

Star Formation History of the Local Group Dwarf Irregular Galaxy, NGC 6822

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Abstract

NGC 6822 is an isolated dwarf irregular galaxy in the local group at a distance of ~ 490 kpc. In this paper, we present the star formation history (SFH) within a field with a radius of ~ 3 kpc, beyond the optical body of the galaxy (~ 1.2 kpc). We utilized a novel method based on evolved asymptotic giant branch (AGB) stars. We collected the Near-Infrared data of 329 variable stars, including long-period and -amplitude variables and Carbon-rich AGB stars. We used a stellar evolutionary track and theoretical isochrones to obtain the birth mass, age, and pulsation duration of the detected stars to calculate the star formation rate (SFR) and trace the SFH of the galaxy. We studied the history of galaxy star formation for the mean metallicity value of $Z \approx 0.003$. We reconstructed the SFH for two regions: the bar region, a central rectangular area, and the outer region, which covers a circular field beyond the bar region and extends to a radius of 3 kpc. Our results show a significant burst of star formation around 2.6 and 2.9 Gyr ago in the bar and outer regions, respectively. Additionally, we observed a notable enhancement in the SFR in the bar region over the past 200 Myr.

Keywords: stars: AGB and LPV – stars: formation – galaxies: Local Group: Dwarf Irregular; – galaxies: evolution – galaxies: star formation – galaxies: individual: NGC 6822

1. Introduction

Investigating the star formation history (SFH) of galaxies provides profound insights into their formation and evolution. NGC 6822 is an isolated dwarf irregular (dIrr) galaxy within the local group, located at a distance of ~ 490 kpc (Lee et al., 1993; Mateo, 1998) in constellation Sagittarius. The exotic structure of NGC 6822 features a central bright bar, stretching from North to South (Hodge, 1977; Hodge et al., 1991). The central bar is embedded in an HI envelope, extending from the northwest (NW) to the southeast (SE); this central structure is surrounded by a extensive elliptical halo located at a radial distance of ~ 12 kpc (De Blok & Walter, 2000; Hwang et al., 2005; Zhang et al., 2021). Despite its gas-richness, NGC 6822 has a relatively low metallicity. While a wide range of metallicities have been associated with various ages of the galaxy, the studies by Tolstoy et al., 2001 and Davidge, 2003 reported a mean value of $[\text{Fe}/\text{H}] \approx -1.00$ dex ($Z = 0.003$), derived based on the red giant branch (RGB) Ca II triplet and the slope of RGB (J, K bands), respectively.

The evolved stellar population of NGC,6822, including the asymptotic giant branch (AGB; Marigo et al., 2008) and the red supergiant (RSG) stars, are excellent implements for tracing SFH over periods ranging from a few million to 10 billion years (Ekström et al., 2013). The significant brightness of AGBs ($\sim 10^3 - 10^4 L_{\odot}$; Höfner & Olofsson, 2018), along with their radial pulsations, makes these stars conveniently detectable at infrared wavelengths. In this work, we apply a method developed by Javadi et. al. (2011a, 2011b, 2013, 2015) based on AGBs that pulsate with periods longer than 100 days, known as long-period variable (LPV)

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stars (Iben Jr & Renzini, 1983; Whitelock et al., 2003). The SFH of many nearby galaxies in the LG has been derived utilizing this method (Rezaei kh et al., 2014; Javadi et al., 2016, Javadi et al., 2017; Hamedani Golshan et al., 2017; Hashemi et al., 2019; Navabi et al., 2021; Saremi et al., 2021; Abdollahi et al., 2023; Aghdam et al., 2024); in the following, we will apply this method using the evolved stellar population of NGC 6822 to reconstruct its SFH.

2. Data and Method

The sample used for derivation of the SFH contains the data of 329 evolved stars in J, H, and K_s bands, selected and combined from several catalogs published by Kacharov et al., 2012, Whitelock et al., 2013, and Sibbons et. al.(2012, 2015). Most of the stars in the sample, including 228 long-period and long-amplitude variables and spectroscopy-confirmed Carbon-rich AGB stars, are distributed within the bar region. This region is defined as a rectangular area of 9×21 arcmin², situated in the center of the galaxy. Meanwhile, the remaining 101 stars are only spectroscopy-confirmed Carbon-rich AGBs dispersed beyond the bar region, extending up to a radius of 3 kpc, which we refer to as the outer region throughout this paper. We must note that due to insufficient available data, the outer region stars are solely spectroscopy-confirmed Carbon-rich AGBs. As a result, this limitation restricts and narrows the age range of the derived SFH associated with this area.

In order to obtain the SFH, we calculated the star formation rate (SFR), $\xi(t)$ ($M_{\odot} \text{ yr}^{-1}$), which is defined as the mass of gas that has converted into stellar mass over a specific time interval. To do so, we used the Padova stellar evolutionary tracks and isochrones (Marigo et al., 2008, 2017), assuming constant metallicities, to relate the magnitude of each star to its birth mass. Similarly, we obtained the age and pulsation duration (when LPVs are in pulsating phase). Subsequently, we sorted the stars based on age and divided them into several bins. Then, we derived the SFR for each bin, with its associated age and mass range, using the following relation:

$$\xi(t) = \frac{\int_{m_{\min}}^{\max} f_{\text{IMF}}(m) m dm}{\int_{m(t)}^{m(t+\delta t)} f_{\text{IMF}}(m) dm} \frac{dn'(t)}{\delta(t)}, \quad (1)$$

where the m is mass, dn' is the number of observed LPVs in each bins, $\delta(t)$ is the pulsation duration, and f_{IMF} is the initial mass function (IMF) (Kroupa, 2001). We also consider a statistical error for each bin, derived based on the Poisson statistics:

$$\sigma_{\xi(t)} = \frac{\sqrt{N}}{N} \xi(t), \quad (2)$$

where N is the number of LPVs in each bin.

3. Results

We calculated the SFRs in two regions of NGC 6822: the bar region and the outer region, using the method and the dataset explained in Section 2. Furthermore, we assumed that the metallicity remained constant over time and derived the SFH adopting the mean metallicity of $[\text{Fe}/\text{H}] = -1.05$ dex ($Z \approx 0.003$). The model utilized to obtain the parameters required to calculate the SFR was obtained from Khatamsaz et al., 2024 and Khatamsaz et al., in preparation.

The left panel of Fig. 1 shows the results for the bar region. In this area, star formation began as early as ~ 12.7 Gyr ago, with a rate of $1.1 \pm 0.3 \times 10^{-3} M_{\odot} \text{ yr}^{-1}$. Following this, the SFR increases gradually for ~ 10.0 Gyr and peaks at ~ 2.6 Gyr ago, reaching a rate of $5.3 \pm 1.4 \times 10^{-3} M_{\odot} \text{ yr}^{-1}$. The star formation in the bar region then decreases for ~ 1.6 Gyr. However, it has begun to increase once again in the past ~ 1.0 Gyr and experiences a significant enhancement in its rate, reaching the maximum rate of $\sim 17.0 \pm 4.3 \times 10^{-3} M_{\odot} \text{ yr}^{-1}$ over the past 300 Myr. This rate is in good agreement with the recent SFR of $21.0 \times 10^{-3} M_{\odot} \text{ yr}^{-1}$ derived by Hodge, 1993 based on the H α luminosity.

As we mentioned previously, the dataset of the outer region, as defined in Section 2, is limited to Carbon-rich AGB stars. Therefore, our results are confined to the age range of the used sample, which falls within the range of $15.0 \text{ Gyr} < \text{look-back time} < 620 \text{ Myr}$, considering the mean metallicity of $Z \approx 0.003$. The right panel in Fig 1 presents the results for the outer region. Similar to the bar region, the SFR peaks at

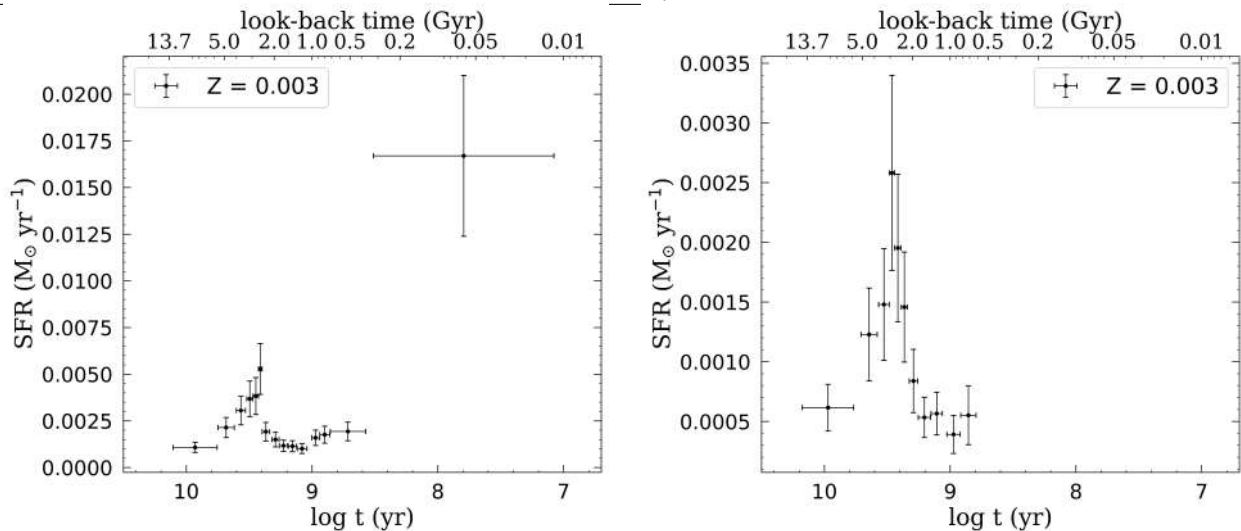


Figure 1. The SFH in NGC 6822 with the adoption of the mean metallicity of $Z \approx 0.003$. The left panel presents the results for the bar region, and the results for the outer region are displayed on the right panel.

~ 2.9 Gyr ago, reaching the maximum rate of $\sim 2.6 \pm 0.8 \times 10^{-3} M_{\odot} \text{ yr}^{-1}$, which is roughly as half as the rate obtained for the same epoch of star formation burst in the bar region. Following this, the SFR gradually decreases up until ~ 830 Myr ago. However, as mentioned before, due to the limitation of data in the outer region, we cannot retrieve any results for ages younger than ~ 620 Myr ago. Consequently, it remains unclear whether the most recent bin indicates the initiation of a new epoch of star formation similar to the one observed in the bar region.

4. Conclusion

In this paper, we applied a novel method to evolve AGB stars to find the SFH of NGC 6822. Our results show that the SFR in the galaxy has increased significantly during the last 200 Myr in the bar region. Furthermore, star formation bursts and peaks ~ 2.6 and ~ 2.9 Gyr in the bar and outer regions, respectively. The presence of this peak provides evidence for the tidal interaction of NGC 6822 and the Milky Way proposed by Zhang et al., 2021. Furthermore, the non-uniform SFH shows that, despite the noticeable isolation of the galaxy, it has gone under events that triggered the star formation activities. Our upcoming paper on the SFH of NGC 6822 will discuss the subject further and present a new plausible scenario to explain the recent unusual burst of star formation in this galaxy.

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