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Red giants in open clusters⋆,⋆⋆

XIV. Mean radial velocities for 1309 stars and 166 open clusters

J. C. Mermilliod[1], M. Mayor[2], and S. Udry[2]

[1] Laboratoire d'Astrophysique de l'École polytechnique fédérale de Lausanne (EPFL), Observatoire, 1290 Versoix, Switzerland
e-mail: Jean-Claude.Mermilliod@epfl.ch
[2] Observatoire de Genève, 51 Ch. des Maillettes, 1290 Sauverny, Switzerland

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ABSTRACT

Context. Radial velocities have proved to be an efficient method for membership determination if there are at least 2 or 3 red giants in a cluster. They are necessary for galactic studies, but are still missing for many open clusters.
Aims. We present the final catalogues of a long-term observing programme performed with the two CORAVEL spectrovelocimeters for red giants in open clusters. The main aims were to detect spectroscopic binaries and determine their orbital parameters, determine the membership, and compute mean velocities for the stars and open clusters.
Methods. We computed weighted mean radial velocities for 1309 stars from 10 517 individual observations, including the systemic radial velocities from spectroscopic orbits and for cepheids.
Results. The final results are contained in three catalogues collecting 10 517 individual radial velocities, mean radial velocities for 1309 red giants, and mean radial velocities for 166 open clusters among which there are 57 new determinations. We identified 891 members and 418 non-members. We discovered a total of 288 spectroscopic binaries, among which 57 are classified as non-members. In addition 27 stars were judged to be variable in radial velocities and they are all red supergiants.
Conclusions. The present material, combined with recent absolute proper motions, will permit various investigation of the galactic distribution and space motions of a large sample of open clusters. However, the distance estimates still remain the weakest part of the necessary data. This paper is the last one in this series devoted to the study of red giants in open clusters based on radial velocities obtained with the CORAVEL instruments.

Key words. Galaxy: open clusters and associations: general – techniques: radial velocities – stars: late-type

1. Introduction

Studies of the open-cluster population is very demanding on observational data. Due to the development of the CCDs, photometric data have been obtained for a large number of clusters. Astrometric data of unprecedented precision are now available thanks to the Hipparcos satellite. The Tycho-2 mission (Hog et al. 2000) and UCAC 2.0 (Zacharias et al. 2004) catalogues provide proper motions for a significant number of open clusters.

Hron (1987) published a compilation of mean radial velocities for 105 open clusters. More recently, Dias & Lepine (2005) collected mean velocities for 234 clusters, and claimed that mean RVs are available only for 13.8% of the known clusters, while proper motions are available for 612 clusters (36.8%). In this context, we provide first radial-velocity determinations for 57 open clusters and improved values for another 19.

Distance, the third parameter needed to compute precise space velocities, is still the weakest component. Although the principle of the determination is simple, the large differences between various existing sets show that determining this fundamental parameter is not obvious. Consequently, there are presently no homogeneous and reliable set of distances, although it would be highly desirable to have one.

The general observing programme with the CORAVEL instruments was undertaken to determine the membership of red giants to their parent cluster, to determine the binary frequencies, and when possible to obtain orbital elements for the spectroscopic binaries. One of the important astrophysical aims of the programme was to study the evolution patterns in the red-giant region of the colour−magnitude diagram on the basis of the membership determination and binary detection. This topic was addressed in several papers of this series, see for example Mermilliod & Mayor (2007) and Girardi et al. (2000b).

Summary of the spectroscopic-binary studies has recently been submitted to A&A. Mermilliod et al. (2007) present new and updated orbital elements for 86 spectroscopic binaries observed from La Silla (Chile) and for 70 binaries observed at the Haute-Provence Observatory (France). Finally, Mermilliod & Mayor (?) analysed the distributions of orbital elements on the basis of 134 spectroscopic-binary members.

This paper is the last one in the series devoted to the study of red giants in open clusters by means of accurate radial velocities

⋆ Based on observations collected at the Haute-Provence Observatory (France) and on observations collected with the Danish 1.54-m telescopes at the European Southern Observatory, La Silla, Chile.
⋆⋆ Full Tables 2 to 5 are only available and Tables 6 and 7 are also available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via
http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/485/303

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obtained with the CORAVEL instruments (Baranne et al. 1979). We summarise the long-term observing programme conducted between 1978 and 1997. We present and make publicly available three major catalogues containing (1) the 10 517 individual measurements for 1309 different stars in the field of 187 galactic open clusters, (2) the mean radial velocities for these 1309 stars, and (3) the mean radial velocities for 166 open clusters.

2. Observations

The observations used in this paper result from a systematic observing programme covering both hemispheres. The decommissioning of the instruments in 1997 put an end to the observing campaigns. The observations in the northern hemisphere were made with the photoelectric scanner CORAVEL (Baranne et al. 1979; Mayor 1985) installed on the Swiss 1-m telescope at the Haute-Provence Observatory (OHP), France, during the 19 years from January 1978 to October 1997.

The radial-velocity observations in the southern hemisphere were made with the second photoelectric scanner CORAVEL mounted on the Danish 1.54-m telescope at ESO, La Silla (Chile), during 13 years from March 1983 to July 1996. The runs were distributed between ESO and Danish time, generously attributed to this long-term program.

The radial velocities were placed on the system defined by Udry et al. (1999), calibrated with high-precision data from the ELODIE spectrograph (Baranne et al. 1996). This new calibration introduced a small change of zero point, which changes the individual and mean velocities previously published by about 0.3−0.5 km s^{-1}. Accordingly, the present data supersede those published before 2001.

The stars were observed as frequently as possible to detect binaries, at least once a year during the first years at the OHP. The observation rate was then adapted to the status: member – non-member, single – binary. Suspected single stars were observed at longer intervals while binaries were monitored more frequently to obtain enough measurements and determine an orbit. Determination of their systemic velocity was often necessary to estimate their membership.

The observations were made by a large number of observers, mostly from the Geneva Observatory. Althogether, J.-C. Mermilliod, M. Mayor, A. Duquennoy, J. Andersen (Copenhagen), and G. Burki contributed to more than 80 percent of the total amount of observations.

3. Previous publications

Table 1 collects names of the clusters already studied and the references of the paper where the results were published. The orbits of 20 spectroscopic binaries were discussed in Paper II (Mermilliod et al. 1989) and VI (Mermilliod et al. 1997a) of this series. The spectroscopic binaries in the southern and northern clusters were discussed by Mermilliod et al. (2007, Paper XIII).

Table 1. Previously published clusters.

Cluster	Reference
IC 2488	Clariá et al. (2003)
IC 2714	Clariá et al. (1994)
IC 4651	Mermilliod et al. (1995), Paper IV
IC 4725	Mermilliod et al. (1987)
IC 4756	Mermilliod & Mayor (1990), Paper III
Ly 6	Mermilliod et al. (1987)
Mel 71	Mermilliod et al. (1997b), Paper VII
NGC 129	Mermilliod et al. (1987)
NGC 752	Mermilliod et al. (1998), Paper VIII
NGC 1817	Mermilliod et al. (2003), Paper X
NGC 2099	Mermilliod et al. (1996), Paper V
NGC 2112	Mermilliod & Mayor (2007), Paper XII
NGC 2204	Mermilliod & Mayor (2007), Paper XII
NGC 2243	Mermilliod & Mayor (2007), Paper XII
NGC 2324	Mermilliod et al. (2001), Paper IX
NGC 2354	Clariá et al. (1999)
NGC 2360	Mermilliod & Mayor (1990), Paper III
NGC 2420	Mermilliod & Mayor (2007), Paper XII
NGC 2423	Mermilliod & Mayor (1990), Paper III
NGC 2447	Mermilliod & Mayor (1989), Paper I
NGC 2477	Eigenbrod et al. (2004), Paper XI
NGC 2489	Piatti et al. (2007)
NGC 2506	Mermilliod & Mayor (2007), Paper XII
NGC 2539	Mermilliod & Mayor (1989), Paper I
	Lapasset et al. (2000)
NGC 2632	Mermilliod & Mayor (1989), Paper I
NGC 2682	Mermilliod & Mayor (2007), Paper XII
NGC 2818	Mermilliod et al. (2001), Paper IX
NGC 3680	Mermilliod et al. (1995), Paper IV
NGC 3960	Mermilliod et al. (2001), Paper IX
NGC 5822	Mermilliod & Mayor (1990), Paper III
NGC 6067	Mermilliod et al. (1987)
NGC 6087	Mermilliod et al. (1987)
NGC 6134	Clariá & Mermilliod (1992)
NGC 6192	Clariá et al. (2006)
NGC 6208	Clariá et al. (2006)
NGC 6259	Mermilliod et al. (2001), Paper IX
NGC 6268	Clariá et al. (2006)
NGC 6633	Mermilliod & Mayor (1989), Paper I
NGC 6649	Mermilliod et al. (1987)
NGC 6664	Mermilliod et al. (1987)
NGC 6811	Mermilliod & Mayor (1990), Paper III
NGC 6940	Mermilliod & Mayor (1989), Paper I
Ru 79	Mermilliod et al. (1987)

4. Catalogues

4.1. 10517 individual radial velocities of red giants

A small part of the present data has been published in previous papers of this series devoted to the analysis of various clusters, mainly those containing more than 8−10 red giants. The present paper provides a complete catalogue of all 10 517 individual radial velocities obtained with the CORAVEL scanners, available in electronic form only at the CDS. The beginning of Table 2 presents the content and column arrangement.

The internal errors are $\epsilon_1 = (\epsilon^2_{\rm ph} + \epsilon^2_{\rm scint} + \epsilon^2_{\rm inst})^{1/2}$ where the subscripts denote photon, scintillation, and instrumental noise, respectively. Here $\epsilon_{\rm inst}$ is the instrumental unavoidable error, even in the absence of photon or scintillation noise:

CORAVEL – OHP	JD < 2 444 700	$\epsilon_{\rm inst}$ = 0.4 km s^{-1}
	JD > 2 444 700	$\epsilon_{\rm inst}$ = 0.3 km s^{-1}
CORAVEL – La Silla		$\epsilon_{\rm inst}$ = 0.2 km s^{-1}.

If we denote by $\bar{\epsilon}_1$ the mean uncertainty of the different measurements of a given star, we can deduce an estimate of the variability by comparing the rms to $\bar{\epsilon}_1$: $E/I = \sigma_{\rm vr}/\bar{\epsilon}_1$. We can also derive the quantity $\chi^2 = \sum_i (v_i - v)^2/\bar{\epsilon}^2_{1i}$ and we have a quantitative estimate of the probability $P(\chi^2)$ that the observed rms is due to random errors.

Table 3 presents general data, i.e. J2000 coordinates, HD and DM identification, and V and $B - V$ photometric data, for

Table 2. Individual radial velocities.

Cluster	No	HJD	*RV*	ϵ_1	Date	Integ	Counts	Obs
Bas 10	0027	2 446 766.342	–34.62	0.36	01 12 1986	893	1651	OHP
Bas 10	0027	2 447 114.438	–31.16	0.38	14 11 1987	925	1842	OHP
Bas 10	0027	2 448 209.492	–30.94	0.33	13 11 1990	1153	2705	OHP
Bas 10	0027	2 448 506.640	–30.33	0.40	06 09 1991	534	1166	OHP
Bas 10	0027	2 448 900.517	–32.37	0.34	04 10 1992	1225	2291	OHP
Bas 10	0027	2 449 687.336	–35.27	0.38	30 11 1994	500	1699	OHP
Bas 10	0027	2 450 428.384	–30.12	0.35	10 12 1996	734	1769	OHP

Note: the columns contain the cluster names, the star identification according to the bibliographic references contained in Table 4, the heliocentric Julian date, the radial velocity, and error in km s^{-1}, the external- to internal error ratio, $E/I = \sigma/\epsilon$, the number of observations used in the UT date of observation, the integration length in [s] and the number of counts, the observation place (OHP for Haute-Provence Observatory of LS for La Silla, Chile), the indication of the component of double-lined spectroscopic binaries (A, B) or visual doubles (1, 2).

Table 3. General information for the programme stars.

Cluster	No	RA	Dec	HD	DM	*V*	$B-V$
Bas 10	0027	2 20 03.04	+58 22 58.7			10.79	2.32
Be 82	0002	19 11 19.31	+13 07 01.0			10.460	2.120
Be 82	0003	19 11 20.42	+13 07 04.9			10.200	1.780
Cr 121	0001	6 54 07.95	–24 11 03.1	50877	–24.04567	3.837	1.737
Cr 121	0028	7 01 43.15	–27 56 05.4	52877	–27.03544	3.469	1.735
Cr 121	0031	7 06 21.44	–26 18 45.3	54605	–26.03916	1.834	0.676

Table 4. References for the numbering systems.

Cluster	Reference
Basel 10	Wooden II, W. H. 1971, A&A, 13, 218
Berkeley 82	Forbes, D. 1986, Publ. Astron. Soc. Pacific, 98, 218
Collinder 223	Claria, J. J., & Lapasset, E. 1991, Publ. Astr. Soc. Pacific, 103, 998
Collinder 258	Moffat, A. F. J., & Vogt, N. 1973, A&AS, 10, 135
Collinder 268	Moffat, A. F. J., & Vogt, N. 1975, A&AS, 20, 155

each star. CORAVEL was working in the blue region of the spectrum and the *B* magnitude is therefore the most relevant to selecting the stars and computing the expected count rates. Most information was found in the database for stars in open clusters (WEBDA, http://www.univie.ac.at/webda/webda.html) or extracted from the UCAC2.0 catalogue (Zacharias et al. 2004) through the VizieR facility offered by the CDS.

Table 4 gives the bibliographic references for the star numbering in each cluster. The references presently used in WEBDA (February 2008) were adopted for all clusters to enable an easy use of WEBDA and facilitate the inclusion of these data in the database.

Tables 2–4 are available in electronic form only at the CDS or through WEBDA. We present here only the very beginning of the tables as examples for their layout and content.

4.2. Mean radial velocities of 1309 red giants

We computed the mean radial velocities for the 1309 stars. The individual errors of the measurements are used to compute weights as $1/\epsilon_1^2$. The estimated internal uncertainty of a radial-velocity measurement is denoted by $\epsilon = \max(\sigma, \bar{\epsilon}_1)/\sqrt{n}$.

The results are collected in Table 5 which is available in electronic form only at the CDS or through WEBDA. We present here only the very beginning of the table as an example of its layout and content.

Stars in northern clusters were observed 5−10 times, while southern red giants received 2−5 observations (Fig. 1). This difference arises because the telescope at OHP was operated full time for CORAVEL observations. In contrast, observing runs at La Silla were always discrete, short runs (5−6 nights per periods). The adopted minimum integration time was 180 s, which was usually sufficient for reaching the required precision on the radial velocity. However, values of 300, 600, or even 900 s were also used, as shown by the secondary peaks in the integration-time distribution (Fig. 2).

The distribution of $P(\chi^2)$ (Fig. 3) is flat as expected and proves that the values of ϵ_1 were correctly estimated. The high peak for $P(\chi^2) = 0.0$ corresponds the numerous spectroscopic binaries discovered. Only the stars with a $P(\chi^2)$ value equal to 0.000 have been considered as binaries. Stars with values below 0.003 are considered as candidate binaries (SB?).

4.3. Mean radial velocities of 166 open clusters

The mean radial velocities of the open clusters and information on membership are collected in Table 6. The status of the radial velocities is indicated in the last column (Notes). *New* means that no mean values were published before or exists in the literature. *Updated* means that a value for the cluster mean radial velocity based on CORAVEL observations was published in a previous paper, *Confirmed* means that the literature value is confirmed by our results, *Improved* means that the present values are better defined than those existing in the literature and that they should used instead, *Membership* means that the cluster has only one red giant in its field and that it is not possible to check its membership because no velocities are available for other stars in the cluster. In some cases, the examination of the colour−magnitude diagram supports the membership, but it is

Table 5. Mean radial velocities for individual stars.

Cluster	No	$\bar{RV}$	ϵ	σ	E/I	N	ΔT	$P(\chi^2)$	Notes
Bas 10	0027	–32.08	0.77	2.03	5.66	7	3662	0.000	Var
Be 82	0002	–2.08	0.19	0.17	0.41	5	3626	0.955	
Be 82	0003	–3.76	0.23	0.36	0.70	5	3626	0.745	
Cr 121	0001	+34.52	1.66	2.35	8.42	2	374	0.000	Var
Cr 121	0028	+22.11	0.19	0.10	0.38	2	374	0.706	NM
Cr 121	0031	+33.67	0.24	1.07	2.04	19	4040	0.000	

Note: the columns contain the cluster names, the star identification according to the bibliographic references contained in Table 4, the mean radial velocity, the uncertainty on the mean ϵ, the formal standard deviation, σ, of radial velocities, all three in km s^{-1}, the external- to internal error ratio, $E/I = \sigma/\epsilon$, the number of observations used in the computation of the mean velocity, the time span [days] covered by observations, and $P(\chi^2)$, the probability that the scatter is due to random noise, and notes on membership (NM for non members), binarity (SB1: spectroscopic binary, SB1O: binary with an orbit, SB2 and SB2O: double-lined binary, Ceph: cepheid variable, Var: variable radial velocity, probably of intrinsic origin, for example, the red supergiants.

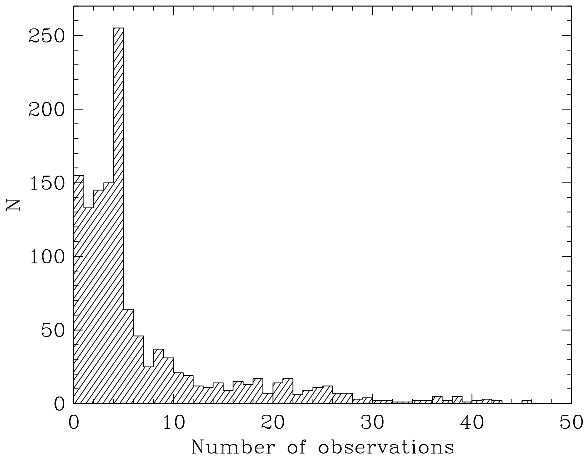

Fig. 1. Distribution of the number of observations per star.

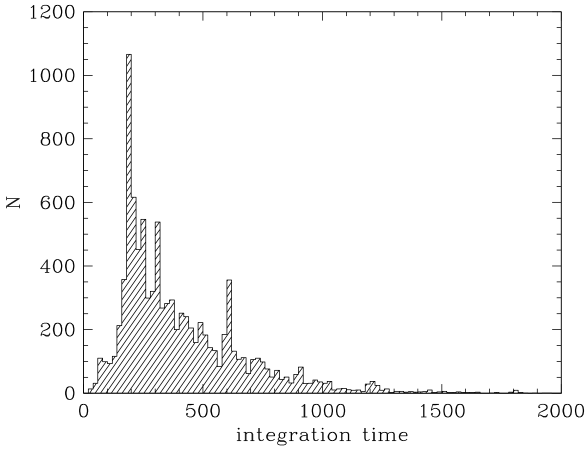

Fig. 2. Distribution of the measurement integration length in [s]. As a rule, a minimum length of 180 s was usually used, except for a few very bright stars.

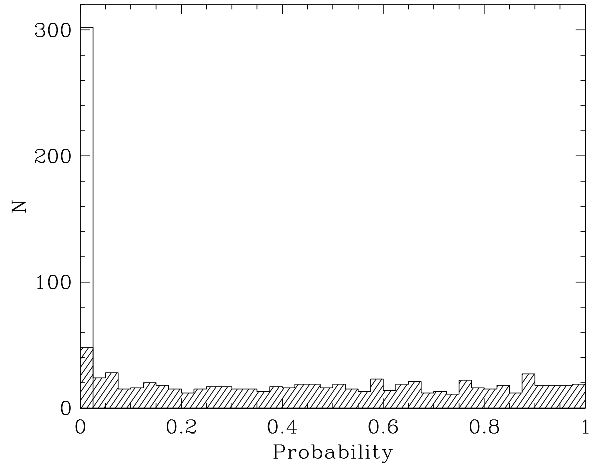

Fig. 3. Distribution of the probability $P(\chi^2)$. The distribution is flat, as expected (hatched part). It only presents a maximum at $P = 0.000$ (open histogram) corresponding to the spectroscopic binaries.

not a sufficient criterion. Finally, *None* means that none of the red giants observed is a member. No mean velocity could obviously be computed.

The dispersion of the cluster mean radial velocities will be discussed later on (Sect. 5.2).

5. Results

5.1. Membership

The catalogue of mean radial velocities for the 1309 red giants contains information on the membership derived from the radial velocities. In many cases, the membership or non-membership is evident, because the radial velocity is constant over many years and is very different from the cluster mean velocity.

The modal value of the radial-velocity dispersion in open clusters is around 0.5 km s^{-1} as shown by Fig. 4. As a rule, we have considered as members those stars that have their radial velocity within 3σ, i.e. 1.5 km s^{-1} of the cluster mean. For values up to 2.5 km s^{-1} from the mean cluster value, we examined the position in the colour-magnitude diagramme to see if the location agrees with membership and to detect any indication that the red giant may have a companion.

In many cases, we assumed that the stars are binaries (SB?) because the distribution of semi-amplitudes (Mermilliod & Mayor **?**) indicates that they can reach 20 km s^{-1} or more. Accordingly, it is sometimes difficult to judge if a star is a non-member or a binary member, especially when the difference between the star velocity and the cluster velocity is around 2 to 5 km s^{-1} and $P(\chi^2)$ is not very small. For example, star NGC 2548−1260 remained nearly stable for 10 years with an

Table 6. Mean radial velocities for NGC clusters.

Cluster	Nobs	NM	NMSB	M	SB	Orb	Frac	V_r	ϵ	σ	N	Notes
NGC 0129	4	2	0	2	2	2	1.00	–37.36	0.46	0.65	2	Confirmed
NGC 0225	2	2	1									None
NGC 0433	1	0	0	1	0	0	0.00	–36.91	0.18	0.25	1	New
NGC 0436	2	0	0	2	0	0	0.00	–73.78	0.45	0.63	2	Confirmed
NGC 0457	2	0	0	2	0	0	0.00	–29.79	0.33	0.47	2	Confirmed
NGC 0581	1	0	0	1	0	0	0.00	–44.20	0.12	0.73	1	Confirmed
NGC 0654	1	0	0	1	0	0	0.00	–34.20	0.18	1.17	1	Confirmed
NGC 0663	2	0	0	2	1	0	0.50	–33.09	0.34	1.74	1	Confirmed
NGC 0752	30	13	3	17	4	3	0.24	+5.04	0.08	0.32	16	Updated
NGC 0869	1	1	0									None
NGC 0884	5	0	0	5	0	0	0.00	–42.64	0.27	0.61	5	Improved
NGC 1027	3	2	0	1	1	1	1.00	+15.63	0.20	0.29	1	Confirmed
NGC 1039	3	3	1									None
NGC 1342	3	0	0	3	0	0	0.00	–10.67	0.11	0.19	3	Confirmed
NGC 1496	3	1	0	2	1	0	0.50	–14.43	0.18	0.27	1	New
NGC 1502	1	1	1									None
NGC 1528	3	0	0	3	1	1	0.33	–9.70	0.27	0.47	3	Confirmed
NGC 1545	5	2	1	3	0	0	0.00	–12.42	0.66	1.14	3	Confirmed
NGC 1647	2	0	0	2	0	0	0.00	–7.02	0.22	0.31	2	Confirmed
NGC 1662	2	0	0	2	0	0	0.00	–13.35	0.29	0.41	2	Confirmed
NGC 1664	5	1	0	4	0	0	0.00	+7.50	0.05	0.07	2	Improved
NGC 1778	1	0	0	1	1	1	1.00	+4.95	0.08	2.24	1	Improved
NGC 1807	2	2	0									None
NGC 1817	69	31	0	38	11	4	0.29	+65.31	0.09	0.50	31	Updated
NGC 1912	6	4	0	2	1	0	0.50	–44.98	0.11	0.40	1	Confirmed
NGC 2099	55	20	8	35	10	6	0.29	+8.30	0.20	1.08	30	Updated
NGC 2112	6	3	0	3	2	0	0.67	+32.53	1.87	2.64	1	Confirmed
NGC 2168	3	0	0	3	0	0	0.00	–8.17	0.22	0.38	3	Confirmed
NGC 2186	1	0	0	1	0	0	0.00	+20.15	0.19	0.51	1	New
NGC 2204	35	10	1	25	4	0	0.16	+92.35	0.52	2.56	24	Improved
NGC 2215	1	0	0	1	1	1	1.00	–3.43	0.12	7.50	1	New
NGC 2232	1	1	0									None
NGC 2243	3	1	0	2	0	0	0.00	+59.84	0.41	0.58	2	Improved
NGC 2251	3	0	0	3	0	0	0.00	+25.33	0.05	0.09	3	Confirmed
NGC 2264	5	5	1									None
NGC 2281	3	1	0	2	0	0	0.00	+19.05	0.04	0.05	2	Confirmed
NGC 2287	8	2	2	6	4	4	0.67	+23.30	0.11	0.25	5	Confirmed
NGC 2301	2	1	0	1	0	0	0.00	+13.54	0.12	0.48	1	Membership
NGC 2323	1	0	0	1	0	0	0.00	+6.13	0.09	0.37	1	Confirmed
NGC 2324	17	9	1	8	3	0	0.38	+41.81	0.22	0.50	5	Updated
NGC 2335	4	3	0	1	1	1	1.00	–3.59	0.30	0.67	1	New
NGC 2343	1	0	0	1	0	0	0.00	+14.89	0.15	0.41	1	New
NGC 2345	5	0	0	5	1	0	0.20	+59.19	0.36	0.73	4	New
NGC 2354	27	14	4	13	5	0	0.38	+33.45	0.35	0.98	8	Updated
NGC 2355	12	4	0	8	1	0	0.12	+35.02	0.16	0.42	7	Confirmed
NGC 2360	26	6	1	20	6	5	0.30	+27.28	0.18	0.77	18	Updated
NGC 2374	2	1	0	1	0	0	0.00	+29.25	0.22	0.44	1	Improved
NGC 2383	1	0	0	1	0	0	0.00	+57.37	0.24	0.65	1	New
NGC 2420	31	9	0	22	4	2	0.18	+73.57	0.15	0.62	18	Improved
NGC 2421	1	1	0									None
NGC 2422	3	3	1									None
NGC 2423	13	3	1	10	3	1	0.30	+18.47	0.11	0.33	9	Updated
NGC 2437	4	0	0	4	3	2	0.75	+49.20	0.36	0.62	3	Improved
NGC 2439	2	0	0	2	0	0	0.00	+66.00	0.13	0.18	2	Confirmed
NGC 2447	13	0	0	13	3	2	0.23	+22.08	0.18	0.63	12	Updated
NGC 2451	1	0	0	1	0	0	0.00	+16.83	0.14	0.27	1	Confirmed
NGC 2453	2	1	1	1	0	0	0.00	+33.94	0.52	1.03	1	New
NGC 2477	83	7	0	76	27	15	0.36	+7.26	0.12	1.00	64	Updated
NGC 2482	5	2	1	3	2	1	0.67	+38.17	0.30	0.43	2	New
NGC 2489	7	1	0	6	1	1	0.17	+38.20	0.12	0.29	6	Updated
NGC 2506	34	4	0	30	0	0	0.00	+83.25	0.29	1.57	30	Improved
NGC 2516	4	0	0	4	0	0	0.00	+23.08	0.25	0.50	4	Confirmed
NGC 2527	2	0	0	2	0	0	0.00	+39.60	0.06	0.09	2	New
NGC 2533	7	4	0	3	1	1	0.33	+35.22	0.32	0.56	3	New
NGC 2539	19	8	1	11	4	4	0.36	+28.89	0.21	0.68	11	Updated
NGC 2546	2	0	0	2	0	0	0.00	+15.24	0.48	0.68	2	Confirmed

Table 6. continued.

Cluster	Nobs	NM	NMSB	M	SB	Orb	Frac	V_r	ϵ	σ	N	Notes
NGC 2548	6	1	0	5	3	2	0.60	+7.70	0.18	0.36	4	Confirmed
NGC 2567	9	4	0	5	1	1	0.20	+36.15	0.13	0.30	5	New
NGC 2571	1	0	0	1	0	0	0.00	+26.56	0.15	0.19	1	New
NGC 2627	4	1	0	3	1	0	0.33	+25.99	1.19	2.06	3	New
NGC 2632	4	0	0	4	1	1	0.25	+34.07	0.26	0.51	4	Confirmed
NGC 2660	9	3	0	6	0	0	0.00	+21.34	0.46	1.03	5	New
NGC 2669	2	1	0	1	0	0	0.00	+21.06	0.15	0.35	1	New
NGC 2670	1	0	0	1	1	1	1.00	+6.69	0.11	6.75	1	New
NGC 2682	26	3	0	23	5	5	0.22	+33.52	0.29	1.41	23	Confirmed
NGC 2818	23	8	1	15	3	0	0.20	+20.69	0.28	0.97	12	Updated
NGC 2925	3	0	0	3	1	1	0.33	+12.20	0.59	1.03	3	New
NGC 2972	4	1	0	3	1	1	0.33	+20.89	0.26	0.45	3	New
NGC 3033	2	1	1	1	1	1	1.00	+27.15	0.09	6.38	1	Updated
NGC 3114	11	4	0	7	0	0	0.00	–1.72	0.13	0.34	7	Confirmed
NGC 3228	1	0	0	1	0	0	0.00	–22.39	0.15	0.23	1	New
NGC 3247	1	0	0	1	0	0	0.00	–13.00	0.20	0.41	1	New
NGC 3293	1	0	0	1	0	0	0.00	–13.63	0.42	1.38	1	Confirmed
NGC 3532	11	3	0	8	2	2	0.25	+4.33	0.34	0.96	8	Confirmed
NGC 3680	13	4	2	9	3	1	0.33	+1.28	0.11	0.32	8	Updated
NGC 3766	2	0	0	2	0	0	0.00	–16.66	0.37	0.53	2	Confirmed
NGC 3960	14	2	0	12	5	3	0.42	–22.26	0.36	1.13	10	Updated
NGC 4349	13	2	0	11	3	2	0.27	–11.87	0.24	0.75	10	New
NGC 4463	1	0	0	1	0	0	0.00	–12.20	0.21	0.29	1	Improved
NGC 4609	1	0	0	1	0	0	0.00	–21.30	0.14	0.20	1	New
NGC 4755	1	0	0	1	0	0	0.00	–21.24	0.26	0.89	1	Confirmed
NGC 5138	4	0	0	4	2	0	0.50	–9.58	0.57	0.99	3	New
NGC 5168	1	0	0									None
NGC 5281	1	0	0	1	0	0	0.00	–19.33	0.13	0.16	1	New
NGC 5316	6	2	2	4	0	0	0.00	–15.10	0.28	0.55	4	New
NGC 5460	2	1	0	1	0	0	0.00	–5.23	0.12	0.18	1	Improved
NGC 5617	7	4	0	3	0	0	0.00	–35.77	0.47	0.82	3	New
NGC 5662	3	1	0	2	0	0	0.00	–21.27	0.24	0.34	2	Confirmed
NGC 5749	2	2	1									None
NGC 5822	28	7	0	21	9	8	0.43	–29.31	0.18	0.82	20	Updated
NGC 5823	9	8	1	1	1	1	1.00	–19.27	0.18	9.68	1	Updated
NGC 6067	15	1	0	14	3	0	0.21	–39.99	0.18	0.60	11	Updated
NGC 6087	4	2	1	2	1	0	0.50	+5.83	0.05	11.16	1	Updated
NGC 6124	8	0	0	8	2	2	0.25	–21.07	0.19	0.53	8	New
NGC 6134	24	5	1	19	8	2	0.42	–25.70	0.19	0.70	14	Updated
NGC 6192	11	6	0	5	2	0	0.40	–7.93	0.21	0.37	3	New
NGC 6208	10	7	0	3	1	0	0.33	–32.47	0.23	0.33	2	New
NGC 6242	1	0	0									None
NGC 6249	2	0	0	2	1	1	0.50	–37.63	2.77	3.92	2	New
NGC 6259	19	5	1	14	0	0	0.00	–34.66	0.61	2.30	14	Updated
NGC 6268	5	1	0	4	0	0	0.00	–15.12	0.07	0.13	4	New
NGC 6281	2	0	0	2	0	0	0.00	–5.58	0.26	0.37	2	New
NGC 6396	1	0	0	1	0	0	0.00	–13.55	0.31	0.69	1	Improved
NGC 6405	1	0	0	1	0	0	0.00	–7.99	0.20	0.49	1	Improved
NGC 6416	7	7	0									None
NGC 6425	6	6	0	2	0	0	0.00	–3.46	0.20	0.28	2	New
NGC 6475	3	0	0	3	2	2	0.67	–15.53	1.04	1.80	3	Improved
NGC 6494	6	2	0	4	0	0	0.00	–8.18	0.09	0.18	4	Confirmed
NGC 6520	3	0	0	3	0	0	0.00	–23.54	0.25	0.43	3	Improved
NGC 6530	2	2	0									None
NGC 6546	2	1	0	1	0	0	0.00	–31.10	0.18	0.06	1	New
NGC 6633	8	2	0	6	1	1	0.17	–28.95	0.09	0.23	6	Updated
NGC 6649	5	0	0	5	1	0	0.20	–8.59	0.20	0.40	4	Updated
NGC 6664	6	1	0	5	3	1	0.60	+18.58	0.40	0.69	3	Updated
NGC 6694	2	0	0	2	1	1	0.50	–9.10	0.59	0.83	2	Confirmed
NGC 6705	21	4	0	17	2	0	0.12	+35.08	0.32	1.23	15	Confirmed
NGC 6709	2	0	0	2	1	1	0.50	–10.22	0.40	0.56	2	Improved
NGC 6755	11	8	0	3	1	0	0.33	+26.63	0.04	0.05	2	Improved
NGC 6811	10	6	0	4	1	0	0.25	+7.28	0.11	0.19	3	Confirmed
NGC 6866	4	2	0	2	0	0	0.00	+13.68	0.06	0.09	2	New
NGC 6882	11	9	0	2	1	1	0.50	–17.80	0.13	0.18	2	Improved
NGC 6940	26	5	1	21	7	6	0.33	+7.89	0.14	0.64	21	Updated
NGC 7031	1	0	0	1	0	0	0.00	+0.24	0.20	0.49	1	New

Table 6. continued.

Cluster	Nobs	NM	NMSB	M	SB	Orb	Frac	V_r	ϵ	σ	N	Notes
NGC 7063	2	2	0									None
NGC 7082	3	3	1									None
NGC 7086	3	1	0	2	1	0	0.50	–18.95	0.76	3.13	1	New
NGC 7209	4	1	0	3	1	1	0.33	–18.63	0.17	0.30	3	Confirmed
NGC 7235	1	0	0	1	0	0	0.00	–53.71	0.49	1.39	1	Confirmed
NGC 7654	1	0	0	1	0	0	0.00	–32.98	0.11	0.32	1	Confirmed
NGC 7790	1	0	0	1	0	0	0.00	–77.48	0.13	10.63	1	Confirmed

Note: the columns contain: the cluster designation (Cluster), the number of stars observed (Nobs), the number of non members (NM), the number of binary non members (NMSB), the number of members (M), the number of binary members (SB), the number of orbits determined (Orb), the frequency of binary (Frac), the mean radial velocity ($\langle V_r \rangle$), the uncertainty on the mean (ϵ), the dispersion (σ) and the number of stars used in the computation of the mean velocity. The status of the radial velocities is indicated in the last column (Notes). *New* means that the no mean value has been published before or exists in the literature. *Updated* means that a value for the cluster mean radial velocity based on CORAVEL observations has been published in a previous paper, *Confirmed* means that the literature value is confirmed by our results, *Improved* means that the present values are better defined than thoses existing in the literature and that they should replace them, *Membership* means that the cluster has only one red giant in its field and that it is not possible to check its membership because no velocities are available for other stars in the cluster. In some cases, the examination of the colour−magnitude diagram supports the membership, but it is not a sufficient criterion. Finally, *None* means that none of the red giants observed is a member. No mean velocity could obviously be computed.

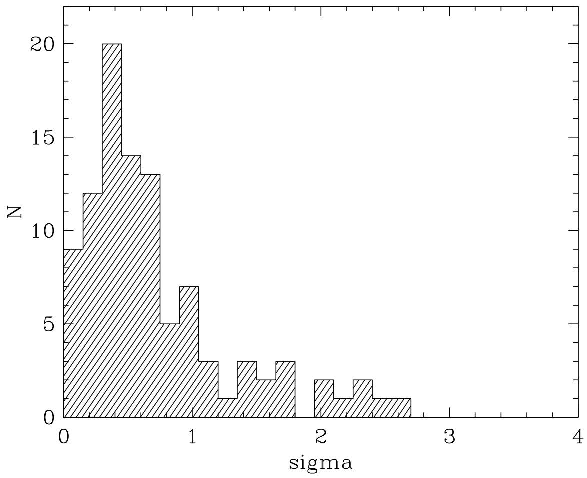

Fig. 4. Distribution of the internal radial-velocity dispersion [km s^{-1}] of the clusters. The mode is close to the value of the observational errors.

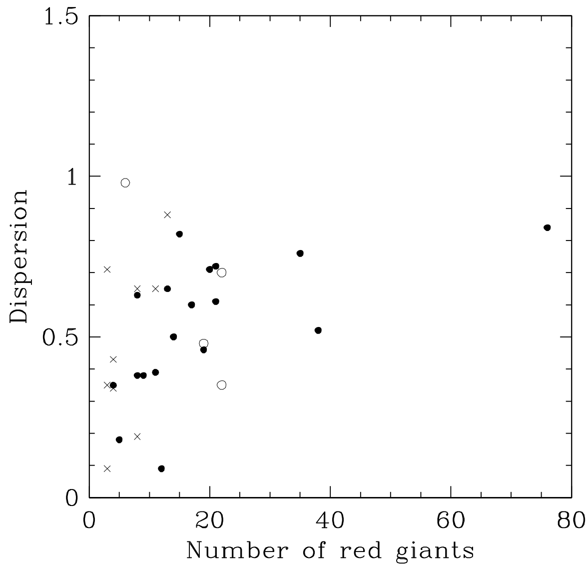

Fig. 5. Internal dispersion [km s^{-1}] as a function of the number of red-giant members. Filled circles stand for clusters with $8.35 < \log t < 8.95$, open circles for clusters with $\log t > 8.95$, and crosses for younger objects ($\log t < 8.35$).

RV differing by 3 km s^{-1} from the cluster velocity and finally started to decline rapidly. This period is probably close to 50 yrs.

5.2. Cluster internal radial-velocity dispersion

The distribution of the dispersion of the cluster mean radial velocities is displayed in Fig. 4. Only those clusters with at least two red-giant members have been taken into account. The mode of the distribution is around 0.5 km s^{-1}, similar to the observational errors. Only a few rich clusters have a velocity dispersion that is significantly greater. One example is NGC 2477 (Eigenbrod et al. 2004). Part of the observed dispersion arises from as yet undetected binaries.

We computed the intrinsic dispersion by substracting from the observed dispersion the contribution of the observations $\sigma_{\rm int} = \sqrt{(\sigma^2_{\rm total} - \sigma^2_{\rm obs})}$ for 31 clusters with at least 3 red giants with constant radial velocities, i.e. excluding the spectroscopic binaries without an orbit. The results were plotted as a function of the total number of red giants, taken as a proxy for the cluster masses (Fig. 5). Different symbols indicate different age ranges: young clusters: $\log t < 8.35$, intermediate age: $8.35 < \log t < 8.95$, and old clusters: $\log t > 8.95$, because the masses of the brightest stars are different in each interval.

There is a general trend toward the internal dispersion increasing with increasing number of red giants, from 0.4–0.5 to 0.85. The point at (76, 0.84) is NGC 2477, the richest cluster in our sample, for which the dispersion is significantly greater than the instrumental errors (Eigenbrod et al. 2004). The minimum dispersion is about 0.5 km s^{-1}, which is the value estimated for the internal dispersion for open clusters (Lohmann 1972). We are not able to detect intrinsic velocity dispersion below 0.5 km s^{-1} due to the precision of the instruments.

The presence of binaries distorts the distribution of the rms towards values higher than the actual cluster velocity dispersion (Mathieu 1985, 1988). The scatter observed in Fig. 5 for

Table 7. Mean radial velocities for IC and anon clusters.

Cluster	Nobs	NM	NMSB	M	SB	Orb	Frac	V_r	ϵ	σ	N	Notes
Basel 10	1	0	0	1	0	0	0.00	–32.08	0.77	2.03	1	New
Berkeley 82	2	0	0	2	0	0	0.00	–2.76	0.58	0.82	2	New
Collinder 121	3	1	0	2	0	0	0.00	+33.69	0.08	0.12	2	Confirmed
Collinder 223	7	4	0	3	1	0	0.33	–7.86	0.67	0.95	2	Improved
Collinder 258	2	1	0	1	0	0	0.00	+20.17	0.15	0.30	1	New
Collinder 268	2	1	0	1	0	0	0.00	–27.18	0.30	0.66	1	New
Collinder 463	9	7	2	2	1	0	0.50	–7.19	0.28	0.68	1	New
Feinstein 1	1	1	1									None
Harvard 20	1	0	0	1	0	0	0.00	+6.23	0.15	0.26	1	New
Haffner 8	3	2	0									None
IC 2488	13	10	1	3	1	0	0.33	–2.70	0.01	0.01	2	Updated
IC 2714	15	4	0	11	3	0	0.27	–13.64	0.18	0.50	10	Updated
IC 2944	1	0	0									None
IC 4651	20	1	0	19	5	5	0.26	–30.98	0.11	0.49	19	Updated
IC 4725	5	2	0	3	1	1	0.33	+2.72	0.13	0.23	3	Improved
IC 4756	23	2	0	21	6	4	0.29	–25.15	0.17	0.70	17	Updated
Loden 1409	16	14	2	2	1	0	0.50	–33.78	0.29	0.38	1	None
Lynga 6	2	0	0	2	1	0	0.50	–56.29	0.18	14.32	1	Updated
Melotte 20	1	0	0	1	0	0	0.00	–2.04	0.05	0.56	1	Confirmed
Melotte 25	4	0	0	4	2	2	0.50	+38.68	0.17	0.34	4	Confirmed
Melotte 71	24	7	0	17	9	4	0.53	+50.71	0.12	0.43	13	Updated
Melotte 101	1	0	0	1	0	0	0.00	+8.96	0.23	0.51	1	New
Melotte 105	4	0	0	2	1	1	0.50	+0.37	0.21	0.30	2	New
Melotte 111	1	0	0	1	1	1	1.00	+1.06	1.50	10.80	1	Confirmed
Moffat-FitzGerald 1	1	0	0	1	0	0	1.00	+8.75	0.29	0.51	1	New
Pismis 4	1	0	0	1	0	0	0.00	–6.01	0.26	0.51	1	New
Pismis 21	1	0	0	1	0	0	0.00	–41.20	0.69	0.90	1	New
Ruprecht 18	1	0	0	1	0	0	0.00	+31.03	0.35	0.52	1	New
Ruprecht 20	4	2	0	2	0	0	0.00	+29.89	0.04	0.05	2	New
Ruprecht 36	3	3	0									None
Ruprecht 46	2	2	1									None
Ruprecht 79	6	2	0	4	1	1	0.25	+28.29	0.34	0.68	4	Updated
Ruprecht 97	7	5	2	2	0	0	0.00	–14.90	0.16	0.22	2	Improved
Ruprecht 107	1	0	0	1	0	0	0.00	–45.40	0.22	0.62	1	New
Ruprecht 127	1	0	0	1	0	0	0.00	–18.43	0.39	0.88	1	Improved
Stock 2	7	4	2	3	2	0	0.67	–17.39	0.16	0.40	1	Confirmed
Stock 14	1	0	0	1	0	0	0.00	–16.44	0.25	2.48	1	Membership
Trumpler 2	1	0	0	1	0	0	0.00	–3.16	0.12	0.39	1	Improved
Trumpler 3	2	0	0	2	0	0	0.00	–8.58	1.12	1.59	2	New
Trumpler 9	1	0	0	1	0	0	0.00	–16.36	0.17	0.23	1	New
Trumpler 15	1	0	0	1	0	0	0.00	–20.91	0.98	3.24	1	Improved
Trumpler 26	4	1	0	3	2	1	0.67	–9.61	0.16	0.22	2	New
Trumpler 27	2	0	0	2	0	0	0.00	–17.34	0.30	0.42	2	New
Trumpler 33	1	0	0	1	0	0	0.00	–3.78	0.49	0.97	1	New
Trumpler 35	2	0	0	2	0	0	0.00	+25.87	0.30	0.42	2	Improved
Trumpler 37	2	1	0	1	0	0	0.00	+23.75	0.67	3.99	1	Confirmed
van den Bergh 1	1	0	0	1	0	0	0.00	+19.11	0.23	11.84	1	Improved

Note: column contents as in Table 6.

$N_{gk} < 15$ indicates that not all possible binaries were detected in some clusters. The semi-amplitudes of spectroscopic binaries with long periods ($P > 50{-}100$ yrs) may be in the range of 0.5 to 1.5 km s^{-1} and are therefore within the same order of magnitude as the internal dispersion. Consequently, undetected binaries increase the apparent internal dispersion.

5.3. Cepheids

Twelve cepheid variables in the field of open clusters were observed frequently to determine radial-velocity curves. Between 14 (for SV Vel) and 69 (for U Sgr) measurements were obtained. The observations were analysed in a similar manner to Mermilliod et al. (1987) to derive mean radial velocities. The results are given in Table 8, which contains the cluster name, the cepheid name, the adopted period, σ on the fit, the number of measurements, the number of harmonics, the mean velocity, and its error in km s^{-1}.

These new data and the orbits derived for several binary members in these clusters provide better support for the membership of these cephied variable to their parent clusters. They confirm the results obtained by Mermilliod et al. (1987). In particular, CS Vel and 3 other red giants are clearly members of Rup 79.

5.4. Red and yellow supergiants

The red supergiants of the Persei arm region belonging to well-known clusters (NGC 457, NGC 581, NGC 663, NGC 884) have been monitored frequently during the first years. Additional

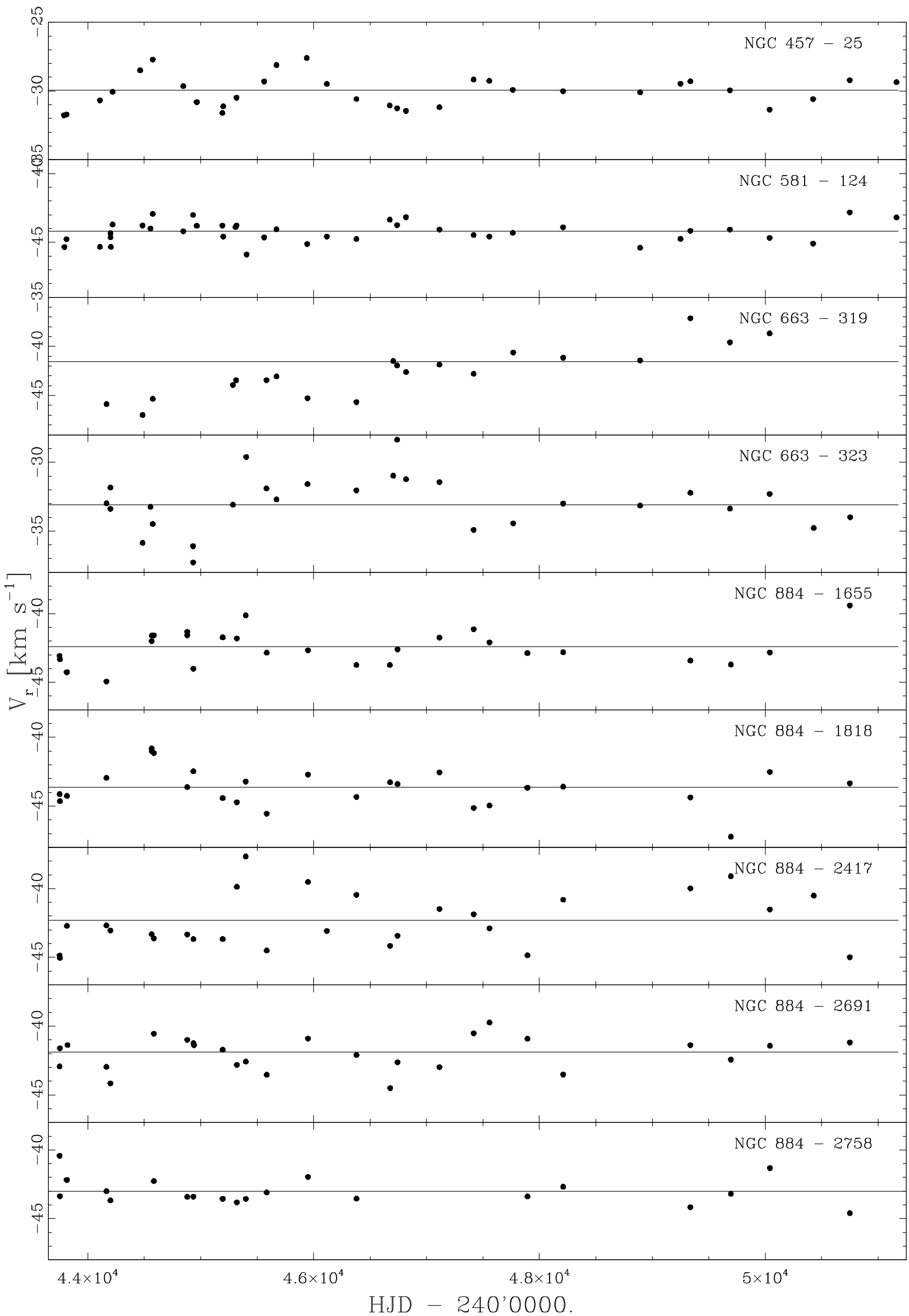

Fig. 6. Radial-velocity curves for 9 red supergiants. All show signs of intrinsic variablity. NGC 663-319 presents a systematic drift in function of time, and is most probably a spectroscopic binary.

observations with the CORAVEL instrument were obtained independently by Prévot (Marseille) at OHP. They are used in the present discussion.

All stars present an intrinsic variability, i.e. $P(\chi^2) = 0.000$. The correlation dip is very deep and narrow and the measuring errors are typically of the order of 0.4 $\mathrm{km\,s^{-1}}$. The full

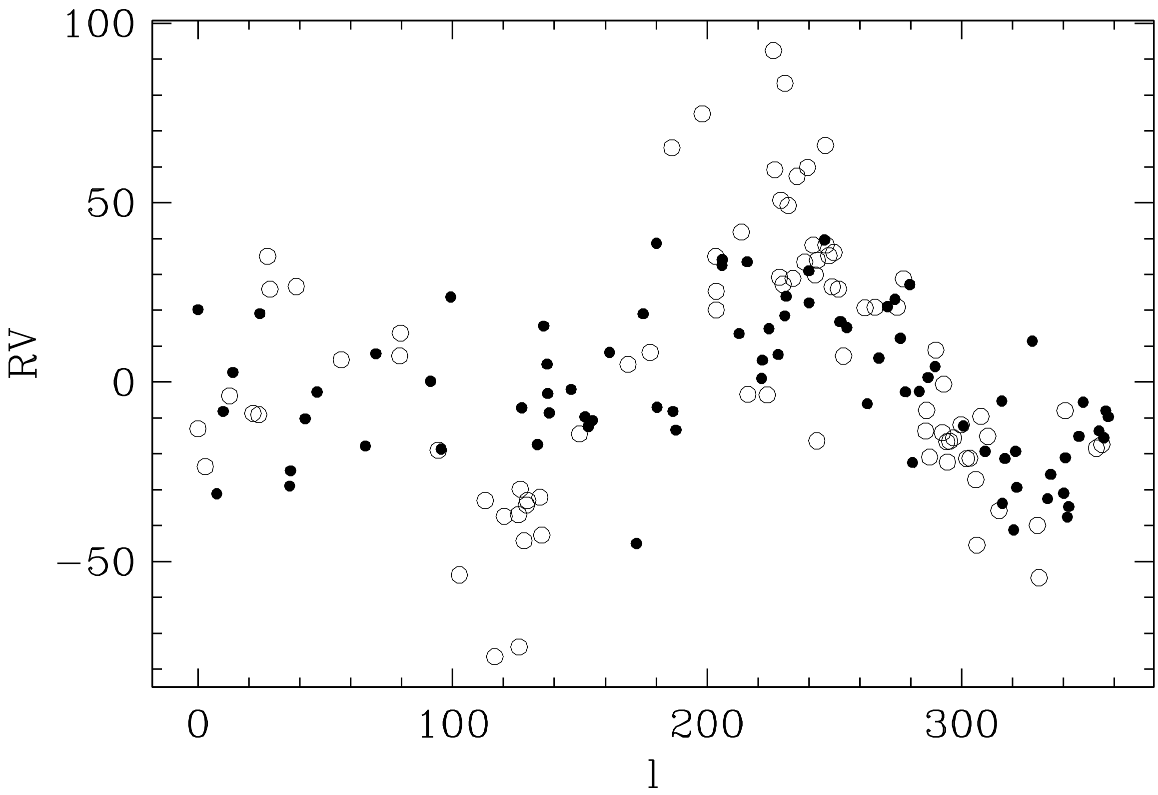

Fig. 7. Galactic distribution of the radial velocities. Filled circles: clusters closer than 1200 pc, open circles: clusters more distant than 1200 pc.

amplitudes observed vary between 5 and 10 km s^{-1}. The variation is not periodic and has variable amplitude in function of time. We attribute it to intrinsic variations. We are not aware of any photometric monitoring of these stars that could permit us to compare the behaviour of the light- and velocity curves. NGC 457 #25 presented regular variations over the first 2000 days, but the amplitude diminished strongly at JD dates later than 2 447 500.

One star, NGC 663 #319, showed a systematic drift in function of time, underlying the intrinsic variations. This indicates that this red supergiant is a binary with a very long period, i.e. much longer than the 20 years spanned by the observing program.

A similar behaviour was observed for the red supergiants in NGC 7235 and Basel 10 and in several southern open clusters (NGC 2439, NGC 3293, NGC 3766, NGC 4755, Tr 15, and Tr 27). The number of observations is however smaller ($7 < N < 12$) and the time interval shorter. The radial-velocity curves are not reproduced here.

Two yellow supergiants belong to the sample: α Persei (F5 Ib) and NGC 654 #554 (F5 Ia). One hundred six observations were obtained for α Persei, a standard star, and $P(\chi^2)$ = 0.053. This value is low but not low enough to be certain of the variability of this supergiant. Butler (1998) found a period of 77.17^d with an amplitude of 56 m s^{-1}. Such an amplitude is out of reach of our observations, which present a mean error of about 500 m s^{-1}.

NGC 654 #554 presents clear sign of variability with a full amplitude of 5 km s^{-1}, while the individual errors are close to 0.65–0.70 km s^{-1}. No regular pattern can be detected, mainly because the density of observation in function of time is not high enough.

5.5. Galactic radial velocity distribution

Most clusters are close to the galactic plane and thus should share the differential rotation of the Galaxy. The distribution of the cluster mean radial velocities in function of the galactic longitude l is presented in Fig. 7. We have plotted the values for the clusters closer to the Sun than 1.2 kpc separately from those at larger distances. The rotation trend is quite evident, for both samples, for $180° < l < 360°$ and is, as expected, more pronounced for the more distant clusters.

6. Comments on some clusters

Many open clusters for which we determined orbital elements for one or more binaries were discussed in Mermilliod et al. (2007). A few for which the analysis was not presented in previously published papers (see Table 1) are briefly discussed here.

NGC 1664. The two stars #17 and 75 (Larsson-Leander 1957) are clearly members. Star 88 lies within the Hertzprung gap and is supected of being a binary. $P(\chi^2)$ is small (0.078), but not zero. If correct, the period should be long and the amplitude small. Star 55 deviates by 2 km s^{-1} from the cluster mean, but does not show signs of variability. Its photometry supports its membership. Glushkova & Rastorguev (1991) published radial velocities for another 6 stars in this cluster but none of them appeasr to be member. Star #733, brighter and redder than the clump, has a low proper-motion probability.

NGC 1912. Stars #3 and 70 (Hoag et al. 1961) are the only members. Star 3 is a long-period binary that showed a change in radial velocity of more than 2 km s^{-1} over 7000 days. Glushkova & Rastorguev (1991) published radial velocities for another

Table 8. Mean radial velocities for cepheids.

Cluster	Cepheid	Period	σ	Nobs	Nharm	V_r	ϵ	Notes
IC 4725	U Sgr	6.74538	0.541	69	5	2.76	0.07	
NGC 6067	V340 Nor	11.2885	0.391	38	5	–40.11	0.06	
	QZ Nor	3.78658	0.450	52	3	–39.27	0.06	
NGC 6087	S Nor	9.75434	0.287	33	6	5.83	0.05	
NGC 6649	V367 Sct	6.29308	0.731	22	2	–8.54	0.16	Fund.
		4.38484	0.731	22	1			1st harm.
NGC 6664	EV Sct	3.09108	0.849	37	4	17.69	0.14	
Ly 6	TW Nor	10.7847	0.685	15	4	–56.29	0.18	
Ru 79	CS Vel	5.90480	0.773	26	4	27.53	0.15	
Ru 97	SV Cru	7.00398	0.801	14	4	–14.82	0.21	
vdb 1	CV Mon	5.37869	1.39	37	5	19.11	0.23	
	RU Sct	19.7078	0.549	32	3	–4.84	0.10	

6 stars in this cluster. Stars #63, 200, and 641 are too faint to be cluster members.

NGC 2168. Three stars, # 81, 310, 662 (Cuffey 1938), have similar velocities, which are very close to the values derived by Barrado y Navascues et al. (2001) for G and K dwarfs in this cluster. None of them appears to be variable in velocity. The magnitude and colours of star #310 would locate it on a blue loop because it is brighter and bluer than the other two red giants.

NGC 2251. The three red giants have very similar colours and are all members.

NGC 2281. Although the (V, $B-V$) colour−magnitude diagram presents three red giants that are well aligned on an ascending giant branch, the star in the middle, #18 (Vasilevskis & Balz 1959), is clearly a non-member.

NGC 2345. All five stars observed are bright giants of type K3 II (Moffat 1974). The binary nature of star #34, classified K3II + B by Moffat is confirmed by the radial-velocity observations. The period should be quite long. The values for $P(\chi^2)$ for the other stars are also zero, but this does not result from duplicity, but from a small zero point difference between the first observations made at OHP and the next ones obtained at La Silla. No convincing explanation has been found so far. Such a difference is not seen among the set of standard stars observed from both hemispheres.

NGC 2355. This object was added in 1993 to the observing list and only two observations have been obtained for each star, but 4 for #599 (Ann et al. 1999) which is a binary. The eight members, among the twelve stars observed, form a well-defined clump in the colour−magnitude diagram.

NGC 2516. One new red giant, #225 (HD 64320, #98 in Dachs & Kabus 1989) was found to be a member, in addition to the three known members. It has the same colour and magnitude as #128 and a very similar radial velocity, although it is located well outside the cluster, at about 2° from the centre.

NGC 2660. Due to the faint B magnitude of the clump stars, only 9 candidate red giants could be observed. Six members were identified. Our mean radial velocity is in good agreement with what is published by Sestito et al. (2006), +21.2 ± 0.6 km s^{-1} from 5 stars.

NGC 3114. Seven stars closely share the same radial velocity and form a wide clump in the colour−magnitude diagram. Star #170, classified G3 II−III by Levato & Malaroda (1975) is bluer and brighter and could be located at the extremity of a blue loop, like that produced by the $\log t = 8.05$ isochrone for $z = 0.019$ of Girardi et al. (2000a).

NGC 6416. No two red giants have the same velocity and it is difficult to estimate membership from the colour−magnitude diagram based on the old *UBV* photographic data of Thé & Stokes (1970).

NGC 6425. Two stars, #46 and 61 (Thé & Stokes 1970), have similar radial velocities. The analysis of *UBV* and DDO photometry (Clariá et al. 2008) favoured the membership of these two stars. We then consider that these two stars are probable members of the cluster NGC 6425.

NGC 6494. Four stars share the same velocities very closely, which remained remarkably stable over 18 years.

NGC 6755. Eleven stars were observed in this field, and only three red giants are considered as members. The present values are in good agreement with the unpublished data of Glushkova found in WEBDA. Stars #41 and 44 (Hoag et al. 1961) from her list could also be members. A few stars, not observed in this program, could be members, for example #42.

Loden 1409. This object was included in the list of suspected clusters by Loden (1973), later called loose clustering, and *UBVRI* photomery was obtained by Jorgensen & Westerlund (1988). Because the original clustering of Loden was based on red stars in the range G9 to M0, it was put on the observing list. Fourteen stars were observed. Except for stars # 1 and 2, which have the same velocities, the 12 other stars have very different velocities. Stars 1 and 2 are not close on the map and do not have similar colours and magnitude. One may wonder if the agreement is only fortuitous or if they are really related. Therefore, "None" has been entered in the last column (Notes) of Table 7. These results cast serious doubts on the reality of the loose clustering called Loden 1409 and on the physical association between these stars.

7. Discussion

The systematic programme undertaken with the CORAVEL instruments produced numerous results, which have been published in various papers. In combination with photometric data, the red-giant membership based on radial velocities permitted study of the morphology of the red-giant phase in several intermediate-age and old open clusters. One of the most interesting result concerns the peculiar shape of the clump observed in NGC 752 and NGC 7789 (Girardi et al. 2000b). Composite colour−magnitude diagrams can be very helpful for bringing out features of the red-giant distribution in the CMDs (Mermilliod & Mayor 1989).

A major result of this programme was the discovery of 288 spectroscopic binaries and the determination of orbital elements for 156 systems (Mermilliod et al. 2007). The $(e, \log P)$ diagrams for dwarfs and red giants initiated theoretical and observational advances in the understanding of the interaction between duplicity and rotation. The new orbital-element sample confirm the conclusions of Mermilliod & Mayor (1992) on the cut-off periods, namely the shortest possible period and transition between circular and elliptic orbits. The exact value of this transition clearly depends on the mass of the red-giant primary, as was already shown by Mermilliod & Mayor (1996).

8. Conclusion

The final catalogues presented in this paper make available the individual radial velocities (10 517 RVs), mean radial velocities for 1309 red giants in galactic open clusters, and mean radial velocities for 166 open clusters. We obtained first radial-velocity determinations for 57 clusters, and we updated the velocities for 32 clusters previously published based on CORAVEL observations. We confirmed the mean radial velocity of 47 clusters with respect to those published in the literature and improved the literature values for 25 clusters. In 23 cases, none of the observed red giants were found to be members and so no cluster velocity could be determined. We redetermined the mean RV of several cluster cepheids. Finally we found that all M-type red supergiants display irregular radial-velocity variations. Only one seems to be a binary.

This last paper dealing with red giants in open clusters is the end of this long-term program. It would, however, be very desirable to continue monitoring a number of systems to derive additional orbits. Monitoring of spectroscopic binaries in southern clusters will be continued with the CORALIE spectrometer at La Silla observatory. D. Latham at the CfA continues regularly observations on some northern objects and J. Sperauskas (Vilnius) started the observations of a number of objects with a new instrument. Multi-object spectrographs presently allow 100 or so velocities at a time, as compared to the star by star observations permitted by the CORAVELs, providing a factor of 100 or more in the observing efficiency. They should allow observations of fainter giants in more distant clusters.

We nevertheless feel that the present observations have contributed to the study of open clusters, to the determination of membership and duplicity of the red giants, and to the understanding of stellar evolution at the red-giant stage. They have largely improved the knowledge of these fundamental objects that open clusters are for astrophysics.

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