A METHOD TO ANALYSE VELOCITY STRUCTURE

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INTRODUCTION

- There are methods looking at spatial structure of star clusters
  - $Q, \Lambda, \Sigma \ldots$ [1], [2], [3]
- Learn a lot from that
- What about velocity structure?
- Very relevant right now (Gaia + others)

THE METHODS IN BRIEF

- Calculate $\Delta r$ and $\Delta v$ for every pair
- Sort into $\Delta r$ bins
- Average $\Delta v$ in each bin
- Plot $\Delta r$ against $\Delta v$
- Not going into errors
DEFINITIONS OF $\Delta V$

- **Magnitude definition** $\Delta v_M$
  - $|v_i - v_j|$
  - Always positive

- **Directional definition** $\Delta v_D$
  - $\frac{d\Delta r}{dt}$
  - How fast moving towards/away
DEFINITIONS OF $\Delta v$

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  - $| v_i - v_j |$
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  - $\frac{d\Delta r}{dt}$
  - How fast moving towards/away
PLUMMER SPHERES

- Low $\Delta r$ high $\Delta v$
- Stars in core move faster
- Clear difference
- Pulls out collapse / expansion
SUBSTRUCTURED DISTRIBUTIONS
SUBSTRUCTURED DISTRIBUTIONS
ERRORS (LOW MASS STARS)

- **Magnitude definition**

The Results

The Errors

The End
ERRORS (LOW MASS STARS)

- Directional definition

Graph showing the distribution of Δν/Δr for different mass ranges greater than $1.0 M_\odot$ (1000 stars), $0.3 M_\odot$ (428 stars), $0.6 M_\odot$ (207 stars), $0.9 M_\odot$ (128 stars), and $1.2 M_\odot$ (83 stars).
ERRORS (UNCERTAINTIES)

- **Magnitude definition**

![Graph showing the probability distribution of differences in radial velocity](image)

- $\sigma_{\text{sim}} = 0.0 \text{ km s}^{-1}$
- $\sigma_{\text{sim}} = 0.8 \text{ km s}^{-1}$
- $\sigma_{\text{sim}} = 0.4 \text{ km s}^{-1}$
- $\sigma_{\text{sim}} = 1.2 \text{ km s}^{-1}$
ERRORS (UNCERTAINTIES)

- **Magnitude definition**

![Graph showing error magnitude definitions](image)
The Method

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ERRORS (UNCERTAINTIES)

- Directional definition

![Graph showing error bars with different colors for different values of $\sigma_{\text{sim}}$.]
ADVANTAGES

- 1D, 2D, 3D
- Any frame of reference
- No assumptions about physical morphology
  - E.g no need to define cluster centre/radius
- Online - https://github.com/r-j-arnold/VSAT
CONCLUSIONS

- Developed a method for studying velocity structure
- Two definitions of $\Delta v$
- Robust
- Future work: apply to observational data