Distances to 18 Dwarf Galaxies from the Arecibo Survey

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Abstract—Based on archival Hubble Space Telescope images, we have performed stellar photometry for 18 dwarf galaxies. Branches of young and old stars are seen on the constructed Hertzsprung–Russell diagrams. Using the photometry of red giants and applying the TRGB method, we have determined accurate distances for all 18 galaxies for the first time. The galaxies AGC 238890 and AGC 747826 have minimum ($D = 5.1$ Mpc) and maximum ($D = 12.0$ Mpc) distances, respectively. The distances to the remaining galaxies lie within this range. Low-metallicity galaxies have been identified by measuring the color indices of the red giant branch: AGC 102728, AGC 198691, AGC 205590, AGC 223231, AGC 731921, and AGC 747826. We have determined the distance to AGC 198691 with a record low metallicity. Since AGC 223254, AGC 229053, AGC 229379, AGC 238890, AGC 731921, and AGC 742601 are projected onto the Virgo cluster of galaxies, the distances estimated by us together with the velocities of these galaxies measured previously at Arecibo can be used to refine the effect of galaxy infall to the Virgo cluster.

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INTRODUCTION

A catalog of almost 16,000 objects, for which the coordinates, H I fluxes, radial velocities, and H I line widths were measured, was produced while conducting the ALFALFA survey (Giovanelli et al. 2005; Haynes et al. 2011) at the Arecibo radio telescope. In addition, these radio sources were identified with optical counterparts from SDSS (Sloan Digital Sky Survey). Most objects of the catalog turned out to be extragalactic sources, many of which are identified with dwarf galaxies. Some objects, probable galaxies, were visible in the radio band, but were absent in optical sky surveys. These were assumed to be the so-called dark galaxies, i.e., galaxies where star formation has not yet begun or proceeds very slowly. Such galaxies have a very low surface brightness and, therefore, are absent in optical surveys, but they are detected with confidence at the radio telescope (Janowiecki et al. 2015).

Radio observations allow the dwarf population of the Local Group or nearby groups of galaxies to be found in their neighborhoods (Cannon et al. 2011), which can change significantly the form of the luminosity function for the galaxy groups in the segment of their low-mass members. The dwarf galaxies containing hydrogen and located far from neighboring galaxies arouse special interest. The evolution in such galaxies occurs without any extraneous influence, and this allows the factors that trigger the star formation processes in these galaxies to be studied.

However, the radio data alone are not enough to study the nature of the galaxies. To calculate the galaxy masses or to determine the existence of neighbors, we need to know accurate distances to the galaxies by invoking optical observations for this purpose. The TRGB method (Lee et al. 1993), which is based on measuring the position of the tip of the red giant branch, is most accurate and popular. We used this method to determine the distances to 18 galaxies whose images were obtained with the Hubble Space Telescope (HST) in 2015, but their distances were not determined.

stellar photometry

HST ACS/WFC images were obtained on proposal ID 13750 (J. Cannon) in the F814W and F606W filters with exposure times of 2648 and 2510 s. Additional HST WFC3 images in the F814W and F606W filters with exposure times of 18618
Fig. 1. HST ACS/WFC images of the galaxies. The sizes of each image are 1.0′ × 1.0′. A large difference between the galaxy sizes is clearly seen.

and 15018 s were obtained on proposal ID 15243 (K. McQuinn) for AGC 198691, which turned out to be a dwarf galaxy with a very low luminosity (Hirschauer et al. 2016).

The averaged images of the galaxies with the F814W and F606W filters are presented in Fig. 1. All images are presented on the same scale, which clearly shows a variety of linear sizes and masses of the investigated galaxies, even despite the difference in the distances to these galaxies. AGC 198691, the smallest one among the 18 galaxies, has a size of 0.43 kpc, while AGC 731921 is almost 10 times larger, 3.4 kpc. The linear sizes of the galaxies were estimated from the distribution of red giants along their radius. The exponential distribution of red giants is represented by a linear function on a logarithmic scale, which allows the limiting radius at which the distribution of red giants merges with the background consisting of distant galaxies and CCD noise to be established quite accurately.

The stellar photometry of all galaxies was performed with two software packages: DAOPHOT II (Stetson 1987, 1994) and DOLPHOT 2.0 (Dolphin 2016). The stellar photometry in DAOPHOT II was carried out in a standard way, as we described previously (Tikhonov et al. 2009), while the calibrations were obtained on the basis of stellar photometry with different detectors and at different telescopes (Tikhonov and Galazutdinova 2009). The results of our stellar photometry were subjected to selection by the CHI and SHARP parameters, which define

\[ \text{http://americano.dolphinsim.com/dolphot/dolphot.pdf} \]
the photometric profile shape for each measured star (Stetson 1987). This allowed us to remove all diffuse objects (star clusters, distant or compact galaxies) from the photometry tables, because the photometric profiles of these objects differed from those of the isolated stars that we chose as standard ones.

The DOLPHOT 2.0 package was used in accordance with Dolphin’s recommendations, while the photometry procedure consisted of bad pixel pre-masking, cosmic-ray particle hit removal, and further PSF photometry for the stars found in two filters. The selection of our list of stars by the CHI and SHARP image profile parameters was made in the same way as in DAOPHOT II.

The principles of DOLPHOT and DAOPHOT photometry are the same, but there are some differences in using them. For example, we used stars in the images of the investigated galaxies as PSF stars in DAOPHOT, while a library of PSF profiles was used in DOLPHOT. A difference between the results of the two codes is seen when comparing the apparent distributions of very faint stars over the image field. Because of the charge transfer inefficiency and the existence of residual cosmic-ray particle hits, DOLPHOT shows an excessive number of faint stars in the central region of the field instead of their even distribution, while the distribution of stars in DAOPHOT is closer to the real one. However, the problem of choosing normal PSF stars arises in DAOPHOT because of the appearance of “tails” due to the charge transfer inefficiency. Bearing in mind the pluses and minuses of the two software packages, we used them both by comparing the results obtained. Since we used stars brighter than the photometric limit of the images by two or more magnitudes for our measurements of the TRGB jumps
and stellar metallicity, both methods yielded similar results and no significant differences between them were found.

The Hertzsprung–Russell diagrams (color–magnitude (CM) diagrams) for the 18 galaxies constructed from our stellar photometry are presented in Fig. 2. The horizontal lines mark the TRGB jumps, i.e., the TRGB positions that we used to determine the distances to the galaxies.

**DISTANCE MEASUREMENTS**

The intensive use of red giants to determine the distances to galaxies by the TRGB method was begun after the work by Lee et al. (1993), and by now accurate distances to several hundred galaxies have been measured by this method. As any distance measurement method, the TRGB method has its difficulties of application. A small number of red giants in a galaxy on the constructed CM diagram or an insufficient photometric limit of its images lead to great uncertainties in measuring the position of the TRGB jump and, hence, to a low accuracy in measuring the distance to the galaxy. Furthermore, the fact that a charge transfer inefficiency appeared in the ACS/WFC CCD arrays in the time of their operation under cosmic radiation conditions (Anderson and Bedin 2010; Massey et al. 2010; Tikhonov and Galazutdinova 2016), which becomes progressively larger from year to year, should be taken into account. The central part of the ACS/WFC CCD field became virtually unsuitable for accurate photometric measurements due to this effect. Bearing this in mind,
we did not use the central part of the ACS/WFC field with $1200 < Y < 3000$ pix where this was possible. Apart from red giants, there are brighter asymptotic giant branch (AGB) stars in each galaxy, which smear the TRGB jump on the CM diagram and make it difficult to measure the distance. Since the red giants and AGB stars have different number density gradients along the galactic radius (Tikhonov 2005, 2006), we can reduce the number of AGB stars in the sample using only the galactic periphery for our measurements, which allows the position of the TRGB jump to be measured more accurately.

For most galaxies the TRGB is seen on the CM diagrams quite clearly, but for several galaxies this position is not obvious. For these galaxies Fig. 3 presents the luminosity functions of red giants and AGB stars. We used samples of stars on the periphery of the galaxies to construct these luminosity functions. There are no bright supergiants in such a sample, and the number of undesirable AGB stars is reduced significantly. The thin line on the luminosity function of each galaxy (Fig. 3) indicates the Sobel function (Madore and Fridman 1995) whose maxima correspond to abrupt changes in the number of stars, which is observed at the RGB boundary and is defined as the TRGB jump.

In the galaxies where the RGB is clearly seen, the selection by CHI, SH, and CCD coordinates $Y > 3000$ was sufficient to determine the TRGB jump. These selections turned out to be insufficient for the remote galaxies, and additional selections were applied. The stars in the central parts of the galaxies were removed, which increased the percentage of red giants in such a sample. In addition, we made the selection by color, usually $1.0 < (V-I) < 1.7$, which eliminated the main-sequence stars and the

![Fig. 2. (Contd.)](image-url)
AGB stars with a large color index in the sample. Since we studied the dwarf galaxies where sparsely populated RGBs are visible, a difference by ten stars per each bin of the luminosity function was enough for the TRGB jump to be clearly seen. The actual position of the TRGB jump was checked by examining the available luminosity function in logarithmic coordinates of the number of stars. As a rule, a break at the point of the TRGB jump is seen on the luminosity function, which validated the choice.

When determining the distances, we measured the positions of the TRGB jumps as well as the TRGB colors \((V-I)_{TRGB}\) and RGB colors \((V-I)_{-3.5}\) at \(M_I = -3.5\). Using these quantities in Eqs. (1)–(5) from Lee et al. (1993), we determined the metallicities of red giants and the distance moduli for the galaxies.

The distance modulus of a galaxy is defined as the difference between the apparent and absolute magnitudes of its stars:

\[
(m - M) = I_{TRGB} - M_I. \tag{1}
\]

The absolute magnitude is the difference between the bolometric magnitude and the bolometric correction for the stellar temperature:

\[
M_I = M_{bol} - BC_I. \tag{2}
\]

In turn, these quantities are determined from the following equations:

\[
BC_I = 0.881 - 0.243(V - I)_{TRGB}, \tag{3}
\]

\[
M_{bol} = -0.19[Fe/H] - 3.81. \tag{4}
\]

The stellar metallicity needed for our calculations can be found from the equation

\[
[Fe/H] = -12.64 + 12.6(V - I)_{-3.5} - 3.3(V - I)^2_{-3.5}. \tag{5}
\]
The extinction toward each galaxy was taken from Schlaufy and Finkbeiner (2011). Our results are presented in Table 1, where $\alpha$ and $\delta$ are the right ascension and declination of each galaxy, $I_{\text{TRGB}}$ is the position of the TRGB jump on the luminosity function in the $I$ band, $A_V$ is the extinction in the $V$ band in magnitudes, $(m-M)$ is the distance modulus, $[\text{Fe}/\text{H}]$ is the metallicity of red giants on the galactic periphery, $D$ is the distance to the galaxy in Mpc, $\Delta D$ is the external distance measurement accuracy, and $\Delta_{M87\text{--galaxy}}$ is the angular distance (in deg) from the galaxy to M87, the central galaxy of the Virgo cluster.

The accuracy of the distance is individual for each galaxy. However, all galaxies can be arbitrarily divided into two groups by the distance measurement accuracy. The first group includes most of the galaxies where the RGB is clearly seen and the position of the TRGB jump is determined with an accuracy of $0.02^m - 0.03^m$. For these galaxies the internal accuracy is $0.2$ Mpc. To determine the external accuracy, we should take into account the accuracy of the TRGB method itself, which is $0.1^m$. Given the accuracy of other quantities, the external accuracy of the distances for such galaxies will be $0.4 - 0.5$ Mpc. For the galaxies where the RGB is seen more poorly (Fig. 3), the accuracy of measuring the TRGB jump is $0.04^m - 0.06^m$. For these galaxies the internal accuracy is $0.3 - 0.4$ Mpc, while the external accuracy is $0.7 - 0.8$ Mpc. For each galaxy Table 1 gives the external distance measurement accuracy determined from the width of the peak of the Sobel function, the accuracy of our photometry for PSF stars, and the accuracy of the TRGB method itself.

For the galaxy AGC 198691, in which Hirschauer et al. (2016) obtained a record low luminosity, the applicants of the observing program failed to measure the distance from the ACS images (ID 13750). Therefore, McQuinn obtained deeper WFC3 images for it (ID 15243). We processed these additional images (Fig. 4) by the above technique and presented the CM diagram and the luminosity function with the marked position of the TRGB jump in Fig. 5. The distance estimated from the WFC3 images corresponds to the distance estimated from the ACS images.

**CLOSE NEIGHBORS**

The HST image size is $3.5'$. For a galaxy at a distance of 10 Mpc this corresponds to 10 kpc. If there is a neighboring galaxy at a distance less than 5 kpc near an AGC galaxy, then it will be seen in the same
Table 1. Parameters of the 18 AGC galaxies

| N  | AGC  | α, deg | δ, deg | \(I_{\text{TRGB}}\) | \(A_V\) | \((m - M)\) | [Fe/H] | \(D\) | \(\Delta D\) | \(\Delta M_{87 - \text{galaxy}}\) |
|----|------|--------|--------|----------------|--------|-------------|--------|------|-----------|----------------|
| 01 | 102728 | 00 00 21.42 | +31 01 18.7 | 25.94 | 0.126 | 29.73 | -2.77 | 08.84 | 0.68 | 136 |
| 02 | 123352 | 02 48 39.19 | +23 16 27.1 | 26.07 | 0.678 | 29.64 | -2.18 | 08.47 | 0.65 | 131 |
| 03 | 198507 | 09 15 25.79 | +25 25 10.4 | 26.45 | 0.090 | 30.37 | -2.19 | 11.85 | 0.85 | 48 |
| 04 | 198508 | 09 22 56.97 | +24 56 48.5 | 26.20 | 0.098 | 30.09 | -2.22 | 09.97 | 0.70 | 46 |
| 05 | 198691 | 09 43 32.40 | +33 26 58.2 | 25.90 | 0.038 | 29.74 | -2.88 | 08.88 | 0.75 | 44 |
| 06 | 200232 | 10 17 26.50 | +29 22 11.0 | 26.07 | 0.082 | 30.01 | -1.80 | 10.06 | 0.72 | 35 |
| 07 | 205590 | 10 00 36.56 | +30 32 10.1 | 25.95 | 0.051 | 29.85 | -2.23 | 09.34 | 0.68 | 39 |
| 08 | 223231 | 12 22 52.68 | +33 49 44.4 | 25.37 | 0.035 | 29.26 | -2.46 | 07.13 | 0.46 | 22 |
| 09 | 223254 | 12 28 05.07 | +22 17 28.2 | 25.00 | 0.057 | 28.94 | -1.96 | 06.15 | 0.40 | 10 |
| 10 | 229053 | 12 18 15.49 | +25 34 05.1 | 26.23 | 0.049 | 30.21 | -1.84 | 11.02 | 0.82 | 14 |
| 11 | 229379 | 12 30 34.01 | +23 12 20.2 | 25.12 | 0.075 | 29.03 | -2.18 | 06.40 | 0.41 | 11 |
| 12 | 238890 | 13 32 30.35 | +25 07 24.5 | 24.47 | 0.036 | 28.53 | -1.22 | 05.08 | 0.37 | 19 |
| 13 | 731448 | 10 23 44.97 | +27 06 39.8 | 25.96 | 0.077 | 29.94 | -1.61 | 09.73 | 0.70 | 33 |
| 14 | 731921 | 12 05 34.27 | +28 13 56.2 | 26.07 | 0.057 | 29.98 | -2.23 | 09.89 | 0.72 | 17 |
| 15 | 739005 | 09 13 38.98 | +19 37 07.8 | 25.55 | 0.121 | 29.47 | -1.80 | 07.83 | 0.50 | 48 |
| 16 | 740112 | 10 49 55.40 | +23 04 06.2 | 26.04 | 0.122 | 29.98 | -1.61 | 09.90 | 0.70 | 26 |
| 17 | 742601 | 12 49 36.87 | +21 55 05.6 | 25.03 | 0.095 | 29.00 | -1.60 | 06.31 | 0.40 | 11 |
| 18 | 747826 | 12 07 49.99 | +31 33 07.9 | 26.48 | 0.055 | 30.40 | -2.16 | 12.01 | 0.87 | 20 |

AGC 198507 has such a neighbor, where a dwarf galaxy that may be called AGC 198507A (Fig. 1) is seen at a distance of 30′′ (corresponding to 1.8 kpc). This galaxy contains few stars, but we were able to measure the position of the TRGB jump and to determine that the distance to this galaxy is equal, within the measurement error limits, to the distance to the main AGC 198507. Thus, these galaxies constitute a physical pair. The asymmetry in the shapes of these galaxies can possibly be explained by their interaction.

Two centers are observed in the apparent distribution of AGC 739005 stars. This is particularly clearly seen in the distribution of young stars, red supergiants. Based on the apparent morphology, AGC 739005 can be represented as two galaxies spaced 0.73 kpc apart one of which is a symmetric Sph/Irr galaxy and the other one is irregular. Since two concentration centers of stars are also seen in the distribution of red giants (Fig. 6), one of which corresponds to AGC 739005A, this satellite cannot be a star-forming region, but is a dwarf irregular galaxy with young and old stellar populations and a very low stellar metallicity.

AGC 198508 has an approximately similar shape, where a star-forming region or a small galaxy is located at the edge of the galaxy. It is impossible to check this based on the available results. Likewise, in AGC 731921 a star-forming region or a very small galaxy is projected onto the body of the galaxy. It is
impossible to draw any conclusions due to the small number of stars.

Several galaxies (AGC 102728, AGC 123352, AGC 229379, and AGC 229053) have an asymmetric shape that could be explained by the interaction with neighbors, but no galaxies with similar distances are observed nearby.

POSSIBLE NEIGHBORING GALAXIES

Searching for neighboring galaxies seems a separate big work to us. Therefore, we will touch on this complex issue only briefly. All of the AGC galaxies investigated by us have low masses and can enter into galaxy groups as dwarf members. If we assume that the radius of a galaxy group can be 0.5 Mpc, then bright galaxies forming groups, which can include AGC galaxies, should be searched for within this radius. For a distance of 10 Mpc a radius of 0.5 Mpc corresponds to 2.9°. For closer groups this size is even larger. Dozens of galaxies with velocities less than 1000 km s\(^{-1}\) that are located within this radius around each AGC galaxy from our list can be found in
Table 2. Possible neighbors to the 18 AGC galaxies

| N  | Galaxy name                  | α, deg | δ, deg | \(v_h\), km s\(^{-1}\) | \(R\), arcmin | \(D\), Mpc | Distance determination method |
|----|-----------------------------|--------|--------|------------------------|--------------|----------|--------------------------------|
| 01 | AGC 102728                  | 0.088333 | 31.01056 | 566                    | 08.84        | TRGB*   |
| 02 | AGC 123352                  | 42.147500 | 23.27278 | 467                    | 08.47        | TRGB*   |
| 03 | SDSS J091815.92+260841.2    | 139.566370 | 26.14481 | 515                    | 58           | –       |
| 04 | AGC 198508                  | 140.739583 | 24.94750 | 519                    | 09.97        | TRGB*   |
| 05 | AGC 198691                  | 145.888750 | 33.45333 | 514                    | 08.88        | TRGB*   |
| 06 | UGC 05186                   | 145.753333 | 33.26306 | 549                    | 13           | 8.31    | TF[1]                          |
| 07 | SDSS J101902.38+284321.5    | 154.759941 | 28.72267 | 305                    | 44           | –       |
| 08 | AGC 200232                  | 150.144167 | 30.53917 | 494                    | 09.34        | TRGB*   |
| 09 | AGC 205590                  | 149.899577 | 30.81266 | 651                    | 21           | –       |
| 10 | UGC 5340(DDO68)             | 149.195417 | 28.82556 | 507                    | 114          | 12.00   | TRGB[2]                        |
|    | UGC 5427                    | 151.168750 | 29.36389 | 494                    | 88           | 11.29   | TRGB[5]                        |
|    | UGC 5272                    | 147.595000 | 31.48583 | 520                    | 143          | 7.11    | BS[7]                          |
|    | UGC 7427                    | 185.719583 | 33.83111 | 571                    | 07.13        | TRGB*   |
|    | AGC 223231                  | 185.477917 | 35.05056 | 725                    | 74           | –       |
| 11 | AGC 223254                  | 187.022083 | 22.28889 | 603                    | 06.15        | TRGB*   |
|    | UGC 7584                    | 187.017083 | 22.58694 | 602                    | 18           | 9.20    | TF[1]                          |
|    | NGC 4455                    | 187.185417 | 22.82167 | 643                    | 34           | 6.70–12.50 | TF[1, 6, 9–16]               |
| 12 | AGC 229053                  | 184.563750 | 25.57139 | 425                    | 06.40        | TRGB*   |
|    | AGC 229100                  | 185.129150 | 25.37056 | 221                    | 33           | –       |
|    | SDSS J121531.12+253944.4    | 183.879686 | 25.66236 | 226                    | 37           | –       |
|    | SDSS J121934.24+262531.5    | 184.892677 | 26.42542 | 242                    | 54           | –       |
|    | AGC 229379                  | 187.662917 | 23.20000 | 624                    | 11.02        | TRGB*   |
|    | NGC 4455                    | 187.185417 | 22.82167 | 643                    | 34           | 6.70–12.50 | TF[1, 6, 9–16]               |
|    | UGC 7584                    | 187.017083 | 22.58694 | 602                    | 18           | 9.20    | TF[1]                          |
|    | AGC 229053                  | 184.563750 | 25.57139 | 425                    | 06.40        | TRGB*   |
| 12 | AGC 229100                  | 185.129150 | 25.37056 | 221                    | 33           | –       |
| 13 | SDSS J121531.12+253944.4    | 183.879686 | 25.66236 | 226                    | 37           | –       |
| 14 | SDSS J121934.24+262531.5    | 184.892677 | 26.42542 | 242                    | 54           | –       |
| 15 | AGC 229379                  | 187.662917 | 23.20000 | 624                    | 11.02        | TRGB*   |
| 16 | NGC 4455                    | 187.185417 | 22.82167 | 643                    | 34           | 6.70–12.50 | TF[1, 6, 9–16]               |
| 17 | UGC 7584                    | 187.017083 | 22.58694 | 602                    | 18           | 9.20    | TF[1]                          |
| 18 | AGC 229053                  | 184.563750 | 25.57139 | 425                    | 06.40        | TRGB*   |
Table 2. (Contd.)

| N  | Galaxy name                  | α, deg   | δ, deg   | \(v_h\), km s\(^{-1}\) | \(R\), arcmin | \(D\), Mpc | Distance determination method |
|----|------------------------------|----------|----------|--------------------------|---------------|-----------|-----------------------------|
| 12 | AGC 238890                   | 203.134583 | 25.11417 | 360                      | 05.08         | TRGB*    |                             |
|    | SDSS J133130.60+242313.3     | 202.877519 | 24.38705 | 335                      | 46            | –         |                             |
|    | SDSS J132959.46+243140.9     | 202.497765 | 24.52804 | 227                      | 49            | –         |                             |
|    | UGC 8638                     | 204.834167 | 24.77000 | 274                      | 95            | 4.03      | TRGB [5]                     |
|    |                              |          |          |                          |               | 4.29      | TRGB [15]                    |
|    |                              |          |          |                          |               | 4.29      | TRGB [6, 18]                 |
|    |                              |          |          |                          |               | 2.30      | BS [19]                      |
| 13 | AGC 731448                   | 155.938750 | 27.11806 | 517                      | 09.73         | TRGB*    |                             |
|    | SDSS J102746.49+272030.9     | 156.943724 | 27.34195 | 377                      | 55            | –         |                             |
| 14 | AGC 731921                   | 181.386250 | 28.23250 | 505                      | 09.89         | TRGB*    |                             |
|    | AGC 220071                   | 181.350833 | 28.36750 | 565                      | 8             | –         |                             |
| 15 | AGC 739005                   | 138.409583 | 19.61889 | 429                      | 07.83         | TRGB*    |                             |
|    | 2MASS J09124191+1928561      | 138.174618 | 19.48237 | 348                      | 16            | –         |                             |
|    | SDSS J091558.74+193914.1     | 138.994769 | 19.65395 | 377                      | 33            | –         |                             |
|    | SDSS J091056.45+194931.9     | 137.735219 | 19.82554 | 342                      | 40            | –         |                             |
| 16 | AGC 740112                   | 162.477083 | 23.09000 | 609                      | 09.90         | TRGB*    |                             |
|    | SDSS J104825.55+232323.3     | 162.106467 | 23.38982 | 796                      | 28            | –         |                             |
|    | SDSS J105230.99+230005.0     | 163.129177 | 23.00141 | 783                      | 36            | –         |                             |
|    | NGC 3344                     | 160.879167 | 24.92056 | 588                      | 141           | 9.82      | TRGB [6]                     |
|    |                              |          |          |                          |               | 6.10–9.91 | TF [9, 20]                   |
| 17 | AGC 742601                   | 192.400833 | 21.91806 | 539                      | 06.31         | TRGB*    |                             |
|    | IC 3840                      | 192.942362 | 21.73640 | 583                      | 32            | 5.50      | TF [1]                      |
|    | UGC 08011                    | 193.096250 | 21.63056 | 765                      | 42            | 21.40     | TF [9]                      |
| 18 | AGC 747826                   | 181.965833 | 31.55444 | 558                      | 12.01         | TRGB*    |                             |
|    | SDSS J120634.52+312034.7     | 181.643833 | 31.34297 | 568                      | 20            | –         |                             |
|    | SDSS J120531.04+310431.1     | 181.379354 | 31.07615 | 569                      | 41            | –         |                             |
|    | NGC 4062                     | 181.021250 | 31.90028 | 766                      | 52            | 9.7–23.0 | TF [6, 9, 10, 12, 13, 20–26]|
|    | IC 2992                      | 181.316250 | 30.85306 | 611                      | 53            | 12.7      | TF [1]                      |

The last column lists the object distance determination methods taken from NED: TRGB—from the tip of the red giant branch, TF—the Tully–Fisher method, BS—from the brightest stars. The coordinates and velocities were taken from the HyperLeda database. For most objects they were determined based on the ALFALFA survey (Haynes et al. 2018). In the absence of an object in the HyperLeda database, we used data from NED.

* The distance was determined in this paper.

[1]—Karachentsev et al. (2013); [2]—Tikhonov et al. (2014); [3]—Sacchi et al. (2016); [4]—Makarov et al. (2017); [5]—Tikhonov (2018); [6]—Tully et al. (2013); [7]—Makarova and Karachentsev (1998); [8]—Schulte-Ladbeck and Hopp (1998); [9]—Tully and Fisher (1988); [10]—Tully et al. (2016); [11]—Springob et al. (2009); [12]—Bottinelli et al. (1985); [13]—Willick et al. (1997); [14]—Yasuda et al. (1997); [15]—Tully et al. (2009); [16]—Nasonova et al. (2011); [17]—Karachentsev et al. (2006); [18]—Jacobs et al. (2009); [19]—Makarova et al. (1998); [20]—Bottinelli et al. (1984); [21]—Aaronson and Mould (1983); [22]—Tully et al. (1992); [23]—de Vaucouleurs et al. (1981); [24]—Sorce et al. (2014); [25]—Theureau et al. (2007); [26]—Ekholm et al. (2000).
Fig. 6. The distribution of young (a) and old (b) stars along the major axis of AGC 739005. The vertical line marks the position of the dwarf satellite near the main galaxy. The concentration centers of red giants and young stars are slightly shifted relative to each other due to the low statistics and the real asymmetry of the star-forming region.

the search databases (NED, HyperLeda), and they can enter into the same groups as the AGC galaxies. Almost all of these galaxies have very small sizes, and there are no distance measurements for them. Among the 18 AGC galaxies, seven lie at an angular distance less than $20^\circ$ from M87, which may be deemed the central galaxy of the Virgo cluster. Therefore, galaxies from the Virgo periphery, whose distances are not yet known or have been measured unreliably, fall within the neighbor search radius. To identify the actual neighbors, we cannot use the radial velocities of these galaxies to determine their distances, because the velocity of a galaxy can change in a wide range due to its motion inside the cluster.

Adams et al. (2015) searched for neighbors near similar AGC galaxies by comparing the radial velocities from the ALFALFA survey. They found the dwarf galaxy AGC 226967 to enter into a system of the same dwarf galaxies, AGC 229490 and AGC 229491, which closely resembles the system AGC 198507 from the list of our galaxies. There are more massive neighbors with similar radial velocities near several AGC galaxies. These galaxies together with the AGC galaxies are probably members of more extended groups. The results of the search for neighbors to galaxies are presented in Table 2, where $v_h$ are the heliocentric velocities of the AGC galaxies taken from HyperLeda, $D$ is the distance to the galaxy, and $R$ is the angular distance to the neighboring galaxy.

CONCLUSIONS

Based on HST images for 18 dwarf galaxies, we constructed the CM diagrams on which both young stars (blue and red supergiants) and an old stellar population (red giants) are seen. For each galaxy we determined the position of the tip of the red giant branch (TRGB jump) and the color index of the RGB. This allowed us to determine the distances to these galaxies and the metallicity of red giants in these galaxies based on the equations from Lee et al. (1993). AGC 102728, AGC 198691, and AGC 223231 have a very low metallicity, with an extremely low metal content in one of the galaxies (AGC 198691) having been determined during spectroscopic observations (Hirschauer et al. 2016).

Star formation processes with different intensities and spatial concentrations of young stars proceed in all galaxies. In most cases, young stars are distributed over the galaxy body, but in some galaxies young stars are concentrated in small star-forming regions. AGC 198507 and AGC 739005 turned out to be binary galaxies, but this result was obtained only due to the neighbors that fell into the HST images being located very closely. It would be impossible to find such galaxies if they were outside the image. The apparent asymmetry of the galaxies can be explained by their interaction with neighbors, but, in many cases, we do not know any neighboring galaxies. Since many faint dwarf galaxies with unknown distances are observed around the galaxies investigated by us, it is possible that close neighbors for the AGC galaxies from our list will be found while obtaining new measurements.
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REFERENCES

1. M. Aaronson and J. Mould, Astrophys. J. 265, 1 (1983).
2. E. A. K. Adams, J. M. Cannon, K. L. Rhode, W. F. Janesh, S. Janowiecki, L. Leisman, R. Giovanelli, M. P. Haynes, et al., Astron. Astrophys. 580, 134 (2015).
3. J. Anderson and L. R. Bedin, Publ. Astron. Soc. Pacif. 122, 1035 (2010).
4. L. Bottinelli, L. Gouguenheim, G. Paturel, and G. de Vaucouleurs, Astron. Astrophys. Suppl. Ser. 56, 381 (1984).
5. L. Bottinelli, L. Gouguenheim, G. Paturel, and G. de Vaucouleurs, Astron. Astrophys. Suppl. Ser. 59, 43 (1985).
6. J. M. Cannon, R. Giovanelli, M. P. Haynes, S. Janowiecki, A. Parker, J. J. Salzer, E. A. K. Adams, E. Engstrom, et al., Astrophys. J. Lett. 739, L22 (2011).
7. A. Dolphin, ascl:1608.013 (2016).
8. T. Ekholm, P. Lanoix, P. Teerikorpi, P. Fouque, and G. Paturel, Astron. Astrophys. 355, 835 (2000).
9. R. Giovanelli, M. P. Haynes, B. R. Kent, P. Perillat, A. Saintonge, N. Brosch, B. Catinella, and G. L. Hoffman, Astron. J. 130, 2598 (2005).
10. M. P. Haynes, R. Giovanelli, A. M. Martin, K. M. Hess, A. Saintonge, E. A. K. Adams, G. Hallenbeck, et al., Astron. J. 142, 170 (2011).
11. M. P. Haynes, R. Giovanelli, B. R. Kent, E. A. K. Adams, T. J. Balonek, D. W. Craig, D. Fertig, et al., Astrophys. J. 861, 49 (2018).
12. A. S. Hirschauer, J. J. Salzer, E. D. Skillman, D. Berg, K. B. W. McQuinn, J. M. Cannon, A. J. R. Gordon, et al., Astrophys. J. 822, 108 (2016).
13. B. A. Jacobs, L. Rizzi, R. B. Tully, E. J. Shaya, D. I. Makarov, and L. Makarova, Astron. J. 138, 332 (2009).
14. S. Janowiecki, L. Leisman, G. Jozsa, J. J. Salzer, M. P. Haynes, R. Giovanelli, K. L. Rhode, et al., Astrophys. J. 801, 96 (2015).
15. I. D. Karachentsev, A. Dolphin, R. B. Tully, M. Sharina, L. Makarova, D. Makarov, V. Karachentseva, S. Sakai, et al., Astron. J. 131, 1361 (2006).
16. I. D. Karachentsev, D. I. Makarov, and E. I. Kaisina, Astron. J. 145, 101 (2013).
17. M. G. Lee, W. L. Freedman, and B. F. Madore, Astrophys. J. 417, 553 (1993).
18. B. Madore and W. Fridman, Astron. J. 109, 1645 (1995).
19. D. I. Makarov, L. N. Makarova, S. A. Pustilnik, and S. B. Borisov, Mon. Not. R. Astron. Soc. 466, 556 (2017).
20. L. N. Makarova and I. D. Karachentsev, Astron. Astrophys. Suppl. Ser. 133, 181 (1998).
21. L. N. Makarova, I. D. Karachentsev, L. O. Takalo, P. Heinaeaeaki, and M. Vallonen, Astron. Astrophys. Suppl. Ser. 128, 459 (1998).
22. R. Massey, G. Strom, A. Leauthaud, J. Rhodes, A. Koekemoer, R. Ellis, and E. Shaghbaouli, Mon. Not. R. Astron. Soc. 401, 371 (2010).
23. O. G. Nasonova, J. A. De Freitas Pacheco, and I. D. Karachentsev, Astron. Astrophys. 532, 104 (2011).
24. E. Sacchi, F. Annibali, M. Cignoni, A. Aloisi, T. Sohn, M. Tosi, R. P. van der Marel, A. J. Grocholski, et al., Astrophys. J. 830, 3 (2016).
25. E. F. Schlaly and D. P. Finkbeiner, Astrophys. J. 737, 103 (2011).
26. R. E. Schulte-Ladbeck and U. Hopp, Astron. J. 116, 2886 (1998).
27. J. G. Sorce, R. B. Tully, H. M. Courtois, T. H. Jarrett, J. D. Neill, and E. J. Shaya, Mon. Not. R. Astron. Soc. 444, 527 (2014).
28. C. M. Springob, K. L. Masters, M. P. Haynes, R. Giovanelli, and C. Marinoni, Astrophys. J. Suppl. Ser. 182, 474 (2009).
29. P. B. Stetson, Publ. Astron. Soc. Pacif. 99, 191 (1987).
30. P. B. Stetson, Publ. Astron. Soc. Pacif. 106, 250 (1994).
31. G. Theureau, M. O. Hanski, N. Coudreau, N. Hallet, and J.-M. Martin, Astron. Astrophys. 465, 71 (2007).
32. A. Tikhonov, Astron. Rep. 49, 501 (2005).
33. A. Tikhonov, Astron. Rep. 50, 517 (2006).
34. A. Tikhonov, Astrophys. Bull. 73, 22 (2018).
35. A. Tikhonov and O. A. Galazutdinova, Astron. Lett. 35, 748 (2009).
36. A. Tikhonov and O. A. Galazutdinova, Astron. Lett. 42, 428 (2016).
37. A. Tikhonov, O. A. Galazutdinova, and E. N. Tikhonov, Astron. Lett. 35, 559 (2009).
38. A. Tikhonov, O. A. Galazutdinova, and V. S. Lebedev, Astron. Lett. 40, 1 (2014).
39. R. B. Tully and J. R. Fisher, Catalog of Nearby Galaxies (Cambridge Univ. Press, Cambridge, UK, 1988), p. 224.

ASTRONOMY LETTERS Vol. 45 No. 11 2019
40. R. B. Tully, E. J. Shaya, and M. J. Pierce, Astrophys. J. Suppl. Ser. 80, 479 (1992).
41. R. B. Tully, L. Rizzi, E. J. Shaya, H. M. Courtois, D. I. Makarov, and B. A. Jacobs, Astron. J. 138, 323 (2009).
42. R. B. Tully, H. M. Courtois, A. E. Dolphin, J. R. Fisher, P. Heraudeau, B. A. Jacobs, I. D. Karachentsev, et al., Astron. J. 146, 86 (2013).
43. R. B. Tully, H. M. Courtois, and J. G. Sorce, Astron. J. 152, 50 (2016).
44. G. de Vaucouleurs, W. L. Peters, L. Bottinelli, L. Gouguenheim, and G. Paturel, Astrophys. J. 248, 408 (1981).
45. J. A. Willick, S. Courteau, S. M. Faber, D. Burstein, A. Dekel, and M. A. Strauss, Astroph. J. Suppl. Ser. 109, 333 (1997).
46. N. Yasuda, M. Fukugita, and S. Okamura, Astrophys. J. Suppl. Ser. 108, 417 (1997).

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