

The Nature of the UV-optical Continuum in Seyfert 2 Galaxies

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Abstract.

The nature of the UV-Optical continuum in Seyfert 2 galaxies is a matter of current debate, fundamental to which is the issue of characterizing and quantifying the stellar population contribution to the nuclear spectra. Using high S/N long-slit spectroscopy of a sample of 20 Seyfert 2 galaxies, we have applied a novel approach to investigate the nuclear stellar population in these galaxies. Our main results are: (1) the stellar populations in Seyfert 2 galaxies are varied, and in most cases **cannot** be adequately represented by an elliptical galaxy template, as done in previous works; (2) the central kpc of Seyfert 2's contain substantially larger proportions of 100 Myr stars than either elliptical galaxies or normal spirals of the same Hubble type. One important consequence of our findings is that the controversial nature of the so called "second" featureless continuum (FC2) in Seyfert 2s is most likely a result of inadequate evaluation of the stellar population.

1. Introduction

The nature of the UV-Optical continuum of Seyfert 2 galaxies has long been a matter of investigation. If, in one hand, these galaxies are known to present a bluer continuum than "normal" galaxies of the same Hubble type (this characteristic allowed them to be found in the Byurakan survey, for example), on the other hand, in the Unified Model (Antonucci & Miller 1985, Antonucci 1993), a Seyfert 1 nucleus, comprising the nuclear source and broad-line region, is hidden by an obscuring dusty molecular torus. In this scenario, the nuclear featureless continuum (FC) and broad lines are only seen via scattered light, as indeed observed in a number of polarimetric studies (Miller & Goodrich 1990; Kay 1992, Tran 1995).

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Nevertheless, Tran (1995) observed that, after subtraction of the stellar population contribution (usually about 70-80% at $\lambda 5500\text{\AA}$) the polarization in the continuum was smaller than in the broad lines. To reconcile the two polarization values, he concluded that there were two "featureless" continua components: FC1, consisting of scattered light from the nuclear source, contributing typically 5% to the total observed continuum, and FC2, an unpolarized component contributing the remaining 15-25% of the continuum.

This study raised the new issue of the nature of the FC2 component. One possibility first proposed by Cid-Fernandes & Terlevich (1992, 1995) was the contribution from young stars in a nuclear burst of star formation. A handful of Seyfert 2's is known to have composite nuclei, classified as Starburst + Seyfert (Kinney et al. 1993), and recent studies (Heckman et al. 1997; Gonzalez-Delgado et al. 1998) have shown that the signatures of the starburst in these cases are evident in the UV-blue nuclear spectra of the galaxies. In these few Seyfert 2's, FC2 could indeed be identified with young (< 10 Myr) stars. Another possibility, proposed by Tran (1995), based on previous results by Barvainis (1993), was that FC2 is due to thermal free-free emission from a hot plasma wind. Recently, Axon, Capetti & Macchetto (1998) argued that the blue continuum can be due to free-free emission from gas shocked by the passage of a radio jet.

In this paper we discuss the results of our recent work, dedicated to investigate the nuclear stellar population and possible additional continuum in Seyfert 2 galaxies. We have used a novel approach which combines a spatially resolved study of the stellar population and spectral synthesis of the nuclear spectra.

2. The Stellar Population in Active Galaxies

In order to investigate the stellar content of Seyfert galaxies, as well as to compare it with that of other galaxies, Cid-Fernandes, Storchi-Bergmann & Schmitt (1998), have analyzed long-slit optical spectra (obtained with the CTIO 4m telescope) of 20 Seyfert 2's, 6 Seyfert 1's, 7 LINER's, 5 radio-galaxies, 1 elliptical and 3 "normal" galaxies with nuclear rings of star formation.

Our approach was to measure the continuum flux in selected windows and the equivalent widths (W 's) of several stellar absorption features as a function of distance from the nuclei, at a spatial sampling of $2'' \times 2''$.

The main conclusions of this work were: (1) there is a large diversity of nuclear stellar population characteristics among Seyfert galaxies, and in most cases, differ from those of an elliptical galaxy; (2) the W 's in regions of star-formation (e.g., star-forming rings), in the nuclear spectra of Seyfert 1's and for the Seyfert 2 galaxies classified as composite (SB+Sy 2) are observed to be smaller than in nearby regions, indicating a dilution by an underlying continuum, as expected; (3) for most Seyfert 2's (17 out of 20), we found no dilution in the nuclear EW's, leading to the conclusion that if there is a FC continuum present, it contributes *at most* 10% at all optical wavelengths. Conclusions (2) and (3) are illustrated in Figure 1.

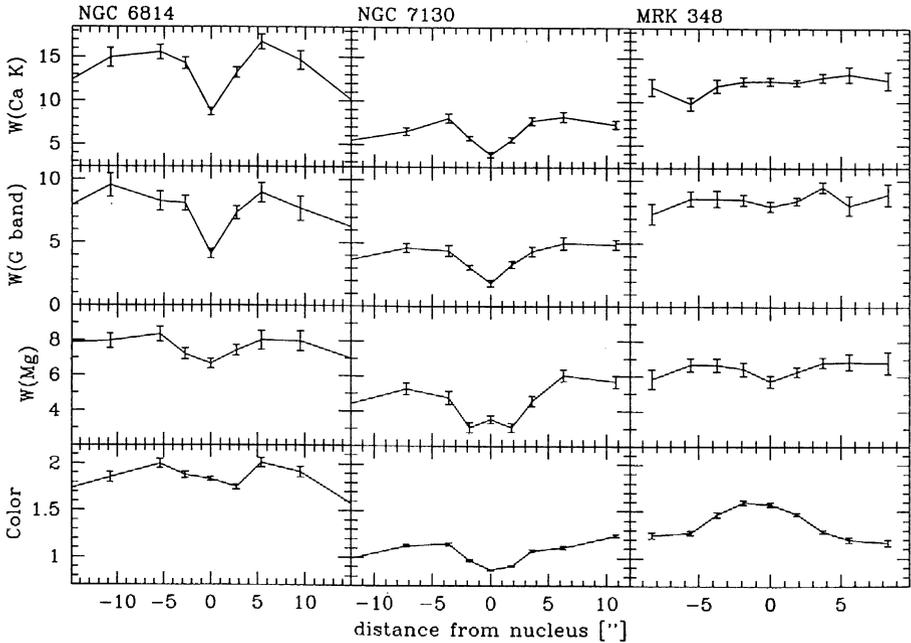


Figure 1. From top to bottom: Radial variations of the equivalent widths of the absorption features Ca II K ($\lambda 3930\text{\AA}$), G-band ($\lambda 4301\text{\AA}$), Mg I + MgH ($\lambda 5176\text{\AA}$) and continuum ratio $\lambda 5870/\lambda 4020$ for the Seyfert 1 galaxy NGC 6814 (left), the composite Seyfert + Starburst galaxy NGC 7130 (center) and the Seyfert 2 Mrk 348 (right). (Adapted from Paper I).

3. The Nature of Optical Light in Seyfert 2 Galaxies with Polarized Continuum

In a subsequent work, Storchi-Bergmann, Cid-Fernandes & Schmitt (1998) look closely at the spectra of 4 Seyfert 2's with no dilutions in the nuclear stellar absorption W_s 's, but with previous determinations of FC contributions larger than 10%. The 4 galaxies are: *Mrk 348*, with 27% contribution at 5500Å of a nuclear FC (Tran 1995): from polarimetry, it was concluded that 5% was due to the polarized continuum (FC1), but 22% was due to FC2; *Mrk 573*, with 20% contribution at 4400Å of a nuclear FC (Kay 1994); *NGC 1358*, also with 20% contribution of FC at 4400Å (Kay 1994); and *Mrk 1210*, with 25% contribution at 5500Å (Tran 1995): from polarimetry, 6% of FC1 and 19% of FC2.

In both Kay's (1994) and Tran's (1995) work, it was assumed that the nuclear stellar population was well represented by the spectrum of a typical elliptical galaxy.

The above contributions of a nuclear FC seem to be in contradiction with the results of Cid Fernandes et al. (1998), if: (1) FC is confined to the nucleus (inner $2'' \times 2''$); (2) the stellar population does not vary within the bulge of the galaxy – it was verified that the bulges have average effective radius of $6''$ for the sample. If these two conditions are true, then the results of Cid Fernandes et al. (1998) indicate that the FC contribution to the nuclear spectra should be smaller than 10%, in contradiction with the results of previous works.

Storchi-Bergmann et al. (1998) then adopted the first hypothesis above and tested the second, extracting spectra from the bulge of the same galaxy from windows at $4''$ from the nucleus, which were used as stellar population templates for the nuclear spectra.

These extranuclear spectra were then used in combination with a small percentage ($\approx 5\%$) of FC1 (represented by a power-law spectrum) as derived by Tran (1995) to reproduce the nuclear spectrum. It was concluded that, after applying some reddening to the extranuclear spectra, this combination provided a good representation of the nuclear spectrum, with no need of FC2, as illustrated in Figure 2 for Mrk 348.

Population synthesis of these extranuclear spectra then showed that an elliptical galaxy template was only valid for Mrk 573, with the other three galaxies presenting larger proportions of younger components. It was thus concluded that the need of FC2 in these cases was a consequence of the fact that an elliptical template is not adequate to represent the stellar population of most Seyferts.

4. Spectral Synthesis of the Nuclear Region of Seyfert 2 Galaxies

In order to investigate the above result for the whole sample of Seyfert 2 galaxies, Schmitt, Storchi-Bergmann & Cid Fernandes (1998) performed spectral syntheses for the nuclear spectra of the 20 Seyfert 2's, comparing the results with those of an elliptical galaxy template. The spectral base comprised star cluster spectra of different ages (Bica, 1988), an HII continuum and a power-law component to represent the scattered component (FC1).

The results can be summarized through the contribution of the different age components to the light at $\lambda 5780\text{Å}$ for the nuclear Seyfert 2 spectra compared

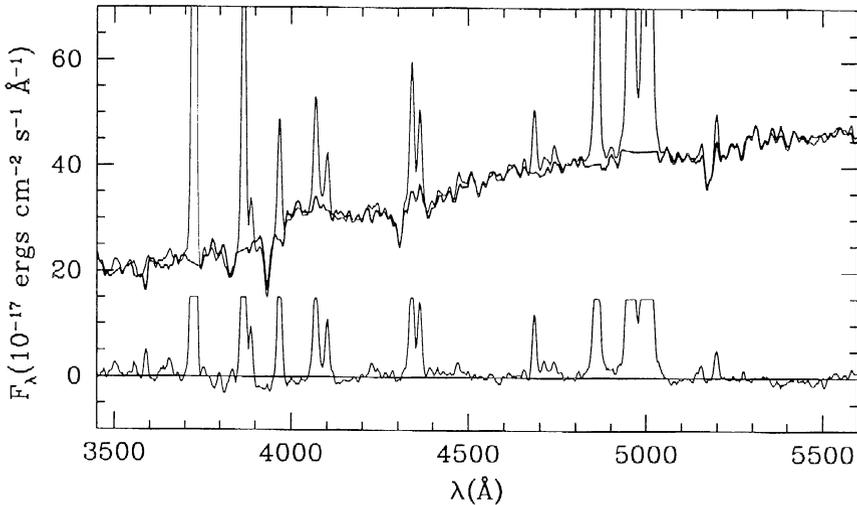


Figure 2. The Mrk 348 nuclear spectrum (thin line) is compared with the extranuclear spectrum reddened by $E(B-V)=0.09$, combined with 5% contribution (at $\lambda 5500\text{\AA}$) of the FC1 component, represented by a $F_\lambda \propto \lambda^{-1}$ power-law (thick line). The residual between the two is plotted at the bottom, where the emission lines have been chopped for clarity.

with that for the elliptical template: 19/24 (80%) have larger contributions of stars of 100 Myrs; 7/24 (30%) have larger contributions of stars of 10 Myrs; 5/24 (20%) have larger contributions of an HII continuum.

It is also interesting to compare the above results with those for the bulge of early type spirals, the dominant Hubble types of the Seyfert 2's. From Bica (1988), it can be concluded that in only 20% of a sample of 51 early type spirals, there are contributions of stars of 100 Myrs or younger. It can be concluded that *the main difference between the stellar population of Seyfert 2's and of elliptical or early-type spiral galaxies is the large contribution from stars of 100 Myrs.*

5. Conclusions

The main conclusions of this work can be summarized as follows.

- (1) Galaxies with Seyfert nuclei have a varied nuclear stellar population.
- (2) In most cases this population differs from that of an elliptical galaxy. When a proper template is used, preferably from the bulge of the same galaxy, there is no need of FC2. Alternatively, if FC2 is identified with the difference between the unpolarized continuum and the elliptical template, it is due to stars with ages 0-100 Myr.
- (3) The main difference between the nuclear stellar population of Seyferts and of early-type spirals and ellipticals is the larger contribution of a 100 Myr population.

(4) We could speculate that if there is a causal link between star-formation and nuclear activity, the 100 Myr star-formation timescale should be comparable to the duration of the nuclear activity cycle. Since 100 Myr is $\approx 1\%$ of the Hubble time, $\approx 1\%$ of the galaxies should be active, in agreement with recent estimates (e.g., Huchra & Burg 1992).

References

- Antonucci, R. R. J. 1993, *ARA&A*, 31, 473
- Antonucci, R. R. J. & Miller, J. S. 1985, *ApJ*, 297, 621
- Axon, D., Capetti, A. & Macchetto, F. D. 1998, preprint
- Barvainis, R. 1993, *ApJ*, 412, 513
- Bica, E. 1988, *A&A*, 195, 76
- Cid Fernandes, R. & Terlevich, R. 1992, in *Relationships between Active Galactic Nuclei and Starburst Galaxies*, ASP Conf. Ser., 31, Astron. Soc. Pac. (San Francisco)
- Cid Fernandes, R. & Terlevich, R. 1995, *MNRAS*, 272, 423
- Cid Fernandes, R., Schmitt, H. R. & Storchi-Bergmann, T. 1998, *MNRAS*, 297, 259
- González Delgado, R. M. et al. 1998, *ApJ*, 505, 174
- Heckman, T., Krolik, J., Meurer, G., Calzetti, D., Kinney, A., Koratkar, A., Leitherer, C., Robert, C. & Wilson, A. S. 1995, *ApJ*, 452, 549
- Heckman, T. M., Gonzalez-Delgado, R., Leitherer, C., Meurer, G. R., Krolik, J., Wilson, A. S., Koratkar, A. & Kinney, A. 1997, *ApJ*, 482, 114 (H97)
- Huchra, J. & Burg, R. 1992, *ApJ*, 393, 90
- Kay, L. 1994, *ApJ*, 430, 196
- Kinney, A. L., Bohlin, R. C., Calzetti, D., Panagia, N. & Wyse R. F. G. 1993, *ApJS*, 86, 5
- Miller, J. S. & Goodrich, R. W. 1990, *ApJ*, 355, 456
- Schmitt, H. R., Storchi-Bergmann, T. & Cid Fernandes, R. 1998, in press
- Storchi-Bergmann, T., Cid Fernandes, R. & Schmitt, H. R. 1998, *ApJ*, 501, 94
- Tran, H. D. 1995, *ApJ*, 440, 597