Revista Mexicana de Astronomía y Astrofísica, **27**, 165-169 (1993)

HST FOC/48 UV IMAGERY OF GR8

B. Patterson, R. J. Wyatt, and R. J. Dufour
Department of Space Physics and Astronomy, Rice University

RESUMEN

Durante Julio de 1991 se obtuvieron imagenes de GR8 con el Telescopio Espacial Hubble. Utilizando la "Wide Field Camera" se observo a la galaxia completa a 5500 Å (F555W), 4390 Å (F439W) y 3360 Å (F336W); con la "Faint Object Camera" se observaron dos campos mas pequeños alrededor de las regiones HII HL5 y HL19 a 1400 Å (F150W). Magnitudes B y V para estas estrellas se tomaron de la fotometria de Wyatt de las imagenes de la WFC. Estas magnitudes se usaron para elaborar diagramas color-magnitud y color-color para HL5 y HL19. Todas las estrellas observadas en HL5 se encuentran en la region superior de la sequencia principal. La mayoria de las estrellas en HL19 ocupan posiciones similares en los diagramas color-magnitud y color-color; sin embargo, dos de las estrellas mas brillantes (en el visible) muestran comportamiento anomalo. El bajo brillo de estas estrellas en longitudes FUV nos lleva a conduir que son estrellas de fondo y no miembros de GR8.

ABSTRACT

Imagery observations of GR8 were made in July 1991 with the Hubble Space Telescope. The Wide Field Camera imaged the entire galaxy at 5500 Å (F555W), 4390 Å (F439W), and 3360 Å (F336W); and two smaller fields around the HII regions HL5 and HL19 were imaged at 1400 Å (F150W) with the Faint Object Camera. B and V magnitudes for these stars are from Wyatt's photometry on the WFC images. These magnitudes are used to construct color-magnitude and color-color diagrams for HL5 and HL19. All of the stars imaged in HL5 fall along the upper portion of the main sequence. Most stars in HL19 occupy similar positions in the color-magnitude and color-color diagrams; however, two of the brightest stars (at visual wavelengths) show anomalous behavior. The low brightness of these stars at FUV wavelengths leads to the conclusion that they are likely foreground stars rather than members of GR8.

Key words: **GALAXIES: IRREGULAR — GALAXIES: ISM — GALAXIES: PHOTOMETRY**

1. INTRODUCTION

The dwarf irregular galaxy GR8, also known as DDO 155 and A1256 + 14, is located on the edge of the Local Group at a distance of about 1.1 Mpc (distance modulus of 25.25 ± 0.4) (de Vaucouleurs & Moss 1983). The galaxy was first discovered by Reaves (1956) who thought it a member of the Virgo cluster; Hodge (1967) first estimated its distance at 1.0 ± 0.5 Mpc (distance modulus of 25.0), placing it within the Local Group. Hodge, Lee, & Kennicutt (1989) have identified 32 HII regions in GR8 using narrow band Hα CCD imaging. The brightest two, classified HL5 and HL19, were the first HII regions detected (Hodge 1974).

GR8 is intrinsically very small and faint: the mass of its luminous matter is $3.2 \times 10^6 \mathcal{M}_\odot$ (Carignan *et al.* 1990); it has total blue luminosity of $2.5 \times 10^6 \mathcal{L}_\odot$ and absolute magnitude $M_B = -10.5$ (Hodge *et al.* 1989); and at surface brightness $\mu = 25$ mag arcsec^{-2}, the major axis of GR8 is only 427 pc (de Vaucouleurs & Moss 1983). In addition, GR8 has one of the lowest oxygen abundances, 0.024 solar, measured in an extragalactic HII region (Skillman *et al.* 1987).

2. OBSERVATIONS

The 1400 Å ultraviolet images of H II regions HL5 and HL19, labeled as such in Hodge *et al.* (1989), were taken with the Hubble Space Telescope Faint Object Camera (FOC) in its F/48 mode (Figure 1, a and b). This mode produces images with a plate scale of 1.792 arcsec mm^{-1}, or 0.04514 arcsec pixel^{-1} and has a maximum field of 22.5 × 22.5 arcsec^2. The F150W filter, through which the FOC images were obtained, has a peak wavelength λ_o = 1400 Å with $\Delta\lambda$ = 606 Å. At 1400 Å, the transmission T(λ_o) = 0.23 (FOC Instrument Handbook). These ultraviolet data were taken with the FOC because the Wide Field Camera (WFC) CCD is not sensitive at these short wavelengths. However, images of GR8 in visual, blue, and near ultraviolet were taken of the entire galaxy by the WFC with the F555W, F439W, and F336W filters (Figure 1c).

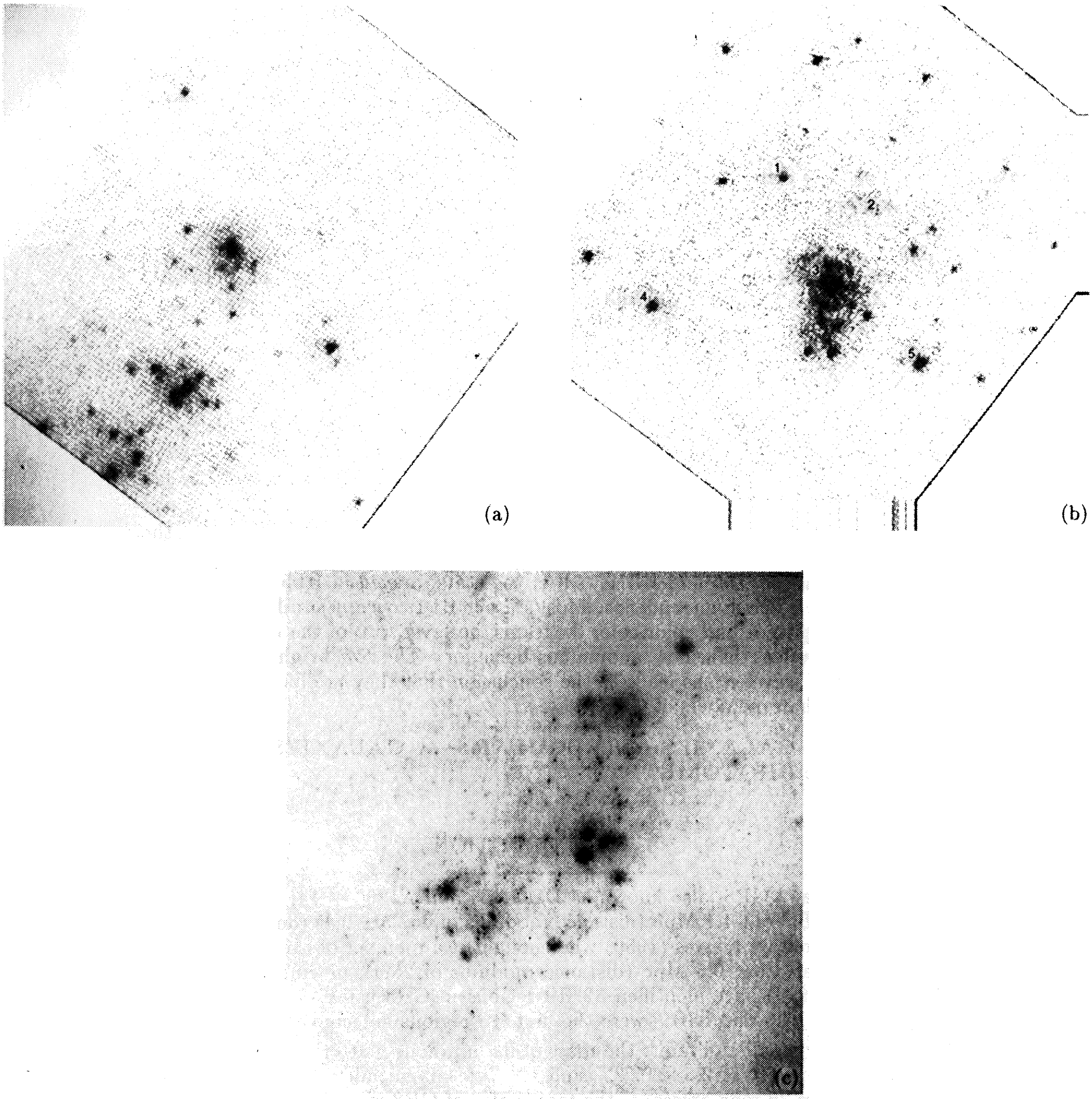

Fig. 1. — Images of GR8. (a) HL5 (FOC image with F150W filter), (b) HL19 (FOC image with F150W filter), (c) GR8 in its entirity (WFC image with F555W filter).

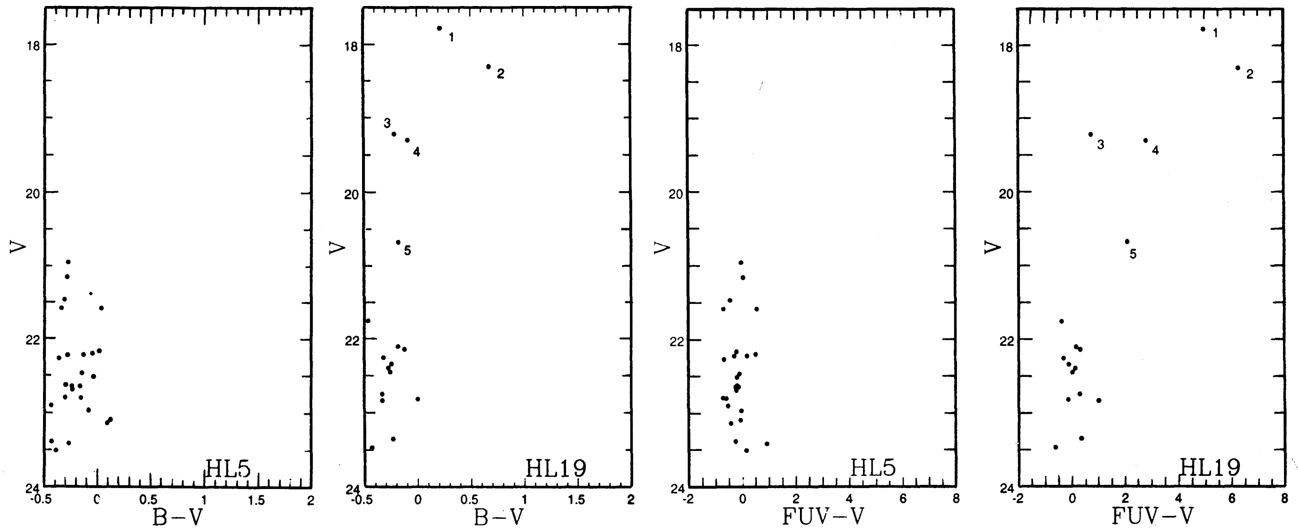

Fig. 2. — (Left) V vs. $B - V$ for stars in HL5 and HL19. Five stars in HL19 are labelled with numbers; these stars exhibit anomalous behavior in these and other diagrams. The stars are identified in Figure 1. (Right) V vs. $FUV - V$ for stars in HL5 and HL19. Stars 1, 2, 4, and 5 have higher $FUV - V$ than any other stars in HL19; they are much brighter in visual wavelengths than they are in the far UV. Star 3 is brighter in visual than are other stars in HL19, but it has similar color.

3. ANALYSIS

Routine image reduction such as background subtraction and geometric corrections specific to the FOC and WFC data was performed by the Space Telescope Science Institute before the data were sent to Dufour on magnetic tape. Further processing was performed using the Image Reduction and Analysis Facility (IRAF)[1] on a Sun workstation. IRAF routines were used to north-south align the FOC images and extract the HL5 and HL19 regions from the WFC images. These areas were scaled to and aligned with the FOC images for easier comparison and star identification among images of different wavelengths. Raw "FUV" magnitudes (far ultraviolet; from the FOC frame with the F150W filter) are found using the IRAF aperture photometry package *apphot*. Corrected FUV magnitudes are found by defining $FUV - V = 0$ for stars with $B - V = 0$. Color-magnitude and color-color diagrams are constructed for HL5 and HL19 using these magnitudes as well as B and V magnitudes previously determined by Wyatt.

4. RESULTS

Figure 2 presents color-magnitude diagrams for GR8. For each of the HII regions V vs. $B - V$ and V vs. $FUV - V$ are plotted including all stars for which FUV, B, and V magnitudes have been determined. The B and V magnitudes were derived from photometry on the WFC images of the entire galaxy. FUV magnitudes are from the FOC images of the HII regions. Several stars which have FUV magnitudes were below the intensity cutoff for photometry in the blue or visual frames and have undetermined B and V.

Color-color diagrams ($FUV - V$ vs. $B - V$) are shown in Figure 3. A theoretical main sequence has been drawn on the right plot. This has been determined from Planck's blackbody equation and the definition $FUV - V = 0$ for $B - V = 0$. $B - V$ for a given temperature is based on accepted color–spectral type–temperature relationships for stars in our Galaxy. This could explain why the majority of stars in the HII regions are to the left of the main sequence: the stars in GR8 could be bluer than galactic stars because their spectra contain fewer absorption lines. Because B is on top of weak metal lines, $B - V$ for a given spectral type is higher for galactic stars.

[1] IRAF is distributed by the National Optical Astronomy Observatories, which is operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation

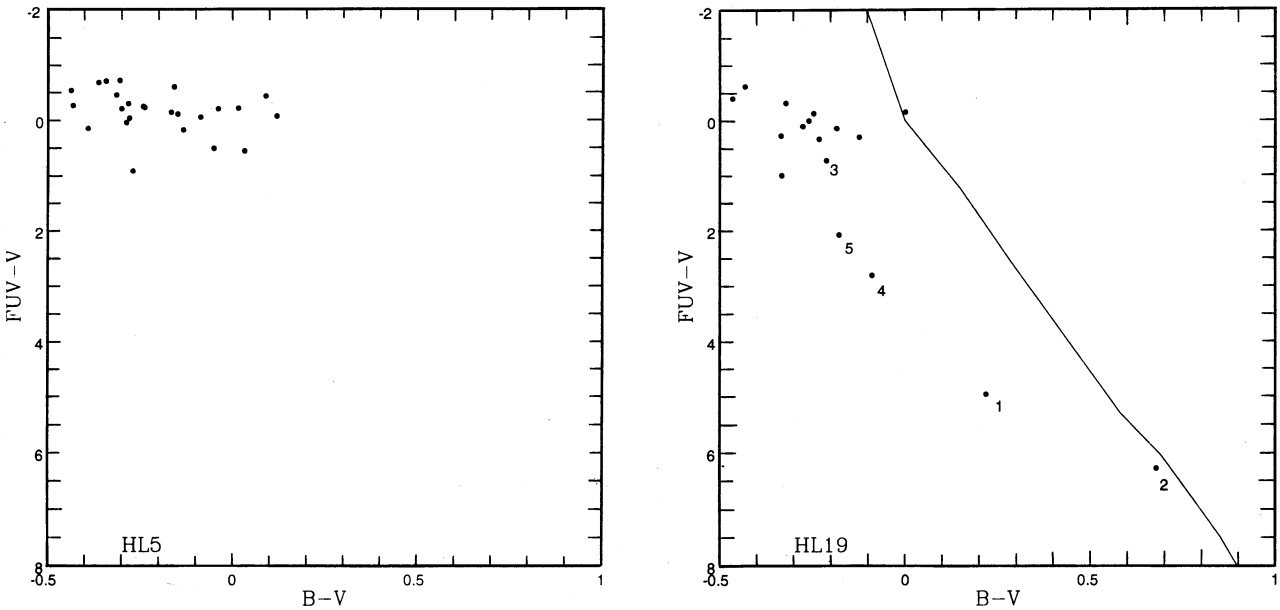

Fig. 3. — $FUV - V$ vs. $B - V$ for stars in HL5 and HL19. A theoretical blackbody main sequence is shown. Stars 1, 2, 4, and 5 differ from other stars in HL5 and HL19 while star 3 (the brightest star in HL19 at far UV wavelengths) is similar to others in GR8. However, none of the stars fall too far from the theoretical main sequence.

In each of these color-magnitude or color-color diagrams the stars in HL5 are all fairly similar. They cluster together and fall along or near theoretical curves. (The FUV vs. $B - V$ color magnitude diagrams have also been examined; a theoretical main sequence was determined and plotted, but introduced uncertainty because V must be defined at $FUV - V = 0$ in order to find necessary constants. However, this curve did show that the far ultraviolet output of a star is highly temperature dependent.) The stars seen in these two HII regions are in general very bright, fairly blue stars near the top of the main sequence. There is a red supergiant in the HL5 area which does not appear on these diagrams due to its very low far ultraviolet luminosity.

It is obvious from these diagrams that a few of the stars in HL19 are different from all of the stars in HL5 and most in HL19: they are quite bright visually and have high $FUV - V$. These stars have been labeled 1, 2, 3, 4, and 5. Though each of these stars is brighter in V than are others in HL19, only star 3 is brighter than average in FUV. Stars 1, 4, and 5 are as bright in FUV as other stars in HL19 while star 2 is quite dim. This star does have a higher $B - V$ than other stars in the region, but it is not red enough to be a red giant. Therefore, it should radiate more in FUV if it is like other stars in HL5 and HL19.

Star 3 has a $FUV - V$ color very similar to most stars in HL19 while stars 1, 2, 4, and 5 have higher color indices, indicating that they are comparatively much brighter in V than other stars with approximately the same FUV.

If the $FUV - V$ vs. $B - V$ theoretical main sequence is shifted along the $B - V$ axis so that it more closely fits most stars in HL5 and HL19, the outlying stars 1, 4, and 5 show a reasonable fit while star 2 is away from the main sequence.

5. CONCLUSIONS

When comparing HL5 and HL19 diagrams in Figures 2 and 3, it is obvious that some stars in HL19 are anomalous. Based on its brightness at far ultraviolet wavelengths, star 3 appears merely to be a very bright member of GR8. One explanation for the other four stars is that they are foreground stars, members of our own Galaxy. It has already been suggested that star 2 is not a member of GR8 (Moss & de Vaucouleurs 1986). That this and perhaps the other stars are members of our Galaxy is reasonable because higher metallicity would cause higher opacity at far ultraviolet wavelengths due to C, N, and O absorption lines.

In addition, de Vaucouleurs & Moss (1983) show that Hα from hot HII regions does not completely map around the bright stars 1 and 2. On the other hand, star 3 is in the center of an Hα isodensity contour, indicating that it is the exciting star of at least part of HL19. Despite being comparably bright and as blue as star 3, stars 4 and 5 show no related HII structure; they are therefore likely not a part of the galaxy or are too separated from the HL19 association to excite surrounding hydrogen gas.

The conclusion that some of these stars are not members of GR8 would alter the estimate of the distance modulus. A change in the distance modulus of GR8 modifies the estimate of its age (as determined by comparison with theoretical isochrones) and therefore the understanding of its stellar population.

Statistically, it seems quite unlikely that four stars in this small field are foreground stars. However, the data presented confirms that star 2 is probably a foreground star. Because star 1 has many of the same characteristics as star 2, its behavior could also be explained in this way. Star 3 is definitely a member of GR8. Stars 4 and 5, while somewhat anomalous, are more similar to GR8 members than are 1 and 2. It is possible that these are double star systems; the light from the two stars would combine and could result in odd colors. Because of the many possible explanations for these results, further observation, such as spectroscopy, should be performed in order to determine the true nature of these stars.

REFERENCES

Carignan, C., Beaulieu, S., & Freeman, K.C. 1990, AJ, 99, 178
de Vaucouleurs, G., & Moss, C. 1983, ApJ, 271, 123
Hodge, P.W. 1967, ApJ, 148, 719
Hodge, P.W. 1974, PASP, 86, 645
Hodge, P.W., Lee, M.G., & Kennicutt, R.C. 1989, PASP, 101, 640
Moss, C., & de Vaucouleurs, G. 1986, PASP, 98, 1282
Reaves, G. 1956, AJ, 61, 69
Skillman, E.D., Melnick, J., Terlevich, R., & Moles, M. 1987, A&A, 196, 31
Space Telescope Science Institute. April 1992, Hubble Space Telescope Faint Object Camera Instrument Handbook, Version 3.0

Reginald J. Dufour, B. Patterson, and R.J. Wyatt: Rice University, Space Physics & Astronomy Dept., P.O. Box 1892, SS Bldg., Rm. 232, Houston, TX 77251-1892, U.S.A.