Multifrequency surveys of the Virgo cluster: **ALFALFA, HeViCS, SMAKCED, NGVS, GUViCS**

Alessandro BOSELLI,
on behalf of the different science teams

Introduction: the general context

Which are the main driver of galaxy evolution ?

Galaxies are distributed within the Universe in a non homogeneous way (voids, groups, superclusters, clusters..)

In high density environments both gravitational interactions and interactions with the cluster IGM can heavily affect the physical properties of galaxies

Which is the role of the environment on galaxy evolution?

Introduction: the multifrequency approach

1) Important to trace the different galaxy components (stars, gas, dust…)

2) Necessary to reconstruct the intrinsic SED (dust extinction….)

3) Critical for identifying the nature of the undergoing perturbation

Introduction: the Virgo cluster

1) The closest rich cluster of galaxies ⇒ perfect target to study the effect of the environment on galaxy evolution (dwarf galaxy population, angular resolution, multifrequency data…)

2) Unrelaxed, spiral rich cluster ⇒ example of ongoing formation process

3) Different ongoing blind/pointed surveys (NGVS, HeViCS, ALFALFA, SMAKCED, GUViCS…) ⇒ complete multifrequency coverage

ALFALFA (The Arecibo Legacy Fast ALFA Survey): HI 21 cm survey with ALFA at Arecibo

http://egg.astro.cornell.edu/alfalfa/docs/index.php

PI: R. Giovanelli & M. Haynes (Cornell)

Area: 104 sq.deg (7000 sq.deg)

Integration time: 4130 h

Angular resolution : 3.5'

Velocity range: -1600 km/s < cz < 18000 km/s

Sensitivity: 2.4 mJy/beam @ 5 km/s

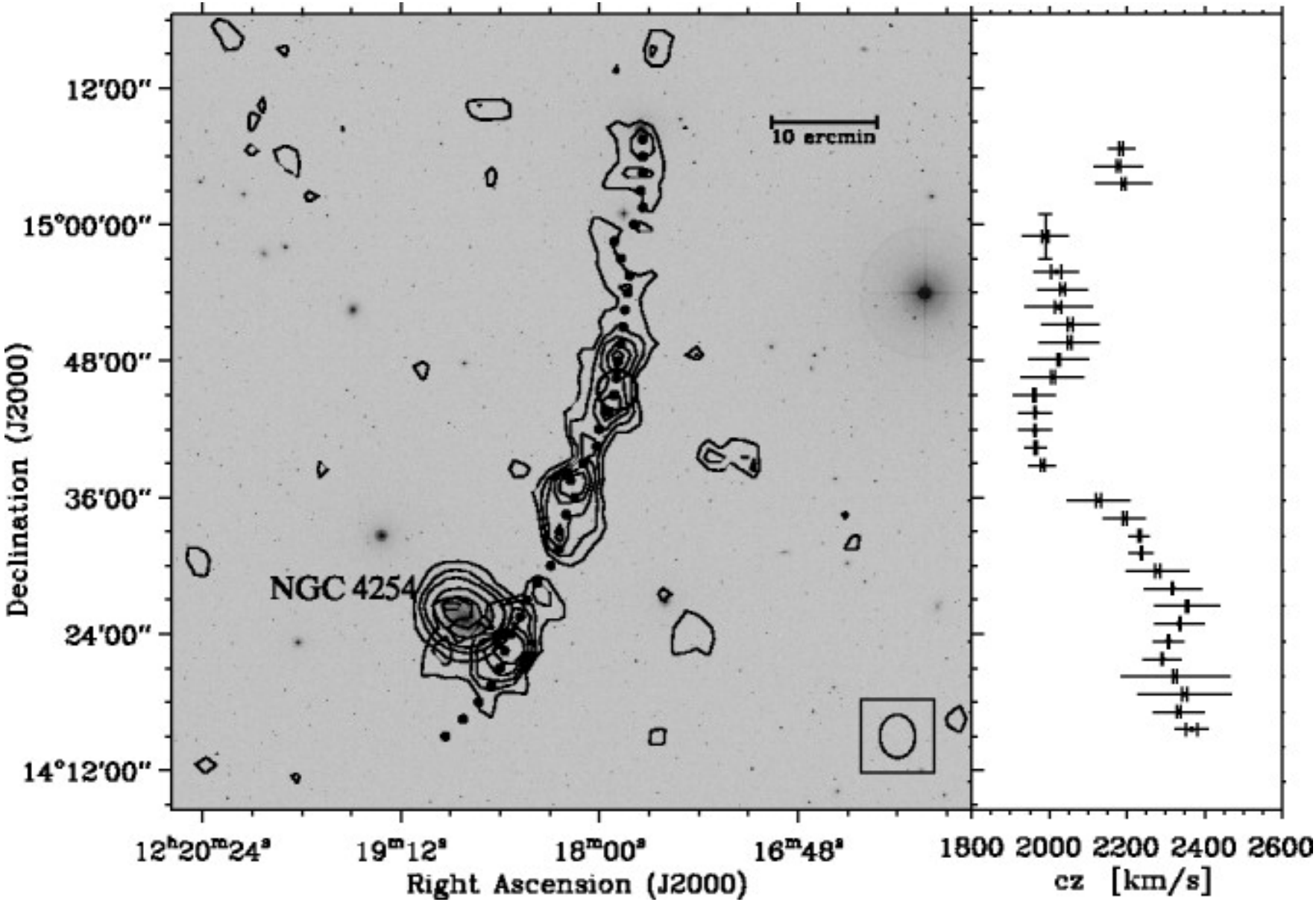
HI mass limit: ~ $10^{7.5}$ Mo

Status: Completed

Publications: Giovanelli et al 2005, **2007**; Kent et al 2007, **2008**, 2009; Koopmann et al 2008; Gavazzi et al 2008, di Serego Alighieri et al 2007, Haynes et al 2007….

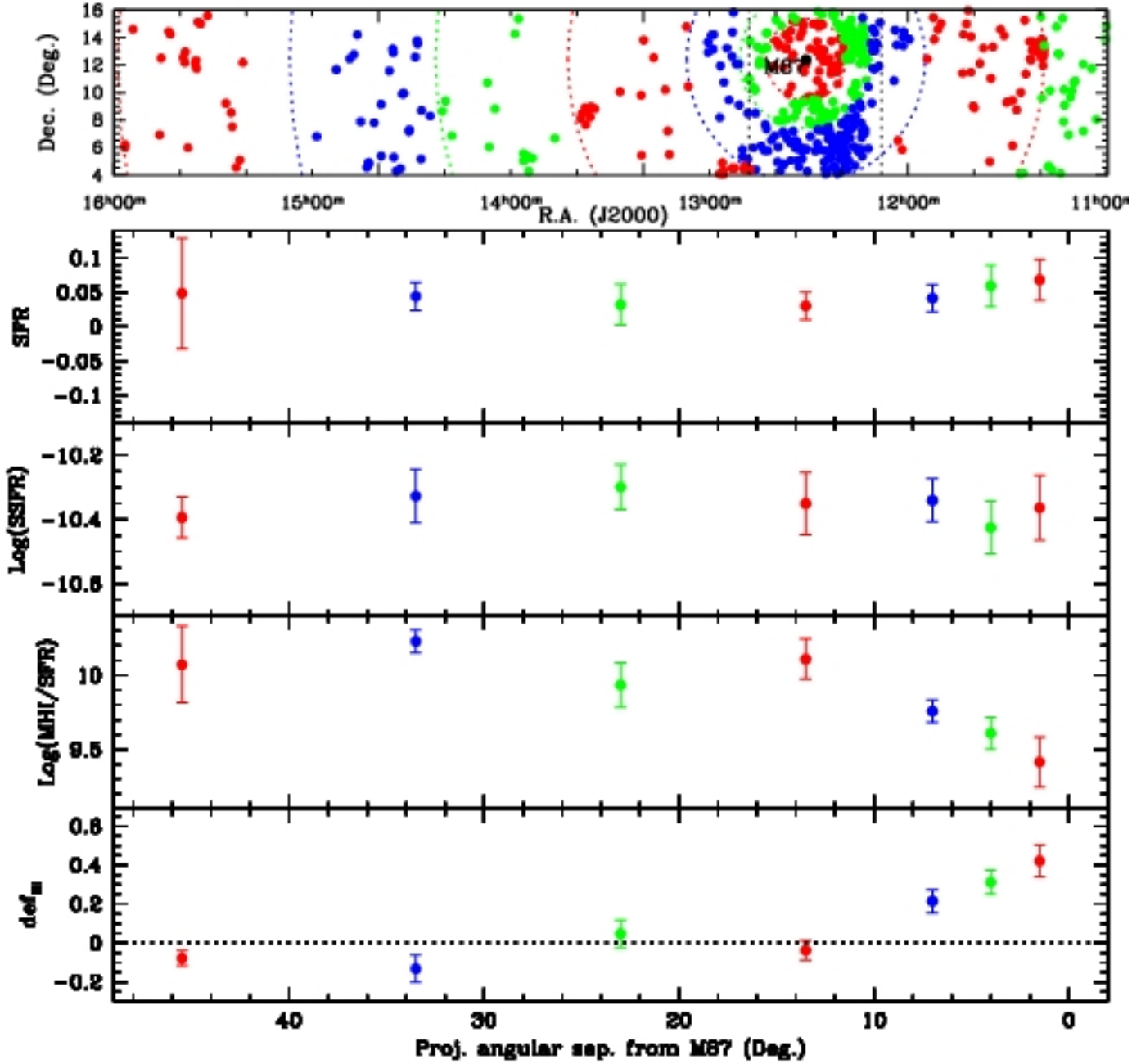
Haynes et al 2011 (+4<dec<+16)

NGC4254 an act of harassment seen by ALFALFA



Haynes et al 2007

ALFALFA HI data: Halpha follow up (SPM)



Gavazzi et al 2012a,b

HeViCS (The Herschel Virgo Cluster Survey): FIR: 100, 160, 250, 350, 500 mic

http://www.arcetri.astro.it/twiki/bin/view/HeViCS/WebHome

PI: J. Davies (Cardiff)

Area: 60 sq.deg

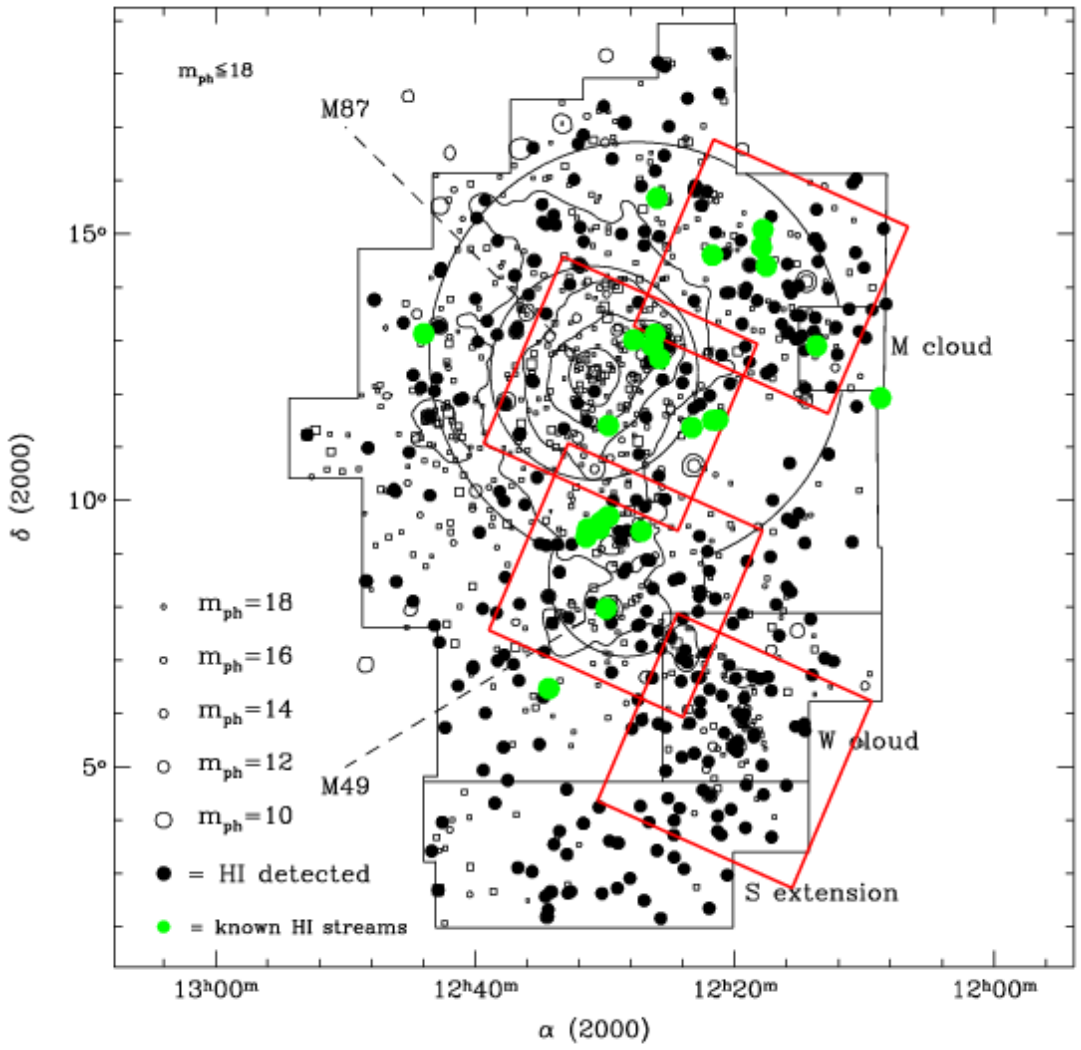
Integration time: 286 h

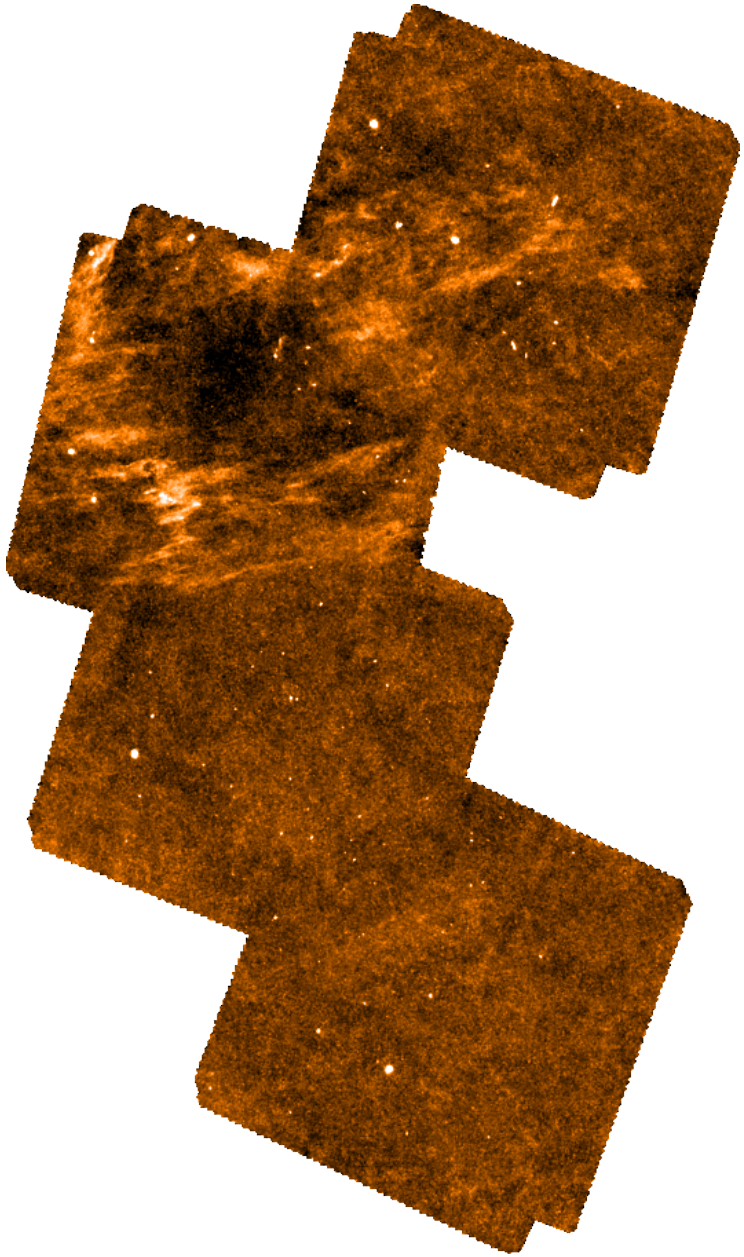
Sensitivity: ~ confusion limit: 6.8, 3.1 (PACS), 1.0, 0.7, 0.3 (SPIRE) MJy/sr

Resolution: ~7-35 arcsec

Status: completed

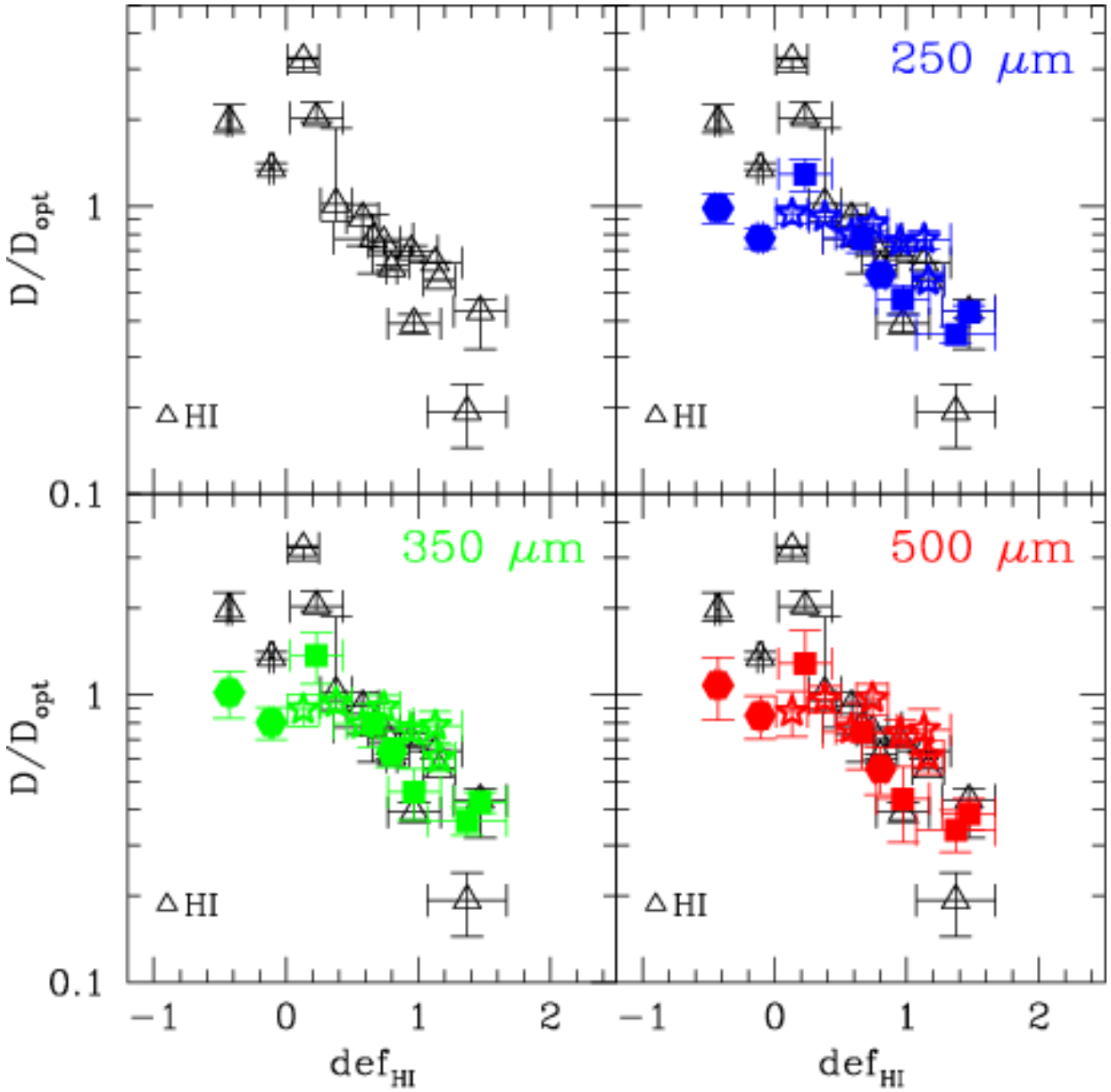
HeViCS (The Herschel Virgo Cluster Survey): FIR: 100, 160, 250, 350, 500 mic





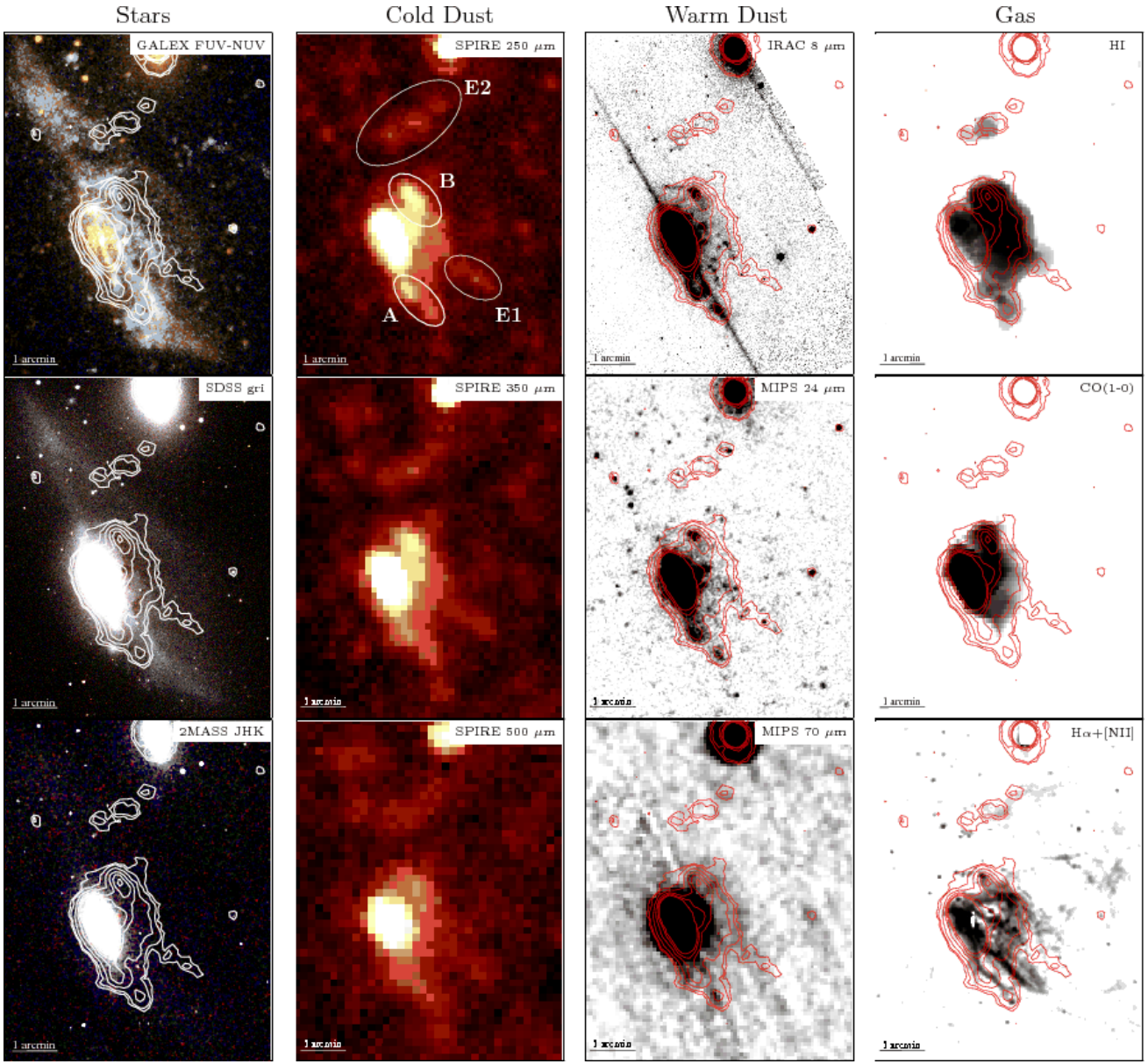
Davies et al 2011

Dust stripping in gas deficient galaxies



Cortese et al 2010a

NGC4438: dust stripping in tidal interactions



Cortese et al 2010b

SMAKCED (Stellar populations, Masses and Kinematics of Clusters Early Type Dwarfs): NIR (H,K) imaging and high resolution optical spectroscopy

PI: T. Lisker, J. Janz (NIR imaging) & E. Toloba (spectroscopy)

http://smakced.net

Pointed observations on ~ 100-200 dE galaxies in Virgo

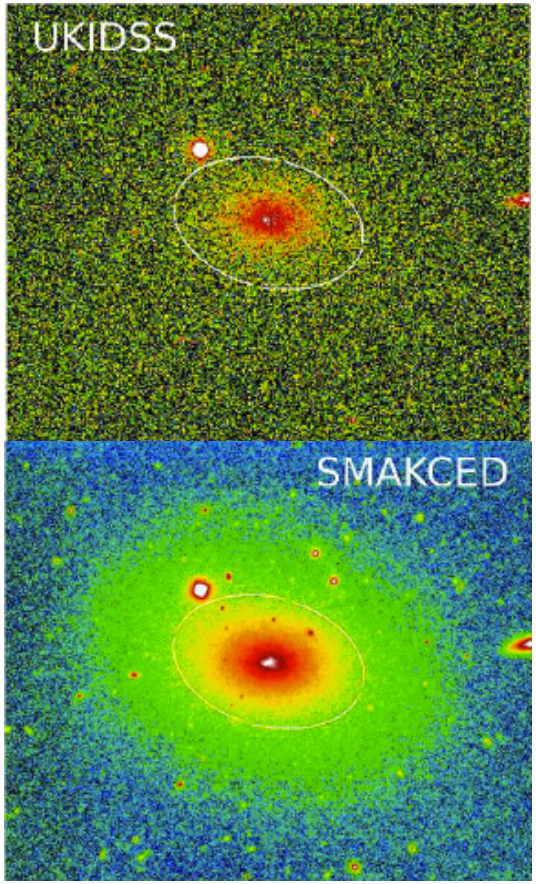
NIR imaging

Telescope	Nights
NOT, TNG, NTT	50

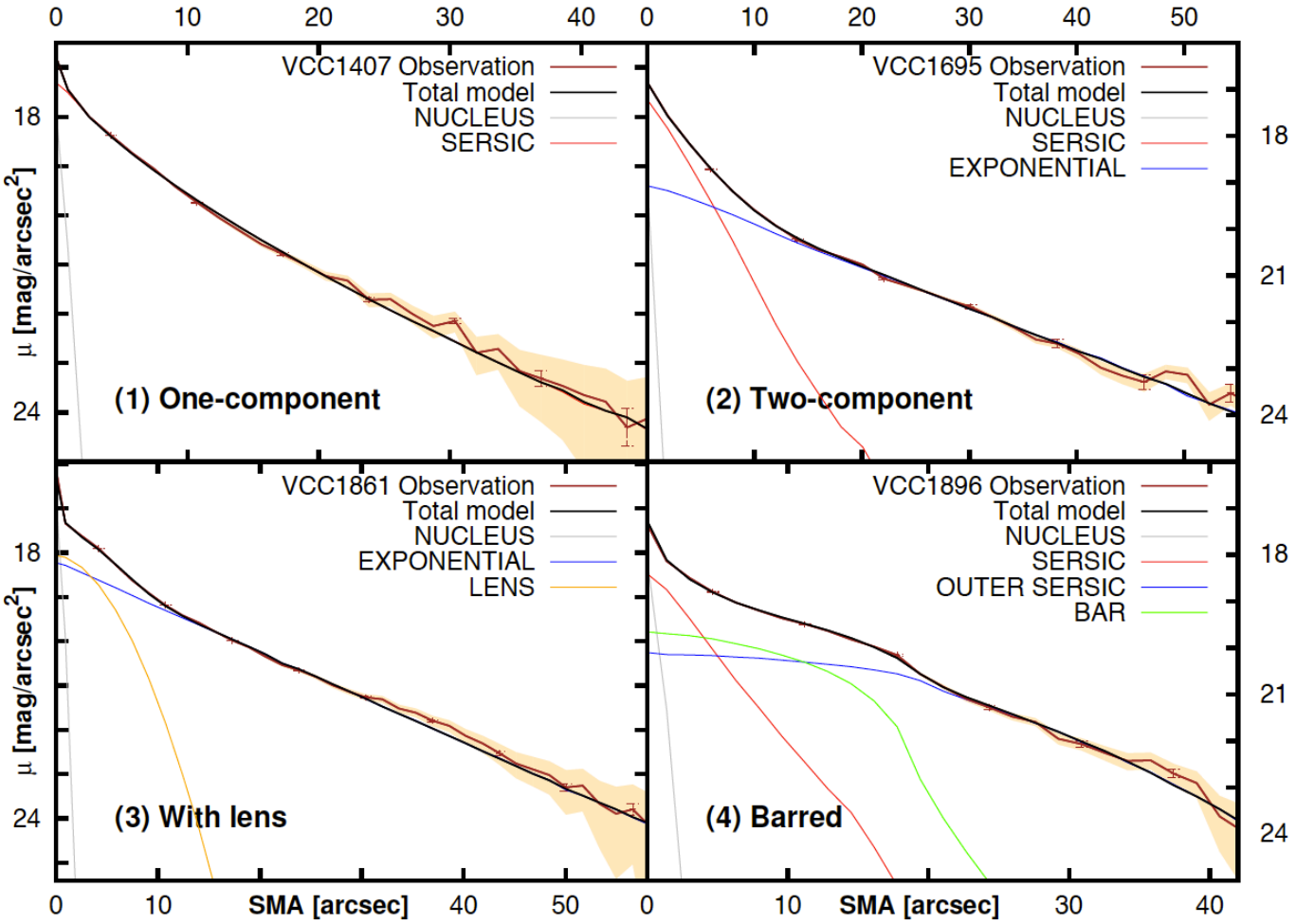
HR spectroscopy

Telescope	Nights
WHT, VLT	21

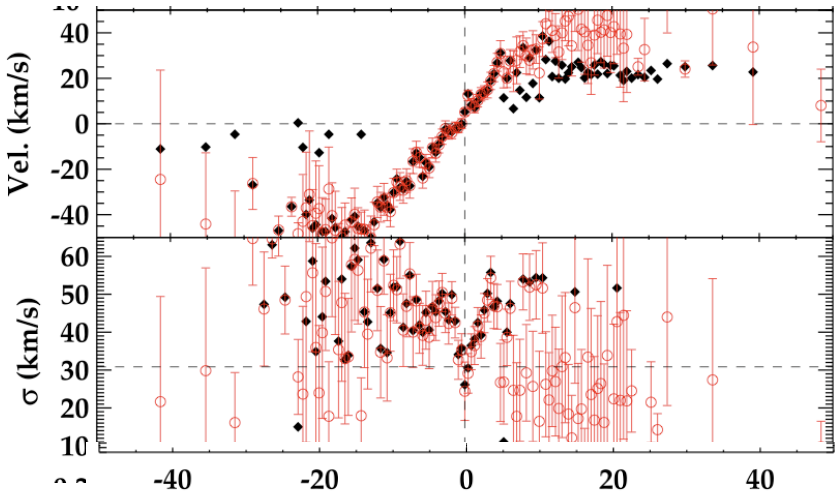
SMAKCED: NIR imaging; dE have a multiple component structure

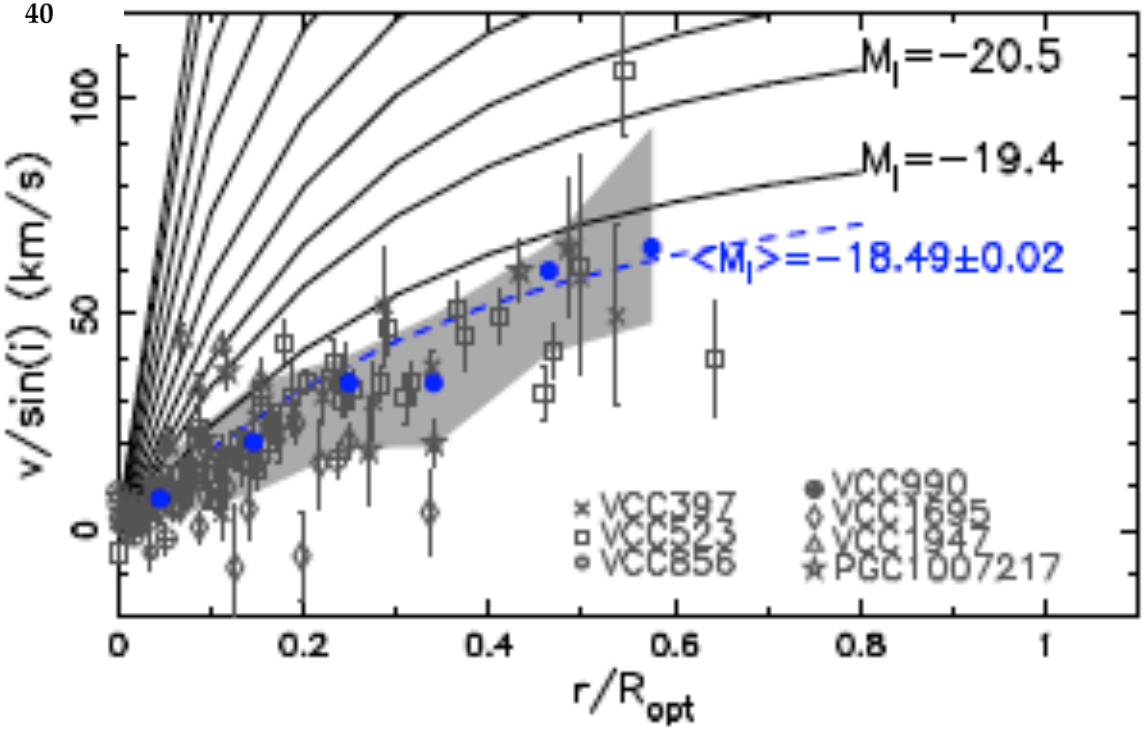


Janz et al 2012



SMAKCED: HR spectroscopy; dE have rotation curves similar to late type spirals





Toloba et al 2011

NGVS: Next GenerationVirgo cluster Survey

https://www.astrosci.ca/NGVS/The_Next_Generation_Virgo_Cluster_Survey/Home.html

PI L.Ferrarese

Sky area: ~ 104 sq.deg. *ugriz*

771 h with MEGACAM at the CFHT (2009-2012)

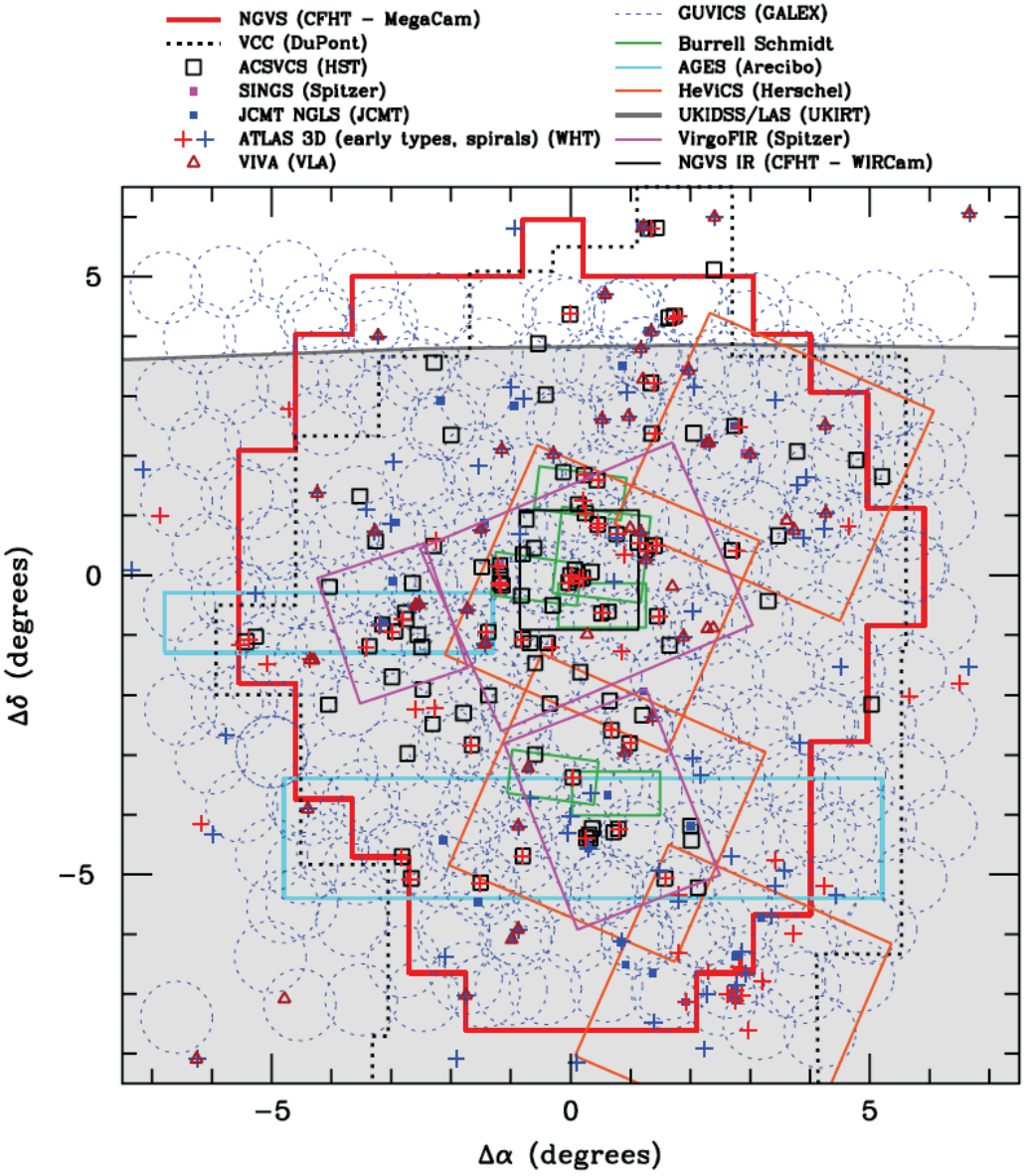
Sensitivity: ~ *g* 25.9 AB mag ; ~ g 29 AB mag arcsec^{-2}

Detection rate: ~ 3 10^7 sources

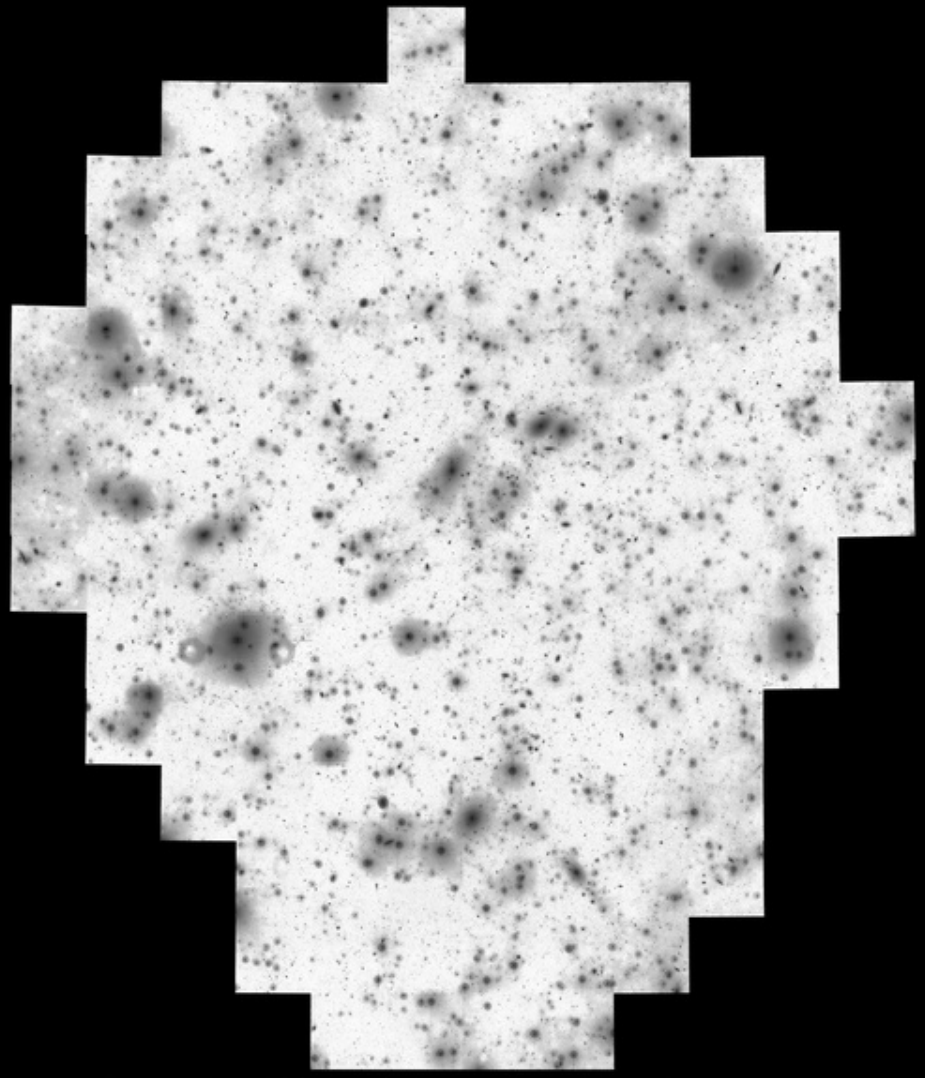
Mean seeing: < 1arcsec

Status: lost 123 h this semester for dome failure

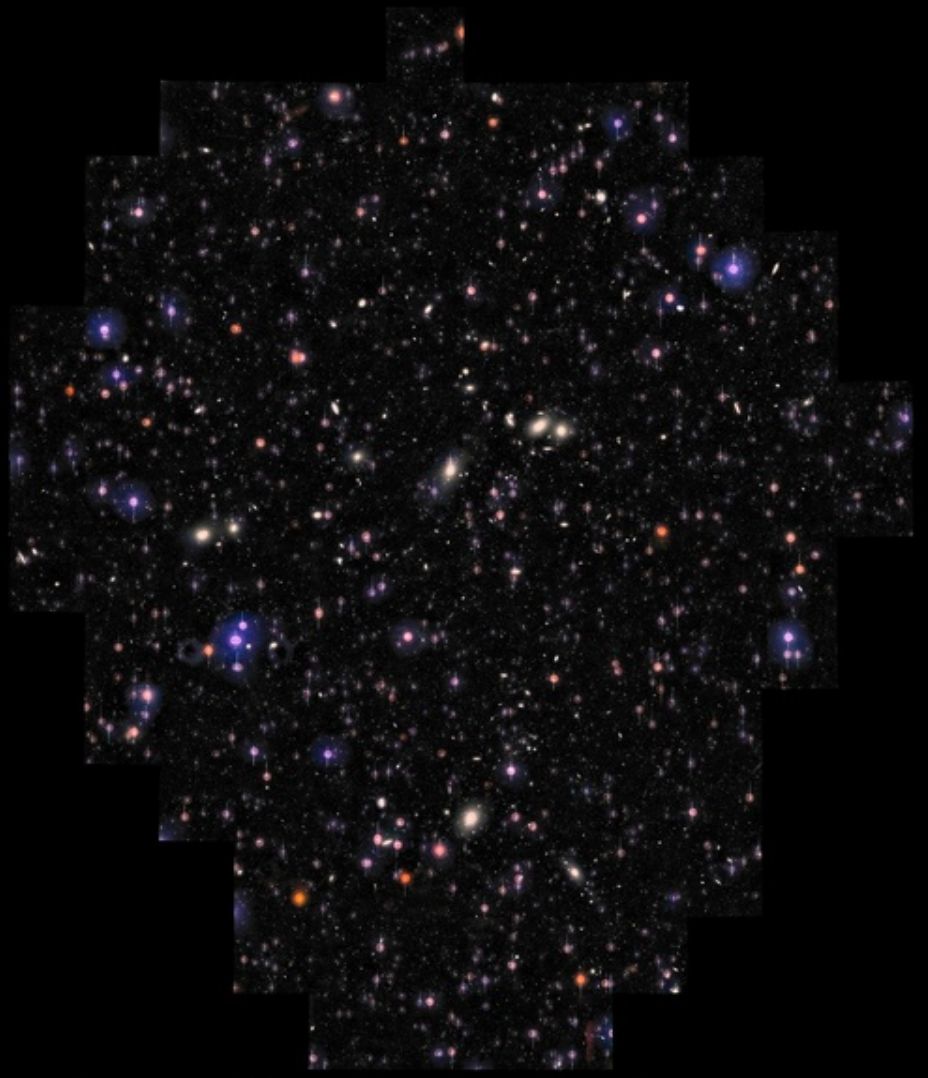
NGVS



Ferrarese et al 2012



Completed 104 sq. deg. mosaic in MegaCam g'–band
Image quality: 0.8'', 53 mn integration per 0.187'' pixel
Point source detection at SNR=5: g'=26.2



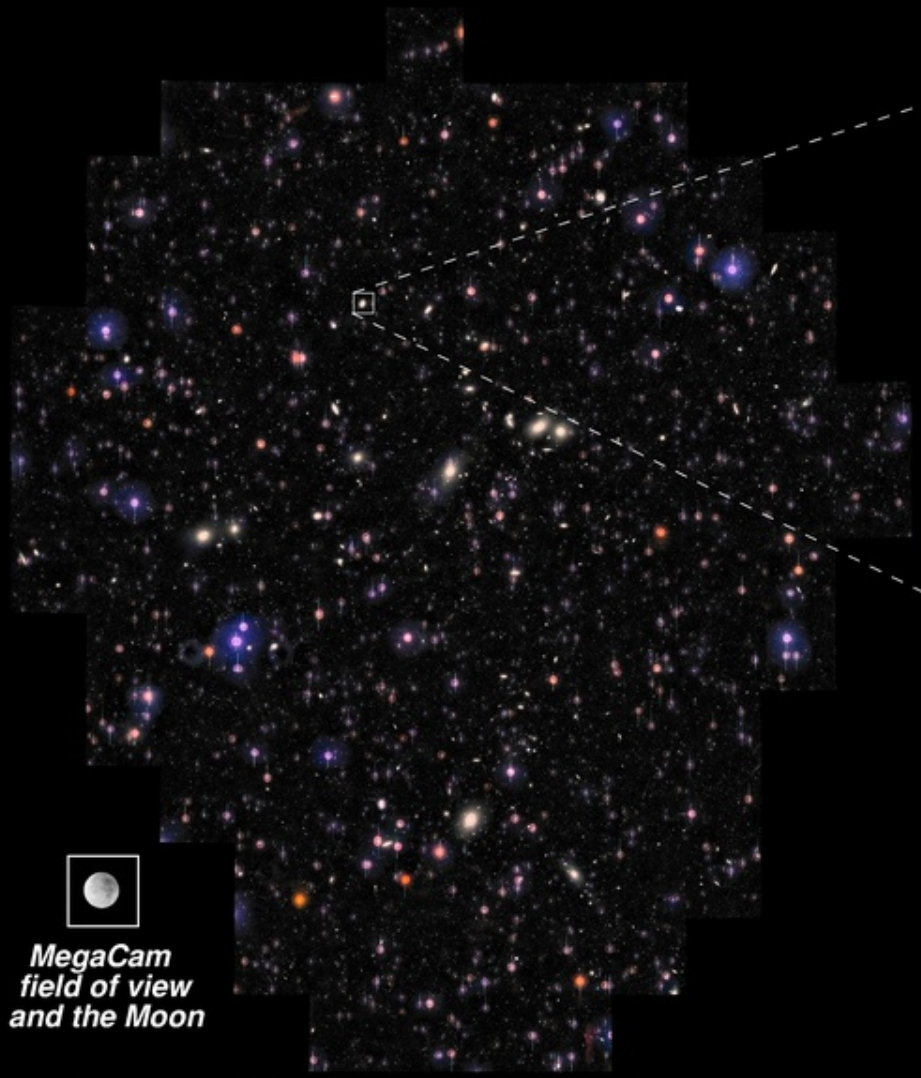
Completed 104 sq. deg. mosaic in MegaCam g'i'z' bands
Image quality: 0.8'', 0.6'', 0.7'' (53/34/64 mn per pixel)
Point source detection at SNR=5: g'=26.2 i'=24.9 z'=24.2

NGVS

The Next Generation Virgo Cluster Survey

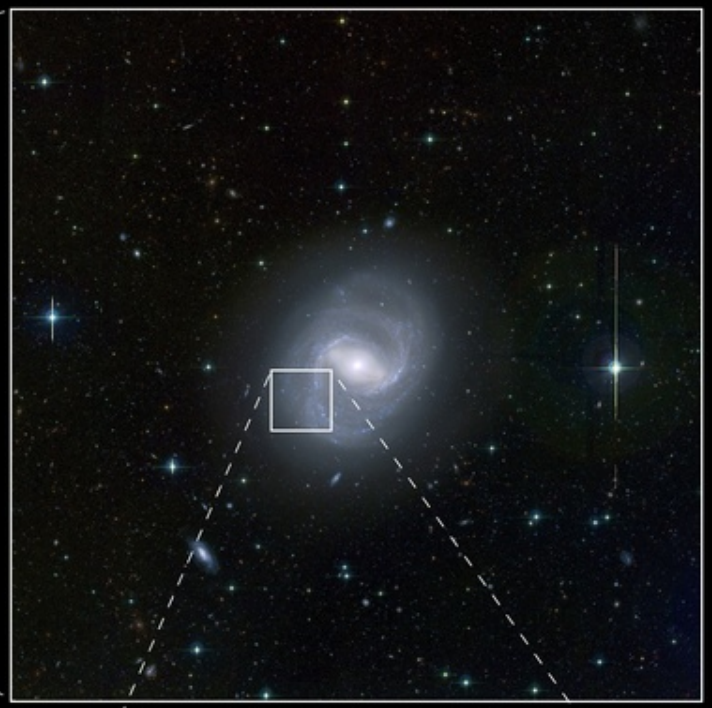
The NGVS is five–year large program with MegaCam on CFHT (2009/2013)

CFH

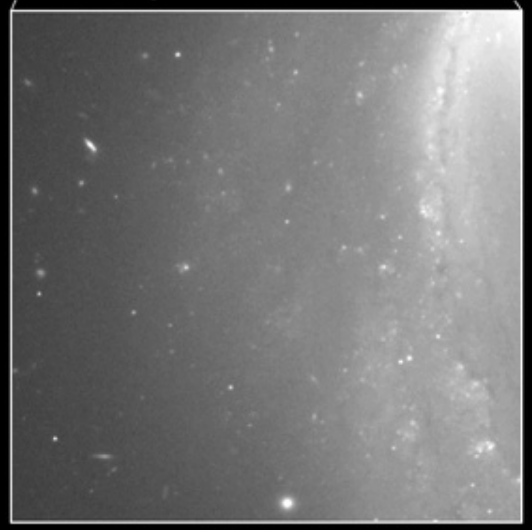


MegaCam field of view and the Moon

Completed 104 sq. deg. mosaic in MegaCam g'i'z' bands
Image quality: 0.8'', 0.6'', 0.7'' (53/34/64 mn per pixel)
Point source detection at SNR=5: g'=26.2 i'=24.9 z'=24.2



Messier 91 in u*g'i' (NGVS u* = 0.9''), 20'x20' field



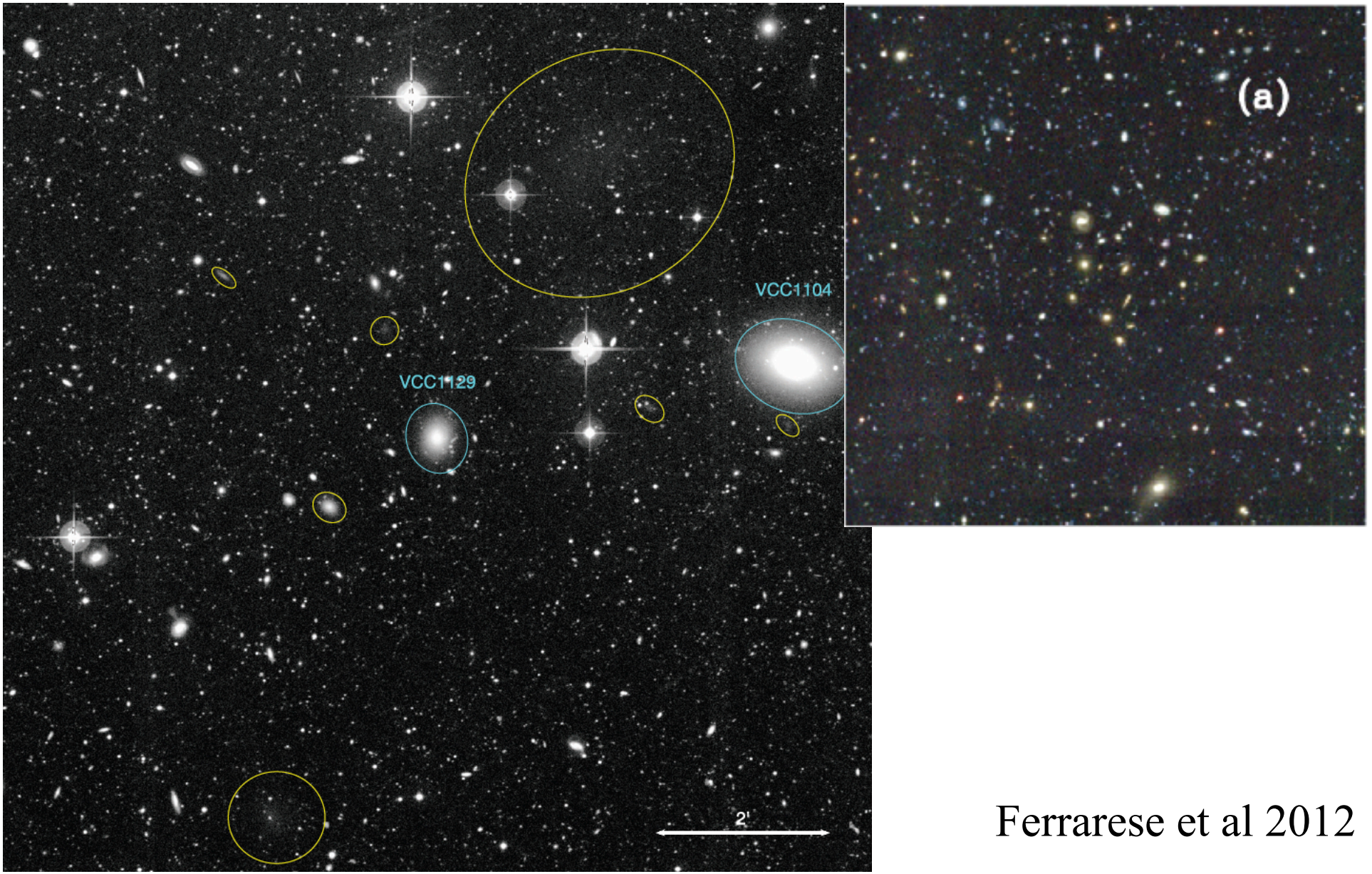
i'-band, 0.55'', 2'x2' field

The Next Generation Virgo Cluster Survey

The NGVS is a sub-arcsecond survey thanks to Mauna Kea's superb seeing

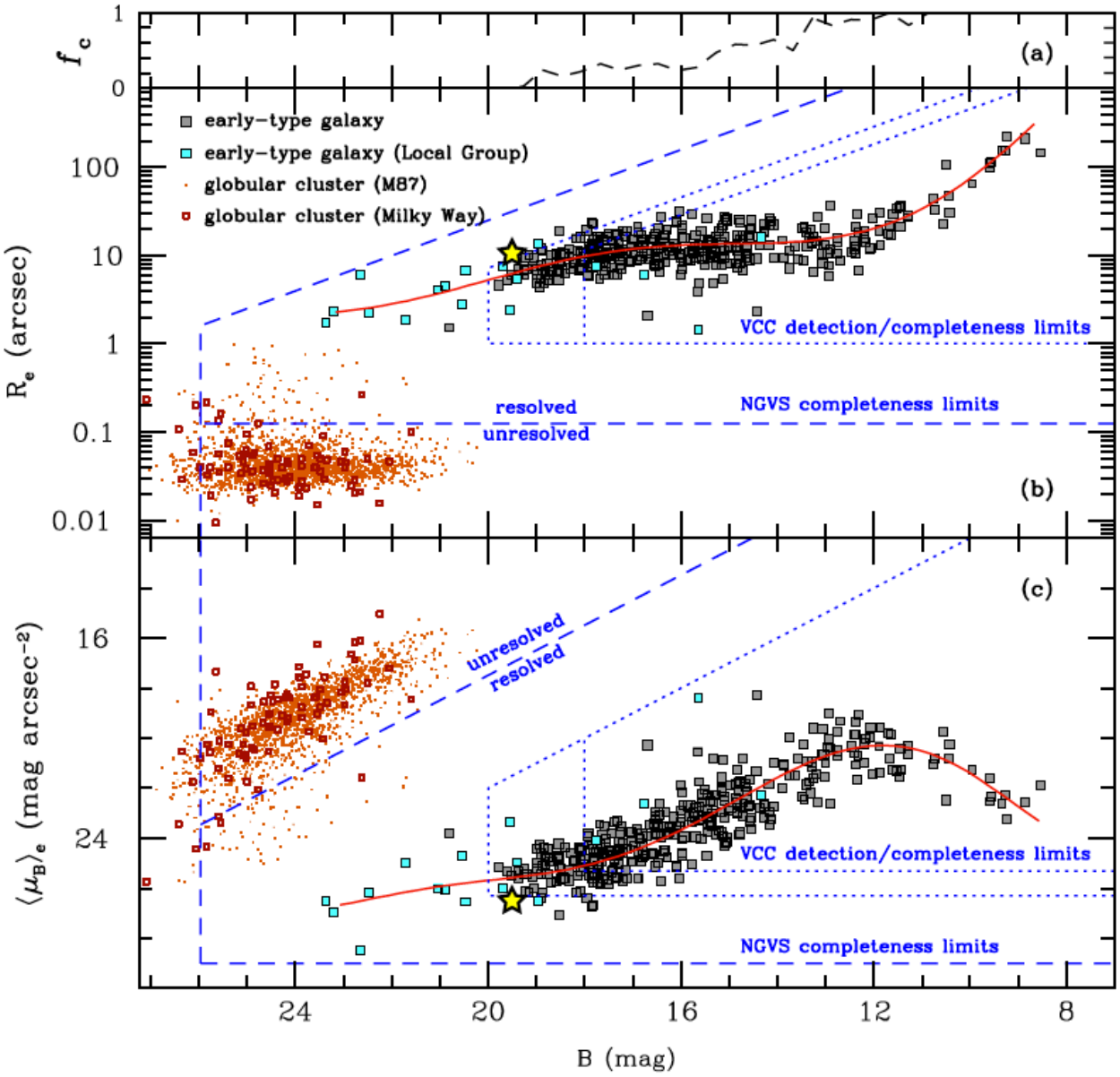
CFH

NGVS



Ferrarese et al 2012

NGVS: testing scaling relations down to GC scales



Ferrarese et al 2012

GUViCS: a complete GALEX survey of the Virgo cluster (cycle 6)

http://galex.oamp.fr/guvics/index.html

PI A. Boselli

Sky area: ~ 120 sq.deg. NUV (2316 A) and ~ 40 sq.deg. FUV (1539 A) survey of the Virgo cluster (**94 sq.deg. covered by the present survey in the NUV band**)

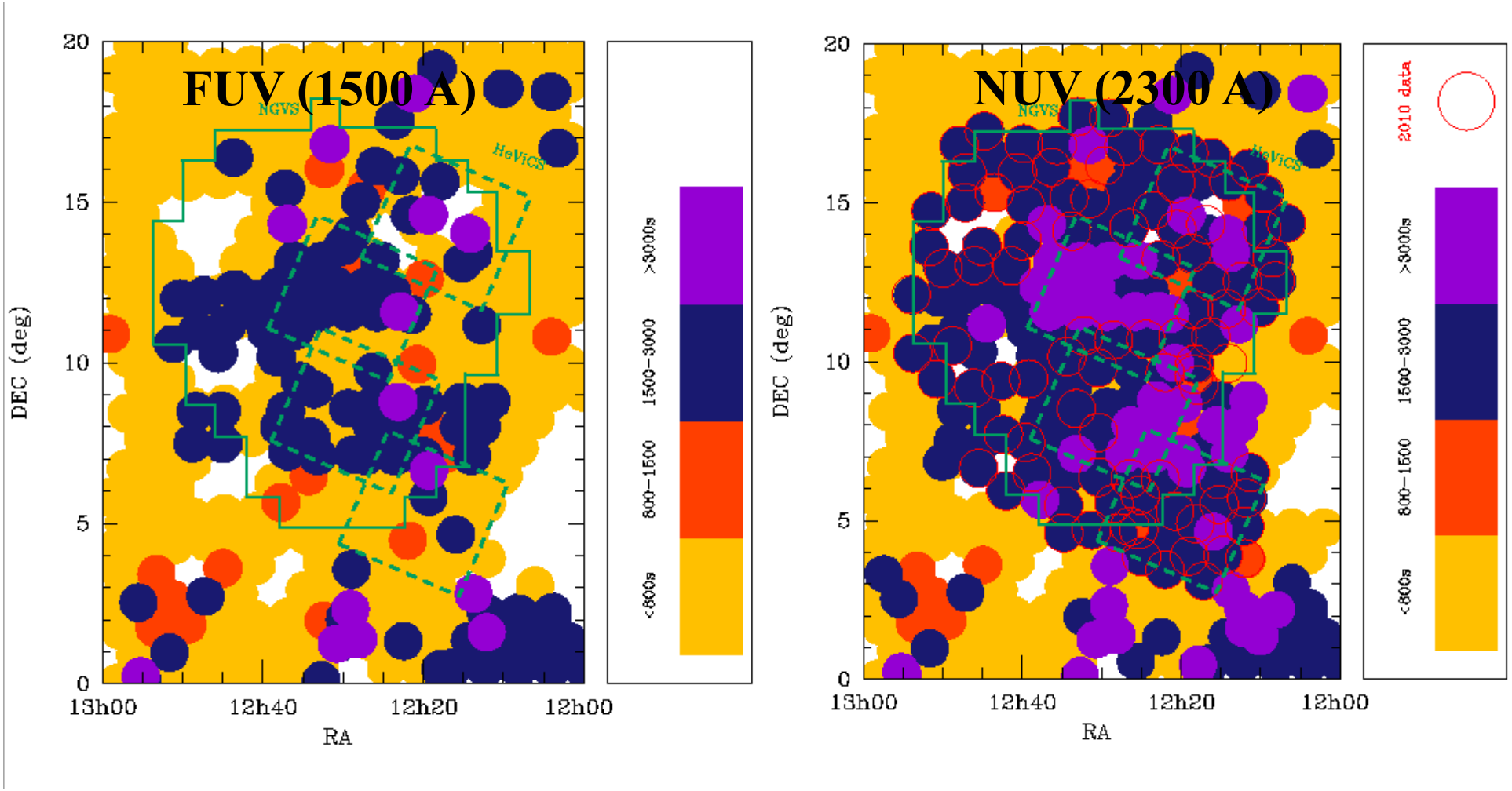
Exp. Time: ~ 1 orbit (1500 sec)

Completness: ~ 21.5 AB mag; ~27.5 AB mag arcsec^{-2}

Detection rate: NUV ~ 10^6 sources; FUV ~ 10^5 sources

Angular resolution: 4-5 arcsec

The GALEX UV Virgo cluster survey: GUViCS



Boselli et al 2011

Chemo-spectrophotometric multizone model of galaxy evolution

Boissier & Prantzos 2000

- disc with an exponentially declining surface density profile formed from a halo of mass given by the CDM models of Mo et al (1998).

- SFR: rotation modulated Schmidt law (Boissier et al 2003)

$$SFR(R,t) = \alpha \, \Sigma_{gas}(R,t)^{1.5} \, V(R) R^{-1}$$

- infall rate exponentially decreasing with time

- calibrated on the Milky Way: the resulting free parameters are
λ (spin parameter) and *Vrot* (rotational velocity)

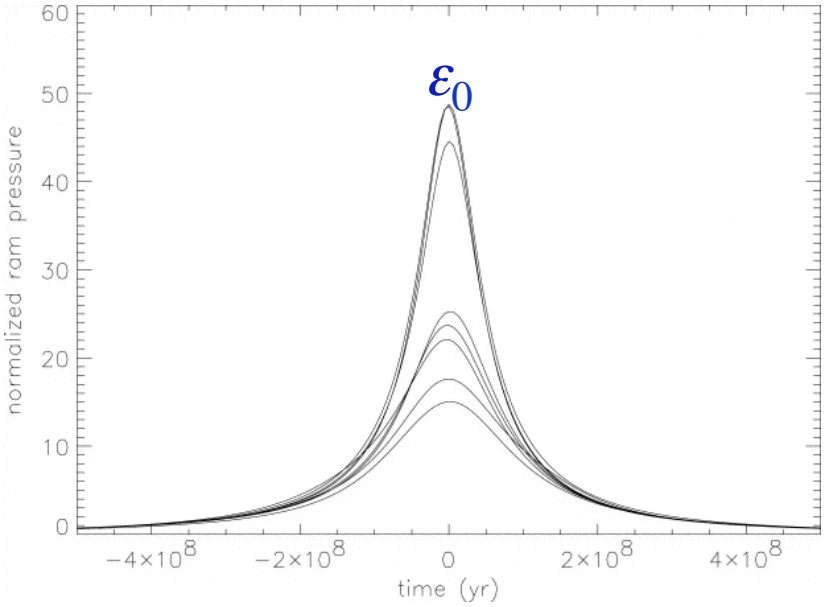
-

Modelling the interaction

1) Starvation ----> stopping infall

2) Ram pressure $\rho_{IGM} V^2_{gal} > 2\ G\ \Sigma_{star}\ \Sigma_{gas}$

Vollmer et al. 2001



time

Gas loss rate = $\varepsilon\ \Sigma gas\ /\ \Sigma potential$

$\varepsilon(t)$ = efficiency (ε_0 free parameter)

Σgas = gas column density

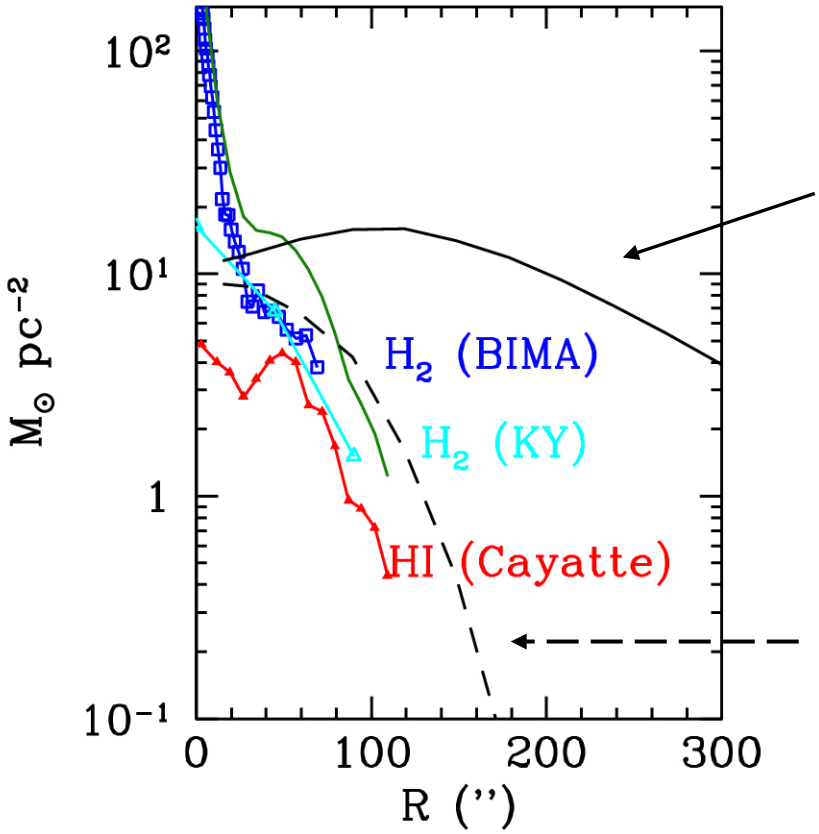
$\Sigma potential$ = total local density (potential of the galaxy)

t = age of the interaction (free parameter)

Δt = duration of the interaction ($9\ 10^7$ years)

Model calibration on the Virgo cluster anemic galaxy NGC 4569

Model calibration (Boissier & Prantzos 2000): constrain of the free parameters λ (spin parameter) and *Vrot* (rotational velocity)



Continuum line: unperturbed model

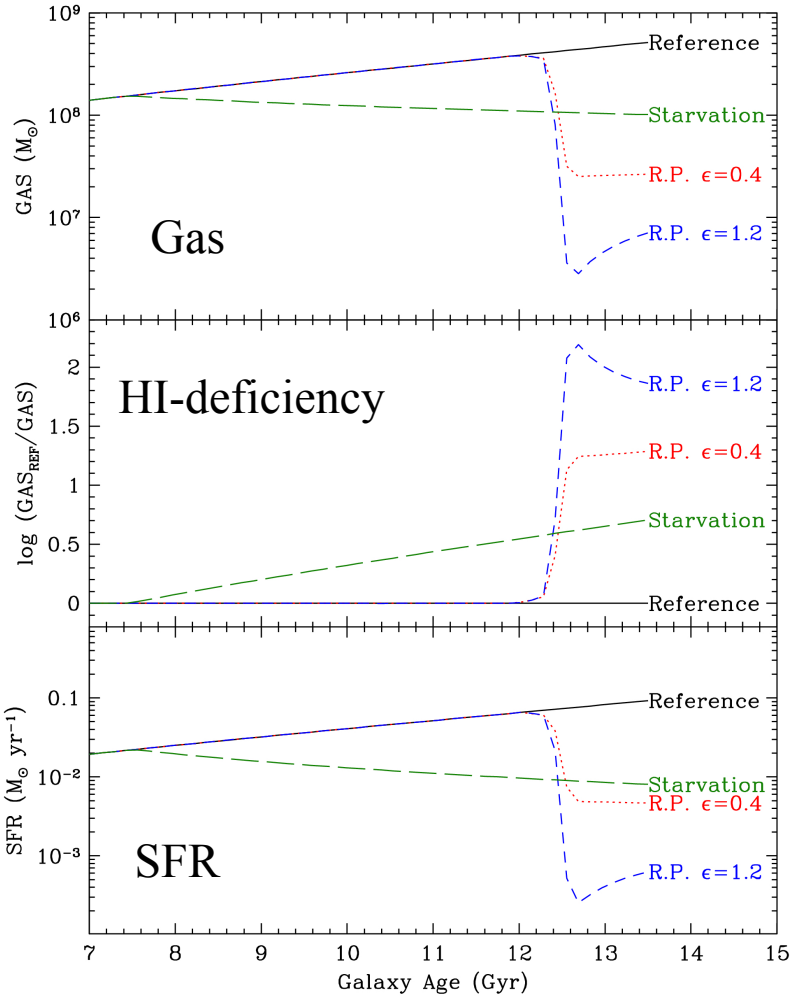
Dashed line: ram pressure model

Total gas (HI+H_2+He) profile

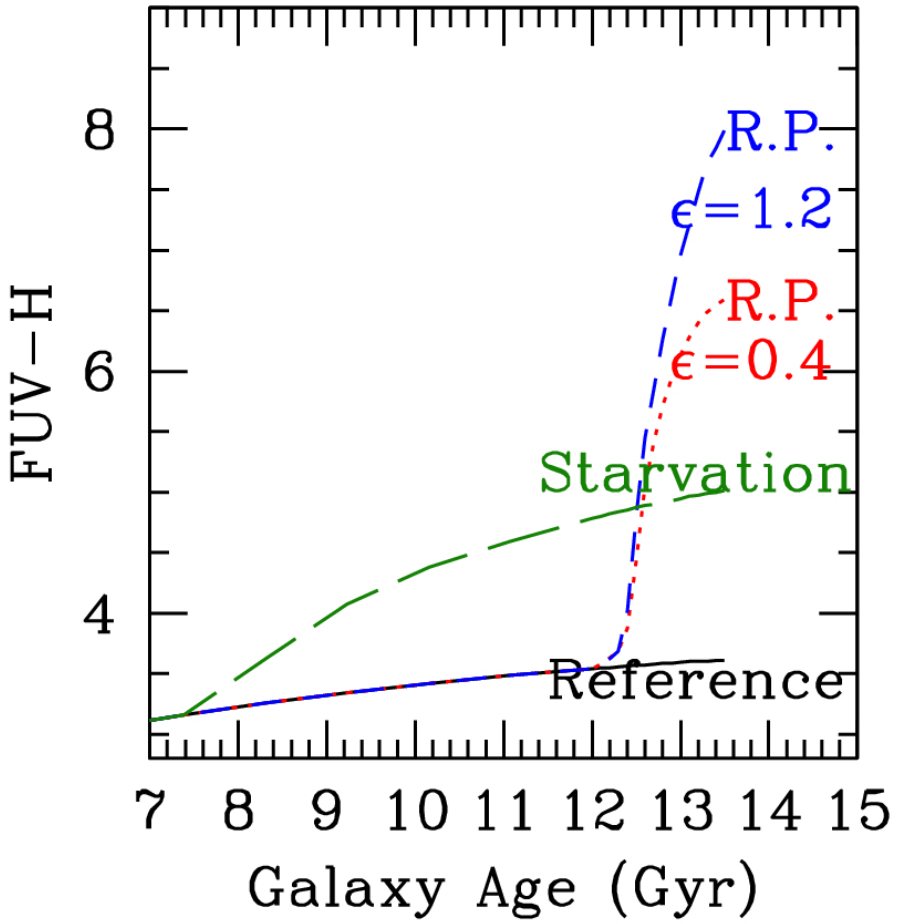
Boselli et al 2006

The origin of dE in clusters

Continuum line: unperturbed model



Age



Age

ε_0 *(NGC4569)*$= 3\varepsilon_0$

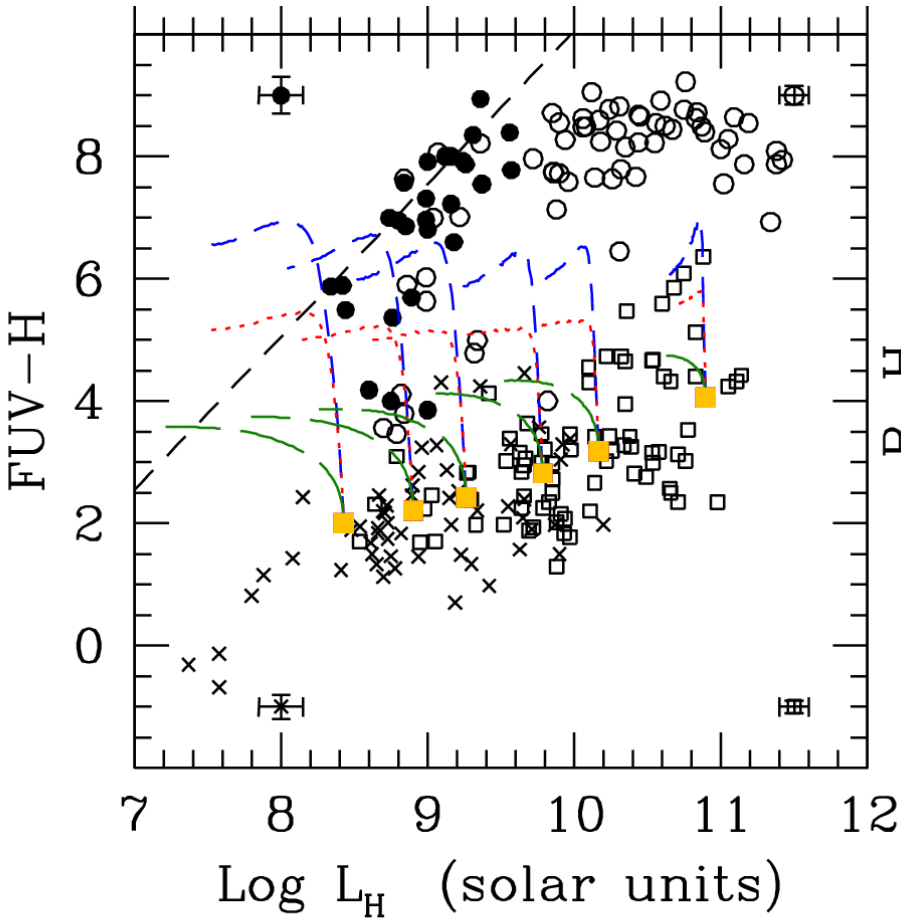
The origin of dE in clusters

Open squares: Sa-Scd
Crosses: Sd-Im-BCD
Filled circles: dE-dS0
Opne cirlces:E-S0-S0a

Ram pressure ε_0 *(NGC4569)*
Ram pressure ε_0
Starvation
Yellow square: unperturbed model

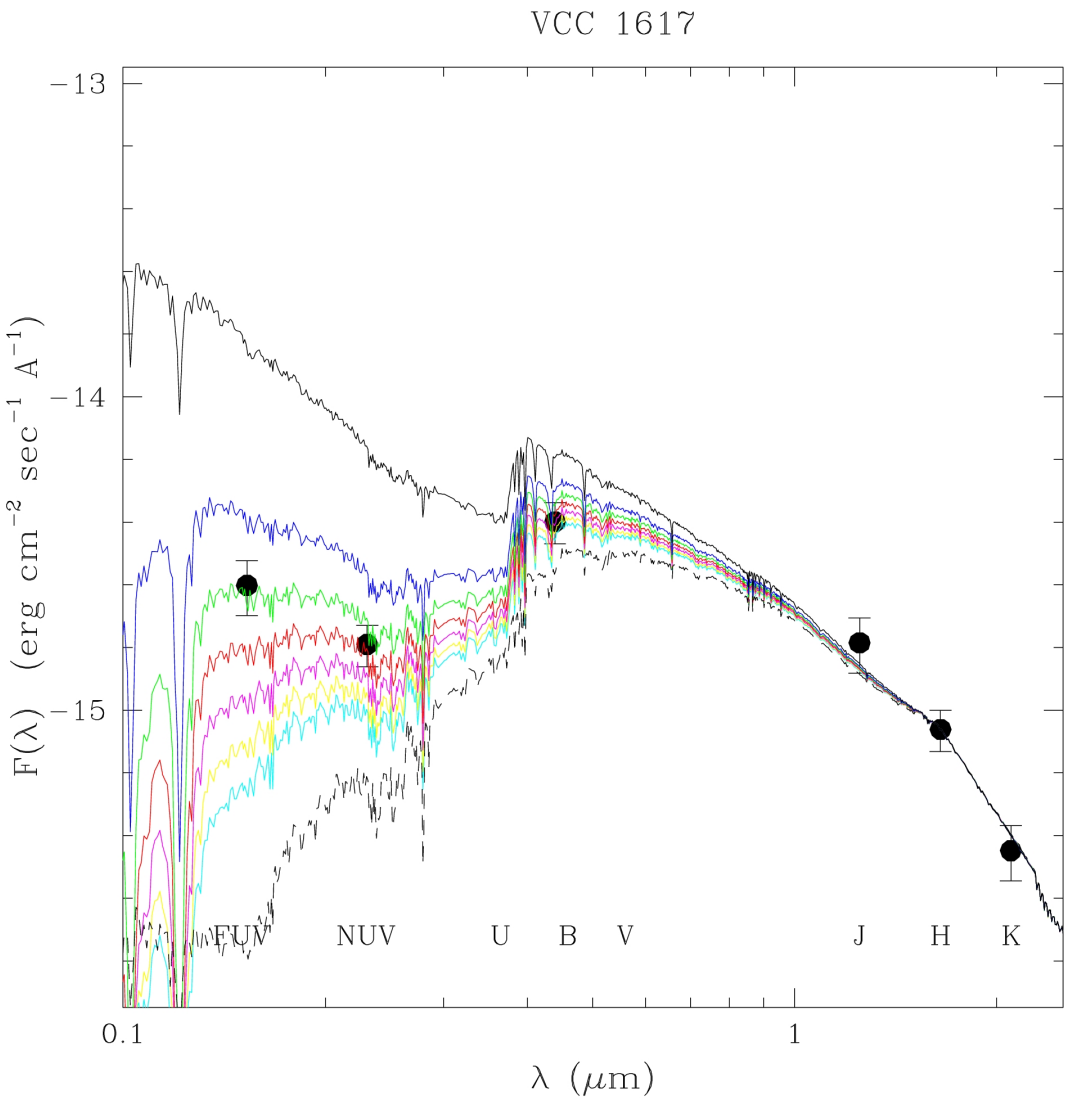
Dashed line: GALEX detection limit

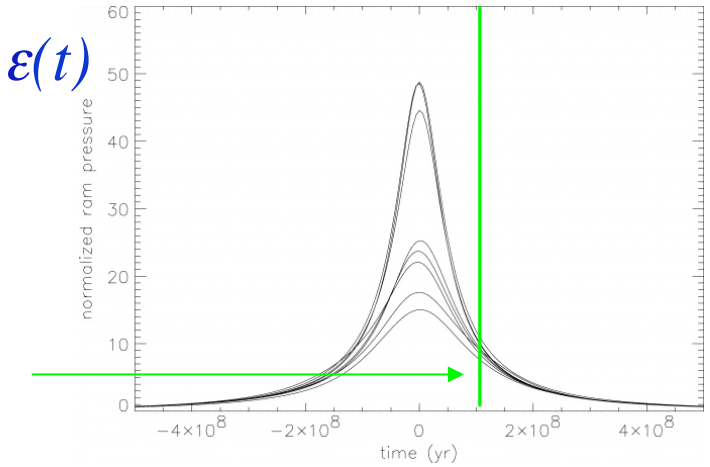
Galaxies get redder



Boselli et al 2008a,b

The origin of dE in clusters

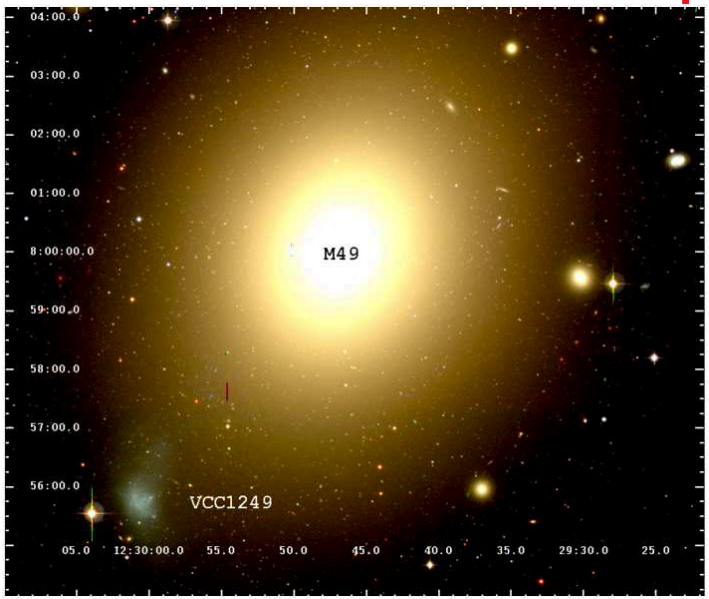


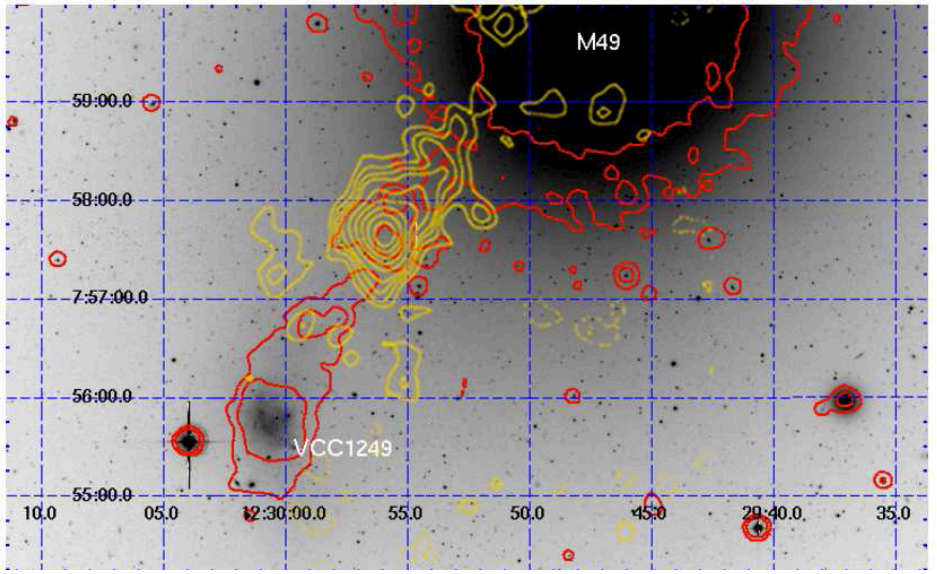


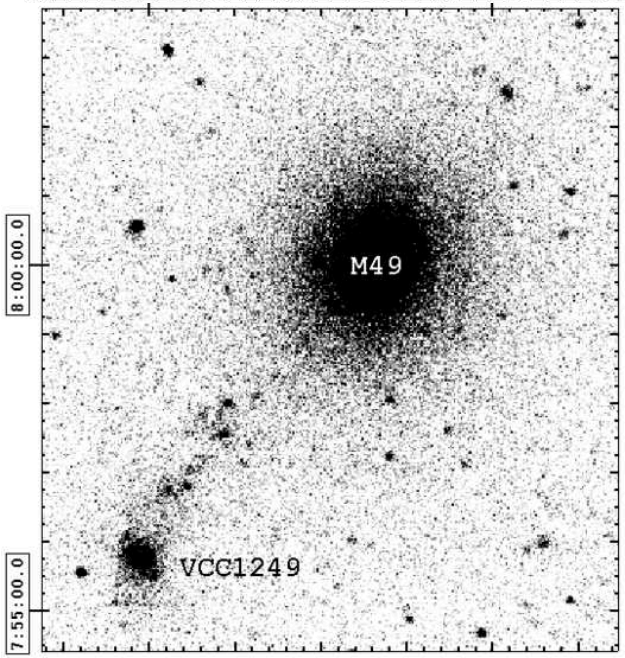
field cluster-core

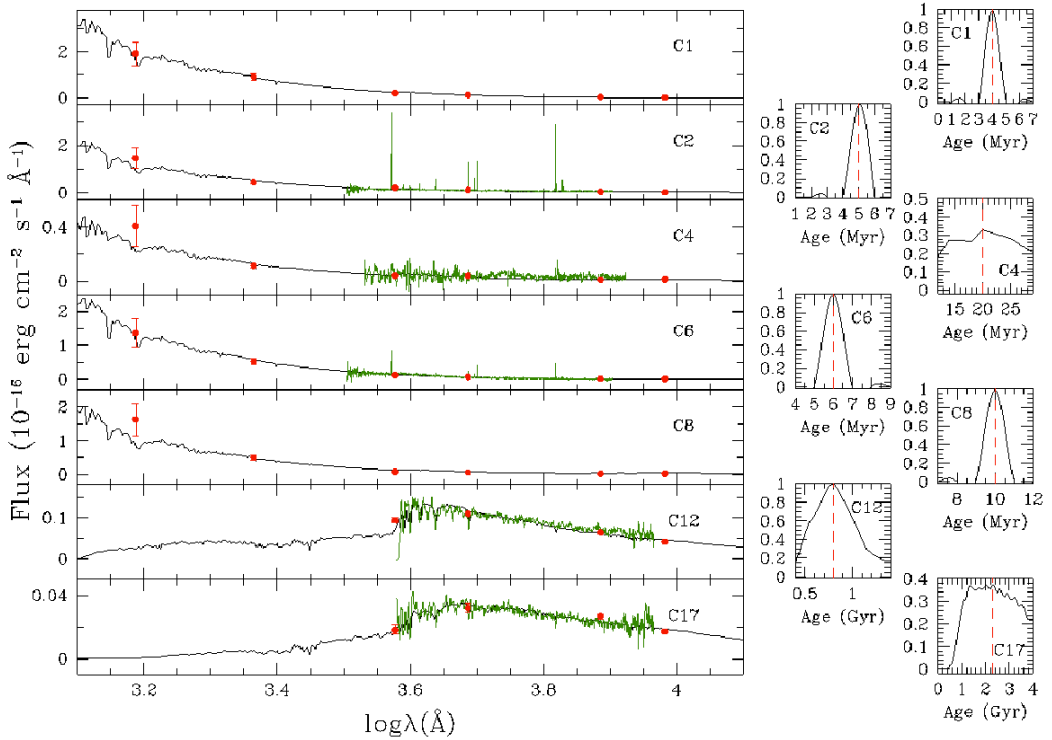
Continuum Black=without interaction Blue:t=0 green:t=100 red t=200 magenta:t=300 yellow:t=400 cyan:t=500 Dashed black=1300 Myr

The fate of the stripped gas in Virgo cluster galaxies



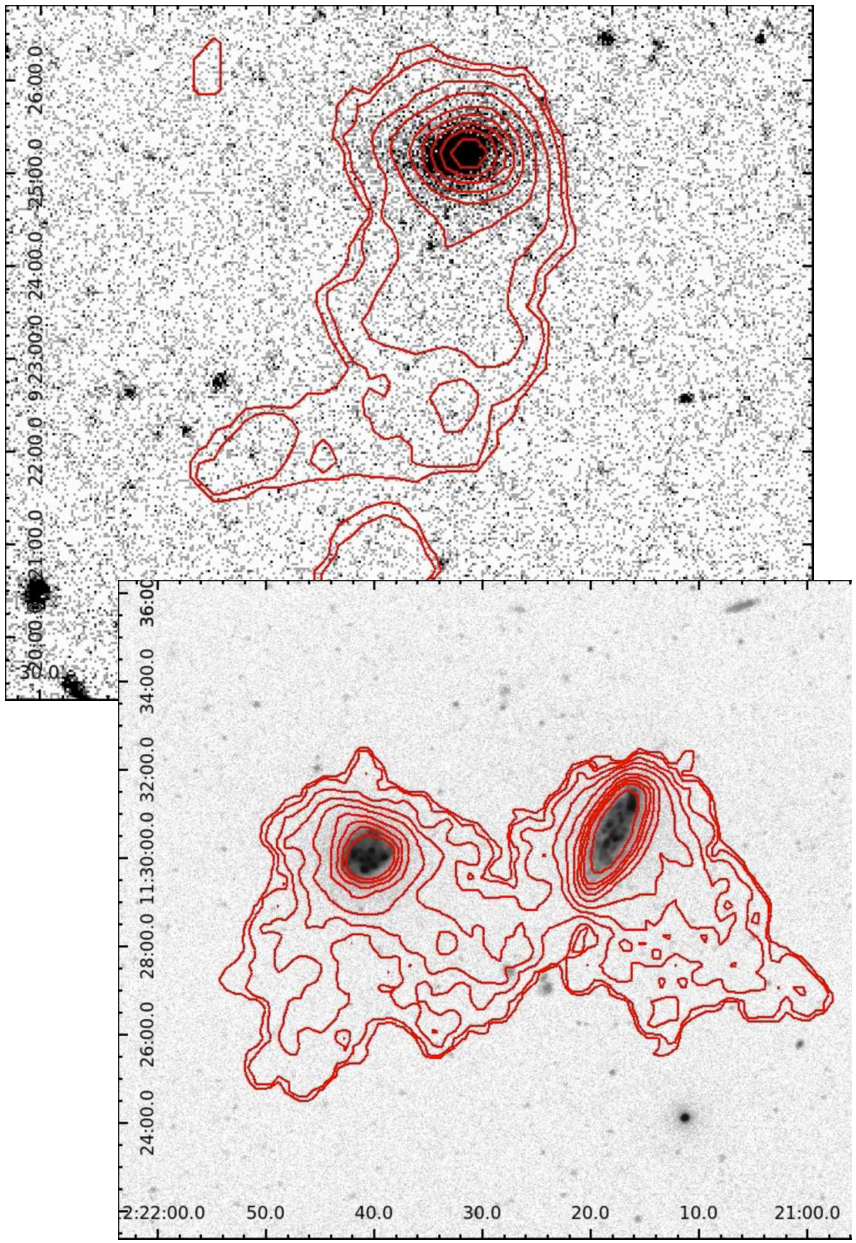


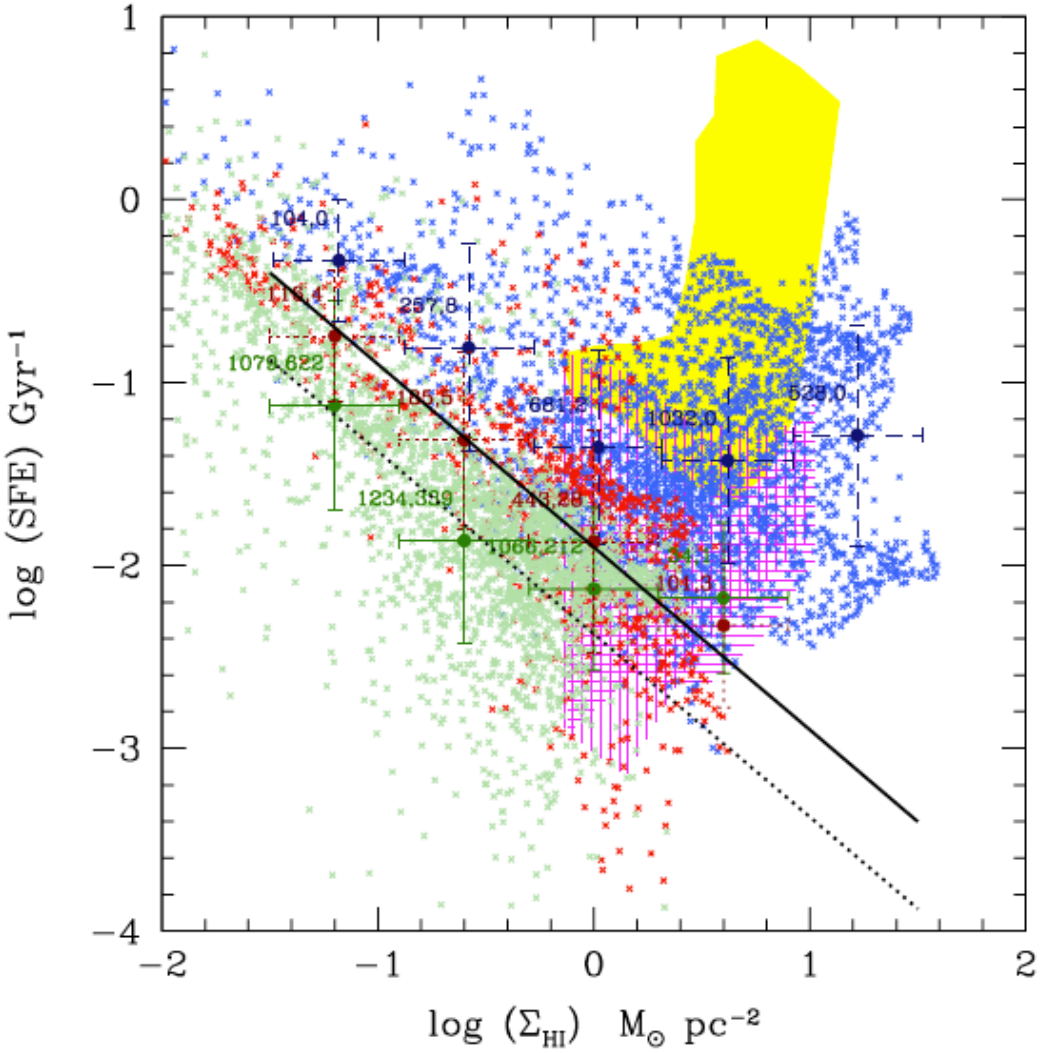




Arrigoni-Battaia et al 2012

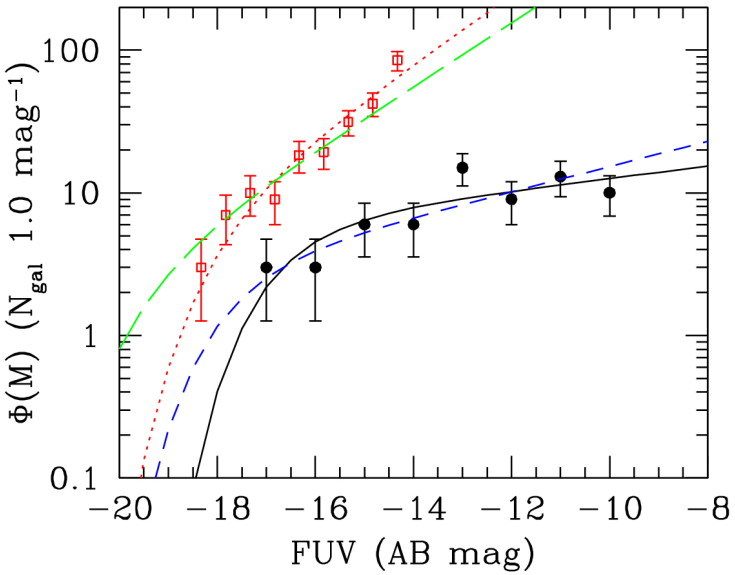
The fate of the stripped gas in Virgo cluster galaxies

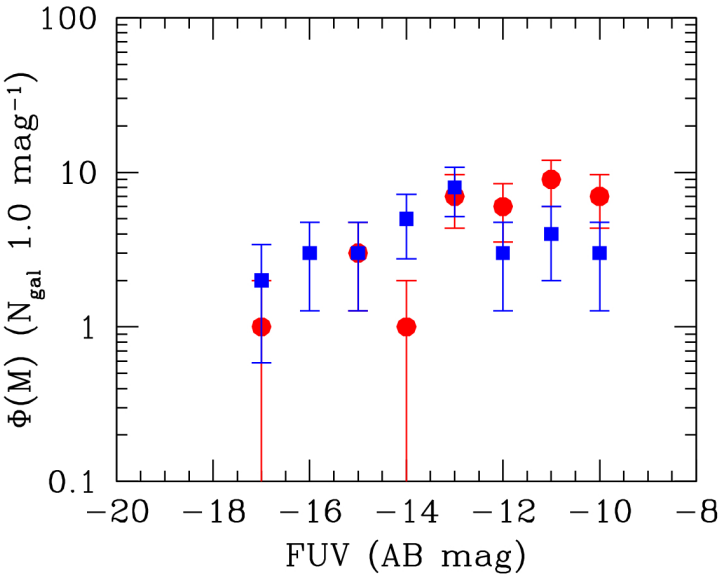


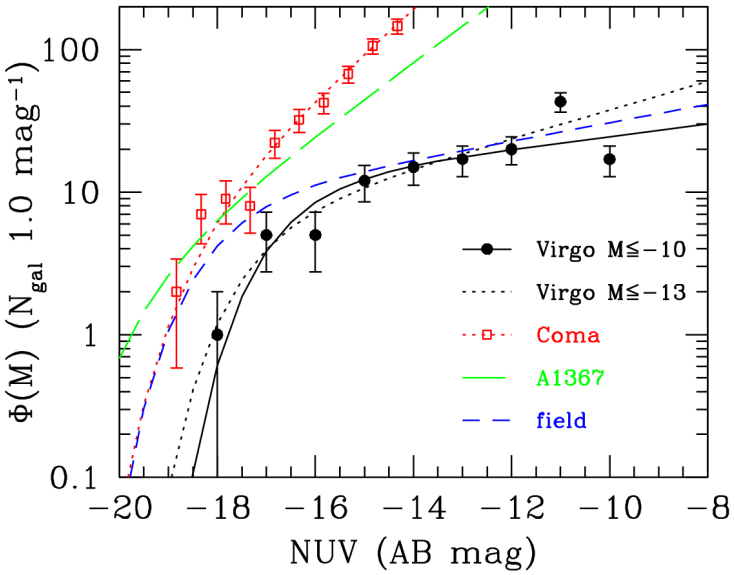


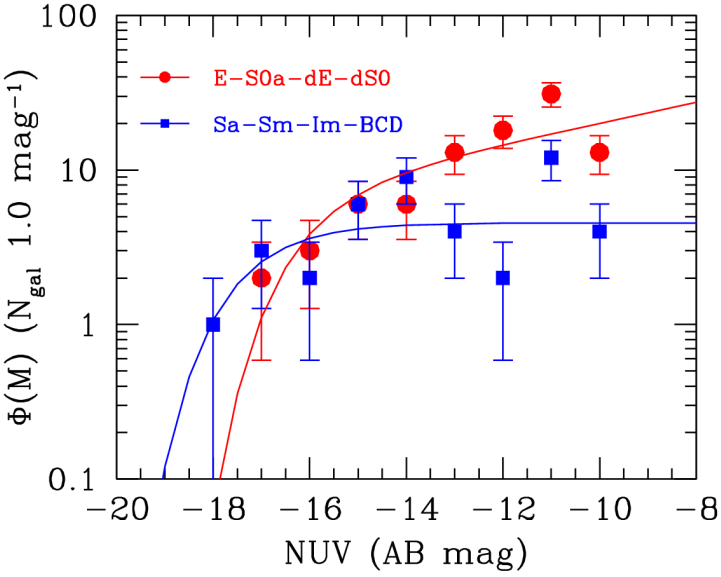
Boissier et al 2012

The UV luminosity function of the central 12 sq.deg









Boselli et al 2011