The Nearby Starforming Dwarf Galaxy NGC 4214*

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1 Introduction

NGC 4214 is a nearby metal-deficient dwarf starburst galaxy in the direction of the Canes Venatici cloud. Relatively gas rich even for a Magellanic irregular, this galaxy has unusually blue colours and an interstellar medium (ISM) with a complicated structure. There are several features and detected flows, which offer the possibility of assessing the importance of both photoionization and mechanical energy deposition by strong stellar winds and SNe on structuring the ISM.

We present in this work the first deep optical-infrared study of the stellar populations in NGC 4214, using data from the HST NICMOS and WFPC2 cameras. Multi-colour stellar photometry provides us with the opportunity to study resolved stellar populations of different masses, ages and chemical abundances. The analysis of stellar distributions on colour-magnitude diagrams (CMDs) is the most direct way to investigate the star formation history of a galaxy, and in many cases provides the best available distance estimate. The advantage of using NICMOS to search for intermediate-mass/old stars is that the spectral energy distribution of such stars peaks in the near-IR. The WFPC2 camera, on the other hand, has a larger field of view, allowing the possibility to study spatial variations of different stellar populations. In addition, stellar metallicities of the red giant branch (RGB) may be directly derived from optical CMDs.

2 Results

Figure 1 shows the HST images. The NICMOS/NIC2 camera was centered on NGC 4214-II, the smaller and younger of two major star-forming regions in this galaxy. (cf. Maíz-Apellániz et al., 1999). The center of NGC 4214-I was placed on the WF3 chip of the WFPC2, while NGC 4214-II is on the WF2 chip and intersects the NIC2 field.

We performed V, R, I, J, H photometry of the resolved stars, and achieved limiting magnitudes of $F110W \approx 25$ in the NIC2 and $F814W \approx 27$ in the WFPC2. There are ~ 1500 stars detected in both the $F110W$ and $F160W$ filters, and ~ 20000 stars detected in both the $F555W$ and $F814W$ filters in all four WFPC2 frames.

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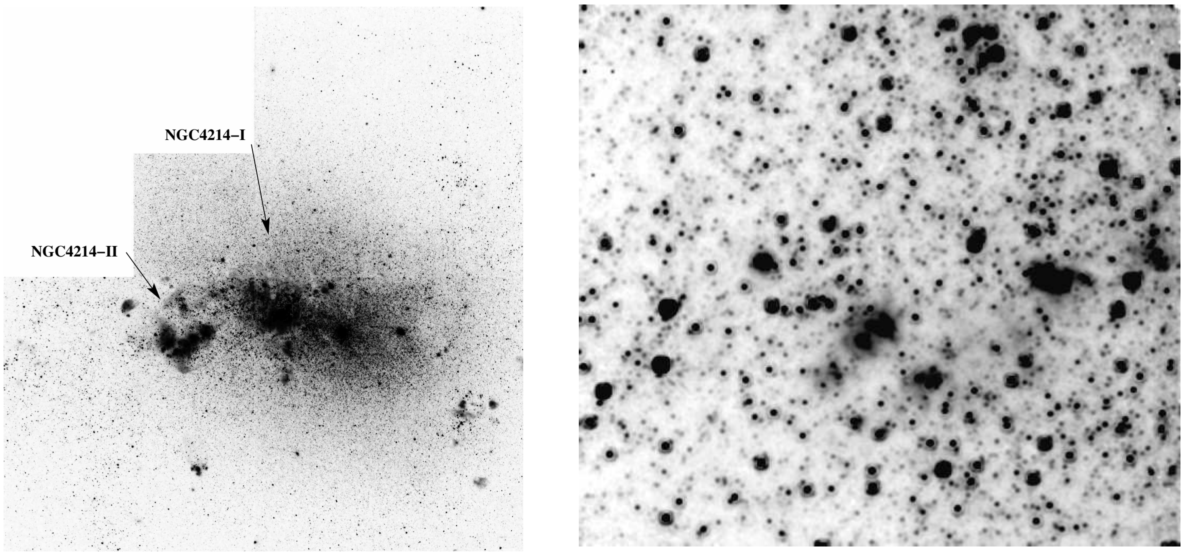

Figure 1: *Left* is the WFPC2 image of NGC 4214 in the $U+V+R+I$ + Hα + [OIII] bands. *Right* is the NIC2 $F160W$ band image of NGC 4214-II.

The resolved stars exhibit a complex spatial distribution. Whereas the distribution of red intermediate-age and old stars is almost uniform and traces the large stellar disk extending out to at least $8'$ (7 kpc), the distribution of the brightest blue young stars is clumpy and follows the central bar ($\sim 1.'5$ or $\sim$ 1 kpc), as well as arm-like chains of stellar associations and HII regions. Figure 2 illustrates the position of the brightest blue and red stars. They are concentrated in the two main star formation complexes. Spectroscopic observations suggest these complexes are rich in Wolf-Rayet stars of both the WN and WC sub-types (Sargent & Filippenko, 1991; Mas-Hesse & Kunth, 1999). Some of the WR stars might be included among the brightest blue stars we detect.

The CMDs (Fig. 3) contain many features, including blue and red plumes, a conspicuous asymptotic giant branch, a heavily populated red giant branch. These features show that NGC 4214 has been actively forming stars as far back as at least 1-2 Gyr ago.

The I and H-band luminosity functions show a sudden jump at $I \approx 23.^{\rm m}1$ and $H \approx 21.^{\rm m}8$, which is identified as the tip of the red giant branch (TRGB). Our estimates of the TRGB distance from these two measurements are consistanat with each other. From the I-band we derive a distance modulus of $27.^{\rm m}13 \pm 0.^{\rm m}15 \pm 0.^{\rm m}18$ (random and systematic), or a distance of about 2.7 Mpc. Past estimates have varied from 3.6 to 7 Mpc (Allsopp, 1979; Thronson et al., 1988; Leitherer et al., 1996; Makarova et al., 1997; Martin, 1998). However, these were based on either the brightest supergiant method or on models of flows in the Local Universe; the TRGB method provides a much more secure value. Our new distance leads to a revision of all distance-dependent global parameters. As our value is about 1.5 times closer than was typically adopted before, previous absolute luminosity estimates should be decreased by a factor of about two.

From the mean colour of the RGB, the mean metal abundance of the halo population is estimated as [Fe/H] $\simeq -1.7$ dex with a large internal abundance spread, which can be characterized by $\sigma_{\rm int}$([Fe/H]) ≈ 0.7 dex.

The use of optical and near-IR CMDs allow us to define more precisely the dependence of the RGB tip luminosity in the near-IR on [Fe/H]. We show in (Fig. 4) our results for NGC 4214, along with determinations from Schulte-Ladbeck et al. (1999) for VII Zw 403 and 2MASS data obtained for the Magellanic clouds (Hopp et al., 2000). A comparison of empirical data with the 15 Gyr isochrones in the Padova library (Bertelli et al., 1994) shows that there is an excellent agreement

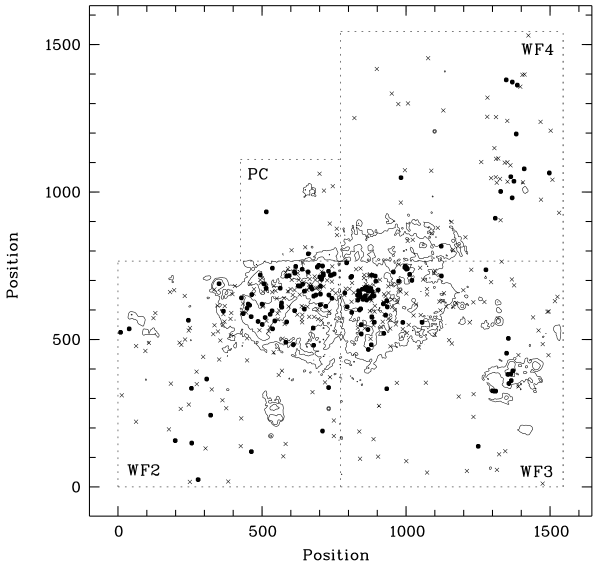

Figure 2: Distribution of the brightest blue (filled circles) and red stars (x's) from the WFPC2 image of NGC 4214.

between observation and theory.

Existing data on the distance of CVn cloud galaxies do not allow us to reach conclusions concerning its spatial structure. Based on our new distance we may argue only that NGC 4214 is in the foreground of the CVn cloud of galaxies. This loose complex is not compact, and possibly is not gravitationally bound, having a size of several Mpc. Fig. 5 illustrates the 3D distribution of the Canes Venatici cloud.

As one of the most prominent galaxies of the CVn Cloud, NGC 4214 has some possible nearby companions: the dwarf galaxies DDO 113 and NGC 4190 which have close radial velocities and a separation $\lesssim 30'$ on the sky. Allsopp (1979) argued from an extension in the HI envelope of NGC 4214 towards NGC 4190 that the two galaxies may be interacting. Accurate TRGB distance determinations for other galaxies are necessary to understand the spatial structure and kinematics of the CVn cloud.

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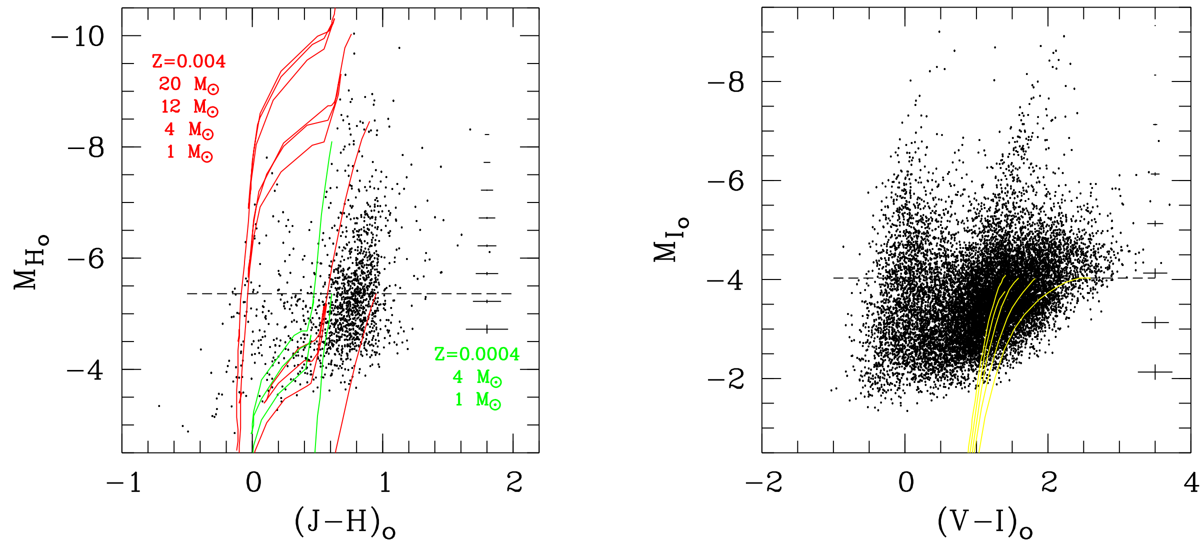

Figure 3: CMDs of NGC 4214. *Left* is the NICMOS M_{H_0} *versus* $(J-H)_0$ diagram of the NGC 4214-II complex. Stellar tracks for metallicities of Z=0.004 and Z=0.0004 (only for stars of 4 and 1 $M_\odot$) from Padova library are shown. *Right* is the $[(V-I)_0, M_{I_0}]$ CMD of selected external fields of NGC 4214 obtained with WFPC2. Giant branches of the standard globular clusters M 15, NGC 6397, M 2, NGC 1851, and 47 Tuc, from Da Costa & Armandroff (1990) are superimposed. A distance modulus of $(m-M)_I = 27\overset{\mathrm{m}}{.}13$ is used.

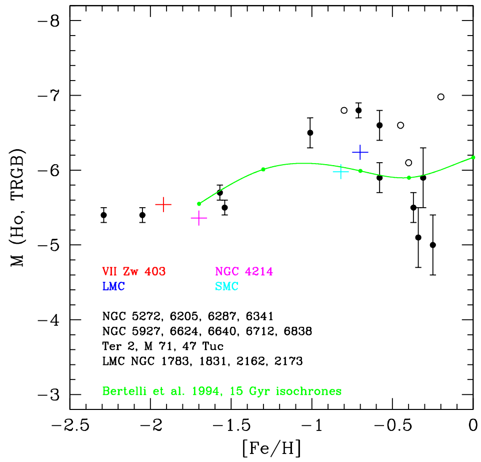

Figure 4: Absolute H-band magnitude at the TRGB versus metallicity. The crosses mark the positions of the galaxies discussed in this work. The H-band magnitudes from the Padova isochrones for 15 Gyr old stars for the largest available metallicity range are shown by the line.

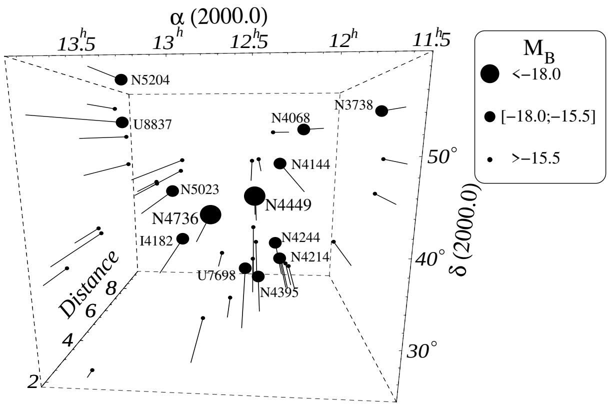

Figure 5: A 3-D representation [(α; δ; *Distance to the baricenter of the LG*] of the Canes Venatici cloud. The size of the circle corresponds to the galaxy's absolute magnitude in the indicated ranges. The length of lines, having parallel direction to the distance axes, is proportional to the galaxy's distance.