Kinematic morphology, and its relationship to local and global environment

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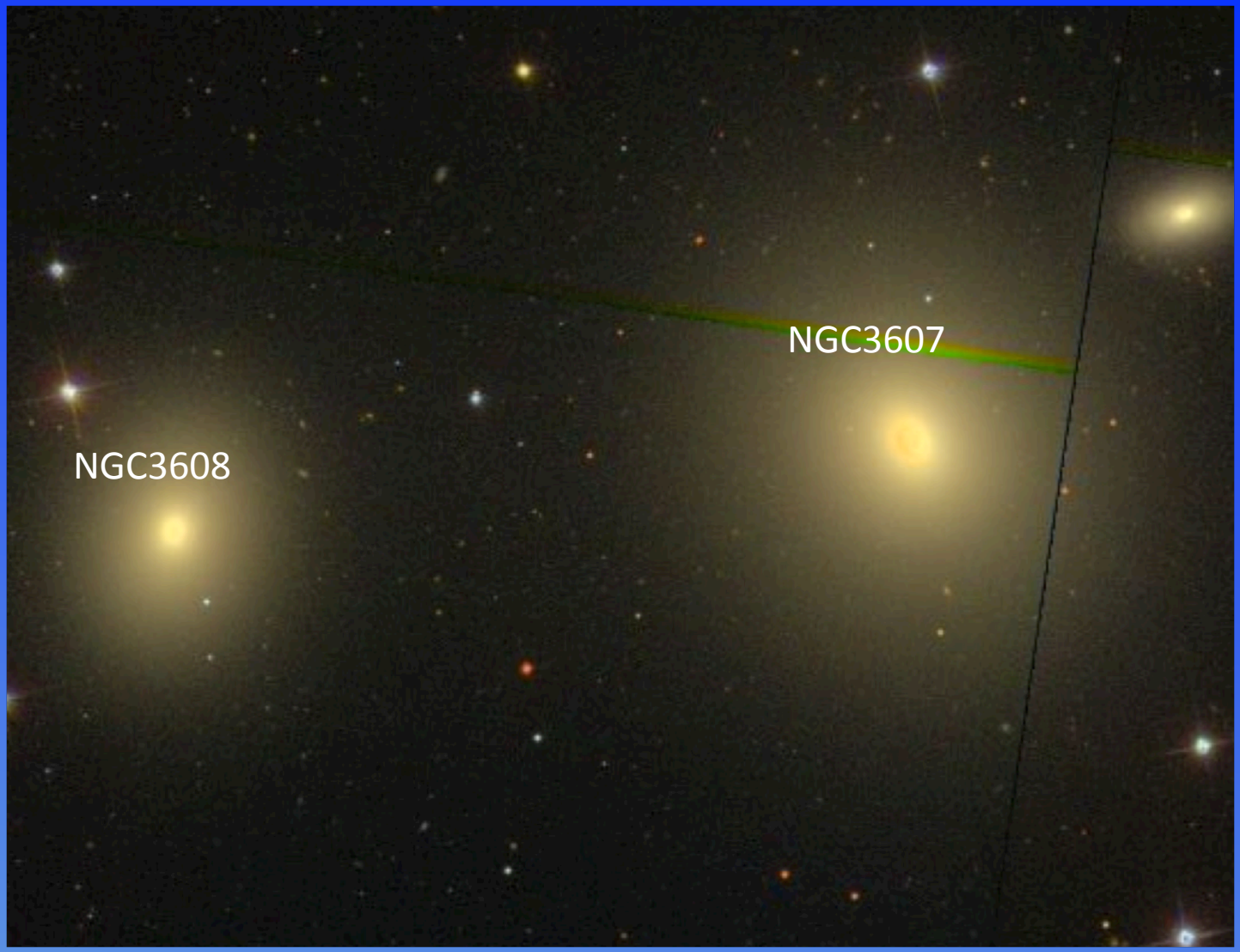
THE UNIVERSITY OF SYDNEY

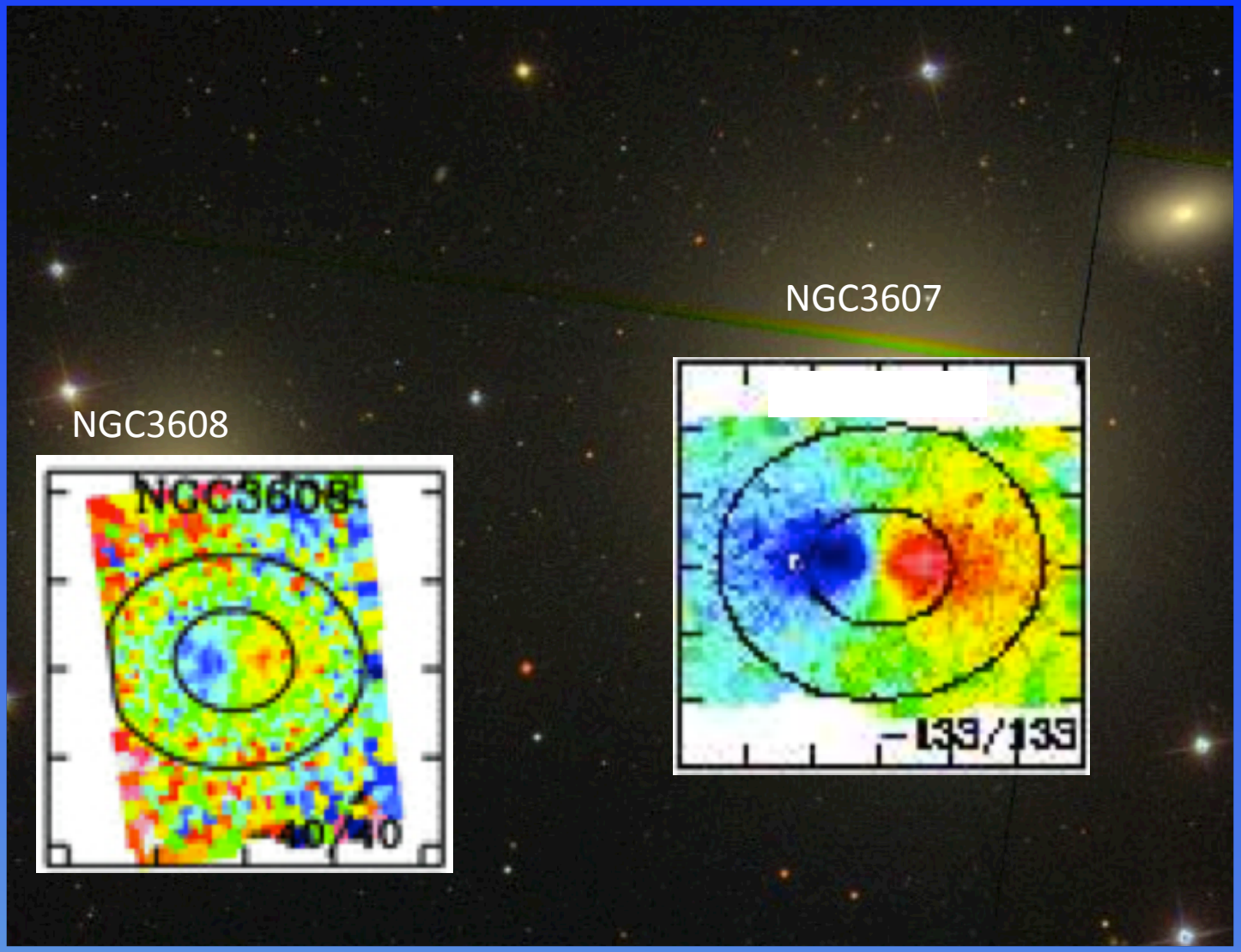
CAASTRO
ARC CENTRE OF EXCELLENCE FOR ALL-SKY ASTROPHYSICS

What is kinematic morphology?



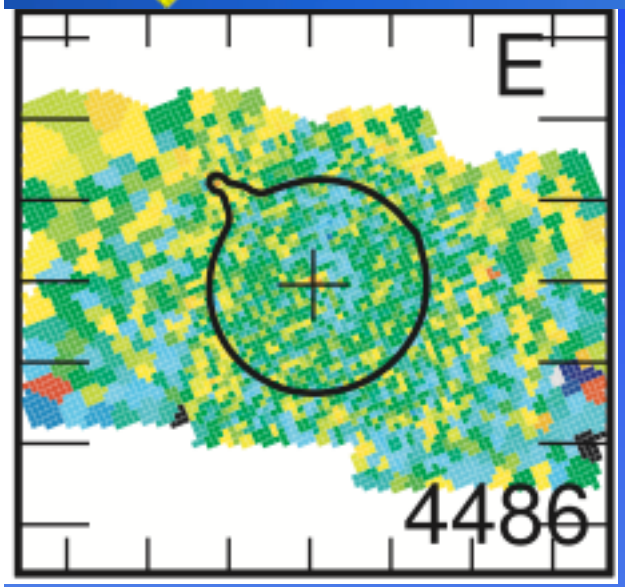
- Both galaxies have similar shapes, colours, Sersic n, etc.

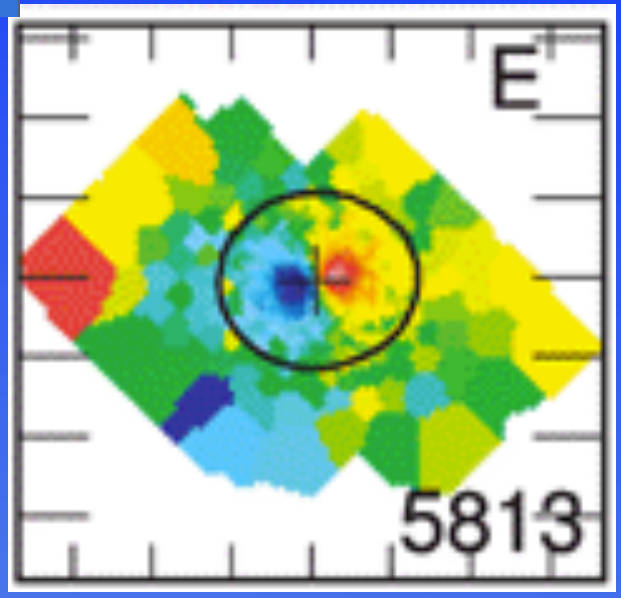
What is kinematic morphology?

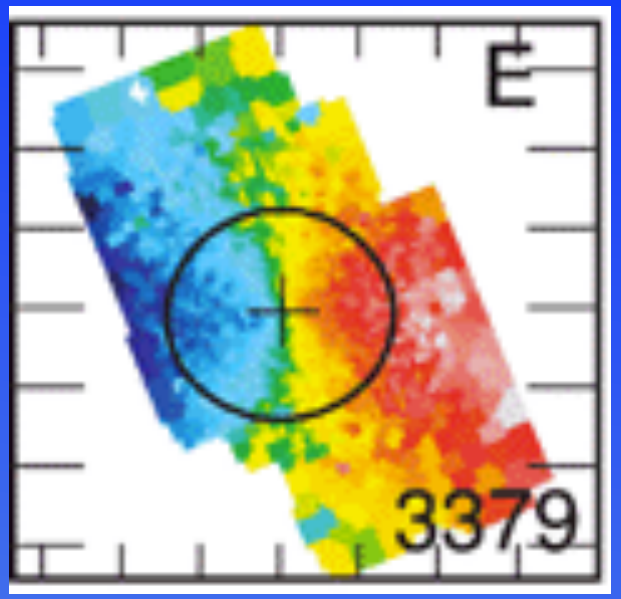


- Yet their kinematics look like this!

– a new kinematic classification for ETGs

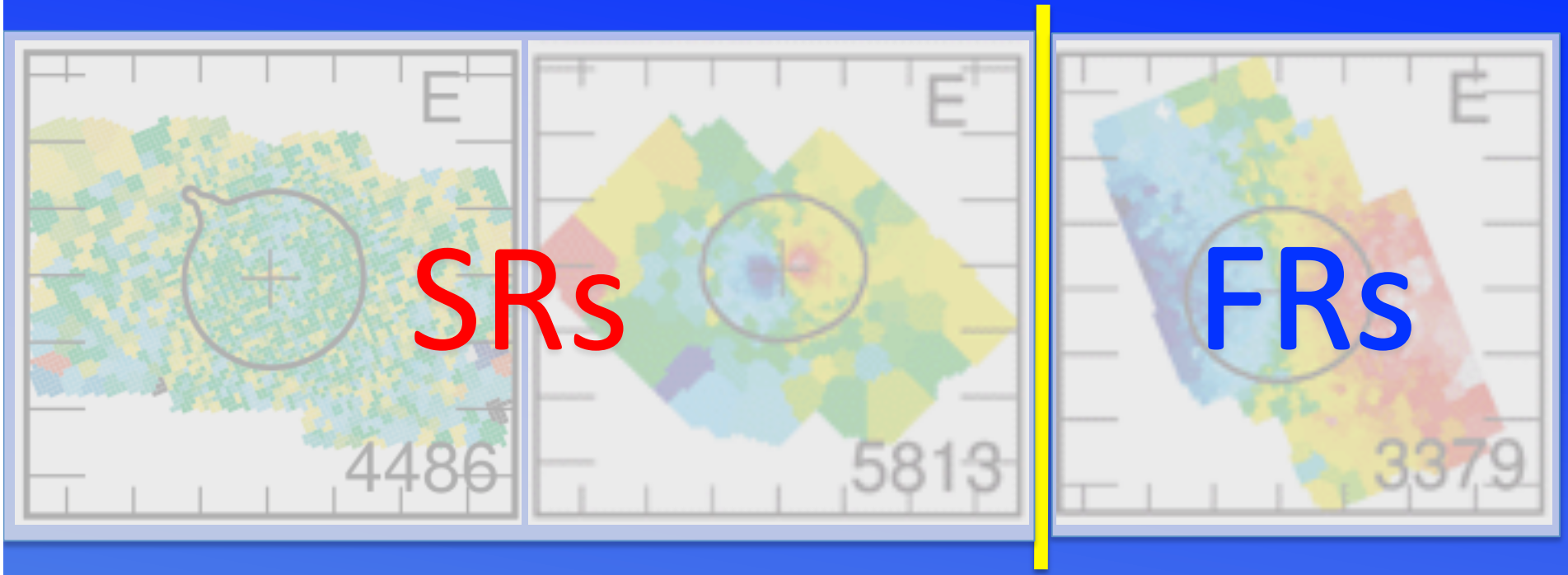






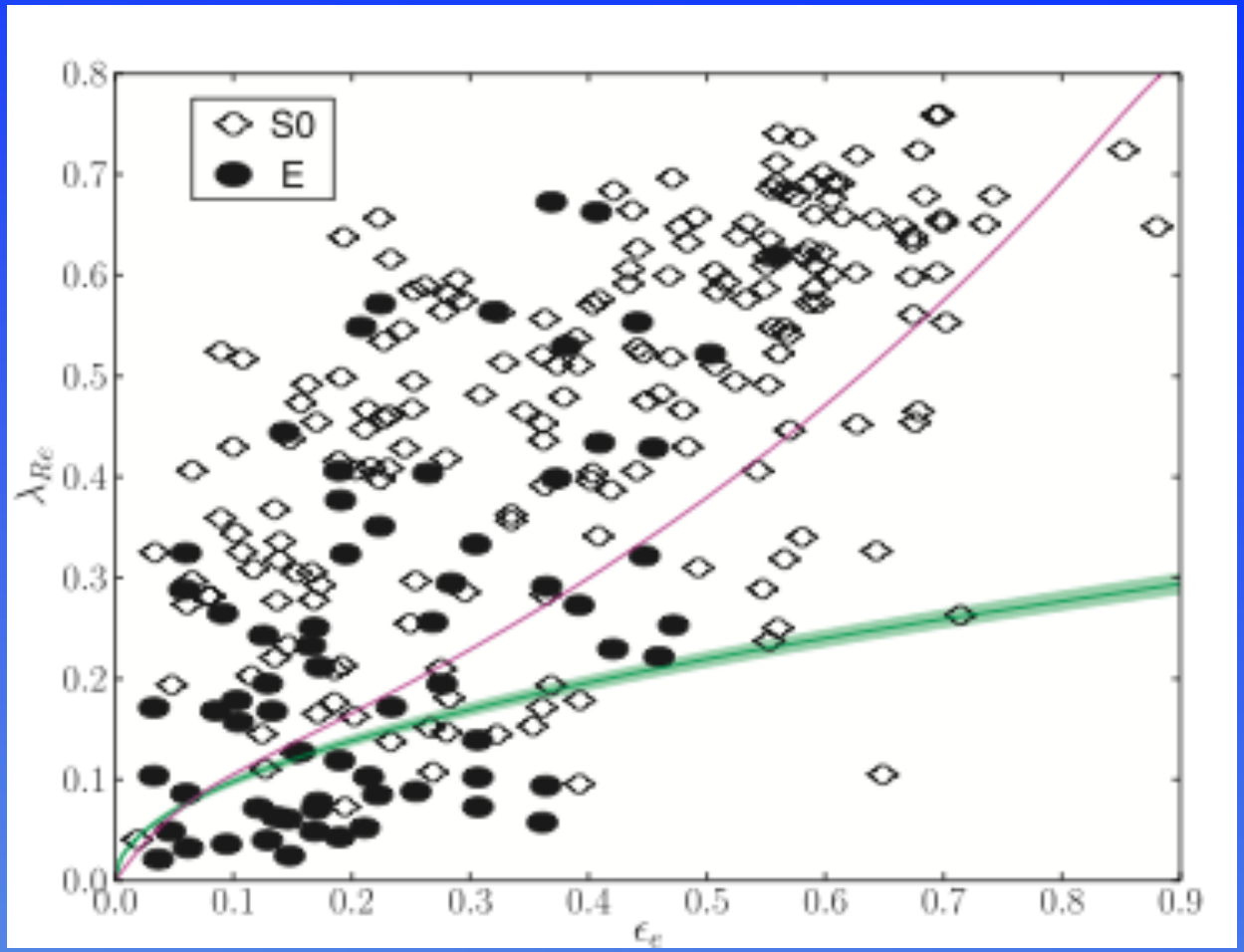
- SAURON survey (Emsellem et al. 2007, Cappellari et al. 2007) proposed a new kinematically-based classification system for ETGs
- Galaxies divided into Slow Rotators (SRs) and Fast Rotators (FRs) based on the morphology of their velocity maps and their specific stellar angular momentum, λ_R

SAURON – a new kinematic classification for ETGs



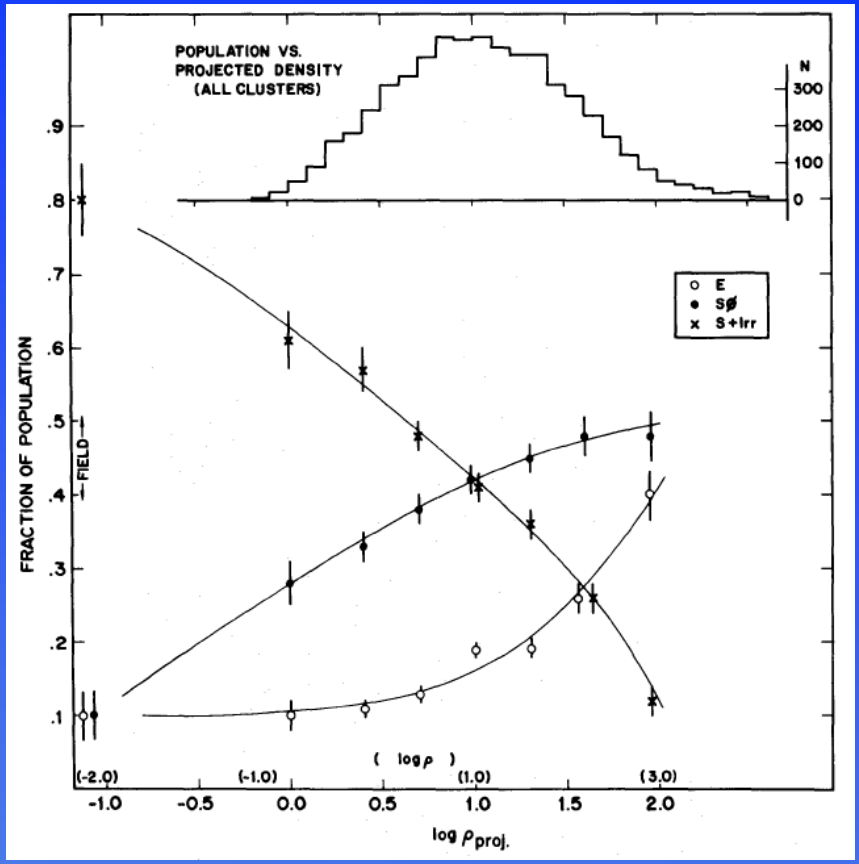
- SAURON survey (Emsellem et al. 2007, Cappellari et al. 2007) proposed a new kinematically-based classification system for ETGs
- Galaxies divided into Slow Rotators (SRs) and Fast Rotators (FRs) based on their specific stellar angular momentum, λ_R
- SRs are (typically): massive, boxy, round, contain KDCs or other kinematic structures, have X-ray halos
- FR/SR classification closely related to a galaxy's formation history

ATLAS^{3D} – a lack of 'true' ellipticals



- ATLAS^{3D} survey (Cappellari et al. 2011a) extended SAURON classification to a volume-limited sample of galaxies (Krajnović et al. 2011, Emsellem et al. 2011)
- Found a dearth of SRs (traditional 'ellipticals') – only 3.6% of all galaxies are SRs ('morphological' ellipticals are twice as common at 8% of all galaxies)

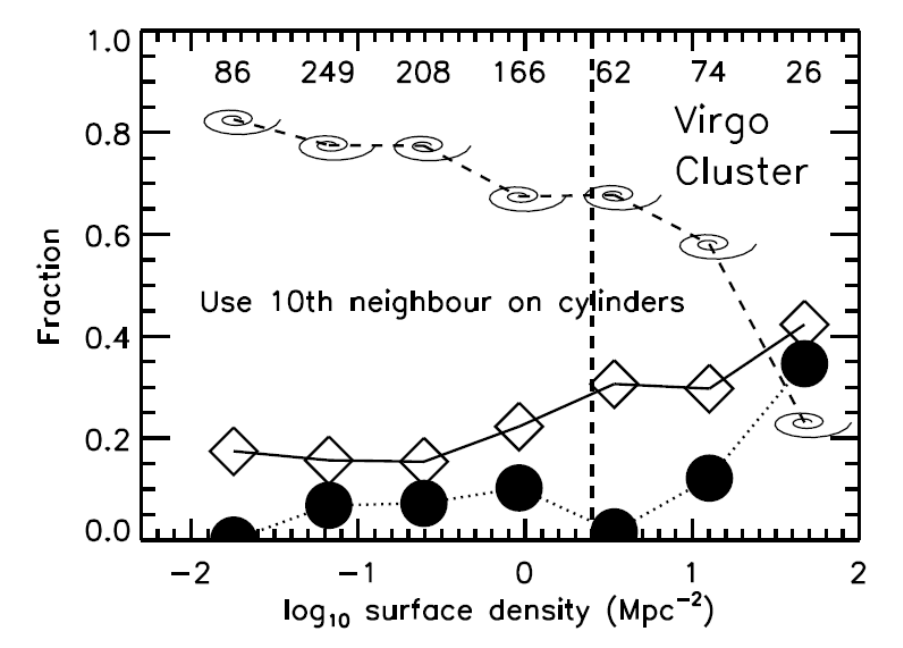
The morphology-density relation

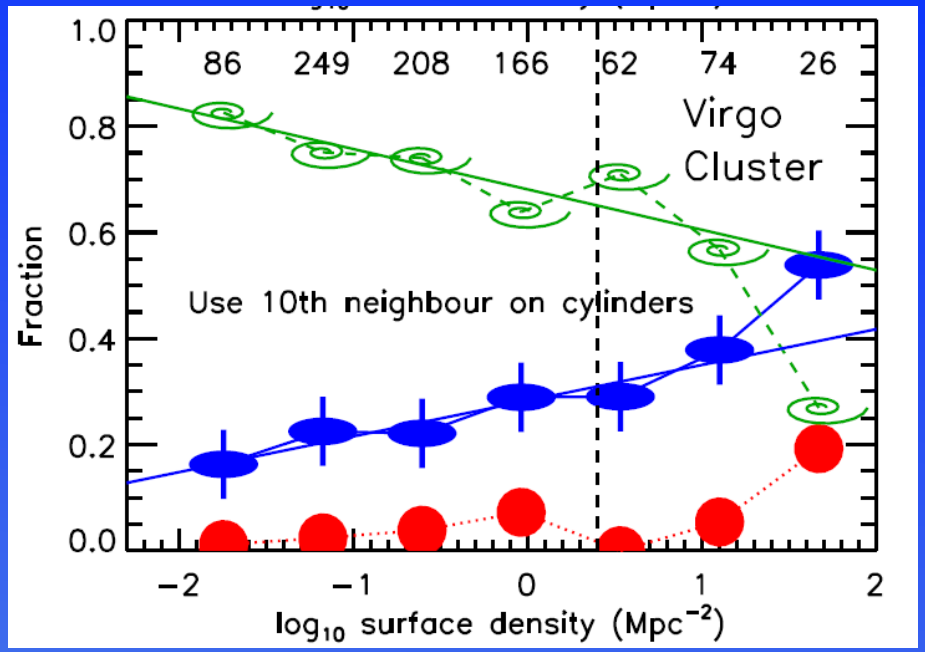


Dressler (1980)

- Early-type systems (Es and S0s) are much more common in dense environments
- This has often been interpreted as evidence for morphological transformation in clusters

ATLAS^{3D} – kinematic morphology-density relation

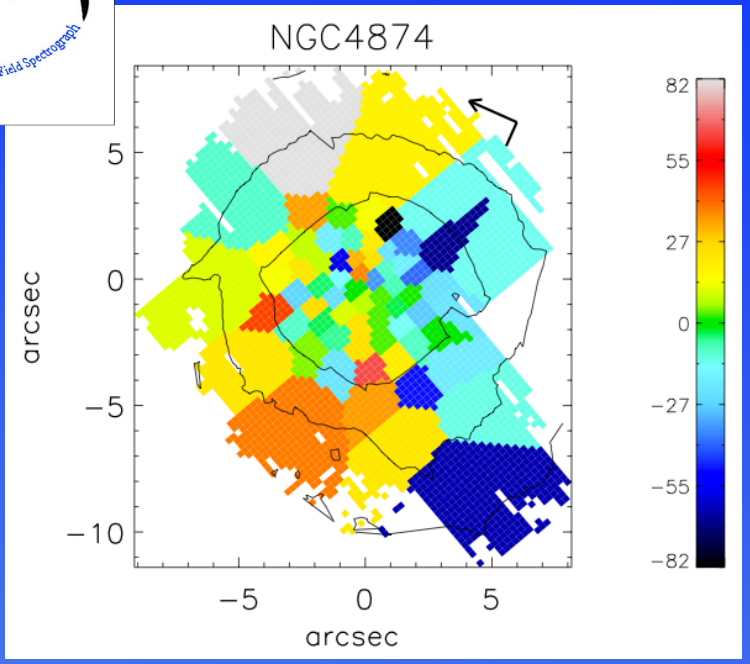


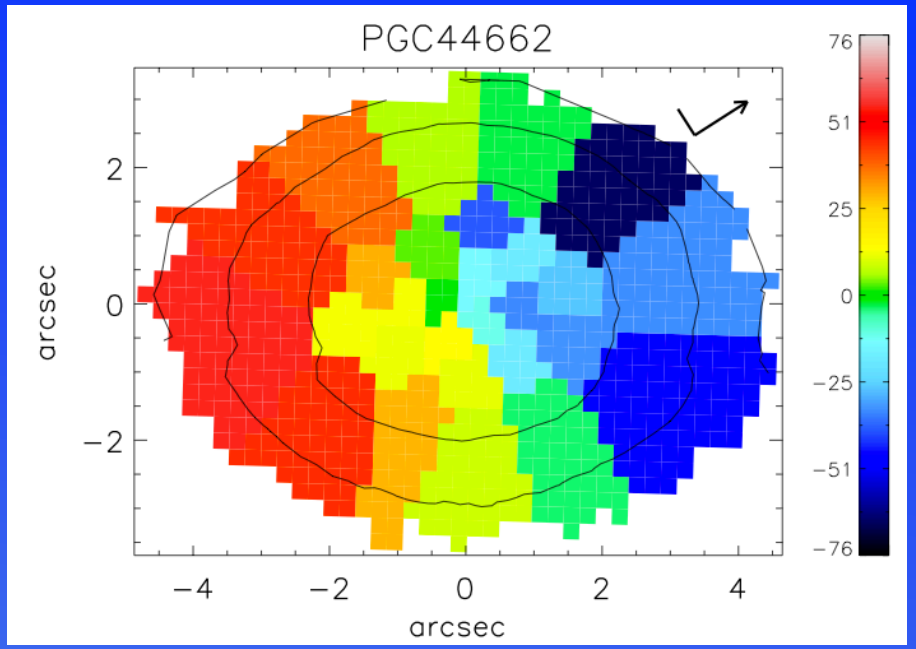


Cappellari et al. (2011b)

- Revisited the morphology-density relation (Dressler et al. 1980) using the revised kinematic classification system
- Found a steady increase of FRs wrt. spirals across all environments
- SR fraction increases significantly **only** in the centre of Virgo
- But the ATLAS^{3D} volume probes only a limited range of environments (essentially Virgo and non-Virgo)

Coma – a nearby massive cluster





Scott et al. (2012)

- Coma is the most massive 'local' cluster, falling between Virgo and Abell1689
- We have observed a subset of Coma ETGs with the Oxford SWIFT IFS
- Velocity and dispersion maps constructed from measurements of the calcium triplet
- A full survey of all bright galaxies in Coma is currently underway with the SAURON IFS

Coma – a nearby massive cluster

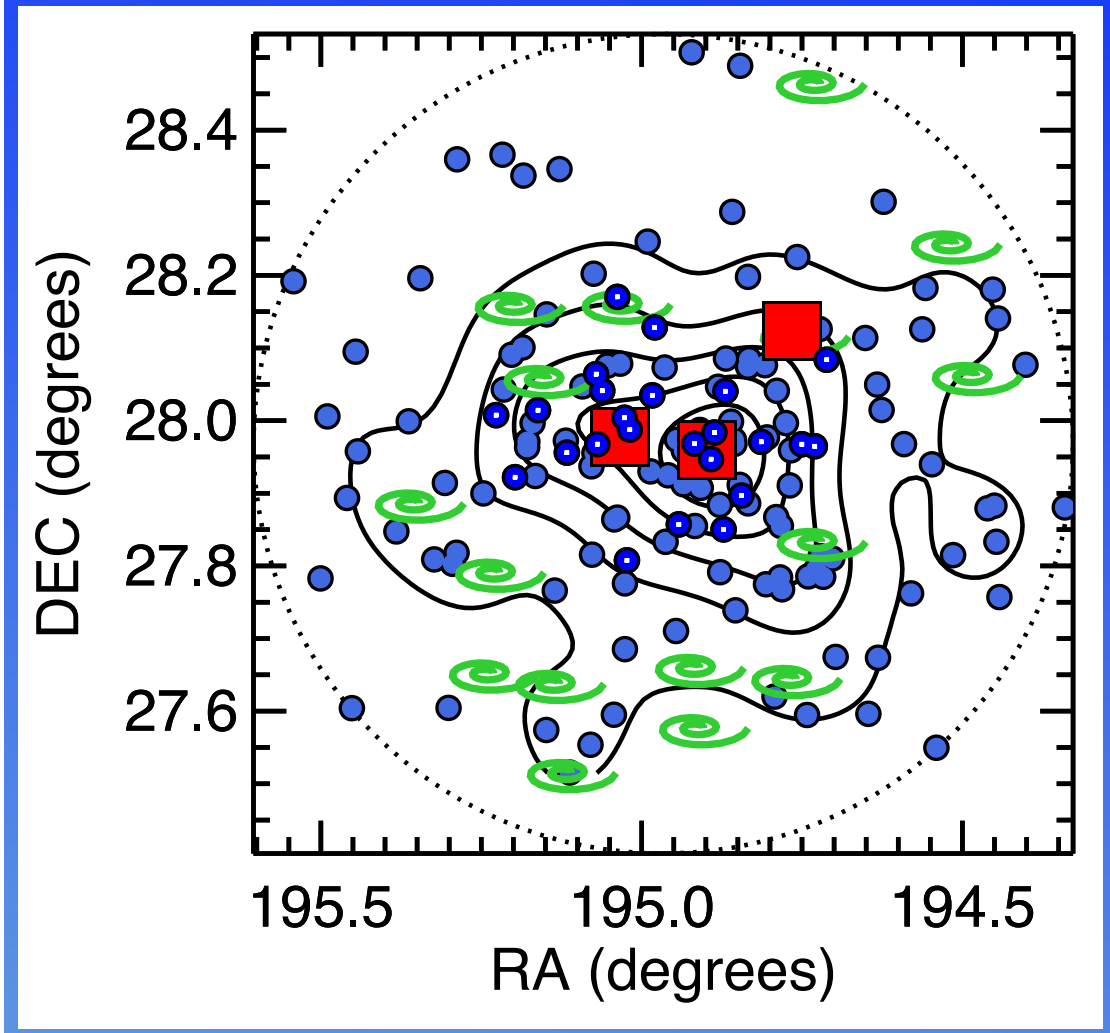
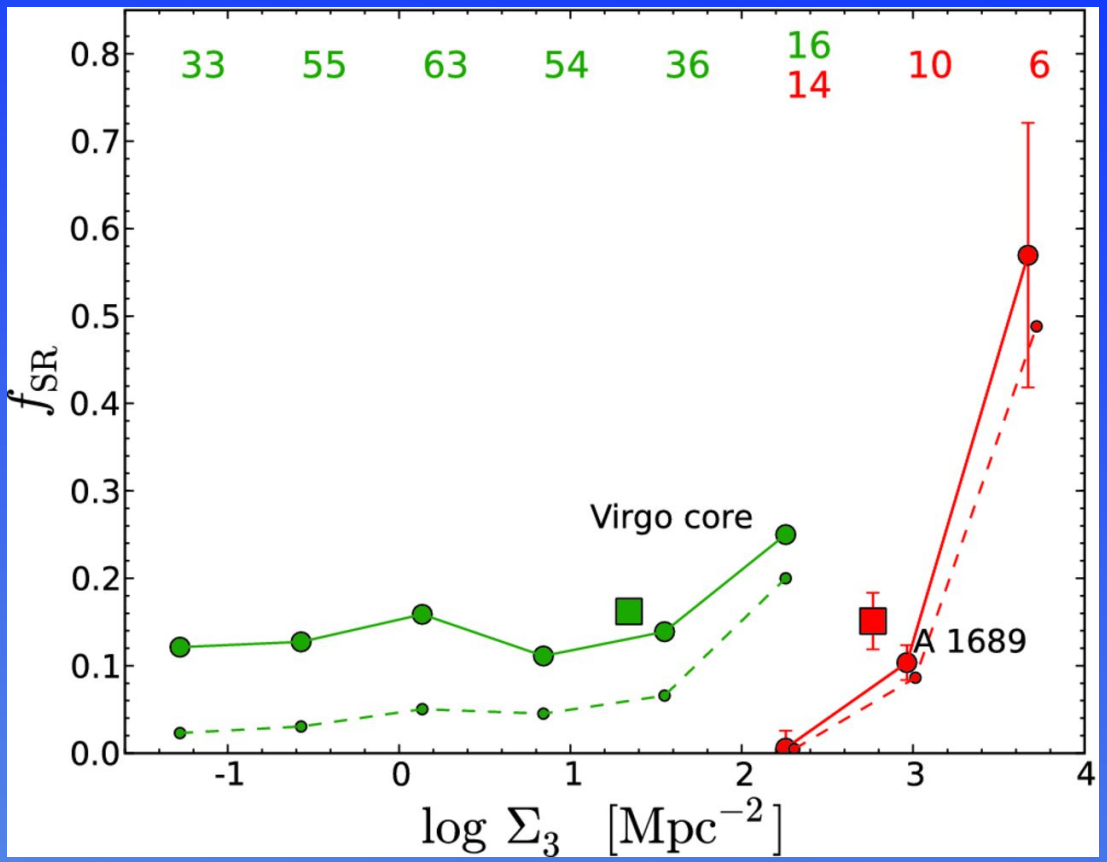


Figure from Cappellari (2013), because it's a prettier version

- Results presented in Scott et al. (2012) and Houghton et al. (2013)
- Late-type galaxies almost entirely absent from the cluster core
- SR fraction of ~15% for the whole cluster
- SRs again strongly concentrated in the cluster core

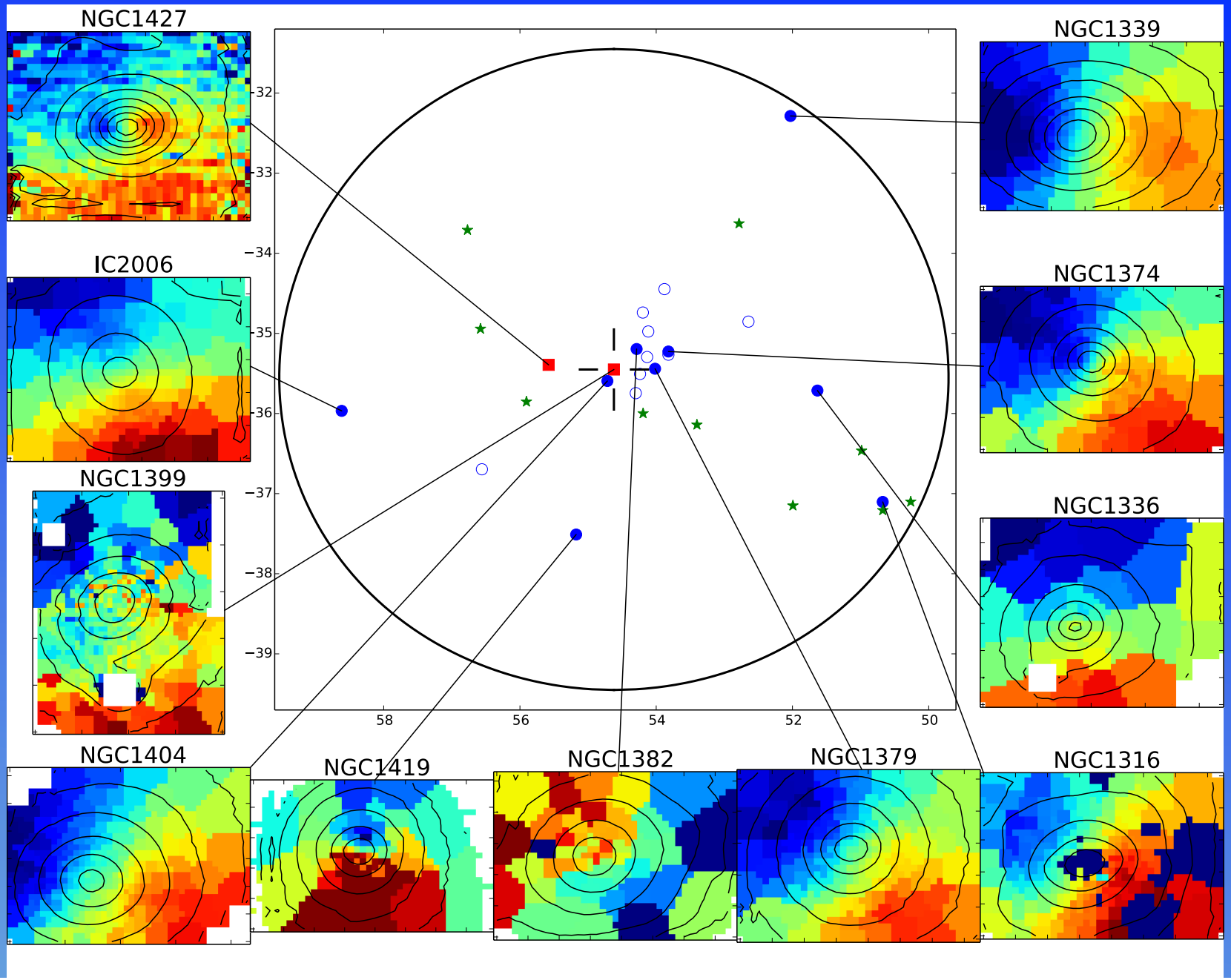
Abell1689 – a truly massive cluster

- Massive cluster at z~0.2
- Central density ~100 times higher than Virgo
- Observed with the VLT-FLAMES multi-IFS instrument
- Total SR fraction of 15% consistent with Virgo and Coma
- SR fraction again rising significantly in the cluster core



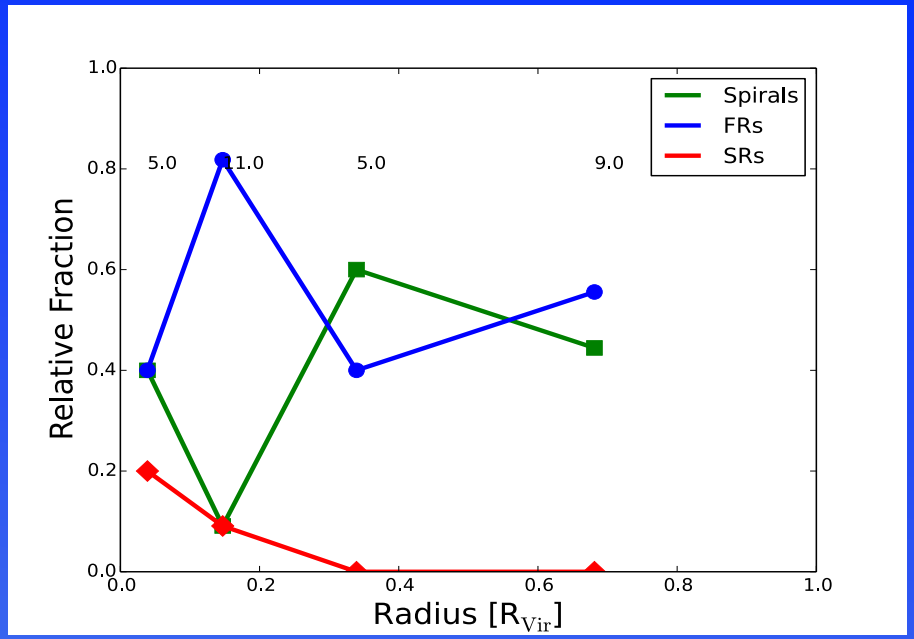
D'Eugenio et al. (2013)

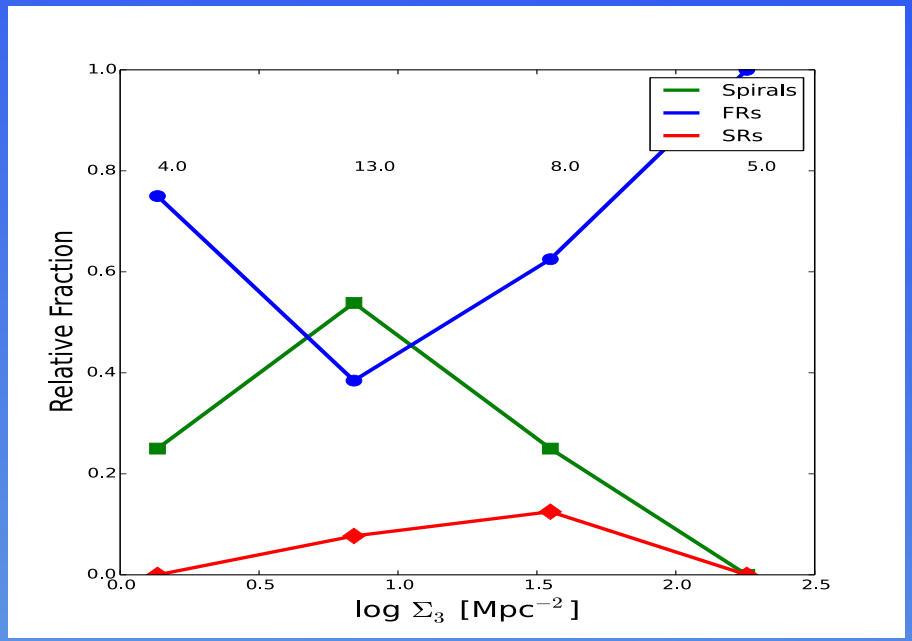
Fornax – a local low-mass cluster



Adding other clusters – Fornax

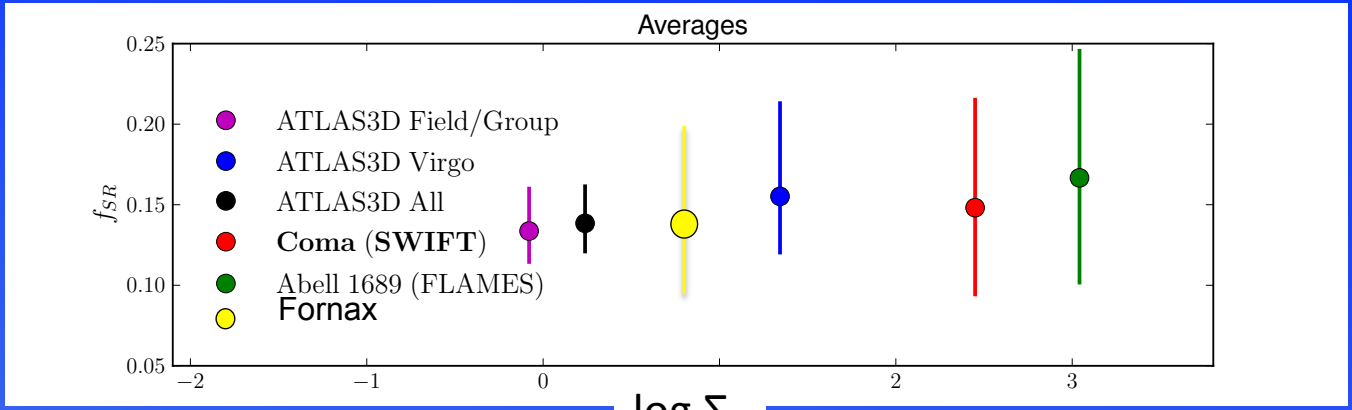
- Reuslts again give a SR fraction of ~15% with SRs concentrated in the core of the cluster
- Fornax results hint that SRs *not* in the densest regions but low statistics so far…

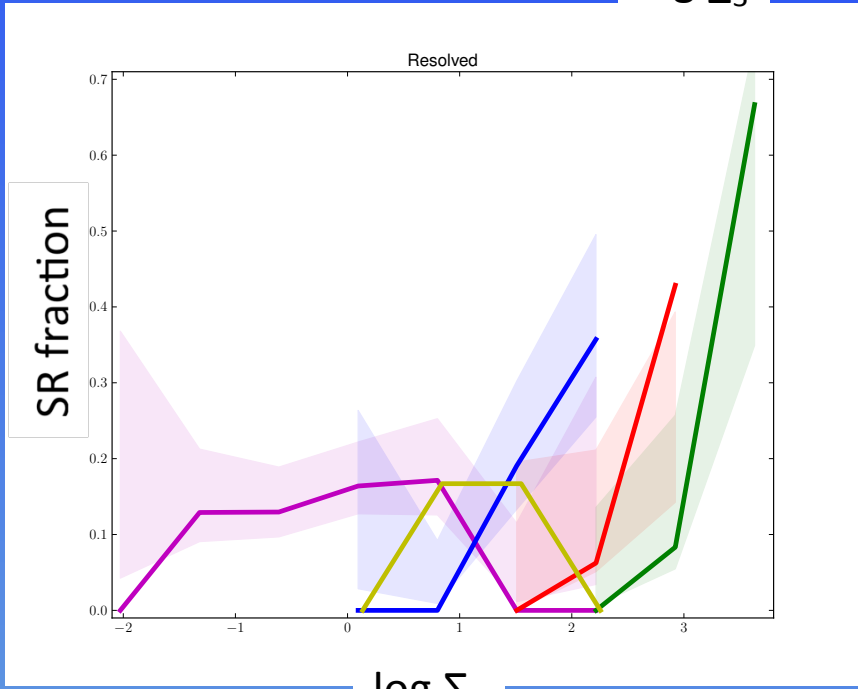




Scott et al. (in prep)

Summary of the current clusters





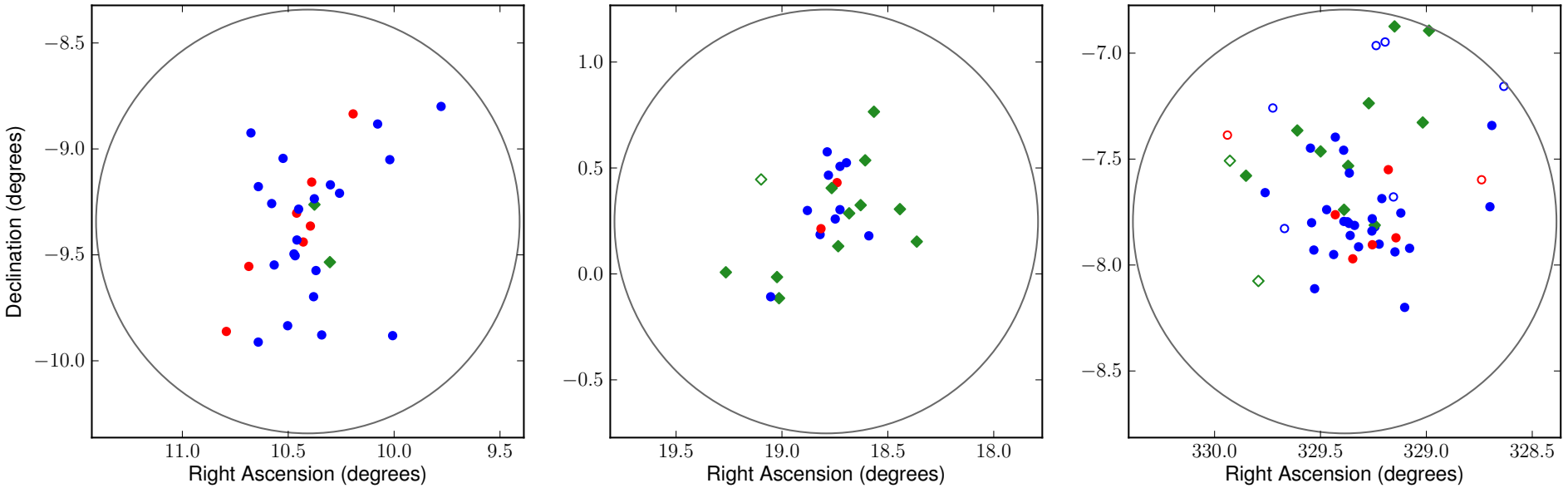
Houghton et al. (2013) + Fornax

- SR fraction appears to be a constant ~15%, as long as one considers a large enough volume
- Cores of clusters have high SR fractions, whereas cluster outskirts are deficient in SRs

SAMI

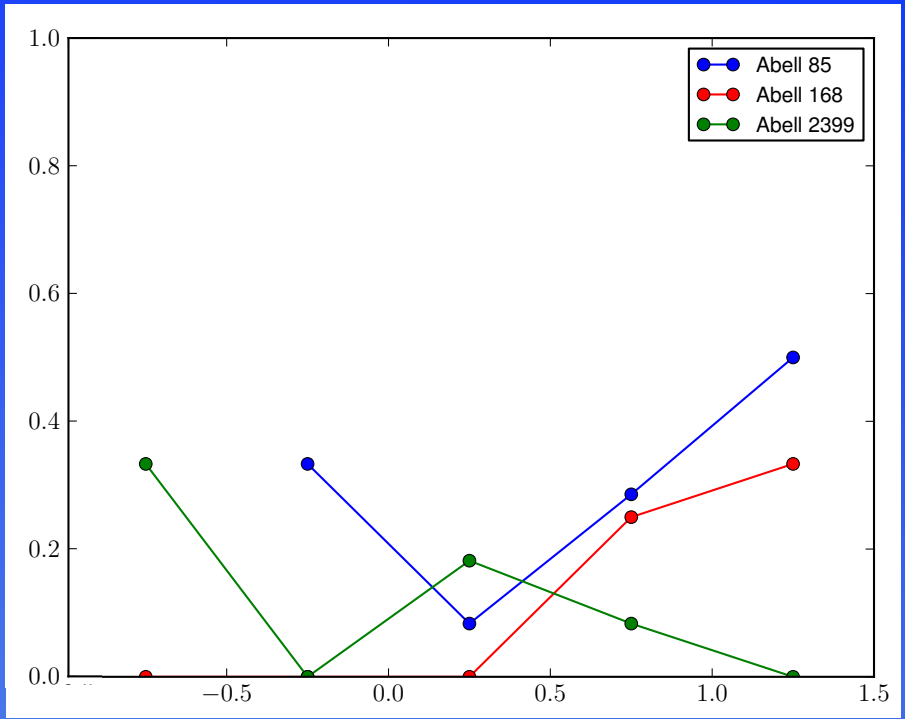
sami galaxy survey

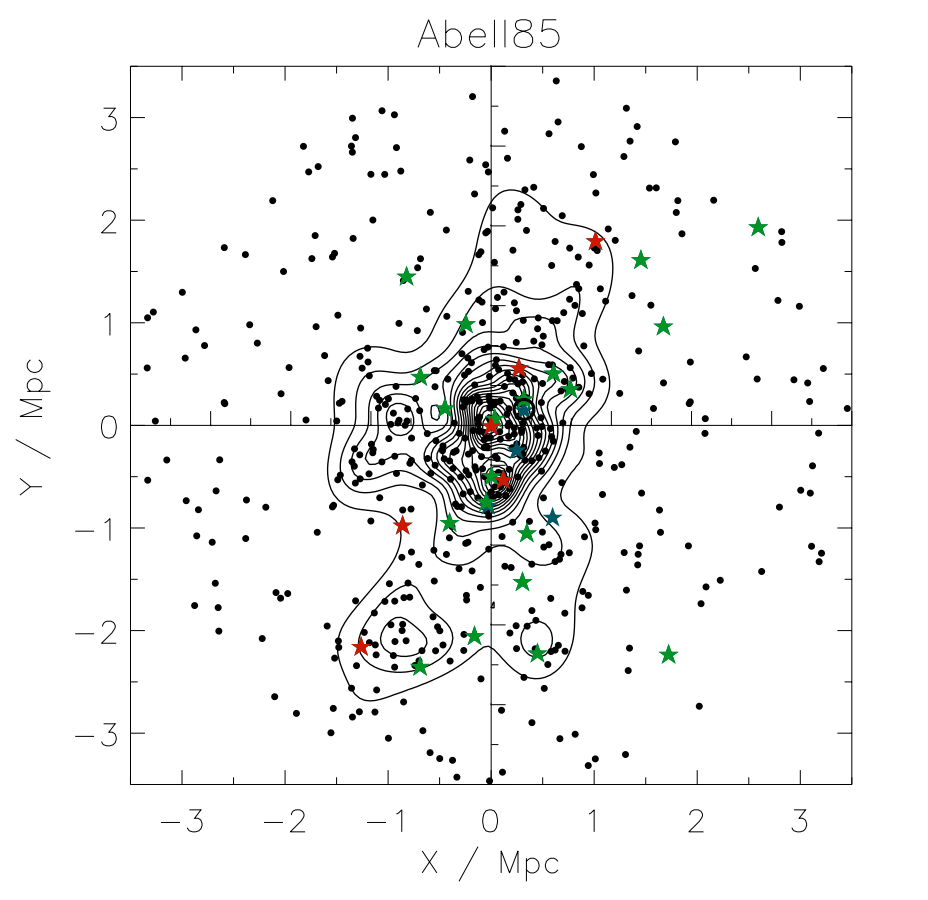
Abell 85 | Abell 168 | Abell 2399



Fogarty et al. (in prep.)

- SAMI is a multi-IFS instrument (see Scott Croom's talk on Thursday)
- SAMI pilot survey has already looked at 3 clusters in 18 nights (the 4 clusters I presented here took ~50 nights!)
- The SAMI main survey will look at 8 clusters (5 partially observed already), more than doubling the current sample, as well as a large number of groups which are as yet completely unexplored





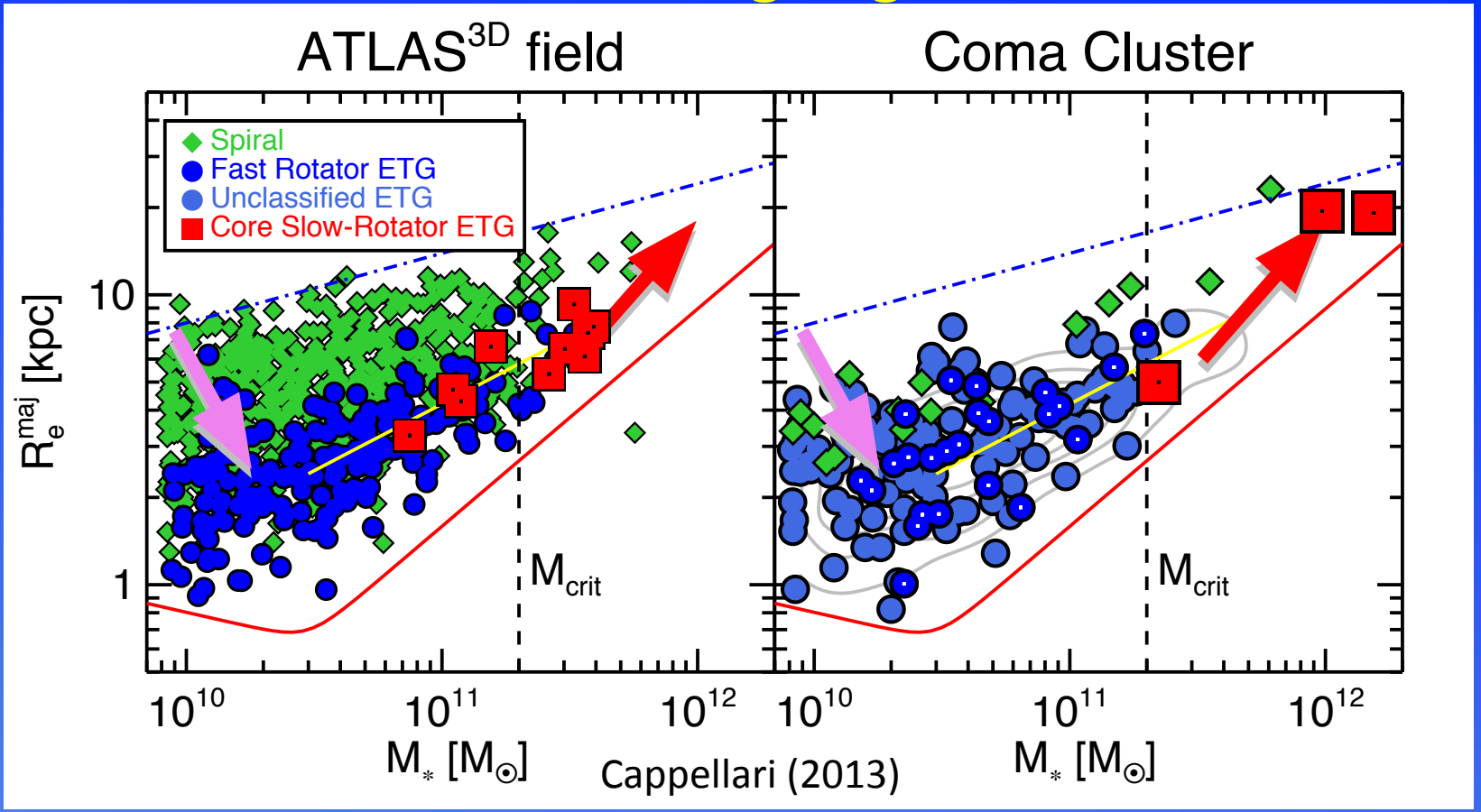
Fogarty et al. (in prep.)

- Abell 168 shows the previous behaviour of centrally concentrated SRs
- Abell 85 and Abell 2399 show a much broader distribution of SRs, with a significant population in the outskirts of Abell 85
- At least one of these outlying SRs is associated with an in-falling group

Summary of kinematic morphology-density results

- Early-type fraction increases smoothly with environmental density from the field to cluster outskirts, then shows a sharp increase
- Slow rotators make up a constant ~15% of early-type galaxies across all global (halo) environments
- Slow rotators are strongly segregated in clusters, with very few found in cluster outskirts and a significant over-abundance in cluster cores
- This behaviour is seen from small to large clusters

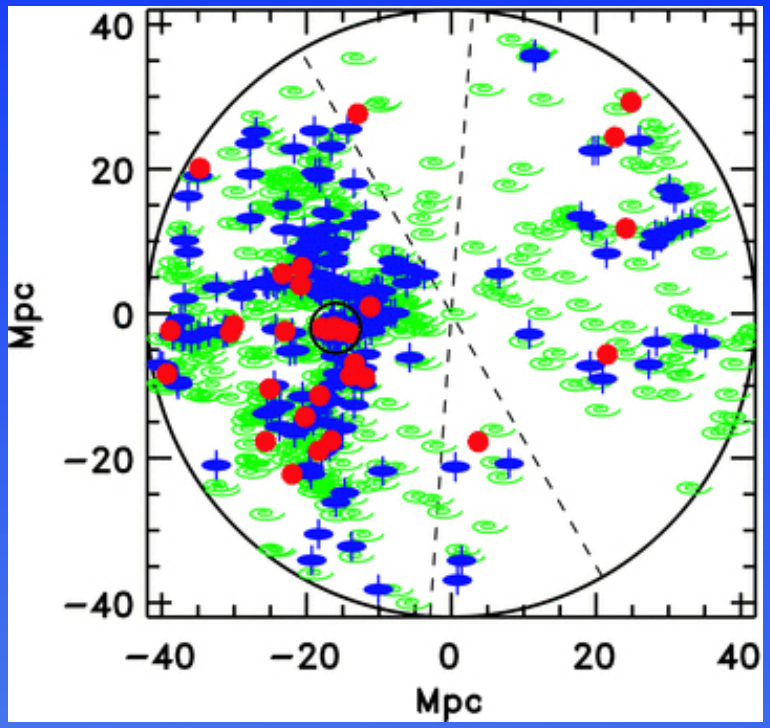
So what's going on?

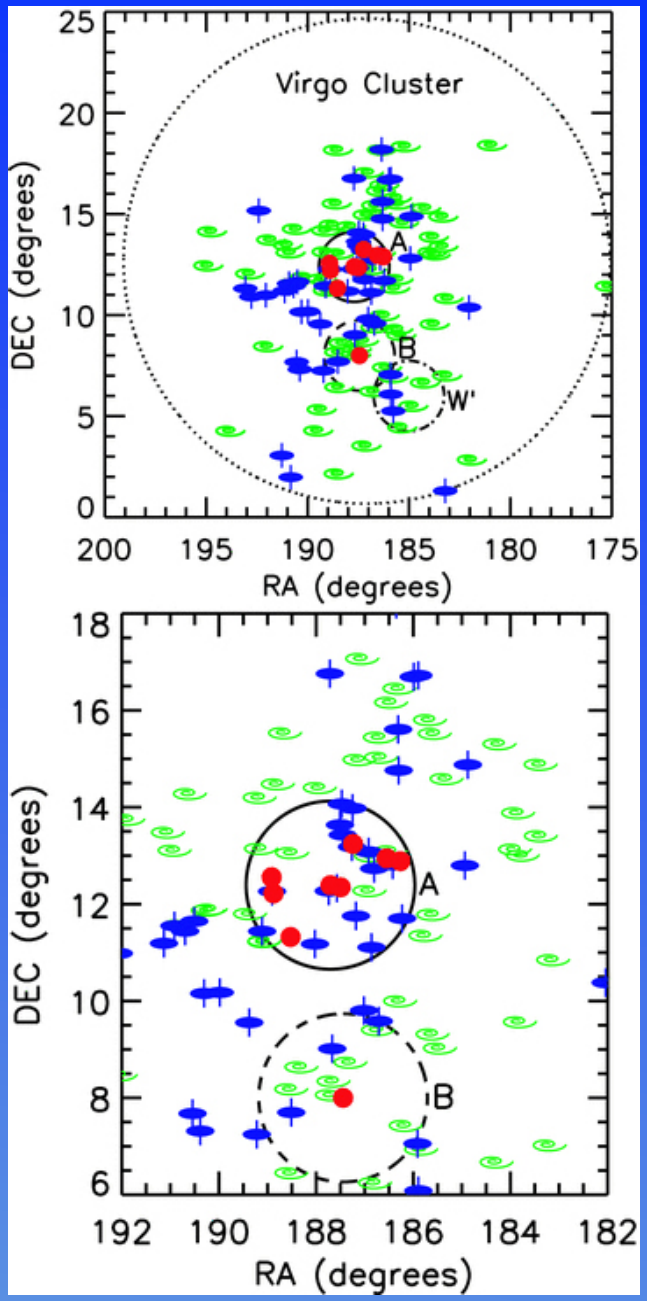


- Two processes responsible for the observed kinematic morphology – density relations:
  - Late-types transformed to early-type more efficiently in high-density environments through quenching +bulge growth without significant mass growth
  - SRs produced as a constant fraction of all early-types, independent of environment, then concentrated in high local density environments due to mass segregation

Questions?

Where are the Slow Rotators?

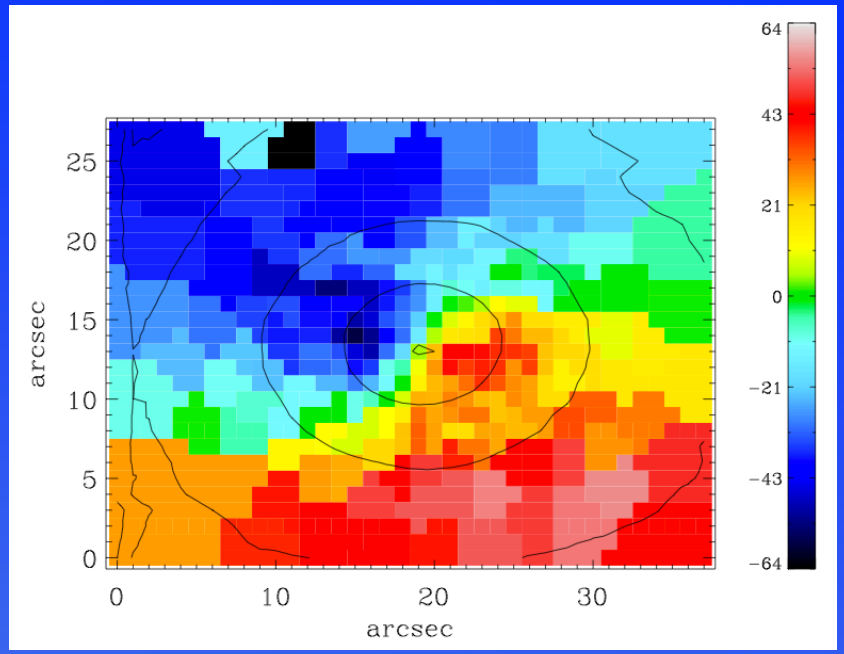


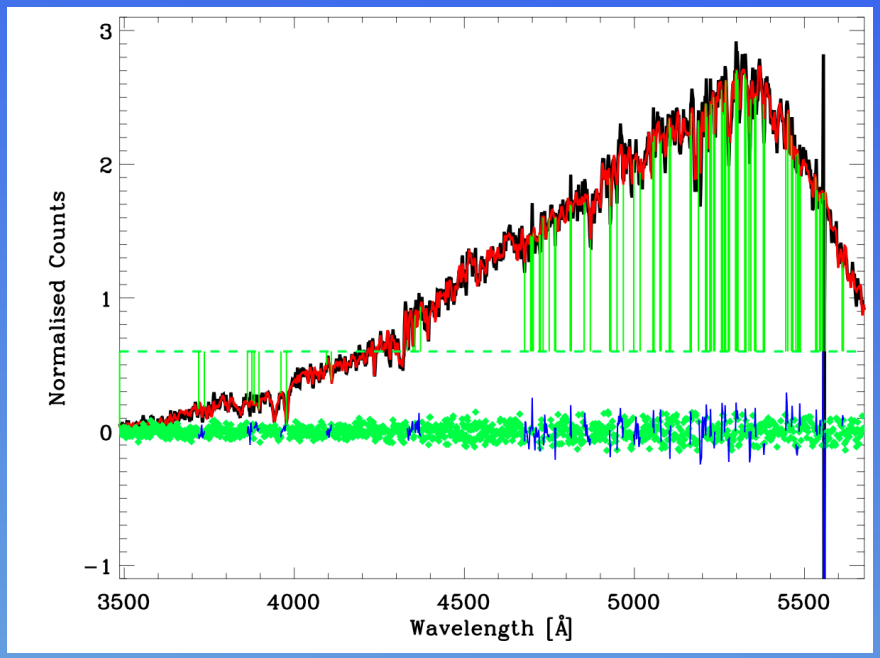


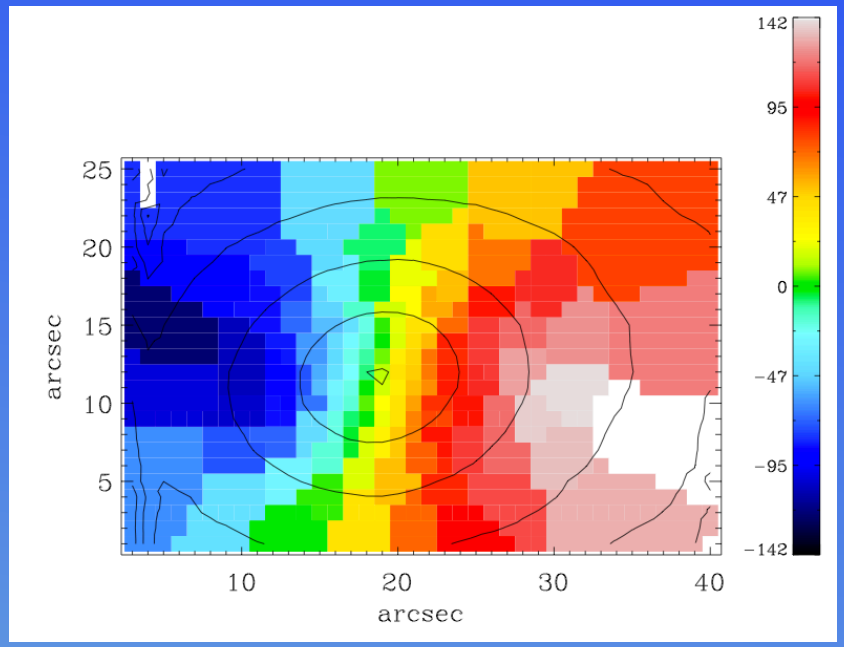
- Given our new classification of ETGs, revisiting the morphology-density relation was an obvious thing to do (Cappellari et al. 2011b)
- Also, kinematic morphology and classical morphology are influenced by different physical processes, so in combination they may help address which mechanisms dominate in different environments

Adding other clusters – Fornax I

- We have observed 11/20 ETGs in the Fornax cluster with WiFeS
- Fornax is a low-mass cluster lying on the cluster/group boundary, though it has a high galaxy density in its centre
- We have constructed maps of the stellar velocity and velocity dispersion from absorption lines







Adding other clusters – Abell1689 I

- Massive cluster at z~0.2
- Central density ~100 times higher than Virgo
- Observed with the VLT-FLAMES multi-IFS instrument

D'Eugenio et al. (2012)

The issue

- But disentangling the effects of mass and environment has proved extremely challenging, with many papers based on large samples arguing both for and against any detectable influence of environment

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- "There is no difference between the [stellar populations] in the clusters and their outskirts." – Harrison, Colless et al., 2010
- "The ages of red-sequence giants are primarily determined by galaxy mass, …with only weak modulation by environment, in the sense that galaxies at larger cluster-centric distance are slightly younger." – Smith et al. 2012

- "Massive early-type galaxies in low-density environments seem on average 2 Gyr younger and slightly more metal-rich than their counterparts in high-density environments." – Thomas et al. 2004
- "At fixed stellar mass, early-type galaxies in dense regions are on average older and more metal rich than early-type galaxies in low density regions." – Gallazzi et al. (2006)

- "…the main factor driving the evolutionary rate is mass rather than environment. In this context, the cluster-to-field differences can be understood mainly as a result of a different mass function for magnitude-selected samples." – Treu et al. (2005)
- "The shapes of the mass functions of the general field and clusters are indistinguishable" – Calvi et al. (2013)
- "differences between cluster and low-density environment populations are seen even when the velocity dispersion is the same in both environments; the environment plays an important role in determining galaxy properties." – Bernardi et al. (2005)