ASTRONOMY & ASTROPHYSICS
SUPPLEMENT SERIES

FEBRUARY 1995, PAGE 329

*Astron. Astrophys. Suppl. Ser.* **109**, 329-332 (1995)

# Long-term photometry of variables at ESO.* III. The third data catalogue (1990-1992)

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Received June 14, accepted July 13, 1994

**Abstract.** In this paper we present the third catalogue of photometric data in the Strömgren system obtained during the period October 1990 – January 1992 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:** catalogs — stars: variables: other — techniques: photometric

## 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), to the *First Catalogue of stars measured in the Long-Term Photometry of Variables project (1982–1986)* (Manfroid et al. 1991), and to the *Second Catalogue of stars measured in the Long-Term Photometry of Variables project (1986–1990)* (Sterken et al. 1993). The present catalogue contains the data resulting from observations collected between October 1, 1990 and February 1, 1992. The presentation of the catalogue is similar to the presentation of the first two catalogues. Stars are numbered according to their membership in one of 9 pre-defined sections, that each more or less represents 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).

**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, C. Sterken |

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

** Belgian Fund for Scientific Research (FNRS/NFWO)

**Table 2.** Log of observations. The number of useful data (the number of groups (P, A, B, ...) that have been observed) 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 |
|---|---|---|---|---|---|---|
| 1 | October 1990 | 8166–8200 | 20 | 924 | N. Vogt, R. Kneer | SAT |
| 2 | November 1990 | 8215–8239 | 21 | 700 | B. Cunow | SAT |
| 3 | December1990/January 1991 | 8244–8294 | 24 | 1325 | M. Niehues, A. Jorissen | SAT |
| 4 | June/July 1991 | 8413–8464 | 26 | 778 | R. Krenzin, W. Schöneich | SAT |
| 5 | August/September 1991 | 8486–8530 | 28 | 1325 | M. Kruijswijk, M. Sevenster | SAT |
| 6 | October/November 1991 | 8531–8578 | 27 | 830 | M. Naumann, N. Vos | SAT |
| 7 | January 1992 | 8645–8660 | 14 | 677 | M. de Groot | SAT |

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 more than 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 instrumental configuration

The Strömgren *uvby* photometric system was 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 Danish 50 cm telescope (from December 1987 on, 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). The data obtained in that configuration were referred to as *System 7* in the first two catalogues. Departing from the philosophy adopted in these previous catalogues, all data listed here are in the natural (instrumental) SAT system.

## 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.

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 standards adopted for the first two catalogues were taken from the list of Olsen (1983), supplemented by a few stars from Olsen (1984) that were used as comparison stars. We used the same standard stars for the present catalogue, however, we did not use the standard values from above-mentioned catalogues, but we used own mean instrumental magnitudes and colors.

## 4. The data reduction

A thorough description of the mathematical methods can be found in Sterken & Manfroid (1992). 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, the complete set corresponding to the SAT system is reprocessed. The only modifications in the reduction procedure, relatively to that described in the First

Catalogue (Manfroid et al. 1991) concerns the color transformation.

The color-transformation equation used for the first two catalogues was 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. $\mathbf{K}$ is the vector of zero-points.

The color-transformation matrix $\mathbf{M}$ is

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

For the reductions of the measurements reported in this catalogue, we forced the data to be in the natural system, that is

$$m_{i,j} = \delta_{i,j} \tag{4}$$

This procedure, of course, is only justified when we adopt adequate "standards" in the natural system. Because of the vast amount of data accumulated throughout the LTPV project we do have such standards: the about 400 constant stars having the very best measurements were selected as standards. Part of these already were HR standards, others are very reliable comparison stars. The adopted standard values in the natural system (in the catalogue identified as "System N") are the instrumental values of those stars, to which only a zero point correction was applied. The zero point correction is such that by applying the transformation parameters listed in Table 3 of Catalogues 1 and 2, one obtains data directly compatible with the ones listed in those catalogues. Of course, for old data it is better still to access the complete data base which is constantly updated, and which we plan to have installed at the CDS (up to now, CDS data consist of the original Catalogues, with few corrections).

Out of those standards, 75 are present in the list recently published by Olsen (1993). The average differences Olsen minus LTPV computed for these 75 stars are $0.0015 \pm 0.0049$, $0.0083 \pm 0.0027$, $-0.0126 \pm 0.0069$ and $0.0416 \pm 0.0061$, respectively in $y$, $b-y$, $m_1$ and $c_1$. The individual differences are given in Table 3. Part of the differences is simply due to the somewhat arbitrary choice of zero points. Another part reflects the declination trend mentioned by Olsen (1993), an effect which is marginally detectable in our data: a regression analysis yields coefficients $-6.6 \pm 2.7$, $-5.7 \pm 1.3$, $-14.1 \pm 3.5$, $7.7 \pm 3.3$ in units of $10^{-5}$ mag/°, respectively for $\Delta y/\Delta\delta$, $\Delta(b-y)/\Delta\delta$, $\Delta m_1/\Delta\delta$ and $\Delta c_1/\Delta\delta$. These gradients are different from the values deduced by Olsen (1993), especially in $m_1$, and it is likely that, due to the derivation of our instrumental standards, part of the effect is already corrected. This remaining $\delta$ effect has no influence at all on any analysis based on differential LTPV data. However, the $\delta$ effect could be much more important when comparing absolute data obtained at other telescopes.

**Table 3.** Differences between Olsen (1993) instrumental standards and LTPV standards (Olsen *minus* LTPV, in units of $0\overset{\mathrm{m}}{.}0001$ mag) for the stars in common between both catalogues

| HR | $y$ | $b-y$ | $m_1$ | $c_1$ | HR | $y$ | $b-y$ | $m_1$ | $c_1$ |
|---|---|---|---|---|---|---|---|---|---|
| 100 | 7 | −5 | −3 | 33 | 4515 | 13 | −3 | −14 | 34 |
| 493 | 7 | −1 | −19 | 48 | 4695 | 13 | 2 | −22 | 49 |
| 531 | 6 | −6 | −12 | 42 | 4889 | 7 | 1 | −6 | 33 |
| 672 | 9 | −1 | −19 | 46 | 5011 | 13 | 1 | −21 | 43 |
| 811 | 7 | −3 | 1 | 42 | 5168 | 8 | 1 | −9 | 36 |
| 962 | 9 | 1 | −15 | 43 | 5270 | 12 | −2 | −23 | 45 |
| 1024 | 9 | −1 | −21 | 50 | 5530 | 8 | 1 | −16 | 44 |
| 1030 | 5 | −4 | −6 | 40 | 5660 | 5 | 8 | −11 | 39 |
| 1089 | 8 | −1 | −22 | 50 | 5825 | 4 | 2 | −10 | 41 |
| 1292 | 6 | −2 | −19 | 47 | 5868 | 10 | −7 | −12 | 37 |
| 1409 | 8 | −6 | −8 | 43 | 5885 | 5 | 6 | −4 | 45 |
| 1861 | 10 | 3 | −11 | 44 | 5997 | 6 | 3 | −11 | 41 |
| 2233 | 12 | 1 | −21 | 44 | 6141 | 3 | 2 | −6 | 43 |
| 2236 | 7 | −4 | −21 | 47 | 6243 | 7 | 0 | −12 | 38 |
| 2251 | 9 | 1 | −18 | 46 | 6603 | 8 | 6 | −9 | 40 |
| 2313 | 8 | 2 | −19 | 47 | 6930 | 5 | 1 | −7 | 33 |
| 2622 | 8 | 7 | −20 | 45 | 7254 | 5 | 1 | 1 | 26 |
| 2779 | 17 | −2 | −26 | 44 | 7446 | 8 | 0 | −11 | 50 |
| 2798 | 12 | 6 | −23 | 48 | 7447 | 6 | −6 | −3 | 34 |
| 2807 | 9 | 10 | −18 | 42 | 7525 | 8 | 3 | −15 | 46 |
| 2866 | 9 | 8 | −18 | 47 | 7602 | 8 | 0 | −9 | 40 |
| 2880 | 10 | 3 | −17 | 43 | 7773 | 8 | −4 | −10 | 34 |
| 2883 | 8 | 2 | −20 | 45 | 7858 | 13 | −13 | −17 | 38 |
| 2918 | 11 | 6 | −21 | 46 | 7936 | 8 | 0 | −10 | 40 |
| 2927 | 7 | 7 | −11 | 36 | 8060 | 9 | −2 | −15 | 41 |
| 3131 | 7 | 9 | −5 | 34 | 8181 | 6 | 1 | −9 | 42 |
| 3249 | 6 | −1 | −13 | 45 | 8313 | 7 | 7 | −13 | 50 |
| 3297 | 11 | 10 | −18 | 47 | 8431 | 9 | −2 | −9 | 34 |
| 3314 | 10 | 7 | 1 | 26 | 8515 | 0 | 18 | −15 | 58 |
| 3454 | 13 | 3 | 3 | 38 | 8551 | 9 | 0 | −18 | 50 |
| 3459 | 5 | 7 | −12 | 42 | 8729 | 9 | 2 | −18 | 47 |
| 3538 | 10 | 6 | −20 | 48 | 8826 | 8 | 1 | −12 | 41 |
| 3759 | 11 | 3 | −14 | 39 | 8848 | 9 | −1 | −10 | 41 |
| 3849 | 7 | 10 | −7 | 43 | 8969 | 6 | −5 | −9 | 42 |
| 3856 | 6 | 9 | 0 | 33 | 9072 | 8 | −4 | −7 | 32 |
| 3901 | 13 | 0 | −24 | 45 | 9076 | 8 | 1 | −6 | 37 |
| 4293 | 8 | 5 | −5 | 31 | 9091 | 9 | 0 | −13 | 47 |
| 4343 | 6 | 4 | −2 | 29 | | | | | |

By selecting other standard values, one could reprocess the data according to other color-transformation schemes. In particular, it is possible to use the transformations given by Olsen (1993).

The following non-linear transformations (Eqs. (5-7)) are also possible and give a good fit to the standard values published by Olsen (1983), and supplemented by a few stars from Olsen (1984). The stars are divided into two subgroups, according to the value of $b-y$ — except for $y$, which allows a single transformation:

$$y_s = y_0 - 0.001 + 0.013(b-y) \tag{5}$$

Let $r = b - y - 0.41$. For blue stars ($r < 0$), we use

$$\begin{aligned}(b-y)_s &= 0.418 + 0.979r - .089r^2 \\ m_{1,s} &= -0.008 + m_1 + 0.074r + 0.192r^2 \\ c_{1,s} &= .043 + 1.009c_1 + 0.068r - 0.103r^2\end{aligned} \tag{6}$$

while redder stars ($r \geq 0$) obey

$$\begin{aligned}(b-y)_s &= 0.418 + 1.028r \\ m_{1,s} &= -0.008 + 1.000m_1 + 0.129r \\ c_{1,s} &= .043 + 1.009c_1 + 0.530r\end{aligned} \tag{7}$$

## 5. Accuracy of the data

Comparison of magnitudes and color indices obtained for the same stars in different systems can give an assessment 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 are listed in Table 4 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 one run containing fewer than 4 such stars.

**Table 4.** Mean value (in units of $0\overset{\text{m}}{.}0001$ mag) of the rms deviations of the differential measurements of comparison stars for individual observing runs. Run #2, with too few observations, was excluded

| Run # | $y$ | $b-y$ | $m_1$ | $c_1$ |
|---|---|---|---|---|
| 1 | 42 | 17 | 20 | 35 |
| 3 | 47 | 23 | 36 | 58 |
| 4 | 52 | 22 | 32 | 59 |
| 5 | 54 | 23 | 34 | 52 |
| 6 | 47 | 20 | 35 | 55 |
| 7 | 45 | 32 | 42 | 55 |

## 6. Update to the first and second catalogue

The CDS will be provided with updated values of the data printed in the first and second catalogues (Manfroid et al. 1991; Sterken et al. 1993). Several misidentifications were corrected, and data of poor quality are taken out.

*Acknowledgements.* This research has made use of the Simbad database, operated at CDS, Strasbourg, France. We thank ESO and the ESO Observing Program Committee for their full support, which has made this project possible. We are indebted to the University of Copenhagen for providing the telescope and photometer, and we are grateful to the technical staff at La Silla for their support, and for the necessary nightly interventions at the telescope. N.Vogt acknowledges the support by the Chilean "Comisión Nacional de Investigación Científica y Tecnológica" (grant FONDECYT 637-91). Financial support from the Belgian Government, Vrije Universiteit Brussel, Université de Liège and NFWO/FNRS is acknowledged.

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