1 The aim

The aim of this contribution is to present the two first phases of the optical monitoring programme of the Gravitational Lenses group at the Universidad de Cantabria (GLUC, http://grupos.unican.es/glendama/). In an initial stage (2003 March-June), the Estación de Observación de Calar Alto (EOCA) was used to obtain $VR$ frames of SBS 0909+532 and QSO 0957+561. These observations in 2003 led to accurate fluxes of the two components of both double QSOs, which are being compared and complemented with data from other 1-1.5 m telescopes located in the North Hemisphere: Fred Lawrence Whipple Observatory (USA), Maidanak Observatory (Uzbekistan) and Wise Observatory (Israel). On the other hand, the GLUC started the second phase of its monitoring programme in 2005 January. In this second phase, they are using the 2 m fully robotic Liverpool Telescope (LT). The key idea is the two-band photometric follow-up of four lensed QSOs with different main lensing galaxies: SBS 0909+532 (elliptical), QSO 0957+561 (giant cD), B1600+434 (edge-on spiral) and QSO 2237+0305 (face-on spiral). Thus, the light rays associated with the components of the four gravitational mirages cross different galaxy environments, and the corresponding light curves could unveil the content of these environments. While SBS 0909+532 and QSO 0957+561 are the targets for the two first years with the LT (2005-2006), the rest of targets (B1600+434 and QSO 2237+0305) will be monitored starting from 2007.

The photometry and the analysis of data are conducted by the GLUC members and collaborators in several non-Spanish institutes, and we focus on the most relevant measurements, i.e., detection of intrinsic events (caused
by the sources), time delay and flux ratio estimates, quantitative study of the structure and chromaticity of the intrinsic signals, determination of chromatic (between two optical filters) delays, and detection of extrinsic fluctuations (due to intervening objects in the involved galaxies, e.g., microlenses or dusty clouds). These measurements are used to tackle three hot astrophysical subjects: current expansion rate of the Universe, structure of the main lensing galaxies and nature of the sources (QSOs). The discovery of variable field stars or supernova explosions might be a bonus of the programme.

2 SBS 0909+532

SBS 0909+532 consists of two components (double QSO) separated by about 1 arcsec [1, 2, 3, 4]. The lensing elliptical galaxy has a large effective radius with a correspondingly low surface brightness [3]. In Fig. 1 (top panel) we show a Maidanak subframe in the $R$ band, where there are two close quasar components, but the very faint galaxy is not apparent. Although the presence of a faint galaxy has a positive aspect: simple photometric model with only two close point-like sources (we can avoid additional complications arising from the use of a galaxy profile), the faint and extended lenses are not a good business for cosmological studies. The relative astrometry of the quasar components (with respect to the centre of the lens galaxy) is not accurate, and this fact plays a crucial role in the estimation of the Hubble constant or the surface density of the lens (see below).

During the Phase I monitoring (EOCA/2003), the set of optical frames cover the period between 2003 March 4 and June 2. Exposures in the $V$ and $R$ Johnson-Cousins filters were taken every night when clear. We have checked (via Wise data) the reliability of the EOCA differential photometry between widely separate and neighbouring stars (see the six field stars in the bottom panel of Fig. 1), and we have concluded that only the relative fluxes for neighbouring objects seem to be reliable. Therefore, as the photometric ruler (empirical PSF to compare with) is the normalised 2D profile of the "a" star and there is clear evidence of variability of the "c" star, measurements of the brightness of both quasar components (A and B) are always made with respect to the brightness of the nearby non-variable star "b". The $R$-band EOCA light curves are complemented with $R$-band fluxes from Maidanak frames, so the global monitoring period and the mean sampling rate (in the $R$ band) are 4 months ($\sim$ 120 days) and one point each 6 days, respectively. These are the first resolved brightness records of SBS 0909+532 [5].

Our data do not show any evidence for extrinsic fluctuations, and they can be interpreted as intrinsic signals. Moreover, the direct AB cross-correlation leads to very accurate $1\sigma$ determinations of the time delay ($\Delta \tau_{BA} = -45 \pm 1$ days, where the sign "−" means that the intrinsic signal is observed first in B and later in A) and the flux ratio in the $R$ band. Thus, the EOCA + Maidanak light curves rule out a delay close to three months, which has
been favoured in a recent prediction by the COSMOGRAIL collaboration [6]. This longer delay is viable only if a very particular extrinsic variability is considered. However, the new analysis has one weak point that we want to comment on here. There is a relatively poor overlap between the A and B records, when the A light curve is shifted by the best solutions of the time delay and the flux ratio, so we are trying to get a confirmation of the delay and the absence of extrinsic signal. The LT is being used for this purpose. On the other hand, the inaccurate position of the lensing galaxy (see above) does not permit to accurately measure the cosmic expansion rate ($H_0$) and the mean surface density of the lens ($<\kappa>$) [7, 8]. Using the concordance cosmological model, the redshifts of the deflectors and the source, basic astrometry of the system and the measured delay, our $1\sigma$ constraints are $H_0 = 82 \pm 41$ km s$^{-1}$ Mpc$^{-1}$ (isothermal profile) and $1 - <\kappa> = 0.43 \pm 0.21$ ($H_0 = 70$ km s$^{-1}$ Mpc$^{-1}$) [9]. In order to obtain new accurate astrometry of SBS 0909+532, we are applying for observation time in Cycle 16 of the Hubble Space Telescope.

The Phase II monitoring (LT/2005-2006) is more ambitious than the previous one. We take exposures in the $g$ and $r$ Sloan filters (RATCAM optical CCD camera), and the robotic procedure is optimised to get frames all nights when SBS 0909+532 is visible (no occultation) if ideal conditions happen (no rain, no clouds, no technical problems, no fires...). From 2005 October to 2006 June we achieved a good sampling, so we focus in the preliminary $r$-band light curves of this double QSO in that period. In relation to the EOCA + Maidanak campaign in 2003 ($R$-band), the new 2005 October-2006 June season with the LT ($r$-band) has a better time coverage and resolution. Now we
Fig. 2. Preliminary $r$-band comparison between the shifted SBS 0909+532A light curve (red circles) and the SBS 0909+532B light curve (blue circles). In order to shift the A record, we use the EOCA + Maidanak delay, $\Delta \tau_{BA} = -45$ days, and a magnitude offset $\Delta m_{BA} = 0.65$ mag.

have a global monitoring period and a mean sampling rate of 8 months (\sim 240 days) and one point each 3 days, respectively. In Fig. 2 we use the EOCA + Maidanak delay (see above) and a magnitude offset $\Delta m_{BA} = 0.65$ mag to compare the B fluxes (blue circles) and the shifted fluxes of A (red circles). There is a reasonable agreement between the two components in Fig. 2, and these preliminary results encourage us. After to set a final selection criterium and include all the available fluxes, we hope to obtain accurate measurements (variability, time delay, flux ratio, etc) as well as important astrophysical information [10].

3 QSO 0957+561

The double quasar QSO 0957+561 was discovered 27 years ago in a radio survey [11]. At optical wavelengths, the main lens galaxy in the system appears as a relatively bright source close to the image B. This giant cD galaxy is part of a cluster of galaxies that also contributes to the lensing [12, 13]. The angular separation between B image and the centre of the cD galaxy is only of \sim 1", whereas the angular separation between A image and the galaxy is about five times larger [14]. In spite of almost 30 years of optical monitoring, there are several points of view about the origin of the variability in the QSO components. For example, while some people think that the records contain both long (\sim years) and short (\sim 100 days) timescale microlensing (extrinsic) events [15], other people have a very different opinion: there are no
clear evidences for microlensing variability [10]. From previous $g$-band light curves of the system, it was also inferred the existence of two different delays (associated with 100-day intrinsic events of amplitude $\sim 100$ mmag), $\Delta \tau_{BA} = 417.0 \pm 0.6$ days and $\Delta \tau_{BA} = 432.0 \pm 1.9$ days (1$\sigma$) [17]. The time delay difference ($15 \pm 2$ days) leads to a strong constraint for the separation of the two flares (in the far QSO) that cause the $g$-band intrinsic events: $\delta r \geq 300$ pc (concordance cosmology).

![Figure 3](image_url)

**Fig. 3.** LT light curves of QSO 0957+561A: deconvolution technique (blue/red points) and PSF fitting method (black points/lines). We use arbitrary zero points in the $gr$ flux (magnitude) scales.

The $VR$ frames taken in 2003 March-June (*Phase I monitoring*) are consistent with flat light curves for the B component. However, we detect moderate events of about 50 mmag (amplitude) in the records of A (lasting 10-30 days). In order to fully describe these $VR$ fluctuations, we looked for additional $VR$ images, which were taken in the Fred Lawrence Whipple Observatory (FLWO) and the Wise Observatory. Up to now we have only analysed the EOCA + FLWO records in the $V$ and $R$ bands. We do not find clear evidences in favour of chromaticity, but a proper interpretation of the events will require more effort and data (Wise?). Complementary data could help to fill the gaps and trace the moderate fluctuations with better accuracy [9].

Finally, just one year ago (2005 October-November) the LT caught a prominent gradient in the $g$-band brightness of the A component (*Phase II monitoring*), so a similar gradient will be very probably seen in the $g$-band light curve of B in 2006 December-2007 January ($\Delta \tau_{BA} \sim 14$ months). A detailed reduction of frames from two different techniques (deconvolution and PSF fitting) indicates the existence of a prominent fluctuation in the $g$-band...
record of A, which seems to be chromatic, with a smaller fluctuation in the r band (see Fig. 3). This exciting discovery will probably permit to measure a new high-quality g-band delay, the structure and chromaticity of the intrinsic signal, etc.

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