the MUSE Most Massive Galaxies campaign

Eric Emsellem

Duc, JCC, PS, et al. 2011 (Atlas3D IX)
Duc, JCC, EK et al. 2015 (Atlas3D XXIX)

Dark Matter

10 Mpc

Mergers
Interactions, harassment…
Secular evolution, bars

Gas Density

Cooling and shocks
2D/3D Turbulence
Scale-coupling

Gas T

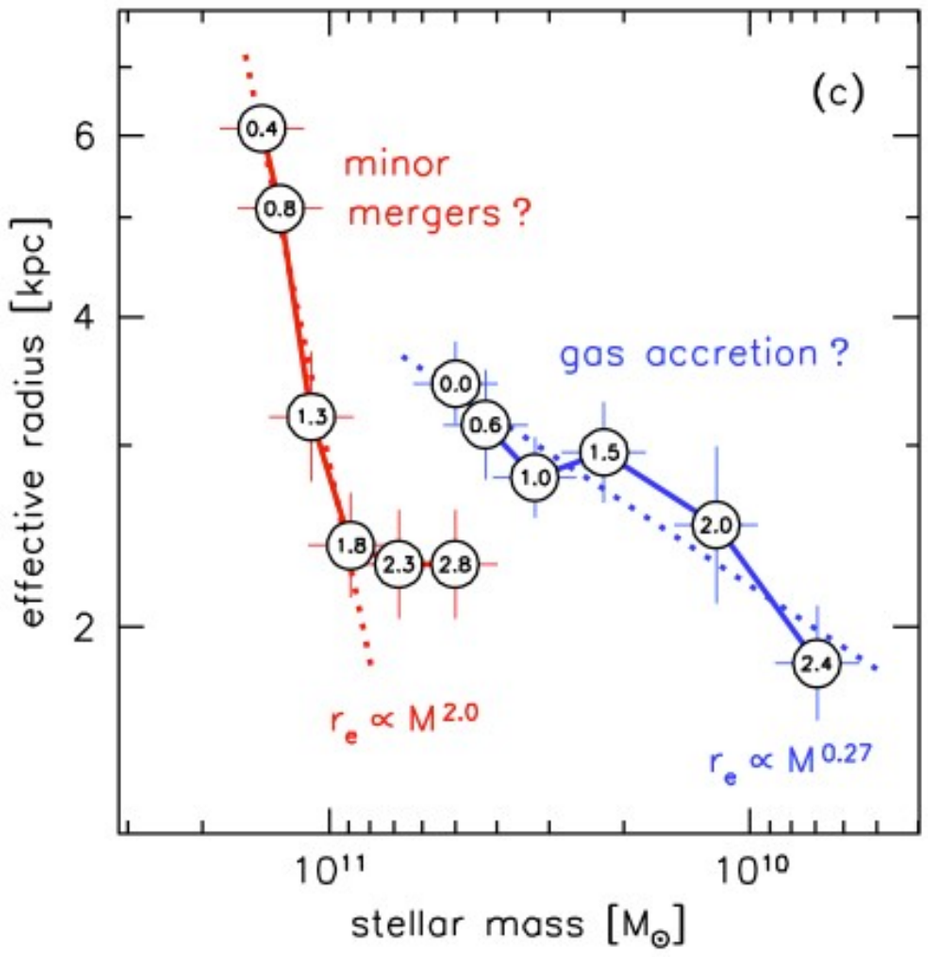
Star formation
Feedback

Stars

Disk instabilities
Cold accretion

The Mare Nostrum Simulation = Teyssier et al.

Galaxy evolution & Mass Trends



van Dokkum et al. (2013)

EVOLUTION

Low mass vs High mass

Bezanson et al. 2009 /Patel et al. 2013 /van Dokkum et al. 2013

OBSERVATIONS

Low mass systems

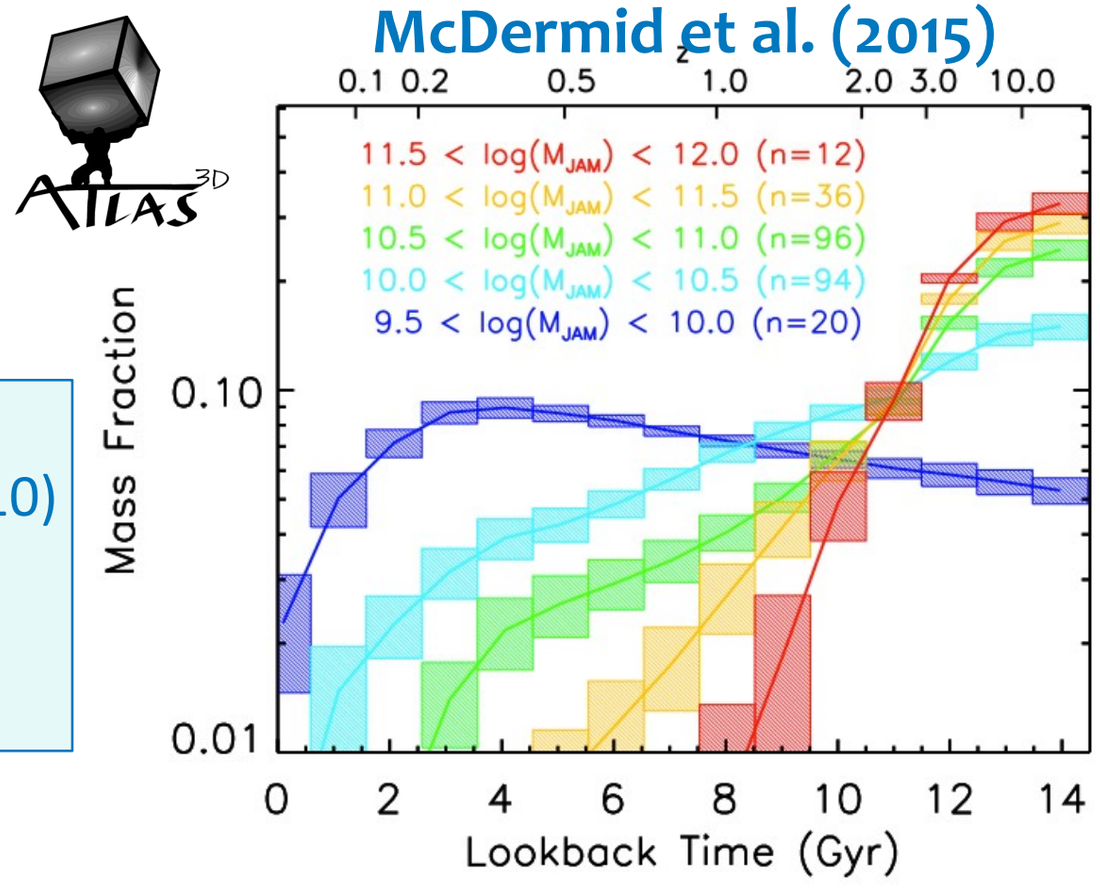
- Slower evolution
- Mass growth at all radii
- Extended star-formation and mass growth

SIMULATIONS

→ **two phases of galaxy formation** (e.g. Oser et al. 2010)

- Rapid early phase (z>2) – In Situ
- Extended later phase (z<3) – Ex Situ

McDermid et al. (2015)



> 1 Re

> 2 Re

> 3 Re

N[M] Re

[Annette Ferguson's talk]

But What

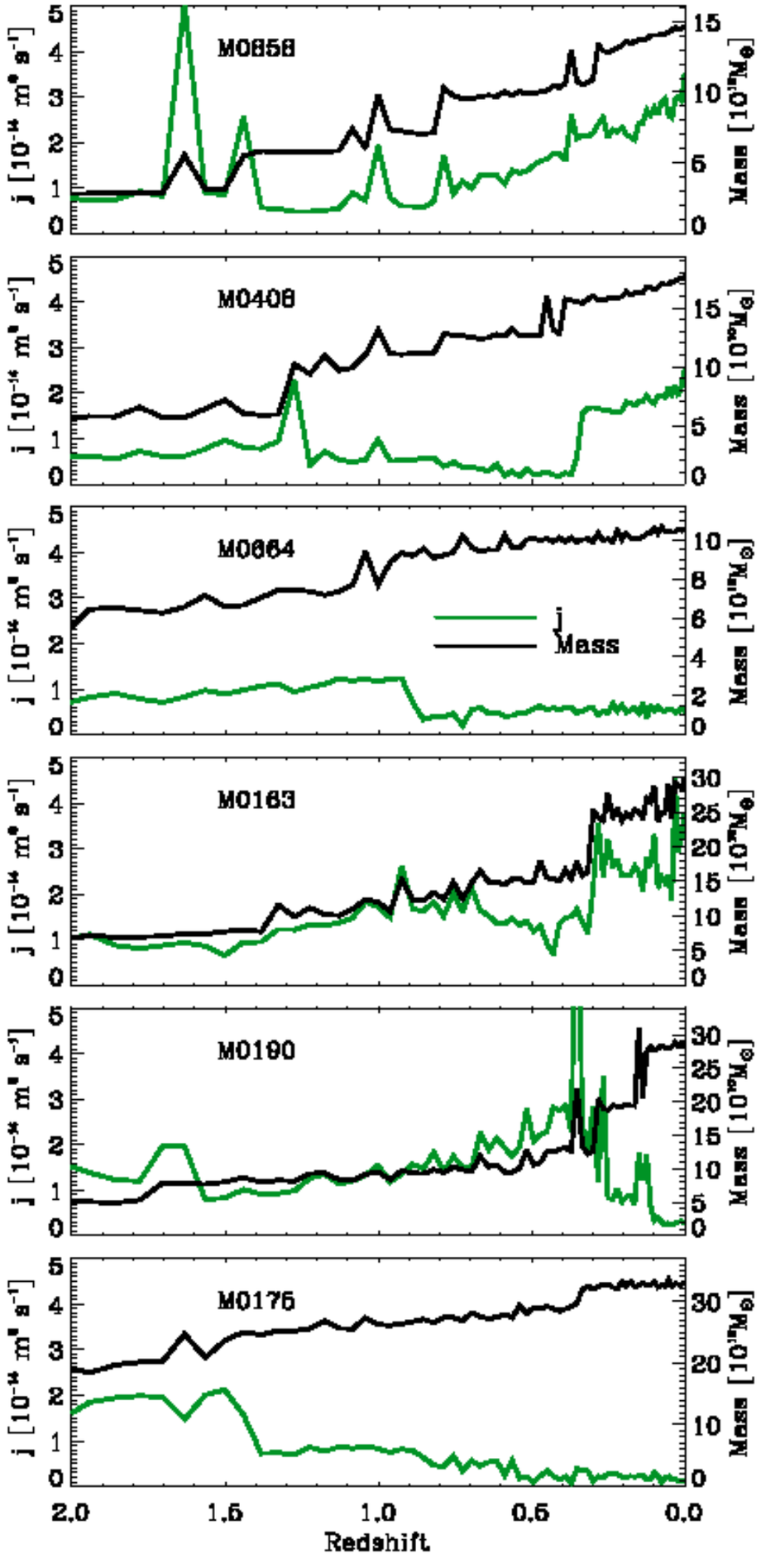
Re ?

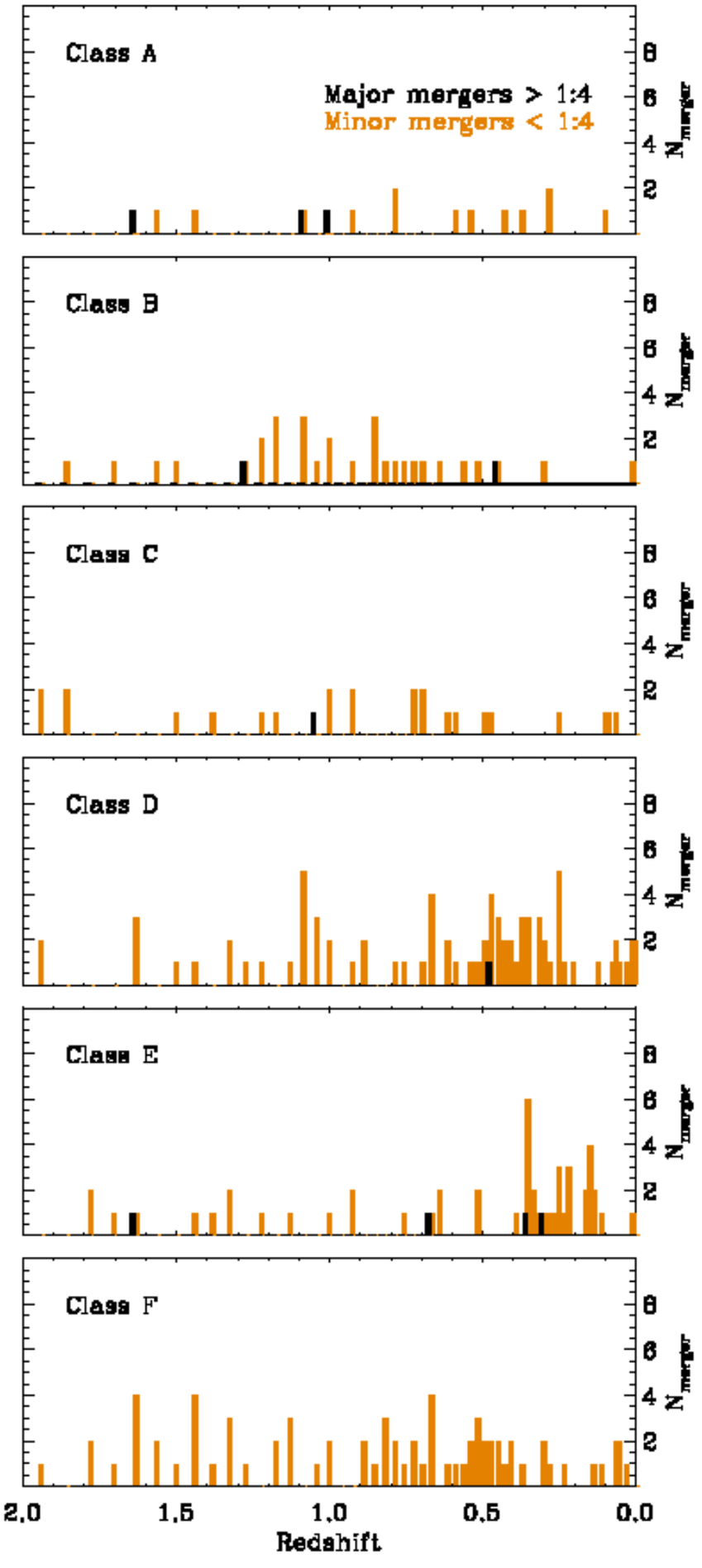
Pick "your halo" – and tell us

% of V200

Break (ρ , [Fe/H] ?)

Angular momentum

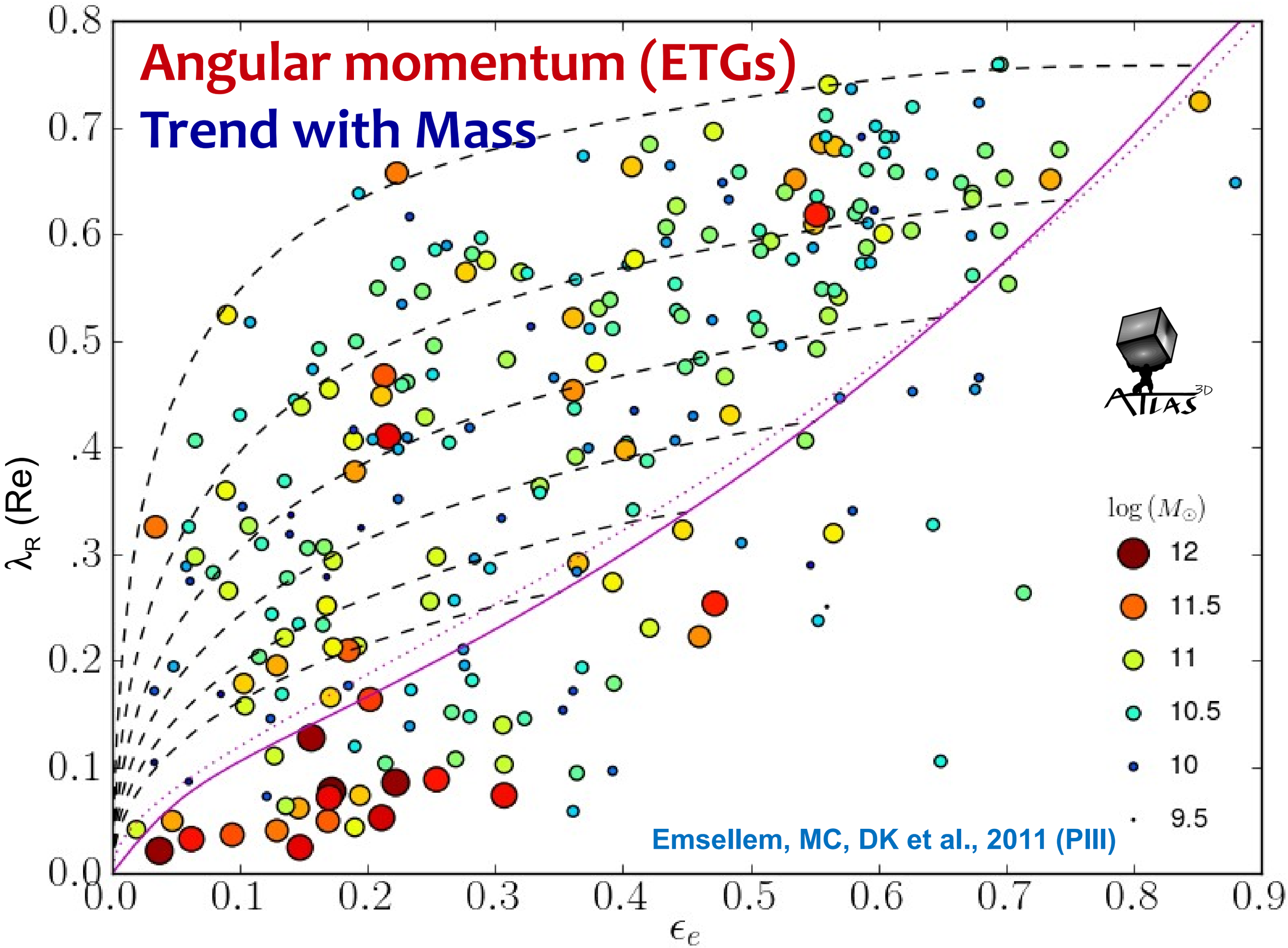




Naab, Oser, EE et al. (2014)

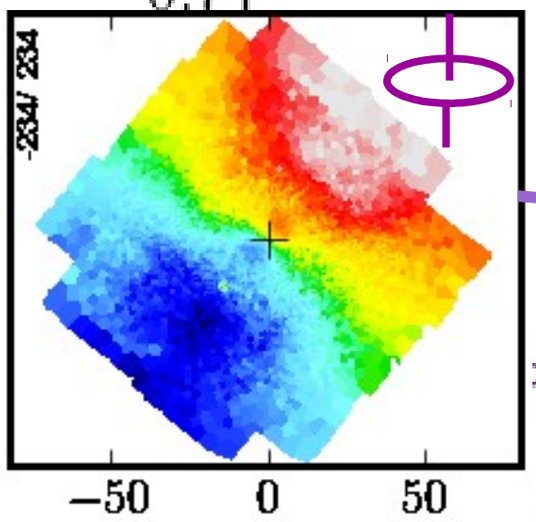
ATLAS 3D

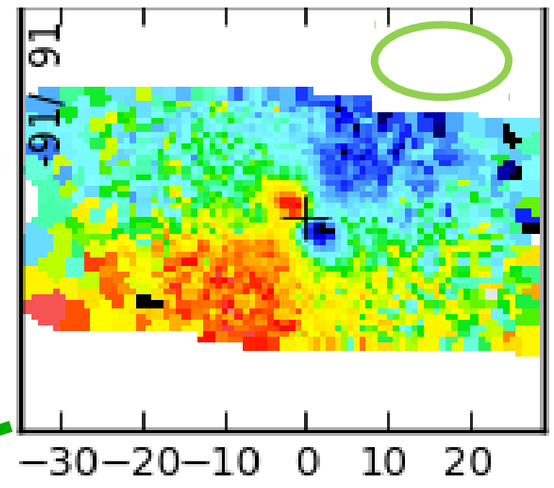
Angular momentum (ETGs)
Trend with Mass



Emsellem, MC, DK et al., 2011 (PIII)

Angular momentum the kinematic Zoo





λ_R (Re)

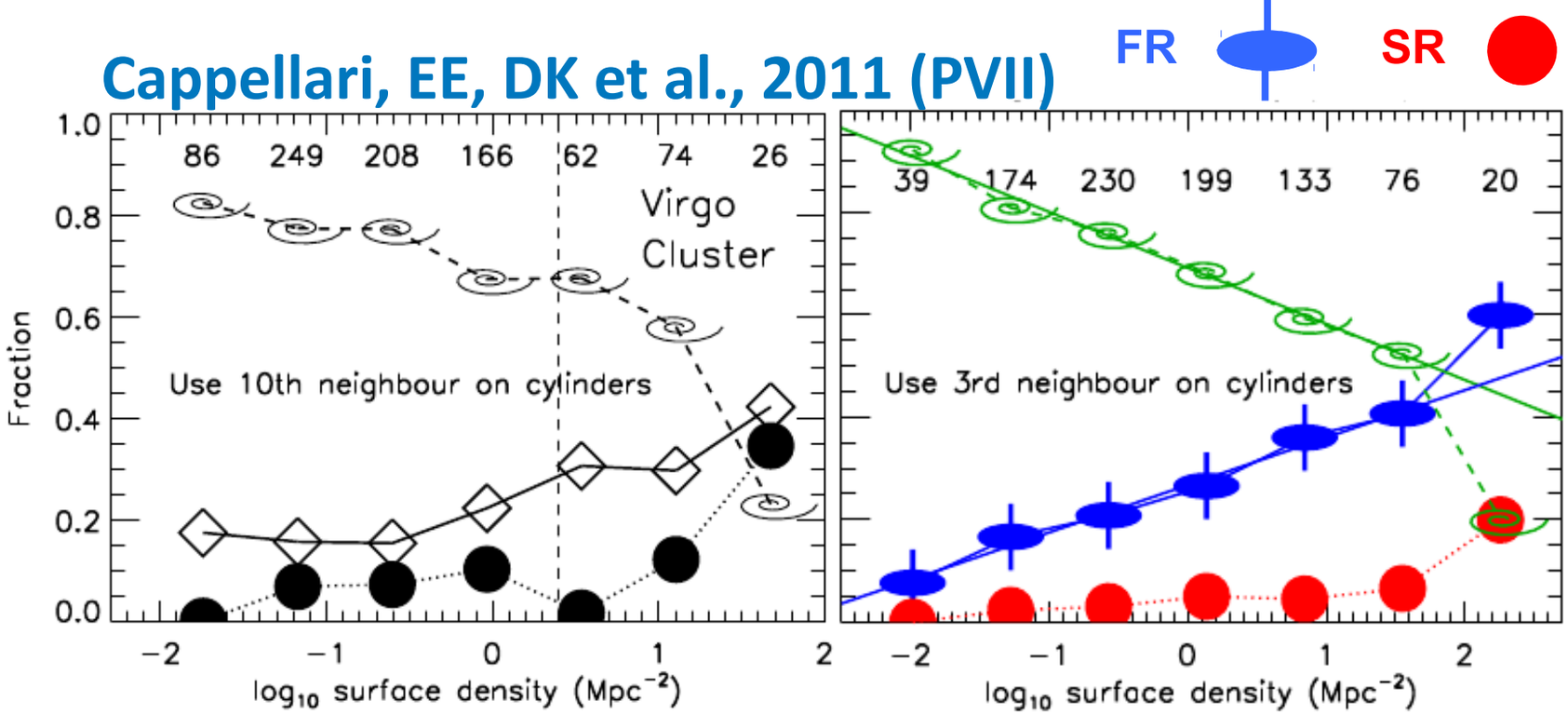
ϵ_e

Emsellem, MC, DK et al., 2011 (PIII)

Krajnović, EE, MC et al., 2011 (PII)

Non-Rotators

Cappellari, EE, DK et al., 2011 (PVII)



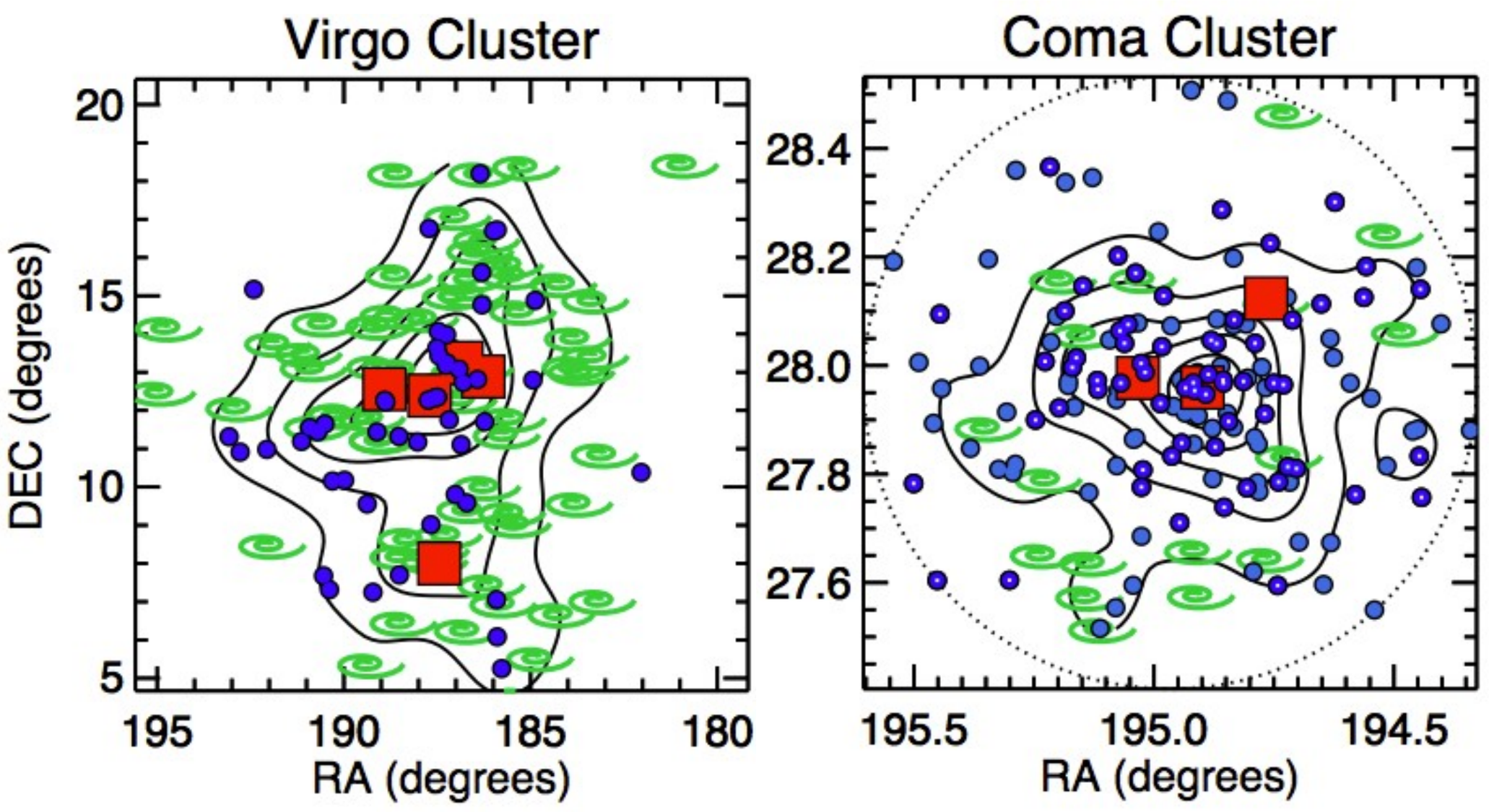
Slow rotators

⇒ efficient formation @ high densities

Monotonic trend

Importance of group scale

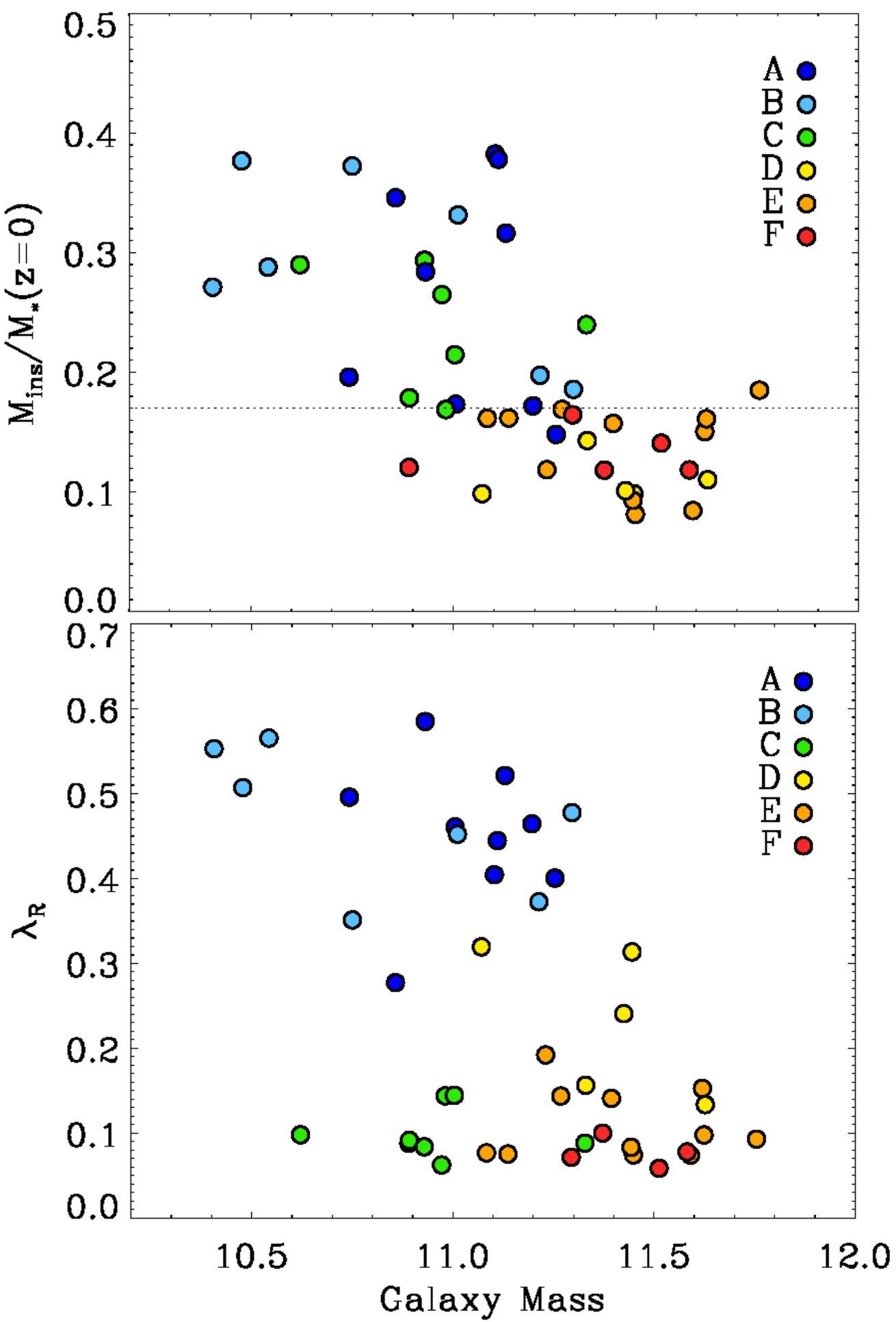
Environment



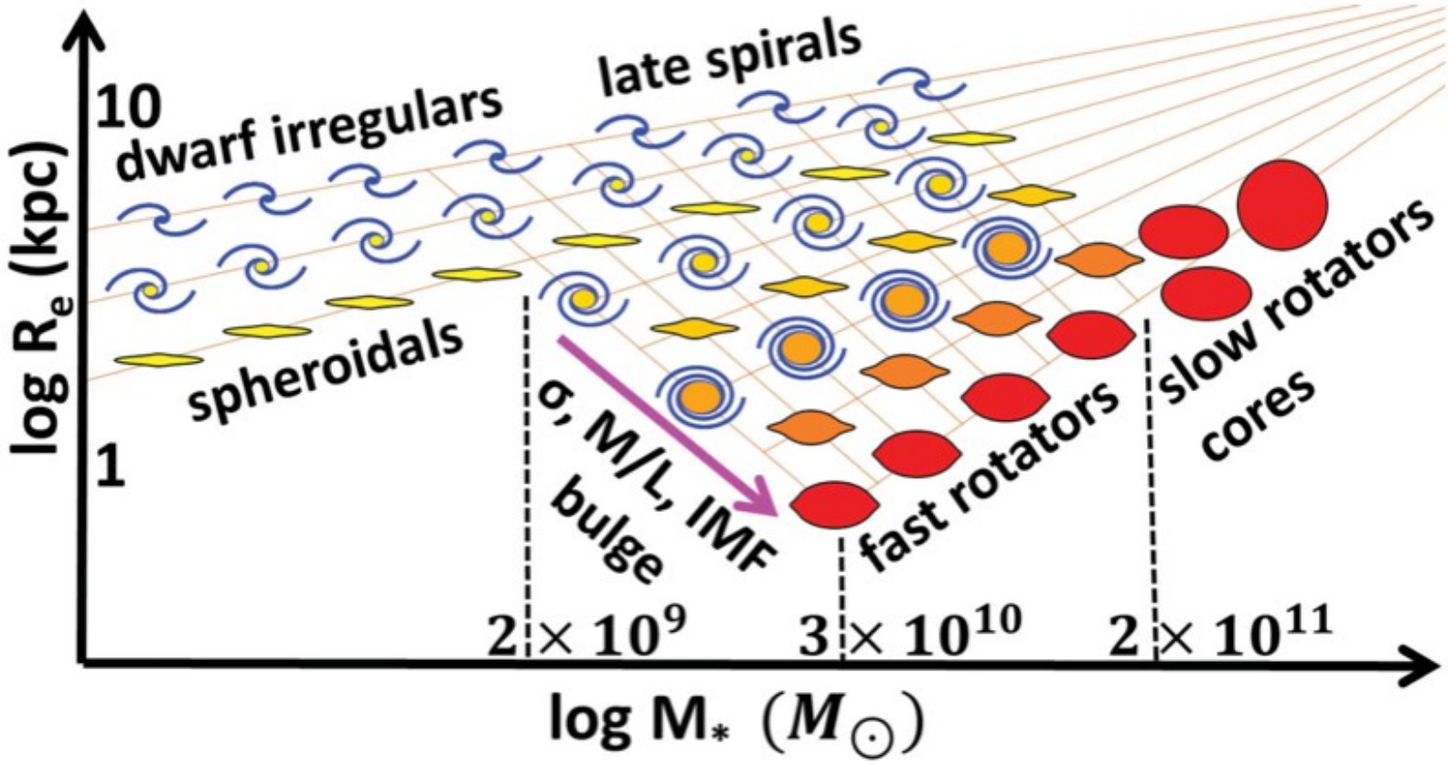
Cappellari (2013)

In situ – Stellar Mass

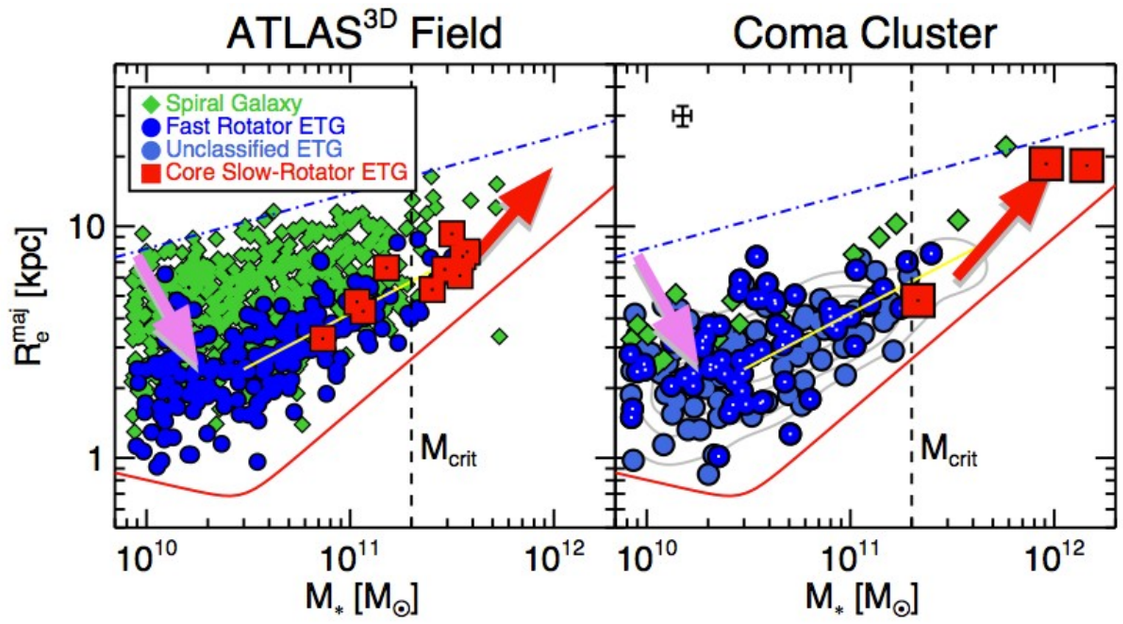
Angular momentum



Naab, Oser, EE et al. (2014)



What happens for $M > 10^{11.3}\ M_{sun}$?

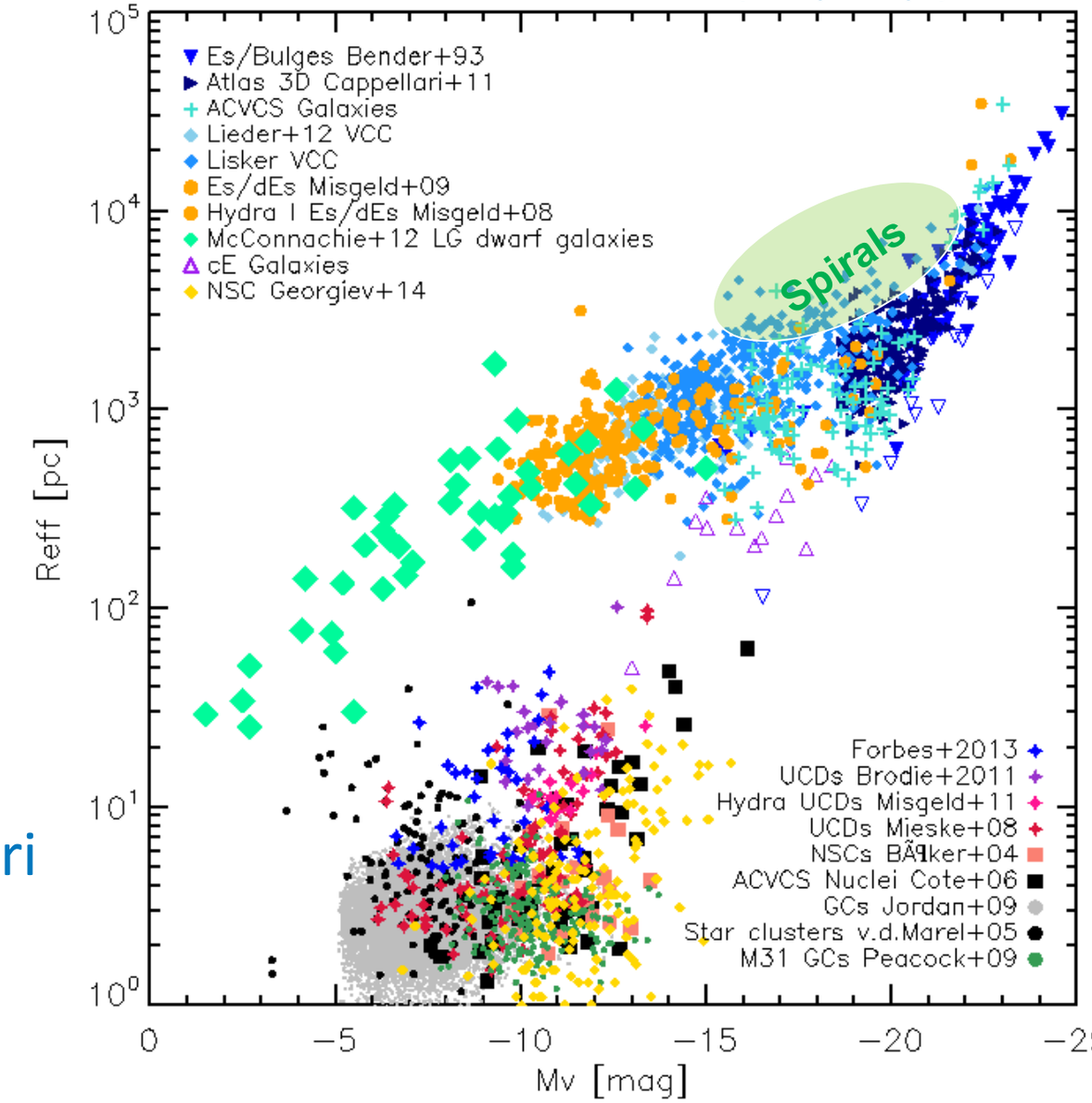


Cappellari (2013)

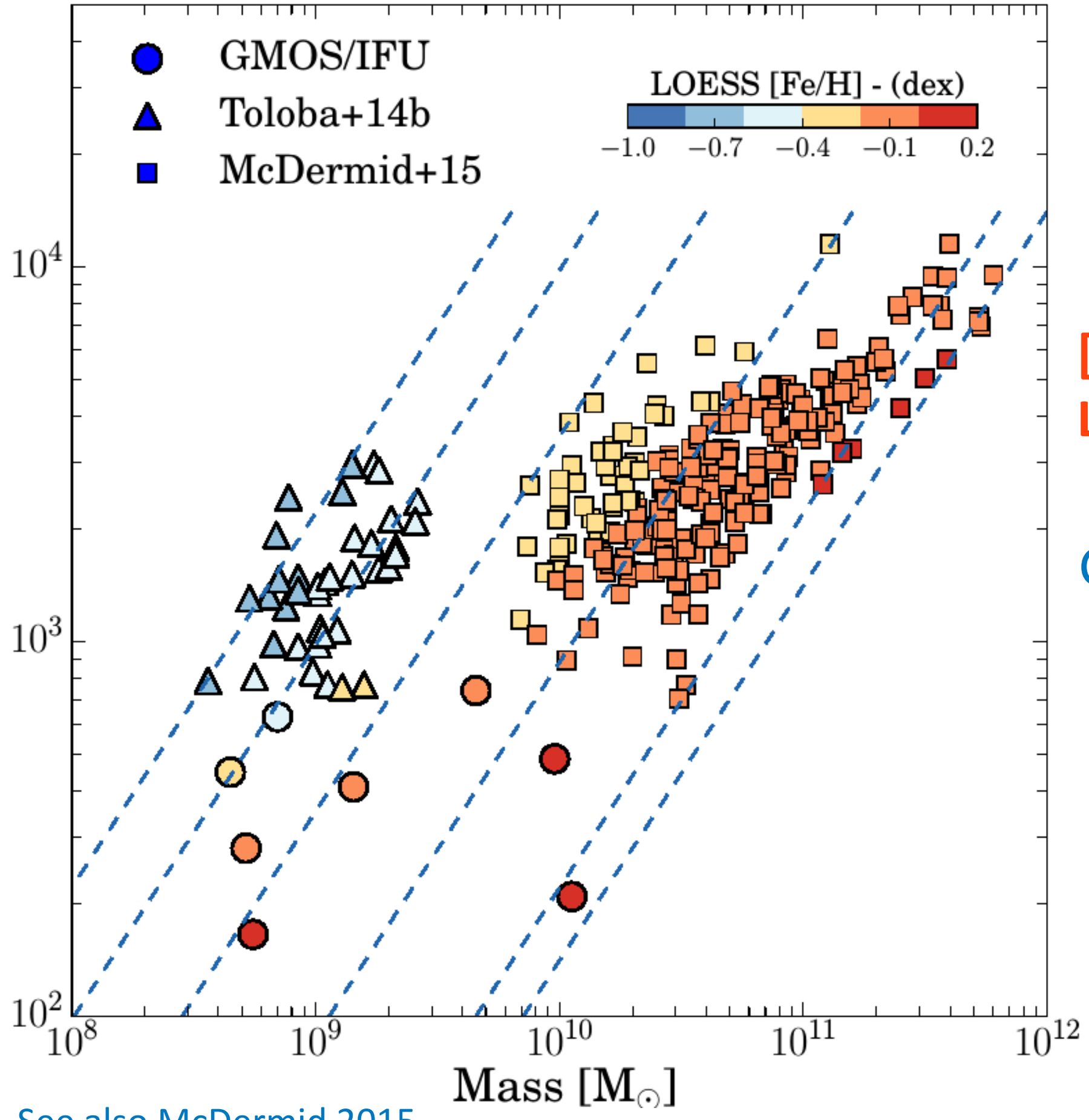
Cappellari et al 2013 (Atlas^{3D} Paper XX)

Mass-Size relation

Voggel et al. (in prep)



Mass-Size relation



[FE/H]

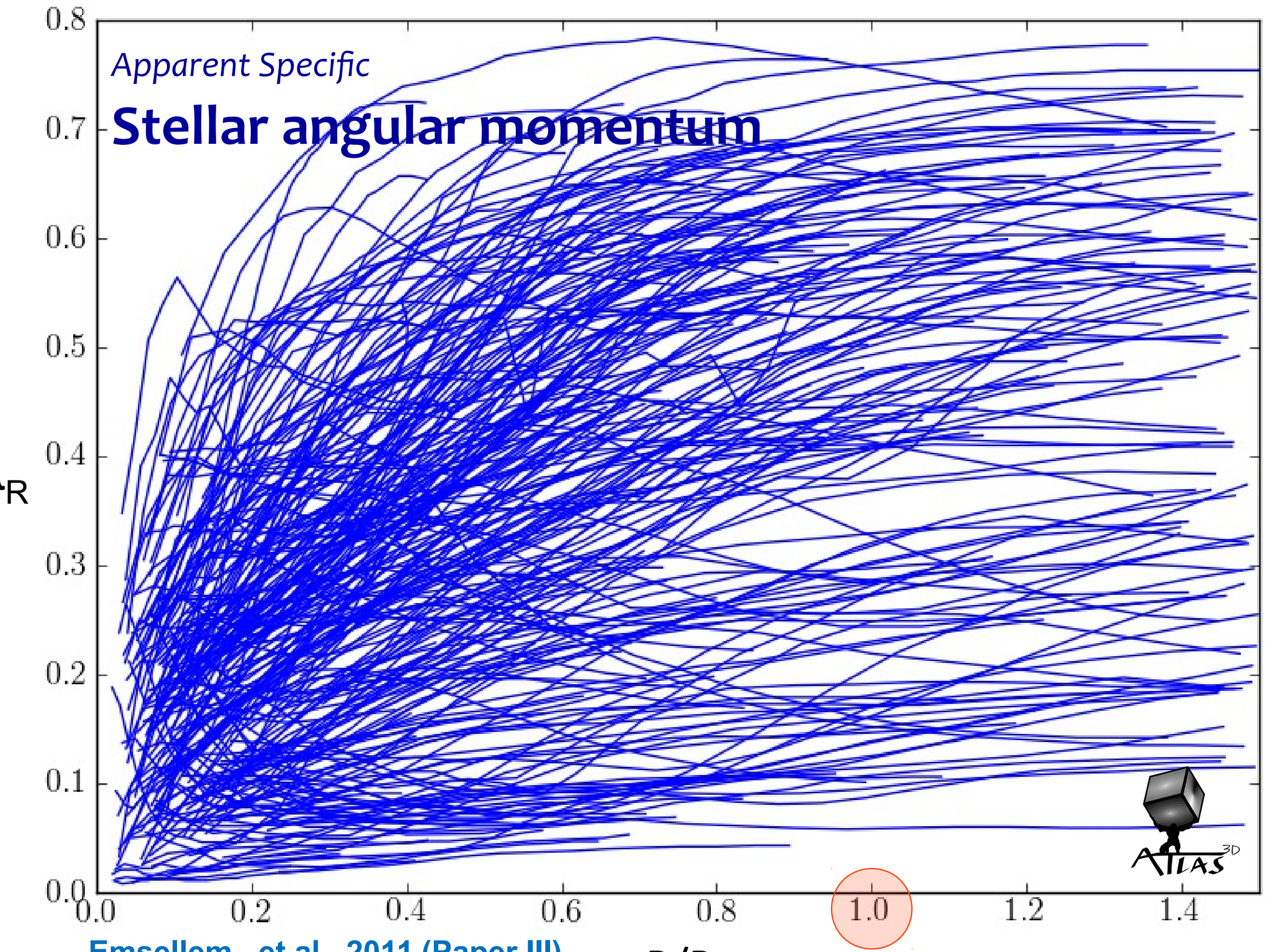
LOESS = SMOOTHED

Guérou et al. 2015

See also McDermid 2015

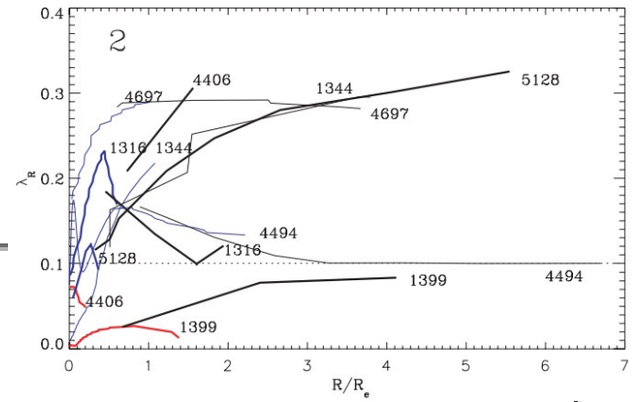
Apparent Specific

Stellar angular momentum

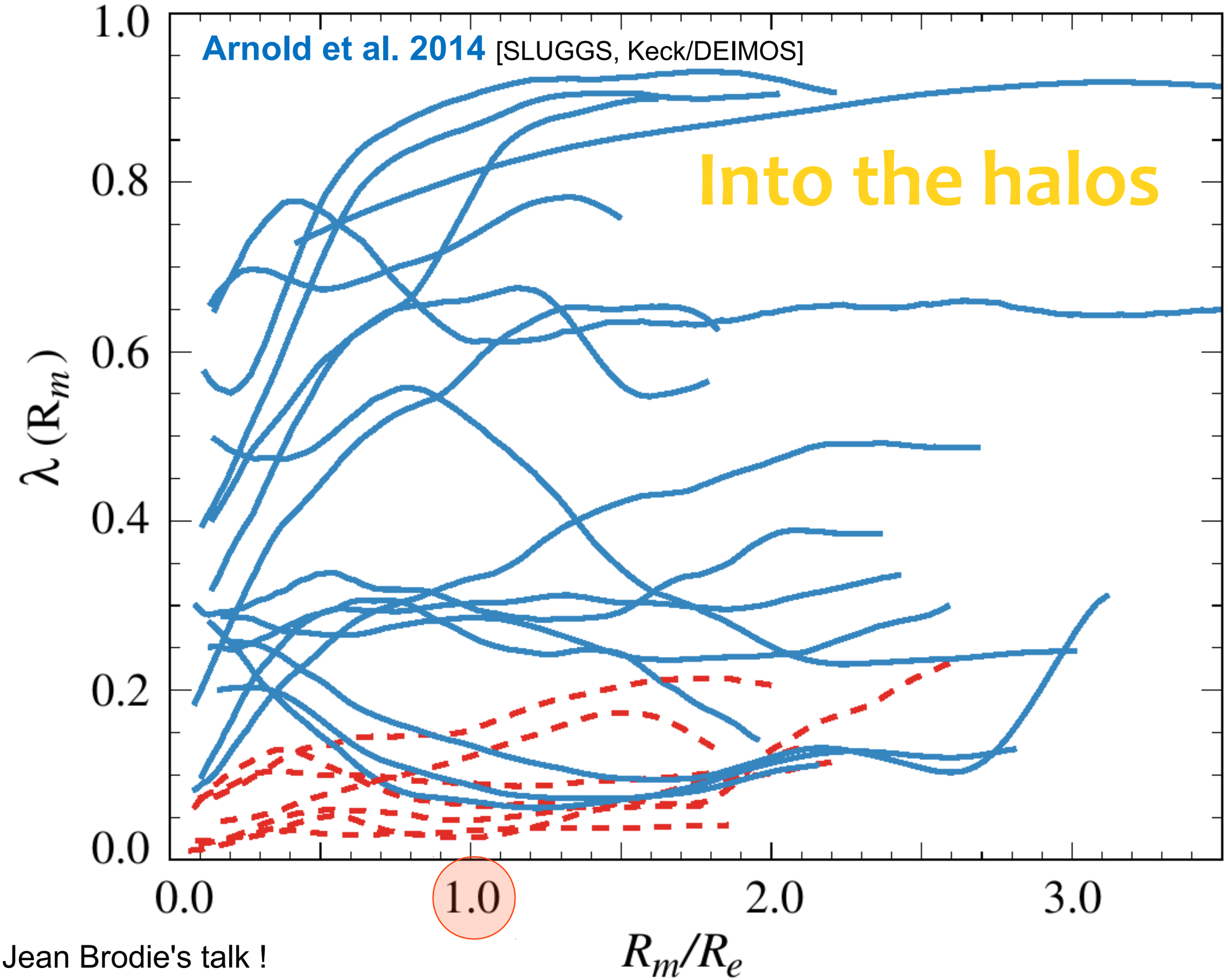


Emsellem, et al., 2011 (Paper III)

Into the halos

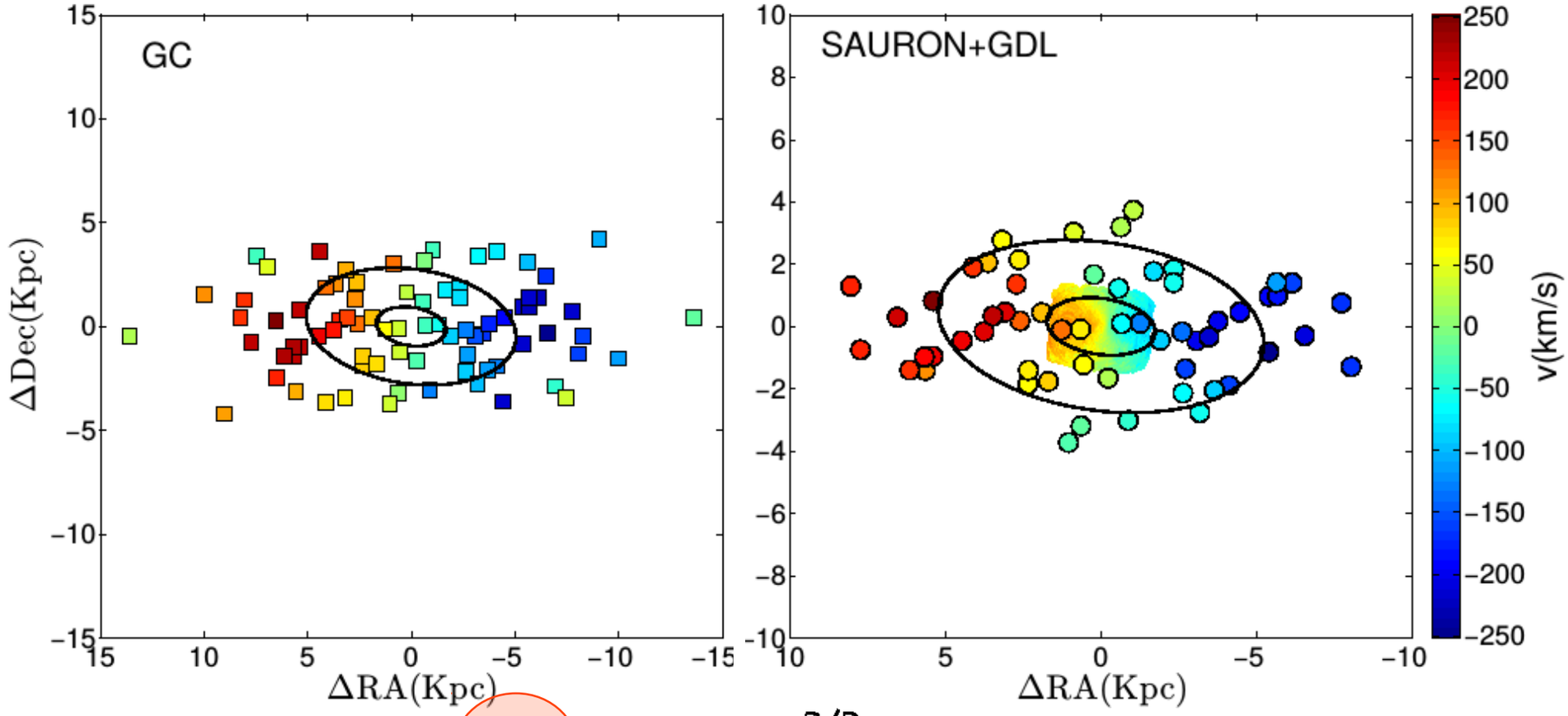


Coccato et al. 2009 [PNS]



& Jean Brodie's talk !

VCC 1062

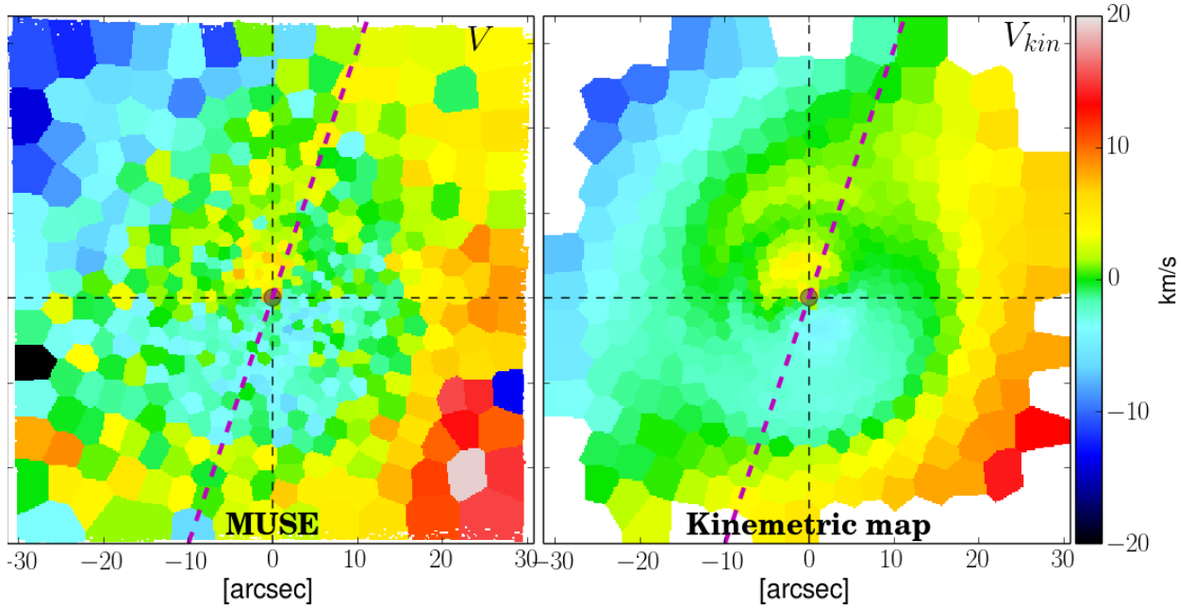


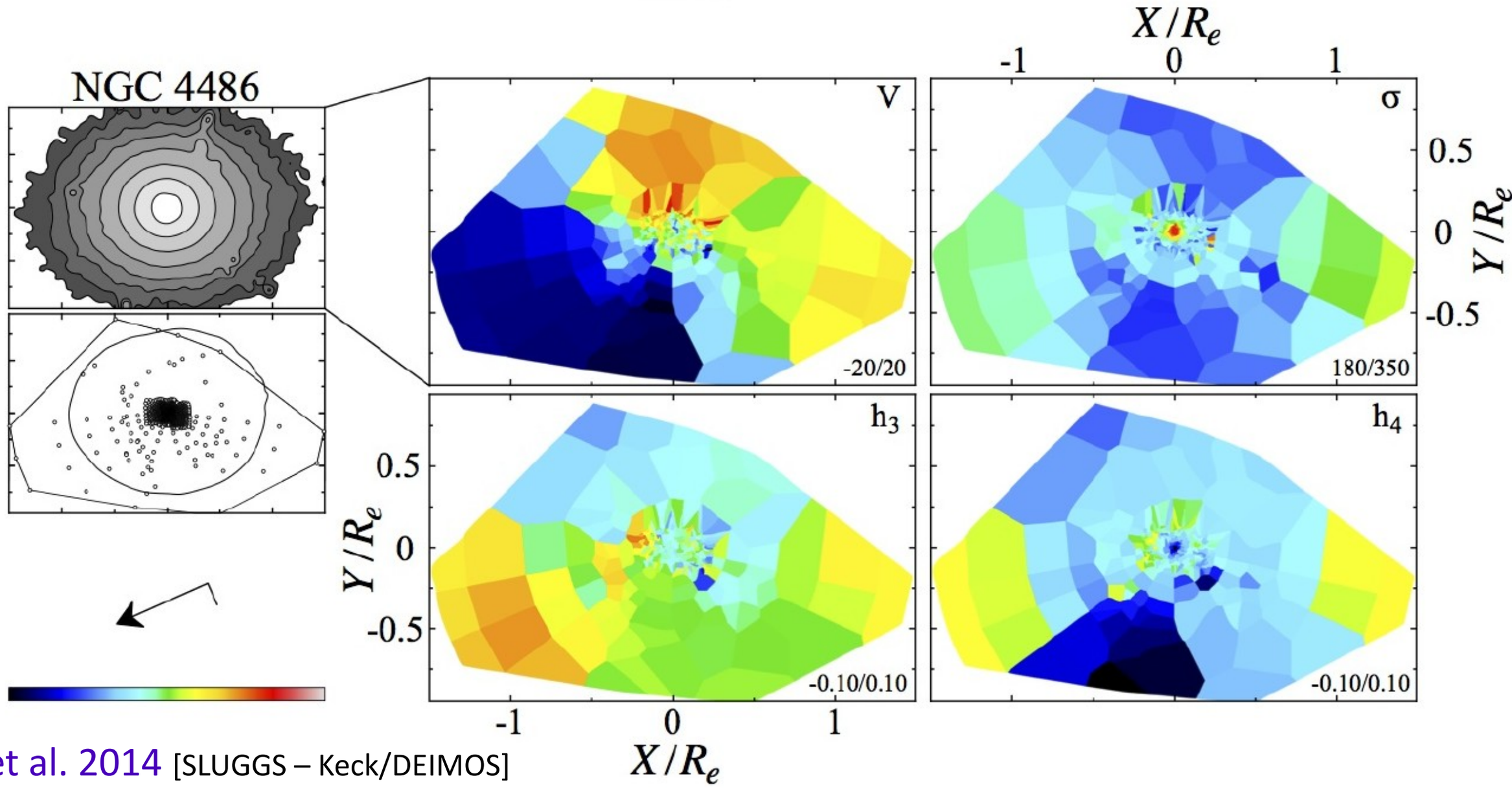
Li, Peng, Côté et al. 2015 [GMOS]

M 87

See also Sarah Bird's talk
+ Murphy et al. 2011, Romanowsky et al. 2012, Longobardi et al. 2013 Agnello et al. 2014, Zhu et al 2014, ...

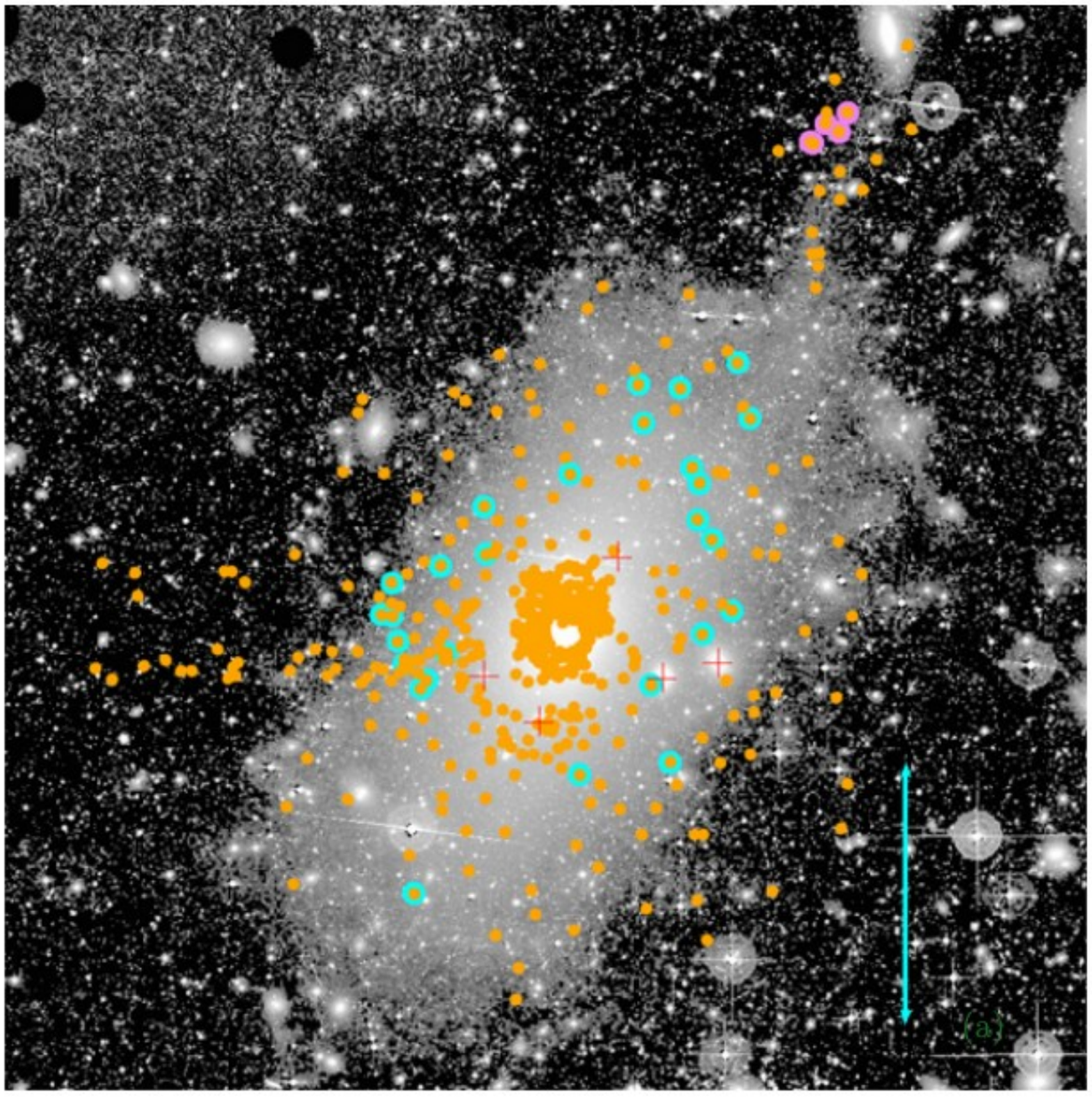
Emsellem, Krajnović, Sarzi 2014

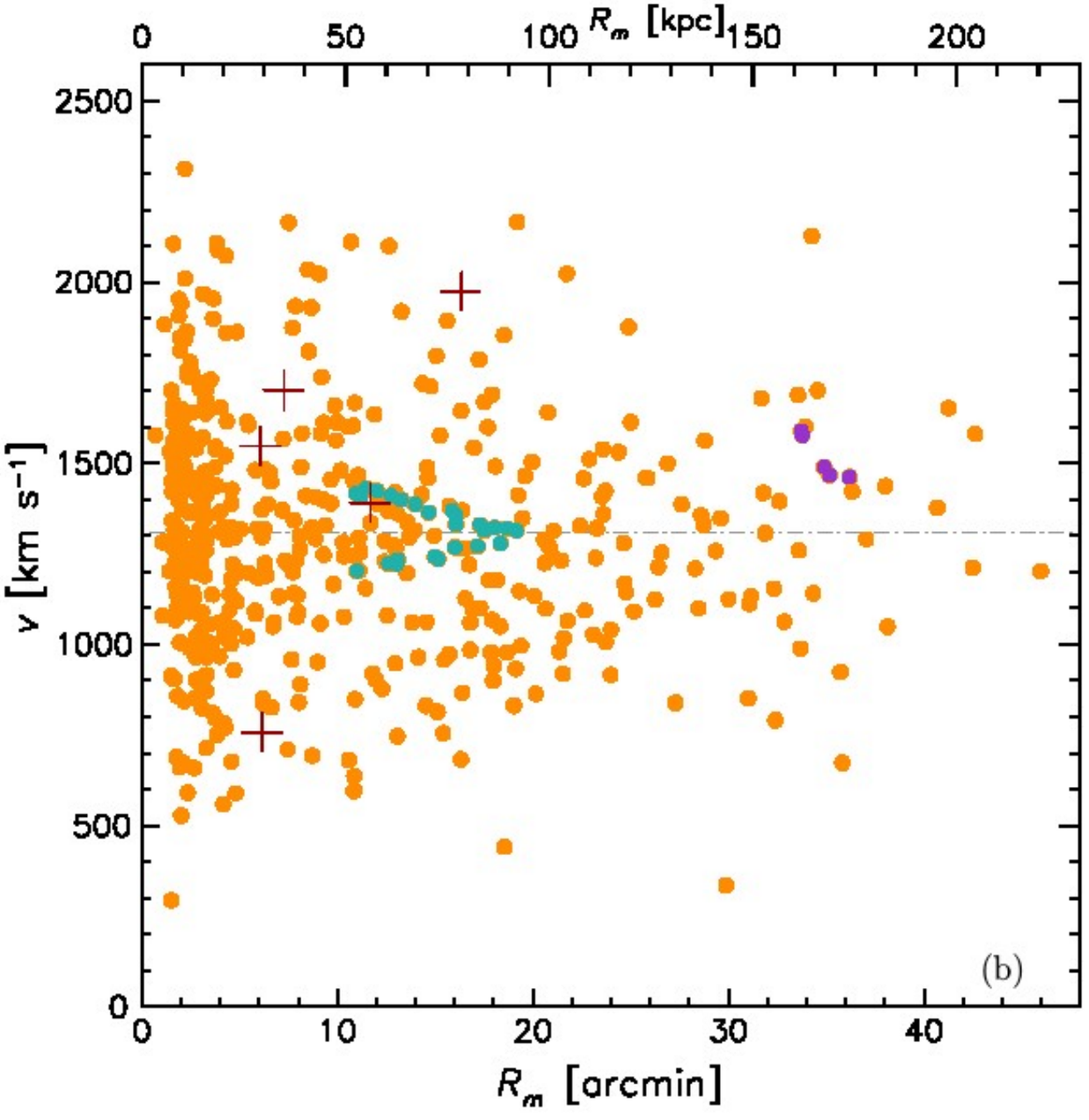




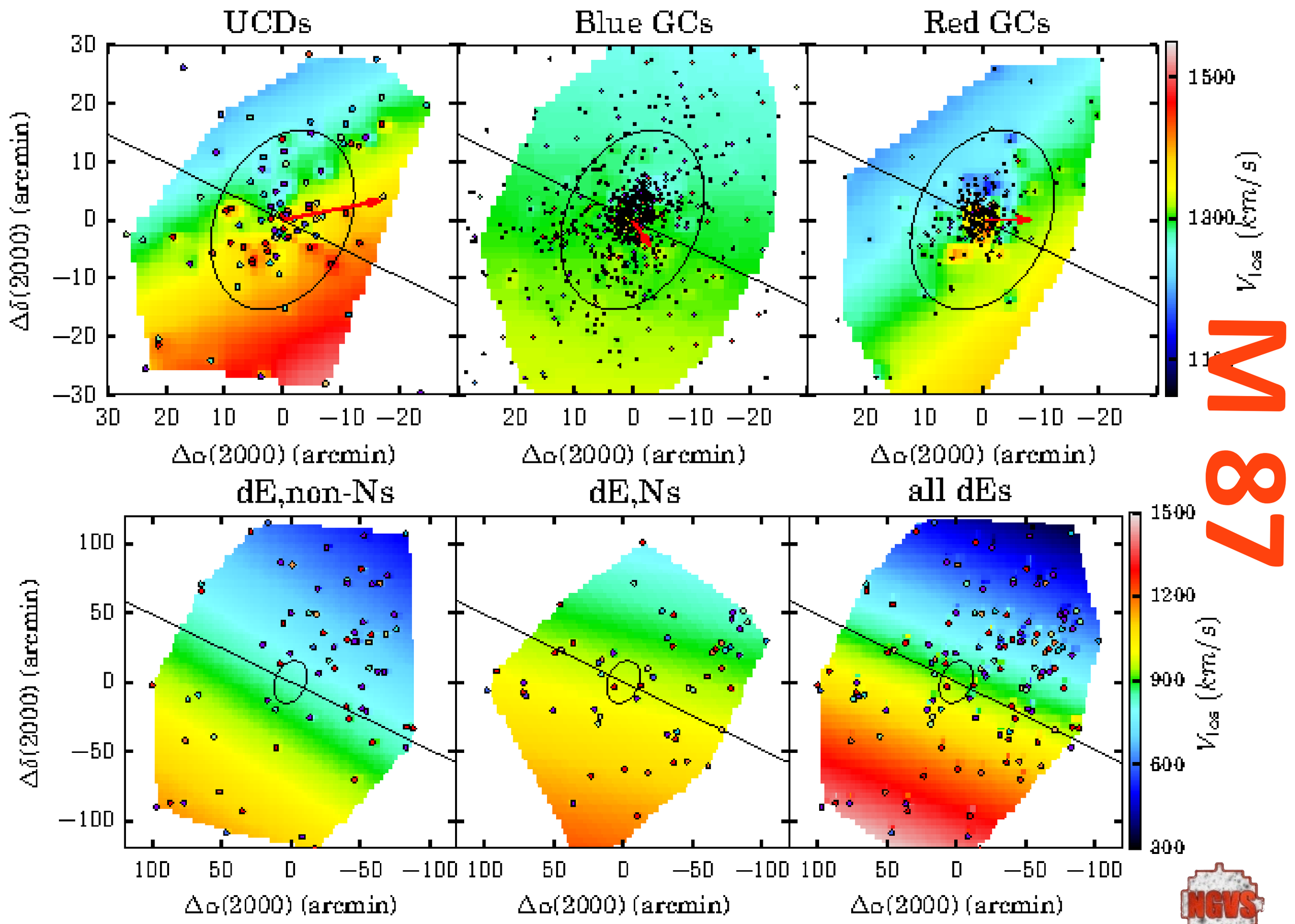
Arnold et al. 2014 [SLUGGS – Keck/DEIMOS]

M 87

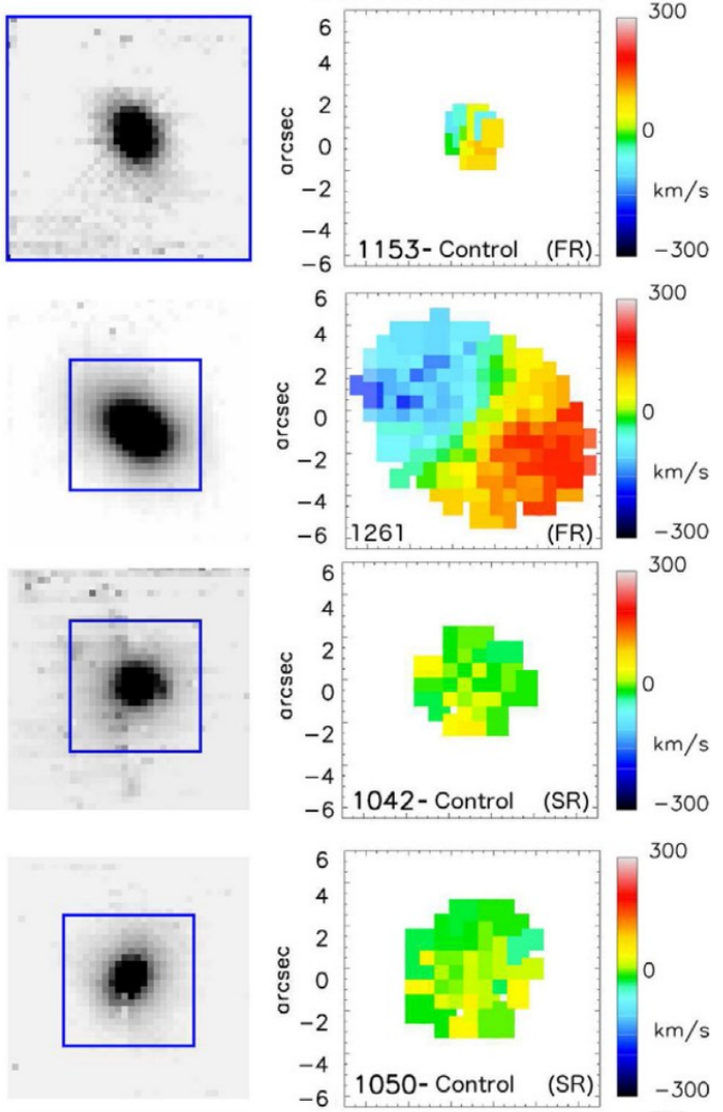




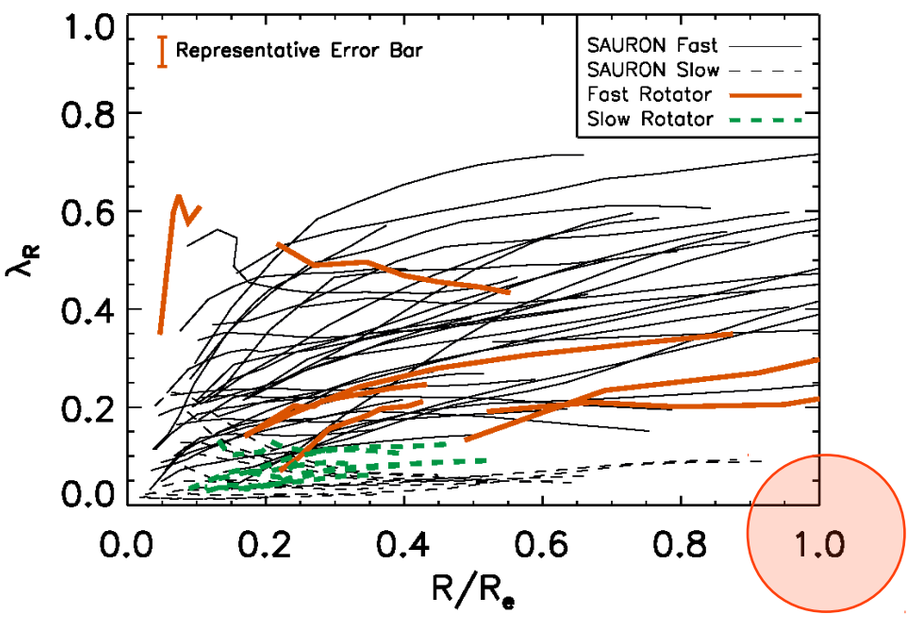
Romanowsky et al. 2012 [GCs - Keck/DEIMOS]

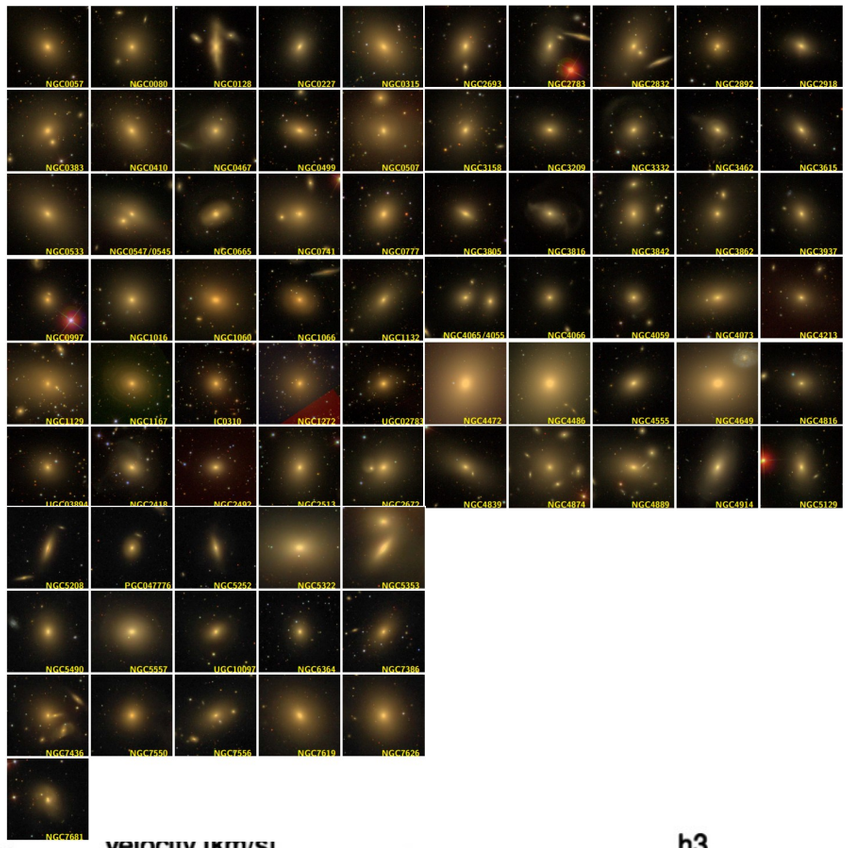


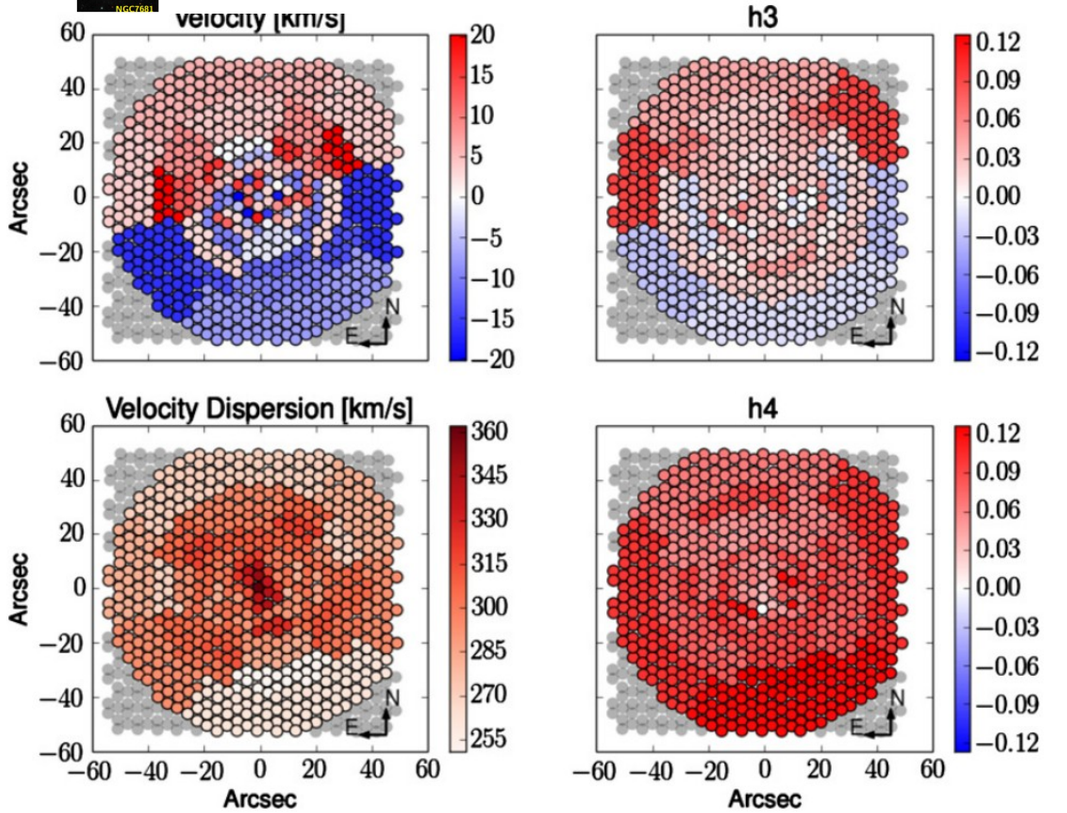
Zhang et al. 2015 [AAT/AAOmega+MMT/Hectospec]



BCGs







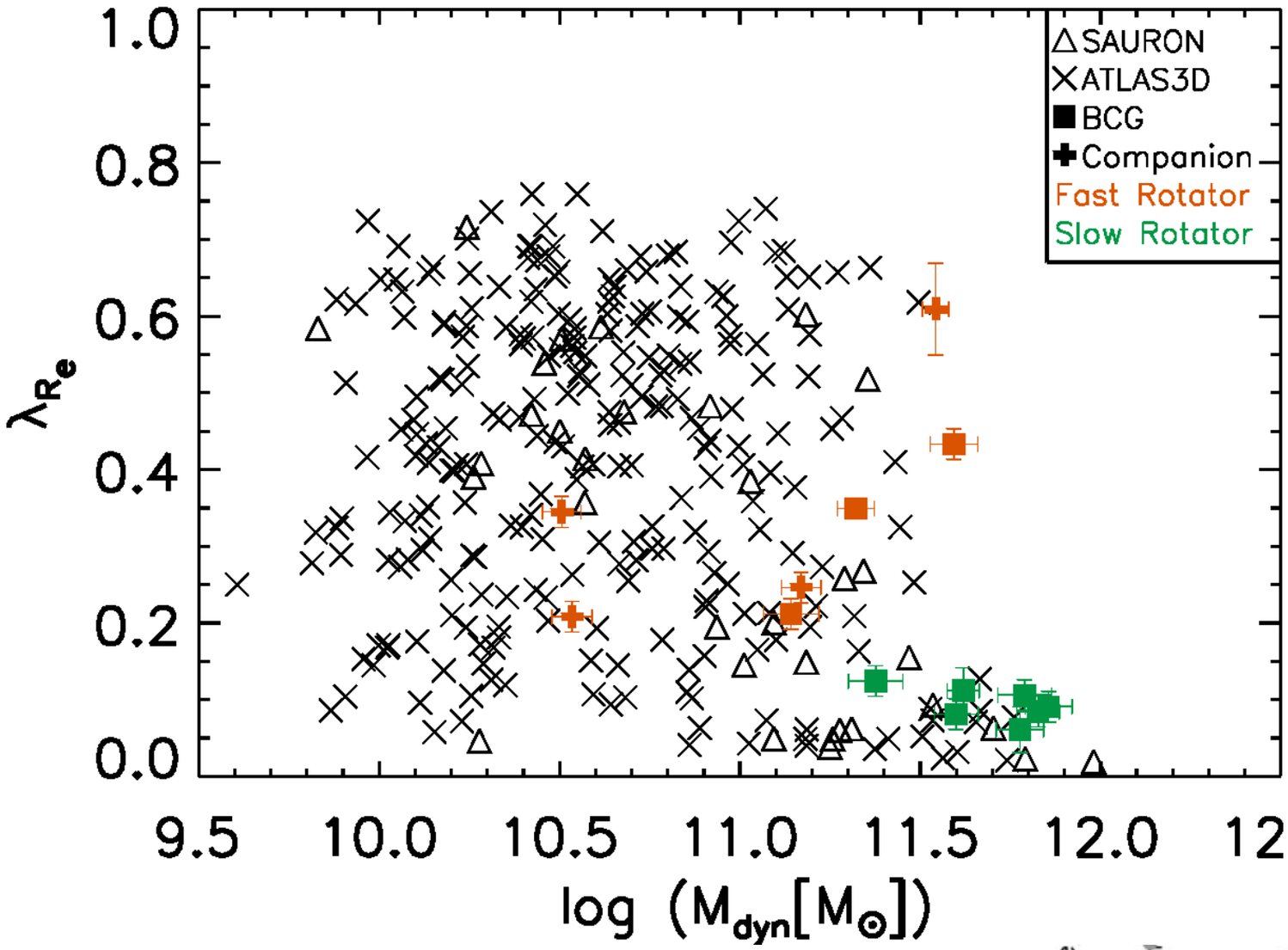
Jimmy, Brough et al. 2013

[VLT/VIMOS]

Ma et al. 2014

[MASSIVE – Mitchell Spec + AO-NIFS]

log10[M] > 11.5

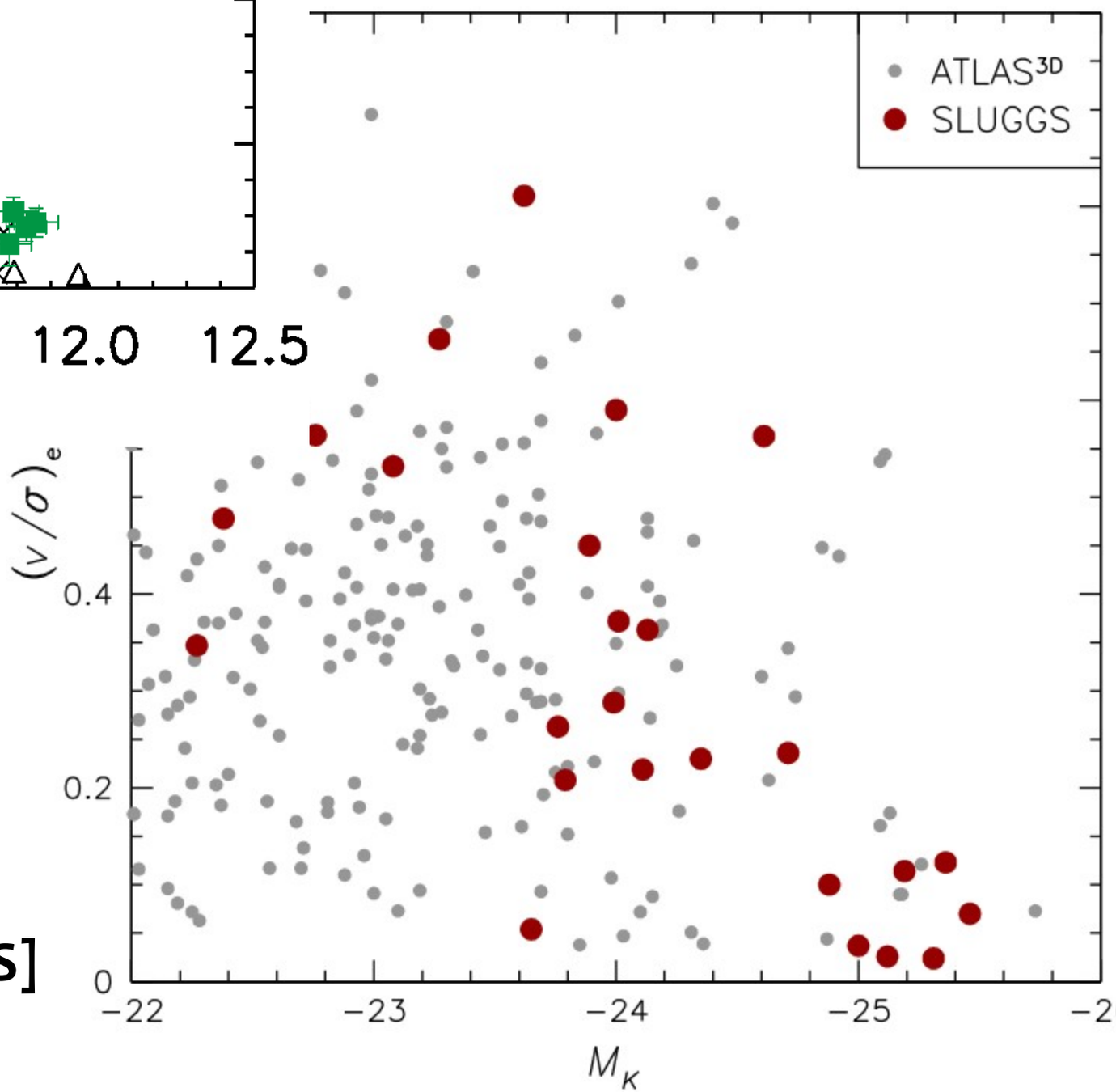


Jimmy, Brough et al. 2013

[VLT/VIMOS]

Brodie et al. 2014

[SLUGGS- Keck/DEIMOS]



The M3G Project

A MUSE GTO programme

PI Eric Emsellem; Davor Krajnović

& the MUSE GTO Team

Goals:

Dynamical state, Dark matter content

SFH, IMF

+ Test predictions of numerical simulations

e.g. Hoffman et al. 2010, Bois et al. 2011, Naab et al. 2014, Röttgers et al. 2014, Vogelsberger et al. 2014 (Illustris), Schaye et al. 2015 (EAGLE), Hirschmann et al. 2015…

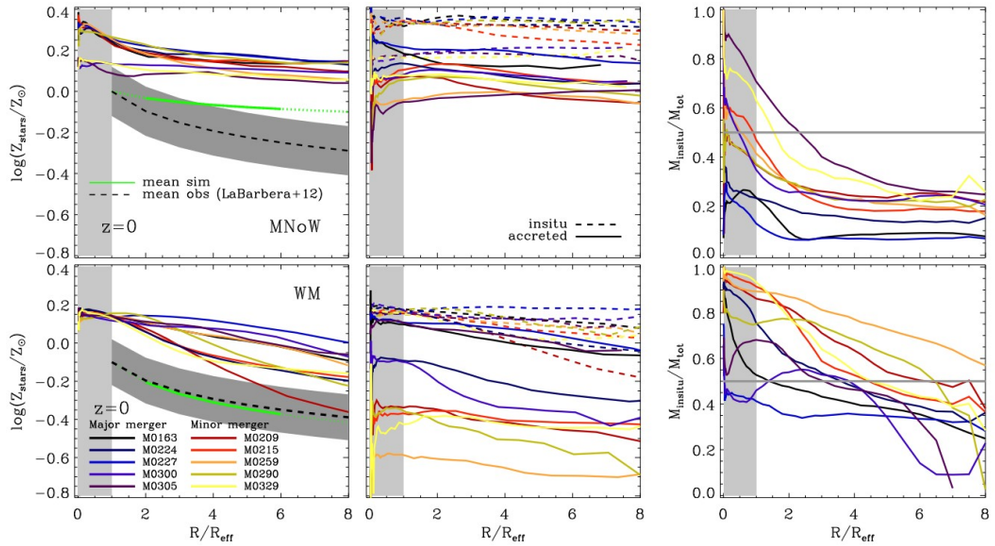
How:

Stellar content + dynamics

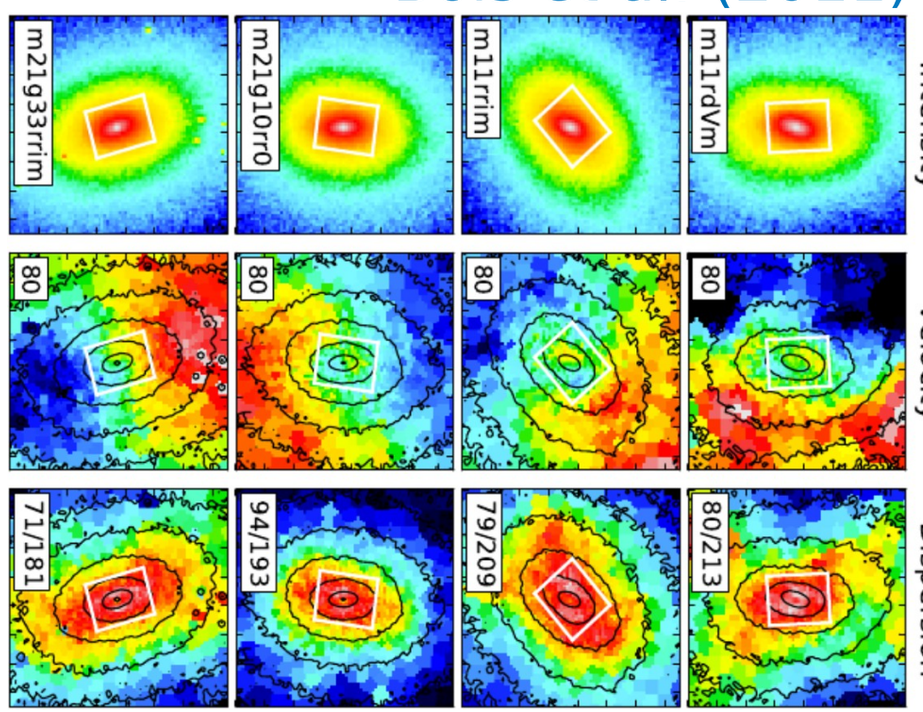
of the most massive galaxies

in densest environments

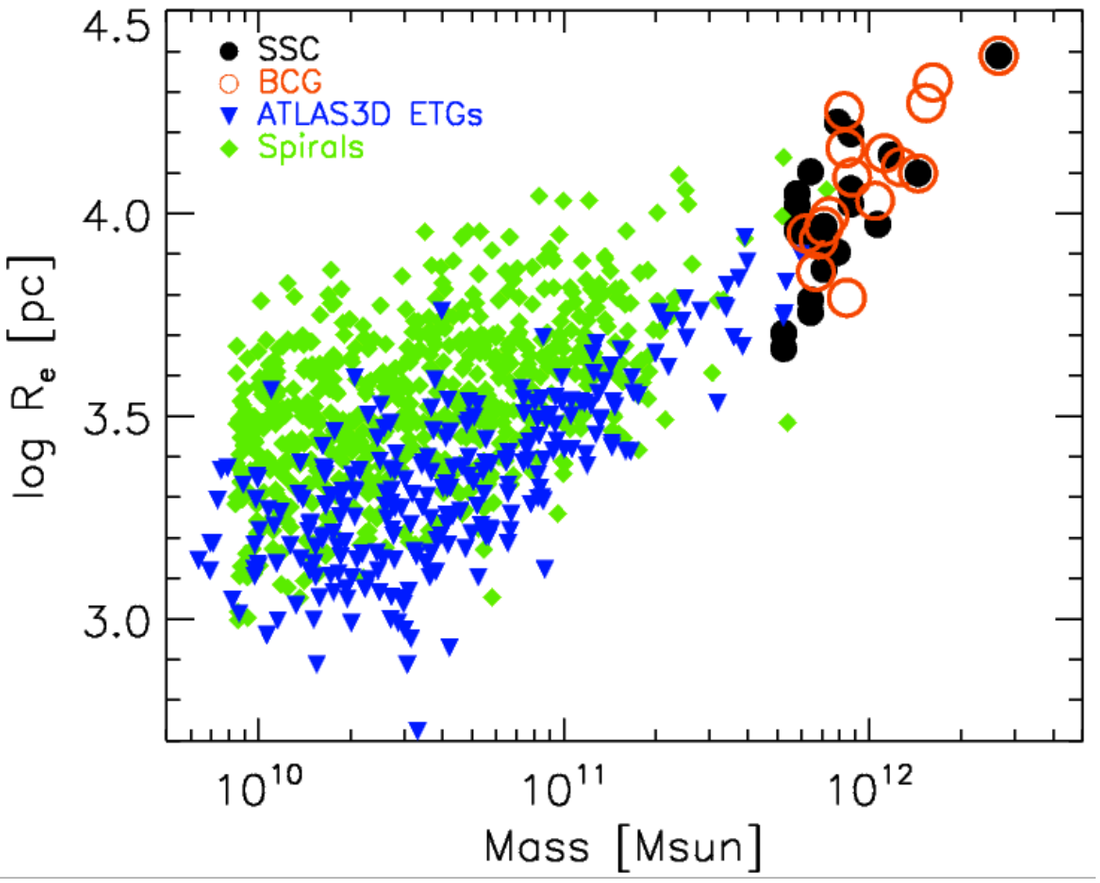
Hirschmann et al. (2015)

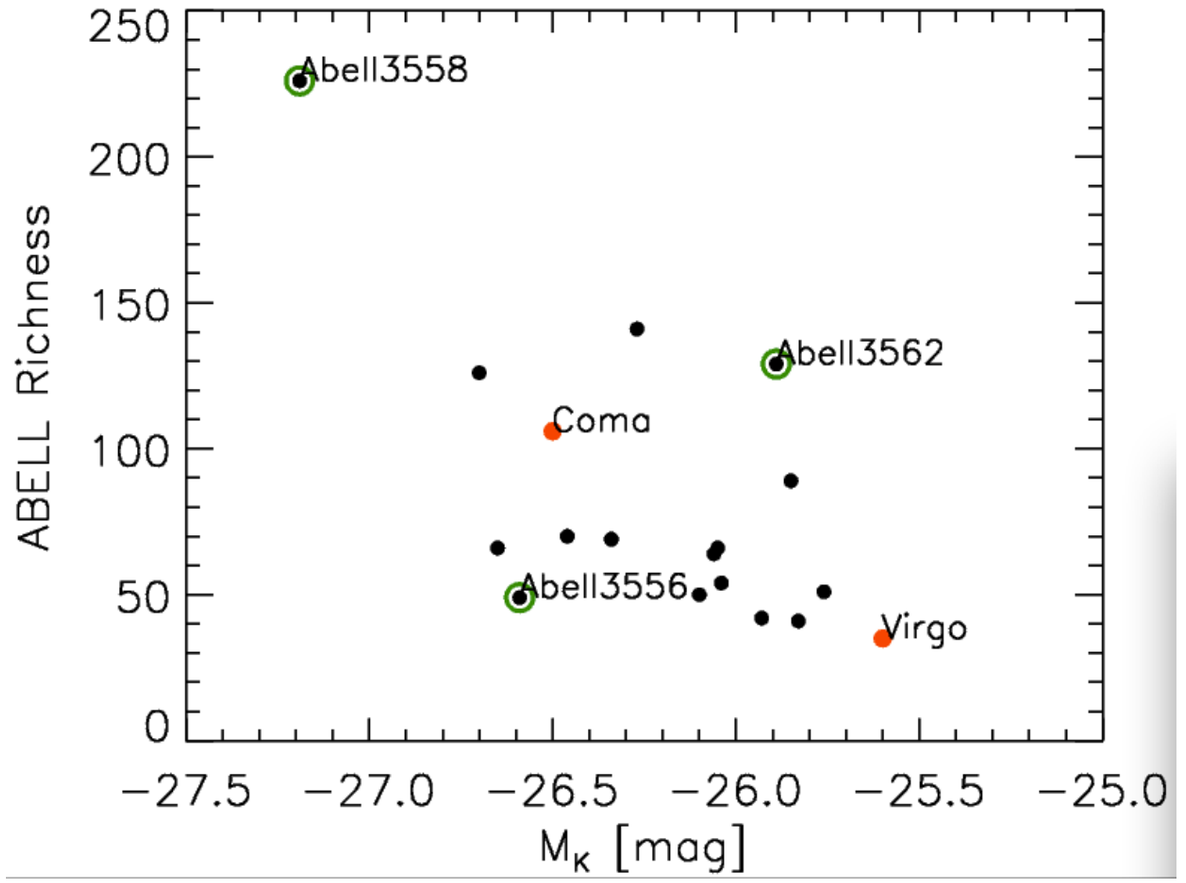


Bois et al. (2011)



The 3D Sample





More massive, denser, richer clusters → 2 sub-samples at z~0.04

1. Most massive galaxies in Shapley Super Cluster (brighter than -25.7 mag)

+

2. BCGs in rich clusters (richness of clusters)

Observing with MUSE

- Panoramic integral field unit on VLT
- 1x1 arcmin^2 Field of view
- 0.2 arcsec sampling in WFM
- High image quality
- 4650-9300 A simultaneous wavelength range
- R = 1500-3500
- ~90000 spectra
- End-to-end throughput 0.35
- Advanced data reduction pipeline

Two fold observing strategy:

- Snapshot
  - good seeing (<0.8 arcsec) ~ 20-30min
- Deep exposures:
  - reach S/N of 30 at 2 Re

MUSE (V-R-I) "Snapshot" Images

MUSE (V-R-I) "Snapshot" Images

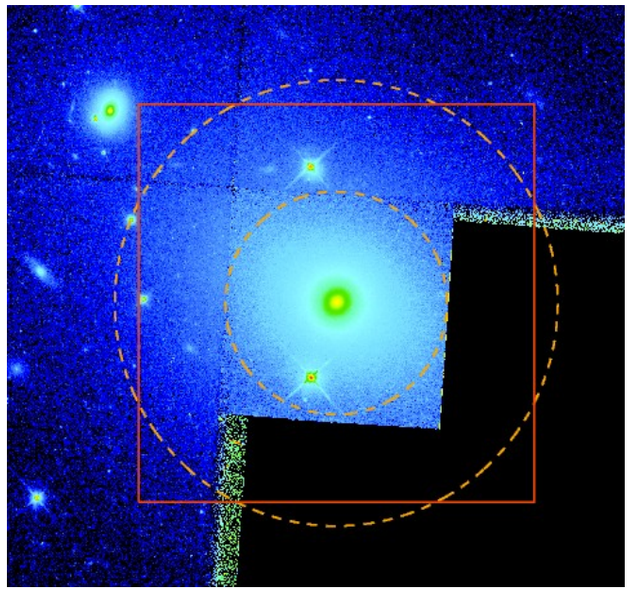
X 90,000

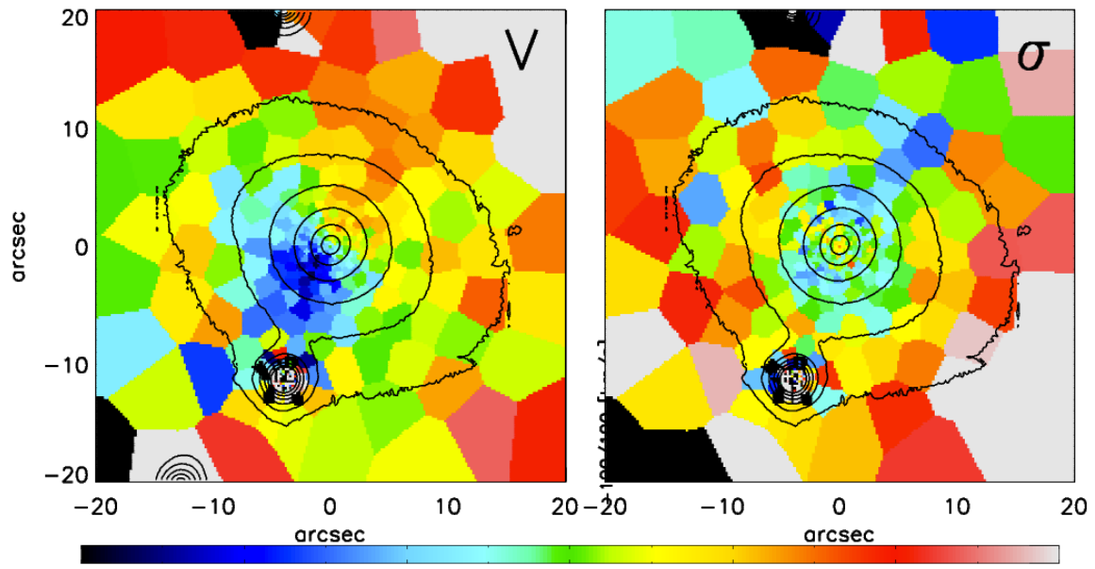
HST - WFPC2

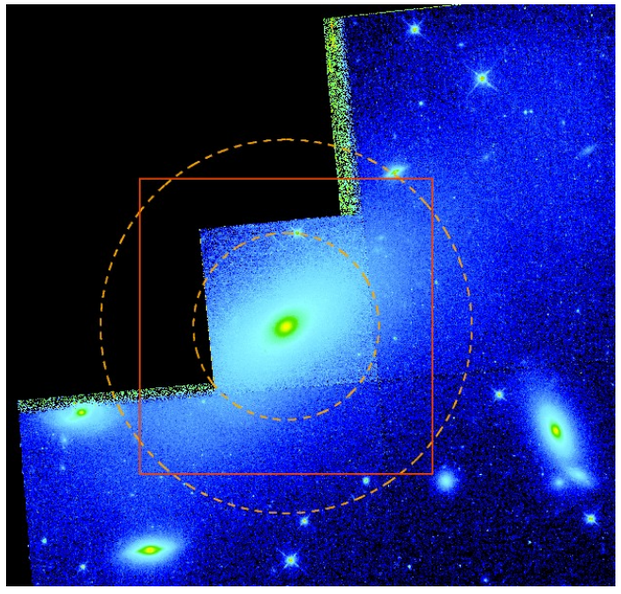
MUSE colour

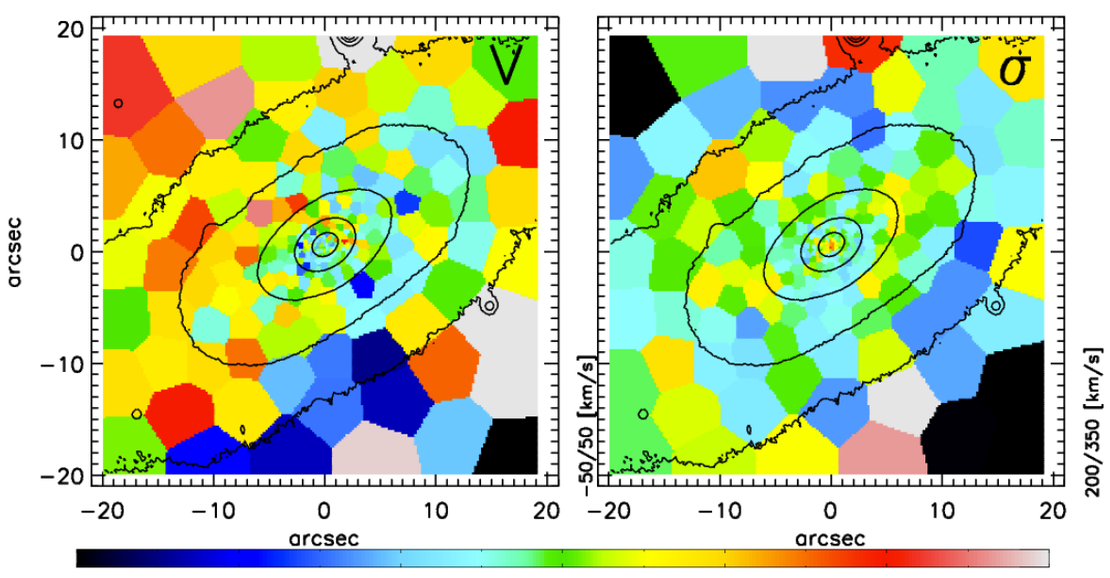
Velocity

Velocity dispersion









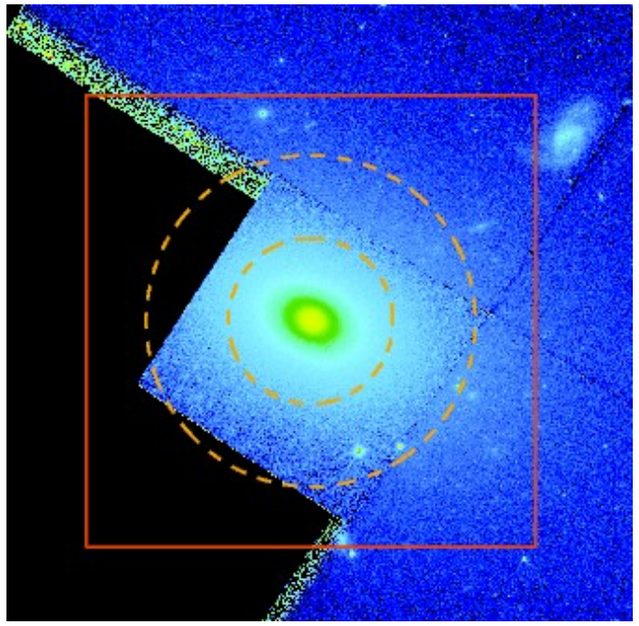
Preliminary (snapshot) Results

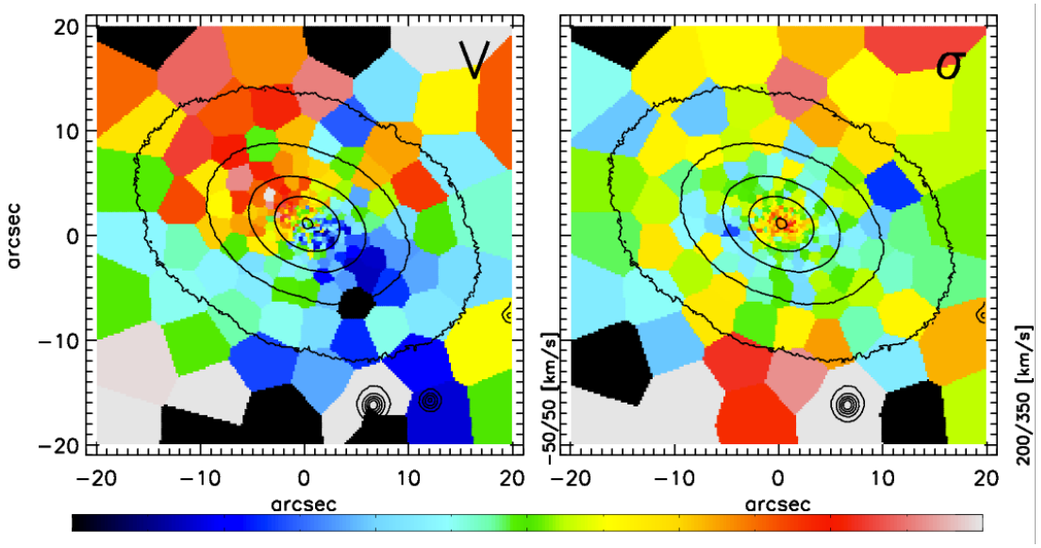
HST - WFPC2

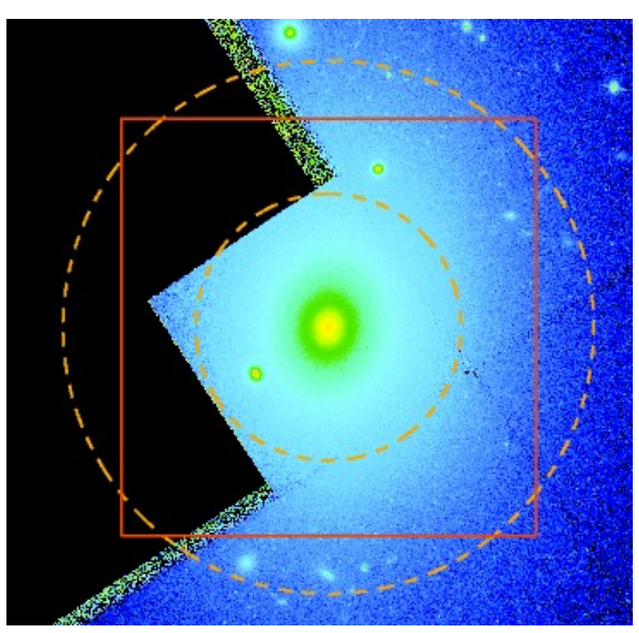
MUSE colour

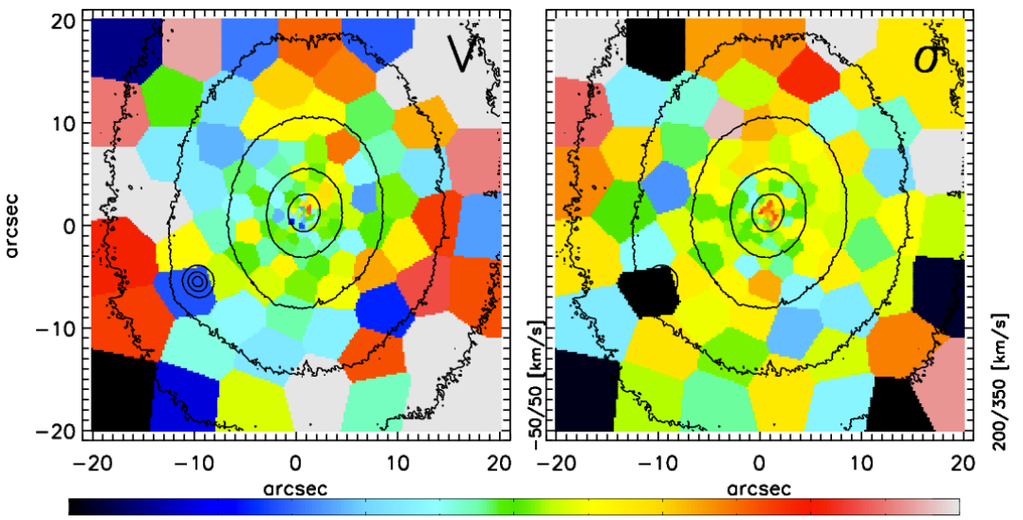
Velocity

Velocity dispersion









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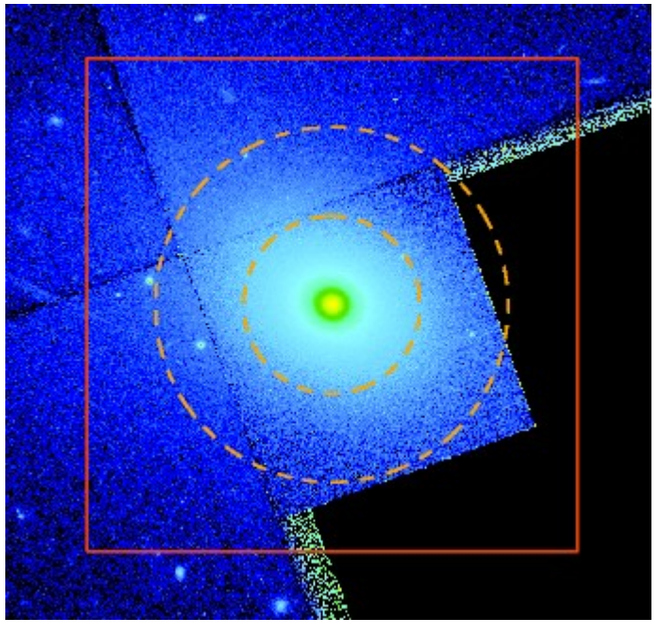
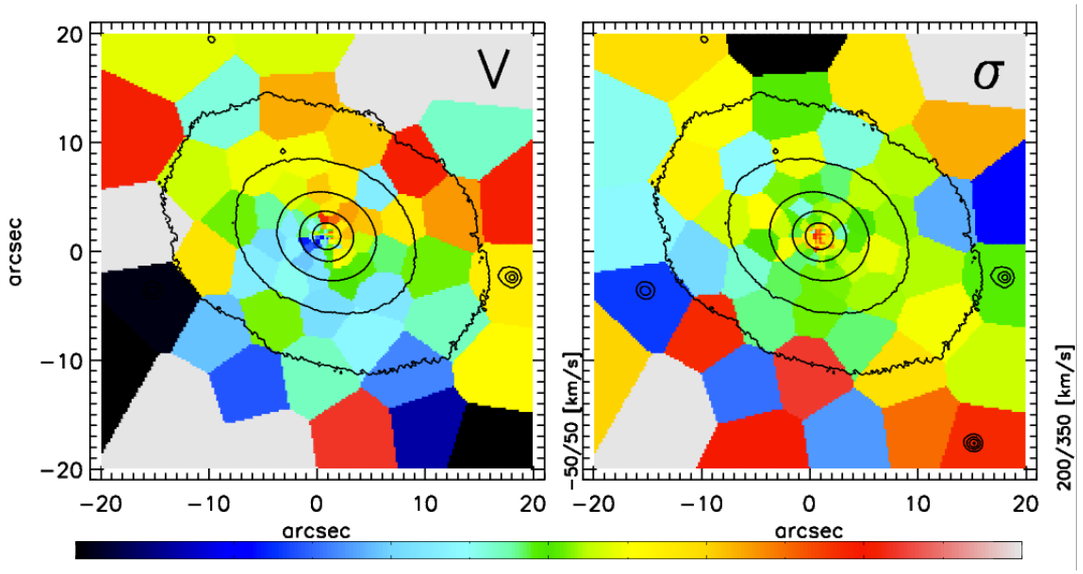
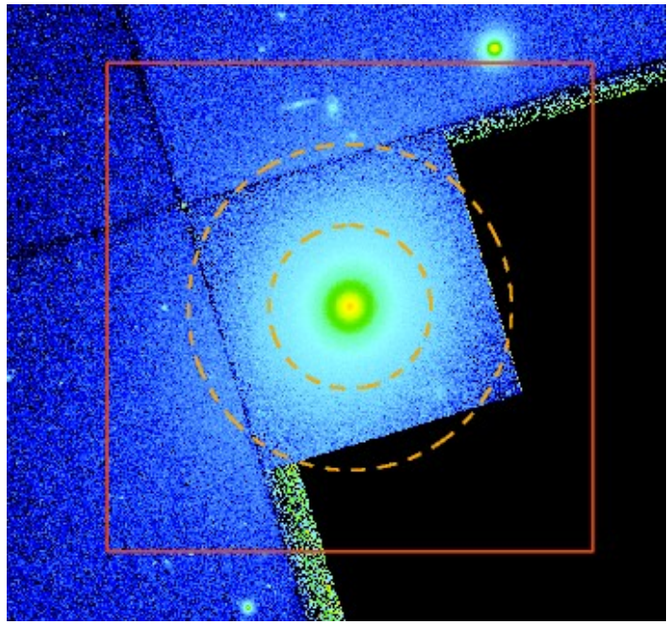
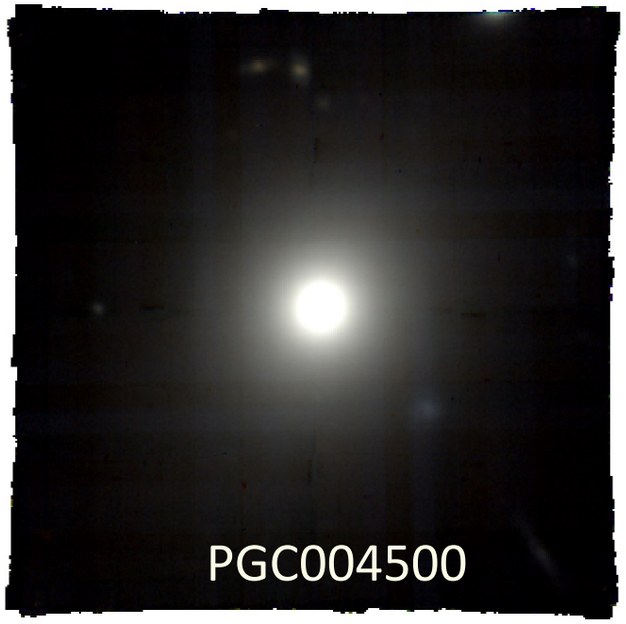
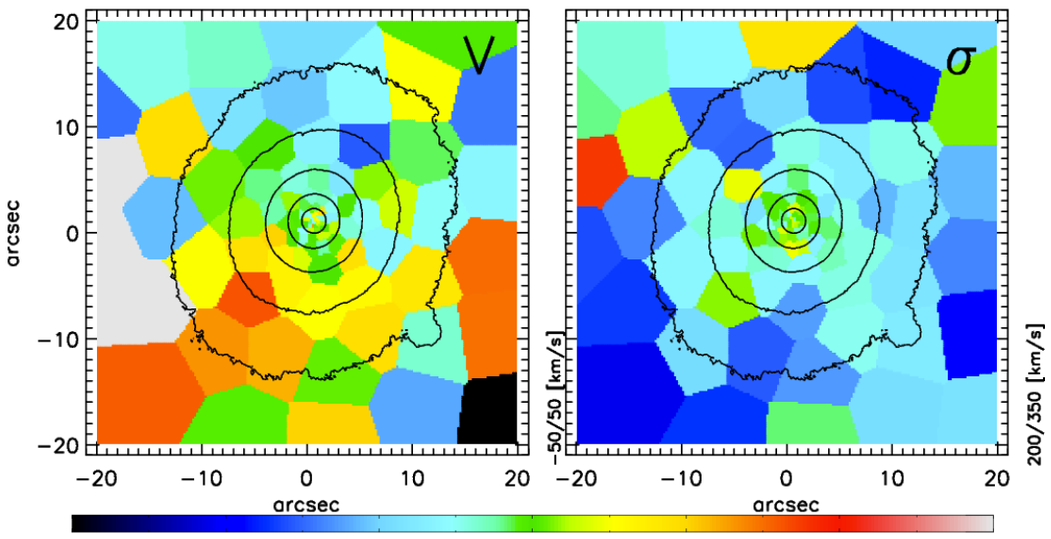




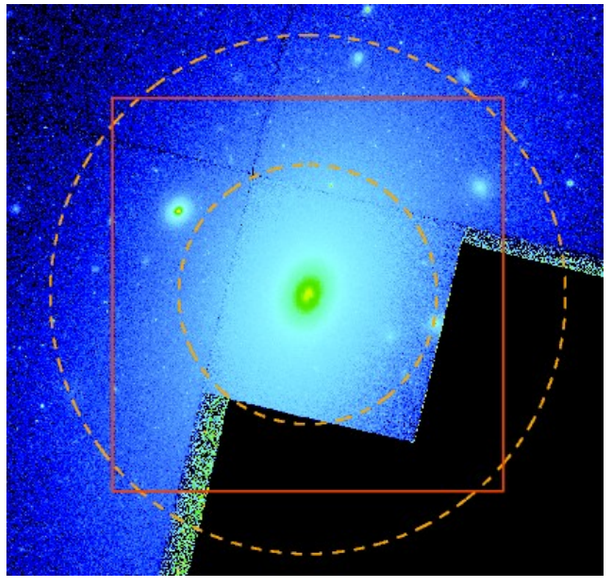




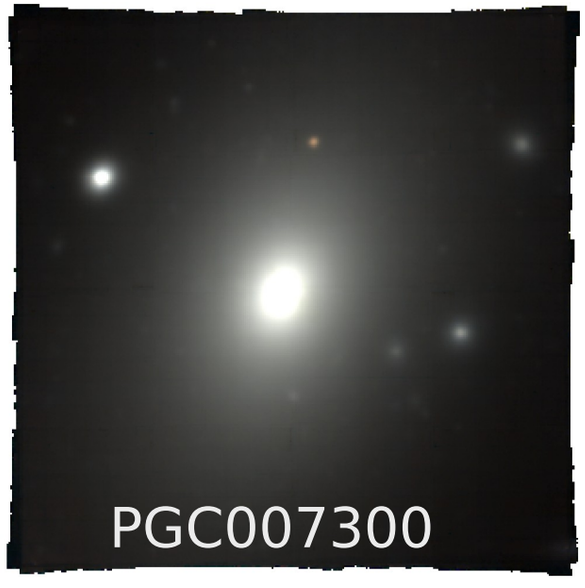


Preliminary (snapshot) Results

HST - WFPC2

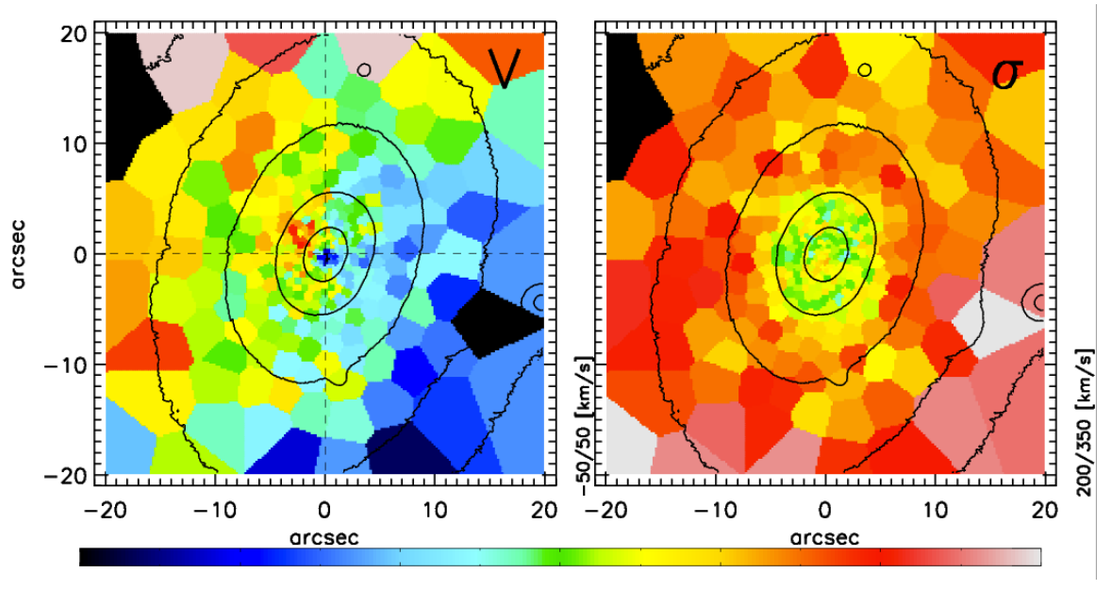


MUSE colour



Velocity

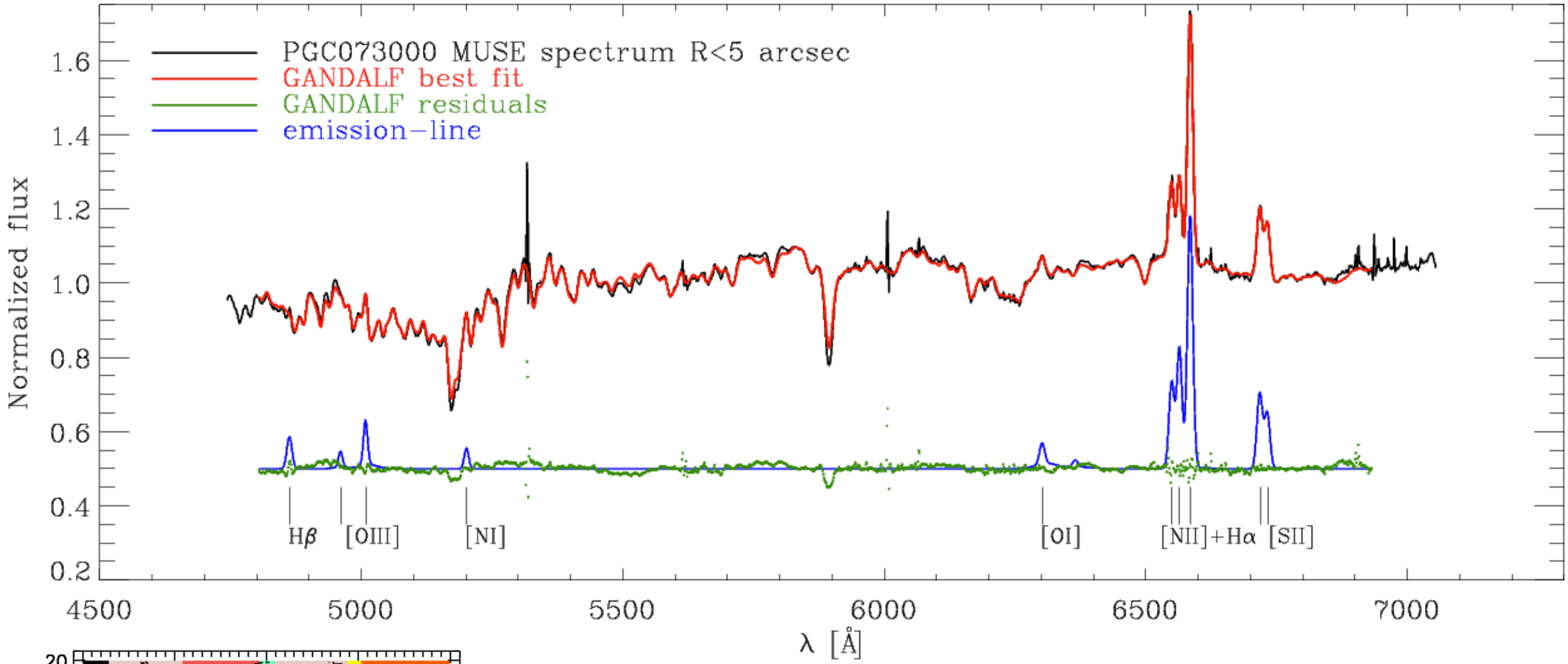
Velocity dispersion

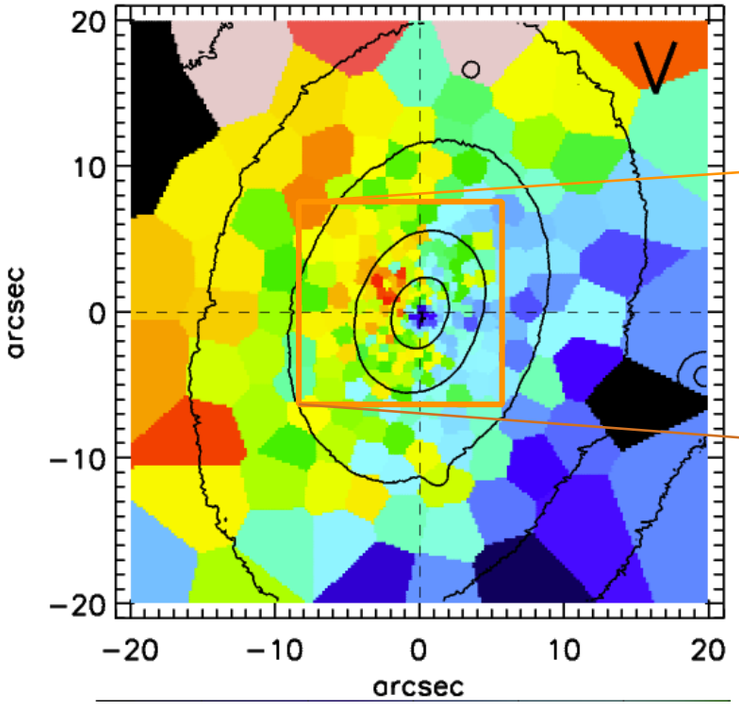


More detailed analysis
(SR/FR, masses, SFH, IMF, Emission lines)
will follow

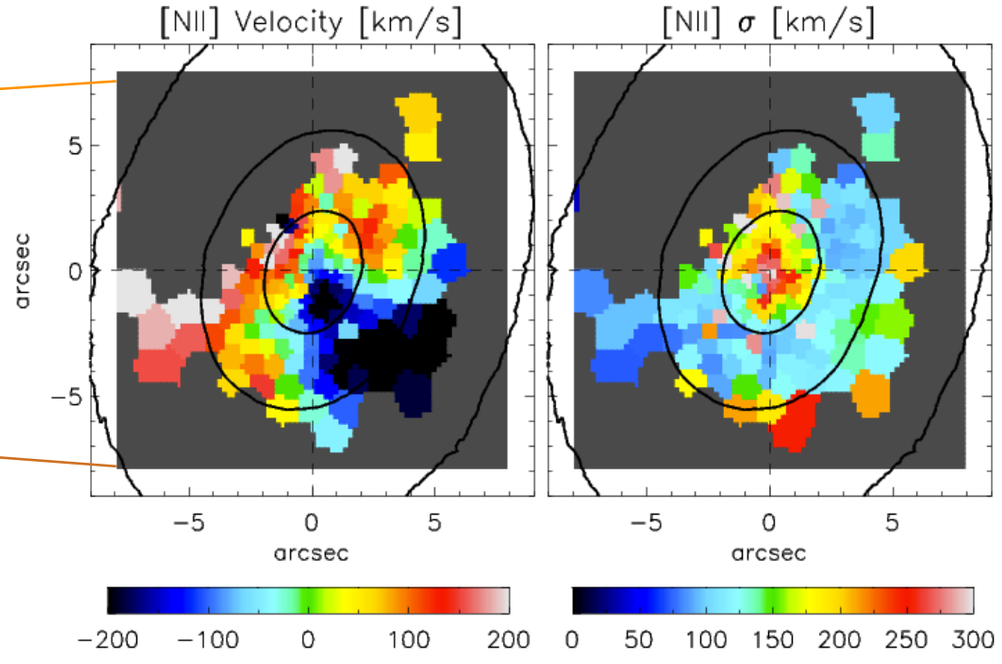
Prolate	KDC	no-rotation	regular
3	***2(3?)***	***2***	***1***

Preliminary (snapshot) Results





Two emission-line systems detected so far



MUSE emission-line kinematics

- Zoo of λ profiles – the zoo is preserved, need for the big picture
- In-situ vs Ex-situ?

- **Above log10[M] of 11.5** → Slow Rotators : galaxy assembly?
- BCGs are big – (**stellar**) halos are tough to probe

The  project

- Most massive galaxies in densest environments (at low z)
  [see Loubser et al. 2008, 2009,2011,2012; Brough et al. 2011, Jimmy et al. 2013, Ma et al. 2014, ...]
- Kinematics + Stellar pops between 1 and 3 Re
- Comparison with simulations [prolateness?]
- Observations ~15% complete – stay tuned
  + Ancillary data (e.g., deep imaging)

MUSE MUSE MUSE MUSE

An ESO Workshop on:

23–27 February 2015
ESO HQ, Garching, Germany

Baryons at low densities:
The stellar halos around galaxies

Main science topics include:

• What is a stellar halo? • Physical properties of stellar halo tracers from across the Universe •
• Kinematics and dynamical evolution of stellar halos • Origin and assembly of stellar halos •

Contact: stellarhalos2015@eso.org
http://www.eso.org/sci/meetings/2015/StellarHalos2015.html

Registration deadline: 20 January 2015

SOC:
- Magda Arnaboldi (co-Chair, ESO, Germany)
- Annette Ferguson (Edinburgh University, UK)
- Laura Ferrarese (NRC, Canada)
- Ortwin Gerhard (MPE, Germany)
- William E. Harris (McMaster Univ., Canada)
- Amina Helmi (Groningen University, The Netherlands)
- Guinevere Kauffmann (MPA, Germany)
- Christopher J. Mihos (Case Western Reserve Univ., USA)
- Marina Rejkuba (co-Chair, ESO, Germany)
- Patricia Tissera (Buenos Aires University, Argentina)

LOC:
- Maryam Arabsalmani
- Stella Chasiotis-Klingner
- Michael Hilker
- Emin Karabal
- Florian Niederhofer
- Martino Romaniello
- Elena Valenti (Chair)

Sombrero Galaxy: ESO/IDA/Danish 1.5 m/R. Gendler and J.-E. Ovaldsen; Omega Centauri: ESO/WFI/ VST/ OmegaCAM

Emsellem et al. (in prep)

multi unit spectroscopic explorer

1.4 10^6 spectra