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An astrometric catalogue for the area of Coma Berenices

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Abstract. A catalogue[1] of stellar positions and proper motions down to the 14th photographic magnitude in the area of the open cluster in Coma Berenices is compiled from data of 12 different sources. The accuracy of the proper motion data is comparable to that of the Hipparcos Catalogue.

Key words: astrometry — catalogues — methods: data analysis — open clusters: coma cluster

1. Introduction

The principal purpose of this work is to present a catalog of positions and proper motions for stars in the area of the open star cluster in Coma Berenices. The data are based on a compilation of 12 different catalogs. The first exhaustive study of the cluster was carried out by Trumpler (1938), determining definite cluster membership for the brighter stars. For some of the fainter stars the membership remained in doubt. The small number of members, a little more than 50, can be considered to be characteristic for most of the known open clusters. The determination of membership probability based on proper motions is somewhat difficult in this case because the motion of the cluster is not very different from that of the surrounding field stars. Thus it is important to have proper motions of high accuracy for the selection of cluster members which is the aim of this work. The precision of the proper motions determined in this paper is comparable to that of the Hipparcos data. This is due to the large epoch difference covered by the catalogs which contribute to the compilation of data, to the quality of the plate model used in the reduction of a series of photographic plates, and to the validity of the process with which systematic errors with respect to the Hipparcos system were eliminated from the various source data. Initially this work was part of the Ph. D. thesis of C. Abad (Abad 1996), where the PPM Catalogue of Positions and Proper Motions by Bastian & Roeser (1991) was used as reference system. The Hipparcos Catalogue was not available yet at that time. The reduction method employed was that described by Abad (1993). In this work, the reference system and the reduction method were both improved. The reference system is now the Hipparcos Catalogue, and the reduction is based on a model described by Abad (1998). The catalog compiled in this paper is based on 12 source catalogs of different types. They include meridian circle observations, photographic plates, and position observations with CCD detectors. One of the sources is photographic plates obtained with the CIDA 1-meter Schmidt telescope, and it is these plates which define the limits of the area survey. The source catalogs for which we either had the plates or the measured rectangular coordinates X, Y of stellar objects were reduced in the process. We wish to mention in particular the POSS plates whose microdensitometer scans were made available to us by the Space Telescope Science Institute. A list of all sources, giving the respective epoch and indicating whether the date was reduced by us or not is given in Table 1.

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[1] The catalogue Table 5 is only 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/Abstract.html

2. Reduction of the photographic plates

The process of the reduction of photographic plates starts with the determination of the cartesian coordinates X and Y. For the catalogs POSS, Schmidt 88, and Schmidt 94 the plates were first digitized with PDS microdensitometers. The plates of the series Schmidt 88 were digitized with the PDS microdensitometer of the Observatory of Munster, Germany, and the coordinates X and Y were determined using their computer software. The plates of the series Schmidt 94 were digitized with the PDS microdensitometer of the Department of Astronomy of the Yale University. The respective X and Y coordinates were

Table 1. List of used catalogues

Number	Mean epoch	Catalogue	Type	Reduction	Numbre of stars
1	1900	Paris	photographic	yes	675
2	1900	Oxford	photographic	yes	2783
3	1926	Heckmann	photographic	yes	212
4	1928	Yale	meridian	no	280
5	1930	AGK2	photographic	no	383
6	1956	POSS	photographic	yes	8930
7	1958	AGK3	photographic	no	383
8	1988	Schmidt88 CIDA	photographic	yes	3359
9	1990	Schmidt90 CIDA	photographic	yes	4951
10	1991	Carlsberg	meridian	no	301
11	1991	Tycho	Hipparcos	no	702
12	1994	Schmidt94 CIDA	photographic	yes	5924

Table 2. Final errors for the entire Paris Zone and part of the Oxford Zone of the AC and for the POSS plates covering the coma area

Errors	AC Paris zone			AC Oxford zone			POSS (PPM)		
Magnitude	σ_α (s)	σ_δ ($''$)	img.	σ_α (s)	σ_δ ($''$)	img.	σ_α (s)	σ_δ ($''$)	img.
2	0.014	0.34	6	0.039	0.47	10			
3	0.029	0.54	17	0.023	0.52	10			
4	0.019	0.34	79	0.034	0.32	68			
5	0.018	0.23	331	0.023	0.31	79			
6	0.016	0.21	1343	0.023	0.32	222	0.074	0.33	7
7	0.014	0.20	4747	0.022	0.29	627	0.026	0.26	25
8	0.014	0.20	14504	0.022	0.28	2058	0.028	0.40	56
9	0.014	0.19	43720	0.022	0.28	6574	0.024	0.27	46
10	0.013	0.19	114957	0.021	0.27	35301	0.020	0.26	168
11	0.014	0.19	90985	0.022	0.29	36682	0.020	0.28	93
12	0.015	0.20	7275	0.023	0.29	543	0.028	0.33	63
13							0.018	0.41	18
total errors	0.014	0.19	277974	0.022	0.28	82179	0.024	0.30	443
*'s Hipp.	0.018	0.25	6996	0.023	0.32	2398			

Table 3. Final errors for the three Schmidt CIDA plates series covering the coma area

Errors	Schmidt plates 1988			Schmidt plates 1990			Schmidt plates 1994		
Magnitude	σ_α (s)	σ_δ($''$)	img.	σ_α (s)	σ_δ($''$)	img.	σ_α (s)	σ_δ($''$)	img.
4	0.003	0.11	14	0.026	0.24	27			
5	0.004	0.08	31	0.020	0.39	35	0.012	0.13	1 16
6	0.019	0.17	102	0.022	0.37	150	0.011	0.13	163
7	0.007	0.10	102	0.017	0.28	173	0.014	0.13	285
8	0.013	0.20	285	0.017	0.28	388	0.013	0.15	582
9	0.013	0.19	384	0.017	0.28	644	0.011	0.12	1520
10	0.011	0.14	866	0.017	0.28	1543	0.010	0.13	2829
11	0.008	0.12	1471	0.017	0.30	3855	0.011	0.13	4679
12	0.009	0.12	3216	0.017	0.29	4734	0.014	0.18	5807
13	0.010	0.16	1714	0.018	0.28	4749	0.014	0.17	7091
14	0.009	0.11	29	0.020	0.30	3061	0.017	0.21	5144
15				0.017	0.32	10	0.023	0.28	1560
16							0.035	0.48	374
total errors	0.010	0.14	8214	0.018	0.29	19372	0.015	0.18	30150
*'s Hipp.	0.004	0.02	138	0.005	0.12	140	0.008	0.17	133

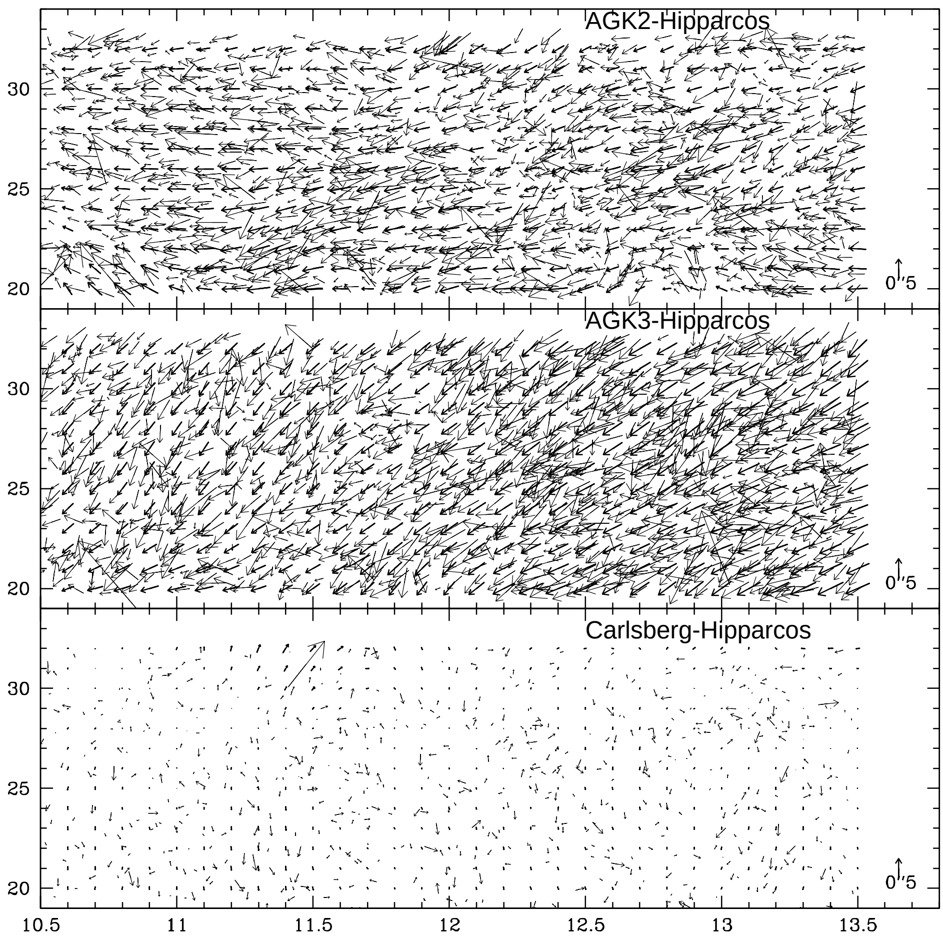

Fig. 1. Vector fields representing the positions differences between specific catalogues and the Hipparcos Catalogue. Light arrows represent individual differences. Each arrow has its origin on the point of coordinates (α, δ) of the respective common star. Modulus and direction are given by the composition of the two α and δ differences. Hipparcos system and epoch of the catalogue to study are used. The heavy arrows represent the systematic difference obtained after adjustment of a sliding polynomial to real differences (see text). The AGK2, the AGK3, and the Carlsberg catalogues are represented in a separating form

derived from these scans by J. Lee of the Yale University using programs developed by himself. The original scans of this series were used to test an image adjustment method which was subsequently applied to the scans of the POSS plates. The POSS plates were digitized using the PDS microdensitometer of the Space Telescope Institute, and the data were made available to us. The plates of the series Schmidt 90 were measured with the Zeiss PSK2 stereocomparator of CIDA. For the Paris and Oxford zones of the Astrographic Catalogue and for the plate series by Heckmann (1929) the original measurements were used.

Each of the Schmidt plate series presented different specific problems. Systematic errors caused by the plate bending mechanism of the Schmidt Camera were found in Schmidt 88 series (Abad 1995). A small movement of the mirror of the telescope mainly on the y-axis direction was present when the Schmidt 90 plates were taken. And finally, light came into the box containing the Schmidt 94 plates, before they were taken, producing a small degradation of the back ground over one side of each plate.

Such problems as well as the saturation of the brightest stars of the POSS plates, were used to check a new function which reproduce the real profile of the digitalized images better than the gaussian functions. The function created make use of the arctangent function (Abad 1996).

$$d(u,v) = \frac{A}{4atn(b_u c_u)atn(b_v c_v)}$$
$$(atn(b_u(u-c_u)) - atn(b_u(u+c_u)))$$
$$(atn(b_v(v-c_v)) - atn(b_v(v+c_v))) + \phi_1 + \phi_2 u + \phi_3 v \quad (1)$$

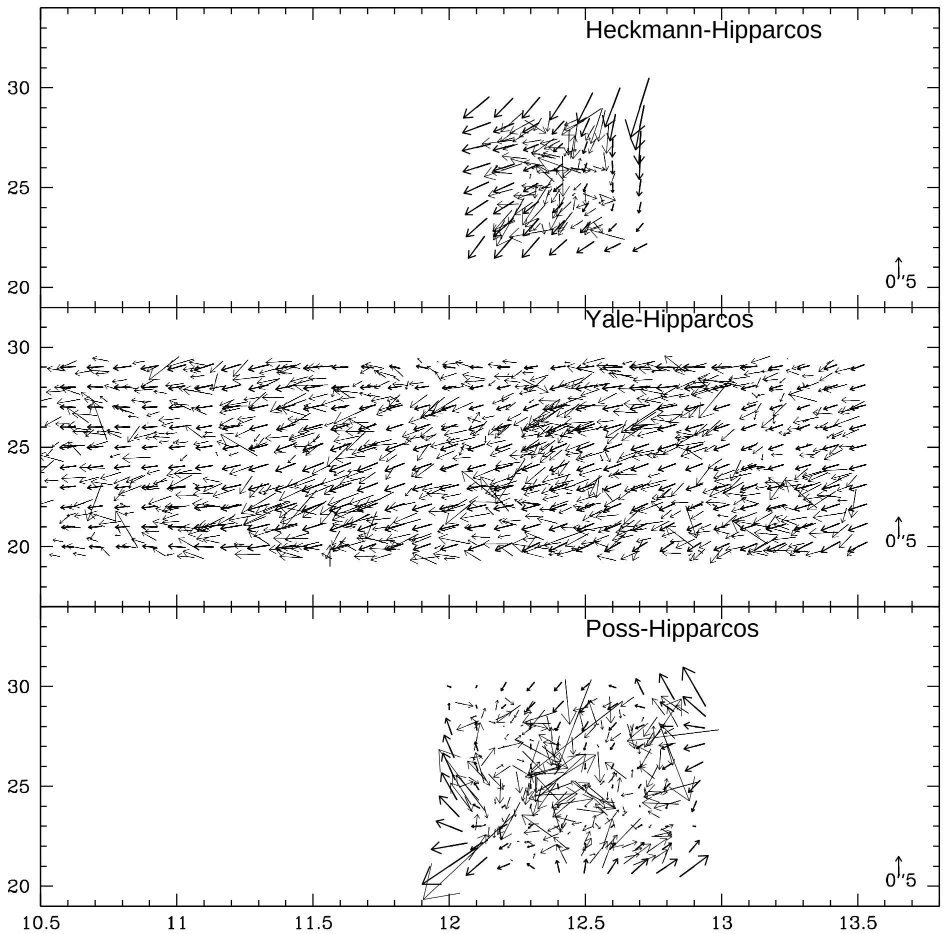

Fig. 2. Vector fields representing the positions differences between specific catalogues and the Hipparcos Catalogue. Light arrows represent individual differences. Each arrow has its origin on the point of coordinates (α, δ) of the respective common star. Modulus and direction are given by the composition of the two α and δ differences. Hipparcos system and epoch of the catalogue to study are used. The heavy arrows represent the systematic difference obtained after adjustment of a sliding polynomial to real differences (see text). The Heckmann, the Yale and the POSS catalogues are represented in a separating form

Table 4. Proper motion error analysis of the catalogue

Catalogues	Stars	α mean error	δ mean error	mean epoch differences
n^0	n^0	σ_α (s/year)	σ_δ(″/year)	years
≥ 4	2410	0.00019	0.0028	85.45
≥ 5	1674	0.00012	0.0014	92.86
≥ 6	638	0.00006	0.0008	94.78
≥ 7	371	0.00005	0.0005	94.02
≥ 8	265	0.00004	0.0004	93.92
≥ 9	196	0.00003	0.0003	94.25
≥ 10	138	0.00003	0.0003	94.31
≥ 11	62	0.00003	0.0003	94.63
≥ 12	7	0.00002	0.0003	100.11

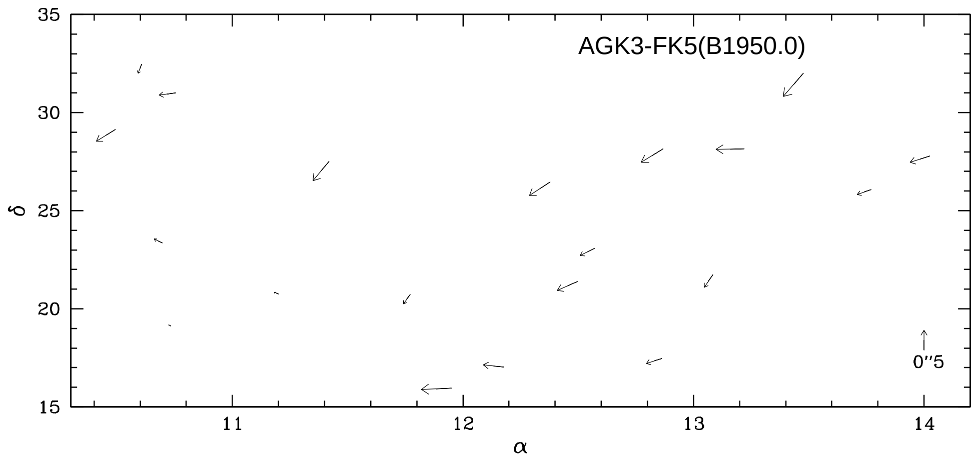

Fig. 3. Position differences between the AGK3 and the FK5 catalogs. For the FK5 positions the B1950.0 version was used, and corrected to the epoch of the AKG3 plates, using the proper motions of the FK5 catalog

where,

$$u = (x - x_0)\cos(\phi) + (y - y_0)\sin(\phi) \quad (2)$$

$$v = -(x - x_0)\sin(\phi) + (y - y_0)\cos(\phi) \quad (3)$$

$(x_0,\ y_0)$ center of the image,
ϕ angle between axis of symmetry of the image and axis of the digitalization,
A maximum density of the image,
b_u and b_v slope parameters,
c_u and c_v width parameters and,
ϕ_1, ϕ_2, ϕ_3 coefficients representing the background.
A simple modification of the above equation would make it possible to adapt the artificially created profile to the asymmetric real profile. Varying b_u, b_v, c_u and c_v different symmetries can be produced in either axis, thus permitting adaptation to a large variety of image shapes. The above profile is particularly useful for images with a saturated center and hence a flat-topped profile. The latter is the case for at least most of the reference stars. In fact, for saturated images the above profile equation is superior to the gaussian approximation, while for faint images the latter gives more consistent results. The parameters of the function, above all the coordinates of the center, are determined by least squares in an iterative process. The profile parameters are strongly related to the image brightness, which is related to the total pixel count. Thus initial values for all parameters can readily be found once the mentioned relations are approximately known.

In this paper only images of the POSS plates were analyzed with the new function.

In order to get the equatorial coordinates a linear block adjustment method derived by Stock (1981) was used for each plate series. After this first step, the plate model explained and applied by Abad (1998) is used. It consists in obtaining the field deformation depending on the position on the plate and on the magnitude from the differences, star by star, between the individual plate position and their averaged final position or the reference catalogue position if the star is contained in the reference catalogue. The individual plate position and their averaged final position were calculated both from the linear block adjustment. From these differences a general plate distortion pattern is derived which is then applied to the measured coordinates. A new block adjustment is carried out with the corrected coordinates, and these are again analyzed for a systematic distortion pattern. This process can be repeated until no systematic pattern is evident. Tables 2 and 3 contain the final results, separated into magnitude intervals for everyone of the series of plates or catalogs.

The catalogs which give their data in equatorial coordinates (Yale, Carlsberg, AGK2, AGK3, and the POSS data which were reduced with the PPM catalog as reference system) were all reduced to the Hipparcos system applying a weighted sliding polynomial scheme described by Stock & Abad (1988). The process interpolates the differences between the Hipparcos positions and the positions given by the respective catalog for stars common to both, making use only of stars up to a given maximum distance from the star whose position is to be corrected.

In order to convert the equinox and orientation of the catalog data to coincide to Hipparcos system, expressions given by Fricke et al. (1988) are used. An inadequate precession constants will simply add to the systematic differences which have to be determined anyway. To the position of the Hipparcos catalog the respective proper motions were added to allow for the epoch differences between Hipparcos and the catalog.

Weights are assigned to the differences, based on the same distances in the sense that the weight reaches unity at the point to be interpolated, and zero at the maximum distance. Using this interpolation scheme at equidistant coordinate intervals the distortion pattern of the respective catalog can be found. Example are shown in Figs. 1 and 2. Systematic differences, at times surprisingly large, are found between the AGK2 and AGK3 catalogs and the

Hipparcos catalog. In order to show that these differences are real we shall compare as an example the difference between the AGK3 and the FK5, using the B1950.0 version of the latter. The coordinates of the AKG3 are given in the same system. Thus only the epoch difference of around nine years has to be taken into account. Proper motions corrections were applied to the positions of the FK5. The resulting differences are shown as an arrow diagram in Fig. 3. It may be noted that the pattern in this figure is quite similar to that in Fig. 1 in the case of the AGK3.

3. The catalog

The final catalog (Table 5) contains positions and proper motions for approximately 2400 stars which have been selected with the following criteria: (1) the star must appear in at least 4 of the contributing catalogs, and (2) the maximum epoch difference must be at least 40 years. A photographic magnitude is also given for every object. In the case of the photographic sources the image sizes or total pixel counts were calibrated using the magnitudes in the PPM catalog, and extrapolated to fainter magnitudes. Spectral types are also given, taken from any of the sources. For the determination of the final data weights are given to each of the contributing catalogs according to the average respective mean errors. The contents of the catalogue are as follows:

1 (N) running number of this catalog,
2 (m) estimated photographic magnitude,
3 (st) spectral type,
4 (α) right ascension (hours),
5 (α) right ascension (minutes),
6 (α) right ascension (seconds),
7 (σ_α) mean error of right ascension (seconds of time $\times$ 0.001),
8 (μ_α) proper motion in right ascension (seconds of time/year),
9 (σ_{μ_α}) error of proper motion in right ascension (seconds of time $\times$ 0.00001/year),
10 (δ) declination (degrees),
11 (δ) declination (arcminutes),
12 (δ) declination (arcseconds),
13 (σ_δ) mean error of declination (arcseconds $\times$ 0.01),
14 ($t_{\rm m}$) epoch of right ascension and declination,
15 (μ_δ) proper motion in declination (arcseconds/year),
16 (σ_{μ_δ}) mean error of proper motion in declination (arcseconds $\times$ 0.0001/year),
17 (ΔT) maximum epoch difference,
18 (C) number of contributing catalogs.

The average mean errors of the proper motions, both in right ascension and declination, are 0.003 arcsec/year if there are at least 4 contributors, going down to 0.0005 arcsec/year if there are 7 or more contributors. A proper motions error analysis is given in Table 4. A comparison of our catalog with the Hipparcos data, both positions and proper motions, show no systematic pattern. Thus our catalog can be considered to be on the system defined by Hipparcos.

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