Main Sequence of Galaxies from Local Volume and Simulations

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Local Volume

1. Majority are Dwarf Galaxies
2. low luminosity, low mass, small size, often as companions to larger galaxies
3. dE little gas, low SF, $M \approx 10^7 - 10^9 M_\odot$, $\sim 10kpc$ diameter, quenched-passive
4. dSph $M \approx 10^7 - 10^8 M_\odot$, $\sim 1kpc$ diameter
5. dIrr full of gas, on-going SF
6. through merger in DM halos or tidal origin...?

Figure: DDO092 from SDSS

What is a Galaxy?

Kroupa 1998, arXiv:astro-ph/9806206

A stellar-dynamical system of stars and gas which has a median two-body relaxation time longer than a Hubble time $\rightarrow t_{rel} \approx \frac{0.1N}{lnN} t_{cross} > t_{Hubble}$

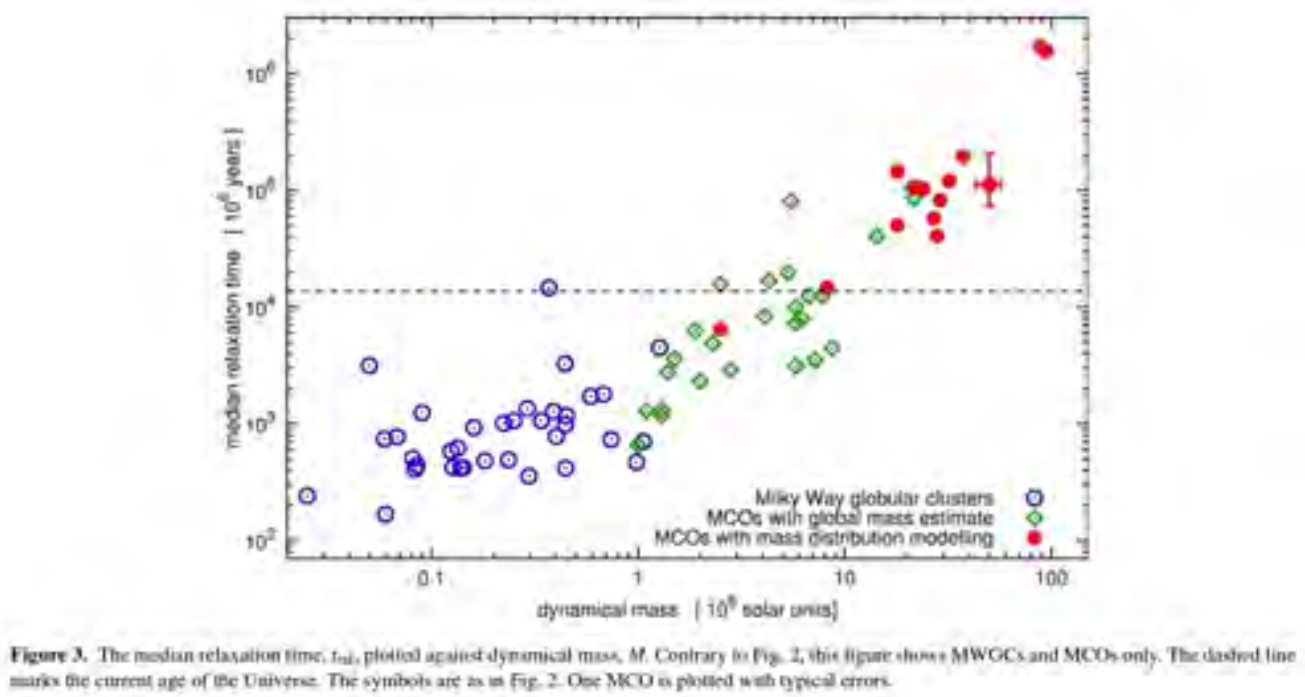


Figure 3. The median relaxation time, t_{rel}, plotted against dynamical mass, M. Contrary to Fig. 2, this figure shows MWGCs and MCOs only. The dashed line marks the current age of the Universe. The symbols are as in Fig. 2. One MCO is plotted with typical errors.

Figure: Dabringhausen, J. et al 2008, arXiv:0802.0703

The Kennicutt-Schmidt(KS)relation

Schmidt 1959; Kennicutt 1998b

- Star Formation (SF) depends on the amount of gas available
- SF is unrelated to other properties of the host galaxy or any past star formation
- SFR surface density $\Sigma_\psi[M_\odot yr^{-1}kpc^{-2}]$ - Gas surface density $\Sigma_G[M_\odot pc^{-2}]$
- $\Sigma_\psi \propto \Sigma_G^{1.4}$
- $SFR(M_\odot yr^{-1}) = \frac{L(Ha)}{1.26\times10^{41}ergs^{-1}}$

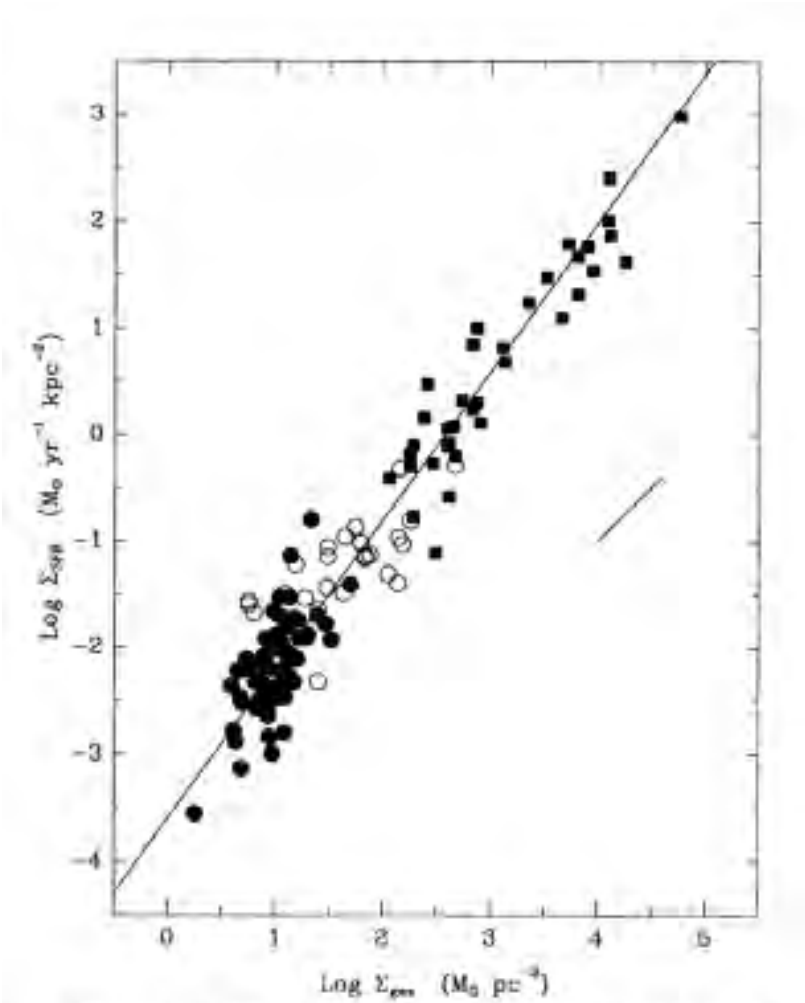
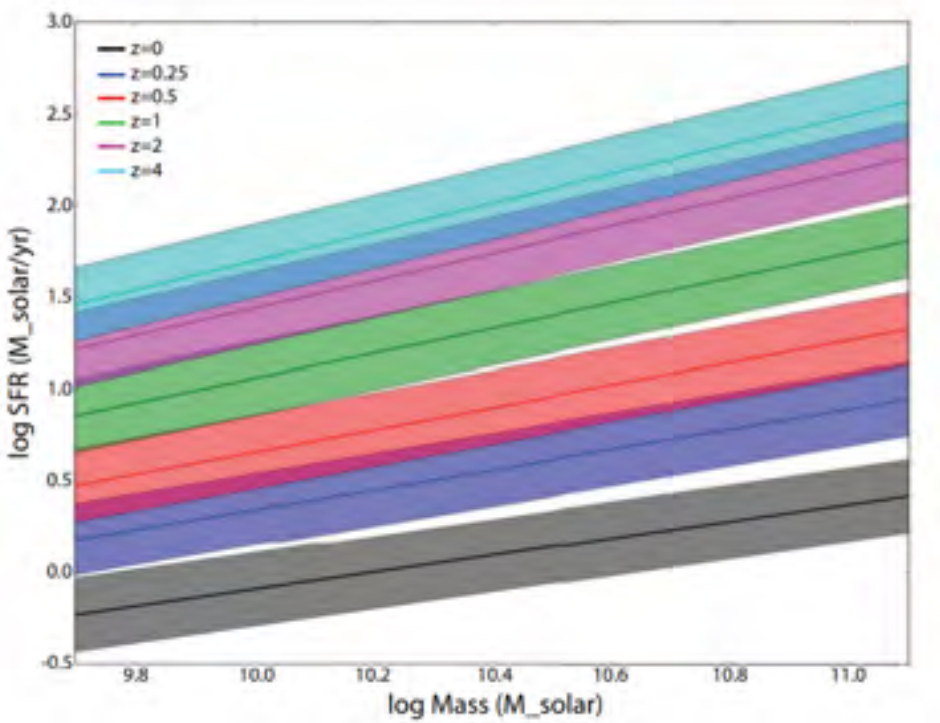


FIG. 6.—Composite star formation law for the normal disk (*filled circles*) and starburst (*squares*) samples. Open circles show the SFRs and gas densities for the centers of the normal disk galaxies. The line is a

Main Sequence of Galaxies

Speagle et al 2014, arXiv:1405.2041

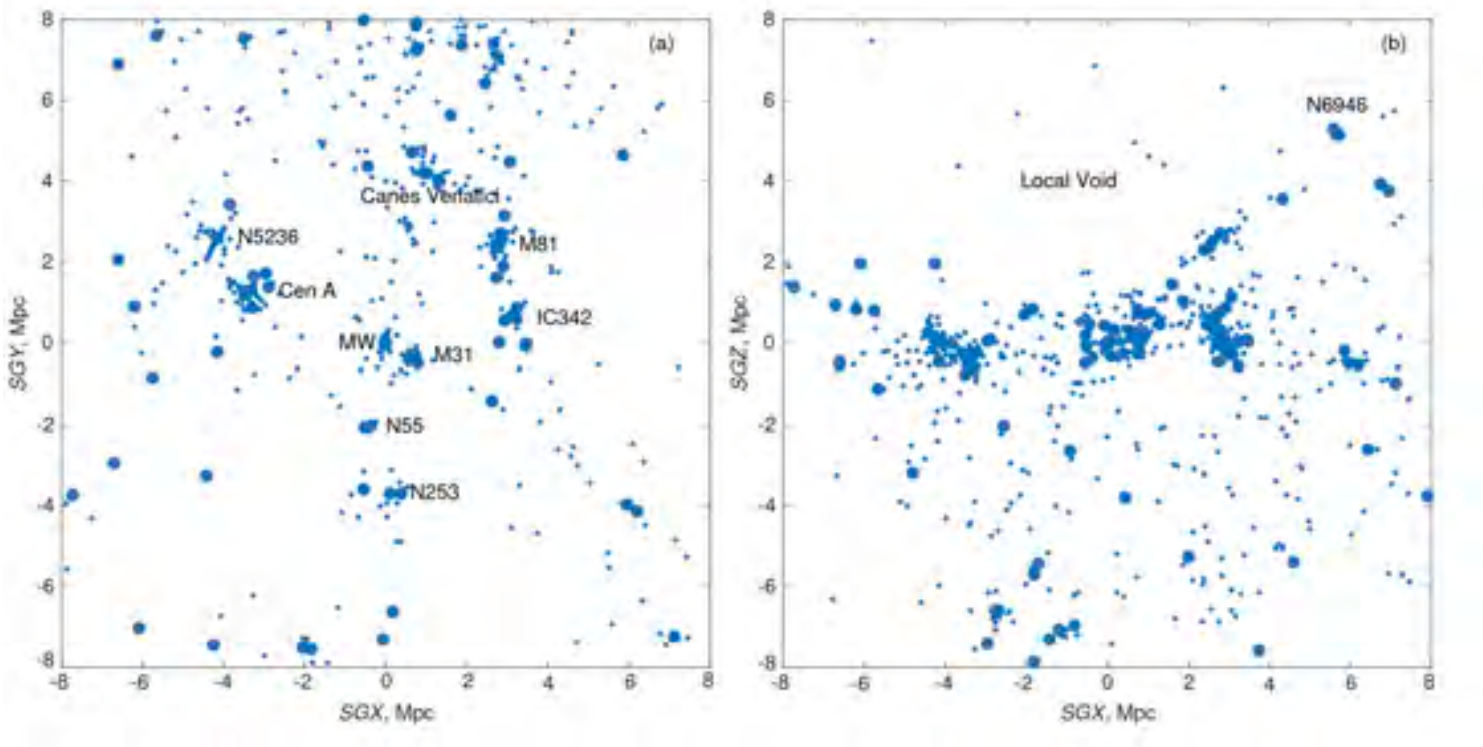


- $log\Psi(M_\star, t) = (0.84 \pm 0.02) - 0.026 \pm 0.003 \times t) logM_\star - (6.51 \pm 0.24 - 0.11 \pm 0.03 \times t)$
- time-dependant MS
- see also Donnari et al 2019 arXiv:1812.07584

Dwarf Galaxies in the Local Volume

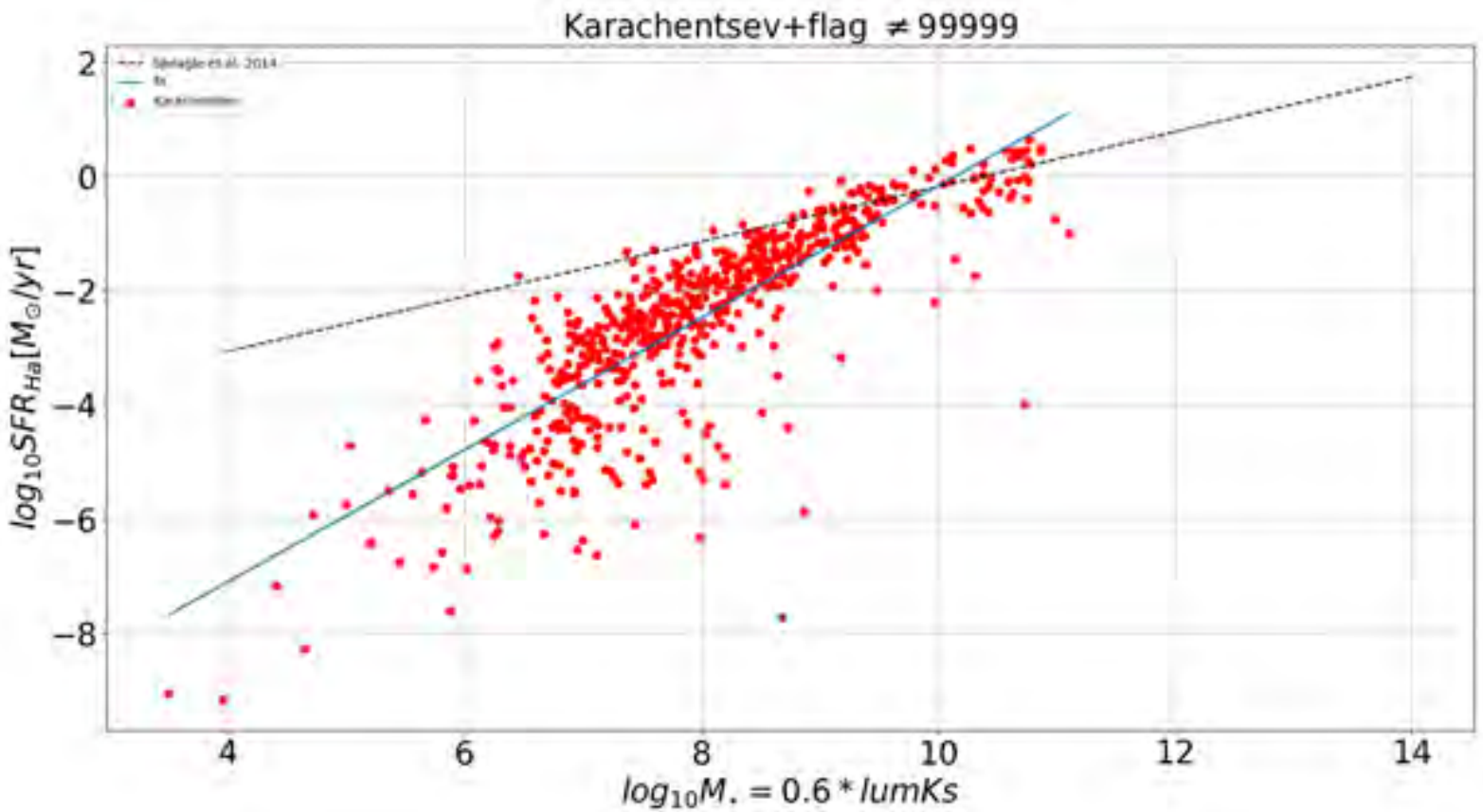
I.D. Karachentsev, E.I Kaisina 2019 (arXiv:1905.08477)

- ~ 1000 galaxies within 11Mpc of the Milky Way
- $M_\star/M_\odot < 9dex \approx 90\%$ of the sample ("dwarfs")
- Hubble space telescope
- Test Cosmological Model (eg. ΛCDM)



Dwarf Galaxies in the Local Volume

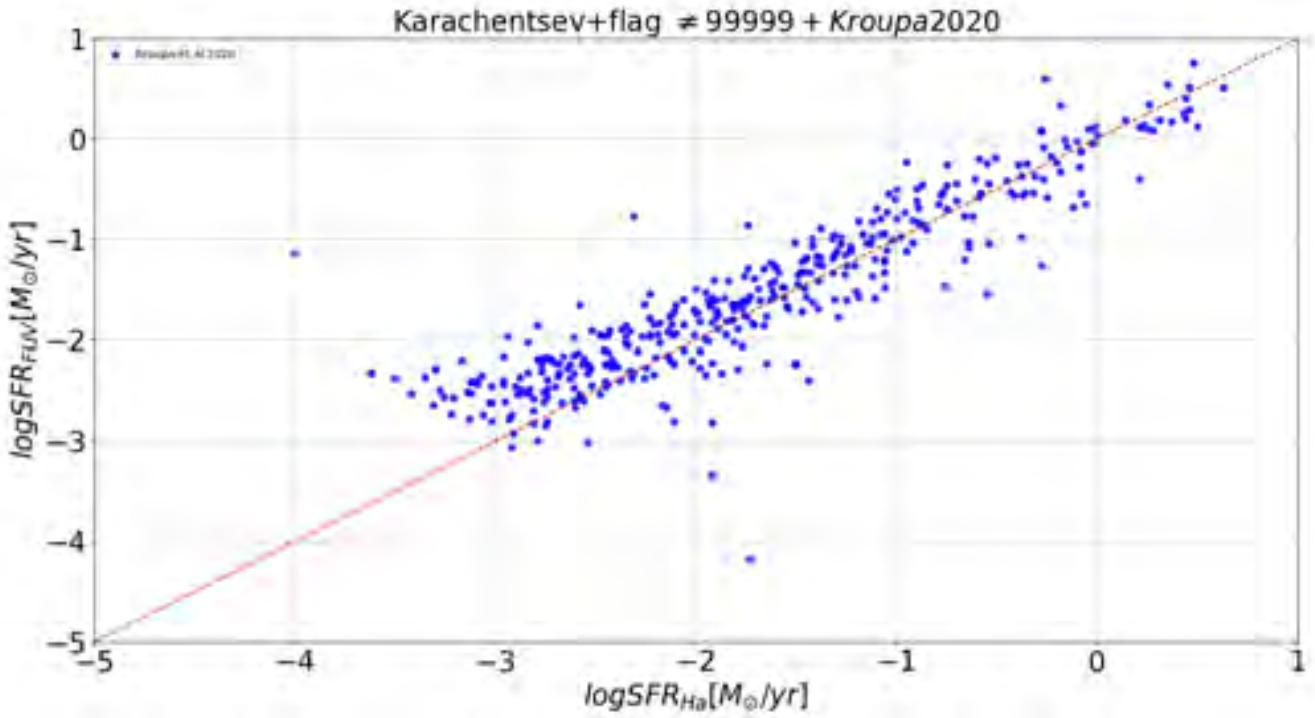
- Around massive galaxies are mostly dSph with no gas or young stars
- In the general field are dIrr with ongoing Star Formation
- Their morphology is mainly determined by the amount of gas (Hα or UV).



Small scale cosmology open questions

Kroupa P. arXiv:161003854 (2016)

- observed deficit of low-and very low-mass galaxies
- observed lack of the central "cusps" in the RC of dG
- abundance of thin flat structures made of dG around massive galaxies
- Where is the DM bulk (if any)? around galaxies or between them?



Simulating Galaxy Formation with the IllustrisTNG Model

A. Pillepich, V. Springel, et al. 2017 (arXiv:1703.02970)

- Cosmological Simulations of the formation and evolution of galaxies (ΛCDM)
- moving mesh code AREPO
- includes star formation, stellar evolution, chemical enrichment, primordial and metal-line cooling of the gas
- volume of $51 Mpc^3$ TNG50 & $110 Mpc^3$ TNG100

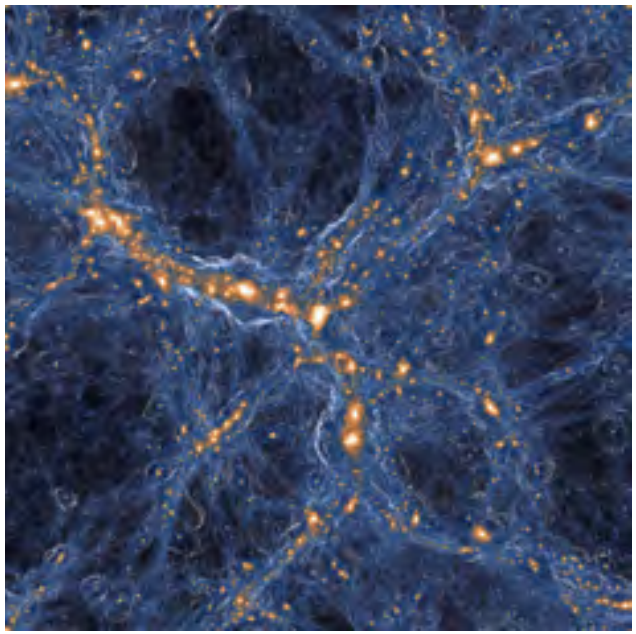
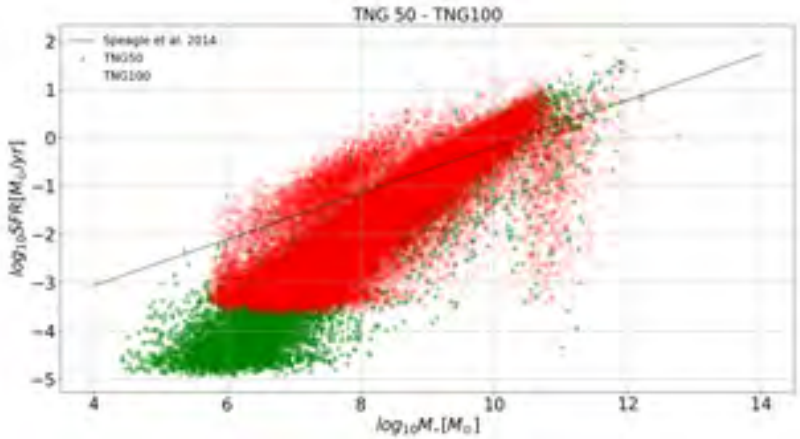
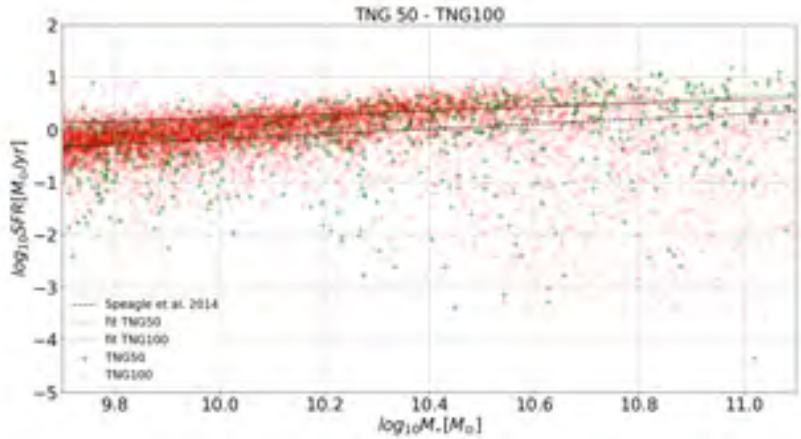


Figure: TNG Simulations

Main Sequence - Illustris





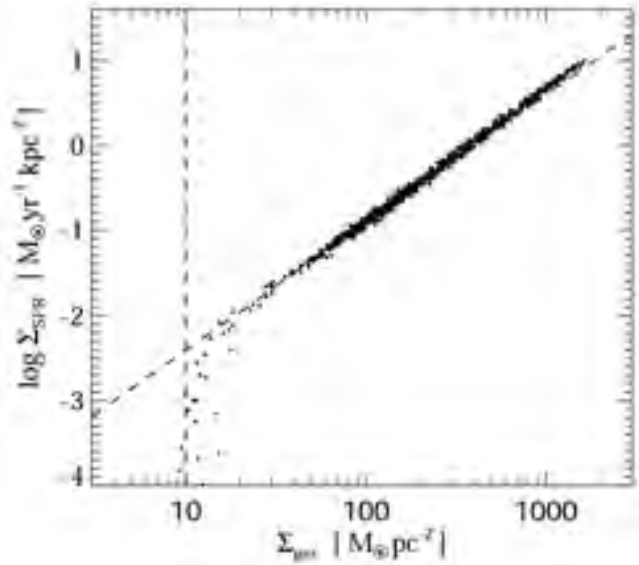
- ✦ big scatter after $10^{10} M_\odot$
- ✧ starburst galaxies above MS
- ★ passive galaxies below MS

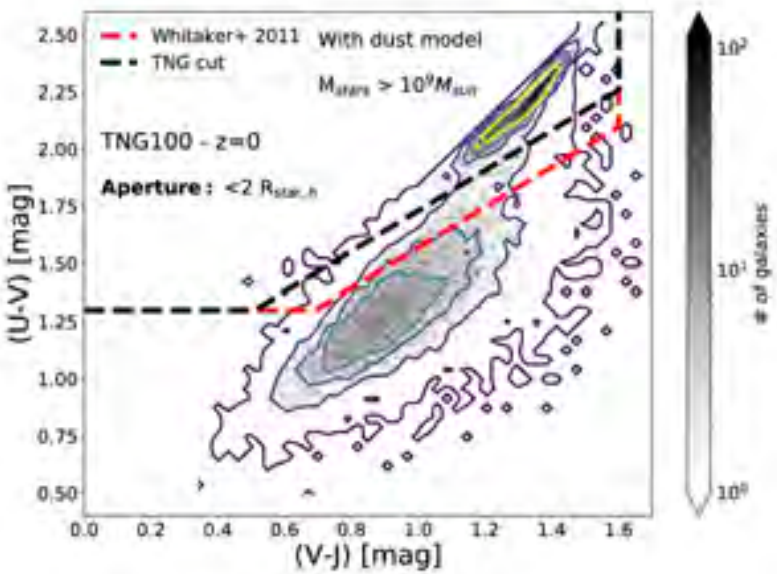
- ♠ Speagle limits
- ♦ $M_\star = 10^{9.7} - 10^{11.1} M_\odot$

TNG Illustris Star formation physics

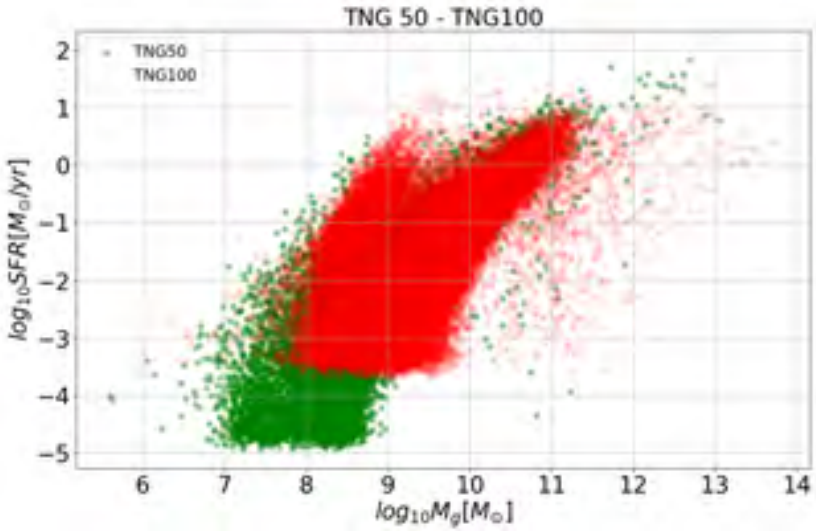
Springel and Hernquist (2003) - arXiv:astro-ph/0206393 & Donnari et al 2014

- gas is stochastically converted into star when density exceeds $n = 0.1cm^{-3}$
- but fine-tuned to reproduce Kennicutt-Schmidt law ...
- Chabrier IMF
- bending if classification of galaxies into star-forming & quiescent is based on UVJ cut

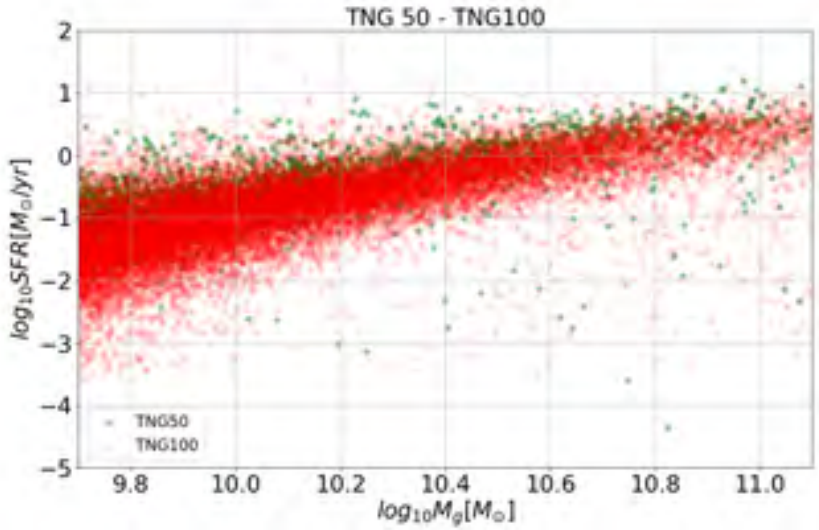




SFR-Mgas



- scatter after $10^{10} M_\odot$

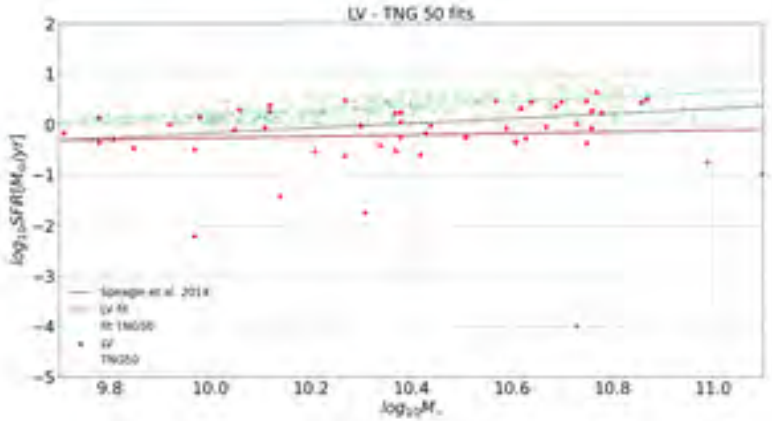


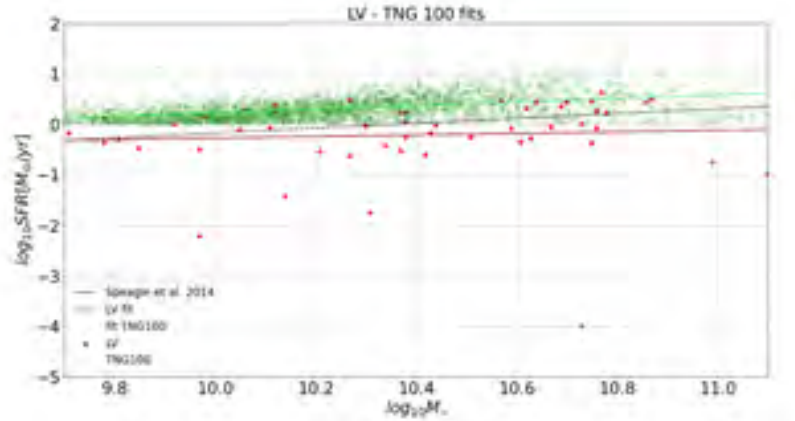
- Speagle limits
- $M_\star = 10^{9.7} - 10^{11.1} M_\odot$

Preliminary results

Samaras N., Haslbauer M., Kroupa P. (in prep)

- Morphological studies to explain the bending (Abramson et al.2014; (AGN feedback, etc..))
- MS slope steeper in simulations
- one more ΛCDM problem
- Dark matter crisis blog for more discussion





Conclusions and Prospects

- ☆ quantify MS scatter (different binning dex)
- ☆ $sSFR - M_\star$ relation
- ☆ EAGLE simulation - 7 Billions particles - different subgrid physics - GADGET-2
- ☆ IGIMF theory connection - Jerabkova et al 2018 - arXiv:1809.04603
- ☆ expose ΛCDM physics