THE ASYMPTOTIC GIANT BRANCH OF NGC 205: THE CHARACTERISTICS OF CARBON STARS AND M GIANTS IDENTIFIED FROM JHK’ IMAGES

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ABSTRACT

J, H, and K’ images are used to investigate the asymptotic giant branch (AGB) content of the Local Group dwarf elliptical galaxy NGC 205. The AGB on the (K, H – K) and (K, J – K) color–magnitude diagrams consists of two sequences: a near-vertical plume of giants with spectral types K and M and a red arm containing C stars. There are 320 C stars with $M_{bol} < -4.1$ and $J - K > 1.5$ within 2’ of the nucleus. C stars account for 10% of the integrated luminosity of AGB stars brighter than $M_{bol} = -3.75$ near the center of NGC 205, and this is in excellent agreement with what is measured in intermediate-age clusters in the LMC. The most luminous AGB star has $M_{bol} = -6.5$, although variability introduces an uncertainty of a few tenths of a magnitude when using this as an estimate of the AGB tip brightness. Comparisons with models suggest that the brightest AGB stars formed within the past 0.1 Gyr and that the previous episode of star formation occurred a few tenths of a Gyr earlier. These results are consistent with star formation in NGC 205 being triggered by interactions with M31. These data also demonstrate that near-infrared imaging provides an efficient means of identifying C stars in nearby galaxies. The techniques used here to identify C stars and probe the AGB are well suited to studies of galaxies outside of the Local Group using data obtained with adaptive optics systems on large ground-based telescopes.

Subject headings: galaxies: dwarf — galaxies: individual (NGC 205) — galaxies: stellar content — stars: AGB and post-AGB

1. INTRODUCTION

The Local Group spiral galaxy M31 has a rich entourage of companions, including the three dwarf elliptical galaxies (dEs) NGC 147, NGC 185, and NGC 205, the compact elliptical galaxy M32, and a number of dwarf spheroidal galaxies (dSphs). NGC 205 is the brightest of the dEs and is the nearest example of a nucleated dE (Zinnecker & Cannon 1986). With a distance modulus of 24.6 (Saha, Hoessel, & Krist 1992), NGC 205 is 100 kpc behind M31, and there are indications that NGC 205 has interacted with M31 and its companions in the past. Cepa & Beckman (1988) point out that NGC 205 and M32 have similar orbital properties, and Ibata et al. (2001) find a tidal stream in the M31 halo that is aligned with M32 and NGC 205. Sato & Sawa (1986) argue that NGC 205 may have warped the H I disk of M31, and the structural characteristics of NGC 205 show classic signatures of tidal interactions (Choi, Guhathakurta, & Johnston 2002). The ISM of NGC 205 is also smaller than expected, given the rate of replenishment from stellar mass loss (Welch, Sage, & Mitchell 1998), as expected if the gas and dust are periodically stripped away by tidal interactions.

Previous studies of the resolved stellar content of NGC 205 have found stars spanning a range of ages. Stars evolving on the red giant branch (RGB), which has a color indicative of [Fe/H] = −0.85 and a width suggesting that $\sigma_{[Fe/H]} = 0.5$ dex (Mould, Kristian, & da Costa 1984) are among the brightest members of the old stellar substrate. There is an extended AGB, which Richer, Crabtree, & Pritchet (1984), Davidge (1992), and Lee (1996) find has a peak $M_{bol}$ between −5.5 and −6, indicating that NGC 205 formed stars during intermediate epochs: Richer et al. (1984) also identified seven C stars near the center of NGC 205, while Demers, Battinelli, & Letarte (2003) have recently found 500 C stars scattered throughout the galaxy. It has long been known that there are young blue stars in the central regions of NGC 205 (see Baade 1951 and discussion therein), and many of these have since been found to be associations or clusters (Cappellari et al. 1999). While the nuclear regions of NGC 205 have a flat spectral energy distribution (SED) in the UV with UV-bright stars contributing 60% of the flux between 1200 and 2450 Å (Bertola et al. 1995), young stars likely account for less than 1% of the total stellar mass (Wilcots et al. 1990).

In the present study, deep J, H, and K’ images are used to conduct the first investigation of the resolved stellar content of NGC 205 at wavelengths longward of 1 μm. The reddest, most extreme AGB stars can be difficult to detect at visible wavelengths and are more easily detected in the infrared. The resulting increased sensitivity to the cool stars that are the brightest members of old and intermediate-age populations makes it easier to probe the star-forming history of the crowded central regions of the galaxy. The majority of bright C stars (i.e., those that are not “warm”) also have near-infrared SEDs that differ from those of oxygen-rich M giants (Wood, Bessell, & Paltoglou 1985; Hughes & Wood 1990) so that broadband infrared colors, which can be obtained from moderately short exposures, can be used to distinguish between these two types of objects.

2. OBSERVATIONS, REDUCTIONS, AND PHOTOMETRIC MEASUREMENTS

The data were recorded on 2001 June 4 UT with the CFHTIR imager, which was mounted at the Cassegrain focus of the 3.6 m Canada-France-Hawaii Telescope.
CFHTIR contains a $1024 \times 1024$ Hg:Cd:Te array. Each pixel samples $0''21$ on a side so that a $3'6 \times 3'6$ field is imaged. Data were recorded through $J$, $H$, and $K'$ filters, with a total exposure time of $240$ s filter$^{-1}$. A four-point square dither pattern was used to assist with the identification and rejection of bad pixels and cosmic rays as well as with the construction of on-sky calibration frames. The final images have FWHM $= 0''7$.

The data reduction sequence for each exposure consisted of (1) the subtraction of a dark frame, (2) the division by a dome flat, which was obtained by differencing images of a dome spot recorded with the flat-field lamps on and off, (3) the subtraction of the DC sky level, and (4) the subtraction of interference fringes and the thermal signatures of objects along the optical path, using a calibration frame that was constructed by median-combining flat-fielded and sky-subtracted images of various fields. The processed images were aligned to correct for the dither offsets, median-combined, and then trimmed to the region having a full $240$ s exposure time. The final $K'$ image of NGC 205 is shown in Figure 1.

Stellar brightnesses were measured with the point-spread function (PSF) fitting program ALLSTAR (Stetson & Harris 1988) using target lists, preliminary photometric measurements, and PSFs obtained from tasks in DAOPHOT (Stetson 1987). The photometric calibration was based on observations of UKIRT faint standard stars (Hawarden et al. 2001). Completeness and the photometric uncertainties due to crowding and sky noise were estimated from artificial star experiments, and the results are summarized in Figure 2 for the two radial intervals used in the photometric analysis ($\frac{3}{5} 3$). Incompleteness becomes significant when $J$ and $K'$ are fainter than $18$ mag.

3. COLOR-MAGNITUDE DIAGRAMS AND COLOR DISTRIBUTIONS

The CFHTIR field was divided into two equal area regions centered on the galaxy nucleus to investigate radial trends in stellar content. The inner region has a radius of $80''$, while the outer region covers the remainder of the field.
Based on the $r$-band surface photometry measurements made by Kent (1987), the inner region has an integrated brightness $M_r = -15$, while $M_r = -14$ for the outer region.

### 3.1. Color-Magnitude Diagrams and the Incidence of Blending

The ($K$, $H-K$) and ($K$, $J-K$) color-magnitude diagrams (CMDs) of the inner and outer regions are shown in Figure 3. Ferraro et al. (2000) calibrated the $K$-band RGB tip brightness in globular clusters as a function of metallicity, and their relation predicts that $M_{\text{RGB}T}^K = -6.5$ for an old population with [Fe/H] = -0.85, which corresponds roughly to $K = 18$ at the distance of NGC 205. The artificial star experiments indicate that incompleteness and errors in the photometry become significant when $K > 18$, while the incidence of blending between stars will also increase markedly when $K \geq 18$ due to the onset of the RGB. Therefore, the present study focuses on stars with $K \leq 18$, which are evolving on the upper AGB.

The AGB in the CMDs has two components: (1) a vertical sequence, which consists of oxygen-rich K and M giants, and (2) a red plume with $K < 17.2$ and $H-K > 0.4$ and $J-K > 1.5$, which contains C stars (Hughes & Wood 1990; Wood et al. 1985). The upper envelopes of sources in the inner and outer regions differ by 0.4 mag, in the sense that the brightest sources occur in the inner region. The stellar density in the inner region is higher than in the outer region, and this raises the concern that the brightest stars in the inner region may be blends. The spatial distribution of the brightest stars in the inner region suggests that this is not the case. If these stars were blends, then they would be concentrated near the nucleus. However, the stars with $K < 16$ are scattered throughout the inner region, including along the minor axis near the edge of the inner region. A more quantitative assessment of the incidence of blending than can be inferred from the spatial distribution of the brightest stars is highly desirable, and this was done in the present study using two different approaches, both of which assume that there is not a significant population gradient. While there almost certainly is a population gradient in NGC 205 (see below), accounting for this gradient would not alter the results of this analysis by a significant amount.

The probability of blending can be estimated from star counts. However, the star counts upon which the estimates are based may, in turn, be affected by blending. One way to lower the chances of this being an issue is to measure number counts in a field that has a lower surface brightness than that being studied and then scaling the results to match those expected in the higher surface-brightness field. For the following calculations, the number counts are based on measurements in the outer field, and these are scaled.
to match those expected in the inner field to estimate the number of blends.

If two stars of equal magnitude fall in the same resolution element on the sky, they will appear as a single source that is 0.75 mag brighter than the unblended stars.\(^2\) The inner region contains stars with $K$ between 15.8 and 16.2 that are not seen in the outer field and, if these are the result of blends, then the unblended stars will have $K$ between 16.6 and 17.0. There are 130 stars with $K$ between 16.6 and 17.0 in the outer region, where the mean surface brightness is $\mu_r = 21.3$. If the radius of each resolution element is one-half the FWHM of the PSF (i.e., $0.35$), then the density of stars with $K$ between 16.6 and 17.0 is $2.50 \times 10^{-3}$ per resolution element, and the expected number of two-star blends in the outer region is then 0.3. The mean surface brightness in the inner region is $\mu_r = 20.7$, and if the stellar content is like that in the outer region, then there will be $4.34 \times 10^{-3}$ stars per resolution element with $K$ between 16.6 and 17.0. The number of sources with $K$ between 15.8 and 16.2 in the inner regions that are due to two-star blends is then 0.9.

Another way to assess the effects of blending is to combine low surface brightness fields to simulate regions of high surface brightness. The brightnesses of stars in the original and simulated fields can then be compared to study directly the effects of crowding. In the current study, seven $100 \times 100$ pixel subfields, located along the minor axis of NGC 205 at the edge of the CFHTIR field and with surface brightnesses $\mu_r = 21.6$ mag arcsec\(^{-2}\) based on the measurements in Table III of Kent (1987), were combined to create a field with a surface brightness $\mu_r = 19.5$ mag arcsec\(^{-2}\) to simulate the $100 \times 100$ pixel region centered on the nucleus of NGC 205.

The brightest source in the simulated high-density field is 0.1 mag brighter in $K$ than the brightest source in the original fields, indicating that the peak stellar brightness is not sensitive to stellar density, even near the nucleus of NGC 205. While there are 34 sources in the top two magnitude intervals in the original fields, 44 sources were found in this same interval in the simulated field, and this difference is due to blends of fainter stars in the simulated field that appear as brighter composite objects. These simulations indicate that blending is a concern only well below the AGB tip: even in the densest regions of the inner field, the majority of objects within 2 mag of the AGB tip are unblended stars. It should be emphasized that the mean surface brightness in the inner field is 1.2 mag arcsec\(^{-2}\) lower than in the $100 \times 100$ pixel field simulated here, so the effects of blending throughout most of the inner field are less than in this worse-case simulation.

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\(^2\) The discussion is restricted to blends involving two stars, as the incidence of blends between three or more stars of comparable brightness is considerably lower than for two stars.

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![Graph](image_url)  
**Fig. 3.**—($K, H-K$) and ($K, J-K$) CMDs of the inner (top row) and outer (bottom row) regions.
3.2. Color Distributions

The histogram distributions of the $H-K$ and $J-K$ colors of stars with $K$ between 16.2 and 17.2 are shown in Figures 4 and 5. The color distributions have a main peak, containing K and M giants and a red tail containing C stars. Also shown are Gaussians with $\sigma$ values equal to the random photometric errors predicted from the artificial star experiments and normalized to match the number of stars in the central bins of the M giant peaks. C stars produce an excess population of objects with respect to K and M giants when $H-K > 0.4$ and $J-K > 1.5$ in both regions. The M giant sequence in the inner region also has a blue tail when $J-K < 1.2$, which is due to younger AGB stars than those along the M giant peak. A corresponding blue tail is not seen in the outer region, indicating that the youngest AGB stars are restricted to the inner region. This is qualitatively consistent with the difference in peak brightness between the inner and outer regions noted in § 3.1.

The AGB becomes bluer toward fainter magnitudes, and if fainter stars occur in sufficient numbers to blend together, they will appear as brighter objects with bluer colors than the main AGB locus. Could the blue population of stars in the inner region $J-K$ color distribution be the result of blends? This question is answered using the procedure described in § 3.1. The blue population in Figure 5 has a mean color $J-K = 1.1$ and, if due to blends, would come from stars that are 0.8 mag fainter and have similar colors. The color distributions in Figure 5 are based on stars with $K$ between 16.2 and 17.2, and there are 123 stars in this magnitude range with $J-K$ between 1.0 and 1.2. For comparison, there are 280 stars with $K$ between 17.2 and 18.2 and $J-K$ between 1.0 and 1.2 in the outer region. After scaling upward to match the surface brightness in the inner field, the density of stars with $K$ between 17.2 and 18.2 expected in the inner region is then 0.0093 stars per resolution element. These will produce 4–5 blends with $K$ between 16.2 and 17.2 in the inner region. The number of suspected blends is thus much smaller than the number of detected stars in the blue envelope, indicating that this feature is not an artifact of blending.

3.3. Comparison with Models

Girardi et al. (2002) compiled isochrones in the $JHK$ photometric system, and these have been compared with the peak stellar brightnesses and the $J-K$ color distribution of the brightest stars in each region. The transformed models, which include evolution on the thermally pulsing AGB, do not apply to C stars. The comparisons are restricted to two metallicities; $Z = 0.004$, which corresponds roughly to the RGB metallicity measured by Mould et al. (1984), and $Z = 0.019$, which was considered since the brightest AGB stars are younger than the main body of RGB stars and so might be more metal-rich. Caution should, of course, be exercised when making comparisons between computed and observed quantities, as there are uncertainties in the transformation onto the observational plane and in the input physics due to uncertainties in the core mass versus luminosity relation and the methods used to model convection, mass loss, and envelope burning.
spread in $J-K$ on the upper AGB. Given that the width of the K and M giant peak in the $J-K$ color distribution in Figure 5 is comparable to that predicted by photometric errors, then if a spread in metallicity is present, it can only introduce a spread of a few hundredths of a magnitude in $J-K$, which in turn corresponds to $\Delta[M/H] = 0.1-0.2$ dex.

4. THE LUMINOSITY FUNCTIONS OF M GIANTS AND CARBON STARS

Bolometric corrections in the $K$ band, $BC_K$, were computed for individual stars using the relation between $BC_K$ and $J-K$ for Galactic and LMC AGB stars given by Bessell & Wood (1984). While this relation is based on oxygen-rich stars, it is evident from Figures 3 and 4 of Bessell & Wood (1984) that it gives $BC_K$ for C stars that are reliable to within a few tenths of a magnitude.

The composite bolometric LFs of oxygen- and carbon-rich giants in the inner and outer regions are compared in Figure 7. Objects with $M_K < -9.5$ and/or $M_{bol} > -7$ were not considered to be AGB stars, as these are likely red supergiants or star clusters. After removing these objects, the brightest star in the CFHTIR field has $M_{bol} = -6.5$, while the next two brightest stars have $M_{bol} \sim -6.4$. These three stars fall along the M giant sequence and, hence, are likely present. At a given age, the $Z = 0.004$ and $Z = 0.019$ models have $J-K$ colors that differ by 0.1 mag on the upper AGB, indicating that

$$\Delta\frac{[M/H]}{\Delta(J-K)} = 7.0 \text{ dex mag}^{-1}.$$ 

For comparison, photometric errors introduce a $\pm 0.1 \text{ mag}$ error in $J-K$ colors of these objects favoring the lower value (see below).

The models in Figure 6 predict that the peak AGB brightness in a population with $\log(t_{yr}) = 10.0$ should occur near $K = 17$ at the distance of NGC 205, and so the color distributions in Figure 5 are dominated by stars that formed during intermediate epochs. The comparisons with the predicted colors in Figure 5 indicate that the mean $J-K$ color of the blue tail in the inner region color distribution is consistent with these stars having $\log(t_{yr}) \sim 7.8$, which agrees with the lower age estimate predicted from the peak AGB brightness in Figure 6. The models also indicate that the stars in the blue tail in the top panel of Figure 5 are at least a few tenths in $\log(t_{yr})$ younger than the stars that contribute to the main peak in the color distribution. Finally, the model predictions in Figure 5 also demonstrate that the ability to resolve age differences diminishes with increasing age, and the M giant peak in the color distributions could contain stars spanning a range of ages.

If there is an age-metallicity relation among stars in NGC 205, then this will also cause a spread in the colors of upper AGB stars over and above that expected only from age effects. However, only a modest spread in metallicity is likely present. At a given age, the $Z = 0.004$ and $0.019$ models have $J-K$ colors that differ by 0.1 mag on the upper AGB, indicating that

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likely not C stars. The LFs in Figure 7 were not extended fainter than $M_{bol} = -3.75$ to avoid (1) sample incompleteness in excess of 50%, which occurs when $M_{bol} \geq -3.7$ and (2) the RGB tip, which occurs near $M_{bol} = -3.6$ in moderately metal-poor populations (Ferraro et al. 2000).

The LFs in the upper panel of Figure 7 are not parallel, indicating that the inner and outer regions have different AGB contents. To better compare these data, the LF of the outer region was scaled upward to match the number density of stars in the inner region on the basis of $r$-band surface brightness measurements made by Kent (1987), and the result is shown in the lower panel of Figure 7. When compared in this manner, the LFs of the two regions differ significantly between $M_{bol} = -5.75$ and $-4.75$ in the sense that the inner region contains a higher fraction of luminous AGB stars. While the LFs do not differ significantly when $M_{bol} < 5.75$, the LF of the inner region still falls above that of the outer region in this interval. These results are consistent with the youngest stars being concentrated toward smaller radii.

The comparisons in the lower panel of Figure 7 provide further evidence that blending is not a significant problem among bright AGB stars in the CFHTIR field. If a significant amount of blending occurs in the inner region, then this will be most evident near the faint end of the AGB LF, which terminates just above the RGB tip, in the sense that the number of sources in the inner region will be higher than in the outer region after accounting for differences in stellar density using surface brightness measurements. The LFs in the lower panel of Figure 7 are in excellent agreement at the faint end, as expected if blending is not a significant issue in the inner region.

Davidge (1992) examined the AGB content in a 2.2 arcmin$^2$ field centered on the nucleus of NGC 205, and in the lower panel of Figure 7, the composite LF from that study, scaled to match the number of stars in the inner region between $M_{bol} = -5.5$ and $-4.5$ is shown. The Davidge (1992) LF matches that of the inner region at the faint end but falls above the inner region LF when $M_{bol} = -5.5$. The Davidge (1992) observations sample a smaller range of galactocentric radii than is covered in the inner region, and the comparison in the lower panel of Figure 7 is thus consistent with the number density of stars with $M_{bol} = -5.5$ increasing toward the nucleus of NGC 205.

The bolometric LF of only C stars, which are assumed to have $J-K > 1.5$ and $K < 17.2$, is shown in Figure 8. The $J-K = 1.5$ criterion is based on the 2 $\sigma$ width of the M giant AGB sequence at $K = 17$ in Figure 5 and is only slightly different from the $J-K = 1.6$ criterion adopted by Hughes & Wood (1990). The $K < 17.2$ selection criterion is based on the approximate lower envelope of the C star plume in the CMDs, and this brightness cutoff largely limits the C star sample to $M_{bol} < -4.1$.

Richer et al. (1984) used narrowband images that monitored the strength of CN and TiO absorption bands to identify seven C stars near the center of NGC 205. While all seven of these stars are in the CFHTIR field, only four can be identified with confidence in the CFHTIR images, and the colors and brightnesses of these are listed in Table 1. The near-infrared colors and brightnesses of these stars

\begin{table}
\centering
\caption{Near-Infrared Photometry of C Stars Found by Richer et al. (1984)}
\begin{tabular}{cccc}
\hline
Number & $K$ & $J-K$ & $H-K$ \\
\hline
2 & 16.491 & 1.524 & 0.528 \\
3 & 16.869 & 1.826 & 0.470 \\
4 & 15.795 & 1.652 & 0.605 \\
7 & 16.362 & 1.676 & 0.606 \\
\hline
\end{tabular}
\end{table}

place them on the red plume on the $(K, H-K)$ and $(K, J-K)$ CMDs in Figure 3, and so these objects are successfully identified as C stars using the brightness and color criteria described in the previous paragraph.

The brightest C stars likely formed in the most recent star-forming episode, and while the LFs of both regions in the lower panel of Figure 8 are similar when $M_{bol} > -5$ after adjusting for differences in surface brightness, the outer region has a deficiency of stars with $M_{bol} = -5.5$ when compared with the inner region. This is consistent with the comparison between the inner and outer region LFs of all AGB regions in Figure 7.

The large number of C stars in the CFHTIR field is worth noting: after adjusting for sample incompleteness, 224 C stars with $M_{bol} < -4.1$ are found in the inner field, while 96 are found in the outer field. This is not a complete census of C stars near the center of NGC 205, as warm C stars with $J-K < 1.5$, which may account for 20% of the sources with $J-K < 1.5$ in the LMC (Wood et al. 1985), are missed.

\footnotesize
3 C stars 1, 5, and 6 are located close to the center of NGC 205 and cannot be unambiguously identified using the finding chart in Fig. 7 of Richer et al. (1984).
Nevertheless, C stars still account for a significant fraction of the total light from AGB stars near the center of NGC 205. The integrated bolometric magnitude of C stars with $J-K > 1.5$ is $M_{\text{bol}} = -10.6$ in the inner region and $-9.6$ in the outer region. For comparison, the integrated bolometric magnitude of all oxygen- and carbon-rich AGB stars with $M_{\text{bol}} < -3.75$ is $-13.0$ in the inner region and $-12.2$ in the outer region. C stars thus contribute at least 11% of the integrated AGB luminosity in the inner region and 9.1% in the outer region. C stars make a similar contribution to the integrated AGB luminosity of LMC clusters with ages between 0.4 and 2 Gyr (Maraston 1998).

5. DISCUSSION AND SUMMARY

$J$, $H$, and $K'$ images with subarcsec angular resolution have been used to investigate the near-infrared photometric properties of bright AGB stars in the Local Group dE galaxy NGC 205. The $(K, H-K)$ and $(K, J-K)$ CMDs of NGC 205 split into two branches near the bright end, with a vertical sequence made up of oxygen-rich K- and M-type giants and a red plume containing C stars. The onset of the C star plume occurs at $H-K = 0.5$ and $J-K = 1.5$, which is roughly consistent with the near-infrared properties of cool C stars in the LMC (Hughes & Wood 1990; Wood et al. 1985).

The data suggest that the M-giant AGB sequence in NGC 205 terminates near $M_{\text{bol}} = -6.5$, while the most luminous C stars have $M_{\text{bol}} = -5.5$. A source of uncertainty in these values is that the brightest AGB stars are very rare, and small number statistics may cause the brightness of the AGB tip to be underestimated, as was found to be the case in NICMOS observations of the outer regions of NGC 5128 (Davidge 2002). In addition, the brightest AGB stars may be variable, and this will introduce uncertainties of a few tenths of a magnitude in the peak AGB brightness. In fact, if the measured AGB tip brightness is based on LPVs at the peak of their light curves, then this will bias upward the luminosity of the AGB tip. The effects of variability on the luminosity of the AGB tip can be checked by reobserving this field.

The uncertainties in the luminosity of the AGB tip notwithstanding, C stars contribute at least 10% of the total luminosity coming from all AGB stars with $M_{\text{bol}} < -3.75$ near the center of NGC 205. This is a lower limit, as warm C stars with $J-K < 1.5$ are not identified in the current census. Therefore, based on the fuel consumption theorem, it can be concluded that at least 10% of the nuclear fuel consumed during AGB evolution near the center of NGC 205 is processed by C stars. This is consistent with what is seen in intermediate-age clusters in the LMC (Maraston 1998).

The inner region of NGC 205 contains an excess population of AGB stars with respect to the outer region when $M_{\text{bol}} < -4.75$, indicating that the brightest AGB stars are not uniformly mixed with fainter stars near the center of NGC 205; rather, there is an age gradient. On the basis of the peak brightness of AGB stars in the inner field and the $J-K$ colors of the blue AGB sequence in Figure 5, the Girardi et al. (2002) isochrones indicate that the youngest evolved stars near the center of NGC 205 have ages $\log(t_{\text{yr}}) < 8.0$. This is consistent with the ages of star clusters near the center of NGC 205 measured by Cappellari et al. (1999).

Cepa & Beckman (1988) investigated the orbit of NGC 205 about M31 and concluded that (1) the orbital period is 0.3 Gyr and (2) NGC 205 last crossed the disk of M31 0.1 Gyr in the past. The colors and brightnesses of the youngest AGB stars in the inner region, which include the brightest AGB stars and the blue tail in the $J-K$ distribution, are consistent with these objects having formed during the most recent crossing of the M31 disk, suggesting that this interaction likely spurred star formation in NGC 205. The relative amplitudes of the blue and red peaks in the inner region $J-K$ color function indicates that the older M giant sequence contains 3 times more stars than formed during the most recent interaction. The color offsets between the blue AGB stars in the inner region and the older M giant peak in Figure 5 is consistent with a hiatus of at least a few tenths of a Gyr between the most recent and any previous star-forming episode, once again in agreement with the Cepa & Beckman (1988) orbital parameters. Interactions with NGC 205 have evidently not had a major impact on the star formation rate in the disk of M31, which has been low outside of spiral arms for the past 1 Gyr (Williams 2002).

We close by noting that the observations used in this paper amount to only a few minutes of total integration time per filter on a 3.6 m telescope, and the resulting data are able to clearly separate the C star and M giant sequences on near-infrared CMDs. $J$, $H$, and $K'$ images thus provide an efficient means of identifying C stars in nearby galaxies. With adaptive optics (AO) systems on large telescopes, it should be possible to probe the AGB content of galaxies outside of the Local Group. That a C star plume is clearly seen in the $(K, H-K)$ CMD of NGC 205 indicates that observations in $H$ and $K$, where AO systems not intended for use in the thermal infrared regime will deliver the highest Strehl ratios, should be sufficient to detect C stars. This being said, it is worth noting that C star sequences are not seen in the $(K, H-K)$ CMDs of the central regions of M32 (Davidge et al. 2000) and M31 (Davidge 2001). If there is an inverse correlation between C star content and metallicity, as suggested by Brewer, Richer, & Crabtree (1996), then the absence of C stars in M32 and the bulge of M31 is likely due to the relatively high metallicities of these systems, although it is still not clear if the central regions of these galaxies contain stars as young as those in NGC 205.

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