

# Star Clusters in the Galactic Anticenter Stellar Structure: New Radial Velocities & Metallicities

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**Abstract.** The Galactic Anticenter Stellar Structure (GASS) has been identified with excess surface densities of field stars in several large area sky surveys, and with an unusual, string-like grouping of star clusters. Some members of the cluster grouping have radial velocities (RVs) consistent with the observed GASS velocity-longitude trend. We provide new RV measurements of stars in six clusters that have been suggested to be associated with the GASS. We show that the RVs of at least four clusters are consistent with the previously measured RV trend for GASS. We also derive spectroscopic metallicities for four clusters, and provide an improved age-metallicity relation for the clusters apparently associated with GASS.

We have found that the outer most open clusters found to date seem to be strung along the Galactic anticenter stellar structure (GASS) [5]. This structure [8], [10], [6], [7], [9], [4] was discovered as an excess of stars beyond the apparent limit of the Galactic disk. Previous work [4] has resulted in a number of parameters of the stream including: (1) a velocity-longitude trend indicating a slightly non-circular orbit, (2) a velocity dispersion smaller than even that of disk stars, (3) a wide metallicity spread from  $-1.6 < [\text{Fe}/\text{H}] < -0.4$ .

Spectra for stars in the clusters Berkeley 29, BH 176, and Saurer 1 were collected with the Hydra Spectrograph and clusters Berkeley 22, BH 144 (ESO 096-SC04), and ESO 093-SC08 were collected using the RC Spectrograph on the Blanco 4-meter telescope. The data were reduced using standard IRAF reduction methodology with RVs determined using `fxcor`. The CaII infrared triplet was measured using the index definitions of [1], transformed to the common system derived in [3]. The resulting RVs and metallicities are presented in Table 1. The typical error in the metallicities ( $\sigma_{[\text{Fe}/\text{H}]}$ ) are  $\sim 0.3$  dex. All clusters measured are shown with the GASS longitude-velocity ( $l$  vs.  $V_{gss}$ ) trend (Fig. 1a) and members are used to produce an age-metallicity relation (Fig. 1b). We find that the clusters Berkeley 29, Saurer 1, ESO 0903-SC08, and possibly BH 144 & 176, have RVs consistent with being part of the GASS cluster system; however, further work is needed to confirm actual membership in GASS.

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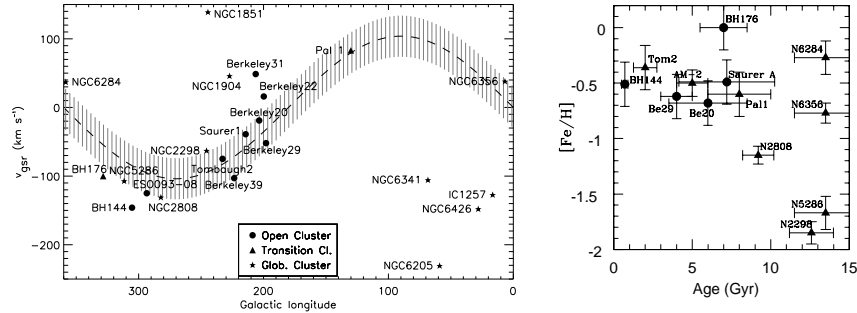
**Table 1.** GASS Cluster Candidate Radial Velocities and Metallicities

Cluster	$l$	$b$	# stars Metallicity(RV)	$V_r$ (km/s)	$V_{gsr}$ (km/s)	[Fe/H]	GASS?
Berkeley 22	199.8	-8.1	4(5)	$106 \pm 9$	+16	-0.97	N
Berkeley 29	198.0	+8.0	8(8)	$26 \pm 6$	-52	-0.62	Y
Berkeley 20	203.5	-17.3	3(3)	$78 \pm 6$	-19	-0.68	(Cal)
Saurer 1	214.3	-6.8	2(4)	$98 \pm 9$	-39	-0.49	Y <sup>1</sup>
Berkeley 39	223.5	+10.1	19(19)	$59 \pm 4$	-103	-0.27	(Cal)
ESO093-SC08	293.5	-4.0	0(1)	$86 \pm 10$	-125	.....	Y
BH 144 (ESO096-SC04)	305.3	-3.2	2(3)	$40 \pm 10$	-146	-0.51	? <sup>2</sup>
47 Tuc	305.9	-44.9	5(.)	.....	.....	-0.78	(Cal)
BH 176	328.4	-4.3	0(3)	$13 \pm 5$	-100	.....	Y <sup>2</sup>

<sup>1</sup>We find Saurer 1 to be a member due to its  $V_{gsr}$ ; [2] did not correct this RV to  $V_{gsr}$  before incorrectly excluding Saurer 1 from the GASS member clusters. <sup>2</sup> It is noted from the spatial distribution of the clusters that GASS should have an elliptical orbit. If this change is made, BH 144 and BH 176, along with NGC5286 and NGC 2808, should fit the corrected  $l - v_{GSR}$  trend.

## References

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**Fig. 1.** (a, left) The  $l - v_{GSR}$  distribution of objects lying within 2.35 kpc of the GASS cluster plane. The hash marks represent a velocity dispersion of  $30 \text{ km s}^{-1}$  about the  $v_{gsr}$  of a circularly orbiting object at  $r_{GC} = 18 \text{ kpc}$  with  $v_{circ} = 220 \text{ km s}^{-1}$ , which reasonably matches GASS M giant velocities[4]. (b, right) AMR of all GASS candidate clusters. Circles denote values measured and listed in table, triangles are data from [5].