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Quenching in gas-rich Milky Way-type galaxies

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Abstract. To explore the relation between bar formation and star formation in Milky Way-type galaxies quantitatively, we simulated gas-rich disk isolated galaxies. We find that the action of the stellar bar efficiently quenches star formation, reducing the star-formation rate by a factor of 10 in less than 1 Gyr. Analytical and self-consistent galaxy simulations with bars suggest that the action of the stellar bar increases the gas random motions within the co-rotation radius of the bar. Indeed, we detect an increase in the gas velocity dispersion at the end of the bar formation phase. The star formation efficiency decreases rapidly, and in all of our models, the bar quenches the star formation in the galaxy. The star-formation efficiency is much lower in simulated barred compared to unbarred galaxies and more rapid bar formation implies more rapid quenching.

Keywords. galaxies: evolution, galaxies: structure

1. Introduction

Optical and near-IR observations reveal that nearly 60% of disk galaxies in the local universe are barred, thus it is important to understand the relationship between bars and star formation in disk galaxies (Eskridge *et al.* 2000, Marinova & Jogee 2007). Recent observational results imply that the Milky Way quenched its star formation about 9−10 Gyr ago, at the transition between the cessation of the growth of the kinematically hot, old, metal-poor thick disk and the kinematically colder, younger, and more metal-rich thin disk (Haywood *et al.* 2016). Although perhaps coincidental, the quenching episode could also be related to the formation of the bar. In this paper we briefly describe the basic result of our work on the simulations of the star formation quenching in gas-rich barred galaxies.

2. Results and conclusions

By means of N-body/hydrodynamical simulations of the stellar-gaseous disks we study the star formation in gas-rich barred galaxies. Our simulations also include prescriptions for star formation, stellar feedback, and for regulating the multi-phase interstellar medium (Khoperskov *et al.* 2014). For simulation of unbarred galaxy we consider rigid halo potential model (model RB in Khoperskov *et al.* 2017), meanwhile in the model with live dark matter halo bar arises naturally as the result of energy and angular momentum redistribution within the galaxy (model LB in Khoperskov *et al.* 2017).

The star formation histories of the simulated barred and unbarred galaxies provide a summary of the efficiency of gas consumption for systems with different disk structures.

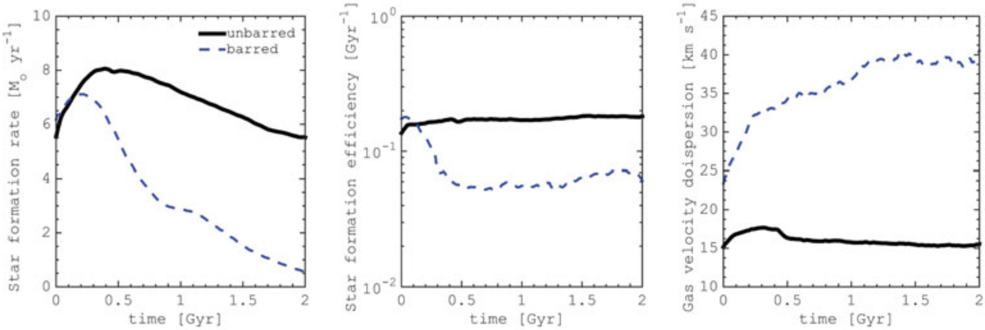

Figure 1. Comparison of the star formation rate (left), star formation efficiency (center) and gas velocity dispersion (right) in a barred galaxy model (dashed blue line) and in unbarred galaxy model (solid black line).

At the end of simulations, the star formation rate in the barred galaxy model is a factor of ≈ 6 lower than that observed in the unbarred galaxy (see left frame Fig. 1). In our barred galaxy model the star formation is suppressed rapidly right after the bar strength reaches its saturation level meanwhile the star formation rate of the unbarred galaxy varies very slowly. We find that the formation of the bar strongly affects the star formation efficiency, by reducing it significantly (see middle frame in Fig. 1). The decrease of the star formation efficiency is not related to a substantial consumption of gas. Gas random motions, in particular, may provide an important mechanism counteracting gravity to prevent collapse of the gas and star formation. Indeed, for the model with bar, gas velocity dispersion increases rapidly after $0.2 - 0.5$ Gyr, right after the bar amplitude becomes significant (see right frame in Fig. 1). In this model, the leading shock waves swing in the center and amplify, inducing gravitational torques in the gas and hence increasing the local velocity dispersion (see also Kim & Ostriker 2002). Despite the gas is still present in the disk in our simulations, its high turbulence has significantly limited the star formation in the disk.

By means of N-body/hydrodynamical simulations we have shown that a sensible growth of the gas velocity dispersion driven by the bar reduces the star formation efficiency. We conclude that the transfer of energy from the large-scale shear induced by the bar to increasing turbulent energy could stabilize the gaseous disk against star formation and quench the galaxy.

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