Astrophysical Parameters of A-stars in the Young Open Clusters NGC 3293 and NGC 6705

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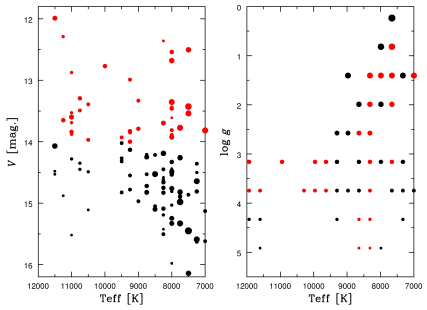
ABSTRACT

We present a comparative analysis of A-type stars ($T_{\rm eff}$ = 7000-12000 K) observed with VLT-Giraffe in young open cluster NGC 3293 (~20 Myr) and intermediate-age open cluster NGC 6705 (~220 Myr). The astrophysical parameters $T_{\rm eff}$, log g, $v_{\rm mic}$, $v\sin i$, and [Fe/H] of 133 stars in NGC 3293, and 121 stars in NGC 6705 are determined with 1-D LTE spectrum synthesis calculations. In NGC 3293 we mainly observe low-luminosity pre-MS A-stars (L_* < 500 $L_\odot$) of intermediate mass (1.5 $M_\odot$ < M_* < 4 $M_\odot$ from pre-MS evolutionary tracks) that are gravitationally contracting onto the ZAMS over K-H timescales below 20 Myr. We find that the variance of [Fe/H] rapidly decreases and approaches the solar value towards the earlier A-type stars. In NGC 6705 we observe a larger number of A-stars that are closer to the ZAMS. We find an average of [Fe/H] ≅ -0.5 ± 0.2 in NGC 6705, independent of the projected rotation velocity $v\sin i$ < 200 km s^{-1}. Towards the earliest A-stars the average [Fe/H] increases, indicating that these stars have already spent some time on the ZAMS.

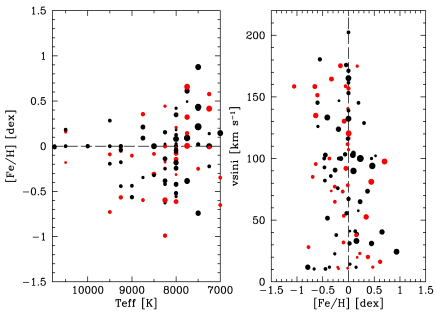
1. INTRODUCTION

We report first science results of an analysis of VLT-Giraffe spectra observed in the young open clusters NGC 3293 and NGC 6705 (M11) for the Gaia ESO Survey. We perform an analysis of stars with 7000 K ≤ $T_{\rm eff}$ ≤ 12000 K, mainly targeting the A-type stars. We determine the astrophysical parameters (APs) $T_{\rm eff}$, surface gravity log g, atmospheric iron abundance [Fe/H], radial microturbulence velocity $v_{\rm mic}$, and projected rotational velocity $v\sin i$ with LTE spectrum synthesis calculations using 1-D atmosphere models. The young open clusters are excellent laboratories for studying the formation physics of intermediate-mass stars (1.5 $M_\odot$ < M_* < 4 $M_\odot$). These low-luminosity stars (L_* < 500 $L_\odot$) provide important new information about metal abundances in galactic young clusters. The APs will allow us investigate the relationship between the fundamental stellar parameters M_* and R_* (for ~130 stars in both clusters), together with their dependences of $v\sin i$ and stellar ages from (pre-MS) evolutionary tracks. The analysis will help to improve current models of angular momentum transport for the formation processes of intermediate-mass stars.

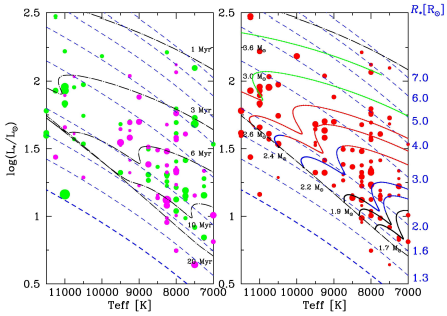
NGC 3293



NGC 3293



NGC 3293



2. NGC 3293

Left-hand top panels: The V-magnitude of 133 stars is plotted against $T_{\rm eff}$. Stars with V < 14$^{\rm m}$.0. are shown in red color. Fainter stars are plotted in black. We observe a large fraction of late A-type stars with $T_{\rm eff}$ ≤ 9500 K. The size of the symbols in the graphs is inversely proportional to log g. The sample contains a large number of A-stars with log g ≤ 3 (dwarfs and subgiants), and a smaller number of giants. Interestingly, we do not observe giants with $T_{\rm eff}$ > 10000 K, while more low-gravity stars are observed towards smaller $T_{\rm eff}$.

Left-hand middle panels: We determine the [Fe/H]-abundance with detailed spectrum synthesis calculations of selected iron lines. The lines are fitted including microturbulence velocities from 0 to 6 km s^{-1}. We find the variance of [Fe/H] to decrease from the late A-type stars towards early A-stars, approaching the solar iron abundance value (*dashed drawn lines*). The [Fe/H]-values are practically independent of $v\sin i$, although the fastest rotating stars (with $v\sin i$>100 km/s) appear more iron-deficient.

3. NGC 6705 (M11)

Right-hand top panels: The A-stars in NGC 6705 are observed with various Giraffe gratings for V < 14$^{\rm m}$.0. As in NGC 3293 we observe a clear increase of log g towards larger $T_{\rm eff}$, although a much larger fraction of stars in NGC 3293 are early A-type stars with $T_{\rm eff}$ > 10000 K. In contrast to NGC 3293 we do not observe A-dwarfs with log g ≥ 4. Also late A-type dwarfs and sub-giants are absent in the NGC 6705 sample.

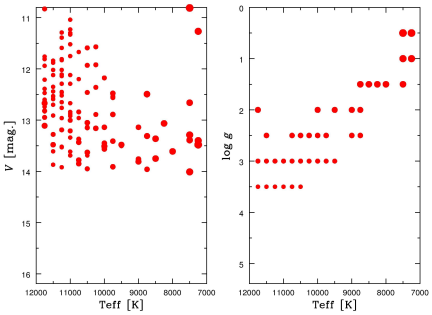
Right-hand middle panels: We determine the [Fe/H]-values of 121 stars by fitting 4 Fe II lines with detailed spectrum synthesis. We also compute sigma-errorbars from the spectral noise levels around the 4 lines. We find a significant decrease of [Fe/H] from the early A-stars (average [Fe/H] = -0.5 ± 0.3) to the late A-stars with [Fe/H] < -0.5 ± 0.4. We observe the small iron abundances for almost all stars with $v\sin i$-values ranging from 10 to 200 km/s.

4. Stellar evolutionary tracks & isochrones

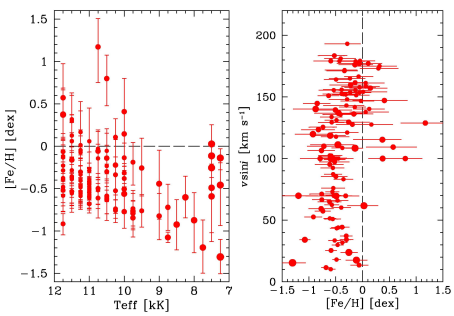
Left-hand bottom panels: The size of the red dots in the rightmost H-R diagram is proportional to $v\sin i$. The bottom dash-dotted line marks the ZAMS, while the solid lines show pre-MS evolutionary tracks for 1.7 $M_\odot$ ≤ M_* ≤ 3.6 $M_\odot$. The size of the dots in the leftmost panel is proportional to [Fe/H] (< 0 in magenta color, > 0 in green). The majority of stars we observe in NGC 3293 are pre-MS stars contracting onto the ZAMS over 1 to 20 Myr (*pre-MS isochrones are shown with dash-dotted lines*).

Right-hand bottom panel: The majority of the A-stars we observe in NGC 6705 are already on (or closer to) the ZAMS. Since the age of this cluster is ~220 Myr, the evolutionary tracks (*solid drawn lines are post-MS isochrones)* indicate a number of early A-stars that have already spent some time on the ZAMS.

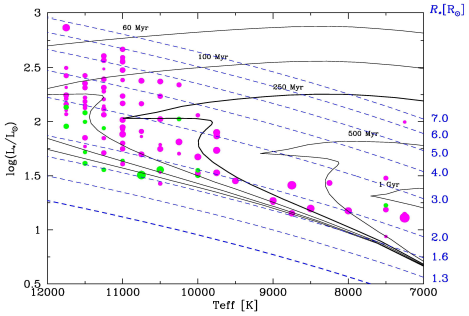
NGC 6705



NGC 6705



NGC 6705



5. SUMMARY

NGC 3293: We observe a large number of pre-MS A-type stars in the galactic young open cluster NGC 3293 (d~2.5 kpc; b=0.047). They are mainly dwarfs and giants with L_* < 500 $L_\odot$ contracting onto the ZAMS. We determine from pre-MS evolutionary tracks they are intermediate-mass stars of 1.5 $M_\odot$ < M_* < 4 $M_\odot$, with -1 < M_v < 4. The low-mass A-stars in the sample are observed for pre-MS isochrone ages below 20 Myr. The stellar radii range from 1 $R_\odot$ to ~7 $R_\odot$. Many A-stars close to the ZAMS show increased $v\sin i$-values, possibly signaling spin-up towards larger $T_{\rm eff}$. The astrophysical parameters and pre-MS tracks will be used to investigate the relationship between stellar mass and radius as a function of rotation rate.

NGC 6705: In comparison to NGC 3293 we observe significantly more early A-type stars in the sample that are closer to the ZAMS in NGC 6705. Our sample however contains stars only brighter than V = 14$^{\rm m}$.0. NGC 6705 is an intermediate-age (~220 Myr), rather compact, galactic open cluster at d~1.9 kpc. We observe a remarkable under-abundance of iron for A-stars with log g ≤ 3.5. We compute an average of [Fe/H] = -0.5 ± 0.3 for the early A-stars of the sample, which further decreases to below -0.5 towards the late A-stars with Teff ≤ 9000 K. We observe the small iron abundance in NCG 6705 independently of the $v\sin i$-values that range from 10 to 200 km s^{-1}. It signals that the intermediate-mass (A-)stars in NGC 6705 have formed in sub-solar metallicity conditions. The sample contains only a small number of early A-stars with [Fe/H] >~ 0 which are practically observed on the ZAMS (*green dots in right-hand bottom panel*). Possibly, these stars have arrived on the ZAMS, and have already spent a considerable fraction of their lifetimes on the ZAMS.