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Spectral energy distributions of a hard X-ray selected AGN sample in the EGS

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Abstract. We present ultraviolet to mid-infrared spectral energy distributions for a sample of 116 AGN in the Extended Groth Strip selected both in the X-rays and mid-infrared (96 with single detections and 20 with multiple optical counterparts). A complete set of different AGN types and starburst galaxy templates are used to fit the objects spectral energy distributions. Five main template groups are considered, namely, *Starburst-dominated* AGN (24 % of the sample), *Starburst-contaminated* AGN (7 %), *Type-1* AGN (21 %), *Type-2* AGN (24 %), and *Normal galaxy hosting* AGN (24 %). *Type-2* AGN and *Normal galaxy hosting* AGN sources are concentrated at low redshifts, whereas *Starburst-dominated* AGN and *Type-1* AGN show a larger span. Correlations between hard/soft X-ray and ultraviolet, optical and infrared luminosities, respectively, are reported, showing a noticeable improvement when only *Type-1* AGN-fitted objects are considered. For the rest of the populations, these correlations get worse when we consider the soft X-ray instead of the hard X-rays, probably due to the higher obscuration that affects the objects in these populations. The percentage of *Starburst-dominated* AGN objects amongst the subset of objects with double detections increases up to 48%.

Key words. galaxies:active – galaxies:nuclei – galaxies:starburst – ultraviolet:galaxies – infrared:galaxies – X-rays:galaxies

1. Introduction

Searching for signatures of AGN feedback in the properties of AGN host galaxies is one of the most promising ways of testing the role of AGN in galaxy evolution. One way of finding variations in the AGN population with redshift is to compare their spectral energy distributions (SEDs) defined over a broad wavelength range. The SED of an AGN can reveal the presence of the underlying central engine, together with the luminosity of the host galaxy, the reddening, and the role of the star formation in the various frequency regimes. For these reasons, SEDs determination in samples of AGN at different redshifts is an efficient way to search for evolutionary trends.

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2. Sample and multi-wavelength data

The sample studied in this work comprises 116 AGN candidates taken from Barmby et al. (2006) in the Extended Groth Strip. These objects were originally selected in the X-ray and in the mid-infrared, using data from Chandra (Nandra et al. 2005) and XMM-Newton (Waskett et al. 2003), and from Spitzer, respectively. This is the most complete compilation of multi-wavelength data for such a big sample of AGN in the EGS. In addition to the Chandra, XMM-Newton, and Spitzer data, we have compiled near and far-ultraviolet data from GALEX, optical data from the CFHTLS (Boulade et al. 2003), plus near-infrared data from the AEGIS dataset (Davis et al. 2007). Our sample consists on 96 sources that have unique detections in all bands (N=1), plus other 20 objects with double detections (N=2) in the ground-based images. For a more detailed description of the cross-matching and aperture photometry see Pérez-González et al. (2005, 2008).

3. Spectral energy distributions and photometric redshifts of objects with unique detection.

In order to classify the 96 (N=1) spectral energy distributions and to estimate their photometric redshifts, we combine optical, near-infrared, and mid-infrared data to build well sampled SEDs that we then fit with the library of starburst, AGN and galaxy templates taken from Polletta et al. (2007). We make use of the photometric redshift code HyperZ (Bolzonella, Miralles & Pelló 2000) to perform the fits. The code also takes into account the effects of dust extinction according to the selected reddening law (Calzetti et al. 2000), with A_V ranging, in this work, from 0.0 to 1.2. The chosen set of templates contains 23 SED-types (Polletta et al. 2007), that we have arranged into five main groups: *Starbursts-dominated* AGN, *Starbursts-contaminated* AGN, *Type-1* AGN, *Type-2* AGN, and *Normal galaxy hosting* AGN. Examples of HyperZ fits for each of the employed templates are shown in Fig. 1.

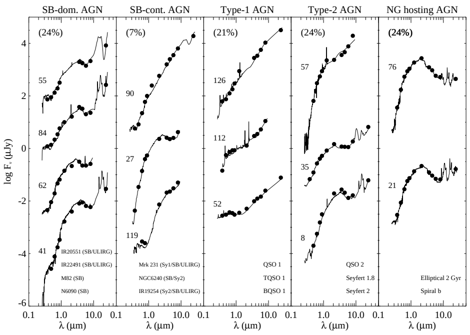

Fig. 1. Examples of SEDs in our sample (dots) fitted with different templates from Polletta et al. (2007) for the five main groups considered. . The data have been scaled. The X-axis corresponds to observed wavelength. The percentages of objects enclosed in each group are typed in the upper left corner of each panel.

A comparison between the photometric and spectroscopic redshifts for the 39 sources with publicly available z_{spec} from the DEEP data archive (Weiner et al. 2005) is shown in Fig. 2. Notice that only 28 out of these 39 galaxies have reliable spectroscopic redshifts. If we consider only those with reliable spectroscopic redshifts, Δz = -0.02, and σ_z = 0.03, with no outliers. These results point to the goodness of our fits, and thus we rather trust our photometric redshifts better than the spectroscopic ones for the outliers indicated (all of them with z_{spec} with flags = 1 or 2).

4. Discussion

4.1. Classification by SEDs and photometric redshift distribution of the sample.

We have obtained spectral energy distribution fits, that allow us to distinguish between different types of AGN populations, i.e., whether they are pure AGN, AGN hosted by starburst-dominated galaxies, or AGN in otherwise normal galaxies. For the five main groups described before we obtain the following distribution: *Starbursts-dominated* AGN (24 % of the sample), *Starbursts-contaminated* AGN (7 %), *Type-1* AGN (21 %), *Type-2* AGN (24 %),

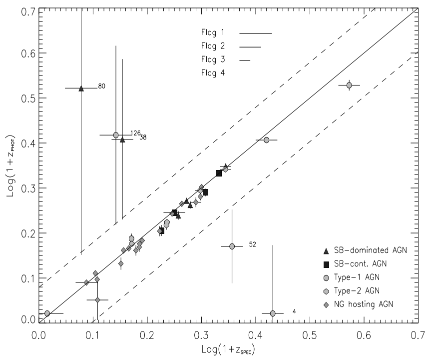

Fig. 2. Comparison between photometric and spectroscopic redshifts for the 39 sources with publicly available z_{spec} from the DEEP data archive. The solid line corresponds to z_{spec}=z_{phot} and dashed lines to the 20% boundaries in (1+z).

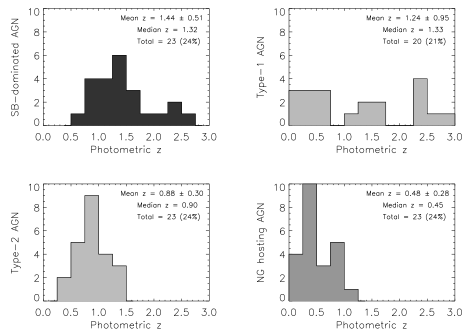

Fig. 3. Histograms for the *Starbursts-dominated* AGN, *Type-1* AGN, *Type-2* AGN, and *Normal galaxy hosting* AGN groups.

and *Normal galaxy hosting* AGN (24 %). We consider the *Type-1* AGN, *Type-2* AGN and *Starbursts-contaminated* AGN as representative groups of AGN-dominated galaxies (since their SEDs are AGN-like at all or almost all wavelength ranges).

Figure 3 shows histograms for the photometric redshift distributions of the different groups. Figure 3 shows that both the *Type-2* AGN and *Normal galaxy hosting* AGN are concentrated at low redshifts, whereas the *Starbursts-dominated* AGN show a high concentration around z_{phot}=1.3. This indicates that the *Starbursts-dominated* AGN constitute the high-redshift population of AGN masked by powerful host emission, whilst the *Normal galaxy hosting* AGN group represents the low-redshift population of low-luminosity AGN also masked by their host galaxies. In the AGN-dominated group, the *Type-1* AGN span a large redshift distribution, the *Starbursts-contaminated* AGN are located at intermediate values of redshift, and the *Type-2* AGN are the low-z objects in this subsample.

4.2. Correlations

One of the main advantages of the sample we are discussing is the multi-wavelength coverage of the data, which allows us to study for the first time various correlations between ultraviolet/optical/infrared luminosities and X-ray luminosities for such a big AGN sample and within this range of redshift.

The expected slopes for AGN-dominated objects should be close to unity, since if the active nucleus is the dominant emitting source at all wavelengths, tight linear correlations should be drawn. Reality is different, and AGN are actually hosted by different types of galaxies. Both the X-ray and mid-infrared emissions are mostly dominated by the active nuclei, whereas the optical and, to a lesser extent, the near-infrared bands are more affected by extinction, by stellar emission from the host galaxy, or by both. This is clearly reflected in the slopes and correlation coefficients of the global fits. Examples of these correlations for the far-UV/near-UV/r/K/IRAC 4.5 μm /MIPS 24 μm luminosities and the hard/soft X-ray luminosities are shown in Fig. 4.

4.3. Objects with double detections (N=2) in the optical bands.

Twenty out of the 116 objects that comprise our full sample show double detections in the ground-based images, thanks to their better spatial resolution. In the same way as we have done for the objects with unique detections in previous sections, we distribute here the fitted-objects with N=2 in the same five main categories described before. The percentages for

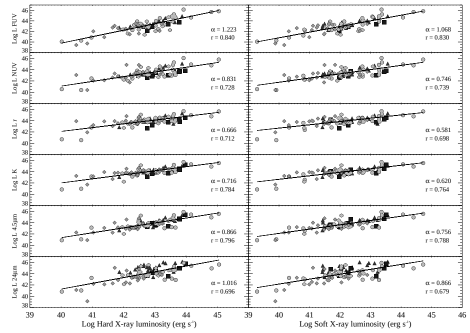

Fig. 4. Examples of luminosity-luminosity scatter diagrams for all the objects in our sample. Logarithms of νL_ν in the Far-UV, near-UV, r, K, IRAC 4.5 μm, and MIPS 24 μm bands (erg s^{-1}) are represented versus their hard and soft X-ray counterparts.

each group are: *Starbursts-dominated* AGN (48 % of the mid-infrared emitters), *Starbursts-contaminated* AGN (0 %), *Type-1* AGN (17 %), *Type-2* AGN (22 %), and *Normal galaxy hosting* AGN (13 %). Note that for this subsample of objects with double detections, almost half of the objects are described by starburst-type SEDs. If we split the objects into AGN-dominated and host-dominated galaxies, we find that 39% show AGN-like SEDs while 61% are host-dominated, a clear over-representation. This is expected since if the pairs of galaxies are interacting objects, the number of starbursts in this subsample of galaxies should consequently increase.

5. Conclusions

- The following percentages have been found for objects with unique detection: *Starbursts-dominated* AGN (24 %), *Starbursts-contaminated* AGN (7 %), *Type-1* AGN (21 %), *Type-2* AGN (24 %), and *Normal galaxy hosting* AGN (24 %). 52% of the sample has AGN-dominated SEDs and the remaining 48% host-dominated SEDs.
- The *Starbursts-dominated* AGN constitute the high-redshift population of the host-dominated AGN, whilst the *Normal galaxy hosting* AGN are concentrated at low redshifts. In the AGN-dominated group, *Type-1* AGN are randomly distributed in distance, the *Starbursts-contaminated* AGN are located at intermediate values of redshift, and the *Type-2* AGN are the lowest-z objects.
- Correlations between hard/soft X-ray luminosities and ultraviolet/optical/infrared data are reported for such a sample of AGN spanning a wide range of redshift, being in this way represented the behavior of the different AGN types in the various wavelengths considered.
- A classification of objects with double detections into the five main population groups considered through this paper shows an increase of the *Starbursts-dominated* AGN of up to 48%, while the others decrease. 61% of the fitted objects show AGN-like SEDs, while 39% is host-dominated.

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