WIDE BINARIES IN THE HYADES CLUSTER

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Abstract. With the purpose of studying the time evolution of the distribution of separations of binary systems, a long term effort is being made to obtain homogeneous samples of binaries of different ages. In this work, the results of a search for binaries in the Hyades cluster are presented. The search was done by means of the nearest neighbor statistic, complemented with numerical simulations. The data base was Luyten's list of 929 probable Hyades. A total of 53 probable binaries was detected; 22 of them are the 22 binaries in Luyten's list that were previously known, and the other 31 are new probable identifications.

1. Introduction

The time evolution of the distribution of separations of selected samples of binary stars should throw light on the nature of their interactions with surrounding matter and on the nature of the objects with which they interact. Since the effect of these interactions is expected to be more evident in the less bounded systems, a long term effort is being made to derive the distribution of separations of samples of wide binaries of different ages. A first step in this direction was the elaboration of a quasicomplete catalogue of wide binary and multiple systems in the solar vicinity (Poveda et al., 1994). A second step, now in process, is the derivation of the distributions of separations of other samples with different ages. This work presents preliminary results of a search for wide binaries in the Hyades cluster based on Luyten's sample of 929 probable members of the cluster (Luyten, 1981).

2. Theory

The identification of probable binaries was made following the classical approach of comparing the observed angular separations of the stars in the sample with those expected for a two-dimensional random distribution of points. In particular, we based our analysis in the 2-D nearest neighbor statistic. If we assume that the projected positions of the stars on the sky follow a Poisson distribution, then it is easy to show that, for any star, the probability of its nearest neighbor lying at an angular distance between s and $s + ds$ is $p(s)ds = 2\pi s \exp(-s^2/2S^2)ds$, where S, the average angular separation between two nearest neighbors, is related to the mean surface density of stars, n, by $S = 1/(2n^{1/2})$. For each star, the probability of finding its nearest neighbor closer than a given distance s

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is $P(s) = (2/\pi)\exp(-s^2/2S^2)$, and the expected total number of nearest neighbors closer than s, if the sample consists of N stars (randomly ditributed on a plane), is $NP(s)$. The basic idea of the method is that when this number is much less than the number of nearest neighbors closer than s observed in the actual sample, then we may assume that most of these pairs are real (physical) binaries.

3. Numerical simulations

In practice, the application of this theoretical distribution to a given sample yields only an order of magnitude idea of the number of actual binaries in the sample because it does not take into account possible edge effects and also because real clusters do not show the constant density profile assumed in the theory. Therefore, we decided to test the range of applicability of the theoretical formulation in a number of randomly built artificial clusters with boundaries and with a given non-constant density profile. To this end, we first found an analytical fit to the density profile of the stars in our sample in the form of the well known formula proposed by King for the light intensity of globular clusters (King, 1962). The best fit was obtained for a core radius $r_c = 4.915$ pc and a tidal radius $r_t = 16.352$ pc (here, and through he rest of this work, we assume a distance of 45 pc to the Hyades). The observed densities and the analytical fit are shown in Fig. 1, where it is readily seen that the fit is rather good (in fact, it is better than 2% for all points except 5).

To simulate the real cluster, we then constructed an artificial cluster of 900 "stars" -500 "singles" and 200 "binaries"- by the following procedure. First, we placed the 500 "singles" randomly in an area equal to that occupied by our sample, using a Monte Carlo technique to assure that they followed statistically the previously derived analytical density distribution (King's formula). Then, we added the 200 "primaries", also randomly distributed and also following the real cluster's density profile. Finally, we added to each primary its corresponding secondary at a randomly selected position angle, uniformly distributed between 0 and 2π, and with a separation taken from a set of 200 random separations built in such a way that they followed an Öpik distribution $f(s) \sim s^{-1}$ (Öpik, 1924). This procedure was used to build three different "clusters" of 900 "stars" and with the density profile of the real sample. One of them is shown on Fig. 2. It may be compared with the real cluster (Fig. 3).

In each of the three artificial clusters we then found, for each star, the distance to its nearest neighbor. Measuring these distances in units of the average separation $S(r)$ *at the distance of the star from the center of the cluster*, we then counted the number of nearest neighbors with separations less or equal than 1/10, 2/10, etc. Finally, we compared these numbers with those given by the theory, always taking into account the dependence of the average separation S on the position of the star. The results of this comparison showed that it is convenient to define a "probable binary" as a pair of stars which are mutual nearest neighbors, i.e., pairs A-B where A is the nearest neighbor of B and B is the nearest neighbor of A. If this definition is adopted, we find that: 1. 100% of the original binaries are never recovered and there are always spurious binaries. 2. The best compromise between number of recovered binaries and proportion of recovered original binaries vs. spurious binaries occurs for separations less or equal to three tenths of the average separation between stars. In this case, an average of 74% of the original binaries is recovered and the inevitable number of spurious binaries amounts on the average to 7% of the original binaries. 3. All the original binaries farther than half the tidal radius from the center of the cluster are recovered. 4. 99.5% of the original binaries with separations

$< 25,000$ AU are recovered (remember that this number assumes a distance of 45 pc to the Hyades).

4. Results and conclusions

The statistical nature of the present work made it desirable to work with the largest possible number of stars. Therefore, from the numerous lists of probable members of the Hyades cluster (van Bueren, 1952, van Altena, 1966, etc.), we chose as our working sample the one with the largest number of entries, i.e., the list of 929 probable Hyades published by Luyten in 1981 (Luyten, 1981). In this list, 624 entries are Luyten's own identifications on the Palomar plates, 184 come from van Bueren's classical work and the rest were taken from several other sources (all the relevant references may be found in Luyten's work). The sample covers an area of approximately $30° \times 30°$ on the sky. Figure 3 shows all the stars in an $\alpha - \delta$ plot.

The application to the sample of the "probable binarity" criterion discussed in the previous section (mutual nearest neighbors closest than three tenths of the average separation) yielded the following results: 1. There are a total of 301 pairs which are mutual nearest neighbors, but only 53 of them have separations less or equal than three tenths of the average separation corresponding to their distance to the center of the cluster and are, therefore, probable real systems. 2. As far as we know, 22 of these 53 probable real binaries have not been mentioned before as probable binaries. 3. The remaining 31 pairs, previously recognized in the literature as probable systems, seem to be *all* the previously known systems in Luyten's list. In other words, the statistical method recovered 100% of the previously known binaries in the sample. This is important because it may be interpreted as meaning that the 22 new candidates have a good chance of also being real systems. The list of the 53 probable binaries found will be published in a forthcoming more detailed paper. Finally, we state some preliminary results that follow from assuming that these 53 probable binaries are, indeed, members of the cluster (and assuming, as always, a distance of 45 pc to the cluster): 1. The minimum separation of the binaries in the Hyades is 67.5 AU. 2. 50% of the binaries in the Hyades have separations less or equal than 3,871 AU. 3. 80% of the binaries in the Hyades have separations less or equal than 9,455 AU. 4. The separations of the binaries in the Hyades accumulate in the range 3,200 - 4,525 AU.

References

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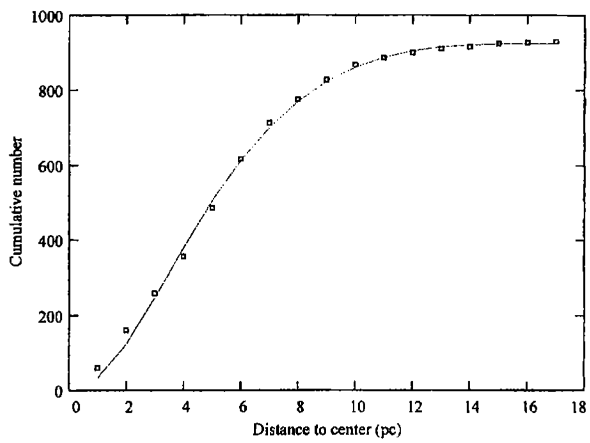

Figure 1. Observed accumulated fraction of stars in Luyten's list (squares) and analytical fit to them by means of King's formula (solid line) as a function of the distance to the center of the cluster

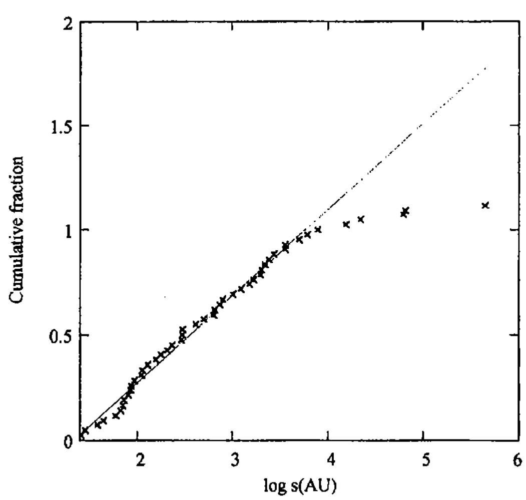

Figure 2. Artificial cluster of 900 "stars" in a Right Ascension-Declination plane. The points are distributed according to the analytical density profile fitted to the actual cluster

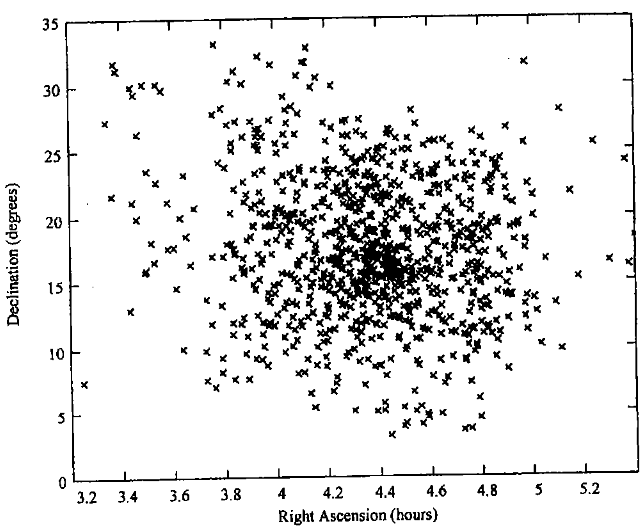

Figure 3. Luyten's 929 probable Hyades in a Right Ascension-Declination plane.