# Investigating The Star Formation History of the Nearby Dwarf Irregular Galaxy, NGC 6822

F. Khatamsaz *and M. Abdollahi †

School of Astronomy, Institute for Research in Fundamental Sciences (IPM), Tehran, 19568-36613, Iran

**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 stellar evolutionary tracks 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.

***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 envelop, 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 to various ages of the galaxy, the studies by Tolstoy et al., 2001 and Davidge, 2003 reported a mean value of [Fe/H] $\approx -1.00$ dex (Z $\approx$ 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 asymptotic giant branch (AGB; Marigo et al., 2008) and red supergiant (RSG) stars, are excellent implements to trace the SFH over periods spanning from a few million years to 10 billion years (Ekström et al., 2013). 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 a 100 days, known as long-period variable (LPV) 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 Surveys and Method

The sample used for derivation of the SFH contains the data of 329 evolved stars in J, H, and $K_s$ bands. We collected 97 stars, including 27 large-amplitude variables (LAVs) and 70 LPVs from Whitelock et al., 2003. Their survey was carried out in JHK bands, using the Japanese–South African Infrared Survey Facility (IRSF) equipped with the SIRIUS camera over a period of 3.5 years. In addition to the 97 LPVs,

*fate.khatamsaz@gmail.com, Corresponding author
†m.abdollahi@ipm.ir


doi:https://doi.org/10.52526/25792776-25.72.2-447

we collected 101 spectroscopy-confirmed carbon stars from Sibbons et al., 2012, which used the Wide-Field Camera (WFCam) on the 3.8m UK InfraRed Telescope (UKIRT) to obtain JHK photometry of a 3 $\deg^2$ area at the center of the galaxy. Later, Sibbons et al., 2015 used the AAOmega multi-fiber spectrograph at the 3.9m Anglo-Australian Telescope (AAT) to determine the spectral type of some potential AGB candidates at a radial distance of $\leq$ 3 kpc and $\geq$ 5 kpc, primarily selected from Sibbons et al., 2012. Additionally, we selected 168 spectroscopy-confirmed C-rich AGBs from Kacharov et al., 2012. They used the VIMOS instrument at the ESO VLT to obtain the lowresolution multi-object spectroscopy of approximately 800 stars in seven fields centered on NGC6822. After removing the identical stars, we were left with a total of 134 carbon stars, 79 of which are in the bar region, and the remaining 55 stars are dispersed in the outer region. 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 $\times$ 21 $\mathrm{arcmin}^2$, 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), $\xi(t)$ ($\mathrm{M}_\odot\,\mathrm{yr}^{-1}$), 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:

$$\xi(t) = \frac{\int_{\mathrm{min}}^{\mathrm{max}} f_{\mathrm{IMF}}(m)\, m\, \mathrm{d}m}{\int_{m(t)}^{m(t+\mathrm{d}t)} f_{\mathrm{IMF}}(m)\, \mathrm{d}m}\, \frac{\mathrm{d}n'(t)}{\delta(t)}, \tag{1}$$

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

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

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. Additionally, we assumed that the metallicity remained constant over time and derived the SFH adopting the mean metallicity of [Fe/H] = $-1.05$ dex (Z $\approx$ 0.003). The utilized model to obtain the parameters required to calculate the SFR were 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, assuming only the 97 LPVs of Whitelock et al., 2013. However, ro improve the completeness of our data, we have added 131 spectroscopy-confirned c-rich AGBs and created the Bar region catalog, the middle pannel of Fig. 1. Based on the bar region catalog, the star formation begins as early as $\sim$ 12.7 Gyr ago, with a rate of $1.1 \pm 0.3 \times 10^{-3}$ $\mathrm{M}_\odot\,\mathrm{yr}^{-1}$ in this area. Following this, the SFR increases gradually for $\sim$ 10.0 Gyr and peaks at $\sim$ 2.6 Gyr ago, reaching a rate of $5.3 \pm 1.4 \times 10^{-3}$ $\mathrm{M}_\odot\,\mathrm{yr}^{-1}$. The star formation in the bar region then decreases for $\sim$ 1.6 Gyr. However, it begins to increase once again in the past $\sim$ 1.0 Gyr and experiences a significant enhancement in its rate, reaching the maximum rate of $\sim 17.0 \pm 4.3 \times 10^{-3}$ $\mathrm{M}_\odot\,\mathrm{yr}^{-1}$ over the past 300 Myr. This rate is in good agreement with the recent SFR of $21.0 \times 10^{-3}$ $\mathrm{M}_\odot\,\mathrm{yr}^{-1}$ derived by Hodge, 1993 based on the H$\alpha$ 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 Gyr < look-back time < 620 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 $\sim$ 2.9 Gyr ago, reaching the maximum rate of $\sim 2.6 \pm 0.8 \times 10^{-3}$ $\mathrm{M}_\odot\,\mathrm{yr}^{-1}$, which is roughly as half as the rate obtained for the same epoch of star formation


doi:https://doi.org/10.52526/25792776-25.72.2-447

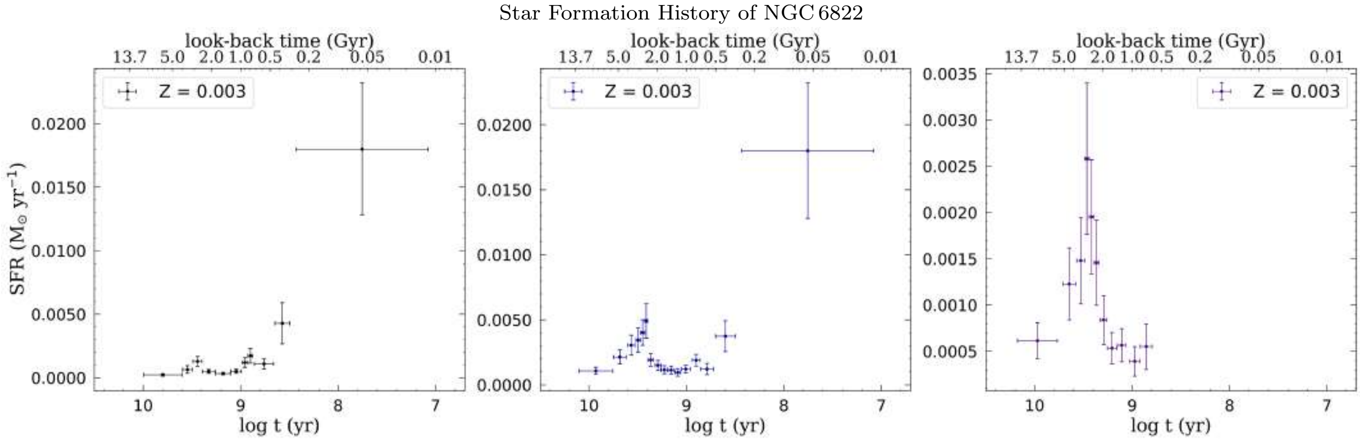


Figure 1. The SFH results are presented for the mean metallicity of Z ≈ 0.003, assuming that the metallicity remains constant over time. **Left panel:** The SFH for the bar region is derived using the 97-LPVs catalog. **Middle panel:** The SFH for the bar region is determined using the bar region catalog, which includes 97 LPVs and 131 spectroscopy-confirmed carbon stars. **Right panel:** The SFH for the outer region is obtained utilizing the outer region catalog, which consists solely of 101 spectroscopy-confirmed carbon stars.

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. 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.

## References


Abdollahi H., et al., 2023, The Astrophysical Journal, 948, 63

Aghdam S. T., et al., 2024, The Astrophysical Journal, 972, 47

Davidge T., 2003, Publications of the Astronomical Society of the Pacific, 115, 635

De Blok W., Walter F., 2000, The Astrophysical Journal, 537, L95

Efremova B. V., et al., 2011, The Astrophysical Journal, 730, 88

Ekström S., Georgy C., Meynet G., Groh J., Granada A., 2013, EAS Publications Series, 60, 31

Hamedani Golshan R., Javadi A., van Loon J. T., Khosroshahi H., Saremi E., 2017, Monthly Notices of the Royal Astronomical Society, 466, 1764

Hashemi S. A., Javadi A., van Loon J. T., 2019, Monthly Notices of the Royal Astronomical Society, 483, 4751

Hodge P. W., 1977, Astrophysical Journal, Suppl. Ser., Vol. 33, p. 69-82, plates 13-16, 33, 69

Hodge P. W., 1993, ESO Conference and Workshop Proceedings, No. 49, p. 501

Hodge P., Smith T., Eskridge P., MacGillivray H., Beard S., 1991, Astrophysical Journal, Part 1 (ISSN 0004-637X), vol. 379, Oct. 1, 1991, p. 621-630., 379, 621

Höfner S., Olofsson H., 2018, The Astronomy and Astrophysics Review, 26, 1

Hwang N., et al., 2005, Proceedings of the International Astronomical Union, 1, 257

Hwang N., Lee M. G., Lee J. C., Park W.-K., Park H. S., Kim S. C., Park J.-H., 2011, The Astrophysical Journal, 738, 58

Iben Jr I., Renzini A., 1983, IN: Annual review of astronomy and astrophysics. Volume 21 (A84-10851 01-90). Palo Alto, CA, Annual Reviews, Inc., 1983, p. 271-342., 21, 271

Javadi A., van Loon J. T., Mirtorabi M. T., 2011a, Monthly Notices of the Royal Astronomical Society, 411, 263

Javadi A., van Loon J. T., Mirtorabi M. T., 2011b, Monthly Notices of the Royal Astronomical Society, 414, 3394

Javadi A., van Loon J. T., Khosroshahi H., Mirtorabi M. T., 2013, Monthly Notices of the Royal Astronomical Society, 432, 2824

Javadi A., Saberi M., van Loon J. T., Khosroshahi H., Golabatooni N., Mirtorabi M. T., 2015, Monthly Notices of the Royal Astronomical Society, 447, 3973



doi:https://doi.org/10.52526/25792776-25.72.2-447

Javadi A., Van Loon J., Khosroshahi H., 2016, arXiv preprint arXiv:1610.00254

Javadi A., van Loon J. T., Khosroshahi H. G., Tabatabaei F., Hamedani Golshan R., Rashidi M., 2017, Monthly Notices of the Royal Astronomical Society, 464, 2103

Kacharov N., Rejkuba M., Cioni M.-R., 2012, Astronomy & Astrophysics, 537, A108

Khatamsaz F., Abdollahi M., Abdollahi H., Javadi A., Van Loon J., 2024, IAU General Assembly, p. 648

Kroupa P., 2001, Monthly Notices of the Royal Astronomical Society, 322, 231

Lee M. G., Freedman W. L., Madore B. F., 1993, Astrophysical Journal v. 417, p. 553, 417, 553

Marigo P., Girardi L., Bressan A., Groenewegen M. A., Silva L., Granato G. L., 2008, Astronomy & Astrophysics, 482, 883

Marigo P., et al., 2017, The Astrophysical Journal, 835, 77

Mateo M., 1998, Annual Review of Astronomy and Astrophysics, 36, 435

Navabi M., et al., 2021, The Astrophysical Journal, 910, 127

Rezaei kh S., Javadi A., Khosroshahi H., van Loon J. T., 2014, Monthly Notices of the Royal Astronomical Society, 445, 2214

Saremi E., Javadi A., Navabi M., van Loon J. T., Khosroshahi H. G., Arbab B. B., McDonald I., 2021, The Astrophysical Journal, 923, 164

Sibbons L., Ryan S. G., Cioni M.-R., Irwin M., Napiwotzki R., 2012, Astronomy & Astrophysics, 540, A135

Sibbons L., Ryan S. G., Napiwotzki R., Thompson G., 2015, Astronomy & Astrophysics, 574, A102

Tolstoy E., Irwin M. J., Cole A. A., Pasquini L., Gilmozzi R., Gallagher J., 2001, Monthly Notices of the Royal Astronomical Society, 327, 918

Whitelock P. A., Feast M. W., Loon J. T. v., Zijlstra A. A., 2003, Monthly Notices of the Royal Astronomical Society, 342, 86

Whitelock P. A., Menzies J. W., Feast M. W., Nsengiyumva F., Matsunaga N., 2013, Monthly Notices of the Royal Astronomical Society, 428, 2216

Zhang S., Mackey D., Da Costa G. S., 2021, Monthly Notices of the Royal Astronomical Society, 508, 2098


doi:https://doi.org/10.52526/25792776-25.72.2-447