АСТРОФИЗИКА

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ON THE EXPANSION OF STELLAR ASSOCIATION PER OB2

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The analysis of the proper motions of bright members of the Per OB2 association on the basis of Hipparcos high-accuracy astrometric observations is presented. The existence of two different subgroups of OB-stars in the Per OB2 association are considered being in the state of expansion. The expansion ages are calculated as 1.3 and 1.9×10^6 years. The membership of the observed OB-stars to these subgroups is considered.

1. *Introduction.* The discovery of stellar associations by Ambartsumian [1,2] has shown that one of the unexpected and mysterious peculiarities of new stellar systems is the unusual character of motions in them. An analysis of the forces acting in stellar associations carried out by him has revealed that the stellar motions in associations differ from motions in other known stellar systems.

The motions of stars in the known stellar systems, for example in open star clusters, are conditioned mainly by the influence of the center of gravity. Under this influence all stars of the cluster are rotating around its center.

The tidal influence of the differential rotation of the Galaxy on star clusters is comparatively small because of the high stellar density and limited sizes of them.

Only owing to rare close encounters of stars in the cluster their velocities can be changed essentially. As a consequence of the close encounters of stars during their motions around the center from time to time some stars in the cluster gain the velocities which exceed the escape velocity and leave the cluster. This continuous process being repeated for many times brings to the disintegration of the cluster (Ambartsumian [3]).

The situation is quite different in stellar associations. Because of low stellar density the mutual gravitational forces between stars in these systems are not sufficient to keep them together around the gravity center for a long time. As a result the stellar associations must be expanding. It means that stellar associations have to disintegrate for a short period of time, compared with the age of the Galaxy.

The fundamental result obtained by Ambartsumian [1,2] in fact was the prediction of a quite new phenomenon, of new type of stellar motions, which were unknown in stellar dynamics: motions of stars away from the maternal regions of their formation.

In his study of the expansion phenomenon in stellar associations Ambartsumian [1,2] has accepted, that these systems are expanding with velocities about 5-10 km/s, in order to account for the shapes of the approximately spherical associations, where the influence of expanding motions apparently predominates the effect of differential galactic rotation. Taking into account that the diameters of the OB-associations are of the order of 100pc, for upper limit of the kinematic ages of these systems he obtained 10^7 years.

The first investigations of the observed star motions in stellar associations began just after the theoretical prediction of their expansion. They were based on the proper motions of stars-members of OB-associations.

The Per OB2 (Per II) association was the first group in which a reliable expansion gradient was found. Blaauw [4] obtained an expansion age 1.3×10^6 yr for this association. Soon after Delhaye & Blaauw [5], using improved proper motions, revised the age estimate to 1.5×10^6 yr.

Lesh [6] studying kinematics of the Gould Belt on the basis new proper motions confirmed expansion of this association with the expansion age 1.3×10^6 yr.

Later on observational testimonies have been obtained testifying the expansion of other nearest OB-associations (see, for example, Mirzoyan [7]). All of them were based on the proper motions of stars - members of the OB-associations. The majority of these investigations confirmed the run away motions of stars from their "maternal" nuclei in stellar associations.

In a few papers on this subject, however, the results contradicting the expansion of OB-associations have been obtained. For example, the conclusion made by Blaauw & Morgan [9] on the expansion of the OB-association in Lacerta was disputed by Wooley and Eggen [8].

Blaauw [10] returning to this question has found telling arguments against the criticism of the above mentioned authors. Later on Blaauw [11] discussing the proper motions of stars in the Upper Scorpio subassociation has shown that they indicate on the expansion if were determined with enough high accuracy.

The data in favor of the expansion of OB-associations have been obtained by Keller [12] in a detailed study of star motions in 47 OB-associations carried out on the base of both proper motions and radial velocities.

These remarkable results were the observational establishments of expansion of stellar associations, as stellar systems, really possess dynamical instability and therefore disintegrating for only a dozen million years. This is too short time compared with the age of the Galaxy. It means, that the stellar associations are, as it was predicted, very young stellar systems in the Galaxy where the star formation process is still continuing.

In the framework of the Hipparcos astrometry mission (Perryman et al [13]) a scientific proposal was accepted with the aim to obtain high-quality astrometric data (positions, proper motions and parallaxes) of bright members in some nearest OB-associations. In this paper we present the results of the analysis concerning the Per OB2 association.

2. *The Hipparcos data analysis and discussion.* The Hipparcos mission was the first space experiment dedicated to astrometry, launched in August 1989 and terminated on 15 August 1993.

The products of the Hipparcos mission are two major astrometric catalogues, the Hipparcos Catalogue and Tycho Catalogue [14,15]. For the Hipparcos Catalogue (HIP), the Hipparcos Input Catalogue (HIC) (Turon et al. [16]) was necessary for the observations, which represented a compilation of ground based available data. Owing to this mission it was possible to acquire high quality astrometric data (positions, annual proper motions and absolute parallaxes, at level of around 1 miliarcsec) for over 120 000 stars.

For the Per OB2 association region, in the framework of our proposed programe, 17 known members - OB-stars were observed. Among them there are 8 multiple systems, some components of which also were observed. Thus, in our analysis we have used available data of 22 stars.

In Table 1 are presented a combined data of these stars taken from catalogues HIP and HIC, where in the corresponding columns submitted postions, paral-

Table 1

ASTROMETRIC AND ADDITIONAL PARAMETERS OF STARS IN THE PER OB2 ASSOCIATION ACCORDING TO HIP AND HIC DATA

Star		Positions						Parallaxes		Proper motions				V_r	Group
HIP	Other	R.A. (2000)			Dec (2000)			π	σ_π	$\mu_\alpha\cos\delta$	σ_{μ_α}	μ_δ	σ_{μ_δ}		
№	name	(^{h})	(^{m})	(^{s})	(^{0})	(′)	(″)	mas	mas	masyr^{-1}	masyr^{-1}	masyr^{-1}	masyr^{-1}	kms^{-1}	
16203		3	28	46.65	30	22	31.3	1.60	1.05	-1.78	1.09	-9.88	1.09	-4.8	I
16518		3	32	40.02	35	27	42.2	1.99	0.82	-6.72	0.86	3.66	0.80	25.0	I
17313	40 Per	3	42	22.64	33	57	54.1	3.53	0.88	4.39	0.96	-5.21	0.87	22.3	I
17387		3	43	24.01	34	6	58.5	2.09	0.93	4.83	1.08	-3.38	0.91	28.2	I
17448	Ø Per	3	44	19.13	32	17	17.8	2.21	0.84	8.11	0.83	-10.32	0.78	18.5	I
17448[a]		3	44	19.16	32	17	18.7	2.21	0.84	8.11	0.83	-10.32	0.78	-	I
17465		3	44	34.19	32	9	46.2	4.52	3.30	1.12	3.46	-9.43	3.91	14.0	II
17465[b]		3	44	34.20	32	9	46.8	4.52	3.30	1.12	3.46	-9.43	3.91	-	II
17465[b]		3	44	35.35	32	10	4.7	4.52	3.30	1.12	3.46	-9.43	3.91	-	II
17631		3	46	40.87	32	17	24.7	4.19	1.03	8.08	0.78	-8.03	0.68	-	I
17735		3	47	52.66	33	35	59.6	2.63	1.00	4.41	1.04	-4.45	0.85	20.0	I
17735[c]		3	47	52.72	33	36	2.8	2.63	1.00	4.41	1.04	-4.45	0.85	-	I
18081		3	51	53.72	34	21	32.9	3.15	0.84	4.28	0.68	-4.22	0.58	16.9	I
18111		3	52	18.96	34	13	19.6	2.04	1.00	4.31	0.88	-4.93	0.66	13.0	I
18246	ζ Per	3	54	7.92	31	53	1.2	3.32	0.75	4.41	0.88	-9.15	0.69	20.3	II
18350	X Per	3	55	23.08	31	2	45.1	1.21	0.94	-1.99	0.91	-4.51	0.88	15.0	
18434		3	56	28.69	35	4	51.3	3.36	0.76	2.56	0.67	-3.96	0.58	17.4	II
18614	ξ Per	3	58	57.90	35	47	27.7	1.84	0.70	1.92	0.74	2.30	0.62	67.1	II
19039		4	4	43.07	32	34	16.4	4.19	0.97	6.58	1.04	-10.54	0.89	29.9	II
19178		4	6	39.04	32	23	6.3	2.78	0.95	5.42	0.76	-4.25	0.76	20.0	II
19201	AG Per	4	6	55.82	33	26	47.0	3.89	1.31	4.41	1.50	-6.55	1.38	15.8	II
19201[d]		4	6	55.78	33	26	46.4	3.89	1.31	4.41	1.50	-6.55	1.38	-	II

[a] Component B of double system CCMD 03424+3358 [17]
[b] B and C components of triple system CCDM 03446+3210 [17]
[c] Component B of double system CCDM 03479+3336 [17]
[d] Component B of triple system CCDM 04069+3327 [17]

laxes, proper motions with probable errors and radial velocites.

There are two classical methods for deriving kinematical age of association on the basis of observations of proper motions of members (for discussion, see Brown et al [18]). First, the proper motion in a certain direction is plotted versus the corresponding coordinate and then the linear expansion coefficient is measured to derive the kinematic age (Blaauw [10]). Second, the proper motions of stars are traced back in time to the smallest configuration in the past (Blaauw [11]).

Following to the method described in the paper Blaauw [4], these 22 OB-stars have been used in least-squares solutions for $\mu_\alpha \cos\delta$ vs $\alpha\cos\delta$, and μ_δ vs δ. In these solutions each star was weighted according to the inverse square of the probable error of its proper motion component. The results are given in Fig.1, where the symbols have the following meaning: k_α is the gradient in right ascen-

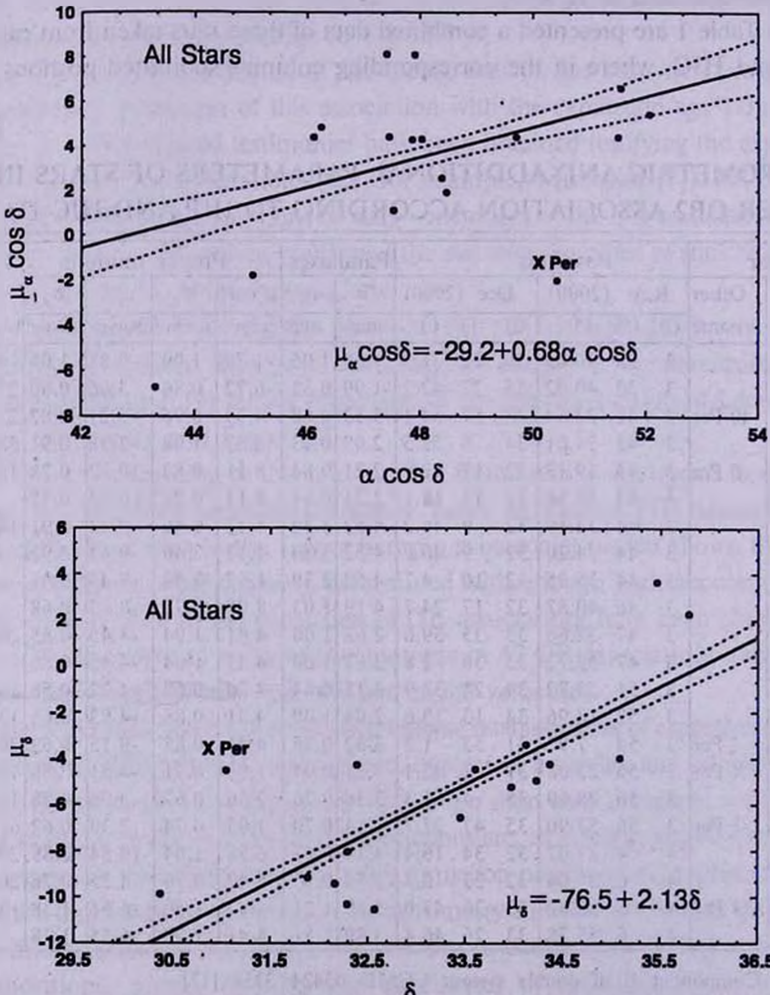

Fig. 1: Linear relations between the proper-motion components and the corresponding coordinates for stars Per OB2 association. The dashed lines indicate 95% confidence level.

sion and k_δ the gradient in declination. The weighted mean of these two estimates after the correction for projected radial motion was used (see Blaauw [4]) for estimation of the expansion age.

It should be added that in the case spherically symmetric linear expansion of the association there must be coincidence of the values of above mentioned gradients in both directions within the errors limits of them.

As it seen from Fig.1 this is not in the case, and therefore it is likely that some real deviations are present, still noted in the paper by Lesh [6]. The difference in the solutions is large, even after the remonal of some most highly deviated points.

One of such points regards to the double system X Per, having trigonometric parallax 1.21 mas, and most probably not belonging to the Per OB2 association. This is obviously seen also in the Fig.2, where the motions of stars are presented, preliminary removing the mean proper motion vector of the association.

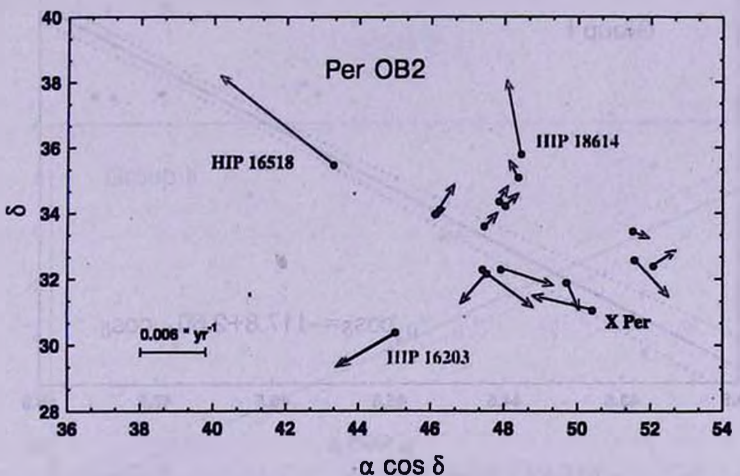

Fig. 2: Proper motions of stars of the OB-associations (Persei OB2), observed near the star ζ Persei, relative to the centre of the system, on the basis Hipparcos observations. The lengths of arrows correspond to the proper motions of stars.

The disagreement between gradients k_α and k_δ and the observed picture presented in Fig.2 allowed us to suppose on the existence of two different subgroups of OB-stars in the Per OB2 association, i.e. there are two centers of expansion, which is clearly distinguishible. The members of them are indicated in Table 1 correspondingly denoted by roman numbers first and second. For each group the least-squares solutions have been obtained for the both directions (in right ascension and declination) and the inverse quantities of errors of the proper motions as weights have been used. The results are presented in the Table 2 and in Fig.3 and 4.

As it seen from Table 2 and Fig.3 and 4, the correlation between proper motions and corresponding coordinates became more tighter and disagreement between k_α and k_δ more or less was removed (for the first group completely).

Table 2

THE ESTIMATED PARAMETERS OF THE SUBGROUPS OF OB-STARS IN THE PER OB2 ASSOCIATION BASED ON THE HIP DATA

Group	d_{mean} (pc)	$d_{med.}$(pc)	V_r^{mean} (km/s)	$V_r^{med.}$ (km/s)	k_α	k_δ	T_{exp}x10^6
I	308	283	17.4	19.2	2.60	2.63	1.3
II	278	257	26.4	20.0	0.92	2.37	1.9
All	292±70	283	21.6±14.9	20	0.68	2.13	2.2

3. *Conclusions.* The reliable expansion of Per OB2 association is confirmed on the basis of high accuracy astrometric Hipparcos data. Most probably there are two different subgroups of OB-stars being in the state of expansion with

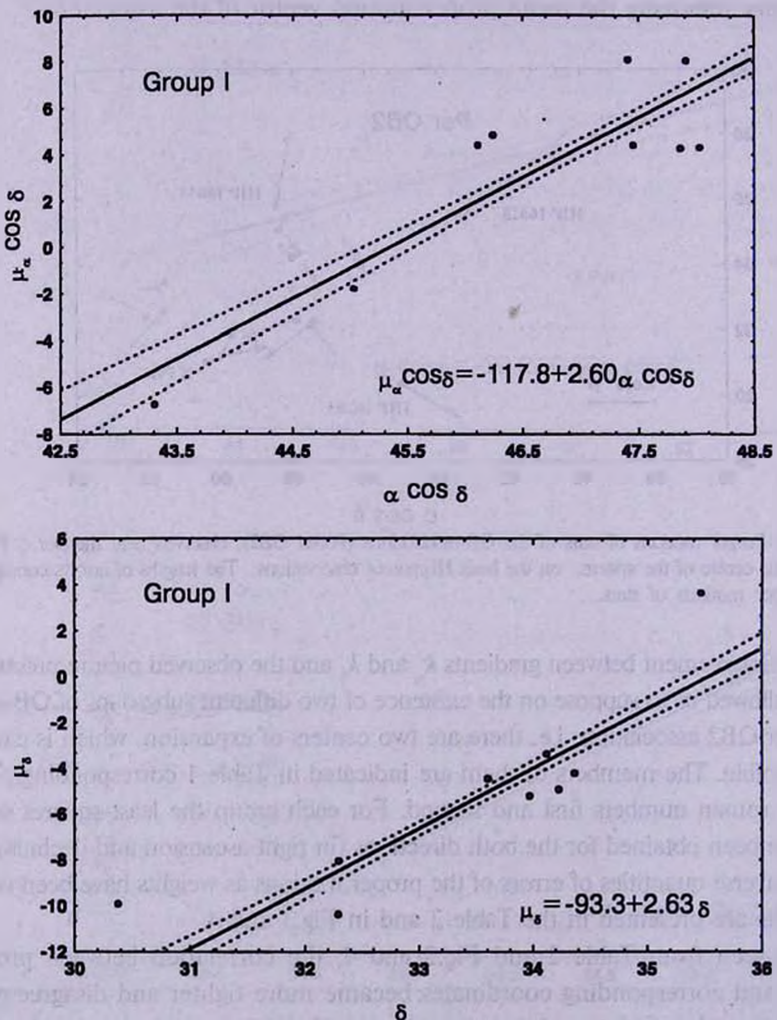

Fig. 3: Linear relations between the proper-motion components and the corresponding coordinates for stars of Group I of the Per OB2 association. The dashed lines indicate 95% confidence level.

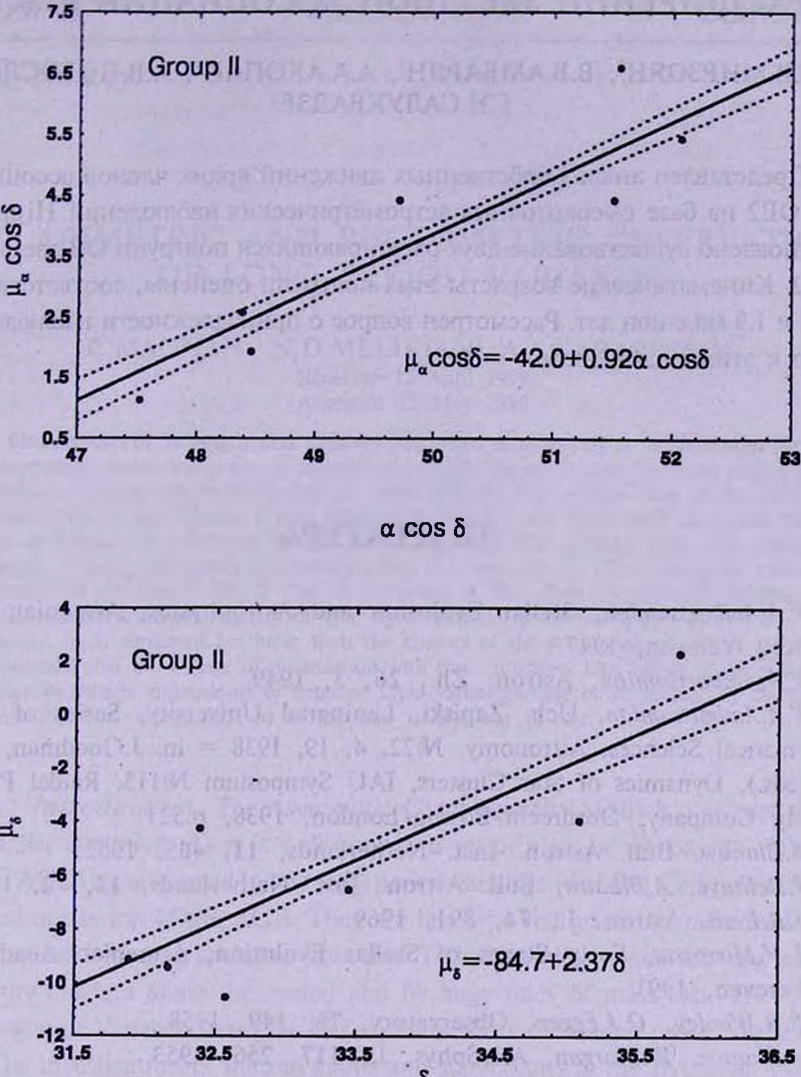

Fig. 4: Linear relations between the proper-motion components and the corresponding coordinates for stars of Group II of the Per OB2 association. The dashed lines indicate 95% confidence level.

calculated ages 1.3 and 1.9 million years. HIP 16518 and HIP 18614=ξ Per can be considered as run away stars from Per OB2 association.

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О РАСШИРЕНИИ ЗВЕЗДНОЙ АССОЦИАЦИИ PER OB2

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Представлен анализ собственных движений ярких членов ассоциации Per OB2 на базе высокоточных астрометрических наблюдений Hipparcos. Установлено существование двух расширяющихся подгрупп ОВ звезд в Per OB 2. Кинематические возрасты этих подгрупп оценены, соответственно, в 1.3 и 1.9 миллион лет. Рассмотрен вопрос о принадлежности наблюденных звезд к этим подгруппам.

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