Stellar population gradients in Seyfert 2 galaxies

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Abstract.
We study the variation of the stellar population properties as a function of distance from the nucleus for a sample of 35 Seyfert 2 galaxies using the technique of stellar population synthesis. We sample regions at the galaxies with dimensions in the range $200 \times 200$ to $400 \times 400$ pc and compare the synthesis results with those of a control sample of non-Seyfert galaxies. We find that both at the nucleus and up to 3 kpc from it the oldest age component (10 Gyr) presents a smaller contribution to the total flux in the Seyfert than in the non-Seyfert galaxies of the same Hubble type, while the components younger than 100 Myr present a larger contribution in the Seyfert’s than in non-Seyferts. In addition, while for the non-Seyferts clear gradients are present, in which the contribution of the oldest components decrease with distance from the nucleus and the contribution of the 1 Gyr component increases – we do not find such gradients in most Seyferts. These results suggest that the AGN-starburst connection is a large scale phenomenon affecting not only the inner few hundred parsecs, but the inner kiloparsecs.

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1. Introduction

The present work has roots in the early and polemic work of Roberto Terlevich and collaborators, in which they argued that starbursts instead of mass accretion into supermassive black holes were the source of energy of Active Galactic Nuclei (AGN; Terlevich & Melnick 1985; Terlevich, Diaz & Terlevich 1990; Cid Fernandes & Terlevich 1995). By 1995, other groups would also find evidences for the presence of starbursts around Seyfert nuclei (e. g. Heckman et al. 1995, 1997; González Delgado et al. 1998), or smaller mass-to-light ratios than in non-Seyfert galaxies (Nelson & Whittle 1996, Oliva et al. 1999).

Our work in this subject comprises a number of papers in which we have investigated the stellar population in the nuclear region of these galaxies using the technique of spectral synthesis, obtaining in particular robust age indicators (Cid Fernandes et al. 1998; Storchi-Bergmann et al. 1998; Schmitt et al. 1999; Storchi-Bergmann et al. 2000). We have also investigated the correlation between the age of the stellar population and with other properties, such as the infrared luminosity, galaxy morphology and environment (Cid Fernandes et al. 2001a; Storchi-Bergmann et al. 2001).

In the present work, we discuss the results of two on-going studies (Raimann et al. 2002, 2003), in which we investigate the radial variation of the stellar population properties of a sample of 35 Seyfert 2 galaxies and compare them with those of a control sample of non-Seyfert galaxies. The questions we want to answer are: Which are the main differences between the stellar population of Seyfert and non-Seyfert galaxies of the same Hubble type? How far from the nucleus can we find this difference? In Storchi-Bergmann et al. (2001) we have proposed an evolutionary scenario in which interactions are responsible for triggering the activity and circumnuclear bursts of star formation. If this is true, wouldn’t the more external regions of the host galaxy also be affected?

2. Sample and Data

The Seyfert 2 sample comprises two subsamples, which we call the northern (N) sample (González Delgado et al. 2001) and southern (S) sample (Storchi-Bergmann et al. 2000). The N sample comprises the 20 brightest Seyfert 2 galaxies with $L([\text{OIII}]) > 10^{40}$ ergs s$^{-1}$ while the S sample comprises the 20 closest Seyferts 2 obeying the same luminosity criterium.

As a control sample of non-Seyfert galaxies we use the spectra of 10 nearby galaxies, distributed in Hubble type as follows: 3 S0, 2 Sa’s, 2 Sb’s and 3 Sc’s. In addition, we will also use as a control sample the one of Bica (1988), comprising approximately 100 non-active galaxies spanning all Hubble types.

The data consists of long-slit optical spectra, which are described in the papers listed above, except in the case of Bica (1988) sample, which uses single aperture data. Extraction of one-dimensional spectra from the long-slit data were performed at typical apertures of $2 \times 2$ arcsec$^2$, sampling regions at the galaxies of $200 \times 200$ pc$^2$ to $400 \times 400$ pc$^2$. A sample of spectra at different distances from the nucleus for one S0 Seyfert 2 is compared to that of a non-Seyfert S0 galaxy, in Fig. 1.
3. Measurements and Spectral Synthesis

The measurements consist of equivalent widths (hereafter W’s) of six to eight absorption features characteristic of the stellar population plus continuum flux ratios (hereafter C’s) at selected pivot points. The resulting values are illustrated in Fig. 2 for one Seyfert and one non-Seyfert galaxy of Hubble type S0.

The spectral synthesis was performed using the probabilistic formalism described in Cid Fernandes et al. (2001a). We reproduce the observed W’s and C’s using a base of star cluster spectra with different ages and metallicities. We use 12 spectral components representing the age-metallicity plane plus a 13th component representing a canonical AGN continuum $F_\nu \propto \nu^{-1.5}$.

As we have pointed out in our previous works, in the optical spectral range used in our work, it is not possible to discriminate between the FC and 3 Myr old components for flux contributions smaller than 40 per cent at 4020Å, because they have very similar continua. Therefore, in the description of the synthesis results we combine the 3 Myr and FC components in one, the 3 Myr/FC component.

These results are illustrated in Fig. 3 for one non-Seyfert and one Seyfert galaxy of Hubble type S0, where we compare the contribution of different age components to the flux at $\lambda 4020\AA$ as a function of distance from the nucleus. For the later Hubble types, the gradients observed for the Sa-Sc non-Seyferts are similar to those observed for the non-Seyfert S0 galaxies. Nevertheless, the values for the contribution of the different age components to the flux at $\lambda 4020\AA$...
Figure 2. Radial variations of the equivalent widths in Å(WS), continuum color and surface brightness ($10^{-15}$ erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$ arcsec$^{-2}$) for a S0 non-Seyfert (left) and one Seyfert. From top to bottom: $W_{wlb}$ (solid line) and $W_{H\alpha}$ (dotted); $W_{CaIIK}$ (solid) and $W_{CaIIH+H\epsilon}$ (dotted); $W_{CN-band}$ (solid) and $W_{G-band}$ (dotted). Vertical lines mark distances of 1 kpc and 3 kpc from the nucleus.

differ from those of the S0 galaxy. For example, the nuclear contribution of the 10 Gyr component in the case of the S0 galaxies is larger than 80%, while in the Sa-Sc control galaxies, it is around 60%. Consistently, the corresponding values for the contribution of the 1 Gyr component are smaller than 20% for the former and reach about 40% for the latter. But the comparison between Seyfert and non-Seyfert galaxies gives similar results to those illustrated in Fig. 3: the contribution of the old age components is always smaller in Seyfert’s than in non-Seyferts.

4. Summary and Conclusions

Table 1. Average contribution to the total flux at 4020Å

| Hubble type | 1Gyr Nuc. | 1Gyr 1kpc | 1Gyr 3kpc | 10Gyr Nuc. | 10Gyr 1kpc | 10Gyr 3kpc | 100/10M Nuc. | 100/10M 1kpc | 100/10M 3kpc | 3M/PC Nuc. | 3M/PC 1kpc | 3M/PC 3kpc |
|------------|-----------|------------|------------|------------|------------|------------|--------------|--------------|--------------|------------|------------|------------|
| S0 Sy 2    | 29        | 29         | 29         | 29         | 29         | 29         | 29           | 29           | 29           | 29         | 29         | 29         |
| Non-Sy     | 61        | (45)       | 61         | 61         | 61         | 61         | 61           | 61           | 61           | 61         | 61         | 61         |
| Sa-Sb Sy 2 | 56        | (56)       | 56         | 56         | 56         | 56         | 56           | 56           | 56           | 56         | 56         | 56         |
| Non-Sy     | 53        | (53)       | 53         | 53         | 53         | 53         | 53           | 53           | 53           | 53         | 53         | 53         |
| Bica’s Sa  | 31        | 31         | 31         | 31         | 31         | 31         | 31           | 31           | 31           | 31         | 31         | 31         |
| Sbc Sy 2   | 68        | (68)       | 68         | 68         | 68         | 68         | 68           | 68           | 68           | 68         | 68         | 68         |
| Non-Sy     | 46        | (46)       | 46         | 46         | 46         | 46         | 46           | 46           | 46           | 46         | 46         | 46         |
| Bica’s Sc  | 27        | (27)       | 27         | 27         | 27         | 27         | 27           | 27           | 27           | 27         | 27         | 27         |
| S Sy 2     | 31        | 31         | 31         | 31         | 31         | 31         | 31           | 31           | 31           | 31         | 31         | 31         |

* Results for non-Seyfert galaxies from Bica (1988), in a region of 1 kpc × 1 kpc.
The results of the synthesis are summarized in Table 1, which shows that, for the Seyferts of all (S0-Sc) Hubble types, the percent contribution of the oldest 10 Gyr stellar component is always smaller than in the control sample. This result seems to hold up to at least 1 kpc from the nucleus and in a few cases up to 3 kpc (in which the data with high signal-to-noise ratio could be obtained that far from the nucleus). Another difference is in the contribution of the stellar components younger than 100 Myr, which are obviously larger in the Seyfert than in the non-Seyferts, both at the nucleus and outside.

The only exception regards the Sc Seyferts, when we compare the results with those of Bica (1988), probably due to the larger aperture of Bica’s study, which may be including the contribution of recent star-formation in the disk of the galaxies.

Regarding the radial variation of the contribution of the different age components, we can clearly see a gradient in the non-Seyfert galaxies, which shows a decrease in the contribution of the 10 Gyr age component and an increase of that of the 1 Gyr component with distance from the nucleus (the other components contributing with very small percentages). This clear gradient observed in the non-Seyfert’s is not to present in most Seyfert galaxies.

The higher incidence of recent/intermediate age stellar populations in Seyfert galaxies when compared with the control sample support an AGN-star formation connection. Our results further suggest that, in the evolutionary scenario proposed by Storchi-Bergmann et al. (2001), in which interactions are responsible for triggering both star-formation and the AGN activity (which outlives
the starburst), the triggering of star-formation is not restricted to the nuclear region but seems to extend to up to 3 kpc from the nucleus.

References

Bica, E. 1988, A&A, 195, 76
Cid Fernandes, R. et al. 2001a, MNRAS, 325, 60
Cid Fernandes, R., et al. 2001b, ApJ, 558, 81
Cid Fernandes, R. et al. 1998, MNRAS, 297, 579
Cid Fernandes, R. & Terlevich, R.1995, MNRAS, 272, 423
González Delgado, R., Heckman, T.M., Leitherer, C. 2001, ApJ, 546, 845
González Delgado, R., Leitherer, C. & Heckman, T.M. 1999, ApJS, 125, 489
González Delgado, R., et al. 1998, ApJ, 505, 174
Heckman, T.M., et al. 1995, ApJ, 452, 549
Heckman, T.M., et al. 1997, ApJ, 482, 114
Nelson, C. & Whittle, M. 1996, 465, 96
Oliva, E., et al. 1999, A&A, 350, 90
Raimann, D., et al. 2001, MNRAS, 324, 1087
Raimann, D. et al. 2002, MNRAS, in press
Raimann, D. et al. 2003, in preparation
Schmitt, H.R., et al. 1999, MNRAS, 303,173
Storchi-Bergmann, T., et al. 1998, ApJ, 501, 94
Storchi-Bergmann, T., et al. 2000, ApJ, 544, 747
Storchi-Bergmann, T. et al. 2001, ApJ, 559, 147
Terlevich, R. & Melnick, J. 1985, MNRAS, 213, 841
Terlevich, R., Diaz, A. & Terlevich, R. 1990, MNRAS 242, 271

5. Discussion

Angelas Diaz: How have you handled in your models the possible presence of metallicity gradients through the inner parts of your galaxies?

Thaisa Storchi-Bergmann: The base of star cluster spectra contemplates different metallicities, thus the effect is being taken into account. Nevertheless, our experience has shown that the synthesis results are more robust in terms of age, thus in the presentation of the results we add the contribution of the components of different metallicities which have the same age.