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Colour, rotation, and age correlations in late–type main sequence stars

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Abstract. We propose an interpretation of the complex correlations that exist between mass, rotational period, and age in single main sequence stars of spectral type F or later. Our analysis of the rotation period data of a sample of field stars and members of open clusters shows that the rotational period decreases linearly with increasing mass in stars of the same age and evolves as a power of age as $t^{0.45}$, so providing a simple analytical representation of the rotation period as a function of age and stellar mass.

1. Introduction

It is generally accepted that the rotational velocity of low main sequence stars declines with advancing age (Kraft, 1967), due to angular momentum loss through magnetized winds (Schatzman, 1962). Moreover Skumanich (1972), basing on equatorial velocities for the G stars in the Pleiades and Hyades and for the Sun, has reported that the rotational decay curve varies as the inverse square root of the age. However, the problem of the dependence of rotation on age is not completely solved since slow rotators ($P > 20$), which are present among G and K stars, are totally absent among stars of spectral type F - G0.

2. Analysis and discussion

We have studied the relationships between mass, period, and age in 94 luminosity class V single field stars and stars in three representative open clusters: the Hyades, the Pleiades, IC 2602. The study is based on rotation period data from the literature and on magnitudes, colours, and parallaxes taken from the Hipparcos catalogue. Stellar masses were estimated by interpolating the mass–colour relationship reported by Allen (1983) for stars of luminosity class V.

We found that the rotational period is linearly correlated with stellar mass and can be expressed as:

$$P_{rot} = f(t) \times (1.4 - M/M_{\odot}) \quad (1)$$

The slope coefficient f(t) at different ages can be evaluated:

- From the slope of the linear relation period–mass for the Hyades ~ 600 Myr old (f(t) = 19.2) (dashed line in Fig. 1).
- From the younger clusters the Pleiades ~ 100 Myr old and IC 2602 ~ 30 Myr old, for which one can define a linear upper limit to the rotational period expected at a given mass (f(t) = 12.0) (dash-dotted line in Fig. 1).

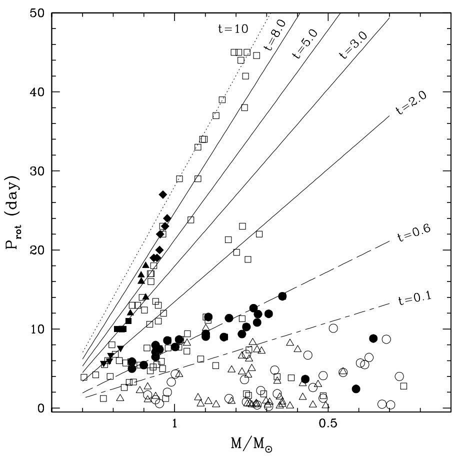

Fig. 1. Mass–period diagram for: IC 2602 (○); Pleiades (△); Hyades (●); field stars ∼ 2 Gyr old (▼); ∼ 3 Gyr (■); ∼ 5 Gyr (▲); ∼ 8 Gyr (♦); field stars with no indication of age (□). The overplotted lines represent the functional dependence of P_{rot} on $M/M_{\odot}$ for different ages as explained in the text.

– From the clear upper limit to the rotational period for each mass which is linear for $M < 1M_{\odot}$ (f(t) = 70.11). The subset of stars which lie along this upper bound corresponds to the oldest Galactic disk population (∼ 10 Gyr) (Caloi et al. , 1999) (dotted line in Fig. 1).
– From stars which are "just evolving" from the MS (see Fig. 1 and 2) whose ages are known from the isochrones (f(t) = 33.6, 44.9, 53.2, 61.8 for ages of 2, 3, 5, 8 Gyr respectively) (continuous lines in Fig. 1).

A fit to the values of f(t) (shown in Fig. 3) provides the following analytical form:

$$f(t) = (25.6 \pm 2.5) \times t^{0.45\pm0.06} \quad (2)$$

This result is compatible with that obtained by Skumanich (1972) for 1 solar mass stars, but is valid for a wide range of masses (0.25 to 1.29 $M_{\odot}$). The specific dependence of P_{rot} on mass and time allows one to derive stellar ages if rotational periods and masses (or B–V) are known. The scenario outlined in this paper has large consequences for the interpretation of stellar magnetism and chromospheric or coronal activity.

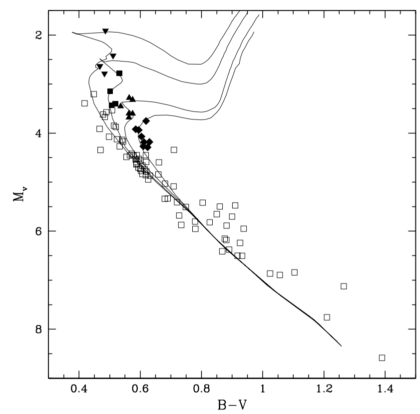

Fig. 2. H–R diagram for our sample of field stars. Isochrones correspond to ages (from the top) of 2, 3, 5 and 8 Gyr (composition Y = 0.27, Z = 0.017) (Ventura et al., 1998). Symbols are the same as in Fig. 1.

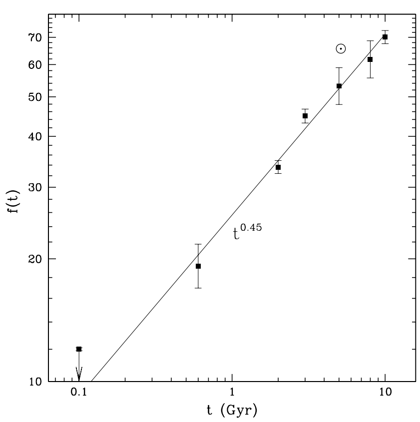

Fig. 3. Values of f(t) vs. age. The solid line shows the best fit to the data.

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