LONG-TERM MONITORING, TIME DELAY, AND MICROLENSING IN THE GRAVITATIONAL LENS SYSTEM Q0142-100

A. Oscoz1,2, M. Serra-Ricart1,2, E. Mediavilla1,2, and J. A. Muñoz3

1 Instituto de Astrofísica de Canarias, C. Vía Láctea s/n, E-38205 La Laguna, Spain
2 Departamento de Astrofísica, Universidad de La Laguna, E-38200 La Laguna, Spain
3 Departamento de Astronomía y Astrofísica, Universidad de Valencia, E-46100-Burjassot, Valencia, Spain

Received 2013 March 18; accepted 2013 October 22; published 2013 December 3

ABSTRACT

We present 12 yr of monitoring of the gravitational lens Q0142-100 from the Teide Observatory. The data, taken from 1999 to 2010, comprise 105 observing nights with the IAC80 Telescope. The application of the $\delta^2$ method to the dataset leads to a value for the time delay between both components of the system of $72 \pm 22$ days (68% confidence level), consistent within uncertainties with the most recent results. With this value in mind a possible microlensing event is detected in Q0142-100.

Key words: gravitational lensing: micro -- gravitational lensing: strong -- methods: observational

Online-only material: color figure

1. INTRODUCTION

Q0142-100 (UM 673), discovered by MacAlpine & Feldman (1982), was classified as a gravitational lens system for the first time by Surdej et al. (1987, 1988). This double quasar shows two identical images ($z = 2.719$) separated by 2′′ with the lensing galaxy ($z = 0.49$) placed among them (Surdej et al. 1988; Smette et al. 1992; Eigenbrod et al. 2007); see Figure 1. The especially propitious configuration of Q0142-100, with a large separation between both images, and their magnitudes ($m_R(A) \sim 16.5$ and $m_R(B) \sim 18.4$) make this system adequate for photometric monitoring from a medium-sized telescope. Moreover, a predicted time delay of only some months should have turned Q0142-100 into a very attractive target for time delay determinations. However, the difficulties arising from a lensing galaxy placed very close to the B fainter component, the low variations in magnitude of the light curves of both components, and the large annual gaps in monitoring make the calculation of the time delay very difficult. From the Teide Observatory, for example, reasonably close to the equator, Q0142-100 can be observed about 250 days per year, but this is more realistically a 210–220 day window each year when the mechanical limits of the telescope are taken into account.

This gravitational lens has been monitored since its discovery without very effective results. Daulie et al. (1993) observed it in the $B$ band from 1987 to 1993, but their observations were of modest quality, concluding that no significant variability was seen at the quasar. Some years later, Sinachopoulos et al. (2001) presented 29 $R$-band observations taken from 1995 to 2000, detecting variations of $0.2$ mag in their data and a global variation of $\sim 0.5$ mag since the system was discovered. Nakos et al. (2005) performed two-band, $V$ (23 points) and $i$ (18 points) photometry over 3 yr, 1998 October to 2001 December. Unfortunately, they were unable to measure the time delay due to the small variations in magnitude of the light curves, but found possible evidence for microlensing: component A, the brighter component, became bluer as it became brighter. Microlensing should be achromatic but, for the inner parts of compact accretion disks, the size of the emitting region varies with wavelength, and hence the microlensing magnification depends on the wavelength (see, e.g., Mediavilla et al. 2011 and references therein). The results of Nakos et al. (2005) point to a microlensing of the compact accretion disk: the central, bluer, part of the source is more amplified than the outer, redder parts.

Recently, Koptelova et al. (2010) obtained an estimate of the time delay between both components of Q0142-100 from observations made in the $V$, $R$, and $I$ bands during the period 2003–2005. These authors used a telescope at the Maidanak Observatory, and they were able to observe this lens for only three months each year. They claimed that the time delay between the A and B components of Q0142-100 is of about 150 days, with component B following the brightness variations of component A. To obtain this value, the observations at different bands were combined and then they interpolated up to 120 days to fill in the large gaps in which Q0142-100 cannot be observed. Finally, Koptelova et al. (2012) mixed these data with archival data from the Maidanak Observatory, additional Maidanak observations, and 2008–2010 CTIO data. Their new database covers the period 2001–2010, i.e., 10 observational seasons, and leads them to a new and lower value for the time delay: $95^{+14}_{-16} \pm 29$ days (68% and 95% confidence intervals), with $89 \pm 11$ days as the most probable result.

In this paper, we present the results of a photometric follow-up of Q0142-100 made with the IAC80 Telescope over more than 10 yr. This is, to our knowledge, one of the longest monitoring studies ever made of a gravitational lens system and comparable, of course at a lower scale, to what the Large Synoptic Survey Telescope will do. This monitoring includes 105 valid sessions of observation in the $R$ band, and has been performed within the gravitational lens program carried out at the Instituto de Astrofísica de Canarias. The observations and reduction processes are presented in Section 2, and the time delay determination is given in Section 3. A search for microlensing events is depicted in Section 4. Finally, the discussion is found in Section 5.

2. OBSERVATIONS AND DATA REDUCTION

Lens monitoring was performed over 12 yr, 1999–2010, using the 82 cm IAC80 Telescope at the Instituto de Astrofísica de Canarias’ Teide Observatory (Tenerife, Canary Islands, Spain). Two different CCDs were used. From 1999–2005 a Thomson 1024 × 1024 chip was employed, giving a field of view (FOV) of about 7.5′, with a pixel size of 0.′43. Since 2005 a new CCD, CAMELOT, was installed. CAMELOT hosts an
Figure 1. $R$-band image taken with CAMELOT@IAC80 (see text) of the field surrounding Q0142-100 (labeled as GL) where the main reference stars are marked as 1–6 following the notation of Nakos et al. (2003). North is up and east is to the right, with a field of view of 10$''$.4 × 10$''$.4. A zoomed view of the lens system has been included in the lower right corner of the image.

E2V 2048 × 2048 chip with 0$''.304$ pixels, corresponding to a 10.4 × 10.4 arcmin$^2$ FOV. A standard $R$ broadband filter was always used for the observations, corresponding fairly closely to the Landolt system (Landolt 1992). The final dataset comprises 105 points, each of them corresponding to several 900 s exposures.

A remarkable characteristic of the photometric data presented here is their high degree of homogeneity; they were obtained using the same telescope and filter over the entire monitoring campaign. Therefore, the reduction process can be the same for all of the frames. As a first step, the data were reduced using standard procedures included in IRAF$^4$ (Image Reduction and Analysis Facility$^5$) ccdred package.

We consider two main sources of error in our observations.

1. On the one hand, we take into account extinction errors: the main part of the variability of the observed target magnitude is explained in terms of atmospheric extinction and air-mass variability. Extinction errors are complicated by color terms when broad multi-band photometry is used.

2. On the other hand, we consider aperture photometry errors: due to the configuration of the Q0142-100 system, there are some specific aperture photometry errors to take into account. As demonstrated in Serra-Ricart et al. (1999), these errors are driven by seeing variations, and can be separated into two parts as follows. (1) The influence of the lens galaxy: since the core of the lens galaxy is very close to the $B$ image, most of the galaxy’s light lies inside the image $B$ aperture, but outside the image $A$ aperture. (2) Overlapping of images: the separation between the two images is 2$''$.2, and hence, when poor seeing conditions prevail, there is an important effect of cross-contamination of light between the two quasar images.

For extinction errors, the best and most traditional method to use is to measure differential photometry with several field stars close to the lens components (Kjeldsen & Frandsen 1992). Five stars in the vicinity of Q0142-100—defined as 1, 2, 3, 4, and 5 in Nakos et al. (2003)—are used. These stars were examined differentially in sets of four versus one star. This allowed us to establish the stability of each comparison star.

---

$^4$ IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under a cooperative agreement with the National Science Foundation.

$^5$ See http://www.noao.edu for more information.
After careful analysis, only two stars—1 and 3 for 1999–2005, 1 and 2 for 2007–2010—were selected as comparison stars for differential photometry. Photometric errors were calculated using the statistical error analysis developed by Howell et al. (1988), which uses the rms of the differential photometry of comparison stars (1–3 or 1–2 in our case) to deduce the photometric errors of lens components A and B. Figure 2 shows the differential $R$ magnitude for comparison stars. The final results are in good concordance with the values obtained by Nakos et al. (2003), who gave $R_3 - R_1 = 1.20 \pm 0.02$ and $R_2 - R_1 = 0.73 \pm 0.02$.

The solution for aperture photometry errors presents a higher level of difficulty. Although the two quasar images appear separated in the individual frames, the lensing galaxy is too faint to be detected ($R = 19.35$), and therefore its light is not considered in the final model fitting. Accurate photometry was obtained by simultaneously fitting a stellar two-dimensional profile on each lens component by means of point-spread function (PSF) profiles derived from bright field stars (1, 3, 4, 5 stars in the 1999–2005 data, and 1, 2, 3, 4 stars in 2007–2010 data). The automated PHO2COM IRAF task, described in Serra-Ricart et al. (1999), was used. In order to check the feasibility of the PHO2COM method, the $R$ magnitude and errors for both components are plotted versus FWHM in Figures 4–7. As demonstrated in Serra-Ricart et al. (1999), aperture photometry errors (mainly due to the influence of the lens galaxy and an overlapping of the lens component images) are driven by seeing variations. No seeing dependences are detected in the photometric error (or magnitudes), as can be seen in Figures 6 and 7 (and Figures 4 and 5), which means that aperture errors are minimized. On the other hand, it is also useful to show the final field obtained as a combination of all of the individual subtracted images for the 2007–2010 data. As shown in Figure 3, whereas the lens components are eliminated (the residuals of component A are around 0.01% of the original flux), some galaxy light remains, an additional proof that the PHO2COM method works well.

Finally, the apparent magnitudes of the A and B components were derived by comparing the instrumental fluxes with the star labeled as 1 (see Nakos et al. 2003) in both datasets. The results are shown in Figures 4 and 5. The average magnitudes of the A and B components are 16.42 and 18.42, with a standard deviation of 0.19 and 0.23, respectively, for the 1999–2005 data, whereas for 2007–2010, the results are 16.51 and 18.50 for the $A$ and $B$ magnitudes with errors of 0.06 and 0.07, respectively.
The mean difference in magnitude among both components, $\Delta M = M_B - M_A$, is $2.00$ for the two datasets. For the 1999–2005 data, the photometric errors (derived using the 1 and 3 field stars) of the A component data are of the order of 0.02 mag, while those of the B component are around 0.2 mag (see Figure 6). On the other hand, for the 2007–2010 data the use of the new CCD, with a different pixel size and closer comparison stars (1 and 2), allows the improvement of the error bars of both components, 0.05 and 0.007 mag for B and A, respectively (see Figure 7).

The result of the monitoring program is shown in Figure 8, where the light curves for components A (black) and B (red) in the $R$ band are presented.

3. TIME DELAY

Extracting useful information from the light curves of the components of a gravitational lens system requires a high degree of photometric accuracy. However, Q0142-100 is quite a difficult system to analyze, and not only due to its very complicated configuration, with the underlying lensing galaxy close to the faintest component. Additional general drawbacks are the small variation in magnitude of the light curves during the whole period and, in our particular case, the large errors in the magnitude of component B when the IAC80’s old CCD was used, the two large gaps in the data, and the relatively small amount of data points obtained during some of the observational seasons. On the other hand, the system can be observed for 210–220 days each year from the Teide Observatory, much longer than from other observatories, which seems sufficient for time delay calculations given the value obtained by Koptelova et al. (2012).

Each of our observational seasons covered several months of data, from the shortest final campaign of 53 days to a maximum of 201 days in the second, with five seasons covering more than 125 days. On the other hand, the inter-seasons gaps—besides the two large ones—are in the 150–240 day interval. These two

Figure 4. Apparent magnitudes of the A component for the old (red points) and new (black points) CCD when comparing the instrumental fluxes with those of reference star 1.

Figure 5. Same as Figure 4 for the B component of Q0142-100.
facts mean that our database allows the detection of a large range of possible time delays, between 10 and 250 days, except for time delays between 160 and 190 days for which the gaps in the observations prevent us from detecting the delay.

The dataset presents two main gaps (see Figure 8): TJD-2935 to TJD-3985 and TJD-4677 to TJD-5305, so three different natural subsets can be selected, in which the average magnitudes are $M_A(1) = 16.54$ ($\sigma = 0.12$), $M_B(1) = 18.55$ ($\sigma = 0.16$), $M_A(2) = 16.33$ ($\sigma = 0.13$), $M_B(2) = 18.34$ ($\sigma = 0.13$), $M_A(3) = 16.51$ ($\sigma = 0.06$), and $M_B(3) = 18.50$ ($\sigma = 0.07$).

The average magnitudes for the whole dataset are $M_A = 16.47$ ($\sigma = 0.14$) and $M_B = 18.47$ ($\sigma = 0.15$).

Prior to calculating the time delay, data must be checked to remove possible strong and simultaneous (not time-shifted) variations of data points in both components. These points probably originated from failures in the CCD or bad weather conditions, and their inclusion leads to artificial features in the light curves and so to wrong time delay determinations. To avoid this, we have eliminated the points with a simultaneous difference in magnitude in both components larger than 2.5 times their
error bar, as compared with the previous and subsequent records. This has been applied to those points with a difference in their observation dates of less than 10 days. Only 3 of the 105 initial points had to be removed.

### 3.1. The $\delta^2$ Method

There are several “classical ways” of obtaining the time delay between the components of a variable quasar from discrete, unevenly sampled temporary series: the discrete correlation function (Edelson & Krolik 1988), dispersion spectra (Pelt et al. 1996), linear interpolation (Kundić et al. 1997), and the $z$-transformed discrete correlation function (Alexander 1997), etc (see Oscoz et al. 2001 and references therein for a brief description of all these methods). In this paper, we will use the $\delta^2$ method (Serra-Ricart et al. 1999) to calculate the time delay of Q0142-100, as it offers very good results even with large gaps (Oscoz et al. 2001) and small variations in the flux of the components.

This method makes use of the similarity between the discrete autocorrelation (DAC) function of the light curve of one of the components (A, for example) and the A–B discrete cross-correlation function (DCF). This second order technique helps to improve the estimation of the time delay, as was stated in Oscoz et al. (2001), where a comparison of the results obtained with several statistical methods is made. Oscoz et al. (2001) demonstrate, with simulated and real data obtained from different telescopes, that the $\delta^2$ method offers the best results without interpolating data, even when large gaps are present.

The light curves of both components of a gravitationally lensed quasar have the same origin, and thus the same shape, which guarantees the fulfillment of the relationship $\text{DCF}(\tau) \simeq \text{DAC}(\tau - \Delta t_{BA})$, of course given that no strong microlensing masks the QSO’s intrinsic variability. From the DAC and DCF functions, one can define a function,

$$\delta^2(\theta) = \left( \frac{1}{N} \right) \sum_{i=1}^{N} S_i [\text{DCF}(\tau_i) - \text{DAC}(\tau_i - \theta)]^2,$$

for every fixed value $\theta$ (days), with $S_i = 1$ when both the DCF and DAC are defined at $\tau_i$ and $\tau_i - \theta$, respectively, and 0 otherwise. The most probable value of the time delay will correspond to the minimum of this function.

To calculate the DAC and the DCF functions, the procedure described in Edelson & Krolik (1988; see also Oscoz et al. 1997) was used. For two discrete datasets, $a_i$ and $b_j$, the DCF is defined as

$$\text{DCF}(\tau) = \frac{1}{M} \frac{(a_i - \bar{a})(b_j - \bar{b})}{\sqrt{(\sigma_a^2 + e_a^2)} \sqrt{(\sigma_b^2 + e_b^2)}},$$

averaging over the $M$ pairs for which $\tau - \delta \leq \Delta t_{ij} < \tau + \delta$, $\delta$ and $e_k$ being the bin semi-size and the measurement error associated with the dataset $k$, respectively, while $\sigma_k$ is its standard deviation. This equation leads to the expression for the DAC in a straightforward manner.

### 3.2. Results

Our first test to calculate the time delay from our data consisted in checking that it is in fact the B component light curve which follows the component A. For this, we applied the $\delta^2$ method to the whole dataset, with $\delta = 5$ days, taking into account both possibilities: A follows B and B follows A. In both cases, a time delay between 10 and 250 days was considered and the A component data were selected for the DAC calculations.
due to the lower error bars in the photometry. No clear pattern
for the time delay was found when the component A delayed
option was chosen, and the results of the $\delta^2$ test when component
B follows component A were 30 times better. Then, under
the assumption that component B follows component A, the
application of the $\delta^2$ test to the DAC and DCF curves appears in
Figure 9 (normalized to its minimum value), where the minimum
of the curve appears at 72 days, corresponding to the best delay.

To calculate the uncertainty in our estimate of the time delay,
we used a Monte Carlo algorithm. A random number generator
added a variable to each point of the dataset, giving a modified
value inside the range of its observational errors (see Efron &
Tibshirani 1986), thereby obtaining standard bootstrap samples.
The $\delta^2$ test was then applied to the bootstrap samples to obtain
the time delay. This process was repeated 10,000 times, a
number large enough for the results to be treated statistically.
The use of this Monte Carlo algorithm, again for delays between
10 and 250 days, gives a complicated distribution of values, as
it is multimodal. The results of the Monte Carlo procedure are
shown in Figure 10, in which the number of times that each
time delay is obtained for the whole dataset is plotted. A sharp
peak appears, corresponding to a time delay of 72 days, with
68% (1σ) of the iterations giving a time delay in the interval
50–94 days. Thus, we will consider a value of 72 ± 22 days as
the most probable time delay.

As was explained in previous sections, our database allows
the study of time delays between 10 and 250 days. None of
our results clearly favor the 150 days obtained by Koptelova
et al. (2010). However, our time delay estimate, 72 ± 22 days,
does agree within uncertainties with the time delay derived by
Koptelova et al. (2012), $95^{+14}_{-16} - 29$ days, and agrees even more
closely with their most probable value of 89 ± 11 days.

4. MICROLENSING

The light curves of the A (black) and B (red) images are
represented again in Figure 11, this time delaying the B data
by 72 days and shifting them by $-2.00$ mag, the result of

$$\langle M_A \rangle - \langle M_B \rangle.$$  
As can be seen, both curves follow a similar
trend, mainly for the last set of data where the error bars
of component B are lower. However, when these curves are
inspected in more detail, it seems that between roughly half of
the second observational season, TJD-2800, and the end of the
third season, TJD-4039, component B delayed and shifted data
are systematically fainter than component A data.

This effect is better observed when the data corresponding to
each season are grouped and averaged. The second season, the
one with more observations and when this difference appears to
start, is divided into two. The results appear in Table 1. While
the values for most of the seasons (1, 2-first half and 4–9) are
The Astrophysical Journal, 779:144 (9pp), 2013 December 20

Oscorz et al.

Table 1
Average Values for Each Observational Season

| Season | (TJD) | SD | ED | NE | (MA) | (MB) | EA | EB | (MA)−(MB) |
|--------|-------|----|----|----|------|------|----|----|-----------|
| 1      | 2516.50 | 2454.64 | 2578.36 | 14 | 16.49 | 18.43 | 0.03 | 0.03 | -1.94     |
| 2 (1H) | 2811.62 | 2780.71 | 2842.53 | 9  | 16.60 | 18.61 | 0.02 | 0.02 | -2.01     |
| 2 (2H) | 2889.98 | 2844.60 | 2935.37 | 10 | 16.55 | 18.62 | 0.04 | 0.04 | -2.07     |
| 3      | 4001.92 | 3985.45 | 4018.38 | 4  | 16.25 | 18.38 | 0.01 | 0.02 | -2.13     |
| 4      | 4302.53 | 4229.71 | 4375.34 | 13 | 16.28 | 18.26 | 0.03 | 0.04 | -1.98     |
| 5      | 4631.05 | 4584.71 | 4677.39 | 12 | 16.36 | 18.39 | 0.02 | 0.02 | -2.03     |
| 6      | 5331.62 | 5305.69 | 5357.54 | 6  | 16.43 | 18.42 | 0.02 | 0.02 | -1.99     |
| 7      | 5741.58 | 5665.72 | 5817.44 | 9  | 16.48 | 18.45 | 0.01 | 0.02 | -1.98     |
| 8      | 6114.56 | 6056.62 | 6172.5  | 10 | 16.57 | 18.55 | 0.02 | 0.02 | -1.98     |
| 9      | 6442.00 | 6414.50 | 6469.5  | 11 | 16.52 | 18.53 | 0.01 | 0.02 | -2.00     |

Note. SD represents the starting date of the season, ED is the end date, NE the number of epochs included, 

\[ E_A = \sqrt{\frac{\sum (x_A - \langle x_A \rangle)^2}{n(n-1)}} \]

\[ E_B = \sqrt{\frac{\sum (x_B - \langle x_B \rangle)^2}{n(n-1)}} \]

where \( n \) is the number of epochs. 1H is the first half of season 2, and 2H is the second half.

Figure 12. Upper panel: seasonal averaged data, taken from Table 1, for the A (black) and B (blue) component. The red points correspond to the B component data shifted by -1.99 mag. In both cases, the B component data have been shifted by 72 days. The error bars are also included. Lower panel: \( \langle M_A \rangle - \langle M_B \rangle \) for each observational season. The dashed line represents the average value for most of the seasons, 1.99.

 Quite homogeneous, the second half of season 2 and season 3 are significantly different. In fact, \( \langle M_A \rangle - \langle M_B \rangle \) = -2.10 for these one and half seasons and -1.99 for the rest of the dataset. This is represented in Figure 12. In the upper panel, the seasonal averaged data are displayed, the black points represent the A component and the blue and red points represent the B component and the -1.99 mag shifted B component, respectively. Notice the coincidence of the black and red points except for these one and half seasons. The average data are shown in the lower panel, with the dashed line representing -1.99.

The variation in the difference of the average magnitude of both components during ~1200 days suggests the presence of a possible microlensing event, with our observations corresponding to the entrance and exit of the event. Although the season 3 points for component A do not overlap in time with the shifted season 3 points for component B, and the discrepancy could also be caused by a decrease in the intrinsic flux of the quasar, it seems that microlensing is indeed the most plausible explanation for this behavior. Unfortunately, we lack data for most of this period, and hence further evidence of this event cannot be obtained.

5. DISCUSSION

The result of a photometric follow-up of the gravitational lens system Q0142-100 in the R band is presented in this paper. The observations, taken with the 82 cm IAC80 Telescope at Teide Observatory, Spain, were made from 1999 to 2010, with 105 points obtained, as part of an on-going lens monitoring program. A calculation of the time delay between both components using the \( \delta^2 \) test has been performed. The resulting delay is 72 ± 22 days, very different from that obtained by Koptelova et al. (2010), but within the error bar of a later result given by Koptelova et al. (2012), 95 ±10 days (68% and 95% confidence intervals) and 89 ± 11 days as their most probable result.

Lehár et al. (2000) selected four models to fit several gravitational lens systems, among which is Q0142-100: (1) a dark matter model (singular isothermal ellipsoid, SIE), (2) a model based on photometric fits (constant \( M/L \)), (3) a dark matter model in an external shear field (SIE + \( \gamma \)), and (4) a photometric model in an external shear field (\( M/L + \gamma \)). However, neither an \( M/L \) nor a SIE model are good solutions for Q0142-100. In the first case, a poor fit to the positions and magnifications is obtained, whilst a great degree of misalignment relative to the luminosity is required to obtain a good fit for the SIE model. Both models improve their results when an external shear of \( \gamma \sim 0.07 \) is added, but this shear does not correspond to any shear estimate for the nearby galaxies.

The time delays predicted by Lehár et al. (2000) for Q0142-100 for the four different models are, given as \( h \Delta t \): SIE = 80.1 ± 0.3, SIE + \( \gamma \) = 84–87, \( M/L \) = 121.3, and \( M/L + \gamma \) = 115 ± 3. All of these are larger than the time delay we have derived and even larger than the results given by Koptelova et al. (2012).

We have attempted to use the time delay to fit the lens models but unfortunately, given the large error bar, our current time delay estimation cannot yet be used as an extra constraint to clarify the properties of the lens mass model.

Our estimate of the time delay and the one derived by Koptelova et al. (2012) are below the time delay predicted by the theoretical models, even taking into account the large uncertainties. This could be explained if some nearby, not yet detected (maybe the bright galaxy just to the north of the lens
system, see Figures 1 and 3), components of the system have been missed and not included into the models. These missing components can be located either around the lens galaxy or on the line of sight to the quasar. Although a more accurate value of the time delay could help to reduce the uncertainties in the model, it seems clear that finding more details on the system environment will help even more in understanding it and reconcile the values of the time delay with those of the Hubble constant derived by other methods.

We are especially grateful to the Instituto de Astrofísica de Canarias’ support astronomer and night assistant teams for their help in the observations of most of the data appearing in this paper during routine and service times.

The 0.82 m IAC80 Telescope is operated on the island of Tenerife by the Instituto de Astrofísica de Canarias in the Spanish Observatorio del Teide.

Facilities: OT:0.8m

REFERENCES

Alexander, T. 1997, in Astronomical Time Series, ed. D. Maoz, A. Sternberg, & E. M. Leibowitz (Dordrecht: Kluwer), 163

Daulie, G., Hainaut, O., Hutskoers, D., et al. 1993, in 31st Lige Intl. Astrophys. Collow., Gravitational Lenses in the Universe, ed. J. Surdej et al. (Lige: Univ. Lige Press), 181
Edelson, R. A., & Krolik, J. H. 1988, ApJ, 333, 646
Efron, B., & Tibshirani, R. 1986, StaSc, 1, 54
Eigenbrod, A., Courbin, F., & Meylan, G. 2007, A&A, 465, 51
Howell, S. B., Mitchell, K. J., & Warnock, A. III 1988, AJ, 95, 247
Kjeldsen, H., & Frandsen, S. 1992, PASP, 104, 413
Koptelova, E., Chen, W. P., Chiueh, T., et al. 2012, A&A, 544, 51
Koptelova, E., Oknyanskij, V. L., Artamonov, B. P., & Burkhonov, O. 2010, MNRAS, 401, 2805
Kundić, T., Turner, E. L., Colley, W. N., et al. 1997, ApJ, 482, 75
Landolt, A. U. 1992, AJ, 104, 340
Lehár, J., Falco, E. E., Kochanek, C. S., et al. 2000, ApJ, 536, 584
MacAlpine, G. M., & Feldman, F. R. 1982, ApJ, 261, 412
Mediaville, E., Muñoz, J. A., Kochanek, C. S., et al. 2011, ApJ, 730, 16
Nakos, Th., Courbin, F., Poels, J., Libbrecht, C., et al. 2005, A&A, 441, 443
Nakos, Th., Ofek, E. O., Bounis, P., et al. 2003, A&A, 402, 1157
Oscoz, A., Alcalde, D., Serra-Ricart, M., et al. 2001, ApJ, 552, 81
Oscoz, A., Mediavilla, E., Goicoechea, L. J., Serra-Ricart, M., & Buítrago, J. 1997, ApJL, 479, L89
Pelt, J., Kayser, R., Refsdal, S., & Schramm, T. 1996, A&A, 305, 97
Serra-Ricart, M., Oscoz, A., Sanchís, T., et al. 1999, ApJ, 526, 40
Sinachopoulos, D., Nakos, Th., Bounis, P., et al. 2001, AJ, 122, 1692
Sméte, A., Surdej, J., Shaver, P. A., et al. 1992, ApJ, 389, 39
Surdej, J., Magain, P., Swings, J.-P., et al. 1987, Natur, 329, 695
Surdej, J., Magin, P., Swings, J.-P., et al. 1988, A&A, 198, 49