Astrofísica Numérica

The origin and evolution of the Tully-Fisher Relation in a Λ-CDM Universe

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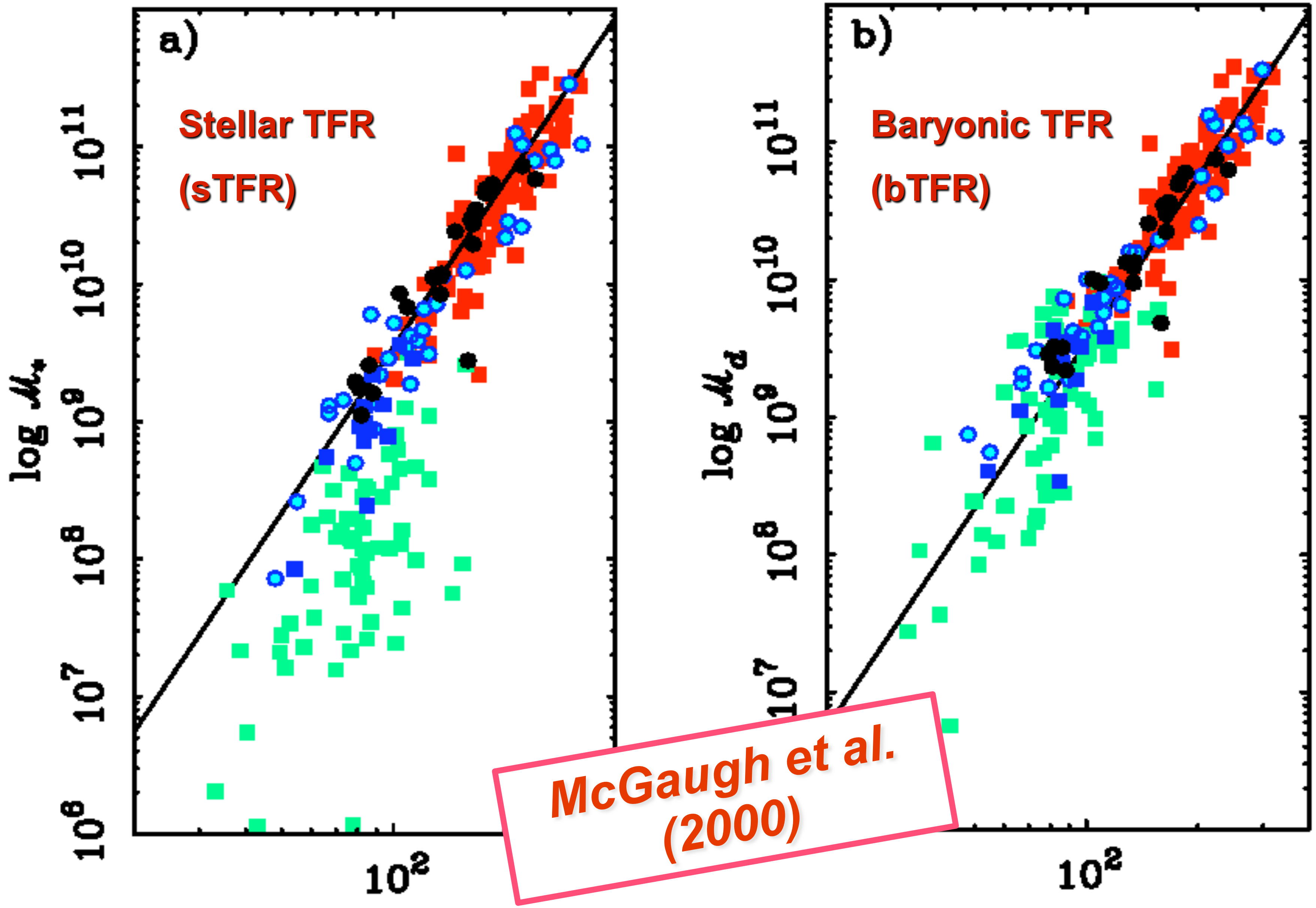
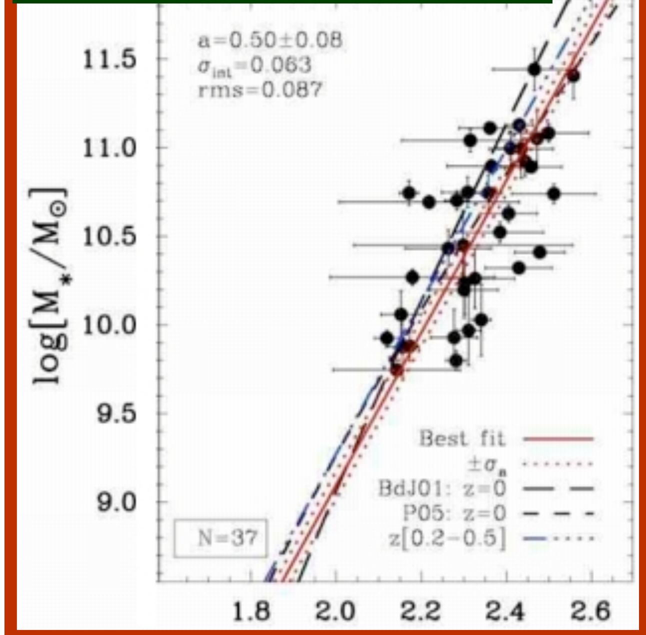
LOCAL STELLAR AND BARYONIC TFR



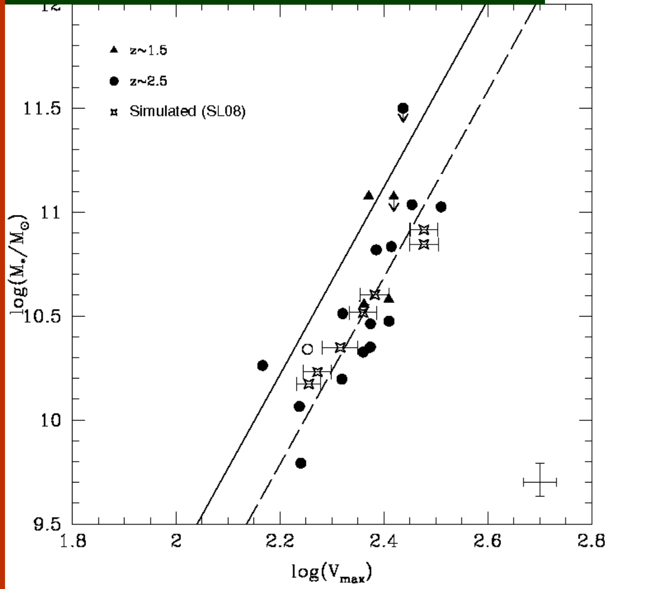
THE OBSERVED EVOLUTION

Miller et al. (2011)



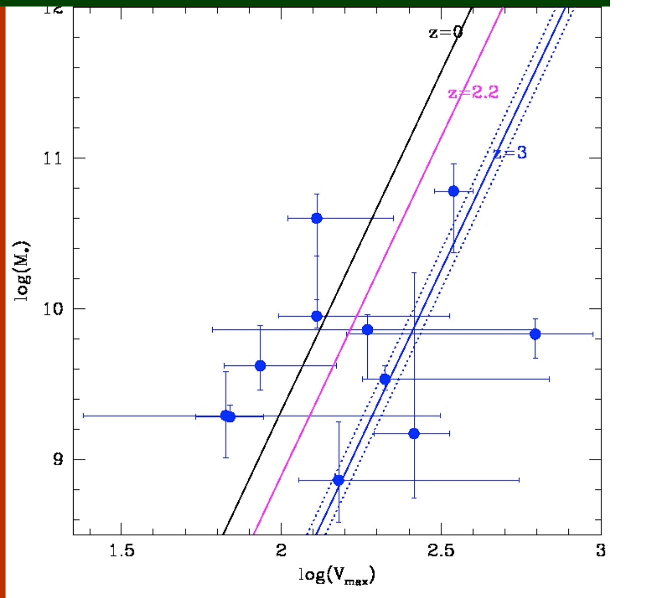
Evolution by 0.14 ± 0.11 dex in M* from z~1 to z~0.3

Cresci et al. (2009)



Evolution by 0.41 ± 0.11 dex in M* since z~2

Gnerrucci et al. (2011)



Large scatter (~1.5 dex) of the TFR at z~3 suggests that the relation is not yet in place at this redshift

Numerical Simulations

- Chemical code **GADGET-3** (Scannapieco et al. 2008).
- **Λ-CDM cosmology**, with Ω_m=0.3, Ω_Λ=0.7, Ω_b=0.04 and H_0=100 h^{-1} km s^{-1} Mpc^{-1} with h=0.7.
- Comoving cubic volumen of **10 Mpc h^{-1} side length.**
- **Mass resolution of 6 x 10^6 M_o h^{-1} and 9 x 10^5 M_o h^{-1}** for dark matter and initial gas-phase particles, respectively.

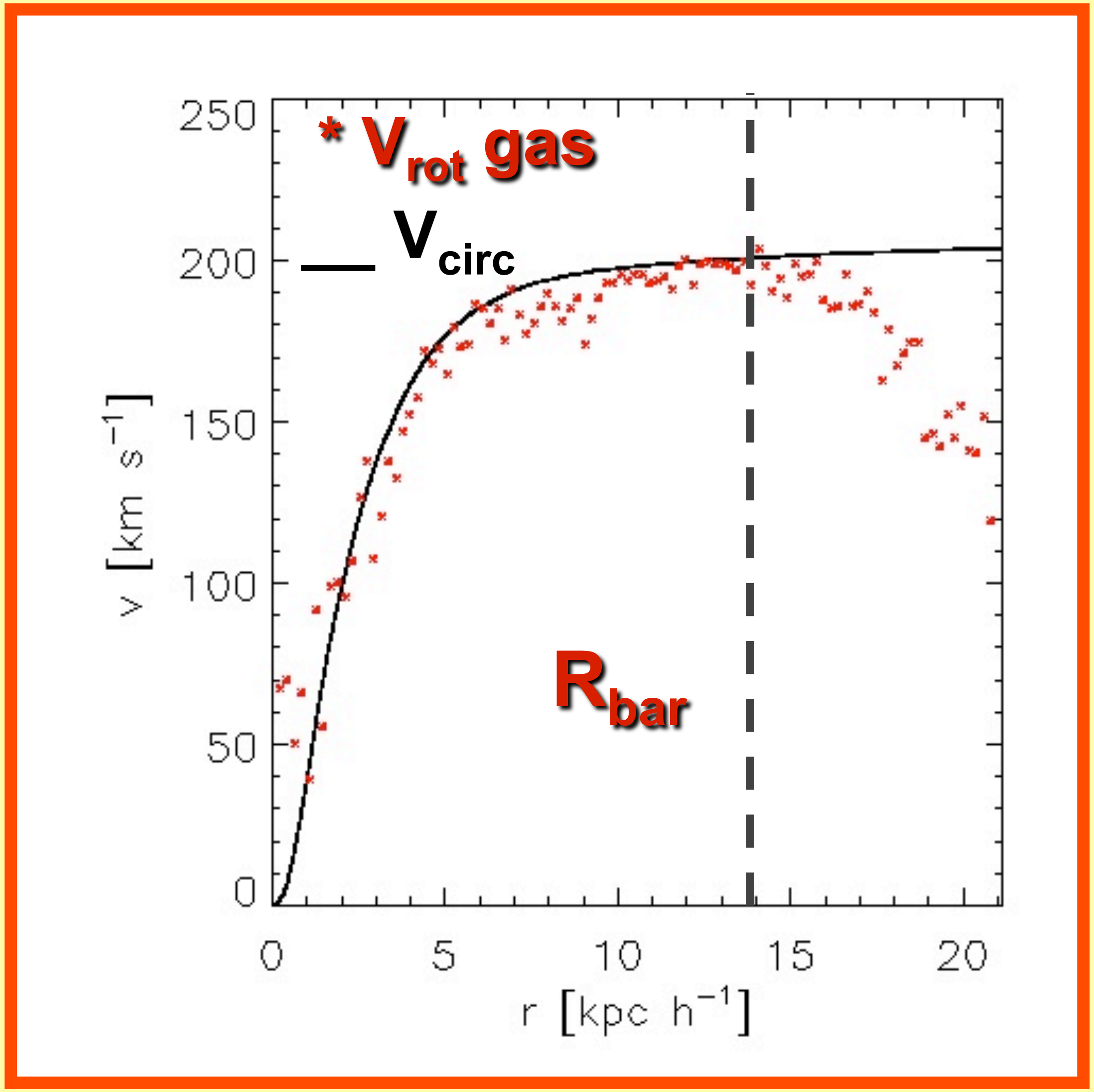
Physical model

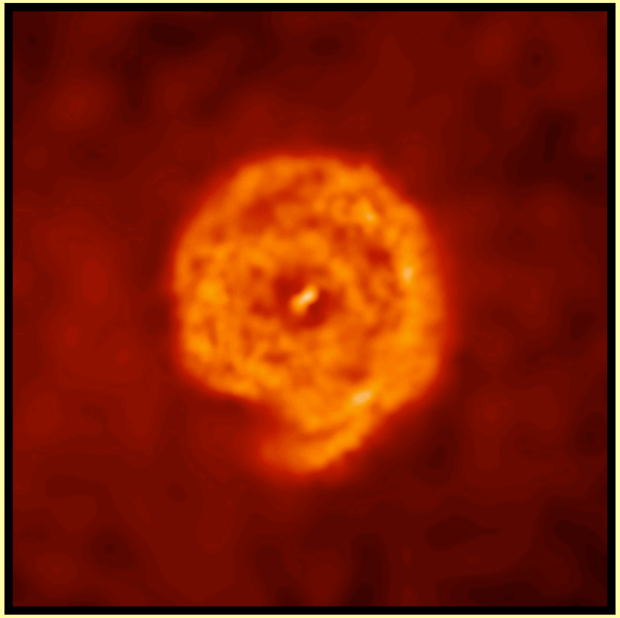
Scannapieco et al. (2005, 2006)

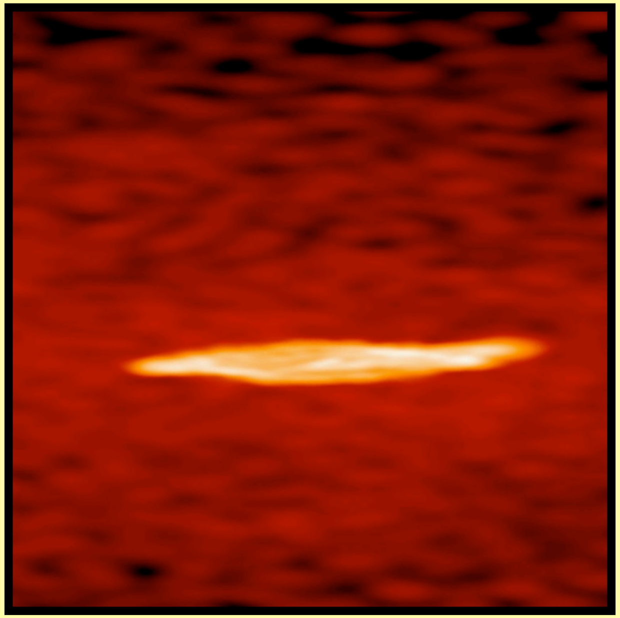
- ✓ *Metal-dependent radiative cooling*
- ✓ *Star formation*
- ✓ *Chemical enrichment*
- ✓ *Supernova feedback*

Rotation curves and selection of '*disk-like galaxies*'

$M_{bulge} / M_{total} < 0.25$

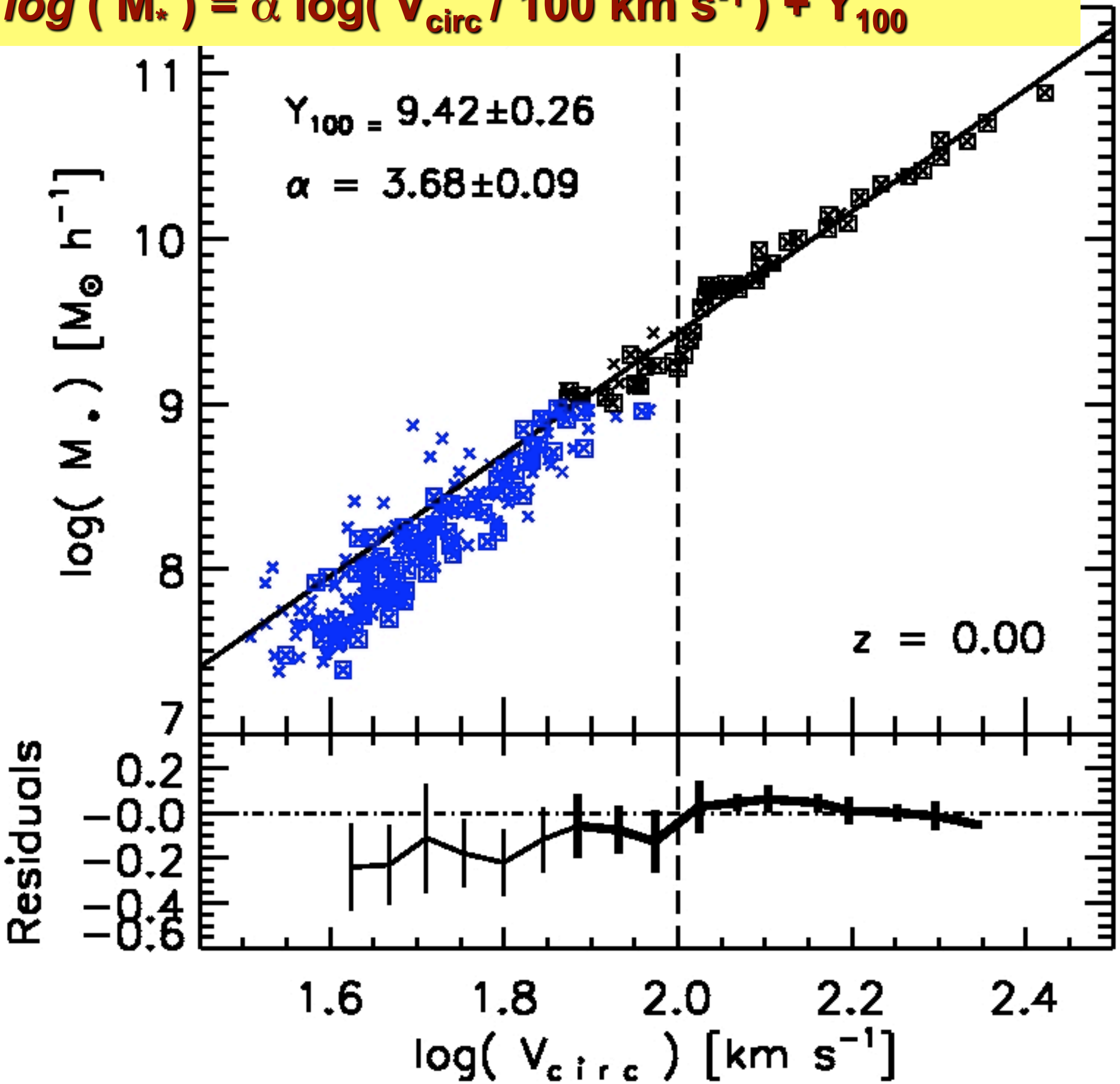






Local Simulated stellar TFR

$\log (M_*) = \alpha \log(V_{circ} / 100 \text{ km s}^{-1}) + Y_{100}$



General agreement with observations.

Residuals: systematic departure from zero below 100 km/s.

THERE IS A BEND: slow-rotators exhibit smaller stellar masses than those predicted by the fitting.

a SN feedback effect?

Local Simulated stellar TFR

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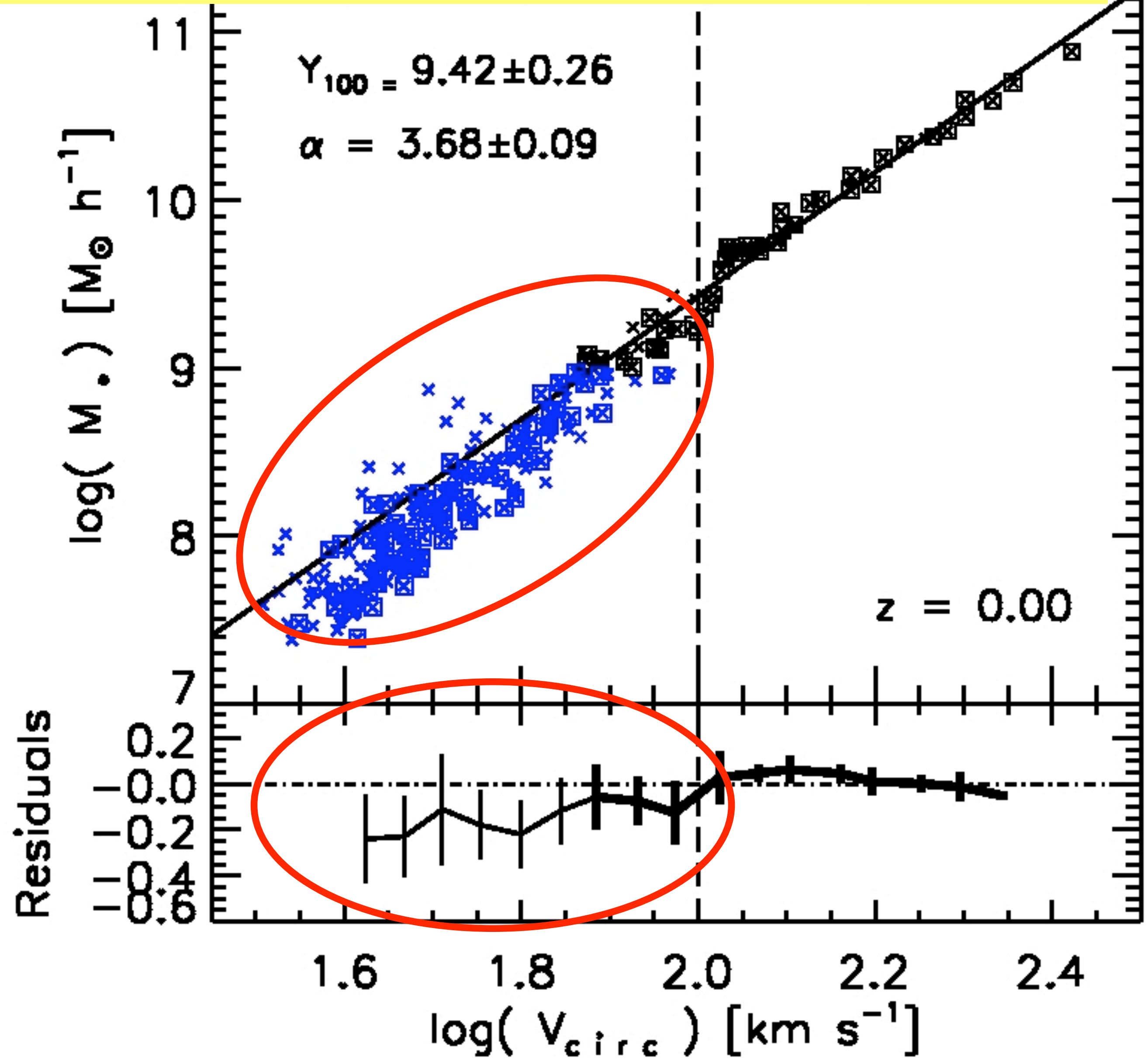

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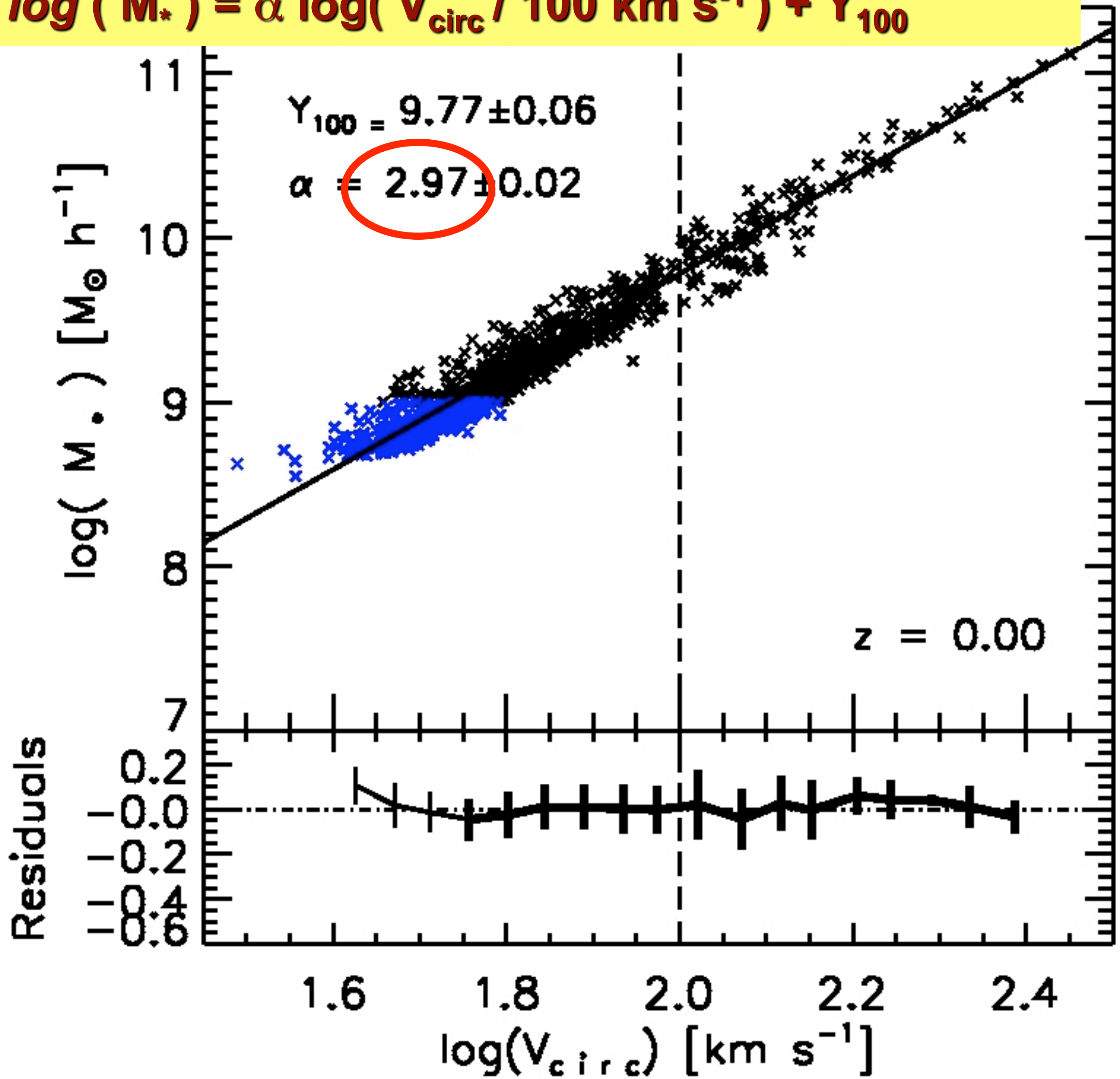
Stellar TFR in a wind-free model

$log (M_*) = \alpha \log(V_{circ} / 100 \text{ km s}^{-1}) + Y_{100}$



Linear behaviour

At similar velocities, larger stellar masses than in the SN-free model.

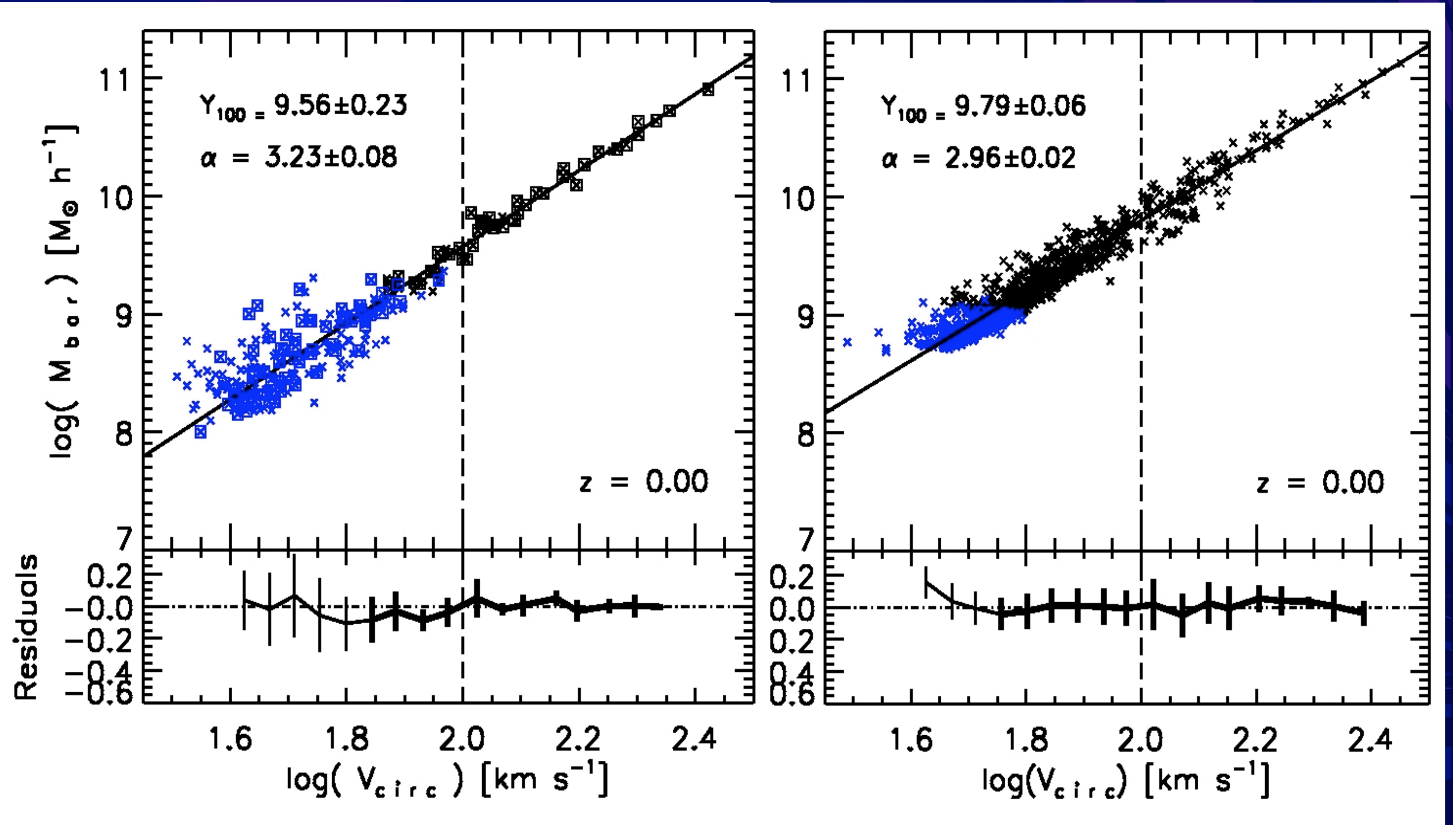
Flatter slope

Galactic winds, crucial to reproduced the observed bend.

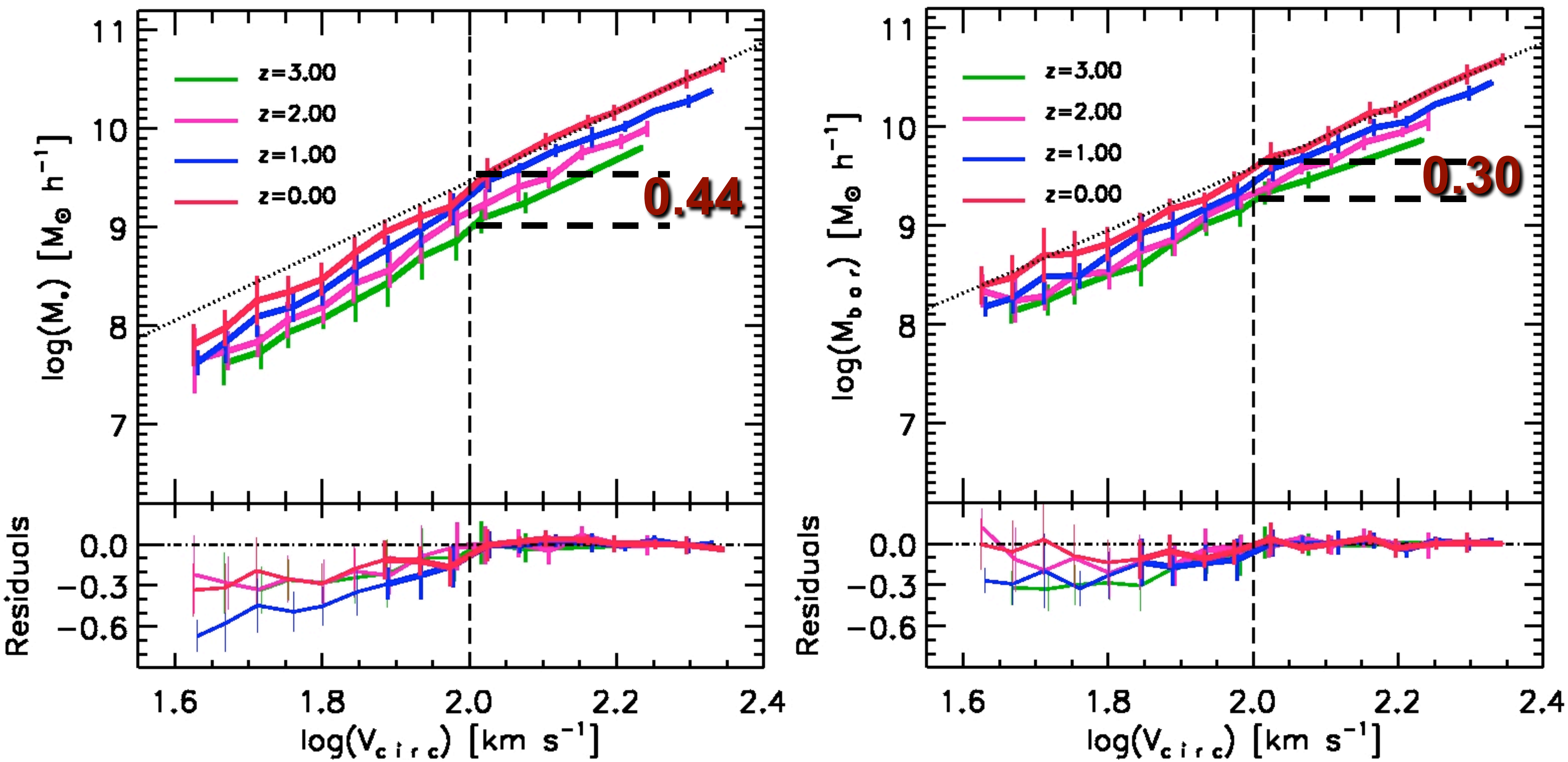
Local Baryonic TFR

SN feedback model

Wind-free model

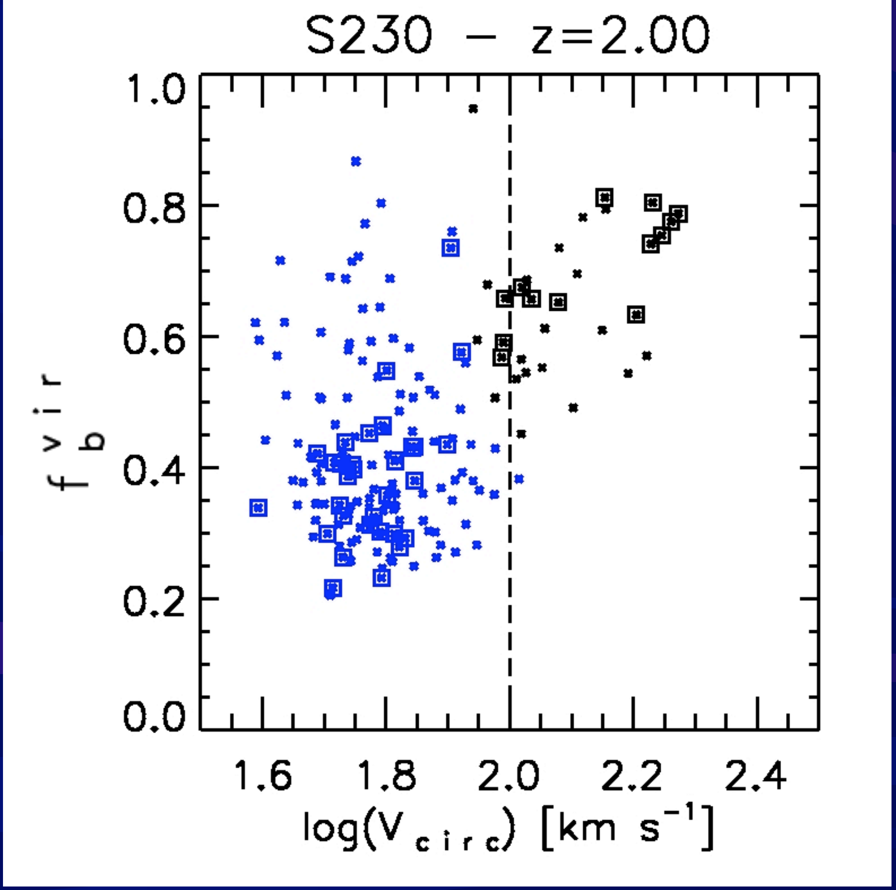


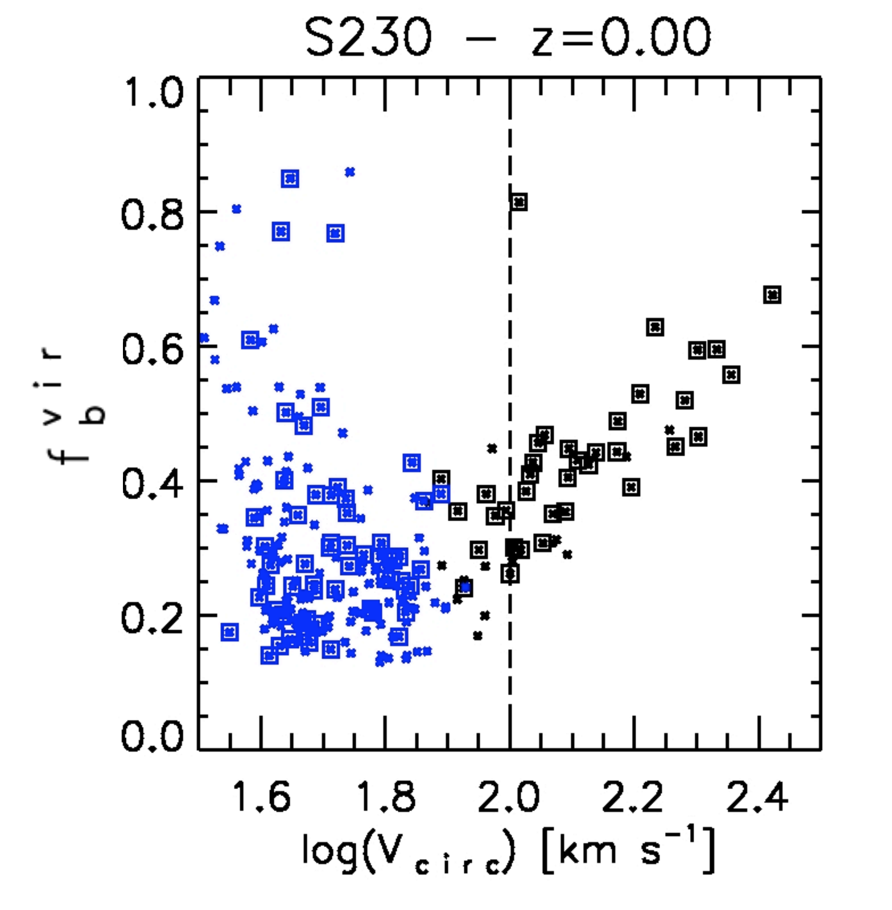
- These trends are also observed at higher redshifts (z>3).
- Our results are robust against numerical resolution.



The impact of SN-driven outflows

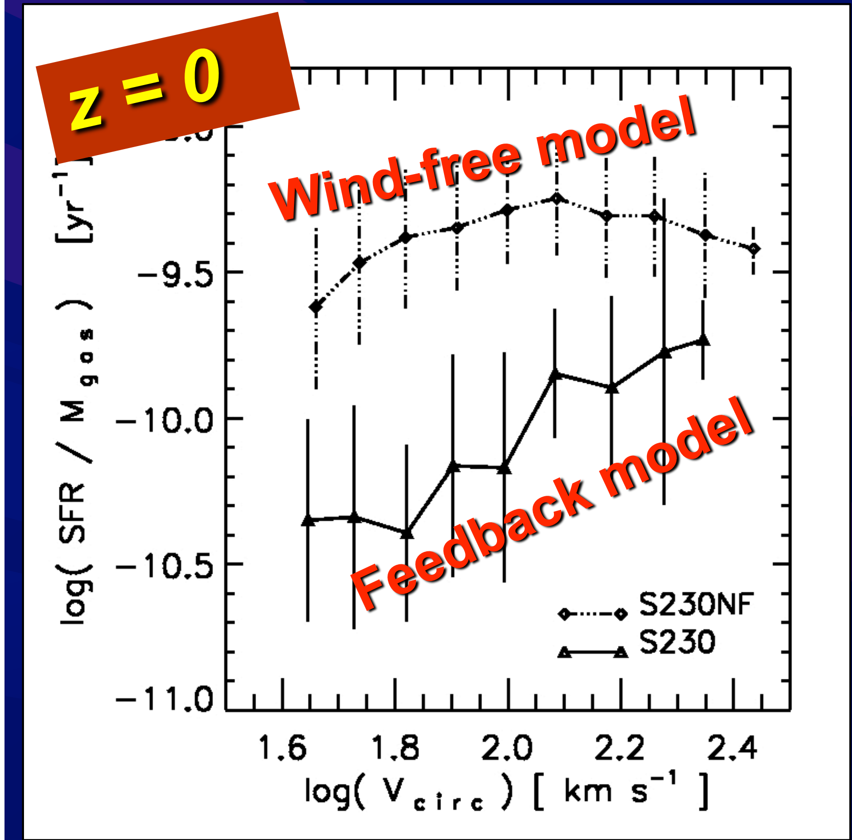
$$\frac{M_{bar} \text{ inside } R_{vir}}{(\Omega_b/\Omega_m)\, M_{vir}}$$





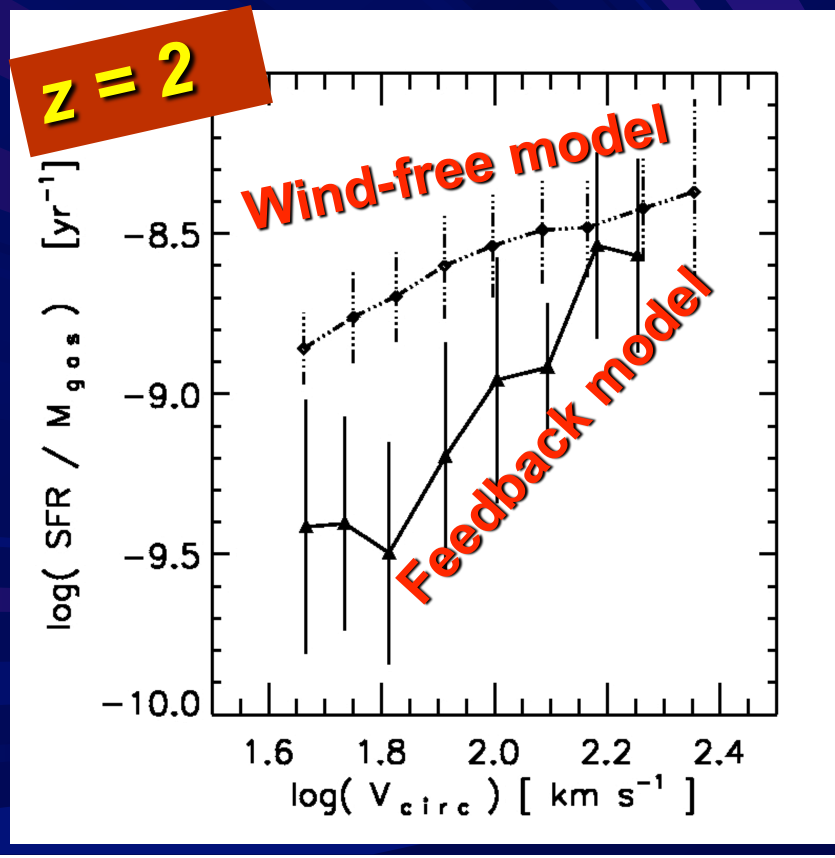
Smaller systems more affected by galactic outflows

The influence of SN feedback on the SFR



The wind-free model predicts larger eSFR at a given circular velocity.

Larger changes obtained at the low-mass end of the relation.



Consistent with the bend of the sTFR

Smaller vs massive galaxies

Slow rotators
(smaller virial temperatures)

Cold phase:
Star formation

Efficient SN heating and outflows

Hot-phase

Efficient radiative cooling

Fast rotators
(larger virial temperatures)

Cold phase:
Star formation

Inefficient SN heating and outflows

Hot-phase

Inefficient radiative cooling

SN feedback is not efficient at regulating star formation in larger galaxies.

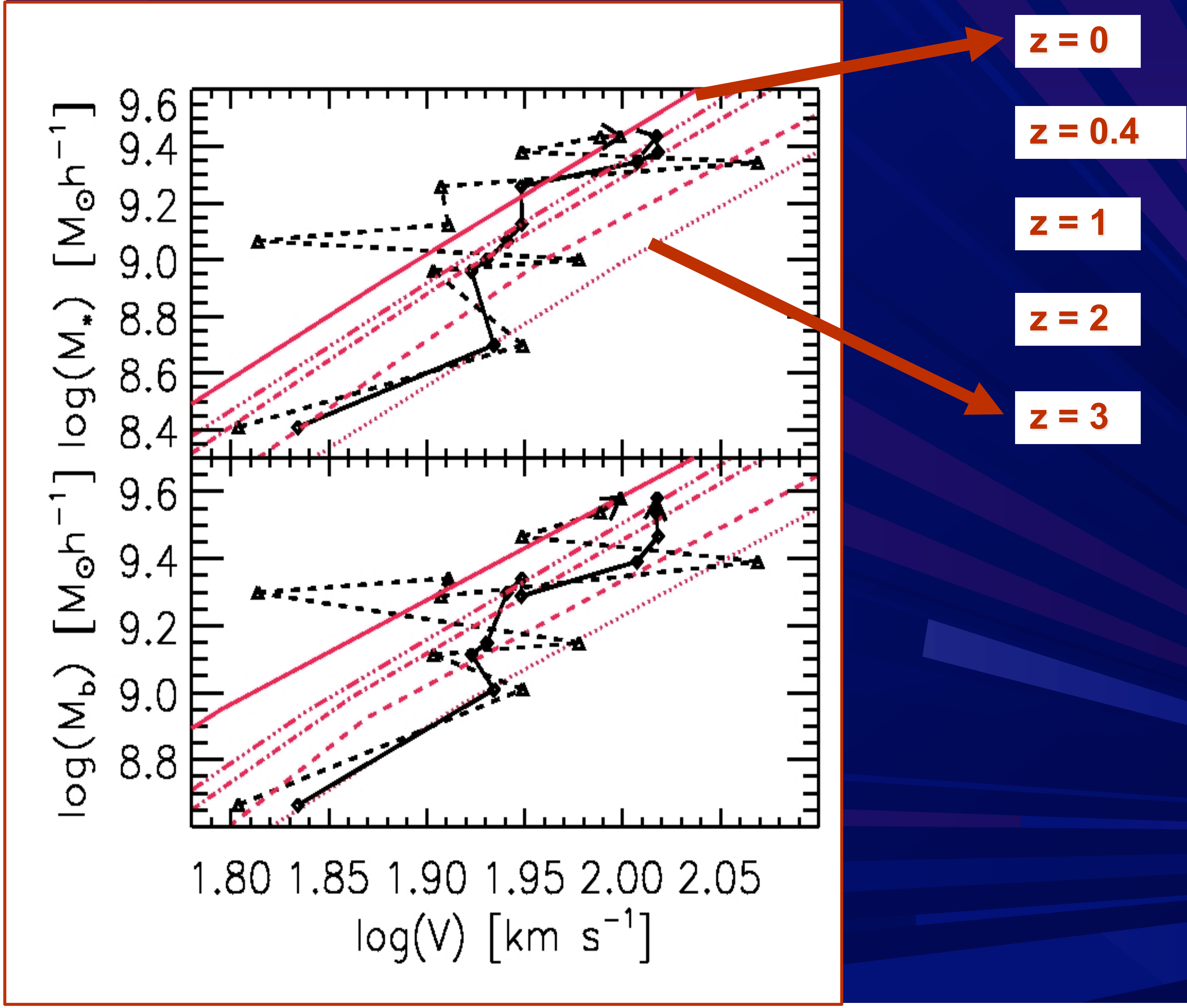
Smaller vs massive galaxies

TRANSITION VELOCITY: 100 km/s

- Consistent with the bend of the TFR
- Agreement with previus observational (McGaugh et al. 2000; Amorín et al. 2009) and theoretical expectations (Larson 1974; Dekel & Silk 1986)

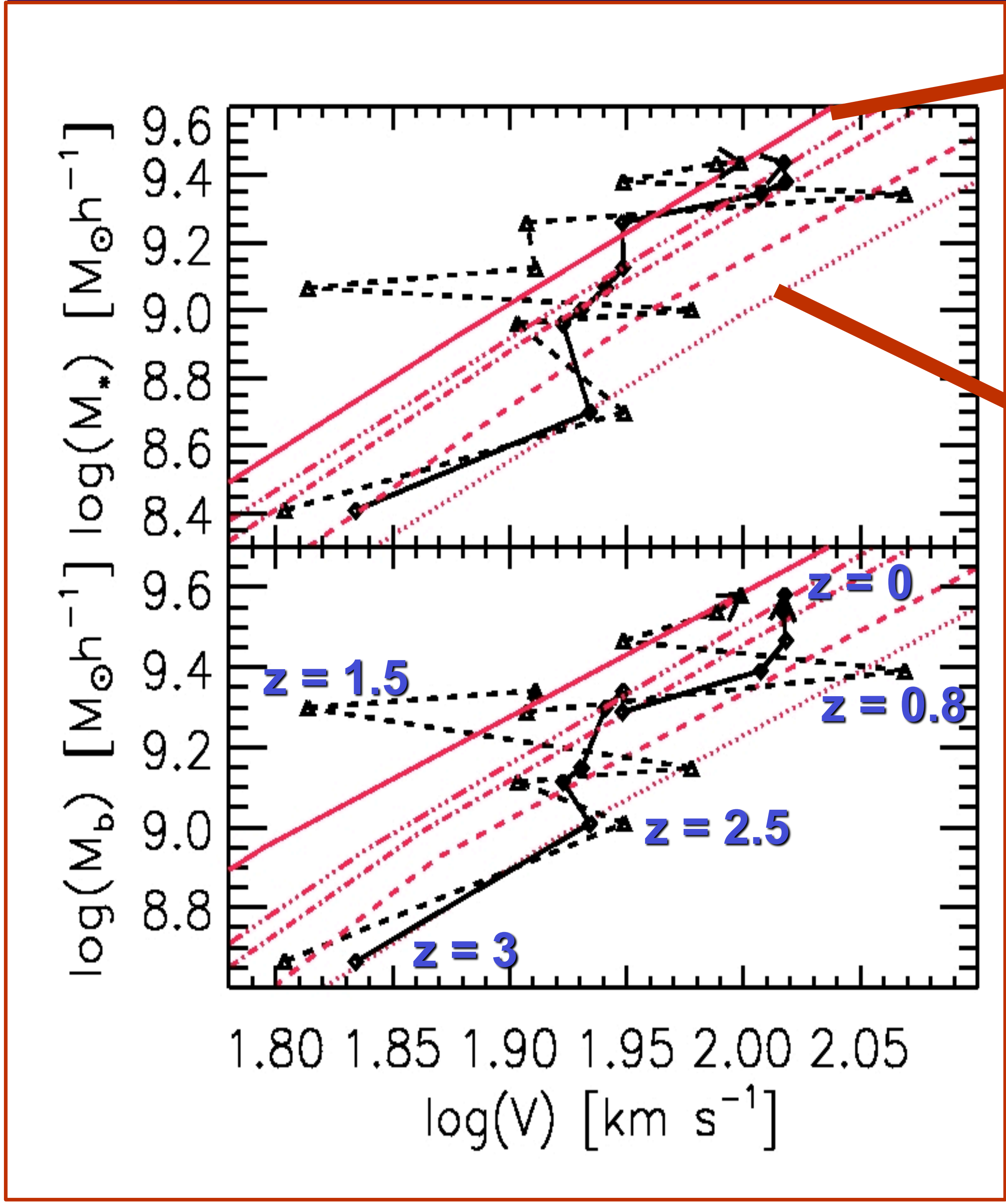
De Rossi, Tissera & Pedrosa (2010)

Scatter of the TFR in a Λ-CDM Universe



Mean sTFR and bTFR by using V_{circ} as kinematic indicator.

Scatter of the TFR in a Λ-CDM Universe



z = 0

z = 0.4

z = 1

z = 2

z = 3

Mean **sTFR** and **bTFR** by using V_{circ} as kinematic indicator.

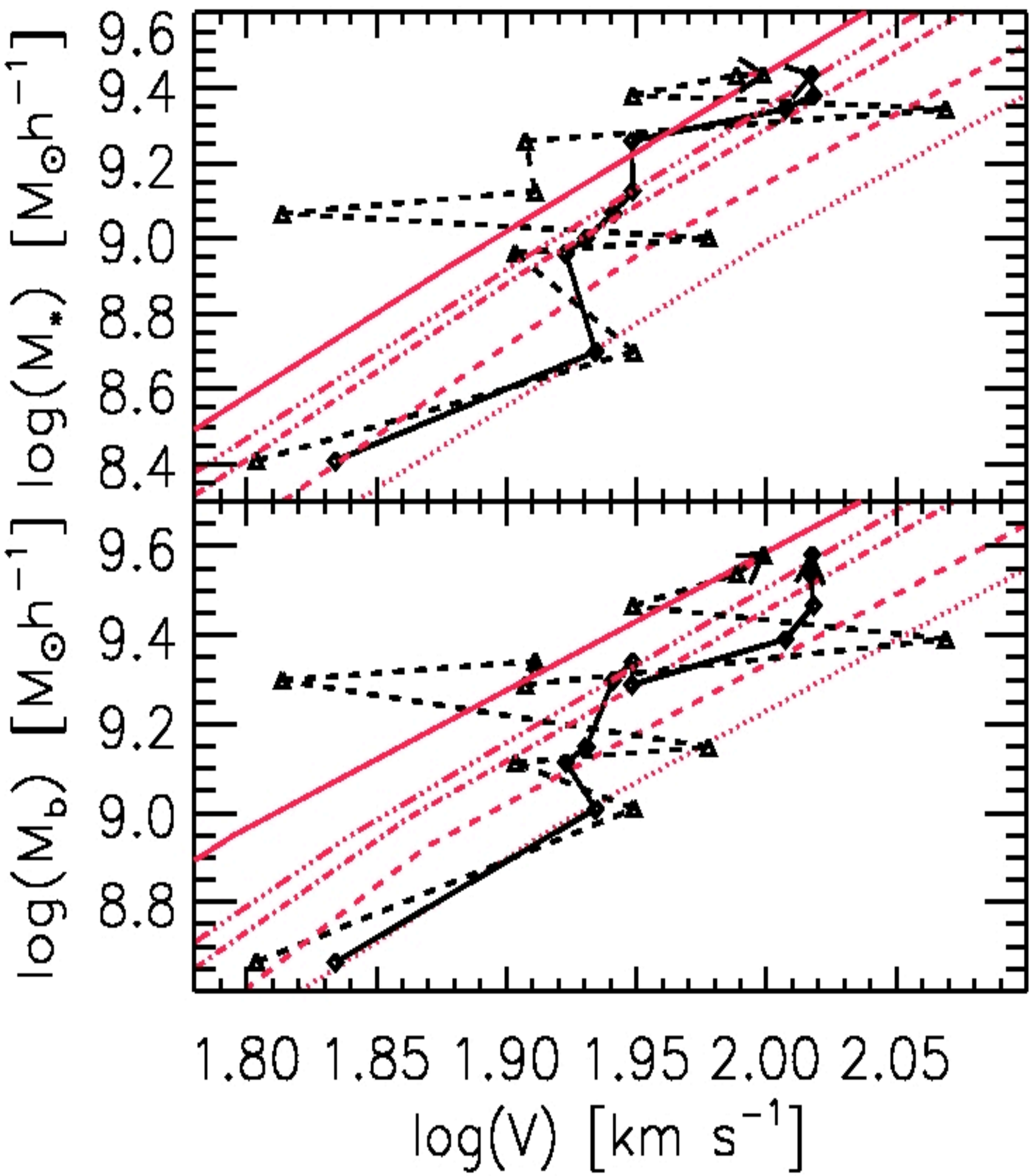
Evolutionary track of a typical galaxy on the TFR-plane by using:

V_{circ} ————

V_{rot} — — —

as kinematic indicators.

Scatter of the TFR in a Λ-CDM Universe



Tracks given by V_{rot} noisier than those given by V_{circ}, with a **scatter** greater than the level of evolution of the mean TFR based in V_{circ}.

Merger and interactions strongly influence the TFR tracks given by V_{rot} by disturbing the rotation curves of galaxies, in agreement with previus works *(Weiner et al. 2006; Kassin et al. 2007; Covington et al. 2010).*

In these simulations, **mergers and interactions** play a key role in modulating the gas kinematics a z<3 by regulating other physical processes such as gas infall, outflows and starbusts, leading to **TFR outliers**.

The joint action of these processes in our simulations generates a **mean TFR in good agreement with observations since z~3**.

CONCLUSIONS

- We studied the TFR by using cosmological simulations.
- SN feedback seems to be crucial to reproduced the observed bend in the sTFR.
- Our model is capable to described the observed behaviour as a consequence of the more efficient action of SN feedback in the regulation of the SF in smaller galaxies.
- Without introducing scale-dependent parameters, the model predicts a transition velocity at around 100 km/s, consistent with previus observational and theoretical works.

See De Rossi et al. (2010) for more details about this work.

- Our results suggest that the hierarchical building up of the structure influence the evolutionary paths of galaxies on the TFR-plane modulating the evolution of its scatter with cosmic time (De Rossi et al. in preparation).

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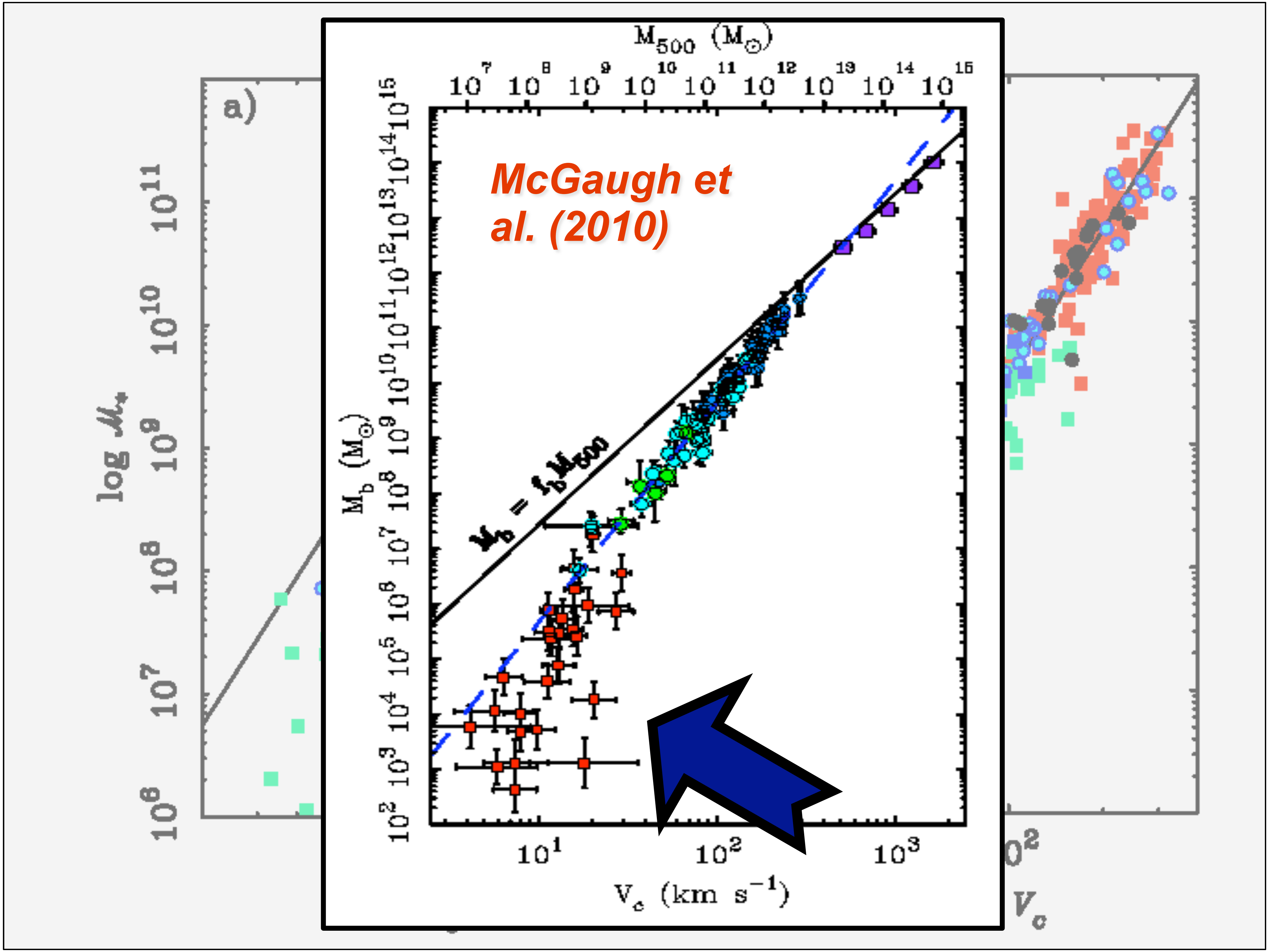
DEFINITIONS

- $V_{circ}^2 = G\ M(r<R)\ /\ R$
- $t_{dyn}^2 = 3\ \pi\ /\ 6\ G\ \rho$
- $t_{cool} = 3\ k\ T\ \mu\ m_p\ /\ 2\ \Lambda\ \rho$



McGaugh et al. (2010)
M500 (M⊙)
Mb (M⊙)
Vc (km s−1)
Mb = fb M500
a)
log M*
Vc

GALAXY CATALOGUES

IDENTIFICATION

FRIENDS-OF-FRIENDS

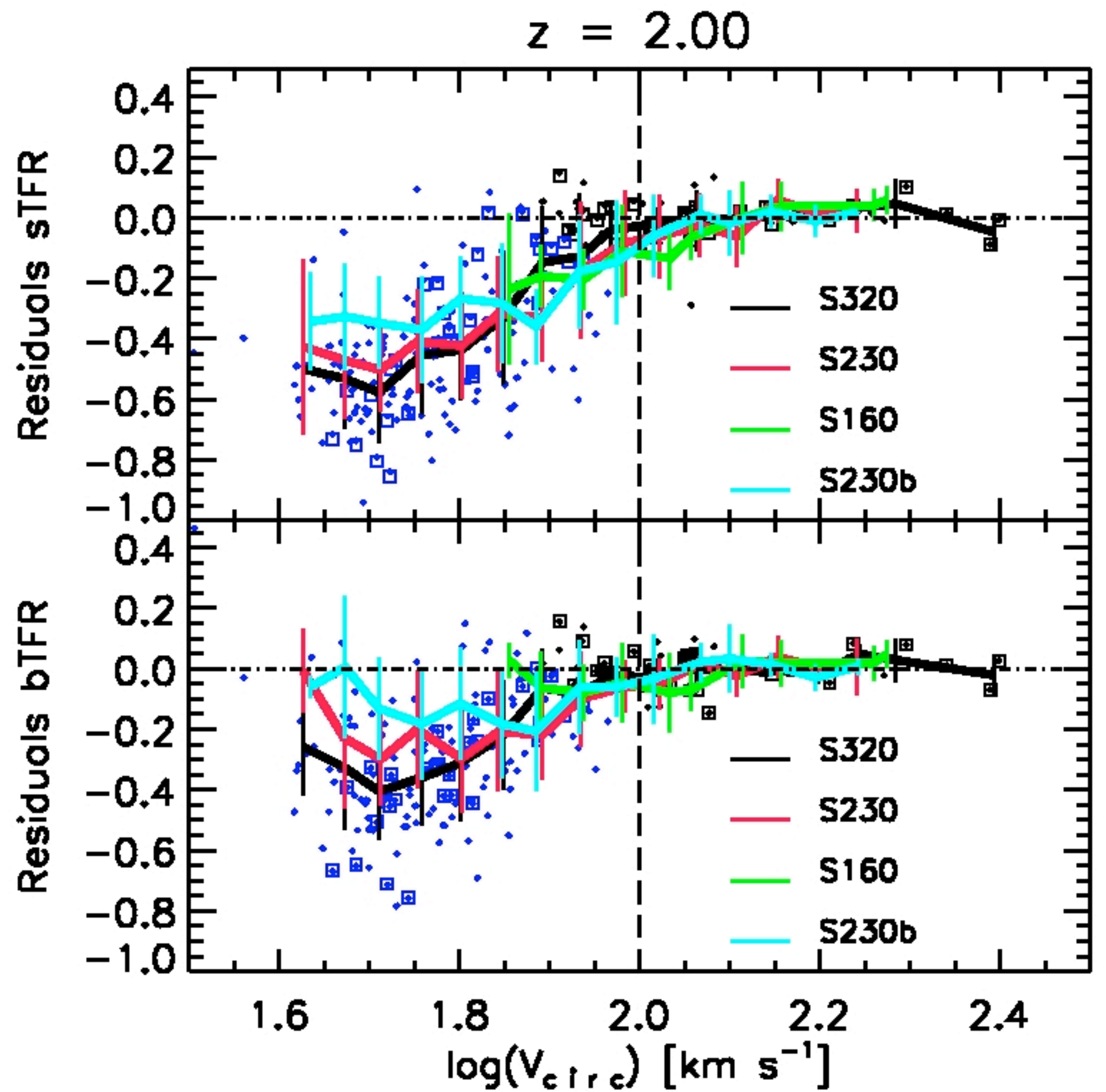
SUBFIND (Springel et al. 2001)

*We estimate the mean properties of galactic systems within a **BARYONIC RADIUS.***

*A **BARYONIC RADIUS** is defined as the one which encloses 83% of the baryonic mass of the system.*

Cosmological Hydrodynamical Simulations				
Name	F/NF	$N_{\rm p}$	$M_{\rm dark}$	$M_{\rm gas}$
S160	F	2×160^3	1.76×10^7	2.71×10^6
S230	F	2×230^3	5.93×10^6	9.12×10^5
S230NF	NF	2×230^3	5.93×10^6	9.12×10^5
S320	F	2×320^3	2.20×10^6	3.39×10^5

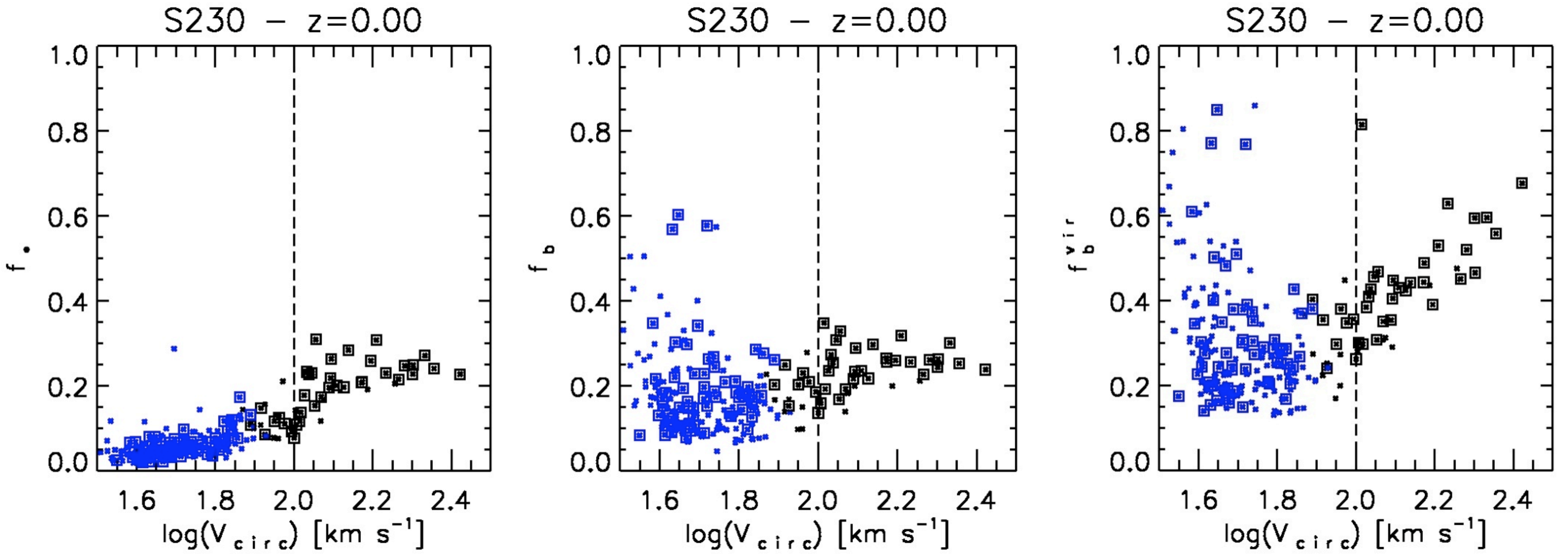
Col. 1: Name of the simulation. Col. 2: Model with/without SN feedback (F/NF). Col. 3: Initial number of particles in the simulation. Col. 4: Mass of dark matter particles in units of $M_{\odot} h^{-1}$. Col. 5: Initial mass of gas-phase particles in units of $M_{\odot} h^{-1}$.


z = 2.00
Residuals sTFR
Residuals bTFR
S320
S230
S160
S230b
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
1.6
1.8
2.0
2.2
2.4
log(V_circ) [km s^-1]

The impact of SN-driven outflows

$f_i = M_i / (\Omega_b / \Omega_m) M_{vir}$

$M_i = M_* \text{ in } R_{bar}$	$M_i = M_{bar} \text{ in } R_{bar}$	$M_i = M_{bar} \text{ in } R_{vir}$



f_* is an increasing function of the circular velocity.

f_b has a weaker dependance on the circular velocity.

Important fraction of baryons blown away

Smaller systems more affected by galactic outflows

Fraction of the gas component within R_{vir} which satisfies $t_{cool} / t_{dyn} > 0.1$