ISSN 1063-7737, Astronomy Letters, 2006, Vol. 32, No. 11, pp. 759–771. © Pleiades Publishing, Inc., 2006.
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Pulkovo Compilation of Radial Velocities for 35 495 Hipparcos Stars in a Common System

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Received March 9, 2006

Abstract—The Pulkovo Compilation of Radial Velocities (PCRV) has been made to study the stellar kinematics in the local spiral arm. The PCRV contains weighted mean absolute radial velocities for 35 495 Hipparcos stars of various spectral types and luminosity classes over the entire celestial sphere mainly within 500 pc of the Sun. The median accuracy of the radial velocities obtained is 0.7 km s^{-1}. Results from 203 publications were used in the catalogue. Four of them were used to improve the radial velocities of standard stars from the IAU list. The radial velocities of 155 standard stars turned out to be constant within 0.3 km s^{-1}. These stars were used to analyze 47 768 mean radial velocities for 37 200 stars from 12 major publications (∼80% of all the data used). Zero-point discrepancies and systematic dependences on radial velocity, $B-V$ color index, right ascension, and declination were found in radial velocity differences of the form "publication minus IAU list of standards." These discrepancies and dependences were approximated and taken into account when calculating the weighted mean radial velocities. 1128 stars whose independent radial-velocity determinations were available at least in three of these publications and agreed within 3 km s^{-1} were chosen as the work list of secondary standards. Radial-velocity differences of the form "publication minus list of secondary standards" were used by analogy to correct the zero points and systematic dependences in the radial velocities from 33 more publications (∼13% of the data used). In addition, the radial velocities from 154 minor publications (∼7% of the data used) pertaining to well-known instruments were used without any corrections.

PACS numbers: 98.62.Lv; 06.30.Gv; 97.10.-q
DOI: 10.1134/S1063773706110065

Key words: *Galaxy, radial velocities, stellar kinematics.*

INTRODUCTION

The stellar kinematics in the solar neighborhood within the local spiral arm of the Galaxy is being studied at the Pulkovo Astronomical Observatory of the Russian Academy of Sciences and the Astronomical Institute of the St. Petersburg State University as part of the OSACA (Orion Spiral Arm Catalogue, http://www.geocities.com/orionspiral/) project (Gontcharov 2004). The study is based on six quantities that describe the stellar positions and velocities: α, δ, π, μ_α, μ_δ, and V_r, as well as the coordinates X, Y, and Z and space velocities U, V, and W calculated from them in the standard Galactic rectangular coordinate system, where X, Y, and Z increase in the directions of the Galactic center, the Galactic rotation, and the Galactic North Pole, respectively.

At present, the coordinates and proper motions are known for a larger number of stars and with a higher relative accuracy than the parallaxes and radial velocities. For example, the coordinates and proper motions of ∼96 000 Hipparcos stars (ESA 1997) within 500 pc of the Sun are known with a relative accuracy higher than 10^{-7} and an accuracy higher than 3 km s^{-1}, respectively, while the parallaxes of only ∼69 000 Hipparcos stars are known with a relative accuracy higher than 0.3 and the radial velocities of only ∼20 000 stars from the WEB (Duflot et al. 1995b) and Barbier-Brossat and Figon (below referred to as BBF) (2000) catalogues are known with an accuracy higher than 5 km s^{-1}.

Several major *observational* catalogues of radial velocities, including the Geneva–Copenhagen survey of radial velocities for more than 14 000 stars in the solar neighborhood (below referred to as GCS) (Nordström et al. 2004) and the kinematic survey of more than 6000 K and M giants based on observations with CORAVEL spectrometers (below referred to as KMG) (Famaey et al. 2005), have been

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Table 1. IAU standard stars used to make the PCRV (the full table is available in electronic form)

HIP	HD	V_r	$\sigma(V_r)$	α	δ	m_V
910	693	14.4	0.1	2.816	−15.468	4.89
1499	1461	−10.2	0.1	4.674	−8.053	6.47
1803	1835	−2.6	0.1	5.716	−12.209	6.39
2920	3360	−0.3	0.1	9.243	53.897	3.69
3179	3712	−4.3	0.1	10.127	56.537	2.24

compiled since the publication of these compilation catalogs. Thus, making a new compilation of radial velocities presented in this paper has become a necessity. By combining data from the WEB, BBF, GCS, and KMG catalogues and 199 more catalogues of radial velocities, we have made the Pulkovo Compilation of Radial Velocities (PCRV) for 35 495 Hipparcos stars to study their kinematics. Supplementing the PCRV by new observations and improving the weighted mean radial velocities are an important part of the long-term OSACA project. The size of this paper is too small to describe the kinematic studies using the PCRV that have been considered in other publications, for example, by Bobylev et al. (2006).

COMBINING THE RADIAL VELOCITIES FROM VARIOUS PUBLICATIONS

The radial-velocity measurements performed with different instruments have different systematic errors. In contrast to the relative radial-velocity measurements to detect extrasolar planets, the difficulties in determining the absolute radial velocities for stellar kinematics, i.e., the velocities relative to the barycenter of the Solar System, are particularly great. The systematic errors in measuring the absolute radial velocities and the attainable level of accuracy were discussed, for example, by Nidever et al. (2002). They showed that apart from well-known effects, for example, the Earth's motion around the Sun, of greatest importance for the absolute radial velocities are the gravitational redshift of spectral lines in the stellar gravitational field, the convective blueshift of lines in the upper stellar layer, and the difference between the observed and comparison spectra. According to the calculations by Nidever et al. (2002), partly compensating each other, these effects do not exceed 1 km s^{-1} and must be approximated by linear or quadratic dependences on the color index or the radial velocity itself. Such dependences are commonly found in the radial-velocity differences from various publications.

The new astrometric methods of radial-velocity measurements that are free from the above-mentioned systematic errors (Madsen et al. 2002) are promising. However, they can be implemented with acceptable accuracy and massiveness only in future space astrometry missions. The catalogue by Madsen et al. (2002) was not used to make the PCRV, since the radial-velocity differences of the form "astrometric minus spectroscopic" were found to depend significantly on parallax, which requires a detailed analysis.

Traditionally, when the radial velocities are measured, the positions of spectral lines in the observed spectrum and the spectrum of a standard star with a constant and exactly known radial velocity are compared. The International Astronomical Union (IAU) has approved a list of standard stars. Over several decades, this list, on the one hand, has been supplemented and, on the other hand, stars with variable radial velocities have been excluded from it on the basis of regularly repeated measurements. The current observations of IAU standard stars were presented, for example, by Stefanik et al. (1999), Udry et al. (1999a, 1999b), and Fekel (1999). After these data have been averaged and the known binary and variable stars have been excluded, I have used the remaining 155 stars with radial velocities constant within 0.3 km s^{-1} for many years as primary standards (below referred to as the IAU list of standards). These stars are presented in Table 1: it gives their Hipparcos and HD numbers, mean radial velocities with their accuracies $\sigma(V_r)$ from the four mentioned publications (in km s^{-1}), approximate α and δ in degrees with fractions (J2000), and V magnitudes. These stars do not represent the whole variety of stellar classes and cover nonuniformly the celestial sphere. Therefore, standard stars are difficult to select for many observational programs and the compiled catalogs are difficult to compare with other catalogs. Thus, expanding the list of standard stars or compiling a list of secondary standards, especially by incorporating faint stars, with the inclusion of stars of all spectral types and luminosity classes uniformly distributed over the celestial sphere, are of current interest.

Twelve major publications contain the observations of the above-mentioned IAU standard stars that are enough to estimate and correct the zero points and systematic errors of the radial velocities in these publications. For these publications, Table 2 gives a bibliographic code of the publication in the SIMBAD database, (http://simbad.u-strasbg.fr/sim-fid.pl) a reference to the publication, the number of stars from the publication used in the PCRV (N), and the number of IAU standards used (n). A total of 47 768 mean radial velocities for 37 200 stars were taken from these publications (but, in the end, some

Table 2. Radial-velocity publications with a sufficient number of IAU standard stars

CDS bibcode	Reference	N	n	$\overline{\Delta V_r}$	σ	σ'
2004A&A...418..989N	Nordström et al. (2004)	11 545	59	−0.2	0.3	0.1
1995A&AS..114..269D	Duflot et al. (1995b)	11 291	58	+0.3	0.9	0.8
2000A&AS..142..217B	Barbier-Brossat and Figon (2000)	11 193	86	+0.0	1.7	1.7
2005A&A...430..165F	Famaey et al. (2005)	5406	8	+0.0	0.2	0.2
1999A&AS..137..451G	Grenier et al. (1999b)	2876	9	+0.7	4.2	2.0
1999A&AS..139..433D	de Medeiros and Mayor (1999)	1414	29	−0.3	0.2	0.1
2004PASP..116..693M	Moultaka et al. (2004)	1248	65	+0.0	0.5	0.4
2000A&AS..142..275S	Strassmeier et al. (2000)	1087	11	+0.3	0.7	0.6
2002ApJS..141..503N	Nidever et al. (2002)	849	54	+0.1	0.1	0.1
1994AJ....107.2240C	Carney et al. (1994)	773	8	−0.2	0.5	0.2
1991AJ....101.1495M	Morse et al. (1991)	61	10	−0.6	1.2	1.0
2000PASP..112..966S	Skuljan et al. (2000)	25	14	+0.1	0.2	0.1

of the spectroscopic binaries were not included in the PCRV). These account for ∼80% of the catalogued mean radial velocities used to make the PCRV.

For the IAU standards, we calculated radial-velocity differences of the form "publication minus IAU list of standards." The mean of these differences presented in the $\overline{\Delta V_r}$ column (in km s^{-1}) of Table 2 is considered as a zero-point discrepancy between the publication and the IAU list of standards. The standard deviation of the differences presented in the σ column (in km s^{-1}) is considered as an objective estimate of the mean radial-velocity accuracy in a given publication. The significant and physically justified systematic dependences of the differences on various factors are considered as systematic radial-velocity errors in a given publication. They are approximated by the equations presented in Table 3 with the opposite sign (in km s^{-1}). In the correction formulas, α and δ are in degrees, the radial velocity V_r is in km s^{-1}, and the color index ($B-V$) is in magnitudes. After the corrections to the radial velocities have been applied, residual differences of the form "publication minus IAU list of standards" are calculated. The standard deviation of these differences presented in the σ' column of Table 2 is considered as an objective estimate of the mean radial-velocity accuracy after the correction. The latter is compared with the mean accuracy declared by the authors of the publication for stars of the same magnitude. For all the 12 publications, these accuracies are in good agreement. Therefore, the accuracy declared by the authors of the publications (changing within the publication from star to star) was used to calculate the weighted mean radial velocities and their accuracies: the weights were assigned as $1/(\sigma_0^2 + \sigma_1^2 + 0.2^2)$, where σ_0 is the accuracy declared by the authors of the publication (in km s^{-1}) and σ_1 is an estimate of the error due to uncertainty in the approximation factors (in km s^{-1}). The value of 0.2 km s^{-1} was added to eliminate the unjustifiably great weights in the cases where the formally declared accuracy is less than 0.3 km s^{-1}. Among the approximation factors, α and δ were taken from the Hipparcos catalogue and may be considered accurate, $B-V$ from Hipparcos for the stars under consideration is known with an accuracy higher than $0^m\!.1$, and V_r is known for the standard stars with an accuracy higher than 0.3 km s^{-1}. As a result, σ_1 does not exceed 1 km s^{-1}.

Initially, we considered the dependences of the radial-velocity differences on the radial velocity itself, equatorial and Galactic coordinates, parallax, V magnitude, and $B-V$ color index taken from Hipparcos, and absolute magnitude M_V calculated here from Hipparcos data by applying the correction for interstellar extinction as prescribed by Arenou et al. (1992). For checking purposes, we also considered the dependences on stellar rotational velocity $v \sin i$, metallicity Fe/H, age, effective temperature, $b-y$ color index in Strömgren photometry, and other quantities taken from the publications under consideration or from the GCS, where many of these quantities were determined with a high accuracy for thousands of stars, but not for all stars. Therefore,

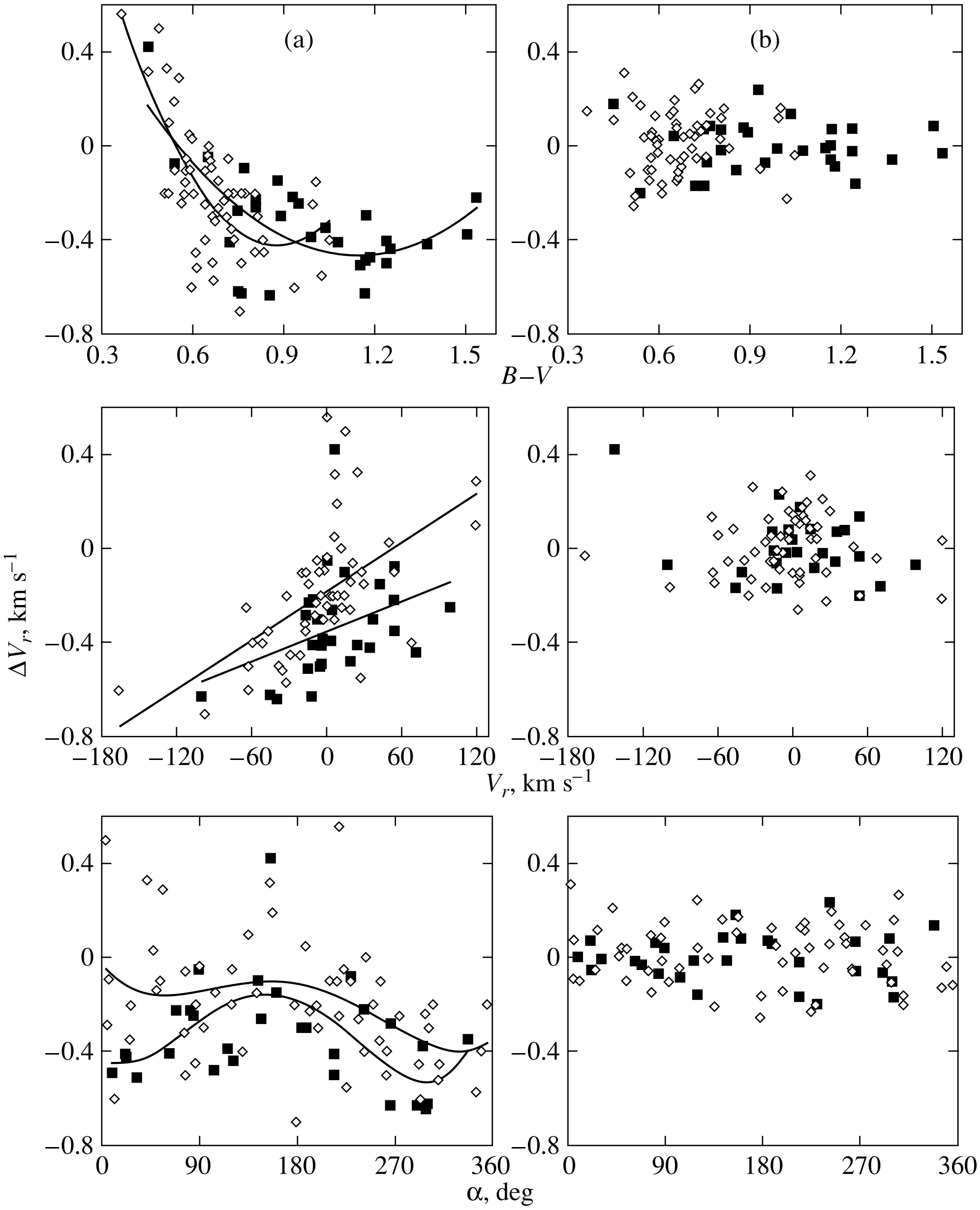

Fig. 1. Radial-velocity differences of the form "publication minus IAU list of standards", vs. $B-V$ color index, radial velocity, and α before and after applying the corrections from Table 3 for the GCS and the catalog by de Medeiros and Mayor (1999), diamonds and squares, respectively, for 59 and 29 IAU standard stars.

although slight dependences on $v \sin i$, Fe/H, and age were found in several cases, they were disregarded and will be analyzed at a later time.

A multifactor regression analysis was used to analyze the dependences. Significant dependences were sought at a multiple correlation coefficient larger than 0.6 and pair correlation coefficients larger than 0.4. The factors were considered in order of decreasing pair correlation coefficient. If the number of stars is much larger than the number of factors, then a dependence that is formally significant according to the F test will always be found. Therefore, it is particularly important to physically justify the dependences found and to exclude the factors that correlate with one another from the analysis.

As expected, a strong correlation was found between the effective temperature and the $B-V$ and $b-y$ color indices. Moreover, for the publications that include only main-sequence stars or only giant stars, these quantities correlate with the absolute magnitude M_V, since the main sequence itself and the giant branch reflect the color–magnitude relation for stars. In many cases, the dependence on $b-y$ was more pronounced than that on $B-V$. However, $B-V$ was

Table 3. Systematic radial-velocity corrections for the publications with a sufficient number of IAU standard stars

References	Correction
Nordström et al. (2004)	$-2.52(B-V)^2 + 4.7(B-V) - 0.002V_r + 0.0006\alpha + 0.04\cos(\alpha - 40) - 1.88$
Duflot et al. (1995b)	0
Barbier-Brossat and Figon (2000)	0
Famaey et al. (2005)	0
Grenier et al. (1999b)	$-0.231\delta + 5.52$
de Medeiros and Mayor (1999)	$-1.23(B-V)^2 + 2.9(B-V) - 0.002V_r + 0.0004\alpha + 0.06\cos(\alpha + 20) - 1.30$
Moultaka et al. (2004)	$+0.84(B-V) - 0.6$ at $B-V < 0.4$, $+0.87(B-V) - 0.9$ at $B-V > 1.1$
Strassmeier et al. (2000)	$-0.5\cos(2(\alpha + 10)) - 0.2$
Nidever et al. (2002)	$+0.12(B-V) - 0.001V_r - 0.2$
Carney et al. (1994)	$-0.85(B-V) - 0.0038V_r + 0.58$
Morse et al. (1991)	$-0.036V_r - 0.77\cos(\alpha) - 0.023\delta + 1.56$
Skuljan et al. (2000)	$+0.2016(B-V) + 0.0029V_r - 0.3$

chosen by tradition and, besides, it is known for all of the stars under consideration.

A dependence of the radial velocity on hour angle is possible in Coudé observations. In some of the observational programs, the hour angle correlates with α, while the relationship between hour angle and atmospheric dispersion depends on δ. The linear and sinusoidal dependences of the radial velocity on equatorial coordinates can be explained in this way. The dependence on hour angle could be found explicitly by analyzing not cataloged mean radial velocities, but individual observations; however, this is possible only in collaboration between all the authors of the publications.

The dependences on Galactic coordinates seem to be physically unjustified. Therefore, in all of the cases where they showed up, we sought for the dependences on equatorial coordinates. The unique relationship between the Galactic and equatorial coordinates helps to choose a fit in the case where the stars are distributed in Galactic latitude or longitude more uniformly than they are in α or δ.

As a result, the list of independent factors includes the radial velocity, the $B-V$ color index, α, δ, the parallax, and the V magnitude. Linear and quadratic dependences of the radial-velocity differences on the radial velocity itself and $B-V$ as well as linear and sinusoidal dependences on α and δ were found in the publications under consideration.

As an example, for two publications, GCS and de Medeiros and Mayor (1999), radial-velocity differences of the form "publication minus IAU list of standards" are plotted against $B-V$, radial velocity, and α in Fig. 1 for 59 and 29 standards (diamonds and squares, respectively) before (a) and after (b) applying the corrections from Table 3 (the lines in the Fig. 1 are shown for clarity and do not correspond to the fits). Both publications present CORAVEL data, but for different stars, main-sequence and giant ones. The systematic dependences are clearly seen to be similar.

After applying the corrections, we used the 12 publications under consideration to compile a work list of secondary radial-velocity standards (below referred to as the WLSS). It includes 1128 stars that meet the following conditions: (1) a star is presented at least in 3 of these 12 publications; (2) the accuracy of the weighted mean velocity is higher than 1 km s^{-1}; (3) the standard deviation of the results from different publications is less than 3 km s^{-1}; (4) for GCS stars, the standard deviation of the results of individual observations is less than 5 km s^{-1}, while the probability that this scatter was caused by observational errors and not by radial-velocity variations is higher than 0.1 (the values were taken from the GCS); (5) a star is marked as a spectroscopic binary with radial-velocity variations larger than 0.5 km s^{-1} neither in any of the publications under consideration nor in the Ninth Catalogue of Spectroscopic Binary Orbits by Pourbaix et al. (2004); (6) a star does not belong to binaries of the O, X, and G categories from Hipparcos (the catalog's field H59); (7) a star is not a visual pair with a component separation of less than 20 AU (this value was calculated from the

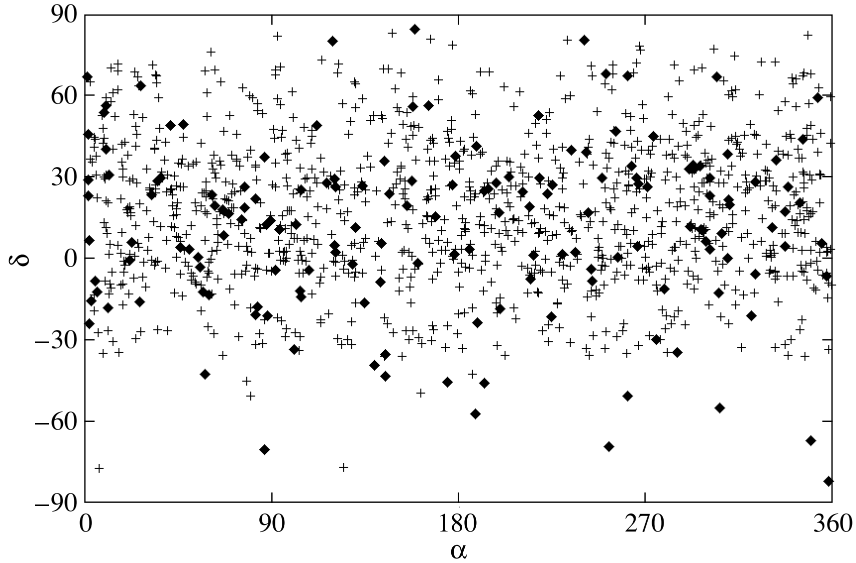

Fig. 2. Distribution of 155 IAU standards (diamonds) and 1128 WLSS stars (crosses) over the celestial sphere in equatorial coordinates.

angular separation between the components and the Hipparcos parallax).

The WLSS is presented in Table 4: it gives Hipparcos and HD numbers, weighted mean radial velocities with their accuracies $\sigma(V_r)$ in the PCRV (in km s^{-1}), approximate α and δ in degrees with fractions (J2000), and V magnitudes.

The distributions of the 155 IAU standards and 1128 WLSS stars under consideration over the celestial sphere are indicated in Fig. 2 by diamonds and crosses, respectively. The stars are distributed uniformly in α and predominate in the Northern Hemisphere. The distributions of the same stars in $B-V$ color index and absolute magnitude M_V are indicated in Fig. 3 by the same symbols. We see that, in contrast to the IAU standards, the WLSS includes red dwarfs, subgiants, and main-sequence stars in the interval A5–F5. However, this interval, with a large number of peculiar and rapidly rotating stars, remains a problem in radial-velocity measurements. In addition, there are no supergiants, white dwarfs, and O-type stars in the WLSS. Of considerable interest are the distributions of the same stars in distance, as derived from the Hipparcos parallax, and apparent V magnitude, which are indicated in Fig. 4 by the same symbols. Here, we clearly see the division of stars into three groups: (1) nearby red dwarfs from the WLSS, (2) F5V–G8V stars from both lists at intermediate distances, and (3) distant red giants together with early-type stars with a predominance of IAU standards.

Table 4. Work list of secondary standards used to make the PCRV (the full table is presented in electronic form)

HIP	HD	V_r	$\sigma(V_r)$	α	δ	m_V
379	225 216	−28.9	0.2	1.175	67.166	5.68
400	225 261	7.5	0.2	1.235	23.270	7.82
428		−0.2	0.2	1.295	45.787	9.95
544	166	−6.5	0.1	1.653	29.022	6.07
616	283	−43.1	0.2	1.886	−23.819	8.70

We used the combined list of 1283 standard stars (IAU+WLSS) to estimate and correct the radial-velocity zero points and systematic errors in 33 publications with the results of observations for these stars. For these publications, Tables 5 and 6 give characteristics similar to those presented in Tables 2 and 3, but the combined list of standards is used instead the IAU list of standards. We used 8258 mean radial velocities from these publications, which accounted for ∼13% of the PCRV material. The analysis of this material, the list of factors, and the procedure for calculating the weights and weighted mean radial velocities are similar to those described above for the 12 major publications. No significant dependences on any factors were found for most of these publications; only the zero point was corrected.

In making the PCRV, we considered a total of more than 1000 publications with radial-velocity measurements. The full list is accessible at the OSACA page (http://www.geocities.com/orionspiral/). However, most of them pertain to single observations of individual stars that are not only nonstandard ones,

Table 5. Radial-velocity publications with a sufficient number of IAU and WLSS standard stars

Reference	N	n	$\overline{\Delta V_r}$	σ	σ'
Fehrenbach et al. (1997)	1525	42	+4.3	9.8	9.8
Fehrenbach et al. (1992)	1166	18	−8.2	14.4	11.8
Duflot et al. (1992)	819	21	−1.7	6.2	4.8
Reid et al. (1995)	658	104	−2.7	16.8	16.8
Yoss and Griffin (1997)	631	19	+0.0	0.6	0.6
Grenier et al. (1999a)	547	6	−0.2	1.1	1.1
Duflot et al. (1995a)	535	10	−1.1	3.4	3.4
Tokovinin and Smekhov (2002)	424	20	+0.0	0.5	0.5
Gizis et al. (2002)	413	98	−0.1	1.1	1.1
Rastorguev and Glushkova (1997)	358	8	+0.2	0.6	0.6
Ryan and Norris (1991)	143	19	−1.2	10.1	10.1
Abt and Willmarth (1994)	139	14	−0.2	0.7	0.7
Cutispoto et al. (2002)	104	5	−0.1	0.2	0.2
King et al. (2003)	86	7	+0.5	1.0	1.0
Tokovinin (1990)	85	32	−0.1	0.3	0.3
Marrese et al. (2003)	83	21	−0.4	1.0	1.0
Griffin and Suchkov (2003)	70	5	+0.3	0.6	0.6
Clementini et al. (1999)	62	29	+0.0	0.8	0.8
Delfosse et al. (1998)	60	45	+0.0	0.4	0.4
Garcia-Sanchez et al. (1999)	58	22	−0.1	0.3	0.3
Morrell and Abt (1992)	43	6	−0.2	1.2	1.2
Soderblom and Mayor (1993)	37	8	+0.1	0.1	0.1
Gaidos et al. (2000)	34	17	+0.1	0.3	0.3
Metzger et al. (1992)	32	8	+0.0	0.7	0.7
Takeda et al. (1998)	32	15	+0.3	0.6	0.6
Qiu et al. (2002)	24	10	+0.3	0.5	0.5
Olszewski et al. (1995)	20	8	+0.2	0.2	0.2
Orosz et al. (1997)	13	12	−0.7	0.7	0.4
Mazeh et al. (2002)	13	6	−1.4	1.6	1.6
Gonzalez et al. (2001)	12	12	+0.1	0.4	0.2
Metzger et al. (1991)	12	10	+0.4	0.4	0.4
Dubath et al. (1997)	10	10	+0.5	1.2	1.2
Metzger et al. (1998)	9	9	+0.3	1.5	0.8

Table 6. Systematic radial-velocity corrections for publications with a sufficient number of IAU and WLSS standard stars

Reference	Correction
Fehrenbach et al. (1997)	-4.3
Fehrenbach et al. (1992)	$-38.88(B{-}V) - 0.369\delta + 36.64$
Duflot et al. (1992)	$-4.05\cos(\alpha) - 0.0114\delta^2 + 1.16\delta - 23.2$
Reid et al. (1995)	$+2.7$
Yoss and Griffin (1997)	0
Grenier et al. (1999a)	$+0.2$
Duflot et al. (1995a)	$+1.1$
Tokovinin and Smekhov (2002)	0
Gizis et al. (2002)	-0.2
Rastorguev and Glushkova (1997)	0
Ryan and Norris (1991)	$+1.2$
Abt and Willmarth (1994)	$+0.2$
Cutispoto et al. (2002)	$+0.1$
King et al. (2003)	-0.5
Tokovinin (1990)	$+0.1$
Marrese et al. (2003)	$+0.4$
Griffin and Suchkov (2003)	-0.3
Clementini et al. (1999)	0
Delfosse et al. (1998)	0
Garcia-Sanchez et al. (1999)	$-0.37\cos[2(\alpha - 30)]$
Morrell and Abt (1992)	$+0.2$
Soderblom and Mayor (1993)	-0.1
Gaidos et al. (2000)	-0.1
Metzger et al. (1992)	0
Takeda et al. (1998)	-0.3
Qiu et al. (2002)	-0.3
Olszewski et al. (1995)	$+0.005V_r - 0.17$
Orosz et al. (1997)	$-1.99(B{-}V) + 0.0145V_r - 3.0$
Mazeh et al. (2002)	$+1.4$
Gonzalez et al. (2001)	$-0.56\sin(\alpha) - 0.002\alpha + 0.29$
Metzger et al. (1991)	-0.4
Dubath et al. (1997)	-0.5
Metzger et al. (1998)	$-2.12\cos(\alpha) - 1.2$

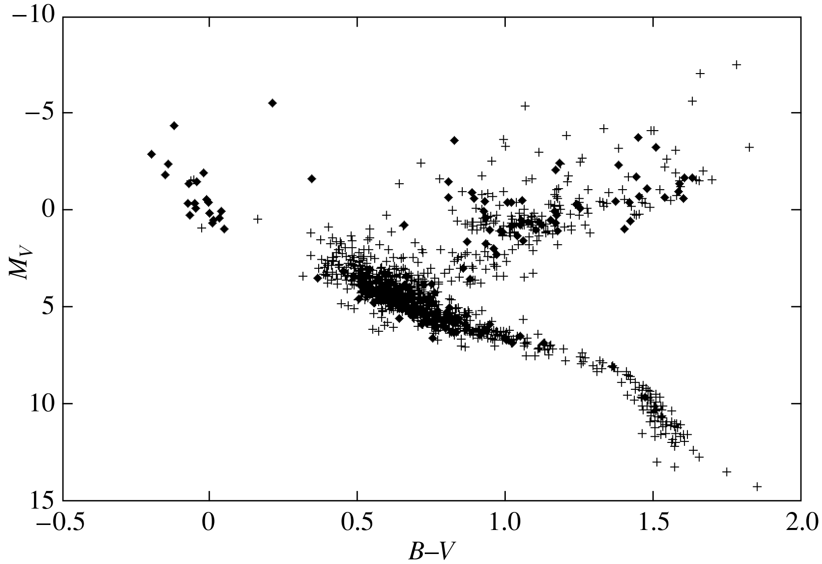

Fig. 3. Distribution of 155 IAU standards (diamonds) and 1128 WLSS stars (crosses) in $B-V$ color index and absolute magnitude.

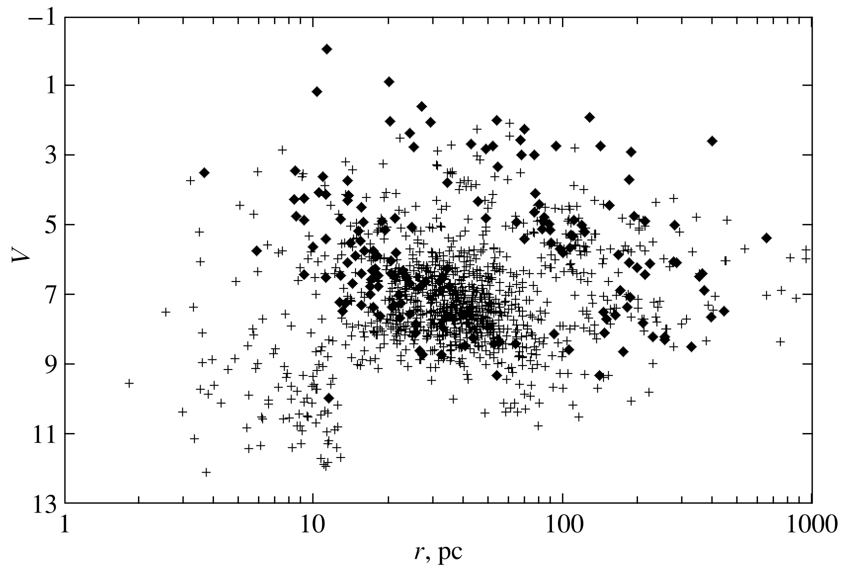

Fig. 4. Distribution of 155 IAU standards (diamonds) and 1128 WLSS stars (crosses) in distance and V magnitude.

but generally belong to spectroscopic binaries or peculiar stars. In such cases, the systematic errors of the derived radial velocities are difficult to estimate. Nevertheless, we selected 154 publications among those that did not include IAU and WLSS standards for which rough estimates of the systematic errors can be given. These publications were produced with the same instruments as those considered above or the publications themselves provide convincing evidence that the systematic errors of the derived radial velocities do not exceed 1 km s^{-1}. The weights were assigned on this basis. The radial velocities from these publications were used in the PCRV without corrections. The largest of these 154 publications are presented in Table 7: it gives a reference to the publication, the number N of stars from the publication used in the PCRV, and an estimate of the accuracy in assigning the weight σ. We analyzed 4181 mean radial velocities from these publications, which accounts for ∼7% of the PCRV material.

We analyzed a total of 60 207 mean radial velocities for 40 825 stars. However, the PCRV contains only those of the numerous spectroscopic binaries for which the radial center-of-mass velocity (sys-

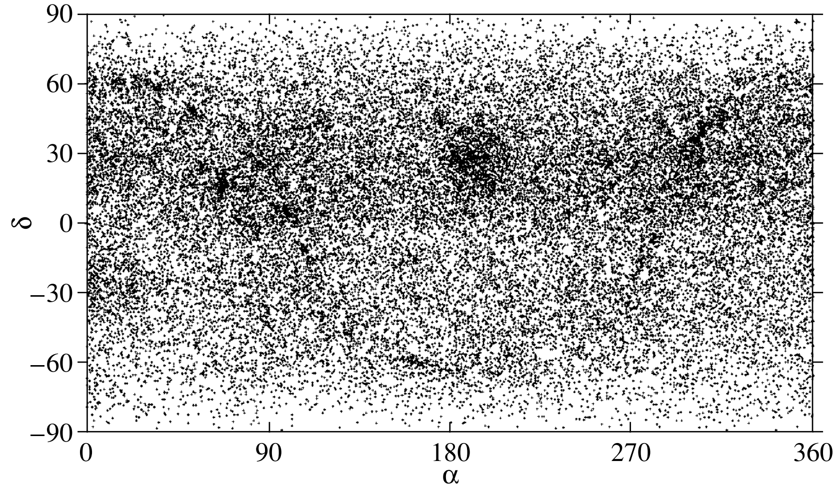

Fig. 5. Distribution of 35 495 PCRV stars over the celestial sphere in equatorial coordinates.

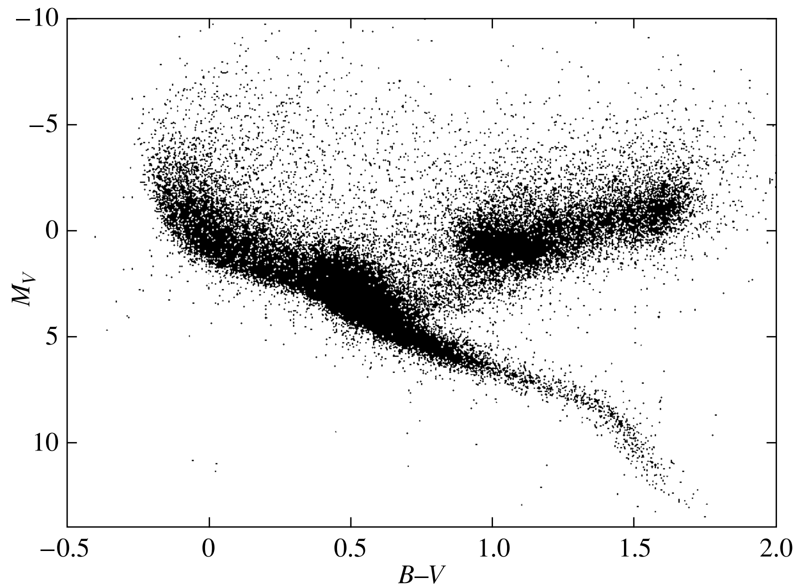

Fig. 6. Distribution of 35 495 PCRV stars in $B-V$ color index and absolute magnitude.

temic velocity) can be calculated. As a rule, these are orbital pairs from the Ninth Catalogue of Spectroscopic Binary Orbits by Pourbaix et al. (2004). In addition, we found several hundred cases where the same component was designated differently in different publications or different components were designated identically. As a result, more than 5000 "problem" stars were put off until the publication (presumably in 2006) of the Washington Multiplicity Catalog (WMC), in which a unique designation will probably be given for the components of nonsingle stars.

There are two compilation catalogs among the publications used (see Table 2): WEB and BBF. As we see from the table, they are fairly accurate, at least with regard to the radial velocities of IAU standard stars. The distribution of radial-velocity differences of the form "publication minus IAU list of standards" is nearly Gaussian. The accuracies declared by the authors of these publications may be considered plausible. These rather than the much more "optimistic" values of $\sigma'(\Delta V_r)$ from Table 2 were used to calculate the weights. The unexpectedly high accuracy of these publications probably stems from the fact that they are actually based on the results of a few scientific groups and instruments: for example, the 48 largest catalogs of the 459 initial catalogs used in BBF include 75% of the data and they were compiled by

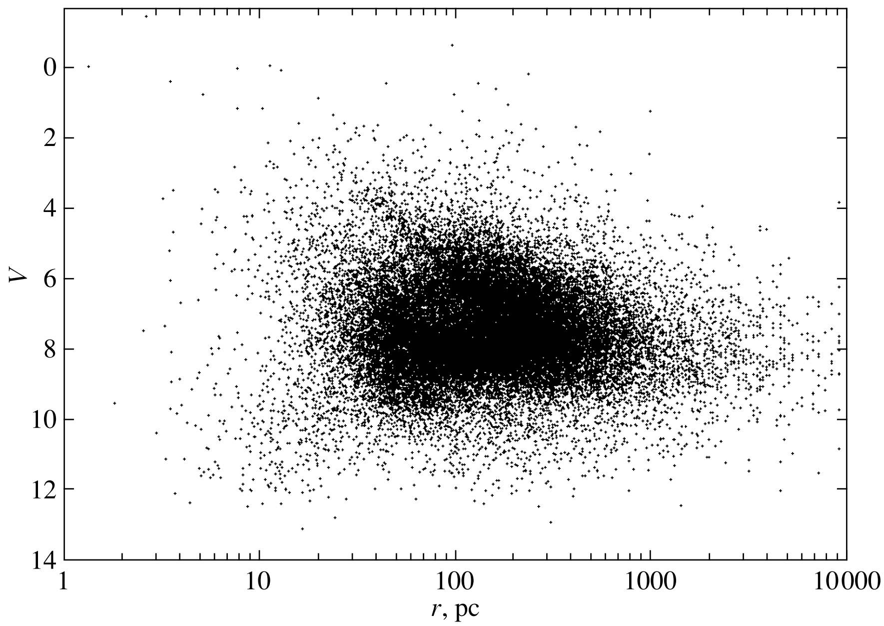

Fig. 7. Distribution of 35 495 PCRV stars in distance and V magnitude.

no more than 20 scientific groups. In the future, the material from these publications is planned to be used on the level of initial observational catalogs.

THE PULKOVO COMPILATION OF RADIAL VELOCITIES

The Pulkovo Compilation of Radial Velocities (PCRV) is presented in Table 8: it gives Hipparcos and HD numbers, weighted mean radial velocities V_r in km s^{-1}, their accuracies $\sigma_{\rm int}$ in km s^{-1} (calculated using the standard formula $1/(\sum p)^{-1/2}$, where $\sum p$ is the sum of the weights), the number n of publications used, the radial-velocity accuracy $\sigma_{\rm ext}$ calculated as the standard deviation of the differences "publication minus weighted mean velocity" for the case of two or more publications in km s^{-1}, approximate α and δ (J2000) in degrees with fractions, and Hipparcos V magnitudes.

The distribution of 35 495 PCRV stars over the celestial sphere is shown in Fig. 5: a predominance of stars in the Northern Hemisphere and a concentration to the Galactic equator and the Galactic North Pole are clearly seen. The distribution in $B-V$ color index and absolute magnitude M_V is shown in Fig. 6. This distribution is are the same as that for all Hipparcos stars: all classes are represented. The distribution in distance, as derived from the Hipparcos parallax, and apparent magnitude V is shown in Fig. 7. About 30 000 (85%) stars lie at distances from 30 to 500 pc.

The median accuracy of the weighted mean radial velocity in the PCRV is 0.7 km s^{-1}. The radial velocities of 21 015 (59%) and 29 804 (84%) stars have accuracies higher than 1 and 3 km s^{-1}, respectively. Unfortunately, the stars whose radial velocities are given in only one publication predominate, i.e., 24 437 (69%) stars. The radial velocities of 8319 (23%) and 2739 stars are given in 2 and from 3 to 11 publications, respectively. The median of $\sigma_{\rm ext}$, the standard deviation of the differences "publication minus weighted mean velocity" for the case of two or more publications, is 1.5 km s^{-1}. Since hundreds of spectroscopic binaries may be hidden in the PCRV, we conclude that the systematic errors of the publications used have been successfully taken into account.

Table 7. Some publications with radial velocities used in the PCRV without corrections

Reference	N	σ
Nordström et al. (1997)	574	0.3
Griffin (2006)	207	0.4
de Medeiros et al. (2002)	178	0.2
Carrier et al. (2002)	108	2.7
Behr (2003)	95	1.4
de Medeiros et al. (2004)	94	1.2
Carney et al. (2003)	84	0.3
Gorynya et al. (1996)	72	0.3

Table 8. Pulkovo Compilation of Radial Velocities (the full table is presented in electronic form)

HIP	HD	V_r	$\sigma_{\rm int}$	n	$\sigma_{\rm ext}$	α	δ	m_V
3	224 699	0.0	4.2	1	–	0.005	38.859	6.61
7		8.3	1.5	1	–	0.022	20.036	9.64
8	224 709	–31.0	4.6	1	–	0.027	25.886	9.05
11	224 720	–25.8	2.4	1	–	0.037	46.940	7.34
14	224 726	21.7	0.9	1	–	0.048	–0.360	7.25
19	224 721	6.3	0.7	2	9.7	0.053	38.304	6.53

CONCLUSIONS

The Pulkovo Compilation of Radial Velocities (PCRV) for 35 495 Hipparcos stars has been made by analyzing more than 60 000 mean radial velocities from 203 publications. Owing to the observations of 155 IAU standard stars, 12 publications containing ∼80% of all the radial velocities used were freed with confidence from systematic errors and errors in the radial-velocity zero points that depend on the radial velocity itself, $B-V$ color index, and equatorial coordinates. Based on the data from these publications, we compiled a work list of 1128 secondary standards. This list is an important result of our study, since it is considerably better than the IAU list, represents the whole variety of stellar classes, includes many faint stars, and covers more uniformly the celestial sphere. This allows it to be used to analyze and evaluate new radial-velocity observations. Our study has shown that the increasing flow of current radial-velocity measurements cannot be analyzed without producing such a list of secondary standards. The two lists of standards were used together to free 33 more publications containing ∼13% of all the radial velocities used from systematic errors and errors in the radial-velocity zero points. The objective estimates of the accuracy of the publications obtained from comparison with the lists of standards allow the median estimate of the PCRV accuracy to be considered plausible: 0.7 km s^{-1}. All the main classes stars over the entire celestial sphere mostly within 500 pc of the Sun are presented in the PCRV.

The derived radial velocities, together with the Hipparcos three-dimensional coordinates, Tycho-2 proper motions, photometry, and data on the duplicity, chemical compositions, and ages of stars in the form of OSACA, are already used in kinematic studies. For example, Gontcharov and Vityazev (2005) showed that although many Galactic structures within 400 pc of the Sun (the Local Bubble, the Great Tunnel, Gould's Belt) consist of stars of different ages up to several hundred million years, they were formed recently, no earlier than 20 Myr ago in processes related to two stellar streams, Orion and Sirius. Based on the Milne–Ogorodnikov model, Bobylev et al. (2006) have demonstrated significant differences in the kinematics of the nearest single and multiple main-sequence stars and accurately determined the Galactic rotation parameters from the motions of stars farther than 200 pc.

ACKNOWLEDGMENTS

I wish to thank R. Griffin and A.S. Rastorguev for advice, consultations, and unpublished materials. I am grateful to the anonymous referee for helpful remarks. In this study, I have intensively used the SIMBAD Astronomical Database and other resources from the Astronomical Data Center in Strasbourg (France) (http://cdsweb.u-strasbg.fr/). This study was supported by the Russian Foundation for Basic Research, project no. 05-02-17047.

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Translated by V. Astakhov