The braking of slow rotators in ZAMS clusters

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ABSTRACT. We present new accurate velocity measurements of slow and moderate rotators in the ALPHA PERSEI cluster. Equatorial velocity distributions are presented as a function of mass, and are compared to the velocity distributions in the PLEIADES for the same mass bins. The observed braking between the 2 clusters is compared to an angular momentum evolutionary model.

1. Velocity distributions in the Alpha Per cluster

The original sample comes from the census from Prosser(1992). In the $(B-V)_0 = 0.4$–1.4 range, 132 AP and HE stars are probable or confirmed members. Using the CORAVEL and ELODIE spectrographs, we obtained 63 new measurements and 129 members now have resolved $v\sin i$ (Fig 1).

Equatorial velocity distributions are computed from $v\sin i$ distributions using Chandrasekhar and Münch relations (1950) and assuming that rotational axes are randomly distributed in space (Fig 2). In Tab 1 we present the characteristics of the distributions. N represents the number of stars in each color and mass bin. Columns 4, 5 and 6 give the fraction of stars with velocities lower than 20, 10 and 5 km.s^{-1}, respectively. Columns 7, 8 and 9 give the velocity corresponding to 10, 20 and 50% of the sample stars. There are no significant differences in the distributions between the different mass ranges 0.6–0.9 and 0.9–1.1 $M_\odot$. A very small fraction of G-K stars (4-5%) have a velocity less than 5 km.s^{-1} , 25% have a velocity less than 10 km.s^{-1} , and half of the stars rotate more slowly than 20 km.s^{-1} .

Tab 1 - Characteristics of the distributions.

$(B\text{-}V)_0$	Mass $M_\odot$	N	$v<20$ %	$v<10$ %	$v<5$ %	$F(v)<10\%$ v (km/s)	$F(v)<20\%$ v (km/s)	$F(v)<50\%$ v(km/s)
0.4 − 0.58	> 1.1	40	30±7	9.0±4.8	1.4±1.8	10.6±2.2	15±3	41±11
0.58 − 0.72	0.9 − 1.1	28	56±9	29±9	7.0±5.0	5.9±1.4	8.1±1.6	20±11
0.72 − 1.38	0.6 − 0.9	61	59±6	26 ±5	4.3±1.8	6.9±0.8	9.0±0.8	16±3

2. Braking rate between Alpha Per and the Pleiades

We now compare the v distributions of Alpha Per to those of the Pleiades to determine the braking rate on the ZAMS (Fig 3)(distributions for the Pleiades cluster are presentend by Queloz et al., 1997). 1 $M_\odot$ slow rotators, with velocities less than

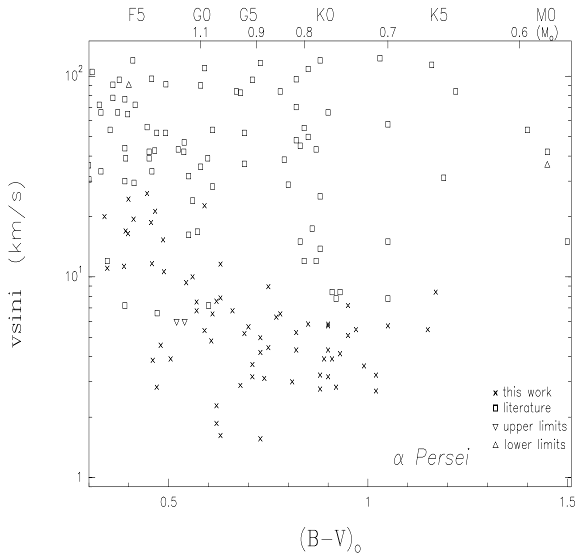

Fig. 1. $V\sin i$ measurements as a function of $(B\text{-}V)_0$ color. Measurements from literature come from Prosser (1992, 1994) and Stauffer (1993).

10 km.s^{-1} experience little braking. In contrast slowly rotating 0.6-0.9 $M_\odot$ stars are significantly braked between the age of α Per (50 ± 10 Myr) and the age of the Pleiades (100 ± 20 Myr).

3. Comparison to the models

The model of angular momentum evolution used is fully described in Allain (1997) and important hypotheses are just recalled here. The rotational period is assumed constant as long as disk-locking is active. The minimum disk lifetime corresponds to a disk that disappears on the birth-line, and the maximum disk lifetime is 30 Myr. The core and the envelope both rotate as solid-bodies, and angular momentum exchanges occur between both parts. The description of J exchanges comes from McGregor and Brenner (1991) prescription and we define τ_c as the characteristic coupling time. Finally, stars are submitted to a saturated magnetic wind braking, and we use the parametric description from Kawaler (1988).

On Fig 4, theoretical evolutionary tracks are presented with two different coupling times, 10^6 and 10^8 yrs. The first one models a quasi-solid body as the coupling time is far shorter than the evolutionary, or contracting, time-scale of the stars in the mass range considered here. ZAMS rapid rotators and their early MS braking are consistent with a solid-body model, while the existence of many slow rotators, and their MS evolution is more consistent with a long coupling-time model.

Comparison between models and observations thus suggests a coupling between the core and the envelope which depends upon the star's velocity.

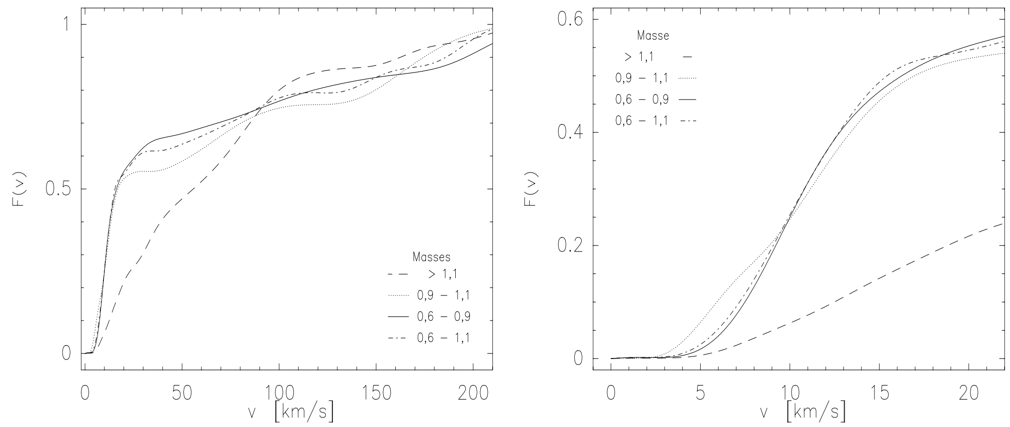

Fig. 2. V distributions in the Alpha Per cluster for different mass ranges.

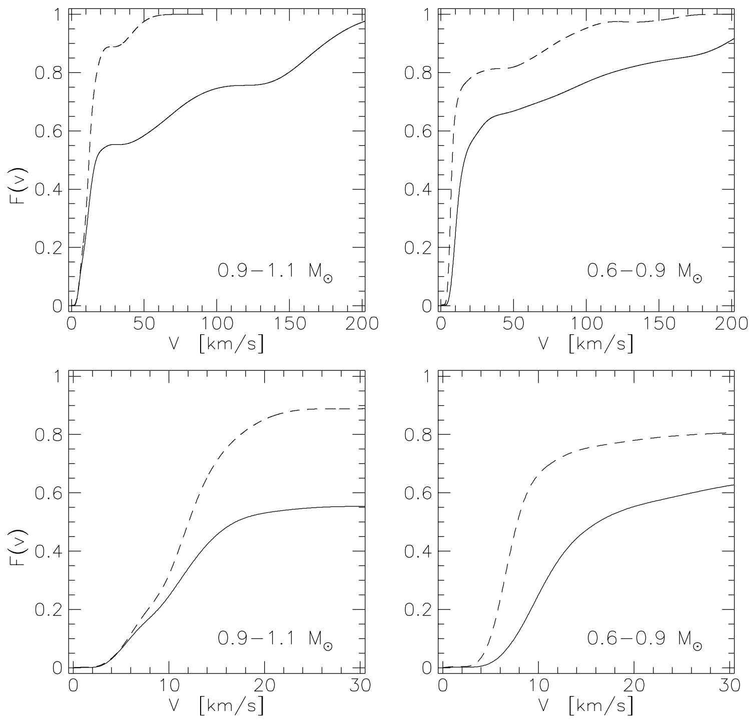

Fig. 3. Comparison of the equatorial velocity distributions in Alpha Per (solid line) and the Pleiades (dashed line) clusters for the 0.9-1.1 $M_{\odot}$ and 0.6-0.9$M_{\odot}$ mass ranges.

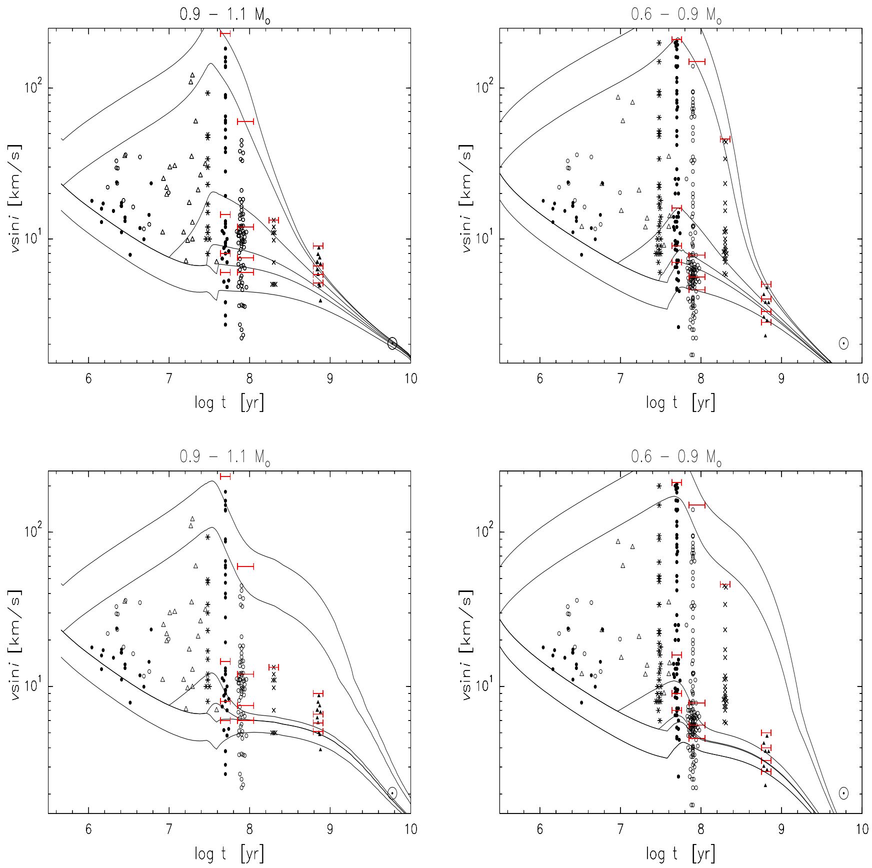

Fig. 4. Theoretical evolutionary tracks for angular velocity for 1 and 0.8 M$_\odot$ stars, and two types of models. Upper panels show a model with a short coupling-time model ($\tau_c = 10^6$ yr) and lower panels show a model with $\tau_c = 10^8$ yrs (see text). Dashed horizontal lines are placed so that velocities correspond to the different percentages 10, 20, 50 and 100% (from bottom to top respectively), as computed in Tab. 1.

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