Discovery of new bright quasars by the core - host galaxy ratio

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Abstract: Though some 100,000 quasars are known, we are not complete with the bright ones. These are especially important for detailed studies, including their core - host galaxy relation. Surprisingly, $< 16^m$ objects may still be found. The discovery of all bright quasars is really a problem, as there is not a single method allowing reveal them independent of their color, presence of radio and/or X-ray, etc. However, it seems the only feature typical for all of them is the presence of the host galaxy. These objects may be easily distinguished by the core - host galaxy ratio if compared from the three DSS2 colors. Thus, a special technology using the multiband images allows reveal new quasars that could not be found by radio, X-ray or other features. A search with a goal to find all bright quasars in the region with $\delta > 0°$ and $|b| > 20°$ has been undertaken in Byurakan.

1 Introduction

There are 64,866 AGN in the latest Catalogue of quasars and active nuclei, 11th Edition (Véron-Cetty & Véron 2003). 28,400 more have been discovered later in SDSS Data Release 3 (Abazajian et al. 2005), given in SDSS Quasar Catalog, 3rd edition (Schneider et al. 2005). Thus, at present more than 93,000 AGN are known. However, very few bright AGN are known compared to their whole number. Altogether, there are only 1,424 QSOs brighter than $V = 17.0^m$ (2.8% of all QSOs), 401 with $V \leq 16.0^m$, 142 with $V \leq 15.0^m$, and only 38 with $V \leq 14^m$! Interestingly, new large surveys add only a few objects to these numbers (bright objects having saturated images in these surveys).

In fact, there are no objects brighter than 15^m in SDSS, only $\sim 10\%$ of known QSOs are being discovered at $15^m - 16^m$, $\sim 30\%$ are being discovered at $16^m - 17^m$ (most of SDSS QSOs have $19^m < g < 21^m$). For the 2QZ/6QZ (2QZ; Croom et al. 2001), the same conclusion is true for bright QSOs (there are no objects brighter than 15^m both in j and r), it finds some 5-10% of all known QSOs at $16^m - 17^m$, $\sim 10\%$ (if taking the j magnitude) or 44% (r magnitude) at $17^m - 18^m$ (the vast majority of 2QZ/6QZ QSOs have $19^m < b_j < 21^m$).

The first bright QSO sample (BQS, 69 objects with $B \leq 16.16^m$ on 10,714 deg^2) was constructed by Schmidt & Green (1983). The surface density estimated was 0.0064 deg^{-2}. However, a number of works show that this and other samples of bright QSOs are not complete (Wampler & Ponz 1985; La Franca & Cristiani 1997; Wisotzki et al. 2000; Mickaelian et al. 2001; Véron-Cetty et al. 2004), the BQS completeness being estimated as 30-50%. The difficulty of finding bright QSOs and the reason for their incompleteness is the needed large area (as their surface density is low). The recent estimations for the surface density of objects with B <16.16^m (BQS completeness limit) are 0.012-0.013 deg^{-2}.

2 Search for Bright QSOs

The modern large surveys are quite efficient at fainter magnitudes (>18^m-19^m) and provide large number of objects for statistical study of QSO populations, cosmology, etc., but the bright QSOs are being missed. These objects are still rare, and even discovery of a few objects can be crucial.

Bright QSOs are important for a number of reasons. First, their sample is still not complete. Their advantage is that they are mostly nearby objects allowing study the properties of the Local Universe. In addition, there is a possibility to study them in details (spectra, morphology, core-host relation, etc.). Bright AGN are probable strong sources of gamma, X-ray, IR, and radio, and they are good targets for the space telescopes. The AGN classification is based on bright QSOs, and their better studies are important in this sense too. It is worthwile mentioning that there are only bright QSOs among the very high luminosity objects: there are 69 QSOs with M_{abs} <-30.0, and only 4 with M_{abs} <-31.0, all with 3< z <4 and V <17^m.

There have been a few methods of search for bright AGN:

- large area colorimetric surveys: BQS (Schmidt & Green 1983), LBQS (Hewett et al. 1995), etc.
- large area spectroscopic surveys: FBS (Markarian et al. 1989), SBS (Stepanian 2005), HQS (Hagen et al. 1995), HES (Wisotski et al. 2000), Case (Pesch & Sanduleak 1989)
- identifications of X-ray and radio sources: HRC (Zickgraf et al. 2003), ROSAT-FSC AGN (Véron-Cetty et al. 2004).

All these methods have some disadvantages and miss objects. Colorimetric surveys miss objects at so-called "redshift gaps", when a QSO having a strong emission line in the measured photometric band, artificially has different color. Spectroscopic surveys find mainly blue objects, i. e. low-redshift QSOs. And radio and X-ray sources give $\sim$ 50% or less of all QSOs (Véron-Cetty et al. 2004). However, there is a feature, typical for all bright AGN (including the QSOs). They all have a host galaxy, which is not observed at blue wavelengths, but is significant in red.

3 Core-Host Ratio for the Bright QSOs

To obtain a homogeneous set of magnitudes and colors for all bright QSOs (for further analysis and statistics, including estimation of their true surface density), we have cross-correlated the Véron-Cetty & Véron catalog (2003) with the MAPS catalog (Cabanela et al. 2003), where 0.2^m rms O and E magnitudes and corresponding $O-E$ colors are given. Moreover, a diameter defined (dO and dE, reliable for stars) and integral (iO and iE, reliable for extended objects) magnitudes have been measured for each object from DSS1 (Lasker et al. 1996). This allows obtain an accurate magnitude if only the classification for the given object (into "star" or "galaxy") is correct. MAPS artificial neural network (ANN) classification into "s" and "g" has a number of problems. The objects are artificially classified as "g" when in some fields images are elongated, in case of superposition of 2 images (binary images) (the DSS1 images being not good enough); and vice versa: the objects are classified as "s" when the galaxy is barely seen (in case of bright nuclei), if the galaxy is round-shaped, etc. To correct the erroneous classes from MAPS, we have extracted all DSS2 (Lasker et al. 1998) blue, red and IR images for the 1193 bright and/or low-reshift QSOs and re-classified them into "s" or "g". This significantly improved the magnitudes, and now we had a homogeneous sample of bright QSOs with reliable photometry.

There are significant differences between the obtained magnitudes and those given in the AGN catalog, reaching up to $3^m - 4^m$. One of the reasons is because heterogeneous magnitudes are listed in the catalog. Another important reason is the difference between the pure core magnitude and the integral (core+host) ones. We have noticed that more than 80% of all bright QSOs have a bright point-like image in DSS2b, but an extended image in DSS2r. The rest of objects anyway show extension in the DSS2i. In IR (for all objects), the core is so weak in IR that only the host galaxy is observable. Thus, every QSO could be found by the ratio of its core - host galaxy images from DSS2. This is the only unified feature for all objects with $O < 17.0^m$ and/or $z < 0.3$. Hence, to obtain a complete sample of bright QSOs, one needs to find all objects having a core - host galaxy ratio different from the stars. A few objects may appear to be e.g. planetary nebulae, however, at high galactic latitudes the contamination is rather low.

4 Results and Conclusions

We have undertaken a program of search and discovery of all bright AGN in the region with $\delta > 0°$ and $|b| > 20°$ using the MAPS calatog for a pre-selection, DSS2 (Lasker et al. 1998) bri images for estimation of the core - host galaxy ratio and the surface brightness distribution of objects, and the Digitized First Byurakan Survey (DFBS, Mickaelian et al. 2005) low-dispersion spectra for confirmation of the candidates selected. The Byurakan Observatory 2.6m telescope with the SCORPIO spectral camera (Movsessian et al. 2001) is being used for the spectroscopic identification of the objects.

A special technology using the multiband images allows reveal new quasars that could not be found by radio, X-ray or other features. The idea is to find out all QSOs before obtaining their slit spectra and observe very good candidates only to have near to 100% detection efficiency.

First, the MAPS (POSS) fields are being surveyed comparing the iO/dO and iE/dE magnitudes and making a core-host ratio estimation for all objects with a special developed technology. Additional data, like MAPS classes, USNO-B1.0 magnitudes are being used as well. A cross-correlation with the 2MASS catalog (Cutri et al. 2003) is being made to have NIR colors for better selection of the candidates (2MASS images are used too, when necessary). Later on, a cross-correlation is being made with the AGN catalog (to exclude the known objects) and with X-ray (ROSAT BSC, Voges et al. 1998; ROSAT FSC, Voges et al. 1999), and radio (NVSS, Condon et al. 1998; FIRST, Becker et al. 1997) catalogs to distinguish X-ray and radio sources.

We have surveyed 14 MAPS (POSS) fields so far and found 10-12 bright candidates in each, 50-60% being known AGN. Altogether, 145 objects have been found, 81 are known QSOs/Sys. Thus we are left with 64 new good candidates, 23 being radio sources. The objects are believed to be true AGN even before spectroscopic observations, as optical BRI images give understanding on color, extension, and brightness distribution (different from that of stars). We found a number of by-product objects too: blue/red objects, variables, proper motion stars. All objects are inspected, but $O = 17.5^m$ is the limit for reliable selection, appropriate for the DFBS spectra too. A test sample (19 objects) has been observed with the 2.6m telescope, and all but one candidates turned to be genuine AGN.

A number of improvements may be made for further search. Deeper BVRI images with 2.6m telescope could extend our detection limit to fainter magnitudes (in some small test fields). The Virtual Observatories (VOs) technology will be used for better matching and quicker use of the large data.

Having a complete and homogeneous (statistically useful) sample of bright AGN will allow a revision of their surface density, populations (the classification scheme), luminosity functions, space density, etc. Their multiwavelength data will provide a better understanding of AGN properties and their interrelationship. A Multiwavelength catalog of bright AGN will be compiled and multiwavelength spectra for bright AGN will be constructed. A further search for new candidate objects with the similar SED may be undertaken.

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