*Dwarf Galaxies: From the Deep Universe to the Present*
*Proceedings IAU Symposium No. 344, 2019*
*K. B. W. McQuinn & S. Stierwalt, eds.*

doi:10.1017/S1743921318003927

# Comparing the star formation history of three nearby disk galaxies

**Ruixiang Chang**[1], **Xiaoyu Kang**[2,3,4] **and Fenghui Zhang**[2,3,4]

[1]Key Laboratory for Research in Galaxies and Cosmology, Shanghai Astronomical Observatory, CAS, 80 Nandan Road, Shanghai, 200030, China
email: crx@shao.ac.cn

[2]Yunnan Observatories, CAS, 396 Yangfangwang, Guandu District, Kunming, 650216, China

[3]Key Laboratory for the Structure and Evolution of Celestial Objects, CAS, 396 Yangfangwang, Guandu District, Kunming, 650216, China

[4]Center for Astronomical Mega-Science, Chinese Academy of Sciences, 20A Datun Road, Chaoyang District, Beijing 100012, China

**Abstract.** Understanding the effect of environment on galaxy formation and evolution is one of the hot topics in extragalactic astronomy. Here we constructed a chemical evolution model of disk galaxies. By comparing the model predictions with the observed profiles, we investigated the star formation history of M33, NGC 300 and NGC 2403. We found that M33 has much longer infall timescale than NGC 300 and NGC 2403, and the star formation process of M33 is still active at later phase. Our results suggested that the cold gas supply of M33 is sufficient in the present-day, which may originate from the HI bridge between M33 and M31. In other words, we argue that the local environment plays an important role on the star formation history of a galaxy, at least for M33.

## 1. Introduction

M33, NGC 300 and NGC 2403 are three nearby pure-disc galaxies with similar stellar masses but in different environments. Table 1 summarizes their basic properties. We emphasize that M33 has a close companion and they may interact with each other in the past. NGC 2403 is an isolated galaxy, while NGC 300 has a low-mass companion with no strong interaction. In other words, these three galaxies are ideal laboratories to explore the role of the local environment on galactic evolution.

The simple chemical evolution model has been proven to a powerful tool to explore the formation and evolution of disk galaxy. Our main aim is to construct a simple model and compare the star formation history of M33, NGC 300 and NGC 2403 and then investigate the effect of the local environment on the evolution of galaxy.

## 2. The model

Similar to our previous models (Chang *et al.* 2012, Kang *et al.* 2012, Kang *et al.* 2016), we assume that the formula of the gas infall rate can be expressed as $f_{\rm in}(r,t) = A(r) \cdot t \cdot e^{-t/\tau}$, where $\tau$ is the gas infall timescale and it is the most important free parameter in our model. The $A(r)$ are a set of normalized quantities, which are constrained by the present-day stellar mass surface density. Regarding the star formation law, we adopt the star formation rate (SFR) is proportional to local molecular gas surface density as $\Psi(r,t) = \Sigma_{\rm H_2}(r,t)/t_{\rm dep}$, where $t_{\rm dep}$ is the molecular gas depletion time (Leroy *et al.* 2008). We also consider the influence of gas outflow process and assume the gas outflow rate

**Table 1.** Basic properties of M33, NGC 300 and NGC 2403.

| Property | M33 | NGC 300 | NGC 2403 |
|---|---|---|---|
| Morphology | SA(s)cd | SA(s)d | SAB(s)cd |
| Distance(Mpc) | 0.8 | 2.0 | 3.2 |
| $M_B$(mag) | −18.4 | −17.66 | −18.6 |
| $M_K$(mag) | −20.4 | −20.1 | −21.3 |
| Stellar mass ($10^9$ $M_\odot$) | 4.0 | 1.9 | 5.01 |
| Scale-length (kpc) | 1.4 | 1.29 | 1.6 |
| Rotation velocity($km\,s^{-1}$) | 110 | 91 | 136 |

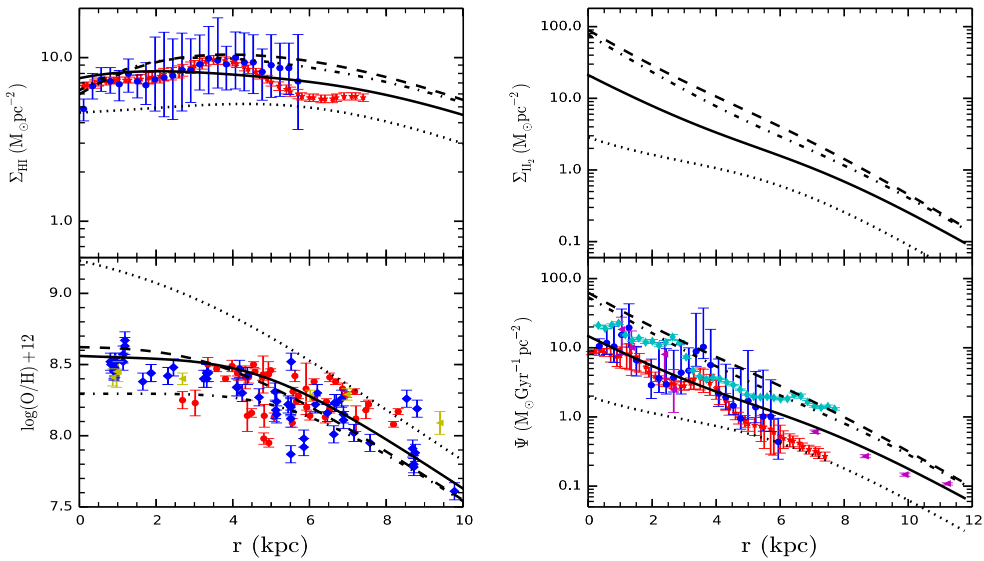


**Figure 1.** Comparisons of the observed radial profiles of NGC 2403 with the model predictions. The mass surface density of atomic hydrogen, molecular hydrogen and the SFR are displayed in top-left, top-right and bottom-right panel, while the oxygen abundance are shown in bottom-left panel. Different line types are corresponding to various parameter groups: dotted lines $(\tau/\mathrm{Gyr}, b_{\rm out}) = (0.1, 0)$, dashed lines $(\tau/\mathrm{Gyr}, b_{\rm out}) = (15, 0)$, dot-dashed lines $(\tau/\mathrm{Gyr}, b_{\rm out}) = (15, 1)$, and the solid lines are the best-fitting model $(\tau/\mathrm{Gyr}, b_{\rm out}) = (0.2r/\mathrm{r_d} + 3.2, 0.6)$.

is proportional to the SFR as $f_{\rm out}(r,t) = b_{\rm out}\Psi(r,t)$, where $b_{\rm out}$ is the outflow efficiency, and it is another free parameter in our model.

## 3. Results

Through comparing the model predictions with observations, we investigate reasonable ranges of free parameters and then explore the main properties of the evolution of galaxy. As an illustration, Figure 1 demonstrates the comparison between the model predicted radial profiles and the observations (Kang *et al.* 2017). It is shown that the model predictions are very sensitive to the adopted infall timescale $\tau$, while the outflow efficiency $b_{\rm out}$ mainly influence the shape of metallicity. To fit the observed radial profiles, it is necessary to consider the inside-out scenario, which assumes the infall time-scale increases linearly with galactic radius. We use the classical $\chi^2$ technique to select the best-fitting model and plot their predictions as solid lines in Fig. 1.

Investigations of the best-fitting models for M33 and NGC 300 are presented in Kang *et al.* (2012) and Kang *et al.* (2016). We summarize the adopted parameters of the best-fitting models of these three galaxies in Table 2. Comparing with NGC 300 and

https://doi.org/10.1017/S1743921318003927 Published online by Cambridge University Press

**Table 2.** Free parameters of the best-fitting models of M33, NGC 300 and NGC 2403.

| **Individual** | **M33** | **NGC 300** | **NGC 2403** |
|---|---|---|---|
| Molecular gas depletion time $t_{\rm dep}$ (Gyr) | 0.46 | 1.9 | 1.9 |
| Infall time-scale $\tau(r)$ (Gyr) | $r/r_{\rm d}+5.0$ | $0.35r/r_{\rm d}+2.47$ | $0.2r/r_{\rm d}+3.2$ |
| Outflow efficiency $b_{\rm out}$ | 0.5 | 0.9 | 0.6 |

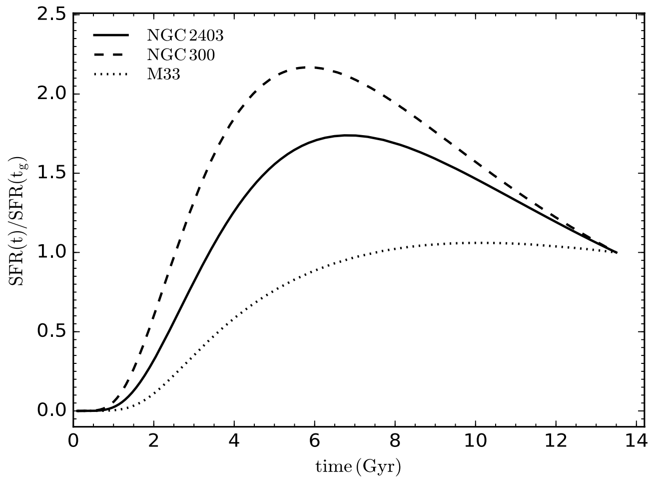


**Figure 2.** The evolution of SFR predicted by best-fitting model of M33, NGC 300 and NGC 2403. The *SFR* is normalized by its value of present-day. It is shown that the star formation process of M33 is active at later phase, which indicates that the cold gas supply of M33 is still sufficient in the present-day.

NGC 2403, the infall timescale of M33 is much longer, which indicates that the cold gas supply of M33 is still sufficient in the present-day. This point is also demonstrated in Fig. 2, in which we plot the star formation history predicted by the best-fitting model of these three galaxies. The *SFR* is normalized by its value of present-day. It can be seen that the SFR of NGC 300 and NGC 2403 decreases dramatically after reaching its peak, while the SFR of M33 increases with time and then almost keeps constantly at the later phase. Combining the fact that M33 has smaller molecular gas depletion time $t_{\rm dep}$ and then higher star formation efficiency than the other two galaxies (see Table 2), our results indicate that the active star formation process of M33 in the present-day does attribute to the adequate gas provider, which probably may originate from the HI bridge between M33 and M31. In other words, our results suggest the local environment plays an important role on the evolution and SFH of a galaxy, at least for M33.

## Acknowledgements

Ruixiang Chang is supported by the NSFC (No. 11373053 and 11390373). Xiaoyu Kang and Fenghui Zhang are supported by NSFC (No. 11573062, 11403092, 11390374 and 11521303), the YIPACAS Foundation (No. 2012048), the Yunnan Foundation (No. 2011CI053), and the Youth Project of Western Light of Chinese Academy of Sciences.

## References

Chang, R. X., Shen, S. Y. & Hou, J. L. 2012, *ApJ* (Letters), 753, L10
Kang, X. Y., Chang, R. X., Yin, J., *et al.*, 2012, *MNRAS*, 426, 1455
Kang, X. Y., Zhang, F. H., Chang, R. X., *et al.*, 2016, *A&A*, 585, A20
Kang, X. Y., Zhang, F. H. & Chang, R. X. 2017, *MNRAS*, 569, 1636
Leroy, A. K., Walter, F., Brinks, E., *et al.* 2008, *AJ*, 136, 2782

https://doi.org/10.1017/S1743921318003927 Published online by Cambridge University Press