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SCIENTIFIC RESEARCHES

Photometric investigation of the field around gravitational lens SBS 1520+530 with the 6 m telescope

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Abstract. We present the results of the photometric study of the gravitational lens SBS 1520+530 field, which was carried out with the 6 m telescope of the Special Astrophysical Observatory (North Caucasus, Russia). Direct images of this field, taken with a CCD camera installed at the prime focus of the 6 m telescope in the B, V, R, I bands with a seeing (FWHM) from 0.″9 to 1.″4, allowed new data on both the structure of the system itself and the environment of this unique object to be obtained.

Key words: quasars: gravitational lens – galaxies: photometry – quasars: individual: SBS 1520+530

1. Introduction

The phenomenon of gravitational lensing remains in the focus of interest of astrophysicists, providing data for many applications, such as the problem of dark matter, determination of cosmological parameters, investigation of internal structure of quasars, etc.

The gravitationally lensed system SBS 1520+530 was discovered by the authors in 1996 using a fast spectrograph of the 6 m telescope (Chavushyan et al., 1996). Two brighter components of the system have been revealed to be lensed images of a quasar located at a redshift of 1.855 and separated by 1.″6. The identity of redshifts and similarity of emission features as well as absorption lines — broad and narrow — allowed us to conclude that SBS 1520+530 is a gravitationally lensed BAL QSO, the second known after Clover Leaf H1413+117 (Magain et al., 1988). Any traces of the lensing object were not found in that paper.

H-band observations with a spatial resolution of 0.″15, carried out with the Canada-France-Hawaii Telescope adaptive optics system (Crampton et al., 1998), showed, as the authors concluded, a lensing galaxy between the brighter components of the system. This result confirmed SBS 1520+530 to be a gravitational lens. The lensing galaxy was located 0.″4 north–east of the fainter component B.

Nevertheless, a final conclusion about the structure of SBS 1520+530 is still open to question because of the unknown redshift of NW and SE system components: the former is very similar to the A and B components in colours, the latter is much redder.

2. Observations and data reduction

We continued gathering photometric data with the 6 m telescope hoping to improve the accuracy of photometric parameters of the known sources, to detect and measure colours of faint objects below the limit of previous studies.

All data were taken during observing runs in 1996 June and 1997 May. All nights within these runs were photometric and had seeing conditions (FWHM) between 0.″8 and 1.″5. A 1040×1160 pixel CCD gave a field of view of 143″×160″. Spatial sampling of data was equal to 0.″275 per pixel, using CCD 2×2 binning while seeing was worse than 1″. Data with a seeing FWHM ≈ 0.″8–0.″9 were acquired without binning and the scale was equal to 0.″137/pixel.

A combination of detector and broad-band filters realized a system which is very close to the standard one — Johnson's B, V and Cousins's R, I. All obser-

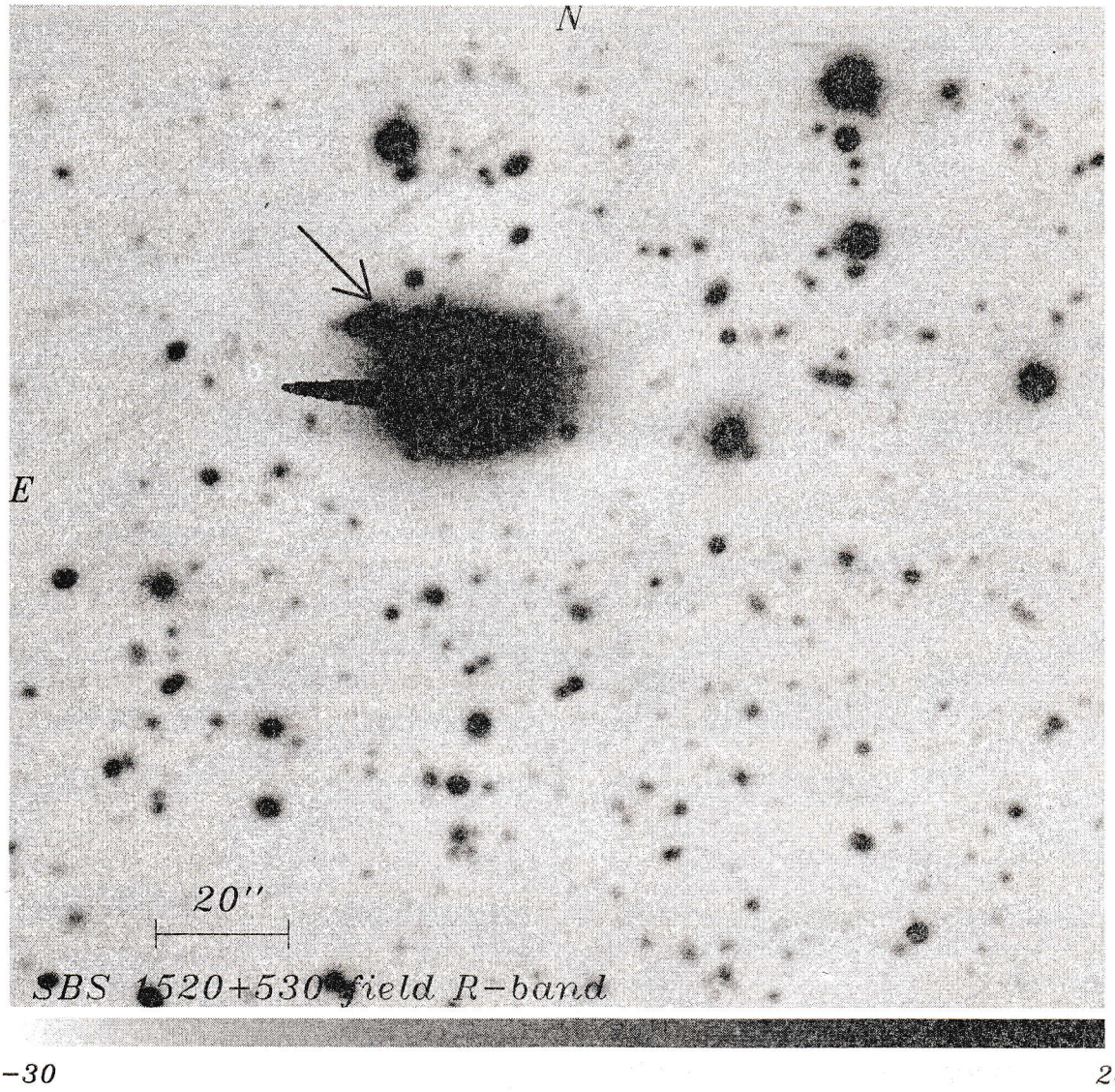

Figure 1: *The resulting image in the R-band of the field surrounding SBS 1520+530. The gravitationally lensed system is marked by an arrow. The total exposure time is 2400 s, seeing FWHM=1.″4.*

vations consisted of a set of 600 s exposures.

Data reduction was performed with the software developed in SAO by one of the authors (VVV). After bias–subtraction, flat–fielding and calibration, the individual frames were median combined in order to remove cosmic–ray events. Measurement of individual object fluxes was carried out by signal integrating in growing circular apertures with robust estimates of flux in the current circular sub-aperture.

3. Results

The detailed analysis of the obtained results is beyond the scope of the present paper. Below we present the preliminary results of the photometric study of galaxies in the field surrounding the SBS 1520+530 system in R and I colours and BVRI measurements

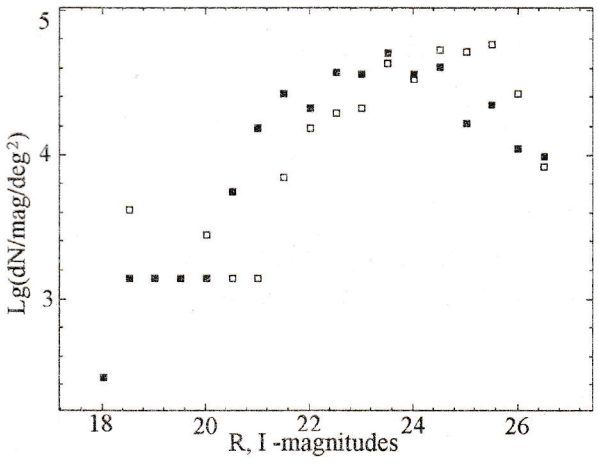

Figure 2: *Differential counts of galaxies in R (open squares) and I (filled squares) bands.*

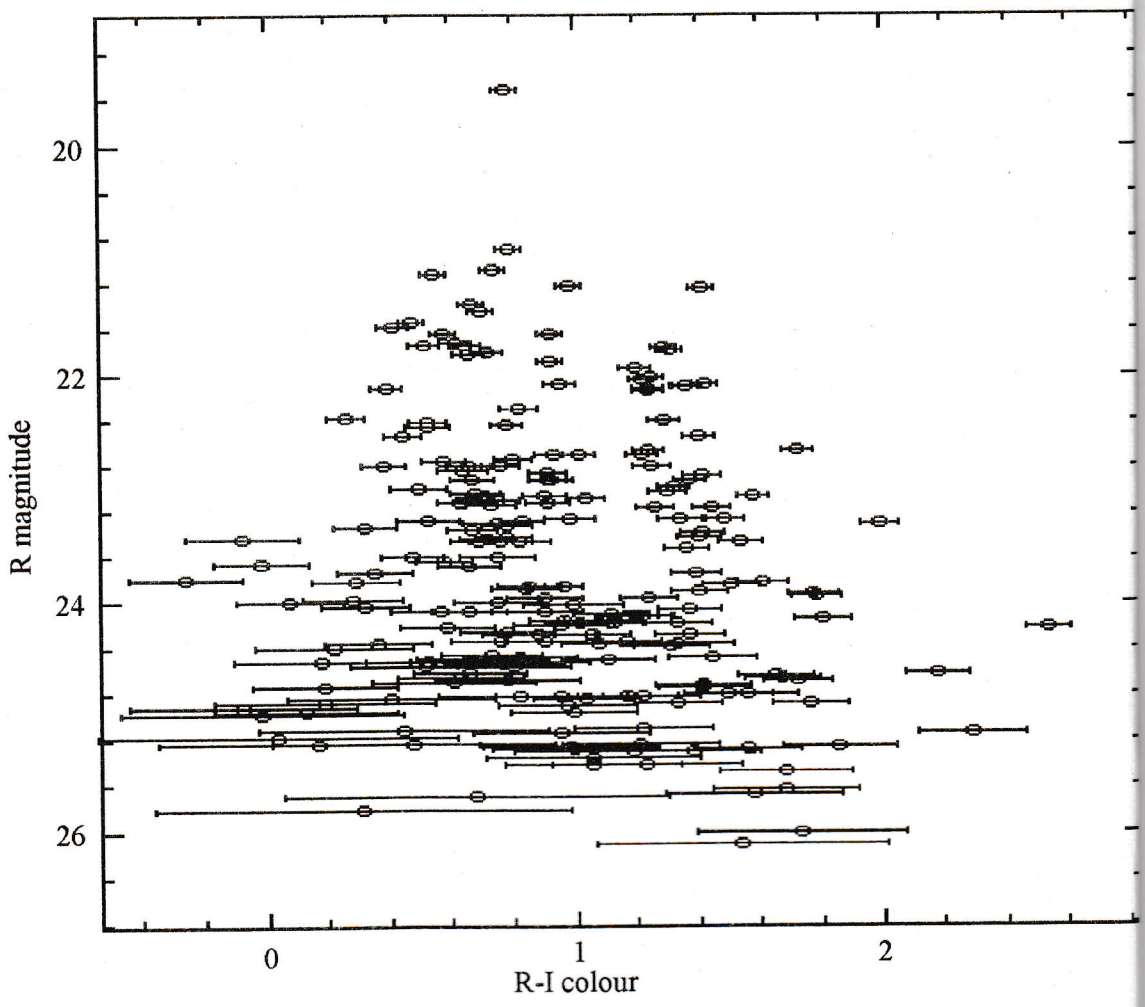

Figure 3: *Colour—magnitude relationship for galaxies detected around the SBS 1520+530 system.*

for the components of the system itself. A new result obtained here is an estimate of colours of a new object which is very close to the system.

3.1. RI photometry of galaxies in the field around SBS 1520+530

Observational data presented below were taken in 1997 May 10 with a seeing FWHM=1.″4–1.″5. R and I band observations consisted of 4×600 s and 3×600 s exposures, respectively, and covered one field (size see above) around SBS 1520+530. The 5σ detection limit was $\approx 25.^m7$ in deep R data and $\approx 24.^m2$ in the I band.

In Fig. 1 we present a grey–scale resulting image in the R band. Almost 280 objects were found in this frame, and most of them, as was defined by automatic procedure of star–galaxy classification, were faint galaxies.

The same objects were measured on the resulting I frame in order to get its (R – I) colours. Due to the lower detection limit in the I band the faintest objects did not get colours — only ≈200 galaxies remained in the final photometric list.

As faint object statistics shows, this sub–sample of galaxies cannot contain more than 10% faint stars and we can ignore pollution of our sample of galaxies with stars. The completeness limit of the sample of galaxies can easily be determined from differential number counts, which are shown in Fig. 2. The data are normalized per 1 sq.degree and 1^m bin.

These number counts are not corrected for the incompleteness because of the lower probability of object detection at the faint end and demonstrate that our list is complete up to $R=25.^m0$ and $I=23.^m5$ at least. The data are quite well approximated by a linear law :

$$\mathrm{Log}N(m) = K \times m + \mathrm{Const.}$$

The slope values K for R and I magnitudes are 0.26±0.03 and 0.23±0.05, which is in agreement with the estimates from other deep counts of galaxies as well as a total surface density of galaxies (see, for example, Williams et al., 1996; Fried, 1997).

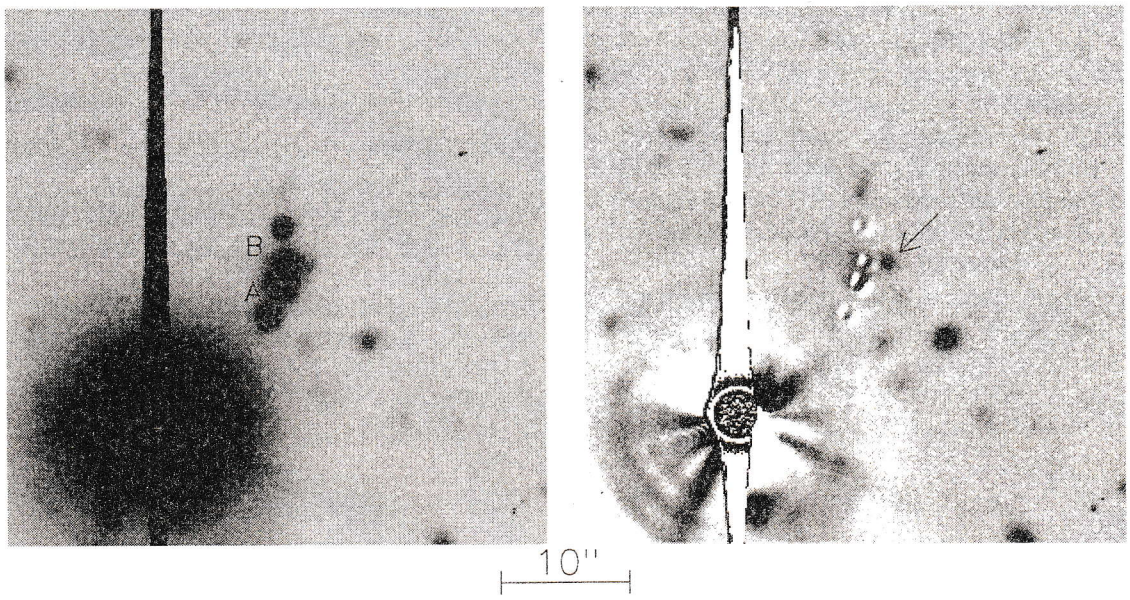

Figure 4: *Image of SBS 1520+530 in R band before(left) and after (right) subtraction of neighbouring star and bright components. Total exposure time — 1800 s. Seeing FWHM = 0.″85.*

In Fig. 3 we present a colour—magnitude diagram, relationship between R – I colour and R–magnitudes. Horizontal bars show errors in colour measurements. Two sub–samples of galaxies are clearly seen in this figure — one has blue colours ($0^m < R - I < 1^m$) and the other has red colours ($R - I > 1^m$). Among other galaxies, some number of very blue and red ones can be found in this field. Undoubtedly, the reddest galaxies ($R - I > 1.^m5$–$1.^m7$) are distant objects with a redshift more than 0.5–0.6 and the bluest galaxies are undergoing burst of star formation and probably located at z<0.5 (Roche et al., 1998).

3.2. Photometry of SBS 1520+530 system

For a detailed study of the SBS 1520+530 system structure, we used first of all the data, taken during the night of May 12, 1997 with the best seeing conditions (FWHM=0.″8–0.″9) and with 0.″137 sampling. This data sampling provides us a possibility of subtracting the brighter system components with a maximum accuracy.

Three independent 600 s exposures were included into our analysis. An image of a neighbouring bright star with $R=17.^m2$ was used as a point–spread function (PSF) for subsequent subtraction. Unfortunately, some variations of the PSF form across a detector frame limited the accuracy of this procedure.

In Fig. 4 are shown enlarged fragments of the images before and after procedures of removing bright saturating star and subtraction of 4 brighter system components, using the normalized point–spread function. Orientation of the image — east is to the top, north is to the right.

As it is clearly seen on the right panel of Fig. 4, after subtraction only one companion object is visible ≈1.″8 to the north–east of the B component. It is marked by an arrow. Its magnitude in the R band is equal to $22.^m6 \pm 0.^m2$. The same procedures were applied to data taken through the B, V and I filters. We estimate the brightness of this object as $23.^m6 \pm 0.^m3$ in the V and $21.^m5 \pm 0.^m3$ in the I band. In B data we can only give an upper limit on its brightness — $23.^m5$. The shape of the new component image does not allow us to make a suggestion concerning its nature — probably, the imperfections of PFS in the subtraction procedure masked its extended structure. But as it follows from our measurements, the size of this companion object is very similar to that of the PSF itself — the difference is less than 10%.

Careful inspecting of objects which surround the gravitationally lensed system allows us to find at least 5 galaxies located within 10″ from the system with R magnitudes between 22^m and 24^m. The most interesting galaxies are located ≈6″east and west of the system. They have colours R – I between $1.^m2$ and $1.^m6$, which are very similar to that of the new component of the system ($1.^m1$).

4. Conclusions

We have presented preliminary analysis of deep direct images taken with the 6 m telescope for the field around the gravitational lens SBS 1520+530 dis-

covered recently. The counts of galaxies, complete to $25\overset{m}{.}0$ in the R and $23\overset{m}{.}5$ in the I bands, demonstrate good agreement with previous deep counts of galaxies. The sample of galaxies in this field shows the presence of two sub-samples, which are separated by (R – I) colours. Probably, we see a mixture of background galaxies with redshifts of 0.5–0.6 and higher, having $(R - I) > 1^m$, and foreground galaxied with z less than 0.5, having $(R - I) < 1^m$.

Careful subtraction of the bright components of the system allow us to provide measurements of brightness of a new object which is very near to the line of sight. Its colours were found to be similar to those of the SW component and some neighbouring galaxies. Meanwhile, we could not establish definitely whether the morphology of this object is star-like or extended.

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