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HIGH REDSHIFT QUASAR SURVEY WITH IMS

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ABSTRACT

We describe a survey of quasars in the early universe, beyond z ∼ 5, which is one of the main science goals of the Infrared Medium-deep Survey (IMS) conducted by the Center for the Exploration of the Origin of the Universe (CEOU). We use multi-wavelength archival data from SDSS, CFHTLS, UKIDSS, WISE, and SWIRE, which provide deep images over wide areas suitable for searching for high redshift quasars. In addition, we carried out a J-band imaging survey at the United Kingdom InfraRed Telescope with a depth of ∼23 AB mag and survey area of ∼120 deg^2, which makes IMS a suitable survey for finding faint, high redshift quasars at z ∼ 7. In addition, for the quasar candidates at z ∼ 5.5, we are conducting observations with the Camera for QUasars in EArly uNiverse (CQUEAN) on the 2.1m telescope at McDonald Observatory, which has a custom-designed filter set installed to enhance the efficiency of selecting robust quasar candidate samples in this redshift range. We used various color-color diagrams suitable for the specific redshift ranges, which can reduce contaminating sources such as M/L/T dwarfs, low redshift galaxies, and instrumental defects. The high redshift quasars we are confirming can provide us with clues to the growth of supermassive black holes since z ∼ 7. By expanding the quasar sample at 5 < z < 7, the final stage of the hydrogen reionization in the intergalactic medium (IGM) can also be fully understood. Moreover, we can make useful constraints on the quasar luminosity function to study the contribution of quasars to the IGM reionization.

Key words: galaxies: high-redshift - quasars: supermassive black holes - intergalactic medium - survey

1. INTRODUCTION

In recent years, dozens of quasars at z > 5 have been discovered in large area surveys. These high redshift quasars enable us to study the evolution of supermassive black holes (SMBHs), showing vigorous mass evolution in the early universe when the age of the universe was less than 1 Gyr (Shen et al. 2011; Jiang et al. 2010; Im et al. 2009). In addition, they allow us to examine the line of sight conditions of the intergalactic medium (IGM). Quasars at z ∼ 6 show highly absorbed spectra at wavelengths shorter than Lyman α (e.g., Fan et al. 2006), indicating that the optical depth increases towards higher redshift. Also, constraints on the quasar luminosity function (LF) at high redshift can improve our understanding of the IGM ionization process in the early universe.

To increase the sample size of quasars and expand the range of their physical properties, we are performing a survey of quasars at 5 < z < 7; the Infrared Medium-deep Survey (IMS). In these proceedings, we introduce the IMS, which is designed to be suitable for selecting high redshift quasars at z > 5. Since quasar selection methods can be different depending on the redshift range, survey area and depth, our survey is divided into five parts (Table 1). We will show the data we use, selection methods, and preliminary results of our survey.

2. DATA

We use multi-wavelength data such as the Sloan Digital Sky Survey (SDSS), Canada-France-Hawaii Telescope Legacy Survey (CFHTLS)-Wide, United Kingdom Infrared Telescope (UKIRT) Infrared Deep Sky Survey (UKIDSS), *Spitzer* Wide-area InfraRed Extragalactic survey (SWIRE), and the *Wide-Field Infrared Survey Explorer* (WISE) survey, with unique optical and near infrared (NIR) data from IMS.

Our survey is based on NIR photometric data. We conducted our own NIR survey with Y and J-band filters, using the Wide Field Camera on UKIRT, with a depth of is Y/J ∼ 23 AB mag. With the inclusion of the latest UKIDSS data, which is only accessible to the UKIDSS collaboration, our NIR data are deep and wide enough to find high redshift objects. In case of archival optical data, either SDSS or CFHTLS-Wide data is used. For the optical follow-up imaging observations, we developed an imaging instrument, Camera for QUasars in EArly uNiverse (CQUEAN; Park et al.

Table 1
ONGOING HIGH REDSHIFT QUASAR SURVEY OF CEOU

Redshift	5–6	6	6	6	7
Data	SDSS UKIDSS LAS CQUEAN Is & Iz WISE	SDSS UKIDSS LAS	SEGUE BOAO J UKIRT J	CFHT MegaPipe IMS(UKIRT J/Y) UKIDSS DXS SWIRE	CFHT MegaPipe IMS(UKIRT J/Y) UKIDSS DXS SWIRE
Field	SDSS DR10 UKIDSS LAS DR10	SDSS DR10 UKIDSS LAS DR10	SEGUE 2	ELAIS-N1, ELAIS-N2 Lockman Hole, EGS COSMOS, VIMOS	ELAIS-N1, ELAIS-N2 Lockman Hole, EGS COSMOS, VIMOS
Area [deg^2]	∼4000	∼4000	∼1000	∼120	∼120
Depth [AB]	$z < 19.5$	$J < 19.2$	$z_{err} < 0.1$	$J_{err} < 0.15$	$J < 23$

2012), which is equipped with two new custom filters, Is and Iz. Since 2010, we have been performing Is and Iz follow-up observations using CQUEAN at the McDonald 2.1m telescope. We also use infrared data from *Spitzer Space Telescope* survey SWIRE, which can distinguish z ∼ 7 quasars from dwarf stars. Table 1 shows the multi-wavelength data set for each redshift range.

3. ANALYSIS

By cross-matching the multi-wavelength data, we found the most efficient color-color diagram for each redshift range to reduce contaminating sources such as M/L/T dwarf stars, low redshift galaxies, and instrumental defects. For candidates without accurate photometry, we can do follow-up imaging observations to narrow down the candidates. For the most promising candidates, we perform spectroscopic observations. From the spectroscopic data, we confirm the redshifts of the candidates by identifying the redshifted Lyman break and ultraviolet (UV) emission lines. Then we measure the SMBH mass using UV emission lines. We also investigate the Lyman α forest to understand the ionization state of the IGM along various lines of sight.

4. RESULTS

So far, we have confirmed six quasars at z ∼ 5, two at z ∼ 6, and found ∼5 candidates at z ∼ 7. Figure 1 shows example spectra of our confirmed quasars. We selected these quasars using SDSS and UKIDSS LAS data and performed follow-up imaging observations using CQUEAN Is and Iz-bands. The spectra were obtained using an R-C CCD Spectrograph at the Kitt Peak National Observatory (KPNO) 4m telescope. One can see the strong Lyman α emission lines at 0.7 μm, which allow us to derive the redshifts of the objects.

5. SUMMARY

Due to the limitations of previous high redshift quasar surveys, the studies of high redshift objects and IGM condition lack sufficient quality and quantity. Therefore, we are performing high redshift quasar selection using a new imaging survey and by developing a new technique. From our own Y & J-band survey using UKIRT with

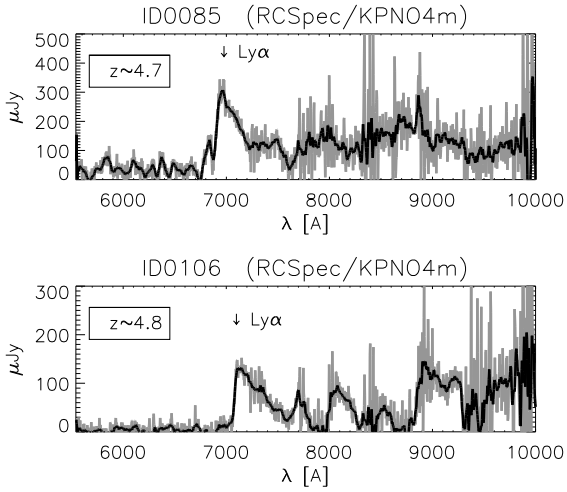

Figure 1. Example spectra of our confirmed quasars

∼120 deg^2 up to 23 AB mag, and CQUEAN observations with our new selection method, we confirmed high redshift quasars with various redshifts. Our deep and wide survey data with the new selection technique can provide us with clues to the growth of SMBHs at high redshift, a deeper understanding of the final stage of reionization and provide useful constraints on the quasar LF in the early universe.

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