

From evolved Long-Period-Variable stars to the evolution of M31

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Abstract. One of the ways to understand the genesis and evolution of the universe is to know how galaxies have formed and evolved. In this regard, the study of star formation history (SFH) plays an important role in the accurate understanding of galaxies. In this paper, we used long-period variable stars (LPVs) for estimating the SFH in the Andromeda galaxy (M31). These cool stars reach their peak luminosity in the final stage of their evolution also their birth mass is directly related to their luminosity. Therefore, using stellar evolution models, we construct the mass function and hence the star formation history.

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

1. Introduction

Andromeda as the closest spiral giant galaxy offers us a unique opportunity to know how its various components have formed and evolved. M31 is located at 785 ± 25 kpc, $(m - M)_o = 24.47$ mag (McConnachie et al. 2004) and has low foreground reddening $E(B - V) = 0.06$ mag. Our approach to investigating the star formation history (SFH) is based on employing long-period variable stars (LPVs) which we have successfully applied to other galaxies in the Local Group such as M33 (Javadi et al. 2011a,b, 2017), Magellanic Clouds (Rezaeikh et al. 2014), NGC147 and NGC185 (Golshan et al. 2017), IC1613 (Hashemi et al. 2019), Andromeda VII (Navabi et al. 2020, 2021) and Andromeda I (Saremi et al. 2021). Asymptotic giant branch (AGB) and red super giants (RSGs) are basic pillars in our research.

2. DATA and Technique of Star Formation

In this paper, we used the catalogue of LPVs in the M31 from (Mould et al. 2004) to determine star formation (Torki et al. 2019). It should be noted that their results included near-infrared photometry of almost 2000 variables which most of them were AGBs. We used the Padova stellar evolutionary models (Marigo et al. 2017) to obtain SFH and assuming that the metallicity is constant over time, we were able to calculate the mass, age, and pulsation duration of the stars. The SFH is described by the star formation rate (SFR) and conveys the concept of how much gas has become a star each year in the past. In fact, SFR, ξ (in $M_\odot \text{ yr}^{-1}$) is a function of time and estimated by:

$$\xi(t) = \frac{\int_{\min}^{\max} f_{\text{IMF}}(m) m \, dm}{\int_{m(t)}^{m(t+dt)} f_{\text{IMF}}(m) \, dm} \frac{dn'(t)}{\delta t}. \quad (2.1)$$

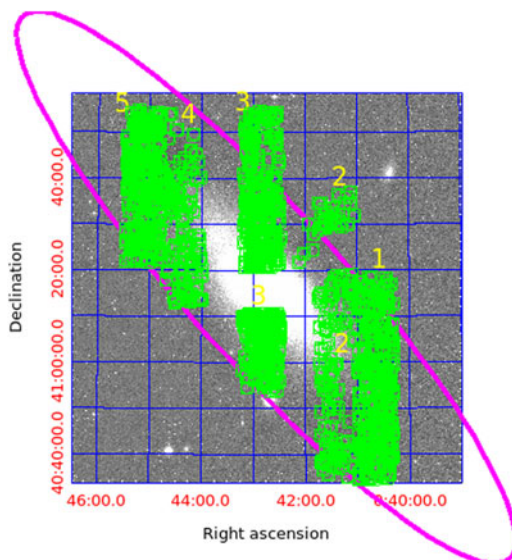


Figure 1. The 2MASS image of the M31 galaxy. The green dots indicate the LPVs from Mould *et al.* (2004). The magenta ellipse shows the twice half-light radius.

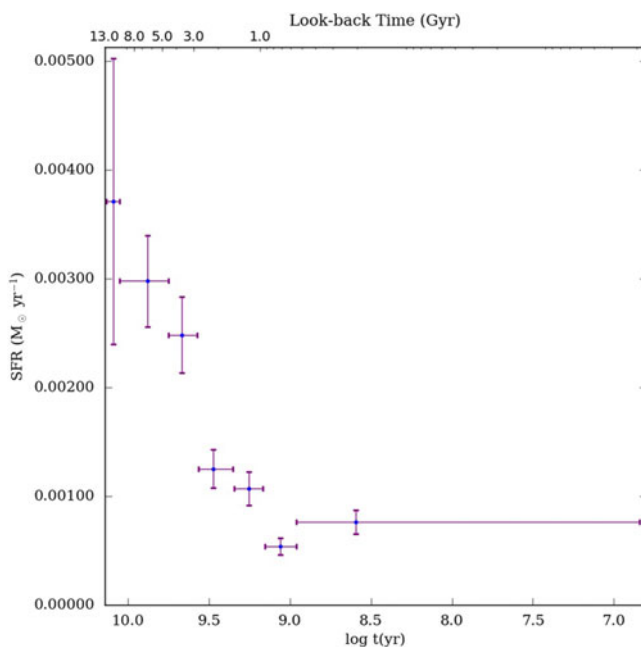


Figure 2. The SFH of the M31 galaxy for constant metallicity of $Z = 0.008$ based on data in box 1. The horizontal “error bars” show the spread in age within each bin and the statistical errors are presented in the vertical “error bars”.

where the m is mass, f_{IMF} is the Initial Mass Function (IMF) (Kroupa 2001). The minimum and maximum mass in Kroupa’s IMF are considered 0.02 and $200 M_{\odot}$ respectively. In the above equation, it is assumed that stars with mass between $m(t)$ and $m(t + dt)$ (t is look back time) are LPVs at the present time, and δt is the duration of the star oscillation which the number of variables observed ($dn'(t)$) in intervals t and $t + dt$ depends on it.

3. Results

The LPVs are scattered in 5 rectangular boxes (Figure 1). In this paper, we estimated the SFH of the M31 galaxy during the broad time interval from 11.8 Gyr ($\log t = 10.07$) to 400 Myr ($\log t = 8.59$) ago in Box 1, which has dimensions of $1.49 \text{ kpc} \times 13.09 \text{ kpc}$. The SFR as a function of look-back time in M31 is shown in Figure 2. The horizontal “error bars” correspond to the start and end time for which the SFR was calculated in that bin. We see a peak of star formation at 11.8 Gyr ago, after that, the star formation begins to decrease until the present-day.

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