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UBVRI photoelectric photometry of nearby stars

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Summary. — *UBVRI* photometry results are presented for nearby stars of Gliese's Catalogue (1969) and its supplements.

Key words : photoelectric photometry — nearby stars.

1. Introduction.

The « Catalogue of Nearby Stars » (Gliese, 1969) contains a list of 1529 nearby stars and multiple systems. This catalogue has been enlarged with a supplement and a list of suspected nearby stars (Gliese and Jahreiss, 1979). Among other parameters, it contains *UBVRI* photometric data for some stars. These data have been partially completed by Nicolet (1978). The stars in Gliese's catalogue play an important role in several topics, i.e. galactic dynamics and luminosity function.

Hipparcos space astrometry mission will include an exhaustive survey of the stars with magnitude lower than 8 and a selection of the stars with magnitude greater than 8, not belonging to multiple systems. So, most of these nearby stars, for which photometric data are needed, will be observed by Hipparcos. In order to complete photometric data of the catalogue, and also to use these data for the Hipparcos mission, we have selected as program stars those stars of Gliese's catalogue and its supplements having an incomplete set of *UBVRI* photometric data with magnitude lower than 13, not belonging to multiple systems. We here publish a first set of results, of which we have given a preliminary report in Calafat *et al.* (1983).

2. Observations.

The observations were made at Calar Alto with the 1.23 m telescope of the Centro Astronomico Hispano-Alemán (C.A.H.A.) and with the 1.52 m telescope of the Observatorio Astronómico Nacional (O.A.N.). Both telescopes are equipped with a one channel photometer with a dry-ice cooled RCA 31034 photomultiplier, and with the conventional *UBVRI* Johnson system filters. The observations were carried out during the period 1981-1984. In table I are described for the 12 runs the whole number of nights, the number of useful ones, as well as the number of observations of program and standard stars. The standard stars have been taken from the list of Neckel and Chini (1980), usual for *UBVRI* photometry at Calar Alto.

Each observation for each colour has been made by five-seconds integrations while relative instrumental error was greater than 0.005 up to a maximum of eight.

During each night, groups of three or four program stars were intercalated into the sequence of standard stars, which is beginning and ending with a group of four or five. After each program or standard star observation, background measurements were made for each passband. A neutral filter of 10 % transmission has been used during the nights in which the program stars to be observed were too bright.

3. Data reduction.

3.1 DETERMINATION OF THE REDUCTION COEFFICIENTS. — The observational data have been reduced for each single night using the method given by Harris *et al.* (1981). The utilization of the neutral filter during some nights in each period makes not very suitable the multinight solution of Harris method. The single night method has been adapted to the five colours *UBVRI*. The equations for a standard star observed during a single night are

$$\begin{aligned}
(v\text{-}V) &= a_1 + a_2 X + a_3(B\text{-}V) + a_4 X(B\text{-}V) + a_5(B\text{-}V)^2 \\
(b\text{-}v) &= b_1 + b_2 X + b_3(B\text{-}V) + b_4 X(B\text{-}V) + b_5(B\text{-}V)^2 \\
(u\text{-}b) &= c_1 + c_2 X + c_3(U\text{-}B) + c_4 X(U\text{-}B) + c_5(U\text{-}B)^2 \\
(v\text{-}r) &= d_1 + d_2 X + d_3(V\text{-}R) + d_4 X(V\text{-}R) + d_5(V\text{-}R)^2 \\
(v\text{-}i) &= e_1 + e_2 X + e_3(V\text{-}I) + e_4 X(V\text{-}I) + e_5(V\text{-}I)^2 .
\end{aligned} \quad (1)$$

For each single one of them the determination of the transformation coefficients is carried out by solving each of the equations stated for each one of the standard stars observations by a least square method. In equation (1), u, b, v, r, i are the instrumental magnitudes of the standard stars, U, B, V, R, I are the catalogued magnitudes and X is the air mass.

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Rejection of poor quality standard stars has been done for the magnitude and each colour index independently through an iterative method which refuses those stars to have a residual higher than n-sigma, analyzing several possibilities taking different values for n, with $1 \leqslant n \leqslant 2$. This range was adopted in order to eliminate both poor quality measurements due to bad photometric conditions and systematic differences between catalogued and obtained magnitudes for some standard stars. A not so severe range appears to be useful only for photometric nights. A more detailed study of those differences is in progress. We have also taken into account a method which rejects only one star per iteration : the one having higher residual. Following Harris *et al.* (1981) the computing program takes as the optimum solution for the coefficients and their errors that one having the third coefficient nearest to $a_3 = 0$ in the case of the equation that determines V magnitude and nearest to $b_3 = 1, c_3 = 1, d_3 = 1$ and $e_3 = 1$ in the case of the equations determining the colour indices. This criterium was used considering that the dominant terms in the equations are those which give the instrumental slopes. Differences among zero-points are not significative when using the same telescope provided or not with a neutral filter. By this method we obtain the lowest error coefficients among all the possibilities analyzed by this process.

No weights have been applied to the data points in the resolutions of the least square systems. It has been checked that weights depending on air masses ($w_j = X_j^{-\varepsilon}$) do not decrease internal errors. We should mention that the correlations among the coefficients obtained are sometimes strong, especially in the case of nights with bad photometric conditions.

3.2 DETERMINATION OF THE MAGNITUDES AND COLOUR INDICES FOR PROGRAM STARS. — The reduction coefficients obtained for each night have been applied to equations (1) in order to find the magnitude and colour indices in the standard system of program stars observed during the night. The error assigned to each magnitude and colour index has been computed by propagating the reduction coefficient errors and the instrumental error of each measurement.

Reduction coefficients errors are mainly responsible for those errors, the instrumental errors being negligible in front of them. Final magnitude and colour indices for each program star have been determined after having observed that star no less than three times.

If the star has been observed N times, for the V-magnitude and each colour index we shall have

$$(x_i, \sigma_{x_i}) \qquad i = 1, ..., N$$

σ_{x_i} being the computed error.

Then the magnitude and colour indices are obtained by the weighted average

$$\bar{x} = \sum w_i x_i / \sum w_i \tag{2}$$

where

$$w_i = 1/\sigma_{x_i}^2 .$$

We have developed a program which rejects any determination of any magnitude or colour index that has a residual greater than 2 σ', σ' being the standard deviation for the determinations of unit weight, where

$$\sigma' = [\sum p_i (x_i - \bar{x})^2 / (N - 1)]^{1/2}$$

being

$$p_i = N w_i / \sum w_i .$$

With the remaining determinations the final V-magnitude and colour indices are then computed by equation (2) and we have adopted as the error σ for magnitude and colour indices the standard deviation of the average given by

$$\sigma = [\sum w_i (x_i - \bar{x})^2 / (N - 1) \sum w_i]^{1/2} .$$

Table II contains the final results for 64 stars. The final column gives the total number of observations for each program star.

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TABLE I. — *Observation period.*

Period	Nights	Useful nights	Gliese stars	Standard stars
16-27 Nov. 1981 (OAN)	12	6	44	92
16-25 Mar. 1982 (OAN)	10	3	18	41
24Ap.-2May 1982 (OAN)	9	1	6	12
10-19 Aug. 1982 (OAN)	10	8	50	107
19Oc.-1No. 1982 (CAHA)	14	4	33	62
18-31 Mar. 1983 (CAHA)	14	1	5	14
13-16 May 1983 (CAHA)	4	2	17	30
2-12 Jun. 1983 (OAN)	11	6	45	87
26Au.-5Se. 1983 (CAHA)	11	8	85	132
5-14 Nov. 1983 (OAN)	10	–	–	–
21Fe.-1Ma. 1984 (CAHA)	10	2	15	20
22-28 May 1984 (CAHA)	7	1	8	10
	122	42	326	607

CAHA : Centro Astronómico Hispano-Alemán
OAN : Observatorio Astronómico Nacional

TABLE II. — *Photometry for program stars.*

Gliese number	HD number	V	error	B-V	error	U-B	error	V-R	error	V-I	error	Obs.
46.1	5857	7.365	0.005	1.028	0.000	0.939	0.004	0.775	0.001	1.378	0.006	3
50.1	6027	7.824	0.002	1.414	0.006	1.753	0.027	1.051	0.000	1.925	0.007	3
53.2		10.514	0.033	1.268	0.007	1.232	0.003	1.064	0.007	1.954	0.071	3
56.0	7808	9.758	0.006	0.978	0.003	0.793	0.005	0.838	0.002	1.446	0.003	5
59.3	9546	6.717	0.005	0.929	0.014	0.780	0.001	0.727	0.000	1.256	0.001	4
65.1	10086	6.618	0.010	0.649	0.007	0.261	0.000	0.555	0.001	0.933	0.000	4
79.0	11507	8.924	0.027	1.446	0.006	1.228	0.002	1.212	0.004	2.258	0.009	4
83.3	12208	7.498	0.013	1.596	0.003	2.009	0.002	1.597	0.016	3.291	0.084	6
97.2	14914	7.003	0.010	0.963	0.003	0.834	0.001	0.724	0.009	1.273	0.004	4
112.0	17190	7.884	0.006	0.834	0.000	0.476	0.018	0.631	0.014	1.126	0.002	3
114.0	17660	8.884	0.000	1.115	0.020	1.228	0.002	0.963	0.005	1.614	0.001	7
120.2	18803	6.635	0.008	0.716	0.006	0.305	0.001	0.560	0.006	0.950	0.007	3
141.1	21242	6.517	0.039	0.864	0.000	0.458	0.001	0.763	0.008	1.383	0.000	4
165.1	26581	8.664	0.000	0.958	0.000	0.853	0.007	0.784	0.011	1.310	0.005	5
172.1	29203	6.997	0.025	1.301	0.001	1.035	0.000	0.913	0.002	1.644	0.009	4
182.1	31966	6.766	0.001	0.641	0.006	0.240	0.005	0.560	0.002	0.933	0.004	4
251.1		10.529	0.005	1.263	0.008	1.234	0.009	1.018	0.002	1.787	0.002	4
268.3		10.837	0.003	1.617	0.025	1.279	0.020	1.485	0.003	3.231	0.041	4
270.0		10.044	0.016	1.505	0.040	1.359	0.038	1.219	0.001	2.267	0.001	4
277.1		10.417	0.017	1.599	0.019	1.264	0.058	1.274	0.009	2.552	0.024	3
285.1	61994	7.081	0.025	0.652	0.004	0.276	0.007	0.602	0.007	0.977	0.005	3
295.1		10.317	0.005	1.283	0.002	1.300	0.011	1.008	0.002	1.758	0.001	4
296.2	66751	6.596	0.095	0.604	0.002	0.010	0.005	0.450	0.014	0.849	0.009	7
297.0		11.210	0.009	0.399	0.003	0.040	0.002	0.375	0.001	0.610	0.007	3
316.0		9.826	0.009	1.428	0.025	1.289	0.011	1.146	0.002	2.107	0.019	3
328.0		9.932	0.002	1.423	0.026	1.281	0.004	1.214	0.024	2.226	0.024	3
353.0		10.157	0.011	1.589	0.010	1.260	0.002	1.261	0.002	2.434	0.008	3
406.1		10.255	0.002	1.434	0.006	1.354	0.014	1.179	0.002	2.162	0.000	4
410.0	95650	9.569	0.029	1.551	0.015	1.315	0.004	1.316	0.036	2.437	0.009	3
430.0		9.920	0.009	1.378	0.002	1.287	0.010	1.096	0.005	1.986	0.017	3
430.1		10.275	0.012	1.528	0.000	1.223	0.000	1.342	0.054	2.578	0.023	3
438.1	101998	7.120	0.003	1.456	0.023	1.741	0.020	1.027	0.017	1.821	0.001	3
450.0		9.666	0.007	1.510	0.010	1.197	0.012	1.348	0.037	2.737	0.015	5
452.4		10.446	0.015	1.383	0.010	1.321	0.072	1.157	0.000	2.106	0.001	4
458.2		10.500	0.018	1.455	0.015	1.338	0.031	1.245	0.002	2.347	0.001	3
461.0		10.146	0.096	1.529	0.009	1.201	0.004	1.281	0.009	2.538	0.010	4
480.2	110296	7.817	0.010	1.547	0.011	1.900	0.002	1.173	0.041	2.213	0.004	3
521.0		10.234	0.008	1.450	0.006	1.082	0.018	1.305	0.006	2.629	0.012	4
540.0		10.336	0.009	1.473	0.001	1.144	0.009	1.324	0.019	2.580	0.003	4
541.2		10.151	0.029	1.445	0.000	1.223	0.023	1.173	0.028	2.259	0.023	6
550.1		10.822	0.021	1.275	0.004	1.080	0.052	0.955	0.051	1.734	0.015	3
585.1		10.163	0.013	1.373	0.013	1.228	0.045	1.060	0.049	1.965	0.026	3
596.0		10.706	0.002	1.288	0.004	1.304	0.014	1.015	0.017	1.862	0.008	6
606.0		10.945	0.005	1.537	0.041	1.238	0.024	1.439	0.014	2.783	0.087	4
612.1		10.413	0.004	1.197	0.000	1.275	0.002	0.984	0.001	1.775	0.005	3
635.1	151623	6.321	0.000	1.111	0.000	1.242	0.012	0.776	0.011	1.355	0.000	6
654.2	154653	7.102	0.024	0.918	0.009	0.669	0.004	0.732	0.002	1.296	0.002	3
694.2		10.757	0.007	1.401	0.009	1.240	0.048	1.309	0.018	2.488	0.011	3
708.0		10.098	0.003	1.237	0.009	1.326	0.001	1.062	0.012	1.944	0.003	6
708.2		10.180	0.001	1.393	0.012	1.205	0.024	1.179	0.010	2.254	0.013	3
751.0		9.710	0.012	1.290	0.008	1.282	0.004	1.086	0.004	2.007	0.011	3
756.2	182196	8.170	0.030	1.589	0.006	2.014	0.043	1.222	0.001	2.197	0.022	4
757.0		10.916	0.021	1.446	0.004	1.164	0.017	1.140	0.011	2.089	0.000	4
762.2	184385	6.895	0.004	0.707	0.001	0.349	0.000	0.542	0.011	1.006	0.005	3
801.0		9.863	0.012	1.252	0.001	1.055	0.019	0.995	0.019	1.778	0.000	5
912.0		11.149	0.019	1.467	0.010	1.142	0.074	1.406	0.004	2.842	0.009	5
1229.0	171067	7.189	0.004	0.660	0.003	0.239	0.002	0.549	0.000	0.937	0.000	3
1233.0	180161	7.015	0.003	0.762	0.007	0.473	0.006	0.615	0.004	1.056	0.001	4
1237.0	183255	8.012	0.006	0.886	0.004	0.695	0.006	0.787	0.000	1.374	0.000	3
1249.0	190771	6.189	0.000	0.644	0.005	0.219	0.007	0.530	0.001	0.911	0.000	4
1255.0	199476	7.807	0.003	0.668	0.001	0.196	0.004	0.562	0.004	1.000	0.003	4
2024.0		8.450	0.010	1.199	0.010	1.399	0.024	0.917	0.002	1.658	0.001	3
2155.0		10.567	0.010	1.353	0.009	1.271	0.009	1.212	0.003	2.295	0.000	3
2157.0	222366	7.518	0.009	0.826	0.002	0.569	0.011	0.663	0.003	1.165	0.000	3