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New AGNs Discovered with the 2.16-m Telescope at Xinglong Station of Beijing Astronomical Observatory [1]

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Abstract. The preliminary results of several on-going AGN programs using the 2.16-m telescope at Xinglong Station of Beijing Astronomical Observatory are described. About 150 new AGNs including QSOs, BL Lac objects, and Seyferts have been discovered in the last two years.

1. Introduction

Xinglong Station is the optical observing site of Beijing Astronomical Observatory, Chinese Academy of Sciences, which is located at Xinglong county, Hebei Province, about 170 km away from Beijing. The observatory is located at east longitude 117.5°, latitude 40.4° north, and altitude 950 meters.

There are five telescopes on the Xinglong mountain site: a 60-cm reflector with a TI-Japan TC-215 CCD camera, a 60/90-cm Schmidt telescope with a Ford 2048 × 2048 CCD camera, a 85-cm reflector with multi-channel photon-counting system, a 1.26-m infrared telescope with an InSb detector, and a 2.16-m reflector.

The 2.16-m telescope was made in China, and was installed in 1989. The telescope has a Cassegrain focal ratio $f/9$ and Coudé focal ratio $f/45$. A modified Zeiss universal spectrograph with Tektronix 1024 × 1024 CCD camera and gratings of 150, 325, 651, and 1302 lines mm^{-1} give spectral resolution of 9.6, 4.7, 2.3, and 1.2 Å/pixel, respectively. Usually we can obtain a low-dispersion spectrum of a quasar $B = 19$ mag in a one-hour exposure on a fine night.

Identification of X-ray and IR sources through slit spectroscopy of has been one of the key projects for this telescope since 1995. During the past two years, over a hundred of new AGNs were identified by several groups (Table 1).

In the following sections, we shall give a brief account of this work.

2. AGNs Selected from ROSAT Sources

Among 80,000 *ROSAT* all-sky sources and 70,000 pointed sources, most are newly discovered X-ray sources and a large fraction of them have not yet been optically identified (Brinkmann et al. 1995). The X-ray sources at higher Galac-

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Table 1. New AGNs Discovered with the 2.16-m Telescope

Group	QSOs	BL Lacs	Seyferts	Total
BAO	60	3	45	108
NU/PMO	...	...	23	23
YAO	4	10	...	14
BNU	6	...	...	6
NNU	2	...	...	2
Total	72	13	68	153

BAO: Beijing Astronomical Observatory

NU: Nanjing University

PMO: Purple Mountain Observatory

YAO: Yunnan Astronomical Observatory

BNU: Beijing Normal University

NNU: Nanjing Normal University

tic latitude are often identified as AGNs from the spectra of their optical counterparts.

At Beijing Astronomical Observatory, we have started a program to identify *ROSAT* X-ray sources using the 2.16-m telescope. Initially, a new quasar with redshift $z = 0.32$ and $V = 17.91$ mag was discovered by Zhao et al. (1994) in a $2° \times 2°$ area of the *ROSAT* All-Sky Survey (RASS). More recently, two new quasars and several Seyfert galaxies have also been identified in the same area (Zhao et al. 1996).

After the release of the catalogue of *ROSAT* PSPC pointed sources, we selected a bright sample from it according to the criteria (1) count rate $\geq 0.05\,s^{-1}$, (2) declination $\delta \geq 0°$, (3) Galactic latitude $|b| \geq 20°$, (4) angular extent $\leq 6''$, and (5) no previous identification as an AGN, cataclysmic variable, white dwarf, or X-ray binary.

The optically bright subsample with $13.5 \leq V \leq 16.5$ mag, as estimated from CD-ROM version of of the Digitized Sky Survey (DSS), includes about 150 objects. The slit spectra of 96 sources have been obtained with the 2.16-m telescope at a resolution of 4.7 Å/pixel and wavelength coverage of 3800–8000 Å. Classification of the spectra shows that there are 5 quasars and 11 Seyfert galaxies in this group. The redshifts of these quasars are $z = 0.081$, 0.143, 0.165, 0.312, and 0.760, and the apparent magnitudes, measured with the 60-cm reflector, are $V = 15.4$, 15.6, 16.0, 16.4, and 15.7 mag, respectively. These results show that optical identification of *ROSAT* PSPC sources is an effective way to identify bright low-redshift quasars. These data may prove to be useful for study of the luminosity function and evolution of quasars (Wei et al. 1996).

The optically faint subsample with $16.5 \leq V \leq 18.5$ mag (as estimated from the DSS) includes about 350 sources. The spectra of 62 objects have been

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obtained so far, leading to the identification of 23 quasars, 13 Seyferts, and 10 quasar-like Seyferts.

Another sample was selected from the comparison of the *ROSAT* PSPC source catalog and the 5 GHz radio source catalog, according to the criteria (1) declination $\delta \geq -10°$, (2) Galactic latitude $|b| \geq 20°$, (3) angular extent $\leq 6''$ (4) not listed in the Véron-Cetty & Véron (1993) catalog and cannot be identified with stars brighter than $V = 13.5$ mag, and (5) apparent optical counterparts can be found on the DSS.

There are about 160 objects meeting these criteria, 56 of which have now been observed, yielding 24 quasars, 3 BL Lac candidates and 2 Seyfert galaxies so far. As a first report, the data on 8 quasars with redshifts ranging from $z = 0.333$ to $z = 1.091$ has been published by Wei et al. (1995).

It is worth mentioning that an unusually high-luminosity LINER, 1RXP J160338+1554.1, has been identified from *ROSAT* pointed observations. It may be either an intrinsically luminous LINER, which runs contrary to the conventional view of these sources, or a just a reflection of radiation from the central region caused by its nearby objects (X. B. Wu 1996).

3. Active Galaxies Selected from IRAS EGCAT

Since the *IRAS* survey provided IR data for over 20,000 galaxies, it has been shown that the Seyfert galaxies present a strong 25 μm component. De Grijp et al. (1985) suggested that selection of objects by the relatively warm 25 to 60μm color is a highly efficient way of detecting hitherto unknown Seyfert galaxies, and showed that this method has a success rate of 40%. Following their criteria, a sample was selected from the *IRAS* Extragalactic Catalog (EGCAT 1994) to search for new Seyfert galaxies, all in the range of $-1.5 \leq \alpha(60, 25) \leq 0.5$. In order to be sure that the objects are not foreground sources such as stars and planetary nebulae, the image of each one has been inspected on CD-ROM of the DSS. During the past two years, the spectra of 45 sources were obtained using the 2.16-m telescope, and 23 new Seyferts including one Seyfert 1, thirteen Seyfert 2s, and nine LINERs were identified. The first results have been been reported by Gu et al. (1995).

In addition to Seyfert galaxies, most of the rest are starbursts. Some interesting examples are the following:

F06296+5743, a very massive starburst. This object has strong Balmer absorption lines and blue continuum. The measured Balmer equivalent widths of Hβ, Hγ, and Hδ are 8.2 Å, 8.2 Å, and 8.3Å, respectively, indicating a dominant population of A dwarfs in the nuclear region of the object. The dereddened continuum index $V-R$ is about -0.29 to -0.37, corresponding to B8–A0 energy distribution. This might be expected only if there has been a very massive starburst, more than 10% burst strength at least, and the age of the starburst to be $< 10^8$ years (Huang et al. 1996a).

F07164+5301, an extreme starburst with WR features. Extreme starburst galaxies (ESB), defined by Allen et al. (1991), are those galaxies with a very recent burst of star formation. The dozen ESB objects they found populate the

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high–[O III]/Hβ and low–[N II]/Hα region of the diagnostic diagram. However, they have not detected any WR features in these sources, which are supposed to characterize the youngest starbursts. The spectrum of F07164+5301 taken with the 2.16-m telescope in 1995 March shows that it is a new ESB source with a WR bump at 4605–4656 Å. The number of WR stars derived from the luminosity of He II λ4686 is about 8100. The oxygen abundance is about 9.06×10^{-4}, greater than the solar value. This result supports the suggestion that the absence of WR stars in ESB sources may be due to low metallicities (Huang et al. 1996b).

4. AGNs Discovered in a Sample of Very Luminous IRAS Galaxies

There is much evidence that shows that both AGN and starbursts could account for the infrared enhancement of luminous *IRAS* galaxies. But what is dominant is still a controversial issue. H. Wu et al. (1996) selected a sample of very luminous *IRAS* galaxies (VLIRGs) from the 1.96 Jy catalog (Strauss et al. 1992) meeting the criteria (1) declination $\delta \geq 0°$, (2) IR luminosity $\log(L_{IR}/L_{\odot}) \geq 11.5$, (for $H_0 = 50\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ and $q_0 = 0.5$), and (3) Zwicky magnitude $m_z \leq 15.5$.

The spectra of 73 sources in the sample and 50 more objects which are mainly the companions of these sources were taken with the 2.16-m telescope. The spectral resolution is about 10 Å (2 pixels) and wavelength coverage is 3700–7000 Å. Several dereddened emission-line ratios were used to classify all objects following the prescription of Veilleux & Osterbrock (1987). Fourteen new AGNs including one Seyfert 1, two Seyfert 2s, four LINERs, and seven AGN-like objects were found in the sample. The analysis of all these data leads to the following conclusions:

1. About half (37/73) of VLIRGs present AGN-like spectra corresponding to Seyfert 1, Seyfert 2, LINER, and a mixture of LINER and H II-region characteristics. This fraction increases to 73% for the *ultraluminous* infrared galaxies (ULIRGs) subsample, i.e., those with $\log(L_{IR}/L_{\odot}) \geq 12.0$.

2. Fifty-six percent of VLIRGs and 91% of ULIRGs are found to be in strongly interacting or merging systems.

3. There are 7 groups of galaxies confirmed to have at least 3 members whose relative velocity is about several hundred km/s. For example, *IRAS* 23532+2513 is found to be in a compact group including a disturbed starburst galaxy and a Seyfert 1 (Zou et al. 1995).

4. The infrared luminosities increase with decreasing projected separation between the source and its companion.

5. The relationship between projected separation and specific angular momentum shows that dynamical friction could play an important role even for the interacting galaxies with large separations.

5. Optically Selected Quasars

Several groups of Chinese astronomers (for example, Huang & Huang 1986, He & Impey 1986, Zhan & Chen1989) have been devoting effort to identifying quasars by optical methods such as multicolor surveys and/or objective-prism surveys. Several hundreds of QSO candidates have been found by them since 1980. Although many of the QSO candidates seem to be too faint for identification with the 2.16-m telescope, we have made an encouraging start.

The first object, with $B \approx 18.5$ mag, was selected from the sample of He & Chen (1993). The slit spectrum of the object taken with the 2.16-m telescope shows that there are two broad emission lines at 4123 Å and 5083 Å, which can be identified C IV λ1549 and C III] λ1909 at a redshift $z = 1.662$ (Wu et al. 1995).

A more recent example was selected from the Beijing-Arizona-Taiwan-Connecticut (BATC) multicolor survey (Chen 1995). The goal of this survey is to obtain the spectral energy distributions (SEDs) of objects in 500 selected fields down to $V = 21$ mag using the 60/90-cm Schmidt of Beijing Astronomical Observatory with 15 intermediate-band and 4 narrow-band filters. A Ford 2048× 2048 CCD at the prime focus gives a field of view of $\sim 1^\circ \times 1^\circ$. One of the scientific goals is to find high-redshift QSOs. As the first stage, QSO candidates were selected on the color-color diagram of the T329 field. The QSOs fall in parts of the color-color diagram not populated by stars. A candidate with $V \approx 19$ mag and colors f–$g = -0.33$ and e–$f = 0.1$ has been identified as a QSO with redshift $z = 1.88$ with the 2.16-m telescope this year.

6. Summary

Using 2.16-m telescope of Beijing Astronomical Observatory which was installed in 1989, Chinese astronomers have found over 150 new AGNs during the past two years. This is just first step in entering this exciting field. Some new equipment, such as an automated B&C spectrograph and a faint-object spectrograph like EFOSC, will be attached on the 2.16-m telescope in near future. Several key projects in the field of AGNs are underway.

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