COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS

Number 5459

Konkoly Observatory
Budapest
9 October 2003

HU ISSN 0374 – 0676

REVISED [Fe/H] AND RADIAL VELOCITIES FOR 28 DISTANT RR LYRAE STARS

PIER, J. R.[1]; SAHA, A.[2]; KINMAN, T. D.[2]

[1] U.S. Naval Observatory, Flagstaff Station, P.O. Box 1149, Flagstaff, Arizona 86002-1129, USA.

[2] NOAO[†], P.O.Box 26732, Tucson, Arizona 85726, USA; email: kinman@noao.edu

We discuss 20 RR Lyrae stars found in the Anticenter fields of the Lick Survey (Kinman, Mahaffey and Wirtanen (1982) (KMW) and 8 RR Lyrae variables discovered by Saha (1984). Butler, Kemper, Kraft and Suntzeff (1982)(BKKS) have given abundances for the Lick Survey stars; Saha and Oke (1984)(SO) gave both abundances and radial velocities for 7 of the 8 Saha stars discussed here. We give both abundances and radial velocities for all these stars with improved accuracy and on a common system. Our spectra were obtained in 1983 with the intensified image dissector scanner (IIDS) attached to the Gold spectrograph on the KPNO 2.1-m telescope. For calibration we observed 18 brighter RR Lyrae stars for which Suntzeff, Kinman & Kraft (1991) (SKK) have given the Preston ΔS (Preston, 1959) and [Fe/H] on the Zinn-West system. The phases (ϕ) for the program stars were computed using the ephemerides of KMW and Saha (1984). The ephemerides for the brighter RR Lyrae stars were taken from the GCVS (`http://www.sai.msu.su/groups/cluster/gcvs`) and supplemented by those given in the Hipparcos Catalogue (Vol. 11) (1997) and by ephemerides derived from unpublished photometry by Kinman.

The abundances were determined by measuring the equivalent widths of the Ca II K-line, and the Balmer lines H_γ and H_δ. The Preston index ΔS was determined from these equivalent widths on a plot of the K-line equivalent width against the mean of the Balmer equivalent widths on which a grid of ΔS curves was superposed (see SO, Fig. 3). The grid was calibrated by using the 18 RR Lyrae stars whose ΔS is known from SKK. The ΔS for the program stars were then converted to [Fe/H] using the formula given by SKK (Eqn. 3). This formalism strictly applies only to the type *ab* RR Lyrae stars. We also applied it to the type *c* variables because our single calibrating star of type *c* (T Sex) showed no difference from those of type *ab* on the calibrating plot. The results are given in Table 1. The mean ΔS quoted from BKKS omits the spectra which they took on the rising branch; the number of their spectra (N) in col. (6) are only those in the range $0.00 \leq \phi \leq 0.85$. [Fe/H] was derived from their ΔS using the conversion of SKK. In the case of our data, we only derived ΔS from spectra whose ϕ was in the range 0.40 to 0.85 (i.e. near minimum) and (unlike BKKS) no phase correction was applied to our ΔS. The quality of our spectra and those of BKKH is similar, so our adopted [Fe/H] is the mean of our new [Fe/H] and those from BKKH data weighted by N the number of spectra. We adopted the [Fe/H] from our new data alone for the remaining stars.

[†]The National Optical Astronomy Observatories are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation

Table 1. Abundances of the RR Lyrae Variables.

Identification				Previous Data			New Data			
GCVS[1]	KMW[2]	Saha[3]	RR Type	ΔS Source	N	[Fe/H] Source	ΔS[4]	N	[Fe/H]	Adopted [Fe/H]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
LV And	01	···	ab	6.8(a)	3	−1.48(c)	7.7	3	−1.62	−1.55
MP And	12	···	ab	6.8(a)	2	−1.48(c)	8.0	2	−1.67	−1.57
MR And	14	···	c	5.6(a)	3	−1.29(c)	5.2	2	−1.23	−1.26
MU And	18	···	ab	7.2(aA)	4	−1.55(c)	7.7	2	−1.62	−1.57
MV And	20	···	ab	8.2(a)	3	−1.70(c)	9.3	3	−1.88	−1.78
DU And	21	···	ab	11.0(aA)	2	−2.15(c)	10.6	2	−2.08	−2.11
MX And	23	···	ab	7.6(aA)	2	−1.61(c)	6.4	2	−1.42	−1.50
MY And	24	···	ab	5.2(a)	3	−1.23(c)	6.7	2	−1.47	−1.32
VX Lyn	34	II v104	ab	7.4(a)	2	−1.58(c)	(8.0)	0	···	−1.58
VY Lyn	35	···	c	7.8(a)	3	−1.64(c)	6.0	1	−1.36	−1.57
VZ Lyn	36	···	c	6.8(a)	1	−1.48(c)	6.9	1	−1.50	−1.48
WX Lyn	38	II v208	ab	9.6:(a)	1	−1.92:(c)	7.0	1	−1.51	−1.72
YY Lyn	44	···	c	9.6(a)	1	−1.92(c)	9.0	1	−1.83	−1.87
ZZ Lyn	46	III v201	ab	6.4(a)	2	−1.42(c)	(5.8)	0	···	−1.42
RW Lyn	48	···	ab	7.1(a)	3	−1.53(c)	(7.4)	0	···	−1.53
AC Lyn	50	III v204	ab	6.2(aA)	2	−1.39(c)	7.8	2	−1.64	−1.50
AD Lyn	52	···	c	6.6(a)	1	−1.45(c)	6.7	1	−1.47	−1.46
AF Lyn	55	···	ab	7.0(a)	3	−1.51(c)	8.3	1	−1.72	−1.56
AK Lyn	60	···	ab	7.8(aA)	1	−1.64(c)	6.9	1	−1.50	−1.56
AL Lyn	61	···	ab	9.9(aA)	1	−1.97(c)	9.0	1	−1.83	−1.90
KO Peg	···	IV v103	ab	9.4(b)	1	−1.7 (b)	10.9	1	−2.13	−2.13
KM Peg	···	IV v104	ab	7.7(b)	1	−1.5 (b)	6.0	1	−1.36	−1.35
KL Peg	···	IV v106	ab	4.9(b)	1	−1.0 (b)	6.1	1	−1.37	−1.36
KN Peg	···	IV v107	ab	7.7(b)	1	−1.5 (b)	7.5	1	−1.59	−1.59
NO And	···	IV v108	c	···	···	···	8.0	1	−1.67	−1.67
NN And	···	IV v201	ab	8.8(b)	1	−1.6 (b)	6.0	2	−1.36	−1.35
NQ And	···	IV v301	ab	8.6(b)	1	−1.6 (b)	6.2	1	−1.39	−1.38
IQ Peg	···	IV v401	ab	6.9(b)	1	−1.3 (b)	7.0	1	−1.51	−1.51

[1] GCVS (http://www.sai.msu.su/groups/cluster/gcvs)
[2] Kinman, Mahaffey and Wirtanen (1982) (KMW)
[3] Saha (1984)
[4] Parentheses indicate ΔS derived from observations not at minimum light
Sources of Data:
(a) Butler, et al. (1982) (BKKS); (aA) adjusted from BKKS (see text)
(b) Saha and Oke (1984)
(c) Derived from ΔS using equation (3) in Suntzeff et al. (1991) (SKK)

The mean difference between the adjusted mean values of ΔS from BKKS and our new values is $+0.03\pm0.03$. The corresponding difference between the estimates of [Fe/H] is -0.00 ± 0.05.

Radial velocities were determined from the IIDS spectra by a Fourier method (Pier, 1983) in which the program spectra are cross correlated with that of a star of known velocity; the velocity in this case is defined by both the Balmer and weak metal lines. The velocity was also derived from the three strong lines (H_γ, H_δ and the Ca II K-line) and weights of 2, 1 and 0 were given if the σ_{rms} of a single line was < 40 km s^{-1}, between 40 and 70 km s^{-1} or >70 km s^{-1} respectively.

The γ-velocity was derived for type *ab* stars using the recipe given by Liu (1991). For type *c* stars, we scaled the velocity curve of T Sex by the relative V-amplitudes and got

Table 2. Radial Velocities of the RR Lyrae Variables.

Variable	RR Type	Saha & Oke (1984) Rad. Vel. km s^{-1}	N[1]	IIDS Spectra Rad. Vel.[2] km s^{-1}	Wt[3]	Rad.Vel.[4] km s^{-1}	Wt[3]	Adopted Rad. Vel. km s^{-1}
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
LV And	ab	···	···	−028.1	8	−038.4	4	−031.5
MP And	ab	···	···	−102.6	4	−104.1	4	−103.4
MR And	c	···	···	−081.7	4	−079.6	4	−080.6
MU And	ab	···	···	−099.6	4	−091.7	4	−095.6
MV And	ab	···	···	−066.1	8	−068.2	8	−067.2
DU And	ab	···	···	−343.0	4	−362.3	3	−351.3
MX And	ab	···	···	···	···	−187.8	2	−187.8
MY And	ab	···	···	−138.8	4	−130.3	4	−134.6
VX Lyn	ab	+48±23	1	−024.9	4	+027.5	4	+001.3
VY Lyn	c	···	···	+103.9	2	+125.1	2	+114.5
VZ Lyn	c	···	···	−167.4	2	−196.8	2	−182.1
WX Lyn	ab	+2±20	2	+020.2	4	+034.4	3	+026.3
YY And	c	···	···	−082.3	4	−103.9	4	−093.1
ZZ Lyn	ab	+255±54	1	+157.0	2	+137.5	2	+147.2
RW Lyn	ab	···	···	−140.7	4	−158.9	4	−149.8
AC Lyn	ab	···	···	−022.5	4	−029.0	4	−025.8
AD Lyn	c	···	···	+124.0	2	+123.2	2	+123.6
AF Lyn	ab	···	···	−108.0	2	−149.0	1	−121.7
AK Lyn	ab	···	···	+234.8	2	+243.1	1	−237.6
AL Lyn	ab	···	···	−058.0	4	−073.6	4	−065.8
KO Peg	ab	−272±25	1	−342.9	2	−331.1	2	−335.0
KM Peg	ab	−164±25	1	−230.1	2	−235.7	2	−233.8
KL Peg	ab	−342±35	1	−393.8	2	−376.9	2	−382.5
KN Peg	ab	−74±36	1	−194.9	2	−199.4	1	−196.4
NO And	c	···	···	−079.7	2	−064.2	1	−074.5
NN And	ab	−276±24	1	−293.5	4	−305.0	3	−298.4
NQ And	ab	−235±29	1	−247.7	2	−240.5	2	−242.9
IQ Peg	ab	−207±34	1	−203.5	2	−203.9	2	−20-3.7

Notes:
[1] No. of spectra [3] Weight as described in text
[2] Derived by Fourier method. [4] Derived from H_γ, H_δ and the Ca II K-line.

a correction from that. For the type *ab* variable SU Dra, the velocity amplitude of H_γ is about 100 km s^{-1} compared with 60 km s^{-1} for the weaker metal lines (Oke, Giver & Searle, 1962). The use of the Liu-correction could therefore produce systematic effects in the difference (D) between the velocity based on the strong lines and that based on the weaker lines: D should be positive just before phase zero and negative just after. We did not observe this and conclude that the effect is too small to affect our results. The mean difference $\langle D \rangle$ is -3.7 ± 4.9 km s^{-1} so there is no systematic difference between the two methods. The rms value of D for each star is 21 km s^{-1}; on average therefore, these adopted velocities have an error of about ±15 km s^{-1}.

In Table 3 we give the most recent coordinates for these variables. These have been taken from the USNO-B1.0 Catalog (Monet et al., 2003) and checked against the original finding charts using the Digital Sky Survey (`http://cadcwww.dao.nrc.ca/dss/`).

Table 3. Coordinates of the RR Lyrae Variables.

Variable	⟨V⟩ (mag.)	J2000 R.A.	J2000 Dec.	Variable	⟨V⟩ (mag.)	J2000 R.A.	J2000 Dec.
LV And	15.44	02 19 26.39	+41 45 57	RW Lyn	12.91	07 50 39.18	+38 27 15
MP And	16.13	02 24 13.74	+41 19 47	AC Lyn	16.38	07 54 42.16	+38 54 21
MR And	15.56	02 25 27.81	+40 57 26	AD Lyn	15.85	07 56 22.99	+39 22 59
MU And	16.00	02 29 26.44	+39 31 45	AF Lyn	16.12	08 35 57.43	+41 01 11
MV And	15.99	02 30 12.29	+40 53 15	AK Lyn	16.00	08 45 55.10	+39 14 55
DU And	13.59	02 30 31.33	+40 50 34	AL Lyn	16.52	08 49 13.07	+38 49 31
MX And	17.18	02 32 03.09	+42 08 31	KO Peg	16.03	00 02 15.33	+30 04 37
MY And	15.56	02 32 09.47	+43 04 47	KM Peg	17.67	23 55 45.11	+29 09 52
VX Lyn	17.01	07 31 51.83	+39 07 48	KL Peg	16.85	23 46 57.08	+29 51 02
VY Lyn[1]	15.75	07 32 26.04	+38 50 07	KN Peg	17.44	23 56 46.56	+31 40 23
VZ Lyn	16.20	07 32 40.75	+41 37 39	NO And	16.54	00 06 58.32	+32 02 07
WX Lyn	16.84	07 35 38.47	+39 15 27	NN And	16.68	00 06 55.84	+31 28 13
YY Lyn	14.98	07 45 30.07	+37 22 59	NQ And	16.31	00 11 32.68	+30 51 41
ZZ Lyn	15.80	07 50 21.77	+37 42 00	IQ Peg	16.11	00 06 05.68	+29 19 13

Notes:
[1] The catalog lists two stars of similar brightness close to this position. The DSS only shows one star.

References:

Butler, D., Kemper, E., Kraft, R. P., and Suntzeff, N. B., 1982, *AJ*, **87**, 353 (BKKS)

ESA (1997), *The Hipparcos & Tycho Catalogues* (**Vol. 11**), (ESA SP-1200) (Noordwijk: ESA)

Kinman, T. D., Mahaffey, C. T. and Wirtanen, C. A. 1982, *AJ*, **87**, 314 (KMW)

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

Monet, D. G., Levine, S. E., Casian, B. et al. 2003, *AJ*, **125**, 984

Oke, J. B., Giver, L. P., and Searle, L. 1962, *ApJ*, **136**, 393

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

Preston, G. W., 1959, *ApJ*, **130**, 507

Saha, A. 1984, *ApJ*, **283**, 580

Saha, A. and Oke, J. B. 1984, *ApJ*, **285**, 688 (SO)

Suntzeff, N. B., Kinman, T. D., Kraft, R. P. 1991, *ApJ*, **367**, 528, (SKK)