DWARF PROPERTIES AND SATELLITE PLANES BEYOND THE LOCAL VOLUME

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Dwarf satellite galaxies in our Milky Way and different galaxy systems in the Local Volume appear to be arranged in thin, vast planes. It has been argued that these phase-space correlations can not be explained to a satisfactory degree by the standard model of cosmology but it is unclear whether these planes in our neighborhood are statistical outliers, or if they are perhaps a common phenomenon in the Universe. Recent deep imaging surveys have significantly increased the number of known dwarf galaxies and allow us to advance such small-scale tensions beyond the Local Volume. We present our study analyzing the spatial distribution of 2210 dwarf galaxies identified in the MATLAS survey as well as results from follow-up observations with the MUSE instrument on the VLT. Spectral information for 56 of these dwarf galaxies, situated in low-to-moderate density environments, allow for a deeper dive into their properties and for a comparison to the Local Volume dwarfs.

Planes-of-Satellites (PoS) in MATLAS

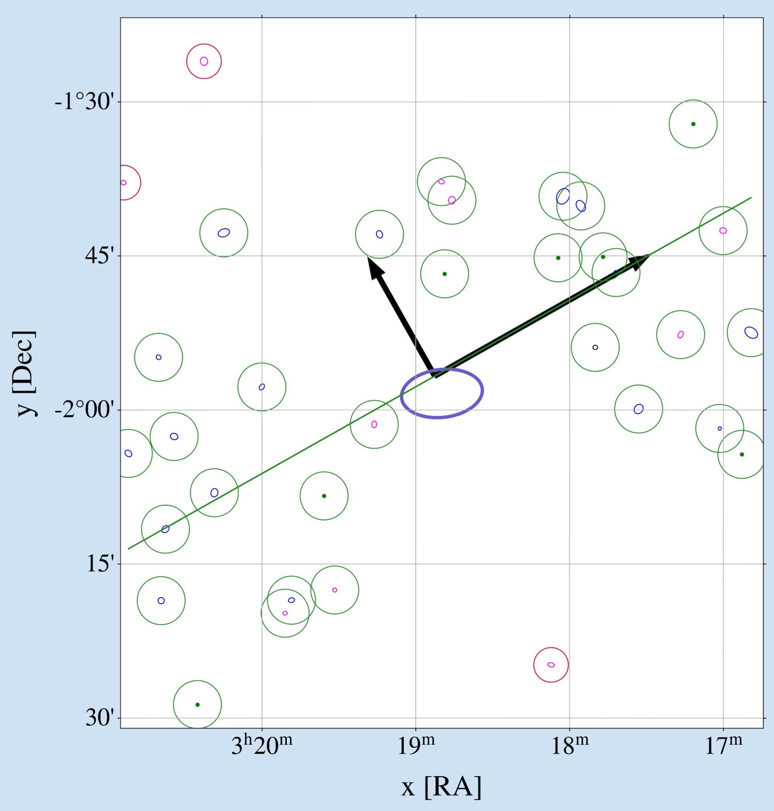
(Heesters et al. 2021, A&A 654, A161 (2021); https://doi.org/10.1051/0004-6361/202141184)

DATA: MATLAS Survey

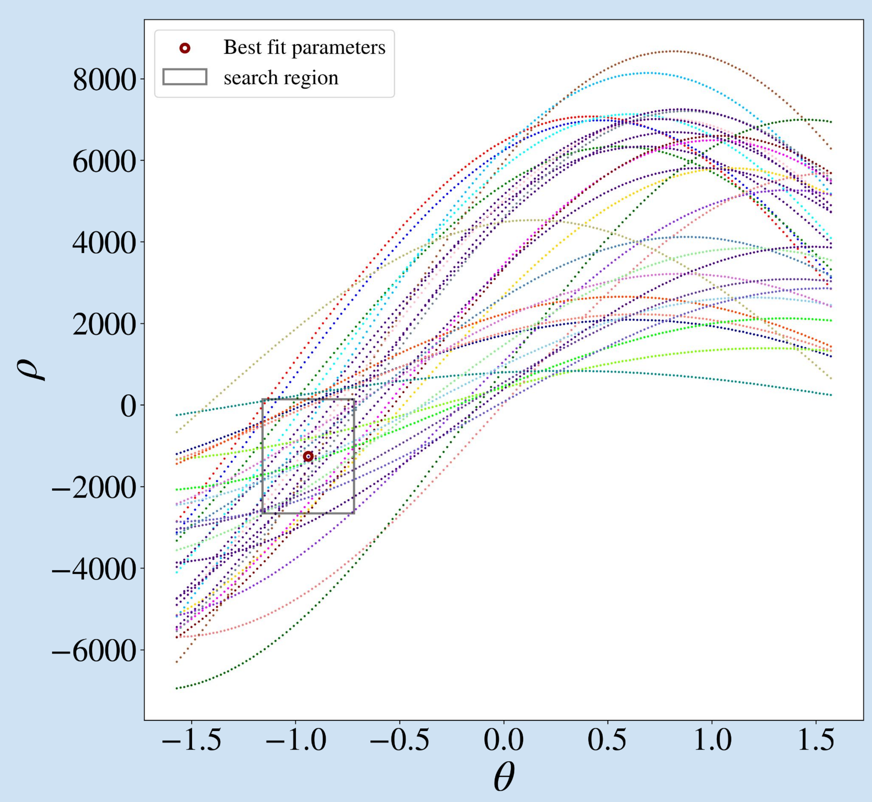
- Mass Assembly of early-Type GaLAxies and their fine Structures
- Early-type galaxies (ETGs) situated in low-to-moderate density environments
- MegaCam camera of the Canada-France-Hawaii telescope (CFHT)
- Deep optical images down to 28.5 mag/arcsec^2 in the g band
- 150 one square degree fields around different ETGs (mostly in groups)
- 2210 dwarf galaxies identified (see Habas et al. 2020)
- Predominantly dwarf elliptical galaxies (~75%)
- No distance measurements for most dwarfs (~85%) ➡ 2D analysis
- Assumption: all dwarfs are at the distance of the central ETG in each field

METHOD: Hough Transform

- Used for detection of straight lines in digital image processing (Hough 1962)
- Modified to detect planes of satellites candidates
- Finds the most tightly packed linear substructure through "voting" system



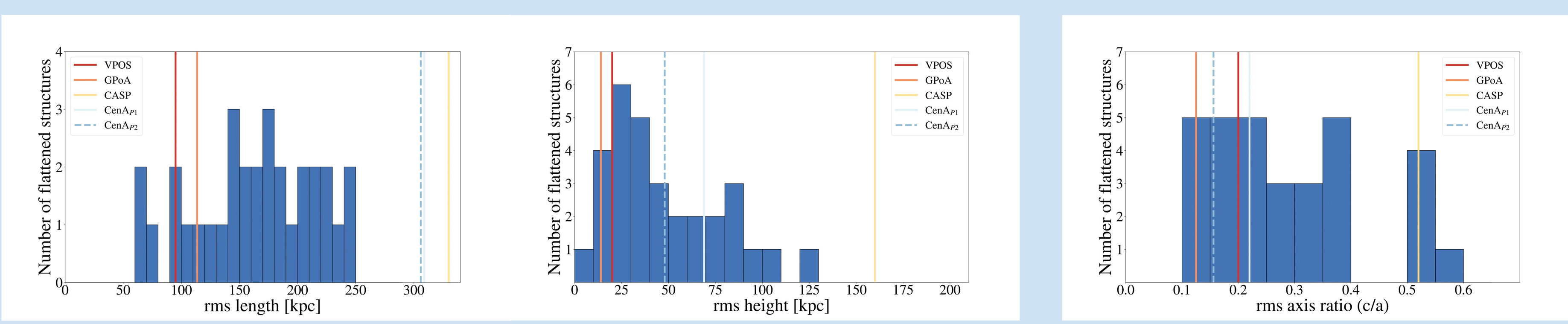
Scatter plot showing the NGC1289 (central blue ellipse) satellite system in right ascension and declination. The green line is the fit produced by the Hough method. The dwarfs circled in green voted for the best fit parameters. The points circled in red do not match the best fit parameters and are thus considered outliers. The rms dimensions of the detected flattened structure are indicated by the length of the black arrows. Dwarf ellipticals (dE) are shown as blue ellipses, dwarf irregulars (dIrr) as magenta ellipses and dwarfs with bad GALFIT results are shown as green points.



NGC1289 dwarfs in the Hough parameter space. Each curve results from the voting process of a single dwarf. The densest crossing region shows the parameter pair fitting the majority of the data. The black rectangle shows the size of the search area. The dark red circle points to the parameter pair which best describes the clustered substructure.

RESULTS

- We identify 31 (26%) statistically significant ($p \leq 0.05$) flattened structures in 119 satellite systems
- Median value of 10 dwarf members per structure
- Dimensions between LG PoS and Centaurus A satellite plane.
- 50% of the flattened structure aligned with the estimated large scale structure (consistent with filamentary accretion scenario; see e.g., Zentner et al. 2005, Libeskind et al. 2005, Lovell et al. 2013)
- No correlations with properties of the assumed host galaxy



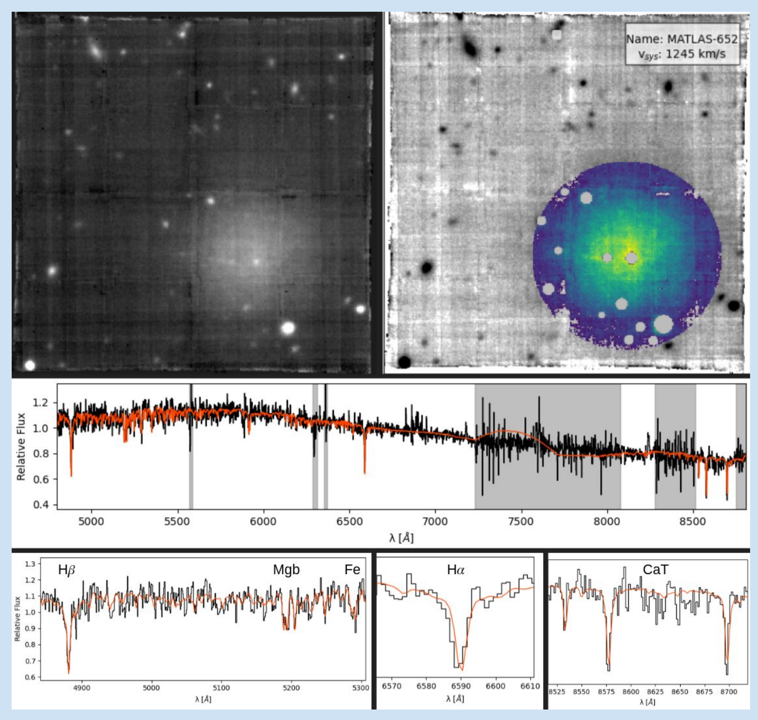
Rms dimensions of the automatically detected ($p \leq 0.05$) structures. These dimensions were calculated via the small angle approximation assuming all dwarfs are at the distance of the targeted host galaxy. Shown are the structure length (left), height (center), and axis ratio (right). Measured values of several well-studied planes are over plotted for comparison purposes. References for these are: Pawlowski et al. (2013) (VPOS, GPoA), Müller et al. (2018a) (CASP), Tully et al. (2015); Müller et al. (2016) (CenAP1, CenAP2). Figure from Heesters et al. 2021.

VLT/MUSE follow-up

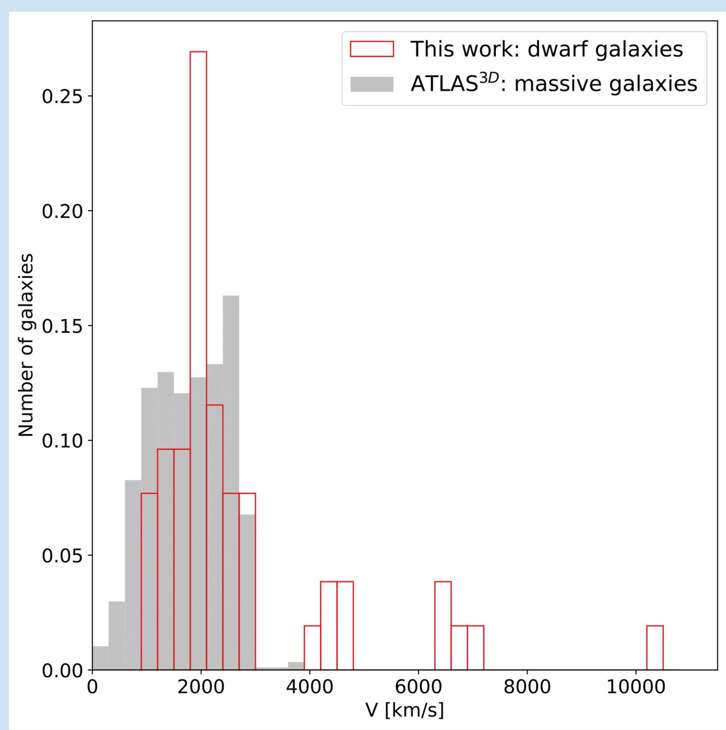
(Heesters et al. 2023, in prep.)

DATA

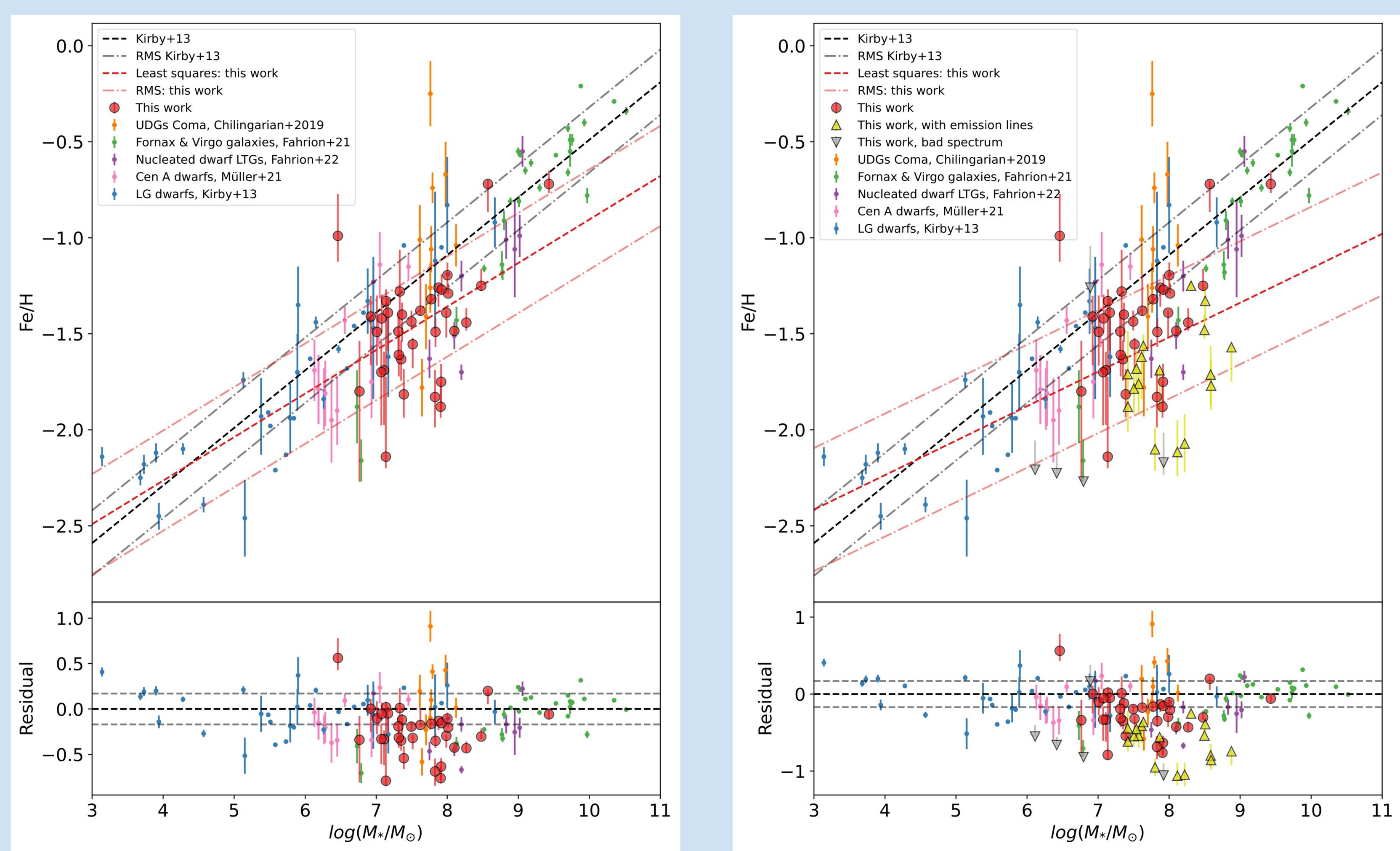
- 56 dwarf galaxies identified in the MATLAS survey observed with MUSE (Bacon et al. 2010) on the VLT
- Data from different filler proposals (PI: Marleau, F.) with the primary goal of obtaining a reference sample of dwarfs beyond the Local Volume (LV):
  - Confirm dwarf and satellite nature via line-of-sight velocity
  - Stellar population properties
- Not enough dwarfs with spectral information per system to do phase-space analysis for PoS
- Full spectrum fitting using the penalized Pixel-Fitting algorithm (pPXF; Cappellari & Emsellem 2004; Cappellari 2017)
- MC simulations for error estimation



Spectrum of dwarf galaxy MATLAS 652. Bottom: Zoom in on important absorption lines.



Distribution of the measured dwarf line-of-sight velocities studied in this work. The first peak corresponds to the velocity space which is consistent with the hosts (grey) targeted in the MATLAS survey.



Universal stellar mass- metallicity relation from Kirby et al. (2013) as the black dashed line with its rms as the two grey dashed lines. Left: data from this work (red circles), excluding star forming and low SNR galaxies from this sample. Right: full sample from this work. Star forming galaxies are shown as yellow upward pointing triangles, while low SNR galaxies are grey downward pointing triangles. We compare our results with galaxies from other works: LG dwarfs (blue; Kirby et al. 2013), Cen A dwarfs (pink; Müller et al. 2021), galaxies in Fornax and Virgo (green; Fahrion et al. 2021), nucleated dwarf LTGs (purple; Fahrion et al. 2022) and UDGs in the Coma cluster (orange; Chilingarian et al. 2019). Bottom: residual plots, i.e. metallicity dwarf - metallicity fit. The grey dashed lines indicate the rms of the fit from Kirby et al. (2013).

RESULTS

- 75% of the dwarfs match the line-of-sight velocities of massive hosts targeted by MATLAS, 30% of these show star formation activity
- 18% of the dwarfs are located further in the back, outside of the MATLAS target distance – 70% of these show emission lines
- Our sample is systematically offset towards lower metallicities as compared to the universal stellar mass-metallicity relation for the LG dwarfs presented by Kirby et al. (2013)
- Offset is also present in other studies for this mass range (~ $10^{6.5}$-$10^{8.5}$ $M_\star/M_\odot$)
- Could indicate a non-linear stellar mass-metallicity relation
- May be caused by different methods for measuring the metallicity (spectroscopy from RGB stars vs. full spectrum fitting)