Occultation Observations in Moscow During 1992 -1994.

S.V. Korobkin, A.Yu. Solov'ev, N.V. Kulakova, O.I. Mitin

House of Youth Science and Technology, Moscow, Russia
E-mail: mitin@astropbr.msk.su

At the end of 1991 the small group of teenagers had been formed on the base of astronomical circle of Moscow House of Youth Sceince and Technology. We all decided to start the observations of star's occultation by the Moon. This task was choosed due to the clarity of results, the possibility of various equipments from watch to photoelectric measuring devices and the absence of nessecerity in long homogenous observational sets.

We have the precomputation program written by O. I. Mitin in 1986 - 1988. This program allows to calculate: disappearance and appearance moments, position angles of contact points, stellar coordinates, the position of Moon's sickle, Moon's phase and components of contact point velocity at the the lunar limb. The last is calculated in according with next article (O. I. Mitin, The precomputation program for occultation observations., Preprint of the Stenberg Institute #5).

All the calculations are carried out according with the Bessel method, except of the grazing and near grazing events for which this method does not work. In a such case the moment of minimum distance between lunar limb and star are calculated. We assume that Moon is the sphere of 1737.3 km diameter. All the others parameters of events named before calculated too. We use SAO catalogue as containing big quantity of the stars up to 9 m evenly distributed over the sky. The lunar motion is calculated on the base of the numerical DE200/LE200 theory. All calculations are performed in topocentric coordinate system, as it looks for the observer at the moment of the event. We do not take into account the influence of the lunar limb zone profile and the distortion of the lunar shadow cylinder by refraction. The precomputation accuracy is about few seconds in the most cases, except of grazings, near grazing events and the catalogue errors. The precomputation program had been written in FORTRAN. The cumputing time for one night predictions is aboute 1/2 min for 486DX2-66. In Table 1 we give the comparison between predictions and observations for April 1 1993 as example.

Table 1

SAO	mag.	R.A.	Decl.	UT comp.	UTC obs.	P	h
97703	9.0	08 16 42.99	15 20 10.17	19 25 36.72	19 25 24.48	34.3	42
97726	8.7	08 18 50.86	15 02 20.16	20 19 54.80	20 19 52.28	68.0	35
97746	8.7	08 20 48.88	14 43 36.75	21 16 26.92	21 16 20.52	94.7	28
97754	9.1	08 21 20.78	14 37 18.13	21 32 49.76	21 32 42.99	105.4	26
97759	9.1	08 21 31.82	14 37 50.61	21 37 24.90	21 37 19.17	100.1	25
97762	7.4	08 21 36.08	14 47 15.17	21 42 38.13	21 42 32.97	62.0	24
97765	9.1	08 21 45.74	14 45 44.03	21 46 27.83	21 46 24.52	64.9	24
97756	8.0	08 21 27.61	14 20 18.02	21 59 34.18	21 59 18.08	167.5	22
97779	9.0	08 22 51.40	14 21 55.86	22 20 17.98	22 20 16.85	127.8	19

We have worked out several registrations methods. In each of them we use quartz generator for keeping the time with the $10E^{-5}$ s accuracy. In the case of observations at the Sternberg Institute observatory (20-cm refractor at 15-m high dome) we can use our ordinary equipment with the 220 V AC power supply (professional radio receiver, oscilloscope, frequency measurer, thermostabilized quartz clock). We ordinary use RWM & RID broadcasting stations to equal quartz clock scale with UTC through oscilloscope measurements. Due to considerable variations of observers' delays we do not take into account the delays which arise due to radio signals propagation. The equalization accuracy of scales is about or less then 2 ms, as it had been tested in special experiments. Our equipment is described in details in other our article, and now we want to describe our methodics.

1. Field conditions.

We use tape recorder, quartz second generator and additional watches. Difference between generator scale and UTC one ordinary is measured and recorded long before observations and is controlled after ones; the additional watches control at the same time. Next, the precision time scale is kept by the quartz generator. The signals of generator and pressed button are recorded on the magnetic tape. Minutes are marked manually by the button press according the whatches just before and after observations. In this method we have to measure different kinds of observer's delays. But due to difficulties for observers with minute marking the accuracy of this method was hardly better than 0.1 s. However this way of registration can be performed in every situation because small size, little weight of used equipment and using the battery supply only. The observer's delays are measured in laboratory conditions. By this way we obtained our first results in 1992. But only one of them was confident: March10, SAO76388 (6.9 m_{vis}), UTC = $= 17^h40^m50^s.98 \pm 0.10$.

2. Observatory conditions.

We use all the availible technics without any limitations of weight, size or power supply. Hence, we use oscilloscope for time scale adjusting, frequency meter for the press button moment definition and industrial quartz clock standard for time keeping. Moreover, we can carry out the measurements of observers' delays during the observations throw the artifical star occultation (appearance or disappearance). For each observer we get the samples of 20-30 delays and the statistical processing of these sets permits to estimate the true error for each observation. Also, we can provide the observers' training all over the observational set in original conditions and trace the delay variations through the observer's feeling and attention level. In additional, our technique allows to registrate events for bright stars by two observers at the same time and independent. The second observer uses the 15-cm telescope big enough for this purpose.

Next results were obtained by this method:

Date	UTC obs.	SAO,BD	m vis.	Ob-r	Ev-t	Obs'del	std.dev	sicle	Sun's angl
Mar27	18 21 29.34	76010	9.1	DS	occ 54300	0.342	0.048	0.172	-104.6
	18 44 55.26	+19 560	9.5	DS	occ 54300	0.342	0.048		
	19 05 45.71	93507	7.5	DS	occ 54300	0.342	0.048	0.174	-104.4
Apr 1	19 25 24.48	97703	9.0	OU	occ 54300	0.290	0.031	0.662	-79.2
	20 19 52.28	97726	8.7	OU	occ 54300	0.290	0.031	0.681	-78.7
	21 16 20.52	97746	8.7	OU	occ 54300	0.290	0.031	0.684	-78.6
	21 32 42.99	97754	9.1	DS	occ 54300	0.290	0.017	0.686	-78.6
	21 37 19.17	97759	9.1	DS	occ 54300	0.291	0.018	0.686	-78.6
	21 42 32.97	97762	7.4	DS	occ 54300	0.291	0.018	0.686	-78.6
	21 46 24.52	97765	9.1	DS	occ 54300	0.292	0.019	0.686	-78.6
	21 59 18.08	97756	8.1	DS	occ 54300	0.293	0.019	0.686	-78.6
	22 20 16.65	97779	9.0	DS	occ 54300	0.297	0.022	0.687	-78.6
Apr 3	21 20 38.19	118164	5.9	DD	occ 54300	0.330	0.051	0.876	-75.8
Apr28	18 34 56.29	97455	8.9	IE	occ 42200	0.307	0.035	0.415	-77.8
	18 36 43.02	97456	9.3	IE	occ 42200	0.307	0.035	0.415	-77.8
	19 00 22.34	97457	8.7	AS	occ 44300	0.380	0.048	0.417	-77.7

Remarks.

Observers:

IE - Igor Egorov, AS - Alexei Solov'ev, DS - Dmitrij Sokolov, PN - Pavel Naumov, OM - Oleg Mitin, OU - Oleg Ugolnikov, SK - Serg Korobkin, DD - Dmitrij Dorofeev, JP - Juriy Pakhomov, ChV - Chernetskiy Vladimir, SCh - Sergey Chernov.

Telescope:

AVR -1. (Astronomical Visual Refractor; Mirror diameter is 20 cm; 240x magnification). It belongs to Sternberg Astronomical Observatory and is used by students.

Longitude: $2^{h}30^{m}10^{s}.910$,

Latitude: $55^{o}41'57.''10$ (both are in the old pole system, that is equal geodetic coordinats on Krasovsky ellipsoid).

Altitude: 210 m (the high of the dome included).

During all observations the dark limb was not visible.

The set of digits means conditions of observations:

The first (from left to right) digit means the weather: 5 - clear, 4 - haze, 3 - dense clouds, 2 - very bad weather, 1 - too cold.

The second one means the character of atmosferic turbulence: 4 - sharp and quiet image, 3 - sharp, but trembling image, 2 - unqiet and glimmer one, 1 - the star looks as stormy spot.

The third digit means character of star's disappearance: 3 - momentary, 2 - gradually weaken, 1 - sharp change of star's ligh in moment of disappearance.

Last two digits mean the number of special remark.

Special remarks: 1 - two stars disappeared wiht time interval about 0.2 - 0.4 sec., 2 - by by-sight, 3 - star disappeared in Moon's crater, 4- slight brightness fluctuation before disappearence, 5 - on light fone. 6 - the beginning of dissapearence. 7- the end of it.

*) ashy light has been observed, #) dark limb has been visible.

Revelation of SAO 78380 Duplicity from Processing of Photoelectric Lunar Occultation Curve by Tikhonov's Regularization Method

O.I. Mitin, E.M. Trunkovsky

Sternberg Astronomical Institute, Moscow State University Moscow, 119899, Russia
E-mail: tem@sai.msk.su

Abstract: The results of the processing of the photoelectric lunar occultation curve of the star SAO 78380 are presented. Observation was made with 100 cm reflector of Mt. Maidanak observatory (Uzbekistan, longitude is $4^h\ 27^m\ 36^s$, latitude - $39^o\ 41'18''$) in the spectral band "R" with a time resolution of 1 ms. Processing was carried out by applying Tikhonov's regularization method in order to solve a Fredholm integral equation with respect to the brightness strip distribution over the source observed along the lunar limb normal. The results obtained give evidence of the duplicity of the star with 20 arcmilliseconds angular separation between its components in projection along perpendicular to the lunar limb and magnitude difference 1.7^m.

Since 1988 photoelectric observations of the lunar occultations of stars with a time resolution of 1 ms were begun at the Mt. Maidanak observatory of the Sternberg Astronomical Institute in Uzbekistan (altitude is about 2600 m). Description of the photometer and accompanying equipment used during observations, and of a program for precomputation of the circumstances of occultations of stars by the Moon is given in the paper [2]. It is known that one of the main kinds of information which could be obtained from lunar occultation observations is revelation of duplicity or multiplicity of the stars under investigation and determination of their parameters. We present here the results obtained when one of the photoelectric occultation curves recorded was processed.

Occultation of the star SAO 78380 = BD +28 1120 which has visual magnitude about 9.0^m and spectral class K2 [5] was observed with 100 cm reflector of Mt. Maidanak observatory (Uzbekistan) on April 21, 1988 at $22^h01^m52^s$ UT. Unfortunately recording of the time of occultation with more high accuracy was not carried out because of technical reasons. The occultation point's position angle on the lunar limb was P=53°. Computational velocity of the lunar limb motion along its radius-vector in the occultation point was about 525 m/s. Observation was obtained in the spectral band "R" which is close to standard one. Photoelectrical occultation curve of about 300 ms period which is a part of record obtained is presented in Fig.1.

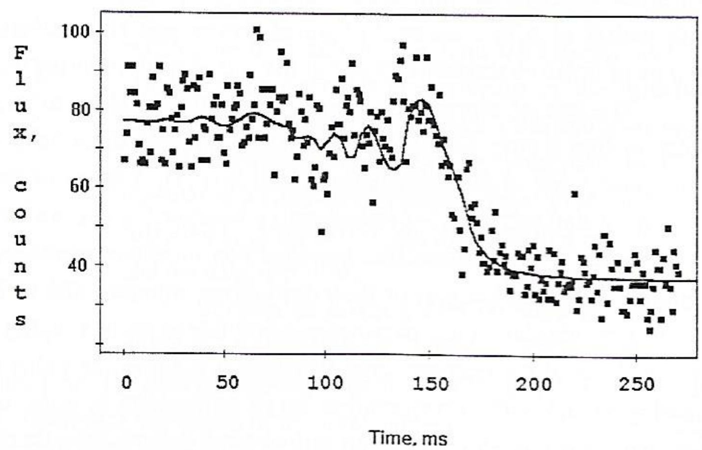

Figure 1.
Photoelectric occultation curve of SAO 78380 recorded with a time resolution of 1 ms, and model diffraction curve for occultation of a double star, corresponding to the strip brightness distribution found from processing of the data.

There are a few various algorithms for processing a data of photoelectric lunar occultation observations of stars. One can represent an occultation curve recorded, when it is free from a stochastic noise as a convolution of the one-dimensional strip brightness distribution across the source under study with the Fresnel diffraction curve for a heterochromatic point-like source. Thus mathematically the problem is reduced to search of the solution of Fredholm integral equation of the 1st kind [1]. The problems of solution stability and of convergence arise when equations of this type are examined. Various methods exist for finding the solution desired which are based on the various assumptions.

A method of fitting the best finite-number-dimensional parametric model is the most widely employed [4]. When the method is applied the strip brightness distribution across the object observed (as a rule, across a stellar disk) is assumed to be known. This method yieldes reliable results when the model used is described by a small number of parameters, for instance in determining of angular diameter of a single star from photoelectric occultation diffraction curve which was recorded. But when we deal with a possible close duplicity of the star investigated, a number of model parameters increases, hence convergence of fitting algorithm in the presence of noise in the data recorded becomes worse, and the problem of statistical assurance of the results obtained becomes considerably more complex.

There are two main sources of a noise in photoelectric occultation observations: quantum noise of the light flux and atmospheric scintillation. The latter phenomenon manifests itself in the light intensity fluctuations on the telescope aperture. When we try to solve a Fredholm integral equation with respect to the brightness strip distribution it is necessary to take into account that differing noise factors affect in different ways the required function of interest. As it is known from numerical experiments, Poisson noise leads to smoothing of this brightness strip distribution curve, while stellar scintillation could perturb its form. Thus an obtaining of a reasonably trustworthy solution of the equation mentioned turns out to be very complicated problem, and we should use all available additional information in order to solve a matter of duplicity of the star in question.

With this purpose we can use the following a priori information:

1) light source occulted by the Moon has a small finite angular size and positive brightness. Hence, one-dimensional strip brightness distribution along the lunar limb normal can be described as non-negative bounded function $b(x)$, which is defined on the finite interval: $b(x)=0$ if $x<a$ or $x>b$, and $0 \leq b(x) \leq M$ (M is some positive value) if $a \leq x \leq b$;

2) data recorded $S(t)$ may be represented as a sum of a diffraction light curve $S0(t)$ corresponding to the flux behaviour during occultation process without any noise influence, and function $N(t)$ describing the noise that is being present:

$$S(t) = S0(t) + N(t) \tag{1}$$

3) one may consider a quantity of the sum of values $N(t)$ squared to be known. It is quite fair assumption since we can determine some statistical properties of the available noise from the photoelectric record with period of a few seconds obtained before and after occultation section of data, and account for a change of noise characteristics due to the flux downfall during occultation.

The use of aforesaid a priori information enables to apply Tikhonov's regularization method in order to find a strip distribution $b(x)$ from integral equation mentioned, i.e. to restore the function $b(x)$ from processing of the observational data $S(t)$ [1]. A range of possible solutions $b(x)$ belongs to the space of interval-defined bounded non-negative functions. Next, we have to confine a space of possible solutions to the space W of differentiable bounded non-negative functions, which have both finite integral of values squared and finite integral of their derivatives squared. The level of "smoothness" of the solution $b(x)$ is defined by regularization parameter α and has to be in keeping with the accuracy of the initial data $S(t)$. By the form of the restored strip distribution $b(x)$ we can judge about the validity of application of one or another model with corresponding set of parameters in order to data processing by means of fitting the best parametric model, and about influence of noise factors on the results derived. In particular, in the case of a double star the resulting function $b(x)$ must show two-maxima contour which cannot be explained by influence of noise factors.

To describe the method used we can write a basic equation, which relates functions b(x) and S(t) one with another. It can be written in operator form as

$$Ab = S \tag{2}$$

where A – integral operator of a convolution of Fresnel diffraction curve for a heterochromatic point-like source with the function b(x) sought-for. This operator involves the apparature effects which consist in the factors of finite width of spectral band, of finite telescope aperture and of finite integration time in the flux measurements. Next, let F(x) belongs to the space W, described above, and $F'(x)=f(x)$. Let us define the norm L[F] of function F(x) as integral of F(x) squared over all possible values of x. Then we introduce the norm W[F] in the space W as

$$W[F] = L[F] + L[f] \tag{3}$$

Tikhonov's functional can be written now as

$$T[b] = L[\,Ab\text{-}S\,] + \alpha \cdot W[b] \tag{4}$$

This functional should be minimized in order to find its extremal function b(x) in W space, which could be designated as the solution desired. In searching for this solution we have used the conjugate gradient's projection algorithm [6]. The value of parameter α should be fitted such that the sum of deviations (i.e. values N(t) in eq.(1)) squared of data recorded from model curve S0(t) for solution founded (this sum is equal to L[Ab-S]) would be in accord with a priori value. In that case the "smoothness" of the solution b(x) will be in keeping with the accuracy of initial data S(t) and, as it was proved, an extremal function b(x) of functional T will converge to the true solution of eq.(2), when the data accuracy will become higher [6].

In processing of SAO 78380 occultation curve a blackbody spectrum of the star's radiation with the temperature 4590 K was assumed, in accord with characteristic temperature of K2 stars. Such approximation is quite permissible because the solution b(x) is a weak function of the spectral energy distribution in stellar radiation.

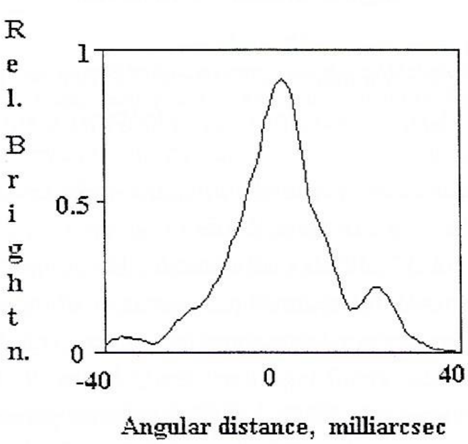

Figure 2.
The one-dimensional strip brightness distribution b(x) restored by processing of the initial observational data.

Fig.2 shows the one-dimensional strip brightness distribution across the source observed which results from processing of the data presented in Fig.1, by procedure described above. This function b(x) has two maxima, and its form remains steady when regularization parameter α varies within reasonable limits. Thus we have a serious basis to presume a close duplicity of the star. Corresponding model diffraction curve for occultation of a double star with 0.02 arcsec angular separation between its components in the direction along a perpendicular to the lunar limb and their magnitude difference about 1.7^m is presented in Fig.1 together with the observational data. One can see a sufficiently good agreement between this model curve and the data recorded.

In order to investigate a problem of reliability of the result obtained we studied an effect of the available stochastic noise on the solution found from the data processing. The main difficulty here is to estimate effects of atmospheric scintillation. Stochastic variations of the light intensity due to this phenomenon result in the noise function N(t) appears to be partially correlated. Hence a statistics of the light flux recorded will be essentially different from the Poisson one. There are algorithms, which allow to take into account explicitly an information on the statistics of the light flux fluctuations attributed to atmospheric scintillation (for instance, some features of correlation functions), but they are very complicated and require a great computations (see, for example, Ref. [3]). Therefore we have chosen the line of using the available record of the really registered noise.

We took the model occultation curve for a point-like single star, and superimposed the real noise recorded on this curve, producing by such a way a number of man-made realizations of occultation process, which could be observed in principle with given characteristics of noise. With this purpose we have used the available photoelectric record of the noise fluctuations of the light flux which was obtained long before occultation section of data. Here it is necessary to take into consideration that the noise recorded after occultation is the Poisson noise, but the noise recorded before occultation has much greater variance and includes a powerful scintillation component with other statistics. For this reason the Poisson noise from the part of record which was obtained later than occultation occured was superimposed on the background section of theoretical diffraction curve.

We have produced 4 various man-made noisy occultation curves and have restored the strip brightness distributions b1(x) by their processing, which are shown in Fig.3. We can see that these brightness distributions b1(x) are much more close to exponential distribution than the function b(x) found from original occultation curve. And if we would superimpose a pure Poisson noise on the model diffraction curve for a point-like source we would obtain a restored function b2(x) which is very similar to exponential distribution (as it follows from Tikhonov's regularization theory).

As it was mentioned above the distribution b(x) recovered from actually observed occultation curve shows two-maxima profile which is evidently different from a single exponential one. It is important to emphasize that the area under secondary maximum of the strip distribution curve b(x) obtained from initial data, reaches about 12-13% fraction of the area under main maximum of this curve, just as the areas under secondary maxima of the curves b1(x) recovered from the man-made realizations (if we consider these secondary maxima to be actual) account for a fraction of the area under main one, which is smaller by a factor of 2-2.5.

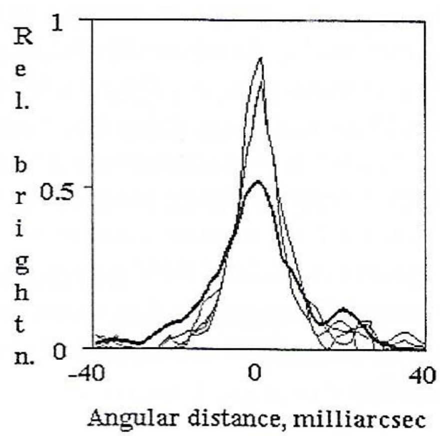

Figure 3.
The strip brightness distributions recovered from actually observed occultation curve (b(x), heavy line), and from the man-made noisy occultation curves (b1(x), thin lines).

Thus we have rather convincing evidence for the star SAO 78380 is really double. The projected angular separation between its components was about 20 milliarcsec, the assumed position angle of the direction along which the Moon's limb appeared to scan the object occulted was about 53 degrees, and the magnitude difference between the components is about 1.7^m.

An analysis of the available observational data concerning SAO 78380, and further investigations of this star are required.

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Angular Sizes of the Stars σ Aqr, SAO 138638, 23 τ Sco and 91 ν Leo Obtained from the Lunar Occultation Data

T.R. Irsmambetova, O.I. Mitin, E.M. Trunkovsky

Sternberg Astronomical Institute, Moscow State University Moscow, 119899, Russia
E-mail: tem@sai.msk.su

Abstract: Photoelectric observations of the lunar occultations of stars σ Aquarii, SAO 138638, 23 τ Scorpii and 91 ν Leo with a time resolution of 1 ms were obtained in 1988-1989 with 60-cm reflector of the High-Altitude Middle-Asian observatory of the Sternberg Astronomical Institute (Uzbekistan, Mt. Maidanak). Processing of the data obtained were carried out by fitting the best model diffraction curve and, in the case of σ Aqr, by applying the Tikhonov's regularization method to solve a corresponding integral equation with respect to the brightness distribution over the stellar disk. The result obtained for SAO 138638 allows to suggest a duplicity of the star but perhaps this is a consequence of considerable noise in the curve recorded. Processing of σ Aqr occultation curve yielded the value of angular size of the object observed of about 0.003 - 0.004 arc second. The result obtained gives a basis to suggest that the star is actually binary or multiple system with a low limit of angular separation between two components equal to the value pointed above and perhaps with a faint third component at the angular distance (along the perpendicular to the lunar edge) of about 0.007 arc seconds from the main one. The fitting of the best single-star model diffraction curves in the cases of the stars 91 ν Leo and 23 τ Sco shows that the point-like source diffraction curves are the best for these stars.

In 1988 the photoelectric photometer which allows to carry out an observations of rapid processes with a high time resolution was designed at Mt. Maidanak observatory of the Sternberg Astronomical Institute (Uzbekistan, longitude is $4^h27^m36^s$, latitude – 39°41'18", altitude is about 2600 m). One of the main tasks which were solved with use of this device were photoelectric observations of the lunar occultations of stars with the purpose of measuring the angular diameters of stars and revealing of close binary stellar systems.

The device was built according to the standard scheme of one-channel photometer. The multialkaline photomultiplier was used as detector of radiation. The available set of the glass light filters allows to conduct observations in standard broad spectral bands B, V, R, in ultraviolet spectral band W of the Straizys photometric system, and in integral light.

Characteristic feature of the photometer described is the use of the two-channel counter which ensures a possibility of the light flux recording with 1 ms time resolution. During every cycle of a count accumulation one of the channels detects pulses arrived, while information which has been accumulated in the other channel is being transfered into computer memory. On the next cycle the channels exchange their roles. Such technique ensures a continuous recording with a count accumulation time of 1 ms and without losses of time by information exchange. When photometric data are being entered into computer memory, the ring buffer with capacity of 10000 storage locations is used. This allows to conduct a continuous data recording with a time resolution of 1 ms during 10 seconds. Recording should be stopped manually.

Precalculations of the occultation circumstances were made with use of the computer program that has been written by O.I.Mitin. It calculates the moments of disappearances of stars beyond and their reappearances from beyond the dark edge of the Moon, position angles of the contact points on the lunar limb, velocities of these points and their normal and tangential components (under the assumption of perfectly circular profile of the limb), linear distances from the observation point to the lunar edge, and other necessary parameters.

The position and motion of the Moon are determined by the polynomials of DE200/LE200 numerical theory. The Moon is assumed to be a sphere having 1737.3 km in diameter. We used the SAO Catalogue as a source of information on the stars occulted, which contains nearly all stars brighter than approximately 9^m. In calculating we didn't take into account the irregularities of the real lunar limb profile. The occultation moments are calculated according to the Bessel method. But in the grazing or near grazing cases, when the Bessel method does not operate, the time of the closest approach of the lunar limb to the star and the angular distance between them are computed.

An accuracy of our precomputations accounts for in most cases about 2-5 sec in time, with the exception of the cases when we deal with catalogue errors or near-grazing occultations; in those cases the deviations of the occultation moments recorded from precomputed ones could reach 20-30 seconds and more. This program has permitted to carry out a number of successful occultation observations.

Photoelectric observations of lunar occultations of the stars which are a subject of this paper, were carried out in 1988-1989 with 60-cm reflector of Mt.Maidanak observatory with use of the equipment described above. Unfortunately recording of the times of occultations with high accuracy of the order of 1 ms were not carried out because of technical reasons. During observations the diaphragm with angular diameter of about 12 arcsec in the cassegrain focus of the telescope was used.

Computer processing of the data obtained were conducted by fitting the best model diffraction curve in the framework of a single-star occultation model and, besides, in the case of Sigma Aqr, by applying the procedure of Tikhonov's regularization method in order to find a solution of the Fredholm integral equation with respect to the strip brightness distribution across the object occulted. Algorithms of the data processing which were employed are described in the papers [3,4]. In the processing we took into account an effect of a nonlinearity of photoelectric apparatus which is being usually presented when the level of the light flux recorded is sufficiently high; this factor could be specified by the dead time constant. With this purpose we corrected the values of the signal observed and processed the resulting realizations.

Occultation of the subgiant star Sigma Aquarii, which has a magnitude V = 4.82 and spectral class A0IVs [2], was observed in the spectral band "V" on November 17, 1988 at $16^h29^m03^s$ UT. The occultation point's position angle on the lunar limb was P=142°. The star is known as spectroscopic binary [2] but the detailed information concerning variability of radial velocities is absent in the Catalogue [2], as well as some data on this star are absent in the Catalogue [1]. This leads to suggestion that amplitude of such variability is small, and complete radial velocity curve was not obtained.

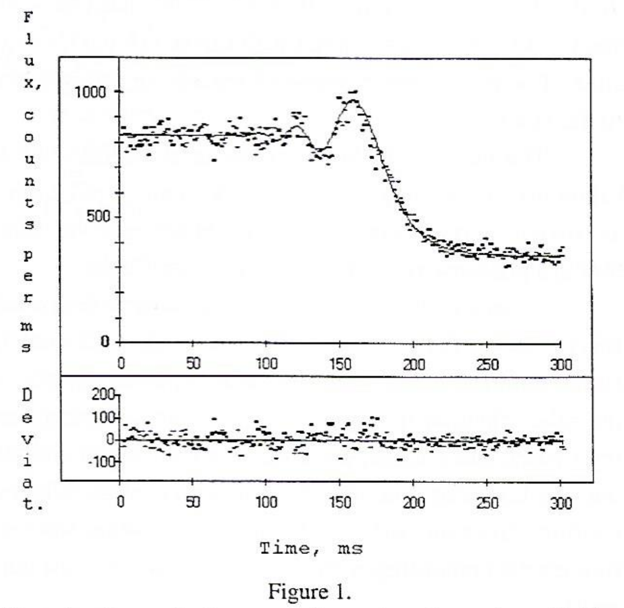

Figure 1.
Photoelectric occultation curve for σ Aqr observed on 17 Nov 1988 in the "V" band, and the best model diffraction curve which results from data processing. Here and in the other similar figures deviations of data recorded from the best model curve are presented in their lower parts.

Photoelectric occultation curve of Sigma Aqr consisting of 300 readings that corresponded to an accumulation time of 1 ms, and the best model diffraction curve for occultation of a single star having a uni-

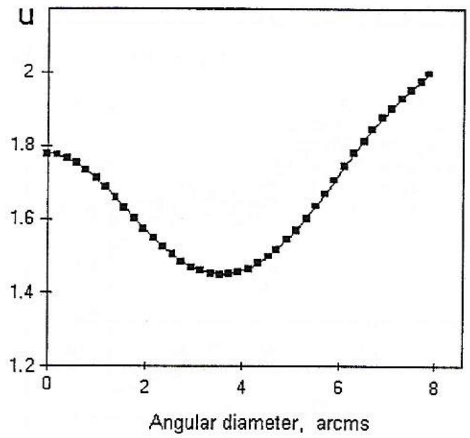

Figure 2.
Dependence $u(d)$ for σ Aqr's occultation curve which was obtained in data processing.

formly bright disk with the angular diameter d=0.0036 arcsec, are presented in Fig.1. In processing of observational data by fitting the best model diffraction curve we obtained a function $u(d)$ which represents a dependence of the sum of deviations squared of data recorded from the best model curve u on the given values of angular diameter d. This dependence for σ Aqr' occultation curve is presented in Fig.2. We can see a pronounced minimum of the function $u(d)$ near the value d=0".0036. Corresponding value of occultation velocity along a perpendicular to the real lunar edge derived in the processing is V_x=303 m/s, and the relative rms deviation of the readings from the optimal model curve (in percentage of the amount of signal falloff during occultation) is about 7%.

According to our precalculations, occultation of σ Aqr should be near grazing, i.e. the star should pass beyond the disk of the Moon at the angular distance 6,8 arcsec from the dark lunar edge. The position angle of the radius-vector of the lunar limb which intersects the line of star's relative motion in its middle point at right angles, was about 142 deg; the total predicted velocity of the lunar limb motion in the direction perpendicular to this radius-vector was equal to $V = 821$ m/s. On the basis of these data we can derive the value of the predicted occultation velocity as a projection of a total velocity on the direction of radius-vector which joins the lunar disk centre to the point of the first contact. That predicted value $V_p = 102$ m/s was used for determining the local slope of the lunar edge ($+14^o$) and in data processing.

We have also restored the strip brightness distribution b(x) across the object occulted from the observational data by applying the procedure of Tikhonov's regularization method in order to find a solution of the Fredholm integral equation [4]. When regularization parameter is in accord with the accuracy of the initial data, the total width of a central maximum is about 4.8 arcms, and its width at the level of 0.5 of maximum is about 3 arcms. This result is in a good accord with the one derived when we used the method of the best model fitting. Next, the strip brightness distribution shows a secondary peak at the angular separation of 0".007 ± 0".0005 from the main one.

As one can see, the value d obtained exceeds the reasonable indirect estimate of angular diameter of the star with a given spectral class and luminosity class by several times. Really, with the values of trigonometric parallax of σ Aqr 0".021 [2] and of linear radius for the star of spectral class A0 IV (R = 4 solar radii) we obtain δ = 0".0008 .

The results presented could mean that the star Sigma Aqr is actually a close binary or multiple system. It is possible also that we deal with extended shell or disk-like structure around the star. The angular size of emitting region which has been measured corresponds to the linear dimension of about 37 solar radii. As we can judge by available literature sources, there were no any other measurements of the angular size of Sigma Aqr by lunar occultation observations.

Occultation of SAO 138638 was observed on 22 Jun 1988, at $15^h45^m01^s$ UT. It has visual magnitude 6.9^m and spectral class F5. Observation was carried out in spectral band "V". Photoelectric occultation curve of SAO 138638 is presented in Fig.3. One can see that this record unfortunately was burdened with considerable noise. The data processing by the best model fitting shows that the u value decreases while star's angular diameter increasing up to rather considerable values. Therefore we have improbable great value of the star's angular diameter. Formally this allows to suggest a duplicity of the star with relatively great separation between its components. But most likely such the result could be a consequence of the noise influence. Thus this occultation curve probably can be considered as the marginal case of application of model fitting method.

Occultation of the star 23 Tau Sco (= HR 6165 = HD 149438 = SAO 184481) having visual magnitude 2.9^m, spectral class B0 V, trigonometric parallax 0.02 arcsec [2] was observed in the spectral band "R" on 11 Aug 1989. Occultation point's position angle on the lunar limb was 152^o. Photoelectric occultation curve recorded and the best model diffraction curve for a point-like source are shown in Fig.4. Corresponding *u(d)* function is shown in Fig.5. We can see the pronounced minimum of the *u(d)* function at d=0. The point-like source suggestion rusults naturally from this picture. Indirect estimate of the angular diameter of the star gives the value of about 1.4 milliarcsec. We suggest that the real diameter of the star could be less than estimated one since the possible error of measured value is probably not too much exceeds 1 marcsec.

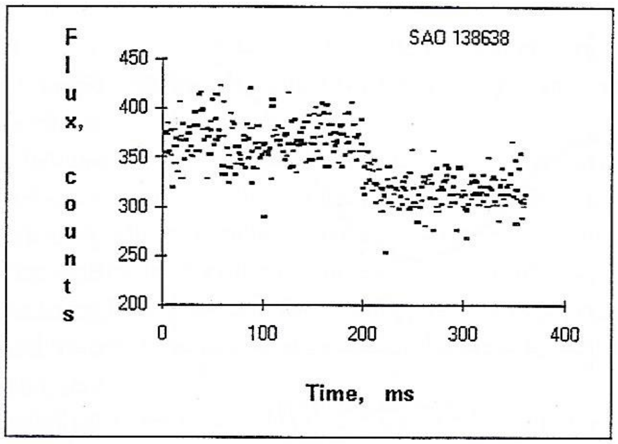

Figure 3.
Photoelectric occultation curve for SAO 138638 observed on 22 Jun 1988 in the "V" band.

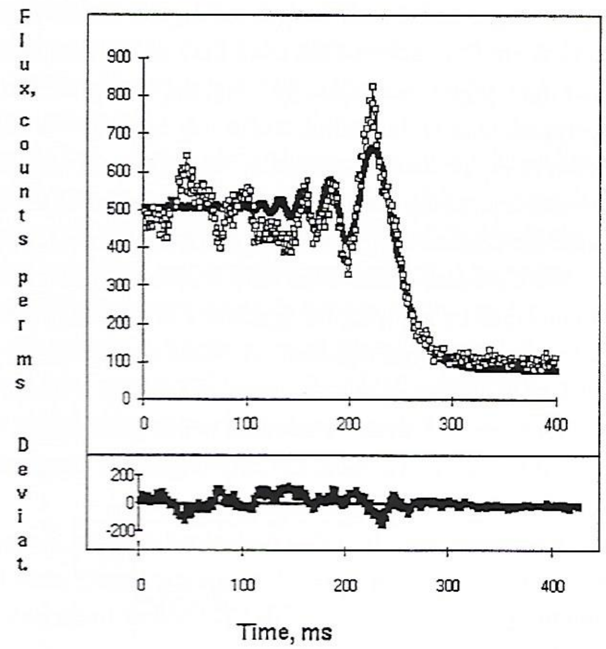

Figure 4.
Photoelectric occultation curve for 23 Tau Sco observed on 11 Aug 1989 in the "R" band, and the best model diffraction curve which results from data processing.

Occultation of the star 91 v Leo = HR 4471 = SAO 138298 = HD 100920, which has a magnitude V = 4.30 and spectral class G8.5 III CN 0.5 [2], was observed in the spectral band "R" on June 11, 1989 at $15^h58^m11^s$ UT. This star is the infrared source IRC 00209. The occultation point's position angle on the lunar limb was $P=139^o$. The star is known as occultation binary, with angular separation between components of 0.1 arcsec and magnitude difference 4.5^m [2]. The angular diameter of the star was determined from the lunar occultation observations and found to be 2.1 arcms (observation on 30 Apr 1977, uniformly illuminated stellar disk assumed) and 2.9 arcms (the same event, but the other observatory, fully limb-darkened stellar disk assumed) [5]. Photoelectric occultation curve of 91 v Leo consisting of 400 readings that corresponded to an accumulation time of 1 ms and the best model diffraction curve for occultation of a single point-like star is shown in Fig.6 . In processing of observational data by fitting the best model diffraction curve we obtained a function *u(d)* which we can see in Fig. 7. We can see the minimum of the function *u(d)* near the zero value of *d* . Therefore the model of point-like source is the best for this occultation curve. On the basis of the result obtained we can assert that the real angular diameter of the star could not be more than the probable error of determination (which accounts for, as it

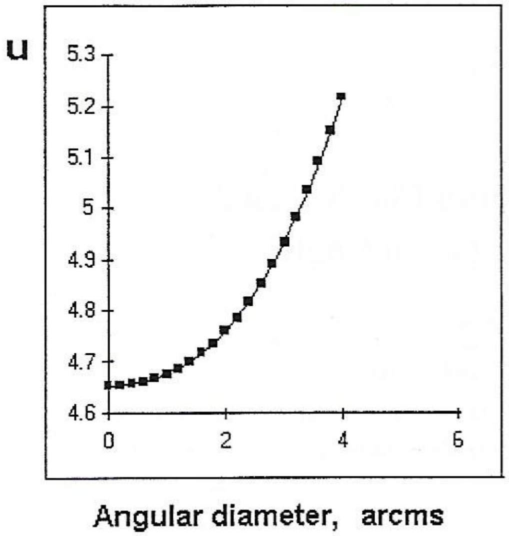

Figure 5.
Dependence *u(d)* for 23 Tau Sco's occultation curve which was obtained in data processing.

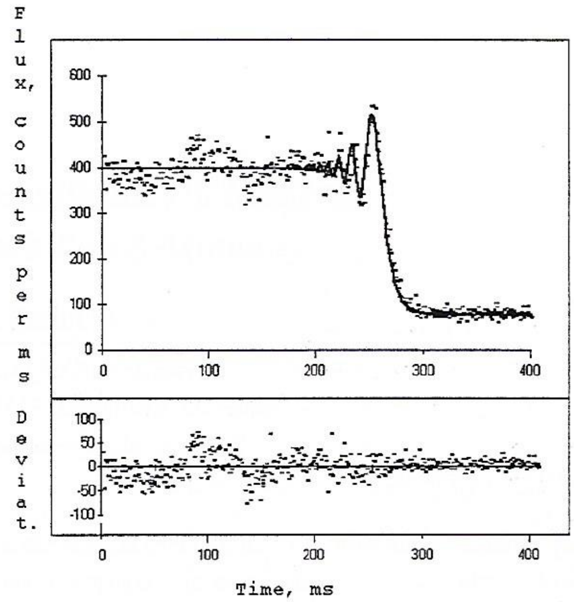

Figure 6.
Photoelectric occultation curve for 91 Leo observed on 11 Aug 1989 in the "R" band, and the best model diffraction curve which results from data processing.

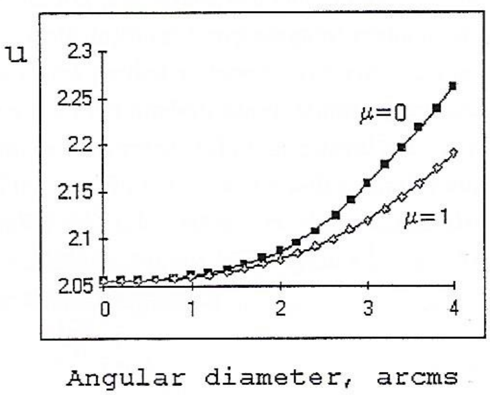

Figure 7.
Dependence *u(d)* for 91 Leo's occultation curve which was obtained in data processing.

follows from our experience, a quantity of the order of 1 arcmillisec). Such discordance of results may appear to be very interesting in connection with the other observational data. May be the orbital motion of binary system components can explain the available set of results.

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Equipment for Occultation Timing Observations

I.V. Egorov, O.I. Mitin, N.V. Kulakova

House of Youth Science and Technology, Moscow, Russia
E-mail: mitin@astropbr.msk.su

There are a lot of technics to mark time moments during occultation observations using "eye-key" method. Everybody from you does this best. Unfortunately, in our country there are not ordinary cheap devices for clock comparing and timings with necessary accuracy. The equipment in our method consists of universal devices which are used in couple with the simple self-made equipment to complete its possibilities. We think, that timings hardware have to replay for the next demands:

1. Accuracy of UTC moments preservation up to 1 ms of time.
2. Possibility of observer's training.
3. Comfort of use.
4. Small size and weight.

Of course, we know that the such kind of microprocessor devices exist, but we hadn't the resources for constructing or buying up such devices. Morever, in many cases we couldn't use the universal devices because they were contradictable to our demands. For our field observations we use some modification of method, which was recommended by Danlop (S. T. Danlop, "A step by step quide to the night sky", 1985, Gamlin Publisher Group Ltd.), where second signals from simple quartz generator and signal from push-button are registered on the taperecoder. But decoding the record with the wanted accuracy is the serious task, and observer's training becomes difficult. We've made up the equipment for observations in field conditions, when the main demands are not only the accuracy and the transportability of equipments, but and their power independence. Our devices we'll describe a little below.

The profits of using in the normal observatory conditions the universal professional equipment are obvious. When there aren't problems with the AC power supply, the using of thermostabilized quartz clock becames possible. More, the using of clock synchronization with the radio signals throw oscilloscope becomes possible too. And industrial calibrated frequency meter allows for us quickly to define short time intervals. Such equipment set we used in obtaing the main part of our results. In addition, simple measuring of observers delays (personal equations) and the permanent observer's training become possible, what we think is neccesary for all observations.

The field set of devices was made up at first. The recording device was the compact tape recorder with the battery supply source. The mixed signals from quartz second's and key-controlled generators were recorded by it. We have constructed the special device attached to tape recorder which generated the following signals:

– the signal of internal quartz generator for the second's marking;

– press button signal.

Simultaneously, this device permits mixing the radio timings from the radio receiver with the previous ones. All the signals had the various sound frequencies and amplitudes. Hence, it is possible to distinguish them both in audio experience and visually at the oscilloscope screen. This device had the small

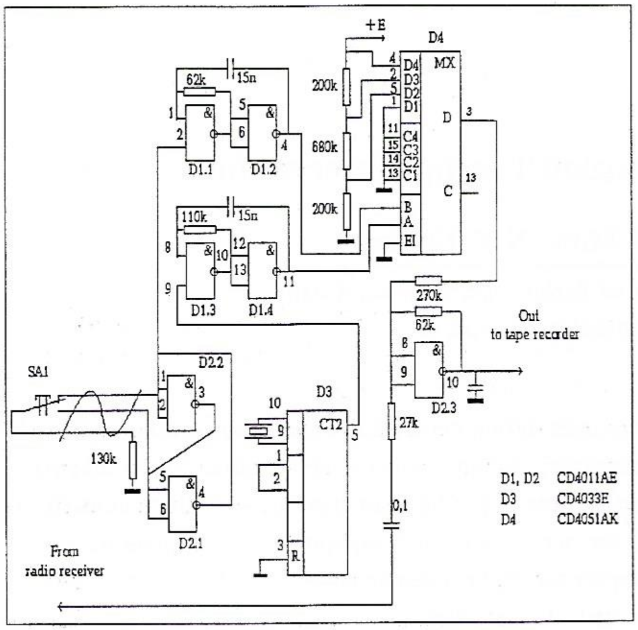


Figure 1.

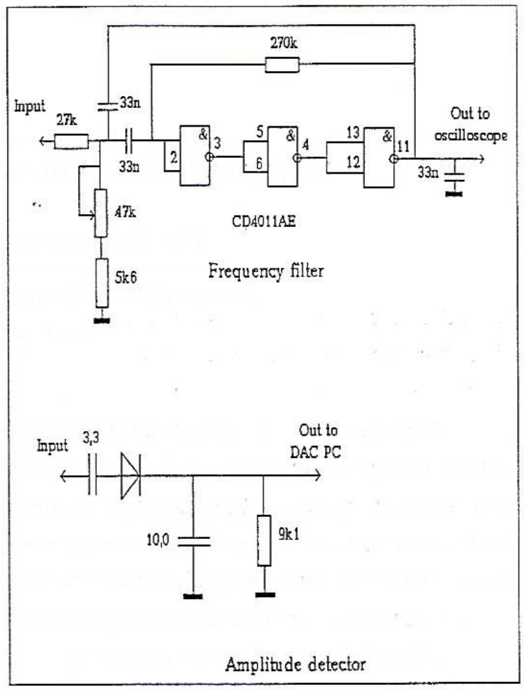


Figure 2.

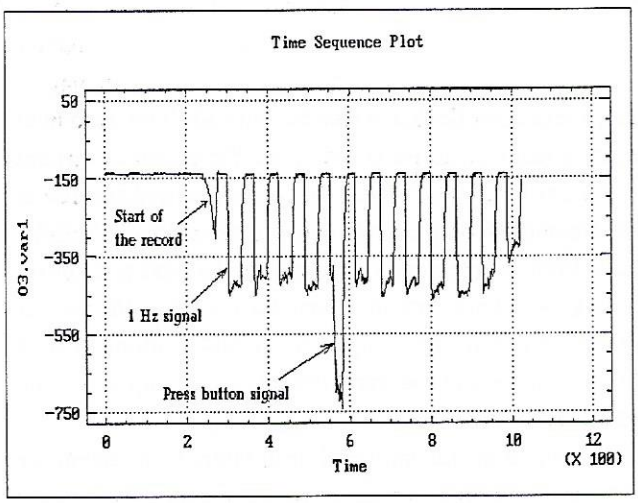


Figure 3.

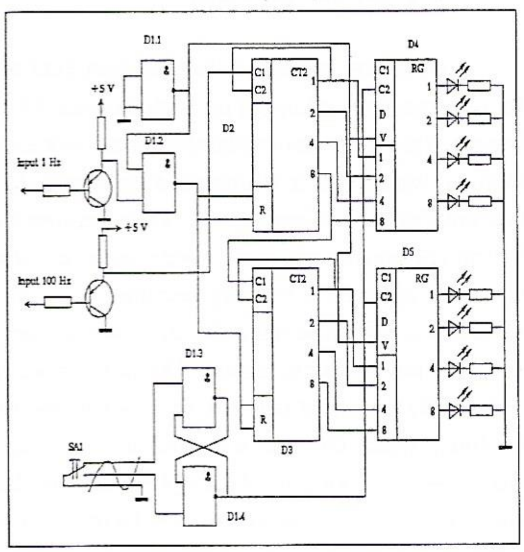
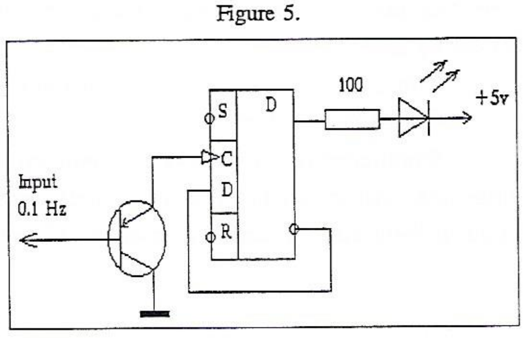


Figure 4.

Figure 5.



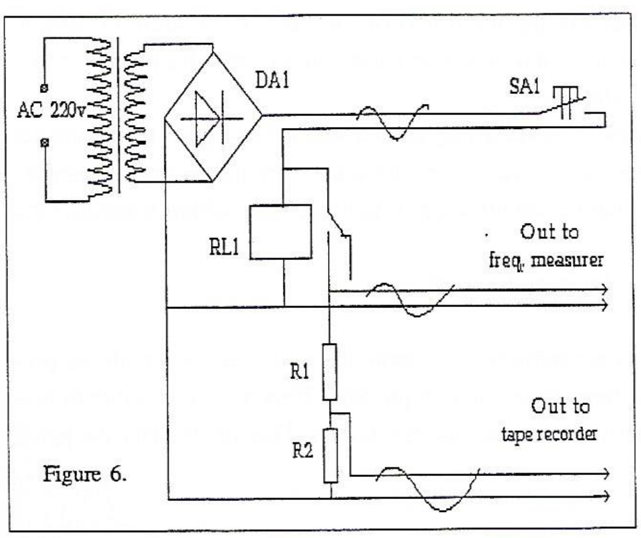


Figure 6.

size, battery supply and small current of supply. Therefore, the difference between the device's internal scale and UTC one may conserve during some days. The scheme of this device is shown in Fig.1.

The CMOS chips are used. D2.1-D2.2 trigger is performing the front steepness. The second impulses are produced by the D3 generator. D1.1-D1.2 generator is controlled by the button press. D1.3-D1.4 generator is controlled by the D3 impulses. All of them are completely undependent. D4 multiplexer performs the amplitude and frequency modulations of output signal. And D2.3 is the mixer for the radio time signals.

But the tape decoding in this case is the difficult task. It was possible, for example, to observe the record on the oscilloscope screen. The resulting accuracy was 0.1 sec or worse. The using of the frequency filter and the amplitude detector which are shown in Fig. 2 in complex with the digitazing equipment permits to get records similar to that shown in Fig. 3 and insignificant to increase the accuracy.

For the purposes of the observer's training we used the other device which is shown in Fig. 4 in complex with so named "artifitial star" which is shown in Fig. 5. The main constructive feature of the first one is the binary code LED indication. It looks possible to use this device and as registrating one in the occultation observing process.

There are not the small-size and low-current demands at the our stationary observatory where we can use the fair 20-cm visual refractor and some standart electronic devices – oscilloscope, radio receiver, frequency measurers and universal quartz clock with the delicate time delay adjust. In such conditions observations are simple and pleasant. The main cycle of observations is described in other our article. The only self-made device is the button, which have to stop the time interval measuring of the frequency measurer. According scheme which is shown in Fig. 6 all the signals can be also written on the magnetic tape, in the case of grazing observations for example. Power AC 220 V supply is using. When the button pressed, the 100 Hz signal stops the frequency meter counting, started ordinary by the minute signal from quartz clock. So we obtain the precision time of the event after taking into account the observer's delay.

Methodology of observations and obtained results are discribed in the other our article. Accuracy of the most part of our results due to both methodics and hardware possibilities is about 0.05 second.

□