The distance to the irregular galaxy Cassiopeia-1

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INTRODUCTION

Cassiopeia 1 (Cas1) is located in the Milky Way zone and was discovered via radio observations (Huchtmeier et al., 1995). The new galaxy had a low radial velocity of $v_h = 35$ km/s, and the line width in HI ($w_{50} = 49$ km/s) indicated that it was an irregular galaxy. In the images from the 1m Zeiss-1000 telescope and the 6m BTA obtained at SAO RAS, Cas1 was resolved to stars, which allowed Tikhonov (1996) to estimate the distance (D = 790 kpc) to Cas1 and the value of light absorption ($A_V = 4.0$) using the brightest stars method. From the 6m BTA images, Karachentsev et al. (1997) estimated the value of light absorption as $A_V = 4.16$, and the distance D = 1.7 Mpc. Weinberger & Saurer (1998) measured the value of light absorption as $A_V = 2.5$, and the distance to Cas1 D = 3 Mpc. Marvel & Wilcots (2000) believed that Cas1 was at a distance of 4.5 Mpc. At present, the absorption of light in the direction on Cas1 is taken as $A_V = 2.79$ (Schlafly & Finkbeiner, 2011); in the SAO RAS database for local-area galaxies, D is indicated as 5.27 Mpc*.

PHOTOMETRY OF STARS

In 1999, the images of Cas1 (ID 8192) with a WFPC2 camera in F606W (600 s) and F814W (600 s) filters were taken on the Hubble Space Telescope. The indicated images, with markings of visible star complexes, are presented in Fig. 1 and Fig. 2. Some complexes are identified with HII areas*, which indicates their youth.

Stellar photometry was carried out in a standard way using the DAOPHOT II package (Stetson, 1994). The results obtained are presented in Fig. 3, as a Hertzsprung-Ressel diagram (CM-diagram). The diagram shows a band of background stars, a branch of blue supergiants shifted by $1.^m4$, and a branch of red stars formed by red supergiants and AGB stars. The branch of red giants, which is necessary for measuring the distance, is not visible on the CM diagram, since the brighter AGB stars mask it.

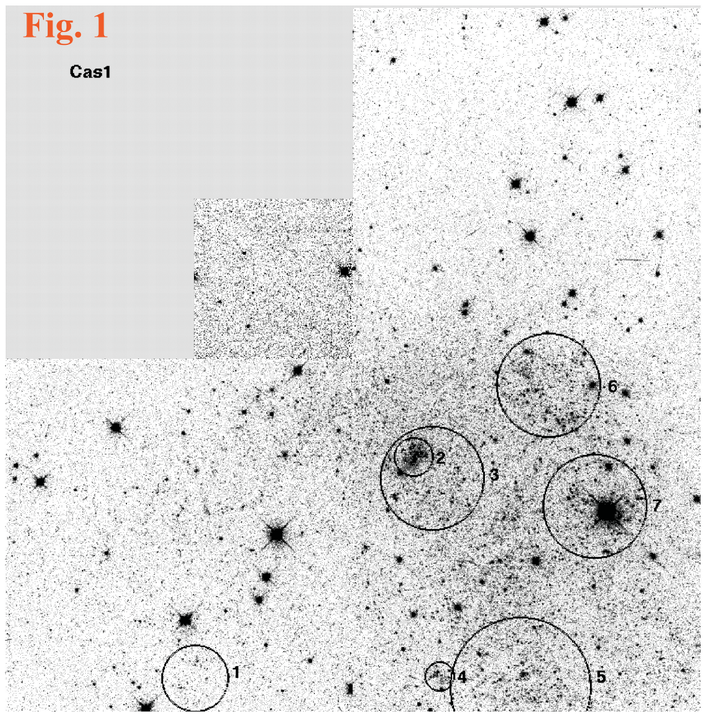

Fig1. Cassiopeia 1 on the WFPC2 image of the Hubble Space Telescope. Star complexes containing young stars are marked with circles. Image size 2.5′ ′ 2.5′.

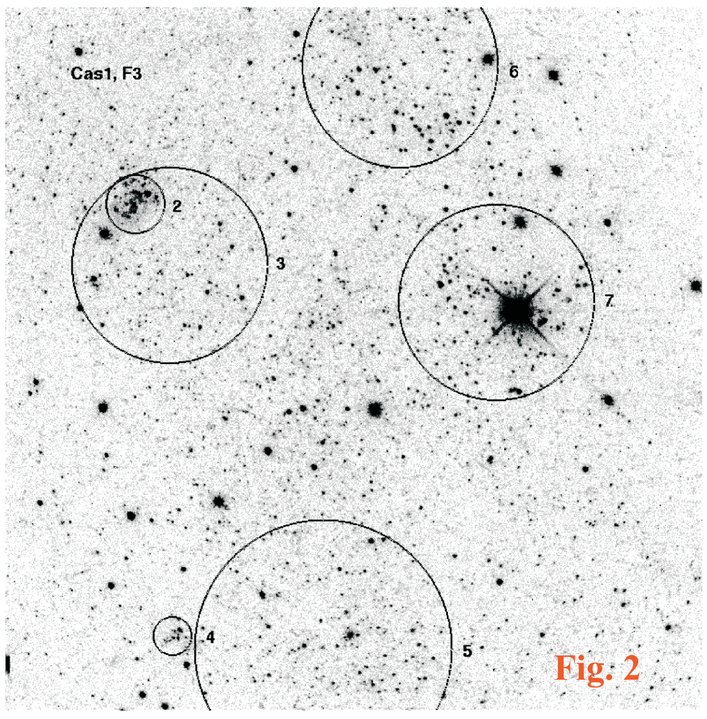

Fig 2. Central part of Cas1. The concentration of stars in star complexes is clearly visible. Image size 1.3′ ′ 1.3′

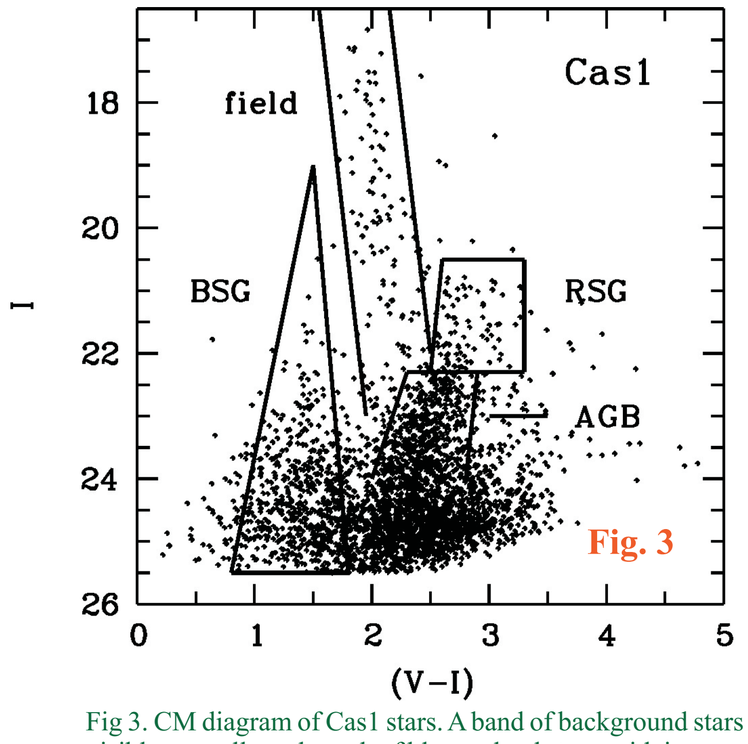

Fig 3. CM diagram of Cas1 stars. A band of background stars is visible, as well as a branch of blue and red stars, with increased color indices due to reddening of the light on the dust-gas clouds of the Galaxy.

DETERMINATION OF THE DISTANCE

Initially, it is necessary to find out which types of stars are visible on the CM diagram. The branch of stars with $(V\ \ I) = 1.^m4$ can be identified with the branch of the reddened blue supergiants. The branch of red stars with $(V\ \ I) = 2.^m5$ is clearly divided into two parts, with the boundary at $I = 22.^m2$.

Each type of star has a characteristic form of distribution over the galactic body. Blue stars are mostly included in the star complexes (Fig. 4), i.e. they are blue supergiants (BSG). The distribution of bright red stars with $I < 22.^m2$ is also shown in Fig.4. The concentration of these stars is noticeable only in two complexes, while in the remaining complexes there's only few of them or none at all. The difference is due to insufficient statistics and the age difference of the complexes. The concentration of bright red stars in complexes where there are blue supergiants means that the age of red stars is slightly different from the age of blue supergiants, that is, they can only be red supergiants. Hence, red stars weaker than $I = 22.^m2$ must be AGB stars. There is a relationship between the age of AGB stars and their luminosity: the smaller the luminosity of AGB stars, the greater their age.

Since the type of distribution of stars over the galactic body depends on their age, we divide the branch of the supposed AGB stars into two parts according to their luminosity and consider the type of distribution of each sample. Fig. 5 shows that the brighter (younger) stars are concentrated near the star complexes, while the weaker (older) ones are concentrated in the center of the galaxy. The form of the distribution of stars in Fig. 5 proves that the branch of red stars from $I > 22.^m2$ cannot be a branch of red giants whose distribution forms a disk.

To determine the distance, it is necessary to find the TRGB-jump which corresponds to the beginning of the branch of red giants. In order to increase the content of red giants in the sample, we will select stars according to the color index ($2.^m0 < (V\ \ I) < 2.^m8$). The resulting luminosity function is shown in Fig. 6 (left). The diagram shows the beginning of the AGB branch of stars at $I = 22.^m2$, and the TRGB jump is almost invisible. In order to reduce the content of AGB stars in the sample, we will conduct the second selection and leave the stars only on the periphery of the galaxy. The luminosity function after this selection is shown in Figure 6 (right). In this diagram, the TRGB jump of the red giants is clearly visible at $I=23.^m67$.

Having determined position of the TRGB-jump and taking the value of light absorption in the direction of Cas1 $A_V = 2.79$ from Schlafly & Finkbeiner (2011), we calculated the distance to the galaxy Cas1 based on the equation from Lee et al. (1993). The obtained values $(m\ \ M) = 26.^m01$, $D = 1.61$ and $[Fe / H] = 2.77$ indicate that the galaxy Cassiopeia-1 is located near the Local Group of galaxies and has a very low metallicity of stars. In the direction of Cas1 there are no galaxies at the same distance, that is, Cas1 belongs to isolated galaxies and undergoes the evolution without the influence of neighbors.

In the work of Tikhonov (1996) for Cas1, its magnitude is indicated as $V = 14.^m66$. Using the obtained distance, we calculate the absolute luminosity of Cas1: $M_V = 14.^m16$, which corresponds to the apparent morphology of this galaxy.

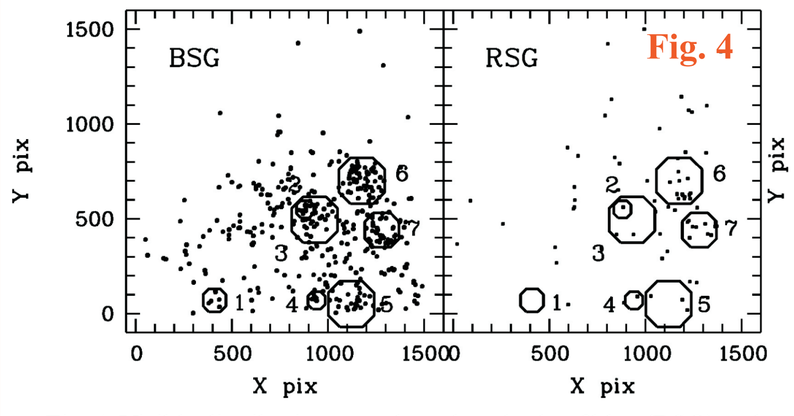

Fig. 4. Visible distribution over the galaxy body of blue (BSG) and red (RSG) supergiants. Star complexes are marked with circles (Fig. 1 and Fig. 2).

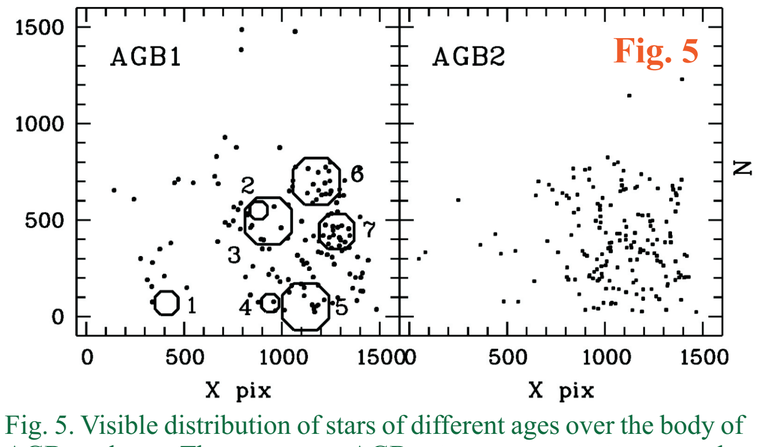

Fig. 5. Visible distribution of stars of different ages over the body of AGB galaxy. The younger AGB stars concentrate near the complexes (AGB1), and the older stars (AGB2) concentrate in the

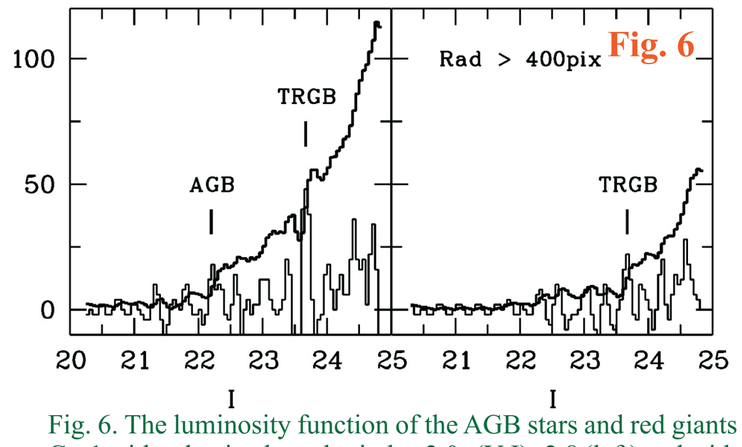

Fig. 6. The luminosity function of the AGB stars and red giants Cas1 with selection by color index 2.0<(V-I)<2.8 (left) and with additional selection along the galaxy radius (right).

CONCLUSIONS

Based on archival images from the Hubble Space Telescope, stellar photometry of the Cassiopeia-1 dwarf galaxy was carried out. On the obtained CM-diagram, various types of stars are highlighted and their distributions in the galaxy are studied. On the basis of TRGB-method, the exact distance (D = 1.61 Mpc) to Cas1 was first determined, which shows that it is located on the border of the Local Group of galaxies and is isolated. Measurements showed very low metallicity of Cas1 stars, i.e. despite the star formation processes, the accumulation of metals in Cas1 occurs very slowly.

*http://www.sao.ru/lv/ lvgdb /

Weinberger R. & Saurer W., A&A, 332, 523 (1998)
Karachentsev I. et al., A&AS, 124, 559 (1997)
Lee M.G., Freedman W.L. & Madore B.F., ApJ, 417, 553 (1993)
Marvel K.B. & Wilcots E.M., AJ, 120, 2038 (2000)
Stetson P.B., PASP, 106, 250 (1994)
Tikhonov N., Astron. Nachr., 317, 175 (1996)
Huchtmeier W.K. et al., A&AL, 293, L33 (1995)
Schlafly E.F. & Finkbeiner D.P., ApJ, 737, 103 (2011)