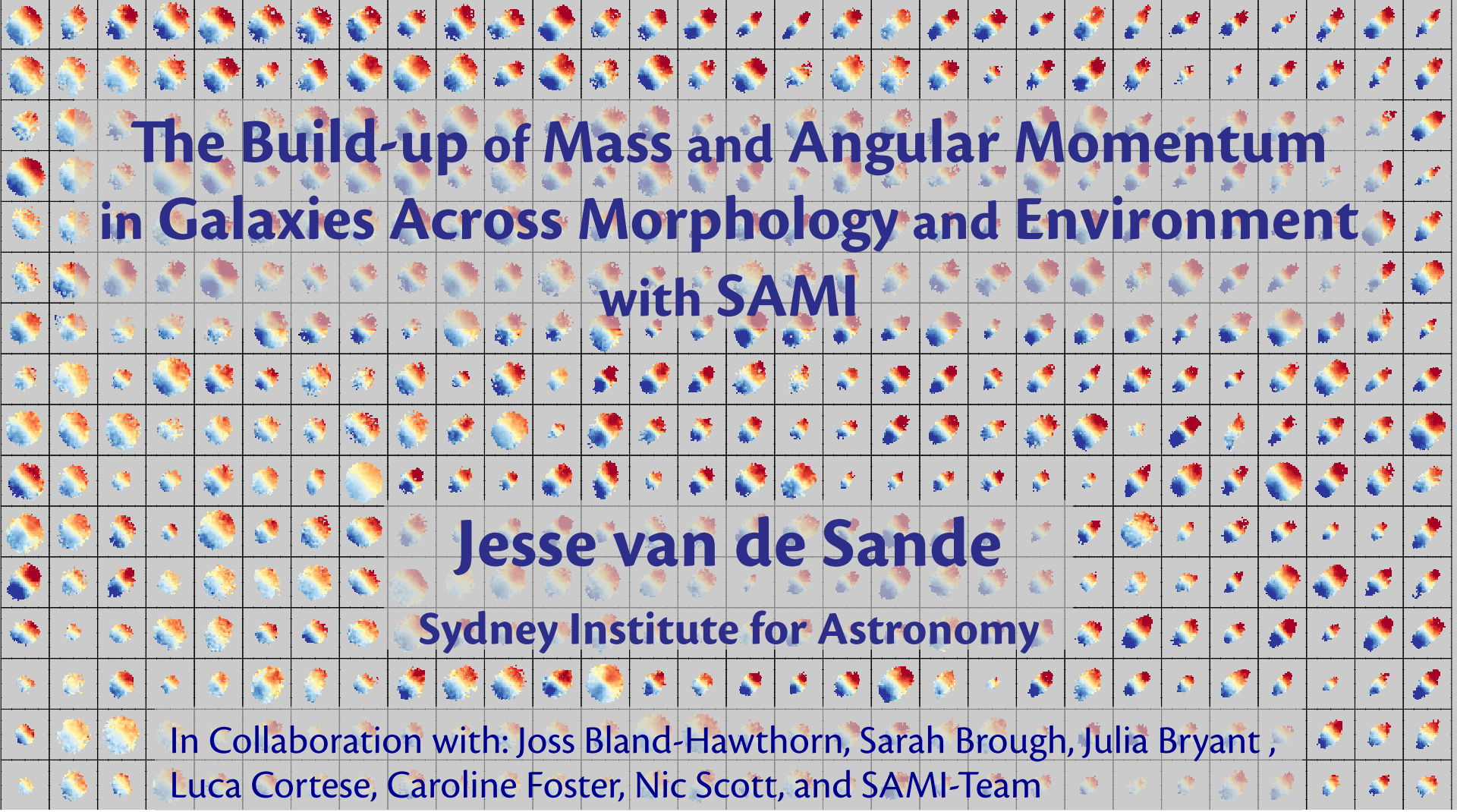

The Build-up of Mass and Angular Momentum in Galaxies Across Morphology and Environment with SAMI

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In Collaboration with: Joss Bland-Hawthorn, Sarah Brough, Julia Bryant , Luca Cortese, Caroline Foster, Nic Scott, and SAMI-Team

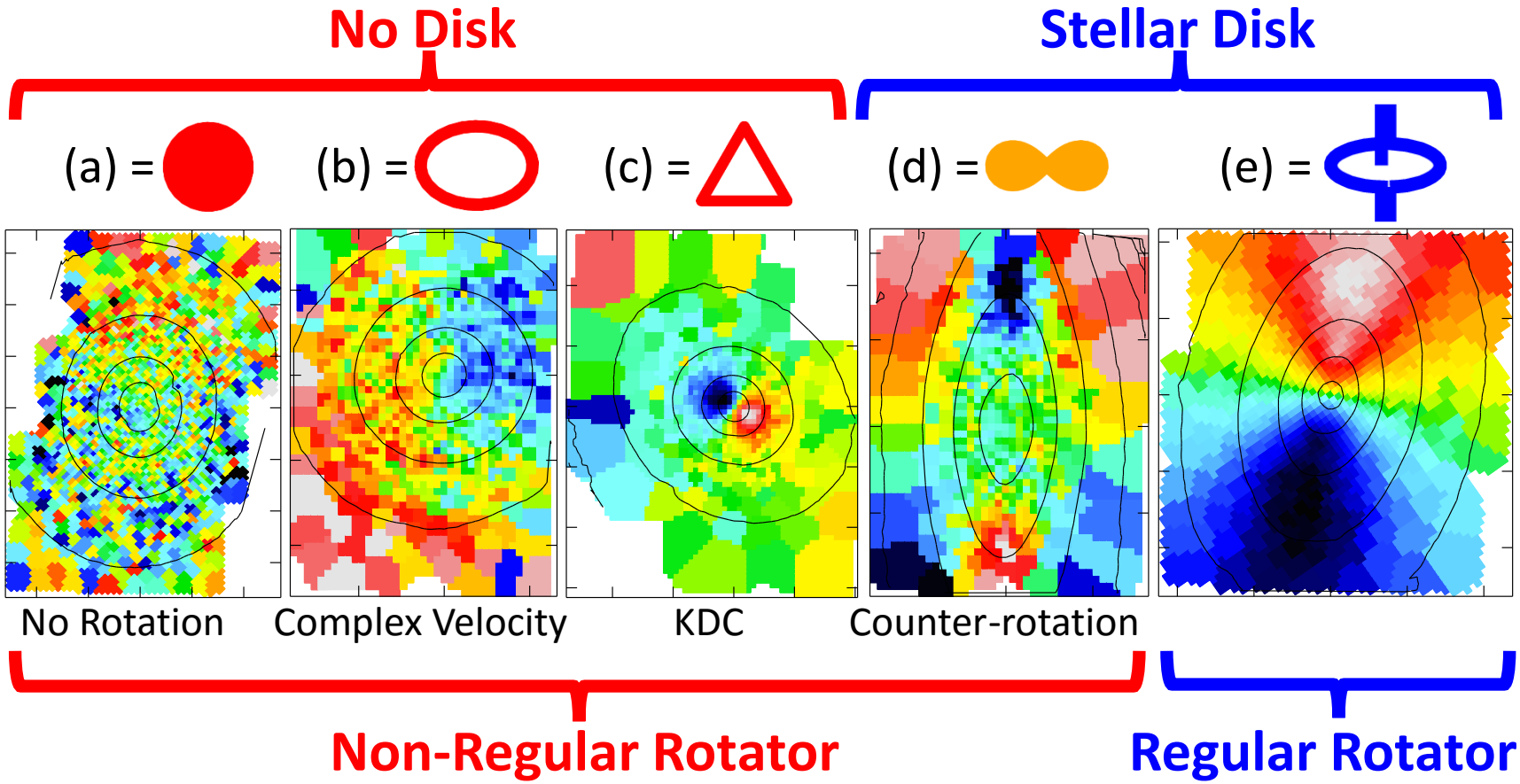
THE UNIVERSITY OF SYDNEY

Galaxy Evolution Across Time

Paris, June 2017

sami galaxy survey

majority of early-type galaxies have regular 2D velocity fields

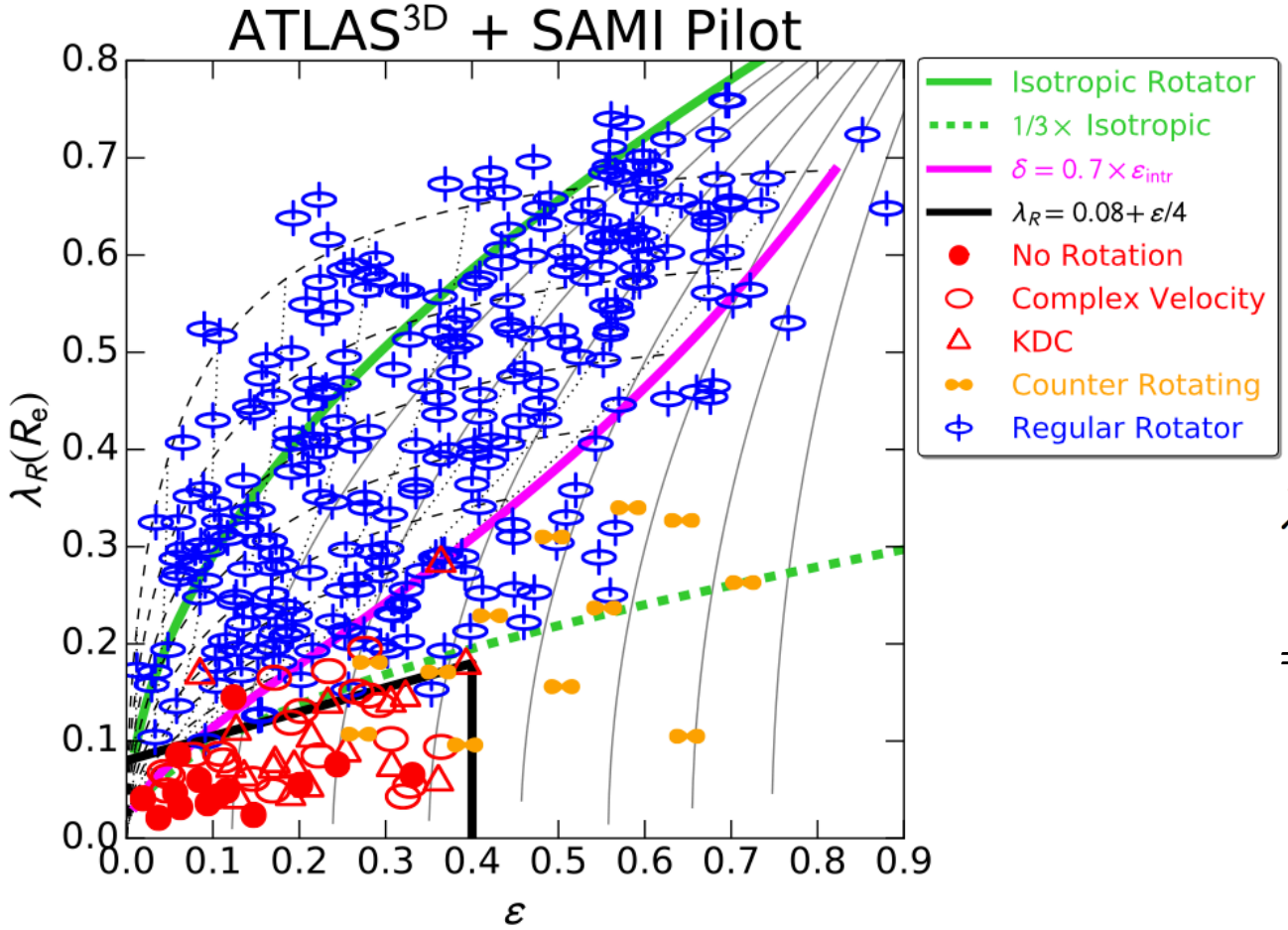


ATLAS^{3D} Krajnović+ 2011; Cappellari 2016

ATLAS^{3D} results suggest two kinematic families:

1) ~85% nearly oblate fast-rotators &

2) ~15% slow rotators with complex dynamical structures



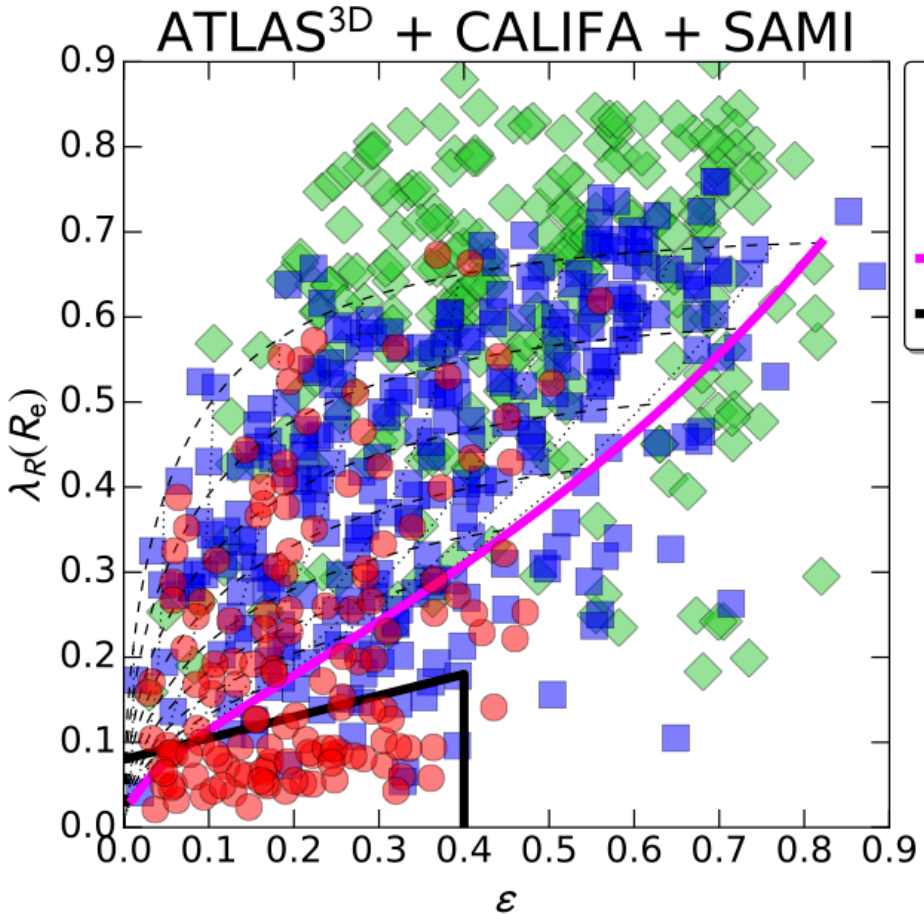
Cappellari 2016
Emsellem+ 2011
Fogarty+ 2015

$$\lambda \equiv \frac{J|E|^{1/2}}{GM^{5/2}}$$

$$\lambda_R \equiv \frac{\langle R|V|\rangle}{\langle R\sqrt{V^2+\sigma^2}\rangle}$$

= Proxy for spin parameter. Characterises overall importance of angular momentum relative to random motion.

Link between morphology and kinematic structure?



Cappellari 2016; Fogarty+ 2015; Falćon-Barroso+2015

What are the physical processes responsible for galaxy transformations?

How does mass and angular momentum build up?

How do we dissect the assembly history of individual galaxies?

THE BUILD-UP OF MASS AND ANGULAR MOMENTUM IN GALAXIES ACROSS MORPHOLOGY AND ENVIRONMENT WITH SAMI

- The Sydney-AAO Multi-object Integral field spectrograph (Croom et al. 2012).
- 1 degree diameter field-of-view.
- 13 x 61 fibre IFUs using hexabundles (Bland-Hawthorn et al. 2011; Bryant et al. 2014).
- Fused fibre bundles; high fill factor, 75%.
- 15” diameter IFUs, 1.6” diameter fibres.
- Feeds AAT’s ground-based AAOmega spectrograph.
- Wavelength coverage/resolution:
  Blue: 3700-5800A, R~1800, sigma=70km/s
  Red: 6300-7400A, R~4260, sigma=30km/s

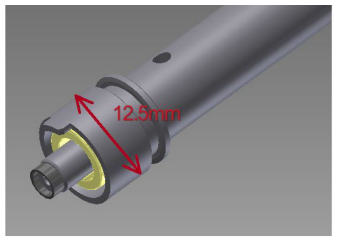
sami galaxy survey

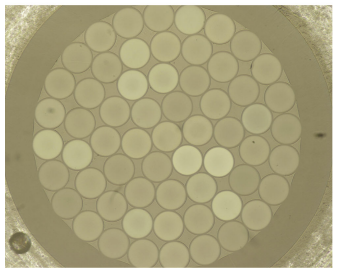
IFS Survey of 3600 galaxies
~2300 observed

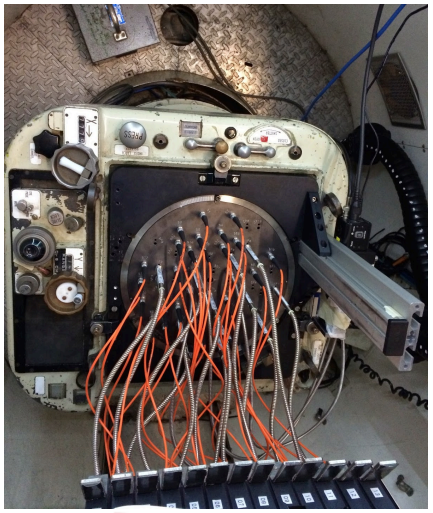
- Total of ~200 nights, due to complete in mid-2018.
- Primary fields using GAMA (Driver et al. 2010)
  - Robust group/pairs catalogue (Robotham et al. 2011).
  - GALEX, SDSS, VST, UKIDSS, VISTA, WISE, Herschel imaging.
- HI 21cm from ALFALFA (half the area), and in the future ASKAP.
- 8 clusters targeted (~800 gals) – (Owers et al. 2017)

Coming Soon: Data Release 1

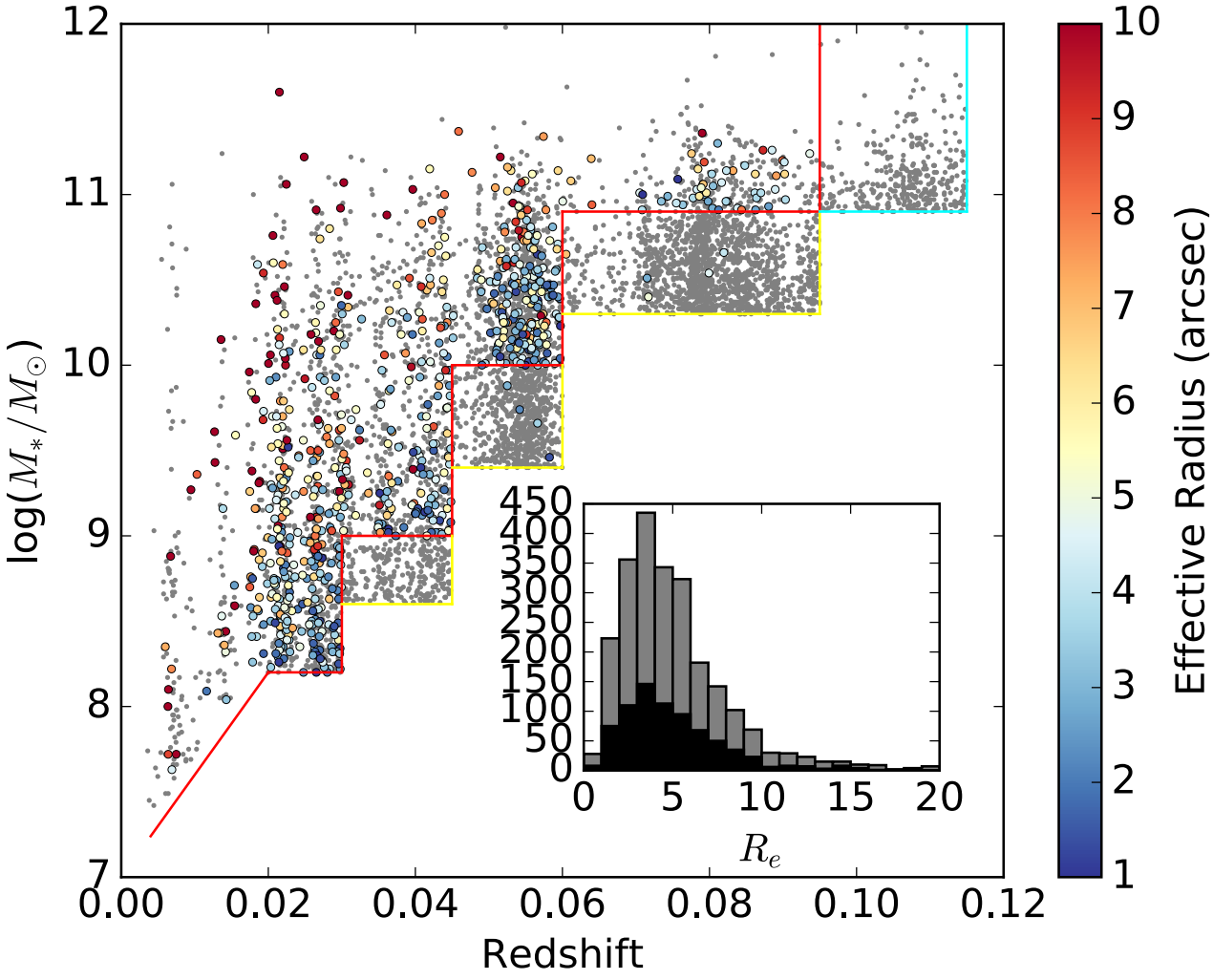
772 galaxies, reduced spectral cubes, emission-line & star-formation maps







SAMI Galaxy Survey Target Selection

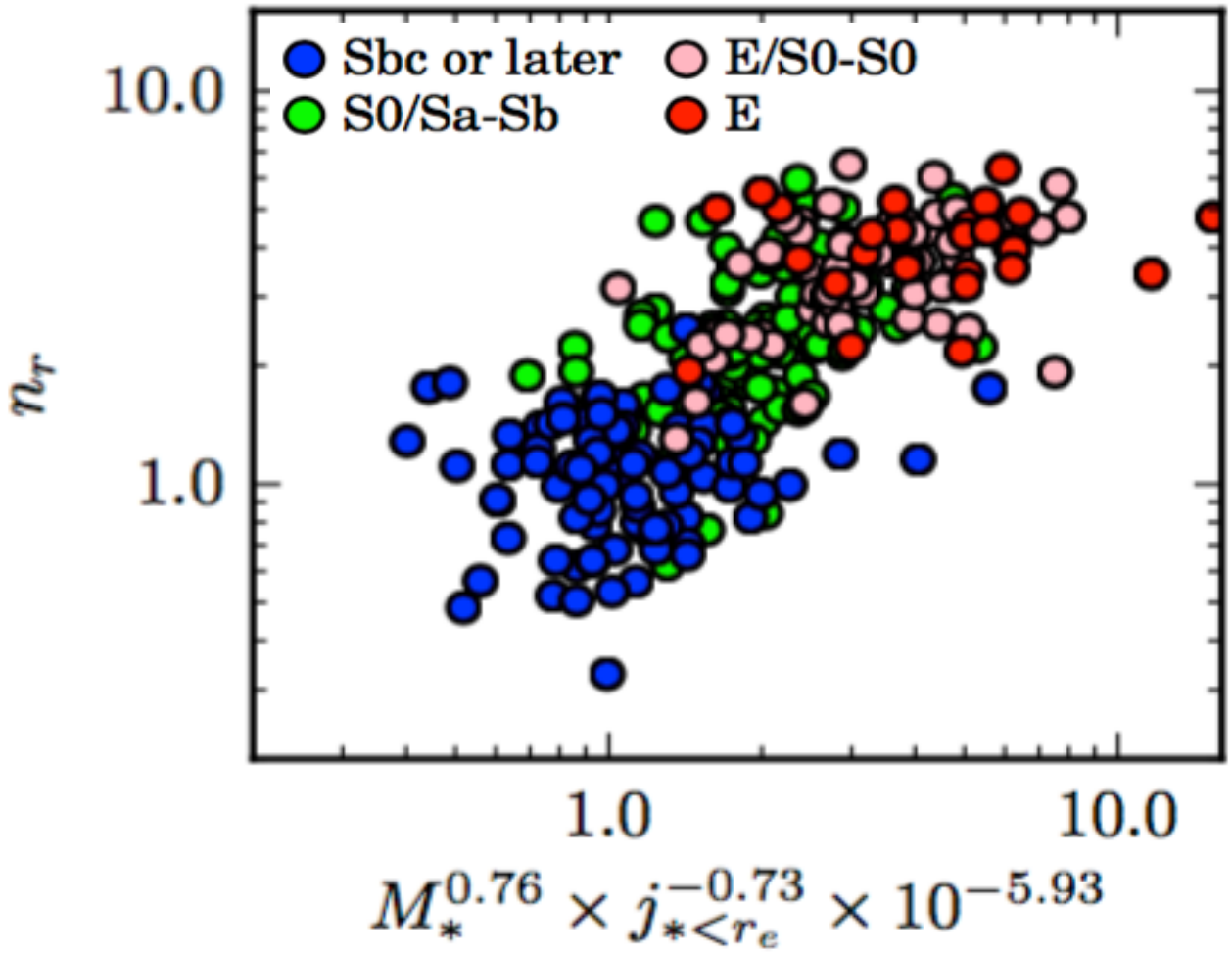


- Median major axis Re=4.4” (10-90% range 1.8-9.4”)
- IFU samples to median 1.7Re.
- ~2/3 of galaxies in GAMA group cat (Robotham+11).

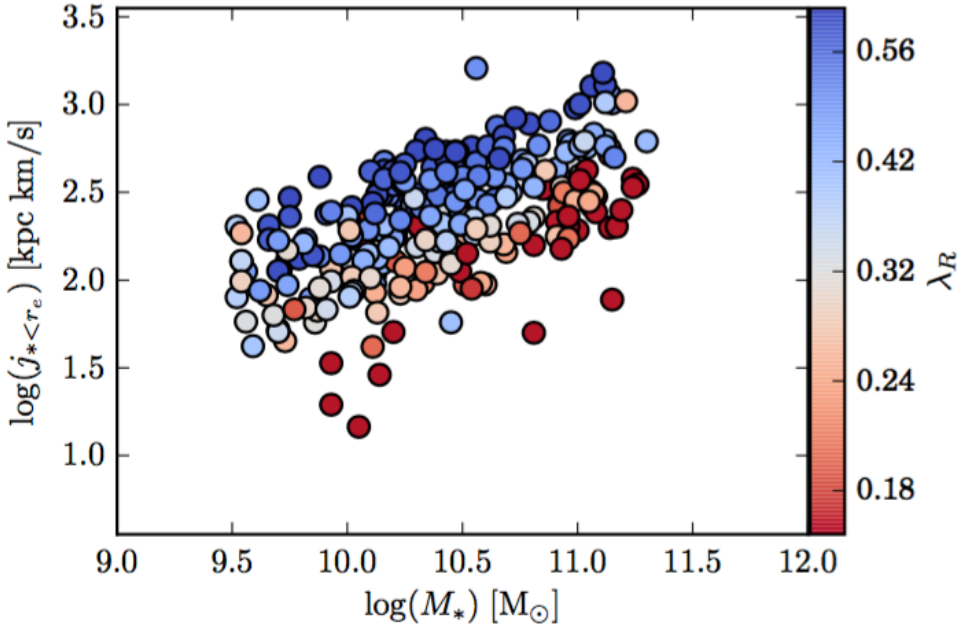
The diversity of SAMI science so far

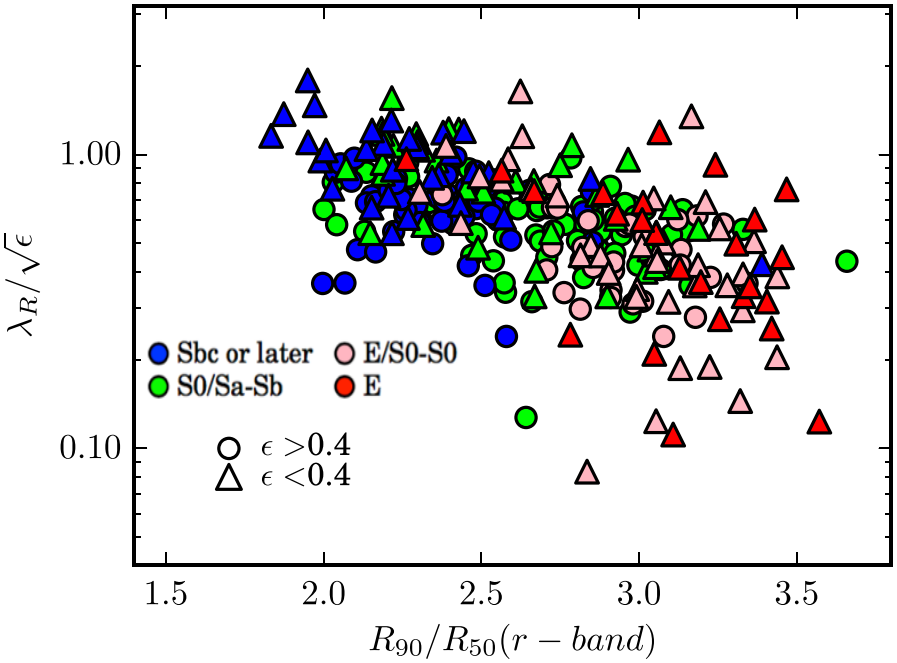
- **Kinematics and Angular Momentum** – Fogarty++ 2014; Fogarty++ 2015; Cecil++ 2016; Oh++ 2016; **Cortese++ 2016; van de Sande++ 2017**; Bloom++ 2017a, Bassett++ 2017; Taranu++ 2017; **Brough++ 2017; Foster++ 2017.**
- **Stellar populations** – **Scott++ 2017**
- **Scaling relations** – Cortese++ 2014; Scott++2015, Bloom++ 2017b
- **Winds and outflows** – Fogarty++ 2012; Ho++ 2014; Ho++ 2016
- **Star formation** – Richards++ 2014; Richards++ 2016; Schaefer++ 2017a; Federrath ++ 2017; Schaefer++ 2017b; Zhou++ 2017, Medling++ 2017
- **AGN** – Allen++ 2015.
- **Instrument/Survey** – Croom++2012; Sharp++2015; Allen++2015; Bryant++2015; Owers++ 2017; Green++ 2017

Galaxies of all types lie on a plane relating mass, angular momentum and stellar-light distribution (Cortese et al. 2016)



large-scale morphology of a galaxy is likely regulated by its mass and dynamical state (Cortese+16)





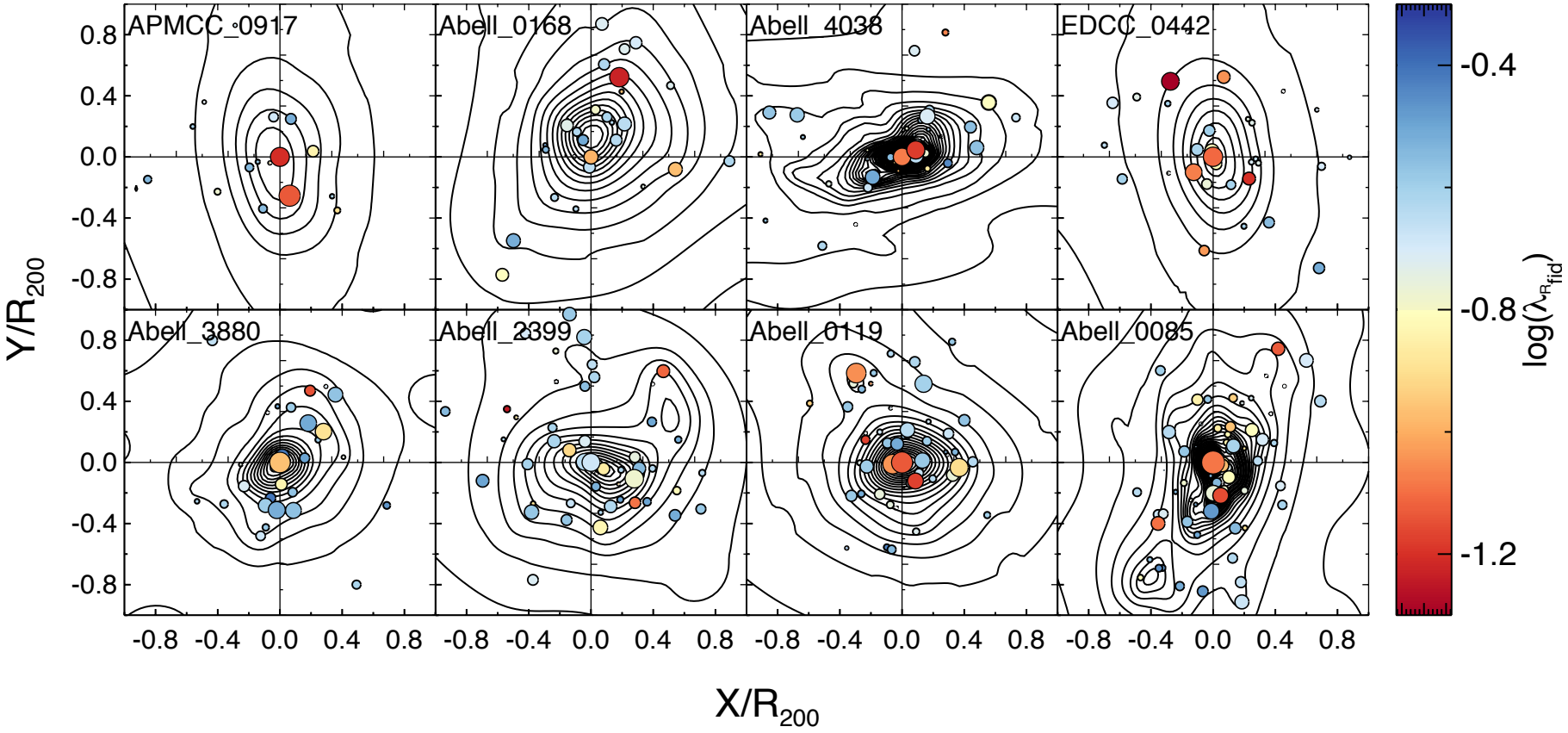
The correlation between the offset from the M_*–j relation and spin parameter λ_R shows that at fixed M_* the contribution of ordered motions to dynamical support varies by >3x

Late *and* Early-type fast-rotators form a continuous class in terms of their kinematic properties

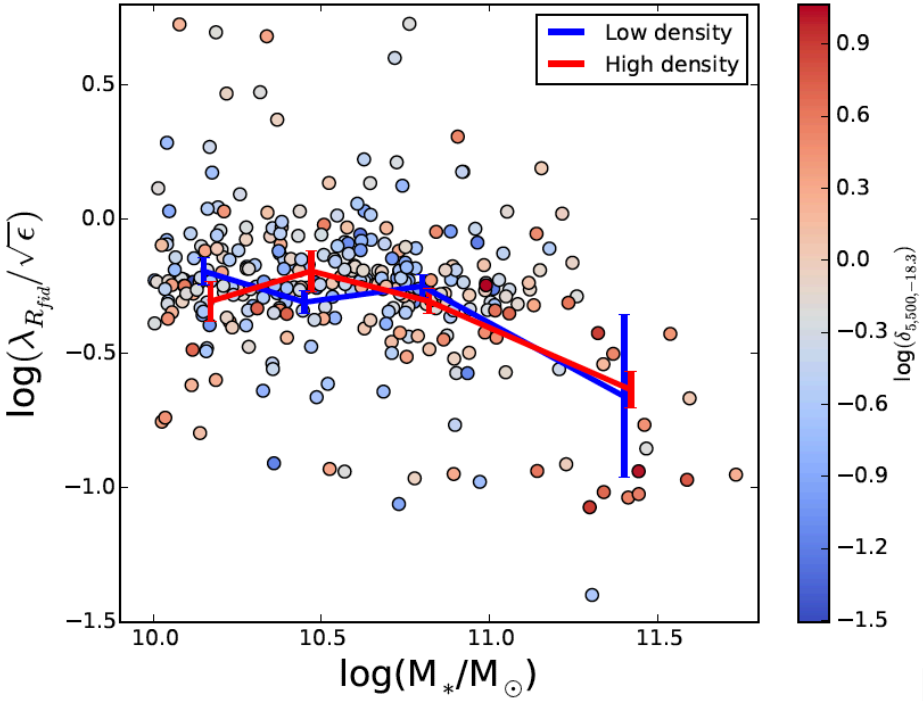
The role of environment in building slow rotators

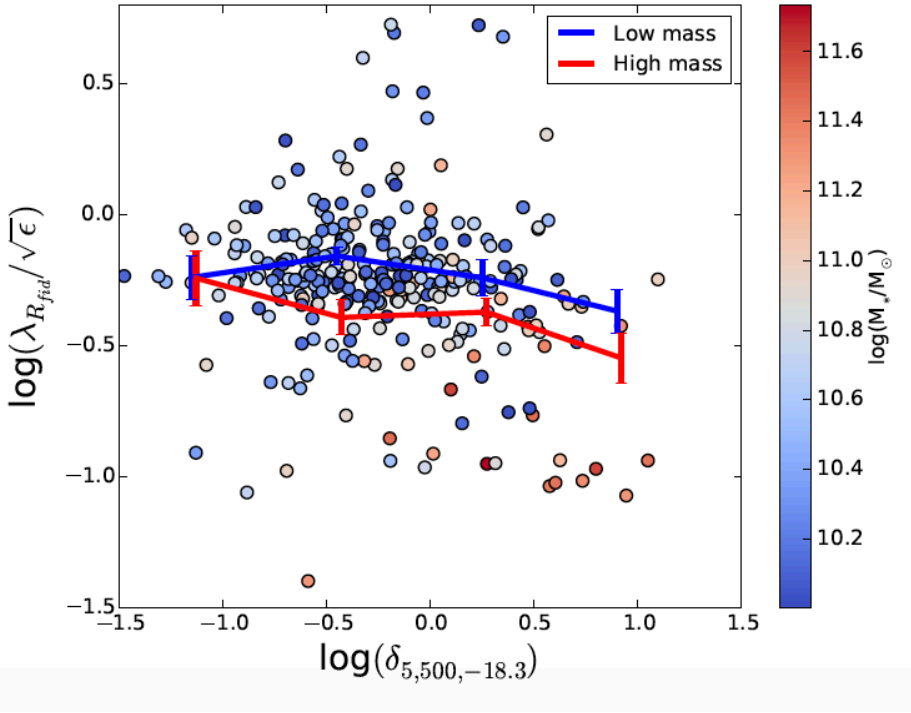
- Increased fraction of slow rotators in cluster centres
  (Cappellari et al. 2011b; Cappellari 2013; Houghton et al. 2013;
  D'Eugenio et al. 2013; Scott et al. 2014; Fogarty et al. 2014).

(Brough+17)



Fraction of slow rotators correlates stronger with stellar mass than environment (Brough+17)





- The cluster kinematic morphology-density relationship likely due to mass segregation via dynamical friction.
- Also recently seen in ATLAS3D+MASSIVE (Veale et al. 2017).

Hydro Simulations suggest that galaxies with similar λ_{re}- ε values can have very different assembly histories

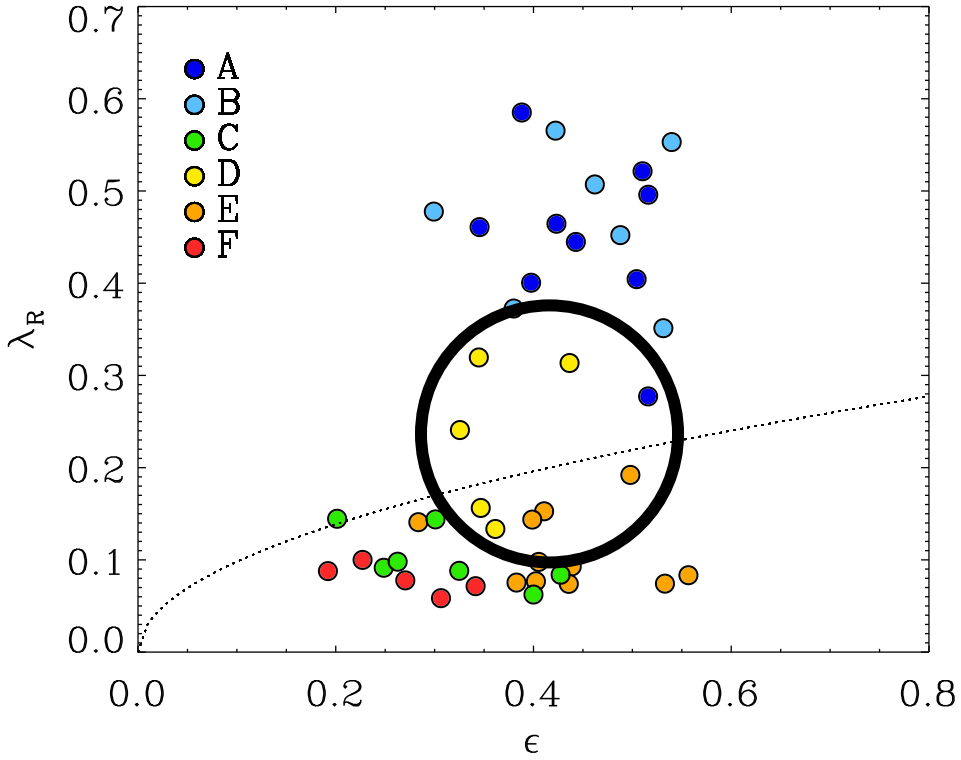
Naab et al. 2014

A. FRs with **gas-rich** minor-mergers

B. FRs with late **gas-rich** major mergers.

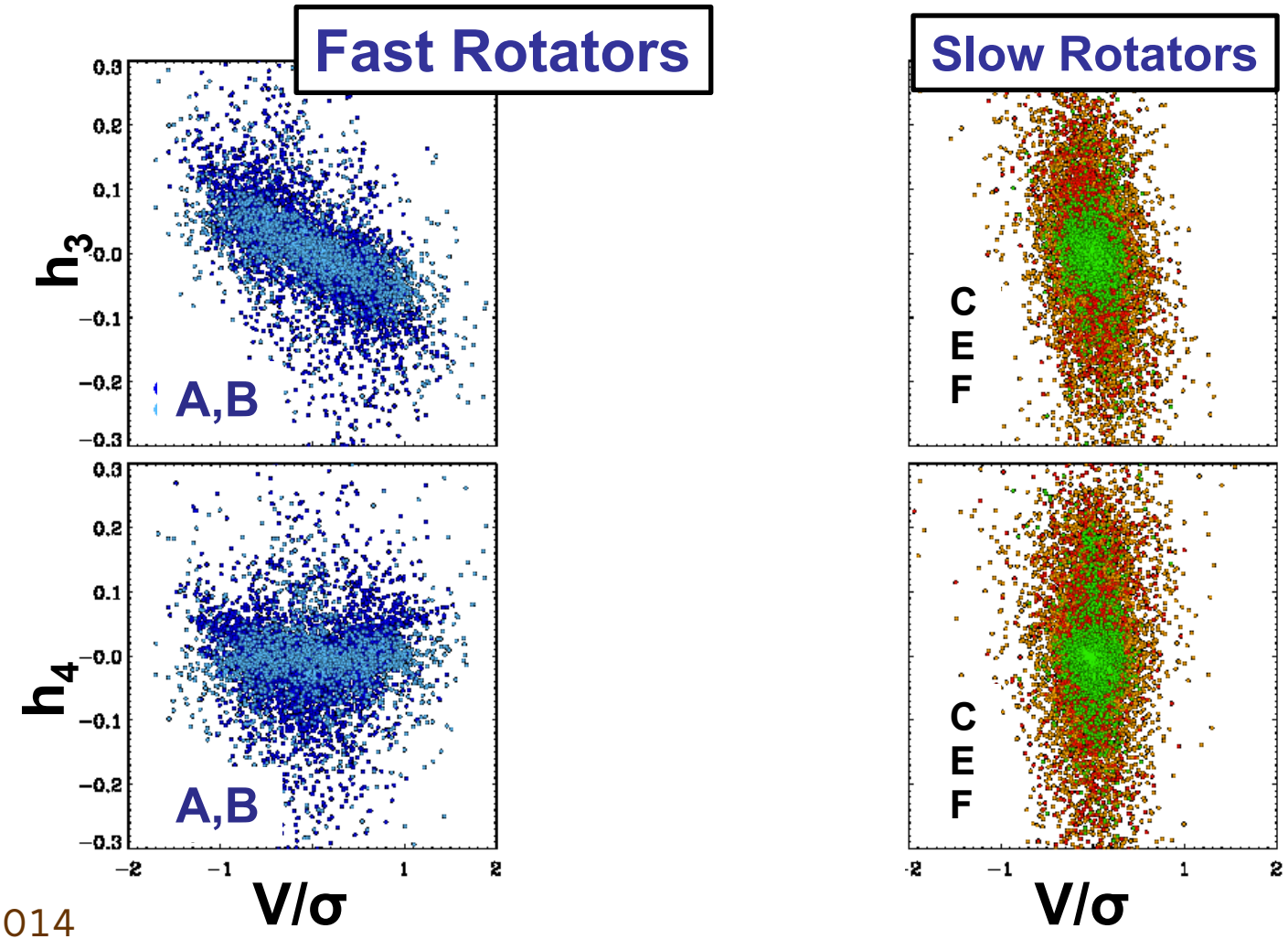
D. FRs with late **gas-poor** major mergers.

C. E. F. Slow rotators



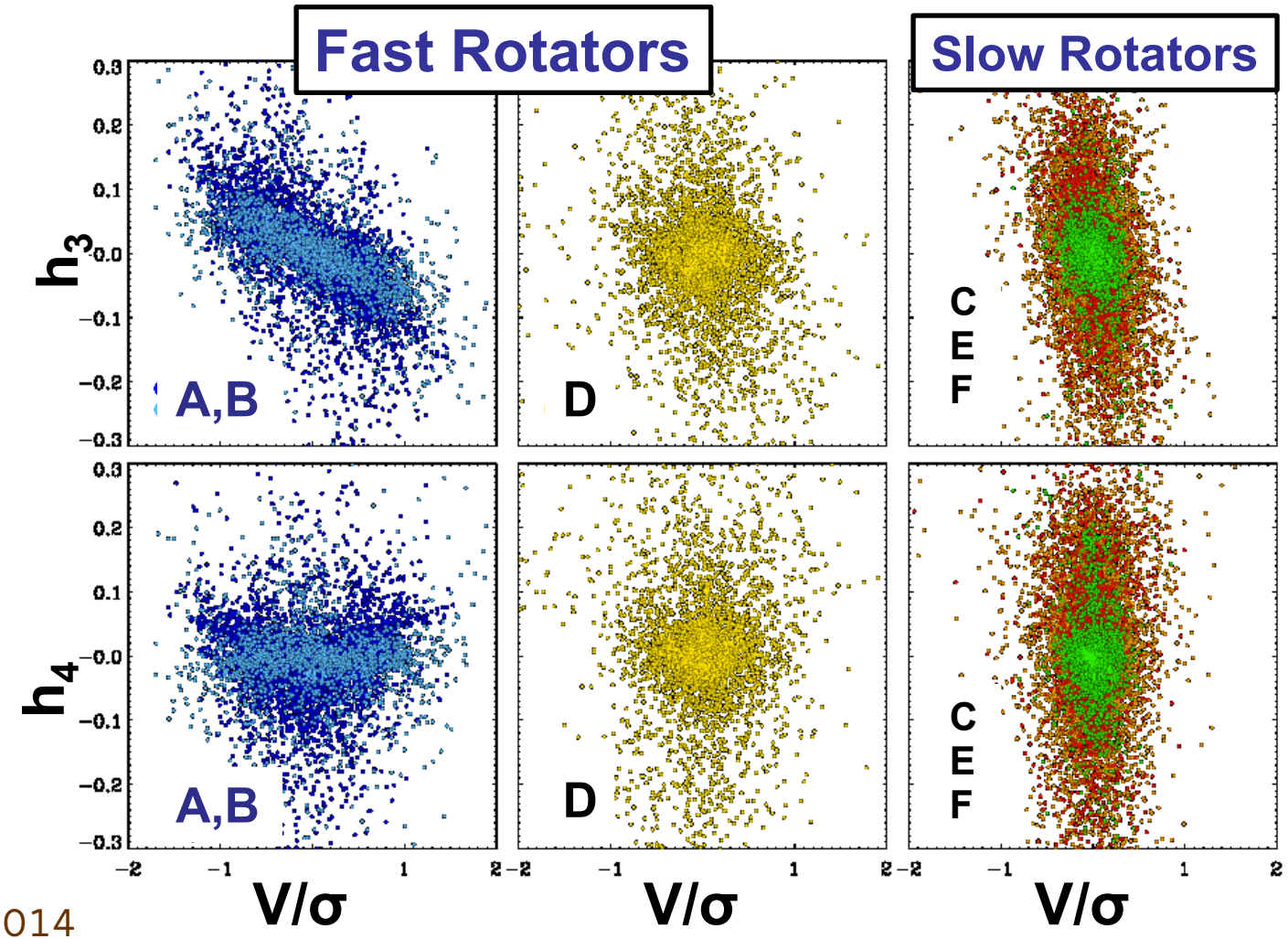
To better understand the assembly and merger history of individual galaxies, we have to study high-order kinematic features.

FRs with gas-rich mergers show a strong h_3-(v/σ) anti-correlation

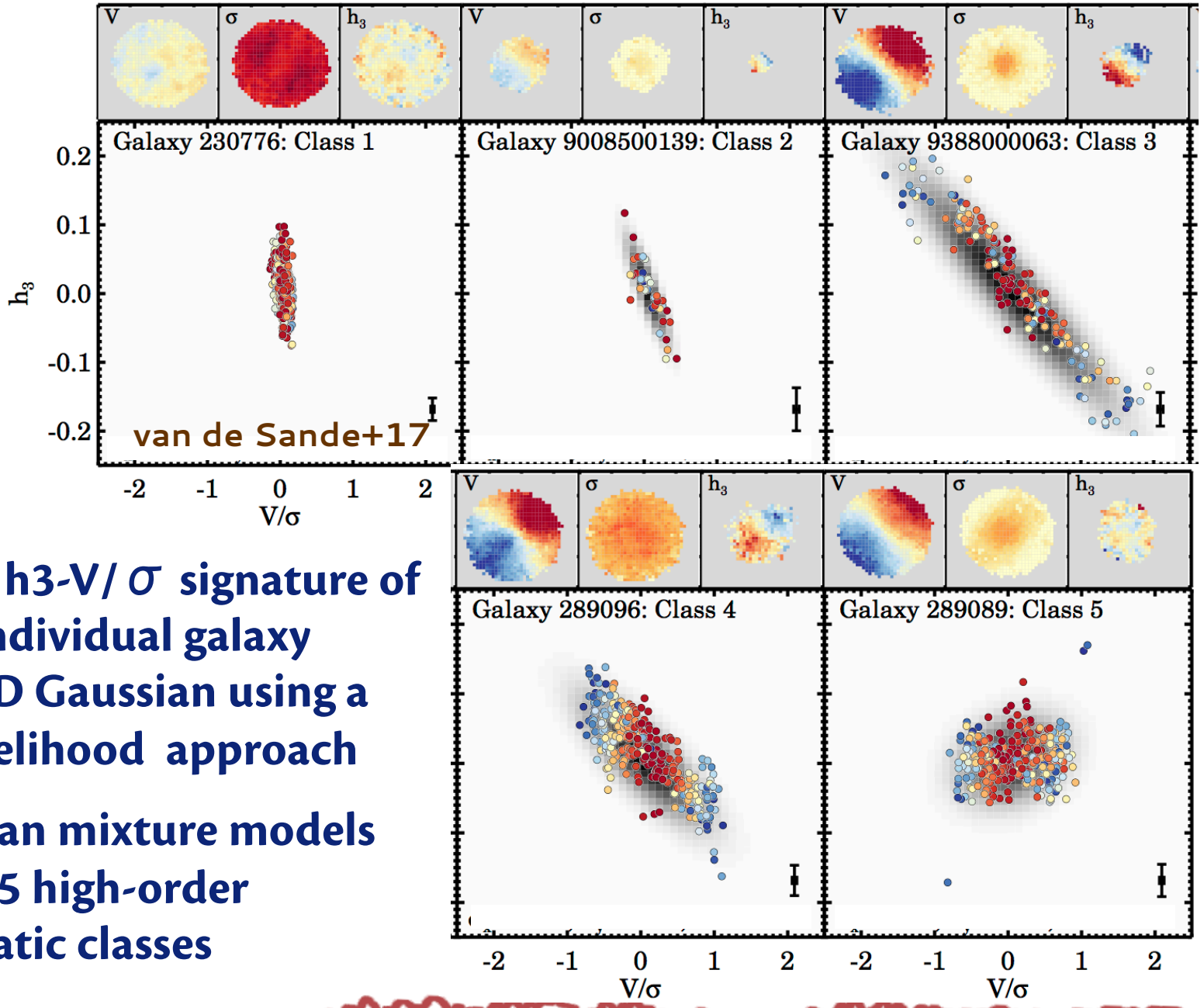


Naab et al. 2014

FRs with gas-rich mergers show a strong h_3-(v/σ) anti-correlation; **FRs with gas-poor mergers do not**



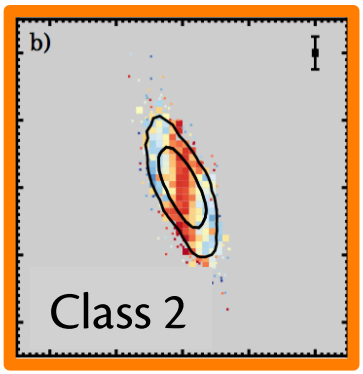
Naab et al. 2014

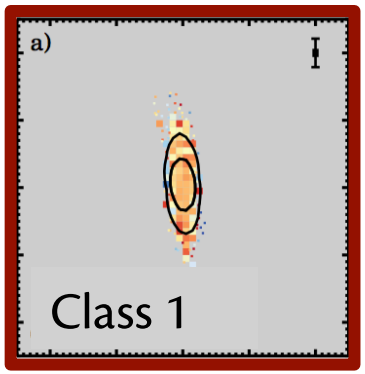


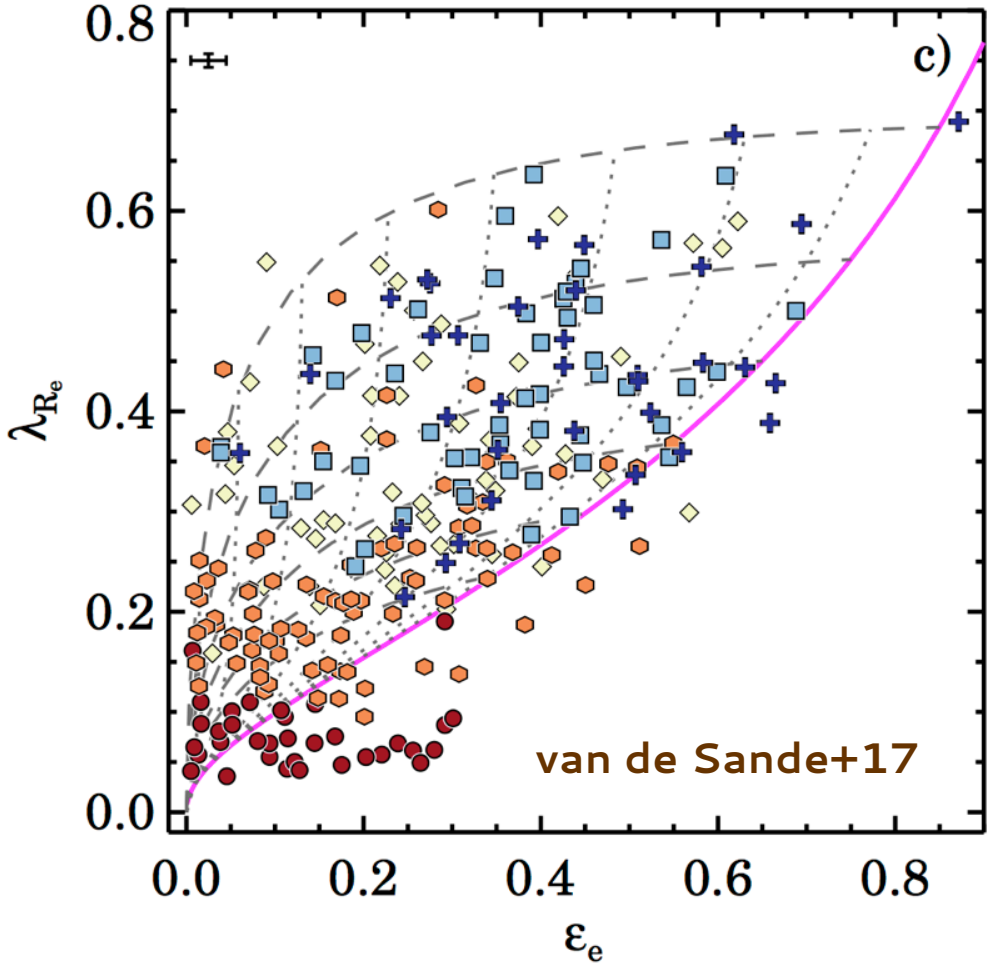
Model h3-V/σ signature of each individual galaxy with 2D Gaussian using a log-likelihood approach

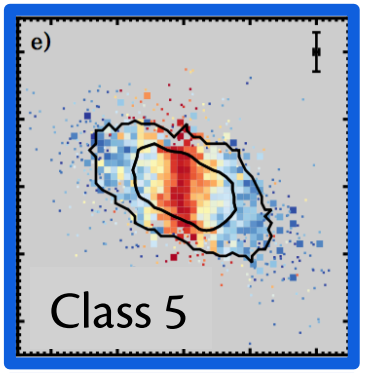
Gaussian mixture models reveal 5 high-order kinematic classes

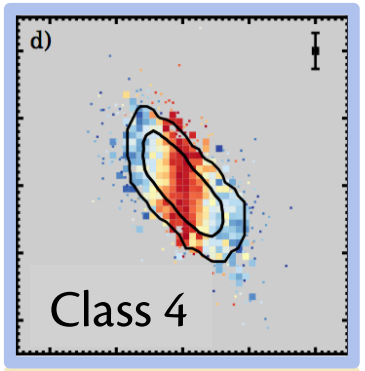
Galaxies with similar λ_{re}- ε values can show different h_3-V/σ signatures

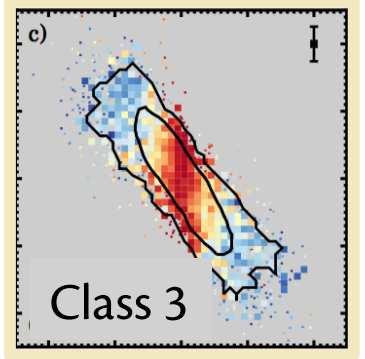






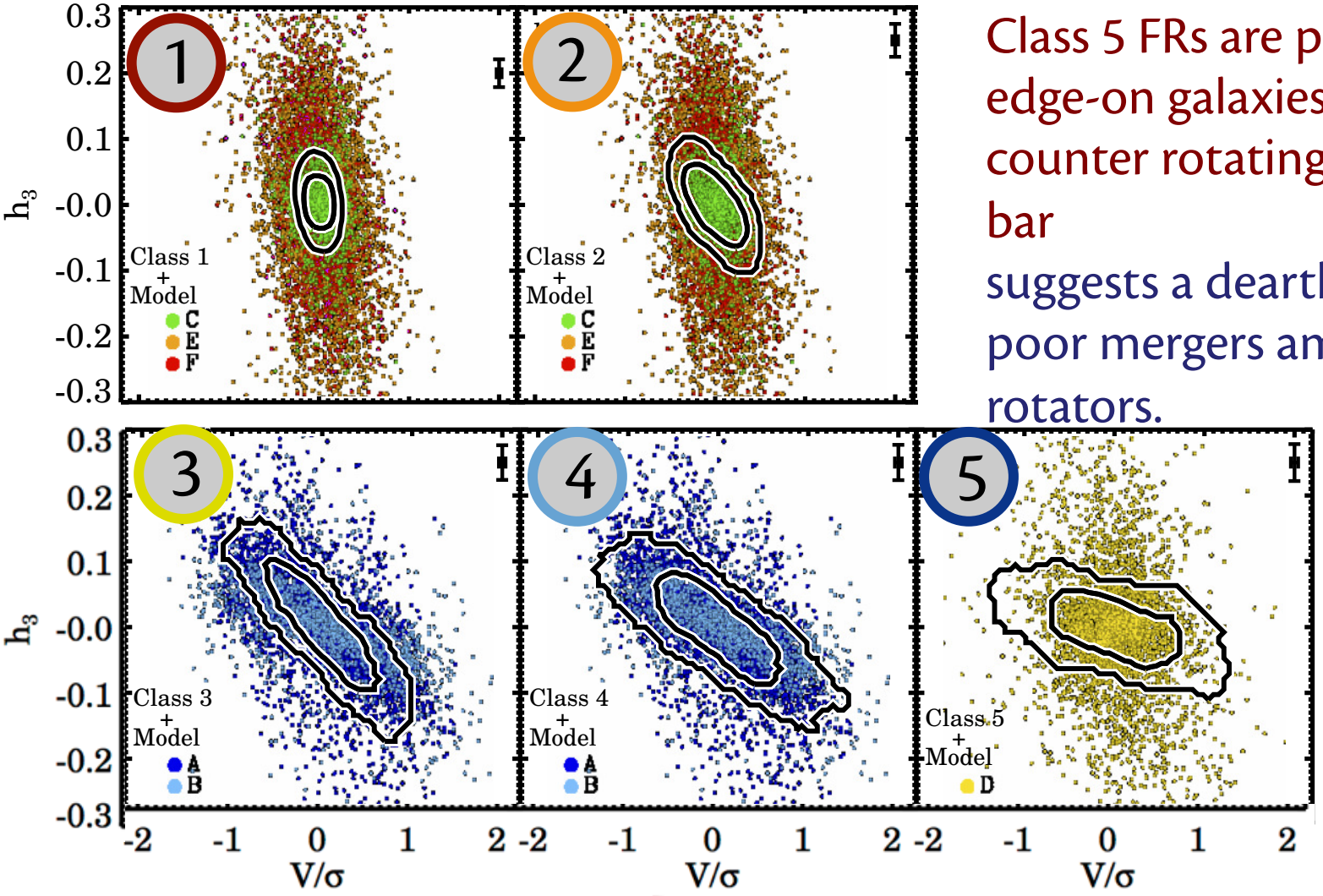






Revisiting galaxy classification through high-order stellar kinematics with SAMI

van de Sande+17



Class 5 FRs are probably edge-on galaxies with counter rotating disc or bar

suggests a dearth of gas-poor mergers among fast rotators.

Take Home Message

- **IFS surveys (SAMI, MaNGA, CALIFA, ATLAS^{3D}, MASSIVE) are now mass-producing 2D spatially resolved stellar population and kinematic measurements in galaxies (N> 2500)**

- **SAMI Galaxy Surveys highlighted here today:**
  - Galaxies of all types lie on a plane relating mass, angular momentum and stellar-light distribution (Cortese+16)
  - Fraction of slow rotators correlates stronger with stellar mass than environment (Brough+17)
  - Galaxies with similar λ_{re}-ε values can show different h_3-V/σ signatures that can be linked to their individual assembly history (van de Sande+17)