A global view of stellar populations in M82

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Abstract. We present photometric and spectroscopic studies of the stellar content of M82, including the resolved halo stellar population and the halo globular clusters. M82 is a nearby peculiar galaxy that recently went through a close encounter with its more massive companion, M81. As a result, M82 has a high star formation activity and unusual stellar content. We studied the resolved stellar population using the imaging data from the Hubble Space Telescope (HST) data archive. Then, their metallicities were analyzed to understand a global view of the stellar populations in M82. We found that the old stellar population in M82 shows typical characteristics for a disk galaxy, while the young stellar population shows a sign of disruption as a result of the recent interactions.

1. Introduction

M82 is a nearby disk galaxy known for its starburst activity, which gives it a distinctive optical appearance. It is located 3.53 Mpc [1] away in the center of the M81 group of galaxies. A survey of neutral hydrogen (HI) in the center of the group by [2] revealed streams of HI connecting between the three main galaxies including M81, M82, and NGC3077, indicating ongoing interactions among those galaxies. Numerical simulation by [3] suggested that the most recent close encounter between M82 and M81 occurred approximately 220 Myr ago, which is consistent with the ages of the young stars found in the tidal debris between those galaxies [4].

Unlike M81, the stellar content of M82 is not relatively well studied. Many studies on its stellar content were also focused on its young stellar population such as the young massive star clusters that were formed as a result of the interactions. Despite its unusual stellar content, some characteristics of the old stellar population in M82 are similar to those of the normal disk galaxies. [5] and [6] reported a discovery of a non-star-forming spiral arm in the disk of M82. [7] found that M82 is embedded in a smooth halo of the old population of stars, with evidence suggesting a higher mean metallicity than that of M81 and NGC3077. However, the old stellar population in M82 is still not relatively well explored. For example, only two globular clusters have been confirmed [8, 9] and 35 old star cluster candidates have been identified in M82 so far [10].

In this study, we examine the stellar content of M82 including its resolved halo stars and its halo globular clusters. Our goal is to better understand the global view of its stellar populations, especially the old population. The paper is organized as followed, Section 2 describes the data we used and our analysis method. The results and discussions are presented in Section 4. Finally, we summarize our study in Section 5.
2. Data and analysis

We obtained the archival data of M82 from the ACS Nearby Galaxy Survey Treasury (ANGST) [1]. The data was a part of the surveys for the resolved stars in the nearby galaxies (D < 4 Mpc) in multi-color photometry, using the Advanced Camera for Surveys (ACS) on the Hubble Space Telescope (HST). Figure 1 shows the field of view of the data. The multiple pointing fully covered the disk of M82 and some of its halo region. There are 6 fields of images in total, all were taken in three filters including F435W, F555W, and F814W. The total exposure times for each filter were 1800s, 1360s, and 700s respectively. In this study, we selected only the F555W and F814W imaging data for our color-magnitude diagram (CMD) analysis. These two specific filters were selected since they are less affected by reddening than the shorter wavelength filter.

Figure 1. Field of view of the data obtained from ANGST. The multiple pointing images were centered at M82. The data points in the figure represent positions of all resolved stars in M82 in the archive and are independent of magnitude. The disk plane of the galaxy is oriented along the blue solid line and the disk region can be seen as an area with high stellar density. Note that stars in the central region of the galaxy are partially missing due to the effect of the crowding and dust obscuration. The boundaries of the selected sample are indicated by the blue dash lines.

Data reduction was performed following the standard manner by the STScI ACS pipeline which includes bias subtracted and flat-fielded. Then, PSF photometry was performed by using the DOLPHOT software package [11] and calibrated into the VEGAMAG system [12]. Finally, only point sources were retained in the final catalog that we retrieved. Following [1], these data were only used to determine the distance of M82. However, no further analysis has been done on these data due to its crowding and extremely high reddening. Figure 2 shows the CMDs of all 6 imaging fields. The CMDs are very crowded due to the crowding as shown in figure 1. In addition, the reddening in the disk region of M82 is extremely high, with AV up to approximately 3.5 magnitudes in the center of the galaxy [9]. In this study, we adopted AF555W = 0.191 and AF814W = 0.109 from [1] for the Galactic extinction.

To avoid the effects of the crowding and the intrinsic reddening of M82, we only selected stars with great distances from the galaxy. Figure 1 shows the field of view of our data, centered at M82, with each data point represents a resolved stars in the galaxy. The blue-solid line in the figure represents the disk plane of the galaxy, which is very crowded. Our experiments showed that stars within the projected distances of 2.5 arcminutes perpendicular to the disk plane of the galaxy are highly reddened and show very crowded CMDs. In contrast, stars outside of the range show very well defined CMDs, as shown in the figure 2. Therefore, we adopted this empirical number, which is represented by the blue dashed lines in the figure 1, as our selection criteria for our sample stars. We will refer to the selected stars as halo stars hereafter.
Figure 2. CMDs of all stars in the selected imaging field. The field number on the top of each plot is the same as labeled in the figure 1. (a) POS1; (b) POS2; (c) POS4; (d) POS5. The CMDs are very crowded especially those of POS2 and POS5, which do not show any clear features. Overplotted on the CMDs are isochrones of 100 Myr, 200 Myr, both with Z = 0.008, and isochrones of Z = 0.0001, 0.0004, 0.001, 0.004, 0.008, and 0.02, all with age of 9 Gyr respectively. CMDs of the selected imaging field with only the selected sample of halo stars are also presented. (e) POS1; (f) POS2; (g) POS4; (h) POS5. All CMDs show a clear feature of the red giant branch (RGB) and a hint of a sequence of blue stars. The isochrones on the CMDs are the same as those in (a) – (d).

We used Girardi isochrones [13] as a guide to select a sample for metallicity analysis. We used the color of the RGB stars to represent their metallicities. Although the color of the RGB stars is dependent on both metallicity and age, since the color is more sensitive to metallicity than age, we assumed that the age of the halo stars are uniform and the spread in the color of the RGB stars directly indicates the spread in metallicity. Then we selected only halo stars with $m_{F814W} < 25$ to avoid the effect of the incompleteness and $m_{F555W} - m_{F814W} > 1$ to avoid contamination from blue stars. Finally, we examined the spatial variation of the mean metallicities of the selected halo stars by comparing color histograms of the halo stars in each imaging field.

3. Results and discussion
The CMDs after stars in the crowded and highly reddened region have been removed are shown in the figure 2. The CMDs show a very well defined structure of the RGB, which is also the most prominent feature in the CMDs. This indicates that stars in the halo are mostly old. In addition, few blue stars can be found in all CMDs especially in the position 4. This indicates the presence of young stars in the halo of M82, which is unusual for a disk galaxy. Then, the spatial distribution of the halo stars shows that they are uniformly distributed within the observed magnitude range. Finally, figure 3 shows the color histograms of the selected halo stars in each imaging field. The histograms indicate no significant difference in the mean colors and, therefore, no significant difference in the mean metallicities of the halo stars among the imaging fields.
Although the old stars in the halo of M82 are uniformly distributed, there is a concentration of young stars in the southern halo of M82. This concentration of young stars was studied by Suwannajak & Sarajedini (2020, in preparation). The study suggested that the young stars were likely to be originated from the gas content that was stripped out from the disk of M82 due to the recent interactions with M81. Apart from the resolved halo stars, globular clusters in M82 were studied by Suwannajak & Sarajedini (accepted to the IAU GA Focus Meeting, IAU GA 2018). In this study, spectra of 8 globular candidates in M82 were obtained from OSIRIS LongSlit Spectrograph on the Gran Telescopio CANARIAS (GTC). We confirmed the globular cluster nature of all candidates, which indicated that M82 also exhibits some old globular clusters similar to M81 and the Milky Way, but with smaller number due to its smaller mass. Most of the globular clusters in M82 are old and metal-poor similar to those in M81 and the Milky Way, with one exception being a globular cluster that is significantly more metal-rich than the rest. This metal-rich cluster also shows a motion in the same sense as the disk of M82. We suspected that this globular cluster was a part of the disk population that was stripped into the halo during the interactions with M81.

4. Conclusions
In this study, we examine the stellar content including the resolved halo stars and globular clusters in the galaxy M82. The stellar populations in M82 show typical characteristics of a disk galaxy with some peculiarities which can be related to the recent encounter with its larger companion, M81.

The old stars in the halo of M82 do not show a concentration or a spatial variation in metallicities. This is typical for a disk galaxy despite M82 being embedded within an interacting system of galaxies. However, the same is not true for its young stellar population. In typical disk galaxies, young stars cannot be found in their halos. However, the halo of M82 contains some young stars especially in the concentration in its southern halo. These young stars were likely to be formed due to the recent interactions from the stripped gas content.

Most of the halo globular clusters in M82 are old and metal-poor, with no radial metallicity gradient, similar to those of M81 and the Milky Way. This is also consistent with M82 being
a disk galaxy, contradicts the scenario where M82 is a nearby galaxy in formation discussed by [6]. However, there is also a metal-rich globular cluster in the halo of M82 which is unusual for a disk galaxy. This metal-rich globular cluster was suspected to be stripped out of the inner region of the galaxy due to the interaction. The situation is consistent with the origin of the young stars in the southern concentration. In summary, our analysis shows that while the old stellar population of M82 shows typical characteristics of a disk galaxy, while its young population and a metal-rich globular cluster show a sign of disruption by the recent interaction with its companion.

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