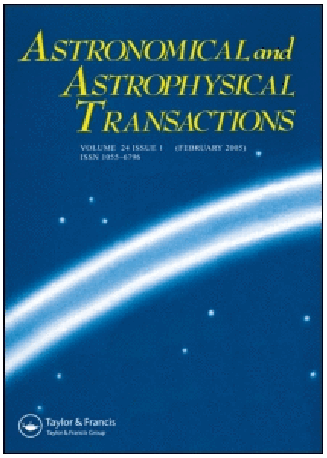

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ANALYSIS OF OBSERVATIONS OF THE SOLAR LIMB DARKENING

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An analytical function describing the limb darkening in the continuum is obtained from analysis of the observational data. The dependence of the temperature on the monochromatic optical depth corresponding to this darkening is compared with similar dependencies for some models of the solar photosphere. A satisfactory agreement is obtained only for the model VAL-M.

KEY WORDS Solar limb darkening, approximating function, dependence of the temperature.

The inverse problem of radiative transfer theory for the solar atmosphere consists in computation of the source function S_λ as a function of the optical depth τ_λ (or the temperature as a function of τ_λ, if the Local Thermodynamic Equilibrium (standard) (LTE) is assumed) from the absolute brightness distribution on the solar disk I_λ. To simplify treatment of this problem, the relative limb darkening $i_\lambda(\theta) = I_\lambda(\theta)/I_\lambda(0)$ is usually approximated by an analytical function having a few free parameters. These parameters are determined from observation. In an earlier paper (Markarova *et al.*, 1990) we proposed the following function with three free parameters u_λ, v_λ, w_λ:

$$i(\mu) = u + \mu[1 - u + (v - w)\ln 2 + (w\mu - v)\ln(1 + \mu^{-1})], \quad (1)$$

where $\mu = \cos\theta$ (here and below the index λ is omitted, although we use only monochromatic quantities).

The form (1) is a consequence of the radiative transfer theory if, first, $S(\tau)$ can be expressed in terms of the integral exponential functions $E_n(\tau)$,

$$S(\tau)/I(0) = a + b\tau + vE_2(\tau) + wE_3(\tau), \quad (2)$$

where $E_n(\tau) = \int_1^\infty e^{-\tau x} \cdot x^{-n}\,dx$, and, second, the following obvious condition is fulfilled: in the center of the disk we have $i(\mu) = i(1) = 1$. It follows from the latter that $a = u - v - w/2$ and $b = 1 - u + v\ln 2 + w(1 - \ln 2)$. In the range $\lambda = 300$–2400 nm this approximation provides a good fit to the limb darkening observations of Pierce and Slaughter (1977) and Pierce *et al.* (1977) in 112 sections of the quasi-continuum spectrum and also agrees with averaged data of many authors discussed and reviewed by Makarova *et al.* (1991b). In both cases the approximation errors are found to be much smaller than the errors of the limb darkening observations. For $w = 0$, which presumption is often made, the approximation is not quite reliable in the visible and near UV spectral ranges. Details and results of estimation of parameters u, v and w were published by Makarova *et al.* (1990) and Makarova *et al.* (1991a). The inverse problem was solved basing on expressions (1) and (2) in the continuum for the standard wavelength $\lambda = 500$ nm under the LTE presumption. The limb darkening observations of five authors in the range $\lambda = (500 \pm 10)$ nm were analyzed and generalized and the most reliable limb darkening function was determined for the range $0.15 \leqslant \mu \leqslant 1.0$. The derived parameters of Eqs. (1) and (2) are as follows:

$$u_{500} = 0.2072, \qquad v_{500} = 0.0692, \qquad w_{500} = -1.1782.$$

Dependence of the temperature on the standard optical depth with the value of $I_{500}(0)$ taken from Table IX of Makarova *et al.* (1991b) is the following:

$\lg \tau_{500}$	−1.2	−1.0	−0.8	−0.6	−0.4	−0.2	0.0	0.2	0.4
T, K	4998	5128	5302	5525	5796	6115	6480	6901	7407

Within the limits of expected accuracy ±50 K, this empirical dependence of the temperature in the photosphere agrees with the modification M of the well-known models VAL (Maltby *et al.* 1986).

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