Statistical Parallax Analysis of RR Lyrae Stars

Suzanne L. Hawley and Christopher Hanley

Michigan State University, E. Lansing, MI 48824

Andrew C. Layden

McMaster University, Hamilton, ON L8S 4M1, Canada

Robert B. Hanson

Lick Observatory, Santa Cruz, CA 95064

Abstract. We present results from a new statistical parallax analysis of the field RR Lyrae stars. New and improved data, together with a careful population separation, allow us to investigate the dependence of the RR Lyrae absolute magnitude on metallicity.

1. Introduction

The absolute magnitude of the RR Lyrae stars is integral to determining the distances to old stellar systems in our Galaxy and other nearby galaxies. The variation in absolute magnitude with metal abundance [Fe/H] is also a key to deriving the age spread and age-metallicity relation in the Galactic globular cluster system, which in turn places important constraints on Galactic formation scenarios.

A number of methods have been used to estimate the RR Lyrae absolute magnitude, including Baade-Wesselink (surface brightness) analyses (Jones et al. 1992), main sequence fitting of globular clusters (Buonanno et al. 1988), application of stellar pulsation theory to field stars (Sandage & Cacciari 1990), horizontal branch evolution theory (Lee et al. 1990) and previous applications of the statistical parallax method (Hawley et al. 1986, Strugnell et al. 1986). Carney et al. (1992) reviewed these recent efforts and formed an absolute magnitude – metallicity relation using several of the methods. There is still a rather large zero point discrepancy between the statistical parallax value (from field stars) and many of the globular cluster and theoretical methods.

Recent improvements in the data available for the local field RR Lyrae stars make it an opportune time for a new statistical parallax investigation. We follow the method of Hawley et al. 1986, using improved data, more stars, and with more care in the population separation in order to determine whether a trend in the absolute magnitude with metallicity can be detected.

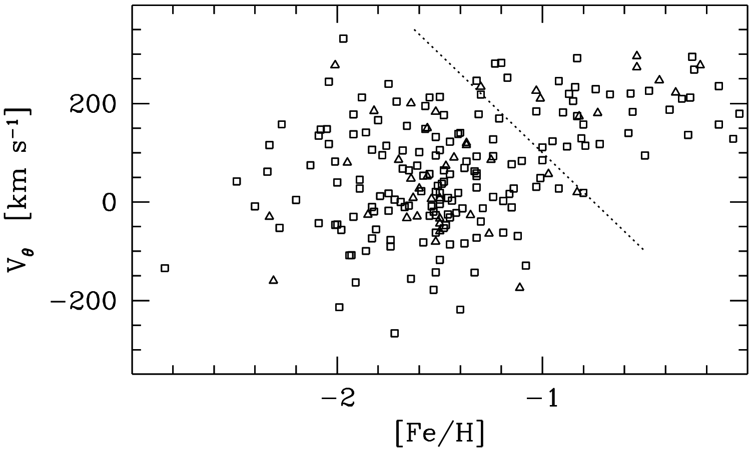

Figure 1. The rotational component of space velocity plotted against abundance for the 214 stars in our sample. Squares mark stars with NPM proper motions, and triangles mark stars with proper motions from the literature. The dotted line is described in the text.

2. Method

We used a maximum likelihood model as in Hawley et al. 1986 (taken originally from Murray 1983) to solve for the three components of solar motion, six components of the velocity ellipsoid (three velocity dispersions, three unit vectors), the absolute magnitude and its dispersion. All eleven paramters were allowed to vary independently and simultaneously. A geometric minimization technique known as simplex optimization was used to solve the equations and find the maximum likelihood solution.

The improvements in this study include better proper motions (from the Northern Proper Motion survey, see Klemola, Hanson & Jones 1995), new and improved abundances, radial velocities and photometry (Layden 1994), and the addition of about 70 new stars to the sample. The technique for calculating errors from the method was refined. Also, we now include a separation of disk and halo populations on the basis of metallicity and kinematics (see below) in order to define homogeneous subsamples for analysis.

3. Population Separation

For a first cut at population separation, we adopt provisional distances from Layden (1994), using $M_v = 0.15$ [Fe/H] + 1.01 (Carney et al. 1992); the choice of this relation does not significantly affect the population separation. Using distances, proper motions and radial velocities, we then obtain space motions (V_π, V_θ, V_Z) and plot the velocity components against each other and against metallicity to isolate regions where the disk and halo components are well separated (although we note that there is always some overlap). Figure 1 shows V_θ plotted as a function of [Fe/H] for our sample. We then obtain three definitions for the disk and halo, and determine statistical parallax solutions for each set of definitions. Finally, we split the halo #2 sample (see below) further into two groups with [Fe/H] ≤ -1.6 and [Fe/H] > -1.6. The final definitions we adopt are:

DEFINITION 1

Disk-1: all stars with [Fe/H] > -1.0 and $V_\theta > 80$ km s^{-1}.

Halo-1: all other stars

DEFINITION 2

Disk-2: all stars lying at higher (positive) velocity and higher metallicity, above/rightward of dotted line given by $V_\theta = -400$ [Fe/H] $- 300$ km s^{-1} in plot of V_θ vs. [Fe/H] (Figure 1).

Halo-2: all stars lying at lower (negative) velocity and lower metallicity, below/leftward of this line. Halo-2a consists of Halo-2 stars with [Fe/H] > -1.6; Halo-2b has stars with [Fe/H] ≤ -1.6.

DEFINITION 3

Disk-3: all stars in definition 2 *plus* all stars meeting all of requirements for metal weak, "disk-like" stars: $|V_\pi| < 100$ km s^{-1}, $V_\theta > 80$ km s^{-1}, $|V_Z| < 60$ km s^{-1}, $|Z| < 1.0$ kpc, [Fe/H] > -1.6

Halo-3: all stars not meeting disk requirements

Table 1 shows the results we have obtained thus far, for these population definitions and for the additional halo subsamples from definition 2.

4. Conclusions and Future Work

Our conclusions are as follows:

1. The kinematics of the thick disk and halo RR Lyrae stars found here are in excellent agreement with other recent work on RR Lyrae stars (Layden 1995) and with other old stellar components of the Galaxy (cf. Majewski 1993).

2. The mean absolute magnitude of the halo RR Lyrae is well determined: $M_V = 0.74 \pm 0.12$ mag at [Fe/H] $= -1.6$ dex.

3. The formal solution for the thick disk RR Lyrae stars gives $M_V \sim 1.1 \pm 0.35$ mag at [Fe/H] ~ -0.6 dex. The small number of stars in the disk samples make this result less robust.

4. The halo M_V value is in good agreement with the previous statistical parallax analyses (Hawley et al. 1986; Strugnell et al. 1986) and with Baade-Wesselink results (Carney et al. 1992). It is still in disagreement with values found from globular cluster fitting and theoretical period/evolution models.

Table 1. Statistical Parallax Results

Sample	N	⟨[Fe/H]⟩	U[a,b]	V	W	σ_U	σ_V	σ_W	M_V
Disk-1	39	−0.58	1	−29	−12	53	50	26	1.12 ± 0.38
Halo-1	175	−1.58	−1	−183	−4	160	107	92	0.75 ± 0.12
Disk-2	45	−0.66	−4	−21	−11	47	45	26	1.19 ± 0.36
Halo-2	169	−1.60	1	−192	−4	164	102	94	0.74 ± 0.12
Halo-2a	96	−1.37	−20	−194	−7	171	91	93	0.78 ± 0.15
Halo-2b	73	−1.90	28	−188	2	149	116	96	0.76 ± 0.18
Disk-3	52	−0.76	−2	−32	−8	53	50	29	0.96 ± 0.31
Halo-3	162	−1.61	0	−197	−4	167	101	96	0.74 ± 0.12

[a](U,V,W) are the velocity components relative to the Local Standard of Rest; σ's are the velocity dispersions. Both have units of km s^{-1}.

[b]Velocity components and dispersions have uncertainties of order 10 km s^{-1}.

We are currently working on incorporating the metallicity dependence, $M_V = a * [Fe/H] + b$, directly into the maximum likelihood solution. We are also performing Monte Carlo simulations to assess the reliability of the solutions with small samples.

References

Buonanno, R., Corsi, C.E. & Fusi Pecci, F. 1989, å, 216, 80

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

Hawley, S.L., Jefferys, W.H., Barnes, T.G. III & Wan Lai 1986, ApJ, 302, 626

Jones, R.V., Carney, B.W., Storm, J. & Latham, D. 1992, ApJ, 386, 646

Klemola, A.R., Hanson, R.B. & Jones, B.F. 1995, AJ, in press

Layden, A.C. 1994, AJ, 108, 1016

Layden, A.C. 1995, AJ, in press

Lee, Y.-W., Demarque, P. & Zinn, R.J. 1990, ApJ, 350, 155

Majewski, S.R. 1993, ARA&A, 31, 575

Murray, C.A. 1983, *Vectorial Astrometry*, (Bristol:Adam Hilger Ltd.)

Sandage, A. & Cacciari, C. 1990, ApJ, 350, 645

Strugnell, P., Reid, I.N. & Murray, C. 1986, MNRAS, 220, 413