

Connecting Small and Large Scales:

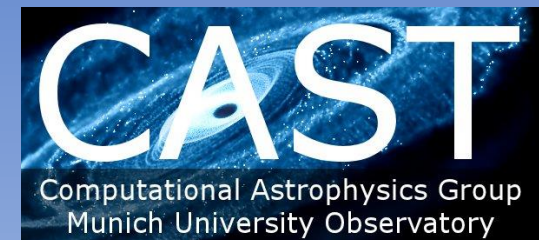
The Role of Feedback in Establishing Global Galaxy Properties over Cosmic Time

Rhea-Silvia Remus

with Klaus Dolag, Thorsten Naab, Michaela Hirschmann, Felix Schulze, Lisa Steinborn, Adelheid Teklu

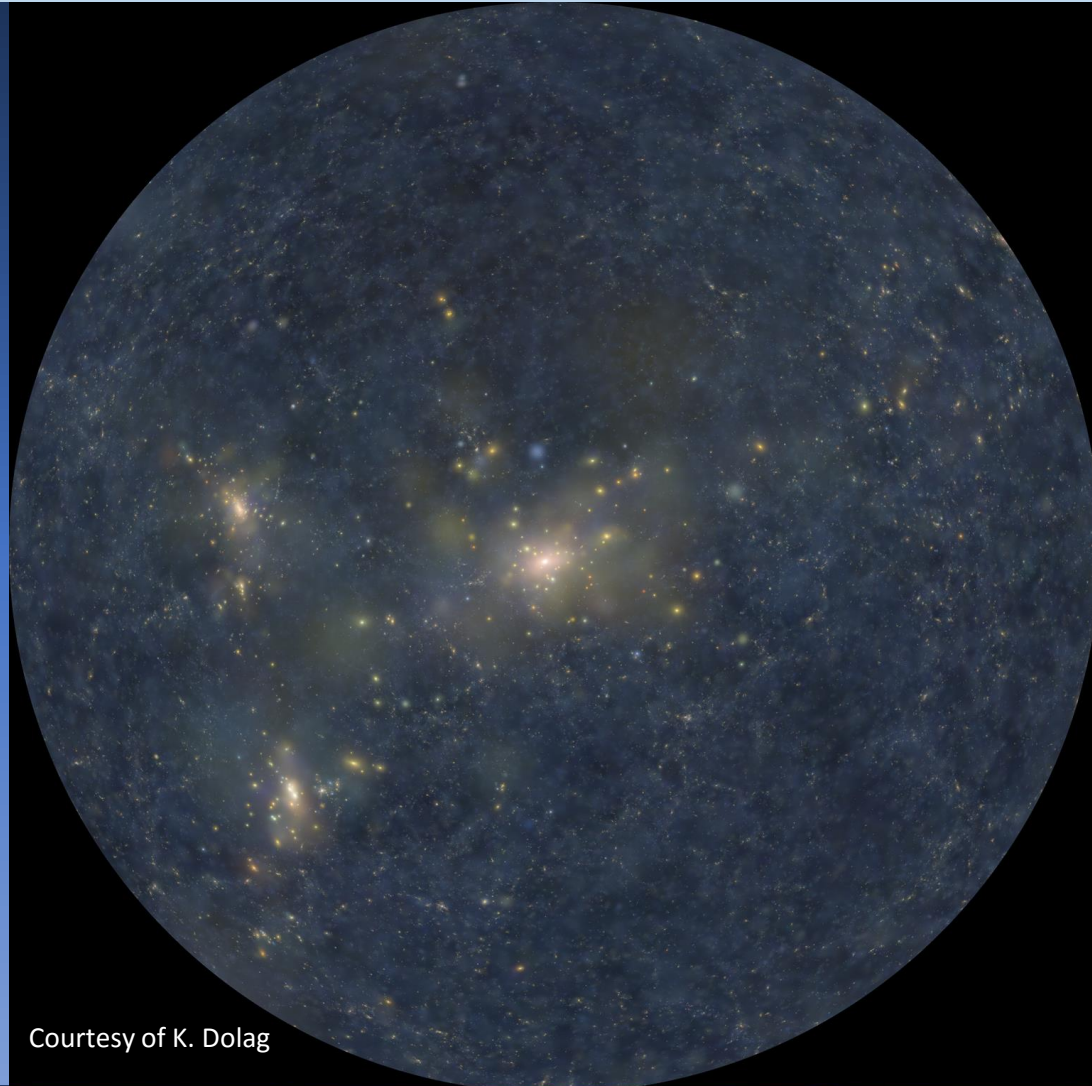
& the Magneticum Pathfinder Team

Galaxies 2016, Cozumel, 12.4.2016



The Simulations: Magneticum

www.magneticum.org



Courtesy of K. Dolag

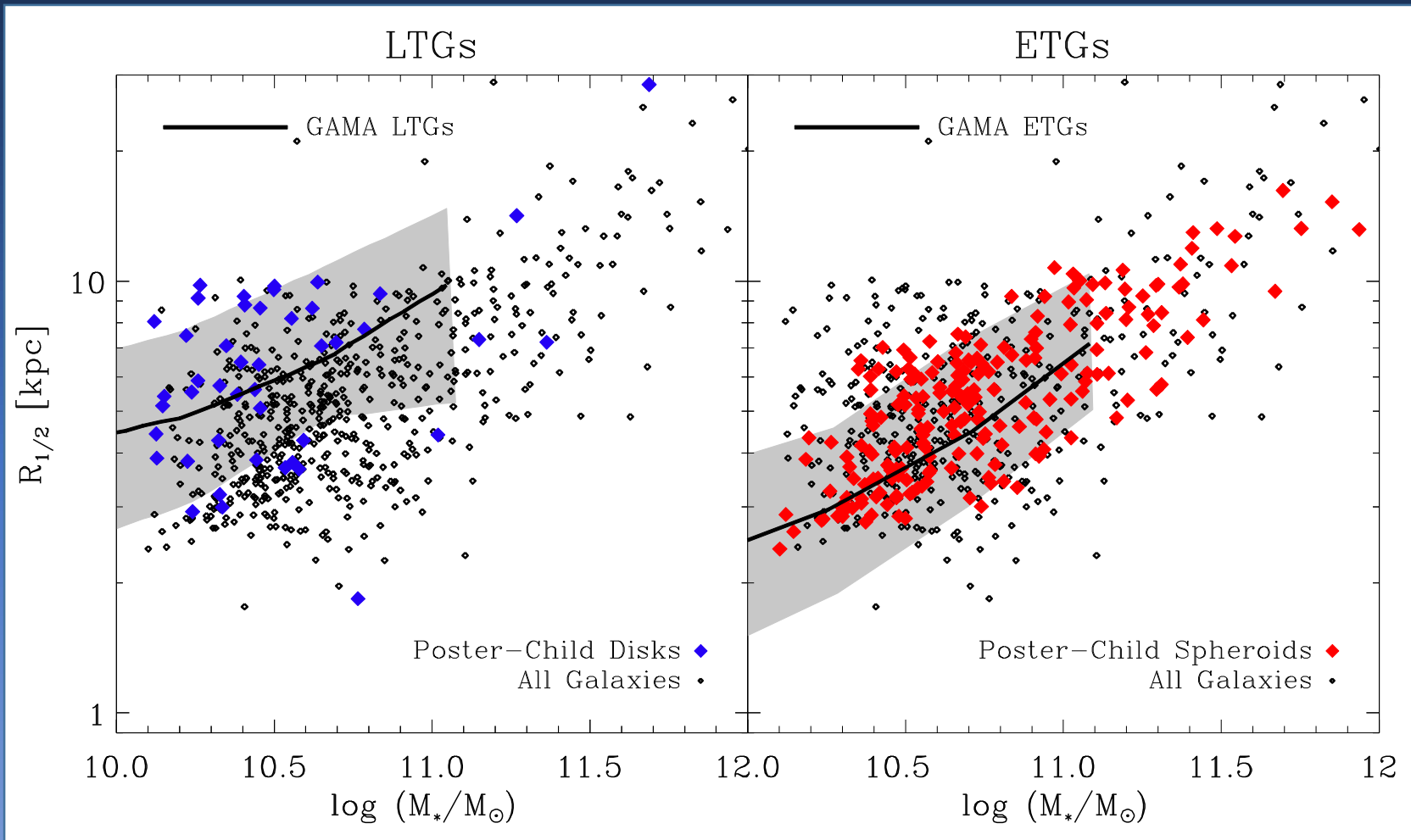
Box	Mpc/h	mr	hr	uhr
0	2688	y		
1	896	y		
2	352	y	y	
3	128	y	y	(z=2)
4	48	y	y	y

	mr	hr	uhr
$m_{DM} (M_{\odot}/h)$	$1.3 \cdot 10^{10}$	$6.9 \cdot 10^8$	$3.7 \cdot 10^7$
$m_{Gas} (M_{\odot}/h)$	$2.6 \cdot 10^9$	$1.4 \cdot 10^7$	$7.3 \cdot 10^6$

- Modified SPH version of GADGET-3
- Feedback from stellar winds
- Feedback from AGN
- Metal enrichment and star formation follow pattern of metal production from SNIa, SNII & AGB
- Gas cooling depends on local metallicity

See Poster by Klaus Dolag

Reproducing Global Scaling Relations

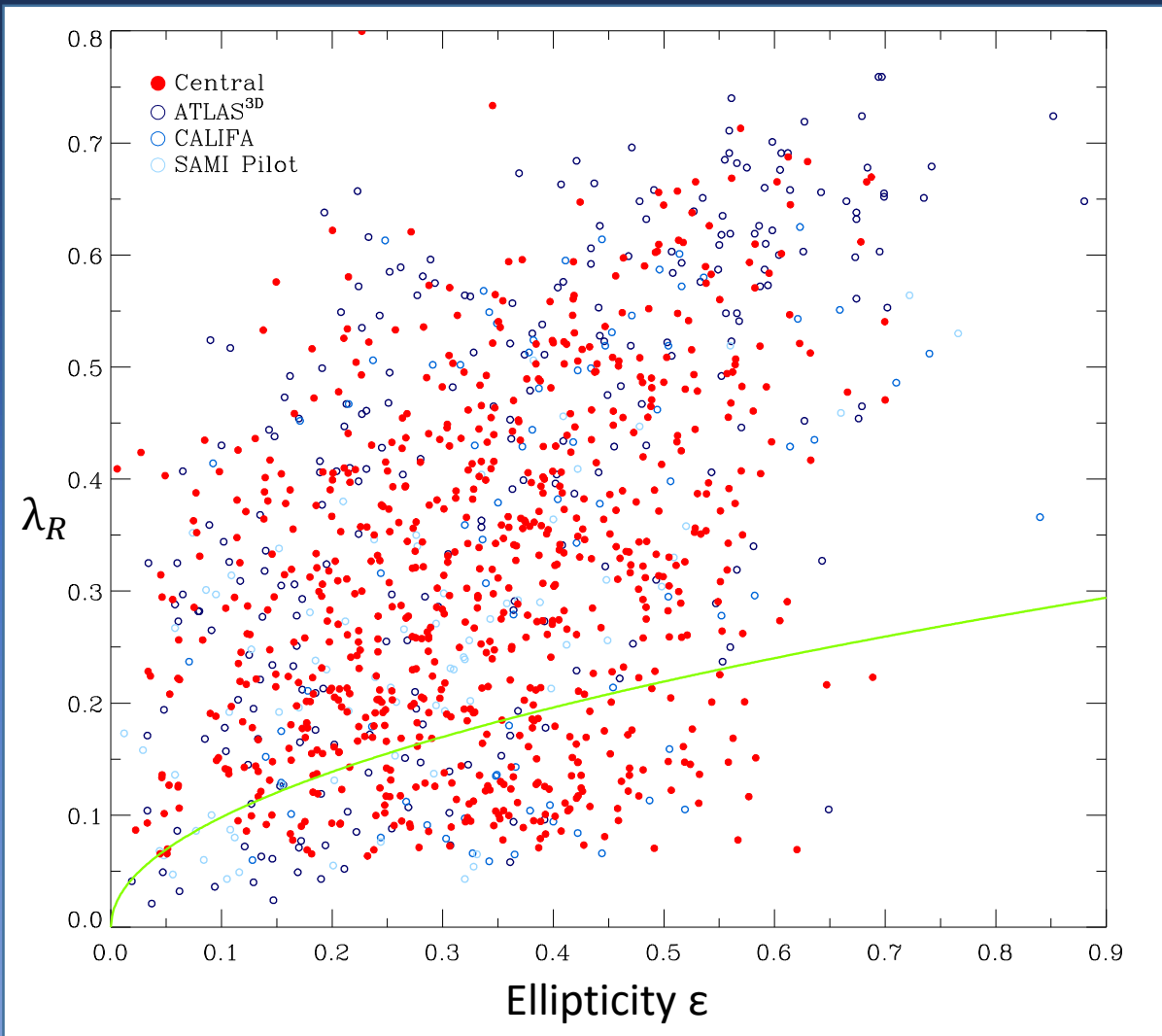


1. Mass-Size Relation

Observations:
GAMA; Baldry et al., 2012

Remus et al., 2015

Reproducing Global Scaling Relations



Fast rotating ETGs

Slow rotating ETGs

Schulze et al., in prep

1. Mass-Size Relation
2. λ_R - ϵ - Plane

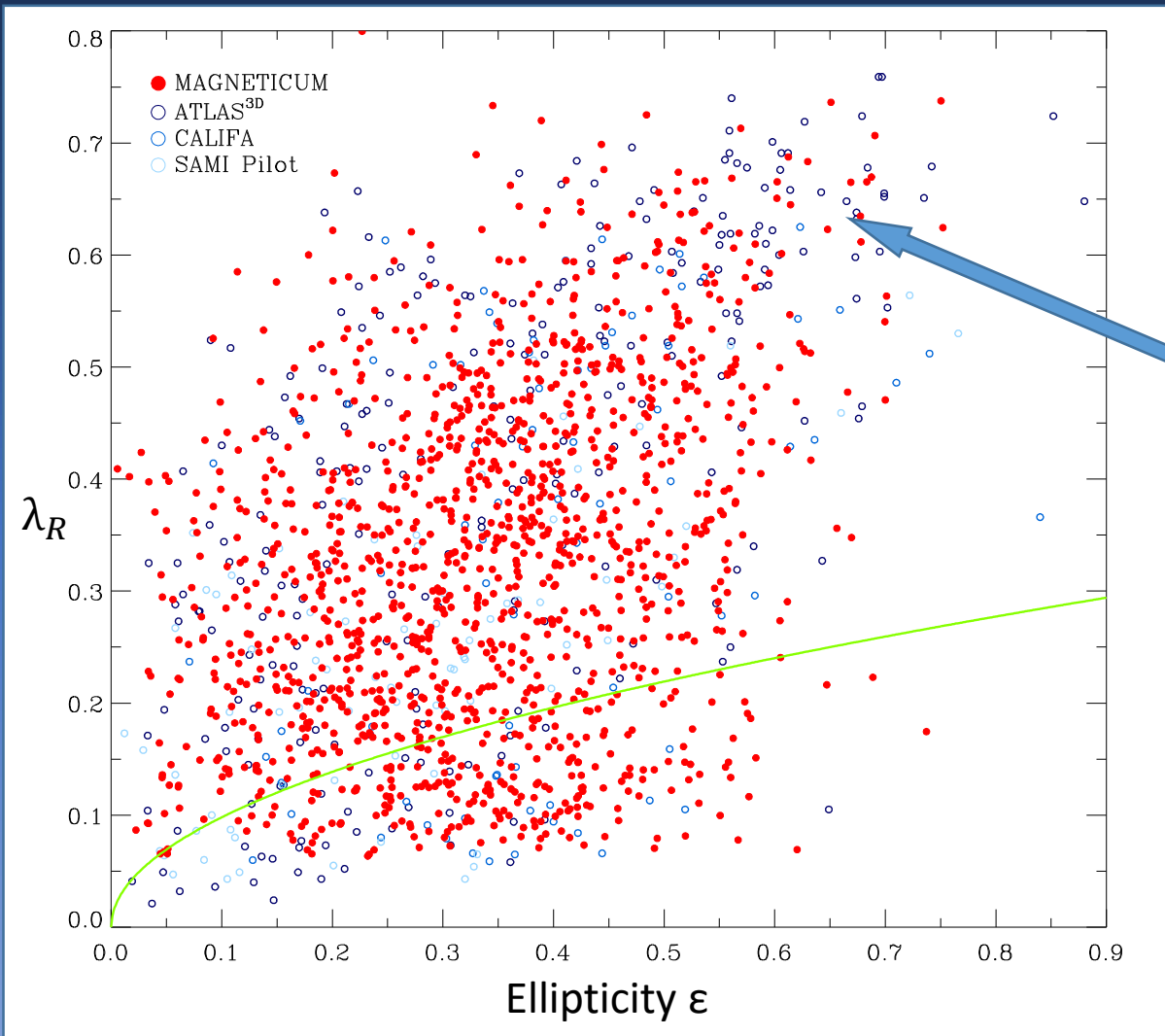
$$\lambda_R \equiv \frac{\langle R |V| \rangle}{\langle R \sqrt{V^2 + \sigma^2} \rangle}$$

Emsellem et al., 2007; 2011

Observations:

- ATLAS^{3D}: Cappellari et al., 2011
- Califa: Querejeta et al., 2015
- SAMI Pilot: Fogarty et al., 2015

Reproducing Global Scaling Relations



1. Mass-Size Relation
2. λ_R - ϵ - Plane

Fast
rotating
ETGs

Adding Satellite ETGs:
Satellite-ETGs populate especially the ultra-
fast rotating end

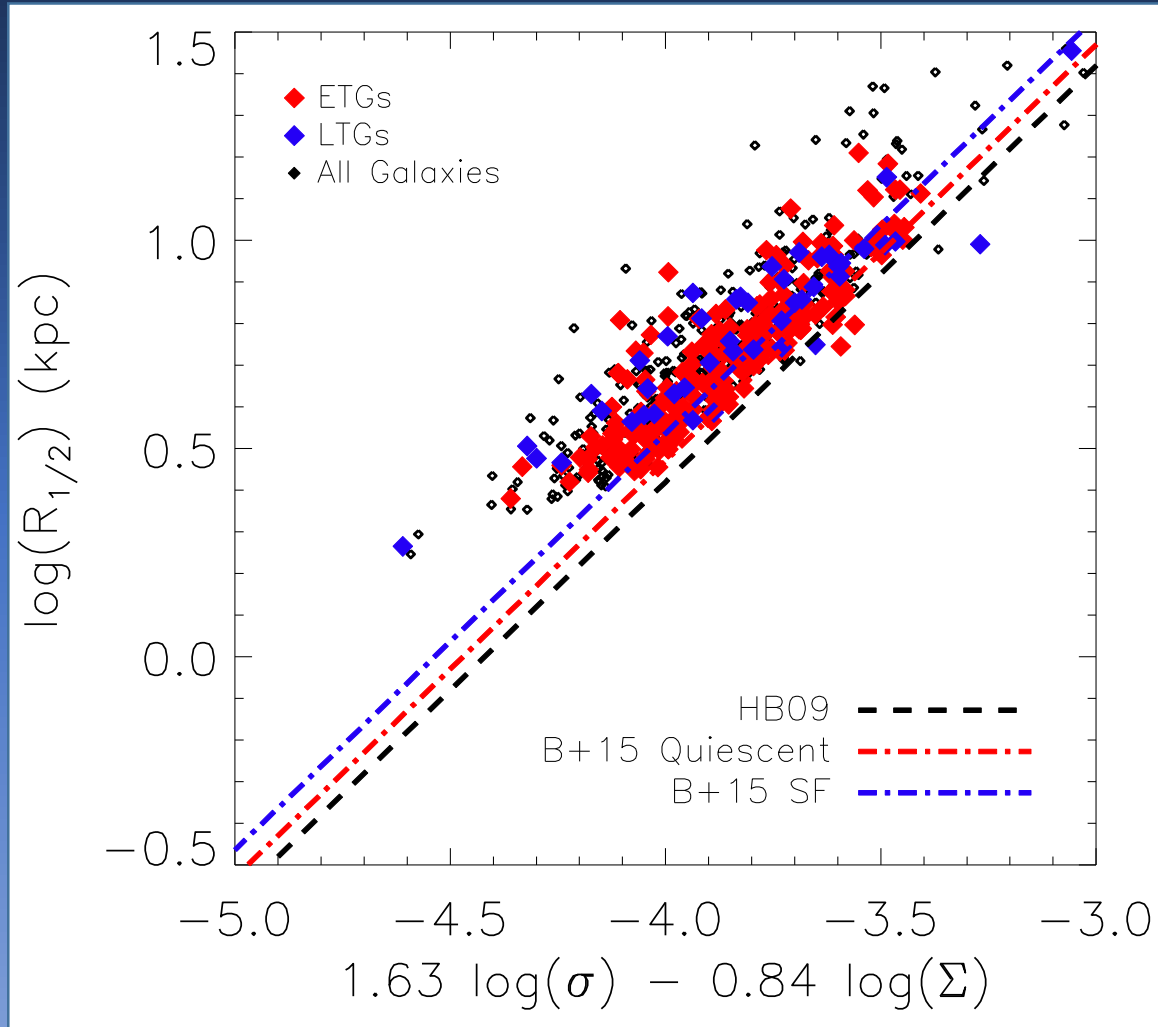
Slow
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ETGs

Observations:

- ATLAS^{3D}: Cappellari et al, 2011
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Reproducing Global Scaling Relations



1. Mass-Size Relation
2. λ_R - ϵ - Plane
3. Mass - Fundamental Plane

Stellar mass surface density:

$$\Sigma_* = M_*/(2\pi R_{\text{eff}}^2)$$

Observations (SDSS):

- Hyde & Bernardi, 2009
- Bezanson, Franx & van Dokkum, 2015

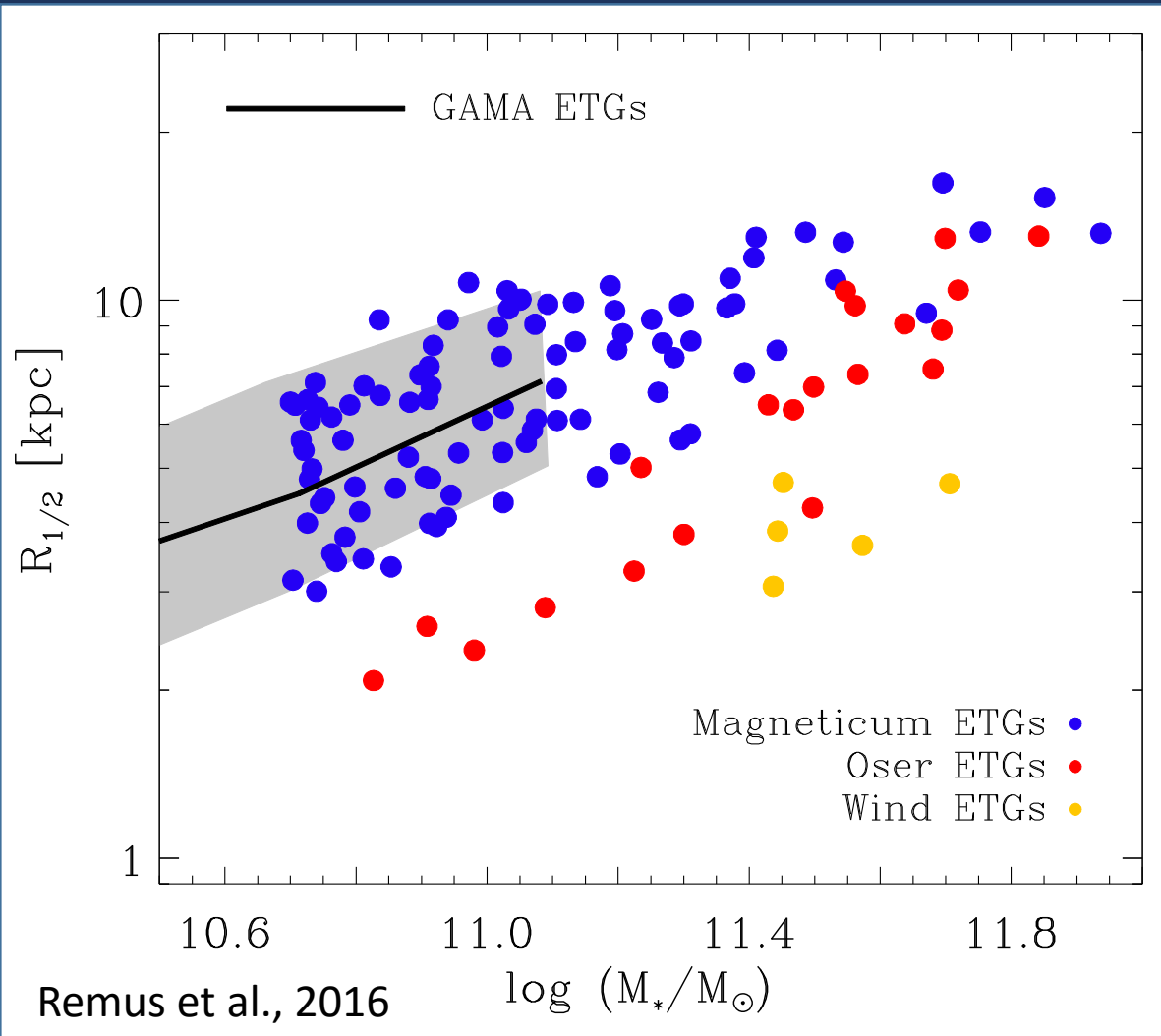
The Role of Feedback

To understand the impact of the different feedback models on the implementation of these scaling relations, we use ETGs from simulations with different feedback models:

	SPH	AGN	Stellar Wind	Cooling	References
Magneticum	Improved	Yes	Weak	Incl. metals	Hirschmann et al., 2014; Teklu et al., 2015
Oser	Standard	No	No	Primordial	Oser et al., 2010;2012
Wind	Standard	No	Strong	Incl. metals	Hirschmann et al., 2013; 2015

The Role of Feedback

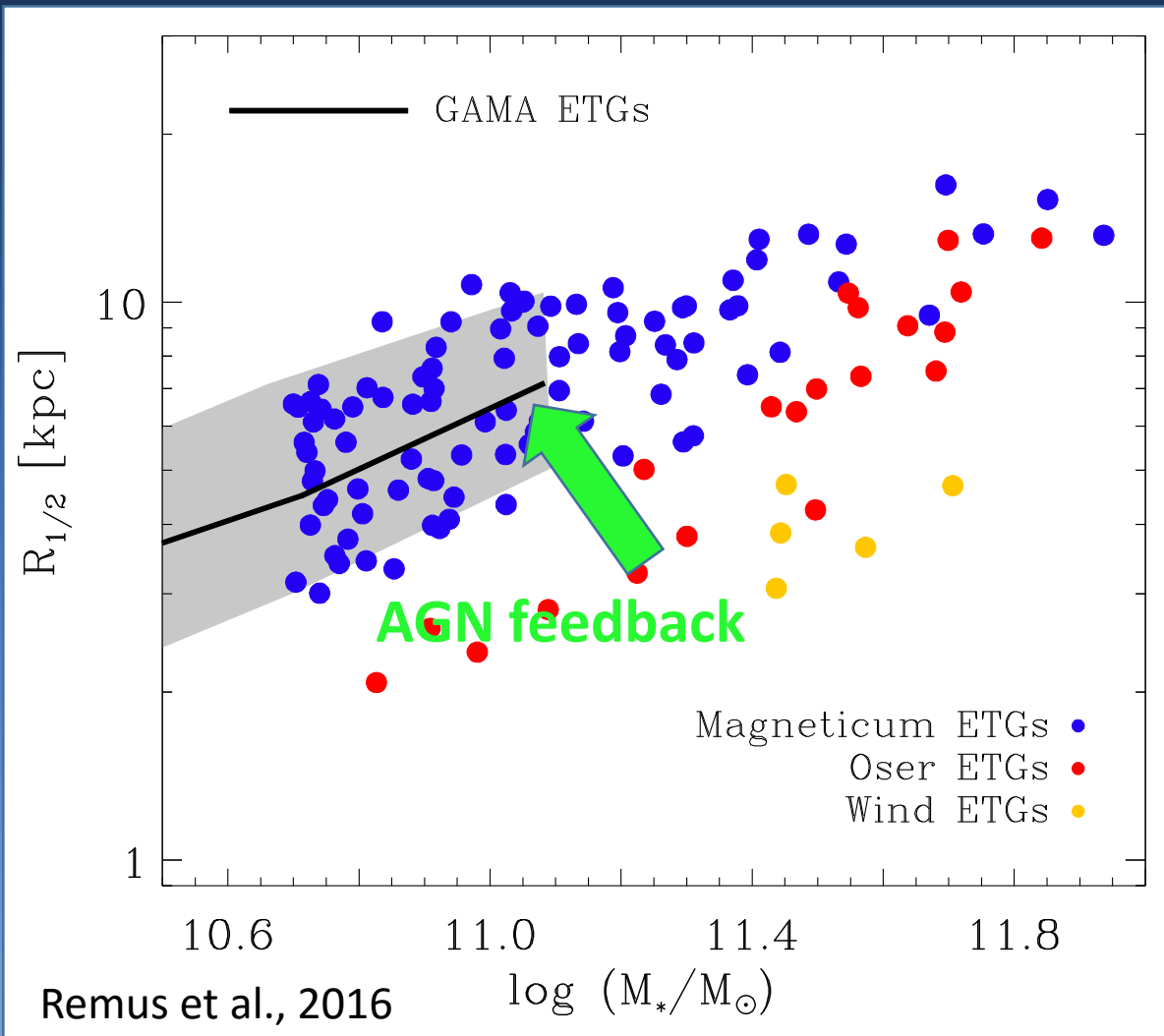
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Observations:
GAMA; Baldry et al., 2012

The Role of Feedback

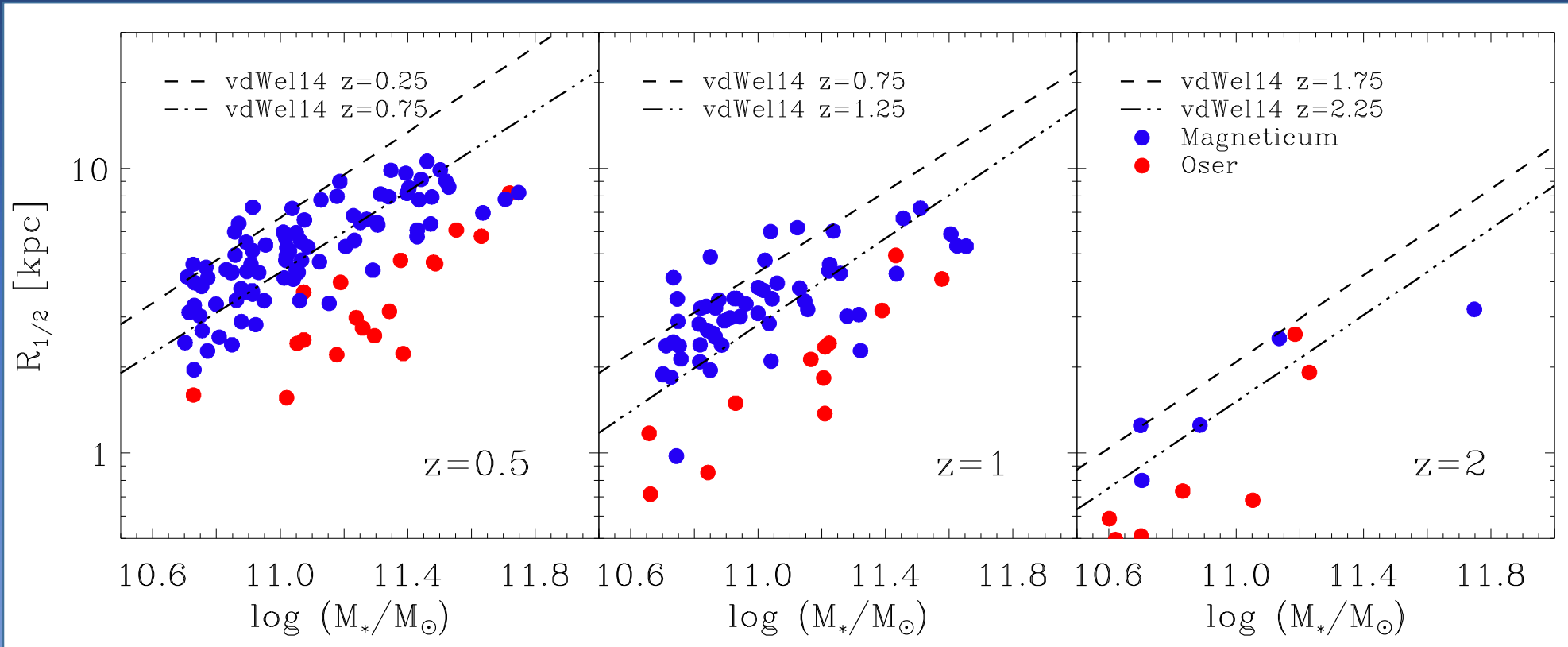
1. Mass-Size Relation



Observations:
GAMA; Baldry et al., 2012

The Role of Feedback

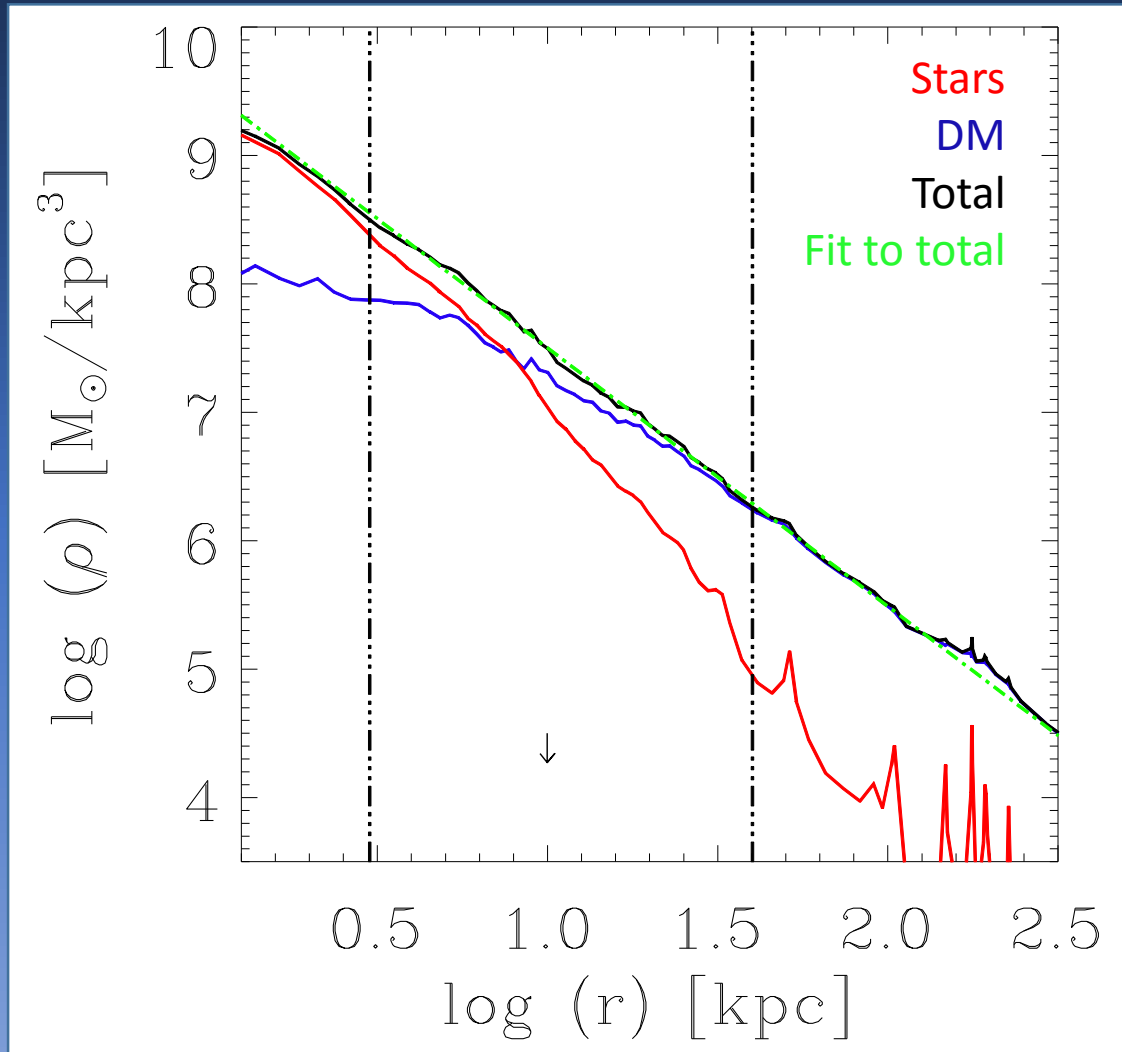
1. Mass-Size Relation



Observations:
Van der Wel et al., 2014

Remus et al., 2016

The Role of Feedback



1. Mass-Size Relation
2. $f_{DM} - \gamma_{tot}$ Relation

$$\gamma = \frac{d \log(\rho)}{d \log(r)}$$

Total radial density profiles can be fit by a single power law.

Inner part: Stars dominate the total profiles.

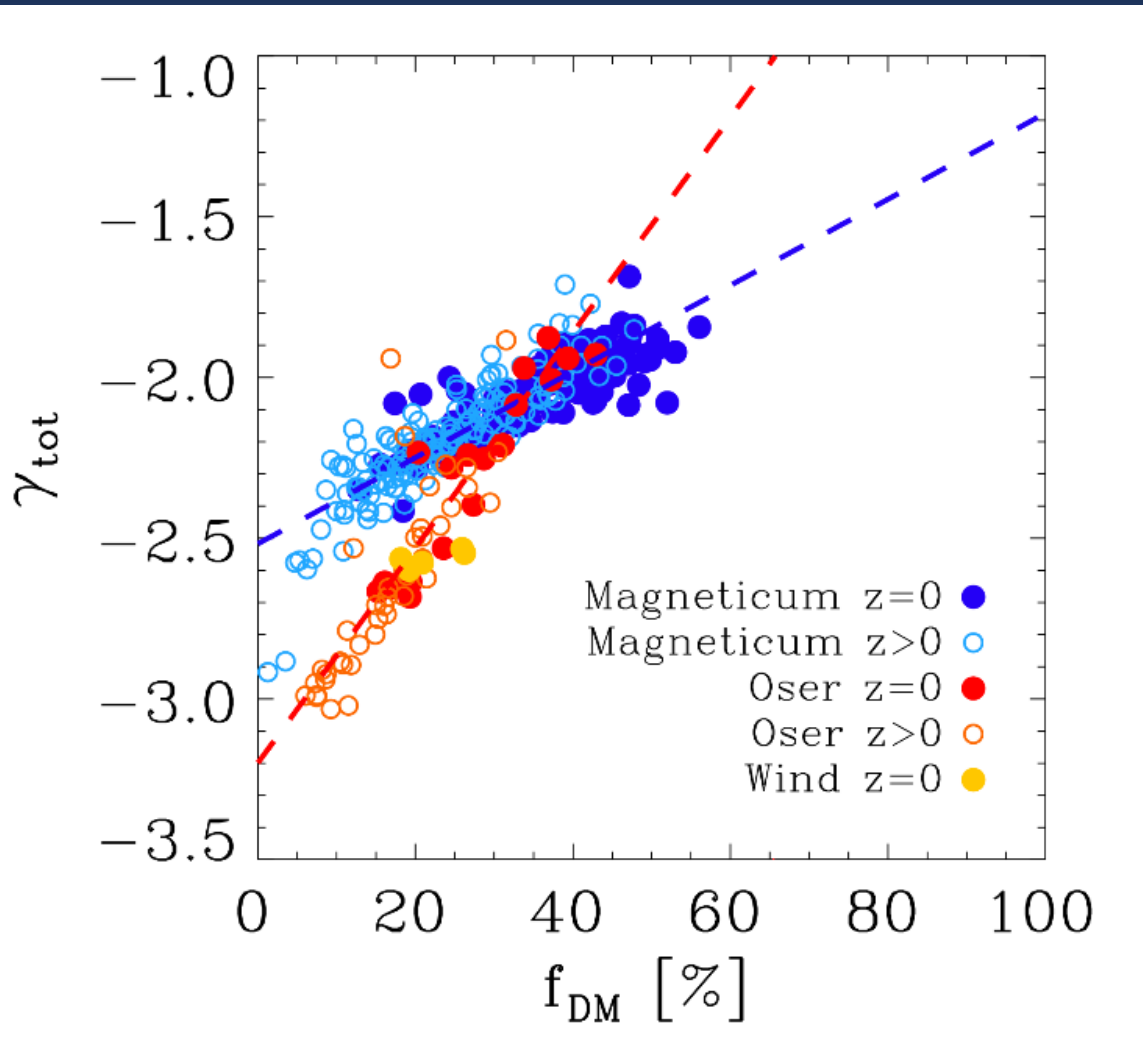
Outer part: Dark Matter dominates the total profiles.



This is independent of the included feedback models

see Remus et al., 2013; 2016

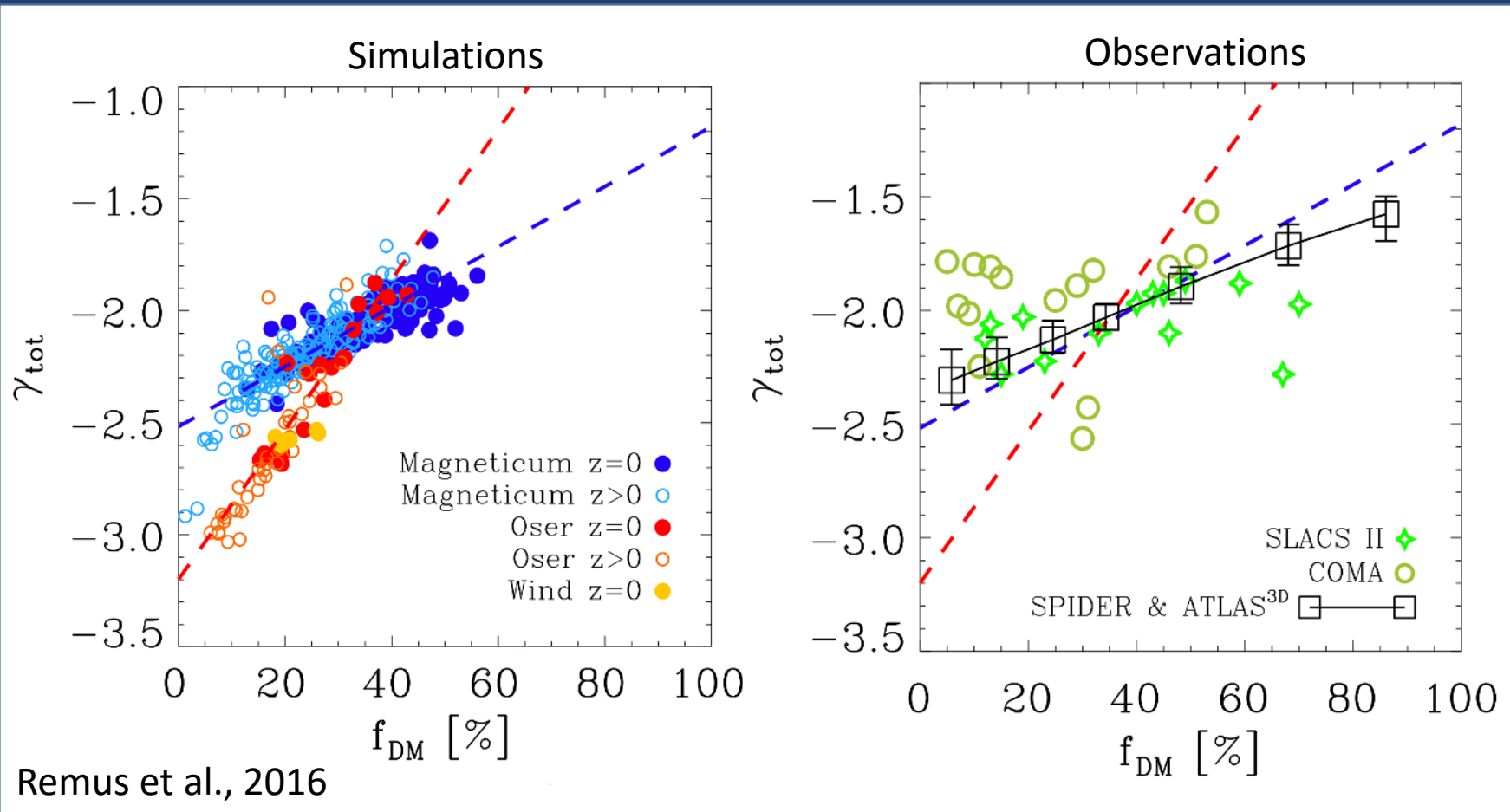
The Role of Feedback



Remus et al., 2016

1. Mass-Size Relation
2. $f_{\text{DM}} - \gamma_{\text{tot}}$ Relation

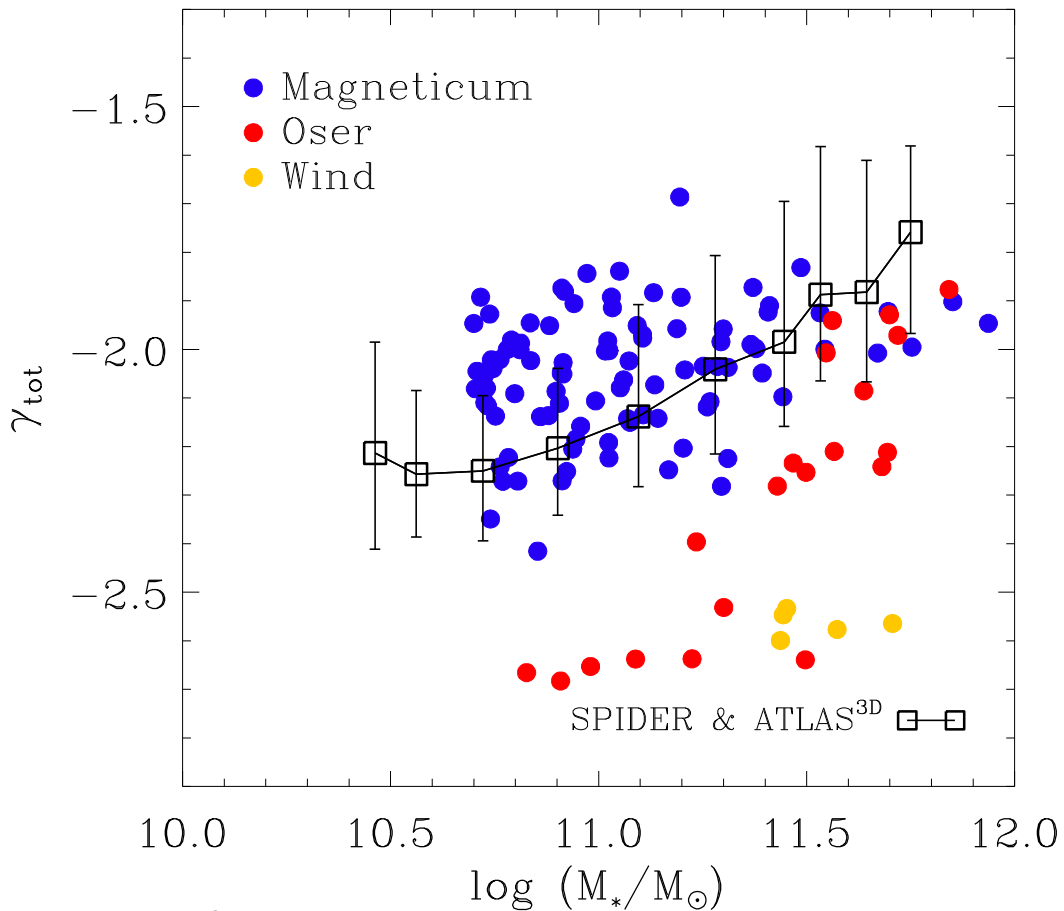
The Role of Feedback



1. Mass-Size Relation
2. $f_{DM} - \gamma_{tot}$ Relation

Observations:
SPIDER & ATLAS^{3D} : Tortora et al., 2014
Coma: Thomas et al., 2007
SLACS: Barnabé et al., 2011

The Role of Feedback



Remus et al., 2016

Observations:

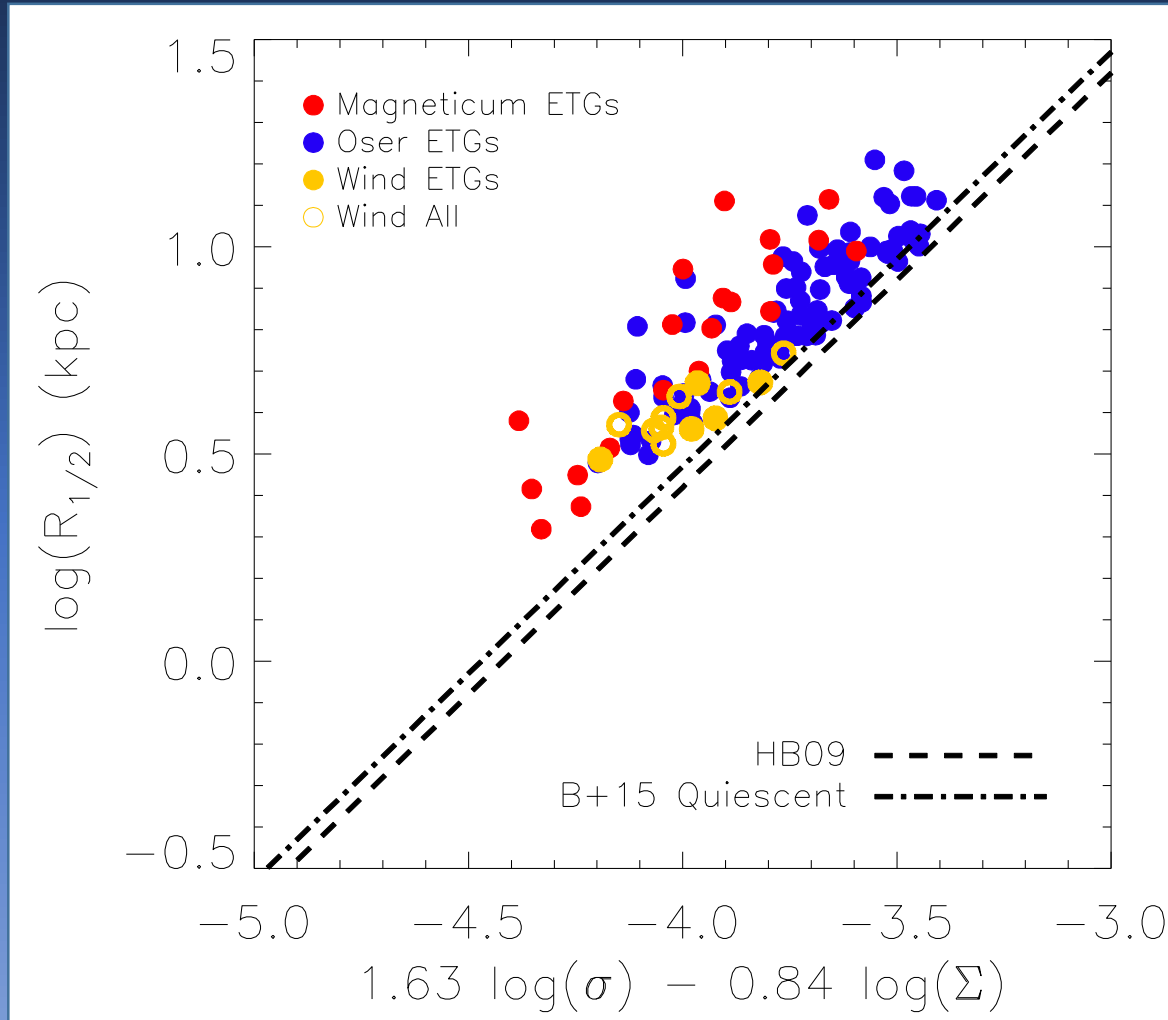
SPIDER & ATLAS^{3D} : Tortora et al., 2014

1. Mass-Size Relation
2. $f_{DM} - \gamma_{tot}$ Relation
3. $M_* - \gamma_{tot}$ Relation

Summary & Conclusion

- With the Magneticum Pathfinder simulations we can successfully **reproduce** galaxy scaling relations such as the **mass-size relations** or the **mass-fundamental plane**.
- We find an additional **tight correlation between the central dark matter fractions and the total density distribution of ETGs**, established by the individual formation histories depending on the amount dry and wet accretion.
- The included feedback has crucial influence on all **these relations**, which thus **can be used to test the different feedback models**:
 - Stellar feedback is especially important for smaller galaxies, and it leads to more discy galaxies, and more compact ETGs.
 - AGN feedback counteracts the effects of stellar feedback for larger mass galaxies, and it especially prevents the central over-cooling of stars in ETGs.

The Role of Feedback



1. Mass-Size Relation
2. $f_{DM} - \gamma_{tot}$ Relation
3. $M_* - \gamma_{tot}$ Relation
4. Mass –
Fundamental Plane