Resolving the Rise and Fall of Star Formation in Galaxies
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Spatial variation of the star formation history in the disc of M31 galaxy using evolved stars

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Abstract. The rate of star formation (SFR) is one of the important quantities that helps to study galaxies' evolutionary path. In fact, measuring the SFR during the life of the Universe shows us how galaxies have acquired their metallicity and star mass. In this regard, the galaxies of the Local Group give us a great opportunity to study the connection between different stellar populations and galaxy evolution. In this paper, we use the Long-Period variable stars to estimate the radial star formation in the disc of the M31 galaxy. These stars are powerful instruments to achieve this goal. They reach their peak luminosity and coldest state at the final point of their evolution. Also, there is a directly related between their mass and luminosity, so using stellar evolution theoretical models, we construct the mass function and hence the star formation history (SFH). In the disc of M31, we see an increase in the rate of star formation and a decrease in the age of stars in the outer parts. These results predict the inside-out growth well.

Keywords. stars: evolution – stars: AGB and LPVs – stars: luminosity function, mass function – galaxies: stellar content – galaxies: structure – galaxies: evolution – galaxies: formation – galaxies: individual: M31

1. Introduction

In the Local Group, the M31 galaxy is the best target for detailed observations of its metallicity, star formation rate (SFR), and stellar population. As a result, this galaxy presents an excellent opportunity to study the detailed evolutionary history of a large spiral galaxy, both because it is the closest galaxy and because it has been undergoing star-forming activity recently. The radial gradient distribution of abundance in spiral galaxy disks shows the chemical evolution of those discs. These galaxies are formed from the inside-out, so metallicity and age are expected to have negative slopes. Galaxy growth inward-outward causes the metallicity gradient, while old stars at the center cause the age gradient. According to recent Hubble Space Telescope studies of M33 and NGC300, older populations are more concentrated in the center, and younger stars are found in larger radii (Williams et al. 2009; Gogarten *et al.* 2010).

2. Data

In this research, we took advantage of the catalogue of long period variable stars (LPVs) in the M31 from Mould *et al.* 2004 to estimate its star formation history (Torki et al. 2019, 2023). Infrared photometry of the M31 has been obtained by Kitt Peak National

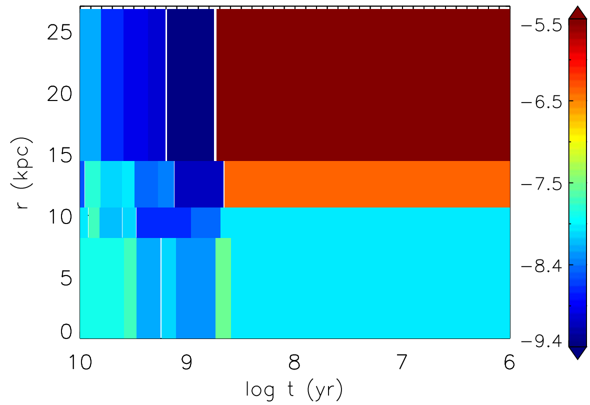

Figure 1. SFH at different radial distances from the centre of M31, in the galaxy (de-projected) plane. The colour bar values are on a logarithmic scale and represent the fraction of the total stellar mass as it formed each year. All radius bin contains the same stars.

Observatory (KPNO) and their results included photometry of almost 2000 variables, most of which were asymptotic giant branch stars (AGBs).

3. Method

Our method for reconstructing star formation history(SFH) is based on using LPVs which previously have successfully applied to other local group galaxies such as M33 (Javadi *et al.* 2011a,b; 2017), Magellanic Clouds (Rezaeikh et al. 2014), NGC147 and NGC185 (Hamedani Golshan *et al.* 2017), IC1613 (Hashemi et al. 2019), Andromeda VII (Navabi *et al.* 2020; 2021) and Andromeda I (Saremi *et al.* 2019; 2020; 2021). In this technique, we used Padova stellar evolutionary models (Marigo *et al.* 2017). In order to obtain SFH, we assumed metallicity was constant over time and obtained the stars' mass, age, and pulsation duration.

SFH is described by the SFR, which provides information about how much gas has become a star each year in the past. SFR, ξ (in $M_\odot$ yr^{-1}) is a function of time and estimated by the equation below (Javadi et al. 2011):

$$\xi(t) = \frac{dn'(t)}{\delta t} \frac{\int_{\min}^{\max} f_{\rm IMF}(m) m \, dm}{\int_{m(t)}^{m(t+dt)} f_{\rm IMF}(m) \, dm} \tag{3.1}$$

4. Results

The variation of SFH as a function of radial distance from the center of M31 is shown in Figure 1. All radius bins contain the same number of variable stars. As can be seen, the old epoch of star formation is more robust in the inner parts $0 < r < 9$ kpc of the disc, and as it moves towards the outer parts, it weakens and finally disappears at the outermost part. On the other hand, the recent star formation and the accumulation of young stars increase as it moves outward and this positive trend is seen across the entire disc for stars younger than log t (yr)=8.6. In addition, star formation in all parts has an almost identical rate at intermediate ages ($1 < \log t < 3$ Gyr ago). Our results are consistent with the result derived by (Sick et al. 2014). They used Bayesian modeling of the optical-infrared spectral energy distribution to estimate stellar mass profiles in the M31 galaxy. Their results also provide evidence of the inside-out disk formation.

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