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SUPPORT FOR THE GRAVITATIONAL LENS INTERPRETATION OF SBS 0909+532

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ABSTRACT

The system SBS 0909+532A, B is a double consisting of a quasar and a fainter component that was, until now, spectroscopically unresolved. Spectra taken in good seeing conditions (FWHM = 1″) with the 4.2 m William Herschel Telescope separate the A and B components, showing that both are quasars with the same redshift, $z = 1.377$, and identical spectra. Consequently, this supports the gravitational lens interpretation of SBS 0909+532. The Mg II λλ2796, 2803 doublet is found in absorption at the same redshift ($z = 0.83$) in both components, although the equivalent width of the faintest one is 3 times stronger. We discuss the possibility that these absorption features arise from the photometrically unidentified lensing galaxy.

We have also observed another double system, Q1222+226, which was recently reported to be a gravitationally lensed quasar. Comparison of the spectra of both components indicates that Q1222+226 is in fact composed of a quasar and a star.

Subject heading: gravitational lensing — quasars: individual (SBS 0909+532; Q1222+226)

1. INTRODUCTION

In the last few years, several gravitational lens surveys have been conducted (see, e.g., Kochanek 1993 and references therein), both in the optical and the radio. One of the aims of this hunt for new, multiple-imaged quasars is to constrain the statistical properties of the lens population. The number density of multiple imaged quasars (QSOs) in the universe is a very effective tool for proving (or for restricting) cosmological models. Moreover, the results of the search—whether positive or not—give information on the number density of galaxies in the universe and their cosmological evolution. Another main motivation in searching for new gravitationally lensed quasars is to discover a system that would be well suited for deriving the value of the Hubble constant, H_0. At the moment, only a few systems (for a review, see Wu 1996) have been confirmed as multiple-imaged QSOs, and owing to several difficulties (components too close together, long time delays, faintness, complex geometry, etc.), only two have been used to compute H_0 (0957+561, see Oscoz et al. 1997; 1115+080, see Keeton & Kochanek 1997). In this Letter, we report on the results of our observations of the two candidates for gravitational lenses SBS 0909+532 and Q1222+226.

The quasar SBS 0909+532 was discovered by Stepanyan et al. (1991) and identified by the Hamburg–CfA Bright Quasar Survey (Engels et al. 1997). Very recently, Kochanek et al. (1997) resolved the system into a close pair of objects separated by $\Delta\theta \approx 1''.1$. Consequently, they pointed out the possibility that this system was a new gravitational lens. However, the bad seeing conditions of their spectroscopic observations and certain inconsistencies in the broadband photometry prevented these authors from reaching a conclusion. Motivated by E. E. Falco (1997, private communication) in this respect, we took spectra of SBS 0909+532 using the 4.2 m William Herschel Telescope (WHT) at the Roque de los Muchachos Observatory (La Palma, Canary Islands, Spain).

We also observed Q1222+226, which was presented as a possible lens candidate in the Nordic Optical Telescope Gravitational Lens survey for multiple imaged quasars (see Jaunsen et al. 1995).

2. OBSERVATIONS AND DATA REDUCTION

The spectra of the gravitational mirage candidates presented in this Letter were collected at the WHT on 1997 February 4. Long-slit spectra of the two candidates were obtained with a 1″ × 240″ slit parallel to component separation (P.A. = 123° for Q1222+226; P.A. = 110° for SBS 0909+532). The red arm of the Intermediate-dispersion Spectrograph and Imaging System (ISIS) was used with a Tek CCD camera. The spatial scale of the image is 0″.36 pixel^{-1}, the gain is 1.2, and the read noise is 4.4 e^-. The 158 lines mm^{-1} grating, R158R, gave a dispersion of 1.21 Å pixel^{-1}, covering a spectral range from 5000 to 8000 Å. The seeing was 1″ FWHM and the spectral resolution, derived from comparison lamps, was ∼2.2 Å. The total integration time for each object was 900 s.

Data reduction was carried out using the standard software package IRAF.[1] The spectral images were bias-subtracted and trimmed, flat-field corrected, and cleaned of cosmic rays. Wavelength calibration and distortion correction were performed with polynomial fits to the Cu-Ne arc lamps. Later, sky subtraction was carried out using the parts of the images free from object emission.

3. Q1222+226

The spectra of the Q1222+226 components are clearly separated on the CCD, so we performed a standard extraction using apertures centered on each component and a total width of 4 × FWHM = 3″.6. Figures 1 and 2 show the resulting spectra of components 1 (C1; southeast direction) and 2 (C2; northwest direction), respectively. The spectrum obtained for the C1 component corresponds to a star (spectral class F), whereas the C2

[1] IRAF is distributed by the National Optical Astronomy Observatories, which is operated by the Association of Universities for Research in Astronomy, Inc. (AURA) under cooperative agreement with the National Science Foundation.

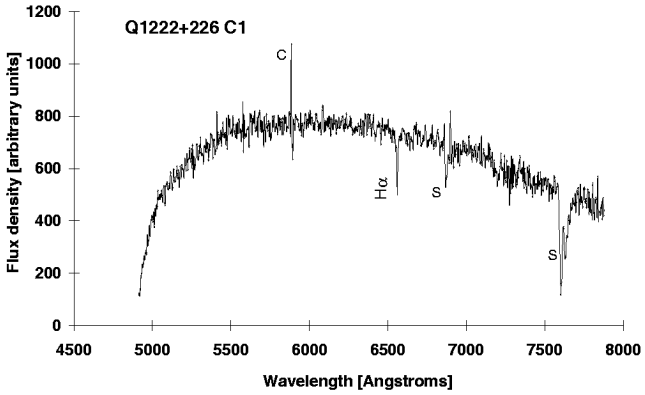

FIG. 1.—Spectrum of the Q1222+226 southeast component. Imperfectly subtracted night skylines are denoted by "S" and cosmic-ray events by "C".

component is clearly a quasar. In Figure 2 we identify several spectral features, from which we derive a redshift of $z = 0.436 \pm 0.002$. This redshift is very different from the one ($z = 2.29$) reported by Jaunsen et al. (1995). Concerned by this, we have checked the observation's log and found that the telescope was indeed pointing to the correct coordinates during the exposure. This excludes, reasonably, any source of confusion. However, in the original source for the redshift (Sramek & Weedman 1978), it is indicated that the redshift measurement for Q1222+226 is uncertain because the emission feature was just on the blue end of the spectrum and partially defocused. Everything indicates that the correct redshift is $z = 0.436 \pm 0.002$ instead of $z = 2.29$.

4. SBS 0909+532

The extraction of the spectra is different in the case of SBS 0909+532A, B. As the components of the system are quite close, we first fitted a double Gaussian function to the spatial intensity profile along the slit axis of the spectrum image that was obtained integrating along the wavelength axis (Fig. 3). The good seeing (FWHM = 1″) at the time of observation made it possible to separate both components, as shown in Figure 3. We have calculated the center of the two Gaussians. The separation between them is 1″.14 ± 0″.01, in agreement with the object separation given by Kochanek et al. (1997). We define three identical apertures (see Fig. 3) of width 1″. It is important to notice that aperture 2 is centered on the emission peak of the fitted A Gaussian, whereas apertures 1 and 3 are

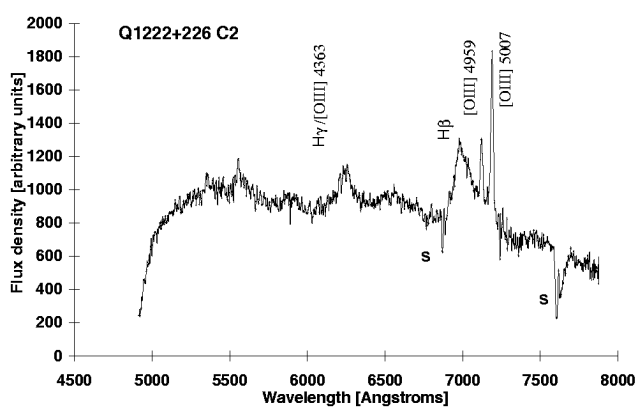

FIG. 2.—Spectrum of the Q1222+226 northwest component

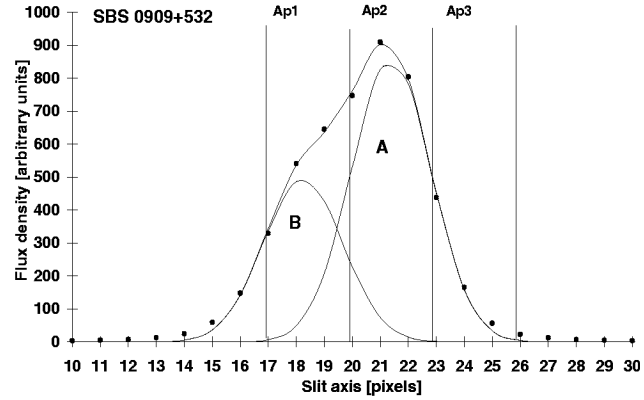

FIG. 3.—Spatial profile of SBS 0909+532 spectra. Circles are observational data, and the line is a double Gaussian fit. Three identical apertures were defined: aperture 2 centered on the A component and apertures 1 and 3 on two symmetric opposite sides. The width of the apertures is 1″.

symmetrically disposed at both sides of the A Gaussian peak. In Figure 4, the spectra extracted from apertures 1 and 2 are shown. These spectra are basically identical, having the same Mg II λ2798 emission line from which a redshift of $z = 1.377$ can be deduced. To check that the line appearing in the spectrum of the B image is not due to light from the A image falling into aperture 1, we have computed the difference between apertures 1 and 3, which (as noted above) are symmetrically disposed at the opposite sides of the emission A peak (see Fig. 3). The resulting spectrum (Fig. 5) also shows the Mg emission line, proving that this feature is not coming from A light contamination. We have calculated, too, the quotient between the components (aperture 1/aperture 2) in the wavelength range observed (5000–8000 Å). The resulting $m_{\rm ap1} - m_{\rm ap2}$ (see Fig. 6) remains almost constant, which supports the idea that this system is a new gravitational mirage.

We observe, superposed on the QSO spectra, the presence of an absorption system characterized by the Mg II λλ2796, 2803 absorption doublet in the spectra corresponding to apertures 1 and 2 (see also Kochanek et al. 1997). The rest equivalent widths of the Mg II doublet are 2.0 ± 0.1 Å (λ2796) and 1.7 ± 0.1 Å (λ2803) for the B (fainter) component and 0.7 ± 0.1 Å (λ2796) and 0.7 ± 0.1 Å (λ2803) for the A component. The redshifts are $z_{\rm B} = 0.82981 \pm 0.00008$ and $z_{\rm A} = 0.8299 \pm 0.0003$, and the FWHMs are 7.7 ± 0.4 Å (B) and 10.8 ± 1.5 Å (A). There are some uncertainties in these de-

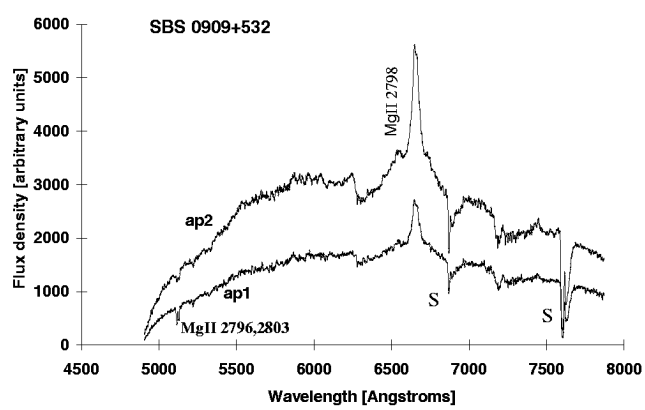

FIG. 4.—Resulting spectrum of the B (aperture 1) and A (aperture 2) components of lens candidate SBS 0909+532.

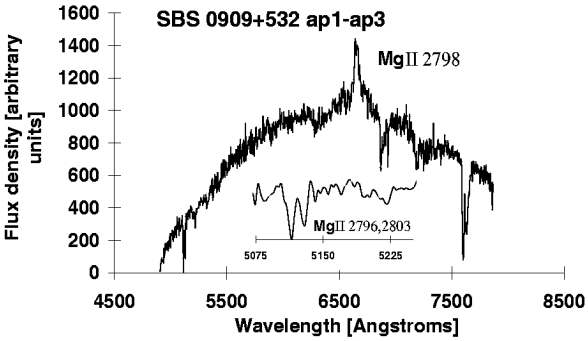

FIG. 5.—Resulting spectrum from the spectrum subtraction of aperture 1 from aperture 3. The Mg emission peak and absorption doublet are clearly visible.

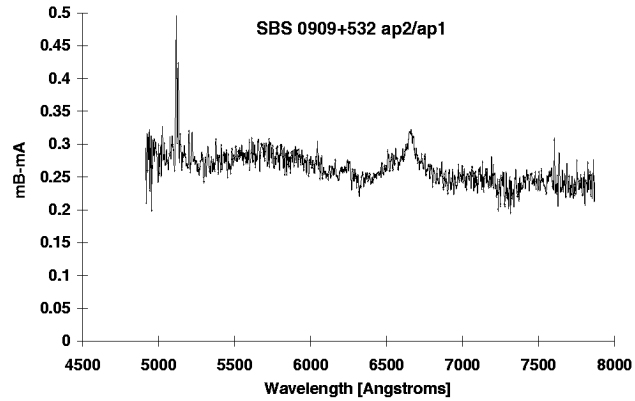

FIG. 6.—Resulting difference, $m_{ap1} - m_{ap2}$ (see text for details)

terminations due to the difficulties in the definition of the continuum, especially for the A component. The good coincidence in redshift indicates that the absorption features in both components arise, with high probability, from the same system. In addition, the equivalent width of the absorption features is higher (by as much as a factor of 3) in the fainter component. Hence, this component could be the nearest to the center of the absorption system, as would be typically expected if this system were the lens galaxy.

To obtain information on some essential parameters of the gravitational mirage, we assume a singular isothermal sphere (SIS) lens model (Schneider, Ehlers, & Falco 1992). In this simple model, assuming a flat universe, the redshifts of the lens and source and the angular separation between the images determine the velocity dispersion for the lens galaxy. Adopting $z_d = 0.83$, $z_s = 1.377$, and a separation of 1″.1, we obtain $\sigma_{SIS} = 272$ km s^{-1}, a value that is very close to the velocity dispersion that can be inferred from the FWHMs of the Mg II doublet in image A ($\sigma_A = 268 \pm 37$ km s^{-1}), although it is greater than that obtained from B ($\sigma_B = 192 \pm 10$ km s^{-1}). As we do not have a secure value of the true flux ratio, A/B (this parameter must be measured from observations at radio frequencies), and estimation of the time delay is not possible. However, we can infer an upper limit (on the time delay between both images) of about 3.3 h^{-1} months.

5. SUMMARY

We have spectroscopically resolved the two components of SBS 0909+532, finding that they basically are images from the same object, a QSO at $z = 1.377$. The lens galaxy is not definitively identified, but the absorption system at $z = 0.83$, which appears stronger in the fainter component, seems to be a good candidate. If this is confirmed, we are dealing with a bright gravitational mirage of less than 100 h^{-1} days time delay, which could be a suitable system for computing H_0. In order to exclude the possibility that the system is a binary quasar, observations at radio frequencies as well as the identification of the lens galaxy are fundamental steps.

The spectra obtained from Q1222+226 reveal that one of its components is a quasar ($z = 0.436 \pm 0.002$), while the other is indeed a star. The gravitational lens hypothesis is discarded for this candidate.

The 4.2 m William Herschel Telescope is operated on the island of La Palma by the Isaac Newton Group of Telescopes in the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias. We are especially grateful to Emilio Falco for advising us on the presence of the candidate SBS 0909+532 and providing us with the preprint of his paper. This work was supported by the P6/88 project of the Instituto de Astrofísica de Canarias (IAC), grant BFI93127 of the Spanish Departamento de Educación, Universidades e Investigación del Gobierno Vasco (for A. O.), and several projects of the Universidad de Cantabria.

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