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SOME ASPECTS OF STELLAR MODELLING IN THE GAIA TEAM AT THE OBSERVATOIRE DE LA CÔTE D'AZUR

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Abstract. The objective of the Gaia mission (2012) is to provide the largest and most accurate astrometric survey of our Galaxy. From Gaia measurements, information will be derived about the history of our Galaxy, its early formation and its chemical composition. It is therefore of crucial importance to develop and test the methods and tools that will be used in the processing and analysis of the data. The derivation of the chemical abundances will impact on the formulation of the galactic evolutionary models. We present our investigations on –1– NLTE effects on atomic line profiles, the use of 1D or 3D modelling of the atmospheres and –2– radiative diffusion and rotation on stellar evolution models.

1 3D NLTE line formation

We are currently building new accurate and up-to-date atomic models that will be used with different model atmospheres to produce reliable line data to perform the chemical abundance determinations. Tests are performed in the framework of the SAM group which involves different institutes, namely Uppsala, Nice, Meudon, Oslo (Stellar Atmosphere Modelling : `http://www.astro.uu.se/∼ulrike/GaiaSAM`).

The atomic models in progress are Ca I, Ca II, Mg I and II. They are important for the chemical evolution of the Galaxy because they are good α–elements tracers. Several studies modelizing Ca lines exist (one of the most recent is Mashonkina et al. 2007), demonstrating the importance of NLTE effects on Ca II IR triplet lines. These lines are essential for the Gaia RVS (Radial Velocity Spectrometer). In this respect, we are performing a very realistic and complete atomic model of Ca I & II. We will use these atomic models together with 3D models of stellar atmospheres to perform full 3D NLTE line synthesis with the code MULTI (Carlsson 1986).

We show on Fig. 1 a comparison between LTE (code MOOG) and NLTE (code MULTI) 1D line synthesis with a MARCS atmospheric model (Gustafsson et al. 2008) of Sun for the 8498 Å line of the CaII IR triplet. The synthetic profiles are compared with the integrated solar flux called FTS (Brault & Neckel 1987). The NLTE treatment fits better the line core of the observed flux than the LTE treatment. The line core cannot be fitted perfectly because of the absence of chromosphere in the MARCS atmospheric model. Indeed, the line core of Ca II triplet is formed in the upper layers of the atmosphere. Moreover, we can note the asymmetry in FTS data due to the convection that can be impossible to reproduce with 1D static atmospheric model.

We are also currently working on 3D models of the Sun and stars to get better fits (asymmetry, line shifts). The 3D approach gives a more realistic interpretation and prediction of the velocity fields in the atmosphere, something that 1D hydrostatic models are incapable of. Indeed, because of their hydrodynamical approach, the 3D models do not need any free parameters such as the macro-, micro- turbulence and mixing-length. The use of these time-dependent, 3D, hydrodynamical atmospheric models to compute stellar abundances has already proven to give significative differences compared with 1D modelling in particular for metal-poor stars and has already led to a significant revision of the solar abundances (Asplund et al. 2005), even if it is still debated (see, for instance, the last review of Aspund et al. 2009).

2 Improvements of stellar evolution models

We are testing the contribution of the rotation on the theoretical evolutionary tracks in the HR diagram for 1D models of stars. As a first application, we follow the work of Lebreton et al. (2001), using the Hyades

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cluster because there are 5 binary stars with estimated masses and the metallicity is well known. Moreover, the projected rotational velocities for the binary systems and for several single stars have been measured by several authors (Glebocki et al. 2000 and Nordstroem et al. 2004). For the binary systems we have an estimate of the rotational velocity V_{rot} and for the other stars we proceed with a statistical inversion approach (Chandrasekhar et al. 1950). The V_{rot} estimate will be used in the code Cesam2k (see `http://www.oca.eu/cesam`) with implemented theory of rotation described in Mathis & Zahn (2004) and the chemical element diffusion. In this manner, we investigate the contribution of these processes for the stellar evolution and their effect on chemical abundances concerning the determination of masses and ages. Now, we can build new theoretical isochrones of the Hyades cluster and determine its age. Several other clusters will be investigated with the same procedure to test the influences of the rotation on stellar age determination with the future Gaia data.

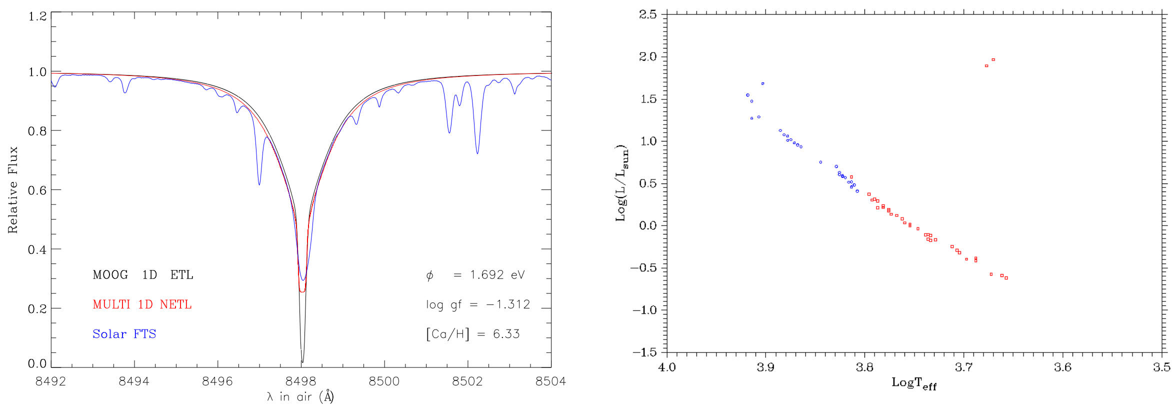

Fig.1. Left: comparison LTE / NLTE of a flux profile of the Ca II line at 8498 Å. Right: HR diagram of Hyades cluster. Red dots represent stars with $V_{rot} \leq 20$ km s^{-1} and blue dots stars with $V_{rot} \geq 20$ km s^{-1}.

3 Conclusion

The use of realistic stellar atmospheres (3D hydrodynamic LTE atmosphere + NLTE radiative transfer with accurate atoms) and stellar evolutions (evolution with radiative diffusion with/without rotation) would provide astrophysical analysis tools for a better determination of stellar parameters which will be of crucial importance for the interpretation of results of the Gaia mission. In particular, it will lead to:
- More realistic stellar abundances which will provide better Galactic abundances;
- Better constraints on ages and masses for the open clusters like the Hyades;
- Calculation of convective lineshifts for Zero-Point Radial velocities with applications to Gaia;
- New limb darkening calculations for stellar interferometry diagnostics providing more accurate stellar diameters using VLTI (Bigot et al. 2006) or the CHARA instruments;

which are the recent works in progress in our group.

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