https://arxiv.org/abs/2603.01726v1

The Galaxy Stellar Mass–SFR–Size Relation in EAGLE, TNG100, and Observations

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1. Introduction

- stellar mass(M_*) - star formation rate (SFR) relation
  - star-forming main sequence (SFMS): **tight correlation** with intrinsic **scatter ~ 0.3 dex**
  - There exists "red sequence" below the SFMS in the local universe
- M_*-size relation
  - sizes increase with cosmic time. **More massive → Larger size**
  - star-forming galaxies exhibit larger sizes than quenched ones at fixed M_*
- size-SFR relation (suggested by some simulation works)
  - **angular momentum** environment of cool gas have some impact on both the **disk size** and **star formation activity**
  - **feedback process** regulate SFR, which can in turn modify the disk size
- **Wuyts 2011** (observational work, HST imaging)
  - deviate further from SFMS ridge → smaller size(**compact**) / galaxies on the ridge are more **extended**

This study aims to

investigate the existence of such size relation in the latest cosmological simulations

2. Observational Data (for comparison)

- SDSS (local universe)
  - M_* from SED fitting, SFR from Hα line (spec)
  - size from R_e ; r-band half light radius
- CANDELS($0.5 < z < 1.5,\ 1.5 < z < 2.5$)
  - M_* from SED fitting, SFR from UV+IR
  - size from R_e ; F160W half light radius

3. Simulation Data

- EAGLE
  - hydrodynamical galaxy formation simulation
  - can reproduce key galaxy properties
    - SFMS, quenched population
    - with modest offset (0.2-0.5 dex)
    - M_*-size relation
  - use samples with $M_* > 10^{9.7} M_\odot$ because of the restraint of its resolution
- TNG100
  - MHD simulation
  - can reproduce key galaxy properties
  - same restraint on M_* as EAGLE

4. Relative size of galaxies

This study utilizes **relative** size .

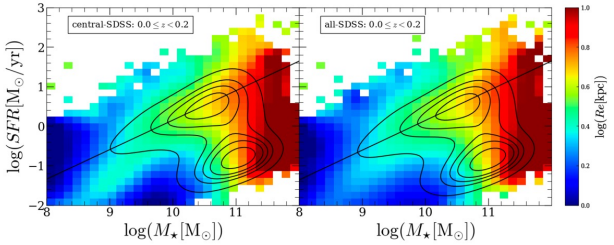
- This approach largely removes the explicit dependence on M_*
- while retaining information about **variations** in star-forming activity
- Also reduce systematic difference between observations and simulations

Identification of SFMS

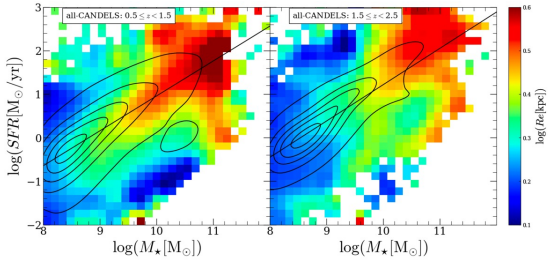
- **iterative fitting** to exclude quenched galaxies
- fit M_*-R_e relation of the SFMS to obtain average size at fixed M_*

5. Results

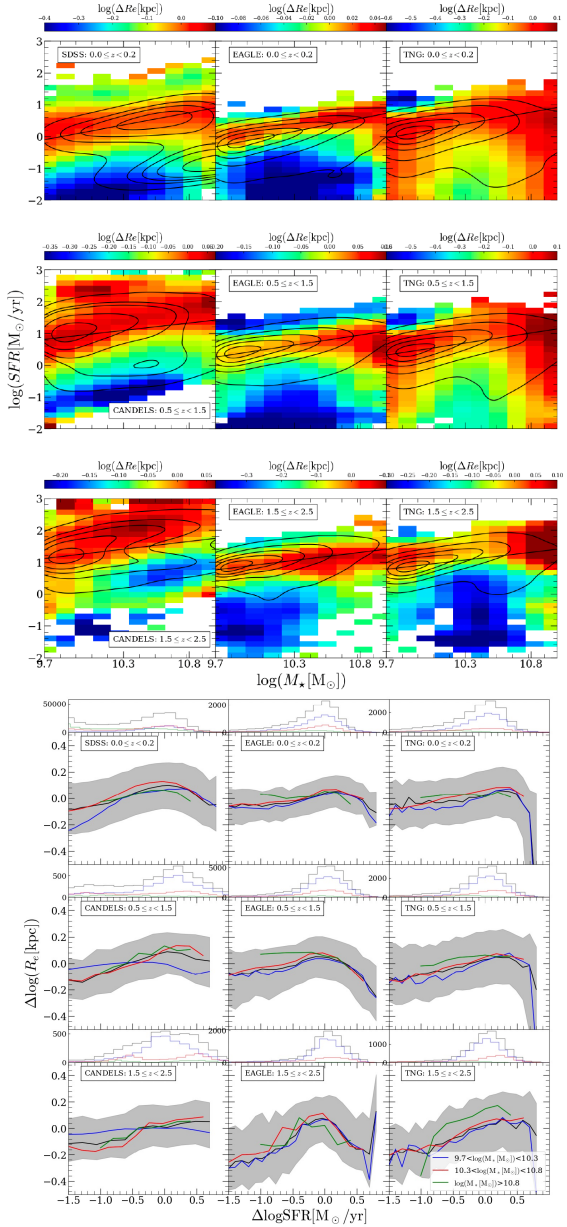
- SDSS sample



  - slight difference between two distributions → "environmental effect" is negligible
  - more massive → larger size (consistent)
  - At $M_* \sim 10^{9.5} M_\odot$, around the ridge possess larger size (consistent with Wuyts 11)
  - steeper slope ← aperture correction bias ?
- CANDELS sample



- the trend becomes weaker at $1.5 < z < 2.5$ maybe due to increased uncertainty



- Two simulations show generally similar size distribution, but differ from observations
- Both reproduce the trend over wide range
- The EAGLE samples exhibit the trend even at $1.5 < z < 2.5$.
- The TNG100 samples shows the weakest dependence
- The most massive galaxies ($M_* < 10^{10.8} M_\odot$) exhibit little trend

6. Discussion

- The trend (size decreases with increasing off set) exist in observational data (z<1.5), and simulations (0<z<2.5)
- The existence of the trend over wide range and in both simulations implies that it likely reflects **general physical processes**
- At fixed stellar mass, more compact galaxies exhibit a larger **temporal scatter in SFR** than their more extended galaxy counterparts
- **Bursty** star-formation
  - compact → lower gas content (Wang el al. 2019)
  - compact → higher star formation efficiency(Shi et al. 11)
- Then those galaxies **run out** their cold gas rapidly and **shift toward the lower** envelope of SFMS