RXJ 0921+4529: A BINARY QUASAR OR A GRAVITATIONAL LENS?

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ABSTRACT

We report the new spectroscopic observations of the gravitational lens RXJ 0921+4529 with the multi-mode focal reducer SCORPIO of the SAO RAS 6 m telescope. The new spectral observations were compared with the previously observed spectra of components A and B of RXJ 0921+4529, i.e., the same components observed in different epochs. We found a significant difference in the spectrum between the components that cannot be explained with microlensing and/or spectral variation. We conclude that RXJ 0921+4529 is a binary quasar system, where redshifts of quasars A and B are 1.6535 ± 0.0005 and 1.6625 ± 0.0015, respectively.

Key words: galaxies: active – galaxies: individual (RXJ 0921+4529) – quasars: emission lines

1. INTRODUCTION

Gravitational lenses provide a useful tool for cosmological investigations, i.e., they can be used to address astrophysical problems such as the cosmological model, the structure and evolution of galaxies, and the structure of quasar accretion disks. Especially, large separated images of a quasar reveal the dark-matter content of the lensing galaxies (or galaxy clusters). However, there are also large separated binary quasar systems that cannot be interpreted as images of a lensed quasar. Several methods are developed to confirm or rule out the lens hypothesis for an observed system (see, e.g., Muñoz et al. 1998; Kochanek et al. 2006; Mortlock et al. 2008), but, due to similar quasar spectra, it is sometimes a complex task.

One of the lenses with the large separation between the A and B images (6′′97) is RXJ 0921+4529 (Muñoz et al. 2001).8 Muñoz et al. (2001) reported multi-wavelength observation of RXJ 0921+4529 finding that the system contains two images of a quasar at $z_s = 1.66$. They also observed a spiral galaxy between the quasar images, which is probably a member of an X-ray cluster at $z_l = 0.32$. It was interesting that an extended source was detected near the fainter quasar image B (denoted as B′), but not in the image A (Muñoz et al. 2001). If this extended source around image B corresponds to the quasar host then the system would be a binary quasar rather than a gravitational lens. Moreover, Peng et al. (2006) found that RXJ 0921+4529 is a binary quasar rather than a gravitational lens. They analyzed the host galaxies of lensed quasars and in RXJ 0921+4528 they did not find any effects of an Einstein ring structure to the host galaxies. Also, when they modeled the system as a lens, they found that the host galaxy has a huge inferred mass deficit (around 7–8 times more than expected), while when they treated the system as a binary quasar they found a mass deficit that is typical for the other host galaxies at that redshift.

In principle, there may be several reasons for the difference between the spectra of the images of a lensed quasar (Popović & Chartas 2005): (1) in the continuum/line it may be caused by the gravitational microlensing (see, e.g., Abajas et al. 2002; Sluse et al. 2007; Mosquera et al. 2009); (2) it may be by the intrinsic variations; (3) extinction can cause difference in the line profiles and in the continuum shapes (see, e.g., Muñoz et al. 2004; Popović & Chartas 2005); and finally (4) there is a small probability, but nevertheless it is also possible that an image (in this case B) is projected very close to another object with emission lines (Muñoz et al. 2001 reported about an extensive source around the image B of RXJ 0921+4529).

The spectra of active galactic nuclei can show a very high variability, not only in the continuum but also in line shapes (as, e.g., in the case of NGC 4151; see Shapovalova et al. 2008, 2010). In the case of intrinsic variability, one can expect that the spectra from two epochs (as well as for both images) are similar (see, e.g., Small et al. 1997). For a lens with a time delay ~100 days, as it was estimated for RXJ 0921+4529 by Muñoz et al. (2001), the observed velocity difference could be created by quasar variability coupled with a long time delay. Moreover, the extended object near the B quasar may be a faint galaxy rather than the host galaxy of quasar B, therefore the system can be a lens with large separation of images.

In order to clarify the nature of the RXJ 0921+4529, we performed the new spectroscopic observations of this system with the 6 m telescope of SAO, using the long-slit spectroscopy. The observed spectra were compared with those published in Muñoz et al. (2001). In this Letter, we report our observations in Section 2, discuss the obtained results in Section 3, and outline our conclusions in Section 4.

2. OBSERVATIONS AND DATA REDUCTION

Long-slit spectral observations were performed on 2008 October 29/30 (hereafter spectra from epoch 1) with the multi-mode focal reducer SCORPIO (Afanasiev & Moiseev 2005) installed at the prime focus of the BTA 6 m telescope at the Special Astrophysical Observatory of the Russian Academy of Sciences. The seeing was 1′′2–1′′4. A 1″ wide slit was placed along A and B components of RXJ 0921+4529 at the position angle P.A. = 115°. The spectral range was 3650–7540 Å with a spectral resolution 8–10 Å FWHM. With
Figure 1. Observed spectra of components A (solid line) and B (dashed line), the intensity of component B was multiplied five times for the comparison of the spectra. The intensity is given in $10^{-16}$ erg cm$^{-2}$ s$^{-1}$. Positions of C iv $\lambda$1550, He ii $\lambda$1640, O iii $\lambda\lambda$1662, and C iii $\lambda$1909 redshifted at 1.66 are denoted with vertical dashed lines.

a CCD EEV 42–40 2048 $\times$ 2048 pixels detector, the reciprocal dispersion was 1.9 Å pixel$^{-1}$. The total exposure time was 9600 s, divided into eight 20 minute exposures. The target was moved along the slit between exposures to ease background subtraction and CCD fringes removal in the data processing. The bias subtraction, geometrical corrections, flat fielding, sky subtraction, and calibration to flux units ($F_\lambda$) were performed by means of IDL-based software shortly described in Afanasiev & Moiseev (2005).

To compare the spectra of images between two different epochs, we used the already published spectra of A and B obtained with the MMT and Blue Channel Spectrograph (hereafter spectra from epoch 1; for more details see Figure 2 and corresponding text in Muñoz et al. 2001).

3. RESULTS AND DISCUSSION

3.1. Analysis of Long-slit Spectra

First inspection of the RX J0921+4529 A and B component spectra shows a big difference between the lines as well as the continuum (see Figure 1). The lines of component B are narrower than those of component A. Additionally, in the spectrum of component B there are prominent He ii $\lambda$1640 and O iii $\lambda\lambda$1661, 1663 emission lines, which are not present (or they are too weak) in component A. On the other hand, it seems...
that the Si iii] λ1892 line in the blue wing of C iii] λ1909 is more intensive in component A than in component B of the system.

Next, we measured the line parameters of the most intensive C iv line in the spectra of both components, and also, we measured the redshift from the line peak. We found the redshifts 1.654 for component A and 1.664 for component B. Also, the line widths of C iv in component A is 5300 km s⁻¹ and in component B is 3000 km s⁻¹. The lines in component A show a blue asymmetry, while in component B a red one.

Additionally, we compared line profiles of C iv lines from components A and B (see Figure 2, top) and found that line profiles are different between components; also, the line profiles of C iv and C iii] are the same in component B (see Figure 2, bottom right), while they are quite different in component A (see Figure 2, bottom left), the difference in the blue wing of C iv and C iii] in component A may be caused by the contribution of the Si iii] λ1892 line.

3.2. Comparison of Long-slit and MMT Spectra

First, we subtracted continuum in spectra of both components in both epochs, then normalized the spectra on the maximum intensity of the C iv line. By comparing the spectra between the same images obtained from two different epochs (see Figure 3), we found that the line shapes in component A from the two epochs are similar (there are differences in intensity that may be caused by variability), but in the case of component B the lines observed in epoch 1 have a stronger red asymmetry (stronger red wing) than ones observed in 2008 (especially in the C iv line). Also, we found different redshifts in components A and B which are 1.653 and 1.661, respectively. That is close to the measured redshifts of components A and B in epoch 2. From two epochs, we found that the redshifts of components A and B are significantly different (averaged 1.6535 ± 0.0005 for component A and 1.6625 ± 0.0015 for component B), as well as other parameters in both epochs, implying that the source of radiation is not identical. The difference between components A and B cannot be explained by intrinsic variability, and therefore we can conclude that the system is rather binary quasar than gravitational lens. Taking the average redshift of A and B quasars (z = 1.658) and assuming flat cosmological model with Ω_m = 0.27, Ω_L = 0.73, and H_0 = 71 km s⁻¹ Mpc⁻¹, the corresponding angular diameter distance of RX J0921+4529 is 1765 Mpc and the transverse separation (i.e., projected linear distance) between A and B components is 59.6 kpc.

Note here, that the spectrum of component B may be composed of the light of two sources, since Muñoz et al. (2001) reported about an extended source near component B (denoted as B′, see also observations at http://www.cfa.harvard.edu/castles/Individual/RXJ0921.html). Then, one hypothesis may be that the spectrum of component B is composed of the light of one component of a lensed quasar (the same as component A) and of the emission of an additional
Line spectrum of component B when we assume that four times weaker emission from the component A is present in the spectra of the component B (two first panels: epochs 1 and 2, respectively). The third panel presents the comparison between component B spectra in epochs 1 (dashed line) and 2 (solid line) when assumed that the contribution of component A is subtracted. Source. To check it, we tried to fit the spectra of component A into the spectra of component B, and we found that a weak spectral component of A may be present in component B (see Figure 4). We multiplied the intensity (normalized to the C iv line maximal intensity) of component A with 0.25 and found that it fitted well the blue wings of lines observed in component B. After subtraction of the A spectral component in both epoch (see Figure 5), we obtained that the red asymmetry observed in epoch 1 remained. It means that there is line shape variability present only in component B. Of course, the spectra of quasars are very similar, and this should be taken with caution. Future observations are needed to distinguish if RXJ 0921+4529 is an ordinary binary quasar or a unique object.

4. CONCLUSION

In this Letter, we report briefly the spectroscopic observations of the system RXJ 0921+4529. From our spectral observations of the system, we can conclude that the spectral properties (line parameters) of RXJ 0921+4529 A and B components are quite different indicating that it is a binary quasar. The intrinsic variability coupled with a long time delay cannot explain such difference in spectra of components A and B. Also, the future precise spectral observations of components B and B' would give more information about the structure of the system, that may be more complex than an ordinary binary quasar.

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