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THE NOT SO EXTRAORDINARY GLOBULAR CLUSTER 037-B327 IN M31[1]

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ABSTRACT

A velocity dispersion has been measured for the luminous globular cluster M31 037-B327, claimed to be the most massive star cluster in the Local Group and to be a young "super star cluster" that has survived to an old age. M31 037-B327 has a mass comparable to that of M31 G1 but not significantly larger. Although near the upper end for the mass distribution of globular clusters, it is not an unprecedented extraordinary object.

Subject headings: galaxies: individual (M31) — galaxies: star clusters

1. INTRODUCTION

The globular cluster 037-B327 is an extremely red nonstellar object close to the disk of M31. Barmby et al. (2002b) calculated its reddening, using photometry in the compiled catalog of M31 globular clusters of Barmby et al. (2000) to be $E(B-V) = 1.30 \pm 0.04$ mag, and from this inferred that it was extremely luminous, with $M_V = -11.7$ mag, making it the most luminous globular cluster in M31. The recent compilation of data for M31 globular clusters by the Bologna group (Galleti et al. 2004) also confirms the unusual properties of this object.

Recently, Ma et al. (2006a) have studied this cluster in more detail. They compare their new multicolor photometry to theoretical spectral energy distributions of varying ages to determine the reddening and age of this cluster. They find that it has a photometric mass of $(3.0 \pm 0.5) \times 10^7\ M_\odot$; they then claim this object to be the most massive star cluster of any age in the Local Group. This claim is based in part on data from the compiled catalogs of Barmby et al. (2000) for the M31 system and of Harris (1996) for the Milky Way globular cluster system. Ma et al. (2006a) predict that 037-B327 has a one-dimensional velocity dispersion of 72 ± 13 km s^{-1}, far larger than that of any other known M31 globular cluster. Velocity dispersions for a number of the brightest globular clusters in M31 were determined by Djorgovski et al. (1997); the highest value they measured was 25.1 ± 0.3 km s^{-1} for G1.

2. σ_v FOR M31 037-B327

We have obtained high spectral resolution spectra with High Resolution Echelle Spectrometer (HIRES) at Keck (Vogt et al. 1994) of 037-B327 and of G1 in M31, as well as of several metal-rich giants on the upper red giant branch of the Draco dwarf spheroidal galaxy that served as template stars. We took two 1500 s exposures of the object of interest, one 600 s exposure of the much brighter (at V) object G1, and several suitable spectra of template red giants from the same run in early 2006 September. All these spectra were taken with a $1\farcs1 \times 7''$ slit, giving a spectral resolution of 35,000 with 5 pixels per spectral resolution element (~1.3 km s^{-1} pixel^{-1}).

We chose for analysis parts of three different echelle orders with strong broadened spectral features visible in the spectrum of 037-B327. Since the flux for this object was dropping rapidly toward the blue, but the number of strong lines was dropping rapidly toward the red, this was something of a compromise. Cutouts of the spectra in one of the regions analyzed, that near Hα, are shown for the two M31 globular clusters and one of the template objects in Figure 1. It is immediately apparent that σ_v for 037-B327 is comparable to that of G1 but is not significantly larger. This impression is sustained when one examines the strongest lines in these spectra over their full useful wavelength range, which for the object of interest is from about 5100 to 8350 Å.

We used the Fourier quotient method of Sargent et al. (1977) to determine σ_v. We subsequently applied an aperture correction factor of 1.14 following Djorgovski et al. (1997). The resulting σ_v are given in Table 1. Our measured σ_v for G1 is in good agreement with that of Djorgovski et al. (1997) 25.1 ± 0.3 km s^{-1}.

3. COMPARISON OF M31 037-B327 WITH M31 G1

G1, if one ignores 037-B327, is widely believed to be the most luminous globular cluster in M31 (see, e.g., Meylan et al. 2001). Gebhardt et al. (2003) suggested, based on *Hubble Space Telescope* (*HST*) Space Telescope Imaging Spectrograph spectroscopy, that it contains a 20,000 $M_\odot$ central black hole. Baumgardt et al. (2003) dispute this; they obtain a good fit to all available data for G1 with their dynamical model, which does not include an intermediate-mass central black hole.

Ma et al. (2006b) utilize an Advanced Camera for Surveys (ACS) image from *HST* to determine the structural parameters of 037-B327, and discuss the possibility, suggested earlier by Barmby et al. (2002b) that this object is the nucleus of a dwarf galaxy accreted by M31. The ACS image reveals a dust lane crossing the face of the cluster. Toy models of a uniform extinction over most of the cluster, with much larger $E(B-V)$ over a smaller part of the cluster, suggest that substantial errors in the values of the dereddened fluxes can occur in such circumstances if a standard extinction curve as a function of wavelength is applied assuming a constant $E(B-V)$. The reddening of G1 is small as it has a projected distance from the center of M31 of ~40 kpc; we assume only the foreground Galactic reddening applies.

We compare the properties of 037-B327 with those of G1. The values of σ_v are comparable (see Table 1), with that of G1 perhaps being slightly larger. Since the reddening of 037-B327 is large and spatially variable across the face of the cluster, we prefer to compare the luminosities at K where the impact of the reddening is minimized. We assume both objects are old stellar clusters. This comparison is sure to be more reliable than a similar one making the same assumption carried out at V by Ma et al.

[1] Based on observations obtained at the W. M. Keck Observatory, which is operated jointly by the California Institute of Technology, the University of California, and the National Aeronautics and Space Administration.

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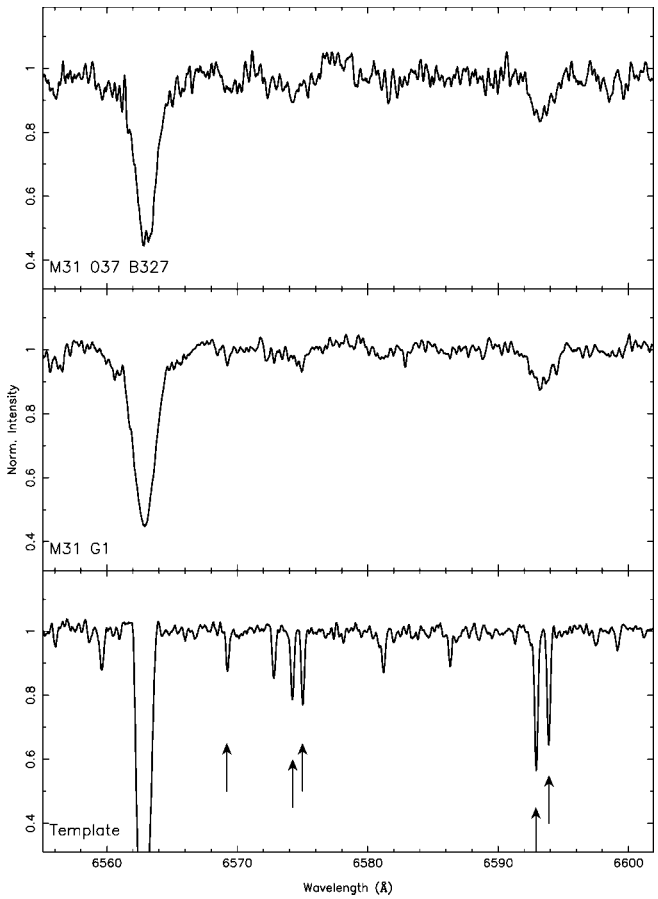

FIG. 1.—Region of the spectrum including Hα, shown for 037-B327 (*top*), G1 (*middle*), and a template luminous red giant (*bottom*). The spectra have been normalized, shifted to the rest frame, and slightly smoothed by a Gaussian with FWHM = 5 km s^{-1}. The spectral features marked by arrows in the bottom panel are all Fe I lines.

(2006a), which suggested that 037-B327 is a factor of ~2.5 times more luminous than G1.

In late 2006 September we acquired an image at K of the field of 037-B327 with the Wide-Field Infrared Camera (Wilson et al. 2003) at the Hale Telescope on Palomar Mountain to verify the IR photometry of this cluster. We find $K_s = 11.06 \pm 0.05$ mag in the Two Micron All Sky Survey (2MASS; Skrutskie et al. 2006; Cutri et al. 2003) system for an aperture 11″ in diameter. This is within 0.01 mag of that derived from the 2MASS database by Galleti et al. (2004).[3] K_s for G1 from 2MASS as reported by Galleti et al. (2004) is 0.025 mag fainter than that of 037-B327. If one takes $E(B-V)$ for the heavily reddened cluster 037-B327 as 1.3 mag with a more realistic error than that adopted by Ma et al. (2006a) given the spatially varying reddening, of ± 0.3 mag, then 037-B327 has M_K brighter by 0.16 ± 0.03 mag. We thus find that 037-B327 has L_K comparable to that of G1 and at most 20% larger, even allowing for a generous uncertainty in $E(B-V)$. M_K is well known to be a good measure of the total luminosity for old stellar systems; the dependence of L_λ on [Fe/H] is smaller at 2.4 μm than at optical wavelengths.

In order to determine the virial mass of each of these objects, we must assume that the same initial mass function prevails in both of these clusters and combine σ_v with the half-light radius determined from *HST* or other high spatial resolution imaging. Ma et al. (2006b) have measured R_h for 037-B327, while there are two independent and discrepant determinations of R_h for G1 (that of Meylen et al. 2001 and of Barmby et al. 2002a). R_h for the highly reddened cluster 037-B327 is not larger than that of G1. Thus, there is no evidence that the highly reddened globular cluster 037-B327 is substantially more massive than G1.

[3] Table 2 of Galleti et al. (2004) presents IR magnitudes measured from 2MASS transformed into the Caltech system using the transformation equation of Carpenter (2001). We made the required inverse transformation for the comparison quoted above.

4. CONCLUSIONS

The luminous object 037-B327 believed to be a globular cluster in M31 is indeed a massive object that may or may not be the nucleus of an accreted galaxy, as was suggested by Meylan et al. (2001) and others. However, although it is among the most massive globular clusters in M31, at least four other globular clusters, G1, G78, G280, and G213, studied by Djorgovski et al. (1997) whose earlier σ_v for G1 is confirmed here, have comparable masses. The first three of these are probably more massive than 037-B327. Among the Galactic globular clusters, ω Cen and NGC 6441 have σ_v comparable to that of 037-B327, based on the compilation of Pryor & Meylan (1993). Contrary to the conclusion of Ma et al. (2006a), we find it to be very similar to the well-studied cluster G1. The globular cluster 037-B327 is not an extraordinarily massive old cluster and is almost certainly not the most massive cluster of any age in the Local Group.

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TABLE 1
VELOCITY DISPERSION MEASUREMENTS FOR TWO M31 GLOBULAR CLUSTERS

ID	Wavelength Range (Å)	σ_v (1 σ, km s^{-1})	Uncertainty (km s^{-1})	Apperture Correction σ_v[a] (km s^{-1})
037-B327	5150–5190	19.2	3.5	21.9
	6105–6190	…[b]	…	…
	6545–6600	19.9	3.4	22.6
G1	5150–5190	19.6	1.8	22.4
	6105–6190	22.3	1.5	25.4
	6545–6600	22.4	1.5	25.6

[a] Aperture correction set to a factor of 1.14 following Djorgovski et al. (1997).
[b] Features were too weak to permit a reliable determination of σ_v in this spectral region.

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