WHY IS THE X-RAY LUMINOSITY FUNCTION DIFFERENT FOR THE HYADES AND PRAESEPE?

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ABSTRACT. We have studied dF-dK and dM stars belonging to Praesepe in order to determine membership via radial velocities and to compare several stellar properties, such as X–ray luminosities, Hα equivalent width, etc, between this cluster and Hyades, which have similar age. We show that all properties are analogous in both clusters except the distribution of Lx. This fact could be related to difficulties in the analysis of the Lx upper limits or to more fundamental reasons, such as binarity rates and differences in the properties of the binaries of each cluster.

1. Introduction

Randich & Schmitt (1995), using ROSAT PSPC data, have studied the X-ray properties of the Praesepe cluster and have shown that the X-ray luminosity function is very different from that corresponding to the Hyades, which has a similar age and metallicity. This result seems to contradict our assumptions about the evolution of stellar rotation and the age-rotation-activity paradigm. However, Mermilliod (1997a) has established that the rotational velocity distribution is very similar for both clusters. The goal of this paper is to try to disentangle the problem and explain the apparent dichotomy of these coeval clusters.

The observations analyzed in this paper were collected during Jan 11–13, 1995, and Jan 27–28, 1996, at the MMT. The first observing run was devoted to late dF-dK Praesepe stars, in order to measure their radial velocities (with a resolution of 0.2 Å). During the second run, we obtained radial velocities and Hα equivalent widths of Praesepe dM members (resolution$\sim$1.5 Å). Figure 1a,b shows both color-magnitude diagrams for these samples (solid symbols for the targets).

2. dF-dK stars in Praesepe

In order to determine whether non–members significantly contaminate the Praesepe catalog used by Randich & Schmitt (1995), we have measured radial velocities of a sub-sample which contains 16 stars having X–ray detections and 21 stars with X-ray upper limits. 22 of these stars have radial velocities consistent with that expected for single Praesepe members. Of the other 15 stars, 8 have been shown to be spectroscopic binary

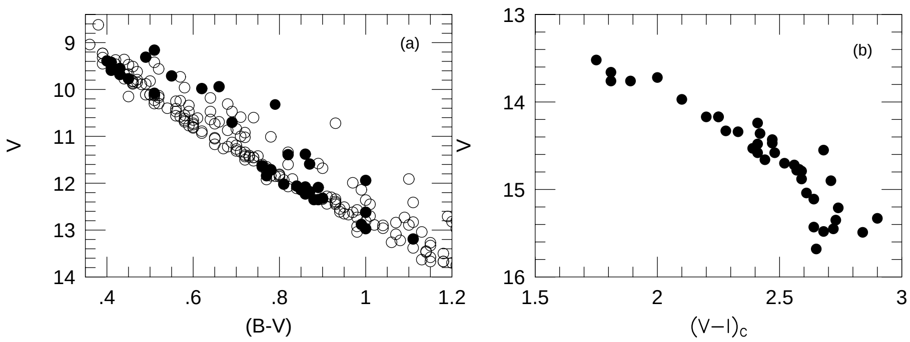

Fig. 1. Color magnitude diagrams for the dF-dK (a) and dM (b) Praesepe stars. Our targets are shown as solid circles.

members by extensive radial velocity studies (Mermilliod 1997b). One star, KW460, is a probable non-member. Based on incomplete information about photometry, lithium abundances, proper motions, etc, we believe that the remaining 6 stars are also binaries and members of the cluster. Our conclusion is that the Praesepe sample is not significantly contaminated by non-members. Therefore, we must search elsewhere to explain the apparent difference between the X-ray detection frequency in binaries of Praesepe (56%) and Hyades (96%, Stern et al. 1995).

Figure 2a,b shows Lx against (B–V) color for dG Praesepe and Hyades stars (detection are shown as solid circles, whereas upper limits appear as open triangles, the solid lines represent where the lowest X-ray detection lies in each cluster). Proper motions, photometry and radial velocities prove that there are not a significant number of spurious members in the Praesepe dF–dK sample. Therefore, the obvious differences in the X-ray distribution seem real. We emphasize the difference in the distributions below Log Lx=28.4. Praesepe has 12 stars with luminosities under this value, whereas Hyades only has 1. We have analyzed a deep pointing, retrieved from the the ROSAT archive, to verify if the previous upper limits in Praesepe were assigned correctly. We detected the same stars which were detected in the raster scan (and did not detect those that were not detected). The ULs which we got for undetected stars are consistent with those from the raster, although we cannot exclude that some of the latter were underestimated by a factor of 2. This, however, would not be enough to fully explain the discrepancy between Hyades and Praesepe dG XLDF. This situation leads to the interpretation that the different X-ray properties of dF–dK members of both clusters could be related with the binarity rates and different distributions of the orbital elements, such as the orbital period. Fig. 2a,b suggests that the sensitivity of the Hyades and the Praesepe data could be different, and this fact would also help to solve, partially, the problem.

3. dM stars

The difference between the X–ray luminosity function of dF–dK members of the two clusters extends also to the M dwarfs, as shown in Figure 2c,d. X-ray detections and

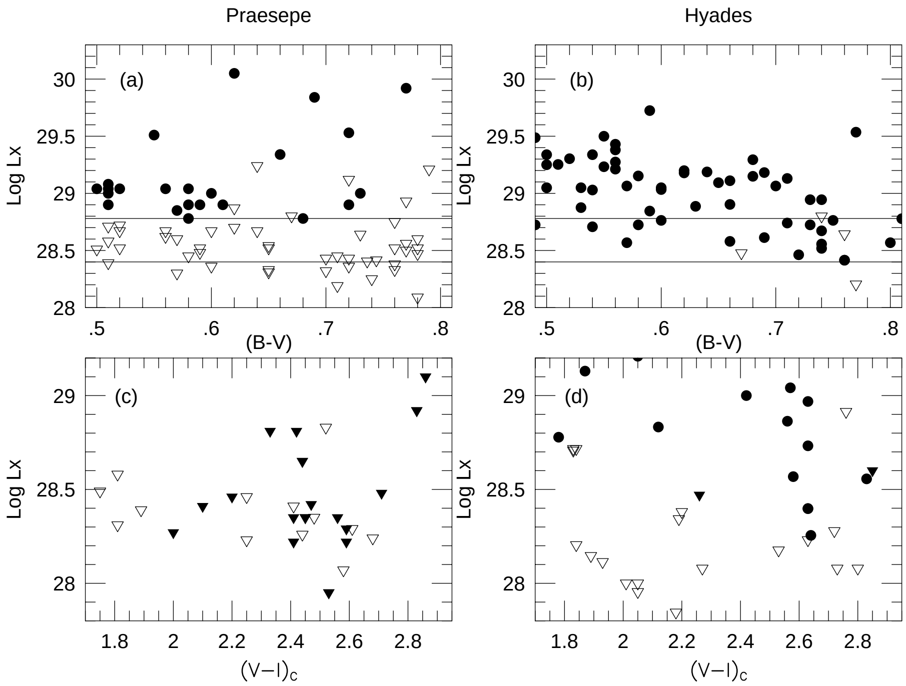

Fig. 2. X-ray luminosities against color indices. a,c Praesepe; b,d Hyades. See text.

upper limits are represented as circles and triangles, respectively; the strong and weak Hα features, as defined from Figure 3 are shown as solid and open symbols, respectively. Note that none of our dM Praesepe stars were detected in X–rays. There is a clear correspondence between strong Hα emission and detection in X-rays in the case of Hyades, as expected. However, this relation does not appear to hold for Praesepe. Although it is possible to understand the fact that there are stars with high X-ray upper limit and weak Hα (after all, the actual Lx can be much smaller than the upper limit), it is difficult to explain the presence of several stars having strong Hα emission but, simultaneously, very low X–ray upper limits. Figure 3a,b, where the Hα equivalent width (our data and values from William et al. 1994 are included) is represented against the $(V\text{-}I)_C$ color, shows that there is no obvious difference in the Hα distribution, except that several Praesepe M dwarfs are quite active. However, the situation in X-rays is the opposite. Again, the factor 2 in the re-assignation of the Lx upper limits could help, but it would not be enough to explain all the differences, in particular the lack of correspondence between Hα and Lx (stars having strong Hα and low Lx upper limits).

4. Conclusions

We have tried to understand the reasons for the different X-ray properties of late type stars in the Hyades and Praesepe. We have studied two different samples of stars: dF-dK Praesepe members for which we have derived radial velocities and dM Praesepe stars for which we have determined chromospheric activity levels. We have shown that the Praesepe members catalog has few or no spurious members and so the inclusion of non–

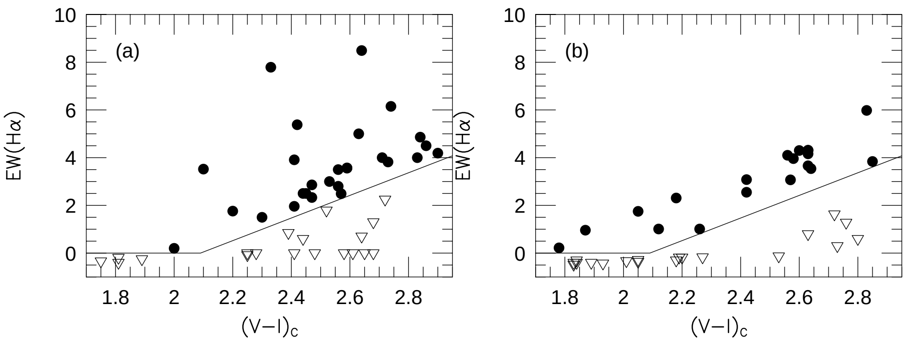

Fig. 3. EW(Hα) against (V–I)$_C$ color for Praesepe (a) and Hyades (b). The solid line separates strong and weak Hα, as discussed in the text.

members is not the cause for Praesepe's apparent lower X–ray activity. Other stellar activity indicators, such as Hα, have the same distribution in both clusters, as do other properties such as the rotational velocities and the lithium abundances. That is, the only difference is the X–ray distribution.

One possibility is that the X–ray upper limits of Praesepe stars have been underestimated. Our new analysis shows that they could be increased only a factor 2, and we think it is unlikely that this can be the complete explanation. Alternatively, there may be real intrinsic difference between some additional property –the binary frequency or metallicity, for example– which could contribute to the dichotomy in the coronal properties. Further optical spectroscopy of Praesepe may help to answer this question. A definitive answer could be obtained by new X–ray observations once AXAF or XMM are launched.

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References

Mermilliod, J-C., 1997a, this issue

Mermilliod, J-C., 1997b, priv. comm.

Randich, S., Schmitt, J. H. M. M., 1995, *Astron. Astrophys.* **298,**, 115

Stern, R. A., Schmitt, J. M. H. H., Kahabka, P. T., 1995, *Astrophys. J.* **448,**, 683

Williams, S. D., Stauffer, J. R., Prosser, C. F., Herter, T., 1994, *Publ. Astr. Soc. Pacific* **106,**, 817