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Optical spectroscopy of four young radio sources

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HIGHLIGHTS

- The Eddington ratio of young radio source is relative high
- The optical properties of young radio sources are similar with those of NLS1s
- The broad Hβ of 4C12.50 is the blue wing of the narrow component, not from the BLR

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ABSTRACT

We report the optical spectroscopy of four young radio sources which are observed with the Lijiang 2.4 m telescope. The Eddington ratios of these sources are similar with those of narrow-line Seyfert 1 galaxies (NLS1s). Their Fe II emission is strong while [O III] strength is weak. These results confirm the NLS1 features of young radio sources, except that the width of broad Hβ of young radio sources is larger than that of NLS1s. We thus suggest that the young radio sources are the high black hole mass counterparts of steep-spectrum radio-loud NLS1s. In addition, the broad Hβ component of 4C 12.50 is the blue wing of the narrow component, but not from the broad line region.

1. Introduction

The young radio sources, including compact steep spectrum (CSS) and gigahertz peaked spectrum (GPS) radio sources, are believed to represent the earliest stages in the evolution of the powerful radio galaxies (O'Dea, 1998). Some of them are found to be associated with galaxies mergers (Gilmore and Shaw, 1986) or ultraluminous infrared galaxies (ULIRGs) (Holt et al., 2011; Norris et al., 2012). Recent observations also manifest that some radio-loud narrow-line Seyfert 1 galaxies/quasars (NLS1s) have the radio properties consistent with CSS radio sources (Gu and Chen, 2010; Caccianiga et al., 2014; Liao et al., 2015). NLS1s are classified based on their narrow Balmer lines (with the full width at half maximum, FWHM < 2000 $km\ s^{-1}$), small ratio between [O III]λ5007 and Hβ ([O III]λ5007/Hβ < 3) and strong emission of Fe II complexes (Fe II λ4570/Hβ > 0.5, Osterbrock and Pogge 1985; Véron-Cetty et al. 2001). These features are explained as a result of relatively small mass of the central black hole with high accretion rate (Boroson 2002; Xu et al. 2012 , but also see Decarli et al. 2008). Thus NLS1s are suggested to be during the early stage of the accretion activities.

The accretion rates of young radio sources are found to be relatively high, with the average value similar with NLS1s (Wu, 2009; Fan and Bai, 2016). Thus the young radio sources can also stand during the early stage of accretion activities. Moreover, there is another similar feature between the young radio sources and NLS1s. That is the blue wing of narrow [O III] (Bian et al., 2005; Holt et al., 2008; Wu, 2009; Holt et al., 2009). This feature is always explained as the outflow originated from the disk wind or galactic wind. Some results indicate that the strength of the blueshift is related to the Eddington ratio (Komossa et al., 2008), while other explanations refer to the jet - ISM interaction (Holt et al., 2008).

Although the common radio properties between NLS1s and young radio sources have been discussed frequently in the literature, the common optical properties between them are less discussed. In this paper, we obtain the optical spectra of four young radio sources, and explore their emission lines properties. Throughout this paper, the luminosity is calculated using a ΛCDM cosmology model with h = 0.71, $\Omega_m = 0.27$, $\Omega_\Lambda = 0.73$.

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Table 1
The Observation Log

Source Name	Date	Exp. (s)	slit (″)	Grim	λ Range (Å)	Res. (Å)
GB6 J0140+4024	2014/11/25	2400	1.8	G3	4264 - 8603	16
TXS 0942+355	2015/03/13	3000	2.5	G3	3892 - 9110	20
IRAS 11119+3257	2015/03/16	3000	2.5	G3	4156 - 9109	20
4C 12.50	2014/05/30	2400	1.8	G8	5182 - 9518	8

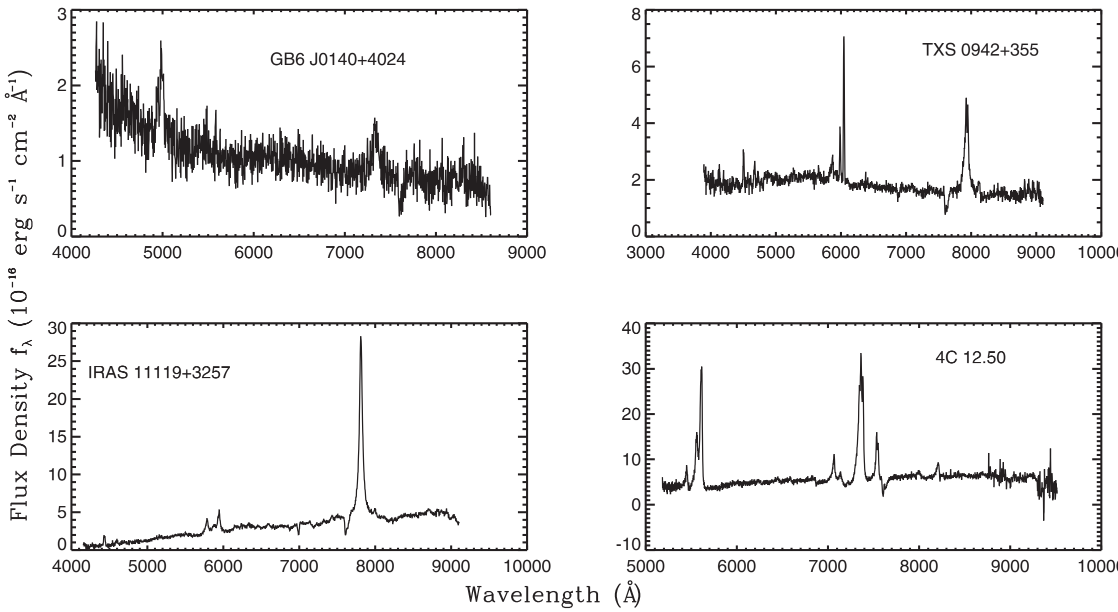

Fig. 1. The spectra of young radio sources.

2. Observations and data reduction

The spectra were obtained between 2014 and 2015, with the Yunnan Faint Object Spectrograph and Camera (YFOSC) on the Lijiang 2.4 m telescope in Yunnan Observatories. The YFOSC is equipped with a back-illuminated, blue sensitive CCD with 2048 × 4608 pixels, which works in both imaging and spectroscopy modes. Each pixel of the YFOSC corresponds to the sky angle $0.283''$. The spectra were taken with two gratings, G8 and G3. The dispersions of G8 and G3 are 1.5 $Å\ pixel^{-1}$ and 2.9 $Å\ pixel^{-1}$, respectively. The wavelength coverage is about 4970 - 9830 Å and 3200 - 9200 Å for G8 and G3, respectively. The details of observations are listed in Table 1.

The spectra are reduced with the standard IRAF routines, including the bias substraction, flat field corrections and the removal of cosmic rays. Wavelength calibration is performed with the neon and helium lamps. The spectra are flux calibrated with the spectrophotometric flux of standard stars observed at a similar air mass on the same night. The spectral resolution is estimated using the FWHM of the sky emission lines (Table 1). The four reduced 1-d spectra are plotted in Fig. 1.

3. Results on individual objects

The galactic extinction is firstly corrected using the dust map from Schlegel et al. (1998) and the extinction curve from Cardelli et al. (1989) with $R_V = 3.1$. Then we fit the four spectra in the rest frame. The pseudo-continuum are decomposed with a power-law AGN continuum, a host galaxy component (for the optical band in the rest frame), and a Fe II template. The fitting algorithm is followed Hu et al., (2015) (also see Hu et al. 2012; Wang et al. 2009; Shen et al. 2011). The emission lines are fitted with Gaussian profiles or Gauss - Hermite function. Throughout this paper, we just focus on the Hβ and Mg II region. The Hβ and Mg II are treated as a broad component plus a narrow one. If one single Gaussian can not fit the broad component well, we model it with a Gauss - Hermite function (for IRAS 11119+3257). Each of [O III] doublet is fitted with one Gaussian. For 4C 12.50, two Gaussian profiles are performed to model the unusual [O III]. Then the fitted FWHM is corrected for the instrumental broaden listed in Table 1. The strength of optical Fe II is represented by Fe II λ4570 (integrated between λ4434 and λ4684). The ultraviolet (UV) Fe II is integrated in the range 2200 - 3090 Å. The details of each sources are discussed below.

GB6 J0140+4024. This source encounter a low signal/noise ratio (S/N). However, the Mg II and C III lines are prominent (upper left panel in Fig. 1). The spectrum in rest frame which is corrected the Galactic extinction around Mg II is plotted in Fig. 2, along with the modeled components. The flux and FWHM of the broad Mg II are $21.59 \pm 3.10 \times 10^{-16}$ $erg\ s^{-1}$ and 4389 ± 714 $km\ s^{-1}$, respectively. The flux of Fe II is $100.86 \pm 24.17 \times 10^{-16}$ $erg\ s^{-1}$.

TXS 0942+355. Kunert-Bajraszewska et al. (2010) labelled this sources as a low-luminosity CSS source. Kunert-Bajraszewska and Labiano (2010) noted that the optical image showed weak extended emission. The optical spectrum manifests a large contribution of host galaxy component (Fig. 3). We obtain the flux and FWHM of the broad Hβ which are $50.52 \pm 3.52 \times 10^{-16}$ $erg\ s^{-1}$ and 4726 ± 605 $km\ s^{-1}$, respectively. The [O III] λ5007/Hβ and Fe II/Hβ (the so called R4570 parameter) are 1.59 and 0.8, respectively.

IRAS 11119+3257. This is a famous ULIRG with high velocity outflows observed at optical and X-ray band (Lípari et al., 2003; Tombesi et al., 2015). Komossa et al. (2006) labelled this sources as a radio-loud NLS1 and presented that its radio feature was compact and steep spectrum. The optical spectrum of IRAS 11119+3257