THE COLOURS OF THE SUN

B. J. TAYLOR
Brigham Young University, Provo, UT 84602, USA

ABSTRACT. In this paper, arguments are developed for treating \((R-I)_c\) as the most important colour to be derived for the Sun. The solar value of \((R-I)_c\) is then found to be \(0.335 \pm 0.002\) mag. This result updates a counterpart given by Taylor in 1992.

1. Introduction

Which colour index should be derived for the Sun?

Papers on this subject rarely consider this question. Authors sometimes explain that one wants to know the solar colours to learn how the Sun compares to similar stars. In addition, authors cite a number of previous studies—likely including those which piqued their interest in the first place. However, one seldom sees an explanation for the fact that (almost always) \(B-V\) is being determined. Was \(B-V\) the best choice historically? Is it still the best choice now? Let us see what answers these questions may have.

2. \(B-V\): Blanketing Effect And Accidental Errors

When the solar-colours problem “came of age” in 1964, at least some people knew that field stars should be measured to the red of the \(V\) passband to minimize blanketing effects (see Sandage & Smith 1963). Putting this idea into practice for the Sun, however, seems to have been ruled out by a shortage of high-precision red photometry for solar stars and a tacit “1P21 limit” in general thinking. The Strömgren system was just getting started, so \(b-y\) was not yet a realistic option. Only \(B-V\) and \(U-B\) were serious contenders, and since \(B-V\) is less blanketed than \(U-B\), one can see why \(B-V\) would have been an obvious choice historically.

Let us re-examine that choice, using resources that were not available in 1964. The blanketing effect on \(B-V\) is an obvious concern, so one should probably derive a numerical estimate of its size before doing almost
anything else. This may be done by using the calculations of VandenBerg & Bell (1985). Data for stars with the solar temperature and surface gravity are used. The blanketing estimate may be expressed as the value of $|\Delta(B-V)|$ as $[M/H]$ increases from $-0.5$ dex to $0.0$ dex. $|\Delta(B-V)|$ is increased by a factor of 1.5 to allow for the difference between theoretical and empirical calculations (see Table 3 of Taylor 1994).

Since $(B-V)_\odot$ is often determined from field-star values of $B-V$, one would also like to know something about the rms errors of the field-star data. The best rms error found commonly for $B-V$ has been calculated by Nicolet (1978), who obtains a value of 0.009 mag. Since $|\Delta(B-V)|$ turns out to be 0.053 mag, one sees at once that the blanketing effect is inescapable if one cannot restrict attention to field stars with $[\text{Fe/H}] \sim 0$. This is an especially serious matter if $B-V$ is used as a temperature proxy.

3. Tactics For Deriving $(B-V)_\odot$

The next issue that might be considered is the best choice of tactics for determining a solar colour index. For $B-V$, one procedure which has attracted much attention is the search for solar twins. High-dispersion analysis is used to identify dwarfs whose metallicity resembles that of the Sun closely (see, for example, Cayrel de Strobel & Bentolila 1989). With a “short list” of such stars in hand, one can then correct their values of $B-V$ for residual temperature, gravity and metallicity differences between the stars and the Sun. (See Edvardsson et al. 1993, who use this procedure for $b-y$).

The obvious advantage in this procedure is that if the corrections are small, the uncertainties they introduce into the final value of $(B-V)_\odot$ will be small as well. There is also a disadvantage, though: can one obtain a reliable rms error for $(B-V)_\odot$ by using only a small number of stars? This question will be considered again below.

A second common tactic is to measure an index (usually a spectroscopic index) which can readily be secured for both field stars and the Sun. By comparing field-star indices and values of $B-V$ to the solar index, one can then determine $(B-V)_\odot$. The chief question here is what to do about the $B-V$ blanketing problem. If the adopted index has no metallicity sensitivity, the blanketing problem has its full scope, and metallicities for the field stars will be required in order to mitigate it (Cayrel de Strobel 1996). One might cancel out the blanketing problem by choosing an index with compensating metallicity sensitivity, and an assumption is often (if tacitly) made that such cancellation takes place. This assumption is not always tested, however (see, for example, Croft et al. 1972).