The Herschel Virgo Cluster Survey: VII. Dust in cluster dwarf elliptical galaxies

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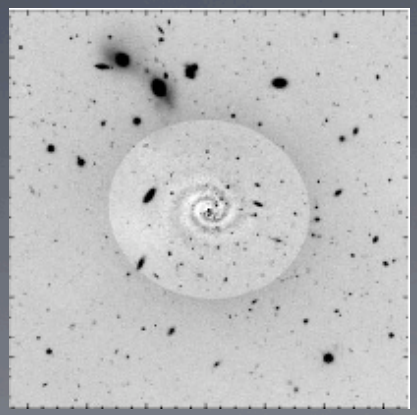
Dust in dEs

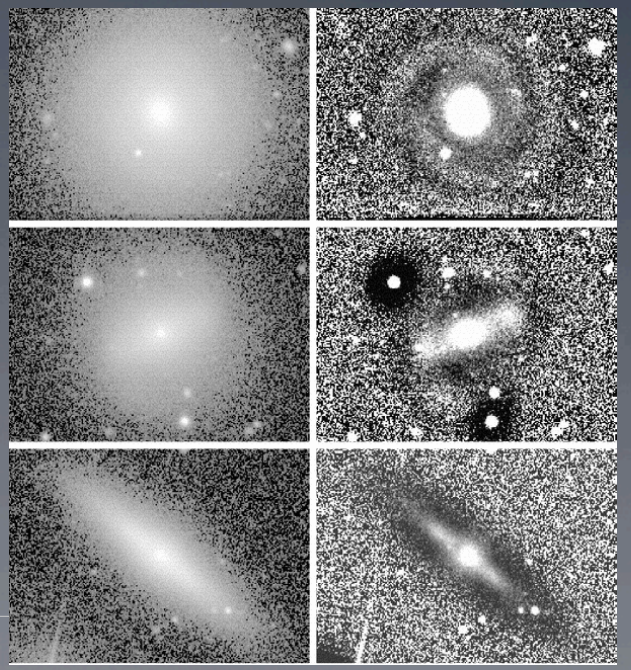
Early-type dwarf galaxies (dEs) are the dominant morphological type in galaxy clusters (both genuine elliptical dE and lens-shaped dSo)

The last years, the heterogeneous character of the population of early-type dwarf galaxies (dEs) revealed:

* (non-)nucleated subclasses
* rotationally / pressure-supported systems
* evidence for substructure: - disks
  - spiral structure
  - bars



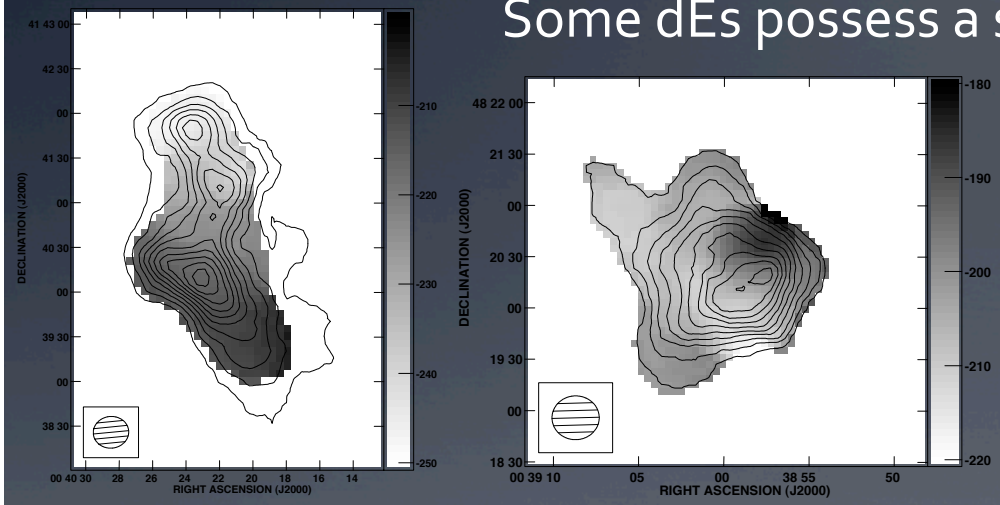
Jerjen et al. (2000)



Lisker et al. (2006a)

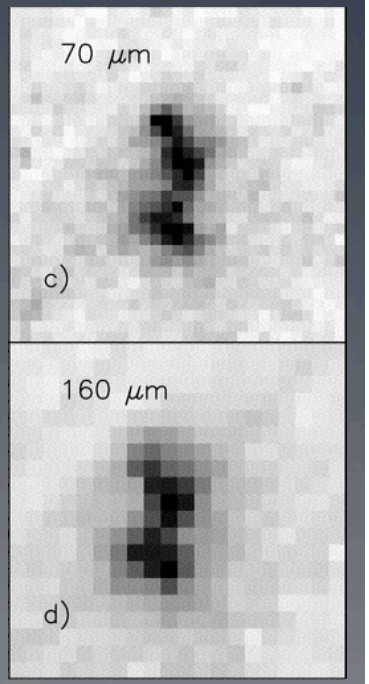
Dust in dEs

NGC205 and NGC185 , Young & Lo (2007)



Some dEs possess a significant interstellar medium (ISM):

➔independent detections of both atomic and molecular gas



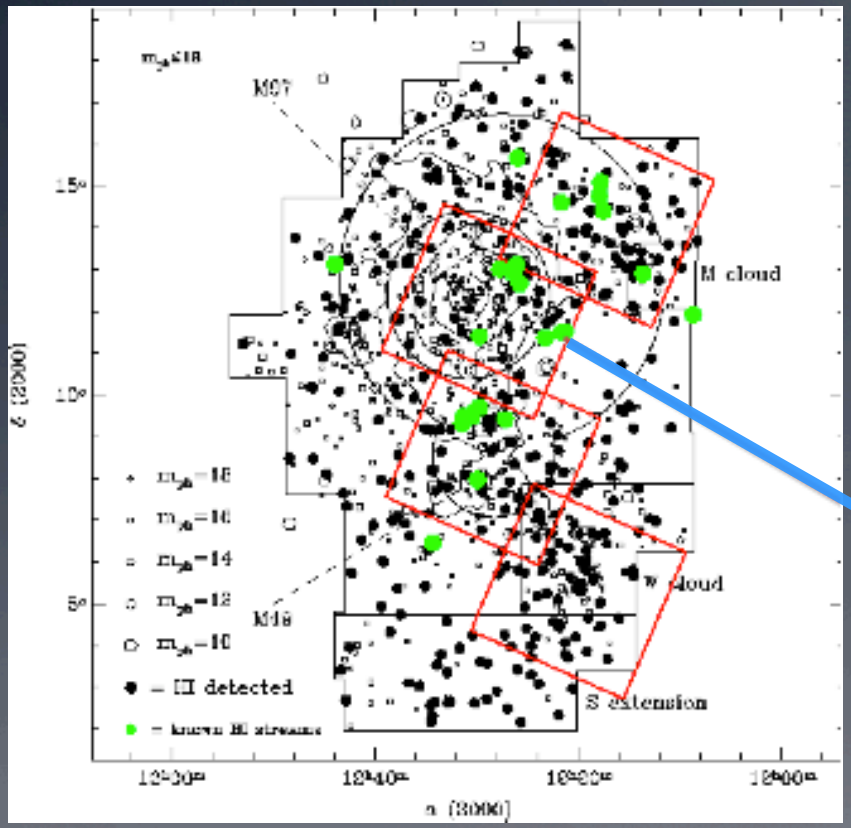
➔ we use the HeViCS SDP data to look for dust emission as an alternative way of tracing the interstellar medium

➔so far dust has only been detected in Andromeda satellites:

NGC 205 (3.2×10^5 $M_\odot$) and NGC 185 (1.9×10^3 $M_\odot$)

NGC205,Marleau et al.(2006)

HeViCS Science Demonstration Phase



SDP data = 1 cross-scan in parallel "fast" scan mode (PACS+SPIRE data, scan speed = 60 arcsec/s) of a 4° by 4° field, covering the central region of the Virgo cluster

Sample selection

We select 370 galaxies in Goldmine with morphological type dE and dSo

↓

removal of 16 background galaxies and 115 sources with a contaminating optical source within 6 arcsec

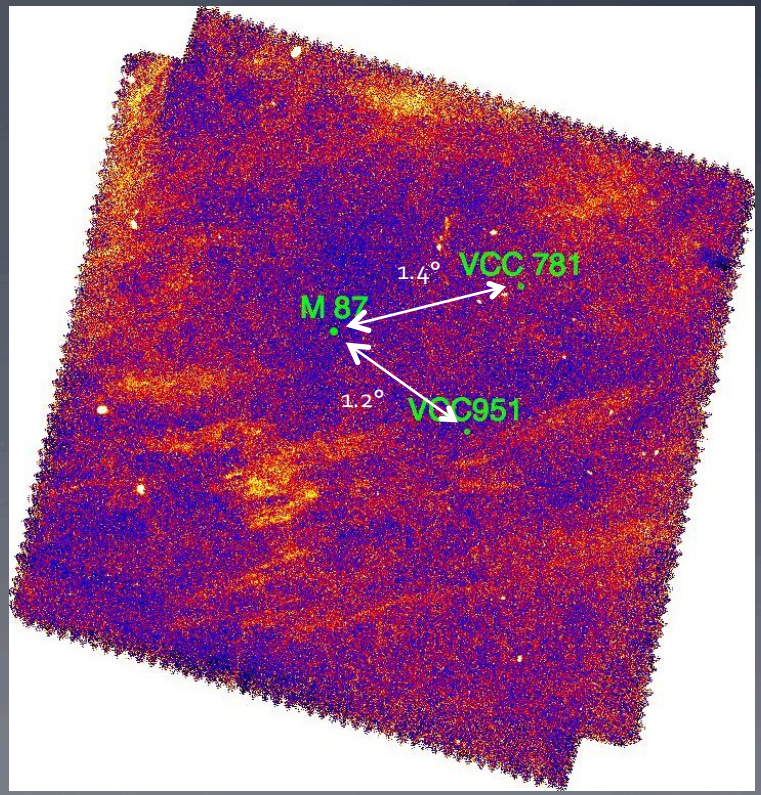
↓

blind aperture photometry based on the positions of the remaining 239 galaxies in our sample

Results

- **The dwarfs** VCC 781 and VCC 951 were detected in the SPIRE 250 μm image at 10 σ and > 3σ at several other PACS + SPIRE wavelengths

- 9 other dEs were tentatively detected at ~ 2-3 σ



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we excluded them for the moment being as these detections raised some kind of doubt

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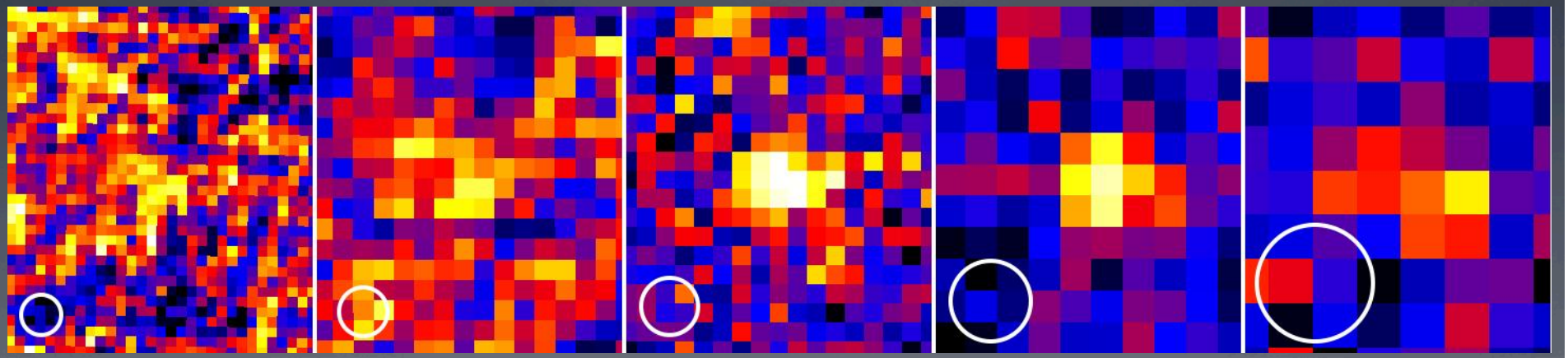
deeper optical/NIR images might reveal the true origin of their infrared emission

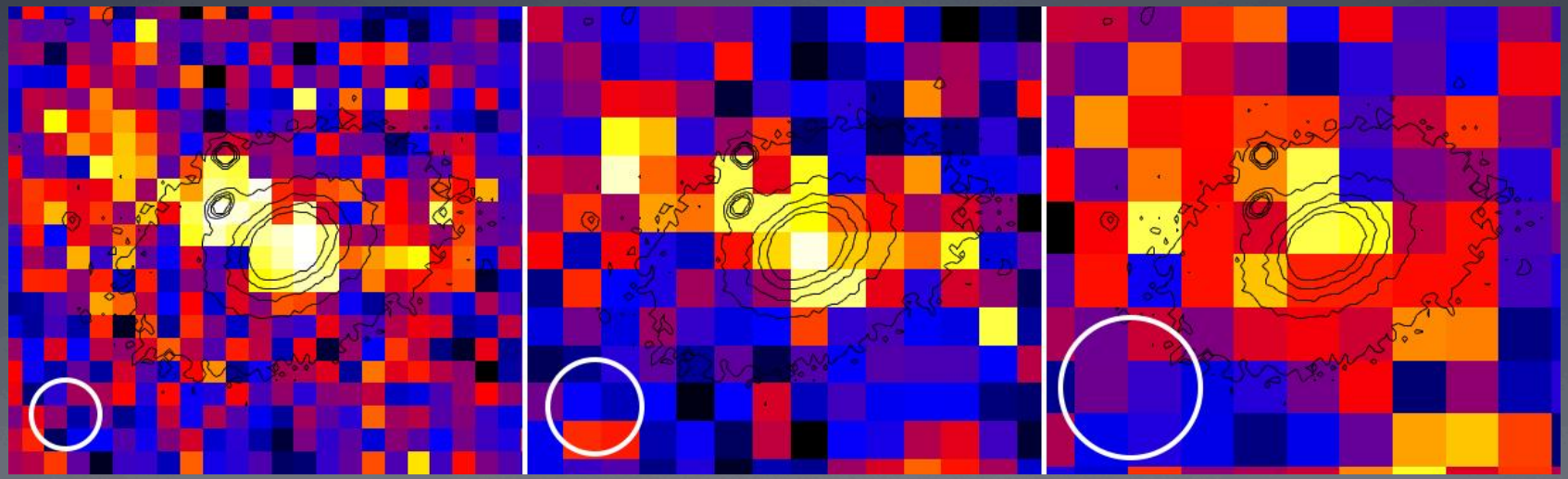
Detection of dust in VCC 781

PACS 110 µm	PACS 160 µm	SPIRE 250 µm	SPIRE 350 µm	SPIRE 500 µm



Detection of dust in VCC951

SPIRE 250 μm SPIRE 350 μm SPIRE 500 μm



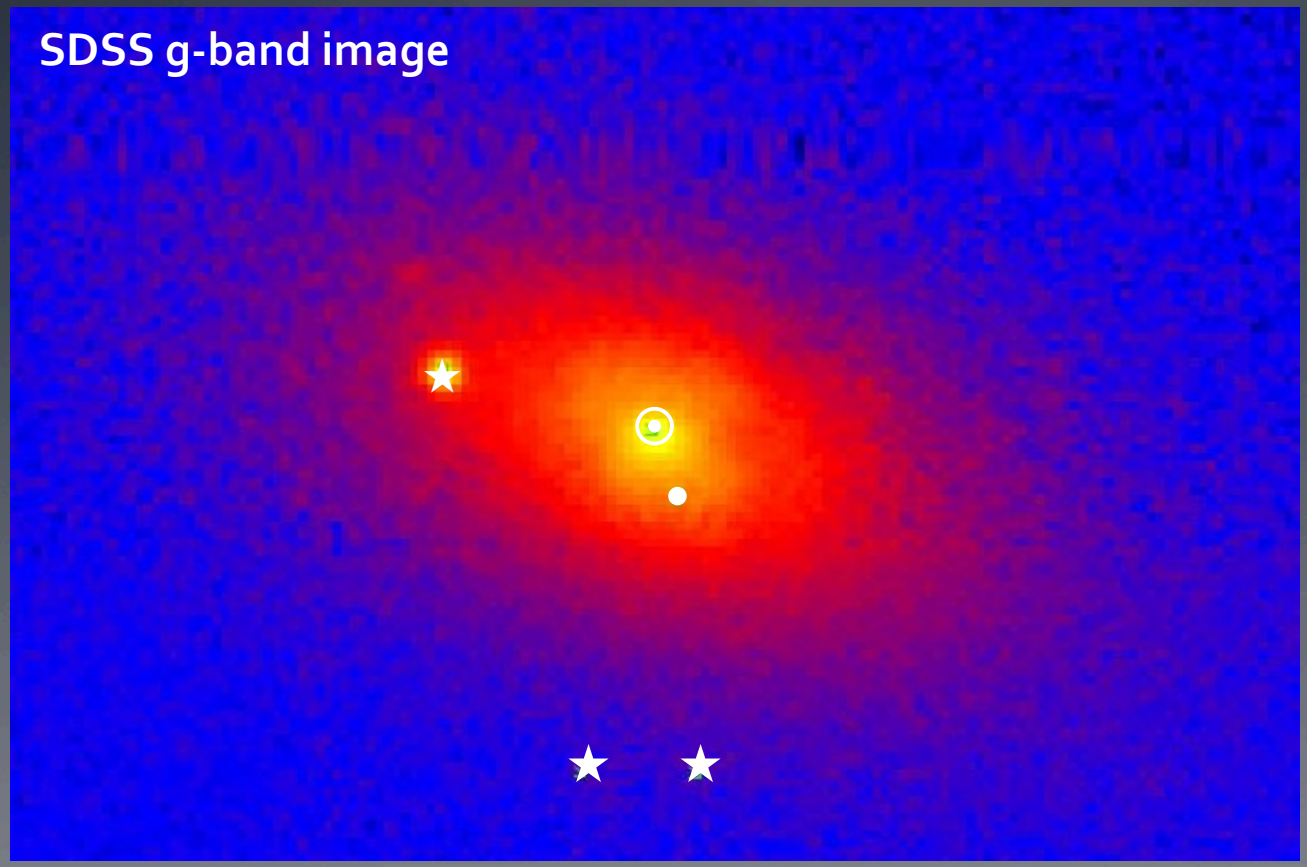
How convincing are these detections?

Testing the reliability of both detections:

- look for possible contaminating background sources within 18.1" (= FWHM of SPIRE 250 μm) of the dwarf positions in all relevant images/catalogs (SDSS, 2MASS, UKIDSS, Spitzer)
- check whether the dwarfs possess properties supporting the presence of dust in those dwarf galaxies.

Background sources for VCC 781

We identify 4 SDSS sources within the SPIRE 250 μm PSF region.



Classified as

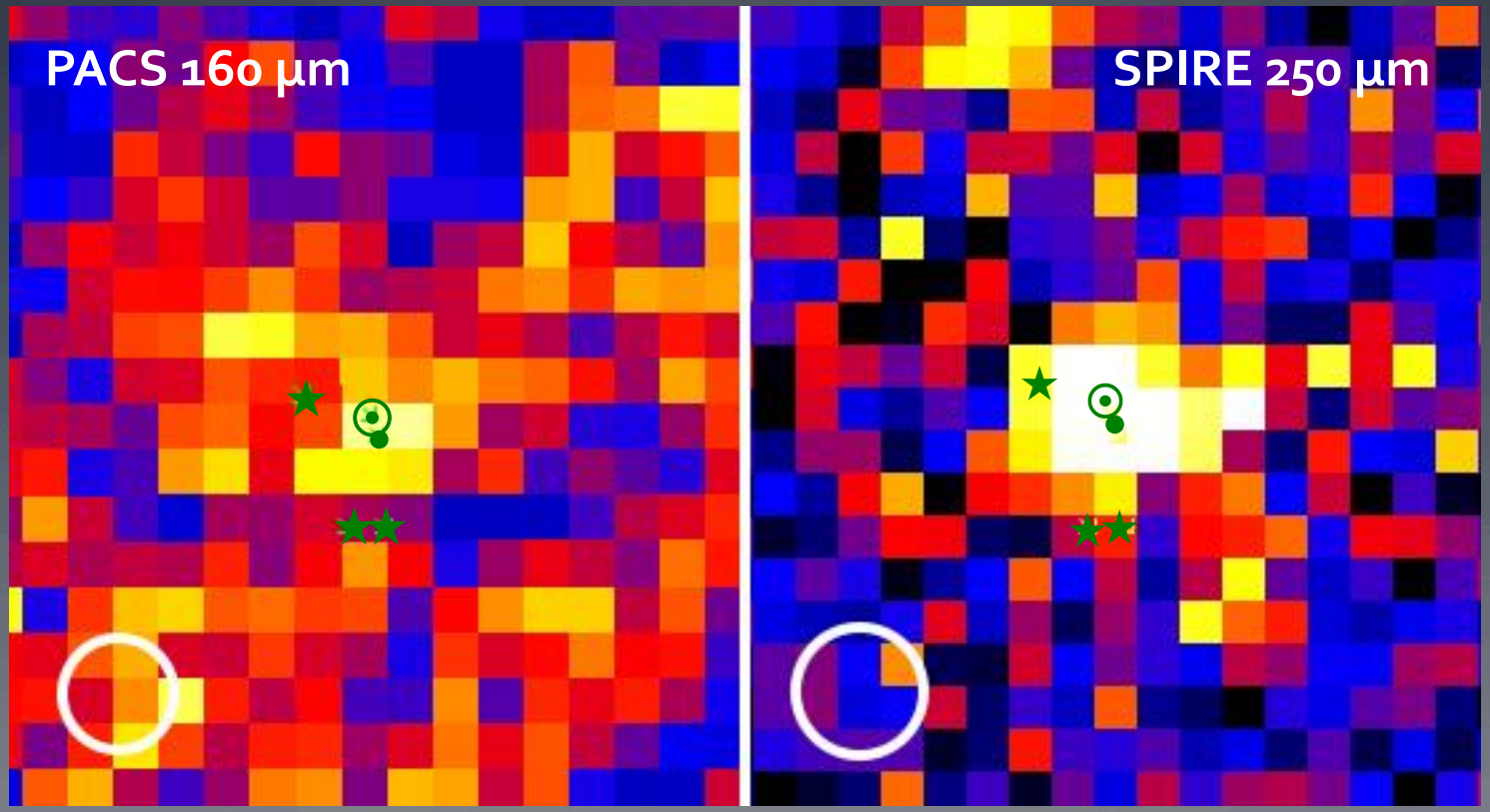
★ : star

⊙ : galaxy

• : no SDSS classification

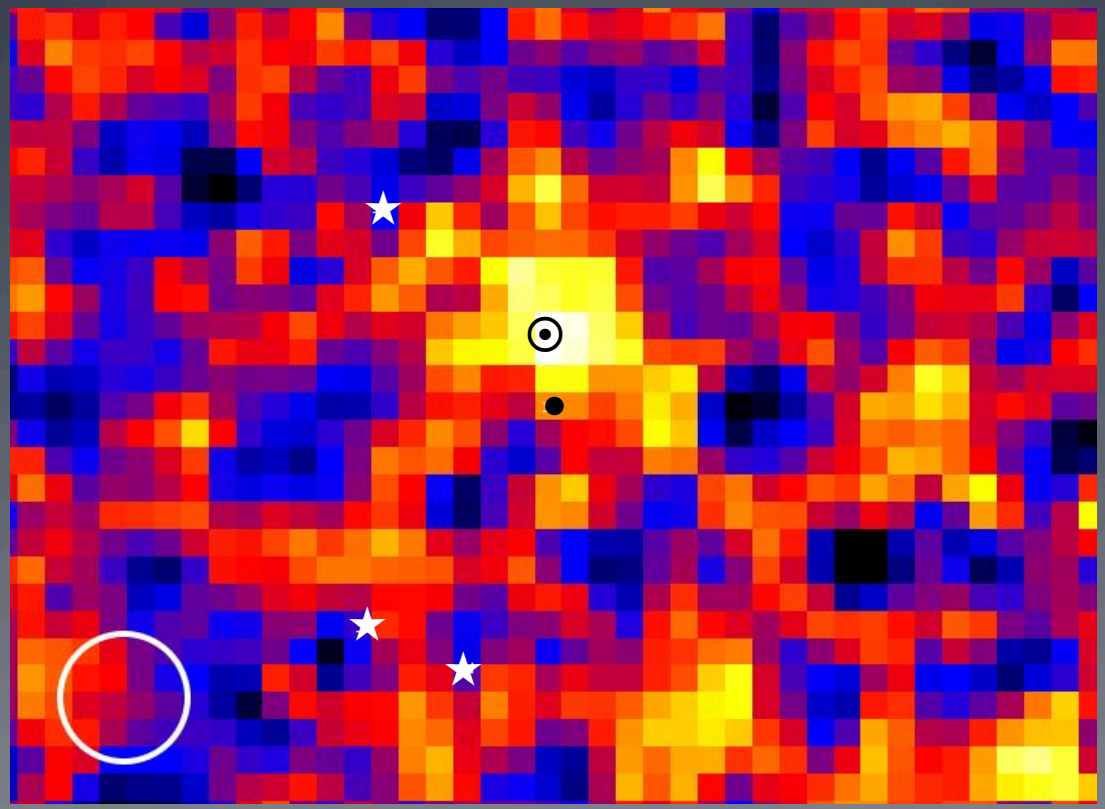
Background sources for VCC 781

- Superior resolution in PACS 160 μm image discards 3 background sources possibly contaminating the dwarf emission.



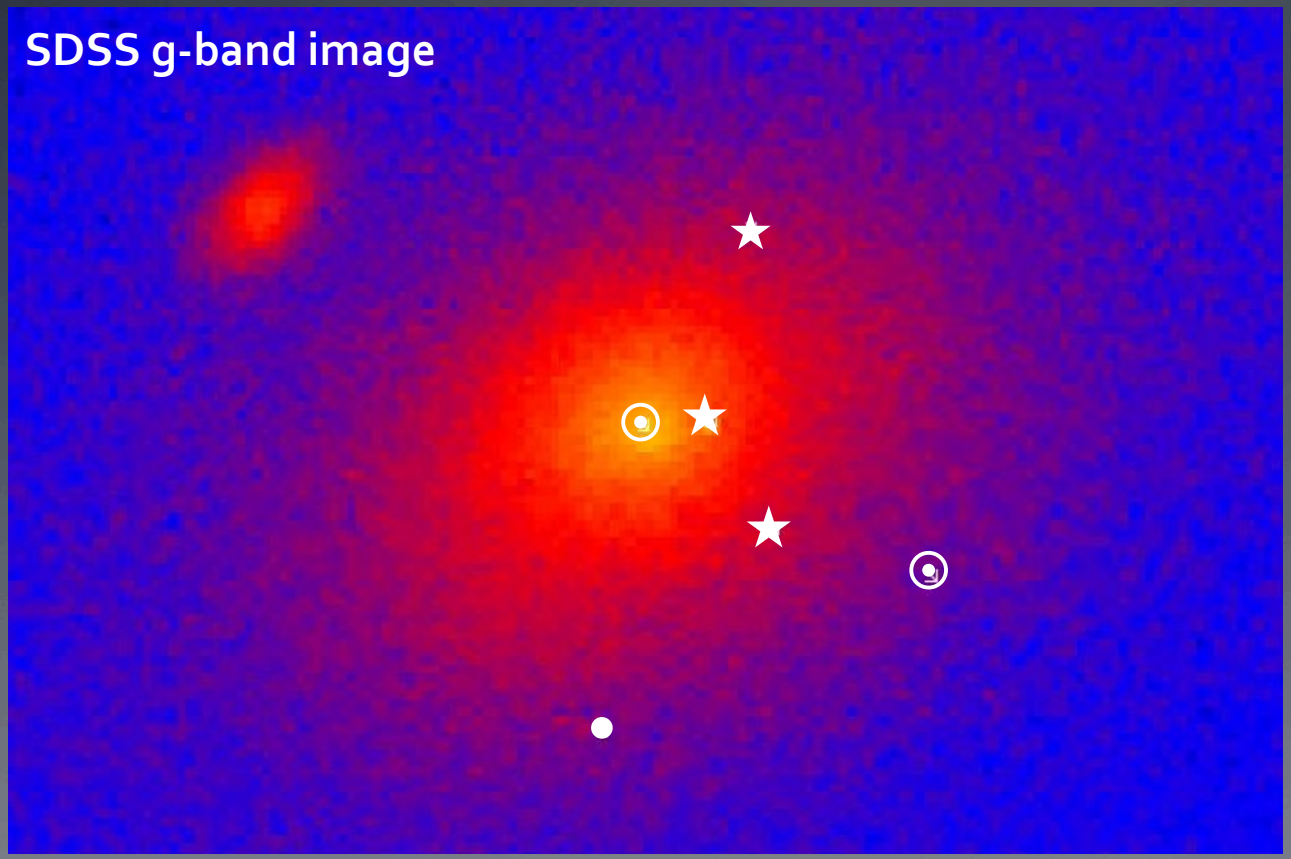
Background sources for VCC 781

- Superior resolution in Spitzer 24 μm image rules out the last background source (data from Fadda et al. in prep.).



Background sources for VCC 951

We identify 5 SDSS sources within the SPIRE 250 μm PSF region.



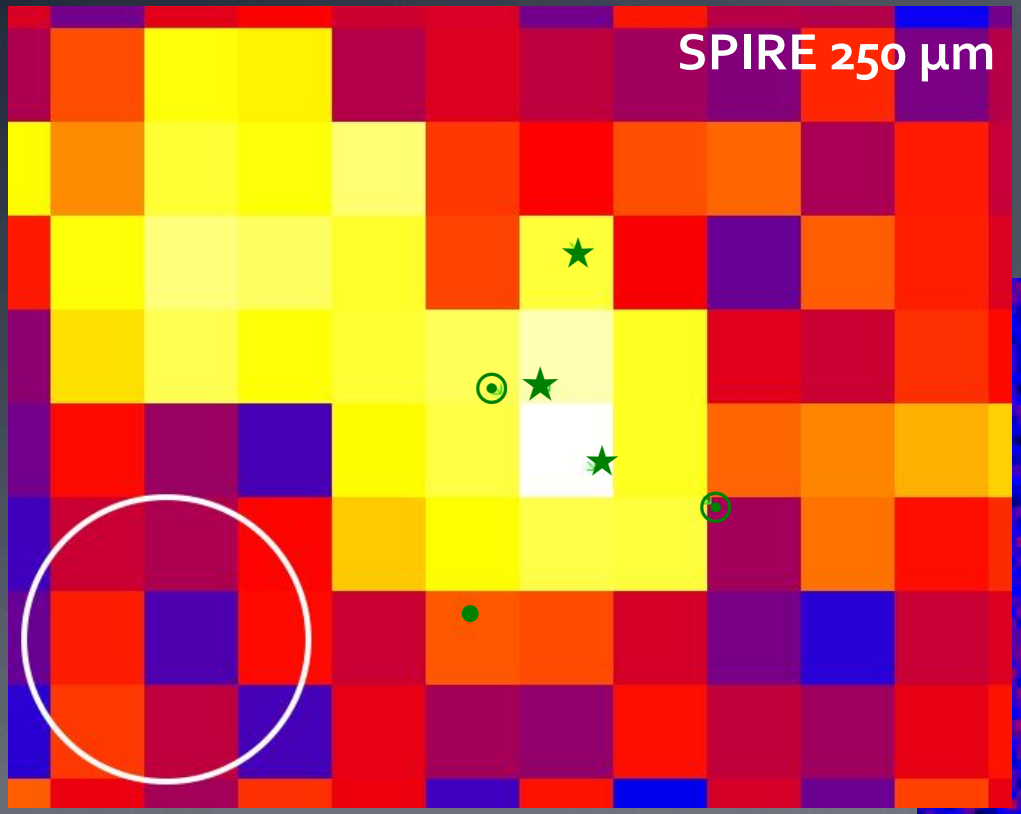
Classified as

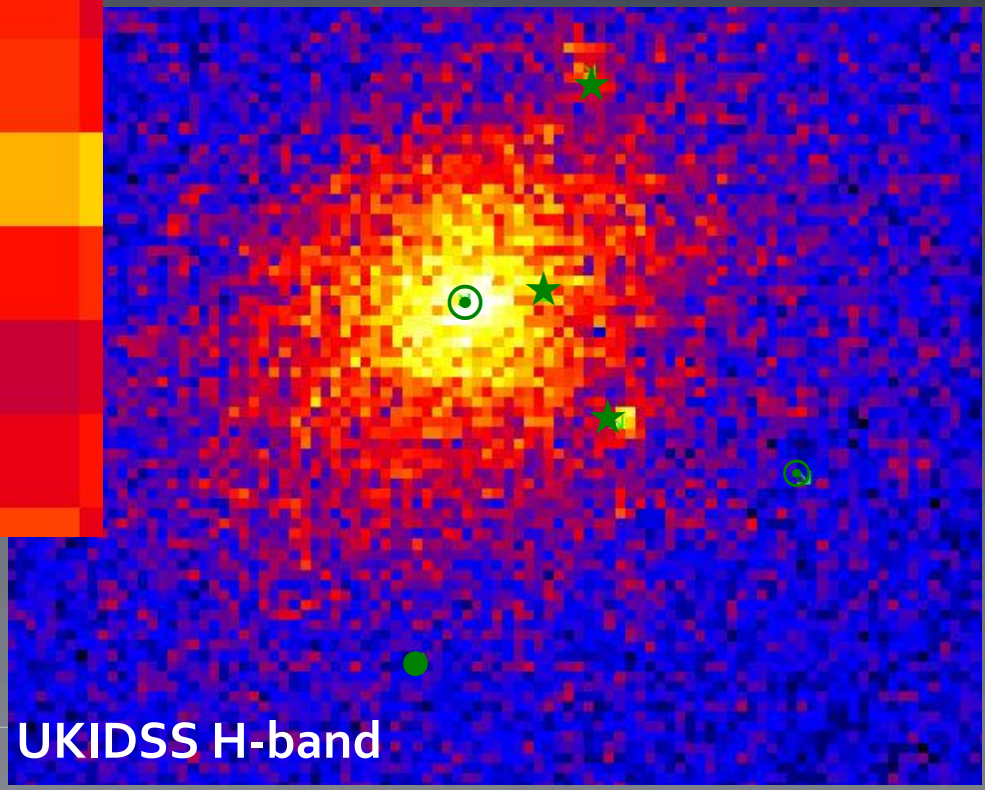
★ : star

⊙ : galaxy

• : no SDSS classification

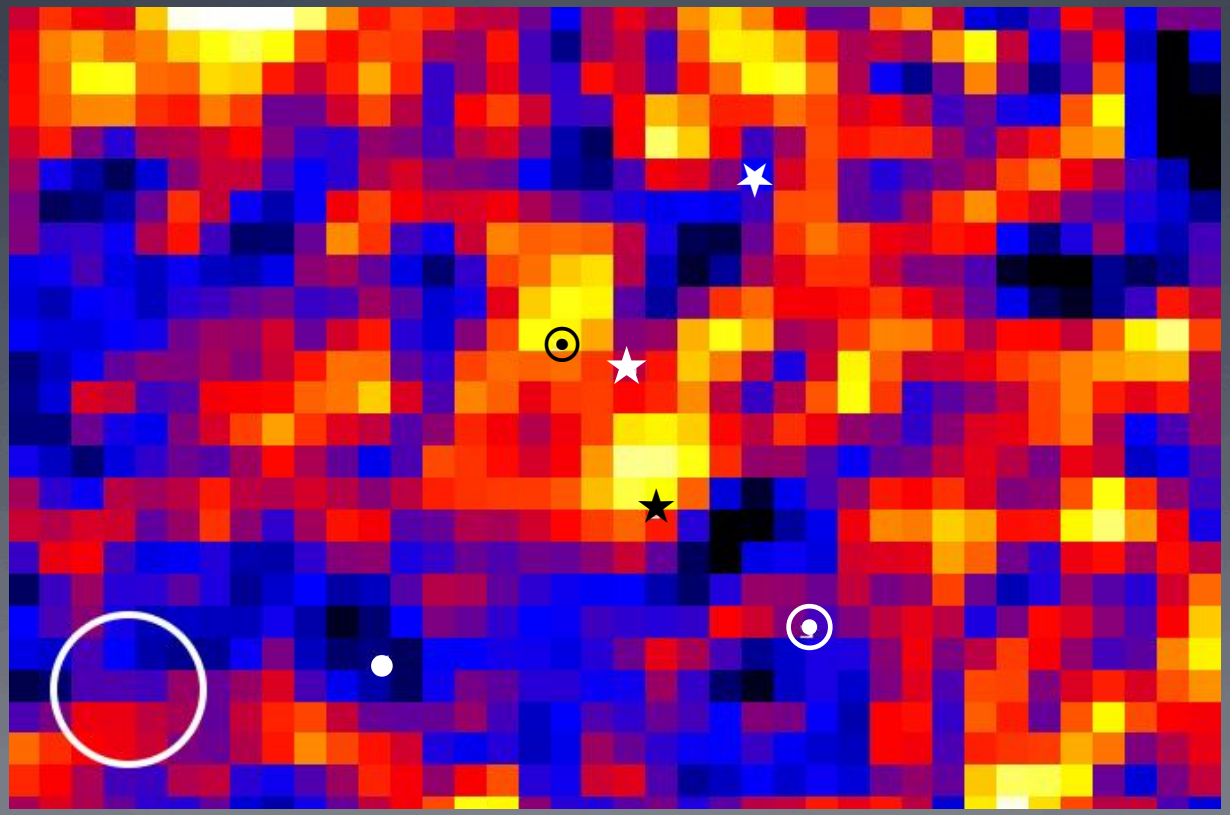
Background sources for VCC 951





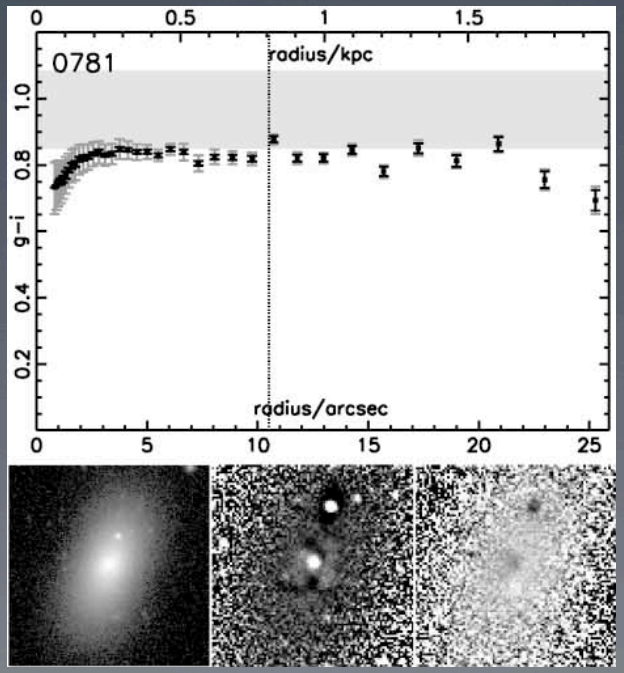
Background sources for VCC 951

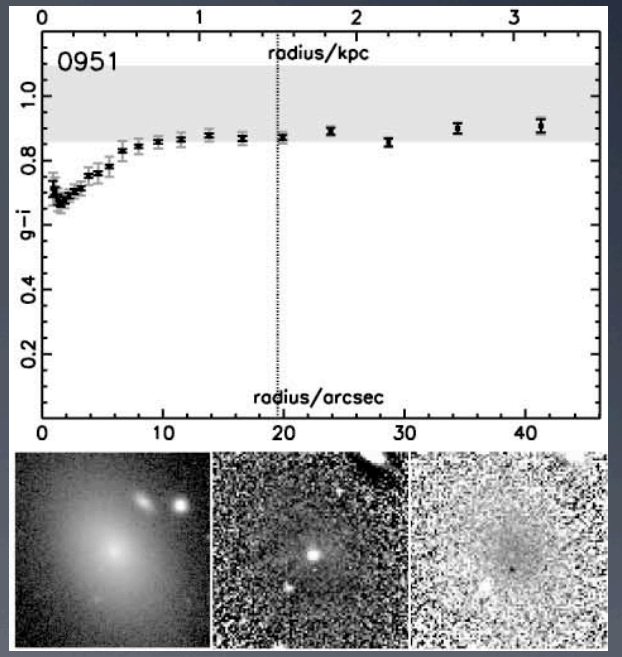
Superior resolution in Spitzer 24 μm image can not definitely exclude one background source classified as a star (data from Fadda et al. in prep.).



Morphology of both galaxies

- Classified as: $dSo_3(5)$,N VCC781
  dSo(2),N / dE2 pec,N VCC951
  (Binggeli et al. 1985)
- Central substructure (Lisker et al. 2006a)
- Blue central colors (Lisker et al. 2006b)

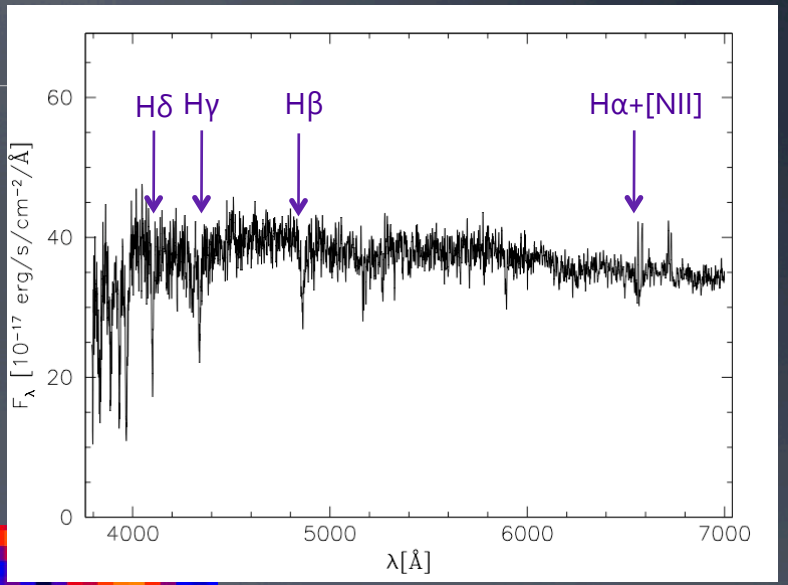




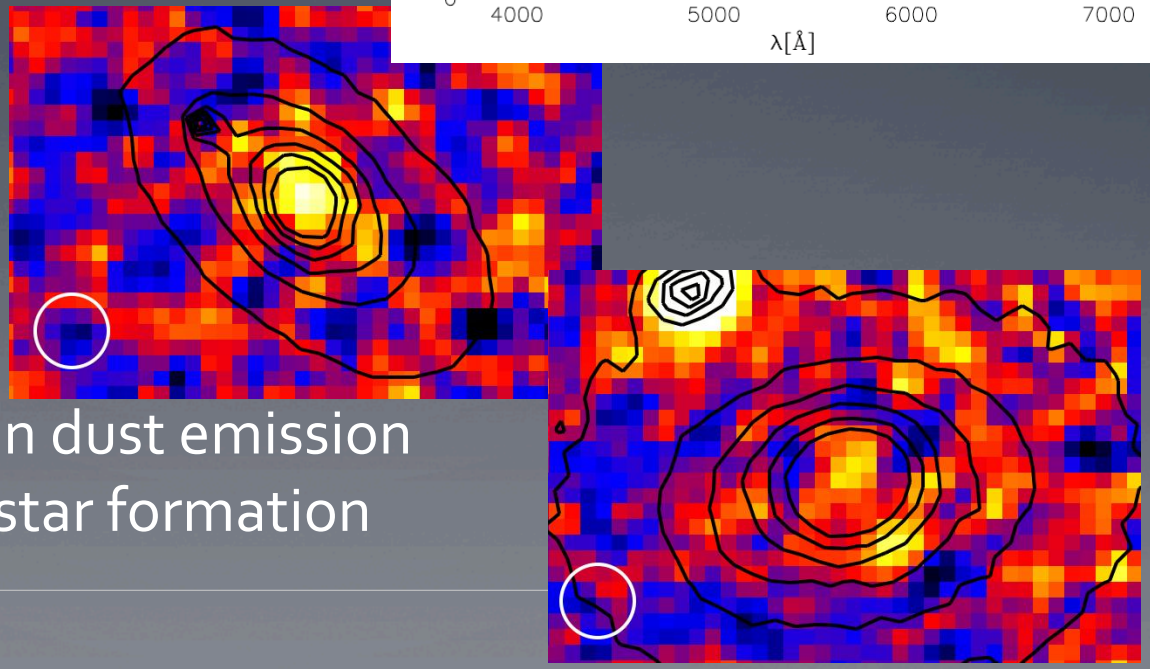
indicative for recent star formation

Photometric & spectral properties

- SDSS spectrum exhibits deep Hydrogen absorption lines: (EW[Hδ]) > 4 Å



- 24 μm emission is centered on and more concentrated than the optical nuclei



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both galaxies are in a post-starburst phase

➔ connection between dust emission and a recent episode of star formation

Photometric & spectral properties

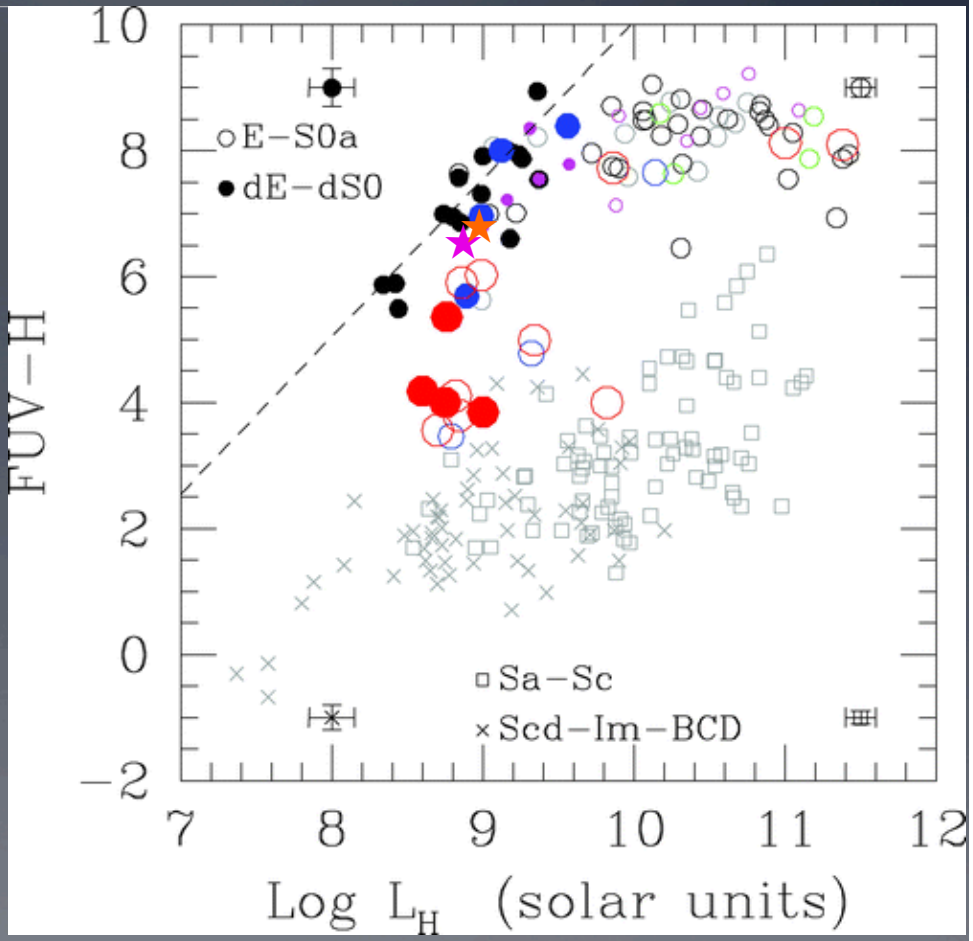
Boselli et al.(2008) define a **transitional class** of dwarf galaxies having properties in between:
* star-forming late-type galaxies
* quiescent early-type galaxies

Transitional class

$\log L_H < 9.6\ L_{H\odot}$

$3 < FUV - H < 6$

VCC 781 : ★
VCC 951 : ★



Boselli et al. (2008)

How convincing are these detections?

VCC 781

background sources?

➔ 24 μm image confirms that VCC 781 is responsible for the IR emission (the only other option is a **perfect** alignment with a background source and the center of VCC 781)

➔ VCC 781 has also been clearly detected at MIPS 70 and 160 μm

VCC 951

background sources?

➔ 24 μm image is unable to exclude contamination by a SDSS source, classified as a star, based on the 24 μm emission.

Combined with the post-starburst phase of both dEs, the weight of evidence is in favour of a true detection of dust in dEs !

Temperature and dust mass estimation

Two different procedures:

1. a. Determine dust temperature using Monte Carlo radiative transfer simulations.
   * stellar body is represented as an exponential profile
   * dust distribution is similar to stellar one
   * elliptical galaxy template SED from PEGASE library

   b. Compute corresponding dust masses according to

$$M_d = \frac{S_{250} D^2}{\kappa_{250} B_{250}(T_d)}$$

2. Simple grey body fit to Herschel data points

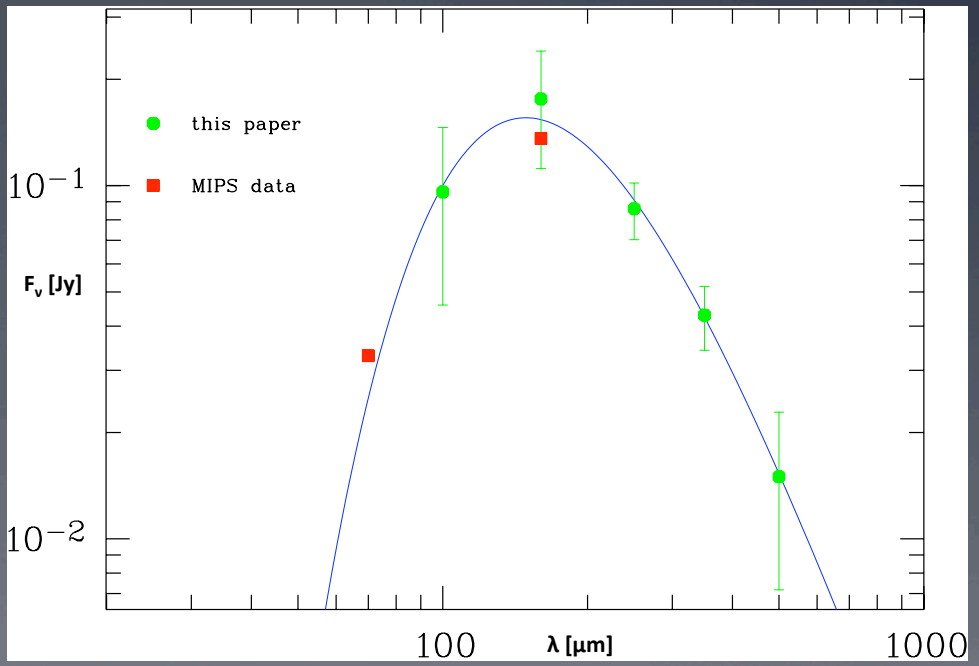
Temperature and dust mass estimate

Results for two different procedures:

1. VCC 781 $T_d = 20.7$ K
   $M_d = 1.9 \times 10^5 M_\odot$

   VCC 951 $T_d = 19.4$ K
   $M_d = 1.3 \times 10^5 M_\odot$

2. VCC 781 $T_d = 19.5$ K
   $M_d = 2.2 \times 10^5 M_\odot$



Gas-to-dust ratio

VCC 781 and VCC 951 were not detected in HI (angular separation from M87 of 1.39° and 1.2°, respectively)

➔we determine upper limits for the gas-to-dust ratio.

VCC 781

$M_{HI} < 2.3 \times 10^7 M_\odot$ (Gavazzi et al. 2003)

Gas-to-dust ratio < 124.3

VCC 951

$M_{HI} < 8.0 \times 10^6 M_\odot$ (Conselice et al. 2003)

Gas-to-dust ratio < 62.5

➔ low compared to Lisenfeld & Ferrara (1998), Walter et al.(2007)

Conclusion

- We have detected two objects (VCC 781 and VCC 951) at 10 σ with a high probability of being true detections of dEs ➔ detection rate ≈ 1 %
- 1.7 % HI detection rate in Virgo (di Serego Alighieri et al. 2007)

$3\sigma\ M_{HI}\ limit$ $3\sigma\ M_{d}\ limit$

$3.5 \times 10^{7}\ M_{\odot}$ ➔ $3.5 \times 10^{4}\ M_{\odot} \approx 10^{4}\ M_{\odot}$ (HeViCS SDP limit)

Our detection rate is **high**:
dEs with sufficient HI are preferentially located in the outskirts of Virgo
➔ if gas and dust are tightly coupled, we expect the central regions to be most dust deficient.
➔evidence of dust stripping in the Virgo Cluster is seen for the first time in HI-deficient spiral galaxies (Cortese et al. 2010)

Future work

Future HeViCS observations will go

* deeper (each field will be covered by 4 cross-scans)
* wider (the total observed area ~ 64 deg^2)

➔ we can perform better statistics
➔ reveal why some dwarf ellipticals possess a significant amount of dust while others are dust deficient

link with - gas-to-dust ratio
- metallicity
- position in the cluster (environmental effects)