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ASTRONOMY AND ASTROPHYSICS

# Ultraviolet spectrophotometry of isolated galaxies*

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**Summary.** We have obtained ultraviolet spectrophotometry of five isolated galaxies with the IUE which confirms the existence of the ultraviolet excesses first found by *UBV* photometry. Observations from the optical part of the spectrum to the radio bands are combined with the ultraviolet data to explain the nature of the UV excesses as the signature of a young stellar population in addition to that normally observed in nuclei of galaxies.

**Key words:** ultraviolet – spectrophotometry – isolated galaxies – nuclei of galaxies – stellar synthesis

## I. Introduction

Among more than $10^4$ galaxies in the Zwicky catalog only 12 have been classified as isolated by a criterion which requires them to be relatively bright ($m \leqq 14.0$) and to be more distant than 45′ from any other galaxy brighter than 15.7 mag. These galaxies, first listed by Huchra and Thuan (1977, hereafter HT), are henceforth called HT galaxies.

Brosch and Shaviv (1982, hereafter Paper I) have studied the HT galaxies with *UBV* photometry through different sized apertures. They found that the photometry through small apertures placed the galaxies in the region of the $(U-B)$ vs. $(B-V)$ diagram usually populated by nuclei of active galaxies, Seyfert (Sy) I and II, and N galaxies. Since no reasonable mixture of co-eval stars could have reproduced the observed colors, Brosch and Shaviv proposed that the additional component contributing to the nuclear light emission could be non-stellar. This hypothesis was strengthened when Balkowski and Charmaraux (1981) found that most HT objects showed an excess of neutral hydrogen as compared to a sample of field objects. The existence of an excess of hydrogen could provide fuel for any sort of energy producing mechanism in the nuclei, or could fuel an intense burst of star formation, or both.

Some galaxies with active nuclei show, in addition to ultraviolet excesses, an excess of near-infrared radiation, Because of this, Balzano and Weedman (1981) have proposed that all galaxies with infrared color $(J-K) \geqq 1.1$ should show some sign of a non-thermal active source in their nuclei. If the converse argument were also true, it might be expected that galaxies which show signs of nuclear non-thermal activity would also have $(J-K) \geqq 1.1$. However, Brosch and Isaacman (1982, hereafter Paper II) found that none of the six HT galaxies they studied with *JKL* photometry from UKIRT showed an infrared excess. The nuclear spectral energy distributions (SED) were found to resemble those of late K stars (or $T \cong 3400$ K blackbodies).

Brosch and Krumm (1984, hereafter Paper III) observed all HT galaxies, together with a control sample of galaxies which are members of sparse groups (not isolated in the given sense), with the Westerbork radio interferometer at $\lambda = 6$ cm. They found that only two HT objects contain compact ($\leqq 5''$) nuclear radio sources, both having flux density levels of $\sim 5$ mJy ($5\,10^{-29}$ erg s$^{-1}$ cm$^{-2}$ Hz$^{-1}$), while the rest of the sample gave $3\sigma$ upper limits of only about 2 mJy. The lack of stronger nuclear radio fluxes rules out those explanations of the UV excesses detected by the optical photometry which invoke either the existence of synchrotron sources with spectral indices steeper than $\simeq 0.2$, or emission from thermal bremsstrahlung of optically thin, moderately hot ($T = 10^4$ K) gas.

At least two alternate explanations of the nuclear UV excesses have not yet been tested. These are (a) thermal bremsstrahlung from hot gas ($T \geqq 10^5$ K), and (b) the existence, in the nuclei of isolated galaxies, of very unbalanced stellar population mixtures, like K and later type stars, combined with B and earlier type stars (Paper II). Both these explanations require the existence of significant contributions to the continuum spectrum in the satellite UV region ($\lambda \leqq 3000$ Å). Hot gas would also be expected to show strong emission lines at resonance transitions (C IV $\lambda$ 1550 Å among others). In this paper we report on observations of five nuclei of HT galaxies obtained with the spectrometers on the IUE spacecraft with the specific purpose of diagnosing the ultraviolet excesses through spectrophotometry.

## II. Observations

Five isolated galaxies were observed in October 1982 with the spectrometers of the IUE spacecraft in the low dispersion mode. Some properties of the observed objects are presented in Table 1. A journal of the observations is given in Table 2.

All spectra have been obtained through the large entrance apertures of the spectrometers, with properties as listed in Table 3 (from Bohlin et al., 1980; Bianchi et al., 1982).

The apertures were centered on the exact optical positions of the centers of the objects, given in Brosch (1982). These centers are

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**Table 1.** Observed galaxies

| Name | de Vaucouleurs *T*-type | Aperture | *V* | *B−V* | *U−B* | *E(B−V)* | *a×b*(blue) | Distance (Mpc) |
|---|---|---|---|---|---|---|---|---|
| NGC 2684 | 0: | 22″ | 13.99 | 0.86 | −0.37 | 0.02 | 0′.9×0′.8 | 29 |
| Z0 902+36 | −3: | 22 | 13.54 | 1.15 | 0.00 | 0.03 | 1.3×1.1 | 71 |
| NGC 3622 | 1 | 22 | 13.86 | 0.59 | −0.39 | 0.00 | 1.3×0.5 | 15 |
| NGC 3682 | 1? | 15 | 13.55 | 0.73 | −0.02 | 0.00 | 2.3×1.6 | 17 |
| NGC 4566 | 2 | 22 | 13.82 | 1.13 | −0.19 | 0.00 | 1.2×0.8 | 54 |

*Note:* All data from Brosch and Shaviv (1982) except blue diameters $a \times b$ (from Nilson, 1973) and distances (from Brosch and Krumm, 1983)

**Table 2.** Log of observations

| Galaxy | Date | Camera | Image no. | Exposure (min) |
|---|---|---|---|---|
| NGC 2684 | 15 Oct 82 | SWP | 18295 | 125 |
| NGC 2684 | 16 Oct 82 | LWR | 14419 | 100 |
| Z0 902+36 | 15 Oct 82 | SWP | 18294 | 120 |
| Z0 902+36 | 15 Oct 82 | LWR | 14411 | 120 |
| NGC 3622 | 13 Oct 82 | SWP | 18270 | 60 |
| NGC 3622 | 13 Oct 82 | SWP | 18271 | 60 |
| NGC 3622 | 13 Oct 82 | LWR | 14400 | 120 |
| NGC 3682 | 16 Oct 82 | SWP | 18305 | 100 |
| NGC 3682 | 13 Oct 82 | LWR | 14401 | 73 |
| NGC 4566 | 16 Oct 82 | LWR | 14420 | 86 |

**Table 3.** IUE apertures

| Spectrometer | Dimension | Spectral width | Solid angle (sterad) |
|---|---|---|---|
| SWP | 23″.2(±1.)× 10″.4(±1.) | 11.3±1.0 Å | 5.03(10$^{-9}$) |
| LWR | 23″.9(±1.)× 10″.3(±1.) | 18.0±1.8 Å | 5.19(10$^{-9}$) |

**Table 4.** Line-free spectral segments

| Galaxy | $\lambda_c$ [Å] | $\Delta\lambda$ [Å] | $\langle F_\lambda \rangle$ [$10^{-14}$ erg s$^{-1}$ cm$^{-2}$ Å$^{-1}$] |
|---|---|---|---|
| NGC 2684 | 1360 | 233 | 0.316±0.102 |
| | 1624 | 175 | 0.208±0.133 |
| | 2721 | 842 | 0.295±0.036 |
| Z0 902+36 | 1299 | 205 | 0.199±0.241 |
| | 1644 | 205 | −0.037±0.126 |
| | 2614 | 608 | 0.100±0.043 |
| NGC 3622 | 1325 | 205 | 1.044±0.113 |
| | 1618 | 205 | 0.773±0.170 |
| | 2045 | 442 | 0.643±0.181 |
| | 2685 | 701 | 0.574±0.113 |
| NGC 3682 | 1338 | 234 | 0.558±0.151 |
| | 1573 | 176 | 0.637±0.270 |
| | 1821 | 146 | 0.671±0.054 |
| | 2687 | 842 | 0.669±0.127 |
| NGC 4566 | 2302 | 608 | 0.210±0.188 |
| | 2877 | 374 | 0.127±0.160 |

defined to be the locations of the brightest nuclear areas on the glass copies of the Palomar Sky Survey at the Leiden Observatory and their use ensures that these ultraviolet observations cover the same regions as the *UBV* observations reported in Paper I and the IR observations from Paper II. Moreover, as these positions were also used to align the radio maps, the same regions have been searched for 6 cm continuum emission (Paper III).

We have attempted to obtain the long-wavelengths (LWR) and short-wavelengths (SWP) spectra of the same object consecutively during the same observing shift, while keeping the fine error sensor (FES) tracking the same guide star. This was done to minimize the danger of mismatching the SWP and LWR spectra, by having the same region in the galaxy sampled by both spectrometers. Mismatching, probably due to imperfect centering on exactly the same location, is apparent as a step in the flux density level setting at $\lambda \sim 1900$ Å, when tying SWP and LWR spectra of the same galaxy obtained in different observing shifts. In most cases the observed objects were visible on FES frames sampled at a telemetry rate of 1.2 kbit.

The spectra have been extracted from the raw images by the VILSPA staff according to the normal procedures in use at the station at the time of the observations. The exposure levels are low and, in some instances, the extraction of the spectra was performed on their nominal position on the detectors. Unfortunately we could find no evidence for any spatial dependence of the UV luminosities in the IUE apertures, because of the low signal-to-noise ratios of the spectra. In all instances, the extraction was performed as for an extended source which fills the entrance apertures of the spectrometers. The discussion which follows is based on the "abnet" extracted spectra, which are absolutely calibrated spectrophotometrically and have had the detector pedestal background substracted. The abnet spectra have been rebinned to ~6 Å SWP and ~9 Å LWR by averaging every 5 pixels in the original spectra. Before that, pixels flagged by negative epsilon values on our VILSPA guest observer tapes had been replaced by the average flux level of their 60 closest neighbors. The total number of pixels replaced in this manner was in all cases less than 5% of the total number of pixels in the spectrum.

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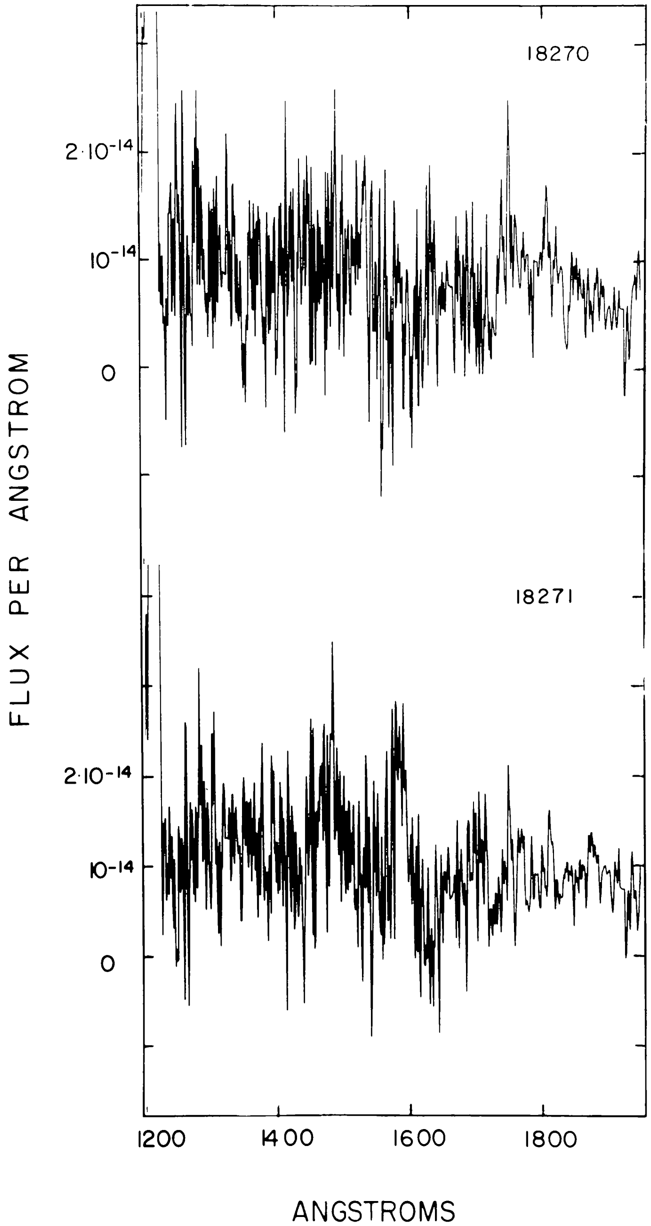


**Fig. 1.** Two SW raw spectra of NGC 3622

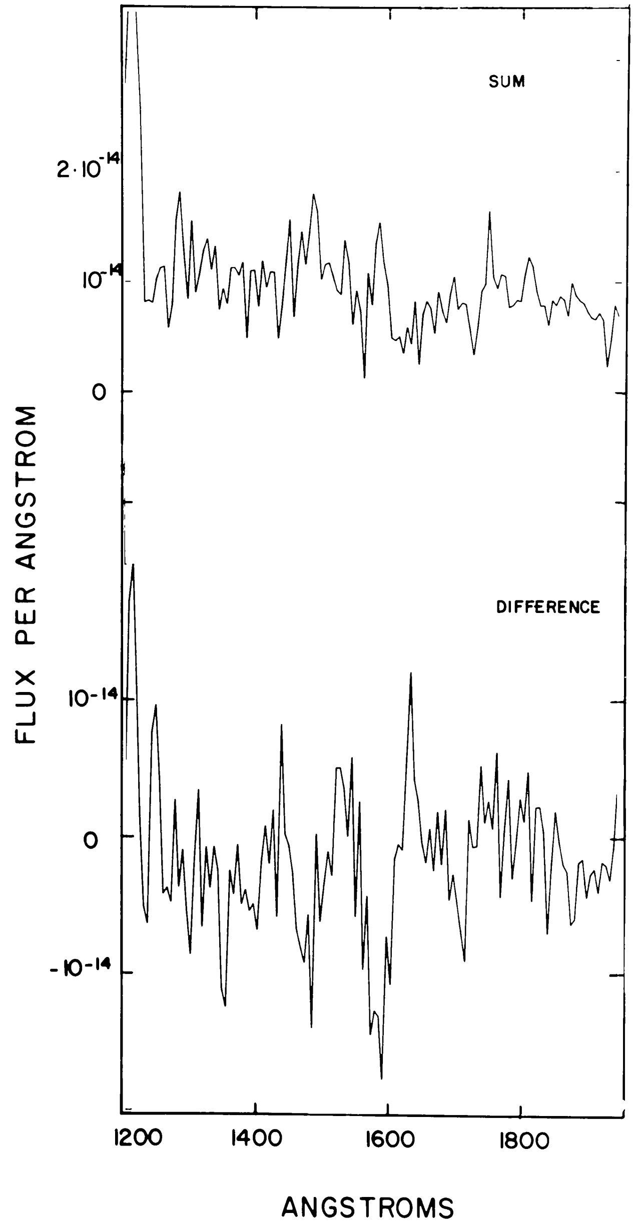


**Fig. 2.** Sum and difference of the raw spectra in Fig. 1

## III. Results

In this section we describe the spectra obtained in this observational program. Two independently-obtained spectra of NGC 3622 (SWP 18270 and SWP 18271) can be used to estimate the reality and recognizability of spectral features. Both raw spectra are shown in Fig. 1. Their sum and difference is displayed in Fig. 2.

Probably all line-resembling features apparent in these spectra are unreal. Some emission-like features are due to non-reproducing events in one of the two frames. Notice, in particular, the apparent emission line shortward of ~1600 Å, due to a positive event in SWP 18271. Other line resembling features are clearly reproducible, for example, those at $\lambda\lambda \sim 1270$ Å, 1490 Å 1750 Å, and 1810 Å, as well as the absorption at $\lambda \sim 1725$ Å. All these features show up at about the same wavelength in the unbinned SWP spectra of most of our objects, despite their widely different redshifts (Table 1). We assign them to the spurious emission features identified in SWP exposures of BL Lac objects and of empty sky by Hackney et al. (1982). As these are the strongest "emission lines" in our spectra (outside the low sensitivity region of the LWR spectrometer, between ~1900 Å and ~2200 Å) we believe that this indicates that the objects studied here *do not* show strong intrinsic emission lines in the satellite UV region of the spectrum.

On the other hand, it appears that the HT galaxies possess significant continuum fluxes at ultraviolet wavelengths. We have selected spectral segments free of obvious emission-, or absorption-like features and present for these the relevant averaged flux density values, in the frame of reference of the observer, in Table 4. We give there, along with the name of the

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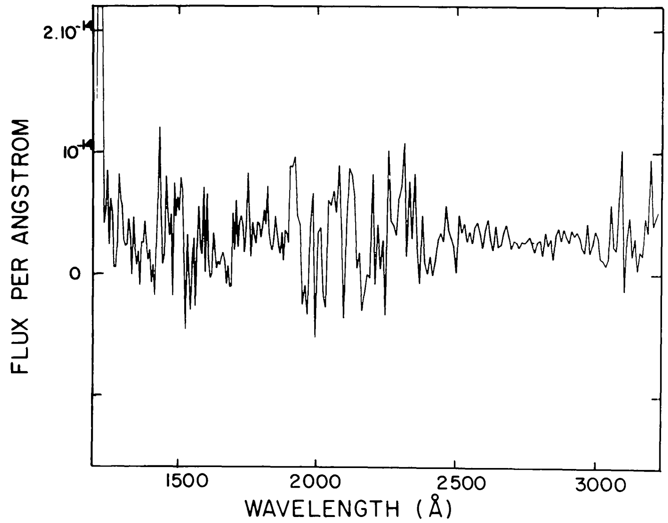


**Fig. 3a.** UV spectrum of NGC 2684

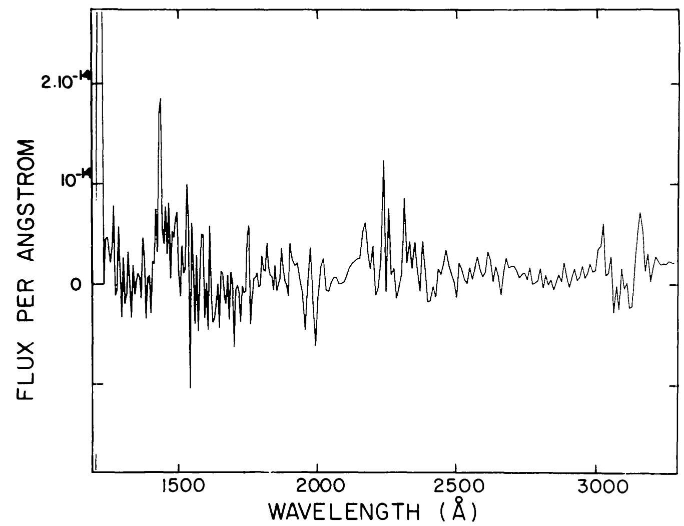


**Fig. 3b.** UV spectrum of Z0 902+36

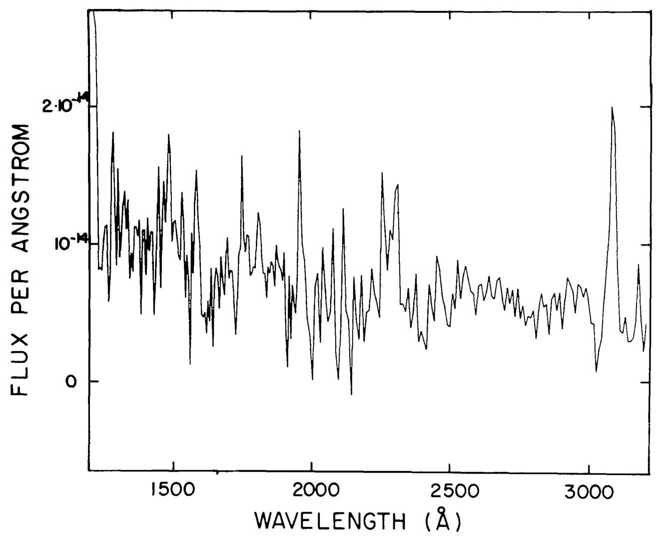


**Fig. 3c.** UV spectrum of NGC 3622

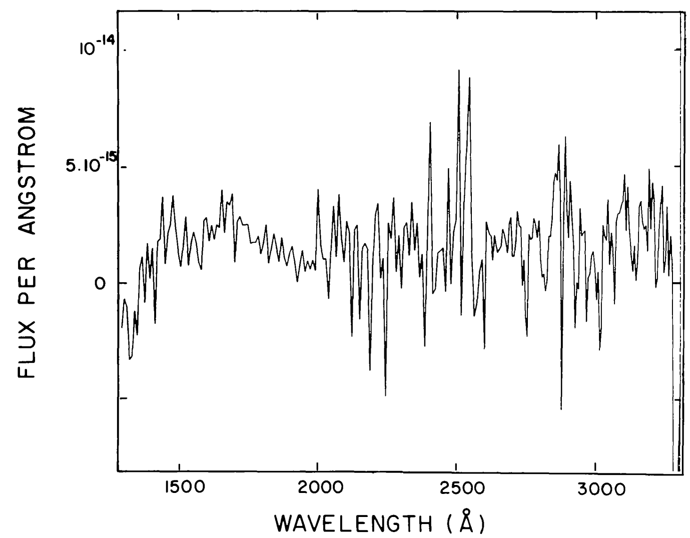


**Fig. 3d.** UV spectrum of NGC 3682

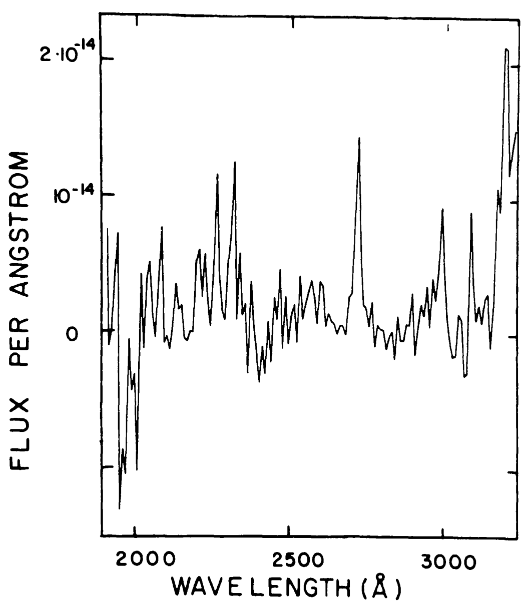


**Fig. 3e.** UV spectrum of NGC 4566 (only LWR was obtained)

object, the central wavelength of the spectral segment over which the flux density levels were averaged, its spectral width, and the resulting averaged flux density. The errors on the flux density values are formal $1\sigma$ deviations of the individual values from their average.

We have chosen not to correct the spectra for wavelength-dependent extinction either internal or external to the objects. The reason for not doing this are (a) the low values of $E(B-V)$ for these objects, due to their relatively high galactic latitudes (Table 1), (b) the lack of a prominent "2200 Å dip" in the LWR region, and (c) the finding that the correction for extinction in the ultraviolet, at least in our galaxy, cannot, with uniform reliability, be derived from optical-region data or from the 2200 Å feature (Greenberg and Chlewicki, 1983). The final spectra of all five objects are shown in Fig. 3 a through e.

## IV. Discussion

The new data presented here confirm the conclusions of Paper I that the HT galaxies possess ultraviolet excesses. Their presence is

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indicated in Fig. 4, where the SED's are plotted for all the objects studied here.

To produce Fig. 4 we used UV data from Table 4, optical values from Paper I, infrared photometry from Paper II, and radio data from Paper III. The optical and infrared photometry have been translated into flux density values using the transformations given in Table IV of Johnson (1966), and have been scaled to an equivalent aperture of diameter 17.″6, equal in solid angle to the IUE apertures. The scaling was done from the photometry through the nearest-sized aperture (14″, 15″ or 22″ in diameter). The radio data have been taken from Tables 4a and 5a of Paper III. The amount of extended 5 GHz emission has also been scaled to that which would have been collected in a circle of diameter 17.″6. The scaling procedure assumes the absence of strong gradients in the light distribution, between the circular aperture used for photometry and radio and the oval ones used for the ultraviolet spectrophotometry.

Figure 4 demonstrates that the ultraviolet excess shows up as a deviation of the SED from the steep slope imposed in the blue by the optical-infrared photometry. Note, for comparison, the behaviour at high frequencies of the SED for a 3400 K blackbody, found in Paper II to reproduce quite well the infrared observations. The ultraviolet component is also visible in Figs. 3a and 3c as a flat or even increasing continuum level towards the short wavelength end of the spectra. Note also that the contribution of cooler sources, which assert themselves fully only at infrared wavelengths, is present in Figs. 3d and possibly also 3e, as a rising continuum level at wavelengths longer than $\sim 2900$ Å.

In Paper III is has been shown that if the ultraviolet excess radiation detected with *UBV* photometry was due to thermal bremsstrahlung, the absence of radio sources in the nuclei should imply high gas temperatures ($T_g \gtrsim 2\,10^5$ K) for optically thin (at 5 GHz) gas, or high emission measures for gas at lower temperatures. Another possibility, also mentioned in Paper III, is a particular mixture of stellar populations residing in the nuclei; this would automatically explain the lack of strong radio emission.

We have shown that the five HT galaxies studied here do not possess strong emission lines in the UV. On the other hand, a significant amount of continuum radiation is present. This indicates that the component detected at ultraviolet wavelengths is more probably due to an aggregate of stars. We cannot fully rule out the possibility that extremely hot gas is producing the flattish continuum, but note that the requirement of high temperature should in this case be even more accute: to radiate efficiently at $\sim 1000$ Å the gas temperature must be $T_g \gtrsim 10^6$ K! This coronal-like gas would produce high excitation emission lines, which we fail to detect.

Even though the early-type population in the nuclei produces a significant level of continuum flux, it cannot consist of *very* early, *very* hot stars. In Fig. 5a and b we compare our spectra with those of early-type stars published in the IUE Spectral Atlas (Wu et al., 1981). The IUE Atlas was obtained at the same resolution as the spectra of the HT galaxies, and is therefore ideal for comparison purposes. Very early stars therein, dwarfs earlier than O7 or supergiants earlier than B0.5, show a very characteristic and prominent absorption profile in C IV $\lambda$ 1550 Å, as well as a wealth of blanketing in the region $\lambda\lambda$ 1400–1600 Å. For this reason we have limited the comparison shown in Fig. 5a to dwarfs later than O7. These have been chosen also for very low reddening ($0.00 \leqq E(B-V) \leqq 0.07$) and for being mostly primary MK standards. The corresponding flux density distribution for HT galaxies have been plotted directly from Table 4.

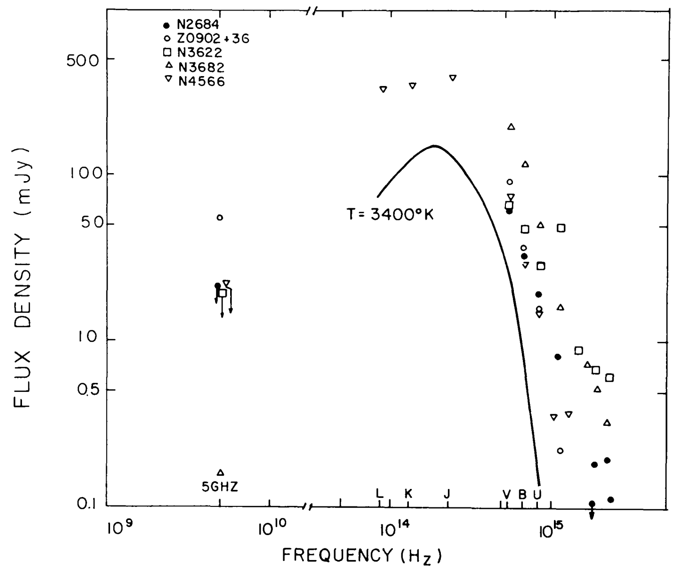


**Fig. 4.** SED's of all five isolated galaxies

A comparison of these two figures shows that the population dominating in the satellite UV cannot be much earlier than about B0.

The flux density values given in Table 4 and shown in Fig. 5b demonstrate that in most cases the continuum does not rise very sharply towards Lyman $\alpha$, whereas stars of spectral type earlier than $\sim$B 5 (main sequence) show strong gradients in their SED's towards $\sim 1000$ Å. Norgaard-Nielsen and Kjaergaard (1981) used photometry of stars through the photometric bands of the TD 1 ultraviolet observing satellite to synthesize the nuclear population in NGC 4472. The photometry quoted in their paper can be used to roughly estimate the type of stars making up the UV emitting component in the nuclei of the HT galaxies. Two stellar population groups approximately fit the requirements imposed by the observations, (a) globular cluster stars, i.e. objects on the horizontal branch, or (b) main sequence B to A stars. The quality of our spectra, particularly in the extremely noisy region between $\sim 1900$ Å and $\sim 2200$ Å due to the low sensitivity of the LWR spectrometer is not sufficient to permit the synthesis of reliable TD 1 magnitudes. This is because both the 1965 Å and 2365 Å bands include this noisy region in the passband of the filters. We theerefore use the flux densities in the nearest feature-free spectral segments from Table 4 and compare these to the TD 1 flux densities. Main sequence stars earlier than B 2 can definitely be ruled out as main contributors to the ultraviolet light in the nuclei of HT galaxies because they emit at least 4 times more energy at $\sim 1560$ Å than they do at $\sim 2750$ Å. On the other hand, stars of spectral type later than A 5 have no significant flux shorter than $\sim 1700$ Å. Horizontal branch globular cluster stars have, as mentioned above, flat continua in the IUE range. Note however that this result is derived from the table of adopted fluxes from Norgaard-Nielsen and Kjaergaard (1981) and originally from the ANS data on a single globular cluster (NGC 6752, see van Albada et al., 1971). On the other hand, Cacciari et al. (1982) have shown that among the globular clusters in the Magellanic Clouds they have observed, at least one (NGC 1866) has a SED rising towards shorter wave lengths.

The observation, that in most objects studied here, the flux appears to rise towards the short wavelength end of the spectrum

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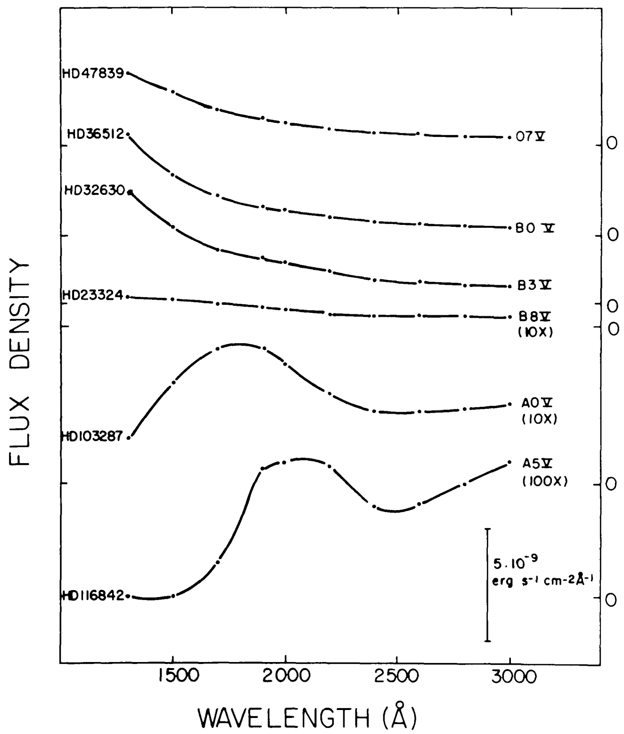


**Fig. 5a.** UV energy distribution of early-type main sequence stars

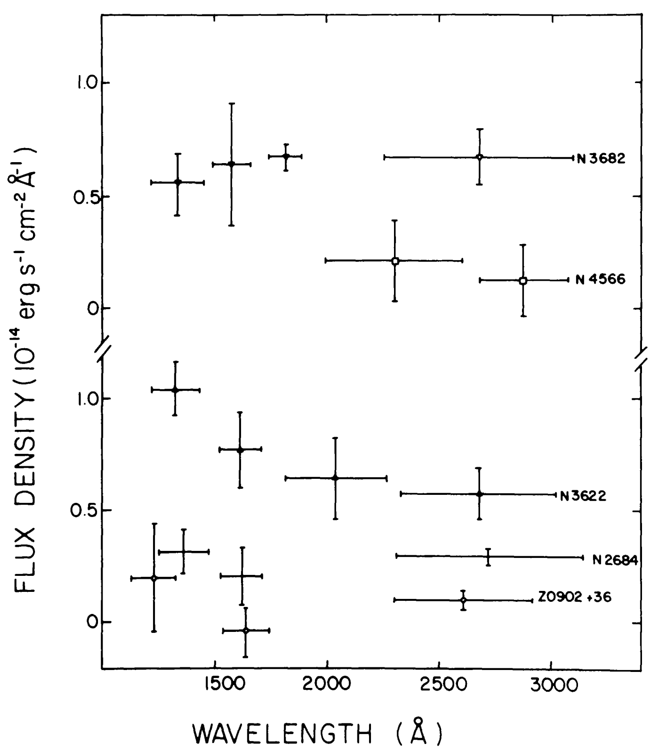


**Fig. 5b.** Binned UV flux density distribution of observed HT galaxies

indicates to us that a mixture containing horizontal branch stars probably does not reproduce our data well. Therefore in the HT galaxies' nuclei the representative population is that of moderately early type stars along with the usual component of evolved population of later types (K giants). We have plotted in Fig. 6 the

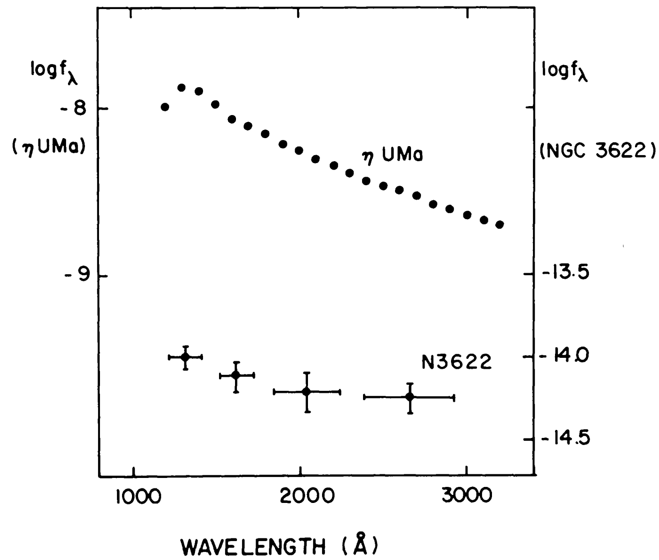


**Fig. 6.** SED of $\eta$ UMa and of NGC 3622 in the IUE range

flux density distribution of NGC 3622 and of $\eta$ UMa (B4V, "the star with the best known ultraviolet intensity distribution", Underhill and Doazan, 1982, p. 46). A similar trend is apparent, the rising continuum towards shorter wavelengths. The gradient is smaller in NGC 3622, but keep in mind that there is probably also an older population present as well. We require about $4\,10^4$ B4V stars like $\eta$ UMa to be present in the sampling aperture in order to reproduce the flux level of the 1300 Å point in NGC 3622.

Early-type stars like $\eta$ UMa contribute, in the $V$ band region, only about 6% of the flux density they emit at $\sim$1300 Å. This implies that in the $V$ band, the relative contribution of the nuclear early-type stars is only of order 10%, the rest of the light coming from the older population. In case this population is composed exclusively of K giants, about $3\,10^5$ stars would be required in order to match the observed flux. For comparison, Norgaard-Nielsen and Kjaergaard (1981) modelled the observed fluxes of NGC 4472 with only 2% early-type stars and $\sim$40% light from late-type giants. For a late-type component of purely main-sequence stars in NGC 3622, the required proportion would be 2400 such objects for each B5V star. Note that in Paper II we have suggested a similar mixture of stars. These exercises in simple-minded stellar synthesis are indicative of the composition of the HT galaxies' nuclei.

The existence of an admixture of a moderately hot stellar component in these galactic nuclei may account for the presence of narrow emission lines in the spectra (3500 Å to 7000 Å) of some of the objects studied here (J. Huchra, private communication to N. B.). These spectra, which shall be reported in a subsequent paper, are indicative of low excitation. In only one case is [O III] $\lambda$ 5007 Å detected, while usually only H$\alpha$, [N II] and [S II] appear in emission. Other nuclei show only absorption lines in the Balmer series, again indicative of early-type stars. We can therefore conclude that even though some ionizing flux ($\lambda \leqq 912$ Å) is available, the amount of photons capable of twice ionizing oxygen atoms is probably severely limited. Thus again, stars earlier than spectral type B are ruled out.

An additional indication against the present birth of very massive stars in the nuclei of isolated galaxies comes from the presence of excess neutral hydrogen. If such objects were created in

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the star-forming precesses, it is probable that the supernova explosions which end their lives would have swept the H I out of the isolated galaxies (Bregman, 1978).

Finally we mention that in a number of instances star formation with the creation of massive stars being suppressed, has been suggested in the literature for a number of objects (Fabian et al., 1982). A similar situation may exist in the nuclei of isolated galaxies. The unique conditions in the inner regions of these objects may well have contributed to that.

## V. Conclusion

1. All five isolated HT galaxies observed with the IUE show significant continuum flux in the ultraviolet without exhibiting prominent emission lines.
2. The UV flux shows a flat or slightly rising tendency towards shorter wavelengths.
3. It appears that the most probable explanation is that we observe in all HT objects a mixture of stellar populations, one older and peaking in the near IR (Paper II), and a second consisting essentially of moderately early-type stars, probably not earlier than mid-B.
4. This hypothesis presents a challenge to galactic evolution theories. Circumstantial evidence for the lack of very massive stars can be derived from the fact that no galactic wind is observed and the galaxies contain significant amounts of neutral hydrogen.

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## References

van Albada, T.S., de Boer, K.S., Dickens, R.J.: 1979, *Astron. Astrophys.* **75**, L11
Balzano, V., Weedman, D.: 1981, *Astrophys. J.* **253**, 756
Bianchi, L., Northover, K., Clavel, J.: 1982, *IUE and VILSPA User's Guide*
Bohlin, R.C., Holm, A.V., Savage, B.D., Snijders, M.A.J., Sparks, W.M.: 1980, *Astron. Astrophys.* **85**, 1
Bregman, J.N.: 1978, *Astrophys. J.* **224**, 768
Brosch, N.: 1982, *Astron. Astrophys. Suppl.* **48**, 63
Brosch, N., Isaacman, R.: 1982, *Astron. Astrophys.* **113**, 331
Brosch, N., Krumm, N.: 1984, *Astron. Astrophys.* (in press)
Brosch, N., Shaviv, G.: 1982, *Astrophys. J.* **253**, 526
Cacciari, C., Fusi-Pecci, F., Zamorani, C., Freeman, K.C., Cassatella, A., Benvenuti, P., Bianchi, L., Patriarchi, P., Wamsteker, W.: 1982, *Proc. 3rd European IUE Conf.*, ESA *Publ.*
Capaccioli, M.: 1982, *Proc. 3rd European IUE Conf.*, ESA *Publ.*
Fabian, A.C., Nulsen, P.E.J., Canizares, C.R.: 1982, *Monthly Notices Roy. Astron. Soc.* **201**, 933
Greenberg, J.M., Chlewicki, G.: 1983, *Astrophys. J.* **272**, 563
Hackney, R.L., Hackney, K.R.H., Kondo, Y.: 1982, *Advances in Ultraviolet Astronomy: Four Years of IUE Research*, Y. Kondo, J. M. Mead, R. D. Chapman, eds., NASA *Conf. Publ.* 2238, p. 335
Huchra, J., Thuan, T.X.: 1977, *Astrophys. J.* **216**, 694
Johnson, H.L.: 1966, *Ann. Rev. Astron. Astrophys.* **4**, 193
Norgaard-Nielsen, H.U., Kjaergaard, P.: 1981, *Astron. Astrophys.* **93**, 290
Underhill, A., Doazan, V.: 1982, *B Stars with and without Emission Lines*, NASA SP-456
Wu, C.C., Bogess, A., Holm, A., Shiffer, F., III, Turnrose, B.: 1981, IUE Ultraviolet Spectral Atlas, IUE NASA Newsletter No. 14, p. 1

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