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STELLAR ROTATION IN OPEN CLUSTERS

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Abstract.
The goal of this work is the analysis of rotation impact on the age determination of open clusters. In this preliminary study we discuss on a statistical method to know the key parameter V_{rot}. Then we use V_{rot} estimate in stellar evolution computations (Cesam2k code) with implemented Maeder-Zahn's theory of stellar rotation.

Keywords: rotating star, statistical distribution

1 Introduction

Open clusters (OCs), young and metal rich, have an advantage on Globular clusters: they host a wide variety of stellar masses. If one want to test the influence of rotation of stars on the structure of the HR diagram and on the change of properties of stars induced by rotation, one will adopt to work on OCs. The limit of these OCs as laboratories is in the distribution of chemical abundances, most of them being close to solar abundances within a factor 3. If we prefer to test stellar physics influenced by the opacity one would use the oldest ones: the Globular clusters. In the present work we are concerned by the distribution of rotational velocities varying with the mass of the stars within a cluster and to perform test of macroscopic properties of the rotating stars induced by this parameter.

To understand how the impact of stellar rotation affect the star evolution we need to handle two difficulties: on one hand an adequate formulation of the rotation implemented in 1D stellar codes and on the other hand how we can test the theory with observations. The stellar rotation has an impact on the star evolution and on the position of the star in the HR diagram. Vega (α Lyr) had its rotational velocity ignored during all the 20th century because its spectrum did not exhibit evidence of rotation distortion of the shape of the lines. Recently interferometric measurements revealed its oblateness and its V_{rot} estimate was possible thanks to very high resolved spectrograph (Peterson et al. 2006).

In 1998, Maeder & Zahn (Maeder and Zahn 1998) have proposed a formulation of the theory of the stellar rotation adapted to 1D models. This theory has permitted some progresses in the comprehension of the HR diagrams with stellar mass above $1M_{\odot}$. For test on OCs we have to estimate the real distribution of Vrot with mass.

Why to test the Cesam2k code with the implemented theory of stellar rotation? It takes place in the ESA mission Gaia context and in particular this work is related to the group FLAME (Final Luminosity Age Mass Estimation) of CU8 (Coordination unit 8 for the astrophysical parameters) of DPAC (Data Process Analysis Consortium). Here we propose to estimate the difference on age determinated of OCs and then of stars when one use or not the rotation in the 1D codes.

2 How estimate V_{rot}

As metioned above, we need to estimate the rotational velocity to test the theory implemented in the code and then to predict the discrepancies with previous work ignoring this parameter. V_{rot} does't come from observations in a direct way. In fact the spectrum of a star gives only the projected component of rotation on the line of

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Parameters	Pleiades	Hyades
q	1.38	1.51
σ	8.75	4.27

Table 1. The results of our statistic analysis for Hyades and Pleiades clusters. Row 1 and row 2 represented the results of χ^2 test for the distribution parameters: the shape parameter q and the standard deviation σ.

sight: ($V_{rot}\sin i$) for which "i" is generally unknown. The position on HR diagram of rotating star is affected by this inclination factor of $\sin i$ (Kraft and Wrubel 1965) (Maeder 1998). In cluster stars in which we are interested, we consider the random distribution of the inclination angle i (Struve 1945) and we follow the work of Chandrasekhar and Munch (1950) to estimate V_{rot}. Following this work, we have an integral relation between the distributions of $V_{rot}\sin i$ and V_{rot} that allow us to estimate V_{rot} for each cluster star. The problem turn out in finding the mathematical expression of the distribution that describes both the observed distribution (Fig. 1) built with the data from catalogues (as for example Mermilliod et al. (2009) and WEBDA database, `http://www.univie.ac.at/webda/`).

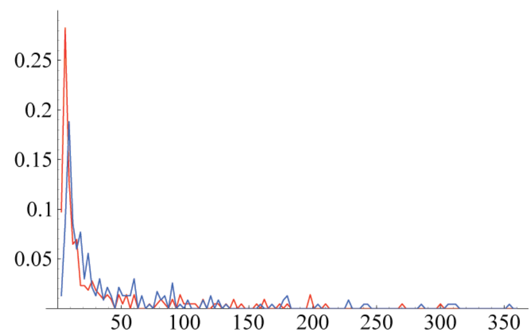

Fig. 1. V_{rot} distribution for Hyades (red) and Pleiades (blue) clusters. In x-axis there is $V_{rot}\sin i$ in km/s and in the y-axis there is the frequency normalized to 1. The important features of the distributions are a peak in the low-rotators zone and very flat in the fast-rotators zone

The Hyades cluster among several open clusters was choosen for the following reasons: its distance, its metallicity and its helium content are known with good accuracies, and there is an accurate set of measures of $V_{rot}\sin i$ also for several binary systems with well known orbital parameters, masses (Patience et al. 1988; Cayrel de Stroebel et al. 1997; Perryman et al. 1998; Lebreton et al. 2001). The $V_{rot}\sin i$ distribution shows two important features (fig. 1): it has a peak in the low rotators zone and it is very flat in the fast rotators zone. Such distribution were studied in the past and several attempts were done to fit the observed one. Chandrasekhar and Munch (1950) used a gaussian function in their pionnering work, later Deutsch (1970) proposed to use a maxwellian function to try to fit the the $V_{rot}\sin i$ distribution, but they failed to fit the whole velocities range. Similar work was done by Gaigé (1993) with a non-uniform function. For the Pleiades cluster Soares et al (2006) found a good distribution with a uniform function (Tsallis distribution) to fit the $V_{rot}\sin i$ data set. Here we follow the work of Soares et al (2006) and we use the Tsallis distribution on the Hyades and Pleiades clusters. This distribution has some parameters that we calculated through a χ^2 for the Hyades and the Pleiades clusters. We confront our results for Pleiades and we found the same values as Soares et al (2006) with a different test of convergence and a different data set. But we found different results between Hyades and Pleiades clusters, as shown in table 1, and we are investigating to understand where the difference is coming from (Santoro et al. in preparation).

Thanks to these parameters we built the uniform function that describe the $V_{rot}\sin i$ distribution and we use the relation given by Chandrasekhar and Munch (1950), in order to get the distribution of V_{rot} for all cluster stars. Besides of this, we use binary stars of the Hyades cluster to test the statistical procedure described before, we have all the orbital information for those particular system. Adding an hypothesis that the star rotational axis orientation is perpendicular to the orbital plane of the binary system(Peterson & Solensky 1988; Torres et al. I 1997; Torres et al. II 1997). we deduce two different V_{rot} estimates for the binary stars and the results are presented in the table 1 of Santoro (2010). Applying this method on the OC we estimate the ages of the OCs and we compare them with those obtain when ignoring the rotation of star in the stellar evolution codes. Non neligeable discreapencies exist and lead us to conclude that for the inversion of the HR diagram in the context of Gaia ignoring rotation lead for single stars to wrong mass (without rotation the mass are underestimated) and age estimate reach 15 percent older.

3 Conclusions

Adding this information in Cesam2k code with implemented theory of rotation of Maeder and Zahn (1998) we can evaluate the impact of rotation on cluster age determination. Now we need to introduce the von Zeippel's effect which change the uniformity of the temperature and the gravity at the surface of fast rotators. In a near future we shall work on multiple stars binary or with more components to validate all these concept and derive tables of corrections for star cluster ages whan ignoring this parameter.

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