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Southern Spectrophotometric Standards. I

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ABSTRACT. We have obtained new observations of both secondary and tertiary spectrophotometric standards with the RC spectrographs and charge-coupled device (CCD) cameras on the 1.5-m and 4-m telescopes at CTIO in the wavelength range 3300–7550 Å, as well as $UBV(RI)_{\rm KC}$ photometry for these stars. We have modified the monochromatic fluxes of the secondary spectrophotometric standards published by Taylor (1984) according to the new calibration of Vega provided by Hayes (1985). We have also tuned the zero point of the energy distribution of these stars by matching their V synthetic magnitudes to the observed magnitudes. We use these adjusted spectrophotometric standards in order to calculate new fluxes for the tertiary standards of Stone and Baldwin (1983), as well as for three stars of the northern hemisphere from Stone (1977). We find that the synthetic magnitudes calculated from our spectra through the B and V bands agree extremely well with our photometry, to better than 1% on average. For the monochromatic fluxes, we find an internal precision better than 0.01 mag at all wavelengths, and a fair agreement with previous measurements of the tertiary standards. We present also a fine grid of averaged monochromatic fluxes (at continuous steps of 16 Å) for the ten secondary standards selected for our program, to be used in the flux calibration of high-dispersion spectra.

1. INTRODUCTION

In order to derive accurate effective temperatures, bolometric luminosities, and surface gravities for astronomical objects from their energy distribution, it is necessary to calibrate spectroscopic observations with sources of known spectral energy distribution.

The *primary* standard star for these calibrations is the bright star Vega located in the northern hemisphere at a declination of +39°. The optical energy distribution of this star has been measured by several observers relative to terrestrial blackbodies whose monochromatic fluxes are known. The earliest efforts in this direction correspond to Hayes (1967, 1970) at Lick Observatory; Oke and Schild (1970) at Palomar Mountain; and Hayes, Latham, and Hayes (1975) at Mount Hopkins. A revised spectral-energy distribution of Vega that combined all of the previous calibrations was published by Hayes and Latham (1975) (HL 75 system hereafter). More recently, Hayes (1985) updated the fundamental calibration of Vega with the addition of new calibrations obtained by Tüg, White, and Lockwood (1977), Terez and Terez (1979), Kharinotov et al. (1980), and Dragomiretskij, Komarov, and Terez (1983).

The flux calibration of the primary star has been transferred by several observers to a number of *secondary* bright stars (V=1–6) located mostly in the northern hemisphere and on the celestial equator. Breger (1976) collected a large number of spectrophotometric measurements of the secondary standards obtained by different observers in the wavelength range 3300–6800 Å. Breger transformed all of these observations, which are all tied to Vega, to the HL 75 calibration of the primary standard. An extension of this work to longer wavelengths and to a larger number of stars was accomplished by Taylor (1984), who published flux measurements for 15 bright secondary stars in the wavelength range 3300–10800 Å in the spectrophotometric HL 75 system.

The secondary standards are generally too bright for modern detectors on large telescopes. Stone (1974, 1977) published energy distributions for *tertiary* stars in the northern hemisphere in the brightness range V=9–13, calibrated with respect to the HL 75 secondary standards. The transfer of the spectrophotometric calibration to the southern hemisphere was done by Stone and Baldwin (1983) and Baldwin and Stone (1984) for 18 stars with visual magnitudes between 10 and 14.5. These fluxes in the HL 75 system were obtained with the Cerro Tololo Inter-American Observatory (CTIO) scanner on the 1.5-m telescope at discrete wavelengths in the range between 3200 and 10400 Å, and the SIT Vidicon spectrometer on the 4-m and 1.5-m telescopes. More recent spectrophotometry data for tertiary standards have been published by Gutiérrez-Moren et al. (1988), Massey et al. (1988), Massey and Gronwall (1990), and Filippenko and Greenstein (1984). When observing with a charge-coupled device (CCD) these sets of intermediate brightness stars permit adequate signal-to-noise ratios in relatively short exposure times. For certain applications however, these tertiary standards are not sufficient. For example, when the CCD is replaced with a photon-counting system, the observer is forced to use neutral-density filters in order to avoid detector saturation. A set of fainter standards is needed. Also, with the availability of high-quality digital detectors it has

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become evident that the southern standard stars calibration has significant errors.

In 1987 a group of the scientific staff of CTIO initiated a project to recalibrate the tertiary southern spectrophotometric standards in the wide wavelength range permitted by the CCDs and to measure new fainter standards. This paper reports newly calibrated fluxes in the wavelength range 3300–7550 Å gathered in the course of the last four years for the Baldwin and Stone tertiary standards, reduced with respect to the recent calibration of Vega published by Hayes (1985). We also report accurate $UBV(RI)_{KC}$ photometry obtained at CTIO for the tertiary standards included in our program. We include a fine grid of fluxes (at continuous steps of 16 Å) for the ten secondary standards selected for our program, useful for the calibrations of high dispersion spectrophotometry. In forthcoming papers we will extend the spectrophotometric calibration for these stars to the red through 1 μm, blueward to 3150 Å, and will report fluxes obtained at CTIO for a new set of relatively line-free spectrophotometric standards with V between 14–17.

Astronomers interested in the use of the fluxes of the secondary and tertiary standards presented here may request copies of our data files by contacting us at the offices of CTIO. We will provide our data in the form of electronic ASCII tables, or spectra in FITS format. Our postal address is

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TABLE 1
Secondary Standard Stars

HR	Star	MK Type	(U-B)	(B-V)	V	$(V-R)_{KC}$	$(V-I)_{KC}$
718	ξ^2 Cet	B9 III	-0.107 C	-0.056 C	4.279 C	-0.023 C	-0.063 C
1544	π^2 Ori	A1 V	...	0.01 C	4.355 C	0.014 C	0.039 C
3454	η Hya	B3 V	-0.743 C	-0.200 C	4.295 C	-0.083 C	-0.200 C
4468	θ Crt	B9.5 V	-0.18 C	-0.07 C	4.700 C	-0.023 C	-0.063 C
4963	θ Vir	A1 IV	-0.01 C	-0.00 C	4.375 C	0.003 C	0.010 C
5501	108 Vir	B9.5 V	-0.080 C	-0.023 C	5.681 C	0.004 H	-0.026 H
7001	α Lyr	A0 V	0.00 J	0.00 J	0.03 J	-0.037 J	-0.045 J
7596	58 Aql	A0 III	-0.01 C	0.10 C	5.62 C	...	...
7950	ϵ Aqr	A1 V	0.029 C	-0.001 C	3.778 C	-0.005 C	-0.010 C
8634	ζ Peg	B8 V	-0.24 J	-0.09 J	3.40 J	-0.037 J	-0.079 J
9087	29 Psc	B7 III-IV	-0.501 C	-0.136 C	5.120 C	-0.052 C	-0.122 C

Code for references:

J: Johnson et al (1966)
C: Cousins (1984,1980,1971)
H: This paper

2. CONSTRUCTION OF THE STANDARD SYSTEM

We have chosen the *secondary* standards published by Taylor (1984) as the defining spectrophotometric system since the *primary* standard is, unfortunately, not observable from Chile. Some of these stars are suitably located in the sky (near the equator) to be observed from CTIO. However, given their apparent brightness, only ten of these standards are faint enough to be observed in a 1-s exposure without saturating the CCD. Exposures shorter than 1 s are not permitted by our data acquisition system. In Table 1, we list the secondary standard stars (and Vega) selected to calibrate our instrumental system along with their *MK* spectral types and $UBV(RI)_{KC}$ photometry. The spectral types are from Hoffleit (1982). The source of each magnitude is also specified in this table. Preference was given to South African photometry in the following order: Cousins (UBV, 1984); Cousins (VRI, 1980); and Cousins (UBV, 1971). For the stars not included in Cousins' papers we list Johnson et al.'s (1966) UBVRI photometry. It was necessary to transform these Johnson RI magnitudes to the Kron–Cousins system via the equations derived by Taylor (1986), viz.,

$$(V-R)_{KC}=0.717[(V-R)_J-C_2]-0.021,$$

$$(R-I)_{KC}=0.902[(R-I)_J-C_1]-0.087\delta_{BJ}(U-B)+0.073.$$

The definitions of C_1, C_2, and $\delta_{BJ}(U-B)$ may be found in Taylor (1986). For HR 5501, which has no RI photometry published, we list our own measurement obtained with a single-channel photometer on the CTIO 0.4-m telescope. We used the standard Tololo set of $V(RI)_{KC}$ filters system, and a dry-ice cooled RCA 31034 GaAs photomultiplier with a 26 arcsec diameter diaphragm as described by Hamuy et al. (1990). The instrumental magnitudes were transformed to the standard system, based on observations of E region standards published by Menzies et al. (1980) and Cousins (1980). The values quoted in Table 1 for HR 5501 are the averages of two observations taken on different nights. The differences between the two observations were 0.013 in $V-R$ and 0.021 in $V-I$.

The monochromatic fluxes published by Taylor for the secondary standards are tied to the fundamental calibration of Vega given by HL 75. The new calibration of the primary star provided by Hayes (1985) led us to modify Taylor's fluxes accordingly. The comparison of the two calibrations of Vega is not straightforward since each calibration used different wavelengths and bandpasses. To compare the two calibrations, we interpolated the new Hayes calibration of Vega, which is given as a continuous spectrum with monochromatic fluxes given at 25 Å, to the wavelengths listed by Taylor. This process is hampered by the fact that, except at 8712 Å, Taylor did not specify the bandwidth around the tabulated wavelengths over which the monochromatic flux was estimated. We have reviewed the original sources of spectrophotometry used in his calibration (see Table 1 in Taylor's paper). Overall, we found a wide range of bandwidths between 30 (Hayes 1970) and 100 Å (Schild et al. 1971) and, somewhat arbitrarily, we adopted a width of 45 Å for all wavelengths but 8712 and 3300 Å. For the former we used a band of 32 Å, as was explicitly pointed out by Taylor. For the latter we were forced to use Hayes' (1985) original value of 25 Å since his calibration does not extend blueward of this wavelength. Figure 1 shows the differences in flux (expressed in magnitudes) between the two calibrations of Vega, plotted as a function of wavelength. Overall, the differences between

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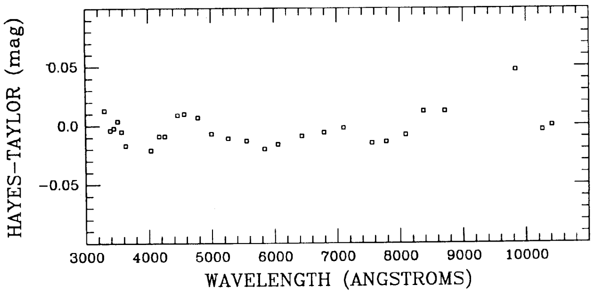

FIG. 1—Differences between Hayes (1985) and Taylor's (1984) fluxes (expressed in magnitudes) for Vega plotted as a function of wavelength.

the two energy distributions do not exceed 0.020 mag, except at 9834 Å where the difference amounts to 0.047 mag. The mean difference (in units of magnitudes) is

$$\Delta(\text{Hayes}-\text{Taylor})=-0.003\pm0.014\ (\text{rms}).$$

Note that the difference of −0.013 mag at 5556 Å corresponds to the change in the absolute flux of Vega at this wavelength between the two calibrations, from 3.500×10^{-20} (HL 75) to 3.542×10^{-20} ergs $\text{cm}^{-2}\,\text{s}^{-1}\,\text{Hz}^{-1}$ (Hayes 1985).

The conversion of the adopted monochromatic fluxes into the traditional monochromatic magnitudes scale used when publishing spectrophotometric fluxes involves the adoption of a zero point for the magnitude scale. Although this is a purely arbitrary constant without any physical meaning, there is some confusion in the numerical value to be used since a range of zero points may be found in the literature. As an example, Table 2 summarizes some of these values. We have chosen to use in this paper the recent value from Massey et al. (1988), namely

$$m_0=-48.590, \qquad (1)$$

which corresponds to a flux $(f_\nu)_0=3.664\times10^{-20}$ ergs $\text{cm}^{-2}\,\text{s}^{-1}\,\text{Hz}^{-1}$, for a zero monochromatic magnitude. With this zero point, we calculated monochromatic magnitudes from Hayes (1985) energy distribution of Vega by means of

$$m_\nu=-2.5\log_{10}[f_\nu]-48.590, \qquad (2)$$

where f_ν is the monochromatic flux in ergs $\text{cm}^{-2}\,\text{s}^{-1}\,\text{Hz}^{-1}$ interpolated at Taylor's wavelengths. The resulting monochromatic magnitudes are given in Table 3. It should be noted that we have adopted a magnitude flux system [Eq. (2)] where the actual V magnitude of Vega is not explicitly used. The zero point in Eq. (2), however, is chosen so that at the effective wavelength of the V band, the flux magnitude system gives a monochromatic magnitude which is

TABLE 2
Zero Points for the Monochromatic Magnitude Scale

Reference	Zero-point
Oke & Gunn (1983)	-48.600
Stone & Baldwin (1983)	-48.595
Baldwin & Stone (1984)	-48.595
Taylor (1984)	-48.597
Massey et al. (1988)	-48.590

TABLE 3
Adopted Calibration for Vega in Magnitudes $m_\nu=-2.5\log_{10}[f_\nu]-48.590$ and Corrections to Taylor's (1984) Magnitudes

λ (Å)	Adopted	Adopted minus Taylor	bandwidth (Å)
3300.	1.200	0.020	25.
3390.	1.178	0.003	45.
3448.	1.164	0.005	45.
3509.	1.148	0.011	45.
3571.	1.122	0.002	45.
3636.	1.092	-0.010	45.
4036.	-0.270	-0.014	45.
4167.	-0.237	-0.002	45.
4255.	-0.222	-0.002	45.
4464.	-0.179	0.016	45.
4566.	-0.139	0.017	45.
4785.	-0.096	0.014	45.
5000.	-0.060	0.000	45.
5264.	-0.011	-0.004	45.
5556.	0.037	-0.006	45.
5840.	0.092	-0.013	45.
6058.	0.145	-0.009	45.
6440.	0.208	-0.002	45.
6792.	0.261	0.001	45.
7102.	0.320	0.005	45.
7554.	0.396	-0.008	45.
7782.	0.434	-0.007	45.
8092.	0.471	-0.001	45.
8376.	0.525	0.019	45.
8712.	0.512	0.019	32.
9834.	0.603	0.054	45.
10256.	0.618	0.003	45.
10406.	0.637	0.007	45.

TABLE 4
Grey Shifts Applied to the Modified Taylor's Magnitudes

Star	Grey-shift
HR 718	+0.002
HR 1544	+0.005
HR 3454	+0.003
HR 4468	+0.003
HR 4963	-0.008
HR 5501	+0.040
HR 7596	+0.002
HR 7950	+0.010
HR 8634	-0.001
HR 9087	+0.021

TABLE 5
Spectrophotometric Secondary Standards

λ [Å]	Δλ	HR 718	HR 1544	HR 3454	HR 4468	HR 4963	HR 5501	HR 7596	HR 7950	HR 8634	HR 9087
3300	25	5.218	5.542	4.135	5.552	5.601	6.712	6.999	5.060	4.125	5.399
3390	45	5.188	5.519	4.145	5.530	5.563	6.675	6.955	5.018	4.111	5.389
3448	45	5.185	5.498	4.168	5.519	5.544	6.667	6.928	5.002	4.115	5.396
3509	45	5.175	5.485	4.185	5.517	5.519	6.654	6.906	4.983	4.108	5.404
3571	45	5.155	5.466	4.203	5.502	5.499	6.639	6.872	4.952	4.093	5.395
3636	45	5.117	5.422	4.197	5.474	5.451	6.608	6.831	4.909	4.077	5.372
4036	45	3.930	4.065	3.822	4.337	4.084	5.373	5.470	3.501	3.019	4.722
4167	45	3.983	4.110	3.892	4.383	4.123	5.410	5.495	3.526	3.076	4.780
4255	45	4.006	4.123	3.916	4.409	4.144	5.427	5.514	3.550	3.109	4.802
4464	45	...	4.160	3.983	4.461	4.181	5.476	5.539	3.587	3.151	4.853
4566	45	4.091	4.194	4.034	4.502	4.224	5.510	5.563	3.634	3.202	4.904
4785	45	4.134	4.222	4.104	4.545	4.247	5.551	5.572	3.651	3.247	4.967
5000	45	4.182	4.274	4.175	4.592	4.290	5.587	5.590	3.693	3.303	5.014
5264	45	4.235	4.322	4.239	4.653	4.339	5.638	5.598	3.743	3.353	5.068
5556	45	4.291	4.363	4.318	4.713	4.376	5.689	5.610	3.785	3.408	5.132
5840	45	4.336	4.403	4.388	4.770	4.422	5.738	5.629	3.824	3.468	5.202
6058	45	4.393	4.452	4.460	4.822	4.474	5.791	5.667	3.870	3.532	5.258
6440	45	4.465	4.516	4.544	4.902	4.543	5.846	5.703	3.936	3.602	5.335
6792	45	4.532	4.562	4.623	4.961	4.590	5.889	5.732	3.981	3.666	5.412
7102	45	4.593	4.616	4.709	5.019	4.646	5.952	5.769	4.042	3.734	5.477
7554	45	4.678	4.693	4.797	5.104	4.718	6.031	5.823	4.126	3.824	5.580
7782	45	4.720	4.728	4.852	5.149	4.760	6.067	5.853	4.161	3.868	5.619
8092	45	4.766	4.763	4.912	5.194	4.796	6.099	5.876	4.198	3.913	5.678
8376	45	4.829	4.825	4.986	5.253	4.847	6.147	5.919	4.253	3.975	5.742
9834	45	4.944	4.885	5.225	5.354	4.910	6.243	5.951	4.319	4.107	5.946
10256	45	4.944	4.898	5.261	5.378	4.926	6.240	5.932	4.326	4.130	5.962
10406	45	4.968	4.914	5.296	5.414	4.960	6.271	5.961	4.356	4.145	5.996

Note: All values are in monochromatic magnitudes $m_\nu = -2.5 \log_{10}(f_\nu) - 48.590$

approximately equal to the V magnitude of Vega, namely 0.03 (Johnson et al. 1966). In particular, we find that $\lambda_{\mathrm{eff}} = 5446$ Å for Vega and $m_{5446} = 0.016$, which is close to the real V magnitude. With this definition of the magnitude flux scale it should be noted that for bands other than V (UBRI, for instance) the monochromatic magnitudes will be quite different than the photometric magnitudes.

The corrections to bring Taylor's magnitudes to Hayes' (1985) spectrophotometric system using our *zero point* are given in Table 3. We then applied this wavelength dependent correction to the monochromatic magnitudes published by Taylor for the ten selected standard stars, and we reduced several nights of observations to test the internal consistency of these *modified* fluxes. From these tests we discovered that a few adjustments to these new values were still necessary, which we summarize as follows.

(1) When calculating the "response curve" for a night's data, i.e., the curve that must be multiplied into wavelength-calibrated, flat-fielded, extinction-corrected spectra to bring the data to an absolute flux system, one generally uses a low-order polynomial or spline curve to fit the data, since discontinuous changes in sensitivity as a

TABLE 6
Synthetic Magnitudes for the Secondary Standards

Star	B_{syn}	$B_{syn}-B_{obs}$	V_{syn}	$V_{syn}-V_{obs}$	R_{syn}	$R_{syn}-R_{obs}$	I_{syn}	$I_{syn}-I_{obs}$
HR 718	4.232	+0.009	4.279	0.000	4.302	0.000	4.341	-0.001
HR 1544	4.345	-0.020	4.355	0.000	4.348	+0.007	4.341	+0.025
HR 3454	4.098	+0.003	4.295	0.000	4.376	-0.002	4.487	-0.008
HR 4468	4.626	-0.004	4.700	0.000	4.732	+0.009	4.773	+0.010
HR 4963	4.368	-0.007	4.375	0.000	4.373	+0.001	4.368	+0.003
HR 5501	5.654	-0.004	5.681	0.000	5.681	+0.004	5.680	-0.027
HR 7596	5.722	+0.002	5.620	0.000	5.541	...	5.455	...
HR 7950	3.782	+0.005	3.778	0.000	3.769	-0.014	3.774	-0.014
HR 8634	3.312	+0.002	3.400	0.000	3.434	-0.003	3.483	+0.004
HR 9087	4.999	+0.015	5.120	0.000	5.167	-0.005	5.250	+0.008
Zero-point		-13.024		-13.711		-13.640		-14.426
RMS		0.009		0.000		0.007		0.014
HR 7001	0.014	-0.016	0.030	0.000	0.042	-0.025	0.052	-0.023

TABLE 7
Tertiary Standards

Star	α (2000.0)	δ	Type	(U-B)	(B-V)	V	$(V-R)_{KC}$	$(R-I)_{KC}$	n	μ_α	μ_δ
										("/yr)	
LTT 377	00:41:46.6	-33:39:10	f	-0.065	+0.478	11.229	+0.295	+0.289	4	-0.45	-0.25
LTT 1020	01:54:49.7	-27:28:29	g	-0.186	+0.557	11.522	+0.361	+0.364	4	0.33	-0.21
EG 21	03:10:30.4	-68:36:05	DA	-0.661	+0.039	11.379	-0.093	-0.064	3	0.00	-0.30
LTT 1788	03:48:22.2	-39:08:35	f	-0.281	+0.469	13.155	+0.317	+0.332	3	0.24	-0.19
LTT 2415	05:56:24.2	-27:51:26	-	-0.215	+0.400	12.214	+0.267	+0.293	3	0.30	-0.18
Hiltner 600	06:45:13.5	+02:08:15	B1	-0.574	+0.179	10.441	+0.120	+0.140	2	...	...
LTT 3218	08:41:33.6	-32:56:55	DA	-0.547	+0.220	11.858	+0.096	+0.111	4	-1.26	1.31
LTT 3864	10:32:13.8	-35:37:42	f	-0.167	+0.495	12.171	+0.323	+0.329	3	-0.34	-0.01
LTT 4364	11:45:36.6	-64:50:24	C_2	-0.664	+0.162	11.504	+0.173	+0.127	1	6.19	-0.33
Feige 56	12:06:39.7	+11:40:39	B5p	...	...	...	...	...	...	...	...
LTT 4816	12:38:50.7	-49:47:58	DA	-0.656	+0.166	13.794	+0.013	+0.027	2	-0.86	-0.13
CD -32°9927	14:11:46.3	-33:03:15	A0	...	...	...	...	...	...	0.01	-0.02
LTT 6248	15:38:59.8	-28:35:34	a	-0.197	+0.491	11.797	+0.319	+0.345	1	-0.25	-0.18
EG 274	16:23:33.7	-39:13:48	DA	-0.969	-0.144	11.029	-0.093	-0.096	1	0.10	-0.01
LTT 7379	18:36:26.2	-44:18:37	G0	-0.020	+0.605	10.225	+0.366	+0.346	6	-0.22	-0.16
LTT 7987	20:10:57.1	-30:13:03	DA	-0.670	+0.046	12.230	-0.062	-0.078	2	-0.43	-0.24
LTT 9239	22:52:40.9	-20:35:27	f	-0.110	+0.609	12.068	+0.397	+0.372	2	0.10	-0.33
Feige 110	23:19:58.3	-05:09:56	sd0	...	...	...	...	...	...	...	...
LTT 9491	23:19:35.2	-17:05:28	DC	-0.843	+0.007	14.112	+0.045	+0.031	4	0.27	0.05

function of wavelength are not expected, except at atmospheric bands which are excluded from the fit. One can turn this argument around and assume that the response curve must be fit by a slowly varying function to search for residuals from the fit that appear in the standards used in the flux calibration. Such a correlated residual would be indicative of an error in the fundamental calibration of the spectrophotometric system at that wavelength. Indeed, for all of the standards, we found a systematic residual of ~0.06 mag for the flux point at 8712 Å in the fit of the instrumental response of our system. The location in wavelength of this flux point in the spectrum, between two absorption lines of the Paschen series, is very critical, since any small shift in the wavelength scale or any difference in spectral resolution could yield significant differences in the flux detected in that bandpass. An inspection of the fundamental spectrum of Vega given by Hayes (1985) shows, on average, a blueshift of 10 Å of the Paschen lines with respect to the rest wavelengths. This shift is obviously not consistent with the radial velocity of Vega of -14 km s^{-1} (Hoffleit 1982), and probably accounts for this abnormal residual at 8712 Å. We decided to delete the flux point at 8712 Å since it is so poorly defined. Unfortunately, with the lack of this flux point, there is a resulting gap of 1500 Å (in the range 8376–9834 Å) with no flux points, which is highly undesirable. Even with a low-order polynomial the interpolation over such a wide wavelength range may lead to errors as high as 0.05 mag around 9000 Å. These interpolation errors can be somewhat minimized by averaging spectra obtained on separate nights, which will be presented in a later paper in this series.

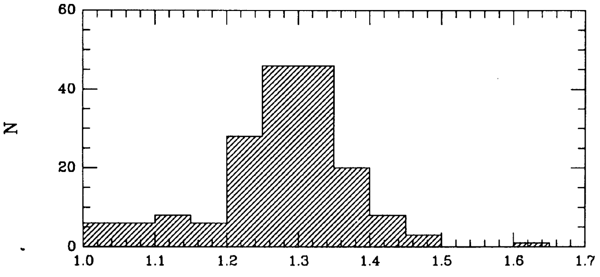

FIG. 2—Histogram with the airmass of all of our observations of the tertiary standards.

(2) In deriving the response curve for our instrumental system we found that the flux points at 4036 and 4464 Å always showed systematic residuals of the order of 0.02 mag with respect to the neighboring points. Taylor however, corrected the fluxes in these bandpasses to zero absorption in the lines He I λ4009, He I λ4026, He I λ4471, and Mg II λ4481 for the three stars with the strongest lines, HR 3454, HR 8634, and HR 9087. Once we removed these absorption lines from our spectra, the residuals of these points dropped to 0.01 mag.

(3) By comparing response curves obtained from different secondary standards, we discovered that some of the published flux distributions for the secondary standards were apparently in error by small multiplicative scale factors. The worst case, HR 5501, showed systematic residuals of the order of 0.05 mag at all wavelengths with respect to the other stars.

Previous authors have used the *V* magnitude of the secondary or tertiary standards to adjust the flux distribution, on the assumption that the relative flux distribution is accurate. This procedure requires turning the broadband magnitude *V* into a monochromatic flux at a given wavelength. Taylor, for instance, performed this operation by forcing the flux of each standard to a monochromatic flux based on the observed *V* magnitude at the effective wavelength of the *V* filter of 5480 Å. This approach is not entirely correct since the effective wavelength does change from star to star due to the differing spectral types. For example, we find a shift of 20 Å in the effective wavelength between the two standards with the most extreme spectral

TABLE 8
Shutter Timing Errors

Date	Telesc	Time (sec)	rms	n
1987 Sep 08/09	1.5-m	0.050	± 0.003	2
1988 Aug 08/09	4-m	0.006	...	1
1989 Jun 14/15	1.5-m	0.040	± 0.001	3
1989 Jun 26/30	1.5-m	0.032	± 0.004	9
1990 Jan 09/11	1.5-m	0.030	± 0.010	5
1991 Jan 14/16	1.5-m	0.021	± 0.005	6

TABLE 9
Summary of the Spectrophotometric Observations

Star	B_{SYN}(rms)	V_{SYN}(rms)	m	n
LTT 377	11.715(07)	11.224(05)	11	4
LTT 1020	12.084(08)	11.522(14)	12	5
EG 21	11.423(07)	11.384(07)	12	4
LTT 1788	13.622(11)	13.155(06)	10	4
LTT 2415	12.606(07)	12.215(10)	6	3
Hiltner 600	10.610(08)	10.445(07)	6	3
LTT 3218	12.084(18)	11.861(12)	6	3
LTT 3864	12.659(10)	12.169(05)	9	5
LTT 4364	11.692(10)	11.500(09)	8	4
Feige 56	10.934(20)	11.057(16)	8	4
LTT 4816	13.966(09)	13.780(11)	9	5
CD -32°9927	10.795(06)	10.452(04)	8	4
LTT 6248	12.280(09)	11.794(13)	5	3
EG 274	10.896(09)	11.021(13)	8	3
LTT 7379	10.848(17)	10.231(12)	16	5
LTT 7987	12.288(16)	12.226(12)	14	5
LTT 9239	12.694(07)	12.072(08)	14	5
Feige 110	11.544(06)	11.826(05)	6	2
LTT 9491	14.136(07)	14.102(06)	10	4

types of our list, viz., 5436 Å for HR 3454 and 5455 Å for HR 7596. Although the change in effective wavelength is relatively small, the error introduced by adjusting the flux scale of each star at a fixed wavelength proves to be as high as 0.02 mag. Instead of using Taylor's approach we adjusted the flux distribution of our ten standards by the direct calculation of the synthetic V magnitudes. To do this, we first fabricated from our observations of the secondary stars, a set of *master* spectra matching all of the modified Taylor's fluxes. Then, we convolved these continuous energy distributions $[f_{\lambda}(\lambda)]$ with the response function for the V filter $[R(\lambda)]$ given by Bessell (1990a), to calculate synthetic magnitudes by means of

$$V_{\rm SYN}=-2.5\log_{10}\left(\int f_{\lambda}(\lambda)R(\lambda)d\lambda\right)+{\rm ZP}, \qquad (3)$$

where ZP is the zero point for the V magnitudes. We calculated ZP by forcing the synthetic magnitude of Vega to match its actual V magnitude of 0.03 mag (Johnson et al. 1966). Finally, for each star we derived the multiplicative ("greyshift") correction required for the modified Taylor's fluxes to match the V synthetic magnitudes with the published values given in Table 1. For all of the stars but HR 5501, we found that the required greyshift was small. For HR 5501 however, the necessary correction proved much larger, at 0.04 mag, in agreement with all of our preliminary reductions. Table 4 summarizes the greyshifts applied to the modified Taylor's fluxes.

Table 5 presents our corrected standard system for the secondary standards, fabricated in the manner previously described. Monochromatic fluxes expressed in magnitudes

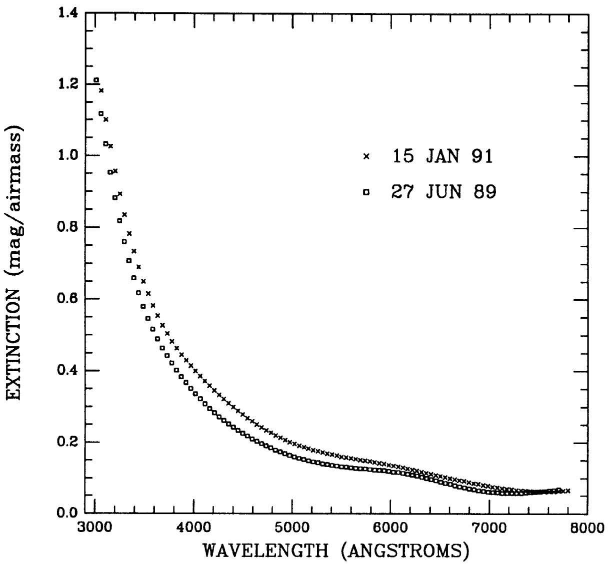

FIG. 3—Atmospheric extinction curves obtained at CTIO on 1991 January 15 and 1989 June 27 (UT). These curves represent typical seasonal atmospheric extinction at Cerro Tololo.

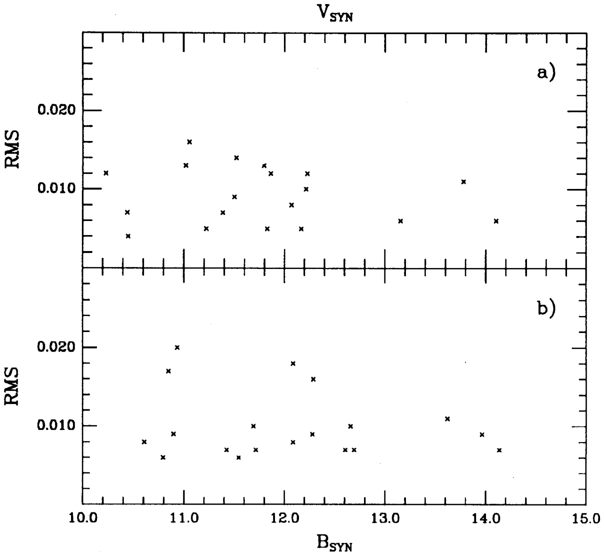

FIG. 4—(a) Root mean square of the mean V synthetic magnitude calculated from the multiple spectra obtained for the tertiary standards, plotted as a function of the V synthetic magnitude. (b) same as (a) but for the B band.

TABLE 10
Night-to-Night Comparison over Broad Bands

Night	B_{SYN}-B_{AVE} (rms)	V_{SYN}-V_{AVE} (rms)
1987 Sep 8/9	+0.003 ± 0.013	+0.002 ± 0.011
1988 Aug 8/9	+0.002 ± 0.007	... ...
1989 Jun 14/15	-0.015 ± 0.006	-0.008 ± 0.002
1989 Jun 26/27	-0.000 ± 0.011	-0.002 ± 0.009
1989 Jun 27/28	-0.009 ± 0.004	-0.009 ± 0.003
1989 Jun 28/29	+0.007 ± 0.008	+0.001 ± 0.008
1989 Jun 29/30	+0.007 ± 0.005	-0.004 ± 0.004
1990 Jan 9/10	+0.001 ± 0.015	+0.007 ± 0.012
1991 Jan 14/15	-0.001 ± 0.011	+0.001 ± 0.009
1991 Jan 15/16	-0.000 ± 0.009	-0.000 ± 0.007

per unit frequency interval are given at the wavelengths used by Taylor for the ten stars selected.

As a by-product of our master spectra we determined the zero point (ZP) of the magnitude scale of the *B*, *V*, *R*, and *I* filters. Except for the *V* filter, we decided not to include in this calculation the spectrum of Vega given that the photometry for this star in $(RI)_{KC}$ is not very reliable. Synthetic magnitudes were obtained by convolving our master spectra of the greyshifted secondary standards with the filter functions B_{90}, V_{90}, R_{90}, and I_{90} given by Bessell (1990a). For each filter, each star yielded a ZP obtained by forcing its synthetic magnitude to match its observed value given in Table 1. The ZP adopted for each filter is the average obtained from the ten spectra. Table 6 summarizes the average ZP for each filter, the synthetic magnitudes obtained for each star from the average ZP, and the mismatch to the observed value. Overall, the ten spectra yield synthetic magnitudes quite consistent with the observed values. Note that the rms of the ZP of the *V* filter is zero, since all of our master spectra were greyshifted in this manner.

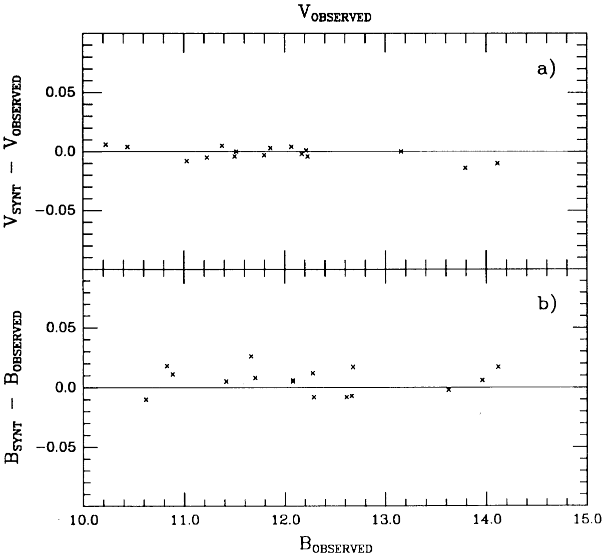

FIG. 5—(a) Comparison of the mean synthetic magnitudes obtained through the *V* band given by Bessell (1990a) and our CCD photometry for the tertiary standards, in the sense synthetic *minus* observed, plotted as a function of the observed *V* magnitudes. (b) same as (a) but for the *B* band.

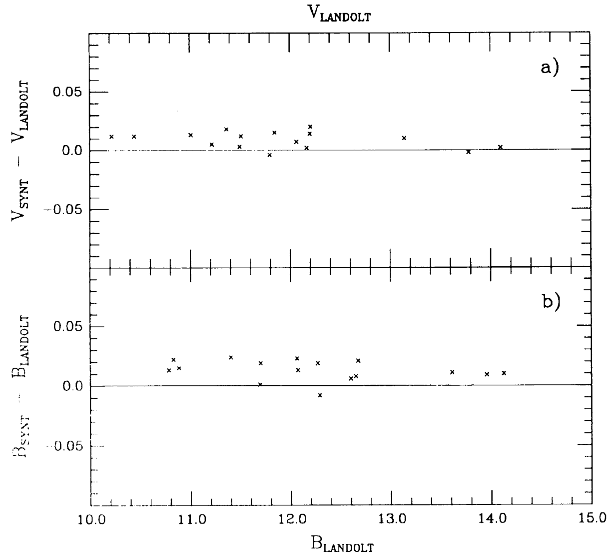

FIG. 6—(a) Comparison of the mean synthetic magnitudes obtained through the *V* band given by Bessell (1990a) and Landolt's (1992a) photometry for the tertiary standards, in the sense synthetic *minus* Landolt, plotted as a function of Landolt's magnitudes. (b) same as (a) but for the *B* band.

All these ZPs were obtained with the telluric absorption features left in the master spectra. In the *R* and *I* filters the ZPs change somewhat when the telluric absorptions are removed from the master spectra, viz., −13.631 and −14.389, respectively. There is no effect in the *B* and *V* filters since no telluric lines lie in these bands. The utility of the zero points given in Table 6 is that spectrophotometry properly calibrated to the standards here, can be converted to accurate broadband photometry, provided the response functions used in Eq. (3) and the zero points in Table 6 are employed.

At the bottom of Table 6 we have included the synthetic magnitudes obtained from the energy distribution of Vega where we have removed the telluric features from the RI bands and used the ZP quoted above. The differences found with respect to the observed magnitudes are rather large in $(RI)_{KC}$ for Vega. It should be remembered however, that the *R* and *I* magnitudes of Vega given in Table 1 resulted from transforming observations from the Johnson instrumental system to the Kron–Cousins system. We are also disturbed by the −0.016 residual for *B*, which is much larger than expected. Photometry of Vega on the $BV(RI)_{KC}$ system with respect to the equatorial standards in the Kron–Cousins system is needed to resolve this conflict.

3. OBSERVATIONS

We included in our program the stars observed by Stone and Baldwin (1983), except for LTT 2511 and L 745-46A.

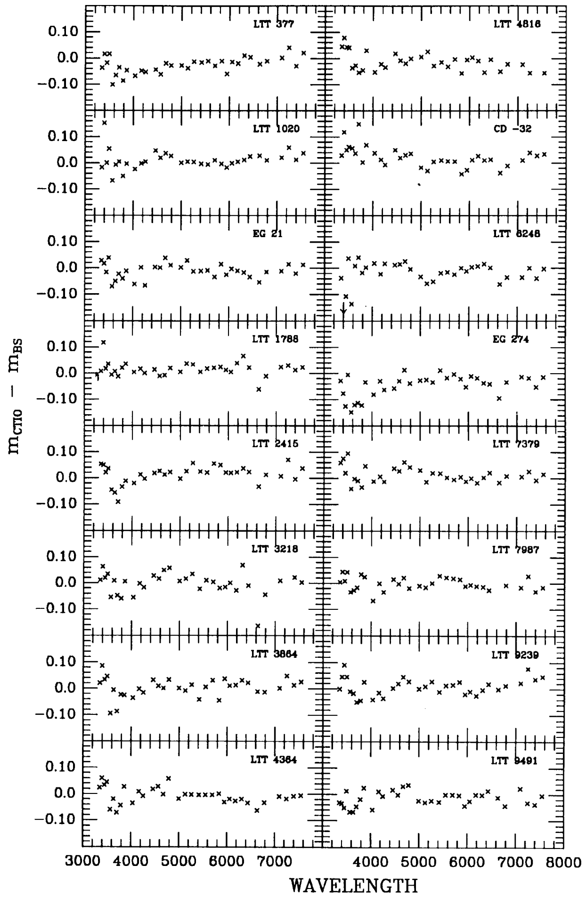

FIG. 7—Comparison between the new CTIO monochromatic fluxes and Baldwin and Stone's (1984) measurements, in the sense of CTIO *minus* Baldwin and Stone, plotted as a function of wavelength for the 16 stars in common. The differences are all expressed in magnitudes. For LTT 6248 the arrow at 3400 Å indicates one point which is out of scale in this plot (see the text).

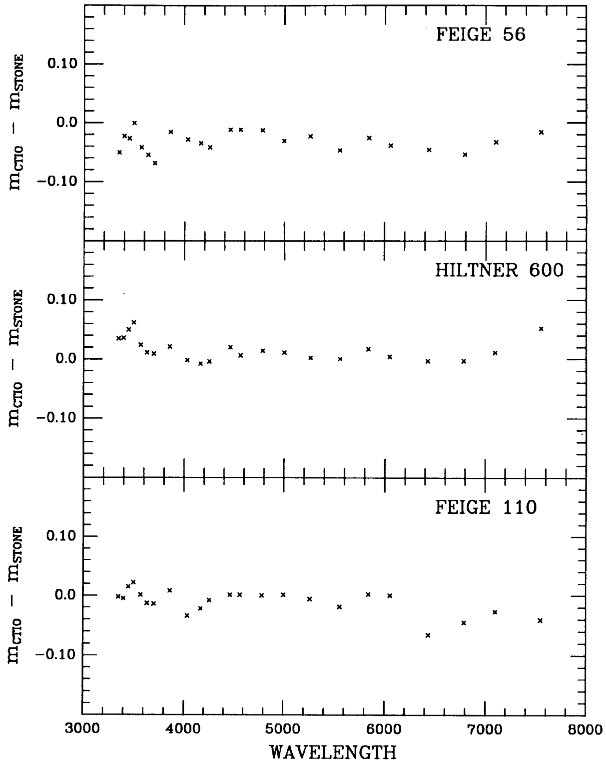

FIG. 9—Comparison between the new CTIO monochromatic fluxes and Stone's (1977) measurements, in the sense of CTIO *minus* Stone, plotted as a function of wavelength for the three stars in common. All differences are expressed in magnitudes.

We excluded the former because of its photometric variability as pointed out by Landolt (1992a). We removed the latter because it lies in a crowded field which introduces contamination through a wide slit. We also included in our list three nearly equatorial standards from the northern hemisphere tertiary calibrations, for comparison of our spectrophotometry with other work. Table 7 presents our tertiary standards, with their equatorial coordinates, spectral classification, and proper motions taken from Stone (1977), Stone and Baldwin (1983), and Massey et al.

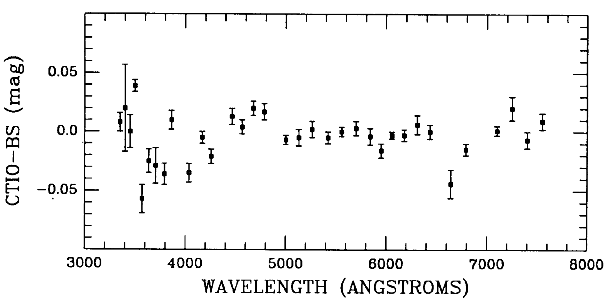

FIG. 8—Mean differences between the new CTIO monochromatic fluxes and Baldwin and Stone's (1984) measurements (expressed in magnitudes), plotted as a function of wavelength, obtained from the 16 stars in common.

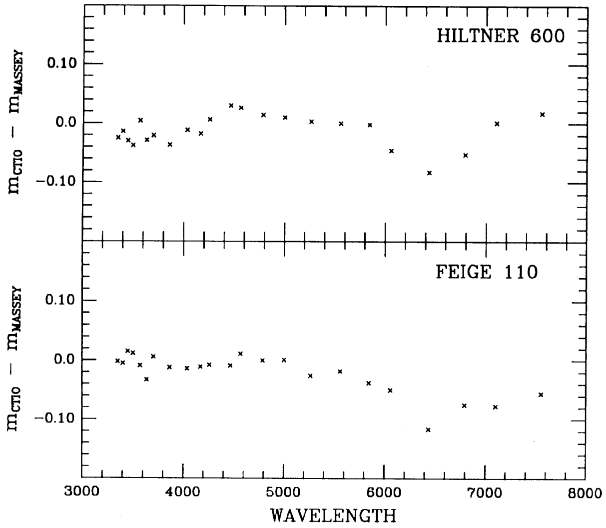

FIG. 10—Comparison between the new CTIO monochromatic fluxes and the measurements of Massey et al. (1988), in the sense of CTIO *minus* Massey et al., plotted as a function of wavelength for the two stars in common. All differences are expressed in magnitudes.

TABLE 11
Magnitudes of Tertiary Standards at Baldwin and Stone (1984) Flux Points

λ [Å]	Δλ	LTT 377	LTT 1020	EG 21	LTT 1788	LTT 2415	LTT 3218	LTT3864	LTT 4364
3350	40	12.658(06)	12.858(06)	11.424(08)	14.313(03)	13.418(21)	12.326(12)	13.516(10)	11.859(08)
3400	40	12.601(05)	12.797(06)	11.432(06)	14.282(06)	13.384(17)	12.328(08)	13.461(07)	11.844(07)
3450	40	12.597(06)	12.795(04)	11.459(03)	14.282(08)	13.366(19)	12.324(07)	13.428(10)	11.838(07)
3500	40	12.551(05)	12.729(06)	11.474(05)	14.230(04)	13.310(19)	12.309(12)	13.391(06)	11.820(06)
3571	40	12.504(08)	12.678(02)	11.475(06)	14.159(06)	13.249(15)	12.280(10)	13.331(08)	11.775(05)
3636	40	12.400(03)	12.578(06)	11.455(03)	14.072(04)	13.159(07)	12.254(09)	13.229(11)	11.735(04)
3704	40	12.299(07)	12.519(04)	11.482(03)	14.032(02)	13.093(08)	12.237(07)	13.148(07)	11.694(08)
3790	40	12.099(02)	12.385(03)	11.495(03)	13.895(04)	12.901(09)	12.206(14)	12.962(10)	11.661(12)
3862	40	11.978(06)	12.321(04)	11.474(06)	13.770(03)	12.713(07)	12.151(16)	12.830(11)	11.632(11)
4036	40	11.688(03)	12.101(03)	11.203(03)	13.608(01)	12.534(03)	11.929(12)	12.630(05)	11.599(03)
4167	40	11.617(02)	12.023(02)	11.157(02)	13.551(04)	12.497(09)	11.883(05)	12.573(06)	11.584(09)
4255	40	11.612(04)	12.030(02)	11.119(02)	13.535(03)	12.481(06)	11.868(08)	12.559(03)	11.567(02)
4464	40	11.491(02)	11.872(04)	11.128(03)	13.439(03)	12.423(05)	11.852(07)	12.467(01)	11.543(02)
4566	40	11.433(03)	11.814(03)	11.126(02)	13.393(02)	12.391(07)	11.841(06)	12.414(04)	11.544(05)
4675	40	11.395(02)	11.762(02)	11.163(02)	13.357(03)	12.358(07)	11.844(03)	12.366(05)	11.584(05)
4785	40	11.357(01)	11.721(02)	11.305(02)	13.324(02)	12.337(09)	11.882(06)	12.338(05)	11.523(06)
5000	40	11.337(05)	11.655(04)	11.287(03)	13.260(02)	12.281(02)	11.842(08)	12.276(04)	11.507(03)
5130	40	11.287(03)	11.609(05)	11.284(04)	13.222(03)	12.260(03)	11.841(08)	12.237(03)	11.574(04)
5263	40	11.272(02)	11.568(04)	11.312(03)	13.188(03)	12.242(05)	11.839(06)	12.209(04)	11.483(04)
5420	80	11.219(02)	11.521(03)	11.354(03)	13.150(02)	12.209(04)	11.842(05)	12.164(03)	11.482(04)
5556	80	11.185(02)	11.479(03)	11.386(03)	13.122(02)	12.186(06)	11.845(05)	12.131(01)	11.491(03)
5700	80	11.166(04)	11.455(04)	11.431(04)	13.106(02)	12.180(06)	11.868(05)	12.116(02)	11.482(05)
5840	80	11.135(02)	11.412(04)	11.460(03)	13.069(03)	12.154(07)	11.865(05)	12.080(03)	11.476(04)
5950	80	11.126(02)	11.398(04)	11.500(04)	13.057(02)	12.146(05)	11.879(06)	12.071(02)	11.484(05)
6056	80	11.121(02)	11.384(04)	11.532(03)	13.049(02)	12.134(03)	11.885(04)	12.055(02)	11.486(03)
6180	80	11.106(05)	11.360(06)	11.545(06)	13.034(03)	12.127(07)	11.896(04)	12.047(03)	11.489(04)
6310	80	11.105(05)	11.356(07)	11.598(05)	13.031(04)	12.131(05)	11.924(03)	12.046(03)	11.505(05)
6436	80	11.090(02)	11.330(05)	11.651(04)	13.007(03)	12.108(06)	11.935(04)	12.017(03)	11.491(05)
6640	80	11.063(02)	11.292(04)	11.761(04)	12.974(03)	12.082(02)	11.981(04)	11.984(01)	11.492(05)
6790	80	11.055(02)	11.275(04)	11.700(03)	12.964(04)	12.077(06)	11.940(03)	11.971(02)	11.502(06)
7100	80	11.047(03)	11.256(05)	11.764(05)	12.949(01)	12.072(04)	11.974(05)	11.956(03)	11.526(06)
7250	80	11.085(07)	11.293(14)	11.840(10)	13.005(05)	12.135(08)	...	12.013(07)	11.597(07)
7400	80	11.045(07)	11.237(08)	11.824(10)	12.948(04)	12.080(06)	12.017(03)	11.958(04)	11.557(08)
7550	80	11.056(07)	11.243(07)	11.877(07)	12.948(03)	12.082(05)	12.037(06)	11.960(02)	11.579(06)

λ [Å]	Δλ	LTT 4816	CD -32	LTT 6248	EG 274	LTT 7379	LTT 7987	LTT 9239	LTT 9491
3350	40	14.049(12)	11.994(08)	13.057(11)	10.576(08)	11.853(09)	12.328(06)	13.574(07)	14.043(03)
3400	40	14.053(07)	11.973(08)	13.035(10)	10.598(05)	11.749(08)	12.348(05)	13.479(06)	14.040(04)
3450	40	14.067(09)	11.964(03)	13.017(12)	10.649(06)	11.754(06)	12.373(04)	13.475(06)	14.064(03)
3500	40	14.065(10)	11.936(11)	12.981(08)	10.659(03)	11.679(08)	12.387(07)	13.409(05)	14.047(02)
3571	40	14.038(11)	11.861(05)	12.909(13)	10.676(06)	11.644(06)	12.381(07)	13.385(06)	14.028(01)
3636	40	14.017(05)	11.761(07)	12.823(06)	10.684(03)	11.522(06)	12.367(04)	13.238(06)	14.008(02)
3704	40	14.021(07)	11.674(08)	12.765(07)	10.712(04)	11.415(07)	12.398(09)	13.205(06)	14.008(03)
3790	40	14.009(09)	11.307(13)	12.577(06)	10.743(08)	11.279(05)	12.408(07)	13.050(06)	14.005(06)
3862	40	13.995(07)	11.033(11)	12.447(06)	10.751(09)	11.271(08)	12.379(09)	13.030(05)	13.999(07)
4036	40	13.812(06)	10.693(03)	12.253(07)	10.624(03)	10.882(05)	12.058(03)	12.734(02)	13.985(04)
4167	40	13.753(09)	10.678(04)	12.192(04)	10.635(03)	10.781(04)	12.014(06)	12.650(03)	13.995(03)
4255	40	13.721(05)	10.608(02)	12.172(07)	10.642(04)	10.821(05)	11.981(04)	12.660(03)	13.998(05)
4464	40	13.683(03)	10.554(02)	12.086(06)	10.688(03)	10.602(05)	11.970(03)	12.457(03)	14.042(05)
4566	40	13.657(03)	10.524(03)	12.050(07)	10.715(05)	10.521(05)	11.973(02)	12.394(03)	14.023(03)
4675	40	13.686(06)	10.485(03)	12.010(06)	10.767(05)	10.466(04)	12.015(03)	12.339(03)	14.036(03)
4785	40	13.814(04)	10.470(02)	11.990(08)	10.866(06)	10.416(02)	12.165(04)	12.292(03)	14.050(02)
5000	40	13.741(02)	10.478(03)	11.902(07)	10.878(04)	10.385(05)	12.125(03)	12.225(03)	14.051(03)
5130	40	13.720(04)	10.465(03)	11.855(07)	10.900(04)	10.330(05)	12.119(02)	12.174(01)	14.054(03)
5263	40	13.726(05)	10.470(02)	11.833(07)	10.941(03)	10.294(03)	12.155(02)	12.132(02)	14.071(02)
5420	80	13.750(03)	10.445(02)	11.796(06)	10.996(06)	10.233(03)	12.194(03)	12.073(02)	14.086(02)
5556	80	13.773(07)	10.422(01)	11.759(08)	11.028(01)	10.187(03)	12.227(02)	12.027(02)	14.104(02)
5700	80	13.802(04)	10.431(03)	11.741(06)	11.092(04)	10.149(02)	12.273(02)	11.990(04)	14.134(02)
5840	80	13.818(06)	10.413(03)	11.705(06)	11.123(06)	10.110(03)	12.300(02)	11.951(03)	14.171(02)
5950	80	13.839(03)	10.418(04)	11.694(07)	11.162(06)	10.102(04)	12.334(03)	11.935(02)	14.162(03)
6056	80	13.858(05)	10.426(03)	11.678(06)	11.204(10)	10.084(04)	12.368(05)	11.915(03)	14.170(06)
6180	80	13.886(06)	10.441(04)	11.662(08)	11.227(09)	10.067(03)	12.384(03)	11.890(06)	14.184(04)
6310	80	13.921(04)	10.455(04)	11.661(07)	11.267(09)	10.057(02)	12.431(03)	11.881(05)	14.203(05)
6436	80	13.980(06)	10.448(05)	11.626(08)	11.294(09)	10.035(04)	12.479(03)	11.853(03)	14.209(04)
6640	80	14.075(05)	10.446(03)	11.593(06)	11.380(07)	9.998(04)	...	11.814(03)	14.234(05)
6790	80	13.993(07)	10.444(03)	11.580(07)	11.371(07)	9.983(04)	12.527(03)	11.797(03)	14.251(04)
7100	80	14.022(05)	10.465(01)	11.560(06)	11.451(07)	9.961(02)	12.589(02)	11.768(03)	14.298(05)
7250	80	14.109(08)	10.544(10)	11.605(11)	11.527(09)	10.000(04)	12.672(03)	11.792(06)	14.373(08)
7400	80	...	10.512(05)	11.556(07)	11.532(05)	9.947(03)	12.653(04)	11.742(07)	14.357(06)
7550	80	14.119(07)	10.528(02)	11.562(08)	11.590(07)	9.950(03)	12.699(04)	11.751(07)	14.390(08)

Notes: All values are in monochromatic magnitudes $m_\nu = -2.5 \log_{10}(f_\nu) - 48.590$
Errors are in units of mmag

TABLE 12
Magnitudes of Tertiary Standards at Stone (1977) Flux Points

λ [Å]	Δλ	Hilt 600	Feige 56	Feige 110
3350	49	10.875(10)	11.229(11)	11.008(08)
3400	49	10.876(07)	11.237(13)	11.035(06)
3450	49	10.880(06)	11.253(12)	11.085(04)
3500	49	10.872(08)	11.259(15)	11.112(08)
3571	49	10.844(07)	11.248(12)	11.131(07)
3636	49	10.811(06)	11.235(12)	11.147(02)
3704	49	10.799(07)	11.201(10)	11.196(06)
3862	49	10.531(10)	10.764(08)	11.238(10)
4036	49	10.468(05)	10.681(08)	11.256(03)
4167	49	10.452(07)	10.715(13)	11.318(04)
4255	49	10.456(05)	10.748(08)	11.372(05)
4464	49	10.490(04)	10.818(06)	11.471(02)
4566	49	10.456(04)	10.838(09)	11.511(01)
4785	49	10.464(05)	10.897(09)	11.600(05)
5000	49	10.461(04)	10.949(05)	11.681(02)
5263	98	10.432(04)	11.017(07)	11.764(01)
5556	98	10.420(04)	11.063(06)	11.861(03)
5840	98	10.447(05)	11.134(07)	11.962(02)
6056	98	10.454(04)	11.181(06)	12.030(10)
6436	98	10.487(03)	11.264(07)	12.094(07)
6790	98	10.497(04)	11.326(08)	12.195(06)
7100	98	10.531(03)	11.397(07)	12.283(09)
7550	98	10.612(02)	11.524(07)	12.429(07)

Notes:
All values are in monochromatic magnitudes
$m_\nu = -2.5 \log_{10}(f_\nu) - 48.590$.
Errors are in units of mmag.

(1988), along with our own $UBV(RI)_{KC}$ photometry. Finding charts for all these stars may be found in Stone (1977), Baldwin and Stone (1984), and Massey et al. (1988).

3.1 Photometric Observations

The photometric observations and reductions of the Stone and Baldwin (1983) standards have been discussed in some detail by Walker (1990), and only a brief summary will be presented. The magnitudes given here are to be used in preference to those in Walker (1990). In particular the $U-B$ values have been improved.

All observations were made on five clear nights during 1988 with the CCD camera on the CTIO 0.9-m telescope using either TI No. 1 or No. 2 CCD (0.5 arcsec pixels^{-1}, gain ~3 electrons/adu, read noise ~10 electrons rms) and a filter set matching *UBV* (Johnson) and *RI* (Kron–Cousins). On each night large numbers of standards from Graham (1982), plus some of the stars with very blue and red colors from Landolt (1983) were observed, interspersed between the measurements of the program stars. Some of the standards were observed at high zenith distance in order to solve explicitly for the extinction coefficients, along with the zero points and color equations.

Since the time of these observations, photoelectric photometry for many of the program stars has been presented by Kilkenny and Menzies (1989) and Landolt (1992a). The latter work contains a comparison between the two photoelectric studies and an early version of the present work. In addition, new lists of photometric standards (Menzies et al. 1989, 1990, 1991; Landolt 1992b) have appeared, as well as a critical comparison between UBVRI photometric systems (Bessell 1990a). It seems clear that the three sets of UBVRI standards most often used in the southern hemisphere[2] agree very well for V, $V-R$, and $V-I$ except for the reddest stars. Unfortunately the same is not true for $B-V$ and $U-B$. Bessell (1990a) and Menzies et al. (1991) both state that Landolt (1983) $B-V$ and $U-B$ are not on the standard system (Johnson and Harris 1954; Johnson et al. 1966), whereas the Cousins $B-V$ is identical to Johnson, and Cousins $U-B$ is very close. Graham $B-V$ appears to be on the Johnson standard system, but there are systematic differences in $U-B$ (e.g., Ryan 1989). The systematic difference in $U-B$ between Cousins and Landolt reaches ~0.1 mag for the bluest stars (Bessell 1990a, 1991).

We therefore must take great care when using standard stars from different sources to place them all on some well-defined system, and also to be aware that for very blue stars large differences exist in the various implementations of $U-B$. We have chosen the following procedure. We will assume that the V, $B-V$, $V-R$, and $V-I$ colors of the standard stars we have utilized are on the standard (Johnson *UBV*, Kron–Cousins *RI*) system. This is a reasonable assumption since we are not interested in red stars where problems typically occur. The $U-B$ colors for the few Landolt (1983) standards we used were instead taken from those tabulated by Menzies et al. (1991). All the Graham (1982) $U-B$ values were converted to Cousins $U-B$ using relations derived by one of us (A.R.W.) from a comparison between stars in common to Graham (1982) and Menzies et al. (1989). We then find that our standard star data are adequately fit by a linear color equation.

The results are given in Table 7 along with the number of observations gathered for each star (n). For V, $B-V$, $V-R$, and $V-I$ the comparisons by Landolt (1992a) are still valid; these show that the present results are comparable in accuracy with the two photoelectric lists; from the scatter of values the average accuracy of an individual

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[2] The Cousins $UBV(RI)_{KC}$ system is accurately reproduced by the E-region standards in Menzies et al. (1989). This list does not contain many very red or blue stars, however it could if necessary be supplemented with additional such stars chosen from Menzies et al. (1991), Laing (1989), and Bessell (1990b). All these lists contain some stars fainter than V~10 and thus suitable for use with CCDs. The Graham (1982) standards contain a number of stars of moderate brightness suitable for use with CCDs. The photometry for the brighter stars is probably less accurate than the Menzies et al. (1991) data, while the use of the fainter stars as CCD standards on moderate to large telescopes is largely superseded by the Landolt (1992b) work. The latter, together with many of the Landolt (1983) stars, provide numerous standards for use with CCDs and have the advantage, since they are equatorial, of being available to observers in both hemispheres. Users should, however, be aware of systematic differences between the Landolt and the Cousins implementations of the UBV system, as demonstrated most recently by Menzies et al. (1991).

TABLE 13

Monochromatic Magnitudes of Tertiary Standards through 50 Å Bandpasses at 50 Å Steps

λ [Å]	LTT 377	LTT 1020	EG 21	LTT 1788	LTT 2415	Hilt 600	LTT 3218	LTT 3864	LTT 4364
3300	12.663(03)	12.898(07)	11.450(07)	14.376(04)	13.460(29)	10.905(11)	12.359(10)	13.526(17)	11.909(07)
3350	12.658(06)	12.856(06)	11.425(07)	14.314(03)	13.419(20)	10.875(10)	12.326(11)	13.516(10)	11.860(07)
3400	12.604(05)	12.799(06)	11.433(06)	14.281(05)	13.388(18)	10.876(07)	12.326(09)	13.461(06)	11.851(04)
3450	12.595(06)	12.797(04)	11.461(03)	14.270(06)	13.361(19)	10.880(06)	12.323(07)	13.428(10)	11.837(07)
3500	12.551(03)	12.729(05)	11.474(04)	14.238(08)	13.310(19)	10.872(08)	12.307(12)	13.390(06)	11.820(06)
3550	12.477(07)	12.669(05)	11.478(05)	14.168(07)	13.254(12)	10.848(07)	12.290(09)	13.323(08)	11.788(06)
3600	12.476(04)	12.651(03)	11.465(04)	14.117(07)	13.223(14)	10.832(06)	12.270(10)	13.295(08)	11.749(05)
3650	12.363(03)	12.549(05)	11.464(04)	14.054(05)	13.144(11)	10.804(06)	12.250(08)	13.199(09)	11.723(07)
3700	12.303(07)	12.520(04)	11.481(03)	14.034(02)	13.096(09)	10.801(07)	12.237(07)	13.152(07)	11.696(08)
3750	12.253(07)	12.522(03)	11.492(05)	13.985(06)	13.007(06)	10.717(05)	12.229(09)	13.092(08)	11.679(09)
3800	12.094(04)	12.388(04)	11.494(03)	13.858(09)	12.863(06)	10.623(07)	12.198(15)	12.946(10)	11.656(12)
3850	12.049(05)	12.368(02)	11.481(05)	13.805(03)	12.760(05)	10.539(09)	12.160(16)	12.881(10)	11.636(10)
3900	12.017(08)	12.353(07)	11.490(05)	13.784(03)	12.731(07)	10.526(07)	12.146(16)	12.869(08)	11.625(11)
3950	12.154(03)	12.448(02)	11.472(04)	13.803(02)	12.735(04)	10.524(09)	12.161(13)	12.952(08)	11.615(11)
4000	11.780(03)	12.165(03)	11.397(03)	13.651(05)	12.597(02)	10.490(06)	12.033(15)	12.693(08)	11.606(06)
4050	11.693(03)	12.096(03)	11.231(03)	13.603(01)	12.538(03)	10.458(05)	11.953(11)	12.632(04)	11.597(03)
4100	11.733(02)	12.083(03)	11.616(05)	13.629(05)	12.622(04)	10.556(05)	12.233(10)	12.680(06)	11.589(06)
4150	11.622(02)	12.029(01)	11.256(03)	13.556(05)	12.512(12)	10.466(07)	11.924(06)	12.580(07)	11.585(10)
4200	11.613(04)	12.026(04)	11.086(03)	13.548(04)	12.485(05)	10.441(06)	11.860(09)	12.572(03)	11.576(06)
4250	11.612(04)	12.033(03)	11.111(03)	13.534(04)	12.481(06)	10.453(05)	11.867(08)	12.559(04)	11.569(03)
4300	11.681(02)	12.077(03)	11.336(04)	13.535(03)	12.493(03)	10.481(05)	11.984(09)	12.592(04)	11.566(02)
4350	11.640(03)	11.998(04)	11.689(06)	13.553(03)	12.557(04)	10.570(06)	12.218(12)	12.595(03)	11.567(03)
4400	11.543(02)	11.935(04)	11.278(03)	13.473(02)	12.442(05)	10.490(06)	11.899(10)	12.495(06)	11.554(03)
4450	11.498(02)	11.882(04)	11.143(03)	13.446(02)	12.424(02)	10.493(05)	11.855(07)	12.473(02)	11.545(02)
4500	11.451(03)	11.843(04)	11.113(02)	13.414(03)	12.404(03)	10.459(04)	11.842(07)	12.438(03)	11.546(02)
4550	11.445(03)	11.825(03)	11.122(03)	13.401(02)	12.393(05)	10.454(04)	11.839(06)	12.422(04)	11.544(05)
4600	11.413(03)	11.793(03)	11.136(02)	13.381(01)	12.373(05)	10.459(04)	11.838(06)	12.395(04)	11.548(05)
4650	11.402(02)	11.772(02)	11.153(01)	13.364(03)	12.367(09)	10.461(05)	11.839(05)	12.374(06)	11.570(06)
4700	11.388(02)	11.756(01)	11.179(02)	13.347(04)	12.356(08)	10.463(05)	11.844(03)	12.362(04)	11.585(06)
4750	11.373(02)	11.736(02)	11.231(02)	13.331(04)	12.345(08)	10.462(07)	11.857(06)	12.347(04)	11.540(06)
4800	11.353(01)	11.715(02)	11.365(02)	13.319(02)	12.333(09)	10.463(05)	11.904(05)	12.332(05)	11.517(05)
4850	11.441(02)	11.741(03)	11.755(03)	13.360(05)	12.403(03)	10.553(04)	12.202(08)	12.386(04)	11.508(05)
4900	11.365(04)	11.688(03)	11.561(01)	13.292(02)	12.328(05)	10.480(04)	11.971(06)	12.316(05)	11.502(04)
4950	11.327(05)	11.663(03)	11.335(03)	13.267(03)	12.289(04)	10.451(04)	11.857(07)	12.284(04)	11.499(03)
5000	11.336(05)	11.654(04)	11.288(03)	13.260(02)	12.281(02)	10.460(04)	11.842(09)	12.275(03)	11.508(03)
5050	11.310(05)	11.639(04)	11.284(04)	13.249(02)	12.277(02)	10.455(05)	11.842(08)	12.260(03)	11.532(03)
5100	11.287(03)	11.618(04)	11.282(04)	13.235(03)	12.268(03)	10.449(05)	11.842(07)	12.244(04)	11.561(03)
5150	11.303(03)	11.617(05)	11.286(03)	13.222(03)	12.262(05)	10.447(04)	11.839(06)	12.242(01)	11.565(03)
5200	11.300(02)	11.611(04)	11.295(03)	13.212(02)	12.254(04)	10.436(04)	11.839(05)	12.240(02)	11.485(04)
5250	11.272(02)	11.570(04)	11.309(03)	13.194(02)	12.244(05)	10.433(04)	11.839(05)	12.211(03)	11.481(04)
5300	11.244(02)	11.550(03)	11.321(03)	13.175(02)	12.228(06)	10.428(03)	11.840(05)	12.194(04)	11.481(04)
5350	11.236(03)	11.536(03)	11.337(03)	13.165(03)	12.219(05)	10.426(03)	11.840(05)	12.181(03)	11.479(04)
5400	11.228(02)	11.527(03)	11.351(02)	13.155(01)	12.212(05)	10.423(03)	11.840(05)	12.171(03)	11.480(03)
5450	11.207(02)	11.512(03)	11.362(03)	13.141(02)	12.203(04)	10.427(03)	11.843(06)	12.154(03)	11.486(04)
5500	11.194(02)	11.493(03)	11.372(03)	13.128(02)	12.191(07)	10.423(03)	11.844(04)	12.144(02)	11.489(04)
5550	11.182(02)	11.479(03)	11.385(03)	13.124(02)	12.188(07)	10.421(04)	11.845(04)	12.129(01)	11.492(04)
5600	11.185(02)	11.475(04)	11.398(03)	13.112(01)	12.184(06)	10.421(04)	11.847(06)	12.130(02)	11.487(03)
5650	11.169(04)	11.459(04)	11.414(04)	13.107(02)	12.181(06)	10.433(04)	11.855(05)	12.116(01)	11.481(03)
5700	11.168(04)	11.456(04)	11.430(04)	13.107(03)	12.179(05)	10.440(05)	11.869(05)	12.116(03)	11.481(04)
5750	11.153(03)	11.441(05)	11.447(04)	13.098(02)	12.180(07)	10.444(04)	11.875(04)	12.110(02)	11.487(04)
5800	11.144(02)	11.424(04)	11.454(04)	13.081(03)	12.165(07)	10.445(05)	11.870(05)	12.094(03)	11.480(05)
5850	11.132(02)	11.409(04)	11.462(03)	13.066(03)	12.151(07)	10.439(04)	11.863(05)	12.077(03)	11.476(04)
5900	11.143(02)	11.412(05)	11.481(04)	13.068(03)	12.156(04)	10.478(04)	11.874(06)	12.090(03)	11.486(04)
5950	11.125(02)	11.398(04)	11.502(04)	13.056(03)	12.148(06)	10.450(05)	11.879(07)	12.072(02)	11.484(05)
6000	11.129(03)	11.391(04)	11.515(04)	13.049(02)	12.137(03)	10.453(04)	11.879(05)	12.065(01)	11.485(04)
6050	11.118(02)	11.383(03)	11.526(03)	13.046(03)	12.134(02)	10.454(04)	11.885(04)	12.055(01)	11.486(04)
6100	11.115(02)	11.374(05)	11.533(04)	13.040(02)	12.134(07)	10.455(05)	11.887(03)	12.049(01)	11.488(03)
6150	11.117(05)	11.366(06)	11.538(06)	13.040(03)	12.129(07)	10.463(05)	11.891(04)	12.053(03)	11.489(05)
6200	11.098(05)	11.356(06)	11.550(06)	13.030(03)	12.126(08)	10.473(04)	11.899(04)	12.043(03)	11.488(04)
6250	11.106(05)	11.359(06)	11.572(06)	13.031(04)	12.126(05)	10.478(03)	11.912(04)	12.046(02)	11.495(05)
6300	11.110(05)	11.363(07)	11.599(05)	13.036(04)	12.136(05)	10.506(04)	11.927(04)	12.053(03)	11.508(05)
6350	11.091(04)	11.337(06)	11.600(05)	13.018(04)	12.117(07)	10.486(04)	11.919(03)	12.027(02)	11.494(06)
6400	11.089(03)	11.333(05)	11.623(05)	13.012(04)	12.113(09)	10.487(05)	11.925(04)	12.022(05)	11.492(06)
6450	11.087(02)	11.328(05)	11.663(03)	13.006(03)	12.106(05)	10.487(03)	11.939(04)	12.014(02)	11.490(04)
6500	11.086(01)	11.320(06)	11.761(05)	13.003(03)	12.103(03)	10.493(03)	11.991(06)	12.014(03)	11.492(06)
6550	11.160(03)	11.367(06)	12.017(04)	13.071(07)	12.177(07)	10.573(03)	12.251(05)	12.075(03)	11.498(07)
6600	11.083(03)	11.309(04)	11.889(04)	12.997(03)	12.118(06)	10.511(03)	12.079(03)	12.010(03)	11.493(06)
6650	11.061(02)	11.290(05)	11.736(04)	12.969(04)	12.079(02)	10.491(03)	11.965(05)	11.981(03)	11.491(05)
6700	11.055(03)	11.282(05)	11.695(04)	12.965(05)	12.072(02)	10.494(02)	11.942(05)	11.976(02)	11.489(05)
6750	11.055(03)	11.277(04)	11.693(03)	12.962(04)	12.078(06)	10.489(03)	11.938(04)	11.971(02)	11.494(05)
6800	11.054(02)	11.274(04)	11.702(02)	12.966(04)	12.075(05)	10.501(04)	11.942(03)	11.969(02)	11.503(06)
6850*	11.097(02)	11.318(05)	11.755(03)	13.010(05)	12.126(06)	10.553(04)	11.997(03)	12.016(03)	11.552(07)
6900*	11.153(05)	11.370(05)	11.821(03)	13.056(05)	12.178(06)	10.608(04)	12.053(04)	12.071(03)	11.615(05)
6950	11.063(05)	11.277(07)	11.740(06)	12.971(03)	12.091(06)	10.535(04)	11.976(04)	11.981(03)	11.537(08)
7000	11.056(03)	11.268(07)	11.743(07)	12.959(02)	12.080(04)	10.526(03)	11.972(04)	11.971(02)	11.532(06)
7050	11.050(03)	11.260(06)	11.755(06)	12.954(02)	12.079(06)	10.532(03)	11.974(05)	11.961(04)	11.527(06)
7100	11.046(03)	11.256(05)	11.764(04)	12.948(02)	12.071(05)	10.526(03)	11.972(05)	11.956(03)	11.526(06)
7150*	11.060(02)	11.268(07)	11.790(06)	12.964(03)	12.092(05)	10.549(04)	11.999(05)	11.972(03)	11.545(06)
7200*	11.103(08)	11.312(15)	11.844(13)	13.022(07)	12.149(07)	10.614(04)	12.063(10)	12.032(08)	11.609(07)
7250*	11.088(08)	11.297(15)	11.846(10)	13.011(05)	12.143(08)	10.613(03)	12.062(10)	12.019(08)	11.605(07)
7300*	11.077(08)	11.281(13)	11.840(11)	12.999(07)	12.125(09)	10.604(04)	12.047(07)	12.003(06)	11.592(08)
7350	11.048(05)	11.248(09)	11.823(10)	12.962(05)	12.090(07)	10.571(05)	12.018(05)	11.966(04)	11.559(08)
7400	11.046(08)	11.237(08)	11.824(10)	12.946(04)	12.078(06)	10.566(03)	12.017(03)	11.961(03)	11.556(09)
7450	11.035(09)	11.230(08)	11.826(10)	12.951(05)	12.074(04)	10.566(03)	12.018(03)	11.958(03)	11.559(08)
7500	11.038(10)	11.233(09)	11.842(09)	12.943(02)	12.073(05)	10.572(03)	12.022(05)	11.951(04)	11.563(08)
7550	11.043(06)	11.227(06)	11.861(07)	12.936(03)	12.069(06)	10.569(02)	12.028(06)	11.948(02)	11.566(06)

Notes : All values are in monochromatic magnitudes $m_\nu = -2.5 \log_{10}(f_\nu) - 48.590$
Bands with * include telluric features
Errors are in units of mmag

TABLE 13
(Continued)

λ [Å]	Feige 56	LTT 4816	CD -32	LTT 6248	EG 274	LTT 7379	LTT 7987	LTT 9239	Feige 110	LTT 9491
3300	11.237(12)	14.078(15)	12.029(07)	13.132(14)	10.585(05)	11.852(09)	12.355(04)	13.581(04)	11.017(08)	14.085(02)
3350	11.229(11)	14.049(11)	11.997(08)	13.061(09)	10.578(08)	11.853(09)	12.328(06)	13.571(05)	11.008(08)	14.047(04)
3400	11.237(13)	14.052(07)	11.972(08)	13.035(08)	10.599(05)	11.755(08)	12.349(07)	13.486(05)	11.035(06)	14.042(04)
3450	11.253(12)	14.068(09)	11.967(04)	13.017(11)	10.648(06)	11.748(06)	12.371(04)	13.476(06)	11.085(04)	14.064(03)
3500	11.259(15)	14.065(10)	11.936(12)	12.980(08)	10.660(04)	11.681(07)	12.383(06)	13.411(05)	11.112(08)	14.047(02)
3550	11.251(11)	14.050(13)	11.854(10)	12.926(12)	10.671(06)	11.601(07)	12.379(05)	13.355(07)	11.128(08)	14.035(01)
3600	11.242(13)	14.034(08)	11.832(07)	12.866(10)	10.677(04)	11.622(05)	12.371(05)	13.328(04)	11.134(05)	14.021(03)
3650	11.237(11)	14.019(07)	11.737(07)	12.804(04)	10.689(03)	11.468(05)	12.370(04)	13.203(06)	11.154(03)	14.007(02)
3700	11.209(10)	14.021(06)	11.681(07)	12.766(07)	10.710(04)	11.418(06)	12.397(08)	13.204(05)	11.194(05)	14.007(03)
3750	11.036(11)	14.010(07)	11.507(11)	12.682(05)	10.729(06)	11.441(06)	12.404(11)	13.204(06)	11.215(07)	14.005(03)
3800	10.858(07)	14.007(09)	11.265(12)	12.563(08)	10.745(08)	11.301(05)	12.401(08)	13.089(07)	11.223(04)	14.003(05)
3850	10.769(09)	13.996(08)	11.100(11)	12.477(05)	10.749(09)	11.345(06)	12.384(09)	13.077(03)	11.233(09)	13.994(06)
3900	10.757(09)	13.990(10)	11.062(12)	12.462(07)	10.761(08)	11.280(07)	12.379(08)	13.083(10)	11.255(07)	14.007(06)
3950	10.779(08)	14.021(04)	11.038(11)	12.469(04)	10.807(10)	11.444(06)	12.389(08)	13.177(04)	11.285(06)	13.999(06)
4000	10.705(08)	13.924(07)	10.804(07)	12.303(02)	10.736(04)	10.982(07)	12.250(07)	12.790(02)	11.274(02)	14.003(03)
4050	10.684(08)	13.845(08)	10.723(03)	12.256(06)	10.652(02)	10.883(05)	12.102(04)	12.735(03)	11.264(02)	13.981(04)
4100	10.842(10)	14.159(07)	10.945(06)	12.315(04)	10.948(03)	10.853(06)	12.514(04)	12.700(03)	11.387(04)	13.986(03)
4150	10.718(15)	13.825(08)	10.710(05)	12.207(04)	10.691(03)	10.782(04)	12.111(07)	12.655(03)	11.313(04)	13.993(02)
4200	10.721(10)	13.690(04)	10.648(04)	12.181(05)	10.606(03)	10.790(05)	11.946(04)	12.654(05)	11.340(08)	13.993(03)
4250	10.746(08)	13.713(05)	10.615(03)	12.172(07)	10.635(04)	10.821(05)	11.975(05)	12.661(03)	11.370(04)	13.997(05)
4300	10.786(04)	13.917(04)	10.666(03)	12.190(07)	10.797(03)	10.909(04)	12.218(04)	12.722(03)	11.403(05)	14.001(03)
4350	10.907(05)	14.223(03)	10.802(03)	12.214(07)	11.054(03)	10.767(05)	12.552(06)	12.598(02)	11.516(05)	14.013(02)
4400	10.796(05)	13.814(02)	10.575(01)	12.117(04)	10.753(03)	10.704(04)	12.123(03)	12.539(03)	11.442(03)	14.018(03)
4450	10.810(06)	13.698(03)	10.553(02)	12.092(06)	10.691(02)	10.614(05)	11.986(03)	12.471(02)	11.465(02)	14.037(04)
4500	10.820(07)	13.669(04)	10.514(02)	12.066(07)	10.694(05)	10.549(05)	11.962(03)	12.425(02)	11.484(03)	14.027(03)
4550	10.833(09)	13.653(02)	10.532(01)	12.057(06)	10.709(05)	10.538(05)	11.969(03)	12.408(03)	11.509(02)	14.022(03)
4600	10.842(09)	13.661(05)	10.494(04)	12.033(05)	10.728(03)	10.498(04)	11.984(02)	12.376(03)	11.527(02)	14.026(03)
4650	10.854(10)	13.675(05)	10.486(04)	12.015(07)	10.751(03)	10.474(04)	12.004(03)	12.353(02)	11.553(02)	14.036(02)
4700	10.866(11)	13.697(06)	10.480(04)	12.003(06)	10.781(06)	10.459(04)	12.029(03)	12.330(03)	11.594(02)	14.038(02)
4750	10.885(09)	13.748(07)	10.475(04)	11.994(07)	10.813(03)	10.434(04)	12.085(03)	12.305(03)	11.586(06)	14.046(03)
4800	10.901(09)	13.869(04)	10.480(02)	11.982(08)	10.905(06)	10.411(03)	12.228(03)	12.284(02)	11.610(03)	14.049(02)
4850	11.040(08)	14.246(04)	10.719(03)	12.038(07)	11.205(04)	10.456(04)	12.638(04)	12.310(03)	11.729(03)	14.052(03)
4900	10.933(09)	14.005(05)	10.546(04)	11.948(07)	11.032(04)	10.410(05)	12.396(03)	12.256(03)	11.661(04)	14.051(03)
4950	10.923(07)	13.800(04)	10.463(04)	11.914(09)	10.894(04)	10.377(05)	12.174(03)	12.230(03)	11.661(03)	14.049(03)
5000	10.949(05)	13.741(02)	10.476(03)	11.902(07)	10.878(04)	10.383(05)	12.126(03)	12.224(03)	11.681(02)	14.052(02)
5050	10.969(05)	13.722(03)	10.448(02)	11.887(07)	10.886(04)	10.356(06)	12.119(03)	12.200(03)	11.703(04)	14.055(03)
5100	10.977(05)	13.718(02)	10.460(03)	11.868(07)	10.898(05)	10.332(05)	12.117(03)	12.181(02)	11.715(03)	14.057(02)
5150	10.989(01)	13.719(04)	10.472(02)	11.856(06)	10.906(05)	10.359(05)	12.122(02)	12.197(02)	11.726(02)	14.056(02)
5200	11.011(07)	13.716(03)	10.482(01)	11.848(07)	10.921(04)	10.353(04)	12.133(02)	12.176(02)	11.739(01)	14.061(02)
5250	11.015(07)	13.724(05)	10.468(03)	11.835(07)	10.937(03)	10.295(03)	12.151(02)	12.133(02)	11.759(01)	14.068(02)
5300	11.021(07)	13.731(03)	10.453(01)	11.824(06)	10.959(05)	10.259(03)	12.164(02)	12.108(02)	11.778(02)	14.079(02)
5350	11.027(07)	13.735(03)	10.447(02)	11.809(06)	10.974(06)	10.250(04)	12.177(03)	12.096(02)	11.796(03)	14.078(02)
5400	11.036(07)	13.751(05)	10.451(02)	11.801(06)	10.989(06)	10.240(04)	12.189(03)	12.081(02)	11.830(02)	14.083(02)
5450	11.046(07)	13.750(03)	10.438(02)	11.788(06)	11.005(06)	10.219(03)	12.201(03)	12.061(02)	11.830(03)	14.092(02)
5500	11.056(07)	13.753(02)	10.432(01)	11.775(08)	11.017(05)	10.199(03)	12.216(04)	12.042(01)	11.846(02)	14.097(02)
5550	11.062(06)	13.775(08)	10.421(02)	11.759(08)	11.026(01)	10.183(04)	12.227(02)	12.024(02)	11.861(02)	14.104(02)
5600	11.071(06)	13.777(06)	10.424(02)	11.750(09)	11.051(05)	10.186(03)	12.239(02)	12.022(02)	11.874(05)	14.106(03)
5650	11.094(06)	13.785(03)	10.426(02)	11.745(08)	11.070(04)	10.157(02)	12.257(02)	12.000(03)	11.892(06)	14.122(02)
5700	11.109(07)	13.803(04)	10.434(03)	11.741(06)	11.088(03)	10.152(02)	12.276(02)	11.990(04)	11.917(08)	14.135(02)
5750	11.117(04)	13.822(06)	10.424(03)	11.737(07)	11.112(06)	10.133(02)	12.290(02)	11.981(03)	11.934(05)	14.143(02)
5800	11.128(06)	13.820(06)	10.422(04)	11.719(06)	11.121(05)	10.122(03)	12.297(03)	11.962(03)	11.948(04)	14.148(02)
5850	11.130(07)	13.818(07)	10.411(03)	11.702(05)	11.125(06)	10.108(03)	12.301(02)	11.948(03)	11.963(02)	14.179(03)
5900	11.162(08)	13.832(06)	10.429(05)	11.709(07)	11.141(05)	10.127(04)	12.320(02)	11.950(02)	11.984(02)	14.185(05)
5950	11.164(06)	13.839(03)	10.416(04)	11.695(07)	11.163(06)	10.102(04)	12.334(03)	11.935(03)	12.001(04)	14.162(03)
6000	11.169(05)	13.848(03)	10.426(03)	11.685(06)	11.179(06)	10.098(04)	12.347(03)	11.929(03)	12.018(04)	14.164(03)
6050	11.181(06)	13.859(03)	10.424(03)	11.680(06)	11.191(05)	10.084(03)	12.360(02)	11.914(02)	12.033(03)	14.170(04)
6100	11.190(06)	13.871(05)	10.429(04)	11.671(06)	11.218(12)	10.078(03)	12.371(04)	11.906(04)	12.028(08)	14.172(05)
6150	11.201(06)	13.875(03)	10.450(04)	11.665(08)	11.222(10)	10.079(03)	12.379(03)	11.899(05)	12.020(07)	14.180(05)
6200	11.211(07)	13.887(06)	10.434(05)	11.661(08)	11.230(09)	10.057(03)	12.387(04)	11.885(06)	12.026(04)	14.186(05)
6250	11.227(07)	13.899(04)	10.449(04)	11.657(08)	11.250(10)	10.063(03)	12.405(03)	11.881(06)	12.038(08)	14.193(05)
6300	11.254(06)	13.922(04)	10.459(04)	11.667(07)	11.267(09)	10.063(02)	12.432(03)	11.887(05)	12.070(08)	14.211(05)
6350	11.254(07)	13.926(06)	10.447(04)	11.642(08)	11.264(06)	10.040(02)	12.434(04)	11.862(05)	12.061(09)	14.195(06)
6400	11.257(08)	13.951(06)	10.441(02)	11.633(08)	11.274(07)	10.034(03)	12.450(04)	11.858(03)	12.085(09)	14.208(05)
6450	11.266(06)	13.987(05)	10.445(04)	11.623(08)	11.303(10)	10.034(04)	12.493(03)	11.850(03)	12.095(09)	14.208(05)
6500	11.274(07)	14.092(04)	10.456(01)	11.621(08)	11.358(08)	10.028(04)	12.588(04)	11.845(03)	12.116(06)	14.212(04)
6550	11.376(10)	14.389(12)	10.630(08)	11.692(08)	11.559(08)	10.072(04)	12.851(03)	11.891(03)	12.216(01)	14.250(05)
6600	11.306(07)	14.221(03)	10.498(04)	11.609(06)	11.462(08)	10.015(05)	12.719(02)	11.826(04)	12.156(04)	14.230(05)
6650	11.295(06)	14.046(05)	10.440(03)	11.591(06)	11.365(07)	9.996(04)	12.570(05)	11.812(03)	12.147(03)	14.236(05)
6700	11.302(07)	14.001(04)	10.431(03)	11.583(08)	11.352(09)	9.990(05)	12.529(05)	11.804(03)	12.170(01)	14.244(04)
6750	11.312(07)	13.991(06)	10.439(04)	11.580(09)	11.361(09)	9.985(04)	12.522(04)	11.799(03)	12.177(03)	14.236(04)
6800	11.331(08)	13.993(06)	10.444(03)	11.579(07)	11.373(07)	9.982(04)	12.528(04)	11.797(03)	12.202(10)	14.255(04)
6850*	11.389(08)	14.031(03)	10.499(05)	11.624(07)	11.434(06)	10.022(03)	12.579(03)	11.836(04)	12.258(02)	14.303(07)
6900*	11.458(08)	14.094(04)	10.563(04)	11.685(06)	11.502(09)	10.075(02)	12.648(03)	11.889(04)	12.321(05)	14.369(05)
6950	11.385(08)	14.014(04)	10.478(06)	11.591(07)	11.434(10)	9.987(02)	12.572(02)	11.797(04)	12.245(07)	14.297(05)
7000	11.382(09)	14.011(04)	10.476(05)	11.577(07)	11.433(07)	9.980(02)	12.575(02)	11.781(04)	12.240(01)	14.293(04)
7050	11.382(05)	14.011(07)	10.465(01)	11.569(06)	11.438(06)	9.966(03)	12.579(02)	11.774(03)	12.268(06)	14.300(04)
7100	11.396(07)	14.021(05)	10.465(01)	11.560(07)	11.453(08)	9.960(02)	12.588(02)	11.768(04)	12.281(10)	14.297(04)
7150*	11.424(07)	14.047(06)	10.491(07)	11.568(07)	11.469(09)	9.972(03)	12.612(02)	11.774(03)	12.306(01)	14.310(05)
7200*	11.497(10)	14.115(09)	10.556(09)	11.624(11)	11.530(07)	10.021(05)	12.668(05)	11.812(06)	12.354(01)	14.375(09)
7250*	11.500(11)	14.115(07)	10.548(11)	11.609(12)	11.530(08)	10.002(04)	12.678(03)	11.796(07)	12.351(09)	14.380(10)
7300*	11.491(09)	14.117(13)	10.542(11)	11.594(09)	11.532(10)	9.988(04)	12.669(05)	11.780(06)	12.340(09)	14.369(06)
7350	11.458(08)	14.095(07)	10.505(07)	11.563(07)	11.529(13)	9.952(02)	12.651(04)	11.753(06)	12.350(03)	14.358(07)
7400	11.461(09)	14.079(05)	10.515(06)	11.555(08)	11.533(05)	9.950(03)	12.654(04)	11.741(07)	12.345(07)	14.355(05)
7450	11.464(06)	14.089(03)	10.511(05)	11.553(06)	11.548(06)	9.934(04)	12.659(05)	11.736(08)	12.354(18)	14.361(06)
7500	11.475(06)	14.103(07)	10.513(02)	11.552(07)	11.559(07)	9.936(04)	12.672(04)	11.736(07)	12.358(12)	14.371(05)
7550	11.482(07)	14.105(08)	10.515(03)	11.551(07)	11.583(11)	9.938(04)	12.685(04)	11.739(07)	12.398(01)	14.382(08)

Notes : All values are in monochromatic magnitudes $m_\nu = -2.5 \log_{10}(f_\nu) - 48.590$
Bands with * include telluric features
Errors are in units of mmag

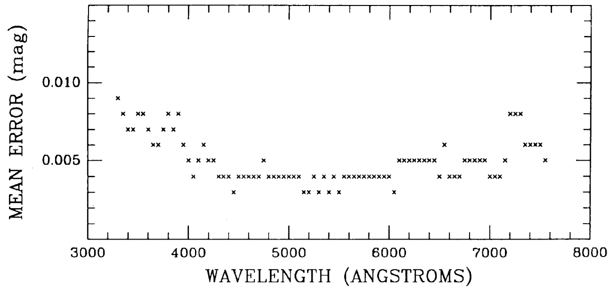

FIG. 11—Mean errors of the mean monochromatic magnitudes obtained from the 19 tertiary standards observed at CTIO, plotted as a function of wavelength.

magnitude appears to be ~0.01 mag. Our $U-B$ values should not differ systematically from those of Kilkenny and Menzies (1989), since in principle both sets of observations should be on the same system. This is indeed true, since we find, in the sense Table 7 minus Kilkenny and Menzies (1989),

$$\Delta(U-B) = -0.006 \pm 0.013 \text{ (s.d.)},$$

or if the result for LTT 7987 is disregarded, then

$$\Delta(U-B) = -0.004 \pm 0.010 \text{ (s.d.)}.$$

For Table 7 minus Landolt (1992a),

$$\Delta(U-B) = +0.027 \pm 0.012 \text{ (s.d.)},$$

which is to be expected from an inspection of Fig. 2(d) of Menzies et al. (1991).

3.2 Spectroscopic Observations

We obtained our observations with the Cassegrain spectrographs on the CTIO 1.5-m and 4-m telescopes starting in September 1987. We used the 1.5-m telescope during nine photometric nights, with a low-dispersion grating (158 lines mm^{-1}) blazed at 5000 Å and a GEC CCD with a fluorescent coating that extends the useful blue sensitivity to the atmospheric cutoff near 3000 Å. We observed in first order with a total wavelength coverage of 4600 Å (3000–7600 Å) and resolution of 16 Å (FWHM). We observed with the 4-m telescope on one photometric night, with a low-dispersion grating (158 lines mm^{-1}) blazed at 4000 Å and the same type of CCD employed in the observations on the 1.5-m telescope. With a resulting wavelength coverage of 3300 Å and a resolution of 10 Å in first order, we observed in the wavelength range 3100–6400 Å. On this telescope, it was necessary to observe the secondary standards with a 2.5 mag neutral density filter to avoid saturation of the CCD. We determined the transmission function of this filter from observations of six SAO stars on the same night of observation of our program made with and without the neutral density filter. All six measurements of the transmission curve were the same to 1%. We estimate the transmission curve was accurate to better than 0.5%.

In neither telescope did we use a second-order blocking filter. On the 4-m telescope, given that the reddest wavelength of our spectra in first order correspond to 3200 Å in second order, both the grating blaze and the transmission of the atmosphere effectively suppresses any contamination of our spectra by second-order light. Because of the wavelength coverage on the 1.5-m telescope, second-order leak may be potentially significant redward of 6000 Å. To check this, we compared our data with spectra obtained in the wavelength range 6000–10000 Å, taken with the same telescope and an RG 610 filter. We found that the blue and red spectra match to better than 1%–2% in the overlap region (6000–7600 Å), and no significant trend could be seen as a function of wavelength. However, the ratios of the blue spectra and red spectra in the overlap region show a slight dependence on the color of the star. On the average, the red end of our blue spectra shows an excess of 1% for the bluest stars of our program list, and a deficit of 1% for the reddest stars. Therefore, we warn the observer to use the values with caution. In the near future these fluxes will be superseded with our observations of these stars in the red.

Every night, we observed as many of the bright secondary standards listed in Table 1 as possible, typically four or five. We made 15–25 observations of these stars on 2 positions along the slit in order to average out any residual pixel-to-pixel structure not removed by the flat field. We were particularly careful in centering the star in the slit. To do this, we narrowed the slit to 2–3″, centered the star on the slit, and then opened the slit up to 21″ on the 1.5-m telescope and to 10″ on the 4-m telescope. At the 4-m telescope, we rotated the spectrograph in order to minimize atmospheric refraction effects, using the parallactic angles tabulated by Filippenko (1982). Although this technique could not be applied in the observations on the 1.5-m telescope due to restrictions in the spectrograph rotation, the slit width was big enough to make light loss due to refraction negligible. The telescopes were guided with an offset guider tracking on a nearby field star.

We observed the program objects in the same manner as the standards. In order to minimize errors due to incorrect extinction values, we have done the following two procedures. First, we determined nightly extinction curves by observing the secondary standards at a wide range of airmasses (between 1.1 and 2.0 both east and west). Second, we only observed our secondary and tertiary standards used in calculating the fluxes in a very restricted airmass range between 1.2 and 1.4. We selected this specific range of airmass since some of the secondary standards and three of our program objects are too far north and cannot be observed at a lower airmass from CTIO. Figure 2 shows a histogram with the mean airmass of all of our observations of the program objects. From that figure it can be seen that most (79%) of our observations were obtained in the desired airmass range.

We selected the exposure times such that the average number of photons was nearly the same between our program objects and the standard stars, and large enough to get reasonable photon statistics, of the order of 1%–5% per pixel. For our program objects the integration times ranged between 2 and 30 min, while the secondary standards required exposures times in the range of 1 to 5 s.

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Clearly, the determination of the shutter time is critical. On every observing run, we sampled several early-type stars of the SAO Catalogue (generally B- or A-type stars with few features in their spectra) with 1- and 20-s exposures. In order to keep the total number of photons nearly the same in the two measurements, we co-added 20 1-s exposures (without reading out the CCD in between the individual exposures) instead of just a single 1-s exposure. We repeated this test at different positions on the sky, and determined that there was no dependence of the shutter time upon the position of the telescope. Table 8 presents our results with the rms and the number of measurements obtained for every observing run. We assumed the shutter timing error was a simple additive constant to the re-

TABLE 14

Monochromatic Magnitudes of the Secondary Standards through 16 Å Bandpasses at 16 Å Steps

λ [Å]	HR 718	HR 1544	HR 3454	HR 4468	HR 4963	HR 5501	HR 7596	HR 7950	HR 8634	HR 9087
3300	5.223(06)	5.577(04)	4.116(04)	5.537(07)	5.592(03)	6.719(02)	7.004(03)	5.044(02)	4.139(02)	5.381(03)
3316	5.220(06)	5.568(07)	4.115(02)	5.530(06)	5.584(05)	6.720(03)	7.005(02)	5.041(03)	4.134(04)	5.376(02)
3332	5.218(08)	5.573(06)	4.118(02)	5.532(04)	5.587(03)	6.707(02)	6.990(02)	5.042(02)	4.125(03)	5.377(05)
3348	5.205(10)	5.560(06)	4.122(02)	5.517(04)	5.573(03)	6.699(02)	6.977(02)	5.026(02)	4.117(04)	5.367(04)
3364	5.202(12)	5.562(06)	4.133(03)	5.519(03)	5.562(04)	6.692(03)	6.962(02)	5.018(03)	4.107(02)	5.361(05)
3380	5.200(10)	5.554(05)	4.131(02)	5.511(04)	5.556(04)	6.685(03)	6.958(03)	5.005(02)	4.114(03)	5.364(05)
3396	5.202(11)	5.543(04)	4.141(02)	5.511(04)	5.546(03)	6.682(03)	6.948(03)	4.996(02)	4.109(03)	5.371(05)
3412	5.194(07)	5.536(05)	4.145(01)	5.509(04)	5.541(03)	6.678(01)	6.944(03)	4.993(02)	4.119(03)	5.378(04)
3428	5.200(09)	5.537(06)	4.155(01)	5.518(05)	5.548(03)	6.691(03)	6.943(03)	4.991(02)	4.127(04)	5.394(03)
3444	5.197(04)	5.540(04)	4.163(01)	5.520(05)	5.553(02)	6.695(02)	6.951(03)	5.000(02)	4.134(04)	5.402(02)
3460	5.202(05)	5.543(06)	4.168(01)	5.519(06)	5.545(03)	6.693(03)	6.948(03)	5.001(02)	4.134(03)	5.407(03)
3476	5.203(06)	5.535(05)	4.175(02)	5.519(06)	5.544(03)	6.687(02)	6.940(03)	4.998(02)	4.132(03)	5.411(03)
3492	5.199(08)	5.537(05)	4.180(02)	5.519(05)	5.541(04)	6.684(02)	6.929(02)	4.990(01)	4.127(04)	5.412(04)
3508	5.188(09)	5.524(04)	4.183(02)	5.511(05)	5.526(03)	6.674(01)	6.915(03)	4.974(02)	4.116(03)	5.400(03)
3524	5.179(08)	5.501(03)	4.188(04)	5.501(05)	5.506(03)	6.659(02)	6.896(02)	4.960(01)	4.110(03)	5.395(04)
3540	5.166(08)	5.492(04)	4.185(02)	5.492(04)	5.490(03)	6.650(02)	6.892(03)	4.943(02)	4.104(03)	5.390(04)
3556	5.166(07)	5.494(05)	4.185(02)	5.489(04)	5.491(03)	6.645(03)	6.880(02)	4.942(02)	4.099(03)	5.388(04)
3572	5.160(09)	5.490(04)	4.185(02)	5.488(04)	5.485(03)	6.642(02)	6.875(02)	4.936(02)	4.088(02)	5.384(04)
3588	5.150(08)	5.480(04)	4.195(05)	5.480(04)	5.478(03)	6.635(01)	6.863(02)	4.928(02)	4.086(02)	5.381(04)
3604	5.140(07)	5.467(04)	4.183(03)	5.474(05)	5.467(03)	6.630(03)	6.857(03)	4.918(02)	4.084(04)	5.378(03)
3620	5.139(05)	5.453(05)	4.185(02)	5.465(05)	5.456(02)	6.619(02)	6.844(02)	4.906(02)	4.078(03)	5.377(02)
3636	5.129(05)	5.437(05)	4.182(02)	5.458(05)	5.442(04)	6.612(02)	6.833(02)	4.895(03)	4.074(04)	5.376(02)
3652	5.124(05)	5.425(04)	4.184(04)	5.453(05)	5.430(03)	6.600(02)	6.820(02)	4.887(02)	4.072(04)	5.376(02)
3668	5.120(04)	5.417(04)	4.183(02)	5.450(05)	5.426(03)	6.596(03)	6.815(02)	4.878(02)	4.075(04)	5.378(02)
3684	5.122(05)	5.393(04)	4.191(03)	5.444(05)	5.406(03)	6.591(03)	6.796(03)	4.861(03)	4.066(04)	5.383(02)
3700	5.096(03)	5.333(02)	4.194(03)	5.407(05)	5.351(04)	6.551(04)	6.734(05)	4.800(03)	4.028(05)	5.376(02)
3716	5.036(06)	5.231(04)	4.173(04)	5.330(06)	5.243(04)	6.468(06)	6.626(06)	4.694(02)	3.943(08)	5.340(04)
3732	4.942(07)	5.117(03)	4.133(03)	5.221(05)	5.122(04)	6.353(06)	6.490(06)	4.574(02)	3.823(08)	5.276(04)
3748	4.838(07)	4.997(05)	4.084(03)	5.101(07)	4.987(06)	6.230(07)	6.352(05)	4.446(02)	3.702(07)	5.203(03)
3764	4.715(07)	4.870(04)	4.045(03)	4.989(05)	4.865(04)	6.109(05)	6.218(05)	4.316(02)	3.596(05)	5.132(02)
3780	4.552(05)	4.714(02)	3.978(02)	4.835(08)	4.681(07)	5.956(07)	6.051(05)	4.140(03)	3.462(04)	5.035(03)
3796	4.555(11)	4.707(06)	4.009(02)	4.835(06)	4.674(06)	5.928(04)	6.034(03)	4.126(03)	3.468(07)	5.044(05)
3812	4.322(10)	4.499(05)	3.915(03)	4.627(10)	4.455(08)	5.733(09)	5.829(05)	3.901(04)	3.280(06)	4.901(03)
3828	4.440(14)	4.656(07)	3.995(03)	4.781(07)	4.610(07)	5.875(08)	5.979(08)	4.084(06)	3.414(13)	4.993(12)
3844	4.319(21)	4.429(04)	3.881(02)	4.599(08)	4.405(07)	5.698(12)	5.792(09)	3.852(04)	3.280(13)	4.904(06)
3860	4.076(14)	4.274(05)	3.809(04)	4.433(09)	4.225(09)	5.516(11)	5.623(07)	3.659(05)	3.117(08)	4.770(07)
3876	4.262(31)	4.495(07)	3.929(04)	4.641(08)	4.456(07)	5.750(09)	5.825(13)	3.917(04)	3.286(22)	4.896(17)
3892	4.434(18)	4.536(07)	3.952(01)	4.709(07)	4.517(05)	5.789(05)	5.876(04)	3.969(05)	3.379(11)	4.981(03)
3908	4.058(05)	4.234(04)	3.809(02)	4.408(08)	4.203(08)	5.490(07)	5.595(04)	3.639(03)	3.110(04)	4.775(04)
3924	3.971(11)	4.192(04)	3.800(02)	4.353(08)	4.152(07)	5.426(08)	5.541(06)	3.594(03)	3.058(08)	4.730(08)
3940	4.018(18)	4.245(06)	3.807(03)	4.394(09)	4.193(08)	5.474(11)	5.581(07)	3.634(04)	3.092(11)	4.747(09)
3956	4.243(29)	4.463(06)	3.928(04)	4.623(08)	4.429(06)	5.713(16)	5.802(11)	3.881(06)	3.281(20)	4.890(16)
3972	4.456(21)	4.573(07)	4.011(02)	4.750(06)	4.553(05)	5.829(05)	5.908(03)	4.000(02)	3.417(11)	5.017(05)
3988	4.094(06)	4.235(03)	3.848(02)	4.431(06)	4.212(06)	5.509(06)	5.604(04)	3.643(04)	3.146(03)	4.806(02)
4004	3.968(06)	4.132(04)	3.842(02)	4.341(04)	4.103(04)	5.401(04)	5.502(03)	3.516(03)	3.079(03)	4.756(03)
4020	3.951(07)	4.112(04)	3.869(01)	4.332(03)	4.084(02)	5.384(03)	5.483(02)	3.488(02)	3.065(02)	4.745(02)
4036	3.946(07)	4.105(04)	3.832(02)	4.329(03)	4.076(03)	5.381(03)	5.472(01)	3.486(02)	3.047(02)	4.734(02)
4052	3.952(08)	4.117(05)	3.822(01)	4.337(03)	4.088(03)	5.392(03)	5.482(02)	3.498(02)	3.047(03)	4.731(02)
4068	3.998(13)	4.166(05)	3.839(01)	4.377(04)	4.133(04)	5.439(05)	5.528(03)	3.549(03)	3.078(05)	4.750(04)
4084	4.181(22)	4.366(05)	3.929(01)	4.555(05)	4.325(03)	5.640(05)	5.722(03)	3.760(04)	3.219(11)	4.861(09)
4100	4.511(09)	4.598(08)	4.070(04)	4.806(08)	4.595(07)	5.888(09)	5.945(06)	4.043(05)	3.470(08)	5.057(05)
4116	4.192(11)	4.314(03)	3.920(03)	4.532(05)	4.309(04)	5.598(06)	5.674(05)	3.726(03)	3.227(07)	4.884(04)
4132	4.010(03)	4.150(03)	3.886(07)	4.397(07)	4.155(04)	5.448(04)	5.535(02)	3.561(02)	3.110(03)	4.790(03)
4148	3.971(02)	4.111(03)	3.878(08)	4.364(07)	4.114(04)	5.416(04)	5.499(02)	3.519(02)	3.086(02)	4.770(03)
4164	3.976(04)	4.121(04)	3.866(06)	4.366(06)	4.115(04)	5.415(03)	5.498(01)	3.521(02)	3.087(03)	4.768(03)
4180	3.982(03)	4.127(05)	3.868(05)	4.367(05)	4.120(03)	5.417(03)	5.503(02)	3.526(01)	3.092(03)	4.773(02)
4196	3.987(03)	4.126(04)	3.874(03)	4.366(04)	4.111(03)	5.414(02)	5.497(02)	3.516(02)	3.092(03)	4.773(03)
4212	3.993(05)	4.132(04)	3.878(02)	4.374(02)	4.112(03)	5.415(02)	5.497(02)	3.516(02)	3.095(04)	4.775(03)
4228	4.001(04)	4.145(04)	3.889(02)	4.377(03)	4.117(03)	5.420(02)	5.502(02)	3.524(03)	3.100(04)	4.782(03)
4244	4.008(03)	4.151(04)	3.898(01)	4.388(02)	4.123(03)	5.427(03)	5.506(03)	3.530(03)	3.106(04)	4.790(03)
4260	4.009(02)	4.153(04)	3.913(02)	4.398(02)	4.134(02)	5.439(02)	5.516(02)	3.540(02)	3.118(04)	4.800(02)

TABLE 14
(Continued)

λ [Å]	HR 718	HR 1544	HR 3454	HR 4468	HR 4963	HR 5501	HR 7596	HR 7950	HR 8634	HR 9087
4276	4.021(05)	4.165(04)	3.916(01)	4.406(02)	4.141(03)	5.449(02)	5.521(02)	3.549(02)	3.123(03)	4.806(02)
4292	4.040(07)	4.194(05)	3.925(02)	4.419(03)	4.164(02)	5.464(02)	5.539(02)	3.576(02)	3.133(04)	4.816(01)
4308	4.095(09)	4.249(05)	3.944(01)	4.462(03)	4.214(02)	5.511(03)	5.585(03)	3.630(02)	3.166(04)	4.840(02)
4324	4.287(15)	4.442(04)	4.038(02)	4.639(04)	4.405(04)	5.701(06)	5.772(02)	3.832(03)	3.308(05)	4.954(05)
4340	4.593(07)	4.664(06)	4.174(03)	4.885(06)	4.655(06)	5.952(09)	5.979(04)	4.102(06)	3.547(09)	5.140(05)
4356	4.250(04)	4.380(03)	4.017(04)	4.594(02)	4.359(02)	5.649(02)	5.698(04)	3.775(03)	3.283(06)	4.949(04)
4372	4.091(03)	4.226(03)	3.975(02)	4.466(02)	4.206(02)	5.502(02)	5.565(02)	3.614(02)	3.176(04)	4.862(02)
4388	4.070(05)	4.206(04)	3.989(02)	4.451(03)	4.183(02)	5.486(02)	5.551(02)	3.593(02)	3.169(04)	4.858(02)
4404	4.059(05)	4.195(04)	3.968(03)	4.442(03)	4.175(02)	5.479(03)	5.546(01)	3.585(02)	3.160(03)	4.851(01)
4420	4.060(04)	4.188(03)	3.971(02)	4.441(02)	4.170(02)	5.477(02)	5.549(02)	3.577(02)	3.162(04)	4.853(01)
4436	4.059(05)	4.189(03)	3.984(01)	4.444(03)	4.168(02)	5.479(02)	5.543(02)	3.574(03)	3.163(04)	4.854(01)
4452	4.064(06)	4.201(04)	3.999(02)	4.451(03)	4.176(02)	5.485(02)	5.541(02)	3.581(02)	3.166(03)	4.868(01)
4468	4.075(06)	4.209(04)	4.047(02)	4.472(02)	4.185(02)	5.496(02)	5.550(02)	3.595(02)	3.186(02)	4.885(01)
4484	4.087(05)	4.213(04)	4.011(02)	4.477(02)	4.196(03)	5.505(02)	5.555(02)	3.603(02)	3.194(02)	4.884(01)
4500	4.074(06)	4.200(04)	3.998(03)	4.468(02)	4.185(03)	5.496(02)	5.543(02)	3.592(02)	3.183(02)	4.872(02)
4516	4.080(05)	4.205(03)	4.003(02)	4.472(03)	4.190(03)	5.500(02)	5.543(02)	3.595(02)	3.190(03)	4.882(02)
4532	4.080(05)	4.209(04)	4.005(03)	4.473(03)	4.196(02)	5.504(03)	5.546(01)	3.604(02)	3.189(02)	4.883(02)
4548	4.091(04)	4.217(04)	4.013(02)	4.482(04)	4.206(03)	5.514(02)	5.554(01)	3.618(01)	3.198(02)	4.894(02)
4564	4.088(04)	4.212(03)	4.020(03)	4.483(04)	4.203(03)	5.513(02)	5.554(02)	3.614(01)	3.200(02)	4.897(03)
4580	4.095(04)	4.214(03)	4.019(02)	4.487(04)	4.208(03)	5.515(03)	5.556(02)	3.615(02)	3.205(02)	4.901(02)
4596	4.096(04)	4.210(03)	4.029(04)	4.485(04)	4.202(04)	5.514(03)	5.550(02)	3.608(01)	3.209(02)	4.904(02)
4612	4.096(04)	4.207(04)	4.036(04)	4.489(04)	4.201(03)	5.517(02)	5.550(02)	3.610(02)	3.212(02)	4.906(02)
4628	4.105(03)	4.212(04)	4.044(05)	4.498(04)	4.209(04)	5.525(02)	5.557(02)	3.619(02)	3.221(02)	4.916(01)
4644	4.101(03)	4.208(04)	4.047(05)	4.496(05)	4.206(04)	5.523(03)	5.552(02)	3.613(02)	3.219(02)	4.917(02)
4660	4.108(03)	4.213(04)	4.048(05)	4.501(05)	4.213(04)	5.530(03)	5.557(02)	3.621(02)	3.224(02)	4.919(02)
4676	4.113(04)	4.217(04)	4.056(05)	4.504(05)	4.212(04)	5.533(03)	5.557(02)	3.622(02)	3.231(02)	4.924(02)
4692	4.115(04)	4.217(03)	4.063(05)	4.508(05)	4.213(04)	5.534(03)	5.560(01)	3.625(01)	3.232(02)	4.928(03)
4708	4.121(03)	4.224(04)	4.070(03)	4.513(05)	4.225(03)	5.539(03)	5.562(02)	3.627(02)	3.239(02)	4.935(02)
4724	4.124(03)	4.224(03)	4.070(03)	4.519(05)	4.223(04)	5.543(03)	5.566(02)	3.634(02)	3.244(02)	4.942(02)
4740	4.131(04)	4.230(03)	4.074(03)	4.525(04)	4.234(02)	5.548(03)	5.571(02)	3.641(02)	3.250(03)	4.949(03)
4756	4.138(04)	4.236(03)	4.080(03)	4.527(04)	4.235(04)	5.555(02)	5.574(02)	3.644(02)	3.256(03)	4.951(02)
4772	4.143(04)	4.246(03)	4.092(05)	4.535(05)	4.247(02)	5.562(01)	5.580(02)	3.652(02)	3.261(03)	4.959(03)
4788	4.148(03)	4.242(04)	4.097(05)	4.539(05)	4.246(02)	5.563(02)	5.581(01)	3.655(02)	3.265(03)	4.964(03)
4804	4.155(03)	4.250(04)	4.101(05)	4.545(05)	4.256(02)	5.569(02)	5.589(02)	3.666(02)	3.268(03)	4.967(03)
4820	4.178(04)	4.270(04)	4.100(03)	4.562(04)	4.276(02)	5.592(02)	5.605(02)	3.686(02)	3.284(03)	4.977(03)
4836	4.255(06)	4.346(04)	4.126(04)	4.623(05)	4.346(02)	5.660(04)	5.672(03)	3.765(03)	3.332(03)	5.014(02)
4852	4.549(06)	4.606(05)	4.267(05)	4.892(05)	4.625(04)	5.940(03)	5.949(02)	4.064(03)	3.562(02)	5.188(03)
4868	4.608(06)	4.672(06)	4.304(04)	4.941(05)	4.677(05)	5.975(05)	5.963(02)	4.106(03)	3.605(06)	5.233(03)
4884	4.280(04)	4.383(03)	4.144(04)	4.644(05)	4.376(02)	5.674(03)	5.677(02)	3.787(03)	3.347(02)	5.032(01)
4900	4.194(04)	4.289(04)	4.125(03)	4.574(04)	4.290(02)	5.595(01)	5.603(02)	3.693(02)	3.292(03)	4.993(02)
4916	4.181(04)	4.274(04)	4.146(03)	4.568(04)	4.272(03)	5.585(02)	5.594(03)	3.683(02)	3.289(03)	4.997(02)
4932	4.177(05)	4.271(04)	4.142(03)	4.564(04)	4.265(03)	5.580(01)	5.579(02)	3.674(02)	3.287(03)	4.994(02)
4948	4.173(05)	4.266(04)	4.130(03)	4.563(04)	4.260(03)	5.579(02)	5.575(02)	3.670(02)	3.287(03)	4.990(02)
4964	4.176(05)	4.269(04)	4.136(03)	4.565(04)	4.263(02)	5.579(01)	5.576(02)	3.672(03)	3.291(04)	4.993(03)
4980	4.181(05)	4.276(04)	4.143(03)	4.568(03)	4.264(02)	5.580(02)	5.576(02)	3.673(02)	3.294(03)	4.998(03)
4996	4.189(06)	4.283(04)	4.157(03)	4.580(03)	4.273(02)	5.590(03)	5.583(02)	3.683(02)	3.299(03)	5.006(03)
5012	4.199(06)	4.298(03)	4.175(03)	4.588(02)	4.285(02)	5.597(02)	5.591(02)	3.694(02)	3.311(03)	5.019(03)
5028	4.203(06)	4.300(03)	4.174(03)	4.595(02)	4.288(02)	5.600(02)	5.591(02)	3.694(02)	3.318(03)	5.022(02)
5044	4.208(06)	4.303(03)	4.183(02)	4.595(02)	4.288(02)	5.600(02)	5.591(02)	3.695(03)	3.321(03)	5.029(02)
5060	4.209(06)	4.302(03)	4.183(02)	4.598(02)	4.293(03)	5.602(02)	5.589(02)	3.695(02)	3.325(03)	5.030(03)
5076	4.207(05)	4.305(03)	4.186(02)	4.596(01)	4.290(02)	5.603(02)	5.585(02)	3.692(03)	3.319(03)	5.027(03)
5092	4.209(06)	4.302(03)	4.188(02)	4.597(02)	4.292(02)	5.603(03)	5.585(02)	3.692(03)	3.326(03)	5.029(02)
5108	4.209(05)	4.302(03)	4.195(02)	4.599(02)	4.292(02)	5.604(03)	5.585(02)	3.692(03)	3.326(03)	5.033(02)
5124	4.211(05)	4.306(03)	4.200(02)	4.601(02)	4.297(02)	5.605(03)	5.586(02)	3.699(02)	3.328(03)	5.035(02)
5140	4.214(06)	4.310(03)	4.203(02)	4.609(02)	4.300(02)	5.610(03)	5.590(02)	3.704(02)	3.331(02)	5.041(02)
5156	4.220(06)	4.318(03)	4.207(02)	4.618(02)	4.311(02)	5.615(03)	5.597(02)	3.714(02)	3.339(02)	5.049(03)
5172	4.234(05)	4.332(03)	4.209(02)	4.628(02)	4.325(02)	5.628(03)	5.609(02)	3.726(02)	3.345(02)	5.051(02)
5188	4.230(05)	4.328(03)	4.213(02)	4.629(03)	4.325(03)	5.627(03)	5.605(02)	3.727(02)	3.347(02)	5.052(03)
5204	4.228(04)	4.323(03)	4.219(02)	4.628(03)	4.318(02)	5.627(04)	5.599(02)	3.723(02)	3.349(02)	5.057(03)
5220	4.232(04)	4.325(03)	4.220(02)	4.633(03)	4.321(02)	5.627(02)	5.602(02)	3.726(02)	3.354(01)	5.064(03)
5236	4.238(04)	4.331(03)	4.224(02)	4.639(03)	4.330(02)	5.636(03)	5.605(01)	3.737(02)	3.361(02)	5.068(02)
5252	4.239(04)	4.329(04)	4.230(02)	4.641(03)	4.329(03)	5.637(03)	5.605(01)	3.730(02)	3.362(02)	5.071(02)
5268	4.244(04)	4.340(03)	4.236(02)	4.650(03)	4.340(02)	5.644(03)	5.610(01)	3.750(02)	3.368(01)	5.075(02)
5284	4.246(04)	4.338(04)	4.239(01)	4.650(04)	4.337(02)	5.646(03)	5.607(01)	3.740(01)	3.369(02)	5.077(03)
5300	4.245(04)	4.329(03)	4.243(01)	4.651(04)	4.334(02)	5.647(03)	5.603(01)	3.740(02)	3.371(02)	5.082(02)
5316	4.255(04)	4.341(03)	4.248(02)	4.662(04)	4.349(02)	5.656(03)	5.613(01)	3.754(02)	3.381(02)	5.093(04)
5332	4.255(04)	4.345(04)	4.251(02)	4.660(04)	4.349(02)	5.657(03)	5.612(01)	3.753(02)	3.382(02)	5.088(03)
5348	4.253(04)	4.337(03)	4.257(03)	4.658(04)	4.342(02)	5.653(03)	5.606(02)	3.745(01)	3.379(03)	5.089(02)
5364	4.255(03)	4.336(03)	4.258(03)	4.660(04)	4.346(02)	5.656(03)	5.608(02)	3.749(01)	3.383(02)	5.092(02)
5380	4.258(04)	4.340(03)	4.264(03)	4.663(04)	4.345(02)	5.657(03)	5.606(02)	3.750(01)	3.388(03)	5.094(02)
5396	4.263(03)	4.342(03)	4.267(03)	4.668(04)	4.349(02)	5.661(03)	5.611(02)	3.755(01)	3.393(02)	5.101(03)

TABLE 14
(Continued)

λ [Å]	HR 718	HR 1544	HR 3454	HR 4468	HR 4963	HR 5501	HR 7596	HR 7950	HR 8634	HR 9087
5412	4.268(03)	4.348(03)	4.273(03)	4.671(04)	4.356(02)	5.662(03)	5.614(02)	3.758(02)	3.400(04)	5.104(02)
5428	4.270(03)	4.353(03)	4.279(03)	4.676(03)	4.357(02)	5.668(03)	5.613(02)	3.760(01)	3.401(04)	5.107(02)
5444	4.271(04)	4.347(04)	4.283(03)	4.677(03)	4.355(02)	5.669(03)	5.614(02)	3.758(02)	3.403(04)	5.108(02)
5460	4.275(04)	4.348(03)	4.286(03)	4.680(03)	4.358(03)	5.672(03)	5.615(02)	3.761(02)	3.403(02)	5.114(03)
5476	4.279(04)	4.352(03)	4.291(03)	4.684(03)	4.361(02)	5.675(02)	5.614(02)	3.765(02)	3.412(04)	5.117(03)
5492	4.282(03)	4.354(03)	4.295(03)	4.686(03)	4.364(03)	5.675(02)	5.616(02)	3.763(03)	3.415(04)	5.122(02)
5508	4.286(03)	4.357(03)	4.297(03)	4.691(03)	4.365(03)	5.680(03)	5.615(02)	3.769(02)	3.415(03)	5.125(01)
5524	4.288(04)	4.363(03)	4.303(03)	4.690(02)	4.366(02)	5.678(02)	5.617(02)	3.770(03)	3.419(03)	5.124(02)
5540	4.293(03)	4.365(03)	4.308(03)	4.695(02)	4.369(02)	5.683(01)	5.617(02)	3.773(03)	3.426(03)	5.131(02)
5556	4.296(04)	4.364(02)	4.313(03)	4.697(03)	4.368(02)	5.681(02)	5.614(02)	3.770(02)	3.428(03)	5.135(02)
5572	4.299(03)	4.368(03)	4.315(03)	4.700(03)	4.372(02)	5.686(02)	5.614(02)	3.776(02)	3.427(02)	5.139(01)
5588	4.304(03)	4.372(03)	4.319(03)	4.703(02)	4.376(02)	5.689(02)	5.618(02)	3.780(03)	3.436(03)	5.144(02)
5604	4.307(03)	4.376(03)	4.327(03)	4.707(02)	4.378(02)	5.694(02)	5.618(02)	3.782(03)	3.434(02)	5.147(02)
5620	4.312(03)	4.378(03)	4.333(03)	4.709(02)	4.382(02)	5.698(02)	5.621(02)	3.785(03)	3.442(03)	5.151(01)
5636	4.319(04)	4.382(04)	4.340(03)	4.715(02)	4.385(02)	5.703(03)	5.623(01)	3.789(02)	3.445(02)	5.158(01)
5652	4.324(03)	4.386(03)	4.348(03)	4.723(02)	4.392(02)	5.706(02)	5.624(02)	3.795(03)	3.451(04)	5.164(02)
5668	4.328(04)	4.395(04)	4.354(03)	4.729(01)	4.398(02)	5.711(02)	5.627(02)	3.802(02)	3.453(03)	5.172(02)
5684	4.334(04)	4.397(02)	4.361(03)	4.732(02)	4.402(02)	5.717(02)	5.633(02)	3.804(02)	3.462(03)	5.174(03)
5700	4.339(03)	4.400(03)	4.365(03)	4.738(01)	4.407(02)	5.722(02)	5.636(02)	3.809(02)	3.464(03)	5.183(02)
5716	4.342(02)	4.405(04)	4.367(02)	4.740(02)	4.408(02)	5.725(01)	5.636(02)	3.813(03)	3.471(03)	5.189(02)
5732	4.350(04)	4.407(04)	4.376(03)	4.748(01)	4.414(02)	5.731(02)	5.641(02)	3.818(02)	3.475(02)	5.193(02)
5748	4.353(04)	4.411(04)	4.378(02)	4.753(02)	4.417(03)	5.735(02)	5.644(02)	3.822(02)	3.479(02)	5.200(04)
5764	4.351(03)	4.414(04)	4.383(02)	4.755(02)	4.420(02)	5.740(02)	5.647(02)	3.826(02)	3.482(02)	5.202(04)
5780	4.358(04)	4.413(04)	4.383(02)	4.758(01)	4.420(01)	5.741(02)	5.657(01)	3.826(02)	3.484(02)	5.201(05)
5796	4.353(03)	4.413(04)	4.383(01)	4.757(02)	4.421(03)	5.740(02)	5.651(02)	3.827(02)	3.484(02)	5.200(04)
5812	4.352(04)	4.410(04)	4.384(02)	4.757(02)	4.418(03)	5.736(02)	5.641(02)	3.824(02)	3.480(02)	5.196(03)
5828	4.353(05)	4.408(04)	4.384(01)	4.755(02)	4.416(02)	5.734(02)	5.640(01)	3.823(02)	3.478(02)	5.200(04)
5844	4.352(04)	4.407(04)	4.385(02)	4.757(02)	4.416(03)	5.734(02)	5.639(02)	3.822(02)	3.479(02)	5.198(03)
5860	4.355(05)	4.414(04)	4.394(02)	4.761(01)	4.418(03)	5.739(02)	5.642(01)	3.825(02)	3.484(02)	5.204(03)
5876	4.367(06)	4.422(04)	4.432(03)	4.773(01)	4.429(03)	5.748(03)	5.653(02)	3.835(03)	3.494(02)	5.218(03)
5892	4.380(06)	4.438(04)	4.422(03)	4.782(02)	4.447(03)	5.762(03)	5.682(02)	3.852(03)	3.502(01)	5.223(04)
5908	4.378(06)	4.437(04)	4.414(01)	4.779(02)	4.440(03)	5.759(03)	5.661(02)	3.846(03)	3.499(02)	5.222(03)
5924	4.376(05)	4.432(04)	4.423(04)	4.781(02)	4.441(02)	5.759(03)	5.655(02)	3.845(03)	3.501(02)	5.224(03)
5940	4.382(06)	4.440(04)	4.429(04)	4.785(02)	4.445(03)	5.764(03)	5.656(01)	3.847(03)	3.508(01)	5.230(03)
5956	4.390(06)	4.444(04)	4.433(04)	4.793(02)	4.450(03)	5.768(03)	5.663(02)	3.855(03)	3.514(02)	5.239(03)
5972	4.389(05)	4.443(03)	4.431(02)	4.795(02)	4.452(02)	5.770(03)	5.663(02)	3.855(03)	3.517(02)	5.242(02)
5988	4.394(05)	4.446(04)	4.432(02)	4.795(02)	4.452(02)	5.772(03)	5.667(02)	3.858(02)	3.523(01)	5.245(02)
6004	4.394(05)	4.449(03)	4.439(02)	4.798(02)	4.453(01)	5.772(02)	5.667(02)	3.862(02)	3.522(02)	5.247(02)
6020	4.398(05)	4.451(03)	4.444(03)	4.798(02)	4.457(01)	5.777(02)	5.667(02)	3.865(02)	3.526(02)	5.253(02)
6036	4.405(05)	4.454(03)	4.446(02)	4.803(02)	4.461(01)	5.780(02)	5.672(03)	3.867(02)	3.532(02)	5.260(02)
6052	4.407(04)	4.453(04)	4.451(02)	4.807(02)	4.462(01)	5.782(03)	5.673(02)	3.870(02)	3.535(02)	5.260(02)
6068	4.411(04)	4.455(03)	4.453(02)	4.810(01)	4.466(02)	5.785(03)	5.675(02)	3.872(03)	3.538(02)	5.258(01)
6084	4.420(05)	4.458(03)	4.458(02)	4.813(02)	4.471(02)	5.791(01)	5.673(02)	3.871(02)	3.542(05)	5.265(04)
6100	4.426(05)	4.460(04)	4.464(03)	4.815(02)	4.471(02)	5.790(03)	5.675(01)	3.878(03)	3.545(04)	5.265(04)
6116	4.425(03)	4.464(04)	4.467(04)	4.818(01)	4.473(02)	5.794(03)	5.679(02)	3.881(03)	3.549(05)	5.265(05)
6132	4.431(05)	4.466(04)	4.464(02)	4.821(02)	4.479(02)	5.796(03)	5.679(02)	3.887(02)	3.554(05)	5.268(05)
6148	4.438(04)	4.476(03)	4.478(04)	4.830(02)	4.488(02)	5.805(02)	5.689(02)	3.897(03)	3.561(04)	5.279(04)
6164	4.441(04)	4.480(04)	4.478(03)	4.834(02)	4.490(02)	5.811(02)	5.693(02)	3.898(03)	3.564(04)	5.283(04)
6180	4.439(04)	4.470(03)	4.481(04)	4.830(01)	4.487(02)	5.805(03)	5.693(02)	3.894(03)	3.564(05)	5.278(06)
6196	4.442(04)	4.473(04)	4.484(04)	4.833(01)	4.486(02)	5.811(01)	5.692(01)	3.893(03)	3.565(04)	5.285(03)
6212	4.446(03)	4.477(04)	4.489(03)	4.837(02)	4.490(02)	5.811(02)	5.693(02)	3.896(02)	3.568(05)	5.290(04)
6228	4.453(04)	4.486(04)	4.492(03)	4.844(01)	4.496(02)	5.814(03)	5.696(01)	3.903(03)	3.575(04)	5.295(03)
6244	4.460(04)	4.494(04)	4.497(04)	4.851(01)	4.505(02)	5.820(03)	5.703(01)	3.914(03)	3.581(04)	5.296(06)
6260	4.463(05)	4.493(04)	4.505(03)	4.853(01)	4.506(02)	5.824(03)	5.704(01)	3.915(03)	3.586(04)	5.299(06)
6276	4.490(04)	4.515(04)	4.530(03)	4.872(01)	4.526(02)	5.848(02)	5.732(01)	3.931(03)	3.603(04)	5.318(06)
6292	4.488(04)	4.518(03)	4.532(03)	4.877(01)	4.531(02)	5.850(03)	5.735(01)	3.939(02)	3.611(04)	5.324(06)
6308	4.482(03)	4.513(03)	4.526(03)	4.874(02)	4.524(02)	5.842(02)	5.720(02)	3.930(02)	3.605(04)	5.317(05)
6324	4.478(04)	4.508(04)	4.523(02)	4.869(01)	4.520(02)	5.838(02)	5.713(02)	3.927(03)	3.600(04)	5.313(05)
6340	4.485(03)	4.512(03)	4.529(02)	4.872(01)	4.523(02)	5.841(02)	5.716(02)	3.929(02)	3.604(04)	5.316(05)
6356	4.483(04)	4.512(04)	4.530(03)	4.875(01)	4.523(02)	5.840(03)	5.716(02)	3.931(03)	3.607(04)	5.318(04)
6372	4.486(04)	4.512(03)	4.533(04)	4.875(01)	4.526(02)	5.840(04)	5.718(02)	3.934(03)	3.609(04)	5.323(05)
6388	4.487(04)	4.509(03)	4.532(03)	4.873(01)	4.522(02)	5.842(03)	5.712(02)	3.929(02)	3.607(04)	5.320(04)
6404	4.485(05)	4.512(03)	4.536(04)	4.874(01)	4.523(02)	5.840(03)	5.712(02)	3.929(02)	3.607(03)	5.321(04)
6420	4.491(04)	4.517(03)	4.536(03)	4.877(01)	4.526(03)	5.842(04)	5.714(02)	3.935(02)	3.611(04)	5.325(04)
6436	4.490(02)	4.517(03)	4.536(03)	4.881(01)	4.531(03)	5.844(03)	5.716(02)	3.938(02)	3.613(04)	5.328(04)
6452	4.502(04)	4.525(03)	4.538(02)	4.886(01)	4.537(02)	5.848(03)	5.724(02)	3.945(02)	3.618(03)	5.333(03)
6468	4.509(03)	4.533(03)	4.545(02)	4.891(01)	4.540(02)	5.854(01)	5.724(02)	3.948(02)	3.621(04)	5.337(04)
6484	4.516(02)	4.538(03)	4.556(03)	4.898(02)	4.547(02)	5.859(03)	5.730(02)	3.952(02)	3.625(04)	5.344(03)
6500	4.520(03)	4.539(03)	4.555(02)	4.897(01)	4.549(02)	5.863(02)	5.727(02)	3.954(02)	3.626(04)	5.343(02)
6516	4.529(03)	4.548(04)	4.562(03)	4.908(01)	4.559(02)	5.870(03)	5.736(01)	3.964(03)	3.634(04)	5.350(03)

TABLE 14
(Continued)

λ [Å]	HR 718	HR 1544	HR 3454	HR 4468	HR 4963	HR 5501	HR 7596	HR 7950	HR 8634	HR 9087
6532	4.565(03)	4.575(03)	4.572(03)	4.934(02)	4.587(02)	5.900(03)	5.763(02)	3.996(03)	3.653(03)	5.363(04)
6548	4.703(07)	4.683(04)	4.630(04)	5.063(03)	4.718(03)	6.025(04)	5.897(02)	4.136(02)	3.754(03)	5.441(04)
6564	4.892(02)	4.837(04)	4.758(02)	5.257(06)	4.923(06)	6.221(06)	6.079(01)	4.340(03)	3.925(08)	5.592(06)
6580	4.687(02)	4.688(03)	4.634(02)	5.046(02)	4.709(03)	6.015(04)	5.860(04)	4.118(03)	3.763(03)	5.440(03)
6596	4.565(03)	4.581(02)	4.585(02)	4.940(01)	4.597(03)	5.905(04)	5.762(03)	4.000(02)	3.665(03)	5.375(03)
6612	4.537(03)	4.553(02)	4.579(02)	4.922(01)	4.568(03)	5.882(04)	5.739(02)	3.974(03)	3.649(04)	5.366(03)
6628	4.534(04)	4.548(03)	4.578(02)	4.918(01)	4.561(03)	5.876(04)	5.732(02)	3.967(03)	3.649(03)	5.365(02)
6644	4.530(04)	4.545(03)	4.581(02)	4.916(02)	4.559(03)	5.875(03)	5.730(02)	3.964(02)	3.649(04)	5.367(03)
6660	4.532(02)	4.546(02)	4.585(02)	4.917(01)	4.560(02)	5.875(04)	5.730(01)	3.964(02)	3.650(03)	5.372(03)
6676	4.536(05)	4.549(02)	4.607(02)	4.921(02)	4.561(02)	5.873(02)	5.729(02)	3.966(02)	3.655(04)	5.374(03)
6692	4.536(02)	4.548(03)	4.595(01)	4.920(01)	4.561(03)	5.876(04)	5.727(02)	3.965(02)	3.652(03)	5.373(03)
6708	4.537(03)	4.549(03)	4.594(02)	4.922(01)	4.563(02)	5.879(03)	5.728(02)	3.966(02)	3.654(04)	5.375(02)
6724	4.537(05)	4.550(02)	4.596(02)	4.924(02)	4.566(02)	5.879(02)	5.732(03)	3.969(02)	3.658(04)	5.379(03)
6740	4.541(04)	4.551(02)	4.601(02)	4.930(01)	4.567(02)	5.882(03)	5.732(02)	3.972(01)	3.662(03)	5.383(02)
6756	4.543(05)	4.556(02)	4.604(01)	4.935(01)	4.574(03)	5.886(03)	5.735(02)	3.978(02)	3.667(03)	5.391(03)
6772	4.548(05)	4.556(02)	4.612(01)	4.936(01)	4.575(02)	5.894(03)	5.739(02)	3.979(02)	3.671(03)	5.395(03)
6788	4.552(03)	4.562(02)	4.620(02)	4.942(01)	4.582(03)	5.896(03)	5.742(02)	3.986(02)	3.677(04)	5.402(03)
6804	4.555(02)	4.565(02)	4.622(02)	4.948(02)	4.581(02)	5.901(03)	5.745(01)	3.987(02)	3.682(03)	5.407(03)
6820	4.557(04)	4.566(02)	4.625(02)	4.951(02)	4.588(03)	5.905(04)	5.748(01)	3.995(02)	3.686(04)	5.411(03)
6836	4.557(02)	4.569(02)	4.627(01)	4.953(01)	4.591(03)	5.905(03)	5.749(01)	3.994(02)	3.688(04)	5.414(04)
6852*	4.581(06)	4.584(03)	4.639(02)	4.972(02)	4.605(02)	5.920(03)	5.765(01)	4.008(02)	3.703(03)	5.429(04)
6868*	4.718(03)	4.726(02)	4.782(03)	5.101(01)	4.740(04)	6.061(02)	5.894(01)	4.141(03)	3.827(04)	5.559(04)
6884*	4.723(03)	4.731(02)	4.792(01)	5.114(02)	4.752(02)	6.073(03)	5.919(02)	4.163(02)	3.865(04)	5.579(05)
6900*	4.682(02)	4.689(01)	4.755(02)	5.073(02)	4.715(03)	6.029(01)	5.873(02)	4.121(02)	3.821(04)	5.538(04)
6916*	4.628(03)	4.641(02)	4.706(02)	5.026(01)	4.665(03)	5.981(04)	5.820(02)	4.070(02)	3.766(05)	5.492(04)
6932*	4.611(03)	4.619(03)	4.690(02)	5.001(01)	4.643(03)	5.959(03)	5.795(01)	4.042(02)	3.739(06)	5.466(06)
6948*	4.609(03)	4.614(04)	4.682(02)	4.998(02)	4.636(04)	5.952(03)	5.789(02)	4.038(03)	3.732(06)	5.460(06)
6964*	4.597(02)	4.605(03)	4.673(02)	4.990(01)	4.628(03)	5.942(03)	5.778(02)	4.029(02)	3.722(03)	5.453(05)
6980	4.594(02)	4.602(03)	4.671(01)	4.992(01)	4.625(03)	5.940(03)	5.774(01)	4.027(02)	3.724(04)	5.452(04)
6996	4.606(02)	4.616(03)	4.682(02)	4.999(01)	4.632(03)	5.949(02)	5.781(01)	4.037(03)	3.732(05)	5.460(05)
7012	4.611(01)	4.619(03)	4.687(01)	5.002(01)	4.634(03)	5.951(02)	5.783(02)	4.037(03)	3.732(05)	5.463(05)
7028	4.610(02)	4.617(03)	4.689(02)	5.001(02)	4.634(02)	5.950(03)	5.782(01)	4.038(03)	3.735(05)	5.466(05)
7044	4.607(04)	4.614(03)	4.688(01)	5.001(02)	4.634(03)	5.950(03)	5.781(01)	4.035(02)	3.738(04)	5.465(05)
7060	4.610(03)	4.617(03)	4.701(02)	5.004(01)	4.634(02)	5.951(03)	5.782(01)	4.039(02)	3.741(04)	5.469(04)
7076	4.609(03)	4.615(02)	4.698(02)	5.005(01)	4.637(03)	5.950(03)	5.782(02)	4.039(02)	3.743(03)	5.470(04)
7092	4.614(02)	4.621(03)	4.694(02)	5.006(02)	4.635(03)	5.951(03)	5.781(02)	4.040(02)	3.742(03)	5.470(04)
7108	4.616(01)	4.622(03)	4.696(01)	5.009(01)	4.639(02)	5.954(03)	5.782(02)	4.046(02)	3.743(03)	5.477(02)
7124	4.619(04)	4.628(03)	4.704(02)	5.013(03)	4.643(03)	5.956(03)	5.784(02)	4.047(02)	3.748(04)	5.476(04)
7140	4.625(03)	4.631(03)	4.707(02)	5.019(03)	4.646(03)	5.960(03)	5.789(02)	4.048(02)	3.751(04)	5.482(03)
7156*	4.641(02)	4.642(04)	4.723(03)	5.031(02)	4.658(02)	5.975(02)	5.799(02)	4.060(02)	3.762(05)	5.494(04)
7172*	4.703(11)	4.701(07)	4.779(04)	5.078(04)	4.705(04)	6.019(03)	5.837(02)	4.107(04)	3.796(07)	5.528(08)
7188*	4.747(18)	4.749(10)	4.823(05)	5.119(06)	4.749(06)	6.064(04)	5.879(03)	4.150(06)	3.831(12)	5.564(12)
7204*	4.718(13)	4.726(08)	4.803(03)	5.103(06)	4.732(05)	6.044(03)	5.868(03)	4.135(04)	3.824(10)	5.554(11)
7220*	4.682(07)	4.680(05)	4.761(04)	5.058(03)	4.696(03)	6.007(03)	5.829(02)	4.094(03)	3.789(02)	5.520(05)
7236*	4.714(10)	4.716(07)	4.803(04)	5.096(05)	4.724(05)	6.036(03)	5.855(02)	4.124(04)	3.814(08)	5.549(08)
7252*	4.724(11)	4.725(08)	4.808(04)	5.102(07)	4.731(05)	6.043(03)	5.857(02)	4.129(05)	3.824(10)	5.553(09)
7268*	4.721(11)	4.715(07)	4.802(04)	5.098(05)	4.727(04)	6.039(03)	5.854(02)	4.128(04)	3.822(08)	5.550(09)
7284*	4.716(09)	4.716(07)	4.807(04)	5.098(06)	4.723(04)	6.037(03)	5.852(02)	4.127(04)	3.822(09)	5.550(09)
7300*	4.711(07)	4.712(06)	4.800(04)	5.094(05)	4.717(03)	6.034(03)	5.849(02)	4.125(03)	3.813(04)	5.547(09)
7316*	4.704(06)	4.699(06)	4.787(04)	5.084(05)	4.711(04)	6.026(02)	5.839(02)	4.112(04)	3.812(03)	5.540(08)
7332*	4.684(05)	4.679(04)	4.772(04)	5.066(03)	4.694(03)	6.009(03)	5.826(02)	4.097(02)	3.801(02)	5.529(07)
7348	4.685(05)	4.678(04)	4.768(04)	5.068(03)	4.690(02)	6.008(03)	5.822(02)	4.096(02)	3.804(04)	5.534(04)
7364	4.690(04)	4.679(04)	4.772(03)	5.067(04)	4.695(03)	6.008(02)	5.824(02)	4.096(03)	3.804(03)	5.531(07)
7380	4.684(04)	4.675(03)	4.770(03)	5.070(03)	4.694(03)	6.012(02)	5.823(02)	4.098(02)	3.807(04)	5.537(04)
7396	4.682(07)	4.676(03)	4.772(03)	5.072(03)	4.693(03)	6.011(02)	5.822(02)	4.098(02)	3.807(04)	5.534(04)
7412	4.684(04)	4.677(03)	4.773(03)	5.074(04)	4.695(02)	6.012(03)	5.825(02)	4.101(02)	3.811(04)	5.540(04)
7428	4.687(05)	4.678(03)	4.775(02)	5.074(02)	4.700(03)	6.014(02)	5.827(02)	4.102(02)	3.812(04)	5.545(04)
7444	4.689(03)	4.681(03)	4.781(03)	5.078(03)	4.702(03)	6.018(03)	5.832(02)	4.107(02)	3.817(03)	5.545(04)
7460	4.694(04)	4.682(03)	4.779(03)	5.079(02)	4.704(03)	6.021(03)	5.832(02)	4.108(02)	3.819(03)	5.545(05)
7476	4.697(05)	4.686(03)	4.787(03)	5.086(02)	4.708(03)	6.025(03)	5.835(02)	4.112(02)	3.824(03)	5.554(05)
7492	4.698(04)	4.682(03)	4.785(03)	5.083(02)	4.704(02)	6.021(03)	5.832(02)	4.112(02)	3.822(04)	5.554(06)
7508	4.696(05)	4.688(03)	4.791(02)	5.090(02)	4.711(02)	6.030(03)	5.836(02)	4.119(02)	3.831(03)	5.562(05)
7524	4.700(06)	4.685(03)	4.792(02)	5.089(02)	4.711(02)	6.028(02)	5.837(02)	4.120(01)	3.828(04)	5.563(05)
7540	4.692(04)	4.681(03)	4.789(02)	5.085(01)	4.708(02)	6.026(04)	5.834(02)	4.114(02)	3.825(03)	5.559(05)
7556	4.699(02)	4.687(03)	4.797(02)	5.092(02)	4.714(03)	6.034(04)	5.842(02)	4.121(01)	3.836(03)	5.569(04)

Notes : All values are in monochromatic magnitudes $m_{\nu} = -2.5 \log_{10}(f_{\nu}) - 48.590$
Bands with * contain telluric features
Errors are in units of mmag

quested exposure time, and solved for that constant by comparing the mean charge level of the two spectra.

4. SPECTROSCOPIC REDUCTIONS AND RESULTS

We performed all of the image reductions with the Image Reduction and Analysis Facility (IRAF) running on Sun workstations and the addition of our own code designed to interpolate fluxes from our spectra. The data were corrected for mean dc level by subtracting a low-order fit to the overscan area, trimmed, corrected for periodic bias structure introduced by the on-chip amplifier and preflash (bias frame subtraction), and divided each CCD image by a normalized flat field image. We obtained the flat field image from daytime observations of a white screen illuminated by quartz lamps ("domeflats"). It was necessary, however, to take a series of flats ("quartzflats") with a bright quartz lamp located inside the spectrograph, since the domeflat did not provide enough photons to illuminate the ultraviolet. To perform this operation without saturating the CCD at the redder wavelengths we observed the internal quartz lamp through a $CuSO_4$ and a Corning 9863 filter. The two types of flats were then merged into a single final flat field image.

We extracted sky-subtracted spectra from the two-dimensional images using an aperture of 23″ for the 1.5-m data and 13″ for the 4-m data, quite similar to the slit width that we used in the observations. We rebinned the spectra to a linear wavelength scale using a wavelength calibration based on He–Ar lamp exposure taken at the zenith. We applied a shutter time correction to every observation by multiplying the spectrum by the following factor:

$$\mathrm{ET}/(\mathrm{ET}+\mathrm{ST}),$$

where ET is the exposure time of the spectrum (in s) and ST is the shutter time given in Table 8. We then corrected the spectra for atmospheric extinction using the extinction curve obtained on that night from the observations of the secondary standards selected for this purpose. As an example, in Fig. 3 we show curves obtained on 1991 January 15 and 1989 June 27 which are representative of typical atmospheric extinctions at Cerro Tololo in winter and summer. The noticeable differences between the two curves are significant. This effect is probably associated with the seasonal increase of the amount of dust in the lower atmospheric layers, which may be also visually identified on the mountain at sunsets at that epoch of the year. A similar result was found at the European Southern Observatory in La Silla by Rufener (1986).

For HR 3454, HR 8634, and HR 9087 we removed the absorption lines He I λ4009, He I λ4026, He I λ4471, and Mg II λ4481 from the spectra as suggested by Taylor (1984). Finally, we flux-calibrated our spectra with the nightly response curve, which was fit with a cubic spline function to the observed flux values of the secondary standards. The process of flux calibration treated the data at the two slit positions as two entirely independent groups. Thus, for each observing night we derived two response curves and therefore, two independent spectra for each object. No greyshifts to bring the spectra to mean values were applied.

We obtained a total of 178 spectra of the tertiary standards over the ten nights of observations. In order to check the overall internal precision of our spectra, we calculated synthetic B and V magnitudes using Eq. (3) and the ZP given in Table 6. Table 9 gives the average synthetic magnitudes obtained for each star along with the rms (in parentheses, in units of mmag), the number of observations obtained for each star (m), as well as the number of different nights on which that star was observed (n). In Figs. 4(a) and 4(b) we plot the rms in Table 9 as a function of the V and B synthetic magnitude of the star. From these plots it can be seen that the dispersion of the synthetic magnitudes is typically 0.01 mag in both bands and in all cases $\leqslant$0.02 mag, regardless of the brightness of the star. These results are extremely encouraging and we conclude that the internal precision over the broad bandpasses is of the order of 1% in the mean.

We also searched for night-to-night differences by comparing the individual synthetic magnitudes of our program objects with the average magnitudes given in Table 9. We summarize our results on Table 10 for the B and V bands. In a few cases there are some significant differences. In particular, on the night of 1989 June 15 we found a departure of -0.015 mag from the average in B, and -0.008 mag in V. This level of difference is not surprising given that the extinction corrections in the B band are quite large. Overall, most of the night-to-night differences are smaller than 0.01 mag and may be ignored.

In Figs. 5(a) and 5(b) we compare the synthetic magnitudes and the CCD photometry (given in Table 7) for the proposed tertiary standards plotted as a magnitude difference as a function of the observed magnitude of the star, for V and B, respectively. We find excellent agreement in both bands with no significant dependence on magnitude or color. The average differences are

$$V_{\mathrm{SYN}}-V_{\mathrm{OBS}}=-0.002\pm0.006\ \ (\mathrm{s.d.}),$$

$$B_{\mathrm{SYN}}-B_{\mathrm{OBS}}=+0.006\pm0.011\ \ (\mathrm{s.d.}).$$

The small dispersions confirm the high internal accuracy of our photometry and spectrophotometry. We also performed the comparison of the synthetic magnitudes with photometry by Landolt (1992a). Figures 6(a) and 6(b) show the differences in the sense synthetic minus Landolt versus magnitude. Evidently, there is a small systematic difference between magnitudes synthesized from the spectrophotometry and Landolt's data by the amounts

$$V_{\mathrm{SYN}}-V_{\mathrm{LANDOLT}}=+0.009\pm0.007\ \ (\mathrm{s.d}),$$

$$B_{\mathrm{SYN}}-B_{\mathrm{LANDOLT}}=+0.013\pm0.009\ \ (\mathrm{s.d.}).$$

This difference also has been reported by Landolt (1992a) when comparing his photometry with ours.

Next we compare our new values of the monochromatic fluxes with other published values. To do these comparisons we interpolated our monochromatic magnitudes to the same wavelengths and bandwidths used by the other observers. Since the zero points of the monochromatic magnitude scale changes from paper to paper, we shifted the published monochromatic magnitudes onto the same zero point scale that we use here. In Fig. 7 we show the comparison between our spectrophotometry and Stone and Baldwin (1983) and Baldwin and Stone (1984) data. Significant differences can be seen in this figure. Most of the discrepancies are within 0.05 mag but occasionally reach 0.1 mag. For one star, namely LTT 6248, we found a discrepancy of −0.49 mag at 3400 Å which is off scale in this figure. LTT 377 and EG 274 show the largest systematic discrepancies which vary by as much as 0.15 mag as a function of wavelength. Figure 8 shows the mean differences in fluxes between both datasets from the 16 stars in common, together with their corresponding errors. Significant differences of up to ∼0.05 mag may be seen between both datasets at some wavelengths, mostly blueward of 4400 Å. The large error bar at 3400 Å is mainly due to the star LTT 6248. Some of these differences may be attributed to the fact that the fluxes provided by Stone and Baldwin (1983) and Baldwin and Stone (1984) are on the HL 75 system, whereas our data are on the Hayes (1985) spectrophotometric system. Indeed, a comparison of Figs. 1 and 8 shows some similitudes, especially in the range 3000–4400 Å.

For the three stars of the northern hemisphere included in our program we compared the data given by Stone (1977) and Massey et al. (1988), which were all obtained in the HL 75 system. The comparison with Stone is shown in Fig. 9 for the three stars in common. Except for some small greyshifts, the comparison is good for all three stars. In Fig. 10 we show the comparison with Massey et al. (1988) for the two stars in common. Here the comparison is fair since differences of up to 0.1 mag may be seen at the longest wavelengths for both stars. Shortward of 6000 Å the comparison with Massey is much better since most of the discrepancies are smaller than ∼0.03 mag.

Our results are first tabulated at Stone and Baldwin's (1984) and Stone's (1977) bandpasses to allow a direct comparison of our data with theirs. In Table 11 we present the fluxes for the tertiary standards of the southern hemisphere expressed in monochromatic magnitudes according to Eq. (2), using Stone and Baldwin's (1984) bandpasses. Analogously, Table 12 shows our results for the three stars of the northern hemisphere at Stone's (1977) bandpasses. In both tables are also given (in parentheses, in units of mmag) the errors ($\sigma/\sqrt{n}$) in the mean monochromatic magnitudes. Table 13 gives monochromatic magnitudes for the tertiary standards calculated through 50 Å bandpasses at continuous steps of 50 Å, to allow better use of our spectrophotometric measurements. The fluxes in each band are actual integrations of the real spectrum including absorption lines and telluric features. We warn observers that bandpasses containing telluric features are particularly inaccurate and of higher internal errors since their strengths are variable in time. Bandpasses containing part or total telluric bands are indicated with an asterisk. The values given in parentheses (in units of mmag) are the errors ($\sigma/\sqrt{n}$) in the mean. Figure 11 shows for each wavelength the typical error of the monochromatic magnitudes given in Table 13, obtained by averaging the errors of all the program stars. Overall, the uncertainties increase towards the shortest wavelengths due to the decrease in the sensitivity of our instrumental system and also because of the increase in the extinction corrections.

The secondary standards that we selected to flux calibrate the tertiary standards are excellent flux standards for echelle data. In Table 14 we present monochromatic magnitudes for the ten secondary standards at steps of 16 Å [calculated with Eq. (2)] which corresponds to the resolution of our 1.5-m telescope spectra. These magnitudes are the average of all the observations gathered for these stars. We include in parentheses (in units of mmag) the error ($\sigma/\sqrt{n}$) in each magnitude. Wavelengths with an asterisk are those which include telluric features. We also warn the reader not to trust fluxes very close to strong absorptions where the low resolution of our observations causes the features to artificially broaden.

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