Photometric Variability of the Gravitational Lens 0142-100 (UM 673)

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Abstract

We report on the results of a photometric monitoring of the gravitational lens UM 673 (0142-100) through the years 1995-2000, with conclusions to significant variations in the total light (R band) of the system (component A + component B + lens galaxy). We also present R magnitudes and $V - R$ colours of seven field stars, situated in the neighborhood of UM 673. The latter results, based on data which were accumulated during a period of 3.5 months, consist in a preliminary tool for directly checking the photometric variability of the quasar.

1 Introduction

UM 673 was discovered by Surdej et al, in 1986. The angular separation between component A and B was found to be $2.''2$, while the magnitude of the QSO images and the lens galaxy, at the time of the discovery, was $R_A = 16.9$, $R_B = 19.1$ and $R_G \approx 19.1$ respectively, resulting in a total magnitude $R_{A+B+G} = 16.65$, with a standard deviation of the order of 0.2 magnitude. Daulie et al. (1993) claimed for a long term stability between 1987 and 1993, with observations in the B filter. Lehár et al. (2000) reported on HST observations of UM 673 performed in November 1994. The R magnitude of the components A, B, and the galaxy was $16.67 \pm 0.06, 18.96 \pm 0.05$ and 19.35 ± 0.04 respectively, resulting in an integrated magnitude of $R_{A+B+G} = 16.47$. The error on the total magnitude was of the order of $\sigma_R \approx 0.07^m$. UM 673 was also observed by the Sloan Digital Sky Survey in 1995 and 1996 (one night/filter/year), in their own photometric system (Richards et al. 1997 & Newberg et al. 1999). However, their results seem to be contradictory, since observations through different filters indicate a different trend (brightening/faintening) from one year to the other.

2 Observations

During the six-year monitoring period, we performed CCD photometry of UM 673 from four different observing sites. In detail, we observed at: (a) La Silla (Chile) in November 1995 and December 1996 with the 0.6 m Bochum telescope and in October 1997, with the 0.9 m Dutch telescope. (b) Kryonerion (Greece) in 1998 October 29, using the 1.2 m telescope. (c) Tenerife (Spain) in 2000 August 23, using the 1.0 m OGS telescope. (d) Skinakas, Crete (Greece) from 2000 September to 2000 December, using the 1.3 m telescope.

3 Data reduction and results

3.1 Photometry of UM 673

The data reduction was performed by developing scripts in the ESO-MIDAS environment. We applied aperture photometry on our CCD frames in order to study the photometric behavior of the *total* light of UM 673, which is composed of the two lensed images plus the lensing galaxy. We used a circular aperture of 15.″0 to 18.″5 diameter for this purpose, depending on the observing run conditions (i.e. exposure time, quality of optics, seeing). A ring external to the primary aperture (the so-called "no-man's-land") was properly set to avoid contamination from the faint galaxy seen at the south of our target. A precise calculation of the sky background near the gravitational lens was performed by using a 2.″5 width ring, external to "no-man's-land".

Several equatorial photometric standard stars were observed during each night and a mean extinction coefficient and zero point were applied to the data of UM 673.

The incorporation of errors, apart from the aperture photometry errors, included the uncertainty due to the extinction correction and the zero point correction, as computed with the help of the photometric standard stars. The reduction of the data showed that the contribution of the first factor on the daily averaged values was practically negligible (of the order of a few milli-magnitude), thanks to the numerous exposures and the good observing conditions. The error due to the zero point and extinction correction was of the order of 0.055^m, $0.04^m, 0.015^m, 0.04^m$ and 0.015^m for the 1995 to 2000 missions, respectively.

Table 1 contains the R-band photometric results. Column 2 contains the number of nights per observing run, while column 3 contains the mean value and its standard deviation for each run. Our results, together with the two R-band measurements available in the literature (Surdej et al. 1987, Lehár et al. 2000) are plotted in Fig. 1.

Table 1. Mean R magnitudes (total light) of UM 673 and its standard deviation per photometric run

Date	**N**	**R**
03 - 10 Nov. 1995	3	16.30 ± 0.02
09 - 19 Dec. 1996	12	16.08 ± 0.01
22 - 26 Oct. 1997	5	16.30 ± 0.01
29 Oct. 1998	1	16.23 ± 0.05
23 Aug. - 15 Dec. 2000	9	16.34 ± 0.01

3.2 Reference stars in the vicinity of UM 673

Thanks to the relatively large field of view of the configuration of the Skinakas 1.3 m telescope, it was possible to perform aperture photometry on ten field stars in the neighborhood of UM 673, which were present in the majority of our frames. The variability of the field stars was checked by properly co-adding all the frames of the given night and then performing aperture photometry on them. The results obtained from the differential photometry of all the possible combinations showed that for most cases the mean errors in the magnitude differences were between 0.01-0.03 magnitude, except for three stars. Therefore, we finally decided to reject them, and to use the rest for checking the variability of UM 673.

A finding chart with the identification of the field stars is given in Fig. 2. By using the same photometric standards that were used for the lens, we performed a zero-point and extinction correction, converting the instrumental values to V and R magnitudes. Second-order extinction correction and colour transformation were not performed. We also performed a preliminary astrometric identification

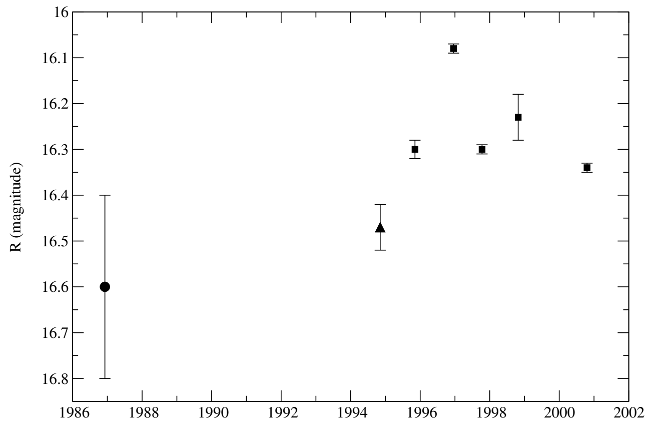

Figure 1. R-band variability of UM 673 during a fourteen-year interval (total light). The symbols "bullet", "triangle" and "square" correspond to Surdej et al. (1987), Leár et al. (2000) and our measurements, respectively.

with the help of the *XEphem* software, developed by E. Downey (2000)[1]. By correlating our results with the co-ordinates presented in Newberg et al. (1999), we identified the seven field stars. Table 2 lists the RA-Dec co-ordinates of the reference stars, their R magnitude and $(V-R)$ colour, including errors associated with the determination of the instrumental magnitudes.

Table 2. New reference stars in the field of UM 673

N^o	RA (2000) (hh mm ss)	Dec (2000) ($\circ$ $'$ $''$)	R (mag)	$V-R$ (mag)
1	01 45 12.05	−09 47 49	15.92 ± 0.02	0.51 ± 0.03
2	01 45 07.15	−09 49 01	16.61 ± 0.02	0.94 ± 0.03
3	01 45 08.73	−09 43 13	17.12 ± 0.02	0.33 ± 0.03
4	01 45 03.43	−09 44 18	17.37 ± 0.02	0.84 ± 0.04
5	01 44 57.90	−09 44 09	17.42 ± 0.02	0.84 ± 0.04
6	01 44 56.26	−09 44 15	17.80 ± 0.02	0.42 ± 0.04
7	01 44 56.63	−09 43 02	16.75 ± 0.03	0.38 ± 0.04

4 Conclusions

We have been monitoring the gravitational lens UM 673 through the years 1995 - 2000. To measure the total light of the lens (component A + component B + lensing galaxy) we constrained ourselves to aperture photometry. The photometric calibration was performed with the help of several photometric standard stars. Although the observations were performed using several configurations, all measurements agree with the conclusion that the QSO has undergone a long term variability, that corresponds to a brightening in the total light of the system of $\approx$ 0.3 magnitude with respect to its discovery value, in 1987. From the agreement between the 1995 and 1997 measurements we see that this variability had its peak (additional $0.^{m}2$ brightening) in 1996.

Thanks to the optimized configuration of the Skinakas observatory, we managed to have V and R measurements of seven field stars in the vicinity of UM 673 during the period September - December 2000. Although more observations are needed for a better knowledge about the stability of these stars over a longer time-basis, the photometric reduction showed no significant variability at the level $0.02 - 0.03$ magnitude.

[1] *XEphem - An Interactive Astronomical Ephemeris Program for X Windows* is available at http://www.ClearSkyInstitute.com/xephem

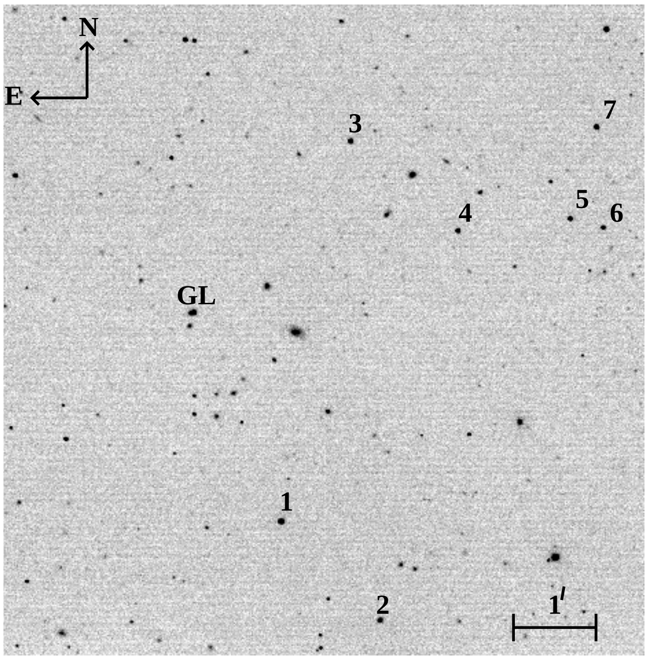

Figure 2. Finding chart (8" × 8") of UM 673 in the R-band, where the reference field stars (labeled 1−7) are shown. The position of the lens system is also marked. This figure consists of four different combined images resulting in a total exposure time of 16 min (4 min each).

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