



# Activity and Rotation in the Zero Age Main Sequence cluster *h Per*

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## 1. Introduction

We describe the initial results of the deep Chandra/ACIS-I observation of *h Persei*, a young (13 Myr) cluster at the transition between the Pre Main Sequence and the Zero Age Main Sequence phases. This is the crucial age at which the stars should reach the fastest rotation, since the contraction has finished and there has not been enough time for losing significant angular momentum via magnetic braking. Moreover fast and slow rotators may co-exist, depending on the previous disk evolution, and may have dynamos and therefore coronae in different regimes.

### *h Persei*

*h Persei* is a cluster in the northern sky lying at a distance of 2300 pc and having an age of  $13.5 \pm 1.5$  Myr (Currie et al. 2010). The cluster is very rich and compact and has been recently studied in several papers. Its distance and age have been accurately determined (Mayne & Naylor 2008, Currie et al. 2010) and Spitzer/IRAC observations have been analyzed in detail to study disks in the near infrared (Currie et al. 2007a, 2008). *h Per* is one of the targets of the MONITOR project (Aigrain et al. 2007; Irwin et al. 2007) aimed at studying in a systematic and homogeneous way the variations of optical light curves of members of star formation regions and open clusters, in order to investigate among the various subjects, angular momentum evolution of low mass stars.

## 2. X-ray Observations

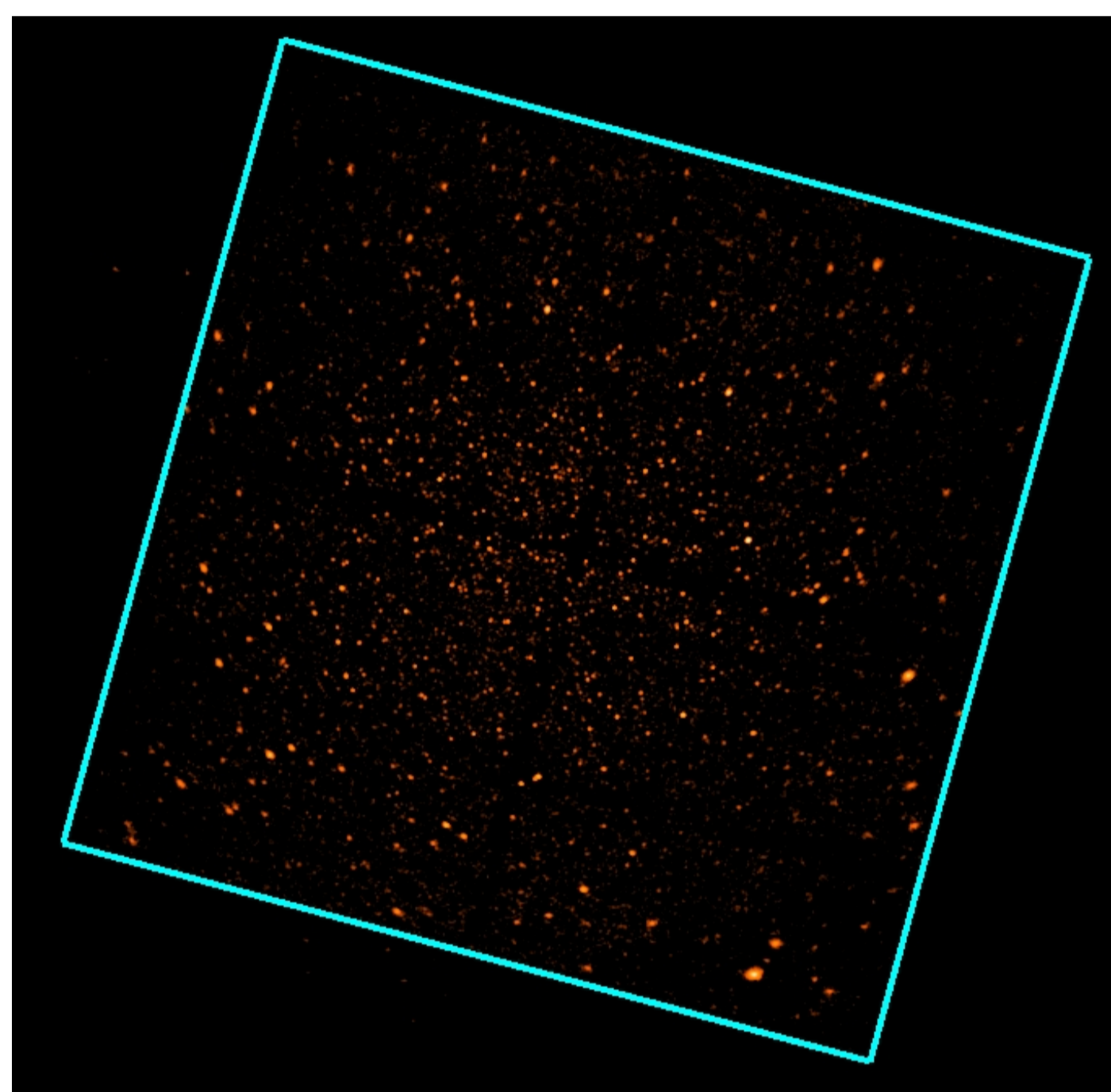


Figure 1. Acis-Chandra X-ray Image

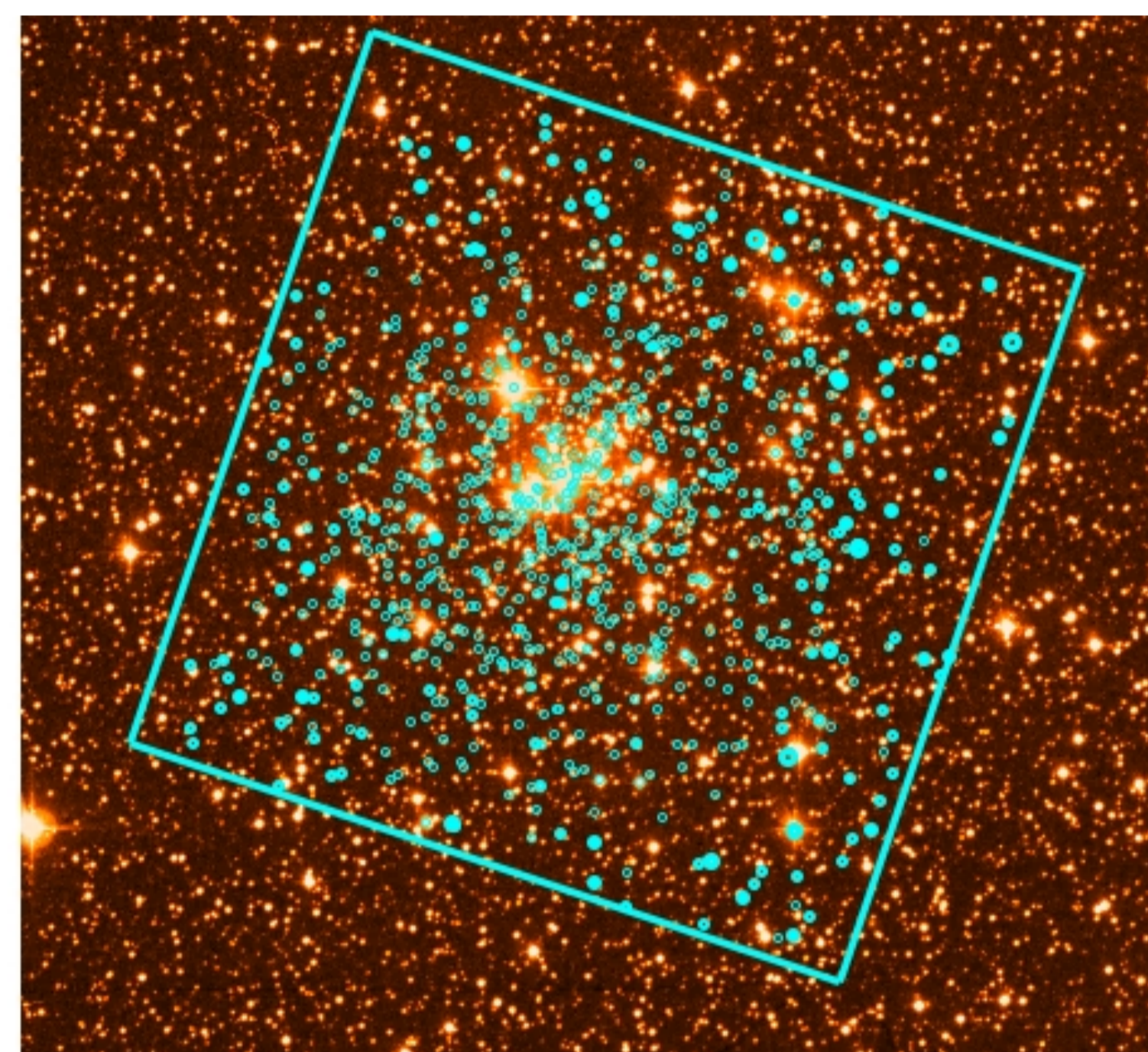


Figure 2. DSS Image with overlaid Acis-Chandra Field of view and X-ray sources

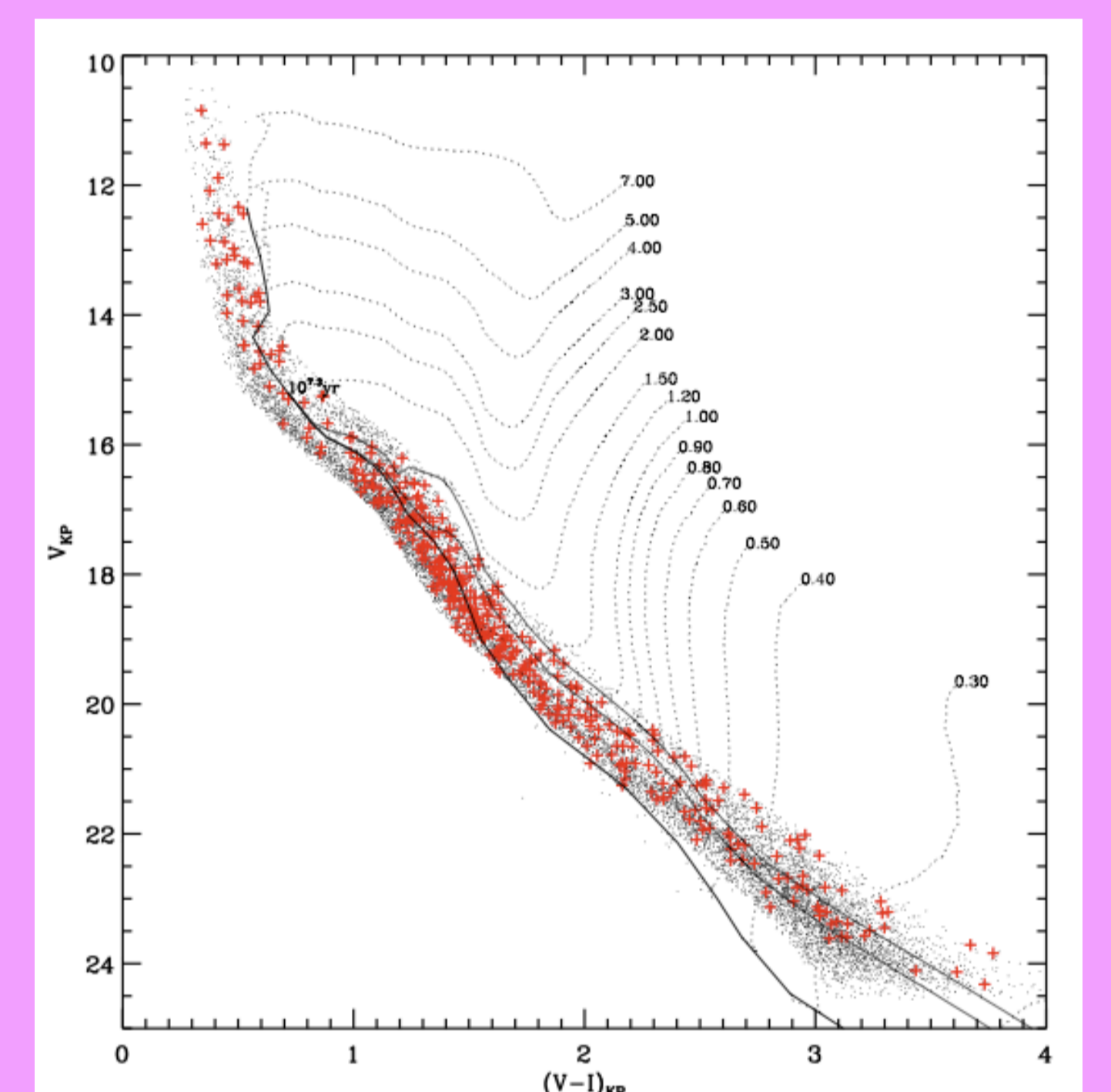
X-ray observation combines 3 consecutive exposures of *h Persei*, with a total exposure time of  $\sim 200$  ksec in the range 0.5-8.0 keV. Such a long observation is ideal for studies of short and medium term variability. The observations were obtained with the ACIS-I camera on-board Chandra (Weisskopf et al., 2002; Garmire et al., 2003), covering  $17' \times 17'$  in the sky. Thanks to the long exposure time, we have detected 1010 X-ray sources.

## 3. Optical Sample

The cluster is one of the targets of the MONITOR project (Aigrain et al. 2007; Irwin et al. 2007), a large-scale programme of photometric and spectroscopic monitoring of young open clusters using telescopes at ESO and other observatories. The reduction of the optical data needed for the estimation of periods is completed and periods have been obtained (Moraux et al. in prep.).

We combined the X-ray source list with the optical catalog finding that 627 X-ray sources have been identified as photometric candidate members.

Figure 3. HR Diagram for candidate members of *h Persei*. Red crosses correspond to X-ray sources. Siess evolutionary tracks and isochrones at 13, 23 and 100 Myr



## 4. X-ray activity versus rotation

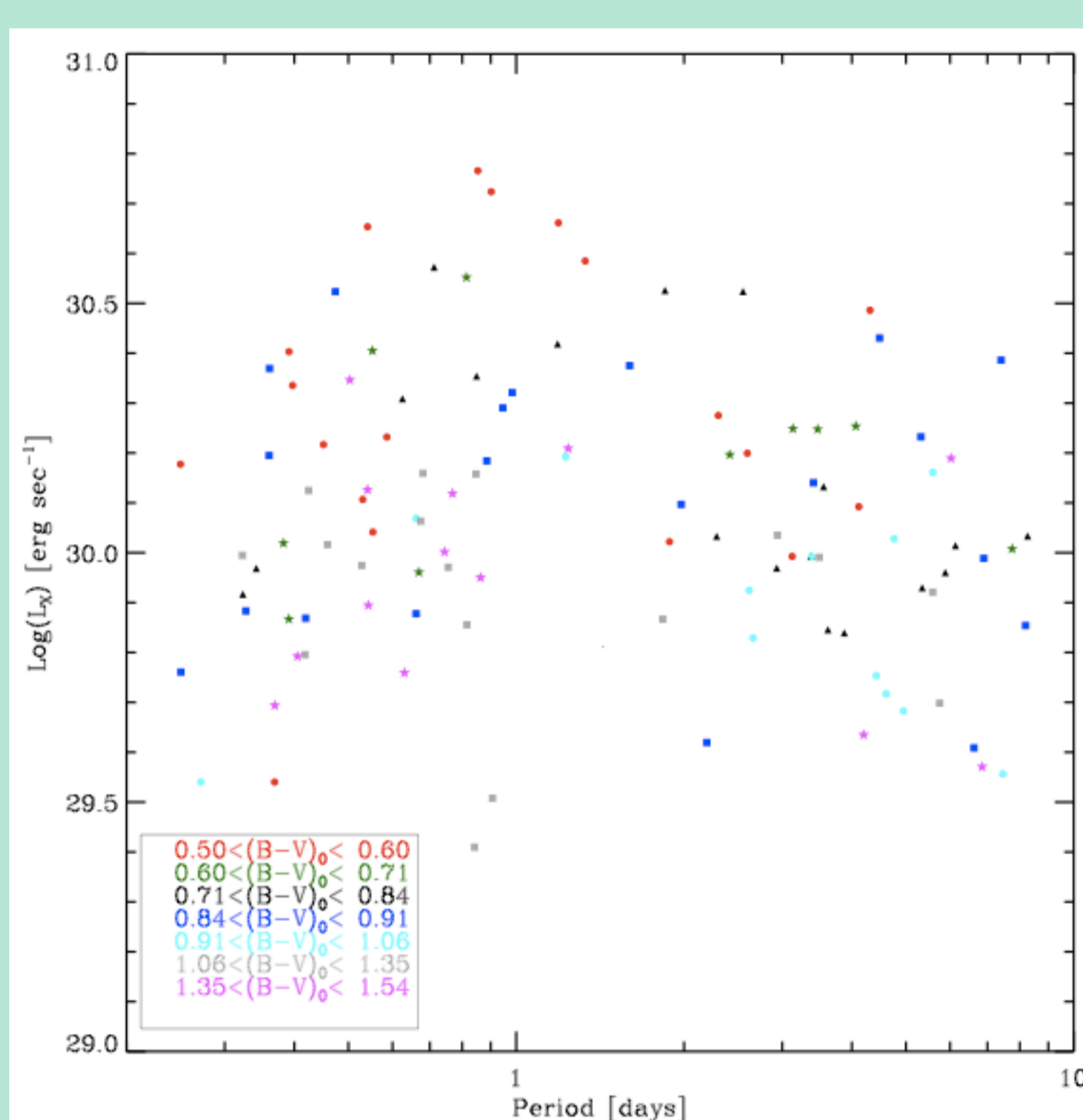


Figure 4.  $\text{Log}(L_x)$  versus Period for *h Per* members in different range of  $(B-V)_0$  color.

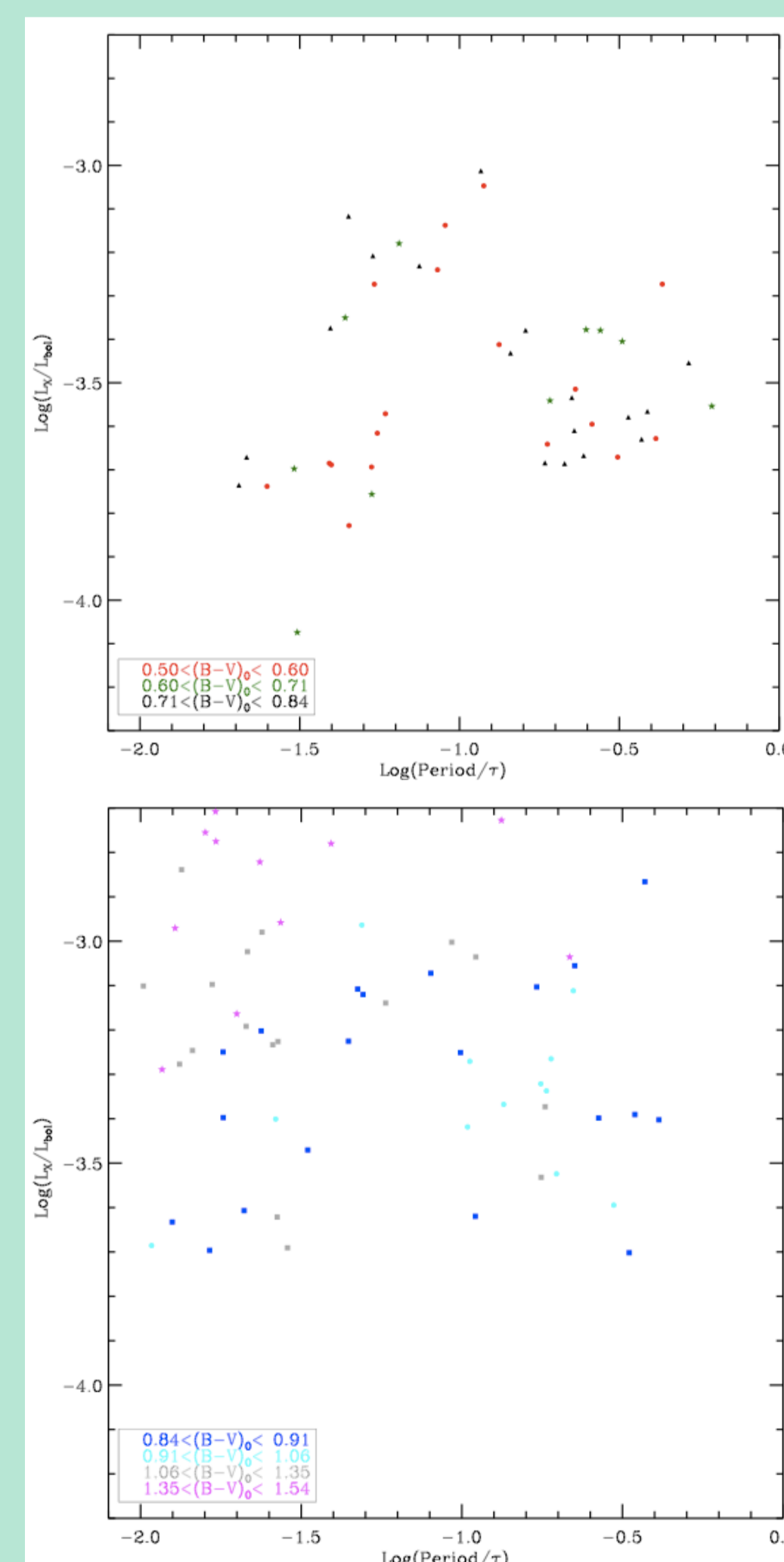


Figure 4 and 5 show the relation between X-ray activity and rotation for *h Per* members. While below a certain Rossby number ( $\text{Period}/\tau$ ) the saturation of the dynamo is expected, it is evident that below  $\text{Log}(\text{Period}/\tau) = -1.8$ ,  $\text{Log}(L_x/L_{\text{Bol}})$  starts to decline, showing the phenomenon known as supersaturation (Prosser et al., 1996, Randich 1998). This phenomenon is evident for  $0.5 < (B-V)_0 < 0.84$  (corresponding to a mass range: 1-1.3 solar masses), while the spread for spectral type corresponding to lower mass, is compatible with a saturation regime (see also Jeffries et al. 2010).

Figure 5.  $\text{Log}(L_x/L_{\text{Bol}})$  versus  $\text{Log}(\text{Rossby number})$  for periodic members in different range of  $(B-V)_0$  color.

## 5. Results

1. We have detected 1010 X-ray sources in the central field of *h Persei*.
2. The Luminosity range for detected sources is  $29.3 < \text{Log}(L_x) < 31.8$  erg/sec at a distance of 2300 pc.
3. 627 X-ray sources have as optical counterpart a candidate member of the cluster.
4. We have detected X-ray members down to 0.3 solar Masses.
5. While solar type stars (1-1.3 solar masses) show evidence of supersaturation for short periods, this phenomenon is unobserved for lower mass stars. This was also observed for NGC 2547, a cluster 25-28 Myr old (Jeffries et al. 2010), showing that this result is independent of age.

## References

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