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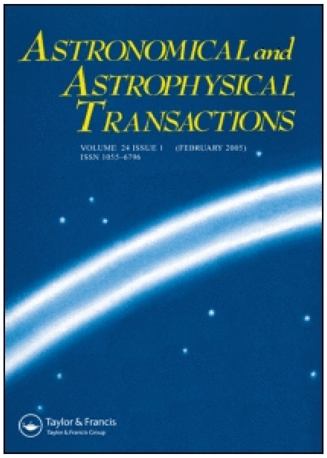

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Stellar streams: origin and evolution

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Stellar streams: origin and evolution

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We have made a statistical analysis of the space velocity distribution for stars in the solar neighbourhood. Three large, probably non-random stellar streams were revealed. Those correspond to well-known moving clusters: Hyades, Pleiades and UMa. Small clumps of stars were found within the streams. We have estimated the statistical significance of these groups. We found that massive high-precision data (proper motions, parallaxes and radial velocities) are necessary for studying the fine structure of the streams. Various scenarios for streams formation are discussed: the decay of open clusters, the presence of superclusters, and the perturbations from spiral arms. The evolution of streams in a smoothed Galactic gravitational field is studied. We take into account the interactions between stream stars and giant molecular clouds (GMC). The dependence of the lifetimes of four streams on the adopted stream size r_c in coordinate space were estimated. When $r_c = 200$ pc, the mean lifetime is about 1 Gyear. Interactions with GMCs can shorten the mean lifetimes by as much as a fifth.

Keywords: Moving clusters; Search for the origin; Evolution

The first indications of stellar moving groups were made in the middle of the nineteenth century [1–3]. The numerous papers by Kholopov and by Artyukhina devoted to the search for coronae of open clusters and the papers by Eggen concerning the kinematic groups and superclusters (see the references in Kholopov's [4] book) should also be noted. In recent years, many workers have tried to search for moving clusters using different mathematical approaches (a short review of these efforts was given in [5]).

Amongst the methods employed to search for moving clusters, we can mention the convergent-point method [6], cluster analysis [7], the spaghetti method [8] and wavelet analysis [9]. A few moving clusters were found using different techniques. Amongst these, we can mention the following:

(i) Hyades (heliocentric space velocities $(U, V, W) = (-42, -18, -1)\ \mathrm{km\,s^{-1}}$);
(ii) Sirius supercluster ($(U, V, W) = (+14, +3, -8)\ \mathrm{km\,s^{-1}}$);
(iii) Pleiades ($(U, V, W) = (-12, -22, -6)\ \mathrm{km\,s^{-1}}$);
(iv) Supercluster IC 2391 ($(U, V, W) = (-25, -16, -3)\ \mathrm{km\,s^{-1}}$).

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There are also other moving groups; however, sometimes their reliability is in doubt.

Some researchers have revealed a fine structure (subclustering) in the moving clusters (see, for example, [9]). However, these subgroups may be random fluctuations inside large structures (see the discussion in [10]). Using the maximum-density method, we have found 24 subgroups among three large streams. Many of these groups may be accident clumps.

As for formation of moving clusters, a few scenarios can be suggested:

(i) the disruption of open clusters [11];
(ii) the presence of superclusters [12];
(iii) the perturbations from spiral arms [13].

In the first scenario, the stars that have escaped will have a small velocity dispersion, so that they can form a moving group for a long time. The moving group will dissolve in a smoothed Galactic field owing to its tidal force and to encounters with giant molecular clouds (GMCs).

We have estimated the dependence of the disruption times on the adopted critical radius r_c of a cluster and initial velocity dispersion for three Galactic models. The results are shown in table 1. The initial positions of the group centres were set in the Sun position; their space velocities were adopted as those for four actual groups. The disruption times were estimated as the average times of star ejection outside the radius r_c from the cluster centroid. These times strongly depend on r_c.

The interactions with GMCs cause these times to be shortened by up to a fifth (table 2). Therefore, the GMCs could strongly influence the disruption of the star clusters and co-moving stellar streams.

Table 1. Mean times (and their rms deviations) of moving-group disruption (the initial velocity dispersion is 1 km s^{-1} and the initial radius of a group is 20 pc).

	Mean time (10^2 Myears) for the following groups				
r_c (pc)	Hyades	Pleiades	UMa	HR 1614	Model
50	0.98 ± 11	1.05 ± 11	1.16 ± 24	0.97 ± 7	Kutuzov and Ossipkov [14]
100	2.7 ± 2	3.7 ± 4	4.9 ± 1.8	3.1 ± 2	
200	7.0 ± 7	10.4 ± 1.9	8.1 ± 1.6	8.8 ± 6	
400	14.4 ± 1.3	21.1 ± 3.4	15.6 ± 3.0	16.4 ± 1.1	
50	1.27 ± 16	1.42 ± 19	1.24 ± 15	1.22 ± 11	Flynn *et al.* [15]
100	3.9 ± 4	5.0 ± 5	8.9 ± 4.2	3.7 ± 2	
200	12.2 ± 1.2	19.3 ± 4.2	12.5 ± 1.9	9.5 ± 6	
400	18.0 ± 1.4	29.1 ± 3.4	24.2 ± 3.8	21.5 ± 1.7	
50	1.21 ± 19	0.90 ± 6	0.80 ± 7	1.00 ± 8	Allen and Santillan [16]
100	2.6 ± 4	3.7 ± 6	3.8 ± 8	3.2 ± 2	
200	6.6 ± 6	14.3 ± 3.3	6.5 ± 7	8.3 ± 6	
400	19.8 ± 2.1	20.8 ± 3.2	16.7 ± 1.6	15.6 ± 1.2	

Table 2. Comparison of results with and without GMCs for Hyades.

	Mean time (10^2 Myears)	
r_c (pc)	Without GMCs	With GMCs
50	0.98 ± 11	0.53 ± 11
100	2.74 ± 22	1.00 ± 2
200	7.0 ± 7	1.68 ± 3
400	14.4 ± 1.3	2.61 ± 5

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Thus, modern statistical methods allow us to reveal probably non-random star clumps in velocity space: moving groups. A few small local clumps may be random density fluctuations on the background of large stellar streams. Typical disruption times of moving groups in a smoothed Galactic field are approximately a few gigayearss (the effect of GMCs shortens these times by up to a fifth).

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