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On the possible existence of different populations in the double cluster h and χ Persei

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Astrofisica. — *On the possible existence of different populations in the double cluster h and χ Persei.* Nota [(*)] di PIERO GALEOTTI, GIOVANNI SILVESTRO e EDOARDO TRUSSONI, presentata dal Socio G. WATAGHIN.

RIASSUNTO. — Sulla base di nuovi dati osservativi di velocità radiali, moti propri e distanze delle stelle supergiganti appartenenti all'ammasso doppio *h* e χ Persei, si mette in evidenza la possibile esistenza di diverse popolazioni, con età differenti. Si discute la struttura cinematica dell'ammasso.

1. INTRODUCTION

The galactic double cluster *h* and χ Persei has been investigated by various Authors (see Stothers (1969) for a general discussion including references to earlier works), from the point of view of both its dynamical and spatial structure and its implications on the problem of direct $e - \nu$ coupling.

The structure of the association proposed by Schild (1967) implied different ages and distances between the two clusters *h* and χ Persei. This seemed to agree with earlier proper motion measurements by Meurers and Aksoy (1960), who obtained a difference $\Delta\mu_\alpha = -0''.0034 \pm 0''.0004$, $\Delta\mu_\delta = 0''.0004 \pm 0''.0005$ in the annual proper motion of χ Persei compared with that of *h* Persei and the background. However, subsequently more precise measurements by Lavdoskii (1965), including a larger number of stars, gave identical proper motions for both clusters ($\Delta\mu_x = -0''.0002 \pm 0''.0002$, $\Delta\mu_y = 0''.0001 \pm 0''.0002$ between *h* and χ in one year), and concluded that *h* and χ Persei must belong to a unique system, physically connected. An analysis of radial velocities alone (Gahm and Arkling, 1971) also does not support the structure of the cluster as proposed by Schild. Recent observations by Crawford, *et al.* (1970) on the B stars of *h* and χ Persei gave a difference $\Delta m \lesssim 0.1$ in distance moduli between the two clusters; this confirms that they are located at nearly the same distance, and does not agree with the conclusions of Schild, who estimated $\Delta m \approx 0.34$.

These new observational data, together with the analysis by Bronnikova (1968) of its H—R diagram, have reopened the problem of interpreting the structure of the cluster. In an earlier paper, the Authors (Ferrari, *et al.*, 1970) pointed out, on the basis of proper motions alone, the lack of a genetic correlation between the supergiants in *h* and χ Persei, due to the possible existence of at least two distinct populations. We shall here discuss the absolute motion of the individual supergiants and the stellar content of the cluster, taking into account the above mentioned data.

(*) Pervenuta all'Accademia il 16 settembre 1971.

2. KINEMATIC ANALYSIS

We present in Table I a list of those supergiants in *h* and χ Persei, whose radial velocities, proper motions and distances are known (these parameters are the basic criteria to decide whether a star belongs to a cluster). The radial velocities are those given by Humphreys (1970), measured at Kitt Peak from infrared spectra, which agree reasonably well with recent measurements by Gahm and Arkling (1971). The distances are those given by Humphreys (1970), corrected for interstellar extinction, determined on the basis of spectroscopic absolute magnitudes. The proper motions are from high-precision measurements made at Pulkovo by Lavdoskii (1961, 1965).

TABLE I

Absolute velocities of supergiant stars in h and χ Persei.

n.	Oo. No.	Class	V_x	V_y	V_z	V	R (kpc)	Sp.
1	899	I	− 2.7	+18.7	−45.9	49.6	1.87	M4 Ib
2	1655	II	+ 12.1	+36.3	−47.0	60.6	2.13	M2 Iab
3	1818	II	+ 17.9	+28.4	−47.6	58.2	2.22	M1 Ia Ib
4	2417	I	+ 4.2	+32.5	−39.9	51.6	2.98	M4 Iab
5	2691	I	− 8.3	+15.4	−45.5	48.7	2.50	M0 Ia Ib
6	2758	III	− 19.0	+69.6	−49.3	87.4	2.67	M0 Ia Ib
7	SUPer	I	− 2.2	+26.4	−38.7	46.9	2.32	M3 Ia Ib
8	HD14826	II	− 45.6	− 7.6	−42.8	63.0	2.29	M2 Ia Ib
9	3	II	+ 20.9	+41.8	−39.0	60.9	2.32	B2 Iab
10	16	II	+ 22.1	+26.3	−40.2	52.9	2.22	B1 Iab
11	662	I	− 15.2	+31.8	−41.0	54.1	2.91	B1 Ib
12	1057	III	− 43.7	+19.0	−43.7	64.7	2.00	B3 Ia
13	2227	III	− 44.2	−35.1	−40.0	69.2	2.74	B2 Ib
14	2589	IV	−111.9	−37.3	−53.5	129.5	3.93	A2 I
15	1162	IV	− 36.9	−36.9	−41.7	66.8	1.91	B2 Ia
16	2178	IV	− 75.2	−37.6	−46.7	96.2	2.64	A1 Ia
17	2621	IV	− 89.4	0.0	−47.4	101.2	2.69	B8 Ia
18	HD14818	IV	−139.6	+59.8	−46.0	158.7	2.10	B2 Ia

Column (2): number in Oosterhoff list (Oosterhoff P. T., « Ann. Sterre. Leiden », *17*, 5 (1937)), or others; column (3): class according to Bronnikova (1968): I) reliable cluster member; II) probably cluster member; III) probably background star; IV) definitely background star; columns (4), (5), (6), (7): velocity in km/sec; column (8): distance R according to Humphreys (1970); column (9): spectral type.

Fig. 1.

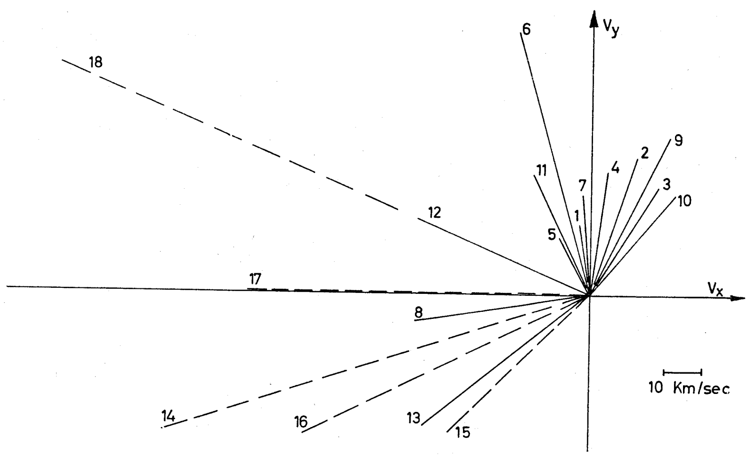
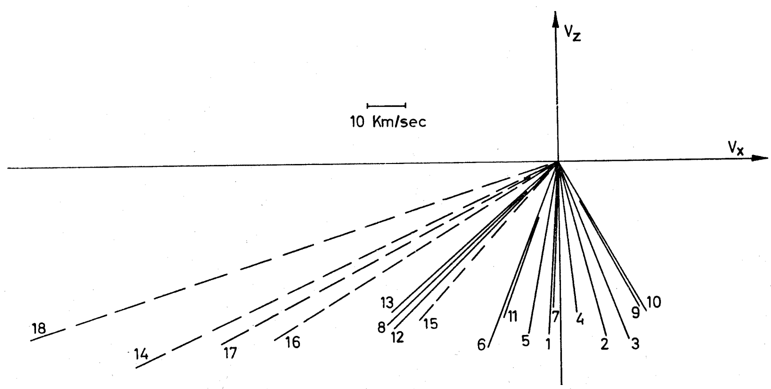


Fig. 2.



We think that Table I gives a complete sample of all the supergiants in *h* and χ Persei for which one can evaluate the absolute velocities.

Figs. 1, 2 and 3, give the velocity projections onto the three fundamental planes (the z–axis is in the radial direction); the dotted lines refer to those supergiants in the blue elbow, classified by Bronnikova (1968) as class IV stars (see caption to Table I), that should not belong to the cluster.

The most uncertain parameter is clearly the distance of the individual supergiants; indeed, Humphreys' (1970) values show a large dispersion (from 1.9 to 3 kpc, with one star at 3.95 kpc), and seem not to give evidence for a double structure of the cluster, as proposed

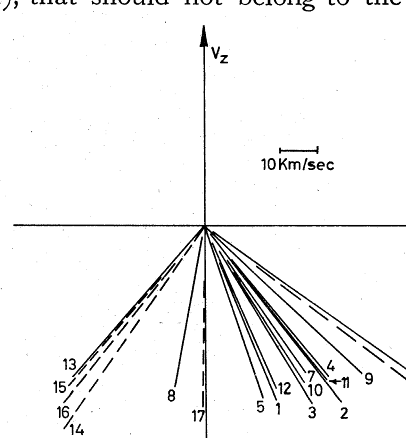


Fig. 3.

Figs. 1, 2 and 3. – Vector diagram of velocities of supergiant stars in *h* and χ Persei. Full line vectors: stars of classes I, II, III; dotted line vectors: stars of class IV.

by Schild (1967). On the other hand it is well known that a reliable distance estimate for each supergiant is very difficult; in order to estimate the sensitivity of the results to the distances used, we made a new evaluation of the tangential velocities, assuming, according to Schild (1967), a distance

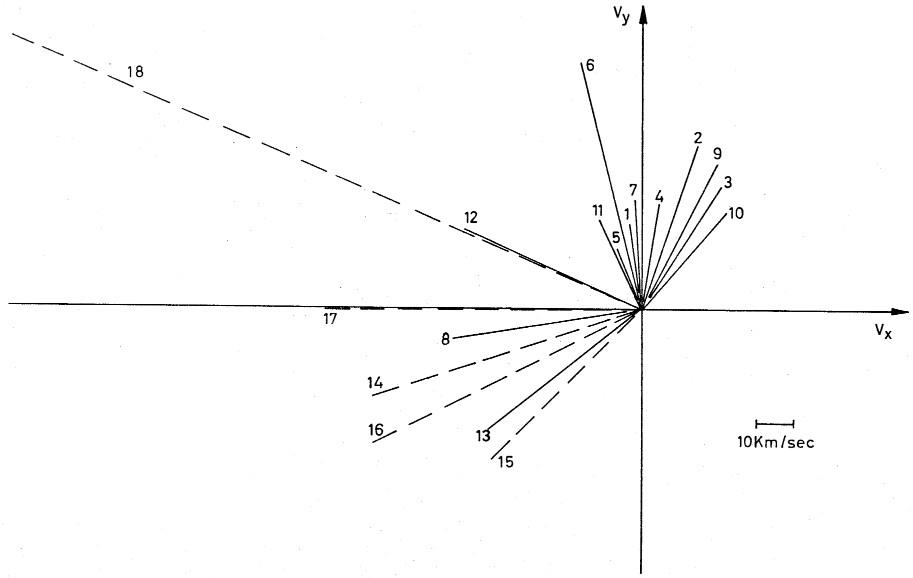


Fig. 4. – Tangential velocities (as fig. 1), assuming a mean distance for the stars in *h* Persei (2.15 kpc), and χ Persei plus inner group (2.5 kpc).

2.5 kpc for the stars in χ Persei and the inner group, and 2.15 kpc for the stars in *h* Persei. The results are shown in fig. 4, and one can see that the velocity distribution is not appreciably modified. We can thus conclude that the distance estimates, although very uncertain, do not affect the kinematics of the cluster.

3. DISCUSSION

The limited statistics of supergiant in Table I does not allow to identify the complex spatial structure of the cluster, but one can however draw some conclusions on its stellar populations content. Inspection of figs. 1, 2 and 3 shows that some supergiants (no. 8, 12, 13), classified by Bronnikova as class II and III are more likely to belong to class IV; the class III supergiant n. 6 should be in our opinion of class I or II, in spite of its large μ_y. Furthermore, it seems that stars of classes III and IV do not display an isotropic velocity distribution; rather one can define a preferential velocity direction, as for classes I and II (with the exception of star no. 18 in the V_y — V_z plane). The lack of isotropy in the velocity distribution of the supergiants of the blue elbow, considered by Bronnikova as background stars of class IV, leads us, in spite of the limited statistics, to think that the massive and very bright supergiants could actually belong to a very young population in the cluster. We notice that Schild himself (1970, Table 4) suggested a correlation between the age of a populations and the number of its red supergiants, according to which these are found only in intermediate and late clusters. One could thus distinguish three populations, as already suggested by Wildey (1964) on the basis of the H—R diagram alone, in *h* and χ Persei (and this could be confirmed by the observed rather large thickness of its main sequence):

a) a very young population (Schild's type D), including the supergiants in the blue elbow, the supergiant HD 14826, and probably YZ Persei (no proper motion available; $M \sim 27 M_{\odot}$ from the period-mean density relation if it oscillates on the fundamental mode). We notice that HD 14826, YZ Persei and the anomalous case RS Persei are the most luminous red supergiant in the bolometric H—R diagram and can thus be connected with the youngest and most luminous blue population;

b) an intermediate population (Schild's types B and C), to which belong the supergiants in the " branch with the hollow ", and the most luminous red supergiants;

c) an older population (Schild's type A or older), including the evolved main sequence and the lowest region of red supergiants.

The two last populations cannot be distinguished on the basis of their velocity alone, and were previously discussed by Ferrari, *et al.* (1970), who pointed out that different populations can be mixed in the red supergiant region.

One could recall that evidence for the existence of several populations in an association was given previously: a well known and significant example is I Ori (Blaauw, 1964), where one can see at least three populations.

Schild (1967) gave evidence for a difference in age between the stars in *h* and those in χ Persei; however, Crawford, *et al.* (1970) do not find any difference in location and age between the stars in *h* and χ. The scheme we are presenting, in agreement with the results of Crawford, *et al.*, suggests that each of the three populations is distributed almost evenly in both clusters.

In addition, the probable existence of three populations in the double cluster *h* and χ Persei arises serious objections on the validity of any statistical analysis of young galactic clusters. Indeed *h* and χ Persei plays a crucial role in any statistical analysis of galactic clusters, since it contains the majority of supergiants belonging to them. Thus a comparison between the ratios n_b/n_r and τ_b/τ_r seems to have a rather uncertain meaning. One could only estimate a ratio $n_b/n_r \sim 4\text{–}5$ for the youngest population; this ratio, taken at face value, would seem to agree with the existence of the direct $e — \nu$ coupling.

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