The connection between mass, environment and slow rotation in simulations

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MERAC

Australian Government
Australian Research Council

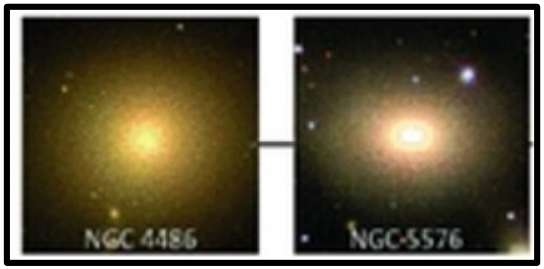
CAASTRO ALL-SKY ASTROPHYSICS

Curtin University

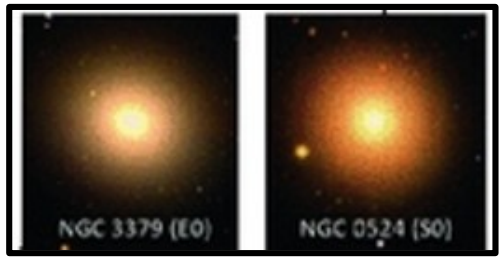
The University of Western Australia

Kinematics as a morphological classification

Slow rotators

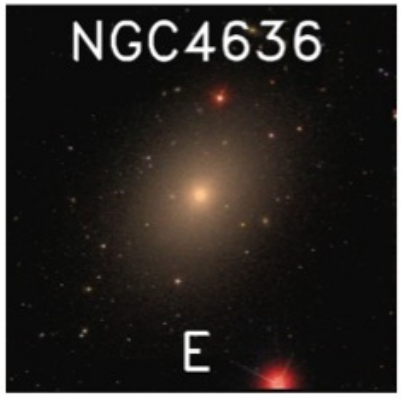


Fast rotators

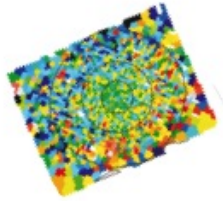


Emsellem et al. (2007):
The stellar spin parameter

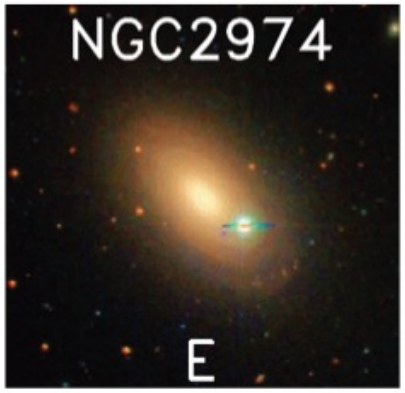
$$\lambda_R = \frac{\sum_i L_i r_i |V_i|}{\sum_i L_i r_i \sqrt{V_i^2 + \sigma_i^2}},$$

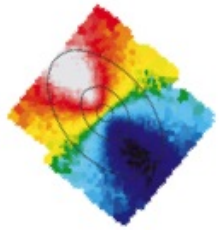


ATLAS^{3D} velocity fields

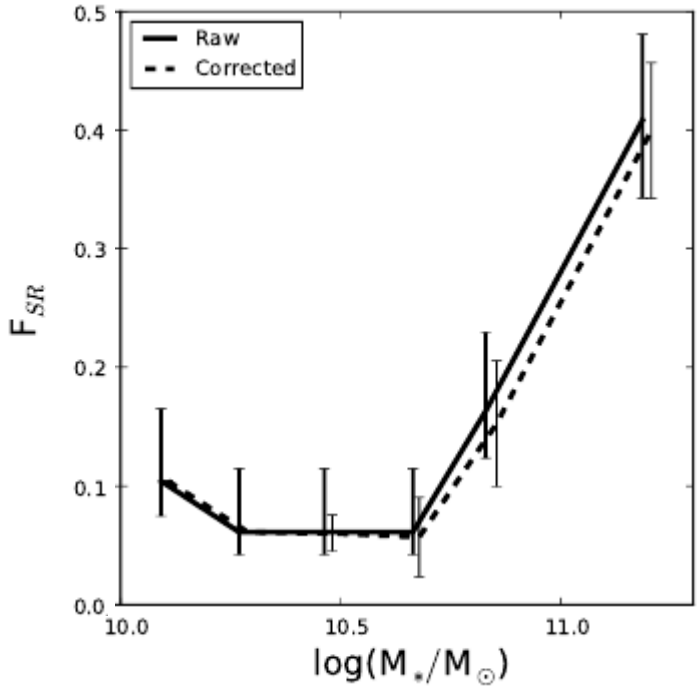


Slow rotator (λ_R = 0.04), ± 40 km/s





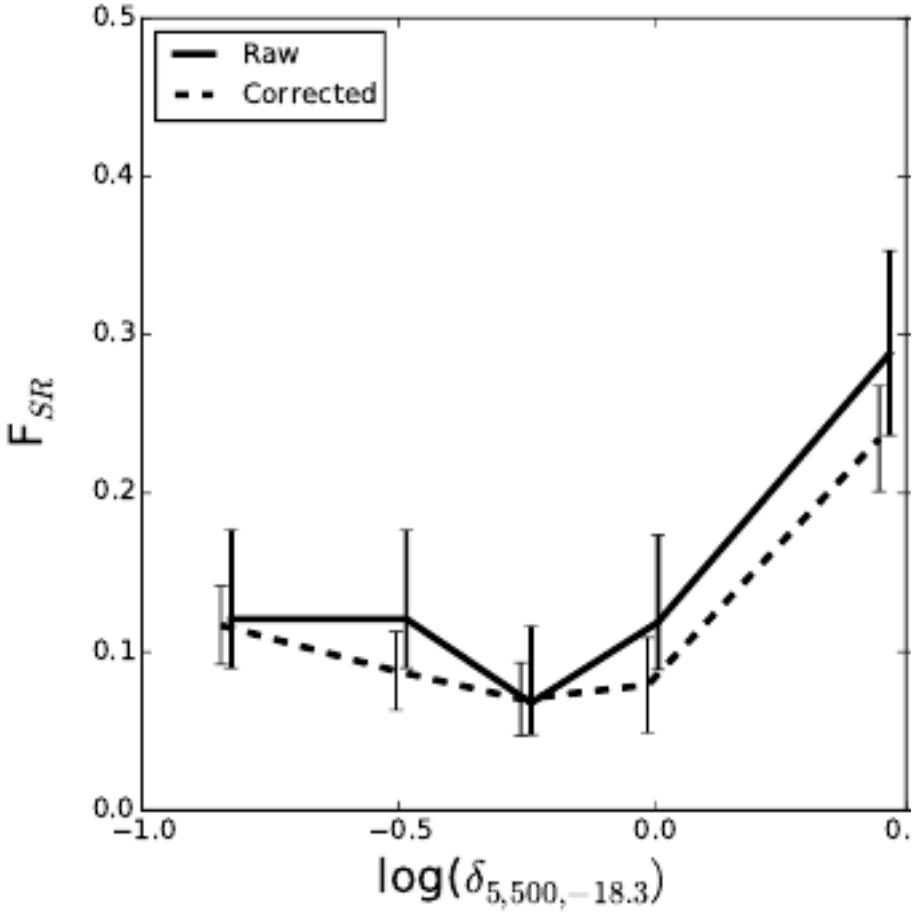
Fast rotator (λ_R = 0.66), ± 220 km/s

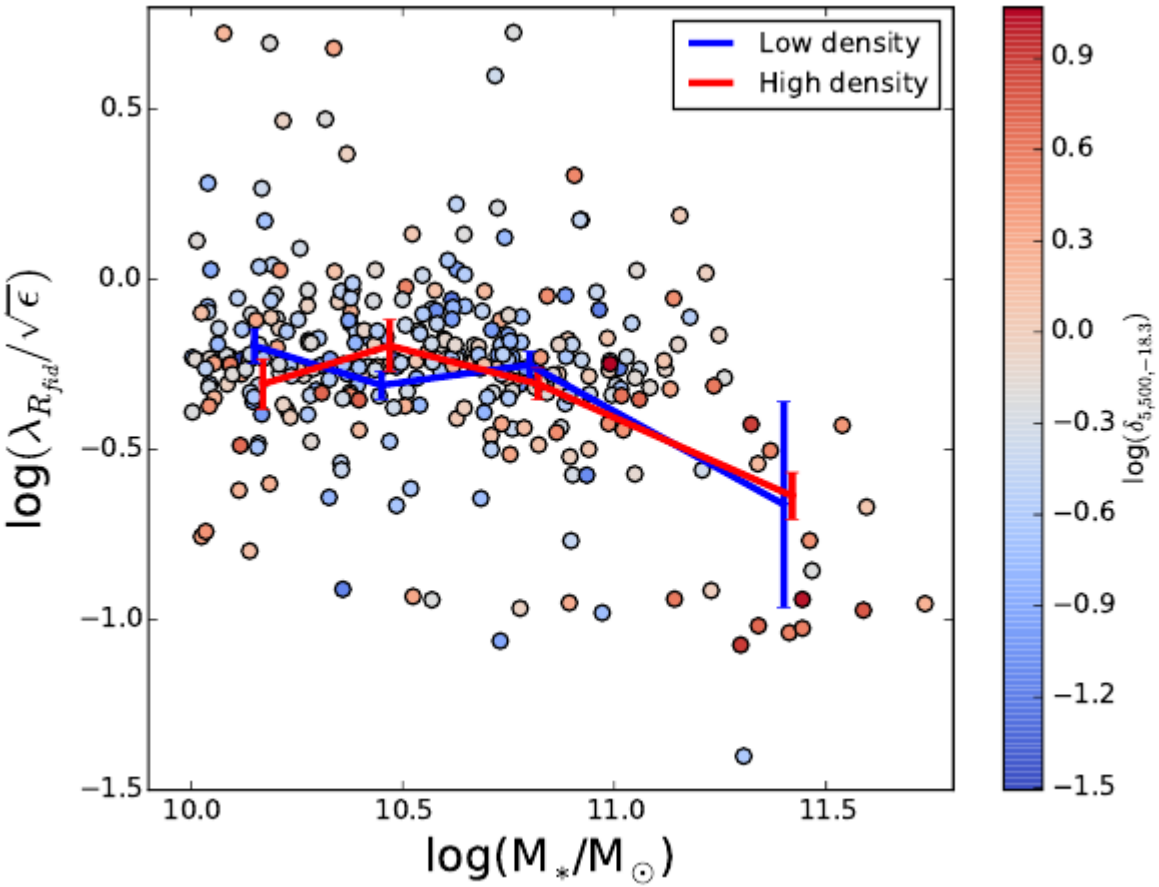


Brough et al. (2017; SAMI)

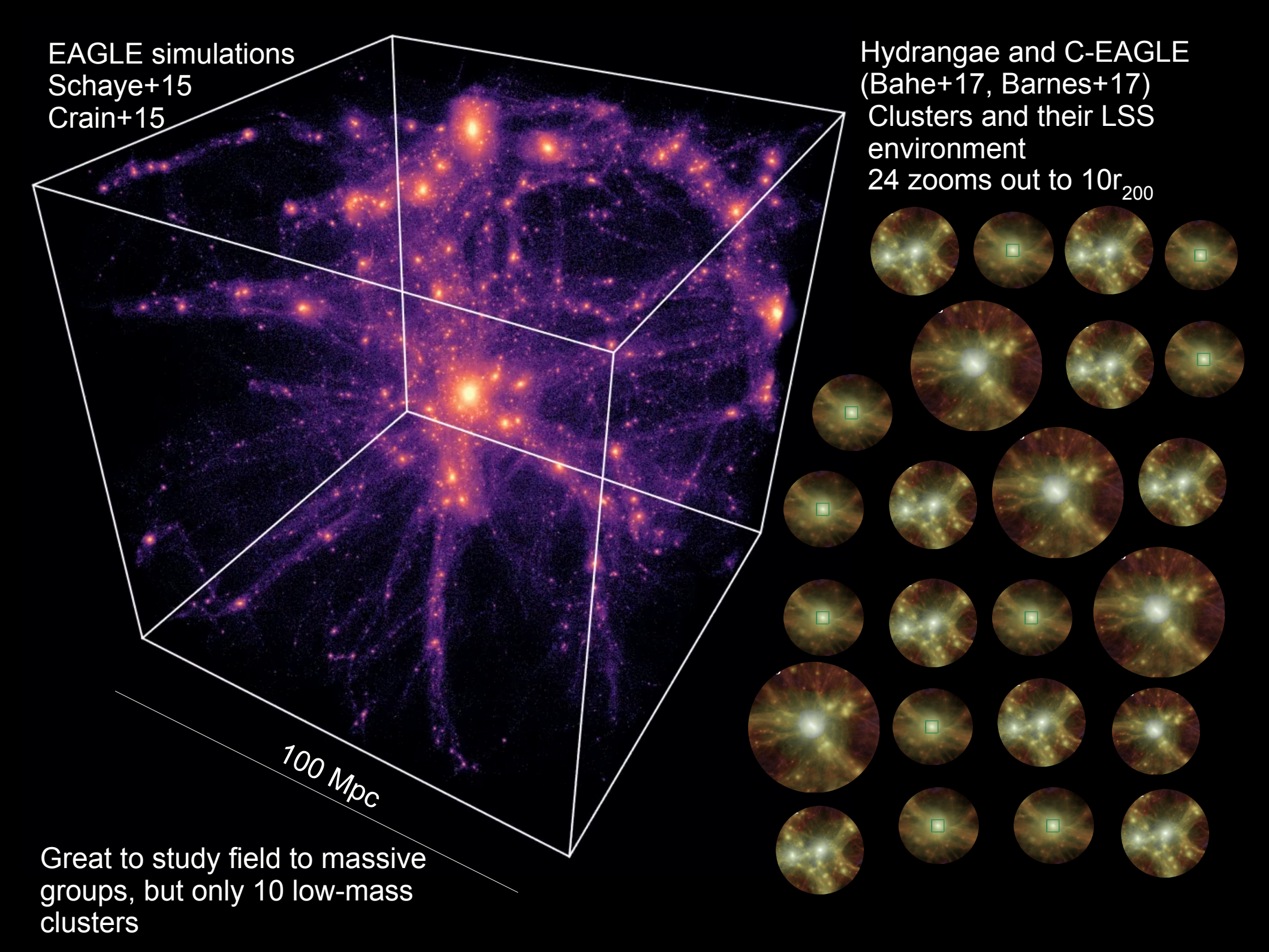
The (lack of) environmental effect

Brough et al. (2017; SAMI) (see also Veale et al. 2017 and Greene et al. 2017)





Are the simulations **consistent with the lack** of environmental effect?
If there are environmental effect where can they be more easily found?
How are slow rotators formed?


EAGLE simulations
Schaye+15
Crain+15
Hydrangae and C-EAGLE
(Bahe+17, Barnes+17)
Clusters and their LSS
environment
24 zooms out to 10r200
100 Mpc
Great to study field to massive
groups, but only 10 low-mass
clusters

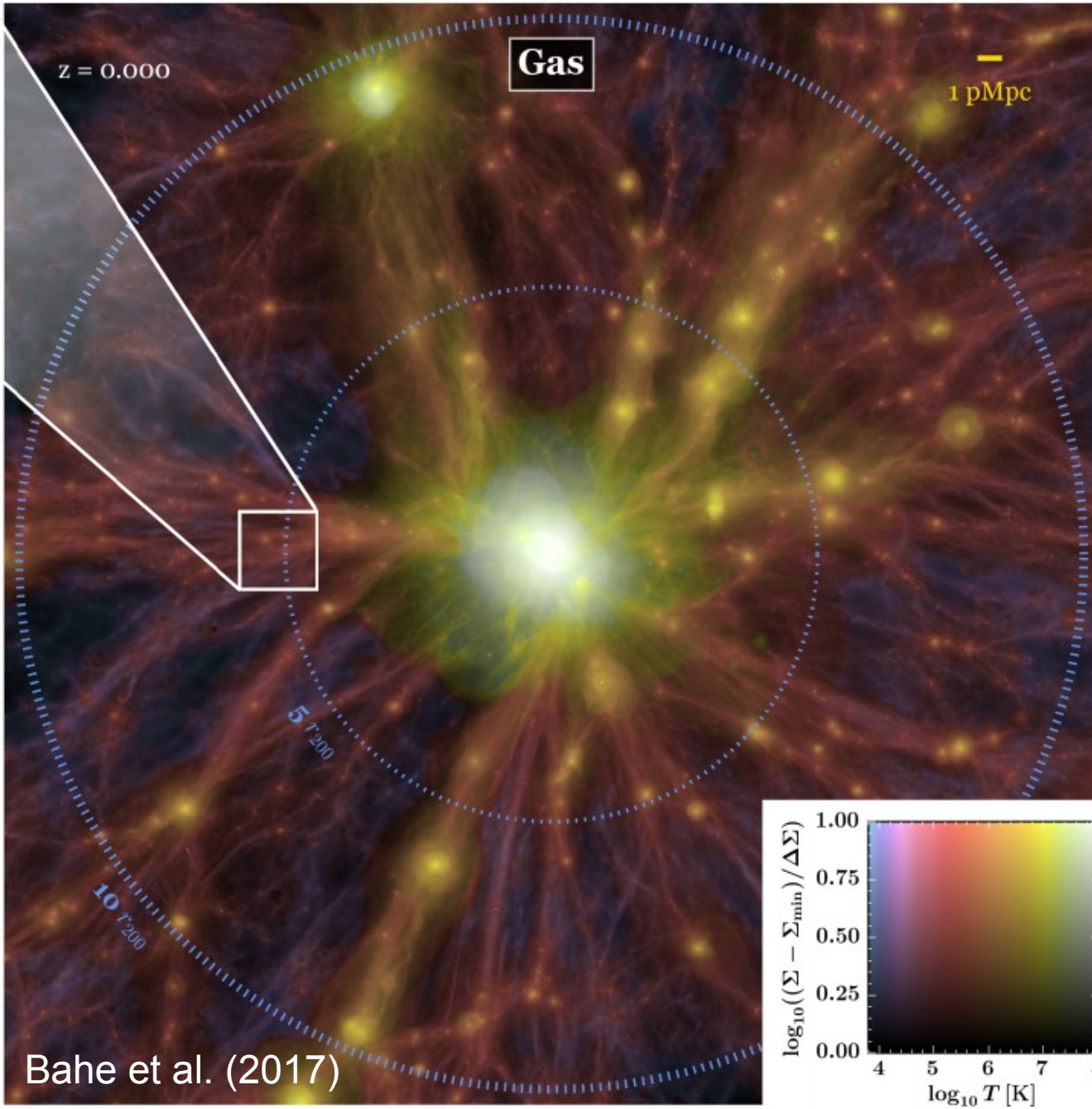
The complementarity of EAGLE and C-EAGLE

Same code (model, numerical technique, time stepping, etc.)

→ Improved hydrodynamics (Anarchy)
→ Metal-dependent cooling
→ Reionisation
→ Star formation
→ Stellar recycling
→ SNe feedback
→ AGN feedback

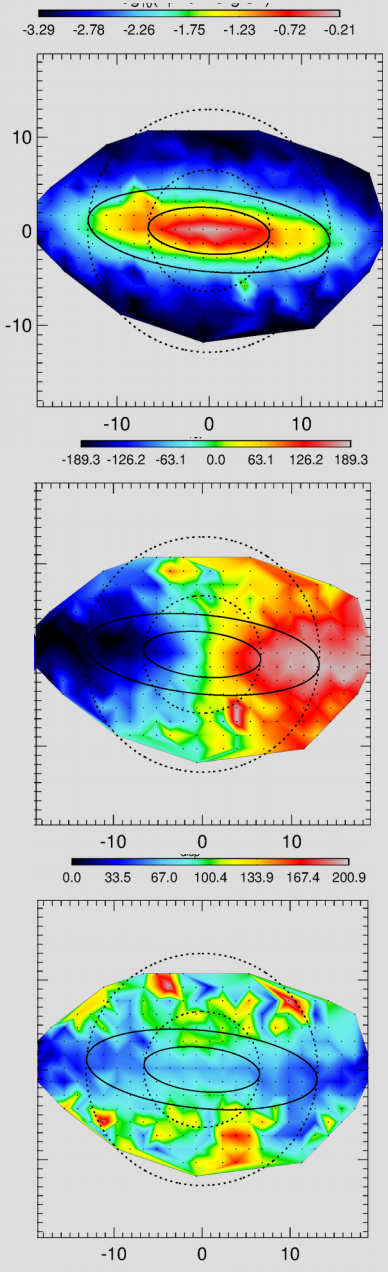
(~700pc resolution, 1e6Msun)

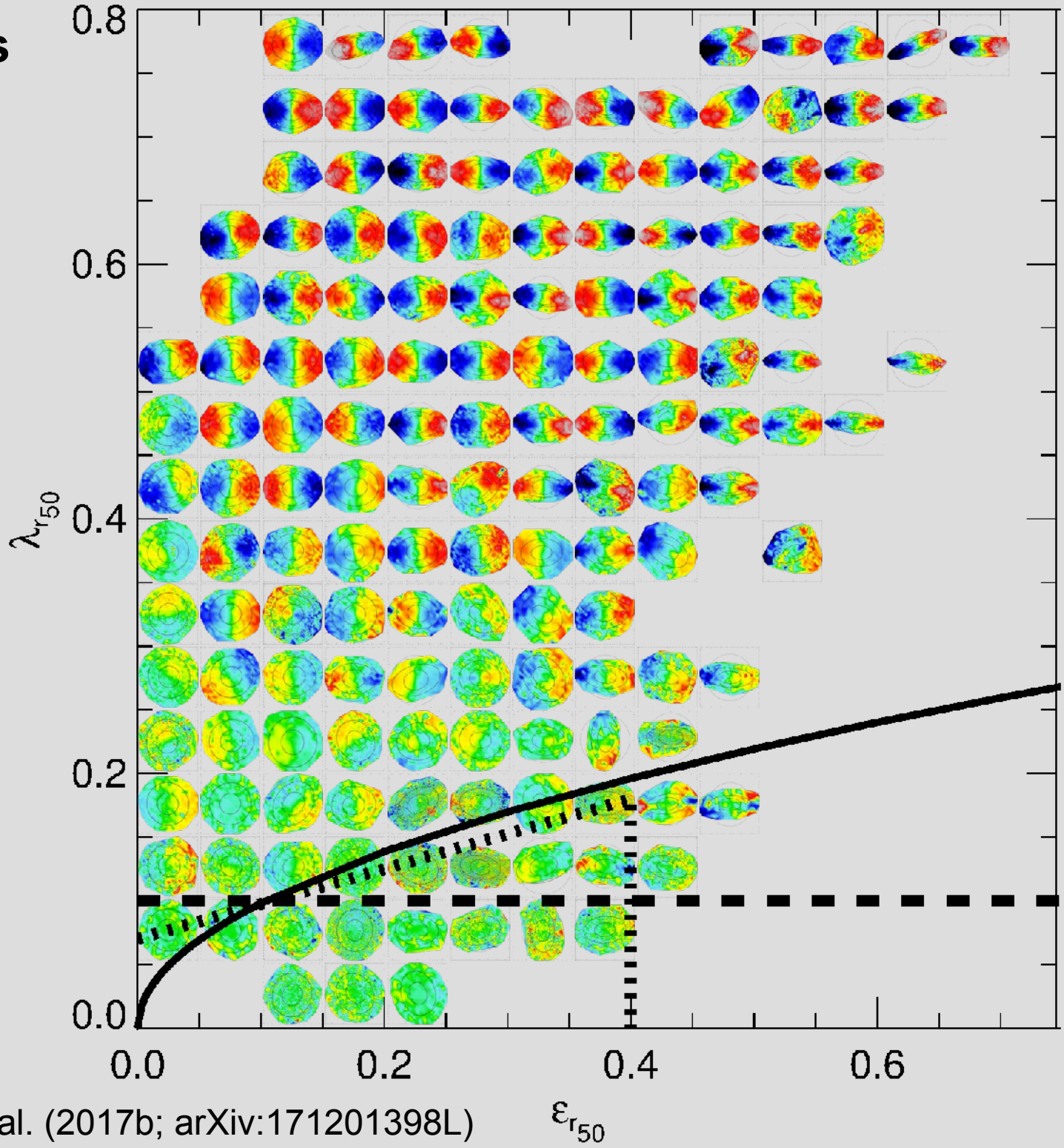
At z=0:
44 clusters (>$10^{14}M_o$)
16,431 galaxies >$10^{9.5}M_o$
Perfect to study
environmental/mass effects!



Bahe et al. (2017)

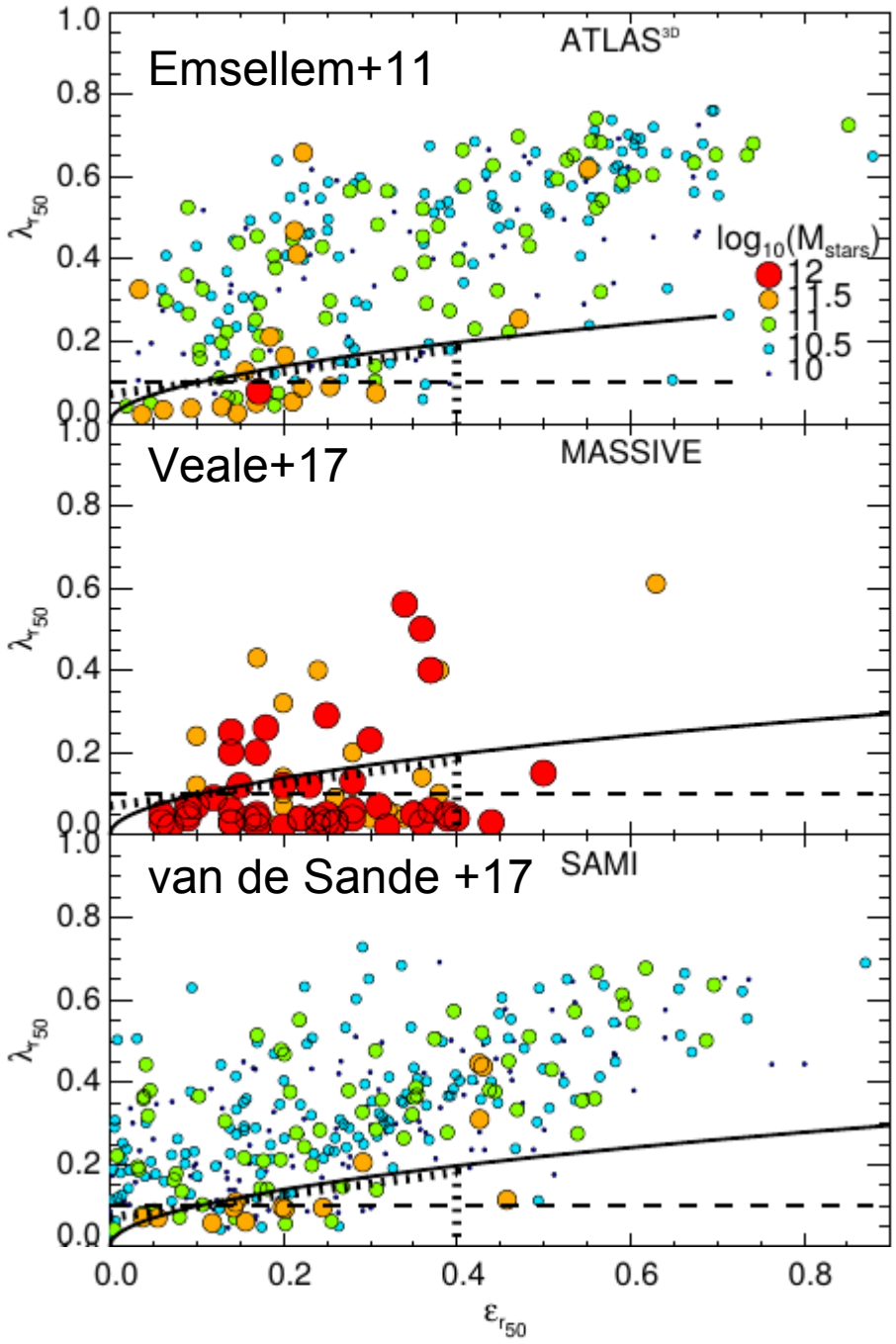
Building IFU cubes for simulated galaxies



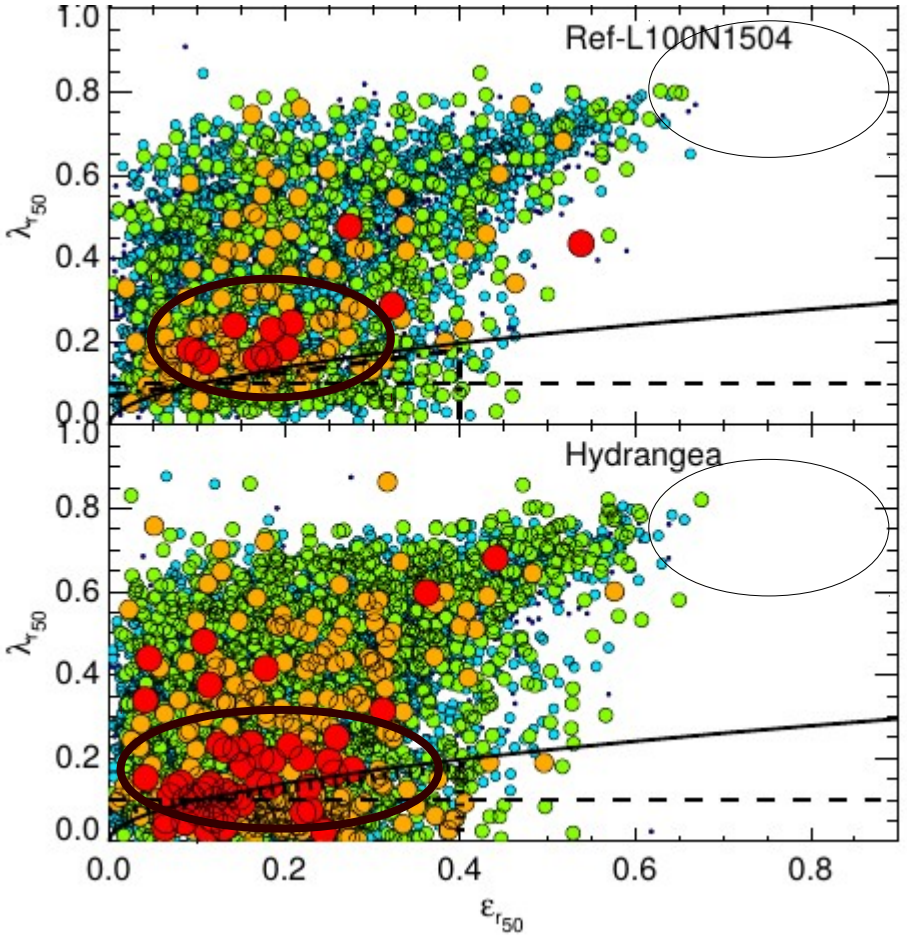


Lagos et al. (2017b; arXiv:171201398L)

Selecting slow rotators: the λ_R -ε view



No very thin galaxies: ISM modelling imposing a minimum scaleheight of ~1kpc

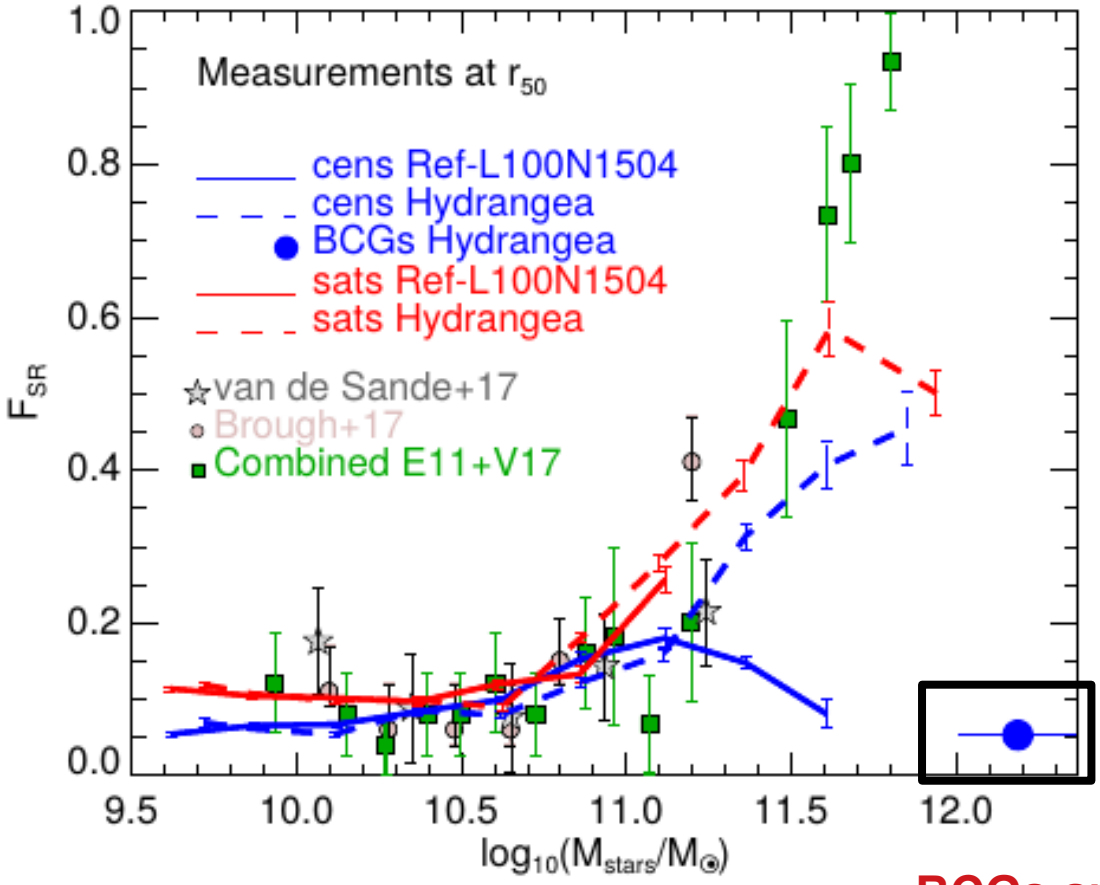


Very massive galaxies: overly rotating?

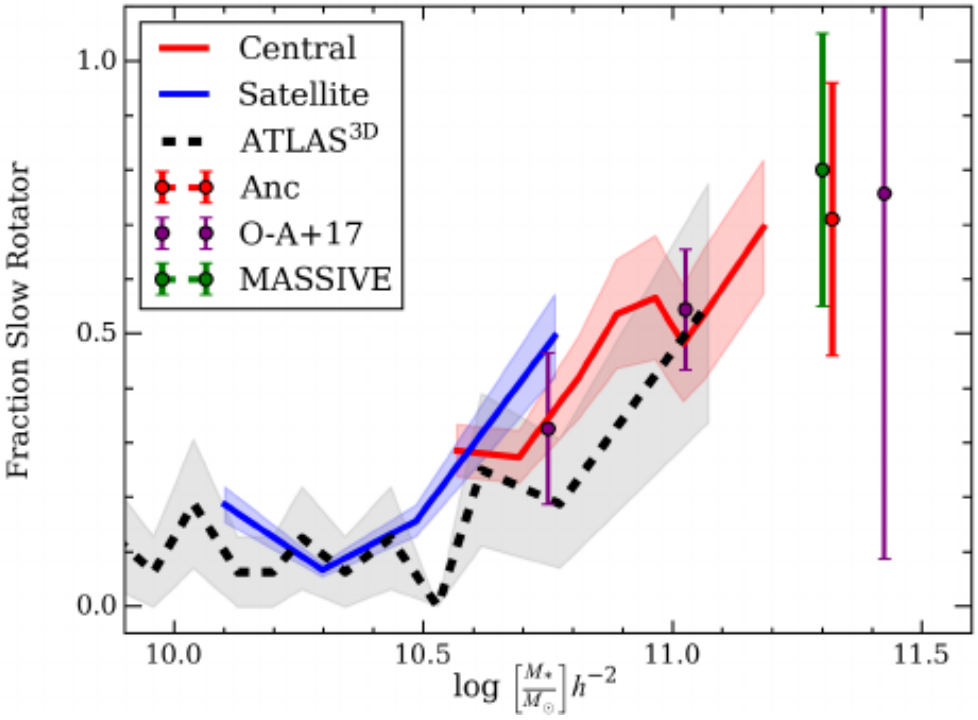
Lagos et al. (2017b; arXiv:171201398L)

Mass vs. environment

Lagos et al. (2017b; arXiv:171201398L)



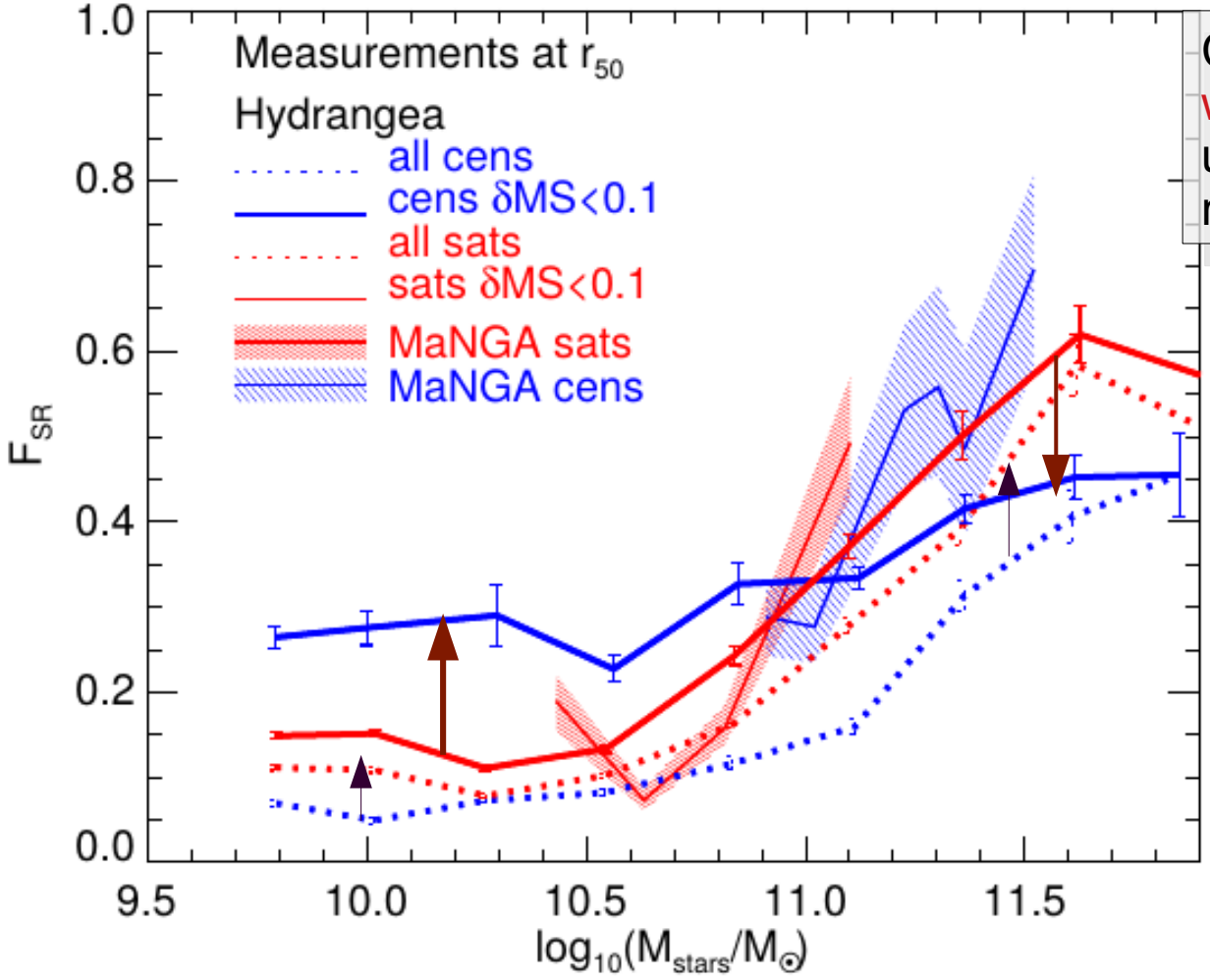
Greene et al. (2017; MaNGA)



BCGs are almost all fast rotators!:
too massive for their halo mass, AGN feedback not strong enough (Bahe+17, Barnes+17)

Mass, environment and quenching

Lagos et al. (2017b; arXiv:171201398L)



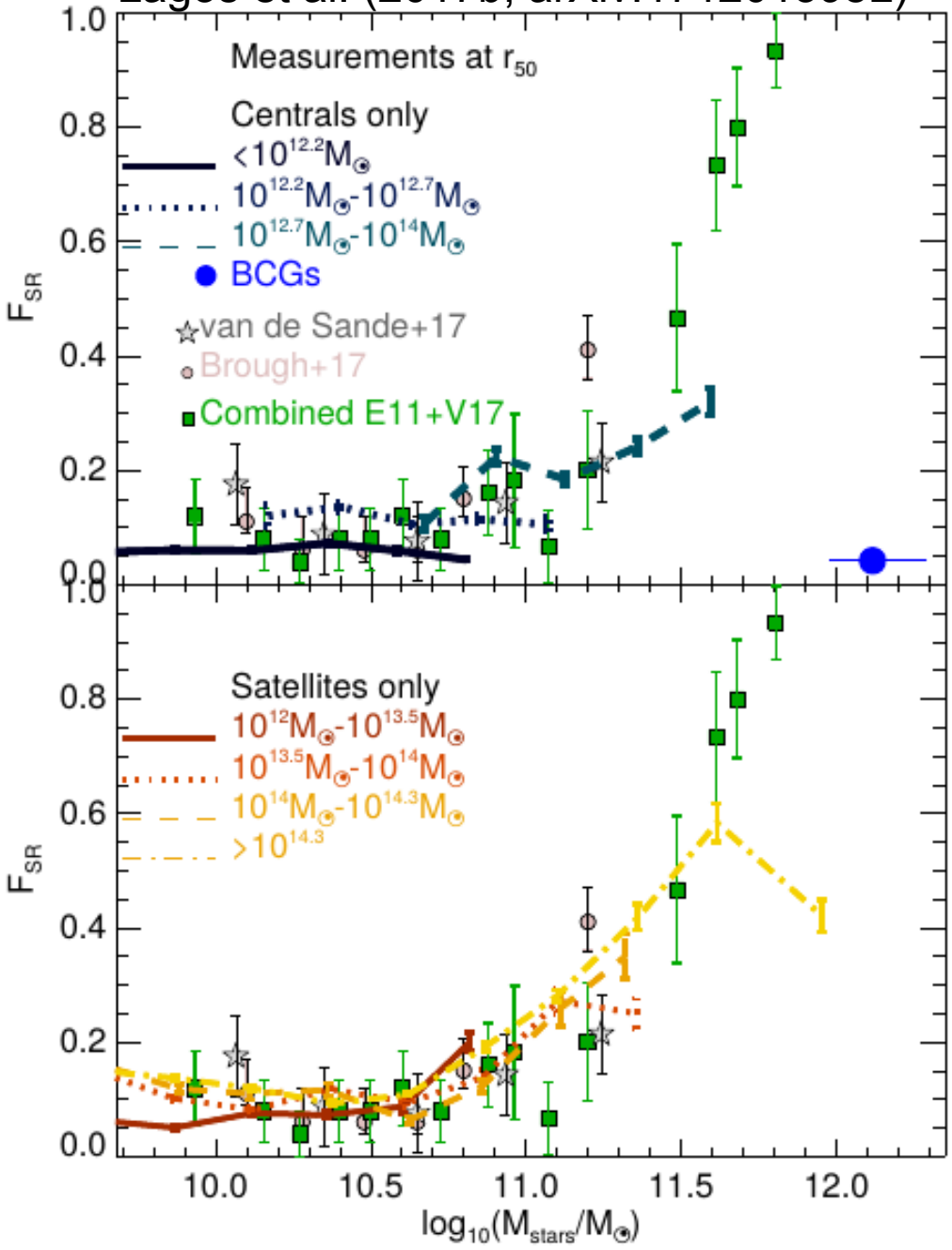
Centrals undergo quenching together with morph transformation, while sats undergo quenching without having morph transformation necessarily

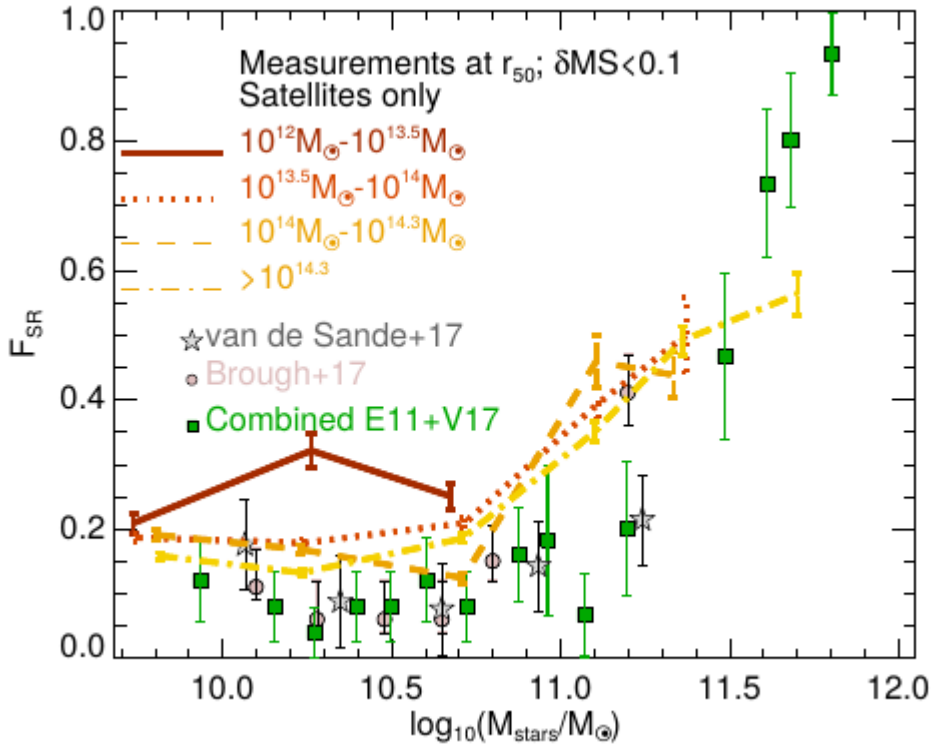
See Correa et al. (2017): quantified this in EAGLE in terms of B/T.

Observers: please go and measure FSR for satellite/centrals passive/active!

Effect of environment on slow rotators

Lagos et al. (2017b; arXiv:171201398L)

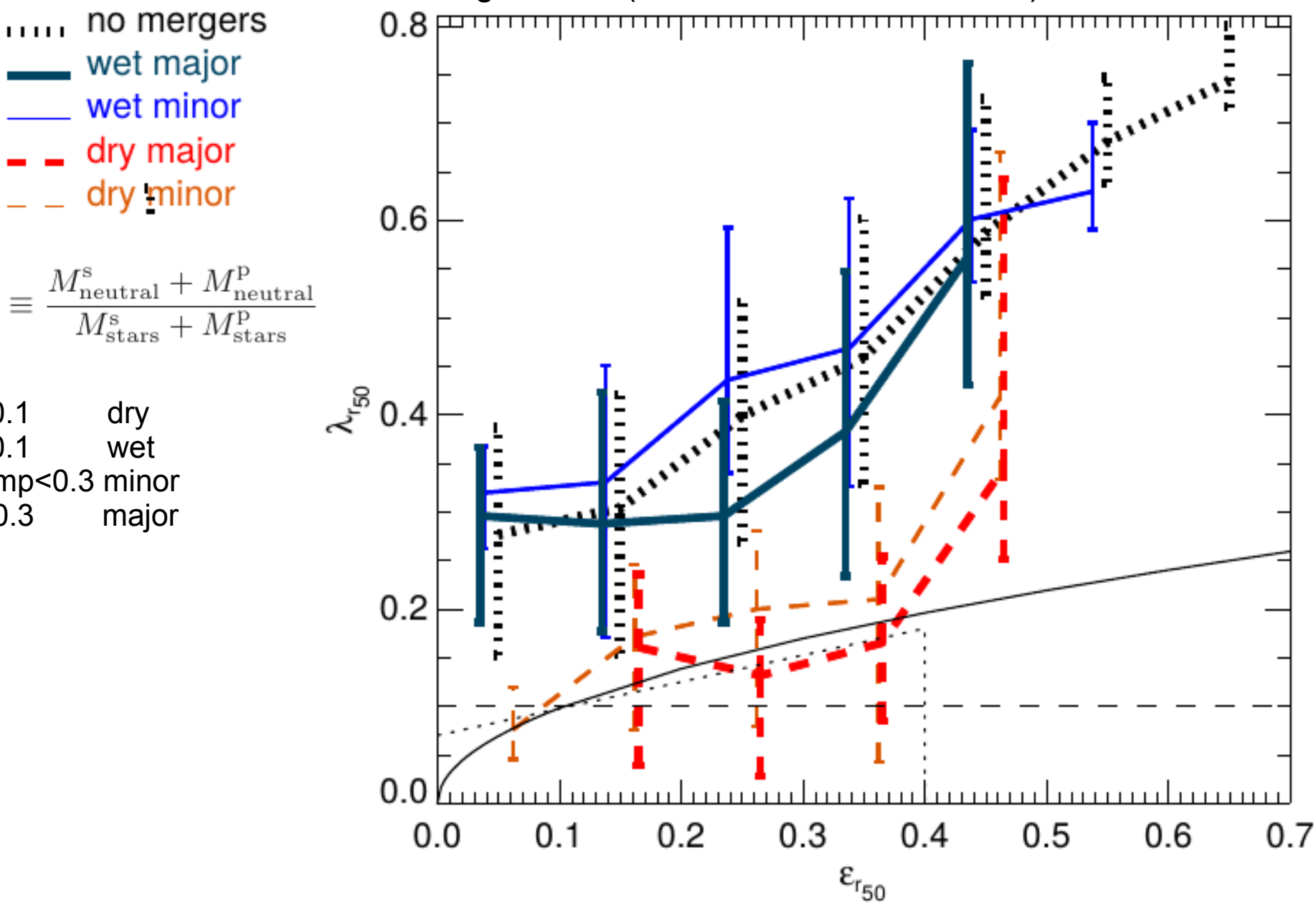




Satellite galaxies in low mass halos need to have had morph transformation in order to be passive

Formation mechanisms of slow rotators

Lagos et al. (2017b; arXiv:171201398L)

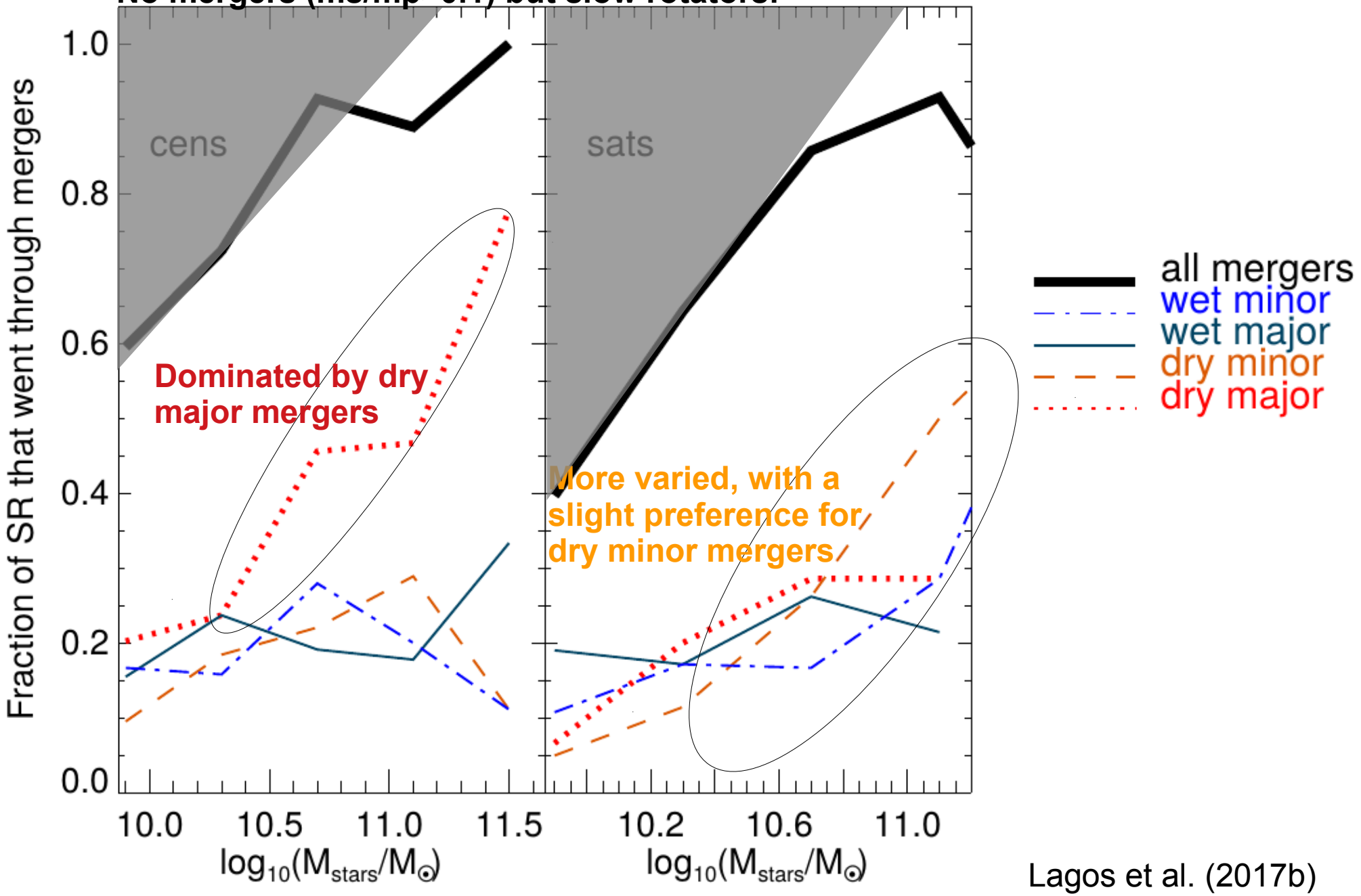


$$R_{\rm gas,merger} \equiv \frac{M^{\rm s}_{\rm neutral} + M^{\rm p}_{\rm neutral}}{M^{\rm s}_{\rm stars} + M^{\rm p}_{\rm stars}}$$

- Rgas < 0.1 dry
- Rgas > 0.1 wet
- 0.1<ms/mp<0.3 minor
- ms/mp>0.3 major

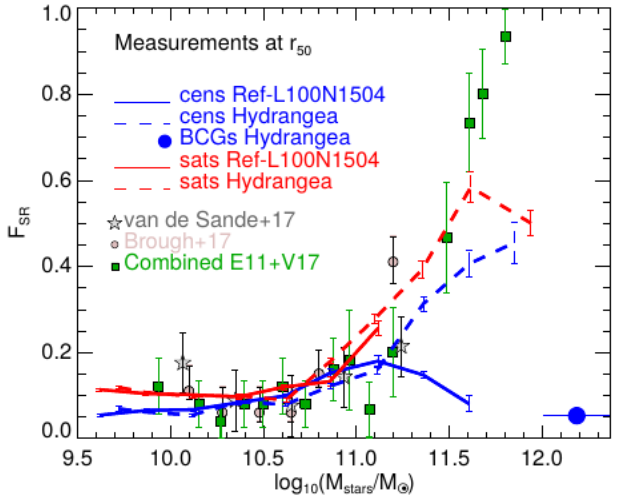
The incidence of mergers on SRs

No mergers (ms/mp>0.1) but slow rotators!

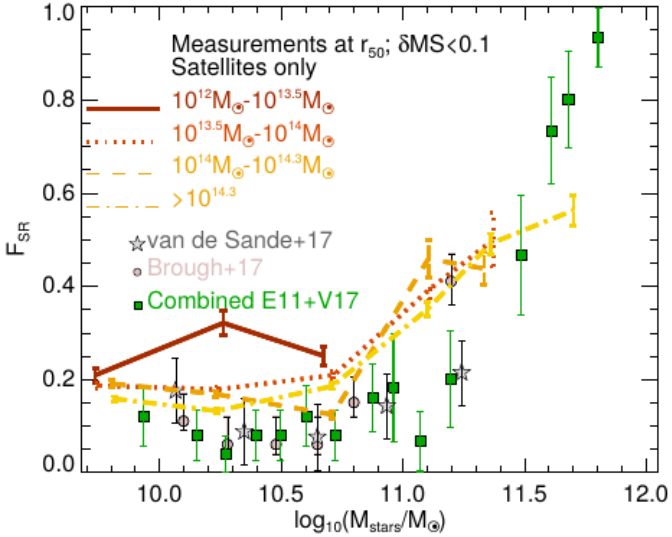


Lagos et al. (2017b)

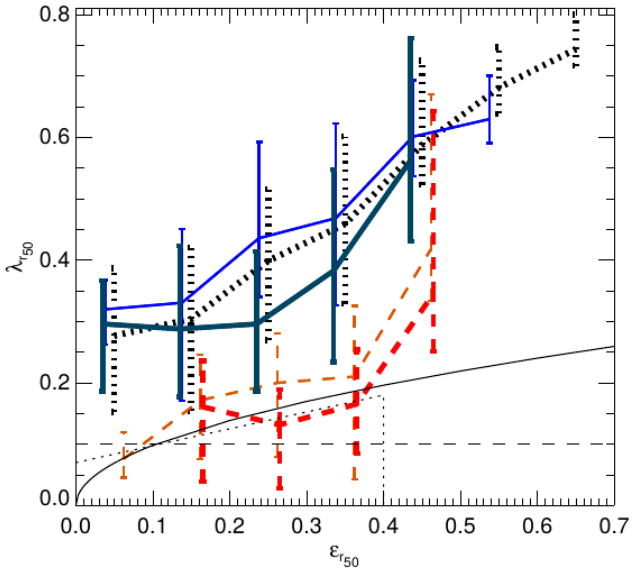
Conclusions



(1) **Combination of EAGLE+ C-EAGLE is very powerful.** The fraction of slow rotators vs. mass is relatively well reproduced, except for BCGs, which are overwhelmingly fast rotators.



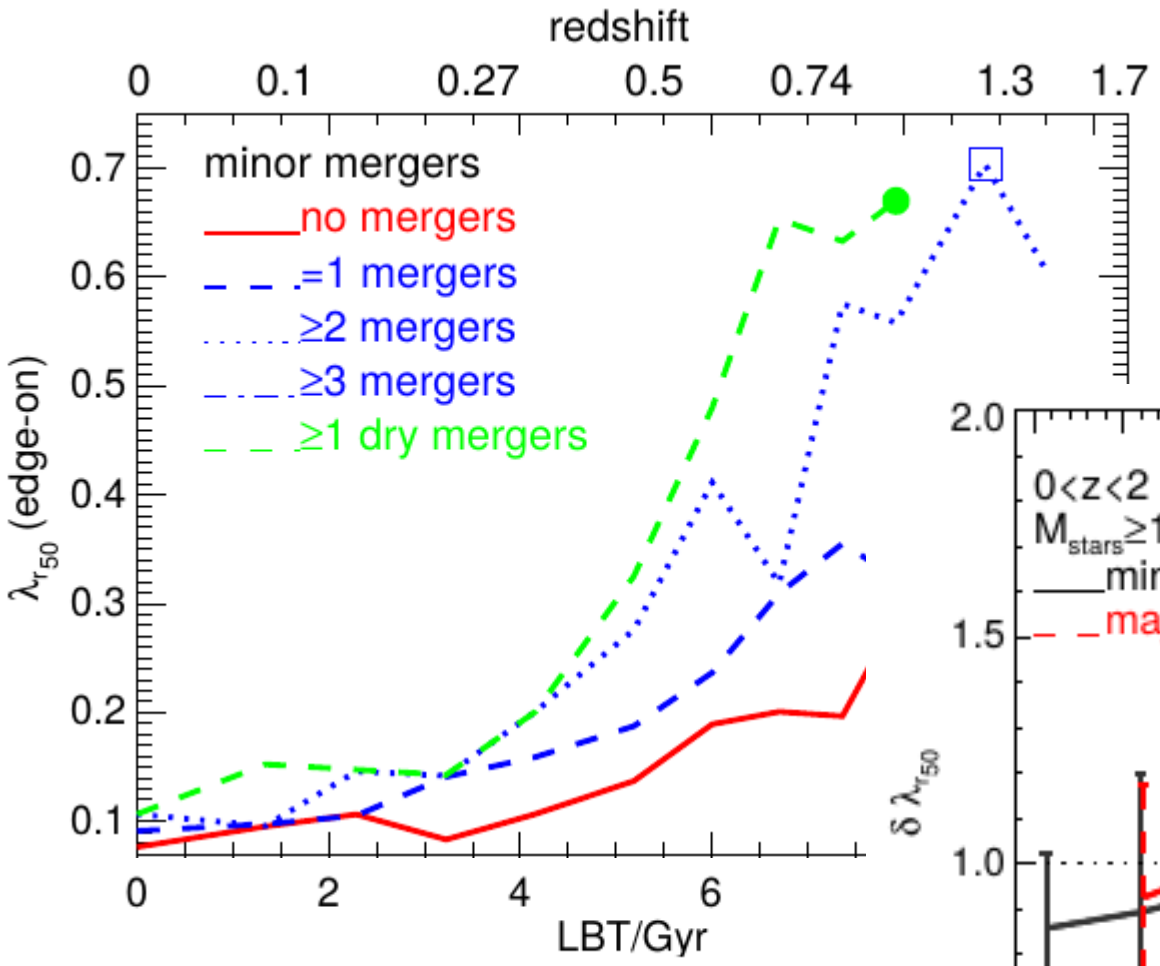
(2) **Environment appears to be a secondary effect**, but most clearly appears when we isolate central galaxies and satellite/passive galaxies:



(3) Formation path of slow rotators is varied, but **there is clear preference for dry major/minor mergers and low spin halos.**

Lagos et al. (2017b; arXiv:171201398L)

The cumulative effect of mergers



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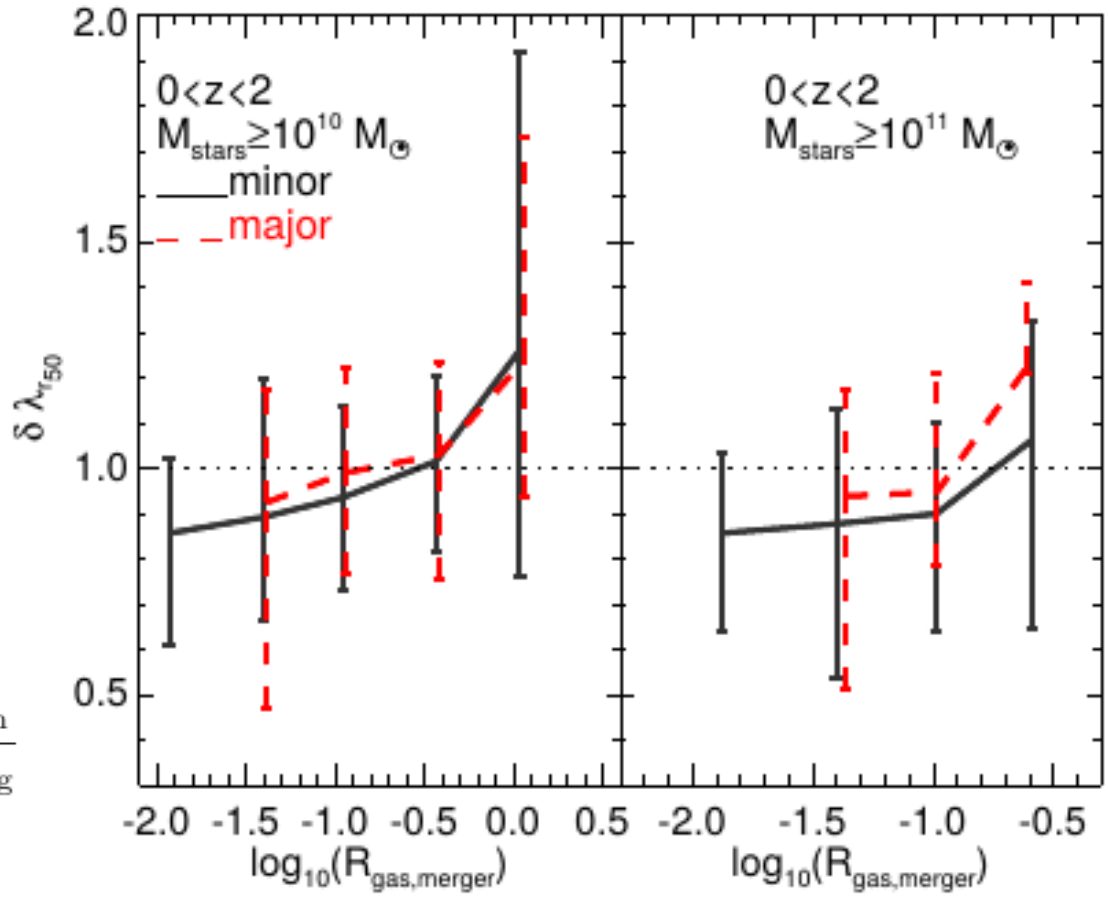
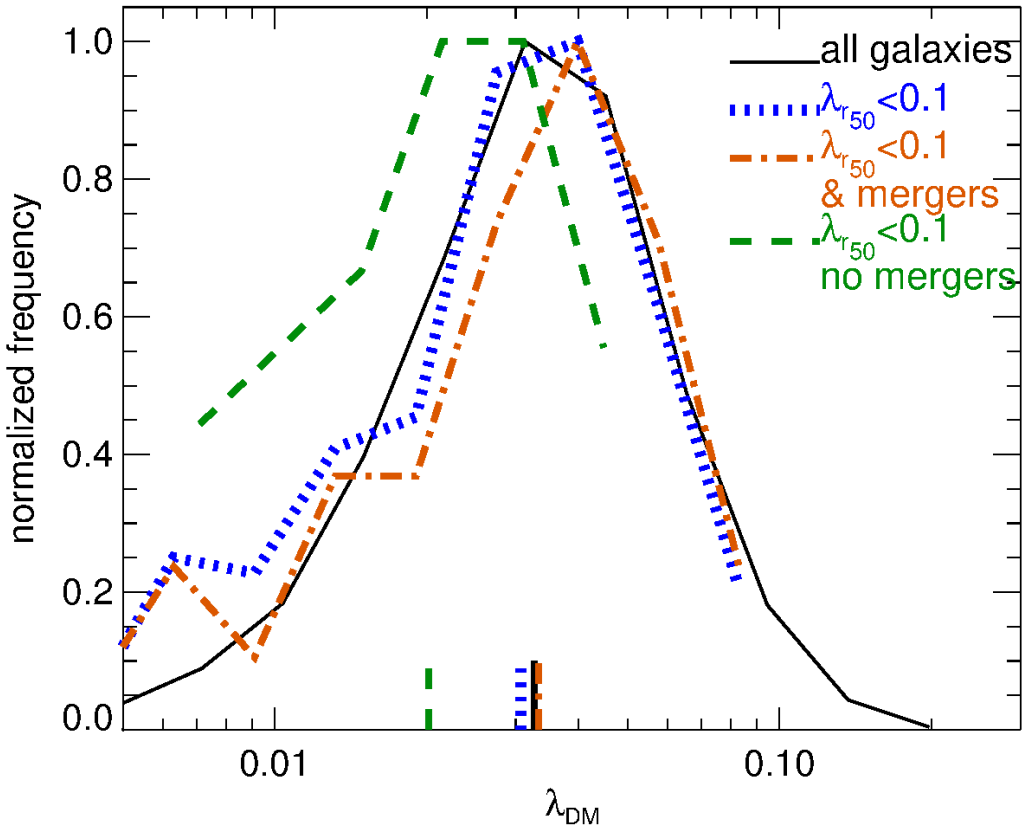
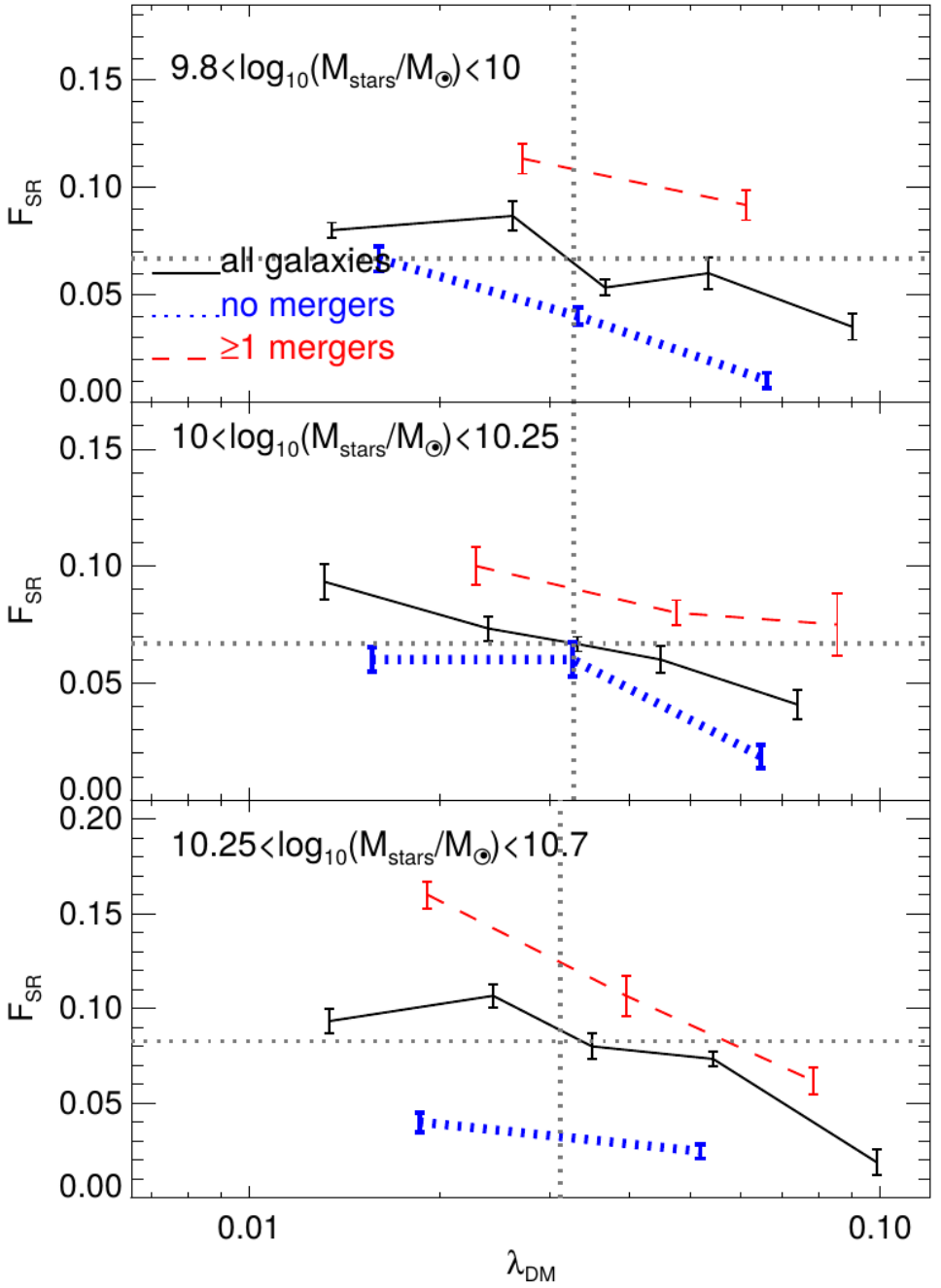


$$\delta\,\lambda_{\rm R} = \frac{\lambda_{\rm R,rem}}{\lambda_{\rm R,prog}}$$

The connection between halo and galaxy spin

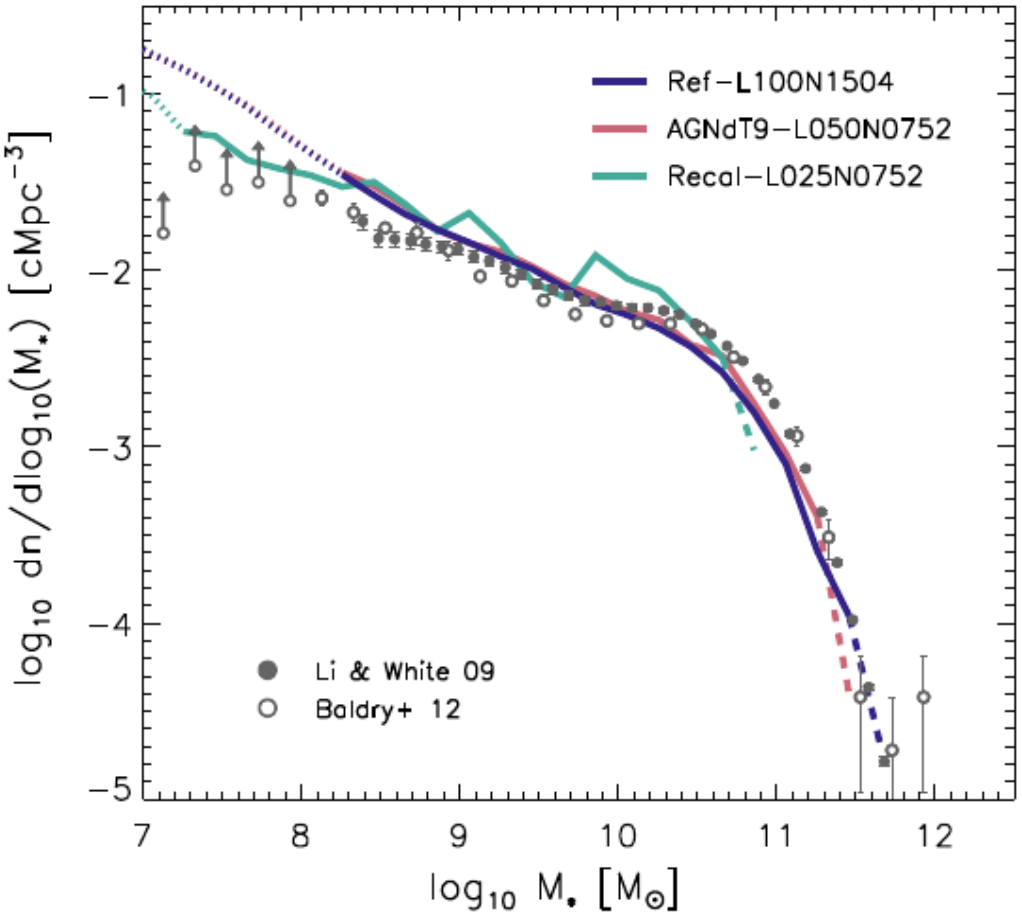


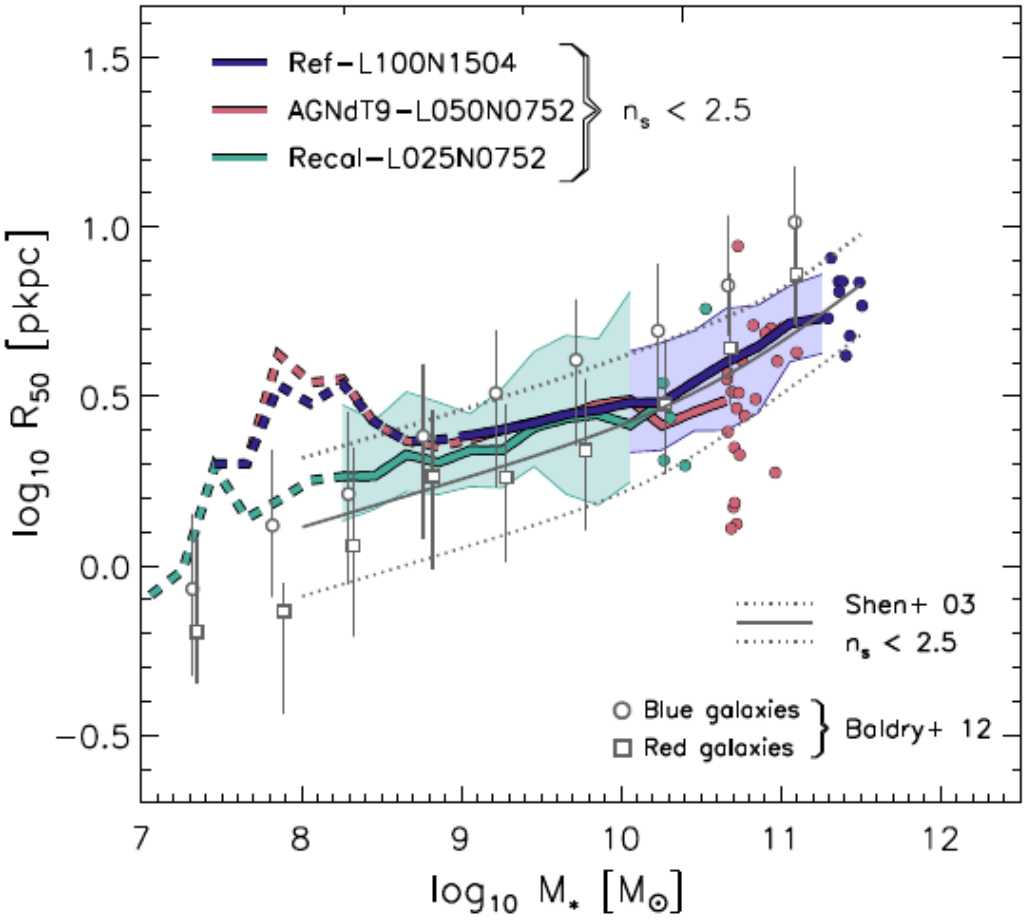


Lagos et al. (2017b; arXiv:171201398L)

The EAGLE Simulation: parameter tunning

Schaye et al. (2015) and Crain et al. (2015)





Mass, environment and quenching

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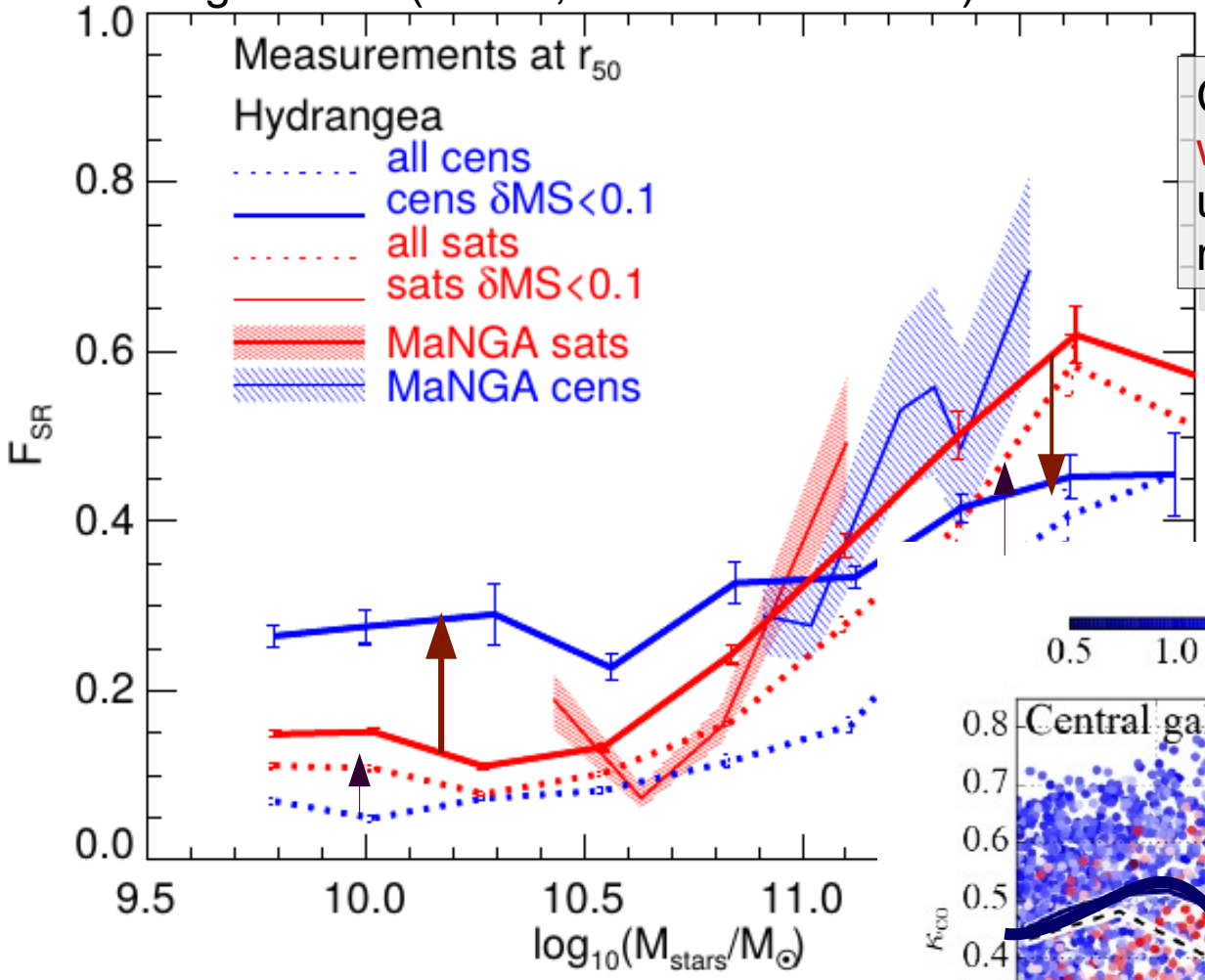
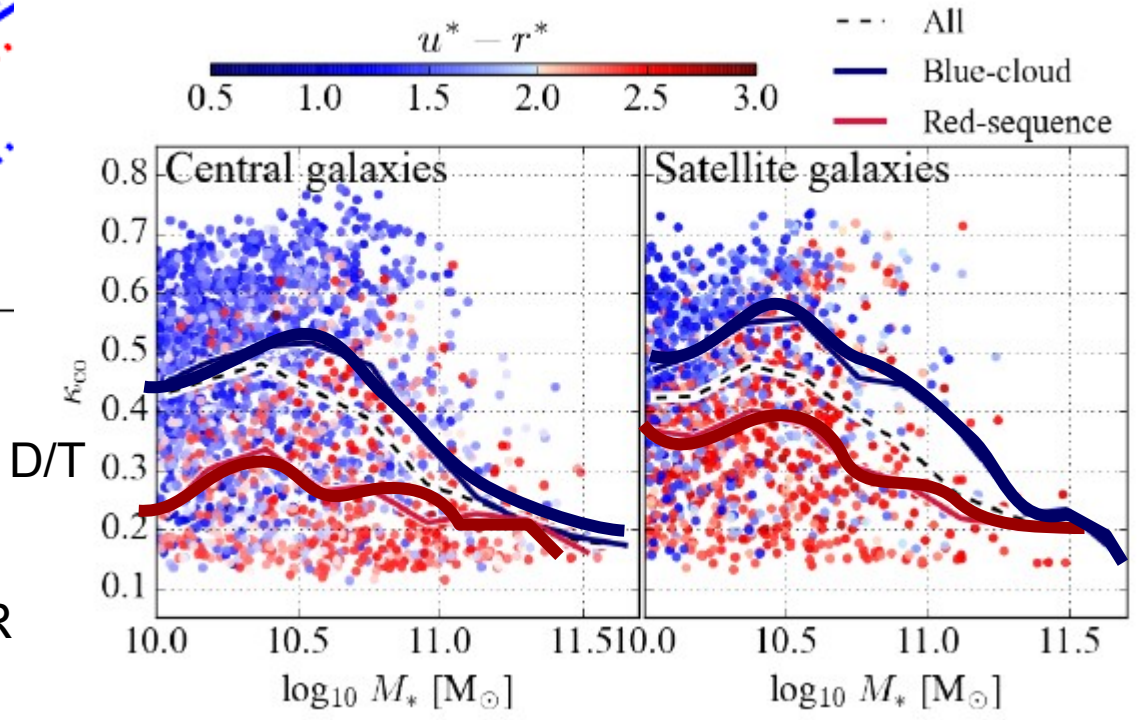


Centrals undergo quenching together with morph transformation, while sats undergo quenching without having morph transformation necessarily

Correa et al. (2017)



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