Galaxies in Clusters and Groups Behind the Magellanic Clouds

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The VISTA Magellanic Clouds Survey (VMC) is a high-resolution near-infrared survey, which covers the Magellanic Clouds and Magellanic Bridge, but also contains information about many background galaxies. We locate and study galaxy clusters and groups in the VMC survey, using VMC data in combination with other surveys covering the Magellanic Clouds.

We will use machine learning combined with multiwavelength observations to identify cluster members and study their properties. Near-infrared may be used as a tracer of stellar mass and AGN dust, and radio lobes probe the intracluster medium. From these measurements and by studying galaxy morphology, we can study interactions and galaxy evolution within the clusters we find.

VMC Facts

- Instrument: VISTA Survey Telescope
- Survey Area: 170 degrees^2
- Coverage: Small & Large Magellanic Clouds, Magellanic Bridge, Part of the Magellanic Stream
- NIR Filters: Y, J and Ks
- Observation Period: November 2009 – October 2018
- Resolution: 0.8 arcsec
- Sensitivity: 20.3 -- 21.9 Vega mag

Why Look Behind the Magellanic Clouds?

- A variety of multiwavelength data is available
- There is a clear line of sight to background galaxies outside of the densest stellar regions
- Background galaxies act as a reference frame for stellar studies
- Discovering new galaxy clusters and expanding our knowledge of known ones provides new opportunities to study galaxy evolution
- The VMC has a high enough resolution to see morphological detail in background galaxies and is sensitive enough to detect high-redshift galaxies

Known Clusters

There are known galaxy clusters at z~0.037 and z~0.065. Within the cluster at z~0.037 is an example of galaxy interaction with the intergalactic medium that can be seen in radio images.

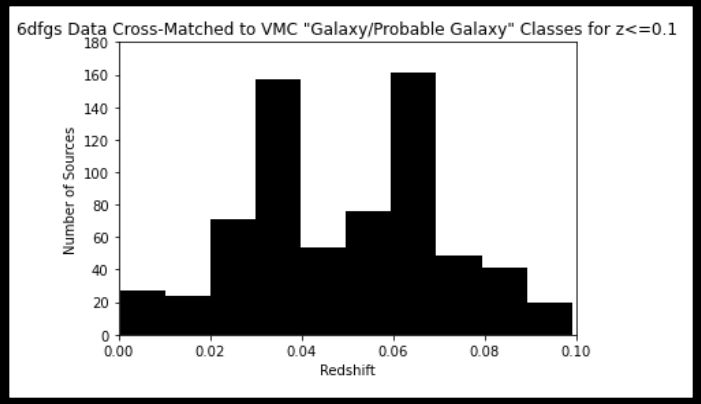
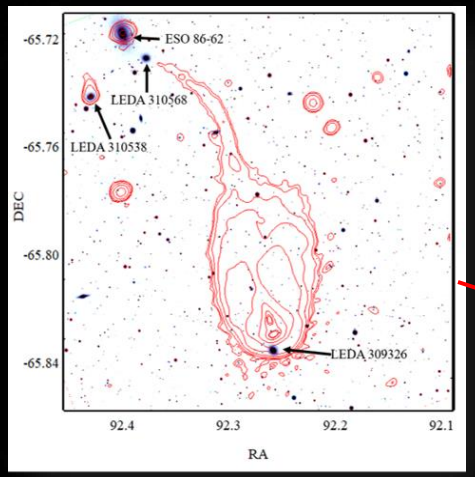
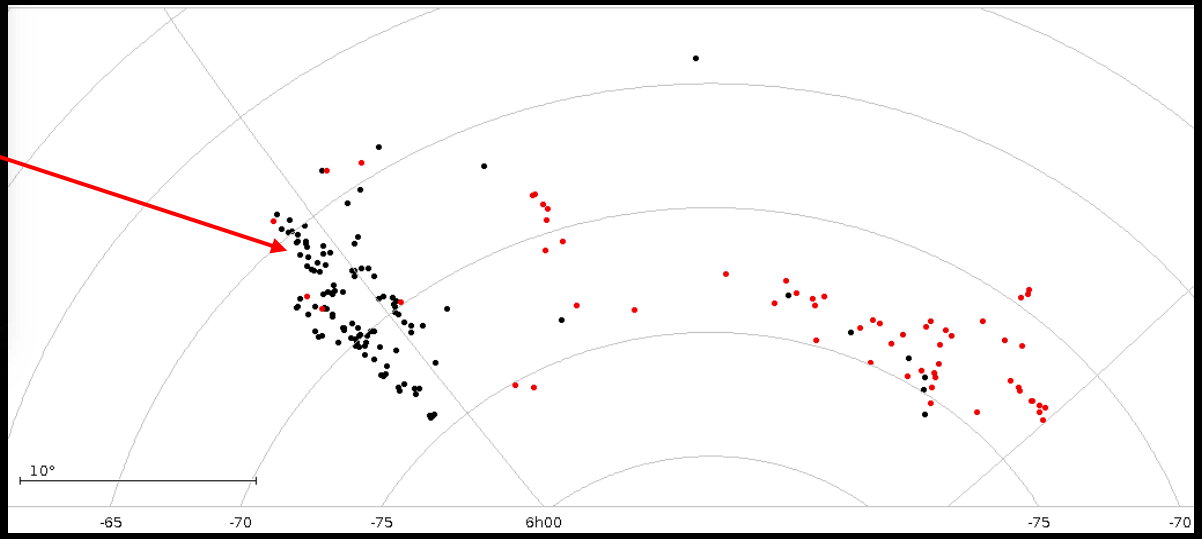


Figure 1 (left): A histogram showing redshifts for sources classed as galaxies or probable galaxies in VMC, matched to 6dFGS (Jones et al. (2009)), showing only z≤0.1 for clarity.





Figures 2&3 (above)

Figure 3 (right) shows a map of all sources classed as galaxies or probable galaxies (method of Hambly+2008) in VMC data, cross-matched to 6dFGS (Jones+2009) with sources at $0.035 \leq z \leq 0.04$ shown in black and sources at $0.063 \leq z \leq 0.067$ shown in red.

Figure 2 (left) is a radio image from the Australian SKA Pathfinder (ASKAP) showing interactions with the IGM within the cluster at z~0.037. (Radio Image Credit: Pennock+2021)

Searching for Higher-Redshift Clusters

We will use machine learning to search for new clusters and additional members of known clusters.

Key Challenges

- Distinguishing background galaxies from foreground stars
- Classifying cluster membership
- Idenification of redshift and other cluster properties

Distinguishing Galaxies from Stars

- Classifying based on morphology alone may result in blends of stars being classified as galaxies and high-redshift galaxies being classified as stars
- Classifying based on colour alone may result in RGB stars being classified as galaxies and AGN being classified as stars
- Machine learning can consider many variables at the same time, so potentially avoids these issues

Classifying Cluster Membership

- Cluster members can be identified by colour, morphology and other properties
- Once we have a sample of cluster members, others in the same cluster may be identified by association

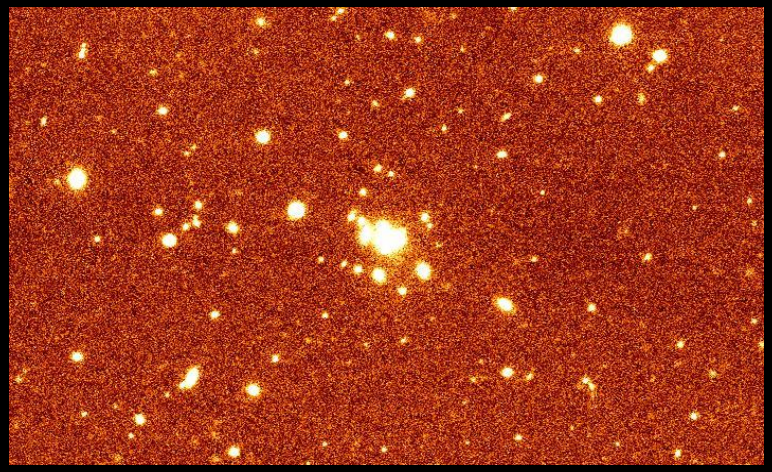


Figure 4 (above): An example of a galaxy cluster with a condensed core at z~0.8* (VMC Y-band)

*Redshift estimate from a model based on Bruzual & Charlot 2003

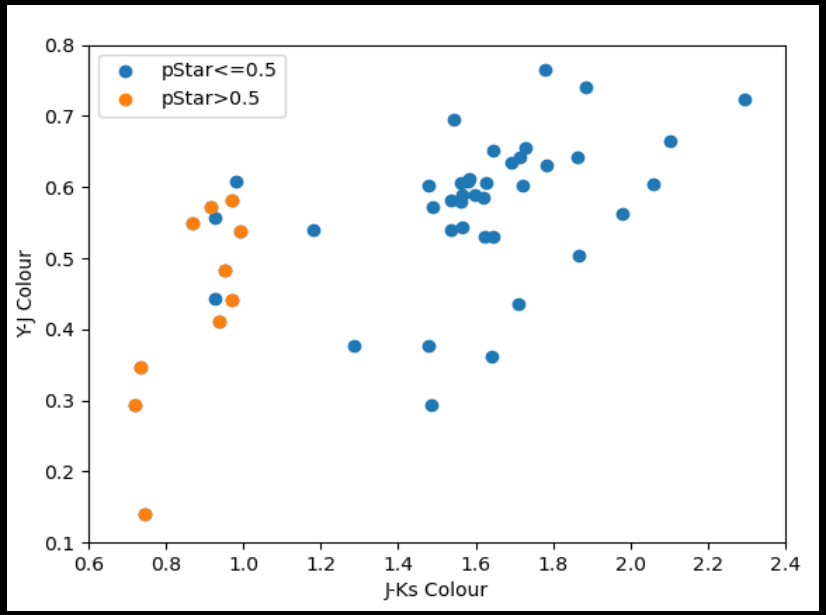


Figure 5 (above): A colour-colour diagram for sources in the cluster shown in Figure 4. There is a clear separation between stars, sources within the cluster and isolated galaxies

Identifying Redshift

- Photometric redshifts exist for some background galaxies in the VMC (Bell+2019,2020)
- We can use existing photometric models or machine learning algorithms
- For some low-redshift galaxies, spectroscopic redshifts exist from other surveys (e.g. 6dfGS (Jones+2009))
- We may take our own spectroscopic observations for interesting cluster candidates

Potential Science Outcomes

- Nearby clusters can be used to study interactions with the ICM (as demonstrated in Figure 2)
- Higher-redshift clusters (z>1) can be used to study quenching and cluster formation
- An automated classification system may be adapted for use in other VISTA surveys and/or other areas of sky with high stellar contamination (e.g. the Milky Way galactic plane)

Summary

- We are searching for galaxy clusters among the background galaxies in the VISTA Magellanic Clouds Survey using VMC photometry and any available multiwavelength data for this area of sky
- Distinguish Galaxies from Stars --> Identify Cluster Members --> Calculate Redshift ---> Study Properties and Evolution
- We will use machine learning to distinguish galaxies from stars and identify cluster members

References

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- Galaxy/Star Classifications: Hambly et al. (2008), MNRAS, Vol. 384, Issue 2, pp. 637-662
- 6dfGS: Jones et al. (2009), MNRAS, Vol. 399, Issue 2, pp. 683-698
- Radio Observations: Pennock et al. (2021), arXiv: 2106.12013
- Bruzual & Charlot (2003), MNRAS, Vol. 344, Issue 4, pp. 1000-1028
- Bell et al. (2019), MNRAS, Vol. 489, Issue 3, p. 3200-3217
- Bell et al. (2020), MNRAS, Vol. 499, Issue 1, pp. 993-1004