Unmasking the Hercules-Aquila Cloud in the North

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Abstract

We present the velocity substructure in the direction of the northern portion of the Hercules Aquila Cloud using observations taken at Apache Point Observatory (APO) and the Data Release 10 of the Sloan Digital Sky Survey (SDSS). The Hercules Aquila Cloud is an over density of halo stars found at low Galactic latitudes, towards the Galactic center. Using Blue Horizontal Branch stars (BHBs), we identify several structures as over densities in distance and velocity. The most prominent of these structures covers ~ 250 deg^2 of the sky centered around (l,b)$\sim (55^\circ, 45^\circ)$ and ranges in distance from $16 \sim 27$ kpc. This structure is found to be metal poor, [Fe/H] ~ -2.0, with a tight velocity distribution of -60 km s^{-1} $< v_{\rm gsr} < -20$ km s^{-1}. Although this halo substructure has about the same location and distance as the Hercules Aquila Cloud, the line-of-sight velocity differs by 220 km s^{-1} from the published velocity for this cloud. The other low metallicity substructures that appear to clump in distance and velocity have similarly large spatial distributions on the sky, which may point to additional ancient accretion events.

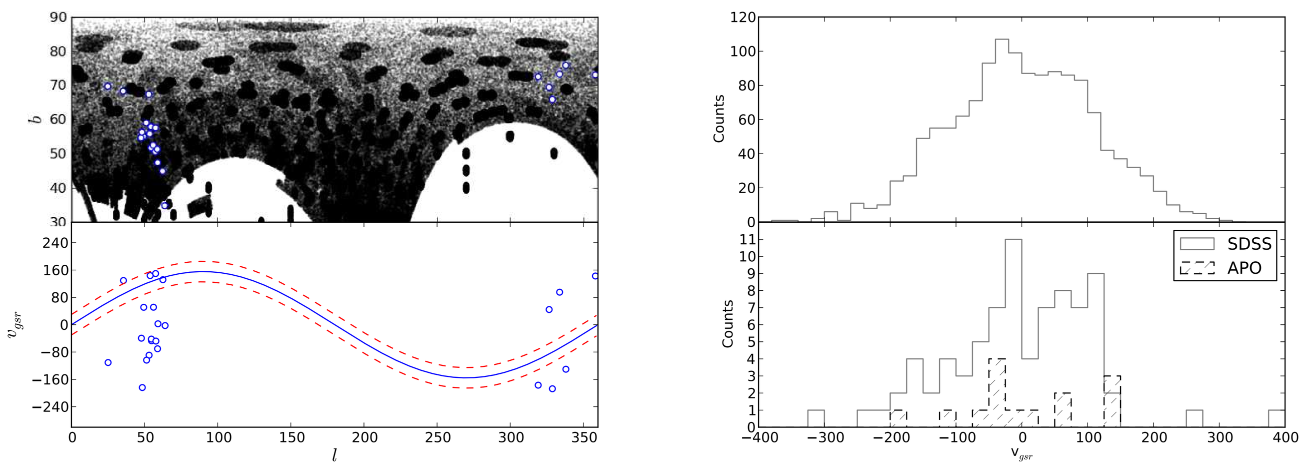

Figure 1: *Lef figure:* TOP: Galactic coordinate distribution of SDSS and APO spectra. Black points represent the spectral footprint of the SDSS in this region, while the open circles are 23 APO observations. BOTTOM: $V_{\rm gsr}$ vs galactic longitude of the same 23 APO stars. The blue solid line represents the velocity that thin disk stars would have at a galactic latitude of 45° ($V = 220 * \sin(l) * \cos(45^\circ)$). The red dotted lines represent the same disk velocity ± 30 km s^{-1}. From this plot there looks to be a grouping of stars around $l \sim 50^\circ$ with velocities ~ -50 km s^{-1}. *Right figure:* TOP: All spectra from the SDSS in the region $0^\circ < l < 100^\circ$, $0^\circ < b < 60^\circ$ selected to be blue metal poor giant stars ($(g-r)_0 < 0.0$, $0.8 < (u-g)_0 < 1.5$, [Fe/H] < -1.2, $0 < \log g_{\rm WBG} < 3.5$). BOTTOM: SDSS data taken from $0^\circ < l < 80^\circ$, $0^\circ < b < 60^\circ$ with the same limits as the APO data: $-0.28 < (g-r)_0 < -0.15$, $0.96 < (u-g)_0 < 1.5$, and $16.7 < g_0 < 17.0$. Only the APO data with $0^\circ < l < 80^\circ$, $0^\circ < b < 60^\circ$ were selected.

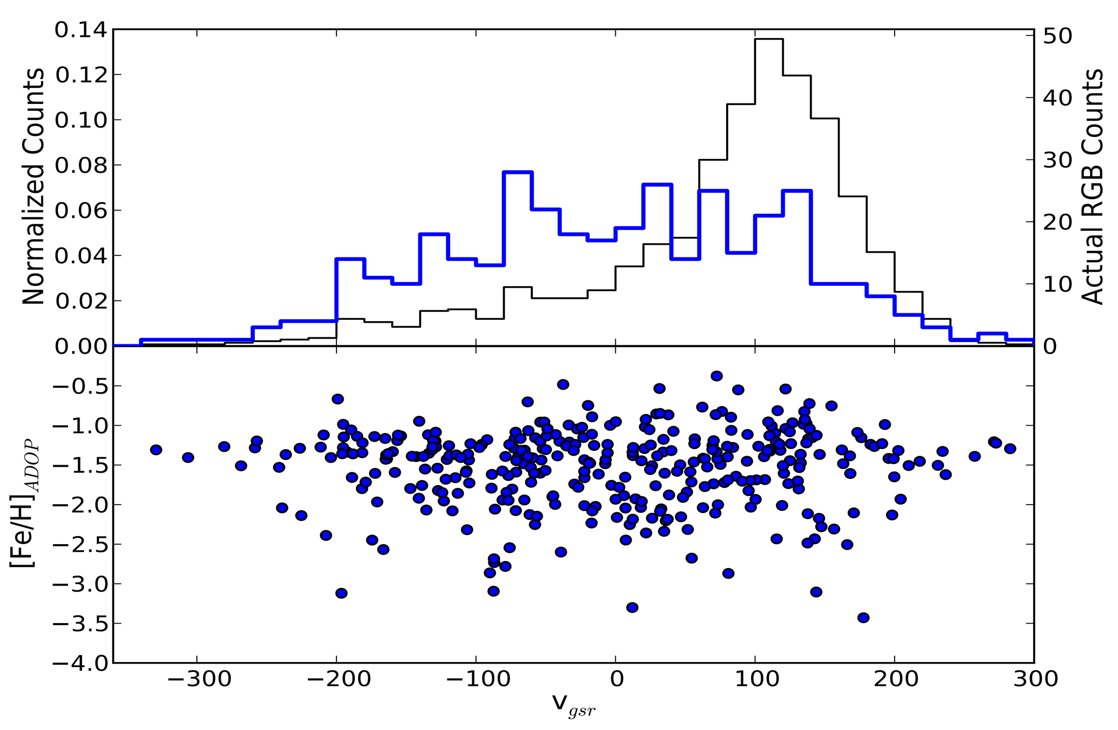

Figure 2: Stellar spectra selected from region $20^\circ < l < 75^\circ$ and $20^\circ < b < 55^\circ$ from Belokurov et al (2007). *Top panel:* Normalized histogram of $v_{\rm gsr}$. The black histogram represents all possible Red Giant Branch (RGB) spectra. These cuts select 1422 stars from the on field similar to the selection from Belokurov et al (2007). The blue, thicker, histogram represents the same set of spectra that also have surface gravities $\log g < 3.0$ to select against foreground contamination. This leaves 365 stars from the original 1422. The right axis contains the actual star counts for the thicker blue histogram of RGB giants stars. *Bottom panel:* Plot of [Fe/H]$_{\rm ADOP}$ vs $v_{\rm gsr}$ of the 365 giants stars from the thick histogram in the above panel.

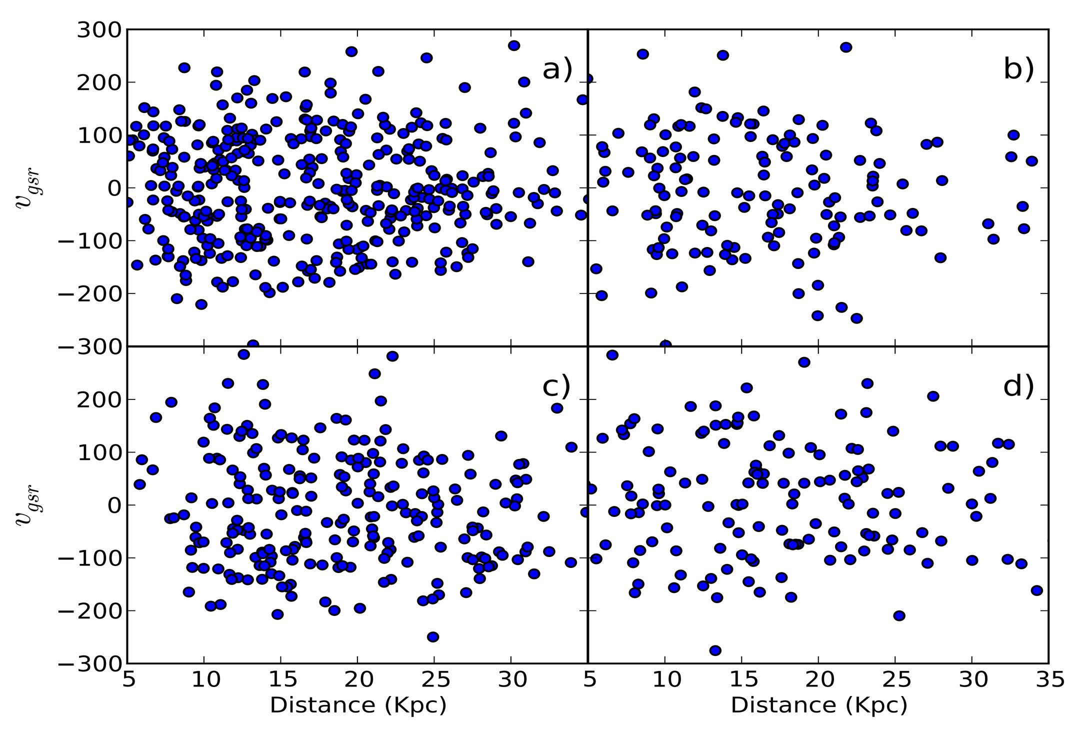

Figure 3: $V_{\rm gsr}$ vs Distance plots of metal poor BHB stars in the Northern Galactic Cap. Each panel has the following selection: $b > 0^\circ$, $-0.23 < (g-r)_0 < -0.1$, $0.0 < \log g_{WBG} < 3.5$, and $-2.2 <$[Fe/H]< -1.6. *Panel a:* First quadrant ($l < 90^\circ$) BHB stars. This quadrant is the most interesting of the four. There appear to be several obvious densities and trends with distance. Most notable are groups at ($v_{\rm gsr}$, dist)$\sim (100, 12)$, ($v_{\rm gsr}$, dist)$\sim (-100, 13)$, and ($v_{\rm gsr}$, dist)$\sim (-30, 24)$ *Panel b:* Second quadrant ($l < 90^\circ$) BHB stars. *Panel c:* Third quadrant ($l < 90^\circ$) BHB stars. *Panel d:* Fourth quadrant ($l < 90^\circ$) BHB stars.

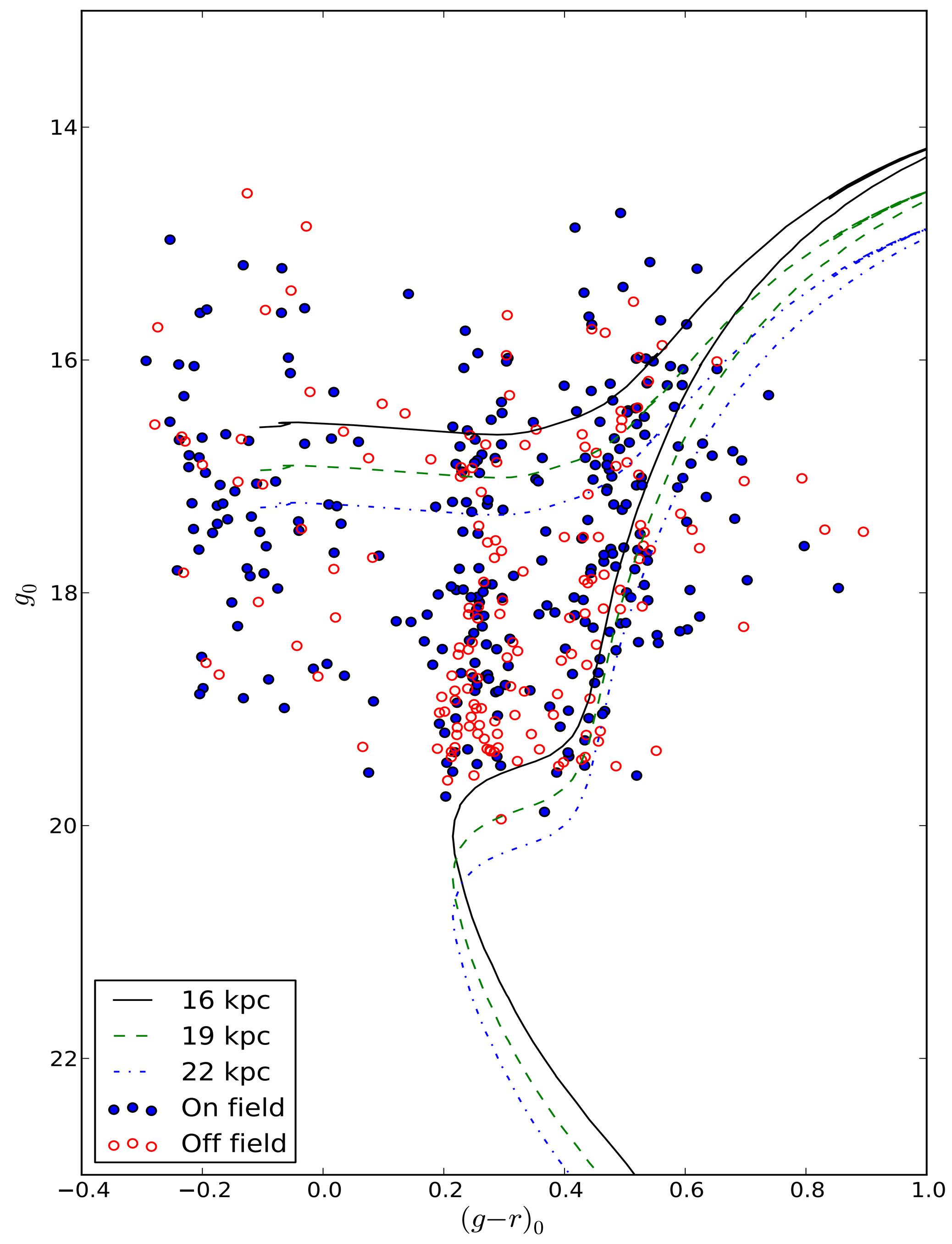

Figure 4: CMD of stars, with metallicity $-2.2 <$[Fe/H]< -1.6, in the On and Off fields represented as close blue circles and open red circles respectively. Padova isochrones of metallicity [Fe/H] ~ -2.0 and age 12.5 Gyr are plotted at distances of 16, 19, and 22 kpc shown as a black solid line, a green dashed line, and a blue dot-dashed line respectively. While there doesn't appear to be a strong Red Giant Branch (RGB) when comparing the On field to the Off field there is a clear excess of Blue Horizontal Branch (BHB) stars at $(g-r)_0 \sim -0.2$ and ranging from g_0 16.5 $\sim$ 17.5.

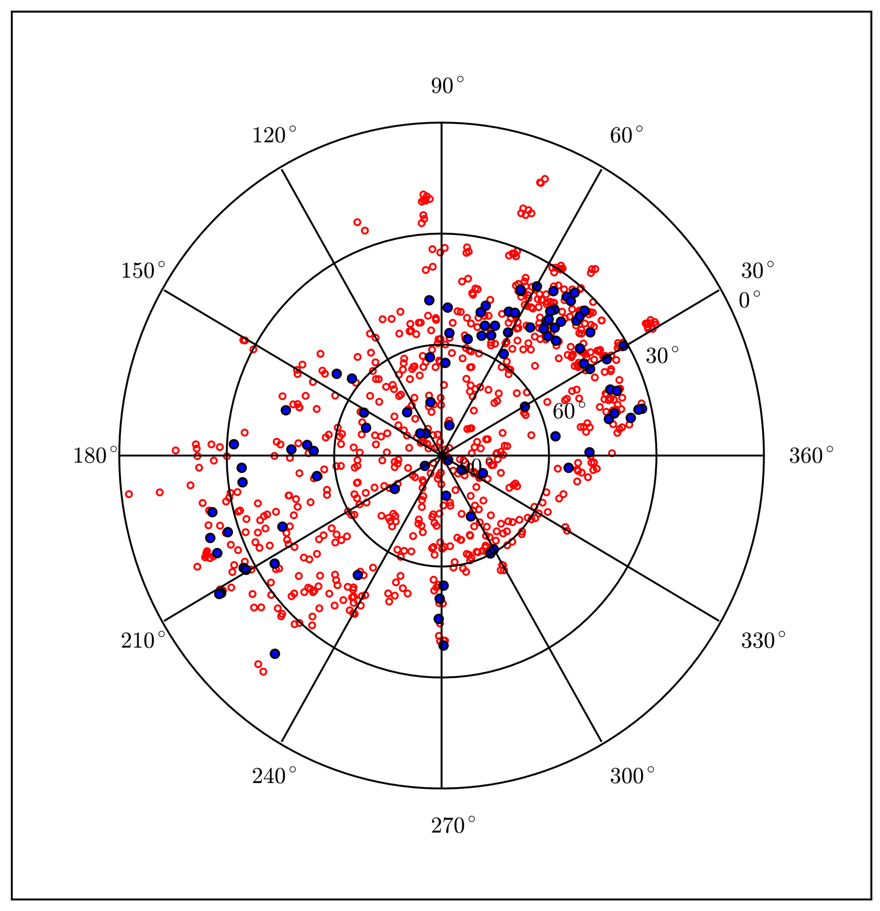

Figure 5: Polar plot of all BHB stars from Figure 3 selected to have distance between 16 and 27 kpc and a velocity range of -60 and 0 km s^{-1}, blue filled circles. Comparing these stars to all BHB candidates in the same distance range at all metallicities and velocities other than $-60 < v_{\rm gsr} < 0$ km s^{-1}, red open circles, we see that the group in the first quadrant is significant (0.0283 from KS test). This means that the metal poor BHBs selected at these distances are not just the expected selection from the distribution of BHB stars in the SDSS footprint.

Conclusions

We identify a velocity substructure from APO observations in conjunction with data from SDSS DR10. This velocity substructure is shown to be metal poor, [Fe/H]~ -1.8, and have a velocity of vgsr ~ -50 km s^{-1} using BHB and RGB stars in the direction of the Hercules-Aquila Cloud. Analysis of Belokurov et al (2007) reveals that the original velocity of 180 km s^{-1} is actually the thin disk along the line of sight, and The Hercules-Aquila Cloud instead has a velocity consistent with the velocity substructure found in this paper. From this work there doesn't appear to be any velocity or distance radiant along Galactic latitude or longitude of the Hercules-Aquila Cloud so we maintain that it is most likely a cloud-like over density or the extension of the inner spheroid. We therefore conclude that the over density described in this paper is in fact the Hercules-Aquila Cloud and is consistent in and location on the sky with the original detection in Belokurov et al (2007) although may extend to a slightly further distance.

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References

[Belokurov et al.(2007)] Belokurov, V., Evans, N. W., Bell, E. F., et al. 2007, , 657, L89