Microturbulence velocity of A-type stars in the Gaia ESO Survey

A. Lobel[1] and the GES Team

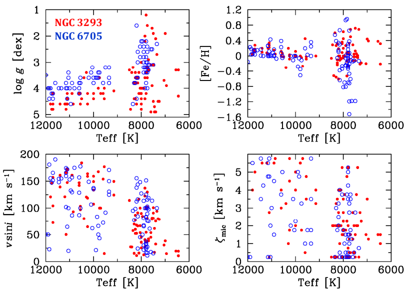
[1] ROB Royal Observatory of Belgium, Brussels

ABSTRACT

We highlight the importance of astrophysical microturbulence in stellar atmosphere models for determining reliable astrophysical parameters (APs) of observed spectra. We determine accurate APs of ~200 A-type stars in the Galactic open clusters NGC 3293 and NGC 6705 observed in the Gaia ESO Public Spectroscopic Survey, revealing maximum microturbulence velocity values of Vmic = 5 – 6 km s^{-1} around the mid-A types (Teff ≅ 7800 K). The input 1-D ATLAS9 ODFNEW models computed with convection (MLT *l/H*=1.25) show only minor effects of turbulence pressure (Pturb = 0.5 × density × $Vturb^2$) for Vmic < 5 km s^{-1} in the absorption lines formation regions. We discuss the clear correlation between the maximum convective energy flux at the top of the convection zone in the models and the maximum Vmic-values observed in the A-stars sample.

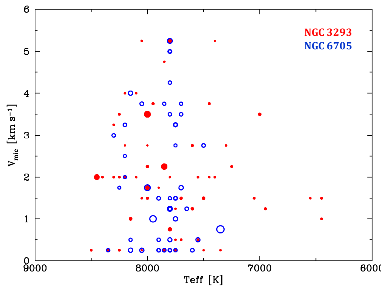
1. INTRODUCTION

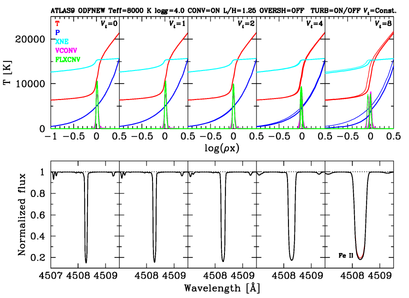
The importance of astrophysical microturbulence (Vmic) cannot be overstated for accurately determining astrophysical parameters (APs) from stellar spectra (see Lobel 2011, JPhCS 328, 012027). The values of Vmic are known for example to exceed the local speed of sound in the extended atmospheres of cool supergiants, which raises profound questions about the physical nature of microturbulence in stellar spectra. Over recent years a number of studies have been published that attempt to calibrate Vmic with Teff for large samples (i.e., 93 stars) of FG dwarfs (with log*g*=4.5, see Bruntt et al. 2012, MNRAS 423, 122). The values of Vmic do typically not exceed 2.5 km s^{-1} for Teff < 7200 K. Takeda et al. 2008 (J. of Korean Astron. Soc. 41, 83) also obtain an analytical relation for Vmic in 46 A-type field stars with Teff=7000 K to 10000 K. They find maximum Vmic-values of 4 km s^{-1} around 8000-8500 K. The Vmic-maximum was also observed by Gebran et al. 2013 in 55 A-stars of the open clusters Pleiades, Coma Berenices, Hyades, the Ursa Major moving group, and in 61 field stars. In this poster we confirm the remarkable Vmic-maximum around the mid A-type stars in the open clusters NGC 3293 and NGC 6705, however for a sample of stars with log*g*-values ranging from 1.0 to 5.0. We discuss the origin of the Vmic-maximum by considering the effects of turbulence pressure and the maximum convective velocity and energy flux of 1-D stellar atmosphere models.



2. Microturbulence velocities in A-type stars

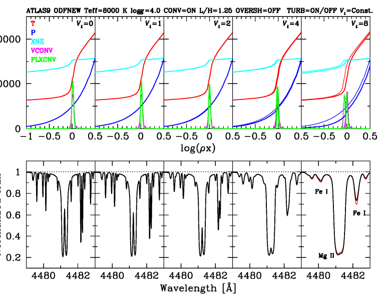
Left-hand panels: We perform an analysis of ~200 stars with 6000 K ≤ Teff ≤ 12000 K observed with VLT-Giraffe for the Gaia ESO Public Spectroscopic Survey in the Galactic young open clusters NGC 3293 (~20 Myr) and NGC 6705 (~220 Myr). We determine the Teff, surface gravity log*g*, atmospheric iron abundance [Fe/H], radial microturbulence velocity Vmic, and projected rotational velocity *vsini* with LTE spectrum synthesis and equivalent line width (EW) calculations using 1-D ATLAS9 ODFNEW atmosphere models. The open clusters are excellent laboratories for studying atmospheric physics of intermediate-mass stars (1.5 $M_\odot$ < M_* < 4 $M_\odot$) with L_* < 500 $L_\odot$. **Right-hand panel:** We iteratively determine the Vmic-values of Fe I and Fe II lines. We find a distinct maximum of the Vmic-values around the mid A-type stars (Teff≅7800 K). The size of the symbols is proportional to the stellar radius.

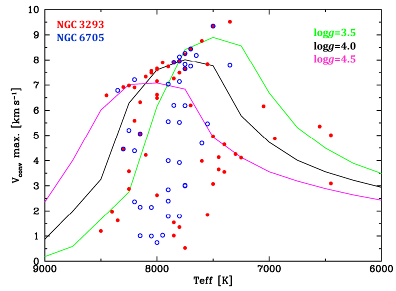




3. Effects of turbulent pressure in the models

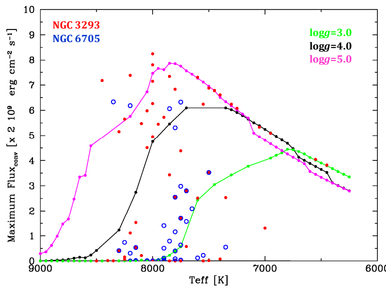
Left-hand panels: We converge five ATLAS9 models with Teff=8000 K, log*g*=4.0, [M/H]=0.0, and [α/H]=0.0 for constant Vturb=0, 1, 2, 4, and 8 km s^{-1} (*left- to right-hand panels*). The mixing length parameter is set to *l/H*=1.25, while overshooting is not included. The gas pressure P (*blue lines*) is computed with turbulence pressure Pturb = 0.5 × ρ × $Vturb^2$ (*boldly drawn lines*), and without Pturb (*thin drawn lines*). The convective velocities are maximum at the top of the convection zone (near log(ρx)~0), where the convective energy flux is largest (*green lines*). The bottom panels show the spectra we compute around the Fe II λ4508 and Mg II λ4481 lines (see right-hand bottom panels). The black lines are computed using atmosphere models including Pturb, while the red lines without Pturb. We measure rather small effects of Pturb on the line profiles, becoming significant only for Vturb ≥ 8 km s^{-1} (*rightmost bottom panels*). For example, the Fe II line is not appreciably stronger including Pturb, except for the atmosphere model with Vturb = 8 km s^{-1}.





4. Convective velocities and energy fluxes

Left-hand panel: We compute the maximum convective velocity Vconv in the ATLAS9 models for all stars of our sample. We find maximum Vconv ≲ 10 km s^{-1} for Teff≅7500 K. Towards larger and smaller Teff-values the maximum Vconv-values decrease at the top of the convection zone in the models. From 7500 K to 8500 K we find a steady decrease of the maximum Vconv to ~6.5 km s^{-1}. Towards lower Teff=6500 K the maximum Vconv-values also decrease to ~3 - 5 km s^{-1}. The maximum Vconv-values in the models are correlated with the distribution of Vmic-values we measure in the spectra using these models of the stellar atmosphere. The solid drawn lines show the maximum Vconv in the models we converge for log*g*=3.5, 4.0, and 4.5. Towards larger log*g*-values the maximum Vconv-values at the top of the convection zone decrease. The maxima decrease and occur for larger Teff-values of models with increasing log*g*.



5. CONCLUSIONS

Turbulence pressure in stellar atmosphere models does not cause the maximum in microturbulence velocities we observe for A-type stars of Teff≅7800 K. We find rather small effects of extra turbulent pressure Pturb on the 1-D T and P model structures. The EWs of Mg II and Fe II lines we compute by including the Pturb in the models do not significantly change, except for Vturb ≥ 8 km s^{-1}. The limited increase of the EW-values we compute for Vturb < 8 km s^{-1} does not cause the maximum microturbulence velocities of ≲ 5 - 6 km s^{-1} for Teff≅7800 K. We find however a strong correlation between Teff and the maximum convective velocity at the top of the convection zone in the models, showing largest Vconv-values for Teff≅7500 K. We compute the maximum convective energy flux in the models (*see bottom right-hand panel*), also revealing largest values for Teff~8000 K, very similar to the observed distribution of largest Vmic-values in our sample of A-stars. For given Teff (between 6000 K and 9000 K) the Vmic-values we observe in the spectra do not exceed the maximum convective velocity at the top of the convection zone in the ATLAS9 atmosphere models. The maximum Vconv and convective energy flux values decrease above Teff≅7500 K, comparable to the observed Vmic-values.