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Analysing the database for stars in open clusters

I. General methods and description of the data

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Abstract. We present an overview and statistical analysis of the data included in WEBDA. This database includes valuable information such as coordinates, rectangular positions, proper motions, photometric as well as spectroscopic data, radial and rotational velocities for objects of open clusters in our Milky Way. It also contains miscellaneous types of data like membership probabilities, orbital elements of spectroscopic binaries and periods of variability for different kinds of variable stars. Our final goal is to derive astrophysical parameters (reddening, distance and age) of open clusters based on the major photometric system which will be presented in a follow-up paper. For this purpose we have chosen the Johnson *UBV*, Cousins *VRI* and Strömgren *uvbyβ* photometric systems for a statistical analysis of published data sets included in WEBDA. Our final list contains photographic, photoelectric and CCD data for 469 820 objects in 573 open clusters. We have checked the internal (data sets within one photometric system and the same detector technique) and external (different detector technique) accuracy and conclude that more than 97% of all investigated data exhibit a sufficient accuracy for our analysis. The way of weighting and averaging the data is described. In addition, we have compiled a list of deviating measurements which is available to the community through WEBDA.

Key words. open clusters and associations: general – catalogs

1. Introduction

The study of open clusters is very important in several respects. It allow one to estimate different important astrophysical parameters within individual clusters as well as the study of the wider solar neighbourhood concerning its structure.

For this purpose it is essential to have a homogeneous set of photometric and additional (e.g. membership probability, proper motion) data for a statisticaly significant number of open clusters.

One of the most compelling databases in this respect is the WEBDA interface which has been developed at the Institute for Astronomy at the University of Lausanne, Switzerland. It offers astrometric data in the form of coordinates, rectangular positions, and some proper motions, photometric data in the major systems in which star clusters have been observed (e.g. Johnson-Cousins *UBVRI*, Strömgren *uvbyβ* and Geneva 7-color), spectroscopic data, like spectral classification, radial velocities, rotational velocities. It also contains miscellaneous types of data like membership probabilities, orbital elements of spectroscopic binaries and periods of variability for different kinds of variable stars. Finally a whole set of bibliographic references allows the community to locate the relevant publications for each individual cluster easily.

In this first paper we present the compilation of 573 open clusters for which photometric measurements are available within WEBDA. The statistical methods used to derived weighted means are described. Lists with objects showing deviating photometric measurements within one system and/or different observing techniques (photographic, photoelectric and CCD) were generated. We discuss the internal and external measurement accuracies based on a statistically significant sample of independent sources from the literature.

Our final goal of Paper II will be the determination of the ages, distances and reddening for the presented open clusters using the newest isochrones. This analysis will include the Johnson-Cousins *UBVRI* and Strömgren *uvbyβ* photometric systems and should supersede the work of Janes & Adler (1982) who presented a compilation of 434 open cluster of our Milky Way for which they summarized the reddening, ages and distances from 610 references in order to analyse the galactic structure. Their compilation was highly nonuniform since they made no attempt to redetermine the appropriate astrophysical parameters.

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2. Description of the database

WEBDA (accessible via `http://obswww.unige.ch/webda/`) and its predecessor BDA has been developed since 1987 at the Institute for Astronomy, University of Lausanne, Switzerland by JCM. The progress of its development was described by Mermilliod (1988, 1992, 1995). We will give here a brief overview of its current status and content.

The database tries to collect all published data for stars in open clusters that may be useful either to determine the star membership, or to study the stellar content and properties of the clusters.

It is divided into three levels: 1) database; 2) cluster and 3) star level.

The database contents includes measurements in most photometric systems in which cluster stars have been observed, spectroscopic observations, astrometric data, various kinds of useful information, and extensive bibliography. It is possible to perform selection of clusters based on the amount of available data. The data are usually recorded in their original form, with an indication of the source, but also as averaged values or selected data when relevant.

The greatest effort has been spent in solving the identification problems raised by the definition of so many different numbering systems and a special interface has been developed to query the cross-reference tables.

Maps for more than 200 clusters have been scanned and included in the database. They are active maps and permit to retrieve basic data (e.g. positions, cross identifications and Johnson *UBV* values) simply by clicking on the star images.

The database structure uses the directory hierarchy supported by the Unix system. The main directory is the database itself. It contains several sub-directories: description of the database, help information, references, bibliography, programs and perl scripts. Each cluster defines an independent directory identified by its name and containing the available data in distinct files, one for each data type. This structure allows easy inclusion of any new cluster and any additional data type.

Whenever possible, the records of the various data files have the same structure: star identification, source, data. The files are organised sequentially and, within the files, the entries are sorted by star number and source reference.

The star identification is the main key to access the data, but it is also possible to use filters based on the bibliographic references or astrophysical parameters.

The database engine WEBDA is a relational database built upon the package "/rdb" developed by Manis et al. (1988) which is a high performance relational database management and application development system designed for Unix environments.

Samples of clusters can be obtained by performing a selection on the clusters parameters, i.e. coordinates, distances, ages, diameters. The form prepared permits to do the selection on all parameters simultaneously. Clusters may also be selected on active plots, drawing the clusters in right ascension versus declination plane, galactic longitude versus latitude, distance from the Sun or above the galactic plane.

Table 1. Excerpt of the content of WEBDA from the 8th of April 2003.

Data description	Clusters	Measurements	Stars
Fundamental			
Identifications	403	12 079	12055
Transit Tables	315		349171
Coordinates J2000	408	110 385	109256
Coordinates B1950	480	143 775	134028
Positions (round off)	482		142422
Positions (x, y)	514		461873
Double stars	198	2063	1631
Photometry			
UBV (photographic)	294	126 775	100221
UBV (photoelectric)	439	34 000	23038
UBV (CCD)	261	315 374	261135
VRI (Cousins)	43	1460	412
VRI (Cousins; CCD)	86	45 596	42788
RI (Cousins; CCD)	12	2803	2712
VI (Cousins; CCD)	192	286 357	257731
VRI (Johnson)	97	2598	2145
uvby (photoelectric)	214	7260	4949
uvby (CCD)	25	21 371	20277
β (photoelectric)	248	7277	4771
β (CCD)	16	2685	2414
Geneva 7-color	190	4618	4496
RGU (photographic)	79	10 369	10332
Spectroscopy			
MK types	300	10 397	6399
HD types	319	13 148	12625
$v \sin i$	107	4636	3199
V_r (mean)	92	3734	3492
V_r (individual)	214	44 606	5927
V_r (GPO)	10	702	699
V_r (RFS)	7	141	141
Orbits	59	419	275
Miscellaneous			
Proper motion (abs)	7		3653
Proper motion (rel)	12	6304	6302
Probability (μ)	81		39384
Probability (V_r)	8		655
Periods (Var)	50	2482	1905
X-ray flux	28	3910	3351
gK stars	260		5189
Am stars	34		110
Ap stars	84		218
Be stars	86		368
Blue stragglers	209		930
Spectroscopic binaries	49		934

The database is in a dynamic growing process as new data are published and included. Table 1 lists an excerpt of the content of WEBDA based on the status from the 8th April 2003. This date is also used as a "deadline" for our final analysis.

3. Analysis and compilation of the data

The final goal of this extensive statistical analysis is not only to investigate the consistency of the published data but more importantly to derive ages, reddening values and distances for a large number of open clusters. It is therefore necessary to select photometric systems for which enough data and appropriate isochrones are available. Table 1 lists the numbers for the most common photometric systems included in WEBDA. From a close inspection we have chosen the following photometric systems for our analysis:

- Johnson *UBV*; photographic, photoelectric and CCD measurements
- Cousins *VI*; CCD
- Cousins *VRI*; photoelectric and CCD
- Strömgren *uvbyβ*; photoelectric and CCD
- *RGU*; photographic, for comparison.

We have not included the Johnson *VI* systems because there are usually only a few measurements for the brightest objects within one cluster making an isochrone fitting impossible. The Geneva 7-color system is outstanding compared to the other photometric systems. For most of the open clusters, only the brightest members are investigated whereas for a few ones also the faintest members were observed. Furthermore, WEBDA already includes the mean values for all these objects, so no improvement can be done within our analysis. We have used the data of the Geneva 7-color system for several open clusters in order to check the results from the other photometric systems.

The list with available photometric data in the mentioned above systems contains 573 open clusters (listed in Table 2) with a total of 469 820 objects.

The data analysis of the relevant photometric systems includes several different steps in order to perform a careful check of the homogeneity of the individual sources. Much effort was already spent to improve the homogeneity of WEBDA by investigating the published data, finding charts and listed coordinates (Mermilliod 1988, 1992, 1995). This process is very time consuming and not straightforward. During the first stages of our new analysis we have already found some wrongly identified objects and misprints in the literature. These errors have already been fixed in WEBDA. But we have to emphasize that these are only the "eye hitting" divergences, still there are many unsolved cases (see the lists mentioned above) which have to be investigated in the future.

As the first step of our analysis we have checked the intrinsic consistency of different sources for one photometric system (e.g. photographic Johnson *UBV* data) of all individual open clusters. In general, we have used the following (very conventional) limits for a measurement being "oustanding" if the difference of the data are larger than:

- 0.5 mag: *UBV* photographic; *RGU*
- 0.2 mag: *UBV*, *VRIc*, photoelectric and CCD; *uvby*, photoelectric
- 0.1 mag: *uvby*, CCD; *β* photoelectric and CCD.

The compiled list includes 4467 entries (2914 from photographic measurements). Excluding these objects, we have searched for intrinsic correlations for data sets which have more than five objects in common using a simple linear correlation algorithm. We only find twelve statistically significant deviating cases for ten open clusters. These deviating cases are listed in Table 3. Paunzen & Maitzen (2002) reported one deviating case for NGC 6451 for which they were able to show that the photometry by Piatti et al. (1998) has an unidentified error and was therefore excluded from our analysis.

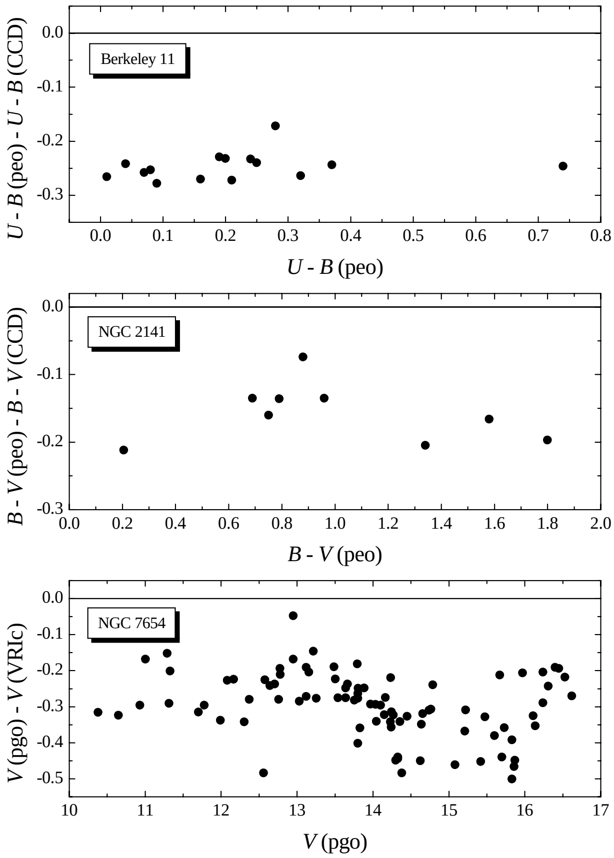

Fig. 1. Three examples for deviating measurements from different observing techniques as listed in Table 4.

As a next step we have used the averaged mean values of different photometric systems (e.g. *UBV* photographic and photoelectric) to search for "external" discrepancies between measurements for the individual clusters. Again, a list of outstanding objects was created with the limits given as:

$$\mathrm{limit(ext)} = \sqrt{\mathrm{limit(system_1)}^2 + \mathrm{limit(system_2)}^2}. \qquad (1)$$

This list has 7061 entries. Table 4 shows the deviating data sets from this external check. Figure 1 shows three examples for the Johnson *UBV* system graphically.

Since it is well known that photographic measurements have in general larger errors we have used averages of photoelectric and CCD data only. If such data are not available, photographic ones were used. The final averaged weighted values were calculated following the approach described in Mermilliod & Mermilliod (1994) which is a two step iterative procedure. The first step consists of a weighted mean, the weight being the number of measurements to the 2/3 power. The next step uses the differences between the weighted mean

Table 2. 573 open clusters with the number of objects from WEBDA with photometric measurements used for our analysis.

Cluster	*N*	Cluster	*N*	Cluster	*N*	Cluster	*N*	Cluster	*N*	Cluster	*N*	Cluster	*N*
Afgl 4029	8	Cr 347	20	Mel 71	795	NGC 2343	56	NGC 5823	163	NGC 7380	1686	Tr 17	147
Am 2	2277	Cr 359	13	Mel 101	22	NGC 2345	64	NGC 5999	341	NGC 7419	716	Tr 18	153
Bas 1	151	Cr 394	162	Mel 105	384	NGC 2353	141	NGC 6005	727	NGC 7510	674	Tr 21	368
Bas 11a	89	Cr 399	8	Mel 111	435	NGC 2354	299	NGC 6025	179	NGC 7654	1247	Tr 22	100
Bas 12	61	Cr 463	82	Mel 227	25	NGC 2355	829	NGC 6031	288	NGC 7686	81	Tr 24	442
Bas 13	73	Cr 469	82	NGC 103	2836	NGC 2360	181	NGC 6067	1401	NGC 7762	580	Tr 26	98
Bas 14	94	Cz 2	2351	NGC 129	1404	NGC 2362	100	NGC 6087	1334	NGC 7772	52	Tr 27	82
Bas 15	107	Cz 8	19	NGC 133	312	NGC 2367	18	NGC 6124	299	NGC 7788	133	Tr 28	85
Be 1	181	Cz 13	56	NGC 146	641	NGC 2374	83	NGC 6134	637	NGC 7789	16000	Tr 31	79
Be 2	223	Cz 29	18	NGC 188	3893	NGC 2383	722	NGC 6167	48	NGC 7790	2470	Tr 32	1786
Be 7	722	Do 24	8	NGC 189	93	NGC 2384	335	NGC 6178	58	NGC 7822	21	Tr 33	74
Be 11	590	Do 25	128	NGC 225	326	NGC 2395	53	NGC 6192	242	Pis 1	23	Tr 35	306
Be 12	1671	Do 42	37	NGC 366	1014	NGC 2414	12	NGC 6193	635	Pis 2	3536	Tr 37	291
Be 14	1904	Eso92sc18	1804	NGC 381	2918	NGC 2420	910	NGC 6200	15	Pis 3	761	Tu 1	91
Be 17	4050	Eso93sc08	1240	NGC 433	2119	NGC 2421	117	NGC 6204	160	Pis 4	16	Up 1	7
Be 18	8734	Eso96sc04	999	NGC 436	897	NGC 2422	131	NGC 6208	243	Pis 5	9	Vdb 1	196
Be 19	158	Ha 8	23	NGC 457	3888	NGC 2423	149	NGC 6216	199	Pis 8	26	Wat 3	7
Be 20	429	Ha 20	28	NGC 559	217	NGC 2437	295	NGC 6231	1544	Pis 11	17	Wat 6	30
Be 21	1645	Haf 6	699	NGC 581	5814	NGC 2439	305	NGC 6242	138	Pis 12	17	Wat 7	7
Be 22	2017	Haf 8	78	NGC 609	84	NGC 2447	104	NGC 6249	15	Pis 16	115	Wes 1	233
Be 23	1410	Haf 10	9	NGC 637	651	NGC 2451	322	NGC 6250	37	Pis 17	9	Wes 2	93
Be 28	542	Haf 14	25	NGC 654	666	NGC 2451A	136	NGC 6253	7975	Pis 18	344		
Be 29	1125	Haf 15	13	NGC 659	767	NGC 2451B	19	NGC 6259	563	Pis 19	5183		
Be 30	1923	Haf 16	15	NGC 663	3765	NGC 2453	382	NGC 6268	75	Pis 20	219		
Be 31	2075	Haf 17	122	NGC 744	117	NGC 2467	352	NGC 6281	85	Pis 21	294		
Be 32	3283	Haf 18	78	NGC 752	589	NGC 2477	19384	NGC 6318	244	Pis 22	198		
Be 33	1869	Haf 19	280	NGC 869	3816	NGC 2482	41	NGC 6322	113	Pis 23	627		
Be 39	4395	Haf 20	33	NGC 884	3300	NGC 2483	75	NGC 6383	595	Pis 24	17		
Be 42	556	Haf 21	51	NGC 957	255	NGC 2489	155	NGC 6396	22	Pl 1	152		
Be 54	2495	Her 1	16	NGC 1027	153	NGC 2506	1417	NGC 6405	635	Ros 3	83		
Be 58	420	Hm 1	803	NGC 1039	1078	NGC 2516	2558	NGC 6416	330	Ros 4	14		
Be 60	2121	Ho 9	9	NGC 1193	503	NGC 2527	404	NGC 6425	74	Ros 5	46		
Be 62	1583	Ho 10	24	NGC 1220	234	NGC 2533	124	NGC 6451	744	Ru 18	20		
Be 64	2042	Ho 11	6	NGC 1245	712	NGC 2539	354	NGC 6475	896	Ru 20	11		
Be 65	42	Ho 12	11	NGC 1252	41	NGC 2546	688	NGC 6494	218	Ru 32	133		
Be 66	1677	Ho 14	11	NGC 1342	311	NGC 2547	227	NGC 6514	311	Ru 34	17		
Be 68	126	Ho 15	454	NGC 1348	1030	NGC 2548	47	NGC 6520	412	Ru 36	72		
Be 69	144	Ho 16	86	NGC 1444	99	NGC 2567	275	NGC 6530	1028	Ru 44	82		
Be 70	2464	Ho 17	41	NGC 1496	51	NGC 2571	1662	NGC 6531	408	Ru 46	597		
Be 79	60	Ho 18	28	NGC 1502	155	NGC 2579	56	NGC 6546	52	Ru 47	10		
Be 81	3301	Ho 22	30	NGC 1513	228	NGC 2627	507	NGC 6603	3598	Ru 49	9		
Be 82	20	IC 166	208	NGC 1528	619	NGC 2632	605	NGC 6604	117	Ru 55	29		
Be 86	736	IC 348	201	NGC 1545	67	NGC 2635	6	NGC 6611	1359	Ru 59	21		
Be 87	105	IC 361	19	NGC 1605	38	NGC 2645	74	NGC 6613	119	Ru 67	27		
Be 93	87	IC 1311	976	NGC 1624	14	NGC 2658	123	NGC 6618	671	Ru 76	7		
Be 94	50	IC 1369	155	NGC 1647	362	NGC 2659	16	NGC 6631	5533	Ru 79	361		
Be 96	10	IC 1442	105	NGC 1662	73	NGC 2660	914	NGC 6633	693	Ru 82	144		
Be 99	867	IC 1590	255	NGC 1664	318	NGC 2669	31	NGC 6649	566	Ru 83	93		
Be 104	3173	IC 1795	191	NGC 1750	7396	NGC 2670	393	NGC 6664	60	Ru 92	59		
Bh 66	735	IC 1805	1984	NGC 1778	140	NGC 2671	62	NGC 6683	163	Ru 93	93		
Bh 99	621	IC 1848	74	NGC 1798	1416	NGC 2682	3192	NGC 6694	122	Ru 97	251		
Bh 176	9999	IC 2157	2017	NGC 1807	39	NGC 2818	624	NGC 6704	569	Ru 98	16		
Bh 222	301	IC 2391	329	NGC 1817	370	NGC 2866	23	NGC 6705	8377	Ru 103	163		
Bh 245	122	IC 2395	61	NGC 1857	79	NGC 2910	134	NGC 6709	1365	Ru 107	17		
Biu 2	132	IC 2488	145	NGC 1893	1656	NGC 2925	185	NGC 6716	888	Ru 108	11		
Bl 1	355	IC 2581	398	NGC 1901	43	NGC 2972	14	NGC 6755	310	Ru 115	486		
Bo 1	15	IC 2602	376	NGC 1907	324	NGC 3033	19	NGC 6756	402	Ru 118	7		
Bo 2	87	IC 2714	224	NGC 1912	778	NGC 3105	131	NGC 6791	9229	Ru 119	239		
Bo 3	8	IC 2944	138	NGC 1931	163	NGC 3114	2277	NGC 6802	225	Ru 120	149		
Bo 4	30	IC 4651	15845	NGC 1960	1132	NGC 3228	434	NGC 6811	1018	Ru 124	424		
Bo 6	5	IC 4665	429	NGC 1976	3192	NGC 3255	8	NGC 6819	2565	Ru 127	18		
Bo 7	1433	IC 4725	1461	NGC 2099	3896	NGC 3293	511	NGC 6823	890	Ru 129	55		
Bo 8	8	IC 4756	507	NGC 2112	612	NGC 3324	988	NGC 6830	158	Ru 130	345		
Bo 9	2907	IC 4996	718	NGC 2129	203	NGC 3330	66	NGC 6834	1251	Ru 140	259		
Bo 10	425	IC 5146	734	NGC 2141	3309	NGC 3496	272	NGC 6866	599	Ru 146	163		
Bo 11	514	Ki 2	1031	NGC 2158	4672	NGC 3532	728	NGC 6871	1979	Ru 166	954		
Bo 12	12	Ki 4	151	NGC 2168	2102	NGC 3572	85	NGC 6882	76	Ru 175	113		
Bo 13	13	Ki 5	1347	NGC 2169	36	NGC 3590	79	NGC 6883	196	Sh 1	41		
Bo 14	11	Ki 6	475	NGC 2175	155	NGC 3603	515	NGC 6910	234	Sha 138	259		
Bo 15	33	Ki 7	698	NGC 2186	23	NGC 3680	905	NGC 6913	464	St 1	160		
Cr 69	132	Ki 8	259	NGC 2192	409	NGC 3766	2658	NGC 6939	462	St 2	4297		
Cr 74	739	Ki 9	2058	NGC 2194	2146	NGC 3960	317	NGC 6940	395	St 7	29		
Cr 96	14	Ki 10	1183	NGC 2204	2771	NGC 4103	4091	NGC 6994	197	St 8	23		
Cr 97	29	Ki 11	1163	NGC 2215	43	NGC 4337	18	NGC 7031	73	St 13	112		
Cr 107	267	Ki 12	31	NGC 2232	43	NGC 4349	216	NGC 7039	220	St 14	137		
Cr 110	471	Ki 13	80	NGC 2236	495	NGC 4439	24	NGC 7044	2531	St 16	104		
Cr 121	47	Ki 14	196	NGC 2243	3705	NGC 4463	20	NGC 7062	431	St 17	10		
Cr 132	35	Ki 15	2771	NGC 2244	1253	NGC 4609	52	NGC 7063	103	St 24	2121		
Cr 135	77	Ki 19	264	NGC 2251	615	NGC 4755	8612	NGC 7067	85	Ste 1	179		
Cr 140	80	Ki 21	26	NGC 2254	97	NGC 4815	8596	NGC 7082	182	Ter 7	1731		
Cr 185	74	Ly 1	24	NGC 2259	1422	NGC 5138	92	NGC 7086	220	To 1	1000		
Cr 197	21	Ly 2	97	NGC 2264	1791	NGC 5168	307	NGC 7092	193	To 2	2905		
Cr 205	18	Ly 4	6	NGC 2266	464	NGC 5281	1434	NGC 7127	70	Tr 1	1431		
Cr 223	110	Ly 6	124	NGC 2269	12	NGC 5316	131	NGC 7128	513	Tr 2	129		
Cr 228	1193	Ly 7	19	NGC 2281	1113	NGC 5367	10	NGC 7142	520	Tr 5	5150		
Cr 232	122	Ly 14	16	NGC 2287	217	NGC 5381	3239	NGC 7160	341	Tr 7	16		
Cr 258	36	Ma 38	36	NGC 2301	1608	NGC 5460	328	NGC 7209	119	Tr 9	52		
Cr 261	3523	Ma 50	256	NGC 2302	16	NGC 5606	191	NGC 7226	259	Tr 10	57		
Cr 268	23	Mel 20	701	NGC 2304	1449	NGC 5617	468	NGC 7235	666	Tr 11	355		
Cr 271	10	Mel 22	770	NGC 2323	253	NGC 5662	910	NGC 7243	60	Tr 14	586		
Cr 272	1249	Mel 25	1430	NGC 2324	213	NGC 5749	112	NGC 7245	338	Tr 15	869		
Cr 307	12	Mel 66	3909	NGC 2335	63	NGC 5822	709	NGC 7261	148	Tr 16	461		

Table 3. Deviating data sets within one photometric system. The errors in the final digits of the corresponding quantity are given in parenthesis.

Cluster	Photometric system	Set1	Set2	Mean	N(obj)
Berkeley 64	UBV: V (CCD)	Pandey et al. (1997)	Ann et al. (2002)	−0.161(44)	26
Markarian 50	UBV: $U-B$ (pgo)	Turner et al. (1983)	Grubissich (1965)	+0.174(27)	27
Melotte 71	UBV: V (pgo)	Pound & Janes (1986)	Hassan (1976)	+0.388(102)	33
NGC 1348	VIc: V	Ann et al. (2002)	Carraro (2002)	+0.197(55)	124
NGC 2244	VIc: $V-I$	Park & Sung (2002)	Berghöfer & Christian (2002)	−0.237(68)	124
NGC 6611	UBV: $U-B$ (peo)	Hiltner & Morgan (1969)	Thé et al. (1989)	+0.083(22)	15
NGC 6791	VIc: $V-I$	Garnavich et al. (1994)	von Braun et al. (1998)	+0.104(34)	12
NGC 6910	UBV: V (peo)	Hoag et al. (1961)	Heiser (private communication)	+0.088(26)	13
NGC 7044	UBV: V (CCD)	Aparicio et al. (1993)	Sagar & Griffiths (1998)	+0.135(36)	553
NGC 7654	UBV: V (CCD)	Choi et al. (1999)	Stetson (2000)	−0.164(23)	49
	UBV: $B-V$ (CCD)	Choi et al. (1999)	Stetson (2000)	+0.153(22)	73
	VIc: $V-I$	Choi et al. (1999)	Stetson (2000)	−0.231(32)	57

Table 4. Deviating data sets within different photometric systems.

Cluster	Photometric system	mean	N(obj)
Berkeley 11	$U-B$ (peo, CCD)	−0.247(25)	15
	$B-V$ (peo, CCD)	−0.083(25)	17
Berkeley 58	V (pgo, CCD)	−0.346(84)	36
Bochum 10	V (pgo, CCD)	−0.346(84)	36
Haffner 8	$U-B$ (pgo, peo)	−0.303(86)	7
NGC 637	V (pgo, peo)	−0.268(60)	25
	V (pgo, CCD)	−0.303(76)	35
NGC 884	m_1 (peo, CCD)	+0.130(35)	17
NGC 1245	V (peo, CCD)	−0.241(40)	15
NGC 2112	V (peo, CCD)	+0.168(46)	16
	V (peo, $VRIc$)	−0.241(40)	15
	V (CCD, $uvby$)	+0.221(52)	9
NGC 2141	$B-V$ (peo, CCD)	−0.158(41)	9
NGC 2158	V (peo, CCD)	−0.129(24)	8
	V (peo, VIc)	−0.124(32)	8
NGC 3680	V (CCD, VIc)	+0.077(12)	6
NGC 6005	V (CCD, VIc)	−0.053(17)	529
NGC 7654	V (pgo, $VRIc$)	−0.296(89)	89
	V (peo, $VRIc$)	−0.157(28)	18
	V ($VRIc$, $uvby$)	+0.147(41)	9

and the individual values to compute new weighted mean values. This procedure gives a lower weight to discrepant values.

We also find a few cases (e.g. for NGC 6705) for which data sets show a trend within different photometric systems, e.g. $(U-B)_{\rm Set1} - (U-B)_{\rm Set2}$ versus $(B-V)_{\rm Set1}$. There is no straightforward solution for these data sets. However, we have excluded those data from our final analysis.

The complete tables with the available weighted mean values will be available at WEBDA only or upon request from the authors.

4. Discussion

For the analysis of the overall accuracies of the available data sets, we have used Gaussian distributions (Christensen 1996) to fit the histograms of all mean values for the different data. The calculated histograms were normalized to the overall percentage of the sum. The results for the Johnson UBV and Strömgren $uvby\beta$ photometric systems are summarized in Figs. 2 to 4. These figures include the most important fit parameters such as the mean value, width, R^2, χ^2 as well as the the number of data sets and objects. The corresponding histograms in the other photometric systems are not plotted since there are too few data points to compare which makes a statistically sound analysis impossible.

The way of calibrating observed magnitudes is either to simultaneously measure "well established" standard stars or to use already known standard transformations for the individual telescope and filter set. Both approaches are certainly not straightforward. Sung & Bessell (2000) summarize and discuss the problems concerning the variations of atmospheric extinction coefficients, transformation equations, different filter systems, CCDs as well as the difference between two sets of standard stars (SAAO and Landolt). They also include a compelling list of references concerning this special topic.

It is out of the scope of this statistical analysis to reproduce the used transformation technique of the individual references. We have to rely on the published data. The only possible check is to search for misidentified objects or typos. Otherwise undetected variability of any kind could also lead to several divergent observations, again a fact which we are not able to prove.

We will now discuss the internal and the external accuracy separately.

4.1. The internal accuracy

The most important check for the reliability of published data is the comparison with other independent measurements within the same photometric system and the same technique. Figure 2 shows the histograms (bin size is 0.02 mag) for the Johnson UBV system. We have separated the photographic, photoelectric and CCD measurements.

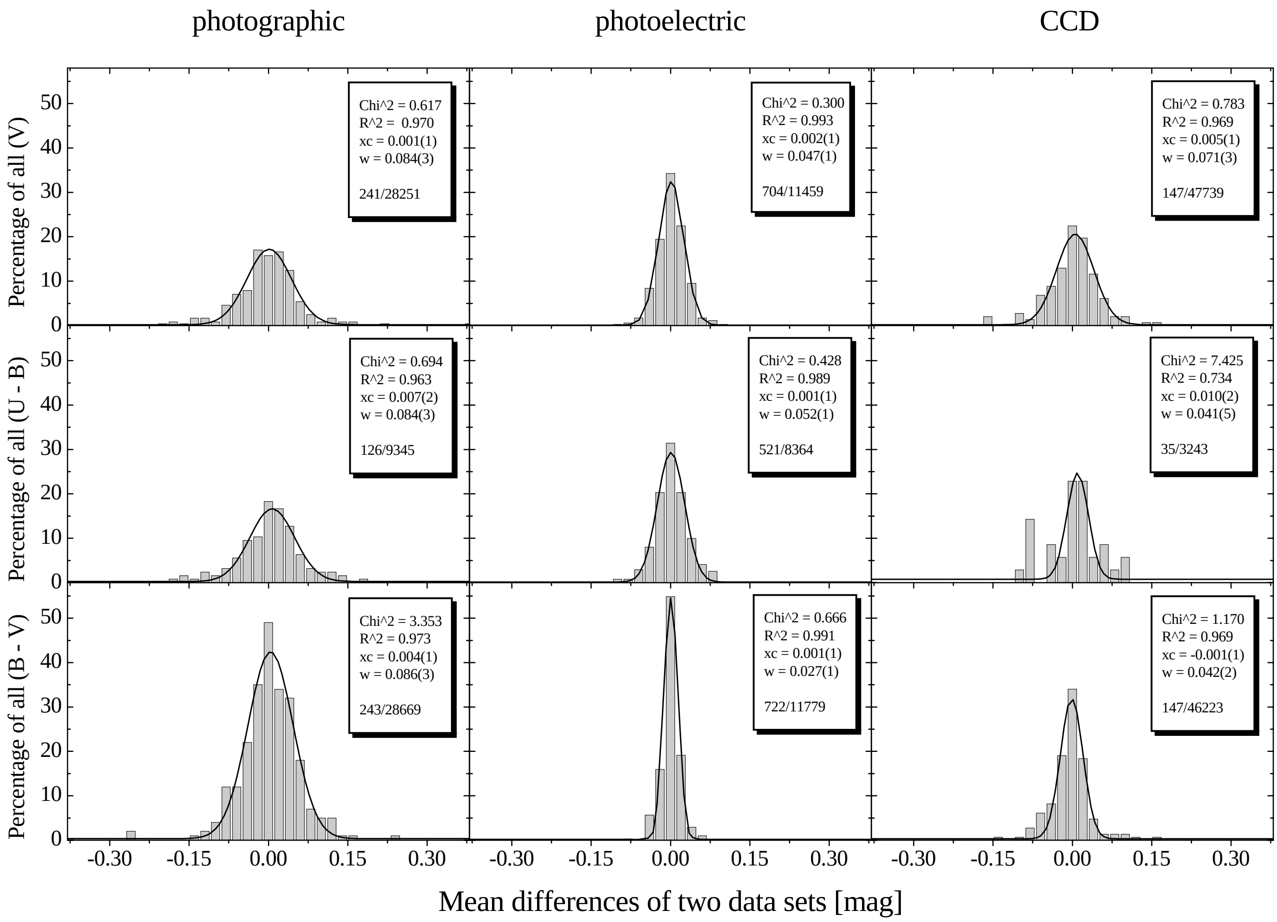

Fig. 2. Histograms of the internal accuracy of the Johnson *UBV* photometric system for photographic (left panel), photoelectric (middle panel) and CCD (left panel) measurements; listed are the most important parameters of the fitted Gaussian distributions together with the number of data sets and objects (N_1/N_2).

The histograms are based on a statistically significant number of individual data sets and objects. The only exception is CCD measurements for $U - B$. This is probably caused by the insensitivity of the modern CCD detectors in the ultraviolet region which makes the observations in the standard U band almost impossible. From Fig. 2 we are able to conclude:

– The bandwidth of the Gaussian distributions for the photographic measurements is twice (≈0.09 mag) as large as the corresponding ones from the other two sources.
– The only exception is the CCD V data which might be due to the relative faintness and thus the larger observational error reach with this technique.
– All mean values of the fitted distributions are close to zero.

The corresponding histograms for the Strömgren $uvby\beta$ photometric system have a bin size of 0.01 mag and are shown in Fig. 3. The widths of the fitted distributions are all between 0.01 and 0.03 mag which shows the high quality of the published data.

In total, 4467 deviating measurements were found (Sect. 3) within 4056 different data sets and 266 779 objects. This corresponds to 1.7% which is an extremely low percentage. If we exclude the outlyers from photographic measurements, this percentage even lowers to 0.6%.

4.2. The external accuracy

After having shown that the accuracies within the individual photometric systems are very good. We then investigated the errors for different measurement techniques and thus mainly different quantum efficiencies characteristics of detectors.

Figure 4 shows the result for the Johnson *UBV* photometric system (bin size is 0.02 mag). The results for the other systems are similar. We have summarized the data for V, $B - V$ and $U - B$, otherwise we would run into poor number statistics. However, it shows that the distributions for the three different indices with the same detector technique are essentially the same.

The bandwidth of the Gaussian distributions for comparison of the photoelectric data sets (upper and lower panel) is about 0.05 mag whereas the comparison of the CCD versus photographic measurements results in an almost three times higher value (0.12 mag). This reflects the most different quantum efficiency characteristics of these detectors whereas the photoelectric one is in between. In addition, the larger scatter may be due to the faintness of the photographically observed objects. Usually, the photoelectric data magnitude limit is brighter than that of the photographic one. We conclude that the photoelectric measurements are still the most valuable to connect the photographic to the CCD ones.

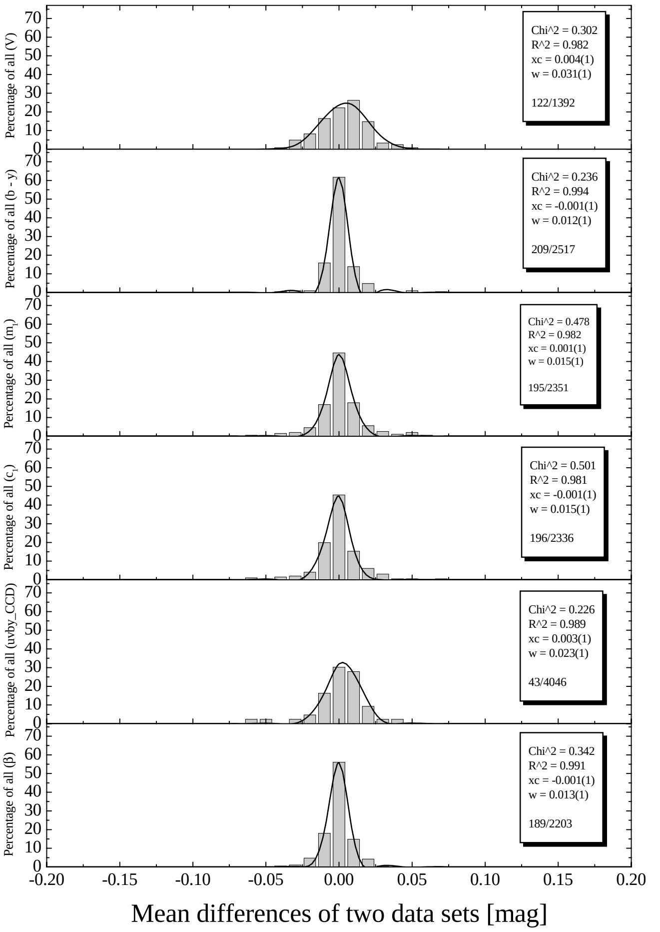

Fig. 3. Histograms of the internal accuracy of the Strömgren *uvbyβ* photometric system. The upper four panels show the results for photoelectric *uvby*, the fifth CCD *uvby* and the last panel all *β* measurements; listed are the most important parameters of the fitted Gaussian distributions together with the number of data sets and objects (N_1/N_2).

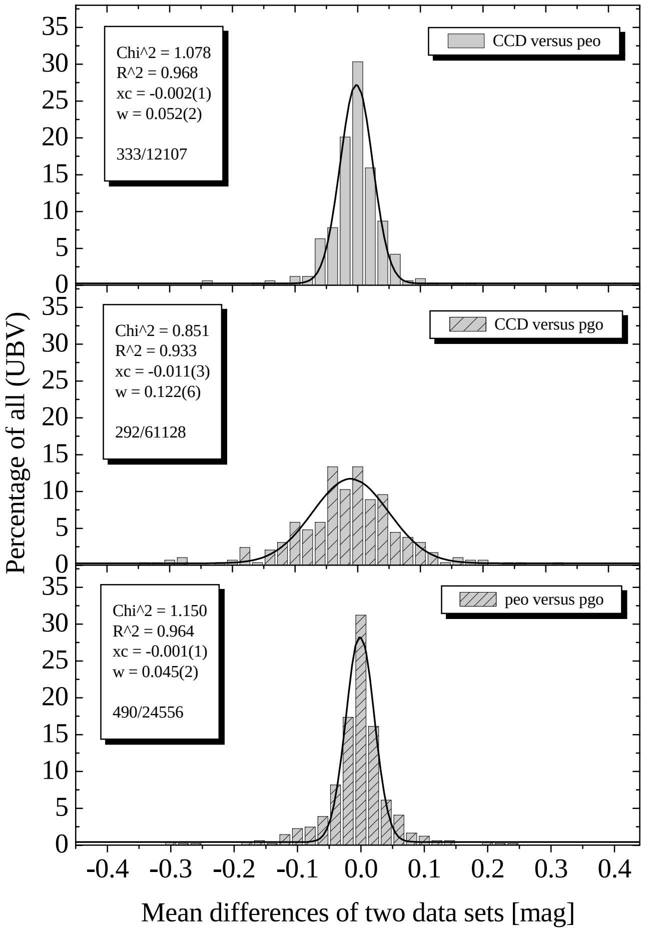

Fig. 4. Histograms of the external accuracy of the Johnson *UBV* photometric system for CCD versus photoelectric (upper panel) and photographic (middle panel) as well as photoelectric versus photographic (lower panel) measurements; listed are the most important parameters of the fitted Gaussian distributions together with the number of data sets and objects (N_1/N_2).

This analysis is based on 1960 data sets with 292 770 measurements. Again, the number of deviating data points is surprisingly low (7061 or 2.4%). This shows the high capability of WEBDA to analyse the astrophysical properties of open clusters in the Milky Way.

5. Conclusions and outlook

The enormous amount of photometric data within WEBDA was analysed in order to check for the internal and external accuracies of published data for open clusters. This analysis is based on photographic, photoelectric and CCD measurements for five different photometric systems which includes 573 open clusters and 469 820 objects. The way of weighting and averaging the data is described.

We have investigated 4056 data sets which have more than five objects in common and concluded that the internal accuracies are very good. The accuracy is best for the Strömgren *uvbyβ* system and drops significantly towards photographic Johnson *UBV* data. Less than 2% of deviating measurements were found and tabulated.

A surprisingly good agreement between photoelectric and photographic as well as CCD data was found. The higher error for CCD versus photographic data reflects the differences of the individual quantum efficiency curves of these systems. Nevertheless, the amount and homogenity of data will allow us to derive astrophysical parameters such as the ages, distances and reddenings for the 573 open clusters investigated. This will be done in a second paper which includes isochrone fitting and the discussion of different statistical issues concerning the structure of our Milky Way.

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