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Hints from chromospheric activity to constrain stellar modelling

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Abstract. We discuss on the possibility to use measurements of chromospheric activity and rotation period as indicator of the age and location of the base of the convective envelope in low-mass main sequence stars. This is expected to have strong impact on studies of pulsations and modelling of solar-type stars.

1. Introduction

It is generally accepted that the rotational velocities of low main–sequence single stars decline with increasing age (Kraft 1967), due to angular momentum loss through magnetized winds (Schatzman 1962) and/or sporadic mass ejection from stars with deep surface convection zone.

Analysis of data of mass, rotation period, and age in a large sample of cluster and field stars allowed Cardini & Cassatella (2007) to determine that the rotation period P_{rot} of a star can be expressed as:

$$P(t, M) = (25.6 \pm 2.5) \times t^{0.45\pm0.06}(1.4 - M/M_{\odot})$$

where t and $M/M_{\odot}$ are respectively the age (in Gyr) and the mass of the star (in solar masses). The expression applies to stars with mass from 0.25 $M_{\odot}$ to 1.3 $M_{\odot}$.

2. Evolution with age of the chromospheric activity

It has been known for a long time that age, rotation, and the level of magnetic activity are related each other in main–sequence stars (Smith 1979).

Analysis of the level of chromospheric activity, as measured by the Mg II line surface flux, for a sample of stars with different masses and ages allowed Cardini (2007) to conclude that the chromospheric emission of late main–sequence stars is linearly correlated, in log variables, to the rotation period and hence to age. However this correlation is valid up to some "critical ages", different for each stellar mass, after which the correlation rotation–activity ends and the activity suddenly drops.

From the comparison of the chromospheric activity evolution with the evolution of various structural parameters in stars with different masses, we have found that the convective envelope depth should be the parameter whose rapid change can determine the drop of the level of activity. Figure 1 (*bottom panels*) shows the time evolution of chromospheric activity for stars with mass $0.45 < M/M_{\odot} < 0.75$ (left) and $1.14 < M/M_{\odot} < 1.3$ (right) and (*top panels*) the time evolution of the depth of convective envelope, relative to the total star radius, for two evolutive models of 0.6 $M_{\odot}$ (left) and 1.2 $M_{\odot}$ (right) calculated with the

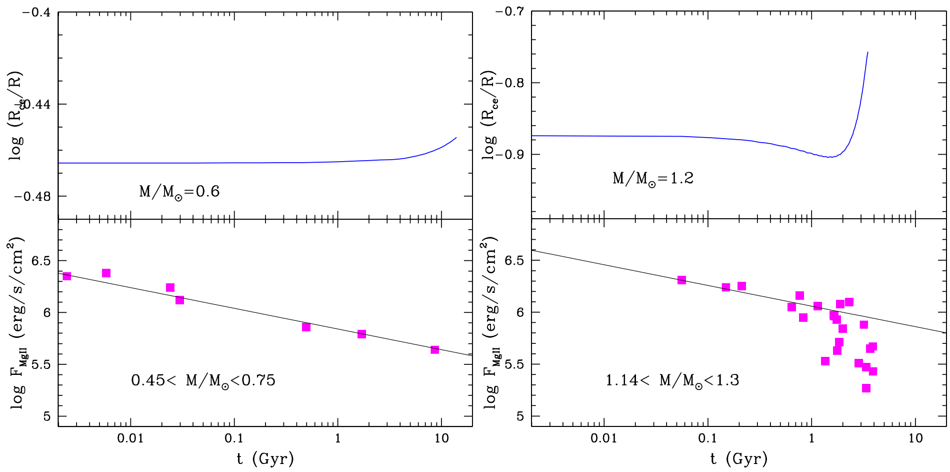

Fig. 1. Top: The width of the convective envelope, relative to the total star radius, versus age for two evolutive models. Bottom: Evolution with age of $F_{\rm Mg\,II}$ for stars in two mass bins. The solid lines show the functional dependence, derived by a fitting procedure, of $F_{\rm Mg\,II}$ on age in the early evolutive stages.

code by Christensen-Dalsgaard (2007). As can be seen, for what concerns lower mass stars, which have a slow evolutionary time, the chromospheric activity is proportional, in log variables, to the stellar age along all their life time up to now. Actually their convective zone depth does not undergo any significant change along this time. Vice versa, in higher mass stars, which evolve very rapidly, the decline in activity is correlated to the age, and hence to the loose of rotation velocity, only for a little span of time after which a qualitative change in chromospheric behavior appears in correspondence with the onset of the deepening of the convective envelope. The authors are actually working to explicit the relationship between the level of chromospheric activity and the depth of convective envelope.

3. Implications for studies of solar–type stars

It is well known that the potential of asteroseismology strongly depends on the availability of accurately identified pulsation frequencies and global parameters in order to constrain stellar structure properties. Here we have shown a preliminary study on the possibility of using measurements of chromospheric activity and rotation period, as obtained from photometric and spectroscopic observations, to determine the age and the location of the base of the convective envelope in a number of main–sequence stars with mass $M < 1.4 M_{\odot}$. We believe that the scenario outlined in this paper has large consequences on studies of main–sequence solar–type stars and on the progress of our understanding of stellar structure and evolution. The idea is to combine asteroseismic data and measurements of magnetic activity and rotation period in order to better constrain stellar properties such as age and extension of the convective region. In the next future we plan to apply this method to a number of well known targets of asteroseismic studies (e.g. β Hyi, α Cen A, α Cen B, ϵ Eri) for which measurements of period and chromospheric activity are available in literature.

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