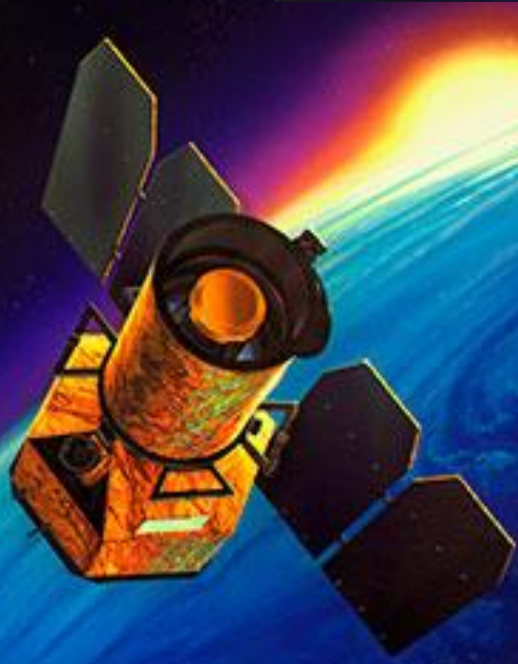


The GALEX Ultraviolet Virgo Cluster Survey

GUViCS

A. Boselli, S. Boissier, S. Heinis, L. Cortese, O. Ilbert, T. Hughes, O. Cucciati, J. Davies, L. Ferrarese, R. Giovanelli, M.P. Haynes, M. Baes, C. Balkowski, N. Brosch, S.C. Chapman, V. Charmandaris, M.S. Clemens, A. Dariush, I. De Looze, S. di Serego Alighieri, P.-A. Duc, P. R. Durrell, E. Emsellem, T. Erben, J. Fritz, D. A. Garcia-Appadoo, G. Gavazzi, M. Grossi, A. Jordan, K. M. Hess, M. Huertas-Company, L. K. Hunt, B.R. Kent, D. G. Lambas, A. Lancon, L.A. MacArthur, S.C. Madden, L. Magrini, S. Mei, E. Momjian, R. P. Olowin, E. Papastergis, M. W. L. Smith, J.M. Solanes, O. Spector, K. Spekkens, J. E. Taylor, C. Valotto, W. van Driel, J. Verstappen, C. Vlahakis, B. Vollmer, E.M. Xilouris.

GALEX Galaxy Evolution Explorer



The Galaxy Evolution Explorer was launched on April 28, 2003.

The 50-centimeter-diameter (19.7-inch) telescope onboard the Galaxy Evolution Explorer sweeps the skies in search of ultraviolet-light sources.

The GALEX Ultraviolet Virgo Cluster Survey (GUViCS) is a complete blind survey of the Virgo cluster covering ~ 40 sq. deg. in the far UV (FUV, $\lambda_{\text{eff}} = 1539\text{\AA}$, $\Delta\lambda = 442\text{\AA}$) and ~ 120 sq. deg. in the near UV (NUV, $\lambda_{\text{eff}} = 2316\text{\AA}$, $\Delta\lambda = 1060\text{\AA}$).

The goal of the survey is to study the ultraviolet (UV) properties of galaxies in a rich cluster environment, spanning a wide luminosity range from giants to dwarfs, and regardless of prior knowledge of their star formation activity.

The UV data will be combined with those in other bands (optical: NGVS; far-infrared - submm: HeViCS; HI: ALFALFA) to make a complete and exhaustive study of the effects of the environment on the evolution of galaxies in high density regions.

There are several reasons why Virgo has been chosen for these studies:

- It is a close cluster (16.5 Mpc; Mei et al. 2007)
- It is a rich cluster
- galaxies in a wide range in morphology and luminosity, from giant spirals and ellipticals down to dwarf irregulars, blue compact dwarfs (BCDs) and dwarf ellipticals (dE) and spheroidals (dS0).

There are three surveys are of particular relevance to study Virgo Cluster:

- The Next Generation Virgo Cluster Survey (NGVS, Ferrarese et al. 2011).
- The Herschel Virgo Cluster Survey (HeViCS, Davies et al.2010).
- The Arecibo Legacy Fast ALFA survey (ALFALFA, Giovanelli et al. 2005).

NGVS

The Next Generation Virgo Survey (Ferrarese et al., in preparation) is an optical (ugriz) survey covering 104 deg^2 of the Virgo cluster with MegaPrime on the CFHT to a point-source depth of $g \sim 25.7 \text{ mag}$ and a corresponding surface brightness of $\mu_g \sim 29 \text{ mag arcsec}^{-2}$.

The survey, which is now starting its third year of operations, will be completed in 2012. The goals of the NGVS are the study of faint end slope of the galaxy luminosity function, the characterization of galaxy scaling relations over a dynamic range of 7 orders of magnitude in mass, and the study of the diffuse and discrete intracluster population.



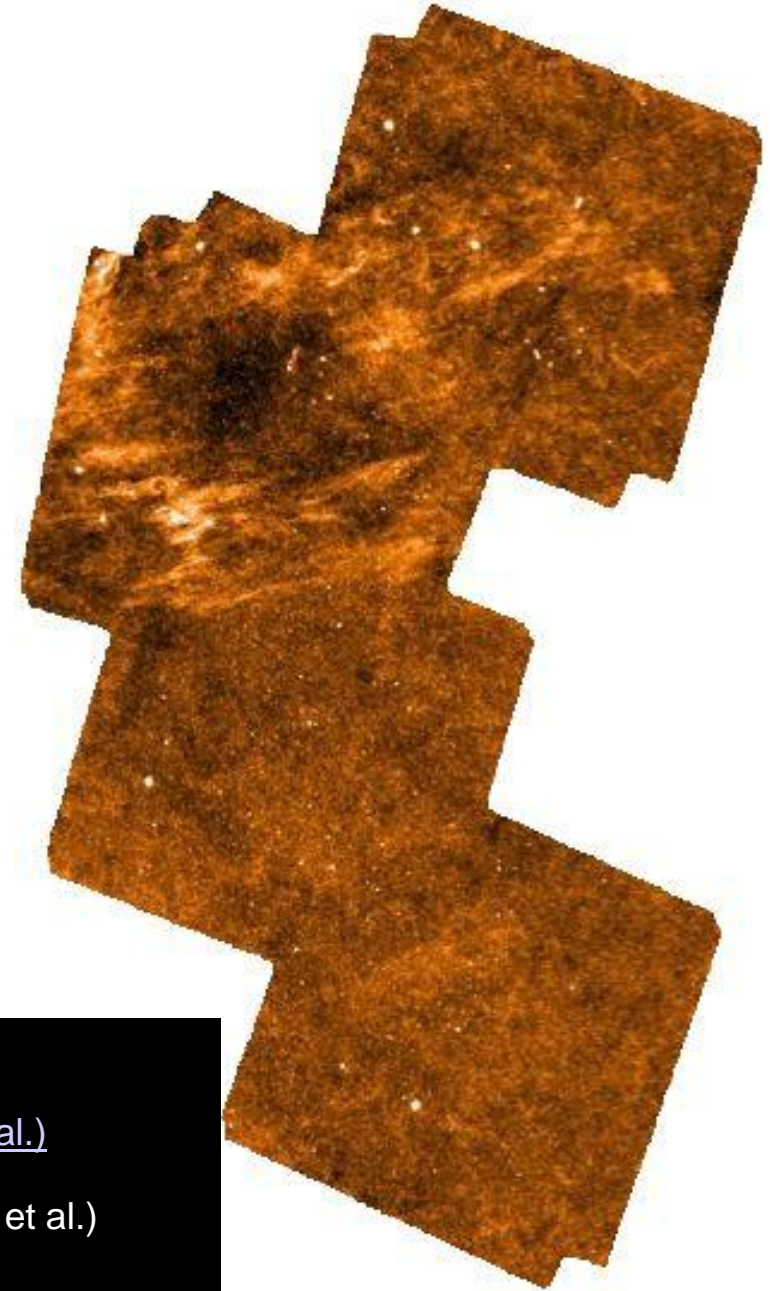
The CFHT/MegaCam CCD mosaic

- The faint-end shape of the luminosity function
- The characterization of galaxy scaling relations
- The study of stellar nuclei and their connection to supermassive black holes
- The connection between cluster, galaxies and the intracluster medium
- The fossil record of star formation and chemical enrichment in dense environments

HeViCS

The Herschel Virgo Cluster Survey (Davies et al. 2010) is a blind far-IR survey of 60 deg² in five photometric bands from 100 to 500 μm with PACS and SPIRE on the Herschel Space Observatory down to the confusion limit (at 250 μm; 286 hrs allocated as an open time key program on Herschel).

The goal of this survey is to study the dust properties of cluster galaxies, including the extended dust distributed around galactic discs or associated with tidal debris and low surface brightness galaxies, and to reconstruct the far-IR luminosity function as well as to detect dust in the intra cluster medium.



[Luminosity functions \(Davies et al.\)](#)

[Truncated dust disks in HI-deficient spirals \(Cortese et al.\)](#)

[A constraint on dust grain lifetimes in early-type galaxies \(Clemens et al.\)](#)

[Resolved dust analysis of spiral galaxies \(Smith et al.\)](#)

[Star-forming dwarf galaxies - dust in metal-poor environments \(Grossi et al.\)](#)

[The far-infrared view of M87 \(Baes et al.\)](#)

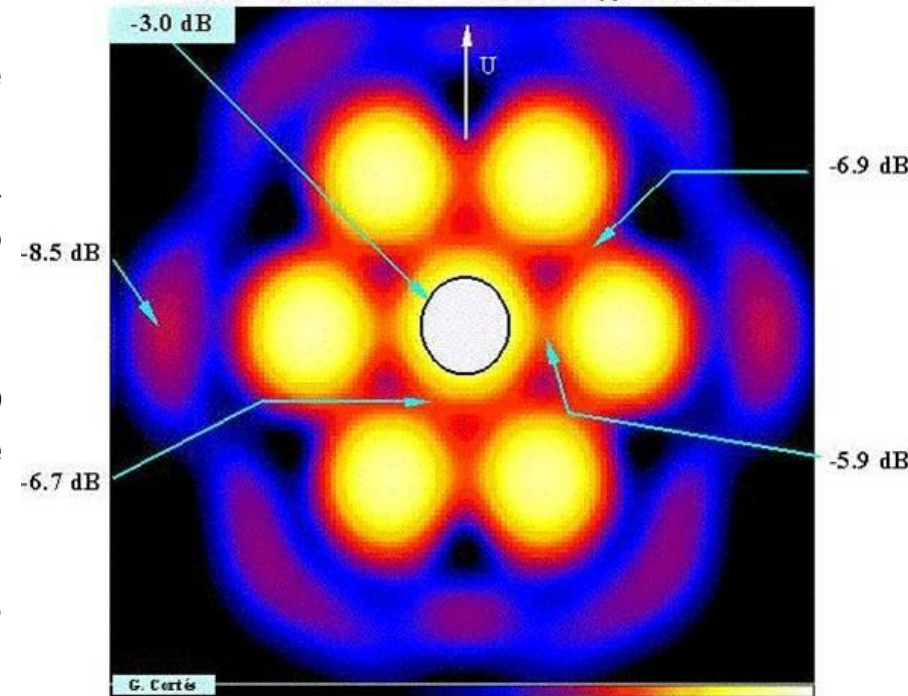
[Dust in cluster dwarf elliptical galaxies \(De Looze et al.\)](#)

[FIR colours and SEDs of nearby galaxies observed with Herschel \(Boselli et al.\)](#)

ALFALFA

The Arecibo Legacy Fast ALFA survey is a blind HI survey covering 7000 deg² in the declination range $0 < \text{dec} < 32$ and velocity range $-1600 < \text{vel} < 18000$ km s⁻¹ with a spectral resolution of 5 km s⁻¹ down to a sensitivity limit of 2.4 mJy, corresponding to $\sim 107.5 M_{\odot}$ at the distance of Virgo (Giovanelli et al. 2005).

The survey, which has already completed the Virgo cluster region, has been designed to provide the basis for studies of the dynamics of galaxies within nearby superclusters, allow measurement of the HI diameter and mass function, and enable a first wide-area blind search for local HI tidal features and HI absorbers



- A Legacy Survey: HI in the Nearby Universe
- The HI Mass Function and the "Missing Satellite Problem"
- Galaxy Evolution and Dynamics within Local Large Scale Structures
- The Extent and Origin of HI Disks
- The Nature of High Velocity Clouds
- A Blind Survey for 21 cm Absorbers at $z < 0.06$
- A Blind Survey for OH Megamasers at $0.16 < z < 0.25$

These surveys contain important information:

- The stellar population of Virgo galaxies
- Properties of the neutral gas (available for star formation)
- The dust (produced during stellar evolution) in the cluster.

A major ingredient is lacking for a complete study of the evolution of galaxies in clusters:

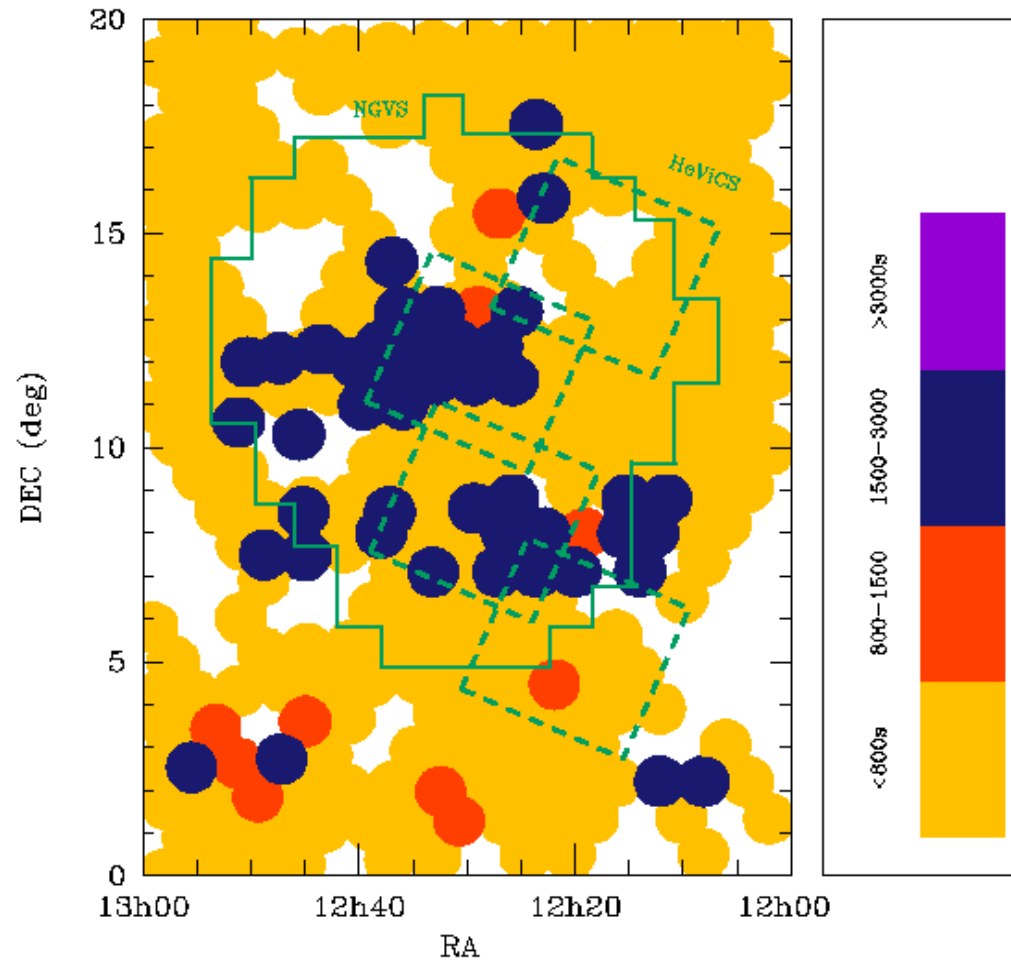
The present day star formation activity.

This can be determined from the UV flux emitted by the youngest stellar population, provided that dust extinction can be accurately determined,

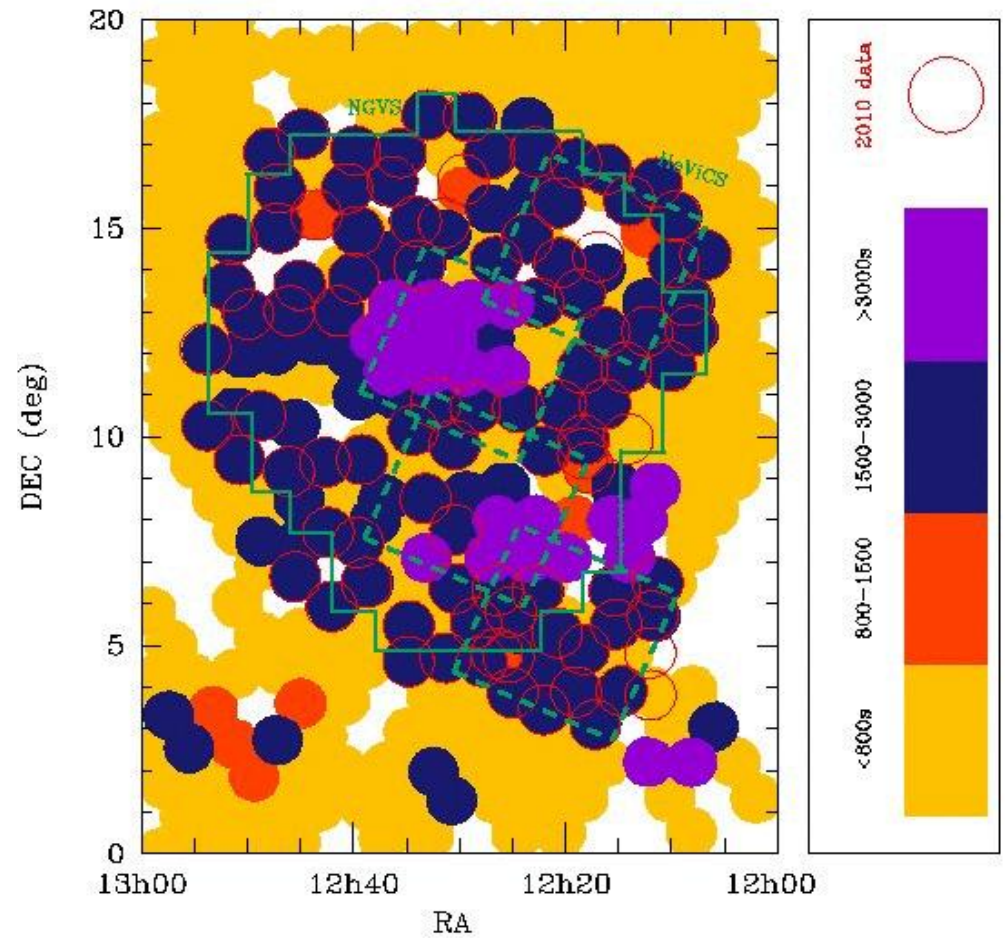
The combination of UV (GALEX), optical (NGVS), far infrared (HeViCS) and HI (ALFALFA) data of the whole Virgo cluster region will provide us with a unique dataset for a complete and coherent study of all kind of galaxies in different environments.

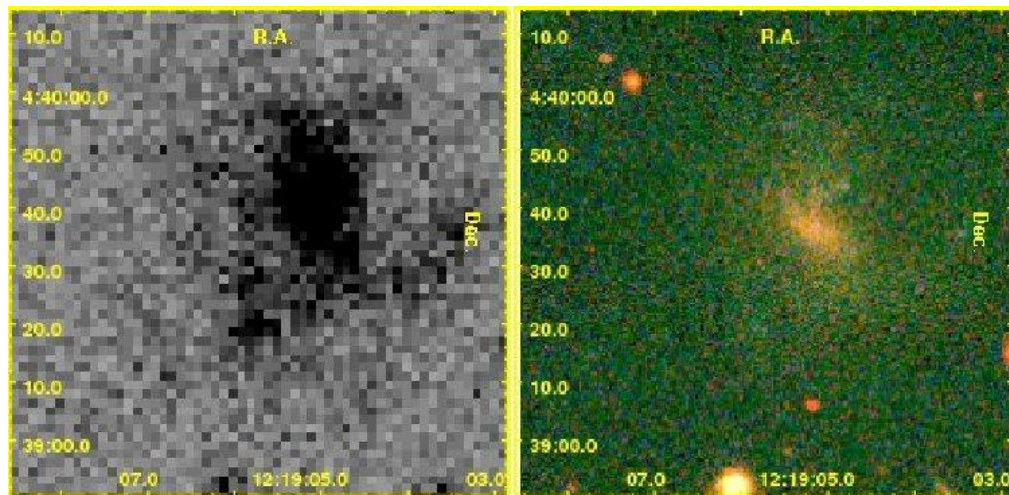
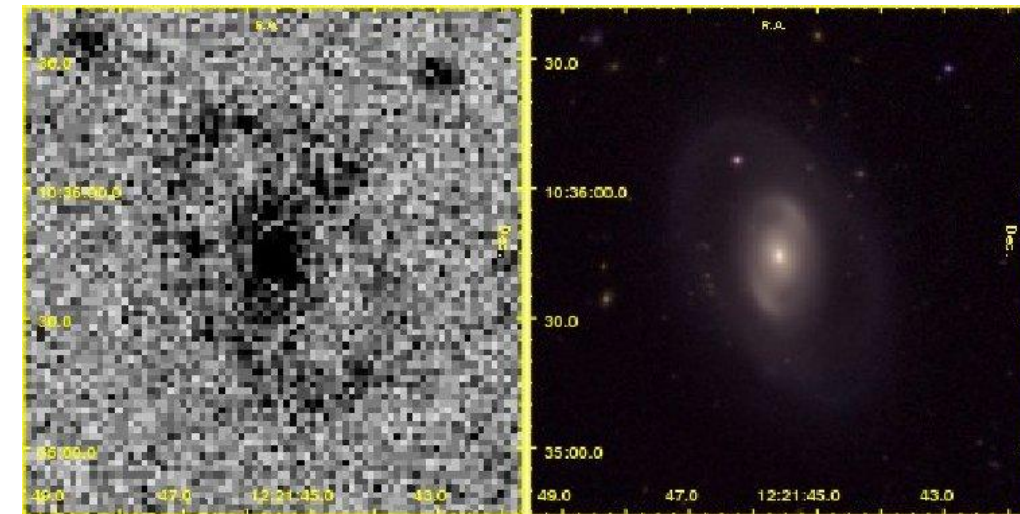
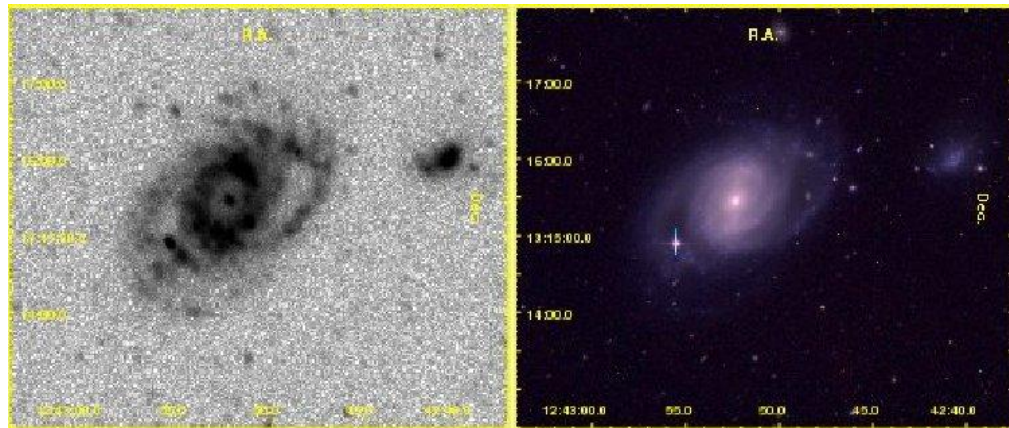
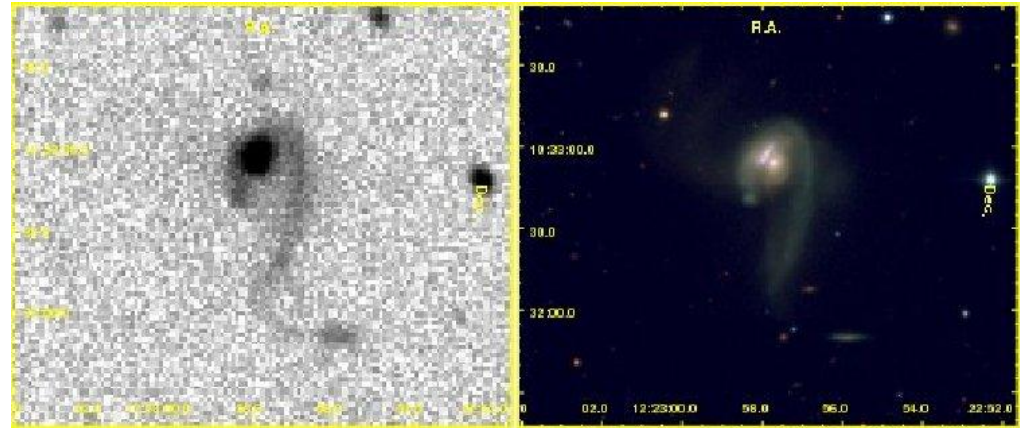
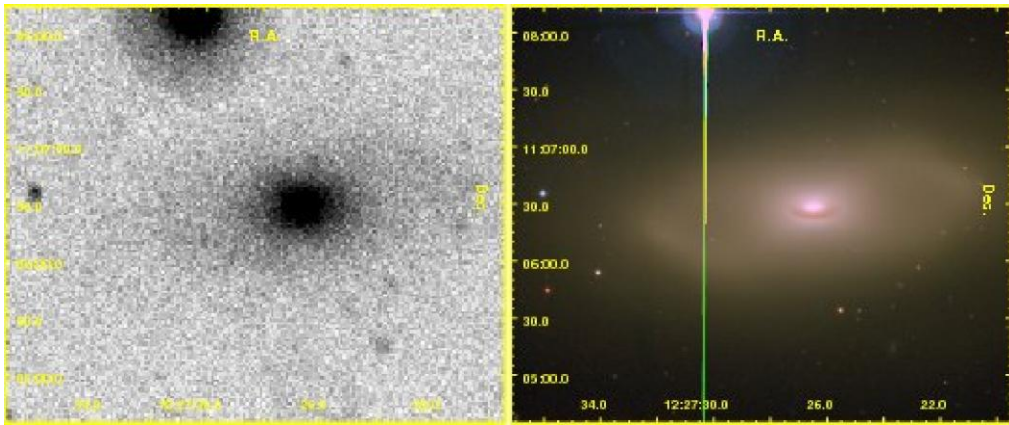
The GUViCS survey

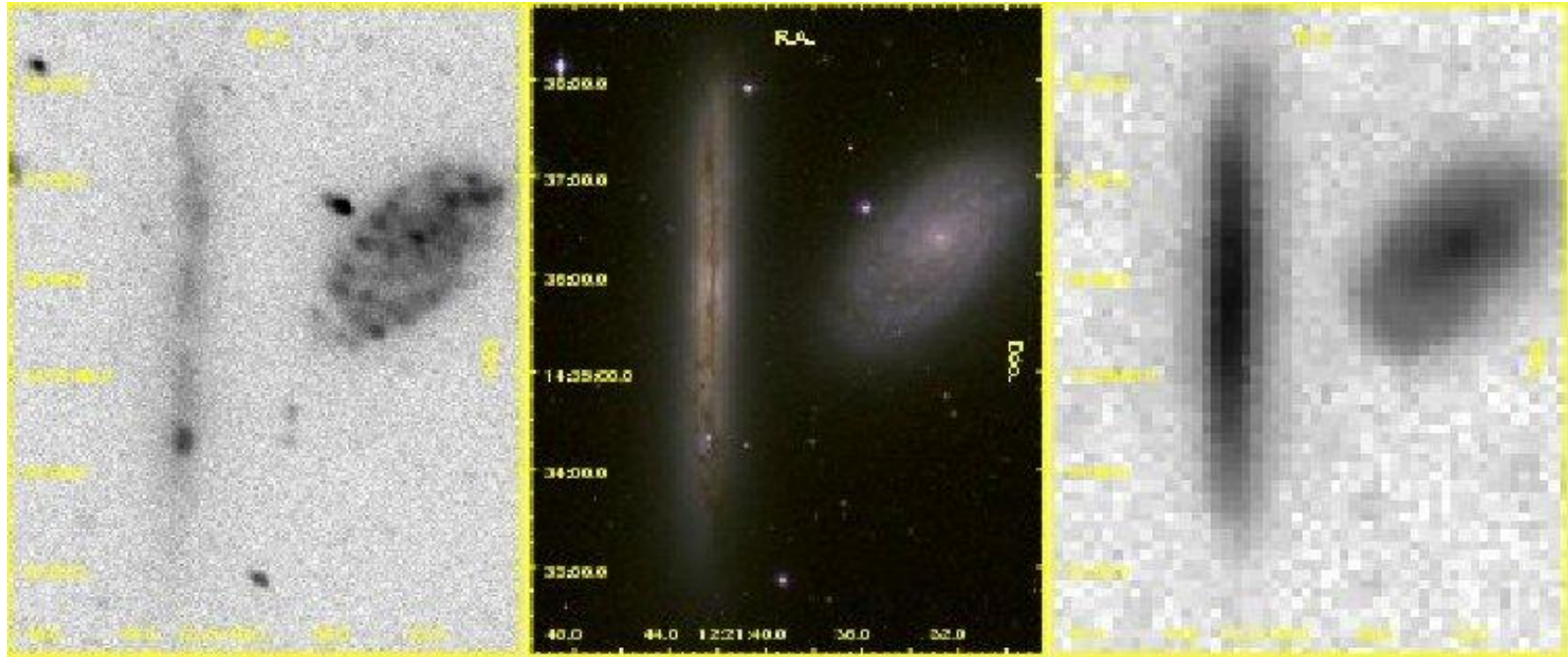
Virgo cluster
FUV band



Virgo cluster
NUV band

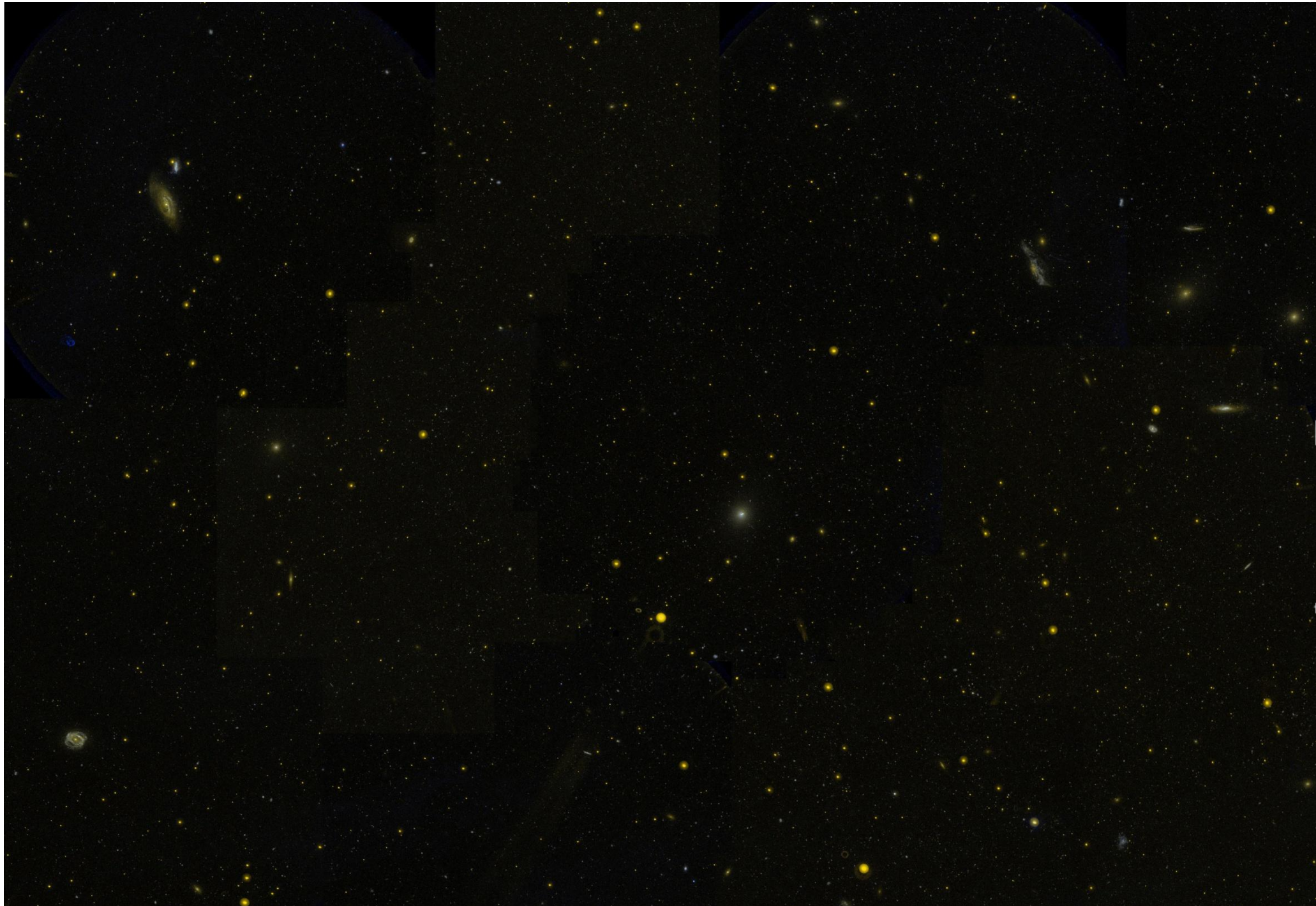




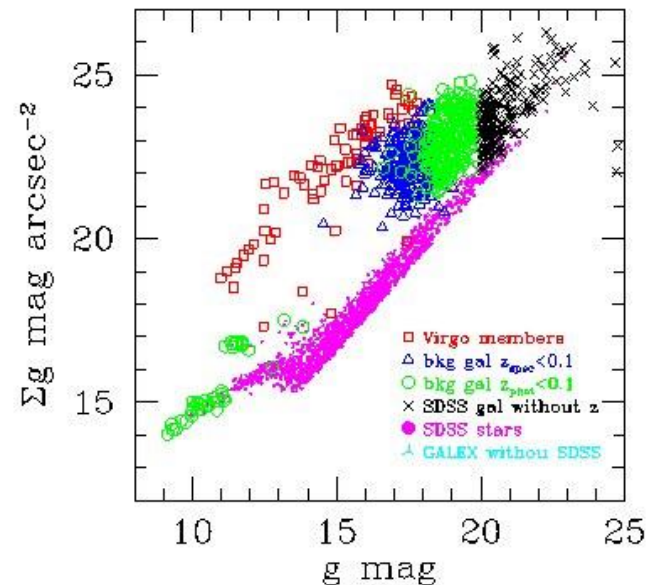
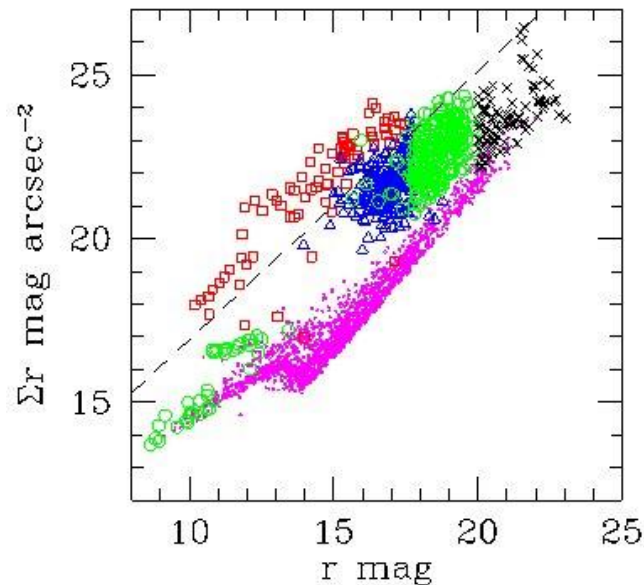
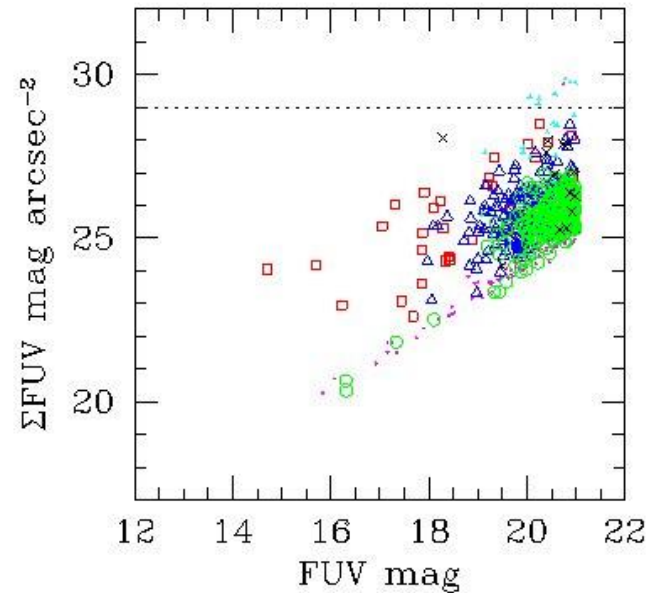
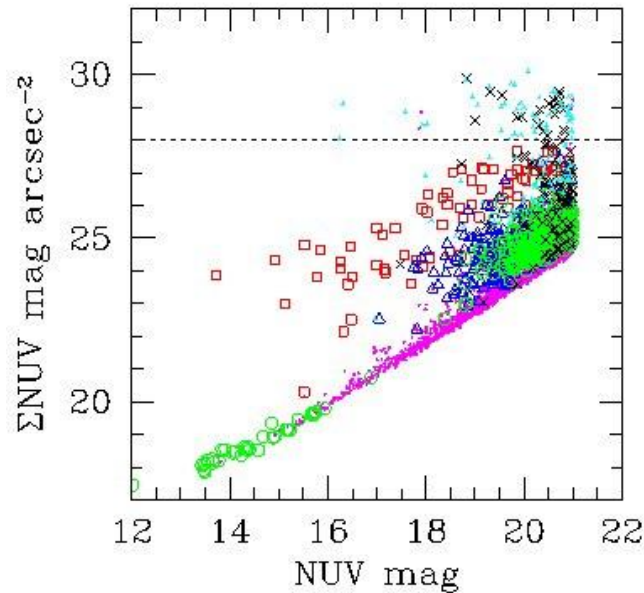


NUV (GUViCS) *gri* (NGVS) *far infrared* (HeViCS, 250 μm)
face-on NGC 4298 and the edge-on NGC 4302 spiral galaxies
in the Virgo cluster.

A mosaic of the central part of Virgo as seen with GALEX



The identification of Virgo cluster members



Cluster members are identified among the NUV and FUV detected galaxies adopting the following criteria:

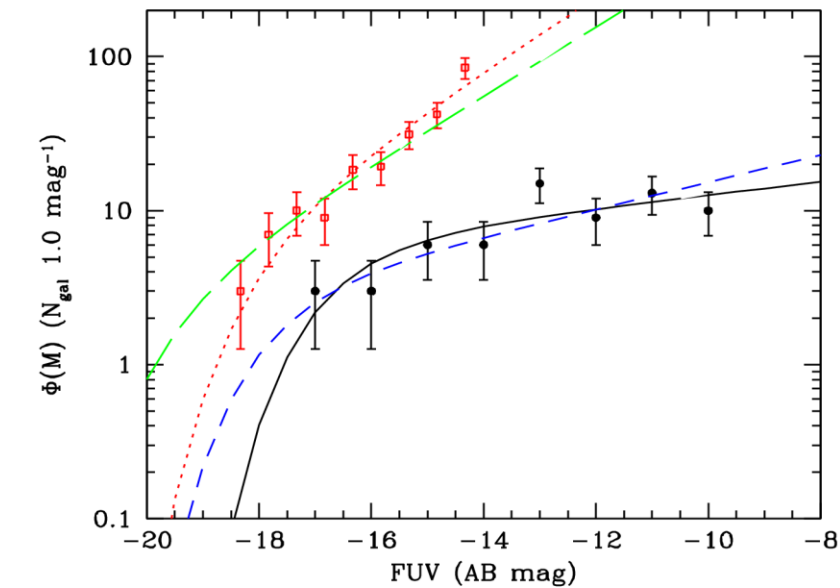
- Cross-correlate our catalogue with NED and SDSS to identify galaxies with available spectroscopic redshift

- Consider as Virgo members those with $z_{\text{spec}} < 0.01167$ to include galaxies in substructures of the cluster.

- For the remaining galaxies, rejected all objects with SDSS photometric redshift $z_{\text{phot}} \geq 0.1$

- The dashed line indicates the surface brightness vs. magnitude limit used for discriminating members from background objects.

The UV Luminosity Function of the central 12 deg²

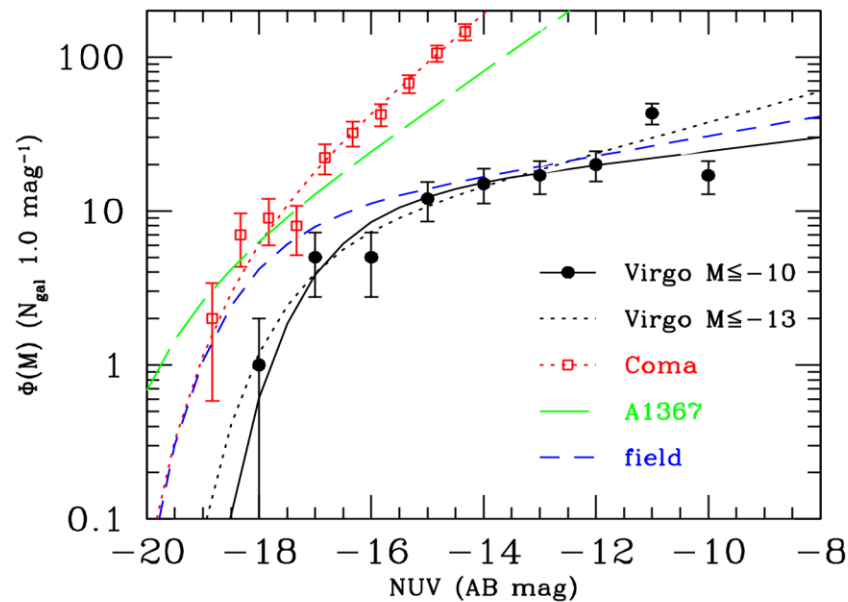


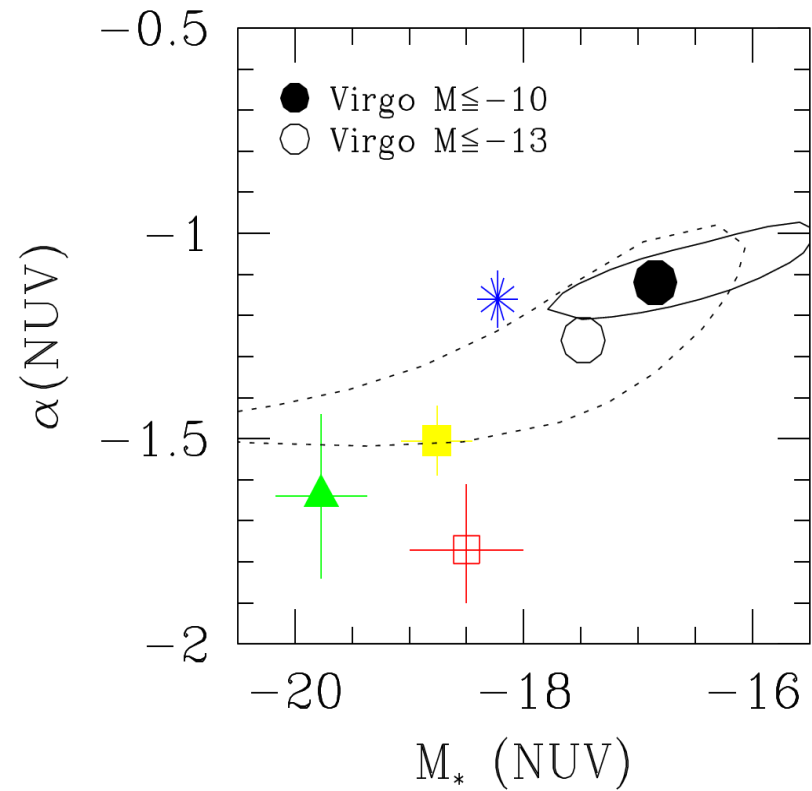
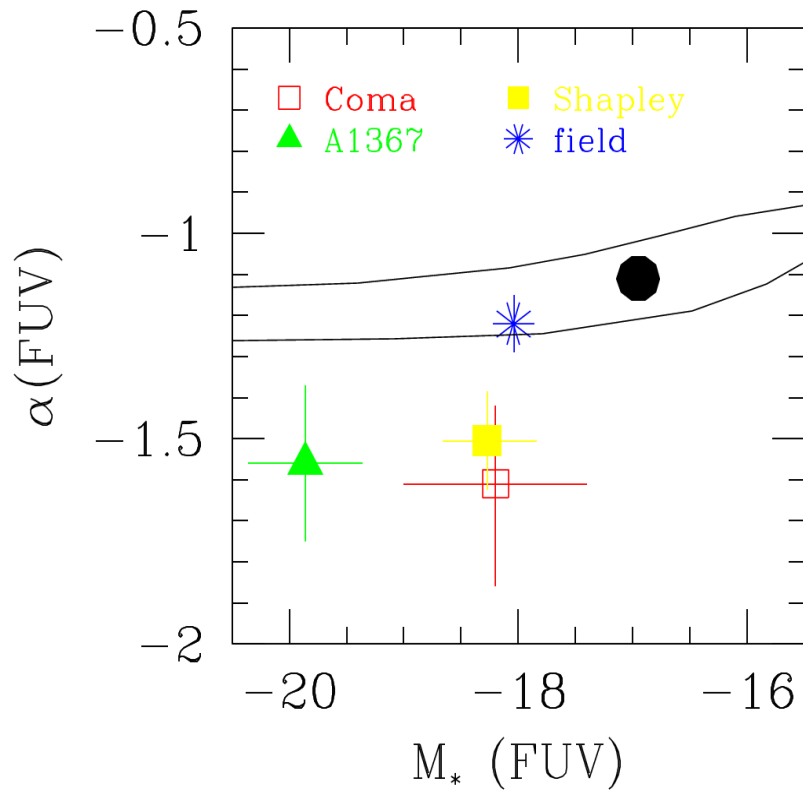
-The FUV and NUV (lower) luminosity functions of the Virgo cluster ($M \leq -10$ and $M \leq -13$) compared to those

-Coma cluster (Cortese et al. 2008),

-A1367 (Cortese et al. 2005)

-Field galaxies (Wyder et al. 2005).





Schechter functions parameters of Virgo cluster:

- $M \leq -10$ (black filled circles and solid contours)

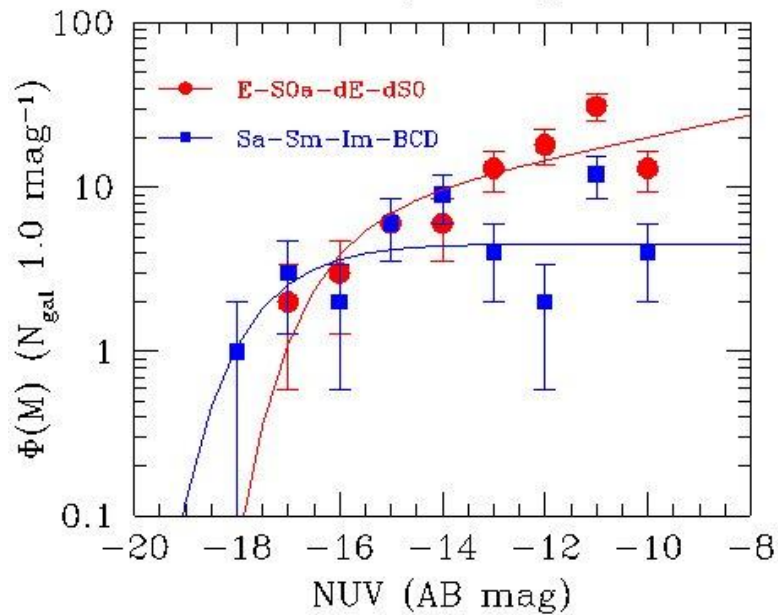
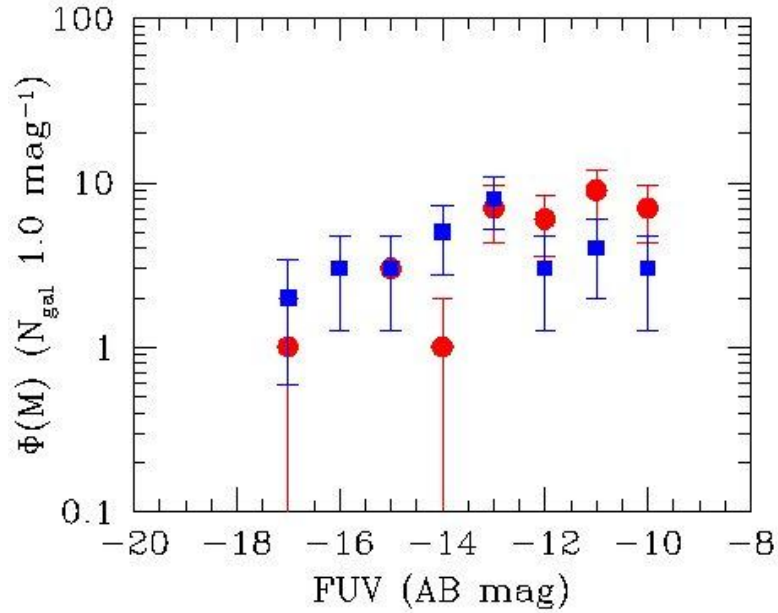
- $M \leq -13$ (black empty circles and dotted contour or error bars)

-Coma cluster (red empty square)

-A1367 (green filled triangle)

-Shapley supercluster (yellow filled square; from Haines et al. 2010)

-Field galaxies (blue asterisk)



UV luminosity function separately for:
 -late type (Sa-Sm-Im-BCD)systems
 -early type (E-S0a-dE-dS0) systems

Globular Clusters in Virgo Cluster Galaxies



Jordán et al. 2009, present catalogs of globular cluster candidates for the 100 galaxies of the Advanced Camera for Surveys Virgo Cluster Survey, a large program to carry out imaging of early-type members of the Virgo Cluster using the Advanced Camera for Surveys (ACS) on the *Hubble Space Telescope*.

For each detected source we have its position, magnitudes in the F475W (\approx Sloan *g*) and F850LP (\approx Sloan *z*) bandpasses, and half-light radii by fitting point-spread function convolved King models to the observed light distribution.

These measurements are presented for 20,375 sources, of which 12,763 are likely to be globular clusters.

GUVICS data



0.0015 0.0045 0.01 0.022 0.046 0.094 0.19

FUV band

NUV band



0.012 0.036 0.085 0.18 0.38 0.76 1.5 3.1 6.2

Our project

The data on globular clusters of Virgo galaxies available in Jordan et al. 2009, with information on angular positions, galactocentric distances, and model ACS magnitudes in the F850LP & F475W bands will be correlated with GUVICS FUV and NUV data.

The main idea is to analyse the projected spatial distribution of globulars and their properties cross correlated to extended UV emission.

-Is there a relation between the extent of the UV emission of Virgo galaxies and their GC system?

-How does GCs characteristics are related to the galaxies and to their UV emission?

A joint study of these issues may provide an insight on the formation and evolution of GCs and its relation to star formation and galaxy evolution in clusters.