Searching for solar twins in the open cluster M67

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Introduction

The search for exo-planets has been mostly developed around field stars. Such stars present several advantages, for instance a wide range of stellar characteristics (mass, age, chemical composition, etc), which allows us to study the dependence of planet formation on stellar parameters. Another line of research is the specificity of our Sun and the opportunity to find solar stars hosting exo-planets. This search is best performed in open clusters, which, showing homogeneous age and chemical composition, common birth and early dynamical environment (Randich et al. 2005), provide us an excellent laboratory for investigating the physics of planetary system formation. The old open cluster M67 is to this purpose a perfect target, having many main sequence stars and showing an age encompassing that of the Sun (3-5 Gyrs), a solar metallicity ([Fe/H]=0.03±0.02, Randich et al. 2006) and lithium depleted G stars (Pasquini et al 1997).

Observations

We observed M67 for 2.5 hours during three nights in February 2007 with the multi-object FLAMES/GIRAFFE spectrograph at the UT2/Kueyen ESO-VLT in Paranal (Chile). We chose the HR15N MEDUSA mode, which allows us to cover the spectral range 6470-6790 Å and, consequently, to catch the H Å and the lithium lines. With this configuration, the resolution of 17 000 gives us the possibility to obtain for almost 100 stars good radial velocities and to perform effective temperature and lithium abundance measurements. We have chosen from the Yadav et al. (2007)'s catalogue the bright stars (13^m Å V Å 15^m) with B-V in the solar neighbour (0.63-0.75) which shown the best combination of proper motions measurements ($\mu_\alpha\cos\delta$, μ_δ) and proper-motion membership probability (P_μ) allowing us to catch at a time almost 100 stars to be observed with FLAMES/GIRAFFE. In Fig. 1 a portion of the colour-magnitude diagram (CMD) of M67 is shown (Yadav et al. 2007).

Some Results

Radial velocity. From the radial velocity variations of the 90 stars observed in three nights with FLAMES/GIRAFFE, we find that 62 of them are probable cluster members with an average radial velocity $\langle V_{rad}\rangle$= 33.3 km/s (σ=0.8 km/s). The histogram of the radial velocity distribution of these stars is shown in Fig. 2.

Effective temperature. Thanks to synthetic spectra computed in the temperature range between 5450-6300 K, we have studied in the spectral region covered by our spectra, which lines were sensitive to temperature. At the end, we have selected six couples of them to apply a method based on line-depth ratios (LDRs) to derive the effective temperature of the probable members (Gray & Johanson 1991, Catalano et al. 2002, Biazzo et al. 2007). Thus, we have developed appropriate LDR—$T_{\rm eff}$ calibrations on synthetic spectra and derived the effective temperature of the probable members (Fig. 3).

Lithium. Since the lithium element is likely a 'thermometer' of the complex interaction taking place in the past between the stellar external layers and the hotter interior, we have computed the equivalent width of the lithium line at λ=6707.8 Å. One of the important points characterizing M67 is that many main sequence stars share the same lithium abundance of the Sun, as shown in our (B-V)$_0$—$T_{\rm eff}$ diagram of the 62 probable members (Fig. 3).

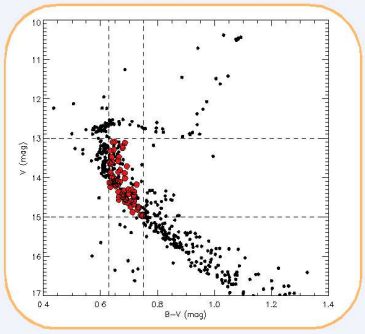

Fig. 1 – CMD of M67. The black points represent the proper motion probable members (Yadav et al. 2007). Inside the area marked with the dashed lines, the stars effectively observed with FLAMES/GIRAFFE are shown with red points.

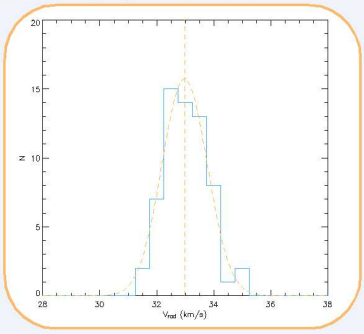

Fig. 2 – Histogram of the radial velocity distribution of the 62 members selected in M67 (continuous blue line) with a gaussian fit superimposed (dashed orange line).

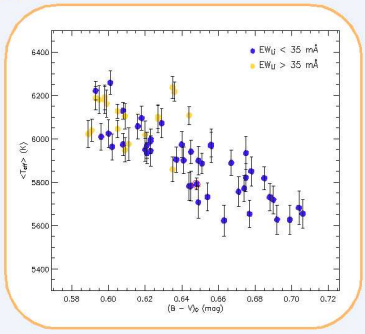

Fig. 3 – Average effective temperature as derived by means of six LDRs as a function of the de-reddened B-V ($E(B$-$V)$=0.041, Taylor 2007). The position of the Sun is also shown.

Work in Progress ...

Hα line. Since the wings of the Hα line profile are very sensitive to temperature, we are also studying the behaviour of this diagnostics. As a matter of fact, the effective temperature of a star can be derived from the strength of its Hα wings measured for example between 3 and 5 Å from the Hα line-center, as compared to synthetic spectra Hα line-wings in the same Δλ interval (Cayrel et al. 1985). Fig. 4 shows a spectrum of the Sun obtained with FLAMES/GIRAFFE and three synthetic spectra at 5657 K, 5777 K (theoretical effective temperature of the solar atmosphere, Wilson & Hudson 1991) and 5867 K. Because of the difficulties in the placement of the continuum for this very broad line, this comparison can be seen as a rough check. Nevertheless, we find that fitting the wings of Hα of the solar spectrum observed with FLAMES/GIRAFFE provides an effective temperature in the range 5657-5777 K.

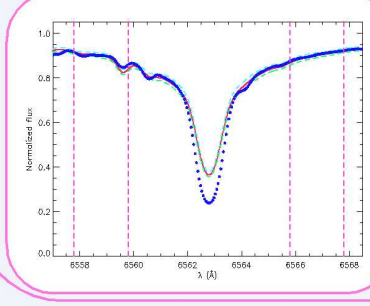

Fig. 4 – Observed Hα profile of the FLAMES/GIRAFFE solar spectrum (blue points) compared to three synthetic spectra with [Fe/H]=0.0, log$g$=4.4377, $T_{\rm eff}$=5657 K (blue dashed line), 5777 K (red line) and 5867 K (green dashed line).

Future Work

- Our first aim is to select from this stellar sample in M67 the best 'solar analogues' obtained both with the LDR and the Hα wings methods.
- Then, we'll use the best solar analogues to derive the solar colours and the M67 distance.
- We would also observe the pre-selected sample of solar analogues with a spectrograph at high resolution (for instance, HARPS@3.6.m in La Silla Observatory or SOPHIE@1.93m in *Observatoire de Haute-Provence*) to have the possibility of resolving radial velocities with an accuracy of 10 m/s per measurement.
- With high-resolution spectra it is also possible to perform a differential spectral analysis to the Sun and to determine the stellar parameters with a very high level of accuracy.

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