The Hercules-Aquila Cloud and Virgo Overdensity with Gaia DR2

Keith T. Smith,[1★] A. N. Other,[2] Third Author[2,3] and Fourth Author[3]
[1] *Royal Astronomical Society, Burlington House, Piccadilly, London W1J 0BQ, UK*
[2] *Department, Institution, Street Address, City Postal Code, Country*
[3] *Another Department, Different Institution, Street Address, City Postal Code, Country*

Accepted XXX. Received YYY; in original form ZZZ

ABSTRACT
200 words for Letters. No references should appear in the abstract.

Key words: keyword1 – keyword2 – keyword3

1 INTRODUCTION

Introduction.

2 OBSERVATIONS

Normally the next section describes the techniques the authors used. It is frequently split into subsections, such as Section 2.1 below.

2.1 Maths

Simple mathematics can be inserted into the flow of the text e.g. $2 \times 3 = 6$ or $v = 220\,\mathrm{km\,s^{-1}}$, but more complicated expressions should be entered as a numbered equation:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}. \tag{1}$$

Refer back to them as e.g. equation (1).

2.2 Figures and tables

Figures and tables should be placed at logical positions in the text. Don't worry about the exact layout, which will be handled by the publishers.

Figures are referred to as e.g. Fig. **??**.

3 CONCLUSIONS

The last numbered section should briefly summarise what has been done, and describe the final conclusions which the authors draw from their work.

★ E-mail: mn@ras.org.uk (KTS)

ACKNOWLEDGEMENTS

The Acknowledgements section is not numbered. Here you can thank helpful colleagues, acknowledge funding agencies, telescopes and facilities used etc. Try to keep it short.

REFERENCES

Author A. N., 2013, Journal of Improbable Astronomy, 1, 1
Others S., 2012, Journal of Interesting Stuff, 17, 198

APPENDIX A: SOME EXTRA MATERIAL

If you want to present additional material which would interrupt the flow of the main paper, it can be placed in an Appendix which appears after the list of references.

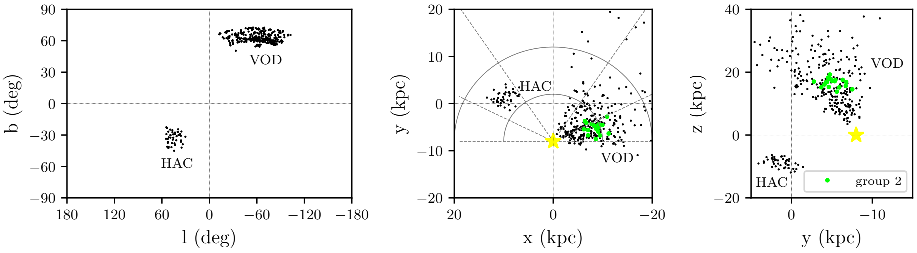

Figure 1. Spatial distribution of the RR Lyrae used in this work with full 6-D phase space measurements, in Galactic coordinates (left panel) and in the $x-y$ (middle) and $y-z$ (right) planes. The HAC field contains 44 RR Lyrae which likely belong to the Cloud with measured line-of-sight velocities (Simion et al. 2018) and Gaia DR2 proper motions. The VOD field contains 411 RRL which belong to several halo associations, including the Sagittarius stream and the VOD, with line-of-sight velocities provided by Vivas et al. 2016 and proper motions from Gaia DR2. In particular we mark three 'high significance' groups, excluding the Sagittarius stream, identified by Vivas et al. 2016: 'group 2' contains 18 stars (green circles), 'group 3', 7 stars (orange squares) and 'group 4', 5 stars (blue triangles). Two other 'high significance' groups are not marked in this figure as they are situated at distances larger than 30 kpc and contain only 3 stars each. We exclude from all the plots in this letter 'group 1' which contains Sagittarius members (112 stars). The Sun (yellow star) is located at ($x_\odot$, $y_\odot$, $z_\odot$) = (0,-8,0) kpc .

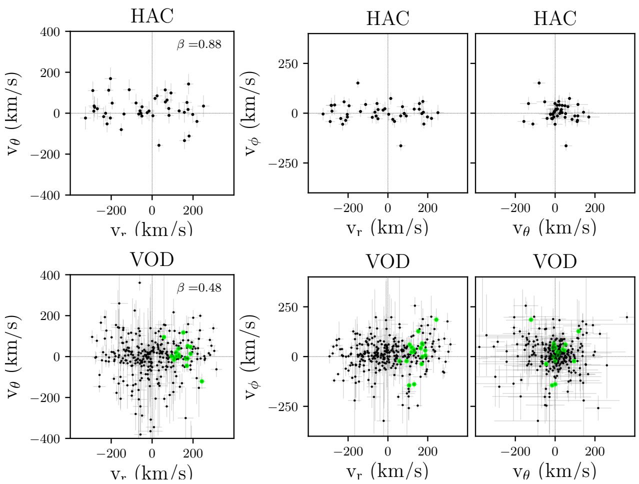

Figure 2. RRL velocity distribution in spherical polar coordinates (v_r, v_θ, v_ϕ are the radial, azimuthal and polar components respectively) in the HAC field (top row) and the VOD field (middle and bottom rows). The error on the velocity components of each star i, [$\sigma^i_{v_r}$, $\sigma^i_{v_\theta}$, $\sigma^i_{v_\phi}$], has been propagated by randomly drawing 1000 stars from a multivariate Gaussian distribution with mean the measurement (ra^i, dec^i, d^i, pmra^i, pmdec^i, v^i_h) and full covariance matrix (takes into account the covariances between ra,dec and proper motions). The orbital anisotropy, is highly radial in the HAC field ($\beta = 0.88$) where the stars are most likely members of the Cloud and mildly radial in the VOD field ($\beta = 0.48$) in which stars span a much wider range of distances (see Fig. 1). *NOTE: need to update β for both panels to include the errors on the velocities.*

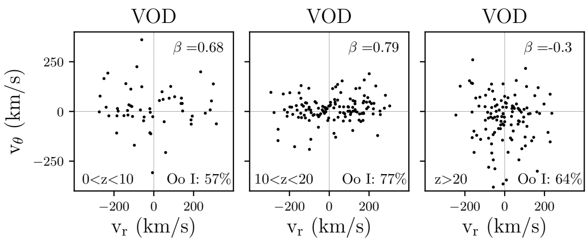

Figure 3. Radial versus azimuthal velocity in the VOD field, in three slices of Z, colour coded as in the bottom row of Fig. 2. We calculate the fraction of RR Lyrae of Oosterhoff type I and II (reported in each panel for Oo I) and find that in the 10<z/kpc<20 range, where the orbital anisotropy is the highest, the Oo I type dominates (77%), as in the HAC field (note: add number here). In the same slice, 73% of the stars belong to the 'sausage' component. The same behaviour but less accentuated can be noticed in the 0<z/kpc<10 slice where β is less radial but the fraction of Oo I stars decreases drammatically (note: comment if this is expected?). Further from the plane, at z>20 kpc, the velocity ellipsoid is almost isotropic with $\beta = -0.3$. We have excluded the most likely members of the Sagittarius stream but several others may remain, decreasing β. *NOTE: to add colours (maybe) after I do the extreme deconvolution. What about these β? also need errors?*

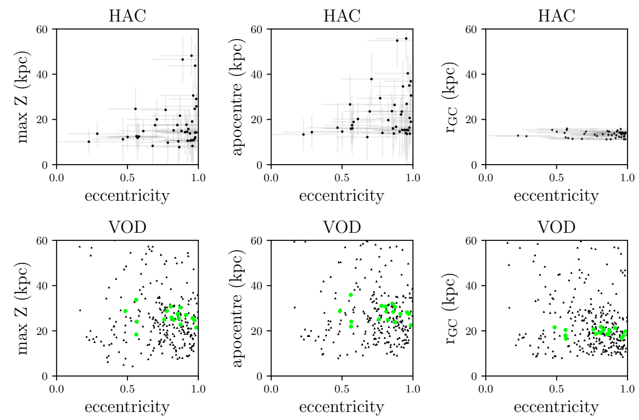

Figure 4. Orbital properties of the stars in the HAC and VOD fields. 'group 2' has similar orbital properties to the HAC, however it does not display a sausage velocity distribution (see middle row figure 2) - they are concentrated at vr = 135km/s as calculated by Vivas et al. 2016. *NOTE: to add eccentricities pdf for both HAC and VOD in the same plot.*

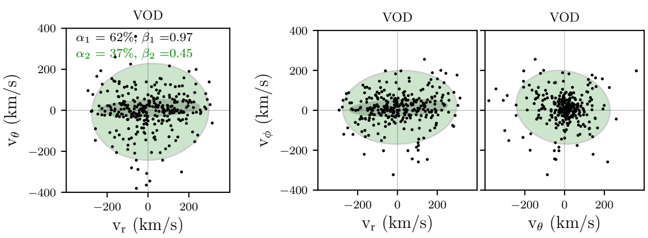

Figure 5. Result of the extreme deconvolution.