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$uvby-\beta$ PHOTOMETRY OF HIGH-VELOCITY STARS. PHOTOMETRIC PARALLAXES AND PRELIMINARY KINEMATIC RESULTS

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RESUMEN. Se han explorado dos métodos para la determinación de paralajes fotométricos usando fotometría *uvby*-β. Estos métodos dependen de las relaciones estándar de Crawford (1975) y de Olsen (1984) y de colores y magnitudes sintéticas de VandenBerg y Bell (1985). Ambos métodos incluyen una corrección evolucionaria de forma $f\delta c_0$.

Se calculan las distancias para las 711 estrellas de alta velocidad y pobres en metales en el catálogo *uvby*-β de Schuster y Nissen (1988). Se comparan éstas con las distancias de Sandage y Fouts (1987) y Laird, Carney y Latham (1988) para las estrellas en común. También son aplicables nuestros métodos a estrellas de paralaje. En general las comparaciones son satisfactorias y las diferencias sistemáticas son despreciables o pequeñas.

Las distancias finales de nuestras 711 estrellas se aplican a un número de problemas cinemáticos. Se estudian algunos diagramas interesantes, tales como el diagrama de energía de Toomre y el diagrama V(rot) versus [Fe/H].

ABSTRACT. Two methods for the determination of photometric parallaxes using *uvby*-β photometry are being explored. These methods depend upon the standard relations of Crawford (1975) and of Olsen (1984) and upon synthetic colors and magnitudes of VandenBerg and Bell (1985). Both methods include an evolutionary correction of the form $f\delta c_0$.

Distances are calculated for the 711 high-velocity and metal-poor stars in the $uvby-\beta$ catalogue of Schuster and Nissen (1988). These are compared to the distances of Sandage and Fouts (1987) and Laird, Carney, and Latham (1988) for stars in common. Also our methods are applied to parallax stars. In general the comparisons are good with negligible or small systematic differences.

The final distances of our 711 stars are applied to a number of kinematical problems. Several interesting diagrams are studied, such as the Toomre energy diagram and the plot of V(rot) versus [Fe/H].

Key words: **DISTANCES – PHOTOMETRY – STARS-POPULATION II**

I. INTRODUCTION

A catalogue of $uvby-\beta$ photometry for 711 high-velocity and metal-poor stars has been published l Schuster and Nissen (1988, Paper I). In Papers II and III (Schuster and Nissen, 1989*a,b*) intrinsic color and metallici calibrations were derived and the ages and metallicities of the halo stars were studied. Our ultimate aim is to reach better understanding of the early dynamical and chemical evolution of the Galaxy by studying the relations betwee metallicity, age, and kinematics for the stars of our catalogue.

Using many literature sources, complete kinematic data have been obtained for 658 of our high-veloci and metal-poor stars. The obvious next step is to derive a calibration for photometric parallaxes that uses $uvby$ – photometry. Two methods are compared here; these depend upon the standard photometric relations of Crawfor (1975) and of Olsen (1984) and upon the synthetic colors and magnitudes of VandenBerg and Bell (1985,VB). The methods are applied to parallax stars and to stars in common with Sandage and Fouts (1987, SF) and with Lair Carney, and Latham (1988, LCL).

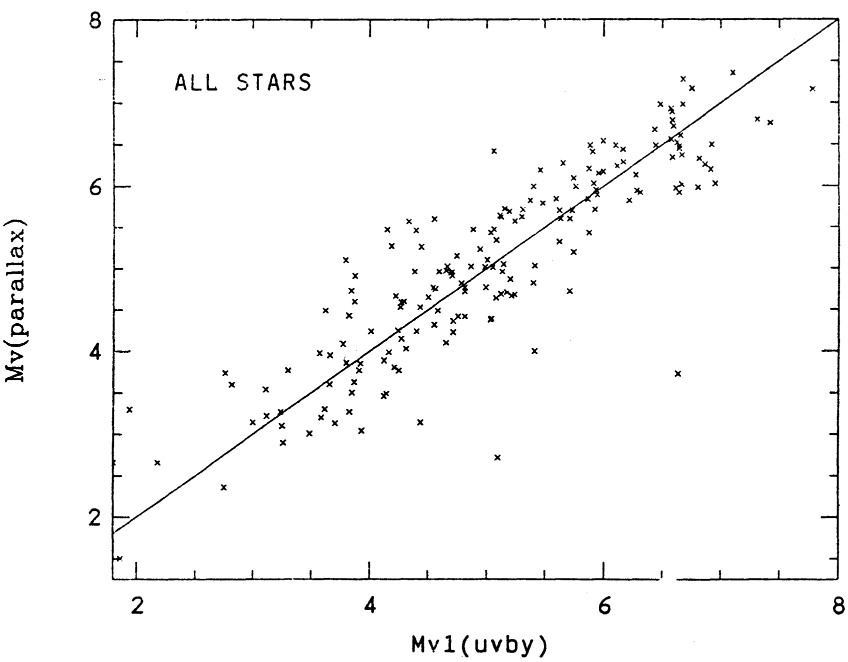
. PHOTOMETRIC PARALLAXES

The first method for photometric parallaxes depends directly upon the M_v,(b–y) standard relations of ·awford (1975) and of Olsen (1984). The displacement of the ZAMS in the M_v,(b-y) diagram as a funcion of metallicity .s been obtained from the least-evolved isochrones of VB at (b–y)= 0.38. An equation for $\Delta M_v(Z)$ has been derived, ıere Z is the heavy-element abundance of the models and ΔM_v is the displacement of the ZAMS.

For the second method the zero point of the visual absolute magnitudes depends exclusively upon the odels of VB. The least evolved isochrones (8.0 Gyr) are used to derive an expression for M_v(Z,b–y), the absolute agnitudes of little-evolved main sequences as a function of the heavy-element abundance and of b–y. For [Fe/H]≤-75 and b–y≥0.32, the 8 and 10 Gyr isochrones of VB differ by less than $0^m.2$ in M_v at constant b–y, and so the 8 Gyr ›chrone should be little evolved for this (b–y) range.

For both of the above methods, evolutionary corrections of the form $-f\delta c_o$ are applied, where f = $M_v/\delta c_o$ is taken from Nissen *et al.* (1987) and δc_o is the displacement in c_o at constant b–y for a given star from its ›rresponding ZAMS. That is, to calculate δc_o for the metal-poor stars, the displacement of the ZAMS in the c_o, b–y agram as a function of [Fe/H] needs to be known. An equation for this displacement, $\Delta c_0([Fe/H],(b-y)$, has been :rived using our $uvby-\beta$ photometry of the 711 high-velocity and metal-poor stars divided into 23 groups according [Fe/H]; lower envelopes in the c_o, (b–y) diagram were compared to the standard c_o, (b–y) relations of Crawford 975) and Olsen (1984). Finally, $\delta c_o = c_0(observed) - c_0(ZAMS) = c_0(observed) - [c_0(STD) + \Delta c_0([Fe/H],(b-y)]$ and $_v = M_v(ZAMS) - f\delta c_o$.

In Figure 1 is shown the comparison between the photometric absolute magnitudes of method 1 above ıd parallactic absolute magnitudes. Mostly these parallax stars are from the lists of Crawford (1975), Olsen (1984), ıd LCL. All metallicities are represented from approximately solar to [Fe/H]≈–2.5. To obtain agreement with the one- -one line in Figure 1, the lower envelopes in the c_o,(b–y) diagrams, mentioned above, had to be revised downward r the bluer, more metal-rich stars, [Fe/H]≥–0.35 and b–y≤0.40; most of our hotter, more metal-rich high-velocity stars ·e significantly evolved.



ɟ. 1. Visual absolute magnitudes from trigonometric parallaxes versus the photometrically derived values using the first method discussed in ᵌ text. The parallax stars are mainly those selected by Crawford (1975), Olsen (1984), and LCL.

The photometric absolute magnitudes of our methods have also been compared for parallax stars w [Fe/H]≤−0.5 only, and for those with [Fe/H]≤−1.0. The distances of our two methods, D_1's and D_2's, respectively, h been compared to those of SF and of LCL. In the following kinematic diagrams only our D_1's have been used. T first method works for the entire metallicity range of our high-velocity and metal-poor stars and provides reasona agreement with the parallactic M_v's for all metallicities; also, the D_1's agree very well with the distances of LCL.

III. KINEMATIC DIAGRAMS

In Figure 2 the Toomre energy diagram is given for those stars with [Fe/H]≤−1.0; the asymmetry of halo stars, as discussed by Norris and Ryan (1989, NR), is confirmed. Most of the halo stars fall in the range −37 V' ≤ 0 km s^{-1}. However, eight stars with strongly retrograde orbits, V'≤ −400 km s^{-1}, are present, but no stars w strongly prograde orbits. NR explain this asymmetry using the coalescence-of-fragments scheme of Searle and Z (1978) for the formation of the halo, plus the dynamical friction model of Quinn and Goodman (1987). They prop that fragments in retrograde or highly inclined orbits lost little of their orbital energy due to dynamical friction wl fragments in direct orbits were dragged into the galactic disk relatively quickly, leading to the asymmetry seen in Figure 2 and in their Figure 1.

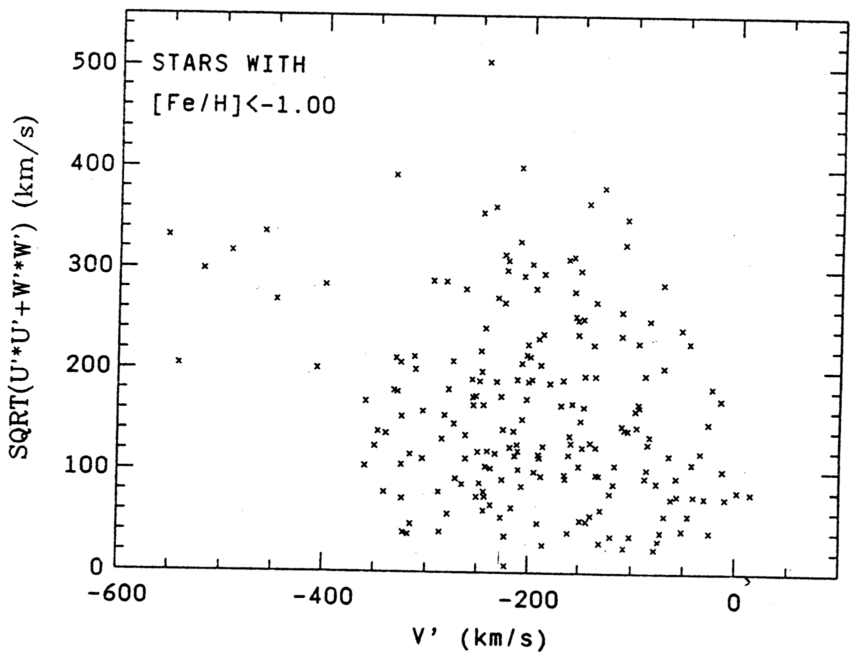
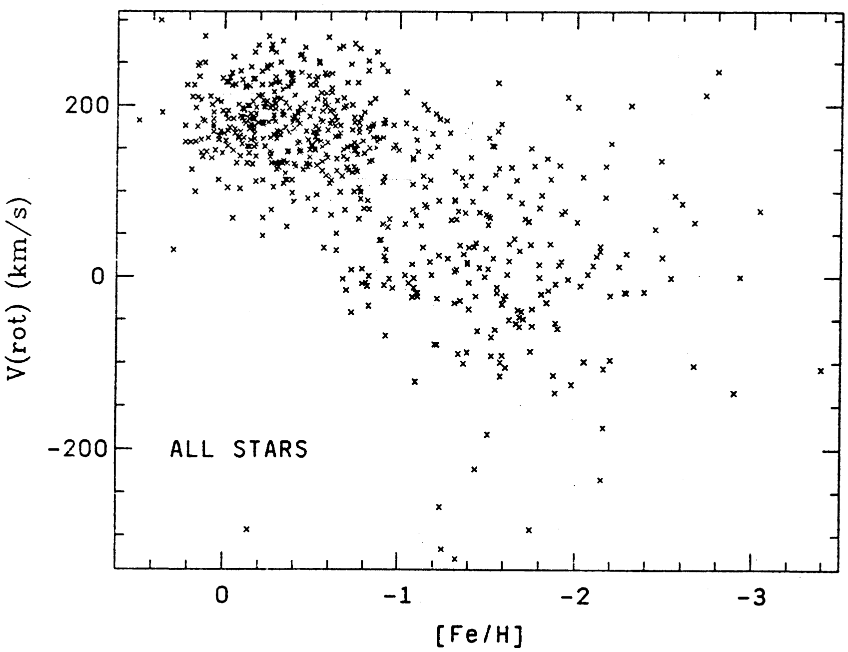
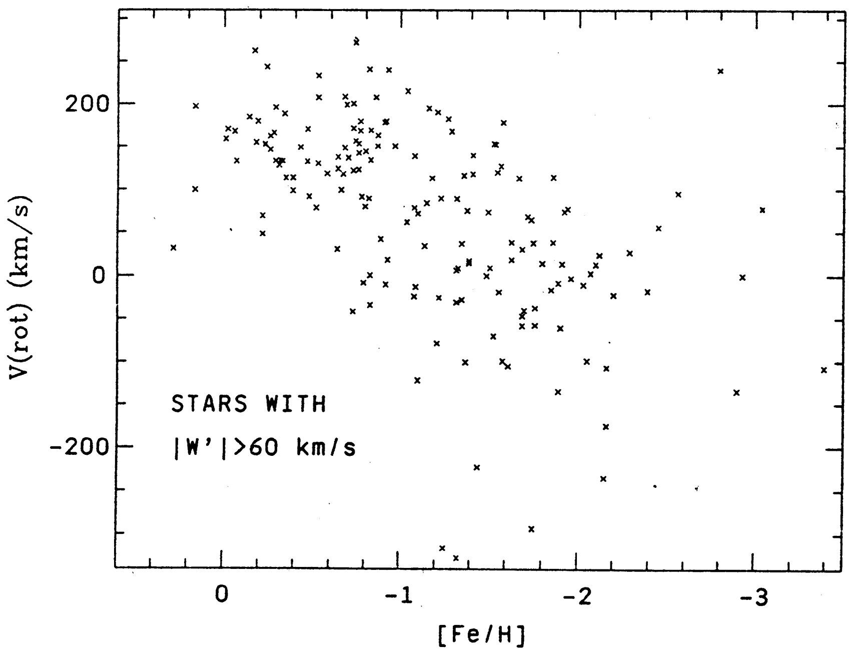


Fig. 2. The Toomre energy diagram for stars with [Fe/H] ≤ −1.00. U', V', W') are the galactic space velocities, defined as usual, with respect the Local Standard of Rest.

In Figures 3 and 4 are plotted the V(rot) versus [Fe/H] diagrams for all of our stars and for stars wi |W'|≥ 60 km s^{-1}, respectively, where V(rot)= V'+225 km s^{-1} is the rotational velocity about the galactic center f a given star. There has been considerable discussion, for example, in SF, in Norris (1986), and in NR whether not V(rot) undergoes a transition somewhere in the range −1.0≤[Fe/H]≤−1.5. SF argue that there is no transitic for halo stars defined as those stars with |W'|≥ 60 km s^{-1}, that V(rot) continues decreasing monotonically to at lea [Fe/H]= −2.3. NR conclude on the other hand, that the "large abundance errors" of SF have led them to an erroneo conclusion. They argue that there is a transition near [Fe/H]≈−1.4, that for [Fe/H]≤−1.4 the average stellar kinemati no longer vary with [Fe/H].



g. 3. The V(rot) versus [Fe/H] plot for our total sample of stars. V(rot) is the rotational velocity about the galactic center.



;. 4. The same as Figure 3, but only for stars with $|W'| \leq 60$ km s^{-1}.

In our Figures 3 and 4 it is seen that either of the above conclusions could be supported depending how : select our sample. For the subset with $|W'| \geq 60$ km s^{-1}, the average V(rot) decreases approximately linearly to at ıst [Fe/H]= −2.0. On the other hand for our full set of stars the average V(rot) does not change significantly for [Fe/H] -1.3. In Paper II it was shown that our metallicities are fairly accurate, $\sigma([Fe/H]) \approx 0.20$. It can be concluded then at the conflicting results of SF and NR are not due entirely to the "large abundance errors" in the data of SF. Some her factor, such as differing selection effects in the stellar samples or the use of the criterion $|W'| \geq 60$ km s^{-1} by SF, .s led to the different V(rot) versus [Fe/H] diagrams. For example, the $|W'| \geq 60$ km s^{-1} criterion selects stars in more clined orbits, and these stars or their parent fragments may have undergone different dynamical friction effects than r stars with orbits more nearly in the galactic plane.

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