Photoelectric photometry era at the Astronomical Institute of the Slovak Academy of Sciences II.

Software and reduction techniques

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Abstract. We present a continuation of Paper I describing the photoelectric photometry at the Astronomical Institute of the Slovak Academy of Sciences at Tatranská Lomnica. In this article we show the observation principles and the basic ideas and philosophy of the photometer control software – the code UNIV, written by R. Komžík and V. Kollár, and used for the data resulting from observations.
Key words: photoelectric photometry – software – observation

1. Introduction

In the previous paper (Vaňko *et al.*, 2014a, Paper I), we presented the main properties of the last photoelectric photometers used at the observatories Skalnaté Pleso (hereafter SP) and Stará Lesná (hereafter SL). Our description contained the following items:

– basic parts of photoelectric photometers (`OPTEC SSP/5A` and `EMI 9789 Q`) used at SP and SL observatories in the period from 1996 to 2014,

– technical limitations and problems discovered during the first observations, solutions of presented problems and some technical improvements which were carried out by the authors (R. Komžík and V. Kollár).

In addition, we presented optical properties based on the photometric system measurements.

Here, we will continue with user software and data reduction (instructions) prepared for the presented detectors. The remainder of this paper is organized as follows. In Section 2, we describe basic ideas and philosophy of the user software UNIV, created by the authors (R. Komžík and V. Kollár). This section includes installation of the observational code UNIV, configuration files and how to prepare a catalogue of targets/stars. We continue with the configuration of a photometer, observational principles and output files of the code UNIV. We also

describe possible errors and warning messages of the code as well as auxiliary codes necessary to perform the observations. Finally, in Section 3 we summarize our description.

2. The user software

2.1. The basic ideas, philosophy

The basic purpose of the observational code UNIV is differential photometry of variable stars. The code UNIV also includes possibility to observe in the mode of the fast photometry (with integration time one second and less) but this option will be described in a separate paper.

The direct output of this code is an output file (Section 2.5), where (raw) observational data are stored. To get "astronomical quantities" (magnitudes) suitable for further analysis, these data must be reduced. The reduction can be done with the help of the reduction codes package.

The code UNIV will not allow you to change the diaphragm or integration time during the observation of a given object. This is the way how it tries avoiding errors during the observation. In spite of this behavior an observer is asked to follow another guidelines (given in Section 2.4) to obtain as good results as possible.

As the UNIV code was developed step by step following experience with the photoelectric photometry at the Stellar Department of the Astronomical Institute of the Slovak Academy of Sciences at Tatranská Lomnica, there was the need for "backward compatibility". Consequently, there are two principal disadvantages: the structure of the output file is obsolete; a very complicated way of referring the objects (stars) at the auxiliary file KATALOG.

An explanation of many terms (seasonal extinction coefficients, Johnson's international UBV system, transformation coefficients,...) used in this part can be found in a book by Henden & Kaitchuck (1982).

2.2. Installation

The steps needed for a proper installation of the observational code UNIV at your computer are described in this section. Computer requirements: an IBM-compatible PCx86, operating system DOS, and about 150 KB of free disk space at your computer hard disk.

The code UNIV itself consists of several parts:

- the observational code **UNIV.EXE** itself. This code controls the observation process, raw data are obtained;

- the resident part of the code **FOT??.EXE** At the position of the first "?" you can find: 1 = for a photometer controlled by synchronization impulses from the COM (serial) port, 2 = the synchronization impulses are generated

by the computer. The second "?" stands for one of the following possibilities: H = Hlohovec, G = Kryonerion (Greece), R = Roztoky, P = Skalnaté Pleso (an American photometer Optec with adjustments), O = Skalnaté Pleso (a "raw" American photometer Optec without any adjustments), L = Stará Lesná. This resident part serves for communication between the computer and the photometer.

– **configuration files**. Various information about a given photometer and objects (stars) are given in these files. The content and their format are described in detail in Section 2.3.

The code UNIV is distributed on a 3.5" (or 5.25") DOS diskette. Installation should be done as follows:

1. Create the directory **C:\OBSERV** and copy to this directory from the installation diskette the files **UNIV.EXE** and **FOT??.EXE**.

2. Create the directory **C:\KATALOG** and copy here the configuration files **KATALOG** and **OBSERVAT.??** from the installation diskette (explanation of these two "??" can be found in Section 2.3.2). You can copy OBSERVAT.LST, TIME.COR and TR_KOEF.DAT here as well. These last three files are not used during the observation by the UNIV code itself, they are, however, needed during the reduction process and are used by codes from the reduction package (Section 2.8).

3. Create the directory **C:\DATA**. The output files with raw observational data will go here by default.

4. In the file **C:\CONFIG.SYS** there must be the driver ANSI.SYS started, because the UNIV code uses ANSI Escape sequences. Put the line:

   ```
   DEVICE=C:\DOS\ANSI.SYS
   ```

   into C:\CONFIG.SYS (depending on which directory the file ANSI.SYS can be found in).

5. We suggest that you have a colour **monitor**. If your monitor is monochromatic, it is necessary to put into your **C:\AUTOEXEC.BAT** file the line (depending on which directory the file MODE.COM can be found in):

   ```
   C:\DOS\MODE co80
   ```

   To make things simpler, you can also include to the PATH variable the directory C:\OBSERV in your C:\AUTOEXEC.BAT file.

6. Reboot your computer and you can start the observational code by entering the command:

```
C:\OBSERV\UNIV.EXE
```

7. To run the observational code even in a simpler and more elegant way, it is possible (although not necessary) to copy the file NOTE from the installation diskette into the directory C:\OBSERV. Very basic observational principles and various remarks can be given here. Copy the batch file OBSERVAT.BAT from the installation diskette into a directory within your PATH (given in C:\AUTOEXEC.BAT) e.g., C:\DOS or C:\BAT. This batch file types the file POZNAMKA on the screen, sets the working directory, reminds you of the amount of free disk space, and starts the observational code UNIV itself. The best way to run the batch file OBSERV.BAT is to place it as an item named OBSERVATION in the Norton Commander's menu.

The names of given directories where files should be placed can differ (e.g., your hard disk is not divided into multiple partitions: a disk E does not exist; or you do not have a hard disk at all: are there still such computers these days?).

2.3. Configuration files

The code UNIV reads some information from auxiliary configuration files. In the file KATALOG information about stars is stored, the file OBSERVAT.?? (the explanation of these two ?? can be found in Section 2.3.2) contains the information about filter positions (order) in the photometer at a given time. Both configuration files are described in detail in Sections 2.3.1 and 2.3.2.

2.3.1. Stars catalogue

The information about stars (observation objects): star identification; the HD, SAO and HR numbers; coordinates right ascension α and declination δ with their equinox and epoch; proper motions (without precession!) in coordinates α, δ; optionally (if the object is a variable with a known period) the time of minimum JD_{0hel} and the period given in days is stored in the file KATALOG.

For every object (star) there are 2 lines in the file. For example, 8 lines from the file given below. They represent the records corresponding to 4 various objects (stars):

```
tx uma    cmp 1                    HD92764      SAO43442       HR
      .000000      .000000000 10.4029338  45.1245810     .0007   -.009
1950
tx uma    cmp 2                    HD92787      SAO43444       HR4191
      .000000      .000000000 10.4037108  46.2801900   -.0261   -.072
1950
tx uma    cmp 3                    HD93213      SAO43467       HR
      .000000      .000000000 10.4336024  44.2200600   -.0135   -.036
1950
tx uma                             HD93033      SAO43460       HR
```

```
2448594.479570    3.063329000 10.4224445   45.4945740      .0014    .001
1950
```

A disadvantage of a historical origin is the way of object identification. The stars used during the observation of variable stars (see Section 2.4) can basically be divided into 2 groups: variable stars and standard stars. The next historical convention is that a variable star is denoted as an object with number 4, a comparison star has number 1, a check is the object number 3. For other possible standard stars we have numbers 2 and 5 – 99. The standard star number 2 is, following this convention, the object with number 2 and so on. (This notation is originally adopted from the Stellar Department of the Astronomical Institute at Ondřejov, Czech Republic, and number 1 was to denote the "blue standard", 2 for the "red standard"). From this notation we have identification in the file KATALOG. Let us take as an example the observation of the variable star TX UMa. The object identification is a string 14 characters long. First 9 characters serve to denote a variable star under consideration. The best way is to use a variable star name in lowercase, in this example `tx uma`[1]. To these 9 characters we append at 10–12 positions a string `cmp` and the number of the object in format I2 (FORTRAN convention). The last sentence does not apply to a variable. See:

object	denotation in file KATALOG
comparison star for variable TX UMa	`tx uma   cmp 1`
check for variable TX UMa	`tx uma   cmp 3`
variable star TX UMa	`tx uma`
standard star No. 15 for variable TX UMa	`tx uma   cmp15`

A disadvantage is clear from given facts: if a star used as a comparison is used as a check as well (theoretically) for a different variable star, let us say TY UMa, it would have to be in file KATALOG twice: for the first time with identification `tx uma   cmp 1` and the second time as `ty uma   cmp 3`. Having in mind a small number (to tell the true, this has not happened at Stellar department of the Astronomical Institute of the Slovak Academy of Sciences yet) of these cases, we can tolerate this "nuisance" of the file KATALOG.

To ensure unambiguous identification of an object in the file KATALOG, there are (if they exist) the **catalogue numbers** from various stellar catalogues: HD – the Henry Draper Catalogue (Cannon & Pickering, 1918–1924), SAO – the Smithsonian Astrophysical Observatory Star Catalog (1966) and HR – the Yale Catalogue of Bright Stars (Schlesinger & Jenkins, 1940, Hoffleit, 1964). It is

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[1]It is necessary to specify clearly the notation for "problematic" variables; do not use once `n cyg`, then `nova cyg` and the third time `novacyg`, or `hd 8912` and then `hd8912`. To avoid this situation you can have an agreement and in the observational form should be a cell "Star name"; an applicant for the observation is expected to write the information about observation objects into the file KATALOG.

necessary to find as many as possible catalogues numbers of a given object. The data are archived and this can help in the distant future to identify the observed objects. Keep in mind that the experiment (observation) cannot be repeated in astronomy, and every *good* observation has its great value. The following internet URL can help you to find the catalogue numbers:

– http://adswww.harvard.edu/list_abs.html or

– http://adsabs.harvard.edu/abs_doc/list_abs.html

If the period of a variable is known, give the time of its minimum in Heliocentric Julian Days (HJD) and the period in days. If the object is not periodic (all standard stars must be of this type) put in this place 0 (zero) for both these values (i.e., the time of minimum and the period).

Right ascension and declination are given for a certain equinox and epoch which can be arbitrary. The right ascension is to be given in hours, minutes and seconds. The number 10.4224445 from the example above for the variable star TX UMa means $\alpha_{1950} = 10^h 42^m 24\overset{s}{.}445$. Declination is to be given in degrees, arc minutes and arc seconds. The number 45.4945740 from the example above stands for $\delta_{1950} = 45°49'45''.740$.

The "raw" proper motions (i.e., without precession!) in right ascension and declination are given in the file KATALOG as well. The proper motion in right ascension is given in seconds per annum; the proper motion in declination is given in arc seconds per annum.

The precise position (format) of all data in the file KATALOG is described by the following lines from a FORTRAN source code:

```
      double precision jd0, per
      real mirs, midas
      integer rh, rm rs1000, dd, dam, das1000, epoch
      character*11 hd, sao, hr
      character*14 ident

      open(12, file='KATALOG')
      write(12, 100) ident, 'HD', hd, 'SAO', sao, 'HR', hr
100   format(A14, 18X, A2, A11, 1X, A3, A11, 2X, A2, A11)
      write(12, 200) jd0, per, rh, '.', rm, rs1000,
     +               dd, '.', dam, das1000, mirs, midas, epoch
200   format(D14.6, 1X, A2, D14.9, 1X, I2, A1, I2, I5, 2X,
     +       2X, I3, A1, I2, I5, 3X, F8.4, 1X, F7.3, 3X, I4)
      close(12)
```

The meaning of the symbols (variables): `ident`: object's identification, `hd`: HD number, `sao`: SAO number, `hr`: HR number, `jd0`: time of minimum in JD, `per`: period in days, `rh`: right ascension-hours, `rm`: right ascension-minutes,

rs1000: $1\,000 \times$ right ascension-seconds, dd: declination-degrees, dam: declination-arc minutes, das1000: $1\,000 \times$ declination-arc seconds, mirs: raw proper motion in right ascension - seconds, midas: raw proper motion in declination - arc seconds, epoch: the coordinates - integral year.

The file KATALOG can be created/appended following the given rules by using an arbitrary editor or you can take advantage of the auxiliary code KATIN.EXE; see Section 2.8.

If the file KATALOG does not exist, the code UNIV will warn you; see Section 2.7.

2.3.2. Photometer configuration

The configuration of your photometer may change (e.g. by adding new filters). For this reason, the code UNIV uses the configuration file **C:\KATALOG\ OBSERVAT.??** (at the positions of ?? there must be one of the following codes – depending on observatory: HL = Hlohovec, GR = Kryonerion (Greece), RO = Roztoky, SP = Skalnaté Pleso, SL = Stará Lesná, where the "time-dependent" information about your photometer is stored. In addition to the information about the filters order, there is also the information not used by UNIV, however, needed during the reduction of the observational raw data: extinction coefficients for all the filters and transformation coefficients from the instrumental magnitudes in Johnson's filters into the international system.

After every change in your photometer configuration it is necessary to up-date this file! You must add a new group of five lines, following the notation and format given below.

The format of the file C:\KATALOG\OBSERVAT.?? is as follows. There are remarks explaining briefly the contents and format of the file on the first 15 lines. After these mandatory 15 lines there is an arbitrary number of 5-line groups. Each of these groups describes the photometer configuration from a given Julian date (JD). These groups must be chronologically ordered with increasing JD! An example of two such groups is given here:

```
---SKALNATE PLESO Observatory   Pleiades 27/28 JAN '92 ($UBV$ STANDARDS)
 2448649.4
U  B  V
0.675 0.386 0.277 0 0 0 0 0 0 0
  -0.14626   1.02690   1.03747
---SKALNATE PLESO Observatory   IC4665   10/11 MAY '93  (MIRROR WASHING)
  2449094.5
U  B  V  R  u  v  b  y
0.675 0.386 0.277 0 0 0 0 0 0 0
  -0.00748   0.99970   1.03690
```

- **(15+(n × 5)+1)-st line:** a remark is given here. It is advisable to make a note here what was changed (e.g., new filters added, a computation of new transformation coefficients,...)

- **(15+(n × 5)+2)-nd line:** in format F11.1 (FORTRAN convention) the JD is given here. It is the JD from which the values are valid.

- **(15+(n × 5)+3)-rd line:** in format 10(A3) the signs of filters are given. It is not possible to have more than 10 filters. The 0 position is to be used as a "free" position. If you do not have as many filters as the positions in the photometer, place them in positions starting from the position number 1 and in this line of the configuration file set just signs of really existing filters in your photometer. If you decide to have a free position between filters, it is necessary to set a sign for it here as well; let us say NUL. 3 spaces cannot serve as a sign, the code would not recognize subsequent filters.

- **(15+(n × 5)+4)-th line:** the first-order seasonal extinction coefficients are given here in free format (there must be 10 of them). They must be given in the order of filters (following the previous line). If you have not measured an extinction coefficient for a given filter yet, or there is no filter in the photometer at this position, place 0 (zero) at the respective position.

- **(15+(n × 5)+5)-th line:** the transformation coefficients (ϵ, μ, ψ) without zero points in format 3(F10.5) for the transformation into international UBV magnitudes are given here. The transformation equations are:

$$
\begin{aligned}
V - v &= \epsilon \times (B - V) + \zeta_v \\
B - V &= \mu \times (b - v) + \zeta_{bv} \\
U - B &= \psi \times (u - b) + \zeta_{ub}
\end{aligned}
\tag{1}
$$

Capital letters U, B, V denote Johnson's international magnitudes, lowercase letters u, b, v denote instrumental magnitudes (for the detailed information also on other filters, see Henden & Kaitchuck, 1982).

If we write down the system of transformation equations for a comparison star S_1 and the same for variable V, we can subtract them to get:

$$
\begin{aligned}
\Delta V - \Delta v &= \epsilon \times (\Delta B - \Delta V) \\
\Delta B - \Delta V &= \mu \times (\Delta b - \Delta v) \\
\Delta U - \Delta B &= \psi \times (\Delta u - \Delta b)
\end{aligned}
\tag{2}
$$

without zero points $(\zeta_v, \zeta_{bv}, \zeta_{ub})$. The symbols Δ's stand for differential magnitudes, the differences of the magnitudes of a variable V and a comparison star S_1 for a given filter, e.g.: $\Delta U = U_V - U_{S_1}$. This is the reason why in the (15+(n × 5)+5)-th line of the configuration file just the transformation coefficients (ϵ, μ, ψ) without zero points are given. However, we suggest that

the differential photometry is done. If we want to have Johnson's international UBV magnitudes of a variable V after reduction, we must know (find in the catalogue) Johnson's international UBV magnitudes of a comparison star S_1.

The configuration file can be modified/appended by using an arbitrary editor.

The file must exist, otherwise the code UNIV will stop with an error message; see Section 2.7.

2.4. Observation principles

The code UNIV was written to make, on the one side, a variable stars observation easier and, on the other side, to exclude possible errors of an observer during the observation. Such features are: impossibility to change the integration time and diaphragm during the observation of a given object and so on. Anyway, an observer and an applicant for an observation must follow certain principles even during the preparation of an observation:

– As a **standard comparison star** $\mathbf{S_1}$ it is necessary to choose a constant object of approximately the same brightness as the variable star (dynamic range of the photometer), approximately of the same spectral type (the second order extinction coefficients are not taken into account during the reduction) in a relatively small angular distance (maximally a few degrees) from the variable star (if this condition is satisfied you minimize the time needed for transitions between objects; moreover, the extinction corrections will be negligible, so even the first order extinction coefficients given with a big error will not lead to a result with a great error; finally there are given limits for "telescope fine movements"). Because it is not possible to be sure about invariability of an object chosen as the standard comparison star (you can be the first human being to discover its variability), it is recommended to choose another standard star, the so-called **check**, and measure it during the observation approximately every 30 minutes. If you find that S_1 was not chosen well, you can use the check star instead of it during the reduction.

– It is needed to be prepared for every observation in advance. A good, high–quality **map** is needed for any observation. It must contain notations for all objects. Such a map can be, for example, produced by means of the code $STARCHART$ freely available in the INTERNET. The resolution of the map should be good enough for the observer to find all the objects which he can see through the pointer (or on the TV monitor). It is also useful to attach a very good photography of a given field with very faint objects in order for the observer to be able to choose the place where the sky can be measured. For this purpose a xerox copy from the Palomar photographic atlas (Dixon, Gearhart & Schmidtke, 1985) is suitable. You must enter all needed data

on photometer setting (e.g., voltage, diaphragm) and also the data on the observation (integration time, used filters, objects sequence).

- The observation can start only when the sky is dark enough and its brightness does not change dramatically. The **nautical twilight** (the Sun is 12 degrees below the horizon) is adequate in most cases for a photometric observation. Stars under standard weather conditions can be observed with good results in **heights > 30° over the horizon**. In lower heights, smog and dust in the Earth's atmosphere will spoil or even prevent a really good observation in most cases.

- As the brightness of the sky is not zero due to light scatter, you must perform a **sky measurement** before every object measurement. The sky should be measured close to the object at a place where no faint stars bringing their own light into the measurement are present. To choose such a place the above mentioned photography of the field is useful.

- You must begin and end the observation with the measurement of this comparison star S_1. If this condition is satisfied during reduction, just an interpolation will be used and there will be no need for any extrapolation. For example, a suitable **cycle** is: S_1 - CH - n×[S_1 - V - S_1 - V - S_1 - V - S_1 - CH] - S_1. The object's sky measurement must be done before the measurement of object itself, of course.

- At the end of the observation it is a good idea to describe the **night quality** and write down all **remarks** concerning the observation. This can be very useful for you when trying to understand older observations in the future.

- It is also useful to have an **observation diary/journal**. At least the following entries should be present there: date, observed variable star, observer, used filters, voltage, diaphragm, the exact time of observation (the time of the first and last integration, optionally observer's remarks. Systematic **archiving** deserves your attention as well.

- The simplest and non-confusing thing is to use **GMT** (Greenwich Mean Time) for your observations. The code UNIV requires to set this time in your computer. If you use GMT strictly in all data you will have no problems in the future with trying to find out what time was used.

2.5. Output file of the code UNIV

The output from the UNIV code contains all data measured during the observation and needed for further reduction.

The **name of the output file** follows a convention which allows a fast orientation concerning the observation. The DOS operating system has some file-naming restrictions: the name of a file can be just 8 characters long plus

3 characters for extension. For this reason we choose for the first `n` (`0 < n ≤ 5`) characters of the file-name the observation identification (best is to use the variable star's name), e.g. `txuma`. The rest is appended automatically by the code UNIV following the rules: in the (`n+1`)-th position there is the code of the observatory (H = Hlohovec, K = Kryonerion, R = Roztoky, S = Skalnaté Pleso, G = Stará Lesná); in the (`n+2`)-th and (`n+3`)-th positions is the day of the month (as the actual date always the **"evening"** date is taken, even if the observation started after midnight); in the 1-st position in extension there is the code for the month: (`1–9` for January–September, `O` - October, `N` - November, `D` - December); the 2-nd and 3-rd positions in extension denote the year. For example, the output file name `txumas04.O96` means that it was the observation of TX UMa at SP Observatory in the night 4/5 October 1996. Following these rules the name of the output file is generated by the UNIV code.

First, we will show an example of an output file:

```
"STAR NAME:","tx uma","DISKETTE:","sp"
"INT.TIME [S]:","10","OBSERVERS:","ko"
"DATE:","4","-","10"
"-","1996","JULIAN DATE:",2450360.500000
"TEMPERATURE, HUMIDITY, SEEING: ","4","70","7"
"OBJECT:","TIME:","FILTER:","COUNTS:"
" 0"," 17:42:12"," 4"," 8516"
" 0"," 17:42:24"," 6"," 4850"
" 1"," 17:42:58"," 4"," 554489"
" 1"," 17:43:10"," 6"," 147196"
" 0"," 17:48:39"," 4"," 8785"
" 0"," 17:48:51"," 6"," 4803"
" 4"," 17:49:23"," 4"," 629356"
" 4"," 17:49:35"," 6"," 165624"
   .
   .
   .
" 0"," 18:49:20"," 4"," 9233"
" 0"," 18:49:31"," 6"," 5002"
" 1"," 18:50:03"," 4"," 528666"
" 1"," 18:50:15"," 6"," 132046"
# NIGHT QUALITY FLAG: 2 (1=excellent 2=good 3=variable 4=poor 5=unusable)
# NIGHT QUALITY REMARK: night was good, but the seeing is bad
# NIGHT QUALITY REMARK: great scintillation
```

The file consists of 3 parts: the header (first 6 lines), the body with observational data themselves and remarks at the end of the file.

The **header** of an output file is described already in Section 2.3.1. The **body** of an output file consists of 4 columns which store the measured data. In the **first column** there is the object code following convention described in Section 2.3.1, let us recall: 4 - variable star, 1 - comparison star, 3 - check,

2 and 5 – 99 - optional other standard stars. The code 0 denotes the sky; it must be emphasized that it is the sky for the following measured object (from the example given above the first and second lines of the body contain the measurements of the sky of the comparison star S_1, while the fifth and sixth lines contain the measurement of the sky of the variable star V.

The **second column** contains the time of the middle of integration in GMT: hours, minutes, seconds. In the **third column** there is the position of a used filter in the photometer (see Section 2.3.2). The **fourth column** contains pulses measured by the photometer during the integration time (this value is proportional to the energy from a light source falling onto a photocathode of a photo-multiplier if the dead time is zero).

The **remarks** at the end of the output file (the last 3 lines in the example given above) may have an arbitrary number of lines. Each of these lines begins with the sign # (hash). In the first line there is the code (range 1–5) for the night quality. The subsequent lines may contain all important facts which occurred during the observation. An observer enters them at the end of the observation of a given variable star.

2.6. Running the UNIV code

Controlling the UNIV code should be intuitively clear. It can communicate in English or Slovak language. The possible answers to its questions are in brackets, e.g.: `Is this setting correct? [Y/n] =>` . Here you have the possibility of answering "yes" by entering `Y` (or `y`) or "no" by entering `N` (or `n`). The capital letter in the bracket means an implicit value (in this case it is `Y`). If you simply hit `ENTER`, the implicit answer will be used (in this case "yes").

After starting the UNIV code the initial screen is displayed for a few seconds with the information about the authors and the **UNIV version**. An initial dialog follows. You must enter the **name of the variable star** which is to be observed. You must enter the name which appears as the object identification in the file KATALOG (see Section 2.3.1), e.g. `tx uma`. The next question is the **"evening" date**. The third question asks you to set the observers' codes. These codes are signs which you use for observers. The code accepts maximally 10 characters.

The **integration time** is accepted within the range of 2 - 254 seconds and it must be an even number. This is the time how long a single integration (one measurement of a given object in one filter) will take. This time is the same for all measurements and cannot be changed: the sky, standard stars and variable star measurements must be done with the same integration time. At the Stellar Department of the Astronomical Institute at Tatranská Lomnica in most cases 10 second integration time is used. If you find during the observation that a wrong integration time was chosen (e.g. there is a bad signal-to-noise ratio), you must finish the actual measurement and start a new one with a new "good" integration time setting in the initial dialog. Following questions on **temper-**

ature, **humidity** and **seeing** have just an informational meaning. You must enter a **directory** where the **output file** will be placed and first maximally 5 characters from the name of the output file (see Section 2.5 regarding the output file naming convention). The code again offers you default answers. Existence of the directory and non-existence of the file with the same name as the output file (not to overwrite it) is checked. If the file exists the code asks you again to enter new values for the directory and name of the output file. At the end of this first screen the code asks if all questions were answered correctly. If not, the initial dialog starts again and you can enter the correct values.

The next step is the **GMT setting** (see Section 2.4). This must be entered as precisely as possible: this is an astronomical observation!

The following screen allows you to enter the required **sequence of filters**. To be provided with all possibilities (all filters you have currently in your photometer), the configuration file OBSERVAT.?? (see Section 2.3.2) must be properly written. Enter all filters you want to use, e.g. U–B–V.

Next is to enter the required **sequence of stars** (objects) you want to measure during the observation. This cycle will be re-started (repeated) when finished. Following the rules in Section 2.4, let us suppose you enter the following cycle: S_1–S_2–CH–S_1–V–S_1–V (at the end of observation it is needed to measure S_1). Next you must set the **number of measurements of the sky of standard stars** (all stars except for the variable): let us answer 1; **number of measurements of standard stars**: let us answer 1; **number of measurements of the sky of the variable star**: let us answer 1; **number of measurements of the variable star**: let us answer 2. To understand the questions and answers from the last two screens, here is the scheme of the observation following the request from the given example. The order of individual integrations will be:

OS_1^U - OS_1^B - OS_1^V - S_1^U - S_1^B - S_1^V - OS_2^U - OS_2^B - OS_2^V - S_2^U - S_2^B - S_2^V - OCH^U - OCH^B - OCH^V - CH^U - CH^B - CH^V - OS_1^U - OS_1^B - OS_1^V - S_1^U - S_1^B - S_1^V - OV^U - OV^B - OV^V - V^U - V^B - V^V - V^U - V^B - V^V - OS_1^U - OS_1^B - OS_1^V - S_1^U - S_1^B - S_1^V - OV^U - OV^B - OV^V - V^U - V^B - V^V - V^U - V^B - V^V The superscript stands for the filter used within the integration and "O" before the star sign means the sky measurement for that star.

After answering all these questions the code sets the filters into their home position, optionally sets the required diaphragm, tries to find the data about stars which are to be observed within a given star cycle in the configuration file KATALOG (Section 2.3.1). If this file does not exist, or there is no record in it about the given star, the code UNIV displays a warning; see Section 2.7.

After this, the screen with some information about the given settings appears. It also offers you the following possibilities within the **main menu**:

- by pressing the + key the code starts the measurement of the next object within a given sequence (star cycle). It asks you to position the telescope onto the required object, its sky (if the number of measurement of skies is

not set to zero) and, after the sky onto the star itself. If there were previous measurements of this object within this observation, the code displays the information about the last measured values in all filters and the number of measurements done so far. If you press "+", the actual integration begins. It will be performed in all filters given in a filter cycle and it will be repeated as many times as it was the number of measurements for the actual object set. The measured values are displayed in a simple table on the screen. Pressing the "-" key, you can reject the measured values and following the subsequent answer to repeat the measurement (this is useful if the object position in the diaphragm was not good), or you may go back to the main menu and perform the desired action. If the measured value differs from the previous one by the amount greater than 10%, the measured value is displayed blinking. After finishing the measurement in all filters you can decide whether to repeat such a measurement (default) or to accept it. The mentioned 10% is just a conventional value.

– the **I** key brings you to the Info-screen. At first you must choose the star. Then the screen with information appears. In addition to the number of measurement done so far, last values of measurements of the star itself and its sky in all filters, you can also find further helpful information: actual declination, hour angle (both in real time) so that you may use it for **positioning the telescope** on a given object. The phase (if the star is a periodic variable), air mass, heliocentric JD, local sidereal time and other values are displayed as well.

– the **B** key causes a skip from the actual object within a given sequence of stars to its beginning.

– the **F** key allows you to enter a new filter cycle.

– the **C** key allows you to enter a new star cycle (sequence of objects).

– If the timing of your computer is not good, or for any other reason you must set the correct time again, use the key **T**.

– If you finished the observation of the given variable star and you want to start the observation of another variable star use the key **N**. The current observation comes to its end: the code asks about the night quality, allows you to enter your remarks (Section 2.5), optionally to print the measured values on a printer. After these tasks, the code starts again the initial dialog.

– If you want to finish the observation entirely, use the key **E**: the observation finishes: the code asks about the night quality, allows you to enter your remarks (Section 2.5), optionally you can print the measured values on a printer. The resident part of the code is being uninstalled, the code UNIV exits and you are set back to the DOS shell (operating system) from where the UNIV was initialized.

2.6.1. The UNIV code; the new implemented features

To simplify and fasten transitions between the objects, we intended to implement into the UNIV code automatic transition from the last measured object to the next object in a given object sequence. For this purpose fine movements of the telescope were equipped with stepper motors and the code will control them. At the beginning of the observation the observer have to set positions of objects "manually", following a finding chart. The code stores differences (the number of steps of the stepper motor) between the objects and during the following transition is able to switch from one object to another. However, the observer still retains the possibility of refining this "rough" positioning: the code will store the new position. This behavior (position corrections) is required due to various errors in telescope construction, refraction, backlash of stepper motors...

2.7. Error and warning messages of the UNIV code

During the run of the UNIV code some errors or warnings may appear. Error messages appear if the code cannot find some configuration files which are necessary for its work: the code stops after these errors. Warnings will not lead to code abortion as the code can go on, but some functions will not be available any more:

– ERRORS:

  – **FOT??.EXE file not found**. As it was explained in Section 2.2, the UNIV code needs its resident part to run. This resident part is stored in this file. Without it the code cannot communicate with the photometer so it stops with an error message. Following the instructions in Section 2.2 you must correctly install this file from the installation diskette.

  – **the configuration file OBSERVAT.?? not found** (Section 2.3.2). In this case the UNIV code cannot find the configuration of your photometer: the number and the order of filters. It stops with this error message. Following the instructions in Section 2.3.2 you must create and install (Section 2.2) this file.

  – **disk full**. The amount of free disk space for the UNIV code work is about 10 KB at least. This space is used to store output data (an output file). Moreover, during its run the code creates some temporary working files. For this reason it is reasonable to start the code from a directory on a disk with a sufficient amount of free space. If the disk becomes full during the observation, the code stops with this fatal error. The last temporary file remains in the working directory so it is possible to restore the last measurements which have not been written into the output file yet. Nevertheless it is recommended to have the file OBSERV.BAT in the batch (see Section 2.2), which starts the UNIV code. A part providing

the observer with the information about the amount of free disk space available in the working directory. If this error occurs, you must create a sufficient amount of free disk space on your disk and re-start the code UNIV.

– WARNINGS:

– **the configuration file KATALOG not found** (Section 2.3.1). In this case the code cannot find the information about any star from the given star cycle. This is the reason why when pressing the key "I" in the main menu (see Section 2.6), you cannot get any information regarding the star. Instead the warning reminding you of non-existence of the KATA-LOG file will be displayed. We strongly recommend that you create the file KATALOG (e.g., you may use the code KATIN.EXE: Section 2.8) and install it (Section 2.2), respectively, to check whether the KATALOG file is placed in the correct directory.

– **the star ... not found in the KATALOG file**: the situation similar to the previous one. Though the file KATALOG exists and is installed correctly (the UNIV code can find it), there is no record in the KATA-LOG file for a given requirement. For this reason the information screen (key "I" in the main menu: Section 2.6) for this particular star will be incomplete. It is recommended to enter the information about this star into the KATALOG file before the observation: you may use the code KATIN.EXE (Section 2.8), or an arbitrary editor as described in Section 2.3.1.

2.8. Auxiliary codes

The codes described in this part should facilitate your work with management of the configuration file KATALOG, controlling the photometer functionality, and in computing various astronomical data which make the observation planning easier. The reduction process of raw data is mentioned here:

– **KATIN.EXE** This code serves for simple entering the data about particular stars into the configuration file KATALOG (see Section 2.3.1). Besides entering new records it will allow you to delete bad records or to fix errors in records. The code tries to be self-explanatory.

– **DEMOFOT.EXE** This code was written as a simple front-end code to demonstrate controlling the photometer operation by means of a personal computer. It uses the resident part **FOT??.EXE** (see Section 2.2). It enables you to set the integration time and to perform a particular integration. It can remove the resident part from the computer memory as well. The code should be used for quick checking of the correct photometer functionality and its communication with the computer.

– **MINF.EXE** This code basically computes the **observability of a star**. To get the information about a star (coordinates, etc.) it uses the configuration file KATALOG (Section 2.3.1). It computes the times of twilights; times of the setting and rise for a particular star (to be more precise: when the star's height above the horizon is greater than a given value); the phases of periodic variables; times of minimum; culmination time; etc. Many parameters can be modified when the code starts (e.g., the latitude, the longitude, the "height" (better to say "depth") of the Sun for twilight timings; the height above the horizon for times of star "setting" and "rise" computations). The output of this code should enable you to plan your observations in an optimal and effective way, indeed.

– **SPHEL.EXE** The output of this code contains almost all astronomical data on a particular star in a given time: local sidereal time, actual right ascension, declination, height above the horizon, zenith distance, hour angle, air mass, heliocentric Julian date, heliocentric and barycentric corrections of time and radial velocities, optionally the phase and epoch if the star is a periodic variable. This code uses the configuration file KATALOG (Section 2.3.1) as well, and the geographic location of the observatory can be modified when the code starts.

– **the reduction codes package for raw photometric data reduction** Explaining the whole process of raw photometric data (e.g. obtained via the UNIV code) reduction is beyond the scope of this document. This reduction package can be obtained upon request from the Stellar Department of the Astronomical Institute at Tatranská Lomnica. The output of the reduction contains the data usable in astronomy: heliocentric observation time, magnitudes (they can be instrumental or Johnson's international UBV ones) and further helpful information. By means of this package it is possible to compute the first order extinction coefficients. If you average these values over a particular time period (a season), you can get seasonal extinction coefficients mentioned in Section 2.3.2. By reducing the observations of UBV standard stars (see Paper I) you can compute the transformation coefficients into Johnson's international UBV system (see Section 2.3.2). Many configuration files (some of them mentioned in Section 2.3) are used by the reduction codes package as well.

3. Conclusion

This article descibes the user software UNIV used for data obtained with photoelectric photometry at SP and SL observatories. The main goal of the presented paper was to conclude our long-term experience with PEP. The part about fast photometry including examples of our results will be published in Vaňko *et al.*,

(2015). This paper, together with Paper I, could be also used as a manual for other observers using photoelectric photometry.

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