The physical origin of long gas depletion times in galaxies

Vadim Semenov
(University of Chicago)

Andrey Kravtsov
Nick Gnedin

Semenov, Kravtsov & Gnedin 2016, ApJ 826, 200
Semenov, Kravtsov & Gnedin 2017, arXiv: 1704.04239

Star formation is surprisingly **inefficient**

Galaxies convert gas into stars **very slowly**:

$$\tau_{\rm dep} \equiv M_{\rm g}/\dot{M}_{\star} \approx 2-10\ {\rm Gyr}$$

1. **slower** than local conversion of gas in star-forming regions:

$$\tau_{\rm dep,GMC} \equiv M_{\rm GMC}/\dot{M}_{\star,\rm GMC} \sim 50-300\ {\rm Myr}$$

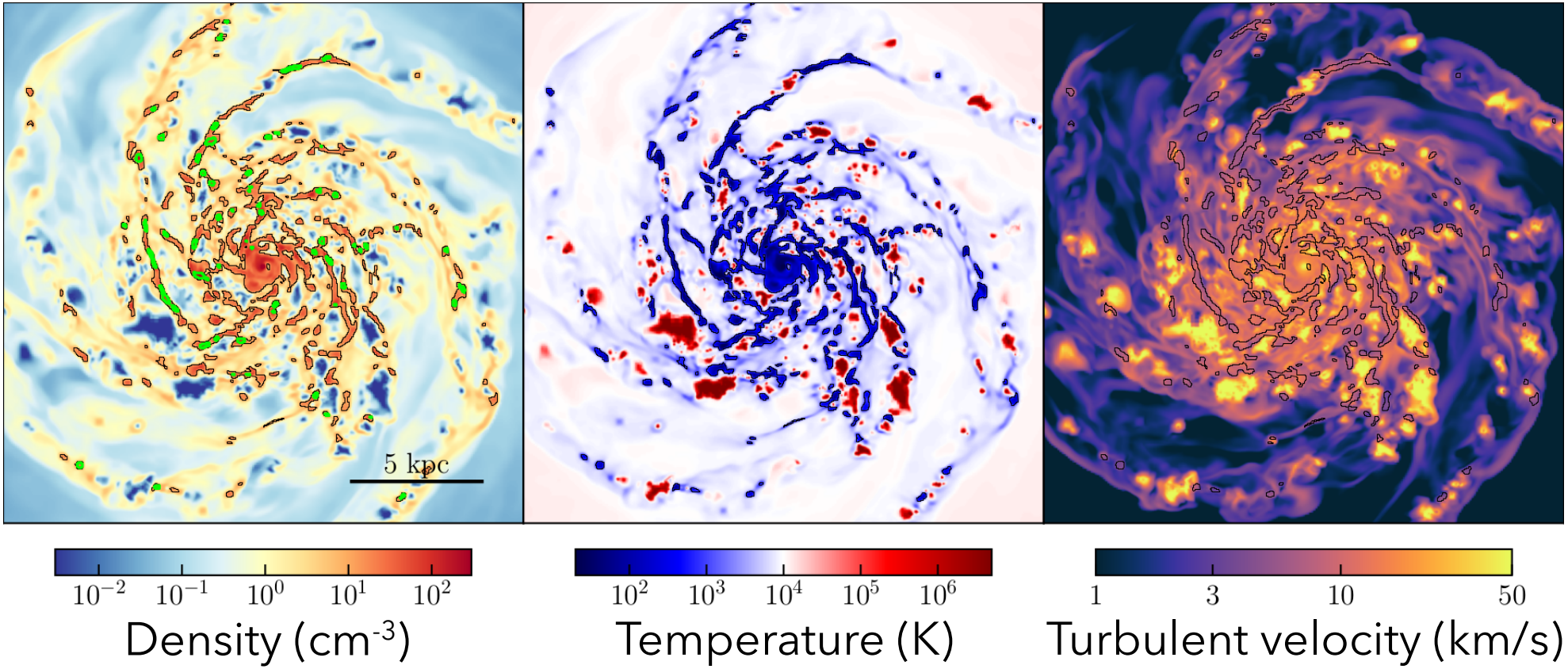
2. **much slower** than any relevant dynamical process:

$$t_{\rm orb} = \frac{2\pi R}{V_{\rm rot}} \approx 200\ {\rm Myr\ at}\ R_{\odot}$$ → orbital period of galaxy

$$t_{\rm ff} = \sqrt{\frac{3\pi}{32G\rho}} \sim 2-20\ {\rm Myr}$$ → gravitational collapse time

$$t_{\rm turb} = \frac{h}{\sigma} \sim 10-30\ {\rm Myr}$$ → turbulent time

Hydrodynamical simulations



Semenov, Kravtsov & Gnedin 2016, ApJ 826, 200
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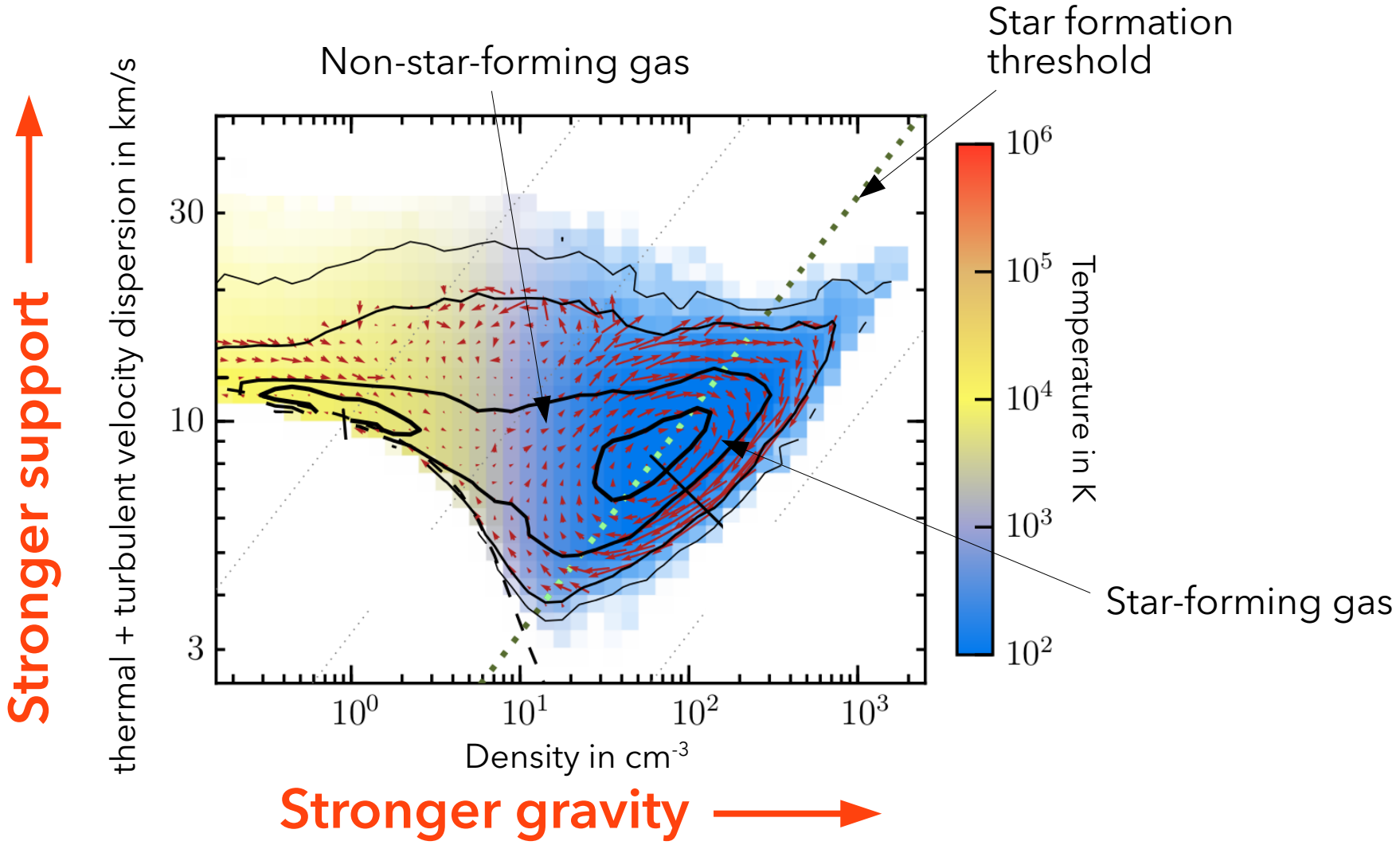
Slow star formation as a result of gas evolution



From mass conservation: $\dot{M}_\star = F_{\rm sf}$

slow star formation <=> small net gas inflow into star-forming state

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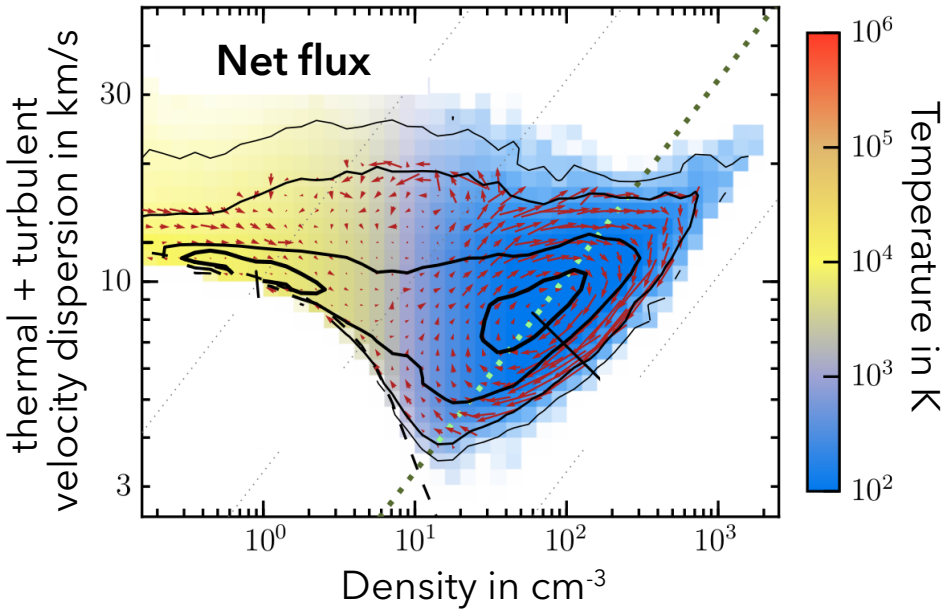
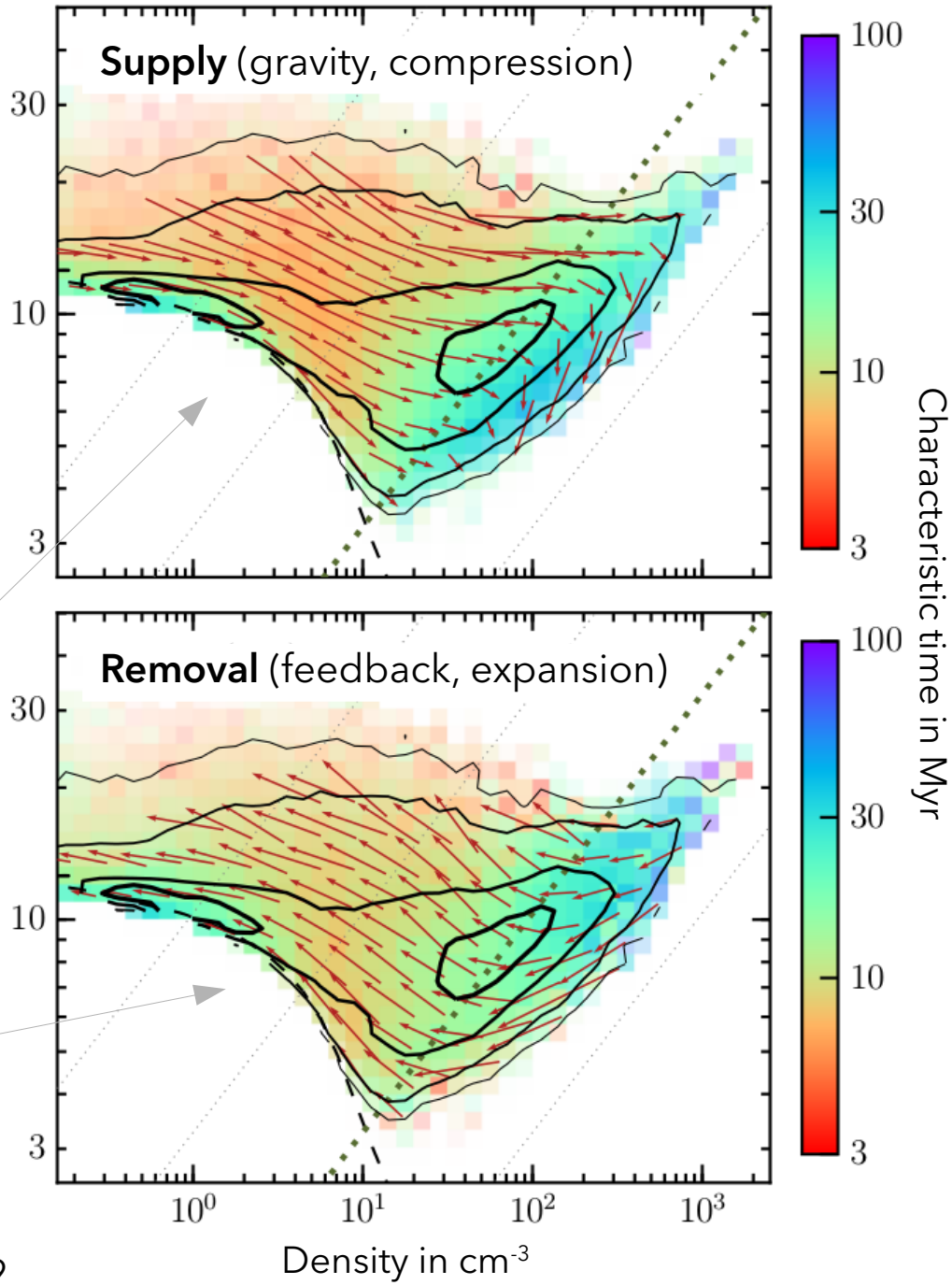
Gas evolution is rapid



$$\dot{M}_\star = F_{\rm sf}$$

Net flux is small due to cancellation of strong opposite fluxes:

$$F_{\rm sf} = F_+ - F_-$$



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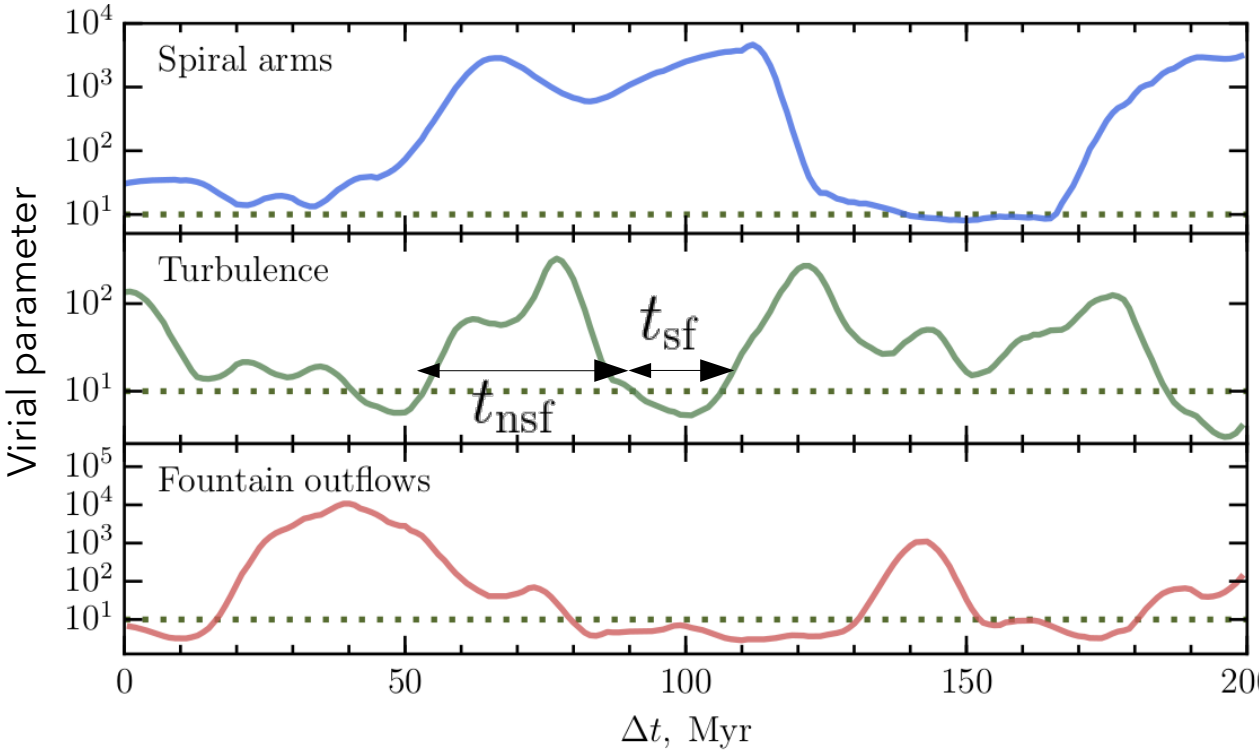
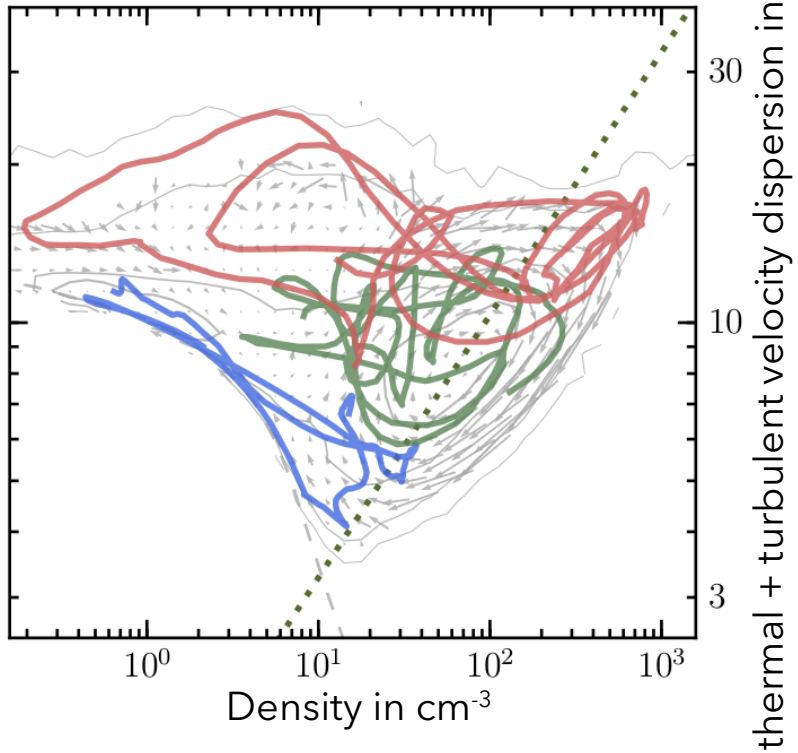
Slow star formation is a result of rapid gas cycling





$$\tau_\star \equiv \frac{M_{\rm sf}}{\dot{M}_\star}$$ → total time spent in star-forming state before gas is converted into stars

This happens after one global depletion time:

$$\tau_{\rm dep} \equiv \frac{M_{\rm g}}{\dot{M}_\star} = N_{\rm c} t_{\rm nsf} + \tau_\star$$

non-SF SF

Required # of cycles:

$$N_{\rm c} = \frac{\tau_\star}{t_{\rm sf}}$$

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Resolved puzzle of inefficient star formation

Galaxies convert gas into stars **very slowly**:

$$\tau_{\rm dep} \equiv M_{\rm g}/\dot{M}_\star \approx 2-10\ {\rm Gyr}$$

$$\tau_{\rm dep} = N_{\rm c} t_{\rm nsf} + \tau_\star$$

$\tau_{\rm dep} \gg t_{\rm nsf}$

much slower than any relevant dynamical process:

$$t_{\rm ff} = \sqrt{\frac{3\pi}{32 G\rho}} \sim 2-20\ {\rm Myr}$$

$$t_{\rm turb} = \frac{h}{\sigma} \sim 10-30\ {\rm Myr}$$

Large # of cycles is required

$\tau_{\rm dep} > \tau_\star$

slower than local conversion of gas in star-forming regions:

$$\sim 50-300\ {\rm Myr}$$

Significant fraction of time is spent in non-star-forming state

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