Resolving the Rise and Fall of Star Formation in Galaxies
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Anatomy of Galactic Star Formation: Roles of Different Modes of Gas Accretion, Feedback, and Recycling

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Abstract. Existence of the cold-mode gas accretion along with the hot-mode accretion can explain the diversity in the galactic star formation history across galaxy mass. We examine the role of various physical processes in producing the observed diversity.

Keywords. galaxies: evolution, galaxies: high-redshift, galaxies: starburst

1. Introduction

Recent observations reveal a rich variety in galactic star formation history (SFH) across galaxy mass. To understand the origin of this diversity and elucidate roles of various baryonic processes, we build a simple model of galaxy evolution including cosmological gas accretion, star formation, ejection of interstellar medium (ISM) by supernovae, recycling of the ejected ISM, and preventive feedback that hinders gas from accreting to the galactic disk (Fig. 1). Cosmological simulations suggest that the property of the halo gas depends on the halo mass and redshift (Fig. 2 'fiducial scheme'). In each Domain, the gas accretes onto the disk with either the free-fall time ($t_{\rm ff}$) (cold mode) or the radiative cooling time ($t_{\rm cool}$) (hot mode) as indicated. Evolution of a series of models (indicated by gray trajectories) is calculated under these accretions. The shock-heating scheme assumes heating to virial temperature for all halos.

2. Star Formation History (SFH)

As shown in Fig. 3, the fiducial scheme predicts that more massive halos reach the peak star formation rate (SFR) earlier and the decrease after that is more prominent, in qualitative agreement with the observation. On the other hand, SFHs in the shock-heating scheme depend little on the halo mass.

3. Main-sequence Evolution

Fig. 4 shows the evolution of the SFR-$M_\star$ relation (Main sequence). The fiducial scheme produces stronger 'turn-over' (decreasing slope) at high masses with time in agreement with the observation, whereas the shock-heating scheme shows an opposite trend.

4. Effect of Feedback and Recycling

We consider the reference model in which only gas accretion of the fiducial scheme is included. Then we add to this accretion-only model, ejective feedback, ejective feedback + recycling, and preventive feedback separately to examine the role of each process.

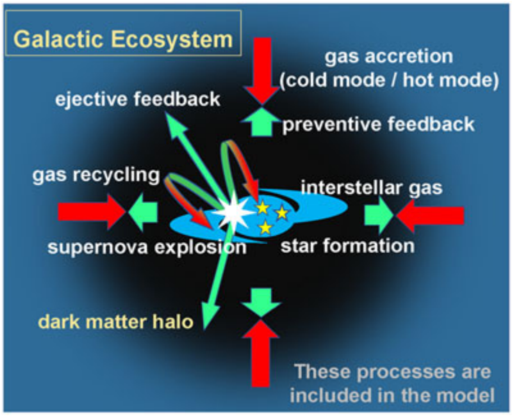

Figure 1. Physical processes included in the model.

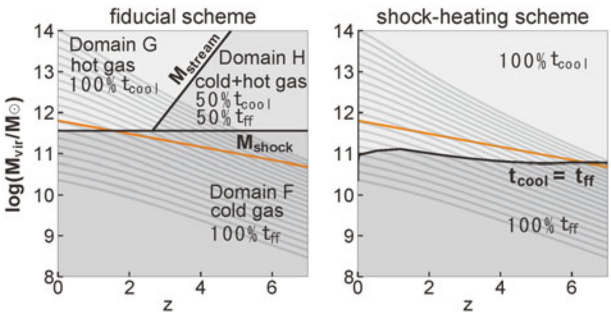

Figure 2. Physical state of the halo gas. Preventive feedback operates below the orange line.

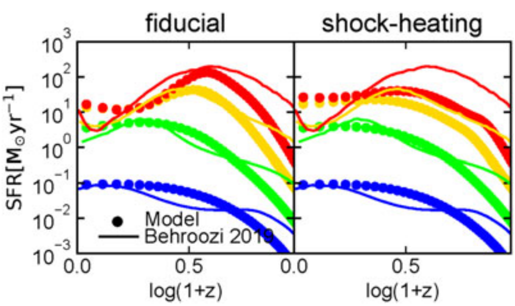

Figure 3. Dots: Model star formation history for the present halo mass of 10^{11} (blue), 10^{12} (green), 10^{13} (yellow), and $10^{14} M_\odot$ (red), respectively. Lines: Empirical analyses by Behroozi et al. (2019).

Fig. 5 shows that the ejective or preventive feedback does not change the ratio of peak and minimum SFRs and the redshift for peak SFR ($z_{\rm peak}$) while gas recycling moves $z_{\rm peak}$ for low mass galaxies to much recent epoch and turns their SFHs to monotonically rising ones (i.e., $\mathrm{SFR_{peak}/SFR_{min}} \sim 1$). This also makes low-mass galaxies younger. These changes improve the agreement with the observation.

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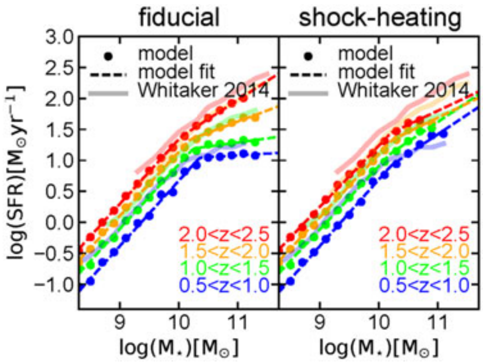

Figure 4. Redshift evolution of the star-forming galaxy main sequence. Broad lines represent the analysis of Whitaker et al. (2014).

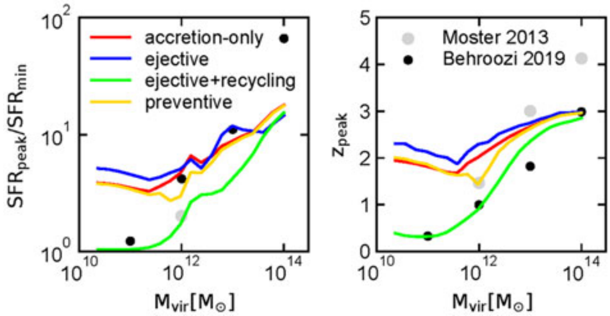

Figure 5. Ratio of the peak and minimum star formation rates and the redshift for the peak SFR. Effect of each added process on the accretion-only model is illustrated.

5. Conclusions

The transition from the cold-mode to hot-mode gas accretion constitutes the basis of star formation history of massive galaxies. Ejective and preventive feedback help reduce the stellar mass of low-mass galaxies to the observed level but the recycling of ejected ISM is required to make these galaxies young enough to match the observation.

References

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