THE ASTRONOMICAL JOURNAL VOLUME 106, NUMBER 5 NOVEMBER 1993

NEW LIMB-DARKENING COEFFICIENTS FOR MODELING BINARY STAR LIGHT CURVES

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Received 1993 February 4; revised 1993 July 30

ABSTRACT

We present monochromatic, passband-specific, and bolometric limb-darkening coefficients for a linear as well as nonlinear logarithmic and square root limb-darkening laws. These coefficients, including the bolometric ones, are needed when modeling binary star light curves with the latest version of the Wilson–Devinney light curve program. We base our calculations on the most recent ATLAS stellar atmosphere models for solar chemical composition stars with a wide range of effective temperatures and surface gravities. We examine how well various limb-darkening approximations represent the variation of the emerging specific intensity across a stellar surface as computed according to the model. For binary star light curve modeling purposes, we propose the use of a logarithmic or a square root law. We design our tables in such a manner that the relative quality of either law with respect to another can be easily compared. Since the computation of bolometric limb-darkening coefficients first requires monochromatic coefficients, we also offer tables of these coefficients (at 1221 wavelength values between 9.09 nm and 160 μm) and tables of passband-specific coefficients for commonly used photometric filters.

1. INTRODUCTION

The center-to-limb darkening of a stellar surface plays an important and well-known role in the study of light curves of eclipsing binaries. Light curve modeling programs use analytical approximations of the intensity at the surface of a star. One such approximation expresses the monochromatic (wavelength λ) intensity $I_\lambda(\mu)$ at a point on the surface, in a direction θ with the normal to the surface, and normalized to the specific intensity at the star's center, as a linear function of μ, where $\mu=\cos\theta$. This is the linear limb-darkening law

$$D_\lambda(\mu)=I_\lambda(\mu)/I_\lambda(1)=1-x_\lambda(1-\mu). \tag{1}$$

in which x_λ is called the linear limb-darkening coefficient. A widely used tabulation of linear limb-darkening coefficients by Al-Naimiy (1978) is based on the Carbon & Gingerich (1969) stellar atmosphere models. Many authors have advocated the use of a two-parameter limb-darkening law in order to improve the representation of the actual emergent intensity over the stellar disk. Such nonlinear limb-darkening laws usually adopt the form of

$$D_\lambda(\mu)=1-x_\lambda(1-\mu)-y_\lambda(1-\mu)^p, \tag{2}$$

in which there are two limb-darkening coefficients x_λ and y_λ. For example, Manduca *et al.* (1977), Wade & Rucinski (1985), and Claret & Giménez (1990) examine the quadratic case ($p=2$) and present tables of linear as well as quadratic limb-darkening coefficients. A variety of stellar atmosphere models, as well as computational methods, are used to calculate these coefficients. Manduca *et al.* (1977) used the grid of model atmospheres for cool giants and supergiants by Bell *et al.* (1976), whereas the Wade & Rucinski (1985) coefficients were obtained using the Kurucz (1979) stellar atmosphere models. The limb-darkening study by Claret & Giménez (1990) was based on the Uppsala model atmospheres by Gustafsson *et al.* (1975). Limb-darkening laws of the form given by Eq. (2) with exponents p larger than 2 have also been proposed. Based on limb-darkening curves derived by Grygar (1965) from atmosphere models by Mihalas (1965), Kiperman & Shul'berg (1969) showed that the best approximation to the model specific intensity is obtained using Eq. (2) with an exponent $p=4$. Earlier, Van 't Veer (1960) found, for most spectral types, Eq. (2) with $p=3$ to represent $I(\mu)$ to within 2%.

Other limb-darkening laws include the logarithmic law

$$D_\lambda(\mu)=1-x_\lambda(1-\mu)-y_\lambda\mu\ln\mu \tag{3}$$

proposed by Klinglesmith & Sobieski (1970), and which will be discussed in detail further in this paper. Finally, Díaz-Cordovés & Giménez (1992) compare results obtained with the nonlinear law

$$D_\lambda(\mu)=1-x_\lambda(1-\mu)-y_\lambda(1-\sqrt{\mu}) \tag{4}$$

with those obtained with a linear [Eq. (1)] and a quadratic expression [Eq. (2) with $p=2$]. They find the square root law (4) to better represent the theoretical intensities of the Kurucz (1979) models for stars hotter than 8500 K.

Tabulations of limb-darkening coefficients x_λ and y_λ have been made by many of the above cited authors. They are given as a function of the effective temperature $T_{\rm eff}$, the logarithm of the surface gravity $\log g$, the wavelength λ, and also possibly for different chemical compositions. Some authors (e.g., Manduca *et al.* 1977; Claret & Giménez 1990) integrate the monochromatic limb-darkening coefficients over the most commonly used photometric passbands. Such a procedure requires a convolution with the appropriate response function of the photometric system. This somewhat restricts the generality of these coefficients and therefore limits their usefulness.

Recently, Wilson (1990) developed a new rigorous treatment of the binary star reflection effect and incorporated this treatment into the latest version of the Wilson–Devinney (WD) light curve program (Wilson & Devinney 1971; Wilson 1979). This new version of the WD program not only needs effective wavelength-specific limb-darkening coefficients, but also *bolometric* coefficients which enter in the bolometric analogues of Eqs. (1) to (4).

This paper presents bolometric limb-darkening coefficients for the linear limb-darkening law (1) and the nonlinear laws (3) and (4). Since the computation of bolometric coefficients begins with monochromatic coefficients, we also present the latter for the same limb-darkening laws. We base our limb-darkening calculations on the most recent ATLAS stellar atmosphere models by Kurucz (1991), who kindly provided magnetic tapes containing fluxes and specific intensities for 1221 values of the wavelength (ranging from 0.00909 to 160 μm), and 17 values of the aspect angle $\theta=\cos^{-1}\mu$. A total of 410 models with solar chemical composition are available. Temperatures range from 3500 to 50 000 K, and $\log g$'s from 0.0 to 5.0. This paper is restricted to solar chemical composition models. Our method of calculating limb-darkening coefficients is outlined in Sec. 2. In Sec. 3 we compare various limb-darkening laws qualitatively and suggest the ones which should be used for eclipsing binary light curve modeling. A description of the various limb-darkening tables follows in Sec. 4.

2. COMPUTATIONAL METHOD

Limb-darkening coefficients based on stellar atmosphere models can be computed in different ways. Once a law of any particular form has been chosen, the coefficient(s) can be determined by least-squares fitting of the chosen expression to the normalized intensities of the atmosphere model, tabulated as a function of μ. This is the method followed, for instance, by Claret & Giménez (1990) and Díaz-Cordovés & Giménez (1992). This approach does not conserve the total emergent flux of the star; i.e., there will be a difference between the flux obtained by integrating the model specific intensities over all angles and the flux obtained by integrating the selected limb-darkening approximation. However, Claret & Giménez (1990) never find this difference to be larger than 2% in the case of a linear limb-darkening law, and all differences disappear when a quadratic law is used. Díaz-Cordovés & Giménez (1992) draw the same conclusion. In the case of a linear law, flux conservation errors reach a maximum for stars with temperatures of 8000 K and a minimum for stars of 5500 K. However, since the use of a nonlinear law greatly reduces the problem, Díaz-Cordovés & Giménez (1992) favor a least-squares fitting procedure.

Al-Naimiy (1978) used a method suggested by Al-Naimiy & Budding (1977). Linear limb-darkening coefficients are obtained by averaging the I_λ vs μ slopes from the Carbon & Gingerich (1969) models, using the product $\mu\times I_\lambda(\mu)$ as a weight factor. Other authors, including Rubashevskii (1990) and Wade & Rucinski (1985), follow yet a different method. Depending on how many coefficients need to be determined (one in case of a linear law, two in case of the nonlinear laws given above), a number of physical *a priori* conditions are introduced. Solving the equations representing these additional constraints yields the limb-darkening coefficients. For example, Wade & Rucinski (1985) require fluxes computed directly from the atmosphere model intensities and from the approximation to be equal. For a quadratic law they also require that the specific intensity at $\mu=0.1$, calculated from the model atmosphere, be equal to that of the approximation.

In this paper we follow the method of Wade & Rucinski (1985), with some modifications. In the case of a linear law, we need to determine only one coefficient (x), which is done by using the condition of conservation of total flux. Following Van Hamme (1993), we define for any given wavelength λ, a quantity A_λ which, apart from a constant factor and the intensity $I_\lambda(1)$ at the center, is equal to the emergent flux:

$$A_\lambda=\int_0^1 D_\lambda(\mu)\mu\, d\mu. \tag{5}$$

After substituting Eq. (1) into Eq. (5) we get the well-known result

$$x_\lambda=3\text{–}6A_\lambda. \tag{6}$$

In the case of a two-parameter law, we apply the extra condition that the limb-darkening approximation produces the same *mean intensity* as the atmosphere model. We require that x_λ and y_λ satisfy the equation

$$B_\lambda=\int_0^1 D_\lambda(\mu) d\mu. \tag{7}$$

Indeed, B_λ is the mean intensity (over 2π steradian) of the star, again apart from $I_\lambda(1)$ and a constant factor. Given the value of the limb-darkening factor D_λ at a selected number of directions μ, for any given stellar atmosphere model, Eqs. (5) and (6) can be integrated numerically,

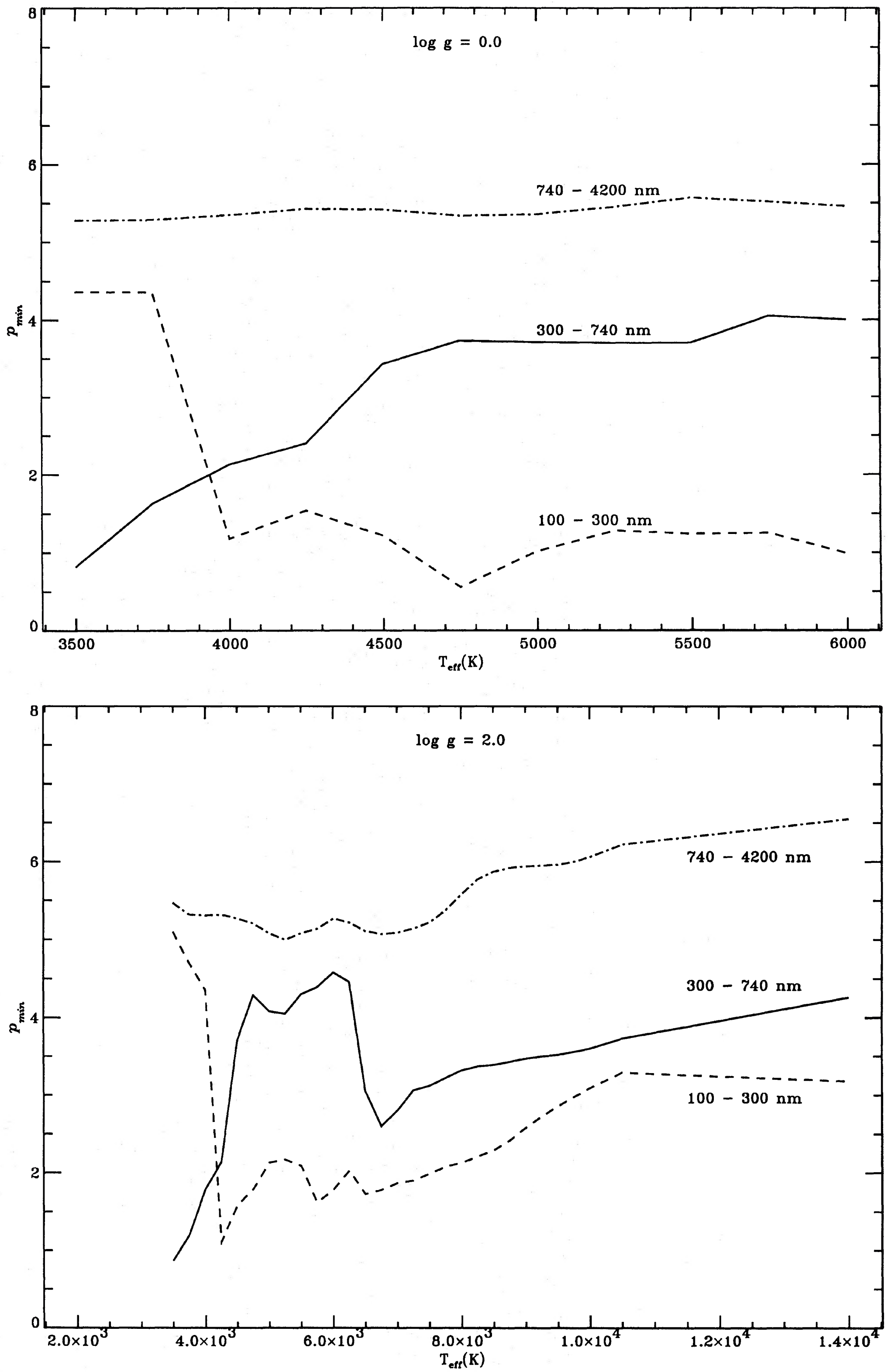

FIG. 1. The value $p_{\min}$ of the exponent p in Eq. (2) which minimizes Q_{λ_1,λ_2}, as a function of effective temperature and for different surface gravities.

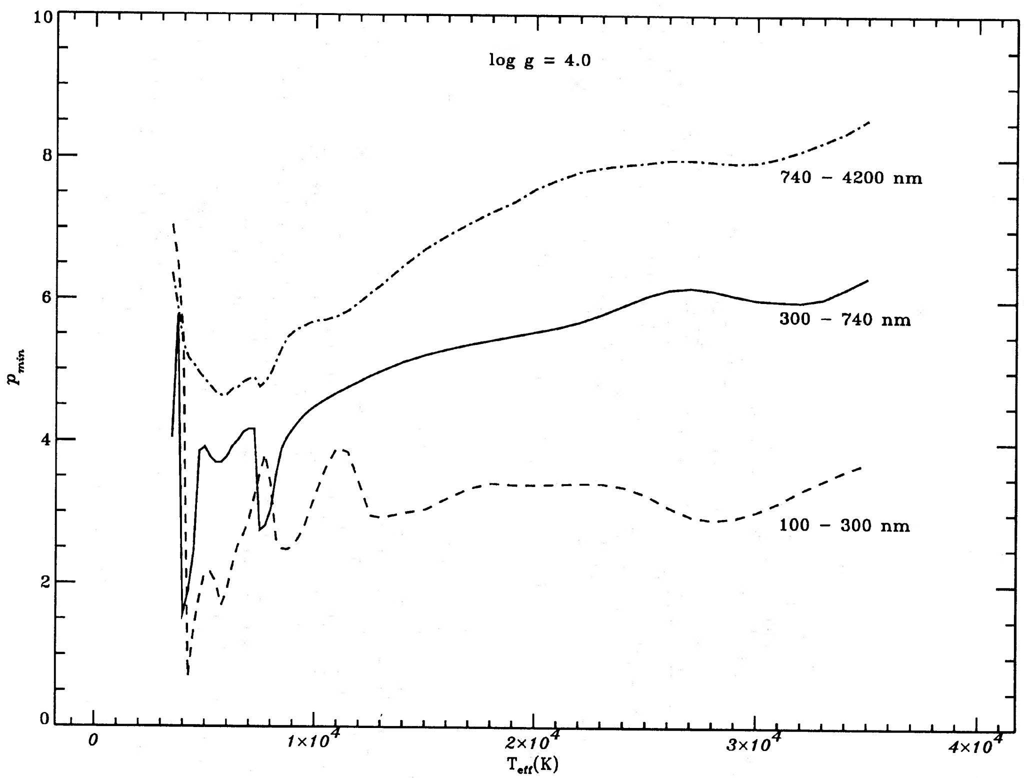

FIG. 1. (continued)

yielding values for A_λ and B_λ. Substitution of Eqs. (1) to (4) into Eqs. (5) and (6) leads to the following solutions for the coefficients x_λ and y_λ. For a power law of the form (2), with $p \neq 1$, we have

$$x_\lambda = \frac{3p - 6(p+2)A_\lambda + 6B_\lambda}{(p-1)} \tag{8}$$

and

$$y_\lambda = \frac{(p+1)(p+2)(6A_\lambda - 2B_\lambda - 1)}{2(p-1)}. \tag{9}$$

The logarithmic law (3) gives

$$x_\lambda = 18A_\lambda - 8B_\lambda - 1 \tag{10}$$

and

$$y_\lambda = 36A_\lambda - 12B_\lambda - 6. \tag{11}$$

Finally, a square root law of the form (4) yields

$$x_\lambda = 60A_\lambda + 18B_\lambda + 12 \tag{12}$$

and

$$y_\lambda = 90A_\lambda - 30B_\lambda - 15. \tag{13}$$

Similar expressions for the *bolometric* limb-darkening coefficients exist. These require bolometric specific intensities $I(\mu)$ and limb-darkening factors $D(\mu) = I(\mu)/I(1)$ which can be obtained by numerically integrating the model monochromatic specific intensities over all wavelengths. The Kurucz stellar atmosphere models list specific intensities at 1221 wavelength points ranging from 9.09 nm to 160 μm. We subdivided this range into intervals, each of which is characterized by a fixed step in wavelength. In each of these subintervals, and for each value of μ, the specific intensity was integrated using Simpson's extended formulas (Press *et al.* 1986), and the results were then summed over all subintervals. Finally, bolometric coefficients were obtained with the bolometric analogues of Eqs. (5) to (10).

3. COMPARISON OF LIMB-DARKENING LAWS

Our goal is to find a limb-darkening approximation which will represent, as accurately as possible, the emergent specific intensity from a stellar surface as a function of

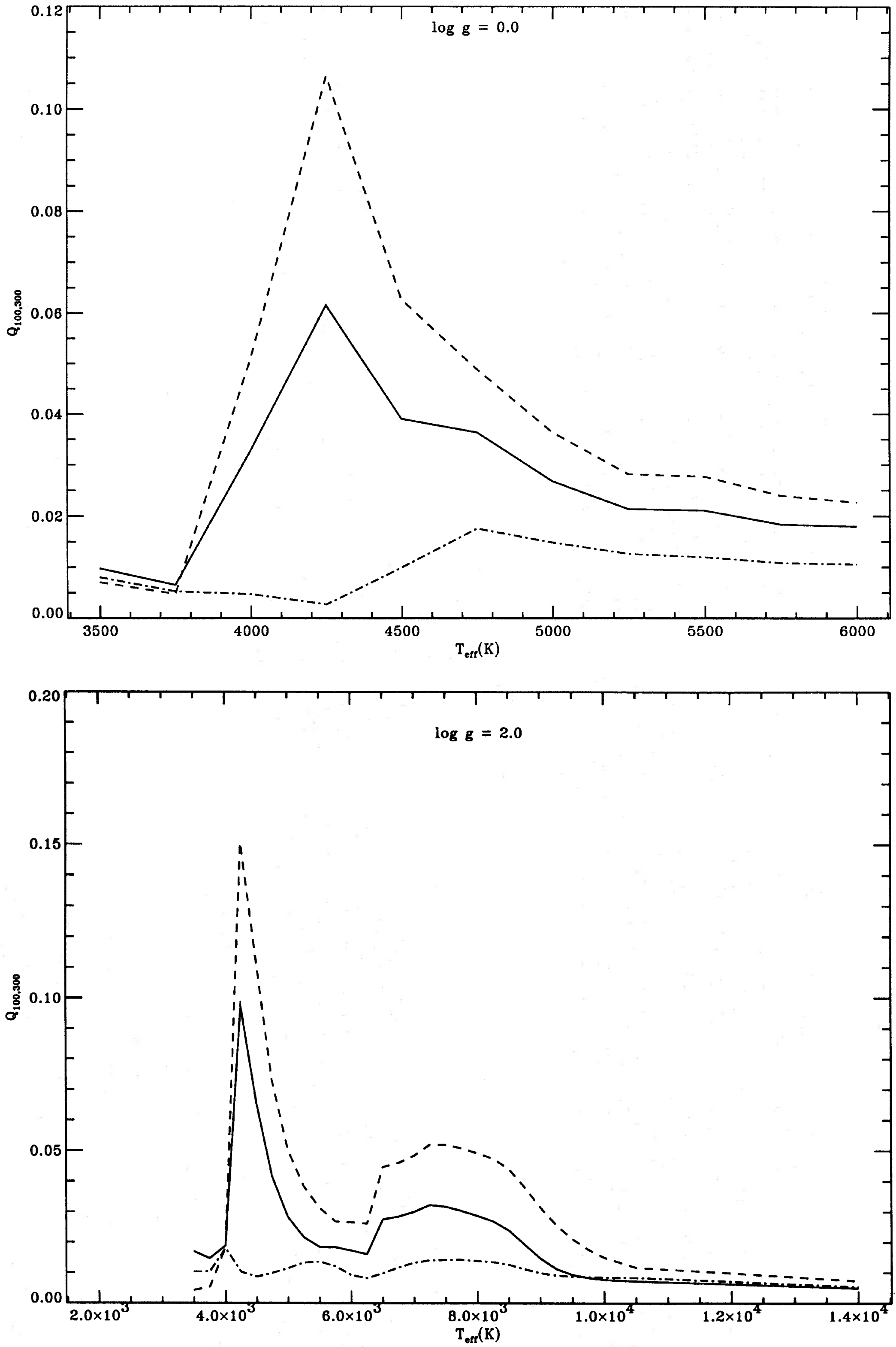

FIG. 2. The quality factor Q_{λ_1,λ_2}, with $\lambda_1=100$ nm and $\lambda_2=300$ nm, vs effective temperature and for different surface gravities. See text for legends.

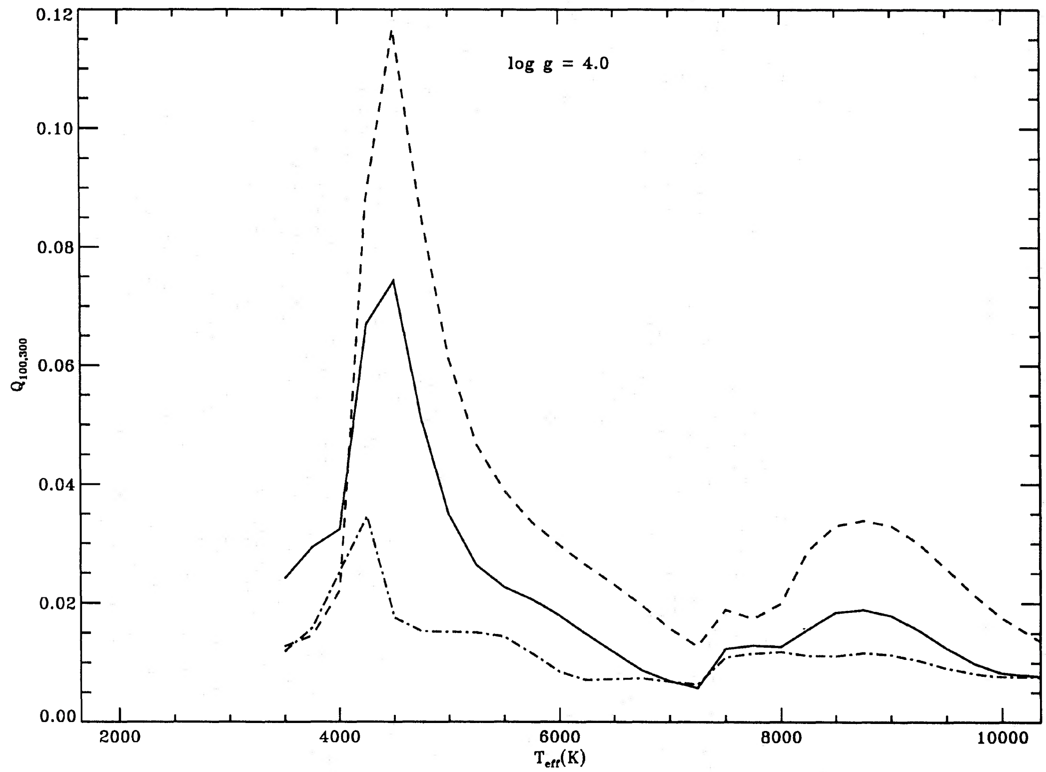

FIG. 2. (continued)

the angle between the local normal and the line of sight. In most cases, this specific intensity is obtained from a theoretical stellar atmosphere model. Only in the case of the Sun can the specific intensity be directly observed as a function of aspect angle. Obviously, a two-parameter law will be superior to a one-parameter linear law. The question is, however, which nonlinear law is to be preferred? Our choice may have to depend on the characteristics of the star ($T_{\rm eff}$, $\log g$, chemical composition), and on the considered wavelength or wavelength domain.

In order to examine how well each of the individual limb-darkening laws given by Eqs. (1) to (4) represent the model specific intensity, we proceed as follows. We quantify the "quality" of any individual law by following a procedure similar to the one used by Díaz-Cordovés & Giménez (1992). If $I_\lambda(\mu)=D_\lambda(\mu)\times I_\lambda(1)$ denotes the theoretical model specific intensity, and $\hat{I}_\lambda(\mu)=\hat{D}_\lambda(\mu)\times\hat{I}_\lambda(1)$ the specific intensity according to the limb-darkening approximation [clearly, $\hat{I}_\lambda(1)=I_\lambda(1)$], we define a quality factor

$$Q_\lambda=\sqrt{\frac{\Sigma_{i=1}^{17}[D_\lambda(\mu_i)-\hat{D}_\lambda(\mu_i)]^2}{17-m}}, \tag{14}$$

in which $m=1$ for the linear limb-darkening law (1), and $m=2$ for all two-parameter laws. Clearly, Q_λ is analogous to, but not the same as, a standard deviation. The number of terms in the summation corresponds to the number of angles for which specific intensities are listed in Kurucz's models.

Before a Q-based comparison is made between the different limb-darkening laws, we need to decide which exponent to use in Eq. (2). We expect the value of p, which produces the smallest possible value of Q_λ, to depend on the wavelength λ. Determining this optimal p value at every given wavelength would not be practical. It makes more sense to select a certain wavelength range, bounded by wavelengths λ_1 and λ_2, and to determine the value $p_{\rm min}$ of the exponent p in Eq. (2) which minimizes the flux-weighted average

$$Q_{\lambda_1,\lambda_2}=\frac{\int_{\lambda_1}^{\lambda_2}F(\lambda)Q(\lambda)d\lambda}{\int_{\lambda_1}^{\lambda_2}F(\lambda)d\lambda}. \tag{15}$$

Indeed, our experiments show Q_{λ_1,λ_2} to be a well behaved function of p with a single minimum in the interval (0,10). Three wavelength intervals were considered: (100, 300 nm) in the near-UV part of the spectrum, (300, 740 nm) in the optical region which includes the U, B, V (and u, v, b, y) passbands, and a near-IR interval (740, 4200 nm). Equation (12) was integrated trapezoidally. Figure 1 shows, for each wavelength interval, the variation of $p_{\rm min}$ with the effective temperature $T_{\rm eff}$, for the cases $\log g=0.0$, 2.0, and 4.0, respectively. A general trend is clearly present. For each wavelength interval, and except for the very cool models ($T_{\rm eff}$<4500 K), $p_{\rm min}$ appears to fluctuate in rather narrow ranges. The UV favors a value of around 1.0 for stars with surface gravities log g=0.0, a value of 2.0 for log g=2.0, and 3.0 for log g=4.0 stars. In the optical region, optimal p values range from 3.0 to 5.0, and the IR favors exponents between 5.0 and 7.0. Of more interest, perhaps, are Figs. 2 to 4. They show, again as a function of $T_{\rm eff}$ and for various surface gravities, the behavior of the

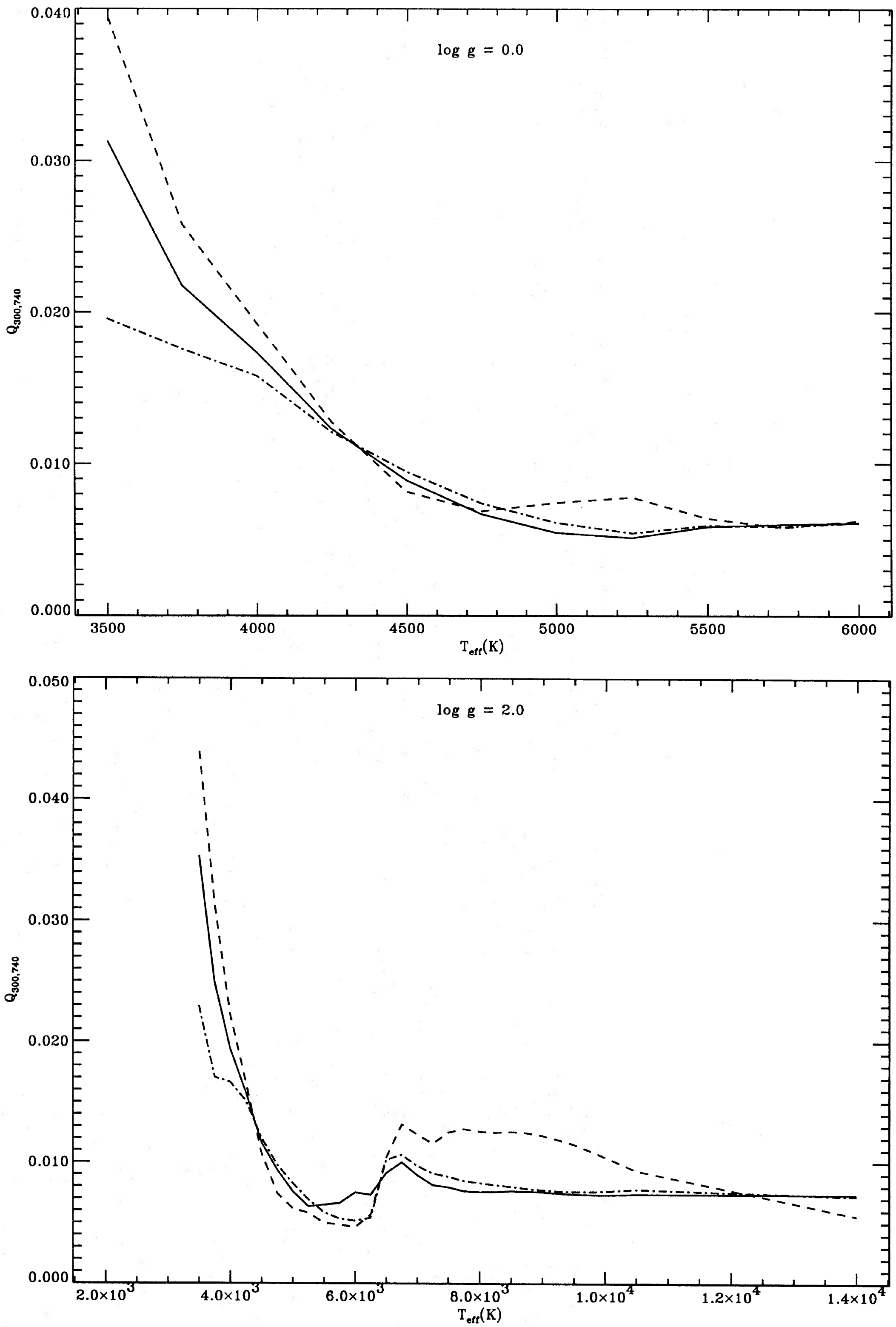

FIG. 3. The same as Fig. 2, with λ_1=300 nm and λ_2=740 nm.

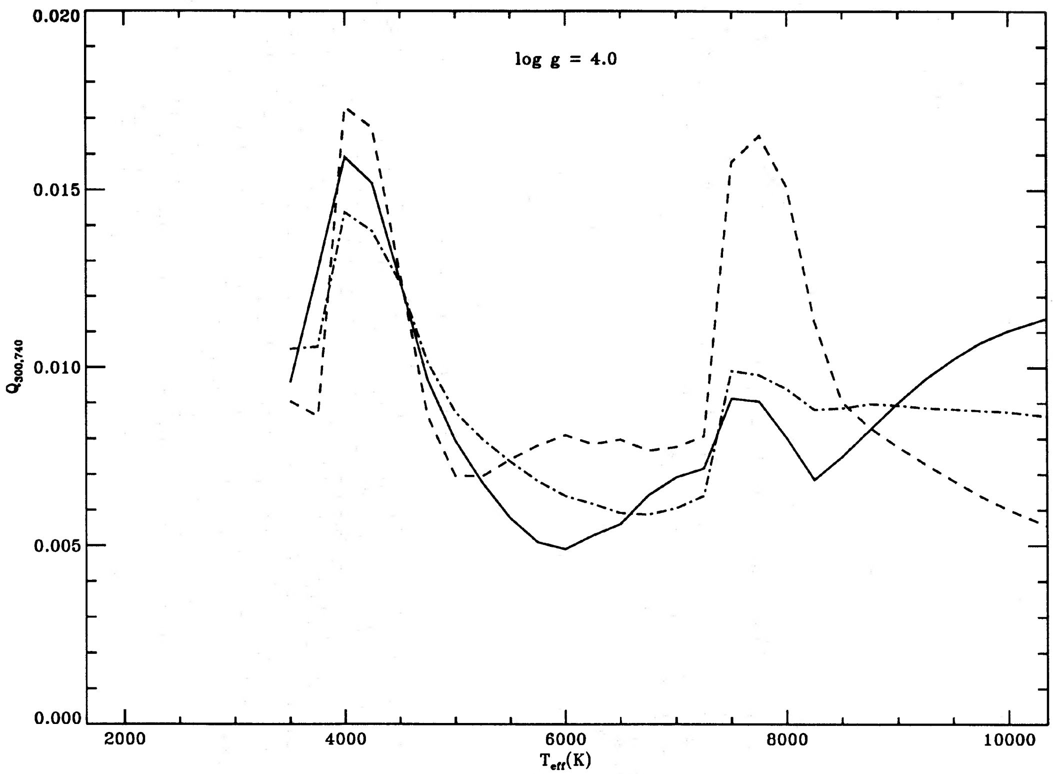

FIG. 3. (continued)

wavelength interval integrated quality factor Q_{λ_1,λ_2} for the limb-darkening law (2) with $p=p_{\min}$ (dashed–dotted line), the logarithmic law (3) (solid line), and the square root law (4) (dashed line). On average, the linear law (1) yields Q values at least one order of magnitude larger than those for the three other laws, therefore, it is omitted from the figures. The quality Q fluctuates within a range of 0.005 to 0.02, and differences between Q values for the three competing limb-darkening laws appear to be small. For certain models and wavelength ranges (for example, in the UV for low surface gravity and cool main-sequence stars, and in the IR for very hot main-sequence stars) a value $p_{\min}$ of the exponent p in Eq. (2) can be found which results in lower Q values compared to those for the logarithmic or square root laws. However, the difference is too small to warrant favoring the use of a law of the form (2) in such cases. Furthermore, abandoning the expression (2) relieves us from having to choose the optimal exponent, which would be different for every different wavelength. In most cases, this optimal value is not 2. Consequently, we do not favor the use of a quadratic limb-darkening law. If a two-parameter law is desired, the preferred choice appears to be either a logarithmic law (3) or a square root law (4). Towards the longer wavelengths and in the IR, a square root law gives the best results, yielding an average Q value of 0.005 vs 0.015 for the logarithmic law. In the UV, the roles are reversed and a logarithmic law is better for all models. In the optical region, better results are obtained using a logarithmic law in the case of cooler stars and a square root law in the case of higher temperature stars, in agreement with Díaz-Cordovés & Giménez (1992). This distribution becomes more pronounced towards larger values of the surface gravity. Characteristic transition temperatures are between 8000 and 10 000 K.

4. DESCRIPTION OF THE TABLES

Bolometric limb-darkening coefficients are listed separately in Table 1. For each of the 410 Kurucz (1991) stellar atmosphere models with solar chemical abundances, we list the model number, the effective temperature, T_{eff}, the logarithm of the surface gravity, $\log g$, the bolometric linear limb-darkening coefficient, x, and the coefficients x and y for a logarithmic and square root law, respectively. For each law, the numbers in parentheses indicate the quality factor Q, as defined in Sec. 3. This number may help in choosing which limb-darkening law to use in any particular case.

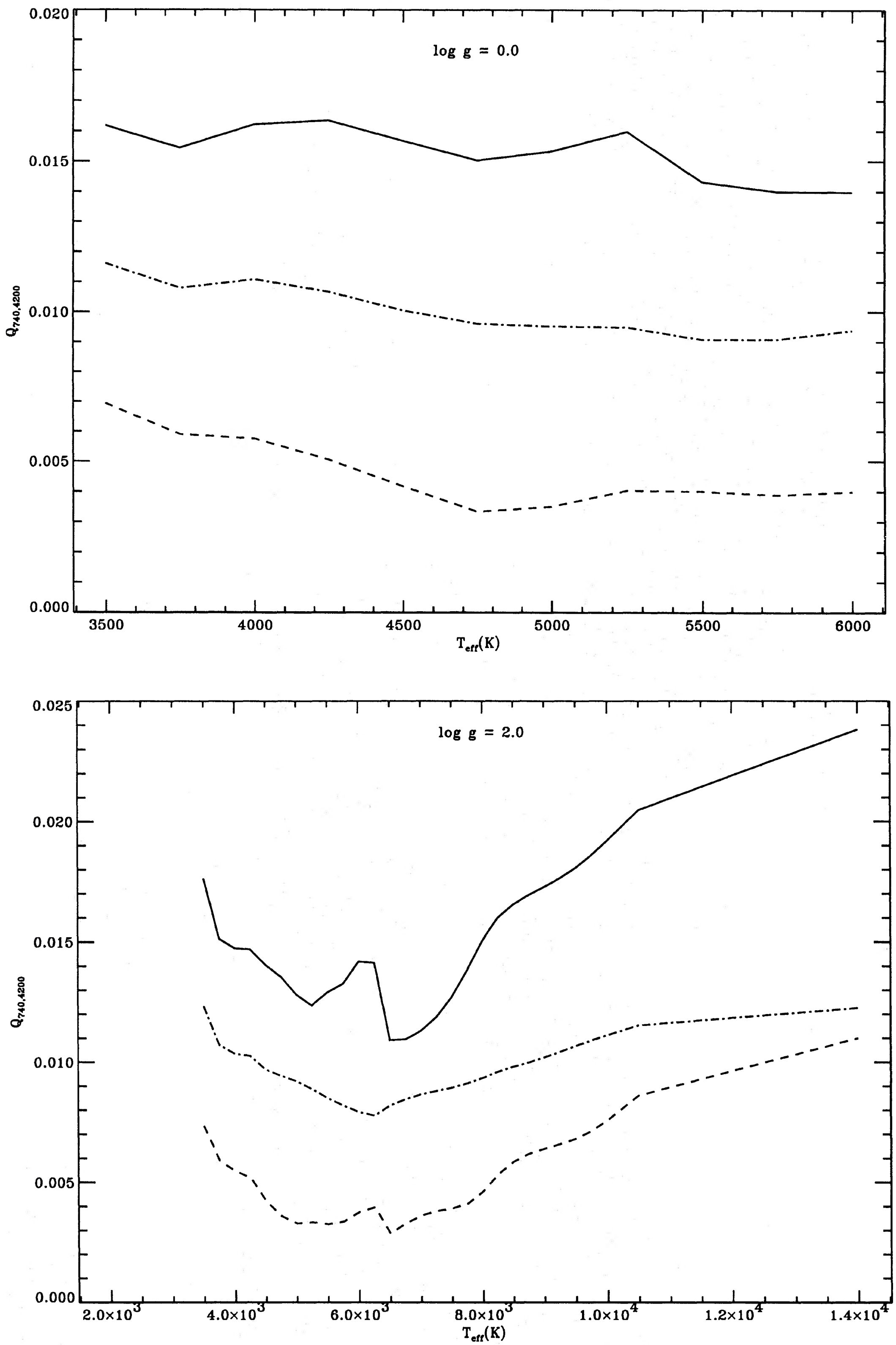

FIG. 4. The same as Fig. 2, with $\lambda_1=740$ nm and $\lambda_2=4200$ nm.

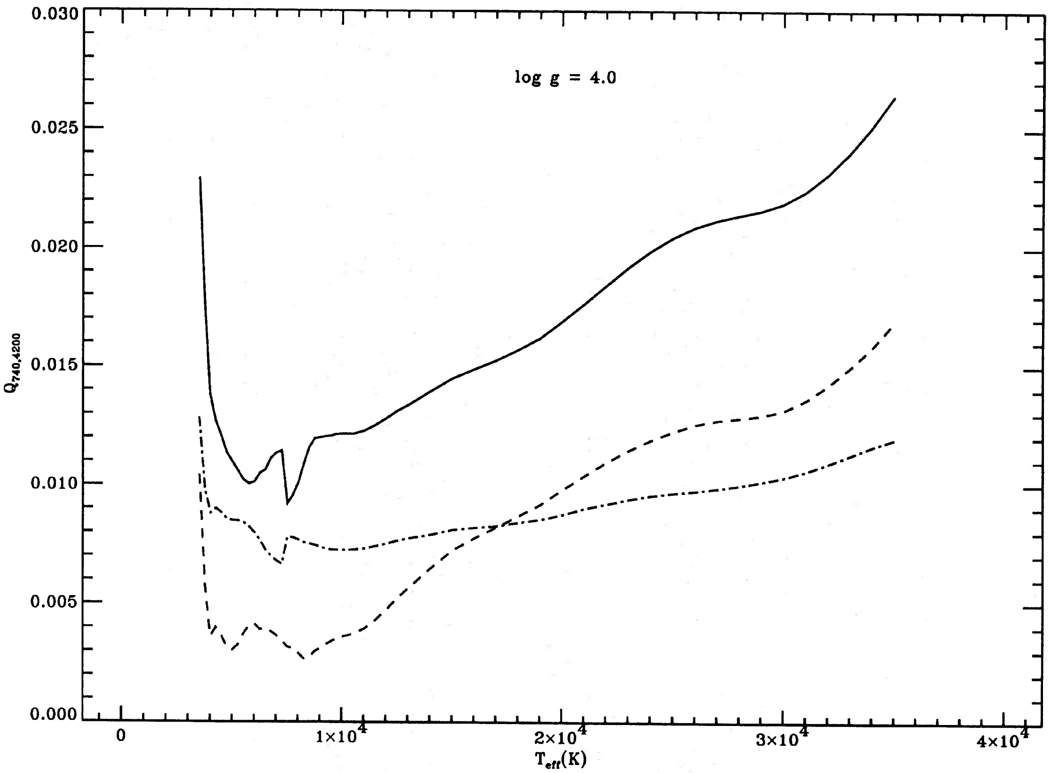

FIG. 4. (continued)

Table 2[1] contains passband-specific limb-darkening coefficients. If such coefficients are to obey equations of the form (1) to (4), integrated over a selected passband α, with a characteristic response function $S(\lambda)$, one can easily show that x_α will be given by

$$x_\alpha = \frac{\int_{\lambda_1}^{\lambda_2} I(\lambda,1) S(\lambda) x(\lambda) d\lambda}{\int_{\lambda_1}^{\lambda_2} I(\lambda,1) S(\lambda) d\lambda}. \qquad (16)$$

A similar expression for y_α exists. λ_1 and λ_2 are the passband's lower and upper boundaries.

The following response functions were used in producing Table 2. For the Strömgren *u*, *v*, *b*, *y* passbands, $S(\lambda)$ includes the filter transmission curves given by Crawford & Barnes (1970), the atmospheric transmission listed in Allen (1976), reflection from two aluminum coated mirrors (Allen 1976), and the sensitivity of a 1P21 photomultiplier listed in Kurucz (1979). We used Buser's (1978) response curve for the *U* passband, and those by Ažusienis & Straižys (1969) for the *B* and *V* bands. The infrared (*R* to *N*) response functions were taken from Johnson (1965). Finally, for the Cousins R_c and I_c bands we used the passband response functions listed in Bessell (1983).

Passband-specific limb-darkening coefficients for all 410 models are listed in Table 2. Unlike Table 1, which lists previously unpublished bolometric limb-darkening coefficients, Table 2 contains coefficients which can be compared to similar ones computed by other authors. Differences may be due to our use of the new Kurucz (1991) atmosphere models, to our different computation method, and perhaps to some slight differences in the response functions. Some comparisons with previous results and observations are made in the next section.

If necessary, passband-specific coefficients based on other response functions can be calculated with Eq. (13) and our monochromatic coefficients given for each of the 1221 wavelength values of Kurucz's (1991) models (from 9.09 nm to 160 μm). Monochromatic coefficients, together with intensities $I(\lambda,1)$, needed to evaluate Eq. (16), were generated for all 410 models and are stored in 410 different computer files, each approximately 120 KB in size. These files can be made available to the interested reader. They have names encoded with the corresponding model num-

[1]Table 2 is presented in its complete form in the ApJ/AJ CD-ROM Series, volume 1, 1993. The first page of this table is presented here for guidance regarding its form and content.

TABLE 1. Bolometric limb-darkening coefficients.

No.	T_{eff}	log g	Linear Law		Logarithmic Law			Square Root Law		
			x	Q	x	y	Q	x	y	Q
1	3500	0.0	0.481	(0.0692)	0.608	0.190	(0.0176)	0.196	0.475	(0.0084)
2	3500	0.5	0.474	(0.0693)	0.600	0.189	(0.0182)	0.190	0.474	(0.0091)
3	3500	1.0	0.466	(0.0700)	0.593	0.191	(0.0186)	0.180	0.477	(0.0094)
4	3500	1.5	0.461	(0.0700)	0.588	0.190	(0.0188)	0.175	0.476	(0.0096)
5	3500	2.0	0.455	(0.0714)	0.584	0.194	(0.0191)	0.163	0.486	(0.0097)
6	3500	2.5	0.448	(0.0726)	0.581	0.198	(0.0190)	0.151	0.496	(0.0094)
7	3500	3.0	0.436	(0.0754)	0.574	0.207	(0.0191)	0.125	0.519	(0.0092)
8	3500	3.5	0.386	(0.0835)	0.542	0.234	(0.0198)	0.036	0.584	(0.0086)
9	3500	4.0	0.322	(0.0943)	0.500	0.267	(0.0208)	-0.079	0.668	(0.0080)
10	3500	4.5	0.286	(0.0999)	0.475	0.284	(0.0217)	-0.139	0.709	(0.0081)
11	3500	5.0	0.270	(0.1023)	0.464	0.290	(0.0222)	-0.165	0.726	(0.0082)
12	3750	0.0	0.510	(0.0668)	0.634	0.186	(0.0164)	0.232	0.464	(0.0075)
13	3750	0.5	0.509	(0.0647)	0.628	0.178	(0.0165)	0.241	0.446	(0.0079)
14	3750	1.0	0.506	(0.0631)	0.622	0.173	(0.0165)	0.247	0.432	(0.0082)
15	3750	1.5	0.504	(0.0609)	0.615	0.166	(0.0166)	0.256	0.414	(0.0086)
16	3750	2.0	0.501	(0.0599)	0.609	0.162	(0.0166)	0.257	0.406	(0.0088)
17	3750	2.5	0.496	(0.0593)	0.603	0.160	(0.0165)	0.256	0.400	(0.0088)
18	3750	3.0	0.490	(0.0596)	0.598	0.161	(0.0165)	0.249	0.403	(0.0088)
19	3750	3.5	0.471	(0.0638)	0.588	0.176	(0.0164)	0.208	0.439	(0.0079)
20	3750	4.0	0.411	(0.0782)	0.560	0.222	(0.0167)	0.078	0.556	(0.0060)
21	3750	4.5	0.341	(0.0940)	0.522	0.271	(0.0182)	-0.066	0.678	(0.0052)
22	3750	5.0	0.298	(0.1021)	0.494	0.294	(0.0198)	-0.143	0.735	(0.0057)
23	4000	0.0	0.518	(0.0666)	0.641	0.185	(0.0164)	0.240	0.463	(0.0075)
24	4000	0.5	0.520	(0.0647)	0.639	0.179	(0.0164)	0.251	0.448	(0.0079)
25	4000	1.0	0.521	(0.0630)	0.636	0.174	(0.0164)	0.260	0.434	(0.0081)
26	4000	1.5	0.523	(0.0605)	0.633	0.166	(0.0161)	0.274	0.414	(0.0082)
27	4000	2.0	0.522	(0.0588)	0.630	0.161	(0.0157)	0.281	0.402	(0.0080)
28	4000	2.5	0.521	(0.0571)	0.626	0.156	(0.0152)	0.287	0.391	(0.0077)
29	4000	3.0	0.519	(0.0556)	0.621	0.152	(0.0147)	0.291	0.381	(0.0074)
30	4000	3.5	0.515	(0.0551)	0.616	0.152	(0.0143)	0.287	0.379	(0.0070)
31	4000	4.0	0.493	(0.0605)	0.606	0.170	(0.0141)	0.238	0.425	(0.0060)
32	4000	4.5	0.429	(0.0780)	0.578	0.224	(0.0152)	0.092	0.561	(0.0044)
33	4000	5.0	0.356	(0.0955)	0.540	0.276	(0.0178)	-0.059	0.690	(0.0045)
34	4250	0.0	0.517	(0.0649)	0.638	0.182	(0.0151)	0.243	0.456	(0.0064)
35	4250	0.5	0.521	(0.0633)	0.639	0.177	(0.0153)	0.255	0.443	(0.0069)
36	4250	1.0	0.524	(0.0618)	0.639	0.172	(0.0152)	0.265	0.431	(0.0070)
37	4250	1.5	0.528	(0.0592)	0.638	0.165	(0.0150)	0.281	0.411	(0.0072)
38	4250	2.0	0.530	(0.0575)	0.636	0.159	(0.0149)	0.291	0.398	(0.0073)
39	4250	2.5	0.531	(0.0559)	0.634	0.154	(0.0146)	0.300	0.386	(0.0073)
40	4250	3.0	0.531	(0.0545)	0.632	0.150	(0.0143)	0.306	0.375	(0.0071)
41	4250	3.5	0.530	(0.0535)	0.629	0.148	(0.0138)	0.308	0.370	(0.0068)
42	4250	4.0	0.527	(0.0534)	0.626	0.149	(0.0132)	0.303	0.372	(0.0062)
43	4250	4.5	0.505	(0.0592)	0.617	0.168	(0.0131)	0.254	0.419	(0.0051)
44	4250	5.0	0.445	(0.0763)	0.591	0.219	(0.0150)	0.116	0.548	(0.0044)
45	4500	0.0	0.511	(0.0628)	0.631	0.179	(0.0134)	0.243	0.448	(0.0049)
46	4500	0.5	0.516	(0.0622)	0.635	0.177	(0.0135)	0.250	0.444	(0.0051)
47	4500	1.0	0.521	(0.0613)	0.637	0.174	(0.0136)	0.259	0.436	(0.0054)
48	4500	1.5	0.526	(0.0591)	0.638	0.168	(0.0134)	0.274	0.420	(0.0055)
49	4500	2.0	0.530	(0.0572)	0.638	0.162	(0.0131)	0.287	0.406	(0.0055)
50	4500	2.5	0.534	(0.0550)	0.638	0.156	(0.0129)	0.300	0.389	(0.0056)
51	4500	3.0	0.536	(0.0532)	0.636	0.150	(0.0126)	0.311	0.376	(0.0055)
52	4500	3.5	0.537	(0.0517)	0.634	0.146	(0.0124)	0.318	0.365	(0.0055)
53	4500	4.0	0.536	(0.0512)	0.632	0.145	(0.0121)	0.319	0.361	(0.0053)
54	4500	4.5	0.532	(0.0514)	0.630	0.146	(0.0117)	0.313	0.366	(0.0048)
55	4500	5.0	0.515	(0.0567)	0.623	0.163	(0.0118)	0.271	0.407	(0.0041)
56	4750	0.0	0.504	(0.0625)	0.625	0.181	(0.0119)	0.233	0.452	(0.0033)
57	4750	0.5	0.512	(0.0611)	0.630	0.177	(0.0119)	0.246	0.443	(0.0036)
58	4750	1.0	0.517	(0.0606)	0.634	0.175	(0.0121)	0.254	0.438	(0.0039)
59	4750	1.5	0.522	(0.0594)	0.637	0.172	(0.0120)	0.264	0.430	(0.0040)
60	4750	2.0	0.526	(0.0584)	0.639	0.169	(0.0118)	0.272	0.423	(0.0040)
61	4750	2.5	0.530	(0.0568)	0.640	0.165	(0.0115)	0.282	0.413	(0.0039)
62	4750	3.0	0.534	(0.0548)	0.640	0.159	(0.0111)	0.296	0.398	(0.0039)
63	4750	3.5	0.537	(0.0529)	0.640	0.154	(0.0109)	0.307	0.384	(0.0039)
64	4750	4.0	0.538	(0.0517)	0.639	0.150	(0.0105)	0.313	0.376	(0.0037)
65	4750	4.5	0.538	(0.0509)	0.637	0.148	(0.0103)	0.315	0.371	(0.0036)

TABLE 1. (continued)

No.	T_{eff}	log g	Linear Law x	Linear Law Q	Logarithmic Law x	Logarithmic Law y	Logarithmic Law Q	Square Root Law x	Square Root Law y	Square Root Law Q
66	4750	5.0	0.535	(0.0513)	0.635	0.150	(0.0100)	0.309	0.375	(0.0032)
67	5000	0.0	0.495	(0.0623)	0.616	0.181	(0.0112)	0.224	0.453	(0.0025)
68	5000	0.5	0.502	(0.0622)	0.623	0.182	(0.0109)	0.229	0.455	(0.0023)
69	5000	1.0	0.509	(0.0613)	0.629	0.180	(0.0107)	0.239	0.451	(0.0024)
70	5000	1.5	0.514	(0.0612)	0.634	0.181	(0.0105)	0.242	0.452	(0.0024)
71	5000	2.0	0.517	(0.0610)	0.637	0.181	(0.0104)	0.245	0.452	(0.0025)
72	5000	2.5	0.523	(0.0594)	0.641	0.177	(0.0101)	0.257	0.442	(0.0026)
73	5000	3.0	0.527	(0.0581)	0.642	0.173	(0.0099)	0.267	0.433	(0.0027)
74	5000	3.5	0.532	(0.0563)	0.644	0.168	(0.0097)	0.280	0.420	(0.0027)
75	5000	4.0	0.535	(0.0547)	0.644	0.163	(0.0094)	0.290	0.408	(0.0027)
76	5000	4.5	0.537	(0.0536)	0.643	0.160	(0.0091)	0.296	0.401	(0.0026)
77	5000	5.0	0.536	(0.0530)	0.642	0.159	(0.0088)	0.298	0.397	(0.0025)
78	5250	0.0	0.487	(0.0618)	0.607	0.181	(0.0105)	0.216	0.452	(0.0018)
79	5250	0.5	0.493	(0.0622)	0.615	0.183	(0.0102)	0.219	0.457	(0.0015)
80	5250	1.0	0.499	(0.0625)	0.622	0.185	(0.0101)	0.221	0.462	(0.0014)
81	5250	1.5	0.503	(0.0632)	0.629	0.188	(0.0097)	0.221	0.471	(0.0013)
82	5250	2.0	0.508	(0.0633)	0.634	0.190	(0.0093)	0.223	0.475	(0.0016)
83	5250	2.5	0.513	(0.0627)	0.639	0.189	(0.0089)	0.228	0.474	(0.0021)
84	5250	3.0	0.517	(0.0618)	0.642	0.188	(0.0087)	0.235	0.469	(0.0024)
85	5250	3.5	0.522	(0.0604)	0.645	0.184	(0.0085)	0.247	0.459	(0.0026)
86	5250	4.0	0.527	(0.0586)	0.647	0.179	(0.0084)	0.259	0.447	(0.0027)
87	5250	4.5	0.530	(0.0578)	0.647	0.176	(0.0082)	0.265	0.441	(0.0027)
88	5250	5.0	0.531	(0.0572)	0.648	0.175	(0.0080)	0.268	0.437	(0.0027)
89	5500	0.0	0.546	(0.0360)	0.613	0.100	(0.0094)	0.396	0.251	(0.0046)
90	5500	0.5	0.483	(0.0631)	0.606	0.185	(0.0102)	0.205	0.462	(0.0015)
91	5500	1.0	0.487	(0.0642)	0.613	0.189	(0.0101)	0.203	0.473	(0.0012)
92	5500	1.5	0.490	(0.0660)	0.620	0.195	(0.0099)	0.197	0.488	(0.0010)
93	5500	2.0	0.494	(0.0666)	0.627	0.199	(0.0094)	0.196	0.497	(0.0010)
94	5500	2.5	0.498	(0.0674)	0.634	0.204	(0.0084)	0.192	0.510	(0.0021)
95	5500	3.0	0.505	(0.0663)	0.640	0.203	(0.0079)	0.200	0.507	(0.0028)
96	5500	3.5	0.511	(0.0649)	0.644	0.200	(0.0075)	0.211	0.500	(0.0033)
97	5500	4.0	0.517	(0.0633)	0.647	0.196	(0.0074)	0.223	0.489	(0.0035)
98	5500	4.5	0.520	(0.0623)	0.649	0.193	(0.0074)	0.231	0.481	(0.0035)
99	5500	5.0	0.522	(0.0620)	0.650	0.192	(0.0072)	0.234	0.480	(0.0037)
100	5750	0.0	0.554	(0.0342)	0.620	0.099	(0.0074)	0.405	0.249	(0.0030)
101	5750	0.5	0.554	(0.0356)	0.623	0.104	(0.0076)	0.398	0.260	(0.0030)
102	5750	1.0	0.479	(0.0664)	0.611	0.197	(0.0095)	0.184	0.492	(0.0011)
103	5750	1.5	0.483	(0.0671)	0.616	0.199	(0.0096)	0.184	0.498	(0.0009)
104	5750	2.0	0.486	(0.0687)	0.623	0.206	(0.0092)	0.177	0.514	(0.0013)
105	5750	2.5	0.489	(0.0698)	0.630	0.211	(0.0085)	0.173	0.528	(0.0020)
106	5750	3.0	0.494	(0.0700)	0.636	0.214	(0.0077)	0.173	0.535	(0.0031)
107	5750	3.5	0.500	(0.0691)	0.642	0.214	(0.0071)	0.179	0.534	(0.0039)
108	5750	4.0	0.505	(0.0678)	0.646	0.211	(0.0068)	0.189	0.527	(0.0043)
109	5750	4.5	0.510	(0.0666)	0.648	0.207	(0.0068)	0.199	0.519	(0.0044)
110	5750	5.0	0.513	(0.0662)	0.650	0.207	(0.0067)	0.203	0.516	(0.0045)
111	6000	0.0	0.564	(0.0330)	0.629	0.098	(0.0064)	0.417	0.245	(0.0022)
112	6000	0.5	0.558	(0.0368)	0.633	0.113	(0.0059)	0.389	0.282	(0.0024)
113	6000	1.0	0.557	(0.0386)	0.636	0.118	(0.0063)	0.380	0.295	(0.0026)
114	6000	1.5	0.474	(0.0717)	0.616	0.214	(0.0097)	0.153	0.534	(0.0017)
115	6000	2.0	0.476	(0.0723)	0.620	0.216	(0.0097)	0.153	0.539	(0.0016)
116	6000	2.5	0.479	(0.0731)	0.626	0.220	(0.0090)	0.149	0.550	(0.0022)
117	6000	3.0	0.483	(0.0735)	0.633	0.224	(0.0081)	0.148	0.559	(0.0031)
118	6000	3.5	0.489	(0.0731)	0.639	0.225	(0.0072)	0.151	0.562	(0.0040)
119	6000	4.0	0.495	(0.0720)	0.644	0.224	(0.0066)	0.159	0.559	(0.0047)
120	6000	4.5	0.499	(0.0710)	0.647	0.221	(0.0064)	0.167	0.553	(0.0049)
121	6000	5.0	0.502	(0.0708)	0.649	0.221	(0.0063)	0.170	0.553	(0.0051)
122	6250	0.5	0.567	(0.0364)	0.642	0.112	(0.0052)	0.398	0.281	(0.0023)
123	6250	1.0	0.558	(0.0416)	0.646	0.132	(0.0050)	0.360	0.330	(0.0038)
124	6250	1.5	0.556	(0.0433)	0.647	0.137	(0.0055)	0.351	0.342	(0.0037)
125	6250	2.0	0.471	(0.0760)	0.624	0.228	(0.0092)	0.129	0.571	(0.0025)
126	6250	2.5	0.472	(0.0766)	0.625	0.230	(0.0094)	0.127	0.575	(0.0024)
127	6250	3.0	0.476	(0.0766)	0.630	0.232	(0.0085)	0.127	0.581	(0.0031)
128	6250	3.5	0.480	(0.0764)	0.636	0.234	(0.0076)	0.129	0.585	(0.0040)
129	6250	4.0	0.485	(0.0753)	0.640	0.232	(0.0070)	0.137	0.581	(0.0046)
130	6250	4.5	0.490	(0.0743)	0.644	0.231	(0.0065)	0.144	0.577	(0.0051)
131	6250	5.0	0.493	(0.0742)	0.647	0.231	(0.0064)	0.146	0.578	(0.0053)
132	6500	0.5	0.576	(0.0365)	0.651	0.113	(0.0047)	0.405	0.284	(0.0023)

TABLE 1. (continued)

No.	T_{eff}	log g	Linear Law x	Q	Logarithmic Law x	y	Q	Square Root Law x	y	Q
133	6500	1.0	0.566	(0.0418)	0.654	0.132	(0.0046)	0.367	0.331	(0.0037)
134	6500	1.5	0.555	(0.0471)	0.657	0.152	(0.0046)	0.328	0.379	(0.0053)
135	6500	2.0	0.553	(0.0482)	0.656	0.154	(0.0052)	0.322	0.385	(0.0050)
136	6500	2.5	0.469	(0.0799)	0.630	0.242	(0.0088)	0.106	0.605	(0.0034)
137	6500	3.0	0.469	(0.0802)	0.631	0.243	(0.0089)	0.105	0.607	(0.0034)
138	6500	3.5	0.473	(0.0794)	0.635	0.242	(0.0080)	0.110	0.605	(0.0040)
139	6500	4.0	0.478	(0.0784)	0.639	0.241	(0.0072)	0.116	0.603	(0.0047)
140	6500	4.5	0.482	(0.0775)	0.642	0.240	(0.0068)	0.123	0.599	(0.0051)
141	6500	5.0	0.485	(0.0772)	0.645	0.240	(0.0065)	0.125	0.599	(0.0054)
142	6750	0.5	0.573	(0.0415)	0.661	0.132	(0.0034)	0.375	0.330	(0.0039)
143	6750	1.0	0.573	(0.0422)	0.661	0.133	(0.0042)	0.373	0.332	(0.0034)
144	6750	1.5	0.562	(0.0475)	0.663	0.152	(0.0043)	0.334	0.379	(0.0048)
145	6750	2.0	0.551	(0.0524)	0.664	0.170	(0.0045)	0.296	0.425	(0.0063)
146	6750	2.5	0.549	(0.0524)	0.662	0.169	(0.0050)	0.296	0.422	(0.0059)
147	6750	3.0	0.468	(0.0823)	0.635	0.251	(0.0085)	0.092	0.626	(0.0040)
148	6750	3.5	0.467	(0.0824)	0.634	0.251	(0.0086)	0.091	0.627	(0.0039)
149	6750	4.0	0.472	(0.0812)	0.638	0.248	(0.0079)	0.100	0.621	(0.0045)
150	6750	4.5	0.477	(0.0799)	0.641	0.246	(0.0072)	0.108	0.615	(0.0049)
151	6750	5.0	0.480	(0.0792)	0.644	0.245	(0.0068)	0.113	0.612	(0.0053)
152	7000	0.5	0.567	(0.0470)	0.667	0.151	(0.0023)	0.340	0.378	(0.0056)
153	7000	1.0	0.568	(0.0473)	0.669	0.151	(0.0033)	0.342	0.377	(0.0047)
154	7000	1.5	0.567	(0.0480)	0.668	0.152	(0.0043)	0.340	0.379	(0.0040)
155	7000	2.0	0.557	(0.0522)	0.668	0.166	(0.0044)	0.307	0.416	(0.0052)
156	7000	2.5	0.546	(0.0563)	0.668	0.182	(0.0045)	0.273	0.455	(0.0068)
157	7000	3.0	0.546	(0.0554)	0.665	0.179	(0.0049)	0.278	0.447	(0.0065)
158	7000	3.5	0.468	(0.0838)	0.639	0.256	(0.0082)	0.083	0.641	(0.0045)
159	7000	4.0	0.469	(0.0835)	0.639	0.255	(0.0081)	0.086	0.638	(0.0046)
160	7000	4.5	0.472	(0.0824)	0.641	0.253	(0.0077)	0.093	0.632	(0.0048)
161	7000	5.0	0.477	(0.0813)	0.644	0.251	(0.0070)	0.100	0.628	(0.0054)
162	7250	0.5	0.557	(0.0516)	0.667	0.165	(0.0019)	0.309	0.413	(0.0062)
163	7250	1.0	0.561	(0.0522)	0.672	0.166	(0.0028)	0.312	0.415	(0.0055)
164	7250	1.5	0.563	(0.0523)	0.673	0.165	(0.0039)	0.315	0.413	(0.0045)
165	7250	2.0	0.563	(0.0517)	0.671	0.162	(0.0048)	0.320	0.405	(0.0038)
166	7250	2.5	0.552	(0.0559)	0.670	0.178	(0.0046)	0.285	0.444	(0.0054)
167	7250	3.0	0.543	(0.0591)	0.670	0.191	(0.0044)	0.256	0.477	(0.0071)
168	7250	3.5	0.543	(0.0579)	0.668	0.188	(0.0047)	0.262	0.469	(0.0071)
169	7250	4.0	0.468	(0.0850)	0.642	0.260	(0.0080)	0.077	0.651	(0.0049)
170	7250	4.5	0.470	(0.0843)	0.642	0.259	(0.0079)	0.082	0.646	(0.0049)
171	7250	5.0	0.474	(0.0832)	0.645	0.257	(0.0072)	0.089	0.642	(0.0055)
172	7500	0.5	0.545	(0.0533)	0.656	0.166	(0.0034)	0.295	0.416	(0.0048)
173	7500	1.0	0.554	(0.0549)	0.669	0.173	(0.0032)	0.295	0.431	(0.0052)
174	7500	1.5	0.555	(0.0564)	0.672	0.176	(0.0043)	0.291	0.440	(0.0043)
175	7500	2.0	0.557	(0.0556)	0.672	0.172	(0.0052)	0.299	0.431	(0.0034)
176	7500	2.5	0.561	(0.0529)	0.670	0.163	(0.0059)	0.317	0.407	(0.0026)
177	7500	3.0	0.548	(0.0584)	0.671	0.185	(0.0048)	0.270	0.462	(0.0053)
178	7500	3.5	0.540	(0.0611)	0.672	0.198	(0.0044)	0.244	0.494	(0.0074)
179	7500	4.0	0.540	(0.0600)	0.671	0.195	(0.0045)	0.248	0.488	(0.0077)
180	7500	4.5	0.469	(0.0860)	0.645	0.264	(0.0079)	0.072	0.660	(0.0051)
181	7500	5.0	0.471	(0.0853)	0.647	0.263	(0.0074)	0.077	0.658	(0.0056)
182	7750	1.0	0.551	(0.0535)	0.661	0.165	(0.0043)	0.303	0.413	(0.0038)
183	7750	1.5	0.550	(0.0571)	0.667	0.176	(0.0053)	0.287	0.439	(0.0033)
184	7750	2.0	0.551	(0.0581)	0.669	0.177	(0.0062)	0.285	0.443	(0.0024)
185	7750	2.5	0.554	(0.0567)	0.669	0.172	(0.0067)	0.296	0.430	(0.0018)
186	7750	3.0	0.559	(0.0536)	0.667	0.162	(0.0070)	0.316	0.405	(0.0015)
187	7750	3.5	0.565	(0.0497)	0.665	0.150	(0.0072)	0.341	0.374	(0.0015)
188	7750	4.0	0.538	(0.0628)	0.673	0.203	(0.0043)	0.233	0.507	(0.0076)
189	7750	4.5	0.472	(0.0859)	0.649	0.265	(0.0075)	0.075	0.662	(0.0055)
190	7750	5.0	0.472	(0.0864)	0.650	0.267	(0.0071)	0.071	0.668	(0.0060)
191	8000	1.0	0.555	(0.0481)	0.651	0.144	(0.0058)	0.339	0.360	(0.0019)
192	8000	1.5	0.552	(0.0542)	0.661	0.163	(0.0063)	0.307	0.408	(0.0020)
193	8000	2.0	0.550	(0.0571)	0.664	0.171	(0.0075)	0.294	0.427	(0.0011)
194	8000	2.5	0.551	(0.0572)	0.665	0.171	(0.0081)	0.295	0.426	(0.0006)
195	8000	3.0	0.554	(0.0556)	0.665	0.166	(0.0081)	0.306	0.414	(0.0007)
196	8000	3.5	0.554	(0.0552)	0.665	0.166	(0.0075)	0.305	0.416	(0.0013)

TABLE 1. (continued)

No.	T_{eff}	log g	Linear Law x	Q	Logarithmic Law x	y	Q	Square Root Law x	y	Q
197	8000	4.0	0.541	(0.0617)	0.671	0.195	(0.0050)	0.248	0.488	(0.0055)
198	8000	4.5	0.536	(0.0644)	0.675	0.209	(0.0042)	0.222	0.522	(0.0081)
199	8000	5.0	0.477	(0.0859)	0.655	0.267	(0.0065)	0.076	0.668	(0.0066)
200	8250	1.0	0.567	(0.0404)	0.645	0.117	(0.0067)	0.391	0.293	(0.0015)
201	8250	1.5	0.560	(0.0483)	0.655	0.142	(0.0070)	0.346	0.356	(0.0013)
202	8250	2.0	0.555	(0.0526)	0.658	0.154	(0.0084)	0.325	0.384	(0.0014)
203	8250	2.5	0.554	(0.0544)	0.659	0.158	(0.0094)	0.317	0.394	(0.0019)
204	8250	3.0	0.555	(0.0542)	0.660	0.157	(0.0097)	0.319	0.393	(0.0021)
205	8250	3.5	0.558	(0.0528)	0.661	0.154	(0.0093)	0.328	0.384	(0.0020)
206	8250	4.0	0.555	(0.0547)	0.664	0.164	(0.0078)	0.309	0.410	(0.0011)
207	8250	4.5	0.539	(0.0633)	0.673	0.201	(0.0048)	0.237	0.504	(0.0062)
208	8250	5.0	0.533	(0.0666)	0.678	0.217	(0.0040)	0.208	0.542	(0.0089)
209	8500	1.0	0.582	(0.0341)	0.647	0.097	(0.0066)	0.436	0.243	(0.0020)
210	8500	1.5	0.572	(0.0421)	0.653	0.121	(0.0072)	0.389	0.304	(0.0018)
211	8500	2.0	0.567	(0.0464)	0.655	0.132	(0.0089)	0.368	0.331	(0.0027)
212	8500	2.5	0.564	(0.0486)	0.655	0.137	(0.0103)	0.359	0.342	(0.0038)
213	8500	3.0	0.562	(0.0495)	0.655	0.139	(0.0109)	0.354	0.347	(0.0043)
214	8500	3.5	0.563	(0.0494)	0.656	0.139	(0.0108)	0.355	0.347	(0.0041)
215	8500	4.0	0.565	(0.0489)	0.658	0.139	(0.0102)	0.356	0.348	(0.0035)
216	8500	4.5	0.555	(0.0547)	0.665	0.165	(0.0077)	0.308	0.412	(0.0013)
217	8500	5.0	0.536	(0.0656)	0.676	0.211	(0.0044)	0.220	0.526	(0.0073)
218	8750	1.5	0.583	(0.0371)	0.654	0.106	(0.0069)	0.424	0.265	(0.0021)
219	8750	2.0	0.580	(0.0410)	0.656	0.115	(0.0087)	0.407	0.287	(0.0033)
220	8750	2.5	0.577	(0.0429)	0.655	0.117	(0.0105)	0.401	0.294	(0.0049)
221	8750	3.0	0.575	(0.0436)	0.654	0.118	(0.0115)	0.399	0.294	(0.0059)
222	8750	3.5	0.575	(0.0437)	0.653	0.117	(0.0118)	0.398	0.294	(0.0062)
223	8750	4.0	0.574	(0.0439)	0.654	0.119	(0.0115)	0.396	0.297	(0.0058)
224	8750	4.5	0.573	(0.0452)	0.657	0.126	(0.0105)	0.383	0.316	(0.0045)
225	8750	5.0	0.551	(0.0575)	0.669	0.177	(0.0066)	0.286	0.442	(0.0028)
226	9000	1.5	0.593	(0.0337)	0.657	0.096	(0.0065)	0.449	0.240	(0.0020)
227	9000	2.0	0.591	(0.0370)	0.660	0.103	(0.0082)	0.437	0.258	(0.0033)
228	9000	2.5	0.591	(0.0383)	0.660	0.103	(0.0100)	0.435	0.259	(0.0051)
229	9000	3.0	0.590	(0.0386)	0.658	0.101	(0.0114)	0.438	0.253	(0.0065)
230	9000	3.5	0.589	(0.0384)	0.655	0.099	(0.0121)	0.440	0.248	(0.0073)
231	9000	4.0	0.588	(0.0385)	0.654	0.099	(0.0121)	0.439	0.249	(0.0073)
232	9000	4.5	0.587	(0.0388)	0.655	0.102	(0.0117)	0.435	0.254	(0.0068)
233	9000	5.0	0.588	(0.0391)	0.658	0.105	(0.0110)	0.430	0.263	(0.0059)
234	9250	2.0	0.601	(0.0340)	0.664	0.095	(0.0076)	0.459	0.237	(0.0031)
235	9250	2.5	0.602	(0.0351)	0.665	0.094	(0.0093)	0.460	0.236	(0.0048)
236	9250	3.0	0.603	(0.0350)	0.664	0.091	(0.0107)	0.467	0.228	(0.0064)
237	9250	3.5	0.603	(0.0344)	0.662	0.087	(0.0116)	0.473	0.218	(0.0074)
238	9250	4.0	0.603	(0.0339)	0.659	0.085	(0.0120)	0.476	0.212	(0.0079)
239	9250	4.5	0.601	(0.0340)	0.658	0.085	(0.0119)	0.473	0.213	(0.0078)
240	9250	5.0	0.600	(0.0346)	0.659	0.088	(0.0116)	0.467	0.221	(0.0073)
241	9500	2.0	0.608	(0.0319)	0.667	0.089	(0.0071)	0.474	0.223	(0.0028)
242	9500	2.5	0.612	(0.0328)	0.671	0.088	(0.0086)	0.479	0.221	(0.0044)
243	9500	3.0	0.614	(0.0325)	0.671	0.085	(0.0100)	0.487	0.212	(0.0059)
244	9500	3.5	0.616	(0.0317)	0.670	0.080	(0.0109)	0.496	0.201	(0.0070)
245	9500	4.0	0.616	(0.0308)	0.667	0.076	(0.0114)	0.502	0.190	(0.0077)
246	9500	4.5	0.616	(0.0303)	0.665	0.074	(0.0116)	0.505	0.185	(0.0080)
247	9500	5.0	0.614	(0.0305)	0.664	0.075	(0.0115)	0.501	0.187	(0.0079)
248	9750	2.0	0.614	(0.0303)	0.670	0.084	(0.0067)	0.487	0.211	(0.0027)
249	9750	2.5	0.619	(0.0310)	0.675	0.084	(0.0080)	0.493	0.210	(0.0040)
250	9750	3.0	0.623	(0.0308)	0.677	0.081	(0.0093)	0.502	0.202	(0.0054)
251	9750	3.5	0.627	(0.0299)	0.677	0.076	(0.0101)	0.512	0.191	(0.0064)
252	9750	4.0	0.628	(0.0290)	0.676	0.072	(0.0106)	0.520	0.180	(0.0071)
253	9750	4.5	0.628	(0.0282)	0.674	0.069	(0.0109)	0.525	0.172	(0.0075)
254	9750	5.0	0.627	(0.0278)	0.672	0.067	(0.0110)	0.526	0.168	(0.0077)
255	10000	2.0	0.618	(0.0290)	0.672	0.081	(0.0064)	0.497	0.202	(0.0026)
256	10000	2.5	0.625	(0.0296)	0.679	0.081	(0.0075)	0.504	0.202	(0.0036)
257	10000	3.0	0.631	(0.0295)	0.683	0.078	(0.0086)	0.514	0.196	(0.0048)
258	10000	3.5	0.635	(0.0288)	0.685	0.074	(0.0093)	0.524	0.186	(0.0058)
259	10000	4.0	0.638	(0.0277)	0.685	0.070	(0.0098)	0.533	0.175	(0.0065)
260	10000	4.5	0.639	(0.0269)	0.683	0.067	(0.0100)	0.539	0.167	(0.0068)
261	10000	5.0	0.638	(0.0263)	0.681	0.065	(0.0102)	0.542	0.161	(0.0071)
262	10500	2.0	0.624	(0.0267)	0.674	0.074	(0.0061)	0.513	0.186	(0.0026)

TABLE 1. (continued)

No.	T_{eff}	log g	Linear Law x	Q	Logarithmic Law x	y	Q	Square Root Law x	y	Q
263	10500	2.5	0.634	(0.0275)	0.684	0.076	(0.0068)	0.520	0.189	(0.0031)
264	10500	3.0	0.642	(0.0277)	0.692	0.075	(0.0075)	0.530	0.187	(0.0039)
265	10500	3.5	0.649	(0.0272)	0.697	0.072	(0.0081)	0.540	0.181	(0.0046)
266	10500	4.0	0.653	(0.0265)	0.699	0.069	(0.0085)	0.549	0.173	(0.0051)
267	10500	4.5	0.655	(0.0259)	0.700	0.067	(0.0087)	0.555	0.168	(0.0055)
268	10500	5.0	0.656	(0.0255)	0.700	0.066	(0.0087)	0.557	0.165	(0.0056)
269	11000	2.5	0.640	(0.0256)	0.687	0.070	(0.0063)	0.535	0.176	(0.0030)
270	11000	3.0	0.650	(0.0263)	0.698	0.072	(0.0068)	0.542	0.180	(0.0033)
271	11000	3.5	0.658	(0.0265)	0.706	0.072	(0.0072)	0.550	0.180	(0.0037)
272	11000	4.0	0.664	(0.0262)	0.711	0.071	(0.0074)	0.558	0.177	(0.0040)
273	11000	4.5	0.668	(0.0257)	0.714	0.069	(0.0075)	0.564	0.174	(0.0042)
274	11000	5.0	0.670	(0.0255)	0.715	0.069	(0.0076)	0.566	0.172	(0.0043)
275	11500	2.5	0.646	(0.0234)	0.689	0.064	(0.0060)	0.550	0.160	(0.0029)
276	11500	3.0	0.656	(0.0247)	0.702	0.068	(0.0063)	0.555	0.169	(0.0031)
277	11500	3.5	0.665	(0.0256)	0.712	0.070	(0.0066)	0.560	0.176	(0.0032)
278	11500	4.0	0.672	(0.0259)	0.720	0.072	(0.0067)	0.565	0.179	(0.0033)
279	11500	4.5	0.677	(0.0260)	0.725	0.072	(0.0067)	0.569	0.180	(0.0033)
280	11500	5.0	0.680	(0.0260)	0.728	0.073	(0.0067)	0.571	0.181	(0.0033)
281	12000	2.5	0.652	(0.0212)	0.690	0.058	(0.0055)	0.565	0.145	(0.0027)
282	12000	3.0	0.663	(0.0229)	0.704	0.063	(0.0059)	0.568	0.157	(0.0028)
283	12000	3.5	0.671	(0.0244)	0.716	0.067	(0.0061)	0.570	0.168	(0.0029)
284	12000	4.0	0.679	(0.0254)	0.726	0.071	(0.0062)	0.572	0.177	(0.0028)
285	12000	4.5	0.684	(0.0260)	0.733	0.073	(0.0062)	0.575	0.183	(0.0027)
286	12000	5.0	0.688	(0.0264)	0.738	0.075	(0.0061)	0.575	0.187	(0.0026)
287	12500	2.5	0.657	(0.0192)	0.692	0.053	(0.0048)	0.578	0.132	(0.0023)
288	12500	3.0	0.668	(0.0211)	0.707	0.058	(0.0053)	0.581	0.145	(0.0025)
289	12500	3.5	0.677	(0.0231)	0.720	0.064	(0.0056)	0.581	0.160	(0.0026)
290	12500	4.0	0.684	(0.0247)	0.731	0.069	(0.0058)	0.580	0.174	(0.0025)
291	12500	4.5	0.690	(0.0259)	0.739	0.074	(0.0058)	0.580	0.184	(0.0023)
292	12500	5.0	0.694	(0.0267)	0.745	0.077	(0.0057)	0.579	0.191	(0.0022)
293	13000	2.5	0.661	(0.0176)	0.694	0.049	(0.0041)	0.588	0.122	(0.0018)
294	13000	3.0	0.674	(0.0196)	0.710	0.055	(0.0046)	0.592	0.137	(0.0019)
295	13000	3.5	0.683	(0.0219)	0.724	0.062	(0.0050)	0.590	0.154	(0.0021)
296	13000	4.0	0.690	(0.0241)	0.735	0.068	(0.0053)	0.587	0.171	(0.0021)
297	13000	4.5	0.695	(0.0258)	0.745	0.074	(0.0054)	0.584	0.185	(0.0019)
298	13000	5.0	0.699	(0.0270)	0.752	0.078	(0.0054)	0.582	0.196	(0.0017)
299	14000	2.0	0.644	(0.0158)	0.674	0.045	(0.0031)	0.576	0.113	(0.0010)
300	14000	2.5	0.666	(0.0152)	0.696	0.044	(0.0028)	0.600	0.110	(0.0007)
301	14000	3.0	0.682	(0.0173)	0.715	0.050	(0.0030)	0.606	0.126	(0.0006)
302	14000	3.5	0.692	(0.0203)	0.731	0.059	(0.0037)	0.603	0.148	(0.0009)
303	14000	4.0	0.699	(0.0233)	0.744	0.068	(0.0043)	0.597	0.170	(0.0011)
304	14000	4.5	0.703	(0.0259)	0.754	0.076	(0.0047)	0.589	0.190	(0.0011)
305	14000	5.0	0.707	(0.0281)	0.762	0.083	(0.0048)	0.583	0.207	(0.0010)
306	15000	2.5	0.667	(0.0142)	0.695	0.043	(0.0017)	0.602	0.108	(0.0004)
307	15000	3.0	0.686	(0.0160)	0.718	0.049	(0.0016)	0.612	0.123	(0.0008)
308	15000	3.5	0.698	(0.0194)	0.737	0.059	(0.0022)	0.609	0.148	(0.0007)
309	15000	4.0	0.705	(0.0231)	0.752	0.070	(0.0031)	0.601	0.174	(0.0004)
310	15000	4.5	0.710	(0.0264)	0.763	0.079	(0.0038)	0.591	0.198	(0.0005)
311	15000	5.0	0.712	(0.0292)	0.771	0.088	(0.0043)	0.581	0.220	(0.0006)
312	16000	2.5	0.663	(0.0143)	0.693	0.045	(0.0010)	0.596	0.112	(0.0012)
313	16000	3.0	0.686	(0.0156)	0.719	0.050	(0.0003)	0.610	0.126	(0.0021)
314	16000	3.5	0.701	(0.0193)	0.742	0.062	(0.0008)	0.608	0.154	(0.0022)
315	16000	4.0	0.709	(0.0235)	0.758	0.074	(0.0018)	0.599	0.184	(0.0018)
316	16000	4.5	0.714	(0.0274)	0.770	0.084	(0.0029)	0.588	0.211	(0.0013)
317	16000	5.0	0.717	(0.0306)	0.779	0.094	(0.0036)	0.576	0.234	(0.0010)
318	17000	2.5	0.656	(0.0155)	0.689	0.049	(0.0006)	0.582	0.123	(0.0017)
319	17000	3.0	0.683	(0.0160)	0.718	0.053	(0.0006)	0.603	0.132	(0.0031)
320	17000	3.5	0.700	(0.0198)	0.744	0.065	(0.0005)	0.602	0.163	(0.0036)
321	17000	4.0	0.710	(0.0245)	0.763	0.079	(0.0006)	0.592	0.197	(0.0032)
322	17000	4.5	0.716	(0.0288)	0.777	0.091	(0.0019)	0.580	0.227	(0.0025)
323	17000	5.0	0.719	(0.0324)	0.786	0.100	(0.0030)	0.568	0.251	(0.0019)
324	18000	2.5	0.647	(0.0177)	0.684	0.056	(0.0007)	0.562	0.141	(0.0020)
325	18000	3.0	0.677	(0.0169)	0.715	0.057	(0.0010)	0.592	0.142	(0.0037)
326	18000	3.5	0.697	(0.0207)	0.743	0.069	(0.0014)	0.593	0.173	(0.0047)
327	18000	4.0	0.709	(0.0258)	0.765	0.085	(0.0005)	0.582	0.211	(0.0045)
328	18000	4.5	0.716	(0.0305)	0.781	0.098	(0.0010)	0.569	0.245	(0.0038)
329	18000	5.0	0.719	(0.0345)	0.791	0.108	(0.0023)	0.556	0.271	(0.0030)
330	19000	2.5	0.636	(0.0207)	0.679	0.065	(0.0012)	0.538	0.163	(0.0020)

TABLE 1. (continued)

No.	T_{eff}	log g	Linear Law x	Linear Law Q	Logarithmic Law x	Logarithmic Law y	Logarithmic Law Q	Square Root Law x	Square Root Law y	Square Root Law Q
331	19000	3.0	0.669	(0.0185)	0.710	0.062	(0.0010)	0.576	0.154	(0.0040)
332	19000	3.5	0.691	(0.0219)	0.741	0.074	(0.0019)	0.581	0.185	(0.0054)
333	19000	4.0	0.706	(0.0273)	0.766	0.091	(0.0013)	0.570	0.226	(0.0056)
334	19000	4.5	0.714	(0.0326)	0.784	0.106	(0.0002)	0.555	0.264	(0.0049)
335	19000	5.0	0.718	(0.0369)	0.796	0.117	(0.0016)	0.541	0.294	(0.0040)
336	20000	3.0	0.659	(0.0206)	0.704	0.068	(0.0007)	0.557	0.170	(0.0039)
337	20000	3.5	0.684	(0.0234)	0.737	0.079	(0.0021)	0.565	0.198	(0.0059)
338	20000	4.0	0.700	(0.0291)	0.765	0.097	(0.0018)	0.554	0.242	(0.0064)
339	20000	4.5	0.709	(0.0349)	0.785	0.114	(0.0005)	0.539	0.284	(0.0059)
340	20000	5.0	0.714	(0.0396)	0.799	0.127	(0.0012)	0.524	0.317	(0.0050)
341	21000	3.0	0.648	(0.0231)	0.698	0.075	(0.0001)	0.535	0.189	(0.0037)
342	21000	3.5	0.675	(0.0253)	0.732	0.085	(0.0020)	0.547	0.213	(0.0061)
343	21000	4.0	0.692	(0.0311)	0.762	0.104	(0.0021)	0.537	0.260	(0.0071)
344	21000	4.5	0.703	(0.0374)	0.785	0.123	(0.0009)	0.519	0.306	(0.0067)
345	21000	5.0	0.709	(0.0426)	0.800	0.137	(0.0008)	0.503	0.343	(0.0058)
346	22000	3.0	0.636	(0.0261)	0.692	0.084	(0.0005)	0.509	0.211	(0.0036)
347	22000	3.5	0.664	(0.0276)	0.726	0.093	(0.0018)	0.525	0.232	(0.0062)
348	22000	4.0	0.683	(0.0334)	0.758	0.112	(0.0023)	0.515	0.280	(0.0076)
349	22000	4.5	0.695	(0.0401)	0.783	0.132	(0.0012)	0.497	0.330	(0.0075)
350	22000	5.0	0.701	(0.0459)	0.800	0.148	(0.0006)	0.479	0.370	(0.0066)
351	23000	3.0	0.623	(0.0296)	0.687	0.096	(0.0008)	0.479	0.239	(0.0039)
352	23000	3.5	0.652	(0.0303)	0.720	0.102	(0.0015)	0.500	0.254	(0.0064)
353	23000	4.0	0.672	(0.0361)	0.753	0.121	(0.0023)	0.491	0.303	(0.0081)
354	23000	4.5	0.685	(0.0432)	0.780	0.142	(0.0014)	0.471	0.356	(0.0082)
355	23000	5.0	0.692	(0.0494)	0.799	0.160	(0.0005)	0.452	0.400	(0.0074)
356	24000	3.0	0.609	(0.0340)	0.682	0.110	(0.0008)	0.443	0.276	(0.0047)
357	24000	3.5	0.639	(0.0336)	0.714	0.112	(0.0014)	0.471	0.281	(0.0068)
358	24000	4.0	0.660	(0.0392)	0.748	0.132	(0.0024)	0.463	0.329	(0.0087)
359	24000	4.5	0.673	(0.0466)	0.776	0.154	(0.0016)	0.442	0.385	(0.0090)
360	24000	5.0	0.681	(0.0533)	0.797	0.173	(0.0004)	0.422	0.433	(0.0082)
361	25000	3.0	0.592	(0.0391)	0.676	0.127	(0.0007)	0.401	0.317	(0.0056)
362	25000	3.5	0.625	(0.0377)	0.709	0.126	(0.0016)	0.436	0.315	(0.0076)
363	25000	4.0	0.646	(0.0428)	0.742	0.144	(0.0025)	0.430	0.360	(0.0094)
364	25000	4.5	0.660	(0.0504)	0.771	0.167	(0.0018)	0.409	0.418	(0.0099)
365	25000	5.0	0.668	(0.0577)	0.793	0.188	(0.0003)	0.387	0.469	(0.0091)
366	26000	3.0	0.576	(0.0429)	0.668	0.138	(0.0011)	0.368	0.345	(0.0056)
367	26000	3.5	0.609	(0.0423)	0.703	0.141	(0.0016)	0.397	0.353	(0.0084)
368	26000	4.0	0.630	(0.0470)	0.736	0.158	(0.0027)	0.393	0.395	(0.0103)
369	26000	4.5	0.644	(0.0547)	0.765	0.182	(0.0021)	0.372	0.454	(0.0108)
370	26000	5.0	0.653	(0.0624)	0.789	0.203	(0.0004)	0.348	0.508	(0.0100)
371	27000	3.5	0.591	(0.0471)	0.695	0.156	(0.0014)	0.356	0.391	(0.0089)
372	27000	4.0	0.613	(0.0517)	0.729	0.174	(0.0028)	0.353	0.434	(0.0111)
373	27000	4.5	0.627	(0.0594)	0.759	0.197	(0.0023)	0.331	0.494	(0.0118)
374	27000	5.0	0.636	(0.0673)	0.782	0.220	(0.0005)	0.306	0.549	(0.0110)
375	28000	3.5	0.574	(0.0507)	0.685	0.167	(0.0007)	0.324	0.416	(0.0087)
376	28000	4.0	0.595	(0.0565)	0.720	0.188	(0.0026)	0.312	0.471	(0.0117)
377	28000	4.5	0.608	(0.0644)	0.751	0.213	(0.0023)	0.288	0.534	(0.0125)
378	28000	5.0	0.617	(0.0725)	0.775	0.236	(0.0005)	0.263	0.591	(0.0117)
379	29000	3.5	0.561	(0.0523)	0.674	0.169	(0.0006)	0.307	0.422	(0.0076)
380	29000	4.0	0.576	(0.0604)	0.709	0.200	(0.0019)	0.276	0.500	(0.0116)
381	29000	4.5	0.589	(0.0691)	0.740	0.228	(0.0020)	0.247	0.569	(0.0129)
382	29000	5.0	0.597	(0.0776)	0.765	0.252	(0.0006)	0.219	0.630	(0.0123)
383	30000	3.5	0.555	(0.0521)	0.665	0.166	(0.0021)	0.306	0.414	(0.0059)
384	30000	4.0	0.559	(0.0626)	0.696	0.205	(0.0009)	0.252	0.512	(0.0107)
385	30000	4.5	0.569	(0.0728)	0.727	0.238	(0.0014)	0.212	0.594	(0.0126)
386	30000	5.0	0.577	(0.0819)	0.753	0.265	(0.0011)	0.180	0.661	(0.0122)
387	31000	3.5	0.553	(0.0516)	0.661	0.161	(0.0033)	0.311	0.404	(0.0045)
388	31000	4.0	0.548	(0.0630)	0.683	0.203	(0.0009)	0.243	0.507	(0.0092)
389	31000	4.5	0.552	(0.0746)	0.713	0.241	(0.0011)	0.190	0.603	(0.0116)
390	31000	5.0	0.557	(0.0849)	0.738	0.272	(0.0020)	0.149	0.680	(0.0116)
391	32000	4.0	0.541	(0.0624)	0.673	0.198	(0.0023)	0.243	0.496	(0.0074)
392	32000	4.5	0.539	(0.0746)	0.698	0.239	(0.0020)	0.181	0.596	(0.0102)

TABLE 1. (continued)

			Linear Law		Logarithmic Law			Square Root Law		
No.	T_{eff}	log g	x	Q	x	y	Q	x	y	Q
393	32000	5.0	0.540	(0.0859)	0.721	0.273	(0.0033)	0.131	0.681	(0.0104)
394	33000	4.0	0.537	(0.0616)	0.666	0.193	(0.0036)	0.247	0.483	(0.0059)
395	33000	4.5	0.529	(0.0735)	0.684	0.232	(0.0033)	0.181	0.580	(0.0083)
396	33000	5.0	0.527	(0.0850)	0.705	0.267	(0.0046)	0.127	0.667	(0.0088)
397	34000	4.0	0.537	(0.0604)	0.661	0.187	(0.0048)	0.256	0.467	(0.0043)
398	34000	4.5	0.524	(0.0720)	0.674	0.225	(0.0045)	0.186	0.563	(0.0067)
399	34000	5.0	0.517	(0.0832)	0.689	0.258	(0.0060)	0.130	0.645	(0.0070)
400	35000	4.0	0.541	(0.0574)	0.657	0.174	(0.0064)	0.280	0.435	(0.0022)
401	35000	4.5	0.521	(0.0703)	0.666	0.217	(0.0057)	0.196	0.543	(0.0050)
402	35000	5.0	0.512	(0.0809)	0.678	0.249	(0.0070)	0.138	0.622	(0.0055)
403	37500	4.5	0.534	(0.0600)	0.652	0.177	(0.0092)	0.269	0.441	(0.0013)
404	37500	5.0	0.512	(0.0726)	0.656	0.216	(0.0098)	0.187	0.541	(0.0016)
405	40000	4.5	0.565	(0.0484)	0.657	0.138	(0.0095)	0.357	0.346	(0.0028)
406	40000	5.0	0.539	(0.0577)	0.648	0.163	(0.0120)	0.295	0.408	(0.0042)
407	42500	5.0	0.569	(0.0485)	0.659	0.136	(0.0109)	0.365	0.339	(0.0044)
408	45000	5.0	0.588	(0.0437)	0.670	0.122	(0.0098)	0.405	0.306	(0.0039)
409	47500	5.0	0.604	(0.0391)	0.676	0.109	(0.0090)	0.440	0.272	(0.0038)
410	50000	5.0	0.616	(0.0352)	0.681	0.098	(0.0082)	0.469	0.245	(0.0035)

TABLE 2. Passband-specific limb-darkening coefficients (sample).

	Linear Law		Logarithmic Law			Square Root Law		
Band	x	Q	x	y	Q	x	y	Q
	Teff = 3500 K, log g = 0.0, 1.00 x Solar Abundance							
bolo	0.481	(0.0692)	0.608	0.190	(0.0176)	0.196	0.475	(0.0084)
u	0.735	(0.0391)	0.775	0.060	(0.0251)	0.645	0.150	(0.0223)
v	0.895	(0.0615)	0.722	-0.259	(0.0370)	1.284	-0.648	(0.0491)
b	1.087	(0.1208)	0.779	-0.463	(0.0408)	1.782	-1.158	(0.0628)
y	0.987	(0.0672)	0.811	-0.264	(0.0314)	1.383	-0.660	(0.0441)
U	0.745	(0.0403)	0.782	0.056	(0.0276)	0.660	0.141	(0.0250)
B	1.031	(0.1014)	0.766	-0.397	(0.0399)	1.626	-0.993	(0.0587)
V	0.970	(0.0589)	0.814	-0.234	(0.0307)	1.320	-0.585	(0.0419)
R	0.825	(0.0233)	0.799	-0.038	(0.0286)	0.882	-0.096	(0.0305)
I	0.627	(0.0555)	0.712	0.128	(0.0247)	0.435	0.321	(0.0185)
J	0.491	(0.0566)	0.598	0.161	(0.0132)	0.250	0.401	(0.0058)
K	0.323	(0.1077)	0.534	0.317	(0.0173)	-0.152	0.792	(0.0021)
L	0.242	(0.0777)	0.393	0.226	(0.0139)	-0.097	0.565	(0.0030)
M	0.149	(0.0599)	0.254	0.158	(0.0192)	-0.088	0.394	(0.0118)
N	0.117	(0.0366)	0.183	0.100	(0.0098)	-0.033	0.250	(0.0050)
R_c	0.879	(0.0264)	0.816	-0.095	(0.0285)	1.020	-0.236	(0.0331)
I_c	0.707	(0.0463)	0.765	0.087	(0.0271)	0.576	0.218	(0.0229)
	Teff = 3500 K, log g = 0.5, 1.00 x Solar Abundance							
bolo	0.474	(0.0693)	0.600	0.189	(0.0182)	0.190	0.474	(0.0091)
u	0.781	(0.0266)	0.769	-0.017	(0.0309)	0.806	-0.043	(0.0317)
v	0.935	(0.0733)	0.733	-0.303	(0.0386)	1.389	-0.757	(0.0528)
b	1.110	(0.1233)	0.796	-0.471	(0.0404)	1.817	-1.178	(0.0628)
y	0.991	(0.0661)	0.817	-0.261	(0.0317)	1.382	-0.653	(0.0442)
U	0.789	(0.0275)	0.777	-0.019	(0.0320)	0.817	-0.047	(0.0328)
B	1.045	(0.1017)	0.780	-0.398	(0.0396)	1.642	-0.995	(0.0585)
V	0.973	(0.0588)	0.817	-0.234	(0.0310)	1.324	-0.585	(0.0422)
R	0.816	(0.0243)	0.786	-0.044	(0.0302)	0.882	-0.110	(0.0323)
I	0.618	(0.0562)	0.704	0.128	(0.0255)	0.427	0.319	(0.0194)
J	0.481	(0.0574)	0.588	0.160	(0.0145)	0.240	0.401	(0.0070)
K	0.321	(0.1063)	0.530	0.313	(0.0171)	-0.148	0.782	(0.0021)
L	0.240	(0.0753)	0.386	0.219	(0.0134)	-0.089	0.548	(0.0029)
M	0.142	(0.0582)	0.243	0.152	(0.0190)	-0.087	0.381	(0.0118)
N	0.113	(0.0357)	0.178	0.098	(0.0096)	-0.033	0.244	(0.0049)
R_c	0.874	(0.0284)	0.805	-0.105	(0.0300)	1.031	-0.262	(0.0350)
I_c	0.698	(0.0461)	0.753	0.082	(0.0283)	0.575	0.205	(0.0243)

TABLE 3. Monochromatic limb-darkening coefficients (sample).

Model 109, Teff = 5750 K, log g = 4.5, 1.00 x Solar Abundance, Vturb = 2.0 km/s, L/H = 1.25

	Linear Law		Logarithmic Law			Square Root Law			
λ(nm)	x_λ	Q_λ	x_λ	y_λ	Q_λ	x_λ	y_λ	Q_λ	I(λ,μ = 1) (erg/s/cm^2/ster/nm)
bolometric	0.510	(0.0666)	0.648	0.207	(0.0068)	0.199	0.519	(0.0044)	
92.50	1.036	(0.0270)	0.966	-0.105	(0.0085)	1.194	-0.262	(0.0133)	1.581E-05
93.50	1.033	(0.0253)	0.967	-0.098	(0.0079)	1.180	-0.246	(0.0124)	2.190E-05
...									
367.00	0.796	(0.0422)	0.893	0.145	(0.0042)	0.580	0.361	(0.0094)	2.350E+07
369.00	0.788	(0.0394)	0.875	0.131	(0.0040)	0.591	0.328	(0.0067)	2.144E+07
371.00	0.771	(0.0510)	0.889	0.177	(0.0057)	0.506	0.442	(0.0126)	2.278E+07
...									
549.00	0.607	(0.0724)	0.762	0.233	(0.0045)	0.257	0.583	(0.0088)	3.422E+07
551.00	0.607	(0.0722)	0.762	0.232	(0.0046)	0.258	0.581	(0.0086)	3.391E+07
553.00	0.601	(0.0739)	0.760	0.238	(0.0045)	0.244	0.596	(0.0090)	3.398E+07
...									
589.00	0.567	(0.0742)	0.725	0.236	(0.0056)	0.212	0.591	(0.0075)	3.067E+07
591.00	0.567	(0.0778)	0.734	0.250	(0.0048)	0.193	0.624	(0.0088)	3.228E+07
593.00	0.565	(0.0783)	0.732	0.251	(0.0049)	0.188	0.628	(0.0090)	3.217E+07
...									
140000.00	0.033	(0.0249)	0.075	0.063	(0.0091)	-0.062	0.158	(0.0061)	9.362E-02
160000.00	0.033	(0.0253)	0.075	0.064	(0.0094)	-0.063	0.160	(0.0064)	5.463E-02

ber listed in Table 1. Table 3[2] is a shortened example of one of these files showing their form and content. In particular, coefficients for large parts of the UV have never been published before and are now available. They may be of interest when analyzing satellite observations of stars and stellar systems.

5. COMPARISON WITH PREVIOUS RESULTS AND OBSERVATIONS

As mentioned in Sec. 4, differences between limb-darkening coefficients in this paper and those obtained by other authors may be due to differences in the stellar atmosphere models on which they are based, or they may be due to the particulars of the method by which they were computed. Comparing observed limb-darkening (only possible for the Sun) with results obtained using approximations based on tabulated coefficients may tell us more about the agreement (or disagreement) between the underlying atmosphere model and the observed center-to-limb variation of the solar intensity than about the coefficients themselves or the methods by which they were computed. In this section, we make some of these comparisons.

Table 4 compares the Klinglesmith & Sobieski (1970) linear and logarithmic coefficients (top) with those obtained in this paper (bottom). Numbers for stars with $\log g = 4.5$ and effective temperatures of 10 000 and 20 000 K are listed. Differences are small but systematic and appear to decrease toward larger temperatures.

Figure 5 is a plot of the linear limb-darkening coefficient as a function of wavelength for a 10 000 K, $\log g = 4.0$ model. Also shown are similar coefficients by Grygar (1965), Klinglesmith & Sobieski (1970), Al-Naimiy (1978), and Wade & Rucinski (1985). Very good agreement is seen between our coefficients and those of Wade and Rucinski. This is to be expected, since similar models and computational methods were used. In the optical region, the Al-Naimiy coefficients are, compared to ours, systematically larger by about 0.02, while those of Klinglesmith and Sobieski are systematically lower by about the same amount. Differences appear to become smaller in the UV and even change sign. The Grygar coefficients differ by

TABLE 4. Linear and logarithmic limb-darkening coefficients for $\log g = 4.5$ stars. Top numbers are from Klinglesmith & Sobieski (1970), bottom numbers are from this paper.

	$T_{\rm eff}$=10 000 K			$T_{\rm eff}$=20 000 K		
	Linear	Logarithmic		Linear	Logarithmic	
λ(nm)	x	x	y	x	x	y
250	0.75	0.81	0.10	0.50	0.69	0.29
	0.78	0.80	0.03	0.49	0.65	0.24
365	0.40	0.55	0.23	0.33	0.49	0.25
	0.43	0.54	0.16	0.31	0.44	0.20
440	0.45	0.69	0.36	0.32	0.52	0.32
	0.49	0.72	0.34	0.31	0.49	0.27
550	0.38	0.58	0.31	0.26	0.43	0.27
	0.41	0.60	0.29	0.26	0.41	0.22
700	0.29	0.45	0.25	0.21	0.35	0.21
	0.31	0.46	0.22	0.21	0.32	0.17
1250	0.18	0.30	0.19	0.13	0.24	0.17
	0.20	0.31	0.16	0.13	0.21	0.12

[2]Table 3 is presented in its complete form in the ApJ/AJ CD-ROM Series, volume 1, 1993. The first page of this table is presented here for guidance regarding its form and content.

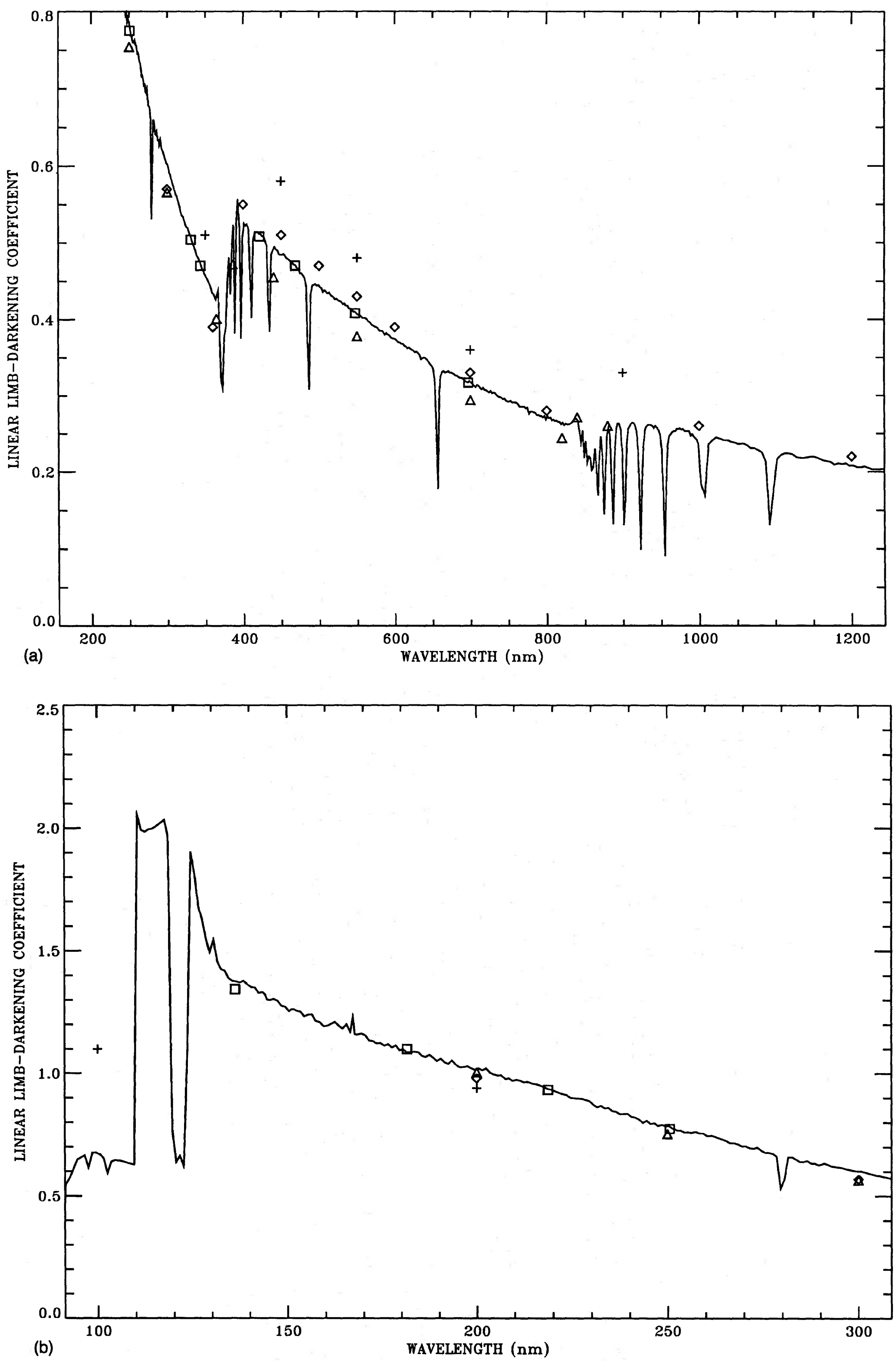

FIG. 5. (a) The linear limb-darkening coefficient for a solar chemical composition star with $T_{\rm eff}=10\,000$ K and $\log g=4.0$. Plus signs indicate coefficients by Grygar (1965); diamonds those by Al-Naimiy (1978); squares those by Wade & Rucinski (1985); triangles are those by Klinglesmith & Sobieski (1970). The solid line represents the coefficients computed in this work. (b) Same as (a) for the UV.

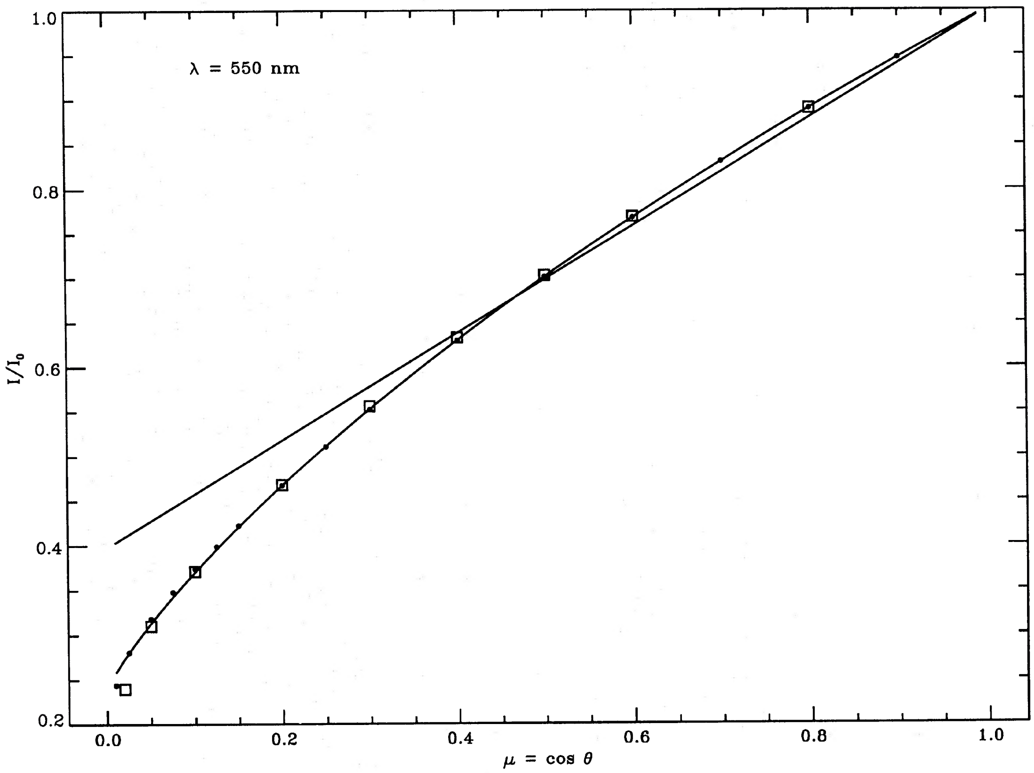

FIG. 6. Solar limb-darkening at wavelength 550 nm. Squares indicate the observed limb darkening compiled in Allen (1976). Dots represent the theoretical limb darkening according to Kurucz (1991). Solid lines are the linear and logarithmic approximations using coefficients of this paper.

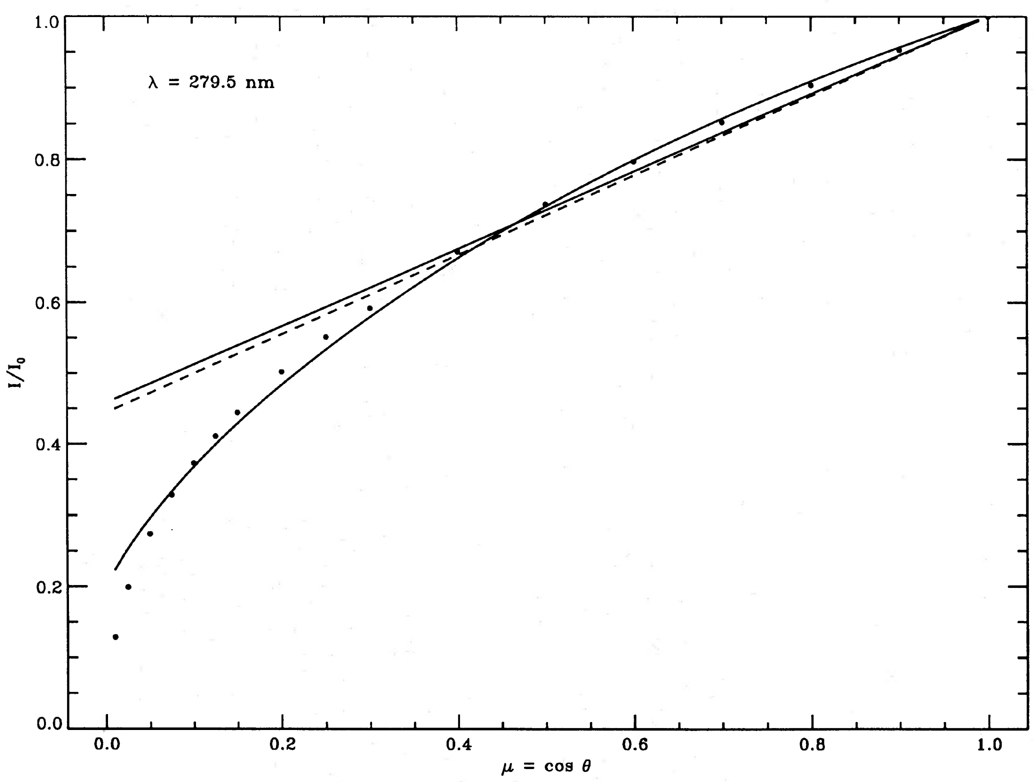

FIG. 7. Solar limb-darkening at wavelength 279.5 nm. For dots and solid lines refer to Fig. 6. The dashed line is a linear approximation using a coefficient due to Moe & Milone (1978) and is based on observations of the Sun made by *Skylab.*

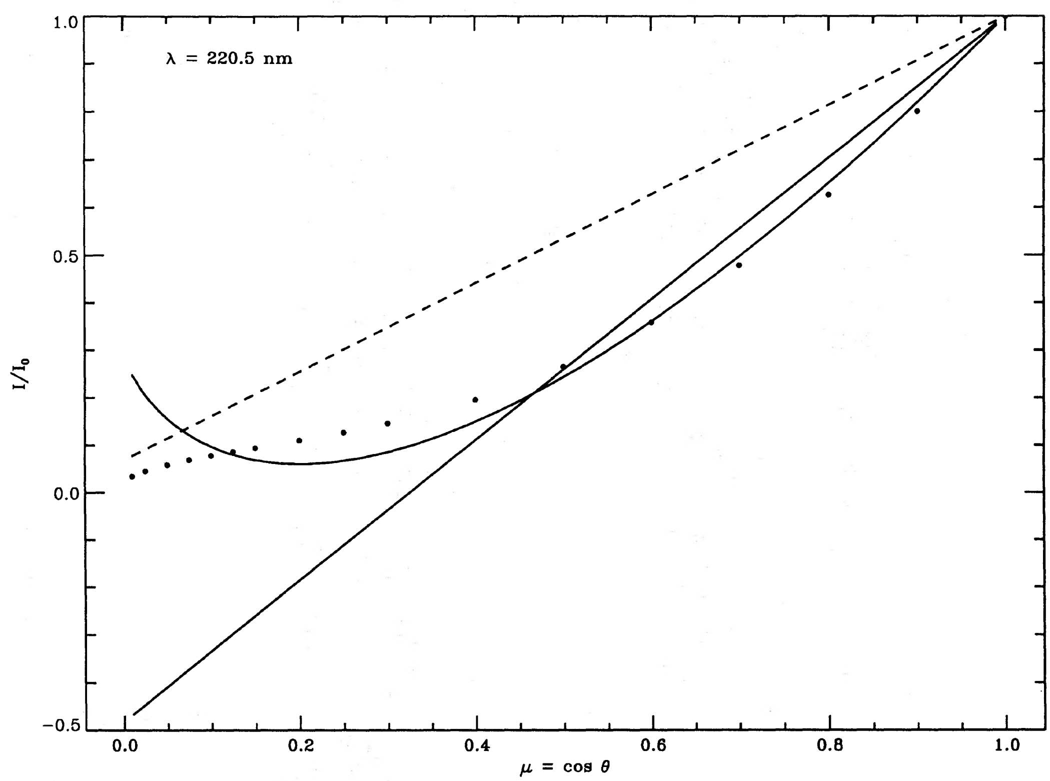

FIG. 8. Same as Fig. 7 for a wavelength of 220.5 nm.

larger amounts and, again, in a systematic way. However, the latter are averages for A0 stars based on a number of older atmosphere models made by different authors.

In a comparison between theoretical and observed limb-darkening, the Sun, of course, is the only star for which the center-to-limb variation of the intensity can be observed directly. In the optical region, we used the solar limb-darkening data compiled by Allen (1976). Figure 6 shows the observed limb-darkening of the Sun (squares) at a wavelength of 550 nm, together with the theoretical limb-darkening (filled circles) according to Kurucz (1991). Also shown, by means of solid lines, are the computed linear and logarithmic limb-darkening using the appropriate coefficients determined in this paper. A very good agreement between theory and observation exists. As expected, the logarithmic approximation gives a much better representation of the true limb darkening. The situation is remarkably different in some parts of the UV, as indicated by Figs. 7 and 8. These figures show the Kurucz solar model limb-darkening at wavelengths 220.5 and 279.5 nm, respectively. At 220.5 nm, neither the linear nor the logarithmic approximation represent the limb-darkening well. At 279.5 nm, the approximations are better. In both figures, dashed lines indicate the linear limb-darkening computed using a coefficient determined from Skylab observations by Moe & Milone (1978). It is clear from most of the figures in Moe and Milone's composite Fig. 1 that the observed limb-darkening is reasonably well represented by these straight line approximations. Hence, we may consider the dashed lines in Figs. 7 and 8 to represent the observed solar limb darkening. Clearly, when a reasonably good agreement exists between the theoretical and observed center-to-limb intensity variation, the various limb-darkening approximations do a better job in representing the true limb darkening. However, any one of the approximations will fail when a mismatch also exists between the observed intensities and those obtained using an atmosphere model. When using our monochromatic limb-darkening coefficients, especially those in the UV, it would seem prudent to pay close attention to the Q quality numbers introduced in Sec. 3.

The effects of using different limb-darkening laws on eclipsing binary light curve solutions will be examined in a future paper, as well as the use of variable limb darkening, in accordance with temperature and surface gravity variations across the surfaces of tidally distorted close binary stars.

We are grateful to Robert L. Kurucz for providing magnetic tapes with fluxes and specific intensities for his latest stellar atmosphere models. We would like to thank R. E. Wilson for many stimulating discussions on both the broad general outline of this project and on the final details of the format for the tables. This work was sponsored in part by a NASA JOVE grant awarded to Florida International University and the University of Florida.

REFERENCES

Allen, C. W. 1976, Astrophysical Quantities, 3rd edition (Athlone, London)
Al-Naimiy, H. M. 1978, Ap&SS, 53, 181
Al-Naimiy, H. M. & Budding, E. 1977, Ap&SS, 51, 265
Ažusienis, A. & Straižys, V. 1969, SvA, 13, 316
Bell, R. A., Eriksson, K., Gustafsson, B., & Nordlund, A. 1976, A&AS, 23, 37
Bessell, M. S. 1983, PASP, 95, 480
Buser, R. 1978, A&A, 62, 411
Carbon, D., & Gingerich, O. 1969, in Theory and Observation of Normal Stellar Atmospheres, edited by O. Gingerich (MIT University Press, Cambridge), p. 377
Claret, A., & Giménez, A. 1990, A&A, 230, 412
Crawford, D. L., & Barnes, J. V. 1970, AJ, 75, 978
Díaz-Cordovés, J., & Giménez, A. 1992, A&A, 259, 227
Grygar, J. 1965, BACz, 16, 195
Gustafsson, B., Bell, R. A., Eriksson, K., & Nordlund, A. 1975, A&A, 42, 407
Johnson, H. L. 1965, AJ, 141, 923
Kiperman, M. E., & Shul'berg, A. M. 1969, SvA, 13, 324
Klinglesmith, D. A., & Sobieski, S. 1970, AJ, 75, 175
Kurucz, R. L. 1979, ApJS, 40, 1
Kurucz, R. L. 1991, Harvard Preprint 3348
Manduca, A., Bell, R. A., & Gustafsson, B. 1977, A&A, 61, 809
Mihalas, D. 1965, ApJS, 9, 321
Moe, O. K., & Milone, E. F. 1978, ApJ, 226, 301
Press, W. H., Flannery, B. P., Teukolsky, S. A., & Vetterling, W. T. 1986, Numerical Recipes (Cambridge University Press, Cambridge)
Rubashevskii, A. A. 1990, SvA, 34, 433
Van Hamme, W. 1993, in Light Curve Modeling of Eclipsing Binary Stars, edited by E. F. Milone (Springer, New York), p. 53
Van 't Veer, F. 1960, L'Assombrissement Centre-Bord des Etoiles, Doctoral thesis, University of Utrecht
Wade, R. A., & Rucinski, S. M. 1985, A&AS, 60, 471
Wilson, R. E. 1979, ApJ, 234, 1054
Wilson, R. E. 1990, ApJ, 356, 613
Wilson, R. E., & Devinney, E. J. 1971, ApJ, 166, 605 (WD)