Dust in Cluster Dwarf Elliptical Galaxies

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Abstract Based on single cross-scan data of the *Herschel* Virgo Cluster Survey, we report the first detections of dust in cluster early-type dwarf galaxies: VCC 209, VCC 781 and VCC 951. All three galaxies have dust masses $M_d \approx 10^5 - 10^6$ $M_\odot$ and average dust temperatures $\approx$ 16–20 K. Since these three early-type dwarfs

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reside in densely crowded regions close to the center of the Virgo cluster, and several HI-detected dwarfs in the outskirts of Virgo were not detected by Herschel (implying a dust content $<10^4$ $M_\odot$), this might imply that dust in dwarfs is more closely related to the molecular gas, which is more centrally peaked in a galaxy's potential well and therefore, not easily removed by any stripping mechanism. We conclude that the removal of interstellar dust from these early-type dwarfs appears to be less efficient than the removal of the HI gas.

1 Introduction

Early-type dwarf galaxies (dEs) are the dominant morphological type in galaxy clusters. They were originally seen as a rather homogeneous population of dwarf galaxies with an old stellar age, no features resembling any recent or ongoing star formation, and no indications of a significant interstellar medium (ISM). This viewpoint has changed radically in the past few years. Deep imaging observations of dEs have revealed a heterogeneous morphology (disks, spiral structure, bars, (non)-nucleated subclasses and pressure- or rotationally supported systems). Adding to

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this morphological and kinematical inhomogeneity is the detection of a significant interstellar medium (both atomic and molecular gas) in various dEs. Large amounts of cold interstellar matter are unexpected in dEs, as both internal (supernova explosions) and external effects (ram-pressure stripping, galaxy interactions, tidal effects) are thought to be able to expel the gas from the shallow potential on short timescales. Continuum emission from interstellar dust is a promising alternative way to determine the ISM content of dEs. To date, the Andromeda satellites NGC 205 and NGC 185 are the only dEs that have been detected in the far-infrared [9, 11, 12]. The advent of the *Herschel* Space Observatory [14] offers new possibilities for mapping the ISM in dEs with an unprecedented sensitivity and spatial resolution.

2 Observations and Results

We use single cross-scan observations of the four 4×4 deg^2 HeViCS fields, observed in June and July 2010, to search for dust emission from dEs in the Virgo Cluster. For more details on the HeViCS survey and data reduction, we refer to the website www.hevics.org and to [3]. Selecting the galaxies with morphological type dE and dS0 in the Goldmine catalogue [7] resulted in a sample of 794 dEs, for which we applied blind aperture photometry to the PACS and SPIRE maps on the corresponding positions. We report the unambiguous detection ($>10\sigma$) of 3 early-type dwarfs in the SPIRE 250 μm image: VCC 209 (dS0), VCC 781 (dS0) and VCC 951 (dE/dS0) (see Fig. 1). For VCC 781 and VCC 951, [5] estimated dust masses of the order of 10^5 $M_\odot$ and average dust temperatures ∼20 K. A similar analysis as in [5] predicts a dust mass of the order of 10^6 $M_\odot$ at a temperature of ∼16 K in VCC 209. Combining the estimated dust masses with the HI detections [8] or upper limits, and neglecting molecular gas, we find HI gas-to-dust ratio of 33, <124.3 and <62.5 in VCC 209, VCC 781 and VCC 951, respectively. For both VCC 781 and VCC 951, central substructures, blue cores and deep Hydrogen absorption lines (EW[Hδ] >4 Å) strengthen the connection between the detected dust emission and a recent episode of star formation in the central regions of these objects [5]. For VCC 209, the Hα line emission (EW[Hα] >12 Å) implies still ongoing star formation.

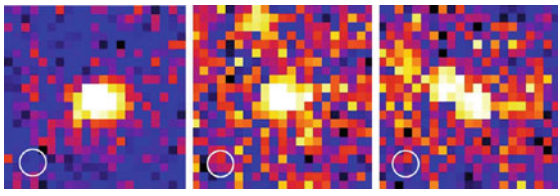

Fig. 1 The detections in the SPIRE 250 μm image for, from left to right, VCC 209, VCC 781 and VCC 951. The FWHM of the beam is indicated as well

3 Discussion and Conclusion

With a detection limit of about 10^4 $M_\odot$, we detected for the first time dust in emission from three cluster dEs. For all three dEs, we determined temperatures of the order of 16–20 K and estimated dust masses of the order $M_d = 10^5 - 10^6$ $M_\odot$, confirming the hypothesis that at least some dEs are transition objects gradually evolving from late-type to early-type, while falling into the cluster.

Considering that HI detected early-type dwarfs are preferentially located in the outskirts of a cluster, where they encounter little influence of the intracluster medium and interactions with other galaxies, one would expect that the dEs in the central regions of the Virgo cluster are more dust deficient, if gas and dust are tightly coupled [2, 5]. Both VCC 781 and VCC 951 reside in the central, densely crowded region of the Virgo cluster (cluster A), and also the HI detected galaxy VCC 209 is well surrounded by galaxies in the N cloud (at the same distance as cluster A, but blue-shifted with respect to Virgo, [6]), while several HI-detected dwarfs in the outskirts of Virgo have not been detected with Herschel (implying a dust content $<10^4$ $M_\odot$). One possible explanation for this could be that dust in dwarfs is more closely related to the molecular gas, which is more centrally peaked in a galaxy's potential well and therefore, not easily removed by any stripping mechanism [1, 10, 15]. Although these three dust-detected dwarfs are located in the immediate surroundings of galaxies with observed HI streams, it seems that the dust is not stripped as efficiently as the HI gas, which might also explain the lower gas-to-dust ratios for those objects.

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