Variability selected Active Galactic Nuclei in the Chandra Deep Field South (CDF-S)

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Abstract

Images collected for supernova surveys can be used for variability based AGN selection, provided that the time sampling is adequate. We present the first results of such a study that we have performed on the "ESO Supernova Search at Intermediate Redshift" database. We consider as candidates the objects that lay above a variability threshold of 3 times the r.m.s noise, which depends on the apparent magnitude. This technique allows selecting intrinsically faint QSOs, since it enables the optical detection of faint, variable nuclei within brighter host galaxies which are hard to detect with the most common color selection technique. In the part of the field that overlaps with the Chandra Deep Field South, 21 of our candidates are detected in the X-rays. All but two of the 19 candidates with optical spectra have been confirmed to be AGN.

Cosmic evolution of Low Luminosity AGNs (LLAGNs)

The evolution in cosmic time of the population of active galactic nuclei (AGNs), and its relation to the birth and growth of the galaxy population, is currently studied through the evolution with redshift of the luminosity function (LF) of samples of both X-ray and optically-detected AGNs.

Optical samples are mainly based on the selection of candidates through their non-stellar colors. They allow to study the evolution of the bright end of the LF at the highest redshifts (z>6). This method is unable to select low luminosity AGNs (LLAGNs), that have a power comparable or smaller than the luminosity of the host galaxy, since galaxies in color space are spread outside the "stellar locus".

The X-ray band is the best suited to detect non-thermal emission, and the hard (e.g. 2-10 keV) band can detect even obscured (type 2) AGNs down to low intrinsic luminosities where the optical detection fails.

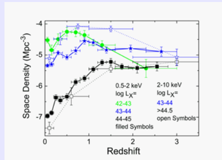

Figure 1a: Evolution of the space density of hard X-rays selected sources with redshift (from Fiore et al. 2003)

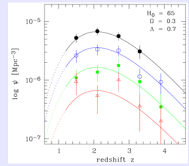

Figure 1b: The evolution of comoving AGN space density with redshift (from Wolf et al. 2003)

However, optical and X-ray surveys imply different evolutionary scenarios. Optical samples 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). On the other hand, X-ray samples indicate a "cosmic downsizing" of the AGN population, with the density of the fainter ones peaking at progressively lower redshifts from z~1.5 to z~0.5, for objects with luminosity in the range $\sim 10^{45}$ to 10^{42} erg/s in the 2-10 keV band (Fiore et al. 2003), as shown in Figure 1a.

A direct comparison of X-ray and optical evolution requires the study of optically selected AGNs well below MR~-23, where color selection cannot be applied. We therefore selected a sample of AGN candidates on the sole basis of variability without any condition on the compactness of the image. This allows us to include LLAGNs where the host galaxy is visible, or possibly dominating, instead of being swamped by the AGN light, as in the case of bright quasars.

The method has already been proved to work by Bershady, Trevese, & Kron (1998) in the field of the Selected Area 57 (see the poster by Vagnetti et al., in this conference). Here we describe the application of the method to one of the databases created for the detection of supernovae.

The ESO Supernova Search at Intermediate Redshift

This is a survey specially designed to determine the supernova rate of the Core Collapse SNe and type Ia SNe (Cappellaro et al. 2005). The observations have been carried out with the Wide Field Imager at the ESO/MPG 2.2 telescope (La Silla, Chile) and 21 fields of ~0.25 deg^2 each have been surveyed. This corresponds to a total useful area of ~5.1deg^2 in the V and R bands. These 21 fields have been monitored over 25 observing runs which provide a total number of 185 epochs (Riello 2003).

Variability studies (Sarajedini et al. 2003) have shown that 75% of the AGN in a field would be detected as varying by at least 3σ with only two observations separated by 5 years. In the present case we have 8 epochs well distributed over a time interval of two years which is sufficient to encourage us to revisit the database in order to look for AGN candidates through variability.

Supernovae appear as single "flares" in the light curve of a galaxy and are efficiently detected by image subtraction. The algorithm used to detect SNe is biased against AGN and for this reason we employ a different approach.

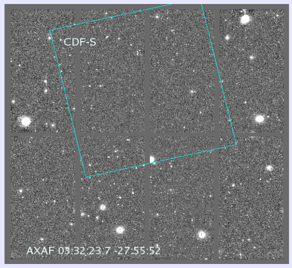

Figure 1: AXAF field with the area of CDF-S depicted

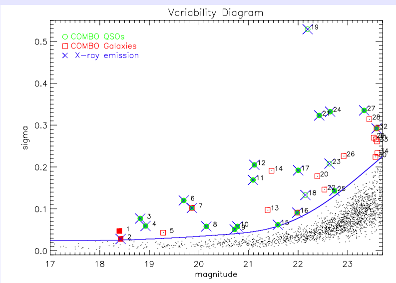

Figure 3: R.M.S variation vs. V band magnitude. Filled green symbols show the spectroscopically confirmed AGN. Filled red symbols show emission line galaxies. The blue line is the 3σ threshold.

Selection of variable AGN candidates

The light curves of AGN show continuous variations with a r.m.s. amplitude increasing, on average, with the time lag.

We chose the AXAF_V_19991288 field (shown in Figure 2), which was observed N=8 times during 2 years at the epochs specified in Table 1.

We obtained the catalogs of all objects detected in the field with SExtractor (Bertin & Arnouts,1996) and selected one reference image with the corresponding "master catalog". The photometry of all objects at all epochs was obtained in fixed apertures, optimized to provide the minimum r.m.s. dispersion.

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

Since our field lays in a well studied area, we have cross-correlated all available information on the candidates from different catalogs. The COMBO-17 object classification (Wolf et al. 2003) was adopted. Multi-band magnitudes and stellarity index from the EIS survey (Arnouts et al. 2001), X-ray fluxes from the CDFS catalog (Alexander et al. 2003) and spectroscopic information from the GOODS-MUSIC catalog (Grazian et al. 2006) and the CDFS optical spectroscopy catalog (Szokoly et al. 2004) were used to derive the properties for all our sources.

Properties of the selected candidates

AXAF_V_19991109.fits	09-11-1999
AXAF_V_19991202.fits	02-12-1999
AXAF_V_19991228.fits	28-12-1999
AXAF_V_20001116.fits	16-11-2000
AXAF_V_20001217.fits	17-12-2000
AXAF_V_20011112.fits	12-11-2001
AXAF_V_20011118.fits	18-11-2001
AXAF_V_20011208.fits	08-12-2001

Table 1: Observation Epochs

We have made the U-B vs. B-V diagram using the EIS catalog magnitudes. We see that 85% of our candidates are out of the stellar locus (Figure 4).

We have also plotted the U-B vs stellarity index (Figure 5) and we see that 94% of the point-like objects selected through variability are characterized as QSOs in COMBO-17 and they show X-ray emission.

We find an intermediate object (SExtractor stellarity index of 0.56 (Bertin & Arnouts,1996)) which shows X-ray emission and it is defined as AGN in the Szokoly et al. (2004) spectroscopic catalog.

The method selects also extended objects that show variability. 4 of these objects show X-ray emission.

71% of the known QSO in the COMBO-17 catalog found in the CDFS area show variability. After converting to flux the X-ray band counts from the CDFS catalog, we plot the Log f_x(2-8keV) vs. the LogF(R), which is the R band flux taken from the COMBO-17 catalog (Figure 6). We see that 91% of the candidates with X-ray emission have an X-ray-to-optical ratio (X/O) between 0.1 and 3, which is typical for AGN. Only one candidate shows X/O ~ 10^{-3}, consistent with star-burst galaxies.

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. High S/N optical spectroscopy is necessary in order to determine their nature.

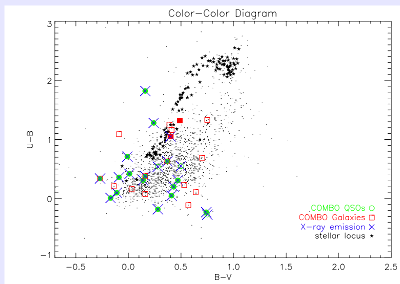

Figure 4: U-B vs. B-V diagram. Filled green symbols show spectroscopically confirmed AGN. Filled red symbols show emission line galaxies.

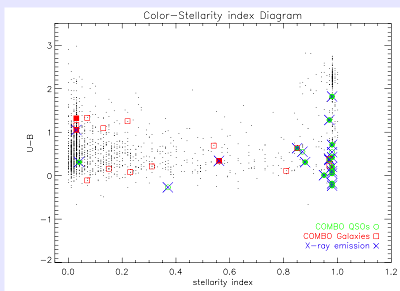

Figure 5: U-B vs. Stellarity index. Filled green symbols show spectroscopically confirmed AGN. Filled red symbols show emission line galaxies.

Summary

- The method selects point like objects as well as extended objects
- 21 out of our 34 candidates (62%) show X-ray emission and are most likely QSOs.
- 17 out of 18 (94%) candidates that have both X-ray emission and optical spectra are confirmed to be AGN.
- In the entire ESO SN Search Survey there are 11 more fields with sufficient time sampling for this method. Extending our search to all of them we expect to find 400 QSOs and 300 extended candidates that could make a large enough sample to statistically study the properties of Low Luminosity AGN.

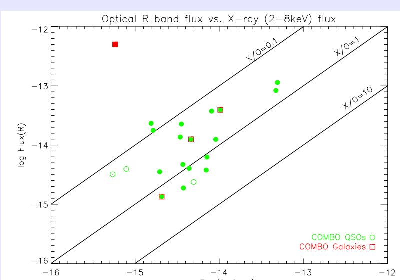

Figure 6: Optical R band luminosity vs. the X-ray (2-8keV) band luminosity. Filled green symbols show spectroscopically confirmed AGN. Filled red symbols show emission line galaxies.

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