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STRÖMGREN PHOTOMETRY AND HIGH RESOLUTION SPECTROSCOPY OF VERY METAL-POOR STARS

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Strömgren photometry plus photometric indices from the HK survey allow us to select potentially interesting stars with probable anomalous chemical abundance ratios. Being stars of very low metal abundances, high-resolution spectroscopy can provide very important clues concerning the chemical enrichment processes of the early Galaxy.

uvby–β photometry of nearly 500 very-metal-poor (VMP) stars has been observed at the San Pedro Mártir (SPM), México, and La Silla (LS), Chile, observatories using 1.5 m telescopes, with photoelectric techniques being used at SPM, and both photoelectric and CCD techniques at LS. The resulting photometry has been published in Schuster et al. (1996; S96) and Schuster et al. (2004a; S04a), along with interstellar reddenings, metallicities, photometric classifications, distances, and relative ages. Indices and calibrations from the HK survey (Beers et al. 1992), the intrinsic-color calibration of Schuster & Nissen (1989), and reddening maps from Schlegel et al. (1998), have also been used in these analyses.

Index diagrams from the *uvby* and HK-survey photometries allow us to pick out stars with probable abundance anomalies for future studies with high-resolution spectroscopy. AGB-star candidates can be identified in the c_0,$(b–y)_0$ diagram, probable Am stars in the $[c_1]$,$[m_1]$, and CH stars in the GP,KP diagram, where GP and KP measure the strengths of the CH G-band and the CaII K line, respectively. Other combinations of photometric data may point to other potentially interesting groups. For example, some metal-poor stars classified as subgiants in the c_0,$(b–y)_0$ diagram show unusually large values of $[m_1]$ and m_1, evidence of photometric variability, and/or discordant values of $(b–y)_0$ and $(B–V)_0$; these may in fact be misclassified (variable) AGB stars with unusual chemical abundance ratios and/or binary companions.

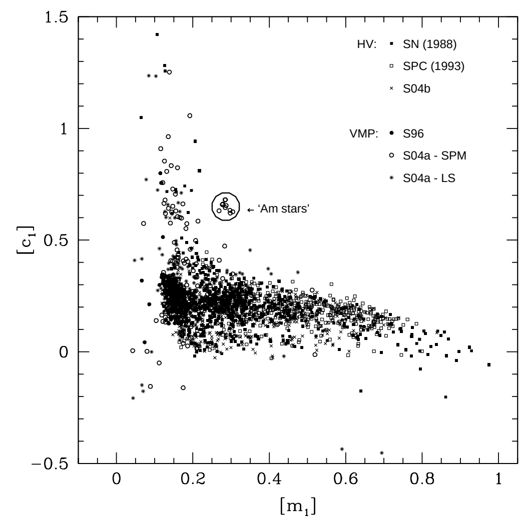

Fig. 1. The $[c_1]$,$[m_1]$ diagram for the VMP stars and for the high-velocity stars of SN, SPC, and Schuster et al. (2004b; S04b). $[c_1]$ and $[m_1]$ are the reddening-free indices defined by $[c_1] = c_1 - 0.20(b–y)$ and $[m_1] = m_1 + 0.30(b–y)$ according to the work of Strömgren (1966) and of Crawford (1975). The *uvby* photometry for the VMP stars has been taken from S96 and from S04a. The larger circle surrounds the "Am" stars discussed in the text, which are clearly separate from the HV and other VMP stars.

The SL–BHB (subluminous-blue-horizontal-branch) stars of the c_0,$(b–y)_0$ diagram may represent an interesting evolutionary phase between the bluest HB stars and white dwarfs (the EHB and B subdwarfs). The subluminous stars which are also CH-star candidates may represent stars which have undergone late helium-core flash on the white dwarf cooling curve, resulting in "flash mixing" and enhanced surface abundances of carbon and helium (Brown et al. 2001)

Discussion and Conclusions

1. A number of VMP stars have been noted with probable anomalous photometric and abundance traits, especially from the m_1, $[m_1]$, and m_0 indices. First, there are several stars with $(b–y)_0 \lesssim 0^{\mathrm{m}}.45$ and with $m_0 \gtrsim 0^{\mathrm{m}}.18$, much

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TABLE 1

UNUSUAL SUBGIANT (AGB?) STARS

STAR	V_{uvby}	$(b–y)_0$	m_1	c_1	$[m_1]$	m_0	$V_{\rm HK}$	$[{\rm Fe/H}]_{\rm F}$
16548–009	13.82	0.43	0.19	0.40	0.33	0.20	....	....
16551–118	12.25	0.41	0.19	0.38	0.34	0.22	12.81	-2.88
16552–086	14.43	0.42	0.19	0.39	0.32	0.20	14.60	-2.89
17572–057	13.61	0.40	0.19	0.34	0.32	0.20	13.61	-1.96
17586–014	11.93	0.42	0.20	0.31	0.34	0.21	12.03	-1.80
22176–018	13.48	0.34	0.16	0.34	0.28	0.18	13.52	-1.11
22180–036	14.57	0.44	0.21	0.37	0.35	0.22	14.95	-2.48
31081–003	13.07	0.45	0.32	0.26	0.46	0.32	13.09	-1.64
31083–069	13.27	0.34	0.12	0.61	0.35	0.24	13.24	-1.48

larger than would be expected for VMP stars with [Fe/H] $\lesssim -1.5$; see Table 1. Most of these have been classified subgiants in the c_0,$(b–y)_0$ diagram. Some show clear evidence of photometric variability; in Table 1 the first V value for each star comes from the *uvby* photometry, and the second from the HK survey. These are perhaps analogous to stars discussed in S96 with larger than expected $[m_1]$ values. These may be misclassified AGB stars with unusual chemical-abundance ratios, variability, and/or binary companions; the c_0 index may be shifted by NH, CH, and CN bands, as discussed in S04a.

2. A second group of anomalous stars are ten classified blue stragglers having m_1, $[m_1]$, and $(U–B)_0$ values indicating nearly solar [Fe/H]. There is a clear discrepancy here between these photometric indices and the KP index used to derive [Fe/H] for the HK survey. These stars are very similar to the Am stars identified by Wilhelm et al. (1999) and have been classified in S04a as "BS (Am)". In Fig. 1 these stars are shown in the $[c_1]$,$[m_1]$ diagram compared to other VMP stars and to high-velocity (HV) stars from several sources; these "Am" stars are clearly separate from other VMP stars.

3. Another potentially interesting group includes the RHB–AGB candidates, classified in the c_0,$(b–y)_0$ diagram. The AGB stars frequently show abundance anomalies, such as overabundances for carbon, the α-elements, and especially the s-process elements, and so very-metal-poor AGBs can provide useful information about the early chemical evolution of the Galaxy. Twenty-one RHB–AGB candidates are found in Table 5 of S04a.

4. CH-star candidates can be identified in the GP,KP diagram, and twenty-two such candidates are identified in Table 3 of S04a. These too probably have anomalously high carbon abundances and may provide useful information concerning the 3rd dredge-up and mass transfer in evolved binary systems.

5. The SL–BHB and SL groupings probably contain stars such as the EHB stars of globular clusters, the B subdwarfs of the field, and the "flash mixed" stars of Brown et al. (2001). These latter stars should be especially interesting to study spectroscopically due to the possible enhanced abundances of elements from the stellar interior, such as carbon and helium; two stars, 22169–002 and 22948–027, have been classified both "SL" and "CH" in S04a.

6. Most of the stars in the above groups have $V \gtrsim 12\overset{\rm m}{.}0$ and so require large telescopes ($\gtrsim 6$ m) for the high-resolution, high-S/N spectroscopy (R $\gtrsim 30{,}000$ and S/N $\gtrsim 150$) required to study well their chemical abundance ratios.

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