The Distance to the Galaxy Coma P

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Abstract

If the extremely low surface-brightness galaxy Coma P lies at 5.5 ± 0.3 Mpc, as recently proposed, then it would have an extraordinarily deviant peculiar velocity of ~900 km s⁻¹ at a location where differential velocities between galaxies are low. We have accessed the images from the Hubble Space Telescope (HST) archives used to derive the literature distance from the magnitude of the tip of the red giant branch. Our analysis gives the distance to be 10.9 ± 1.0 Mpc. At this location the galaxy lies within the infall region of the Virgo Cluster, such that its still considerable peculiar velocity of ~500 km s⁻¹ is consistent with an established model. Coma P has an unusually pronounced asymptotic giant branch (AGB) relative to its red giant branch. The dominant stellar population is just a few Gyr old.

Key words: galaxies: distances and redshifts – galaxies: stellar content – Hertzsprung–Russell and C–M diagrams

1. Introduction

Recently, attention has been given to the “almost dark” low surface-brightness galaxy Coma P (AGC 229385 = PGC 5809449). The object was detected as an H1 source in the blind survey of the extragalactic sky ALFALFA (Haynes et al. 2011) with no counterpart in the Sloan Digital Sky Survey (SDSS), but the suggestion of a detection in the Galaxy Evolution Explorer (GALEX) archival images. Subsequently, Janowiecki et al. (2015) identified an extremely low surface-brightness galaxy at the location of the H1 source with the WIYN 3.5 m telescope and resolved the galaxy at H1 with observations using the Westerbork Synthesis Radio Telescope. Ball et al. (2018) obtained kinematic and imaging information at higher resolution with the Very Large Array (VLA). Brunker et al. (2017) reported on optical imaging with Hubble Space Telescope (HST) and gave a distance of 5.5 ± 0.3 Mpc from resolved stars. These various authors discuss the interesting properties of Coma P, some of which depend on the assumed distance. Here we suggest that asymptotic giant branch (AGB) stars have been mistakenly identified as red giant branch (RGB) stars with the result that the distance has been underestimated by roughly a factor of two. The revised distance has important implications for the peculiar velocity of Coma P and intriguing implications regarding the ages of stars in this poorly understood class of galaxies.

Coma P has an extremely precise heliocentric velocity of 1348 ± 1 km s⁻¹ from the H1 observations, which translates to 1296 km s⁻¹ in the Local Sheet frame (the Tully et al. 2008 variation on the Local Group frame) and 1320 km s⁻¹ in the frame of our galaxy (van der Marel et al. 2012). All of the other galaxies in the projected vicinity of Coma P at roughly the Brunker et al. distance of 5.5 Mpc have velocities ~400 km s⁻¹ in accordance with cosmic expansion, with radial dispersions of only 85 km s⁻¹ (Karachentsev et al. 2003). The implied peculiar velocity of the distance is 5.5 Mpc is ~+884 km s⁻¹. This extraordinary situation caught our attention and caused us to re-evaluate the evidence for the distance to Coma P.

2. The Tip of the Red Giant Branch (TRGB) Distance

The TRGB methodology (Lee et al. 1993) based on imaging with HST can regularly give distances with a reliability of 5% for targets within 10 Mpc (Jacobs et al. 2009; Madore et al. 2009; McQuinn et al. 2014; Jang & Lee 2017). In rare cases when the procedure fails badly it is inevitably because the AGB has been mistaken for the RGB (Aloisi et al. 2007).

To investigate the matter, we acquired the HST images for program GO-14108 (PI: J. Salzer) from the Mikulski Archive for Space Telescopes (MAST). Observations were made over two orbits with roughly equal ~2600 s integrations in the F606W and F814W bands using the Advanced Camera for Surveys (ACS). We carried out our standard analysis: stellar photometry using DOLPHOT (Dolphin 2000, 2016), a maximum likelihood determination of the TRGB including recovery of synthetic stars to monitor completion and photometric uncertainties (Makarov et al. 2006), and zero point calibration (Rizzi et al. 2007). Our color–magnitude diagram as reduced by G.A. and L.R. is seen without commentary in the left panel of Figure 1.

The basis for the fit of the TRGB by Brunker et al. (2017) at F814W,TRGB = 24.64 is apparent. On closer inspection, though, it is seen that there is a step toward the increased density of red stars at ~26. We posit that the true TRGB lies near this magnitude and that the red stars brighter than this level are associated with the AGB. We carried out two independent analyses to determine the value of the TRGB, using similar procedures on the same archival data but at two sites. The two determinations are F814W,TRGB = 26.18 ± 0.17 (G.A. and L.R.) and F814W,TRGB = 26.06 ± 0.18 (L.M. and D.M.). The two measures are consistent and we accept the average of F814W,TRGB = 26.12 ± 0.18. Our best fit is illustrated in the right panel of Figure 1. The corresponding distance for the galaxy is 10.9 ± 1.0 Mpc. Photometry files and color–magnitude diagram fits are available at the Extragalactic Distance Database (PGC 5809449). Our assumption resolves

5 http://edd.lifa.hawaii.edu
several outstanding problems but, if correct, implies a numeric ratio of AGB stars to RGB stars that is unfamiliar.

3. Implications for the Peculiar Velocity of Coma P

As mentioned in the Introduction, if Coma P lies at 5.5 Mpc then its systemic velocity would be a great mystery. By contrast, with a distance of 10.9 Mpc its velocity is easily understood. The situation is summarized in Figure 2. Coma P lies at an angle of 8°0 from the center of the Virgo Cluster, or 2°1 beyond the radius of the second turnaround radius that approximates the virial domain of the cluster (Kourkchi & Tully 2017). The details of the velocity field between our position and the Virgo Cluster have recently received extensive attention (Karachentsev et al. 2014, 2018; Shaya et al. 2017). Galaxies in an extended region around the Virgo Cluster have decoupled from cosmic expansion and are falling toward the cluster, inevitably reaching the cluster within a Hubble time. The zero velocity surface that separates infall from expansion is mapped sufficiently enough to know that it is not round: it is slightly squished on the axis at 90° to our line of sight (LOS) to Virgo in the plane of the figure and extended on the axis at 90° out of the page relative to the LOS axis (Shaya et al. 2017). The exact shape of the zero velocity surface is a detail, but rather assuredly Coma P is within this zone.

In the right panel of Figure 2, there is a comparison of the velocity and our two alternative measures of the distance of Coma P with expectation values from the numerical action orbit model of Shaya et al. (2017). Velocities are reported in the rest frame of the center of our galaxy (van der Marel et al. 2012) as necessitated by the numerical action analysis. The velocities of the two measures are offset in the figure for clarity.

Our distance of 10.9 Mpc to Coma P, the average of the two determinations, is consistent with the numerical action model of Shaya et al., especially given that local dispersion in velocities is expected about the mean relation. As an aside, as Coma P is within the Virgo infall domain there are three locations consistent with the observed velocity (Tonry & Davis 1981): a second at roughly the cluster distance, and a third beyond the infall zone on the far side. The properties of the color–magnitude diagram seen in Figure 1 exclude these latter two possibilities.

Two known galaxies with similar velocities lie in close proximity to Coma P (and a third is further removed). NGC 4561 \( (V_{\text{helio}} = 1396 \text{ km s}^{-1}) \) and IC 3605 \( (V_{\text{helio}} = 1362 \text{ km s}^{-1}) \) are considered by Kourkchi & Tully (2017) to be bound in halo 42020 (the Principal Galaxies Catalog identification of NGC 4561) at 1°4 from Coma P (270 kpc in projection at our Coma P distance). Lacking a reliable distance to this pair, Kourkchi & Tully (2017) placed them at a location in the Hubble flow (17.7 Mpc). We predict that these galaxies all have similar distances, such that they lie on the near side of

![Figure 1. Color–magnitude diagram of stars in close proximity of Coma P. Left: uninterpreted. Right: TRGB fit with 1σ uncertainty.](image)
Virgo within the infall domain. The slightly more removed galaxy is AGC 742507 with $V_{\text{helio}} = 1209$ km s$^{-1}$, and is probably in a similar situation.

4. Implications for the Stellar Population of Coma P

Isochrones that stars would lie along at fixed age (Bressan et al. 2012) are plotted on the color–magnitude diagram analyzed by L.M. and D.M. in Figure 3. The isochrone at 16 Myr is speculative; it is motivated by only a few stars that could lie in the foreground. The 50–100 Myr isochrones are better grounded and would source the UV flux detected by GALEX. Most interesting, though, are the 0.5–1 Gyr isochrones that describe the AGB population.

These fits assume metallicity $Z = 0.001$. With this choice, the RGB is bracketed by ages of 1 and 10 Gyr. Given the sparseness of the representation on the RGB, little can be said of metallicity beyond the fact that it is substantially sub-solar.

The ratio of AGB stars to RGB stars is abnormally elevated. In our experience, our only comparable is the dwarf d0959+68 close to M81 (Chiboucas et al. 2013). This object is suspected to be a “tidal” dwarf that has formed out of debris related to the interaction between M81, M82, and NGC 3077. The overwhelming stellar population is suspected to be young. We do not suggest that the situation with Coma P is so extreme. Nevertheless, an elevated ratio of AGB to RGB stars is an indication of substantial star formation within the last few Gyr (Jacobs et al. 2011). The prominence of the AGB in Coma P is so pronounced that an intermediate age population of 0.5 to a few Gyr may be dominant. An ancient population remains to be identified.

5. Discussion

Ball et al. (2018) described the properties of the H I distribution in considerable detail. The H I velocity field is disjointed, as could be explained by the collision between two units. There are enhanced stellar densities near the centroids of the two components seen in the HST images, and implied by the far- and near-UV light in GALEX images. Our revision of the distance to Coma P does not particularly affect the scenario of Ball et al., except in the implication that the system is twice as large. It would lie at the top end in terms of both H I mass and H I diameter within the sample discussed by Ball et al. (2018) in connection with their Figure 16. Perhaps of relevance to the collision idea is the proximity of H I clouds with no revealed optical counterparts. AGC 229384, with a velocity differential of $-34$ km s$^{-1}$, lies 30 kpc away given our distance, and AGC 229383, itself shredded into two parts and with a velocity differential of $-61$ km s$^{-1}$, lies 50 kpc away.

We review properties of Coma P that need to be reconciled. There is no evidence of ongoing star formation, but the UV flux and brightest stars on the main sequence suggest that there was activity as recently as 50 Myr ago. The well-populated AGB indicates that there was substantial star formation 0.5–1 Gyr ago. The relatively impoverished RGB is consistent with the interesting proposition that any earlier star formation was limited. The blue color of the TRGB, combined with
implications of relatively young RGB ages, suggests a low metallicity in Coma P. Plausibly, an episode of star formation was triggered by the merger of two gas clouds with few or no stars, a possibility supported by the morphology and kinematics of the observed neutral hydrogen.

Our revision of the distance to Coma P eliminates the concern regarding its velocity. Even at 10.9 Mpc, the velocity is a substantial excursion from cosmic expansion, but at this distance the system is within the clutches of the Virgo Cluster and its deviant motion is comfortably explained by the detailed flow model of Shaya et al. (2017). The uncertainty in the distance is large (9%) compared to most TRGB determinations (5%) because of the sparseness of the RGB representation. Deeper observations could be made, but at considerable expense. It would be more fruitful to obtain distances to either or both of the near neighbors in projection and velocity, NGC 4561 and IC 3605. We predict that they, too, will be at distances of ~11 Mpc.

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