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ASTRONOMIE

A LENS MODEL FOR Q2237+0305

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In 1984, HUCHRA et al. [1] serendipitously discovered a gravitational lens system Q2237+0305 later called "Einstein Cross" due to image geometry. It consists of a SBb galaxy ($z = 0.0394$) and four (or five?) images of a distant quasar ($z = 1.695$), very close (about 0.9 arcsec) to the galaxy nucleus (TYSON & GORENSTEIN [2], YEE [3], RACINE [4]).

The gravitational lens system Q2237+0305 has been modelled by many authors (SCHNEIDER et al. [5], KENT & FALCO [6], KOCHANEK [7], MINAKOV & SHALYAPIN [8], RIX et al. [9], WAMBSGANSS & PACZYŃSKI [10], WITT et al. [11]). In these papers, image positions with accuracy equal to or less than ±0.01 arcsec were used, except in the one of Wambsganss & Paczyński [10], where image positions with formal error of ±0.005 arcsec from CRANE et al. [12] are used. But we can better constrain the macrolensing model with higher accuracy in the image position. By reason of that, the aim of the present work is to model the gravitational lens system Q2237+0305 using image positions with accuracy higher, than has been used in the above cited papers.

The projected mass distribution in the lens is represented by a singular isothermal ellipsoid (SIE, KORMANN et al. [13]). We adopt the observational accuracy of ±0.002 arcsec from Racine [4] as variances of the image positions. There are uncertainties larger than Racine's data in our observations taken with the 2m RCC telescope at the NAO Rozhen – Bulgaria with CCD ST-6 camera, so we do not include them as observational constraints. Einstein – de Sitter Universe with Hublle parameter $H_0 = 75$ km/s/Mpc was used.

We use a standard procedure for fitting a lens model to the data (Wambsganss & Paczyński [10], HOGG & BLANDFORD [14]). We do not try to match flux ratios and therefore the number of the observational constraints is 8 (coordinates of the images relative galaxy centre). The number of the parameters is 5 (source coordinates and 3 parameters of the SIE), so we have 3 degrees of freedom (DF). The best model has χ^2/DF about 22. Its parameters are presented in Table 1. Figure 1 shows the observed and predicted image configurations.

The additional parameters are calculated according to Kormann et al. [13]. They are presented in Table 2. These are the magnification ratios μ_{mn} and the relative time

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Table 1

Parametre	Value	Units
Velocity dispersion	179.8 ± 0.1	km/s
Ellipticity	0.356 ± 0.004	
Position angle	66.84 ± 0.06	degree
Source position $\Delta\alpha$	-0.068 ± 0.001	arcsec
Source position $\Delta\delta$	-0.011 ± 0.001	arcsec

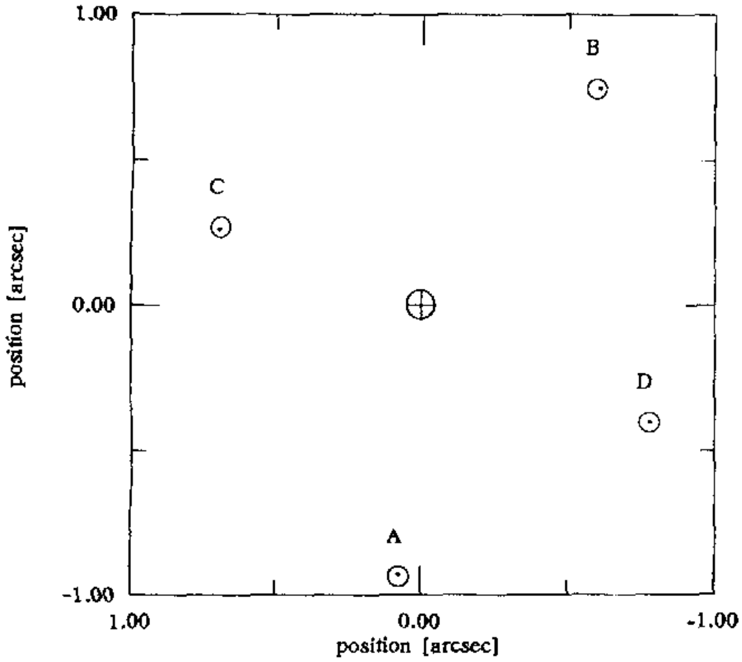

Fig. 1. Observational (circles) and theoretical (points) image positions with respect to the galaxy centre (circle with cross). The differences between the observed and predicted positions (in arcsec) of the images are: for A image – 0.009, for B – 0.010, for C – 0.006 and for D – 0.005

delays t_{mn} between the images, the surface mass densities k_m and the local values of the shear γ_m at the image positions.

The total magnification is $\mu_{tot} = 14.751 \pm 0.097$. The mass inside the "Einstein ring" is $M(\leq 0.88 \text{ arcsec}) = 1.493 \pm 0.003 \times 10^{10}\ M_\odot$.

The parameters presented in this work are in good agreement with the parameters obtained in the above cited papers. In particular, our estimate of the mass inside the "Einstein ring" is very close to the value of the mass obtained by Rix et al. [9] and Wambsganss & Paczyński [10], who used different lens models. This fact confirms the result pointed out by Kochanek [7] (see also Kent & Falco [6]), that only the mass inside the ring of the images is a well determined parametre for the quadruple systems. One can see from Fig. 1 that this simple model successfully reproduces the lens system geometry, but the difference between the observed and theoretical image positions is still larger than the observational uncertainty; even without matching the flux ratios χ^2/DF is much larger than the unity. This fact indicates that the model of the Q2237+0305 lens based on the SIE mass distribution does not work very well and must be improved. This will be done in a following paper.

T a b l e 2

Parametre	Value	Units
μ_{BA}	0.871 ± 0.015	
μ_{CA}	-0.437 ± 0.012	
μ_{DA}	-0.837 ± 0.013	
t_{AB}	0.4 ± 0.2	hours
t_{CB}	13.0 ± 0.2	hours
t_{DB}	11.9 ± 0.2	hours
k_A	0.393 ± 0.001	
k_B	0.377 ± 0.001	
k_C	0.743 ± 0.004	
k_D	0.627 ± 0.002	
γ_A	0.393 ± 0.001	
γ_B	0.377 ± 0.001	
γ_C	0.743 ± 0.004	
γ_D	0.627 ± 0.002	

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