Photometry and Parallaxes of 9 Metal-Poor Stars

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ABSTRACT

Stellar evolution models and isochrones of metal-poor stars are widely used in astrophysics. However, there are few observational tests of the validity of these models below metallicities of [Fe/H] = -1.5. To remedy this situation, HST has determined parallaxes for 9 metal-poor main sequence stars. Here, we present a collection of photometry of these stars. The observations were obtained from a variety of sources, including HST, MDM, New Mexico State Univeristy, and the database of Weis et al. Our photometry is compared to literature values and combined with parallax results to obtain absolute magnitudes for these stars. The locations of the stars on a color-magnitude diagram are compared to theoretical models.

ATTEMPTED CONTRIBUTION TO PHOTOMETRY

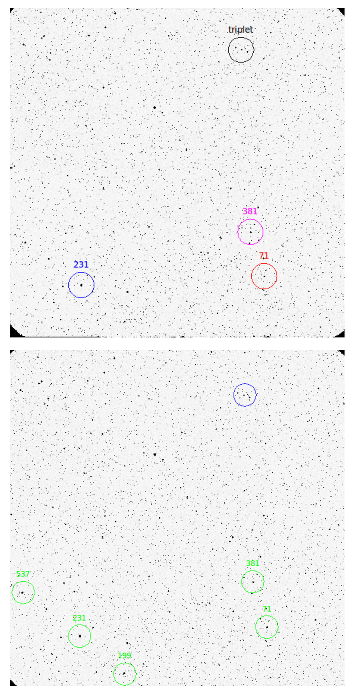


Figure : Locating Landolt stars

Additional data on the metal-poor stars were collected over the course of 5 nights at MDM in the Spring of 2012. Standard data reduction routines in IRAF revealed that two of the nights would not provide useful information. Measurements of Landolt standard stars with literature values were used to fit photometric equations to the remaining data. These equations (1-3) were applied to the data from nights 2 and 3 in two filters and to night 4 in three filters:

$$B_{obs} = B_{known} + \beta_1(B-V) + \gamma_1 X + \alpha_1 \quad (1)$$

$$V_{obs} = V_{known} + \beta_2(B-V) + \gamma_2 X + \alpha_2 \quad (2)$$

$$R_{obs} = R_{known} + \beta_3(I-R) + \gamma_3 X + \alpha_3 \quad (3)$$

where X is the airmass, B-V and I-R are color terms, and α, β, γ are the fit coefficients.

Due to large color terms across the nights and an unphysical airmass term in the R-fit of night 4, it was determined that the CCD likely had a leak. Hence, the data from this observing run are not used.

PRESENTATION OF PHOTOMETRY

Net Photometry of 9 High-Parallax Stars

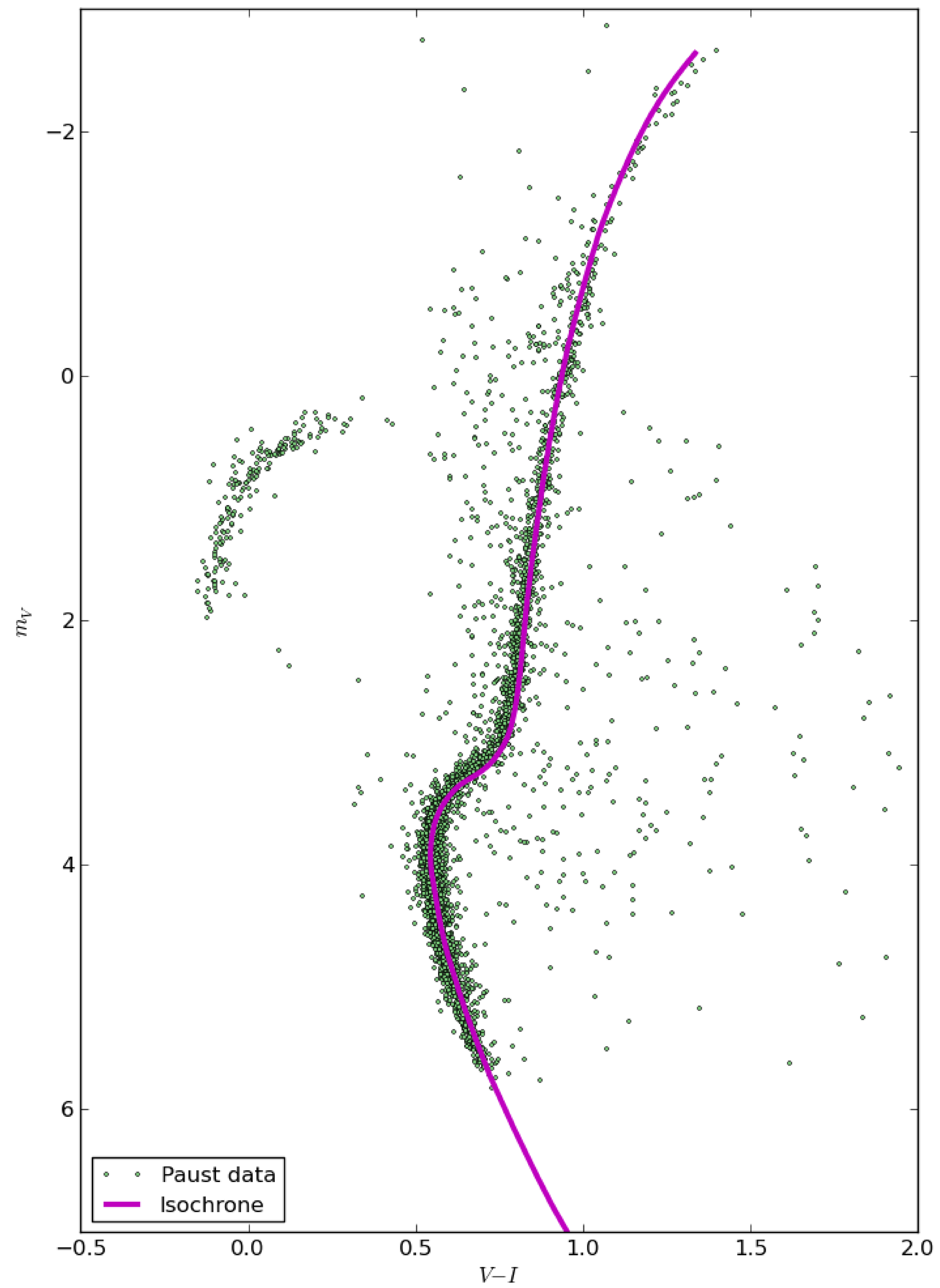
Star	source	B	V	R	I
HIP 46120	HST	N/A	10.10	N/A	9.35
	Average:	N/A	10.10	N/A	9.35
HIP 54639	HST	12.04	11.35	N/A	10.44
	MDM	12.08	11.38	10.93	10.47
	Average:	12.06	11.37	10.93	10.45
HIP 56291	HST	N/A	11.52	N/A	10.65
	MDM	12.25	11.57	11.17	10.73
	Weis et al.	12.22	11.54	11.22	10.89
	Average:	12.24	11.54	11.19	10.76
HIP 87062	HST	N/A	10.56	N/A	9.72
	NMSU	11.16	10.57	10.20	9.74
	MDM	11.15	10.56	10.19	9.74
	Average:	11.16	10.56	10.20	9.73
HIP 87788	HST	N/A	11.30	N/A	10.44
	NMSU	12.07	11.33	10.94	10.46
	MDM	11.93	11.29	10.91	10.46
	Average:	12.00	11.31	10.92	10.45
HIP 98492	HST	N/A	11.56	N/A	10.73
	NMSU	12.23	11.58	11.19	10.78
	MDM	12.190	11.570	11.180	10.771
	Average:	12.210	11.570	11.185	10.759
HIP 103269	HST	N/A	10.25	N/A	9.48
	NMSU	10.92	10.28	9.90	9.49
	MDM	10.88	10.29	9.92	9.54
	Average:	10.90	10.27	9.91	9.50
HIP 106924	HST	N/A	10.33	N/A	9.53
	NMSU	10.99	10.42	9.99	9.55
	MDM	10.96	10.36	10.00	9.61
	Average:	10.98	10.37	9.99	9.56
HIP 108200	HST	N/A	10.97	N/A	10.12
	NMSU	11.64	10.97	10.57	10.14
	MDM	11.67	11.00	10.60	10.18
	Weis et al.	11.69	11.01	10.68	10.37
	Average:	11.67	10.99	10.62	10.20

MAIN SEQUENCE FITTING

Metal-Poor Globular Cluster

The globular cluster M92 is famously metal-poor, placing its cosmological age near that of the Universe, $\approx$ 13.7 Gyr. Its metallicity is given as -2.38 by Kraft et al., 2008 and as -2.35 by Carretta et al., 2009. The average of these values, [Fe/H]= -2.365, fits nicely with our four best-fit metal-poor stars, HIP 46120, HIP 87788, HIP 103269 and HIP 106924. The distance modulus to M92 is estimated using these.

The color-magnitude diagram below is generated from a catalog of approximately 34,000 stars in M92 (Paust et al., 2007). The stars are compared to the mean ridge line of M92 using the known reddening $E(B-V) = 0.02$. The distance modulus based on the four best-fit metal-poor stars is found to be $m_v - M_v = 14.7 \pm 0.1$. We apply the reddening shift and distance modulus to an isochrone of 14.0 Gyr, and superimpose this on low error ($\sigma = 0.01$) selected photometry of M92.



ACKNOWLEDGEMENTS

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References:

Paust, N. E. Q. et al. 2007, ApJ, 113:2787-2798
Sirianni, M. et al. 2005 PASP, 117, 1049
Stetson, P. B. 2000, PASP, 11, 925
Weis, E. W. et al. 1996, ApJ, 112-5

PRESENTATION OF MAGNITUDES

Absolute Magnitudes of 8 Metal-Poor Stars

HIP Star	[Fe/H]	E(B-V)	A_v	M_v	σ M_v
46120	-2.34	0.0	0.000	6.019	$\pm$ 0.032
54639	-2.49	0.0	0.000	6.604	$\pm$ 0.034
87062	-1.62	0.06	0.199	5.521	$\pm$ 0.047
87788	-2.39	0.0	0.000	6.491	$\pm$ 0.044
98492	-1.28	0.08	0.256	4.515	$\pm$ 0.081
103269	-1.89	0.0	0.000	6.022	$\pm$ 0.028
106924	-2.23	0.0	0.000	6.173	$\pm$ 0.033
108200	-1.83	0.02	0.065	6.520	$\pm$ 0.027

Magnitudes are computed using parallax values and the distance modulus:

$$m_v - M_v = 5\log_{10}(d) - 5 - A_v$$

Error is computed from an estimated 10% error in the reddening and known error in the parallax.

COMPARISON TO ISOCHRONES

We present an HR diagram composed of the 8 metal-poor stars with three 12 Gyr isochrones overlaid. Isochrones at metallicities of -1.5, -2.0, and -2.5 are shown.

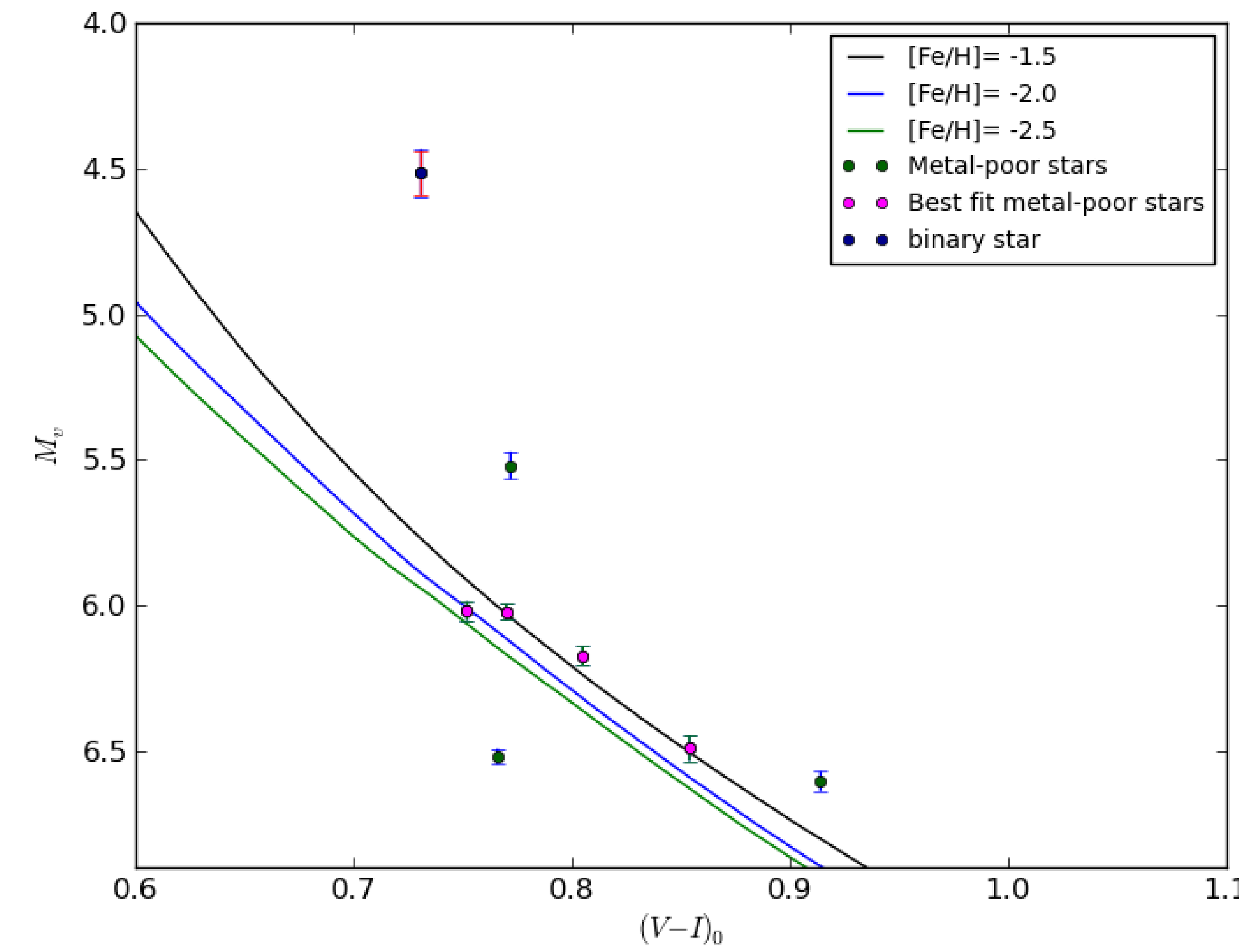

Figure : The four metal-poor stars which fit well to the isochrones, elsewhere referred to as the "best-fit" stars, are HIP 46120, HIP 87788, HIP 103269 and HIP 106924. The three stars shown in green are outliers which do not fit well to the isochrones. It has been recognized that the star shown in blue is actually a binary; hence we do not expect it to fit among the regular metal-poor stars. All of the isochrones presented have [α / Fe] = +0.4

PHOTOMETRY OF THE PARALLAX STARS

All of the program stars were observed by ACS/WFC in the F606W and F814W filters. This photometry was transformed to ground based V and I photometry using the Sirianni et al. (2005) transformations. Ground based photometry in BVRI was obtained on the MDM 1.3meter telescope on Kitt Peak using the a 4K CCD detector over the course of 9 nights in 2009. Transformation to the standard system was accomplished using multiple observations of Stetson (2000) standard star fields. In 2009, photometry of the program stars were also obtained at the NMSU 1.0meter telescope at Apache Point observatory.