Variability selected AGNs in the Chandra Deep Field South

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Abstract

Variability is a fundamental property of active galactic nuclei (AGN) and is adopted here as a selection criterion using multi epoch surveys. Low Luminosity AGNs (LLAGNs) are contaminated by the light of the host galaxies, thus they cannot be detected by the color techniques. Their evolution in cosmic time is poorly known and consistency with the evolution derived from X-ray detected samples has not been established. Since several variability surveys are conducted for the detection of supernovae (SNe), we have re-analyzed the SN datasets with a variability criterion optimized for AGN detection in order to select a new AGN sample and study its properties. We have used images taken in the framework of the STRESS supernova survey. We selected the AXAF field centered in the Chandra Deep Field South where, besides the deep X-ray survey also various optical catalogs exist. Our method has yielded 132 variable AGN candidates and most of them are X-ray sources. A spectroscopic campaign for part of our candidates confirms their AGN nature. Most of the results have been published in Trevese et al. 2008.

Evolution of Active Galactic Nuclei

The evolution in cosmic time of active galactic nuclei (AGN) is studied through the evolution with redshift of the luminosity function (LF) of samples of both X-ray and optically selected AGNs. However, optical and X-ray surveys imply different evolutionary scenarios.

Optical samples, selected through their non-stellar colors, suggest that the cosmic density of AGNs peaks at z~2 independently of the intrinsic luminosity, at least in the range $-23 < M_R < -26$ (Wolf et al. 2003), Figure 1a. X-ray samples, indicate a "cosmic downsizing" of the population, with the density of the fainter sources peaking at progressively lower redshifts from z~1.5 to z~0.5 (La Franca et al. 2005), Figure 1b.

A direct comparison of X-ray and optical evolution requires the study of optically selected AGNs well below $M_R \sim -23$, where color selection cannot be applied. Therefore, we selected a sample of AGN candidates on the sole basis of variability without any condition on the compactness of the image.

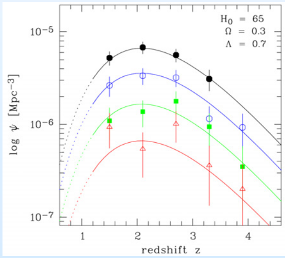

Figure 1a: The evolution of comoving AGN space density with redshift (from Wolf et al. 2003)

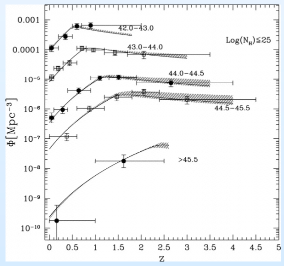

Figure 1b: Evolution of the space density of hard X-rays selected sources with redshift (from La Franca et al. 2005)

The Southern inTermediate Redshift ESO Supernova Survey (STRESS)

This is a SN survey described in Botticella et al. 2008. The observations have been carried out with the Wide Field Imager at the ESO/MPI 2.2m telescope (La Silla, Chile) and 16 fields of ~0.25 deg^2 each have been surveyed regularly in the V, R, I bands.

We chose to use the AXAF field centred at **RA: 03:32:33 DEC:-27:55:52,** with 8 epochs in the V band, distributed over a time interval of 2 years. Such a sampling is sufficient to search for AGNs through variability.

The COMBO-17 catalog provides us with object classification (Wolf et al. 2003). We adopt the U,B,V,R,I magnitudes and stellarity index from the EIS survey (Arnouts et al. 2001). We find X-ray fluxes in the CDFS and ECDFS catalogs (Giacconi et al. 2003, Lehmer et al. 2005) and spectroscopic information in the GOODS-MUSIC catalog (Grazian et al. 2006) and the CDFS optical spectroscopy catalog (Szokoly et al. 2004).

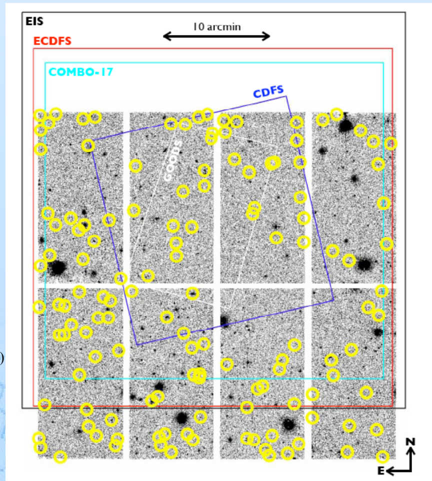

Figure 2: The AXAF field with the areas of the other surveys depicted. Yellow circles represent the variable candidates.

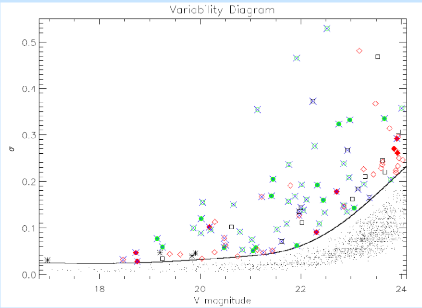

Figure 3: r.m.s. variation σ vs. V band magnitude. Small dots represent all sources in the field. For the sources above the threshold the symbols are as follows: circles: COMBO-17 QSOs, diamonds: COMBO-17 galaxies, crosses: sources detected in the X-rays, squares: sources outside the COMBO-17 region. Filled symbols show sources with spectroscopic redshift and empty symbols indicate objects with no optical spectra. The blue line is the 3σ threshold.

Selection of variable AGN candidates

We obtained the catalogs of all objects detected in the field with SExtractor (Bertin & Arnouts, 1996). The photometry at all epochs was obtained in fixed apertures, optimized to provide the minimum r.m.s. dispersion.

We adopt as variability measure, the r.m.s. variation: $\sigma = (1/N)\sum(m_i - \langle m \rangle)^2$ which is reported in Figure 3 as a function of the V magnitude. Objects are defined as variable when $\sigma \geq Sa(V) + 3sigma(V)$, where Sa(V) and sigma(V) are the mean and standard deviation of σ in bins of the magnitude V.

This procedure yielded 132 variable candidates.

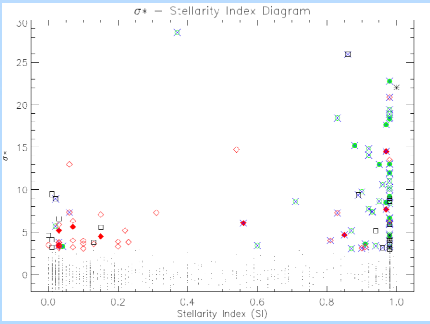

Figure 4: Variability measure vs. stellarity index. Symbols indicate classification information as described in Figure 3.

Properties of the selected candidates

We see that 94% of the point-like sources selected through variability are characterized as QSOs in COMBO-17 (green circles) and they all show X-ray emission (blue crosses). We find sources with SExtractor stellarity index less than 0.8, which indicates extended image structure (Figure 4). Some of them show X-ray emission and two are defined as AGN in the Szokoly et al. (2004) spectroscopic catalog.

4 sources classified as galaxies by COMBO-17 have optical spectra by Szokoly et al (2004) which confirm their AGN nature. They are all detected in the X-ray band. There are 8 additional sources, classified as COMBO-17 galaxies and detected in X-rays, that we consider as *bona fide* AGN. The rest of the variable galaxies have only upper limits in the X-ray bands and could be faint AGN dominated by the host galaxy. Their variability is a strong indication of their AGN nature (Maoz et al. 2005).

Among the 104 candidates which are included in the area surveyed by EIS and for which we have enough information, a total of 63 sources are either confirmed or *bona fide* AGN, based on optical spectra or/and X-ray emission. This corresponds to a lower-limit of ~61% reliability.

In Figures 5, we present the flux in the R band vs. the flux in the 2-8 kev X-ray band as reported in the CDFS and ECDFS catalogs. In Figure 6 we plot the luminosity in the R band vs. the luminosity in the 2-8 kev X-ray band for the sources with spectroscopic redshift.

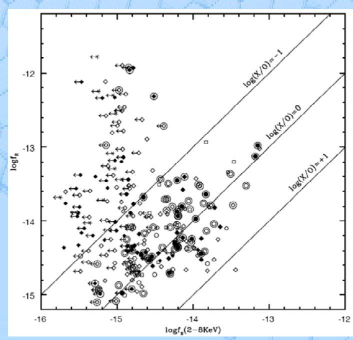

Figure 5: log f_R vs. log f_X (2-8keV) for all sources detected in the field that appear in the ECDFS catalog. Filled symbols indicate sources with spectroscopic redshift. Arrows indicate upper limits in the X-ray band. Circled sources are variable candidates according to our study.

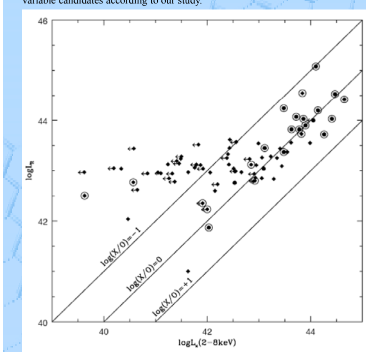

Figure 6: log L_R vs. log L_X (2-8keV) for all sources detected in the field that are included in the ECDFS catalog and have spectroscopic redshift. Circled sources are variable candidates according to our study and we see that two candidates with extended image structure have low X/O ratio.

Spectroscopic follow-up

We performed low-resolution long-slit spectroscopy of the bright part of our candidate list with EMMI on the NTT telescope. Out of the 27 observed candidates, 17 were confirmed to be broad line AGNs. 7 sources exhibit only narrow emission lines and we classify them as Narrow Emission Line Galaxies (NELG). The NELG could be either starburst or faint AGN like LINER or Seyfert 2.

We have strong indication that at least two of the NELG are LINERs due to the [N II]/Hα ratio. All of the NELG have extended image structure and they are not detected in X-rays, although they are in regions surveyed by the X-ray missions.

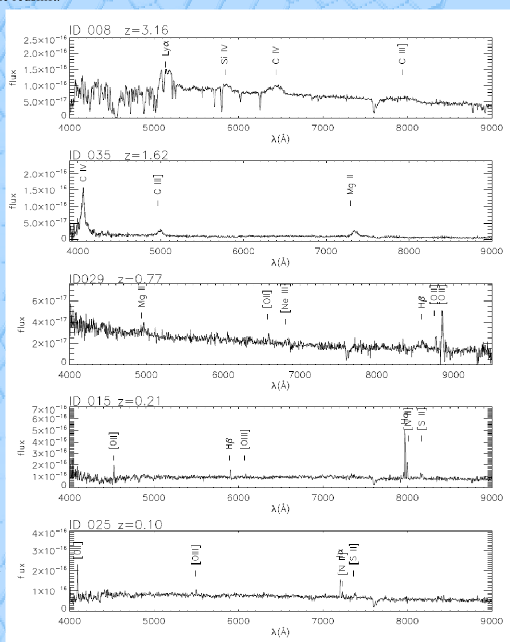

Figure 7: Examples of spectra obtained during the spectroscopic follow-up. In the 3 upper panels we see typical spectra of Broad Line AGN and in the lower two we see spectra of sources classified as NELG.

Summary

- This method selects point-like as well as extended sources
- 55 out of 104 candidates (53%) show X-ray emission and are most likely QSOs
- 90% of the candidates that have both X-ray emission and optical spectra are confirmed AGN
- 62% of our candidate sample remains without spectroscopic confirmation
- The STRESS dataset includes 15 more fields with sufficient time sampling for the application of this method. Extending our search to all of them we expect to obtain a large enough sample for a statistical study of the properties and evolution of Low Luminosity AGN

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