Pressure-Regulated Feedback-Modulated Model of Star Formation:

A plausible explanation for the abundance of high-z galaxies observed by JWST

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with Learning the Universe (LtU) Collaboration

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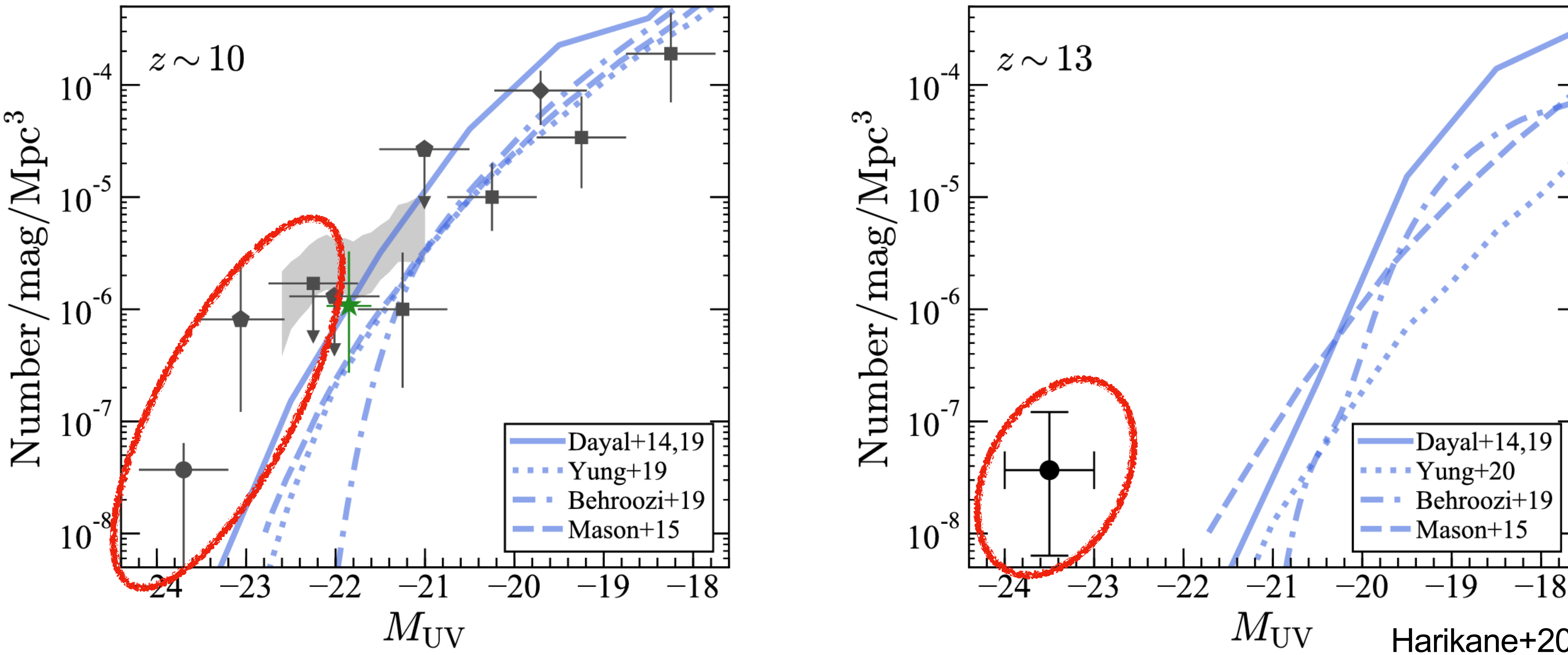
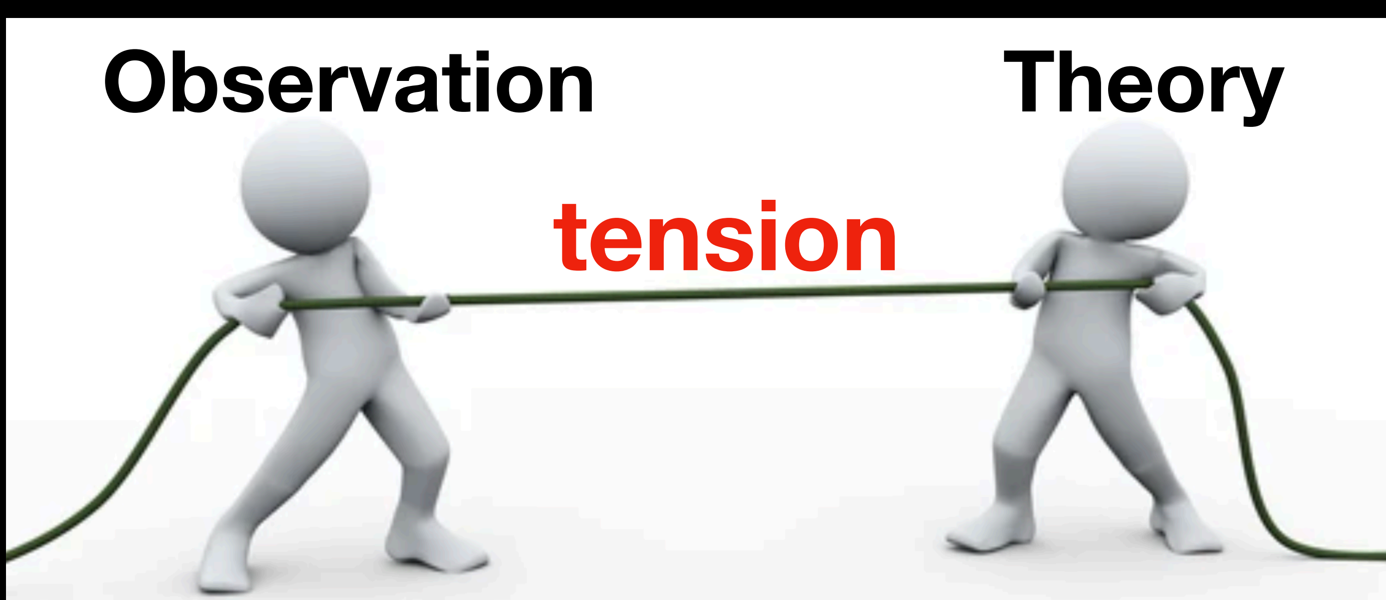
2024 NHFP Symposium

Models struggle to reproduce JWST data ——> too efficient SF



Harikane+2022



- Inaccurate measurements?

- Inaccurate predictions?
    - Astrophysics (e.g. SF)
    - Cosmology
    - Mock observation

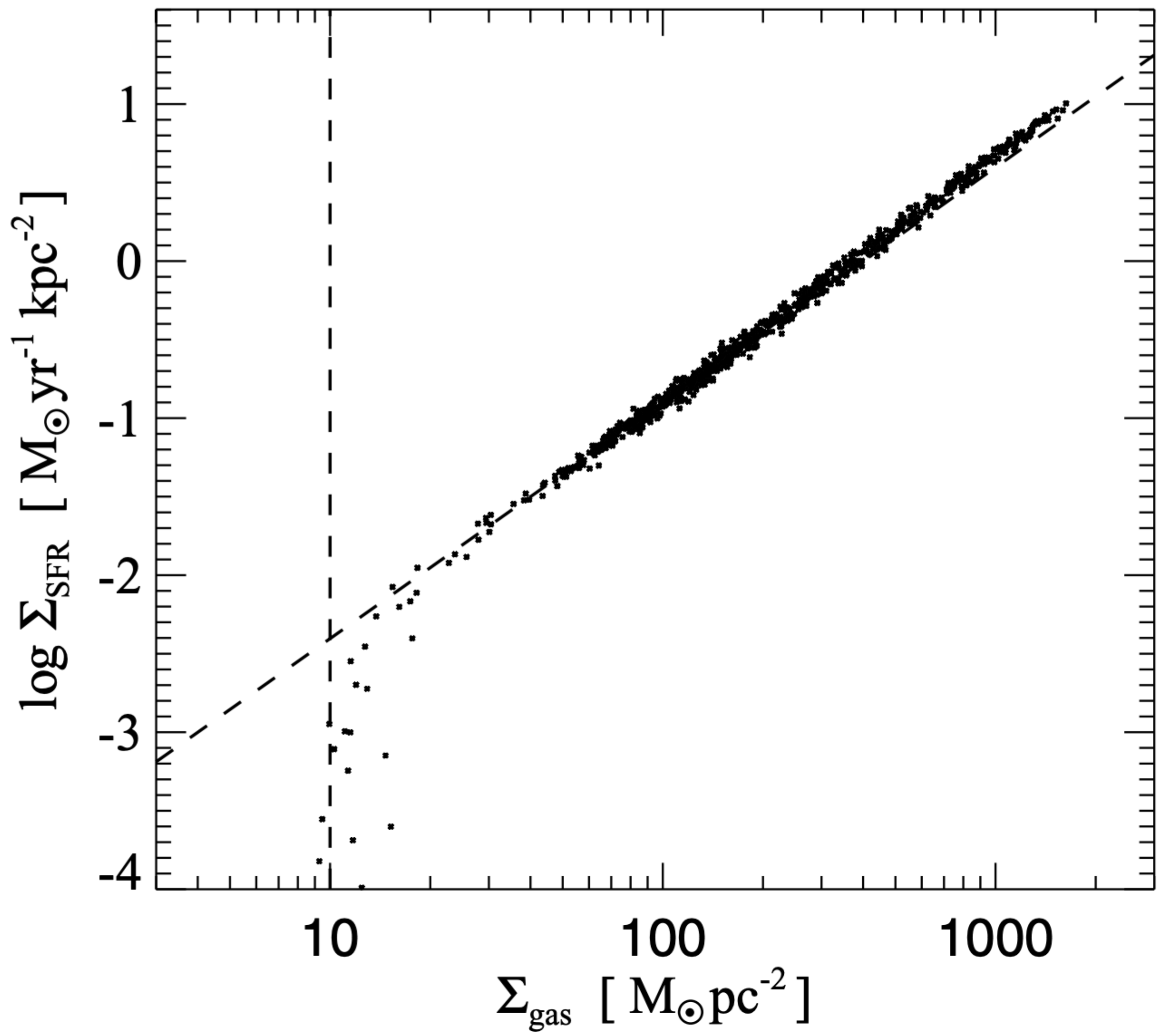
Motivation: Traditional star formation models are *tuned* to reproduce observations (e.g. Global Schmidt relation)

Springel & Hernquist (2003) (SH03):

Hybrid multi-phase model
SF gas = cold clouds embedded within an ambient hot medium

$$\mathrm{SFR} \propto \rho_{\mathrm{cold}}/t_{\mathrm{SF}}$$

Tuning $t_{SF} \sim 1$ Gyr reproduces observations



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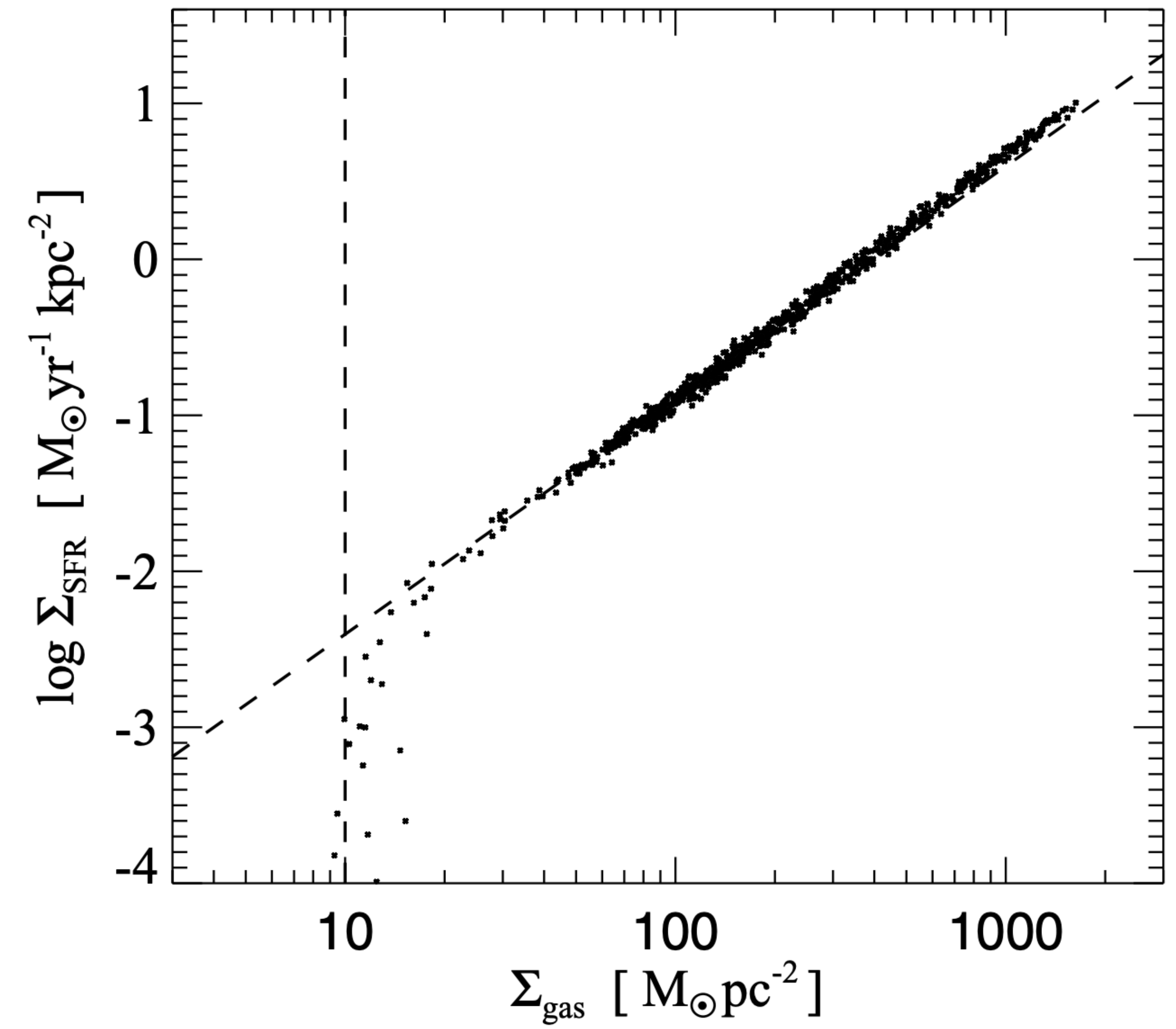
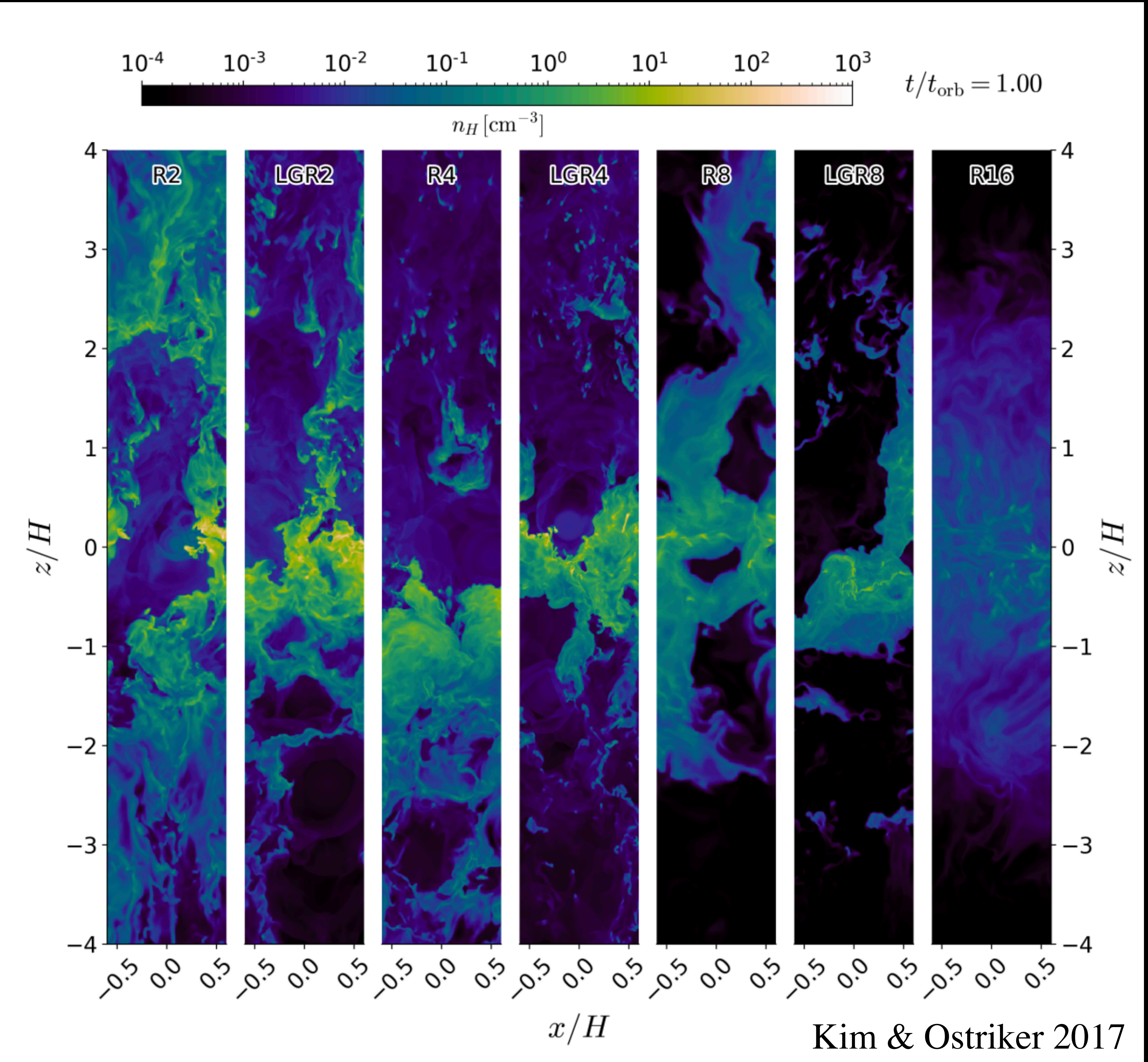


Varying ISM conditions?

Multi-phase ISM?

Depend on resolution/mesh?

Can we use ISM Simulations (e.g. TIGRESS) to inform star formation on large scales?



Kim & Ostriker 2017

PRFM: Pressure-Regulated, Feedback-Modulated Equilibrium Model (Ostriker & Kim 2022)

ISM conditions and SFR co-regulate each other to achieve equilibrium

$$In\ equilibrium \rightarrow \quad Pressure\,(P) = weight\,(W)$$

$$Pressure\,(P) \equiv \sigma_{eff}^2\,\rho_g = \sigma_{eff}^2\,\Sigma_g/2H_g = P_{\rm th} + P_{\rm turb} + \Pi_{\rm mag}$$

$$Weight\,(W) \equiv \int \rho_g\, g\, dz = W_g + W_\star + W_d$$

$$W_g = \frac{\pi G \Sigma_g^2}{2},\ \ W_\star = \pi G \Sigma_g \Sigma_\star \frac{H_g}{H_g + H_\star},\ \ W_d = \Omega_d^2 \zeta_d \Sigma_g H_g$$

Pressure response: feedback modulation and yields

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Pressure response: feedback modulation and yields

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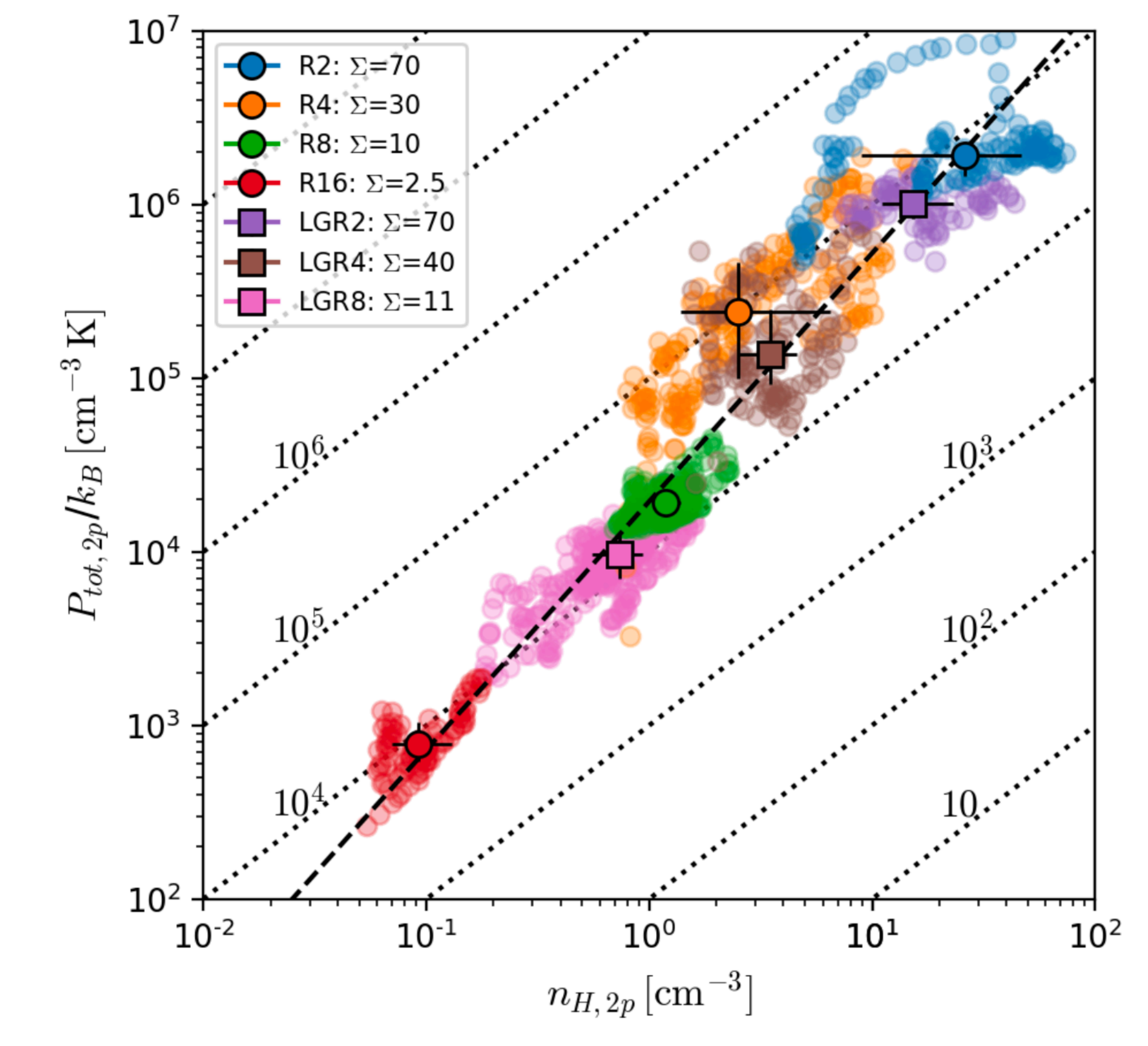
Gas velocity $\sigma_{\rm eff}$ from TIGRESS

From TIGRESS ISM simulations, the effective equation of state is:

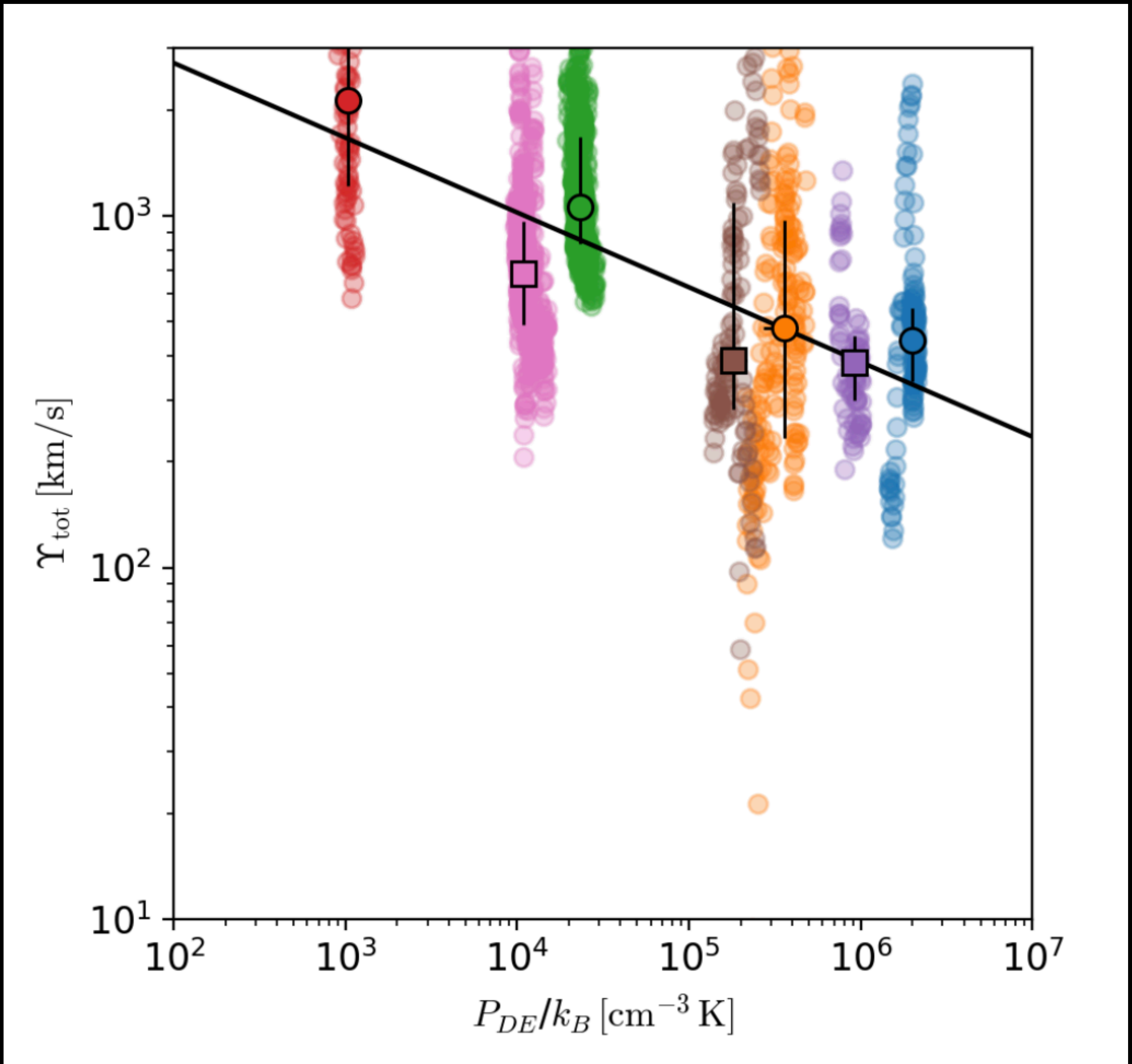
$$\log(P_{\rm tot}/k_{\rm B}) = 1.43\log(n_{\rm H}) + 4.3$$



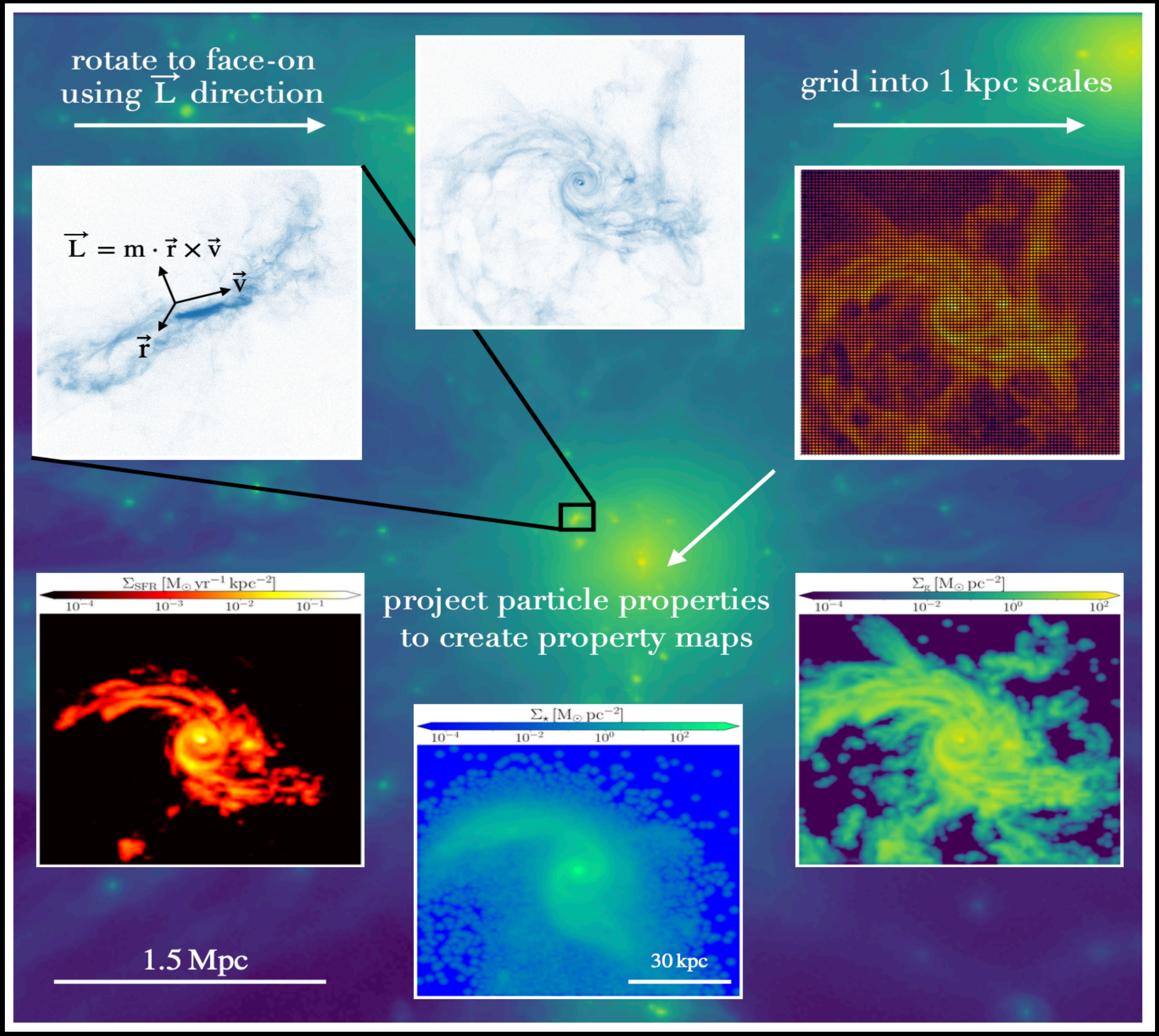
$$\text{recall}\;\; P_{\rm tot} = \sigma_{eff}^2\,\rho_g \;\;\rightarrow\;\; \sigma_{eff} \sim P_{\rm tot}^{0.22}$$

Yield feedback parameter from TIGRESS

$$\log \Upsilon_{\rm tot} = -0.212 \log P_{\rm tot}/k_{\rm B} + 3.86$$

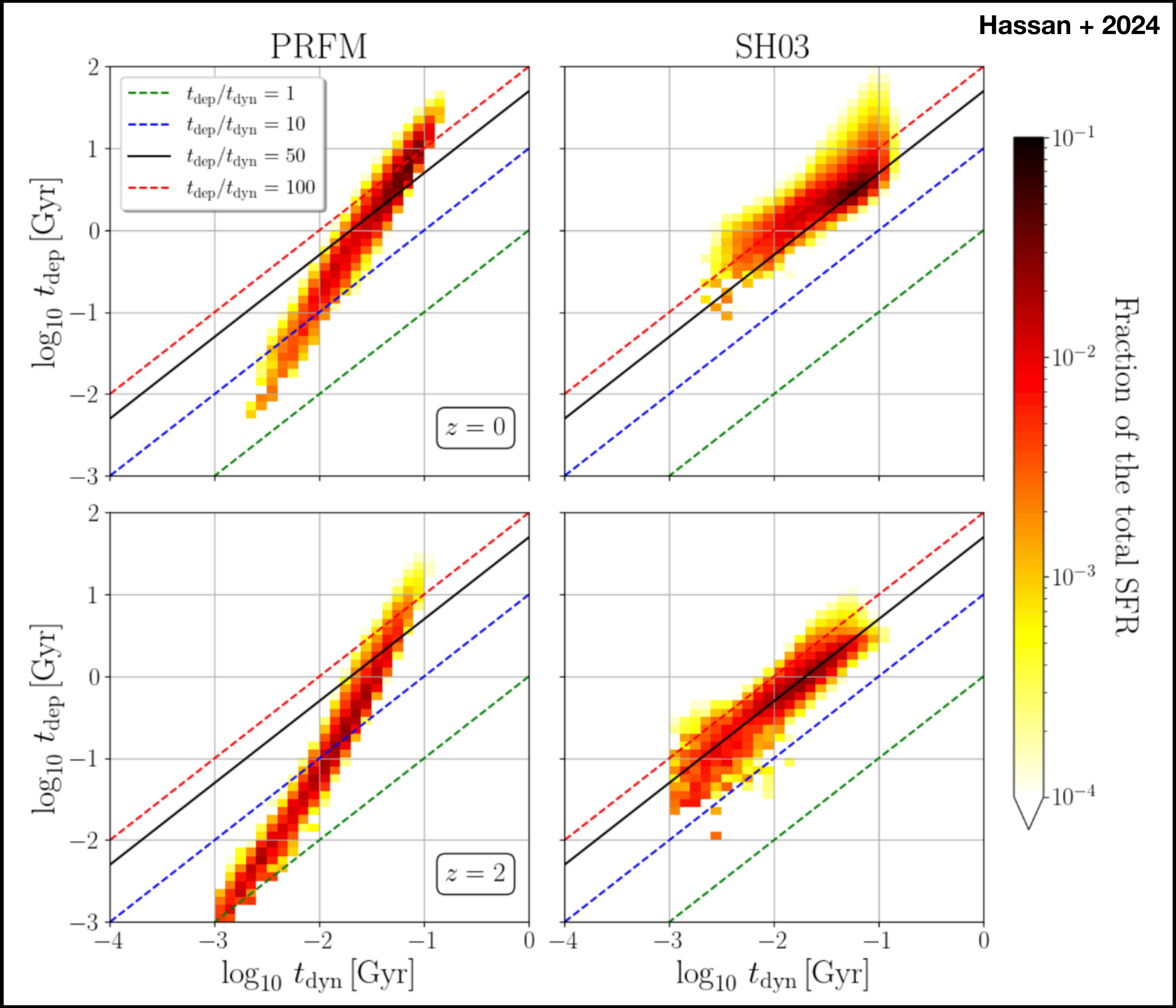


Sample selection & analysis in post-processing



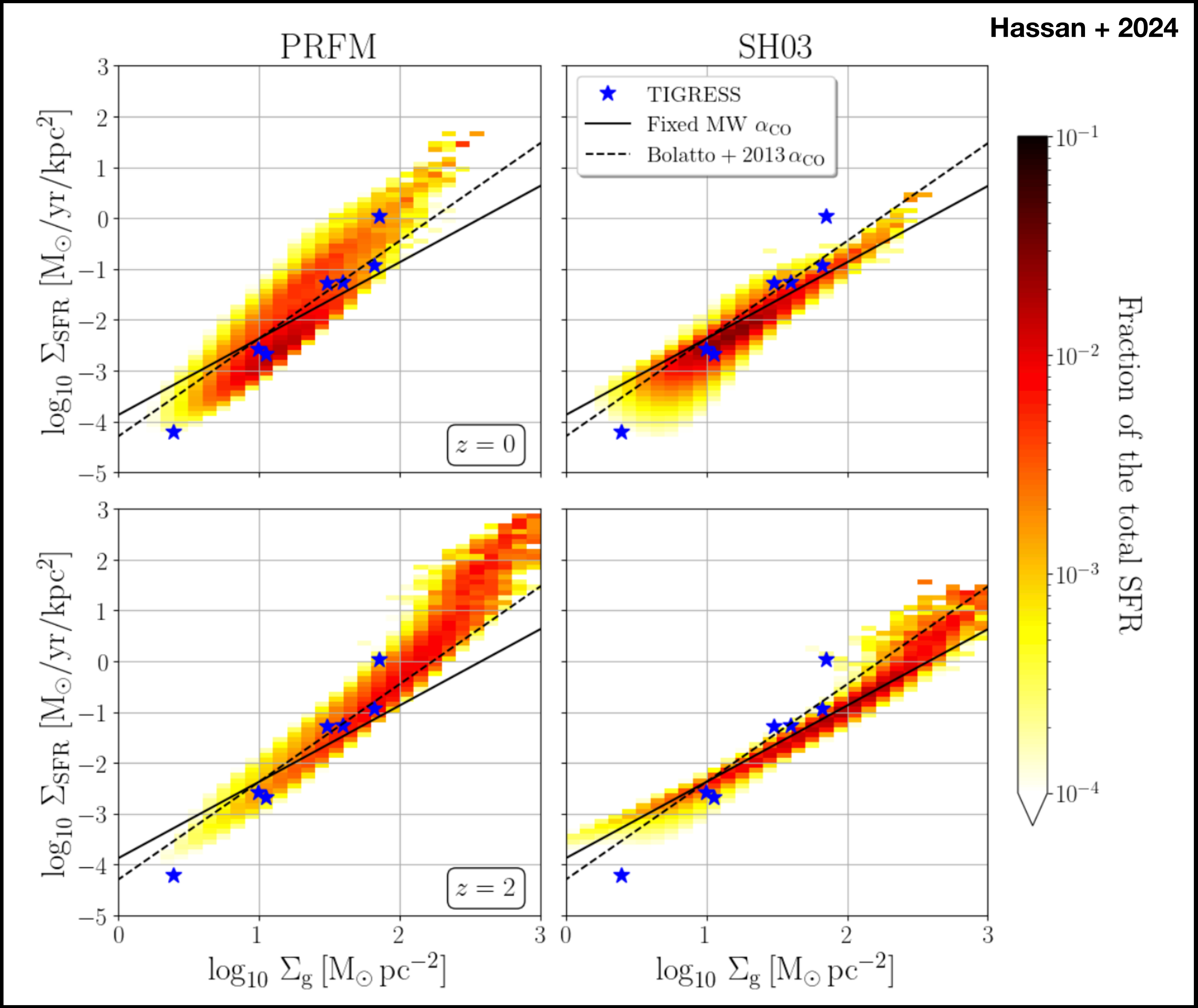
$M_\star \sim 10^{7-11} M_\odot$. $N_{min} > 100$ particles (all types). $\mathrm{SFR} > 10^{-4}\,\mathrm{M_\odot/yr}$.

Relation between depletion and dynamical times.

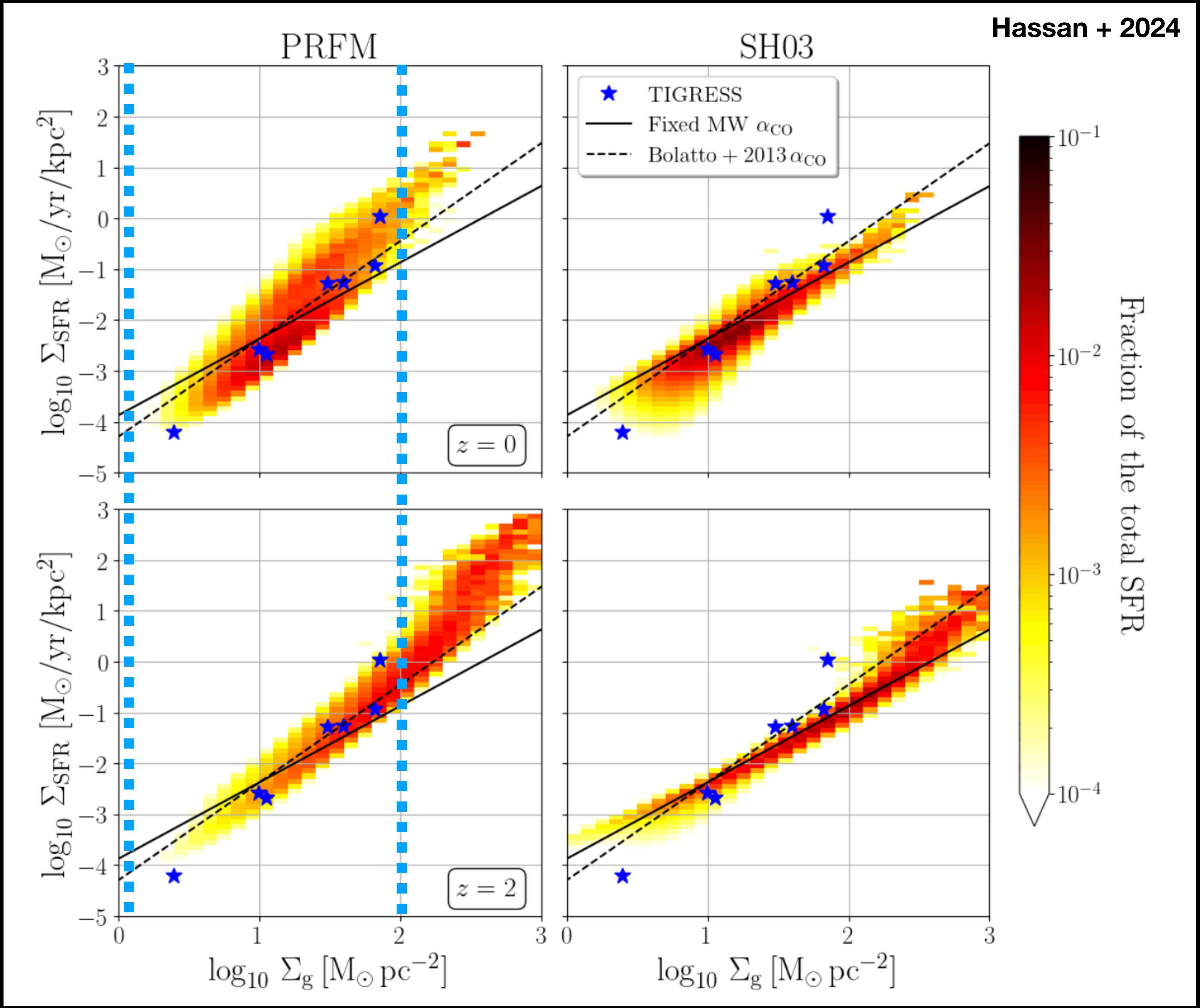


PRFM predicts a non-constant depletion and dynamical time relation

Global Schmidt relation

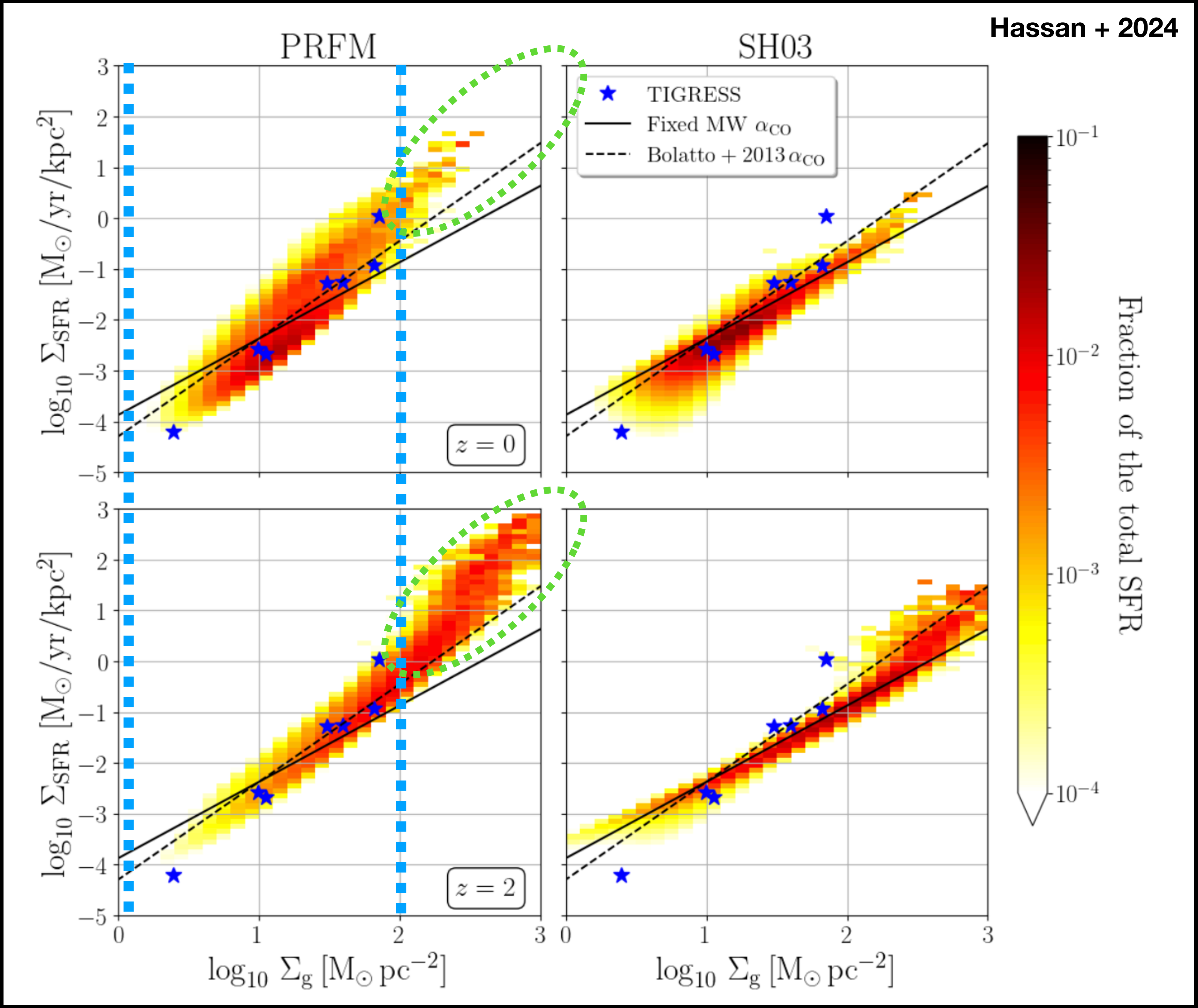


Global Schmidt relation



- Both models are consistent with observations in the range of 1-100 $M_\odot pc^{-2}$

Global Schmidt relation



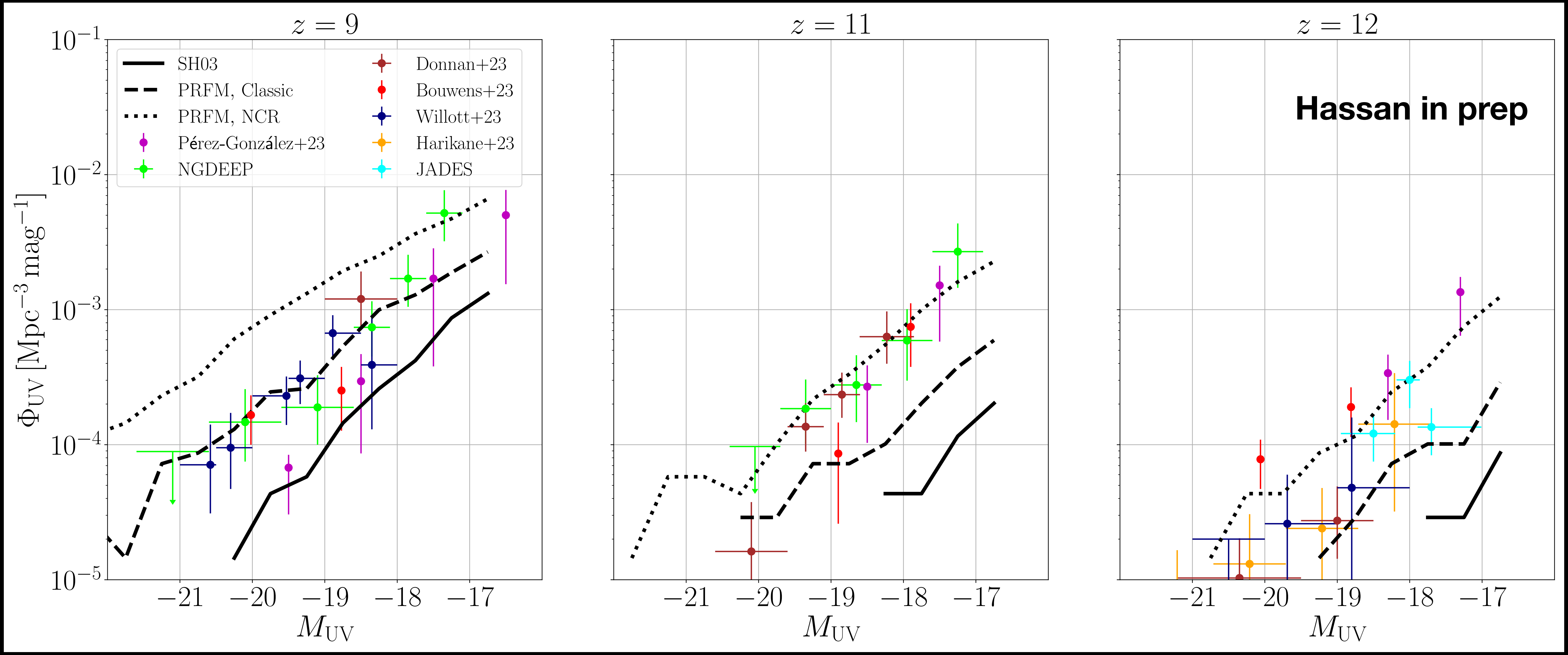
- Both models are consistent with observations in the range of 1-100 $M_\odot pc^{-2}$
- PRFM predicts more efficient star formation at high densities.

PRFM might naturally explain JWST high-z UVLF

Springel & Hernquist (2003, SH03, solid)

PRFM, Classic (dashed) $--> \sigma_{\rm eff} \equiv f(P), \Upsilon \equiv f(P)$

PRFM, NCR (dotted) $--> \sigma_{\rm eff} \equiv f(P, Z), \Upsilon \equiv f(P, Z)$



Key results

- PRFM predicts shorter depletion times, leading to a more efficient star formation at high densities and redshift.
- SH03 and PRFM are consistent with observed Schmidt law in the range of 1-100 $M_{\odot} pc^{-2}$, but PRFM does so without tuning to observations.
- PRFM might naturally explain JWST high-z UVLF.
- On-the-fly implementation in progress….