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THE GIANT GALACTIC H II REGION NGC 3603: OPTICAL STUDIES OF ITS STRUCTURE AND KINEMATICS

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ABSTRACT

NGC 3603, unlike other Galactic giant H II regions, is both similar to numerous often-studied extragalactic giant nebulae and optically visible. Its morphology is found to be that of a highly ionized dense core ($n_e \gtrsim 1800$ cm^{-3}) and faint outer halo ($n_e \sim 100$ cm^{-3}) of dimensions ~ 7 and 50 pc, respectively. Throughout the nebula supersonic turbulent velocities, ~ 40 km s^{-1}, are found; no global pattern of radial or rotational motions is evident. Surrounding the central star cluster there appears to be a small ($r \sim 0.6$ pc) wind-driven "stellar bubble" like those found in association with many WN stars. NGC 3603 is found to be a representative member of the class of giant H II regions. Because of its proximity it affords a unique opportunity to study the physical nature of giant nebulae and to test their validity as cosmological distance indicators. The observed properties of NGC 3603 raise serious doubts concerning the validity of Melnick's empirically established correlation between the diameters and turbulent velocity widths of giant H II regions in Sc I galaxies.

Subject headings: nebulae: general — nebulae: individual — stars: Wolf-Rayet

I. INTRODUCTION

Giant H II regions are nebulae photoionized by the Lyman continuum radiation by $\gtrsim 10^{51}$ ionizing photons s^{-1} (the equivalent of at least 10 O5 stars). These objects are believed to be associated with regions of recent and very active star formation. Giant H II regions are also important as readily studied probes of chemical abundances in the interstellar medium and the history of element synthesis in galaxies (Smith 1975; Jensen, Strom, and Strom 1976; Lequeux *et al.* 1979; Peimbert 1975, and references therein), as well as important calibrators of extragalactic distance scales (Kennicutt 1979; Sandage and Tammann 1974). These nebulae are now being exploited in order to understand the initial mass function of massive stars (French 1980; Shields and Tinsley 1976) and, eventually, how this mass function may depend on environmental conditions such as chemical abundances. Also, the determination of physical conditions and structure of H II regions (including giant H II regions) has traditionally been of interest in astronomy, and much attention has been focused through the years on Galactic H II regions, especially those that are nearby, bright, northern, and optically visible.

The largest identified giant H II regions in the Galaxy are W49, Sgr B2, the Cygnus X and η Carina complexes, and NGC 3603. Most of these are almost completely obscured by dust at optical wavelengths. This situation is unfortunate; the optical and ultraviolet spectra of H II regions are rich in information which cannot be measured directly or easily at other wavelengths (e.g., chemical abundances, ionization structure, properties of the ionizing sources). Thus far much of our understanding of giant H II regions has traditionally been based on studies of these objects in other galaxies, such as 30 Doradus in the LMC (Boeshaar *et al.* 1980) and NGC 2363 in the Irr I galaxy NGC 2366 (Kennicutt, Balick, and Heckman 1980), but the spatial scales in these extragalactic objects preclude an investigation of their structure on microscopic ($\lesssim 0.3$ pc) scales and the ionization sources at their centers.

Fortunately the central regions of one Galactic giant H II region, NGC 3603, can be observed optically. Its central ionizing stars can be seen in a heavily reddened cluster (Walborn 1973, and references therein). NGC 3603 lies at a kinematic distance of 8–9 kpc from the Sun (Goss and Radhakrishnan 1969, hereafter GR; Goss and Shaver 1970, hereafter GS; Wilson *et al.* 1970; McGee, Newton, and Batchelor 1975, hereafter MNB) and is seen through about 4 mag of foreground extinction (Moffat 1974; Frogel, Persson, and Aaronson 1977). Walborn has shown that the central exciting stars have many of the same characteristics of the next-nearest giant H II region

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whose stars can be unambiguously identified, 30 Dor. The relationship of the stars to the nebula is particularly well suited for study in NGC 3603 because of its good spatial scale (1″ corresponds to 0.04 pc $\approx 10^4$ a.u.).

Moreover NGC 3603 exhibits many morphological similarities to other giant H II regions, unlike the η Car complex in which a plethora of enigmatic processes appears to be operative. For example, NGC 3603 seems to have a simple core-halo morphology as do most extragalactic giant H II regions (Kennicutt 1979). Because NGC 3603 may serve as a nearby prototype of giant H II regions and because its central regions can be studied in detail, we undertook a photographic, spectroscopic, and kinematic survey of this nebula at Cerro Tololo Inter-American Observatory (CTIO) in 1977 March.

Here we report the results of the photographic and kinematic portions of the survey and some preliminary results of the moderate-dispersion photographic spectroscopy. In § II we describe the observations. The spatial and kinematic structure of NGC 3603 and the region near the central stars are discussed in § III. In § IV we compare NGC 3603 to 30 Dor and other extragalactic H II regions. Finally, in § V we discuss some problems posed by NGC 3603 and other giant H II regions. In a forthcoming paper we will derive physical and chemical conditions in NGC 3603 and the foreground arm through which it is viewed.

II. OBSERVATIONS

The complex, dusty nature of the galactic plane near NGC 3603 is evident in the wide-field survey photographs of Parker, Gull, and Kirshner (1979; NGC 3603 is best located on the [O III] λ5007 for $l = 293°$, $b = 0°$ image between the Carina nebula and RCW 62,16 mm west and 3 mm south of the field center on the north side of a dust lane). A series of photographs using a variety of filters and exposure times was taken with the 4 m telescope at CTIO on hypersensitized 098–04 plates. In Figure 1 is shown a 45 minute Hα + [N II] exposure on which selected λ6 cm radio brightness isophotes of GR are superposed. Also identified schematically are the major structural features of NGC 3603 as well as the positions and aperture shapes of the Fabry-Perot observations. Enlargements of some of the 4 m plates of the inner 8′ regions surrounding the central star clusters are presented in Figure 2. These plates are taken through filters centered on the emission lines of Hα + [N II] (15 min exposure), [O III] λ5007 (60 min), [S II] $\lambda\lambda$6717 + 6731 (60 min), and He I λ5876 (150 min). Note that in spite of its apparently faint surface brightness in Figure 2 (a result of the filter/plate responses), the [O III] line is generally one of the brightest lines in the emission line spectrum of NGC 3603.

The kinematic data were obtained using a pressure-scanned Fabry-Perot interferometer with a free spectral range of approximately 150 km s^{-1} on the 0.9 m telescope at CTIO. Profiles of Hα and, where possible, [N II] λ6583 (hereafter [N II]) and [O III] λ5007 (hereafter [O III]) were observed at the positions indicated schematically in Figure 1. Absolute calibrations of wavelength and intensity were made by observations of IC 418, and drifts of the instrumental gain and wavelength response were monitored by frequent observations of a sodium lamp. For a more complete description of the data acquisition and calibration technique, refer to Balick, Gull, and Smith (1980). Integrations proceeded until a minimum of 400 counts above background had been measured at the line peak. The final uncertainties in the fitted Gaussian amplitudes, velocities, and line widths are $\lesssim 5\%$ of the peak amplitude, 1 km s^{-1}, and 3 km s^{-1}, respectively. The residuals of the fit show no systematic deviations from zero. Fitted line profiles (with the response of the instrument removed) are shown in Figure 3.

Hereafter, we abbreviate Fabry-Perot as F-P. All velocities quoted refer to the local standard of rest (LSR) defined by solar motion of 20 km s^{-1} toward $\alpha(1900) = 18^h$, $\delta(1900) = +30^0$.

III. STRUCTURAL AND KINEMATICAL MORPHOLOGY

The radio maps of GR and GS, all with $\sim 4'$ spatial resolution, show NGC 3603 to consist of a central core with angular extent comparable to the resolution and a diffuse "halo" of $\sim 20'$ diameter surrounding the core. The halo contains most ($\sim 90\%$) of the radio flux. The optical appearance of NGC 3603 is not inconsistent with this core-halo morphology. The brightest optical nebulosity is 2′ south west of the star cluster and is coincident with the radio core. There are only traces of a diffuse optical counterpart to the radio halo, undoubtedly because of the heavy patchy obscuration in the foreground.

An observer located 100 kpc above the Galaxy would measure a halo structure of the nebula ~ 50 pc in diameter, and the light of the nebula would be dominated by the halo (at least in the recombination lines). The core diameter is about 7 pc; within this region there exists considerable structure on a scale less than 0.3 pc. Our distant observer would not resolve the 0.3 pc structures with 1″ seeing. In the remainder of this section we explore whether the core and halo may be distinguishable by our fabled observer by any other measures, i.e., by measures of line intensity ratios or by kinematics.

Before investigating the nature of NGC 3603 further, we must consider the contribution of foreground nebular emission and effects of extinction associable with material along the line of sight. The F–P data in Figure 3 show that two major kinematic components contribute to the line emission, one with positive velocities ($V_{LSR} \sim 10$–20 km s^{-1}) and the other with negative velocities ($V_{LSR} \sim -25$ km s^{-1}). Based on a rotational model of the Galaxy these motions can be transformed into kinematic distances (Burton 1974, Figure 4.5). The negative velocity component is identified with a nebulosity at a distance of 2–3 kpc with low-ionization [F([O III])/F([N II]) typically less than 0.5, where F is a measured line flux uncorrected for reddening]. This foreground emission can be traced throughout the region of Figure 1 (including the fascinating loop in NGC 3576 seen $\sim 15'$ north west of NGC 3603) and contaminates the total line fluxes seen in the direction to the background giant H II region. Lines with $V_{LSR} > 0$ are spatially restricted to a region $\lesssim 6'$ in radial extent centered on the star cluster in NGC 3603 and generally exhibit a high state of ionization

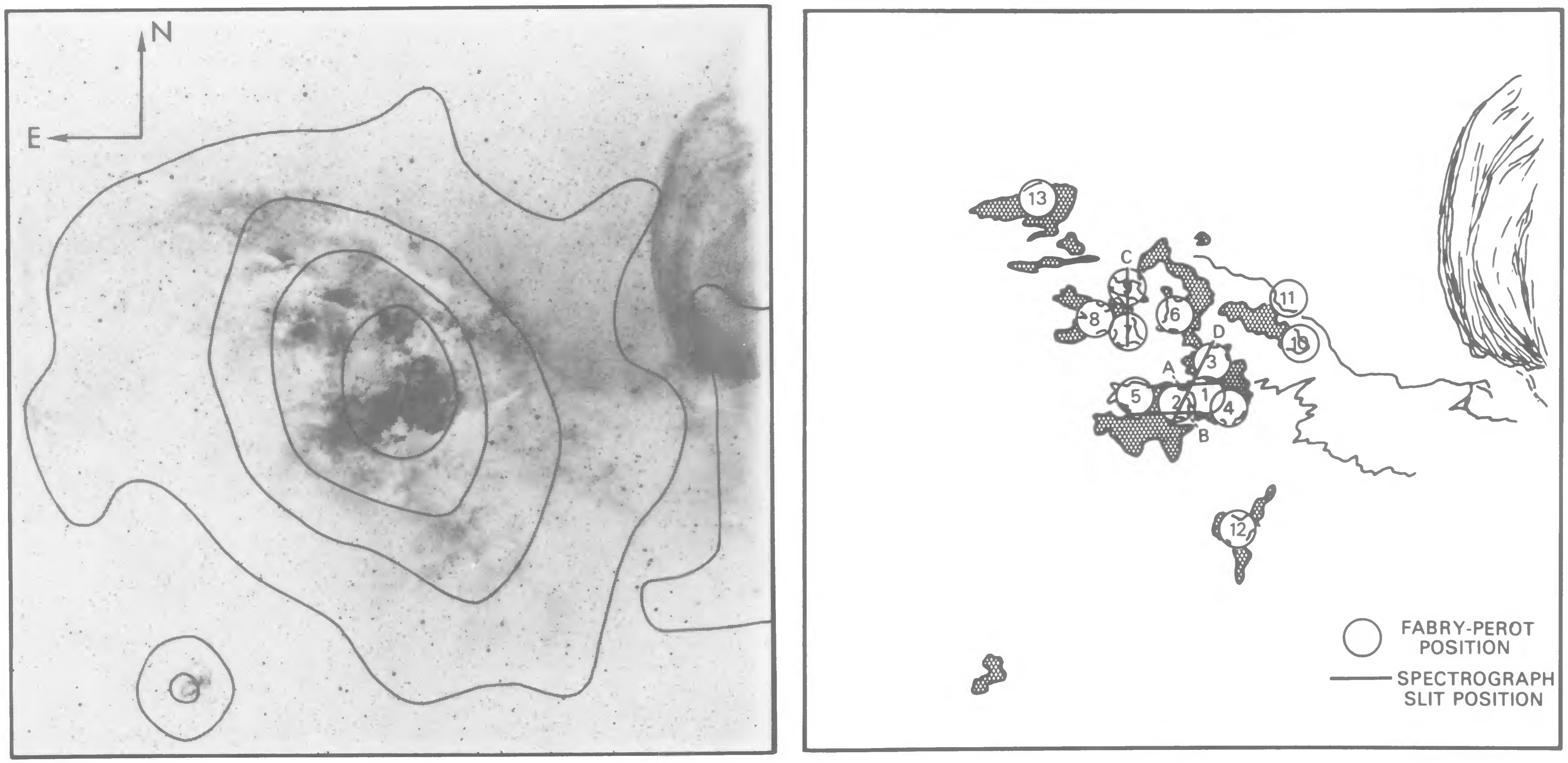

FIG. 1.—NGC 3603: *left*, a 45 minute Hα + [N II] exposure with the 6 cm contours of GR superposed; *right*, a schematic drawing of the major features of NGC 3603 plus the positions and aperture shapes of the Fabry-Perot and slit spectrograph observations. The circles have diameters of 2′ and are drawn to scale.

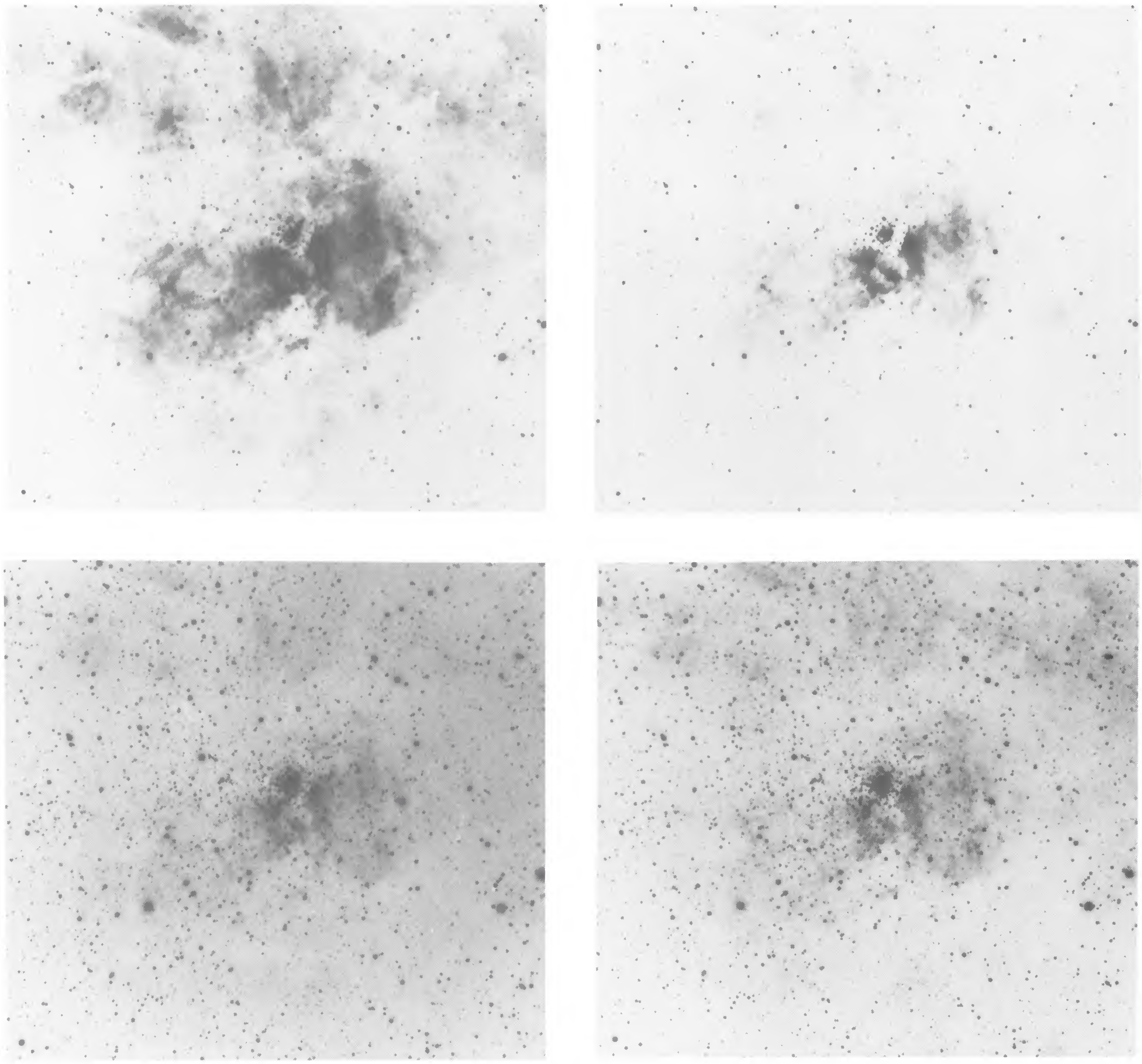

FIG. 2.—The central region of NGC 3603 as imaged in Hα + [N II] (*upper left*), [O III] (*upper right*), [He I] (*lower left*), and [S II] (*lower right*). All plates were recorded at the prime focus of the CTIO 4 m telescope.

F([O III])/F([N II]) $\gtrsim 1$. Within the nebula the core appears to exhibit a higher state of ionization than the halo; by this we mean that F([O III])/F([N II]) is considerably larger in the core than in the halo.

Assuming A_v to be ~ 4 mag, then a substantial reddening correction $E_{\beta-\alpha} \sim 1.2$ mag applies to lines with positive velocities [i.e., I([O III])/I(Hα) ≈ 3 F([O III])/F(Hα), where I is the line flux corrected for reddening].

We next consider the dynamics of the halo. The observed line profiles (at positive velocities) do not exhibit an apparent trend of line velocities or widths with position, and no global pattern of infall, expansion, or rotation is manifest. The average Hα line velocity is 22 km s^{-1} (with an rms scatter of $\sim$ 10 km s^{-1}), and the average FWHM of Gaussian profiles fitted to the lines is about 40 km s^{-1}. There exist regions in the halo where the line centers change by as much as 20 km s^{-1} over projected distances of $\sim$ 10 pc as illustrated by the profiles in the four aperture positions $\sim 5'$ NE of the central star cluster. Conceivably there exist flows of material in nearby regions with relative motions in excess of the sound speed $C_s \sim$ 10–12 km s^{-1}; however, the attendant shock-heated regions where such flows might intersect are not in evidence. In any case if the motions in the halo are disorganized, then an observer outside the Galaxy would measure a line width in the halo of $\sim$ 45–50 km s^{-1}.

The dynamics of the core, observed at relatively poor spatial resolution (the core size is about two aperture diameters), are not strikingly dissimilar from those of the

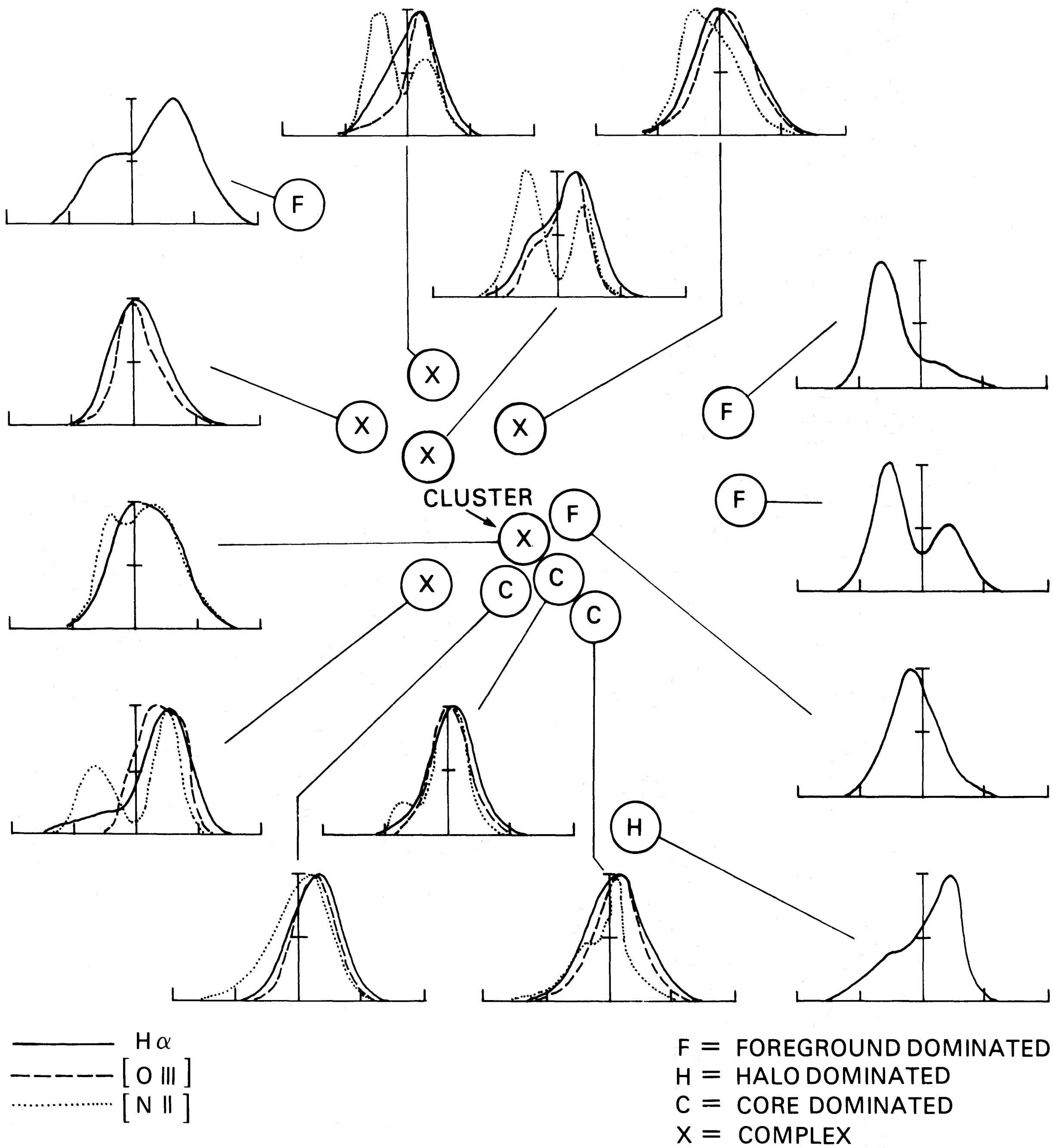

FIG. 3.—The fitted line profiles for Hα, [O III], and [N II] for selected regions in NGC 3603. The positions refer to Fig. 1. The abscissa is incremented by 50 km s^{-1} with $v_{LSR} = 0$ km s^{-1} defined by the vertical axis. The instrumental response has been removed in these profiles. All profiles have been normalized to their respective peaks for display.

halo. An inspection of the F–P data within the core indicates first that the surface brightness of the core is 3–6 times larger compared to the foreground (except the region within $\sim 15''$ of the star cluster where all of the photographs show low nebular surface brightnesses). Second, the widths measured in all lines are typically 35–45 km s^{-1}. Third, the line peak velocities in all lines are blueshifted by 10–20 km s^{-1} with respect to most (but not all) of the lines in the halo (values of -8, 5, 17, and 7 km s^{-1} are measured at positions in the core for Hα). Fourth, there is a systematic increase in line velocities by $\sim 2C_s$ from positions $\sim 2'$ north of the cluster to those $\sim 3'$ to the south. Whether these systematic changes in velocity with position reflect coherent (e.g., rotation) or incoherent motions in the core is not clear at this time. For comparison, the radio recombination line observed with a telescope beam having FWHM of 3′–4′ centered on the core is well fitted by a Gaussian function with line centers at 10 km s^{-1} and having a width of 50 km s^{-1} (Wilson *et al.* 1970; MNB). These radio profiles may contain emission contributions from the foreground; nonetheless, they are strikingly similar to the profile shape that an intensity-weighted sum of the Hα profiles from the core (Fig. 3) would exhibit. We conclude that the core and the halo regions are kinematically distinguishable, primarily by their velocity differences of approximately 15 km s^{-1}. Nonetheless, the integrated nebular line width, $\Delta V \sim 40$ km s^{-1}, is not appreciably affected by the slightly different kinematics of the core compared to the halo because of the small flux contribution of the former.

A preliminary analysis of our moderate-dispersion photographic silt spectra (at five positions in the core and halo) confirms the generally higher state of ionization in the core. Moreover, we find from the ratio of [S II] $\lambda\lambda$6717 and 6731 line intensities that densities along lines of sight to the halo and the core are $n_e < 100$ cm^{-3} and $n_e \gtrsim 1800$ cm^{-3}, respectively. We have not yet attempted to remove the emission contributions of foreground gas from these data which, as the F–P data show, can be particularly important in the case of low-ionization lines in the direction of the halo.

In the central portion of the core and surrounding the star cluster (HD 97950) are two very unusual small-scale structural features. The photographs of Figure 1 show a small "hole" in the surface brightness extending $\sim 15''$ (0.6 pc) from the star cluster, especially to the south and west. Bordering the edge of the hole on the west rim is a bright filament of length $\sim 20''$ and unresolved width. For reasons to be apparent soon we denote the hole as a "bubble."

The filament is much more prominent on the [O III], He I λ5876, and Hα + [N II] photographs than on the [S II] photograph (Fig. 2). Either the [S II] lines are collisionally quenched or S (and presumably N and O) is multiply ionized. The former possibility is more likely since $n_e \lesssim 1800$ cm^{-3} in the core. However, recent maps of NGC 3603 in the lines of [Ne II] λ12.8 μm and [S IV] λ10.5 μm by Lacy and collaborators (J. H. Lacy 1979, private communication), which are unaffected by collisional quenching if $n_e < 10^5$ cm^{-3}, show clearly that the filament is very highly ionized; the filament stands out prominently in the [S IV] line and is not observed in [Ne II]. Their maps also verify the existence of the bubble as a true nebular feature and not a mischievous patch of anomalously large extinction in the foreground.

The singular nature of the bright filamentary rim of the bubble in NGC 3603 is corroborated by our moderate-dispersion spectroscopic data. Only low-resolution tracings of our plates are as yet available. These show an increase of I([O III])/I(Hβ) of at least 50% near the filament compared to the adjacent nebulosity (where this ratio is ~ 3, much as in Orion and other H II regions at 10 kpc from the galactic center with solar-neighborhood metal abundances). Higher-resolution tracings can be expected to show even larger [O III] to Hβ flux ratios in the filament. The simplest explanation for the rise in I([O III])/I(Hβ) in the filament is a larger electron temperature in the filament ($T_e \gtrsim 10{,}000$ K) than in the adjacent nebula ($T_e \sim 8500$ K). Measurements of the [O III] λ4363 to λ5007 line intensity ratios in this region will be of considerable interest.

There are striking morphological similarities between the bubble in NGC 3603 and the class of wind-driven "bubble nebulae" which surround many WN stars (e.g., NGC 2359, NGC 6888, and NGC 7635). All of these bubbles are hot, highly ionized, and filamentary. It is equally interesting that Walborn (1973) shows the spectrum of the central star clusters in NGC 3603 and 30 Dor to exhibit the luminosities and emission lines (such as He II and N IV) which are the signatures of WN stars. HD 97950 has an absolute visual magnitude of ~ -9 (see Walborn 1973).

Models of wind-driven bubbles have been calculated by Dyson (1977, 1979) and Weaver *et al.* (1977). In these models a bubble is heated to a temperature of $\sim 10^6$ K by a stellar wind with a mass-loss rate $\dot{M}_w \sim 10^{-5}\ M_\odot\ \mathrm{yr}^{-1}$ and velocity $v_w \sim 10^3$ km s^{-1} through an interior shock. The bubble cools by conducting heat to an exterior shell at a temperature of $\sim 10^4$ K where the energy is lost by radiation in forbidden lines such as [O III]. There are some differences between the model parameters and the bubble in NGC 3603 (e.g., size scales, ambient densities outside the shell, etc.), and some important but unavailable data (e.g., mass-loss rates, column density in O VI) are needed to strengthen the identification of the bubble in NGC 3603 as wind driven. It would be important to search for ultraviolet lines which are expected to arise at the bubble-shell interface and to determine mass-loss rates of the central star(s) so that the model structure of the bubble can be calculated in more detail and compared to observations.

It is important to emphasize that the wind, if it exists, has little effect outside the shell of the bubble. It cannot supply a major fraction of the nebular ionization and heating, nor can it account for the hypersonic nebular line widths. This can be argued on energetic grounds; the wind luminosity $L_w \lesssim 10^{36.5}$ ergs s^{-1} is very small compared to the ionizing luminosity of the nebula and its sources of ionization, L_* ($\gtrsim 10^{40}$ ergs s^{-1}). The mechanical energy in the turbulent gas of the nebula $E_{\rm kin} \sim \frac{1}{2}M(\Delta V)^2 \sim 10^{50.5}$ ergs, if supplied by the stellar wind and somehow prevented from dissipating, would require a time scale for energization $E_{\rm kin}/L_w \gtrsim 10^{6.5}$ yr, which is longer than the time during which a wind can be sustained by a hot star at a rate $\dot{M}_w \sim 10^{-5}$ $M_\odot$ yr^{-1}. Here a nebular mass of $10^{4.1}$ $M_\odot$ has been assumed for NGC 3603. The estimates for L_* and the nebular mass are based on the radio properties measured by GR.

IV. COMPARISON TO OTHER H II REGIONS

As noted by GR, NGC 3603 has about the same total ionization, mass, and diameter as the largest H II regions in the Galaxy (e.g., W49). Compared to giant H II regions in other galaxies, however, it is not particularly outstanding. For example, 30 Dor in the LMC has about 7 times the total ionization, about 40 times the mass, and about 10 times the diameter as NGC 3603.

In terms of its kinematics, the line width of NGC 3603 exceeds that of all other Galactic nebulae of comparable total ionization. Smith and Weedman (1971) find turbulent velocities $v_{\rm turb} \sim 8$ km s^{-1} for most Galactic H II regions. Values of $v_{\rm turb}$ such as those of NGC 3603, $\gtrsim 35$ km s^{-1}, are found by Smith and Weedman (1970) in giant H II regions in the LMC, M101, and M33. Although considerably smaller and less ionized than 30 Dor, NGC 3603 and this giant LMC complex are very similar in other respects. The photographs of Elliot *et al.* (1977) show 30 Dor to have a bright core surrounded by a halo (in this case filamentary) of lower ionization. In their F–P survey of 30 Dor, Smith and Weedman (1972) find velocity patterns that are highly reminiscent of the irregular hypersonic motions in NGC 3603. The kinetic energy of 30 Dor exceeds that of NGC 3603 by an order of magnitude, principally because of the larger mass of the former.

There is evidence to suggest that a hole in the surface brightness in 30 Dor surrounds the central star cluster HD 38268. Segments of a circumferential rim of about 70″ diameter can be seen around the cluster in Figure 5 of Czyzak and Aller (1977). The distribution of infrared contours in 30 Dor (Werner *et al.* 1978) is similar in morphology to that in NGC 3603. Walborn (1973) has shown that close similarities exist in the spectral properties of the central star clusters in NGC 3603 and 30 Dor; by implication, winds may be forming a hot bubble in the center of both nebulae.

In spite of their many similarities, NGC 3603 and 30 Dor may not share a similar history of formation. NGC 3603 is associated with the disk of the Galaxy in a region of approximately solar-neighborhood metal abundances and densities and where density waves may occasionally form shocks which condense molecular clouds and subsequently several generations of massive stars (Elmegreen and Lada 1977). On the other hand, 30 Dor is situated in an Irr I (like many giant H II regions), where metal abundances and ambient densities are considerably less than solar and density waves may not propagate; in such an environment other processes such as supernova-induced star formation are probably important (Herbst and Assousa 1977; Boeshaar *et al.* 1980). The filamentary nature of the halo of 30 Dor may be an important clue that thermal instabilities have been formed there by a very hot wind behind a supernova-driven shock; such filaments are not present in NGC 3603 except in the immediate vicinity of the star cluster (as noted above).

V. SUMMARY AND CONCLUSIONS

NGC 3603 is a Galactic giant H II region, and probably the only such Galactic H II region which is a typical example of the numerous often-studied extragalactic giant H II regions. It is also unique among giant H II regions in the Galaxy in that its sources of excitation can be located and studied optically. The nebula has a dense core ($r \sim 3$ pc, $\eta_e \gtrsim 1800$ cm^{-3}) and extended halo ($r \sim 25$ pc, $\eta_e \lesssim 100$ cm^{-3}) and large internal motions ($\Delta v \sim 50$ km s^{-1}) of Mach number 3 or 4. At the nebular center and surrounding a star cluster exhibiting strong WN characteristics is a small ($r \sim 0.6$ pc) evacuated partial bubble, possibly heated by a stellar wind. The bubble appears to be very similar to bubbles associated with other WN stars. However, the wind has little effect on the nebula outside the bubble.

In all essential respects NGC 3603 is representative of other more distant giant H II regions even though its total ionization and radius are considerably below the average for such nebulae. Its distance and situation behind large amounts of foreground dust make it difficult, but not impossible, to use this nebula to better study and understand the physical nature of all giant H II regions. The importance of this type of study is underscored by the continuing controversy regarding the utility of giant H II regions as standard metersticks for measuring cosmological distances (Sandage and Tammann 1974; Kennicutt 1979; van den Bergh 1980; and references within). Melnick (1976) has derived a very tight relationship between the diameters and turbulent velocities of extragalactic giant H II regions in Sc I galaxies. Taken at face value, the dimensions and line width of NGC 3603 place it far from that relationship and raise the possibility that giant H II regions have highly individualistic characteristics which may make them unsuitable as distance indicators. However, Sb galaxies have generally fewer and smaller H II regions than Sc galaxies. Hence, if the galaxy is an Sbc, then some deviation from Melnick's relation may be anticipated for NGC 3603.

Dyson (1979) has theoretically explored the possibility that the supersonic line widths measured in giant H II regions can be explained by the expansion of shells on the outsides of wind-driven bubbles powered by the equivalent of 10–100 O5 stars in a central star cluster. In order to serve as an adequate explanation of the line width his model requires that the shell absorb a substantial fraction ($f_s \sim 0.5$) of the stellar Lyman continuum photons. The observed line profile can be decomposed into a broad component from the wind-driven expanding shells (FWHM ~ 3–$4C_s$) and a narrow component from the nebula outside the bubble's sphere of influence (FWHM $\sim 2C_s$) whose relative fluxes are given by f_s and $(1 - f_s)$, respectively.

The structure and kinematics of NGC 3603 suggest that the nebula is not well described by Dyson's model. For example, the rim is the only obvious segment of the shell in NGC 3603. This suggests that the shell is highly filamentary and broken so that $f_s \approx 0.5$ (as in many bubble nebulae). The fraction of the nebular emission contributed by the shell, then, is very small. Moreover, we have found that in contrast to Dyson's model supersonic turbulence is not confined to the inner zone where the bubble is seen in NGC 3603; rather, wide lines are observed along all lines of sight through both the halo and the core regions many parsecs beyond bubble perimeter. Finally, using our values for the wind luminosity, ambient core density, and shell radius, we estimate an age for the bubble of only $\sim 10^4$ yr from equation (2) of Dyson's paper. This age is too small for the shell to have been effective in accelerating much of the ambient gas to supersonic speeds. We suggest that if winds have ever been important in the internal dynamics of NGC 3603, then these winds have arisen at some previous epoch—probably before the development of the WN star in HD 97950. Any wind-driven shells formed during this earlier epoch are no longer identifiable as spatial entities in the complex nebular structure of NGC 3603.

Parenthetically, we add that wind-driven shells in most spatially resolved Galactic bubble nebulae appear to be highly prone to the development of filamentary structures (probably the result of Rayleigh-Taylor instabilities as the bubble expands into a lumpy interstellar medium). If this is the case for the wind-driven shells in the extragalactic nebulae discussed by Dyson (1979), then the fraction of stellar radiation absorbed in shells is likely to be far smaller than the values that he estimated. Thus the fractional contribution of the shells to the nebular permitted-line emission (e.g., Hα) may be much too small for wind-driven shells to explain the supersonic line widths in giant H II regions.

The supersonic line width of NGC 3603 and many other giant H II regions remains somewhat difficult to understand. Such motions, unless highly ordered, are likely to lead to shocks which rapidly convert kinetic energy into radiated energy and dissipate the turbulence. The velocity patterns of young, rapidly evolving model H II regions as calculated by Bodenheimer, Tenorio-Tagle, and Yorke (1979) come very close to explaining the large line widths whose existence is somewhat transient since large motions persist only when large pressure imbalances exist across the H II region; these times are on the order of the sonic crossing time ($\sim 10^6$ yr in NGC 3603). The core-halo morphology of the nebula argues that such pressure gradients presently exist. A better knowledge of the nebular structure, however, is necessary before these model calculations can be meaningfully compared to the data. Radio synthesis maps of NGC 3603 would be an important step in this direction.

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