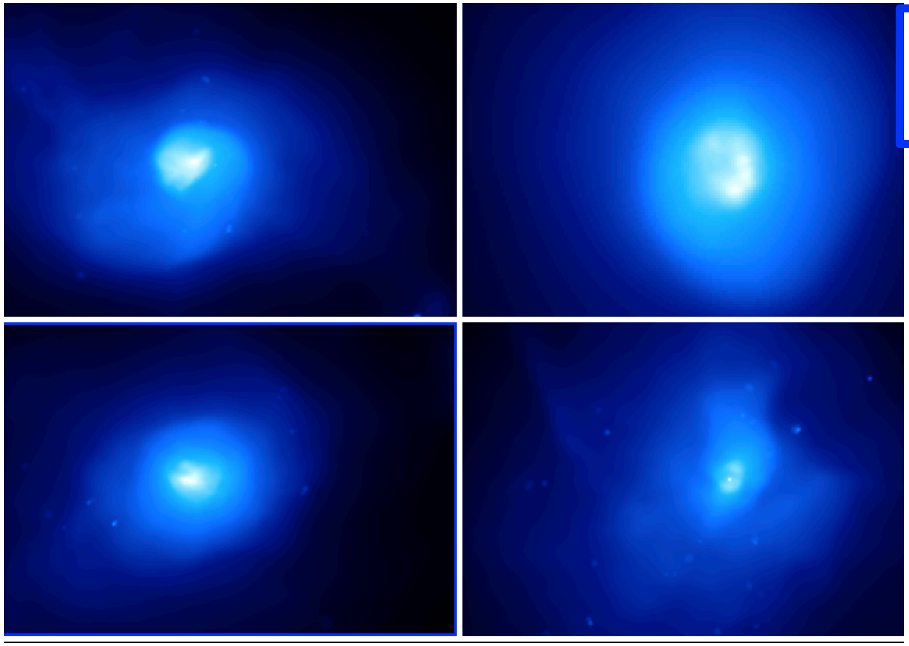
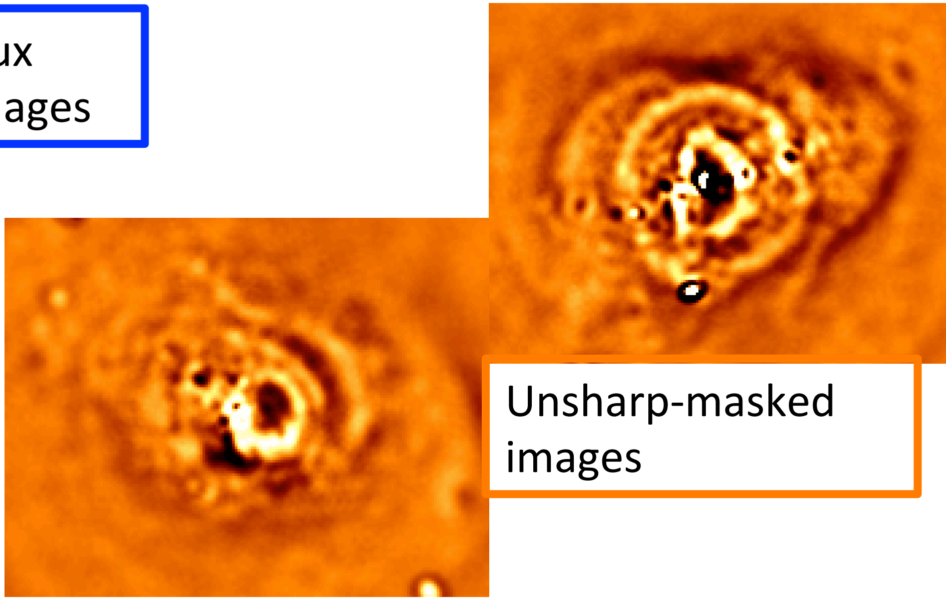


Flux images



Unsharp-masked images

Properties of the ICM from simulations with AGN feedback

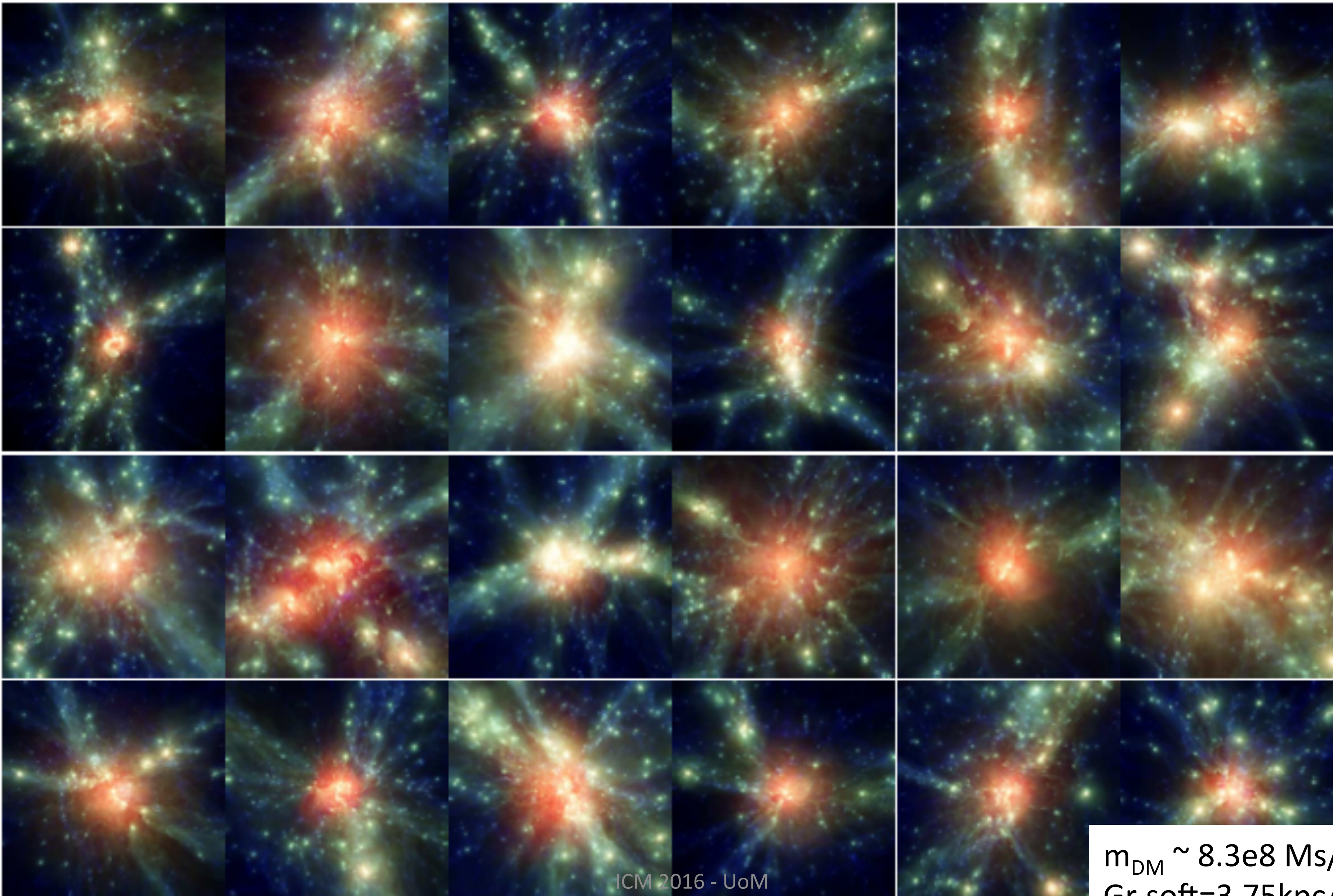
Elena Rasia

(INAF-OATs, University of Michigan)

With:
Veronica Biffi
Nhut Truong
Susana Planelles
Dunja Fabjan
+ TS group
+Munich group

24 massive clusters + 5 groups

Initial conditions from Bonafede+12



m_{DM} ~ 8.3e8 Ms/h
Gr.soft=3.75kpc/h

New BH accretion model

$T_{cold/hot}$=5x10^5 K

$$\dot{M}_\bullet = \min(\underline{\dot{M}_{\rm B,hot} + \dot{M}_{\rm B,cold}}, \underline{\dot{M}_{\rm Edd}})$$

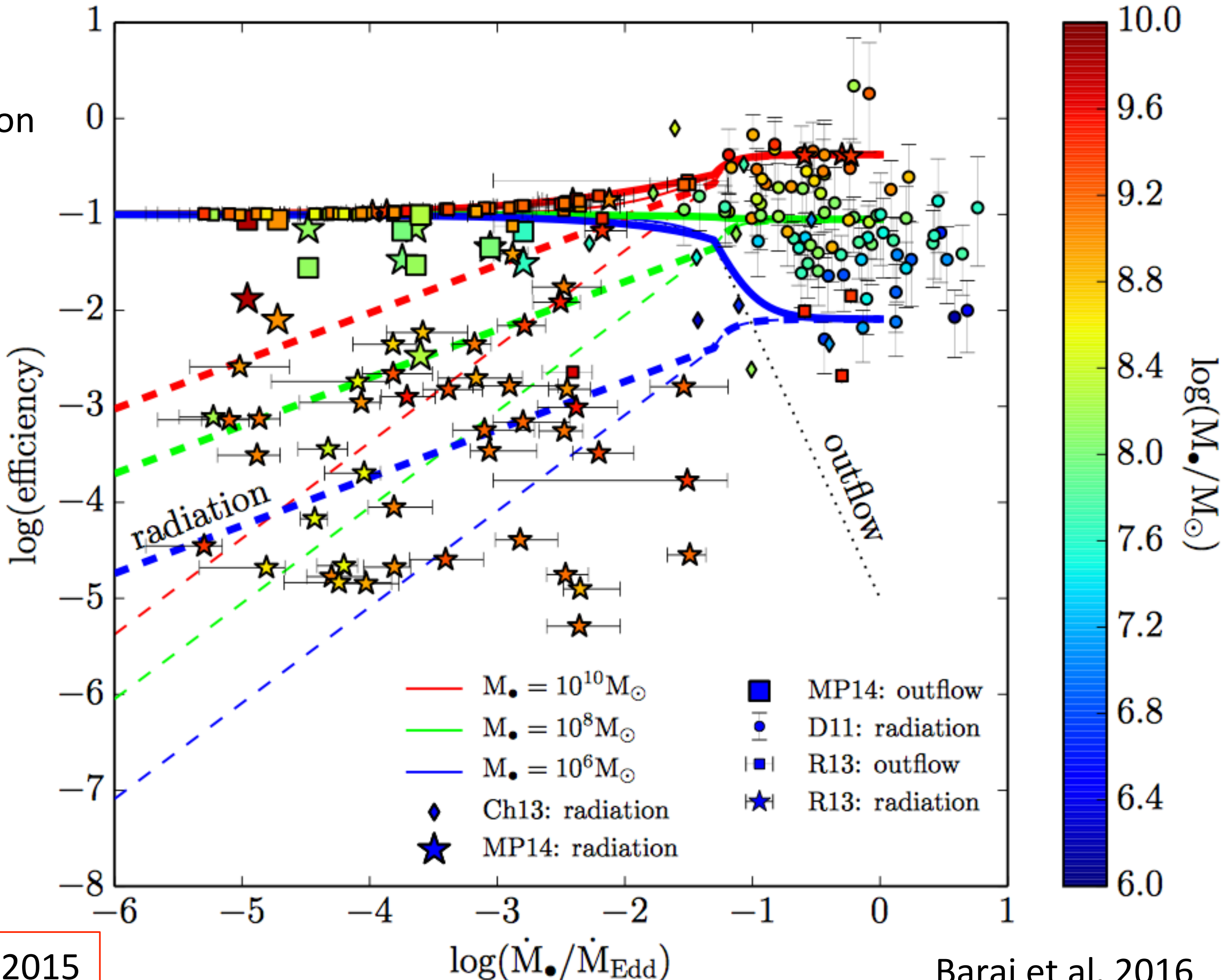
$$\dot{M}_{\rm B} = \frac{4\pi\alpha G^2 M_\bullet^2 \langle\rho\rangle}{(\langle c_{\rm s}\rangle^2 + \langle v\rangle^2)^{3/2}}$$

$$\dot{M}_{\rm Edd} = \frac{4\pi G M_\bullet m_{\rm p}}{\eta_{\rm Edd}\sigma_{\rm T} c}$$

It is the cold mode that drives BH accretion/AGN feedback ("cold chaotic accretion" driven by thermal instabilities, Gaspari et al. 2013, Yuan Li et al. 2015)

New AGN Feedback model

Separated radiation and outflow Efficiencies (Churazov+2005)

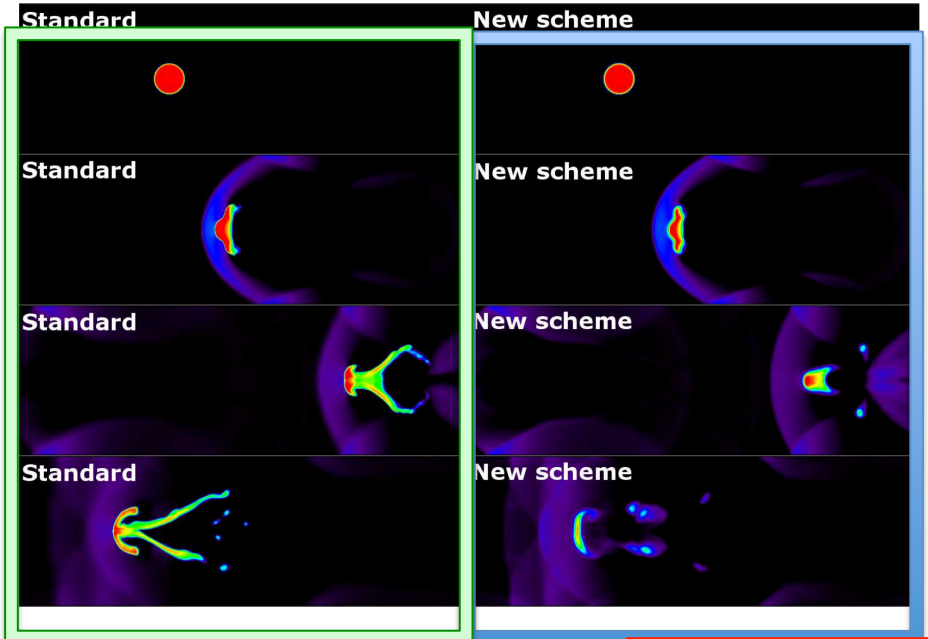


Steinborn et al. 2015

Barai et al. 2016
Valentini+; Fabjan+

New HYDRO: Artificial diffusion

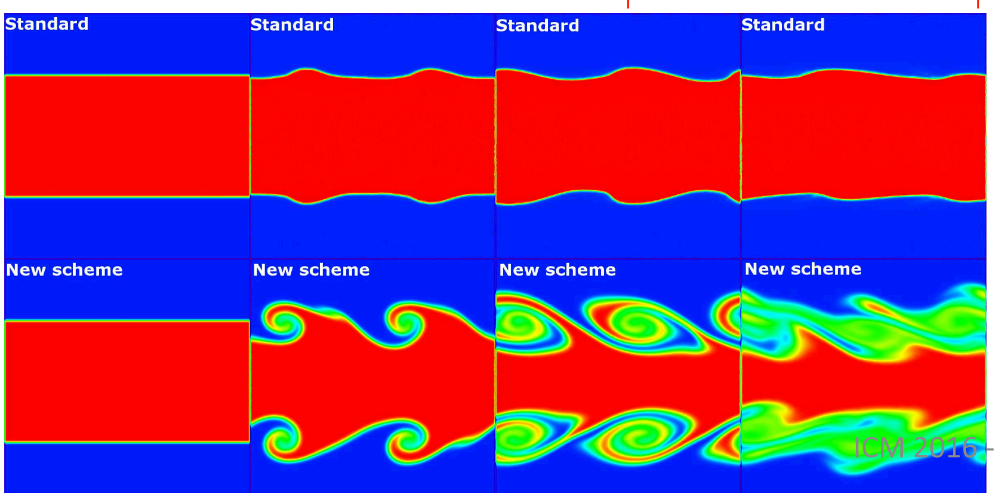
Cold Blob test



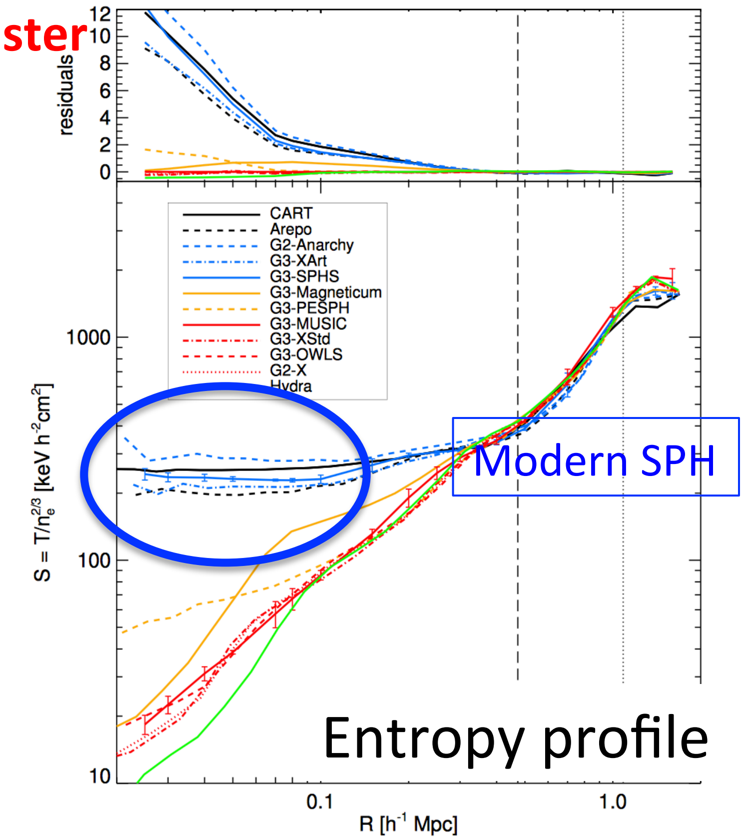
Standard: numerical surface tension as well as too much AV prevent mixing .

Kelvin-Helmholtz instabilities

Beck et al. 2016



Entropy profile of a NCC no-radiative cluster



Sembolini et al. 2016

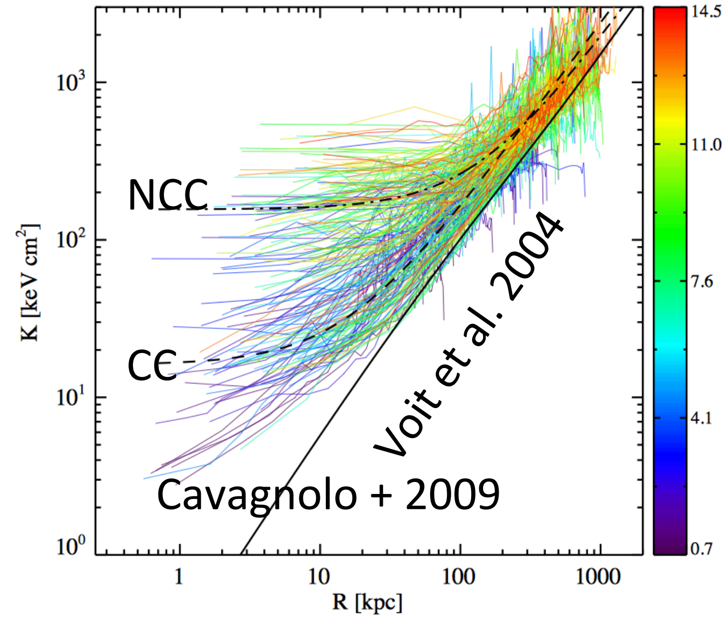
Entropy @ z~0
$K=kT/n_e^{2/3}$

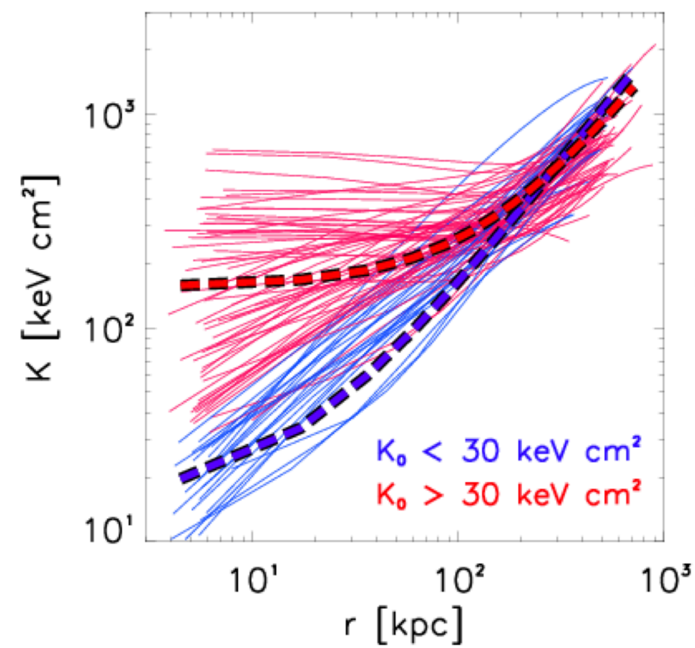
Gravity drives structure formation.

Simply gravity-only models do not explain the observed gas profiles from the core to the outskirts.

Delicate balance between heating and cooling is in place.

Entropy quantifies the history of the energy deposited in the intra-cluster medium.





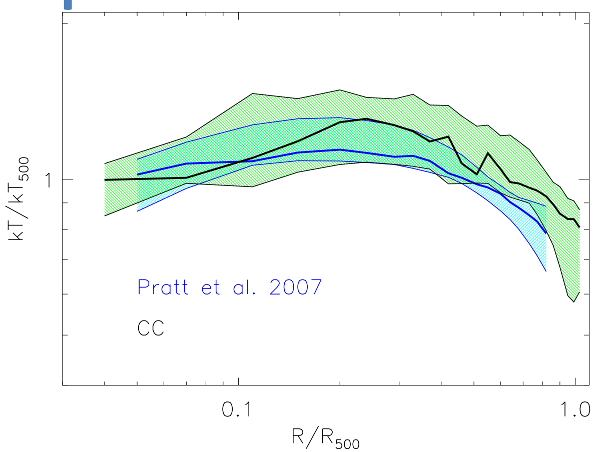
McDonald, SPT+ 2014

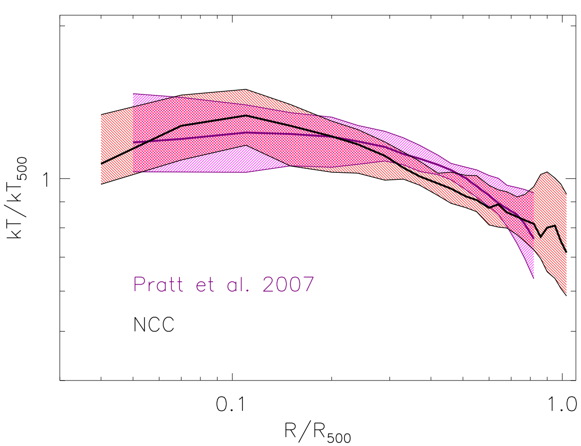
CC defined in Molendi & Pizzolato '01

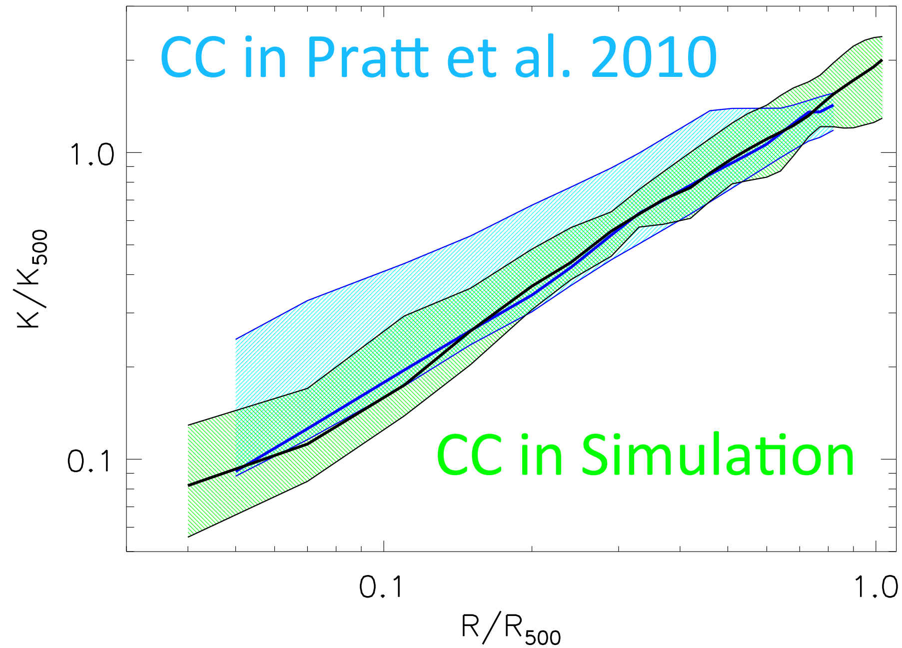
Entropy @ z~0

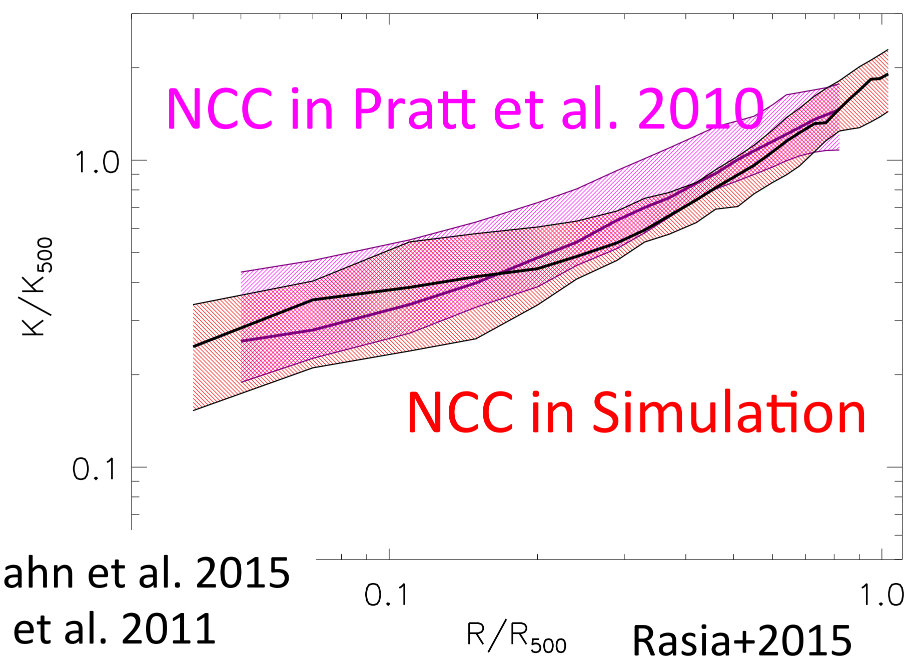
$K = kT/n_e^{2/3}$

Temperature Profiles



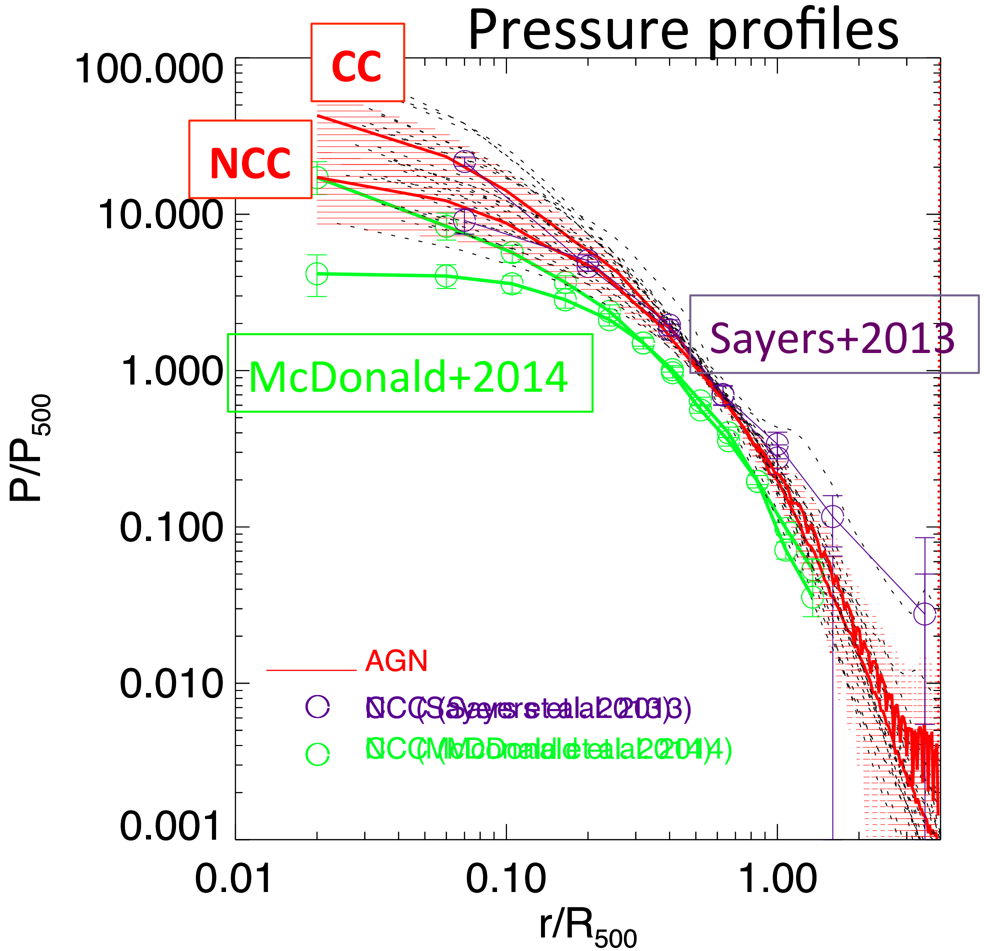




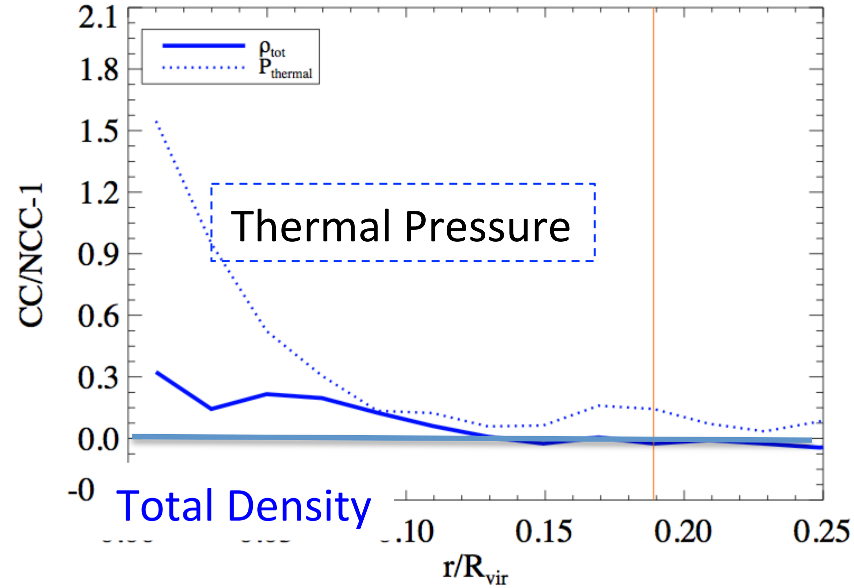


See also Hahn et al. 2015
Valdarnini et al. 2011

Rasia+2015



Planelles+, 2016 submitted MNRAS



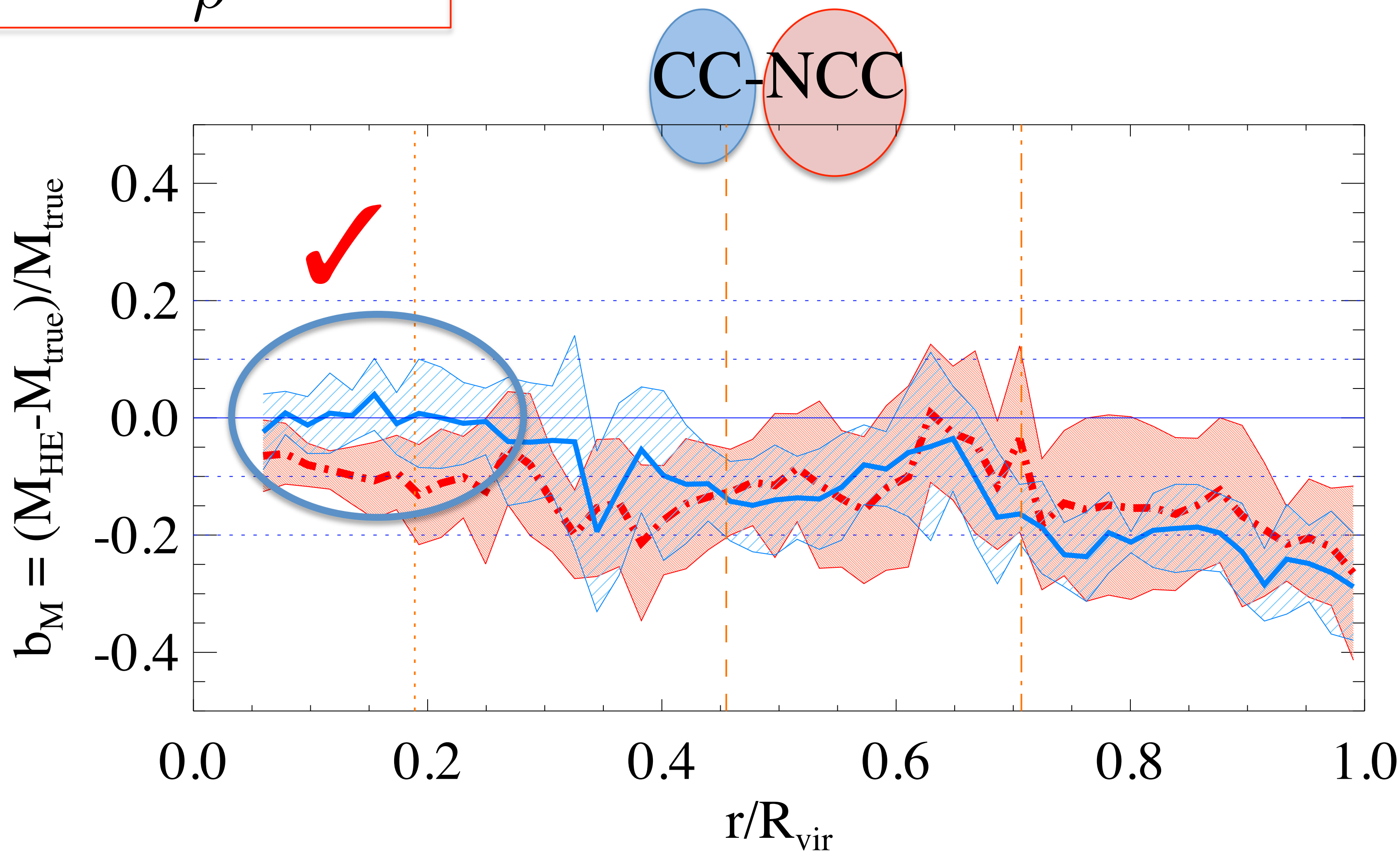
Biffi+, 2016 (reply to Referee)

CC clusters have more thermal Pressure support at the center

Mass computation from HE

$$-\nabla\Phi - \frac{1}{\rho}\nabla P = 0$$

$$b_M = (M_{\rm HE} - M_{\rm true})/M_{\rm true}$$

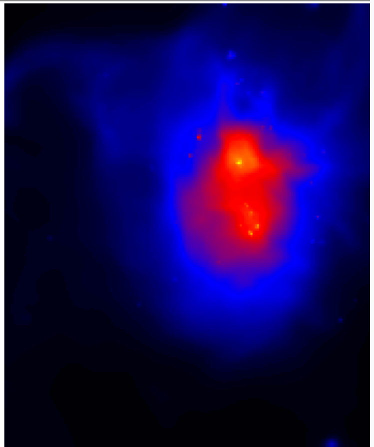


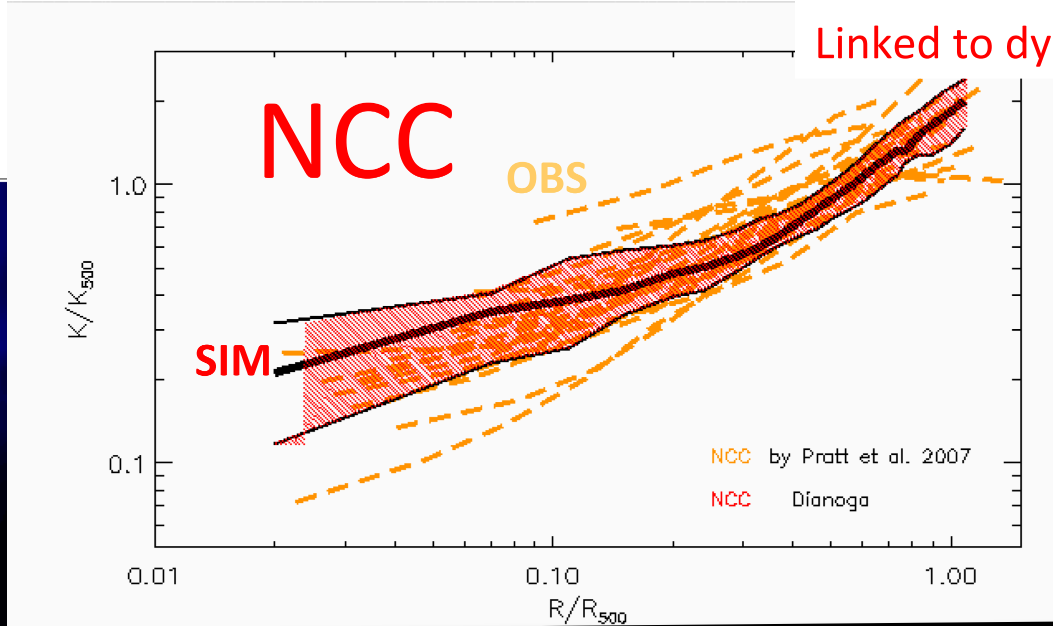
Biffi+2016

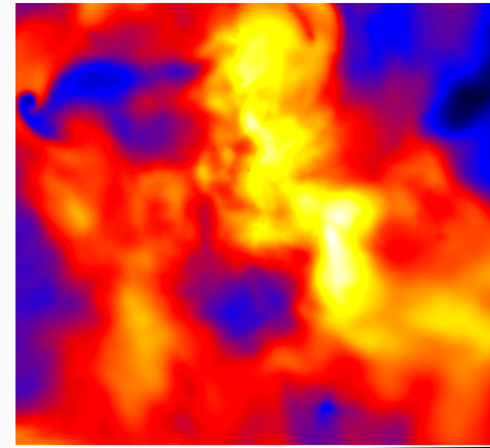
Flux Maps

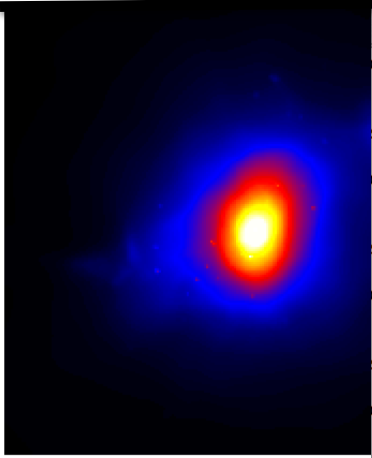
Linked to dynamically active systems

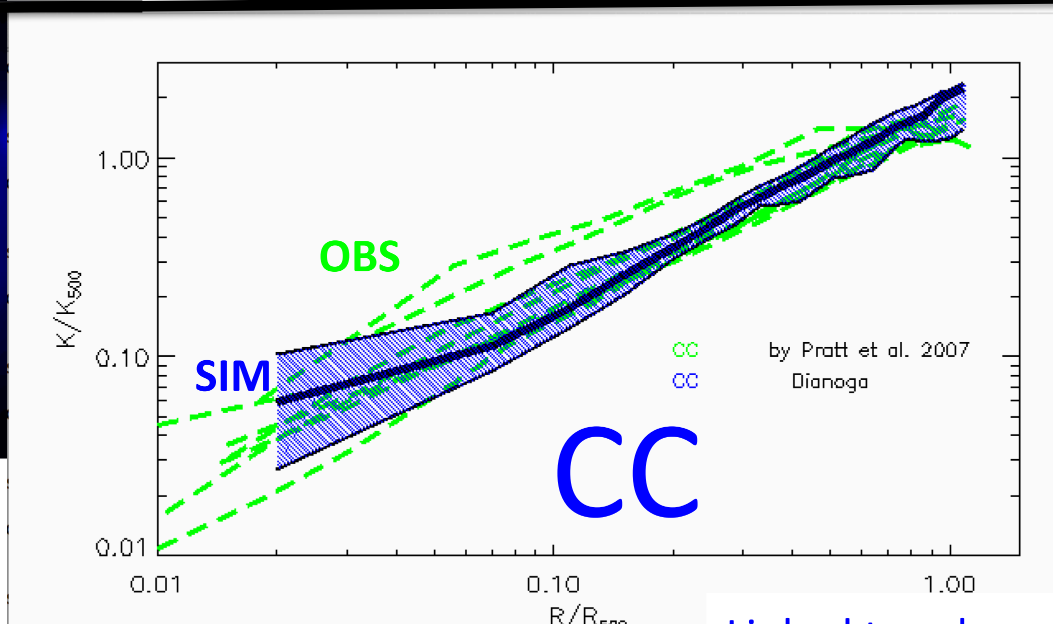
Temperature Maps

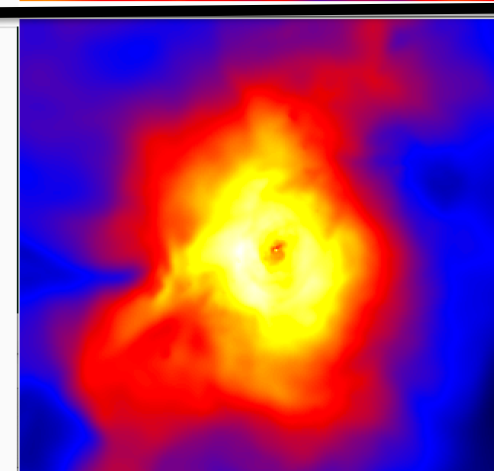












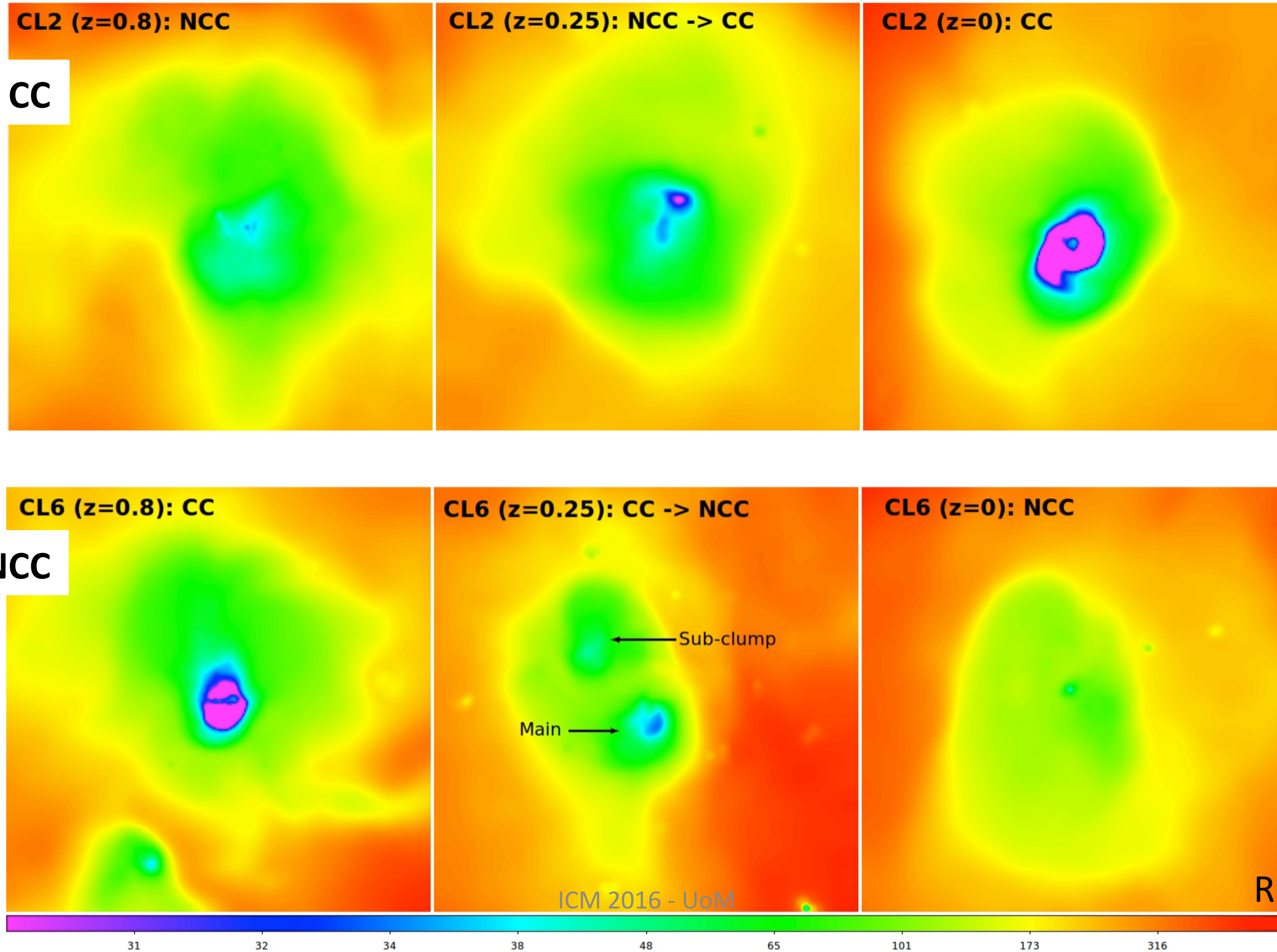
Flux Maps

Temperature Maps

Linked to relaxed and regular objects

Passage between the two classes

Pseudo-Entropy Maps



Rasia+2015

Stellar Properties

M_{BH}-M_* relation to calibrate feedback parameters. Observations from McConnell & Ma 2013.

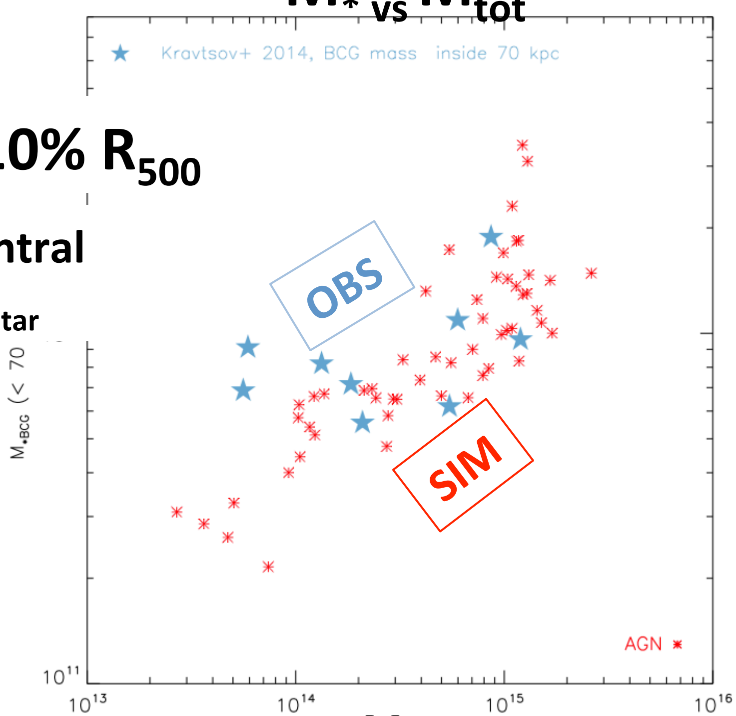
M_{*BCG}-M_{500} in agreement with observations (Kravtsov+14)

Total stellar mass also close to observations (Gonzalez+13, Kravtsov+14)

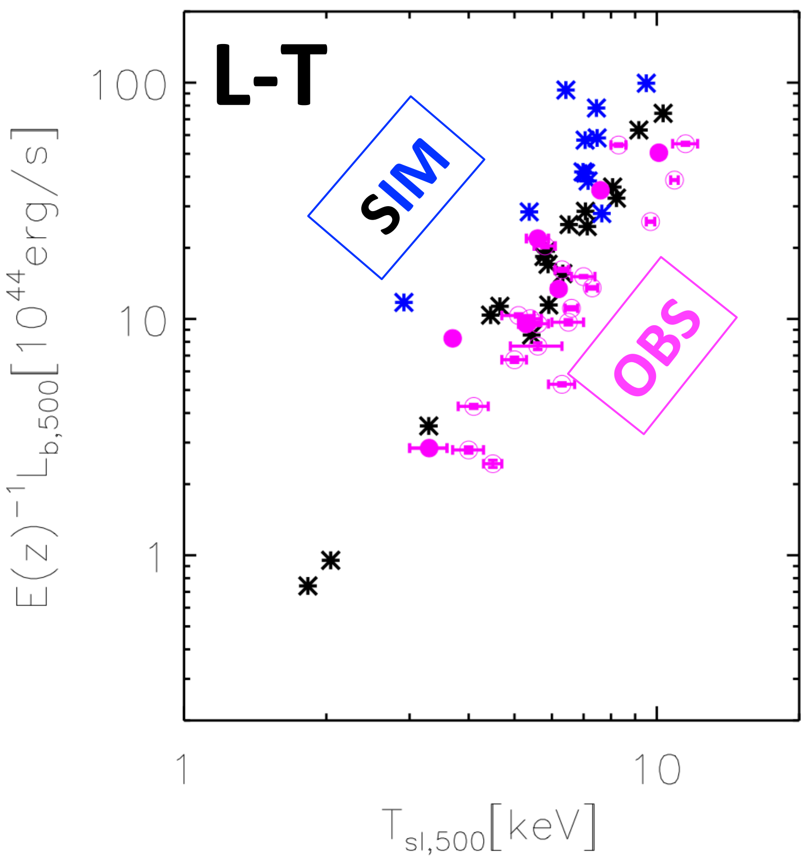
M_* vs M_{tot}

R<10% R_{500}

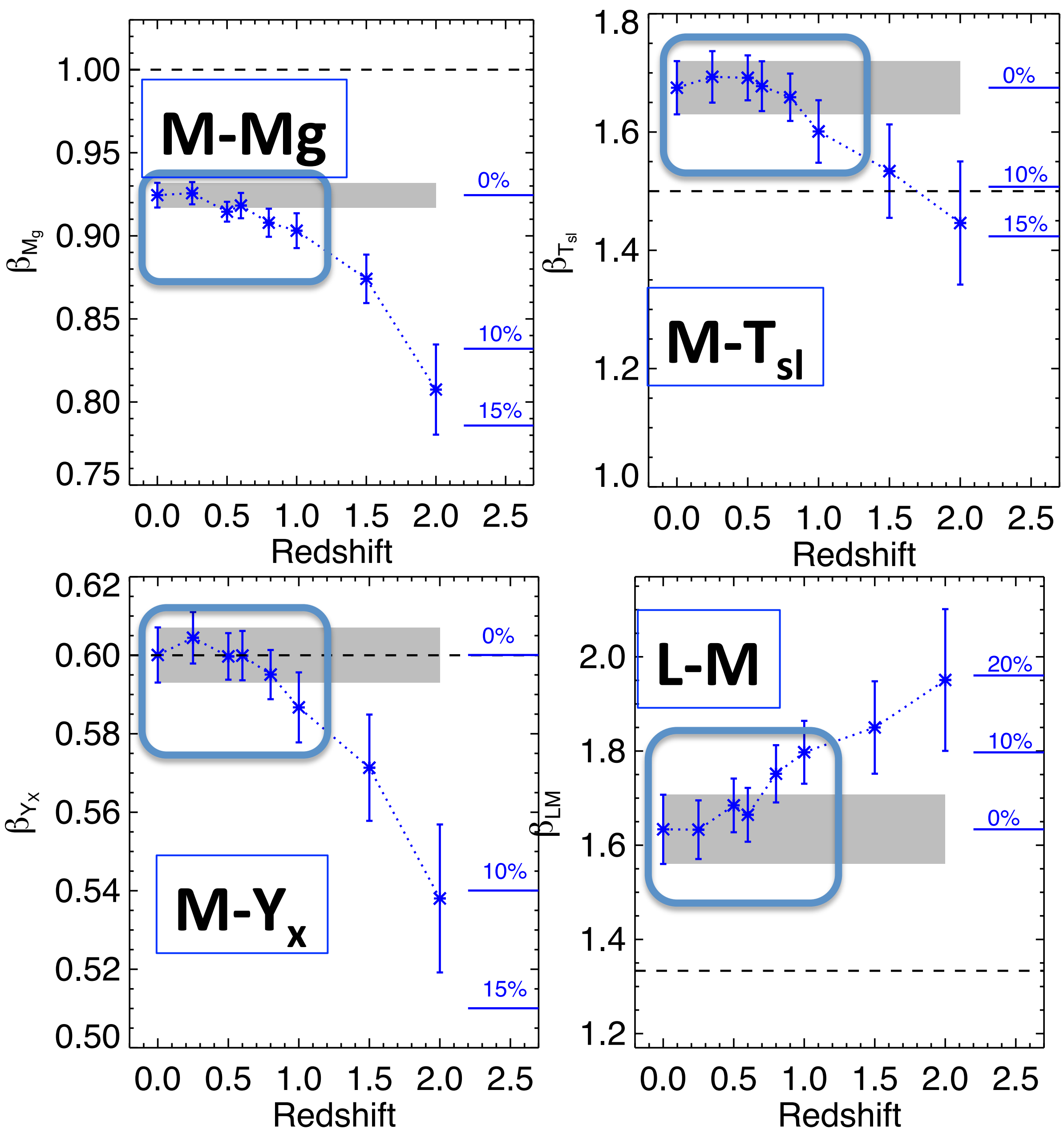
central M_{star}



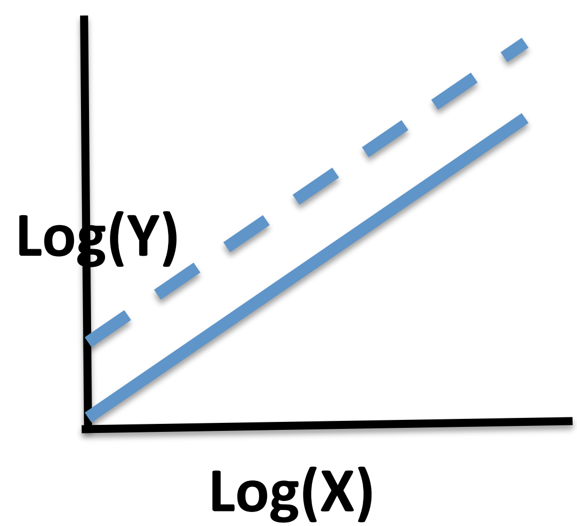
M_{tot}



AGN-Slopes



- β_{Mg} changes due to the z=2 AGN intense activity that provide significant thermal energy to the gas that accretes at slower rate into the cluster potential well
- For the evolution in the normalization one needs to be sure that β is constant
- => cosmology can be done using objects with redshift between 0 ad 1



Troung+ 2016 submitted

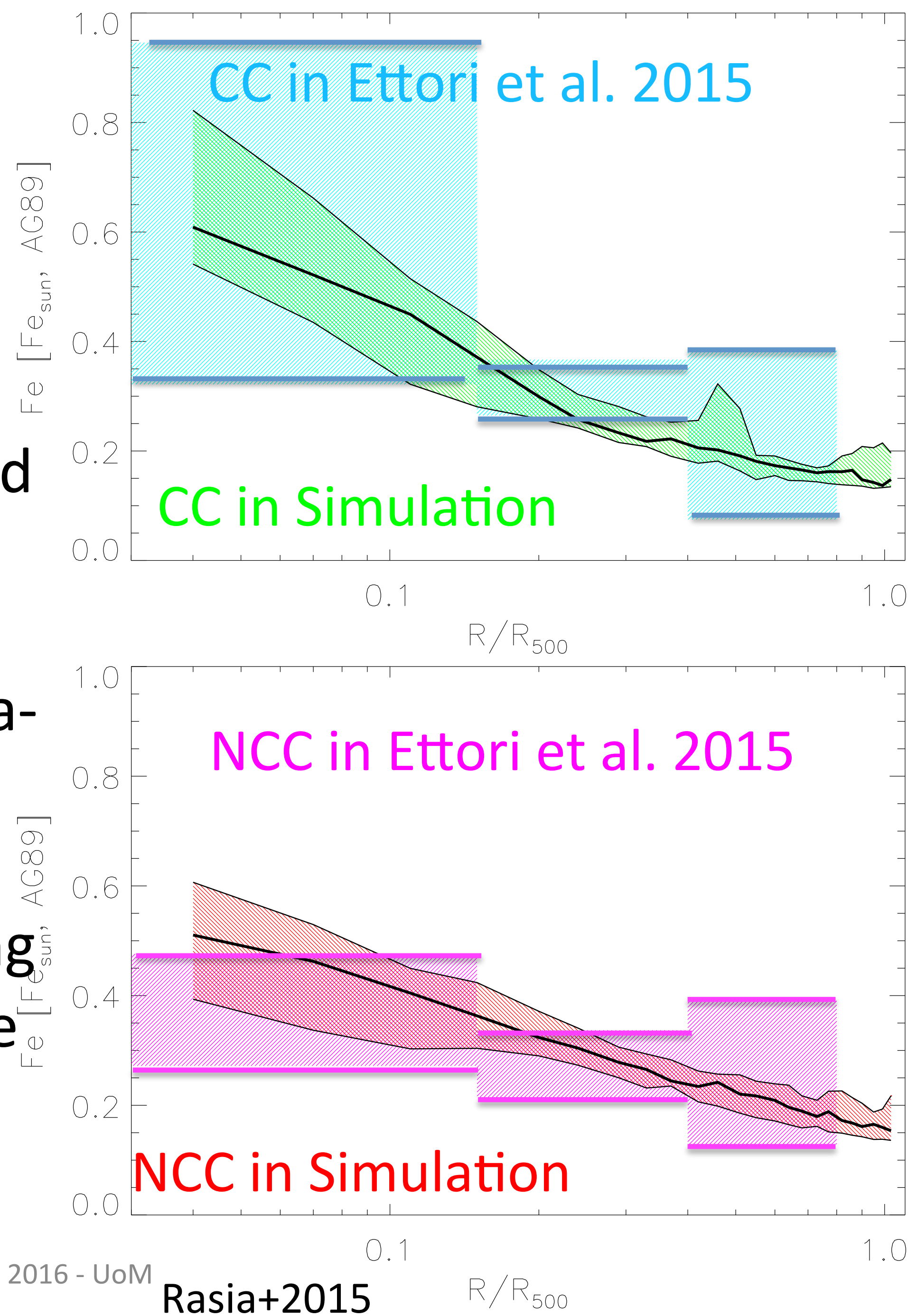
Iron Abundance at z~0

Process driving evolution of chemical enrichment:

- Initial Mass Function
- SNIa, SNcc, AGB yields (and evolution)

Metal diffusion into the intra-cluster medium:

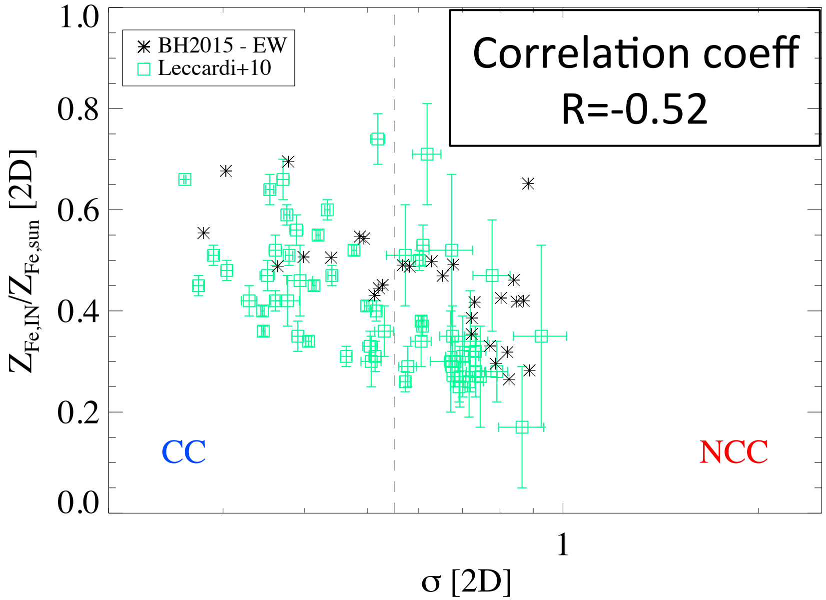
- Early superwinds
- Late ram pressure stripping
- Minor mergers in the core
- Uplift by AGN bubbles



Rasia+2015

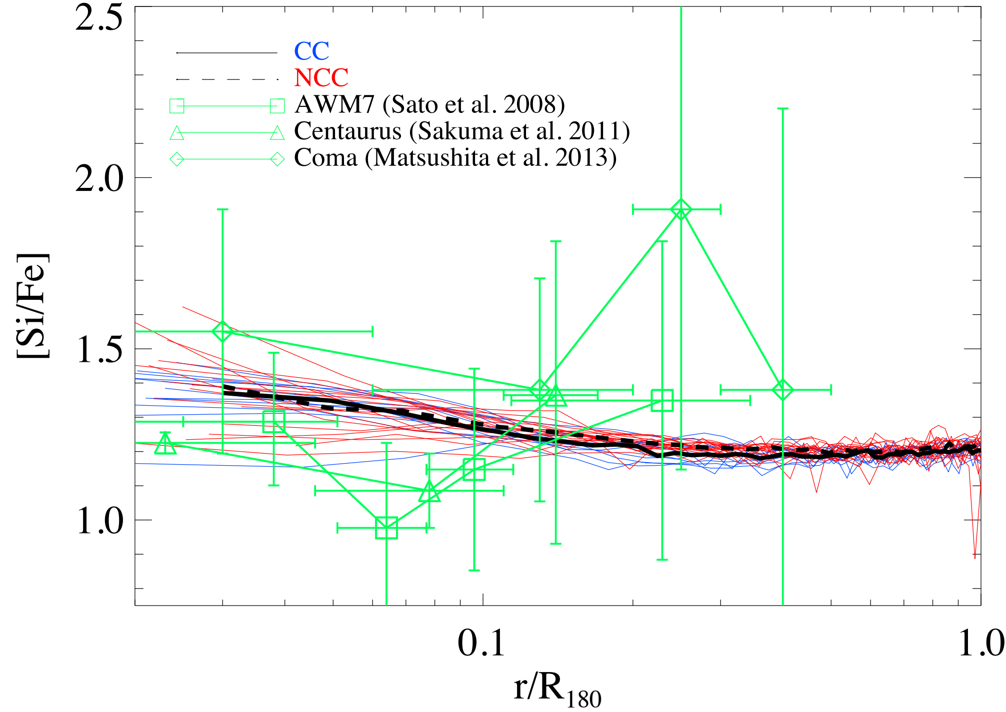
Metals

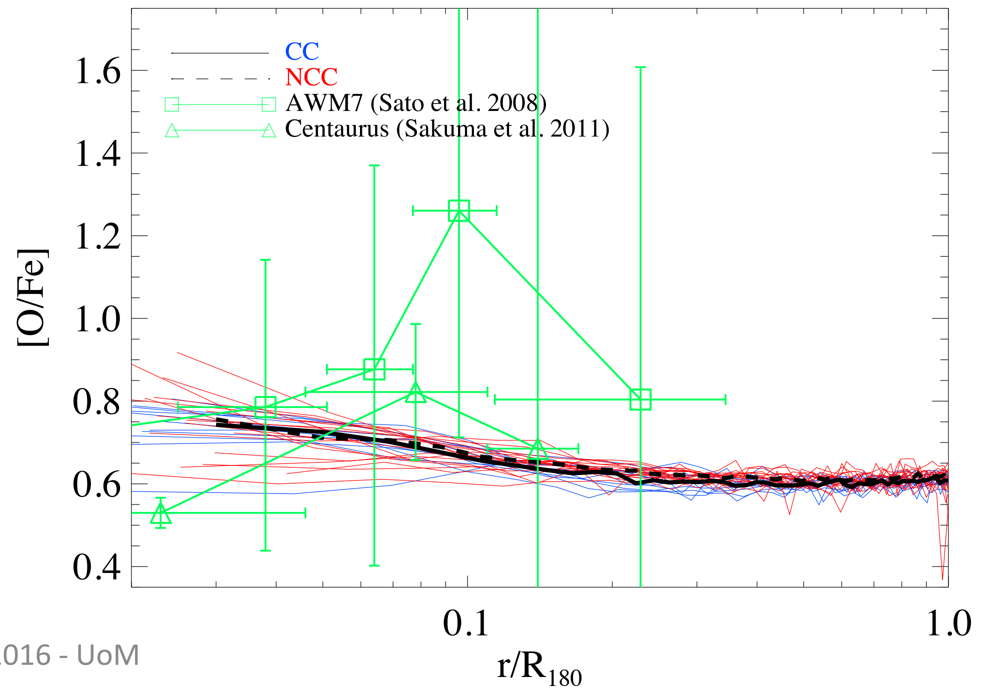
- metal/entropy relation in the core
- [α/Fe] ratio



Pseudo-entropy

In preparation





Where is the flatness of the ratio coming from?

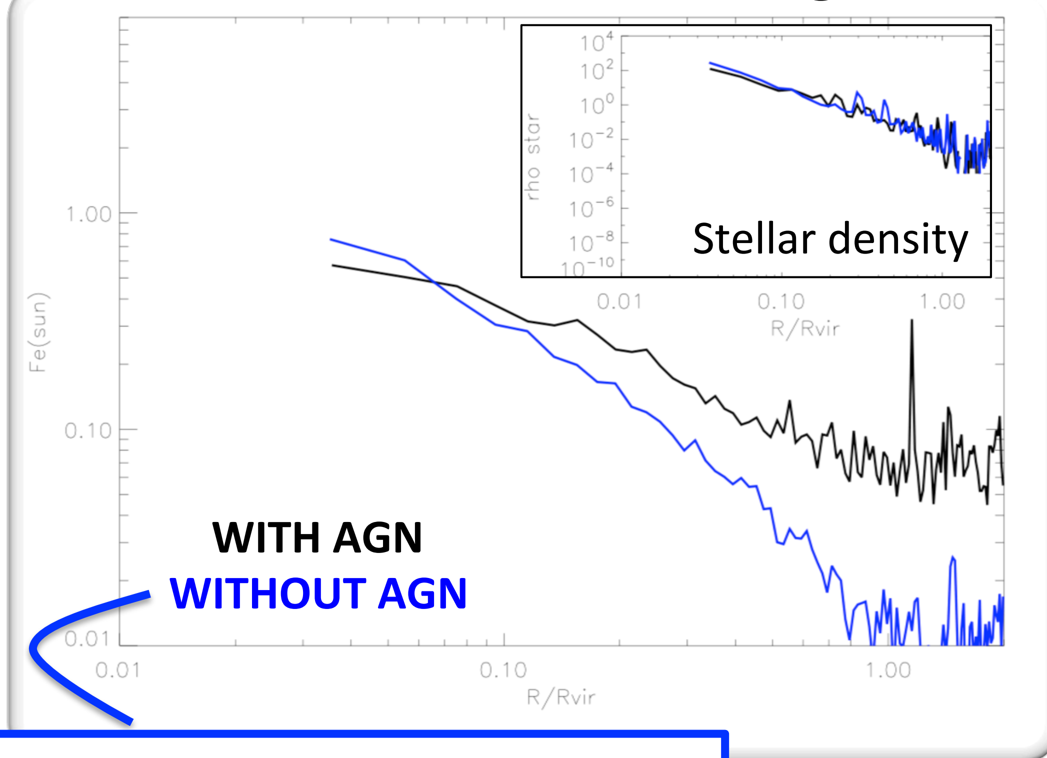
The possible explanations:

1. Metals spread inside-out (AGN outflows + mergers)

2. Gas accreted is already enriched (High-z AGN expelled enriched gas that accretes in a second moment)

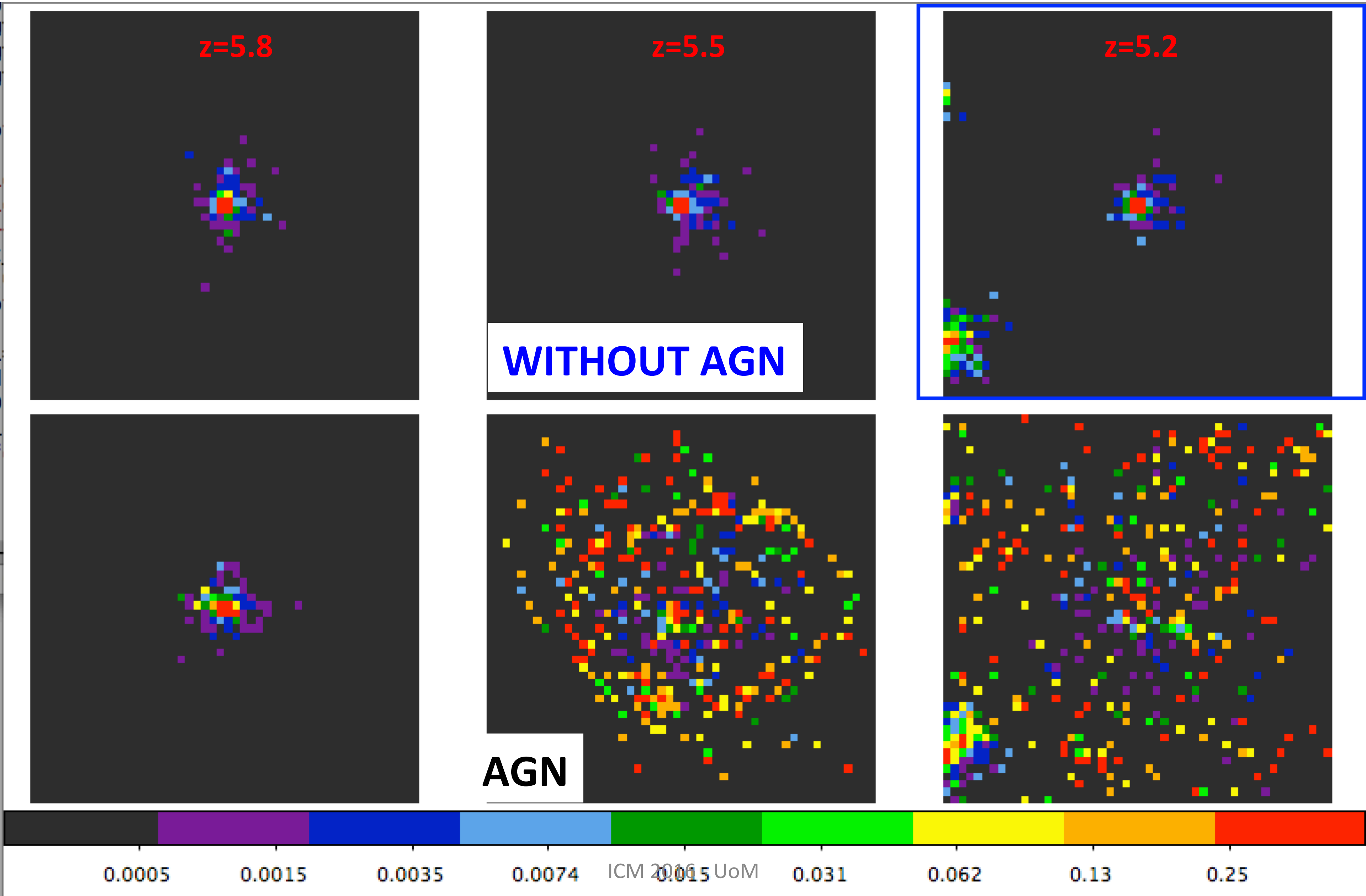
In preparation

Iron radial Profile of 1 cluster @ z=2



Same cosmology
Same merging history
Still similar stellar profiles
Only difference in presence of AGN

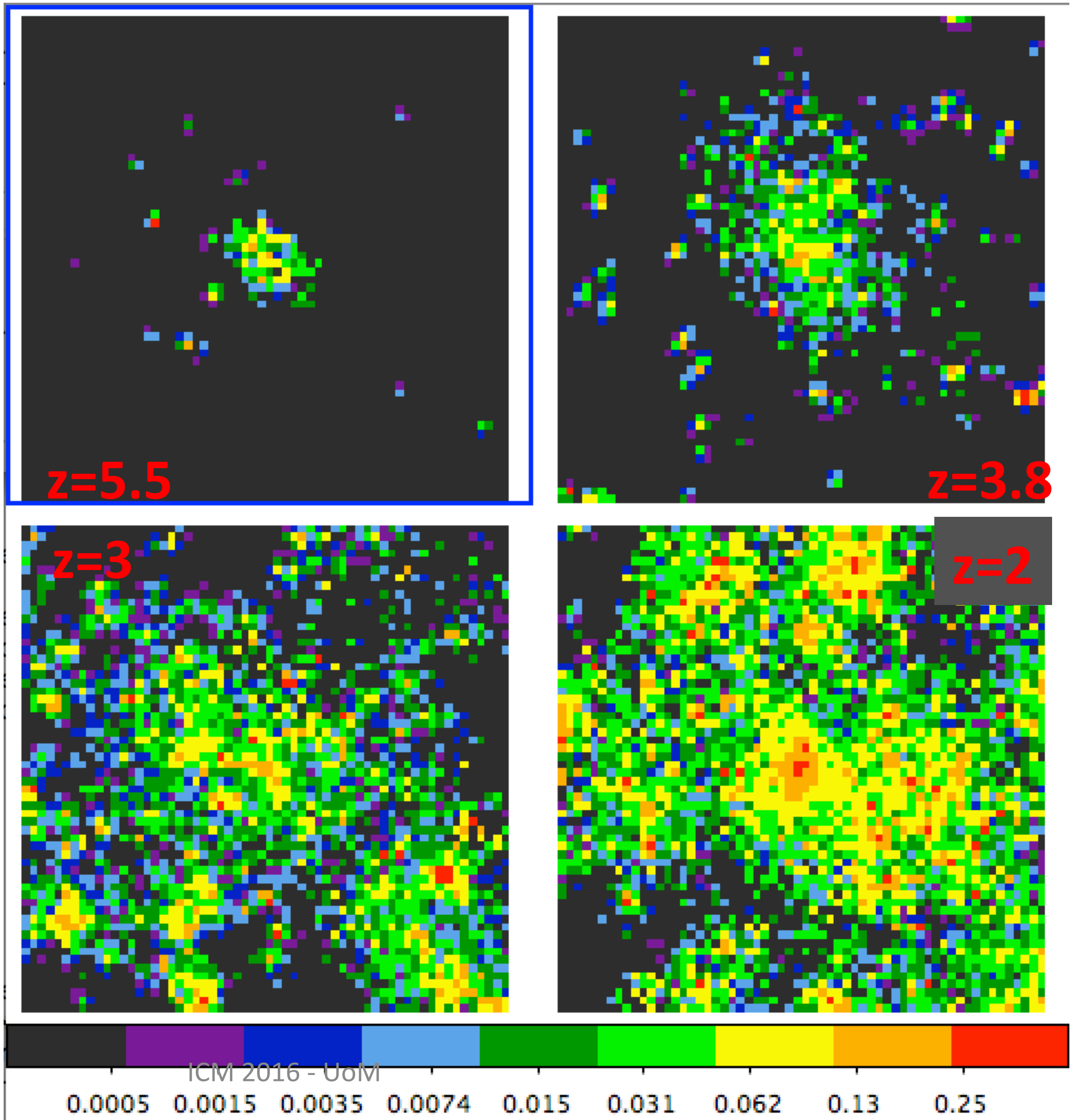
Iron Distribution



Iron Distribution

At larger scales (6 Mpc comoving)

Gas (metals) keep expanding up to z=3-4. By z=2 the large scale medium is all enriched (also by other sources)



Summary

CC/NCC clusters are naturally formed in cosmological hydro-dynamical simulations with realistic thermo- and chemo-dynamical properties.

Flatness of the Iron profile mostly due to the accretion of previously enriched material expelled by the AGN at $z >> 2\text{-}3$

Planelles+ 2016 "*Pressure of the hot gas in simulations of galaxy clusters*"
Truong+2016 "*Simulation of Galaxy Clusters: Scaling Relations & Evolution*"
Biffi+ 2016 "*On the nature of hydrostatic equilibrium in galaxy clusters*"
Rasia+2015 "*Cool Core Clusters from Cosmological Simulations*"