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UV OBSERVATIONS OF BLUE STRAGGLERS AND POPULATION II K DWARFS

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I. Scientific Introduction

(A) Field Halo Blue Stragglers

Blue stragglers are stars found, usually in either open or globular clusters, that appear to lie on the main sequence, but are brighter and bluer than the cluster turn-off. Currently, two rival models are invoked to explain this apparently pathological behavior: internal mixing (so that fresh fuel is brought into the stellar core); and mass transfer (by which a normal main sequence star acquires mass from an evolving nearby companion and so moves up the main sequence). The latter model predicts that in the absence of complete mass transfer (*i.e.*, coalescence), blue stragglers should be binary systems with the fainter star in a post-main sequence evolutionary state. It is important to ascertain the cause of this phenomenon since stellar evolution models of main sequence stars play such a vital role in astronomy. If mass transfer is involved, one may easily exclude binaries from age determinations of clusters, but if mixing is the cause, our age determinations will be much less accurate unless we can determine whether all stars or only some mix, and what causes the mixing to occur at all.

One possible post-main sequence companion for a halo main sequence star is a white dwarf. *IUE* is an excellent means to detect such companions, so we observed one blue straggler in the old open cluster NGC 7789 and five field halo population blue stragglers. These stars require some explanation, for blue stragglers are usually found within clusters. In the field, in general, one has no way of knowing *a priori* what a star's age is and so whether or not it is "straggling". However, for the halo population, one finds that globular cluster main sequence turn-offs define a tight relation between metallicity and color, as is expected if all the halo stars are very old, if not of very similar ages. Assuming the field halo population stars share the same history as the cluster stars, one may identify a field halo blue straggler by finding field dwarfs with high space velocities and low metallicities and colors that are bluer than any globular cluster turn-off. We selected five such stars for observation using *IUE*: HD 100363, BD-12°2669, and BD+25°1981, all of which were known previously, and two new candidates, G202-65 and G206-34, identified in a large photometric and spectroscopic survey of proper motion stars being carried out by B. Carney and D. Latham (Center for Astrophysics).

(B) Population II K Dwarfs

Wallerstein (*Observatory*, **96**, 142, 1976) made the intriguing suggestion that based on then-current data that showed a paucity of extremely metal-poor late type dwarfs compared to earlier types, the metal enrichment phase of the Galaxy must have been very rapid. The more massive F stars, whose protostellar stages are briefer than those of K dwarfs, would be less affected by nucleosynthesis pollution and so more metal-poor F dwarfs would now be found relative to K dwarfs. Subsequently, Bessell and Wickramasinghe (*Ap. J.*, 227, 232, 1979) argued that extremely metal-poor dwarfs exist, but have simply been overlooked. Many of them, they claimed, could be found in a list of "red subluminous stars" published earlier by Eggen (*Ap. J. Suppl.*, **19**, 31, 1969). These stars show extreme ultraviolet excesses (based on *UBV* photometry) which could be caused by extreme metal deficiencies. Alternative explanations, however, are possible. For example, the stars could simply be reddened by $0^{m}.1$ or so. The reddening vector in the *U-B* vs. *B-V* plane is steeply inclined with respect to the canonical locus of metal-rich dwarf stars, especially at later spectral types. Hence modest reddening would move a metal-rich star into the domain occupied by unreddened metal-poor stars. This would also explain the extreme ultraviolet excess values noted by Eggen. A second possibility is that these stars have hot companions that supply the extra ultraviolet flux.

One of us (BWC) then obtained two high-resolution spectrograms of one of the birhgter such stars, BD-16°4187, using the CTIO 4-meter telescope and echelle spectrograph. This star is only slightly reddened, but proved to also be only marginally metal-deficient. It, and a few stars like it, were then chosen as targets for *IUE* satellite to search for white dwarf companions.

II. *IUE* Observations and Results

(A) Field Halo Blue Stragglers

All five field blue stragglers were observed with the SWP camera, and no hot companions were detected. Using archival *IUE* material, R. E. Luck and H. E. Bond (in preparation) have established a relation between the flux in a bandpass covering λλ1250-1550 and the effective temperature of a white dwarf at a distance of 10 parsecs. We estimated the distances to our program stars, and measured upper limits to their fluxes in this bandpass, and in the four cases with the best statistics we found we could set upper limits of 12,000 K for any white dwarf companions. While this does not support the mass transfer model, it does not necessarily contradict it, either, for the expected cooling time to 12,000 K is about 10^9 years. Disk white dwarf progenitors may be very short-lived stars ($M_{prog} \sim 6\ M_0$), and if this is true also for halo stars, then since the observed blue stragglers have main sequence lifetimes of up to 8 x 10^9 years, our chance for finding one white dwarf amongst our four targets was only about 50%. It is certainly possible that in all four cases the mass transfer occurred so long ago that all four white dwarfs have cooled so that they can no longer be seen against the stellar flux.

(B) Population II K Dwarfs

We obtained SWP spectra for K dwarfs with published photometry that revealed extreme ultraviolet excesses. No white dwarfs were found. Although disappointing, this result is very useful, for it now compels us to continue our work on estimating the reddening for these stars as well as measuring their metallicities by spectroscopic means.

III. Publication of Results

(A) Field Halo Blue Stragglers

We have published one short note on our results (B. W. Carney and H. E. Bond, *Bull. Amer. Astron. Soc.*, **18**, 635, 1986). A complete description of the program goals and results will be submitted for publication within the next few months, but we have been awaiting the results from a related program. Specifically, Carney, Latham, and T. Mazeh (University of Tel Aviv) have been monitoring four of the field halo blue stragglers for radial velocity variability. This is the first part of the test of the mass transfer model: the presence of a binary companion. Further, if radial velocity variability is found, an orbital solution is much desired to determine if the two stars were ever in close enough proximity that mass transfer may have occurred. For two of the stars, G202-65 and G206-34, orbital solutions have been obtained, and they are consistent with mass transfer. For another, BD-12°2669, the velocity variability is confirmed, and an orbit should be available soon. For the last star, BD+25°1981, the velocity variability may be present, but although 12 new velocities spanning over 400 days have been acquired, the star may be on a very eccentric orbit with a long period, and many more spectra must be obtained to determine the orbit. It is our intention to publish the results of the *IUE* program simultaneously with the radial velocity results. The latter will be written up and submitted as soon as the orbit for BD-12°2669 is solved, which we expect in early 1987.

(B) Population II K Dwarfs

Although the presence of white dwarf companions to field K dwarfs with large ultraviolet excesses may seem like an obscure topic, it is relevant to models of the formation of our Galaxy. If Wallerstein's suggestion is correct, we have an excellent method to measure the metal enrichment timescale, one capable of more precision than the current two methods (differences in globular cluster ages and the correlation between metallicity and kinematics propounded by Eggen, Lynden-Bell, and Sandage, *Ap. J.*, 136, 748, 1962). If the *IUE* data may be used to rule out, in general, white dwarfs as the cause of the observed ultraviolet excesses of the K dwarfs, then we must study their reddenings and metallicities more carefully. Such studies are underway, and we plan to publish those results at the same time as the *IUE* data. At this stage, we are close to determining the metallicities for one of our target K dwarfs from high-resolution, high-S/N echelle spectra, and hope to do so for one more such target. We are also close to deriving metallicities based on high-resolution, low-S/N echelle-reticon spectra for several hundred K dwarfs. We may be able within the next few months to confirm or reject the idea that there are fewer metal-poor K dwarfs than F dwarfs, and that in consequence the timescale for the initial metal enrichment in the Galaxy was of the order of the star formation timescale. We anticipate the data from our *IUE* observing will be one of three papers submitted for publication together within the next six months.