The AGB populations of Local Group galaxies

W. Nowotny, F. Kerschbaum

Institut für Astronomie der Universität Wien, Türkenschanzstraße 17, A-1180 Wien, Austria

H. Olofsson

SCFAB, Stockholm Observatory/Dept. of Astronomy, SE-106 91 Stockholm, Sweden

H.E. Schwarz

CTIO, Casilla 603, La Serena, Chile

Abstract. We use four band photometry to identify AGB stars in extragalactic systems. Two special narrow band filters (TiO, CN) enable us to characterise different spectral types (M, C and S). We present here first results on some of our survey galaxies, NGC 147, NGC 185, And II, and M32.

1. Introduction

The Asymptotic Giant Branch (AGB) is a relatively short, but decisive phase during the final evolution of stars with low to intermediate masses (≈0.8–8 $M_{\odot}$). The vast majority of all stars experience it after core helium-burning has ceased. Their high luminosity and well defined evolutionary stage make AGB stars important constituents and probes of extragalactic systems. They play an important role in studies of stellar populations. Due to their age, they define relaxed subsystems and are therefore interesting in galactic structure work. Their mass-loss significantly contributes to the enrichment of the interstellar medium. AGB stars are useful distance estimators, too. On the other hand, extragalactic studies are important for our understanding of stellar evolution on the AGB itself. Extragalactic systems with their often well defined distances, metallicities, and star formation histories provide important tests for theoretical models by limiting the parameter space.

2. Our Survey

Starting with an oxygen-rich atmosphere (spectral type M) at the onset of the AGB evolution, stars with ≈1.5–4 $M_{\odot}$ can change their surface chemical composition to carbon-rich (spectral type C), because of repeated explosive helium-burning in a shell (thermal pulses) accompanied by deep convection, leading to a dredge-up of heavy elements. Large samples of AGB stars are needed for most
investigations of their general properties. However, with only a few exceptions, typically <10 C stars are known per galaxy for even the nearest galaxies of the Local Group (Groenewegen 1999). Nearby galaxies in the Local Group are sufficiently close that one can resolve their AGB populations and distant enough that a lot of stars can be observed in one CCD field. As O-rich and C-rich AGB stars have almost the same absolute magnitude and colour, one needs spectroscopic information to separate these two groups of red giants. In earlier work, narrow-band photometry turned out to be the most efficient and powerful tool to identify these objects even in distant, crowded fields. The method, we are using to search for extragalactic AGB stars, uses conventional $V$ and $i$ filters as temperature indicators, whereas two narrow-band Wing-type filters TiO and CN (Palmer & Wing 1982), centred on characteristic molecular bands of O-rich and C-rich objects, respectively, provide low-resolution spectral information to separate the two types of objects. Using this, we started a photometric survey of Local Group galaxies (galactic and M31 subgroup) with the 2.56m Nordic Optical Telescope at La Palma. Further explanations and results on a test field in M31 can be found in Nowotny et al. (2001). Fields of $6.5\times6.5$ centered on the galaxies were observed in all four filters, $V$, $i$, TiO, CN.

<table>
<thead>
<tr>
<th>Galaxy</th>
<th>type</th>
<th>D [kpc]</th>
<th>$[Fe/H]$</th>
<th>#stars</th>
<th>#M</th>
<th>#C</th>
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<tbody>
<tr>
<td>NGC 147</td>
<td>dSph/dE5</td>
<td>725</td>
<td>-1.1</td>
<td>6332</td>
<td>994</td>
<td>123</td>
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<tr>
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<td>-1.22</td>
<td>8546</td>
<td>1760</td>
<td>142</td>
</tr>
<tr>
<td>M32</td>
<td>E2</td>
<td>805</td>
<td>-1.1</td>
<td>4328</td>
<td>2770</td>
<td>43</td>
</tr>
<tr>
<td>AndII</td>
<td>dSph</td>
<td>690</td>
<td>-1.6</td>
<td>286</td>
<td>55</td>
<td>7</td>
</tr>
</tbody>
</table>

3. First Results

Table 1 shows the results for some of the galaxies we observed, Fig. 1 shows preliminary photometric results for two of our survey galaxies, NGC 147 and NGC 185. Even if we select only stars with good quality photometry, we are detecting the uppermost $2-3^{mag}$ of the red giant sequence, as can be seen in the colour-magnitude diagrams on the right-hand side. AGB stars (M and C) are among the brightest and reddest stars of this sequence. Using the narrow-band photometry and the selection criteria according to our synthetic photometry (see Nowotny et al. 2001), we can in addition distinguish M and C stars. A clear bifurcation between them can be seen in the colour-colour diagrams of Fig. 1, whereas hotter, bluer stars don’t show prominent TiO/CN-features and have therefore $(TiO-CN)\approx0^{mag}$. S stars $(C/O\approx1)$ lie between the two selection areas. Table 1 lists the star numbers we found using the above described photometric selection. We are now in the position to compare the two different types of AGB stars, and the identified objects can also be studied separately.

For NGC 147, NGC 185 and And II the galaxy membership of the found C stars is quite certain because of their spatial distribution with respect to the systems and their luminosities. This is not the case for M32, where we suspect a
non-negligible contamination by M31 AGB stars. This would explain the lack of 
concentration of C stars towards the M32 centre, and their somewhat too high 
luminosity if a M32 distance modulus is used. Besides it can also explain the 
steeper distribution of the O-rich objects in the two-colour diagram of M32 (not 
shown) and the lower C/M-star ratio as due to the higher metallicity of M31.

Figure 2 shows the luminosity functions (LFs) of the C stars within the 
selection areas of the two-colour diagrams for the four observed galaxies. While 
the number of stars in And II is low, we identified enough stars in the other 
galaxies (especially NGC 147 and NGC 185) to obtain LFs with statistically 
meaningful numbers in the different bins. Due to their short evolutionary time 
scale, optically detectable C stars have a relatively small scatter in their 
$i$-magnitudes. If we use distances for this galaxies from the literature (e.g. Mateo 
1998), we can calculate a mean absolute $i$-magnitude for C stars, which is also
given in Fig. 2. On the other hand, one can use the narrow LF of C stars to estimate distances of the populations, once a thorough calibration is done with other distance indicators.

A more detailed comparison between NGC 147 and NGC 185 will be very interesting, because these two have the same absolute magnitude \( M_V = -15.5^{\text{mag}} \), but different metallicities. Therefore an independent test of its influence on the properties of C stars can be made.

In the future, the identified extragalactic AGB stars can serve as targets for follow-up spectroscopy and long-term monitoring to get some information on the variability of these objects.

References


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