Cosmic evolution of the local star formation efficiency

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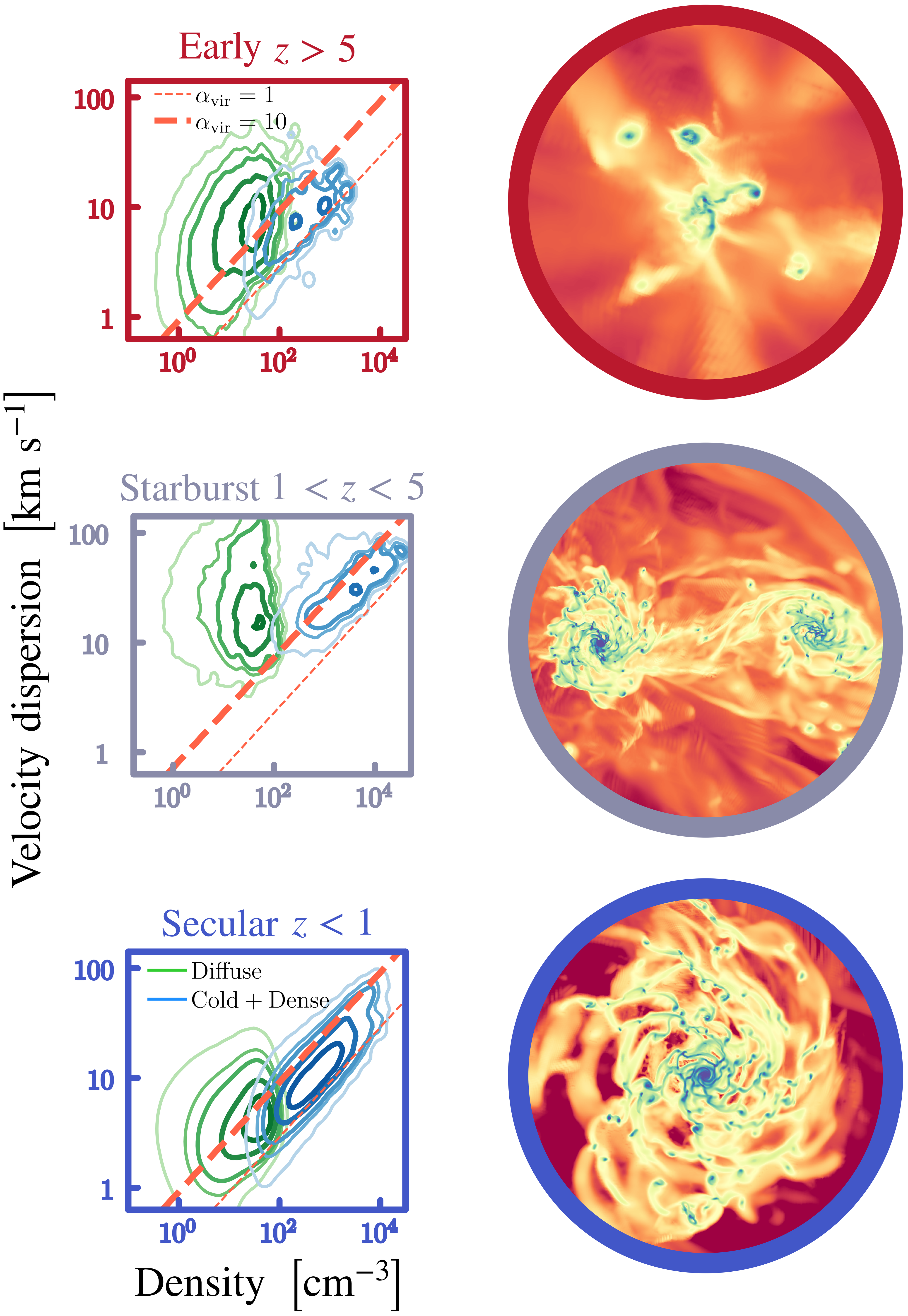
1. Background

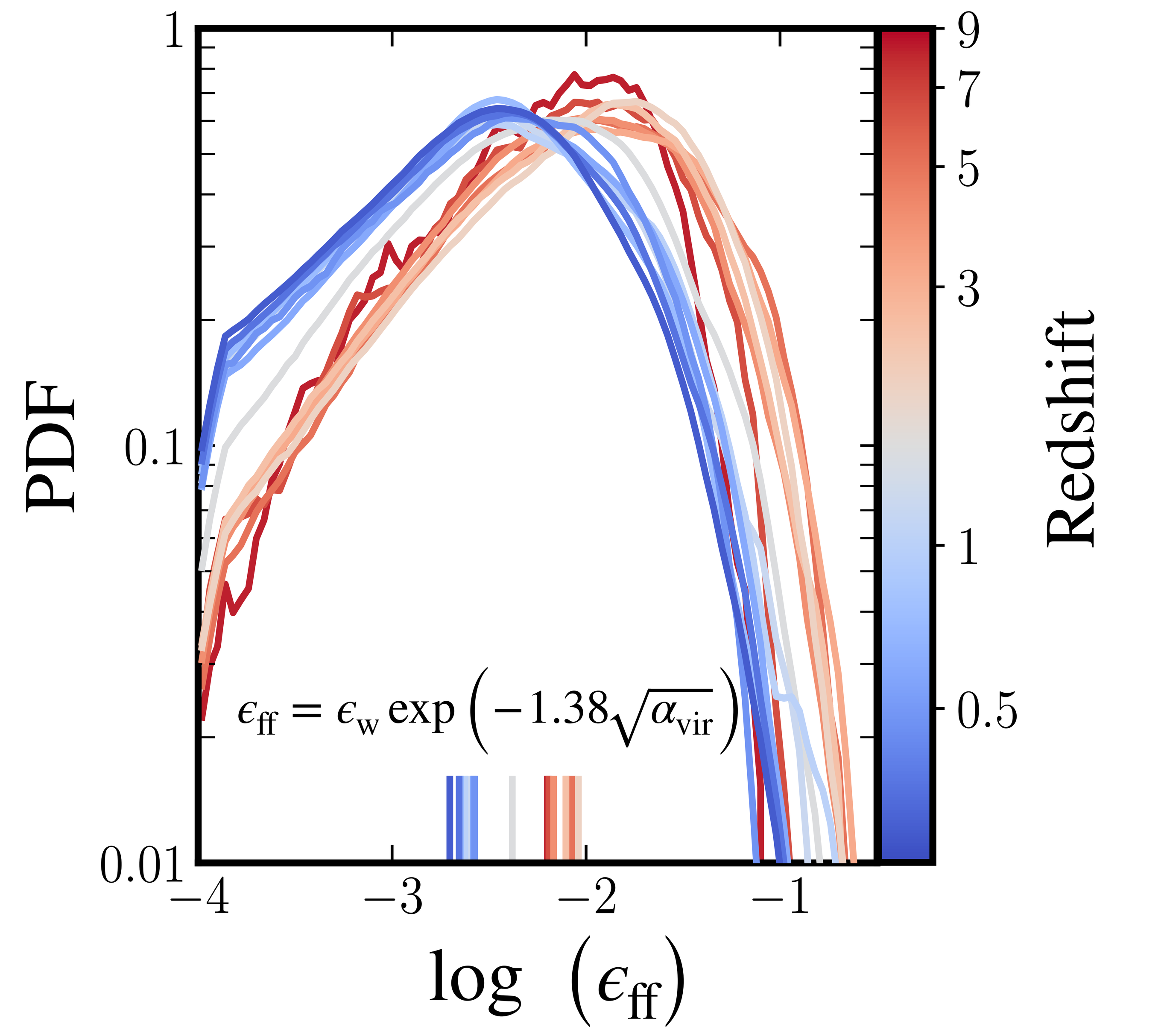
Star formation and feedback processes impact ecosystems within and around galaxies. However, the details on how the local structure of the ISM affects its star formation properties and how these shape star formation histories on galactic scales is yet to be settled. In this work I use VINTERGATAN, a high resolution (20 pc) zoom-in simulation of a Milky Way-like galaxy [1] to describe the interplay between the cosmological environment and star formation sub-grid models [2].

2. ISM structure with comsic epoch



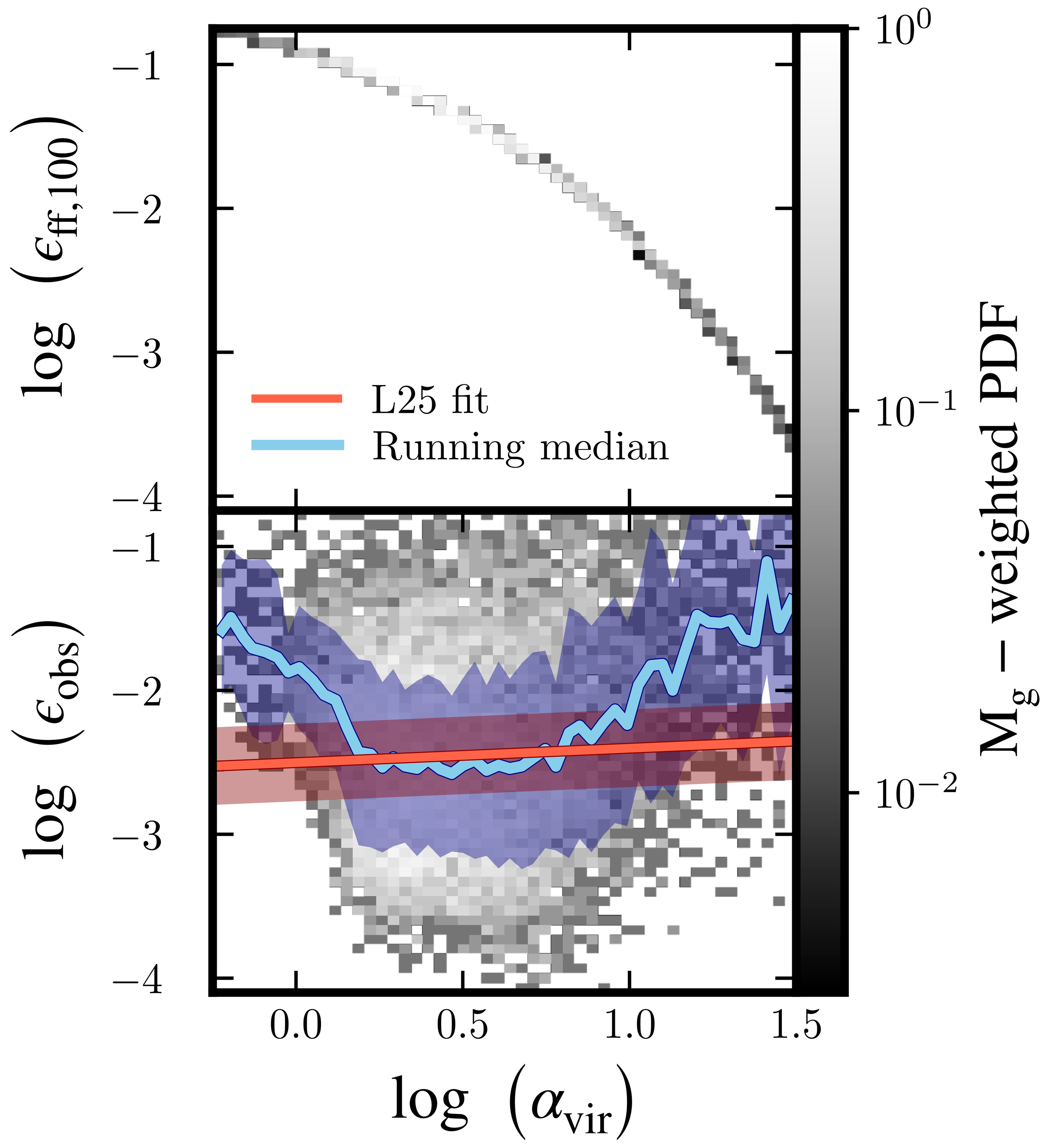
The density and turbulent structure of the ISM evolve with cosmic epoch both for *Diffuse* ($100 < T < 10^4$ K) and *Cold+Dense* ($T < 100$ K and $n > 100$ cm^{-3}) gas phases. The *starburst* epoch shows an ISM in the densest and most turbulent states, coeval with global gas depletion times (t_{dep}) on the order of 100 Myr and the assembly of a galactic disc [3]. Nevertheless, changes in the local gas velocity dispersion and number density distributions over time conspire to render a constant virial parameter ($1 < \alpha_{vir} < 10$) for the "star forming" ISM.

3. On-the-fly ϵ_{ff} distributions



The star formation recipe implemented is based on an ε_{ff} only dependent on α_{vir} [4]. By taking the density and velocity dispersion values at every star formation event and re-computing the cell ε_{ff}, I recover a static distribution over time if the α_{vir} itself is also constant. Hence, the local timescale for star formation $t_{sf} = t_{ff} / \varepsilon_{ff}$ is mainly driven by changes in the gas density distribution through the free-fall time t_{ff}.

4. Model vs. observations



Observational estimators of ε_{ff} ($\varepsilon_{obs} = t_{ff} / t_{dep}$) appear to be in contradiction with theoretical predictions when expressed as a function of the dynamical state of GMCs [5]. My results show that turbulence-based ε_{ff} models render a cold and dense ISM that on 100 pc scales has a comparable ε_{obs} to that of PHANGS [6].

References: [1] Agertz+2021, [2] Segovia Otero+2025, [3] Segovia Otero+2022, [4] Padoan+2012, [5] Leroy & Schinerer 2024, [6] Leroy+2025

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