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THE NATURE OF THE ULTRAVIOLET CONTINUUM IN TYPE 2 SEYFERT GALAXIES

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ABSTRACT

Type 2 Seyfert nuclei are well known to contain a "featureless continuum" which makes a significant contribution in the optical and ultraviolet. However, the nature of this featureless continuum is not clear. Recent optical spectropolarimetry shows that only a minor part of the optical featureless continuum can be light from a hidden Seyfert 1 nucleus scattered into our line of sight. In this paper, we show that this is also true in the ultraviolet.

We have used *International Ultraviolet Explorer* (*IUE*) spectra of 20 of the brightest type 2 Seyfert nuclei to construct an ultraviolet spectral template. While the continuum is well detected in the template, there is no detectable broad-line region (BLR). Comparing this template to a similar spectral template of type 1 Seyfert nuclei implies that no more than 20% of the Seyfert 2 template's continuum can be light from a hidden Seyfert 1 nucleus scattered by dust or warm electrons. One obvious possibility is that most of the nuclei in our sample are "pure" type 2 Seyfert galaxies that do not contain a hidden type 1 Seyfert nucleus (e.g., we have a clear view of the central engine in the ultraviolet, and it simply lacks a broad-line region). This is not compatible with the evidence that at least some Seyfert 2 galaxies can be unified with Seyfert 1 galaxies on the basis of viewing geometry, unless there are two types of Seyfert 2 galaxies.

As an alternative, we consider the possibility of Seyfert 1 light scattered off very hot electrons ($T > 10^7$ K). The BLR emission lines can then be broadened beyond recognition in our data. However, a scatterer this hot is inconsistent with optical spectropolarimetry. Optically-thin thermal emission from the type of warm mirror seen in NGC 1068 cannot produce the ultraviolet continuum we observe because the equivalent width of Lyα and He II λ1640 are at least an order of magnitude too small in the Seyfert 2 template, and the observed ultraviolet continuum is generally much too red to be thermal emission from gas warmer than 10^5 K.

We discuss an alternative in which most of the ultraviolet continuum in these Seyfert 2 galaxies may be produced by a reddened starburst: a circumnuclear population of massive stars which is unusually luminous in type 2 Seyfert galaxies compared to normal galaxies of the same Hubble type. We show that our Seyfert 2 template is consistent with existing *IUE* spectra of metal-rich starbursts in all salient properties. Two consequences of this would be that a significant fraction of the optical Balmer emission lines (as measured in an aperture as large as that of *IUE*) and most of the far-infrared continuum detected from these Seyfert 2 galaxies would be powered by the starburst. Combining this inference with the evidence that many type 2 Seyfert nuclei contain a "hidden" type 1 Seyfert nucleus would then imply that both compact active nuclei and starbursts play important energetic roles in the Seyfert phenomenon. We also show that if NGC 1068 were at the median distance of the Seyfert 2 galaxies in our sample, then about 70% of its ultraviolet continuum as observed through the *IUE* aperture would arise in its circumnuclear star-forming ring. Thus, the "anomalous" behavior of the featureless continuum in NGC 1068 compared to other Seyfert 2 galaxies may be caused at least in part by an aperture effect.

Although the type 2 Seyfert template is not of adequate quality to allow the direct spectroscopic detection of massive stars, if such stars are present then this should be possible in the near future with the *Hubble Space Telescope* (*HST*). Such observations will also be required to ascertain the relationship between the ultraviolet continuum seen by *IUE* and the unpolarized component of the optical featureless continuum (the "FC2"). In an appendix we consider whether any genuine "type 2 quasars" have yet been detected at high redshift.

Subject headings: galaxies: active — galaxies: nuclei — galaxies: photometry — galaxies: Seyfert — galaxies: stellar content — ultraviolet: galaxies

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1. INTRODUCTION

One of the most striking properties of the nuclei of type 2 Seyfert galaxies is the optical "featureless continuum" (FC) (see Koski 1978; Shuder 1981; Yee 1980). This FC does not generally produce any clear optical absorption-line signature and is bluer than the typical old stellar population that dominates the light from the nuclei of normal galaxies whose Hubble types are the same as those of typical Seyfert galaxies. More recently, Kinney et al. (1991b) have used *IUE* to detect the far-ultraviolet continuum in type 2 Seyfert galaxies. Since this continuum is significantly brighter than is seen in normal galaxies of similar Hubble type, they conclude that it is likely to be the ultraviolet counterpart of the optical FC.

It is also well known (Yee 1980; Shuder 1981) that the luminosity of the optical FC in Seyfert 2 nuclei correlates well with the luminosity of the emission lines produced in the narrow-line region (NLR). This suggests a physical connection between the FC and the ionization of the NLR. In the early ("preunification") days it was tacitly assumed that the FC in type 2 Seyfert galaxies afforded us a direct view of the central engine (e.g., an accretion disk or the like) and that this central source was intrinsically weaker in these nuclei compared to type 1 Seyfert nuclei.

The discovery (Antonucci & Miller 1985; Miller & Goodrich 1990) that at least some type 2 Seyfert galaxies contain a "hidden" type 1 Seyfert nucleus that can be seen only in reflected (polarized) light then led naturally to the belief that the FC in type 2 Seyfert galaxies was simply this scattered Seyfert 1 light. That is, there exists a very powerful FC that is seen directly in the type 1 Seyfert galaxies, but only as a dim reflection in the type 2 Seyfert galaxies. However, as has been emphasized by Kay (1994) and extensively discussed by Cid Fernandes & Terlevich (1992, 1995 [hereafter CFT]), there are a number of problems with this picture. These include the generally low continuum polarization in Seyfert 2 galaxies and the weakness of the reflected broad optical emission lines relative to the FC.

These issues have been brought into focus by the recent spectropolarimetric study of type 2 Seyfert galaxies by Tran (1995a, b, c, hereafter T95a, b, c). As foreshadowed by Miller & Goodrich (1990) and Tran, Miller, & Kay (1992), this work shows that even after the contribution to the optical continuum from a normal old underlying stellar population is removed from the data, the remaining continuum is usually significantly less polarized (by a factor of a few) than the reflected emission from the hidden broad-line region (BLR). Put another way, after the contribution to the optical spectrum made by polarized (reflected) light from the hidden type 1 Seyfert nucleus has been removed, most (50%–90%) of the FC is still present in the optical spectrum. This is in striking contrast to the "prototypical" case of NGC 1068, in which spectropolarimetry implies that the reflected light from a hidden type 1 Seyfert nucleus can account for most if not all of the arcsecond-scale FC source (see, however, CFT).

The physical origin of this second and dominant component of the observed optical FC in type 2 Seyfert galaxies, which Miller (1994) and Tran dub the "FC2," is by no means clear. One natural possibility is that FC2 is produced in some way by the active galactic nucleus (AGN). For example, Miller (1994) suggests that the FC2 is optically thin thermal emission from the "mirror" (the warm gas whose free electrons are responsible for scattering light from the hidden Seyfert 1 nucleus into our line of sight). This possibility has been discussed in more detail in T95c.

An interesting alternative suggestion is that the FC2 is actually produced by a population of hot, massive stars (Terlevich, Diaz, & Terlevich 1990; Cid Fernandes & Terlevich 1992; CFT). There is indeed a growing body of evidence suggesting that there may be some causal and/or evolutionary connection between central bursts of star formation and the Seyfert phenomenon (see the recent reviews by Heckman 1991; Filippenko 1993; Terlevich 1994). It is therefore useful to summarize briefly the spectroscopic evidence for a stellar origin for the FC2.

Most Seyfert galaxies close enough to be assigned secure Hubble types are early-type disk galaxies (S0 through Sb; Heckman et al. 1989). Optical and near-infrared spectra of the nuclei of normal early-type galaxies are dominated by cool stars and hence by strong absorption lines produced by neutral and singly ionized metals, such as the Mg I *b* line at 5174 Å, the Na I D doublet at 5892 Å, and the Ca II triplet at 8498, 8542, and 8662 Å (e.g., Heckman, Balick, & Crane 1980; Terlevich et al. 1990). Mixing such a spectrum with a truly featureless AGN continuum should weaken all these stellar lines. However, as first shown by Terlevich et al. (1990) and confirmed by Nelson (1994) and M. Garcia-Vargas (private communication), a significant fraction of type 2 Seyfert nuclei simultaneously have both strong stellar near-infrared Ca II triplet absorption lines and relatively weak optical stellar absorption lines (like the Mg I *b* line). Consistency with the data for those particular Seyfert 2 nuclei then requires that there must be a strong FC at 5200 Å to dilute lines like Mg I, but significantly less FC at 8600 Å to dilute the Ca II triplet.

In fact, just such a situation is expected if a considerable portion of the optical and near-infrared continuum is being produced by a starburst population of high-mass stars. In this case, red supergiants can make a significant contribution in the near-infrared and produce a strong Ca II triplet feature. On the other hand, the optical spectrum of a starburst is dominated by relatively hotter stars, and these have very weak Mg I *b* and other similar lines. These effects have been discussed in Terlevich et al. (1990), Cid Fernandes & Terlevich (1992), CFT, and Nelson (1994). They can be clearly seen in the synthetic starburst spectra published by Bica, Alloin, & Schmidt (1990), as well as in spectra of actual starburst galaxies (e.g., Terlevich et al. 1990; Storchi-Bergmann, Kinney, & Challis 1995; Garcia-Vargas et al. 1992).

To discriminate between the above possibilities for the origin of the FC in type 2 Seyfert galaxies, we were therefore motivated to extend the study of this phenomenon to the ultraviolet. Such a study offers four advantages. First, it significantly increases the logarithmic range in wavelength over which the FC can be probed. Second, the old stellar population which contributes significantly to the optical continuum in many type 2 Seyfert nuclei, and which therefore complicates optical measurements of the FC properties, will be undetectably faint in the ultraviolet. Third, the ultraviolet spectral window is just where the spectroscopic signature of a population of hot stars (if present) will be the clearest. The strongest such lines are the broad, blueshifted stellar wind lines resulting from N V λ1240, Si IV λ1400, and C IV λ1549 (see Leitherer, Robert, & Heckman 1995).

Finally, it should be easier to see the direct spectroscopic signature of reflected light from a hidden type 1 Seyfert nucleus (i.e., to detect the BLR) in the ultraviolet than in the visible. In part, this is because Rayleigh scattering by dust may contribute to the scattering process (see T95b, c). Even for pure electron scattering, the contrast between the reflected light from a hidden BLR and direct light from the NLR should be larger for lines like N v λ1240, Si iv λ1400, and C iv λ1549 than for the optical Balmer lines. That is, while the observed ratio of C iv/Hα in the BLR is typically about unity (see Francis et al. 1991), it is usually $\leq$25% in the NLR of the bright type 2 Seyfert nuclei that we will discuss below (see the spectra in McQuade, Calzetti, & Kinney 1995; Storchi-Bergmann et al. 1995). Thus, we reasoned that it might be possible to see the BLR in the ultraviolet spectra of type 2 Seyfert galaxies in the form of very broad wings on the profiles of the C iv, Lyα, N v, etc., emission lines.

In § 2 we will describe how we have defined the sample of type 2 Seyfert nuclei that we have investigated, and also how we have created several ultraviolet spectral templates of Seyfert and starburst galaxies using archival *IUE* data. In § 3 we will discuss the results of comparing the type 2 Seyfert spectral template to templates of both type 1 Seyfert nuclei and starburst galaxies. In § 4 we will discuss possible interpretations of these results. Finally, in § 5 we will summarize our results and discuss a direct test to determine the nature of the ultraviolet continuum in type 2 Seyfert galaxies. In an appendix, we propose a test by which the relative strengths of UV emission lines can be used discriminate between high-redshift Seyfert 2 nuclei and "narrow-line quasars."

2. SAMPLE SELECTION & DATA PROCESSING

The only available set of ultraviolet spectra of a large sample of type 2 Seyfert galaxies is that contained in the *IUE* archival database (see Kinney et al. 1991b, 1993). The *IUE* data set does have several important limitations. First, the *IUE* aperture size ($10'' \times 20''$) is quite large, both in terms of its projected size at the distances typical of Seyfert galaxies and its size relative to the apertures used to characterize the detailed properties of the optical featureless continuum. This means that it will not be straightforward to relate the ultraviolet continuum to the optical FC. Moreover, with few exceptions, the signal-to-noise ratio of the *IUE* spectra for individual type 2 Seyfert galaxies is too low to do more than crudely characterize the properties of the ultraviolet continuum (e.g., measure the flux and the overall spectral slope). To overcome this particular problem, we decided to use the ensemble of *IUE* data to form a spectral template of a type 2 Seyfert galaxy. This approach has led to useful insights in the case of starburst and star-forming galaxies (see Calzetti, Kinney, & Storchi-Bergmann 1994; Robert, Leitherer, & Heckman 1994).

The *IUE* archival data set also suffers from a lack of completeness and a considerable heterogeneity in the way in which Seyfert 2 nuclei were selected for observation. As one example, the Kinney et al. (1993) atlas contains the galaxy NGC 7496, in which a very faint type 2 Seyfert nucleus is immersed in a bright circumnuclear starburst that completely overwhelms the Seyfert 2 in the optical and (especially) in the ultraviolet. Inclusion of NGC 7496 and other similar objects which may have been selected for observation with *IUE* because of their bright circumnuclear starbursts will undermine any conclusions we can draw about the nature of the ultraviolet continuum in typical type 2 Seyfert galaxies. On the other hand, there may be some causal link between the presence of a Seyfert nucleus and a circumnuclear starburst. Thus, all type 2 Seyfert nuclei already known to be immersed in a starburst should not be excluded from the sample a priori.

In order to define a sample that is representative of type 2 Seyfert galaxies and is unbiased with respect to the presence (or absence) of an associated starburst, we have decided to select strictly on the basis of the brightness of the Seyfert nucleus itself. Therefore we defined a sample of the 30 brightest known type 2 Seyfert nuclei, using the two most widely available measures of the intrinsic brightness of the Seyfert 2 nucleus: the flux of the [O iii] $\lambda\lambda$4959, 5007 emission lines and the flux density of the nuclear nonthermal radio source at 1.4 GHz. For this purpose, we used the compilation of Whittle (1992a) and selected those type 2 Seyfert nuclei that met one or both of the following criteria: (1) $\log F_{[\mathrm{O\,III}]} \geq -12.0$ (2) $\log F_{1.4} \equiv \nu S_\nu \geq -15.0$. Both the [O iii] and radio fluxes are in units of ergs $\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.

Of the resulting flux-limited sample of 30 type 2 Seyfert galaxies, 21 have archival *IUE* data. We exclude NGC 1068 (see above), leaving us with a final sample of 20 of the brightest type 2 Seyfert nuclei. The full list of these galaxies is given in Table 1 along with their most pertinent properties. Note that we have included two Seyfert galaxies sometimes classified as type 1.9 (NGC 2992 and NGC 4388), since in such objects it is possible that the very weak BLR emission is being seen in reflection (see Shields & Filippenko 1988). We have verified that the inclusion of these two "borderline" type 2 Seyfert galaxies in forming our template does not significantly affect any of the conclusions that we will draw below.

Whittle (1992a) compiled [O iii] fluxes with preference given to data obtained with relatively large apertures (for good spectrophotometric precision). This selection also minimizes the sensitivity of these fluxes to the effects of dust obscuration, which seems to most strongly affect measurements made with small apertures (Mulchaey 1994).

Whittle compiled the radio fluxes using relatively high-resolution interferometric data to attempt to minimize contamination by large-scale disk emission from the "host galaxy." However, we cannot exclude the possibility that a circumnuclear starburst may contribute significantly to the radio flux in some cases. Since we do not want to bias our sample in favor of galaxies with unusually strong starbursts, we have tested for the possible "contamination" of the radio emission by a starburst. To do so, we have compared the measured radio fluxes for our sample of 20 type 2 Seyfert galaxies to the radio fluxes predicted by the remarkably tight far-infrared/radio correlation for starburst and star-forming galaxies (Condon 1992). Then we find that the measured radio fluxes for our Seyferts are on average a factor of 4 greater than predicted, so that most of the observed radio emission is not powered by a starburst (see also Heckman et al. 1989). Considering only the nine galaxies in our sample that enter purely on the basis of their radio flux (see Table 1), the measured radio fluxes are on average a factor 3 times larger than predicted for a starburst. Condon (1992) finds a dispersion of 0.2 dex in the far-infrared/radio correlation. Of our nine radio-selected Seyfert galaxies, only five (NGC 4388, NGC 5135, NGC 6221, NGC 7582, and IC 5135) are within 0.2 dex of the mean observed ratio of radio–to–far-infrared flux for starburst and star-forming galaxies. We therefore conclude that it is unlikely that our selection by the union of radio and [O iii] fluxes has significantly biased us toward Seyfert galaxies with unusually strong starbursts. Nevertheless, we have taken the added precaution of also defining a Seyfert 2 subsample that omits the five above galaxies.

TABLE 1

PROPERTIES OF THE SEYFERT 2 SAMPLE

Galaxy (1)	Seyfert Type (2)	T (3)	$\log F_{[O\ III]}$ (4)	$\log F_R$ (5)	log (IR/UV) (6)	γ (7)	β (8)
NGC 2110	2.0	0	−12.6	−14.4	0.9	0.7	...
NGC 2992	1.9	1	−11.9	−14.5	2.1	1.0	...
NGC 3081	2.0	0	−11.8	−16.2	...	1.2	−0.4
NGC 3393	2.0	1	−11.6	...	1.1	1.5	−0.4
NGC 4388......	1.9	3	−12.2	−14.7	1.8	1.0	−0.9
NGC 5135	2.0	2	−12.5	−14.6	1.5	0.4	−0.1
NGC 5506	2.0	1	−12.2	−14.4	2.0	0.9	−0.4
NGC 5643	2.0	5	−12.0	−15.2	2.1	2.0	−0.3
NGC 5728	2.0	2	−12.0	−15.2	1.6	1.4	−0.6
NGC 6221	2.0	4	−13.1	−14.4	2.1	1.0	0.4
NGC 7582	2.0	2	−12.3	−14.6	2.8	2.5	1.7
Mrk 3	2.0	−5	−11.3	−13.8	1.5	1.6	−0.3
Mrk 34	2.0	...	−12.0	−15.6	1.1	0.6	−0.6
Mrk 78	2.0	...	−12.0	−15.3	1.2	1.4	0.0
Mrk 348.........	2.0	0	−12.3	−14.3	1.0	0.2	0.1
Mrk 463.........	2.0	...	−12.0	−14.3	1.0	−0.2	−0.7
Mrk 477.........	2.0	...	−11.7	−15.1	0.8	−0.6	−1.3
Mrk 573.........	2.0	−2	−11.7	−15.7	1.0	0.9	−0.7
IC 3639	2.0	3	−12.6	−14.9	1.2	0.3	−1.0
IC 5135	2.0	1	−12.4	−14.7	1.8	0.9	−0.5

NOTES.—Col. (1)—Name taken from the compilation in Whittle 1992a and Kinney et al. 1993. Note that Mrk 348 is listed as NGC 262, Mrk 463 is listed as UGC 8850, and IC 5135 is listed as NGC 7130 in Kinney et al. 1993. IC 3639 is listed as TOL 1238−364 in Whittle 1992a.

Col. (2)—Seyfert type taken from Whittle 1992a except for NGC 3393, which was taken from de Grijp et al. 1992.

Col. (3)—Hubble type taken from Whittle 1992a except for NGC 3393, taken from the NASA/IPAC Extragalactic Database (NED). The types are on the de Vaucouleurs numerical system where −5 = E, −2 = S0, 1 = Sa, 3 = Sb, and 5 = Sc. In four cases, the Hubble type is very uncertain and is not listed (see Whittle 1992a for details).

Col. (4)—Logarithm of the flux of the sum of the [O III] $\lambda\lambda$4959, 5007 lines in ergs cm^{-2} s^{-1}. Based on fluxes in Whittle 1992a except for NGC 3393 (de Grijp et al. 1992). Nuclei with this parameter ≥ -12.0 are members of the [O III] flux-selected subsample.

Col. (5)—Logarithm of the monochromatic radio continuum flux at 1.4 GHz ($F \equiv \nu F_\nu$, in ergs cm^{-2} s^{-1}). Based on the flux densities in Whittle 1992a. Nuclei with this parameter ≥ -15.0 are members of the radio flux-selected subsample.

Col. (6)—Logarithm of the dimensionless ratio of the far-infrared and ultraviolet luminosity or flux of the galaxy. The far-infrared flux is the "FIR" parameter taken from Fullmer & Lonsdale 1989 and represents the flux measured by *IRAS* between 40 and 120 μm. The ultraviolet flux is defined as λF_λ as measured from the *IUE* spectra at ~1900 Å (and is computed from the flux densities listed in Kinney et al. 1991b or Kinney et al. 1993). These ultraviolet fluxes are corrected for Galactic extinction using the values for A_B given by Burstein & Heiles 1984 and assuming the reddening law in Savage & Mathis 1979. NGC 3081 was not observed by *IRAS*.

Col. (7)—Mean ultraviolet-optical spectral slope between a rest wavelength of 1910 Å and 4250 Å, where $F_\lambda \propto \lambda^\gamma$. These spectral slopes are based on the "matched aperture" *IUE* + optical spectrophotometry described in Kinney et al. 1991b, Storchi-Bergmann et al. 1994, and McQuade et al. 1994. They have been corrected only for Galactic extinction using the values for A_B given in NED and assuming the standard Galactic extinction law in Savage & Mathis 1979.

Col. (8)—Spectral slope of the ultraviolet continuum. These correspond to the value of the power-law index β, where $F_\lambda \propto \lambda^\beta$. We have determined the power-law fits over the range between 1230 and 2600 Å (or 1230–1960 Å for Mrk 348 for which only Short-Wavelength Camera *IUE* data exist). The spectral region beyond 2500 Å has not been considered, to avoid contamination by the underlying red (old) stellar population. The fit excludes the spectral regions containing expected significant emission or absorption lines (≈30 Å wide bins centered on N V λ1240, C II λ1335, Si IV + O IV] λ1400, N IV] λ1485, C IV λ1549, He II λ1640, N III] λ1750, C III] λ1909, C II] λ2325, and [Ne IV] λ2423. It also excludes the *IUE* low-sensitivity region between 1960 Å and 2250 Å (which is also affected by the 2200 Å "bump" in the standard Galactic reddening curve). The spectral slopes have been corrected for the effects of Galactic reddening prior to fitting but have not been corrected for any reddening intrinsic to the Seyfert nucleus. The quoted slope represents the fit that minimized χ^2 in a linear plot of λ vs. F_λ. Minimizing χ^2 in a log-log plot is not feasible in many of these galaxies because of the low signal-to-noise ratio in the continuum. For NGC 2110 and NGC 2992, the *IUE* data were too noisy to attempt a fit (the continuum is only marginally detected).

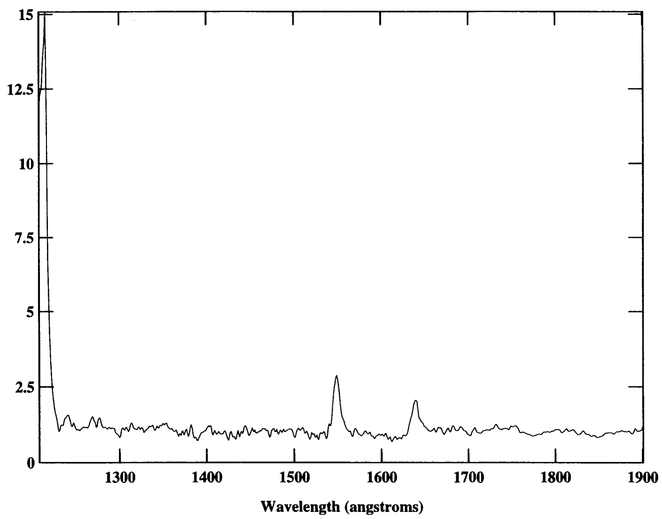

FIG. 1.—*IUE* spectral template of a type 2 Seyfert nucleus, formed by combining an optimally weighted ensemble of the spectra of 20 of the brightest known such nuclei (see text for details).

For each type 2 Seyfert galaxy, we have used the optimal extraction technique of Kinney, Bohlin, & Neill (1991a) to extract spectra from the *IUE* line-by-line data files, utilizing a slit height of nine lines (see also Kinney et al. 1993). After removing *IUE* artifacts (Crenshaw, Breugman, & Norman 1990), we have deredshifted all the spectra and rebinned them to a common wavelength scale in the Seyfert galaxies rest frame (1200–1900 Å pixels). We have a cutoff at 1900 Å in the galaxy rest frame, since not all the Seyfert 2 galaxies have *IUE* long-wavelength spectra. Moreover, our type 1 Seyfert template (see below) shows that the equivalent widths of the C III] $\lambda1909$ and Mg II $\lambda2800$ BLR features are only about half as large as that of the C IV $\lambda1549$ line (which will therefore be our main diagnostic of a hidden BLR). Finally, the principal spectroscopic diagnostics of a starburst population also lie shortward of 1900 Å.

We have then normalized all the spectra to unit mean flux density in the 1200–1900 Å continuum and have weighted each spectrum by the square of the mean signal-to-noise ratio in the continuum. For the computation of the mean flux density and signal-to-noise ratio in the continuum, we have excluded the spectral regions affected by the strongest Seyfert emission lines (Lyα, N V $\lambda1240$, Si IV + O IV] $\lambda1400$, C IV $\lambda1549$, and He II $\lambda1640$). Finally, we have formed an average of these weighted spectra as our final type 2 Seyfert template. This template is shown in Figure 1 and has a mean signal-to-noise ratio in the continuum of about 15:1. We have also formed a template omitting the five radio-selected Seyfert galaxies listed above. This template has a signal-to-noise ratio of about 12:1 but is otherwise qualitatively similar to the template shown in Figure 1.

For comparison purposes, we have followed an analogous procedure to construct a spectral template of a type 1 Seyfert nucleus from the *IUE* archival data. To do so, we combined the *IUE* spectra of 22 Seyfert 1 nuclei and low-redshift quasars. These were selected from the sample in Koratkar, Kinney, & Bohlin (1992) and Kinney et al. (1991c) subject to two criteria: no strong absorption lines or edges, and a signal-to-noise ratio greater than 10:1 in the continuum. The *IUE* spectra were extracted, deredshifted, resampled, normalized, weighted, and combined as described in Koratkar et al. (1992). *IUE* artifacts were removed before the template was generated. The relevant spectral region in the resulting type 1 Seyfert spectral temperature is shown in Figure 2.

Finally, we have formed two *IUE* spectral templates for starburst galaxies. To do so, we have first selected 43 galaxies from the Kinney et al. (1993) ultraviolet spectral atlas. These are just the galaxies classified as starburst or related systems (members of the blue compact galaxy, blue compact dwarf galaxy, starburst nucleus, H II galaxy, or hotspot galaxy "activity classes" in the notation of Kinney et al.) having the highest signal-to-noise ratios in the 1200–1900 Å continuum. The *IUE* spectra were extracted, deredshifted, resampled, normalized, weighted, and combined in essentially the same way as for the type 2 Seyfert galaxies (see above; for details, see Robert et al. 1995). These starbursts have metallicities ranging from about 0.1 to 3 times the solar value (see Storchi-Bergmann, Calzetti, & Kinney 1994; Robert et al. 1995). Since these authors show that the strengths of the ultraviolet absorption lines correlate with the metallicity of the starburst, we have formed two templates that bracket solar metallicity. In one case (hereafter the medium-metallicity template), we have included all 43 galaxies, and the sample has a mean metallicity of 0.7 times the solar value. In the second case (hereafter the high-metallicity template), we have only included the 22 galaxies with metallicity >0.6 times the solar value. The mean metallicity of this sample is 1.5 times the solar value. These two starburst spectral templates are shown in Figures 3*a*–3*b*.

3. RESULTS

3.1. *A Comparison of the Two Seyfert Types*

The principal result of this paper is shown in Figure 2, where we have overplotted the type 2 Seyfert spectral template on three different templates formed from the type 1 Seyfert template. In Figure 2*a* we show the pure type 1 Seyfert template. Since the Seyfert 2 template and the Seyfert 1 template have been scaled to the same continuum level, we would clearly see the scattered light from the BLR *if* the ultraviolet continuum source in the Seyfert 2's were simpy scattered light from a hidden Seyfert 1 nucleus. We do not! CFT have reached a similar conclusion based on the optical Balmer emission lines.

In Figure 2*b* we have mixed the type 1 Seyfert template with an equal contribution from a truly featureless (no emission or absorption lines) ultraviolet continuum. Similarly, in Figure 2*c*, the type 1 Seyfert contribution has been decreased to only 20% of the total continuum flux. It is clear from these comparisons that the lack of any detectable BLR in the type 2 Seyfert template means that no more than about 20% of the ultraviolet continuum can be produced by light from a hidden type 1 Seyfert nucleus scattered into our line of sight by either dust or warm electrons ($T < 10^7$ K).

The strongest single constraint on the presence of BLR emission in our Seyfert 2 ultraviolet template comes from the C IV $\lambda1549$ line, since this is the strongest line (other than Lyα) in the Seyfert 1 template. The Lyα line itself is somewhat confused by geocoronal Lyα contributed by the low-redshift members of the Seyfert 2 sample. However, the blend of the N V $\lambda1240$ line and the red wing of the Lyα line in the Seyfert 1 template also places strong constraints on any BLR emission in the Seyfert 2 template. The C III] $\lambda1909$ and Mg II $\lambda2800$ lines (not included in our Seyfert 2 template) are only about half as strong as C IV $\lambda1549$ in the type 1 Seyfert template. Therefore, they would not

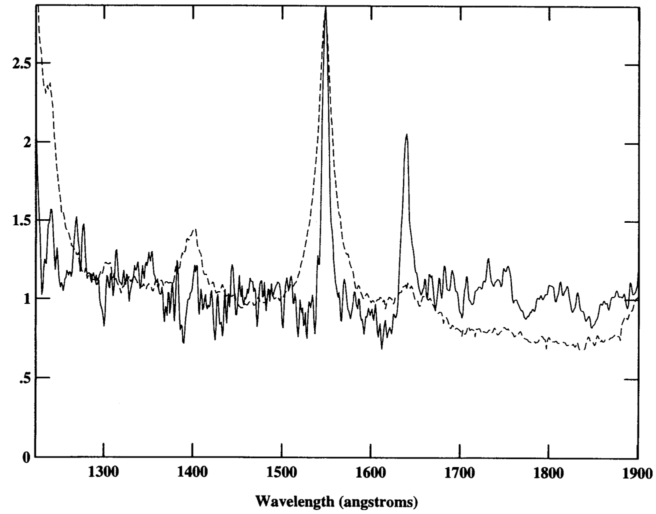

FIG. 2*a*

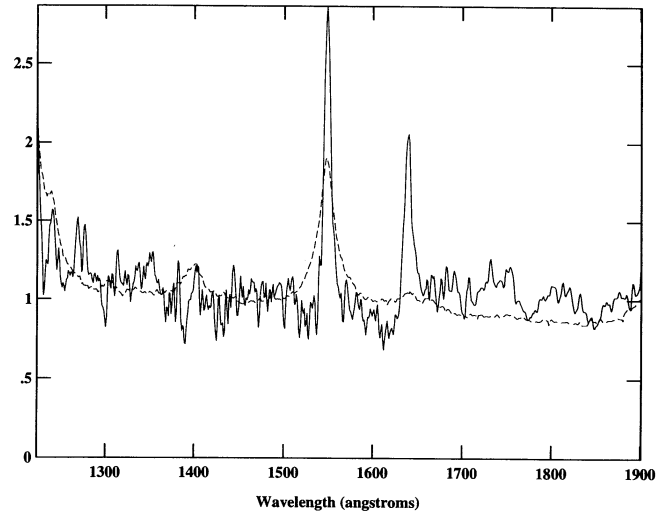

FIG. 2*b*

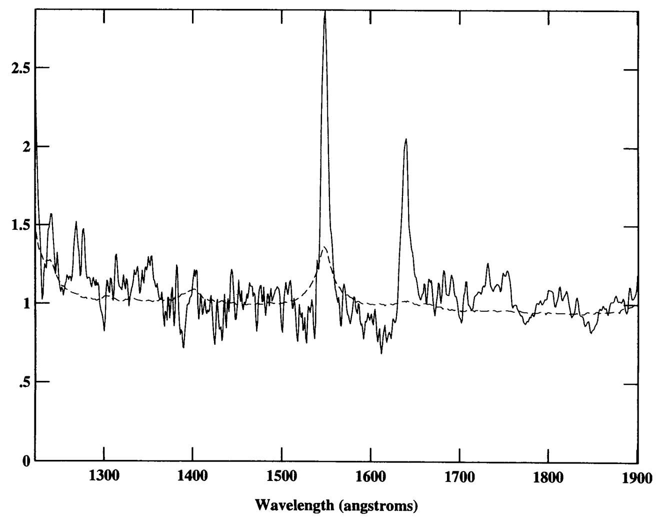

FIG. 2*c*

FIG. 2.—(*a*) The Seyfert 2 template shown in Fig. 1 (*solid line*) is overplotted with the *IUE* spectral template of a type 1 Seyfert nucleus (*dashed line*). This latter was formed by combining the spectra of 22 such nuclei and low- redshift quasars (see text for details). Note that the strong broad C IV line seen in the type 1 Seyfert spectrum is not present in the type 2 Seyfert spectrum, even though the two templates have the same normalized continuum level. (*b*) Same as (*a*), except that the type 1 Seyfert template has been mixed with a truly featureless continuum that provides 50% of the ultraviolet continuum. The strength of the C IV BLR feature is still inconsistent with the lack of such a feature in the Seyfert 2 template. (*c*) Same as (*b*), except that the truly featureless component now provides 80% of the light and the type 1 Seyfert component provides only 20%. The weak residual BLR C IV emission is now consistent with the lack of this feature in the Seyfert 2 template.

provide as strong a constraint as C IV on the presence of a hidden BLR.

We have also compared the Seyfert 1 template to the Seyfert 2 template constructed from the subsample that omitted the five radio-selected type 2 Seyferts whose radio/infrared flux ratios were consistent with starbursts (see § 2). The results are the same as shown in Figure 2, except that the lower signal-to-noise ratio in the Seyfert 2 template means that we can only set an upper limit of 25% on the fractional contribution of Seyfert 1 light.

3.2. *A Comparison to the Starburst Template*

In Figures 3*a*–3*b* we have overplotted the type 2 Seyfert template on the starburst templates (the medium-metallicity and high-metallicity templates, respectively). Given the relatively low signal-to-noise ratio in the type 2 Seyfert template, we cannot rule out the possibility that the majority of the ultraviolet light is produced by a starburst (especially considering the medium-metallicity template, in which the stellar and interstellar absorption lines are weaker).

Indeed, there is a tantalizing hint that absorption features corresponding to the interstellar O I + Si II λ1300 feature, the Si IV λ1400 (potentially stellar plus interstellar) feature, and the Al III λ1860 (potentially stellar plus interstellar) feature may all be present in the Seyfert 2 template. Of course, the detection of purely interstellar absorption lines in the ultraviolet spectrum of a Seyfert 2 would not by itself establish the nature of the ultraviolet continuum. Establishing that the ultraviolet light is dominated by hot stars will require the detection of broad, blueshifted stellar wind absorption lines in transitions like N V λ1240, Si IV λ1400, C IV λ1549, and possibly N IV λ1720 (see Leitherer, Robert, & Heckman 1995). We will consider this in more detail in § 5.2 below.

4. INTERPRETATION

It is clear from Figure 2 that most of the ultraviolet continuum in bright type 2 Seyfert nuclei is not produced by light from a "hidden" type 1 Seyfert nucleus that has been scattered into our line of sight by either dust or warm electrons. What then is the origin of this light? One possibility that cannot be excluded is that most of the galaxies in our sample are "pure Seyfert 2 s." That is, these are objects in which we have a direct view of the central engine and it simply contains no broad-line region. This is not ruled out by existing spectropolarimetry: of the 20 type 2 Seyfert galaxies used to form our template, there are only four definite cases of a BLR visible in polarized light (Mrk 3, Mrk 348, Mrk 463, and Mrk 477) and two more possible cases (Mrk 573 and NGC 4388). The existence of pure type 2 Seyfert nuclei would, of course, be inconsistent with the general unification scheme for Seyfert galaxies. While this is still an unproven hypothesis, there is an impressive body of indirect evidence in its favor (see Antonucci 1993). Moreover, the notion of two entirely different kinds of type 2 Seyfert

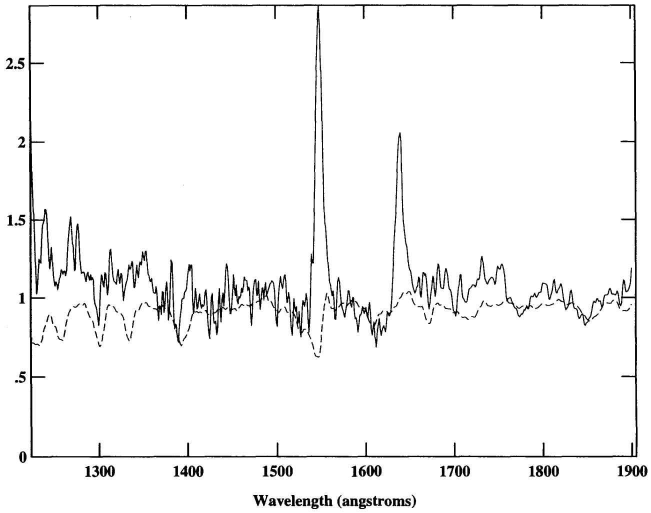

FIG. 3a

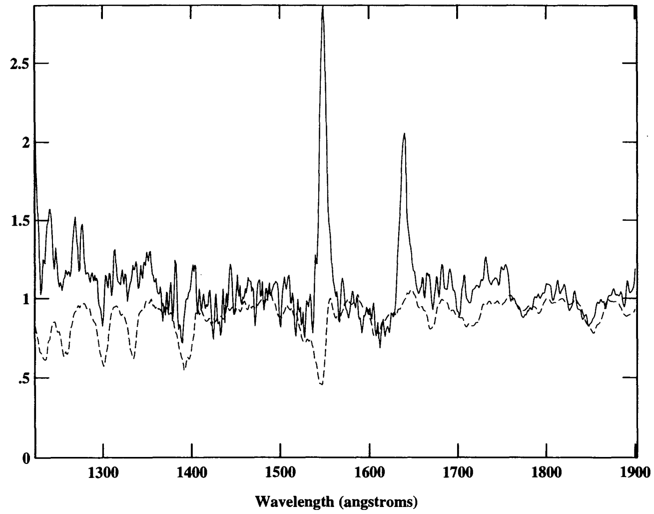

FIG. 3b

FIG. 3.—(*a*) The Seyfert 2 template shown in Fig. 1 (*solid line*) is overplotted with the *IUE* spectral template (*dashed line*) of a medium-metallicity starburst (⟨metallicity⟩ = 70% solar), formed by combining an optimally weighted ensemble of the spectra of the 43 starbursts in the Kinney et al. (1993) atlas with the highest quality *IUE* spectra (see text for details). Apart from the strong nebular emission lines in the type 2 Seyfert template (due to the Seyfert nucleus itself), these two templates are consistent with one another. (*b*) Same as (*a*), except that the high-metallicity (⟨metallicity⟩ = 150% solar) *IUE* starburst template is overplotted. This was formed by combining an optimally weighted ensemble of the spectra of the 20 metal-rich starbursts in the Kinney et al. (1993) atlas with the highest quality *IUE* spectra (see text for details). The interstellar absorption lines in the starburst template are somewhat stronger than any corresponding features in the Seyfert 2 template. However, the presence in the Seyfert 2 template of broad, blueshifted stellar wind lines (N V λ1240, Si IV λ1400, and C IV λ1549) with strengths similar to the corresponding features in the starburst template cannot be ruled out.

galaxies (one with and one without a hidden Seyfert 1 nucleus) is unattractive.

Therefore we consider below three other possibilities for the origin of the ultraviolet light in Seyfert 2 galaxies: hot stars, scattering of Seyfert 1 light by hot electrons, and free-free emission from the warm gas in the "mirror" responsible for the polarized light in at least some Seyfert 2 galaxies.

4.1. *Hot Stars: Comparison to Normal Galaxies*

As discussed in § 1, optical and near-infrared spectra imply that a population of massive stars may make a significant contribution to the continua of at least some type 2 Seyfert nuclei (Terlevich et al. 1990; Nelson 1994; Oliva et al. 1995). Thus, a very natural interpretation of the type 2 Seyfert ultraviolet spectral template is that it is dominated by light from hot, massive OB stars. As we have shown in Figure 3, this interpretation is at least *consistent* with typical starburst spectra.

The *IUE* aperture is relatively large: at the median redshift of our Seyfert 2 sample, its angular dimensions of 10″ × 20″ correspond to linear dimensions of roughly 2 × 4 kpc. Since typical Seyfert galaxies are disk galaxies, it is therefore possible that the normal population of young stars in the inner part of the galaxy disk may make a significant contribution to the ultraviolet flux detected by *IUE*. This interpretation seems unlikely, however, because normal spiral galaxies of similar Hubble types are significantly fainter in the ultraviolet (as we now show).

Typical Seyfert galaxies with secure Hubble types (e.g., the bright Seyfert galaxies in the Revised Shapley-Ames Catalog) range in type from S0 to Sbc (see Heckman et al. 1989). This is also true for the Seyfert 2 galaxies in the present sample (see Table 1). Code & Welch (1982) have published ultraviolet-through-optical spectral energy diagrams for 10 of the nearest normal Sa, Sab, and Sb galaxies using the 10′ aperture of the *OAO* experiment (where we have excluded the two Seyfert galaxies in their sample, NGC 1068 and NGC 4151). The shortest wavelength band in their data at which the detection fraction of these galaxies is high is centered at 1910 Å, and their longest wavelength band is centered at 4250 Å. Therefore we use the ratio of flux densities at 1910 Å and 4250 Å to parameterize the ultraviolet to optical color as a power-law slope γ, where $F_\lambda \alpha \lambda^\gamma$. Then we find that the normal early-type spiral galaxies in Code & Welch (1982) have $\langle\gamma\rangle = 2.34 \pm 0.29$. In contrast, the type 2 Seyfert galaxies in our sample having optical spectrophotometry through an aperture matched to *IUE* (McQuade et al. 1995; Storchi-Bergmann et al. 1995) have $\langle\gamma\rangle = 0.94 \pm 0.16$ (see Table 1). This means that the average ratio of the flux at 1910 Å to that at 4250 Å is about a factor of 3 larger in the type 2 Seyfert galaxies than in normal early-type spiral galaxies (see also Kinney et al. 1991b).

Similarly, Kinney et al. (1995) have recently compiled optical-ultraviolet spectral templates of normal galaxies over the range in Hubble type from E through Sc using *IUE* and optical spectra taken through a matched aperture. The values for spectral slope they find are $\gamma = 3.3$ (E), 3.4 (S0), 2.6 (Sa), 1.6 (Sb), and 0.6 (Sc). Again, the Seyfert 2 galaxies ($\langle\gamma\rangle \approx 1.0$) have significantly larger ratios of ultraviolet-to-optical flux than normal galaxies of similar Hubble type.

Since ultraviolet-optical colors are known to change with radius within spiral galaxies (see Code & Welch 1982), it is important to compare the typical projected aperture sizes (in kiloparsecs) used to obtain the spectral energy distributions of our Seyfert 2 galaxies to those used for the normal galaxies. At the median distance of the 10 normal early-type spiral galaxies with *OAO* data ($\approx$8 Mpc), the *OAO* aperture diameter corresponds to 24 kpc. This is several times larger than the projected size of the *IUE* aperture at the median redshift of our Seyfert 2 sample (see above). The projected *IUE* aperture for the normal galaxies used by Kinney et al. (1995) is typically about 1 × 2 kpc in size (a factor of a few smaller than for the Seyfert 2s). Thus, the Kinney et al. (1995) *IUE* data and the Code & Welch (1982) *OAO* data bracket the Seyfert 2 data in terms of typical projected aperture size. The ultraviolet excess in the Seyfert 2's compared to normal galaxies is therefore not the result of any aperture mismatch.

Therefore, we conclude that *if* a population of hot stars dominates the ultraviolet continuum of type 2 Seyfert galaxies, it must be a population not present with comparable strength in normal galaxies of the same Hubble types as typical Seyfert galaxies. For want of a better term, we will call this unusual stellar population a "starburst."

4.2. *Hot Stars: Comparison to Dusty Starbursts*

4.2.1. *Ultraviolet and Far-Infrared Properties*

Miller (1994) has argued that hot stars are unlikely to produce the optical FC2 because it is significantly redder than expected for such stars. This is also the case in the ultraviolet. As can be seen in Table 1, the median spectral slope of the ultraviolet continuum over the range between 1200–2600 Å is $\beta = -0.4$, where again $F_\lambda \alpha \lambda^\beta$. For comparison, a pure starburst population of hot stars should have much bluer continuum (β typically -2 to -2.5; see Leitherer & Heckman 1995). Thus, if the ultraviolet continuum in Seyfert galaxies is produced by a starburst, this continuum must suffer considerable reddening. This is not unreasonable: very few of the starbursts in the Kinney et al. (1993) *IUE* atlas are as blue in the ultraviolet as expected for a dust-free starburst population (see Calzetti at al. 1995).

As shown by Calzetti et al. (1994) and Storchi-Bergmann et al. (1994), the far-ultraviolet spectral slope in starburst galaxies correlates rather well with the starburst metallicity, in the sense that higher metallicities correspond to redder continua. This is most likely the result of an increase in the dust-to-gas ratio in the starburst interstellar medium (ISM) as its metallicity increases, leading to a corresponding increase in reddening (see Wang & Heckman 1995). The metallicities appropriate to the central regions of luminous early-type spirals like Seyfert galaxies are almost certainly solar or higher (Storchi-Bergmann, Bica, & Pastoriza 1990; Zaritsky, Kennicutt, & Huchra 1994; Schmitt, Storchi-Bergmann, & Baldwin 1994). In fact, the median spectral slope of the ultraviolet continuum of the metal-rich starbursts investigated by Calzetti et al. (1994) and Storchi-Bergmann et al. (1994) is $\beta \approx -0.6$ (very similar to the median for the type 2 Seyfert galaxies). The range of β is also similar in the two classes: -1.3 to $+1.7$ (or -1.3 to $+0.4$, excluding the very red galaxy NGC 7582) for the Seyfert 2 galaxies and -1.4 to $+0.4$ for the metal-rich starbursts. Thus, we conclude that the ultraviolet spectral slopes in the Seyfert 2 sample are quite consistent with empirically based expectations for metal-rich (dusty) starbursts.

If the ultraviolet continuum is starlight from a heavily reddened population of hot stars, then the absorbed ultraviolet energy must be reemitted by dust in the far-infrared. Indeed, Meurer et al. (1995) show that for starbursts the slope of the ultraviolet continuum correlates rather well with the ratio of the far-infrared and ultraviolet continuum fluxes. The most straightforward interpretation of this correlation is that the dustier the starburst, the greater the reddening suffered by the ultraviolet continuum and the correspondingly larger fraction of the ultraviolet continuum that is absorbed by dust and reradiated as thermal far-infrared dust emission (see also Masses & Kunth 1991; Calzetti et al. 1995; Wang & Heckman 1995). If we attribute the relatively red ultraviolet continua of the type 2 Seyfert galaxies to dust extinction, we would therefore expect to see a correspondingly large far-infrared excess. This test is shown in Figure 4, where we have plotted the ultraviolet spectral slope β versus the log of the ratio of the far-infrared and ultraviolet continuum fluxes for both the starbursts studied by Robert et al. (1995) and Meurer et al. (1995), and the type 2 Seyfert galaxies in the present sample.

The Seyfert 2 galaxies are well mixed with the dusty (metal-rich) starbursts at the upper right corner of Figure 4: both classes have a large ratio of far-infrared–to–ultraviolet flux and relatively red ultraviolet colors. Even the extremely red Seyfert galaxy NGC 7582 lies along the extrapolation of the starburst sequence in Figure 4. While Figure 4 in no sense "proves" that the far-infrared or ultraviolet in the Seyfert 2 galaxies is powered by a starburst, it is certainly quite consistent with this hypothesis. Moreover, we note that the average "color temperature" of the far-infrared emission from our sample of type 2 Seyfert galaxies is very close to the corresponding average for starburst and related galaxies. For a dust emissivity

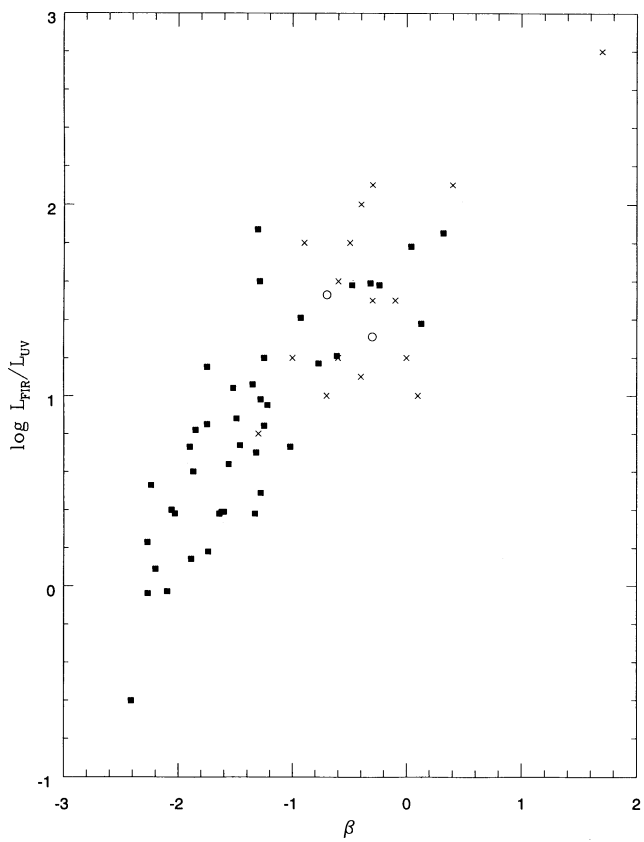

FIG. 4.—A plot of the ratio of the far-infrared and ultraviolet luminosity vs. the ultraviolet spectral slope (β) for the 17 type 2 Seyfert galaxies (*crosses*) in Table 1 for which the relevant measurements exist and for the starburst galaxies used to form the medium-metallicity starburst template (*filled squares*). The Seyfert galaxies seem to lie among the heavily reddened (metal-rich) starburst population at the upper right of this plot. The cross at the extreme upper right is the Seyfert galaxy NGC 7582. We have also plotted NGC 1068 as a pair of open circles, using the ultraviolet data in Neff et al. (1994) for the region within a radius of 1′ of the nucleus (*lower right circle*) and the ultraviolet data in Bruhweiler et al. (1991) plus Kinney et al. (1993) within a radius of about 25″ (*upper left circle*). See Table 2 and text.

law proportional to λ^{-1}, the ratio of the *IRAS* flux densities at 100 μm and 60 μm implies an average dust temperature of 43 K for the Seyfert galaxies in Table 1, compared to an average dust temperature of 42 K for the starburst galaxies studied by Calzetti et al. (1995).

If the far-infrared continuum from the type 2 Seyfert galaxies is in fact produced by a starburst, this starburst would have a very substantial luminosity: taking $H_0 = 75$ km s^{-1} Mpc^{-1}, the log-average infrared luminosity for the Seyferts in Table 1 is about $3 \times 10^{10}\ L_\odot$, with a range from about $10^{10}\ L_\odot$ for NGC 2110, NGC 4388, and Mrk 573 to $>10^{11}\ L_\odot$ in NGC 5135, Mrk 34, Mrk 463, and Mrk 477.

4.2.2. *Optical Properties*

As a further empirical test of the possibility that the ultraviolet light in type 2 Seyfert galaxies originates in a dusty starburst, we can also compare the optical properties of our Seyfert sample to those of dusty starbursts. To do so, we have formed an optical-ultraviolet spectral template (unweighted average of the flux-calibrated spectra) for the 12 Seyfert galaxies in Table 1 for which high-quality optical spectra have been taken through apertures matched in size to that of *IUE* (McQuade et al. 1995; Storchi-Bergmann et al. 1995). The galaxies used are Mrk 348, Mrk 477, NGC 3081, NGC 3393, IC 3639, NGC 5135, NGC 5506, NGC 5643, NGC 5728, NGC 6221, IC 5135, and NGC 7582. We have then compared this to a corresponding optical-ultraviolet template for a dusty, metal-rich starburst. This was formed from NGC 1313, NGC 1672, NGC 4194, NGC 5236, NGC 5860, NGC 5996, NGC 6052, NGC 7496, and NGC 7552 in Calzetti et al. (1994), which all have $\beta > -1.0$ and *IUE* short- and long-wavelength spectra. The Seyfert and starburst templates have been normalized to have the same far-ultraviolet flux.

The results are shown in Figure 5*a*, where we have overplotted the optical portion of the Seyfert 2 and starburst templates, and in Figure 5*b*, where we have plotted the difference between the two. If starbursts with optical properties similar to those of the dusty starburst template provide the bulk of the ultraviolet continuum in the Seyfert 2 template, then we can make the following inferences. First, the dusty starburst would be responsible for $\approx$30% of the Hα and Hβ emission and $\approx$20% of the [O II] λ3727, [N II] $\lambda\lambda$6548, 6584, and [S II] $\lambda\lambda$6717, 6731 emission in the Seyfert 2 template. On the other hand, the starburst would make a negligible contribution to the high-ionization emission lines ([Ne V] λ3426, [Ne III] $\lambda\lambda$3869, 3968, [O III] λ4363, He II λ4686, [O III] $\lambda\lambda$4959, 5007) or to the [O I] λ6300 emission line. We note that the difference between the two spectra shown in Figure 5*b* (by hypothesis, the line emission powered purely by the Seyfert nucleus) is a quite reasonable match to models of gas photoionized by the energetic continuum of an AGN (see Ferland & Osterbrock 1986).

It is also clear from Figures 5*a*–5*b* that the Seyfert template has a considerably brighter and redder optical continuum than the dusty starburst. This spectrum of this excess optical light (Fig. 5*b*) shows the characteristic features of the optical spectra of early-type galaxies and galactic bulges (see Kinney et al. 1995): a strong 4000 Å break (due in part to the Ca II H and K stellar absorption lines), the *g*-band at 4300 Å, the Mg *b*-band at 5174 Å, etc. Figure 5*a* suggests that the starburst would make a significant contribution to the observed Seyfert 2 optical continuum: however, the amount of this contribution is difficult to evaluate quantitatively. This is because the older (prestarburst) stellar population is almost certainly making a major contribution to the optical continuum in the starburst template (e.g., we do not have an optical template of a "pure" dusty starburst).

It is important to emphasize that the above inferences pertain to measurements of type 2 Seyfert galaxies through large (effectively 10″ × 20″) apertures. The relative contribution of a starburst to the optical light in Seyfert 2's as measured through a typical aperture size of a few arcseconds could be significantly less than Figure 5 would imply. As one test, we have compared the ratios of the [O III] λ5007/Hβ emission lines as measured in the large apertures reported by McQuade et al. (1995) and Storchi-Bergmann et al. (1995) to the measurements through small (typically several arcsecond) apertures, as compiled by Dahari & DeRobertis (1988) and Whittle (1992a). In five cases (NGC 3393, NGC 5135, Mrk 477, IC 3639, and IC

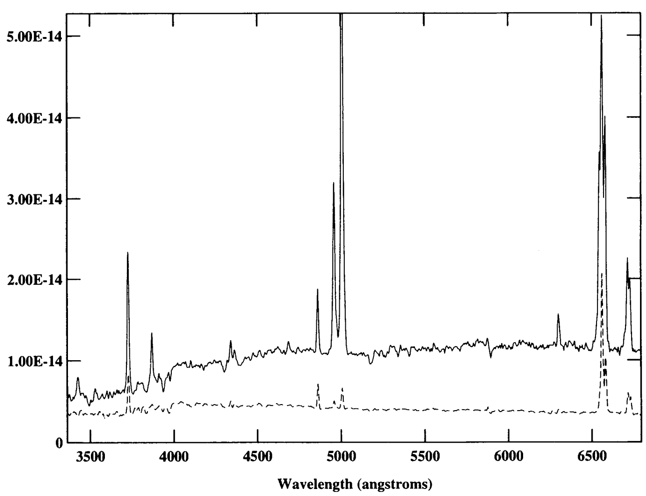

FIG. 5*a*

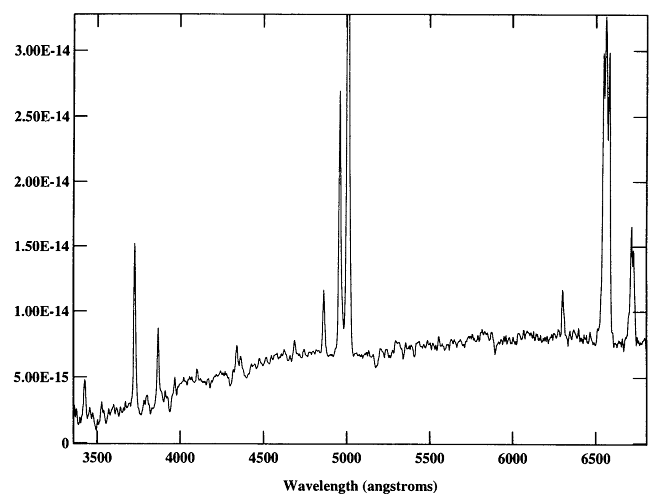

FIG. 5*b*

FIG. 5.—(*a*) An overplot of the optical portions of the optical-ultraviolet spectral templates of a Seyfert 2 galaxy (*solid line*) and dusty starburst (*dashed line*). These templates are described in the text and have been normalized to have the same far-ultraviolet fluxes. (*b*) The difference between the two spectra shown in (*a*) (Seyfert 2 minus starburst).

5135), the line ratio is at least 25% larger (more "Seyfert-like") in the small aperture. However, for the sample as a whole, the ratio increases by an average of only 10% in the small aperture (a difference that is significant at only the 2 σ level). This either means that a starburst contribution to the line emission is usually less than Figure 5 would suggest, or that the relative contribution that the starburst makes to the emission-line fluxes does not change significantly between aperture sizes of several arcseconds versus $\approx 15''$.

For a limited number of cases, detailed comparisons have been made between the optical spectra of our type 2 Seyfert galaxies and semiempirical model spectra of stellar populations (Bonatto, Bica, & Alloin 1989; Storchi-Bergmann et al. 1990). Of these, NGC 6221, NGC 7582, and IC 5135 were all found to show a pronounced contribution by a young, hot stellar population. In NGC 2992 and NGC 4388, hot stars were judged to make a small but detectable ($\approx 10\%$) contribution, while no contribution was discerned in NGC 5643. It would clearly be interesting to extend such studies to more of our sample members and also to map out the stellar content (the above investigations were generally done with several-kiloparsec-scale projected spectroscopic apertures). As emphasized by CFT, the direct spectroscopic detection of hot stars in the optical spectra of Seyfert 2 galaxies will be challenging, since such stars produce only rather weak Balmer and He absorption features that are filled in by the nebular emission lines.

4.3. *Hot Stars: The Aperture-dependent Properties of NGC 1068*

It is important to consider that the starburst interpretation offers a very natural explanation for the "odd" behavior of the FC in NGC 1068: its apparent lack of an FC2 component (see Miller 1994; T95a, b, c). In the ultraviolet, the amount of dilution of scattered Seyfert 1 light by other emission clearly grows as the aperture size of the measurement increases.

To show this, we have compiled in Table 2 measurements of the ultraviolet flux density for NGC 1068 through a variety of apertures whose effective radii span the range from 1".4 (100 pc) to 300" (22 kpc). As Table 2 shows, the ultraviolet continuum flux from NGC 1068 grows steadily as the aperture size is increased (roughly as $F \propto r^{0.5}$ out to a radius of about 1'). To put things in perspective, we note that the flux density of the electron-scattered light from the hidden Seyfert 1 nucleus is about 3.3×10^{-14} ergs cm^{-2} s^{-1} Å^{-1} (Antonucci, Hurt, & Miller 1994), and the analogous flux density of the light scattered by the cloud to the NE of the nucleus is about one-third as large (see Code et al. 1993; Neff et al. 1994). Thus, the total flux density of the ultraviolet continuum contributed by the hidden Seyfert 1 nucleus in NGC 1068 is about 4.4×10^{-14} ergs cm^{-2} s^{-1} Å^{-1}. As Table 2 implies, the fractional contribution of the scattered AGN light is only about 17% for an aperture radius of 1' (4.5 kpc). The remainder is apparently contributed by hot stars primarily located in the circumnuclear starburst. These stars have been detected spectroscopically by the presence of their broad, blueshifted stellar wind lines like C IV 1549 (Bruhweiler, Truong, & Altner 1991; Hutchings et al. 1991; Kriss et al. 1992).

In comparison, the *IUE* aperture used for the type 2 Seyfert galaxies in our sample has an effective projected radius ranging from about 0.6 kpc to 8 kpc with a median of about 1.7 kpc. The fractional contribution of the scattered Seyfert 1 ultraviolet light through the corresponding aperture sizes in NGC 1068 would range from about 60% to 15% with a median of about 30%. Since we have set a limit of <20% fractional contribution by scattered Seyfert 1 light in our type 2 Seyfert template, this means that the relative brightness of the scattered Seyfert 1 component in NGC 1068 would be only slightly brighter than our upper limit for the template.

TABLE 2

APERTURE DEPENDENCE OF THE ULTRAVIOLET FLUX IN NGC 1068

$r_{\rm eff}$ (arcsec; kpc) (1)	$F_{\rm UV}$ (10^{-14} ergs cm^{-2} s^{-1} Å^{-1}) (2)	Instrument (3)	Reference (4)
1.4; 0.10	3.3	*HST*/FOS	1
4; 0.36	5.6	WUPPE	2
8; 0.60	6.0	UIT	3
8; 0.60	6.6	*IUE*	4
9; 0.67	8.0	HUT	5
15; 1.1	11	HUT	5
≈20; 1.5	15	*IUE*	6
60; 4.5	25	UIT	3
300; 22	30	*OAO*	7

NOTES.—Col. (1)–The effective radius of the aperture used [$r_{\rm eff} \equiv (A/\pi)^{1/2}$, where A is surface area of the aperture]. The conversion from arcseconds into kiloparsecs assumes a distance to NGC 1068 of 15.4 Mpc.

Col. (2)—The measured flux density in the continuum around 1550 Å. For the *HST*/FOS entry, this flux density was extrapolated from spectral measurements between 1600 Å and 3300 Å.

Col. (3)—The instrument used for the measurement. *HST*/FOS: *Hubble Space Telescope* Faint Object Spectrograph; WUPPE: Wisconsin Ultraviolet Photo Polarimeter Experiment; UIT: Ultraviolet Imaging Telescope; *IUE*: *International Ultraviolet Explorer*; HUT: Hopkins Ultraviolet Telescope; *OAO*: *Orbiting Astronomical Observatory*.

Col. (4)—References (1) Antonucci et al. 1994. (2) Code et al. 1993. (3) Neff et al. 1994. (4) Kinney et al. 1993. (5) Kriss et al. 1992. (6) Bruhweiler et al. 1991, for which the quoted flux is the sum of nine starburst knots plus the nucleus. (7) Code & Welch 1982.

Similarly, the type 2 Seyfert galaxies with optically detected FC2's are 3–17 times more distant than NGC 1068. The aperture used by T95a for his spectropolarimetry corresponds to a projected effective radius ranging from about 0.3 kpc to 1.7 kpc with a median of 0.7 kpc. Since the inner radius of the NGC 1068 starburst ring is about 1 kpc, this suggests that similar-sized circumnuclear starbursts would make a substantial contribution to the optical FC2 only in the more distant Seyfert 2 galaxies in Tran's sample. For the nearer members of Tran's sample, a starburst origin for the FC2 would require circumnuclear starbursts that are several times smaller than the one in NGC 1068.

It is also interesting to see where NGC 1068 falls in Figure 4. We have used the data in Neff et al. (1994) to determine that the ratio of far-infrared to ultraviolet flux in NGC 1068 is about 21 and that the integrated ultraviolet spectral slope between roughly 1500 Å and 2500 Å is $\beta \approx -0.3$ (within a radius of 1' of the nucleus). The *IUE* spectra discussed by Bruhweiler et al. (1991) for the nine bright extranuclear starburst knots can be combined with the *IUE* nuclear spectrum in Kinney et al. (1993) to derive a rough value $\beta \approx -0.7$ and a ratio of far-infrared to ultraviolet flux of about 34 for the region covered by Bruhweiler et al. (effective radius of about 25"). Either set of values for β and FIR/UV flux place NGC 1068 well within the loci of the other type 2 Seyfert nuclei and dusty starburst galaxies (see Fig. 4). The only somewhat unusual property of NGC 1068 would be its large luminosity ($L_{\rm FIR} \approx 10^{11}\ L_\odot$), although NGC 5135, IC 5135, Mrk 34, Mrk 463, and Mrk 477 are comparably powerful. Again, this suggests that if measured through a suitably large aperture, NGC 1068 is a "normal" (albeit luminous) type 2 Seyfert galaxy.

4.4. *Other Evidence for Starbursts in Type 2 Seyfert Galaxies*

The possibility that type 2 Seyfert galaxies may have unusually high star formation rates is consistent with several other pieces of evidence. Maiolino et al. (1995) have concluded that type 2 Seyfert galaxies as a class exhibit unusually strong *extranuclear* mid-infrared emission from warm dust. They interpret this as evidence for enhanced rates of star formation in type 2 Seyfert galaxies. Heckman et al. (1989) reached the same conclusion based on the strength of the far-infrared continuum and the CO $\lambda = 2.7$ mm emission line.

A significant contribution of a starburst population to the optical light from Seyfert galaxies might be responsible for the offset of Seyfert galaxies relative to normal galaxies in the Tully-Fisher and Faber-Jackson relations (the Seyfert galaxies are too bright for their disk rotation speed and bulge velocity dispersion by an average of about 0.6 mag; Whittle 1992b, Nelson 1994).

As emphasized in § 1 above, the presence of a starburst in or near at least some Seyfert nuclei has also been suggested on the basis of the strong Ca II triplet absorption lines in the near-infrared (Terlevich et al. 1990; Nelson 1994). Oliva et al. (1995) have determined the light-to-mass ratio of the stellar population in a small sample of type 2 Seyfert nuclei in the near-IR. They use the strength of the H-band and K-band CO and Si stellar absorption features to show that the "nonstellar" contribution to the H-band continuum is quite small. After removing this minor contribution, they find that in about half these nuclei, the stellar population has a light-to-mass ratio about 5 times larger than in normal galaxies (quite similar to bona fide starburst nuclei).

The presence of a population of young stars in or near Seyfert nuclei would also be consistent with the AGN scenarios of Perry & Dyson (1985), Norman & Scoville (1988), Terlevich & Melnick (1985), and Terlevich (1994). Pier & Krolik (1993) also predicted a starburst origin for the far-infrared continuum in Seyfert galaxies on the basis of a comparison of the relatively weak far-infrared emission generated by their models of "obscuring tori" compared to the strong observed far-infrared emission.

In a related vein, there is intriguing evidence for a young stellar population in some narrow-line radio galaxies. The case of the radio galaxy 3C 234 is particularly interesting. Antonucci (1984) showed that this object contains a powerful quasar that can be seen in reflection via optical spectropolarimetry. For our adopted $H_0 = 75$ km s^{-1} Mpc^{-1}, the absolute magnitude of the featureless continuum is $M_V \approx -22$ in this case. Antonucci's data also imply that a substantial fraction of this is what would now be called FC2. If this is produced by a starburst, the starburst must then be a very luminous one. Antonucci also found that the FC in 3C 234 is rather red ($\beta \approx 0$), so that the starburst hypothesis would require substantial reddening. Interestingly, 3C 234 is also one of the most powerful known radio galaxies in the infrared, with a luminosity of about 10^{12} $L_\odot$ (Impey & Gregorini 1993; Heckman et al. 1994). Some of this infrared emission could be powered by a dusty starburst. Similarly, Goodrich & Miller (1989) have proposed that the optical FC in Cygnus A is produced by a hot stellar population (since the FC region is several kpc in extent and exhibits very low polarization).

More generally, Smith & Heckman (1989) have used optical imaging of a large sample of relatively low-redshift radio galaxies to show that many of these have host galaxies that are too blue to be normal giant elliptical galaxies. A starburst origin for the far-infrared emission in radio galaxies is also possible (e.g., Golembek, Miley, & Neugebauer 1988; Impey & Gregorini 1993). Finally, the most likely interpretation of the rest frame ultraviolet properties of the high-redshift radio galaxies includes significant contributions from both scattered quasar light and from a young, hot stellar population (McCarthy 1993, and references therein).

4.5. *Scattering by Very Hot Electrons*

In the case of light from a hidden Seyfert 1 nucleus scattered by hot electrons, the random thermal motions of the electrons will Doppler-broaden the profiles of the scattered emission lines (see Shields & McKee 1981). If the temperature of scatterer is high enough, the extreme breadth of the scattered lines could make their contrast against the continuum so low that the lines could not be readily detected in the spectrum of the scattered light. This possibility was discussed by Fabian (1989) in the context of high-redshift radio galaxies and has been considered for Seyfert nuclei by CFT. We refer the reader to that paper for details and will simply outline the constraints on this model and its shortcomings.

As discussed by CFT, the amount of broadening introduced by gas of a given temperature depends upon the assumed scattering geometry. They have explicitly calculated the angular dependence of the kernel for electron scattering for the biconical geometry appropriate to the Seyfert unification picture. Within the context of this unification picture, the ratio of type 2 and type 1 Seyfert galaxies ($\approx$4:1; see Lawrence 1991) implies that the type 1 Seyfert galaxies are those objects in which the line of sight lies within about 37° of the polar axis of the obscuring torus. In this case, the median value for the angle between the polar axis and the observer's line of sight for objects viewed as Seyfert 2 galaxies is about 66°. The calculations of CFT then imply that a scatterer characterized by temperature T_6 in units of 10^6 K will broaden an input δ-function into a line having an FWHM of about $10^4 T_6^{1/2}$ km s^{-1}. Since the typical BLR line widths are about 5000 km s^{-1}, electron scattering by gas with $T >$ few $\times$ 10^5 K will significantly broaden the emission lines.

To simulate this, we show in Figure 6*a*–6*b* overplots of the type 2 Seyfert template with the type 1 Seyfert template after smoothing the latter by a Gaussian having an FWHM of 100 Å and 180 Å, respectively, corresponding to T_e roughly 4×10^6 K and 1.2×10^7 K at a wavelength of 1550 Å. We conclude from this that the type 1 and type 2 Seyfert templates are probably consistent with one another provided that $T_e > 10^7$ K.

Such an interpretation is of course inconsistent with optical spectropolarimetric observations of type 2 Seyfert nuclei (Antonucci & Miller 1985; Miller & Goodrich 1990; Tran et al. 1992; Kay 1994; T95a, b, c). In the cases in which a BLR is detected, the data show that the profiles of the scattered (polarized) BLR emission lines have normal widths for type 1 Seyfert nuclei. This implies that in these cases the scatterer is either dust or relatively cool electrons ($T_e \approx 10^5$ to 10^6 K; see Miller, Goodrich, & Mathews 1991, T95c). On the other hand, of the 20 type 2 Seyfert galaxies used to form our template, there are only four definite cases of a BLR visible in polarized light (Mrk 3, Mrk 348, Mrk 463, and Mrk 477) and two more

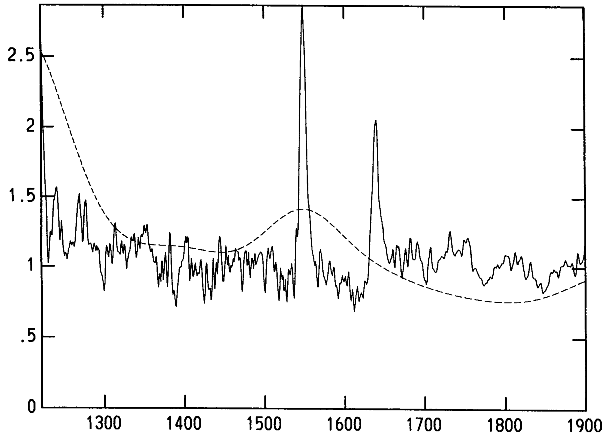

FIG. 6a

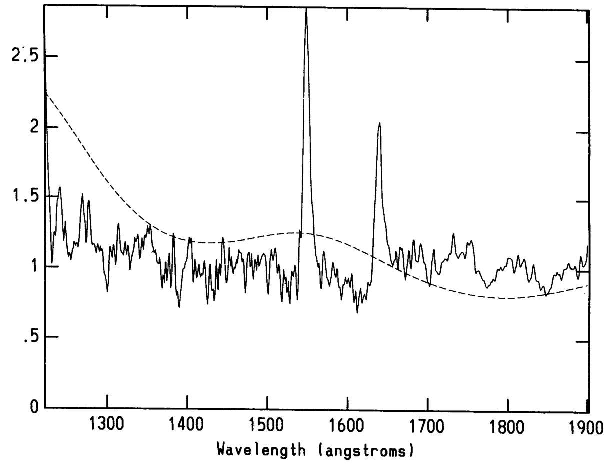

FIG. 6b

FIG. 6.—(a) Same as Fig. 2a, except that the type 1 Seyfert template (*dashed line*) has been broadened by convolving it with a Gaussian having an FWHM of 100 Å (corresponding roughly to the effect of electron scattering by hot gas with $T_e = 4 \times 10^6$ K). (b) Same as (a), but the smoothing Gaussian has an FWHM of 180 Å (corresponding to electron scattering with $T_e = 1.2 \times 10^7$ K). We conclude that scattering by gas with $T_e > 10^7$ K could "wash out" the spectroscopic signature of the BLR so that it could not be clearly detected in the Seyfert 2 spectral template.

possible cases (Mrk 573 and NGC 4388). Thus, scattering by very hot electrons cannot be ruled out for type 2 Seyfert galaxies in general.

If the ultraviolet continuum in type 2 Seyfert galaxies is produced by scattering of light from a hidden Seyfert 1 nucleus by hot electrons, then the spectral slope of the ultraviolet continuum should be the same in the two classes (see Kinney et al. 1991b). We have therefore compared the slopes we measured for the type 2 Seyfert galaxies (Table 1) to the slopes measured in exactly the same way for the type 1 Seyfert galaxies and low-redshift quasars used by us to form our type 1 Seyfert ultraviolet spectral template. We then find that $\langle \beta \rangle = -1.0$ with a dispersion of 0.2 for the type 1 Seyfert galaxies versus $\langle \beta \rangle = -0.3$ with a dispersion of 0.6 for the type 2 Seyfert galaxies. Thus, the ultraviolet continuum is considerably redder in the type 2 Seyfert galaxies.

Therefore, if the ultraviolet continuum in the Seyfert 2 galaxies is indeed electron scattered light from a hidden Seyfert 1 nucleus, it must suffer substantial reddening. This would be difficult to reconcile with the conclusion in T95a that the reflected light from the BLR seen in his sample of type 2 Seyfert nuclei has the same average Balmer decrement as that seen in the BLR in type 1 Seyfert galaxies ($\langle H\alpha/H\beta \rangle = 3.7$ vs. 3.6, respectively).

CFT have also considered the X-ray emission produced by a mirror of hot ($T > 10^6$ K) electrons having the appropriate electron-scattering optical depth and size. They conclude that such mirrors would have X-ray luminosities in excess of the typical observed values for type 2 Seyfert nuclei.

Finally, we note that (unlike the starburst model) an interpretation of the ultraviolet continuum as nuclear light scattered by very hot electrons offers no natural explanation for the unusual properties of NGC 1068 in which the nuclear continuum is dominated by light scattered by warm electrons, while the majority of the ultraviolet continuum measured from within a radius of a few kpc arises in the circumnuclear starburst ring (see § 4.3 above).

4.6. *Optically Thin Thermal Emission*

Miller (1994) has suggested that the FC2 in type 2 Seyfert nuclei is optically thin thermal emission from the "mirror" (the plasma whose free electrons scatter the Seyfert 1 light into our line of sight). This is also the preferred interpretation of the FC2 in T95c. However, these authors did not calculate the emitted ultraviolet spectrum predicted for the mirror.

We have therefore used the photoionization code XSTAR (Kallman & Krolik 1993) to model the ultraviolet and optical emission from gas spanning the range in temperature implied by observations of the mirror in type 2 Seyfert galaxies (viz., $\log T = 5$–6). These models show that the ultraviolet emission from the mirror has moderately strong H I and He II recombination lines. More quantitatively, the equivalent width of the Lyα (He II λ1640) line with respect to the continuum ranges from about 155 Å (28 Å) at $\log T = 6.0$ to 1550 Å (270) Å at $\log T = 5.0$.

For comparison, the equivalent widths of the Lyα and He II λ1640 lines in our type 2 Seyfert template are only about 110 and 15 Å, respectively. Much of this observed Lyα and He II emission must arise in the normal NLR rather than in the mirror. Therefore we conclude that thermal emission from hot gas can dominate the observed ultraviolet continuum only if $\log T \gg 6.0$. This conflicts with the upper limits to the mirror temperatures for seven type 2 Seyfert galaxies measured by T95c, which range from $\log T \leq 4.9$ for Mrk 463 to $\log T \leq 5.9$ for Mrk 348, with a median of $\log T \leq 5.2$. For $\log T = 5.2$, the observed Lyα and He II λ1640 equivalent widths imply that no more than ≈10% of the observed ultraviolet continuum in the Seyfert 2 template can come from such gas.

This is a different conclusion than T95c came to on the basis of the observed equivalent widths of the narrow Hβ emission line relative to FC2 (see his Fig. 4). This could be the result of several different effects. First, the large *IUE* aperture means that it is possible that much of the ultraviolet continuum (but not line emission) in our template comes from regions lying outside the few-arcsecond-scale region studied by Tran. For two of Tran's galaxies, we can compare the ultraviolet fluxes observed with the 10″ × 20″ *IUE* aperture to the fluxes measured with the 4″.3 × 1″.4 aperture with the Faint Object Spectrograph on board the *Hubble Space Telescope* (Hurt 1994; R. Cohen, private communication). At 2700 Å, the flux ratio (FOS/*IUE*) is about 50% for Mrk 3 and 60% for Mrk 477 (compared to an expectation of 100% for a point source). This suggests that aperture effects could be important, but it is difficult to assess this more quantitatively since Tran's data are not flux calibrated. Second, the XSTAR calculations show that at these high temperatures, the predicted Lyα/Hβ emission-line ratio is of order 10^2, and the Lyα equivalent width is about an order of magnitude larger than that of Hβ. Thus, Lyα provides a more sensitive test than does Hβ.

One other result of our XSTAR calculations is of direct relevance to Tran's analysis. For recombination at such high temperatures, the He II λ4686 emission line is predicted to be as strong as Hβ at log $T = 5.0$ and about 1.6 times stronger at log $T = 6.0$. The typical observed flux ratio of narrow He II λ4686/Hβ in Tran's sample is about 0.15. Thus, his Figure 4 implies that if the FC2 is optically thin thermal emission, then essentially all the observed narrow He II λ4686 must be produced by the mirror. Since Tran argues that about 90% of the narrow Hβ is supposed to arise in the NLR, this would then mean that the ratio He II λ4686/Hβ in the NLR must be vanishingly small. In contrast, standard photoionization models of the NLR which successfully reproduce other emission-line ratios predict He II λ4686/Hβ ≈ 0.15 to 0.2 (see Ferland & Osterbrock 1986). In other words, the observed ratio is consistent with the bulk of the observed He II emission arising in the standard NLR, while the observed equivalent width of the He II line relative to FC2 would require nearly all the He II emission to be instead produced by the mirror.

An additional indirect argument against optically thin thermal emission is that the observed spectral slope in the type 2 Seyfert galaxies is much too red: we find that $\langle \beta \rangle = -0.3$ for the Seyfert 2 galaxies, while the continuum emission from the mirror has an effective slope $\beta \approx -1.8$ in the far-ultraviolet for log $T \gtrsim 5.5$ and $\beta \approx -1.2$ for log $T = 5.0$ (Krolik & Kriss 1995). CFT have made a similar argument concerning the optical continuum. If the observed ultraviolet continuum is optically thin thermal emission from gas hotter than 10^5 K it must therefore suffer very significant reddening. In this case, the high extinction associated with the mirror would imply that the Balmer decrement of the scattered light in the Seyfert 2 galaxies would be much steeper than is seen in the BLR in type 1 Seyfert galaxies. Such is not the case: T95a finds that the Balmer decrement seen in scattered light in Seyfert 2 galaxies is almost identical to that seen directly in Seyfert 1 galaxies.

5. CONCLUSIONS & FUTURE PROSPECTS

5.1. *Summary*

One of the most striking properties of type 2 Seyfert nuclei is a "featureless" continuum (FC) in the optical and ultraviolet that is considerably bluer than that produced by the type of old stellar population that dominates the nuclei of normal early-type galaxies (see Kinney at al. 1991b). Recent optical spectropolarimetry (Miller 1994; T95c) has shown that only a minor part of the optical FC in type 2 Seyfert nuclei can be easily understood as scattered light from a hidden type 1 Seyfert nucleus. CFT reached the same conclusion based on the lack of detectable broad emission lines in the total-flux optical spectra of type 2 Seyfert nuclei. We have shown that a similar result holds in the ultraviolet spectral region (1200–1900 Å).

To do so, we have analyzed a "template" spectrum formed by averaging the archival *IUE* spectra of a well-defined sample of 20 of the brightest type 2 Seyfert nuclei. The ultraviolet continuum can be clearly detected in this template, but there is no detectable spectroscopic signature of the BLR. Comparing this Seyfert 2 template spectrum to a similar template for type 1 Seyfert nuclei and low-redshift quasars implies that no more than about 20% of the ultraviolet continuum in the type 2 Seyfert template can be produced by light from a hidden type 1 Seyfert nucleus that is scattered into our line of sight by either dust or warm electrons.

As discussed by CFT, scattering of light from a hidden Seyfert 1 nucleus by very hot electrons ($T > 10^7$ K) can broaden the BLR features beyond recognition, but such very hot gas is ruled out as the mirror in at least some Seyfert 2 galaxies by optical spectropolarimetry showing normal BLR line widths in the reflected light. Moreover, the observed ultraviolet continuum in the Seyfert 2 galaxies is significantly redder on average than is observed in type 1 Seyfert galaxies and low-redshift quasars, so electron scattering would require significant extinction to occur. We have also briefly discussed the possibility that the ultraviolet continuum is optically thin thermal emission associated with the "mirror" responsible for scattering light from a hidden Seyfert 1 nucleus (as suggested by T95c and Miller 1994). We argue that this can account for no more than about 10% of the ultraviolet continuum, given the relatively modest equivalent widths of the Lyα and He II λ1640 emission lines in the Seyfert 2 template spectrum. Important related constraints can be placed in the optical using the He II λ4686 line. Moreover, the observed ultraviolet continuum is much redder than optically thin thermal emission from gas hotter than 10^5 K. This is hard to reconcile with the T95c result that substantial dust extinction along our sight line toward the mirror is ruled out by the normal Balmer decrements seen in scattered light.

We have also compared the type 2 Seyfert template to two similar *IUE* template spectra of starburst galaxies. These starburst spectra are consistent with the Seyfert 2 spectrum. However, the direct spectroscopic signature of hot stars (the broad blueshifted N V, Si IV, and C IV stellar wind lines) cannot be clearly discerned in the Seyfert 2 template because of the confusing effects of the corresponding Seyfert emission lines and the limited spectral resolution and signal-to-noise ratio. Comparing the optical properties of our Seyfert 2 sample to those of dusty starbursts with similar ultraviolet fluxes and colors implies that a significant fraction (≈30%) of the Balmer emission lines may be powered by the starburst (although the starburst would provide only a negligible fraction of the high-ionization optical emission lines). We have also shown that the ultraviolet spectral slopes and the ratios of far-infrared to ultraviolet continuum fluxes of the Seyfert 2 galaxies are very similar to the corresponding properties of typical metal-rich, dusty starburst galaxies. We have noted that the Seyfert 2 "prototype" NGC 1068 does in fact have a compact nuclear source of optical and ultraviolet continuum produced via scattered AGN light, surrounded by a ultraviolet-bright starburst which dominates the integrated ultraviolet continuum flux in apertures with projected sizes larger than about 1 kpc.

By the process of elimination, then, the most likely explanation for the ultraviolet continuum in these type 2 Seyfert galaxies is that a significant fraction of it is produced by a dusty circumnuclear starburst, with an implied bolometric luminosity of typically 10^{10}–10^{11} $L_\odot$ (for $H_0 = 75$ km s^{-1} Mpc^{-1}). This would imply that starbursts play energetically significant roles in type 2 Seyfert galaxies, and by extension, in the Seyfert phenomenon as a whole. The possible presence of a starburst population in Seyfert galaxies has also been inferred on the basis of optical and near-infrared spectroscopy (Terlevich et al. 1990; Oliva et al. 1995), multiaperture mid-infrared photometry (Maiolino et al. 1995), the examination of the Tully-Fisher (Whittle 1992b) and Faber-Jackson (Nelson 1994) relation for Seyfert galaxies, the strength of the millimeter-wave CO emission (Heckman et al. 1989), and comparisons of the predicted and observed far-infrared emission (Pier & Krolik 1993).

We emphasize that we do *not* believe that the entire Seyfert 2 phenomenon can be explained as a dusty starburst. The polarized broad optical emission lines, heavily absorbed hard X-ray sources, strong X-ray iron Kα emission lines, and ionization cones seen in many type 2 Seyfert galaxies provide persuasive evidence that a hidden type 1 Seyfert nucleus must play an important role in the overall energetics of these particular nuclei at least (Antonucci 1993, and references therein). More specifically, optical spectropolarimetry (T95c) shows clearly that in some type 2 Seyfert nuclei, 10%–50% of the optical featureless continuum must be scattered light from a hidden Seyfert 1 nucleus (and not light from a dusty starburst). For Seyfert 2 nuclei in general, we would regard the common presence of double, triple, and jetlike radio sources and the strong high-ionization emission lines from the NLR as empirical evidence that something more exotic than just a dusty starburst is present (see Fig. 5). Thus, the idea we have explored differs in a fundamental way from the "starburst model" for AGNs that has been elucidated by Terlevich and his colleagues (see Terlevich 1994, and references therein).

We also note in passing that much of what we have discussed in the context of the Seyfert 2 galaxies also applies to high-redshift radio galaxies (see McCarthy 1993, and references therein). These also show strong rest frame ultraviolet "featureless continua" (which in these objects arise on galactic size scales). This FC is known in some cases to exhibit substantial polarization, suggesting scattering of light from a hidden quasar. However, no sign of the associated scattered broad Lyα or C IV emission lines can be seen in the composite ultraviolet spectrum discussed by McCarthy. It appears likely that both scattered quasar light and light from a population of young stars are contributors to the ultraviolet continuum in these objects (just as appears likely in the type 2 Seyfert galaxies we have discussed).

5.2. *Caveats and a Proposed Test*

Despite the indirect evidence discussed above, these results certainly do not yet allow us to conclusively identify the nature of the ultraviolet continuum in type 2 Seyfert galaxies, nor even to firmly establish its relationship to the unpolarized component of the optical featureless continuum (the "FC2" of Miller and Tran).

One problem with connecting our results to the FC2 is the relatively poor overlap between the members of the [O III] and radio flux-limited Seyfert 2 sample we have considered here and the Seyfert 2 galaxies with well-established hidden Seyfert 1 nuclei (four of our 20 sample members). Thus, one possible explanation for the lack of a detectable BLR in our template might be that only a minority of type 2 Seyfert galaxies actually contain hidden Seyfert 1 nuclei. That is, most of the objects in our sample are "pure Seyfert 2s" (objects in which we see the central engine directly in the ultraviolet, but no BLR is present). This is inconsistent with the attractive (but unproven) hypothesis of complete unification of the Seyfert classes.

Even for the Seyfert galaxies in our sample in which an FC2 has been detected optically, the gross mismatch in aperture size between the ultraviolet spectroscopic and optical spectopolarimetric measurements makes it difficult to be sure that the FC2 and ultraviolet continuum have the same origin. As noted below, the limited *HST* data available to date do imply that a significant fraction of the ultraviolet continuum in type 2 Seyfert galaxies arises on super-arcsecond scales. Thus, it is possible that the optical FC2 is produced on smaller angular scales than the ultraviolet continuum and has a different origin.

Finally, we caution that because we have constructed our Seyfert 2 template to optimize its signal-to-noise ratio, its properties disproportionately reflect those of the Seyfert 2 galaxies that are brighter than average in the ultraviolet (it is a template, and as such cannot reflect the diversity of the sample). Simply put, the ultraviolet continuum in Seyfert 2 galaxies probably arises from more than one process, and the dominant process may be different in different galaxies.

Given all this, it seems clear that a decisive test concerning the nature of the ultraviolet continuum in type 2 Seyfert galaxies and its relationship to the optical FC2 will require further observations with higher angular resolution and better signal-to-noise ratio. Such observations are possible using the *Hubble Space Telescope* to perform imaging and spectroscopy in the far-ultraviolet.

Images will provide valuable morphological tests. If we have a direct view of the central engine in most of these Seyfert 2 galaxies (contrary to the unification hypothesis), then the continuum source should be very compact. Models in which the ultraviolet continuum is scattered light from a very hot mirror require a size for the mirror of <100 pc in order that bremsstrahlung from the hot gas not exceed upper limits on the X-ray flux from Seyfert 2 nuclei (see CFT). Similar arguments imply that if the ultraviolet continuum is produced by optically thin thermal emission from a warm mirror, then the ultraviolet source will also be <100 pc in size (e.g., Antonucci et al. 1994; Krolik & Kriss 1995).

The *HST* data available to date are inconsistent with such compact structures. There are three type 2 Seyfert galaxies in our sample having both *IUE* fluxes through a $10'' \times 20''$ aperture and fluxes measured through the $4''.3 \times 1''.4$ aperture of the Faint Object Spectrograph (Hurt 1994; R. Cohen, private communication). The flux ratio (FOS/*IUE*) at 2700 Å is 4% (NGC 4388), 60% (Mrk 477), and 50% (Mrk 3), compared to an expectation of 100% for a point source. Images of the ultraviolet continuum in Mrk 3, Mrk 348, and Mrk 573 show the emission to be extended on scales of at least a few arcseconds (D. Axon, private communication). On the other hand, if (as in the case of NGC 1068) most of the ultraviolet continuum seen in the *IUE* aperture is produced by a circumnuclear starburst, the ultraviolet source should be resolved with *HST* (e.g., 1 kpc corresponds to an angular size ranging from about $1''$ to $10''$ for the Seyfert galaxies in Table 1).

However, images alone may not be decisive. To establish unambiguously that the majority of the ultraviolet continuum detected with *IUE* is produced by hot stars will require the direct spectroscopic detection of these stars in the form of the characteristic stellar wind lines (as in the case of the circumnuclear region in NGC 1068—Bruhweiler et al. 1991; Hutchings et al. 1991; Kriss et al. 1992).

Typical wind velocities in O stars are about 2000–3000 km s^{-1} (Groenewegen, Lamers, & Pauldrach 1989; Prinja, Barlow, & Howarth 1990). As a result, all strong ultraviolet lines in the spectra of O stars originate predominantly in the outflow and have strongly blueshifted absorption profiles. As discussed in detail in Leitherer et al. (1995), the strongest and most ubiquitous stellar wind line is C IV λ1549, followed by N V λ1240 and Si IV λ1400. These are all primarily caused by O stars (main-sequence and supergiants) in a typical stellar population.

Note that while blueshifted N V, Si IV, and C IV lines could also arise in outflowing interstellar gas in the Seyfert nucleus (see Shull & Sachs 1993), the starburst hypothesis predicts fairly well defined relationships between the equivalent widths and profile shapes of the stellar wind lines that can be tested by data of suitably high spectral resolution and signal-to-noise ratio (see Robert et al. 1994; Leitherer et al. 1995; Robert et al. 1995). Such data quality should be attainable with *HST* using the FOS and/or GHRS.

The N IV λ1720 stellar wind line is particularly interesting in this regard. It is pronounced in very early O stars and O supergiants and is particularly strong in Wolf-Rayet stars. These latter are the highly evolved descendants of O stars (see Maeder & Conti 1994). In contrast to the C IV, Si IV, and N V lines, N IV 1720 is not a resonance line, and so it is not contaminated by an interstellar contribution. Thus, it would provide a particularly unambiguous diagnostic of the presence of massive stars in or around a Seyfert nucleus. In practice, this line is rather weak and difficult to detect in typical starbursts. It can become detectably strong during evolutionary phases with a relatively large Wolf-Rayet population (Leitherer et al. 1995).

In summary, direct observational tests can be made with *HST* in the near future of the various possibilities for the origin of the ultraviolet continuum in type 2 Seyfert nuclei and its relationship to the optical FC2. If a starburst origin is confirmed, it will represent perhaps the most convincing evidence to date for an intimate physical or evolutionary relationship between starbursts and the Seyfert phenomenon. If the starburst can instead be ruled out by such observations, then the optical FC2 and ultraviolet continuum probably represent a truly new phenomenon in the AGN "bag of tricks." In either case, the result would have significant implications for our understanding of AGNs.

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APPENDIX

THE SEYFERT TEMPLATES AND THE NATURE OF "NARROW-LINE QUASARS"

The strength of the narrow He II λ1640 emission line in the Seyfert 2 template compared to its broad counterpart in the type 1 Seyfert template is noteworthy (see Fig. 2*a*). In the Seyfert 2 template, the He II line is nearly as strong as C IV λ1549, while in the Seyfert 1 template it is only about 10% as strong. McCarthy (1993) shows that strong He II λ1640 (He II/C IV $\approx$ 0.9) is also characteristic of the emission-line spectra of narrow-line radio galaxies (the radio-loud analogs to type 2 Seyfert galaxies). Spectra of high-z quasars (see Francis et al. 1991) show that they strongly resemble the type 1 Seyfert template (He II $\approx$ 15% of C IV).

Since C IV λ1549 is collisionally excited while He II λ1640 is a recombination line, the difference between the spectra of the NLR and BLR presumably reflects the enhanced collisional excitation of lines like C IV as a result of the higher temperature in the BLR than in the NLR. This higher temperature is probably the result of the collisional suppression of the cooling by forbidden lines in the BLR. An enhanced He II λ1640 strength relative to C IV λ1549 and other metal lines in type 2 Seyfert nuclei might also be provided by the emission from the warm "mirror" (Krolik & Kriss 1995). In contrast, the mirror's emission lines will be of negligible strength relative to the BLR in type 1 Seyfert galaxies.

There are several examples known of high-redshift quasars having unusually narrow emission lines (Baldwin et al. 1988). Could such objects be very powerful analogs of Seyfert 2 nuclei (see Stocke et al. 1982; Elston et al. 1994), or are they instead analogs of the "narrow-lined" Seyfert 1 nuclei described by Osterbrock & Pogge (1985)? The result discussed above suggests that the relative strength of the He II λ1640 line might be a good way to discriminate between true type 2 Seyfert nuclei ("quasar 2s") and ordinary quasars whose BLR produces unusually narrow lines. Since known narrow-line quasars have He II/C IV = 5%–19% (Baldwin et al. 1988), this suggests that they are most likely bona fide quasars and not high-redshift type 2 Seyfert nuclei (consistent with the conclusions drawn by Baldwin et al.).

On the other hand, the IRAS source FSC 10214+4724 at $z = 2.286$ (Rowan-Robinson et al. 1991) does have an ultraviolet emission-line spectrum consistent with an ultraluminous Seyfert 2 nucleus (e.g., He II/C IV = 0.5). Its Seyfert 2 nature is confirmed by near-infrared observations of its strong forbidden lines, which have the same width as the permitted lines (Elston et al. 1994).

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