Activity-rotation relation in the young cluster h Per

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Abstract. The activity-rotation relation in PMS stars is still an open issue. To bridge the gap between the well constrained case of MS stars and the puzzling case of very young PMS stars, we studied the activity-rotationrelation in the young cluster h Persei. Because of its age ($\sim 13\,$Myr) h Per contains both fast and slow rotators, allowing us therefore to test the different regimes of stellar dynamo.

We analyzed a deep Chandra/ACIS-I observation to constrain the activity level of h Per members. Rotational periods were derived by Moraux et al. (2013). From the comparison of the 1002 detected X-ray sources, and the 586 h Per members with measured rotational period, we obtained a final catalog of 169 h Per members with measured X-ray luminosity (ranging between 3.5×10^{29} and $1.1 \times 10^{31}\,\mathrm{erg\,s^{-1}}$), rotational period (ranging between 0.22 and 15.9 d), and mass (ranging between 0.2 and $1.8\,\mathrm{M_\odot}$).

We find clear evidence for supersaturation in stars with mass between 1.0 and $1.6\,M_\odot$. This phenomenon is unobserved for lower mass stars.

1. Introduction

Late type stars are known to produce intense magnetic fields. These magnetic fields are thought to be generated by dynamoprocesses, due to motions of plasma in the stellar interior.

Pizzolato et al. (2003) and Wright et al. (2011), by studying large samples of late-type main-sequence (MS) stars, definitely showed that the stellar dynamo, mainly depending on stellar rotational period, is characterized by different regimes. Slowly rotating stars show an X-ray luminosity L_X (a good proxy of magnetic activity) anticorrelated with the rotational period P_{rot}, defining the so called non-saturated regime. For shorter rotational periods, in the saturated regime, MS stars show a constant X-ray emission level, with on average $L_X/L_{\mathrm{bol}} \approx 10^{-3}$. Randich et al. (1996)

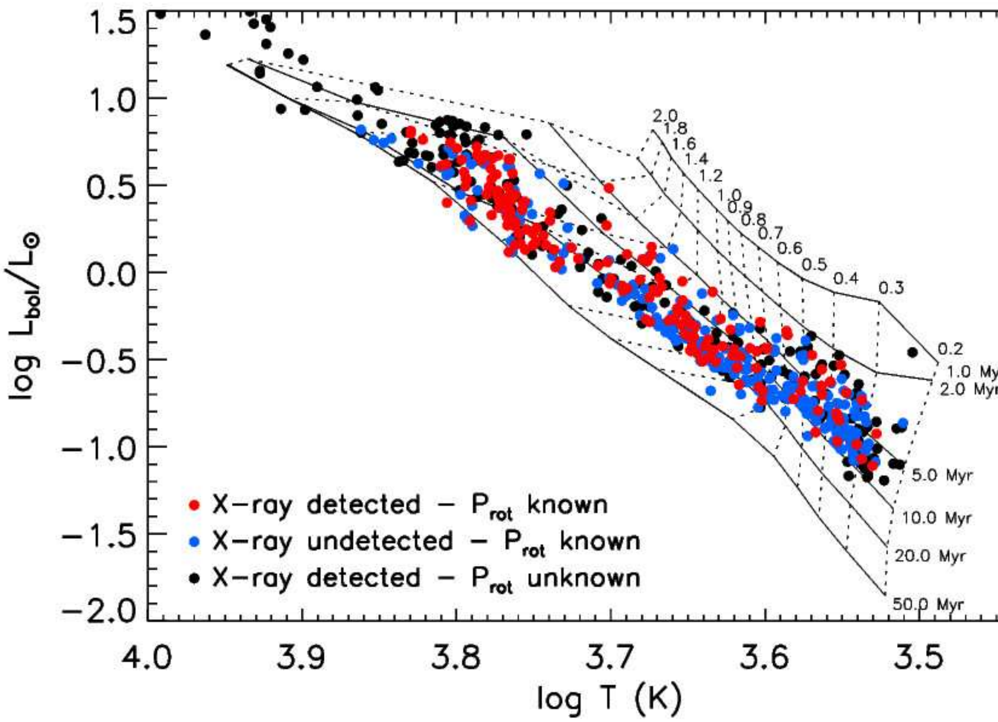

Figure .1: HR diagram of h Per members. Evolutionary models are from Siess et al. (2000).

suggested that a third regime probably occurs, the supersaturation regime: very fast rotators show L_X/L_{bol} lower than the saturated level. While the activity-rotation relation is well constrained for MS stars, the case of very young PMS stars is still unclear (Preibisch et al. 2005, e.g.).

To bridge the gap between the case of MS and the case of very young PMS stars we study the activity-rotationrelation in the young cluster h Per, that, at an age of $\sim$ 13 Myr, is in the transition phase between PMS and zero-age MS. At this young evolutionary phases the activity-rotation relation is crucial since: both fast and slow rotators coexist, accretion process has ended, and stellar internal structure is rapidly changing. We have measured the X-ray luminosity of h Per members from a 200 ks Chandra/ACIS-I observation. Rotational periods were derived by Moraux et al. (2013) in the framework of the MONITOR project (Aigrain et al. 2007).

2. h Per member catalog

To measure the X-ray emission level of h Per members we have analyzed a deep Chandra/ACIS-I observation of 189.8 ks (Obs ID 09912, 09913, and 12021, PI G. Micela), detecting with the `PWDetect` code a total of 1002 X-ray sources. To identify these sources we cross correlated them with the catalog presented by Moraux et al. (2013) containing h Per members with measured rotational periods, and with the h Per member list presented by Currie et al. (2010, Table 6). From these comparisons we have obtained a final X-ray selected catalog of h Per members composed of 452 X-ray detected h Per members, with 201 having measured rotational period, and 420 having optical counterparts with published magnitudes. The HR diagram of these h Per members is shown in fig. .1.

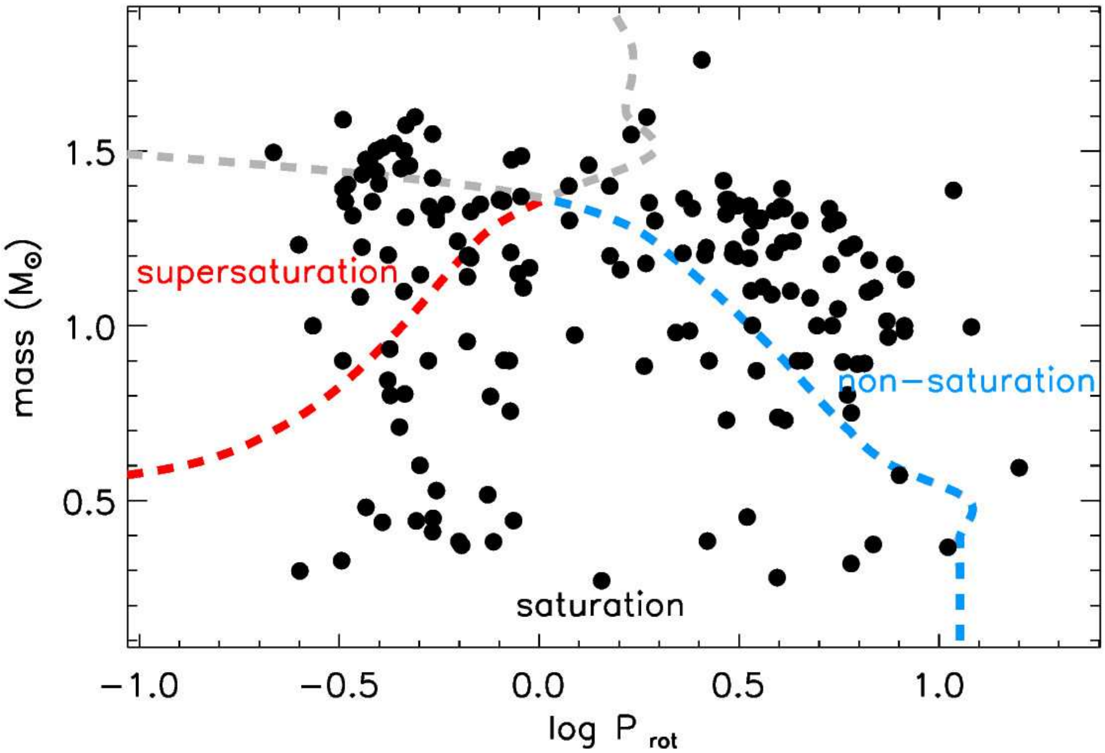

Figure .2: Mass vs rotational period of h Per members. Red and blue dashed lines separate the regions where supersaturation, saturation, and non-saturation are expected to occur (Wright et al. 2011)

Since the thresholds between different activity regimes are expected to depend on stellar mass, to investigate the activity-rotation relation of h Per members we need to know also stellar masses. Therefore in our analysis we have considered the subsample of X-ray detected h Per members with both known rotational period and effective temperature (needed to derive stellar mass). This subset is composed of 169 stars with mass ranging between 0.2 and $1.8\,\mathrm{M}_{\odot}$, period ranging between 0.22 and 15.9 d, and L_{X} ranging between 3.5×10^{29} and $1.1 \times 10^{31}\,\mathrm{erg\,s^{-1}}$.

In fig. .2 we show the scatter plot of mass vs period of these h Per members. We also included in this plot the lines marking the transitions between the supersaturated, saturated, and non-saturated regimes (Wright et al. 2011). The supersaturated threshold has been derived assuming that the driving mechanism is the poleward migration of active regions (Stępień et al. 2001; Wright et al. 2011). This plot shows that our stellar sample allows us to investigate the behavior of stars at 13 Myr in different regimes.

3. Results

We have inspected the activity-rotation relation for h Per members for different mass bins, as shown in fig. .3. We have included in the plot also X-ray upper limits for h Per members not detected in the Chandra observation. We have searched for correlation between L_X and P_{rot} for different mass bins and for different period ranges. For those cases in which a significant correlation has been found (confidence level higher than 90%) we report in fig. .3 the corresponding relation.

We have found clear evidence of supersaturationfor stars with $1.0\,M_{\odot} < M < 1.6\,M_{\odot}$ and period shorter than 1 d. Conversely lower mass stars do not show any evidence of supersaturation, even at the lowest $P_{\rm rot}$ values. Both these results agrees with the thresholds shown in fig. .2, supporting the poleward migration of active regions as the mechanism responsible for supersaturation.

Stars with masses ranging between 1.0 and $1.4\,M_{\odot}$ also display a significant anticorrelation between L_X and $P_{\rm rot}$ for long rotational period, typical of the non-saturated regime.

We note that the h Per cluster is the youngest cluster for which the activity rotation relation typical of MS stars has been observed. Hence at an age of ~ 13 Myr the stellar activity is likely regulated by mechanisms similar to that at work in MS stars.

Acknowledgements. .

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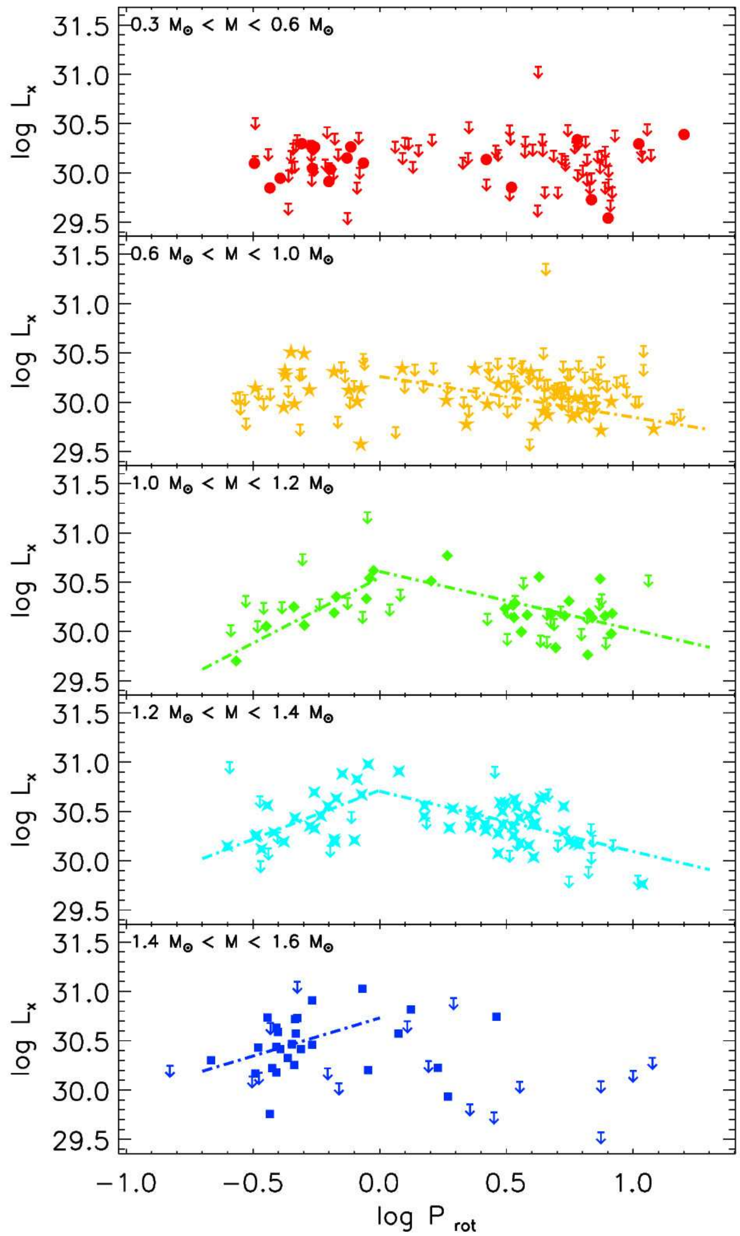

Figure .3: X-ray luminosity vs rotational period of h Per members of different mass. Dash-dotted lines are plotted where a significative correlation has been found.