THE SOUTHERN VILNIUS PHOTOMETRIC SYSTEM.
IV. THE E REGION STANDARD STARS

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1. INTRODUCTION

In the paper by Forbes, Dodd & Sullivan (1993), hereafter referred to as Paper I, measurements of the equatorial stars, already observed in the northern hemisphere Vilnius system, were made using Carter Observatory’s set of filters. It was concluded that these could be accurately transformed to the standard Vilnius system and so a program to establish a set of Vilnius standard stars in the southern hemisphere was begun.

The first results of this program are given by Forbes, Dodd & Sullivan (1994), hereafter Paper II, listing a set of bright standard stars spread across the southern sky. To extend the standards to fainter stars it was decided to measure the Harvard E Region stars, which have already been established as standards in other photometric systems (e.g. Menzies et al. 1989). The Harvard E Regions consist of nine groups which contain approximately sixty stars each, ranging from $V = 3$ to 12, centred near $\delta \approx -45^\circ$ and spaced 2 – 3 hours apart in right ascension. Some measurements of the Harvard E and F Region stars are given by Zdanavičius, Dodd, Forbes & Sullivan (1995), hereafter Paper III.

2. OBSERVATIONS AND REDUCTIONS

The observations were made at the Mt. John University Observatory (University of Canterbury), situated near Lake Tekapo in the South Island of New Zealand, over the period 1992 to 1993. A set of stars previously measured in the Vilnius system (North 1980), which are observable from the southern hemisphere, were selected.
as primary standards, to enable transformation of the local Vilnius filter system to the standard system. Measurements of the primary standard stars were interspersed with those of the southern standard stars. Certain southern standard stars were used as extinction stars. These were selected from F5–G2 V spectral type stars with $\delta \approx -45^\circ$ and measured every hour, using a variation of Nikonov’s method (Nikonov 1953, Straičys 1992). More details on the observing and reduction procedures are given in Paper I.

To date, 96 stars have been observed as possible standard stars. The following criteria were applied to select the stars that have been measured to acceptable precision and accuracy. First, the star must have been measured on at least three different nights, enabling a mean value and standard deviation to be calculated. Next, the standard deviation of the mean for the $V$ magnitude and colors of the star must be less than 0.02 mag. The only exception was the color $U - P$, whose rejection threshold was relaxed to 0.025 mag. The slightly larger errors in the $U$ filter observations imply that longer integration times are required for measurements using that filter. Finally, using either the ‘stellar box’ or $Q(\lambda)$ pseudo-spectrum methods (Straičys 1992), the measurements must enable a star to be classified within two sub-classes and within one class of its MK spectral and luminosity classes, respectively. This left 60 stars suitable for use as standards, with most of the rejections due to an insufficient number of observations per star. The rejected stars remain in the observing program, to see if further observations will enable them to meet the standard star criteria.

3. CATALOG

Table 1 lists the observations of the 60 E region standard stars measured in the southern Vilnius photometric system. The first column is the star name as given by Menzies (1989). The next two columns are the Epoch 2000 equatorial coordinates. These are followed by the Vilnius $V$ magnitude and the six color indices. A colon following the measurement indicates that the standard deviation of the mean exceeds 0.015 mag; a double colon means the standard deviation is greater than 0.02 mag. The number of observations ($n$) of each star is given in the next column. The final two columns give the spectral type as listed by Menzies et al. (1989) and classified from the photometric color indices by K. Zdanavičius. Close
binaries were not classified photometrically since their color indices belong to common light of the two components.

4. DISCUSSION

The overall accuracy and the precision of the observations can be seen in Table 2. This shows the standard deviation $\varepsilon$ of each color calculated using

$$
\varepsilon = \frac{\sigma}{\sqrt{\sum \frac{n}{N}}}
$$

where $\sigma$ is the typical standard deviation of a single observation for the southern system, $n$ is the number of observations of a star and $N$ is the number of observed stars. The accuracy required for establishing a set of standard stars, i.e. 0.01 mag, has clearly been achieved.

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Table 1. Catalog of standard stars in the southern Vilnius photometric system (E regions)

| Star | α(2000) | δ(2000) | V | U−P | P−X | X−Y | Y−Z | Z−V | V−S | n | Sp |
|------|----------|----------|----|------|-----|-----|-----|-----|-----|----|----|
| E136 | 01h19m07s | −45°32′ | 5.05 | 0.49 | 0.61 | 0.76 | 0.32 | 0.20 | 0.51 | 43 | G0 V F9.5 IV |
| E345* | 06 25 43 | −48 11 | 5.78; 0.55; 0.68 | 0.23 | 0.10 | 0.04 | 0.12 | 5 | B9 V |
| E347 | 06 49 54 | −46 37 | 5.12; 0.47; 0.58 | 0.63 | 0.29 | 0.18 | 0.45 | 4 | F5 V F5 V |
| E428 | 09 30 33 | −45 34 | 6.60; 0.64; 1.16 | 1.54 | 0.49 | 0.39 | 0.82 | 8 | K2-3 III K2 III |
| E429 | 09 20 15 | −45 10 | 6.67; 0.66; 1.21 | 1.61 | 0.49 | 0.41 | 0.84 | 8 | K2 III K2 III |
| E439 | 09 12 14 | −45 50 | 6.66; 0.56 | 0.59 | 0.60 | 0.28 | 0.17 | 0.45 | 32 | F3-5 V F3 V |
| E444* | 09 15 14 | −45 33 | 6.27; 0.49 | 0.61 | 0.20 | 0.10 | 0.05 | 0.15 | 8 | B8 V |
| E445 | 09 22 24 | −46 03 | 5.74; 0.57; 0.89 | 1.14 | 0.44 | 0.27 | 0.67 | 8 | G6-8 III G7 III |
| E446 | 09 31 19 | −47 57 | 6.56; 0.53; 0.73 | 0.50 | 0.20 | 0.12 | 0.30 | 8 | A9 IV-V A9 V |
| E447 | 09 38 01 | −43 11 | 5.51; 0.54; 0.88 | 1.25 | 0.47 | 0.29 | 0.69 | 8 | G8 II G8.5 III |
| E478 | 09 14 08 | −44 09 | 5.88; 0.27; 0.45 | 0.17 | 0.08 | 0.03 | 0.10 | 8 | B5 V B6 V |
| E479* | 09 14 24 | −43 14 | 5.27; 0.25; 0.39 | 0.16 | 0.07 | 0.03 | 0.10 | 8 | B3-5 V |
| E493 | 09 11 33 | −46 35 | 5.82; 0.10; 0.19 | 0.11 | 0.05 | 0.01 | 0.06 | 8 | B2 III-IV B1.5 V |
| E494 | 09 13 34 | −47 20 | 5.95; 0.55; 0.73 | 0.25 | 0.10 | 0.04 | 0.14 | 6 | B9 V B9.5 V |
| E496 | 09 16 58 | −45 01 | 6.78; 0.57; 0.81 | 0.29 | 0.11 | 0.05 | 0.13 | 6 | A0 V A0.5 V |
| E497 | 09 23 25 | −48 17 | 6.32; 0.27; 0.35 | 0.16 | 0.08 | 0.03 | 0.11 | 6 | B3 IV B4 IV |
| E498 | 09 23 39 | −46 55 | 6.26; 0.43; 0.51 | 0.19 | 0.09 | 0.04 | 0.13 | 6 | B7 III B7 V |
| E540 | 12 03 38 | −42 26 | 5.17; 0.52 | 0.58 | 0.60 | 0.27 | 0.16 | 0.43 | 52 | F5 V F4 V |
| E612 | 14 56 14 | −44 05 | 7.92; 0.61 | 0.83 | 0.45 | 0.17 | 0.10 | 0.21 | 4 | A3 IV A5 V |
| E613 | 14 55 25 | −44 20 | 8.02; 0.67 | 0.81 | 0.49 | 0.19 | 0.12 | 0.26 | 4 | A4 V A5.5 IV |
| E614 | 14 53 04 | −43 44 | 8.16; 0.66 | 0.81 | 0.49 | 0.20 | 0.13 | 0.29 | 4 | A5 V A6.5 IV |
| E633 | 14 38 12 | −45 52 | 6.90; 0.64; 1.18 | 1.52 | 0.48 | 0.38 | 0.82 | 4 | K2 III K2 III |
| E639* | 14 30 08 | −45 19 | 5.51 | 0.53 | 0.60 | 0.20 | 0.10 | 0.04 | 0.15 | 6 | B8 V |
| E640 | 14 36 18 | −46 15 | 5.58; 0.76 | 1.34 | 1.93 | 0.59 | 0.49 | 0.99 | 14 | K3 III K3.5 III |
| E641 | 14 39 11 | −46 35 | 6.11; 0.51 | 0.58 | 0.69 | 0.30 | 0.19 | 0.48 | 7 | F6 V F7 V |
| E642* | 14 45 57 | −44 52 | 6.95; 0.56 | 0.79 | 0.32 | 0.14 | 0.07 | 0.15 | 5 | A0 V A0 V |
| E643 | 14 46 28 | −47 26 | 5.77; 0.61 | 0.83 | 0.36 | 0.14 | 0.06 | 0.16 | 7 | A1 V A1.5 V |
| E644 | 14 47 31 | −43 33 | 6.34; 0.63 | 1.00 | 1.32 | 0.49 | 0.32 | 0.76 | 17 | G8 III G9.5 III |
Table 1 (continued)

| Star   | α(2000)      | δ(2000)      | V   | U–P | P–X | X–Y | Y–Z | Z–V | V–S | n  | Sp  |
|--------|--------------|--------------|-----|-----|-----|-----|-----|-----|-----|----|-----|
| E645   | 14^h 56^m 24^s | -44° 42'     | 6.77 0.62 0.83 0.35 0.13 0.07 0.15 35 A1 V   | A1.5 V |
| E646*  | 14 59 18     | -43 28       | 7.08 0.56 0.66 0.57 0.24 0.16 0.38 4 F2 III  |
| E647   | 14 59 45     | -43 49       | 6.60 0.49 0.55 0.66 0.29 0.18 0.46 65 F7 IV-V | F5 V   |
| E679*  | 14 26 10     | -45 23       | 4.38 0.72 0.81 0.57 0.27 0.17 0.46 9 F7      |
| E680   | 14 27 12     | -46 08       | 5.85 0.62 0.76 0.58 0.21 0.14 0.32 9 A1m V    | A6 V   |
| E681*  | 14 28 51     | -47 59       | 6.41 0.43 0.53 0.19 0.08 0.05 0.11 8 ApSi     |
| E682   | 14 35 09     | -46 28       | 6.92 0.68 0.68 0.23 0.13 0.06 0.16 8 B9 V     | B9 III |
| E684   | 14 35 49     | -46 49       | 6.82 0.61 0.89 1.18 0.46 0.29 0.71 8 G8 III   | G7 III |
| E687   | 14 37 54     | -48 01       | 6.66 0.53 0.58 0.22 0.13 0.06 0.17 4 B8 V     | B8 III IV |
| E688*  | 14 40 18     | -45 48       | 6.64 0.42: 0.51 0.20 0.04 0.07 0.15 3 ApSi    |
| E690   | 14 50 58     | -42 49       | 6.84 0.65 0.84 0.43 0.15 0.09 0.21 4 A2 V     | A4 V   |
| E691*  | 14 51 37     | -43 34       | 4.34 0.28 0.33 0.15 0.07 0.04 0.10 8 B5 IV    |
| E695   | 14 59 26     | -43 10       | 6.14 0.74 0.72 0.78 0.32 0.22 0.54 6 F7 II    | F7 II  |
| E6100  | 14 54 00     | -43 36       | 8.23 0.59: 0.91 1.30 0.48 0.31 0.73 4 G8 II   | G9 III |
| E748   | 17 24 43     | -45 01       | 6.70 0.54 0.60 0.58 0.26 0.15 0.40 95 F3 V    | F2.5 V |
| E765   | 17 37 53     | -42 34       | 7.22 0.48 0.65 0.83 0.34 0.22 0.56 55 G2-3 V  | G2 IV-V |
| E869   | 19 55 15     | -41 52       | 4.14:0.62 1.00 1.35 0.47 0.34 0.76 4 K0 II-III | K0 III |
| E924   | 22 32 11     | -43 16       | 6.99 0.59 0.95 1.23 0.45 0.29 0.72 6 K0 III   | G9.5 III |
| E929   | 22 33 54     | -44 41       | 6.87 0.58 0.87 1.16 0.45 0.28 0.71 7 G8 III   | G6 III |
| E930   | 22 53 15     | -45 09       | 6.93 0.63 1.11 1.42 0.49 0.34 0.78 7 K0 III   | K0.5 III |
| E940   | 22 30 43     | -44 06       | 7.00 0.62 0.84 0.37 0.14 0.07 0.15 5 A0-1 V   | A2 V   |
| E942   | 22 36 41     | -43 28       | 6.81 0.52 0.57 0.70 0.31 0.20 0.49 37 F8 V    | F6 V   |
| E943   | 22 42 43     | -44 15       | 6.15 0.58 0.90 1.19 0.45 0.29 0.71 7 K0 III   | G8 III |
| E944   | 22 45 41     | -46 33       | 5.60 0.69 1.23 1.71 0.55 0.41 0.89 7 K2 III   | K2.5 III |
| E948   | 22 30 15     | -42 17       | 6.99 0.57 0.74 0.25 0.11 0.04 0.11 7 B9.5 V   | B9.5 V |
| E949   | 22 47 09     | -41 42       | 6.92 0.67 1.22 1.66 0.53 0.41 0.88 6 K2 III   | K2.5 III |
| E963*  | 22 42 37     | -47 12       | 6.05 0.49 0.59 0.74 0.32 0.20 0.53 4 G0 V     |

The Southern Vilnius Photometric System. IV.
Table 1 (continued)

| Star   | α(2000)   | δ(2000)   | V   | U–P | P–X | X–Y | Y–Z | Z–V | V–S | n     | Sp   |
|--------|------------|------------|-----|-----|-----|-----|-----|-----|-----|-------|------|
| E971   | 22°15′35″  | −44°27′6.18 | 0.62| 0.94| 1.26| 0.48| 0.30| 0.73| 6    | G8-K0 III | G8.5 III |
| E972   | 22 23 07   | −45 56 5.69 | 0.56| 0.63| 0.57| 0.25| 0.15| 0.40| 6    | F0 V | F1.5 V |
| E973   | 22 23 25   | −46 40 6.96 | 0.65| 0.83| 0.36| 0.13| 0.08| 0.16| 4    | A1 V | A1.5 V |
| E979   | 22 43 30   | −41 25 4.91 | 0.61| 0.97| 1.26| 0.47| 0.31| 0.74| 5    | K0 III | G9.5 III |

Notes (from Menzies 1989):
- E345 – double, 6.0 + 8.3, 1.5″
- E411 – double, 6.6 + 7.7, 1″
- E479 – double, 5.2 + 9.6, 6″
- E639 – companion approx 8″ NW
- E642 – double, 7.3 + 12.0, 35″, companion not included
- E646 – double, 7.2 + 11.2, 4″
- E679 – double, 5.2 + 5.3, 0.3″, cpm
- E681 – companion 8″ NW
- E688 – companion approx 8″ W
- E691 – double, 0.1″
- E963 – double, 6.4 + 9.8, 8″, cpm

Table 2. Summary of precision of the Vilnius southern standard stars.

|       | V   | U–P | P–X | X–Y | Y–Z | Z–V | V–S |
|-------|-----|-----|-----|-----|-----|-----|-----|
|       | 0.008| 0.008| 0.005| 0.004| 0.004| 0.004| 0.005|

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