Metallicity determination of M dwarfs in the NIR

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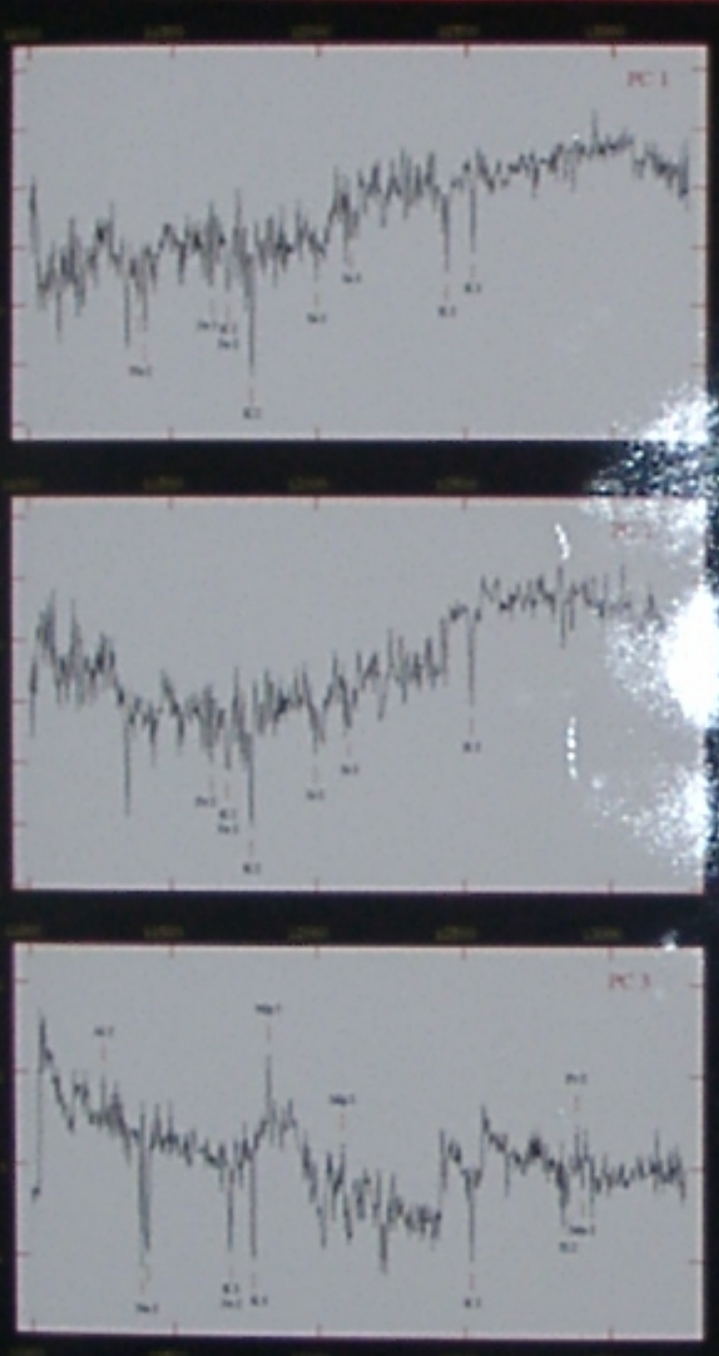
Abstract

Host star metallicity is a determining factor in the abundance of planets. Above solar metallicity, the number of stars with planets and presence of multiple planets increases. M dwarfs planet hosts known to date have shown abundances below solar metallicity when measured with optical spectra, suggesting that M dwarfs have a planetary formation process that differs from F,G and K dwarfs. This can also be due to statistics, with only four M dwarfs with planetary systems known, and/or the lack of reliable abundances estimates for this type of stars. Doppler planet search surveys are starting to be undertaken in the near infrared for planets around cool stars, such as Gemini PRVS (Rayner 2006) and T-EDI (Edelstein et al. 2006). T-EDI is an interferometric spectrometer at Palomar Hale 200" that will explore populations of planets around low mass stars that have been excluded from current Radial Velocity (RV) surveys in the optical band. We are investigating metallicity determination of M dwarfs for preparatory science for NIR Radial Velocity surveys.

Introduction

We analyzed synthetic M dwarf spectra from basic model grids, obtained with the stellar and planetary atmosphere code PHOENIX, using the method of Principal Component Analysis (PCA). PCA, also know as Karhunen–Loeve, is a linear transformation that converts the data to a new coordinate system such that the greatest variance by any projection of the data comes to lie on the first coordinate, the second greatest variance on the second coordinate, and so on. We applied it to samples of synthetic spectra in the J band and we calculated equivalent widths of the most prominent lines of the PCs in M dwarf spectra of the IRTF Spectral Library (Cushing, Rayner, & Vacca (2005)) to get physical insight into the way metallicity affects the spectrum of M dwarfs



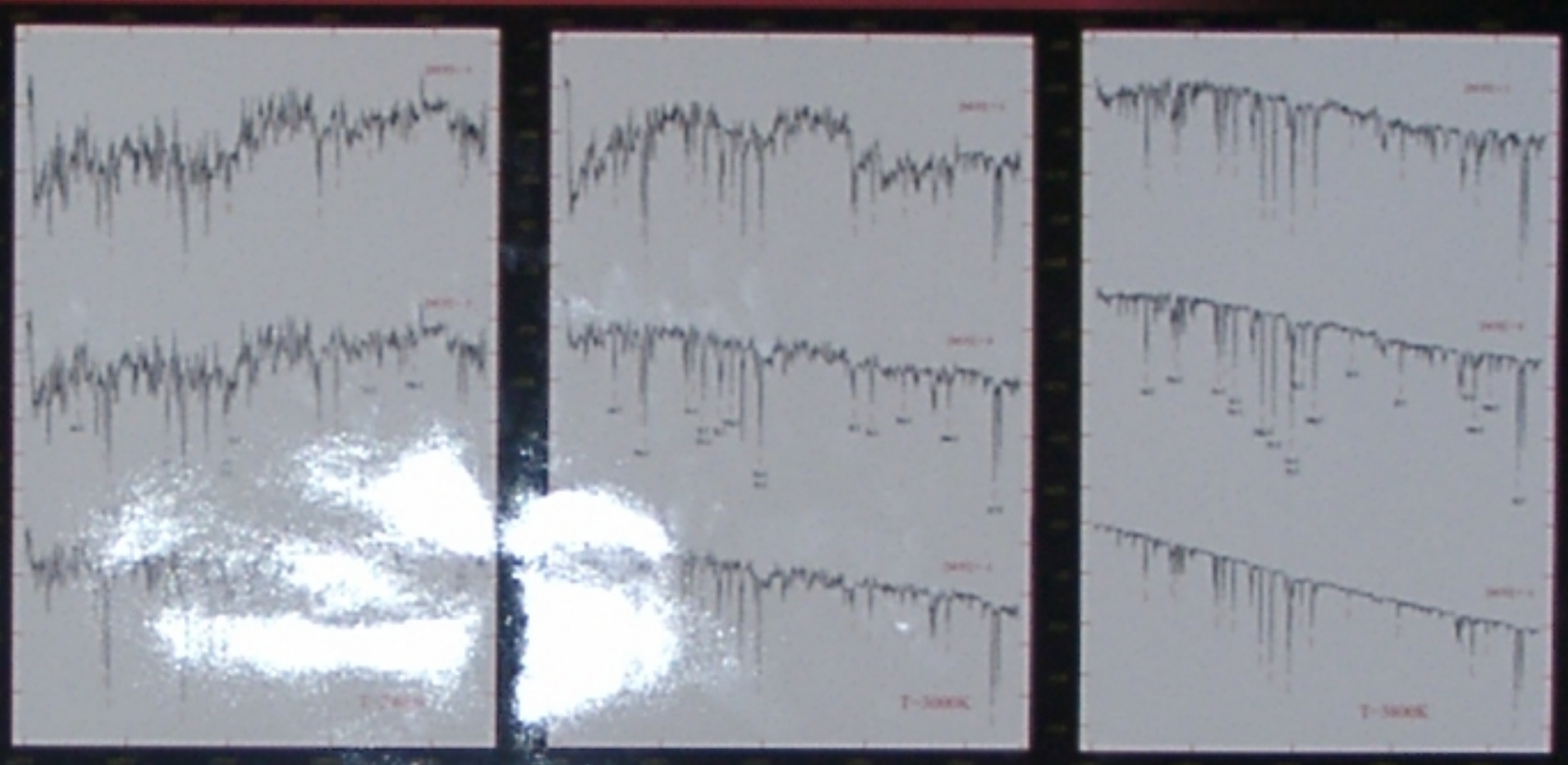


Figure 1 (Top). PHOENIX synthetic spectra of 2400 °K, 3000 °K and 3800 °K M dwarfs with metallicities of -1,0 and 1. M dwarfs exhibit numerous atomic lines in the J and K bands, due to alkaline elements (Na, K), iron, titanium and silicon.

Figure 2 (Left). The first 3 Principal Components (PCs) obtained with 24 synthetic spectra of M dwarfs. The most prominent atomic features are indicated. Note that the absorption lines of K I and Fe I are present in all of them.

Principal Component Analysis (PCA)

Consider a set of N objects (i=1,N) each with M parameters (j=1,M). If X_{ij} are the original measurements, we construct normalized properties as follows:

$$X_{ij} = x_{ij} - \bar{x}_j \qquad \bar{x}_j = \frac{1}{N}\sum_i x_{ij} \qquad C_{jk} = \frac{1}{N}\sum_i X_{ij} X_{ik}$$

Where C_{jk} is a covariance matrix. It can be shown that the axis along which the variance is maximal is the eigenvector e_1 of the matrix equation:

$$Ce_1 = \lambda_1 e_1$$

Where λ_1 is the largest eigenvalue, which is the variance along the new axis e_1. The other eigenvalues and eigenvectors obey similar equations. The matrix of all eigenvectors forms a new set of orthogonal axes. By keeping lower-order principal components that often contain the "most important" aspects of the data, PCA can be used for dimensionality reduction in a dataset, without loosing the characteristics that contribute most to its variance.

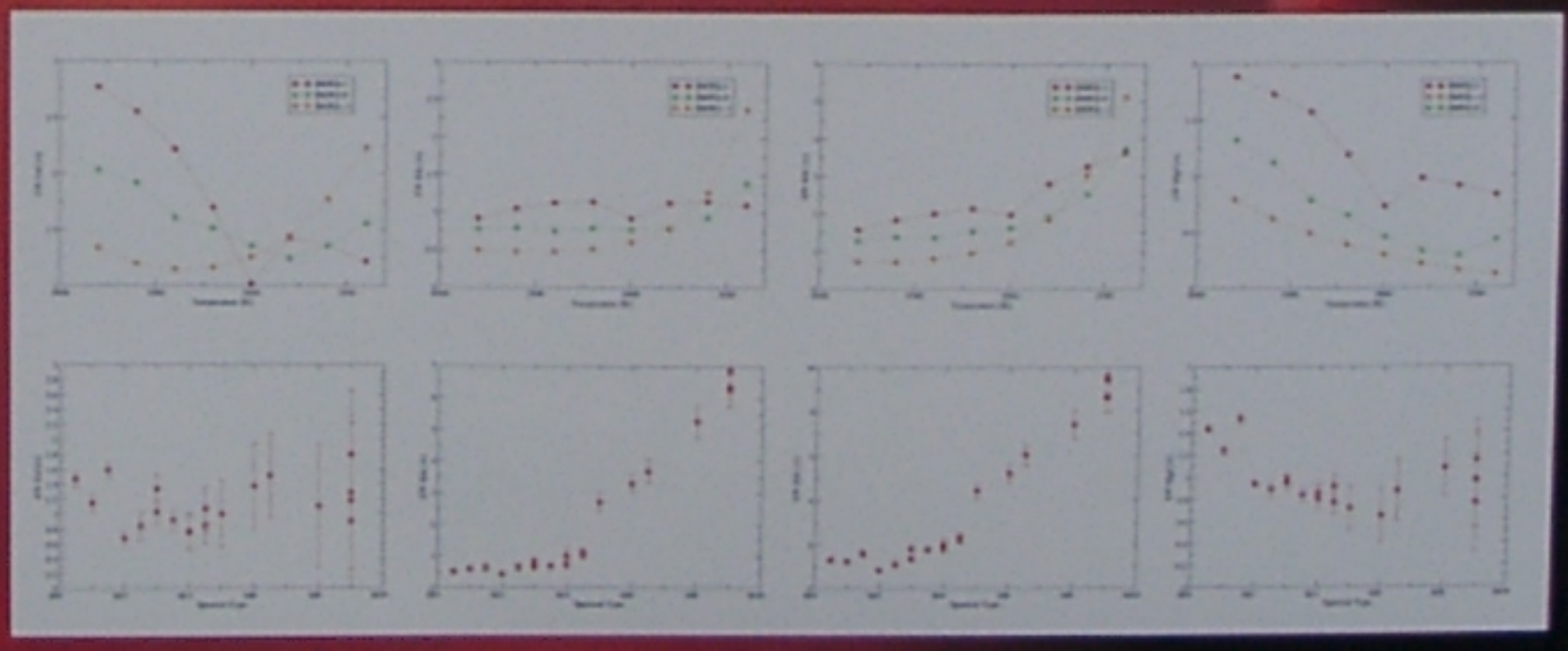


Figure 3 (Top). Equivalent widths (EW) of the Fe I, K I doublet and Mg I lines. The top four plots show the measurements in the synthetic spectra while the other ones show the measurement obtained from M dwarfs of the IRTF Library. The EWs of the two K I lines show a similar behaviour with spectral type (or temperature): they are 'constant' for early types and they rapidly increase for later types. The Fe I line shows almost no correlation with spectral type. The Mg I line weakens with temperature, but from the models is the only line in this study capable to differentiate between M dwarfs of same temperature but different metallicity.

Feature	Wavelength (Angstroms)	Feature Limits (Angstroms)	1st Continuum Level Limits (Angstroms)	2nd Continuum Level Limits (Angstroms)
Fe I	11593 11613 11641	11583.46 - 11653.85	11540.68 - 11583.46	11712.34 - 11743.98
K I	11692 11776	11670.00 - 11710.00 11750.00 - 11800.00	11618.00 - 11638.00 11725.00 - 11745.00	11725.00 - 11745.00 11840.00 - 11860.00
Mg I	11834	11820.32 - 11845.52	11712.34 - 11743.98	11911.85 - 11944.59

Table 1. Defining Bandwidths

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