M3G: the MUSE Most Massive Galaxies campaign

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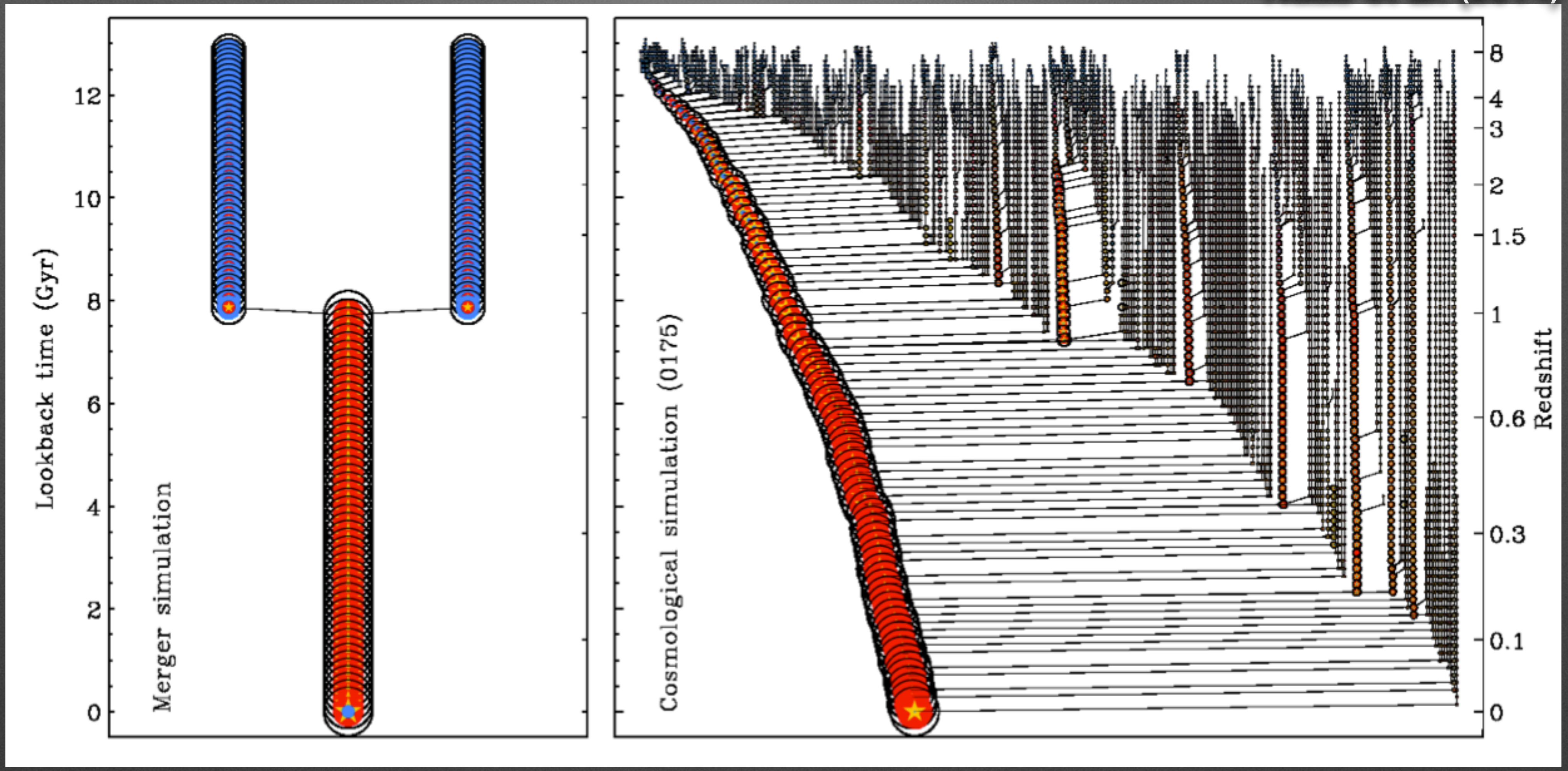
Motivation

Naab et al. (2014)

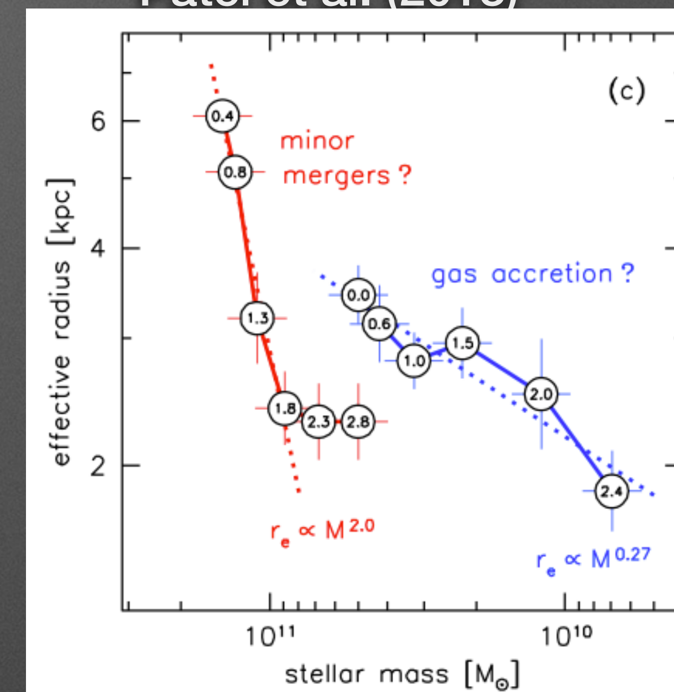


- Complex assembly history, with frequent minor merging and a few major events
- What determines a particular history: (dark halo) mass, environment, availability of baryons?
- Can we find evidence of past events by observing low-z (massive) systems?

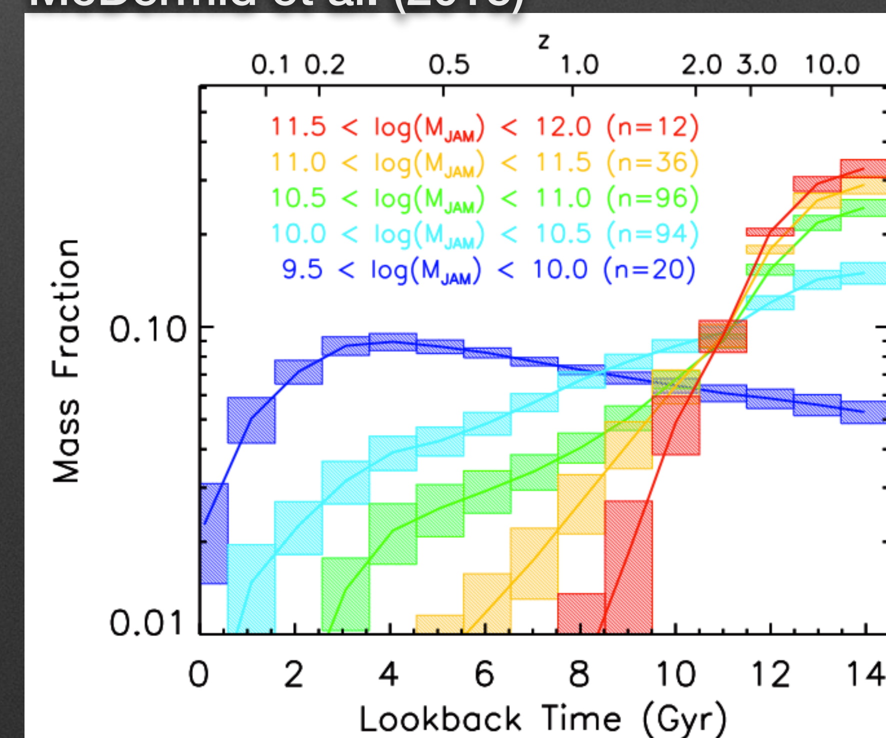
Formation of galaxies

- Low and high mass galaxies show different evolution (e.g. Bezanson et al. 2009; Patel et al. 2013, van Dokkum et al. 2013)
- Observations: low mass (contrary to high mass):
  - structure evolves less
  - 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) - formation of stars (in-situ)
  - extended later phase (z<3) - accretion of (ex-situ) stars

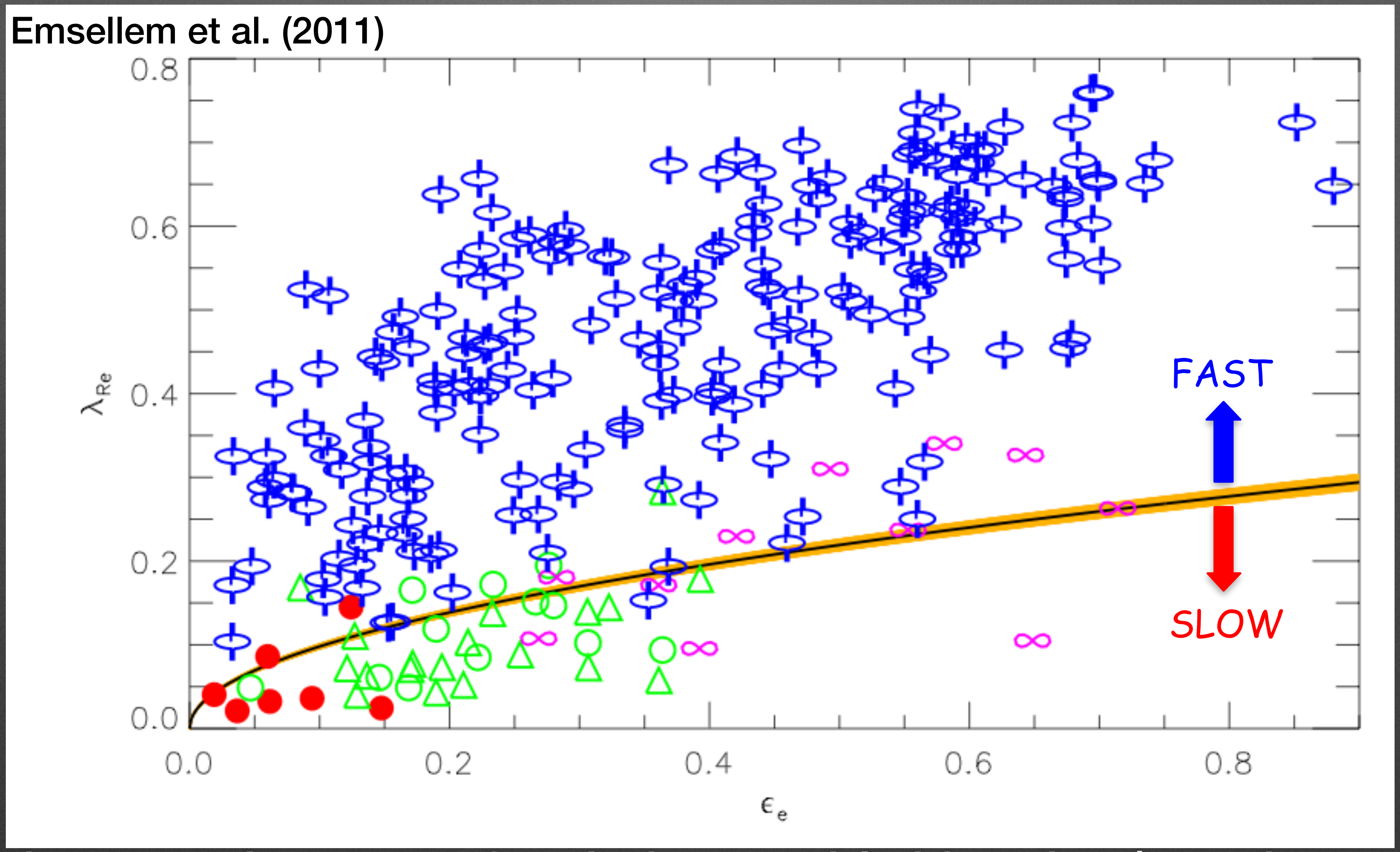
van Dokkum et al. (2013);
Patel et al. (2013)



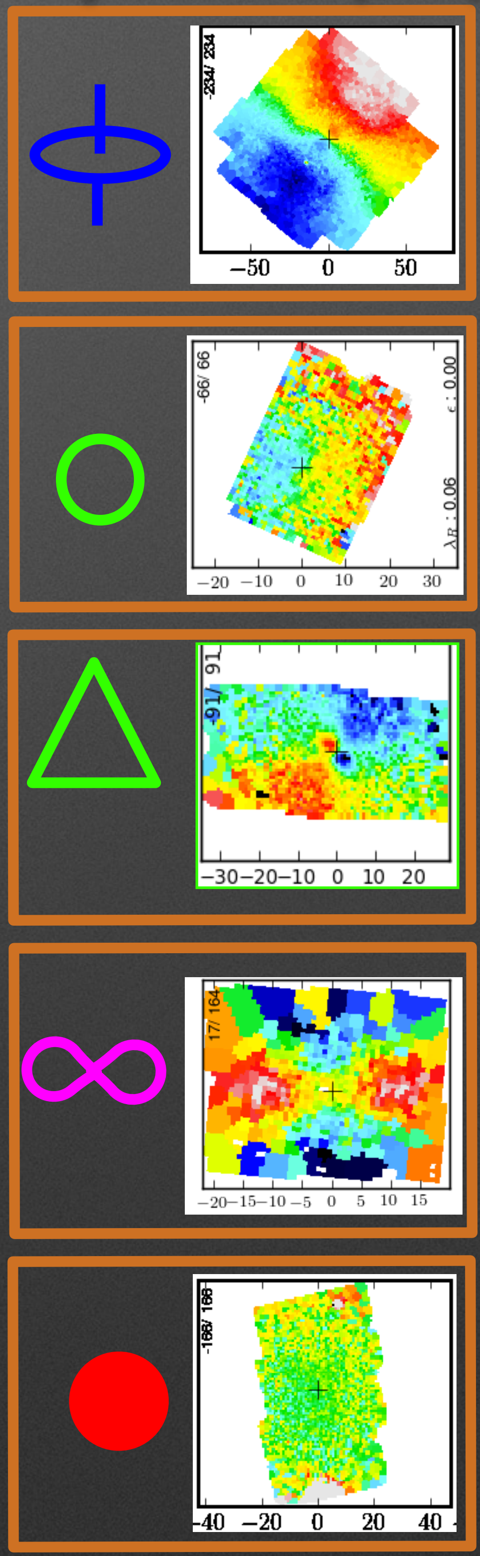
McDermid et al. (2015)



Angular momentum and kinematic structure

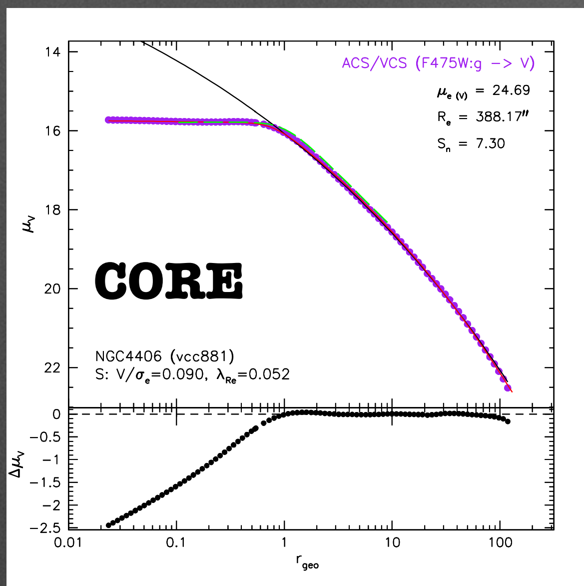


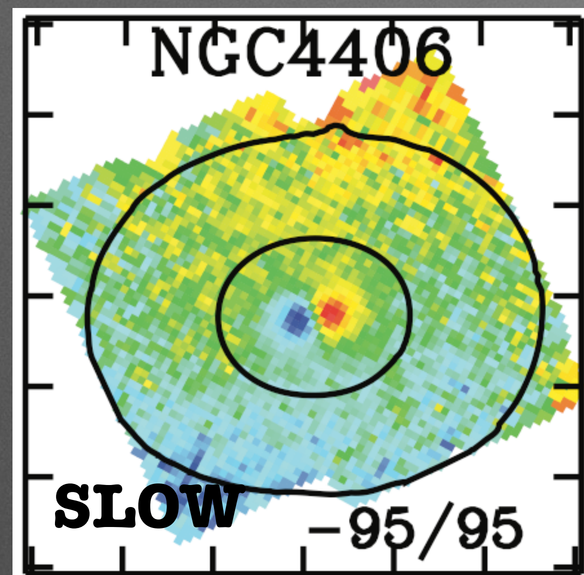
Krajnović et al. (2011)

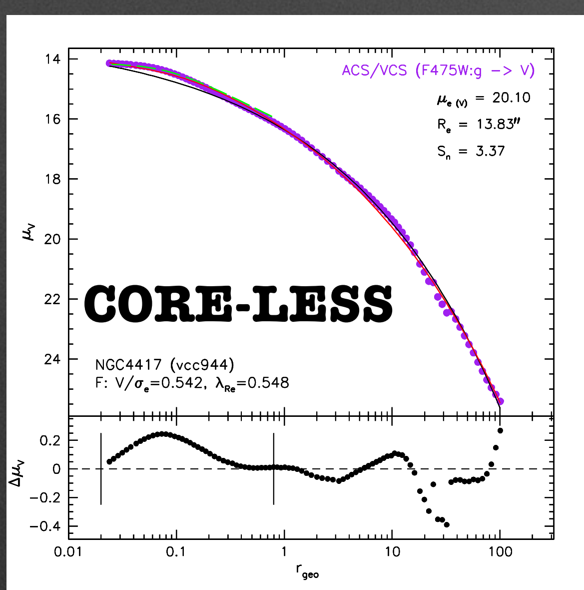


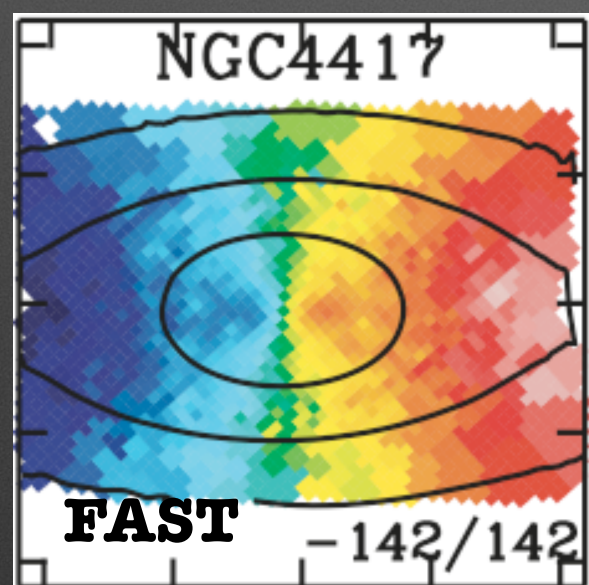
- kinematics as a signature of varied assembly histories (e.g. de Zeeuw & Franx 1991)
- two general types of velocity maps: with regular (disc-like) and irregular rotations (Krajnović et al. 2008, 2011)
- fast and slow rotators (Emsellem et al. 2007, 2011)

Kinematics and light profiles

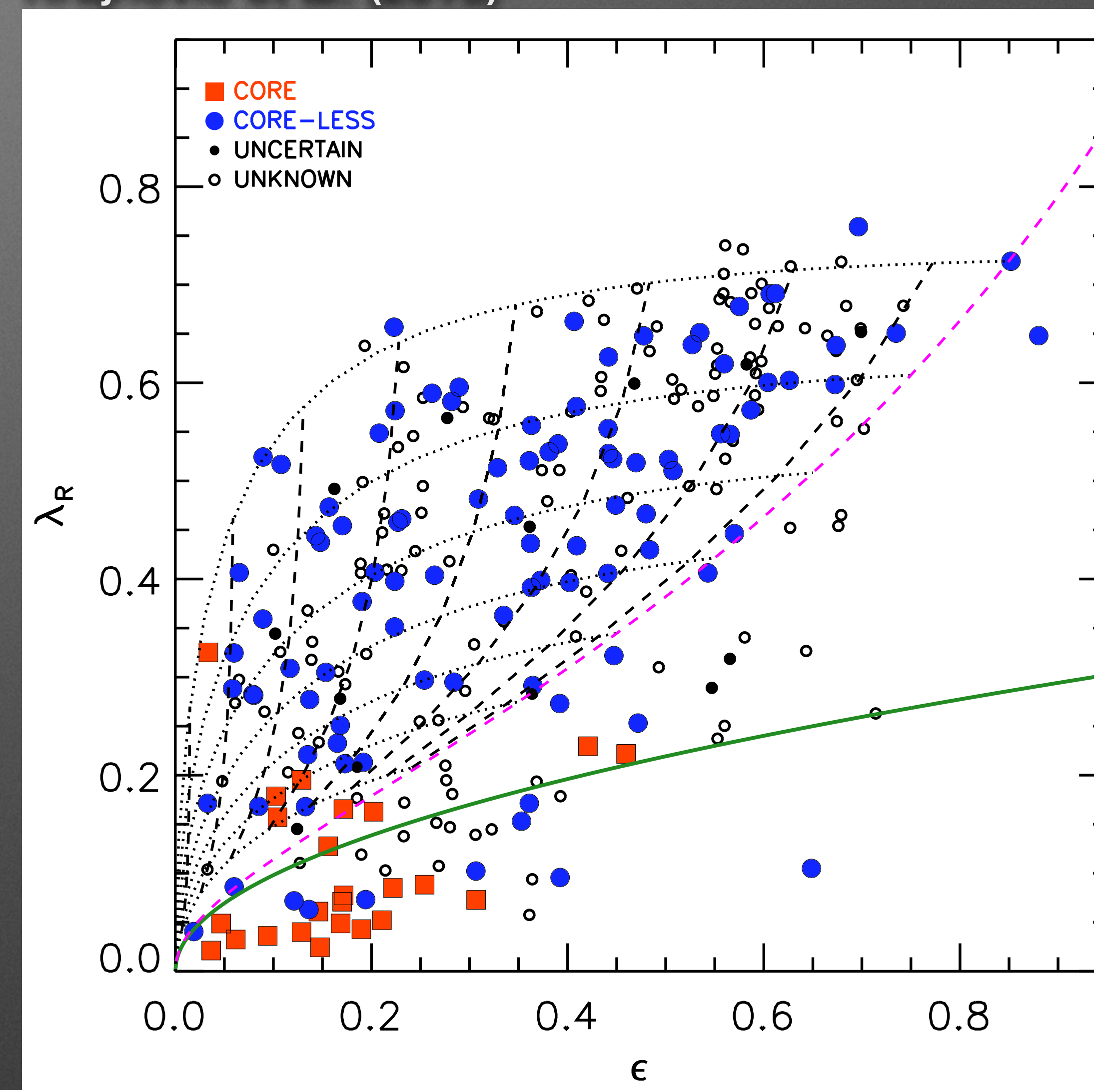








Krajnović et al. (2013)

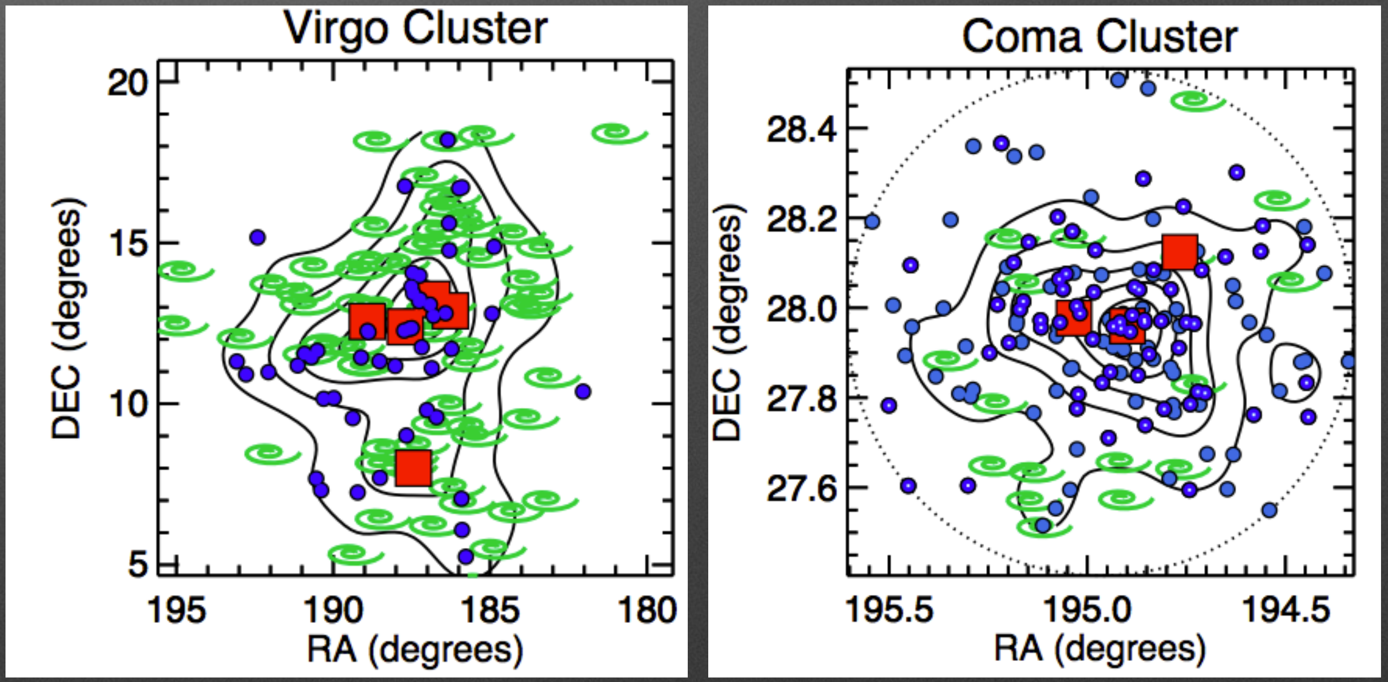


- core galaxies are typically Slow Rotators, but not all (additional formation channels)
- most massive (lowest angular momentum) Slow Rotators have cores

Environment

- morphology density relations (Dressler et al. 1980)
- environmental quenching (Peng et al. 2010)
- Slow rotators (with cores) occupy the centre of dense environments
- distinct processes at work for transforming spirals into Fast Rotators and Fast Rotators into Slow Rotators (especially into BCGs)

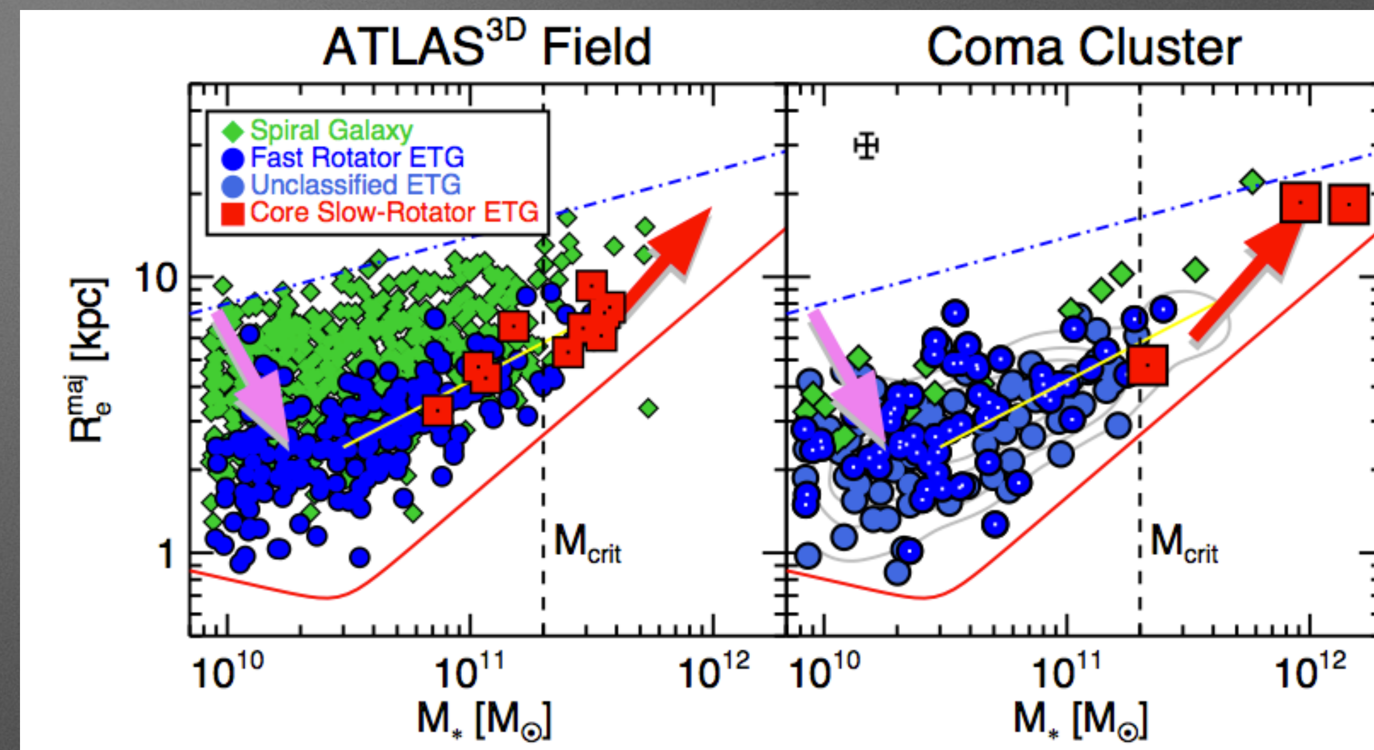
Cappellari et al. (2011); Cappellari (2013)

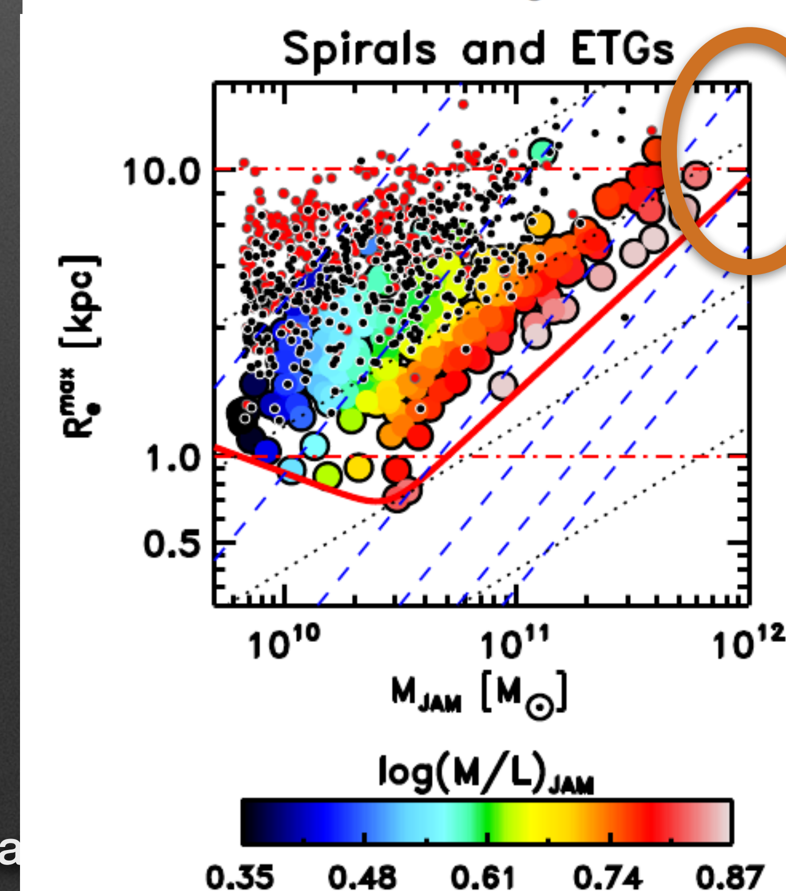


Mass and size

- massive slow rotators (with cores) **segregated** from other galaxies **in mass, size and by location** in centres of clusters

- **what happens for $M>10^{12}M_{sun}$?**
- **what are properties of stellar kinematics and populations in galaxies beyond that mass?**



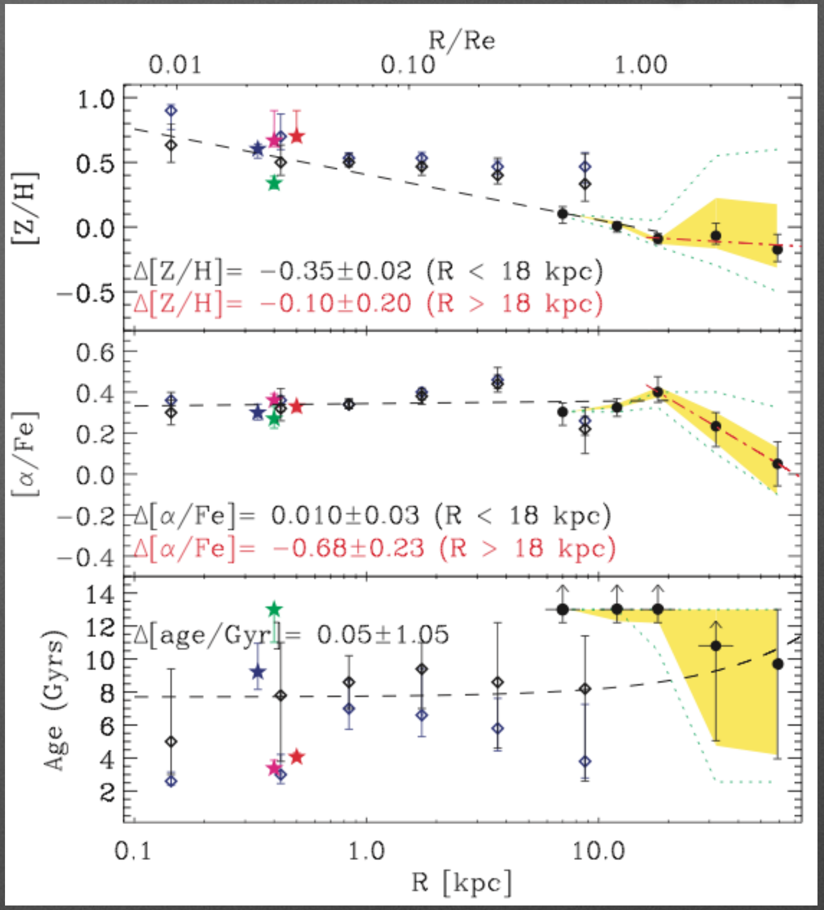


Cappellari et al. (2013); Cappellari (2013)

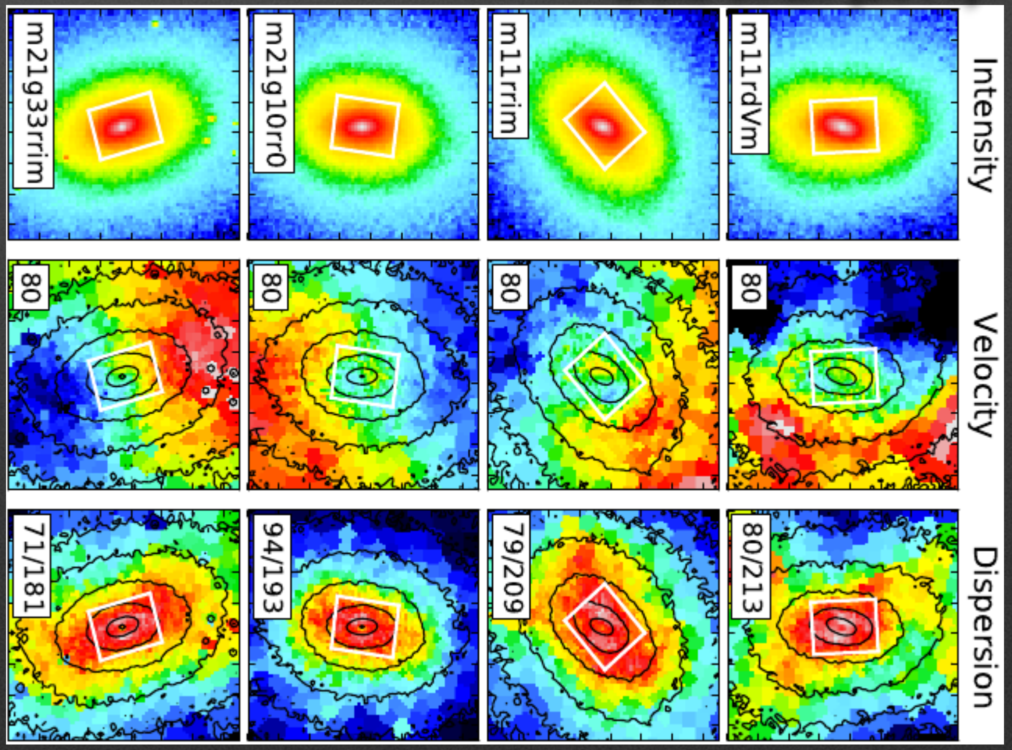
M3G Project

- a MUSE GTO programme
- PI Eric Emsellem; Davor Krajnović, Adrien Guérou, Roland Bacon, Jarle Brinchmann, Marcella Carollo & MUSE GTO Team
- Goals:
    - constrain the stellar content and dynamics of the most massive galaxies in densest environments
    - radial variation of angular momentum and stellar populations (to 2 effective radii)
    - infer dark matter content, 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)…

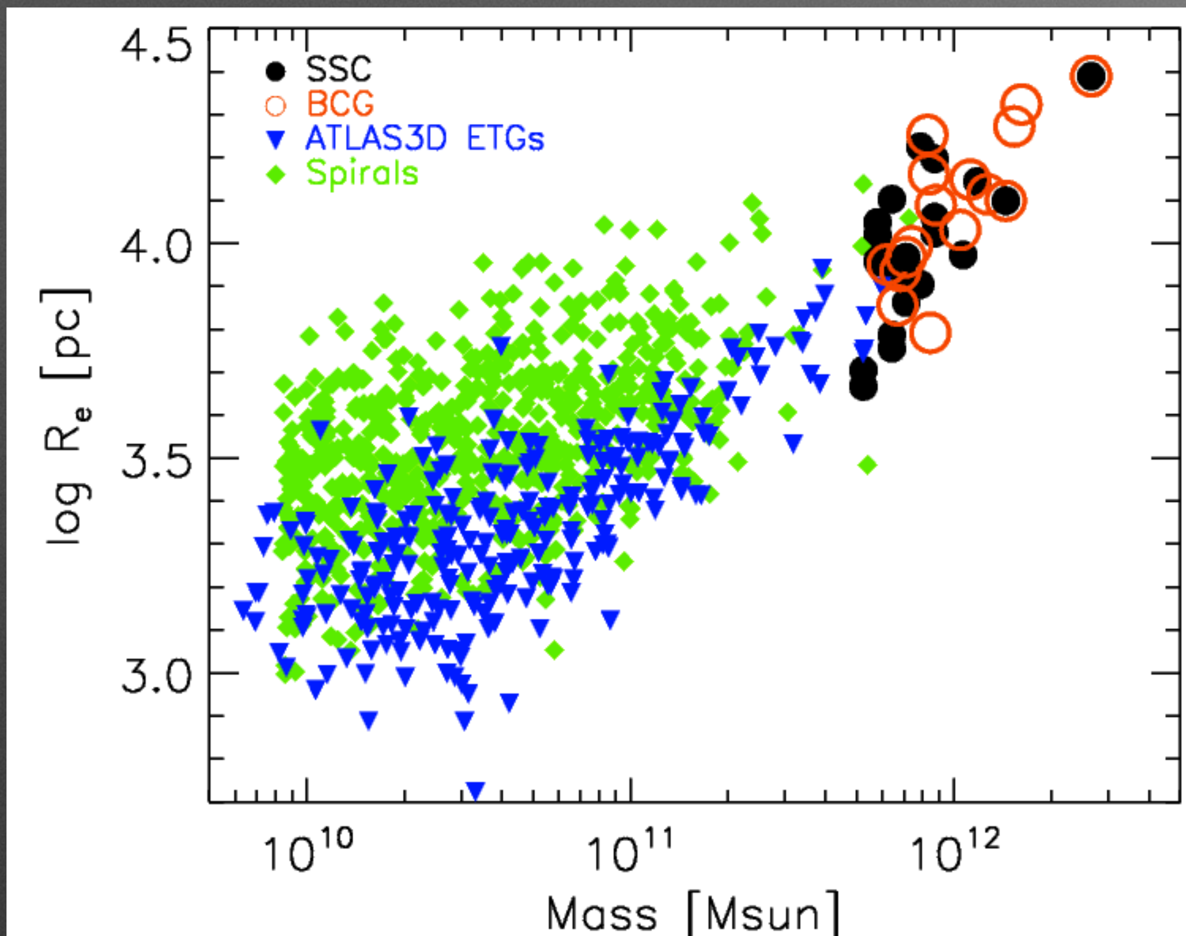
Coccato et al. (2010)

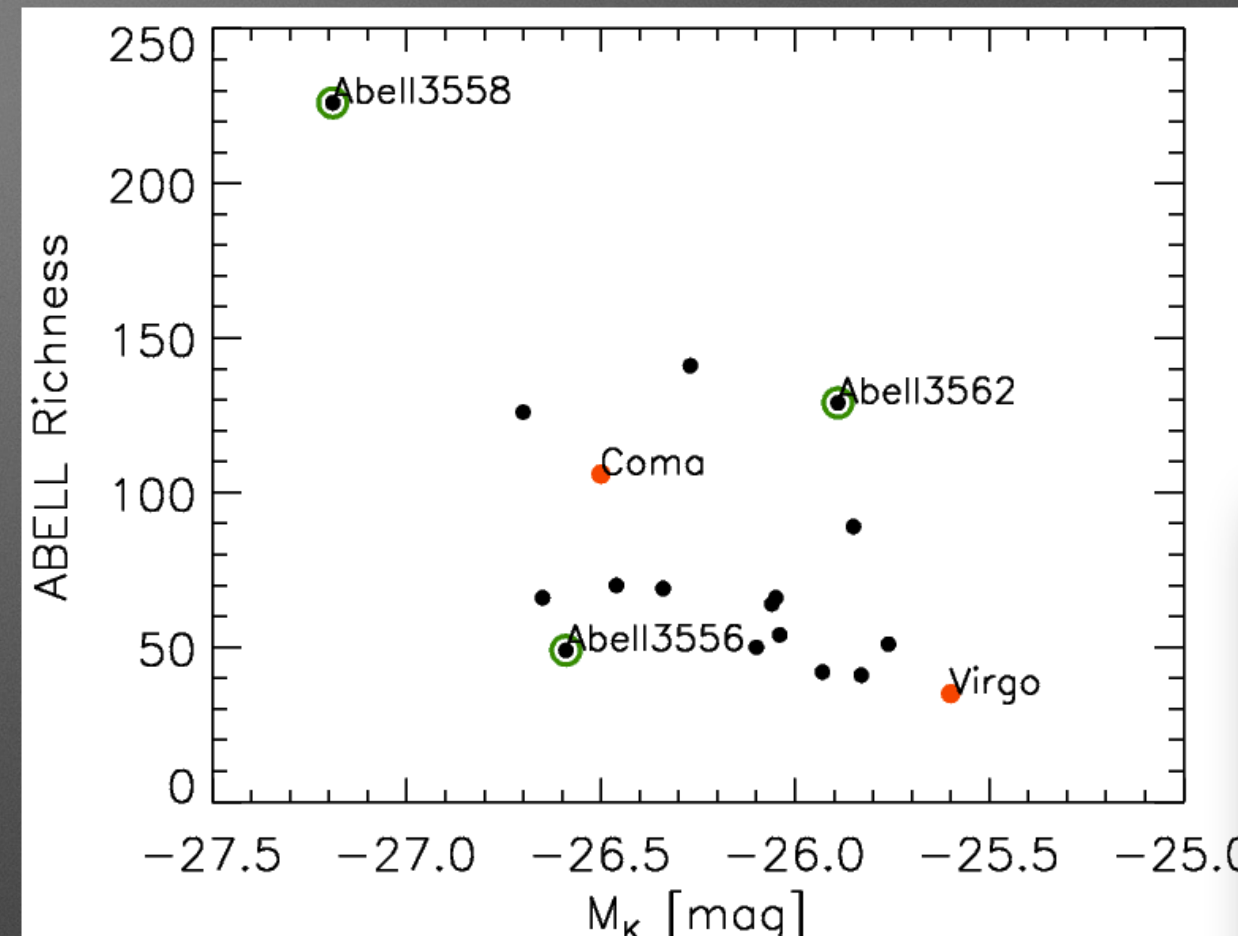


Bois et al. (2011)



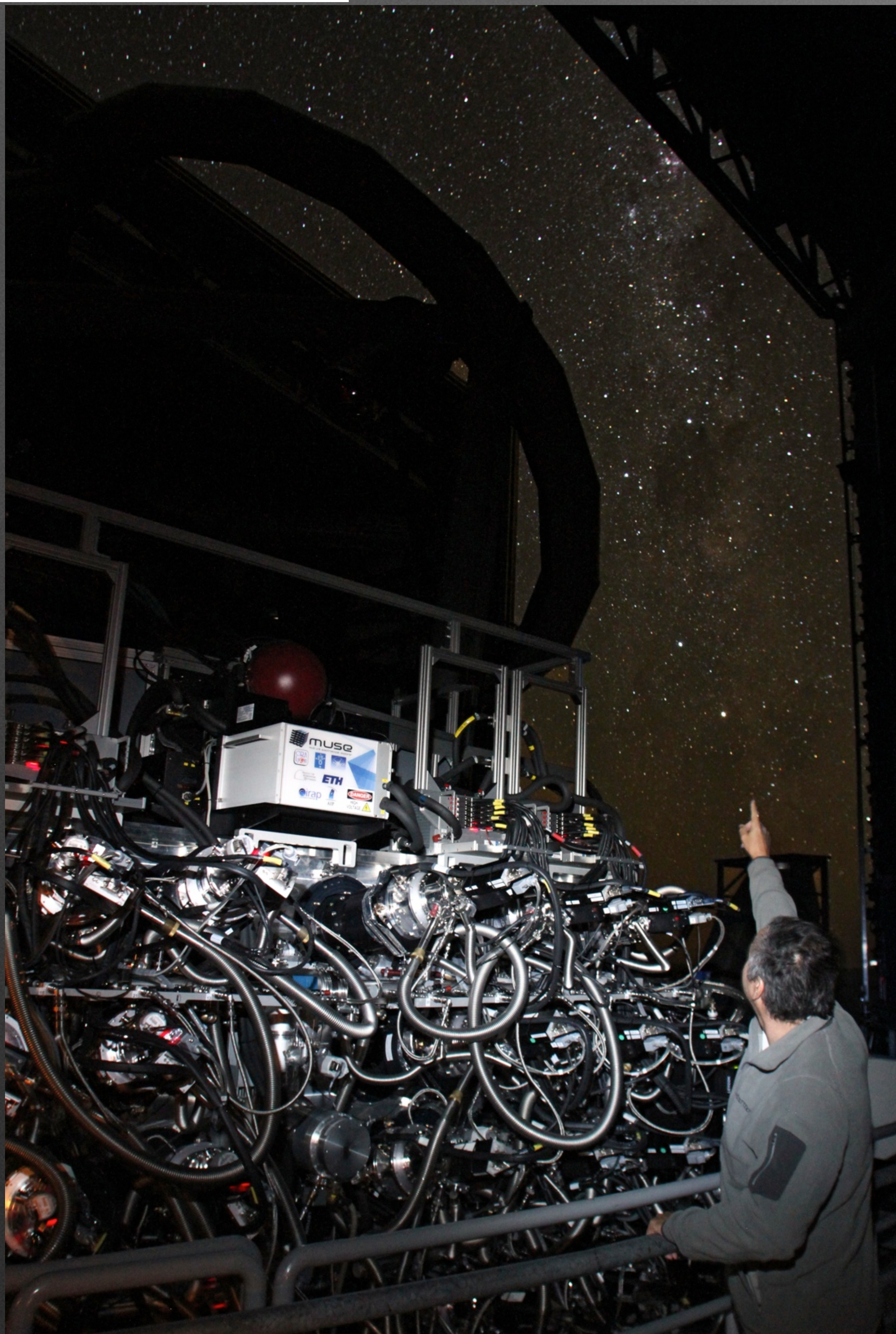
Sample





- galaxies not present nearby (42 Mpc probed by ATLAS^{3D} survey) and clusters richer than Virgo Cluster
- two subsamples at z~0.04:
  - most massive galaxies in Shapley Super Cluster (brighter than -25.7 mag) and BCGs in rich clusters (richness of clusters)

Observing with MUSE

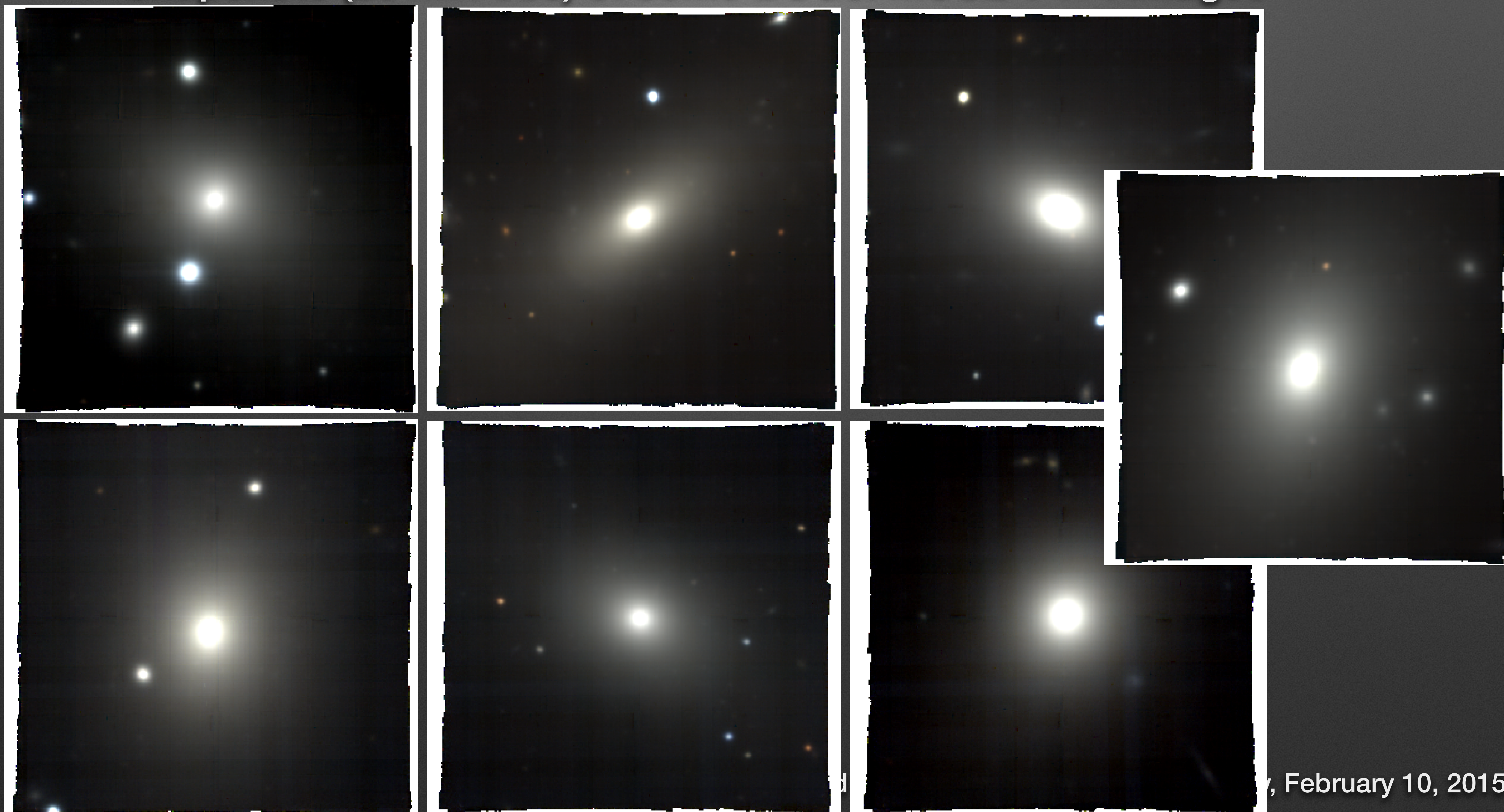


- Panoramic integral field unit on VLT
- 1x1 arcmin^2 Field of view in Wide Field Mode (WFM)
  - 7x7 arcsec^2 in NFM
- 0.2 arcsec sampling in WFM
  - 0.025 arcsec in NFM
- High image quality
- 4650-9300 A simultaneous wavelength range
- R = 1500-3500
- ~90000 spectra
- End-to-end throughput 0.35
- Advanced data reduction pipeline

- Two fold observing strategy:
  - Snapshot - good seeing (<0.8) ~ 20-30min [presented here]
  - Deep exposures: reach S/N of 30 at 2 Re

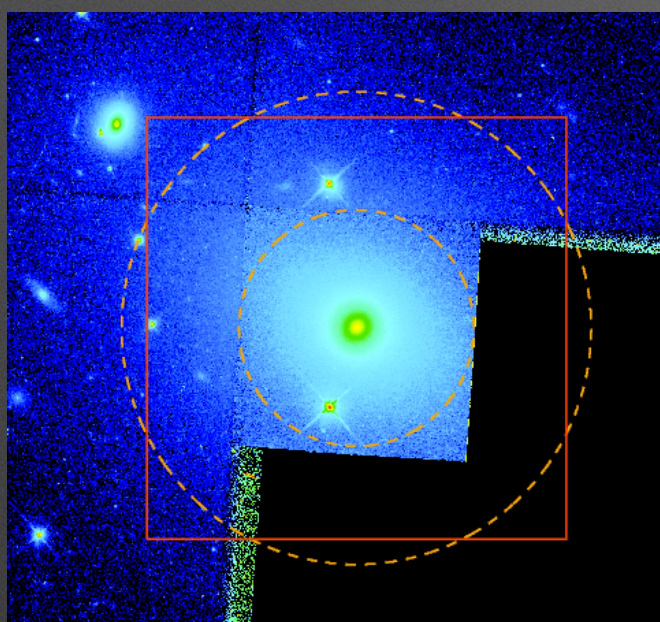
MUSE - images

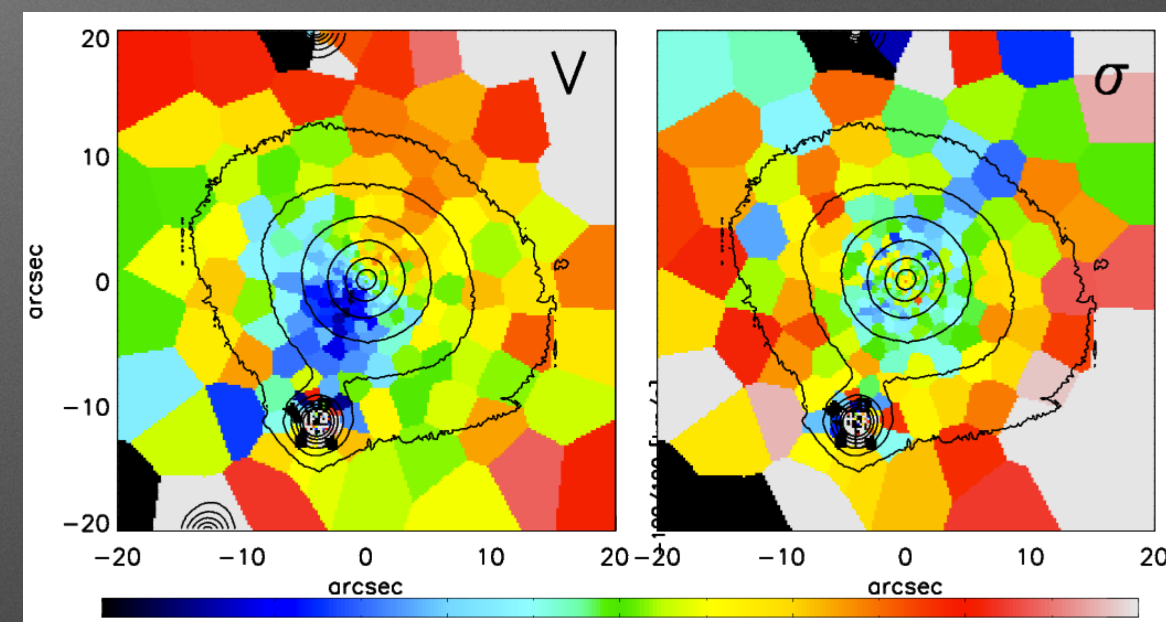
- 1st few GTO runs (shared with other GTO programmes)
- Snapshots (20 min obs) of some BCGs: MUSE V-R-I images

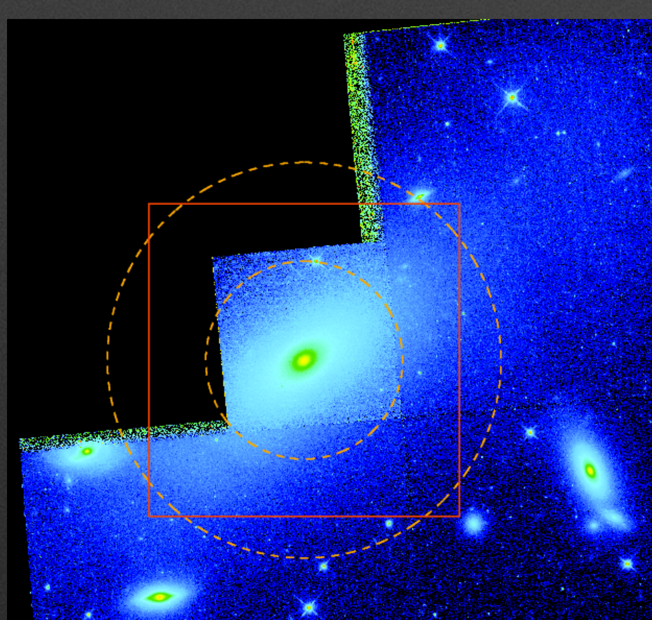


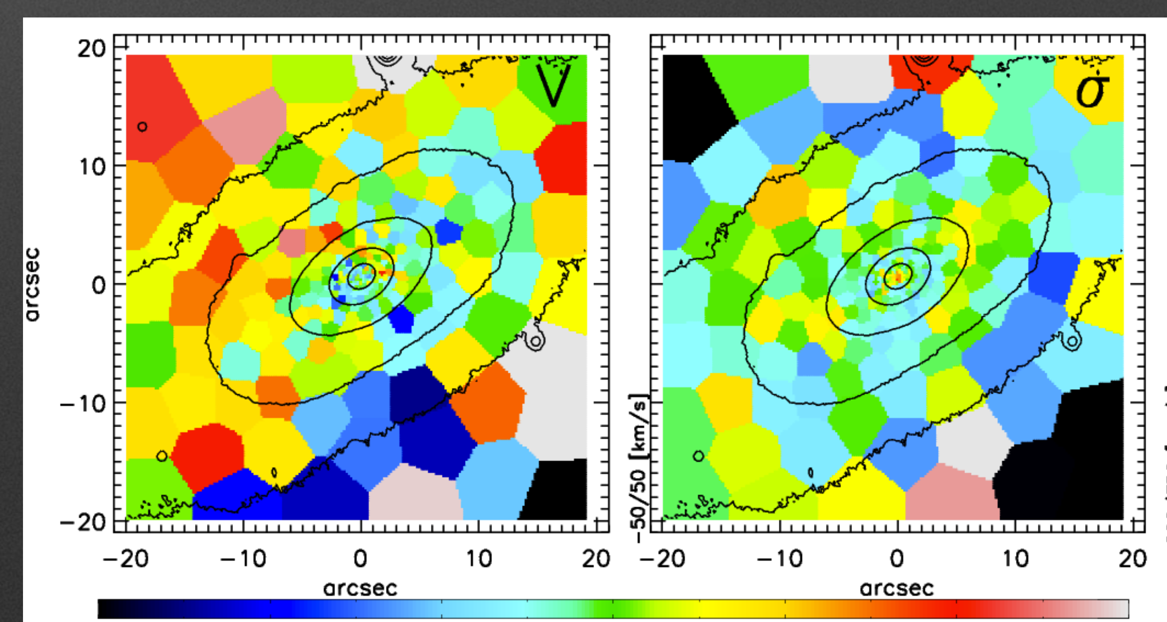
Results - kinematics

HST - WFPC2 | MUSE colour | Velocity | Velocity dispersion









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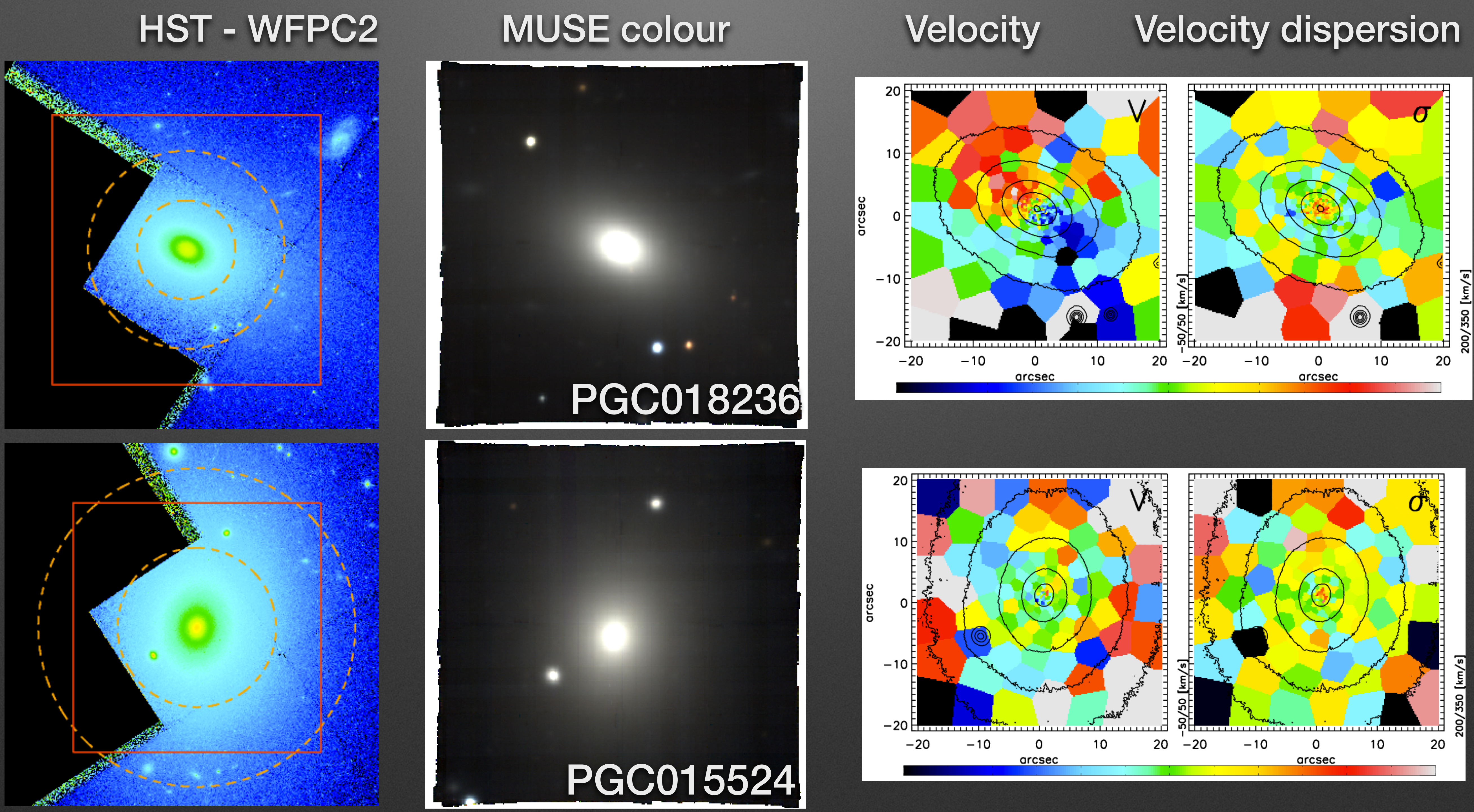

Results - kinematics

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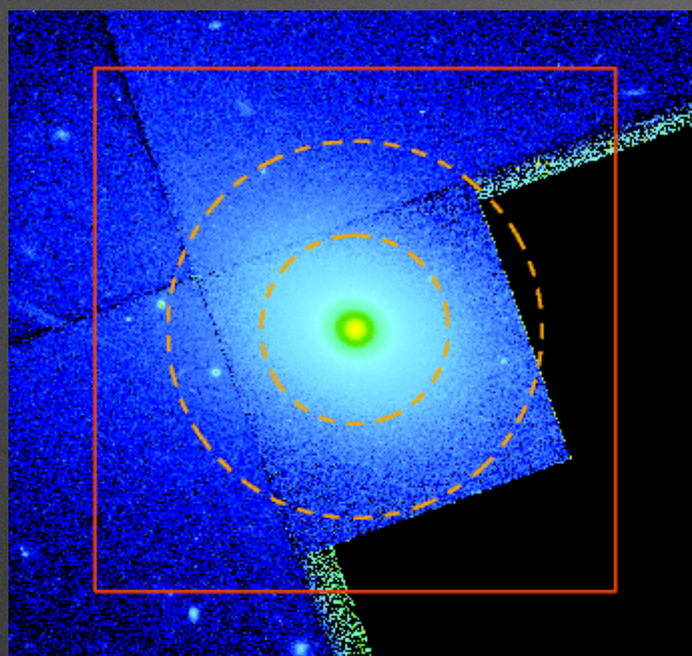

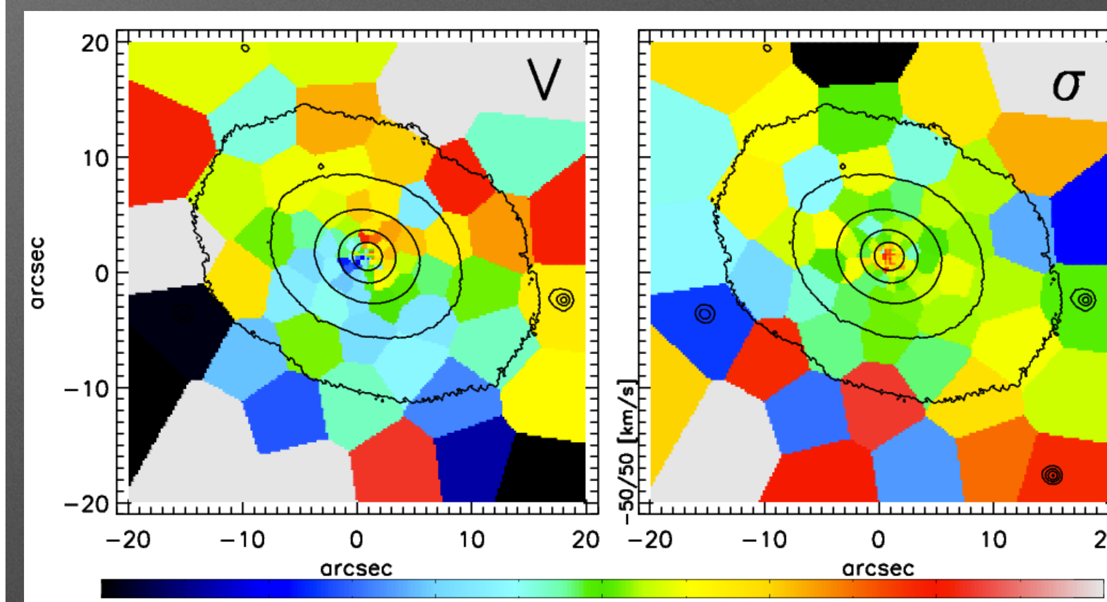

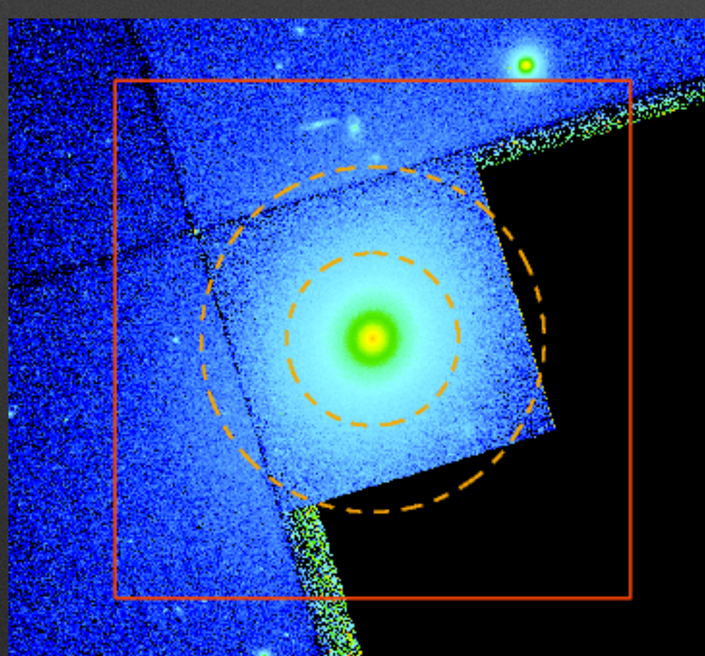

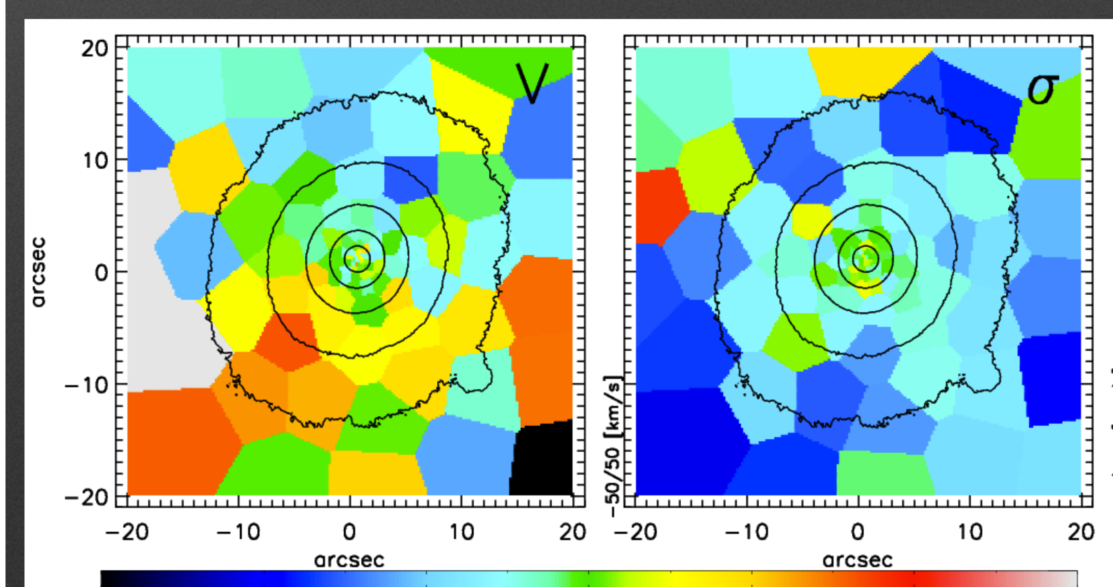

Results - kinematics

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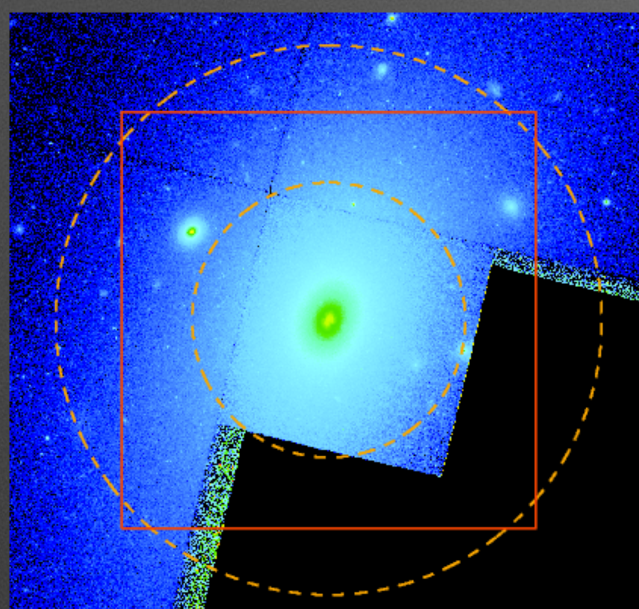
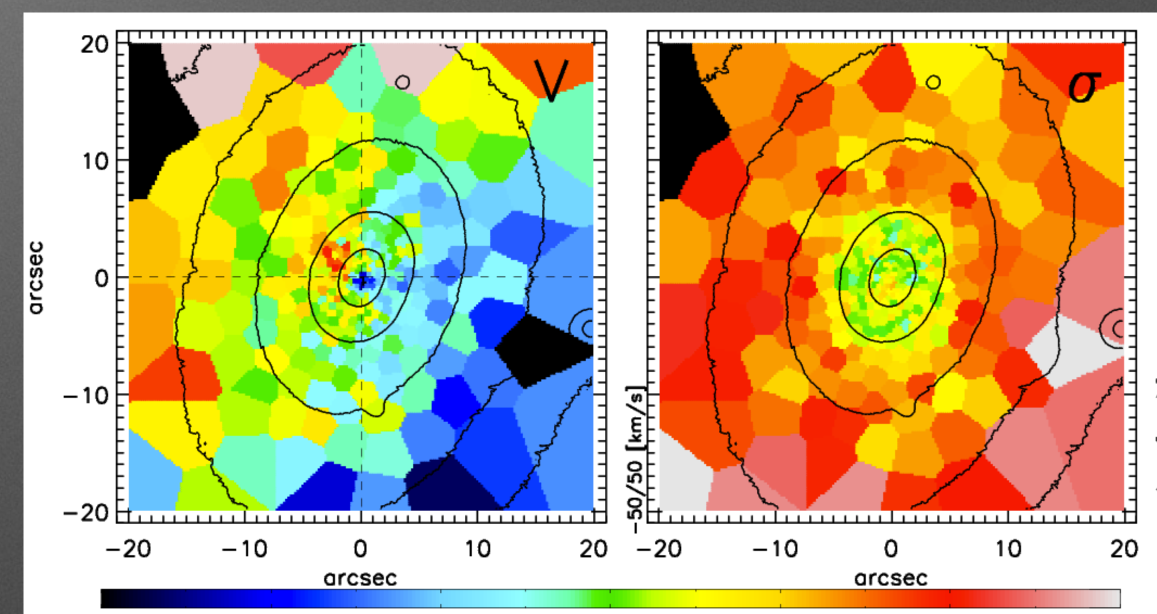
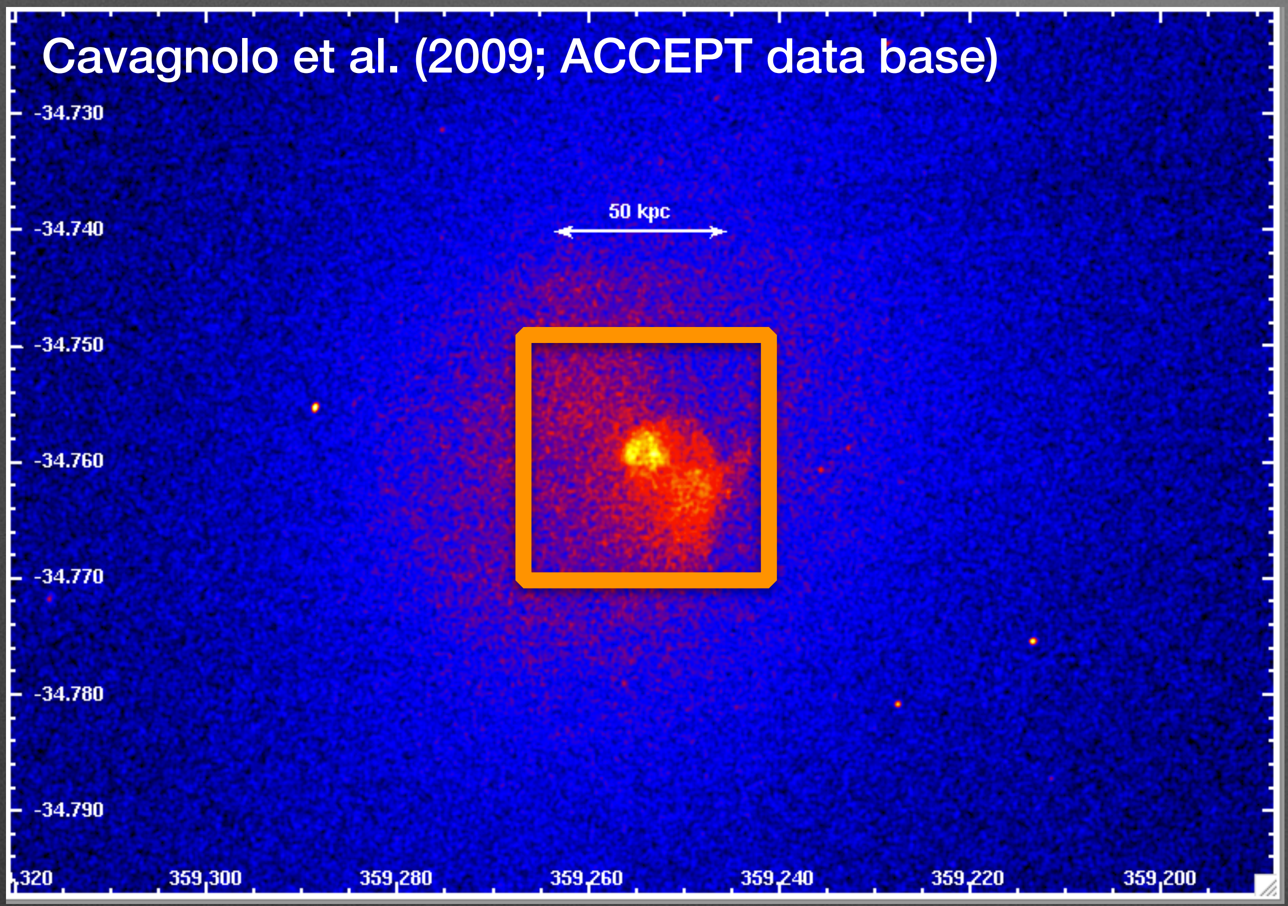


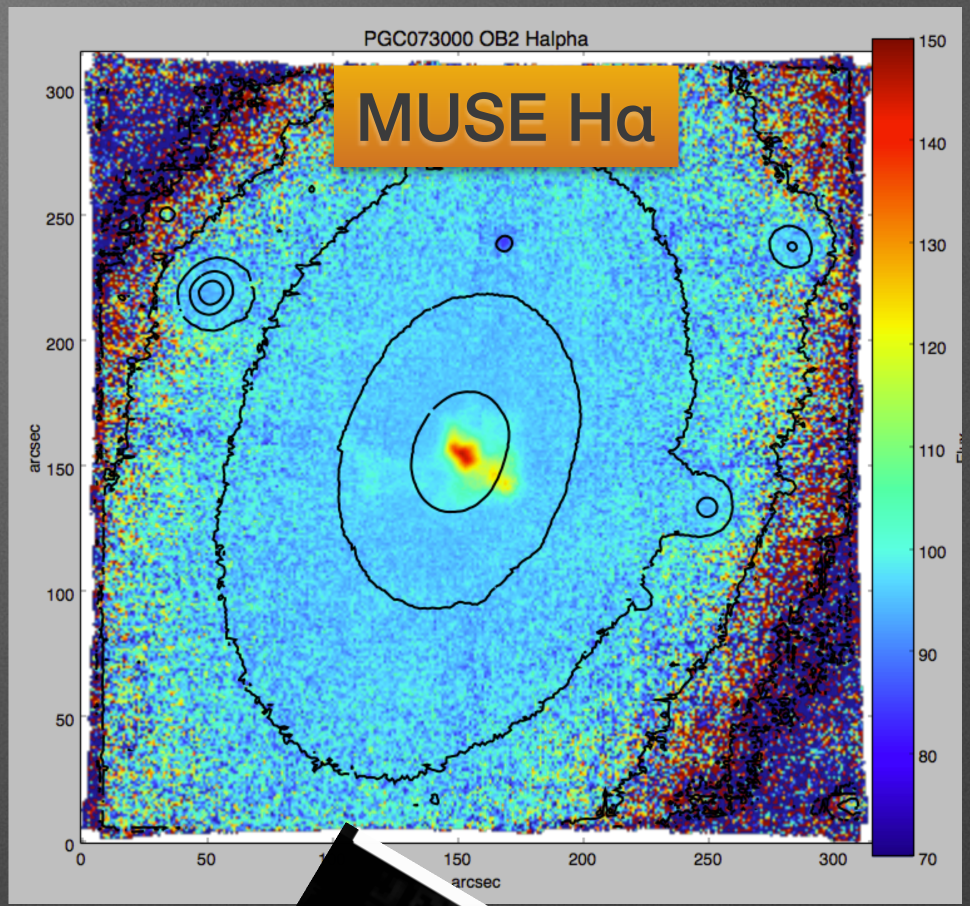


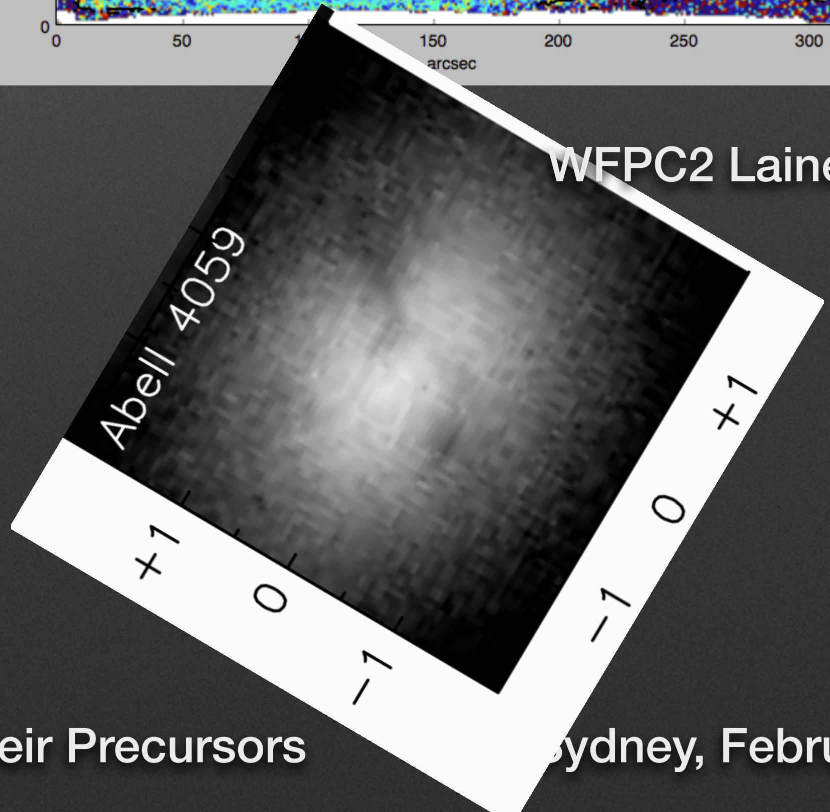
PROLATE	KDC	NO-ROTATION	REGULAR
3	2(3?)	2	1

- more detailed analysis (SR/FR, masses) will follow
- emission-lines?

A cooling flow cluster



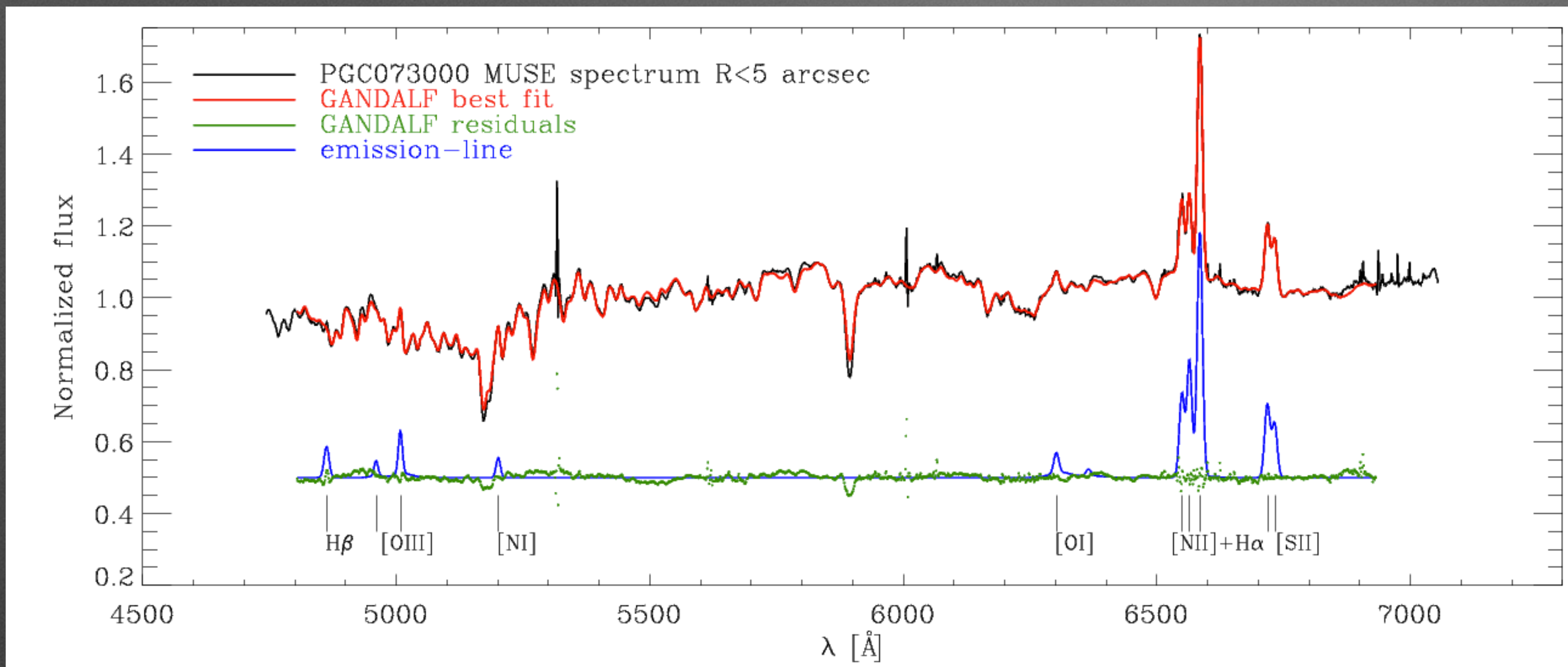


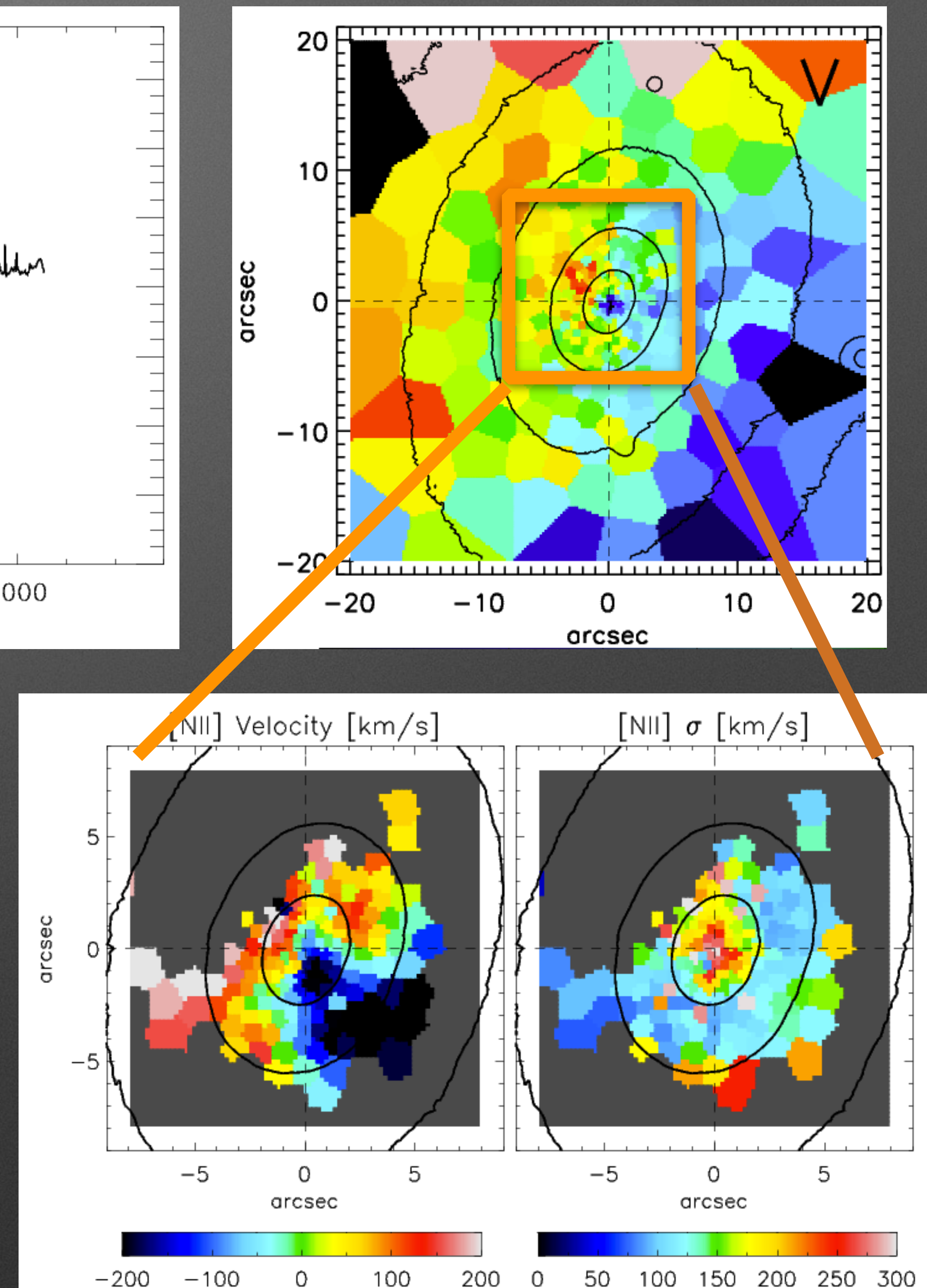


WFPC2 Laine et al. 2003)

- nuclear emission related to the cooling from hot halo gas

MUSE emission-line kinematics





- two systems detected (at the moment)
- (possibly) gas cooling from the hot halo gas
- central stellar velocity feature related to the ionised gas (in PGC073000 = ABELL4059)

Outlook

- addition to a number of interesting surveys (Loubser et al. 2008, 2009,2011,2012; Brough et al. 2011, Jimmy et al. 2013, Ma et al. 2014…)
  - focus on massive galaxies and densest environments at z~0.04
  - focus on resolved kinematics and stellar pops between 1 and 2 effective radii
  - importance of early gas rich mergers
  - probing late assembly (how late, up to z=0?)
  - AGN feedback, cooling flows, accretion of cool gas
  - comparison with simulations
- observations ~15% complete (more coming!!)
- gathering of ancillary data
- MUSE is an excellent instrument!