ABSTRACT

Until recently, it has been possible only for nearby galaxies to study the scaling relations between central black hole and host galaxy in detail. Because of the small number densities at low redshift, (luminous) AGN are underrepresented in such detailed studies. The advent of adaptive optics (AO) at large telescopes helps overcoming this hurdle, allowing to reach small linear scales over a wide range in redshift. Finding AO-suitable targets, i.e., AGN having a nearby reference star, and carrying out an initial multiwavelength classification is an excellent use case for the Virtual Observatory. We present our Virtual-Observatory approach to select an AO-suitable catalog of X-ray-emitting AGN at redshifts $0.1 < z < 1$.

Key words: AGN; X-rays; Adaptive Optics; Virtual Observatory.

1. INTRODUCTION

Extensive observational work on local galaxies (passive and active) has revealed significant correlations between the mass of the central black hole and properties of its host galaxy (e.g., bulge luminosity, bulge stellar velocity dispersion; Marconi & Hunt 2003). Corresponding theoretical work tries to explain the observations in an evolutionary context. The detailed physics, however, can only be studied in the nearest galaxies, since atmospheric turbulences limit the resolving power of large telescopes and, therefore, achievement of small linear scales. From space, the Hubble Space Telescope has successfully extended this work, however, on the cost of sensitivity because of the small light-collecting area. Small linear scales are necessary to properly sample nuclear and host properties. At correspondingly small cosmological distances, the number densities of AGN (and their various subclasses) is low and larger cosmological volumes have to be probed to approach meaningful statistics. Because of surface-brightness dimming and increasing linear scales, large aperture telescopes are required that can overcome the limitations imposed by the atmosphere. This can be achieved with Adaptive Optics (AO; Beckers 1993).

AO requires a bright point source reference (guide star, GS) close to the science target. Such a GS can be a real star (natural GS, NGS) or a light spot produced by a laser beacon in the upper atmosphere (laser GS, LGS). All major large telescopes today are equipped with AO systems that can handle NGS and LGS, though, the latter systems have become available only recently. For typical constraints (see below), the sky coverage in NGS mode is only about a few percent (Roddier 1999). Therefore, much of ’traditional’ astronomical research is not concerned with AO. With LGS systems at hand, the setback of a small sky coverage can be overcome, however, another point source reference for tip-tilt correction is required (Beckers 1993).

The Virtual Observatory (VObs), especially the homogeneous access to large area sky surveys, like the Sloan Digital Sky Survey (SDSS; York et al. 2000), ROSAT All-Sky Survey (RASS; V oges et al. 1999), and cross-matching capabilities (e.g. OpenSkyQuery), allow to search for relevant sets of AO suitable targets.

2. WHY NEAR-INFRARED?

Current AO systems work (e.g., Brandner & Kasper 2005; Prieto et al. 2005; Riffel et al. 2008) in the near-infrared (NIR). This is related to technological limitations, since the number of correcting elements and the

\[ http://www.sdss.org \]
\[ http://www.xray.mpe.mpg.de/cgi-bin/rosat/rosat-survey \]
\[ http://www.openskyquery.net \]
we applied rather weak constraints on the NGSs: brightness of the NGS. For the sake of a larger sample, target (usually on-axis) and the NGS, as well as, therection is a function of angular separation of the science lengths (cf. Anderson et al. 2007). The X-ray/visible angular separation histogram of the remaining candidates (Fig. 3) displays the typical behavior compared to other work (Anderson et al. 2007; Parejko et al. 2008), i.e. a strong correlation of the X-ray and visible positions with a peak at \( \sim 10'' \). Parejko et al. find from their Monte Carlo simulations that the matching fraction for AGN is > 80\% for angular separations < 30''. More details on probabilistic cross-matching can be found in these proceedings.

In addition to these criteria we cross-checked our results by cross-matching the data set with NED\(^4\) and catalogs at different wavelengths like 20 cm radio surveys (FIRST, NVSS) and NIR (2MASS). For the latter catalogs we used our Java-based cross-matching tool (cf. Adorf et al. 2006), which accesses the Vizier database\(^5\) NED provides a comprehensive, but not homogeneous, source description based on references in the literature. One interesting case in our data set is 3C 273, in which the QSO has no SDSS spectrum, but was chosen to be the NGS - as it is unresolved in the SDSS - of a less luminous AGN in the ROSAT cone. Such situation can only be resolved by using an VObs approach as described above, in order to achieve as much information as possible.

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\(^4\)International Virtual Observatory Alliance. http://www.ivoa.net

\(^5\)Platform for Astronomy Tool InterConnection: http://webviz.u-strasbg.fr/viz-bin/VizieR

\(^6\)NED: http://nedwww.ipac.caltech.edu/ via the NED web service at http://voservices.net/NED/ws_v12_ONED.asmx

\(^7\)http://webviz.u-strasbg.fr/viz-bin/vizieRK
Figure 2. Three layers comprising the VObs. The top level consists of the original datasets, like SDSS, RASS, etc. The ‘core’ layer is some kind of middleware that allows the clients/users - at the bottom level - to access the astronomical archives in a standardized way.

Figure 3. Histogram of X-ray/visible angular separations in arcsec.

4. OUTLOOK

Based on the matched sample, we have carried out a rough spectral analysis of the candidates (cf. Zuther 2007). We fitted the spectra with a linear combination of a power-law, a young and an older stellar population, and allowing for dust extinction (Fig. 4). In the ‘continuum subtracted’ spectra, we then fitted narrow and broad components of prominent emission lines (Fig. 4 inset). We used custom-made IDL code for this, but used available data access methods to the SDSS archive and our local, relational sample database. The results, which include power-law index, reddening, fractions of AGN, young and old starburst, emission line width and fluxes, Balmer ratios, etc., are also stored in the database. In a future step, we aim at making this database VObs compliant (i.e., primarily include metadata) and then publicly accessible.

Besides the matching and photometric/spectroscopic analysis, we are currently working on a VObs compliant workflow concerning the morphological decomposition of imaging data using BUDDA (Gadotti 2008). 2D decomposition allows for a better disentangling of nuclear and host emission components. This is important when, e.g., searching for substructures, which might be related to AGN fueling, like inner bars, inner spirals, etc. Figure 5 presents a prototype that makes use of the AstroGrid VODesktop\(^8\). VODesktop unifies the discovery of data and services via registries with an online storage (VOSpace), a facility to create workflows, and provides scripting capabilities. As a preparatory step, images to be fed to BUDDA have to be cleaned of extra-target sources. This task can be accomplished with SExtractor (Bertin & Arnouts 1996) in the form of a web service.

Having established such a workflow, it will be possible to do a morphological decomposition of the SDSS based parent sample and also of the higher angular resolution NIR images of the follow-up programs.

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\(^8\)http://www.astrogrid.org
Tools that allow batch processing within the VObs framework will become essential for the next generation of telescopes like the Large Binocular Telescope (LBT). It will make use of multi-conjugate AO, requiring several GSs within the field-of-view (cf. [Herbst et al. 2008]), also requiring more advanced cross-matching schemes. The LBT will produce large and complex data sets (cf. [Eckart et al. 2008]) that can only be analyzed in highly automated workflows, which will encompass information and services from the VObs.

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