1.1.6

THE $S_{10}(V)$ UNIT OF SURFACE BRIGHTNESS

J. G. SPARROW* AND J. L. WEINBERG
Space Astronomy Laboratory, State University of New York at Albany

Abstract. A source for some of the discrepancies among reported zodiacal light measurements is suggested, and a plea is made for more uniformity in the choice of units used to report zodiacal light results.

It is customary to express zodiacal light measurements in units of $S_{10}(V)$, the equivalent number of tenth magnitude (visual) stars of solar spectral type per square degree. As noted by one of its earliest proponents, F. E. Roach, this is a result of its historical use in studies of the background starlight and because the night sky brightness is conveniently four digits or less when expressed in these units. The conversion to these units is not always consistent from one author to another for a number of reasons:

(1) The $S_{10}(V)$ unit relates to a comparison with stars of "solar type". Although the sun is now generally believed to be a G2V star (Morgan and Keenan, 1973), some authors have expressed their $S_{10}(V)$ units in terms of G0 stars (Weinberg, 1964; Tanabe, 1965; Huruhata, 1965). Roach and coworkers have at time expressed the $S_{10}(V)$ unit in terms of G0V stars (Roach et al., 1954) or of G2 stars (Roach, 1957). A color index B-V = .57 has been used by Weinberg (1967) and Lillie (1972), who obtained it from Roach and Smith (1964) who gave $S_{10}(VIS)/S_{10}(PHOT)$ = 1.69. An indication of the effect of these differences, when measurements are made at say 4400A, is seen by a comparison of the B-V color indices as given by Johnson (1966) viz: G0V = .59, G2V = .63. Croft et al. (1972) found the B-V color index of the sun to be +.631 and listed 7 other values given by earlier workers ranging from .62 to .68.

(2) The apparent visual magnitude of the sun used by different authors contributes appreciably to the uncertainty in the $S_{10}(V)$ unit. Thus, Robley (1965) used -26.9, Dumont (1965) -26.72 and Weinberg (1964) -26.73, the last at an effective wavelength of 5300A. Leinert et al. (1974) used a value of -26.78 obtained from Allen (1963). In reviewing recent data on the solar spectrum, Code (1973) concludes that the sun is best represented by spectral type G2V, color index B-V = .63 and visual magnitude V = -26.74 (see, also, Allen 1973).

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*On leave from Aeronautical Research Laboratories, Melbourne, Victoria, Australia

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(3) Not all zodiacal light data are referenced to the same solar flux values. In order to preserve continuity with previous work from our group, we use the solar spectral irradiance values given by Johnson (1954); the more recent values of Labs and Neckel (1970) might be preferred as they are by Leinert et al. (1974) and Frey et al. (1974). Roach (1957), Dumont (1965), and Robley (1965) use the results of Abbot as published by Minnaert (1924). A comparison of the irradiance values from the three sources is given in Table 1.

TABLE 1

A Comparison of Values of the Solar Spectral Irradiance*

Wavelength A	Johnson (1954)	Labs and Neckel[i] (1970)	Minnaert[ii] (1924)
4000	.154	.138	.156
4500	.220	.197	.228
5000	.198	.193	.230
5500	.195	.185	.210
6000	.181	.175	.195
6500	.162	.156	.184
7000	.144	.143	.150
7500	.127	.127	.129
8000	.113	.115	.110

* in watts/cm$^2\mu$

[i] values obtained as average of two adjacent 100A means.

[ii] data taken from Roach (1957).

(4) Some authors using star calibrations convert from magnitudes to flux using the absolute flux given for Vega. Thus, Frey et al. (1974) chose the photometric measurements of Oke and Schild (1970), while we have preferred to use the more recent data from Hayes and Latham (1975), although the difference between these data sets as given in the paper by Hayes and Latham is generally less than 5%. It should be noted, however, that these flux values are given for the continuum of Vega, whereas the stellar magnitudes refer to the continuum plus lines. In the blue, the effect of the Balmer lines (H_β, H_γ, and H_δ) is to reduce the integrated continuum flux by about 6%.

(5) Earlier studies of zodiacal light were usually normalized to the International photographic or photovisual systems although the UBV system of Johnson and Morgan (1953) is now preferred. There is little difference between the effective wavelengths of the photovisual (λ_{eff} = 5427A for T = 10^4 K) and V systems (λ_{eff} = 5480A for T = 10^4 K; Allen 1955, 1973), and zodiacal light observers often use m_{pv} and m_v interchangeably. The effective wavelengths of the photographic (λ_{eff} = 4253A, T = 10^4 K) and blue (λ_{eff} = 4400A, T = 10^4 K) cause significant differences between zodiacal light brightnesses measured in the two systems.

(6) Finally, the question is asked: Is the $S_{10}(V)$ unit referred to the solar flux at the time of observation or to the mean solar output? Since the earth's heliocentric distance varies by 3.3% over the year, something is changing by 6.6% (assuming an r^{-1} dependence of the zodiacal dust). Is this the magnitude of the $S_{10}(V)$ unit or the brightness of the zodiacal light in $S_{10}(V)$? As yet our measurements are not accurate enough to show this change but one might hope that before long they will be.

Because of the above, we place great importance on the need to bring consistency into the use of the $S_{10}(V)$ unit, and we urge authors to specify the sources of the various factors that combine to determine the size of their $S_{10}(V)$ unit.

As zodiacal light studies become more precise (?), it is more important to have clarity and unanimity in the units used for reporting surface brightness or radiance. To this end we suggest that:

(1) the $S_{10}(V)$ unit be understood to represent 10th magnitude solar (G2V) stars per square degree at mean solar distance;

(2) the V refer to the visual color in the UBV system defined by Johnson and Morgan (1953);

(3) the apparent solar visual magnitude be taken as -26.73 and the B-V color index as .63;

(4) the solar spectral irradiance values of Labs and Neckel (1970) be used;

(5) when using Vega as a standard to obtain brightnesses in $S_{10}(V)$, +.04 be used as its magnitude at all wavelengths and the irradiance values of Hayes and Latham (1975) be used.

Finally, in quoting results, we suggest that the input parameters used to convert to $S_{10}(V)$ be quoted in a conspicuous manner in order to simplify intercomparison with other data in the literature.

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