Heart of Darkness

How Galactic Dynamics Suppress Star Formation in Galaxy Spheroids

Jindra Gensior I 08.09.20
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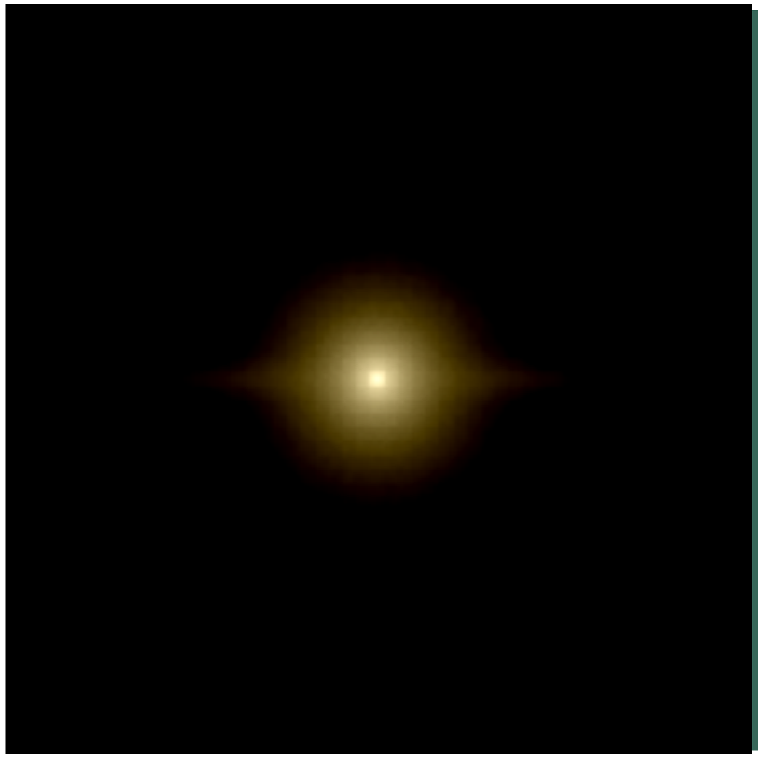
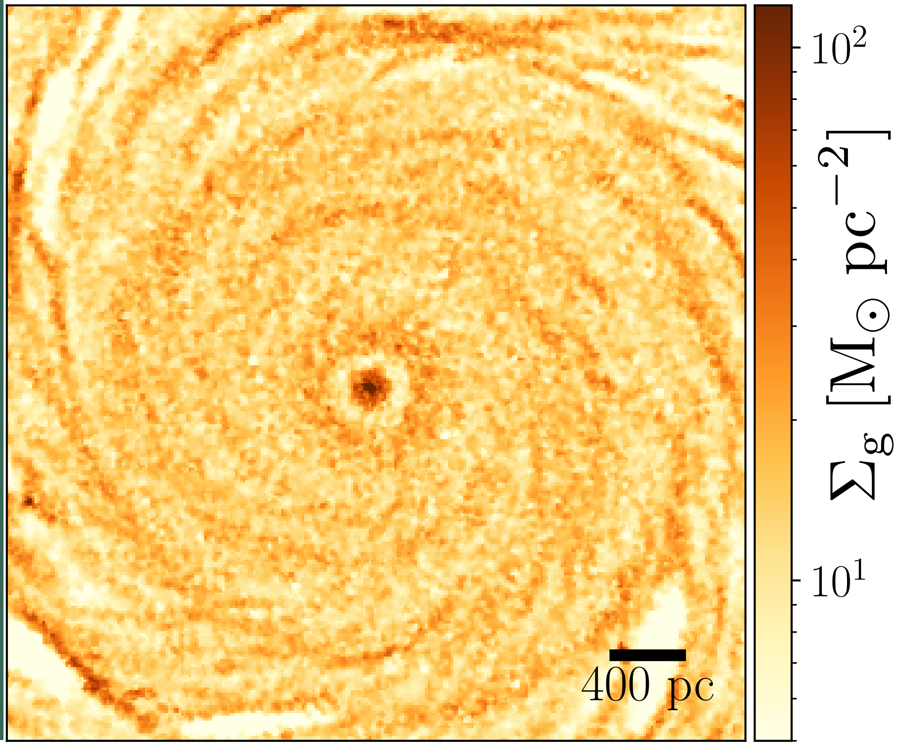
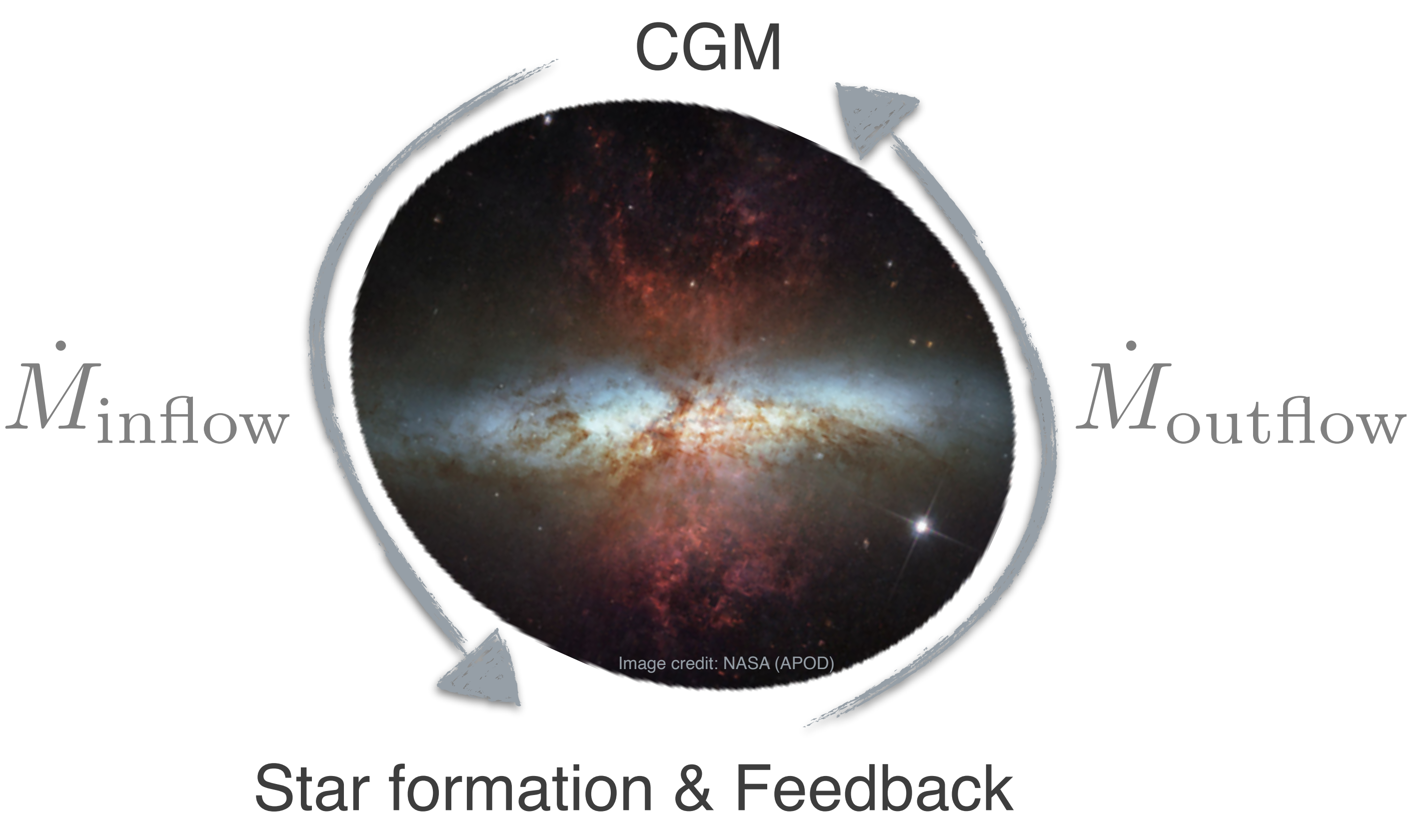




WHAT REGULATES STAR FORMATION?



Gas-regulator or "bathtub model"

e.g. Finlator & Davé 2008, Bouché+ 2010, Lilly+ 2013, Dekel+ 2013, Dekel & Mandelker+ 2014, Peng & Maiolino 2014, Belfiore+ 2019, Tachella+2020

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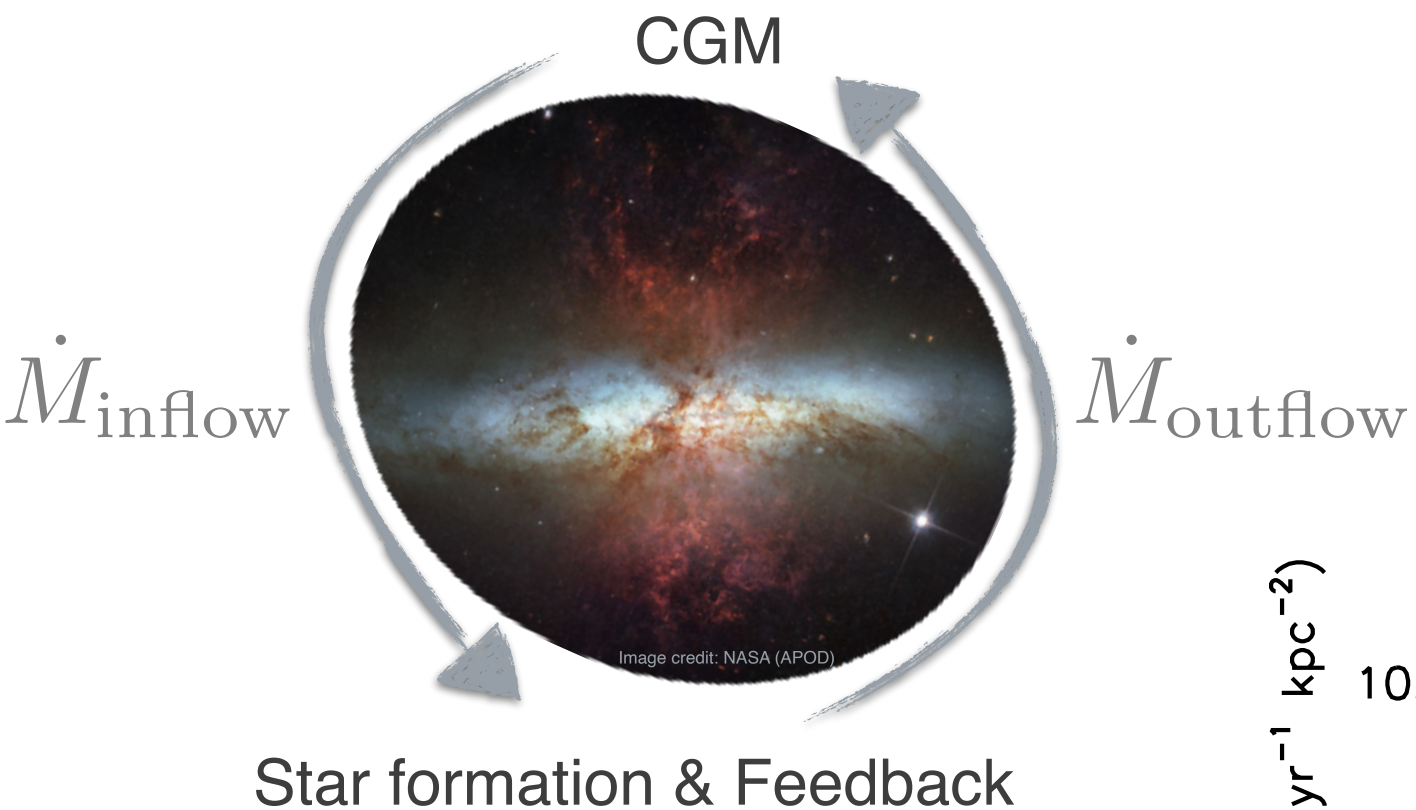

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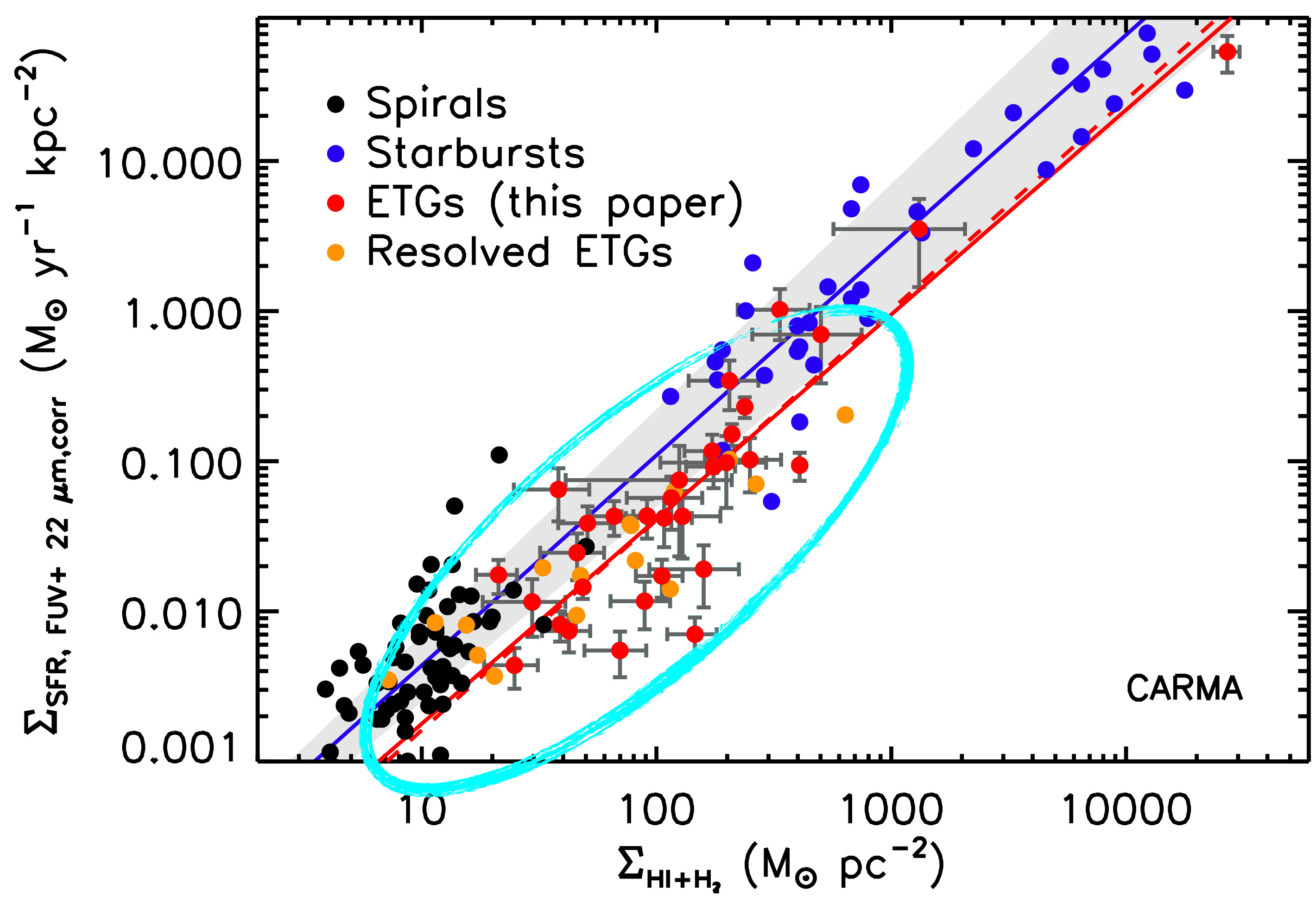
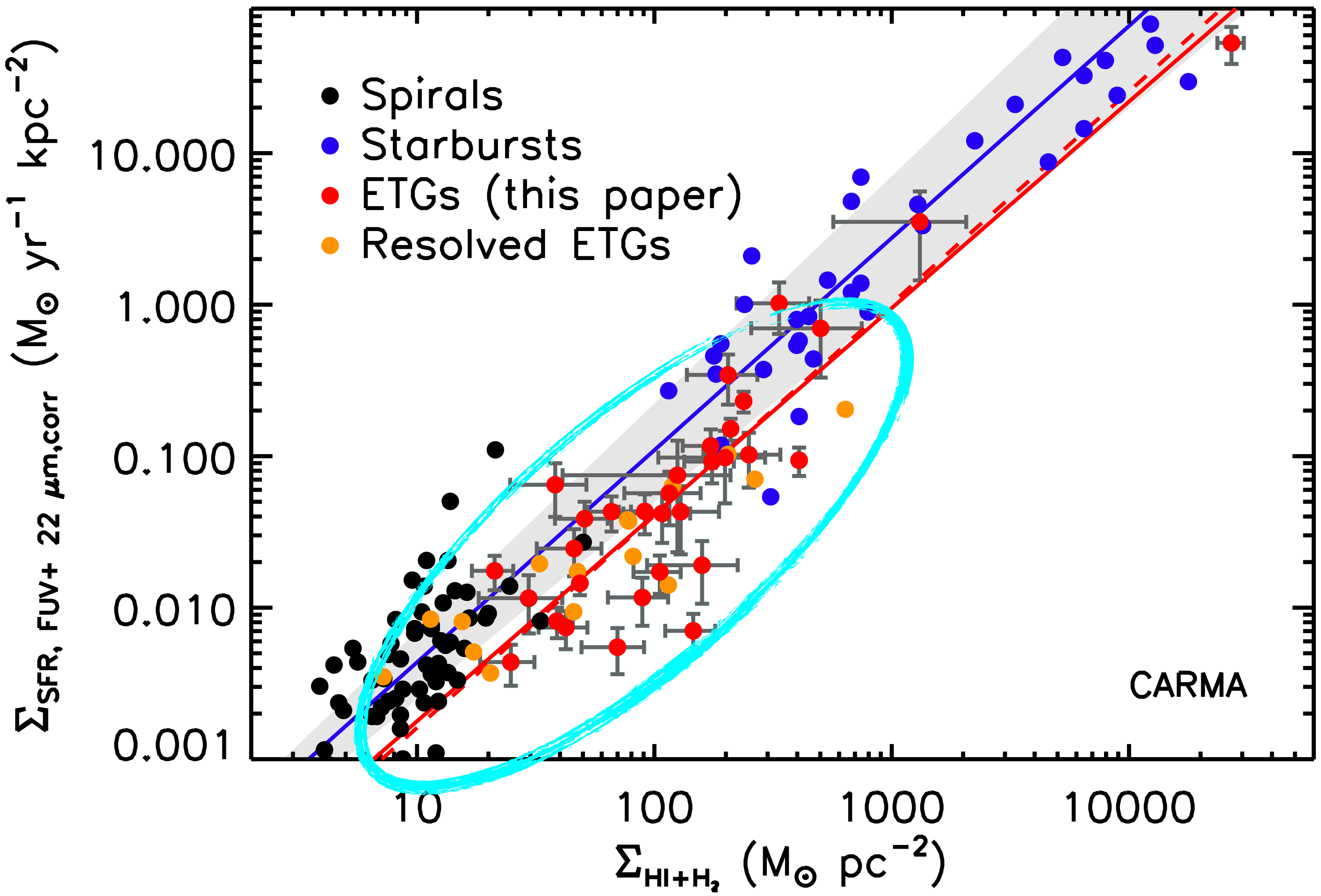
> 20% of ETGs host molecular gas

e.g. Young+2011, Davis+2019



Davis+ 2014

WHAT SUPPRESSES STAR FORMATION (IN ETGS)?

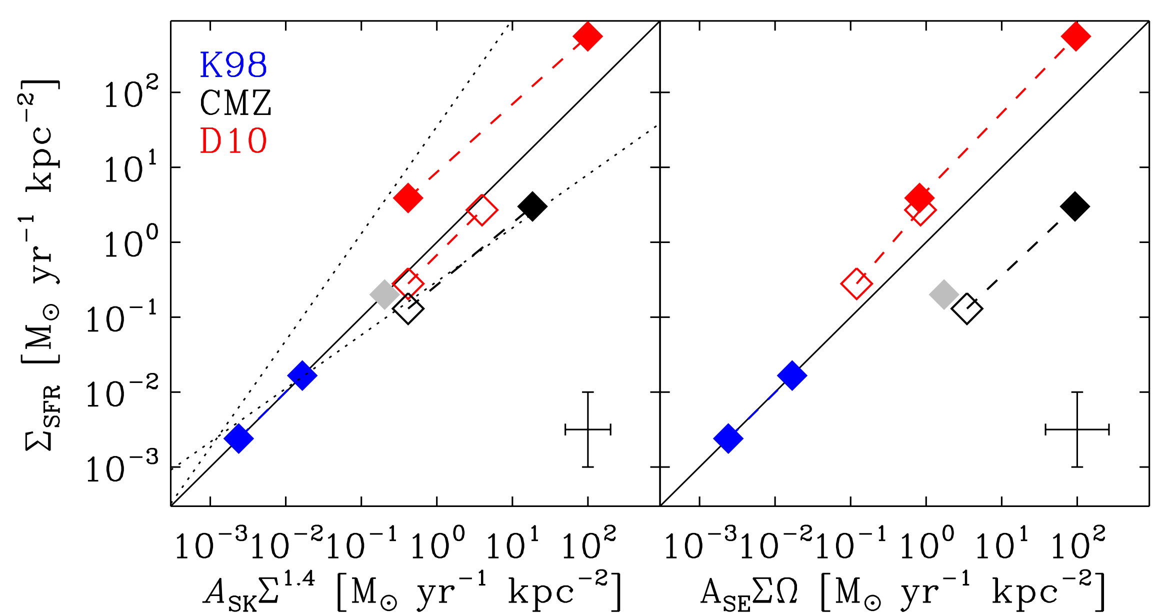


Davis+ 2014

- Bulges?

- Gas Fraction?

SF relation prediction vs. observed Σ_{SFR}

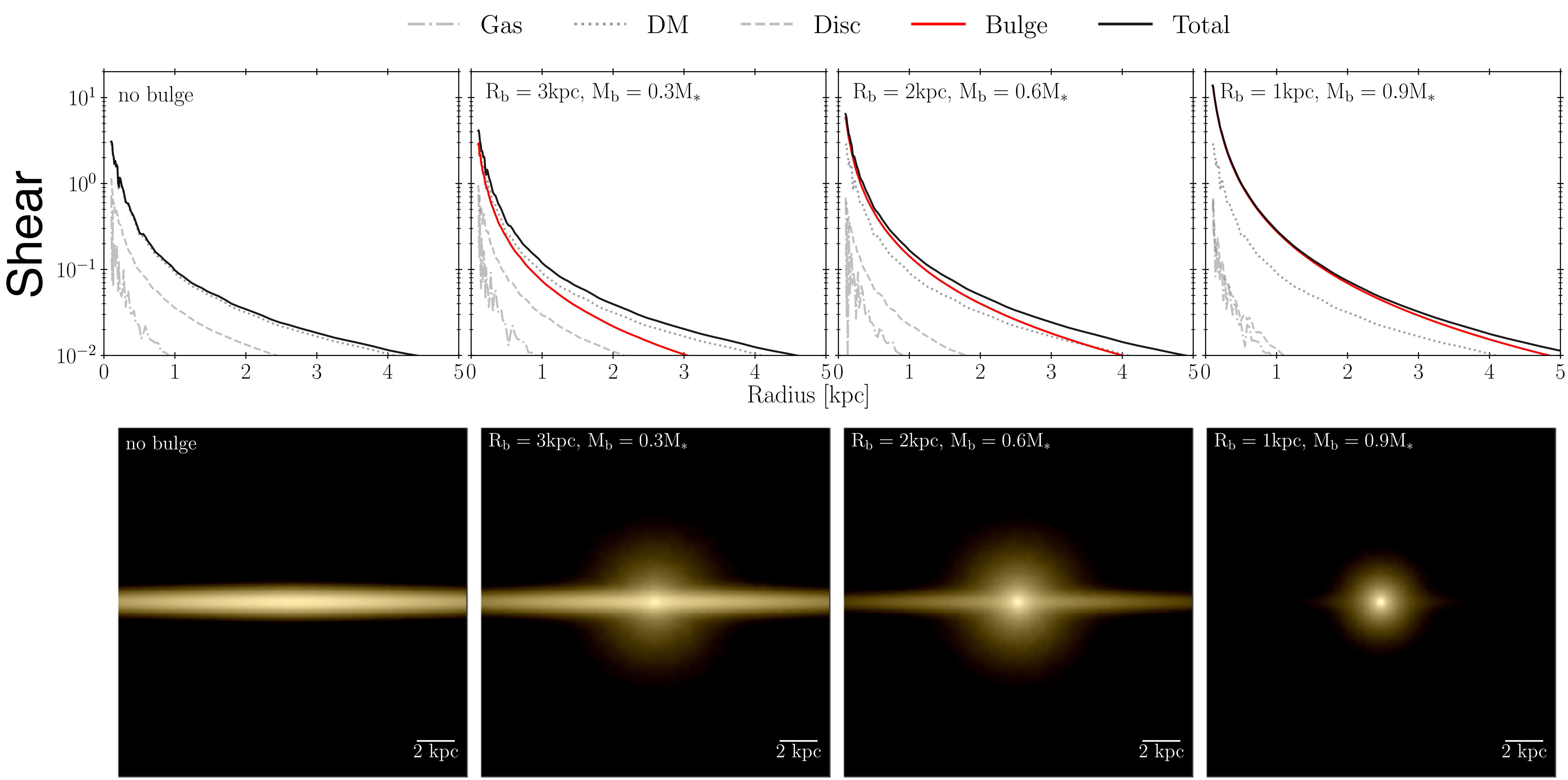


Kruijssen+ 2014

I: GRAVITATIONAL POTENTIAL

Based on Gensior+ 2020a: https://arxiv.org/abs/2002.01484

HOW COULD BULGES SUPPRESS STAR FORMATION?



(see also “morphological quenching” Martig+ 2009, 2013)

STAR FORMATION IN GALAXY SIMULATIONS

$$\dot{\rho}_\star = \epsilon_{ff} \cdot \frac{\rho_g}{t_{ff}}$$

Katz 1992, Cen & Ostriker 1992

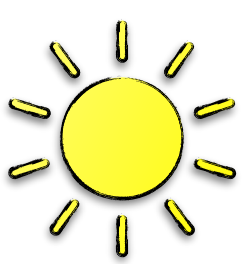
STAR FORMATION IN GALAXY SIMULATIONS

$$\dot{\rho}_\star = \epsilon_{ff} \cdot \frac{\rho_g}{t_{ff}}$$

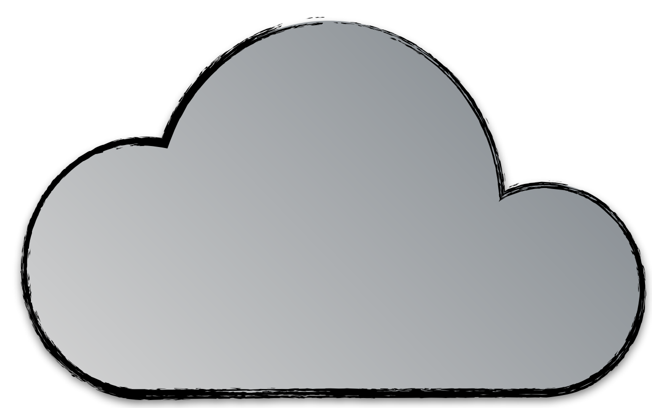
Katz 1992, Cen & Ostriker 1992

$$\epsilon_{ff} = \epsilon_w \exp(-1.6 \cdot \alpha_{vir}^{0.5})$$

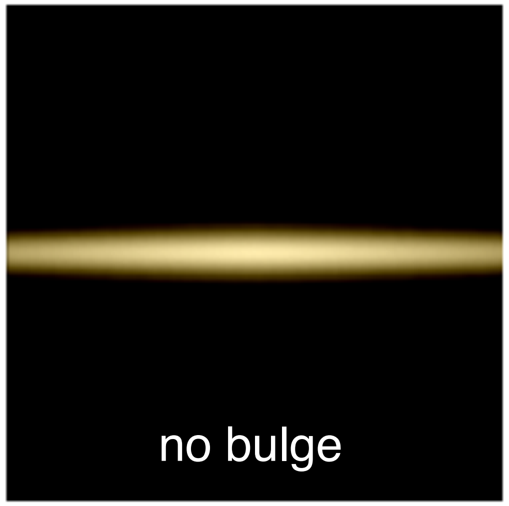
Padoan+ 2012, 2017

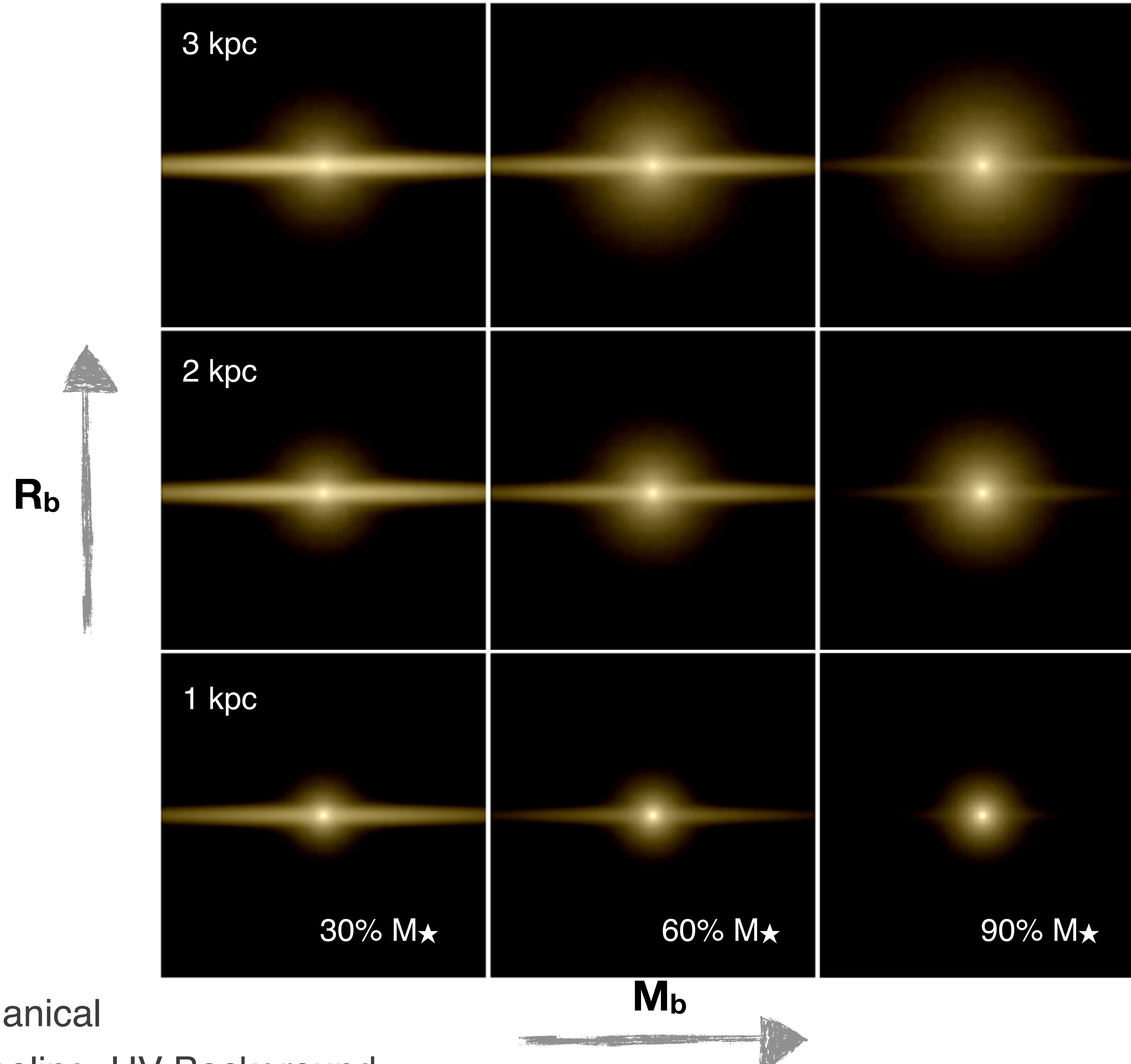


$$\xleftarrow{\text{Low}} \quad \alpha_{vir} \sim \frac{E_K}{E_G} \quad \xrightarrow{\text{High}}$$



ISOLATED GALAXY SIMULATIONS

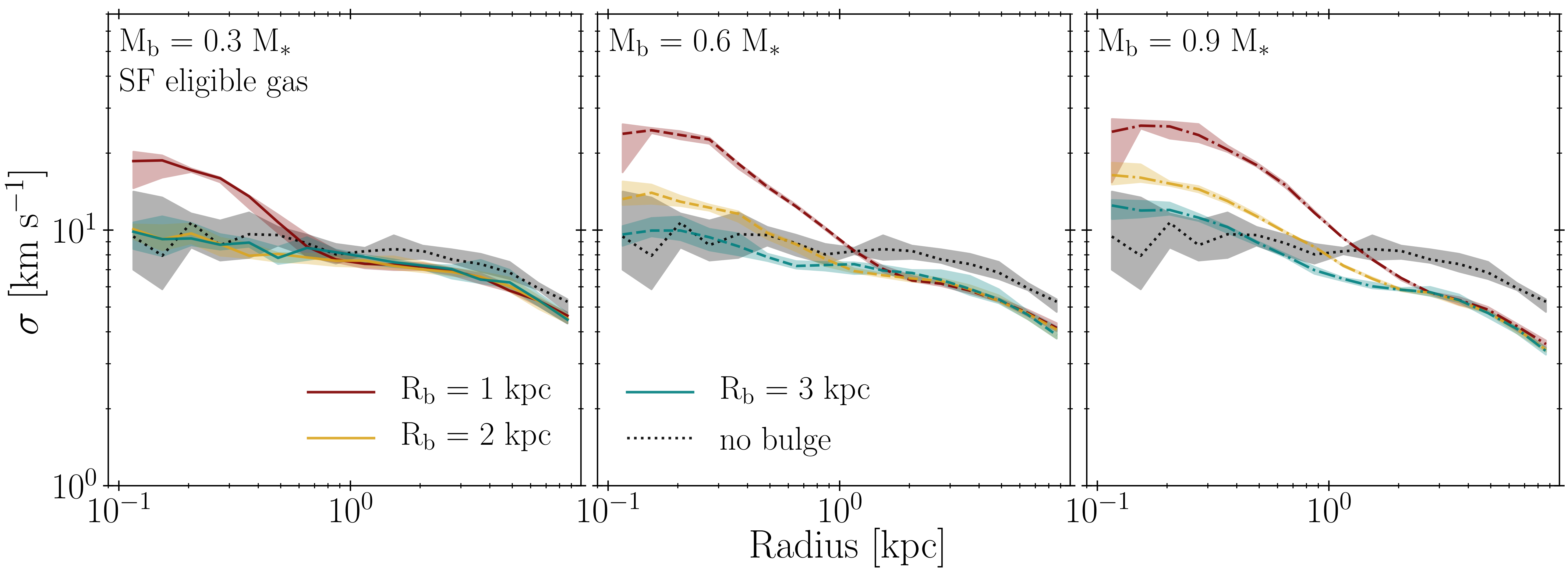




- All galaxies have same M★ (4.7×10^{10} $M_\odot$), $f_{gas} = 5\%$
- Only difference in gravitational potential
- Viral parameter dependent star formation
- Type II Supernova mechanical feedback; atomic line cooling; UV Background

Kimm & Cen 2014, Hopkins+2014; Grackle - Smith+2017; Haardt & Madau 2012

GAS VELOCITY DISPERSION

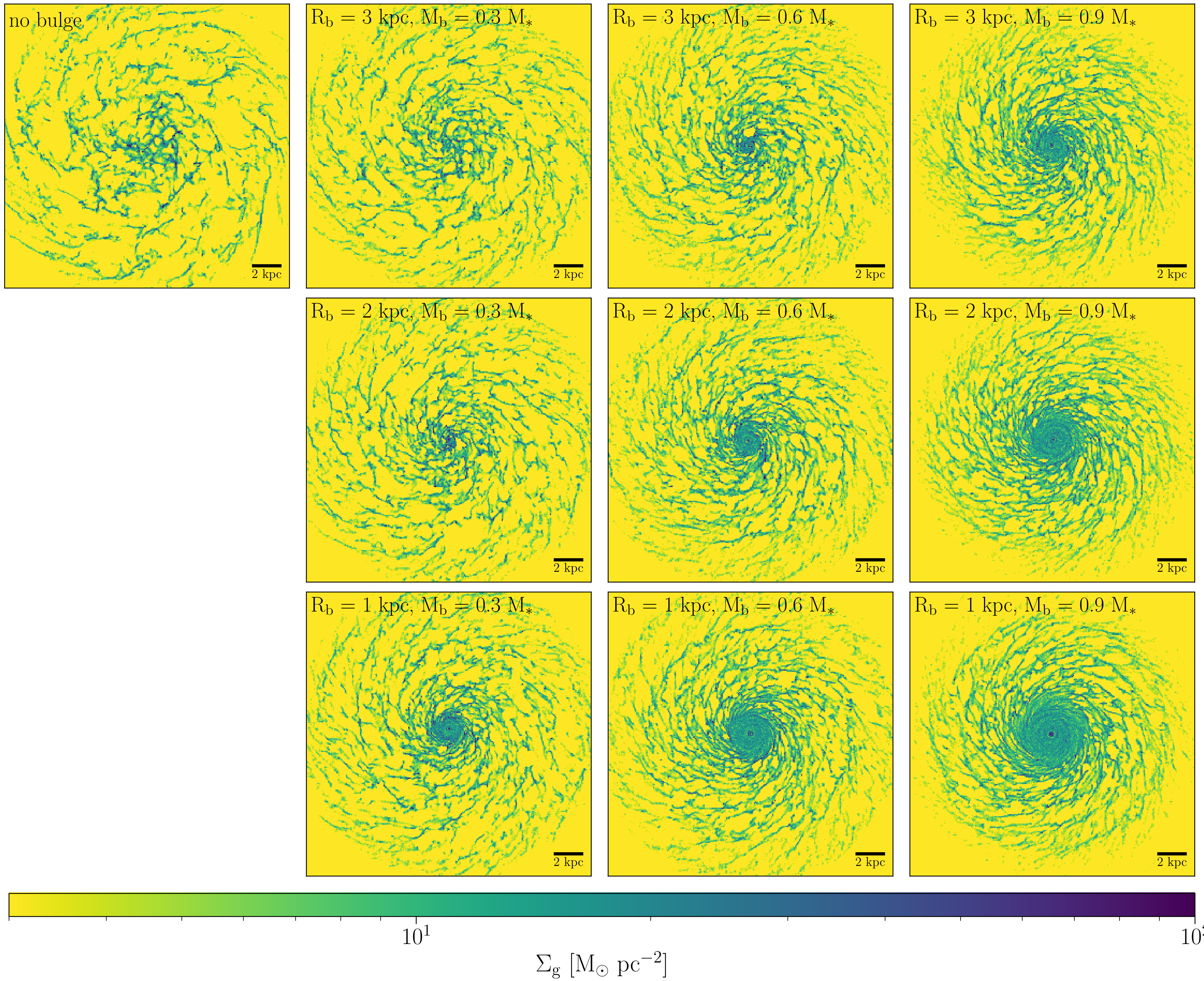


- Velocity dispersion increases towards the centre in presence of bulge

stronger for:
  - Compact bulges (small R_b)
  - Massive bulges (large M_b)

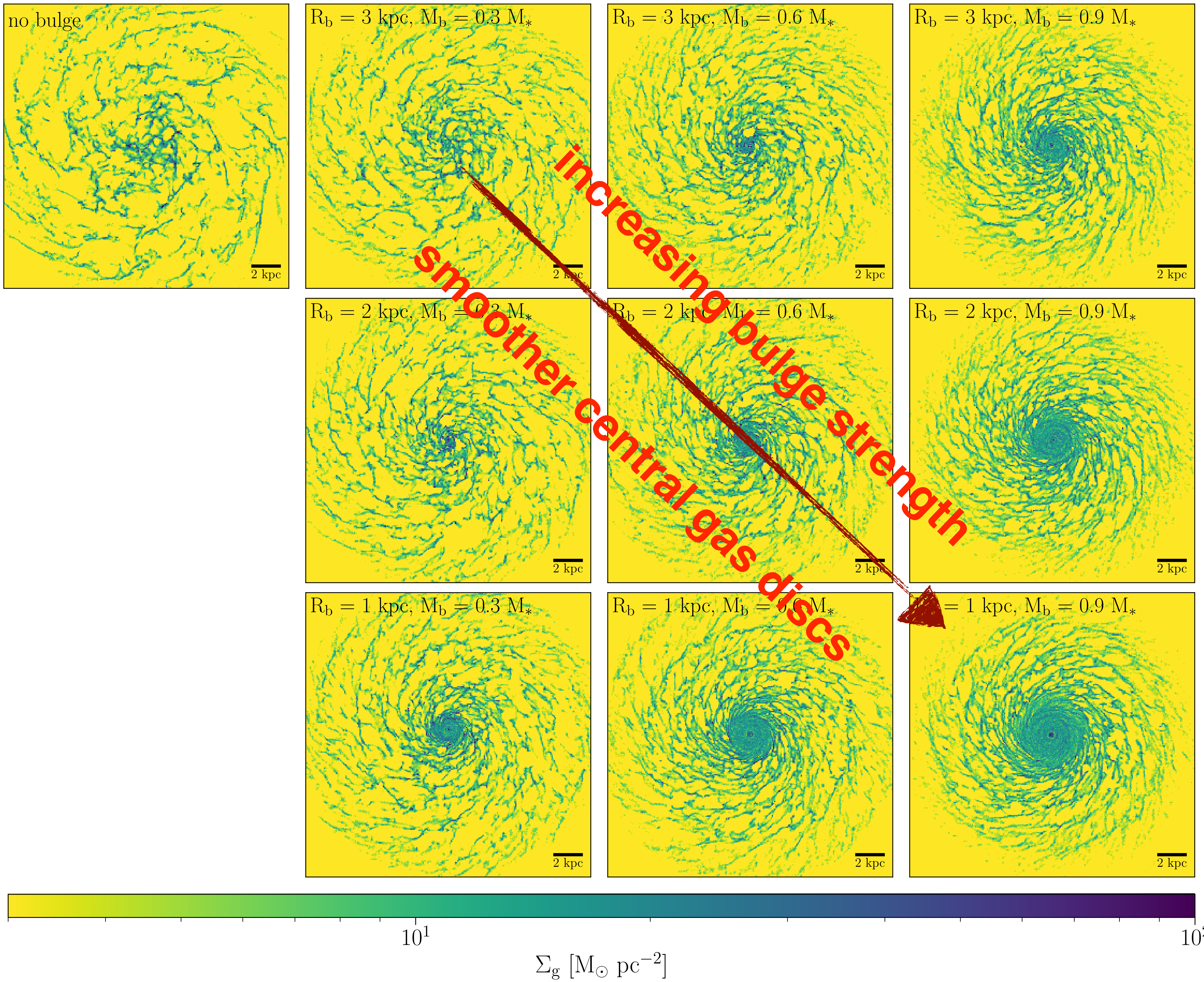
Gensior+ 2020a

ISM MORPHOLOGY - AFFECTED BY GRAVITATIONAL POTENTIAL



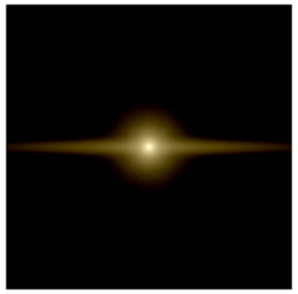
Gensior+ 2020a

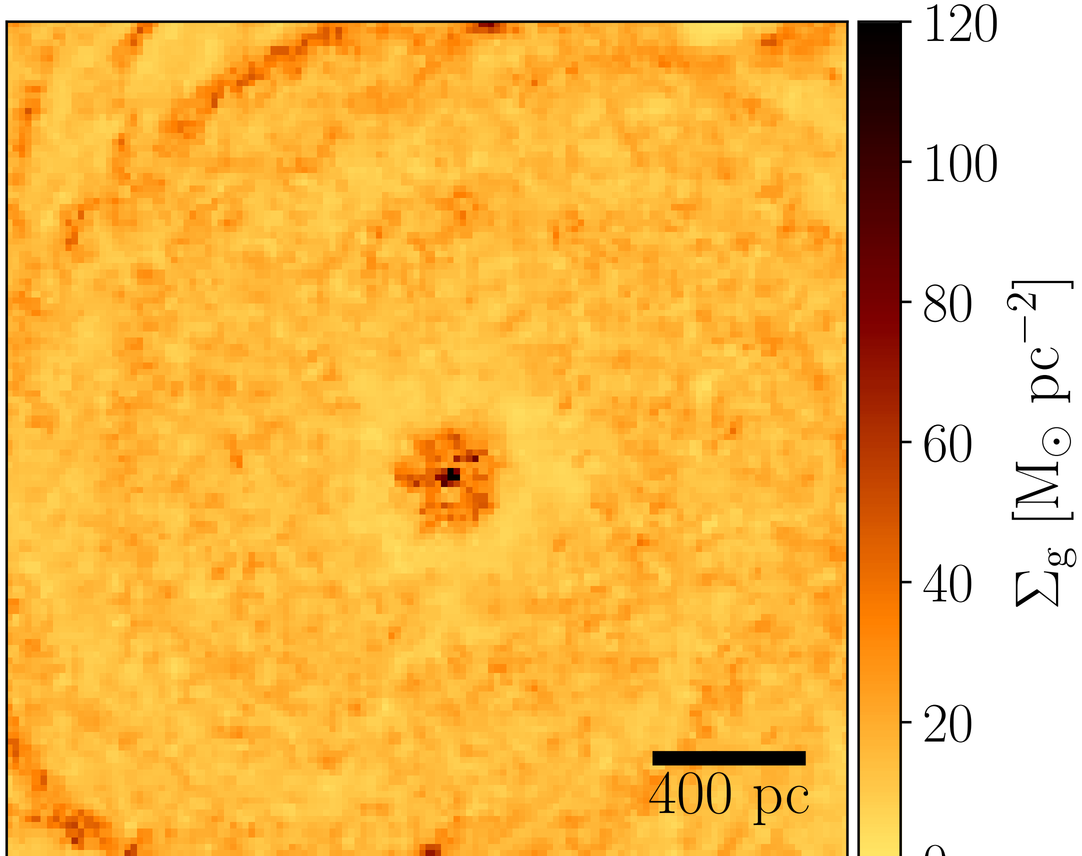
DYNAMICAL SUPPRESSION OF FRAGMENTATION



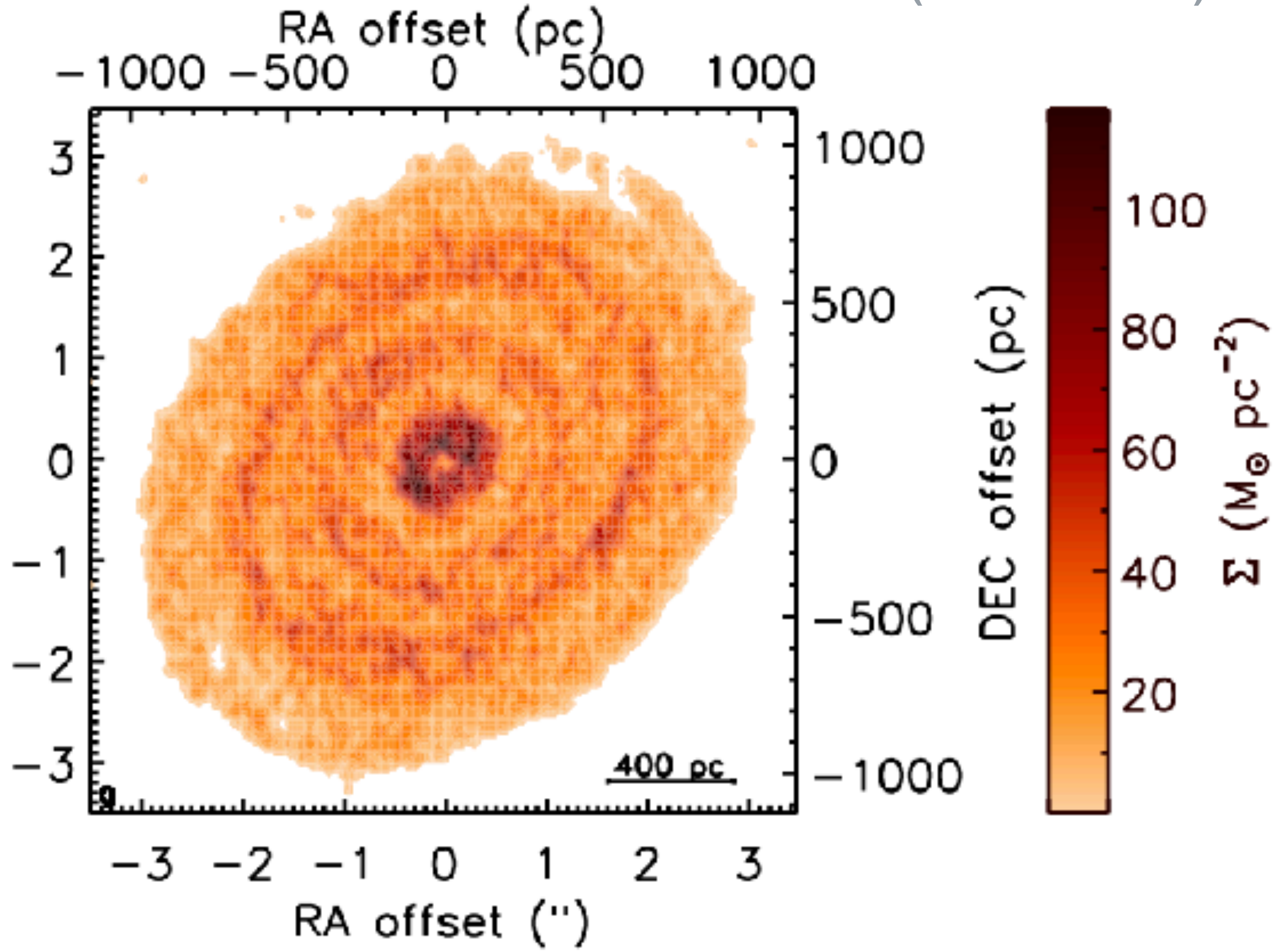
Gensior+ 2020a

COMPARISON TO OBSERVATIONS



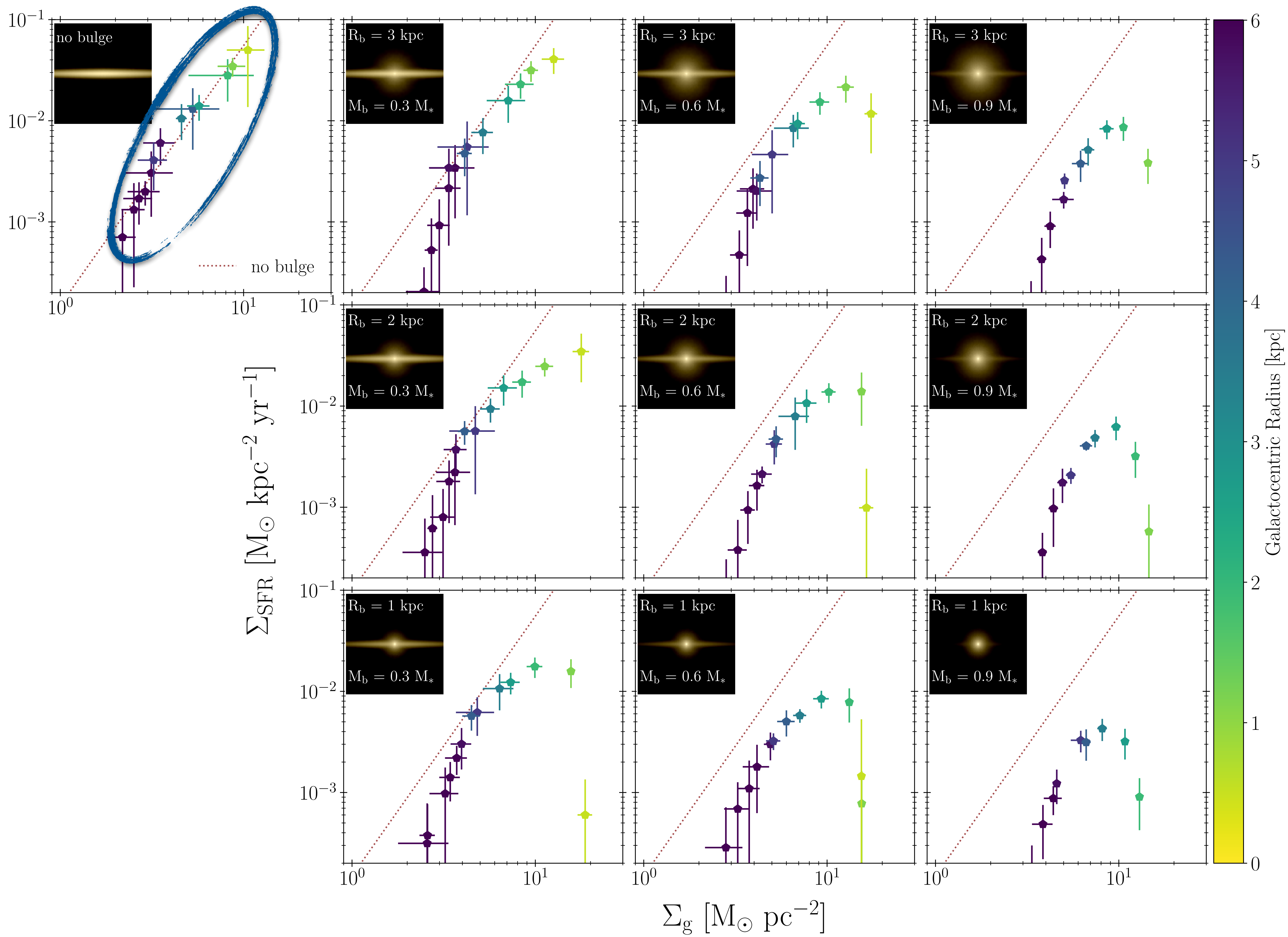


NGC 383 (see North+ 19)



Central region of R_b = 1kpc, M_b= 0.6 $M_\star$

SYNTHESISED STAR FORMATION RELATION



Gensior+ 2020a

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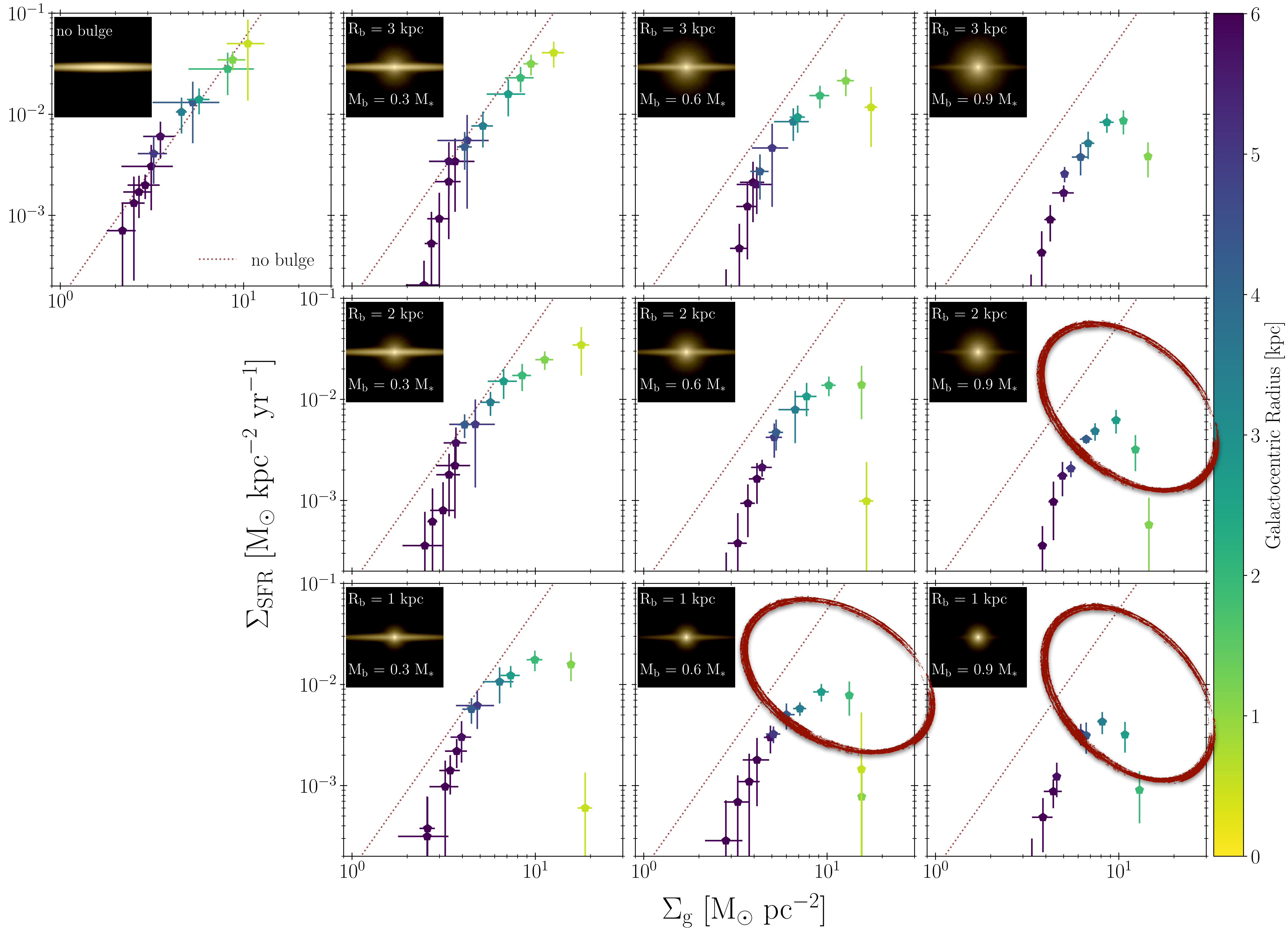

Gensior+ 2020a

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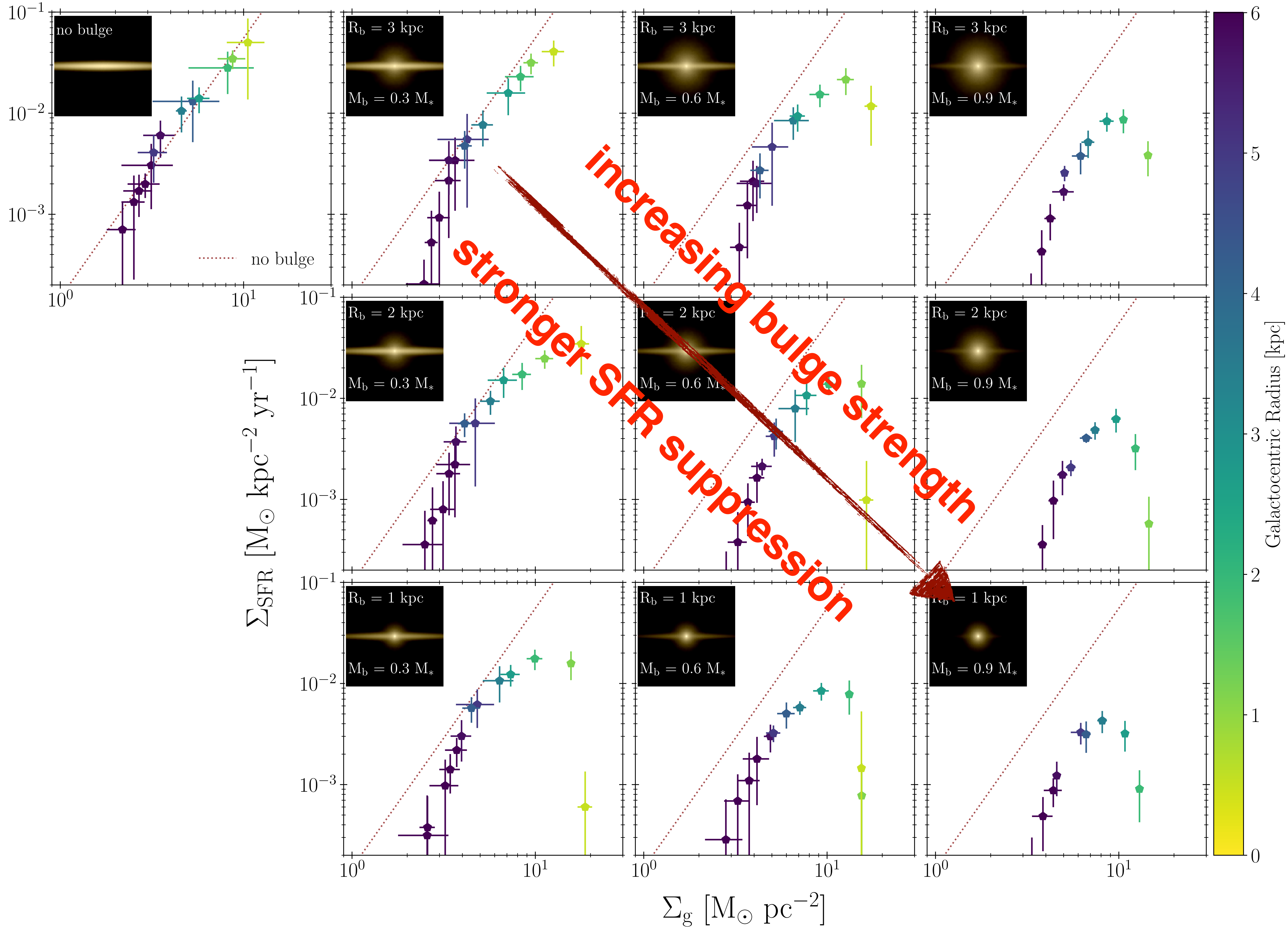
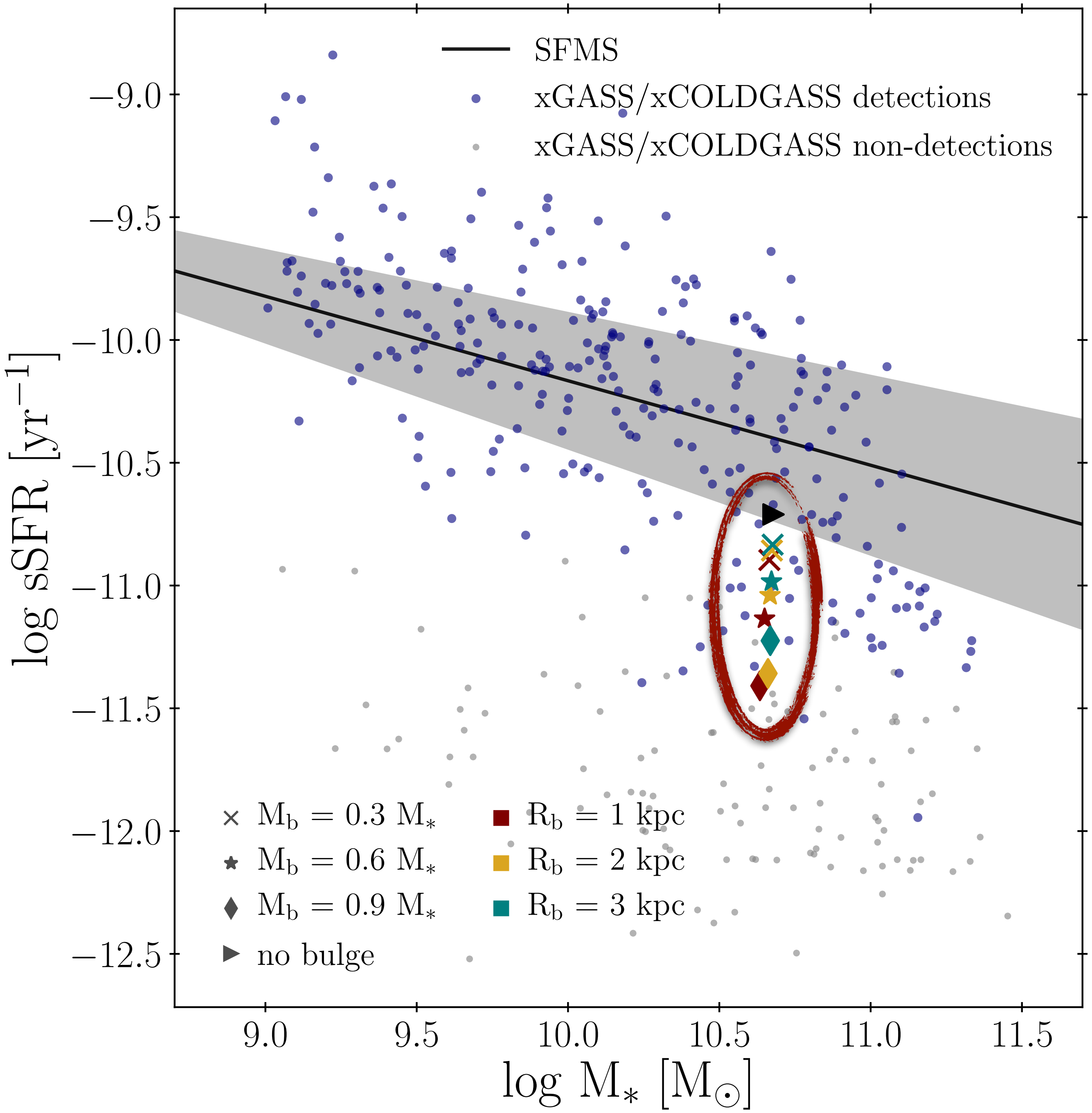


Gensior+ 2020a

STAR FORMATION MAIN SEQUENCE OFFSET DRIVEN BY BULGE DOMINANCE



Gensior+ 2020a

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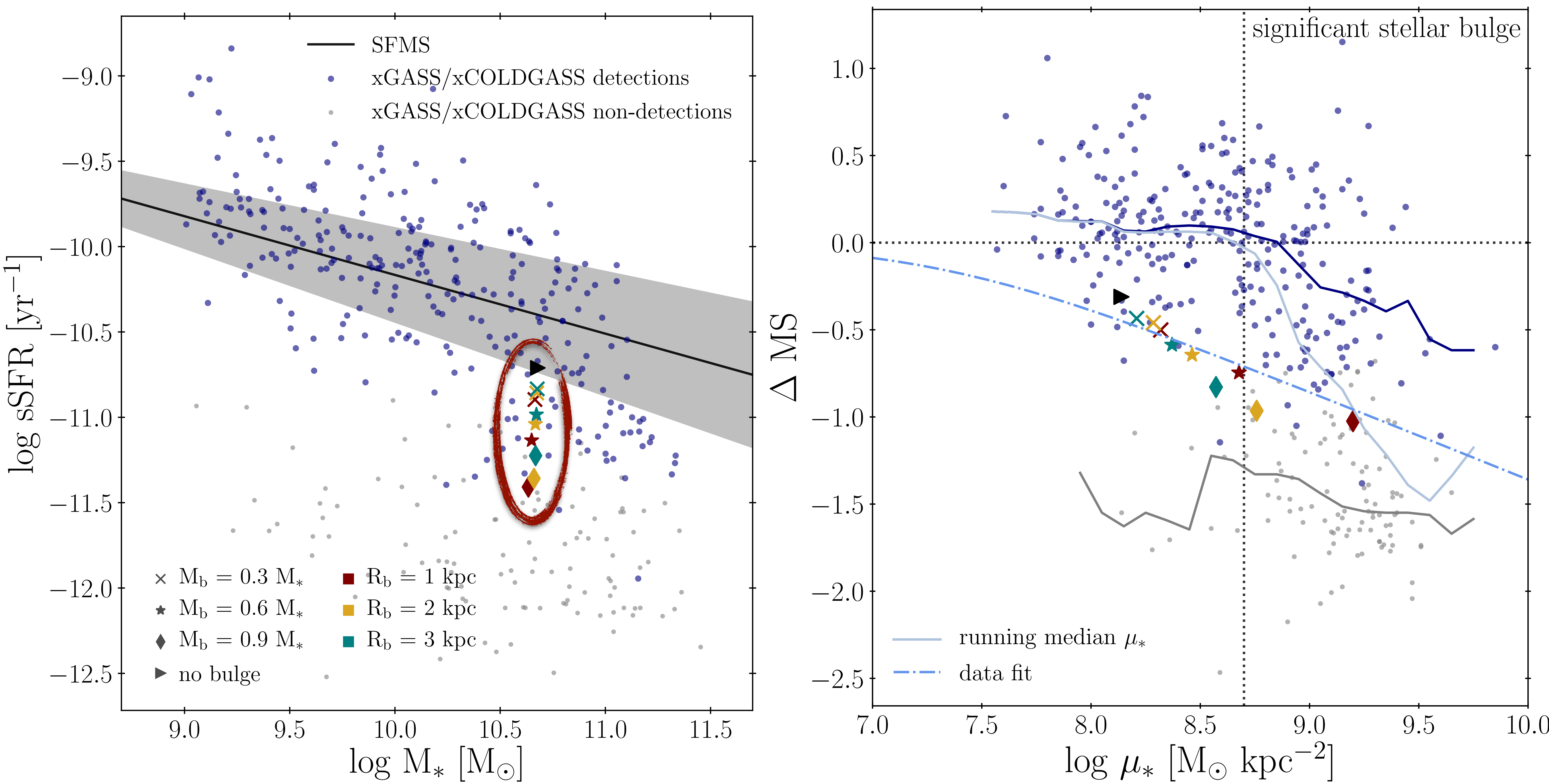

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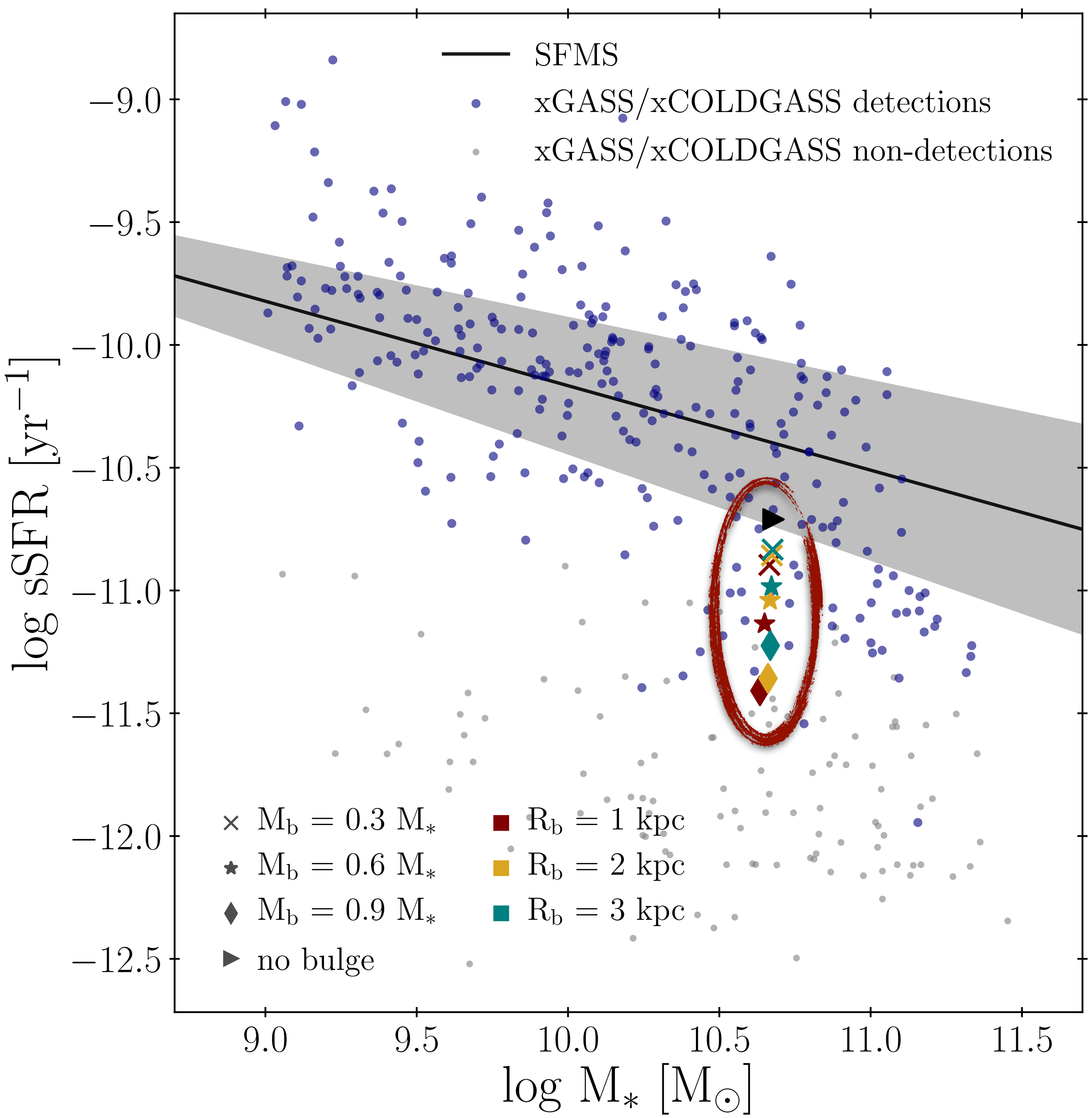
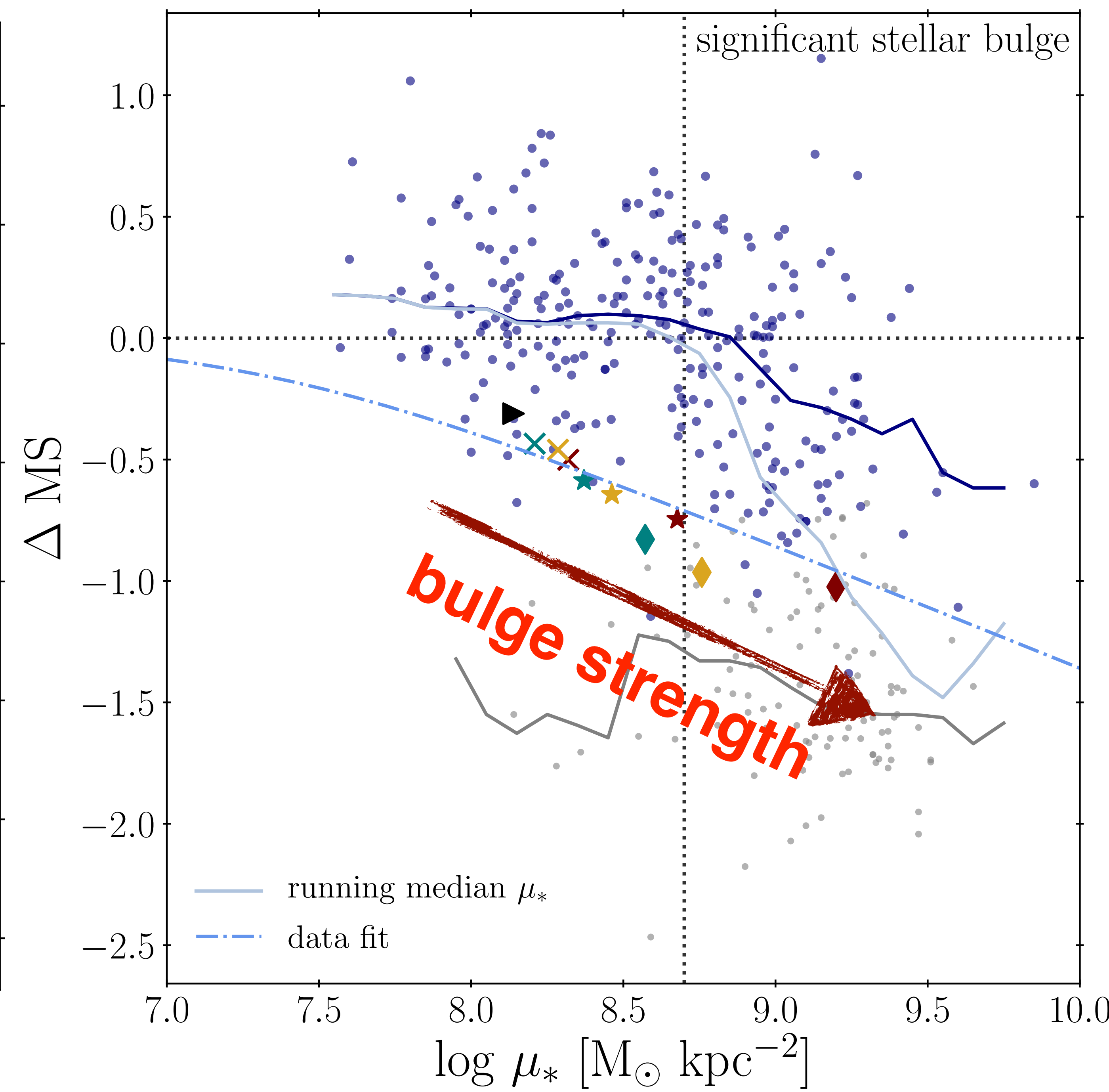


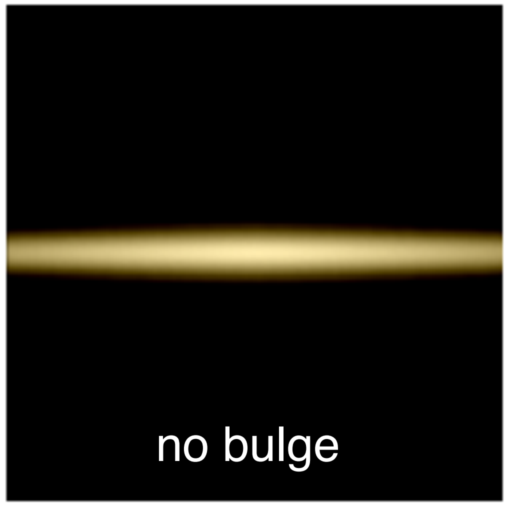


Gensior+ 2020a

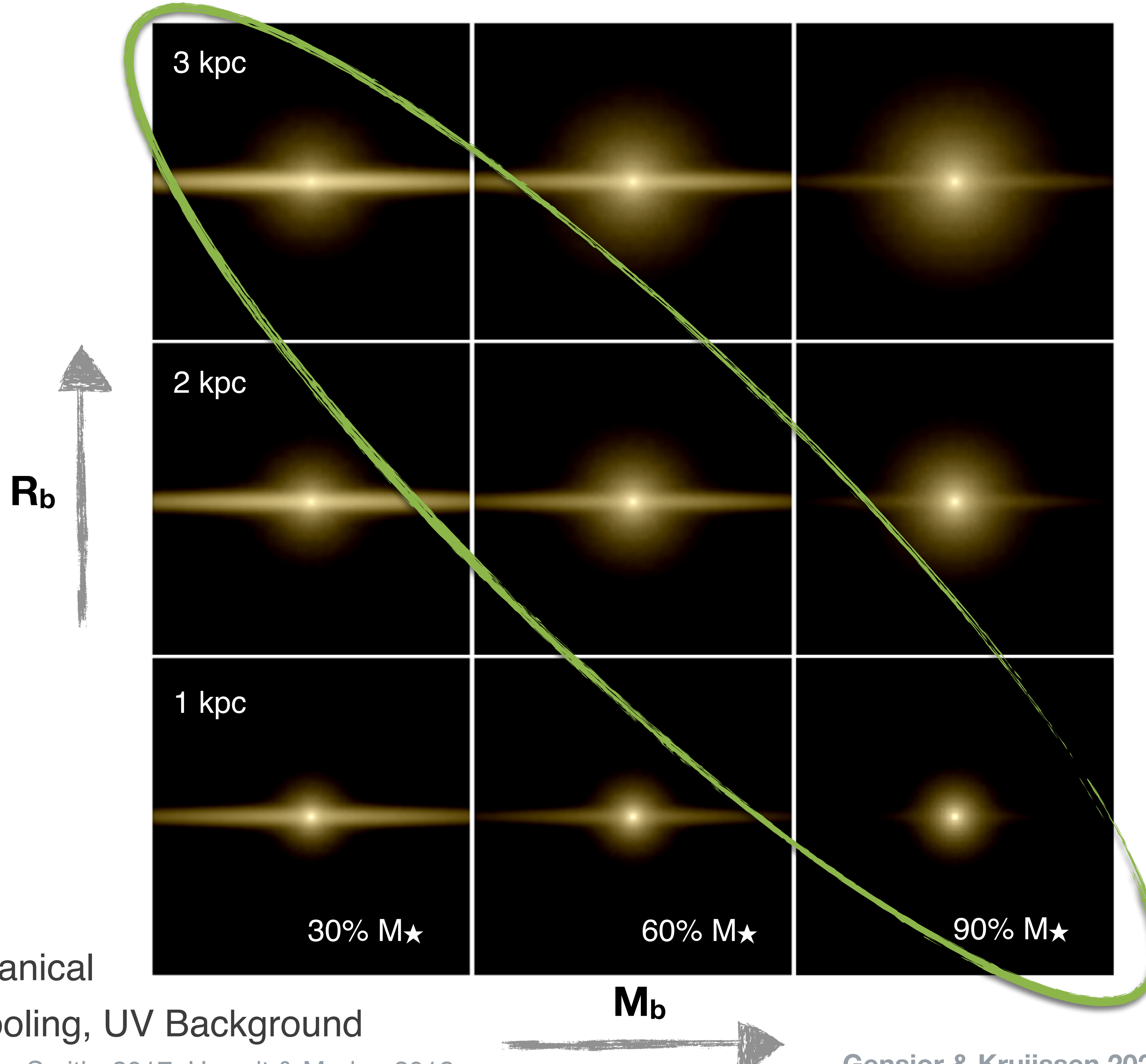
II: INFLUENCE ON THE GALAXY POPULATION

Based on Gensior & Kruijssen 2020b, MNRAS submitted

ISOLATED GALAXY SIMULATIONS



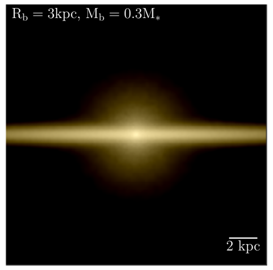
- 3 galaxies with v. different potentials
- f_{gas} = **1, 3, 5, 10 & 20%**
- Viral parameter dependent star formation
- Type II Supernova mechanical feedback, atomic line cooling, UV Background

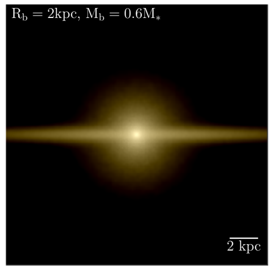


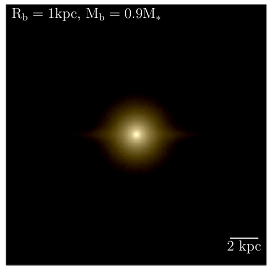
Kimm & Cen 2014, Hopkins+2014, Grackle - Smith+2017, Haardt & Madau 2012

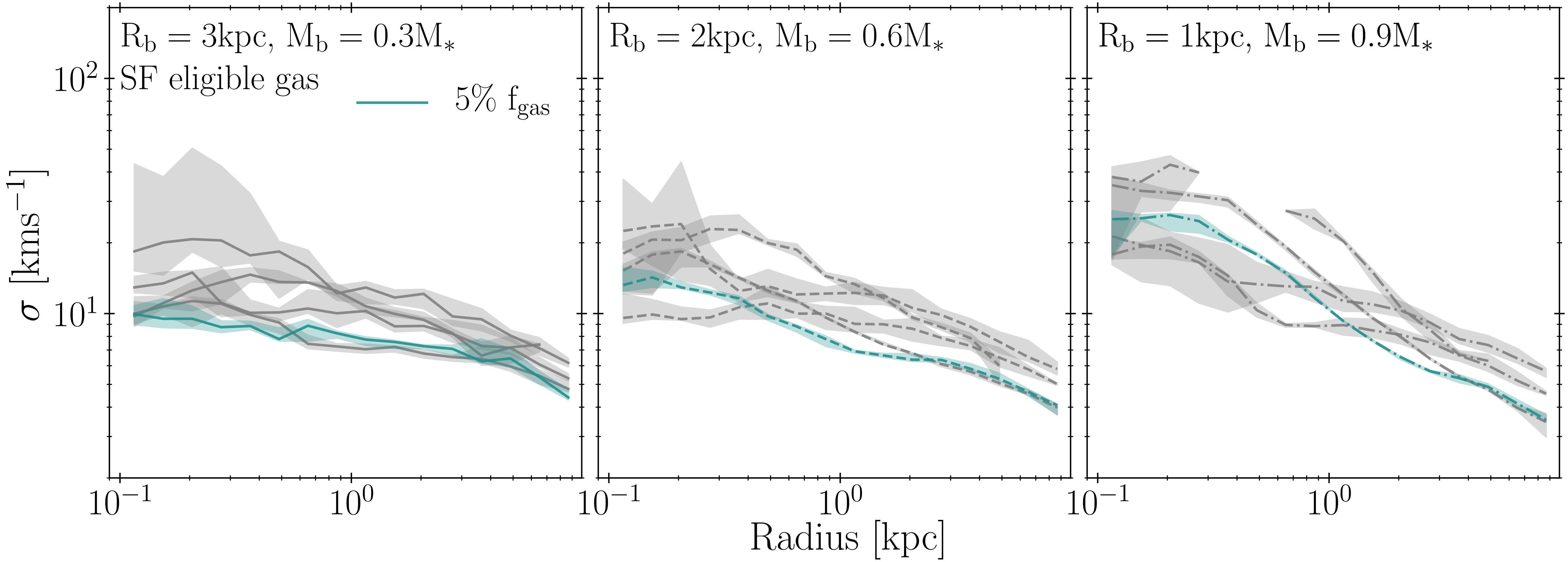
Gensior & Kruijssen 2020b, MNRAS subm.

VELOCITY DISPERSION AND GAS FRACTION









Gensior & Kruijssen 2020b, MNRAS subm.

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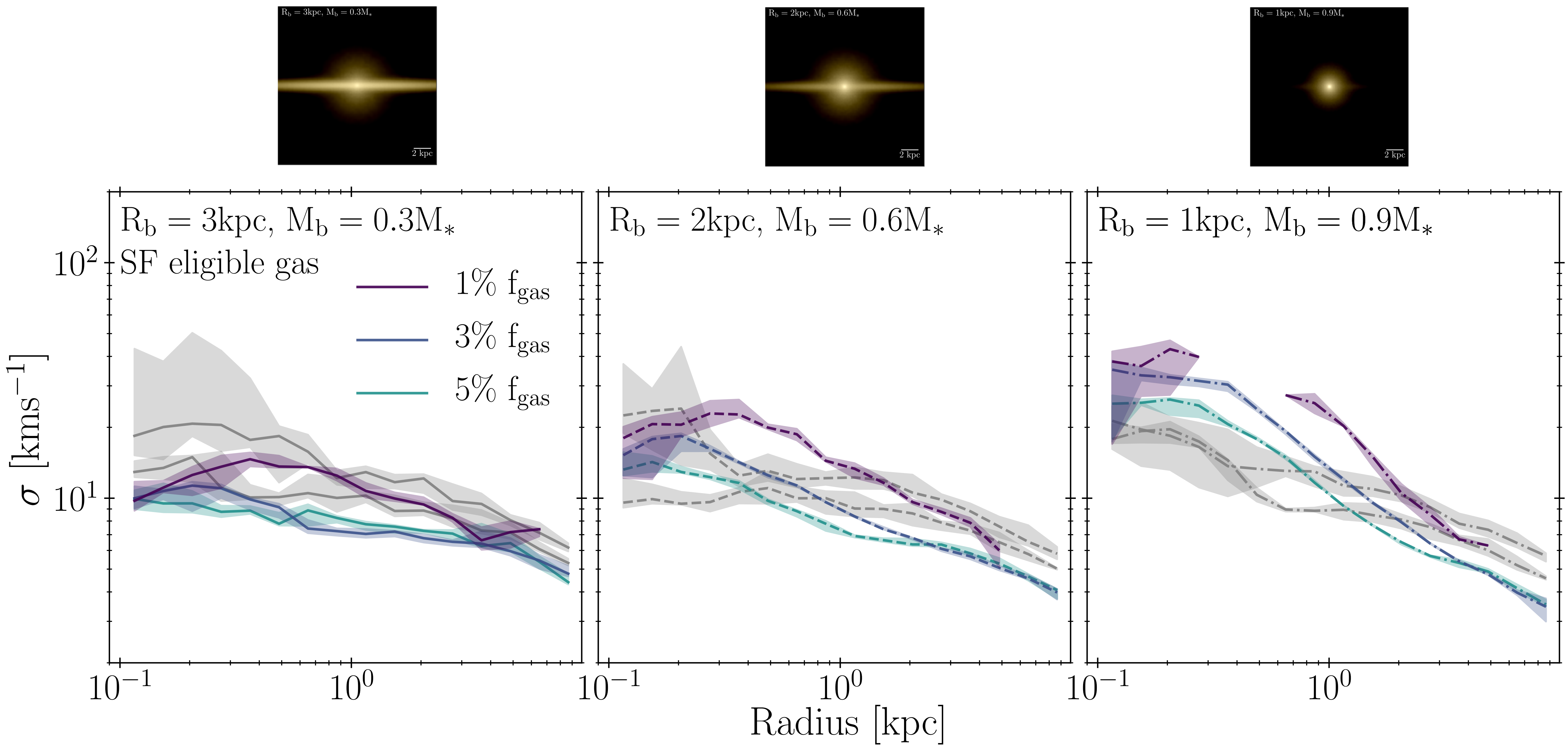

- Influence of bulge more pronounced at low f_{gas}

Gensior & Kruijssen 2020b, MNRAS subm.

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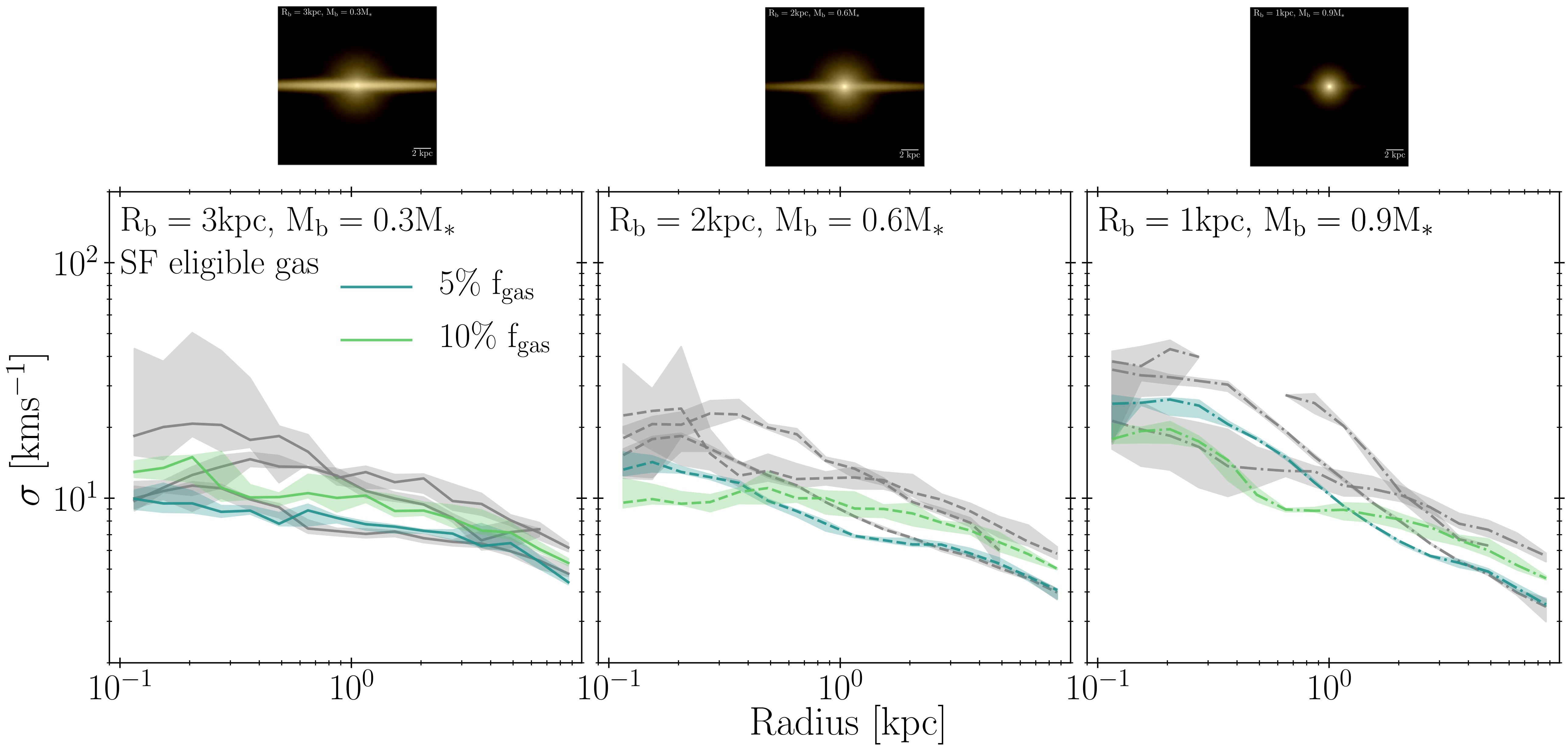
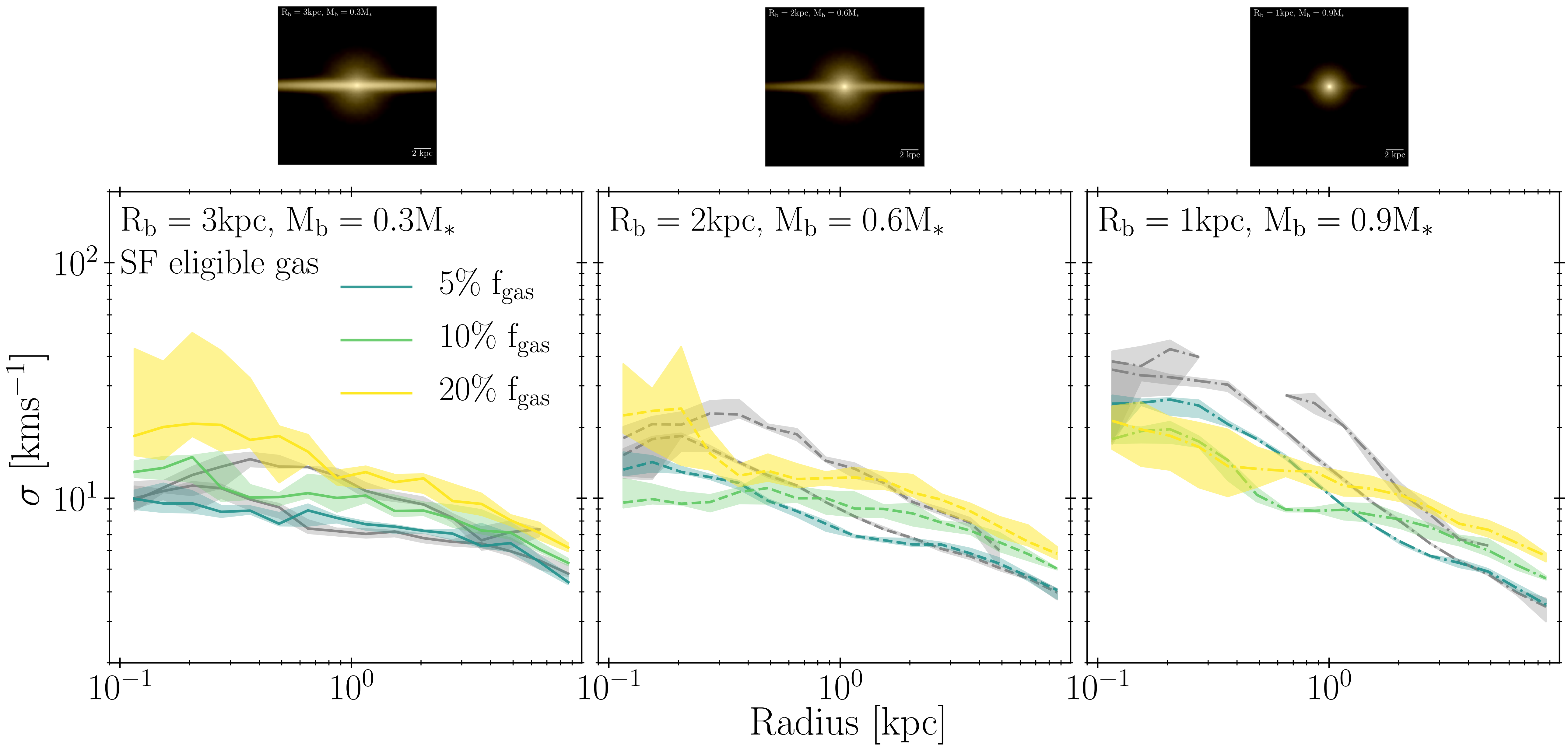


- Influence of bulge weakens the higher f_{gas}

Gensior & Kruijssen 2020b, MNRAS subm.

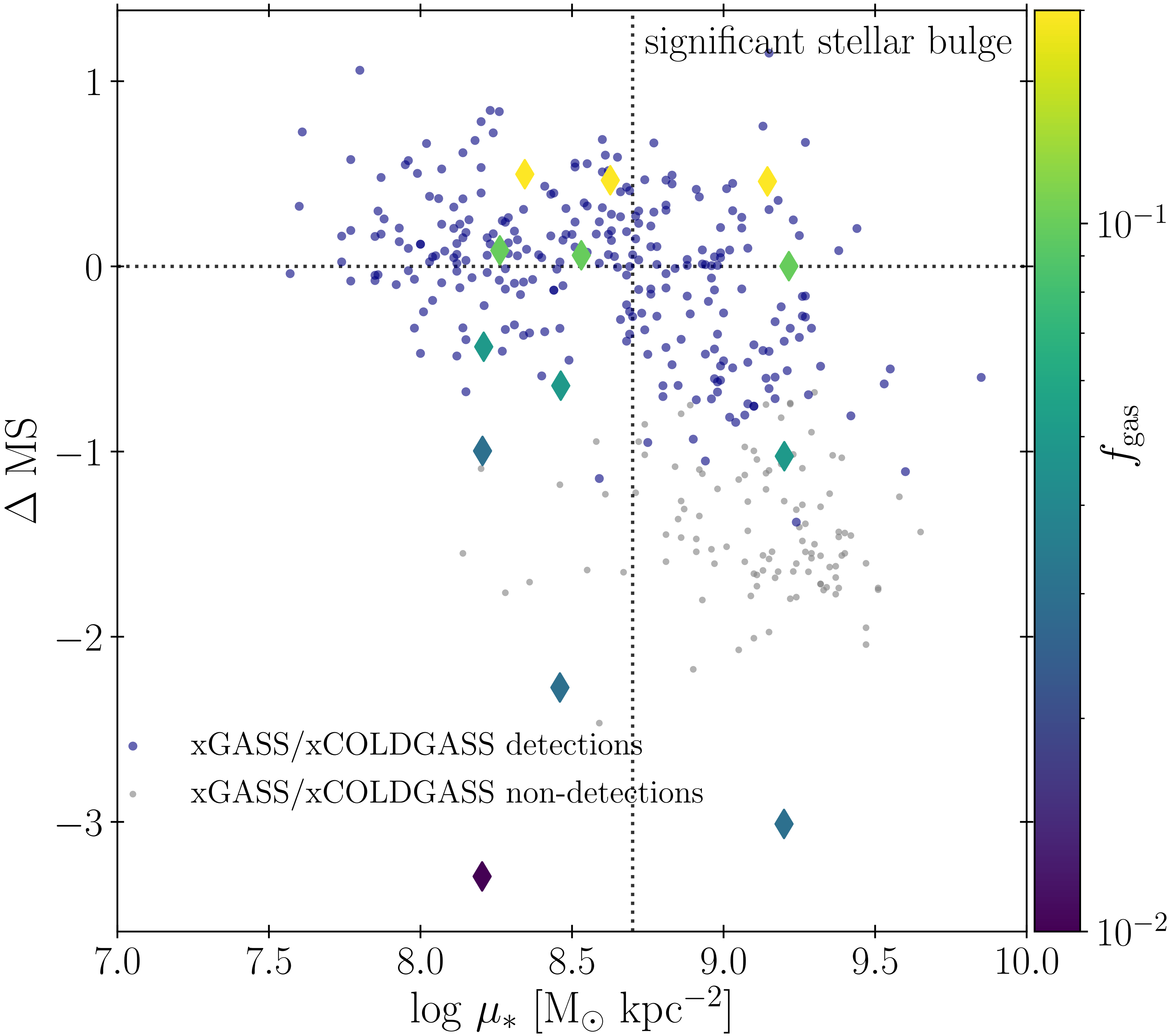
VELOCITY DISPERSION AND GAS FRACTION



- Influence of bulge more pronounced at low f_{gas}
- At 20% f_{gas} the gas is indiscriminate to the potential it sits in

Gensior & Kruijssen 2020b, MNRAS subm.

SFMS OFFSET MORE STRONGLY AFFECTED BY GAS FRACTION



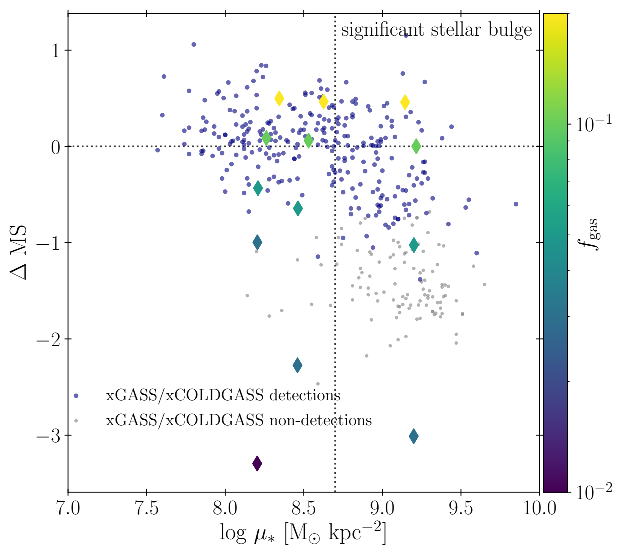
Increased SFR suppression with bulge density only for $f_{gas} \leq 5\%$

Gensior & Kruijssen 2020b, MNRAS subm.

PREDICTING THE ONSET OF DYNAMICAL SUPPRESSION

$$\log\left(\mathrm{sSFR_{sim}}[\mathrm{Gyr}^{-1}]\right) \propto 4\log f_{\mathrm{gas}} - 0.99\log\mu_*$$

Fit to simulations



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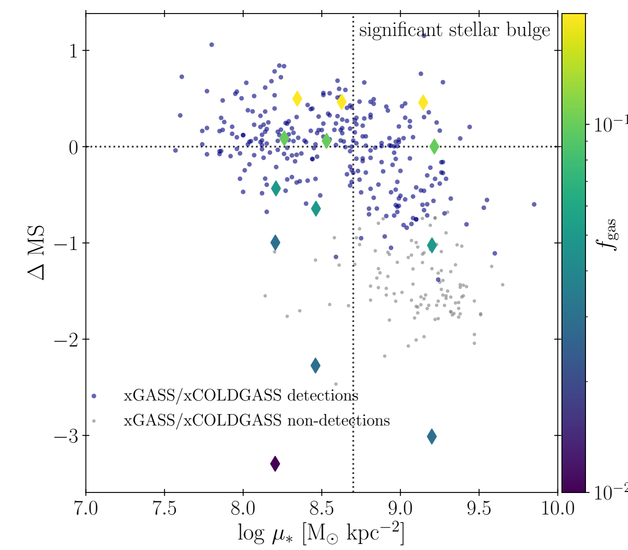

Fit to simulations

+

$$\log f_{\mathrm{gas}} \propto 2.49\log(1+z) + 0.52\Delta\mathrm{MS} - 0.36\log\mathrm{M}_*$$

Tacconi+ 2018: observational relation & **Speagle+ 2014** SFMS

↓

Gensior & Kruijssen 2020b, MNRAS subm.

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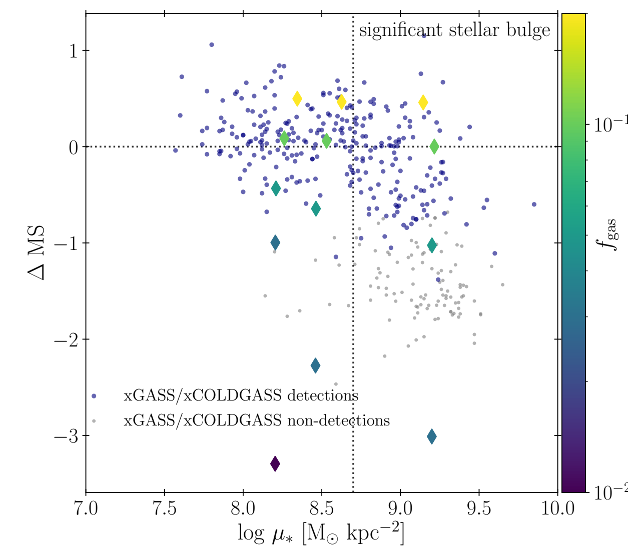

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Tacconi+ 2018: observational relation & **Speagle+ 2014** SFMS

$$\log\left(\frac{M_*}{5\times10^{10}\ M_\odot}\right) > -0.21 + 0.87z - 0.11z^2 + 0.0082z^3$$

$$z < 0.23 + 1.22\log\left(\frac{M_*}{5\times10^{10}\ M_\odot}\right) + 0.17\log^2\left(\frac{M_*}{5\times10^{10}\ M_\odot}\right) + 0.069\log^3\left(\frac{M_*}{5\times10^{10}\ M_\odot}\right)$$

Gensior & Kruijssen 2020b, MNRAS subm.

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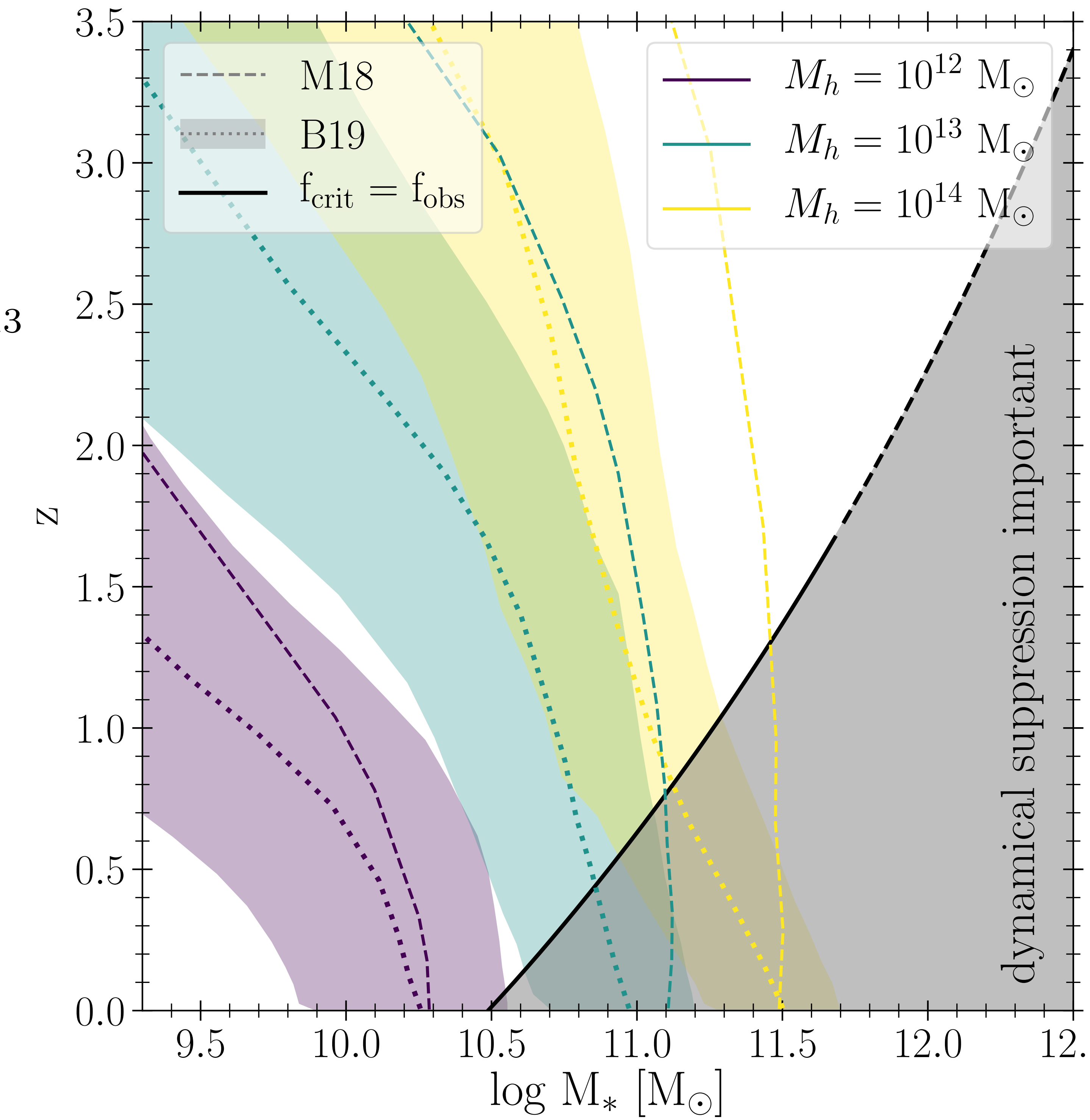
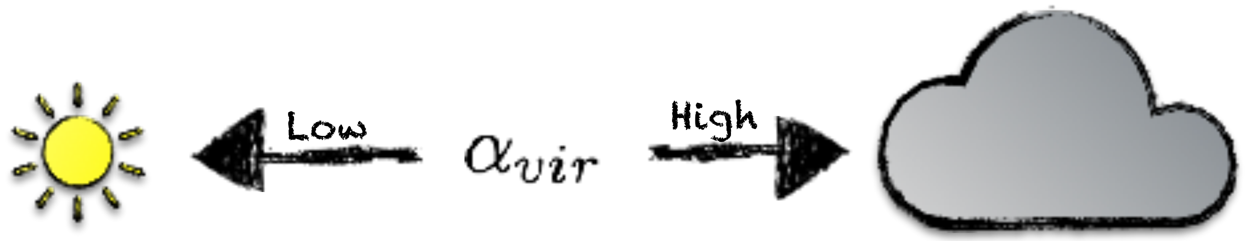


Gensior & Kruijssen 2020b, MNRAS subm.

SUMMARY



- Galactic dynamics matter:
  - High shear creates smooth gas discs at the centres of spheroids
  - SFR suppressed in centre
    - ➡ Higher bulge (surface) density = stronger effect
  - Dynamical suppression only dominant at **low f_{gas}**
  - Physics of star formation may dominate baryon cycle at low redshifts (z<1.4) and high galaxy masses (> $10^{10.5}M_{\odot}$) contrary to the standard picture of gas-regulator models
- To come: Cosmological zoom-ins to make self consistent predictions and further populate the ΔMS, $\mu_{\star}$, f_{gas} parameter space & more disc structure analysis