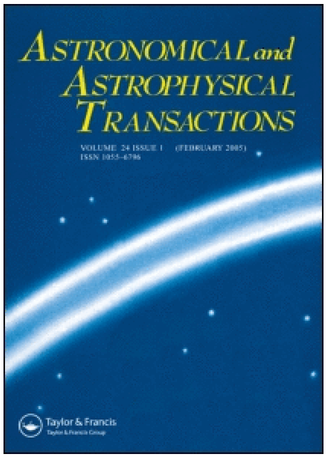

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THE SOLAR CONTINUUM IN THE 0.33–2.45 μm RANGE FROM THE RESULTS OF OBSERVATION

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The solar continuum absolute intensity obtained by means of averages is the most reliable of the observational data from different authors. Measurements of the solar constant, the spectral energy distribution, limb darkening, and the blanketing effect are used. The continuum intensity is obtained for the centre disk and the entire disk. The centre brightness temperature is compared with the similar temperature for the model by Maltby *et al.* (1986).

KEY WORDS Energy distribution, limb darkening, absoption coefficient, brightness temperature

During the last few years new data on energy distribution in the solar spectrum have been published (Lockwood *et al.*, 1992; Burlov–Vasil'ev *et al.*, 1994). Moreover, space-based measurements of the solar constant made it possible to determine the constant value with a far better grade of precision. The integral over the energy distribution in the spectrum of the Sun as a star has been determined with an error ranking down to decimals of a percentage (Makarova *et al.*, 1991). We have used these data, together with new data on the blanketing effect and solar limb darkening, to find the absolute intensity of the solar continuum for the centre of the solar disk and the entire disk for the Earth's atmosphere transparency window 0.33–2.45 μm. This information about the continuum is needed to model the solar atmosphere. This information, together with data on limb darkening permits us to calculate the observed photosphere absorption coefficient and compare it with the predicted photosphere plasma absorption (Pierce and Waddel, 1961; John, 1989, 1991; Makarova *et al.*, 1995).

We used the recently obtained data and the most reliable measurements carried out in the past. We obtained the solar continuum intensity value by bringing together six series of measurements (Pierce, 1954; Arvesen *et al.*, 1969; Peyturaux, 1978; Neckel and Labs, 1984; Lockwood *et al.*, 1992; Burlov–Vasil'ev *et al.*, 1994). Every series of data was converted into brightness temperatures of the disk centre and the entire disk. The disk–centre and reverse conversion were performed by using the ratio averaged over the disk intensity/intensity in the disk centre found on the basis of limb darkening measurements (Pierce and Slaughter, 1977; Pierce *et al.*, 1977; Neckel and Labs, 1994) for the continuum. The critical notes given in Makarova *et al.* (1990) were also taken into account. To process the spectral measurements carried out for the regions containing Fraunhofer lines of absorption, we have previously determined the continuum level with the help of data on the blanketing effect given in Table III from Makarova *et al.* (1991). For $\lambda < 670$ nm the table gives the value of the blanketing effect not only for the disk centre, but for the entire disk also. For $\lambda > 670$ nm only data for the disk centre exist. We used these data for the entire disk as well. This particular spectrum region is relatively poor in lines and the correction for the blanketing effect is small. Below we describe certain details of the processing of every series of spectral measurements.

(1) The series of Peyturaux (1978) is the only series that contains the continuum intensity in the disk centre we wanted, but only for four wavelengths of the spectral region 416–669 nm. Inside this wavelength range the brightness temperature was calculated through linear interpolation between the four given values of temperature.

(2) Neckel and Labs (1984) give the disk and disk centre continuum level for respective brightness temperatures in the form of a polygonal track. These data pass without further conversion.

(3) The Kiev working group (Burlov–Vasil'ev *et al.*, 1994, 1995) has carried out measurements of the disk centre brightness for the spectral regions that contain absorption lines. Analysis of calculated brightness temperatures of the continuum has revealed its anomalous low value for the wavelength ranges 762 ± 2.5 nm and 950 ± 25 nm. Very strong telluric lines of, respectively, oxygen and water, are observed in these ranges. The extinction due to the telluric lines seems to be accounted for incompletely. Thus the brightness temperatures of the continuum for the two wavelengths were found through linear interpolation between the nearest spectral bands comparatively free from telluric lines.

(4) A similar procedure of interpolation of the continuum brightness temperatures was used to work over the measurements of irradiance from the Sun as a star carried out by Lockwood *et al.* (1992). The author did not include in the extinction the telluric lines, save that of ozone. To reveal the spectral regions with small telluric blanketing effect ($\eta \leq 0.003$) Table 2 from the paper by Osipov (1986) was used. Such a method of reduction for telluric lines was successfully used in Kharitonov *et al.* (1994).

(5) Arvesen *et al.* (1969) measured the irradiance of the entire disk too, but for a very ample range 0.3–2.5 mm. The range encloses 95% of the solar constant. To adjust the results of Aversen *et al.* (1969) to the currently adopted solar constant value 1370 Wt m^{-2} it is necessary to reduce it by a factor of 1.6% (Makarova *et al.*, 1994a,b). We have used the Aversen *et al.* (1969) data with

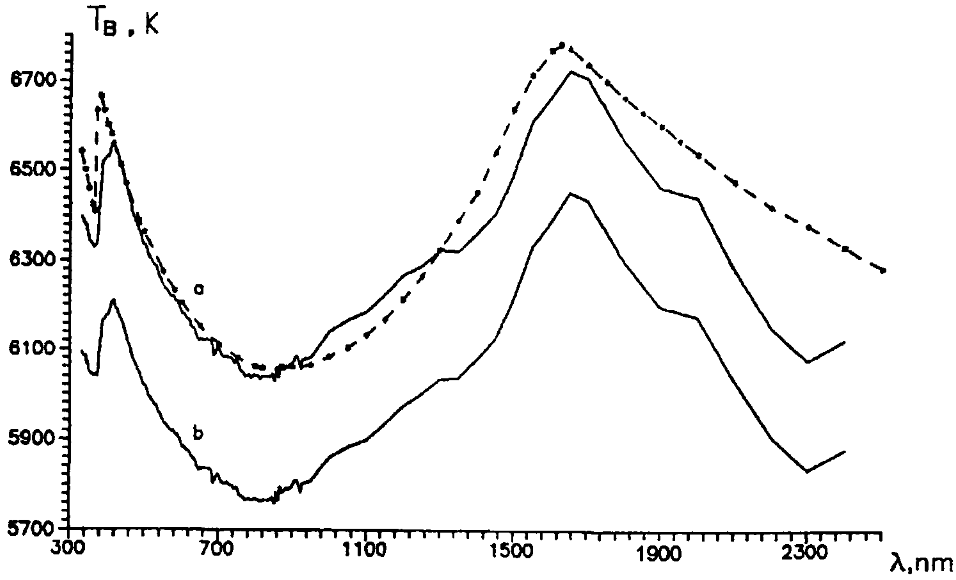

Figure 1 The solar continuum brightness temperature: *a*, at the disk centre; *b*, for the full disk; —, the middle value from the observed data of the different authors; -*-, the calculated value by the model of Maltby *et al.* (1986).

this correction. Thus, the original measurements of irradiance were taken, so to say, in certain relative units, and the absolute scale was based on the solar constant.

(6) Pierce (1954) measured the continuum intensity (in relative units) in the IK spectral range 1.0–2.5 μm. To express the data in absolute units an absoluting coefficient was needed. In Maltby *et al.* (1986) the quantity $K = 600.2$ Wt $m^{-2}sr^{-1}nm^{-1}$ was found by bringing together the mesurements performed for $\lambda = 1.2986$ μm (Pierce, 1954) and for $\lambda \leq 1.25$ μm (Neckel and Labs, 1984). The data from Pierce (1954) for $\lambda < 1.2986$ μm were ignored as unreliable. Such a method of the absolution of the data does not seem to be well-founded to us, so we used three other methods, described below.

(a) By agreeing it with the data from Neckel and Labs (1984) for the range 1.00–1.25 μm of the continuum from the centre of the disk.

(b) By agreeing it with the Sun irradiance measured by Aversen *et al.* (1969) in the range 0.975–2.45 μm. The relative intensity from Pierce (1954) were converted into relative irradiance with the help of the data on the blanketing effect and the disk/centre intensity ratio.

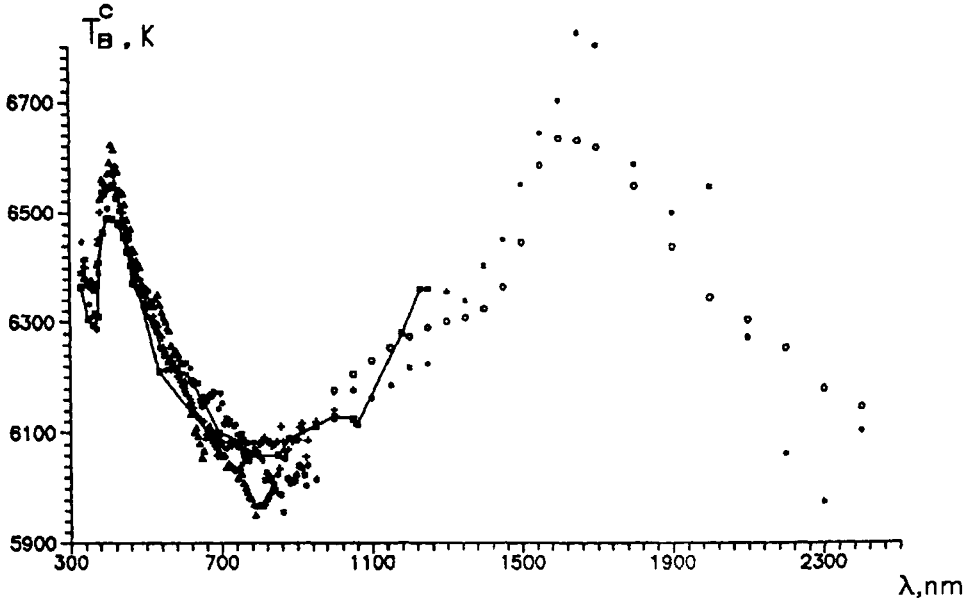

Figure 2 The continuum brightness temperature at the disk centre from the data of the different authors: ∗, Arvesen *et al.* (1969); +, Burlov-Vasil'ev *et al.* (1994, 1995); Δ, Lockwood *et al.* (1992); -□-, Neckel and Labs (1984); -■-, Peyturaux (1978); o, Pierce (1954).

(c) By agreeing the integral over the range 0.975–2.45 μm of the relative irradiance calculated as described in (b) with similar absolute quantity, obtained by discounting the integrals of spectrophotometric data for $\lambda \leq 0.975$ and $\lambda \geq 2.45$ μm from the solar constant value 1370 Wt m^{-2}. The integration over the range 0.33–0.975 μm was based on the above described data from Aversen *et al.* (1969), Neckel and Labs (1984), Lockwood *et al.* (1992), Burlov-Vasil'ev *et al.* (1994) and for the low-value integrals for $\lambda < 0.33$ and $\lambda > 2.45$ the data from Makarova *et al.* (1991) were used. The three correspondent results for K are

$$K(1) = 577.4, \quad K(2) = 582.5, \quad K(3) = 581.0.$$

The K value adopted for absolution of Pierce (1954) measurements is the arithmetic mean of $K(1)$, $K(2)$, and $K(3)$: $K = 580.3$ Wt $m^{-2}sr^{-1}$ nm^{-1}.

We adopted as the most reliable the brightness temperature, the arithmetic mean of the six described series of measurements. The series contain all the absolute spectrophotometric measurements published after 1978 (four series). Two series of relative measurements published more than 25 years ago were also taken into account. We have absoluted the measurements according to the contemporary data. Figure 1 shows the averaged data for the disk centre and the entire disk as converted into brightness temperature. The brightness temperature calculated in the framework of the Maltby *et al.* (1986) model is given in Figure 1 as well as comparative data.

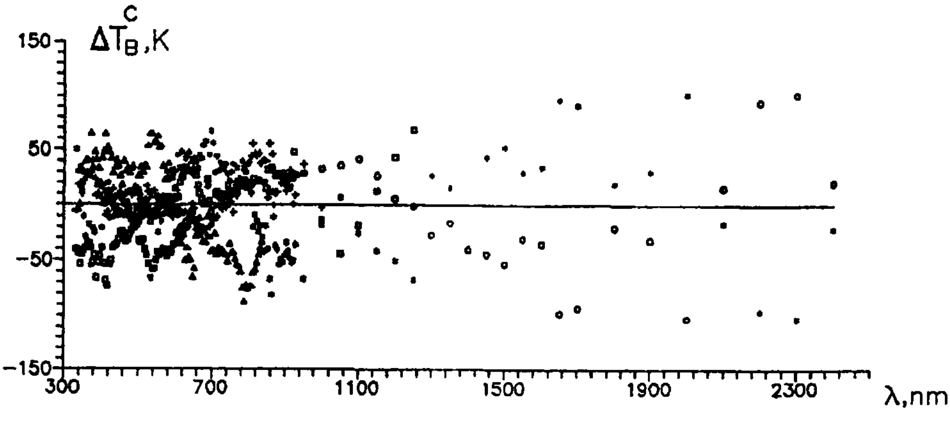

Figure 3 The difference from the middle value of the continuum brightness temperature at the solar disk centre from the results of individual authors: *, Arvesen *et al.* (1969); +, Burlov-Vasil'ev *et al.* (1994, 1995); Δ, Lockwood *et al.* (1992); □, Neckel and Labs (1984); ■, Peyturaux (1978); o, Pierce (1954).

The original data used in the process of averaging for the disk centre are presented in Figure 2. Figure 3 shows the average brightness temperature — the individual brightness temperature value differences.

Figure 3 and an analogous, composed for the entire disk, unpublished figure allow us to estimate the internal agreement of the series we averaged. The error for $\lambda < 1$ μm is about 30 K and does not practically change with the wavelength. For this spectral band It is possible to estimate the error on the basis of the series internal agreement, because the absolute calibration was made independently for each series. For the $\lambda > 1.3$ μm region the situation is worse, for here we have only two aged series of measurements. The error here might be two to three times greater.

Figures 2 and 3 demonstrate that the continuum level for the $\lambda < 1$ μm region is known today far better than for the region $\lambda > 1$ μm. A systematic difference between the model and observed values may be seen in Figure 1. The differences for $\lambda < 1$ μm may be interpreted as a reason for certain corrections of the model; the differences that appear in the farther IR region for which the observed data are less reliable, may be not taken into account. For the region 1.0–2.5 μm new measurements are to be carried out. The urgency of such an observational programme is related to the fact that the data already obtained for the range 2.0–2.4 μm point to the existence in the solar photosphere of an unidentified permanent absorption agent (Makarova *et al.*, 1994a, b).

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