Very young massive stars in the Small Magellanic Cloud, revealed by $HST$*

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Abstract. High spatial resolution imaging with the Hubble Space Telescope allowed us to resolve the compact H\(_\text{II}\) region N81 lying in the Small Magellanic Cloud (SMC). We show the presence of a tight cluster of newborn massive stars embedded in this nebular “blob” of $\sim 10''$ across. This is the first time the stellar content and internal morphology of such an object is uncovered. These are among the youngest massive stars in this galaxy accessible to direct observations at ultraviolet and optical wavelengths. Six of them are grouped in the core region of $\sim 2''$ diameter, with a pair of the main exciting stars in the very center separated by only $0''.27$ or $0.08$ pc. The images display violent phenomena such as stellar winds, shocks, ionization fronts, typical of turbulent starburst regions. Since the SMC is the most metal-poor galaxy observable with very high angular resolution, these observations provide important templates for studying star formation in the very distant metal-poor galaxies which populate the early Universe.

Key words: Stars: early-type -- dust, extinction -- H\(_\text{II}\) regions -- individual objects: N81 -- Galaxies: Magellanic Clouds

1. Introduction

It is now generally believed that massive stars form in dense cores of molecular clouds. Initially, they are enshrouded in dusty remains of the molecular material, and, therefore, are not observable in ultraviolet and visible light. At this stage they can only be detected indirectly at infrared and radio wavelengths, emitted respectively by the surrounding dust and by the ionized stellar winds. At a later stage the far-UV photons dissociate the molecules and ionize the atoms creating ultracompact H\(_\text{II}\) regions. Eventually, the natal molecular cloud is ionized to become a compact H\(_\text{II}\) region. As the ionized volume of gas increases, the advancing ionization front of the H\(_\text{II}\) region reaches the cloud border. The ionized gas then flows away into the interstellar medium according to the so-called champagne effect (Tenorio-Tagle 1979, Bodenheimer et al. 1978). From this time on the opacity drops and the newborn stars become accessible to observation in the ultraviolet and visible.

The youngest H\(_\text{II}\) regions that can be penetrated with ultraviolet and optical instruments provide therefore the best opportunities for a direct access to massive stars at very early stages of their evolution. Because of the small timescales involved, it is difficult to catch the most massive stars just at this very point in their evolution, namely when the young H\(_\text{II}\) regions emerge from the associated molecular clouds. Contrary to the situation in the Galaxy, where interstellar extinction in the line of sight is generally high, the Magellanic Clouds, especially the SMC, provide an environment where the sites of massive star formation are accessible without additional foreground extinction.

Our search for such very young, emerging H\(_\text{II}\) regions in the Magellanic Clouds started almost a decade ago on the basis of ground-based observations at the European Southern Observatory. The result was the discovery of a distinct and very rare class of H\(_\text{II}\) regions in the Magellanic Clouds, that we called high-excitation compact H\(_\text{II}\) “blobs” (HEBs). The reason for this terminology was that no features could be distinguished with those telescopes. So far only five HEBs have been found in the LMC: N159-5, N160A1, N160A2, N83B-1, and N11A
(Heydari-Malayeri & Testor 1982, 1983, 1985, 1986, Heydari-Malayeri et al. 1990) and two in the SMC: N88A and N81 (Testor & Pakull 1985, Heydari-Malayeri et al. 1988a).

In contrast to the typical H II regions of the Magellanic Clouds, which are extended structures (sizes of several arc minutes corresponding to more than 50 pc, powered by a large number of exciting stars), HEBs are very dense and small regions (∼5′′ to 10′′ in diameter corresponding to ∼1.5–3.0 pc). HEBs are, in general, heavily affected by local dust (Heydari-Malayeri et al. 1988a, Israel & Koornneef 1991). They are probably the final stages in the evolution of the ultracompact H II regions whose Galactic counterparts are detected only at infrared and radio frequencies (Churchwell 1990). Because of the contamination by strong nebular background no direct information about the exciting stars of HEBs has been achievable with ground-based telescopes. Furthermore, it is not known whether a single hot object or several less massive stars are at work there.

The compact H II "blob" N81 (Henize 1956, other designations: DEM138 in Davies et al. 1976, IC1644, HD7113, etc.) lies in the Shapley Wing at ∼1.2 kpc (∼1.2 kpc) from the main body of the SMC. Other H II regions lying towards the Wing are from west to east N83, N84, N88, N89, and N90. A study of N81 carried out a decade ago (Heydari-Malayeri et al. 1988a) revealed some of its physical characteristics: age of 1 to 2.5 million years, mass of ionized gas amounting to ∼350 M⊙, low metal content typical of the chemical composition of the SMC, gas density of ∼500 cm−3, electron temperature of 14100°K, etc. However, the study suffered from a lack of sufficient spatial resolution and could not be pursued by available Earth-bound facilities. More specifically, the exciting star(s) remained hidden inside the ionized gas. It was not possible to constrain the theoretical models as to the nature of the exciting source(s) and choose among various alternatives (Heydari-Malayeri et al. 1988a). This is, however, a critical question for theories of star formation.

The use of HST is therefore essential for advancing our knowledge of these objects. Here we present the results of our project GO 6535 dedicated to direct imaging and photometry of the “blobs” as a first step in their high-resolution study. A “true-color” high-resolution image and a brief account of the results for the layman were presented in a NASA/HST/ESA Press Release 98-25, July 23, 1998 (Heydari-Malayeri et al. 1998).

2. Observations and data reduction

The observations of N81 described in this paper were obtained with the Wide Field Planetary Camera 2 (WFPC2) on board the HST on September 4, 1997. The small size of N81 makes it an ideal target for the 36′′-field of WFPC2. We used several wide- and narrow-band filters (F300W, F467M, F410M, F547M, F469N, F487N, F502N, F656N, F814W) with two sets of exposure times (short and long). In each set we repeated the exposures twice with ∼5 pixel offset shifts in both horizontal and vertical direction. This so-called dithering technique allowed us to subsequently enhance the sampling of the point spread function (PSF) and improve our spatial resolution by ∼20%. The short exposures, aimed at avoiding saturation of the CCD by the brightest sources, range from 0.6 sec (F547M) to 20 sec (F656N). The long exposures range from 8 sec (F547M) to 300 sec (F656N & F469N).

The data were processed through the standard HST pipeline calibration. Multiple dithered images where co-added using the stsdas task drizzle (Fruchter & Hook 1998), while cosmic rays were detected and removed with the stsdas task crrj. Normalized images were then created using the total exposure times for each filter. To extract the positions of the stars, the routine daofind was applied to the images by setting the determination threshold to 5σ above the local background level. The photometry was performed setting a circular aperture of 3–4 pixels in radius in the daophot package in stsdas.

A crucial point in our data reduction was the sky subtraction. For most isolated stars the sky level was estimated and subtracted automatically using an annulus of 6–8 pixel width around each star. However this could not be done for several stars located in the central region of N81 due to their proximity. In those cases we carefully examined the PSF size of each individual star (FWHM ∼2 pixels, corresponding to 0.09 on the sky) and did an appropriate sky subtraction using the mean of several nearby off-star positions. To convert into a magnitude scale we used zero points in the VegaMag system, that is the system where Vega is set to zero mag in Cousin broad-band filters. The magnitudes measured were corrected for geometrical distortion, finite aperture size (Holtzman et al. 1995), and charge transfer efficiency as recommended by the HST Data Handbook. The photometric errors estimated by daophot are smaller than 0.01 mag for the brighter (14–15 mag) stars, while they increase to ∼0.2 mag for 19 mag stars.

We note that the filter F547M is wider than the standard Strömgren y filter. To evaluate the presence of any systematic effects in our photometry and color magnitude diagrams due to this difference in the filters, we used the stsdas package synphot. Using synthetic...
Fig. 1. The Small Magellanic Cloud compact nebula N81 in Hα emission. The two bright stars (#1 & #2, see Fig. 2) lying below the small central absorption “hole” are the main exciting stars. See Fig. 3 for a close-up of the inner regions. The field size is $\sim 33'' \times 33''$ ($\sim 10 \times 10$ pc). North is up and east is left.

spectra of hot stars, with spectral types similar to those found in H II regions, we estimated the difference due to the HST band-passes to be less than 0.002 mag, which is well within the photometric errors.

The “true-color” image of N81 (Heydari-Malayeri et al. [1998]) was assembled from three separate WFPC2 images using the IRAF external package COLOR task rgbsum. The basic images were the ultraviolet (F300W) and the hydrogen emission blue and red lines Hβ (F487N) and Hα (F656N).

Two line intensity ratio maps were secured using the normalized Hα, Hβ and [OIII] $\lambda$5007 (F502N) images (§3.2 and §3.3). In order to enhance the S/N ratio in the fainter parts, each image was first smoothed using a $2 \times 2$-pixel Gaussian filter.
3. Results

3.1. Overall view

The WFPC2 imaging, in particular the I band filter, reveals some 50 previously unknown stars lying towards N81, where not even one was previously observable. Six of them are grouped in the core region of \( \sim 2'' \) wide, as displayed in Fig. 1. The brightest ones are identified by numbers in Fig. 2. See also the true-color version of this image accompanying the HST Press Release (Heydari-Malayeri et al. 1998). Two bright stars (\#1 & \#2) occupy a central position and are probably the main exciting sources of the H\( \textsc{ii} \) region. Only 0''27 apart on the sky (projected separation \( \sim 0.08 \) pc), they are resolved in the WFPC2 images (Fig. 3).

Two prominent dark lanes divide the nebula into three lobes. One of the lanes ends in a magnificent curved plume more than 15'' (4.5 pc) in length. The absorption features are probably parts of the molecular cloud associated with the H\( \textsc{ii} \) region (§ 4.2). The extinction due to dust grains in those directions amounts to \( \sim 1 \) mag as indicated by the H\( \alpha \)/H\( \beta \) map (§ 3.2). A conspicuous absorption “hole” or dark globule of radius \( \sim 0''25 \) is situated towards the center of the H\( \textsc{ii} \) region, where the extinction reaches even higher values. The apparent compact morphology of this globule in the presence of a rather violent environment is intriguing. We explore some possibilities of its origin in § 4.1.

An outstanding aspect is the presence of arched filaments, gaseous wisps, and narrow ridges produced by powerful stellar winds and shocks from the hot, massive stars. We are therefore witnessing a very turbulent environment typical of young regions of star formation. The two bright ridges lying west of stars \#1 & \#2 are probably ionization/shock fronts. The filamentary and wind induced structures are best seen in Fig. 4, which presents an unsharp masking image of N81 in H\( \alpha \) without large scale structures. In order to remove these brightness variations and enhance the high spatial frequencies, a digital “mask” was created from the H\( \alpha \) image. First the H\( \alpha \) image was convolved by a \( 2 \times 2 \) pixel Gaussian, and then the smoothed frame was subtracted from the original image. The photometry of the brightest subsample is presented in Table 1. The field size and orientation are the same as in Fig. 1.
Fig. 3. A close-up of the inner part of N81 in Hα emission. The two brighter stars (#1 & #2), 0′′27 apart, and the absorption features as well as the western ridges, representing ionization/shock fronts, stand out prominently. The inner ridge lies at a projected distance of ∼0.7 pc from the two main stars; the outer one at ∼1.0 pc. Field size ∼7′′4 × 4′′6. (∼2.2 × 1.4 pc).

Fig. 4. An unsharp masking image of N81 obtained in Hα, which highlights the filamentary patterns of the nebula (see the text). Field size ∼20″ × 16″ (6.0 × 4.7 pc), orientation as in Fig. 3.

Hα image. Interestingly, the inspection of the orientation of these arched filaments suggests the presence of at least three sources of stellar winds: stars #1 & #2 jointly, #3, and probably #11, which are the four brightest blue stars of the cluster.

3.2. Extinction

A map of the Hα/Hβ Balmer decrement is presented in Fig. 3a. The ratio reaches its highest values towards the dark lanes (∼3.8), the western ridges (∼4.5), and the dark globule (∼4.5). This latter value is very close to the highest ratio (4.3) expected for a medium in which dust is locally mixed with gas. The dark “hole”, while present, does not show up prominently in Fig. 3a, because it is small (∼0′′25 across corresponding to ∼15,000 AU) and the binning by convolution used to enhance the S/N ratio in the fainter parts (§2) has reduced the line ratio. The high Hα/Hβ ratios and the fact that the interstellar extinction is known to be small towards the SMC (Prévot et al. 1984) support the idea that dust is local and probably mixed with gas in this young H II region. Furthermore, the high resolution observations show that the extinction towards N81 is generally higher than previously believed. A mean Hα/Hβ = 3.30 corresponds to AV = 0.40 mag (c(Hβ) = 0.20), if the interstellar reddening law is used. For comparison, the ground-based observations had yielded Hα/Hβ values of 3.05 (Heydari-Malayeri et al. 1988a) and 2.97 (Caplan et al. 1996, using a circular diaphragm of 4′′89 in diameter). We remark that the Balmer ratio decreases with decreasing spatial resolution. This provides another indication that dust is concentrated towards the inner parts of N81.

3.3. Nebular emission

The [O III]λ5007/Hβ intensity map (Fig. 3b) reveals a relatively extended high-excitation zone with a mean value of ∼4.8. The highest intensity ratio, ∼5.5, belongs to the region of shock/ionization fronts represented by the two bright western ridges (Fig. 3). It is not excluded that collisional excitation of the O ++ ions by shocks contributes to the high value of the ratio in that region. Another high excitation zone runs from the east of star #9 to the south. The remarkable extension of the [O III]λ5007/Hβ ratio suggests that the O ++ ions in N81 occupy almost the same zone as H ++. This is in agreement with our previous chemical abundance determination results (Heydari-Malayeri et al. 1988a), showing that more than 80% of the total number of oxygen atoms in N81 are in the form of O ++. The extension of the ratio also suggests that the H II region is not powered by one central, but by several separate hot stars.

We measure a total Hβ flux F(Hβ) = 7.69 × 10^{-12} erg cm^{-2} s^{-1} above 3σ level for N81 without the stellar contribution and accurate to ∼3%. Correcting for a reddening coefficient of c(Hβ) = 0.20 (§3.2) gives F_0(Hβ) = 1.20 × 10^{-11} erg cm^{-2} s^{-1}. From the Lyman continuum flux of N_L = 1.36 × 10^{49} photons s^{-1} can be worked out if the H II region is assumed to be ionization-bounded. A single main sequence star of type O6.5 or O7 can account for this ionizing UV flux (Vacca et al. 1996, Schaerer & de Koter 1997). However, this is apparently an underestimate since the dust grains mixed with gas would considerably absorb the UV photons, and moreover...
Fig. 5. Line intensity ratios in the central part of N81. The darker the color the higher the ratio. White spots are stars; see Fig. 2 for their identification. a) Balmer decrement $H_\alpha/H_\beta$. Its mean value over the region is 3.30 and the ratio goes up to $\sim 4.5$ towards the central small absorption “hole”. The spur extending to the left is the bright end of the eastern absorption lane. b) The $[\text{O III}]\lambda 5007/H_\beta$ ratio. It is everywhere higher than 4.5 and rises to more than 6.

3.4. Stellar content

The results of the photometry for the brightest stars are presented in Table 1, where the star number refers to Fig. 2. The color-magnitude diagram $y$ versus $b-y$ is displayed in Fig. 6a. It shows a blue cluster centered on Strömgren colors $b-y = -0.05$, or $v-b = -0.20$, typical of massive OB stars (Relyea & Kurucz 1978, Conti et al. 1986). This is confirmed by the $U-I$ colors deduced from Table 1. Almost all these stars lie within the H II region and we are in fact viewing a starburst in this part of the SMC. We may neglect some of the ionizing stars if they lie deeper in the molecular cloud and are affected by larger extinctions. The three red stars (#15, #24, and #27), located outside the H II region, show up particularly in the true-color image (Heydari-Malayeri et al. 1998) and are probably evolved stars not belonging to the cluster. The two main exciting stars (#1 and #2) stand out prominently on the top of the color-magnitude diagram.

One can estimate the luminosity of the brightest star of the cluster (#1), although in the absence of spectroscopic data this is not straightforward. Using a mean reddening of $A_V = 0.4$ mag ($\S3.2$), and a distance modulus $M - m = 19.0$ (corresponding to a distance of 63.2 kpc, e.g. Di Benedetto 1997 and references therein), we find a visual absolute magnitude $M_V = -5.02$ for star #1. If a main sequence star, this corresponds to an O6.5V according to the calibration of Vacca et al. (1996) for Galactic stars. The corresponding luminosity and mass would be $\log L = 5.49 L_\odot$ and $M = 41 M_\odot$. The star may be more massive than this, since sub-luminosity and/or peculiar extinction would be consistent with extreme youth (Walborn et al. 1999).

The images obtained through a narrow-band filter (F469N) centered on the He II 4686 Å line were compared with those using the broad-band filter representing the Strömgren $b$ (F467M). The resulting photometry is displayed in the color-magnitude diagram shown in Fig. 6b. Interestingly, three stars show an apparent He II excess. However, one should note that since two of these (#27 and #15) are red types (Fig. 2) and the true-color image in Heydari-Malayeri et al. (1998), such a narrow-band enhancement could also be due to an artifact of molecular absorption bands throughout the spectra. On the other
Table 1. Photometry of the brightest stars towards N81

| Star number | \( \alpha \) (J2000) | \( \delta \) (J2000) | \( v \) (F410M) | \( b \) (F467M) | \( y \) (F547M) | \( \text{He}^\text{II} \) (F469N) | \( \text{wide} U \) (F300W) | \( I \) (F814W) |
|-------------|-----------------|-----------------|-------------|-------------|-------------|-----------------|-------------|-------------|
| 1           | 01:09:13.05     | -73:11:38.27    | 14.04       | 14.28       | 14.38       | 14.30           | 12.64       | 15.80       |
| 2           | 01:09:13.03     | -73:11:38.03    | 14.50       | 14.76       | 14.87       | 14.81           | 12.88       | 14.90       |
| 3           | 01:09:13.35     | -73:11:38.37    | 15.83       | 16.02       | 16.10       | 16.02           | 14.37       | 16.10       |
| 4           | 01:09:12.83     | -73:11:38.31    | 17.20       | 17.48       | 17.41       | 17.46           | 15.65       | 17.17       |
| 5           | 01:09:13.28     | -73:11:37.63    | 18.09       | 18.24       | 18.29       | 18.23           | 16.85       | 18.37       |
| 6           | 01:09:13.28     | -73:11:38.39    | 18.12       | 18.19       | 18.11       | 18.13           | 17.30       | 17.59       |
| 7           | 01:09:13.43     | -73:11:39.29    | 19.25       | 19.69       | 19.64       | 19.27           | 18.15       | 19.06       |
| 8           | 01:09:12.82     | -73:11:40.23    | 18.00       | 17.99       | 17.84       | 17.90           | 16.68       | 17.57       |
| 9           | 01:09:13.54     | -73:11:36.01    | 18.66       | 18.87       | 18.80       | 18.83           | 17.60       | 18.69       |
| 10          | 01:09:13.80     | -73:11:34.17    | 18.13       | 18.46       | 18.47       | 18.38           | 17.01       | 18.49       |
| 11          | 01:09:13.74     | -73:11:33.31    | 15.38       | 15.64       | 15.74       | 15.64           | 13.85       | 16.11       |
| 13          | 01:09:16.08     | -73:11:29.07    | 16.42       | 16.57       | 16.65       | 16.52           | 15.36       | 16.67       |
| 14          | 01:09:15.61     | -73:11:35.63    | 17.76       | 17.90       | 17.99       | 17.86           | 16.50       | 18.14       |
| 15          | 01:09:16.58     | -73:11:51.21    | 18.73       | 18.49       | 18.10       | 18.21           | 19.22       | 17.21       |
| 16          | 01:09:11.22     | -73:11:48.87    | 18.37       | 18.59       | 18.60       | 18.58           | 17.32       | 18.57       |
| 17          | 01:09:11.69     | -73:11:45.00    | 19.18       | 19.13       | 19.39       | 19.23           | 18.05       | 19.07       |
| 18          | 01:09:13.22     | -73:11:46.43    | 19.07       | 19.26       | 19.39       | 19.16           | 18.00       | 19.13       |
| 24          | 01:09:16.16     | -73:11:43.49    | 20.44       | 19.67       | 19.10       | 20.58           | –           | 18.10       |
| 27          | 01:09:13.07     | -73:11:23.24    | 18.81       | 18.38       | 17.74       | 18.13           | –           | 16.82       |

Fig. 6. Color-magnitude diagrams of the brightest stars revealed towards the SMC compact H\(\text{II}\) region N81. a) \(y\) versus \(b\) – \(y\), based on WFPC2 imaging with the Strömgren filters \(b\) (F467M) and \(y\) (F547). b) \(b\) versus \(b\) – He\(\text{II}\) showing the He\(\text{II}\) 4686 excess, based on narrow-band filter F469N and broad-band continuum F467M.

4. Discussion and concluding remarks

Hand, the third star (#7) is blue and has stronger apparent He\(\text{II}\) emission. This star lies deep in the core of the star cluster/H\(\text{II}\) region where the nebular excitation is high. It may be a Wolf-Rayet or Ofpe/WN candidate in the SMC.

4.1. Morphology of N81

N81 is a young H\(\text{II}\) region whose moving ionization front has reached the surface of its associated molecular cloud (see § 4.2), as predicted by the champagne model (Tenorio-Tagle 1979, Bodenheimer et al. 1979). Ionized gas is pouring out into the interstellar medium with a relative velocity of 4 km s\(^{-1}\) (§4.2). The bright central core of N81 is presumably a cavity created by the stellar photons on the surface of the molecular cloud. The two bright ridges lying at projected distances of
0.7 and ∼1.0 pc west of stars #1 & #2 (Fig. 3) are probably parts of the cavity seen edge-on. They represent ionization/shock fronts advancing in the molecular cloud. The higher excitation zones, indicated by the [O III]/Hβ map (§3.3), may be parts of the cavity surface situated perpendicularly to the line of sight. The H II region is probably ionization-bounded in those directions. The outer, diffuse areas with fainter brightness (Fig. 1) are the champagne flow in which strong winds of massive stars have given rise to the filamentary pattern.

The absorption lanes and the the dark globule may represent the denser, optically thick remains of the natal molecular cloud which have so far survived the action of harsh ultraviolet photons of the exciting stars. High resolution imaging observations by HST have shown the presence of massive dust pillars inside the Galactic H II region M16 (Hester et al. 1996) and more recently in the LMC giant H II region 30 Dor (Scowen et al. 1998, Walborn et al. 1999). By comparison, the dark globule in N81 may be the summit of such a dust pillar in which second generation stars may be forming. To further investigate this idea, a follow-up high-resolution near-IR imaging of the central region is essential. At longer wavelengths we are less affected by the absorption and we will be able to probe deeper into the core of the globule.

4.2. Molecular cloud

The molecular cloud associated with N81 has been observed during the ESO-SEST survey of the CO emission in the Magellanic Clouds. Israel et al. (1993) detected 12CO (1-0) emission at two points towards N81 using a resolution of 43′′ (∼13 pc, or ∼4 times the size of the H II region). The brighter component has a main beam brightness temperature of 375 mK, a line width of 2.6 km s⁻¹ and a LSR velocity of 152 km s⁻¹. The molecular emission velocity is in agreement with the velocity of the ionized gas $V_{LSR} = 147.8$ km s⁻¹ which we measured on the basis of high dispersion Hβ spectroscopy (Heydari-Malayeri et al. 1988a). The difference of 4.2 km s⁻¹ is probably due to the local motion of the ionized gas streaming into the interstellar medium towards the observer. The molecular cloud is brighter than those detected towards the neighboring H II regions N76, N78, and N80, but is weaker than that associated with N84 which has a distinct velocity (168 km s⁻¹). We do not know the size, the morphology, nor the mass of the molecular cloud, and we cannot localize the H II region N81 with respect to it.

The SMC is known to have an overall complex structure with several overlapping neutral hydrogen layers (McGee & Newton 1981). We used the recent observations by Stanimirovic et al. (1998) to examine the H I emission towards N81. The authors combine new Parkes telescope observations with an ATCA (Australia Telescope Compact Array) aperture synthesis mosaic to obtain a set of images sensitive to all angular (spatial) scales between 98′′ (30 pc) and 4′ (4 kpc) in order to study the large-scale H I structure of the SMC. An H I concentration focused on N84/N83 extends eastward until N81 (∼30′ apart). The H I spectra towards N81 and N83/N84 show complex profiles ranging from ∼100 to 200 km s⁻¹ with two main peaks at ∼120 and 150 km s⁻¹ but spread over tens of km s⁻¹. The corresponding column densities are $3.94 \times 10^{21}$ and $5.29 \times 10^{21}$ atoms cm⁻² respectively. In consequence, the correlation between the H I and CO clouds towards N81 does not seem simple.

The WFPC2 images reveal a turbulent nebula in which arc-shaped features are sculpted in the ionized gas under the action of violent shocks, ionization fronts, and stellar winds. The presence of shocks in N81 was evoked by Israel & Koornneef (1988) in order to explain the infrared molecular hydrogen emission which they detected towards this object. H₂ emission may be caused either by shock excitation due to stars embedded in a molecular cloud or by fluorescence of molecular material in the ultraviolet radiation field of the OB stars exciting the H II region. According to these authors, shock excitation of H₂ is only expected very close to (within 0.15 pc of) the stars, while radiative excitation can occur at larger distances (∼1 to 2 pc). Our HST observations suggest that the radiative mechanism is the dominant one, since the shock/ionization fronts are situated at projected distances larger than 0.15 pc from the exciting stars (§4.1).

4.3. Star formation

These observations are a breakthrough in the investigation of the exciting source of N81. This compact H II region is not powered by a single star, but by a small group of newborn massive stars. This result is important not only for studying the energy balance of the H II region, but also because it presents new evidence in support of collective formation of massive stars. Recent findings suggest that massive star formation is probably a collective process (see, e.g., Larson 1992 and references therein, Bonnell et al. 1998). This is also in line with the results of high-resolution, both ground-based and space observations (Weigelt & Baier 1983, Heydari-Malayeri et al. 1988, Walborn et al. 1999), in particular the resolution of the so-called Magellanic supermassive stars into tight clusters of very massive components (Heydari-Malayeri & Beuzit 1994 and references therein). It should however be emphasized that these cases pertain to relatively evolved stellar clusters. They are not associated with compact H II regions, probably because the hot stars
have had enough time to disrupt the gas.

N81 is a rare case in the SMC since a small cluster of massive stars is caught almost at birth. It provides a very good chance to check the history of massive star evolution (de Koter et al. 1997). Massive stars are believed to enter the main sequence while still veiled in their natal molecular clouds (Yorke & Krügel 1977, Shu et al. 1987, Palla & Stahler 1990, Beech & Mitalas 1994, Bernasconi & Maeder 1996). implying that these stars may already experience significant mass loss through a stellar wind, while still accreting mass from the parental cloud. This point constitutes an important drawback for current models of massive star evolution since, contrary to the assumption of the earlier models, a proper zero-age-main-sequence mass may not exist for these stars (Bernasconi & Maeder 1996). As shown by Fig. 3, the most massive stars of the cluster, i.e. stars #1, #2, #11, and #3, seem to be at the origin of stellar winds carving the surrounding interstellar medium. Also, if still younger massive stars are hidden inside the central dark globule, they can participate in the emission of strong winds.

Another interesting aspect is the small size of the starburst that occurred in N81. Apparently, only a dozen massive stars have formed during the burst, in contrast to the neighboring region N83/N84 which is larger and richer (Hill et al. 1994). The contrast to the SMC giant region N66 (NGC346), which has produced a plethora of O stars (Massey et al. 1989), is even more striking. The difference may not be only due to the sizes of the original molecular clouds but also to their environments. N81 is an isolated object far away from the more active, brighter concentrations of matter. Star formation may be a local event there, while for N66 and its neighboring regions, N76, N78, and N80, external factors may have played an active role in triggering the starburst. Judging from their radial velocities (Israel et al. 1993), the molecular clouds associated with the H II regions of the Wing seem to be independent from each other, and star formation has not probably propagated from one side to the other. On the other hand, according to Hunter (1995), massive stars formed in very small star-forming regions appear to have a very different mass function, implying that different sizes of star-forming events can have different massive star products. However, the resolution of this question needs more observational data.

We may have overlooked a distinct co-spatial population of lower mass stars towards N81, as our short exposure WFPC2 images were aimed at uncovering the brightest massive stars lying inside the ionized H II region. Note that the Orion Nebula, which contains a low-mass population (Herbig & Terndrup 1986, McCaughrean & Stauffer 1994, Hillenbrand 1997), would have the same size as N81 if placed in the SMC. Interestingly, the I band image shows many red stars not visible in the blue bands, a few fainter ones lying close to stars #1 and #2. Do they belong to N81? The answer to this question which is crucial for star formation theories (Zinnecker et al. 1993), is not straightforward, because of the complex structure of the SMC with its overlapping layers (McGee & Newton 1981, Stanimirovic et al. 1998).

4.4. Wolf-Rayet candidate

Wolf-Rayet stars as products of massive star evolution are generally very scarce, particularly so in the metal poor SMC galaxy, which contains only nine confirmed stars of this category (Morgan et al. 1991). It is therefore highly desirable to identify and study every single new candidate, such as #7.

A noteworthy feature of our new candidate is its apparent faintness. With $V = 19.64$, it is $\sim 3$ mag weaker than the faintest W-R stars in that galaxy detected so far from the ground (Azzopardi & Breysacher 1979, Morgan et al. 1991). It is also much fainter than the known Of stars in the SMC (Walborn et al. 1997). Noteworthy as well is the fact that the small W-R population in the SMC is very peculiar compared to that in our Galaxy. For example, all nine W-R stars are binary systems and all, but one, belong to the nitrogen class. Our candidate may represent the first single W-R detected in the SMC. The true nature of this object can only be clarified with STIS spectroscopy during the second phase of our project. Its confirmation would provide new data for improving massive star evolutionary models in the low metallicity domain.

4.5. Future work

We have presented our first results on the SMC “blob” N81 based uniquely on direct imaging with WFPC2. The high-resolution observations have enabled us to identify the hot star candidates. Forthcoming STIS observations of these stars will provide the stellar spectra. The analysis of the line profiles with non-LTE wind models (Schaerer & de Koter 1997) will allow us to determine the wind properties (terminal velocity, mass loss rate), the effective temperature and luminosity, and to derive constraints on the surface abundances of H, He, and metals (de Koter et al. 1997, Huser et al. 1998). The H-R diagrams so constructed will be compared with appropriate low-metallicity models (Meynet et al. 1994, Meynet & Maeder 1997) to yield the evolutionary status of the stars and to subject the evolutionary scenarios to observational constraints.
Since the SMC is the most metal-poor galaxy observable with very high angular resolution, N81 provides an important template for studying star formation in the very distant metal-poor galaxies which populate the early Universe. Although other metal-poor galaxies can be observed with \textit{HST} and their stellar content analyzed from color-magnitude diagrams (e.g., I Zw 18: Hunter & Thronson 1995; de Mello et al. 1998), the SMC is the most metal-poor galaxy where spectroscopy of individual stars (required to determine the parameters of massive stars) can be achieved with the highest spatial resolution.

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