Exploring the History of the Virgo Cluster of Galaxies through Multiwavelength Photometry of Globular Clusters

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The Virgo Cluster

- Largest concentration of mass in the local universe
- ~16 Mpc away
- Has two subclusters centred on M 87 and M 49 which means it is still in the process of forming
- Heavily studied in optical by the Next Generation Virgo Cluster Survey (NGVS), and now target of Virgo Environmental Survey Tracing Ionised Gas Emission (VESTIGE)
- Also studied in infrared by NGVS - Infrared and Herschel Virgo Cluster Survey
- Not well studied in ultraviolet though there are GALEX observations

Figure 1 and poster background: a composite of several Subaru images of a field in the Virgo Cluster. Image Credit: NASA

Spectral Energy Distribution Fitting

- We are developing a pipeline using an SED fitting software package called Prospector by Johnson et al (2019)
- Prospector uses MCMC fitting with Emcee or dynamic nested sampling with Dynesty as well as population modelling with FSPS
- We fit simple stellar population models with cluster age, stellar mass, and metallicity as free parameters over a range of fixed blue horizontal branch fractions $0 \leq f_{\mathrm{BHB}} \leq 0.5$ which we compare with a χ^2 test
- We are testing this on sources identified as likely globular cluster candidates in the NGVS pilot catalogue
- Globular clusters evolve quite predictably so are good tracers of their formation conditions

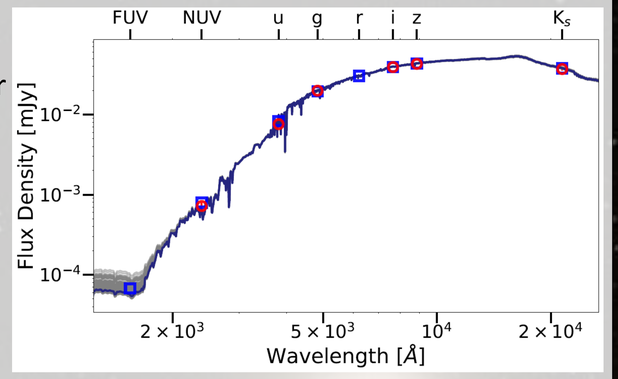

Figure 3: Best fit (blue) to near UV, optical, and infrared photometry (red) of NGVS-J122954.09+121346.1 with prediction for far UV. The grey curves are randomly sampled spectra from the MCMC chains as a proxy for the uncertainty

AstroSat/UVIT Images

- *AstroSat* is a space observatory operated by the Indian Space Research Organisation
- UVIT is the Canadian-made UltraViolet Imaging Telescope aboard *AstroSat*
- We have obtained UVIT images of a region deep in the core of Virgo Subcluster A near M 87
- Images are in near UV ($\lambda \sim 240$ nm) and far UV ($\lambda \sim 150$ nm)
- Photometry extracted from images with SExtractor

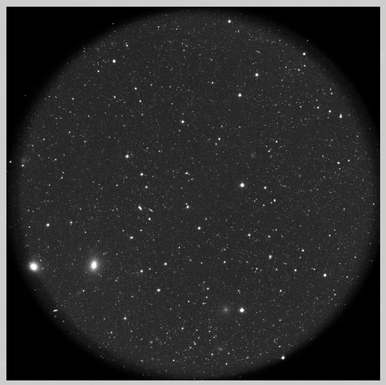

Figure 2: Near UV UVIT image of core field

NGVS + NGVS-IR

- All our optical photometry is from NGVS and all our infrared photometry is from NGVS-IR
- The NGVS is an optical imaging survey with MegaCam on the Canada-France-Hawaii Telescope.
  - It covers the full virial radii of both the M 87 and M 49 subclusters in the u*griz bands
- NGVS-IR is an infrared survey of the Virgo cluster with WIRCam on the Canada-France-Hawaii Telescope.
  - It has so far covered a much smaller region of the Virgo Cluster than NGVS, primarily in the cluster core

Future

- We hope to combine our fitting chains at different f_{BHB} in a way that allows a more robust comparisons and better understanding of our uncertainties
- We have obtained Hectospec spectra from another group that we intend to incorporate into our fits
- Degeneracies in our fits may be related to the "second parameter problem" in the predictions of horizontal branch morphology from stellar population theory so we hope to explore that
- Once we are done with the Deep Core Field discussed here we will expand the scope to the UVIT Legacy Survey currently being carried out. This is a much larger area at various radii

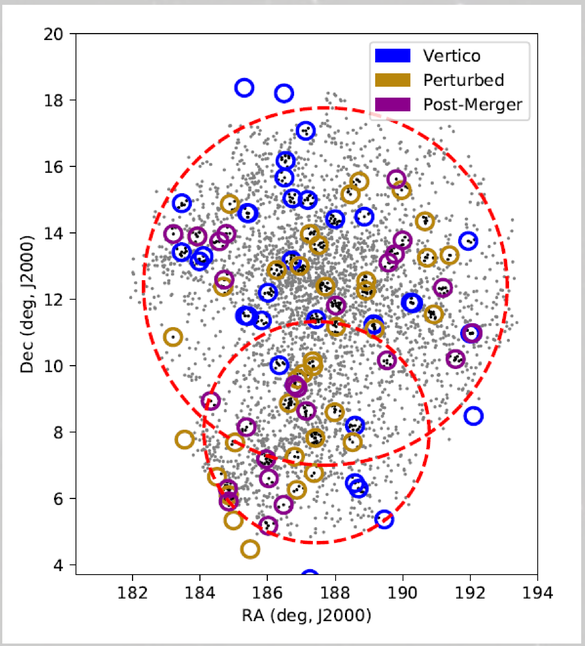

Figure 4: Map of UVIT Legacy Survey Fields (solid circles) compared to the locations of large Virgo galaxies (dots) and the virial radii of M 87 (large dashed circle) and M 49 (smaller dashed circle)