The Effective temperature scale of M dwarfs from spectral synthesis

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Abstract. We present a comparison of low-resolution spectra of 60 stars covering the whole M-dwarf sequence. Using the most recent PHOENIX BT-Settl stellar model atmospheres (see paper by F. Allard, in this book) we do a first quantitative comparison to our observed spectra in the wavelength range 550-950 nm. We perform a first confrontation between models and observations and we assign an effective temperatures to the observed M-dwarfs. Teff-spectral type relations are then compared with the published ones. This comparison also aims at improving the models’ opacities.

1. Introduction

Low-mass dwarfs are the dominant stellar component of the Galaxy. Our understanding of the Galaxy therefore relies upon the description of this faint component. Indeed M-dwarfs have been employed in several Galactic studies. Moreover, M dwarfs are now known to host exoplanets, including super-Earth exoplanets (Bonfils et al. 2007; Udry et al. 2007). The determination of accurate fundamental parameters for M dwarfs has therefore relevant implications for both stellar and Galactic astronomy.

Over the last decade, stellar models of very low mass stars have made great progresses. One of the most important recent improvements is the availability of new atomic line profile data that give a much improved representation of the details of the line shapes in the optical spectra of cool dwarfs, and become especially important in situations where line blanketing and broadening are crucial for the model. Still models have to use some incomplete or approximate input physics such as uncertain oscillator strengths for some line and molecular bands missing opacities sources (VO, FeH, CaOH, and some TiO bands). Descriptions of these stars therefore need a strong empirical basis, or validation.

In section 2, we present a comparison of low-resolution spectra covering the whole M-dwarf sequence with recent stellar atmosphere models. In section 3, we derive a spectral type - effective temperature relation and compare it with the published ones.
2. **Comparison between atmosphere models and M-dwarf spectra**

M-dwarfs remain elusive and enigmatic objects because of their small size and cool surface temperature. M-dwarf spectra are characterized by the presence of strong molecular absorptions such as TiO, VO, H$_2$O and CaH. The temperatures, abundances, sizes and luminosities are not yet well understood. We compared 60 M-dwarfs (from M0 to M9) with optical spectroscopic classification (Reylé et al. 2006), on a large wavelength range, with the most recent PHOENIX stellar atmosphere models, varying the effective temperature, gravity and metallicity. The models used are the most recent version BT-Settl 2010 (Allard, Homeier & Freytag, in this book), taking into account: i) the solar abundances revised by Asplund et al. (2009), ii) the most recent BT2 version of the water vapor line lists by Barber et al. (2008), iii) a cloud model based on condensation and sedimentation timescales by Rossow (1978), supersaturation computed from pre-tabulated chemical equilibrium, and mixing from 2D radiation hydrodynamic simulations by Freytag et al. (2010). The models are available on-line.

Fig. 1 shows the comparison between model (blue line) and observations (red line) along the M-dwarf sequence, from M9 (top) to M0 (bottom). The slope of the optical to near IR spectra is well reproduced by the BT-Settl 2010 models, while some discrepancies remain in the strength of some absorption bands such as the TiO absorption around 6500Å. The quality of the fit deteriorates as one goes from the early M to the late Ms and early L dwarfs. These results will allow to calibrate the missing oscillator strengths of molecular bands.

3. **Effective temperature scale of M-dwarfs**

We used the grid of models and a $\chi^2$ fitting method to derive the stellar parameters (effective temperature, metallicity, gravity) of our sample. The spectral type are known from optical spectroscopy classification (Reylé et al. 2006), using the spectral indices TiO$_5$, CaH$_2$, and CaH$_3$. Multicolour photometry is an alternative way to determin the effective temperature (see e.g. Johnson 1964) but it requires an assumption on the diameter of the star. Fig. 2 shows the relation between spectral type and effective temperature, compared to others found in the literature.

4. **Conclusion**

We compared 60 spectra in the wavelength range 550-950 nm of M dwarfs with synthetic spectra obtained with the most recent PHOENIX BT-Settl stellar model atmospheres (see Allard et al., in this book). Our sample covers the M-dwarf spectral sequence. We found that the slope of the optical to near IR spectra is well reproduced by the models, while some discrepancies remain in the strength of some absorption bands. The quality of the fit deteriorates as one goes from the early M to the late Ms and early L dwarfs. This comparison will allow to calibrate the missing oscillator strengths of molecular bands. We derived the effective temperature of the 60 M-dwarfs and drew a relation between effective temperature and spectral type, that we compared to others found in the literature.

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1http://phoenix.ens-lyon.fr/simulator
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Figure 1. Comparison between model (blue line) and observations (red line) for M0 (bottom) to M9 (top) dwarfs. The strong telluric line around 7600Å is also indicated.
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Figure 2. Our spectral type versus effective temperature (green triangles) compared to relations from Bessell (1991); Gizis (1997); Martín et al. (1999); Leggett et al. (2000); Dahn et al. (2002).