Institute for Research in Fundamental Sciences

مقاله نامه ی بیست و هفتمین کنفرانس بهاره فیزیک – ۴ و ۵ تیرماه ۱۳۹۹

شماره (۲۰)

# THE STAR FORMATION HISTORY OF AND VII DWARF GALAXY DERIVED FROM MONITORING SURVEY OF LONG-PERIOD VARIABLE STARS

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**Abstract.**

And VII (Cassiopeia) is one of the most luminous spheroidal satellites of Andromeda galaxy (M31). Here, we reconstruct the star formation history of this dwarf based on long-period variable stars (LPVs) using optical multi-epochs images from the Isaac Newton Telescope (INT) at the i- and V-band. LPVs are important in our study because they achieve their highest brightness at the final stage of evolution. Moreover, their luminosity can be related to their initial mass by connecting their photometry to theoretical evolutionary tracks models. So, we are able to reproduce the mass function and hence derive the star formation history of And VII. The number of 55 LPVs was detected within two half-light radii ($7 \pm 0.3$ arcmin) of And VII. We derived the distance modulus of $\sim 24.41$ mag based on the tip of the red giant branch (TRGB). Consequently, the star-formation history is estimated by mag-mass and mass-age relations in order of $5-12$ Gyr ago with an average rate of $0.003\ M_{\odot}/yr$.

Keywords: Andromeda VII– variable stars: AGB, LPVs– techniques: photometric– star formation history

## 1 Observation and Data analysis

The Wide Field Camera (WFC) is an optical mosaic camera of the INT on the Canary islands of La Palma, Spain that consists of four $2048 \times 4096$ CCDs, with a pixel size of $0.33$ arcsec/pixel. We used the WFC between 2015 to 2017 for identifying of LPV stars in And VII. We were going to determine the amplitude and mean brightness of LPVs that are variable on timescales from $\approx 100$ days for low-mass AGB stars to $\approx 1500$ days (Javadi et al. 2011a). For this purpose, the observations were done over $8$ epochs spaced by a month or more at WFC Sloan i filter, one epoch at the WFC RGO I filter and $5$ epochs at Harris V filter for obtaining colour information. The data reduction was performed by THELI pipeline and we applied the DAOPHOT II (Stetson 1987) for Point Spread Function photometry (Saremi et al. 2017, 2020).

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## 2 Long-Period Variable stars

To identify long-period variable stars (LPVs), we used a method similar to the NEWTRIAL program described by Welch & Stetson (1993) and developed further by Stetson (1996) to derive variability indices (J, K and L) for stars. We found the optimal variability threshold in order to distinguish LPVs based on the histograms of variability index L (Javadi et al. 2011a,b; Saremi et al. 2020). The number of 55 LPVs was detected in two half-light radii ($2r_h$) of the galaxy that most of them in i-band are between 20.5 to 21.5 mag.

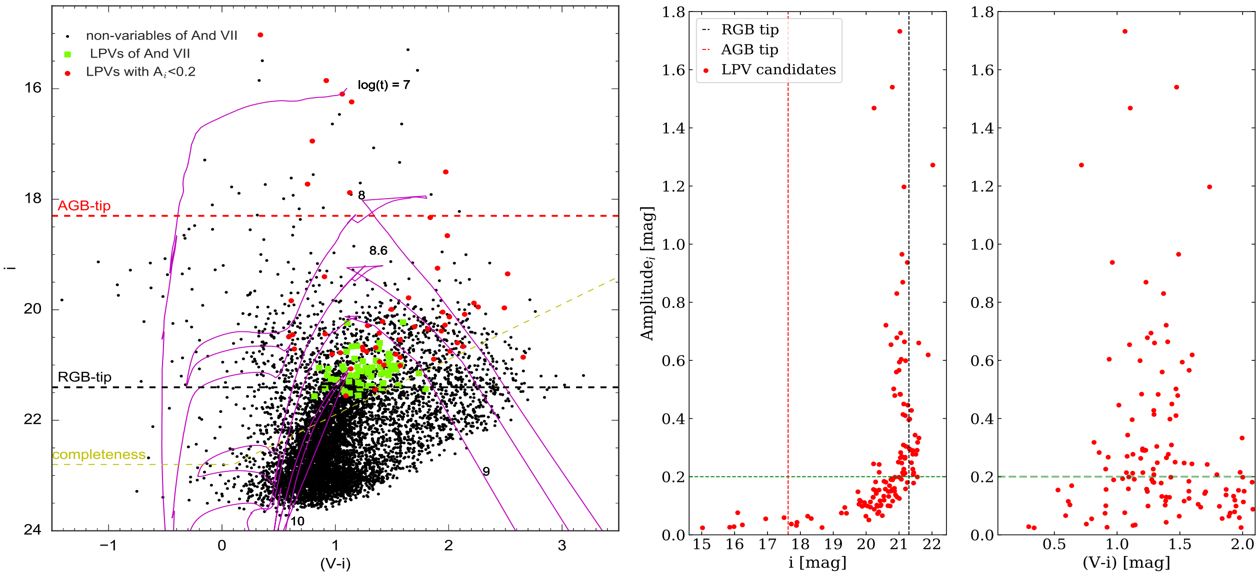


**Fig. 1. Left:** The LPVs are displayed with green points and isochrones from Marigo et al. (2017) are overlaid. **Right:** Estimated amplitude $A_i$ of variability vs. i-band magnitude and colour. The green horizontal lines illustrate LPVs with A$_i$ $< 0.2$, and also AGB and RGB tips are illustrated by the red and black dashed lines.

Figure 1 (left panel) presents the colour magnitude diagram (CMD) of And VII in the i-band vs. V-i colour and show our identified LPV stars in green. The overplotted isochrones are derived from Marigo et al. (2017) and the AGB tip and RGB tip are illustrated with red and black dashed lines, respectively. The 50% completeness limit of our photometry is determined based on a simple simulation (Saremi et al. 2020). The right panels of figure 1 show that the estimated i-band amplitudes of LPVs are increasing towards the redder with decreasing of brightness. The variable stars with $A_i < 0.2$ mag are shown in CMD with red color, but they do not be considered as LPVs in our studies (Saremi et al. 2020).

For obtaining TRGB, we applied the luminosity probability distribution (LPD) developed by (McConnachie et al. 2004). Then the convolution of LPD by employing the Sobel kernel $[-2, -1, 0, 1, 2]$ was enabled us to find the position of the TRGB. The TRGB in I band is derived $20.7 \pm 0.05$. It is according to the TRGB reported by McConnachie et al. (2005). It allowed us to adopt their distance modulus of $(M - m_0) = 24.41 \pm 0.1$ mag to fit isochrones on the CMD of Figure 1 and farther, in star formation history that is explained in section 3. We obtain TRGB of 21.35 mag with transforming again to i Sloan band, which is shown in Figure 1 by a black dashed line.

## 3 Star Formation History

LPVs are recognized easily in IR observing due to reaching their maximum near-IR brightest and enter very ultimate steps of their evolution. So, their brightness can be turned into their birth mass by applying theoretical evolutionary tracks. In this study, we used the latest version of Padova evolutionary tracks (Marigo et al. 2017) because of the reasons explained by (Javadi et al. 2011c, 2017).

Therefore, we detected the birth mass and luminosity (ML) relation for the i band using the endpoint of stellar evolution from isochrones of low-mass (0.5 $M_\odot$) to massive stars (56 $M_\odot$) for the metallicity ($Z = 0.0007$) and represented the correlation in the left panel of Fig 2. Also, the relation between birth mass and age was obtained from the peak of the aforementioned isochrones. The plot of age-mass is presented in the right panel of Figure 2 with the best-fitting function obtained by IRAF task NFIT1D, which are shown with red lines. To obtain the mass of LPVs from theoretical ML relation, we calculate the absolute magnitude of LPVs by subtracting module distance $\mu = 24.41$ and extinction $A_i = 0.36$ of And VII from apparent magnitudes.

The method used here is developed by Javadi et al. (2011c, 2017) and also had been applied and argued extensively by Rezaeikh et al. (2014); Hamedani Golshan et al. (2017); Hashemi et al. (2019). To describe the SFH, we used identified LPV stars in the galaxy and their brightness distribution function $f(i)$ to construct the birth mass function ($f_{IMF}$) that depended on present stellar mass (M), and hence the star formation rate (SFR), $\xi$, as a function of age (t):

$$\xi(t) = \frac{f(i(M(t)))}{\Delta(M(t)) f_{IMF}(M(t))} \tag{3.1}$$

where $\Delta$ is the span of evolutionary phase during which LPV stars demonstrate strong radial pulsation. The stellar mass (M) of a variable star at the end of its evolution is directly related with its age.

We performed the extinction corrections for dusty LPVs that have become dimmer and redder in the i-band due to their high dust and obtained the correct luminosity value of them Javadi et al. (2011c). According to the isochrones, for returning LPVs to their photospheric peak brightness level, the reddening slope of carbon stars (e.g. at t = 1 Gyr, i.e. log $t = 9$) is slower than oxygen-rich stars (e.g. at t = 10 Gyr, i.e. log $t = 10$ or at t = 100 Myr, i.e. log $t = 108$). We hence derived average slopes of isochrones for O-rich stars $a_{oxygen} = 2.04$ for $i \leq 20.05$ and 2.95 for $i > 20.05$, also for C-rich stars $a_{carbon} = 1.37$ if $i \leq 20.87$ and 3.65 if $i > 20.87$. We determined the type of stars base on their mass: $1.5\ M_\odot < M < 4\ M_\odot$ includes carbon stars and more or lower than this range specify for oxygen stars. We applied 3.2 equation for stars that their colours are $(V - i) > 1.4$ mag, while the peak of isochrones is located $(V - i)_0 = 1.16$ :

$$i_0 = i + a((V - i)_0 - (V - i)) \tag{3.2}$$

In order to derive the SFH, we have obtained mass and age of LPVs from corrected magnitudes using relations of mag-mass ($log(M/M_\odot) = a \times i + b$) and age–mass ($log(t) = a \times log(M/M_\odot) + b$) that their coefficients obtained from plots of Figure 2 for $Z = 0.0007$. According to results, it is estimated that $log(M/M_\odot)$ of LPVs is less than 0.2. So, the main part of star formation in And VII is occured between $5 - 12$ Gyr ago with an average rate of $0.002 M_\odot/yr$.

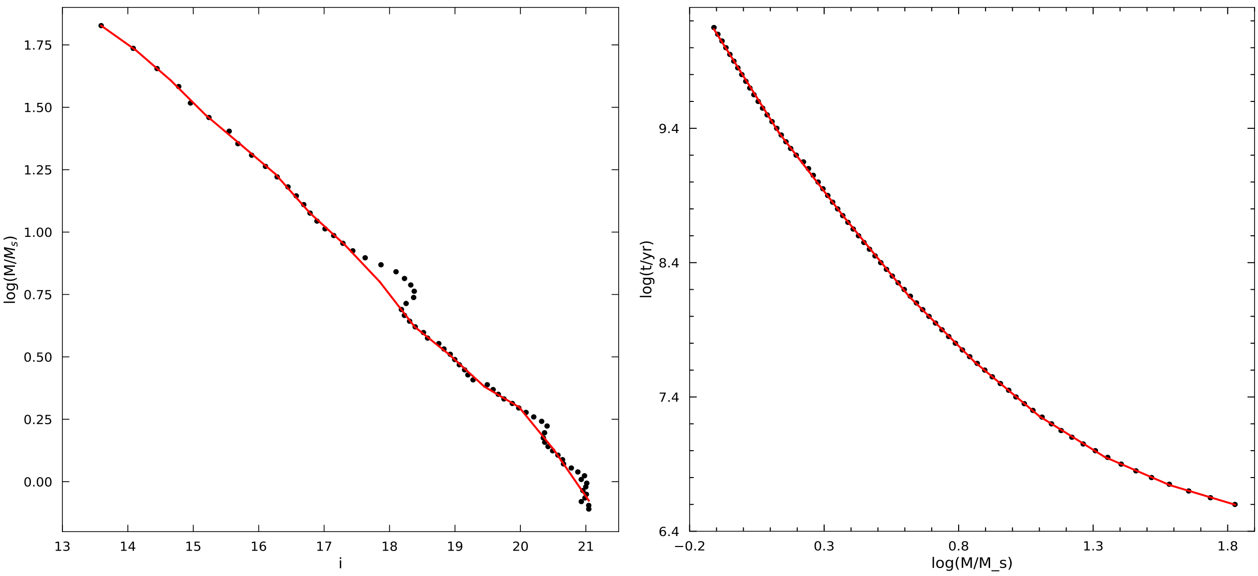


**Fig. 2. Left:** relation between birth mass and i-band magnitude at the end point of isochrones for $Z = 0.0007$ and a distance modulus of $\mu = 24.41$ mag. Solid red lines are fits obtained by IRAF task NFIT1D. **Right:** same as the left, for the relation between age and birth mass.

## 4 On–going works

We are extending the study of And VII by modeling spectral energy distributions of long-period variables stars obtained by a combination of near–IR and optical (our catalogue) and mid–IR data (Spitzer catalogues) to estimate the mass-loss rate and chemical enrichment of the galaxy (Javadi et al. 2013).

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