TABLE 1
Mean Radial Velocities and their Dispersions for RR Lyrae and BHB stars in Three Fields near the North Galactic Pole.

| Type of star. | Range in Z (kpc) | Mean Z (kpc) | Number of stars | Mean Velocity\(^a\) (km s\(^{-1}\)) | Velocity Dispersion\(^a\) (r.m.s.) (km s\(^{-1}\)) |
|---------------|------------------|--------------|-----------------|------------------------------------------|------------------------------------------------|
| RR Lyrae      | < 4.0            | 3.20         | 2               | +56±55                                    | 55±28 97±48                                     |
|               | 4.0 to 8.1       | 6.72         | 9               | -78±28                                    | 78±18 114±27                                   |
|               | 8.6 to 12.3      | 10.76        | 9               | -25±44                                    | 125±29 128±30                                   |
|               | 12.7 to 15.5     | 13.97        | 9               | -48±37                                    | 104±24 116±27                                   |
|               | 15.9 to 20.6     | 18.88        | 9               | +1±44                                     | 124±29 124±29                                   |
|               | 4.0 to 20.6      | 12.58        | 36              | -38±18                                    | 109±13 115±14                                   |
|               | 4.0 to 11.0\(^b\) | 8.97\(^b\)  | 7\(^b\)         | -10±44\(^b\)                             | 107±29\(^b\) 107±29\(^b\)                     |
|               | 4.0 to 11.0\(^c\) | 7.39\(^c\)  | 8\(^c\)         | -102±19\(^c\)                            | 49±12\(^c\) 120±30\(^c\)                      |
| BHB           | < 4.0            | 3.16         | 7               | +12±14                                    | 34±9 36±9                                      |
|               | 4.4 to 6.2       | 5.33         | 10              | -65±35                                    | 104±23 125±28                                   |
|               | 6.7 to 8.6       | 7.84         | 10              | -22±26                                    | 77±17 81±18                                     |
|               | 9.4 to 13.8      | 11.40        | 11              | -8±37                                     | 118±26 118±26                                   |
|               | 4.4 to 13.8      | 8.29         | 31              | -31±18                                    | 102±13 106±13                                   |
|               | 4.0 to 11.0\(^b\) | 6.68\(^b\)  | 9\(^b\)         | -52±37\(^b\)                             | 105±25\(^b\) 119±28\(^b\)                     |
|               | 4.0 to 11.0\(^c\) | 7.62\(^c\)  | 16\(^c\)        | -38±22\(^c\)                             | 84±15\(^c\) 92±16\(^c\)                      |
| Both Types    | < 4.0            | 3.17         | 9               | +22±14                                    | 40±9 47±11                                     |
|               | 4.0 to 11.0\(^b\) | 7.68\(^b\)  | 16\(^b\)        | -34±27\(^b\)                             | 104±18\(^b\) 110±19\(^b\)                    |
|               | 4.0 to 11.0\(^c\) | 7.54\(^c\)  | 24\(^c\)        | -59±16\(^c\)                             | 79±11\(^c\) 99±14\(^c\)                      |

\(^a\) The radial velocity dispersions in col. 6 are relative to the mean; those in col. 7 are relative to zero km s\(^{-1}\).
\(^b\) Stars in SA 57.
\(^c\) Stars in fields RR 2 and RR 3.
A Preliminary Discussion of the Kinematics of BHB and RR Lyrae Stars near the North Galactic Pole.

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ABSTRACT

The radial velocity dispersion of 67 RR Lyrae and BHB stars that are more than 4 kpc above the galactic plane at the North Galactic Pole is $\approx 110 \text{ km s}^{-1}$ and shows no trend with $Z$ (the height above the galactic plane). Nine stars with $Z \leq 4$ kpc show a smaller velocity dispersion ($40 \pm 9 \text{ km s}^{-1}$) as is to be expected if they mostly belong to a population with a flatter distribution. Both RR Lyrae stars and BHB stars show evidence of stream motion; the most significant is in fields RR2 and RR3 where 24 stars in the range $4.0 \leq Z \leq 11.0$ kpc have a mean radial velocity of $-59 \pm 16 \text{ km s}^{-1}$. Three halo stars in field RR 2 appear to be part of a moving group with a common radial velocity of $-90 \text{ km s}^{-1}$. The streaming phenomenon therefore occurs over a range of spatial scales. The BHB and RR Lyrae stars in our sample both have a similar range of metallicity ($-1.2 \leq [\text{Fe/H}] \leq -2.2$). Proper Motions of BHB stars in fields SA 57 (NGP) and the Anticenter field (RR 7) (both of which lie close to the meridional plane of the Galaxy) show that the stars that have $Z < 4$ kpc as well as those with $Z > 4$ kpc have a Galactic V motion that is $< -200 \text{ km/s}$ and which is characteristic of the halo. Thus the stars that have a flatter distribution are really halo stars and not members of the metal-weak thick-disk.

Subject headings: Stars: RR Lyrae, Stars: Horizontal Branch, Galaxy: Kinematics

1. Introduction

The velocity dispersion of the RR Lyrae stars in the solar neighborhood is not isotropic; an interpretation of this inequality is that the galactic system of RR Lyrae orbits is flattened (Woolley, 1978; Hartwick, 1983; Layden 1995). This is to be expected if most of these local halo \(^3\)

\(^3\)Following KSK, we have used the word “halo” in a population sense to describe those field stars that are physically similar to the stars in halo globular clusters. This seems appropriate for the BHB and metal-weak RR Lyrae stars which are known to occur in these clusters but not in the disk (or bulge) globular clusters.
stars have a flattened galactic distribution; direct evidence for such a flattened distribution among the nearby blue horizontal branch (BHB) stars was recently shown by Kinman, Suntzeff and Kraft (KSK)(1994). The more distant halo stars, like the halo globular clusters, would be expected to have a more isotropic velocity distribution in accordance with their more spherical spatial distribution. Ratnatunga and Freeman (1989), however, in their study of K-giants at the South Galactic Pole (SGP), found that the velocity anisotropy persisted out to 25 kpc from the galactic plane and that the velocity dispersion of these distant halo stars was only $\approx 75$ km s$^{-1}$. White (1989) argued that this result could not be reconciled with a spherical halo and that the kinematics of the regions sampled by Ratnatunga and Freeman might be atypical of the whole halo. Sommer-Larsen and Christensen (1989), however, found a significantly higher velocity dispersion ($\approx 100$ to $\approx 110$ km s$^{-1}$) in their study of distant BHB stars at the galactic poles. Some further comments on previous observations at the SGP are given in the Appendix.

Currently there is uncertainty not only about the velocity dispersion of the distant halo stars in the direction of the galactic poles but also about the homogeneity of the distant halo. Some of the uncertainty may come from the rather small samples of stars that have hitherto been available to derive velocity dispersions. To help resolve these problems we need pure samples of halo stars that are unadulterated with thick-disk stars. Halo tracers that meet this criterion are the metal-poor RR Lyrae stars ([Fe/H] $\leq -0.9$) and the BHB stars that have been selected by the criteria discussed by KSK. We discuss here stars of both these types in the three Lick Astrograph RR Lyrae fields RR 2, RR 3 and RR 4 near the North Galactic Pole (NGP) (Kinman, Wirtanen and Janes, 1966). The metallicities [Fe/H] of the RR Lyrae stars in these fields were determined by Butler, Kinman and Kraft (1979). The BHB stars in RR 4 (SA 57) are described by KSK. The BHB stars in the other two fields were selected from the AF stars given by Sanduleak (1988); details will be given in a future paper on the completion of the photometric survey in these fields by one of us (T.D.K.). Radial velocities have now been obtained for the majority of the BHB and RR Lyraes (with B brighter than $\approx 16.5$) in these NGP fields; this paper gives a preliminary discussion of this ongoing work.

2. Observations and Reductions

2.1. RR Lyrae Stars

The radial velocities of 38 RR Lyrae stars in these NGP fields are taken from a larger radial velocity study of RR Lyrae stars by Pier (1996). The observations were obtained with the Intensified Image Dissector Scanner (IIDS) on the Kitt Peak 2.1-m and 4-m telescopes during the period 1983 February to 1985 May. Spectral coverage was from 3780 to 4460 Å using the 831 l/mm grating (second order) which gave a resolution $\approx 2.2$ Å. Radial velocities were determined by cross-correlating spectra of the program stars against those taken as radial-velocity templates (Tonry & Davis, 1979; Pier, 1983). Details concerning data reduction techniques and radial
velocity measurements will be found in Pier (1996).

Multiple observations were obtained for many of the stars. The gamma velocities were derived by correcting for the pulsation velocity using synthetic RR Lyrae velocity curves (Woolley & Savage, 1971; Liu, 1991); sufficiently contemporaneous ephemerides for these stars are given by Butler, Kinman and Kraft (1979). A comparison of the gamma velocities of stars with repeated measures and with published velocities indicates that the standard error in a single velocity measurement is ±15 km/s.

### 2.2. BHB Stars

Some 38 BHB stars were observed in a single five night run in February 1995 with the RC spectrograph at the 4-m Mayall telescope at Kitt Peak; 15 in field RR 4 (SA 57) and 23 in fields RR 2 and RR 3. The program stars cover the magnitude range 11.8 ≤ V ≤ 16.5 and galactic latitude range 79.1° ≤ b ≤ 88.9°. The spectral resolution was 0.4 Å per CCD pixel (resolution~0.8 Å) over the waveband λλ 3880 – 4580. The wavelength solutions were based on helium-argon spectra taken at each slew position. Details about the reduction techniques and radial velocity measurements will be given in a forthcoming paper.

Radial velocities were determined for the program stars by standard cross correlation techniques (Tonry & Davis 1979) as described in KSK. We used field horizontal branch stars with well-determined velocities by Green & Morrison (1993) for the template spectra and for the nightly zero-points of the velocity system. The mean difference (our radial velocities minus those of Green & Morrison) for 13 spectra of HD 60778, HD 74721 and HD 161817 taken over the five night run is −1.0 km s⁻¹ and the r.m.s. value of a single difference is ±1.4 km s⁻¹. These results and the cross-correlation of the comparison spectra show that the nightly velocity zero point is accurate to 1.0 km s⁻¹.

The velocities were measured using the technique described by KSK. Two velocities were measured for each star: v(weak) from the correlation of the weak lines (with the hydrogen Balmer lines masked out), and v(H) based on the correlation of the heavily filtered Balmer lines (with the weak lines masked out). The r.m.s. difference between the two velocity measurements was 2.5 km s⁻¹ for 77 spectra of bright field giants, and 4.3 km s⁻¹ for 56 spectra of program stars. The nightly mean difference between the two systems of velocity measurements was always less than 1.5 km s⁻¹.

As discussed in KSK, the correlation based on the weak lines produces a sharper correlation peak (and a somewhat more accurate velocity) than that based on the hydrogen lines for high S/N data or stars which have strong metallic lines. For 90% of the program stars, the weak-line correlation peak was well defined and we could measure v(weak). For the rest of the stars, we used the hydrogen line correlation peaks to measure the stellar velocity. The velocity errors are ∼4 km s⁻¹ for most program stars, rising to 8 km s⁻¹ for the fainter stars.
3. Discussion

3.1. Absolute Magnitudes and Distances

Absolute magnitudes ($M_v$) were derived for the BHB stars using the cubic expression in $(B-V)_0$ given by Preston et al. (1991) which assumes $M_v$ equals +0.6 for the RR Lyrae stars. The absolute magnitudes of the RR Lyrae stars were calculated from:

$$M_v = 1.05 + 0.29[Fe/H]$$

(1)

which is the mean of the direct and inverse relations given by Feast (1995). A mean $B-V$ of +0.37 was assumed for the RR Lyrae stars and their distances were calculated from the mean $B$ magnitudes given by Kinman et al. (1966). Equation (1) gives $M_v = +0.59$ for $[Fe/H] = -1.6$ (a characteristic metallicity for our sample). This is consistent with our assumed $M_v$ for the BHB stars. Other recent estimates of the $M_v$ of the RR Lyrae stars (e.g. Carney, Storm & Jones, 1992) lie within ±0.20 mag of the value given by equation (1). The corresponding 10% uncertainty in our distances does not affect the conclusions of this paper.

Following KSK, the height $Z$ above the galactic plane was calculated for each star assuming no reddening. The radial velocities were corrected to the local standard of rest and for a solar galactic rotation of 220 km s$^{-1}$. The adoption of a larger solar galactic rotation (e.g. 275 km s$^{-1}$, Majewski (1992)) would not materially change our conclusions.

3.2. Radial Velocities

The mean radial velocities and their dispersions were calculated separately for the RR Lyrae stars and BHB stars and are given as a function of $Z$ in Table 1 and Fig.1. For $Z < 4$ kpc, we would expect most of the stars to come from the flatter halo and have a lower radial velocity dispersion. We find that the nine stars with $Z < 4$ kpc have a velocity dispersion of only 40±9 km s$^{-1}$. The BHB stars with $Z < 4$ kpc at the SGP also show a lower velocity dispersion (for details see Appendix). For $Z > 4$ kpc, both RR Lyrae stars and BHB stars show a radial velocity dispersion of ≈110 km s$^{-1}$ in agreement with the results of Sommer-Larsen et al.(1989) but not with those of Ratnatunga and Freeman (1989). The low velocity dispersion found by Ratnatunga and Freeman may arise partly from adulteration with disk stars (see discussion in Sec. 9 and Fig. 19 of KSK).

The mean radial velocities of both the RR Lyrae and the BHB stars in the NGP fields are negative in the distance range 4 to 14 kpc (Table 1)[4]. In particular, the twenty four RR Lyrae

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4 The SGP stars do not show this effect. As noted in the Appendix, the 15 BHB stars listed by Flynn et al.(1995)
and BHB stars in fields RR 2 and RR 3 that lie in the range in Z of 4.0 to 11.0 kpc have a mean radial velocity of $-59\pm16$ km s$^{-1}$. It is very interesting that in a 0.3 square degree field in SA 57, Majewski, Munn and Hawley (1994, 1996) have found stars in the radial velocity range $-48$ to $-86$ km s$^{-1}$. Their sample contains mostly subdwarfs near the main-sequence turn-off with $5 \leq Z \leq 10$ kpc and are in a relatively small volume of space (around $0.03$ kpc$^3$). Our mean negative velocity in SA 57 of $-34\pm27$ km s$^{-1}$ for the sixteen RR Lyrae and BHB stars in the range in Z of 4.0 to 11.0 kpc is less significant although there are five of these stars in the Z range of 4.6 to 6.2 kpc that have a mean radial velocity of $-108\pm37$ km s$^{-1}$. These last 5 stars have metallicities [Fe/H] in the range $-1.4$ to $-2.1$ and occupy a volume some 6 times larger than the volume of the Majewski et al. field.

There is a peak in the radial velocity distribution in field RR 2 at $-90$ km s$^{-1}$. In particular, there are three stars (one RR Lyrae and two BHB) close to $12^h:09^m:05^s$, $+33^\circ:03^\prime$ (1950) that (within the measuring errors) have the same radial velocity; a summary of their properties is given in Table 2. These three stars have a mean height above the galactic plane of $\sim10.0$ kpc and occupy $\sim0.05$ kpc$^3$ — comparable to the volume occupied by the stars in the Majewski et al. field. It seems likely that these three stars constitute a “moving group” that had a common origin (for references to possible high-velocity moving-groups, see Majewski et al. (1994)); it is very desirable to check whether they also share a common proper motion.

The crossing time of the galactic orbits of halo stars is much less than the likely age of halo stars so it has sometimes been concluded that the halo is reasonably well mixed (Sommer-Larsen & Zhen, 1990; Binney, 1994). Indeed, this may perfectly true of the majority of halo stars. The detection of a few stars with a common motion in a small volume of space may result from the fortuitous discovery of the remnants of a cluster in the process of dissolution. The volume included in fields SA 57, RR 2 and RR 3, however, is of the order of some tens of a cubic kiloparsec. The existence of streaming motions in a volume this size suggests a larger scale phenomenon in which the stars have only entered the galaxy in relatively recent times and/or that their orbits have never taken them into regions in the Galaxy where organized motion would be rapidly destroyed.

The picture given by the RR Lyrae and BHB stars will not be the same as that given by the subdwarfs. The RR Lyrae and BHB stars make up a relatively small fraction of the stellar halo; consequently, although they are useful tracers of large scale structure, they generally do not allow a very fine spatial resolution. The halo subdwarfs (more than a hundred times more numerous) can be used to sample much smaller volumes of space and are useful for investigating the inhomogeneities in the halo that apparently exist on smaller spatial scales.

Majewski, Munn and Hawley (1996) consider the possibility that the streaming that they find in SA 57 may be associated with the disintegrating Sagittarius Dwarf that has recently been found have a mean velocity of $-4\pm22$ km s$^{-1}$ while the 19 BHB stars with $Z > 4$ kpc in Pier’s sample have a mean velocity of $+15\pm21$ km s$^{-1}$. 

by Ibata, Gilmore and Irwin (1994). This seems quite possible. Among recently suggested orbits for the Sagittarius Dwarf, (e.g. Velazquez and White (1995) perigalacticon 10 kpc and apogalacticon 52 kpc; Lynden-Bell and Lynden-Bell (1995) perigalacticon 12 kpc and apogalacticon 36 kpc), our data show best agreement in radial velocity and galactic location with orbit D of Lin, Richer, Ibata and Suntzeff (1995). The determination of proper motions and hence space motions and orbits for the BHB and RR Lyrae stars in RR 2 and RR 3 is clearly very desirable if we are to be certain that these stars are indeed part of a stream that includes the Sagittarius Dwarf Galaxy.

4. Proper Motions

Preliminary absolute proper motions have been determined for 21 BHB stars in the SA 57 field (at the NGP) and 14 BHB stars in the RR 7 Anticenter field of KSK, as part of a larger study by Hanson and Klemola (1995), using the 51-cm Carnegie Double Astograph at Lick Observatory and the photographic plate collection of the Lick Northern Proper Motion (NPM) program (Klemola, Jones, and Hanson 1987).

Four third-epoch blue (103a-O) plates were taken by Klemola in February and April 1995. These were measured along with first-epoch NPM plates taken between 1950 and 1953. Details of the NPM observing, plate measurement, and reduction procedures are given by Klemola, Jones, and Hanson (1987). The proper motions were determined in an absolute reference frame defined by 80–100 galaxies (16 ≤ B ≤ 18) per field. Epoch spans well over 40 years allow the measurement of proper motions with random errors ≈ 0′′.3 cent −1, corresponding to a transverse velocity error ≈ 15 km sec −1 kpc −1.

The proper motions of these BHB stars were converted to transverse velocities using the distances (kpc) given by KSK. Both these fields lie close to the meridional plane of the Galaxy which passes through the Sun, the Galactic Center and the North Galactic Pole. To a first approximation, therefore, the galactic rotation vector (V) is almost entirely given by these transverse velocities. Fig. 2 shows this V vector on a plot of the transverse velocities for (a) SA 57 and (b) the RR 7 field. The filled circles show stars with Z ≤ 4 kpc and the open circles stars with 4 ≤ Z ≤ 6 kpc and show that both these groups of stars lag the galactic rotation of the Sun by at least 200 km s −1. Thus the stars that have Z ≤ 4 kpc which must belong predominantly to the flatter halo of KSK must indeed be identified with the halo and not with the metal-weak “thick-disk” (Morrison, Flynn & Freeman, 1990) whose rotation with respect to the Sun should only be about 40 km s −1.

5. Conclusions

The velocity dispersion of a sample of 67 RR Lyrae and BHB stars in three fields at the NGP and more than 4 kpc above the galactic plane is ≈110 km s −1; this sample shows no trend of velocity
dispersion with Z. The 9 stars with Z ≤ 4 kpc show a smaller velocity dispersion (40±9 km s$^{-1}$) as is to be expected if they belong to a spatially flatter distribution. The mean velocity of both the RR Lyrae and BHB stars shows evidence of stream motion in the halo. The most significant systematic motion is that in fields RR 2 and RR 3 where 24 stars in the range 4.0≤Z≤11.0 kpc have a mean radial velocity (corrected for galactic rotation and to the local standard of rest) of −59±16 km s$^{-1}$. Three halo stars in field RR 2 occupy a volume of ~0.05 kpc$^3$ about 10 kpc above the galactic plane and have the same radial velocity (−90 km s$^{-1}$). The streaming therefore occurs over a range of spatial scales. That on the smaller scale is comparable both in sense and size with that found by Majewski, Munn and Hawley (1994) (1996). The possibility that these streaming stars belonged to the newly discovered Sagittarius Dwarf Galaxy is not in disagreement with some recent orbits that have been calculated for this galaxy and this requires further investigation.

Preliminary proper motion data for BHB stars in SA 57 and the Anticenter field RR 7 show that the stars with Z ≤ 4 kpc have a galactic rotation similar to the BHB stars in the more distant halo; consequently these stars of the flatter halo are really halo stars and not members of the metal-weak thick-disk of Morrison, Flynn and Freeman (1990).

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APPENDIX

The 15 BHB stars near the SGP with Z≤16 kpc given by Flynn, Sommer-Larsen, Christensen and Hawkins (1995) have a radial velocity dispersion ($\sigma$) relative to the mean of ≈82 km s$^{-1}$. If the most distant four stars are omitted from this sample, however, the $\sigma$ of the remaining 11 stars is ≈91 km s$^{-1}$. Pier (1984) found that the $\sigma$ of 31 BHB stars near the SGP was only ≈80 km s$^{-1}$; the dispersion for the 24 of these BHB stars that are more than 4 kpc from the plane is ≈87 km s$^{-1}$, while the 7 with Z < 4 kpc have a dispersion of ≈55 km s$^{-1}$. If we exclude the stars with B−V ≤−0.03 and Hδ-width ≥ 30Å (those least likely to be BHB stars), the dispersions are respectively ≈90 km s$^{-1}$ (19 stars) and ≈48 km s$^{-1}$. These are quite small samples and their uncertainties are correspondingly high; the r.m.s. error in $\sigma$ equals $\sigma$ divided by the square root of twice the number of objects, so ~50 objects must be observed to get an error of ±10 km s$^{-1}$ in the dispersion.
REFERENCES

Binney, J.J. 1994, in “Galactic and Solar System Optical Astrometry”, ed. L. Morrison and G. Gilmore, Cambridge, University Press, Cambridge, p. 141.

Butler, D., Kinman, T.D. & Kraft, R.P. 1979, AJ, 84, 993.

Carney, B.W., Storm, J. & Jones, R.V. 1992, ApJ, 386, 663.

Feast, M.W., 1995, in IAU Colloquium 155, “Astrophysical Applications of Stellar Pulsation”, (ed. R.S. Stobie & P.A. Whitelock), ASP Conf. Ser. (ASP: San Francisco), 83, 209.

Flynn, C., Sommer-Larsen, J. Christensen, P.R. & Hawkins, M.R.S. 1995, A& AS, 109, 171.

Green, E.M. & Morrison, H. 1993, private communication.

Hanson, R.B., & Klemola, A.R., 1995, In Preparation.

Hartwick, F.D.A. 1983, MemSAIt, 54, 51.

Ibata, R.A., Gilmore G. & Irwin, M.J. 1994, Nature, 370, 194.

Kinman, T.D., Wirtanen, C.A. & Janes, C.A. 1966, ApJS, 13, 1379.

Kinman, T.D., Suntzeff, N.B. & Kraft, R.P. 1994, AJ, 108, 1722. (KSK)

Klemola, A.R., Jones, B.F., & Hanson, R.B., 1987, AJ, 94, 501.

Layden, A.C., 1995, AJ, 110, 2288.

Lin, D.N.C., Richer, H.B., Ibata, R.A. & Suntzeff, N.B. 1995, Preprint.

Liu, T. 1991, PASP, 103, 205.

Lynden-Bell, D. & Lynden-Bell, R.M. 1995, MNRAS, 275, 429.

Majewski, S.R., 1992, ApJS, 78, 87.

Majewski, S.R., Munn, J.R. & Hawley, S.L. 1994, ApJ, 427, L37.

Majewski, S.R., Munn, J.R. & Hawley, S.L. 1996, ApJ(in press)

Morrison, H.L., Flynn, C. & Freeman, K.C. 1990, AJ, 100, 1191.

Pier, J.R., 1983, ApJS, 53, 791.

Pier, J.R., 1984, ApJ, 281, 260.

Pier, J.R., 1996, In Preparation.

Preston, G.W., Shectman, S.A. & Beers, T.C. 1991, ApJ, 375, 121.

Ratnatunga, K.U. & Freeman, K.C. 1989, ApJ, 339, 126.

Sanduleak, N., 1988, ApJS, 66, 309.

Sommer-Larsen, J. & Christensen, P.R. 1989, MNRAS, 239, 441.

Sommer-Larsen, J. & Zhen, C. 1990, MNRAS, 242, 10.

Tonry, J. & Davis, M. 1979, AJ, 84, 1511.
White, S.D.M. 1989, MNRAS, 237, 51P.
Velazquez, H. & White, S.D.M. 1995, Preprint
Woolley, R. & Savage, A. 1971, Roy. Obs. Bull., 19, (No. 170), 363.
Woolley, R. 1978, MNRAS, 184, 311.
Fig. 1.— Mean radial velocities (in km s\(^{-1}\)) of program stars as function of their distance \(Z\) (in kpc) above the Galactic plane. The BHB stars are shown by filled circles and the RR Lyrae stars by triangles.

Fig. 2.— The galactic rotation V-vector on a plot of the transverse velocities (in km s\(^{-1}\)) in declination (ordinate) and R.A. (abscissa) for (a) SA 57 and (b) RR 7. Stars with \(Z \leq 4\) kpc are shown by filled circles; stars with \(4 \leq Z \leq 6\) kpc by open circles; stars with \(6 \leq Z \leq 12\) kpc (SA 57 only) by a filled triangle. The dashed line shows the orientation of the V vector in each field; the numbers show the size of the vector in km s\(^{-1}\). The V value at any point is given by its perpendicular projection onto the V-axis.
Kinman et al. Figure 1
Kinman et al. Figure 2
TABLE 1. Mean Radial Velocities and their Dispersions for RR Lyrae and BHB stars in Three Fields near the North Galactic Pole.

TABLE 2. Collected Data for RR Lyrae and BHB stars in Field RR 2 which may have a common origin.
### TABLE 2
Collected Data for RR Lyrae and BHB stars in Field RR 2 which may have a common origin.

| Star Type | RA (1950) | Dec | B (mag) | Rad. Vel. (km/s) | Z (kpc) | [Fe/H] |
|-----------|-----------|-----|---------|-----------------|---------|--------|
| Var. 6a   | RRab      | 12:10:56.7 | +31:41:01 | 16.2       | −88     | 10.7   | −1.2c  |
| AF 11b    | BHB       | 12:03:46.6 | +32:08:18 | 16.0       | −90     | 10.3   | −1.7d  |
| AF 38b    | BHB       | 12:12:30.5 | +32:19:00 | 15.7       | −88     | 8.6    | −1.4d  |

a Kinman et al. (1966).
b Sanduleak (1988).
c As measured by Butler et al. (1979) but on the system of Suntzeff et al. (1991).
d From provisional measurements of the Ca II (λ3933) and Mg II (λ4481) lines using the precepts of Kinman et al. (1994).