DETECTION OF THE RED GIANT BRANCH STARS IN M82 USING THE 
HUBBLE SPACE TELESCOPE

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ABSTRACT

We present color-magnitude diagrams and luminosity functions of stars in two halo regions of the irregular galaxy in M82, based on F555W and F814W photometry taken with the Hubble Space Telescope (HST) and Wide Field Planetary Camera 2. The I-band luminosity function shows a sudden jump at $I \approx 23.95$ mag, which is identified as the tip of the red giant branch (TRGB). Adopting the Lee et al. calibration of the TRGB based on the RR Lyrae distances to Galactic globular clusters, we obtain the distance modulus of $m - M = 27.95(\pm 0.14)_{\text{random}}(\pm 0.16)_{\text{syst}}$ mag. This corresponds to a linear distance of $3.9(\pm 0.3)_{\text{random}}(\pm 0.3)_{\text{syst}}$ Mpc, which agrees well with the distance of M81 determined from the HST observations of the Cepheid variable stars. In addition, we observe a significant number of stars apparently brighter than the TRGB. However, with the current data, we cannot rule out whether these stars are blends of fainter stars, or are indeed intermediate-age asymptotic giant branch stars. 

Subject headings: galaxies: distances and redshifts — galaxies: individual (M82) — galaxies: irregular — galaxies: stellar content

1. INTRODUCTION

M82 has been one of the most frequently targeted candidates in the study of starburst galaxies and is distinguished by its very high IR luminosity ($L_{\text{IR}} = 3 \times 10^{10} L_{\odot}$; Telesco & Harper 1980). A cluster of young supernova remnants has also been observed around the nucleus of M82 (Kronberg, Biermann, & Schwab 1985). This galaxy is located in a small group of galaxies, which is comprised of M81, M82, NGC 3077, and several other smaller dwarf galaxies. The H I map of the M81 group revealed tidal tails bridging M81 with M82 and NGC 3077, suggesting a recent interaction of these galaxies (Yun, Ho, & Lo 1993).

The distance to the M81 group has been measured by Freedman et al. (1994) using the Hubble Space Telescope (HST) observations of Cepheid variables in M81. They report a distance modulus of $(m - M)_0 = 27.80 \pm 0.20$ mag. Two other galaxies in the M82 group have also recently been the HST targets. Caldwell et al. (1998) observed dwarf elliptical galaxies, F8D1 and BK5N, and reported the distances (measured by the tip of the red giant branch [TRGB] method) of $28.0 \pm 0.10$ and $27.9 \pm 0.15$ mag, respectively.

As part of a long-term project to obtain direct distances to galaxies in the nearby universe by using the TRGB method, we observed two fields in the halo of M82, using the HST and Wide Field Planetary Camera 2 (WFPC2). The details of observations and data reductions are reported in § 2. In §§ 3 and 4, we discuss the detection of the red giant branch (RGB) stars and report a distance using the I-band luminosity function. In addition to the RGB stars, we detected a large number of stars brighter than the TRGB in the M82 halo regions. We briefly explore in § 5 what this population of stars may be.

2. OBSERVATIONS AND REDUCTIONS

Two positions in the halo region of M82 were chosen for our HST observations. A digital sky survey image of M82 is shown in Figure 1 on which the HST WFPC2 footprints are superposed, indicating the two regions observed. We refer to the region closer to the center of the galaxy as field I and the other, to the east, as field II. The Planetary Camera (PC) chip covers the smallest area; we refer to this as chip 1. The three Wide Field (WF) chips cover the three larger fields and are referred to as chips 2, 3, and 4, respectively, counterclockwise from the PC. A close-up HST image of one of the chips, WF2 of field I, is shown in Figure 2.

Observations of the M82 halo region were made with the WFPC2 on board HST on 1997 July 9 using two filters, F555W and F814W. Two exposures of 500 s were taken for each filter at each position. Cosmic rays on each image were cleaned before being combined to make a set of F555W and F814W frames.

The subsequent photometric analysis was done using point-spread function fitting packages DAOPHOT and ALLSTAR. These programs use automatic star-finding algorithms and then measure stellar magnitudes by fitting a point-spread function (PSF) constructed from other uncrowded HST images (Stetson 1994). We checked for a possible variation in the luminosity function as a function of the position on each chip by examining the luminosity functions for different parts of the chip. For each frame, we find the identical luminosity function, confirming that there are no significant systematic offsets originating from the adopted PSFs.

The F555W and F814W instrumental magnitudes were converted to the calibrated Landolt (1992) system as follows. (A detailed discussion is found in Hill et al. 1998.) The instrumental magnitudes were first transformed to the Holtzman et al. (1995) 0.5 aperture magnitudes by determining the aperture correction that needed to be applied to

\[ \text{Based on observations made with the NASA/ESA Hubble Space Telescope, obtained at the Space Telescope Science Institute, operated by AURA, Inc., under NASA contract NAS5-26555.} \]
Fig. 1.—Digital sky survey image of M82. Two footprints indicate the regions of the HST WFPC2 observations.

Fig. 2.—Close-up view of a WFPC2 field of field II, WF2 chip
the PSF magnitudes. This was done by selecting 20–30 brighter isolated stars on each frame. Then all the stars were subtracted from the original image except for these selected stars. The aperture photometry was carried out for these bright stars, at 12 different radii ranging from 0 to 0.5. The 0.5 aperture magnitudes were determined by applying the growth-curve analysis provided by DAOGROW (Stetson 1990) and were then compared with the corresponding PSF magnitudes in order to estimate the aperture corrections for each chip and filter combination. The values of aperture corrections for each chip are listed in Table 1. We used a different set of aperture corrections for two fields. Most of the values agree with each other within 2σ; however, slight offsets between the corrections in the two fields are most likely due to the PSFs not sampling the images in the exactly same way. When images are co-added, the combined images are not exactly identical to the original uncombined images; that is, the precise positions of stars on the frames are slightly different. Thus, we should expect some differences in the aperture corrections of the same chip in two fields.

Finally, the 0.5 aperture magnitudes are converted to the standard system via the equation

\[ M = m + 2.5 \log t + C1 + C2(V-I) + C3(V-I)^2 + ac, \]

where \( t \) is the exposure time, \( C1, C2, \) and \( C3 \) are constants, and \( ac \) is the aperture correction. \( C1 \) is comprised of several terms, including (1) the long-exposure WFPC2 magnitude zero points, (2) the DAOPHOT/ALLSTAR magnitude zero point, (3) a correction for multiplying the original image by 4 before converting it to integers (in order to save the disk space), (4) a gain ratio term due to the difference between the gain settings used for M82 and those used for the Holtzman et al. (1995) data (7 and 14, respectively), (5) a correction for the pixel area map which was normalized differently from that of Holtzman et al. (1995), and (6) an offset between long and short exposure times in the HST zero-point calibration. \( C2 \) and \( C3 \) are color terms and are the same for all four chips. In Table 2, we summarize all three constants for each chip.

### Table 1

| Chip  | F555W        | F814W        |
|-------|--------------|--------------|
| Field I |              |              |
| WF2... | -0.048 ± 0.047 | -0.082 ± 0.029 |
| WF3... | +0.094 ± 0.040 | -0.127 ± 0.027 |
| WF4... | +0.091 ± 0.053 | +0.013 ± 0.032 |
| Field II |             |              |
| WF2... | -0.039 ± 0.038 | -0.029 ± 0.015 |
| WF3... | +0.053 ± 0.040 | +0.185 ± 0.022 |
| WF4... | +0.155 ± 0.063 | +0.005 ± 0.024 |

3. DETECTION OF THE RED GIANT STARS IN M82

The \( V \) and \( I \) photometric results are shown in the color-magnitude diagrams (CMDs) in Figure 3. In Table 3, astrometric and photometric data for a set of brighter, isolated reference stars are presented. The \( X \)- and \( Y \)-coordinates tabulated refer to those on the image of rootname u3nka201m for field I, and u3nka201m for field II. We also show luminosity function histograms in Figure 4. In both fields I and II, WF4 samples the least crowded halo region of M82. Based on the observations of Cepheids in M81, the parent galaxy of M82, we know that the distance modulus of M82 is approximately \( \mu_0 = 27.8 \) mag. Then the tip of the red giant branch should therefore be observed at \( I \sim 23.7 \) mag. In all CMDs presented here, we can visually detect the position of the TRGB at \( I \sim 23.7 \)–23.9 mag relatively easily; this TRGB is also evident in the luminosity functions as a jump in number counts, especially in those of field I. If we are observing the TRGB at around \( I \sim 23.8 \) mag, then a significant number of brighter stars are present in the halo regions of M82, which are observed above the tip of the RGB in the CMDs. In addition, comparing two regions, more of these stars are found in field II. This will be discussed in more detail in § 5.

4. TRGB DISTANCE TO M82

The TRGB marks the core helium flash of old, low-mass stars that evolve up the red giant branch but almost instantaneously change their physical characteristics upon ignition of helium. This restructuring of the stellar interior appears as a sudden discontinuity in the luminosity function and is observed at \( M_I \sim -4 \) mag in the I band (\( \sim 8200 \) Å). The TRGB magnitude has been shown both observationally and theoretically to be extremely stable; it varies by only \( \sim 0.1 \) mag for ages 2–15 Gyr, and for metallicities, between \( -2.2 < [\text{Fe/H}] < -0.7 \) dex (the range bounded by the Galactic globular clusters). Here, we use the calibration presented by Lee, Freedman, & Madore (1993), which is based on the observations of four Galactic globular clusters by Da Costa & Armandroff (1990). The globular cluster distances had been determined using the RR Lyrae distance scale based on Lee, Demarque, & Zinn’s (1990) theoretical horizontal branch model for \( Y = 0.23 \) and corresponds to \( M_V(\text{RR Lyrae}) = 0.57 \) mag at \( [\text{Fe/H}] = -1.5 \).

The top panel of each plot in Figure 5 shows an \( I \)-band luminosity function smoothed by a variable Gaussian whose dispersion is the photometric error for each star detected. We apply a Sobel edge-detection filter to all luminosity functions in order to determine quantitatively and objectively the position of the TRGB following \( E(m) = \Phi(I + \sigma_m) - \Phi(I - \sigma_m) \), where \( \Phi(m) \) is the luminosity function at a magnitude defined as \( m \) and \( \sigma_m \) is the typical photometric error of stars of magnitude \( m \). For the details of the Sobel filter application, readers are referred to the Appendix of Sakai, Madore, & Freedman (1996). The
The results of the convolution are shown as in the bottom panels of Figure 5. The position of the TRGB is identified with the highest peak in the filter output function.

The TRGB method works as a distance indicator best in practice when the $I$-band luminosity function sample is restricted to those stars in the halo region only. This is mainly due to three reasons: (1) less crowding, (2) less internal extinction, and (3) less contamination by asymptotic giant branch (AGB) stars, which tend to smear out the “edge” defining the TRGB in the luminosity function. In field I, the tip position is detected clearly in the luminosity function and filter output for the WF4 region at $I_{\text{TRGB}} = 23.82 \pm 0.15$ mag. The $1\sigma$ error here is roughly determined by estimating the “FWHM” of the peak profile defining the TRGB in the filter output function. In the WF3 region, the tip is also observable at $I_{\text{TRGB}} = 23.72 \pm 0.10$ mag, slightly brighter than the case of WF4. The simulations have shown that the position of the tip shifts to a brighter magnitude because of crowding effects (Madore & Freedman 1995), and that is what we observe on WF3.

The stellar population in field II is comprised of more of these brighter stars (which could be AGB stars); thus,

**TABLE 3**

PHOTOMETRY OF REFERENCE STARS IN M82

| Identification Number | Field | Chip | X (J2000) | Y (J2000) | R.A. (J2000) | Decl. (J2000) | $V$ | $I$ |
|-----------------------|-------|------|----------|----------|-------------|-------------|-----|-----|
| 01                    | I     | 2    | 153.3    | 281.5    | 956 04.72   | 69 43 05.5  | 25.70 ± 0.15 | 23.52 ± 0.11 |
| 02                    | I     | 2    | 278.3    | 210.8    | 956 07.16   | 69 43 11.9  | 25.55 ± 0.21 | 23.16 ± 0.13 |
| 03                    | I     | 2    | 561.0    | 231.0    | 956 12.54   | 69 43 08.7  | 25.35 ± 0.22 | 23.96 ± 0.17 |
| 04                    | I     | 3    | 190.8    | 605.8    | 955 52.16   | 69 43 18.3  | 25.38 ± 0.15 | 23.78 ± 0.13 |
| 05                    | I     | 3    | 107.0    | 475.9    | 955 54.72   | 69 43 26.0  | 25.59 ± 0.19 | 23.91 ± 0.12 |
| 06                    | I     | 3    | 112.4    | 349.8    | 955 57.11   | 69 43 24.9  | 26.08 ± 0.19 | 23.90 ± 0.13 |
| 07                    | I     | 4    | 700.6    | 680.5    | 955 51.20   | 69 44 37.9  | 26.10 ± 0.17 | 24.09 ± 0.12 |
| 08                    | I     | 4    | 226.3    | 261.9    | 955 59.75   | 69 43 53.7  | 25.90 ± 0.17 | 23.86 ± 0.10 |
| 09                    | I     | 4    | 217.2    | 206.8    | 955 59.86   | 69 43 48.1  | 26.03 ± 0.20 | 24.27 ± 0.12 |
| 10                   | II    | 2    | 235.3    | 132.9    | 956 30.01   | 69 43 22.3  | 23.24 ± 0.10 | 23.09 ± 0.09 |
| 11                   | II    | 2    | 516.7    | 323.5    | 956 35.29   | 69 43 11.2  | 25.25 ± 0.25 | 23.34 ± 0.14 |
| 12                   | II    | 2    | 692.5    | 465.2    | 956 38.43   | 69 42 47.3  | 24.87 ± 0.18 | 24.24 ± 0.16 |
| 13                   | II    | 3    | 275.3    | 439.4    | 956 18.85   | 69 43 11.7  | 24.41 ± 0.10 | 23.47 ± 0.10 |
| 14                   | II    | 3    | 216.2    | 379.6    | 956 20.04   | 69 43 17.3  | 23.90 ± 0.09 | 23.08 ± 0.08 |
| 15                   | II    | 3    | 264.0    | 296.6    | 956 21.58   | 69 43 12.1  | 25.75 ± 0.17 | 23.70 ± 0.14 |
| 16                   | II    | 4    | 721.8    | 587.0    | 956 14.29   | 69 44 31.3  | 25.70 ± 0.18 | 24.29 ± 0.14 |
| 17                   | II    | 4    | 611.2    | 482.7    | 956 16.26   | 69 44 20.4  | 26.02 ± 0.25 | 23.99 ± 0.16 |
| 18                   | II    | 4    | 231.1    | 417.7    | 956 23.44   | 69 44 11.7  | 25.38 ± 0.21 | 23.59 ± 0.11 |

Note.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.
restricting the luminosity function to the halo region helps especially in determining the TRGB position. Here, we obtain $I_{TRGB} = 23.71 \pm 0.09$ mag and $I_{TRGB} = 23.95 \pm 0.14$ mag for WF3 and WF4, respectively. The tip magnitude of WF3 agrees extremely well with that of the same chip in field I. However, the TRGB magnitude defined by the WF4 sample is fainter by 0.17 mag compared with the halo region of field I. There are several reasons to believe that the TRGB defined by the field II halo region would more likely correspond to the true distance of M82. First, if one exam-
lines the WFPC2 image of field I closely, the presence of wispy, filamentary structures is recognizable. Such features are likely to increase the uncertainties further because of variable reddening. Another but more important reason for putting less weight on the field I WF4 data is that there are far fewer stars observed in this region. Madore & Freedman (1995) showed, using a simulation, that the population size does matter in systematically detecting the TRGB position accurately. That is, if the sample in the first bin does not include enough stars that are immediately fainter than the TRGB magnitude, the distance can be overestimated. We show here again how the population sampling size affects our distance estimates. We used $V$ and $I$ photometric data of the halo of NGC 5253 (Sakai 1999, in preparation), which is comprised of 1457 stars that are brighter than $M_I \leq -3$ and is considered here as a complete sample. The TRGB magnitude for this galaxy is $I = 23.90$ mag. $N$ stars are then randomly selected 100 times from this NGC 5253 database, and the smoothed luminosity function of the stars is determined. The edge-detection filter is then applied to the luminosity function in the usual fashion in order to estimate the TRGB magnitude. This exercise was repeated for the case comprised solely of the RGB stars; that is, the stars brighter than the TRGB were excluded from the parent sample. We show the results for $N = 20$, 100, and 1000 in Figure 6, where the number distribution of TRGB magnitudes is shown for each simulation. And in Table 4, we list the average offset from the TRGB magnitude. In both cases, for the smaller two samples, the TRGB determination becomes very uncertain, as the RGB population becomes indistinguishable from the brighter intermediate-age AGB population. Or in the case where the RGB population is undersampled (the second scenario in which only the RGB stars were included in the sample), the stars around the tip of the RGB are missed, yielding an overestimated distance to this galaxy. Another way to present this effect is to plot the TRGB magnitude as a function of the difference between the 0.15 mag bins that are immediately brighter and fainter than the TRGB. This is shown in Figure 7. For the least complete sample ($N = 300$), the difference in number counts in the consecutive bins around the TRGB is merely $\sim 20$. This figure suggests that at least a number count difference of $\sim 40$ is needed to estimate the TRGB position accurately.

Using the photometric data of the WF4 of field II, we detect the TRGB at $I = 23.95 \pm 0.14$ mag. The foreground extinction in the line of sight of M82 is $A_B = 0.12$ mag (Burstein & Heiles 1984). Using conversions of $A_V/E(V-I) = 2.45$ and $R_V = A_V/E(B-V) = 3.2$ (Dean, Warren, & Cousins 1978; Cardelli, Clayton, & Mathis 1989; Stanek 1996), we obtain $A_I = 0.05$ mag. To calculate the true modulus to M82, we use the TRGB calibration of

| Table 4 | TRGB Systematic Errors Due to Undersampling in the RGB Population |
|---------|---------------------------------------------------------------|
| $N$     | RGB + AGB (mag) | RGB Only (mag) |
| 20      | $-0.24$ | $+0.08$ |
| 50      | $-0.24$ | $+0.04$ |
| 100     | $-0.20$ | $+0.03$ |
| 200     | $-0.11$ | $+0.01$ |
| 500     | $-0.04$ | 0.00 |
| 1000    | $-0.01$ | 0.00 |

Fig. 6.—Number of simulations detecting the TRGB magnitude plotted on the $x$-axis (see text for details)
Lee et al. (1993), according to which the tip distance is determined via the relation \( (m - M) = I_{\text{TRGB}} - M_{\text{bol}} + BC_i \), where both the bolometric magnitude \( M_{\text{bol}} \) and the bolometric correction \( BC_i \) are dependent on the color of the TRGB stars. They are defined by \( M_{\text{bol}} = -0.19[\text{Fe/H}] - 3.81 \) and \( BC_i = 0.881 - 0.243 (V - I)_{\text{TRGB}} \). The metallicity is in turn expressed as a function of the \( V - I \) color: \( [\text{Fe/H}] = -12.65 + 12.6(V - I)_{-3.5} - 3.3(V - I)_{-3.5}^2 \), where \( (V - I)_{-3.5} \) is measured at the absolute \( I \) magnitude of \(-3.5\). The colors of the red giant stars range from \( (V - I)_0 = 1.5 \) to 2.2 (see Fig. 4), which gives the TRGB a magnitude of \( m_I = -4.05 \pm 0.10 \). We thus derive the TRGB distance modulus of M82 to be \( (m - M)_0 = 27.95(\pm 0.14)_{\text{random}}(\pm 0.16)_{\text{systematic}} \) mag. This corresponds to a linear distance of \( 3.9(\pm 0.3)(\pm 0.3) \) Mpc. The sources of errors include (1) the random uncertainties in the tip position \( (0.14 \) mag) and (2) the systematic uncertainties, mainly those due to the TRGB calibration \((0.15 \) mag) and the \( \text{HST} \) photometry zero point \( (0.05 \) mag). Unfortunately, because the TRGB method is calibrated on the RR Lyrae distance scale whose zero point is itself uncertain at a 0.15 mag level, the TRGB zero point subsequently has an uncertainty of 0.15 mag. Recently, Salaris & Cassisi (1997, hereafter SC97) presented a theoretical calibration of the TRGB magnitude that utilized the canonical evolutionary models of stars for a combination of various masses and metallicities for \( Y = 0.23 \) (Salaris & Cassisi 1996). SC97 find that their theoretical calibration leads to a zero point that is \( 0.15 \) mag brighter than the empirical zero point given by Da Costa & Armandrof (1990). They attribute this systematic difference to the small sample of stars observed in the Galactic globular clusters. We did find in the previous section that undersampling the RGB stars leads to a systematically fainter TRGB magnitude, which seems to be in agreement with CS97. Clearly, the issues pertaining to the TRGB calibration need to be reviewed in detail in the future. In this paper, we adopt the TRGB systematic calibration uncertainty of 0.15 mag based on these studies.

5. STARS BRIGHTER THAN THE TRGB: WHAT ARE THEY?

It was noted in Figure 4 that the field II appears to have a considerable number of stars that are brighter than the TRGB. There are two possible scenarios to explain what these stars are: (1) blends of fainter stars due to crowding, or (2) intermediate-age AGB stars. To explain how much effect the crowding has on stellar photometry, we turn our attention to Grillmair et al. (1996), who presented an \( \text{HST} \) observation of M32 halo stars. They concluded that the AGB stars detected in the same halo region by Freedman (1989) were mostly due to the crowding. Upon convolving the \( \text{HST} \) data to simulate the 0.6 arcsecond image obtained at the Canada-France-Hawaii Telescope (CFHT), they successfully recovered these brighter “AGB” stars. While \( \text{HST} \)’s 0.1 arcsecond resolution at the distance of M32 (770 kpc) corresponds to 0.37 pc, 0.6 arcsecond resolution at the same distance corresponds to 2.2 pc. Our \( \text{HST} \) M82 data have a resolution of 1.7 pc (0.1 arcsecond at 3.2 Mpc), indicating that those stars brighter than the first-ascent TRGB stars are, by analogy with M32, likely to be blends of fainter stars.

If instead we were to adopt the second scenario in which these brighter stars are actually AGB stars, the first striking feature in the CMDs shown in Figure 3 is that field II contains significantly more AGB stars in comparison with field I. In particular, we focus on the WF3 chip of each field; we restrict the sample to smaller regions of WF3 chips where the surface brightness is roughly in the range of \( 21.0 \leq m_i \leq 21.5 \). This corresponds to the lower 3/4 of the WF3 chip in field I (regions 3A + 3B in Fig. 8), and the upper 3/4 of the WF3 chip in field II (regions 3A + 3B). The difference in the number of AGB populations of the two fields is compared in terms of \( N_{\text{AGB}}/N_{\text{RGB}} \), defined here as the ratio of the numbers of stars in a 0.5 mag bin that are brighter than the TRGB to those in a 0.5 mag bin that are fainter than the TRGB. We chose the 0.5 mag bin here, as it might be less affected by the incompleteness of stars detected at magnitudes \( \sim 1 \) mag fainter than the TRGB. In calculating the ratios, we also assume that 20% of the fainter giants below the TRGB are actually AGB stars. The ratios of fields I and II are, respectively, \( N_{\text{AGB}}/N_{\text{RGB}} = 58/193 = 0.30 \pm 0.04 \) and 164/484 = 0.64 \pm 0.04. Restricting the samples further in order to avoid the more crowded regions, by using those stars in the section 3A only, we obtain \( N_{\text{AGB}}/N_{\text{RGB}} = 58/193 = 0.30 \pm 0.04 \) and 87/172 = 0.51 \pm 0.06 for fields I and II, respectively. These ratios seem to suggest that the difference between the two fields is significant, at a level of 4–5 \( \sigma \). Because these subregions were chosen to match the surface brightness as closely as possible, the blending of stars that is due to crowding should not be a major factor in systematically making field II much richer in the intermediate-age AGB population compared with field I.

![Figure 7](image_url)  
**Figure 7.**—Observed TRGB magnitude in each simulation, plotted as a function of the difference between the number of stars in the 1.5 mag bin above and below the TRGB \((N_+ - N_-)\).

![Figure 8](image_url)  
**Figure 8.**—Schematics showing the regions used to calculate the ratios of AGB to RGB stars.
Although the present analysis cannot by any means rule out crowding as the dominant effect, and there is strong evidence that these brighter stars above the TRGB are blends of fainter stars, we conclude the paper by mentioning a possible connection between the presence of these brighter stars (if real) with the \( \text{H} \, \text{i} \) distribution around this galaxy. Yun et al. (1993) presented the VLA observations of M82, which revealed tidal streamers extending \( \geq 10 \) kpc from M82, characterized by two main structures. One of these streamers extends northward from the northeast edge of the galaxy, which coincides with our field II position. The integrated \( \text{H} \, \text{i} \) flux map of Yun et al. does not, however, reveal any neutral hydrogen in the region around field I. If M82 is a tidally disrupted system that has undergone direct interaction with M81 and NGC 3077, could this have affected the star formation history of M82, enhancing a more recent star formation in the northeastern edge of the galaxy (field II)? Answering this question is obviously beyond the scope of this paper, requiring much deeper, higher resolution observations, such as those obtained with the Advanced Camera.

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REFERENCES

Burstein, D., & Heiles, C., 1984, ApJS, 54, 33
Caldwell, N., Armandroff, T. E., Da Costa, G. S., & Seitzer, P. 1998, AJ, 115, 555
Cardelli, J. A., Clayton, G. C., & Mathis, J. S. 1989, ApJ, 345, 245
Da Costa, G. S., & Armandroff, T. E. 1990, AJ, 100, 162
Dean, J. F., Warren, P. R., & Cousins, A. W. J. 1978, MNRAS, 183, 569
Freedman, W. L. 1989, AJ, 98, 1285
Freedman, W. L., et al. 1994, ApJ, 427, 628
Grillmair, C. J., et al. 1996, AJ, 112, 1975
Hill, R. J., et al. 1998, ApJ, 496, 648
Holtzman, J. A., Burrows, C. J., Castertano, S., Hester, J. J., Trauger, J. T., Watson, A. M., & Worthy, G. 1995, PASP, 107, 1065
Kronberg, P. P., Biermann, P., & Schwab, F. R. 1985, ApJ, 291, 693
Landolt, A. U. 1992, AJ, 104, 320
Lee, Y. W., Demarque, P., & Zinn, B. 1990, ApJ, 350, 155
Lee, M. G., Freedman, W. L., & Madore, B. F. 1993, ApJ, 417, 553
Madore, B. F., & Freedman, W. L. 1995, AJ, 109, 1645
Sakai, S., Madore, B. F., & Freedman, W. L. 1996, ApJ, 461, 713
Salaris, M., & Cassisi, S. 1996, A&A, 305, 858
———. 1997, MNRAS, 289, 406 (SC97)
Stanek, K. Z. 1996, ApJ, 460, L37
Stetson, P. B. 1990, PASP, 102, 932
———. 1994, PASP, 106, 250
Telesco, C. M., & Harper, D. A. 1980, ApJ, 235, 392
Yun, M. S., Ho, P. T., & Lo, K. Y. 1993, ApJ, 411, L17