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THE CENTRAL STAR CLUSTER OF THE STAR-FORMING DWARF GALAXY NGC 5253

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ABSTRACT

We have observed the star-forming dwarf galaxy NGC 5253 at optical, radio, and infrared wavelengths. Our data, combined with other observations from the literature, indicate that star formation in this galaxy has proceeded from the outer parts inward and that the center of NGC 5253 is now the site of an obscured, concentrated, and extremely young burst of star formation. The centimeter-wavelength radio continuum spectrum is very flat, which indicates that the radio emission is almost entirely due to thermal emission from H II regions. There is no evidence for synchrotron emission from supernova remnants, which is most unusual for a starburst galaxy. The observed radio continuum flux is consistent with infrared recombination-line observations, with $N_{\rm Lyc} \sim 3 \times 10^{52}$ s^{-1}. The infrared spectrum resembles II Zw 40 and no other star-forming galaxy in that it has strong [S IV] 10.5 μm emission. We analyze the infrared spectrum with a grid of model H II regions and conclude that the young star cluster is dominated by stars of 42,000–45,000 K. The star cluster is probably a few Myr, and in any case less than 10 Myr, old, and the stellar density in the starburst is 0.5–1 O stars pc^{-3}.

Subject headings: galaxies: individual (NGC 5253) — galaxies: starburst — galaxies: star clusters — H II regions — radio continuum: galaxies — stars: formation

1. INTRODUCTION

NGC 5253 is a dwarf galaxy with an elliptical underlying structure but with bright, amorphous H II regions in the core, extensive ionized filaments, and over 100 young star clusters in the halo (Van den Bergh 1980; Caldwell & Phillips 1989). It is known to be a site of active star formation, and the starburst typically is estimated to be no older than 10 Myr. Its optical and ultraviolet spectra show the presence of hot young stars, including Wolf-Rayet stars (Walsh & Roy 1987, 1989), and it has strong Brγ emission and weak CO band-head absorption, which lead Rieke, Lebofsky, & Walker (1988) to call it the youngest starburst known. NGC 5253 is only 114′ (93 kpc at 2.8 Mpc) from the large barred spiral M83, which is also undergoing a starburst, and it has been suggested that tidal interaction of the two systems has triggered their activity, although there is no direct evidence for such interaction (Rogstad, Lockhart, & Wright 1974).

The star-formation process in NGC 5253 is clearly unusual and extreme. We set out to study how star formation manifests itself at long wavelengths in this galaxy. Starbursts in large–spiral-galaxy nuclei have been well studied in the infrared, millimeter, and radio regions, and their observational signatures are more or less understood; the long-wavelength appearance of starbursts in dwarfs is much less well known. Since the interstellar medium, dust content, and metal content of dwarf galaxies may differ strongly from spirals, their behavior may be quite different. We have therefore obtained VLA radio continuum data at 2 cm and high-resolution spectra of several lines in the 8–13 μm region, which we combine with published data and a new grid of H II–region models to analyze the present stellar population of the burst and predict its future development. We have also obtained lower frequency VLA continuum data and 3 mm continuum and CO molecular-line data, which will be published separately (Turner, Ho, & Beck 1995b; Turner, Beck, & Hurt 1995a).

2. OBSERVATIONS

Hα images of NGC 5253 were obtained at the 1 m telescope of the Wise Observatory in Mitzpe Ramon, with the use of a 50 Å–wide filter centered at the rest frequency (the heliocentric velocity of NGC 5253 is 360 km s^{-1}) and a 512 × 512 CCD with spatial resolution of 0″.8 pixel^{-1}. An Hα image with the *R*-band continuum emission removed is shown in Figure 1. Astrometry was done on the full image using the Hubble Guide Star Catalog: absolute positions on the Hα image are accurate to ∼1″–2″. The image resembles the Hα contour map in Walsh & Roy (1989) in having a concentrated peak and a weak extension to the south, which Caldwell & Phillips (1989) call the Hα "fork." The bright H II region in the center coincides with the compact infrared and radio emission; we will refer to it as the nucleus since "nucleus" in a star-forming dwarf is not very well defined. There is diffuse Hα emission over at least 40″ that is much weaker than the peak.

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[1] Wise Observatory Preprint 56.

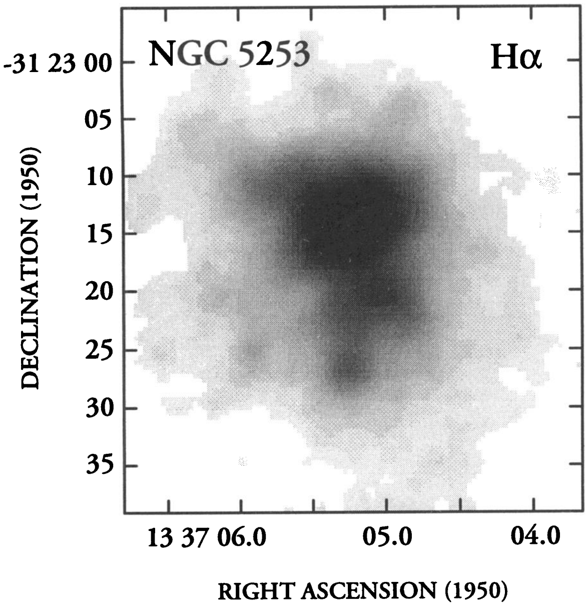

FIG. 1.—Central region of NGC 5253, in continuum-free Hα emission. Absolute positions are accurate to 1″–2″.

TABLE 1

NGC 5253

Right Ascension (2 cm peak) $13^h37^m5^s.124$
Declination (2 cm peak) $-31°23'13''.23$
Distance 2.8 Mpc

Feature	θ_B	Flux	Reference
$S_{21\ \mathrm{cm}}$	<1′	90 ± 40 mJy	1
$S_{20\ \mathrm{cm}}$	20″ × 40″	55 mJy[a]	2
$S_{6\ \mathrm{cm}}$	<2′.5	64 ± 10 mJy	3
$S_{6\ \mathrm{cm}}$	20″ × 40″	49 mJy[a]	2
$S_{2\ \mathrm{cm}}$	6″	35 ± 3 mJy	4
$S_{2\ \mathrm{cm}}$	20″ × 40″	54 mJy[a]	4
[Ne II] 12.8 μm	1″.6	$<10^{-13}$ ergs s^{-1} cm^{-2}	4
[S IV] 10.5 μm	1″.6	3.9×10^{-12} ergs s^{-1} cm^{-2}	4
[Ar III] 8.99 μm	1″.6	3.6×10^{-13} ergs s^{-1} cm^{-2}	4

[a] Fluxes measured from interferometer maps: there may be unresolved flux for size scales larger than 15″–20″ for the 6 and 2 cm maps, and larger than 45″–60″ for the 20 cm map. See text.

REFERENCES.—(1) Lequeux 1971; (2) Turner et al. 1995b; (3) Whiteoak 1970; (4) this paper.

High-resolution radio continuum maps were made at the Very Large Array.[2] The 2 cm observations were made 1992 February 11 with the array in BC configuration. The 2 cm absolute flux is accurate to better than 5%, and the absolute positional accuracy is 0″.05. The synthesized beam size is 1″.9 × 1″.5, FWHM, p.a. 32°. The 2 cm map is shown in Figure 2 (*left*) and is also shown overlaid on the Hα gray-scale image (*right*). The registration accuracy of the latter is limited by the uncertainty in the astrometry of the Hα image, which is ~1″–2″. The radio results, along with those at longer wavelengths from the literature, are shown in Table 1.

Published infrared data on NGC 5253 include *IRAS* fluxes, a spectrum by the Low Resolution Spectrometer on *IRAS*, which did not see any clear features, near-infrared photometry by Moorwood & Glass (1982), measurements of the 2.17 and 4.05 μm Brγ and Brα lines by Kawara, Nishida, & Phillips (1989), searches for H_2 emission by Mouri et al. (1989), and a moderate-resolution 8–13 μm spectrum by Aitken et al. (1982). We obtained a spectrum with high spatial (1″.6) and spectral (30 km s^{-1}) resolution of lines in the 8–13 μm region by use of a cryogenic spectrometer, Irshell (Lacy et al. 1989), on the 3.6 m ESO telescope at La Silla, Chile. Wavelength regions equivalent to 900 km s^{-1} in velocity centered on each of the [Ne II] 12.8 μm, [Ar III] 8.99 μm, and [S IV] 10.5 μm lines were measured. The [S IV] line was observed in three positions separated by 1″.6 north-south and the [Ar III] in three positions separated by 1″ north-south. Fluxes and limits for spectral features in the infrared are shown in Table 1. A typical measurement of the [S IV] line is displayed in Figure 3.

3. RESULTS AND DISCUSSION

3.1. *Spatial Structure; Extinction*

The different long-wavelength measurements result in slightly different sizes for the central source, but all indicate that it is very small—less than 6″ in the 10 μm continuum (Telesco, Dressel, & Wolstencroft 1993). It is not pointlike: the central radio source, which contains nearly half the flux of the central 30″ region, can be fit by a Gaussian of peak intensity $S = 23$ mJy beam^{-1} and size 0″.8–0″.9, FWHM. The position of the radio peak is $\alpha = 13^h37^m05^s.124$, $\delta = -31°23'13''.23$. This central source is surrounded by bright emission that covers ~6″ in diameter, or 80–90 pc. The [S IV] emission extends over 2″–4″, which is significantly larger than the point-spread function. For the adopted distance to NGC 5253, the characteristic size of the infrared source is less than 100 pc, which is a factor of ~5 smaller than the area over which optical emission lines are seen. However, although it is compact, the source is very unlikely to be a Seyfert or other active galactic nucleus (AGN) because of the low velocity width of the [S IV] line (displayed in Fig. 3). It is almost certainly a cluster of very young stars. We discuss in the following sections the stellar contents of this cluster, its age, and how it fits into the overall processes of star formation and evolution in NGC 5253.

Figure 2 (*right*) shows the relative locations of the 2 cm emission and Hα emission in the starburst. Because the 2 cm emission is nearly all thermal bremsstrahlung emisson (§ 3.2), the 2 cm emission and the Hα emission both trace ionized gas. However, the morphologies of these tracers are similar, but not identical, in NGC 5253. The 2 cm and Hα peaks are not coincident, although the offset is small enough, ~2″, that it conceivably could be caused by uncertainties in the optical astrometry. Extinction is also a possibility. The Hα is slightly more extended overall than the 2 cm emission, although this may be due to undersampling of the extended emission by the interferometer, on size scales greater than 15″. The patchy features around the edges of the continuum source (Fig. 2, *left*) suggest that this is the case.

In star-formation regions, only a fraction of the total activity is typically visible at short wavelengths, and although dwarf galaxies have less obscuration than do spiral nuclei, the extinction can still be substantial on small size scales. Walsh & Roy (1989) found $A_v = 1 \pm 1$ mag from the Hα/Hβ ratio in the central part of the galaxy. We estimate the extinction through the star-forming region from the Brackett lines, which may be expected to probe deeper into the galaxy and find greater total obscuration. If we assume $T_e = 12{,}500$ K, similar to the

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[2] The VLA is a facility of the National Radio Astronomy Observatory, which is operated by Associated Universities, Inc., under contract with the National Science Foundation.

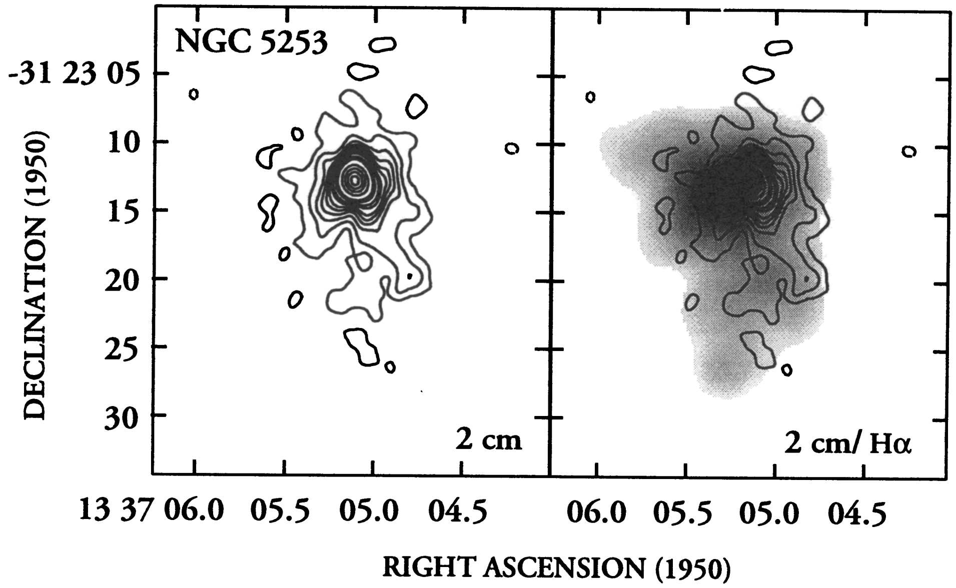

FIG. 2.—The 2 cm emission from the central region of NGC 5253 (*left*). The beam size is 1."9 × 1."5, p.a. 32°. Contour levels are multiples of 0.2 mJy beam^{-1} up to 1.2 mJy beam^{-1}, then 1.6, 2.0, 3.0, and multiples of 4 mJy beam^{-1} thereafter. The peak flux density is 22 mJy beam^{-1}. The 2 cm contours are also shown overlaid on the Hα image (*right*). Registration uncertainties are ~ 1"–2", limited by the optical astrometry.

11,000–13,000 K temperatures derived by Walsh & Roy, the intrinsic value of Brα/Brγ is 2.77 (Ho, Beck, & Turner 1990), and the Brackett-line measurements of Kawara et al. (1989) indicate that there are 0.56 mag of relative extinction between 2.17 and 4.05 μm. This implies A_v of 12 mag if extinction varies as λ^{-2} or 7 mag for a $\lambda^{-1.5}$ extinction law. These values of A_v are consistent with what Kawara et al. found from the depth of the 10 μm feature and are close to the obscuration in typical spiral-galaxy nuclei but are significantly larger than the Hα/Hβ result. That there is extinction of less than 1 mag at 4.05 μm implies that it is unlikely for there to be a very obscured component that is not sampled even in the infrared.

The extinction and spatial structure show that the infrared and radio emission come from a compact region that is so obscured it cannot reliably be studied in the optical or ultraviolet. This cluster is embedded in the extended ionized gas excited by the less obscured young stars seen at optical and shorter wavelengths.

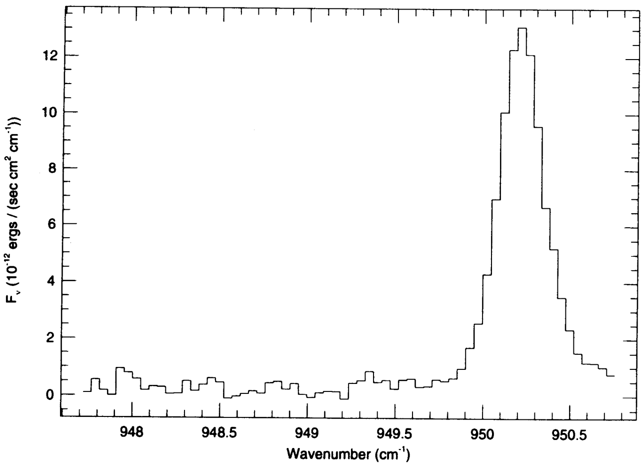

FIG. 3.—[S IV] line observed with Irshell with a 1."6 slit

3.2. *Radio Spectrum*

The plasmas ionized by recently formed OB stars are sources of radio continuum emission as well as Brackett lines. In almost all normal galaxies, the radio spectrum is a mixture of optically thin, thermal free-free emission, with a $\nu^{-0.1}$ spectrum, and nonthermal synchrotron emission, which has a significantly steeper slope. The shorter radio wavelengths will therefore see more thermal and less nonthermal emission, which was our motivation for obtaining 2 cm data on NGC 5253. Analysis of the radio spectrum of NGC 5253 is made difficult by the heterogeneity of the data: the 21 cm and 6 cm measurements of Lequeux (1971) and Whiteoak (1970) were made with single-dish telescopes of differing beam size, and although Lequeux determined that the 21 cm source size was less than 1', these fluxes cannot be simply compared to the high-resolution 2 cm map. The maximum extent of the mapped 2 cm emission is 20" × 40", or 270 pc × 540 pc. The total flux in this map, 54 mJy, is nearly twice that in the central 6", which is 35 mJy. There is evidence that the 2 cm flux is resolved out by the interferometer on size scales greater than 15", although comparison with the single-dish 6 cm flux of Whiteoak indicates that this "missing" flux represents less than 15%–20% of the total. However, the central 15"–20" region is well sampled by the 2 cm map.

The most striking result of the radio data is the flatness of the spectrum. The radio data can be described by a single power law of spectral index ~0 to −0.09—that is, completely thermal. There is no sign of the steeper component of spectral index −0.7 that dominates the continuum emission for wavelengths of 6 cm or longer in starburst galaxies (Turner & Ho 1994). Nor is there a break in the spectrum as is common in extragalactic radio sources (Deeg et al. 1993). While it is possible in theory to reproduce such a flat spectrum from an optically thick synchrotron source, such as the core sources of AGNs, the extended nature of the radio emission rules out this possibility. The simplest and most natural explanation of the spectrum is that NGC 5253 has almost entirely thermal radio emission. We estimate that no more than 10% of the 6 cm flux is nonthermal, and less than 5% at 2 cm. NGC 5253 is comparable to II Zw 40, which is remarkable for its flat spectrum (Deeg et al. 1993), but NGC 5253 is actually flatter, with a slope of -0.1 ± 0.01, compared to -0.21 ± 0.03 for II Zw 40.

How does the radio flux of NGC 5253 compare to the visible and infrared recombination lines of hydrogen? The radio continuum flux expected from Brackett line fluxes may be found from $S_{6\,\mathrm{cm}}(\mathrm{mJy})/S_{\mathrm{Br}\alpha}(10^{-12}$ ergs s^{-1} $\mathrm{cm}^{-2}) \approx 40$, which is appropriate for a $T_e = 12{,}500$ K H II region. From the observed Brackett line fluxes in NGC 5253 (Kawara et al. 1989), we would then predict radio fluxes of ~40 mJy at 6 cm and 35 mJy at 2 cm for the $10'' \times 20''$ region corresponding to the Brackett measurement (we have assumed 0.35 mag extinction at Brα). The observed 2 cm flux in the same region is 45 mJy. The predicted 2 cm flux is therefore 75%–80% of the observed flux. Given that the total radio fluxes of Table 1 indicate that most of the radio emission is thermal, it is likely that the discrepancy between the Brackett prediction and the observed radio flux is due to extinction in the near-infrared, although peculiar nebular conditions (including temperature variations) or a small amount of nonthermal radio emission are also possibilities. It is more difficult to compare the radio and infrared line fluxes to the Hα and Hβ measurements; while the radio continuum and infrared lines are likely to arise in the same volume and are relatively unaffected by extinction, the optical lines are much more susceptible to obscuration and may be dominated by the low-density, unobscured ionized regions that are less important at longer wavelengths. We conclude that the discrepancy between the 20 mJy of 6 cm flux that would be predicted from Osmer, Smith, & Weedman's (1974) measurement of Hβ in a 38″ aperture and the observed value of 51 mJy in the same region (Turner et al. 1995b) is best explained by extinction, the alternative explanation of a major nonthermal contribution to the radio being ruled out by the flat radio spectrum and the basic agreement of the radio and Brackett line fluxes.

The Brackett lines and the radio spectrum of NGC 5253 thus imply that the galaxy contains a large population of OB stars responsible for ionizing the gas, but the absence of a significant nonthermal radio component means the number of supernovae must be very small. Standard supernovae and SNRs have a wide range of radio luminosity, so we cannot calculate an exact upper limit on their number in NGC 5253. Given that the nonthermal fraction in NGC 5253 is less than 5% at 2 cm, or 2–3 mJy, and that the typical Galactic SNR has a spectral luminosity at 2 cm of $L_2 = 2 \times 10^{17}$ W Hz^{-1}, we estimate that we could have detected 10 SNRs. Bright SNRs or radio supernovae (RSNs; Weiler & Sramek 1988) are even harder to hide—we could have detected fewer than half a dozen Cas A's, for example, or a single RSN. This is most unusual for a starburst. For comparison, the starburst in the nucleus of NGC 253 has a nonthermal fraction of 80% at 2 cm (Turner & Ho 1983), and contains the energetic equivalent of hundreds of SNRs, yet has a Lyman continuum rate only twice that of NGC 5253.

The simplest explanation for the lack of radio SNRs in NGC 5253 is that the nuclear starburst is very young [less than $(1\text{–}2) \times 10^7$ yr] and that star formation in the cluster was coeval to a very high degree. This would be consistent with the lack of CO band-head absorption (Rieke et al. 1988). That there are two optically detected supernovae in the last century more than 30″ from the nucleus agrees with the model that star formation in NGC 5253 started in the outer regions well before it started in the center (Caldwell & Phillips 1989). Our maps show no sign of radio emission from the neighborhood of SN 1895b, 32″ northeast of the nucleus, and do not include the region of SN 1972e, 102″ south of the nucleus; the large-beam radio maps were made before SN 1972e and after SN 1895b had faded. The absence of supernovae in the nucleus argues that the unusual [Fe II] and [Fe III] emission observed by Lumsden, Puxley, & Doherty (1994) is more likely to be due to their first suggested mechanism (H II regions with low iron depletion) than to their second (many young supernovae). Similarly, the soft X-ray emission (Martin & Kennicutt 1995) and filamentary morphology (Marlowe et al. 1995) are more likely to be the result of stellar winds or some other mechanism than SNRs.

There are other possible, although far less likely, explanations for the lack of radio SNRs in NGC 5253. Radio synchrotron emission in SNRs is produced by cosmic rays accelerated in the turbulent regions behind supernova shocks. This process is of course very dependent on the circumstellar environment, which probably explains the difference between the bright and short-lived RSNs and the longer lived, standard SNRs. Low-metallicity stars will have low mass-loss rates, so the circumstellar environment in this starburst may not be sufficiently extensive to favor the formation of either RSNs or SNRs. However, these stars are so young that there must be gas left over from the star-formation process that would generate radio emission. Other improbable explanations for the lack of radio SNRs include the lack of a magnetic field, which seems unlikely given the presence of ionized gas and likely turbulence, or an unusually swift evolution of the SNRs into the radiative phase, which would have no obvious cause in NGC 5253, and which would not explain why it is different from other starbursts in this regard. Yet another possibility, even more speculative, is that the highest mass stars may not become supernovae, in which case a top-heavy initial mass function (IMF) could be the reason for the lack of SNRs.

3.3. *Stellar Population*

The current stellar population in the obscured nucleus can be deduced from the mid-infrared spectrum. However, this technique, which has been widely used for Galactic sources, must be applied with care to extragalactic objects, the metallicities of which may differ drastically from solar. The [S IV] line in particular is not a reliable stellar temperature diagnostic unless the metallicity and the details of the nebular structure are known and accounted for. Beck & Sutherland (1995) have shown that the [S IV] line can be enhanced strongly by low metallicity and suppressed by high density. The lines of argon and neon are less affected by nebular structure and metallicity, but only [Ar III] was seen in NGC 5253, so it is necessary to use [S IV] and a more realistic model grid that will take account of the metallicity and nebular parameters if we are to derive the stellar temperature. We have used the program MAPPINGS II (Sutherland & Dopita 1993) to calculate line strengths of isobaric spherical H II regions with nebular characteristics typical of infrared star-formation sources: $\log nt = 8$ or density $\sim 10^4$ and ionization parameters $\log Q = 8.5$ (where $\log Q = \log U + \log c$). The input ionizing spectra were R. L. Kurucz (1992, private communication) models with solar or 0.1 solar metal abundances (these models are, strictly speaking, applicable only to single sources, and the ionizing spectrum of a group of stars may differ from that of a single star, so these results should be taken as approximate). The correction for relative extinction between the [Ar III] and [S IV] wavelengths is negligible.

We found that the [S IV]/[Ar III] ratio observed in NGC 5253 cannot be produced by any solar-abundance model, even one excited by 50,000 K stars. The $Z = 0.1\ Z_\odot$ models, which are closest to the Z of 0.15–0.25 $Z_\odot$ found from optical measurements of Walsh & Roy (1989), indicate that stars between 40,000 and 45,000 K with the above nebular parameters will have [S IV]/[Ar III] and [S IV]/[Ne II] ratios consistent with those seen in NGC 5253. (Aitken et al. 1982, using simple models with solar abundances, deduced that the exciting stars in NGC 5253 must be well over 50,000 K for the [S IV] 10.5 μm line to be so strong. Our much less extreme result reflects the enhancement of [S IV] for a star of a given temperature at low metallicity.) This result is not very sensitive to small (less than a factor of 3) changes in the metallicity or to the presence of a reasonable amount of dust. A main-sequence star of the deduced temperature would have 35–40 $M_\odot$ and a main-sequence lifetime at that temperature of $(1.5\text{–}2) \times 10^6$ yr (Schaller et al. 1993).

The above assumes that the star cluster is very young and coevally formed, which, as discussed above, is the simplest explanation for the lack of supernovae. If we admit one of the more speculative possibilities mentioned above to explain the absence of SNRs, the small [S IV]–emitting cluster may contain more massive stars that have cooled down or entered the W-R stage. Preliminary calculations of the ionizing spectra of clusters (Sutherland, Shull, & Beck 1995) indicate that a coevally formed cluster with this effective temperature would be no older than 2×10^6 yr. If star formation took place in a Gaussian burst in which the star-formation rate is peaked at 5×10^6 yr with a spread of 2×10^6 yr, the cluster could be this hot at ages as advanced as 9×10^6 yr (4×10^6 yr after the peak). If Wolf-Rayet stars form in the cluster and dominate the ionization at late times, when it would otherwise be too cool to produce the observed infrared spectrum, it could be 1.5×10^7 yr old (this possibility is open to speculation, as the behavior and appearance of Wolf-Rayet stars in dense, obscured clusters are neither observationally nor theoretically known). Approximate as these numbers are, they do agree with the thermal radio spectrum, the lack of supernovae, and the absence of supergiants (Moorwood & Glass 1982) in suggesting that the central starburst is no more than 10^7 yr old and probably much younger.

We can estimate the stellar population needed to account for the radio, infrared, and line emission from the total ionization rate. Using Ho et al.'s (1990) calculations relating radio and Brackett line fluxes to ionizing flux and Lacy, Beck, & Geballe's (1982) work on the emission measure from ionic fine-structure lines, we find that the Brackett line fluxes require an ionizing rate of $2.7 \times 10^{52}\ \mathrm{s}^{-1}$, the 2 cm radio continuum (in the same area as the Brackett lines) needs $3.2 \times 10^{52}\ \mathrm{s}^{-1}$, and the [S IV] flux requires $2.2 \times 10^{52}\ \mathrm{s}^{-1}$. The last differs from Aitken et al.'s (1982) result for several reasons. First, the flux we measured is only 65% of theirs, which may be related to the higher spectral resolution. Second, they used 4 Mpc for the distance and we used 2.8 Mpc. Third, they assumed solar abundances and we assumed 0.25 solar abundance for sulfur, which is what is seen in the optical emission region of NGC 5253, and that the fraction of sulfur in S^{+3} was 0.5, which the models indicate is a plausible ionic fraction for 45,000 K stars and 0.1–0.2 $Z_\odot$.

Because of the uncertainties in the sulfur abundance and the difference between the Brackett and radio emission described above, we adopt $3 \times 10^{52}\ \mathrm{s}^{-1}$ for the ionization rate. From Panagia's (1973) results, this ionizing flux could be produced by $\sim 2 \times 10^3$ O6 stars at 42,000 K or $\sim 1 \times 10^3$ O5.5 stars at 44,500 K. Vacca (1994) showed that the ionizing flux from a star at a fixed temperature increases as the metallicity decreases, to the extent that stars of these temperatures will produce roughly twice as much ionizing flux if they are of 0.05 solar metallicity as compared to solar-metallicity stars. For the moderate metallicity of NGC 5253, the effect will be less; we estimate a 25% increase in the ionization per star. Another complication is that the ionization rate of a physical cluster of mixed stellar types will differ from that of simplified model used here. Even with all these uncertainties, it is still apparent that the small obscured star cluster in NGC 5253 contains from several hundred to several thousand early O stars.

Of particular interest is the very compact 2 cm emission core, which has a size of 11–12 pc. The 2 cm flux in this core is 23 mJy, which is about half the total flux. We would therefore expect that this region contains ~500–1000 O stars. If these are all in the $\sim 0\farcs8\text{–}0\farcs9$ area of the radio core, the stellar density will be 0.5–1 O stars pc^{-3}. The total stellar density may be estimated from the number of O stars if we assume an IMF. If we choose an IMF $\propto M^{-3.2}$ for stars larger than 10 $M_\odot$ and flatter for smaller stars, we find for every 35–40 $M_\odot$ star ~40 stars of masses 10–35 $M_\odot$ and 20–90 stars, depending on the exponent chosen in the low-mass region, of 1–10 $M_\odot$. This would lead to a total stellar density of 30–130 stars pc^{-3} in the central star cluster. This high stellar density is uncharacteristic of Galactic star-forming regions and instead is more what one would expect for the central regions of a globular cluster.

4. CONCLUSIONS

Our infrared and radio observations of the obscured nucleus of NGC 5253 show that it contains a dense cluster of a few thousand massive and very young stars. From the high [S IV]/[Ar III] ratio we deduce that the cluster ionization is dominated by metal-poor stars of 40,000–45,000 K; the deduced age of the cluster is no more than 10^7 yr and more likely a few times 10^6 yr. This young age is probably the reason the radio continuum emission is entirely thermal; in fact, this requires that the cluster be not only young but coeval. The youth of the nuclear star cluster agrees with the picture that star formation has proceeded from the outskirts toward the nucleus in this galaxy. We may expect in the near (astronomically speaking) future to see supernovae in this star cluster and, possibly, changes in the ionization as Wolf-Rayet stars develop.

While the youth of the NGC 5253 starburst and its progress through the galaxy are well established, there are still important, unanswered questions about this object. First, the starburst started so recently that the triggering mechanism should still be obvious, but there is no candidate for a trigger except the hypothesized interaction with M83. What started the starburst? Second, what will happen to the dense central star cluster? What are its dynamics? Finally, are the characteristics of NGC 5253 that now appear so unusual—the thermal radio spectrum and the concentrated cluster of coevally formed hot stars—actually common among dwarf-galaxy starbursts?

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REFERENCES

Aitken, D. K., Roche, P. F., Allen, M. C., & Phillips, M. M. 1982, MNRAS, 199, 31P
Beck, S. C., & Sutherland, R. S. 1995, in preparation
Caldwell, N., & Phillips, M. M. 1989, ApJ, 338, 789
Deeg, H.-J., Brinks, E., Duric, N., Klein, U., & Skillman, E. 1993, ApJ, 410, 626
Ho, P. T. P., Beck, S. C., & Turner, J. 1990, ApJ, 349, 57
Kawara, K., Nishida, M., & Phillips, M. M. 1989, ApJ, 337, 230
Lacy, J. H., Achtermann, J. M., Bruce, D. E., Lester, D. F., Peck, M. C., & Gaalema, S. D. 1989, PASP, 101, 1166
Lacy, J. H., Beck, S. C., & Geballe, T. R. 1982, ApJ, 255, 510
Lequeux, J. 1971, A&A, 15, 30
Lumsden, G. L., Puxley, P. J., & Doherty, R. M. 1994, MNRAS, 268, 821
Marlowe, A. T., Heckman, T. M., Wyse, R. F. G., & Schommer, R. 1995, ApJ, 438, 563
Martin, C. L., & Kennicutt, R. C., Jr. 1995, preprint
Moorwood, A. F. M., & Glass, I. S. 1982, A&A, 115, 84
Mouri, H., Taniguchi, Y., Kawara, K., & Nishida, M. 1989, ApJ, 346, L73
Osmer, P. S., Smith, M. G., & Weedman, D. W. 1974, ApJ, 192, 279
Panagia, N. 1973, AJ, 78, 929
Rieke, G. H., Lebofsky, M. J., & Walker, C. E. 1988, ApJ, 325, 679
Rogstad, D. H., Lockhart, I. A., & Wright, M. C. H. 1974, ApJ, 193, 309
Schaller, P. G., Schaerer, D., Meynet, G., & Maeder, A. 1993, A&AS, 96, 269
Sutherland, R. S., & Dopita, M. A. 1993, ApJS, 88, 253
Sutherland, R. S., Shull, M., & Beck, S. C. 1995, in preparation
Telesco, C. M., Dressel, L. L., & Wolstencroft, R. D. 1993, ApJ, 414, 120
Turner, J. L., Beck, S. C., & Hurt, R. L. 1995a, in preparation
Turner, J. L., & Ho, P. T. P. 1983, ApJ, 268, L79
———. 1994, ApJ, 421, 122
Turner, J. L., Ho, P. T. P., & Beck, S. C. 1995b, in preparation
Vacca, W. D. 1994, ApJ, 421, 140
Van den Bergh, S. 1980, PASP, 92, 122
Walsh, J. R., & Roy, J.-R. 1987, ApJ, 319, L57
———. 1989, MNRAS, 239, 297
Weiler, K., & Sramek, R. 1988, ARA&A, 26, 295
Whiteoak, J. B. 1970, Astrophys. Lett., 5, 29