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STANDARD STARS FOR THE HIGH-VELOCITY AND METAL-POOR PROJECT AT SAN PEDRO MÁRTIR

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RESUMEN

Presentamos la documentación principal de las estrellas estándares primarias y secundarias empleadas en el proyecto de observación de estrellas de alta velocidad y baja metalicidad. Los datos observacionales fueron obtenidos con el fotómetro de seis canales en el sistema de Strömgren-Crawford, *uvby*–Hβ, utilizando el telescopio de 1.5-m, H.L. Johnson, en el Observatorio Astronómico Nacional, San Pedro Mártir entre 1987 y 2007. Se reportan los valores fotométricos estándares de la literatura, así como los valores estándares transformados, los errores en el sistema instrumental, los coeficientes de transformación obtenidos en el sistema estándar, los errores en la transformación, así como la metodología con las que se realizaron dichas observaciones y transformaciones al sistema estándar.

ABSTRACT

The main documentation for the primary and secondary standard stars used in the high-velocity and metal-poor stars project is presented. Observations were taken using the Strömgren-Crawford, *uvby*–Hβ, 6-channel, spectrophotometric equipment with the H.L. Johnson 1.5-m telescope at the Observatorio Astronómico Nacional, San Pedro Mártir, between 1987 and 2007. Standard photometric values from the literature are reported for our standard stars, as well as transformed standard values, errors in the instrumental system, the transformation coefficients obtained for the standard system, the transformation errors, and the methods used to obtain such photometric observations and their standard transformations.

Key Words: catalogues — instrumentation: photometers — methods: observational — stars: Population II — subdwarfs — techniques: photometric

1. INTRODUCTION

Beginning in 1878 at the Chapultepec Hill in Mexico City, the Observatorio Astronómico Nacional (hereafter OAN) has been moved to several different sites, finally to be located at the San Pedro Mártir (SPM) Sierra in the 1970s. This final location possesses ideal physical and geographical conditions that have led to its classification as one of the five best sites in the world for optical astronomical observations. The mountains where the observatory is located have an approximate altitude of 2850 m and are surrounded by deserts, providing a dry atmosphere. The pine forest in the mountain gives a natural protection against wind erosion and dust from the deserts leaving a clear sky with low atmospheric extinction (Schuster & Parrao 2001; Parrao & Schuster 2003; Schuster, Parrao, & Guichard 2002), excellent seeing (Michel et al. 2003a; Tapia et al. 2007; Sanchez et al. 2012), and a small temperature variation throughout the nights (Tapia 2003; Michel et al. 2003b). These atmospheric conditions allow astronomers to obtain very high-quality photometric instrumental observations. Also, given its position on top of a ridge, it is possible to observe in any direction without obstruction and to follow objects in the sky for eight or more continuous hours (Schuster, Parrao, & Guichard 2002) with minimal interference from the surrounding pine trees. All these conditions make the OAN-SPM an excellent site for optical astronomical observations. Many characteristics of this site are discussed in Volumes 19 and 31

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In particular, the OAN-SPM has become an important site for photometric studies. The broadband $UBVRI$ (Iriarte et al. 1965) and narrow-intermediate-band 13-color (Johnson & Mitchell 1975) systems were the first to be used at the observatory. Since 1983, with the arrival of the Danish spectrophotometer, astronomers have been able to carry out alternative intermediate-band photometric observations. The 6-channel Danish photometer possesses six non-refrigerated photomultipliers with four continuum filters (u, v, b, and y) and two line filters (Hβ, narrow (N) and wide (W)) in the Strömgren-Crawford system. This system was defined by Strömgren and Crawford in a series of papers (Strömgren 1951, 1954, 1955, 1958, 1963, 1966; Crawford & Mander 1966; Crawford et al. 1966; Crawford & Barnes 1970) that focused mainly on the study of spectral classification for F-type stars but were also applicable to B, A, G, and K stars. Strömgren's analysis consisted of the classification of his sample of 110 stars by temperature, luminosity class, metallicity, and stellar population using spectrophotometric features like the Balmer discontinuity and line blanketing. In this way, Strömgren developed a quantitative photometric system for spectral classification closely related to the spectral features of stars and the filter band-widths. With these filters, Strömgren defined a set of three color indices: $(b-y)$, measuring the continuum slope and therefore the stellar temperature; c_1 which measures the Balmer discontinuity, giving information concerning the stellar surface gravities and absolute magnitudes, defined as

$$c_1 = (u-v) - (v-b), \tag{1}$$

and m_1 related to the stellar metallicity via the effects of line blanketing, and defined as

$$m_1 = (v-b) - (b-y). \tag{2}$$

Reproductions of the original photometers or spectrophotometers with very similar filters and detectors were installed at various observatories, such as the La Silla Observatory in Chile, the Kitt Peak National Observatory in the USA, and the OAN-SPM in Mexico, among others. Since it is very hard to construct filters having exactly the same widths and central wavelengths, or photomultipliers (PMTs) with exactly the same photocathode response, it became very important to have an extensive list of standard stars observed by Strömgren and coworkers. They compiled a set of ≈ 1200 stars homogeneously observed (Strömgren & Perry 1965) from which they selected a subset of 122 stars used as standard stars for the $uvby$ and Hβ systems. The first set of standard stars for the $uvby$ filters was published by Crawford & Barnes (1970). This list was extended by Crawford et al. (1971a,b) to cover stars with $V < 6\overset{\mathrm{m}}{.}5$ leaving a set of 315 standard stars. Both sets of stars were joined to the data of 80 standard stars for the Hβ filters presented by Crawford & Mander (1966), becoming the original list of primary standard stars for the $uvby$–Hβ system. Later, this list was extended by Grønbech et al. (1976) to F-type stars, with a set of 27 late-F and early-G, and by Perry et al. (1987) with 366 bright stars. All these extensions conform a set of secondary standard stars. In this way, with a large set of primary and secondary standard stars, the Strömgren system has become the very homogeneous, consistent, and easy to reproduce photometric system that is widely used today.

In 1973, Lindemann & Hauck (1973) collected the measurements for various photometric systems existing at the time, in particular, those made on the $uvby$–Hβ system were included. They compiled a set of 7603 stars at the Centre de Données Stellaires de Strasbourg (CDS). All data recorded by Lindemann & Hauck were homogenized using the lists of Crawford & Mander (1966); Crawford & Barnes (1970), and Crawford et al. (1971a,b) as reference.

Unfortunately, not all standard stars are constant over time, introducing a source of error in the reproduction of the original system, and here lies the importance of compiling standard-star data for as long a time interval as possible. In 1983 and 1993, Olsen (1983, 1993) published all of his standard star observations made for establishing his photometric catalogues, according to the suggestion of Lindemann & Hauck (1973). The documentation of the standard stars used for various projects and catalogues is necessary for the inclusion of any photometric data into the homogenized data sets, such as that of the CDS.

Since the 1980's $uvby$–Hβ observations have been carried out at the SPM observatory with the 1.5m telescope and the Danish six-channel spectrophotometer. These observations have provided the fundamental data sets for various astronomical programs like the study of high-velocity and metal-poor stars (hereafter HVMPS) (catalogues: Schuster & Nissen 1988; Schuster, Parrao, & Contreras 1993; Schuster et al. 2006), very-metal poor stars (VMPS) (catalogues: Schuster et al. 1996, 2004), stars at the North Galactic Pole (NGP) (Croswell et al. 1991), a Seyfert galaxy (Dultzin-Hacyan, D. et al. 1992), and extinction observations to determine an average atmospheric extinction curve for the OAN-SPM (Schuster & Parrao 2001; Schuster, Parrao, & Guichard 2002; Parrao & Schuster 2003). In all these programs, standard stars have been observed and used to obtain transformation coefficients from the instrumental system to the standard Strömgren system. In the case of the OAN-SPM, the Strömgren system is defined by the slots and filters described in Nissen (1984) and Gutiérrez et al. (2004). The original photomultipliers of this Danish photometer have been replaced occasionally, but all the corresponding photocathodes have been bialkaline with very similar response curves.

In this work, documentation of *uvby*–Hβ observations carried out over a time interval of approximately 20 years, from September 1987 to November 2007, is presented. These data might be included in the homogenized data bases compiled at the CDS, and information useful for this purpose is provided. The main documentation of the primary and secondary standard stars used in the HVMPS and VMPS projects is presented, such as their standard photometric values, taken from the literature at the beginning of these projects, as well as their transformed standard values, and in addition the errors in the instrumental system, the transformation coefficients obtained for the standard system, the transformation errors, and the methods used to obtain such observations and transformations. Further details concerning the methodologies have been given in the works of Schuster & Nissen (1988); Schuster, Parrao, & Contreras (1993); Schuster & Parrao (2001); Schuster, Parrao, & Guichard (2002); Parrao & Schuster (2003), and Schuster et al. (2006).

2. TECHNIQUES

Observations of HVMPS in the Strömgren–Crawford photometric system have been carried out at the OAN-SPM for more than 20 years, since March of 1984. In particular, photometric data observations of 33 observing runs from September 1987 to November 2007 are documented here. In the following sections the observing and reduction techniques used during all of these runs are described. It is worth emphasizing the consistency of the observing and reduction methods followed during all these runs, making this data set a very homogeneous set of photometric observations with reliable transformations to the original *uvby*–Hβ system. In general, the structuring of the observations and data reductions followed the precepts of Grønbech et al. (1976).

2.1. *Observing techniques*

In all 33 observing runs, the observing and reduction techniques as described in detail in a series of papers related to the study of HVMPS (Schuster & Nissen 1988; Schuster, Parrao, & Contreras 1993; Schuster et al. 1996, 2004, 2006), were followed. A brief description of such methods is presented here. Nearly all of the observations were obtained by one of us (W.J.S.) using the 1.5m telescope at the OAN-SPM. Whenever possible, identification charts were used at SPM due to the low pointing accuracy of the telescope. Photometric standard stars were carefully selected (see the following section for details). A six-channel "Danish" photometer was used. The four-channel *uvby* section is really a spectrograph-photometer which employs exit slots and optical interference filters to define the band-passes. At the beginning of each observing run the grating angle of the spectrograph was calibrated using a cadmium lamp, or using a supergiant star (only once), to position the spectra on the exit slots to within about ± 1Å (Nissen 1984; Gutiérrez et al. 2004; Schuster, Parrao, & Guichard 2002).

The centering of stars was done carefully and each observation consisted of at least three integrations of the star and at least one sky integration. Integration times ranged from 3 $\times$ 10 seconds for the brighter standard stars to 2N $\times$ 20 seconds for the fainter program stars, with "N" being an integer. Sky measures were usually made 1.0 to 1.5 arcmin north or south of the stellar position. For the "extinction" and "drift" stars (see below for their definition) a full observation usually consisted of three "star" integrations (both *uvby* and Hβ), "sky" integrations, then again three "star" integrations. At the largest air masses, for atmospheric extinction determinations (for *uvby* only), 9–12 "star" integrations, two "sky" integrations, then again 9–12 "star" integrations were performed. For the other standard stars a full observation was usually three "star" integrations (both *uvby* and Hβ), and then one "sky" integration for each section.

In general, some standard stars ("drift" stars) with declinations similar to the observatory's latitude ($20° \lesssim \delta \lesssim 55°$ for SPM with $\varphi \approx 31°$) were observed symmetrically, approximately 2^h east and 2^h west of the meridian to allow the calculation of possible linear (and quadratic) coefficients of the time terms in the night corrections (Grønbech et al. 1976). For determining the coefficients of atmospheric extinction, optimally, on most nights, a standard star pair near the celestial equator ($\delta \sim 0°$) was observed approximately 4^h and 2.5^h before and after the meridian, as well as on the meridian; at worst, for short nights, the extinction pair was observed only three times, either rising or setting. Since the central wavelengths of the narrow (N) and wide (W) filters are nearly identical, one expects the Hβ extinction coefficient to be zero to a high degree of approximation. Since extinction corrections are not needed for the Hβ filters, the pairs of extinction stars were observed only with the *uvby* filters at the largest air masses. Examples of extinction stars observed during many of our observing runs are presented in Table 1 of Parrao & Schuster (2003).

Approximately 15–25 standard stars (including the "extinction" and "drift" stars) were observed on all nights of an observing run to provide a consistent, connected instrumental photometric system for the data reductions of that run, while other standard stars were added progressively and observed on at least three nights each, to improve the photometric transformations; usually 35–50 standard stars were managed for each full observing run (see Tables 2, 3, and 4).

2.2. *Reduction techniques*

Reduction techniques for all these observing runs followed the precepts of Grønbech et al. (1976) using a computer program kindly loaned to us by T. Andersen. The reduction package contains two main parts: one which creates an instrumental photometric system using all nights of an observing run, and one which transforms this instrumental system to the standard system. Full description of the package and auxiliary codes as used in Mexico are described in Parrao, Schuster, & Arellano Ferro (1988). In every observing run we have assumed a linear time dependence of the night corrections and a constant atmospheric extinction throughout a night. Based on all our data reductions, these assumptions proved to be entirely adequate.

The equations for the transformation to the standard *uvby*–Hβ system are the linear ones of Crawford & Barnes (1970) and Crawford & Mander (1966) (Grønbech et al. 1976). In most of our observing runs (for the HVMPS and VMPS), the redder subgiants and giants, $(b\text{–}y) \gtrsim 0\overset{\text{m}}{.}50$ and $c_1 \gtrsim 0\overset{\text{m}}{.}35$, had to be removed from the standard list to maintain good results with the linear transformations. All of the dwarf and subdwarf stars and the early-type giants and subgiants transformed well together. For wider ranging projects (such as the NGP and a few observations of VMPS), transformation equations were separated with different criteria: $(b\text{–}y) \lesssim 0\overset{\text{m}}{.}40$ and $(b\text{–}y) \gtrsim 0\overset{\text{m}}{.}40$ to include bluer and redder stars, such as these red subgiants and giant stars, similar to Grønbech et al. (1976). Such a separation of the transformation equations was not needed for the HVMPS and (most of the) VMPS.

3. STANDARD STARS

Primary and secondary *uvby* standard stars were selected from the lists of Olsen (1983, 1984, 1993) which include the Crawford & Barnes (1970) list; secondary standards had to be used due to the brightness limits of this photometer (see below). We have checked that those objects reported as probable variable stars were not included. Mostly our standard stars for the different observing runs were selected according to the distributions in their colors and indices, $(b\text{–}y)$, m_1, c_1, and Hβ, as compared to the expected values for our F-, G-, and K-type high-velocity and metal-poor stars (see below). During the duration of this project four of the originally selected standard stars have appeared as definite variable stars in the SIMBAD data base, BS812 (δ Sct type variable star), HD80715 (BY Dra type), HD156026 (RS CVn type), and BS8799 (γ Dor type); these four have been removed from our photometric observations and data reductions. For the Hβ filters, standard stars were also taken from the list of Crawford & Mander (1966). The brightness limit for the *uvby* photometry was $V \gtrsim 6.0$, and $V \gtrsim 4.5$ for Hβ due to the differing sensitivities of these two sections in the 6-channel photometer. These limits also kept our count rates to less than about 300,000 c/s, and the dead-time corrections small, $\lesssim 0\overset{\text{m}}{.}025$. A few brighter stars with good Hβ photometry were selected from the above sources to extend the Hβ transformation to higher values, but finally those few with H$\beta \gtrsim 2.82$ were excluded from the observations and data reductions, since they introduced small non-linearities in the Hβ transformations. So, the Hβ standards: BS63, BS2857, BS4515, and BS8060 were not used in the final transformations to the standard Hβ system.

The list of 111 standard stars used in the HVMPS project is shown in Table 1. This table also contains the following two extensions: 16 stars used in the study of VMPS from the Schuster & Nissen (1988) catalogue, as well as 11 additional standard stars used in the NGP project (Croswell et al. 1991). Table 1 presents 2000.0 positions and the standard photometric values employed during our data reductions for all these stars, as well as comments concerning their use, or non-use, during these three projects. The variability types are given for the four stars,

TABLE 1

uvby-Hβ STANDARD STARS FOR THE OBSERVATION OF HIGH-VELOCITY AND METAL-POOR STARS (HVMPS)

	Name (HD/BS≡HR)	R.A.(2000.0) [h:m:s]	Dec (2000.0) [d:m:s]	V [mag]	$(b–y)$ [mag]	m_1 [mag]	c_1 [mag]	Hβ [mag]	Comments
1	BS9107	00:04:53.8	+34:39:35.3	6.120	0.412	0.170	0.317	2.592	
2	HD330	00:08:04.7	+53:47:46.5	8.151	0.384	0.162	0.383	2.597	
3	BS63	00:17:05.5	+38:40:53.9	4.619	0.026	0.180	1.050	2.879	bright, Hβ only, excluded
4	HD1828	00:22:43.2	−09:37:22.1	8.200	0.290	0.149	0.429	2.648	
5	HD2694	00:30:26.7	−15:54:55.0	8.156	0.323	0.143	0.383	2.625	
6	HD2796	00:31:16.9	−16:47:40.8	8.503	0.544	0.059	0.522	2.544	red subgiant; usually omitted
7	HD3621	00:38:50.3	−18:52:05.1	8.327	0.354	0.154	0.416	2.610	
8	HD3651A	00:39:21.8	+21:15:01.7	5.860	0.508	0.387	0.334	——	*uvby* only
9	HD6268	01:03:18.2	−27:52:50.0	8.116	0.602	0.075	0.533	2.525	red subgiant; usually omitted
10	HD6656	01:08:11.7	+55:09:20.8	7.601	0.272	0.109	0.499	2.656	
11	HD6834	01:09:35.3	+39:46:51.8	8.417	0.302	0.106	0.399	2.629	
12	HD7895A	01:18:41.1	−00:52:03.2	8.002	0.482	0.329	0.303	——	*uvby* only
13	HD8786	01:27:14.3	+39:39:15.7	7.907	0.306	0.130	0.418	2.638	
14	HD9023A	01:29:27.7	+30:53:40.3	7.981	0.344	0.157	0.441	2.629	
15	HD9595	01:34:07.6	+02:26:46.7	8.902	0.403	0.183	0.408	2.609	
16	HD10476A	01:42:29.8	+20:16:06.6	5.240	0.493	0.373	0.300	——	*uvby* only
17	HD11886A	01:57:39.8	+36:46:13.3	8.468	0.245	0.149	0.572	2.704	
18	HD13759	02:15:32.4	+49:12:35.2	8.358	0.382	0.124	0.482	2.635	
19	HD16160A	02:36:04.9	+06:53:12.7	5.791	0.558	0.519	0.285	——	*uvby* only
20	HD17122	02:44:42.8	−00:50:46.1	7.863	0.669	0.473	0.424	——	*uvby* only, red sbgnt; usually omitted
21	BS812	02:44:57.6	+12:26:44.7	5.181	0.135	0.188	0.837	2.804	δ Sct type var., excluded
22	HD19445	03:08:25.6	+26:19:51.4	8.051	0.353	0.050	0.195	2.585	
23	HD19983	03:13:03.2	+11:16:07.1	7.803	0.468	0.081	0.679	2.650	
24	HD20165	03:14:47.2	+08:58:50.8	7.809	0.508	0.411	0.297	——	*uvby* only
25	HD20427	03:18:32.0	+38:27:31.4	7.336	0.331	0.117	0.389	2.609	
26	HD21197	03:24:59.7	−05:21:49.5	7.839	0.666	0.723	0.166	——	*uvby* only
27	HD22879	03:40:22.1	−03:13:01.1	6.684	0.369	0.120	0.273	2.580	
28	HD25322	04:02:15.3	+22:25:20.3	7.817	0.316	0.120	0.416	2.621	
29	BS1430	04:30:37.4	+13:43:27.9	5.402	0.154	0.201	0.814	2.797	bright, Hβ only
30	HD32147	05:00:49.0	−05:45:13.2	6.197	0.608	0.638	0.249	——	*uvby* only
31	HD36003A	05:28:26.1	−03:29:58.4	7.624	0.641	0.676	0.187	——	*uvby* only
32	BS2601A	06:58:47.4	+26:04:51.9	6.190	0.348	0.134	0.390	2.602	
33	BS2835	07:26:50.3	+21:32:08.3	6.540	0.324	0.123	0.356	2.610	
34	BS2857	07:29:20.4	+28:07:05.8	5.050	0.062	0.202	1.013	2.871	bright, Hβ only, excluded
35	HD75596	08:50:55.0	−00:39:34.4	8.644	0.319	0.132	0.351	2.621	
36	HD76910	08:59:06.0	−00:37:25.9	8.489	0.302	0.114	0.393	2.628	
37	HD77354	09:01:56.8	−01:07:31.2	7.943	0.443	0.202	0.360	2.574	

TABLE 1 (CONTINUED)

	Name (HD/BS≡HR)	R.A.(2000.0) [h:m:s]	Dec (2000.0) [d:m:s]	V [mag]	$(b–y)$ [mag]	m_1 [mag]	c_1 [mag]	Hβ [mag]	Comments
38	HD80715	09:22:25.9	+40:12:03.8	7.643	0.592	0.506	0.227	2.532	BY Dra type var., excluded
39	HD81539	09:27:26.5	+41:36:00.2	8.522	0.286	0.122	0.464	2.648	
40	HD84937	09:48:56.1	+13:44:39.3	8.339	0.303	0.054	0.354	2.619	
41	HD85902	09:55:56.7	+38:04:54.1	8.135	0.381	0.159	0.267	2.585	
42	HD87195	10:03:44.5	+18:13:12.0	8.261	0.418	0.239	0.336	2.588	
43	HD87646	10:06:40.8	+17:53:42.4	8.073	0.399	0.232	0.392	2.610	
44	HD88923	10:16:26.2	+45:26:00.0	7.699	0.266	0.098	0.679	2.634	
45	HD94028	10:51:28.1	+20:16:39.0	8.229	0.346	0.074	0.251	2.587	
46	HD97560	11:13:54.8	+39:58:39.9	7.894	0.453	0.136	0.426	2.559	
47	BS4515	11:45:17.0	+08:15:29.2	4.850	0.092	0.195	0.926	2.857	bright, Hβ only, excluded
48	BS4550	11:52:58.8	+37:43:07.2	6.430	0.484	0.224	0.166	2.544	G8Vp, flare star?
49	HD105584	12:09:20.6	+53:23:40.2	7.506	0.245	0.132	0.490	2.684	
50	HD106509	12:14:59.0	+33:15:22.8	8.159	0.332	0.140	0.432	2.622	
51	HD106510	12:15:01.5	+30:08:29.4	8.284	0.369	0.148	0.307	2.592	
52	HD107550	12:21:39.4	+21:18:10.0	8.367	0.498	0.141	0.431	2.557	red subgiant; usually omitted
53	HD107823	12:23:13.4	+42:53:58.8	8.785	0.310	0.129	0.403	2.638	
54	HD108076	12:24:45.9	+38:19:07.5	8.042	0.384	0.134	0.245	2.572	
55	HD108189	12:25:40.6	−00:16:55.8	7.724	0.491	0.257	0.335	2.571	
56	HD108641	12:28:35.3	+47:28:43.0	8.824	0.527	0.251	0.353	2.556	red subgiant; usually omitted
57	HD108678	12:29:03.9	+05:57:38.5	8.059	0.275	0.137	0.548	2.661	
58	BS4845	12:44:59.4	+39:16:44.1	5.950	0.375	0.150	0.280	2.574	
59	HD117243	13:28:39.3	+28:26:54.9	8.350	0.404	0.231	0.394	2.605	
60	BS5270	14:02:31.8	+09:41:09.9	6.208	0.636	0.087	0.545	2.540	red giant; usually omitted
61	HD125375	14:17:59.2	+37:39:30.2	8.129	0.198	0.141	0.824	2.710	
62	HD125455A	14:19:34.9	−05:09:04.3	7.581	0.497	0.387	0.289	2.544	
63	HD125607	14:19:27.2	+37:36:35.9	8.091	0.566	0.372	0.379	2.569	red subgiant; usually omitted
64	HD126531A	14:24:38.9	+47:49:49.7	7.634	0.288	0.143	0.497	2.654	
65	HD127029	14:27:18.6	+53:18:40.1	7.984	0.386	0.164	0.305	2.591	
66	HD128165	14:33:28.9	+52:54:31.7	7.219	0.571	0.566	0.246	2.530	
67	HD128279	14:36:48.5	−29:06:46.6	8.034	0.465	0.056	0.259	2.545	
68	HD129755	14:44:30.6	−03:21:47.9	7.589	0.258	0.150	0.477	2.678	
69	HD130353	14:46:18.1	+43:27:56.5	8.598	0.281	0.180	0.699	2.675	
70	HD130992	14:51:40.5	−24:18:14.9	7.792	0.577	0.577	0.235	2.534	
71	HD131597	14:52:51.6	+48:28:06.3	8.424	0.475	0.213	0.299	2.555	
72	HD132475	14:59:49.8	−22:00:45.8	8.561	0.392	0.074	0.286	2.578	
73	HD134169	15:08:18.1	+03:55:50.1	7.684	0.368	0.120	0.307	2.582	
74	HD135662	15:16:36.8	−09:12:17.4	8.697	0.318	0.145	0.450	2.667	
75	HD136047	15:18:38.9	−02:48:02.4	8.479	0.359	0.128	0.503	2.676	

TABLE 1 (CONTINUED)

	Name (HD/BS≡HR)	R.A.(2000.0) [h:m:s]	Dec (2000.0) [d:m:s]	V [mag]	$(b–y)$ [mag]	m_1 [mag]	c_1 [mag]	Hβ [mag]	Comments
76	HD137778B	15:28:12.2	−09:21:28.3	7.568	0.535	0.463	0.284	2.555	
77	HD140283	15:43:03.1	−10:56:00.6	7.211	0.379	0.033	0.290	2.564	
78	BS5930	15:56:33.4	−14:49:46.0	6.130	0.175	0.117	0.732	2.743	low-amplitude δ Sct type var.
79	HD143131	15:59:13.7	−16:13:18.2	8.064	0.404	0.134	0.616	2.673	
80	HD144253	16:05:40.5	−20:27:00.2	7.383	0.600	0.610	0.206	2.529	
81	BS6189	16:39:39.1	−09:33:16.5	6.350	0.323	0.127	0.402	2.613	
82	HD154363A	17:05:03.4	−05:03:59.4	7.703	0.674	0.632	0.175	—	K star, *uvby* only
83	HD156026	17:16:13.4	−26:32:46.1	6.294	0.667	0.676	0.128	—	*uvby* only, RS CVn var., excluded
84	HD156392	17:17:51.8	−12:18:47.3	8.375	0.315	0.130	0.570	2.701	
85	BS6467	17:20:33.8	+48:11:19.7	6.350	0.294	0.118	0.434	2.656	
86	BS6577	17:38:57.9	+13:19:45.3	6.120	0.382	0.151	0.573	2.626	F giant
87	HD161303	17:44:44.3	+02:26:50.3	8.462	0.294	0.147	0.550	2.697	
88	HD162503	17:51:22.1	+01:31:18.8	8.334	0.465	0.190	0.430	2.600	
89	HD175384	18:55:49.9	−18:32:00.7	8.268	0.253	0.142	0.618	2.710	
90	HD176014	18:58:37.0	−14:46:07.2	8.653	0.320	0.098	0.493	2.637	
91	HD186025	19:41:58.4	+01:10:55.4	8.862	0.382	0.126	0.504	2.661	
92	HD191264	20:09:01.2	+01:38:58.8	8.347	0.465	0.155	0.428	2.588	
93	HD191365	20:10:00.9	−13:02:46.9	8.380	0.383	0.095	0.506	2.644	Algol-type, eclipsing binary
94	HD193901	20:23:35.8	−21:22:14.2	8.658	0.381	0.104	0.217	2.568	
95	HD196892	20:40:49.4	−18:47:33.3	8.242	0.349	0.098	0.302	2.589	
96	HD198486	20:50:42.2	−04:47:27.2	8.043	0.355	0.169	0.458	2.624	
97	HD198585	20:51:12.5	+03:29:26.1	7.673	0.382	0.123	0.418	2.601	
98	BS8060	21:04:24.3	−19:51:18.0	4.858	0.090	0.192	0.946	2.862	bright, Hβ only, excluded
99	BS8086	21:06:55.3	+38:44:31.4	6.044	0.791	0.676	0.067	—	K7V, flare star?, *uvby* only
100	HD206843	21:43:03.8	+55:12:33.5	8.362	0.371	0.103	0.261	2.585	
101	HD207608	21:48:54.7	+46:54:11.1	8.050	0.318	0.154	0.515	2.644	
102	HD207687	21:51:05.6	−10:02:16.9	7.504	0.495	0.231	0.292	2.550	
103	BS8455	22:10:19.0	+19:36:58.8	6.180	0.462	0.199	0.334	2.545	
104	HD210752	22:12:43.5	−06:28:08.1	7.442	0.361	0.132	0.290	2.585	
105	HD212029A	22:20:23.8	+46:25:05.7	8.502	0.365	0.101	0.280	2.591	
106	HD213802	22:33:34.2	+31:17:01.7	7.970	0.409	0.184	0.390	2.598	
107	BS8799	23:07:28.7	+21:08:03.3	5.970	0.184	0.136	0.687	2.746	γ Dor type var., excluded
108	BS8826	23:11:44.2	+08:43:12.4	5.163	0.075	0.165	1.090	2.814	bright, Hβ only
109	HD220339	23:23:04.9	−10:45:51.3	7.789	0.515	0.429	0.251	—	*uvby* only
110	BS8899	23:23:47.5	+32:31:52.7	6.690	0.327	0.120	0.405	2.640	spec. binary
111	BS9039	23:52:37.1	+10:56:50.4	5.314	0.099	0.181	0.967	2.823	low-amp. δ Sct, bright, Hβ only

TABLE 1 (CONTINUED)

	Name (HD/BS≡HR)	R.A.(2000.0) [h:m:s]	Dec (2000.0) [d:m:s]	V [mag]	$(b–y)$ [mag]	m_1 [mag]	c_1 [mag]	Hβ [mag]	Comments
Extension 1: Standard Stars for VMPS Project									
1	HD3567	00:38:31.9	−08:18:33.4	9.255	0.332	0.087	0.334	2.598	
2	HD4306	00:45:27.2	−09:32:39.8	9.035	0.518	0.052	0.348	2.529	
3	BD−17:0267	01:28:40.5	−17:01:56.6	11.111	0.320	0.051	0.336	2.617	
4	G159-50	02:14:40.3	−01:12:05.1	9.086	0.387	0.133	0.231	2.575	
5	HD16031	02:34:11.0	−12:23:03.5	9.781	0.324	0.062	0.304	2.604	
6	CD−24:1782	03:38:41.5	−24:02:50.3	9.934	0.466	0.040	0.287	2.526	
7	G102-47	06:05:57.5	+07:19:03.2	10.327	0.455	0.102	0.232	2.547	
8	HD45282	06:26:40.8	+03:25:29.8	8.028	0.451	0.108	0.277	2.544	
9	HD195636	20:32:48.9	−09:21:51.7	9.550	0.468	0.003	0.465	2.549	
10	G28-43	23:09:32.9	+00:42:38.6	9.928	0.469	0.160	0.142	2.538	
11	HD219617	23:17:05.0	−13:51:03.6	8.168	0.349	0.072	0.243	2.584	
Extension 2: Standard Stars for NGP Project									
1	HD74721	08:45:59.3	+13:15:48.6	8.720	0.025	0.142	1.251	——	*uvby* only
2	HD86986	10:02:29.6	+14:33:25.2	7.990	0.089	0.123	1.266	——	*uvby* only
3	HD92788	10:42:48.5	−02:11:01.5	7.317	0.439	0.243	0.385	——	*uvby* only
4	HD95102	10:58:50.1	−02:14:10.3	7.682	0.599	0.360	0.405	——	*uvby* only
5	HD102096	11:45:01.4	−00:31:04.2	7.328	0.564	0.337	0.410	——	*uvby* only
6	HD104130	11:59:34.0	−01:55:07.0	7.141	0.595	0.373	0.467	——	*uvby* only
7	BD+52:1601	11:59:59.1	+51:46:17.6	8.800	0.555	0.170	0.445	——	*uvby* only
8	HD105089	12:05:59.8	−03:07:53.7	6.371	0.605	0.407	0.412	——	*uvby* only
9	HD108317	12:26:36.8	+05:18:09.0	8.037	0.446	0.057	0.292	——	*uvby* only
10	HD108577	12:28:16.9	+12:20:41.1	9.586	0.519	0.062	0.497	——	*uvby* only
11	HD109995	12:38:47.6	+39:18:31.6	7.620	0.048	0.134	1.286	——	*uvby* only
12	HD118039B	13:34:33.1	−13:26:39.2	8.889	0.674	0.411	0.442	2.564	
13	HD119516	13:43:26.7	+15:34:31.1	9.077	0.404	0.068	0.499	——	*uvby* only
14	HD122956	14:05:13.0	−14:51:25.5	7.237	0.671	0.170	0.519	——	*uvby* only
15	HD136442	15:20:47.0	−02:24:48.0	6.338	0.653	0.493	0.415	——	*uvby* only
16	HD161817	17:46:40.6	+25:44:56.9	6.972	0.137	0.092	1.200	——	*uvby* only

mentioned above, listed as definite variable stars in SIMBAD, plus comments for three additional variable stars identified more recently (see below).

The HVMPS standard stars (first section of Table 1) were selected from the Olsen (1983, 1984, 1993) catalogues, where the precision of the data is reported. In the case of the Olsen (1983) catalogue, the rms internal errors of one observation are ±0.0052, 0.0040, 0.0061, 0.0065 and 0.0065 in V, $(b–y)$, m_1, c_1 and Hβ, respectively. For the Olsen (1984) catalogue, weighted averages of the internal rms errors of one observation were $\leq \pm 0.005$ in V, $\leq \pm 0.004$ in $(b–y)$, $\leq \pm 0.006$ in m_1, and $\leq \pm 0.0065$ in c_1. For those stars in the Olsen (1993) catalogue, internal rms errors of one observation were ±0.0047, 0.0029, 0.0041 and 0.0058, respectively, in V, $(b–y)$, m_1, and c_1. The standard Hβ values from Crawford & Mander (1966) have an rms deviation of ±0.0060.

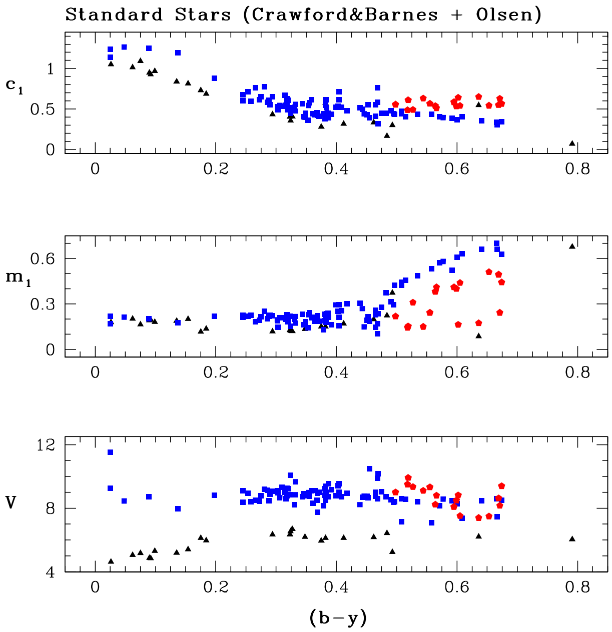

Fig. 1. Strömgren *uvby* standard values reported by Crawford & Barnes (1970) and Olsen (1983, 1984, 1993) for those primary and secondary standard stars used in the HVMPS and VMPS projects, as given in Table 1. The red points show those red subgiants used mainly in the NGP project, those with $c_1 \gtrsim 0.35$ and $(b–y) \gtrsim 0.50$. The Crawford & Barnes (1970) stars are shown as black triangles, while blue squares represent the Olsen (1983, 1984, 1993) stars. The color figure can be viewed online.

The VMPS stars (first extension of Table 1) possess rms errors of ±0.006, 0.003, 0.005, 0.006, and 0.007 in V, $(b–y)$, m_1, c_1, and Hβ, respectively. From these values the great precision and stability provided by this photometric system can be appreciated.

In order to show the spectral coverage of this set of standard stars, the V vs $(b-y)$, m_1 vs $(b-y)$, and c_1 vs $(b-y)$ plots are given in Figure 1. The red points show the red subgiants which have been excluded from the HVMPS project, mostly excluded from the VMPS project, but used for the NGP project due to the greater range in colors and evolutionary states expected for these stars. The Crawford & Barnes (1970) stars are shown as black triangles, and blue squares represent the Olsen (1983, 1984, 1993) stars. In general we can see that this set of primary and secondary standard stars covers well the ranges expected for the HVMPS and VMPS.

For each observing run, histograms for $(b–y)$, m_1, c_1, and Hβ were plotted for the standard stars to be used to check for adequate distributions as expected for F-, G-, and K-type HVMPS and VMPS, as shown in Figure 2 for the entire sample of Table 1. In this way we have covered adequately the following ranges: $5.8 \lesssim V \lesssim 9.0$, $0.20 \lesssim (b–y) \lesssim 0.80$, $0.00 \lesssim m_1 \lesssim 0.65$, $0.10 \lesssim c_1 \lesssim 0.80$, and $2.53 \lesssim \mathrm{H}\beta \lesssim 2.82$ during each observing run.

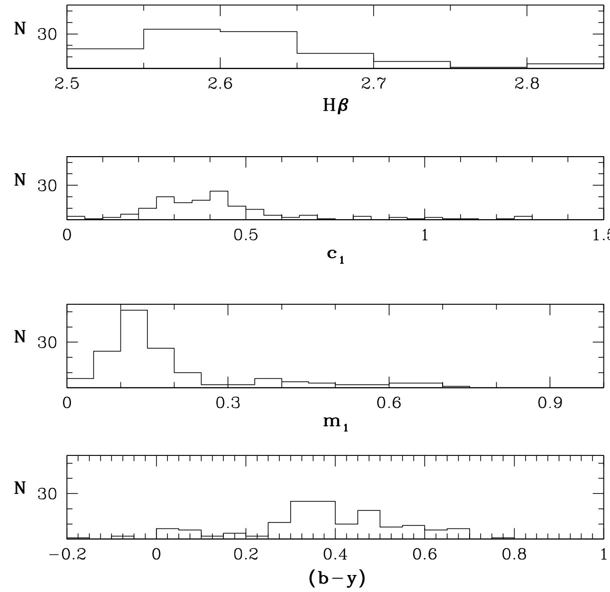

Fig. 2. Histograms showing the distribution of these standard stars for the different indices and colors: Hβ, c_1, m_1, and $(b–y)$.

Figure 3 shows the dependence of the Strömgren indices, $(b–y)$, m_1, and c_1, for our set of standard stars in Table 1, as a function of Hβ. The symbols are the same as in Figure 1. Several of the redder standard stars do not have standard Hβ values, only *uvby*.

4. TRANSFORMATION COEFFICIENTS AND ERRORS

4.1. *Transformation coefficients*

In order to achieve a good transformation between the instrumental and standard photometric systems, the standard stars must be selected with care, as well as the transformation equations to be used, preferably linear ones when a close match of the filters and detectors to the original standard system has been achieved. In this case the optics, band-passes, filters, and detectors (photomultipliers) of the "Danish" 6-channel photometer in use on SPM have been closely matched to the original parameters (central wavelengths and band-passes) of the original Strömgren-Crawford, *uvby*–Hβ, photometric system. In the three main projects (HVMPS, VMPS and NGP) of the present work, the linear transformation equations of Grønbech et

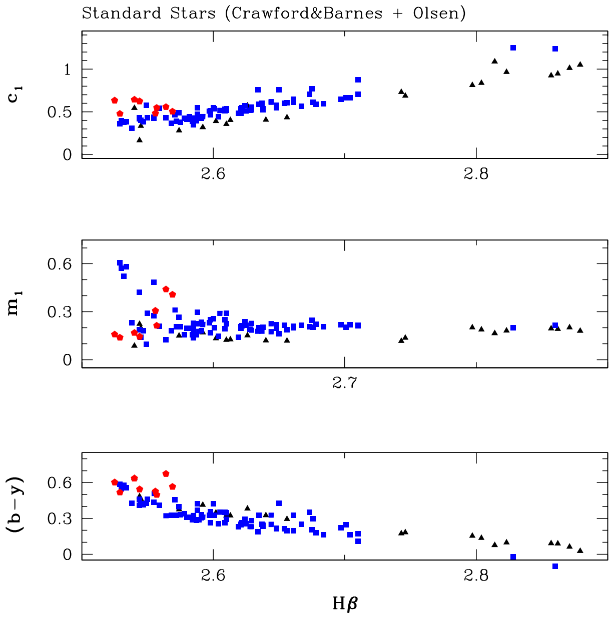

Fig. 3. Plots of these primary and secondary standard stars for c_1, m_1, $(b–y)$, and V versus Hβ, with the symbols as in Figure 1. The color figure can be viewed online.

al. (1976), eqs. (6)–(9), have been used successfully, where the coefficients $A, B, C, D, E, F, J, G, H, I, K$ and L are defined by the following:

$$V_{std} = A + y_{instr} + B\ (b - y)_{std}$$

$$(b - y)_{std} = C + D\ (b - y)_{instr}$$

$$(m_1)_{std} = E + F\ (m_1)_{instr} + J\ (b - y)_{std}$$

$$(c_1)_{std} = G + H\ (c_1)_{instr} + I\ (b - y)_{std}$$

$$(H\beta)_{std} = K + L\ H\beta_{instr},$$

where "std" refers to the standard photometric values, and "instr" to those values from the instrumental solution.

Table 2 shows the transformation coefficients for these equations obtained from different observing runs for the HVMPS. Zero point values $(A, C, E, G,$ and $K)$ are quite similar in all observing runs, showing the largest changes when the telescope mirrors have been cleaned. The first-order color coefficient values $(D, F,$ and $H)$ are approximately 1.0 indicating a good agreement between the original and present filter sets plus detectors. The L coefficient values show a slight deviation from 1.0 mainly due to a difference in the bandwidth of the narrow (N) filter of Hβ; Crawford changed this bandwidth early in his observations from ≈ 15Å to ≈ 30Å to avoid radial velocity effects in high-velocity stars for this Hβ index (Crawford & Mander 1966; Schmidt & Taylor 1979); our bandwidth for this narrow filter is very close to this latter value leading to values of ≈ 1.20–1.35 for L. Second-order color coefficients, B, J, and I, are small, indicating a reasonable, uncomplicated match to the standard photometric system. To first order these transformation coefficients agree well with those given by Olsen (1983, 1993), Tables VIII and XII, and Tables 9 and 11, respectively. Exact agreement is not expected, since the filter-detector combinations are not identical and since Olsen divided his main-sequence stars into two groups, "BAF" and "GKV", while we have worked our main-sequence and subdwarf stars in a single group, early-F to late-K type stars.

A few observing runs, for the NGP project, were reduced using three different standard star groupings, one including the standard stars as "usual", as defined above, and a second and third reduction using only "blue" and "red" standard stars, respectively, to compensate for the wider range in color of the program stars found for this project, such as a "red" solution for the red subgiants and giants, and a "blue" solution for any blue stragglers or blue horizontal-branch stars in the sample. For wider ranging projects, such as the NGP, the red subgiants and the secondary standards in Extension 2 of Table 1 have been used to help obtain the "red" and "blue" transformation equations à la equations (10)–(15) of Grønbech et al. (1976). In Table 2 only these "usual" transformation equations, excluding the red subgiants and giants as well as those secondary standards in Extension 2 of Table 1, are documented.

Since there are no standard stars with $V \gtrsim 8.9$ in the first section of Table 1, the standard V magnitudes have been extrapolated for the fainter HVMPS, VMPS, and NGP stars in our catalogues. Figure 2 of Schuster et al. (1996) and Figure 1 of Schuster et al. (2004) show that our fainter V magnitudes ($\gtrsim$ 12.4 and $\gtrsim$ 11.0, respectively) are quite linear and accurate, when compared to external sources.

4.2. *Errors*

The main error source for the final transformed *uvby*–Hβ photometry for the program stars comes from the color transformations (Manfroid & Sterken 1987, 1992). As can be seen in Table 3, the instrumental errors of our photometric observations (including the "extinction" and "drift" solutions) are

TABLE 2

TRANSFORMATION COEFFICIENTS TO THE STANDARD PHOTOMETRIC SYSTEM (HVMPS)

Date (month/year)	B	D	F	J	H	I	L	No. Standard Stars V/b-y/m_1,c_1/H_β
September 1987	0.0413	0.9660	1.1000	0.0156	1.0337	0.1367	1.3810	48/48/48/43
March 1988	0.0157	0.9763	1.1062	0.0193	1.0162	0.1048	1.3616	42/42/42/45
May 1989	0.0595	0.9803	1.0597	0.0628	1.0505	0.1594	1.2388	20/20/20/21
November 1989	0.0338	0.9623	1.0986	0.0207	1.0335	0.1456	1.2784	42/42/42/37
April 1990	0.0032	0.9718	1.0552	0.0623	1.0340	0.1289	1.2379	30/26/26/29
April 1991	0.0173	0.9837	1.0821	0.0390	1.0458	0.1541	1.2991	49/38/38/46
October 1991	0.0331	0.9784	1.0870	0.0192	1.0480	0.1600	1.3222	51/51/46/44
March 1992	0.0125	0.9880	1.0808	0.0266	1.0311	0.1392	1.2378	37/38/34/37
April 1992	0.0269	0.9969	1.0855	0.0485	1.0283	0.1080	1.3236	32/40/37/41
November 1992	0.0422	0.9794	1.0881	0.0447	1.0269	0.1312	1.1958	37/47/46/38
March/April 1993	0.0200	0.9702	1.0927	0.0522	1.0379	0.1406	1.2707	36/34/34/36
September 1993	0.0676	0.9688	1.0889	0.0751	1.0053	0.0911	1.4661	45/38/38/37
October 1993	0.0096	0.9966	1.0080	0.1374	1.0837	0.1426	1.4140	24/27/20/16
November 1993	0.0634	0.9675	1.0815	0.0469	1.0173	0.1323	1.2689	30/34/34/33
April 1994	0.0171	0.9700	1.0562	0.0969	1.0025	0.0942	1.2886	34/31/31/35
October 1994	0.0473	0.9808	1.0829	0.0502	1.0298	0.1442	1.2310	43/43/43/34
March 1995	−0.0315	0.9603	0.9474	0.1981	1.0070	0.1019	1.2916	22/31/31/34
September 1995	0.0234	0.9979	1.1247	−0.0017	1.0087	0.1141	···	41/41/41/ 0
April 1996	0.0098	0.9905	1.0742	0.0531	1.0172	0.1179	1.3164	42/40/37/40
October 1996	0.0380	0.9763	1.0876	0.0452	1.0385	0.1489	1.2098	40/42/42/35
April 1997	0.0347	0.9731	1.0609	0.0711	1.0355	0.1392	1.2122	32/30/30/32
Aug/Oct/Nov 1997	0.0423	0.9622	1.0977	0.0285	1.0290	0.1462	1.2184	47/52/52/45
April/May 1998	0.0434	0.9966	1.0080	0.0657	1.0581	0.2920	1.2931	50/44/44/41
November 1998	-0.0458	1.0031	0.9577	0.0065	0.9457	0.2377	1.2111	37/34/34/33
April 1999	0.0292	0.9582	1.0264	0.1352	1.0223	0.1372	1.2677	33/33/33/36
April 2000	0.0280	0.9768	1.0892	0.0455	1.0212	0.1108	1.2789	35/31/31/35
November 2000	0.0179	1.0021	1.0805	0.0253	1.0523	0.1123	1.2787	45/42/42/34
April 2004	0.0229	0.9845	1.0836	0.0388	1.0008	0.0630	1.2811	30/28/28/32
October 2004	0.0176	1.0050	1.0414	0.0463	1.0362	0.1199	1.3646	36/33/33/29
October 2006	0.0134	0.9755	1.1122	−0.0289	1.0448	−0.0289	1.1626	39/38/38/43
January 2007	0.0081	0.9871	1.0565	0.0410	1.0106	0.0835	1.2126	46/46/46/44
June 2007	0.0345	0.9731	1.0772	0.0258	1.0502	0.1556	1.3495	39/39/39/40
November 2007	0.0408	0.9891	1.0707	0.0400	1.0381	0.1198	1.3587	36/36/36/29

quite small. To minimize the color transformation errors, an attempt was always made to observe all standard stars on at least three independent nights with approximately 15-25 standard stars observed on all nights, as mentioned in § 2.1.

Statistical standard errors of the transformation to the standard system for different observing runs are shown in Table 4. For most of the observing runs, standard deviations for the different color indices are of the order of a few thousandths of a magnitude, indicating very good transformations to the standard system. These errors are similar in size to the ones reported in Schuster & Nissen (1988) and Schuster et al. (2006).

TABLE 3

INSTRUMENTAL ERRORS SYSTEM FOR HIGH-VELOCITY & METAL-POOR STARS (HVMPS)

Date (month/year)	σ_V [mag]	$\sigma_{(b-y)}$ [mag]	σ_{m_1} [mag]	σ_{c_1} [mag]	$\sigma_{H\beta}$ [mag]	No. Objects $V/uvby/\beta$	No. Nights $V/uvby/\beta$
September 1987	0.007	0.003	0.003	0.006	0.004	50/50/50	12/13/13
March 1988	0.007	0.002	0.003	0.004	0.004	46/46/46	10/10/10
May 1989	0.011	0.003	0.004	0.006	0.004	24/24/24	2/ 2/ 2
November 1989	0.006	0.002	0.003	0.005	0.004	42/43/47	14/17/17
April 1990	0.005	0.003	0.005	0.007	0.005	30/30/30	8/10/10
April 1991	0.006	0.003	0.004	0.005	0.003	52/55/55	14/20/20
October 1991	0.007	0.003	0.004	0.006	0.004	51/51/51	17/19/19
March 1992	0.008	0.003	0.004	0.005	0.005	38/38/39	5/ 6/ 6
April 1992	0.008	0.002	0.003	0.004	0.005	33/43/43	10/12/12
November 1992	0.009	0.008	0.008	0.005	0.007	38/48/50	7/10/11
March/April 1993	0.004	0.002	0.003	0.004	0.003	36/34/36	4/ 5/ 5
September 1993	0.005	0.004	0.007	0.008	0.004	47/38/41	10/11/11
October 1993	0.004	0.003	0.007	0.007	0.004	25/29/16	2/ 2/ 2
November 1993	0.002	0.003	0.006	0.006	0.005	31/42/45	2/ 5/ 5
April 1994	0.007	0.005	0.009	0.007	0.004	36/37/35	10/15/15
October 1994	0.004	0.003	0.005	0.006	0.004	44/44/42	9/10/10
March 1995	0.007	0.004	0.007	0.015	0.006	22/34/34	2/ 5/ 5
September 1995	0.005	0.004	0.007	0.007	0.009	42/45/ 0	6/ 8/ 0
April 1996	0.007	0.003	0.006	0.005	0.007	46/40/40	11/11/11
October 1996	0.006	0.003	0.005	0.006	0.006	40/42/35	12/12/12
April 1997	0.005	0.003	0.006	0.008	0.019	35/35/35	9/10/10
Aug/Oct/Nov 1997	0.003	0.003	0.005	0.006	0.005	47/52/45	15/16/15
April/May 1998	0.011	0.004	0.007	0.008	0.005	52/49/50	18/20/20
November 1998	0.007	0.005	0.006	0.006	0.005	40/41/36	7/ 9/ 9
April 1999	0.005	0.004	0.007	0.009	0.013	36/36/36	3/ 3/ 3
April 2000	0.007	0.002	0.002	0.008	0.003	35/35/35	7/10/10
November 2000	0.005	0.002	0.002	0.007	0.004	45/45/39	9/10/10
April 2004	0.008	0.002	0.003	0.007	0.006	31/32/32	5/ 6/ 6
October 2004	0.004	0.002	0.002	0.006	0.004	36/36/35	5/ 7/ 7
October 2006	0.006	0.002	0.002	0.008	0.005	42/42/42	6/ 6/ 6
January 2007	0.003	0.002	0.003	0.009	0.006	52/52/52	6/ 6/ 6
June 2007	0.007	0.002	0.002	0.008	0.005	44/44/43	10/10/10
November 2007	0.003	0.002	0.002	0.009	0.003	36/36/36	8/ 8/ 8

5. DISCUSSION AND ANALYSIS

5.1. *Instrumental system stability*

One of the mainstays for supporting the instrumental stability of the six-channel "Danish" *uvby*–Hβ photometer at the OAN-SPM has been the calibration of the grating angle. This has been carried out frequently, usually with a cadmium lamp, three or four times a year, always before each one of our observing runs. In this way the position of the stellar spectrum on the mechanical exit slots has been maintained to within ±1Å, and so to a high degree the instrumental photometric system has remained stable over many years. The filters might age, but the first-order band-passes have been maintained to high accuracy.

TABLE 4

TRANSFORMATION ERRORS OF HIGH-VELOCITY & METAL-POOR STARS (HVMPS)

Date (month/year)	σ_V [mag]	$\sigma_{(b-y)}$ [mag]	σ_{m_1} [mag]	σ_{c_1} [mag]	$\sigma_{H\beta}$ [mag]	No. Standard Stars V/b-y/m_1,c_1/H_β
September 1987	0.0081	0.0050	0.0060	0.0084	0.0081	48/48/48/43
March 1988	0.0068	0.0048	0.0057	0.0077	0.0072	42/42/42/45
May 1989	0.0137	0.0056	0.0078	0.0105	0.0055	20/20/20/21
November 1989	0.0058	0.0050	0.0056	0.0081	0.0084	42/42/42/37
April 1990	0.0067	0.0033	0.0068	0.0084	0.0064	30/26/26/29
April 1991	0.0065	0.0067	0.0121	0.0106	0.0086	49/38/38/46
October 1991	0.0071	0.0069	0.0083	0.0078	0.0078	51/51/46/44
March 1992	0.0052	0.0051	0.0072	0.0075	0.0079	37/38/34/37
April 1992	0.0077	0.0050	0.0085	0.0093	0.0076	32/40/37/41
November 1992	0.0086	0.0056	0.0071	0.0080	0.0065	37/47/46/38
March/April 1993	0.0082	0.0045	0.0065	0.0079	0.0069	36/34/34/36
September 1993	0.0064	0.0036	0.0073	0.0092	0.0081	45/38/38/37
October 1993	0.0091	0.0093	0.0207	0.0206	0.0097	24/27/20/16
November 1993	0.0062	0.0046	0.0084	0.0094	0.0072	30/34/34/33
April 1994	0.0057	0.0060	0.0129	0.0085	0.0065	34/31/31/35
October 1994	0.0057	0.0043	0.0066	0.0085	0.0055	43/43/43/34
March 1995	0.0254	0.0068	0.0135	0.0105	0.0063	22/31/31/34
September 1995	0.0062	0.0054	0.0086	0.0081	···	41/41/41/ 0
April 1996	0.0060	0.0072	0.0147	0.0070	0.0064	42/40/37/40
October 1996	0.0060	0.0044	0.0062	0.0078	0.0084	40/42/42/35
April 1997	0.0061	0.0041	0.0093	0.0063	0.0080	32/30/30/32
Aug/Oct/Nov 1997	0.0065	0.0054	0.0058	0.0072	0.0091	47/52/52/45
April/May 1998	0.0088	0.0063	0.0197	0.0202	0.0080	50/44/44/41
November 1998	0.0071	0.0056	0.0051	0.0163	0.0083	37/34/34/33
April 1999	0.0070	0.0045	0.0107	0.0077	0.0084	33/33/33/36
April 2000	0.0081	0.0041	0.0061	0.0100	0.0064	35/31/31/35
November 2000	0.0080	0.0038	0.0065	0.0088	0.0068	45/42/42/34
April 2004	0.0068	0.0032	0.0059	0.0118	0.0076	30/28/28/32
October 2004	0.0081	0.0063	0.0089	0.0082	0.0087	36/33/33/29
October 2006	0.0108	0.0066	0.0092	0.0105	0.0099	39/38/38/43
January 2007	0.0083	0.0045	0.0079	0.0132	0.0085	46/46/46/44
June 2007	0.0073	0.0052	0.0083	0.0117	0.0099	39/39/39/40
November 2007	0.0062	0.0042	0.0083	0.0108	0.0074	36/36/36/29

Another source of possible instability for the instrumental photometry derives from the phototube replacements. The original "Danish" photometer installed at the 1.5 m telescope at the OAN-SPM, possessed uncooled EMI 9789QA phototubes with bialkali cathodes. The *uvby* phototube set worked efficiently for about fifteen years, and then was replaced in October 1999 with uncooled Electron Tubes 9893Q/350A photomultipliers also with bialkali cathodes. (This replacement was required by the misuse of the photometer's neutral filters by some observers and the resulting deterioration of some of the photocathodes.) Since both sets of phototubes have nearly identical bialkali photocathodes, these tube replacements should theoretically not affect instrumental and standard observations. In practice, the only obvious observed change has been the dead-time corrections for the observing runs carried out with these new tubes in the *uvby* section. The Hβ section still retains the uncooled EMI 9789QA phototubes, as of November 2015.

5.2. *Standard system stability*

The high stability observed in the standard system is shown by the transformation coefficients D, F, H, and L which are very similar along the different observing runs, with average values of 0.9803 ± 0.0132, 1.0682 ± 0.0398, 1.0285 ± 0.0233, and 1.2851 ± 0.0682, respectively, as seen in Table 2, even though some variation in these coefficients is expected with changes in the mean nightly temperature affecting the transmission curves of the interference filters, with the aging of the filters, and with slightly differing standard-star selections from observing run to observing run. The same can be said for the coefficients B, J, and I: $+0.0281 \pm 0.0171$, $+0.0575 \pm 0.0467$, and $+0.1335 \pm 0.0419$, respectively. As can be seen, the D, F, and H values are very close to 1.0 during the 20 years of observations with only a few isolated cases in which the values are somewhat different, and the values of B, J, and H are all small, agreeing with their second-order importance. The effect of the phototube replacement is reflected mainly in a change of the zero points of the transformation coefficients A, C, E, and G. Observational errors in the standard-star observations (transformation errors) have also remained on the order of a few thousandths, with the exception of a few isolated cases; see Table 4.

5.3. *Transformed standard values for the uvby–Hβ standard stars*

Table 5 shows the transformed standard values for the *uvby*–Hβ standard stars observed during various observing runs from 1987 through 2007 for the HVMPS and VMPS projects. As suggested by Lindemann & Hauck (1973), and as provided by Olsen (1983, 1984, 1993) for his various *uvby*–Hβ catalogues, such values provide a means for homogenizing our *uvby*–Hβ data onto the CDS data bases. In this table the transformed standard values for each standard star during each observing run have been averaged (for the number of observing runs given in Column 15), and the total number of observations in V, in $(b-y)$, m_1, c_1, and in Hβ are given in Columns 12, 13, and 14, respectively.

The average of the standard deviations given in Table 5 are $\pm 0\overset{m}{.}004$, $\pm 0\overset{m}{.}003$, $\pm 0\overset{m}{.}005$, $\pm 0\overset{m}{.}005$, and $\pm 0\overset{m}{.}004$ for V, $(b–y)$, m_1, c_1, and Hβ, respectively. These small values show the good general constancy of the photometric standard stars used with the six-channel, *uvby*–Hβ photometer of the OAN-SPM over a period of about 20 years.

Such data also provide a means of identifying additional candidate variable stars within our standard-star set. Five of these standard stars (HD77354, HD126531, HD127029, HD130353, and HD137778B) have shown possible significant variations in the V magnitude, $\Delta V \geq 0\overset{m}{.}04$, the difference between the maximum and minimum values throughout our data set, but only the first of these five is clearly confirmed as a variable-star candidate from the given standard deviations in Table 5; the other four may have been observed only very occasionally during nights of less photometric quality.

Other stars in this Table 5 suggesting possible photometric variability (variations $\gtrsim 2.5\sigma$) are HD16031 (in c_1), BS6467 (m_1 and c_1), HD108189 (V and c_1), HD108678 (c_1), HD125607 (c_1), HD154363A (c_1), HD161303 (m_1 and Hβ), and HD198585 (Hβ). None of these stars are indicated as variable or candidate-variable stars in the SIMBAD or VSX data bases. HD2796 and HD132475 show possibly significant standard deviations in c_1 and m_1, respectively, but these two stars have fairly negative declinations ($\sim -17^o$ and $\sim -22^o$, respectively), and so are observed at larger air-masses at SPM; however, for example, the stars HD3621, HD128279, HD143131, HD144253, HD175384, HD193901, and HD196892 have similarly negative declinations (see Table 1) without showing larger standard deviations, indicating in general the high quality of the photometric sky at SPM and suggesting the possible photometric variability of HD2796 and HD132475. SIMBAD and the VSX do not indicate variability for HD2796 (and this star has been mainly used for V and Hβ values in the HVMPS project and only a few times to provide m_1 and c_1 in the VMPS and NGP), but SIMBAD and the VSX do list HD132475 as a suspected variable star with an uncertain range in V of 8.49:–8.66: (FitzGerald 1973); our data of Table 5 do not confirm any clear variability for this star in the V magnitude but do show a marginal dispersion of ± 0.013 ($\approx \pm 2.6\sigma$) for possible variability in m_1.

In addition, the VSX and SIMBAD catalogues indicate that the following stars of Table 1 (first two sections) are suspected variable stars: HD19445, BS1430, HD32147, BS2601A, HD84937, HD94028,

TABLE 5

AVERAGE TRANSFORMED STANDARD VALUES FOR THE $uvby$-Hβ STANDARD STARS (HVMPS,VMPS)

Std Star (HD/BS≡HR)	V [mag]	σ_V [mag]	$(b–y)$ [mag]	$\sigma_{(b-y)}$ [mag]	m_1 [mag]	σ_{m_1} [mag]	c_1 [mag]	σ_{c_1} [mag]	Hβ [mag]	$\sigma_{H\beta}$ [mag]	N_V	N_{uvby}	$N_{H\beta}$	N_{runs}
BS9107	6.099	±0.004	0.412	±0.004	0.166	±0.007	0.320	±0.005	2.583	±0.008	57	95	70	12
HD330	8.147	±0.003	0.385	±0.003	0.162	±0.004	0.377	±0.007	2.596	±0.005	87	109	110	14
HD1828	8.193	±0.004	0.293	±0.002	0.146	±0.003	0.429	±0.005	2.650	±0.006	26	35	33	11
HD2694	8.153	±0.004	0.323	±0.003	0.144	±0.003	0.385	±0.003	2.628	±0.004	53	60	67	12
HD2796	8.506	±0.003	0.545	±0.005	0.065	±0.003	0.510	±0.030	2.539	±0.006	36	9	45	8
HD3621	8.322	±0.004	0.356	±0.002	0.157	±0.003	0.417	±0.004	2.613	±0.004	54	63	65	12
HD3651A	5.874	±0.006	0.506	±0.002	0.394	±0.003	0.334	±0.002	2.574	···	16	20	1	8
HD6268	8.111	···	···	···	···	···	···	···	2.534	···	1	0	1	1
HD6656	7.603	±0.003	0.275	±0.002	0.109	±0.003	0.496	±0.005	2.652	±0.006	97	122	123	16
HD6834	8.421	±0.003	0.300	±0.002	0.111	±0.004	0.394	±0.005	2.633	±0.005	70	90	77	15
HD7895A	8.003	±0.002	0.480	±0.002	0.338	±0.004	0.306	±0.004	2.563	···	256	297	3	13
HD8786	7.903	±0.003	0.308	±0.002	0.131	±0.004	0.413	±0.004	2.639	±0.004	35	51	50	10
HD9023A	7.980	±0.003	0.345	±0.002	0.156	±0.005	0.439	±0.008	2.632	±0.005	31	42	35	13
HD9595	8.913	±0.003	0.391	±0.003	0.197	±0.005	0.402	±0.004	2.610	±0.004	234	259	162	12
HD10476A	5.232	±0.006	0.495	±0.004	0.367	±0.006	0.306	±0.005	···	···	13	19	0	7
HD11886A	8.482	±0.002	0.245	±0.003	0.148	±0.004	0.568	±0.006	2.700	±0.005	50	67	65	14
HD13759	8.359	±0.002	0.382	±0.004	0.126	±0.006	0.486	±0.004	2.634	±0.004	102	129	115	15
HD16160A	5.789	±0.004	0.561	±0.004	0.518	±0.006	0.275	±0.004	2.533	···	46	55	1	13
HD17122	7.866	±0.003	···	···	···	···	···	···	···	···	8	0	0	3
HD19445	8.052	±0.002	0.353	±0.001	0.051	±0.004	0.205	±0.007	2.582	±0.009	182	226	191	17
HD19983	7.807	±0.004	0.460	±0.002	0.090	±0.004	0.695	±0.010	2.648	±0.004	319	349	285	15
HD20165	7.813	±0.003	0.510	±0.003	0.409	±0.005	0.300	±0.007	2.551	···	75	96	2	16
HD20427	7.340	±0.003	0.331	±0.003	0.120	±0.003	0.387	±0.003	2.616	±0.002	120	138	127	15
HD21197	7.841	±0.008	0.664	±0.003	0.733	±0.004	0.156	±0.005	···	···	42	55	0	14
HD22879	6.687	±0.003	0.369	±0.003	0.119	±0.004	0.274	±0.003	2.584	±0.007	300	357	270	14
HD25322	7.820	±0.003	0.318	±0.004	0.120	±0.005	0.420	±0.002	2.625	±0.005	173	195	197	17
BS1430	···	···	···	···	···	···	···	···	2.788	±0.003	0	0	16	7
HD32147	6.200	±0.004	0.610	±0.004	0.640	±0.006	0.240	±0.003	2.545	···	84	93	1	17
HD36003A	7.625	±0.002	0.639	±0.003	0.664	±0.004	0.193	±0.005	2.512	···	38	44	3	9
BS2601A	6.201	±0.005	0.347	±0.005	0.135	±0.008	0.399	±0.008	2.607	±0.005	178	192	219	20
BS2835	6.535	±0.004	0.323	±0.005	0.125	±0.008	0.353	±0.007	2.617	±0.004	188	199	223	20
HD75596	8.637	±0.002	0.324	±0.003	0.126	±0.002	0.349	±0.006	2.612	±0.007	66	77	62	10
HD76910	8.486	±0.005	0.302	±0.002	0.117	±0.004	0.385	±0.005	2.627	±0.007	73	90	80	11
HD77354	7.949	±0.015	0.444	±0.002	0.197	±0.004	0.349	±0.006	2.571	±0.003	44	59	68	11
HD81539	8.523	±0.004	0.285	±0.003	0.127	±0.005	0.455	±0.006	2.645	±0.004	80	100	89	18
HD84937	8.335	±0.003	0.304	±0.003	0.056	±0.008	0.355	±0.007	2.613	±0.006	204	251	239	24
HD85902	8.135	±0.003	0.378	±0.002	0.159	±0.005	0.269	±0.006	2.586	±0.003	57	75	75	17
HD87195	8.256	±0.004	0.419	±0.002	0.232	±0.007	0.348	±0.007	2.591	±0.004	145	182	185	19
HD87646	8.072	±0.003	0.398	±0.002	0.226	±0.007	0.388	±0.008	2.614	±0.003	154	190	188	19
HD88923	7.695	±0.002	0.268	±0.002	0.095	±0.004	0.683	±0.004	2.641	±0.003	106	138	138	17
HD94028	8.224	±0.004	0.344	±0.003	0.078	±0.005	0.253	±0.005	2.588	±0.004	213	265	254	25
HD97560	7.893	±0.005	0.450	±0.002	0.139	±0.006	0.431	±0.006	2.557	±0.003	46	65	54	15
BS4550	6.428	±0.004	0.482	±0.004	0.222	±0.007	0.162	±0.010	2.538	±0.008	121	151	121	15
HD105584	7.504	±0.003	0.248	±0.002	0.130	±0.004	0.490	±0.009	2.680	±0.005	84	83	70	15

TABLE 5 (CONTINUED)

Std Star (HD/BS≡HR)	V [mag]	σ_V [mag]	$(b–y)$ [mag]	$\sigma_{(b-y)}$ [mag]	m_1 [mag]	σ_{m_1} [mag]	c_1 [mag]	σ_{c_1} [mag]	Hβ [mag]	$\sigma_{H\beta}$ [mag]	N_V	N_{uvby}	$N_{H\beta}$	N_{runs}
HD106509	8.158	±0.005	0.330	±0.004	0.142	±0.009	0.438	±0.010	2.621	±0.005	54	73	53	16
HD106510	8.280	±0.005	0.369	±0.005	0.150	±0.012	0.308	±0.009	2.593	±0.004	45	59	59	15
HD107550	8.370	±0.010	0.502	±0.000	0.134	±0.001	0.427	±0.002	2.553	±0.005	8	3	16	6
HD107823	8.789	±0.004	0.307	±0.002	0.137	±0.005	0.401	±0.006	2.633	±0.006	67	84	73	16
HD108076	8.038	±0.005	0.381	±0.003	0.137	±0.009	0.251	±0.007	2.575	±0.005	38	51	50	16
HD108189	7.734	±0.012	0.494	±0.003	0.255	±0.008	0.340	±0.011	2.566	±0.003	133	99	136	13
HD108641	8.823	±0.004	0.519	±0.004	0.272	···	0.334	···	2.557	±0.006	18	3	23	6
HD108678	8.056	±0.003	0.279	±0.004	0.135	±0.010	0.545	±0.013	2.657	±0.004	216	230	246	15
BS4845	5.954	±0.005	0.373	±0.005	0.148	±0.010	0.283	±0.004	2.583	±0.005	22	29	28	8
HD117243	8.347	±0.003	0.404	±0.003	0.216	±0.007	0.400	±0.009	2.610	±0.002	87	104	113	16
HD125375	8.128	±0.002	0.202	±0.001	0.134	±0.005	0.828	±0.006	2.711	±0.006	64	50	78	14
HD125455A	7.576	±0.003	0.495	±0.002	0.388	±0.008	0.290	±0.004	2.556	±0.005	159	177	111	11
HD125607	8.093	±0.003	0.562	±0.001	0.391	±0.005	0.352	±0.013	2.563	±0.005	29	4	42	12
HD126531A	7.633	±0.006	0.290	±0.002	0.141	±0.005	0.495	±0.005	2.657	±0.004	63	84	84	15
HD127029	7.989	±0.009	0.382	±0.004	0.166	±0.009	0.306	±0.006	2.593	±0.004	62	82	73	15
HD128165	7.214	±0.005	0.578	±0.003	0.567	±0.006	0.236	±0.005	2.534	±0.003	62	79	72	15
HD128279	8.031	···	0.455	···	0.077	···	0.268	···	2.551	···	4	4	4	1
HD129755	7.583	±0.004	0.259	±0.004	0.151	±0.009	0.472	±0.008	2.675	±0.005	213	245	125	12
HD130353	8.596	±0.005	0.285	±0.002	0.172	±0.008	0.696	±0.006	2.678	±0.005	57	71	71	15
HD131597	8.427	±0.004	0.475	±0.005	0.208	±0.008	0.309	±0.007	2.555	±0.003	183	226	207	15
HD132475	8.561	±0.006	0.389	±0.004	0.083	±0.013	0.283	±0.006	2.569	±0.005	24	28	28	8
HD134169	7.687	±0.003	0.363	±0.004	0.123	±0.007	0.313	±0.004	2.585	±0.004	90	116	67	13
HD135662	8.701	±0.004	0.315	±0.003	0.154	±0.005	0.450	±0.002	2.653	±0.005	6	9	9	4
HD136047	8.479	±0.004	0.359	±0.002	0.134	±0.003	0.509	±0.004	2.665	±0.006	6	9	9	4
HD137778B	7.570	±0.011	0.535	±0.003	0.463	±0.004	0.291	±0.003	2.559	±0.003	3	6	7	3
HD140283	7.210	±0.005	0.378	±0.004	0.043	±0.011	0.283	±0.007	2.566	±0.006	93	111	101	14
BS5930	6.129	±0.002	0.187	±0.003	0.108	±0.004	0.725	±0.004	2.726	···	25	30	1	5
HD143131	8.061	±0.002	0.405	±0.003	0.144	±0.007	0.607	±0.004	2.668	±0.004	15	22	22	4
HD144253	7.375	±0.005	0.602	±0.002	0.602	±0.006	0.212	±0.007	2.529	±0.008	6	8	8	4
BS6189	6.341	±0.003	0.330	±0.002	0.121	±0.002	0.399	±0.005	2.608	±0.009	35	72	65	8
HD154363A	7.700	±0.003	0.673	±0.004	0.618	±0.010	0.193	±0.013	···	···	26	35	0	4
HD156392	8.368	±0.003	0.312	±0.006	0.148	±0.007	0.561	±0.002	2.697	···	8	8	2	2
BS6467	6.362	±0.006	0.296	±0.008	0.111	±0.022	0.441	±0.015	2.649	±0.007	156	144	157	14
BS6577	6.133	±0.005	0.377	±0.005	0.150	±0.011	0.567	±0.008	2.627	±0.004	44	50	48	13
HD161303	8.460	±0.007	0.295	±0.009	0.147	±0.016	0.548	±0.006	2.686	±0.034	17	19	19	6
HD162503	8.320	±0.002	0.462	±0.008	0.189	±0.012	0.425	±0.005	2.597	±0.007	15	16	19	7
HD175384	8.276	±0.003	0.256	±0.003	0.143	±0.009	0.613	±0.007	2.706	±0.006	16	20	22	5
HD176014	8.655	±0.004	0.328	±0.002	0.087	±0.007	0.494	±0.006	2.645	±0.006	17	21	13	7
HD186025	8.855	±0.005	0.384	±0.004	0.126	±0.006	0.513	±0.005	2.661	±0.004	91	104	90	10
HD191264	8.347	±0.004	0.463	±0.004	0.161	±0.005	0.414	±0.007	2.591	±0.005	81	87	83	10
HD191365	8.381	±0.004	0.381	±0.002	0.102	±0.006	0.504	±0.008	2.643	±0.006	47	63	64	11
HD193901	8.659	±0.003	0.379	±0.002	0.105	±0.007	0.218	±0.005	2.565	±0.003	37	40	33	8
HD196892	8.242	±0.003	0.350	±0.002	0.095	±0.003	0.305	±0.002	2.590	±0.004	32	35	25	6
HD198486	8.047	±0.004	0.357	±0.003	0.167	±0.006	0.464	±0.007	2.627	±0.009	49	60	58	11
HD198585	7.668	±0.002	0.380	±0.002	0.125	±0.002	0.419	±0.005	2.614	±0.023	81	74	86	11
BS8086	6.038	±0.003	0.806	±0.001	0.679	±0.001	0.067	±0.006	···	···	43	49	0	5

TABLE 5 (CONTINUED)

Std Star (HD/BS≡HR)	V [mag]	σ_V [mag]	$(b–y)$ [mag]	$\sigma_{(b-y)}$ [mag]	m_1 [mag]	σ_{m_1} [mag]	c_1 [mag]	σ_{c_1} [mag]	Hβ [mag]	$\sigma_{H\beta}$ [mag]	N_V	N_{uvby}	$N_{H\beta}$	N_{runs}
HD206843	8.359	±0.004	0.371	±0.004	0.098	±0.005	0.263	±0.007	2.584	±0.007	50	52	56	13
HD207608	8.051	±0.004	0.319	±0.002	0.150	±0.004	0.511	±0.006	2.650	±0.008	38	44	48	13
HD207687	7.506	±0.006	0.494	±0.003	0.226	±0.004	0.299	±0.005	2.551	±0.007	100	119	92	13
BS8455	6.174	±0.004	0.450	±0.006	0.202	±0.009	0.340	±0.008	2.565	±0.001	121	129	5	13
HD210752	7.445	±0.005	0.361	±0.002	0.132	±0.003	0.286	±0.003	2.592	±0.003	105	121	74	14
HD212029A	8.508	±0.003	0.363	±0.003	0.099	±0.006	0.286	±0.008	2.587	±0.007	24	34	32	12
HD213802	7.969	±0.002	0.408	±0.002	0.181	±0.005	0.395	±0.009	2.593	±0.004	25	34	30	12
BS8826	5.153	···	0.088	···	0.148	···	1.101	···	2.824	±0.004	2	2	5	4
HD220339	7.791	±0.003	0.515	±0.003	0.419	±0.005	0.263	±0.007	2.548	±0.006	49	64	4	14
BS8899	6.689	±0.003	0.322	±0.003	0.120	±0.005	0.407	±0.005	2.629	±0.005	108	126	67	14
BS9039	···	···	···	···	···	···	···	···	2.826	±0.001	0	0	3	2
HD3567	9.253	±0.007	0.334	±0.003	0.084	±0.003	0.331	±0.006	2.604	±0.009	5	7	5	5
HD4306	9.034	±0.005	0.521	±0.001	0.049	±0.004	0.338	±0.001	2.538	±0.009	4	4	4	3
-17:267	11.097	···	0.317	···	0.054	···	0.336	···	···	···	1	2	0	1
G159-50	9.091	···	0.388	···	0.123	···	0.240	···	2.575	±0.003	1	3	5	2
HD16031	9.780	±0.005	0.325	±0.002	0.061	±0.006	0.308	±0.018	2.596	±0.006	6	7	7	3
G102-47	10.314	±0.003	0.463	±0.007	0.092	±0.006	0.247	±0.005	2.547	±0.001	9	10	10	3
HD45282	8.023	±0.004	0.456	±0.002	0.105	±0.005	0.268	±0.007	2.546	±0.002	25	27	25	7
HD195636	9.557	±0.002	0.466	±0.005	0.004	±0.006	0.477	±0.011	2.555	±0.002	11	12	11	5
G28-43	9.936	···	0.461	···	0.163	···	0.146	···	2.539	···	1	2	2	1
HD219617	8.167	±0.006	0.349	±0.002	0.073	±0.002	0.241	±0.002	2.591	±0.007	6	7	5	4

BS4550, HD128165, HD140283, BS5930, HD162503, HD191365, BS8086, BS8826, and BS9039. However, in Table 5 all of these stars used as standards for *uvby* photometry have $\sigma_V \leq \pm0.006$, and all stars used as Hβ standards have $\sigma_{H\beta} \leq \pm0.009$, with dispersions and differences (as seen in Table 5 or by comparing Tables 1 and 5) significantly less than those suggested by the VSX or by SIMBAD, and thus providing little evidence for photometric variability.

However, more recent studies have shown that BS5930 and BS9039 are indeed "very-low-amplitude" ($\Delta m \leq 0\overset{\text{m}}{.}02$–$0\overset{\text{m}}{.}03$) δ Scuti stars (Paunzen, et al. 2010; Le Contel, et al. 1974). In Table 5 all σ's for BS5930 are $\leq \pm0.004$; BS9039 has been little used for our observations, only for Hβ, and its $\sigma_{H\beta}$ is ±0.001. These values confirm the "very-low-amplitude" nature of these two δ Scuti stars.

In previous studies BS4550 and BS8086 have been tagged as possible flare stars (Beardsley et al. 1974; Blanco et al. 1972); but in Table 5 little evidence for flare activity can be detected: ±0.004 and ±0.003 for σ_V, respectively; the largest dispersion for these two stars is $\sigma_{c_1} = \pm0.010$ for BS4550. Either these stars are not in fact flare stars, or we have been lucky to always observe them outside of eruption; both have received a large number of *uvby* observations, especially BS4550.

HD191365 has been identified as an Algol-type eclipsing binary (Wraight et al. 2011), but again little evidence for this is seen in Table 5, with $\sigma_V = \pm0.004$, and all dispersions less than or equal to ±0.008; it seems that all *uvby*-Hβ observations of HD191365 in Table 5 were taken outside of eclipse.

6. CONCLUSIONS

The main results of this paper are the following:

1. The secondary standards of Table 1 which have finally **not** been used for the observations and transformations of the HVMPS and VMPS projects are those four shown to be definite photometric variables in SIMBAD (BS812, HD80715, HD156026, and BS8799), and those which produce small non-linearities in the photometric transformations, such as the hotter

Hβ standards (BS63, BS2857, BS4515, and BS8060), and the redder subgiants (b–$y \gtrsim 0.5$ and $c_1 \gtrsim 0.35$, such as HD2796, HD6268, HD17122, HD107550, BS5270, ...). These latter, non-linearity restrictions apply only to the *uvby*–Hβ photometer at the OAN-SPM.

2. The instrumental and transformation errors of Tables 3 and 4, as well as the transformation coefficients of Table 2, show that the *uvby*–Hβ photometry of our HVMPS and VMPS projects has remained consistent, precise, and accurate, to a high degree, over the extent of these projects, from 1987 to 2007. The transformation coefficients agree as expected with those obtained previously (Olsen 1983, 1993).

3. The constancy of our techniques and methods, of our photometer, and of the present standard-star list have allowed us to provide a large set of very homogeneous and consistent *uvby*–Hβ photometry for the HVMPS and VMPS projects at the OAN-SPM observatory. By implication, this is true for observing runs prior to 1987 and posterior to 2007, which have made use of the same grating-angle calibration, standard-star list and restrictions, and observing and reduction techniques.

4. The transformed standard values of Table 5 are necessary for putting our *uvby*–Hβ data into the CDS data base in a homogeneous way. These values have also provided us with a means to detect, or refute, variable-star candidates, especially long-period ones due to the long time extent of these projects. For example, a dozen “suspected” variable stars (from SIMBAD or the VSX) in our standard-star data base, Table 1, are not confirmed as variable stars, and three recently documented variable stars (two low-amplitude δ Scuti variables and one eclipsing binary) show very little effect upon the precision or accuracy of our photometric results.

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