Astron. Astrophys. 302, 86–89 (1995)

ASTRONOMY
AND
ASTROPHYSICS

Probable binary open star clusters in the Galaxy

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Received 22 November 1994 / Accepted 13 January 1995

Abstract. The existence of double/binary clusters in the Magellanic Clouds is fairly well established, whereas only one such pair, $h+\chi$ Persei, is known in the Galaxy. From the catalogues of open clusters of the Galaxy, we have identified 18 probable pairs of clusters (with known distances), with spatial separations less than 20 pc. The tidal disruption timescales for these pairs, due to Galactic differential rotation are calculated, using cluster data where available or by assuming typical values. In some cases, these timescales are larger than the average open cluster lifetime, $\approx 10^8$ yr. About 8% of open clusters appear to be members of binary systems, and hence binary cluster systems may not be very uncommon in the Galaxy.

Key words: open clusters: general – galaxies: star clusters

1. Introduction

The total number of open clusters known in our Galaxy is $\sim$ 1400. Of these, the only well established double or binary cluster is $h+\chi$ Persei which consists of the two rich, young clusters NGC 869 & NGC 884, located at a distance of more than 2 kpc from the Sun. The existence of other possible double clusters and cluster complexes has been proposed earlier (Pavloskaya et al. 1989), but not been seriously looked into. On the other hand, the Magellanic Clouds (MCs) are widely believed to have a number of binary clusters and these have been studied in some detail (Bhatia 1990 and references therein). The MCs are at a distance of $\sim$ 50–60 kpc and this makes the identification of the double star clusters easier, as the candidacy is established from the closeness of their projected positions on to the plane of the sky. This method of determining candidate members for double star clusters in our Galaxy is not however feasible. Since we are looking at the Galaxy from the inside, the distance to the clusters should also be taken into account. A probable site for finding Galactic double or binary clusters in the Galaxy may be the spiral arms where the density of open clusters is high. Further, molecular clouds which are the formation sites of young open clusters are known to form more than one star cluster in their lifetime. It is more than likely that some of the clusters formed from a single parent molecular cloud survive as bound objects, even after the disruption of the cloud. Optical sky surveys such as the POSS reveal a large number of closely located clusters, when seen projected on the plane of the sky. The actual physical association of even a few of these clusters has important implications on the evolution of open clusters. Clusters born as binaries could survive as such for their entire lifetime, or get disrupted by the Galactic tidal field. A few clusters with small separations could probably even merge in a few million years. In this paper, we examine existing catalogues of open cluster data and suggest pairs of clusters located closely enough in space, to be considered as possible binaries or double clusters. Tidal disruption timescales for the identified double clusters are estimated.

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2. Open cluster data and analysis

The catalogue of open clusters by Lyngå (1987) has been used for the analysis. This contains around 1400 clusters and $\sim$ 400 of these have known distances.

As the distribution of the open clusters in the Galaxy is highly non-uniform and concentrated along the spiral arms, a statistical analysis based on the projected separation on the plane of the sky cannot be done without appropriate weightage. However, the distribution cannot be modeled accurately and hence the above method may not be very reliable. Therefore, we have restricted our analysis to those open clusters with distances known. Within the resulting database of 416 clusters, we find the distance of the nearest neighbour for each cluster. This is done by finding the angular separations between two clusters, $\Delta\theta$ and assuming the distance, d, to be the mean of the two cluster distances, thus the separation is equal to $\Delta\theta \times d$. We have allowed for a 20% error in the distances given in the catalogue. A cluster pair is termed a binary cluster if the separation is $\leq$ 20 pc. The average separation between open clusters as determined from the cluster formation rate as given by Battinelli et al. (1990) is around 100 pc assuming a typical cluster lifetime of $2\ 10^8$ yr. This implies a less than 1% probability of finding a cluster within 20 pc by chance or random fluctuations in the spatial density of clusters. Besides, a typical giant molecular cloud has an extent of 20 pc and clusters with separations smaller than

Table 1. List of candidate binary clusters with known parameters

Cluster name	Lon.	Lat.	Distance	log age	Rad. vel.	A_V	Separation (pc)	log τ_{tidal}
King 14	120.72	0.36	2600	7.2	–	1.71	8.64	8.54
NGC 146	120.87	0.49	2900	7.10	–	2.16		
NGC 869	134.63	−3.72	2200	6.75	−40	1.68	18.93	7.00
NGC 884	135.08	−3.6	2300	6.5	–	1.68		
NGC 1513	152.6	−1.57	820	8.63	–	1.77	19.00	7.15
NGC 1545	153.36	0.17	800	8.29	−15	1.08		
NGC 1907	172.62	0.30	1380	8.64	+1	1.41	14.12	7.62
NGC 1912	172.27	0.70	1320	8.35	−3	0.72		
NGC 1981	208.09	−18.98	400	–	+28	–	19.38	7.15
Coll 70	204.98	−17.44	430	–	–	–		
Basel 8	203.79	−0.12	1300	–	–	–	7.17	8.95
NGC 2251	203.60	0.13	1550	8.48	−7	0.72		
NGC 2383	235.26	−2.44	2000	7.4	–	0.81	5.84	9.36
NGC 2384	235.39	−2.41	2000	6.0	+31	0.93		
Haff 18	243.11	0.44	6900	6.0	–	–	15.76	6.90
Haff 19	243.04	0.52	6900	6.8	–	–		
Pismis 6	264.81	−2.87	1600	7.5	+30	1.20	12.97	7.94
Pismis 8	265.08	−2.63	1400	7.5	+63	2.22		
NGC 3247	284.59	−0.35	1400	7.7	–	0.96	15.53	7.68
IC 2581	284.60	0.01	1660	7.0	−6	1.29		
Hogg 10	290.80	0.10	2200	6.3	–	1.38	3.9	10.36
Hogg 11	290.89	0.14	2300	6.8	–	0.96		
Basel 18	307.20	0.20	1556	8.2	–	–	11.04	8.37
Coll 271	307.09	−1.62	1600	7.8	–	0.96		
NGC 6152	332.93	−3.14	1030	–	–	–	14.00	7.91
NGC 6208	333.69	−5.82	1000	9.0	–	0.54		
NGC 6383	355.68	0.05	1380	6.65	−2	0.78	6.06	9.59
Tr 28	355.98	−0.26	1500	8.3	–	2.22		
NGC 6755	38.55	−1.7	1500	7.6	+57	3.55	12.45	8.16
NGC 6756	39.067	−1.69	1650	7.7	–	4.41		
NGC 6996	85.46	−0.47	500	–	+10	1.92	11.88	8.15
Coll 428	86.21	−1.41	480	–	–	–		
NGC 7031	91.32	2.26	1000	7.8	–	2.46	16.60	7.48
NGC 7086	94.41	0.20	1200	7.9	–	2.07		
NGC 7429	108.95	0.28	1920	–	–	–	18.15	7.20
Mark 50	111.36	−0.20	2250	7.0	−81	2.58		

this have a higher chance of being physically associated. Thus we form a list of 18 candidate binary clusters as listed in Table 1. We have excluded clusters of dubious nature and OB associations. A search of existing literature has been made for other cluster parameters such as age, mass, radial velocity etc.

3. Tidal disruption

The open clusters in the Galaxy are distributed close to the Galactic plane with a scale height of only 70 pc. They are hence subjected to a strong tidal field due to differential rotation in the Galaxy. The lifetime of a cluster is in fact determined by the tidal field and is disrupted typically after a few 10^8 years. The influence of the galactic tidal field is stronger on the binary/double cluster due to its larger extent and could potentially disrupt the pair in its early stages and the pair may not remain bound for even a fraction of the cluster lifetime. The tidal disruption times for each candidate cluster pair has been estimated using the impulse approximation as in Bhatia (1990). They calculate the disruption time by equating the energy input by the galactic tidal field to the binding energy of the pair. The expression for disruption time is given by

$$t_{\rm tidal} = \frac{4G^{1.5}(m_1 m_2)}{(m_1 + m_2)^{0.5}({\rm d}^2\omega/{\rm d}r^2)a^{4.5}}$$

where a is the separation, m_1, m_2 are the masses of the clusters and the ${\rm d}\omega/{\rm d}r$ is the tidal acceleration. The Galactic rotation curve determined empirically (see Bowers & Deeming 1984) has been used to obtain the acceleration and this is fairly accurate at the cluster galactocentric distances. The separation, a, used here is that determined from the mean cluster distance. It should be noted that for a precise evaluation of the tidal timescale the *true* physical separation should be used, for which better distance estimates to the clusters are required. Masses for some of the clusters are available in literature. Most of these are, however, luminous mass estimates which are systematically lower than the dynamical masses of the clusters (Battinelli et al. 1994). Schmidt (1963) has evaluated the masses of some clusters by taking into account the non-luminous mass as well, which also contributes to the dynamical mass of a cluster. He obtains a value of 1.12 $10^3\,M_\odot$ for the typical mass of a cluster. We have therefore assumed a common mass of $10^3\,M_\odot$ for all clusters. We believe that this assumption is not too bad, as $t_{\rm tidal}$ varies only weakly with mass, its strongest dependence being on the separation between the clusters. The separation and tidal disruption times for each pair are also tabulated in Table 1.

4. Discussion

The candidate binary clusters (18 pairs in number), have been proposed on the basis of their spatial proximity. Other parameters like age, extinction, radial velocities etc. provide additional information on their binarity. Clusters of similar ages suggest a common origin whereas similar radial velocities further strengthen their closeness. Table 1 gives the ages and radial velocities for the clusters in our list, where available (Mermilliod 1994). It is seen that there is only one pair in our sample, NGC 6383+Tr 28, where the members have widely disparate ages, suggesting that most of our candidates could be of a common origin. Radial velocity measurements are not available for both clusters of a pair, except for NGC 1907+NGC 1912 and Pis 6+Pis 8. The radial velocities of Pis 6 and Pis 8 do not match suggesting that these two clusters may not be physically close. NGC 1907 and NGC 1912, on the other hand, have similar radial velocities indicating that they are probably physically associated. It is to be noted that the two disparate pairs, Pis 6+Pis 8 and NGC 6383+Tr 28, are the only ones with extinction values differing by more than one magnitude.

Thus we find 16 pairs of clusters, excluding those with disparate ages and different radial velocities. These constitute about 8% of our sample of 416 clusters. It is to be noted that similar fractions of clusters are found to be in binary systems in the Magellanic Clouds (11% in the LMC and slightly less in the SMC, Hatzidimitriou & Bhatia 1990).

Further the distribution of separations between clusters in a pair, shows an apparent peak for the LMC (~ 6 pc) and the SMC (~ 11 pc). No such preferred separation is observed in Galactic clusters. A comparison of the frequency distribution of ages of the clusters in a pair with that of single clusters in our Galaxy (Fig. 1.) shows that the two differ, especially for larger ages. It is seen that the pairs are preferentially younger and the distribution falls off sharply for ages longer than $\log\tau \geq 8$. This result probably implies that older cluster pairs do not survive the disruptive influence of the Galactic tidal field and molecular cloud encounters. Similar distributions are found for the LMC and the SMC with 'binary clusters apparently following the young rather than old clusters' (Hatzidimitriou & Bhatia 1990).

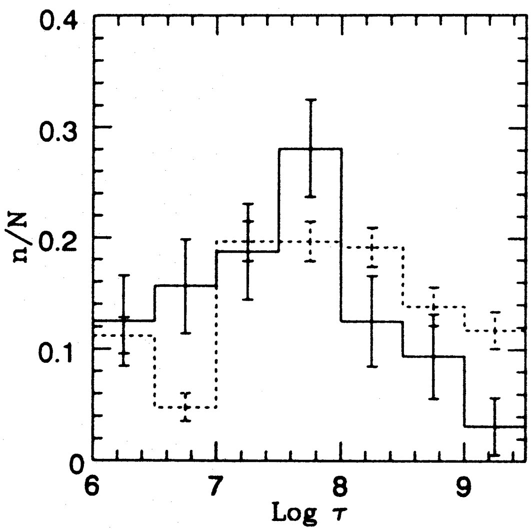

Fig. 1. Histogram of cluster ages (log τ) for binary (solid line) and single clusters (dashed line) from the sample. The number of clusters in each bin have been normalized with respect to the total number in the two categories

A comparison of the cluster disruption time scales with the mean age of a cluster pair, shows that except for three pairs, all others have consistently larger $\tau_{\rm tidal}$ than their mean age. This further strengthens the supposition that the clusters may be physically associated. It is to be noted that the time-scale for tidal disruption as calculated here, is not valid for the system NGC 869+NGC 884 ($h + \chi$ Persei). In the calculation of $\tau_{\rm tidal}$, it is assumed that the separation between the clusters is larger than the sum of their radii and this assumption does not hold for this pair. For a proper analysis on binary cluster stability, merger time scales should also be computed. These, however, involve detailed numerical N-body simulations which have not been attempted.

We thus find that 8% of our sample are probable members of binary systems. Were the distances to all the clusters known, there would be many more candidates within our limiting separation of 20 pc. This indicates that binary clusters are probably a common occurrence in the Galaxy as well and are potentially interesting objects which could provide lot of information on the dynamics of groups of stellar systems. The presence of double or binary clusters with small separations ($\sim$ 20 pc) also has implications on the star-forming processes in the Galaxy. This indicates that star-formation in a molecular cloud (extent $\sim$ 20 pc) is not restricted to a single region in the cloud but probably takes place in two or more concentrations. Examples of such multiple cluster formation sites are the Chamaeleon I cloud (Hartigan 1993) and the young open cluster NGC 2264 (Mathieu 1986; Lada et al. 1993) which show the presence of two central cores. The open cluster OCL 556 (Haffner 3) also shows the presence of two distinct concentrations (Babu 1985). Though only the tidal disruption times have been computed above, it should be noted that merging is an equally important endstate for a binary cluster. Clusters with large disruption times are more likely to merge in times short compared to a cluster lifetime.

5. Conclusion

Binary clusters are believed to be common in the Magellanic Clouds, but the only known binary cluster in the Galaxy is the $h + \chi$ Persei. We propose the existence of more double clusters of which some may be physically associated and unlikely to be disrupted by the Galactic tidal field during their lifetime. From a sample of 416 clusters for which distances were known, we find 16 pairs, which implies that 8% of the clusters are members of binary systems. The fraction of clusters in pairs and the age distributions are found to be similar to those in the Magellanic Clouds. The cluster pairs may get disrupted by encounters with molecular clouds or due to the Galactic tidal field, or merge if the separations are very small. The presence of a companion cluster could greatly influence the dynamical evolution of either member of the pair and such studies could prove very interesting. Further, the possible existence of double clusters with small separations indicates that star-forming activity in molecular clouds takes place in two or more regions at the same time.

Acknowledgements. The authors would like to thank Dr. R. Bhatia and the referee, Dr. P. Battinelli, for helpful comments and suggestions.

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