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Long-term photometry of variables at ESO. II. The second data catalogue (1986–1990) *

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Abstract. — In this paper we present the second catalogue of photometric data in the Strömgren system obtained during the period October 1986 – September 1990 in the framework of the Long-Term Photometry of Variables (LTPV) program at the European Southern Observatory. The catalogue is available in computer readable form at the Centre de Données de Strasbourg.

Key words: photometry — stars: variables — *uvby* — data analysis

1. Introduction

Since October 1982, a considerable amount of photometric observing time at the European Southern Observatory has been allotted to the *Long-Term Photometry of Variables* (LTPV) program. For an introduction to the background of this project, we refer to Sterken (1983, 1986) and to the *First Catalogue of stars measured in the Long-Term Photometry of Variables project (1982–1986)* (Manfroid et al. 1991). The present catalogue contains the data resulting from observations collected between October 1, 1986 and September 30, 1990. The presentation of the catalogue is similar to the presentation of the first catalogue.

Stars are numbered according to their membership in one of 9 pre-defined sections, each more or less representing a discrete research topic. Each section is headed by a Principal Investigator and a co-investigator. Table 1 lists all sections, and the corresponding investigators. Section 7 consists of all objects which required immediate monitoring due to the occurrence of unexpected events (flares or bursts), or due to exceptional observational configurations (e.g., simultaneous ground-based and space observations).

* Based on observations collected at the European Southern Observatory, La Silla

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Table 1. Sections and Principal Investigators

1	Pre-main sequence stars	P.S. Thé, H.R.E. Tjin a Djie
2	Ap Stars	H. Hensberge, J. Manfroid
3	Eclipsing binaries	A. Bruch, H.W. Duerbeck
4	Be stars	N. Vogt, C. Sterken
5	Supergiants	B. Wolf, M. de Groot
6	X-ray sources	M. Burger
7	Targets of opportunity	C. Sterken
8	Peculiar late-type stars	A. Jorissen
9	Wolf-Rayet stars	J.M. Vreux, J. Manfroid

The responsibility for the scientific value of each subprogram rests entirely with the Principal Investigator, who also assumes responsibility for the admission of data in the catalogue. Specific information on program stars can be obtained from these Principal Investigators.

The list of monitored objects contains about 200 stars. This list is evolving—though at a rather slow pace dictated by the nature of the project—as stars are added or are taken out. Within each group a running number identifies the star (the first stars of group 1 are 1001, 1002...). The comparison stars of each object have the same identification as the program star, and they are prefixed by a letter (A, B...); the program-star code is prefixed by the letter P.

About 50% of the stars are observed at a frequency of one measurement per night (throughout the corresponding observing season). The frequency for observing the remaining stars ranges between one measurement every second day to one measurement per month. The majority of objects have negative declinations, but some northern stars have also been observed.

2. The instruments

The Strömgren *uvby* photometric system has been used throughout, because this system is very well suited to the physical interpretation of the results: the intermediate bandwidths make reductions easier (that is, for what concerns extinction determination, but not for the color transformation). The combination of an intermediate-bandwidth filter system and a telescope of modest aperture, of course, puts some constraints on the limiting magnitude of the selected objects (the faintest star is of 10th magnitude), but the advantages of using such a system instead of a broadband system are of higher importance.

All data reported in this catalogue have been obtained with the ESO 50 cm and with the Danish 50 cm telescopes (from December 1987 on, the latter is referred to as SAT, *Strömgren Automatic Telescope*, see Florentin Nielsen et al. 1987). The SAT is equipped with a multichannel *uvby* photometer (Florentin Nielsen 1983). At the ESO 50 cm telescope a sequential photometer equipped with *uvby* filters is employed.

3. The observations

The observations were made in periods of about one month length, each period involving a different observer. Table 2 lists the relevant information, together with the number of useful nights, and the number of useful observations in each period. The last column indicates the particular instrumental system of each observing run.

We have strived to obtain homogeneous data with instrumental systems as close as possible to the standard *uvby* system. This is not perfectly feasible since we had to use telescopes, photometers, and filter sets with different optical characteristics. The various instrumental systems are indicated with a one-digit code.

The first three columns in Table 3 give, respectively, the system code, the filter numbers according to the ESO filter list, and the type of photomultiplier(s). Columns 5–10 list the color transformation coefficients (see Eq. 3) used for each system. They allow to transform the data back to the natural instrumental systems, if necessary.

Depending on the object and on the accuracy needed, an observation may consist of a simple sequence APB or APA, or a more extended one like APBPBPA.

The adopted standards are taken from the list of Olsen (1983). They have been supplemented by a few stars from Olsen (1984) that were used as comparison stars.

4. The data reduction

The reduction procedure is identical to that described in the First Catalogue (Manfroid et al. 1991). A more thorough description of the mathematical methods can be found in Sterken & Manfroid (1992a).

The algorithm uses every measurement of every constant star and of every standard star. Since the LTPV project involves a large number of measurements of comparison stars, the advantages are obvious. The implementation of this reduction procedure equally facilitated the task of the observer who did not have to comply with a tedious and complicated schedule of extinction measurements.

The adopted procedure allows a continuous updating of the data sets. Every time additional measurements are obtained in one of the instrumental systems, the complete set corresponding to this system is reprocessed.

The color-transformation equation is written as:

$$\mathbf{U_s} = \mathbf{M}\mathbf{U}_0 + \mathbf{K} \tag{1}$$

where $\mathbf{U}$ is the vector of indices:

$$\mathbf{U} = \begin{pmatrix} b-y \\ y \\ m_1 \\ c_1 \end{pmatrix} \tag{2}$$

The suffixes s and 0 denote the standard and instrumental values, respectively. **K** is the vector of zero-points.

The color-transformation matrix **M** is written as

$$\mathbf{M} = \begin{pmatrix} m_{11} & 0 & 0 & 0 \\ m_{21} & 1 & 0 & 0 \\ m_{31} & 0 & m_{33} & 0 \\ m_{41} & 0 & 0 & m_{44} \end{pmatrix} \quad (3)$$

The final m_{ij} values, for each instrumental configuration, are listed in the last columns of Table 3. These values can be used to reconstruct the instrumental data and, by means of the standard-star measurements, anyone can reprocess the data according to his or her preferred color-transformation scheme.

In particular, it would be quite possible to split the stars into subgroups, and to reduce the red stars ($b - y \gtrsim 0.4$) in a different way than the blue ones. The transformation matrices may also be useful for other observers who used the same systems during that period.

As can be seen from Table 3, our definition of the natural systems 6 and 8 does not strictly follow the documented changes of photomultiplier tubes. There are two reasons for this: (i) the photomultiplier changes were sometimes reported incorrectly, or not reported at all, and the true information can no longer be retrieved; (ii) some varieties of photomultiplier tubes, such as EMI6256 and EMI9789, may have very similar spectral response curves, and be truly interchangeable. Consequently, we defined the systems empirically, by examination of the color-transformation and extinction data, which clearly indicate the existence of two separated characteristic groups.

5. Accuracy of the data

It is not easy to assign an error bar to absolute photometric measurements (see Manfroid & Heck 1984). Comparison of magnitudes and color indices obtained for the same stars in different systems can give an estimate of the accuracy of the absolute results (such a comparison certainly could give an idea of the incompatibilities between various versions of the *uvby* system, see e.g., Manfroid & Sterken 1987, and Sterken & Manfroid 1987). However, since our goal is not absolute (all-sky) photometry, and since the observations should be used for differential photometry only, a most representative parameter of quality of data is the standard deviation of the differences between comparison stars (see also Sterken & Manfroid 1991).

The mean value of the rms deviations of the differential measurements of comparison stars (for each photometric system) are listed in Table 5, while Table 4 gives the same data for individual observing runs. In computing these indices, we have limited ourselves to relatively bright stars ($u, y < 8\overset{\text{m}}{.}0$) having at least six observations per single observing run. For Table 4, we excluded runs containing fewer than 4 such stars.

Manfroid & Sterken (1992) discern *conformity errors* and *reduction errors*. The former arise from the fact that the photometric systems we used have mutually different passbands, and that there is no way to evaluate the corrections needed to properly transform data from one such system to another. The latter are of a purely methodological nature and are properly handled by the reduction procedure. Conformity errors are often unavoidable, since prescriptions of a purely practical origin (such as the availibility of a given photometric system at one telescope) may force the investigators to rely on data coming from different systems. Sterken &w Manfroid (1987) illustrated that small passband mismatches (in *uvby*) lead to astrophysically contradictory results concerning the evolutionary state of pulsating B stars in the young open cluster NGC 3293. Manfroid (1992) demonstrates that conformity errors have a detrimental effect on the reddening vector, and consequently on the reddening-free indices, and that such is also the case when color indices of composite objects (binaries) are transformed. Deviations from conformity, as well as variations in the atmospheric transparency also reflect in the derived extinction coefficients (see Sterken & Manfroid 1992c).

Table 4. Mean value (in units of $0\overset{\text{m}}{.}0001$) of the rms deviations of the differential measurements of comparison stars for individual observing runs. Runs with too few observations were excluded.

Run	y	$b-y$	m_1	c_1
3	61	62	143	196
6	48	26	33	52
8	54	42	80	64
9	46	32	42	64
10	62	66	120	95
14	68	42	57	70
15	61	32	37	55
17	54	28	32	53
18	57	57	104	100
19	46	20	26	48
20	78	33	42	72
22	106	25	35	65
23	39	22	30	52
24	44	18	23	54
25	50	20	29	53

Reduction errors can arise between batches of data that are treated with a consistent method of reduction, as is the case in long-term and network projects. Some of the parameters in the reduction schemes have larger errors than others (for example, in *uvby* photometry the ratio of the uncertainties of the coefficients in the transformation equation of m_1 to the coefficient related to the

$b-y$ transformation may amount to a factor of five), and the resulting errors are appreciably larger for stars with extreme color-indices. Such effects are random shifts that affect all measurements of a given star by a same amount (during a specific observing run). These reduction errors are effectively removed by the homogenization procedure which forces a same color-transformation matrix on all data of a given system.

Further analysis (Sterken & Manfroid 1992b) shows the accuracy of data obtained at the Danish telescope to be slightly worse since the introduction of the automatic star-centering mode. This can be due to subtle instrumental differences, and/or to the different observational sequences adopted after the automatization of that telescope. Fortunately, no systematic or conformity errors have been noticed.

Table 5. Mean value (in units of $0\overset{m}{.}0001$) of the rms deviations of the differential measurements of comparison stars within each of the 3 instrumental systems.

System	y	$b-y$	m_1	c_1
6	69	58	122	129
7	64	30	39	67
8	68	61	110	97

The data catalogue is published as an ESO Scientific Report (Sterken et al. 1993). It lists the individual magnitudes and color indices of all program stars and comparison stars (identification, heliocentric Julian date, air mass and four-color data). This printed version of the catalogue is distributed to the libraries of the principal astronomical institutes around the world. A magnetic-tape copy with the full catalogue 1982–1990 can be obtained from the Strasbourg Data Centre (CDS).

6. Update to the first catalogue

The magnetic-tape copy contains updated values of the data printed in the first catalogue 1982–1986 (Manfroid et al. 1991). Several misidentifications were corrected, and data of poor quality have been taken out. Also, slightly-modified color transformations were used. A small change in the b band of photometric system #5 was found to have taken place between runs 12 and 13 (see Table 2 of Manfroid et al. 1991). The system in use during runs 13–15 is now considered separately, and is referred to as system #0.

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Table 2. Log of observations. The number of useful data is the number of groups (P, A, B, ...) that have been observed, and is given in column O. N denotes the number of useful nights. $JD_\odot$ is Heliocentric Julian Date -2440000

Run	Month	$JD_\odot$	N	O	Observers	Telescope	System
1	October 1986	6712–6732	15	364	M.V. Mekkaden	ESO	6
2	November/December 1986	6764–6782	16	403	A. Heck	ESO	6
3	July/August 1987	6996–7040	22	1071	H.W. Duerbeck, A. Bruch	ESO	6
4	September 1987	7041–7069	19	632	A. Jorissen	ESO	6
5	October 1987	7072–7100	19	464	R. Duemmler	ESO	6
6	December 1987/January 1988	7133–7180	45	3449	Y.K. Ng, E. Bibo	Danish	7
7	March 1988	7228–7236	9	529	A. Bruch	ESO	6
8	March/April 1988	7237–7259	20	1268	A. Bruch, N. Vogt	ESO	8
9	June/July 1988	7340–7360	12	650	F. Spiller	Danish	7
10	July/August 1988	7361–7379	14	819	F. Inklaar	ESO	8
11	August 1988	7381–7405	16	709	Liu Zongli	ESO	8
12	October 1988	7436–7464	28	2498	I. Wanders	ESO	8
13	November 1988	7467–7474	6	371	M. Hiesgen	ESO	6
14	November 1988	7474–7495	21	1821	M. Hiesgen	Danish	7
15	March 1989	7590–7616	27	2172	E. Bibo	Danish	7
16	July 1989	7709–7731	17	361	H. Hensberge	ESO	8
17	August 1989	7738–7771	26	1312	M. Burger	Danish	7
18	September 1989	7774–7798	19	556	K. Anton	ESO	8
19	October/November 1989	7802–7847	38	2492	A. Barzewski/A. Juettner	Danish	7
20	December 1989	7874–7894	20	1169	M. Püttmann	Danish	7
21	February 1990	7930–7943	10	322	R. Duemmler	ESO	8
22	June 1990	8061–8084	18	910	P. Niarchos	Danish	7
23	July 1990	8088–8113	14	662	T. Szeifert	Danish	7
24	August 1990	8114–8135	18	931	U. Kinkel	Danish	7
25	September 1990	8141–8165	20	1099	R. van Dijk	Danish	7

Table 3. Instrumental systems. The references stand for (1): Danks 1982, (2): Florentin Nielsen 1983

Nr	Filter set	Photomultipliers	Ref.	m_{11}	m_{33}	m_{44}	m_{21}	m_{31}	m_{41}
6	ESO 13,11,8,2	EMI6256S, EMI9789QA	(1)	1.0706	1.0781	1.0534	0.0205	−0.1449	0.3028
7	Danish	EMI9789QB	(2)	1.0232	0.8935	1.0032	0.0122	0.0290	0.1632
8	ESO 13,11,8,2	EMI9789QB, EMI9658RA	(1)	1.0686	1.0747	0.9816	0.0431	−0.1412	−0.3040