The origin of the molecular and atomic gas on early-type galaxies

(a theoretical perspective)

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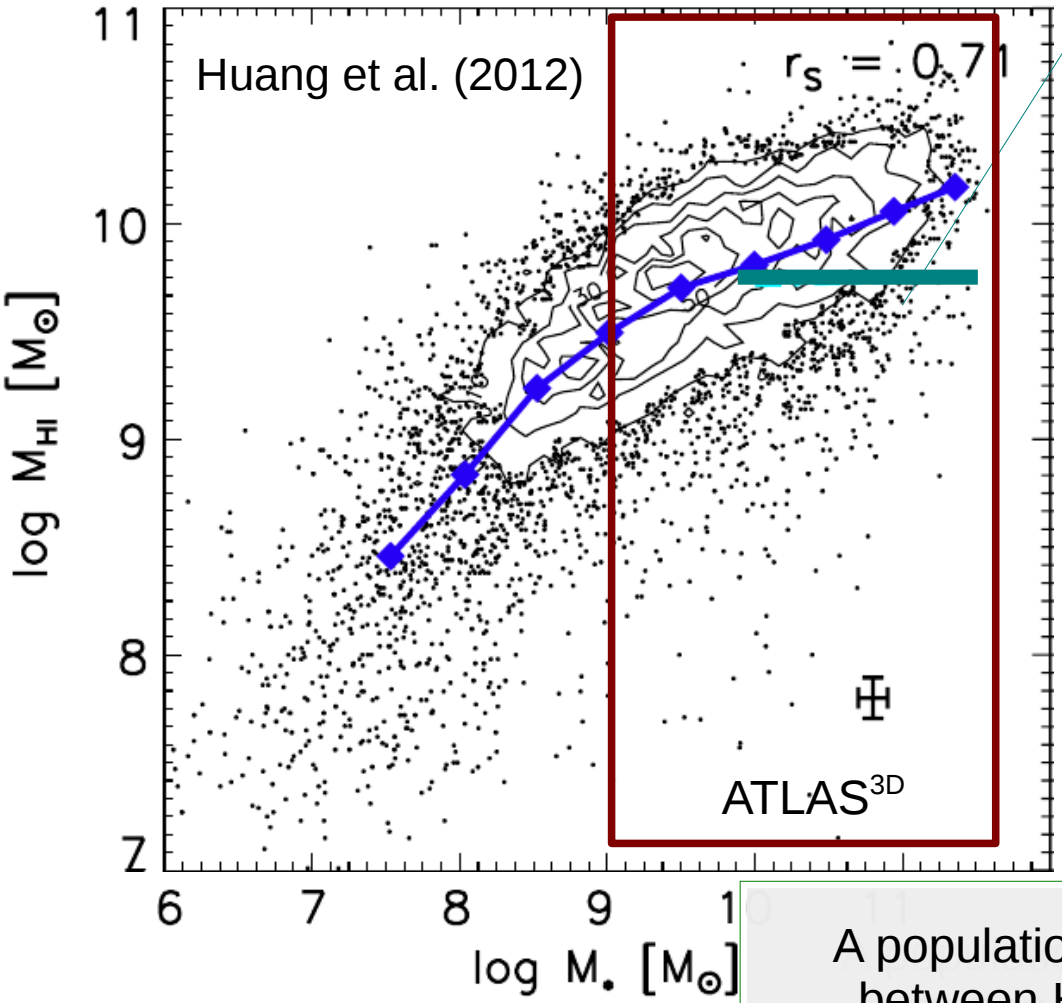
Postdoc and PhD calls open to work on theory group at ICRAR!

Curtin University

The University of Western Australia

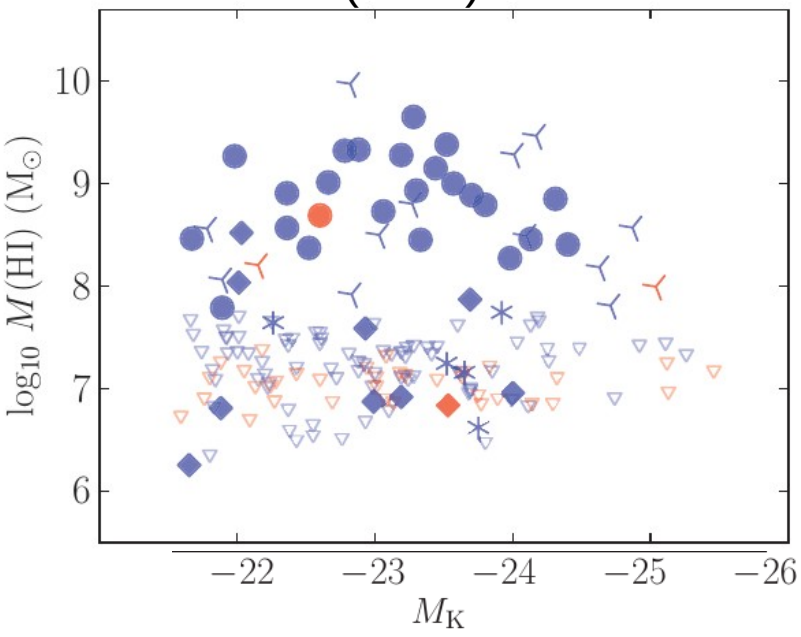
The correlations between gas and stellar mass

More and more information on molecular and atomic hydrogen of galaxies. New generation of surveys:
- HI selected (HIPASS; ALFALFA)
- Stellar mass selected (GASS and COLD GASS)
- Volume limited (ATLAS^{3D}; HRS)



Mass selected sample
No correlation between the HI and stellar masses (Catinella+2010, Schminovich+2010).

Serra et al. (2012): ETGs



A population of galaxies with poor correlations between HI, H2 and other galaxy properties

For molecular gas: Lisenfeld et al. (2011); Saintonge et al. (2011); Young et al. (2011, 2013)

Something very interesting about the gas content of ETGs and its potential connection to quenching.

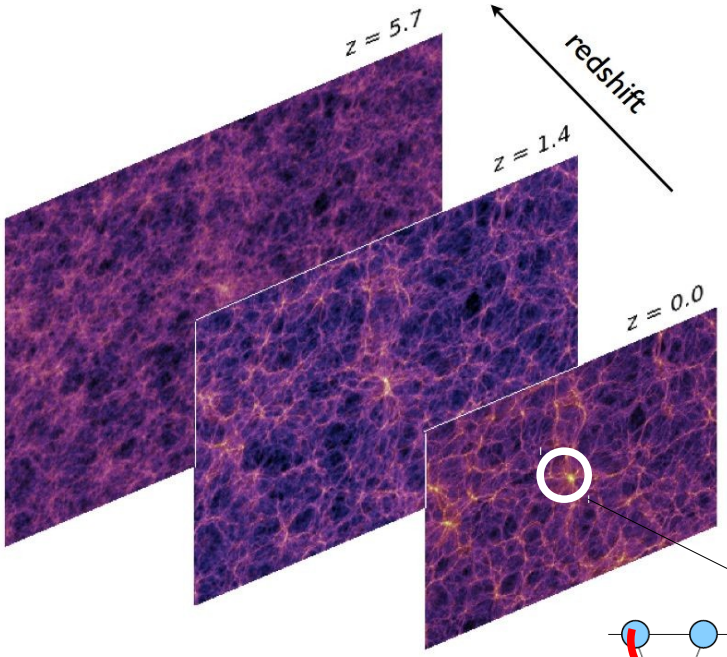
Is the gas content related to shut off of star formation? (timescale of gas accretion?)

How do we understand non-negligible presence of cold gas and the position of ETGs in the red sequence?

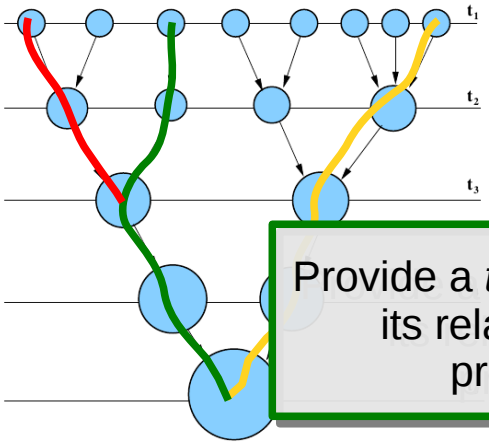
Was this gas accreted recently? Was it originated by internal mechanisms?

The galaxy formation semi-analytic technique

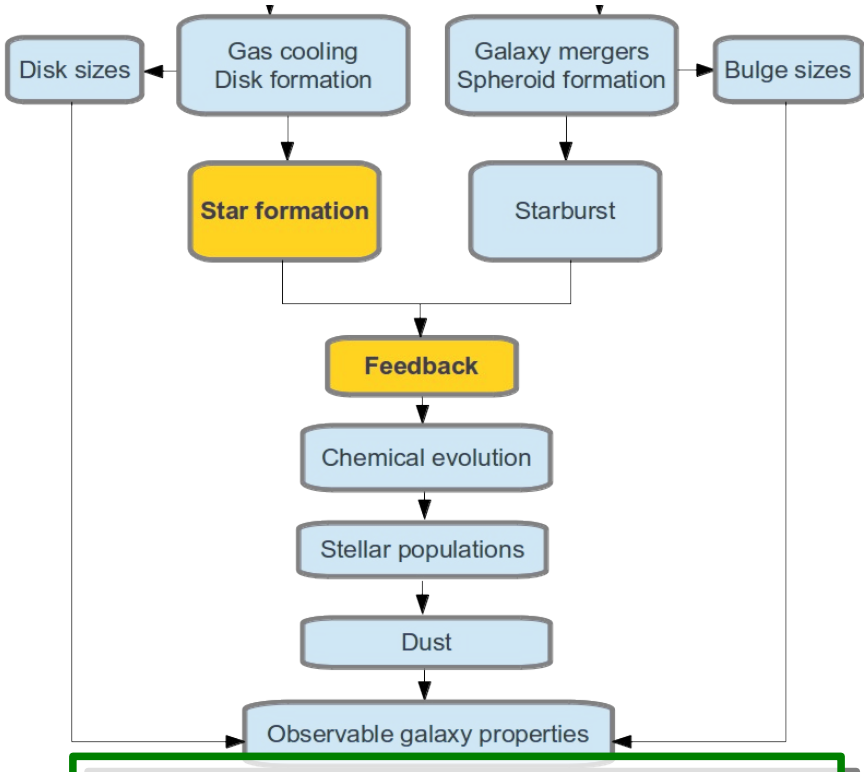
(1) Dark matter N-body simulation



(2) Halo, sub-halo finder and merger trees construction



(3) Semi-analytic technique

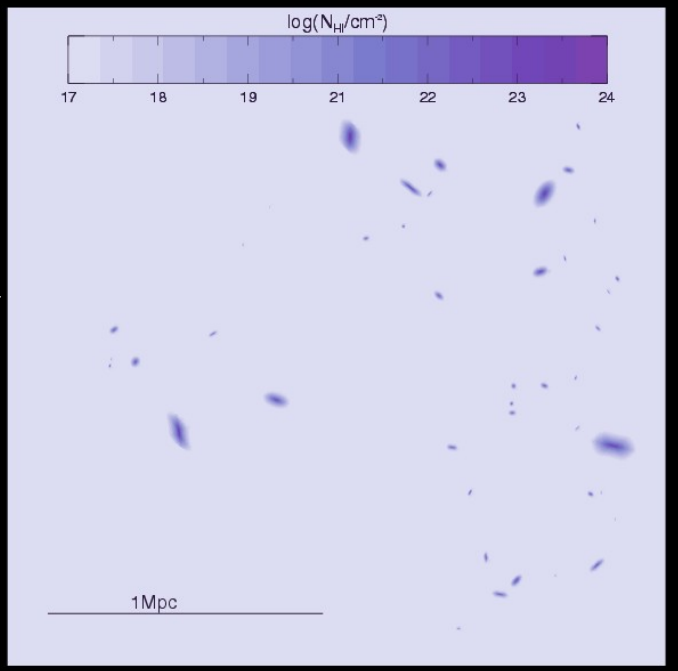


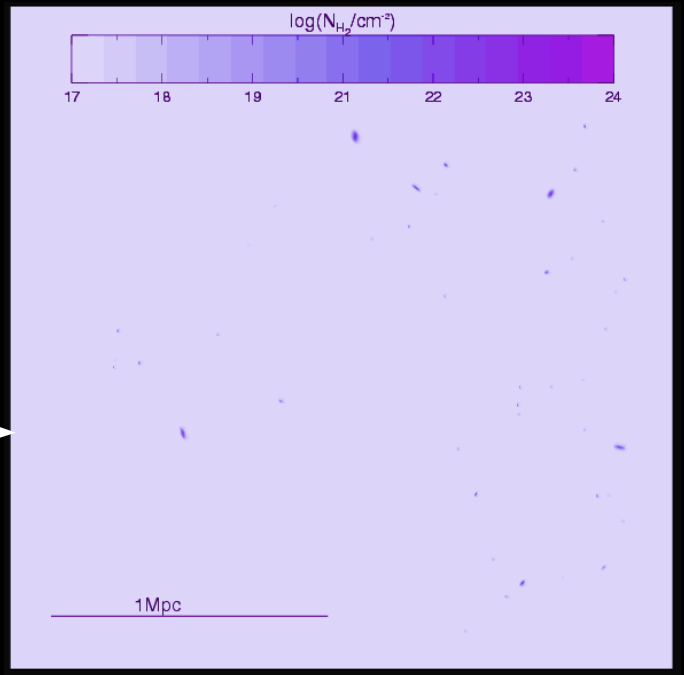
Intrinsic properties, plus full SED and emission lines.

Provide a *theoretical framework* in which we can study SF, its relation with the gas content, and other galaxy properties (stellar mass, colours, B/T, etc).

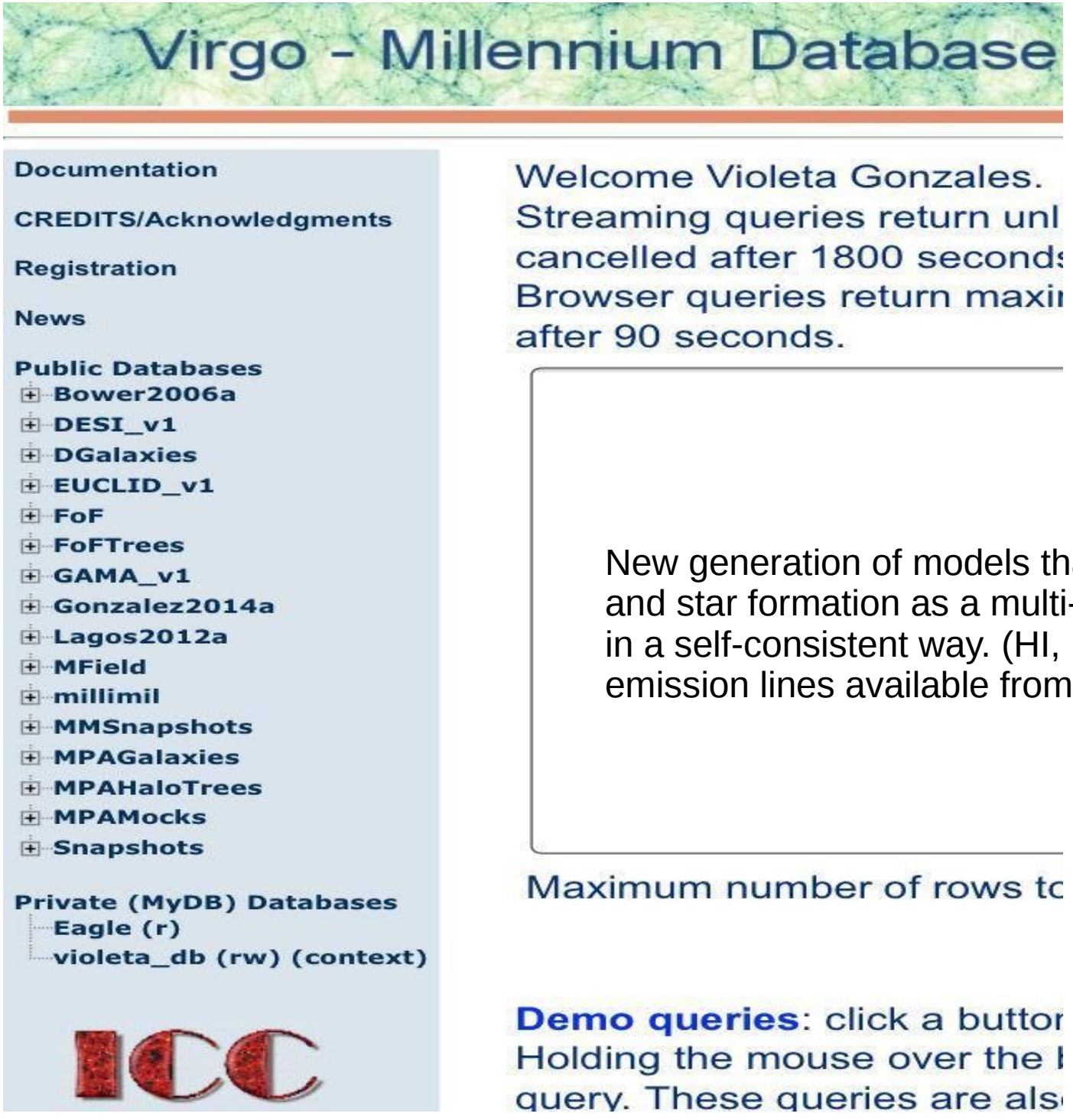
Cole et al. (2000); Baugh et al. (2005); Baugh (2006); Bower et al. (2006); Font et al. (2008); Benson (2010); Lagos et al. (2011a,b; 2013); Fanidakis et al. (2011; 2012); Gonzalez-Perez (2014)

Optical colours of a cluster





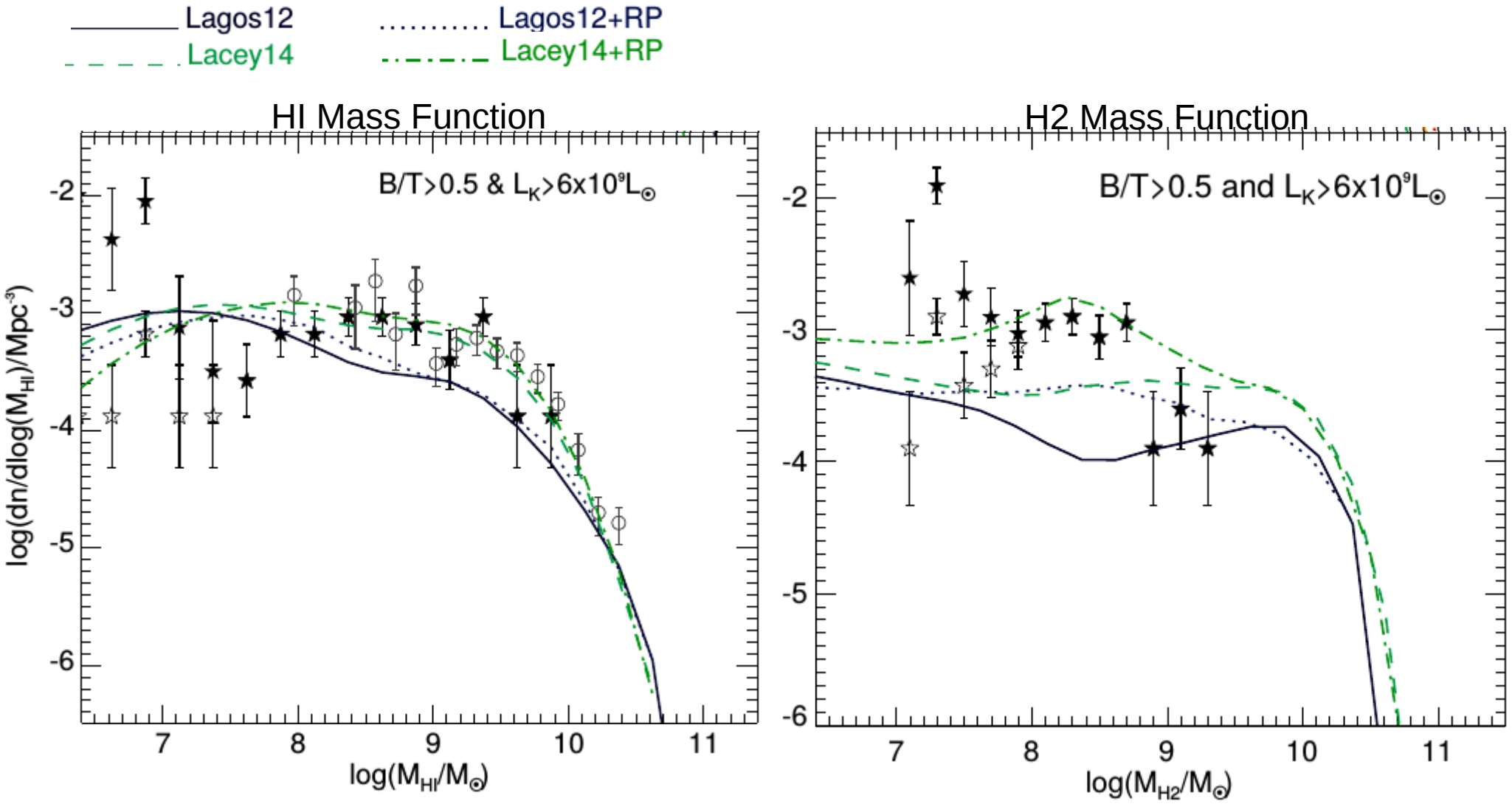
http://galaxy-catalogue.dur.ac.uk:8080/MyMillennium/



New generation of models that treat the ISM and star formation as a multi-phase process in a self-consistent way. (HI, H2 and CO emission lines available from database)

The HI and H2 mass functions of ETGs

All models predict equally good HI ,H2 mass functions and K-band luminosity functions.



Ram pressure stripping of the hot gas is key to reproduce the HI and H2 contents of ETGs.

Connection bulge-gas depletion

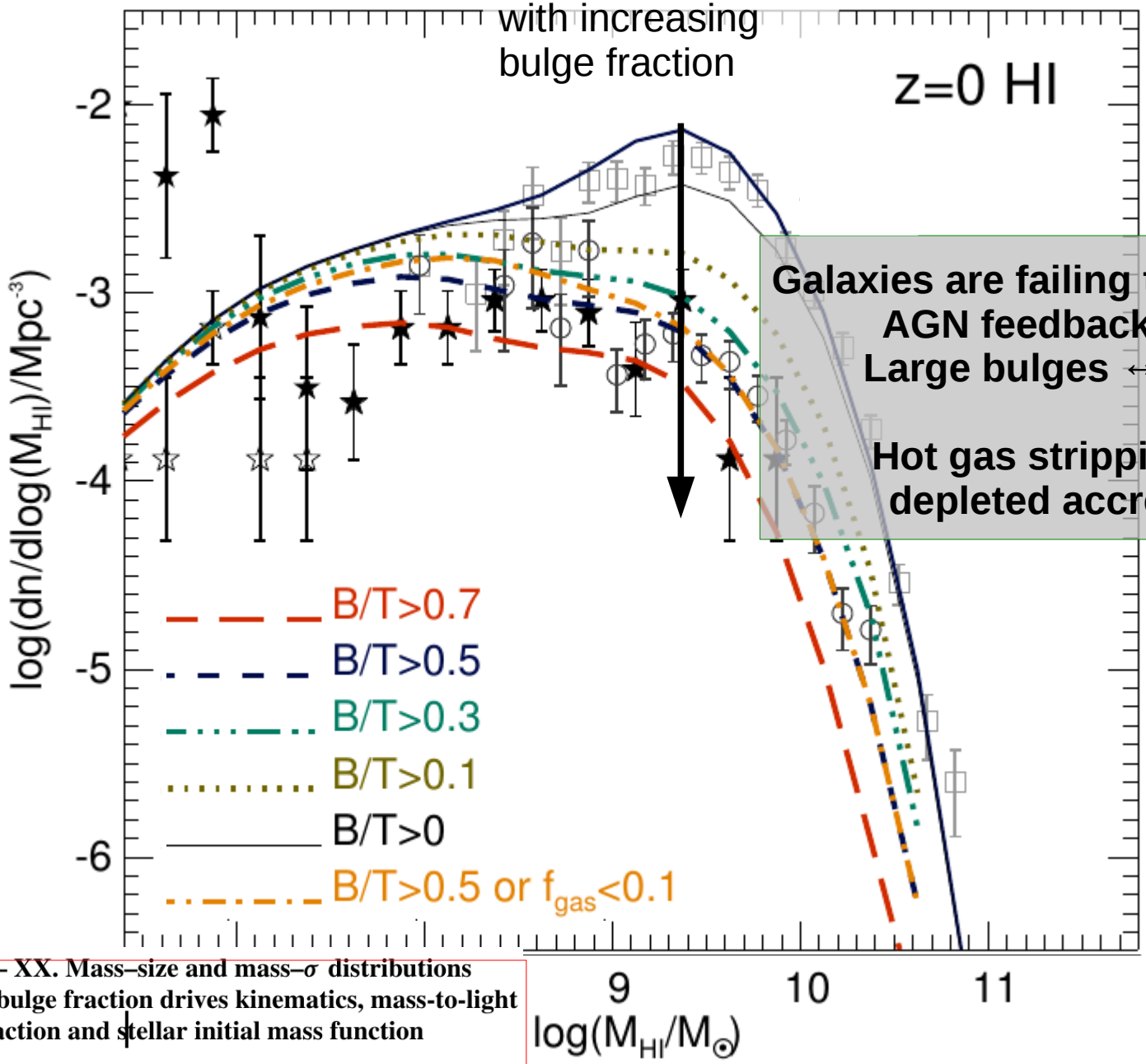
Large depletions with increasing bulge fraction

All galaxies

Bulge>0

B/T>0.1

B/T>0.3



Galaxies are failing to regrow a disk:
AGN feedback (in cens):
Large bulges ↔ Large BHs

Hot gas stripping (in sats)
depleted accretion rates

The ATLAS^{3D} project – XX. Mass–size and mass–σ distributions of early-type galaxies: bulge fraction drives kinematics, mass-to-light ratio, molecular gas fraction and stellar initial mass function

Michele Cappellari,[1]★ Richard M. McDermid,[2] Katherine Alatalo,[3] Leo Blitz,[3]

Where is this gas coming from? (Lagos et al. 2014b)

→ Most of ETGs have HI and H2 supplied by smooth accretion (~92%)

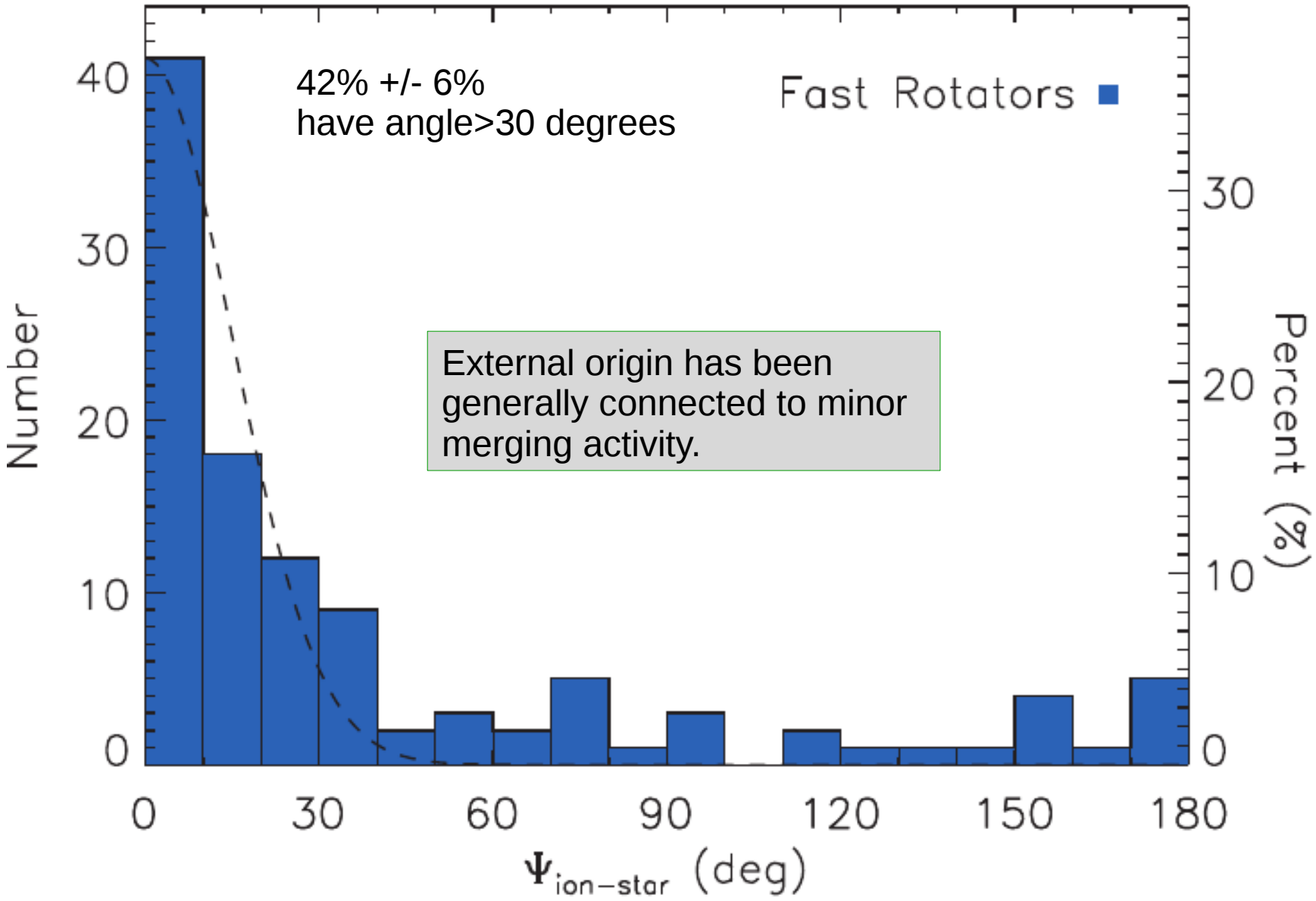
→ 10% of ETGs in clusters are dominated by internal recycling (intermediate and low mass stars)

→ 6% of ETGs are dominated by minor merger accretion (96% of those in non-cluster environments).

These different gas sources impact angular momenta Lagos et al. (2015a)

Kinematic misalignments in ETGs

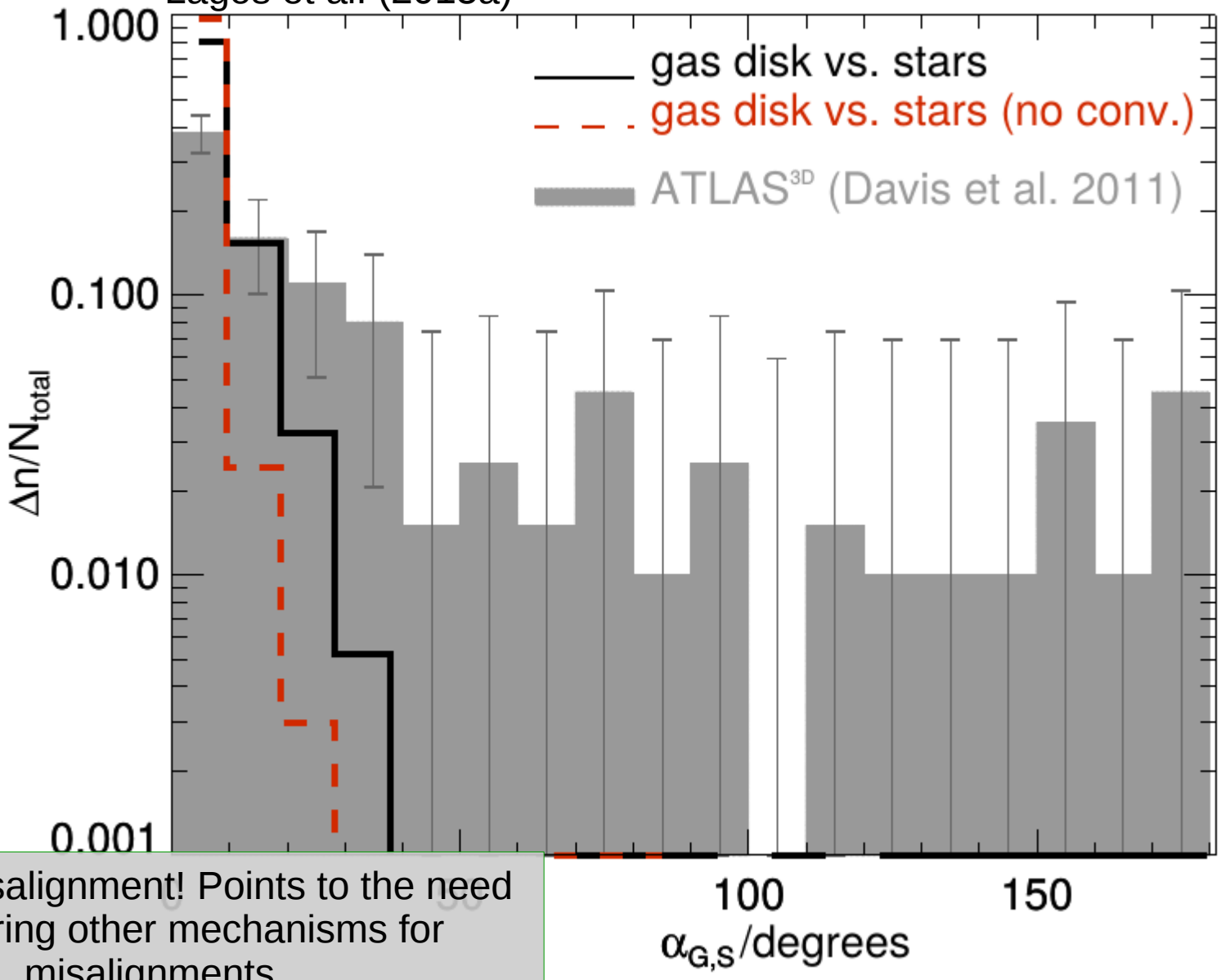
Davis et al. (2011): gas phases aligned with each other (common origin)



Restricting misalignments to galaxy mergers

Experiment: Allow only galaxy mergers to drive misalignments in galaxies

Lagos et al. (2015a)

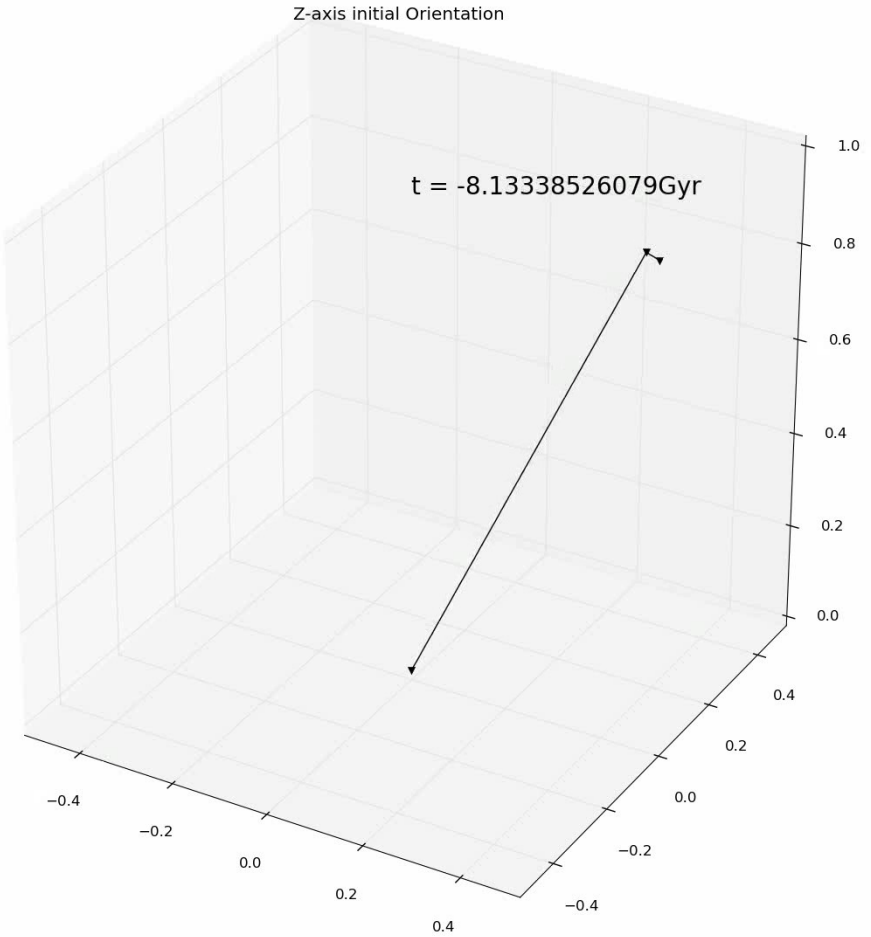


Only 5% misalignment! Points to the need of exploring other mechanisms for misalignments

Following angular momenta flips

Experiment: follow all angular momenta flips, which could be due to either mergers or just smooth accretion coming with a different angular momentum direction.

Example of angular momentum history

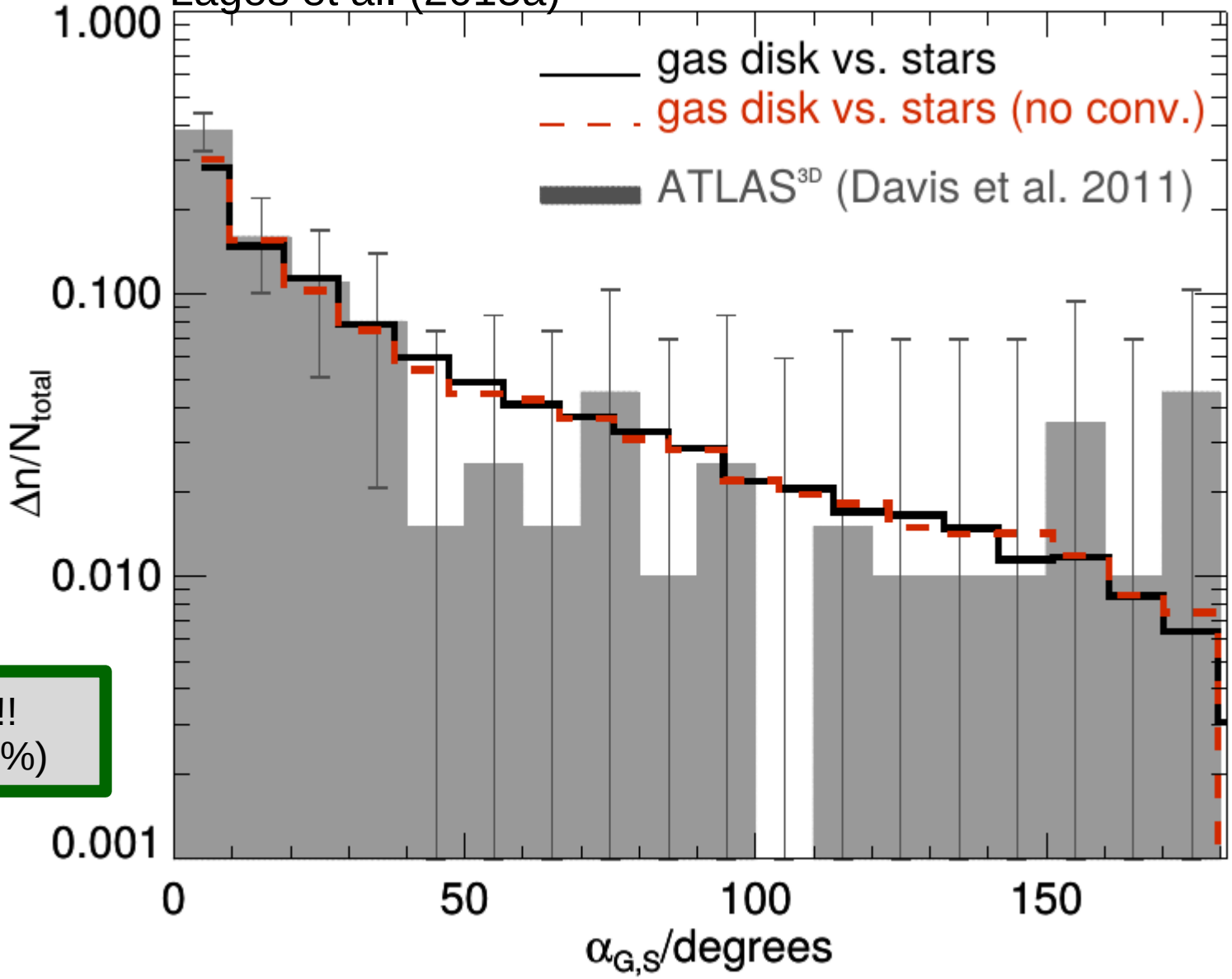


Sergio Contreras et al. (in preparation): halos show coherent change of angular momentum direction throughout time (long-term torques).

Following angular momenta flips

Experiment: follow all angular momenta flips, which could be due to either mergers or just smooth accretion coming with a different angular momentum direction.

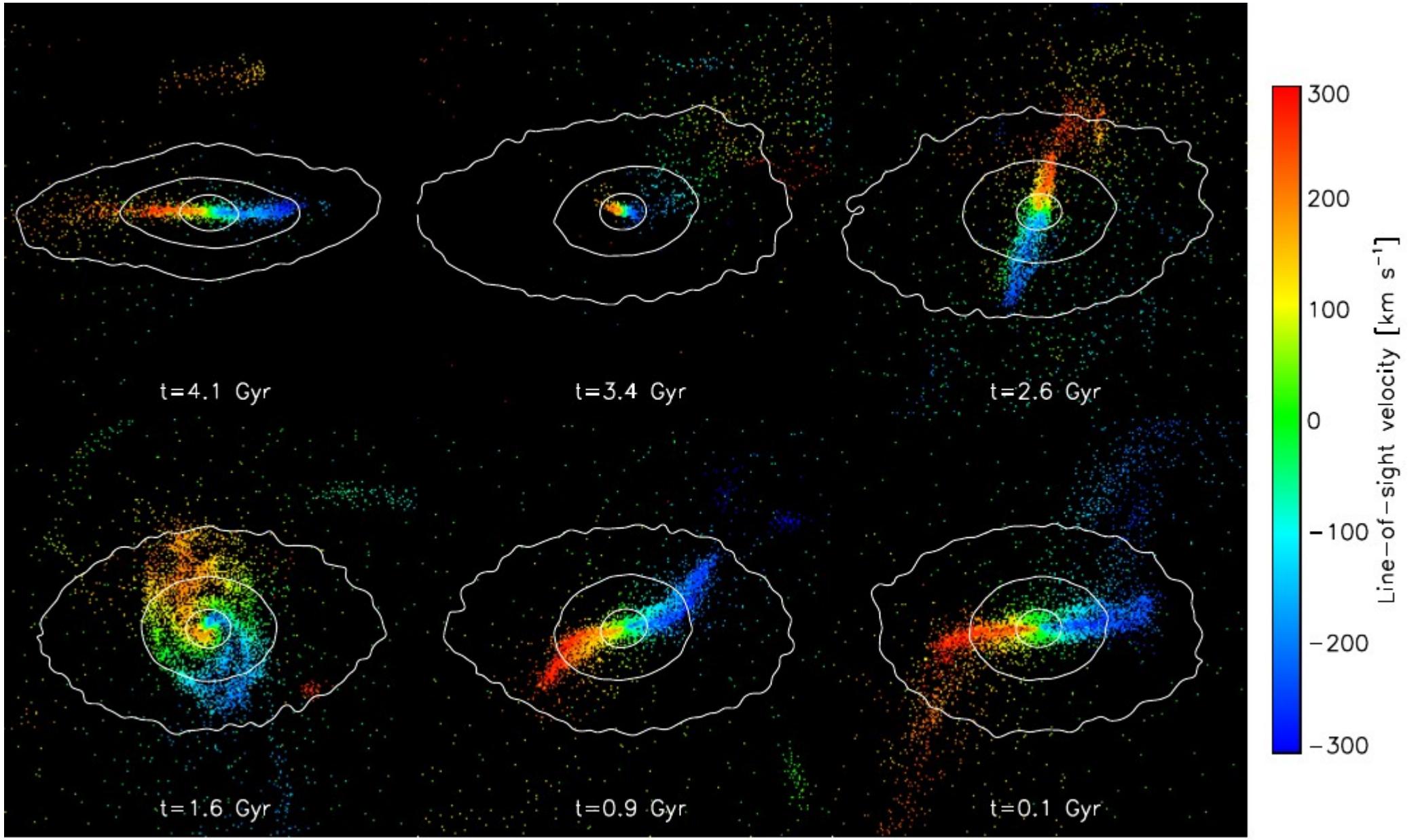
Lagos et al. (2015a)



46%!!
(36-52%)

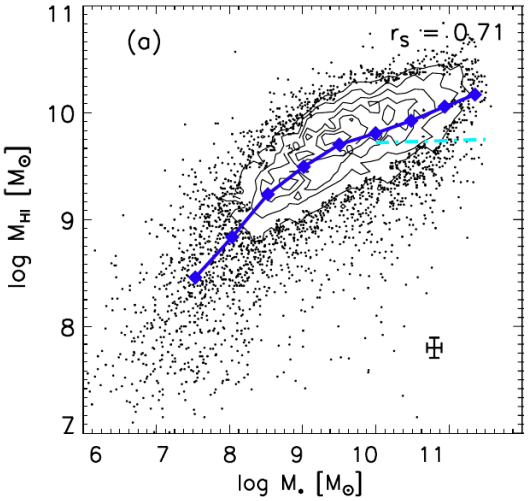
High-res simulation confirms results

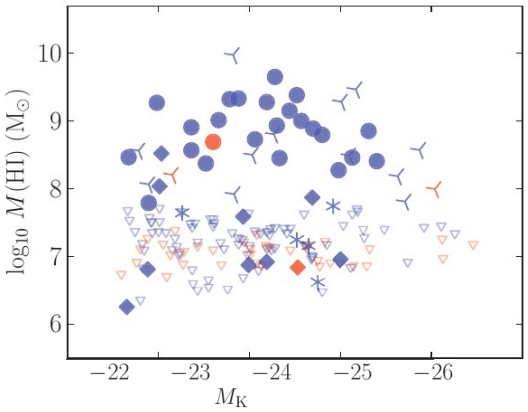
Van de Voort (2015): gas disk remains misaligned due to smooth accretion from the hot halo

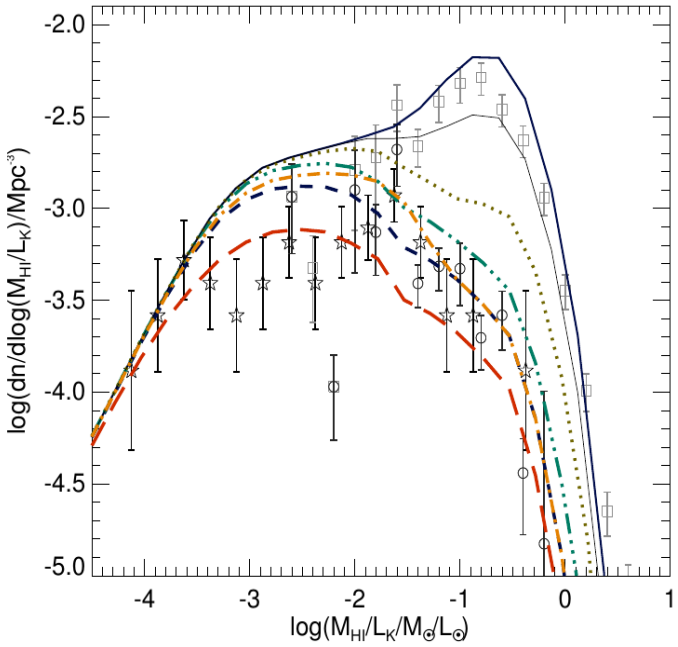


Conclusions

(1) Early-type galaxies and particularly gas content and kinematics offer interesting, *"higher-order" constraints* to models.

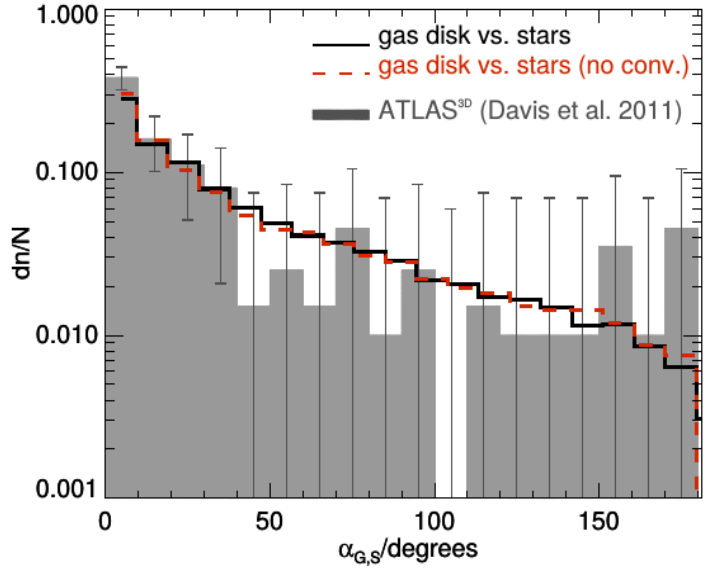






(2) *Environmental effects and AGN feedback* drive strong connections between gas depletion and bulge fraction.

(3) Frequency of misalignments in ETGs are reproduced in the models with of *smooth accretion driving most of them.*



The origin of the atomic and molecular gas contents of early-type galaxies. I. A new test of galaxy formation physics

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The origin of the atomic and molecular gas contents of early-type galaxies. II. Misaligned gas accretion

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