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LETTER

Letter to the Editor

SBS 1520+530: A new gravitationally lensed system at z=1.855⋆

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Abstract. We report the discovery of a new gravitationally lensed BAL QSO SBS 1520+530 (α_{2000} = $15^h21^m44\overset{s}{.}83$, δ_{2000} = $52°54'48\overset{''}{.}6$) at z_{em}=1.855 from the Second Byurakan Survey using observations with the 6m and 1m telescopes of SAO RAS. Two components with apparent V magnitudes $18\overset{m}{.}2$ and $18\overset{m}{.}7$ are resolved with a distance separation of $1\overset{''}{.}6$. The spectra, taken with the long-slit spectrograph, exhibit strong SiIV/OIV], CIV and CIII] emission lines with the redshifts 1.855±0.002 and 1.854±0.002, respectively, and two systems of metal-line absorption at z_{abs}=0.7155±0.0009 and 0.8147±0.0009. The blue wing of CIV line displays BAL futures.

SBS 1520+530, the second gravitationally lensed BAL QSO, offers good opportunity for ground-based and space studies of numerous phenomena connected with physics of lensing because of its apparent magnitude and appropriate separation between companions.

Key words: gravitational lensing – quasars: emission lines – quasars: absorption lines – quasars: individual (SBS 1520+530)

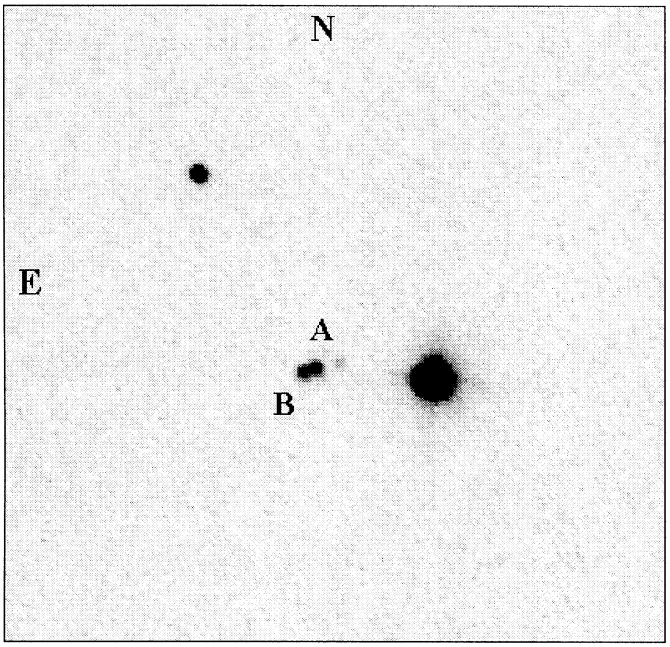

Fig. 1. Finding chart for SBS 1520+530, obtained from B band image. Size of field corresponds to $1\overset{'}{.}3\times1\overset{'}{.}3$. Equatorial coordinates of the A component are : α_{2000} = $15^h21^m44\overset{s}{.}83$, δ_{2000} = $52°54'48\overset{''}{.}6$.

1. Introduction

The phenomenon of gravitational lensing allows a new insight into many fundamental astrophysics problems: dark matter problem (Tyson et al. 1990), value of H_0 (Chang & Refsdal 1979), existence of a cosmological constant (Fukugita & Turner 1991), etc.

The Second Byurakan Survey (SBS) is a low resolution objective prism survey with a limiting magnitude of $B \sim 19.5$. It covers 1000 square degrees in the range $07^h40^m < \alpha < 17^h15^m$ and $+49° < \delta < +61°$. The observing techniques and selection criteria for the SBS objects are described by Markarian & Stepanian (1983). Data for 7 fields of the SBS have been published (Stepanian et al. 1990 and references therein), the data for the remaining 58 fields will be presented in the General Catalog of SBS Objects.

QSO candidates for follow-up spectroscopy were selected from the list of SBS objects. The spectral observations were

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Table 1. Relative positions and photometry of SBS 1520+530 components

Component	$\Delta\alpha('')$	$\Delta\delta('')$	$\rho('')$	V	B−V	V−R	R−I
A	0.00	0.00	0.00	18.17±0.04	0.44±0.05	0.26±0.06	0.20±0.11
B	1.42	-0.67	1.56	18.70±0.02	0.19±0.08	0.14±0.06	0.27±0.15
NW	-2.60	0.78	2.75	19.49±0.04	0.68±0.07	0.41±0.11	0.15±0.17
SE	3.45	-2.70	4.40	21.5±0.5	>0.5	0.54±0.23	1.45±0.31

carried out at both the 6m telescope of the Special Astrophysical Observatory (SAO), and at the 2.6m telescope of the Byurakan Astrophysical Observatory (BAO) (Stepanian et al. 1993 and references therein). The BV CCD photometric observations were carried out with the 1m telescope of SAO (Chavushyan et al. 1995). To date, more than 300 QSOs have been discovered in this survey.

In this Letter we report the discovery of a new gravitationally lensed system SBS 1520+530, which is found among SBS quasars.

2. Observations

SBS 1520+530 was identified as a QSO at z=1.85 during the follow-up spectroscopy at the 6m telescope on the 18th May 1993. A low-resolution spectrum was taken with the 1024-channel TV scaner (Drabek et al. 1985) under mediocre weather conditions. The spectrum revealed presence of some most prominent emission lines and a broad absorption feature in CIVλ1549Å. No assumptions were made regarding the multiplicity of QSO image.

The first direct images of SBS 1520+530 were obtained in May 1995 in the course of a photometric study of SBS QSOs with the SAO 1m telescope. The photometer at the Cassegrain focus was equipped with a CCD camera 530×580 pixels (Zin'kovskii et al. 1994) in combination with Johnson B and V filters. The element of the CCD corresponded to $0''.28\times0''.37$ in the focal plane.

The images were taken under good seeing (FWHM $\sim1''.2$) with exposures of 10 min and 5 min in B and V passbands, respectively. They revealed the apparent multiplicity of QSO image. It appears to be a triple system, aligned approximately in EW direction (see Fig. 1). Two bright components with V=$18^{\rm m}.2$ (component A) and $18^{\rm m}.6$ (component B) are separated by $\sim1''.5$, the third one is located at $\sim2''.5$ from component A and is much fainter: its V magnitude was estimated as $19^{\rm m}.5$. The identical component colours lead us to suspect SBS 1520+530 as a possible candidate for a gravitationally lensed system.

2.1. Spectroscopy

Spectroscopy of the SBS 1520+530 components was carried out on 1996 June 12 with a long-slit spectrograph (Afanasiev at al. 1995), installed in the prime focus of the 6m telescope. A fast (f/1.1) Schmidt camera with the internal focus in combination with the CCD 530×580 pixels provided a spatial sampling of $0''.4$ per pixel. The weather was photometric with seeing about $1''$. The observations were made with a grating 325 mm^{-1} and $2''$ entrance slit, resulting in a spectral resolution about 15Å over the wavelength range 3700-7000ÅÅ. The slit of the spectrograph was positioned to pass through all three components.

Two 1200 s exposures were taken, in order to accurately clean spectral acquisitions from cosmic particles. The shift of components along the slit between two exposures did not exceed $0''.2$ and allowed us to add both images with removal of particle hits without the loss of resolution. The resulting spatial resolution was equal to $1''.1$ and the spectra of the closest components A and B were clearly separated on the obtained image.

The reduction of spectral acquisitions was fulfilled using a software developed in SAO (Vlasyuk, 1993). The resulting spectra (shown in Fig. 2) reveal that both components are quasars having similar spectra with identical redshifts (z_{em}=1.855). Both spectra displayed broad absorption line (BAL) features of CIVλ1549Å line and two systems of narrow absorption lines.

2.2. Additional photometry

Since the nature of SBS 1520+530 was substantiated by spectral investigations, a decision was made to refine the photometric parameters. Direct imaging was performed at the SAO 1m telescope with the same instrumental set-up, as mentioned above, from 12th to 14th June 1996. Broad-band filters B, V, R, I were used. The total integration time was about 30-40 min in each band. The standard stars in NGC 7006 and M 92 fields were used for calibration. The photometric condition and seeing (FWHM $\sim$ $0''.8$-$1''.2$) allowed us to measure the brightness and relative positions of components as well as to detect some faint objects in the surrounding field.

3. Results

The results of SBS 1520+530 photometry are given in Table 1, where relative (with respect to component A) positions of four components and B, V, R, I magnitudes are presented. We had earlier discovered the three components A,B and NW; SE the faintest one, was discovered on deep V, R and I integrated images. The accuracy of relative positions is about $0''.05$. All parameters of the components were derived from the direct image fitting by a set of two-dimensional Gaussian profiles. We could not find any other extended features in its neighborhood.

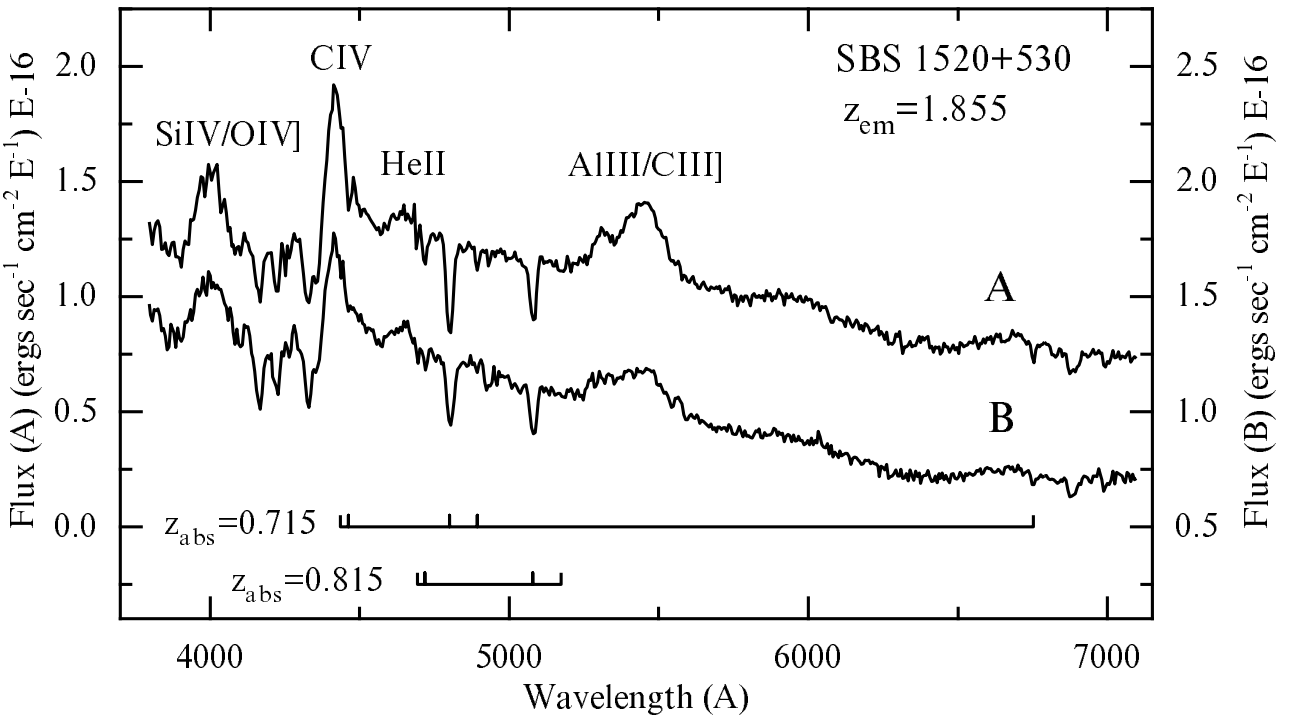

Fig. 2. Flux-calibrated spectra of the A & B components of SBS 1520+530 at 15Å resolution.

The spectra of the A and B components, obtained with the 6m telescope, are shown in Fig. 2, where the ordinate is expressed in energy units. The axis designations for A and B components are presented on the left and right sides of the figure. The strongest emission lines and two absorption systems are marked.

The parameters of emission and absorption lines were derived using the Gaussian approximation of profiles. The observed wavelength and redshift of the emission lines are presented in Table 2.

Table 2. Identification of emission lines in spectra of SBS 1520+530 A & B components

Ion	A component		B component	
	λ_{obs}(Å)	z_{em}	λ_{obs}(Å)	z_{em}
SiIV/OIV] λ1400Å	4000.9	1.858	4000.0	1.857
CIV λ1549Å	4418.5	1.853	4421.5	1.854
HeII λ1640Å	4681.1	1.854	4678.6	1.853
AlIII λ1858Å	5306.1	1.856	5299.2	1.852
CIII] λ1909Å	5450.0	1.855	5446.7	1.853
mean z_{em}	1.855±0.002		1.854±0.002	

Using the spectral data, we could identify reliably two absorption line systems with the same redshifts (z_{abs}=0.715, 0.815) in the spectra of each of the two components. All identified lines together with the observed wavelength and obtained redshift are given in Table 3.

4. Discussions and conclusion

The low-resolution spectra for two components of SBS 1520+530, taken with the 6m telescope, show that both images are quasars with the same redshift: 1.855±0.002 and 1.854±0.002, separated by 1.″56. Both spectra demonstrate presence of identical emission and absorption line profiles: such as the broad feature in the blue wing of CIV λ1549Å and two narrow metal-line absorption systems at redshifts 0.715±0.001 and 0.815±0.001 in each of them. The fact that the redshifts of both components are identical within the measurement errors and the similarity of BAL features in their spectra practically exclude the possibility for this system to be a physical pair. The probability that two independent quasars, even connected physically, may have the same structure of BAL regions is negligibly small. Some difference between the profiles of the blend AlIII/CIII] λλ 1858/1909ÅÅ in the spectra of the components suggests possible microlensing effects (Refsdal & Surdej 1994). Significant differences in (B−V) and (V−R) colours and the continuum shapes between of two components can be interpreted on the basis of gravitational lens hypothesis as due to differences of absorbing matter along two paths of deflected light beams. These differences could also be explained by the emission of the deflecting galaxy. The possibility of strong absorption origin in lens matter should also be noted.

Table 3. Absorption lines in the z_{abs}= 0.7155 and 0.8147 systems towards SBS 1520+530 A & B components

Ion	λ_{vac}(Å)	A component				B component			
		System I		System II		System I		System II	
		λ_{obs}(Å)	z_{abs}	λ_{obs}(Å)	z_{abs}	λ_{obs}(Å)	z_{abs}	λ_{obs}(Å)	z_{abs}
FeII	2587	4436.6	0.7152	4692.6	0.8141	4435.7	0.7148	4694.4	0.8148
FeII	2600	4461.8	0.7160	4717.1	0.8142	4455.7	0.7136	4720.3	0.8154
MgII	2798	4801.3	0.7160	5079.4	0.8154	4803.0	0.7166	5081.0	0.8159
MgI	2853	4894.0	0.7154	5173.5	0.8134				
CaII	3935	6752.2	0.7160			6751.4	0.7158		
mean z_{abs}		0.7157 ± 0.0004		0.8143 ± 0.0008		0.7152 ± 0.0013		0.8154 ± 0.0006	

Table 4. Summary of SBS 1520+530 data

Coordinates	α_{2000} = $15^h21^m44\overset{s}{.}83$
	δ_{2000} = $52^\circ54'48\overset{''}{.}6$
Separation	$1\overset{''}{.}56$
V magnitudes	$18\overset{m}{.}17$, $18\overset{m}{.}70$
z_{em}	1.855±0.002
z_{abs}	0.7155±0.0009
	0.8147±0.0009

Two neighbouring objects, NW and SE, are probably connected with the SBS 1520+530 system. The spectrum of the NW component was detected, but with low signal-to-noise ratio. We could not identify any details in its spectrum, but the shape of the continuum and its colours are similar to those of the brighter components. The SE object exhibited colours that are redder then that of the other components, and may be connected with a lensing galaxy, if it is located at z=0.7÷0.8. Its colours are in good agreement with those expected from spiral galaxies at this distance (Schild 1984).

Further photometric and spectral study of this system may allow us to detect the lens itself and to define the nature of the faint components, NW and SE.

Hence, we can conclude that SBS 1520+530 is a gravitationally lensed BAL QSO, the second known system after Clover-Leaf H1413+117 (Magain et al. 1988), at z=1.855 with a separation of $1\overset{''}{.}56$ between the companions, having V=$18\overset{m}{.}2$ and $18\overset{m}{.}6$, respectively. The identity of the emission and absorption line profiles strongly supports our contention. The apparent brightness and angular separation between lensed images, SBS 1520+530 provides an opportunity for both ground and space based investigations of microlensing effects, and measurements of the global parameters of the gravitational lens.

The basic data, concerning new gravitationally lensed system SBS 1520+530 are summarized in Table 4.

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