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Kinematic structure in the Galactic halo at the North Galactic Pole: RR Lyrae and BHB stars show different kinematics

T. D. Kinman[1], C. Cacciari[2], A. Bragaglia[2], A. Buzzoni[2] and A. Spagna[3]

[1]NOAO, Tucson, AZ, USA; [2]INAF, Bologna, Italy; [3]INAF, Torino, Italy

Abstract. Heliocentric (UVW) and galactocentric (V_R V_Φ V_Z) space motions were derived for 38 RR Lyrae (RRL) and 79 blue horizontal branch (BHB) stars in a 200-sq degree area near the North Galactic Pole (NGP). A kinematic analysis of the 26 RRL and 52 BHB stars whose height (Z) above the plane is < 8 kpc shows that the sample is not homogeneous. Our BHB sample shows zero galactic rotation and roughly isotropic velocity dispersions. whereas the RRL sample shows a definite retrograde rotation and non-isotropic velocity dispersions. The combined BHB and RRL sample shows a smaller retrograde rotation that is similar to that found by Majewski *et al.* (1996) for a sample of subdwarfs in SA 57 at the NGP. There are significantly more RRL with negative W-velocity (streaming down) than positive W-velocity, whereas the numbers of BHB stars are comparable. This indicates the presence near the NGP of an accreted halo component that is rich in RRL (probably Oosterhoff type I) stars.

These results are presented in detail in a forthcoming paper (Kinman *et al.* 2007).

Keywords. Stars: kinematics, Galaxy: halo, Galaxy: structure

1. The data: radial velocities, proper motions, distances

The candidate BHB and RRL stars were selected from various surveys (see Kinman *et al.* 2007). The BHB stars were confirmed by uBV photometry and spectroscopy, and for the RRL stars intensity-weighted V magnitudes were derived from recent light curves.

Table 1. Mean Galactocentic radial velocities for NGP halo stars at different heights (Z) above the plane and different right ascensions (RA). These data show that the streaming down to the plane (negative $< RV_{gal} >$) is largest for stars with Z $>$ 4 kpc and for stars with RA $>$ 13:00.

Z (kpc)	RA (hh:mm)	N	$< RV_{gal} >$ (km/s)	Dispersion (km/s)	Z (kpc)	RA (hh:mm)	N	$< RV_{gal} >$ (km/s)	Dispersion (km/s)
< 4	All	26	+10±14	67±9	> 4	All	84	−26±11	92±7
> 4	<13:00	61	−17±12	92±8	> 4	>13:00	23	−49±21	94±14

The blue and red plates of the first Palomar Sky Survey (POSS-I) together with the Quick-V, blue and red plates of the second Palomar Sky Survey (POSS-II) - digitized and used to construct the GSC-II Catalogue - gave multi-epoch positions with a baseline of $\sim$ 40 yrs. Relative proper motions were transformed to an absolute system by forcing QSOs and compact galaxies to have no tangential motion. The random errors in the individual proper motions ($\sim$3 mas/yr) correspond to $\sim$140 km/s at a distance of 10 kpc and are thus comparable with the random velocities of the halo stars at this distance.

The systematic error was derived from proper motion measures of 121 QSOs and compact galaxies whose mean values were:
μ(RA) = −0.25±0.28 mas/yr $\quad$ μ(DEC) = −0.07±0.31 mas/yr.

A systematic 1-σ error of 0.3 mas/yr in each coordinate corresponds to a 2-σ systematic error of 40 km/s in the rotation velocity (V) at a distance of 10 kpc. Our analysis of the space motions was therefore restricted to the 52 BHB and 26 RRL stars within 8 kpc, whose mean distance is ∼5 kpc and should have a 2-σ systematic error of 20 km/s.

The RRL distances were derived from Mv obtained from a linear relation in [Fe/H] that implies Mv = +0.54 at [Fe/H] = −1.5 and $(m - M)_0 = 18.52$ for the LMC. The BHB stars Mv's were derived from their $(B - V)$ colours using a cubic relation adjusted to give the same Mv as the RRL stars at the blue edge of the instability strip. We refer to Kinman *et al.* (2007) for details.

2. Results: space motions for halo stars with 0 < Z < 8 kpc

Table 2. Mean heliocentric space velocities $< U >$ and $< V >$ (in km/s) for our BHB and RRL stars for different ranges of the space velocity W.

RRL				BHB				All			
Range in W	N	$< U >$ $\pm\sigma$	$< V >$ $\pm\sigma$	Range in W	N	$< U >$ $\pm\sigma$	$< V >$ $\pm\sigma$	Range in W	N	$< U >$ $\pm\sigma$	$< V >$ $\pm\sigma$
W < 0	20	+12 ±41	−321 ±36	W < 0	24	+11 ±20	−216 ±24	W < 0	44	+12 ±21	−264 ±22
W > 0	6	−112 ±41	−351 ±31	W > 0	28	−64 ±20	−258 ±19	W > 0	34	−72 ±21	−275 ±17
All W	26	−17 ±35	−328 ±28	All W	52	−29 ±16	−239 ±15	All W	78	−25 ±16	−268 ±14

The vectors U, V, W are assumed to be positive towards the directions of the galactic centre, galactic rotation and NGP, respectively (Johnson & Soderblom 1987), and zero halo rotation corresponds to $V_{hel} = -225$ km/s (see Dehnen & Binney 1998).

One can note that: i) For all W, the BHB stars have essentially zero heliocentric rotation (−239 ± 15 km/s) and isotropic galactocentric velocity dispersions, like the sample of distant BHB stars found by Sirko *et al.* (2004), whereas the RRL stars have strong retrograde rotation (−328 ± 28 km/s) and their galactocentric velocity dispersions resemble the anisotropic dispersions in the Solar neighbourhood. ii) For all W, the whole sample has an intermediate retrograde rotation similar to that found by Majewski *et al.* (1996) for a sample of subdwarfs at a comparable distance in SA 57 at the NGP. iii) The ratio of RRL to BHB stars is significantly higher for the stars that have negative W (infalling) compared to those with positive W. iv) The $< U >$ space velocity is significantly negative (away from the galactic centre) for all the stars with negative W (infalling) indicating an overall streaming motion.

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