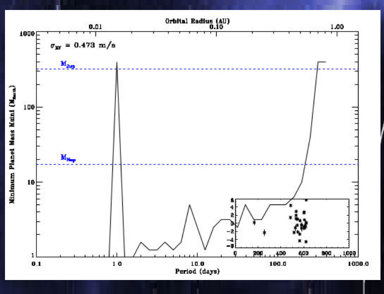

Fig 3. Estimation of our achived sensitivity for one of our tentative planet host. Planets with minimum masses above the limit are excluded with a 99% confidence level. The RV time series are shown in the inner right corner plot.

Characterizing the targets

Exoplanet searches would certainly benefit from a methodology to determine accurate stellar parameters using the same spectra that are being used for the radial velocity determinations. We have been working in identifying features (lines and/or blends of lines) in HARPS and HARPS-N spectra that correlate with T_{eff} and/or [Fe/H].

Ratios of lines with different excitation potentials is a technique which has been widely used in solar-type stars but, to the best of our knowledge, not extended to the low-mass regime (most likely due to the difficulties in analyzing their optical spectra). To overcome this difficulty we make use of pseudo equivalent widths as described in Neves et al. 2014. Using as reference those stars with interferometric radii measurements listed in Boyajian et al. 2012, a total of 2800 temperature sensitve ratios have been identified.

Some examples of the obtained fits are given in Figure 4. The ratios have been fitted to different functional forms:

Hoerl function $ab^r * r^c$; modified Hoerl function $ab^{1/r} * r^c$; power-law ar^b ;

exponential law ab^r ; and logarithmic $a+b\ln(r)$; where $r = EW1/EW2$

is the ratio between the pseudo EWs of the two features and a, b, c are constants. All selected ratios have Spearman's probabilities of correlation greather than 2% and the fits have a standard root mean square error lower than 75 K.

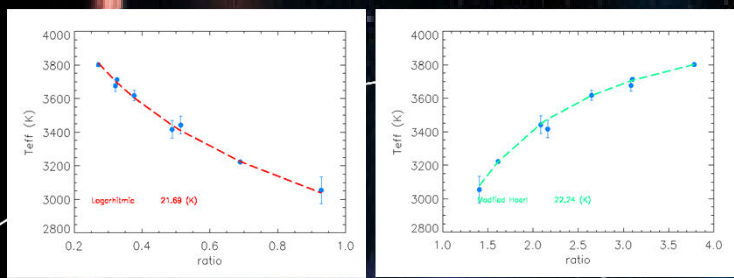

Fig. 4. Example of two of the features ratios identified to be sensitive to T_{eff} in M dwarfs.

Regarding stellar metallicity, we have identified a large number of features whose EWs correlate with [Fe/H]. An example is shown in Figure 5.

In this case we are searching for combinations of features as well as combinations of features and temperature sensitive ratios to derive empirical metallicity calibrations.

As reference stars we are using previous photometric calibrations and/or using spectra of M dwarfs orbiting around a solar-type star with known metallicity.

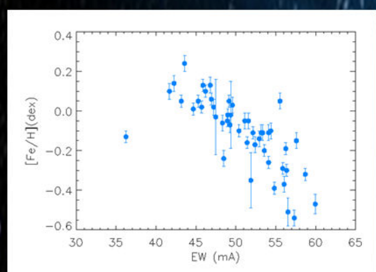

Fig. 5. Example of one of the features identified to be sensitive to [Fe/H] in M dwarfs.

Background image: An artist's conception of an M dwarf with a habitable planet and moons. Credit: David A. Aguilar (CfA)