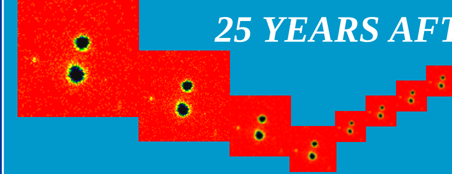


*25 YEARS AFTER THE DISCOVERY: SOME CURRENT TOPICS ON LENSED QSOs*

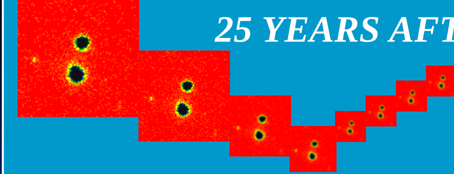
**Santander (Spain), 15th-17th December 2004**

# Short-time scale variability in gravitationally lensed quasars

***A.P. Zheleznyak, A.V.Sergeyev, V.V. Konichek , I.E.Sinelnikov***

Kharkov university, Ukraine

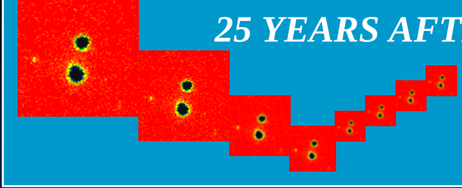
KhAO



*The goal of the work* : reanalyze available data to check for the presence of intranight brightness fluctuation in two gravitationally lensed quasars – Q0957+561 (“First Lens”) and Q2237+0305 (“Einstein Cross”).

An existence of brightness variation for both targets at large time scales now is well established by many researchers. The situation is not so evident for the shorter time scales. Particularly, the presence of fast brightness fluctuation for Q0957+561 A, B was discovered by *ColleyW.N & Schild R.E. ,2000, ApJ 540, p. 104*

***Maidanak observatory ( Central Asia, Uzbekistan altitude ~2500 m)***



# Q0957+561: *observational data*

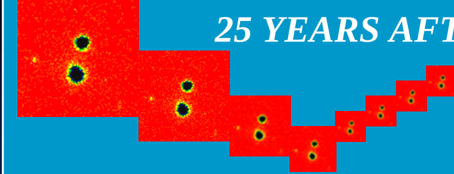
The data were obtained at Maidanak observatory during the second run of QuOC monitoring programme.

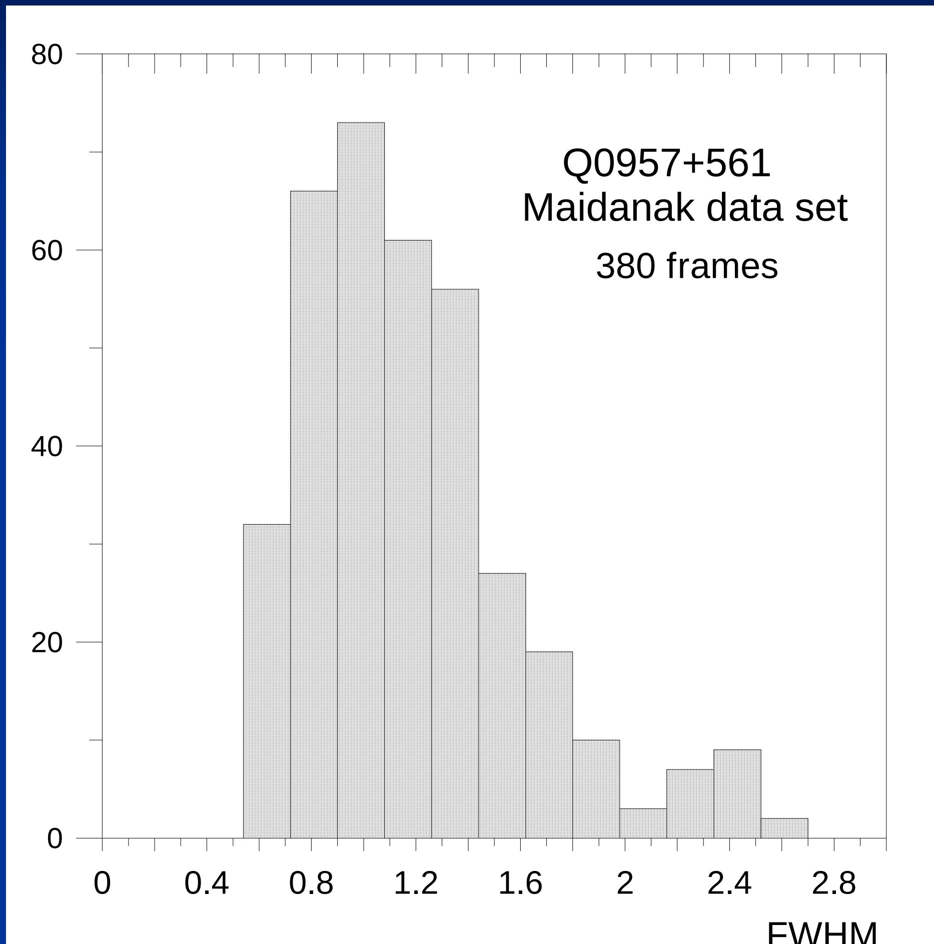
The main QuOC result – the time delay determination of Q0957+561 A,B images with uncertainty of ~ 2h - is presented in Colley W.N., Schild R.E. & 38 coauthors, ApJ 2003, 587, 1, P. 71.

The work similar to our with the QuOC data obtained with NOT, was fulfilled and published by Ovaldsen J.E., Teuber J. et al ., 2003, MNRAS, 345, 3 , P. 795. Reprocessing the NOT data had shown no significant brightness variation of Q0957+561 A,B components.

| Date, March 2001 | Totally frames, R band | Average FWHM, ″ |
|---|---|---|
| 14 | 53 | 0.86 |
| 15 | 57 | 1.16 |
| 16 | 48 | 1.18 |
| 17 | 46 | 1.64 |
| 18 | 40 | 1.89 |
| 20 | 60 | 0.89 |
| 21 | 64 | 1.00 |

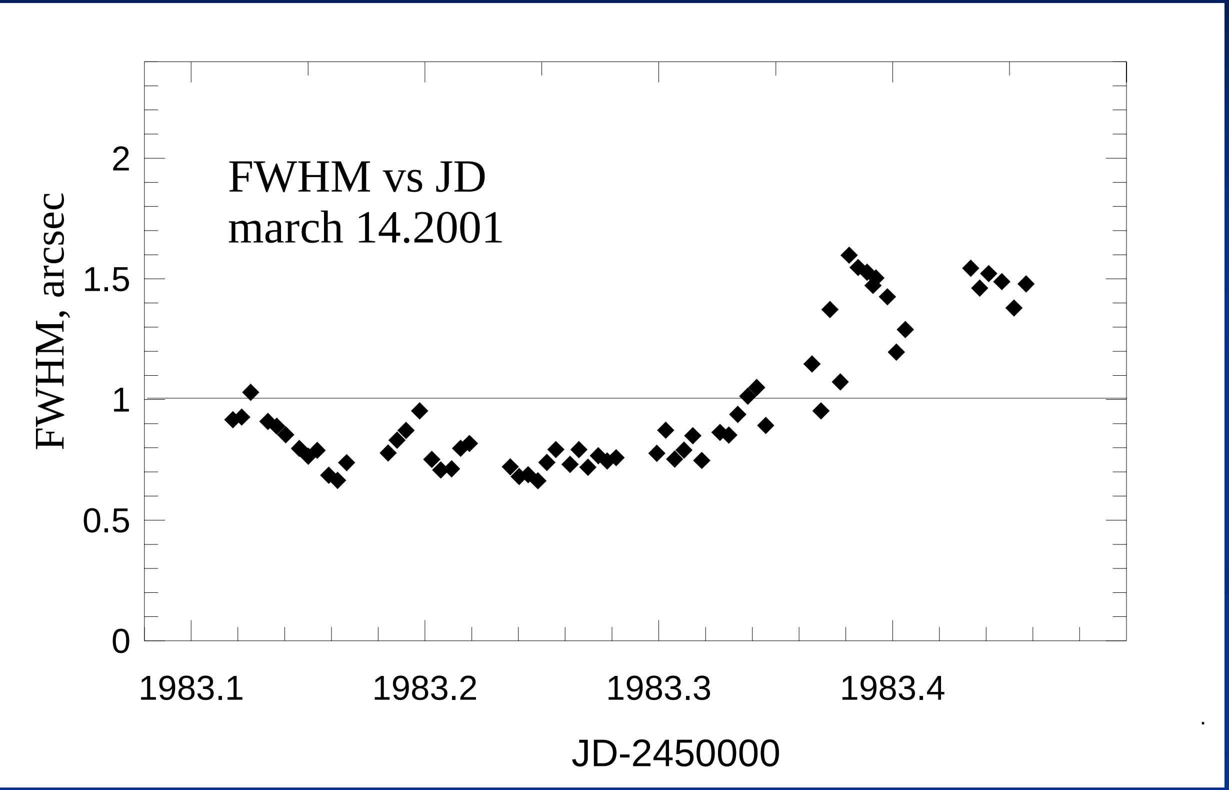
The Maidanak observatory QuOC dataset includes ~ 380 images for 7 nights of continuous observation with frame rate ~10 frames/hour. The main working band was R, the pixel angular size was equal 0.12 ″.





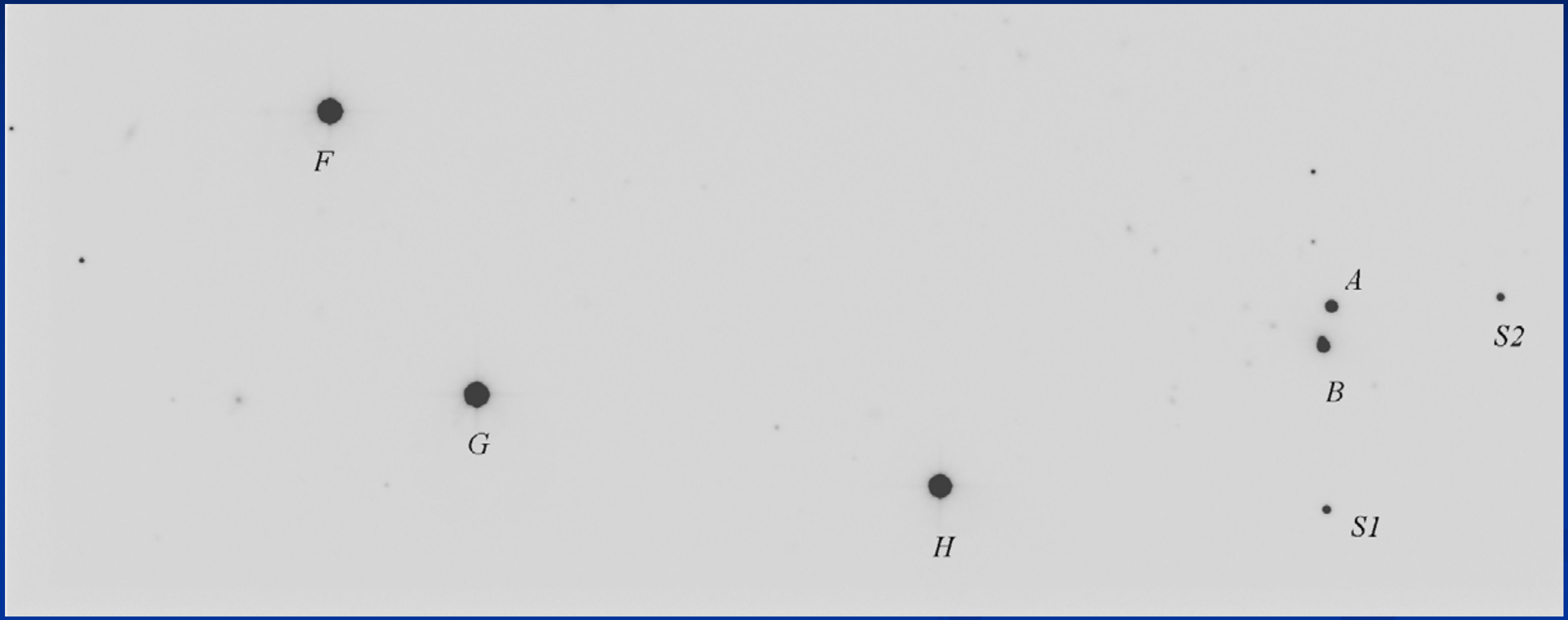

Q0957+561,
all frames

The distribution of seeing estimates (FWHM) for the whole set of frames of Q0957+561



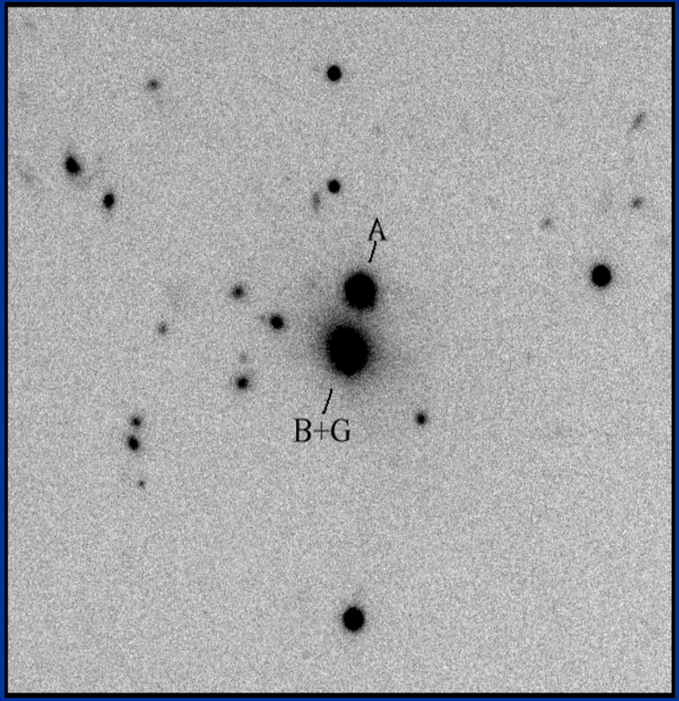

# Q0957+561, March 14

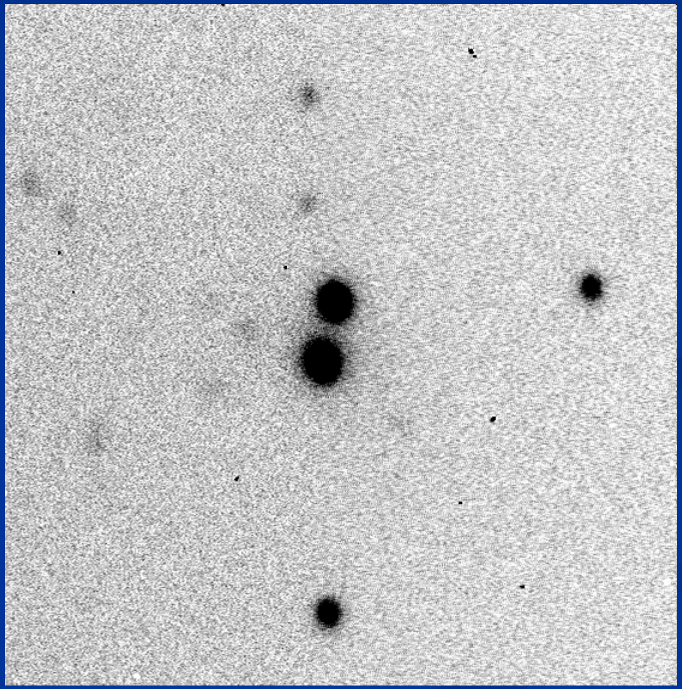
Seeing estimates for the set of frames of Q0957+561 obtained on March 14. 2001




CCD image of the field of Q0957+561 A,B obtained with 1.5 m AZT-22 telescope. The seeing FWHM=0.6", denoted standard stars F,G,H and comparison stars S1, S2.

# Some sources of photometry uncertainty:



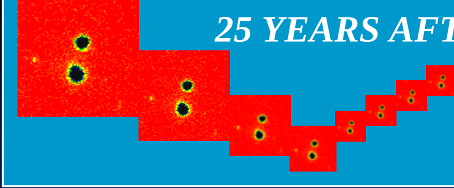



Presence of the lensing galaxy near B component

Variable seeing, tracking errors,…

# Photometry: the approach

The method of Optimal Image Subtraction (Alard C., Lupton R.H., 1998, ApJ 503, 325) was developed for the search of variable objects in crowded star fields, and was pioneered for photometry of Q2237 components by Wozniak P.R., Alard C. et al. 2000, ApJ 529, 88. The idea of the method - to determine the optimal convolution kernel, which reduce PSF of the reference frame to PSF of current frame, analysing PSF’s difference on all significant pixels. The result of subtraction of the reference frame, convolved with optimal kernel, from the given frame, contains only variable part of the flux for all objects in given image.





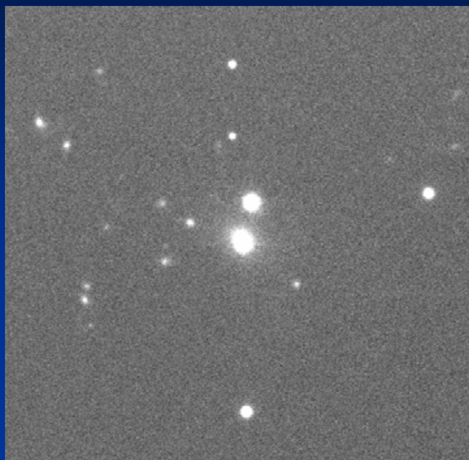
# Photometry: the approach

For centered images *Im(x,y)* and *Ref(x,y)*:

$$Im(x,y)+Bg(x,y) = Ref(x.y)\otimes Ker(u,v)$$

$$Ker(u,v)=\sum_{i,j,k,n} A_n\, e^{-\frac{(u^2+v^2)}{2\cdot\sigma_k^2}}\, u^i\, v^j$$

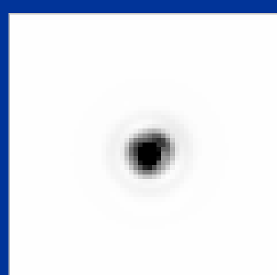
$$\sum_{x,y}([R\otimes Ker](x,y)-Im(x,y)-Bg(x,y))^2 \rightarrow \min$$



Referent frame

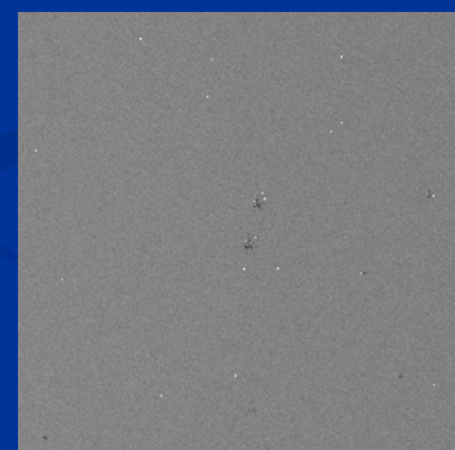
Current frame

Illustration of the work of image subtraction routine

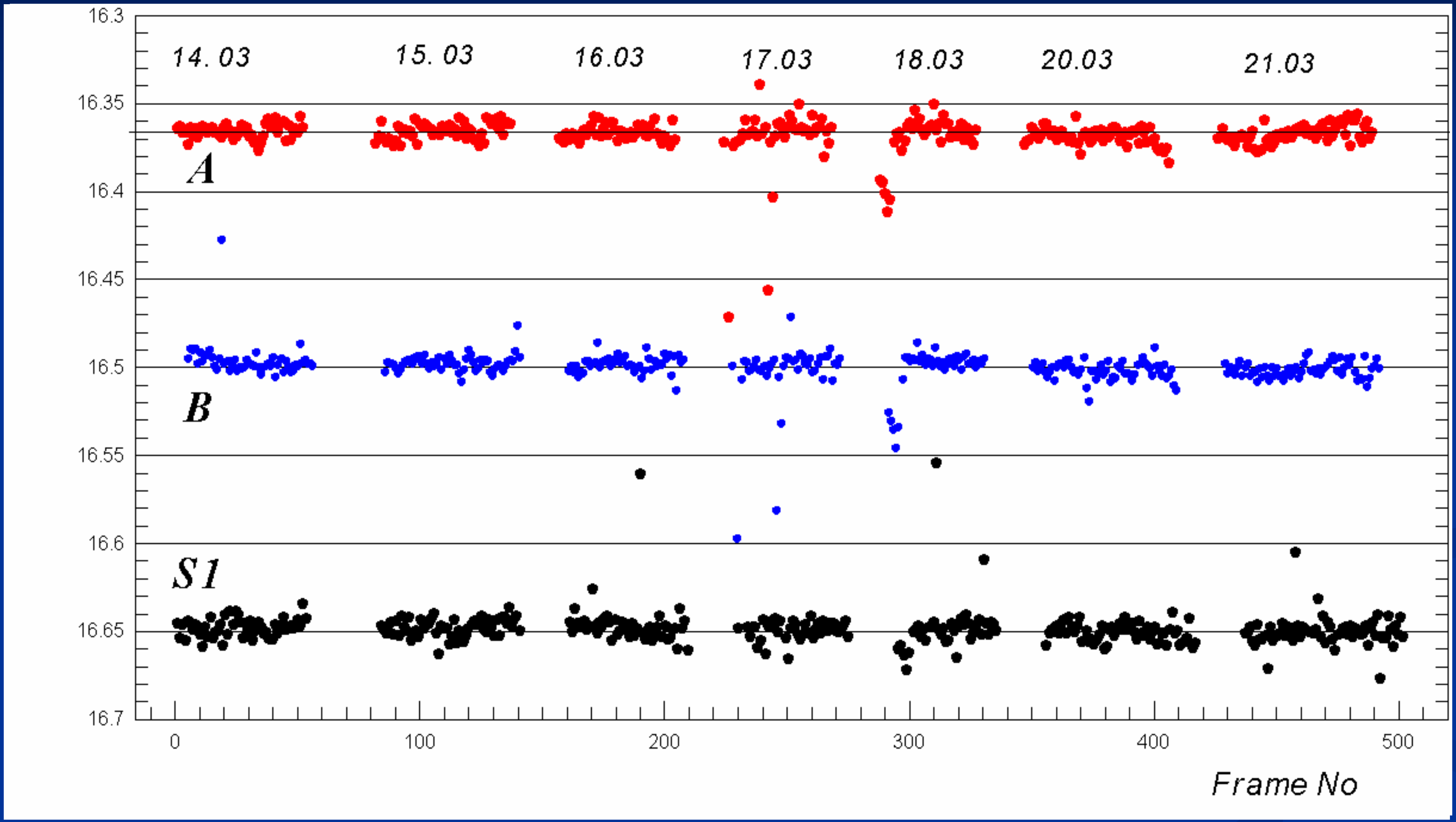


*Convolution kernel*

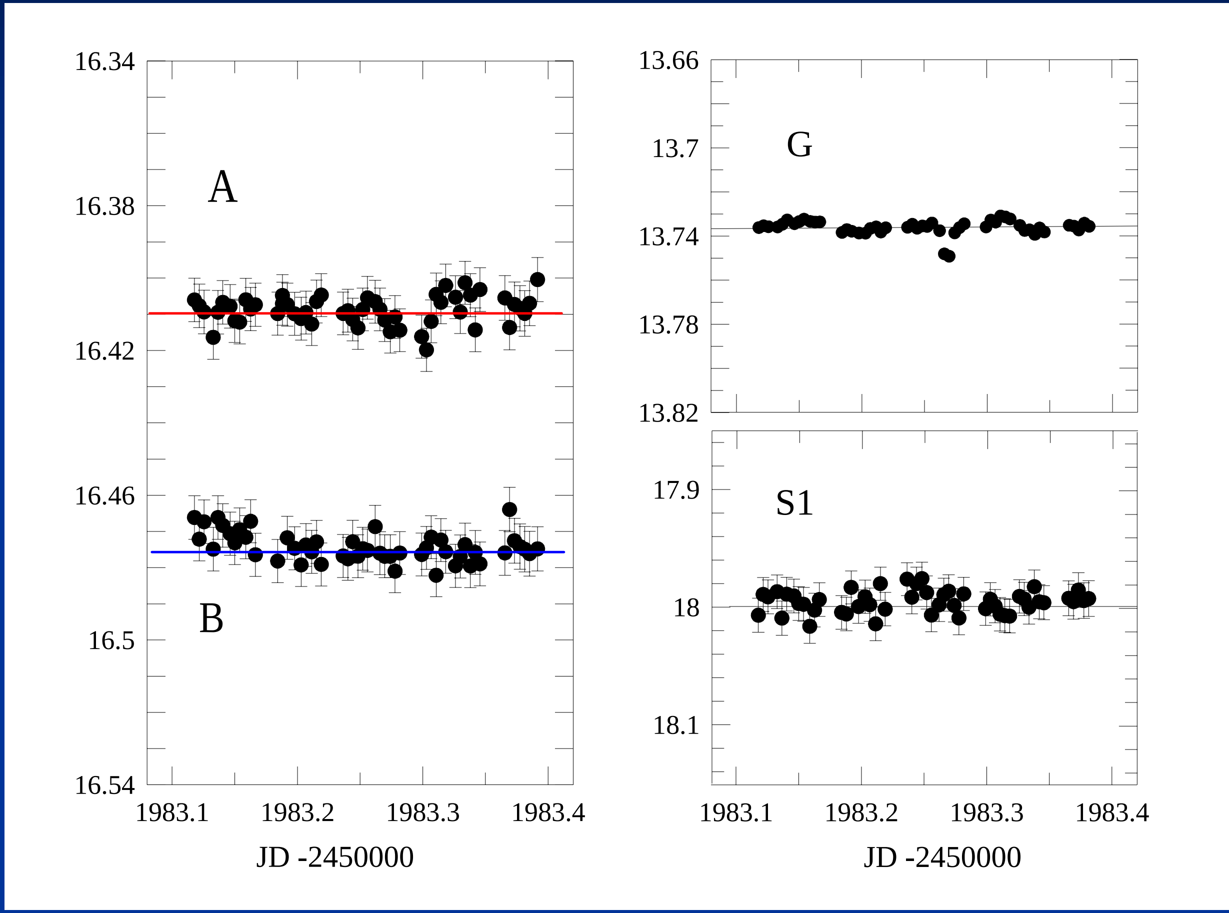
----------->



*Residual image*

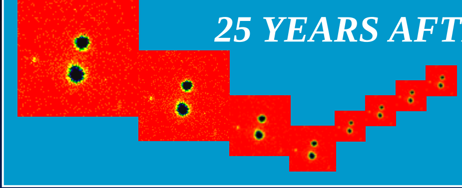


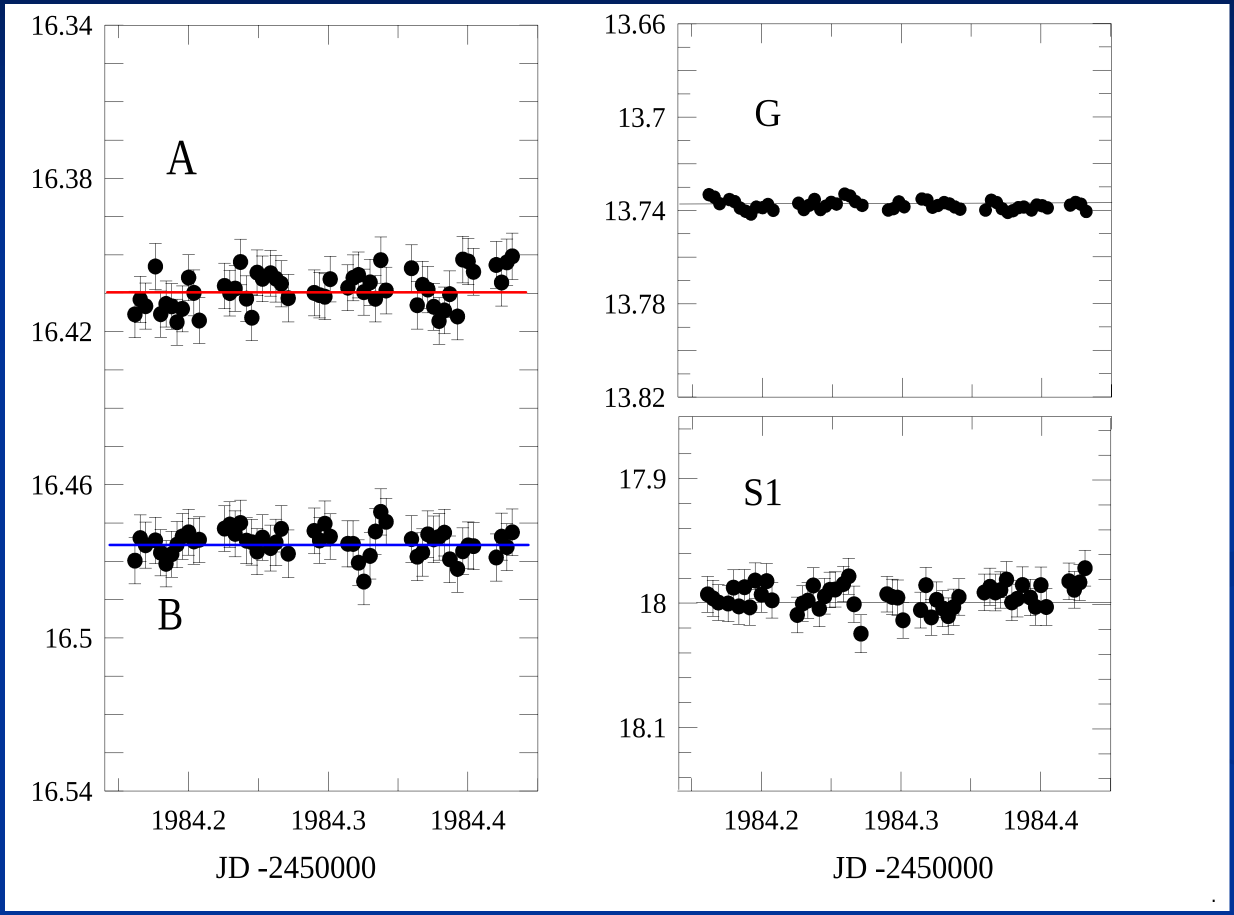

Q0957+561 A,B photometry for Maidanak data for 7 nights in March 2001. All the light curves are in the same scale but arbitrary shifted along Y. "Light curve" for star S1 is also plotted.




# Q0957+561, March 14

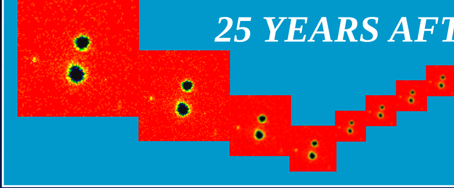
Light curves for Q0957+561 A, B, standard star G and comparison star S1



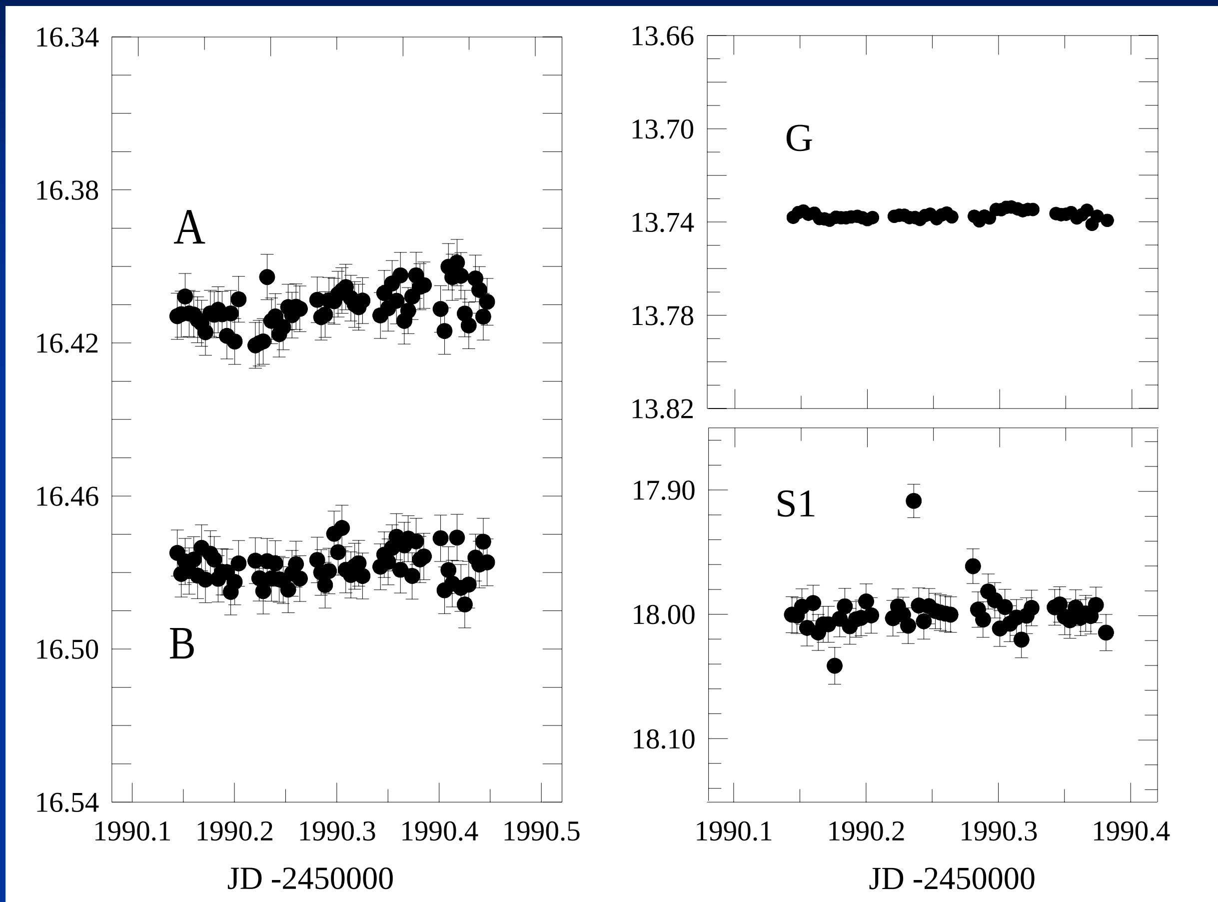



# Q0957+561, March 15

Light curves for Q0957+561 A, B, standard star G and comparison star S1







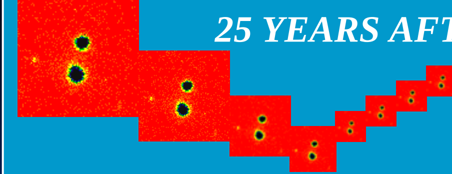

Q0957+561,

March 21

Light curves for Q0957+561 A, B, standard star G and comparison star S1

The results of *F*-test for Q0957+561 A,B components variability (95 % significance)

| Date, 2001 | Object | $N_P$ | $s^2_{V-C}$ | $s^2_{C-K}$ | $\Gamma^2$ | $F_T$ | Rezult |
|---|---|---|---|---|---|---|---|
| 14.03 | Q0957A | 56 | $2.499 \cdot 10^{-05}$ | $13.1 \cdot 10^{-05}$ | 0.13132 | 1.45015 | No |
| | Q0957B | 56 | $11.631 \cdot 10^{-}$ | $13.1 \cdot 10^{-05}$ | 0.13132 | 6.75067 | Yes |
| 21.03 | Q0957A | 52 | $1.667 \cdot 10^{-05}$ | $5.33 \cdot 10^{-05}$ | 0.12834 | 2.43860 | Yes |
| | Q0957B | 52 | $0.910 \cdot 10^{-05}$ | $5.33 \cdot 10^{-05}$ | 0.12834 | 1.33069 | No |

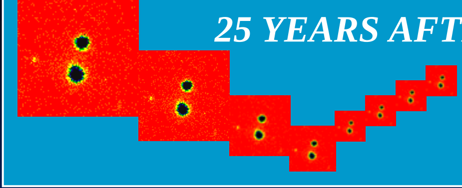


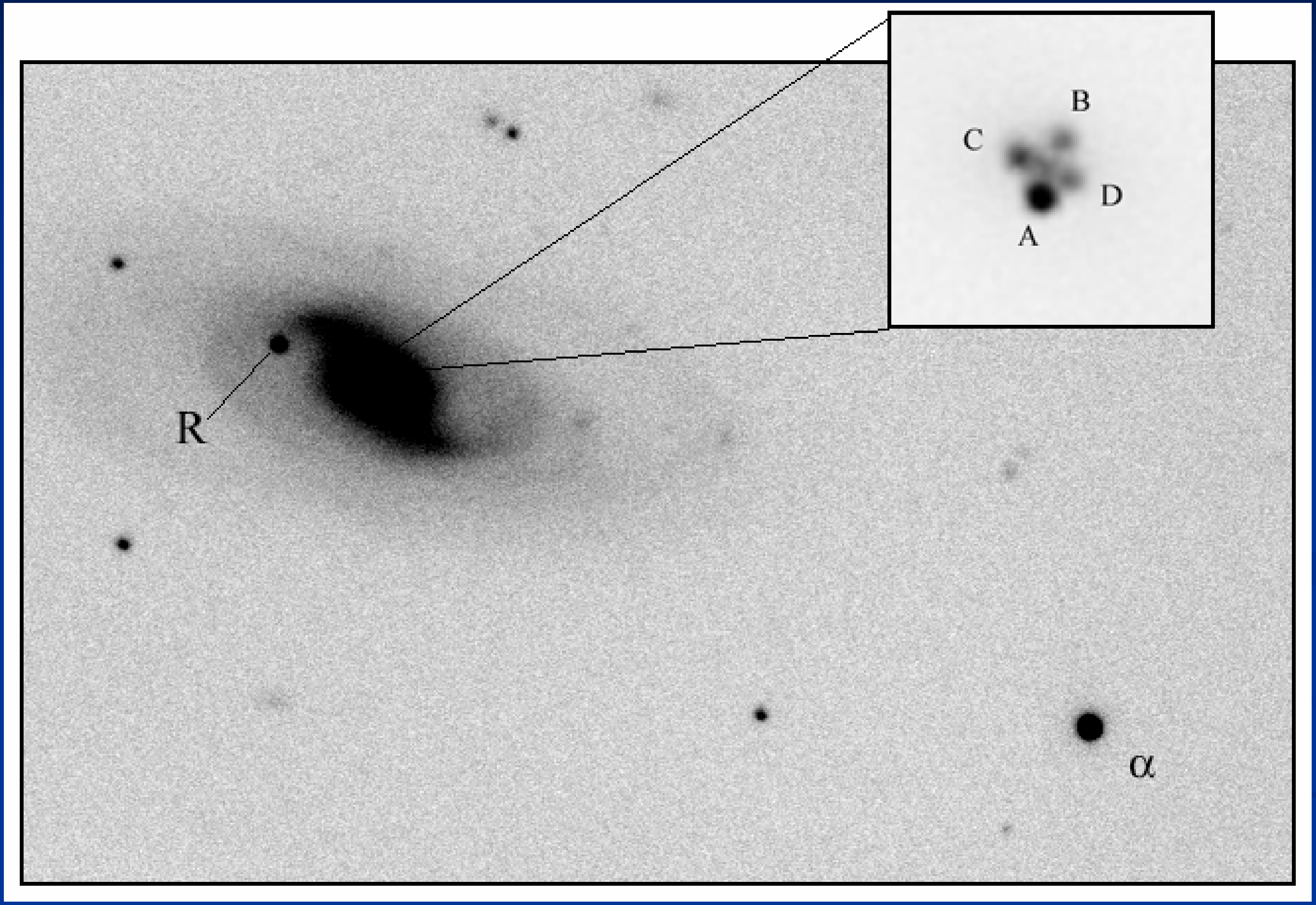


Q2237+0305: *observational data*

The data were obtained with AZT-22 telescope at Maidanak observatory during the continuous monitoring on July-August 2000. Totally 549 frames were aquired during 36 nights in R band. The ST-7 CCD camera was used as the light detector, providing the pixel size 0.12 ″.

The search for short-time scale variability for Q2237+0305 components was fulfilled by many authors, particularly, by C.M.Cumming M.M., de Robertis ( 1995, PASP 107, 469.), HST observations- Blanton M. et al. (MNRAS,298,4, p.1223)

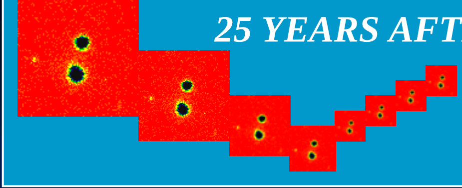


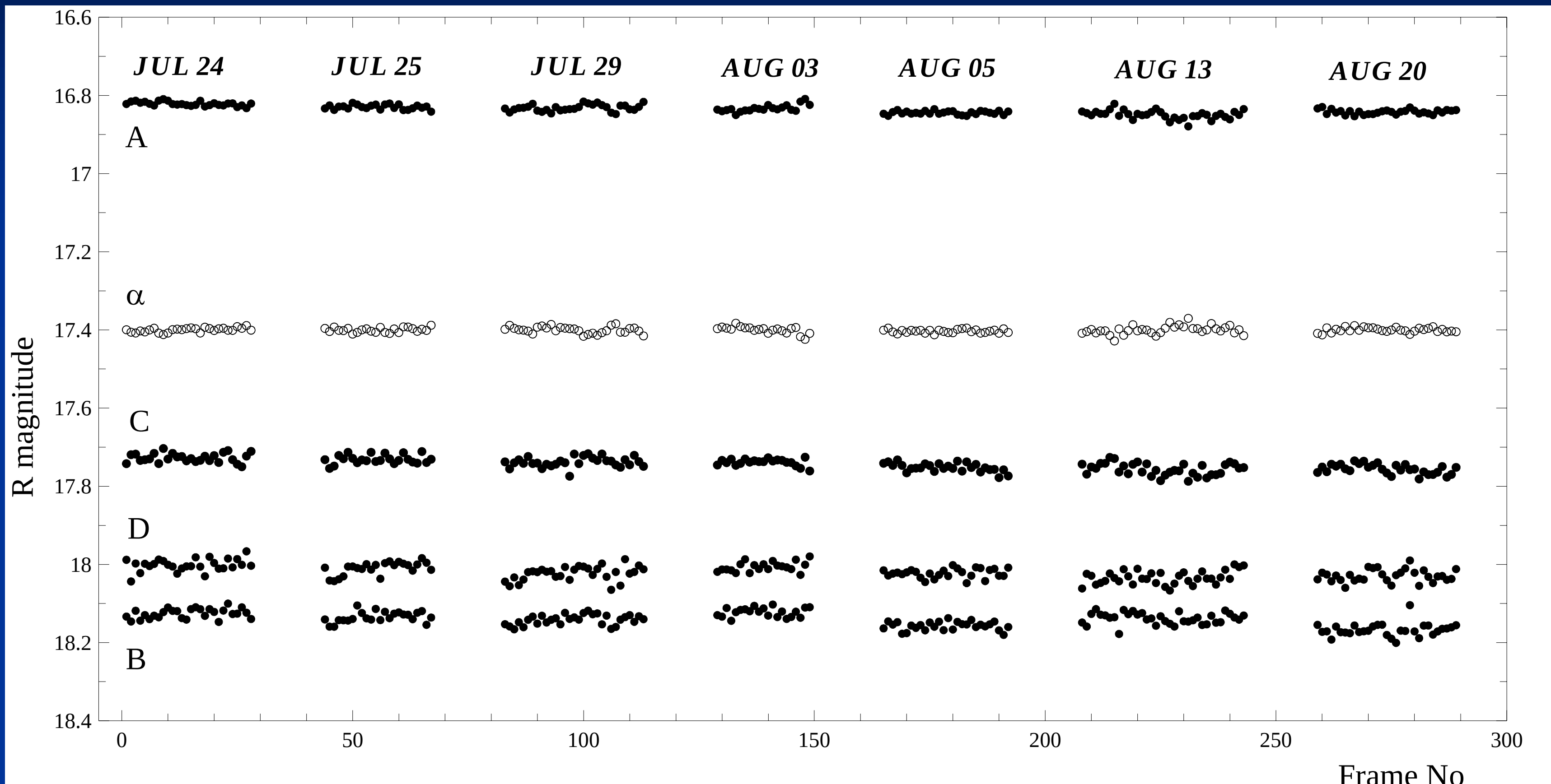



Q2237+0305

CCD image of Q2237+0305 obtained with 1.5 m AZT-22 telescope.

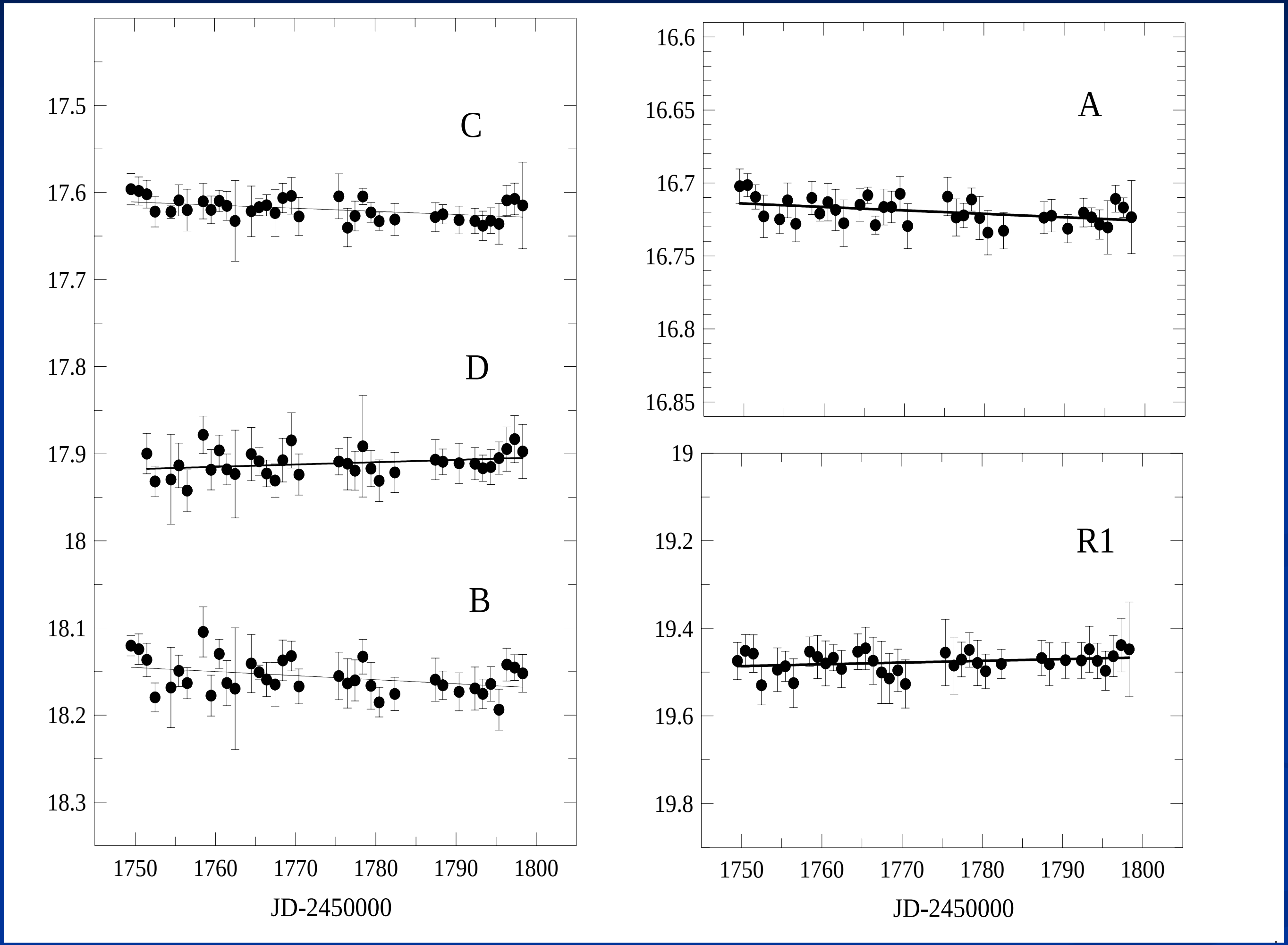
R band, the seeing (FWHM) =0.70 ″.






The brightness records for A-D components of Q2237+0305 and the reference star α for seven nights in July-August 2000.

# Q2237+0305

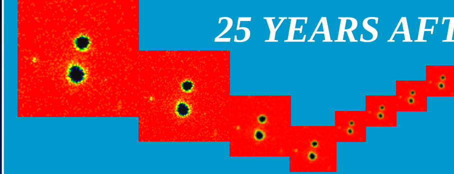



The light curves of A-D components of Q2237+0305 (night average magnitude) for the continuous monitoring period in July-Aug. 2000.

## Some conclusions.

The analysis of the photometry for sets of images of two GLQ - Q0957+561 and Q2237+0305 reveal the presence of significant (comparing to measurement errors) brightness fluctuation for the first system, whereas no such fluctuation was found for the second one. The modern CCD detectors and methods of image processing assures precise photometrical measurements (1% or a little better) of GLQ components with a 1-2 meter class telescope, located in a site with a good astroclimate.

The important information about lens and source could be obtained from studying a fine features of light curves which rise the question about the ways of future improving of measurement precision.





# Acknowledgements

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