

Is the c_1 Strömrgren index a good luminosity indicator?

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Comparison of c_1 - derived luminosities with those obtained using Hipparcos parallax measurements show large discrepancies for G-K high-metallicity dwarves. Stars with a Hipparcos luminosity consistent with that of a single dwarf, or dwarf binary, show c_1 index values consistent with those of giant stars.

Introduction

Strömrgren uvby photometry has been used over the last few decades as a time-efficient way of determining main stellar parameters. The (b-y), m_1 , and c_1 indices provide information about a star's temperature, metallicity, and luminosity. The Strömrgren system was originally developed for low-metallicity stars. More recently, it has also been used for stars with a high metal content. Schuster and Nissen (1989) provide calibrations from which the stellar parameters previously mentioned can be obtained. The Hipparcos data has allowed direct measurements of luminosities, using fluxes and parallaxes, for a much larger number of stars than ever before, so the use of the c_1 index has been superseded for nearby stars. With these new data, it is possible to check for the accuracy of the c_1 index in an independent way for a broad range of stars. It is apparent (Twarog, Anthony-Twarog, & Tanner 2002) that, for G-K, high-metallicity dwarfs, the c_1 index is not providing good information on a star's luminosity. A comparison between a CMD (Figure 1) and the equivalent c_1 vs (b-y) graph (Figure 2)

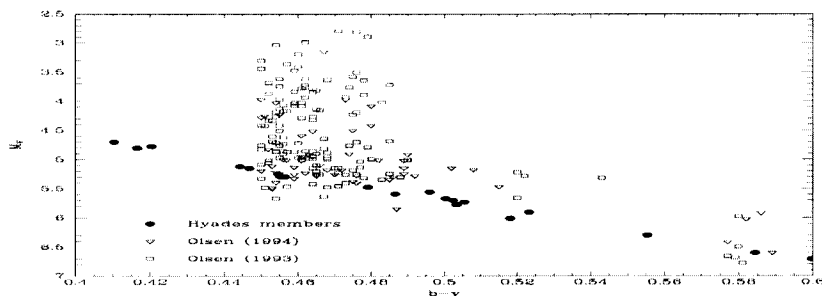


Figure 1. M_v vs (b-y), high-metallicity field stars

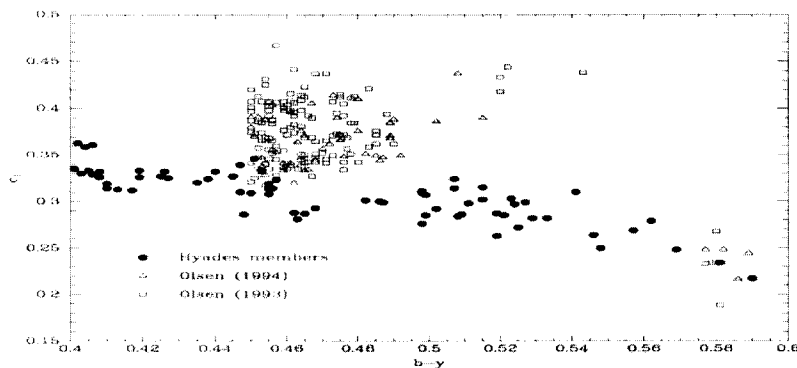


Figure 2. c_1 vs (b-y), high-metallicity field stars

illustrates the discrepancy. The field stars with (b-y) between 0.5 and 0.57 shown on the graph have magnitudes slightly higher than those of Hyades dwarfs of the same temperature. This can be due to a) the presence of a binary star system, b) a star with higher metallicity than the Hyades' stars, or c) the presence of abnormal activity in the star's chromosphere (Twarog, Anthony-Twarog, & Tanner 2002).

However, not many field stars with these characteristics have been measured using Strömgren photometry yet. A better diagnosis can be provided if the data sample is substantially increased.

Observations and Reduction

The program stars were selected from the Hipparcos catalog based on their temperature range: $0.4 < b-y < 0.6$, and absolute magnitude, which should be indicative of the star being a dwarf. Their apparent magnitudes range from 6 to 10. Figure 3 illustrates the selection range by plotting M_v vs $(B-V)$ for all stars on the program list. The standard stars were compiled from Olsen (1993). They share the same range of temperatures, relative magnitudes, and luminosities as the program stars.

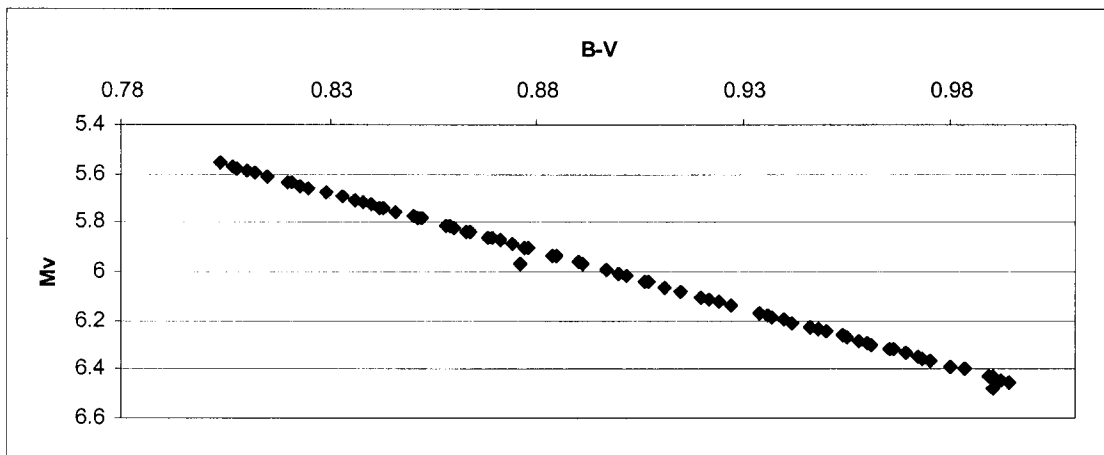


Figure 3. M_v vs $B-V$, program star list

The data were obtained using the Mount Laguna Observatory's 40 inch reflector, coupled to a dry-ice-cooled RCA photomultiplier tube. The measurements were done in the order y , b , v , u , and star counts were kept above 10,000 to achieve 1% precision. Sky counts followed each star measurement in the same order. The observational program was structured so that four to five program star measurements would be followed by two standard stars, and so on. One standard, HD 158332, was observed three times each night, so that it might serve as an extinction star.

The main problem experienced while observing was premature filter motion. Whenever a pair of counts in the same filter was found to be wildly discordant, a third measurement was taken. If the problem was discovered only after analyzing the data, the star was discarded. Abnormally high sky counts were encountered on the first part of the last observation night. More specifically, a number of stars had sky counts of $\sim 10,000$, which was twice what most stars had. This might have been caused by cirrus clouds, or possibly contrails. Those stars whose sky counts stood out were removed from the data for the purposes of this reduction.

The FOTOM reduction program was used to convert the photon counts to magnitudes and indices. The program uses all standard stars to calculate extinction coefficients. The standard stars are then used again to calculate transformation coefficients. The output contains raw magnitudes and colors (before extinction corrections), extinction corrected values (instrumental system), and transformed values (standard system).

Analysis

It is necessary to test the value of the reduced data. One of the most straight-forward ways of assessing whether the data contains significant flaws is to plot the $B-V$ value already known for a given star versus the $b-y$ value obtained from the reductions. Since both $B-V$ and $b-y$ are temperature indicators, there should be a one-to-one relationship between them. This relation should, furthermore, be linear, with a slope of ~ 1.5 . Figure 4 shows a plot of $(B-V)$ vs $(b-y)$ for the second night. The scatter in this image is the largest of all four nights. As a comparison, the fourth night, shown in Figure 5, has relatively little scatter. The slope is also closest to 1.5.

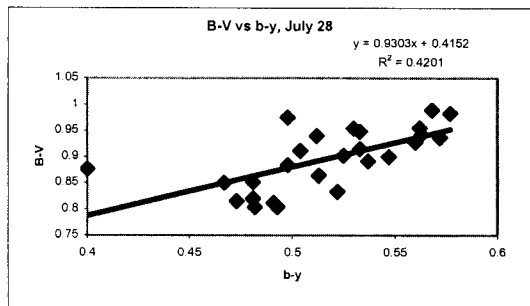


Figure 4. B-V vs b-y, July 28

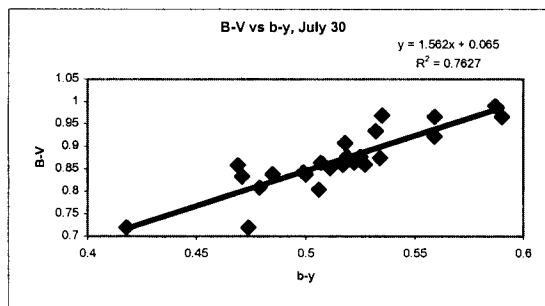


Figure 5. B-V vs b-y, July 30

The stars selected for observation are high-metallicity dwarfs. Figure 6, a plot of M_v , obtained through Hipparcos's parallaxes, versus $b-y$, obtained through photometry, illustrates the selection process. The program stars have a comparable to or higher M_v than the Hyades cluster, shown as a line taken from Twarog, Anthony-Twarog et al (2002). It also shows the uncertainties in M_v .

Graph 7 is a plot of c_1 versus $b-y$ for all program stars. The spread of c_1 values is consistent

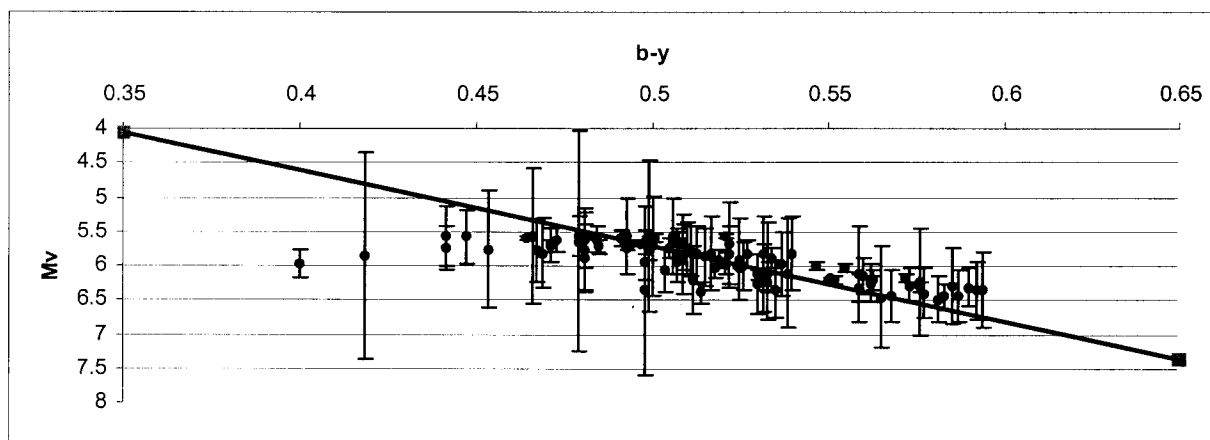


Figure 6. M_v vs $b-y$, from program star list

with that seen on Figure 2. We subdivide the program stars into three groups by their c_1 index. Stars with a c_1 value between 0.2 and 0.25 may be a) binary systems with solar-like metallicities, or b) a single star with a Hyades-like metallicity. From Figure 2, it is evident that the c_1 miscalibration only affects stars with higher metallicity than the Hyades. A c_1 value above 0.35 should be an indication that a star is a giant. Stars with $0.25 < c_1 < 0.35$ cannot be properly identified. According to this criterion, there are 26 program stars identified correctly as dwarfs, 48 that cannot be confidently identified, and 18 that are misclassified as giants.

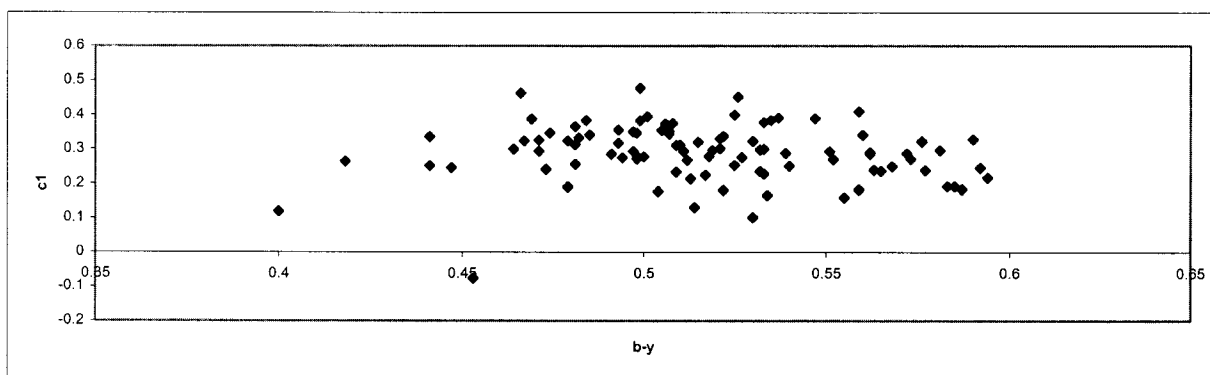


Figure 7. c_1 vs $b-y$, program stars observed

It is important to check for consistency of the index values. Three stars were measured more than once throughout the observing run. HIP 88188 had c_1 values of 0.274 and 0.292. HIP 103055 had values of 0.316 and 0.373. HIP 68801 had 0.25, 0.223 and 0.234. The variation in the first and third stars does not alter their classification. The second star is either unconclusively classified, or classified as a giant. These variations are due to a combination of factors: sky conditions may have changed from one night to the next, the group of standard stars observed each night was never exactly the same and random variations in photon counts, which follow a Poisson distribution, could have affected the c_1 value. The last possibility is particularly important because, since the c_1 index is a combination of all four uvby filters ($c_1 = (u-v)-(b-y)$), random variations will propagate more than on other indices (e.g. $b-y$, m_1). On the other hand, the mean errors for each star given in the reduction program appear to be much larger, ranging in the tenths of a magnitude. This may be related to the data itself, even though, from what was seen in the previous discussion, the variation in c_1 from night to night is nowhere as large as the program would seem to imply. Alternatively, it could be related to the algorithms used for finding the mean errors. Better confidence in the data can be achieved if it is reduced a second time, using a different reduction program, and comparing the results.

Conclusions

The c_1 index is misclassifying a large number of high-metallicity G-K dwarfs as giants. 20 % of our sample stars, which were exclusively main sequence G-K dwarfs, were classified as giants by the c_1 index. Another 52% might have been classified as giants without a large degree of confidence. Only 28% were positively classified as dwarfs. Some of these, however, might have been included in the program star list for a different reason. A binary system gives the same signature as a higher metallicity star on a CMD. However, if its metallicity is not high, its c_1 value is that of a dwarf. Hence some of the stars classified as dwarfs may really be low-metallicity binaries. In this case, the percentage of misclassified stars becomes even larger.

The reason for this calibration problem is not known yet. The amount of absorption at the u and v range of wavelengths for this type of stars might have been underestimated; or there might be a continuum shift, for example. Future work is still needed to find out quantitatively how c_1 is being affected by metallicity.

Acknowledgements

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References:

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